E0102: Science of Disaster

Student Manual

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FEMA

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Unit 1: Course Welcome

Your Notes

Visual 1: Unit 1: Welcome

E/L102 Science of Disaster

Welcome

Key Points

Welcome to E/L102, Science of Disaster.

This course in the National Emergency Management Basic Academy is designed to provide the participants with an overview of scientific principles and concepts that shape our increasingly dangerous world.

Visual 2: Unit 1 Structure

Visual 3: Instructor Introductions

- Instructors
- Course Managers(s)
- Other Course Personnel

Visual 4: Administrative Information

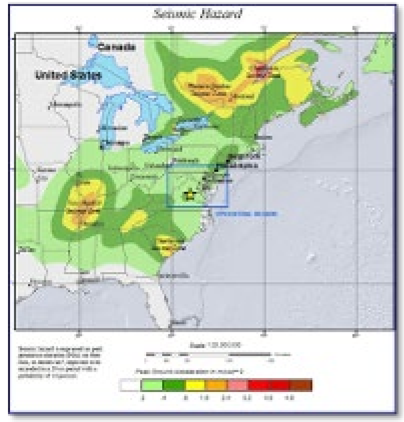
- Emergency Exits
- Restrooms
- Cell phones
- Other logistics

Key Points

Please remember to silence your mobile devices.

Visual 5: Course Goal

The goal of this course is to understand how scientific principles can be used before, during, and after a disaster, including a basic understanding of scientific terminology as it applies to Emergency Management.



Key Points

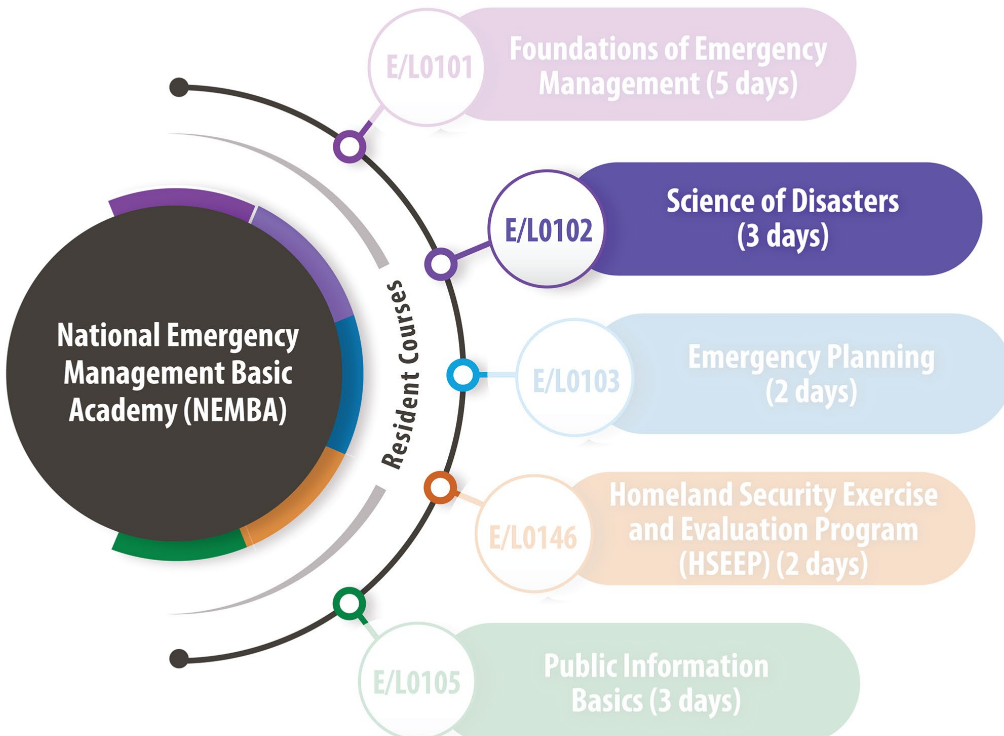
The goal of this course is to enhance understanding of how scientific principles can be used before, during, and after a disaster, including a basic understanding of scientific terminology as it applies to Emergency Management.

We will explore various types of natural and human-caused threats and hazards and consider the science behind:

- How they occur.
- Why they occur.
- Where they occur.
- What we can predict about their occurrence.

We will also consider what Emergency Managers can do with the types of warning and predictions provided by scientists.

Visual 6: NEMBA Resident Courses



National Emergency Management Basic Academy (NEMBA) Resident Courses

Key Points

- ***E/L0101 Foundations of Emergency Management*** covers the basic principles and terminology of Emergency Management.
- ***E/L0102 Science of Disasters*** covers the data.
- ***E/L0103 Planning: Emergency Operations*** covers the plans and how to create them.
- ***E/L/K0146 HSEEP*** shows how to exercise the plans.
- ***E/L0105 Public Information Basics*** shows the relationship of public communications to EM.

Additional information can be found on the National Emergency Management Basic Academy webpage (https://training.fema.gov/empp/basic.aspx)

Visual 7: Participant Introductions

- Name
- Position/organization
- What topic is most relevant to you
- What is your science background, and when was your last science course?

Key Points

You will be given an opportunity to introduce yourself. Please include the information listed on the visual.

Visual 8: Course Agenda

Day 1	Day 2	Day 3
Unit 1: Course Welcome **Unit 2:** Relationship Between Science and our Understanding of Disasters **Unit 3:** Severe Storms, Tornadoes, and Hurricanes **Unit 4**: Other Hazardous Weather	**Unit 5:** Floods **Unit 6:** Earthquakes and Tsunamis **Unit 7:** Landslides and Sinkholes **Unit 8:** Volcanoes Break **Unit 9:** Science of Human Induced Disasters	**Unit 10:** Biological Basics **Unit 11:** Chemistry Fundamentals **Unit 12:** Chemistry Hazards **Unit 13:** Explosive Hazards **Unit 14:** Radiation Hazards **Unit 15:** Emerging Issues in Science and Technology Affecting Emergency Management **Unit 16:** Course Summary

Course Structure

This course will introduce you to scientific concepts and principles in several key areas related to natural and human-caused disasters. It is not possible to cover each and every hazard that might occur. Instead, the course will focus on common and emerging threats that provide a basis for understanding the science of disaster. The course is organized as follows:

- **Unit 1**: Introduction to Class
- **Unit 2**: Relationship Between Science and our Understanding of Disasters
- **Unit 3**: Severe Storms, Tornadoes, and Hurricanes
- **Unit 4**: Other Hazardous Weather
- **Unit 5**: Floods
- **Unit 6**: Earthquakes and Tsunamis
- **Unit 7**: Landslides and Sinkholes
- **Unit 8**: Volcanoes
- **Unit 9**: Science of Human Induced Disasters
- **Unit 10**: Biological Basics
- **Unit 11**: Chemistry Fundamentals
- **Unit 12**: Chemistry Hazards
- **Unit 13**: Explosives
- **Unit 14**: Radiation Hazards
- **Unit 15**: Emerging Issues in Science and Technology Affecting Emergency Management
- **Unit 16**: Course Summary

Visual 9: Course Expectations

- Punctuality
- Participation
- Positive attitude
- Professionalism
- Flexibility
- Commitment

Key Points

The instructors' expectations for you include:

- **Punctuality:** We expect you to be prompt in arriving for the beginning of the training day and returning from breaks.
- **Participation:** This course is most successful if everyone participates in the discussions and activities.
- **Positive attitude:** Being open-minded will help you maintain a positive attitude toward learning.
- **Professionalism:** We expect you to be courteous, conscientious, and considerate of others. Listening skills and accepting constructive criticism are important as well.
- **Flexibility:** Emergency management requires flexibility. During the training, you can practice being flexible by being open to change and new information. In addition, we ask that everyone be able to adapt to new information, changing conditions, and unexpected obstacles.
- **Commitment:** You are expected to make a commitment to continued learning following the classroom training portions. You will complete an individual action plan at the end of each module. We ask that you make a commitment to complete the action form and follow through when you return to your work setting.

Visual 10: Methods

- Presentations: Scientific concepts for understanding natural and human-caused disasters
- Discussions and activities
- Resources for continued learning
- Individual Action Workbook (IAW)

Key Points

The presentations in this course will provide basic scientific information related to natural and human-caused disasters. Presentations will be supplemented with detailed job aids, provided in the Student Manual.

There will be opportunities to apply these concepts in large-group discussions and table group activities.

Finally, each unit will identify resources from which you can continue learning about the topic. There is a wide array of resources available to help you learn more about scientific principles underlying disaster hazards and threats, including web-based resources, training, and local experts.

Visual 11: Participant Course Materials

- Student Manual (SM)
- Individual Action Workbook (IAW)
- Evaluation
- Pre and Post Assessment

Key Points

Course Materials Include:

- **Student Manual (SM):** Here you will find the course slides and course information.
- **Individual Action Workbook (IAW):** This workbook will provide continuity through the Basic Academy curriculum. As you work through the activities in the IAW, there will also be opportunities for Check-In where you can report your progress and activities once you have returned to your jurisdictions.
- **Evaluation:** Please complete the evaluation, this information on the evaluation is relevant in how we review, update, revise and develop curriculum.
- **Pre and Post Assessment:**
    - The pre assessment gages your current knowledge before attending the course or pre-existing knowledge
    - The post assessment gages what your have learned throughout the course or knowledge gained.

Visual 12: IAW Follow-Up

- Have you completed or made progress in the tasks you identified for your community?
- For information that you did not know during class, what methods did you use to find the information?
- Have you met with your identified mentor since E/L0101? How has he/she continued to help you grow in the Emergency Management profession?

Key Points

Based on the topics, issues, activities, and priorities you identified in the E/L0101 Foundations in Emergency Management and course, discuss the following:

1. Have you completed or made progress in the tasks you identified for your community? Provide examples.
2. For information that you did not know during class, what methods did you use to find the information?
3. Have you met with your identified mentor since E/L0101? How has he/she continued to help you grow in the Emergency Management profession?

Visual 13: Assessment and Evaluation Process

- Pre-Assessment (no grade)
- Post-Assessment
  - 75% or better passing grade
- Participation
  - Daily attendance, participation, and interactions
  - Individual Action Workbook (IAW)

Key Points

The course will contain several graded and ungraded testing and evaluation opportunities.

There will be a total of two tests—a pre-test and a post-test. The Pre-Test will not count towards the score to pass the class.

You are required to score a minimum of 75% on the Post Test.

In addition to the required minimum scores on the two Post-Tests, you will also be required to be an active participant in the class. Instructors will be observing your:

- Daily attendance and interactions in the class
- Completion of IAW activities

Student Manual

Student Note

It's better to guess, rather than leave a question unanswered.

Visual 14: Pre-Test

Instructions: Working individually …

1. Write your name on the question packet and answer sheet.
2. Tear the Pre-Test Answer Sheet off the test packet and use it to record your answers.
3. Once you have completed the test, give it to the instructors.
4. You have 25 minutes to complete the Pre-Assessment.

Key Points

Instructions: Working individually…

1. Write your name on the question packet and answer sheet.
2. Tear the Pre-Assessment Answer Sheet off the test packet and use it to record your answers.
3. Once you have completed the test, turn it into the instructors.
4. You have 25 minutes to complete the Pre-Assessment

Unit 2: Relationship Between Science and our Understanding of Disasters

Your Notes

Visual 1: Unit 2: Relationship Between Science and our Understanding of Disasters

Unit 2: Relationship Between Science and our Understanding of Disasters

Key Points

This unit will discuss the discuss the science of extreme temperatures.

Time Plan

A suggested time plan for this unit is shown below.

Topic	Time
Introduction to Science	10 minutes
Science in Emergency Management	15 minutes
Module Summary	5 minutes
Total Time	**30 minutes**

Visual 2: Unit Objectives

- Define what is meant by science.
- Recognize how science supports risk.
- Understand risk and how it applies to emergency management.
- Identify the validity and credibility of science.

Key Points

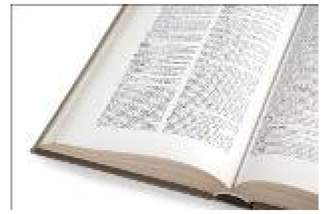
Review the unit objectives as shown on the visual.

Visual 3: Discussion: What Is Science?

Key Points

<u>Discussion Question:</u> How would you define science?

Visual 4: Definitions of Science



- A branch of knowledge or study dealing with a body of facts systematically arranged and showing the operation of general laws.
- Systematic knowledge of the physical or material world gained through observation and experimentation.

Key Points

There are many definitions of science. For example, science can be described in the following ways:

- Science is a branch of knowledge or study dealing with a body of facts systematically arranged and showing the operation of general laws.
- Science is systematic knowledge of the physical or material world gained through observation and experimentation.

Note that what both definitions have in common is "knowledge." Science is a systematic process that builds and organizes knowledge in the form of testable, repeatable explanations and predictions about the universe.

Visual 5: Discussion Question

What are some scientific laws and theories?

Key Points

It is important that people recognize that theories DO NOT become law once they are "proven true." Laws and theories are two entirely different concepts.

Laws describe **how** an object behaves in a given circumstance and under specific conditions. Laws do not explain **why** something happens. For example, Kepler's Laws of Planetary Motion describe how the planets revolve around the Sun, but give absolutely no explanation of why they revolve around the Sun they way they do. Laws are specific and can often be described with a mathematical equation. They describe one type of thing rather than a broad range of observations.

Also highlight those responses that mention the words "truth" and "proof." Scientists do not seek truth! Nor are scientists' intent on proving things true! Proof exists in mathematics and logic because these are self-contained systems. Science deals with the world/universe/nature as it exists. Scientists seek to describe and explain the physical world using empirical evidence. The evidence may support or refute a claim; both results are equally acceptable. This empirical evidence must be substantiated through reproducible experiments or additional evidence. This testing increases the validity of the claim.

Conversely, theories try to explain why something occurs as it does. Plate tectonics explains why mountains form where they do, why volcanoes occur where they do, and why earthquakes occur along localized zones. Theories involve a mechanism or process that explains a wide range of observations. Theories NEVER become laws. Theories, like laws, are the best that we have. Theories that last are well documented with a wide range of confirming evidence that supports the process or mechanism. For example, the process of evolution was recognized in various ways long before Darwin hypothesized the mechanism by which it occurred. Darwin's ideas of natural selection explained the observations in the fossil record, and the observations in animal husbandry, and the observations of biodiversity. DNA studies provide further confirming evidence in support of evolutionary theory.

Visual 6: Science and Emergency Management

Key Points

Scientific information and scientific methods can play an important role in emergency management. Being informed and taking full advantage of scientific analysis and prediction helps communities build and sustain core capabilities that enable us to:

- Prevent
- Protect against
- Mitigate the effects of
- Respond to, and
- Recover from disasters

Prevent and Protect Against: While it is difficult to prevent natural disasters, science has enabled the formation of warning systems (e.g., for flood, severe weather, tsunami) that help prevent loss of life through evacuation strategies.

Mitigate the effects of: Science allows us to address risk by creating and enforcing building codes, defining flood plains, installing artificial and natural barriers to water hazards.

Respond to: Science has helped first responders to identify the location of victims (e.g., SR530 mudslide), identify where to send first responders after an earthquake, determine when to blow levees to protect downstream communities (e.g., 2011 Mississippi River flood).

Recover from: Scientists learn from every natural disaster more that helps us to understand better the triggers of disaster (e.g., mudslides and forest fires), the conditions that exacerbate disaster (e.g., extreme drought), and the conditions that lead to disaster (e.g., severe weather, hurricanes, tornadoes).

Visual 7: Risk

- Definition of risk: The potential for an unwanted outcome resulting from an incident, event, or occurrence, as determined by its likelihood and the associated consequences
- Risk = Threats x Vulnerabilities x Impact
- Risk Assessments (may look different for each organization)—one example of this is the THIRA, which will be discussed in 103

How can science provide facts for risk assessments?

Key Points

This is a nonmathematical construct sometimes used to describe risk with:

- Threats: the frequency of potentially adverse incidents, events, or occurrences
- Vulnerability: the likelihood of success of a particular threat
- Impact: the consequences experienced by the target from the threat

It's important to realize that valid information is important for risk assessments and that correlation does not imply causation.

For more information about correlation and causation: (https://www.khanacademy.org/math/statistics-probability/designing-studies/sampling-and-surveys/v/correlation-and-causality)

Discussion Question: How can science provide facts for risk assessments?

Visual 8: Validity and Credibility

When using scientific facts or resources, you must consider:

- Validity of the original study
- Credibility of the reporting source

Key Points

Not all sources (models, maps, etc.) are equal, so as Emergency Managers you must be mindful of the validity and credibility of a source/resource when gathering scientific information. The popular press and public view is that to be "fair," an article must report both sides. This is a fallacy for scientific writing, which only passes on facts that meet a statistical level of validity. It is important to realize that in fact-based reporting, both sides are not always valid.

Validity:

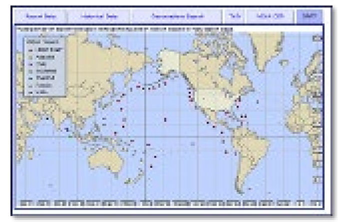
- Who paid for/sponsored the study?
- Was the study large enough to pass statistical muster?
- Was it designed well?
- Did it last long enough?
- Were there any other possible explanations for the conclusions of the study, or reasons to doubt the findings?
- Do the conclusions fit with other scientific evidence? If not, why?
- Do you have the full picture?
- Have the findings been checked by other experts (i.e., peer-reviewed)?
- What are the implications of the research? Any potential problems or applications?

Credibility:

- Type: What kind of content is this?
- Source: Who and what are the sources cited and why should I believe them?
- Evidence: What’s the evidence and how was it vetted?
- Interpretation: Is the main point of the piece proven by the evidence?
- Completeness: What’s missing?
- Knowledge: Am I learning every day what I need?

Visual 9: Scientific Methods

What are some observations, models, predictions, and forecasts that you find valuable?



Key Points

Discussion Question: What are some observations, models, predictions, and forecasts that you find valuable?

Scientists use many methods, instruments, and technologies to observe, measure, and predict hazards and disasters. These activities are fundamental to understanding hazards and helping to make society safer. Some of the scientific methods used include:

- **Scientific observations:** The collection of data through seismometers, satellites, samples, estimations, measurements, and numerous other technologies is essential to understanding past and current disasters and predicting future disasters.
  - **Examples:** USGS Lidar Maps for landslide information; USGS Hydrology for streamflow and flood conditions; USGS Volcano and Earthquake monitoring and alerts
- **Scientific models:** Scientists create models to make sense of their measurements and observations, to extend them to areas where no observations exist, and to make forecasts about the future.
  - **Examples:** USGS & NWS Flood Prediction Models; USGS ShakeMaps
- **Hazard predictions:** A prediction is a specific, testable statement that identifies a particular outcome at a certain time. To be able to make a prediction, scientists need enough data and sufficient understanding of the natural process to recognize patterns and figure out what will happen next. As you will see, in the vast majority of situations it is not realistic for scientists to issue predictions per se. In most cases, scientists instead issue forecasts.
  - **Examples:** National Weather Service (NWS) Severe Weather
- **Forecasts:** Scientists routinely issue forecasts regarding potentially hazardous events—forecasts that may cover short or long timeframes. A forecast is a definitive statement or statistical estimate of the likelihood of occurrence of a future event or conditions for a specific area. Unlike predictions, forecasts involve uncertainty about each of the components

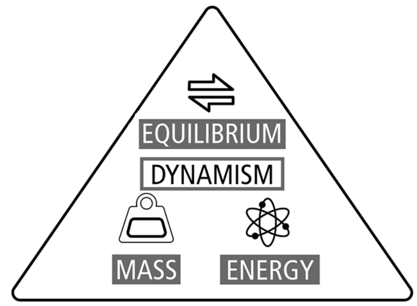
of a prediction—location, size, and timing—and typically communicate some degree of uncertainty about whether the event will happen at all. ◦

- **Examples:** USGS Volcano Alert, USGS Post-Fire Debris Flow Hazard, USGS Earthquake Hazard Forecasts, NWS Hurricane Tracker

- **Advisories and Warnings:** Short-term forecasts may take the form of advisories or warnings. The style, frequency, and terminology of these warnings differ from hazard to hazard, as do the levels of uncertainty. We will see how each of these methods is applied to a particular hazard or disaster as we continue through the course. You will find that while there are great difficulties involved in all of these methods (particularly in forecasting and prediction), the methods contribute enormously to understanding and preparing for disasters.

Visual 10: Principles: Equality, Dynamism, Mass, and Energy

- Equilibrium
- Dynamism
- Mass
- Energy



Key Points

Throughout this course you will notice images with a combination of the icons in the triangle. They are shown to quickly identify topics that relate to that principle. Here are what they mean:

- **Equilibrium** – Everything in nature wants to be equal. Pressures, temperatures, densities – all aspects of our natural environment will mix to equalize as they come into contact with each other.
- **Dynamism** – We live in a dynamic (or changing) environment. We have adapted to thrive in change within certain parameters but change outside of those parameters can be the definition of a disaster.
- **Mass** – All objects have mass. Gravity is the force of attraction between two objects due to their mass. The more massive the object, the stronger the pull.
- **Energy** – The transfer of energy through our environmental systems is a fundamental aspect of the environmental and physical sciences.

Terms:

- Force – A push or a pull on an object due to an interaction.
    - Gravity is a force which causes smaller objects to be attracted to larger ones, such as with the Earth attracting everything from people, to rocks, to water.
- Mass – A property of all matter determined by the type of matter (what it’s made of) and the size of the object (physical dimensions). A mass will be the same for a certain object everywhere in the universe (gold is gold, iron is iron, etc.).
    - Mass and weight are related through gravity. The Earth’s gravitational pull on a mass is called the object’s weight. The more mass (matter) an object has, the more it will weigh. Thus 100 kilograms of mass (a rock, a person, a refrigerator, etc.) will weigh 220 pounds on Earth but 100 kilograms of mass (same object) will weigh 33 pounds on the Moon since it has less gravity. (This is mixing units, but the concept is correct)
- Energy – The amount of word that a force can do.

    - Energy comes in many forms and can be transferred from place to place. For example, heat energy will flow from hot things to cold. Energy can also be stored as potential energy and be released at a later time.
- Equilibrium – An object or a system is in a state of balance or rest due to the equal action of opposing forces is said to be in equilibrium.
    - Equilibrium exists when no forces, or opposing forces act equally and thus no change is produced. When unequal, there will be a net force which will cause a change.
- Dynamism – A state of change or activity due to unequal forces or energy imbalances which cause change.

Visual 11: Unit Summary

You should now be able to:

- Recognize how science supports risk.
- Understand risk and how it applies to emergency management.
- Identify the validity and credibility of science.

Key Points

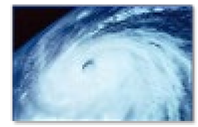
Do you have any questions about the material covered in this unit?

Your Notes

Unit 3: Severe Storms, Tornadoes, and Hurricanes

Visual 1: Unit 3: Severe Storms, Tornadoes, and Hurricanes

Unit 3: Severe Storms, Tornadoes, and Hurricanes


Key Points

Welcome to Unit 3: Severe Storms, Tornadoes, and Hurricanes.

Key Points

This unit consists of the following topics:

Unit	Time
Atmospheric Science Overview • Activity 3.1 – Back-to-Back La Niñas • Activity 3.2 – In Your Community	1 hour 25 minutes
Convective Storms • Activity 3.3 – 2011 Joplin, MO Case Study	1 hour 35 minutes
Tropical Cyclones • Activity 3.4 – New D-FIRM Maps	1 hour 35 minutes
Total Module Time:	**4 hours 35 minutes**

Visual 2: Climate vs. Weather

Climate:

- Long term
- Atmospheric conditions for 30 years or more

Weather:

- Short term
- Atmospheric conditions for minutes to months

Key Points

The difference between climate and weather is essentially one of time.

Climate: Climate describes long-term (i.e., 30 years or more) trends and patterns of weather.

Climatology is the study of the sum total of the meteorological elements that characterize the average and extreme condition of the atmosphere over a long period of time at any one place or region of the Earth's surface; or, the collective state of the atmosphere at a given place or over a given area within a specified period of time.

Understanding climatology provides the basis for future climate expectations and enables planning by assisting in long-term prediction.

Weather: Weather, on the other hand, describes the conditions of the atmosphere over a much shorter period of time (i.e., minutes to months).

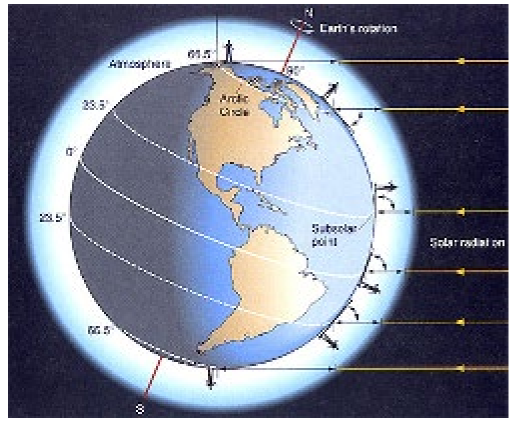
Meteorology is the science dealing with the atmosphere and its phenomena, which sounds quite similar to climatology. The distinction is that climatology is primarily concerned with average, not actual, weather conditions.

Forecast accuracy has increased significantly over the past 30 years due to advances in multiple areas, including:

- Scientific understanding of weather processes
- Instruments (such as satellites and radar) for observing the atmosphere
- Computer model sophistication – for example, as a result of scientific advances, the 3-to-4-day forecasts are now as accurate as the 2-day forecast was in 1985, The average tornado warning lead times have increased from 5 minutes to 13 minutes.
- Training for forecasters

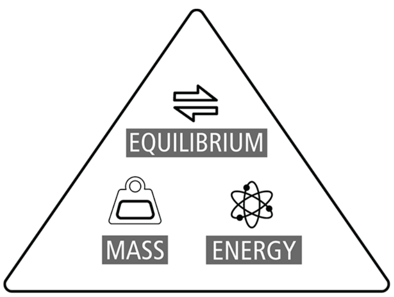
Familiarity with the science of weather can improve decision-making in areas related to hazardous weather. The major limitation is that the science behind weather does not provide all of the answers. Weather is a complicated combination of factors, and conditions can change quickly.

Visual 3: Sun and Earth Effects



- Uneven heating
- Atmosphere
- Gravity
- Planet's structure

This is equilibrium, mass, and energy.



Student Manual

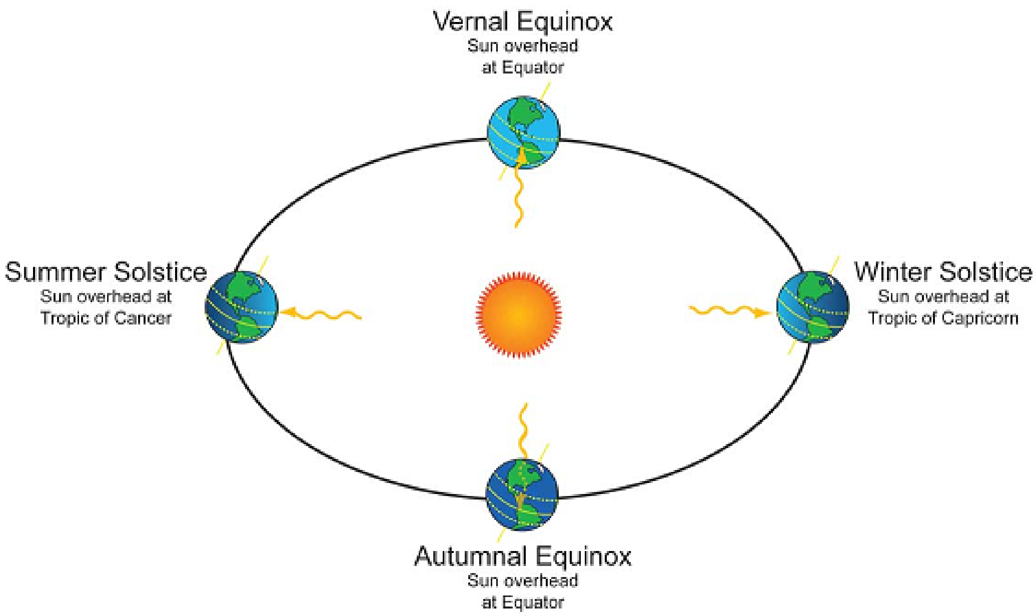
Throughout the course, you will encounter these icons present for several topics.

Key Points

On a global scale, weather is influenced by effects of the Sun and Earth.

- **Uneven heating:** The weather on our planet largely results from the sun heating areas of the planet unequally. This unequal distribution occurs because of:
    - **Tilt, rotation, and orbit:** The Earth's axis is tilted 23.5 degrees. The Earth rotates on its axis every 24 hours, creating day and night. It revolves around the sun on an elliptical path, creating our seasons as it completes its yearly journey.

- As the Earth moves around the Sun, the concentration of sunlight shifts to be either more or less concentrated in the northern hemisphere depending on where the earth is relative to the Sun.



Alt Text of image above: A diagram illustrating the Vernal Equinox – Sun overhead at Equator, Winter Solstice – Sun overhead at Tropic of Capricorn, Autumnal Equinox – Sun overhead at Equator, and Summer Solstice – Sun overhead at Topic of Cancer. A graphic of a globe showing the Earth's rotation, solar radiation, subsolar point, and atmosphere.

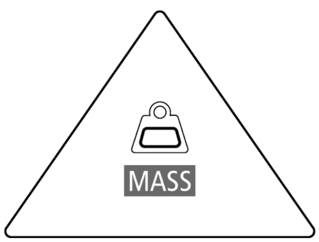
- **Day/night temperature differences:** The sun's radiation reaches only half the planet (the "daylight" side) at any one time. Half the Earth is heating up during the day while the other half, the night side, is cooling down. Sunlight that is striking the planet during the day heats up the Earth's surface-both land and water.
- **Spherical shape:** The amount of radiation reaching the surface varies at different places. Because the Earth is almost a perfect sphere, the sunlight is more concentrated in some areas (e.g., at the equator) and less concentrated in others (the polar regions). This differential heating, along with the rotation of the Earth, creates moving weather.
- **The planet's atmosphere:** The Earth's atmosphere is the layer of gas that surrounds the Earth and is held to the Earth by gravity. The atmosphere is a fluid that moves and circulates because of differences in temperature and pressure.
- **The structure of the planet:** The basic structure of the planet-landforms, oceans and other bodies of water, mountains, deserts, vegetation, and even urban areas-is also important in determining weather.

The oceans are particularly important because they provide much of the water that evaporates into the atmosphere.

Visual 4: Effects of Gravity

How do you think gravity impacts natural hazards?

This is mass.



Key Points

This is mass. We all have gravitational pull, but ours are trivial compared to those of the Earth, the Sun, and the Moon.

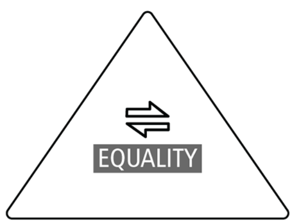
Examples of Gravity in Natural Hazards:

- On the Earth's surface, a plate will subduct beneath another plate because the Earth's gravitational force has a stronger pull on denser rock than on less dense rock.
- In a convection cell inside the Earth, cooler material sinks and hot material rises for the same reason—the cooler material is denser and pulled more strongly.
- On the Earth's surface, water runs downhill because of gravity, eroding mountains and triggering landslides, which also move downhill because of gravity.
- The Moon's gravitational pull affects ocean tides, including those of storm surges.

Visual 5: Atmospheric Factors

- Temperature
- Pressure
- Winds
- Moisture

This is equality.



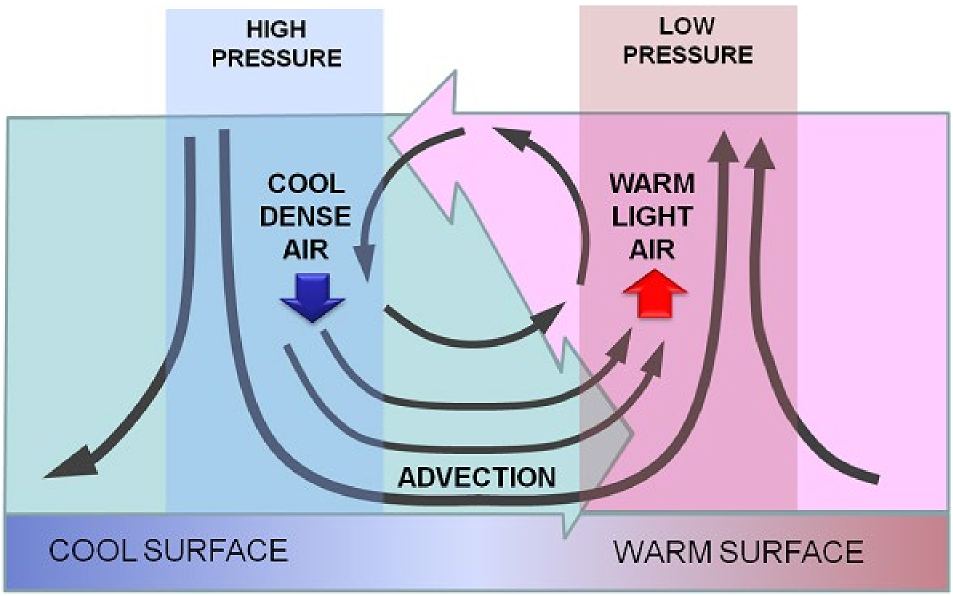
Key Points

Atmospheric factors that affect weather include:

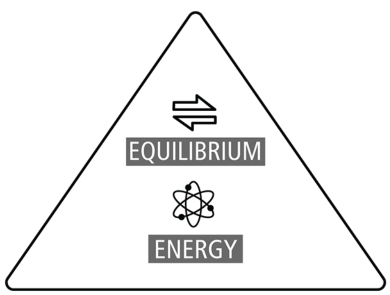
- **Temperature:** Temperature is a measure of heat describing the molecular energy of an object. As the atmosphere heats up or cools down, its density changes. Warm air expands and rises, cool air contracts and sinks. Variations in temperature both on a daily and seasonal basis cause the circulation of the atmosphere as the molecules move to equalize the planet's temperature. Of course, temperatures never actually equalize because of the planet's shape and continual rotation and revolution.
- **Pressure:** Air pressure is the weight of the atmosphere pushing down at a given location. Because air is a gas composed of particles (e.g., water vapor), it is affected by the Earth's gravity.
- **Winds:** The same processes that try to equalize temperature differences over the globe also try to balance the pressure differences between denser and lighter air. These processes create winds that blow from areas with higher pressure to those with lower pressure.

- **Moisture:** While water vapor is not the most abundant gas in the atmosphere, it is very important in terms of weather. In addition to forming liquid and solid particles in clouds that fall as rain or snow, the process of changing from the gaseous state into liquid water or ice releases large amounts of heat that serve as an energy source for weather systems, particularly thunderstorms and hurricanes.

Visual 6: Convection



This is equilibrium and energy.



Key Points

Temperature differences cause pressure differences in the atmosphere. Air that is warmer and moister relative to its surroundings becomes buoyant and rises. Air that is colder and drier is heavier and descends.

Since surface pressure is a measure of the weight of the column of air above, a column of warm, moist air has lower surface pressure. Likewise, a column of cold, dry air results in higher surface pressure.

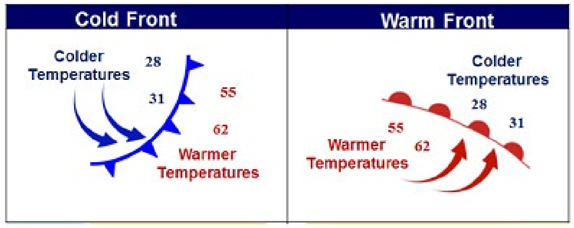
These differences in temperature and pressure cause the atmosphere to circulate:

- When descending air encounters the Earth's surface it spreads out, away from the center of high pressure. The air moves across the earth surface through advection, heating up and collecting moisture. **(Advection** is the transport of an atmospheric property by the wind.)
- As the air becomes warm and moist, it ascends toward the upper atmosphere.
- As the warm moist air rises, it becomes unsettled as it cools and condenses, producing clouds and rain.

It is important to realize that at the Earth's surface, air moves away from regions of high pressure and toward regions of low pressure.

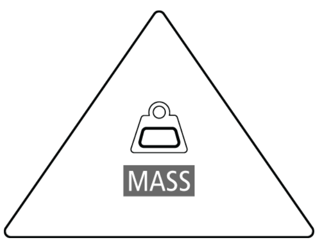
Visual 7: Other Large-Scale Factors

- Air masses
- Fronts
- Mechanism of lift
- Topography



Mass Icon

This is mass.



Key Points

As in the global scale, temperature, pressure, and moisture are crucial in creating weather. In addition, the following factors are important:

- **Air masses:** If a body of air moves slowly or stays over an extensive area that has fairly uniform temperature and moisture characteristics, the air takes on those characteristics and is called an air mass.
- **Fronts:** As air masses move out of the area in which they form, they come in contact with other air masses with different characteristics. The boundaries between different air masses are called fronts.
  - A cold front is the leading edge of an advancing cold air mass.
  - The edge of an advancing warm air mass is a warm front.

    - Stationary fronts occur when a front stops moving and neither air mass replaces the other.
- **Mechanism of lift:** Most hazardous weather conditions require some sort of mechanism for lifting air. These mechanisms include:
    - Air rising in areas of low pressure.
    - Fronts acting like a wedge to lift air.
    - Air encountering upslopes of mountains, which forces the air upward, resulting in lift.
- **Topography:** In addition to creating lift, topography can also affect temperatures. For example, large paved surfaces in urban areas heat and cool at different rates than vegetated areas—a temperature change that translates to local changes in pressure.

Visual 8: Cold Fronts

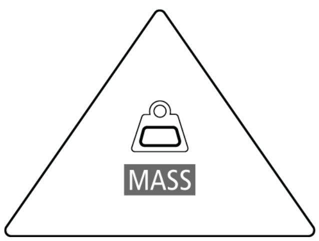
Cold Fronts Video Description

Video description: The clouds form—above the front edge of the front.

This is mass.

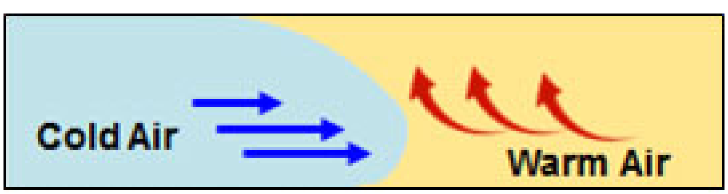
Cold front: At the surface, the front marks where cold air overtakes and replaces warmer air. As the cold air moves in, the cold air mass creates lift as the retreating warm air rises. Notice how the cold front creates lift and changes in the weather.

This is mass.



Key Points

Cold front: At the surface, the front marks where cold air overtakes and replaces warmer air. As the cold air moves in, the cold air mass creates lift as the retreating warm air rises. Notice how the cold front creates lift and changes in the weather.



Concerns with cold fronts:

- When the warm moist air is pushed rapidly into the upper atmosphere, the conditions become very unstable.
- During summer, cold fronts typically create a squall line of thunderstorms just in front of the advancing front.
- Cold fronts can easily produce large thunderstorms with lightning, hail, and tornadoes.

- A large amount of rainfall could occur in a short period of time, leading to flooding.
- You should expect a temperature change to colder conditions as the front passes.
- In cold weather, cold fronts produce hazardous winter conditions.
- Because the slope of the cold air mass is steep, temperature, pressure, and weather tend to change dramatically near the front.

Visual 9: Warm Fronts

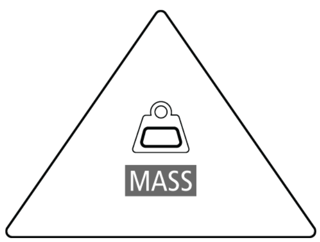
Warm Fronts Video Description

Video description: The clouds form—ahead of the surface front.

This is mass.

Warm front: At the frontal boundary, warmer air overtakes and replaces colder air. As the warm air moves in, it lifts over the wedge of cold air.

This is mass.



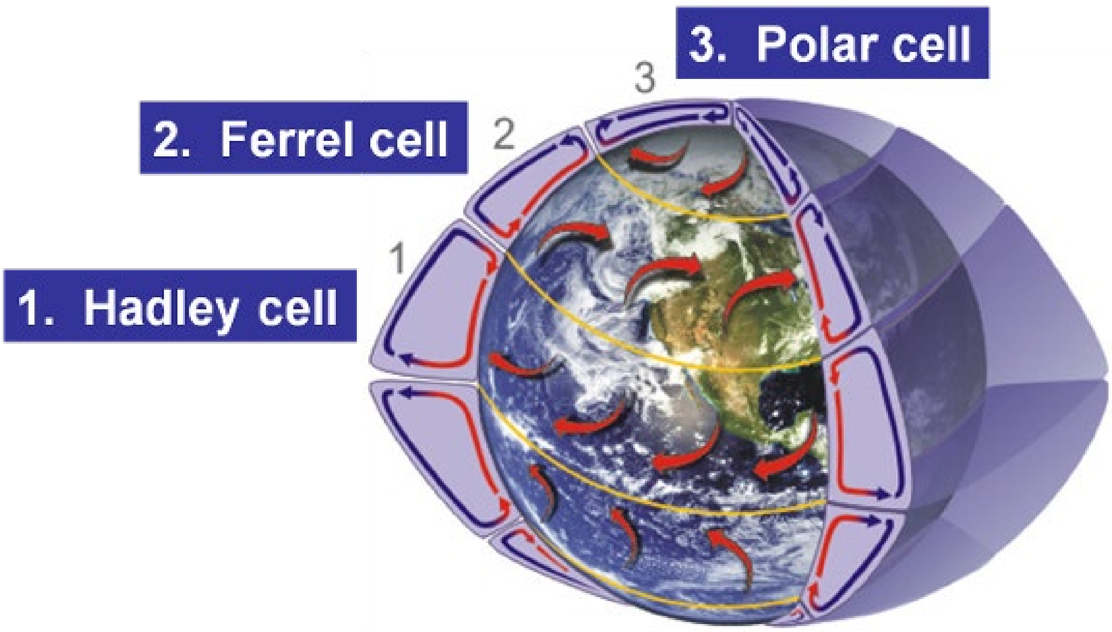
Key Points

Warm front: At the frontal boundary, warmer air overtakes and replaces colder air. As the warm air moves in, it lifts over the wedge of cold air.

Concerns with warm fronts:

- Warm fronts occur when warm, moist air is slowly pushed up over a cooler air mass.
- The results are rain or snow showers ahead of the warm front. Large, heavy rain or snow could fall during this time.
- The effects of a warm front sweep all the way around the north side of the low pressure. Notice the slope of the warm air mass is relatively gentle. Consequently, warm fronts are seldom as distinct on the surface as cold fronts, and they usually move much more slowly.

Visual 10: Global Circulations



Key Points

As you can see, the climate in your area is a function of your location on the planet, topography, proximity to water bodies, etc. But climate can also be affected by long-term global patterns like jet streams, trade winds, and El Nino or La Nina. Take a closer look at what atmospheric patterns factor into climate, particularly on the global scale.

Climate is greatly affected by three large-scale, semi-permanent **global circulations** of air (convective cells) that result from the rotation of the Earth, its axis, and the distribution of land mass in the two hemispheres.

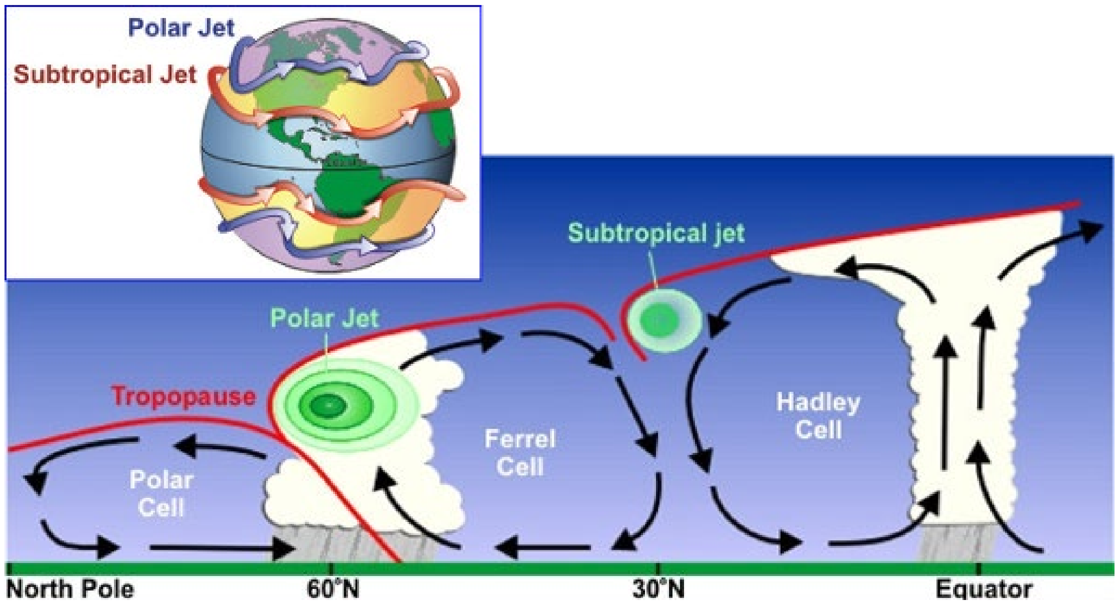
1. **Hadley cell:** In this low-latitude circulation, the movement of air toward the equator rises vertically with heating, resulting in a convection cell that dominates tropical and subtropical climates.
2. **Ferrel cell:** In this mid-latitude atmospheric circulation cell, the air flows poleward and eastward near the surface, and equatorward and westward at higher levels.
3. **Polar cell:** Here the air rises, diverges, and travels toward the poles, resulting in easterly surface winds (polar easterlies).

High-pressure bands exist between these cells at about 30 N/S latitude and at each pole. This high pressure often results in fair and dry/hot weather (e.g., desert conditions around 30 N/S).

Low-pressure bands exist around the equator and 50-60 N/S. In contrast, the low-pressure bands tend to result in higher precipitation rates due to increased storm formation (especially on the west coasts of continents).

Visual 11: Jet Streams

Jet Streams (This link can also be accessed at the following URL: https://www.weather.gov/jetstream/jet)



Key Points

The Earth's rotation is also responsible for the jet stream, another key factor in climate.

Jet stream definition: A jet stream consists of relatively strong winds concentrated in a narrow stream in the atmosphere, normally referring to horizontal, high-altitude winds. Jet streams move and behave like rivers but consist of air blowing from west to east.

Temperature and pressure differences: At the same latitudes mentioned on the previous page (30 N/S and 50-60 N/S) there are great temperature differences as well as pressure differences, resulting in an increase in wind strength in the upper atmosphere.

At 50-60 N/S, there is a jet stream known as the **polar jet.** At 30 N/S, there is a jet stream known as the **subtropical jet.** These jet streams can be 4 to 8 miles high and reach speeds of over 200 mph.

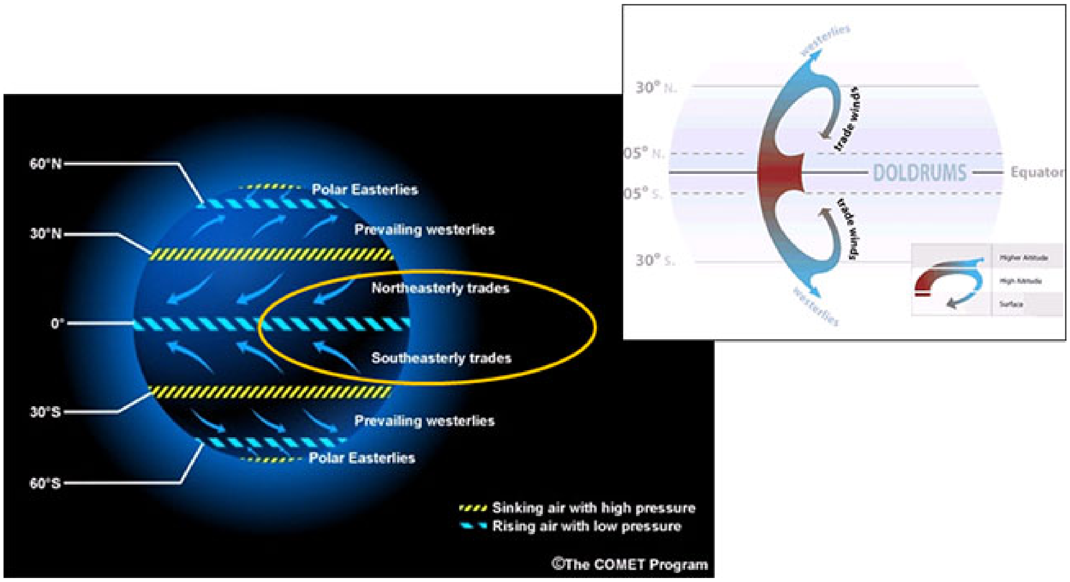
Jet stream movement: The position and orientation of jet streams vary from day to day. General weather patterns (hot/cold, wet/dry) are closely related to the position, strength, and orientation of the jet stream(s).

As seasons change and the atmosphere fluctuates, the jet streams dip and rise, move and meander, and even briefly disappear and reappear; but they always have a major effect on climate.

Visual 12: How Jet Streams Affect United States' Climate

- Temperature
- Tracks of Hazardous storms
- Precipitation levels

Visual 13: Trade Winds



Key Points

The area where the trade winds converge and force air up into the atmosphere was originally labeled "the doldrums" by early sailors, who were well aware of the weak winds and heavy precipitation to be found there. This area-—known now as the Intertropical Convergence Zone (ITCZ)—is essentially a steady band of clouds encircling the globe between the northeast and southeast trade winds near the equator, resulting in frequent showers and thunderstorms. Like the jet streams, the ITCZ follows the sun and has a position that varies seasonally; in the northern summer it moves north, and in the northern winter it moves south.

Another key factor in understanding climate is the movement of the trade winds. The trade winds:

- Are the wind systems, occupying most of the Tropics, that blow from the subtropical ridges of high pressure toward the equator.
- Are major components of the general circulation of the atmosphere.
- Are northeasterly in the Northern Hemisphere and southeasterly in the Southern Hemisphere; hence they are known as the **northeast trades** and **southeast trades,** respectively. The remaining air in both hemispheres (i.e., westerly winds or westerlies) travels toward the poles.
- Have an enormous effect on moisture, temperature, and precipitation patterns, and therefore on climate.

Trade Winds (Continued) -

Trade winds affect climate in some notable ways.

- They can steer hurricanes and other storm systems in the Tropics. However, if the trade winds are weakened, storm movement is less predictable.
- If there is an increase in the strength of trade winds, they can move surface ocean waters, prompting the rising of deep, colder waters below ("**cold upwelling**"). This affects ocean temperatures and therefore global weather patterns.

Visual 14: Video: El Niño, July 2009

This animation, made using data from NOAA satellites, illustrates the onset of an El Niño event in July of 2009.

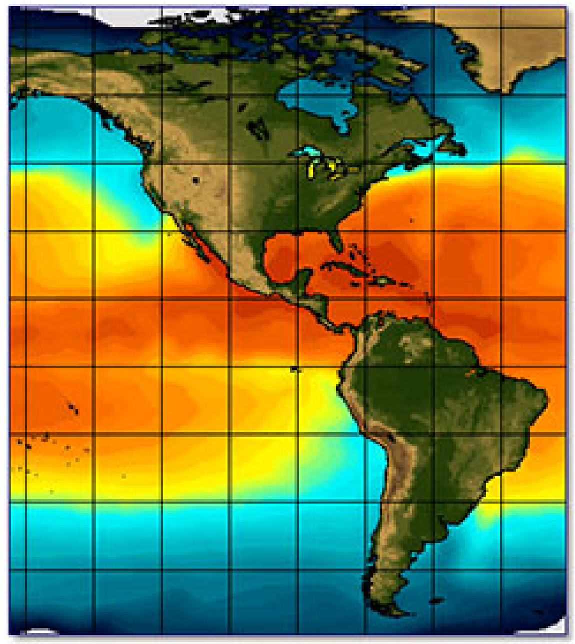
Key Points

The next part of the unit will focus on El Niño and La Niña. This animation, made using data from NOAA satellites, illustrates the onset of an El Niño event in July of 2009.

Discussion Question: What do you notice?

Visual 15: El Niño Characteristics

- Large-scale ocean-atmospheric phenomenon
- Increases Pacific Ocean temperatures
- Occurs every 3-to-7 years
- Lasts 9-to-12 months
- Affects weather globally



Key Points

Definition: El Niño constitutes the warm phase of what is called the El Niño/Southern Oscillation (ENSO) cycle. (La Niña is the cool phase of the same cycle.) The ENSO cycle consists of yearly variations in the equatorial Pacific Ocean in:

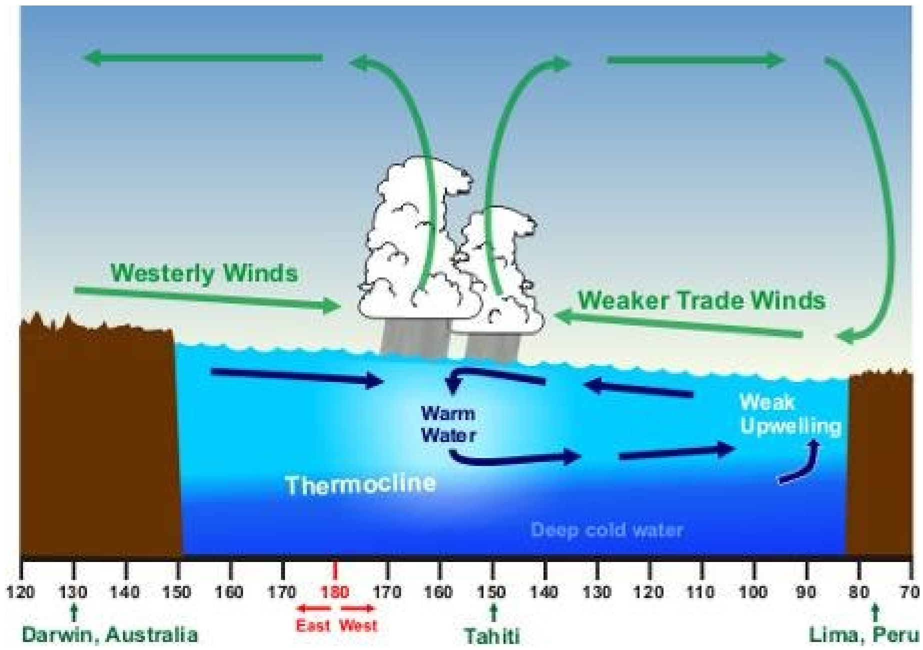
- Sea-surface temperatures
- Convective rainfall
- Surface air pressure
- Atmospheric circulation

Seasonal outlooks are based on El Niño and La Niña.

El Niño:

- Is associated with a warming of the ocean current along the coasts of Peru and Ecuador
- Is generally associated with dramatic changes in the weather patterns of the region and with changes in weather patterns worldwide
- Generally occurs every 3-to-7 years
- Tends to develop between March and June and is typically much stronger during the winter months
- Tends to last for 9 to 12 months

Visual 16: What Causes El Niño?



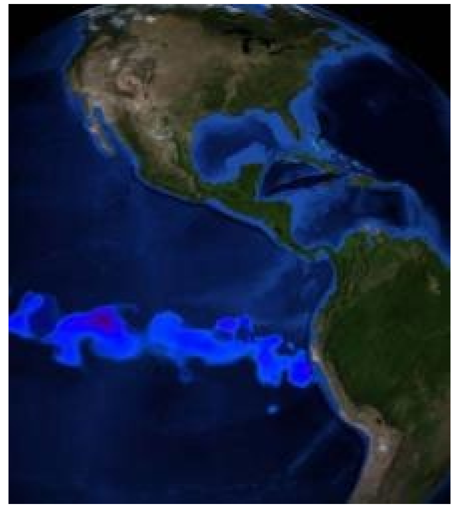
Key Points

El Niño naturally results from the interactions between the ocean surface and the atmosphere in the tropical Pacific Ocean. The process that leads to El Niño is illustrated in this diagram. In short:

- The trade winds calm and weaken, affecting ocean circulation across the Pacific.
- This results in weak upwelling (i.e., less upward movement of deeper, colder ocean water to replace surface waters) and an increase in sea-surface temperatures.
- This impacts precipitation, wind patterns, and eventually global weather.

Although the immediate cause of El Niño (weakening trade winds) is known, and scientists have made great progress in studying El Niño, the precise nature and origin of its repetitive cycle remains somewhat of a mystery.

Visual 17: La Niña Characteristics



- Large-scale, ocean-atmospheric phenomenon
- Decreases Pacific Ocean temperatures
- Lasts 1 to 3 years
- Affects weather globally

Key Points

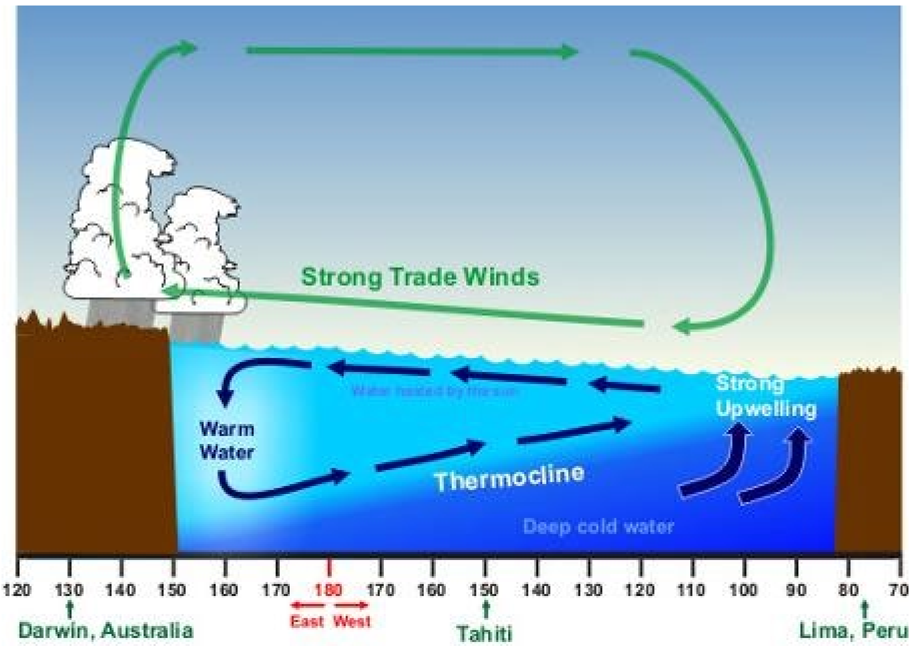
La Niña is another large-scale, ocean-atmospheric climate phenomenon (the cool phase of the ENSO cycle), sometimes referred to as a Pacific cold episode.

Definition: The preliminary Climate Prediction Center (CPC) definition of La Niña is a phenomenon in the equatorial Pacific Ocean characterized by a negative sea surface temperature departure from normal.

La Niña:

- Is a periodic cooling of surface ocean waters in the eastern tropical Pacific along with a shift in convection in the western Pacific further west than the climatological average.
- Affects weather patterns around the world.
- May last 1 to 3 years.
- Tends to develop between March and June.
- Is typically much stronger during the winter months.

Visual 18: What Causes La Niña?

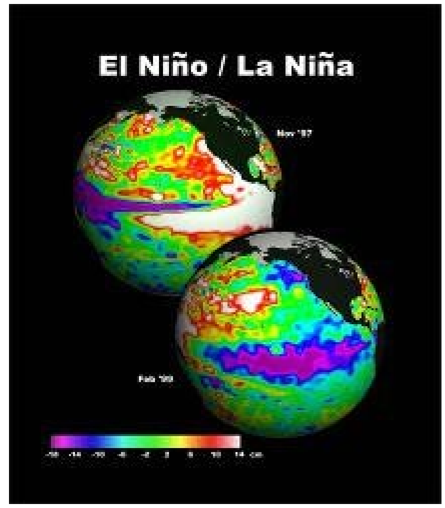


Key Points

Like El Niño, La Niña naturally results from the interactions between the ocean surface and the atmosphere in the tropical Pacific Ocean. The difference is that it begins with the trade winds strengthening, rather than weakening. In short:

- The trade winds strengthen, affecting ocean circulation across the Pacific.
- This results in strong upwelling (i.e., more upward movement of deeper, colder ocean water to replace surface waters) and a decrease in sea-surface temperatures.
- This affects precipitation, wind patterns, and, eventually, global weather.

Visual 19: El Niño /La Niña Relationship



- Episodes alternate in an irregular cycle
- A La Niña does not always follow El Niño
- Gap between periods is called “ENSO-neutral” (ENSO= El Nino South Oscillation)

Key Points

The image portrays ocean temperature levels during two more moderate El Niño (1997) and La Niña (1999) events.

These two phenomena—which are the main sources of climate variability in many areas of the world—tend to alternate in an irregular cycle. For example, a La Niña episode does not always follow an El Niño episode.

There is also a gap between El Niño periods and La Niña periods called “neutral” or “ENSO-neutral.” In these periods, neither El Niño nor La Niña is present, and ocean temperatures, precipitation patterns, and atmospheric circulation around the equatorial Pacific are close to the long-term averages.

The major El Niño and La Niña events from the past 300 years are as follows:

El Niño	La Niña
1789-93	
1876-78	
1891	
1925-26	
	1954-56

El Niño	La Niña
1972-73	
1973-76	
1982-83	
	1988-89
1997-98	
2010	2010
	2020

Visual 20: Winter Impacts on the U.S.

El Niño

- Warmer temperatures in the NW
- Cooler temperatures in the SE and SW
- Drier climate in the North, with less snowfall
- Wetter climate in the South and in California

La Niña

- Warmer temperatures in the SE
- Cooler temperatures in the NW
- Drier climate in the SW and SE
- Wetter climate in the NW

Key Points

El Niño has several notable climatological impacts on the United States. During the winter season of El Niño years, temperatures are warmer than normal in the Northwest and North Central States and cooler than normal in Southeast and Southwest. The climate is drier in the North and wetter and stormier in the South and in California. These changes can result in the following weather hazards:

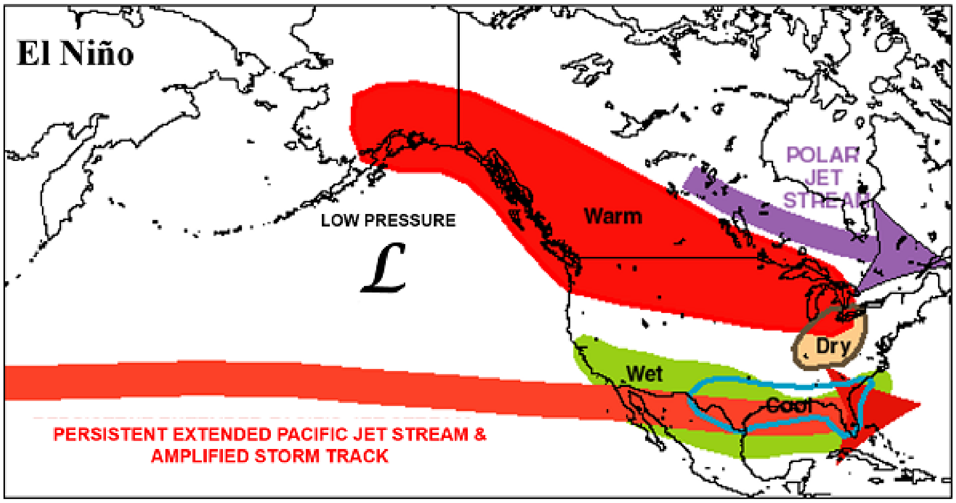
- Droughts in the Northwest.
- Severe flooding or coastal flooding in the South.
- Ice storms in the South.
- Severe weather in the Great Lakes area.
- Severe weather over the northern Gulf of Mexico and northern Florida. This is due to the shift of the Pacific jet stream, as a strong jet stream is a key ingredient in producing severe weather like tornadoes.

It is important to note, however, that **it would be inaccurate to label a hurricane, tropical storm, winter storm, drought, or flood strictly as an El Niño event**. El Niño simply alters or enhances certain climate patterns (e.g., the jet streams) and affects the track of storms and their intensity.

La Niña also has climatological impacts on the United States. During the late fall and winter seasons of La Niña years, there are generally:

- Warmer than normal temperatures in the Southeast.
- Cooler than normal temperatures in the Northwest.
- Drier climates in the Southwest and the Southeast.
- Wetter and stormier climates in the Northwest.

Visual 21: El Niño: Typical Winter Impact



Key Points

This graph illustrates the typical January - March impacts on the United States during a moderate to strong El Niño. Note that:

- There is a strong, persistent jet stream and storm track across the South.
- The North has warmer, milder conditions.

These impacts result from four major changes:

- An extension of the East Asian jet stream eastward into the southwestern United States.
- Above average west-to-east flow of jet stream winds across the country.
- A shift of the storm track southward, moving from the northern to the southern part of the United States.
- A shift of the main region of cyclone formation to the southeast, just west of the coast of California.

For more about how El Niño and La Niña affect precipitation and temperature during the winter visit How El Niño and La Niña affect the winter jet stream and U.S. climate. (This link can also be accessed at the following URL: https://www.climate.gov/news-features/featured-images/how-el-ni%C3%B1o-and-la-ni%C3%B1a-affect-winter-jet-stream-and-us-climate).

El Niño—winter vs. summer: Notice how differently El Niño affects the globe in winter months (December to February) and summer months (June to August). The regions with the greatest precipitation and temperature impacts due to shifts in the jet stream are highlighted with color.

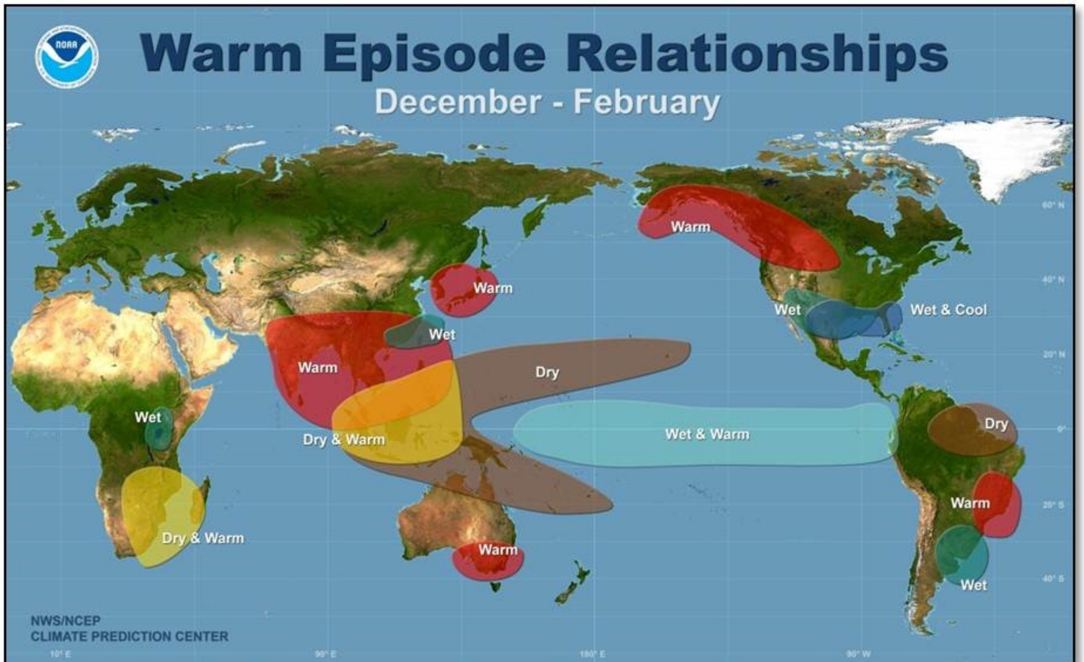
In the summer months, only one small area in the Northwest tends to experience unusually high precipitation. Other than this increase (and the typical heightened tendency for hurricanes to hit), most of the United States is unlikely to suffer any drastic impacts of El Niño during the summer months.

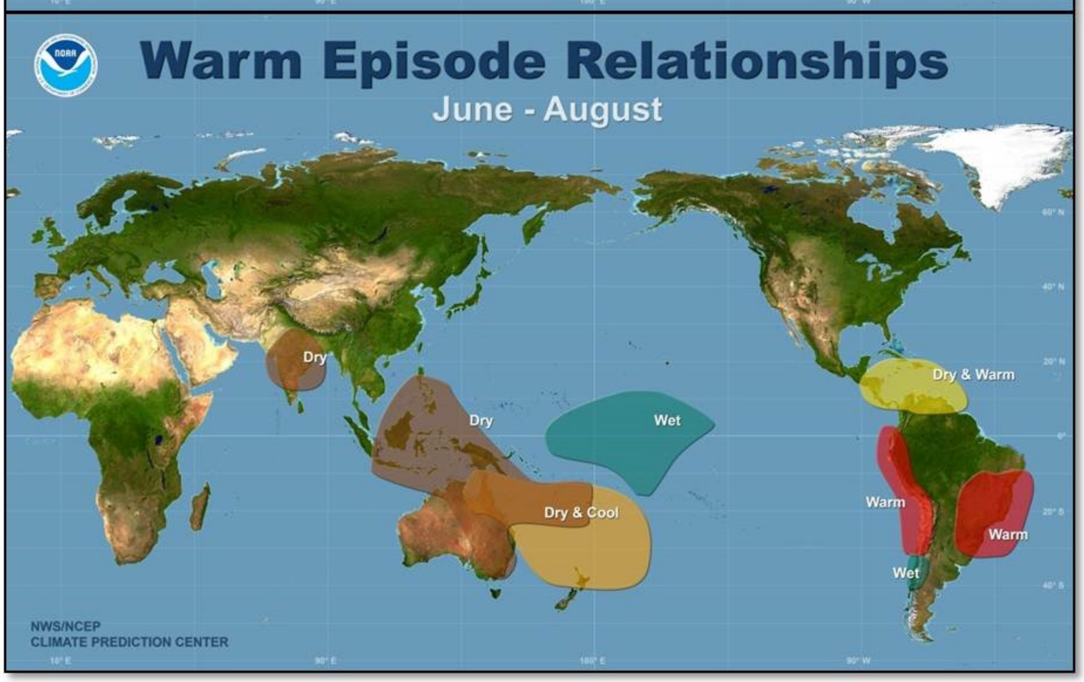
Remember, **El Niño tends to develop between March and June, and it is typically much stronger during the winter months.** This is because the equatorial Pacific sea-surface temperatures are usually at their warmest this time of the year.

El Niño—Winter vs. Summer

The maps below show how differently El Niño affects the globe in winter months (December to February) and summer months (June to August). The regions with the greatest precipitation and temperature impacts due to shifts in the jet stream are highlighted with color.

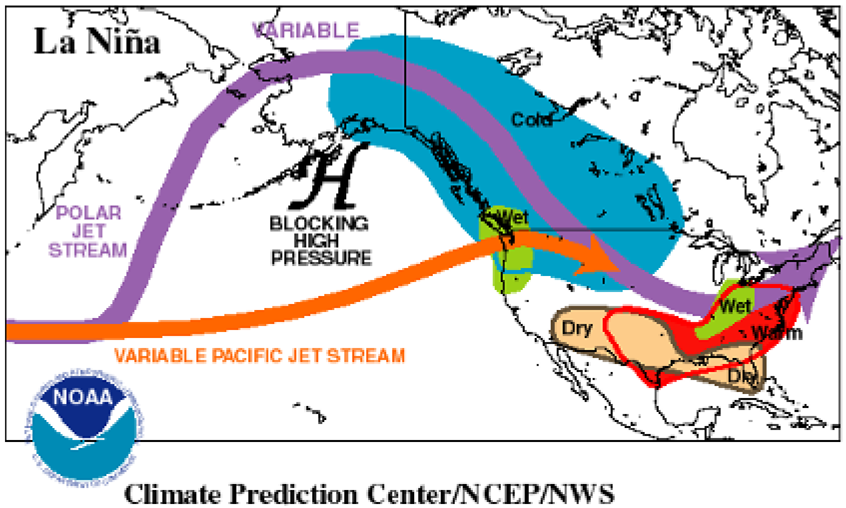
In the summer months, only one small area in the Northwest tends to experience unusually high precipitation. Other than this increase (and the typical heightened tendency for hurricanes to hit), most of the United States is unlikely to suffer any drastic impacts of El Niño during the summer months.





High Resolution Images can be found at:
http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ENSO/ENSO-Global-Impacts/

Visual 22: La Niña: Typical Winter Impact



Key Points

This graph illustrates the typical January - March impacts on the United States during a moderate to strong La Niña. Note that there is a very wavy jet stream flowing over the United States as well as Canada. This generally results in stormier than average conditions in the northern part of the country, and warmer and less stormy conditions in the southern part.

This impact results from three major changes in atmospheric flow:

- An amplification of the mean wave pattern and increased meridional flow across the continent and the eastern North Pacific.
- Increased blocking activity (Black H - "Blocking High Pressure") over the high latitudes of the eastern North Pacific. (High pressure systems are a bit like the "bullies" of weather-they are big, and push everything else around, including weather systems and even jet streams.)
- The variability of the Pacific jet stream (orange line), with an average jet position that enters North America in the northwestern United States or southwestern Canada.

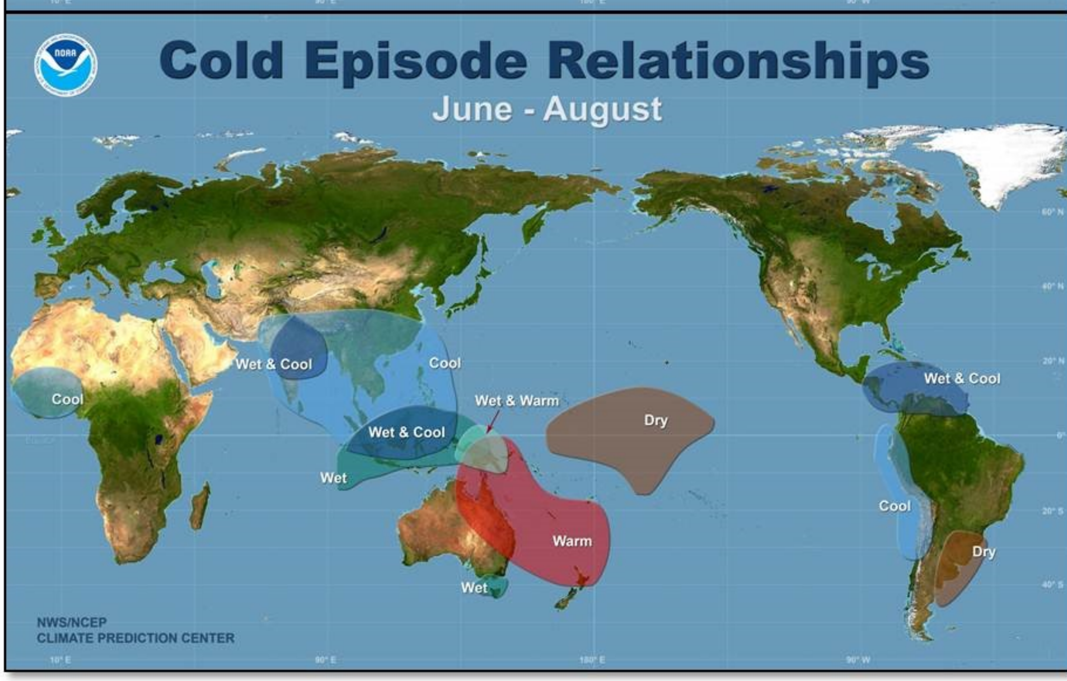
Notice how differently La Niña affects the globe in the winter months (December to February) and the summer months (June to August). The regions with the greatest precipitation and temperature impacts due to shifts in the jet stream are highlighted with color.

Like El Niño, most of the United States is unlikely to suffer any drastic impacts of La Niña during the summer months (again, other than the typical heightened tendency for hurricanes to hit).

La Niña—Winter vs. Summer

The maps below show how differently La Niña affects the globe in the winter months (December to February) and the summer months (June to August). The regions with the greatest precipitation and temperature impacts due to shifts in the jet stream are highlighted with color.

Like El Niño, most of the United States is unlikely to suffer any drastic impacts of La Niña during the summer months (again, other than the typical heightened tendency for hurricanes to hit).



High Resolution Images can be found at:
http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ENSO/ENSO-Global-Impacts/

Visual 23: Activity 3.1 – Back-to-Back La Niñas

Instructions: Working as a team:

1. Review the case study about back-to-back La Niña events at the start and end of 2011 in the Student Manual
2. Discuss the questions and record the answers on your easel
3. Be prepared to present your answers to the class

Instructions: Working as a team:

1. Review the case study about back-to-back La Niña events at the start and end of 2011 in the Student Manual.
2. Discuss the questions and record the answers on your easel.
3. Be prepared to present your answers to the class.

Case Study: El Niño and La Niña don't always follow each other; occasionally, there are back-to-back El Niño episodes or back-to-back La Niña episodes. It is July and you have received a briefing from your regional National Weather Service meteorologist. You are aware that last year there was a La Niña episode and now current models predict that there will be another episode beginning this fall.

The 12 billion-dollar disaster of 2011 in the U.S. caused $200 billion in damages:

- **Texas, New Mexico, Arizona Wildfires, spring- fall:** 1 million acres in Texas were burned during this year's record wildfire season.
    - The Bastrop Fire in Texas was the most destructive fire in Texas history, destroying more than 1,500 homes.
    - The Wallow Fire consumed more than 500,000 acres in Arizona, making it the largest on record in Arizona.
    - The Las Conchas Fire in New Mexico was also the state's largest wildfire on record, scorching more than 150,000 acres while threatening the Los Alamos National Laboratory.
    - More than 3-million acres have burned across Texas during that wildfire season. Total damage in Texas alone due to loss of property, timber, and agriculture exceeds $750 million. Losses for wildfire activity across all three states exceeds $1 billion.
- **Midwest/Southeast Tornadoes and Severe Weather, June 18–22:** An estimated 81 tornadoes struck across Oklahoma, Texas, Kansas, Nebraska, Missouri, Iowa, and Illinois. Additional wind and hail damage occurred across Tennessee, Georgia, North Carolina and South Carolina. The storms caused more than $1 billion in insured losses, and total losses were greater than $1.3 billion.
- **Hurricane Irene, August 20–29:** Irene first struck the United States as a Category 1 hurricane in eastern North Carolina, then moved northward along the Mid-Atlantic coast. Wind damage in coastal North Carolina, Virginia, and Maryland was moderate, with considerable damage resulting from falling trees and power lines. Irene made its final landfall as a tropical storm in the New York City area and dropped torrential rainfall in the Northeast that caused widespread flooding. More than 7 million homes and businesses lost power during the storm, and Irene caused at least 45 deaths and more than $7.3 billion in damages.

- **Upper-Midwest flooding, summer:** Melting of an above-average snowpack across the northern Rocky Mountains, combined with above-average precipitation, caused the Missouri and Souris rivers to swell beyond their banks across the Upper Midwest. An estimated 11,000 people were forced to evacuate Minot, North Dakota because of the record-high level of the Souris River. Numerous levees were breached along the Missouri River, flooding thousands of acres of farmland. The flooding, which is ongoing, has caused more than $2 billion in damages.
- **Mississippi River flooding, spring-summer:** Persistent rainfall nearly tripled the normal precipitation amounts in the Ohio Valley, and, combined with melting snowpack, caused historical flooding along the Mississippi River and its tributaries. The region suffered $2-to-$4-billion in losses.
- **Southern Plains/Southwest drought, heat wave and wildfires, spring-summer:** Drought, heat waves and wildfires scorched through Texas, Oklahoma, New Mexico, Arizona, southern Kansas, western Arkansas, and Louisiana this year. In Texas and Oklahoma, respectively, 75% and 63% of range and pasture conditions were classified as "very poor" as of mid-August. Wildfire-fighting costs for the region are about $1 million per day. Well over $5 billion in damage has occurred so far, with more than 2,000 homes and structures lost.
- **Midwest/Southeast tornadoes, May 22–27:** Central and southern states saw approximately 180 twisters and 177 deaths within a week. A tornado rated EF-5 on the tornado-damage scale struck Joplin, Missouri, resulting in at least 141 deaths, making it the deadliest single tornado to strike the United States since modern tornado record keeping began in 1950. The total losses were greater than $7 billion, and an estimated $3 billion was needed to rebuild Joplin, which made it the single-costliest tornado in United States history.
- **Southeast/Ohio Valley/Midwest tornadoes, April 25–30:** This outbreak of tornadoes over central and southern states led to 327 deaths. Of those fatalities, 240 occurred in Alabama. The deadliest of the estimated 305 tornadoes in the outbreak was an EF-5 that hit northern Alabama, killing 78 people. Several major metropolitan areas were directly affected by strong tornadoes, including Tuscaloosa, Birmingham, and Huntsville in Alabama, and Chattanooga, Tennessee. Total losses exceeded $9 billion.
- **Midwest/Southeast tornadoes, April 14–16:** An outbreak over central and southern states produced an estimated 160 tornadoes. Despite the large overall number of tornadoes, few were classified as intense, with just 14 EF-3, and no EF-4 or EF-5, tornadoes identified. Total losses were greater than $2 billion. Thirty-eight people died, 22 of them in North Carolina.
- **Southeast/Midwest tornadoes, April 8–11:** An outbreak of tornadoes over central and southern states saw an estimated 59 tornadoes. Total losses were greater than $2.2 billion.
- **Midwest/Southeast tornadoes, April 4–5:** An outbreak of tornadoes over central and southern states saw an estimated 46 tornadoes. Total losses were greater than $2.3 billion. Nine people died.
- **Groundhog Day blizzard, Jan. 29–Feb. 3:** A large winter storm hit many central, eastern, and northeastern states. Chicago was brought to a virtual standstill when 1-to-2

feet of snow fell across the city. Total losses were greater than $2 billion, and the storm killed 36 people.

Additionally:

- 3 million residents lost power during an unseasonably early nor'easter storm from October 29–31.
- 19 tropical storms formed in the Atlantic during this year, the third-busiest season on record.

Some events in other countries that resulted from back-to-back La Niñas included:

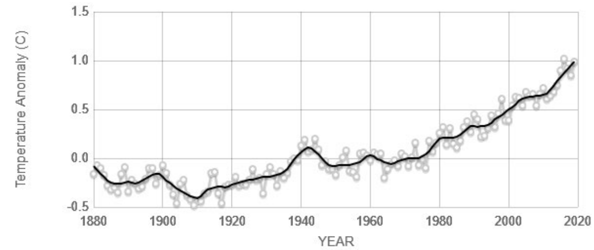
- Historic droughts in East Africa and Northern Mexico
- The wettest 2-year period (2010–2011) in Australia's history, relieving a decade-long dry spell
- The coolest year for the globe on record (2011) since 2008. (However, temperatures remained above the 30-year average because of climate change.)

Activity 3.1 Worksheet

1. What do you think are some of the “expected side effects” of the La Niña associated weather events in your region?

Visual 24: Long-Term Trends

- Long-term shift in weather statistics deviating from expected averages
- Change Indicators (See key points for indicator examples)



Graph Description:

This graph illustrates the change in global surface temperature relative to 1951-1980 average temperatures. Nineteen of the 20 warmest years all have occurred since 2001, with the exception of 1998. The year 2016 ranks as the warmest on record (source: NASA/GISS) This link can be viewed at https://data.giss.nasa.gov/gistemp/graphs/graph_data/Global_Mean_Estimates_based_on_Land_and_Ocean_Data/graph.txt. This research is broadly consistent with similar constructions prepared by the Climatic Research Unit (This link can be viewed at http://www.cru.uea.ac.uk/) and the National Oceanic and Atmospheric Administration (This link can be viewed at http://www.noaa.gov/.

Key Points

Change Indicators include:

- Weather and Climate
  - U.S. and Global Temperature
  - Drought
  - Oceans
- Sea Surface Temperature
- Sea Level ◦Ocean Acidity
- Snow and Ice
  - Sea Ice
  - Glaciers
  - Society and Ecosystems
  - Flora and Fauna Movement
  - Heat-Related Deaths

Another major factor in climate variability is climate change. Climate change is broadly defined as a long-term shift in weather statistics that deviates from expected averages. Scientists have determined that we are, in fact, in a period of climate change; the last few decades have been the warmest period on record (i.e., since the mid-19th century).

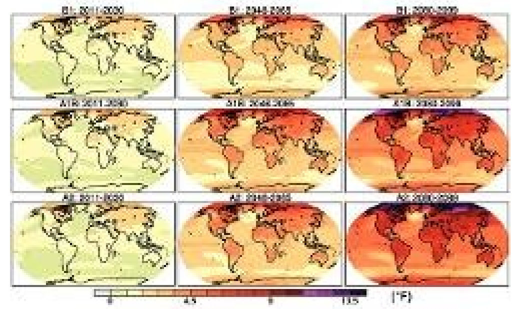
This climate change ("global warming") is signaled by these change indicators:

- **Natural variability:** Climate change is a naturally occurring phenomenon that is related to complex interactions between the oceans, the atmosphere, and land masses, as well as changes in the amount of solar radiation.
- **Greenhouse Gases:** The greenhouse effect was first identified and studied in the early 1800s. Scientists observed that certain gases in the atmosphere such as water vapor, carbon dioxide, and methane absorbed natural long wavelength radiation emitted from the Earth. This process effectively warms the Earth above the temperature we would expect simply from our distance from the sun. The greater the abundance of greenhouse gasses, such as carbon dioxide and methane, in the atmosphere, the greater the degree of warming on the planet. The current level of CO2 in the atmosphere is the highest in 650,000 years. The Intergovernmental Panel on Climate Change (IPCC) concluded in 2007 that "most of the observed increase in the globally averaged temperature since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations."
- **Sea Level is Rising**: Global mean sea level has been rising at an average rate of approximately 1.7 mm/year over the past 100 years. Since 1993, global sea level has risen at an accelerating rate of around 3.5 mm/year." (This link can also be accessed at the following URL: http://www.ncdc.noaa.gov/indicators/) Sea level rises for two reasons: (1) Water expands as it heats up. As the oceans warm, their volume will increase and take up more space. More than half of the sea level rise is a result of the oceans warming. (2) Sea level rises because ice caps on continents melt. As more continental ice sheets melt, more water goes into the oceans. Melting sea ice does not cause sea level to rise.

Note: The record of global average temperatures was compiled by NASA's Goddard Institute for Space Studies. The "zero" on this graph corresponds to the mean temperature from 1961 to 1990, as directed by the Intergovernmental Panel of Climate Change (IPCC).

Visual 25: Key Global Projections

- Higher average temperatures (at least twice the increase by 2100 as in the last 100 years).
- Increased average annual precipitation and intensity of precipitation events.
- Stronger winds associated with tropical storms.
- Reduced ice and snow cover.
- Rise in sea level.
- Increased acidity of oceans.



Key Points

Based on their study of the 26 indicators, scientists project higher average temperatures, increased amount and intensity of precipitation, and other changes. Below are some key projections for the United States:

Temperature

- By 2100, the average U.S. temperature is projected to increase by about 4F to 11F, depending on emissions scenario and climate model.
- An increase in average temperatures worldwide implies more frequent and intense extreme heat events, or heat waves. The number of days with high temperatures above 90F is expected to increase throughout the United States, especially in areas that already experience heat waves.

Precipitation

- Northern areas are projected to become wetter, especially in the winter and spring. Southern areas, especially in the West, are projected to become drier.
- Heavy precipitation events will likely be more frequent. Heavy downpours that currently occur about once every 20 years are projected to occur about every 4 to 15 years by 2100, depending on location.
- More precipitation is expected to fall as rain rather than snow, particularly in some northern areas.
- The intensity of Atlantic hurricanes is likely to increase as the ocean warms. Climate models project that for each 1.8F increase in tropical sea surface temperatures the rainfall rates of hurricanes could increase by 6-18% and the wind speeds of the strongest hurricanes could increase by about 1-8%.
- Cold-season storm tracks are expected to continue to shift northward. The strongest cold-season storms are projected to become stronger and more frequent.

Sea Level Change

Regional and local factors will influence future relative sea level rise for specific coastlines around the world. For example, relative sea level rise depends on land elevation changes that occur as a result of subsidence (sinking) or uplift (rising). Assuming that these historical geological forces continue, a 2-foot rise in global sea level by 2100 would result in the following relative sea level rise:

- 2.3 feet at New York City
- 2.9 feet at Hampton Roads, Virginia
- 3.5 feet at Galveston, Texas
- 1 foot at Neah Bay in Washington State

Relative sea level rise also depends on local changes in currents, winds, salinity, and water temperatures, as well as proximity to thinning ice sheets.

Visual 26: Convective Storm Definitions

- **Convection:** Vertical transport of heat and moisture in the atmosphere
- **Thunderstorm:** A storm with thunder, lightning, often strong winds and heavy rain,
  and sometimes hail.
- **Severe thunderstorm:** Storm that
  produces 1-inch diameter hail,
  and/or winds of 58 mph or greater,
  and/or a tornado.

Key Points

Convection: As seen earlier, convection refers to transport of heat and moisture by the movement of a fluid. In meteorology, the term is used specifically to describe vertical transport of heat and moisture in the atmosphere, especially by updrafts and downdrafts in an unstable atmosphere. Although the terms "convection" and "thunderstorms" are often used interchangeably, thunderstorms are only one weather phenomenon that involves convection. (Source: NOAA)

If the mid to upper atmosphere is cool (more dense) while the lower atmosphere is warm or moist (less dense), then the lower atmosphere becomes buoyant and unstable and begins to rise, initiating convection. This process of convection can be the result of a combination of factors, including:

- Daytime heating (the afternoon is a peak time for thunderstorms because this is when the ground is warmest).
- Topography (e.g., if moving air hits a mountain, it is forced upward).
- The lifting of warm air over cold air along a front.

Thunderstorm: A thunderstorm is defined as a storm with thunder, lightning, often strong winds and heavy rain, and sometimes hail.

A **severe thunderstorm** is defined as a thunderstorm that produces any one or more of the following conditions: 1-inch diameter hail (the size of a quarter), winds of 58 mph or greater, and/or a tornado. Severe thunderstorms can also produce heavy rain, and flash floods. They have strong vertical wind shear.

Visual 27: Impact on Emergency Managers

So What Does That Mean for Emergency Managers?

-
    - Risk Management
-
    - Mitigation
-
    - Worse Case Scenarios

Visual 28: Activity 3.2 – In Your Community

Instructions: Take this home with you to do with your community.

1. Answer the questions in your IAW

Visual 29: Ingredients for Thunderstorms

- Moisture
- Unstable air
- Source of lift

Key Points

The three ingredients necessary for thunderstorm formation are:

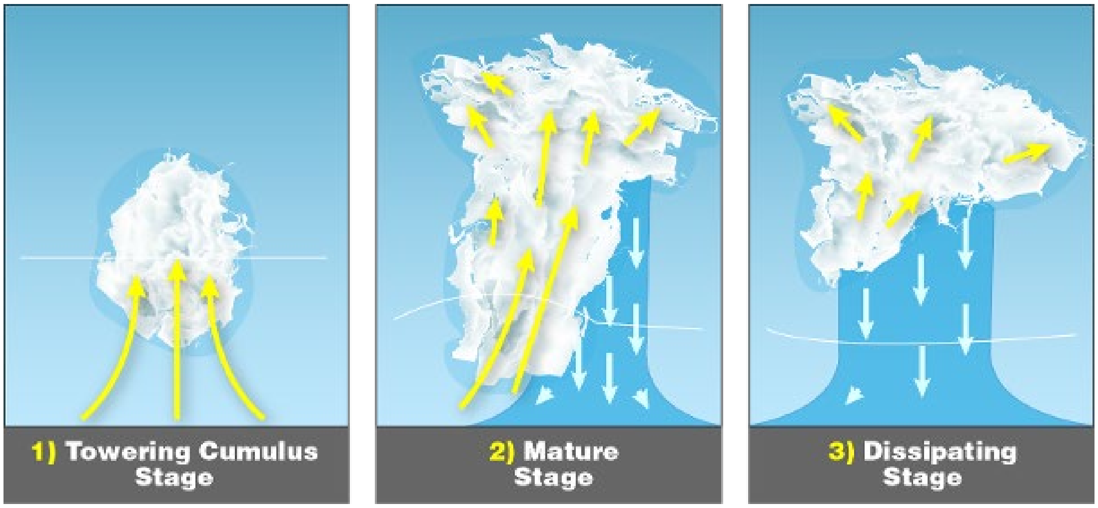
- Moisture (e.g., water vapor from the Atlantic, Pacific, Gulf of Mexico, or Great Lakes).
- Unstable air (i.e., an environment in which warm, rising air can maintain upward motion).
- A source of lift (e.g., cold fronts, warm fronts, gust fronts, sea breezes, or lake breezes).

In short: Thunderstorms require warm, humid air rising in an unstable environment.

As discussed in the previous unit, a cold front is the leading edge of an advancing cold air mass. At the surface, these fronts mark where cold air overtakes and replaces warmer air.

During the summer, cold fronts often initiate thunderstorms. (In cold weather, they produce hazardous winter conditions.)

Visual 30: Lifecycle of Thunderstorms



Key Points

This diagram illustrates the three stages of thunderstorm development:

- **Stage 1: Towering Cumulus Stage or Developing Stage.** Stage 1 consists entirely of updraft-a small-scale current of rising air. In this stage, clouds have a puffy, cauliflower appearance. There is no rain yet.
- **Stage 2: Mature Stage.** Stage 2 consists of both updraft and downdraft. In this stage, a flat cloud formation resembling an anvil forms at the top of the storm, but parts of the cloud are still distinct. The characteristic anvil shape results from warm air being unable to rise any further, and spreading out laterally. Severe weather occurs in this stage.

  Strong downdrafts may result in downbursts (outward burst of damaging winds on or near the ground) or microbursts (strong, concentrated downbursts). Downburst winds can produce damage similar to a strong tornado. Although usually associated with thunderstorms, downbursts can occur with showers too weak to produce thunder.
- **Stage 3: Dissipating Stage.** Stage 3 consists entirely of downdraft-a small-scale column of air that rapidly sinks toward the ground. In this stage, the whole cloud begins to dissipate and appears "fuzzy." This stage occurs when the storm no longer has enough warm air rising to sustain it, and begins to die out.

Visual 31: Lightning

- Is a discharge of electricity in a mature thunderstorm.
- Is initiated by the attraction of positive and negative charges.
- Can heat air up to 70,000 degrees F in a few milliseconds.
- Can strike in different ways.
- Causes thunder.

Key Points

Lightning characteristics: Lightning:

- Is a discharge of electricity in a mature thunderstorm.
- Is initiated by the attraction of positive and negative charges. When the electrical potential builds up to overcome resistance of the air in the atmosphere, lightning will occur.
- Can strike in different ways, including:
    - Within a cloud
    - From cloud to cloud
    - From cloud to surrounding air
    - From cloud to ground
- Creates thunder.

Lightning dangers: Lightning is a serious danger, and strikes the United States an estimated 20 million times a year. You can be struck by lightning even if you are away from the thunderstorm; if you are close enough to hear the thunder, you are close enough to be struck by lightning. Lightning can strike up to 10 miles from a storm.

- In the United States, lightning kills an average of 54 people every year.
- In 2011, there were 26 fatalities in 18 States and Guam.
- Hundreds more are permanently injured every year.

People struck by lightning suffer from a variety of long-term, debilitating symptoms, including:

- Memory loss.
- Attention deficits.
- Sleep disorders.
- Chronic pain.
- Dizziness.
- Stiffness in joints.
- Irritability.
- Fatigue.
- Muscle spasms.

- Depression.

Thunder: Even though lightning only has a diameter of 1-2 inches (2-5 cm), it can heat air up to 70,000 degrees F (39,000 degrees C) in just a few milliseconds. This sudden and drastic increase in temperature causes the surrounding air to expand violently at a rate faster than the speed of sound. This results in a shock wave that-after extending 30 feet-becomes an ordinary sound wave, or thunder.

How close is the storm? Light from lightning travels at the speed of 186,000 miles per second. Sound travels at a much slower rate-only about 1 mile every 5 seconds. This explains why the light from lightning reaches us before the sound of thunder.

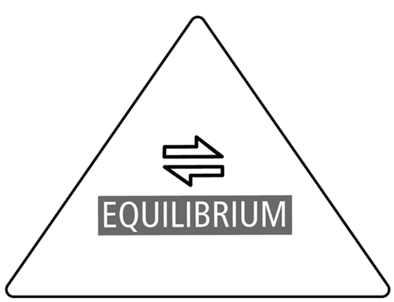
Knowing this information, you can use a "trick" to estimate how close a storm is to you.

1. Count the number of seconds it takes between the time you see a lightning flash and before you hear the thunder.
2. Each 5 seconds counted equals one mile. For example, if you count 15 seconds, the flash was 3 miles away. Anything under 6 miles is still in the high danger zone.

Visual 32: Other Windstorms—Haboobs

- A desert phenomenon created when a thunderstorm collapses and the wind direction changes from updraft to downdraft
- The downdraft (cold air) hits the ground and picks up dust, creating a sediment wall that precedes the storm cloud.
- They occur in the Middle East, North Africa, Australia, and North America
    - Primarily seen in Arizona, New Mexico, eastern California, and Texas in the U.S.

This is equilibrium.



Key Points

- Occasionally seen in eastern Washington and northern Idaho.
- May also be seen in agricultural areas experiencing extreme drought – such as during the Dust Bowl.
- Also known as “sandstorms” or “dust storms.”
- The dust wall can be 62 mi wide and several miles high. The winds can travel 22-62 mph.
- They can approach with little to no warning.
- Rain may or may not appear at ground level.
  - “Dry” ones are called virgas
  - Severe wet ones may be called mud storms
- Moving to shelter is highly recommended.
  - If you must go outside, eye and respiratory protection is advisable.
- NWS may issue a Dust Storm Warning or a Blowing Dust Advisory
  - Since 2018 the National Weather Service issues Polygon-based (i.e., on a map) Dust Storm Advisories/Warnings. A WEA Cellphone alert is issued whenever a Dust Storm Warning is issued, but it is not issued with a Dust Storm advisory. The criteria are:
    - **Blowing Dust Advisory**: Long duration event of widespread or localized blowing dust reducing visibilities to one mile or less, but greater than 1/4 mile.
    - **Dust Storm Warning**: A sudden drop in visibility to 1/4 mile or less, resulting in widespread or localized blowing dust.

Visual 33: Directional Wind Shear

- Is the change in wind direction with height.
- Results from different layers of the atmosphere.
- Can spawn tornadoes.

Key Points

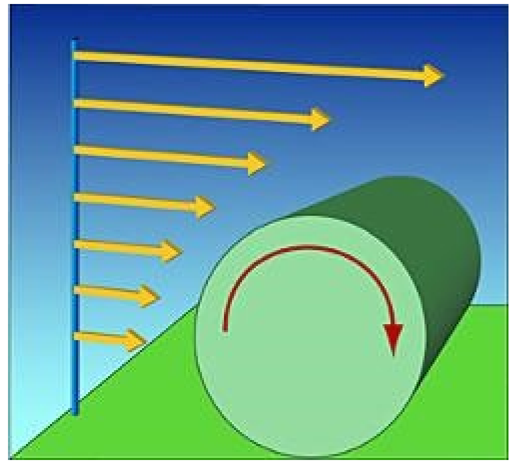
Next we will look at some key components of thunderstorms, including wind shear, speed shear, lightning, and thunder.

- **Wind shear:**
  - Is the rate at which wind velocity changes from point to point in a given direction.
  - Can be speed shear (where speed changes between the two points, but not direction), direction shear (where direction changes between the two points, but not speed), or a combination of the two.
- **Directional wind shear** is the change in wind direction with height resulting from the different layers of the atmosphere.

  For example, say that the image on the visual is looking north. The wind near the surface is blowing to the northwest. However, as the elevation increases, the direction veers (changes direction in a clock-wise motion), changing to south, then southwest, and finally west. This illustrates the danger that directional wind shear can pose for aircrafts, particularly during landing or takeoff.
- **Vertical directional wind** shear-which is a rising, twisting motion-can result in wind rotation, and even spawn a tornado. In fact, because wind shear can make a roaring sound, it is often confused with a tornado.

Visual 34: Other Wind Storms—Shear

- Is the change in wind speed with height.
- Can increase or decrease with height.
- Can occur in any season and in any environment.
- Can contribute to the formation of mesocyclones.



Key Points

Speed shear is the change in wind speed with height.

Speed shear can also decrease with height, resulting in stronger winds at the surface, and can occur in any season, and in any environment.

The image on the visual illustrates how, with an increase in height, there is an increase in wind speed. This tends to create a rolling affect to the atmosphere, and is believed to be a key component in the formation of mesocyclones.

- A **mesocyclone** is a vortex of air, approximately 2 to 50 miles in diameter within a convective storm. Mesocyclones are most often associated with a localized low-pressure region within a severe thunderstorm. Such thunderstorms can feature strong surface winds and severe hail. Mesocyclones often occur together with updrafts in supercells, where tornadoes may form.
- Mesocyclones are believed to form when strong changes of wind speed and/or wind shear set parts of the lower part of the atmosphere spinning in invisible tube-like rolls. The convective updraft of a thunderstorm then draws up this spinning air, tilting the rolls' orientation upward (from parallel to the ground to perpendicular) and causing the entire updraft to rotate as a vertical column.

Key Points

Derechos

A derecho (pronounced similar to "deh-REY-cho" is a widespread, long-lived wind storm. Derechos are associated with bands of rapidly moving showers or thunderstorms variously known as bow echoes, squall lines, or quasi-linear convective systems.

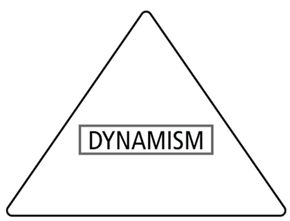
Although a derecho can produce destruction similar to that of a tornado, the damage typically occurs in one direction along a relatively straight path. As a result, the term "straight-line wind damage" sometimes is used to describe derecho damage. By definition, if the swath of wind damage extends for more than 250 miles (about 400 kilometers), includes wind gusts of at least 58 mph (93 km/h) along most of its length, and also includes several, well-separated 75 mph (121 km/h) or greater gusts, then the event may be classified as a derecho.

Source: NOAA Storm Prediction Center (https://www.spc.noaa.gov/misc/AbtDerechos/derechofacts.htm)

Visual 35: Tornadoes (1 of 2)

- **Tornado** - In contact with the ground
- **Funnel cloud** - Not in contact with the ground
- **Waterspout** - Over water

This is dynamism.



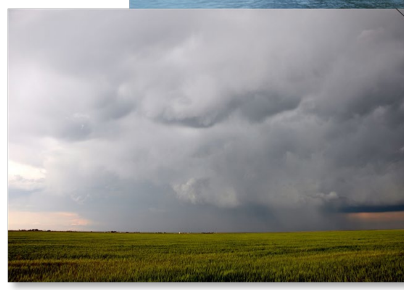
Key Points

A rotating updraft-the result of wind shear-is the key to the development of a tornado, and it is this rotation or spinning that creates the well-known funnel shape. Rotating winds include tornadoes, funnel clouds, and waterspouts.

- A **tornado** is a rapidly rotating column of air that comes in contact with the ground. These columns of air are by-products or side effects of severe thunderstorms.
- A **funnel cloud** is slightly different than a tornado, in that it is a rapidly rotating column of air that is not in contact with the ground.
- **Waterspouts** are tornadoes that form over water.

Visual 36: Tornadoes (2 of 2)

- **Supercell thunderstorm** - Has a deep, steadily rotating updraft
- **Squall line** - A line of closely spaced and usually severe thunderstorms
- **Tornadic activity** - Loosely refers to conditions that are likely to spawn, is spawning, or has spawn tornadoes
- **Tornado outbreak** - Loosely refers to a number of tornadoes that occurred during a single weather event



Key Points

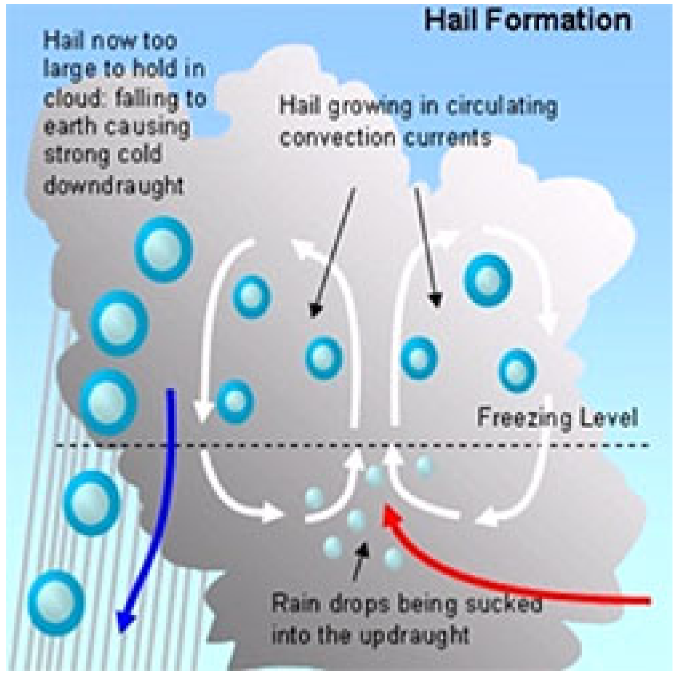
Other terms you will hear associated with the severe thunderstorms that cause tornadoes include the following:

- **Supercell thunderstorm** is a thunderstorm that has a deep, steadily rotating updraft, or a "mesocyclone," which can reach speeds of over 100 miles per hour. These thunderstorms can produce extremely large hail, extreme winds, flash flooding, and violent tornadoes; in fact, almost all major tornadoes in the United States result from supercell thunderstorms.
- **Squall line** is a line of closely spaced and usually severe thunderstorms. Squall lines often occur along or ahead of a cold front and can spawn tornadoes. Squall lines usually advance rapidly into a warm moist air mass, which then feeds into the updrafts of the oncoming thunderstorms and maintains them. If a squall line slows or stalls, it usually weakens because it does not have a new supply of warm moist air.
- **Tornadic activity** is a loosely defined expression that refers to conditions that are likely to spawn tornadoes and also to the tornadoes that are presently occurring, or have already occurred. Note that in some cases, tornadoes are not visible because they have not picked up debris.
- **Tornado outbreak** is another loosely defined term that refers to a number of tornadoes that occurred during a single weather event. A single supercell thunderstorm can produce more than one tornado, but most of the tornadoes in an outbreak occur from separate thunderstorms, often from a line of such storms that constitute a squall line.

Visual 37: Hail

Two conditions are required for hail to develop:

- Sufficiently strong and persistent up-draft velocities
- An accumulation of liquid water in a super-cooled state in the upper storm parts



Key Points

Studies of thunderstorms indicate that two conditions are required for hail to develop: sufficiently strong and persistent up-draft velocities and an accumulation of liquid water in a super-cooled state in the upper parts of the storm. Hailstones are formed as water vapor in the warm surface layer rises quickly into the cold upper atmosphere. The water vapor is frozen and begins to fall; as the water falls, it accumulates more water vapor. This cycle continues until there is too much weight for the updraft to support and the frozen water falls too quickly to the ground to melt along the way.

Hail may be spherical, conical, or irregular in shape and can range in size from barely visible in size to grapefruit-sized dimensions. Hailstones equal to or larger than a quarter are considered severe.

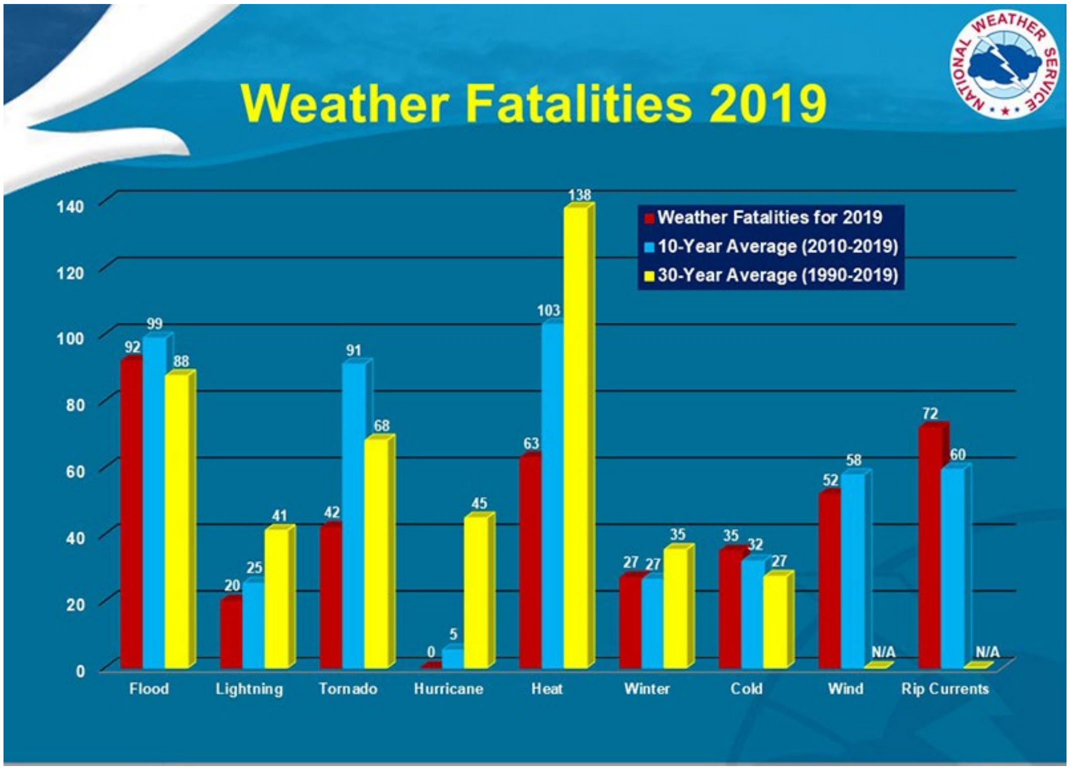
NWS Hail Size Estimates

Size	Inches in Diameter

Size	Inches in Diameter
Pea	1/4 inch
Marble/mothball	1/2 inch
Dime/Penny	3/4 inch
Nickel	7/8 inch
Quarter	1 inch
Ping-Pong Ball	1 1/2 inch
Golf Ball	1 3/4 inches
Tennis Ball	2 1/2 inches
Baseball	2 3/4 inches
Tea cup	3 inches
Grapefruit	4 inches
Softball	4 1/2 inches

Hail falls in swaths that can be from 20 to 100 miles long and from 5 to 30 miles wide. A hail swath is not a large continuous path of hail but generally consists of a series of hail cells that are produced by individual thunderstorm clouds traveling in the same area.

Visual 38: Weather Fatalities



Weather Fatalities Image Description

Flood:

- Weather Fatalities for 2019: 92
- 10 Year Average (2010-2019): 99
- 30 Year Average (1990-2019): 88

Lightning:

- Weather Fatalities for 2019: 20
- 10 Year Average (2010-2019): 25
- 30 Year Average (1990-2019): 21

Tornado:

- Weather Fatalities for 2019: 42
- 10 Year Average (2010-2019): 91
- 30 Year Average (1990-2019): 68

Hurricane:

- Weather Fatalities for 2019: 0
- 10 Year Average (2010-2019): 5

- 30 Year Average (1990-2019): 45

Heat

- Weather Fatalities for 2019: 63
- 10 Year Average (2010-2019): 103
- 30 Year Average (1990-2019): 138

Cold

- Weather Fatalities for 2019: 35
- 10 Year Average (2010-2019): 32
- 30 Year Average (1990-2019): 27

Winter

- Weather Fatalities for 2019: 27
- 10 Year Average (2010-2019): 27
- 30 Year Average (1990-2019): 35

Wind

- Weather Fatalities for 2019: 52
- 10 Year Average (2010-2019): 58

Rip Currents

- Weather Fatalities for 2019: 72
- 10 Year Average (2010-2019): 60

Key Points

We are below the 10 and 30 year averages in 2019.

Visual 39: Ingredients for Tornadoes

- Warm, humid air rising in unstable conditions
- Vertical wind shear
  - Directional
  - Speed

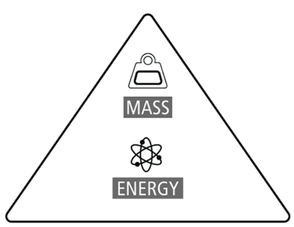
Key Points

Because tornadoes are a by-product of thunderstorms, the ingredients for tornadoes are the same as the ingredients for thunderstorms. In order for a tornado to form, there must be:

- Warm, humid air rising in an unstable environment.
- Vertical wind shear (directional and/or speed).

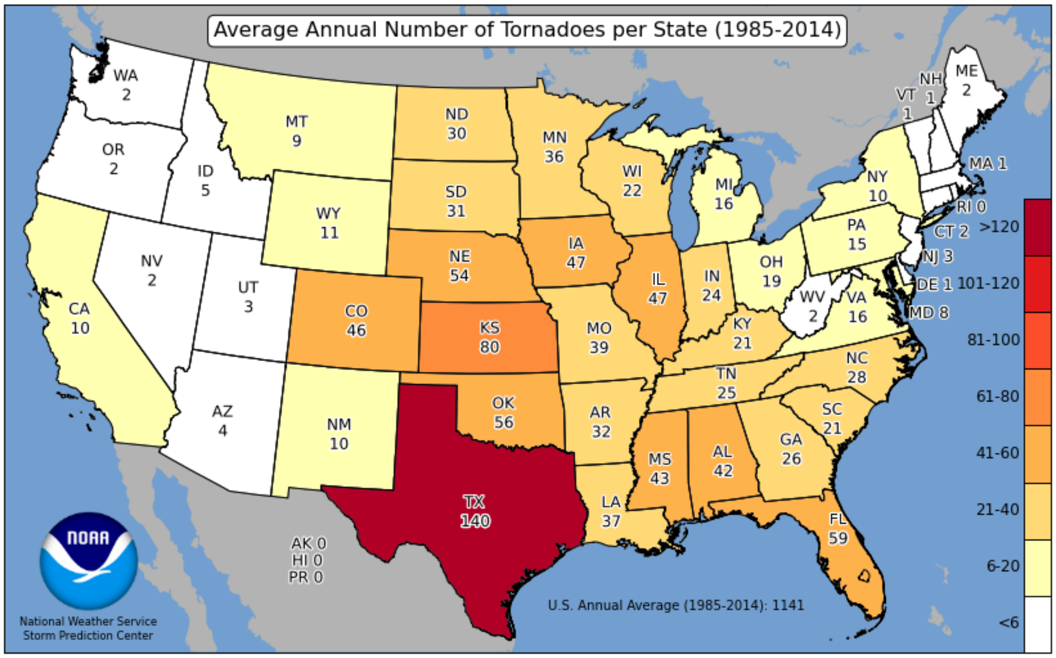
The visible column of a tornado is composed of water droplets formed by condensation in the funnel. The vortex (or multiple vortices) pulls in air from near the ground, along with dirt and debris. The dirt and debris block light, giving the tornado a dark color.

The fast-moving winds of a tornado (either flowing into the tornado or in the main tornadic circulation) are what cause most of the damage.



This is mass and energy.

Visual 40: Tornadoes: Geographical Distribution



Tornadoes: Geographical Distribution Description

State	Average Annual Number of Tornadoes (1985-2014)
AL	42
AK	<1
AZ	4
AR	32
CA	10
CO	46
CT	2

State	Average Annual Number of Tornadoes (1985-2014)
DE	1
FL	59
GA	26
HI	<1
ID	5
IL	47
IN	24
IA	47
KS	80
KY	21
LA	37
ME	2
MD	8
MA	1
MI	16
MN	36
MS	43
MO	39

State	Average Annual Number of Tornadoes (1985-2014)
MT	9
NE	54
NV	2
NH	1
NJ	3
NM	10
NY	10
NC	28
ND	30
OH	19
OK	56
OR	2
PA	15
RI	<1
SC	21
SD	31
TN	25
TX	140

State	Average Annual Number of Tornadoes (1985-2014)
UT	3
VT	1
VA	16
WA	2
WV	2
WI	22
WY	11

Key Points

Like thunderstorms, tornadoes are not limited to any particular part of the country. In fact, tornadoes have occurred in every single State in the United States.

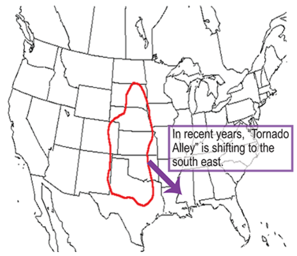
However, some areas are more susceptible to tornadoes due to their unique climate and landscape.

This map shows the geographic distribution of tornadoes across the United States from 1985 to 2014. The two areas with the highest frequency of tornadoes are:

- Florida, because of the high frequency of thunderstorms, as well as the influence of tropical storms and hurricanes, and
- The section of the country referred to as "Tornado Alley."

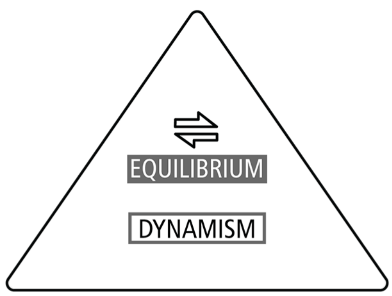
Visual 41: Discussion: Tornado Alley

Why do tornadoes form so often in "Tornado Alley"?



Continue for explanation of "Tornado Alley."

This is equilibrium and dynamism.



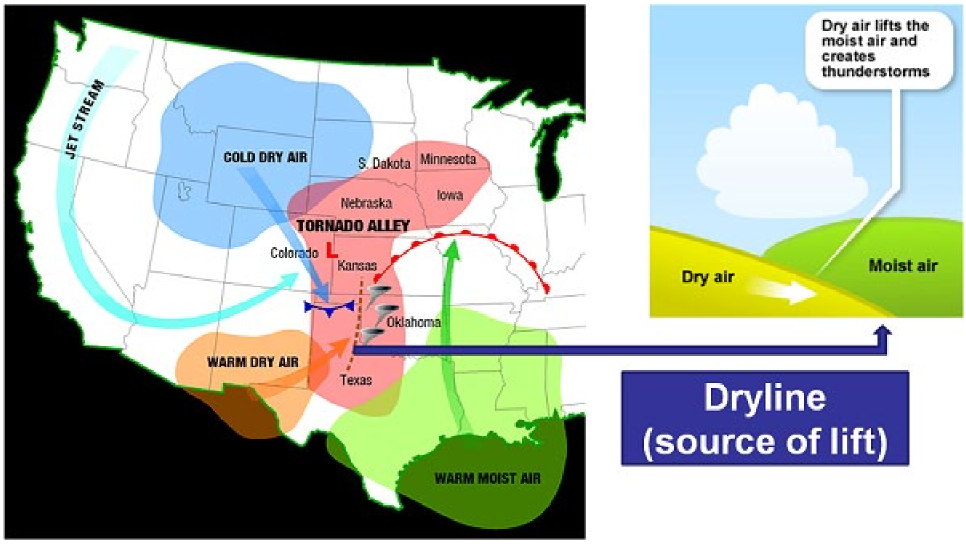
Key Points

"Tornado Alley" is a nickname given to a region of the central United States that experiences a disproportionately high frequency of tornadoes every year. This area stretches from central Texas to northern Iowa. The thunderstorm that brought down Flight 191 mentioned in the case study occurred in the afternoon, in the summer, in "Tornado Alley."

In recent years, "Tornado Alley" is shifting to the southeast.

Discussion Question: Why do tornadoes form so often in "Tornado Alley"?

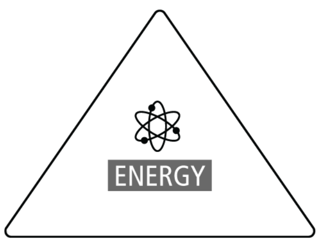
Visual 42: Tornado Alley: Explanation



Visual 43: Common Myths About Tornadoes

Tornadoes are not just a rural phenomenon, cities can also be hit hard and are more highly impacted due to the dense concentration.

This is energy.



Key Points

It is a common myth that tornadoes do not strike urban areas or cities. Tornadoes have, in fact, hit many urban areas and cities, for example:

Cities hit by tornadoes:

- Miami, Florida
- Nashville, Tennessee
- Dallas, Texas
- Salt Lake City, Utah
- Cincinnati, Ohio
- Detroit, Michigan
- Atlanta, Georgia
- New York, New York
- St. Louis, Missouri

The next several pages will present key information about the geographical and seasonal trends of convective storms in the United States.

Visual 44: Tornadoes: Peak Activity

Time of Day:

- Can occur at any time of day or night.
- Peak activity during late afternoon and early evening.

Time of Year:

- Can occur any time of the year.
- Peak activity during spring and summer.

Key Points

Time of Day: Tornadoes can occur at any time of day or night. Peak activity occurs during late afternoon and early evening. In the southeast, many tornadoes do occur in the night and morning hours.

Time of Year: Tornadoes can occur any time of the year. Peak activity occurs during spring and summer.

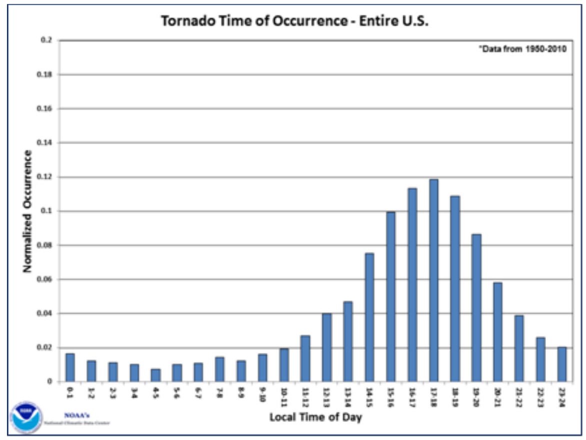
The frequency of tornado formation is closely related to the clash of warm and cold air masses in the progression of the warm season. As a result:

- Early spring tornadoes tend to occur in the southeast and south-central regions.
- Late spring tornadoes generally occur farther north, in and around Kansas and Nebraska.
- In mid-summer, most of Tornado Alley is susceptible to tornadoes.
- In late summer, the upper Midwest and Ohio valleys tend to have stronger tornadoes.
- In late autumn, the pattern shifts back southward.

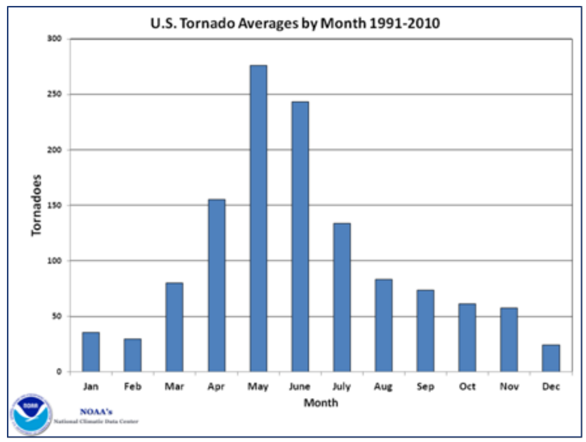
Although the winter months have historically yielded the fewest tornadoes, deadly winter outbreaks can and do occur.

More detail is provided in the following graphs.

This graph shows the average time of day at which tornadoes occurred across the United States from 1980 to 2010, with peak activity in late afternoon and early evening.



This graph shows the average monthly number of tornadoes from 1991 to 2010 in the United States. Although the peak month is May, tornado activity is not limited to any particular time of year. However, tornadoes—like thunderstorms—happen most frequently in the spring and summer months.



Visual 45: 2011: Deadly Tornado Season

- 1,704 confirmed tornadoes
- 553 confirmed fatalities in the U.S.
- Contributing factors:
  - La Nina's effect on jet stream
  - Influx of moist and humid air
  - Formation of massive thunderstorms in Tornado Alley spanning multiple States

Key Points

The 2011 outbreak of tornadoes across the southern United States (which included the massively destructive tornado in Joplin, Missouri) was devastating and record breaking.

- The 2011 tornado outbreak resulted from the formation of massive thunderstorms in Tornado Alley, fed from an influx of moist and humid air. The thunderstorms stretched across multiple States, spawning tornadoes that lasted as long as 10 minutes.
- Researchers have concluded that La Nina played a factor in the 2011 tornado outbreak. As you learned in the previous unit, La Nina affects the position of the jet stream, intensifying and shifting weather patterns on a national scale. The position of the jet stream during the 2011 outbreak was similar to its position during two other massive tornado outbreaks in 2002 and 1974.

Visual 46: Discussion

Why can tornadoes be so hard to predict?

Key Points

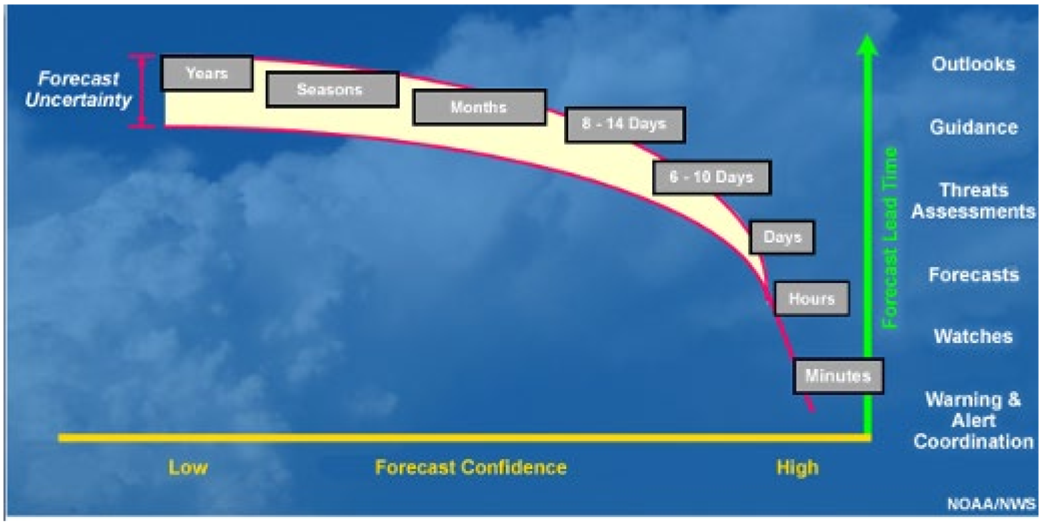
Forecasters generally use the following sources of information to predict these tornado outbreaks:

- Radar technology, including Doppler radar.
- Satellite imagery.
- Computer models.
- Weather balloons.
- People on the ground (i.e., storm chasers, reporters, emergency managers, victims, etc.).

Discussion Question: Why are tornadoes so hard to predict?

Visual 47: Convective Storm Prediction

- Lead time: Hours to minutes
- Accuracy: Fair/good



Key Points

Forecasts of severe convective weather are based on a combination of:

- Extrapolation of current conditions.
- Climatology.
- Application of conceptual models (experience).
- Guidance from numerical forecast models.

Although the lead time for predicting convective storms can be low (hours to minutes), the accuracy is generally fair to good.

In general, forecasts are best expressed probabilistically because:

- The current state of the atmosphere is never completely known.
- Atmospheric flow can vary in time and space from smooth and uniform to turbulent and chaotic.

Visual 48: Enhanced F-Scale

Operational EF Scale

EF Number	3-Second Gust (mph)	Effects
0	65-85	Light damage
1	86-110	Moderate damage
2	111-135	Considerable damage
3	136-165	Severe damage
4	166-200	Devastating damage
5	Over 200	Incredible damage

Key Points

The F-Scale: In 1971, severe storms researcher Ted Fujita introduced a scale for characterizing tornadoes by area and intensity and extrapolating wind speed from tornado-caused damage. The F-Scale became the heart of the tornado database, which contains a record of all tornadoes in the United States from 1950 to the present day.

The EF-Scale: In 2007, an enhanced version of the scale came into use. This Enhanced F-Scale has the same basic structure as the original scale, and it supports and maintains the original tornado database. However, it more accurately estimates wind speeds as they correlate to the damage that has been caused (primarily to buildings).

It is important to understand that this scale is used to classify a tornado **after** the tornado occurs. (For example, if a tornado moves through a neighborhood, the type, area, and extent of damage will be assessed to determine a wind speed range, and finally an EF number, e.g., EF-2.)

Visual 49: Activity 3.3 – 2011 Joplin, MO Case Study

Instructions: Working as a team:

1. View the videos
2. Read the synopsis
3. Answer the provided questions
4. Be prepared to present your lists to the class

Key Points

Instructions: Working as a team…

1. View the videos.
2. Read the synopsis.
3. Answer the provided questions.
4. Be prepared to present your lists to the class.

Activity 3.3 – Job Aid 1

The **2011 Joplin tornado** was a catastrophic EF5-rated multiple-vortex tornado that struck Joplin, Missouri, late in the afternoon of Sunday, May 22, 2011. It was part of a larger late-May tornado outbreak and reached a maximum width of nearly 1 mile (1.6 km) during its path through the southern part of the city.[6] It rapidly intensified and tracked eastward across the city, and then continued eastward across Interstate 44 into rural portions of Jasper County and Newton County.[7] It was the third tornado to strike Joplin since May 1971.[8]

Overall, the tornado killed 158 people (with an additional four indirect deaths), injured some 1,150 others, and caused damages amounting to a total of $2.8 billion. It was the deadliest tornado to strike the United States since the 1947 Glazier–Higgins–Woodward tornadoes, and the seventh-deadliest overall. It also ranks as the costliest single tornado in United. States history.

In a preliminary estimate, the insurance payout was expected to be $2.2 billion; the highest insurance payout in Missouri history, higher than the previous record of $2 billion in the April 10, 2001 hail storm, which is considered the costliest hail storm in history as it swept along the I-70 corridor from Kansas to Illinois.[9] Estimates earlier stated Joplin damage could be $3 billion. By July 15, 2011, there had been 16,656 insurance claims.[10]

Meteorological synopsis

The tornado initially touched down just east of the Kansas state line near the end of 32nd Street at 5:34 pm CDT (22:34 UTC) and tracked due east, downing a few trees at EF0 intensity. Eyewitnesses and storm chasers reported multiple vortices rotating around the parent circulation in this area.[11][12] Civil defense sirens sounded in Joplin 20 minutes before the tornado struck in response to tornado warnings issued by the National Weather Service, but many Joplin residents did not hear them.[13] The tornado rapidly strengthened to EF1 intensity as it continued through rural areas towards Joplin, snapping trees and power poles and damaging outbuildings. The widening tornado then tracked into the more densely populated southwest corner of Joplin, near the Twin Hills Country Club. Several homes were heavily damaged at EF1 to EF2 strength at a subdivision in this area. The tornado continued to strengthen as it ripped through another subdivision just east of Iron Gates Rd. Numerous homes were destroyed at EF2 to EF3 strength at that location, and multiple vehicles were tossed around, some of which were thrown or rolled into homes.[11]

Activity 3.3 – Job Aid 1 (Continued)

EF5 damage to the St. John's Regional Medical Center, which later had to be torn down due to deformation of its foundation and underpinning system.

Destroyed area in the tornado's damage path.

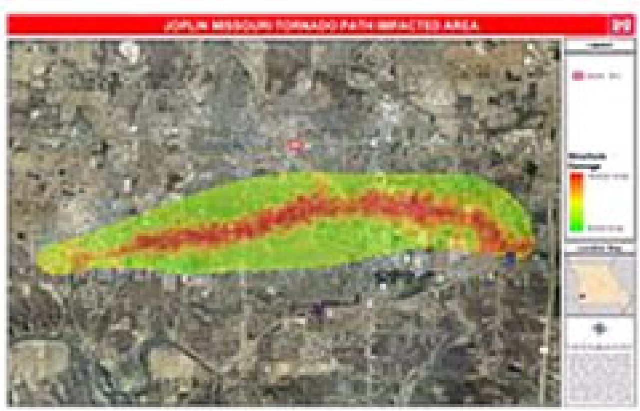
Several 300-pound concrete parking stops anchored with rebar were torn from a parking lot in this area, and were thrown up to 60 yards away. Iowa State University wind engineer Parka Sarkar was able to calculate the force needed to remove the parking stops, and he found that winds exceeding 200 mph were needed to tear them from the parking lot.[14] Damage became remarkably widespread and catastrophic at and around the nearby St. John's Regional Medical Center. The hospital lost many windows, interior walls, ceilings, and part of its roof, and its life flight helicopter was also blown away and destroyed. Six fatalities were reported there, and the nine-story building was so severely damaged that it was deemed structurally compromised and was later torn down. An engineering survey of the building revealed that the foundation and underpinning system were damaged beyond repair. According to the NWS office in Springfield, Missouri, such extreme structural damage to such a large and well-built structure was likely indicative of winds at or exceeding 200 mph.

Activity 3.3 – Job Aid 1 (Continued)

A large church, Greenbriar Nursing Home, Franklin Technology Center, St. Mary's Catholic Church and School, and Joplin High School were all destroyed along this corridor. No one was in the high school at the time; the high school graduation ceremonies held about 3 miles (4.8 km) to the north at Missouri Southern State University had concluded shortly before the storm. Pieces of cardboard were found embedded sideways into stucco walls that remained standing at Joplin High School. Steel beams and pieces of fencing were deeply embedded into the ground in fields near the high school as well, and steel fence posts were bent to the ground in opposite directions. A school bus was thrown into a nearby bus garage. The Greenbriar nursing home was completely leveled, with 21 fatalities occurring there alone. As the tornado crossed Connecticut Avenue further to the east, it destroyed several large apartment buildings, Dillon's grocery, and a bank. Only the concrete vault remained at the bank, and a wooden 2x4 board was found speared completely through a concrete curb at one location as well. The tornado then approached Range Line Road, the main commercial strip in the eastern part of Joplin, flattening additional neighborhoods along 20th Street.

The tornado lifted east of Diamond at 6:12 pm CDT (23:12 UTC) according to aerial surveys. The tornado's total track length was at least 22.1 miles (35.6 km) long. Overall, 6,954 homes were destroyed, 359 homes had major damage, and 516 homes had minor damage. A total of, 158 people were killed, and 1,150 others were injured along the path. A separate EF2 tornado touched down near Wentworth from the same supercell about 25 miles (40 km) east-southeast of Joplin.

Aftermath and impact



Activity 3.3 – Job Aid 1 (Continued)

East of Joplin, a Risk Management Plan facility released 3,000 to 5,000 pounds (1,400 to 2,300 kg) of anhydrous ammonia; it was contained within 2 days.

The $2.8 billion in damage is the largest amount for a tornado since 1950.

Activity 3.3 – Job Aid 1 (Continued)

The *Joplin Globe* reported that 54 percent of the people died in their residences, 32 percent died in non-residential areas and 14 percent died in vehicles or outdoors. Joplin officials after the tornado announced plans to require hurricane ties or other fasteners between the houses and their foundations (devices add about $600 US to the construction costs). Officials rejected a proposal to require concrete basements in new houses. Officials noted that only 28 percent of Joplin's new homes had basements as of 2009, compared with 38 percent two decades before.

Officials said they rescued 944 pets and reunited 292 with owners.

On June 10, 2011, it was announced that a rare fungal infection, zygomycosis, had been noted to cause at least eight serious cases of wound infection among the injured survivors, confirmed by reports to the Missouri Department of Health and Senior Services.[

Response

Activity 3.3 – Job Aid 1 (Continued)

Social Media Response

The tornado also highlighted a new form of disaster response, using social media. This type of disaster response is now known as Social Media Emergency Management. News outlets began aggregating images and video from eyewitnesses shared through social media. Public, citizen-led Facebook groups and websites, such as Joplin Tornado Info coordinated information, needs, and offers. The results were so effective that the project became a finalist in the 2011 Mashable Awards for Best Social Good Cause Campaign.

Media handling

President Barack Obama toured the community on May 29, flying into Joplin Regional Airport and speaking at a memorial at the Taylor Performing Arts Center at Missouri Southern State University about 2 miles (3 km) north of the worst of the devastation. Obama had been on a State visit to Europe at the time of the storm. Members of the controversial Westboro Baptist Church were also scheduled to protest the same day in Joplin, but they did not show up. There was a massive counter protest that was organized in response to the Westboro protest, in which thousands of protesters showed up holding signs saying, "God Loves Joplin" and "We Support You Joplin."

Activity 3.3 – Joplin, Missouri, Case Study Worksheet

1. What conditions made this storm so devastating?

1. What were complicating factors during this tornado incident?

1. What are some ideas to mitigate against repeats of the problems?

Video: Meteorologist

Video Meteorologist (URL: https://www.youtube.com/watch?v=t8aWzAuWOmo)

Key Points

In this video, meteorologist Jeff Penner, breaks down the Joplin weather system that created the deadliest, single tornado since modern record keeping began in 1950.

Video Transcript:

May 22nd 2011, 5 years ago, was a very, very bad day in Joplin and we're gonna take a little bit at the meteorology: how did the weather set up? Well with a low pressure area in South Dakota, there is a cold front right through Omaha and near Kansas City and Oklahoma. Warm front off to the north, and then a dry line down to the south.

Here's Joplin down here, so we had a warm, humid air mass from the Gulf of Mexico, we had a hot dry air mass coming in out of Oklahoma, and a cooler, drier air mass coming in out of Kansas. All intersecting in southeast Kansas and southwest Missouri, and also you had a jet-stream moving from west to east above all of this.

So you had convergence at the surface of all these air masses, and the winds are coming in from the southeast of the low levels while the upper levels are going in from the west and southwest. There was shear turning of the winds with height, and everything was there for thunderstorm development. That's where we had some of these super cells form. When they formed, it was so humid that they became very big thunderstorms and began to rotate and, unfortunately, one of those produced a very large tornado right over Joplin. But now it wasn't just Joplin on that day they got hit it was a whole severe weather outbreak from eastern Oklahoma all the way up into the great lakes. There were 75 tornado reports, 359 reports of hail, and 409 reports of wind for a total of 843 reports of severe weather.

There is even some severe weather in our area and Lafayette County; there are a couple smaller tornadoes on the eastern part of our viewing area, and then it moved off to the east. So, quite an active day 5 years ago

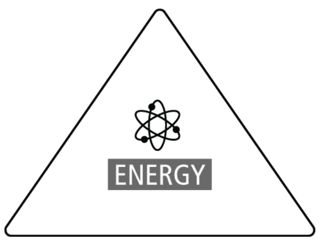
Here's a look at the satellite picture from that day. Here's Kansas City; Joplin's here; see these bumps in the cause? These are anvil, this whole white area, the anvil of the thunderstorms that the bumps the overshooting top— that's where the top of the thunderstorm shoots above the anvil into the lower part of the stratosphere. That means there's some intense rising motion you can see in southeast Kansas--there were some and even in Central Missouri and then these move right in to the Joplin area. The radar is very impressive when you see a radar image like this and a very dangerous signature, the hook, see the red here. This is Joplin and there's a hook and the reason why there's a hook, the rain is wrapping around the thunderstorm and the tornadoes usually are right in there. Uunfortunately, it's right over the city of Joplin, as things continue to move, there are very impressive signatures on radar. The track at this is where it was at five--right through the middle part of the city north of 32nd Street and south of Duquesne there--right through the city. It was in the evening; people were out--just absolutely horrific, Let's hope nothing like this ever happens again in a city because that is just horrible. The Joplin tornado facts: one-mile wide, 200 miles-per-hour winds as strong as it was on the ground for 38th minutes; 7,000 homes destroyed. And there is a picture of the tornado--a very violent day in Joplin and in southwest Missouri. This is tornado season, so just keep in mind the peak for our area is April and May, It's been quiet so far but in the next week to 10 days and early June, it’s gonna be active a lot, so keep an eye to the sky. On average of sixty-eight tornadoes in Kansas and Missouri, that's one tornado per day on average, so have a plan in place; know how to get warnings when they're issued; stay safe, Stay with 41 Action News, and we will keep you advised

Visual 50: Cyclone Terminology

- Cyclone
- Tropical cyclone
  - Tropical depression
  - Tropical storm
  - Hurricane

Cyclone classification is based on wind speed.

This is energy.



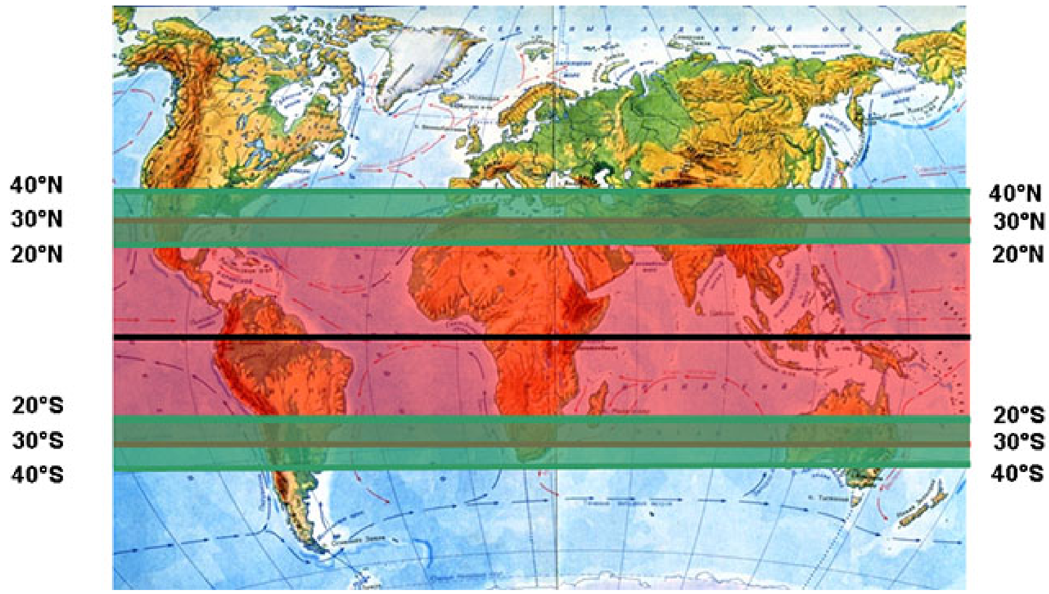
Key Points

What are cyclones? Begin with some important cyclone-related definitions:

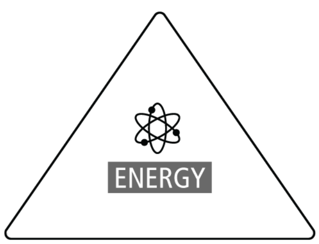
- **Cyclone:** An atmospheric closed-circulation, low-pressure system rotating counter-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.
- **Tropical cyclone:** A cyclone with a warm core originating over tropical or subtropical waters, with surface wind circulation about a well-defined center. Once formed, a tropical cyclone is maintained by extraction of heat energy from the ocean and heat export aloft. Types of tropical cyclones include:
  - **Tropical depression:** A tropical cyclone with winds of 38 mph or less.
  - **Tropical storm:** A tropical cyclone with winds of 39 - 73 mph.
  - **Hurricane:** A tropical cyclone with winds of 74 mph or more.

As you can see, the hierarchy of tropical depression, tropical storm, and hurricane is based on wind speeds. Although tropical depressions and tropical storms do not produce winds and storm surge as severe as those of hurricanes, they can still result in damaging winds and high rainfall amounts that cause freshwater flooding and tornadoes.

Visual 51: Tropical and Subtropical Waters



This is energy.



Key Points

A tropical cyclone can originate over tropical or subtropical waters.

The area in middle on this visual shows the region of tropical waters that is accepted by major experts. This region:

- Stretches from 30° N to 30° S.
- Has sea surface temperatures (SSTs) of 80 °F or higher.
- Is where the greatest potential for cyclones to develop exists.

Unlike extratropical cyclones, which derive energy from the horizontal temperature contrasts in the atmosphere, a tropical cyclone is maintained by the extraction of heat energy from the ocean at high temperature and heat export aloft.

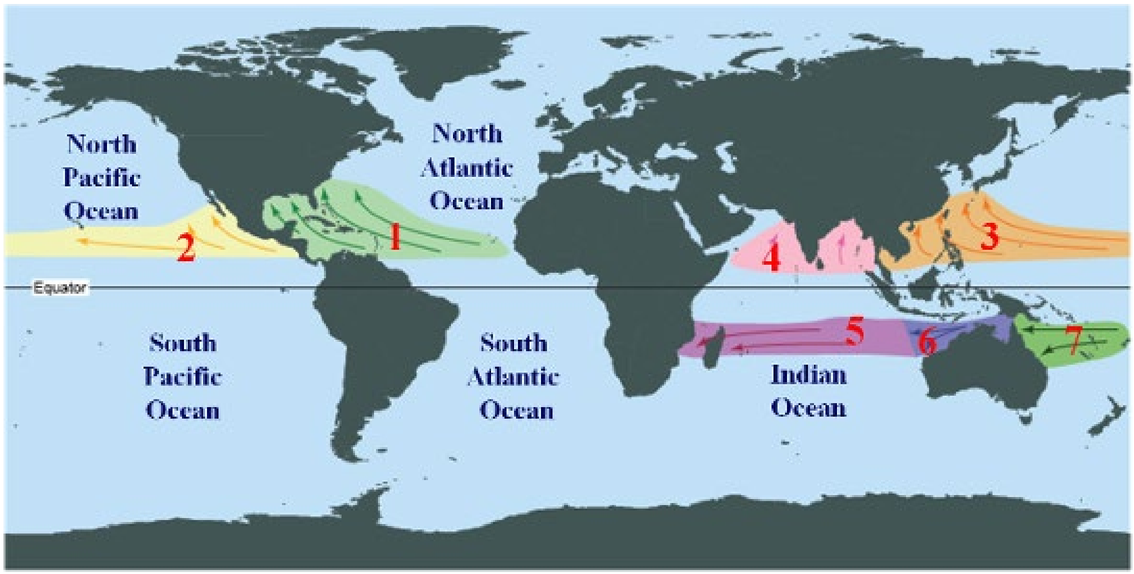
The areas above and below the tropical waters on the map indicate **subtropical waters**—the two regions that make up the border between tropical waters and more temperate regions.

Like tropical cyclones, subtropical cyclones are no frontal, synoptic-scale cyclones. However, unlike tropical cyclones, they:

- Have characteristics of extratropical cyclones—namely, existing in a weak to moderate horizontal temperature gradient region.
- Have a radius of maximum winds which is farther out (60 - 125 miles from the center) than what is observed for purely “tropical” systems.
- Have a less symmetric wind field and distribution of convection.
- Have maximum sustained winds not stronger than about 33 m/s (74 mph).

Often, subtropical cyclones transform into true tropical cyclones. For example, Hurricane Otto (October 2010) began as a subtropical cyclone before becoming fully tropical.

Visual 52: Hurricane Movement



Key Points

This map illustrates the seven "basins" where tropical cyclones form on a regular basis.

The same type of storm (tropical cyclone) is called by different names in different regions of the world.

- **Hurricanes** occur in Regions 1 and 2. The term hurricane is generally used for tropical cyclones east of the International Dateline to the Prime (Greenwich) Meridian.
- **Typhoons** occur in the Western Pacific, in Region 3. The term typhoon is generally used for Pacific tropical cyclones north of the Equator and west of the International Dateline.
- **Tropical cyclones** occur in Regions 4, 5, 6, and 7. This area includes the Indian Ocean and southwestern Pacific Ocean.

For the rest of this unit we will focus primarily on hurricanes. Most U.S. hurricanes are formed off the coast of Africa and move to the United States, sometimes lasting over 2 weeks over the ocean. But how do hurricanes travel from one continent to the other?

Most Northern Hemisphere hurricanes forming between 5° and 30° N typically move from east to west in the trade winds.

As hurricanes are pushed westward, they sometimes turn north or northwest out in the Atlantic, then curve toward the northeast, as a result of shifting winds in the middle and upper levels of the atmosphere.

Storms that do move up the east coast usually pick up speed around North Carolina, and may travel at speeds up to 70 mph.

Refer to color handout 2.2.1: Hurricane Movement

The Seven Tropical Cyclone Basins

Basin	Location	Beginning	Peak	Ending
Atlantic basin	North Atlantic Ocean, the Gulf of Mexico, and the Caribbean Sea	"Officially" June 1st	Early to mid-September	"Officially" November 30th
1. **Northeast Pacific basin**	Mexico to about the dateline	Late May or early June	Late August/early September	Late October or early November
1. **Northwest Pacific basin**	From the dateline to Asia, including the South China Sea	All year round; main season begins in July	All year round; main season peaks in late August/early September	All year round; main season ends in November
1. **North Indian basin**	Including the Bay of Bengal and the Arabian Sea	April	Double peak of activity in May and November	December
1. **Southwest Indian basin**	From Africa to about 100° E	Late October/early November	Double peak of activity – one in mid-January and one in mid-February to early March	May
1. **Southeast Indian/Australian basin**	100° E to 142° E	Late October/early November	Double peak in activity – one in mid-January and one in mid-February to early March	May
1. **Australian/Southwest**	142° E to about 120° W	Late October/early	Late February/early	Early May

Basin	Location	Beginning	Peak	Ending
Pacific basin		November	March	

Visual 53: Hurricane Ingredients ADD LENORA SYMBOL HERE

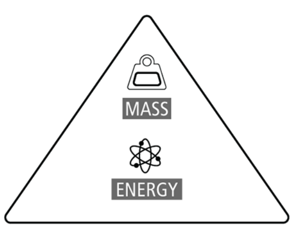
- Rising and cooling of humid air over the ocean
- A weather disturbance
- Ocean water 200 feet deep and over 80 F at the surface
- Unstable air
- Ample moisture in the lower atmosphere
- Steering winds at high altitude moving in one direction
- Upper atmosphere high pressure

Key Points

Hurricanes are generated by the rising and cooling of humid air over the ocean, in combination with the following ingredients:

- A weather disturbance.
- Warm ocean water about 200 feet deep (60 m) and over 80 F (27 C).
- Unstable air (so the warm, moist air will continue rising).
- Ample moisture in the lower atmosphere (to supply heat energy).
- Steering winds at high altitude moving in one direction (to move the storm along without breaking it up).
- Upper atmosphere high pressure (to help move out the rising air of the storm).

This is mass and energy.



Visual 54: Hurricane Growth

- Contact with warm ocean waters adds moisture, heat, and energy.
- Thunderstorms begin to form.
- The storm's cloud tops rise higher into the atmosphere.

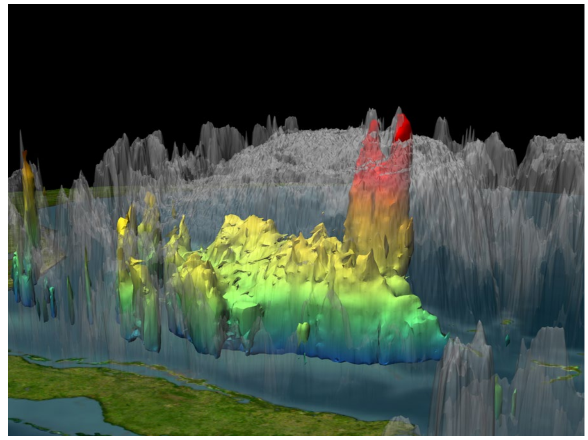
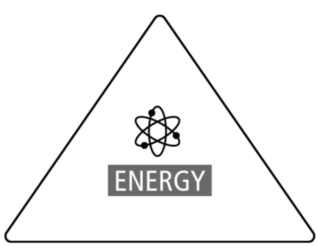


Photo Credit: NASA

Hurricane Growth Image Description: NASA's TRMM spacecraft allows us to look under Hurricane Rita's clouds to see the rain structure on September 19, 2005 at 15Z. Spikes in the rain structure known as 'hot towers' indicate storm intensity. 'Hot Towers' refers to tall cumulonimbus clouds and has been seen as one of the mechanisms by which the intensity of a tropical cyclone is maintained. Because of the size (1-20 km) and short duration (30 minute to 2 hours) of these hot towers, studies of these events have been limited to descriptive studies from aircraft observations, although a few have attempted to use the presence of hot towers in a predictive capacity. Before TRMM, no data set existed that could show globally and definitively the presence of these hot towers in cyclone systems. Aircraft radar studies of individual storms lack global coverage.

This is energy.



Key Points

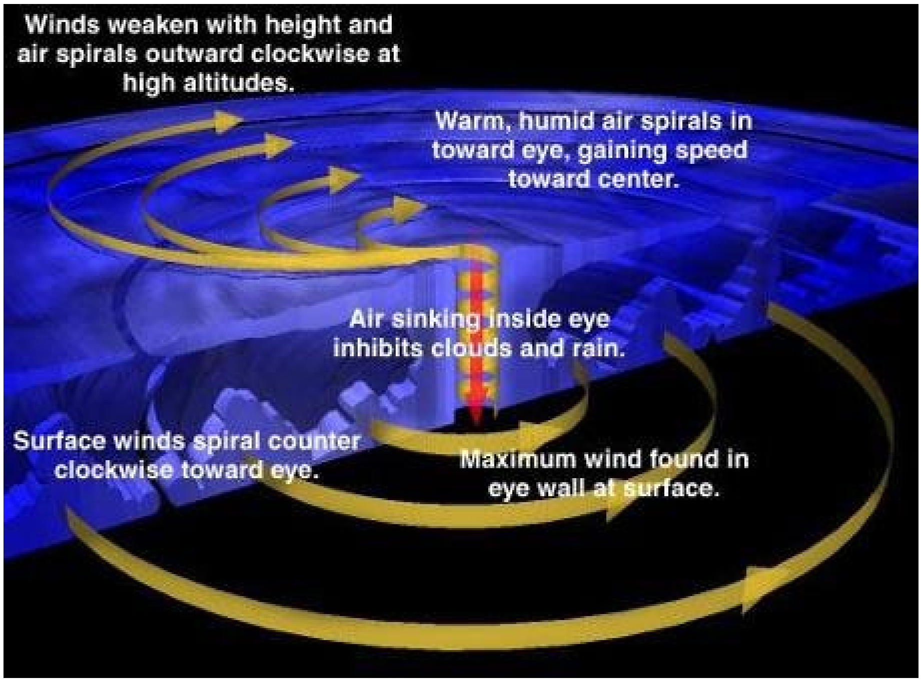
As the storm grows:

- Contact with warm ocean waters adds moisture, heat, and energy.

- Thunderstorms begin to form. In fact, on satellite imagery, the early stages of a tropical cyclone appear as a somewhat unorganized cluster of thunderstorms.
- The storm's cloud tops rise higher into the atmosphere.
- The storm remains intact and gains strength if the winds at these high levels of the atmosphere remain relatively light (meaning little to no wind shear).

With the right ocean and weather conditions, the storm can continue to strengthen until it becomes a tropical depression (winds less than 38 mph). It is at this point that the storm will take on its characteristic spiral appearance, resulting from both the Earth's rotation and wind flow.

Visual 55: Wind in a Hurricane



Wind in a Hurricane Image Description

PHOTO: Left: Shows a cross-section diagram of a hurricane, illustrating how wind moves throughout the system. Winds weaken with height and air spirals outward clockwise at high altitudes. Warm, humid air spirals in toward eye, gaining speed toward center. Air sinking inside eye inhibits clouds and rain. Surface winds spiral counter clockwise toward eye. Maximum wind found in eye wall at surface.

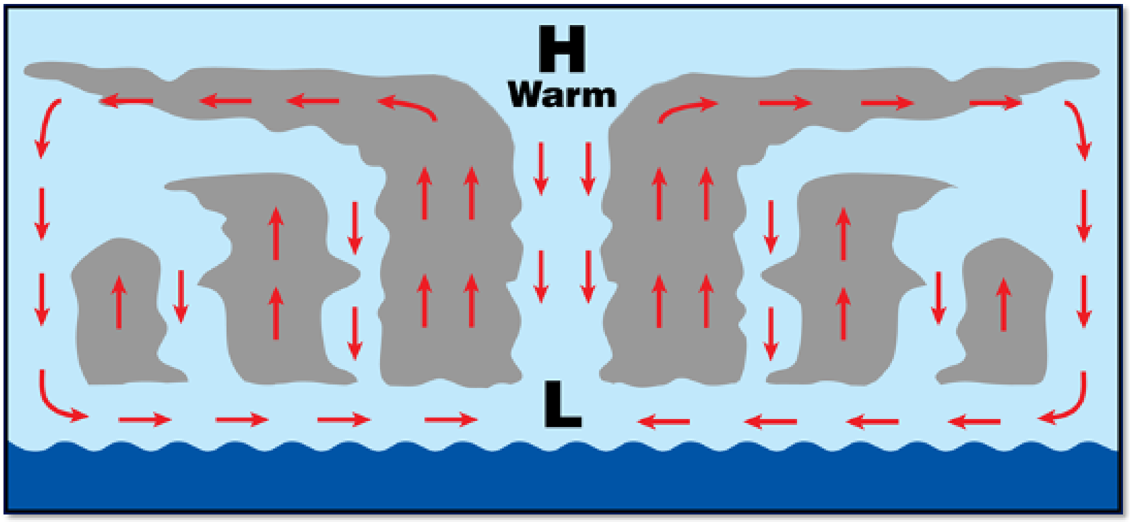
Credit: NASA/NOAA

Key Points

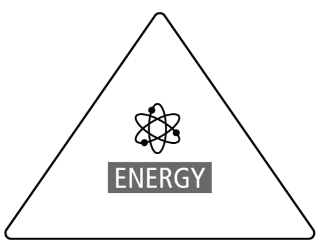
The main structural components of a hurricane are:

- Rain bands on the outer edges.
- The eye.
- The eyewall.

Visual 56: Convection in a Hurricane



This is energy.



Key Points

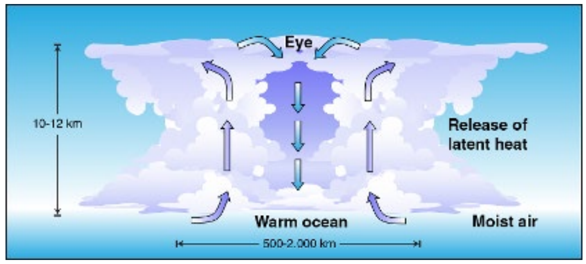
Recall that convection is a key element in all storms.

Convection in a hurricane:

- Occurs in the eyewall and forms and maintains the eye.
- Is organized into long, narrow rain bands. These bands are oriented in the same direction as the horizontal wind, and because they seem to spiral toward the center of a hurricane, are sometimes called spiral bands.
- Is fueled by the warm ocean surface water that supplies heat and moisture to the surface air spiraling in toward the center of the hurricane.

Visual 57: In the Eye

- Calm weather
- Clear, sunny skies
- Much less wind
- Warmer
- Less pressure



Key Points

The eye of a hurricane:

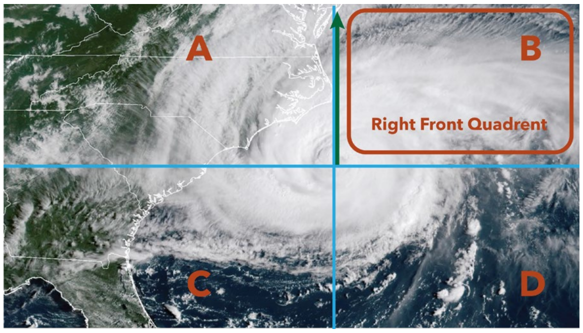
- Is the roughly circular area of comparatively light winds that encompasses the center of a severe hurricane.
- Is either completely or partially surrounded by the eyewall cloud, an organized band or ring of cumulonimbus clouds.

In the eye of the hurricane:

- The weather is calm, with clear, sunny skies. Dry, calm air is descending, and wind velocity dramatically decreases.
- It is much warmer.
- The pressure drops significantly. (Remember, a hurricane has closed wind circulation around a well-defined low pressure center that is warmer than the surrounding air.)

Visual 58: Right Front Quadrant

- Where rotational movement aligns with translational movement.
- Has the most forceful winds.
- Has greater potential for tornadoes and storm surges.



Key Points

Unlike the eye, which is calm, the right front quadrant of a storm has the most forceful and damaging winds, as well as a heightened potential for tornadoes and storm surge. This is why regions that are projected to be hit by this quadrant are often of the greatest concern.

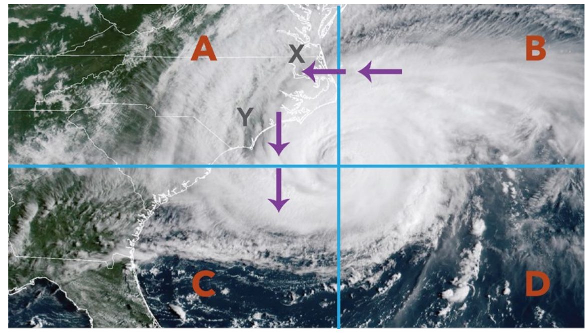
The intensity of the right front quadrant results from two types of movement:

- The rotational movement of the circulation (red arrows).
- The translational movement of the storm actually traveling in its path (blue arrow).

In the right front quadrant, the rotational movement most closely aligns (points in the same direction) as the translational movement. The two movements are essentially added together for a compounded effect, resulting in the most forceful winds (i.e., the greatest power).

Visual 59: Discussion Question: Right Front Quadrant

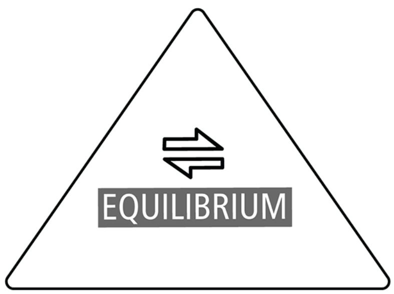
If the hurricane were moving west, where would the right front quadrant be located?



Visual 60: Damaging Components of a Hurricane

- Storm surge and coastal flooding
- Tornadoes and downbursts
- Inland flooding
- Wind
- Rain

This is equilibrium.



Key Points

Damaging components of a hurricane include:

- Beach erosion and structural damage from storm surge and breaking waves.
- Tornadoes. (Tornadoes occur mostly in the outer fringes-e.g., 100-200 miles away, not in the eye-because updrafts stabilize the eye.)
- River flooding and flash flooding inland from torrential rains.
- Wind.
- Rain.

Visual 61: Saffir-Simpson Hurricane Scale

Key Points

This animation illustrates the Saffir-Simpson Hurricane Scale that is used to categorize hurricanes. The rating, which ranges from Category 1 to Category 5, is based on a hurricane's sustained wind speed and is used to estimate potential property damage. Hurricanes that reach Category 3 or higher are considered major hurricanes.

		Barometric Pressure	Barometric Pressure	Storm Surge	Storm Surge	Avg. Wind Speed	Avg. Wind Speed	
Category	**Example**	**mbar**	**In.**	**M**	**ft**	**kph**	**mph**	**Damage**
Normal (No storm)		1,000	29.92	0	0	0	0	
Tropical Storm	Allison (2001)			<1.2	<4	62 - 119	39 - 74	
1.	Danny (1997)	980	>28.94	1.2 - 1.5	4 - 5	119 - 153	74 - 95	**Minor** damage to trees and unanchored mobile homes.
1.	Bertha (1996) Isabel (2003) Wilma (2005)	965 - 979	28.5 - 28.93	1.8 - 2.4	6 - 8	154 - 177	96 - 100	**Moderate to major** damage to trees and mobile homes, windows, doors, some roofing. Low coastal roads flooded 2 to 4 hours before arrival of hurricane eye.

		Barometric Pressure	Barometric Pressure	Storm Surge	Storm Surge	Avg. Wind Speed	Avg. Wind Speed	
1.	Alicia (1983) Fran (1996) Katrina (2005)	945 - 964	27.91 - 28.49	9 - 12	2.7 - 3.3	178 - 209	111 - 130	**Major** damage: Large trees down, small buildings damaged, mobile homes destroyed. Low-lying escape routes flooded 3 to 5 hours before arrival of hurricane eye. Land below 1.5 meters above mean sea level flooded 13 kilometers inland.
1.	Hugo (1989) Iris (2001) Ike (2004)	920 - 944	27.17 - 27.9	4 - 5.5	13 - 18	210 - 249	130 – 156*	**Extreme** damage: Major damage to windows, doors, roofs, coastal buildings. Flooding many kilometers inland. Land below 3 meters above mean sea level flooded as far as 10 kilometers inland.
1.	Camille (1969) Gilbert	920	27.17	>5.5	>18	>249	>157	**Catastrophic** damage: Major damage to all buildings less

		Barometric Pressure	Barometric Pressure	Storm Surge	Storm Surge	Avg. Wind Speed	Avg. Wind Speed	
	(1988) Andrew (1992) Mitch (1998) Rita (2005) Michael (2018)							than 4.5 meters above sea level and 500 meters from shore. All trees and signs blown down. Low-lying escape routes flooded 3 to 5 hours before arrival of hurricane.

*The scale underwent a modification for 2012, broadening the Category 4 wind speed range by one mile per hour (mph) at each end of the range, yielding a new range of 130-156 mph.

Visual 62: Alternative Metrics

Scientists are studying alternative ways to capture the full impact of tropical cyclones.

H*Wind:

- Analyzes distribution of wind speeds in a hurricane.

Integrated Kinetic Energy (IKE) Scale:

- Incorporates information about ocean surface stress resulting in waves and surge.

Key Points

Scientists are continually researching alternative ways to capture the full impact of tropical cyclones beyond the Saffir-Simpson Intensity Scale, which focuses on wind damage. Examples of ongoing research projects include H*Wind and the Integrated Kinetic Energy Scale.

- **H*Wind:**

  H*Wind is designed to improve understanding of the extent and strength of the wind field, and to improve the assessment of hurricane intensity. Wind measurements from a variety of observation platforms over a 4 to 6 hour period are used to develop an objective analysis of the distribution of wind speeds in a hurricane.

  The H*Wind "snapshot" products are provided in image and gridded form for research purposes and have been especially useful for storm surge and wave forecasting applications. The swath map is a relatively new product that is also available in image and gridded form as well as GIS shape files. The swath maps are helpful for damage and loss assessment.

  More information on H*Wind (This link can also be accessed at the following URL: http://www.aoml.noaa.gov/hrd/data_sub/wind.html)
- **Integrated Kinetic Energy (IKE):**

  Tropical cyclone damage potential, as currently defined by the Saffir-Simpson scale and the maximum sustained surface wind speed in the storm, fails to consider the area impact of winds likely to force surge and waves or cause particular levels of damage.

  Whereas the Saffir-Simpson scale only reports top wind speeds, IKE integrates the wind speed with how wide an area in which the winds are blowing.

  Integrated kinetic energy, computed from H*Wind products, captures the physical process of ocean surface stress forcing waves and surge while also taking into account structural wind loading and the spatial coverage of the wind.

The IKE framework:

- Incorporates information about the ocean surface stress that results in waves and surge. Also takes into account the destructive potential of wind.
- Is based on the familiar 1- 5 range of the Saffir-Simpson scale, but with more exact, decimal numbering (i.e., storms as weak as 0.1 or as strong as 5.9).

- **What IKE tells us about Hurricane Sandy:**

IKE better conveys the destructive power from both a hurricane's wind and storm surge. For example, the IKE scale helps explain why Hurricane Sandy (2012), which quickly weakened after landfall, created such widespread flooding and damage. The storm surge, combined with a full moon and high tide, affected hundreds of miles of highly populated coastline.

The metric also incorporates the storm's enormous size. Sandy's wind field was so large that tropical storm force winds (45 mph) extended 485 miles out from the center at landfall. (Out at sea, the wind field reached a maximum extent of 520 miles.)

In modern records, Sandy's IKE ranks second among all hurricanes at landfall, higher than devastating storms like Hurricanes Katrina, Andrew, and Hugo, and second only to Hurricane Isabel in 2003.

Scientists hope that IKE will present a more accurate picture of the potential destruction that can result from a hurricane, particularly from storm surge, before it makes landfall.

Additional information, including a tool for calculating an IKE value based on operational wind radii at the four quadrants of a storm, (This link can also be accessed at the following URL: http://www.aoml.noaa.gov/hrd/ike/index.html.)

Visual 63: Storm Surge

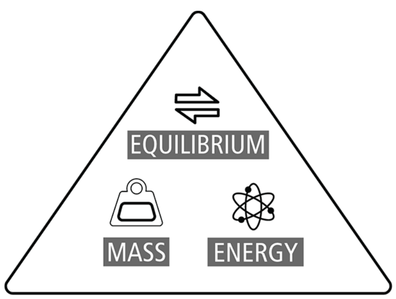
Characteristics of Storm Surge:

- An abnormal rise in sea level accompanying a hurricane
- Height = Difference between the observed level and normal level
- Estimated by subtracting normal tide from observed storm tide

Causes of Storm Surge:

- Low atmospheric pressure allowing sea level to rise
- High winds, plus:
  - Wind direction
  - Wind fetch
  - Wind duration

This is equilibrium, mass, and energy.



Key Points

A storm surge basically is the push of water onto land.

- A storm surge is an abnormal rise in sea level accompanying a hurricane or other intense storm, the height of which is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the cyclone.
- A storm surge is topped by destructive waves, presenting a threat to life and property.
- Storm surge can be 50 to 100 miles wide, and more than 15 feet deep at its peak.
- Storm surge also has the potential to reach very long distances inland. For example, in 1957, Hurricane Audrey inundated the southwestern coast of Louisiana as far as 25 miles inland.

Key Points

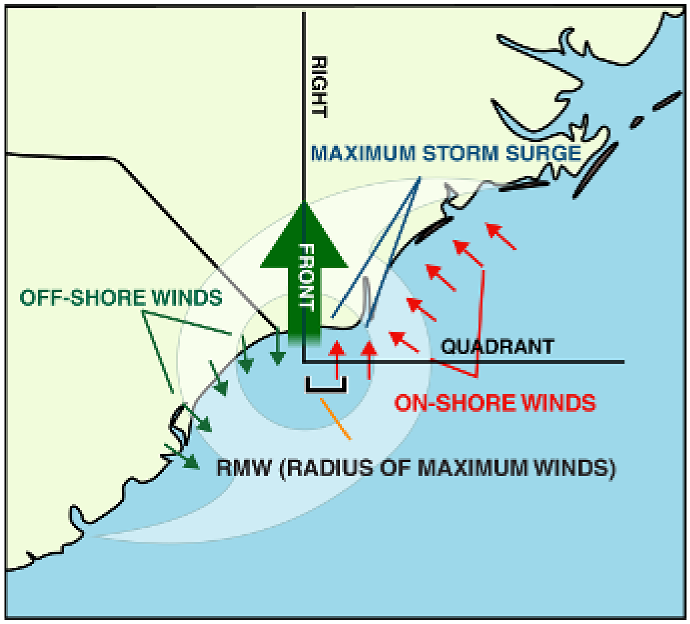
Causes of storm surge: Unlike a tsunami, which is normally caused by a strong earthquake, a storm surge is caused by:

- Low atmospheric pressure allowing the sea level to rise. (There is less push down on the sea surface.)
- High winds associated with hurricanes, as well as:
  - **Wind direction:** The biggest surges are caused by wind blowing at a right angle onto land from the water.
  - **Wind fetch:** Fetch is the area in which ocean waves are generated by the wind. It also refers to the length of the fetch area, measured in the direction of the wind. Fetch can allow for more water to be dragged up against the shore.
  - **Wind duration:** The longer the wind blows onto

shore, the more water piles up.

With intense storms, the impact of the low pressure associated with storm surge is relatively small in comparison to the wind moving the water toward the shore.

Visual 64: Maximum Storm Surge



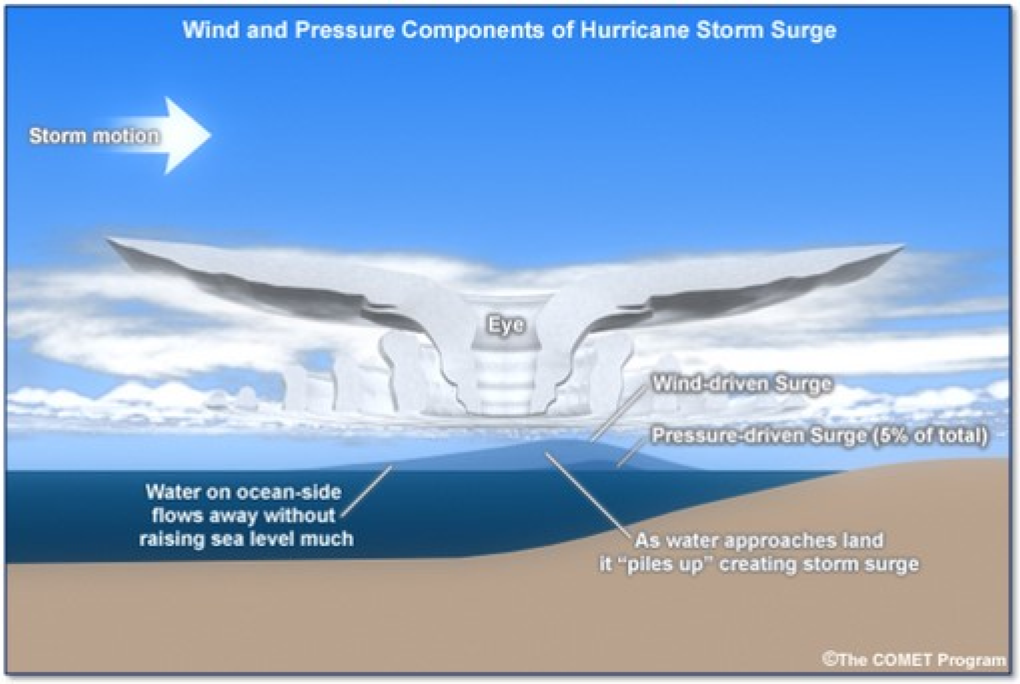
Key Points

The speed, power, direction, and fetch of hurricane winds all mean that storm surge is highest on the right front quadrant of a land-falling hurricane.

This diagram shows a hurricane hitting a coastline with a concave shape. All the ingredients for the maximum amount of water in a surge are present. The green arrows represent an area of lesser concern because off-shore winds are pushing the water out; the right front quadrant (red arrows), however, represents an area of great concern.

(It is important to remember that the "north" of the hurricane is relative to the hurricane's movement and direction. The axis rotates with the movement of a hurricane.)

Visual 65: Wind and Pressure Components



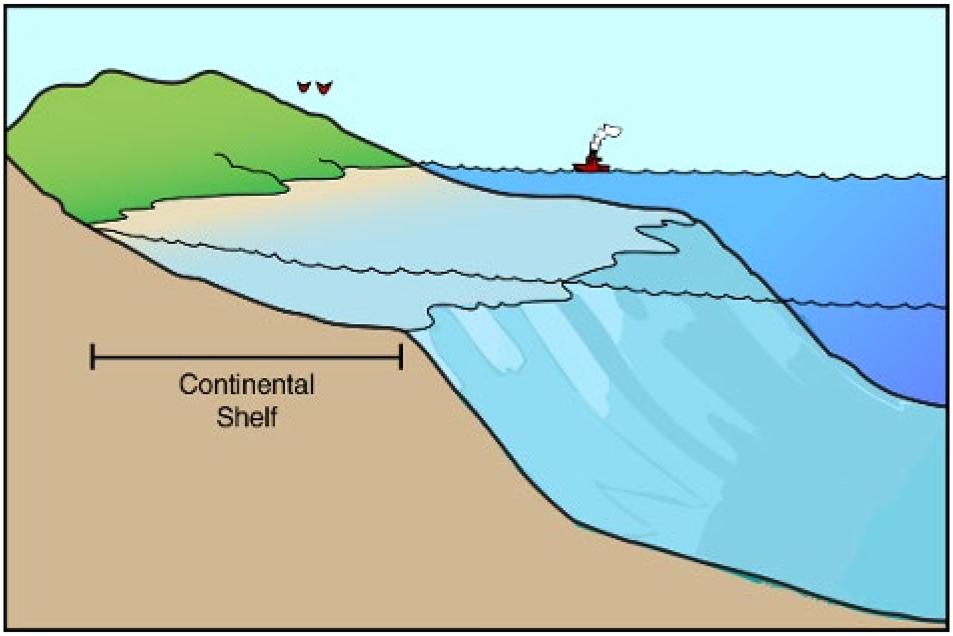
Key Points

This diagram shows an example of storm surge and its wind and pressure components.

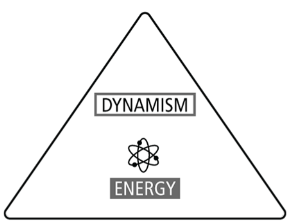
Visual 66: Factors that Affect Storm Surge

- Coastline: Embayments and other concave shapes concentrate the water for high surges.
- Shoaling: Wave shoaling is the effect by which surface waves entering shallower water increase in wave height. A shallow bottom stretching for a distance off-shore causes more surge than a quickly deepening off-shore.
- Eroded surfaces: Already-eroded surfaces increase storm surge.
- Dunes or vegetation: Storm surge can be minimized by dunes or vegetation (e.g., mangroves, which act as a buffer).
- Continental shelf

Visual 67: Storm Surge and Continental Shelf



This is dynamism and energy.



Key Points

The continental shelf (the submerged extension of land out to sea) is also a factor in the strength of storm surge.

A shallower continental shelf (or a more gradual slope) makes it easier for a storm surge to come on land. For example, the Gulf coast has very shallow continental shelves compared to the Atlantic coast, so the storm surges in the Gulf there tend to be much higher.

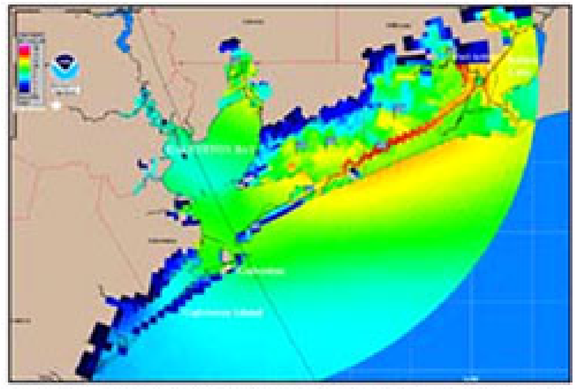
A deeper continental shelf (or a steeper slope) is more difficult for the storm surge to gather the necessary force to push water onto dry land.

Visual 68: Discussion: Hurricane Speed

Which is a greater concern for storm surge: a fast-moving or slow-moving hurricane?

Visual 69: Storm Surge Modeling

- Models for Tropical Systems:
- Sea, Lake, and Overland Surges from Hurricanes (SLOSH)
- Probabilistic Hurricane Storm Surge (P-Surge) Models for Extratropical Systems
- Extratropical Storm Surge (ETSS)
- Extratropical Surge and Tide Operational Forecast System (ESTOFS) Models for Waves
- WAVEWATCH III®



A sample output of the SLOSH model for Hurricane Ike as viewed within the SLOSH Display Program.

Key Points

SLOSH – The Sea, Lake and Overland Surges from Hurricanes (SLOSH) computer model was developed by the National Weather Service for coastal inundation risk assessment and the prediction of storm surge. It estimates storm surge heights resulting from historical, hypothetical, or predicted hurricanes.

SLOSH computes storm surge by taking into account a storm's atmospheric pressure, size, forward speed, track, and winds. The calculations are applied to a specific locale's shoreline, incorporating the unique bay and river configurations, water depths, bridges, roads, levees, and other features. SLOSH Display Program aids emergency managers in evacuation planning by aiding emergency managers with visualizing storm surge vulnerability. The SLOSH model and the display program are two different tools. The National Weather Service uses the SLOSH model to forecast storm surge and model storm surge vulnerability; emergency managers and others use the display program to visualize the SLOSH data.

P-Surge - Numerical storm surge models depend on an accurate forecast of the hurricane's track, intensity, and size but even the best hurricane forecasts still have considerable uncertainty. The National Hurricane Center's forecast landfall location, for example, can be in error by tens of miles even during the final 12 to 24 hours before the hurricane center reaches the coast. These limitations can make the single, deterministic SLOSH surge forecasts incorrect. To help overcome these limitations, forecasters use probabilistic storm surge (P-surge) forecasts.

The Probablistic Hurricane Storm Surge (P-Surge) model predicts the likelihood of various storm surge heights above a datum or above ground level based on an ensemble of SLOSH model runs using the official hurricane advisory. Graphical output shows the storm surge heights which have a certain probability of being exceeded and the probability of storm surge exceeding a certain height

These storm surge heights and probabilities are based on the historical accuracy of hurricane track and wind speed forecasts, and an estimate of storm size. P-Surge also computes the probability of surge above ground to more clearly communicate where the surge will occur.

ETSS - To predict the surge accompanying an extratropical storm, the NWS runs the Extratropical Storm Surge Model (ETSS). This model is a variation on the SLOSH model, which is used for hurricane storm surge forecasting. ETSS predicts storm surge flooding along U.S. coastlines but is not able to predict the extent of overland flooding.

Because extratropical storms have larger time and length scales than tropical storms, the ETSS model uses the basic SLOSH model, but with winds and pressures generated from the Global Forecast System atmospheric model, which is particularly useful for forecasting storm surge associated with East Coast Nor'easters and in western Alaska where storm surge associated with extratropical cyclones can devastate low-lying coastal communities.

Coverage for the model includes the east, west, and Gulf coasts of the continental United States and the Bering Sea and Arctic regions of Alaska (See map).

ESTOFS - The Extratropical Surge and Tide Operational Forecast System, a new generation hydrodynamic modeling system, was developed for the Atlantic and Gulf coasts. ESTOFS provides real-time forecasts of surges with tides.

WAVEWATCH III® - NOAA created WAVEWATCH III® to provide consistent and reliable predictions of potentially dangerous wave heights, including those occurring with storm surge, that could have a devastating impact on lives and property along the shore. The model gives meteorologists and many other users a better understanding of coastal swells and surf conditions, and a better insight on probable effects from hurricane and tropical storm surge.

The models allow NOAA to simulate many different storms in order to understand the risks involved and forecast storm surge.

Visual 70: Emergency Management Software

Programs exist to help emergency managers make protective action decisions in a hurricane, such as evacuation:

- Lead Times
- Geographical Extent

Key Points

Programs exist to help emergency managers make decisions regarding protective action measures in a hurricane. One example of software is:

HURREVAC (short for Hurricane Evacuation) is a storm tracking and decision support tool. The program combines live feeds of tropical cyclone forecast information with data from various state Hurricane Evacuation Studies (HES) to assist the local emergency manager in determining the most prudent evacuation decision time and the potential for significant storm effects such as wind and storm surge. Many Emergency Operations Centers use HURREVAC as a situational awareness and briefing tool.

Program access is restricted to officials in government emergency management. As a general rule, if you are the Emergency Manager for a county in the hurricane prone states (Texas to Maine), in Puerto Rico or the Virgin Islands, state Emergency Management Agency (EMA), a FEMA office, Corps of Engineers office, or National Weather Service office, you are eligible to use the HURREVAC program (The website can also be accessed at the following URL: http://www.hurrevac.com)

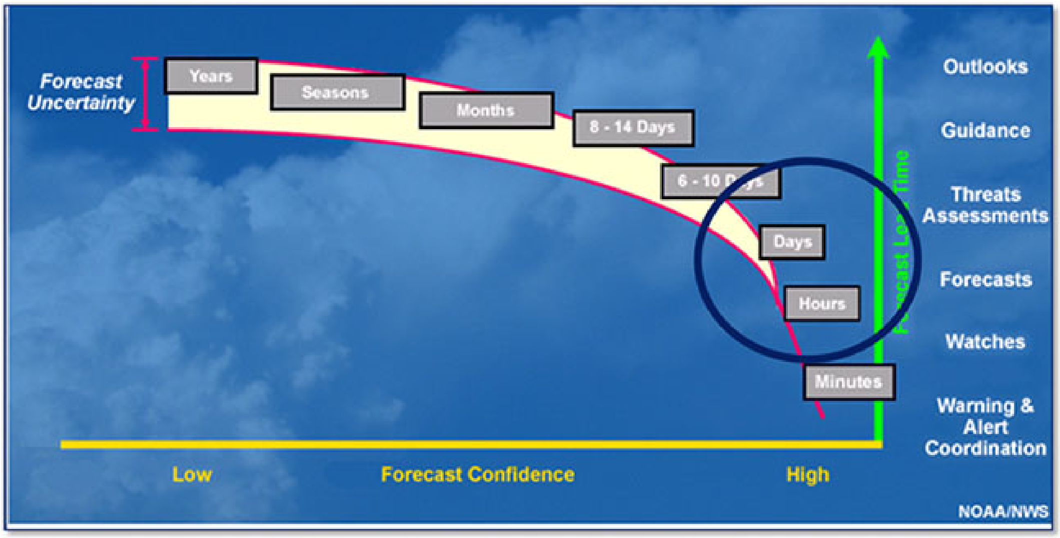
The program is distributed free-of-charge to eligible users and also details regular training and exercise opportunities.

Visual 71: Discussion: Hurricane Decay

What causes a hurricane to decay?

Visual 72: Hurricane Prediction

- Lead time: Days
- Accuracy: Good



Key Points

We saw in the previous unit that tornadoes are difficult to predict. How well are weather forecasters able to predict hurricanes? The lead time for predicting hurricanes is measured in days, and the accuracy is generally good.

Prediction tools: Forecasters use computer and climate models and satellite imagery to gather information about:

- Hurricane intensity and movement (e.g., preliminary path).
- Large-scale climate factors.
- Atmospheric conditions (e.g., atmospheric pressure).
- Oceanic conditions (e.g., surface water temperatures).
- Cloud top temperatures.
- Moisture levels.
- Typical seasonal activity.

Predictable information: Using this information, forecasters are able to provide information on the storm's:

- Intensity:
  - Wind strength.
  - Central pressure.
  - Amount of precipitation.

- Size.
- Duration.
- Track and cone of uncertainty (probable track of the hurricane based on current information and computer models).

Visual 73: Video: Katrina by Satellite

Key Points

Introduction: This video discusses the forecasting of Hurricane Katrina using satellite imagery. The narrative is provided on the next page.

Narrative: Katrina Retrospective: 5 Years After the Storm

August 29, 2005. After passing over the Caribbean, Hurricane Katrina made landfall along the Gulf of Mexico. By the time the skies cleared, Katrina had killed more than 1,800 people, caused roughly $125 billion in damages, and went down as one of the strongest storms to hit the U.S. in a century.

Five years later, NASA revisits Katrina as captured by NASA satellites. While these images can't tell the whole story of the hurricane and its impacts, they remind us of the power and destructive nature of tropical cyclones.

In the weeks leading up to Katrina, NASA's Aqua satellite captures sea surface temperatures with the AMSR-E instrument. Warm ocean temperatures, indicated in red, provide energy to fuel the growing storm. As Katrina moves, it leaves a trail of cooler water in its wake, stirred up from below.

Two days before landfall... NASA's MISR instrument on the Terra satellite witnesses growing cloud tops as the storm gathers strength.

Just before landfall... the TRMM satellite looks inside the hurricane at "hot towers"-powerful thunderstorms that help propel Katrina to category 5 strength. The same satellite reveals heavy rains. Green means at least a half inch of rain is falling per hour. Yellow, an inch. Red, over two inches per hour.

As the hurricane sweeps through, TRMM's multi-satellite analysis reveals where the hurricane delivered the heaviest rains, shown here in yellows and reds.

Finally, Landsat satellite imagery shows us the extent of flooding in New Orleans. First, the city before the storm with Lake Pontchartrain to the north. Two days after the storm made landfall, much of the city is flooded by the catastrophic levee failures.

Today, Landsat sees a city still rebuilding from the storm. NASA satellites continue to provide detailed observations of tropical cyclones around the world-to better understand how they work, and so we can prepare for those yet to come.

(Credit: NASA/Goddard Space Flight Center)

Visual 74: Activity 3.4 – New Digital Flood Insurance Rate (D-FIRM) Maps

Instructions: Working in groups:

1. Review the provided scenario
2. Summarize the views, bolstered by scientific facts, of your side
3. Develop and present a brief summary of your argument to the Mayor of New York City (e.g., your instructor)

Key Points

Instructions: Working in groups…

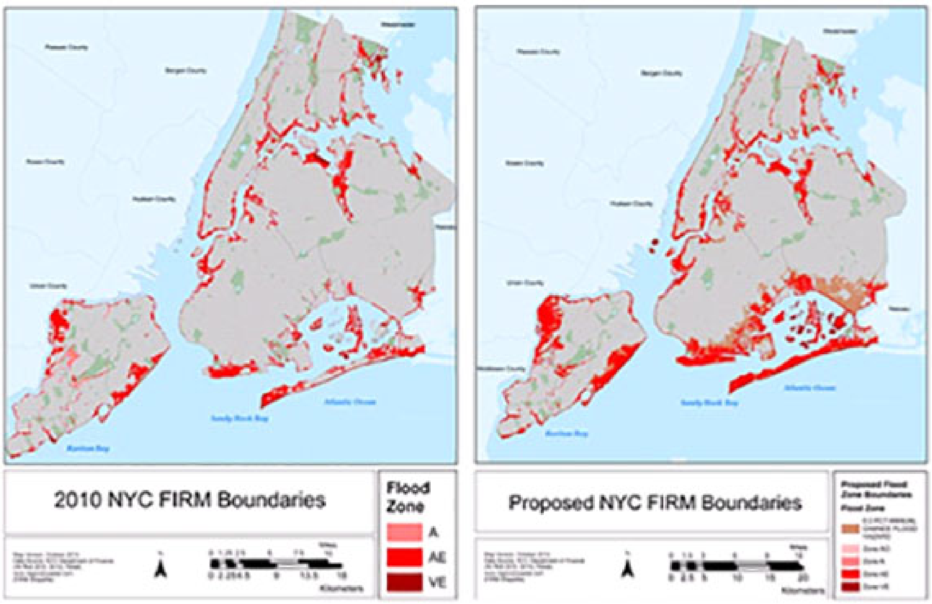
1. Review the provided scenario.
2. Summarize the views, bolstered by scientific facts, of your side.
3. Develop and present a brief summary of your argument to the Mayor of New York City (i.e., your instructor).

Scenario: City officials announced last Friday they will challenge new FEMA maps that greatly expand flood zones in New York City. The federal maps, set to go into effect in 2016, would nearly triple the number of properties included in official flood zones and affect more than 400,000 citizens. Alternative maps proposed by the de Blasio administration would reduce the number of buildings in the proposed FEMA flood zones by nearly half. This could have a profound impact on the flood insurance burdens faced by residents. But questions also linger about the wisdom of reducing flood zones in a post-Sandy era—and some climate experts wonder whether the FEMA maps actually go far enough. There are two views in the community:

1. Bad mapping is putting too many people, at too high a cost, in the flood zone.
2. Climate change will increase sea levels in New York and the new maps do not put enough people in the flood zone to account for future risk.

ACTIVITY 3.4 – Job Aid 1

Whose Maps are Inaccurate?



FEMA maps with 2010 updates compared to proposed 2016 FEMA maps.

Daily News reports that city officials claim up to 35% of the area FEMA designated as flood-prone is labeled inaccurately. The city argues that federal calculations used a flawed analysis of prior storms, among other reasons.

Many of the homes that would be affected by the new maps are in South Brooklyn (Canarsie), South Queens (Howard Beach, the Rockaways), and Staten Island.

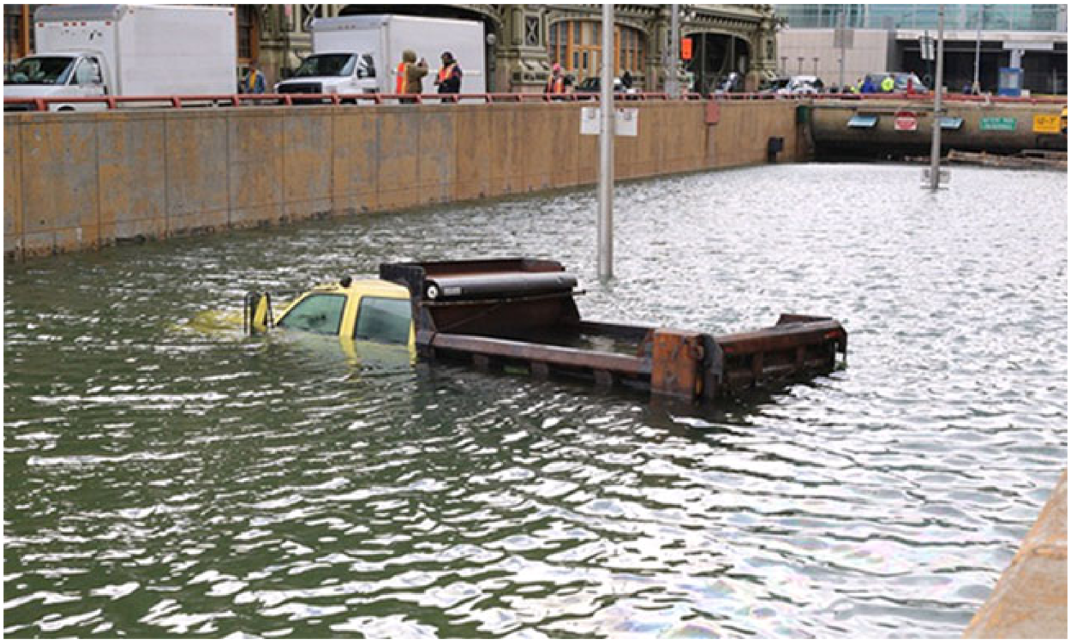
As NYER has reported in the past, these new FEMA maps will have important implications for resiliency projects, human safety, and government policy, but nowhere will the impact be felt more than on individual home flood insurance rates. Under the proposed FEMA maps, a typical home in the high-risk zones could see premiums increase from around $1,000 in 2014 to nearly $14,500 by 2030.

According to Daily News, the city hired outside engineers to create its own maps. By their estimates, only 230,000 New Yorkers live in flood zones, which include 45,000 buildings. That's 26,500 fewer buildings than the new FEMA maps count, and 170,000 fewer people.

The review process could take more than a year to complete; no insurance changes will be made during that time.

ACTIVITY 3.4 – Job Aid 1 (Continued)

A Post-Sandy Era



Flooded Battery Park Tunnel after Hurricane Sandy. Photo credit: Timothy Krause/Creative Commons.

While many, including U.S Senator Charles Schumer, applaud the city's new calculations, there are others who question the wisdom (and safety) of reducing flood zones in a time of changing climate. Indeed, there are some who wonder if FEMA's maps actually went far enough. The Natural Resources Defense Council claims that FEMA's maps are based on outdated data that does not take into account future effects of climate change, including sea level rise that has occurred just in the last 10 years.

In addition, NRDC found FEMA's computer models were not calibrated against data from Hurricane Sandy. As a result "the new 100-year flood zone mapped by FEMA is significantly smaller than the area at risk of flooding assuming 3 feet of sea level rise or the surge from a Category 3 hurricane." By comparison, Sandy was barely a Category 1 storm.

ACTIVITY 3.4 – Job Aid 2

Climate.gov's Brian Kahn interviews Cynthia Rosenzweig, a climate impacts expert at NASA Goddard Institute for Space Studies, co-chair of the New York City Panel on Climate Change, and director of the NOAA-sponsored Consortium for Climate Risk in the Urban Northeast.

ACTIVITY 3.4 – Job Aid 2

Why should New Yorkers care about sea level rise?

First of all, sea level rise is a big issue for millions of people in the U.S., not just New Yorkers. Twenty-three of the 25 most densely populated U.S. counties are on the coast. In New York, the full brunt of Hurricane Sandy has shown how powerful and damaging the effects of coastal flooding can be for infrastructure and communities.

The storm itself we can't immediately link to climate change, but the flooding damage we can. As sea levels continue to rise, a storm of the same magnitude will cause even greater damages due to storm surges coming in on top of a higher "baseline" water level.

What kind of sea level rise has New York Harbor seen over the past century?

We've had roughly a foot of sea level rise in the New York City area in the past century. That's measured at a tidal gauge near Battery Park just off the southern tip of Manhattan. The majority of the sea level rise in the New York City region is due to global warming: primarily, because of thermal expansion of ocean water as it warms and secondly, melting of land-based ice sheets.

Land subsidence [sinking] in the New York City area has been roughly 3-4 inches per century, which is primarily due to the Earth's crust rebounding* from being compressed by massive ice sheets that covered Canada and the northern U.S. about 20,000 years ago near the end of the last Ice Age. Local variations in ocean surface elevation associated with the strength of the Gulf Stream has played a small role as well.

ACTIVITY 3.4 – Job Aid 2 (Continued)

How do sea level rise and storm surge interact?

Sea level rise is like a set of stairs. The 12-inch increase in New York Harbor over the last century means we've already gone up one step. When a coastal storm occurs, the surge caused by the storm's winds already has a step up, literally. For Sandy, that meant greater coastal flooding in New York and the surrounding region than we would have experienced a century ago. Continuing to climb the staircase of sea level rise means we'll see greater extent and greater frequency of coastal flooding from storms, even if storms don't get any stronger.

What's the range of sea level rise we can expect to see in the future for the New York region?

We've created two sets of sea level rise projections for the region by downscaling global climate models for local conditions. Using a similar approach to the last IPCC [Intergovernmental Panel on Climate Change] report, we project 12-23 inches by the 2080s.

We also developed a rapid-ice-melt scenario, based on the same greenhouse gas concentrations, but factoring in observations of accelerated ice sheet melt and paleoclimate data from ice cores, tree rings, and other sources. That projection gives a higher end of 41-55 inches in the 2080s.

ACTIVITY 3.4 – Job Aid 2 (Continued)

It's important to note that these systems don't act in isolation; they are incredibly interdependent. For example, when the power goes down then you can't charge your cell phone. These interdependencies are compounding the impacts that people are experiencing in the New York region from Hurricane Sandy.

What about social vulnerabilities?

All of these infrastructure vulnerabilities feed directly into societal ones. In the New York region, many lower-income communities are located in the coastal flood zone. With Sandy, there has been tremendous damage across many of those communities.

In addition, the elderly, the very young, and the ill are also highly vulnerable. It's much harder for them to evacuate, which in turn puts them at greater risk to infrastructure failure. Just look at the challenges hospitals in Lower Manhattan faced when the back-up generators failed.

Did Sandy reveal any previously unforeseen weaknesses?

We're going to be looking at the impacts of Hurricane Sandy very carefully. Many of the impacts that occurred have been included in previous studies, but we're certainly going to go back and evaluate them so we can better inform planning around extreme weather and climate events. We can always learn more and continue to be better prepared. One thing we do want to look at is the fires that occurred in some of the coastal communities, and the gasoline shortages that persisted throughout parts of the region.

What actions has the city undertaken to help infrastructure and residents deal with sea level rise and attendant impacts from storm surge prior to Sandy?

Hurricane Sandy is a wake-up call, no, a shout, that going forward we have to do more to prepare for these kinds of events. That said, the city has done a great deal to prepare. The city government has a flood evacuation plan, and they implemented it. The Metropolitan Transit Authority (MTA) had a plan to close the subway, and they did it early enough. The loss of life could have been much higher.

There have been some other important initiatives New York has taken. For example, the Mayor's Office has planted vegetation in over 300 places to absorb storm water. It's called the Greenstreets Program. They're also raising the pumps at the Rockaway Wastewater Treatment Plant in response to sea level rise projections. In addition, the MTA has raised some of the subway grates and air vents on the sidewalks as part of a pilot program.

These programs are informed by the work of the New York City Panel on Climate Change (NPCC), an expert panel convened by Mayor Bloomberg to advise the city on climate science and risk management. The NPCC published an extensive, peer-reviewed report about climate change and its impacts on New York. The New York City Council has passed a resolution to have the NPCC write a report on the order of once every three years to ensure the city is using climate research when it comes to planning.

When scientists talk about sea level rise in coming decades, you generally hear them say "projections" rather than "predictions." What's the difference?

There's uncertainty about climate change. Not that it's happening, but as to its future rate of change and magnitude. The term "projection" is better because it includes uncertainty more clearly. “Prediction” implies more certainty, a perspective that doesn’t take into account that there’s still emerging science around climate change, that the climate system is continually evolving, and that there will be updates to future climate and sea level rise scenarios as a result.

Visual 75: Unit Summary

You should now be able to:

- Discuss the overarching concept of energy, equality, mass, and dynamism.
- Distinguish between climate and weather.
- Describe the global causes of climate.
- Describe El Niño and La Niña and their impacts on the United States.
- Define long-term trends and explain their impact on hazardous weather.
- Identify the ingredients for thunderstorms and tornadoes.
- Describe factors that affect the severity of storms.

Visual 76: Unit Summary (Continued)

- Describe the geographical and seasonal trends of convective storms in the United States.
- Distinguish between tropical depression, tropical cyclone, tropical storm, and hurricane.
- Describe the global context of tropical cyclone formation and movement.
- Identify the ingredients of hurricanes.
- Describe the components of a hurricane.
- Describe storm surge and factors that affect its severity.

Unit 4: Other Hazardous Weather

Visual 1:

Unit 4: Other Hazardous Weather

Key Points

This unit will discuss the discuss the science of extreme temperatures.

Time Plan

A suggested time plan for this unit is shown below.

Topic	Time
Introduction	5 minutes
Extra-Tropical Cyclones	15 minutes
Winter Weather Activity 4.1 - Long-Term Power Outage (Optional)	10 minutes

Topic	Time
Extreme Heat Activity 4.2 - Implications of Widespread Power Outage	25 minutes
Module Summary	5 minutes
Total Time	**1 hour**

Visual 2: Unit Objectives

- Compare and contrast nor'easters and hurricanes.
- Identify the ingredients of nor'easters, winter storms, and extreme cold temperatures.
- Explain the scientific differences between various types of frozen precipitation.
- Indicate the predictability of nor'easters, winter storms, and extreme cold temperatures.
- Describe how extreme heat and drought severity are categorized.
- Indicate the predictability of droughts.
- Identify the factors that contribute to wildfires.

Key Points

Review the unit objectives as shown on the visual.

Visual 3: Topics

- **Extra-Tropical Cyclones**
- Winter Weather
- Extreme Heat

Key Points

The next section of this unit will present key points about the science of other types of hazardous weather, including, nor'easters, winter storms, and droughts.

Visual 4: Video: The Nor'easter After Easter

Key Points

Introduction: This video presents a case study that examines in greater detail how the Gulf Stream and other ingredients interact to create a nor'easter.

Video Transcript:

The Tropics provide a steady stream of clouds and storms that generally move east to west. In mid-latitudes weather moves west to east with some twists and turns due to Earth's rotation. An important kind of storm moves north and east along the United States' east coast, especially in winter. People in the New England States call these "nor'easters," and they usually bring snow, rain, and driving wind. In late April, an unusual, post-winter nor'easter brought much-needed rain to an especially dry eastern United States.

To understand the climate connections driving nor'easters, here are satellite loops that track the storm through late April.

A low-pressure system developed off the coast of Florida on April 21 as light, warm moist air rose from the warm ocean surface. Warm water is a climate characteristic of the Gulf, the Caribbean, and the Gulf Stream which warms the entire east coast before heading off towards northern Europe. Earth's rotation interacts with the prevailing movement of air from west to east to spin these storms up and along the east coast.

The difference in temperature between land which is cold, and the ocean which is warm, fuels driving rains. The ocean in this part of the world stays warm due to the Gulf Stream. The land is especially cold when Arctic air plunges southward. During winter, this temperature difference is more common, but notice how the polar jet stream dipped south of the Great Lakes on April 22.

The east coast has been drier than normal so far this year, in part because winter didn't bring any major nor'easters. This map shows rainfall differences from average for January through April. The brown areas were drier than normal for this time of year.

Farmers are often the first to feel water shortages. In Maryland, some farmers lost their spinach crops and had to delay soy and corn planting because the soil was so dry. Farmers and residents in Delaware-Maryland-Virginia, Connecticut, Rhode Island, and Massachusetts have all delayed their spring planting and have been conserving water.

This springtime storm made up for most of April's rainfall deficit in a single event, dumping over 2 along much of the Atlantic coast and between 4 and 6 in parts of Maine. Unfortunately, the year-to-date through April was still well below average, not only for the Mid-Atlantic and New England, but much of the United States.

Recapping the climate connections for a nor'easter: warm ocean water fuels a low-pressure system with moisture; Earth's rotation moves that air mass in a counter-clockwise motion along the east coast; and cold air from the North drives toward the storm's center. That was the climate story for one strange nor'easter after Easter.

For climate.gov, I'm Ned Gardiner.

(Source: NOAA Climate.gov)

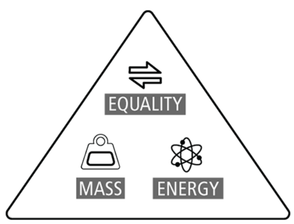
Visual 5: What Is a Nor'easter?

- Low-pressure system
- Moves along east coast
- Counter-clockwise rotation
- Named after northeasterly winds blowing ahead
- Can occur any month (peak September - April)

Types:

- Offshore forming: More catastrophic, heavy snow
- Onshore forming: Less catastrophic, mostly rain

This is equality, mass, and energy.



Key Points

Characteristics of a nor'easter: A nor'easter:

- Is a strong, low-pressure system that moves along the east coast of the United States with a counter-clockwise rotation.
- Gets its name from the strong northeasterly winds that blow in from the ocean ahead of the storm and over coastal areas.
- Can occur any month of the year, but is strongest (and occurs most frequently) between September and April. They are less common in summer because the jet stream is usually missing (farther north).

A nor'easter normally develops within 100 miles of the coastline between Georgia and New Jersey and moves north or northeastward from there. However, a nor'easter can form over the land of the east coast, or out over the Atlantic coastal waters. This difference constitutes the two types of nor'easters.

Types of nor'easters:

- **Offshore forming:** These nor'easters are normally more catastrophic and news-worthy. After forming over the Atlantic waters, these storms will dump heavy snow onto cities like Washington, DC, New York City, and Boston.
- **Onshore forming:** These nor'easters are normally much less catastrophic or news-worthy. They tend to move west of most east coast cities, act like average storms, and mostly produce just rain and wind.

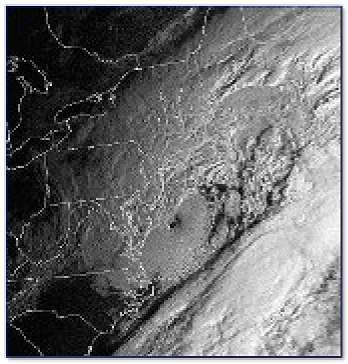
Visual 6: Compared to a Hurricane

Similarities

- Large, low-pressure cyclonic storm off the east coast
- Counter-clockwise rotation
- Similar strength and effects

Differences

- Mid-Atlantic and NE landfall
- Driven by upper air, develop from the top down.



Key Points

When compared to a hurricane, a nor'easter is similar in several key ways:

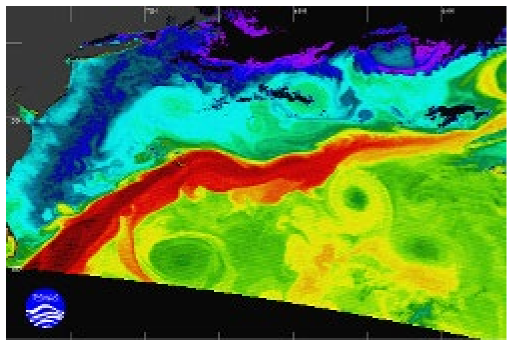
- Both hurricanes and nor'easters are large, low-pressure cyclonic storms that normally have a center of rotation just off the east coast.
- Both are counter-clockwise rotating systems in the Northern Hemisphere.
- Nor'easters can reach the strength of moderate or even strong hurricanes and can produce similar effects.
- Occasionally, a strong nor'easter will form a hurricane-like eye at its center. For example, this visual shows a satellite image of an intense nor'easter with a hurricane-like eye in February 2006.

However, there are also a few key differences:

- Hurricanes normally make landfall in the Southern States, while nor'easters typically afflict the mid-Atlantic and Northeast States.
- Hurricanes develop from the bottom up, whereas nor'easters are driven by upper air and develop from the top down.

Visual 7: The Gulf Stream

- Intense warm ocean current in the Atlantic
- Flows northward along the east coast of the United States from Florida to North Carolina, then veers out into the North Atlantic
- Forms a boundary between the warm waters in the middle of the North Atlantic and the colder, denser waters of the continental shelf
- In winter, helps warm the cold winter air over the water



Key Points

Impact of the Gulf Stream: The Gulf Stream plays an important part in the formation of nor'easters. The Gulf Stream is an intense warm ocean current in the Atlantic that flows northward along the east coast of the United States from Florida to North Carolina and then veers out into the North Atlantic near Cape Hatteras, North Carolina.

The Gulf Stream:

- Forms a boundary between the warm waters in the middle of the North Atlantic and the colder, denser waters of the continental shelf. The current loops and bends as it veers away from the United States coast, so its exact position is variable.
- Influences the climate of the east coast of Florida, keeping temperatures warmer in the winter and cooler than the other southeastern states in the summer. Because it also extends toward Europe, it warms western European countries as well.

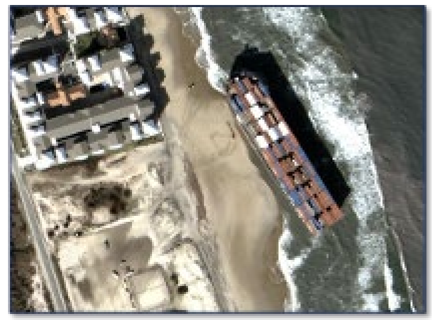
Helps keep the coastal waters relatively mild during the winter which, in turn, helps warm the cold winter air over the water.

The infrared image shows the Gulf Stream as it departs from the coast at Cape Hatteras. The coldest waters are shown as purple, with blue, green, yellow, and red representing progressively warmer water. Temperatures range from about 45-72 °F (7-22 °C).

Visual 8: El Nino & Nor'easters

El Niño episodes affect nor'easter formation as explained in your key points.

Visual 9: Damaging Effects



- Heavy snow and/or rain
- Winds greater than 58 mph and exceeding hurricane force
- Rough ocean waters
- Storm surge and coastal flooding
- Beach erosion

Key Points

Damaging effects of nor'easters can include:

- Heavy snow and/or rain.
- Gale force winds with a speed greater than 58 mph and exceeding hurricane force in intensity.
- Rough ocean waters.
- Coastal flooding and beach erosion.

The bottom image on the slide shows an area off the coast of Virginia where storm surge resulting from a nor'easter grounded a barge on shore.

One of the biggest concerns is the huge amounts of snow dumped on east coast cities. For example, a nor'easter from March 20-22, 2018 brought over 18 inches of snow and whiteout conditions to the Mid-Atlantic states and New England.

On the next page are descriptions of some of the most notable nor'easters in terms of damage.

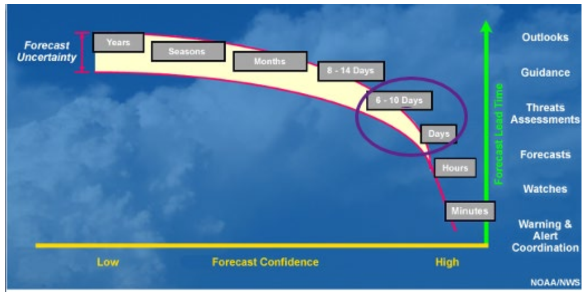
For more information: National Centers for Environmental Information (https://www.ncei.noaa.gov/)

Notable Nor'easters

- **Post-Christmas Storm of 2010:** This late-December nor'easter was initially a low-pressure system from the Gulf but exploded into a nor'easter off the mid-Atlantic coast. It brought heavy snow, thunderstorms, and strong winds of up to 40 mph throughout the Northeast.
- **Blizzard of 1996:** This nor'easter developed in the Gulf, intensified along the mid-Atlantic, and brought heavy snow and wind gusts to the mid-Atlantic and much of the Northeast. Local accumulations in West Virginia were as high as 4 feet, and Philadelphia received 30.7 inches-its highest accumulation on record. After this nor'easter, the same general area was hit with a warmer rainstorm that contributed to widespread melting and flooding.
- **1993 Superstorm:** This storm was named for its wide area of impact (New England to Florida). It took a more inland track rather than moving up the coast. In the Mid-Atlantic States, there was severe flooding and snowfall; in Florida, the superstorm resulted in storm surges of 9 to 12 feet.
- **1992 Great Nor'easter or "The Downslope Nor'easter":** The effects of this December storm were felt most strongly in the northeast and the mid-Atlantic coasts, which were battered with high winds and waves. There was moderate flooding in Maryland, and storm surges of 10 to 12 feet in New Jersey, Delaware, and New York City.
- **Blizzard of 1978:** This February nor'easter was historic due to its long-duration snowfall and hurricane-force winds (gusts of 80-90 mph in eastern Massachusetts) resulting from a strong high-pressure system off the coast of New England. The Northeast was hit the hardest, and Boston and Providence were buried under record snowstorm totals (27.1 inches and 27.6 inches, respectively).
- **1962 Ash Wednesday Storm:** Perhaps the strongest nor'easter of the century, this monstrous March storm resulted in major coastal erosion from New York to North Carolina. As a result of the massive storm surge in Virginia, entire islands off the coast (Chincoteague, Assateague) were completely flooded, and winds as high as 70 mph built up 40-foot waves in the ocean.
- **1956 Nor'easter:** This storm resulted in significant damage from high tides in Virginia. For example, there was a 4.6-foot rise in water levels in Hampton Roads, and a 6.32-foot rise in Norfolk. The storm flooded thousands of homes and washed two ships on shore.
- **Blizzard of 1888:** This massive March nor'easter:
  - Brought devastating amounts of snowfall from Virginia to Maine.
  - Paralyzed Washington, DC, Philadelphia, Boston, and New York City.
  - Dumped up to 50 inches of snow in multiple New England States with snow drifts as high as 40 to 50 feet.
  - Resulted in 200 sunken ships and 400 fatalities.

Visual 10: Nor'easter Prediction

- Lead time: Days
- Accuracy: Good



Key Points

Accuracy of prediction: The lead time for predicting nor'easters is measured in days, and the accuracy is generally good.

Challenges: As with all weather, there is a degree of unpredictability that continually poses challenges to forecasters. As we continue to get more data sets, we will be able to predict with more accuracy.

Informational sources: To predict nor'easters, forecasters rely on many of the same informational sources we have discussed, including:

- Surface observations (e.g., balloon-launched temperature, moisture, and wind measurements).
- Statistical models.
- Coordination with Federal, State, and local emergency managers.

With the necessary information gathered from these sources, forecasters are able to predict:

- Probability of the nor'easter's track and affected areas.
- The probability of precipitation.
- Types and accumulation of precipitation.
- Temperatures.

Visual 11: Bomb Cyclone (1 of 2)

- A bomb cyclone is an extra-tropical mid-latitude storm that intensifies very rapidly.
- They form when air near Earth's surface rises quickly, triggering a sudden drop in barometric pressure — at least 24 millibars within 24 hours.

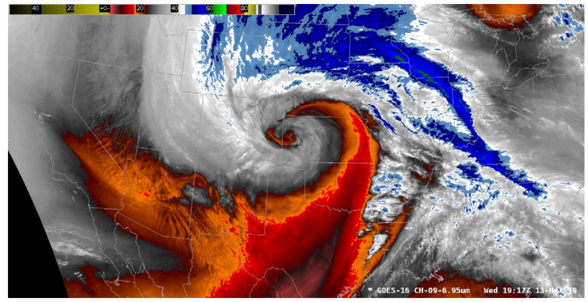


Image Description

On March 13th, 2019 an extremely powerful low pressure system developed over southern Colorado, setting a record for the lowest pressure recorded over Colorado, bringing widespread rainfall over the plains, creating a blizzard over El Paso County, and dropping feet of snow over the mountains. According to local news sources, around 1,500 motorists were stranded over northern El Paso County. According to CDOT, I-25 north of Woodmen Road closed at 11:23 AM MDT due to "adverse weather conditions" and reopened during the later afternoon hours on March 14th. The lowest recorded pressure was 970.4 hPa over Lamar, Colorado, which is the official state record for lowest pressure ever recorded outside of a tornado. KPUB (Pueblo, Colorado) recorded a 974.2 hPa surface pressure at 9:00 AM MDT, which is a record for the lowest pressure over Pueblo

Key Points

This is also known as "explosive cyclogenesis" or "bombogenesis."

Formation

1. **Pre-cyclogenesis**: During the late evening hours and overnight hours of March 12th and March 13th, there were rain bands that formed over the I-25 corridor and the eastern plains. The rain band formations were created by warm air advection (WAA) from the south and southeast of Colorado. Generally, the Raton Mesa creates a rain shadow (compressional heating due to downslope flow resulting in temperatures warming and moisture content remaining stationary, meaning a drier atmosphere relative to where the air came from), but in this case the WAA overcame the effects of orographics to create overnight rain showers. The high temperatures on March 13th actually came during the overnight periods. The extra moisture from the Gulf of Mexico and the stratus deck kept the temperature warm overnight, hence the rain bands and not snow bands.
2. **"Bombogenesis":** So how did this happen? Why did we see the strongest low-pressure system ever recorded in Colorado? Here over the Front Range, we see a phenomenon called Lee Cyclogenesis. Essentially what happens is the upper level low pressure system ejects off of the Rocky Mountains and over the high plains, during that time the upper level circulation must quickly go from the higher elevations all the way down to the

lower elevations which causes the low pressure system to stretch and tighten up, causing it to rotate more quickly and therefore intensify. The best way to describe this phenomenon is by comparing it to ice skater spinning. When the ice skater has their arms out, they will spin slower, but when they bring in their arms tight to their body, they spin more quickly, which is an application of the conservation of angular momentum. The same thing that was previously described happens to a low-pressure system ejecting off of the Rocky Mountains. Lee cyclogenesis happens all of the time, so what made this special? Well, while the low-pressure center ejected off of the Rockies there was a baroclinic zone located over southern Colorado. A baroclinic zone is a region in which a temperature gradient (temperature difference) exists, which is also helps intensify the low-pressure system. In this particular case, there was a 10C temperatures difference within 50 miles. So there was lee cyclogenesis and baroclinic cyclogenesis occurring, but again, this is a relatively common occurrence. There was another element that helped the cyclone to explosively intensify, and that was a trough merger between a low pressure center located over the Pacific Northwest and a cut-off upper level low over the American Southwest. All these interactions created the "bombogenesis" event. The rapid cyclogenesis caused "wrap-around" precipitation bands on the back side of the low-pressure center. This kind of precipitation occurs when the upper level low and the surface transition to becoming vertically stacked or reach the occlusion stage of its life cycle. Isentropic lift (upglide; warm conveyor belt) is responsible for this type of precipitation. The timeline of when rain turned into snow and when blizzard conditions started is located in the "Overview" section of this write-up.

3. **Orographics**: The final stage is when the low-pressure system was located far enough east that the dynamics were overwhelmed by the orographics. The very strong northerly winds (downslope) off of the Palmer Divide ending precipitation over southern El Paso County and Pueblo County is illustrated in Fig. 11. Blizzard conditions still continued over parts of southern El Paso County and all of northern El Paso County (see the "Overview" section), but rain stopped over Pueblo County and south. Generally, the downslope flow off of the Palmer Divide is stronger than the dynamics of the low-pressure system, but in this case, the dynamics were stronger, at least for the middle of the event. A key lesson in Colorado forecasting is that topography manipulates the weather around us, and the topography manipulated the outcome of this explosive cyclogenesis event. During afternoon hours, the strongest winds were observed, and which was caused (partly) by the topography as well. There was ageostrophic accelerations to the south due to wind hitting the mountains and being forced south, evaporational cooling from the downslope effects of the Palmer Divide causing a density acceleration to the lower elevations, and the shear intensity of the low pressure system.

Additional information can be found at the [March 13th, 2019 "Bombogenesis" Event](https://www.weather.gov/pub/Bombogenesis_20190313) page at NWS. (This link can be viewed at https://www.weather.gov/pub/Bombogenesis_20190313).

Visual 12: Bomb Cyclone (2 of 2)

As the air rises, wind spirals in at the base of the storm:

- As long as the air continues to rise at the top of the storm faster than it can be replaced at the bottom, barometric pressure will continue to drop.
- As with a hurricane, lower air pressure yields a stronger storm.
- The difference in temperature between the warm and cold air fuels the pressure drop.

Visual 13: Topics

- Extra-Tropical Cyclones
- **Winter Weather**
- Extreme Heat

Key Points

The next section of this unit will present key points about the science of winter storms, which are related to nor'easters in their effects but they are somewhat different in their causation.

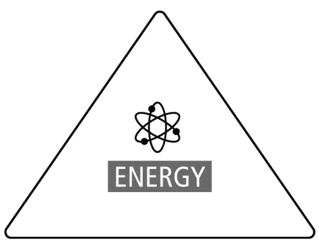
Visual 14: Winter Storms

- Extratropical storms.
- Bring cold temperatures, precipitation, and sometimes high winds.
- Commonly result in heavy snow (a steady fall of snow for several hours or more).

Ingredients:

- Moisture—needed for precipitation
- Lift—causes precipitation
- Cold air—needed for frozen precipitation

This is energy.



Key Points

Description: Winter storms are extratropical storms that bring cold temperatures, precipitation, and sometimes high winds. Heavy snow is a common component of winter storms and is defined as a steady fall of snow for several hours or more.

The accumulations and timeframes for defining heavy snow depend on region and elevation, but are generally defined as:

- Snowfall accumulating to 4 inches (10 cm) or more in 12 hours or less, or
- Snowfall accumulating to 6 inches (15 cm) or more in 24 hours or less.

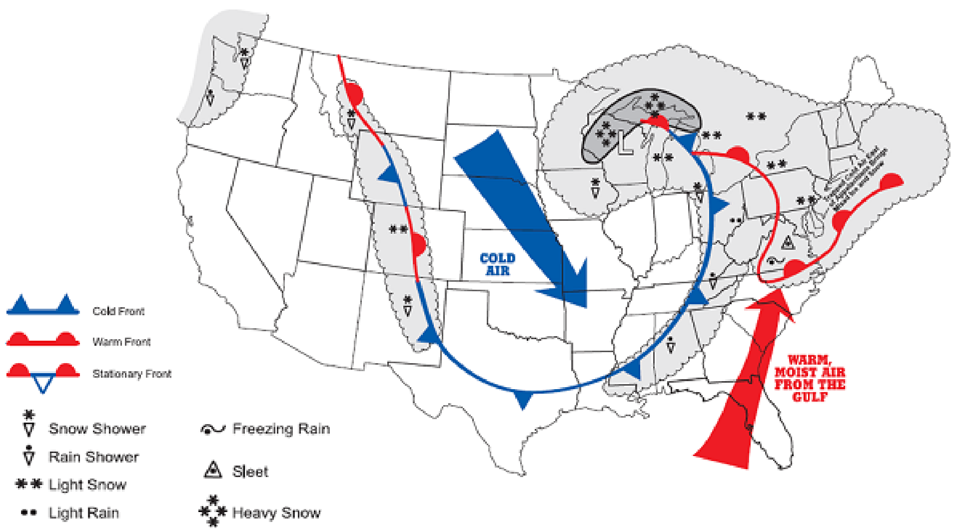
Ingredients: The development of a winter storm requires three ingredients:

- **Moisture:** The air must contain moisture in order to form clouds and precipitation. As you learned in earlier units, air blowing across a body of water, such as a large lake or an ocean, is an excellent source of moisture.
- **Lift:** A mechanism to raise the moist air to form the clouds and cause precipitation must also be present. Lift can be provided by any or all of the following:

    - Orographic flow, i.e., the flow of air up a mountainside.
    - Fronts, where warm air collides with cold air and rises over the cold dome.
    - Upper-level low pressure troughs.
- **Cold air:** Cold air generally refers to subfreezing temperatures (below 32 F) in the clouds and/or near the ground needed to make snow and/or ice.

Visual 15: Ingredients for Winter Storms

- Cold Air
- Moisture Lift



Key Points

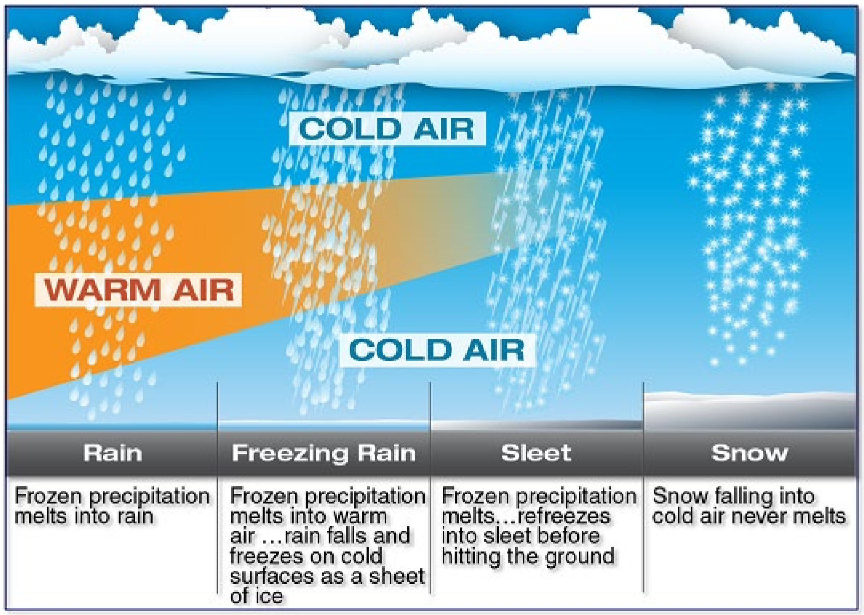
This visual illustrates the three ingredients needed for winter storm formation interacting on a national scale. Note that:

- A front of cold air is represented by the blue line with triangles.
- A front of warm, moist air from the Gulf is represented by the red line with half-circles.
- A stationary front (i.e., a front between warm and cold air masses that is moving very slowly or not at all) is represented as a combination of the two lines.

In this scenario, the three ingredients necessary for winter storm formation—moisture, lift, and cold air—are all present.

Visual 16: Discussion: What's the Difference?

What are the hazards associated with snow, sleet, and freezing rain?



Key Points

The differences are as follows:

- **Rain**: Frozen precipitation from high level clouds melts into rain as it passes through a warm air layer.
- **Freezing Rain**: Frozen precipitation from high level clouds melts into rain as it passes through a warm air layer, but then freezes on cold surfaces as a sheet of ice.
- **Sleet**: Frozen precipitation from high level clouds melts into rain as it passes through a warm air layer, but then refreezes into sleet before hitting the ground.
- **Snow**: Frozen precipitation from high level clouds never melts and remains in the form of snow.

Each condition presents its own unique hazards, especially frozen precipitation which can hinder travel due to slippery conditions, cause icing and breaking of power lines or trees.

Visual 17: Winter Storm Concerns

- Temperature & moisture:
  - Health problems (e.g., hypothermia, frostbite)
  - Melting and refreezing issues (e.g., broken pipes or power lines)
- Amount of sun exposure:
  - Slower melting
  - Ice accumulation
- Snow density/weight:
  - Melting and refreezing increases density

Key Points

There are multiple concerns about winter storms rooted in scientific factors.

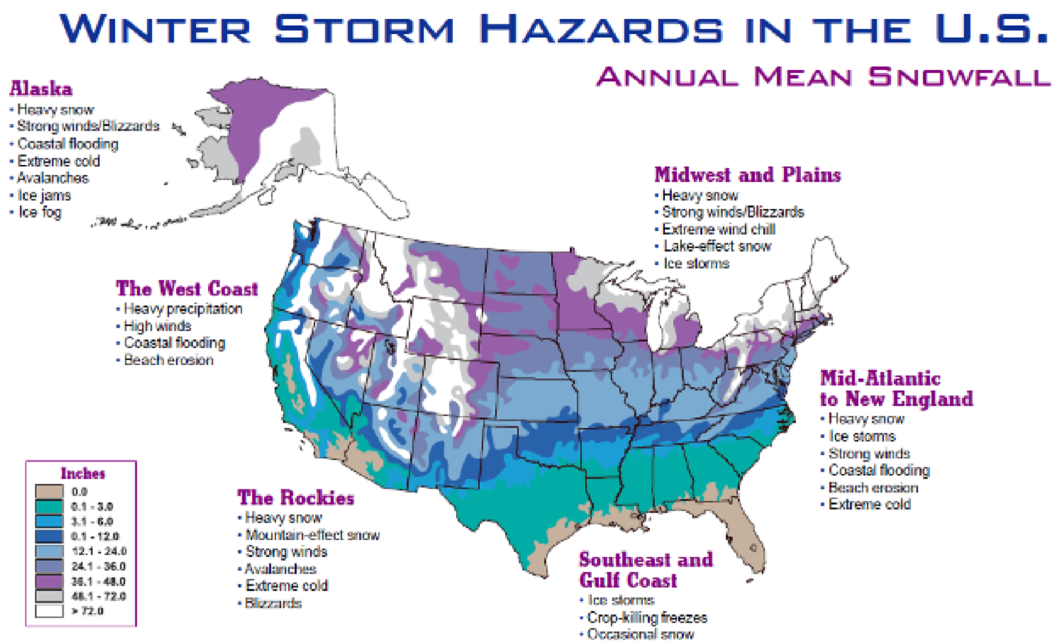
Temperature and moisture: Chronic freezing or subfreezing temperatures can lead to health problems from extreme cold including hypothermia, frostbite, and lowered tolerance. Another concern is that large temperature fluctuations between daytime and nighttime can result in dangerous melting and refreezing. Water that freezes into ice expands, and can cause cracks or breaks in pipes and snap power lines, usually during extended periods of below-freezing temperatures.

Sun exposure: Another concern is the amount of sun exposure in an area hit with a winter storm. For example, north-facing areas get less sun exposure in the winter and will have slower melting snow. Ice accumulation will also be greater in areas facing north.

Snow density: A third concern is snow density, i.e., the weight of snow. The density of snow depends on the amount of moisture it contains. Newly fallen snow is lighter than accumulated snow, and certain areas get less dense, more powdery snow (e.g., Colorado) than other areas (e.g., the east coast, which gets denser, wetter snow).

As snow accumulates, it melts a bit and refreezes, and the density increases. The densest snow (i.e., packed snow) is snow that has been sitting for days without melting.

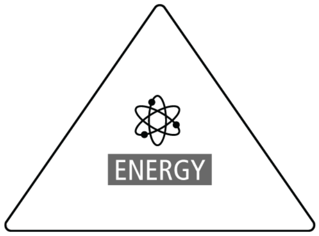
Visual 18: Winter Storm Hazards in the US



Winter Storm Hazards in the U.S. Image Description

- Alaska – heavy snow, strong winds/blizzards, coastal flooding, extreme cold, avalanches, ice jams, and ice fog
- Midwest and Plains – heavy snow, strong winds/blizzard, extreme wind chill, lake-effect snow, and ice storms
- The West Coast – heavy precipitation, high winds, coastal flooding, and beach erosion
- The Rockies – heavy snow, mountain-effect snow, strong winds, avalanches, extreme cold, and blizzards
- Southeast and Gulf Coast – ice storms, crop-killing freezes, and occasional snow
- Mid-Atlantic to New England – heavy snow, ice storms, strong winds, coastal flooding, beach erosion, and extreme cold

This is energy.

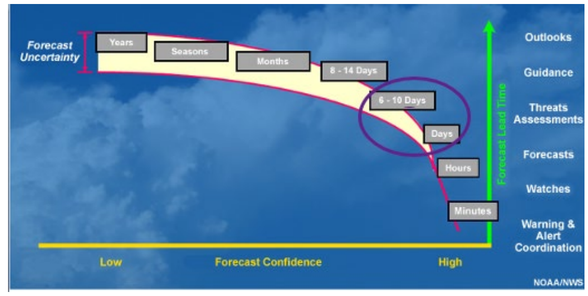


Key Points

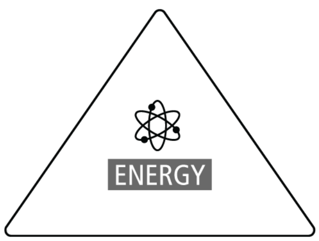
This map shows the annual mean snowfall across the United States and indicates which areas are at a greater risk for damaging winter storms.

Visual 19: Winter Storm Prediction

- Lead time: Days
- Accuracy: Good



This is energy.



Key Points

Gathering information: In order to predict winter storms, forecasters rely on many of the same technologies mentioned in previous units, including radar, surface observation, satellites, and computer models. In the process, they gather information about:

- Air, ground, and cloud top temperatures.
- Wind direction.
- Cold fronts.
- Moisture.
- Type and heaviness of precipitation.
- Comma clouds, i.e., synoptic scale cloud patterns with a characteristic comma-like shape that are associated with large and intense low-pressure systems.

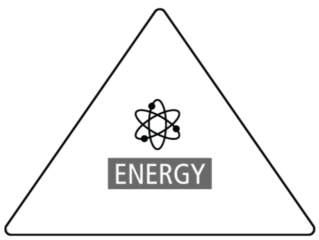
What's predictable: With this information, forecasters are able to predict the probability, types, and accumulation of precipitation along with expected temperatures. The lead time for predicting winter storms is days, and the accuracy is generally good.

Challenges: Forecasts for winter storms are improving but still involve certain challenges. For example, heavy snow often appears as small bands on larger resolution models that are harder to pick up; conversely, extremely light snow can go undetected because of its low moisture and high air content. Also, the boundary line between rain and snow is defined by a very small temperature disparity.

Visual 20: Extreme Cold

- Definition varies according to the normal climate of a region.
- Often accompanies or follows winter storms
- Can occur with or without storm activity

This is energy.



Key Points

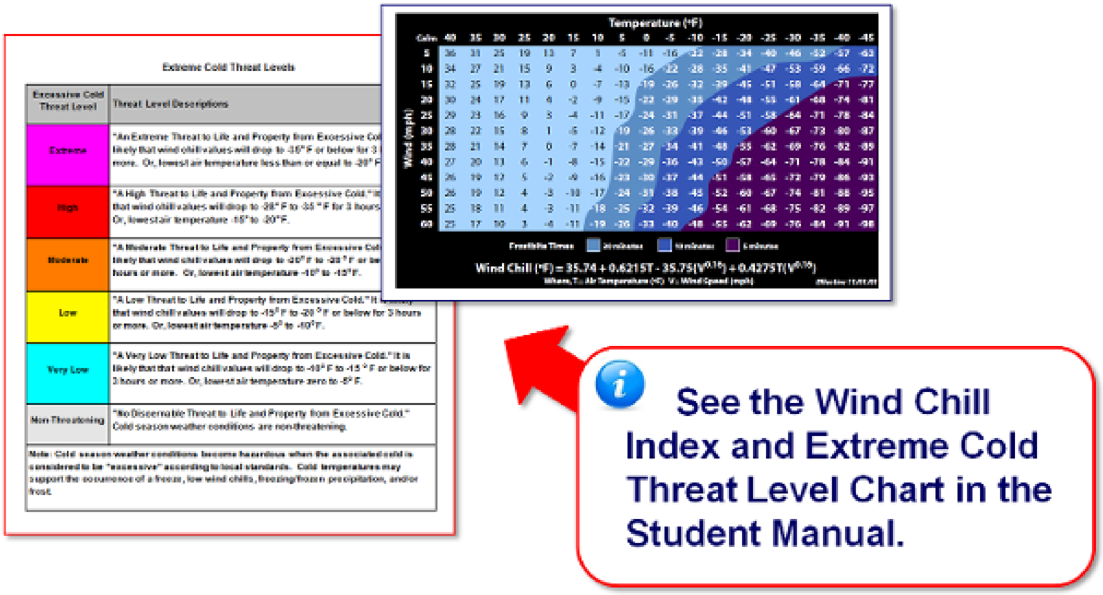
Definition: The criterion for extreme cold varies according to the normal climate of a region. For example, in a relatively warm climate, temperatures just below or at freezing can be hazardous; in the north, temperatures below zero may be considered extreme.

Excessive cold often accompanies or follows winter storms, but it can also occur without storm activity.

Ingredients: The ingredients necessary for extreme cold are:

- **Cold temperatures:** Remember, the temperature boundary of "extreme" varies by region.
- **Cold air mass:** An invasion of arctic air mass (pulled down by the jet stream) is also a necessary ingredient for extreme cold.
- **Prolonged cold conditions:** A prolonged period of cold-even if above-freezing-temperatures can result in the extreme cold that causes hypothermia.
- **Wind:** Extreme cold can be particularly dangerous when accompanied by wind, creating an effect known as wind chill.

Visual 21: Wind Chill and Threat Levels



Key Points

As we all know, "cold" is not just a matter of temperature; it's also wind chill. Wind chill is based on the rate of heat loss from exposed skin caused by the combined effects of wind and cold. As the wind increases, heat is carried away from the body at an accelerated rate, driving down the body temperature.

Wind chill index: Forecasters use a wind chill index as a guide to heat loss resulting from given temperatures and wind speeds.

Excessive cold threat level: Just as storms can be evaluated in terms of threat level, there is an Excessive Cold Threat Level scale that helps forecasters determine the severity of the threat of extreme cold, from nonthreatening to extremely threatening.

Review the NWS Wind Chill Index and the Excessive Cold Threat Level chart on the following pages. On the Wind Chill Index, note that the purple area is the most dangerous for frostbite; the combined low temperatures and high winds can result in a frostbite time of only 5 minutes.

NWS Windchill Chart (https://www.weather.gov/safety/cold-wind-chill-chart)

NWS Windchill Chart

Temperature (°F)

Wind (mph)	Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
	5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
	10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
	15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
	20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
	25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
	30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
	35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
	40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
	45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
	50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
	55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
	60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes; 10 minutes; 5 minutes

Wind Chill (°F) = $35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

See Color Handout 4.2

Excessive Cold Threat Level Chart

Excessive Cold Threat Level	Threat Level Descriptions
Extreme	**"An Extreme Threat to Life and Property from Excessive Cold."** It is likely that wind chill values will drop to -35 °F or below for 3 hours or more, or, the lowest air temperature is less than or equal to -20 °F.
High	**"A High Threat to Life and Property from Excessive Cold."** It is likely that wind chill values will drop to -28 °F to -35 °F for 3 hours or more, or the, lowest air temperature is -15° to -20 °F.
Moderate	**"A Moderate Threat to Life and Property from Excessive Cold."** It is likely that wind chill values will drop to -20 °F to -28 °F or below for 3 hours or more. Or, lowest air temperature -10° to -15 °F.
Low	**"A Low Threat to Life and Property from Excessive Cold."** It is likely that wind chill values will drop to -15 °F to -20 °F or below for 3 hours or more, or the lowest air temperature is -5° to -10 °F.
Very Low	**"A Very Low Threat to Life and Property from Excessive Cold."** It is likely that that wind chill values will drop to -10 °F to -15 °F or below for 3 hours or more, or the lowest air temperature is zero to -5 °F.
Non-Threatening	**"No Discernible Threat to Life and Property from Excessive Cold."** Cold season weather conditions are not threatening.
Note: Cold season weather conditions become hazardous when the associated cold is considered to be "excessive" according to local standards. Cold temperatures may support the occurrence of a freeze, low wind chills, freezing/frozen precipitation, and/or frost.	

Excessive Cold Threat Level Chart

Note: Cold season weather conditions become hazardous when the associated cold is considered to be "excessive" according to local standards. Cold temperatures may support the occurrence of a freeze, low wind chills, freezing/frozen precipitation, and/or frost.

Excessive Cold Threat Level	Threat Level Descriptions
Extreme	**"An Extreme Threat to Life and Property from Excessive Cold."** It is likely that wind chill values will drop to -35 °F or below for 3 hours or more. Or, lowest air temperature less than or equal to -20 °F.

Excessive Cold Threat Level	Threat Level Descriptions
High	**"A High Threat to Life and Property from Excessive Cold."** It is likely that wind chill values will drop to -28 °F to -35 °F for 3 hours or more. Or, lowest air temperature -15 to -20 °F.
Moderate	**"A Moderate Threat to Life and Property from Excessive Cold."** It is likely that wind chill values will drop to -20 °F to -28 °F or below for 3 hours or more. Or, lowest air temperature -10o to -15 °F.
Low	**"A Low Threat to Life and Property from Excessive Cold."** It is likely that wind chill values will drop to -15 °F to -20 °F or below for 3 hours or more. Or, lowest air temperature -5 to -10 °F.
Very Low	**"A Very Low Threat to Life and Property from Excessive Cold."** It is likely that that wind chill values will drop to -10 °F to -15 °F or below for 3 hours or more. Or, lowest air temperature zero to -5 °F.
Non-Threatening	**"No Discernible Threat to Life and Property from Excessive Cold."** Cold season weather conditions are not threatening.

Note: Cold season weather conditions become hazardous when the associated cold is considered to be "excessive" according to local standards. Cold temperatures may support the occurrence of a freeze, low wind chills, freezing/frozen precipitation, and/or frost.

Visual 22: (Optional) Activity 4.1 – Long-Term Power Outage

Instructions:

Working individually…

1. Answer the questions in your IAW.

This is an optional activity.

Instructions: Working individually…

1. Answer the questions in your IAW.

Visual 23: Topics

- Extra-Tropical Cyclones
- Winter Weather
- **Extreme Heat**

Key Points

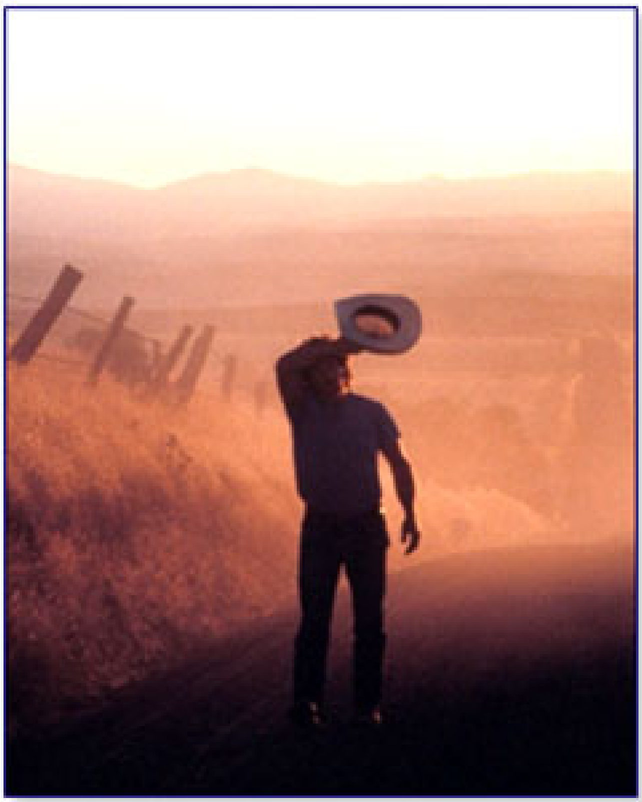
The next section of this unit will present key points about the science of winter storms, which are related to nor'easters in their effects but they are somewhat different in their causation.

Visual 24: Extreme Heat

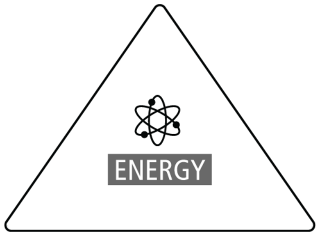
- Can involve sudden and extreme rises in temperature or prolonged heat waves
- Definition varies according to the normal climate of a region

Ingredients:

- High Temperatures
- High Humidity (typically)
- High relative humidity
- High dew points



This is energy.



Key Points

Definition: Extreme heat can involve sudden rises in temperature to extreme levels (taking away people's chance to acclimate) or prolonged heat waves. Either of these cases can cause heat-related fatalities.

As with extreme cold, the exact definition of "extreme heat" varies according to the normal climate of a region. For example, what is considered extreme heat in Seattle would differ from extreme heat in Tucson.

Ingredients: Heat waves and extreme heat are caused by:

- **High temperatures:** Remember that, as with extreme cold, what is considered "extreme" varies by region.
- **High humidity:** This includes:
  - **High relative humidity:** Relative humidity is a function of both moisture content and temperature. Relative humidity refers to how much moisture is in the air compared to the maximum amount the air can hold before the moisture is precipitated out, and is measured by a percentage (higher number = more humidity). Relative humidity is relative; by itself it does not directly indicate the actual amount of atmospheric moisture present. For example, Colorado has relative humidity of about 20 percent, which is dry compared to 97 percent in Washington, DC.
  - **High dew points:** Dew point is a measure of atmospheric moisture. It is the temperature to which air must be cooled in order to reach saturation (assuming air pressure and moisture content are constant). A higher dew point indicates more moisture present in the air. It is sometimes referred to as Dew Point Temperature, and sometimes written as one word (Dewpoint).
- **Heat index:** Just as the combined forces of wind speed and temperature are measured in wind chill, the combined forces of humidity and temperature are measured by the heat index (HI), shown below. What wind chill is to cold waves, heat index is to heat waves—it indicates apparent temperature.

NWS Heat Index

NOAA's National Weather Service

Heat Index

Temperature (ºF)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	126	130					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

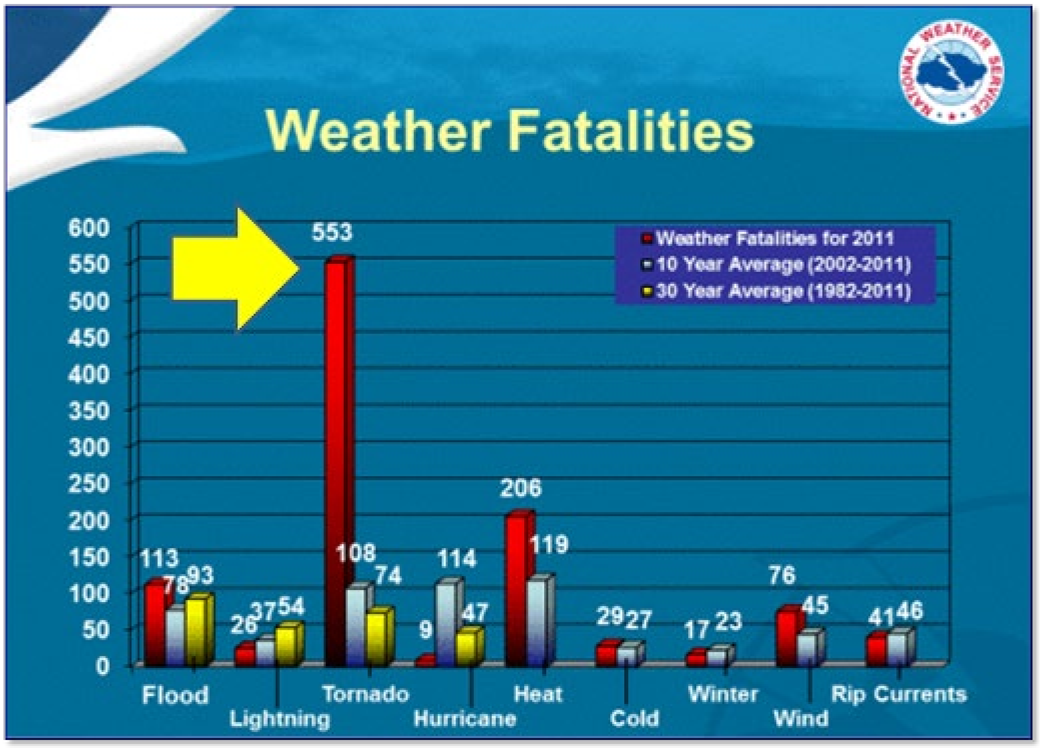
Likelihood of Heat Disorders with Prolonged Exposure or Streuous Activity

Caution Extreme Caution Danger Extreme Danger

Visual 25: Discussion: Other Causes

What are other potential causes of extreme heat?

Visual 26: Extreme Temperatures



Extreme Temperature Image Description

Weather Fatalities chart. The greatest weather-related hazard to life safety has historically been extreme heat. Heat category for 2011 shows 206 Fatalities 10 Year Average (2002-2011): 119

Extreme Temperature Image Alt Text

Weather Event	Weather Fatalities for 2011	10 Year Average (2002-2011)	30 Year Average (1982-2011)
Flood	113	78	93
Lightning	26	37	54
Tornado	553	108	74

Weather Event	Weather Fatalities for 2011	10 Year Average (2002-2011)	30 Year Average (1982-2011)
Hurricane	9	114	47
Heat	206	119	-
Cold	29	27	-
Winter	17	23	-
Wind	76	45	-
Rip Currents	41	46	-

Although extreme cold can be dangerous, the greatest weather-related hazard to life safety has historically been extreme heat.

Notice in the visual, that excessive heat was second highest in 2011 weather fatalities and has the **highest 10-year average fatality count.**

Visual 27: Heat-Related Announcements

Excessive Heat = Heat Index is greater than or equal to 105-110 degrees F.

- Excessive Heat Outlook: Potential for excessive heat in 3 to 7 days.
- Excessive Heat Watch: Potential for excessive heat in 12 to 48 hours.
- Excessive Heat Warning/Advisory: Excessive heat expected within 36 hours.

Key Points

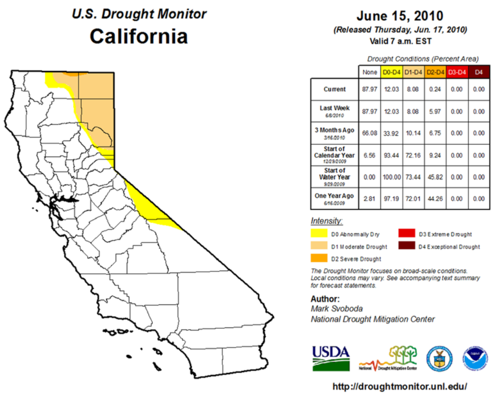
Heat-related announcements are the equivalent of storm-related announcements. However, note that the timeframe in which the heat is expected to occur is the differential between the different types of announcements:

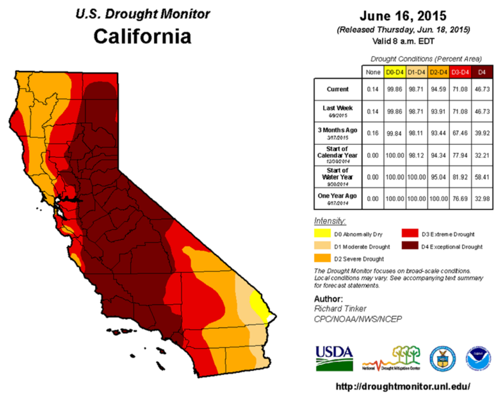
- Excessive Heat Outlook: Potential for excessive heat to occur in the next 3 to 7 days.
- Excessive Heat Watch: Potential for excessive heat to occur in the next 12 to 48 hours.
- Excessive Heat Warning/Advisory: Excessive heat expected to occur within 36 hours.

Although absolute values for extreme heat are also defined regionally, extreme heat is considered to be "officially" a heat index less than or equal to 105-110 F.

A daytime heat index reaching these temperature levels for two consecutive days, with nighttime lows at or above 80 °F, may significantly impact public safety. The local National Weather Service office will generally issue an advisory or warning for these conditions.

Visual 28: California Drought Scenario Part 1





California Drought Scenario Part 1 Image Description

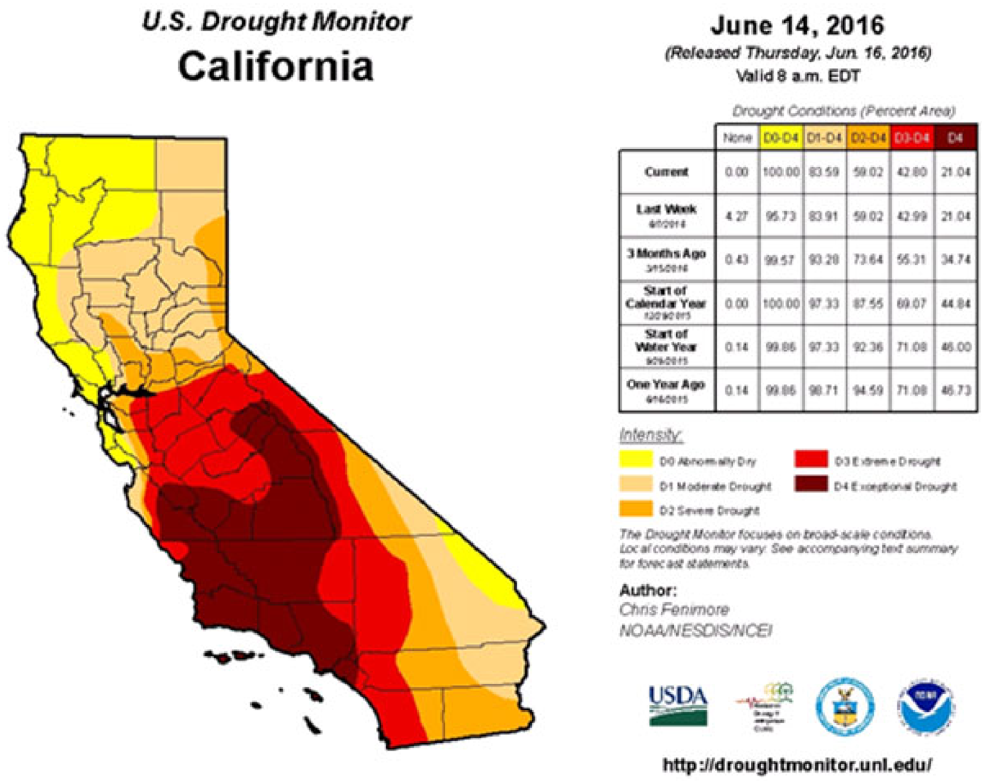
Image 1: California drought scale on June 15th, 2010 where north-east borders had abnormally dry conditions. Moderate drought affect the north-east corner compared to last week, 3 months ago, start of calendar year, start of water year, and one year ago.

Image 2: California drought scale on June 16th, 2015 where the center is in exceptional drought, branching out to extreme and severe drought towards Arizona and north towards Oregon and the coast. Towards Arizona it is abnormally dry and moderate drought.

Key Points

Scenario Part 1: In 2016, California was in its fifth year of severe drought, the primary cause of which was a persistent high-pressure ridge that developed in the western Pacific during the 2011 La Niña. This high pressure failed to dissipate and resulted in extreme temperatures and reduced precipitation throughout the Southwest. In the third year of the drought, on January 17, 2014, Governor Brown declared a Drought State of Emergency.

Visual 29: California Drought Scenario Part 2



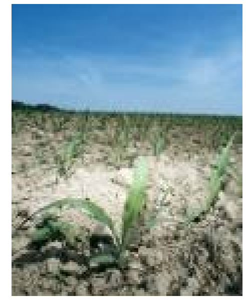
California Drought Scenario Part 2 Image Description

California drought scale on June 14th, 2016 where the south-west is in exceptional drought, branching out to extreme and severe drought towards Nevada. Towards Arizona it is abnormal to moderate drought. North CA goes from abnormally dry (by the coast) to Moderate and down to severe drought compared to last week, 3 months ago, start of calendar year, start of water year, and one year ago.

Key Points

Scenario Part 2: While the 2015 El Niño event helped to reduce drought conditions, more than 55 percent of California remains in extreme drought. Snowpack in the Sierras is a primary water source for California and in 2016 levels in the Sierras were at 87 percent of normal. This is a significant improvement over the 5 percent of average snowpack levels measured in April 2015. Even with greater precipitation in the 2016 Water Year, drought conditions are still much more widespread than they were before the drought began in 2011.

Visual 30: Drought

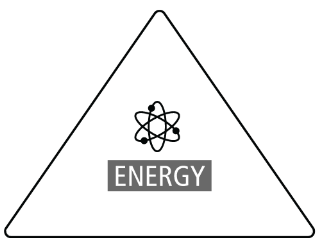


- A period of drier-than-normal conditions
- Results in water-related problems

Types:

- Meteorological
- Agricultural
- Hydrological
- Socioeconomic

This is energy.



Key Points

Description: The USGS defines drought as a period of drier than normal conditions that results in water-related problems. Thus, **there is no universally accepted quantitative definition of drought.**

Instead, a drought is most often defined by its impacts, which are typically economic, environmental, or societal in nature. For example, an agricultural drought is identified when crop production becomes adversely impacted, while a hydrological drought is linked to a very substantial and potentially damaging reduction in water supplies.

Types: In general, there are four "types" of droughts:

- **Meteorological:** A drought in which there is a measure of departure from the normal level of precipitation. Due to climatic differences, what might be considered a drought in one location of the country may not be a drought in another location.
- **Agricultural:** A drought in which the amount of moisture in the soil no longer meets the needs of a particular crop.

- **Hydrological:** A drought in which surface and subsurface water supplies are below normal.
- **Socioeconomic:** A drought in which physical water shortages begin to affect people.

Beginning and end: The onset of any drought is slow, making it difficult to determine start and end times. Often, the onset of drought is not realized until the impacts of the event have been ongoing for some time. Likewise, the end of a drought is not always ascertained until the event has already passed.

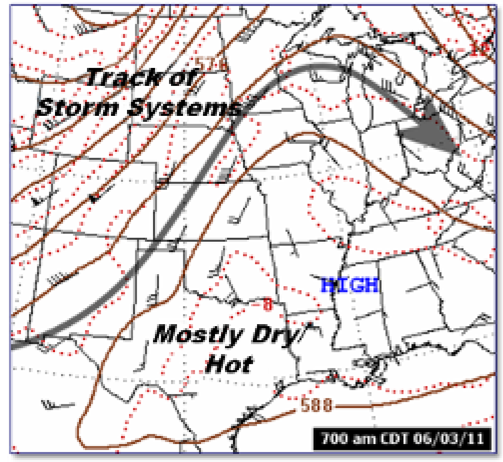
Droughts can span a range of timescales, from monthly or seasonal durations affecting agriculture to multi-year or multi-decade or even century events that dramatically change water quantities.

Geographic span: Droughts can also span very large spatial areas, encompassing larger parts of the country at a given time.

Science helps in planning for drought and in making day-to-day management decisions regarding competing demands for water.

Visual 31: Ingredients for Droughts

- Long-term shifts in storm tracks
- Persistent wind patterns that lessen flow of moisture
- Persistent, stationary high-pressure ridges



NOAA

Key Points

Droughts depend on weather factors including temperature, precipitation, wind speed, and solar radiation, which vary with time of year, the local environment, and regional climate.

In general, the specific ingredients that result in the suppression of precipitation and droughts are:

- Long-term shifts in the storm tracks away from the affected region (for example, recall from the climatology unit that La Niña affects the jet streams, which in turn affects the storm tracks, potentially depriving certain regions of much-needed precipitation)
- Persistent wind patterns that lessen the flow of moisture into a region
- "Blocking weather patterns" that are composed of persistent, stationary high-pressure ridges
    - The California drought began in 2011 after a La Niña-induced weather pattern failed to subside. A high-pressure ridge off the California coast effectively blocked precipitation from falling in California. This ridge did not begin to subside until the 2015 El Niño. This seems to be a fairly consistent pattern for ENSO (El Niño Southern Oscillation) circulation with persistent drier conditions two to three years after the end of La Niña

Visual 32: Droughts and a Changing Climate (1 of 4)

- Depends on weather patterns established by changing ocean currents
- Increased temperatures lead to:
  - Greater precipitation as rain
  - Earlier snowmelt
  - Increased evaporation

Key Points

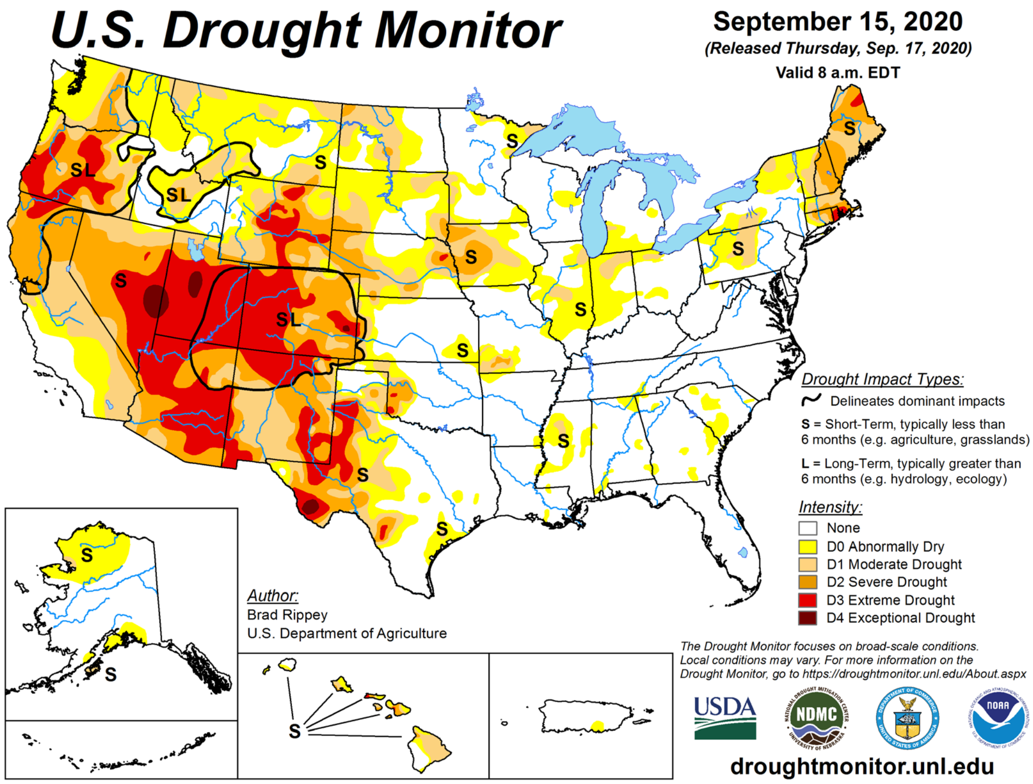
How does climate change affect drought?

Depends on the weather patterns established by changing ocean currents. Some regions will experience greater rainfall, whereas others will experience less. Most models indicate that the American Southwest will be at greater risk of drought.

Increased temperatures lead to

- Greater precipitation as rain rather than snow, reducing snowpack
- Earlier snowmelt, causing water supply to be out of sync with water demand
- Increased evaporation and transpiration, increasing the likelihood of agricultural drought

Visual 33: Droughts and a Changing Climate (2 of 4)



Key Points

The National Oceanic and Atmospheric Administration (NOAA) and the NWS Climate Prediction Center create drought outlook maps. These maps take into account data collected by the USGS, NOAA, and the NWS. However, because droughts result from complex, long-term atmospheric phenomena, the accuracy of drought predictions is not nearly as high as the accuracy of predictions about other weather events.

For example, in this U.S. Seasonal Drought Outlook as of September 2020, the map is divided into the following categories:

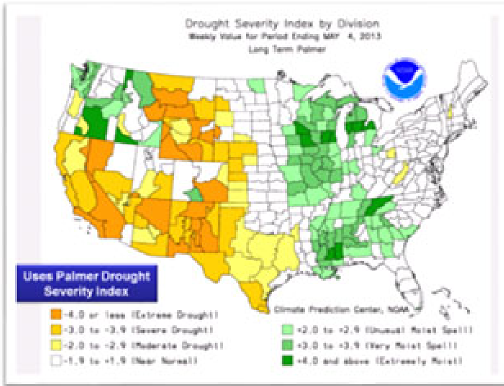
- None
- D0 (Abnormally Dry)
- D1 (Moderate Drought)
- D2 (Severe Drought)
- D3 (Extreme Drought)

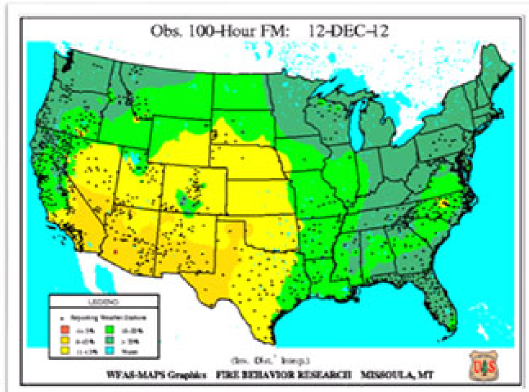
- D4 (Exceptional Drought)
- No Data

This map "depicts large-scale trends based on subjectively derived probabilities guided by short- and long-range statistical and dynamical forecasts."

In short, **there are many complications involved in making these predictions, and the confidence in the forecast is necessarily much lower than for predictions of other weather events.**

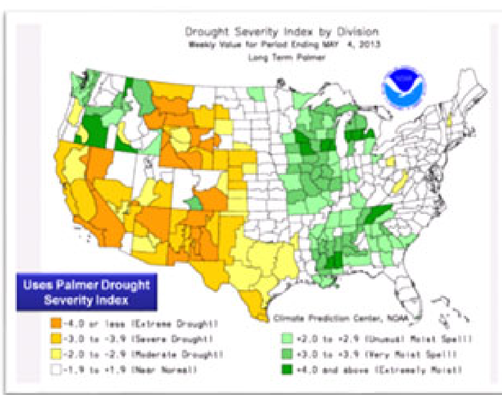
Visual 34: Droughts and a Changing Climate (3 of 4)

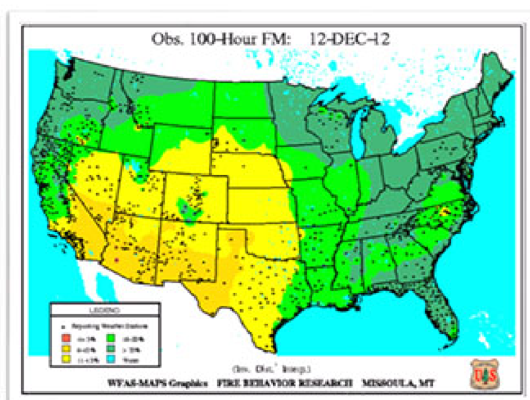




Alt Text for map images

The first U.S. map shows drought severity (This link can also be accessed at the following URL: https://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers/psi/201303-201305) which affects the mid-west and south west. The second U.S. map shows the dead fuel (This link can also be accessed at the following URL: http://www.wfas.net/index.php/dead-fuel-moisture-moisture--drought-38) that is covering the same areas.





This map shows the PDSI for the continental U.S. taken in early May 2013. Note that the index is organized in the following way:

PDSI Level	Description
-4.0 or less	Extreme Drought
-3.0 to -3.9	Severe Drought
-2.0 to -2.9	Moderate Drought
-1.9 to +1.9	Near Normal
+2.0 to +2.9	Unusual Moist Spell
+3.0 to +3.9	Very Moist Spell
+4.0 and above	Extremely Moist

Key Points

Forecasters collect scientific information that evaluates current drought levels. These data are normally expressed with the semi-official Palmer Drought Severity Index (PDSI), a formula developed by Wayne Palmer in the 1960s.

The Palmer Index is effective in using rainfall and temperature information to determine long-term drought (i.e., duration of months). Another advantage to the Palmer Index is that it is standardized according to local climates and can be applied to any region in the country to show the relative drought or rainfall conditions.

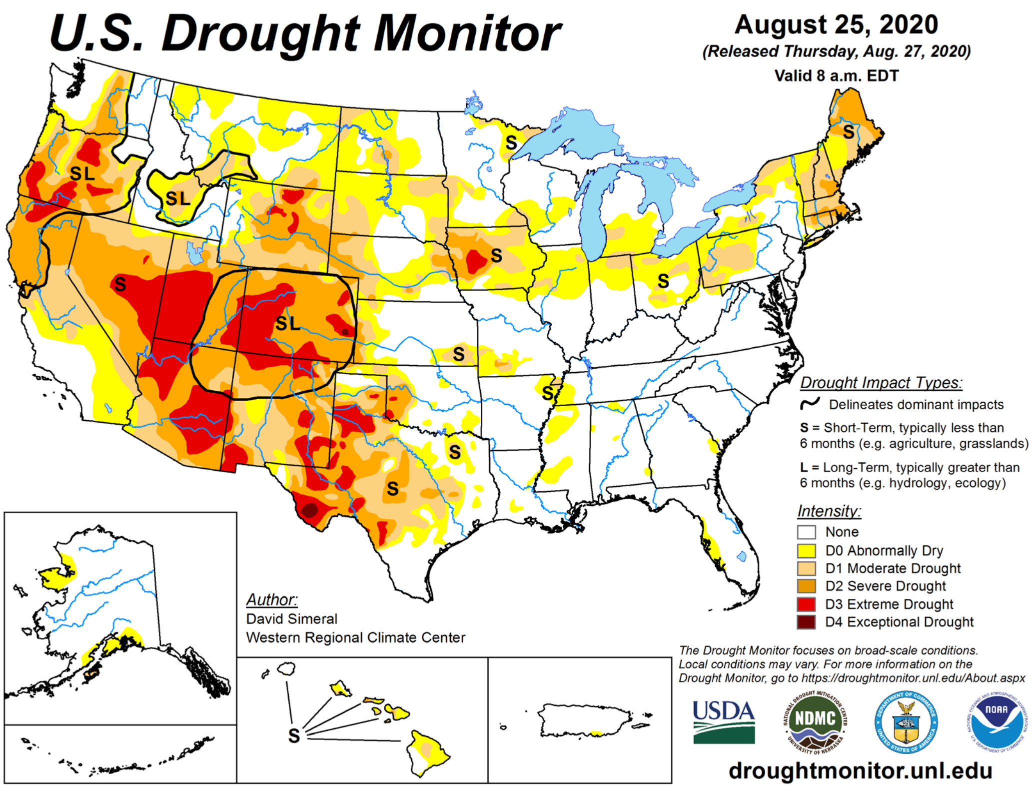
Relationship of droughts to wildfire: Drought is an important ingredient in wildfires, which may be caused by a combination of:

- Dry or drought conditions
- Wind
- Topography (slopes and changes in elevation enable fire to spread more easily)
- Moisture content of the soil
- Buildup of vegetation—especially dead fuel

In the maps above, note the similarity of the areas affected by drought in the left map, and the distribution of dead fuel in the right map.

Visual 35: Droughts and a Changing Climate (4 of 4)

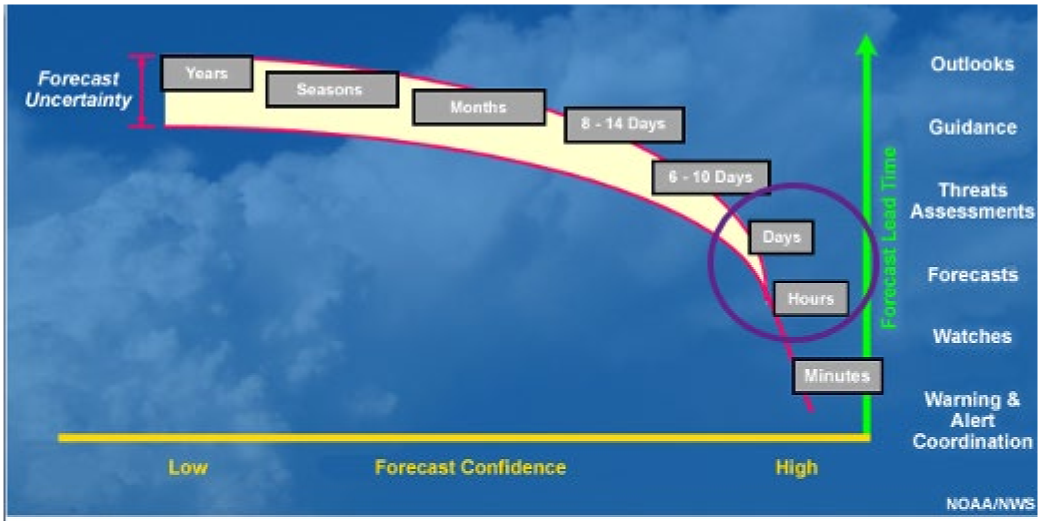
This is an example of a U.S. Drought Monitor map. This one is for August 25, 2020 and shows majority of areas in the western half of the country are experiencing moderate to exceptional drought. It also identifies drought by whether it's impact to the area will be short- or long-term.



The U.S. Drought Monitor is jointly produced by the National Drought Mitigation Center at the University of Nebraska-Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration.

Visual 36: Extreme Temperature Prediction

- Lead time: Days
- Accuracy: Good



Like winter storms, the lead time for predicting extreme temperatures is days, and the accuracy is generally good.

To predict cold waves and heat waves, forecasters gather information about:

- High/low temperatures
- Humidity (heat waves)
- Winds (cold waves)

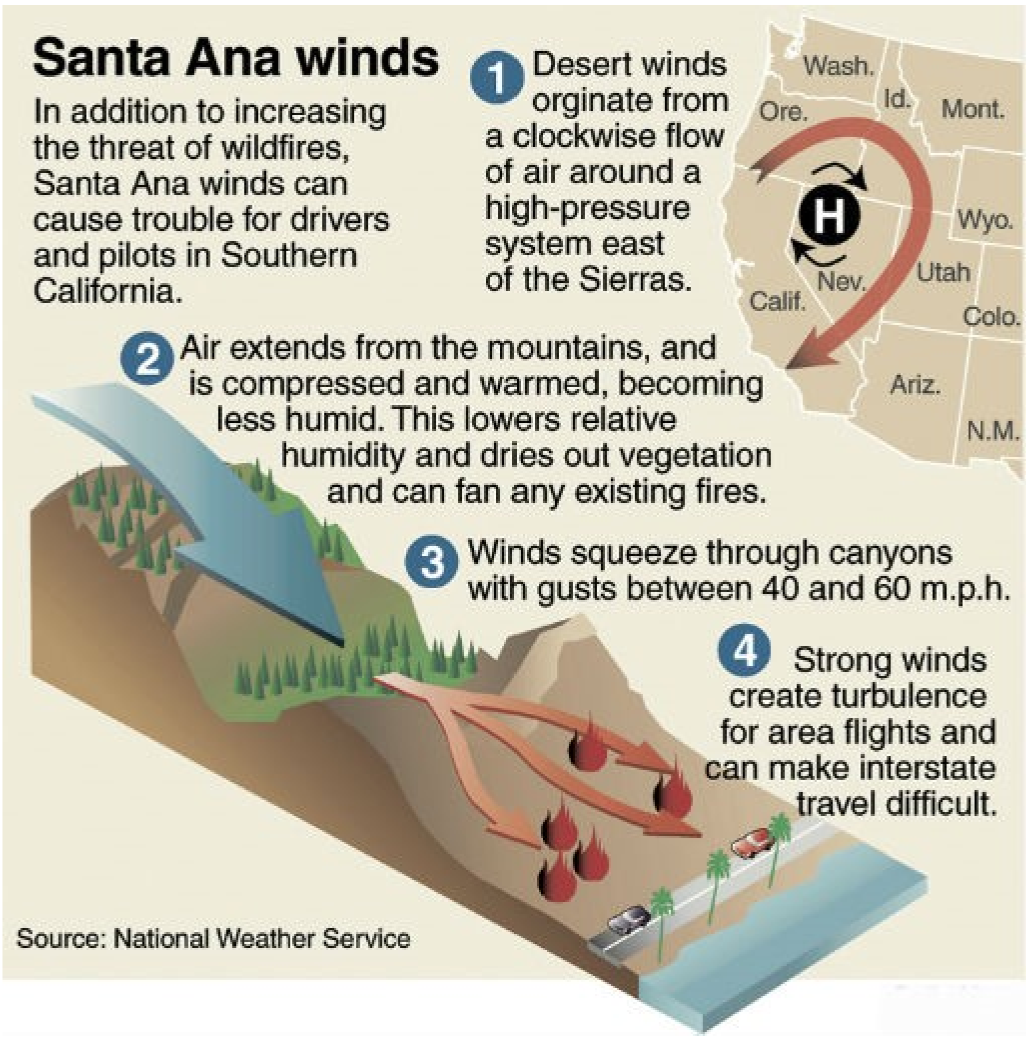
With this information, forecasters are generally able to predict the duration of the system and expected temperatures.

Visual 37: Santa Ana Winds

The Santa Ana winds are strong, extremely dry, downslope winds that originate inland and affect coastal Southern California and northern Baja California.

They originate from cool, dry high-pressure air masses in the Great Basin.

Low humidity, combined with the warm, compressionally-heated air mass, plus high wind speeds, create critical fire weather conditions.



Santa Ana Winds

Visual 38: Effects of Santa Ana Winds

Excessive Heat = Heat Index is greater than or equal to 105-110 degrees F.

- Santa Ana fog
- Drive large ocean waves
- Carry the pathogenic fungal spores that cause Valley Fever (Coccidioidomycosis) into nonendemic areas.
- Increased fire danger

Key Points

Symptomatic infection of Valley Fever occurs in about 40% of cases, which usually present as an influenza-like illness with fever, cough, headaches, rash, and muscle pain. Serious complications include severe pneumonia, lung nodules, and disseminated disease, where the fungus spreads throughout the body. The disseminated form of Valley Fever can devastate the body, causing skin ulcers, abscesses, bone lesions, severe joint pain, heart inflammation, urinary tract problems, meningitis, and often death.

Some of California's largest and most deadly wildfire on record are associated with the Santa Ana winds including: the Camp fire, Thomas fire and the Cedar fire.

"The increasing risk of wildfires, particularly in the Western US, is driven by a complex mix of factors such as:

- Climate change induced drought (drying vegetation)
- Rapid development into the Wildland-Urban Interface (WUI) (caused by factors such as increased urban housing costs)
- Lack of mitigation (not clearing underbrush, not building with fire-resistant materials)
- Aging and not well-maintained infrastructure (power, roads, water)
- Lack of "fire sense" by the pubic (discarded cigarettes, unattended campfires, burning debris

Visual 39: Wildfires

- As many as 90% of wildland fires in the U.S. are caused by people from unattended campfires, burning debris, downed power lines, negligently discarded cigarettes, and intentional acts of arson.
- 10% are started by lightning or lava.
- As of 2019, it is estimated that 4.5 million U.S. homes were identified at high or extreme risk of wildfire with 2+ million in California alone.

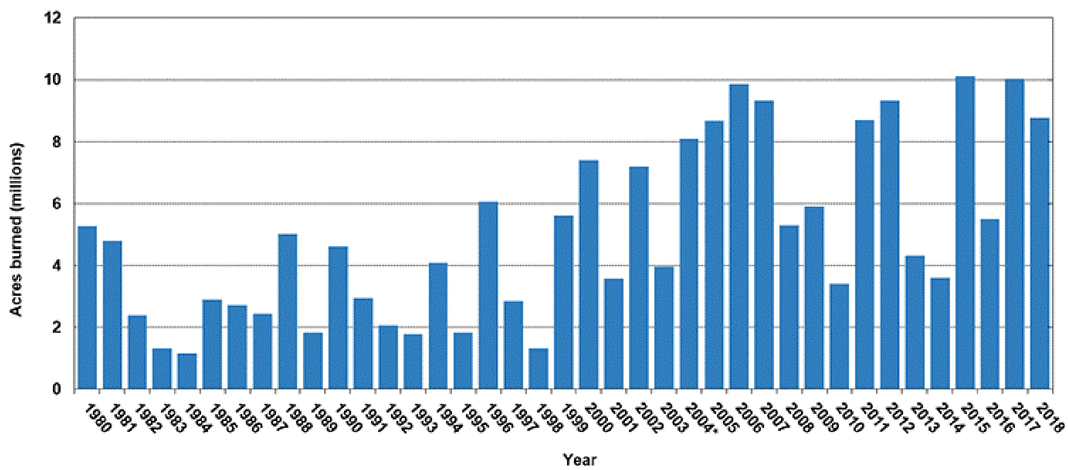
Key Points

At any given time, you can go to: National Interagency Fire Center (https://www.nifc.gov/fireInfo/nfn.htm) to see the wildfire status of the U.S.

Source: Insurance Information Institute (https://www.iii.org/fact-statistic/facts-statistics-wildfires)

Visual 40: Annual Number of Acres Burned in Wildland Fires, 1980-2018

Annual Number of Acres Burned in Wildland Fires, 1980-2018 for the top 10 states.



Top 10 States At High To Extreme Wildfire Risk, 2019

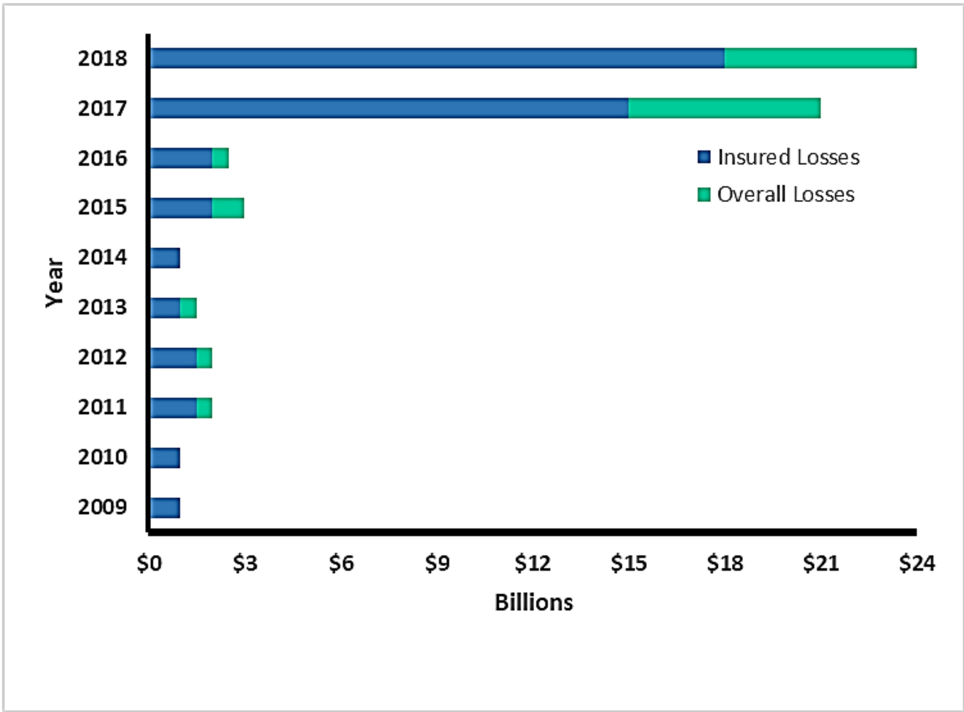
Year	Acres burned (millions)
1980	5
1981	4.4
1982	2.2
1983	1
1984	1
1985	3
1986	2.5
1987	2.1

Year	Acres burned (millions)
1988	5
1989	2
1990	4.3
1991	3
1992	2
1993	1.9
1994	4
1995	1.9
1996	6
1997	3
1998	1
1999	5.5
2000	7
2001	5.1
2002	7
2003	4
2004	8
2005	8.5
2006	10

Year	Acres burned (millions)
2008	5
2009	6
2010	5.1
2011	8.5
2012	9
2013	4.2
2014	3.5
2015	10
2016	
2017	10
2018	9

Source: https://www.iii.org/fact-statistic/facts-statistics-wildfires

Visual 41: Wildfire Losses ($ billions) In The United States, 2009-2018



Year	Insured Losses ($ billions)	Overall Losses ($ billions)
2009	1	1
2010	1	1
2012	1	2
2013	1	1.5
2014	1	1
2015	2	3
2016	2	2.5

Year	Insured Losses ($ billions)	Overall Losses ($ billions)
2017	15	21
2018	18	24

Visual 42: Top 10 States At High To Extreme Wildfire Risk, 2019

Rank	State	Estimated number of properties at risk	Rank	State	Percentage of properties at risk
1	California	2,019,800	1	Montana	29
2	Texas	717,800	2	Idaho	26
3	Colorado	371,100	3	Colorado	17
4	Arizona	237,900	4	California	15
5	Idaho	175,000	5	New Mexico	15
6	Washington	160,500	6	Utah	14
7	Oklahoma	153,400	7	Wyoming	14
8	Oregon	151,400	8	Oklahoma	9
9	Montana	137,800	9	Oregon	9
10	Utah	136,000	10	Arizona	8

Source: Facts + Statistics: Wildfires |III;(https://www.iii.org/fact-statistic/facts-statistics-wildfires)

Visual 43: 2020 Western States Wildfires

Burning in California, Oregon, and Washington as of September 2020:

- 28 major fires in California (including 5 of the state's largest ever) with over 3.2 million acres burned since 1/1/20
- Washington has lost over 600,000 acres in one week
- Over 500,000 Oregon residents (over 10% of the state's population) were under an evacuation warning or order, and over 1 million acres have been charred

Key Points

Burning in California, Oregon, and Washington as of September 2020:

- 28 major fires in California (including 5 of the state's largest ever) with over 3.2 million acres burned since 1/1/20
- Washington has lost over 600,000 acres in one week
- Over 500,000 Oregon residents (over 10% of the state's population) were under an evacuation warning or order, and over 1 million acres have been charred

Air quality has deteriorated significantly, becoming a health hazard.

For more information: Western wildfires: [Climate change-fueled blazes plunge Washington, Oregon and California into crisis - Washington Post](https://www.washingtonpost.com/graphics/2020/national/california-oregon-washington-wildfires/?itid=lk_inline_manual_4) (https://www.washingtonpost.com/graphics/2020/national/california-oregon-washington-wildfires/?itid=lk_inline_manual_4)

Visual 44: Activity 4.2 – Implications of Widespread Power Outage

This is an optional activity.

Instructions: Working as a group:

Read the abbreviated article from the NY Times -*'This Did Not Go Well': Inside PG&E's Blackout Control Room* (https://www.nytimes.com/2019/10/12/business/pge-california-outage.html).

2. Discuss the implications of a private utility purposefully creating a wide-spread power outage.
3. List 1-3 action items for EACH mission area: Prevention, Protection, Mitigation, Response, Recovery.

Visual 45: Unit Summary

You should now be able to:

- Compare and contrast nor'easters and hurricanes.
- Identify the ingredients of nor'easters, winter storms, extreme cold temperatures
- Explain the scientific differences between various types of frozen precipitation.
- Indicate the predictability of nor'easters, winter storms, extreme cold temperatures.
- Describe how extreme heat and drought severity are categorized.
- Indicate the predictability of droughts.
- Identify the factors that contribute to wildfires.

Key Points

Do you have any questions about material covered in this unit?

Unit 5: Floods

Visual 1: Unit 5: Floods

Unit 5: Floods

Key Points

Welcome to Unit 5: Floods.

Time Plan

A suggested time plan for this unit is shown below.

Topic	Time
Introduction	5 minutes
Flood Types • Activity 5.1 - Floods That Could Affect My Area (Optional)	10 minutes
Flood Factors	15 minutes
Flood Dynamics and Impacts	15 minutes
Flood Probability and Forecasting • Activity 5.2 - Using a Risk Map	20 minutes
Module Summary	5 minutes

Topic	Time
Total Time	**1 hour 10 minutes**

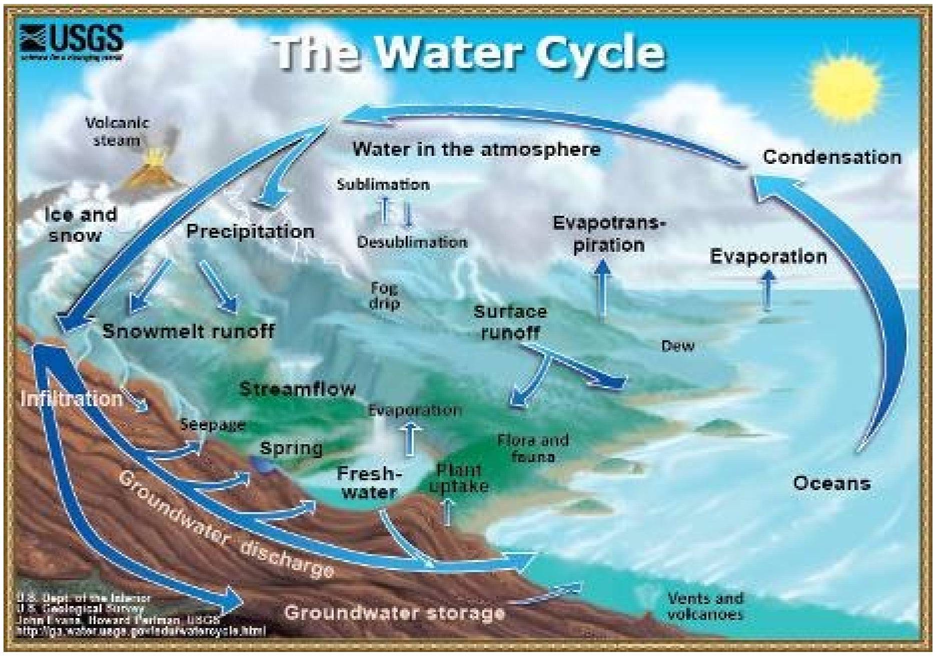
Visual 2: Unit Objectives

- Identify the types of floods.
- Describe flood impacts.
- Explain flood probabilities.
- Describe flood dynamics.

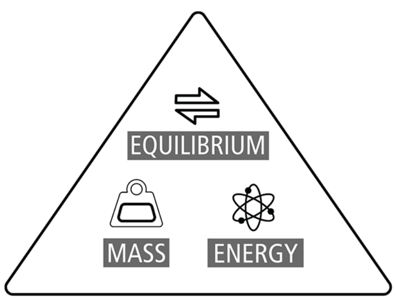
Key Points

Review the module objectives as shown on the visual.

Visual 3: The Water Cycle



This is equilibrium, mass, and energy.



Key Points

Most floods occur in relation to:

- Weather.
- "The water cycle."

On the surface of our planet, water is always moving and circulating. Gravity moves water downhill, and water moves from ground to ocean to atmosphere through fluctuations in pressure and temperature that change water's phases from solid to liquid to gas.

Floods occur when water is delivered to a water body (e.g., stream, river, lake) at a rate and amount that is greater than normal; or, in other words, when the "water cycle" cannot keep up with the amount of water to be accommodated at one time at one location.

See Color Handout 5.1: The Water Cycle.

Visual 4: Discussion: Definition

How would you define "flood"?

Visual 5: Flood Definitions

An overflow or inundation that comes from a river or other body of water and causes or threatens damage.

Any relatively high streamflow overtopping the natural or artificial banks in any reach of a stream.

Too much water in too little time in one location.

Flood Definitions Image Description

An overflow or inundation that comes from a river or other body of water and causes or threatens damage. Image: a flooded trailer park. Any relatively high streamflow overtopping the natural or artificial banks in any reach of a stream. Image: A collapsed bridge. Too much water in too little time in one location. Image: Two people holding on to each other in flood waters.

Key Points

There are many technical definitions, which tend to address different aspects of floods.

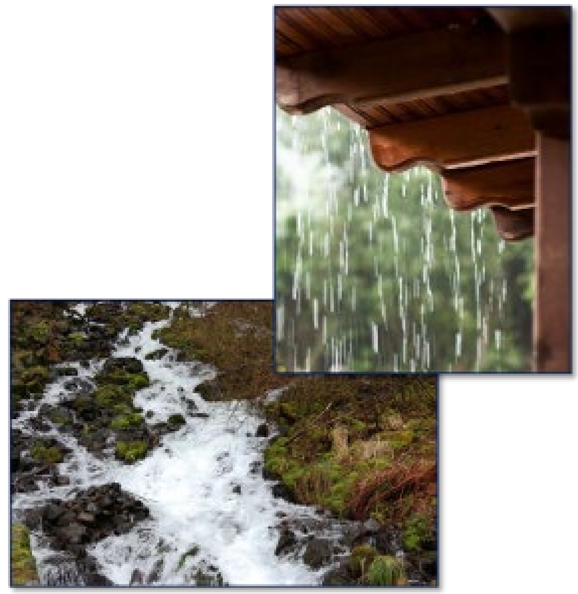
One widely used definition is "an overflow or inundation that comes from a river or other body of water and causes or threatens damage." By this definition, it isn't a flood unless it could cause damage. It turns out to be useful to distinguish between floods and damaging events, which are **flood disasters.**

Another definition is that a flood is "any relatively high streamflow that overtops the natural or artificial banks in any reach of a stream."

The essential point is that a flood is a condition where there is too much water in too little time at a given location.

Visual 6: Ingredients for Floods

- Excessive input
- Excessive rate of input
- Poor ground absorption



Key Points

We'll look next at the factors that contribute to flooding. The major ingredients for floods are:

- **Excessive input,** which may result from:
  - Heavy downpours.
  - Long-duration constant rainfall.
- **Excessive rate of input,** which may result from:
  - Rate of precipitation:
    - Short-duration intense downpours
    - Rapid snowmelt
  - Rate of runoff, caused by:
    - Steep slopes
    - Sparse vegetation
    - Thin soils
  - Failure of flood protection structures:
    - Levee break
    - Dam failure
- **Poor ground absorption,** which may result from:
  - Poor quality soils:
    - Sparse vegetation (often from deforestation).
    - Thin soils (often from deforestation).

- Ground saturation.
- Urban landscapes.
- Closely spaced bodies of water.
- Time of year (e.g., rainfall on frozen ground in winter).

Visual 7: Flood Types

- Riverine flooding
- Coastal flooding
- Shallow flooding
- Flooding in special localized areas
- Tsunamis

Key Points

Floods can be grouped in various ways, but for the purposes of this course, the types recognized by the National Flood Insurance Program (NFIP) will be used. These types are:

- **Riverine flooding**
  - **Riverine overbank flooding** is the most common type of flooding in the United States. This type of flooding occurs when excess water from storms, snowmelt, or blockages due to debris or ice jams overloads the stream channel. When the stream channel is overloaded, excess floodwaters flow onto the adjacent land, called the floodplain. (floodplain concepts will be covered later in this unit). The extent of riverine overbank flooding in a particular area depends on many factors, including topography, size of the river basin, development in the river basin, and geographical location, to name a few.

Visual 8: Flash Floods

- Floodwaters that rise and end quickly
- Can cause extensive damage and loss of life

Key Points

- Can occur suddenly as the name suggests, with little or no warning
- Water can be fast moving and powerful
- Water accumulates quickly
- Caused by:
    - Slow moving thunderstorms or storms moving repeatedly over the same area
    - Hurricanes or tropical storms o Floating debris can cause more damage as flows in flood waters, and can accumulate in areas preventing water flow/flooding
    - Heavy rain on saturated or extremely dry soil
    - Sudden thaw of snow/ice
    - Failure of dams or levees
    - Burn scarring over recent wildfire areas act as water repellent and missing vegetation exacerbates flooding
- May occur in an area where there is no rain as distant storms dump water quickly causing areas to flood as water accumulates in lower lying areas
- Affects/causes damage to:
    - Roads, bridges/underpasses, homes, businesses, farms, cars, people, wildlife

Key Points

Flash floods are characterized by floodwaters that rise and end quickly. Areas with steep slopes and narrow stream valleys, such as mountainous areas, are especially susceptible to flash flooding.

These floods can cause extensive damage and loss of life, especially in recreation areas such as campgrounds. Flash floods are the leading cause of flood-related deaths in the United States, primarily because they can strike with little warning, giving little or no time to evacuate

Visual 9: Flooding in Special Localized Areas

- Closed basins
- Uncertain flow paths
- Dam breaks and levee failures
- Ice jams
- Mudflows

Key Points

The National Flood Insurance Program (NFIP) recognizes other types of flooding as "special localized flooding." These special situations include closed basin lakes, areas with uncertain flow paths, dam breaks and levee failures, ice jams, and mudflows.

Closed basins are lakes that formed after glaciers retreated, primarily from areas in the northern United States. Because these lakes are closed basins, they have no way of draining. As a result, they frequently flood nearby areas as they expand outward. Devils Lake, North Dakota, is an example of a closed basin lake.

Uncertain flow paths describe areas, primarily in mountainous locations, where high-velocity flood waters spread out as they reach the valleys below. As the flood water slows, it seeks various channels in a fanlike pattern. The channels may differ with each successive flood event and are, therefore, less predictable than riverine floods that occur in a defined channel. These fanlike features are called **alluvial fans** because of the large amount of sediment and debris deposited by flood waters as they approach the valley floor.

Dam breaks and levee failures occur when the structural integrity of a dam or levee is compromised, resulting in leakage, fracture, or complete failure of the dam or breaching of the levee. Many private or locally-built dams and levees that are poorly designed or maintained are especially susceptible to failure during extreme flooding conditions.

Ice jams occur when warm air and rain break up frozen rivers and streams or whenever there is a rapid cycle of freezing and thawing in the stream environment.

Broken ice floats downstream until it is obstructed by any feature, including bridges, tunnels, or shallow areas. The resulting jam is similar to a dam which floods adjacent land upstream. Ice jams present three types of hazards:

- Flooding up upstream lands
- Movement of broken ice into structures, trees, and other obstacles downstream
- Sudden release of water and ice when the ice jam breaks apart, similar to a failure of a dam

A **mudflow** is a landslide of saturated soil and debris, usually in hilly or mountainous areas. Mudflow hazards are compounded by the weight and volume of saturated debris that is released into structures and people in the path of the flow.

Visual 10: NFIP Flood Mapping

To identify a community's flood risk, the National Flood Insurance Program (NFIP):

- Conducts a flood insurance study that includes statistical data for:
  - River flow.
  - Storm tides.
  - Hydrologic/hydraulic analyses.
  - Rainfall and topographic surveys.
- Creates maps that outline the community's different flood risk areas.

Key Points

To identify a community's flood risk, the National Flood Insurance Program (NFIP) conducts a flood insurance study that includes statistical data for:

- River flow.
- Storm tides.
- Hydrologic/hydraulic analyses.
- Rainfall and topographic surveys.

These data are used to create maps that outline THE community's different flood risk areas.

Almost 100,000 Flood Insurance Rate Maps (**FIRMs** or **DFIRM**s, if digitized) have been published and are currently being updated.

Note: FIRMs are older maps and have been replaced by D-FIRMs—Digital - Flood Insurance Rate Maps.

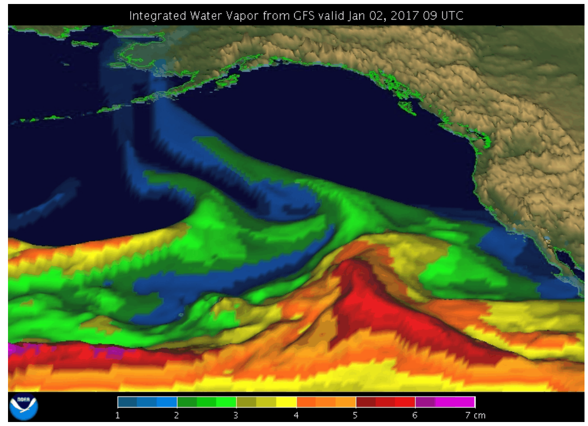
Visual 11: (Optional) Activity: Floods That Could Affect My Area

Instructions: Working individually:

1. Identify the types of floods that could occur in your area or jurisdiction
2. Record your answers on the checklist in your IAW
3. Be prepared to share your answers with the class

Visual 12: Atmospheric Rivers (1 of 2)

Narrow regions in the atmosphere that transport moisture from the tropics to northern latitudes.



Key Points

- Part of the Earth's ocean water cycle and are closely tied to water supply and flood risks.
- Not all atmospheric rivers are disruptive:
  - Many are weak and provide beneficial rain or high-elevation snow that provide crucial inputs to the water supplies of western communities

Visual 13: Atmospheric Rivers (2 of 2)

- Atmospheric rivers come in all shapes and sizes.
- Those with the largest amounts of water vapor and the strongest winds are responsible for extreme rainfall and subsequent flooding.
- They can affect the entire west coast of North America, often disrupting travel and damaging property in the process.

Visual 14: Pineapple Express

- A strong atmospheric river where moisture builds up in the tropical Pacific around Hawaii and may bring heavy rainfall and snow to the U.S. and Canadian West Coasts.
- Prevailing winds cross over warm bands of tropical water vapor to form the "river," which travels across the Pacific as part of the global conveyor belt.
- It can dump as much as five inches of rain on California in one day.

Visual 15: Flood Factors

- Onset time
- Topography
- Proximity to flood source
- Snowmelt potential
- Seasonal variations
- Land use

Key Points

What all floods have in common is the existence of water in some phase (whether solid, liquid, or gas) and the force of gravity acting on the water.

Flood factors describe the conditions associated with different types of floods or under which floods will develop. Although there may be many factors involved, the primary ones are:

- Onset time
- Topography
- Proximity to flood source
- Snowmelt potential
- Seasonal variation
- Land use

These flood factors are described in more detail in the following visuals.

Visual 16: Flood Onset Time

- Some floods develop slowly (days to weeks).
- Flash floods develop quickly (minutes to hours).
- Debris flows - part of flow process continuum.

Key Points

Floods can also be classified based on the time it takes for onset to occur.

Slow developing: Some floods develop slowly, like those on the Mississippi, causing river water to rise about a foot every other day. These floods tend to linger for a long time.

Fast developing: By contrast, in a rapid onset flood (or flash flood), the water can rise 2 or 3 feet in 5 minutes.

Visual 17: Topographic Factors

- Steep slopes:
  - Quicker and greater runoff
  - Landslides
- Flat land:
  - Water accumulation
- Low-lying land downstream:
  - Water accumulation
- Urban landscape downstream:
  - Lack of water infiltration

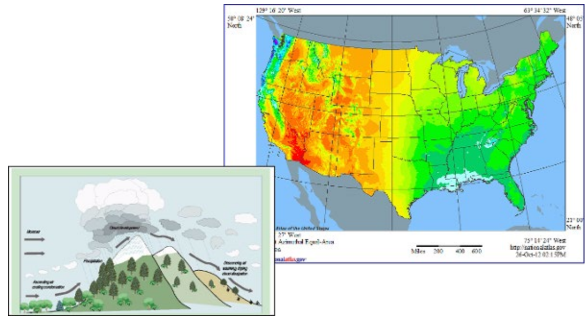
Key Points

There are a number of topographic factors that can contribute to flooding.

- **Steep slopes** may result in quicker and greater runoff or even landslides. Steeper gradients funnel water together to produce more catastrophic floods.
- **Flat land** and low-lying land downstream will facilitate greater water accumulation.
- **Downstream urban landscapes** lack water infiltration.
- In **small river basins** (i.e., the large area of land encompassing the entire river network with the main channel and its tributaries) such as those in mountains, flooding is dominated by precipitation from short duration, high intensity, convective thunderstorms.
- In **larger river basins** like the Mississippi, flooding is dominated by longer duration, widespread rainfall from atmospheric systems like hurricanes that dump a lot of rain over a long period of time.

Visual 18: Topography + Precipitation

- Increased on windward side
- Decreased on leeward side



Topography + Precipitation Image Descriptions

1. The map on the visual shows the annual mean precipitation throughout the continental United States.
2. A diagram to the left shows three mountains. Starting up the mountain is ascending air cooling condensation and precipitation. At the top of the mountain is cloud development. Then going down the mountain is descending air warming dying cloud dissipation.

Key Points

The interaction of topography and precipitation is also a major factor in floods. The map shows the annual mean precipitation throughout the continental United States. Two key factors are at play: proximity to a moisture source and orographic lifting.

- **Proximity to moisture source:** The importance of proximity to moisture source is evident in the rapid drop-off of precipitation as you move inland from the Pacific to the Atlantic and the gulf.

  Certainly, proximity to moisture source is important-and you can see a lot of points north of the gulf, which provides large quantities of moisture. But this factor is not sufficient by itself, because otherwise there would be more floods in Florida than there are.
- **Orographic lifting:** In addition, the precipitation map shows areas of higher precipitation due to orographic lifting (shown in the left-hand drawing), which is what happens when a mass of air is forced to travel from a lower elevation to a higher elevation over a rising mountain. As masses of air move inland and rise up over the highlands, the air cools. If it cools to its saturation point, the water vapor condenses and a cloud forms.
  - On the windward side of mountains (the side that is reached first) there is a lot of rain.
  - On the leeward side (downwind) there is substantially less.

All of the major mountain ranges in the United States have "rain shadows"-more arid areas on the lee side.

Visual 19: Proximity to Flood Source

- Floodplain is any area susceptible to being inundated by flood waters from any source.
- Flood protection structures in the floodplain affect river behavior.

Key Points

Proximity to the flood source is another important factor.

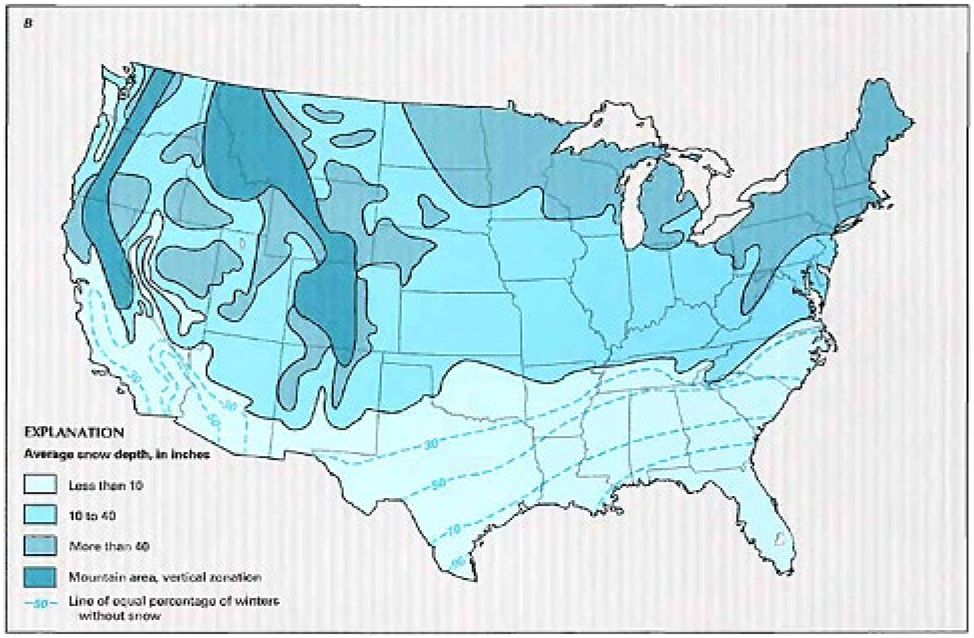
Floodplain: According to the National Flood Insurance Program (NFIP), a floodplain is defined as "any land area susceptible to being inundated by flood waters from any source." During floods, water that normally flows downstream overflows beyond the channel onto the floodplain.

As is true with other hazards, the choices and actions of humans determine whether the natural phenomenon of the flood will become a disaster. There are 3,800 communities in the United States (with at least 2,500 inhabitants) that are located in floodplains.

Flood protection measures: Development in floodplains is sometimes followed by creation of flood protection measures, such as levees or floodwalls. Flood protection structures alter river behavior by:

- Affecting natural deposition process.
- Affecting river cresting/water level.
- Affecting stream path.

Visual 20: Snow Melt Potential



Key Points

Another contributor to flooding is snow melt.

Snow stores a lot of moisture. The moisture content of snow generally varies with the geographical location and time of year.

> For example, 10 inches of soft, "powdery" snow in the Rocky Mountains may have different moisture content than 10 inches of snow in the more humid Appalachian Mountains. Likewise, late spring snowfalls may have greater moisture content than winter snowfalls. The rate at which snow melts and releases its moisture content can have a significant impact on flooding.

This map shows the snow melt potential, based on average snowfall. The darker the color, the thicker the average snow depth, and thus the greater the possible contribution of snow melt to flooding.

Visual 21: Seasonal Variations

Peak Flooding Seasons

Seasonal Variations Image Description

A map of the U.S. showing peak flooding seasons. For the eastern states the peak flooding is in Winter and Spring. The North Eastern and Northern states from Maine through North Dakota floods in early spring. Florida floods in fall. The central state flood in late spring, with early spring to the right of Texas, Arkansas and Missouri. Coastal Western states flood in Winter, with mid-Washington and Oregon flooding in Early Spring, and California through Arizona flooding in Early Spring. Flooding in Arizona and California bordering Mexico floods in Mid-Summer and fall.

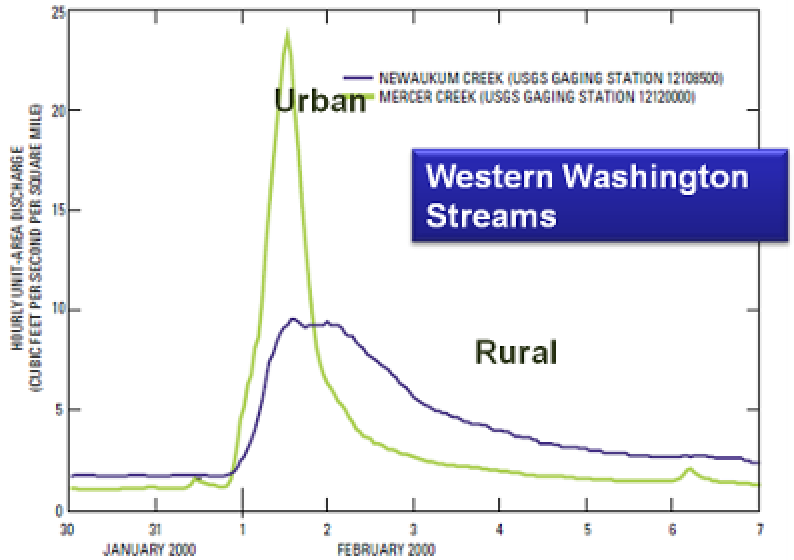
Key Points

The season of the year is another factor that affects flooding; however, typical seasons for the largest annual flood vary by area, as illustrated by this map.

The variation depends on seasonal rainfall patterns and the time it takes snow melt to reach the region’s rivers.

Visual 22: Land Use

Land use affects flooding.



Key Points

Land use affects flooding, especially in terms of the extent of rural use vs. urban use.

Rural land use: In rural areas, there is more opportunity for moisture to move into the ground.

Urban use: In urban areas, pavement keeps water above ground. In addition, efforts to control water flow, as it moves from roofs to gutters to streets to drains, deliver more water into rivers more quickly, causing a rapid rise in flood level.

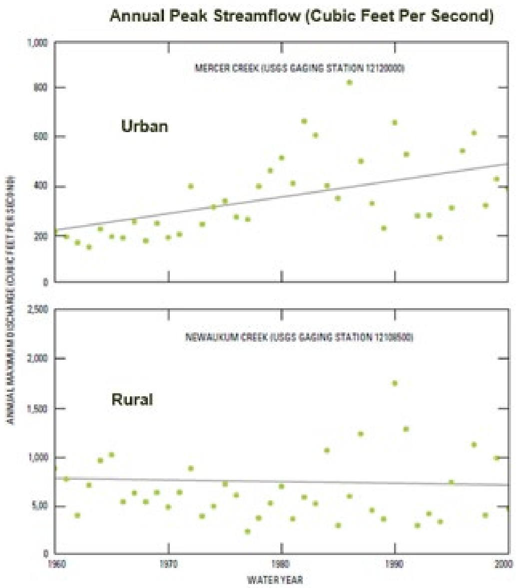
This visual shows two **hydrographs,** from urban and rural gages in Washington State, which depict height of water over time. The tendency for the urban site to show a strong, early pulse of flooding compared to the rural site is a commonly noted difference between urban and rural sites.

Increase in peak flows over time: Another trend related to urban sites is an increase in peak flows over time. The graph on the next page compares peak flows at the same sites shown in the hydrograph.

As an Emergency Manager, you need more advanced training about floods, specifically mitigation. Consider the following courses:

- EMI Course: IS-273: How to Read a Flood Insurance Rate Map (FIRM)
- EMI Course: IS-393.B: Introduction to Hazard Mitigation
- EMI Course: IS-1105.A: EC Made Easy: Elevation Certificate Overview

Association of State Floodplain Managers (https://www.floods.org/training-education/online-training/)



Annual Peak Streamflow (Cubic Feet Per Second)

The dots represent highest flow level for each year. The rural site shows very little change over the decades. The impact of urbanization at the other site (the top graph) is visible in the general rise in maximum water level as the years advance.

Key Points

Additional Resources:

FEMA Floodplain Management (https://www.fema.gov/floodplain-management)

- US Army Corps of Engineers Flood Risk Management Program and Silver Jackets Teams (https://www.iwr.usace.army.mil/Missions/Flood-Risk-Management/Flood-Risk-Management-Program/)

Visual 23: Urban Development

Key Points

During Hurricane Sandy in 2012, areas of dense urban development in New York and New Jersey experienced severe flooding of underground subway systems, as floodwaters sought the lowest level.

Clean-up and recovery efforts required sophisticated pumping equipment to remove huge volumes of water that natural drainage could not handle.

Visual 24: Flood Dynamics

- Hydrodynamic force
- Hydrostatic force
- Debris impact
- Velocity
- Soaking
- Sediments and contaminants

Key Points

Another way of characterizing floods is by the dynamic qualities or forces associated with them.

Flood dynamics describes the damage and injury to structures, people, and the environment caused by flood waters in various stages of formation. The main dynamic forces are:

- Hydrodynamic force.
- Hydrostatic force.
- Debris impact.
- Velocity.
- Soaking.
- Sediments and contaminants.

These forces are explained in the following visuals.

Visual 25: Hydrodynamic Force

Forces imposed on an object by water flowing against and around it—including positive frontal pressure, drag effect along the sides, and negative pressure in the downstream side.

Key Points

The NFIP describes hydrodynamic forces as:

". . . forces imposed on an object, such as a building, by water flowing against and around it. Among the forces are positive frontal pressure against the structure, drag effect along the sides, and negative pressure in the downstream side. Hydrodynamic forces are one of the main causes of flood damage."

The visual shows the effects of hydrodynamic force on a house. In this case, frontal impact resulted from flood waters striking the structure.

Additional hydrodynamic forces involve a "drag effect" as water runs along the sides of a structure, and "eddies or negative pressures" as water passes the downstream side of the structure.

Visual 26: Hydrostatic Force

Pressure exerted against a structure by the weight of water.

Key Points

Hydrostatic force involves the pressure exerted against a structure by the weight of water. This type of pressure is especially damaging to walls of structures and studies have shown that 3 feet of standing water can be sufficient to collapse the walls of a frame house.

Basement walls are especially vulnerable to hydrostatic force. In this visual, part of the basement wall has collapsed because of hydrostatic force exerted on it.

Visual 27: Debris Impact

Impact from debris picked up and carried by flood waters.

Key Points

Another dynamic force is debris impact. Flood waters are powerful and will pick up and move almost anything in their path. Vehicles, lawn furniture, propane tanks, vegetation, and even rocks and boulders can be moved by flood waters. Such flood debris can cause extensive damage when striking buildings, bridges, or other structures in the flood path.

Visual 28: Velocity

The speed (ft/sec) by which flood water travels, which exerts great force on people and objects in its path.

Key Points

Velocity is the speed by which flood water travels and is measured in feet per second. Flood waters moving faster than five feet per second are considered a high-velocity flood.

Even shallow flood water can knock a person down, and it is estimated that water 3 feet deep moving at 3 feet per second is sufficient to do so.

A car will float in only 2 feet of moving water.

These potential impacts of velocity on people and automobiles make it extremely hazardous to wade or drive into flood waters.

Visual 29: Soaking

Effect of standing flood water, which weakens structural components, ruins furnishings, and creates health hazards.

Key Points

Soaking is a major cause of flood damage. Standing flood waters, especially those standing over a long period of time, will weaken or destroy the structural components of buildings and ruin furnishings. In addition to causing structural damage, soaking also presents health hazards for building occupants.

Visual 30: Sediments and Contaminants

Natural and toxic materials carried and deposited by flood waters.

Key Points

The final dynamic force involved in floods is sediments and contaminants. Flood waters carry many types of sediments, including sand and debris. These sediments permeate structures and the environment and are difficult, if not impossible, to remove.

Contaminants include any type of substance that is harmful to living organisms including chemicals, sewage, and other toxic material.

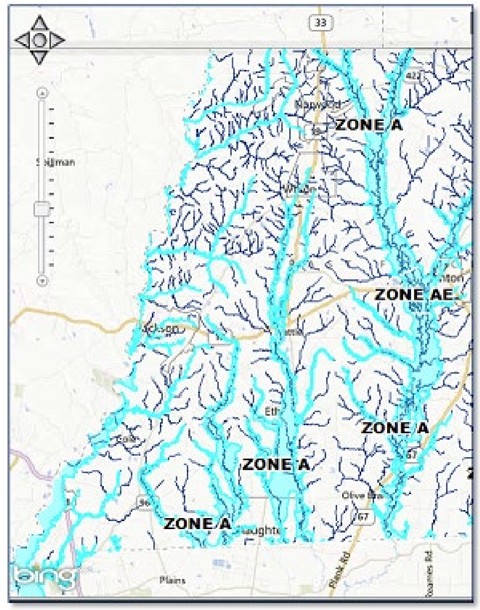
Next, we will look at some health hazards associated with contaminants and other flood hazards.

Visual 31: Discussion: Health Impacts

How can flooding impact health?

Visual 32: Flood Probability (1 of 2)

- **100-year flood:** 1% annual probability
- **500-year flood:** 0.2% annual probability



Key Points

All of the factors we have discussed relate to the probability of flooding in any given area. What do we know about flood probability?

As scientists study river systems over time, patterns emerge:

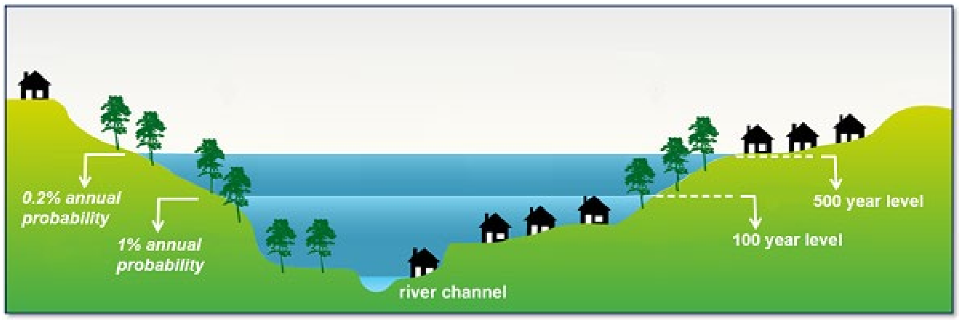
- Areas that have flooded before will often flood again.
- Some areas will flood in garden variety storms that occur frequently.
- Other areas will flood much more rarely and only in larger storms.

Such patterns give rise to efforts to quantify the chance that a particular area will flood in a certain time span, and that in turn requires a statement of probability.

The image on this visual delineates areas that will be flooded in the Louisiana parish of East Feliciana. The bright blue areas have a 1-percent chance of being flooded in any year. These areas are thus, by definition, in a "**100-year floodplain**."

Many communities also have **500-year floodplains**. Any site in a 500-year floodplain has a 0.2-percent chance of being flooded in any given year.

Visual 33: Flood Probability (2 of 2)



Key Points

The 100-year flood probability is the national standard adopted by the National Flood Insurance Program and used by all Federal agencies.

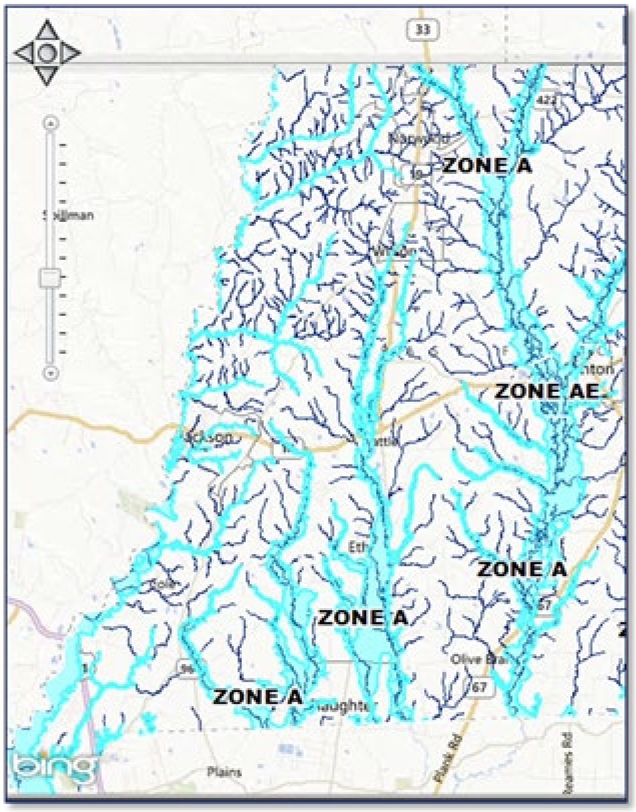
A 100-year flood is a flood that has a one percent chance of occurring in any given year.

The graphic illustrates the difference between a 100-year floodplain and a 500-year floodplain, and the relative percentage of probability.

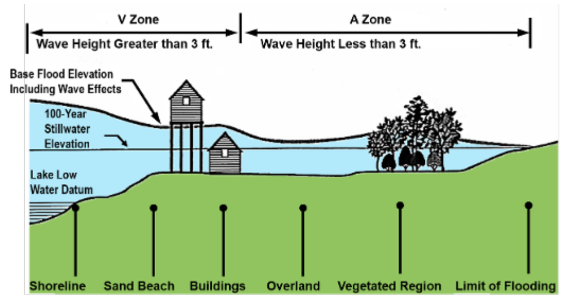
Flood Probabilities

The image on the right delineates areas that will be flooded in the Louisiana parish of East Feliciana. The bright blue areas have a one-percent chance of being flooded in any year. These areas are thus, by definition, in a "100-year floodplain."

Many communities also have 500-year floodplains. Any site in a 500-year floodplain has a 0.2-percent chance of being flooded in any given year.


ZONE A
ZONE AE
ZONE A
ZONE A
ZONE A
Plains

Visual 34: Coastal High Hazard Area



Coastal High Hazard Area Image Description

The Coastal High Hazard Area that extends from offshore to the inland limit of a primary frontal dune along an open coast, plus any other areas subject to high-velocity wave action, is designated a Velocity Zone (V Zone). A diagram illustrating the V Zone (Wave height greater than 3 ft) and the A Zone (Wave height less than 3 ft).

Key Points

Hydrologists have identified a different flood hazard area for coastal regions. The Coastal High Hazard Area that extends from offshore to the inland limit of a primary frontal dune along an open coast, plus any other areas subject to high-velocity wave action, is designated a Velocity Zone (V Zone).

The flood hazard area landward of the V Zone may be affected by flooding associated with astronomical tides, storm surges, seiches, or tsunamis.

Visual 35: This “100-Year Flood” vs. the Next One

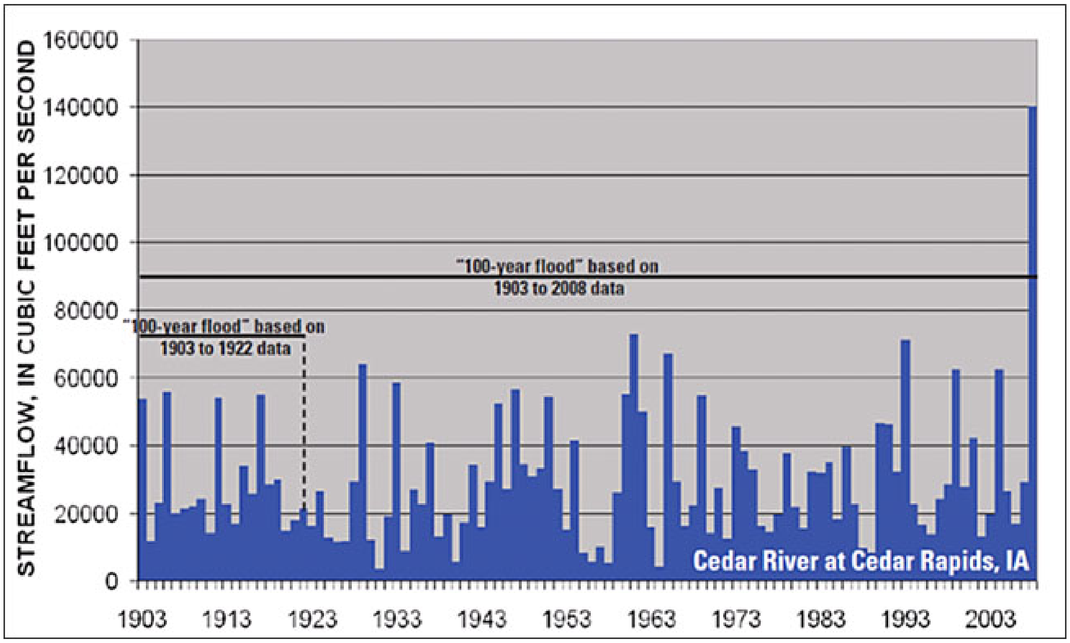
Scenario: We have just had a 100-year flood.

Which one of these statements is **NOT** true?

- We could have another 100-year flood tomorrow.
- We could have another 100-year flood next year.
- We could wait 300 years until the next such flood.
- We are safe from such floods for another 100 years.

Discussion Question: Assume you are in an area that has just suffered a 100-year flood. Which of these statements is NOT true?

Visual 36: Activity: Length of Data Set Influences Uncertainty

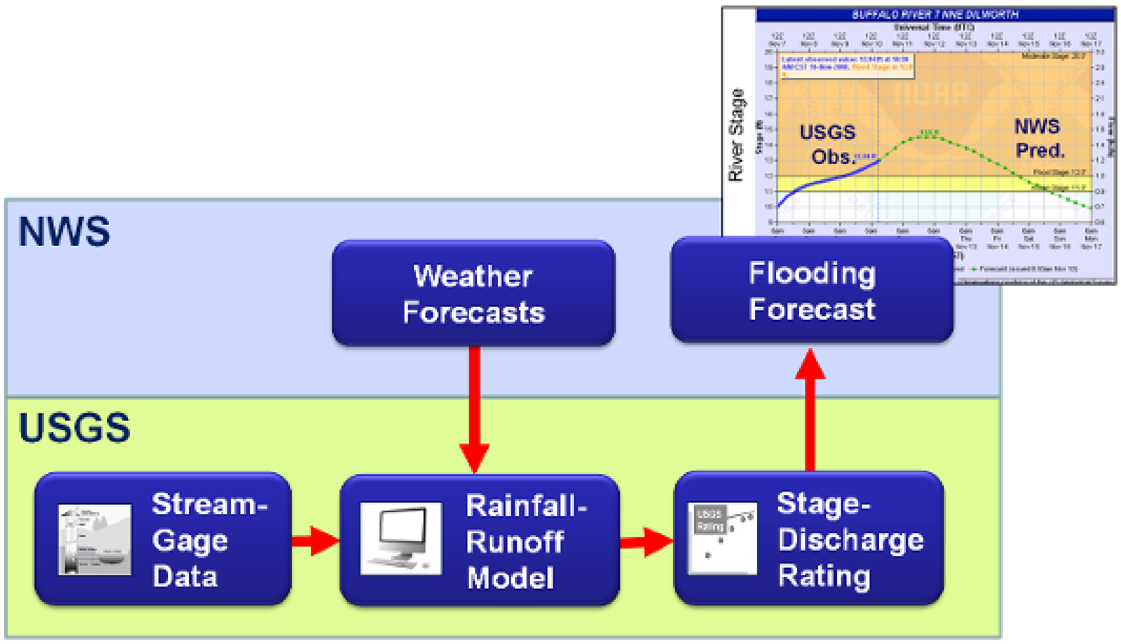


Key Points

It is also important to note that the longer the record of data, the better the chances are that scientists will successfully interpret patterns. This graph of streamflow data from Cedar Rapids, Iowa, shows highest flood levels from 1903 to 2011. (The blue line at the far right of the graph is the 2011 flood level.)

Discussion Question: Look at the data set from 1963–1983. How high would you build a levee to protect against a 100-year flood? Now look at the data set from 1963–2011. How does that change your 100-year flood level?

Visual 37: Flood Forecasting



Key Points

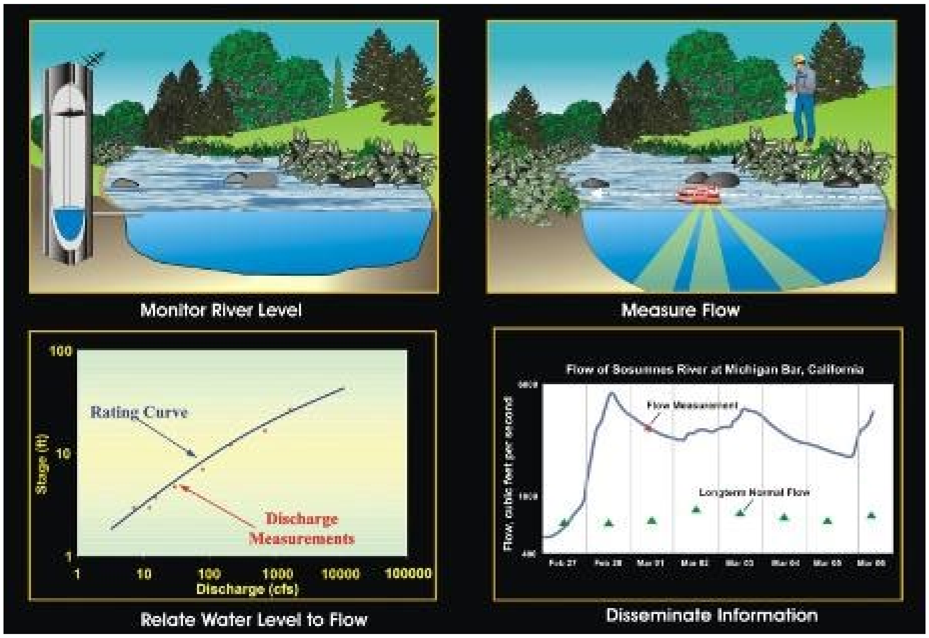
Given the hazards associated with flooding, emergency managers need to have reliable flood forecast information available in order to be prepared for flood emergencies that arise. What kinds of forecast information are available?

Flood forecasting: For rivers around the country, flood forecasts are available that show where and when the river is going to **crest** (reach its highest level). Forecasts can be made 4 to 5 days in advance of the event and can be crucial in decisions such as evacuation and emergency levee building. The National Weather Service (NWS) and U.S. Geological Survey (USGS) partner to make and improve flood forecasts.

Streamgages: Forecasts are based in part on data from streamgages, along with NWS rainfall predictions. Streamgages are devices located beside a river that measure and record the water level in the river. The streamgages reveal what is actually happening on the river and are essential to calibrate flood models and make more accurate forecasts of flood parameters.

USGS operates more than 7,800 streamgages around the Nation.

Visual 38: Streamgaging Process



Key Points

Streamgaging is based on two key factors-water elevation and volumetric streamflow.

- **Water elevation:** Sensors like the one on the upper left sense the water elevation at all hours and at varying frequencies. But water elevation, while important, is not enough information alone.
- **Streamflow:** To assess floods, volumetric streamflow (which only occasionally gets measured) must also be factored in. Based on those occasional measurements, scientists can estimate the flow at a site when the water is at different elevations. Thus, elevation becomes a surrogate for volumetric flow.
- **Rating curve:** As the sensors continually gather observations of water elevation, these elevations get converted to estimates of gallons per minute of volumetric streamflow through what is called a rating curve (stage/discharge rating). The "stage" is synonymous with elevation. In the sample rating curve shown on the lower left, red dots are discrete observations made by a human being. The rest of the curve is estimated.
- **Hydrograph:** A product of this measurement and estimation process is a hydrograph (bottom right). Some hydrographs show the water stage; others, like this one, show **discharge** (the volume of water passing a point per unit time, often measured in cubic feet per second, or cfs). Again, the red dots indicate discrete measurements.

These data are the basic tools of flood forecasting, and these products are available online almost immediately.

Visual 39: NFIP Flood Mapping

To identify a community's flood risk, the National Flood Insurance Program (NFIP):

- Conducts a flood insurance study that includes statistical data for:
  - River flow.
  - Storm tides.
  - Hydrologic/hydraulic analyses.
  - Rainfall and topographic surveys.
- Creates maps that outline the community's different flood risk areas.

Key Points

To identify a community's flood risk, the National Flood Insurance Program (NFIP) conducts a flood insurance study that includes statistical data for:

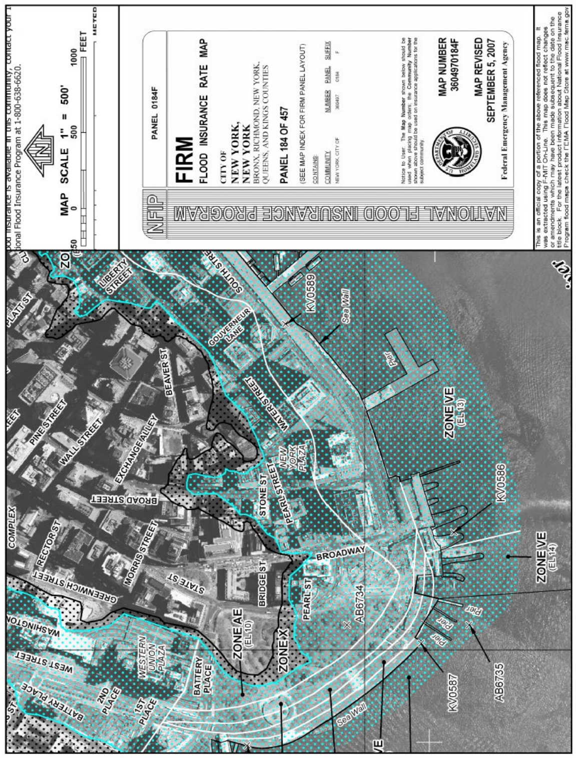
- River flow.
- Storm tides.
- Hydrologic/hydraulic analyses.
- Rainfall and topographic surveys.

These data are used to create maps that outline THE community's different flood risk areas.

Almost 100,000 Flood Insurance Rate Maps (**FIRMs** or **DFIRM**s, if digitized) have been published and are currently being updated.

Note: FIRMs are older maps and have been replaced by D-FIRMs—Digital - Flood Insurance Rate Maps.

Visual 40: NFIP Flood Mapping



Key Points

Flood zones are geographic areas that FEMA has defined according to varying levels of flood risk. These zones are depicted on a community's Flood Insurance Rate Map (FIRM) or Flood Hazard Boundary Map. Each zone reflects the severity or type of flooding in the area.

Moderate-to-Low-Risk Areas

In communities that participate in the NFIP, flood insurance is available to all property owners and renters in these zones:

ZONE	DESCRIPTION
B and X (shaded	Area of moderate flood hazard, usually the area between the limits of the 100-year and 500-year floods. Also used to designate base floodplains of lesser hazards, such as areas protected by levees from 100-year flood or shallow flooding areas with average depths of less than 1 foot or drainage areas less than 1

ZONE	DESCRIPTION
	square mile.
C and X (unshaded)	Area of minimal flood hazard, usually depicted on FIRMs as above the 500-year flood level.

High-Risk Areas

In communities that participate in the NFIP, mandatory flood insurance purchase requirements apply to all of these zones:

ZONE	DESCRIPTION
A	Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas, no depths or base flood elevations are shown within these zones.
AE	The base floodplain where base flood elevations are provided. AE Zones are now used on new format FIRMs instead of A1-A30 Zones.
A1-30	These are known as numbered A Zones (e.g., A7 or A14). This is the base floodplain where the FIRM shows a base flood elevation (old format).
AH	Areas with a 1% annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.
AO	River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of

ZONE	DESCRIPTION
	flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones.
AR	Areas with a temporarily increased flood risk due to the building or restoration of a flood control system (such as a levee or a dam). Mandatory flood insurance purchase requirements will apply, but rates will not exceed the rates for unnumbered A zones if the structure is built or restored in compliance with Zone AR floodplain management regulations.
A99	Areas with a 1% annual chance of flooding that will be protected by a Federal flood control system where construction has reached specified legal requirements. No depths or base flood elevations are shown within these zones.

High-Risk - Coastal Areas

In communities that participate in the NFIP, mandatory flood insurance purchase requirements apply to all of these zones:

ZONE	DESCRIPTION
V	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. No base flood elevations are shown within these zones.
VE, V1 - 30	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.

Undetermined Risk Areas

In communities that participate in the NFIP, mandatory flood insurance purchase requirements apply to all of these zones:

ZONE	DESCRIPTION
D	Areas with possible but undetermined flood hazards. No flood hazard analysis has been conducted. Flood insurance rates are commensurate with the uncertainty of the flood risk.

Other symbols can be found in the FEMA legend book - https://www.fema.gov/media-library-data/20130726-1550-20490-1950/ot_firm.pdf.

Visual 41: Activity 5.2: Using a Risk Map

Instructions: Working individually:

1. Go online and find your community's flood map. Some possible locations to find your mapping might be under the Planning & Zoning section, mapping, or GIS. If you cannot quickly (less than 3 minutes) find your community's flood map, please complete the exercise using the Clark County, Nevada flood map provided below.
2. If you used your community's website, write down the URL for your future reference. Otherwise, skip to Question #4.
3. What department hosts this data on the website?
4. When was the map last updated?
5. Identify:
   - The types of flood zones found on your map
   - The corresponding description of each zone
6. Record your answers in your IAW.

Key Points

Instructions: Working individually:

1. Go online and find your community's flood map. Some possible locations to find your mapping might be under the Planning & Zoning section, mapping, or GIS. If you cannot quickly (less than 3 minutes) find your community's flood map, please complete the exercise using the Clark County, Nevada flood map provided below.
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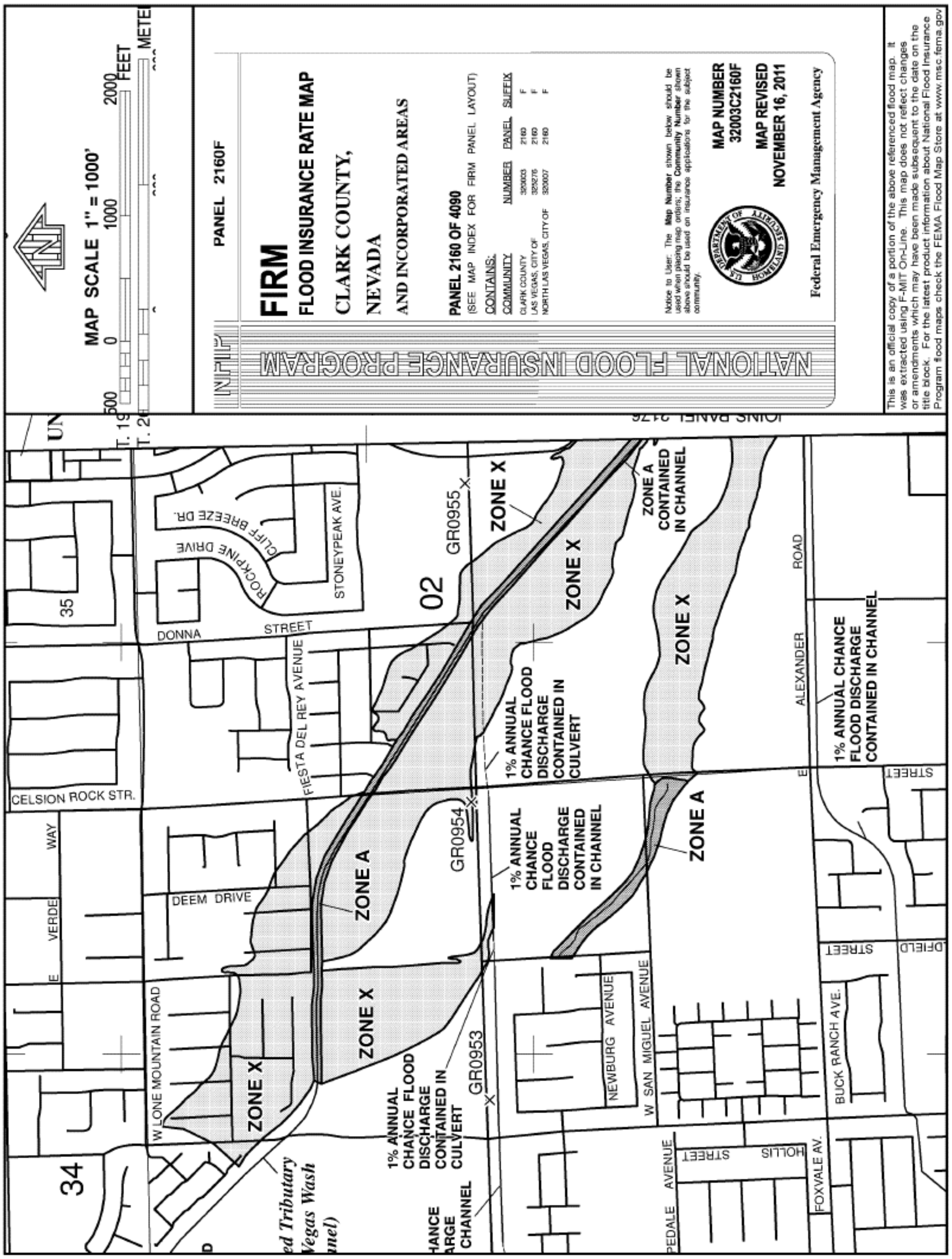
3. What department hosts this data on the website?
4. When was the map last updated?
5. Identify:
   - The types of flood zones found on your map.
   - The corresponding description of each zone.
6. Record your answers in your IAW.

Student Manual

Total Activity Time: 10 minutes

If your community's flood map is unavailable, use the included Clark County, Nevada. Clark County, Nevada Flood Map

Clark County, Nevada Flood Map



Visual 42: Unit Summary

You should now be able to:

- Identify the types of floods.
- Describe flood impacts.
- Explain flood probabilities.
- Describe flood dynamics.

Key Points

Do you have any questions about the material covered in this unit?

Further Information

Unit 6: Earthquakes and Tsunamis

Visual 1: Unit 6: Earthquakes

Unit 6: Earthquakes and Tsunamis

Key Points

This unit will give you an introduction to earthquakes and tsunamis.

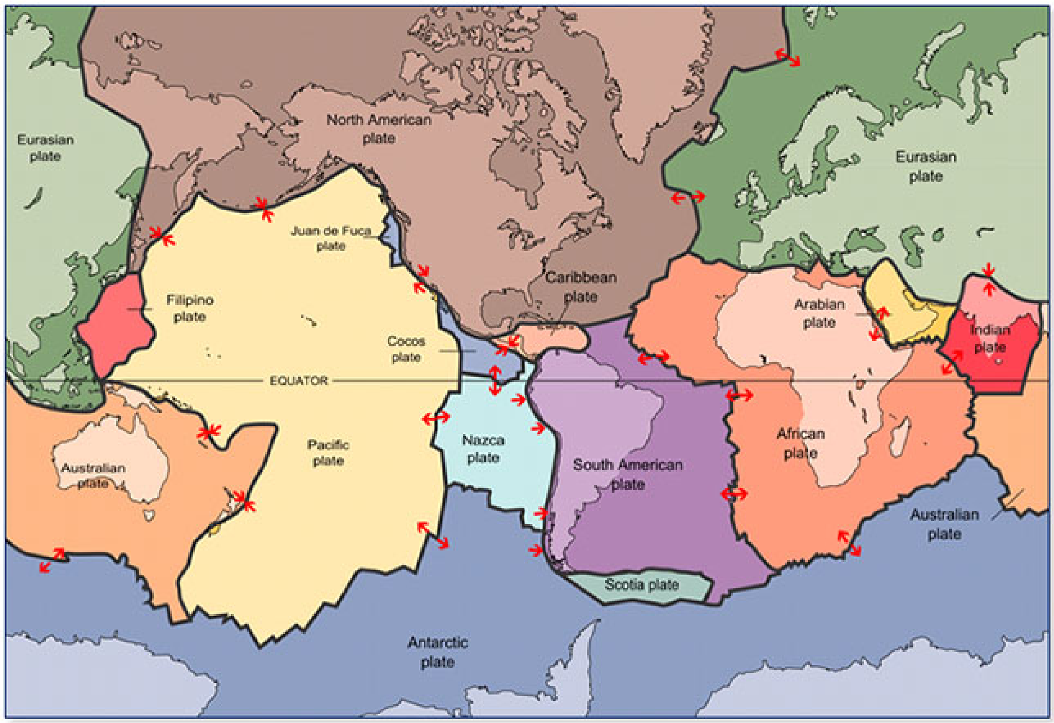
Visual 2: Unit Objectives

- Define earthquake-related terminology and concepts.
- Describe the three types of waves produced by earthquakes.
- Identify the secondary effects of earthquakes.
- Identify methods for measuring earthquake activity.
- Identify the geologic causes of tsunamis.
- Describe natural and official tsunami warning signs.
- Describe tsunami surges and currents.
- Identify the impacts of tsunamis.
- Explain when officials issue tsunami warnings.

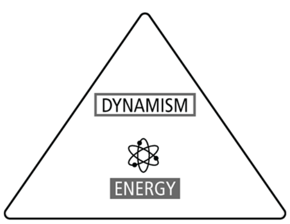
Key Points

Review the unit objectives as shown on the visual.

Visual 3: Plate Tectonics



This is dynamism.



This is dynamism and energy.

Plate Tectonics Image Description

The map on the visual shows the current plates and their boundaries. Most of the contiguous United States and Alaska sit on the North American Plate. Westernmost southern California is along the boundary of the Pacific plate. Hawaii lies on the Pacific Plate. The Pacific and North American Plates slide past each other at about 50 mm a year—about the rate that fingernails grow.

Key Points

Plate tectonics accounts for much of what happens at the surface of the Earth and creates natural hazards. The theory of plate tectonics states that the Earth's lithosphere is fragmented into enormous blocks of rock called plates that are moving relative to one another as they ride atop hotter, more mobile material.

Plate boundaries: There are three types of plate boundaries:

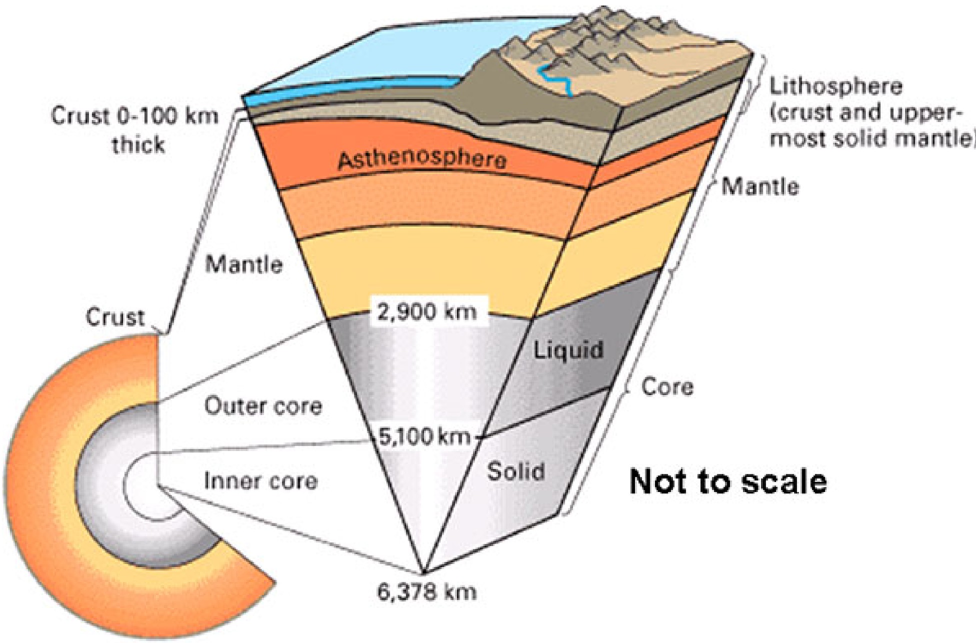
- Divergent boundaries—where new crust is generated as the plates pull away from each other
- Convergent boundaries—where crust is destroyed as one plate dives under another
- Transform boundaries—where crust is neither produced nor destroyed as the plates slide horizontally past each other

The number and sizes of plates, their directions of motion, and their styles of motion change over time, but there is no net change in size (i.e., the circumference of the Earth remains the same).

Plate locations: The map on the visual shows the current plates and their boundaries. Note:

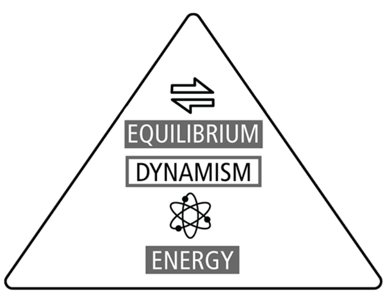
- Most of the contiguous United States and Alaska sit on the North American Plate.
- Westernmost southern California is along the boundary of the Pacific plate. Hawaii lies on the Pacific Plate.
- The Pacific and North American Plates slide past each other at about 50 mm a year—about the rate that fingernails grow.

Visual 4: Structure of the Earth



Equilibrium Dynamism Energy Icon

This is equilibrium, dynamism, and energy.



Key Points

Learning about the interior of the Earth helps us understand some of the forces that affect natural hazards.

Layers: The Earth consists of three internal layers: the core, the mantle, and the crust. This magnified cross-section of the Earth shows some of the details of those three basic layers.

This is another example of a convection current, the movement of the earth layer is due to temperature driving which is coming from radioactive decay from the core of the earth. Refer to subsequent slides for more explanation and visuals.

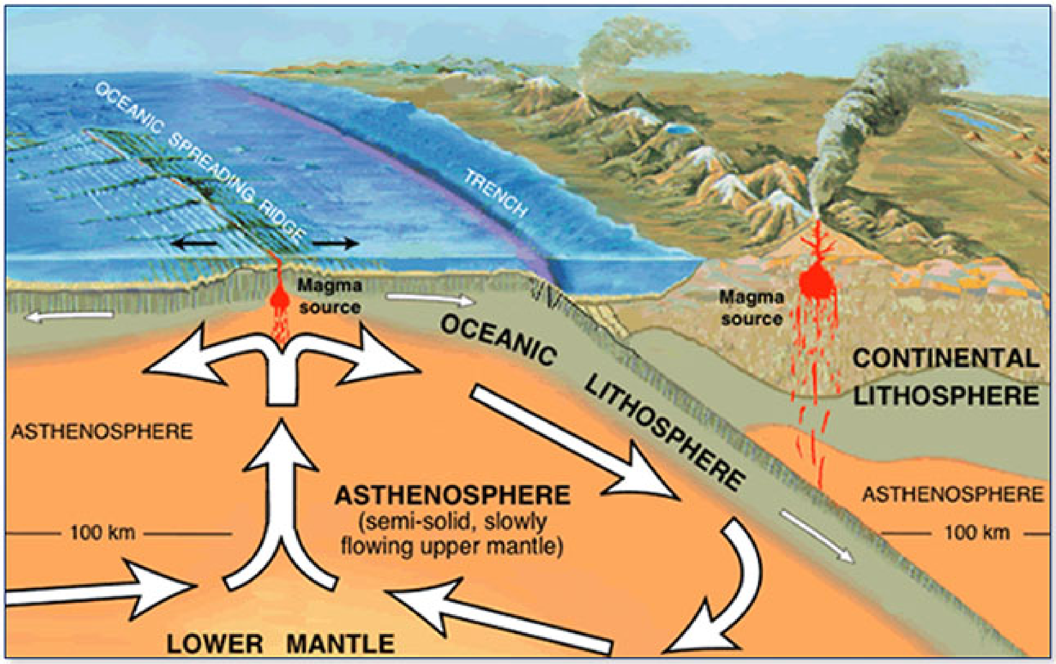
Core: If you programmed your car to drive from San Diego to Nova Scotia, then drove straight down instead, you would near the center of the Earth, which is about 4,000 miles directly beneath us. The layer around the center is called the core. The inner core consists of solid iron nickel, and the outer core consists of liquid iron nickel. The flow of this extremely hot material produces the Earth's magnetic field.

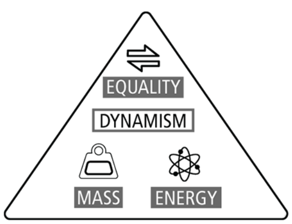
Mantle: This flow of material, called convection, also occurs in the next layer, the mantle (the orange section of the drawing). The mantle is the thickest of the Earth's layers. There are pockets of liquid in the mantle, but most of the mantle is solid rock.

In the mantle layer called the asthenosphere, this rock is under such high pressures and temperatures that it can flow even though it is a solid. Flow in the asthenosphere directly affects hazards on the surface of the Earth.

Lithosphere: The lithosphere includes the uppermost solid mantle and the crust. The crust includes oceanic crust and continental crust. All life exists on the crust of the Earth, a layer so thin that it is barely visible as a thin line when drawn to scale with the other layers of the Earth. Its height is exaggerated in this drawing in order to be visible.

Visual 5: Convection in the Earth





This is equality, dynamism, mass, and energy.

Key Points

A similar process of convection within the Earth is an essential component in the creation of many of our hazards.

The heat source is a process called **radioactive decay**, in which the nucleus of an unstable atom loses energy by emitting radiation, including alpha particles, beta particles, gamma rays and conversion electrons, and release heat as they change. Thousands of miles of rock provide immense insulation, resulting in the trapping of a lot of heat inside the Earth. The hot rock deep in the mantle rises, cools, sinks—creating convection cells in the asthenosphere.

Above the asthenosphere's convection cells is a shell of cold, hard, brittle rock typically about 80 miles thick—the **lithosphere—**which includes rock of the crust and the uppermost mantle.

Visual 6: Plate Tectonics

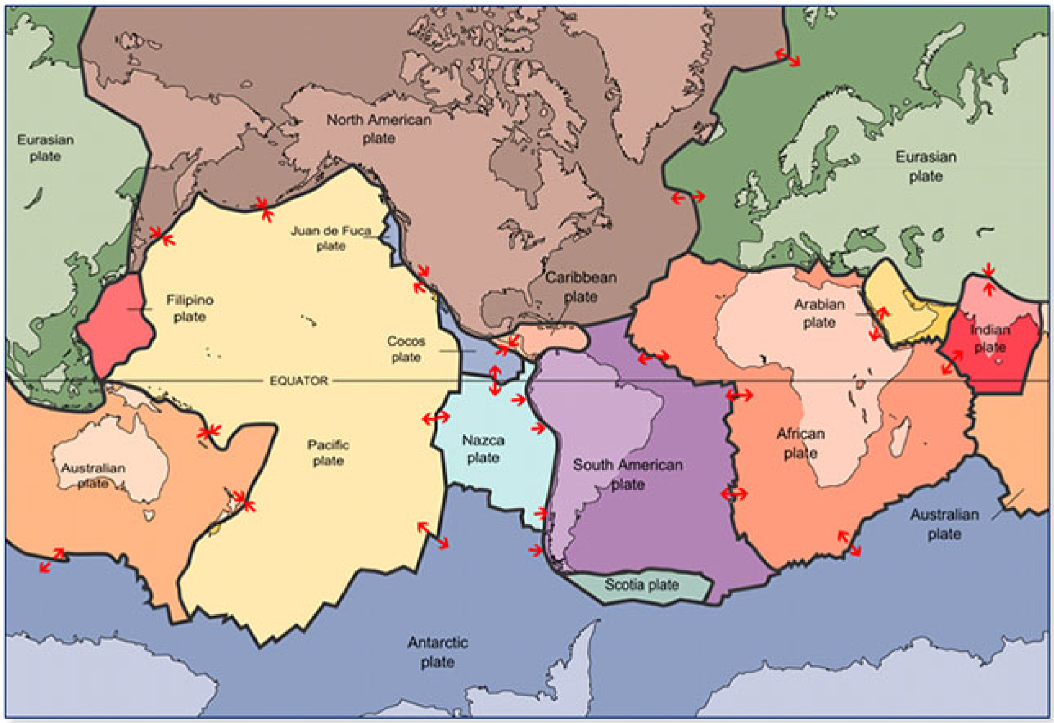
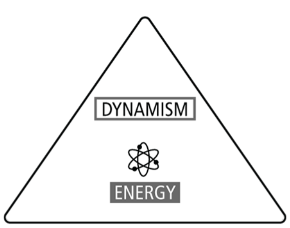


Plate Tectonics Image Description

The map on the visual shows the current plates and their boundaries. Most of the contiguous United States and Alaska sit on the North American Plate. Westernmost southern California is along the boundary of the Pacific plate. Hawaii lies on the Pacific Plate. The Pacific and North American Plates slide past each other at about 50 mm a year—about the rate that fingernails grow.



This is dynamism and energy.

Key Points

Plate tectonics accounts for much of what happens at the surface of the Earth and creates natural hazards. The theory of plate tectonics states that the Earth's lithosphere is fragmented into enormous blocks of rock called plates that are moving relative to one another as they ride atop hotter, more mobile material.

Plate boundaries: There are three types of plate boundaries:

- Divergent boundaries—where new crust is generated as the plates pull away from each other
- Convergent boundaries—where crust is destroyed as one plate dives under another
- Transform boundaries—where crust is neither produced nor destroyed as the plates slide horizontally past each other

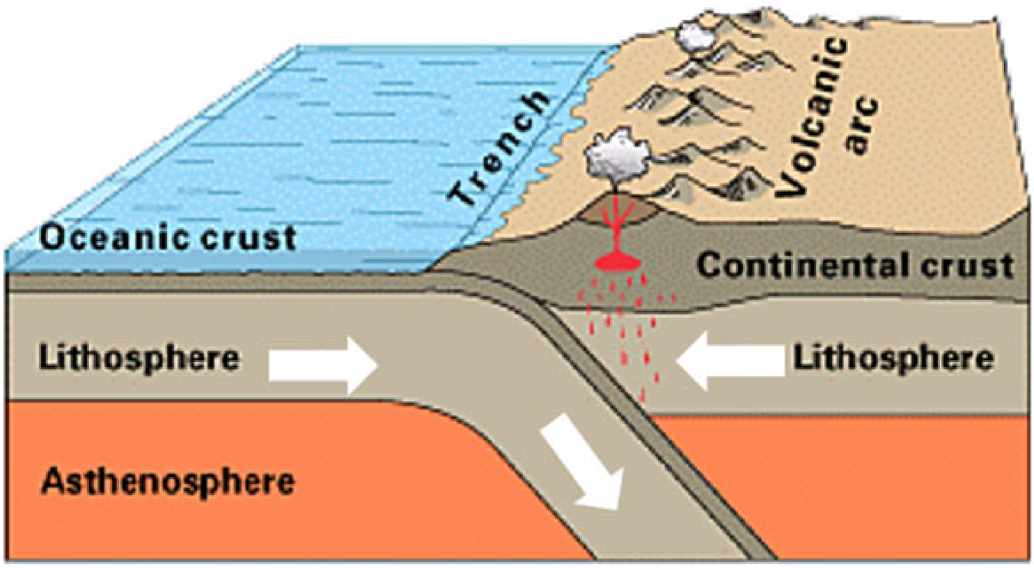
The number and sizes of plates, their directions of motion, and their styles of motion change over time, but there is no net change in size (i.e., the circumference of the Earth remains the same).

Plate locations: The map on the visual shows the current plates and their boundaries. Note:

- Most of the contiguous United States and Alaska sit on the North American Plate.
- Westernmost southern California is along the boundary of the Pacific plate. Hawaii lies on the Pacific Plate.
- The Pacific and North American Plates slide past each other at about 50 mm a year—about the rate that fingernails grow.

Visual 7: Convergent Boundaries (1 of 2)

Ocean-to-Continent



Key Points

Convergent Boundaries (This link can also be accessed at the following URL: https://pubs.usgs.gov/gip/dynamic/understanding.html)

A convergent plate boundary is a location at which two plates collide under compressional stress. This diagram shows one type of convergent plate boundary—an ocean-to-continent boundary. Another convergent boundary is an ocean-to-ocean boundary where the plates meet underneath the ocean. The kinds of rocks that underlie oceans have very different properties than the kinds of rock that make up continents, so scientists make distinctions between oceanic rock and continental rock. At a convergent boundary:

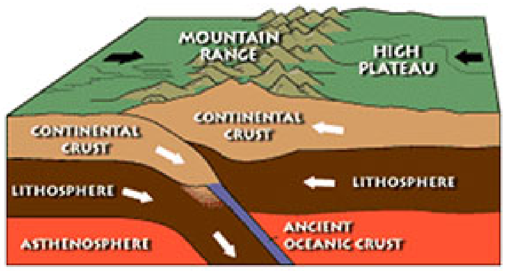
- Two plates meet and are pushed toward each other.
- As the two plates collide, if there is a big difference in density between the plates, one plate slides under the other (subduction), and the boundary of the two plates is marked by a trench.
- Whichever plate is denser is the one that sinks. At a continental boundary, it is always the ocean plate that subducts, because a continental plate is less dense and more buoyant. At an ocean-to-ocean boundary, the plate that is older will be denser and colder and will therefore subduct.
- As the subducting plate descends into the asthenosphere, it releases water, which triggers the melting of rock, generating magma—molten rock below the Earth's surface. The magma is less dense than the surrounding rock and begins to rise toward the surface.

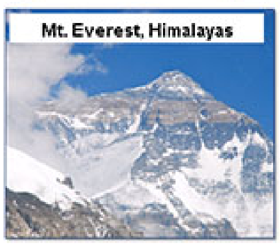
(Recall the discussion of the convection cell.) We'll talk more about magma in a later unit.

- The rising magma creates a line of volcanic islands (if in the ocean) or a row of volcanoes embedded within a coastal mountain range (if on a continent) on the overlapping plate.
- Plate collisions produce very large earthquakes. In particular, in subduction zones, earthquakes occur in the subducting plate, the overriding plate, and in between the plates.
- Subduction zones create the largest earthquakes and the largest tsunamis on the planet.

Visual 8: Convergent Boundaries (2 of 2)

Continent-to-Continent





Convergent Boundaries (2 of 2) Image Description

Four Images: Image 1: A diagram used to show continent-to-continent. The levels are mountain range and high plateau, continental crust, lithosphere, asthenosphere and ancient oceanic crust. Image 2: Mt. Everest, Himalayas. Image 3: Appalachians. Image 4: A map showing India movement from 71 million years ago until today.

Key Points

Another situation occurs when two continental plates converge. Because both plates are buoyant, neither plate subducts, and everything is pushed upward.

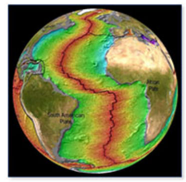
For example, the Himalayan Mountains are the result of India crashing into Eurasia. These mountains, along a current plate boundary, are still growing. Because there is no subduction, there are few (if any) volcanoes, but the region is experiencing tremendous compressional stress over a large area, leading to many earthquakes.

It can take tens of thousands of years to uplift the rock at a plate boundary, one earthquake at a time, until it is tall enough to form a mountain range. It takes even longer to wear a mountain range away.

The Appalachians, along a former plate boundary, are in the process of weathering away. They formed hundreds of millions of years ago, and at one time were mightier than today's Himalayas.

Visual 9: Divergent Boundaries

- Tensional stress
- Fissure cracks
- Formation of new crust from rising magma
- Shallow earthquakes
- Continental rifting



Divergent Boundaries Image Description

Three images: Image 1: A globe showing a crack between the South American Plate and the African Plate. Image 2: A magnified view of a map of East Africa. Image 3: The map shows plate boundaries, the east African rift zone, and different plates. A map showing Iceland and the North American Plate and the Eurasian Plate.

Key Points

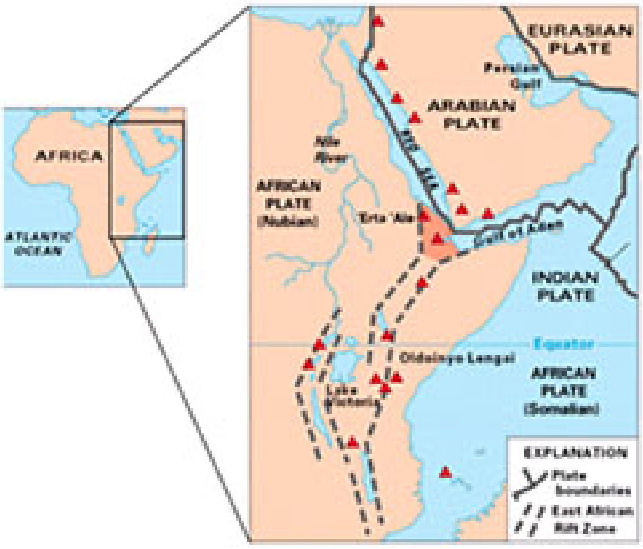
Divergent Boundaries (This link can also be accessed at the following URL: https://pubs.usgs.gov/gip/dynamic/understanding.html)

At a **divergent plate boundary**, two plates move away from each other under tensional stress. Shallow, low-to-medium-magnitude earthquakes occur at divergent plate boundaries.

- **Under an ocean:** When a divergent plate boundary lies under an ocean, the oceanic crust becomes very thin and cracks, opening up fissures. The traditional cone-shaped volcanoes with a central vent do not form at these locations. Rather, magma moves up to the surface through the fissures and solidifies, creating new oceanic crust.
- **Under a continent:** When a divergent plate boundary lies under a continent, the process is similar, and the continent can gradually be ripped apart to form new oceans through a process called continental rifting.

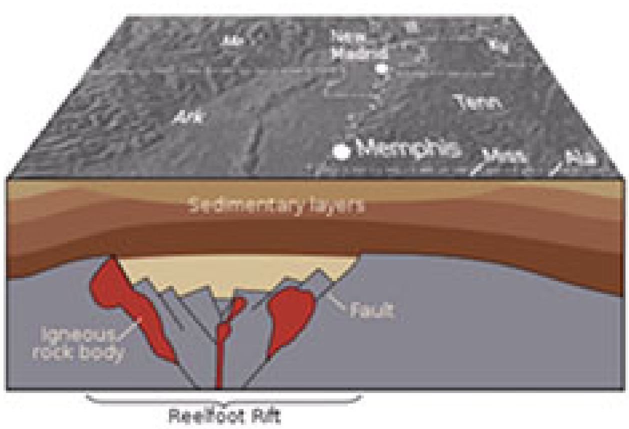
As the crust thins and fissures occur, the overall elevation of the region becomes low enough for shallow seas to form. Modern examples of a continental rifting are the Red Sea and the East African Rift valley. The Red Sea began as a continental rift and is now a mid-ocean ridge. The East African Rift (This link can also be accessed at the following URL: https://pubs.usgs.gov/gip/dynamic/East_Africa.html) valley is in the process of ripping East Africa from the main continent.

See Color Handout 6.1: Continental Rifting



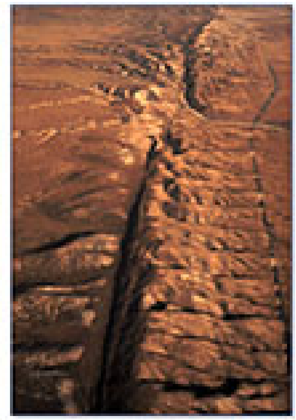
Some scientists think that earthquakes in Tennessee and Missouri result from an old, failed divergent plate boundary. They hypothesize that the New Madrid Earthquake zone (This link can also be accessed at the following URL: http://earthquake.usgs.gov/learn/topics/nmsz/1811-1812.php) is a result of an ancient (500-million-year-old) buried northeast-trending continental rift known as the Reelfoot Rift (shown in cross-section below).

This is an excellent example of how the Earth's internal forces change with time. Plate boundaries are not fixed, permanent features; they develop, change types, change locations, and even cease with time.



Visual 10: Transform Boundaries

- Shear stress
- Large-magnitude earthquakes



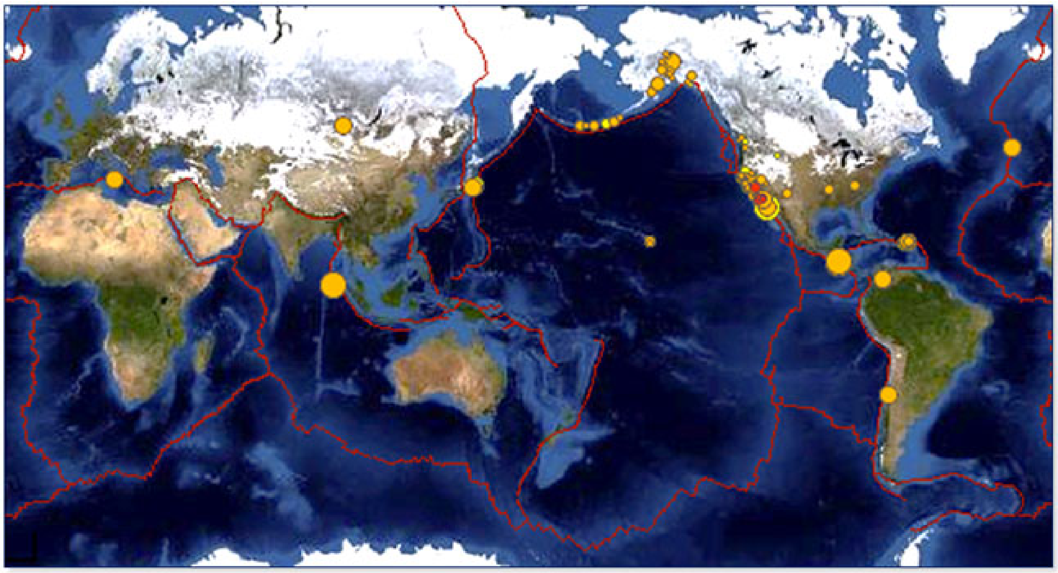
Key Points

Transform plate boundaries (This link can also be accessed at the following URL: https://pubs.usgs.gov/gip/dynamic/understanding.html) occur where two plates slide past each other under shear stress.

In this situation, there is no subduction and volcanoes do not form. However, there is still tremendous frictional stress that can create large, destructive earthquakes.

The most famous example of a transform plate boundary is the San Andreas Fault running through California. This fault marks the boundary between the North American Plate and the Pacific Plate, and will be explored in greater detail in the next unit.

Visual 11: Effects of Plate Motion: Earthquakes



Effects of Plate Motion: Earthquakes Image Description

A global map marking earthquakes and tsunamis along plates. Earthquake points are above Africa, to the left of Indonesia, in mid-Russia and off the coast of Russia. A chain of Earthquakes occur between Russia and Alaska, with a cluster occurring between Alaska and Canada. A cluster of Earthquakes are marked along the US west coast, and across the mid-US. There is a large occurrence around Panama and out to the Leeward Islands, and an occurrence along Chile. There is also an occurrence on the plate in the Atlantic Ocean.

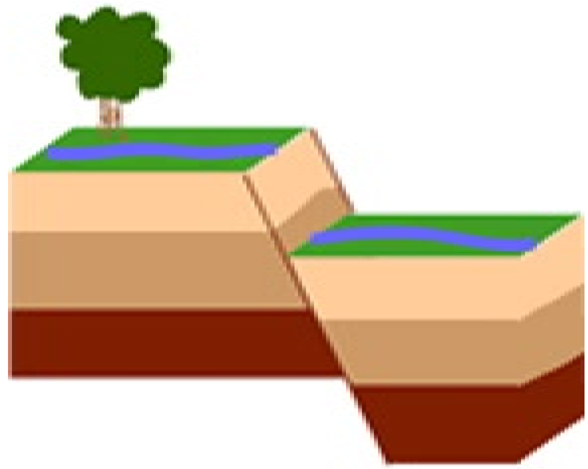
Key Points

The forces of plate tectonics create earthquakes. Most earthquakes occur near plate boundaries, represented by the lines in the map on this visual, which shows one week of earthquakes in August 2012. Earthquakes do occur away from plate boundaries, but less frequently.

Subduction-zone earthquakes can also generate **tsunamis.**

Visual 12: Earthquake Fundamentals

Earthquake Fundamentals



Key Points

This unit will focus on the following main topics:

- Earthquake fundamentals
- Earthquake occurrence and effects
- Earthquake monitoring and forecasting

Visual 13: Video: Nepal Earthquake

Video: Nepal Earthquake Video Description

The video shows different areas that were affected by the April 2015 Nepal earthquake that killed over 8,000 people and injured more than 21,000. It occurred at 11:56 Nepal Standard Time on 25 April, with a magnitude of 7.8. Its epicenter was east of Lamjung District, and its hypocenter was at a depth of approximately 8.2 km.

Key Points

The April 2015 Nepal earthquake killed over 8,000 people and injured more than 21,000. It occurred at 11:56 Nepal Standard Time on 25 April, with a magnitude of 7.8. Its epicenter was east of Lamjung District, and its hypocenter was at a depth of approximately 8.2 km.

It was the worst natural disaster to strike Nepal since the 1934 earthquake. Hundreds of thousands of people were made homeless due to the devastating earthquake. Centuries-old buildings were destroyed at UNESCO World Heritage sites in the Kathmandu Valley, including some at the Kathmandu Durbar Square, the Patan Durbar Square, the Bhaktapur Durbar Square, and the Changu Narayan. Geophysicists and other experts had warned for decades that Nepal was vulnerable to a deadly earthquake, particularly because of its geology, urbanization, and architecture.

Outside the Valley, the Manakamana Temple in Gorkha, the Gorkha Durbar, the Rani Mahal in Palpa District, the Dolakha Bhimsensthan in Dolakha District, and the Nuwakot Durbar were partially damaged.

Visual 14: Simulation: San Andreas Fault Earthquake

Key Points

This animation illustrates many important aspects of the earthquake process, which we will discuss in this unit. This computer simulation, created through the collaboration of earth scientists and computer scientists, shows the travel of earthquake waves generated by a rupture on the San Andreas Fault in southern California. This is a hypothetical magnitude 7.8 earthquake called the Shakeout scenario earthquake.

The San Andreas Fault extends for hundreds of miles along the plate boundary in California. The simulation focuses on the southern terminus of the fault, which begins at the Salton Sea, and extends to the northwest. The San Andreas Fault ruptures all the way to the surface of the Earth, and to a depth that varies from about 6 to 10 miles.

The dashed line indicates the 200 miles of fault that will rupture in this single earthquake. If a shorter section of the fault ruptured, the earthquake would be smaller. If a longer section of the fault ruptured, the earthquake would be bigger.

In the lower left of the screen is a green counter that ticks off seconds after the fault rupture begins. The white, yellow, and red colors indicate the velocity of the waves that carry the energy away.

<u>Discussion Question</u>: What did you notice?

Visual 15: Faults and Earthquakes

Fault:

- A break or weak zone in the Earth's crust.
- Rocks on one side of the break move past those on the other, allowing differential movement.

Earthquake:

- A slip of rock on a fault.
- Ground shaking from energy released during the slip.

Key Points

Faults: A fault:

- Is a break or weak zone between two blocks of rock.
- Allows **differential movement** between two blocks of rock.

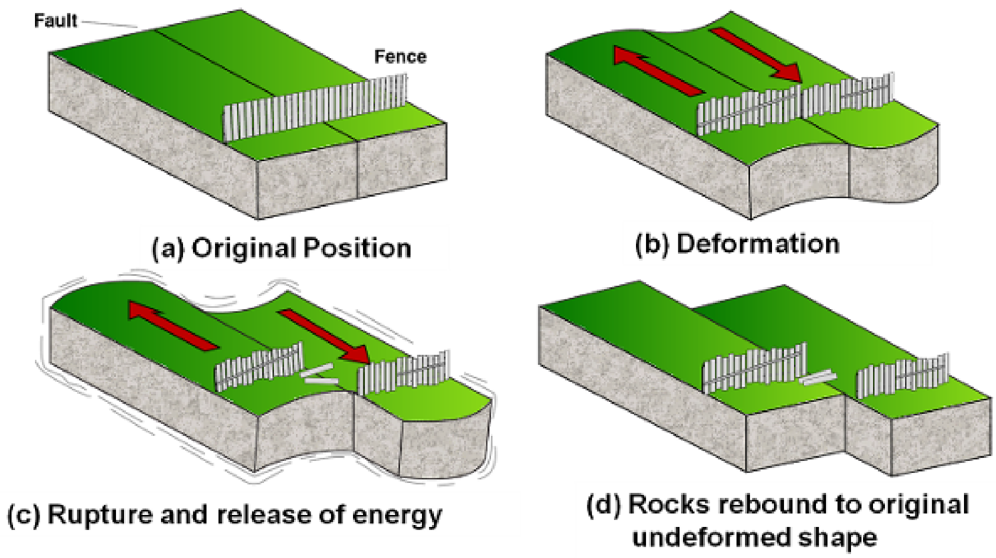
Differential movement means that the two blocks move in different directions. Scientists can measure the relative changes in the positions of the two blocks but, because of a lack of an outside frame of reference, cannot detect how each block moved alone.

Earthquakes: The term *earthquake* is used to describe both:

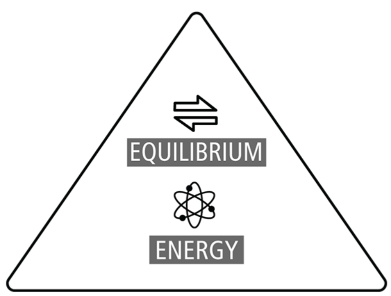
- The slip of rock on a fault, and
- The resulting ground shaking from energy that gets released during the slip, and *sometimes*
- Energy released from volcanic or other processes.

(This very basic definition will be elaborated on throughout this unit.)

Visual 16: Elastic Rebound Theory



This is equilibrium and energy.



Key Points

To understand the science of earthquakes, it is helpful to know about the Elastic Rebound Theory, which forms the basis of scientific investigation into earthquakes.

Following a 1906 earthquake in California, a flurry of scientific investigation studied the root causes of earthquakes. Henry Fielding Reid, a Professor of Geology at Johns Hopkins University, proposed the Elastic Rebound Theory to explain the phenomena of earthquakes, a theory that survives to this day.

The theory states that, like a stretched rubber band, the Earth's lithosphere stores elastic energy that is released suddenly in an earthquake-the equivalent of breaking or cutting a rubber band.

There are four steps in this elastic process:

a. Original position (strain in the rocks builds).
b. Deformation (rocks have elastic strain and bend).
c. Rupture and release of energy (strain is released and rocks snap-i.e., an earthquake).
d. Rocks rebound to original undeformed shape (i.e., become stable).

Regardless of the style of motion, enormous blocks of rock do not move easily. In fact, the edges of the plates are locked by frictional forces most of the time, while the body of the plate continues to move slowly.

Visual 17: Fault Types

- Dip-slip faults:
  - Vertical motion
- Strike-slip faults
  - Horizontal motion
- Oblique faults
  - Combination

Key Points

Fault types: There are different classifications of faults based on the movement of the rock, which we will look at in subsequent visuals:

- Dip-slip faults, including normal and reverse, which involve vertical movement.
- Strike-slip faults, which involve lateral movement.
- Oblique faults, which involve both vertical and lateral movement.

Fault planes and fault zones: Faults are typically modeled as planes between rocks. (The reality is more complicated; it is often more appropriate to think of a fault as a zone of deformation rather than as a sharp planar feature.)

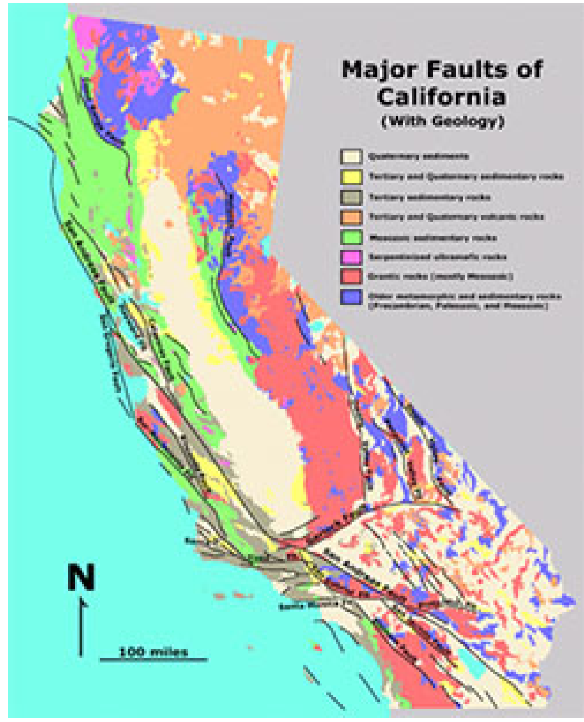
A **fault plane** extends laterally and vertically. A typical fault that is large enough to produce a damaging earthquake will extend at least 6 miles deep into the earth and might be hundreds of miles long.

Typically only part of a fault will allow movement in a single earthquake. Thus, scientists distinguish between the fault plane, which is the full extent of the fault, and the **rupture plane,** which is the part of the fault that allows movement in a single earthquake.

Scientists talk interchangeably about "fault rupture," "fault movement," "fault slip," "earthquake rupture," and "earthquake slip." All of these are ways to talk about the process where a weak zone, the fault, allows movement of blocks of rock that meet at the fault.

Visual 18: Fault Size

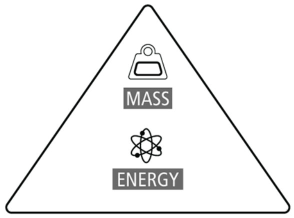
- Faults exist on all scales.
- Plate boundary faults are the largest.
- Bigger faults can produce bigger earthquakes.



San Andreas Fault - One of the largest and most active

Fault Size Image Description

Map of the major fault lines in California with the San Anreads, Hayward, Calaveras, San Gregerio, Sur-Nacimiento, Rinconda, and Santa fault lines along the western coast surrounded by Meszoic sedimentary, Tertiary, Grantic, and Quternanry sedimentary sediments. The Ynez, Santa Montica, San Gabriel, San Janito, and Eisnare fault lines are towards the south coast with Grantic rocks (mostly Mesozoic) and Quaternary sediments . The Garlock Fault, Owens Valley, Panamint, and Death Valley Fault are in the mid-southern section of the state with Grantic, Quaternary, and older metamorphic and sedimentary rocks, (Precambrian, Paleozoic, and Mesozoic). Melones Fault is located in the mid-east of the state surrounded by older metamorphic and sedimentary rocks. The Coast Range fault is the north most in the state surrounded by Mesozoic and older metamorphic and sedimentary rocks .



This is mass and energy.

Key Points

Faults exist on all scales. Some faults are so small that the movement of the rocks can only be detected with a high-power microscope.

Plate boundary faults, which allow movement between two plates, are the largest faults on the planet. For example, the San Andreas Fault (shown in the photo) is easily visible from space.

In general, the bigger the fault, the bigger the earthquakes it can produce.

U.S. Faults: The map on the next page shows areas in the contiguous United States where faults have been identified that have a potential to create damaging earthquakes.

In some places, a broad area is identified as having known faults, but the exact location of each fault is not known. Some faults obviously deform the surface of the earth and can readily be mapped. Other faults are buried under sediments or otherwise hidden, and then can only be found when an earthquake is detected, or when there is examination of subsurface features, such as during oil company exploration. Faults often create barriers that block the movement of oil, gas, and water.

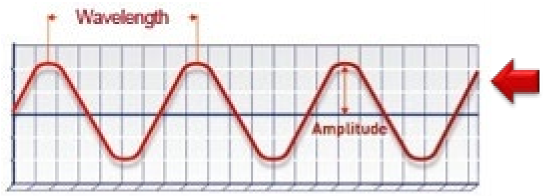
There are many more faults than are shown on this map. Some that are capable of causing earthquakes have not been identified. Some are older faults that are not aligned such that they will produce earthquakes with the current tectonic forces; however, they might become active again should the forces change sufficiently.

See Color Handout 6.2: Known Faults in the United States

Known Faults in the United States

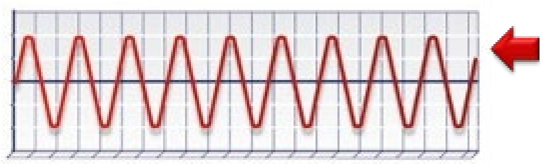
See color handout 2.2.1

Visual 19: Earthquake Waves and Ground Shaking



Longer period:

- Significant damage far from the fault.



Higher frequency:

- Attenuate more quickly.
- Greatest damage close to the fault.

Key Points

In an earthquake, the ground shaking is caused by energy waves propagating through the ground.

Effect of wave properties:

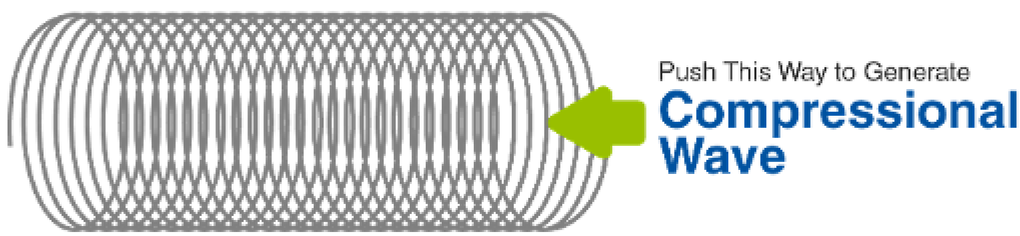
- The highest-frequency waves will attenuate (decrease) the most quickly. Therefore, they will cause the greatest damage close to the fault.
- The longest-period waves, created by the largest earthquakes, can cause significant damage hundreds of miles from the fault.

Student Manual

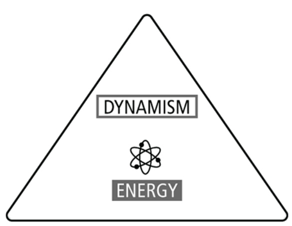
For additional examples of high-frequency vs. high-period of sound waves, imagine a toddler screaming (high frequency) and the difference in the effect you hear if you go down the hall and a few closed doors away vs. an elephant roar (high-period) that you will hear over a very wide-ranging area.

Visual 20: Primary Waves (P Waves)

- Tensional stress
- Fissure cracks
- Formation of new crust from rising magma
- Shallow earthquakes
- Continental rifting



Dynamism Energy Icon



Key Points

Scientists also distinguish between body waves and surface waves. Body waves move through the Earth, and surface waves stay on the surface.

Body waves include primary waves (P waves) and secondary/shear waves (S waves), and they travel through the earth with different types of motion.

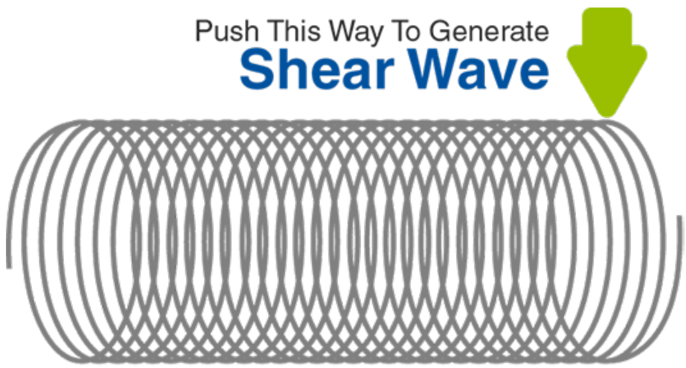
Characteristics of P waves:

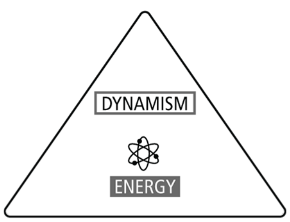
- Are the fastest moving, and the first to arrive. They move at about 6 miles per second, about twice as fast as secondary waves:
  - ~ 1.71 times the speed of secondary waves.
  - ~ 2 to 3 times the speed of surface waves.
  - Typically 1 second separation between P and S waves for nearly every 5 miles traveled.
- Have a high frequency.

- Are compressional.
- Travel through solids, liquids, and gases.
- Travel within the ground.
- Cause little damage.

Visual 21: Secondary/Shear Waves (S Waves)

- Slower than P waves
- Larger amplitude than P waves
- Oscillate in side-to-side or up-and-down motion
- Travel through solids, but not liquids or gases
- Travel within the ground
- Cause a great deal of damage





This is dynamism and energy.

Key Points

Characteristics of S waves:

Secondary/shear waves (S waves) shake the ground more severely and cause more damage.

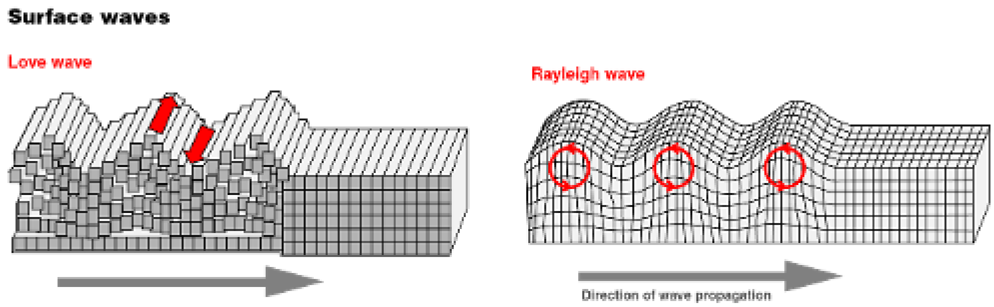
S waves:

- Are slower than P waves.
- Have a larger amplitude than P waves.
- Oscillate in a side-to-side or up-and-down motion.
- Travel through solids, but not liquids or gases.
- Travel within the ground.

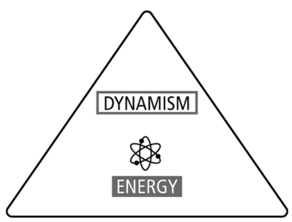
- Cause a great deal of damage.

Visual 22: Surface Waves

- Slowest wave
- Travel along the surface
- Largest amplitudes
- Cause largest amount of damage



This is dynamism and energy.



Key Points

Characteristics of surface waves: Surface waves are the slowest moving and the most damaging of the waves. They also have the largest amplitudes.

Types of surface waves: Surface waves may either be Love waves or a Rayleigh waves (R waves).

- **Love waves:**
  - Are the fastest surface wave.
  - Move side to side.
- **Rayleigh waves (R waves):**
  - Move like ocean waves, rolling up and down and side to side.
  - Are the most damaging wave.

Visual 23: Discussion: Connection to Emergency Management

How can this information about Earthquakes and their cases assist you as an emergency manager? Consider the 5 Mission Areas (Prevention, Protection, Mitigation, Response, and Recovery.

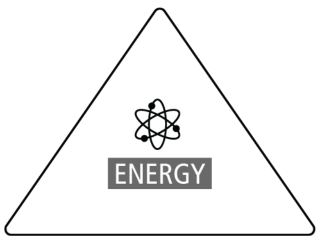
Key Points

How can this information about Earthquakes and their cases assist you as an emergency manager? Consider the 5 Mission Areas (Prevention, Protection, Mitigation, Response, and Recovery.

Visual 24: Ground Type and Liquefaction

- **Ground type** affects how easily waves can move through the ground and the resulting amount of damage

This is energy.



Key Points

Liquefaction can often occur in earthquakes. Soils and sediments contain open spaces called pores that can be filled with water. Many soils start out with water-filled pores, but in some cases, increased pressure during an earthquake can inject water from an underlying layer.

The drawings on the visual show a schematic depiction of soil grains and groundwater before and during liquefaction.

When no shaking occurs, water is held between the soil particles, and the ground can provide a supportive base for structures. Energy from shaking can overcome the friction between soil particles, causing the soil to liquefy temporarily. When liquefied, the soil may no longer be able to support structures; as a result, buildings and other structures can sink into the earth or tip over.

It takes strong shaking, liquefiable soils, and groundwater near the surface to produce liquefaction. The 1994 Northridge, California earthquake caused less liquefaction than it might have because the drought had lowered groundwater levels in many areas.

Transcript:

Narrator: The motion of similar buildings on different bedrock will be exaggerated to show the arrivals of compressive P, shearing S, and rolling surface waves from a regional earthquake. Three consecutive seismograms will show the changing frequency and amplitude resulting from changing rock type.

The initial P wave arrives with a compressive bump and rarely causes much damage. The slower shearing S wave introduces a side-to-side motion that can throw loose objects to the floor and may crack walls.

The rolling surface waves are the most damaging in unconsolidated sediment. As surface waves enter the sedimentary layer they slow down and increase in size, causing buildings to roll. If not engineered for the motion, they can crack and tumble. But even a well-engineered building can sink during the shaking and liquefaction of underlying wet sediment.

The first seismogram from the pink building on solid ground shows low-amplitude high-frequency waves. When the waves hit softer ground they slow down and increase in amplitude. It's this higher, slowing roll that is so destructive during an earthquake.

Visual 25: Soil Liquefaction

Video description:

Still picture with a house "Three factors required for liquefaction to occur: Loose, granular sediment, Water saturated sediment, Strong shaking. San Francisco, 1906

Look below surface: shows layer of loose, granular sediment and then saturated by ground water. Earthquake happens. Liquefaction of ground under house. House shaking

Question "Why did this happen?"

Answer Earthquake waves cause water pressures to increase in the sediment. Sand grains lose contact with each other leading to loss of sediment strength & liquid-like behavior.

Incorporated Research Institutions for Seismology (IRIS) (http://www.iris.edu/hq/programs/epo)

Photo of a house damaged during earthquake with caption: Photo from earthquake, San Francisco 1906. Area is underlain by marsh deposits that were covered by artificial fill in the 1800s. (photo & text from U.S. Geological Survey)

Visual 26: Soil Liquefaction

Video description: The video shows an instructor-led demonstration of soil liquefaction.

Video description:

Demonstrates how soil can become liquefied during the shaking in an earthquake, and the resulting degradation of the structural integrity of the ground to support the building.

The instructor places the sand in the bin and add water so it is saturated but not a slurry.

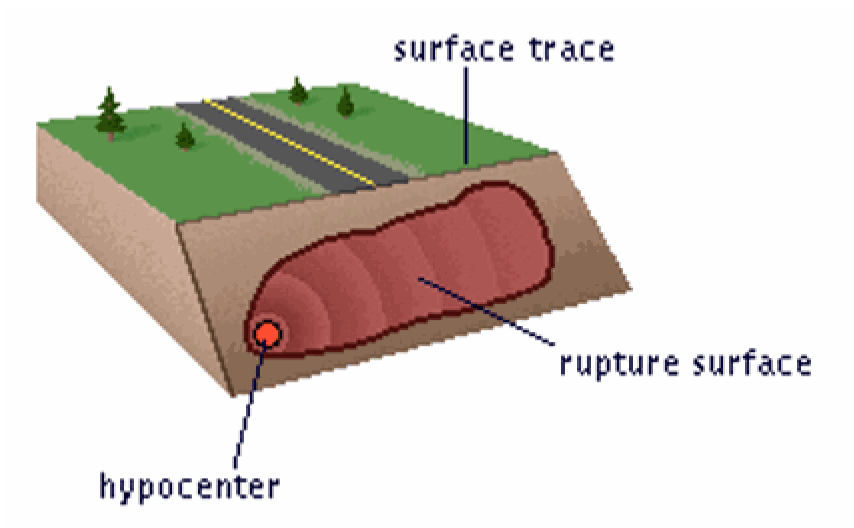
The instructor places the bin so it spans the gap between two tables.

The instructor places an object (such as a brick or bottle) on top of the sand to represent a building. Note that it is stable.

The instructor uses the sander to vibrate the bin from the side or beneath.

The soil "liquefies" as water molecules work their way from between sand particles, causing the brick to sink on this unstable ground.

Visual 27: Epicenter and Hypocenter (Focus)



Key Points

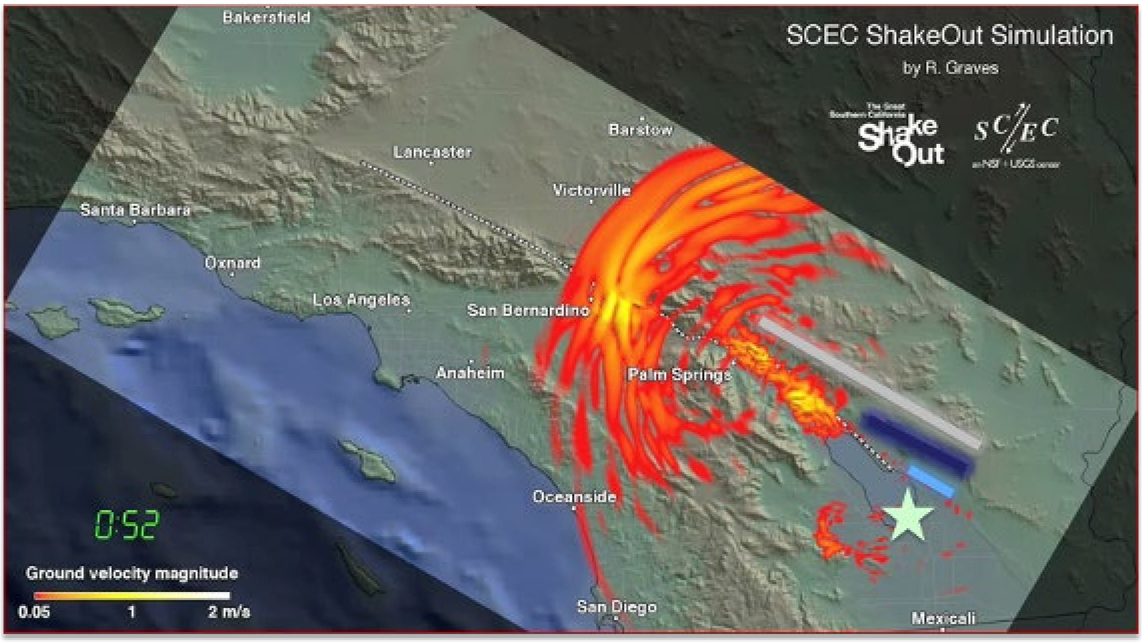
Epicenter: An epicenter is the point on the Earth's surface that is directly above the point where the fault first starts to rupture, which is called the hypocenter or focus.

This image helps to illustrate the relative locations of the epicenter and hypocenter, as well as other key elements of earthquakes.

Here, we see a fault plane that dips into the Earth. This fault happens to reach all the way to the surface of the Earth, and the intersection of the fault plane with the surface is called the surface trace. An earthquake has just occurred.

Hypocenter: Directly below the epicenter, on the fault plane, is the hypocenter where the earthquake begins. The entire fault plane did not rupture in this earthquake. The part of the fault that does allow movement during this earthquake is the rupture surface.

Visual 28: Epicenters and Damage Locations



Key Points

Strongest shaking: During any earthquake, shaking will be strongest closest to the fault. Because the epicenter is directly above the fault, it will experience some of the strongest shaking. As the energy waves move away from the fault, they lose energy.

Small vs. large earthquakes: When an earthquake is small, the fault rupture surface will be small, and the location of the epicenter gives a good indication of where to look for damage from the earthquake. In larger earthquakes, the epicenter only indicates one of many places where strong shaking could cause damage.

Extent of damage: In the image on the visual (from the ShakeOut simulation we watched):

- The green star represents the epicenter-but the dashed line represents the 200 miles of fault that ruptures.
- **Every community along those 200 miles will experience shaking as strong as at the starting point.** (In addition, there are locations away from the fault, such as in sedimentary basins that undergo resonance, where shaking will be strong even though the waves have lost some energy as they travelled away from the fault.)

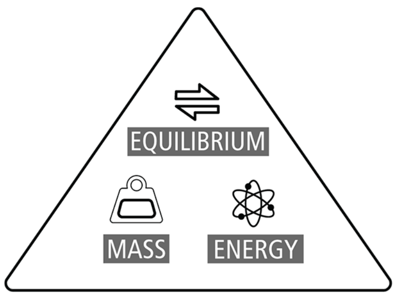
Comparison with other earthquakes: Notice the three lines on the right:

- Light blue-shows the length of fault that would rupture in an earthquake about the size of the 2011 magnitude 5.8 Virginia earthquake.
- Dark blue-shows the comparable length of fault that would rupture in an earthquake about the size of the 1994 magnitude 6.7 Northridge earthquake.

- Gray-shows a rupture for an earthquake comparable to the 2010 Haiti earthquake.

Visual 29: Foreshocks, Mainshocks, and Aftershocks

This is equilibrium, mass, and energy.



Key Points

When an earthquake occurs, the movement of rock along the fault and the traveling energy waves cause stress changes in the earth. The stress changes result in additional earthquakes that are called **triggered** events.

When any earthquake occurs, additional earthquakes must be expected. In fact, after any earthquake, there is an increased likelihood of additional bigger earthquakes for about 3 days.

An earthquake sequence, with foreshocks, a mainshock, and aftershocks.

- A **foreshock** is a relatively smaller earthquake that precedes the largest earthquake in a series.
- A **mainshock** is the largest earthquake in a sequence, sometimes preceded by one or more foreshocks (not all mainshocks have foreshocks), and almost always followed by many aftershocks.
- An **aftershock** is an earthquake that follows the largest shock of an earthquake sequence. It is smaller than the mainshock and within 1 to 2 rupture lengths distance from the mainshock.
  - Aftershocks can continue over a period of weeks, months, or years.
  - In general, larger mainshocks are followed by more numerous aftershocks, which continue longer.
  - About 6% of the time, the aftershock is bigger than the mainshock. When this occurs, scientists rename the events. The earlier earthquake becomes a foreshock and the new, larger earthquake becomes the mainshock.

On July 4, 2019, an earthquake registering 6.4 magnitude occurred at 10:33 a.m. PDT 7.5 miles southwest of Searles Valley. The nearest populated area to the epicenter was Ridgecrest, CA.

On July 5, a 5.0 magnitude earthquake occurred, followed by another later that day at 8:19 p.m. PDT, measured at 7.1 magnitude after being preceded by a foreshock just 3 minutes prior, revealing the previous day's 6.4 magnitude earthquake also to have been a foreshock.

The 6.4 magnitude and 5.0 magnitude and other smaller earthquakes are now considered foreshocks of the 7.1 magnitude earthquake mainshock. Thousands more aftershocks occurred following the 7.1 magnitude event, with the total number of aftershocks exceeding 3,000 by the morning of July 7. Geologists at the USGS estimate an additional 34,000 aftershocks in the six months following the earthquakes.

On June 3, 2020, at 6:32 p.m. PST, a 5.5 magnitude aftershock was recorded 11 miles south of Searles Valley. This aftershock is tied for the strongest aftershock following the 7.1 magnitude mainshock.

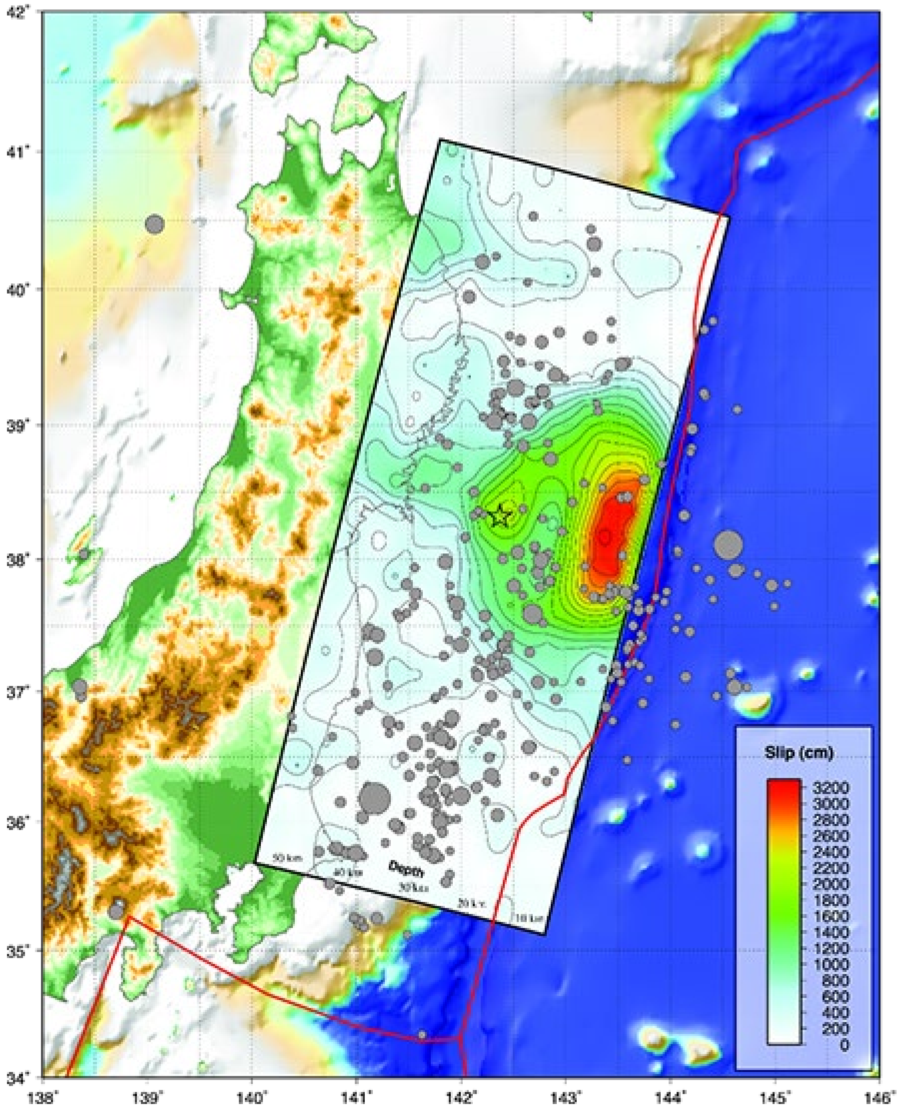
The largest earthquake in a series is always considered the mainshock and can replace a previous shock if it is larger. The smaller previous shocks are then considered foreshocks. Any smaller earthquakes that occur after the mainshock are considered aftershocks.

Below is a surface projection of the slip distribution from the 2011 Japan earthquake superimposed on General Bathymetric Chart of the Oceans (GEBCO) bathymetry. Red lines indicate major plate boundaries. Gray circles are aftershock locations, sized by magnitude.

More information about the Japan earthquake and tsunami of 2011:
https://www.britannica.com/event/Japan-earthquake-and-tsunami-of-2011

Aftershocks in 2011 Japan Earthquake

Below is a surface projection of the slip distribution from the 2011 Japan earthquake superimposed on GEBCO bathymetry. Red lines indicate major plate boundaries. Gray circles are aftershock locations, sized by magnitude.


42°
41°
40°
39°
38°
37°
36°
35°
34°
138°
139°
140°
141°
142°
143°
144°
145°
146°
Depth
Slip (cm)
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0

Visual 30: Measuring Earthquakes

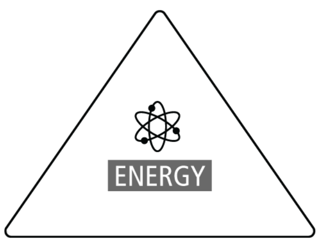
Magnitude Scales

- Measures amplitude of shaking or estimate energy released.
- Are logarithmic (1 point increase = 10 times the shaking, 30 times the release of energy)
- Examples: Richter scale, moment magnitude scale.

Intensity Scales

- Describe effects (intensities I - XII)
- Examples: Modified Mercalli, Rossi-Forel

This is energy.



Key Points

The sense of motion along a fault provides information about the forces acting on the rock and the fault, which affect estimates of how frequent and how large earthquakes can be, and also helps scientists to identify which fault is responsible for a particular earthquake.

Magnitude scales: Earthquake magnitude is a measure of the amount of energy released in an earthquake. When the media reports on an earthquake they talk about magnitude "on the Richter scale." However, the Richter scale was an early method to calculate earthquake size based on the amplitude of shaking measured by a particular kind of seismometer, which is an instrument that records ground shaking. The Richter scale has since been supplanted by methods such as moment magnitude that do a better job of estimating the amount of energy released in an earthquake.

Magnitude scales are base 10 logarithmic scales, so when a magnitude goes up one point, the amplitude of shaking goes up by ten times and the released energy goes up by 30 times.

An earthquake will be assigned only one magnitude, although that measure will probably fluctuate as new data come in that help to refine the number. The bigger the magnitude, the bigger the earthquake-that is, the longer the shaking will last, the stronger the shaking can be, and the greater the likelihood of damage.

Intensity scales: An intensity scale describes the severity of an earthquake in terms of its effects on the Earth's surface and on humans and their structures. There are many intensities for an earthquake depending on location, unlike the magnitude, which is one number for each earthquake. This is a subjective assessment of what the earthquake was like for a particular person at a particular location.

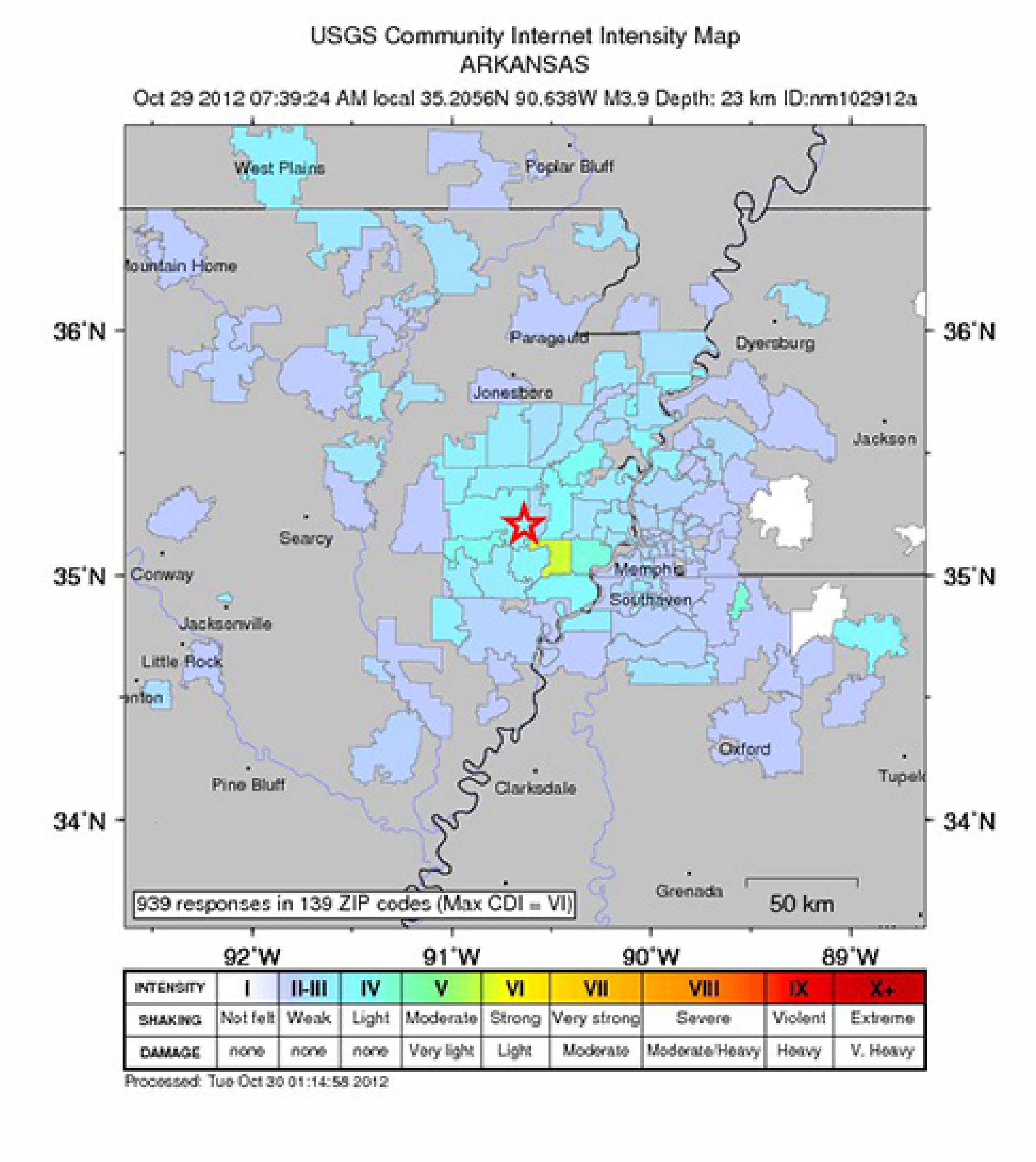
Measuring Earthquake Intensity: The map below shows reports of intensity from nearly 1,000 people who felt a small earthquake in Arkansas in 2012. For this single earthquake of magnitude 3.9, intensities ranged from barely perceptible to strong shaking that could cause some damage. The intensity scale, which is indicated with Roman numerals, ranges from I to XII. Intensities of VI and higher can cause significant damage.

The map below shows reports of intensity from nearly 1,000 people who felt a small earthquake in Arkansas in 2012. For this single earthquake of magnitude 3.9, intensities ranged from barely perceptible to strong shaking that could cause some damage.

The intensity scale, which is indicated with Roman numerals, ranges from I to XII. Intensities of VI and higher can cause significant damage.

Several scales exist, but the ones most commonly used in the United States are the Modified Mercalli scale and the Rossi-Forel scale.

The table on the next page relates the Modified Mercalli scale to earthquake size.



See color handout 2.2.3.

Alt text for graphic

USGS Community Internet Intensity Map of Arkansas on October 29, 2012 at 7:39 AM local 5.2056N 90.638W M3.9 Depth 23 km ID: nm102912a. Image shows that light shaking and no damage is around a star area, with strong shaking and light damage below and weak to no shaking and damage as the map moves away from the star in the middle.

Modified Mercalli vs. Earthquake Size

Modified Mercalli Scale		Richter Scale
1. Felt by almost no one. 2. Felt by very few people.	2.5	Generally not felt, but recorded on seismometers.
1. Tremor noticed by many, but they often do not realize it is an earthquake. 2. Felt indoors by many. 3. Feels like a truck has struck the building. 4. Felt by nearly everyone; many people awakened. Swaying trees and poles may be observed.	3.5	Felt by many people.
1. Felt by all; many people run outdoors. Furniture moved, slight damage occurs. 2. Everyone runs outdoors. Poorly built structures considerably damaged; slight damage elsewhere.	4.5	Some local damage may occur.
1. Specially designed structures damaged slightly, others collapse. 2. All buildings considerably damaged, many shift off foundations. Noticeable cracks in ground.	6.0	A destructive earthquake.
1. Many structures destroyed. Ground is badly cracked.	7.0	A major earthquake.
1. Almost all structures fall. Very wide cracks in ground. 2. Total destruction. Waves seen on ground surfaces; objects are tumbled and tossed.	8.0 and up	Great earthquakes.

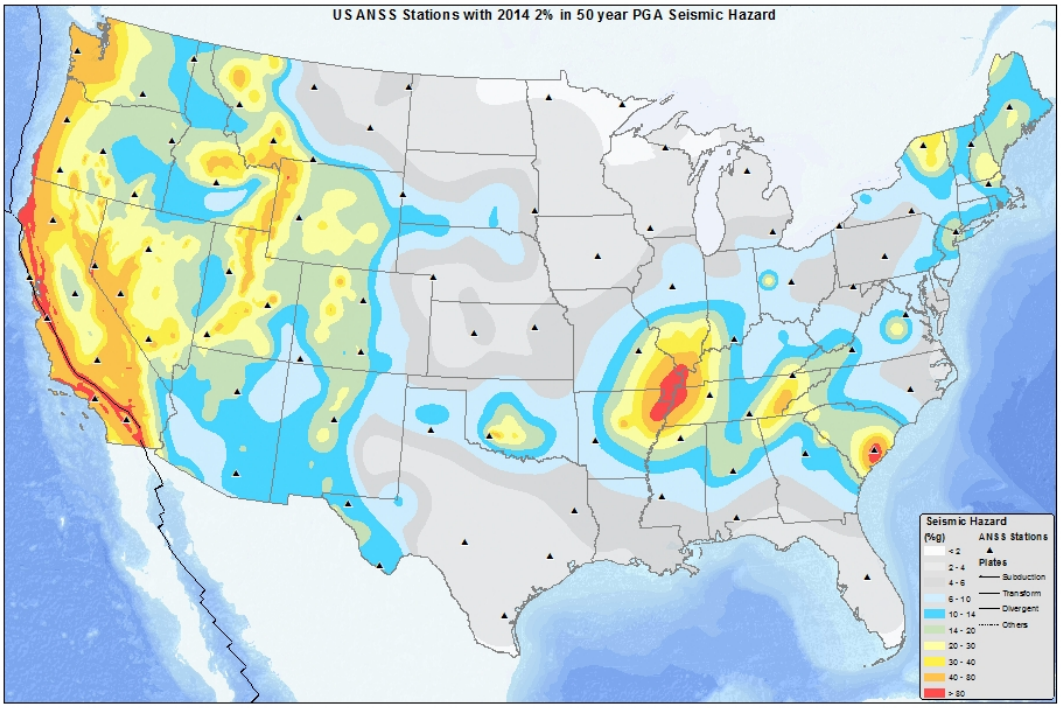
Visual 31: Frequency of Earthquakes Worldwide

According to National Earthquake Information Center worldwide statistics, the average number of earthquakes for each magnitude event are as follows:

Magnitude	Annual Average
8 and higher	1
7-7.9	15
6-6.9	134
4-4.9	1,300
3-3.9	13,000
2-2.9	1,300,000

Larger earthquakes happen less often than smaller earthquakes. The frequency of occurrence changes by approximately a power of 10 with each change of magnitude point. Thus, for every magnitude 7, there will be about 10 magnitude 6 earthquakes and about 100 magnitude 5 earthquakes.

Visual 32: U.S. Rankings: Number of Earthquakes



U.S. Rankings: Number of Earthquakes Image Description

To view map Earthquake occurrence over 250 years (This link can also be accessed at the following URL: https://www.usgs.gov/media/images/anss)

Map showing the levels of horizontal shaking that have a 2-in-100 chance of being exceeded in a 50-year period. Shaking is expressed as a percentage of g (g is the acceleration of the falling object due to gravity). There is the highest hazard along the west coast (with 80+% g) to 16-31%g towards central US. Towards the mid-west the highest hazard moves to 8-16%g. Central US has 4-8 highest hazard, with an increase to 64+%g around the borders where Arkansas, Missouri, Kentucky, Tennessee and Mississippi meet. There is an increase of Earthquakes along South Carolina along the Atlantic Ocean at the highest hazard of 64+%g. The Northeast is from 8-16%g highest hazard. Alaska has an earthquake hazard of 64+ along the south coast, decreasing northwards up to 0-4%g. Hawaii has the highest hazard on the Island of Hawaii at 64+, Kihei is 32-48, Honolulu us 16-32, and Koloa is 8-16%g. The mid-north states have a low hazard from 0-4. South Florida and South Texas also have a low of 0-4%g.

Key Points

State rankings over 29 years: This map ranks the States by the greatest number of earthquakes of magnitude 3.5 or above, based on instrumental records from 1974 to 2003. A magnitude 3.5 earthquake is large enough to feel but unlikely to cause damage.

The top 10 States are colored bright yellow (Alaska was the top producer), the next 10 are colored orange, remaining States with at least 1 event in 30 years are light yellow, and States that had none are colored gray.

Even in this short timeframe, two patterns emerge:

- The western States and the area around the southern Mississippi River have earthquakes more often than other places in the United States.
- It is important to remember that earthquakes can occur anywhere. It is reasonable to expect a "feelable" earthquake anywhere in the country, and the rankings of most States will shift over time.

Earthquake occurrence over 250 years: The map on the next page shows earthquakes detected during about 250 years in the United States—a much larger scale than on the visual.

Looking at this longer data set, the previous trends are still apparent, with more earthquakes in the western U.S. and along the Mississippi River. With the longer time span, important additional information emerges, including the large and very damaging earthquake that occurred in Charleston, South Carolina, in 1886. During that earthquake, few buildings escaped damage and many were completely destroyed.

See Color Handout 6.5 Earthquake Occurrence Over 250 Years and Handout 6.6 Likelihood Projections

Visual 33: Secondary Hazards from Earthquakes (1 of 2)

- Liquefaction
- Landslides
- Avalanches

Key Points

Hazards that result because of another hazard are called secondary hazards.

Many of the hazards related to earthquakes are secondary hazards caused by ground shaking or surface fault rupture. Examples include:

- Liquefaction.
- Landslides and avalanches.
- Tsunamis and seiches (pronounced "SAYSH").
- Fires.

Visual 34: Secondary Hazards from Earthquakes (2 of 2)

- Tsunamis
- Seiches
- Fires


Tsunamis: Underwater earthquakes in the ocean floor can trigger tsunamis—a series of water waves caused by the displacement of a large volume of a body of water. Tsunamis will be covered in a later unit.

Seiches: Seiches are typically caused when strong winds and rapid changes in atmospheric pressure push water from one end of a body of water to the other. When the wind stops, the water rebounds to the other side of the enclosed area. The water then continues to oscillate back and forth for hours or even days. In a similar fashion, earthquakes, tsunamis, or severe storm fronts may also cause seiches along ocean shelves and ocean harbors.

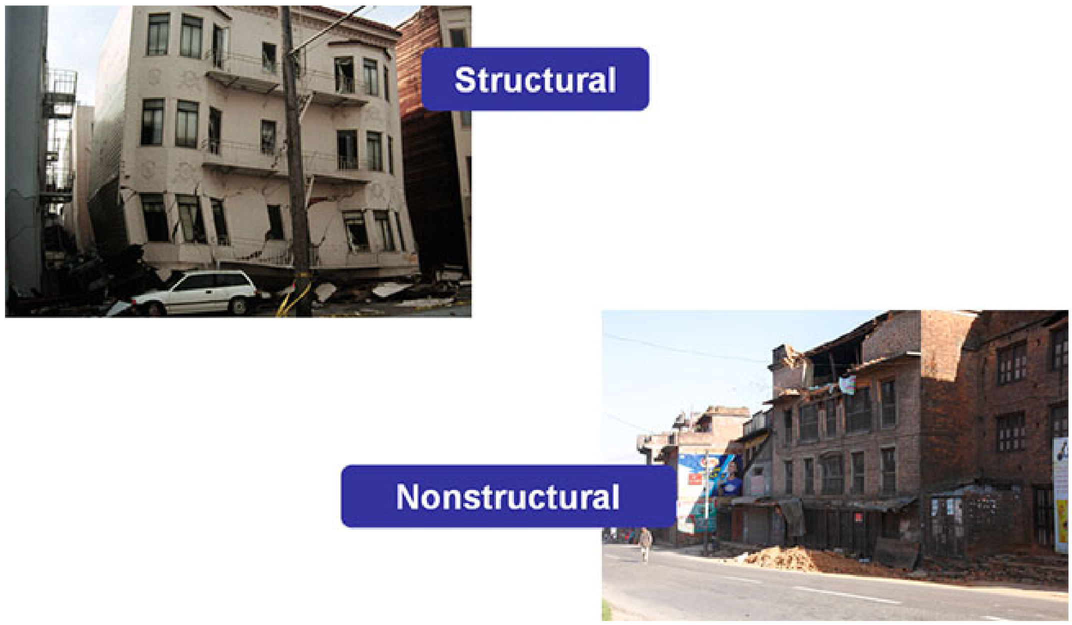
Fires: Sometimes an earthquake's secondary hazard can cause more destruction than the primary hazards of ground shaking or fault rupture. Fires are an example.

Fires occur following all earthquakes that strongly shake human settlements. In large metropolitan areas comprised of densely spaced wood buildings, the fires have grown into catastrophic conflagrations. The two largest peacetime urban conflagrations in history (San Francisco in 1906 and in Tokyo in 1923) were caused by earthquakes.

Earthquakes can start a fire very easily, as well as impede firefighting by damage to buildings, water systems, communications, and transportation systems. For example, earthquakes can contribute to fires through:

- Numerous and simultaneous ignitions.
- Damage that degrades fire-resistive features of buildings.
- Decreased pressure in water supply mains.
- Damage to water conveyance systems.
- Damaged or saturated communications systems.
- Disruption of transportation.

Visual 35: Typical Engineering Effects



There is a saying in the earthquake engineering world: “Earthquakes don’t kill people, buildings kill people.”

Building damage can be structural or nonstructural. Unreinforced masonry construction is especially vulnerable to structural damage.

Nonstructural damage is often the major source of injury and damage in buildings that do not collapse.

Visual 36: Health Impacts of Earthquakes

- Injuries, deaths
- Family displacement
- Psychological impacts
- Greater susceptibility to disease due to stress
- Public health threats from damage to water treatment systems

Direct impacts on health and safety from earthquakes include:

- Injuries and deaths caused by falling debris, building collapse, landslides, and secondary fires.
- Family displacement, leading to stress, unsanitary living conditions, and public health issues.
- Psychological impacts.
- Greater susceptibility to disease, and exacerbation of chronic health issues due to stress.
- Public health threats associated with compromised water treatment and wastewater treatment facilities, refugees living in cramped conditions without adequate sanitation, and damage to public health infrastructure.
- The cholera epidemic in Haiti after the 2010 earthquake resulted in more than 6,000 deaths and more than 350,000 hospitalizations.

Visual 37: Environmental Health Impacts from Earthquakes

- Tsunamis
- Seiches
- Fires

Key Points

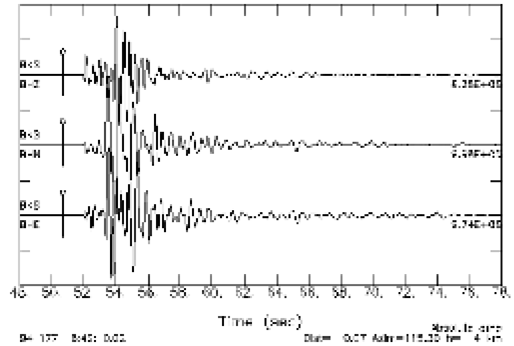
Although the acute direct health impacts of earthquakes are clearly extensive and most visible, environmental geochemists have identified numerous longer term, sometimes less obvious health impacts resulting from environmental contaminants produced by the disaster.

Some of the many possible contaminants that can be produced by earthquakes include:

- Hazardous chemicals released from damaged or burning industrial facilities in the form of toxic gases, liquid chemicals, or smoke.
- Smoke or other combustion products from earthquake-generated urban firestorms.
- Toxicants in dusts from building collapse including:
  - Caustic alkalis.
  - Lead.
  - Antimony.
  - Mercury.
  - Asbestos.

Visual 38: Earthquake Monitoring and Forecasting

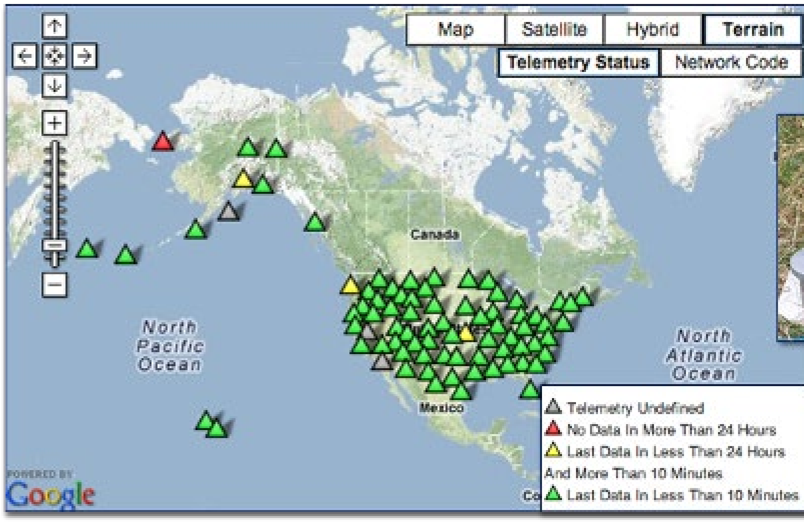
Earthquake Monitoring and Forecasting



Key Points

This final section of the unit will discuss earthquake monitoring and forecasting.

Visual 39: Earthquake Monitoring



Key Points

Earthquake Monitoring (This link can also be accessed at the following URL: http://earthquake.usgs.gov/monitoring/operations/network.php?virtual_network=ANSS)

Throughout the United States, earthquakes are monitored by networks of scientific instruments. This involves two key areas of study:

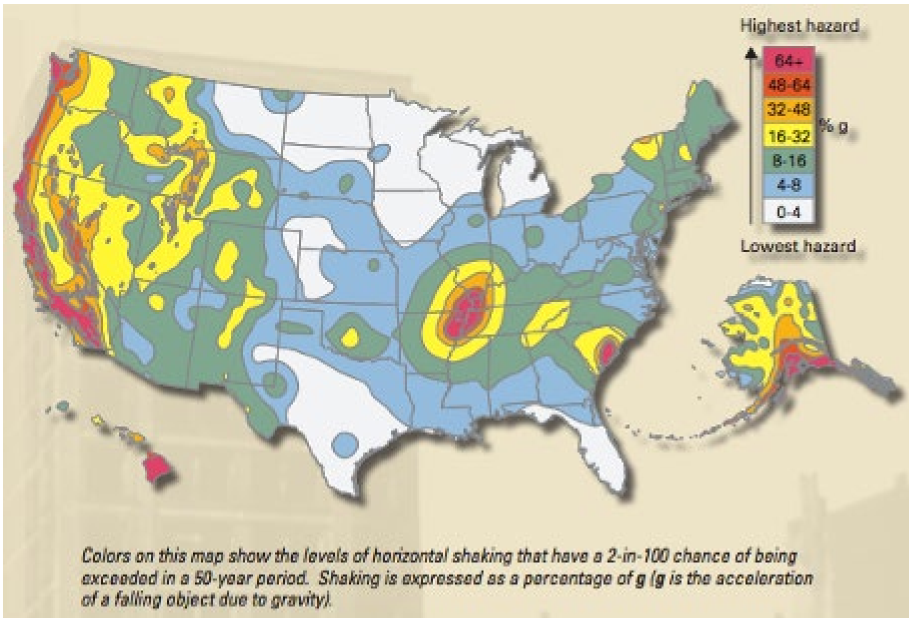
- **Seismicity:** The geographic and historical distribution (the "where?" and "how often?") of earthquakes.
- **Seismology:** The study of earthquakes and the structure of the earth by both naturally and artificially generated seismic waves.

Seismometer system: The map above shows locations of seismometers that continuously record ground motion for the Advanced National Seismic System. Additional stations are operated by regional networks in areas of higher seismicity. Other instruments are deployed temporarily to capture data during aftershock sequences or for other scientific studies.

Seismometers can measure ground motion in three orientations (typically north/south, east/west, and up/down), which captures a complete representation of ground motion at a site.

GPS networks: This map shows locations of global positioning system (GPS) networks, which monitor deformation as earthquake faults accumulate strain, or rupture. Some GPS stations operate continuously, while others are deployed temporarily.

Visual 40: Long-Term Forecasts and Warnings



Long-Term Forecasts and Warnings Image Description

Map showing the levels of horizontal shaking that have a 2-in-100 chance of being exceeded in a 50-year period. Shaking is expressed as a percentage of g (g is the acceleration of the falling object due to gravity). There is the highest hazard along the west coast (with 64+% g) to 16-31%g towards central US. Towards the mid-west the highest hazard moves to 8-16%g. Central US has 4-8 highest hazard, with an increase to 64+%g around the borders where Arkansas, Missouri, Kentucky, Tennessee and Mississippi meet. There is an increase of Earthquakes along South Carolina along the Atlantic Ocean at the highest hazard of 64+%g. The Northeast is from 8-16%g highest hazard. Alaska has an earthquake hazard of 64+ along the south coast, decreasing northwards up to 0-4%g. Hawaii has the highest hazard on the Island of Hawaii at 64+, Kihei is 32-48, Honolulu us 16-32, and Koloa is 8-16%g. The mid-north states have a low hazard from 0-4. South Florida and South Texas also have a low of 0-4%g.

Key Points

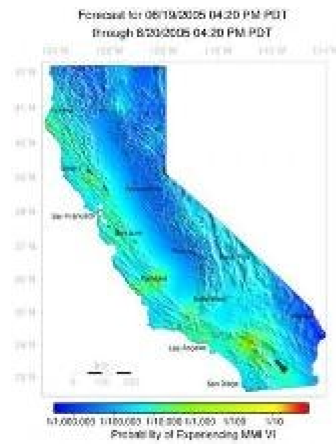
Prediction: To put it simply, scientists cannot predict earthquakes. An earthquake prediction requires three components: statements of when, where, and how big the earthquake will be.

Within the scientific community there is debate about whether it will ever be possible to predict earthquakes, even with unlimited data and additional understanding. Earthquakes involve chaotic processes and may be inherently unpredictable.

Forecasts: What scientists can do instead is develop earthquake forecasts. These are statements that involve probabilities and uncertainties and discuss the likelihood of an earthquake happening over a particular timeframe.

This National Seismic Hazard Map is an example of a long-term forecast-in this case the chance of exceeding a certain level of shaking in 50 years.

Visual 41: Short-Term Forecasts and Warnings



- Short-term forecasts are reliable during an earthquake sequence (after an earthquake occurs).
- Scientists apply statistics to make statements about what to expect.

Key Points

Forecast reliability: Long-term earthquake forecasts are more accurate than short-term earthquakes forecasts. This is the opposite of weather forecasting, where short-term weather forecasts for the next day are substantially more accurate than the long-term climate forecasts that cover decades.

Short-term earthquake forecasts are most reliable during an earthquake sequence—that is, **after** an earthquake has occurred. At that point, scientists can apply the statistics regarding occurrence of foreshocks and aftershocks to make statements about what to expect next.

Earthquake Early Warning is operational in several countries, including Japan and Mexico, and is being prototyped in California. An earthquake early warning system uses computers that detect that a large earthquake has begun, then calculate how long until strong shaking will arrive at a given location, then send an alert that can prepare communities in many ways.

Earthquake Early Warning successfully protected Japan from most damage during the magnitude 9 Tohoku earthquake in 2011. It was the accompanying tsunami that caused widespread devastation.

Visual 42: Activity 6.1 – ShakeMaps

Instructions:

Part 1:

1. Work along in your Student Manual as the Instructor points out the elements of the ShakeMap, filling in the provided table

Part 2:

1. Using the Portland, Oregon ShakeMap, complete the provided table
2. Review the provided article
3. The Instructor will ask the questions provided in your Student Manual and call on volunteers to respond

Activity

Key Points

Instructions: Working in groups:

Part 1:

1. As the Instructor points out the elements of the Portland ShakeMap (Handout 6.8), fill in the provided table in your Student Manual.

Part 2:

1. Review the provided article (Activity 6.2 Job Aid).
2. Answer the questions provided in your Student Manual (Activity 6.2 Worksheet).
3. Select a spokesperson and be prepared to present your answers to the class.

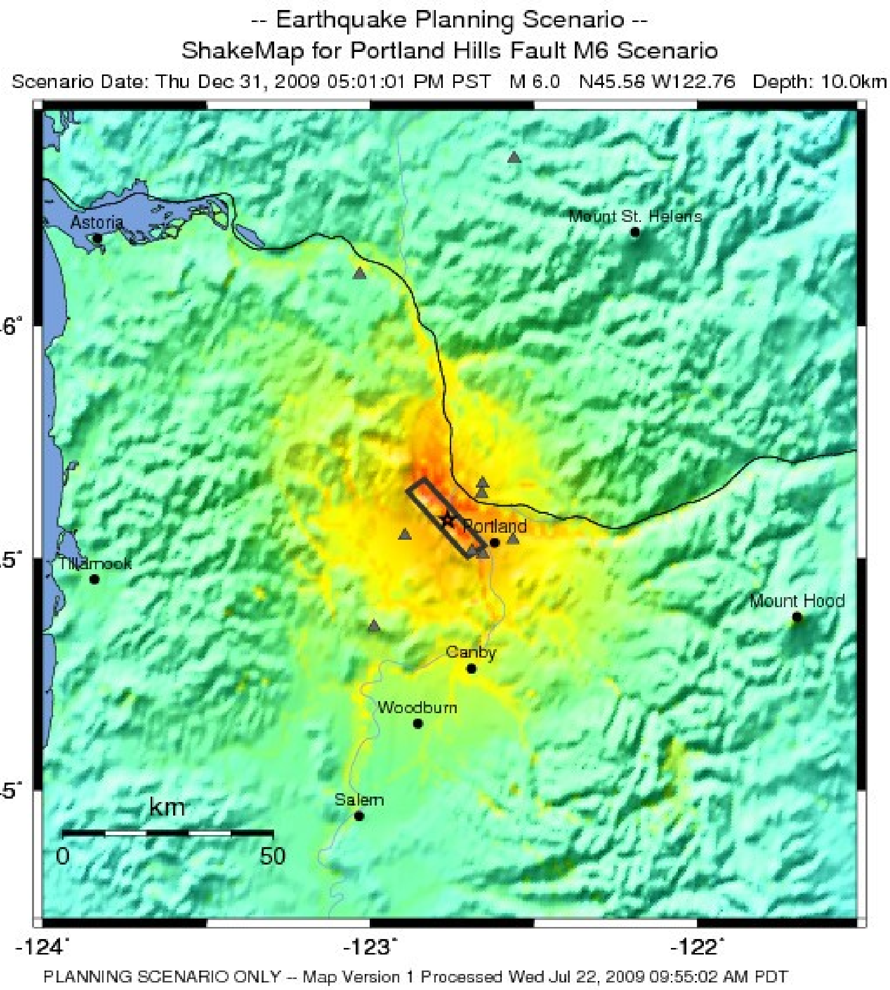
	Event Name	*(Portland)*
Listed at the top (M). □	Magnitude	(6.0)
Fault rupture is shown as □ black lines on the maps. There is a single line when the fault intersects the surface at a right angle. Otherwise, the plane of the fault is projected to the surface and looks like an irregular rectangle. To get the fault length, measure one of the long sides.	Fault Rupture Length (km)	(~20 km)

	Event Name	*(Portland)*
	Highest Intensity	(IX)
Approximate what area of land undergoes shaking strong enough to cause potential damage (measure intensity V and above).	Area w/ Potential Damage (km*2)	(~100*100)
Approximate what area of land undergoes shaking strong enough to cause heavy or very heavy damage (measure the red zones).	Area w/ Heavy or Very Heavy Damage (km*2)	(~15*50 Portland)
List some cities in the areas of heavy damage caused by this event.	Cities in Heavy Damage Zone	(Portland)

Visual 43: Part 2: Portland, Oregon, ShakeMap

ShakeMap Symbology. It is a recent ShakeMap convention to depict seismic stations as **triangles** and intensity observations as **circles** (for cities) or **squares** (for geocoded boxes). On intensity maps, symbols are unfilled so that the underlying intensity values are visible. On peak ground motion maps, observations are (optionally) color-coded to their amplitude according to the legend shown below each map. The epicenter is indicated with a **star**, and for larger earthquakes, the surface projection of the causative fault is shown with **black lines**. **Rectangular boxes** represent the rupture length.

More information: ShakeMaps Manual: (http://usgs.github.io/shakemap/manual3_5/products.html#static-maps-and-plots-images).



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

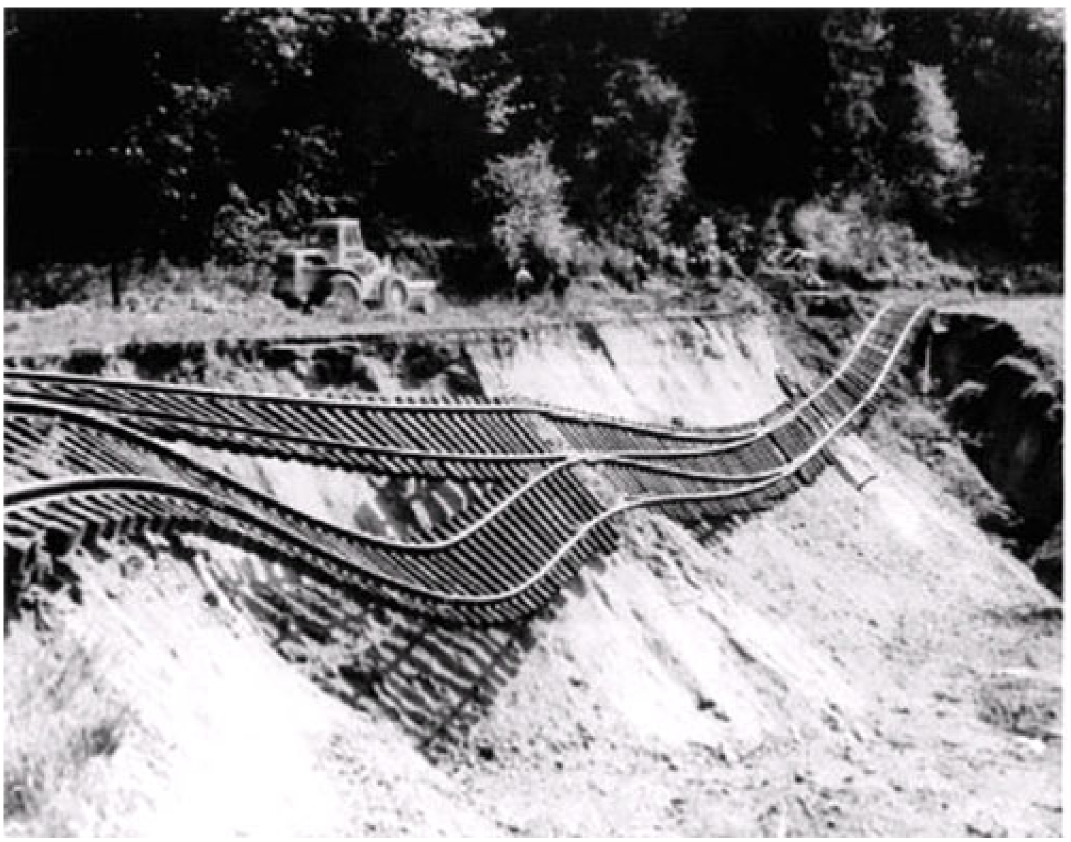
Activity 6.2 Worksheet

<u>Scenario:</u> You are the Emergency Management Director for Multnomah County (Portland), Oregon. The County's Zoning Administrator has drafted for the County Board's consideration for adoption new ordinances that meet current recommendations for your risk profile. There has not been a damaging earthquake in many years, and there is some concern among community leaders that the additional costs of compliance may be an undue burden on the homeowners and businesses in your County. Your supervisor, the County Executive, has asked you to work with the Zoning Administrator to create a tabletop exercise to show community leaders (elected officials, business leaders, leading citizens, media) about the risk of the area.

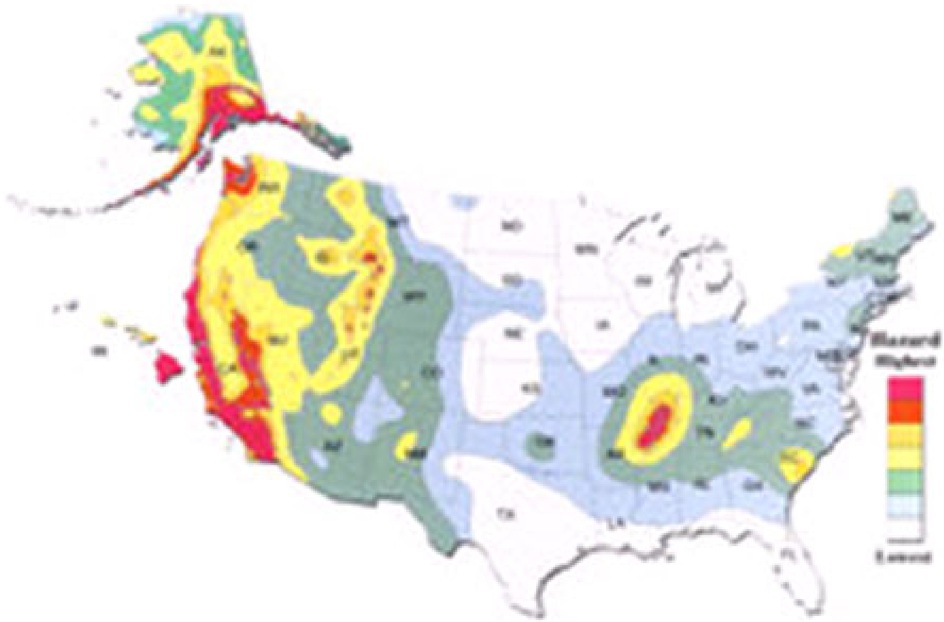
The USGS has provided the Administrator with a “likely but not the most catastrophic” scenario for your area in the form of the following ShakeMap used in Activity 6.1.

Activity 6.2 Job Aid

Cascadia Subduction Zone: Are Portland and Seattle prepared for an earthquake and tsunami?
By on July 22, 2010 at 8:18 AM, updated July 15, 2015 at 5:10 PM



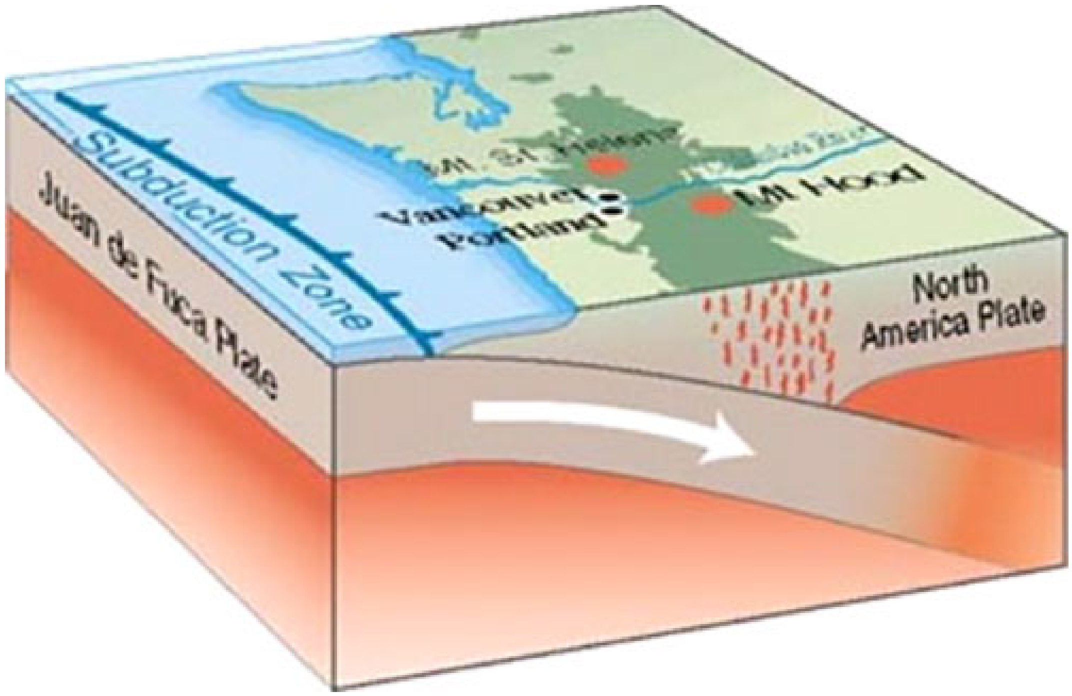
Pacific Northwest Seismic Network (www.pnsn.org)



Earthquake hot spots

Washington and Oregon are in one of the most dangerous U.S. earthquake zones. In a list of states ranked by number of earthquakes with a magnitude 3.5 or higher in the past 30 years, Alaska holds the number one spot and, not surprisingly, California is second.

Washington is ranked fifth with 424 quakes, and Oregon is not far behind in the 10th spot with 73 quakes. Why are Washington and Oregon ranked so high?



Cascadia Subduction Zone

The Cascadia Subduction Zone lies around 50 miles off the coast of Oregon, Washington, British Columbia, and Northern California.

Cascadia Subduction Zone

About 50 miles offshore under the Pacific Ocean runs the Cascadia Subduction Zone, reaching from Northern California to British Columbia—more than 600 miles long. Unlike the San Andreas Fault, where two tectonic plates butt up against each other, in a subduction zone one plate is pushed under the other.

In Cascadia, the *Juan de Fuca Plate* is being shoved under the *North American Plate.*

According to the Pacific Northwest Seismic Network, subduction zones produce the largest earthquakes, which can exceed magnitude 9.0. Cascadia has a history of significant quakes every 400 years and experts predict that after years of storing up energy, another Cascadia quake is due.

In subduction zone earthquakes, not only are there strong, long ground-shaking events, but multiple aftershocks and tsunamis.

Is the Pacific Northwest ready for the next big one?

Peter Yanev, an engineer who advises companies how to build to withstand earthquakes, says not well:

Many seismologists believe the Pacific Northwest is overdue for another mega-quake. Yet in cities like Seattle, Vancouver, and Portland, Ore., hardly any building is designed to withstand such a huge jolt.

...Pacific Northwest cities are full of buildings with slender structural frames and fewer and smaller shear walls. In a mega-quake, many of the region's iconic tall buildings would probably collapse.

Buildings and bridges: How does Portland measure up?

How will structures in the Northwest fare in a major quake and what kind of codes are in place that ensure the public's safety?

Buildings

Oregon's building codes are called the Oregon Structural Specialty Codes, previously the Uniform Building Codes, and have been around since 1973. Scientists' understanding of the Cascadia Subduction Zone is relatively new—around 20 years.

Because of this, Ivan Wong of the URS Corporation said around 99 percent of Oregon's buildings are not designed to withstand the amount of gravitational acceleration or "ground G" found in a subduction zone earthquake.

"Prior to 1988 ... our building code maps did not consider the Cascadia Subduction Zone."

With 30 years of engineering experience, Jed Sampson of the Portland Bureau of Development Services said,

"The problem with our state code is the majority of the things we designed for after 1993, I believe, are going to perform pretty well ... but our old buildings are really going to have problems. Those buildings are not designed for earthquakes. The problem is ... the seismic load was very low until 1988. In 1993 we actually started designing for the seismic forces."

Commercial structures designed before 1993 were not built to withstand earthquakes and according to the codes, it's not until an existing building changes use that it is required to retrofit. A grandfather clause says if an office building in the '20s is still an office building today, then the owners aren't required to retrofit, which means that a substantial number of existing structures have not been upgraded.

Besides commercial structures, a report from 2007 by the Oregon Department of Geology and Minerals Industry (DOGAMI) shows that more than 1,000 schools, hospitals and other emergency facilities are at "high" or "very high" risk to collapse during a major earthquake. Portland Public Schools, with 89 campuses and a population of 46,000 students, not including teachers and staff, could be destroyed. Seventy-five percent of these school facilities were built before 1930 and only two were built in the last 30 years, according to Sampson.

ODOT

Seismic retrofit of Marquam Bridge using restrain cables

Bottom of Form

Bridges and roads

If Oregon's buildings are at risk to tumble during an earthquake, how do its bridges and roads measure up?

According to a study done by ODOT in 2009, 64 percent of Oregon bridges were built before the '70s when earthquakes weren't a major consideration in the construction process. Of approximately 2,550 State-owned bridges studied in 1993 for seismic deficiencies, more than 1,600 were found to have "insufficient capacity to resist earthquake loading."

At the time of the 1993 CH2M Hill Seismic Prioritization Report, a lack of funding limited the retrofitting process. In 2009, only 178 bridges had received a seismic retrofit and not necessarily the State's most vulnerable, according to the report.

Liquefaction

Besides the "G" forces in a subduction earthquake, another cause of structural failure is liquefaction—the process of soil transforming suddenly from a solid to a liquefied state. Many of our roads and bridges sit on soil prone to liquefaction. Wang said, *"The Fremont Bridge was designed in 1960 to very inadequate, if any, seismic standards. Not only the bridge itself, but the approaches and the abutments are subject to problems with poor soils."*

Oregon's bridges and roads are definitely on shaky ground, but according to Wang, so are most of Oregon's liquid fuel supplies and some very important high-voltage electric transmission lines. Should a major quake hit, this reality poses a serious threat to Oregon and Washington's infrastructures.

Activity 6.2 Part 2 Worksheet

1. You are brainstorming what points you want to highlight to the exercise participants. Use the ShakeMap and information from the news article to create bullet points of learning lessons that can be incorporated into the scenario (i.e., use science to highlight the risks and bring people to the idea of mitigating the risk to citizens with stronger building codes).

1. Whom might you invite as technical expertise to answer questions in your exercise?

Visual 44: Truth or Myth?

- A tsunami is a tidal wave
- A tsunami is a single, giant, cresting wave
- A tsunami is a huge slow wave when in the middle of the deep ocean

Key Points

Truth or myth? A tsunami is a tidal wave.

Key Points

Truth or myth? A tsunami is a single giant cresting wave.

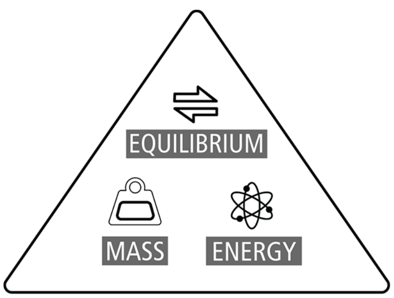
Key Points

Truth or myth? A tsunami is a huge slow wave when in the middle of the deep ocean.

Visual 45: What Is a Tsunami?

A series of very long wavelength ocean waves caused by the sudden displacement of water by earthquakes, landslides, or submarine slumps.

This is equilibrium, mass, and energy.



Key Points

A tsunami is a series of very long wavelength ocean waves caused by the sudden displacement of water by earthquakes, landslides, or submarine slumps. The word tsunami comes from a Japanese word meaning "harbor wave." This is pertinent because tsunamis particularly cause destruction in harbors and marinas. Tsunamis are among the most devastating of geologic disasters. Like other hazards, tsunamis come in many sizes, and the most common are small tsunamis that cause little or no harm.

Tsunamis are **secondary hazards,** which means that they are created as a consequence of another hazard that rapidly displaces a large volume of water. Examples include the Chicxulub meteorite 65 million years ago off the Yucatan Peninsula, which is thought to have killed the dinosaurs.

Undersea earthquakes are the most common cause of tsunamis, and the biggest undersea earthquakes (magnitude 8.8 or larger) create tsunamis with enough energy to cause damage thousands of miles away. Earthquakes large enough to generate extremely large tsunamis occur on the order of decades rather than millennia. Other events that cause tsunamis include:

- Underwater landslides (aka submarine slump).
- Volcanic eruptions.
- Calving icebergs.
- Meteorite impacts (very rarely).

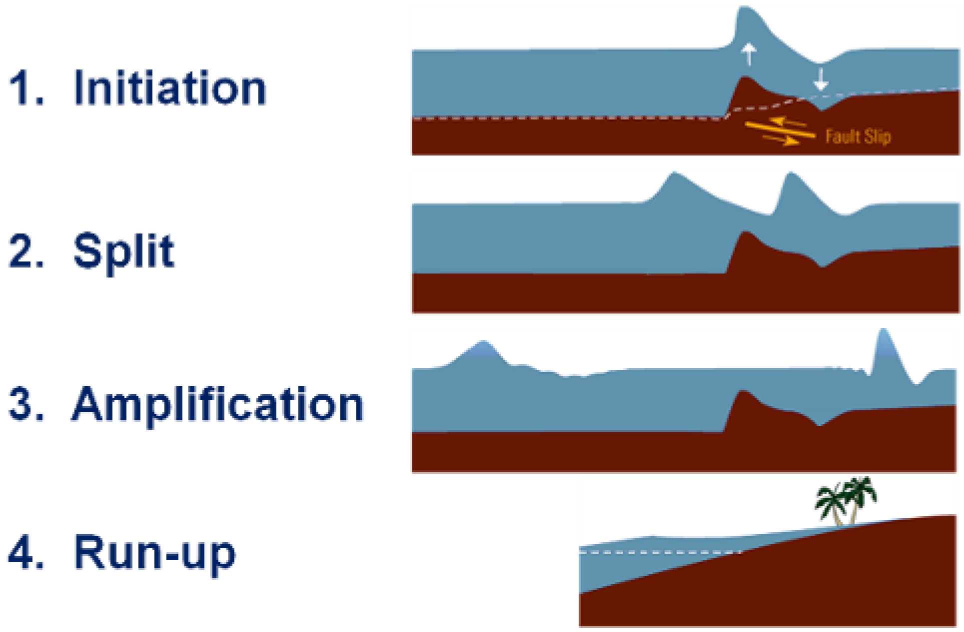
Visual 46: The Power of a Tsunami

Key Points

Tsunamis are among the most devastating of geologic disasters. For example, these photos show:

1. A house and a car destroyed by a tsunami in the coastal city of Dichato, Chile. The tsunami height was about 32 feet following a M 8.8 earthquake on February 27, 2010. Several hundred homes were destroyed. (Credit: U.S. Geological Survey, photo by Walter D. Mooney)
2. A car transported by the 2004 tsunami in Sri Lanka. (Credit: U.S. Geological Survey, photo by Dr. Robert Morton.)

Visual 47: Tsunami Lifecycle



Key Points

Tsunami lifecycle: There are four phases of a tsunami lifecycle:

1. **Initiation:** A geological event causes the tsunami. Water displaced during an earthquake uplifts some seafloor (up arrow) and down-drops other seafloor (down arrow).
2. **Split:** The entire column of water gets displaced and splits into a distant tsunami (moving toward the deep ocean) and local tsunami (moving toward the nearby coast).
3. **Amplification** The local tsunami's amplitude increases. When a tsunami reaches shallower water near shore, it slows down, and the energy that previously went into speed now goes into amplitude.
4. **Run-up:** The tsunami's peak travels on shore.

Height: The wave heights are greatly exaggerated in these images. In the open ocean, the waves may be only inches higher than the ocean surface-even in the largest tsunamis-but the energy is moving through the entire column of ocean water.

Speed: In the open ocean, most of a tsunami's energy goes into wave propagation (i.e., travel), and the wave moves at 500 to 600 miles per hour-about as fast as a jet. When tsunamis reach shallow water, they slow from jet speed to auto speed. On land they slow down still more, to about 20 mph.

Visual 48: Tsunami Wave Development

Tsunami Wave Development Video Description

This animation shows the evolution of tsunami waves caused by the December 26, 2004 Sumatra-Andaman earthquake. Because it takes approximately eight (8) minutes for the entire fault to break, tsunami waves generated near the epicenter of the earthquake have propagated partway into the Bay of Bengal by the time the earthquake has just started to generate tsunami waves near the Andaman Islands. Tsunami waves then cross the Andaman Sea toward Thailand.

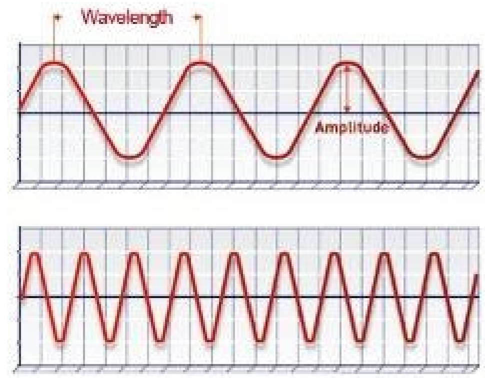
Key Points

This animation shows the evolution of tsunami waves caused by the December 26, 2004, Sumatra-Andaman earthquake.

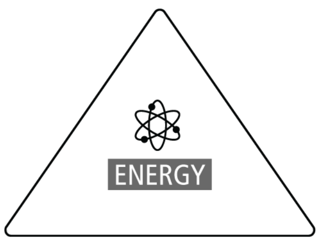
Because it takes approximately 8 minutes for the entire fault to break, tsunami waves generated near the epicenter have propagated part way into the Bay of Bengal by the time the earthquake has just started to generate tsunami waves in near the Andaman Islands. Tsunami waves then cross the Andaman Sea toward Thailand.

Visual 49: Tsunami Wave Properties

- Tsunamis have waves with very long periods, long wavelength, low frequency.
- Tsunami wavelength is 60-to-300 miles.
- The waves repeat every 10 minutes to 2 hours.
- The deeper the water, the faster the tsunami travels.



This is energy.



Key Points

A tsunami, like an earthquake or any other wave phenomenon, is actually a series of waves called a wave train.

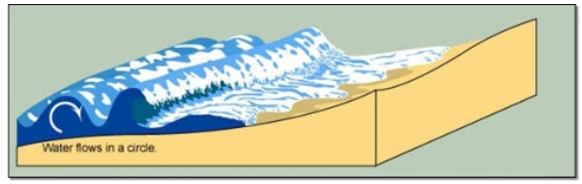
Period: The period measures the time it takes successive waves in the train to pass a given point. Tsunamis have waves with very long periods (also called low frequency). The waves repeat every 10 minutes to 2 hours. In comparison, waves caused by tides or wind have periods of 5-20 seconds.

Wavelength: In a tsunami, the wavelength (distance from peak to peak) is 60-300 miles. In a wave from a tide or wind, the wavelength is 300-600 feet. The speed is equivalent to a high-speed jet.

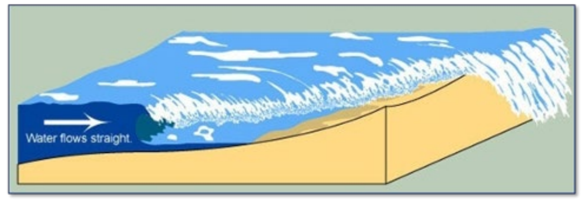
Speed: The speed of a tsunami varies as the square root of water depth. The deeper the water, the faster the tsunami travels.

Visual 50: Wave Period

Wind Waves

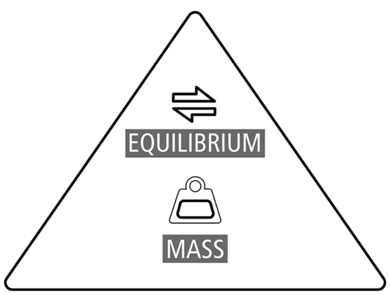


Tsunami



Equilibrium Mass Icon

This is equilibrium and mass.



Key Points

Why do tsunamis act differently than the ocean waves created by wind forces? As you learned in an earlier unit, the rate at which a wave loses energy is inversely related to its wavelength. Short-period, high-frequency waves lose energy more quickly than long-period, low-frequency waves.

- Wind waves are short-period waves. With wind waves, the water flows in a circular pattern, and the waves come and go without flooding higher areas.
- By contrast, tsunamis are long-period, low-frequency waves that move in a straight path as a great surge of water. Tsunamis come on land with enormous force, and recede with nearly equal force. Sometimes, tsunamis crest in shallow water and resemble waves made by tidal forces. More often they appear as walls of water or turbulent surge that resembles hurricane storm surge.

Visual 51: Wave Amplitude

The first surge may not be the largest.

Wave Amplitude Video Description

A tsunami rarely arrives as a single surge; more typically, it has multiple surges. That is because of the complex scattering—the refraction (direction change) and reflection (bounce back)—of tsunami waves as they interact with landforms and other tsunami waves.

This scientific animation shows tsunami wave behavior along the northern California coastline. To better visualize the effects, the wave amplitudes are exaggerated, and 2.5 hours have been compressed into 30 seconds of animation.

Key Points

A tsunami rarely arrives as a single surge; more typically, it has multiple surges. That is because of the complex scattering—the refraction (direction change) and reflection (bounce back)—of tsunami waves as they interact with landforms and other tsunami waves.

The scattering and wave interference processes are complicated in the open ocean and even more complicated near shore, where tsunami energy is scattered by sharp variations in the coastline.

In addition, a tsunami can generate a particular type of trapped wave called an edge wave, which travels back and forth parallel to shore. The effects of wave interference, scattering, and trapping combine to produce multiple arrivals of a tsunami.

The number of arrivals and the amplitudes of each wave will vary depending on the coastal properties, the exact travel direction, and other specifics of how the tsunami was generated. They will vary from place to place and event to event. In the largest tsunamis, surge can continue for many hours and more than a day.

Visual 52: Run-Up and Inundation

- Run-up - the maximum height of the wave
- Inundation - the maximum horizontal distance reached

Arahama Beach, Sendai, Japan, before and after March 11, 2011

Key Points

How tsunami reach is measured: A tsunami's reach on shore is measured in two ways:

- **Run-up,** which is the height above sea level that the tsunami achieves, and
- **Inundation,** which is the maximum horizontal distance-that is, how far inland-the tsunami reaches.

Factors that influence run-up and inundation: The run-up and the inundation depend on many factors, including:

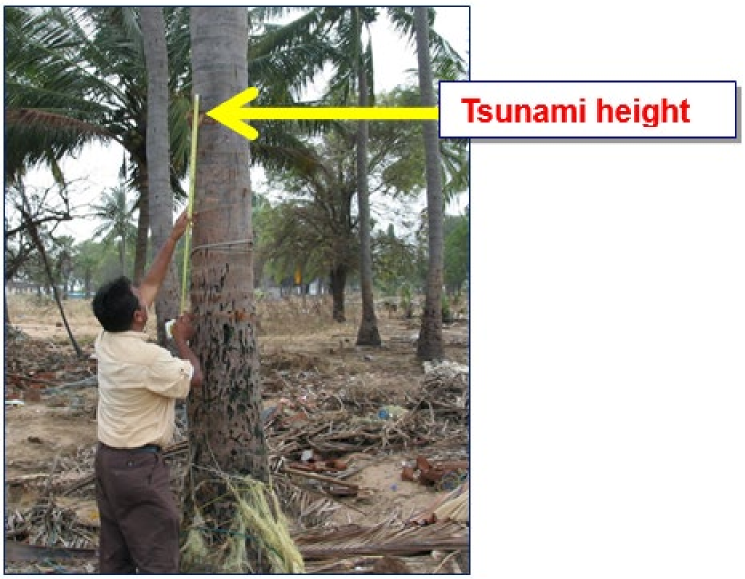
- Energy of the tsunami.
- Topography of the land.
- Orientation of the land to the oncoming wave.
- Tide.

A tsunami that arrives at high tide will reach farther inland than a tsunami that arrives at low tide. The energy of the tsunami depends on how far it has traveled and how large the event was that created it.

The photos on this visual show a beach in Japan, before and after the 2011 tsunami. The white structure between the community and the ocean is a seawall, built for tsunami protection. However, it was not built for a tsunami as large as the one that occurred in 2011. Experts underestimated the possible size of earthquakes that could occur offshore in this region, and when the fault ruptured, the rock under Japan dropped down relative to the rock under the ocean, lowering the elevation along the coast. As a consequence, inundation extended as far as 6 miles inland.

Many communities in Sendai province had seawalls that were overtopped by this tsunami, causing enormous devastation and resulting in tens of thousands of avoidable deaths. Residents did not flee to higher ground when they felt earthquake shaking, because they expected their seawalls to protect them, as had happened in previous, smaller tsunamis.

In the photo below, a researcher is measuring a tsunami's run-up, marked by a gouge in the tree made by floating debris.



Visual 53: Tsunamis on Rivers

- Damaging tsunamis can travel up rivers as far as 6 miles.
- A local tsunami is more likely to inundate a river (though a distant tsunami may as well).

Key Points

Tsunami inundation is not just a threat along coastlines. Damaging tsunamis also frequently travel up rivers, as far as 6 miles and possibly more.

Factors that affect tsunami inundation on rivers include:

- The river's depth, width, and bathymetry (underwater topography).
- Direction of the incoming waves relative to the orientation of the river and the amount of energy in the tsunami.
- Local vs. distant: A local tsunami is more likely to cause extensive inundation on rivers, but distant tsunamis can also cause river inundation.

The photo shows a tsunami wave advancing up the Wailuku River in Hilo, Hawaii, in 1946, just before it tore a span from the railroad bridge in the distance. The tsunami was generated by an earthquake offshore of Alaska.

Visual 54: Tsunami Currents

- Driven by the moving water underneath a tsunami.
- Water exerts force on an object as it tries to entrain it into the flow.
- Incredibly destructive-especially in harbors and marinas.

Key Points

Even in areas where inundation is trivial, tsunamis generate currents that can be incredibly destructive. Tsunami currents are driven by the moving water underneath a tsunami, and exert forces that can be very large, because water is heavy. Hazards include current force and whirlpools.

- **Current force:** Tsunamis have a current force (or drag force) that the water exerts on an object as it tries to entrain that object into the flow.
  - If the current is tripled, the force of the current is increased by a factor of nine!
  - Only a small depth of moving water (e.g., ankle deep) can be enough to knock a person over and mobilize large objects.
- **Whirlpools:** Whirlpools are particularly dangerous in harbors and marinas, where breakwaters and other structures cause the flow to focus and converge into jets and eddies that create whirlpools. This creates very localized, very high-energy areas with high damage potential.

In recent tsunamis, currents have broken nuclear submarines from moorings and sent a 3-block-long container ship spinning in loops around a port. In a tsunami, boats at sea should never return to port. The safest place to be is offshore, if the boat can reach a depth of 100 fathoms (600 feet).

Visual 55: Effects of Tsunami Scour

Key Points

Photos: Scour effects in Sri Lanka, off the coast of India, in the 2004 tsunami that was generated in Sumatra on the other side of the Indian Ocean.

Tsunami currents can cause tremendous scour—a type of erosion—and have the ability to pick up and move very large objects.

In recent tsunamis, cars and trucks being pounded into buildings have been recurring causes of damage. Tsunami currents scour sediment and cement from foundations of buildings and bridges, unearth buried pipelines, and relocate sediment to bury intake valves and other structures that need to remain exposed.

Visual 56: Direct Impacts on Health

- **"Tsunami lung" from uncommon pathogens**
- Drowning
- Injuries from debris
- Infection of wounds
- Damage to public health infrastructure
- Mass relocations
- Psychological impacts
- Exacerbation of chronic diseases

Key Points

The recent tsunamis in Indonesia and Japan underscore the types of direct impacts on public health that can occur.

Tsunami-related deaths and injuries: An impact that is relatively uncommon for other disasters, but more relevant during tsunamis, is the abundance of fatalities (including drowning), injuries, and wounds resulting from debris, and the post-disaster development of infections in the wounds by pathogens in sea water, soils, or debris.

Remember, tsunamis are secondary hazards, which means that they are created as a consequence of another hazard. The map on the next page shows the number of tsunami-related deaths in terms of the cause of the tsunami.

Other effects include:

- **"Tsunami lung" in people who nearly drown (tsunami lung is an infection caused by relatively uncommon pathogens found in the seawaters).**
- Damage to public health infrastructure.
- Relocation of thousands of people from affected areas into refugee camps.
- Psychological impacts.
- Disaster-related exacerbation of chronic diseases.

See Color Handout 6.9 Tsunami Effects

Visual 57: Environmental Health Impacts

Japan 2011

- Physical/chemical damage
- Contaminants
- Smoke and ash
- Infectious diseases
- Vector-borne diseases
- Mold

Environmental Health Impacts

Japan 2011

Key Points

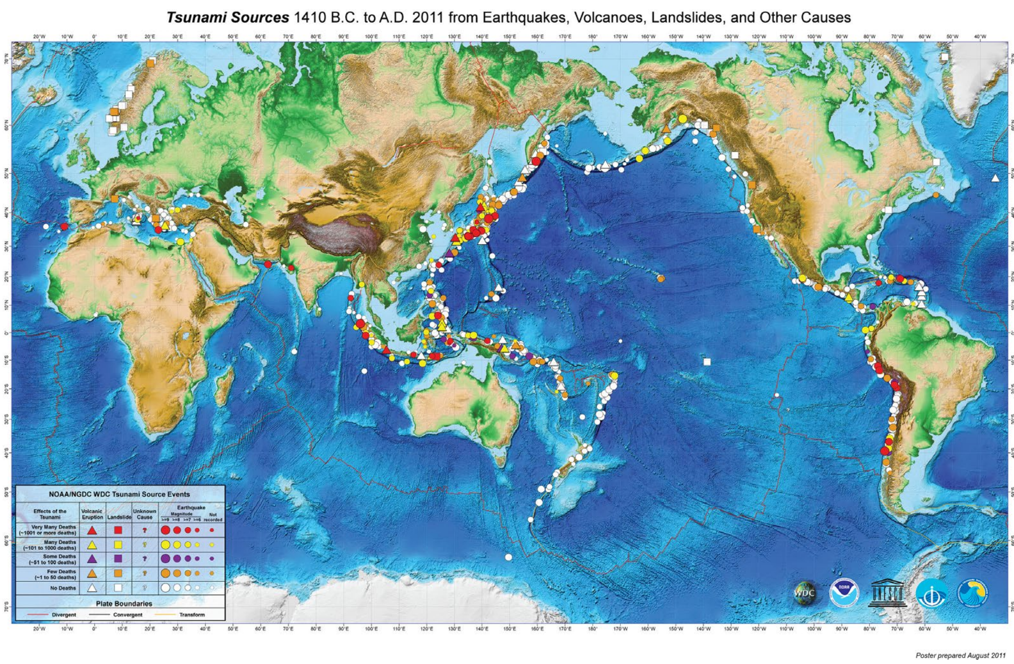
Tsunamis can also have severe impacts on the natural and built environments. For example, disposal of large volumes of debris has turned out to be a major challenge following both the 2004 Indonesian tsunami and the 2011 Japanese tsunami.

The debris can contain high levels of contaminants from the built environment such as asbestos and lead. These contaminants can become windborne, and some can be leached from the debris by rainwater into ground and surface waters.

Environmental health impacts may include:

- Severe environmental damage, both physical and chemical (e.g., impacts of seawater on terrestrial vegetation).
- Exposures to smoke and ash from fires caused by tsunami, and from fires set intentionally as a debris removal practice.
- Infectious diseases from consumption of contaminated ground or surface waters.
- Mosquito- and other vector-borne diseases.
- Exposures to post-flood mold.

Visual 58: Known Tsunami Locations from 1410 B.C. to A.D. 2011



Key Points

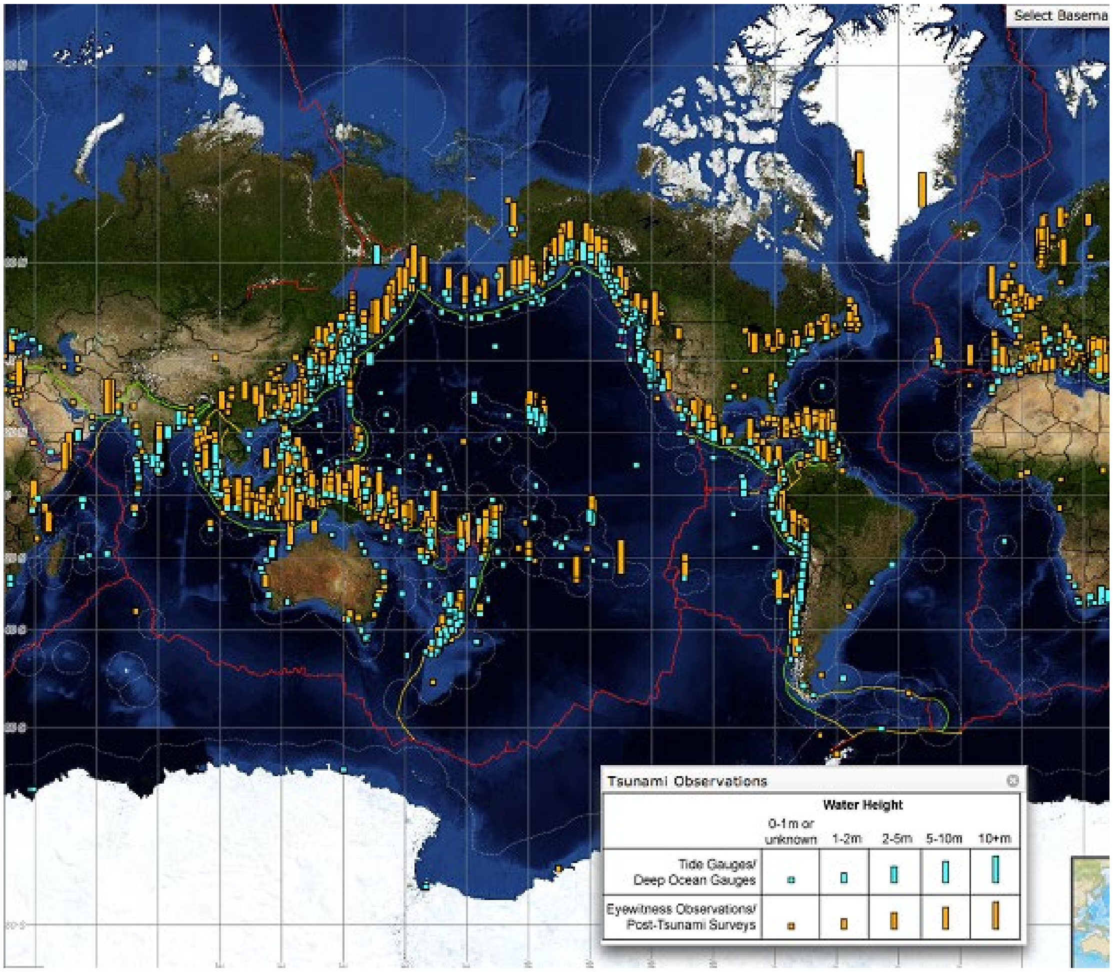
This map shows locations where tsunamis are known to have made landfall. Green squares indicate known locations of tsunami events since 2000 B.C. The coastal areas along all oceans are at risk from tsunamis. (As with any scientific dataset, the recent portions will be the most complete. The coastlines without green squares are more likely to be lacking data than lacking tsunamis.)

Source: Known Tsunami Locations from 1410 B.C. to A.D. 2011 found at [US Climate Resilience Toolkit](https://toolkit.climate.gov/image/241) (https://toolkit.climate.gov/image/241).

The map on the next page shows the locations where tsunami wave heights have been measured.

- The **height of the bar** changes with the height of the observation.
- The color of the bar indicates how the measurement was estimated.
  - **Blue bars** are made with scientific instruments; thus, this data set spans several decades.
  - **Brown measurements** indicate measurements estimated from eyewitness observations or post-tsunami surveys. (The surveys are scientific fieldwork that can be done decades or centuries after the event, if the evidence has not been obliterated by changes to the Earth's surface. In some cases, the tsunami site may no longer be near an ocean.)

Tsunamis by Water Height



See Color Handout 6.10 Tsunami Known Locations

Visual 59: Warning Signs

Natural:

- Strong earthquake shaking
- Water that recedes in an unusual way
- Sound like a train or plane
- Wall of water filling the horizon

Official:

- Tsunami warning
- Evacuation notice
- Media reports

Key Points

A tsunami may arrive without any warning. However, in some cases, there may be signs that a tsunami is approaching.

Natural signs: Signs created by the physical characteristics of the event may include:

- **Strong earthquake shaking** (only if the tsunami is generated locally).
- **Water that recedes in an unusual way.** Depending on exactly how the water is initially displaced, about half the time the first wave motion will be away from shore, and in this case the water will recede far from shore when the tsunami first arrives. This can happen for both local and distant tsunamis.
- **A sound** like a train or plane coming from the ocean. This has been experienced in both local and distantly generated tsunamis, but not in all tsunamis.
- **The appearance of a long wall of water advancing toward land.** However, by the time a tsunami can be seen or heard it is often too late to get away.

Human-created warnings: Other signs are human-created because a tsunami has been detected in the open ocean, or an undersea event has been detected that is capable of producing a tsunami. Human-created warnings may include:

- Sirens.
- Evacuation efforts.
- Word that a tsunami has struck another coastline.

Girl saves tourists after raising tsunami warning

Hundreds of thousands of people died in the December 26, 2004, Indian Ocean tsunami. But as described in these news reports, others saw warning signs, and escaped with their lives.

Thousands died on the beaches of Thailand in the December 2004 tsunami. But a 10-year-old British girl saved more than 100 people because she had just studied the killer waves in school. When the sea suddenly began to boil, then pulled away from the resort she was visiting, leaving fish and boats stranded high and dry, Tilly Smith recognized that a tsunami was approaching. Fortunately, her frantic warnings were heeded, and the beach was evacuated just moments before the huge waves crashed ashore.

Kalutara Beach Detail
Imagery collected December 26, 2004.
Description: Receding waters and beach damage from tsunami

Source: NOAA Ocean Explorer
(http://oceanexplorer.noaa.gov/edu/learning/player/lesson09/l9la2_a.html)

Visual 60: Time of Warning: Local vs. Distant

Comparison	Local Source	Distant Source
Time before tsunami arrives	3 to 30 minutes	1 to 5 hours
Energy attenuation (loss)	Little	Increases with travel
Possible warnings	Natural	Official, some natural

Key Points

For public safety, it is important to distinguish between tsunamis that have a nearby or local source and tsunamis that are generated far away, as shown in this table.

Local tsunamis: Local tsunamis are generated just offshore. Depending on how close to shore they are created, the first wave will arrive in 3 to 30 minutes, with the most typical time being 15 to 20 minutes. The waves will retain most of their initial energy and thus will have enormous force. **Tsunami detection instruments are located offshore in the ocean and cannot detect local tsunamis that occur near the shore. Therefore, official warnings cannot be issued before locally generated waves reach shore.**

Distant tsunamis: For distant source tsunamis, the arrival time depends on how far away the tsunami was created and thus how long it has to travel. Recall that all waves lose energy as they travel. Therefore, the energy of a distantly generated tsunami will lessen, but it can still be enough to cause substantial death and damage. As a distantly generated tsunami travels across an ocean, if there are instruments in place they will detect the tsunami and there will be time for official warnings to be issued.

Again, only the largest earthquakes create tsunamis with enough energy to cause destruction at great distances.

DART II® System

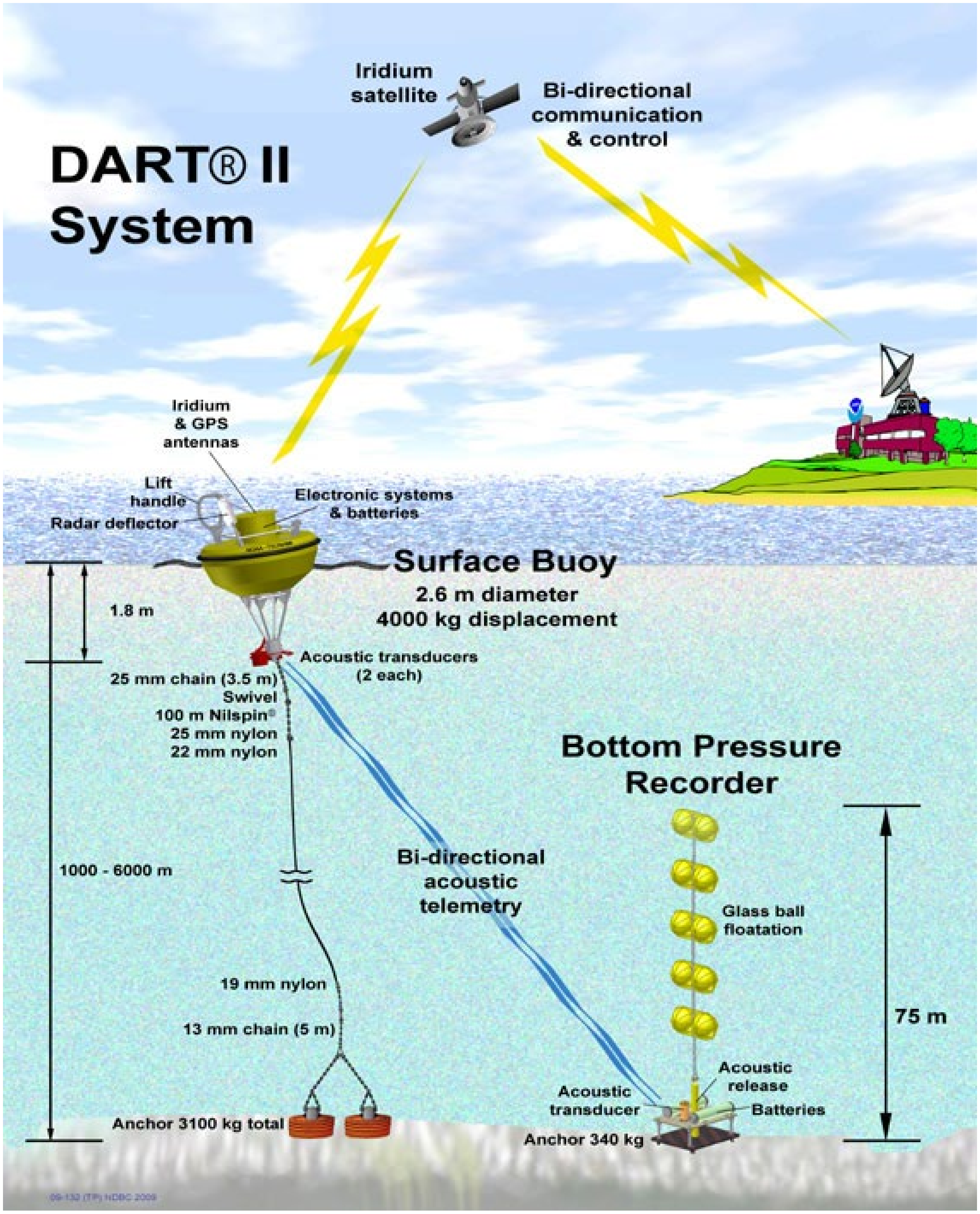
Background

To ensure early detection of tsunamis and to acquire data critical to real-time forecasts, NOAA has placed Deep-ocean Assessment and Reporting of Tsunami (DART®) stations at sites in regions with a history of generating destructive tsunamis. NOAA completed the original 6-buoy operational array (map of original six stations) in 2001 and expanded to a full network of 39 stations in March, 2008.

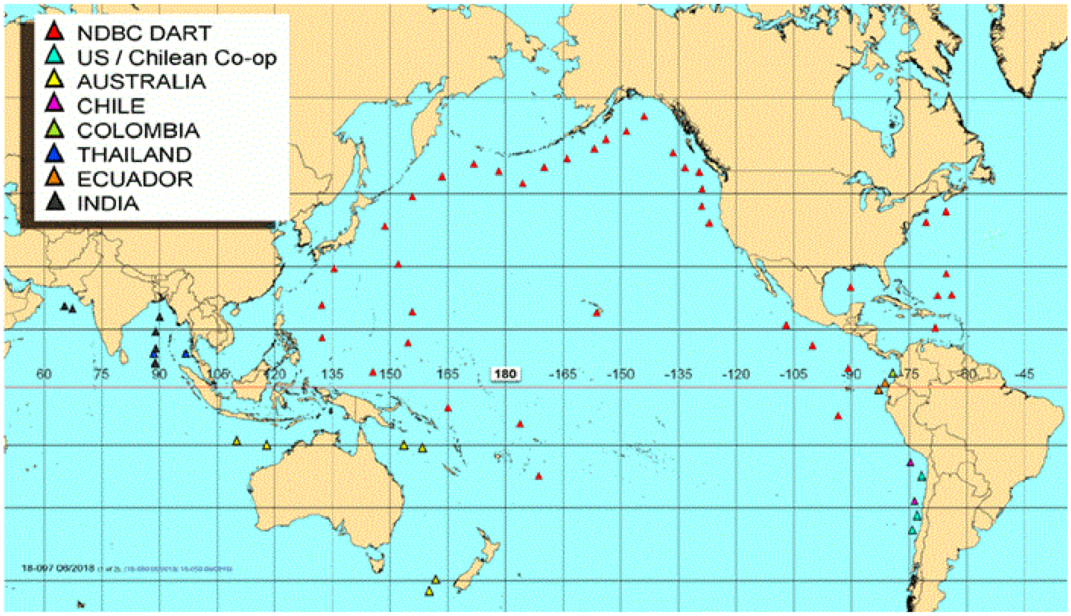
Originally developed by NOAA, as part of the U.S. National Tsunami Hazard Mitigation Program (NTHMP), the DART® Project was an effort to maintain and improve the capability for the early detection and real-time reporting of tsunamis in the open ocean. See DART® development for more info.

For more information, visit the National Data Buoy Center (https://www.ndbc.noaa.gov/dart/dart.shtml).

DART Mooring System



DART Buoys



NDBC DART
US / Chilean Co-op
AUSTRALIA
CHILE
COLOMBIA
THAILAND
ECUADOR
INDIA
60
75
90
105
120
135
150
165
180
-165
-150
-135
-120
-105
-90
-75
-60
-45
18-097 06/2018

Visual 61: Tsunami Warning Systems

Ocean	Percentage of Tsunamis	Status of Warning System
Pacific Ocean	59%	In place for decades
Mediterranean Sea	25%	In development
Atlantic Ocean	12%	In development after 2004
Indian Ocean	4%	In development after 2004

Key Points

Looking at long-term averages, the Pacific Ocean has the most tsunamis of any body of water, and the Indian Ocean has about 4 percent of all tsunamis. On the Pacific Ocean there is an established system of deep ocean and tidal gages to detect and track tsunamis, and a system to provide warnings.

Tsunami frequency: Major tsunamis occur about once per decade when looking at long-term averages. But there is variation from year to year and decade to decade.

In 1964, the whole world paid attention to tsunamis when the Great Alaskan "Good Friday" earthquake created a particularly destructive tsunami in the Pacific Ocean. However, 40 years elapsed until the next really large tsunami in 2004 in the Indian Ocean. When more than a generation elapses between events, society's readiness for those events inevitably lessens.

Development of monitoring systems: Before 2004, there was little or no money available to deploy monitoring equipment where tsunamis are particularly rare. This situation is slowly changing since that time.

Visual 62: Watch/Warning Timeframes

- Estimated arrival times can be accurate within minutes in oceans where good sensor data exist.
- Complexities of wave propagation and interaction limit surge data.
- Seismometers allow computers to broadcast earthquake magnitudes and locations within minutes.

Timeframe	Information Broadcast
1–3 minutes	USGS broadcasts earthquake size and location.
3–5 minutes	NOAA broadcasts tsunami watch.
1–1.5 hours	NOAA broadcasts tsunami advisory or warning.

Key Points

After large earthquakes occur undersea, the National Oceanic and Atmospheric Administration (NOAA) monitors ocean sensors to detect whether a tsunami has been generated, and if so, issues estimates of tsunami arrival times for different locations. NOAA uses the sensor data to refine estimates for when the first tsunami surge will arrive. Estimated arrival times can be accurate within minutes in oceans where good sensor data exist. Typically, information about the event gets conveyed according to the timeline shown on the visual.

- **Watch:** Initially, after the earthquake, NOAA will declare a Tsunami Watch, normally just a few minutes after the earthquake occurs. The worldwide network of seismometers allows computers to broadcast earthquake magnitudes and locations within minutes of the event.
- **Advisory and warning:** A watch gets upgraded to an **advisory** and then a **warning** if a tsunami is detected by sensors or humans. Typically, a warning is issued 1 to 1.5 hours after the event.
- **Updates:** NOAA updates and continues to issue information bulletins, watches, and warnings, for specific areas, until all tsunami danger is past.

Not all oceans have sensors to detect tsunamis, so some advisories must be based on past scientific experience with how earthquakes of different magnitudes create tsunamis.

The complexities of tsunami wave propagation and interaction limit the ability to rapidly model and relay high-resolution, locally specific surge data as part of a warning system.

Visual 63: Unit Summary

- You should now be able to:
  - Define earthquake-related terminology and concepts.
  - Describe the three types of waves produced by earthquakes.
  - Identify the secondary effects of earthquakes.
  - Identify methods for measuring earthquake activity.
  - Identify the geologic causes of tsunamis.
  - Describe natural and official tsunami warning signs.
  - Describe tsunami surges and currents.
  - Identify the impacts of tsunamis.
  - Explain when officials issue tsunami warnings.

Key Points

Do you have any questions about the material covered in this unit?

Unit 7: Landslides and Sinkholes

Visual 1: Unit 7: Landslides and Sinkholes

Unit 7: Landslides and Sinkholes

Key Points

Welcome to Unit 7: Landslides and Sinkholes. This unit will discuss two kinds of ground failure: landslides and sinkholes. These two phenomena are paired because they are both common and destructive forms of mass wasting—e.g., the movement of rocks, sediments, or soils downslope or to lower elevation.

Visual 2: Unit 7 Objectives

- Identify types of ground failures.
- Describe the causes and triggers of ground failures.
- Identify the areas with the greatest risk for ground failures.
- Describe relevant hazard assessment tools and methods.

Key Points

Review the module objectives as shown on the visual.

Visual 3: Introduction Scenario

PHOTO BY TED S. WARREN /THE ASSOCIATED PRESS; GRAPHIC BY THE SEATTLE TIMES

Key Points

On March 22, 2014, a landslide occurred in the town of Oso, Washington. The SR530 landslide overran a Local neighborhood and killed 43 people. The landslide provides an outstanding opportunity to review what scientists know about landslide potential, the means of preventing and mitigating landslide disaster, and the conflict that can occur between developers and the city and emergency planners.

Visual 4:

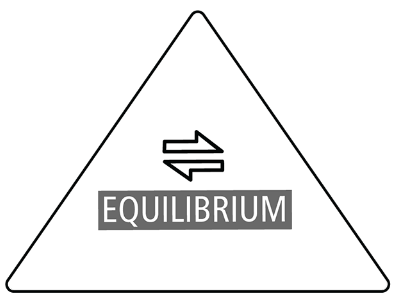
King County Sheriff Air Support Video Description

This video shows a quick before and after from the Oso mud slide, using our Churchill Navigation ARS. It provides a visual to the details discussed in the previous slide about the SR530 landslide.

Visual 5: Landslide

- The downslope movement of a mass of debris, rock, or earth.
- Driving force: Gravity.
- Role of water: Disturbs balance between gravity and resisting forces.

This is equilibrium.



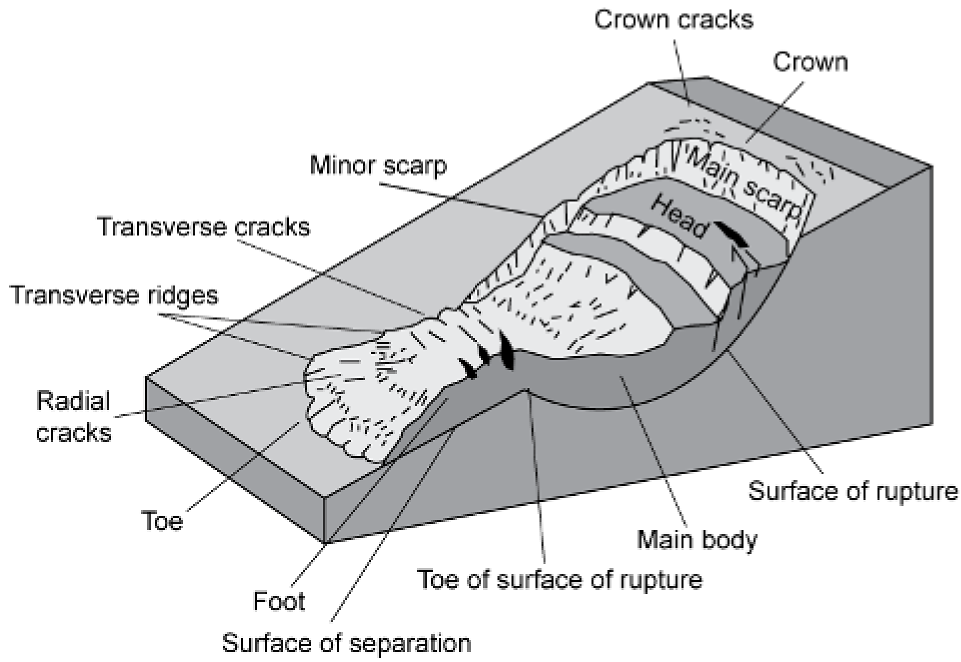
Key Points

Landslides are defined as the downslope movement of a mass of debris, rock, or earth.

The driving force for all mass wasting phenomena is gravity, which pulls the material toward the center of the Earth. Typically, there is a balance of gravity with resisting forces, such as friction. This maintains the stability of the slope.

When the balance is disturbed—ground failure results. Water acts as a lubricant reducing the friction that holds material in place.

Visual 6: Parts of a Landslide



Parts of a Landslide Image Description

Graphic illustrating parts of a landslide. They are: Toe, Foot, Surface of separation, Radial cracks, Transverse ridges, Toe of surface of rupture, Transverse cracks, Main body, Surface of rupture, Minor scarp, Head, Main scarp, Crown, Crown cracks

Key Points

This schematic illustrates the different parts of a landslide. Note that:

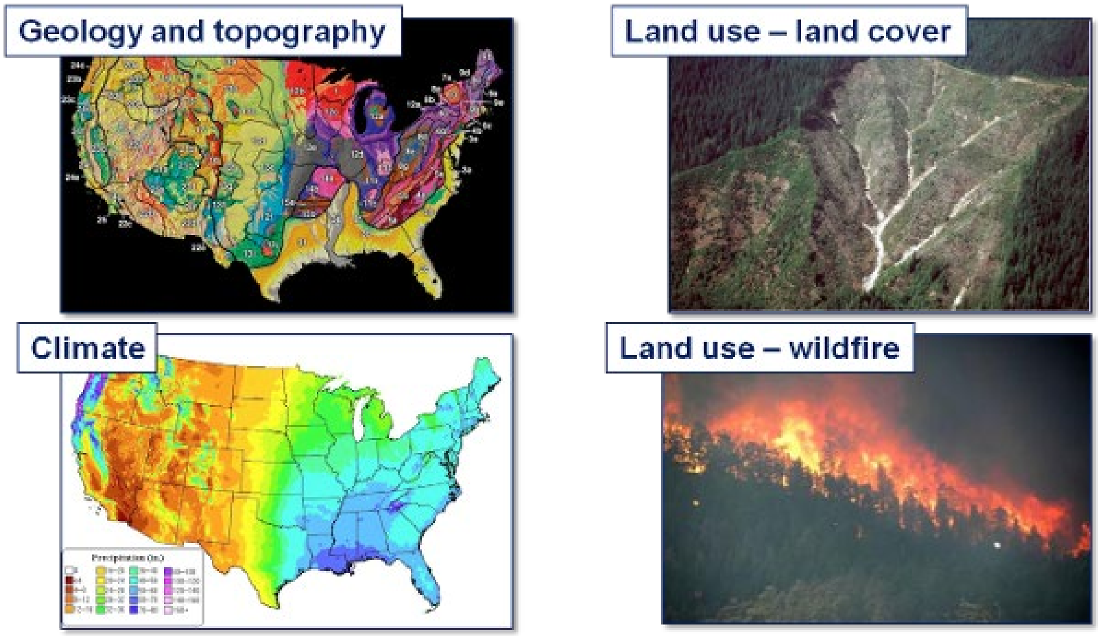
- The **landslide body** moves along a surface of rupture. In this illustration the surface of rupture is curved and the motion is rotational.
- **Rotational landslides** have a failure surface that is curved. In a **translational** slide, the failure surface is roughly parallel to the undisturbed or former ground surface. In a landslide, the main **scarp** is a vertical or subvertical face that is exposed when the slide moves downslope.
- The **toe** is the lower-most extent of the displaced material.

To understand landslides, scientists must understand the many variations that occur, and thus develop terminology to distinguish the variations.

Geologists can identify the scarps and toes of old landslides in both the rock record and in LiDAR (Light Detection and Ranging) imagery. This is remarkably useful in developing land-use restrictions.

See color handout 7.1: Types of Landslides

Visual 7: Landslide Causes



Key Points

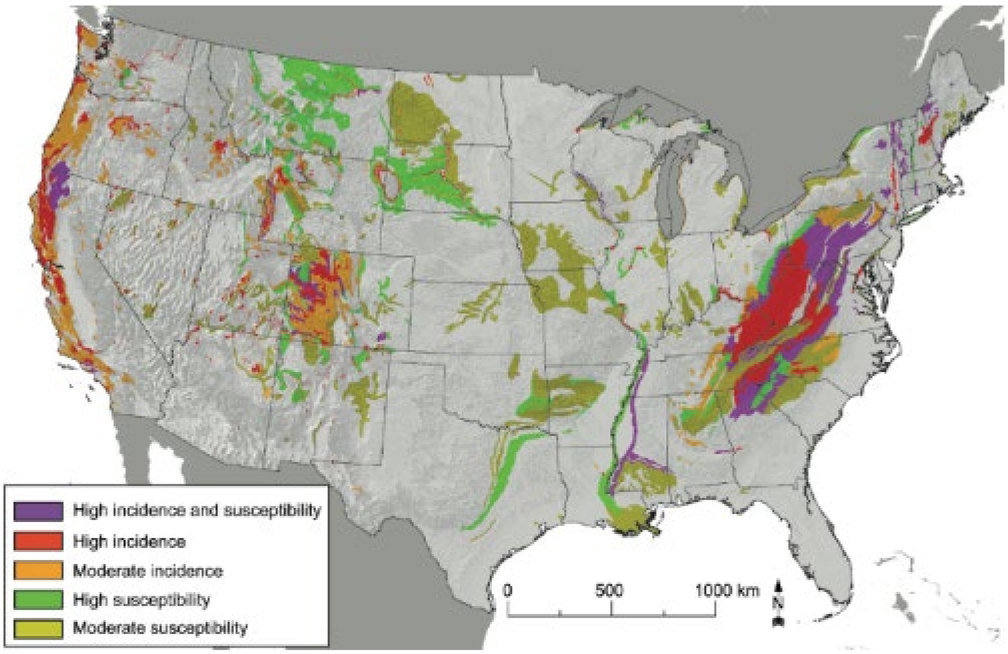
Landslide occurrence is often described using the terms cause and trigger. First, we'll look at causes.

Causes are the topographic, geologic, climatic, and land use characteristics that make an area susceptible to landslides.

- An example of a topographic cause is a steep slope.
- Weak geologic materials include young sedimentary rocks or heavily weathered rocks.
- Climatic conditions include heavy rainfall that can loosen material.
- Land use includes human activities that directly and indirectly have affect, such as industrial forestry, road cuts, and in some cases, wildfire.

Causes create the conditions that make a landslide possible and increase the propensity for landslides.

Visual 8: Landslide Incidence and Susceptibility



Key Points

Landslide Incidence and Susceptibility Map (This link can also be accessed at the following URL: http://landslides.usgs.gov/hazards/nationalmap/)

All 50 States have at least some areas that are at risk from landslides.

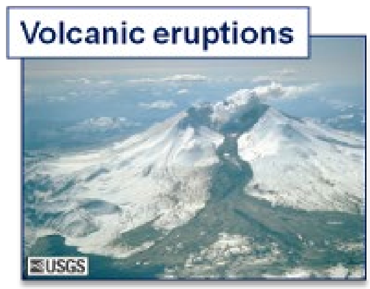
The greatest potential for losses resulting from landslides, however, exists in the:

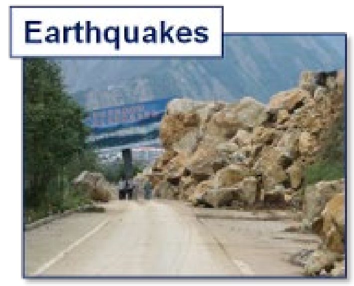
- States along the Pacific coast.
- Rocky Mountains.
- Appalachian Mountains.

Visual 9: Landslide Triggers

What triggers a landslide?

- Nature Process
- Human Activities





Key Points

Many regions are susceptible to landslides because of their climate and topography. However, most landslides are triggered by a particular event or series of events. Most often the culprit is heavy rainfall or human activity. For example, 90 percent of landslides in the Pittsburgh, Pennsylvania region are a result of urban development. However, hurricanes, volcanic eruptions, and earthquakes often trigger the landslide events that take the largest toll on human life.

Landslide triggers include a variety of natural and human processes.

Natural processes may include:

- Heavy rainfall.
- Volcanic eruption.
- Earthquake.
- Thermal variation (extremes of hot and cold that allow moisture to enter cracks, freeze, expand, and force the crack apart).
- Snowmelt.
- Stress relief (as rocks are heaved up and exposed above the ground, they may expand to release pressure, which causes fractures).
- Wave action at a coastline.

Although earthquake-triggered landslides often create the largest death tolls, they are typically not the cause of most landslides. Excessive rainfall triggers most landslides.

Human activities that can trigger landslides include action that changes the topography (e.g., excavations) and activities that change ground or surface water hydrology (e.g., reservoir operation).

Visual 10: Key Distinctions

Slow-moving landslides affect property.

Fast-moving landslides affect lives.

Key Points

For nonscientists, there are two key distinctions with regard to landslide impacts:

- **Slow-moving landslides** that can be quite destructive to structure and infrastructure and, thus, very expensive
- **Fast-moving landslides,** which are more likely to cause deaths and injuries

Visual 11: Landslide Prevention

- Use drainage control
- Ensure properly graded slopes
- Construct appropriate slope supports and retaining walls
- Consider vegetation and logging standards
- Land Use Management/Zoning

Key Points

Reasonable and effective prevention measures include:

1. Drainage Control
    a. Keep water from infiltrating surfaces
        i. Cover the surface
        ii. Install surface drains
    b. Remove water from the subsurface by installing drains.
2. Properly grade slopes
    a. Reduce gradient to improve slope stability
    b. Install benching
    c. Install appropriate drainage in newly graded or benched slopes
3. Construct appropriate slope supports/retaining walls with
    a. Anchors
    b. Backfill
    c. Drainage
4. Consider vegetation
    a. Plant vegetation that
        i. Stabilizes the slope by reducing infiltration of water
        ii. Does not add excess weight to the slope
    b. Consider logging standards
        i. Appropriate setbacks from scarps
        ii. Road construction and maintenance alters surface runoff, which affects slope stability
5. Land Use Management/Zoning
    a. Obtain the professional services of an engineering geologist, a geotechnical engineer, or a civil engineer, who can properly evaluate the hazard potential of a site, built or unbuilt
    b. Avoid construction on steep slopes and existing landslides, or by stabilizing the slopes. Stability increases when ground water is prevented from rising in the landslide mass by:
        i. covering the landslide with an impermeable membrane,
        ii. directing surface water away from the landslide
        iii. draining ground water away from the landslide

iv. minimizing surface irrigation

Visual 12: Annual Impact From Landslides

Worldwide:

- Several thousand fatalities
- Exceptional events may kill tens of thousands

United States:

- More than 20 people are killed
- Direct economic losses exceed $2 billion

Key Points

Every year there are significant losses from landslides, both in lives lost and economic losses. Because a landslide affects a relatively small area, the impacts of these disasters are often underappreciated.

Annually, worldwide, landslides result in several thousand fatalities. Exceptional events may kill tens of thousands.

Annually, in the United States, landslides result in more than 20 fatalities and direct economic losses that exceed $2 billion.

The National Weather Service Forecast Offices uses rainfall threshold information to inform emergency management personnel and the public when landslides are expected.

Visual 13: Economic Impact

Direct:

- Damage to structures (buildings, pipelines, roads)
- Loss of agricultural productivity (crops, timber, fisheries)
- Decrease in real estate value

Indirect:

- Loss of productivity (wages, taxes)
- Increased travel time and inconveniences
- Emergency response and social services to those affected
- Legal and other costs

Northern CA, 1997

Key Points

Economics play an important role in hazard reduction. Economists look at disaster costs based on the type of cost, and whether it is direct or indirect. Examples of direct and indirect costs from landslides include:

Direct costs:

- Damage to structures (buildings, pipelines, roads).
- Loss of agricultural productivity (crops, timber, fisheries).
- Decrease in real estate value.

Indirect costs:

- Loss of productivity (wages, taxes).
- Increase in travel time and inconveniences.
- Emergency response and social services to those affected.
- Legal costs.
- Any other nondirect costs

It is worthwhile to consider that litigation is still pending regarding the SR530 slide. Issues include whether authorities properly warned citizens and whether the logging companies were at fault for the landslide.

Visual 14: Activity 7.1 – Oso Community Public Meeting

Instructions: Working as a team:

1. In preparation for a Public Meeting, review the assigned materials from the *2010 Snohomish County Hazard Mitigation Plan. Each group will be assigned a section to read and report on.*
2. Prepare 3 points from your section to help residents understand their risks as well as the factors that might exacerbate slide potential. Consider the relationship between the desire to develop the area, land use planning, and mitigation needs.
3. Be prepared to share your science brief in 20 minutes

Student Manual

Activity 7.1 – Oso Community Public Meeting

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3. Be prepared to share your science brief in 20 minutes

CHAPTER 14. LANDSLIDES AND OTHER MASS MOVEMENTS

14.1 GENERAL BACKGROUND

A landslide is a mass of rock, earth or debris moving **DEFINITIONS** down a slope. Landslides may be minor or very large, **Landslide—**The sliding movement of masses and can move at slow to very high speeds. They can be of loosened rock and soil down a hillside or initiated by storms, earthquakes, fires, volcanic slope. Slope failures occur when the strength of eruptions, and by human modification of the land. the soils forming the slope is exceeded by the pressure, such as weight or saturation, acting upon them.

Mudslides or mudflows (or debris flows) are rivers of rock, earth, organic matter and other soil materials **Mass Movement—**A collective term for saturated with water. They develop in the soil landslides, debris flows, falls and sinkholes. overlying bedrock on sloping surfaces when water **Mudslide (or Mudflow or Debris Flow)—**A rapidly accumulates in the ground, such as during river of rock, earth, organic matter and other heavy rainfall or rapid snowmelt. Water pressure in the materials saturated with water. pore spaces of the material increases to the point that

Sinkhole—A collapse depression in the ground the internal strength of the soil is drastically weakened. with no visible outlet. Its drainage is The soil's reduced resistance can then easily be subterranean. It is commonly vertical-sided or overcome by gravity, changing the earth into a flowing funnel-shaped. river of mud or "slurry." A debris flow or mudflow can move rapidly down slopes or through channels, and can strike with little or no warning at avalanche speeds. The slurry can travel miles from its source, growing as it descends, picking up trees, boulders, cars and anything else in its path. Although these slides behave as fluids, they pack many times the hydraulic force of water due to the mass of material included in them. Locally, they can be some of the most destructive events in nature. A sinkhole is a collapse depression in the ground with no visible outlet. Its drainage is subterranean, and it is commonly vertical-sided or funnel-shaped.

All these mass movements are caused by a combination of geological and climate conditions. These include steep topography, as well as the encroaching influence of urbanization. The cool, rainy Pacific Northwest climate ensures that soil moisture levels remain high throughout most of the year, and in fact are often at or near saturation during wet winter months. The geological conditions of western Washington are primarily a legacy of repeated episodes of glacial advance and retreat during the past 2 million years, and one of the most active erosive processes in the 13,000 years since the last ice disappeared has been mass wasting—the action of landslides and mudslides. These vulnerable natural conditions are being steadily affected by human residential, agricultural, commercial and industrial development and the infrastructure that supports it.

14.2 HAZARD PROFILE

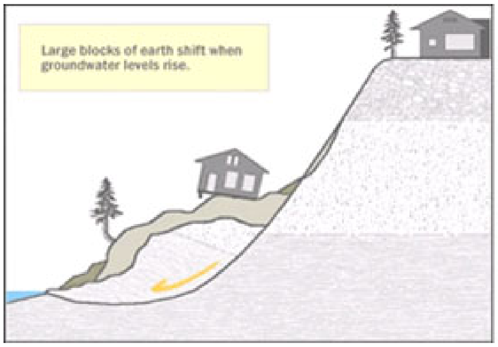
Landslides are caused by one or a combination of the following factors: change in slope of the terrain, increased load on the land, shocks and vibrations, change in water content, groundwater movement, frost action, weathering of rocks, and removing or changing the type of vegetation covering slopes. In general, landslide hazard areas are where the land has characteristics that contribute to the risk of the downhill movement of material, such as the following:

- A slope greater than 33 percent
- A history of landslide activity or movement during the last 10,000 years
- Stream or wave activity, which has caused erosion, undercut a bank or cut into a bank to cause the surrounding land to be unstable
- The presence or potential for snow avalanches
- The presence of an alluvial fan, indicating vulnerability to the flow of debris or sediments
- The presence of impermeable soils, such as silt or clay, which are mixed with granular soils such as sand and gravel.

Flows and slides are commonly categorized by the form of initial ground failure, but they may travel in a variety of forms along their paths. Figures 14-1, 14-2, 14-3 and 14-4 show common types of slides in the Puget Sound region and in Snohomish County. The most common is the shallow colluvial slide, occurring particularly in response to intense, short-duration storms. The largest and most destructive are deep-seated slides, although they are less common than other types. Puget Sound's shoreline contains many large, deep-seated dormant landslides. Occasionally large catastrophic slides occur on Puget Sound.

The preponderance of landslides occurs in January after the water table has risen during the wet months of November and December. In addition to the coastal bluffs, land sliding is most prevalent around the slopes of the Puget Sound's steep, linear hills. Water is involved in nearly all cases; and human influence has been identified in more than 80 percent of reported slides.

Alt Text for Figure 14-1. Deep Seated Slide Graphic of a house in a deep seated slide labeled--Large blocks of earth shift when groundwater levels rise. Alt Text for Figure 14-2. Shallow Colluvial Slide Graphic of a house in a shallow colluvial slide labeled--A thick layer of soil and debris moves rapidly down a steep slope.



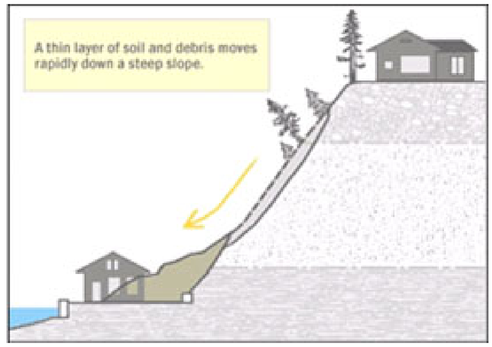
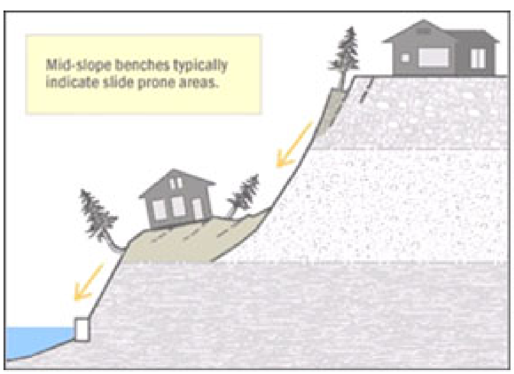


Figure 14-1. Deep Seated Slide Figure 14-2. Shallow Colluvial Slide

Alt Text for Figure 14-3. Bench Slide Graphic of a house in a bench slide labeled--Mid-slope benches typically indicate slide prone areas. Alt Text for Figure 14-4. Large Slide Graphic of a house in a large slide labeled--A large slide cuts deep into the slope, depositing tons of soil and debris at the base.



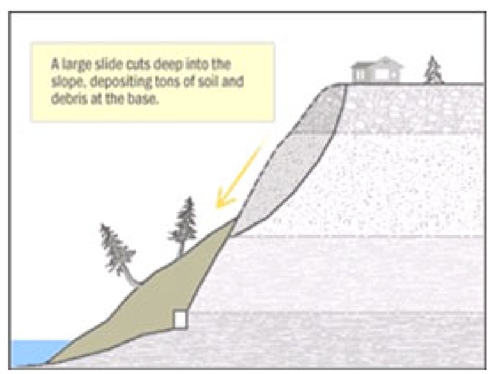


Figure 14-3. Bench Slide Figure 14-4. Large Slide

14.2.1 PAST EVENTS

There is little recorded information for Snohomish County regarding landslides. During the winter storm of 1996-97, more than half of the County's $60-70 million in reported damage occurred as a result of landslides, mudslides and debris flows. Drainage systems and catchment basins could not handle the volume of runoff, focusing the water's energy against vulnerable slopes and man-made structures. In some cases, saturated soils simply became overloaded with the weight of snow and rainwater and collapsed. Private homeowners, particularly in areas where natural drainage has been paved, diverted or otherwise modified by man, reported significant damage. Landslide and mudslide/debris flow activity during this storm caused widespread disruption of surface transportation, closing roads and in one case derailing mail cars from a freight train. The costs of repairing road damage totaled tens of millions of dollars. Given the volume of hazardous substances shipped by road and rail through Snohomish County, it was fortunate that no serious chemical spills occurred as a result of these incidents.

A large slide occurred in Woodway, just north of the Richmond Beach neighborhood, during the early morning of January 15, 1997. It cut 50 feet into the property above, passed over the railroad tracks and knocked a freight train into Puget Sound (see Figure 14-5). Initial estimates placed the volume of the slide at 200,000 to 260,000 cubic yard, but later estimates based on additional data ranged from 100,000 to 200,000 cubic yards. The head of the slide is downslope from the Rosary Heights Convent. The bluff here is about 250 feet high, and the head scarp appears to be about 350 feet wide. The slide deposit extended from the base of the scarp across railroad tracks and into Puget Sound. Except for a large, partially intact slide block resting at the base of the scarp, the deposit consisted mostly of remolded sand and silt, containing logs and boulder-sized, joint-bounded blocks of intact Lawton clay. The remolding indicates that much of the slide broke apart and mobilized into a debris flow.

There are no records in the County of fatalities attributed to mass movement. However, across the Pacific Northwest, a number of deaths have occurred as a result of slides, slope collapses and sinkholes.

Figure 14-5. 1997 Woodway Slide

14.2.2 LOCATION

Map 14-1 shows the landslide hazard areas in Snohomish County. The basis of the mapping is as follows:

- Any area with a combination of:
  - Slopes greater than 33 percent
  - Impermeable soils (typically silt and clay) frequently interbedded with granular soils (predominantly sand and gravel)
  - Springs or groundwater seepage
- Any area that has shown movement during the Holocene epoch (from 12,000 years ago to present), or that is underlain by mass wastage debris of that epoch
- Any area potentially unstable as a result of rapid stream incision, stream bank erosion or undercutting by wave action
- Any area that shows evidence of, or is at risk from, snow avalanches
- Any area located on an alluvial fan, presently subject to or potentially subject to inundation by debris flows or deposition of stream-transported deposits.

The recognition of ancient dormant mass movement sites is important in the identification of areas susceptible to flows and slides because they can be reactivated by earthquakes or by exceptionally wet weather. Also, because they consist of broken materials and frequently involve disruption of groundwater flow, these dormant sites are vulnerable to construction-triggered sliding.

14.2.3 FREQUENCY

Landslides are often triggered by other natural hazards such as earthquakes, heavy rain, floods or wildland fires, so landslide frequency is related to the frequency of these other hazards. In Snohomish County, landslides typically occur during and after major storms.

Recent events occurred during the winter storm of 1996-97 and the October 2003 storm, which generated a few landslides, but not as many as expected, since the soil and bedrock in hilly areas were relatively dry. Recent events also occurred during the winter storms of 2006, 2007 and 2009.

14.2.4 SEVERITY

Landslides destroy property and infrastructure and can take the lives of people. Slope failures in the United States result in an average of 25 lives lost per year and an annual cost to society of about $1.5 billion. The 1996-97 storm caused about $30 million to $35 million in damage due to landslides, mudslides and debris flows. This was about half of all damage caused by the storm. The landslides caused by the storm also caused tens of millions of dollars of damage to road infrastructure.

14.2.5 WARNING TIME

Mass movements can occur suddenly or slowly. The velocity of movement may range from a slow creep of inches per year to many feet per second, depending on slope angle, material and water content. Some methods used to monitor mass movements can provide an idea of the type of movement and the amount of time prior to failure. It is also possible to determine what areas are at risk during general time periods. Assessing the geology, vegetation, and amount of predicted precipitation for an area can help in these predictions. However, there is no practical warning system for individual landslides. The current standard operating procedure is to monitor situations on a case-by-case basis, and respond after the event has occurred. Generally accepted warning signs for landslide activity include:

- Springs, seeps, or saturated ground in areas that have not typically been wet before
- New cracks or unusual bulges in the ground, street pavements or sidewalks
- Soil moving away from foundations
- Ancillary structures such as decks and patios tilting and/or moving relative to the main house
- Tilting or cracking of concrete floors and foundations
- Broken water lines and other underground utilities
- Leaning telephone poles, trees, retaining walls or fences
- Offset fence lines
- Sunken or down-dropped road beds
- Rapid increase in creek water levels, possibly accompanied by increased turbidity (soil content)
- Sudden decrease in creek water levels though rain is still falling or just recently stopped

- Sticking doors and windows, and visible open spaces indicating jambs and frames out of plumb
- A faint rumbling sound that increases in volume as the landslide nears
- Unusual sounds, such as trees cracking or boulders knocking together.

14.3 SECONDARY HAZARDS

Landslides can cause several types of secondary effects, such as blocking access to roads, which can isolate residents and businesses and delay commercial, public and private transportation. This could result in economic losses for businesses. Other potential problems resulting from landslides are power and communication failures. Vegetation or poles on slopes can be knocked over, resulting in possible losses to power and communication lines. Landslides also have the potential of destabilizing the foundation of structures, which may result in monetary loss for residents. They also can damage rivers or streams, potentially harming water quality, fisheries and spawning habitat.

14.4 CLIMATE CHANGE IMPACTS

Climate change will impact storm patterns in Washington. This changing of the hydrograph means that the probability of more frequent, intense storms with varying duration will increase. Increase in global temperature will also affect the snowpack and its ability to hold and store water. Warming temperatures will increase the occurrence and duration of droughts, which will increase the probability of wildland fire, which impacts the vegetation that helps to support steep slopes. All of these factors working in unison would increase the probability for landslide occurrences within the planning area.

14.5 EXPOSURE

14.5.1 Population

Population could not be examined by landslide hazard area because census block group areas do not coincide with the risk areas. A population estimate was made using the structure count of buildings within the landslide hazard areas and applying the census value of 2.65 persons per household for Snohomish County. Using this approach, the estimated county population living in landslide risk areas is 13,642. This approach could understate the exposure by as much as a factor of two, so it is reasonable to assume that the exposed population may be as high as 30,000, roughly 5 percent of the total county population.

14.5.2 Property

Table 14-1 shows the number and assessed value of Snohomish County structures exposed to steep slopes. There are 4,669 structures on parcels exposed to steep slopes, worth an estimated $2.075 billion. Ninety-five percent of the exposed structures are dwellings.

Table 14-2 shows the general land use of parcels exposed to landslides. Lands used for forestry or parks are less vulnerable, while lands used for manufactured homes are highly vulnerable. The predominant land uses for parcels in cities are single-family, vacant and manufactured homes.

These uses as well as timber are the predominant land uses for exposed parcels in unincorporated Snohomish County.

TABLE 14-1. SNOHOMISH COUNTY STRUCTURES EXPOSED TO STEEP SLOPES

Jurisdiction	Buildings Exposed	Assessed Value Structure	Assessed Value Contents	Assessed Value Total	% of AV
Arlington	49	$10,347,000	$9,237,390	$19,584,390	0.9%
Bothell	175	$32,377,900	$22,670,740	$55,048,640	1.9%
Brier	45	$7,032,900	$4,953,420	$11,986,320	1.8%
Darrington	5	$980,700	$979,450	$1,960,150	1.4%
Edmonds	308	$75,028,000	$52,894,210	$127,922,210	1.9%
Everett	467	$208,200,800	$202,950,500	$411,151,300	2.6%
Gold Bar	2	$179,800	$156,130	$335,930	0.2%
Granite Falls	14	$1,570,400	$1,099,280	$2,669,680	0.7%
Index	2	$205,400	$143,780	$349,180	1.5%
Lake Stevens	51	$13,131,900	$9,443,860	$22,575,760	0.6%
Lynnwood	43	$8,192,300	$5,931,830	$14,124,130	0.3%
Marysville	86	$13,778,900	$9,670,700	$23,449,600	0.6%
Mill Creek	10	$22,048,900	$15,434,230	$37,483,130	1.2%
Monroe	37	$9,978,300	$7,053,360	$17,031,660	0.75%

Jurisdiction	Buildings Exposed	Assessed Value Structure	Assessed Value Contents	Assessed Value Total	% of AV
Mountlake Terrace	192	$72,465,600	$50,784,000	$123,249,600	5.7%
Mukilteo	421	$107,087,800	$76,328,490	$183,416,290	4.6%
Snohomish	62	$18,614,200	$15,992,980	$34,607,180	2.8%
Stanwood	7	$667,100	$470,720	$1,137,820	0.1%
Sultan	6	$738,000	$516,600	$1,254,600	0.3%
Woodway	11	$8,004,800	$5,729,760	$13,734,560	3.8%
Unincorporated	2676	$551,288,650	$410,932,140	$972,220,790	2.52%
County Total	**4669**	**$1,161,919,350**	**$903,373,570**	**$2,075,292,920**	**2.1%**

Table 14-2. General Land Use of Parcels Exposed to Landslides

General Land Use	Cities	Unincorporated Snohomish County
Agriculture	35	418
Civic/Government	9	2
Fishery	0	5
Forest	10	238
Hotel/Motel	3	0

General Land Use	Cities	Unincorporated Snohomish County
Industrial/Manufacturing	17	7
Manufactured/Mobile Home	505	1,162
Marine Terminals/Marinas	0	2
Medical/Health	7	0
Mining	13	185
Multi-Family	22	4
Multi-Plex Housing	44	39
Non-Residential Structure	23	161
Open Space	76	162
Other Housing/Group Quarters	1	5
Park/Playground	57	28
Parking	10	0
Recreation/Entertainment	10	33
Reference Account	0	1
Resource Production/Extraction	0	1
Religious	3	6
Retail/Service	115	17

General Land Use	Cities	Unincorporated Snohomish County
Retirement Home/Orphanage	1	0
Roads	11	31
School/Daycare	13	1
Single Family	4,112	4,904
Timber	26	1,150
Transportation	21	61
Vacant	951	4,834
Warehouse	10	1
Water	13	20
Wood Products	1	1
Total	**6,149**	**13,527**

14.5.3 Critical Facilities and Infrastructure

Table 14-3 summarizes the critical facilities exposed to the landslide hazard. No loss estimation of these facilities was performed due to the lack of established damage functions for the landslide hazard. A significant amount of infrastructure (roads, bridges, railroads, and utilities) can be exposed to mass movements. Landslides can block egress and ingress on roads, causing isolation for neighborhoods. Roadway blockages caused by landslides can also create traffic problems, resulting in delays for both public and private transportation. This could result in economic losses for businesses. Other potential problems resulting from landslides are power and communication failures, creating problems for vulnerable populations as well as businesses.

TABLE 14-3. CRITICAL FACILITIES EXPOSED TO LANDSLIDE HAZARDS

Critical Facilities	Hazards
Medical and Health Services	1
Government Function	0
Protective Function	0
Schools	0
Hazmat	0
Other Critical Function	0
Bridges	32
Water	1
Waste Water	2
Communications	0
Total	36

Railroads

The BNSF Railway corridor is exposed to landslides along much of its north-south and east-west routes and spurs. These areas include the tracks located along the Puget Sound bluffs from the King County line up to Everett. The Boeing Spur is located in a ravine and is extremely vulnerable. Other areas exposed to landslides include the bluffs north of Stanwood, the Bothell-Snohomish Branch and tracks located in the Cascade Mountains east of Gold Bar leading to Steven's Pass.

Roads

Many of the major roads in Snohomish County are exposed to mass movement hazards. Access to major roads is crucial to life-safety after a disaster event and to response and recovery operations.

Bridges

Landslides can significantly impact road bridges. Mass movements can knock out bridge abutments or significantly weaken the soil supporting them, making them hazardous for use. Using Washington State bridge data, GIS analysis shows that there are 64 bridges that pass through or over landslide prone slopes.

Power Lines

Power lines are generally elevated above steep slopes; but the towers supporting them can be subject to landslides. A landslide could trigger failure of the soil underneath a tower, causing it to collapse and ripping down the lines. Puget Sound Energy lines pass through steep slope areas.

14.5.4 Environment

Environmental problems as a result of mass movements can be numerous. Landslides that fall into streams may significantly impact fish and wildlife habitat, as well as affecting water quality.

14.6 VULNERABILITY

14.6.1 Population

Due to the nature of census block group data, it is difficult to determine demographics of populations vulnerable to mass movements. In general, all of the estimated 13,642 persons that are exposed to landslides hazards (1.9 percent of total county population) are also vulnerable. Due to Snohomish County's increasing population density and the fact that many man-made structures are built on "view property" atop or below bluffs and on steep slopes subject to mass movement, more lives are now endangered by this hazard than ever before.

14.6.2 Property

A study completed for Seattle Public Utilities in 2000 showed that only about 1 percent of the land area of the region is actually vulnerable to landslides or other mass movements. This study also showed that 84 percent of the slides recorded had human related causes, indicating that people ignore signs of potential disaster in order to possess the most desirable land. Consequently, there is greater potential for damage or destruction to private and public property than if stringent landslide policies were adopted.

Although complete historical documentation of the mass movement threat in Snohomish County is lacking, the effects of slide and flow activity seen during the winter storms of 1996-97 suggest a significant vulnerability to such hazards. Countywide, the millions of dollars in damage attributable to mass movement during those storms affected private property and public infrastructure and facilities.

Loss estimations for the landslide hazard are not based on modeling utilizing damage functions, because no such damage functions have been generated. Instead, loss estimates were developed representing 10 percent, 30 percent and 50 percent of the assessed value of exposed structures. This allows emergency managers to select a range of economic impact based on an estimate of the percent of damage to the general building stock. Damage in excess of 50 percent is considered to be substantial by most building codes and typically requires total reconstruction of the structure. Table 14-4 shows the general building stock loss estimates in steep slope areas.

14.6.3 Critical Facilities and Infrastructure

Thirty-six critical facilities are exposed to the landslide hazard. A more in-depth analysis of the mitigation measures taken by these facilities to prevent damage from mass movements should be done to determine if they could withstand impacts of a mass movement.

Several types of infrastructure are exposed to mass movements, including transportation, water and sewer and power infrastructure. Highly susceptible areas of the county include the mountain and coastal roads and transportation infrastructure. At this time all infrastructure and transportation corridors identified as exposed to the landslide hazard are considered vulnerable until more information becomes available.

14.6.4 Environment

The environment vulnerable to landslide hazard is the same as the environment exposed to the hazard.

TABLE 14-4. ESTIMATED BUILDING LOSSES DUE TO LANDSLIDE HAZARD

Jurisdiction	Building Count	Assessed Value	10% Damage	30% Damage	50% Damage
Arlington	49	$19,584,390	$1,958,439	$5,875,317	$9,792,195
Bothell	175	$55,048,640	$5,504,864	$16,514,592	$27,524,320
Brier	45	$11,986,320	$1,198,632	$3,595,896	$5,993,160
Darrington	5	$1,960,150	$196,015	$588,045	$980,075
Edmonds	308	$127,922,210	$12,792,221	$38,376,663	$63,961,105
Everett	467	$411,151,300	$41,115,130	$123,345,390	$205,575,650
Gold Bar	2	$335,930	$33,593	$100,779	$167,965
Granite Falls	14	$2,669,680	$266,968	$800,904	$1,334,840
Index	2	$349,180	$34,918	$104,754	$174,590
Lake Stevens	51	$22,575,760	$2,257,576	$6,772,728	$11,287,880
Lynnwood	43	$14,124,130	$1,412,413	$4,237,239	$7,062,065
Marysville	86	$23,449,600	$2,344,960	$7,034,880	$11,724,800

Jurisdiction	Building Count	Assessed Value	10% Damage	30% Damage	50% Damage
Mill Creek	10	$37,483,130	$3,748,313	$11,244,939	$18,741,565
Monroe	37	$17,031,660	$1,703,166	$5,109,498	$8,515,830

14.7 FUTURE TRENDS IN DEVELOPMENT

Landslide hazard areas are included in the "geologically hazardous areas," one category of critical areas regulated under the state GMA for Snohomish County. They are defined as follows:

"Landslide hazard areas" means areas potentially subject to mass earth movement based on a combination of geologic, topographic, and hydrologic factors, with a vertical height of 10 feet or more. These include the following:

- Areas of historical landslides as evidenced by landslide deposits, avalanche tracks, and areas susceptible to basal undercutting by streams, rivers or waves
- Areas with slopes steeper than 15 percent that intersect geologic contacts with a relatively permeable sediment overlying a relatively impermeable sediment or bedrock, and which contain springs or ground water seeps
- Areas located in a canyon or an active alluvial fan, susceptible to inundation by debris flows or catastrophic flooding.

Snohomish County's 2007 buildable lands report excludes critical areas from consideration as buildable lands due to the scope of regulations affecting them. Based on the findings of this report, Snohomish County and its planning partners appear to be well equipped to deal with future growth and development within the planning area. The landslide hazard portions of the planning area are regulated by County Code (Title 30.62B) as well as by the International Building Code. Development will occur in landslide hazards within the planning area, but it will be regulated such that the degree of risk will be reduced through building standards and performance measures.

14.8 SCENARIO

Major mass movements in Snohomish County occur as a result of soil conditions that have been affected by severe storms, groundwater or human development. The worst-case scenario for mass movement hazards in Snohomish County would generally correspond with a severe storm that had heavy rain and caused flooding. Mass movement is most likely to occur during late winter when the water table is high. A short intense storm could cause saturated soil to move, resulting in landslides. After heavy rains from November to December, soils become saturated with water. As water seeps downward through upper soils that may consist of permeable sands and gravels and accumulates on impermeable silt, it will cause weakness and destabilization in the slope. As rains continue, the groundwater table rises, adding to the weakening of the slope.

Gravity, poor drainage, a rising groundwater table and poor soil exacerbate hazardous conditions.

Based on historical events and steep slopes with a potential for instability, the most likely landslide areas are Everett, Mukilteo and Edmonds. However, mass movements can occur anywhere in the county that has been affected by historical landslides or that has steep slopes.

Mass movements are becoming more of a concern as development moves outside of city centers and into areas less developed in terms of infrastructure. Most mass movements would be isolated events affecting specific areas. It is probable that private and public property, including infrastructure, will be affected. Mass movements could affect bridges that pass over landslide prone ravines and knock out rail service through the county. Road obstructions caused by mass movements would create isolation problems for residents and businesses in sparsely developed areas. Property owners exposed to steep slopes may suffer damage to either property or building structures. Landslides carrying vegetation such as shrubs and trees may cause a break in utility lines, cutting off power and communication access to residents.

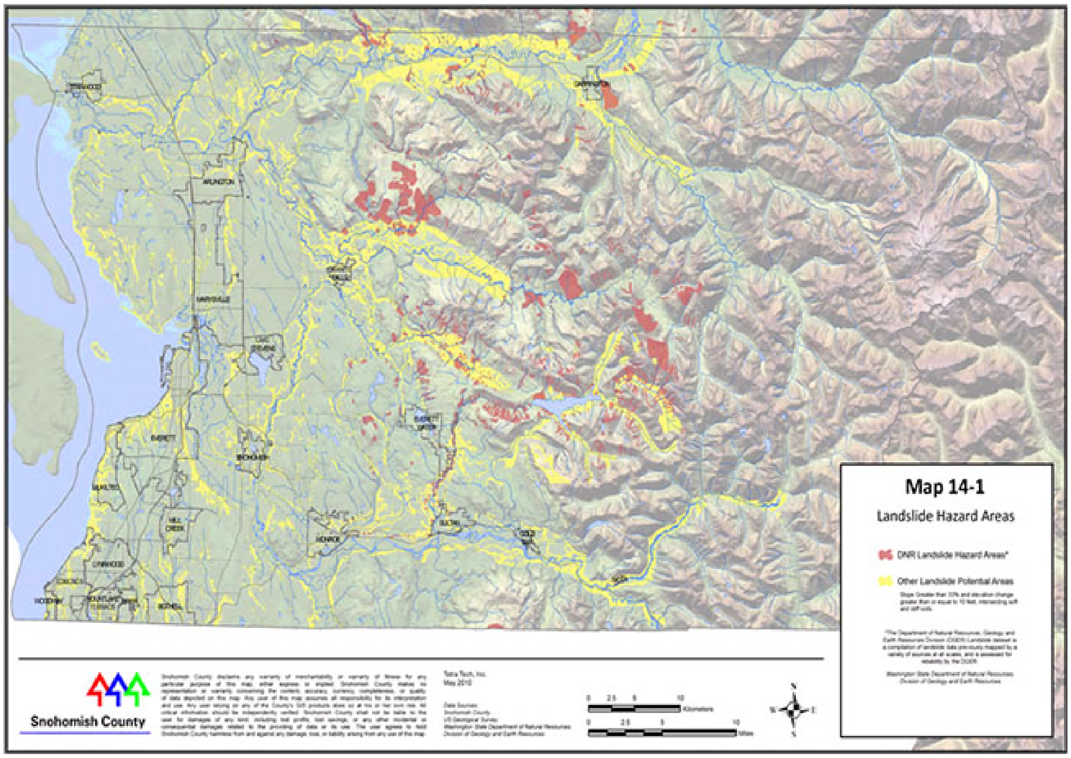
Continued heavy rains and flooding will complicate the problem further. As emergency response resources are applied to problems with flooding, it is possible they will be unavailable to assist with landslides occurring all over Snohomish County.

14.9 ISSUES

Important issues associated with landslides in Snohomish County include the following:

- There are existing homes in mass movement-prone areas, specifically on the Puget Sound shoreline, with the Cities of Everett and Mukilteo being affected significantly.
- Future development could lead to more homes in mass movement prone areas. These areas include the foothills of the Cascades, and steep slope areas above the river floodplains of the North and South Forks Stillaguamish River and the Skykomish River.
- The data and science regarding the mapping and assessment of landslide hazards is constantly evolving. As new data and science become available, assessments of landslide risk should be re-evaluated.
- The impact of climate change on landslides is uncertain. If climate change impacts atmospheric conditions, then exposure to landslide risks in Snohomish County is likely to increase.
- Landslides may cause negative environmental consequences, including water quality degradation.
- The risk associated with the landslide hazard overlaps the risk associated with other hazards such as earthquake, flood and tsunami. This provides an opportunity to seek mitigation alternatives with multiple objectives that can reduce risk for multiple hazards.

Graphical Map 14-1 Landslide Hazard Areas


Map 14-1
Landslide Hazard Areas
DNR Landslide Hazard Areas*
Other Landslide Potential Areas
Snohomish County

Visual 15: Sinkholes

- Sinkhole: A sudden collapse of land surface into a subsurface cavity.
- Rock with salt or gypsum and rock made of limestone are most prone to sinkholes.

Key Points

Gravity doesn't stop working when material is flat on the surface of the Earth. Sinkholes are one result of this scientific reality.

Description: A sinkhole is the sudden collapse of land surface into a subsurface cavity.

Susceptible rock formations: Some rocks are susceptible to dissolving in water and creating sinkholes. Rock with concentrations of salt or gypsum and rock made of limestone are most prone to sinkholes.

Visual 16: Sinkhole Hazard: Evaporite Rocks

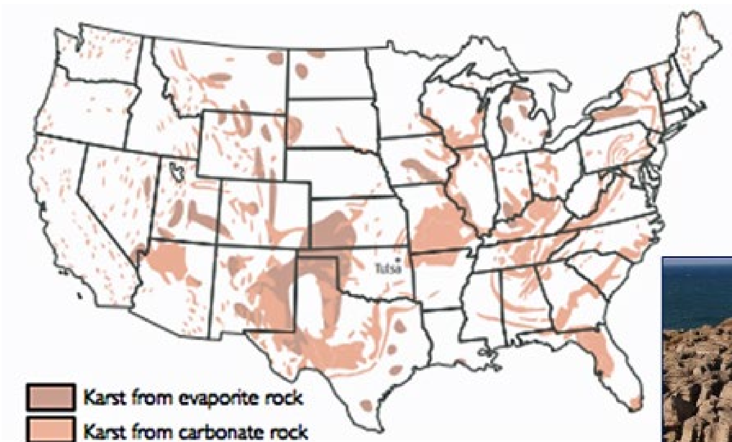
Key Points

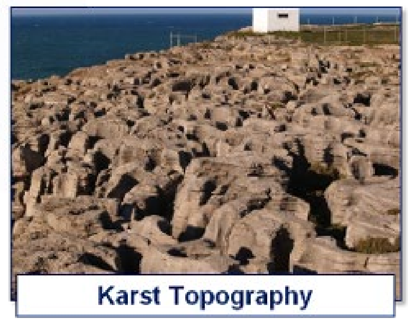
Photo: A 300-foot diameter sinkhole with 18 feet of water in Hutchinson, KS. This sinkhole, attributed to operations at a salt processing company, was stabilized, and the railroad tracks through the center of the hole were relocated.

This map shows areas of the contiguous United States that are underlain by evaporite rocks, which have sufficient quantities of salt and gypsum to pose a sinkhole hazard. Ages ago, these areas were inland seas. They comprise about 40% of the contiguous United States.

Human factors: Regardless of underlying rock type, sinkholes are increasingly common in urban areas with aging water systems. An underground pipe break or crack releases water (sometimes pressurized) that erodes the subsurface. When the subsurface can no longer support the surface, the surface collapses and a sinkhole is formed.

Visual 17: Sinkhole Hazard: Carbonate Rocks





Key Points

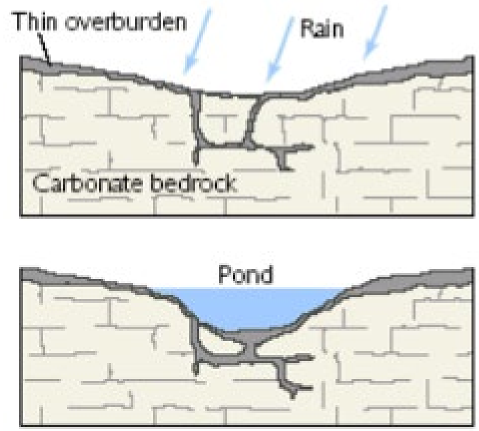
Photo: A map of the U.S. showing Karst from evaporite rock and Karst from carbonate rock. right click on map to open hyperlink This link can also be accessed at [USGS Sinkholes](https://water.usgs.gov/edu/sinkholes.html) (https://water.usgs.gov/edu/sinkholes.html) and Karst topography in Portugal that is above ground and clearly visible.

When evaporite rock (usually containing salt or gypsum) and especially carbonate rock (typically, limestone) dissolve, they form a distinctive terrain called Karst topography, created by the flow of water through pores in the rock. Geographical areas with Karst topography visible on the surface should prepare for the occurrence of sinkholes.

For example, East of Tulsa, OK, about 40 percent of the United States exhibits Karst topography from carbonate rock. (These landscapes also tend to be humid, further promoting sinkhole development.)

Visual 18: How Sinkholes Form

- Rainfall and groundwater movement.
- Dissolution: Cracks and crevices dissolve, transport small soil particles.
- Suffosion: A void develops.
- Slumping or depression at the surface, acting like a funnel.
- Collapse: Weight of overlying ground becomes too great; surface collapses into the void.



Key Points

Sinkholes can be formed by dissolution, by collapse of the covering materials, and by subsidence of the cover.

With dissolution sinkholes, the process begins with rainfall. The groundwater moves through the soil, encountering and dissolving cracks and crevices in the rock (e.g., Karst terrain).

Soon, the cracks and crevices start transporting small soil particles, resulting in formation of a void below (suffusion) and a slumping or depression at the ground's surface.

This depression behaves like a funnel, gathering even more water and washing away more soil below.

At some point, the weight of the overlying ground becomes too great, or the dissolved area becomes too large, and the surface collapses into the void.

More information on the formation of three types of sinkholes is provided on the next page.

Visual 19: Sinkhole Susceptibility

More than 40% of U.S. land is susceptible to sinkholes.

Key Points

More than 40 percent of the land in the United States is susceptible to sinkholes.

As shown on the map, the greatest potential for losses resulting from sinkholes is in:

- Florida.
- Texas.
- Alabama.
- Missouri.
- Kentucky.
- Tennessee.
- Pennsylvania.

Visual 20: Sinkhole Impact

- Can range in size from a few feet across to more than 2,000 feet.
- Can be sudden and incredibly destructive to:
  - People.
  - Property.
  - Subsurface structures.

Key Points

Size and shape: Typically, sinkholes measure in feet across, or tens of feet. Sometimes (but very rarely), they can be hundreds of feet across. The largest known sinkhole is in China and is nearly 2,200 feet across.

Sinkholes also vary in shape—they can be shaped like shallow bowls, saucers, or even have vertical walls.

Impact on people and structures: Sinkholes can be catastrophically destructive to people and structures on the surface.

As an example, in March 2013, a sinkhole 30 feet wide by 30 feet deep opened up under a house near Tampa, Florida, swallowing up a bedroom and the man who was in it. Rescuers were unable to save the man.

Impact on subsurface structures: Sinkholes also pose problems for subsurface structures such as pipelines. This hazard is important enough to the pipeline industry that it has spearheaded study to better identify specific locations at risk from sinkhole development.

Similarly, sinkholes can cause:

- Delay of major construction projects.
- Contamination of groundwater resources.

Visual 21: Sinkhole Hazard Assessments

- Sinkholes occur in localized areas, within regions that are broadly susceptible.
- Small-scale susceptibility maps are only a starting point.
- Intermediate scientific information is available.

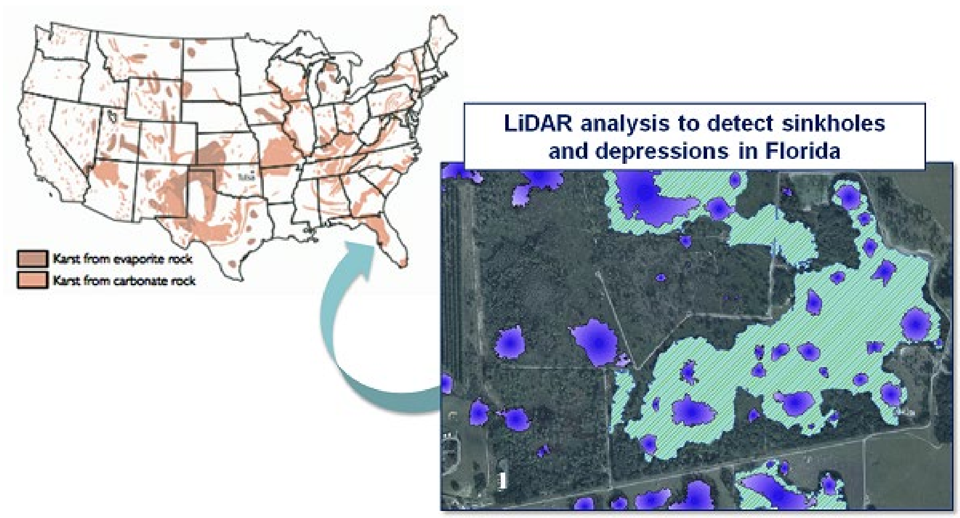
Key Points

Sinkholes occur in localized areas, within regions that are broadly susceptible. Small-scale maps showing the broad areas of susceptibility are only valuable as a starting point to identify areas where more detailed studies are warranted.

There are many scientific methods to get images of the subsurface, but these have not been applied to sinkhole hazard assessments. In most areas, detailed datasets about specific subsurface conditions and Karst topography evolution may never be feasible to maintain and update. (Even if that information were known, the timing of collapse could still be uncertain.)

However, there is scientific information available that is intermediate in map scale and usefulness-intermediate between information that is too broad to be useful in a particular locale, and desired information that is too specific to be feasible except in very limited areas.

Visual 22: Sinkhole Hazard Assessments



Light detection and ranging technology: Aerial photography and airborne LiDAR (Light Detection and Ranging) imaging can identify specific Karst features that may help in planning the location of critical structures. If a region is monitored over time, evolution of these Karst features may provide early warning of dangerous landscape changes.

A particularly interesting study in sinkhole hazard assessments comes from the University of South Florida. This study considers LiDAR mapping of currently visible sinkholes and depressions, as seen in the image here, and compares this with examination of aerial photos from the 1920s to identify sinkholes and depressions that have since been covered by urbanization.

Monitoring groundwater levels: In some places it may be useful to monitor groundwater levels. A 1999 study found that Florida's sinkhole development has to do with pressures at depth, where near-surface groundwater overlies a deeper groundwater reservoir.

Visual 23: Activity 7.2 – Unit 7 IAW

Instructions:

1. Answer the questions in your IAW

Key Points

Instructions:

1. Answer the questions in your IAW

Visual 24: Module Summary

You should now be able to:

- Identify types of ground failures.
- Describe the causes and triggers of ground failures.
- Identify the areas with the greatest risk for ground failures.
- Describe relevant hazard assessment tools and methods.

Key Points

Do you have any questions about the material covered in this unit?

Unit 8: Volcanoes

Visual 1: Unit 8: Volcanoes

Unit 8: Volcanoes

Key Points

Welcome to Unit 8: Volcanoes.

Time Plan

A suggested time plan for this unit is shown below.

Topic	Time
Introduction	5 minutes
Molten Rock	2 minutes
Volcano Geography	5 minutes
Eruption Characteristics	10 minutes
Magma Variables	5 minutes
Precursors	10 minutes
Volcano Impacts	5 minutes

Topic	Time
Volcano Monitoring • Activity 8.1 – Hazard Maps	40 minutes
Unit Summary	5 minutes
Total Time	**1 hour 27 minutes**

Visual 2: Unit Objectives

- Describe the characteristics of volcano formation and eruption.
- Identify variables in the behavior of a volcano.
- Identify expected impacts of a volcanic eruption.
- Describe the methods used to monitor volcanoes and predict eruptions.

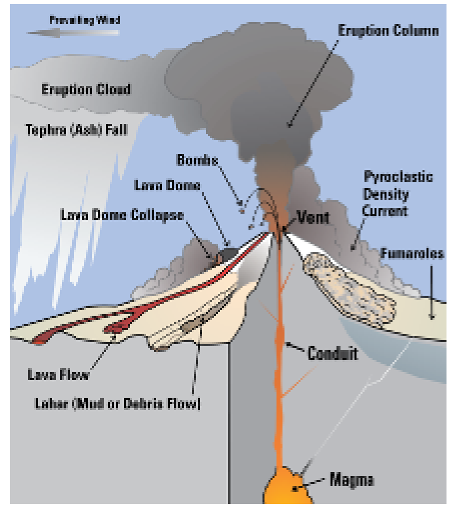
Key Points

Review the module objectives as shown on the visual.

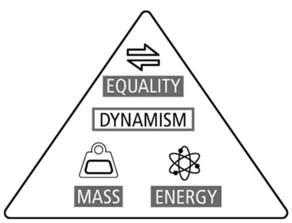
Visual 3: Mount Pinatubo

Visual 4: Key Definitions

- **Volcano:** Landform built by volcanic eruptions
- **Volcanic eruption:** Surface discharge of molten rock and volcanic gas
- **Magma:** Molten rock beneath Earth's surface
- **Lava:** Molten rock at or above Earth's surface



This is equilibrium, dynamism, mass, and energy.



Key Points

Volcanoes and eruptions are complex and varied. As scientists strive to understand volcanic processes, they have had to develop a large number of terms and concepts. Just a few of the basic terms are shown on this visual. We will return to some of these terms later in the module.

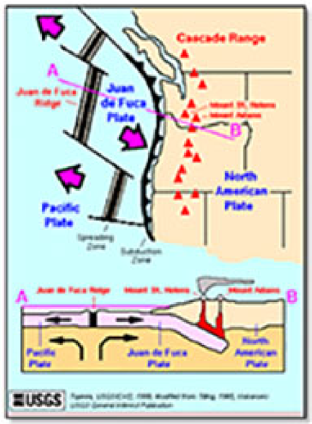
- A **volcano** is a landform—a geographic feature-that exists because of volcanic eruptions.
- A **volcanic eruption** is a surface discharge from a volcano. Note the word "surface." Often, young volcanoes will have subsurface discharges and the subsurface activity may herald a period of unrest. But if nothing reaches the surface, the unrest is a **volcanic crisis,** not an eruption.
- **Molten rock** is a key ingredient in volcanic processes. Volcano scientists need to know whether molten rock has reached the surface or not, and so have two terms:
  - **Magma** is the molten rock beneath the surface.
  - **Lava** is molten rock at or above the Earth's surface.

Also, it is important to note that although most volcano hazards are associated with eruptions, some hazards can occur even when a volcano is not erupting.

Visual 5: Effects of Plate Motion: Volcanoes

- Subduction Zone Volcanoes
- Hot-Spot Volcanoes

Subduction Zone Volcanoes



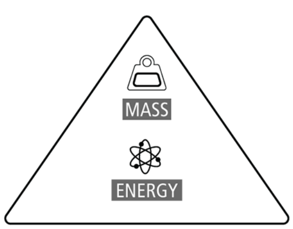
Effects of Plate Motion: Volcanoes Image Description

Image 1: The subduction process melts the rock, which rises as magma, forming long lines of volcanoes above the subducting plate. About 90% of the Earth's volcanoes result from subduction. The Juan de Fuca plate in the Pacific NW is subducting.

Image 2: A map of the pacific ocean with an arrow pointing up and to the left showing the direction of plate motion.

Image 3: A map showing a hot-spot volcano in Hawaii.

This is mass and energy.



Key Points

Plate tectonics aids in our understanding of why the Earth's surface is dynamic and always changing. We have seen several ways in which plate motion affects Earth formations and hazards. The first is volcanoes. Plate motion can create two types of volcanoes:

- **Subduction zone volcanoes:** Plate movement creates volcanoes over subduction zones. The subduction process melts some of the rock, which then rises as magma, forming long lines of volcanoes above the subducting plate. About 90 percent of the Earth's volcanoes result from subduction. The Juan de Fuca plate in the U.S. Pacific Northwest is subducting under the North American plate. The Cascade Volcanic range is a result of this process.
- **Hot-spot volcanoes:** Hot spots are fixed points in the mantle. (The plate moves over the hot spot.) Hot-spot volcanoes are formed when magma flows to the surface and burns a hole in the plate that moves over it. On the visual is a map of the Hawaiian Islands and a corresponding map of the Pacific Ocean floor.

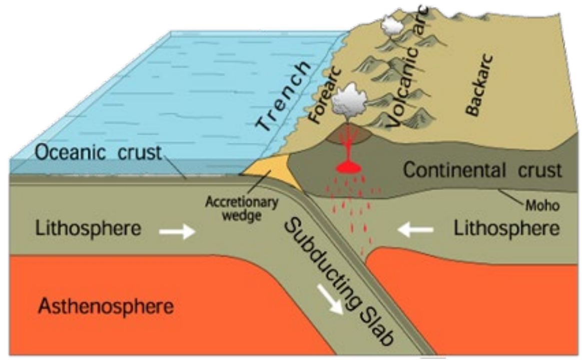
The red circle indicates a hot spot, on which Hawaii currently sits. Other islands in the chain previously sat atop the hot spot and have been moved away as the Pacific plate has moved to the northwest. All of the Hawaiian Islands are composed of volcanoes that at one time erupted with magma originating from the hot spot.

Yellowstone is a hot-spot volcano that erupts rarely, with hundreds of thousands of years between eruptions. Its eruptions are enormous and violently explosive.

Visual 6: Formation of Magma

Necessary conditions:

- Decreases in pressure
- Added water

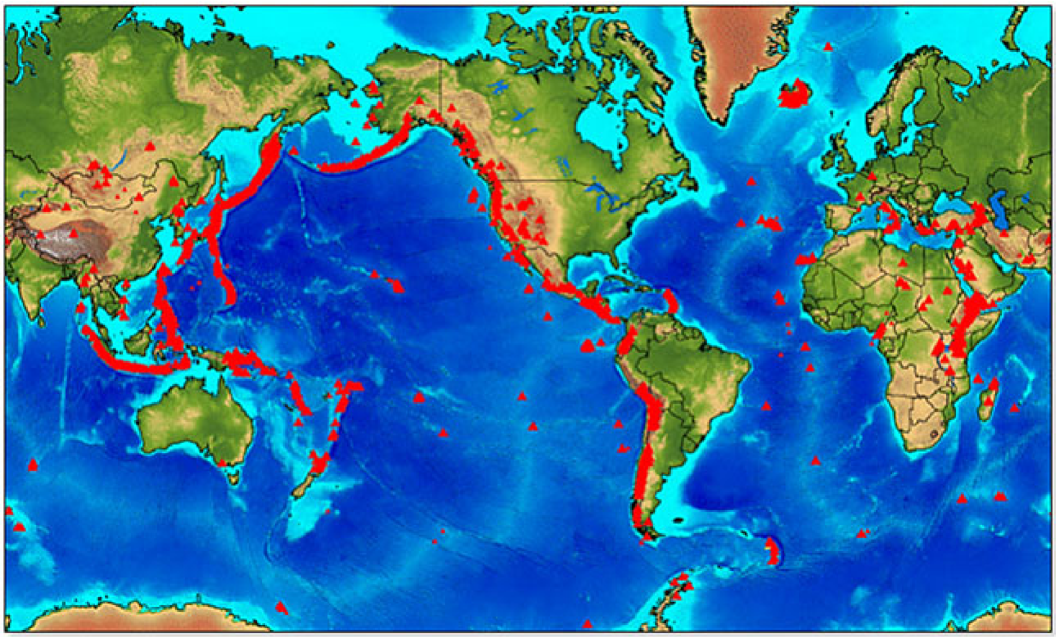


Key Points

Recall from an earlier unit that most of the Earth's mantle consists of solid rock, but there is some molten rock present. It is this molten rock that provides magma to volcanoes. In general, one of two conditions is needed to melt rock into magma:

- **Decreases in pressure:** The melting point of a substance depends on both its temperature and its pressure. Increasing pressure increases the melting temperature of a rock, but a decrease in pressure lower's a rock's melting point. As a result, if solid but 'mushy' mantle rises, it can melt as its pressure drops, even if its temperature does not increase.
- **Added water:** Adding water lowers the melting point of most substances (for instance, wet sugar will melt at a lower temperature than dry sugar). When a plate is subducted, water is driven out as it heats up with depth (the same way water is driven out of wet clothes by heat in a dryer). As water 'cooked out' of the subducting plate accumulates above it, the rock can turn to magma without being heated because its melting point has been lowered.

Visual 7: Known Volcanoes



Key Points

Volcanoes pose a threat to many places in the world, and the largest eruptions have global consequences.

In the last 10,000 years, 1,500 volcanoes have erupted. In recent decades, 50 to 70 different volcanoes have erupted around the world each year. At any one time, about 20 volcanoes are actively erupting. Although the chance is small that any particular volcano will erupt on a given day, it is essentially guaranteed that a volcano will be erupting on any given day.

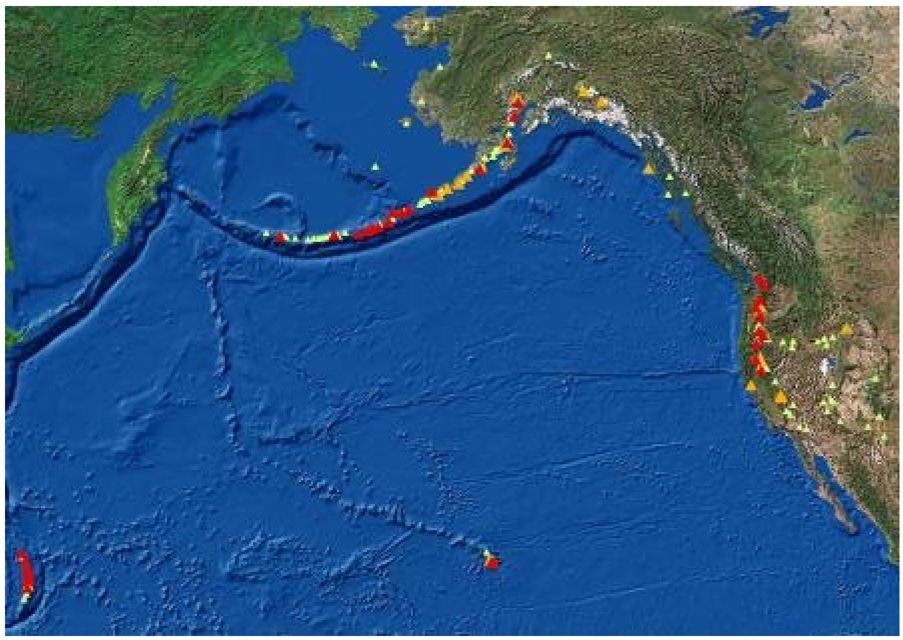
Even more often, volcanoes show signs that eruption may be imminent, resulting in volcanic crises where communities and government entities have to take action or prepare to take action. Unrest periods can go on for years and may or may not lead to eruptions. A single period of unrest may be punctuated with more than one eruption of varying severities and durations.

Triangles on this map indicate locations of known volcanoes in the world. (Remember that "known" does not necessarily mean active.) Recall that volcanoes occur at certain kinds of plate boundaries (and also where there are hot spots). Volcano locations thus tend to delineate plate boundaries; however, volcanoes are hard to count unambiguously.

Visual 8: Active U.S. Volcanoes

Define:

- Active vs. Dormant
- Geologically young



169 “Active” Volcanoes

Key Points

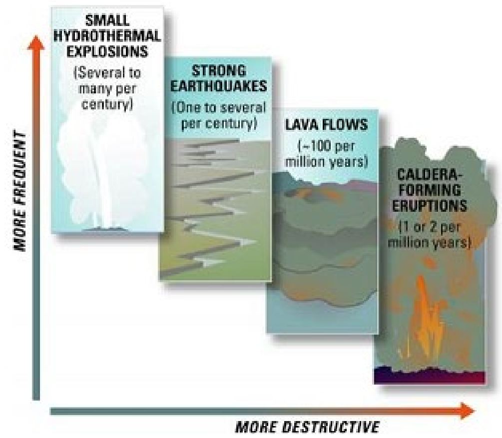
There are 169 volcanoes in the United States that are active-i.e., capable of eruption. These are shown by the colored triangles on the map. Some are much more likely to erupt than others, and are shown in red.

Many scientists, however, are uncomfortable calling a volcano "inactive," as there is no agreed-upon definition of an "active" volcano. Some prefer to identify volcanoes that are geologically young—i.e., those that have been active in the last 10,000 years. (The Smithsonian Institution's Global Volcanism Program database (https://volcano.si.edu/) can be used a resource for these designations. It is updated by ongoing geologic discoveries and improvements to scientific dating of past eruptions.)

In addition, there are areas called "volcanic fields" where an eruption can occur from many sites, rather than from a single distinct structure. Volcanic fields exist in a number of locations in the United States, including Arizona, New Mexico, and within the city limits of Portland, Oregon.

Pauses between eruptions can be as short as months or as long as thousands of years. Some volcanoes erupt only once; most erupt multiple times and result in a large landform.

Visual 9: Yellowstone's Volcanic Field



Yellowstone's Volcanic Field Image Description

A map of a volcanic field in Yellowstone National Park

A graph illustrating disasters that are more frequent versus more destructive.

From Most Frequent and Least Destructive to Less Frequent and Most Destructive are:

- Small Hydrothermal Explosions (Several to many per century)
- Strong Earthquakes (One to several per century)
- Lava Flows (100 per million years)
- Caldera-Forming Eruptions (1 or 2 per million years)

Key Points

The map on the left shows northwestern Wyoming, with the perimeter of Yellowstone National Park (Link can also be found at this URL: https://volcanoes.usgs.gov/volcanoes/yellowstone/) outlined in blue, and the perimeter of the current Yellowstone caldera in orange.

There is no volcanic mountain in Yellowstone, WY. However, there is a volcanic field that produces the largest eruptions in the United States. Yellowstone is a massive hot-spot volcano.

Evidence of ancient hot-spot eruptions exist to the southwest of Yellowstone. These hot spots burned a hole through the North American plate, resulting in the volcanic field. If plate motion does not shift direction, there will eventually be eruptions northeast of Yellowstone.

At some point, a volcano stops producing eruptions, but a volcano can erupt after being inactive for millennia. In fact, the biggest eruptions are the most rare, and as the chart on the right indicates, a supervolcano like Yellowstone keeps active with small steam eruptions, but waits tens of thousands of years between lava flows and waits a million years between eruptions large enough to form volcanic craters called calderas.

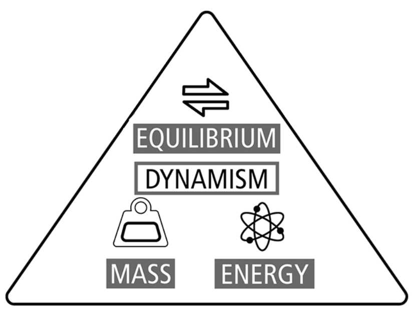
Yellowstone is a good representative of the opposing factors that volcano scientists must juggle in helping society prepare for volcanic eruptions, which are low probability, high consequence events. A Yellowstone eruption is a very low likelihood event, but there is no indication that Yellowstone is "done." At some point, an eruption will occur, and when it does, it will affect the health and economy of the entire Nation and the world.

Visual 10: Eruption Characteristics

Volcanic eruptions vary in:

- Explosivity
- Amount of lava
- Distance the lava travels
- Detectable precursors
- Duration
- Local and global impacts

This is equilibrium, dynamism, mass, and energy.



Key Points

There are several characteristics of volcanic eruptions, including:

- Explosivity.
- Amount of lava.
- Distance the lava travels.
- Detectable precursors.
- Duration.
- Local and global impacts.

In this part of the module, we will look at how variations in molten rock, or magma, influence volcano formation and behavior.

Visual 11: Video: Mount St. Helens Eruption

Key Points

The eruption of Mount St. Helens in Washington State in 1980 was a pivotal event for improving scientific understanding of explosive volcano processes and for coordination of scientific understanding with emergency response.

For more than 4,000 years, Mount St. Helens has been the most active among a chain of volcanoes in the Pacific Northwest, but it had not erupted since the mid-1800s. Its recent eruption timelines offer a good lesson in how suddenly a volcano can become restless, how difficult it can be to have certainty that an eruption is about to start (or end), and how far an eruption's effects can reach.

In this video, USGS scientists recount their experiences before, during, and after the eruption of Mount St. Helens, one of the most dramatic geologic moments in the history of the United States.

Transcript:

Don Swanson: And we were off the ground probably at 9:05 or something like that. It was really, really rapid. And got up to the point where we could really see the mountain well, I suppose, between 9:20 and 9:25. Something like that.

There was this terrific, very vigorous vertical eruption column that was the stem of the mushroom or the toadstool. It then blossomed out at greater height. And, for most of the morning we saw this tremendous ash cloud roiling out toward the northwest, and I can only assume that that was coming off of the big pyroclastic flows that were going off in that direction that later built the pumice plane. It was a very eventful morning, but it was sobering because I remember thinking up in the airplane that Dave just couldn’t have survived this. Especially when we got around to the west side and saw all the ash heading in his direction.

C. Dan Miller: On the morning of May 18, what actually happened . . . the landslide basically uncorked this pressurized body of magma and allowed it to explode or expand out toward the north very rapidly. This is what we call the “lateral blast.” It was a horizontally directed explosion of incredible magnitude. It caused this expanding cloud of ash, rocks, and gases to move out across the countryside to the north at speeds of several hundred miles an hour. The directed blast was really the most destructive event that occurred on the morning of May 18. It completely destroyed an area of 230 square miles in the matter of somewhere between 5 and 9 minutes. It essentially killed every living thing within an area of 230 square miles. And it destroyed hundreds of acres of virgin forest and was an incredibly spectacular event.

Visual 12: The Key to Eruption Style

- Composition
- Viscosity
- Gas emission

Key Points

Key variables of magma that can change an eruption include composition, viscosity, and dissolved gas content (gas emission).

Visual 13: Composition and Viscosity

Viscosity:

- A fluid's ability to resist flow
  - Example: Asphalt is more viscous than corn syrup.

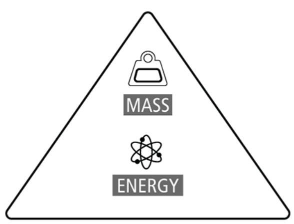
Affected by:

- Amount of silica
- Temperature

More silica content - More viscous

Less silica content - Less viscous

This is mass and energy.



Key Points

Viscosity is a measure of the ability of a fluid to resist flow. If you increase a fluid's viscosity, then you decrease the ability of that fluid to flow. For example, at the same temperature corn syrup is less viscous than asphalt, so it flows more easily. With volcanic fluids, viscosity is affected by the amount of silica and by temperature.

Silica in solid form is the mineral quartz. Different magmas have different amounts of silica. Higher silica occurs in subduction zones, usually because continental rock melts to form the magma, and continental rock is high in silica content.

Different concentrations of silica produce different magma types that when cooled, form different types of rock:

Silica Content	Magma Type	Volcanic Rock

Silica Content	Magma Type	Volcanic Rock
~50%	Mafic	Basalt
~60%	Intermediate	Andesite
~65%	Felsic (low silicon)	Dacite
~70%	Felsic (high silicon)	Rhyolite

For example, Hawaiian magmas are lower in silica, de-gas more easily, and hence produce lava flows that are more effusive. An effusive lava is comparatively “runny” and likely to flow longer distances.

Temperature also affects viscosity, as higher temperatures decrease viscosity (make the magma runnier) and increase flow. (Example: Syrup just out of the refrigerator is more viscous than room temperature syrup.)

Oceanic hot spots such as Hawaii are lower in silica and have a lower viscosity magma. This means that the magmas de-gas more easily, and produce eruptions that are more effusive. An effusive lava is comparatively “runny” and likely to flow longer distances. Oceanic hot spots rarely exhibit cataclysmic eruptions.

Temperature also affects viscosity because higher temperatures decrease viscosity (make the magma runnier) and increase flow. (Example: Syrup just out of the refrigerator is more viscous than syrup at room temperature.) Basaltic magmas like those in Hawaii and Iceland form at higher temperatures than granitic magmas like those at Mount St. Helens. Therefore, not only are the oceanic hot-spot lavas less viscous because of their lower silica content, but they are less viscous because of their higher temperature.

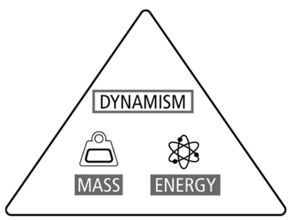
Visual 14: Composition and Explosivity

Less silica content - Less explosive

More silica content - More explosive

Dynamism Mass Energy Icon

This is dynamism, mass, and energy.



Key Points

Why is viscosity important?

Explosivity: More viscous magmas and lavas that cannot flow or de-gas easily are more explosive. Therefore, the less silica content, the less explosive the volcano. The more silica content, the more explosive.

There is a great range in the explosivity of volcanic eruptions. Many eruptions are relatively calm, with nonviolent extrusion of lava flows. Others are highly explosive and are characterized by the violent ejection of fragmented volcanic debris. This variation depends on the composition of the magma, and in particular on the amount of silica in the melt.

Volcano shape and size: The factors that affect explosivity, how much lava will erupt, and how far lava will travel, also influence the shape and size of a volcano. Most volcanoes have characteristic eruptive styles and thus a characteristic shape. On this visual are three examples of distinctly shaped volcanoes. Moving from left to right goes from least to most explosive, and from less to more silica content.

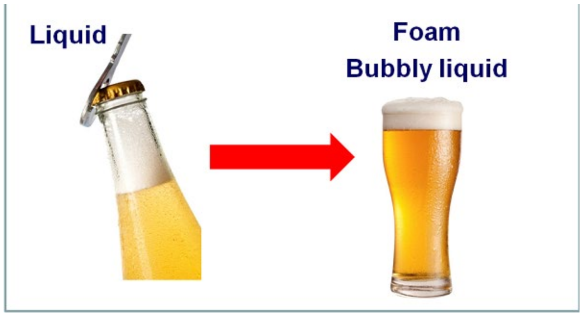
- At left is Mauna Loa in Hawaii.
- In the middle is Mount Shasta and Shastina, California.

- On the right is what is left of Mount Aniakchak in Alaska after the volcano blew itself apart in an explosive eruption some 3,700 years ago. (Such an eruption today would affect air traffic worldwide for months.)

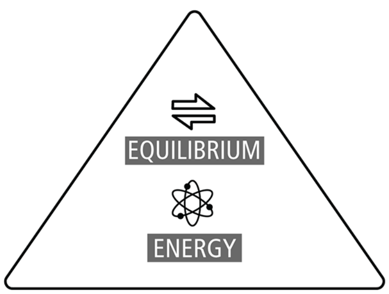
Although a volcano's shape tells scientists important information about past eruptions, any volcano can change its eruptive style during the next eruption. A single volcano can (and often does) have mixtures of magma types and thus many styles of eruption.

Visual 15: Gas Emission (1 of 2)

Gas content of the magma affects explosivity.



This is equilibrium and energy.



Key Points

Gas emission is another variable that affects volcanic behavior. Magmas include varying degrees of volcanic gases such as water vapor, carbon dioxide, and sulfur dioxide.

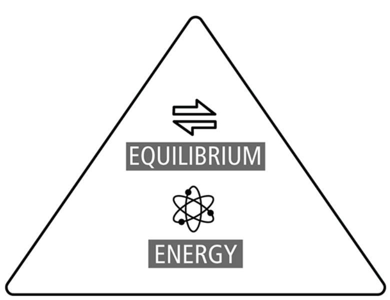
Deeper in the Earth where pressure is higher, the gas is contained in the liquid, much like gas is contained in a carbonated liquid within a pressurized container. If the pressure is released on a bottle by opening the cap, the liquid degasses quickly. First, the foamier and gassy contents will be released, and then the liquid will follow.

Similarly, in a volcanic eruption, there can be rapid changes in pressure as the magma ascends, allowing trapped gas to escape explosively. Although the magma is not always shaken in a volcanic eruption, the escape of gas can be explosive depending on the amount of gas present and the buildup of pressure.

Visual 16: Gas Emission (2 of 2)

The explosivity of an eruption at the surface is affected by how easily the gases escape the magma before eruption.

This is equilibrium and energy.



Key Points

The extent to which the liquid magma and gas can separate before the eruption starts affects eruption behavior. This separation occurs as a result of the following process:

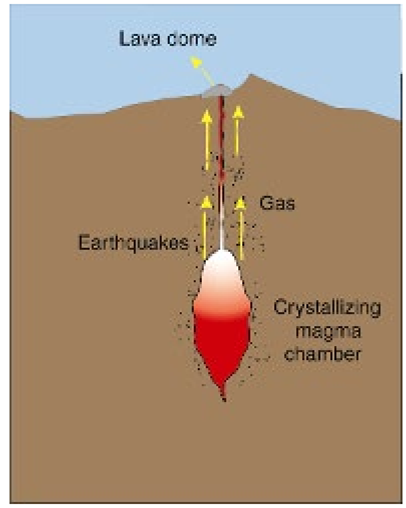
1. As magma rises toward the surface where pressure is lower, gases begin to form tiny bubbles. These take up more volume than the gas did previously, making the magma less dense, more buoyant, and allowing it to continue its upward journey.
2. Closer to the surface, the bubbles increase in size and number. Sometimes, the gas volume exceeds the melt volume, creating a magma foam.
3. Dissolved gases in the magma are released into the atmosphere during eruptions. Water vapor, carbon dioxide, and sulfur dioxide are the most common gases released.

It is more difficult for gas to escape a viscous lava, making explosion more likely when the gas-filled magma reaches the surface.

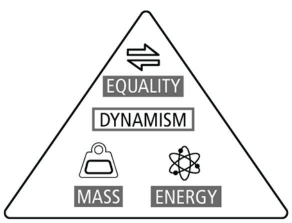
Although the explanation for why volcanoes stop erupting is complex, the simple answer is that as magma reservoirs become depleted of hot gassy magma, they lose their driving force, which is excess buoyancy.

Visual 17: Precursors—Signs of Restlessness

- Number of earthquakes
- Occurrence of style tremor-type earthquakes
- Degassing
- Deformation of the ground
- Thermal output
- Precursors may give lead time (often but not always)



This is equality, dynamism, mass, and energy.



Key Points

Precursors help scientists predict volcanic eruptions. There are several important eruption precursors including:

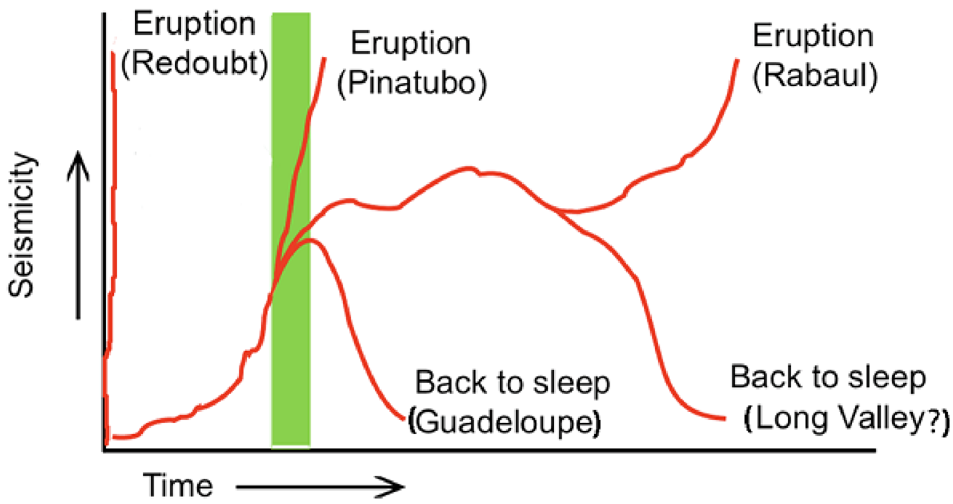
- Number of earthquakes.
- Occurrence of a style of earthquake called tremor.
- Degassing.
- Deformation of the ground.
- Thermal output.

All of these precursory signals are caused by processes associated with magma migration toward the surface.

Magma accumulates a few miles below a volcano. Before an eruption, magma ascends toward the surface through narrow conduits. The magma changes the volume of the rock, and breaks rock, which produces earthquakes. Moving magma and escaping gas can also produce distinctive styles of earthquake together called volcanic tremor.

As magma migrates, it often deforms the volcano or nearby land because of increases and decreases in volume. An increasing volume of hot material will heat groundwater and can change spring water chemistry. Then, gases escape from the magma when the magma reaches lower pressures near the surface.

Visual 18: Seismicity as a Precursor



Key Points

Seismicity—the number and characteristics of earthquakes near the volcano—is a key indicator.

As magma rises it often causes small earthquakes. Sometimes an increase in the seismicity indicates eruption is imminent.

What the graphic shows: This plot shows the behavior of five recently restless volcanoes (Redoubt, Pinatubo, Guadeloupe, Rabaul, and Long Valley) vs. the number of earthquakes near the volcano over time. (Similar plots could be made for other indicators of volcanic unrest, such as gas emission.) In this case the timeframe is months to years, but other examples could be shown that would be in hours, days, or decades.

Visual 19: Impacts of Volcanic Activity

- Destruction of life and property
- Health effects
- Economic impacts
- Environmental effects
- Disruption of travel and communications
- Ground deformation
- Tsunamis triggered by marine eruptions

Key Points

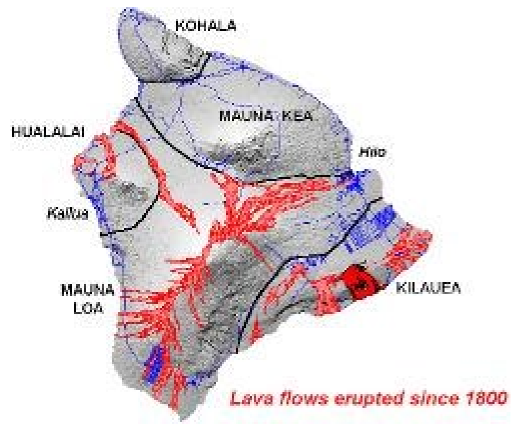
Although eruption styles and intensities vary, a wide array of impacts can generally be seen, including:

- Destruction of life and property.
- Health effects.
- Economic impacts.
- Environmental effects.
- Disruption of travel and communications.
- Ground deformation.
- Tsunamis triggered by marine eruptions.

Long durations of volcanic events (extended eruptions or long periods of unrest) can create significant economic and health impacts. Among the health impacts are mental and physical fatigue, which can impede good decision-making and appropriate action. This impacts animals and plants as well. Plant death can lead to wildfires. In addition, a psychological reaction to extended periods of official alert is to redefine what “normal” is and accept the new conditions as average.

Visual 20: Near Source: Lava Flows

- Have impact near eruption path
- Destroy everything in path
- Follow valleys
- Slow-moving speeds from miles per hour (Hawaii) to inches per hour (St. Helens)
- Likely to kill someone who is unaware
- Devastating to ecosystems and property



Near Source: Lava Flows Image Description

Hawaii: Lava flows erupted since 1800 (This link can also be accessed at the following URL: https://hvo.wr.usgs.gov/maunaloa/hazards/historicalflows.html)

Key Points

Lava flows:

- Have impact near the eruption source.
- Destroy everything in their path.
- Follow paths that can be anticipated-typically through valleys.
- Are relatively slow moving.
  - Less viscous lava flows, such as those on Hawaii, move at speeds of miles per hour.
  - Viscous, high-silica lava travels inches per hour.
- Are most likely to kill someone who is caught unaware.
- Are devastating to ecosystems and property because their high temperatures (often 800 oF) destroy everything in their path.

Visual 21: Near Source: Volcanic Gases

- Produced during and between eruptions
- Can cause:
  - Asphyxiation
  - Asthma
  - Respiratory disease
  - Eye and skin irritation
  - Impacts on vegetation

Key Points

During and between eruptions, volcanoes produce several different acidic gases, including sulfur dioxide and hydrogen chloride. Volcanic gases occur in highest levels near volcanoes that are actively degassing, and can cause a variety of health problems, including:

- Asphyxiation
- Asthma
- Respiratory disease
- Eye and skin irritation
- Impacts on vegetation

For example, the trees in this photo are dying from high concentrations of carbon dioxide gas in the soil from subsurface volcanic activity at Long Valley Caldera, also known as Mammoth Mountain.

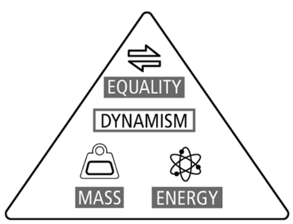
The only protection from these gases is relocation.

Visual 22: Near Source: Pyroclastic Density Currents

- Consist of rolling, superheated mixtures of gas and particles
- Include ash flows, blasts, pyroclastic flows, and surges
- Are most-destructive volcanic hazards
- Destroy life and property
- Are unpredictable

Equality Dynamism Mass Energy Icon

This is equality, dynamism, mass, and energy.



Key Points

Pyroclastic density currents (PDCs), also called pyroclastic flows, are another near-source hazard.

PDCs:

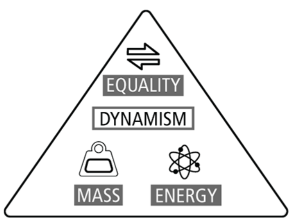
- Are roiling, superheated mixtures of gas and particles that move faster than 100 miles per hour and can blanket a landscape, obliterating everything in their path
- Include ash flows, blasts, pyroclastic flows, and surges
- Are the most devastating of all volcanic hazards, with a long history of destruction of life and property
- Are unpredictable in their path and occurrence

Ancient Pompeii was destroyed by a PDC during an eruption of Mount Vesuvius.

The photo shows a pyroclastic flow during the Mount St. Helens eruption of 1980, which we looked at earlier in this module.

Visual 23: Near Source: Lahars and Floods

- Rapidly flowing mixture of rock, debris, and water.
- Carry debris and destroy everything in their path.
- Speeds up to 80 mph.
- Can travel hundreds of miles.
- Often the long-lived threat after eruption.



This is equality, dynamism, mass, and energy.

Key Points

A lahar is a rapid volcanic mudflow of up to 80 mph. Lahars:

- Carry a mixture of rock, debris, and water, destroying everything in their path.
- Are the volcanic equivalent of a debris flow; in fact, scientists who study one hazard sometimes collaborate with those who study the other.
- Can occur during or between eruptions.
- Are the most far-reaching of volcanic hazards that are ground based (as opposed to air based) and can travel hundreds of miles.
- Are often the long-term threat after eruption.

Lahars can form in a variety of ways, such as:

- When a pyroclastic flow or steam eruption melts snow and ice on a volcano.
- By breakout of a lake dammed by volcanic deposits.
- During intense rainfall on loose volcanic deposits.

Visual 24: Global/Regional Effects: Ash

- Consists of tiny particles that may contain noxious chemicals.
- Causes destruction in the air and on the ground
- Buries plants.
- Poisons livestock.
- Contaminates water supplies.

Key Points

Photo: NASA image of the ash plume from an Icelandic eruption in 2010 that disrupted worldwide aviation for weeks.

An effect that reaches beyond the local hazard area is ash, generated by an explosive volcanic eruption. Ash:

- Consists of tiny particles, fractions of an inch in size.
- Is typically composed of silica—essentially microscopic glass—and may also contain noxious chemical substances.
- Can cause destruction while in the air and when it reaches ground. Even minor amounts cause significant impacts on infrastructure, lifelines, and industry including aviation, ground transportation, communications, utilities, and farming.
- Buries plants, poisons livestock, and contaminates water supplies. In water it becomes extremely abrasive. Ash inhalation and contact have many health consequences for animals and humans.
- Short-term effects include:
  - Asthma, bronchitis, and irritation of airways.
  - Increased risk of stroke or heart attack.
  - Skin and eye irritation.
- Long-term effects include:
  - Chronic obstructive pulmonary disease.
  - Tuberculosis.
  - Pneumoconiosis.
  - Fluorosis.
  - Silicosis and other lung fibrotic diseases.

Visual 25: Deaths by Volcanic Hazards

Volcanic Hazards	1600 – 1982	1900 – 2015
1. Disease/starvation	95,313 (40%)	3,163 (4%)
1. PDC/avalanche	55,695 (23%)	37, 216 (49%)
1. Tsunami	44,356 (19%)	407 (0.5%)
1. Unknown causes	17,182 (7%)	2,133 (3%)
1. Lahar and flood	14,746 (6%)	29,438 (38%)
1. Regional ash fall	10,953 (5%)	3,899 (5%)
1. Lava	305 (0.2%)	75 (0.1%)
1. Gas/acid rain	185 (0.1%)	183 (0.2%)
Total	**238,867**	**76,514**

Lahar and secondary-caused floods can cause many deaths.

Key Points

Deaths from volcanoes can result from many different types of hazards.

This table shows a breakdown of deaths by volcanic hazards for eruptions between 1600 and 1982. Notice that for both time periods, pyroclastic density current (PDC)/avalanche was one of the top two causes of fatalities.

Lahar and secondary-caused floods can cause many deaths.

Instructor Note

With respect to lahar and flood, 23,000 deaths were from a single event at Nevado del Ruiz, which is a volcano in Colombia. A volcanic eruption melted the volcano’s glaciers, creating a lahar that flowed at speeds greater than 50 kilometers per hour and completely destroyed the village of Amero. A total of 20,000 inhabitants died in Amero and another 3,000 died in other

	villages. Advances in communications and transportation have shifted why people die from volcanoes.

Visual 26: Volcanic Monitoring

- Major goal: improving forecast accuracy.
- Best achieved by monitoring earthquakes, deformation, and gases.
- Contributes to hazard assessment, emergency planning, and notifications.

Even well-monitored events involve uncertainty, ambiguity, and missing data.

Key Points

How volcanoes are monitored: Volcanology is the study of volcanoes. A major goal of volcanology is to improve the accuracy of forecasting. Because most volcanoes enter periods of unrest before eruption, monitoring volcanoes for signs of activity provides the best chance of reducing eruption impacts. Signs of activity can vary, and monitoring is best achieved by looking at earthquakes, ground deformation, and volcanic gases. Scientists employ an arsenal of skills and methods to observe and detect the great variety and wide scale of changes volcanoes can make to Earth, air, and water.

- **Earthquake** seismometers must detect energy of different wavelengths.
- **Ground deformation detection** includes techniques from satellite radar, to real-time GPS, to leveling surveys.
- **Satellite, airborne, and in-person methods** are used to sample gas emissions.
- During eruptions, volcanoes generate their own weather, so **worldwide lightning detection** is also a method employed for situational awareness.

Monitoring in the United States: During an eruption, monitoring remains a critical tool to understand what will happen next. In the United States, the USGS has statutory responsibility to monitor U.S. volcanoes and to issue alerts and warnings about volcanic unrest and eruption. It is currently developing a volcano early warning system. However, not all active volcanoes are currently monitored, including some that pose high risk.

Forecasting: For an eruption forecast to be useful, it needs to identify:

- When the eruption will begin
- How long it will last
- How severe it will be
- Then the eruption is over (although unrest might continue)

However, it is important to keep in mind that even well-monitored events involve uncertainty, ambiguity, and missing data.

Visual 27: Volcanic Monitoring and Emergency Management

- Hazard assessment
- Emergency planning
- Notifications

Key Points

Contributions to emergency management: Volcanic monitoring contributes to emergency management in several ways:

- **Hazard assessment:** Before unrest, scientists focus on an individual volcano or hazardous process to develop a hazard assessment, which is based on an understanding of volcanic processes in general and on the history and likely behavior of a particular volcano or process. To fully quantify the hazard in space and time, a hazard assessment will include:
  - Geologic mapping of the volcano
  - Accurate topography from a digital elevation model
  - Analyses of past eruptions at that volcano
  - Knowledge of Local wind directions and other weather features

  Hazard assessments will change as conditions change, including landscape changes and increases in understanding.
- **Emergency planning:** Response plans are in place at the national and regional levels to deal with the widespread potential effects of ash eruptions.

  Developing such plans requires the combination of scientific and emergency management expertise, and the participation of numerous agencies and organizations to delineate interagency roles and coordination requirements for events that can have Local, regional, and national impacts. There exist scattered Local plans for individual volcanoes, but as is true with other hazards, it is difficult to engage communities in preparations for rare events.
- **Notifications:** When a volcano becomes restless, or finally erupts, scientific scrutiny greatly increases. Monitoring of that volcano, its hazard assessment, and understanding of volcanic processes are all more generally brought to bear, quickly, to produce Volcano Activity notifications. These notifications are available by subscription and on the web. Weather science is combined with Earth science to produce special weather statements from the National Weather Service.

During an eruption or crisis, the scientists who create these messages, and those who receive them, must grapple with the difficulty of communicating information and making decisions in a situation with great inherent uncertainty.

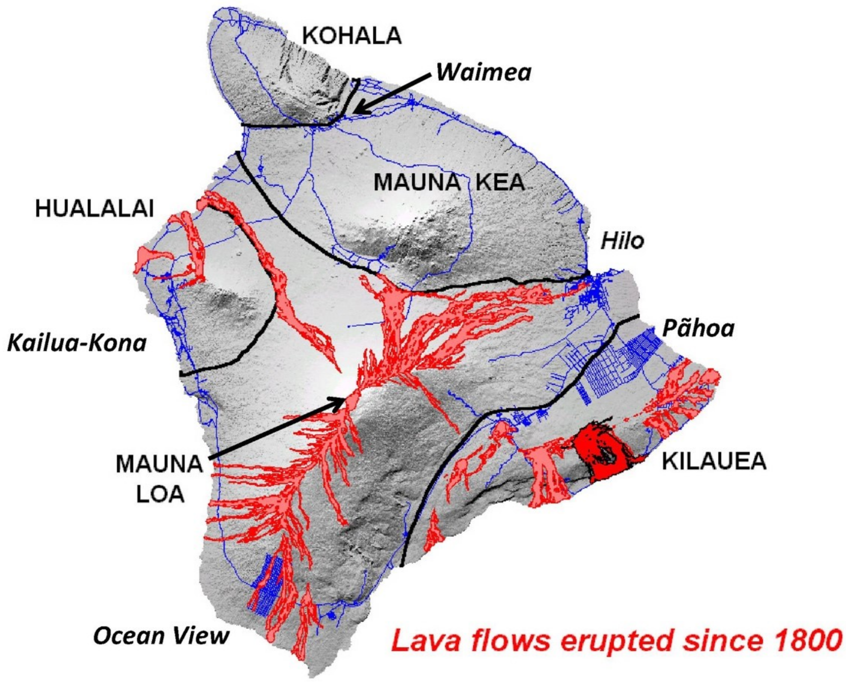
For more information: Ground-based Volcano Alert Levels and Aviation Color Codes (This link can also be accessed at the following URL: https://volcanoes.usgs.gov/vhp/alert_icons.html)

Visual 28: Activity 8.1 – Hazard Maps

Instructions: Working in your table groups…

1. Review the lava flow map and the hazard map assigned to your group
2. Identify the hazards present, based on the hazards covered in this module, and evaluate the risk (e.g., critical, high, medium, low, very low). Consider the extent and the timeframe of the hazard.
    - For those risks deemed critical or very high, what steps should be taken to prepare for these hazards?
1. Using easel paper, create a list of actions to undertake
2. Select a spokesperson and be prepared to present your answers to the class

Lava Flow Map

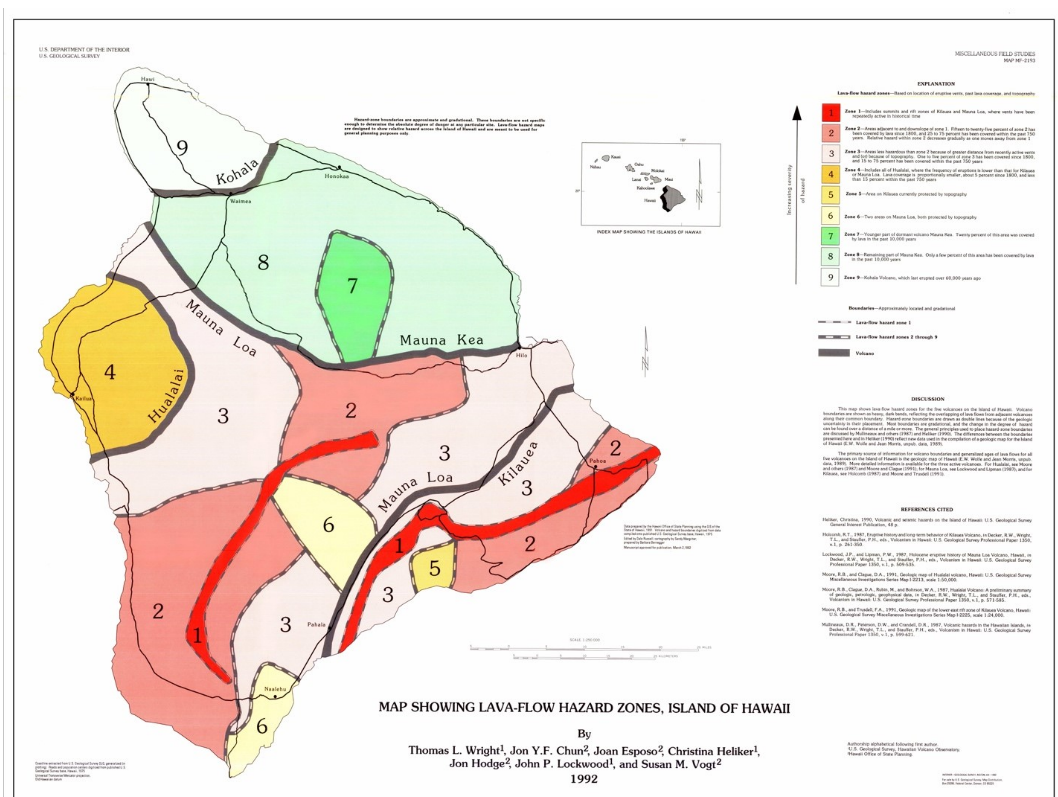


Hawaii Hazard Map

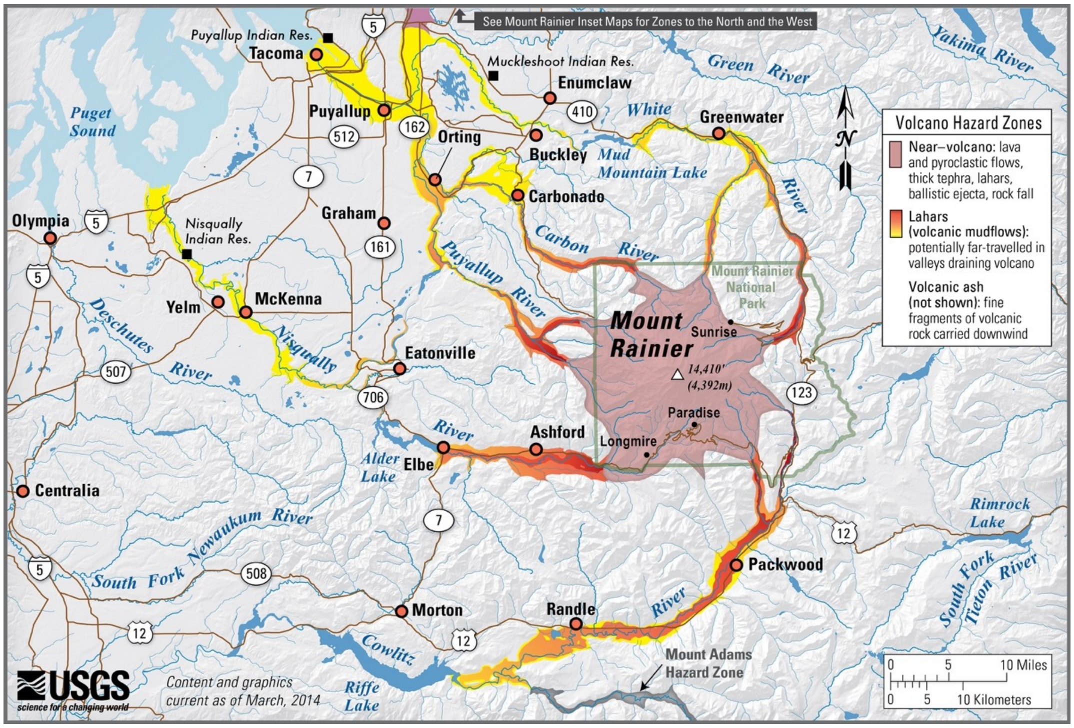
This map shows lava-flow hazard zones for the five volcanoes on the Island of Hawaii. Volcano boundaries are shown as heavy, dark bands, reflecting the overlapping of lava flows from adjacent volcanoes along their common boundary. Hazard-zone boundaries are drawn as double lines because of the geologic uncertainty in their placement. Most boundaries are gradational, and the change In the degree of hazard can be found over a distance of a mile or more. The general principles used to place hazard-zone boundaries are discussed by Mullineaux and others (1987) and Heliker (1990). The differences between the boundaries presented here and in Heliker (1990) reflect new data used in the compilation of a geologic map for the Island of Hawaii (E.W. Wolfe and Jean Morris, unpub. data, 1989). The primary source of information for volcano boundaries and generalized ages of lava flows for all five volcanoes on the Island of Hawaii is the geologic map of Hawaii (E.W. Wolfe and Jean Morris, unpub. data, 1989). More detailed information is available for the three active volcanoes. For Hualalai, see Moore and others (1987) and Moore and Clague (1991); for Mauna Loa, see Lockwood and Lipman (1987); and for Kilauea, see Holcomb (1987) and Moore and Trusdell (1991).

Source: https://pubs.usgs.gov/mf/1992/2193/

Reference: Wright, T.L., Chun, J.Y.F. ,Exposo, Jean, Heliker, Christina, Hodge, Jon, Lockwood, J.P., and Vogt, S.M., 1992, Map showing lava-flow hazard zones, Island of Hawaii: U.S. Geological Survey Miscellaneous Field Studies Map MF-2193, scale 1:250,000.



Mt. Rainier Hazard Map



HAWAII – RISK ASSESSMENT

Hazard	Kailua-Kona	Ocean View	Pãhoa	Waimea
Ash Fall				
Explosive Eruptions				
Ground Cracks and Settling				
Lava Flows				
Lahars				
Pyroclastic				

Hazard	Kailua-Kona	Ocean View	Pãhoa	Waimea
Flows				
Tephra				
Volcanic Gasses				

MOUNT RANIER – RISK ASSESSMENT

Hazard	Ashford	Morton	Paradise	50 miles due east of Ranier
Ash Fall				
Explosive Eruptions				
Ground Cracks and Settling				
Lava Flows				
Lahars				
Pyroclastic Flows				
Tephra				
Volcanic Gasses				

HAWAII – RISK ASSESSMENT

Hazard	Kailua-Kona	Ocean View	Pãhoa	Waimea
Ash Fall	Medium	High	High	Very Low
Explosive Eruptions	Low	Medium	Medium	Very Low
Ground Cracks and Settling	Low	High	High	Very Low
Lava Flows	Low	Critical	Critical	Very Low
Lahars	Very Low	Very Low	Very Low	Very Low
Pyroclastic Flows	Very Low	Low	Low	Very Low
Tephra	Very Low	High	High	Very Low
Volcanic Gasses	Very Low	High	High	Very Low

MOUNT RANIER – RISK ASSESSMENT

Hazard	Ashford	Morton	Paradise	50 miles due east of Ranier
Ash Fall	Critical	High	Critical	High
Explosive Eruptions	High	Low	Critical	Very Low
Ground Cracks and Settling	Very Low	Very Low	High	Very Low
Lava Flows	Very Low	Very Low	Low	Very Low

Hazard	Ashford	Morton	Paradise	50 miles due east of Ranier
Lahars	Critical	Very Low	Critical	Very Low
Pyroclastic Flows	Medium	Very Low	Critical	Very Low
Tephra	Low	Very Low	Critical	Very Low
Volcanic Gasses	Very Low	Very Low	High	Very Low

Visual 29: Unit Summary

You should now be able to:

- Describe the characteristics of volcano formation and eruption
- Identify variables in the behavior of a volcano
- Identify expected impacts of a volcanic eruption
- Describe the methods used to monitor volcanoes and predict eruptions

Key Points

Do you have any questions about the material covered in this unit?

Unit 9: Science of Human Induced Disasters

Visual 1: Unit 9: Human-Induced Disasters

Unit 9: Human-Induced Disasters Overview

Key Points

This unit will give an introduction to Human-Induced Disasters.

Visual 2: Unit Objectives

- Define human-induced/technological hazards.
- Discuss basics of hazard risk management.
- Define common concepts in discussing human-induced/technological hazards, including routes of entry, toxicity measures, and toxicity factors.

Key Points

Review the unit objectives.

Visual 3: Human-Induced/Technological Hazards

Human-Induced

- Intentional actions

Technological

- Accidents
- Failures of systems or structures

Key Points

Human-Induced Hazards are those hazards that result from the intentional actions of an adversary, such as a chemical attack, biological attack, or cyber-attack. (Comprehensive Preparedness Guide (CPG) 201)

Technological Hazards are those hazards that result from accidents or the failures of systems and structures, such as hazardous materials spills or dam failures. (CPG 201).

These hazards are often referred to as "man-made" hazards.

Visual 4: Human-Induced/Technological Hazards (Continued)

- Inevitable product of human development
- Technology increases in complexity
- Increases in the complexity of technological hazards

What are some examples of complex technological hazards that didn't exist 100 years ago?

Key Points

In the realm of possible disasters in the field of emergency management, human-induced and technological hazards are definitely ones to consider. These types of disasters

- Are inevitable products of human development
- Increases in complexity as technology increases in complexity and so does the complexity of technological hazards

Discussion Question

Discussion Question: What are some examples of complex human-induced and technological hazards that didn't exist 100 years ago?

Visual 5: Types of Incidents

- Hazardous Materials Incidents
- Structure Fires
- Nuclear Incidents
- Terrorism
    - "The unlawful use of force or violence against persons or property to intimidate or coerce a government, the civilian population, or any segment thereof, in furtherance of political or social objectives." – FBI
- Active Shooter
- Cybersecurity

Key Points

Review the different types of human-induced incidents on the visual. Point out examples of terrorism listed below.

- Terrorism
    - Chemical, Biological, Radiological and Nuclear (CBRN)
    - Explosives
    - Complex Coordinated Attacks

Visual 6: Hazard Risk Management

How do we deal with these hazards?

1. Identify the hazards.
2. Assess the risk.
3. Analyze the hazards risks in relation to each other.
4. Prioritize efforts to mitigate and respond to hazards, based on the analysis.

Key Points

This is the general hazard risk management process, as defined by George Haddow in *Introduction to Emergency Management.* There are other more defined processes, such as the Threat and Hazard Identification and Risk Assessment (THIRA) process. We will not be discussing a specific process.

Visual 7: What is Risk?

- Risk = Probability x Consequences

Probability	Trivial Impact	Minor Impact	Moderate Impact	Major Impact	Extreme Impact
Rare	Low	Low	Low	Medium	Medium
Unlikely	Low	Low	Medium	Medium	Medium
Moderate	Low	Medium	Medium	Medium	High
Likely	Medium	Medium	Medium	High	High
Very likely	Medium	Medium	High	High	High

Key Points

Once the potential risks to your community have been identified, you will need to determine the likelihood (probability) of the hazard occurring and the impact (severity of consequences to life and health, property, and infrastructure, and the environment).

Using a matrix like the one in the visual can help you organize and determine your risk.

Risk Management is NOT just for natural hazards, it is for ALL disaster types. More information on Risk and Assessments is covered in deeper level during the 103 course.

Visual 8: Common Concepts

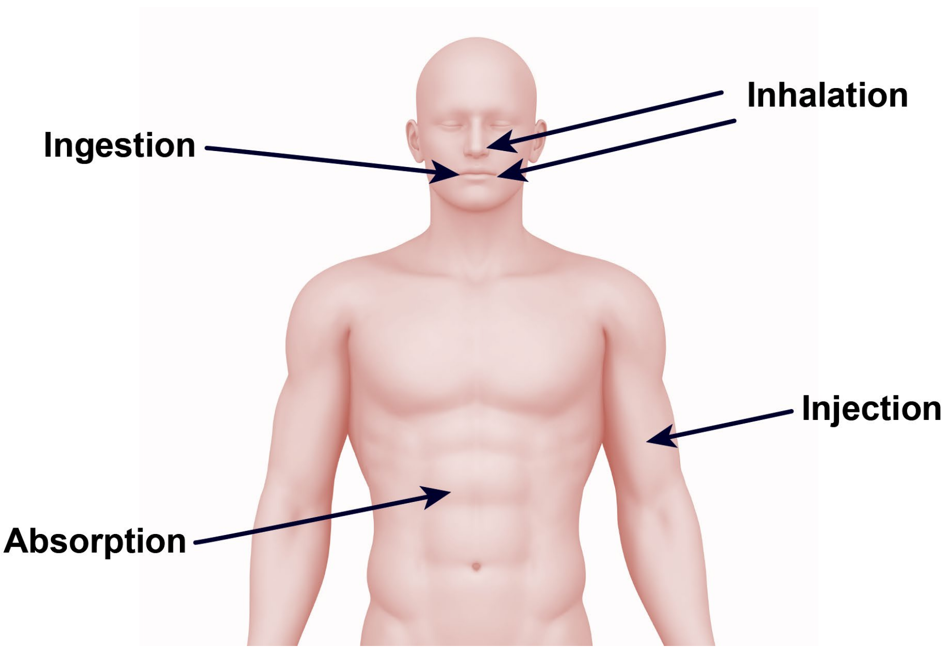
There are some common concepts and terms that are used throughout this lecture:

- Routes of Entry
- Measures of Toxicity
- Factors Impacting Toxicity

Key Points

The next section of this unit will discuss come common concepts and terms that will be used throughout the remainder of this module.

Visual 9: Routes of Entry



Key Points

As we review the chemical classes, we will discuss the various hazards—including health hazards—associated with each. In many cases, the health impacts of exposure to a chemical depend on how an agent gets into the body (the route of entry).

There a several ways a chemical can enter the body:

a. **Ingestion:** Some chemicals may enter the body by ingestion of contaminated food or liquid, or the individual may contaminate themselves and then touch food or their mouth.
b. **Inhalation:** Chemicals that are in a gas phase, that form vapors, or that are dispersed in aerosol form can enter the body through the respiratory tract and enter the lungs.
c. **Injection:** Chemicals may enter the skin through puncture and penetration wounds.
d. **Absorption:** Liquid chemicals may enter via skin contact. Chemicals in gas or vapor form, if the concentration is high enough or the exposure long enough, can also penetrate the skin and cause the same effects as skin contact with liquid agent.

Visual 10: Toxicity Measures

- Lethal Dose, 50% (LD50)
  - Is a standard measurement of acute toxicity that is stated in milligrams (mg) per kilogram (kg) of body weight
  - Represents the individual dose required to kill 50% of a population of test animals
- Permissible Exposure Limit (PEL)
  - Is the time-weighted average threshold limit a person working an 8-hour shift can be exposed to a chemical without suffering ill effects

Key Points

Toxicity can be measured by its effects on the target (organism, organ, tissue, or cell). Because individuals typically have different levels of response to the same dose of a toxin, a population-level measure of toxicity is often used, which relates the probabilities of an outcome for a given individual in a population. One such measure is the LD50.

LD50 description: An LD50 is a standard measurement of acute toxicity that is stated in milligrams (mg) of product per kilogram (kg) of body weight. An LD50 represents the individual dose required to kill 50 percent of a population of test animals (e.g., rats, fish, mice, cockroaches)—i.e., a lethal dose.

Because LD50 values are standard measurements, it is possible to compare relative toxicities among chemicals. The lower the LD50 dose, the more toxic the substance. (For example, a substance with an LD50 value of 10 mg/kg is 10 times more toxic than a substance with an LD50 of 100 mg/kg).

Toxicity in relation to route of entry: The toxicity of a chemical is related to the route of entry of the chemical into an organism.

- **Oral toxicity** refers to:
  - A liquid with a lethal dose (LD50) for acute oral toxicity of not more than 500 mg/kg, or
  - A solid with an LD50 for acute oral toxicity of not more than 200 mg/kg, which, when administered by mouth, is likely to cause death within 14 days in half of the test animals
- **Dermal toxicity** refers to:
  - A material with an LD50 for acute dermal toxicity of not more than 1,000 mg/kg which, when administered by continuous contact with bare skin, is likely to cause death within 14 days in half of the test animals
- **Inhalation toxicity** applies to:
  - A dust or mist with a lethal concentration (LC50) for acute inhalation toxicity of not more than 10 mg/L
  - A saturated vapor concentration in air at 68 °F (20 °C) of more than one-fifth of the LC50 for acute toxicity on inhalation of vapors and with an LC50 for acute inhalation

toxicity of vapors of not more than 5,000 ml/m3 which, when administered by continuous inhalation for 1 hour, is likely to cause death within 14 days in half of the test animals

- **Irritating material** is any liquid or solid substance (such as tear gas) that gives off intense fumes and causes extreme, but reversible, localized irritant effects on the eyes, nose, and throat, temporarily impairing a person's ability to function

Often the inhalation LD50 is lower (more toxic) than the oral LD50, which is, in turn, lower (more toxic) than the dermal LD50.

Permissible exposure limits: OSHA sets enforceable permissible exposure limits (PELs) to protect workers against the health effects of exposure to hazardous substances. PELs are regulatory limits on the amount or concentration of a substance in the air. They may also contain a skin designation. OSHA PELs are based on an 8-hour, time-weighted, average (TWA) exposure. TWA is the employee's average airborne exposure in any 8-hour work shift of a 40-hour work week which shall not be exceeded.

Visual 11: Toxicity Factors

Route of Exposure:

- Whether the toxin is applied to the skin, ingested, inhaled, or injected

Degree of Exposure:

- Time of exposure (brief encounter vs. long term) + number of exposures (single dose vs. Multiple doses over time

Physical Form of the Toxin:

- Solid, liquid, or gas

Individual Health:

- The person's overall state of health

Key Points

The toxicity of a chemical can be affected by many different factors, such as:

- **Route of exposure**—whether the toxin is applied to the skin, ingested, inhaled, or injected
- **Degree of exposure**—including:
  - **Time of exposure**—a brief encounter vs. long term
  - **Number of exposures**—a single dose vs. multiple doses over time
  - **Concentration**—amount of toxic component in relation to total volume
- **Physical form of the toxin**—solid, liquid, or gas phase.
- **Individual health**—the genetic makeup of an individual, an individual's overall health, and other health factors
- It is more difficult to determine the toxicity of a chemical mixture than a pure chemical because each component displays its own toxicity, and components may interact to produce enhanced or diminished effects.
- Common mixtures include gasoline, cigarette smoke, and industrial waste. Even more complex are situations with more than one type of toxic entity, such as the discharge from a malfunctioning sewage treatment plant, with both chemical and biological agents.

Visual 12: Unit Summary

You should now be able to:

- Define human-induced/technological hazards.
- Discuss basics of hazard risk management.
- Define common concepts in discussing human-induced/technological hazards including routes of entry, toxicity measures, and toxicity factors.

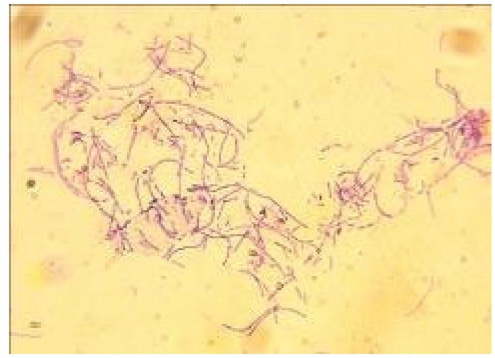
Key Points

Do you have any questions about the material covered in this unit?

Unit 10: Biological Basics

Visual 1: Unit 10: Biological Basics

Unit 10: Biological Basics



Key Points

This unit will explore the scientific basis for biological hazards and threats.

Visual 2: Unit Objectives

- Define what is meant by biology.
- Identify the importance of cells.
- Differentiate between pathogens and toxins.
- Identify the characteristics and significance of bacteria, viruses, and fungi.
- Describe the potential consequences of a pandemic influenza on a jurisdiction's preparedness.
- Identify potential bioterrorism agents of concern.
- Describe the impact of agricultural bioterrorism.
- Identify potential dissemination methods of biological agents.

Key Points

Review the unit objectives as shown on the visual.

Visual 3: What Is Biology?

The science of life and of living organisms, including their structure, function, growth, origin, evolution, and distribution.

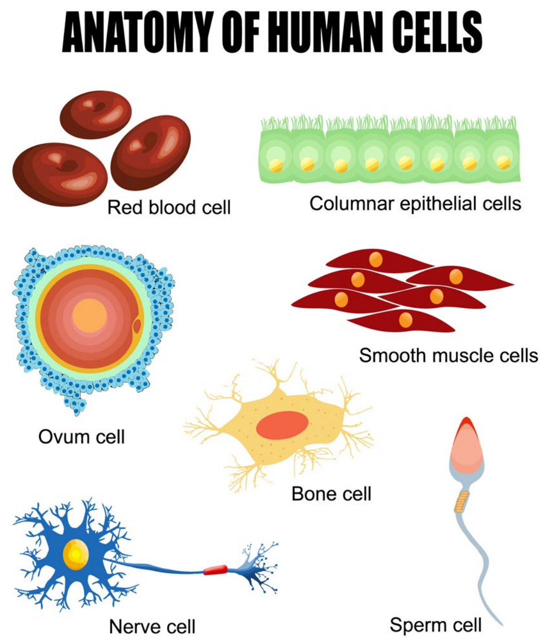
Key Points

Biology is defined as "the science of life and of living organisms, including their structure, function, growth, origin, evolution, and distribution."

There are numerous subdisciplines of biology. For example:

- Cellular biology examines the basic building block of all life-the cell.
- Biochemistry examines the rudimentary chemistry of life.
- Molecular biology studies the complex interactions of systems of biological molecules.

Visual 4: Introduction to Cells



Cells:

- Are the basic units composing all life (i.e., a "biology unit")
- Can be unicellular (made of one cell) or multicellular
- Are very small
- May vary in appearance and function

Discussion: Characteristics of Cells

What are some key characteristics of cells?

Key Points

Cells:

- Are the basic units composing all life (i.e., a "biology unit"), such as:
  - Bacteria, fungi, plants, and animals (including humans) are cellular organisms.
  - Viruses and prions are not cellular organisms.
- Can be unicellular (made of one cell) or multicellular (billions of cells organized at different levels).
- Are very small and the size range is approximately from 1 to 100 micrometers (1 millionth of a meter) – a human hair is approximately 50 times wider than a cell.
- May vary in appearance and function and many conduct specialized functions (e.g., reproductive (sperm and ova); red and white blood cells; epithelial (skin), connective, muscle, and nervous tissue).

Visual 5: Types of Cells

Prokaryotic cells:

- Do not have a nucleus
- Include bacteria and cyanophytes
- Usually single-celled organisms, but can colonize

Eukaryotic cells:

- Have a nucleus
- Found in humans, plants, and other multicellular organisms

Generally Prokaryoticites infect Eukaryote

Key Points

In understanding biological hazards and threats, it is useful to distinguish between cell types. There are two types of cells: prokaryotes and eukaryotes. The following table highlights their differences.

Prokaryotic Cells	Eukaryotic Cells
Are cells without a nucleus	Are cells with a nucleus
Have genetic material but are not enclosed in a membrane.	Have both a cellular membrane and nuclear membrane
Include bacteria and cyanophytes	Are found in humans, plants, and other multicellular organisms
Genetic material is a single DNA strand contained in the cytoplasm, because there is no nucleus. This DNA works in just the same way as it does in other organisms, but is not gathered together into chromosomes visible through a microscope.	Genetic material forms multiple chromosomes.

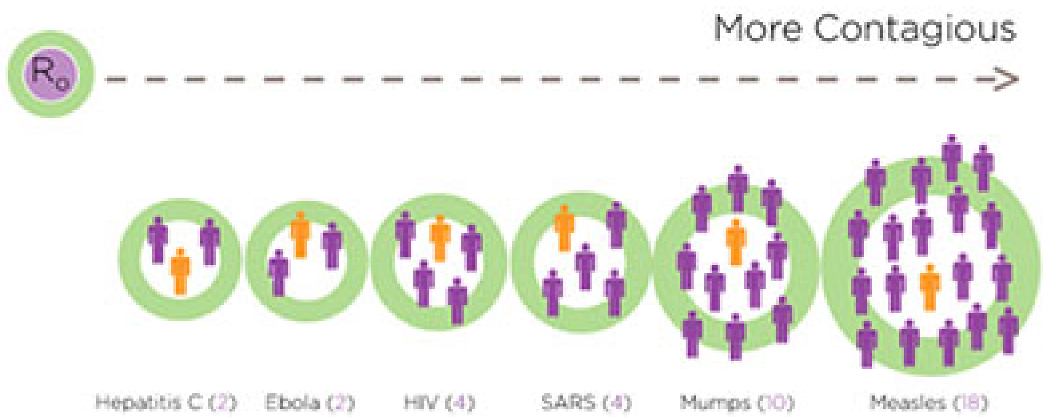
Additional Information

You can learn more about cells in the science education booklet *Inside the Cell,* which explores the interior design of cells and vividly describes the processes that take place within.

Inside the Cell is available online (This link can also be accessed at the following URL: https://www.nigms.nih.gov/education/Booklets/Inside-the-Cell/Documents/Booklet-Inside-the-Cell.pdf) and is published by the U.S. Department of Health and Human Services, NIH Publication No. 07-2778, National Institutes of Health.

Visual 6: Contagious vs. Infectious

- Contagious – A measure of how transmittable a pathogen is from one person to another. Quantified by R_0 or R-nought.
- Infectious - A measure of how much of a pathogen is needed to infect an exposed individual



Key Points

It is important to understand the distinction between the two.

- **Infectious** refers to how many bacteria, virions or other pathogen particles are needed to infect an exposed individual.
- **Contagious** means the bacteria or virus can be transmitted from person to person (a communicable disease), and is quantified by R-nought.

The basic reproduction number, R_0 represents, on average, how many other people a single infected person can be expected to infect. It is simply a calculation of the average "spreadability" of an infectious disease. For example, an R0 of 3.0 means that one person can infect 3 others on average. Those 3 new people can infect 3 more each, and the disease can spread rapidly, especially with higher R0 numbers.

Determining the R_0 for a disease can provide valuable insight into the potential spread of the disease, and scientists use models to estimate the likelihood of spread, drawing from different sources of information and past outbreaks. How quickly a new pathogen can spread among the population is an essential piece of information scientists use in order to make recommendations to officials on how best to mitigate the spread of the disease. Local, state, territorial, tribal, and federal governments, in concert with public health authorities can factor this into their decision making to best control the spread.

The three main factors used to calculate R_0 are the infectious period of the disease, the mode of transmission, and the contact rate. The R_0 can change over time as more information and data is gathered, and as the new disease becomes better understood. Also, as protective measures such as hand hygiene, wearing a mask, and social distancing are implemented, the spread of the disease is typically reduced (thus reducing the R_0) since the mode of disease transmission has been interrupted. R0 has been successfully calculated for diseases in the past such as SARS, MERS, Ebola, AIDS, seasonal flu, and the 2009 H1N1 flu pandemic.

For more information check out this Harvard Global Health article - Understanding Predictions: What is R-Naught? (https://globalhealth.harvard.edu/understanding-predictions-what-is-r-naught/)

Visual 7: Biological Hazards: The Facts

- Not all are contagious
- May have multiple routes of exposure
- May not be evident for days or weeks
- May present a variety of symptoms
- Many are treatable

Key Points

The basic cell concepts just discussed provide a basis for understanding biological hazards and threats that can attack the cells.

What do we know about biological hazards? There are various types of biological hazards, and they vary widely from one to the next in their characteristics. However, there are a few general facts that are important to keep in mind:

- **Contagion:** Not all hazards are contagious. Some are, but others cannot be transmitted from one person to another.
- **Exposure:** Biological hazards may have multiple routes of exposure. The routes of entry for pathogens and toxins are the same as chemicals-ingestion, eyes, inhalation, and absorption. Common means for spread pathogens and toxins include:
  - Airborne: Coughing and/or sneezing
  - Contact: Touching another person or object
  - Ingestion: Eating food touched by someone with dirty hands
  - Bloodborne: Coming in contact with body fluids, such as blood, saliva, etc.
- **Incubation:** A hazard may not be evident for days or weeks.
- **Symptoms:** Different hazards may present a variety of symptoms.
- **Treatment:** Many hazards are treatable.

Isolation vs. Quarantine

- Isolation - separates sick people with a contagious disease from people who are not sick
- Quarantine - separates and restricts the movement of people who were exposed to a contagious disease to see if they become sick

“Twenty U.S. Quarantine Stations, located at ports of entry and land border crossings, use these public health practices as part of a comprehensive Quarantine System that serves to limit the introduction of infectious diseases into the United States and to prevent their spread.” – CDC

Key Points

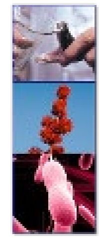
The media also often confuses the terms isolation and quarantine. Especially given recent events regarding Ebola, as well as challenges to the powers of public health officials, it is important to understand what each term means.

"Under section 361 of the Public Health Service Act (42 U.S. Code § 264), the U.S. Secretary of Health and Human Services is authorized to take measures to prevent the entry and spread of communicable diseases from foreign countries into the United States and between states."

"States have police power functions to protect the health, safety, and welfare of persons within their borders. To control the spread of disease within their borders, states have laws to enforce the use of isolation and quarantine. These laws can vary from state to state and can be specific or broad. In some states, local health authorities implement state law. In most states, breaking a quarantine order is a criminal misdemeanor. Tribes also have police power authority to take actions that promote the health, safety, and welfare of their own tribal members. Tribal health authorities may enforce their own isolation and quarantine laws within tribal lands, if such laws exist."

Source: Centers for Disease Control and Prevention (This link can also be accessed at the following URL: https://www.cdc.gov/quarantine/)

Visual 8: Toxins



- Are poisonous substances.
- Are produced by an animal (snake/insect venom), plant (ricin), or bacterium (cholera and botulism).
- May be odorless and tasteless, difficult to detect.
- Are not contagious.
- May be more toxic than other types of chemical agents.
- Have some legitimate medical uses.

Key Points

Description: Toxins are substances produced within living organisms that are poisonous to humans. (Notice that their origin differentiates toxins from chemical or manmade "toxics" or "toxicants.")

Production: Toxins are produced by:

- Animals—e.g., snake or insect venom.
- Plants—e.g., ricin from castor beans.
- Bacteria—e.g., cholera and botulism.

The majority of toxins that are problems for human beings are released by bacteria. In fact, the bacterial toxin *Clostridium botulinum* is the most poisonous substance known to scientists. It causes severe food poising (botulism) that can lead to death by suffocation in just a few days. (We will look at botulism in greater detail later in this unit.)

Many toxins are produced by marine organisms. One such example is saxitoxin, which is synthesized by a type of blue-green algae (cyanobacteria). These algae provide food for different shellfish-for example, mussels. The mussels themselves are not influenced by the poison, but human beings who later eat the mussels may become seriously ill.

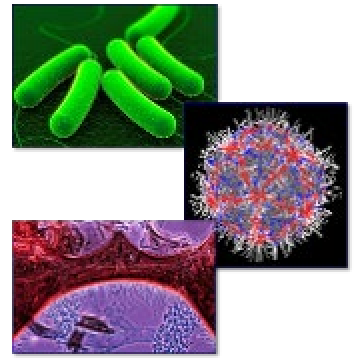
Characteristics: Toxins:

- May be odorless and tasteless, and therefore difficult to detect.
- Are made unstable by heat or other environmental factors.
- Are not contagious like viruses.
- May be more toxic than other types of chemical agents.

Legitimate uses: Although toxins are extremely dangerous (and often fatal), many toxins have legitimate medical use in smaller doses.

For example, *botulinum* toxin is used to treat muscular disorders, and forms of ricin (the plant-generated toxin) are studied in order to treat leukemia and liver cancer.

Visual 9: Pathogens



- Are microorganisms that can cause disease.
- Include:
  - Bacteria
  - Viruses
  - Fungi
  - Other infectious agents

Key Points

Pathogens are microorganisms that can cause disease in a host (another living thing). There are human pathogens and animal pathogens. Pathogens include:

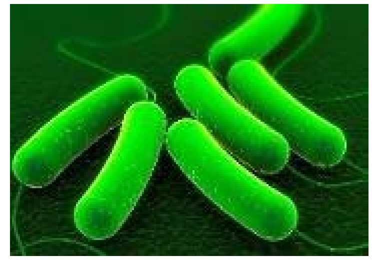
- Bacteria
- Viruses
- Fungi
- Other infectious agents, such as parasites and prions.

A parasite is an organism that lives in or on another organism without benefiting the host organism.

The CDC describes prions as, "abnormal, pathogenic agents that are transmissible and are able to induce abnormal folding of specific normal cellular proteins called prion proteins that are found most abundantly in the brain."

In this section you will take a closer look at bacteria, viruses, and fungi.

Visual 10: Bacteria



- Are single-celled organisms (prokaryotes) that multiply by cell division.
- Exist everywhere, inside and on our bodies.
- Include many strains that are completely harmless and useful.
- Can cause disease by:
  - Invading host tissues, and/or
  - Producing poisons (toxins).

Key Points

Description: Bacteria:

- Are one-celled organisms that multiply by cell division.
- Are visible only with a microscope. Bacteria are so small that if you lined up a thousand of them end to end, they could fit across the end of a pencil eraser.
- Are shaped like short rods, spheres, or spirals.
- Exist everywhere, including inside and on our bodies.

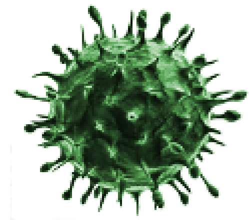
Useful bacteria: Not all bacteria are harmful. In fact, less than 1 percent cause disease, and some bacteria that live in your body are useful. For instance, *Lactobacillus* acidophilus-a harmless bacterium that resides in the intestines-helps digest food, destroys some disease-causing organisms, and provides nutrients to your body.

Disease: Some bacteria cause disease, either by invading host tissues (infection) or by producing toxins—powerful chemicals that damage cells and make you ill. Bacteria cause diseases such as:

- Strep throat.
- Tuberculosis.
- Urinary tract infections.

Visual 11: Viruses

- Cannot multiply on their own
- Invade "host" cells and take over their machinery to make more virus particles
- Attack vulnerable cells such as the mucous membranes (lining the respiratory passages) that are not covered by protective skin
- May be infectious to others before the onset of symptoms



Key Points

Viruses are another type of pathogen.

Description: Viruses are basically just capsules-a protein coat and a core of genetic material, either RNA or DNA. They are much smaller than cells and may be shaped like rods, spheres, or tiny tadpoles.

Survival and reproduction: Unlike bacteria, viruses can't survive without a host. They can only reproduce by attaching themselves to cells and hijacking the cells' cellular machinery. In most cases, they reprogram the cells to make new viruses until the cells burst and die. In other cases, they turn normal cells into malignant or cancerous cells.

Disease: Also unlike bacteria, most viruses **do** cause disease, and they're quite specific about the cells they attack. For example, certain viruses are programmed to attacks cells in the liver, respiratory system, or blood. In some cases, viruses called bacteriophages target bacteria. Viruses are responsible for causing a wide range of diseases, including:

- AIDS
- Common cold
- Ebola hemorrhagic fever
- Herpes (chickenpox and later shingles)
- Influenza
- Measles
- Smallpox

Incubation and transmission: Viruses may be transmitted infectiously before any symptoms appear, as is the case with chickenpox; this is because they have an incubation period (the time between infection and symptoms) after access into your body, during which the virus multiplies "silently."

The following are examples of the incubation periods for some common viral infections:

Infection	Incubation Period
Chickenpox	10 to 21 days

Infection	Incubation Period
Diphtheria	2 to 5 days
Influenza	Up to 7 days, most likely to be 2 to 3 days
Measles	About 10 days, with a further 2 to 4 days before the rash appears
Mumps	Around 17 days, with a range of 12 to 25 days
Rubella (German measles)	14 to 21 days, and the time you can infect someone else is from 1 week until 4 days before the rash appears
Slapped cheek syndrome (also known as parvovirus B19 or fifth disease)	Usually 13 to 18 days, but can be as long as 20 days
Tetanus	Between 4 and 21 days, most commonly about 10 days
Whooping cough (pertussis)	Between 7 and 10 days

Treatment: Antibiotics have no effect on viruses.

Visual 12: Video: Understanding Viruses

Key Points

(Video used with permission of Zirus, Inc., the Anti-Virus Company, and XVIVO Scientific Animation. Originally broadcast on NPR.org on October 2009. Used with the permission of NPR.)

Introduction: This video examines how viruses infect cells and replicate themselves.

Video Transcript:

(Man sneezing)

Robert Krulwich (RK): So, let's say that this guy has the flu, could be any flu, and here's a droplet from his sneeze containing-if we move in and take a really close look, you see each one of those little purple things is a virus, and there are a lot of viruses floating through the air, some of which go inevitably up this unfortunate man's nose.

RK: How did that guy feel when you ripped off half of his face?

David Bolinsky (DB): It was interesting because we did it while he was sleeping. (Laughing)

RK: Okay, I am talking with medical illustrator David Bolinsky who designed this video for Zirus, a research company. So here comes the virus, and it's going to land on one of this guy's throat cells. So notice it's covered with little yellow knobby things-you call these keys, right?

DB: Those are the keys this is a key, this is a key, this is a key.

RK: Okay, if the keys on this virus happen to fit the locks, which are those little purple-y stick-up-y things on the surface of the cell. If there is a match, the cell-watch this-welcomes the virus in and what's this?

DB: This is the welcoming committee. They all interlock with each other and they pull this membrane down into the cell.

RK: And down it goes, deeper and deeper, and that welcoming structure disperses and the virus capsule bursts and out comes the secret recipe for how to make more viruses, those little noodle-y things. So this unsuspecting cell has been tricked into guiding these virus recipes right into its own command center, the nucleus. So in they go

DB: And they are immediately recognized by this big pink molecule, which is a mini-factory.

RK: Yeah, what is it doing?

DB: It threads the nuclear material; the instruction code of the virus, through one hole-and out another hole comes a brand new instruction set.

RK: So it's a copying machine, making copy after copy after copy of virus recipes which then go out of the nucleus to the little chefs-those blue peanut-y things. They cook up proteins that go back into the nucleus where they are reassembled into baby viruses and then out they go. They get covered up and head to the surface, where they get new keys and then boom, here they come. This is an eruption of virus after virus after virus after only one virus entered the cell, but how many came out? Well, millions, millions. So if one virus can produce a million babies and do it again and again and again how come this guy doesn't just drop dead, I don't know, in like 10 minutes?

DB: Well, because you have about a hundred trillion cells.

RK: I see, so a million viruses is just a drop in the bucket when you have a hundred trillion cells. And anyway, remember you do have your own immune system, which when it sees a virus usually kills it. So, while the virus does multiply fast, with any luck your immune system will work just a little faster. So, yes, viruses, all viruses want to spread, that's what they do. But most of the time we do keep them in checkmost of the time.

Visual 13: Influenza (Flu)

Annually in the United States, the flu:

- Infects 3% to 11% of the population.
- Hospitalizes more than 200,000 people.
- Kills approximately 36,000 people.

Key Points

Influenza, or flu, is an example of a virus most of us are familiar with. Every year in the United States, the flu:

- Infects 3 percent to 11 percent of the population.
- Hospitalizes more than 200,000 people with flu-related complications.
- Kills approximately 36,000 people.

People with a high risk for serious complications as a result of the flu include:

- The elderly.
- Young children.
- People with certain health conditions.

Visual 14: Discussion: Seasonal Influenza Outbreak

1. How does a severe flu season affect continuity of emergency management services?
2. What plans do you have in place to address seasonal influenza outbreaks?

Visual 15: Pandemic Influenza

CDC classifications

- **Outbreak**: an increase in cases of a disease above what's normally expected in a certain area. The increase is often sudden.
- **Epidemic**: an outbreak that occurs in a broader region. The two differ only in degree.
- **Pandemic**: an epidemic that has spread over several countries or continents and impacts a large percentage of the population across borders. The World Health Organization (WHO) is the organization that declares a pandemic. *Declaration allows for expansion of public health agencies capacity to contribute to the response.

Key Points

Examples of Pandemics

- 1918–1920: Spanish Flu ϖ
- 1981-Present: AIDS ϖ
- 2009-2010: H1N1 Swine Flu ϖ
- 2020–present: COVID-19

Definitions

- **Infectious**: Rate at which virus/bacteria or other microorganisms spreads within a host causing disease.
- **Contagious**: Rate at which infectious disease-causing organism is passed from one host to another.
- **Virulence**: Severity and harmfulness of a disease on its host

Ebola, Marburg, and Malaria are highly infectious, highly virulent, but not highly contagious. They cause a lot of infection inside a host but transmitting it to another host doesn't happen readily. Additionally, hosts are not alive long enough to spread it widely beyond a village or area.

COVID-19 is not as infectious or widely virulent as Ebola but is very contagious. Infected include asymptomatic (i.e., not showing symptoms) hosts, who can easily spread the disease without knowing they have the disease.

Average Death Rates:

- Ebola, Marburg: up to 90%
- Malaria: 80-90%
- COVID-19: 2-4% (still gathering data)
- Seasonal Flu: 0.1%

Required for a Pandemic:

- Contagion must be highly contagious, like SARS CoV-2, to allow for spread globally. SARS CoV-2 can spread asymptomatically, which increases its rate of spread.
- Contagion must have a lower virulence than Ebola, so it doesn't kill those infected both widely and rapidly, preventing global spread.
- COVID-19 has the perfect ratio of infection rate, contagious rate, and virulence to become a pandemic.

Visual 16: Pandemic Influenza

- Rapid worldwide spread with severe symptoms
- Large numbers of ill due to little or no immunity
- Overloaded health care systems
- Inadequate medical supplies
- Disrupted economy and society
- Infrequent (three times in 20th century)

Key Points

Description: A pandemic is a global disease outbreak. It is determined by how the disease spreads, not how many deaths it causes.

When a new influenza A virus emerges, a flu pandemic can occur. Because the virus is new, the human population has little to no immunity against it. The virus spreads quickly from person to person worldwide.

Characteristics: According to the Centers for Disease Control and Prevention (CDC), the characteristics of a flu pandemic include:

- **Rapid worldwide spread.** A flu pandemic will spread quickly around the world, from country to country, even if governments attempt to close their borders, restrict travel, or otherwise protect their populations.
- **Overloaded health care systems.** As infection and illness rates soar, large populations require medical care, and death rates increase, medical staff and resources will become overloaded and overwhelmed. There may be a shortage of beds and treatment locations, in which case alternative sites like schools may be used as facilities.
- **Inadequate medical supplies.** Just as medical staff will be overwhelmed by a pandemic, the need for vaccines will outrun the supply. High-risk patients will more than likely receive the vaccine (or antiviral medication) first.
- **Disrupted economy and society.** Communities and citizens will be greatly impacted by disruptions to the economy and society, including the banning of travel, cancellation of events, and the closing of schools and businesses. The economy will be affected as employees remain absent to care for sick family members.

Although flu pandemics have happened throughout history, they are infrequent, and occurred just three times in the 20th century. The table below presents the basic facts of the four flu pandemics that have occurred since 1918.

History of Pandemic Influenza in the United States

Pandemic	Description

Pandemic	Description
1918 - 1919 Pandemic	• Called "The Spanish Flu." • Often resulted in deaths from secondary effects such as pneumonia. • Made 20 percent to 40 percent of the worldwide population ill. • Resulted in about 50 million fatalities, 675,000 of which were in the United States. • Noted for high mortality rates among healthy adults rather than the elderly or children; in fact, the highest rates were seen among adults 20 to 50 years old.
1957 - 1958 Pandemic	• Started in February of 1957 with the identification of a new virus in the Far East. Officials predicted a pandemic, monitored outbreaks, and produced a limited supply of vaccine. • Came to the United States through small outbreaks and the spread of the disease in classrooms. October 1957 was the peak of infection rates for the "first wave." • Resurged in "second wave" in January and February 1958. • Resulted in about 69,800 fatalities in the United States, with the highest rates of death occurring among the elderly.
1968 - 1969 Pandemic	• Started in early 1968 with the identification of a new virus in Hong Kong. Became widespread in the United States in September 1968 and peaked that winter. • Resulted in 33,800 deaths between September 1968 and March 1969-the mildest pandemic of the 20th century. • Was similar to 1957 virus, leading researchers to conclude that U.S. citizens had built some immunity. The virus also hit during school vacation (December), which may have slowed the spread among children. • Was treated with improved medical care and antibiotics for secondary infections from bacteria.
2009 - 2010 Pandemic	• Started in the spring of 2009 with the rapid spread of new virus (H1N1 - "swine flu") across the United States and the world. CDC worked to develop a vaccine, and in April the U.S. Government declared a public health emergency.

Pandemic	Description
	• Affected 74 countries, with 18,000 cases reported in the United States by June. By November, 48 States had reported cases. Patients with the highest risk of complications related to the flu received the vaccine first. Minimized by the vaccination of 80 million people against the virus. • Resulted in 43 to 89 million infections between April 2009 and April 2010 (CDC estimate) and 8,870 to 18,300 H1N1-related deaths.

Visual 17: Things to Remember

Diseases may be transmitted:

- Human to Human
- Animal to Animal
- Animal to Human (zoonotic)

Diseases may:

- Exist independently of other disasters
- Be exacerbated by disaster conditions
    - For example, flooding may increase mosquito-borne illnesses

Visual 18: Avian Influenza

- Domesticated birds (chickens, turkeys, etc.) may become infected.
- Infection may be hard to detect and can cause severe disease with high mortality.
- During a 2014–2015 outbreak in the US, there were 211 detections on commercial operations and 21 detections on backyard premises in 21 States
- Approximately 7.4 million turkeys and 43 million egg-layers/pullet chickens, as well as a limited number of mixed poultry flocks, were affected and died, or were depopulated as part of the response.
- The largest event ever recorded in the U.S. and arguably the most significant animal health event in U.S. history.

Key Points

Avian Influenza in Poultry (Domesticated Birds) Domesticated birds (chickens, turkeys, etc.) may become infected with avian influenza A viruses through direct contact with infected waterfowl or other infected poultry, or through contact with surfaces that have been contaminated with the viruses.

Infection of poultry with LPAI viruses may cause no disease or mild illness and may only cause mild signs (such as ruffled feathers and a drop in egg production) and may not be detected. Infection of poultry with HPAI viruses can cause severe disease with high mortality. Both HPAI and LPAI viruses can spread rapidly through flocks of poultry. HPAI virus infection in poultry (such as with HPAI H5 or HPAI H7 viruses) can cause disease that affects multiple internal organs with mortality up to 90% to 100%, often within 48 hours. Some ducks can be infected without any signs of illness.

Avian influenza outbreaks are of concern in domesticated birds for several reasons. The:

- Potential for low pathogenic H5 and H7 viruses to evolve into highly pathogenic viruses
- Potential for rapid spread and significant illness and death among poultry during outbreaks of highly pathogenic avian influenza
- Economic impact and trade restrictions from a highly pathogenic avian influenza outbreak
- Possibility that avian influenza A viruses could be transmitted to humans

When H5 or H7 avian influenza outbreaks occur in poultry, depopulation (or culling, also called “stamping out”) of infected flocks is usually carried out. In addition surveillance of flocks that are nearby or linked to the infected flock(s), and quarantine of exposed flocks with culling if disease is detected, are the preferred control and eradication methods. See Past Outbreaks of Avian Influenza in North America (https://www.cdc.gov/flu/avianflu/past-outbreaks.htm) for more information about avian influenza A virus infections in U.S. poultry. More information about avian influenza in poultry in the United States is available through the United States Department of Agriculture’s Animal and Plant Health Inspection (www.aphis.usda.gov/aphis/ourfocus/animalhealth/animal-disease-information/avian).

Surveillance for Avian Influenza CDC, the United States Department of Agriculture (USDA) (www.usda.gov/topics/animals/one-health/avian-influenza), the World Health Organization (WHO) (www.who.int/influenza/human_animal_interface/en/), the World Organization for Animal Health (OIE) (www.oie.int/animal-health-in-the-world/web-portal-on-avian-influenza/), and the Food and Agriculture Organization of the United Nations (FAO) (www.fao.org/avianflu/En/index.html) conduct routine surveillance to monitor influenza viruses for changes that may have implications for animal and public health. CDC and WHO surveillance efforts are focused on human health. FAO and OIE are concerned with issues affecting animals, food and agriculture.

See also: CDC Avian Flu (https://www.cdc.gov/flu/avianflu/avian-in-birds.htm)

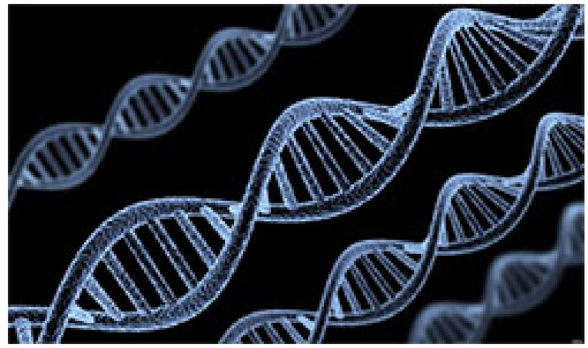
Final Report for the 2014–2015 Outbreak of Highly Pathogenic Avian Influenza (HPAI)in the United States (https://www.aphis.usda.gov/animal_health/emergency_management/downloads/hpai/2015-hpai-final-report.pdf).

Visual 19: Key Points

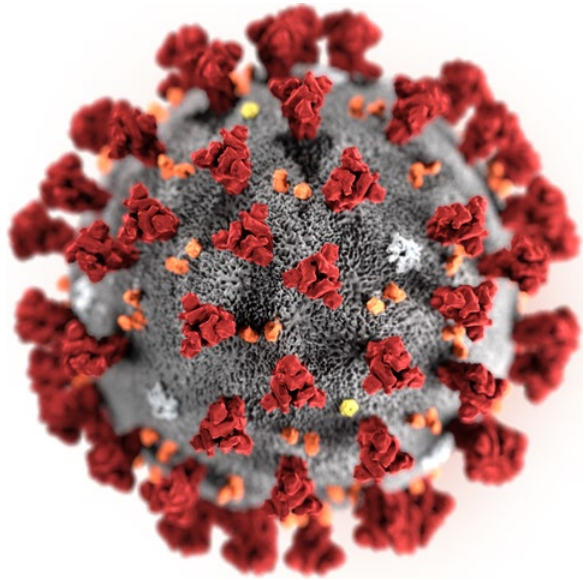
- Also known as Bird Flu or H5N1
- Occur naturally in wild birds worldwide
- Can infect domestic poultry and other bird and animal species.
- Does not normally infect humans. However, sporadic human infections with avian flu viruses have occurred.

Visual 20: Avian Influenza (3 of 3)

- Avian influenza outbreaks are of concern in domesticated birds for several reasons:
  - potential for low pathogenic viruses to evolve into highly pathogenic ones
  - potential for rapid spread and significant illness and death
  - economic impact and trade restrictions
  - possibility of transmission to humans
- When outbreaks occur, depopulation (or culling) of infected birds is carried out.



Visual 21: Coronaviruses



- A large family of respiratory viruses ranging from the common cold to more severe types. Transferred from other mammals to humans.
- Typically causes secondary infection such as pneumonia. Examples include:
  - MERS-CoV - Middle East Respiratory Syndrome
  - SARS-CoV - Severe Acute Respiratory Syndrome
  - SARS-CoV-2 - A novel coronavirus first identified in China, which caused an outbreak of COVID-19 disease beginning in 2019, and ultimately becoming a pandemic.

Key Points

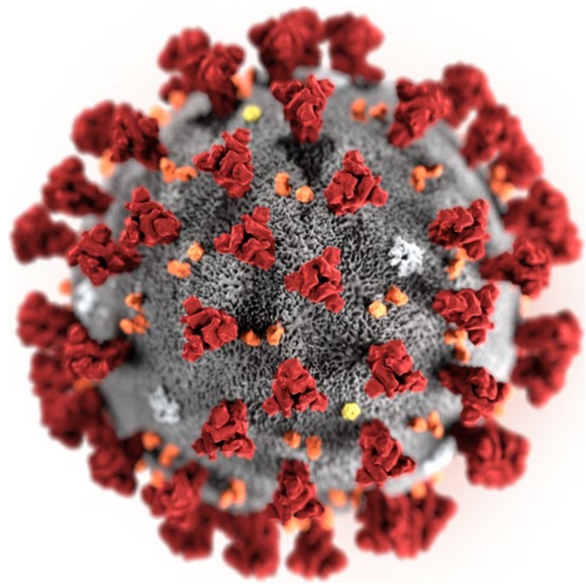
Coronaviruses are zoonotic, meaning they are transmitted between animals and people. Detailed investigations found that SARS-CoV was transmitted from civet cats to humans and MERS-CoV from dromedary camels to humans. Several known coronaviruses are circulating in animals that have not yet infected humans.

Common signs of infection include respiratory symptoms, fever, cough, shortness of breath, and breathing difficulties. In more severe cases, infection can cause pneumonia, severe acute respiratory syndrome, kidney failure, and even death. Standard recommendations to prevent infection spread include regular hand washing, covering mouth and nose when coughing and sneezing, thoroughly cooking meat and eggs. Avoid close contact with anyone showing symptoms of respiratory illness such as coughing and sneezing.

Source: World Health Organization (https://www.who.int/health-topics/coronavirus).

Visual 22: SARS-CoV-2

- "SARS-CoV-2" – is the name of the virus
- "COVID-19" – is the name of the disease resulting from the infection from SARS-CoV-2
- Zoonotic virus that emerged from China in 2019.
- It is called a coronavirus due to its crown-like structures (see photo) and is similar to, but not the same as, the virus SARS-CoV which first emerged in 2003
- Rapidly spread throughout the U.S. and the world in 2020
- Generated health orders for isolation, quarantine, wearing masks, and social distancing



Key Points

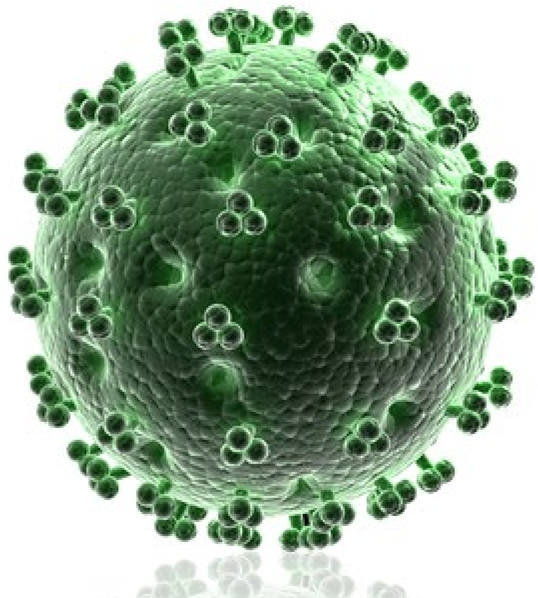
Severe acute respiratory syndrome (SARS) is a viral respiratory illness caused by a coronavirus called SARS-associated coronavirus (SARS-CoV). SARS was first reported in Asia in February 2003. The illness spread to more than two dozen countries in North America, South America, Europe, and Asia before the SARS global outbreak of 2003 was contained..

More information can be found from the CDC at https://www.cdc.gov/sars/index.html or at Johns Hopkins University and Medicine: https://coronavirus.jhu.edu/.

Note: This course is updated, at a minimum, every five years, and it was under revision at the time of the outbreak. As a result of the timing, we are not able to provide as much information, contextualization, learning lessons, and/or best practices as you might expect due an incident of this magnitude.

Visual 23: Noroviruses

- Common virus causing vomiting and diarrhea
- Many different types
- You can get norovirus illness many times since there are so many and immunity is not guaranteed



Key Points

Infection with one type of norovirus may not protect you against other types. It is possible to develop immunity to (protection against) specific types. But, it is not known exactly how long immunity lasts. This may explain why so many people of all ages get infected during norovirus outbreaks. Also, whether you are susceptible to norovirus infection is also determined in part by your genes.

Source: CDC (https://www.cdc.gov/norovirus/about/index.html).

Visual 24: Mosquito-Borne Diseases

- Can be an annoyance or cause illness and/or death
- Typically none or mild symptoms like fever, headache, nausea, and vomiting
- Examples of viruses spread by mosquitos:
    - Eastern Equine Encephalitis (EEE)
    - La Crosse encephalitis
    - St. Louis encephalitis
    - West Nile
    - Zika

Key Points

The most effective way to avoid getting sick from viruses spread by mosquitoes when at home and during travel is to prevent mosquito bites. Mosquito bites can be more than just annoying and itchy. They can spread viruses that make you sick or, in rare cases, cause death. Although most kinds of mosquitoes are just nuisance mosquitoes, some kinds of mosquitoes in the United States and around the world spread viruses that can cause disease.

Mosquitoes bite during the day and night, live indoors and outdoors, and search for warm places as temperatures begin to drop. Some will hibernate in enclosed spaces, like garages, sheds, and under (or inside) homes to survive cold temperatures. Except for the southernmost states in North America, mosquito season starts in the summer and continues into fall. Examples of viruses spread by mosquitoes:

- Chikungunya
- Dengue
- Eastern equine encephalitis
- Japanese encephalitis
- La Crosse encephalitis
- St. Louis encephalitis
- West Nile
- Yellow fever
- Zika

Key Points

When used as directed, insect repellents are the BEST way to protect yourself and family members from getting sick from mosquito bites.

Prevention

Use insect repellent: When used as directed, Environmental Protection Agency (EPA)-registered insect repellents (www.epa.gov/insect-repellents) are proven safe and effective, even for pregnant and breastfeeding women. Use an EPA-registered insect repellent. External with one of the following active ingredients:

- DEET
- Picaridin
- IR3535
- Oil of lemon eucalyptus (OLE)
- Para-menthane-diol (PMD)
- 2-undecanone

Cover up: Wear long-sleeved shirts and long pants.

Keep mosquitoes outside: Use air conditioning, or window and door screens. If you are not able to protect yourself from mosquitoes inside your home or hotel, sleep under a mosquito bed net. Source: CDC Prevent Mosquito Bites (https://www.cdc.gov/features/stopmosquitoes/index.html).

Visual 25: Tick-Borne Diseases

- Ticks can be infected with bacteria, viruses, or parasites
- Examples:
  - Lyme disease
  - Rocky Mountain
  - Spotted Fever
  - Southern Tick-Associated Rash Illness
  - Tick-Borne Relapsing Fever
  - tularemia

Key Points

According to the CDC (www.cdc.gov/lyme/index.html) lyme disease is the most commonly reported tick-borne disease in the United States. In 2010, more than 22,500 confirmed and 7,500 probable cases of Lyme disease were reported to the Centers for Disease Control and Prevention (CDC). Take the following steps to protect yourself from tick bites:

- Wear a hat and light-colored clothing, including long-sleeved shirts and long pants tucked into boots or socks.
- Use Environmental Protection Agency (EPA)-registered insect repellents containing DEET, picaridin, IR3535, Oil of Lemon Eucalyptus (OLE), para-menthane-diol (PMD), or 2-undecanone.

EPA's search tool (www.epa.gov/insect-repellents/find-repellent-right-you) can help you find the product that best suits your needs.

  - Always follow product instructions.

- Treat clothing and gear with products containing 0.5% permethrin.
  - Permethrin kills ticks on contact.
  - Permethrin can be used to treat shoes, clothing, and gear but should not be used on skin.
  - One application of permethrin to pants, socks, and shoes remains protective through several washings.
  - Alternatively, permenthrin-treated clothing is available.

- Check your skin and clothes for ticks every day. The immature forms of these ticks are very small and may be hard to see.
  - Shower or bathe as soon as possible after working outdoors to wash off and check for ticks.
  - Remember to check your hair, underarms, and groin for ticks.

Immediately from your ticks body using fine-tipped tweezers. Source: CDC (www.cdc.gov/ticks/removing_a_tick.html)

- Grasp the tick firmly and as close to your skin as possible.
- Pull the tick's body away from your skin with a steady motion.
- Clean the area with soap and water.
- Removing infected ticks within 24 hours reduces your risk of being infected with the Lyme disease bacterium.

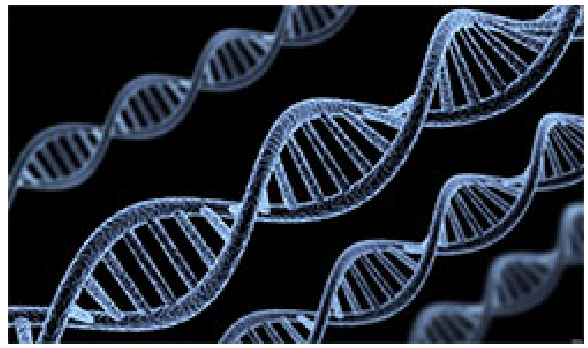
Wash and dry work clothes in a hot dryer to kill any ticks present.

Learn the of tick-borne diseases from the CDC (www.cdc.gov/ticks/symptoms.html)

If you develop symptoms of a tick-borne disease seek medical attention promptly. Be sure to tell your health care provider that you work outdoors in an area where ticks may be present. Source: CDC (https://www.cdc.gov/niosh/topics/tick-borne/recommendation.html).

Visual 26: Public Health

- Local Health Departments (LHD) and Emergency Management are partners in community health response
- Examples of response: 2019 H1N1 pandemic; Ebola (2014), SARS-CoV-2
- Public Health Emergency Preparedness (PHEP) cooperative agreement funds state and LHD efforts
- Technical expertise may be found at the following: Centers for Disease Control (CDC): https://www.cdc.gov/



Health and Human Services (HHS): https://www.hhs.gov/

- Assistant Secretary for Preparedness and Response/Technical Resources Assistance Center and Information Exchange (ASPR/TRACIE): https://asprtracie.hhs.gov/

Funding Streams

Here's some information on recent public health funding streams.

Infection	Programs ($ in millions)	FY2019	NACCHO Request
Emergency Preparedness			
CDC	Public Health Emergency Preparedness Cooperative Agreements$675	-	$824
ASPR	Hospital Preparedness Program	$265	$474
ASPR	Medical Reserve Corps	$6	$11
Infectious Disease Prevention			

Infection	Programs ($ in millions)	FY2019	NACCHO Request
CDC	Section 317 Immunization Program (PPHF)	$611 ($324)	$711
CDC	Core Infectious Disease [Antibiotic Resistance]	$425 [$168]	$457 [$200]
CDC	Epidemiology and Lab Capacity Grants (PPHF)	$195 ($40)	$195 ($40)
CDC	New Initiative for Infectious Diseases Related to IV Drug Use	-	$58
Environmental Health			
CDC	Childhood Lead Poisoning Prevention (PPHF)		
CDC	Vector Control	$39	$129
CDC	Food Safety	$60	$66
Public Health Capacity			
CDC	Public Health Workforce Development	$51	$57
CDC	Preventive Health & Health Services Block Grant (PPHF)	$160 ($160)	$170
Injury Prevention			
CDC	Opioid Overdose Prevention & Surveillance	$476	$650
Chronic Disease Prevention			

Infection	Programs ($ in millions)	FY2019	NACCHO Request
CDC	Racial & Ethnic Approaches to Community Health	$56	$77*
CDC	Tobacco (PPHF)	$80 ($130)	$310

*Includes $21 million for tribal communities

Funding streams Table from the National Association of County and City Health Officials (Naccho) (https://www.naccho.org/uploads/downloadable-resources/Hill-Day-Leave-Packet.pdf)

Visual 27: (Optional) Activity 10.1 – Public Health Emergency

Instructions: Working in your table groups…

1. Review the provided scenario
2. Answer the following questions
    - Identify the hazard(s) and the risks that this situation presents for your community, jurisdiction, and state.
    - What local, state, and federal agencies might be involved at this time, and what others may get involved if the situation worsens?
    - What groups or organizations might be involved from the whole community?
    - Consider the 5 mission areas. What steps might be taken within each mission area to ensure that core capabilities are present or developed to deal with the incident?

Key Points

Scenario: A novel highly pathogenic avian influenza was first detected in Europe several weeks ago and has since been detected in the United States. The transmission vector is known to originate in wild birds, and there are hundreds of domestic bird facilities affected both in Europe and the U.S. as well. The first infected commercial flock in the U.S. was identified in a mid-west state over a week ago and then spread to other surrounding states quickly. In the mid-west, there are currently over 62 detections in commercial operations as well as a handful in backyard farms. While no human infections have been confirmed in the U.S. yet, there are reports out of Europe that people have been infected, including one case of person-to-person transmission between spouses.

Although unconfirmed, there have been nearly a dozen cases of suspected transmission to humans working in the commercial facilities here in the U.S. Tests for humans are being developed for the pathogen by the CDC and will take several days before they can be confirmed. Concerns are spreading in the public that this new avian flu will quickly spread to other communities affecting not only flocks but also people. While depopulation efforts are underway to control the spread among commercial flocks, there is concern that the disease may spread among humans.

Instructions: Working in your groups, answer the following questions:

- Identify the hazard(s) and the risks that this situation presents for your community, jurisdiction, and state.

- What local, state, and federal agencies might be involved at this time, and what others may get involved if the situation worsens?

- What groups or organizations might be involved from the whole community?

- Consider the 5 mission areas. What steps might be taken within each mission area to ensure that core capabilities are present or developed to deal with the incident?

Visual 28: Fungi

- Are primitive forms of vegetables (mushrooms, mold, and mildew).
- Can live in soil; on plants, trees, and other vegetation; and within our bodies.
- May not be dangerous, and many are helpful.
- Can act as pathogens or toxins causing mild (thrush) to severe (fungal pneumonia) diseases.

Key Points

Description: A fungus is actually a primitive vegetable. Mushrooms, mold, and mildew are examples. Fungi can be found in soil; on plants, trees, and other vegetation; and on our skin, mucous membranes, and intestinal tracts.

Reproduction: Some fungi reproduce through tiny spores in the air. Spores can be inhaled, or they can land on the body. As a result, fungal infections often start in the lungs or on the skin. A fungal infection is more likely in a person with a weakened immune system or who has taken antibiotics.

Useful fungi: Most fungi are not dangerous, and some can even be helpful-for example, penicillin, bread, wine, and beer all use ingredients made from fungi.

Health impacts: Some types of fungi can be harmful to health, and like bacteria and viruses, can act as pathogens or toxins. Only about half of all types of fungi are harmful. Fungal diseases are often caused by fungi that are common in the environment.

- Fungal infections can be mild, such as a rash or a mild respiratory illness. More common fungal infections include athlete's foot or thrush (a yeast infection).
- Other fungal infections can be severe, such as fungal pneumonia or bloodstream infection, and can lead to serious complications such as meningitis or death.

The symptoms of fungal diseases depend on the type of infection and location within the body.

Mycotic (fungal) infections pose an increasing threat to public health for several reasons. Categories of fungal infections being studied include:

- **Opportunistic infections** such as cryptococcosis and aspergillosis. These infections are becoming increasingly problematic as the number of people with weakened immune systems rises, including cancer patients, transplant recipients, and people with HIV/AIDS.
- **Hospital-associated infections** such as candidemia. These infections are a leading cause of bloodstream infections in the United States.

- **Community-acquired infections** such as coccidioidomycosis (valley fever), blastomycosis, and histoplasmosis. Fungi that cause these infections live in the soil, on plants, or in compost heaps, and are endemic (native and common) throughout much of the United States.

Treatment: Fungi can be difficult to kill. For skin and nail infections, medicine can be applied directly to the infected area. Oral antifungal medicines are also available for serious infections.

(Source: CDC and NIH: National Institute of Allergy and Infectious Diseases)

Visual 29: Bioterrorism

- Deliberate release of biological agent used to cause illness or death in people, animals, or plants

Key Points

Now that we have reviewed the various types of biological agents, next we will consider how they have been—or could be—used as weapons of terror.

Bioterrorism is the deliberate release of viruses, bacteria, or other germs (agents) used to cause illness or death in people, animals, or plants.

- These agents are typically found in nature, but it is possible that they could be changed to:
  - Increase their ability to cause disease
  - Make them resistant to current medicines
  - Increase their ability to be spread into the environment
- Biological agents can be spread through the air, through water, or in food.
- Terrorists may use biological agents because they can be extremely difficult to detect and do not cause illness for several hours to several days.
- Some bioterrorism agents, like the smallpox virus, can be spread from person to person and some, like anthrax, cannot.

Visual 30: Bioterrorism: Agents of Concern

Bacterial:

- Anthrax (Bacillus anthracis)
- Plague (Yersinia pestis)
- Tularemia (Francisella tularensis)

Viral:

- Smallpox (variola major)
- Viral Hemorrhagic fevers (various agents)

Toxins:

- Botulism (Costridium botulinum)
- Ricin (Ricinus communis)

Key Points

Agents of concern fall into three types: bacterial, viral, and toxins. These are examples of each. We will go into more detail on some of these examples.

Categories: Biological agents fall into one of three categories based on the level of risk (i.e., how easily they can spread, the severity of illness caused, etc.). Category A agents have the highest risk and Category C agents are emerging threats.

The following job aid summarizes these categories.

Biological Agent Categories

Category	CDC Definition	Agents/Diseases

A	The U.S. public health system and primary healthcare providers must be prepared to address various biological agents, including pathogens that are rarely seen in the United States. High-priority agents include organisms that pose a risk to national security because they:
	• Can be easily disseminated or transmitted from person to person;
	• Result in high mortality rates and have the potential for major public health impact;
	• Might cause public panic and social disruption; and
		• Anthrax *(Bacillus anthracis)*
		• Botulism *(Clostridium botulinum toxin)*
		• Plague *(Yersinia pestis)*
		• Smallpox (variola major)
		• Tularemia *(Francisella tularensis)*
		• Viral hemorrhagic fevers:
		  • Filoviruses (e.g., Ebola, Marburg)
		  • Arenaviruses (e.g., Lassa, Machupo)

Category	CDC Definition	Agents/Diseases
	• Require special action for public health preparedness.	
B	Second highest priority agents include those that: • Are moderately easy to disseminate; • Result in moderate morbidity rates and low mortality rates; and • Require specific enhancements of CDC's diagnostic capacity and enhanced disease surveillance.	• Brucellosis *(Brucella species)* • Epsilon toxin of *Clostridium perfringens* • Food safety threats (e.g., *Salmonella* species, *Escherichia coli* O157:H7, *Shigella*) • Glanders *(Burkholderia mallei)* • Melioidosis *(Burkholderia pseudomallei)* • Psittacosis *(Chlamydia psittaci)* • Q fever *(Coxiella burnetii)* • Ricin toxin from *Ricinus communis* (castor beans) • Staphylococcal enterotoxin B • Typhus fever *(Rickettsia prowazekii)* • Viral encephalitis (alphaviruses (e.g., • Venezuelan equine encephalitis, eastern equine encephalitis, western equine encephalitis)) • Water safety threats (e.g., *Vibrio cholerae, Cryptosporidium parvum*)
C	Third highest priority agents include emerging pathogens that could be engineered for mass dissemination in the future because of: • Availability; • Ease of production and dissemination; and • Potential for high morbidity and mortality rates and major health impact.	• Emerging infectious diseases such as Nipah virus and hantavirus

Visual 31: Video: The Anthrax Threat

Key Points

Introduction: This video provides a brief overview of the history of the threat posed by anthrax.

Video Transcript:

Joanne Cono, MD, ScM, Centers for Disease Control and Prevention: The idea of using disease as a weapon gained a new level of sophistication in the early 1930s as nationally funded research programs on biological warfare were developed. The Japanese had a very active offensive biowarfare research program, which included a battalion known as 731. In their program, the Japanese conducted experiments on humans, using 15 to 20 different disease-causing agents, with anthrax being one of their favorites. Allied prisoners of war and innocent Manchurian civilians in nearby villages provided an almost endless supply of experimental subjects. When word of unit 731 leaked to the West, allied forces began their own programs, concerned that Japan and possibly Germany would gain a military advantage in biowarfare research.

Narrator: On the third day after exposure, the casualties begin. Dead sheep can be seen further down the line. It is, of course, necessary to confirm that they have died of anthrax.

Dr. Cono: In 1942, on Gruinard Island off the coast of Scotland, the British conducted their first scientifically controlled biowarfare field trials. Scientists exploded anthrax bombs near immobilized sheep to determine if the spores would survive an explosion and retain the ability to infect anyone nearby. Test results showed that anthrax could in fact be effectively disbursed by explosive devices and could also remain viable in the soil for decades. This brought home the realization that if an anthrax bomb were dropped on a city like London, the results could have been catastrophic. Gruinard Island was declared off limits until it was decontaminated in the 1980s. It's now safe for both humans and animals.

Like our allies, the United States responded to the perceived threats from Germany and Japan. In 1943, we began an offensive biological program with a modest research and development facility at Camp Detrick, which is now Fort Detrick, Maryland. By the end of the program, we had weaponized a total of seven incapacitating or lethal human agents, including anthrax. In 1969, Richard Nixon renounced the use of biological weapons for the United States.

Richard Nixon: I have decided that the United States of America will renounce the use of any form of deadly biological weapons that either kill or incapacitate.

William C. Patrick III, Biological Warfare Consultant: President Nixon visited Fort Detrick on the 25th of November, 1969. I remember that date quite well because following his announcement of taking munitions and beating them into plowshares, we all lost our job and that was a very traumatic experience. But following his presidential announcement on this date, the entire United States offensive program on biological warfare came to a close within two years.

We destroyed all of our seed stocks; we destroyed all of our production material at Pine Bluff, Arkansas; and we completely got out of the biological warfare business.

Dr. Cono: Even at its peak, the U.S. offensive program paled compared to the Soviet Union's. The Soviets had a massive, extensive, sophisticated, top-secret program which employed tens of thousands of scientists and engineers in numerous research and production facilities. The Soviets signed the biological warfare convention in the 1970s and yet their program continued uninterrupted, and, in fact, intensified. Our worst fears were confirmed in 1979 when an accidental release of anthrax occurred at a biological research facility in the town of Sverdlovsk. Much of our recent knowledge about their joint military and civilian program comes from a Soviet defector, Dr. Ken Alibek, formerly known as Dr. Kanatjian Alibekov. He was the deputy director of Biopreparat, a cover organization for their civilian bioweapon and production facilities. Although we had suspected for years that they had continued their offensive program, some of the information he provided was a real wake-up call for the United States.

Prior to the Gulf War, the intelligence community suspected that the Iraqis had done research on anthrax, but they didn't know just how extensive their program was. So as a precautionary measure during the war, about 150,000 U.S. service members were vaccinated against anthrax. And more would have been immunized if the war hadn't ended so quickly. After the war, the Iraqis admitted to producing and weaponizing anthrax, although the weapons were never used.

Dr. Cono: This past decade, anthrax moved from being an agent of concern for biological warfare to the top of the threat list for terrorism. The Aum Shinrikyo cult in Japan, which released the nerve agent sarin from the Tokyo subway in 1995, allegedly made multiple unsuccessful attempts to infect people with anthrax. In October of 2001, the United States experienced anthrax attacks using powder sent through the United States postal service. Twenty-two people got sick and five people died from this attack. We learned just how dangerous anthrax could be.

But there are things we can do. The best defense against a bioterrorism attack is knowledge and preparation. The Web page ready.gov is a good resource for preparedness information. It can be found at www.ready.gov. Visit this Web page for detailed guidelines, facts, and what you can do to be ready in the event of an emergency. A small amount of time spent becoming informed, developing a plan, and preparing yourself against terrorist threats now can prove to be invaluable, should the need arise. Don't be afraid, be ready.

Visual 32: Anthrax

Classification: Bacteria

Routes of Exposure:

- Inhalation
- Absorption
- Ingestion
- Injection

Contagion: Noncontagious (except cutaneous)

First Symptoms: 1 to 7 Days

Signs & Symptoms: Fever, fatigue, chest pain, shortness of breath

Key Points

We have seen the history of anthrax as a weapon of terror. What, exactly, is anthrax? Below is a brief summary:

Classification—bacteria: Anthrax is a serious disease caused by *Bacillus anthracis,* a bacterium that forms spores. There are four types of anthrax: cutaneous, inhalation, gastrointestinal, and injection.

Routes of exposure: There are four routes of exposure, correlating with the types of anthrax:

- Absorption-cutaneous anthrax is absorbed through the skin.
- Inhalation-inhalation anthrax is contracted by breathing it into the lungs (the most hazardous route).
- Ingestion-gastrointestinal anthrax is contracted by eating contaminated food.
- Injection-injected anthrax is usually injected by needle through tainted illicit drugs

Contagion: Anthrax is not known to spread from one person to another. Humans can become infected with anthrax by handling products from infected animals or by breathing in anthrax spores from infected animal products (e.g., wool). People also can become infected with gastrointestinal anthrax by eating undercooked meat from infected animals.

First symptoms: Symptoms can appear within 7 days of coming in contact with the bacterium for all three types of anthrax. However, for inhalation anthrax, symptoms can appear within a week or can take up to 42 days to appear.

Signs and symptoms: The symptoms (warning signs) of anthrax are different depending on the type of the disease:

- Cutaneous: The first symptom is a small sore that develops into a blister. The blister then develops into a skin ulcer with a black area in the center. The sore, blister, and ulcer do not hurt.
- Gastrointestinal: The first symptoms are nausea, loss of appetite, bloody diarrhea, and fever, followed by bad stomach pain.

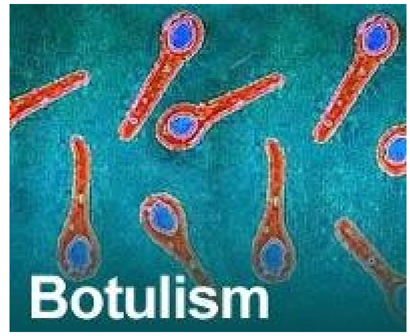
- Inhalation: The first symptoms of inhalation anthrax are like cold or flu symptoms and can include a sore throat, mild fever, and muscle aches. Later symptoms include cough, chest discomfort, shortness of breath, tiredness, and muscle aches. Because the symptoms are generic and flu-like, victims may miss the window of opportunity for effective treatment.
- Injection: Injection anthrax symptoms are similar to those of cutaneous anthrax, but injection anthrax can spread throughout the body faster and be harder to recognize and treat than cutaneous anthrax.

Treatment and prevention: In most cases, early treatment with antibiotics can cure cutaneous anthrax. Even if untreated, 80 percent of people who become infected with cutaneous anthrax do not die. Gastrointestinal anthrax is more serious: between one-fourth and more than half of cases lead to death. Inhalation anthrax is much more severe. In 2001, about half of the cases of inhalation anthrax ended in death.

There is a vaccine to prevent anthrax, but it is not yet available for the general public.

(Source: CDC)

Visual 33: Botulism



Classification: Toxin

Routes of Exposure:

- Ingestion
- Injection

Contagion: Noncontagious

First Symptoms: 1 to 10 Days

Signs & Symptoms:

- Weakness and dizziness
- Dry mouth and throat
- Blurred vision

Key Points

Classification—toxin: Botulism is a muscle-paralyzing disease caused by a toxin made by a bacterium called *Clostridium botulinum.* There are five main kinds of botulism.

- **Foodborne botulism** is caused by eating foods that contain the botulinum toxin. Foodborne botulism is a public health emergency because the contaminated food may still be available to other persons besides the patient.
- **Infant botulism** is caused by consuming the spores of the botulinum bacteria, which then grow in the intestines and release toxin.
- **Wound botulism** is caused by toxin produced from a wound infected with *C. botulinum.*
- **Adult intestinal toxemia botulism** is a very rare kind of botulism that occurs among adults by the same route as infant botulism.
- **Iatrogenic botulism** can occur from accidental overdose of botulinum toxin.

Routes of exposure: The main routes of exposure are ingestion (from food) and injection (through wounds).

Contagion: Botulism is not spread from one person to another. Foodborne botulism can occur in all age groups.

First symptoms: With foodborne botulism, symptoms begin within 6 hours to 10 days (most commonly between 12 and 36 hours) after eating food that contains the toxin.

Signs and symptoms: Symptoms of botulism include:

- Double or blurred vision.
- Drooping eyelids.
- Slurred speech.
- Difficulty swallowing.
- Dry mouth.

- Muscle weakness that moves down the body, usually affecting the shoulders first, then the upper arms, lower arms, thighs, calves, etc. Paralysis of breathing muscles can cause a person to stop breathing and die, unless assistance with breathing (mechanical ventilation) is provided.

Treatment: Antitoxins are used to reduce the severity of symptoms. Most patients eventually recover after weeks to months of supportive care.

(Source: CDC)

Visual 34: Plague

Classification: Bacteria

Routes of Exposure:

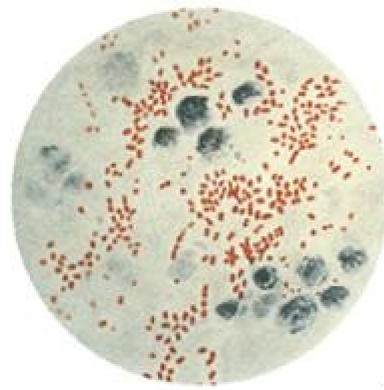
- Inhalation
- Absorption
- Injection

Contagion:

- Contagious (pneumonic)
- Noncontagious (bubonic)

First Symptoms: 1 to 6 Days

Signs & Symptoms: Fever, fatigue, headache, spitting up blood, shortness of breath, and buboes



CDC

Key Points

Classification—bacteria: Plague is a disease caused by *Yersinia pestis (Y. pestis),* a bacterium found in rodents and their fleas in many areas around the world. Two types of plague are pneumonic plague and bubonic plague.

Routes of exposure:

- Pneumonic plague: Exposure occurs through inhalation. This could happen in an aerosol release during a bioterrorism attack or by breathing in respiratory droplets from a person (or animal) with pneumonic plague, usually from coughing or sneezing within 6 feet.
- Bubonic plague: Exposure occurs through absorption or injection-through the bite of an infected flea or exposure to infected material through a break in the skin.

Contagion: Pneumonic plague can be transmitted from person to person; bubonic plague cannot.

First symptoms: A person usually becomes ill with bubonic plague 2 to 6 days after being infected. Someone exposed to *Yersinia pestis* through the air would become ill within 1 to 3 days.

Signs and symptoms:

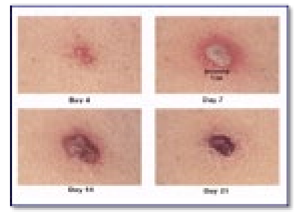
- Pneumonic plague: Patients usually have fever, weakness, and rapidly developing pneumonia with shortness of breath, chest pain, cough, and sometimes bloody or watery sputum. Nausea, vomiting, and abdominal pain may also occur. Without early treatment, pneumonic plague usually leads to respiratory failure, shock, and rapid death.
- Bubonic plague: Symptoms include swollen, tender lymph glands called buboes. If bubonic plague is not treated, however, the bacteria can spread through the bloodstream and infect the lungs, causing a secondary case of pneumonic plague.

Treatment: People who have had close contact with an infected person can greatly reduce the chance of becoming sick if they begin treatment within 7 days of their exposure. Treatment consists of taking antibiotics for at least 7 days. Currently, no plague vaccine is available in the United States.

Bioterrorism concern: Yersinia pestis used in an aerosol attack could cause cases of the pneumonic form of plague. Because of the delay between being exposed to the bacteria and becoming sick, people could travel over a large area before becoming contagious and possibly infecting others. Controlling the disease would then be more difficult.

(Source: CDC)

Visual 35: Smallpox



Classification: Virus

Routes of Exposure:

- Inhalation

Contagion: Highly Contagious

First Symptoms: 79 to 917 Days

Signs & Symptoms:

- High fever, aches, vomiting
- Mouth sores
- Skin rash, blisters, scabs

Key Points

Classification—virus: Smallpox is a serious and sometimes fatal infectious disease caused by the variola virus. The *pox* part of *smallpox* is derived from the Latin word for "spotted" and refers to the raised bumps that appear on the face and body of an infected person. There are two clinical forms of smallpox: variola major and variola minor. Variola major-the severe and most common form of smallpox-includes four types:

- Ordinary (the most frequent type, accounting for 90 percent or more of cases).
- Modified (mild and occurring in previously vaccinated persons).
- Flat.
- Hemorrhagic (both rare and very severe).

Historically, variola major has an overall fatality rate of about 30 percent; however, flat and hemorrhagic smallpox usually are fatal. Variola minor is a less common and much less severe disease, with death rates historically of 1 percent or less.

Routes of exposure: Smallpox is transmitted by inhalation.

- Generally, direct and fairly prolonged face-to-face contact is required to spread smallpox from one person to another.
- Smallpox also can be spread through direct contact with infected bodily fluids or contaminated objects such as bedding or clothing.
- Rarely, smallpox has been spread by virus carried in the air in enclosed settings such as buildings, buses, and trains.
- Humans are the only natural hosts of variola. Smallpox is not known to be transmitted by insects or animals.

Contagion: Smallpox is highly contagious. A person with smallpox is sometimes contagious with onset of fever but becomes most contagious with the onset of rash. At this stage the infected person is usually very sick and not able to move around in the community. The infected person is contagious until the last smallpox scab falls off.

First symptoms: The incubation period is 7 to 17 days (average 12 to 14 days), during which the person is not contagious.

Signs and symptoms: The signs and symptoms of smallpox come in phases.

- The first symptoms of smallpox include fever, malaise, head and body aches, and sometimes vomiting. The fever is usually high (2 to 4 days duration).
- This stage is followed by a rash sequence (about 21 days, during which the person is quite contagious) that includes emergence of mouth sores, skin rash, formation of blisters, crusting, scabbing, and scabs falling off leaving scars.

Treatment: There is no specific treatment for smallpox disease, and the only prevention is vaccination.

Bioterrorism concern: Except for laboratory stockpiles, the variola virus has been eliminated. The last case of smallpox in the United States was in 1949. The last naturally occurring case in the world was in Somalia in 1977. However, the deliberate release of smallpox as an epidemic disease is a remote possibility.

(Source: CDC)

Visual 36: Ricin

Classification: Toxin

Routes of Exposure:

- Inhalation
- Absorption
- Ingestion
- Injection

Contagion: Noncontagious

First Symptoms: 6 to 8 hours

Signs & Symptoms: Fever, cough, excess fluid in the lungs, and heavy sweating

Key Points

Classification—toxin: Ricin is a poison that can be made from the waste left over from processing castor beans. Depending on the route of exposure, as little as 500 micrograms of ricin could be enough to kill an adult. A 500-microgram dose of ricin would be about the size of the head of a pin. A greater amount would likely be needed to kill people if the ricin were swallowed.

Routes of exposure: Ricin poisoning can occur through:

- Inhalation.
- Absorption.
- Ingestion.
- Injection.

Contagion: Ricin poisoning is not contagious. It cannot be spread from person to person through casual contact.

First symptoms: Initial symptoms of ricin poisoning by inhalation (breathing in the ricin) may occur within 8 hours of exposure. Following ingestion (swallowing) of ricin, initial symptoms typically occur in less than 6 hours.

Signs and symptoms: The major symptoms of ricin poisoning depend on the route of exposure and the dose received, though many organs may be affected in severe cases.

- Inhalation: Within a few hours of inhaling significant amounts of ricin, the likely symptoms would be:
  - Respiratory distress (fluid buildup in the lungs, difficulty breathing). o Fever, heavy sweating.
  - Cough.
  - Nausea.
  - Tightness in the chest.

  - Low blood pressure and respiratory failure, leading to death.
- Ingestion: A person who swallowed a significant amount of ricin would develop vomiting and diarrhea that may become bloody, resulting in severe dehydration and low blood pressure. Other signs or symptoms may include hallucinations, seizures, and blood in the urine. Within several days, the person's liver, spleen, and kidneys might stop working, and the person could die.
- Absorption: Ricin in powder or mist form can cause redness and pain of the skin and the eyes.

Death from ricin poisoning could take place within 36 to 72 hours of exposure, depending on the route of exposure and the dose received. If death has not occurred in 3 to 5 days, the victim usually recovers.

Visual 37: Tularemia

Classification: Bacteria

Routes of Exposure:

- Inhalation
- Absorption
- Ingestion
- Injection

Contagion: Noncontagious

First Symptoms: 3 to 14 Days

Signs & Symptoms: Sudden fever, chills, headaches, diarrhea, muscle aches, joint pain, progressive weakness, dry cough

Key Points

Classification—bacteria: Tularemia is a potentially serious illness that occurs naturally in the United States. It is caused by the bacterium *Francisella tularensis* found in animals (especially rodents, rabbits, and hares).

Routes of exposure: People can get tularemia many different ways:

- Inhalation: Breathing in contaminated dusts or aerosols.
- Absorption-skin or eye: Handling infected animal carcasses.
- Ingestion: Eating or drinking contaminated food or water.
- Injection: Being bitten by an infected tick, deerfly, or other insect.

First symptoms: Symptoms usually appear 3 to 5 days after exposure to the bacteria, but can take as long as 14 days.

Contagion: Although the bacterium that causes tularemia is highly infectious, tularemia is not known to be spread from person to person. People who have tularemia do not need to be isolated.

Signs and symptoms: Symptoms of tularemia vary with the route of exposure and can include:

- Sudden fever, chills, and headaches.
- Diarrhea.
- Muscle aches, joint pain.
- Dry cough.
- Progressive weakness.

People can also catch pneumonia and develop chest pain, bloody sputum, and difficulty breathing.

Other symptoms of tularemia depend on how a person was exposed to the tularemia bacteria. These symptoms can include ulcers on the skin or mouth, swollen and painful lymph glands, swollen and painful eyes, and a sore throat.

Treatment: Tularemia is treated with antibiotics. People who have been exposed to the tularemia bacteria should be treated as soon as possible. The disease can be fatal if it is not treated with the right antibiotics.

Bioterrorism concern: The bacteria that cause tularemia occur widely in nature and could be isolated and grown in quantity in a laboratory, although manufacturing an effective aerosol weapon would require considerable sophistication. Because Francisella tularensis is very infectious, a small number (10-50 or so organisms) can cause disease. If F. tularensis were used as a weapon, the bacteria would likely be made airborne for exposure by inhalation.

(Source: CDC)

Visual 38: Viral Hemorrhagic Fevers

Classification: Virus

Routes of Exposure:

- Inhalation
- Absorption
- Ingestion
- Injection

Contagion: Contagious

First Symptoms: 3 to 21 Days

Signs & Symptoms: Fever, fatigue, dizziness, muscle aches, loss of strength, exhaustion, bleeding under skin and within organs, shock, nervous system malfunction, coma, delirium, and seizures

Key Points

Classification—virus: Viral hemorrhagic fevers (VHFs) refer to a group of illnesses that are caused by several distinct families of viruses. In general, the term "viral hemorrhagic fever" is used to describe a severe multisystem syndrome (multisystem in that multiple organ systems in the body are affected). Examples of VHFs include:

- Ebola.
- Marburg.
- Hantavirus.
- Lassa fever.
- Crimean-Congo hemorrhagic fever.
- Tick-borne encephalitis.

Viruses associated with most VHFs are zoonotic, meaning they naturally reside in an animal host or arthropod (e.g., flea, tick, or mosquito) vector and can cross over to humans.

Routes of exposure: Routes of exposure for VHFs include:

- Inhalation—breathing air contaminated with the virus (e.g., when rodent urine, droppings, or nesting materials are stirred up).
- Absorption—e.g., through contact with infected rodent urine, feces, saliva, or other body excretions, or through close contact with infected people or their body fluids.
- Ingestion-—eating food contaminated by urine, droppings, or saliva from an infected host.
- Injection—from mosquito or tick bites, or from contaminated syringes and needles

Vectors may also spread the virus to animals (e.g., livestock). Humans then become infected when they care for or slaughter the animals.

Contagion: Some viruses that cause hemorrhagic fever, such as Ebola, Marburg, Lassa, and Crimean-Congo hemorrhagic fever, can spread from one person to another once an initial person has become infected.

First symptoms: Onset of symptoms varies with the disease. For example, the incubation period for Ebola is 3-21 days; for Marburg, 5-10 days; for hantavirus, symptoms may appear in 1-5 weeks.

Signs and symptoms: Specific signs and symptoms vary by the type of VHF, but initial signs and symptoms often include:

- Marked fever.
- Fatigue.
- Dizziness.
- Muscle aches.
- Loss of strength.
- Exhaustion.

Patients with severe cases of VHF often show signs of bleeding under the skin, in internal organs, or from body orifices like the mouth, eyes, or ears. However, patients rarely die because of blood loss. Severely ill patients may also show shock, nervous system malfunction, coma, delirium, seizures, and kidney failure. Lassa fever can cause deafness.

Ebola Vaccine

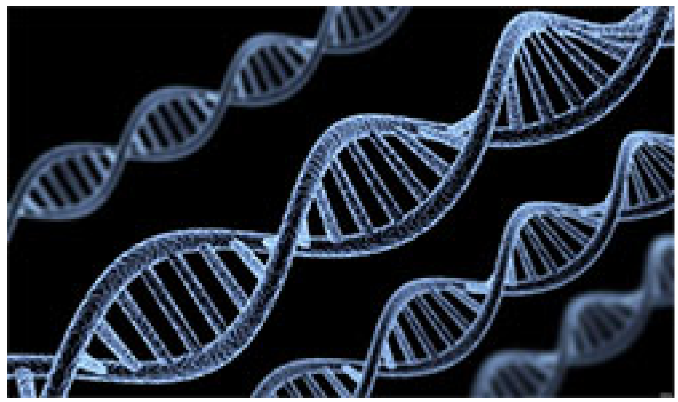
The U.S. Food and Drug Administration (FDA) approved the Ebola vaccine rVSV-ZEBOV (tradename "Ervebo") on December 19, 2019. The rVSV-ZEBOV vaccine is a single dose vaccine regimen that has been found to be safe and protective against only the Zaire ebolavirus species of ebolavirus. This is the first FDA approval of a vaccine for Ebola.

Another investigational vaccine was developed and introduced under a research protocol in 2019 to combat an Ebola outbreak in the Democratic Republic of the Congo. This vaccine leverages two different vaccine components (Ad26.ZEBOV and MVA-BN-Filo) and requires two doses with an initial dose followed by a second "booster" dose 56 days later. The second vaccine is also designed to protect against only the Zaire ebolavirus species of Ebola.

(Source: CDC)

Visual 39: Genetic Modification of Agents

- Genetic modification or selection to become more:
  - Lethal
  - Virulent
  - Antibiotic resistant
- Incorporation of genetic material from another organism to enable the expression of entirely new or additional characteristics



Key Points

Biological agents can be altered genetically to make them more effective weapons. A terrorist's goals for genetic modification of organisms may include:

- Making them more lethal or virulent.
- Making diagnosis difficult by altering the clinical signs or symptoms.
- Making the pathogen resistant to vaccine protection or treatment.

Genetically modified organisms are also of concern because genetically modified crops released into agricultural systems could invade natural ecosystems due to their hardiness and rapid reproductive rates.

Visual 40: Dissemination Methods

- Contamination of water or food sources
  - Salmonella bioterrorism (Oregon)
- Dispersal as vapor or via aerosol
- Transmission indirectly through infected animals or inanimate materials, such as parcels or letters
  - World War II
  - Cold War
  - Postal Anthrax attacks of 2011
- Through direct human contact
  - Georgi Markov assassination
  - Patriots Council

Key Points

Specialists agree that for mass destruction purposes, effective delivery of a biological agent is more problematic than its production. Means of dissemination may include the following:

- **Contamination of water supply:** It is virtually impossible to poison a large water supply. Most lethal biological agents become less viable when transmitted in water and would be further debilitated by the purification system.
- **Contamination of food sources:** Foods are vulnerable to contamination. Unintentional foodborne diseases cause about 5,000 deaths and 325,000 hospitalizations each year, according to CDC.

In 1984, members of an Oregon religious commune-followers of Bhagwan Shree Rajneesh-tried to influence a local election by poisoning salad bars with *Salmonella* bacteria to sicken voters. Although no one died, 751 people became ill. The Oregon attack took place at local restaurants, but an attack could occur at any point between farm and table. Imported food could be tainted with biological or chemical agents before entering the United States, or toxins could be introduced at a domestic food-processing plant.

- **Aerosolization:** The aerosol dissemination of a biological agent is difficult. To work, the agent in suspension would need to be small (< 5m) particles or droplets in the air, and the agent must survive long enough to infect the intended target. Factors such as mechanical stresses in the aerosolization process, moisture, sunlight, temperature changes, and others may reduce the amount or strength of the agent. The most successful aerosolization transmission occurs naturally through coughing, sneezing, talking, or breathing. It is more feasible to spread a chemical agent in a vapor or aerosol.
- **Infected animals and insects:** The release of infected rats, insects, etc., could spread certain diseases to a target location. The animals and insects act as a vector, infecting any

person or animal they might bite. During World War II, the Japanese experimented with plague-infected fleas and cholera-coated flies. During the Cold War, the United States conducted research on the use of yellow fever-infected mosquitoes.

- **Inanimate materials:** Some pathogens and toxins are able to survive on inanimate objects. For example, the smallpox virus lives longer in scabs than in the droplets spread from person to person. According to Dr. Inger Damon, a researcher and epidemiologist at CDC, viruses stored in a smallpox scab in a humidity-controlled environment can survive for a year or longer. The postal anthrax attacks of 2001-the worst biological attacks in U.S. history-are another example of inanimate objects being used to transmit a biological threat.

Human contact: Ricin was used in the assassination of Bulgarian dissenter Georgi Markov, who died several days after being jabbed by a poison-tipped umbrella injector designed by the Soviet intelligence agency KGB. In Minnesota, four members of the Patriots Council planned to mix the ricin with the solvent dimethyl sulfoxide and then smear it on the door handles of a U.S. Marshal's vehicle. The plan was discovered and averted, and the men were convicted.

Visual 41: Agricultural Bioterrorism

- Intentional use of biologicals (toxins, pathogens, or pests) against some component of agriculture industry
- Include natural resources, crops, livestock, and wildlife

An intentional release of foot and mouth disease (FMD) could result in $30 billion in lost trade. A simple fungus called "soybean rust" could result in an $8 billion loss.

Key Points

The U.S. Department of Agriculture defines **agricultural bioterrorism** as "the intentional use of biologicals (toxins, pathogens, or pests) against some component of agriculture in such a way as to adversely impact the agriculture industry or any component thereof, the economy, or the consuming public."

- An act of agricultural terrorism causing billions of dollars in damage could be produced by a limited infection of pathogens delivered by simple methods.
- There are fewer controls monitoring the possession of microorganisms that infect only plants or livestock, compared to those that infect humans.
- Terrorist attacks on agriculture are difficult to distinguish from naturally occurring outbreaks.

History: The United States has not experienced a major agricultural disaster in recent memory. However, history is full of examples of intentional introductions of pests and diseases.

- During World War I, Germany used anthrax and glanders to target horses, mules, cattle, sheep, and reindeer in the United States, Romania, Spain, France, Norway, and Argentina. By World War II, Japan, Russia, Great Britain, France, and the United States had active biological weapons programs. The weapons program by the United States began in response to the threat posed by other countries.
- In more recent times, Rhodesian and South African forces used anthrax to target cattle. In addition to thousands of cattle dying, there were more than 10,000 human cases with 334 known deaths.
- In 1997, New Zealand farmers, dissatisfied with the Government's lack of action in controlling the exploding rabbit population, developed simple methods for extracting and concentrating particles of viral hemorrhagic fever which they used to contaminate carrots and other food sources for rabbits. The plan experienced limited effectiveness.

Potential impact: The impact of an intentional introduction of foot and mouth disease (FMD) would be staggering. The sheer numbers of livestock and wildlife at risk are enormous: 100 million cattle, 70 million swine, 10 million sheep, and 40 million wildlife.

The consequences of a major attack on the livestock industry would be felt almost immediately by consumers. No major city has more than a 7-day supply of food. Such an attack could easily cause widespread fear and panic and undermine public confidence in government. The economic costs could potentially be devastating, resulting in a loss of billions in trade, and costs for diagnostics, surveillance, slaughter, cleaning, disinfection, and indemnities.

An attack on crops would have a similar impact. Plant targets include:

- Food crops:
  - Corn
  - Wheat
  - Soybeans
  - Citrus
  - Sugarcane
- Fiber:
  - Cotton
- Timber:
  - Northwest United States

The threat posed by soybean rust (one of the select agents) alone is estimated at $8 billion if it enters the mainland United States. Soybean rust causes huge production losses in Asia and South America. It is present in Hawaii and Puerto Rico.

Visual 42: Agricultural Vulnerabilities

- Concentrated targets and business practices make the spread of pathogens easier.
- Biosecurity must cover almost a billion acres of farmland.
- Reduced genetic diversity makes crops and animals more vulnerable to a single pathogen.
- Lack of immunity to foreign animal diseases such as FMD.
- Resistant pathogens from widespread use of antibiotics and pesticide use.

Key Points

The following factors make U.S. agriculture vulnerable to bioterrorism:

- **Concentrated targets.** Livestock and crops are found in concentrated areas throughout the United States.
- **Business practices.** Large agribusiness companies control production, processing, and distribution, making the spread of pathogens easier.
- **Security challenges.** Farm biosecurity measures must cover a large area (compare 6,000 miles of national borders with almost a billion acres of farmland).
- **Reduced genetic diversity.** As crops and animals become more similar in their genetic makeup, they become more vulnerable to a single pathogen.
- **Lack of immunity.** The absence of foreign animal diseases means that our livestock have no natural immunity to many diseases.
- **Resistant pathogens.** Widespread use of antibiotics can make livestock susceptible to resistant strains of pathogens. Pesticide use may create resistant strains of exotic plant pests.

Visual 43: Experts

- Industrial Hygienists
- Toxicologists
- Epidemiologists
- Public Health Officers

Key Points

A variety of experts are working to better understand biological threats and develop strategies for controlling them. The following are some of them:

- **Industrial hygienists** use environmental monitoring and analytical methods to anticipate, recognize, evaluate, and control workplace conditions that may cause worker injury or illness.
- **Toxicologists** plan and carry out laboratory and field studies to identify, monitor, and evaluate the impact of toxic materials and radiation on human and animal health, the environment, and the impact of future technology. In general, toxicologists: o Conduct laboratory studies on substances (e.g., drugs, food additives, solvents, herbicides) or on energy (e.g., radiation) to determine their effects on laboratory animals, plants, and human tissue.
  - Conduct research to develop new tests for use in toxicological studies.
  - Evaluate potential risks based on levels and periods of exposure.
  - Analyze and evaluate data gathered from studies and reliable scientific publications to determine appropriate controls for various chemical and physical hazards.
  - Develop standards or guidelines for safe levels of chemical and physical agents in workplaces, air, food, or drinking water.
  - Provide advice and scientific information to policy and program developers concerning the health and legal aspects of chemical use.
- **Epidemiologists** investigate and describe the determinants and distribution of disease, disability, or health outcomes. Epidemiologists may:
  - Develop or refine methods of measuring and evaluating disease occurrences. o Develop and recommend public health policy.
  - Study chronic diseases, infectious diseases, disease outbreaks, injuries, occupations, and environments.
  - Develop the means for prevention and control.

- **Public Health Officers** protect and improve the health of families and communities through promotion of healthy lifestyles, research for disease and injury prevention, and detection and control of infectious diseases. Overall, public health is concerned with protecting the health of entire populations using such methods as implementing educational programs, recommending policies, administering services, and conducting research. Public health officials also work to limit health disparities by promoting healthcare equity, quality, and accessibility.

Local public health officers may:

- Make periodic sanitary inspections of school buildings, restaurants, dairies, grocery stores, meat markets, and public gathering places.
- Disseminate information on the causes, nature, and prevention of prevalent diseases and the preservation and improvement of health.
- Enforce the health laws, rules, and regulations of the State Board of Health, the State, and the city, including the laws relating to contagious diseases.
- Take steps to secure prompt and full reports by physicians of communicable diseases and prompt and full registration of births and deaths.

Visual 44: Activity 10.2 – Hurricane Sandy

Instructions: Working in your teams, please answer the following questions:

1. Identify at least one health concern related to each type of pathogen:
   - Bacteria
   - Viruses
   - Fungi
2. If the disaster resulted in opening shelters, what additional measures would you consider be taken given the above concerns in question 1?
3. If you were to create a table-top exercise for this scenario, who would you include on your exercise planning team based on your answers to questions 1 and 2?
4. Develop 1-2 exercise objectives for your table-top exercise.

Key Points

Scenario: In October 2012, Hurricane Sandy struck the Northeast, causing major flooding, disruption, structural damage, and power outages.

Instructions: Working in your teams, please answer the following questions:

Identify at least one health concern related to each type of pathogen:

- Bacteria:

- Viruses:

- Fungi:

If the disaster resulted in opening shelters, what additional measures would you consider be taken given the above concerns in question 1?

If you were to create a table-top exercise for this scenario, who would you include on your exercise planning team based on your answers to questions 1 and 2?

Develop 1-2 exercise objectives for your table-top exercise.

Visual 45: Unit Summary

You should now be able to:

- Define what is meant by biology.
- Identify the importance of cells.
- Differentiate between pathogens and toxins.
- Identify the characteristics and significance of bacteria, viruses, and fungi.
- Describe the potential consequences of a pandemic influenza on a jurisdiction's preparedness
- Identify potential bioterrorism agents of concern
- Describe the impact of agricultural bioterrorism
- Identify potential dissemination methods of biological agents

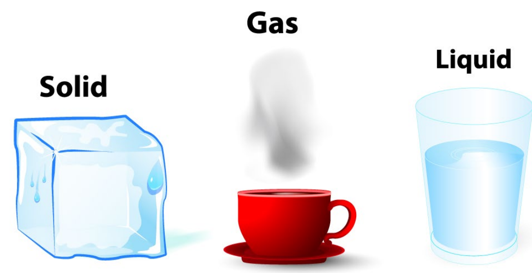
Key Points

Do you have any questions about the material covered in this unit?

Unit 11: Fundamentals of Matter

Visual 1: Unit 11: Fundamentals of Matter

Unit 11: Fundamentals of Matter



Key Points

This unit will explore the scientific basis for chemical hazards and threats.

Time Plan

A suggested time plan for this unit is shown below.

Topic	Time
Introduction	5 minutes
Chemistry Basics	20 minutes
Unit Summary	5 minutes
Total Time	**30 minutes**

Visual 2: Unit Topics

- **Chemistry Basics**
- Types of Chemical Hazards

Key Points

This unit will discuss three main topics: chemistry basics, types of chemical hazards, and chemical agents used as weapons. We'll begin with chemistry basics.

Visual 3: Unit Objectives

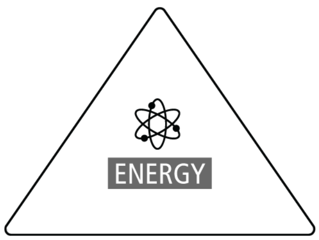
- Describe the phases of matter.
- Identify factors affecting chemical dispersion.
- Identify the elements necessary for fire.
- Indicate the potential hazards related to flammable, oxidizing, toxic, and corrosive materials.

Key Points

Review the unit objectives as shown on the visual.

Visual 4:

Video: Reviewing the Basics: Phases of Matter



This is energy.

Key Points

Video © 2011 About, Inc. Used with permission.

Introduction: This is Energy. Matter can exist in different phases (also called states): solid, liquid, or gas. Most substances can transition between these phases based on the amount of heat the material absorbs (or loses). This video will discuss the phases of matter and how they can change.

Video Transcript:

Phases of Matter

The phases of matter are:

- Solid—which has a definite shape and volume
- Liquid—which has a definite volume, but it can change shape
- Gas—the shape and volume of a gas can change

Phase Changes of Matter

There are several ways in which phases of matter can change from one to another:

- Melting—melting occurs when a substance changes from a solid to a liquid
- Boiling—boiling is when a substance changes from a liquid to a gas
- Condensing—condensation is when a gas changes to a liquid
- Freezing—freezing is when a liquid changes to a solid

Classes of Changes in Matter

The changes that take place in substances may be categorized in two classes:

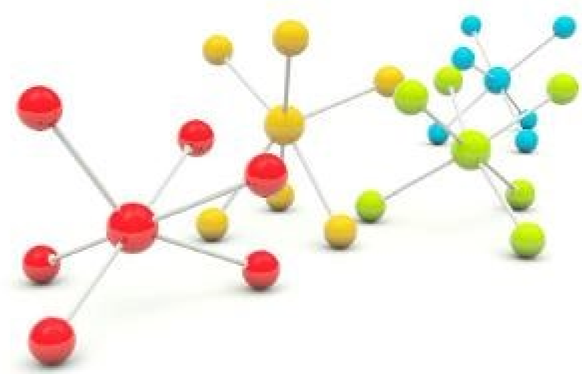
- Physical Change—a new substance is not produced and just the physical properties are changed (for example, phase changes, or crushing a can).
- Chemical Change—a new substance is produced with different chemical properties (for example, burning, rusting, and photosynthesis).

Solutions

Sometimes, when two or more substances are combined, it results in a solution. Making a solution can produce either a physical or chemical change. When there’s a physical change in a solution, the original substances can be separated from one another. If a chemical change takes place while creating a solution, the original substances cannot be separated from one another.

Visual 5: What Is Chemistry? (1 of 2)

Chemistry is the underlying science behind the chemical, radiological, and explosive hazards that we will explore in Units 12, 15, and 14.



Key Points

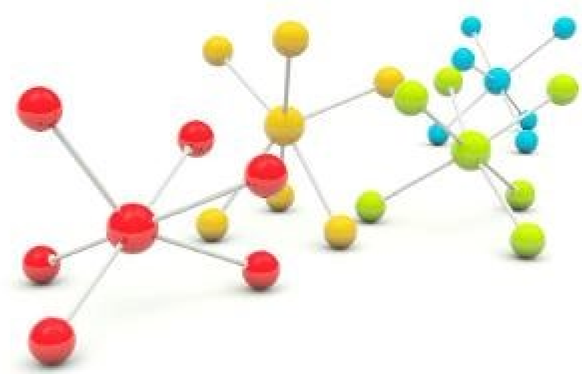
Chemistry, a branch of the physical sciences, studies the composition, structure, properties, and reactions of matter, or substances.

Understanding some basic chemical principles and processes will help you understand the potential hazards and threats associated with chemicals.

Visual 6: What Is Chemistry? (2 of 2)

The composition, structure, properties, and reactions of a substance

Chemistry helps us understand how different substances react with each other or under certain circumstances

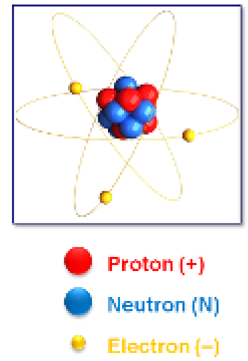


Key Points

Chemistry, a branch of the physical sciences, studies the composition, structure, properties, and reactions of matter, or substances.

Understanding some basic chemical principles and processes will help you understand the potential hazards and threats associated with chemicals.

Visual 7: Atomic Structure



- Protons:
  - Positive charge
  - Determine element's identity
- Neutrons:
  - Neutral charge
  - Determine nuclear properties
- Electrons:
  - Negative charge
  - Determine chemical properties

Protons and Neutron co-exist in the nucleus of the atom.

Key Points

The atom is made up of three fundamental parts: protons, neutrons, and electrons. Protons and neutrons are located in the center part or nucleus of the atom. Electrons revolve around the nucleus similar to the way the planets orbit the sun.

- **Protons** have a positive electrical charge and determine the element's identity.
- **Neutrons** have a neutral electrical charge and determine the nuclear properties of an atom.
- **Electrons** have a negative electrical charge and determine the chemical properties of an atom.

Visual 8: Elements

- Simplest form of matter
- An element is distinguished by the number of protons in its nucleus
- There are 118 elements, of which 90 occur naturally

Key Points

A chemical element is a type of atom that is distinguished by its atomic number; that is, by the number of protons in its nucleus. The term is also used to refer to a pure chemical substance composed of atoms with the same number of protons.

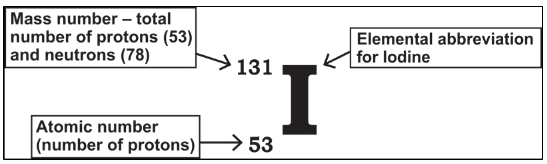
The following are common examples of elements:

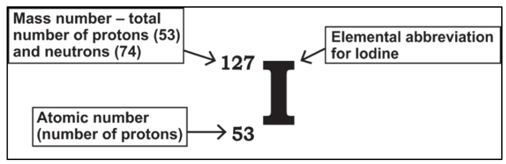
- Iron
- Copper
- Silver
- Gold
- Hydrogen
- Carbon
- Nitrogen
- Oxygen

As of 2011, 118 elements had been observed, of which 90 occur naturally on Earth.

Visual 9: Isotopes

- Atoms of a particular element will always have the **same number of protons** but can **have different numbers of neutrons**. These variants are called isotopes.
- Isotopes have the same chemical properties as the element but different nuclear properties.





The Isotopes of Iodine.

Isotopes Image Description

A diagram illustrating the Isotopes of Iodine. Iodine 131, 53: I - Elemental abbreviation for iodine. Mass number - total number of protons (53) and neutrons (78). Atomic number (number of protons) 53. Iodine 127, 53: I - Elemental abbreviation for iodine. Mass number - total number of protons (53) and neutrons (74). Atomic number (number of protons) 53.

Key Points

An isotope is an atomic species characterized by the number of protons and neutrons, as well as the energy state of the nucleus The notation for a nuclide includes:

- Element (X)
- Atomic Number (Z): Number of protons in the nucleus
- Mass Number (A): Total number of protons + neutrons in the nucleus

The number of protons defines what an element is (Hydrogen, Oxygen, Carbon, etc.). The number of neutrons can be different, which makes them isotopes of that element. Elements with larger numbers of protons like uranium require many more neutrons to prevent the protons from repelling each other too strongly and thus keep the nucleus together.

Visual 10: Radioisotopes—Unstable Isotopes

- The relative number of neutrons and protons in the nucleus of an atom result in either a stable or unstable energy state.
- Atoms with an unstable nucleus give off radiation in an effort to become stable.
- This radioactive decay process causes the atom to change.
- Radioactive decay can be detected and measured.

Key Points

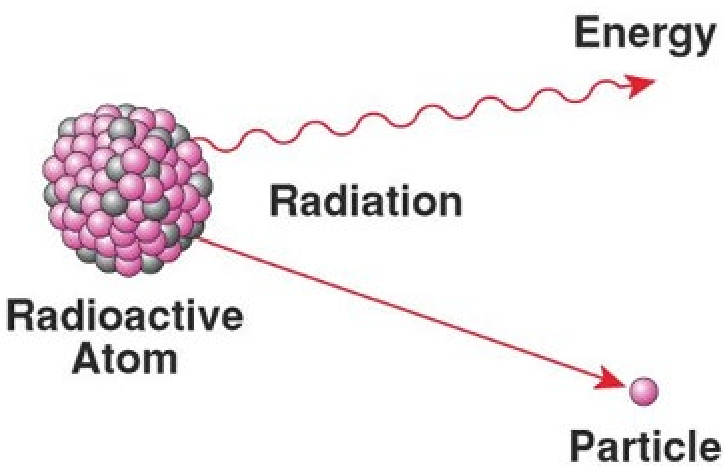
Atoms with an unstable nucleus are radioisotopes, or radionuclides and are radioactive: they give off radiation in an effort to become stable The decay process (ionizing radiation, or radioactivity) causes the atom to change.

Some elements like uranium have different isotopes with different numbers of neutrons. Depending on the number of neutrons in the isotope, some are more unstable than others, which leads to radioactive decay. Uranium in the form of U-234, U-235, and U-238 are found in nature.

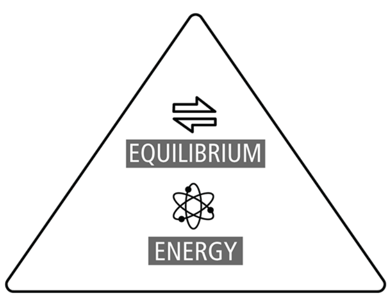
This concept will come back again when we talk about radiation in Unit 14

Visual 11: Radioactivity—Ionizing Radiation

Ionizing radiation can be in the form of energy waves or particles.



This is equilibrium and energy.



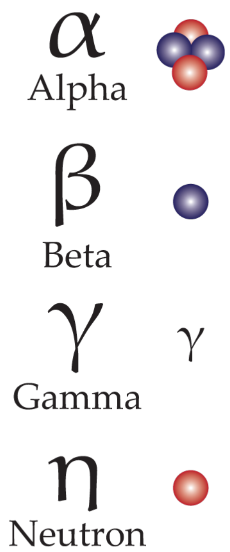
Key Points

In this course, when we speak of radiation, we are referring to radioactive decay, which is more energetic than other types of radiation. It has enough energy to remove electrons from atoms as it passes through matter. (The process of removing electrons from atoms is called **ionization.)**

Ionizing radiation can be in the form of energy waves or particles.

The ability to remove electrons from atoms is what makes ionizing radiation potentially hazardous.

Visual 12: Four Types of Ionizing Radiation



Interaction of Ionizing Radiation with Matter:

- Charged particles interact strongly and ionize directly.
- Neutral particles interact less, ionize indirectly, and penetrate farther.

Key Points

Ionizing radiation carries enough energy to remove electrons from atoms or molecules causing them to become ionized (electrically charged).

The four basic types of ionizing radiation are:

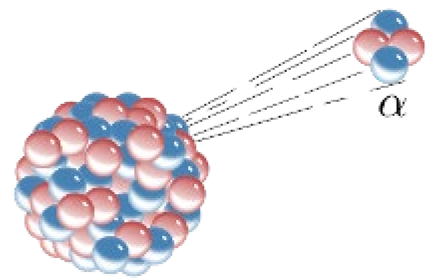
- Alpha radiation.
- Beta radiation.
- Gamma radiation.
- Neutron radiation.

These types differ in their penetrating power and the manner in which they affect human tissue.

Next, you will take a closer look at each type of ionizing radiation and its penetrating ability.

Visual 13: Alpha Radiation

- High-energy particles
- Minimal hazard outside the body



Key Points

Alpha radiation: Alpha radiation consists of particles with two protons and two neutrons (but no electrons) that are ejected from the nucleus of a radioactive atom. Alpha particles:

- Are high-energy particles that are relatively large, heavy, and only travel a short distance (a few inches in air).
- Lose their energy very rapidly.
- Have a low penetrating ability.
- Greatest hazard from alpha-emitting material is when it is inhaled or ingested

PPE with Self-Contained Breathing Apparatus (SCBA) will enhance safety when dealing with alpha

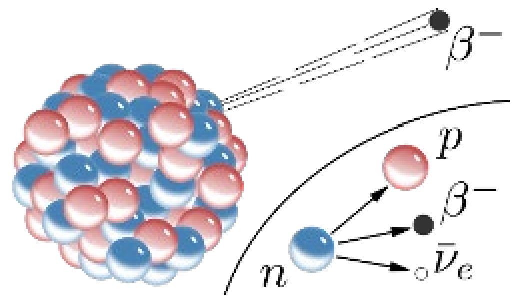
Hazard: Alpha particles pose a minimal biological hazard outside the body. The greatest hazard occurs when the material is inhaled or ingested. Once inside the body, the alpha radiation can cause harm to individual cells or organs.

Note that the alpha "particle" is not what poses the internal hazard; it is the material that is emitting the alpha particles that poses the internal hazard. Once an alpha particle is emitted from the nucleus of an atom, it travels a few inches and stops. When the particle stops, it picks up two free electrons and becomes a harmless helium atom. Therefore, it is not really possible to inhale or ingest alpha particles but, rather, the material that is emitting the alpha particles.

Shielding: The characteristics of alpha radiation make it easy to shield, and something as thin as a sheet of paper can block the passage of alpha radiation.

Visual 14: Beta Radiation

- Smaller, lighter, and travels farther than alpha radiation.
- Exposure to high levels can cause damage to the skin and eyes.



Key Points

Beta radiation: Beta radiation consists of particles-electrons ejected from the nucleus of a radioactive atom. Beta particles:

- Are smaller and lighter than alpha particles.
- Travel farther than alpha particles. In air, beta radiation can travel several feet.
- Outside the body, only a slight hazard.

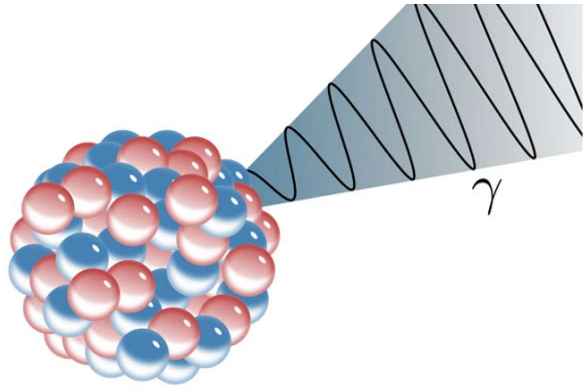
PPE with Self-Contained Breathing Apparatus (SCBA) will enhance safety when dealing with beta radiation.

Hazard: Beta radiation is more penetrating than alpha radiation, but outside of the body is only a slight hazard. The range of penetration in human tissue is less than inch.

Shielding: The characteristics of beta radiation make it easy to shield with moderately dense materials like aluminum.

Visual 15: Gamma Radiation

- Waves of energy that have no mass and no electrical charge.
- Poses a hazard to the entire body.



Key Points

Gamma radiation: Gamma radiation is an electromagnetic wave of energy (not particles) ejected from the nucleus of a radioactive atom. Gamma waves:

- Have no mass and no electrical charge
- Are commonly referred to as "photons"
- Can travel great distances because they have no mass and no electrical charge
- Commonly referred to as photons.
- Can travel a great distance.

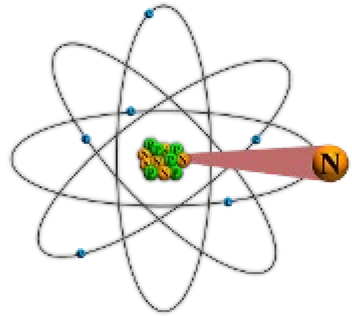
PPE cannot protect against exposure from high-energy, highly penetrating forms of ionizing radiation like Gamma.

Hazard: Gamma radiation poses a hazard to the entire body because it can easily penetrate human tissue.

Shielding: The characteristics of gamma radiation make it very difficult to shield because of its high penetrating ability. Very dense materials, such as concrete, are required to shield gamma radiation.

Visual 16: Neutron Radiation

- Particulates ejected from the nucleus of a radioactive atom.
- Poses a hazard to the entire body.



Key Points

Neutron radiation: Neutron radiation, like alpha and beta radiation, consists of particles ejected from the nucleus of a radioactive atom. Neutrons:

- Do not interact readily with other atoms because they do not have a charge.
- Can travel great distances as a result.
- No electrical charge.
- Can travel great distances and is highly penetrating.
- Best shielded by materials with a high hydrogen content (e.g., water).

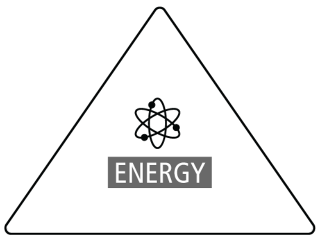
Hazard: Neutron radiation, like gamma radiation, is highly penetrating.

Shielding: The characteristics of neutron radiation make it difficult to shield. Typically, materials with a high hydrogen content (e.g., water) are required to shield neutron radiation. In transportation situations, neutron radiation is not commonly encountered.

Visual 17: Chemicals

- **Element:** Simplest form of matter
- **Chemical Compound:** Two or more elements combined or bonded by a chemical reaction
- **Mixture:** Two or more chemicals combined by mechanical means

This is energy.



Key Points

Next, we'll consider the building blocks of chemical substances.

- An **element—**the simplest form of matter-is a pure chemical substance consisting of one type of atom. There are currently 118 known elements in the periodic table, and new elements continue to be discovered. Examples of elements are aluminum, carbon, chlorine, hydrogen, mercury, and oxygen.
- A **chemical compound** is a substance consisting of two or more elements combined or bonded together so that its constituent elements are always present in the same proportions. A compound can only be created by a chemical reaction, and the components of a compound can only be separated by a chemical reaction.
- A **mixture** is any combination of two or more chemicals if the combination is NOT, in whole or in part, the result of a chemical reaction. Mixtures can be created by mechanical means alone, and the constituents of a mixture can usually be separated by simple mechanical means, such as filtering, evaporation, or magnetic force.

Visual 18: Gases and Vapors

Gas:

- Is easy to compress, will expand to fill its container.
- Occupies more space than the liquid or solid state.
- Has one defined phase at room temperature.

Vapor:

- Is in gaseous and liquid equilibrium at room temperature, at a given pressure.

Key Points

"Gas" and "vapor" may sound synonymous, but they do not refer to the same thing.

Gas: A gas has a single defined thermodynamic phase at room temperature. The molecules of a gas are in constant free motion past each other and can be compressed (also referred to as a compressible fluid). When no liquid or solid can form at the temperature of the gas, it is called a fixed gas.

Recall that in the phases of matter discussed earlier there is a "gas phase" that does not necessarily refer to a gas as a distinct element. Rather, it represents differences in interrelationships of molecules. A gas has its single gas particles vastly separated, making a gas invisible to the eye.

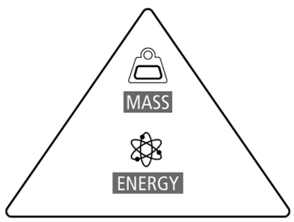
Vapor: A vapor is a mixture of two phases-gaseous and liquid-at room temperature. Vapor results from the two types of vaporization of a liquid-boiling and evaporation-causing the transition from liquid phase to gas phase. Evaporation occurs at the surface of the liquid when its temperature is below the boiling temperature at a given pressure. Boiling occurs below the surface of the liquid.

When a substance is at a temperature below its critical temperature, it is in a gas phase and therefore will be a vapor. A vapor can co-exist with its liquid or solid phase when they are in equilibrium state.

Visual 19: Factors Affecting Vapor Dispersion

- Vapor Pressure
- Atmospheric Pressure
- Vapor Density
- Boiling Point
- Molecular Weight

This is mass and energy.



Dispersion of vapors is affected by several factors, summarized in the following table.

Example: Ammonia boils at -28.17 °F. If ammonia spills, there may be a second phase reaction, which can cause a cloud of ammonia to expand and move very quickly. Ammonia is lighter than air, and once it warms up, it tends to move up and way into the atmosphere.

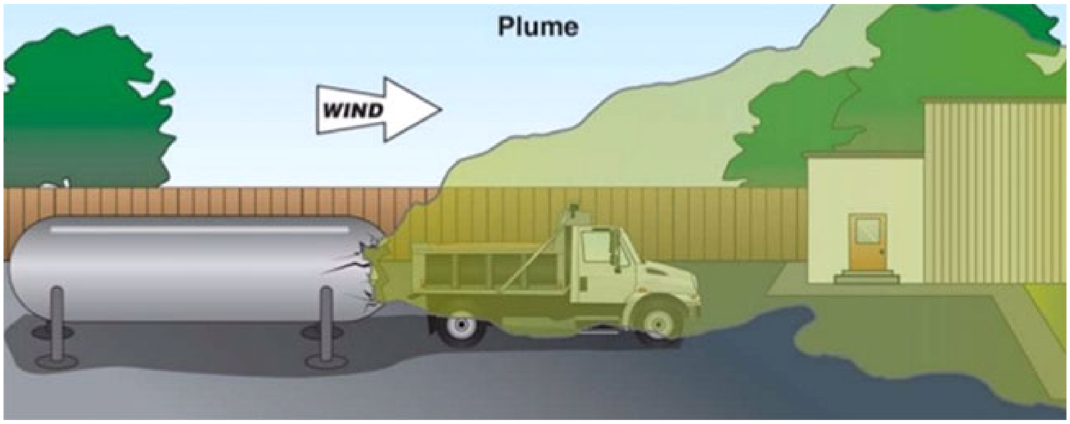
Factors That Affect Vapor Dispersion

Factor	Implications
Vapor pressure—The measurement of a particular liquid chemical's tendency to vaporize. Vapor pressure differs greatly among chemicals.	• Higher vapor pressure may disperse the chemical further. • Temperatures affect vaporization rate. • Amount of exposed surface affects vaporization rates.
Vapor density—The ratio of the density of a pure gas or vapor to the density of air. Vapor density differs at sea level vs. higher altitudes.	• Lighter density vapors float away. • Higher density vapors tend to sink.
Molecular weight—The sum of the weights of the atoms.	• Chemicals with heavier molecular weights will evaporate and float away more slowly.

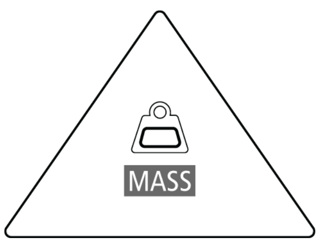
Factor	Implications
	• Chemicals with heavier molecular weights are more likely to move along the ground rather than upward.
Atmospheric pressure—The weight of air. Atmospheric pressure differs at sea level vs. higher altitudes.	• Vapors at higher elevations travel farther than at sea level. • Gas or vapor entering the atmosphere will quickly adjust its volume; upon release, a tank of liquefied gas will expand.
Boiling point—The temperature at which a liquid boils and turns to vapor. Boiling point differs based on altitude.	• Heating liquids above their normal boiling points in sealed containers causes vapor pressures that may become very dangerously high. If pressure is not relieved, the container may burst or rupture. • If a spilled liquid is in an environment above its boiling point, it will rapidly boil and expand, and sometimes explode. • The lower the boiling point, the more likely the liquid will vaporize.

Visual 20: Factors Affecting Vapor Dispersion

What factors may be affecting vapor dispersion in this example?



This is mass.



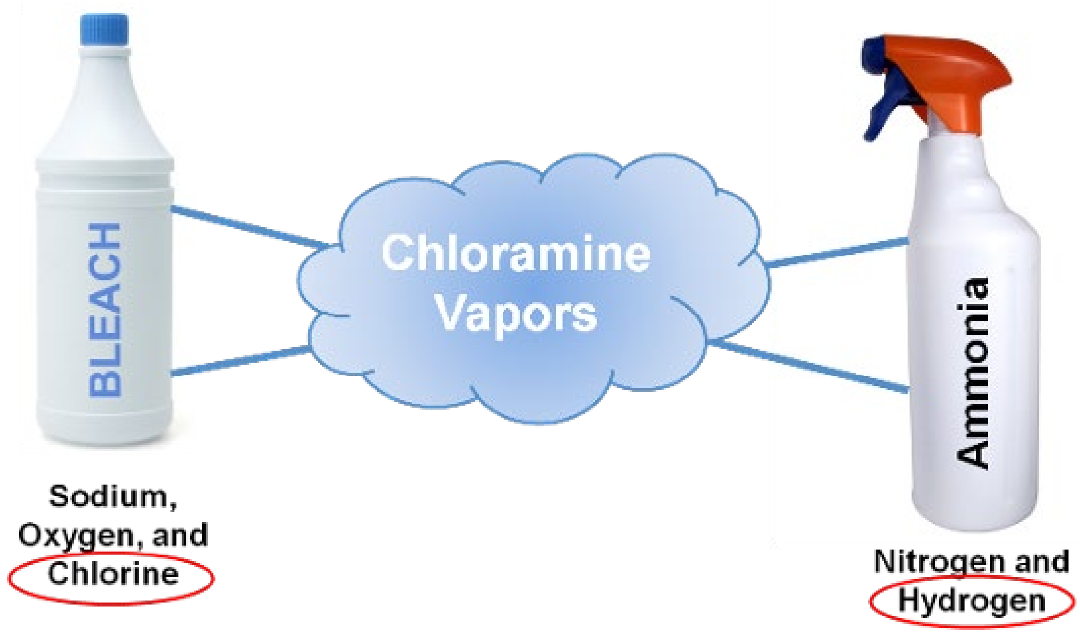
Key Points

Other factors impacting vapor dispersion include:

- Normal physical state – The physical state or form of a material at normal temperature (68F)
- Wind direction – direction of the wind
- Possible temperature inversion: "An "inversion" occurs when a section of the atmosphere becomes warmer as the elevation increases. Inversion layers are a significant factor in the formation of smog in Los Angeles because they create stable atmospheric conditions. Inversions act to prevent mixing in the lower regions of the troposphere, so pollutants become trapped quite easily and contribute to the formation of smog." An inversion layer can trap gasses and vapors near the surface.

These concepts will impact you as an emergency manager. Understanding the above may impact your community and the response actions you may take.

Visual 21: Example: Chemical Reaction



Key Points

An illustration: Let's look at a simple illustration of a chemical reaction.

Mixing bleach and ammonia illustrates a chemical reaction called single displacement. When bleach and ammonia are mixed:

1. First, hydrochloric acid is formed.
2. Then the ammonia and chlorine gas react to form chloramine, which is released as a vapor.
3. If ammonia is present in excess (which it may or may not be, depending on the mixture), toxic and potentially explosive liquid hydrazine may be formed.

Key factors in this reaction include the following:

- Household bleach has one atom each of sodium, oxygen, and chlorine.
- Ammonia has a chemical formula of one atom of nitrogen and three atoms of hydrogen.
- When these two compounds are combined, one part chlorine gas—made up of diatomic (two-atom) molecules—is released from the bleach.
- Chloramines are derivatives of ammonia by substitution of one, two, or three hydrogen atoms with chlorine atoms.

Visual 22: Chemical Reactions: Overview

- Substances mixed together or combined can react chemically
- Reactions can be violent when water, air, heat, or shock are introduced
- Form explosive mixtures with water, air, or other chemicals
- Generate toxic gases, vapors, or fumes
- Reactions can give off energy (Exothermic)

Key Points

Chemistry helps us understand how different substances react. Chemicals have the ability to react when exposed to other chemicals or certain physical conditions. The reactive properties of chemicals vary widely, and they play a vital role in the production of many chemical, material, pharmaceutical, and food products we use daily.

Some chemicals change phase or react violently when exposed to water, air, heat, or shock.

When chemical reactions are not properly managed, they can have harmful, or even catastrophic consequences, such as fires, explosions, or the generation of toxic gases, vapors, and fumes. These reactions may result in death and injury to people, damage to physical property, and severe effects on the environment.

Some **incompatible groups** of chemicals include:

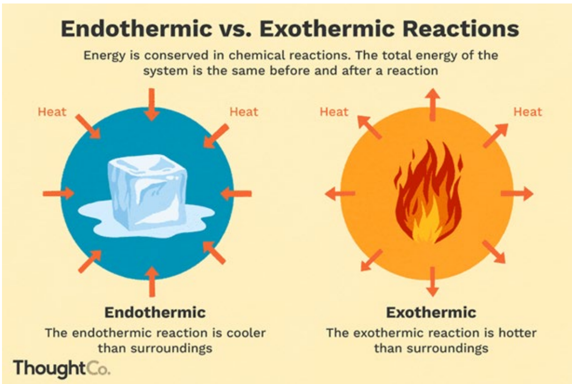
- Acids and bases.
- Flammables and toxics.
- Flammables and oxidizers.
- Oxidizers and reducers.

(Source: OSHA)

Chemical reactions are either exothermic or endothermic. Typically, as emergency management professionals, exothermic chemical reactions are the ones of particular concern for us.

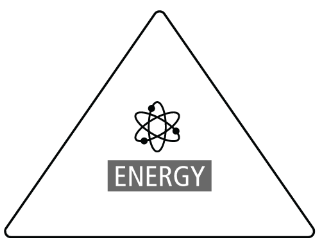
Simple examples – Alka-Seltzer/water – baking soda/vinegar – turn penny green/vinegar – clean penny with lemon juice – Chemical changes can be color changes, gas bubbles, formation of a precipitate, or temperature changes (although physical changes may also involve temperature change)

Visual 23: Exothermic (Heat) Reactions



- Heat and Energy transfer are fundamental to reactions heat
- Exothermic: Chemical reaction that generates heat (heat exits)
- Increasing heat may cause:
  - Materials to vaporize into air
  - Combustible materials to ignite
  - Increased pressure, rupture, or explosion

This is energy.



Key Points

Definition: When one substance is combined with another and the resulting interaction absorbs heat, the process is referred to as an endothermic reaction (endo- is a prefix meaning “within” or “inner”).

Definition: When one substance is combined with another and the resulting interaction generates heat, the process is referred to as an exothermic reaction (exo- is a prefix meaning “out of”). An exothermic reaction is one where the energy flows out of the system into the environment. When heat is generated, it increases the volume and creates pressure.

Combustion reactions are exothermic. Some exothermic reactions may require heating just to get started, and will then proceed on their own.

Results: Exothermic reactions pose special hazards whether they occur in the open environment or within a closed container.

- **Reactions in the open:** In the open, the heat that is produced will raise the temperature of the reactants, of any products of the reaction, and of surrounding materials. The resulting higher temperatures may affect how the materials involved behave in the environment.

- Heat will increase the vapor pressures of hazardous materials and the rate at which they vaporize.
- If very high temperatures are reached, nearby combustible materials may ignite.
- Explosive materials, whether they are the reactants of the reaction or just nearby, may explode upon ignition or excessive heating.

- **Reactions in closed containers:** Exothermic reactions taking place in closed containers pose additional hazards. The increased internal temperatures plus the production of gases from the reaction may increase internal pressures to the point that the container explodes. The explosion suddenly releases large amounts of possibly flammable and/or toxic gases or vapors into the atmosphere.

Visual 24: Highly Reactive Materials

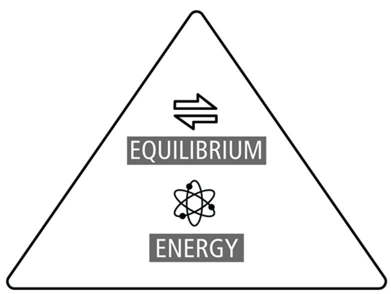
Definition:

- Are inherently unstable and susceptible to rapid decomposition from air, light, heat, mechanical shock, water, and other catalysts.
- Reactions can occur from air, light, heat, mechanical shock, water.
- Can react alone or with other substances.

Results

- Uncontrolled release of heat, toxic gases, or leading to an explosion.
- Reaction rates increase as temperatures increase.
- Rapid reactions that cause high heat and pressure are called explosions

This is equilibrium and energy.



Key Points

When chemical reactions are considered safe, it is generally because the reaction rate is relatively slow or can be easily controlled. However, certain reactions proceed at such a fast rate, and generate so much heat, that they may result in explosion.

Definition: Highly reactive or unstable materials are those that have the potential to vigorously polymerize, decompose, condense, or become self-reactive when exposed to shock, pressure, temperature, light, or contact with another material. Major types of highly reactive chemicals are:

- **Pyrophorics**—These substances will ignite spontaneously in air.
- **Water-reactives—These** substances react vigorously to water or moisture.
- **Peroxides**—Peroxides are shock-sensitive. Organic peroxides are even more shock-sensitive than explosives such as TNT or picric acid.
- **Polymers**—Many polymers generate large amounts of heat upon polymerization (a chemical process of combining single molecules into groups called polymers).
- **Explosives**—Explosives can release extremely large amounts of thermal or physical energy and can cause a true detonation (a shock wave traveling at supersonic speed). You will learn more about explosives later in this course.

Results: When triggering conditions are present, the reaction can occur in a violent uncontrolled manner, liberating heat and/or toxic gases, or leading to an explosion.

Reaction rates almost always increase dramatically as the temperature increases. Therefore, if heat from a reaction is not dissipated, the reaction can accelerate out of control and possibly result in injuries or costly accidents.

Highly Reactive Chemicals

The table below provides additional information about chemicals that react with air, water, heat, or other substances.

Type of Chemical	Description	Examples
Air Reactives (Pyrophorics)	• React violently in contact with air or oxygen or with compounds containing oxygen. • Do not need an ignition source to begin combustion, or to burn. • May be found in gas cylinders or packaged under nitrogen or some other inert atmosphere. • May produce a flame that is clear and not readily visible.	• Alkali metals (potassium, cesium) • Finely divided metal dusts (nickel, zinc, titanium) • Hydrides
Water Reactives	• Can react violently or vigorously in contact with water, wet surfaces, or even the moisture in the air. • May give off a flammable gas (such as hydrogen) or a toxic gas (such as phosgene) or spontaneously burn or explode. • Cannot be extinguished with water; require a class D fire extinguisher.	• Alkali metals • Anhydrides • Carbides • Halides • Hydrides • Organometallics • Oxides • Peroxides • Phosphides
Peroxide Formers	• Can form peroxide either upon aging, or upon contact with air or other substances. • May be shock sensitive and explode if handled roughly or upon heating. • May exist without problem in a solvent until the solvent is evaporated (during distillation, for example) and the peroxides concentrate.	• Ethers • 1,4-dioxane

Type of Chemical	Description	Examples
Polymers	• May generate large amounts of heat upon polymerization. • Some may cause a runaway polymerization reaction that can explode. • May generate heat buildup that can cause bumping, over-booking (too much pressure), or rupture of the container, which can also cause explosive-like damage.	• Acrylic acid • Butadiene • Cyclopentadiene • Ethylene • Styrene • Vinyl chloride

Visual 25: Unit Topics

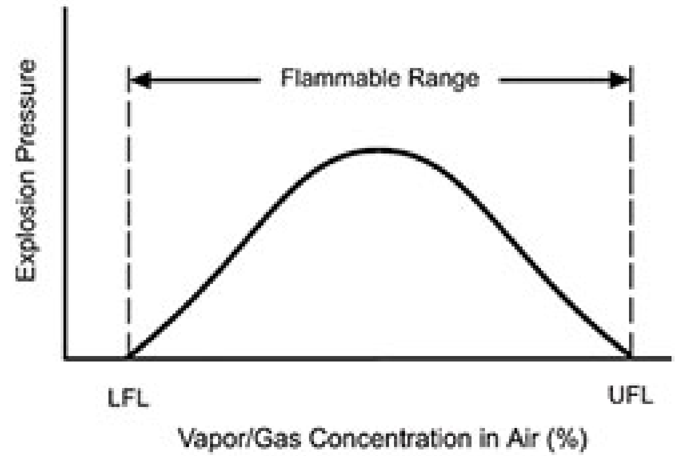
- Chemistry Basics
- **Types of Chemical Hazards**
- Chemical Agents as Weapons

Key Points

This next section will discuss the various types of chemical hazards.

Visual 26: Flammability Limit

What are flammable or explosive limits?



Key Points

<u>Discussion Question:</u> What are flammable or explosive limits?

Visual 27: Explosion

Definition

An explosion is chemical reaction that generates energy in the form of heat or pressure release.

Types of Explosions

- Mechanical
- Chemical
- Electrical
- Nuclear

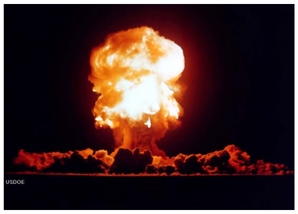
Key Points

You just saw an example of a Mechanical explosion (over pressurizing a cylinder of gas) Lightning is an example of an electrical explosion. We'll spend the rest of our time in Chemical and then Nuclear explosions.

Visual 28: E=mc²

- Two sides of same coin where mass is converted to energy.
- Chemical explosions can never be that strong because it is only a phase reaction

=



Key Points

If you could turn the amount of mass = to a paper clip into pure energy, it would yield an equivalent to about 18 kilotons of TNT. That's roughly the size of the bomb that destroyed Hiroshima in 1945. In the Hiroshima explosion, countless atoms of uranium were split apart in a nuclear chain reaction. Each time an atom split, the total mass of the fragments speeding apart was less than that of the original atom. The bomb, in essence, transformed three-hundredths of an ounce of mass into a cataclysmic burst of heat and light.

Source: Public Broadcasting System (PBS) NOVA, "Einstein's Big Idea" (http://www.pbs.org/wgbh/nova/einstein/)

Energy in The Nucleus:

- A nuclear force of attraction between protons and neutrons help keep the protons together in the nucleus even though their like positive charge causes them to repel.
- There is a certain amount of energy locked up in that nucleus due to forces at play.
- Without enough neutrons to mitigate the negative repulsive force, the nucleus can radioactively decay releasing energy.
- This can happen naturally or we can cause it to happen by shooting neutrons at the nucleus.
- The decay process is called FISSION when the nucleus splits, forming two lighter elements. One neutron splits a U-235 into Ba-141 and Kr-92, plus three new neutrons.
- We can cause it to happen by shooting neutrons at the nucleus like a slow bowling ball at bowling pins, causing some to fly out.
- Those three new neutrons, if they hit more U-235, can cause even more to split, creating three more neutrons each, plus energy.
- This is the process by which nuclear reactors work. The energy from fission heats water to drive turbines and create electricity.
- This reaction can "run-away" if left unchecked.

Fusion

- The opposite of fission.

- Fusion combines two nuclei to create a heavier elements.
- This is the process by which the Sun creates its energy.
- The Sun’s gravity is strong enough to combine hydrogen nuclei into helium, releasing energy.
- The helium is lighter than the sum of its parts. The “missing” mass was converted to energy. E=mc2

Visual 29: Explosives (1 of 2)

A substance that will burn up or decompose almost instantly, producing a violent chemical reaction that creates intense heat, a large volume of expanding gas, and a shock wave.


Key Points

An explosive is anything that, once ignited, burns extremely rapidly and produces a violent chemical reaction that creates intense heat, a large volume of expanding gas, and a shock wave.

Visual 30: Explosives (2 of 2)

- Chemical substances mixed together mechanically (e.g., gunpowder)
- Chemical compounds (e.g., TNT)
- May be detonated by shock, friction, or heat
- Come in many physical forms

Key Points

In the context of chemical hazards, we spoke of the differences between chemical mixtures and chemical compounds. The same holds true for explosives. Explosives may be:

- **Chemical mixtures** (composed of distinct substances that are mechanically conglomerated in varying proportions), such as black powder.
- **Chemical compounds** (homogeneous substances whose molecules contain within themselves the oxygen, carbon, and hydrogen necessary for combustion).

Explosives may be detonated by shock (hitting, shaking), friction (rubbing surfaces together to produce a spark), or heat.

Explosive materials come in many physical forms. Many are known by their commercial names. Examples are described in the following table.

Physical Forms of Explosive Materials

Additional Information

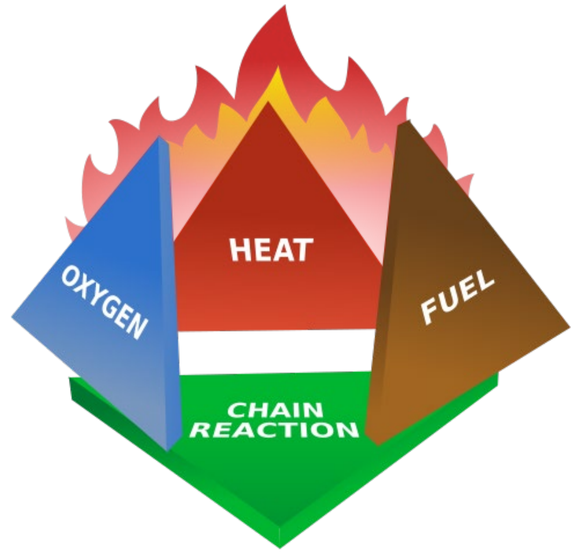
Form	Description
Binary Explosives	Two-part mixtures based on ammonium nitrate plus a volatile fuel that are shipped separately and combined onsite into a slurry or a liquid containing solids. Unlike ANFO, they can be detonated by blasting caps. Examples include Kinestik and

Form	Description
	Marine Pac.
Blasting Agents	Explosive materials or mixtures that are not detonatable by standard #8 blasting caps. They may be prepackaged, like ANFO, or made onsite from fertilizer grade ammonium nitrate and fuel oil. Other examples include Carbomite and Dynatex.
Castable Explosives	Contain at least one component (typically TNT) that can be melted at a temperature at which it is safe to handle the other components. Produced by casting or pouring the molten mixture or material into a form or use container.
Dynamites	An absorbent mixture soaked in nitroglycerin and compressed into cylinders and wrapped in paper. Dynamites, which have a limited shelf life, are used in mining, quarrying, construction, and demolition.
Extrudable Explosives	Viscous liquids similar to caulk. They can be extruded out a nozzle into thin cracks, holes, or along surfaces. Some will remain viscous; others can be hardened using a heat curing process. Examples include Demex-400 and LX-13.
Polymer Bonded Explosives (PBX)	A relatively solid and inflexible explosive form containing a powdered explosive material and a polymer (plastic) binder. Often a very thin coating of the polymer is placed onto the powder grains of the explosive material and then hot pressed to form dense solid blocks of PBX material. Most are based on RDX, HMX, or TATB explosives. There are many different kinds, most used in nuclear weapons.
Putties (Plastic Explosives)	Thick, flexible, moldable, clay-like solid material that can be shaped and will retain that shape after forming. Putties normally contain mostly RDX explosive, but may include some PETN. Examples include C-4, Semtex, and PE-4.
Rubberized Explosives	Flat sheets of solid but flexible material made from a mixture of a powdered explosive such as RDX or PETN and a synthetic or natural rubber compound. Rubberized explosives can be cut to shape, bent around objects, affixed in place, or simply laid on relatively flat surfaces. They are commonly used for explosive welding and for other industrial and military applications.

Form	Description
	Examples include Primasheet and Detasheet.
Slurries and Gels	Fuel-sensitized explosive mixtures containing an aqueous ammonium nitrate solution that acts as the oxidizer and a thickener. They may be pourable or solid. An example is Tovex.

Visual 31: Basic Fire Chemistry

- Fuel or material to be burned, which may be a liquid, a solid, or a gas.
- Heat that raises the temperature of the fuel to its ignition point.
- Oxygen in an atmosphere of less than 20% oxygen, most fuels can be heated until they entirely vaporize, without burning.
- Chemical Chain Reaction that allows oxygen and a fuel source to burn and release heat.



Key Points

Three elements are required to create a chemical exothermic reaction (fire): fuel, heat, and an oxidizing agent (usually oxygen). A fire naturally occurs when the elements are present and combined in the right mixture. If you take any one of these elements away and permanently interrupt the reaction, the fire goes out. Together these elements are called the fire triangle or combustion triangle.

- **Fuel:** Without fuel, a fire will stop. Fuel can be removed naturally (as when the fire has consumed all the burnable fuel) or manually, by mechanically or chemically removing the fuel from the fire. When fuel is removed, the fire stops because a lower concentration of fuel vapor in the flame leads to a decrease in energy release and a lower temperature. Removing the fuel thereby decreases the heat.
- **Heat:** Without sufficient heat, a fire cannot begin, and it cannot continue. Heat can be removed by the application of a substance that reduces the amount of heat available to the fire reaction.
- **Oxygen:** Without sufficient oxygen, a fire cannot begin, and it cannot continue. With decreased oxygen concentration, the combustion process slows.
- **Chemical Chain Reaction**: Fire is a process of combustion where a chemical reaction is sustained to allow oxygen and a fuel source to burn and release heat. Removing one element from the tetrahedron will prevent the chemical chain reaction from continuing.

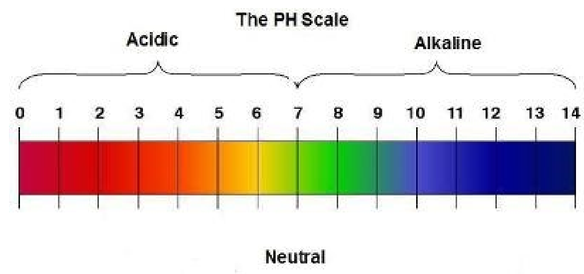
Visual 32: Acids and Bases

Strong Acids:

- Sulfuric Acid
- Hydrochloric
- Nitric Acid

Strong Bases:

- Sodium Hydroxide (lye)
- Potassium Hydroxide



Key Points

Acids and bases: Most corrosives are either acids or bases (alkaline). The relative acidity or alkalinity of a substance is measured on the pH scale.

- An **acid** is a substance that donates hydrogen ions. When an acid is dissolved in water, the balance between hydrogen ions and hydroxyl ions is shifted, resulting in more hydrogen ions than hydroxyl ions in the solution. This kind of solution is acidic. Examples of strong acids include hydrochloric acid (HCL), hydrofluoric acid (HF), nitric acid (HNO3), and sulfuric acid (H2SO4).
- A **base** is a substance that accepts hydrogen ions. When a base is dissolved in water, the balance between hydrogen ions and hydroxyl ions shifts the opposite way. Because the base "soaks up" hydrogen ions, the result is a solution with more hydroxyl ions than hydrogen ions. This kind of solution is alkaline. Examples of strong bases include sodium hydroxide (NaOH) and potassium hydroxide (KOH).

Corrosiveness: The corrosiveness of an acid or base refers to how severely it damages surfaces upon contact, specifically living tissue. Strong acids and bases such as hydrofluoric acid and sodium hydroxide have a very high or very low pH and are extremely corrosive, requiring extensive precautions when handling because they eat through tissue and even bone. While acids and bases damage tissues in somewhat different ways (burning vs. emulsifying), the end result is often irreversible damage at the site of the injury.

pH scale: The pH scale ranges from 0 to 14 and is logarithmic, meaning that each numerical increase on the pH scale represents a tenfold increase in acids and base concentration relative to pure water measured at 7.0 pH. (For example, a 6.0 pH is 10 times more acidic than 7.0 pH; a 5.0 is 100 times more acidic than 7.0 pH.)

Distilled water is 7 (right in the middle of the scale). Acids are found between 0 and 7. Bases are from 7 to 14. Most of the liquids you find every day have a pH near 7. However, the pH of chemicals can reach both extremes.

Health effects of acids: Different corrosives can have different health effects on the human body.

- **Localized damage:** If splashed with a hydrochloric acid solution on 25 square inches (5 x 5) of skin, an immediate sensation of burning will take place and the tissue that was exposed will burn and decompose until the acid is flushed away or neutralized. While the exposed tissues will be damaged, there is no danger of the exposure going "systemic" (body-wide) and killing the person—although infection could be a problem later.
- **Systemic damage:** With systemic damage, the poison causes damage beyond the initial exposed area—for example by contaminating the blood or targeting one or more vital organs. If splashed with a 2% solution of hydrofluoric acid on 25 square inches of skin, the skin will not burn away as with other acids. Rather, the chemical will move to the bone and cause the bone to decompose. The effect will be systemic as the acid lowers the body's calcium level, causing confusion, dizziness, and fainting. Besides the extreme pain of the bone being eaten away, without immediate medical attention, the victim will die.

Visual 33: Unit Summary

You should now be able to:

- Describe the phases of matter.
- Identify factors affecting chemical dispersion.
- Identify the elements necessary for fire.
- Indicate the potential hazards related to flammable, oxidizing, toxic, and corrosive materials.

Key Points

Do you have any questions about the material covered in this unit?

Unit 12: Chemistry Hazards

Visual 1: Unit 12: Chemistry Hazards

Unit 12: Chemical Hazards

Key Points

This unit will explore the scientific basis for chemical hazards and threats.

Time Plan

A suggested time plan for this unit is shown below.

Topic	Time
Introduction	5 minutes
Types of Chemical Hazards	30 minutes
Chemical Agents as Weapons	10 minutes
• Activity 12.1 – Chemical Response Resources • Activity 12.2 – Chemical Response In Your Community	40 minutes
Unit Summary	5 minutes
Total Time	**1 hours 30 minutes**

Visual 2: Unit Objectives

- Understand basic chemistry concepts and how they relate to potential hazards.
- Explain the relationship between chemical reaction and chemical hazards.
- Identify factors affecting chemical dispersion.
- Discuss concerns regarding chemical hazards.
- Explain the potential use of chemical agents as weapons.

Key Points

Review the unit objectives as shown on the visual.

Visual 3: Globally Harmonized System of Classification (GHS)

- An international framework for classifying chemicals to promote consistency and enhance safety
- Introduced by the UN in 2003
- Adopted by the United States in 2009
- Required use by OSHA
- GHS vs. DOT - DOT System (U.S.) divides the hazards into 9 classes

GHS Pictograms & Hazards (https://www.osha.gov/Publications/HazComm_QuickCard_Pictogram.html)

Key Points

After years of research on hazard communications and multiple incidents involving injuries or death where communication of the hazard was not effective, the Globally Harmonized System of Classification and Labeling of Chemicals (GHS) was developed by the United Nations. The UN has identified the GHS as a multinational strategy and communication system to avoid future incidents.

The GHS includes criteria for the classification of health, physical and environmental hazards, as well as specifying what information should be included on labels of hazardous chemicals as well as safety data sheets.

Major changes to the DOT Hazard Communication Standard:

- **Hazard classification:** Chemical manufacturers and importers are required to determine the hazards of the chemicals they produce or import. Hazard classification under the new, updated standard provides specific criteria to address health and physical hazards as well as classification of chemical mixtures.
- **Labels:** Chemical manufacturers and importers must provide a label that includes a signal word, pictogram, hazard statement, and precautionary statement for each hazard class and category.
- **Safety Data Sheets:** The new format requires 16 specific sections, ensuring consistency in presentation of important protection information.

- **Information and training:** To facilitate understanding of the new system, the new standard requires that workers be trained by December 1, 2013 on the new label elements and safety data sheet format, in addition to the current training requirements.

Ever since OSHA implemented new chemical labeling requirements in June of 2015, there has been some confusion among chemical manufacturers in the U.S. In particular, they want to know if they should use the Global Harmonized System (GHS) of classification or U.S. Department of Transportation's (DOT) labeling system. OSHA agreed that there is no reason GHS labels cannot be included on containers that feature a DOT pictogram. The federal agency is currently in the process of revising the rule to reflect that recognition. While manufacturers wait for the official change, they are allowed to include both DOT and GHS pictograms on the same label of hazardous containers.

See Color Handout 12.1 OSHA Quick Card

Visual 4: DOT Hazard Classes

Class 1: Explosives*

Class 2: Gases

Class 3: Flammable and Combustible Liquids

Class 4: Flammable Solids

Class 5: Oxidizing Substances, Organic Peroxides

Class 6: Poison (Toxic) and Poison Inhalation Hazard

Class 7: Radioactive Materials

Class 8: Corrosives

Class 9: Miscellaneous Hazardous Materials

Key Points

The U.S. Department of Transportation organizes hazardous materials into nine classes. (There are other classification systems, such as the one used by the Occupational Safety and Health Administration (OSHA), which vary slightly.) The nine DOT groups are the standard classifications used by responders during a hazardous materials incident. The classes are:

- Class 1: Explosives*
- Class 2: Gases
- Class 3: Flammable and Combustible Liquids
- Class 4: Flammable Solids
- Class 5: Oxidizing Substances, Organic Peroxides
- Class 6: Poison (Toxic) and Poison Inhalation Hazard
- Class 7: Radioactive Materials
- Class 8: Corrosives
- Class 9: Miscellaneous Hazardous Materials

*We'll cover explosives and radiation in other units.

Visual 5: Examples of Different Hazards by DOT Hazard Type

DOT Hazard Type	Examples
Class 1: Explosives	• 1.1 Mass Explosion Hazard - a small ignition source will cause any of these substances to react instantaneously with violent and terrible force. Examples include gunpowder, some fireworks, rocket fuel, trinitrotoluene (TNT). • 1.2 Projection Hazard - these explosives emit dangerous projectiles and include some kind of ammunition and grenades. • 1.3 Fire Hazard - these explosives have a fire hazard in addition to projection or explosive properties. Examples include the flash powder used in pyrotechnics and fireworks. • 1.4 Package Confined - these substances cause minor explosions that are mostly contained to their own packaging. Examples include signal flares, tracers for ammunition, some fireworks and weapon cartridges, and distress signals. • 1.5 Insensitive Substances - these can cause mass explosions but are inert in most conditions. An example is an ammonium nitrate-fuel oil (ANFO) mixture that contains only ammonium nitrate in pellet form and fuel oil. • 1.6 Extremely Insensitive Substances - carry both minimal sensitivity to ignition and will not produce a mass explosion.
Class 2: Gases	• Compressed Gases: Become rockets, burst, or cause runaway reactions • Flammable Gases: Burn or explode • Oxidizing Gases: React rapidly and violently with other materials • Inert Gases: Replace oxygen • Corrosive Gases: Destroy body tissues • Reactive Gases: Produce violent reactions from slight temperature/pressure changes or mechanical shock • Toxic Gases: Create health concerns
Class 3: Flammable and	• Combustible materials include anything that can burn

DOT Hazard Type	Examples
Combustible Liquids and Class 4: Flammable Solids	Flammable substances are those that readily catch fire and burn in air • Flammable substances are those that readily catch fire and burn in air • Flammable solids are any solid, other than an explosive or a blasting agent, that can be ignited easily and burn so vigorously or persistently as to create a serious fire hazard • Liquids can be flammable or combustible depending on their flash point
Class 5: Oxidizing Substances, Organic Peroxides	• Are liquids or solids that readily give off oxygen or other oxidizing substances (such as bromine, chlorine, or fluorine). • Increase the chance of a fire or explosion
Class 6: Poison (Toxic) and Poison Inhalation Hazard	• A toxic substance is a poisonous material, other than a gas, that is known to be so toxic to humans as to cause death, injury, or harm to human health • An infectious substance is a material known or reasonably expected to contain a pathogen. (This will be covered in the next unit.)
Class 8: Corrosives	• Chemical reaction that gradually erodes or dissolves another material is often referred to as corrosion • May cause damage to the skin, eyes, or other bodily tissues upon contact

Key Points

Hazard Class 2, Compressed Gases, includes three divisions:

- Division 2.1: Flammable gas.
- Division 2.2: Non-Flammable/Non-Poisonous Compressed Gas.
- Division 2.3: Gas Poisonous by Inhalation.
- **Compressed gases:** Thousands of products are available that contain gases and mixtures of gases stored under pressure in cylinders. Three major groups of compressed gases are stored in cylinders:
- **Liquefied gases:** These gases exist inside the cylinder in a liquid-vapor equilibrium. They can become liquids at normal temperatures under pressure when inside cylinders.

- **Non-liquefied gases:** These gases do not become liquid when compressed at normal temperatures, even at very high pressures.
- **Dissolved gases:** These gases are chemically very unstable and can explode even at atmospheric pressure. They become stable in solution with an inert solvent (e.g., acetylene in acetone).

Gas pressure basics: It is helpful to understand a few basics about gas under pressure:

- **Pressure units:** The pressure of the gas in a cylinder is commonly given in units of kilopascals (kPa) or pounds per square inch gauge (psig).
- **Atmospheric pressure** is normally about 101.4 kPa (14.7 psi).
- **Gauge pressure** = Total gas pressure inside the cylinder minus atmospheric pressure.

Key Points

Before discussing the next hazard class (flammable and combustible liquids), let's consider a few concepts related to flammability, combustibility, and fire chemistry.

Flammable substances are materials that can easily catch fire under normal circumstances and with the help of minimal ignition source. Just a spark is sufficient. A good example of a flammable substance is propane. (What is considered "flammable" differs among organizations.)

Combustible materials include anything that can burn. More vigorous conditions are required for a combustible material to burn. A simple spark is definitely not enough. Paper and wood are good examples of combustible materials.

Hazard Class 4 consists of three divisions. U.S. DOT defines these divisions as follows:

- **Division 8.2, Flammable Solids—**Any solid material other than one classed as an explosive that, under conditions normally incident to transportation, is likely to cause fires through friction or retained heat from manufacturing or processing, or that can be ignited readily and, when ignited, burns so vigorously and persistently as to create a serious transportation hazard.
- **Division 4.2, Spontaneously Combustible—**A liquid or solid pyrophoric material that even in small amounts and without an external ignition source can ignite within 5 minutes after coming in contact with air, or a self-heating material that when in contact with air and without an energy supply is liable to self-heat.
- **Division 4.3, Dangerous When Wet—**A material that, by contact with water, is likely to become spontaneously flammable or to give off flammable or toxic gas at a rate greater than 1 liter per kilogram of the material per hour.

Examples of flammable solids include certain metallic hydrides, metallic sodium and potassium, oily fabrics, processed metals, matches, and nitrocellulose products.

Key Points

Description: Hazard Class 5 includes two divisions: oxidizers and organic peroxides.

Oxidizing materials are liquids or solids that readily give off oxygen or other oxidizing substances. They also include materials that react chemically to oxidize combustible materials. This means that oxygen combines chemically with the other material in a way that increases the chance of a fire or explosion. This reaction may be spontaneous at either room temperature or may occur under slight heating.

EXAMPLE: Ammonium perchlorate is an oxidizing material with many uses in industry, construction, agriculture, and life support systems. Ammonium perchlorate:

- Can decompose at high temperatures forming toxic gases, such as chlorine, hydrogen chloride, and nitrogen oxides. Closed containers or tanks may rupture and explode if heated
- Does not burn but is a powerful oxidizer and explosive when mixed with combustible materials
- Is highly reactive, and impact or high temperatures can cause violent decomposition or explosion
- Can form shock-sensitive mixtures with finely powdered metals, metal oxides, strong reducing agents, sulfur, and phosphorus
- May cause eye irritation

Examples: Common oxidizers are:

- Concentrated nitric acid.
- Compressed oxygen.
- Hydrogen peroxide.

There are other chemicals that are oxidizing materials. For example, liquid air has been involved in many explosions because of its oxidizing properties. Liquid air itself has about 30% oxygen, which makes it a powerful oxidant. However, when liquid air evaporates, it becomes richer in oxygen content as more volatile components evaporate slightly faster.

Impact of oxidizing materials: Oxidizing materials can:

- Speed up the development of a fire and make it more intense.
- Cause substances that do not normally burn readily in air to burn rapidly. Cause combustible materials to burn spontaneously without the presence of an obvious ignition source such as a spark or flame.

What happens when an oxidizing material comes in contact with a combustible substance largely depends on the chemical stability of the oxidizing material. The less stable an oxidizing material is, the greater the chance that it will react in a dangerous way.

The following table summarizes the hazards associated with oxidizing materials.

Key Points

Hazard Class 6 includes:

- Division 6.1: Poisonous or Toxic Substances.
- Division 6.2: Infectious Substances.

A **toxic substance** is a poisonous material, other than a gas, that is known to be so toxic to humans as to cause death, injury, or harm to human health if swallowed, inhaled, or brought into contact with skin.

An **infectious substance** is a material known or reasonably expected to contain a pathogen.

Key Points

Hazard Class 8 is Corrosives.

Corrosives are materials that can attack and chemically destroy another material, such as exposed body tissues or even metal.

They begin to cause damage as soon as they touch the skin, eyes, respiratory tract, digestive tract, or the metal.

Corrosives might be hazardous in other ways, too, depending on the particular corrosive material.

Visual 6: Characteristics of Chemical Agents

- Generally liquid (when containerized).
- Normally disseminated as aerosols or gas.
- All but one are heavier than air.
- Influenced by weather conditions.
- Can be protected against.

Key Points

In general, chemical agents:

- Are liquid when containerized (even though they are often referred to as gases). Some boil at low temperatures and become gases when exposed to the atmosphere.
- Are normally disseminated as aerosols or as gases, and thus will dissipate with time.
- Are influenced by weather conditions (temperature, wind speed, wind direction, humidity, and air stability).
- Can be protected against, treated, and decontaminated.

Visual 7: Classes of Chemical Agents

Lethal

- Industrial Materials
    - Choking Agents
    - Blood Agents
- Military Agents
    - Blister Agents
    - Nerve Agents
- Other

Less Than Lethal

- Incapacitating and Riot Control

Key Points

Chemical agents are classified as either (1) lethal agents, or (2) incapacitating and riot control agents, according to their intended use.

Our focus is on lethal agents because of their greater potential for terrorist use. Incapacitating and riot control agents are not considered as primary terrorist threats, due primarily to their relatively short duration of effects and minimal toxicity.

Lethal agents are subdivided into:

- **Industrial materials** (choking agents and blood agents), which have various legitimate applications.
- **Military agents** (blister and nerve agents), which have little or no other purpose beyond their destructive nature.

Other agents include:

- Biotoxins
- Caustics/Acids
- Long-Acting Anticoagulants
- Metals
- Organic Solvents
- Toxic Alcohols
- Vomiting Agents

For more detailed information, go to CDC: https://emergency.cdc.gov/agent/agentlistchem-category.asp

Visual 8: Chemical Agents as Weapons

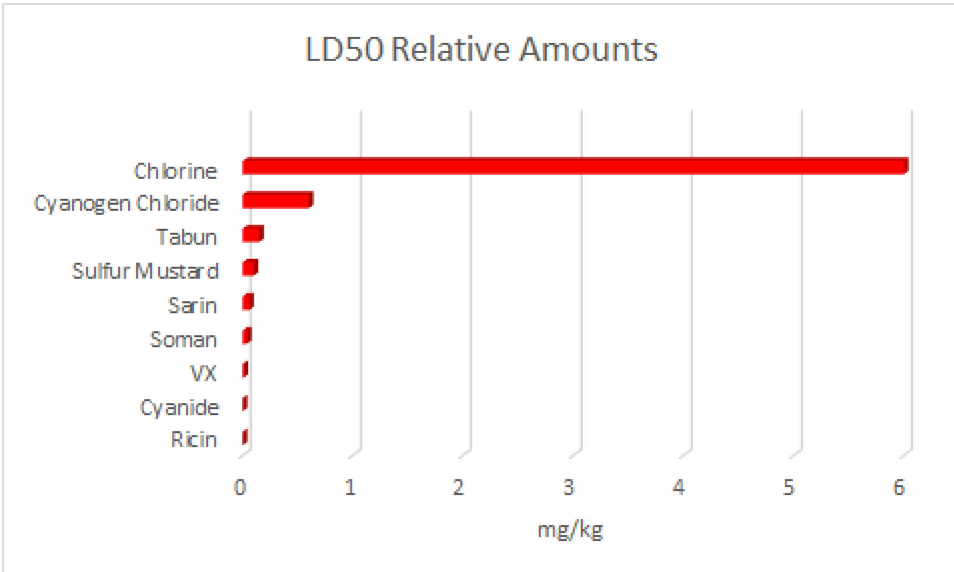
- Can be a liquid or powder
- Survive dissemination
- Can have an immediate or delayed effect on victims

Key Points

Let’s begin with a few basic facts about chemical agents.

- Chemical agents can be a liquid or a powder.
- They can have an immediate effect on victims (but some have a delayed effect and may not affect victims for 12 hours or more).
- Different chemical agents are used in varied quantities, from a few grams to gallons.
- The quantities needed vary. For example, nerve agents require only a few grams, whereas blister agents and blood agents require gallons to have a widespread effect.

Visual 9: Lethal Dose, 50% (LD50) Relative Amounts



Key Points

The graph on the visual shows the amount needed for LD50 based on the amount of the substance in mg (vertical axis).per the mass of the person in kg (horizontal axis).

A little amount of VX or cyanide can be lethal.

Agent	mg/kg
Ricin	0.00002
Cyanide	0.00002
VX	0.008
Soman	0.04
Sarin	0.06

Agent	mg/kg
Sulfur Mustard	0.1
Tabun	0.15
Cyanogen Chloride	0.6
Chlorine	6

Choking Agents, Blood Agents, Blister Agents, and Nerve Agents

	Choking Agents	Blood Agents	Blister Agents	Nerve Agents
Examples	Chlorine, phosgene, chloropicrin	Cyanide (CN), cyanogen chloride (CNCL)	Mustard, Lewisite, Phosgene	Sarin, Tabun, VX, Soman
Signs/Symptoms	Choking, excessive salivation, bluish tint to skin	Air hunger, tachycardia, seizures	Dermal blisters, photophobia, respiratory distress, GI distress	Seizures, salivation, lacrimation, urination, defecation, GI distress, and emesis (SLUDGE)
Mechanism of Action	Varies by adult but typically causes build up of fluid in throat and lungs inhibiting breathing	Prevents oxygen from reaching cells	Varies based on agent. Many cause irritation of exposed tissues, fluid and electrolyte imbalances, edema, and death of white blood cells	Attack the nervous system causing muscles to contract but not relax, leading to asphyxiation or cardiac arrest
Medical Treatment	Oxygen therapy, steroids, rest	Hyperbaric treatment, cyanide antidote kit (amyl nitrate and sodium nitrate)	No known treatment. Supportive care is indicated	Mark I Kit/ NAAK; Atropine, Pralidoxime (2-Pam)

Visual 10: What is a Chemical Explosion?

An oxidation or decay reaction that generates energy in the form of temperature and/or pressure release

Types of Explosions

- **Chemical**
- Mechanical
- Nuclear
- Electrical

Key Points

An explosion is an oxidation or decay reaction generating an increase in temperature **(exothermic change)** or pressure **(positive entropy change),** or both simultaneously.

Put more simply, an explosion is a sudden escape of gases from a confined space accompanied by high temperatures, a violent shock, and a loud noise.

Visual 11: Activity 12.1 – Chemical Response Resources

Instructions: Working as a team…

1. Review the scenario
2. Identify the top three priorities when attempting to manage this incident
3. Answer the provided questions
4. Select a spokesperson and be prepared to share your results with the class

Key Points

Instructions: Working as a team…

1. Review the scenario.
2. Identify the top 3 priorities when attempting to manage this incident.
3. Answer the provided questions.
4. Select a spokesperson, and be prepared to share your results with the class.

Scenario:

At approximately 3am two freight trains collided with each other in your community. One of the freight trains was carrying chlorine gas, sodium hydroxide, and cresol. One of the rail cars has ruptured, releasing about 60 tons of chlorine gas. The immediate community is a mix of industrial production and residential.

Activity 12.1 Worksheet

1. As an emergency management professional, identify your top three priorities when attempting to manage this incident.
2. What are the impacts of chlorine gas to the surrounding community?
3. What are the health impacts?
4. What is the impact to your first responders?
5. How did you find this information?

Visual 12: Activity 12.2 – Chemical Response in Your Community

Instructions: Working individually…

1. Recalling the scenario from the previous activity, answer the questions provided in your IAW

Key Points

Instructions: Working individually…

1. Recalling the scenario from the previous activity, answer the questions provided in your IAW.

Visual 13: BLEVE

- Boiling Liquid Expanding Vapor Explosion (BLEVE)
- One of the most dangerous hazards involved when transporting or storing liquids in a sealed container.
- Significant Incidents:
  - 1957 Factory Mutual Incident–Coined the term BLEVE
  - 1959 Kansas City, Missouri–Five Firefighters Killed
  - 1978 Tarragona, Spain– 217 Killed/200 injured
  - 6 March 2015 MRI machine, Liquid Helium, BLEVE, Oradell Animal hospital, Paramus, NJ
  - 3 April 2017,Semi Closed Receiver, Condensate, BLEVE, Loy-Lange Box Co, St Louis, Missouri

Key Points

“BLEVE" is an acronym that was first coined by three Factory Mutual (FM) researchers.

There are three characteristics of liquids which are relevant to the discussion of a BLEVE:

- If a liquid in a sealed container is boiled, the pressure inside the container increases. As the liquid changes to a gas it expands - this expansion in a vented container would cause the gas and liquid to take up more space. In a sealed container the gas and liquid are not able to take up more space and so the pressure rises. Pressurized vessels containing liquids can reach an equilibrium where the liquid stops boiling and the pressure stops rising. This occurs when no more heat is being added to the system (either because it has reached ambient temperature or has had a heat source removed).
- The boiling temperature of a liquid is dependent on pressure - high pressures will yield high boiling temperatures, and low pressures will yield low boiling temperatures. A common simple experiment is to place a cup of water in a vacuum chamber, and then reduce the pressure in the chamber until the water boils. By reducing the pressure, the water will boil even at room temperature. This works both ways - if the pressure is increased beyond normal atmospheric pressures, the boiling of hot water could be suppressed far beyond normal temperatures. The cooling system of a modern internal combustion engine is a real-world example.
- When a liquid boils it turns into a gas. The resulting gas takes up far more space than the liquid did.

Visual 14: Unit Summary

You should now be able to:

- Understand basic chemistry concepts and how they relate to potential hazards.
- Explain the relationship between chemical reaction and chemical hazards.
- Identify factors affecting chemical dispersion.
- Discuss concerns regarding chemical hazards.
- Explain the potential use of chemical agents as weapons.

Key Points

Do you have any questions about the material covered in this unit?

Unit 13: Explosive Hazards

Visual 1: Unit 13: Explosive Hazards

Unit 13: Explosives

Key Points

This unit will cover the explosive process, explosive materials (including the use of explosive materials for terrorist purposes), and blast effects.

Time Plan

A suggested time plan for this unit is shown below.

Topic	Time
Introduction	5 minutes
Explosive Process and Materials: Process	15 minutes
Explosive Process and Materials: Materials	15 minutes
Improvised Explosive Devices	10 minutes
Blast Effects	10 minutes

Topic	Time
• Activity 13.1 – Prevention & Mitigation of Explosives	30 minutes
Unit Summary	5 minutes
Total Time	**1 hour 30 minutes**

Visual 2: Unit Objectives

- Describe the formation and movement of an explosive shock wave and factors that affect it.
- Describe how different categories of materials work together in an explosive train.
- Describe blast effects on structures and people.

Key Points

Review the unit objectives as shown on the visual.

Visual 3: What Do You See?

What Do You See?

What Do You See? Video Description

The video is a simulation of what occurs during an explosion and the impact it has on the structure, interior of the building, and personnel in the building.

Key Points

This short video demonstrates the force of an explosion.

Discussion Questions:

- **What do you see happening?**

- **What do you think the effects would be on the people? On the building structure?**

Visual 4: What is an Explosion?

- A violent expansion in which energy is transmitted outward as a shock wave.
- A violent and destructive shattering or blowing apart of something, as is caused by a bomb.

Types of Explosions

- **Mechanical**
- **Chemical**
- Electrical
- Nuclear

Key Points

An explosion is an oxidation or decay reaction generating an increase in temperature **(exothermic change)** or pressure **(positive entropy change),** or both simultaneously.

Put more simply, an explosion is a sudden escape of gases from a confined space accompanied by high temperatures, a violent shock, and a loud noise.

There are four types of explosion:

- **Mechanical:** Caused by gas expanding inside a closed space until it exceeds the strength of the container (typically accidental). There is no chemical reaction. The explosion may be followed by fire. An exploding oxygen cylinder is an example. An exploding oxygen cylinder or a BLEVE, as discussed in the last unit, are examples.
- **Chemical:** Caused by uncontrolled chemical reaction between two or more materials that releases energy.
- **Electrical:** Caused by weakening of air resistance around a high-voltage source, allowing electricity to escape and travel to a nearby conductor or ground.
- **Nuclear:** Caused by splitting of nuclei of atoms by fission, or joining of nuclei of atoms by fusion. (Discussed in a later unit.)

Visual 5: Explosives (1 of 2)

A substance that will burn up or decompose almost instantly, producing a violent chemical reaction that creates intense heat, a large volume of expanding gas, and a shock wave.


Key Points

An explosive is anything that, once ignited, burns extremely rapidly and produces a violent chemical reaction that creates intense heat, a large volume of expanding gas, and a shock wave.

Visual 6: Explosives (2 of 2)

- Chemical substances mixed together mechanically (e.g., gunpowder)
- Chemical compounds (e.g., TNT)
- May be detonated by shock, friction, or heat
- Come in many physical forms

Key Points

In the context of chemical hazards, we spoke of the differences between chemical mixtures and chemical compounds. The same holds true for explosives. Explosives may be:

- **Chemical mixtures** (composed of distinct substances that are mechanically conglomerated in varying proportions), such as black powder.
- **Chemical compounds** (homogeneous substances whose molecules contain within themselves the oxygen, carbon, and hydrogen necessary for combustion).

Explosives may be detonated by shock (hitting, shaking), friction (rubbing surfaces together to produce a spark), or heat.

Explosive materials come in many physical forms. Many are known by their commercial names. Examples are described in the following table.

Physical Forms of Explosive Materials

Additional Information

Form	Description
Binary Explosives	Two-part mixtures based on ammonium nitrate plus a volatile fuel that are shipped separately and combined onsite into a slurry or a liquid containing solids. Unlike ANFO, they can be detonated by blasting caps. Examples include Kinestik and

Form	Description
	Marine Pac.
Blasting Agents	Explosive materials or mixtures that are not detonatable by standard #8 blasting caps. They may be prepackaged, like ANFO, or made onsite from fertilizer grade ammonium nitrate and fuel oil. Other examples include Carbomite and Dynatex.
Castable Explosives	Contain at least one component (typically TNT) that can be melted at a temperature at which it is safe to handle the other components. Produced by casting or pouring the molten mixture or material into a form or use container.
Dynamites	An absorbent mixture soaked in nitroglycerin and compressed into cylinders and wrapped in paper. Dynamites, which have a limited shelf life, are used in mining, quarrying, construction, and demolition.
Extrudable Explosives	Viscous liquids similar to caulk. They can be extruded out a nozzle into thin cracks, holes, or along surfaces. Some will remain viscous; others can be hardened using a heat curing process. Examples include Demex-400 and LX-13.
Polymer Bonded Explosives (PBX)	A relatively solid and inflexible explosive form containing a powdered explosive material and a polymer (plastic) binder. Often a very thin coating of the polymer is placed onto the powder grains of the explosive material and then hot pressed to form dense solid blocks of PBX material. Most are based on RDX, HMX, or TATB explosives. There are many different kinds, most used in nuclear weapons.
Putties (Plastic Explosives)	Thick, flexible, moldable, clay-like solid material that can be shaped and will retain that shape after forming. Putties normally contain mostly RDX explosive, but may include some PETN. Examples include C-4, Semtex, and PE-4.
Rubberized Explosives	Flat sheets of solid but flexible material made from a mixture of a powdered explosive such as RDX or PETN and a synthetic or natural rubber compound. Rubberized explosives can be cut to shape, bent around objects, affixed in place, or simply laid on relatively flat surfaces. They are commonly used for explosive welding and for other industrial and military applications.

Form	Description
	Examples include Primasheet and Detasheet.
Slurries and Gels	Fuel-sensitized explosive mixtures containing an aqueous ammonium nitrate solution that acts as the oxidizer and a thickener. They may be pourable or solid. An example is Tovex.

Visual 7: Classifying Explosives

Reaction Speed	Combustion	Velocity	Effects
Slow Reaction	Deflagration: Flame front is slower than the speed of sound*	Low Explosives: Explosive wave moves more slowly than the speed of sound*	There are few noticeable effects.
Rapid Reaction	Detonation: Flame front is faster than the speed of sound*	High Explosives: Explosive wave moves faster than the speed of sound*	• Hot gases rapidly expand • Expanded gases create shock wave • Fragments propel outward at high speed

*The speed of sound is 1,125 feet/second.

Visual 8: Low Explosives

- No pressure wave so need confinement
- Set off by impact, heat, spark, electric charge
- Usually a mixture of a combustible substance and an oxidant such as:
  - Black powder
  - Smokeless powder
  - Flash powder

Key Points

Low explosives are usually a mixture of a combustible substance and an oxidant. Examples of low explosives include black powder, smokeless powder, flash powder.

Visual 9: High Explosives

- High explosives are set off by detonator shock and may be classified by sensitivity—the ease with which they may be detonated by impact, heat, or friction.
- Three classes:

Explosives Classified by Sensitivity

- High explosives may be classified by sensitivity—the ease with which they may be detonated by impact, heat, or friction.
- Three classes:
  - Primary Explosives
  - Secondary Explosives
  - Tertiary Explosives

Visual 10: Primary Explosives

- Extremely sensitive to impact, friction, heat, static electricity, electromagnetic radiation
- Extremely powerful
- Generally used in small quantities to set off other explosives
- Examples:
  - Mercury fulminate
  - Nitroglycerin
  - Acetone peroxide
  - Lead azide

Key Points

Primary explosives are extremely sensitive to stimuli such as impact, friction, heat, static electricity, and electromagnetic radiation. A small amount of energy, such as the blow of a hammer, will usually set them off. Some are so sensitive that they can't be handled without detonating them.

Because of their sensitivity, primary explosives are often used in small quantities as detonators to set off less sensitive explosives. They are commonly used in blasting caps and percussion caps.

There are many primary high explosives. Examples of a few common ones are listed in the following table.

Examples of Primary Explosives

Explosive	Description
Acetone Peroxide (TATP)	• Triacetone triperoxide (TATP); peroxyacetone (TCAP). • White crystalline powder with a distinctive bleach-like odor. • Improvised primary explosive that is relatively easy to synthesize. • Made of a mixture of hydrogen peroxide and acetone with the addition of an acid, such as sulfuric, nitric, or hydrochloric acid. • Very unstable and sensitive to heat, shock, and friction. • Not easily soluble in water. It is more stable and less sensitive when wet.
DDNP	• Diazodinitrophenol (DDNP).

Explosive	Description
	• Yellowish brown powder. • Soluble in acetic acid, acetone, strong hydrochloric acid, and most solvents. Insoluble in water. May be desensitized by immersing it in water. • Less sensitive to impact and friction but more powerful than mercury fulminate. • Used with other materials to form priming mixtures, particularly where a high sensitivity to flame or heat is desired.
HMTD	• Hexamethlene Triperoxide Diamine (HMTD). • Improvised primary explosive prepared from hexamine, a weak acid, and hydrogen peroxide. • Highly sensitive to friction, impact, and electrostatic discharge. • Corrosive in contact with metals. • Can degrade quickly if improperly synthesized or stored.
Lead Azide	• Crystalline, cream-colored compound. • High temperature of ignition. Sensitive to both flame and impact, but less so than mercury fulminate. • Practically insoluble in water. • Must not be exposed to copper, zinc, or metal alloys because of the possible formation of other, more sensitive azides. • Used in detonating fuses and in priming mixtures.
Lead Styphnate	• Orange or brown crystals. • Easily ignited by heat and static discharge but cannot be used to initiate secondary high explosives reliably. • May be mixed with other materials and then pressed into a metallic container (detonators and primers). • Stored under water (or if there is danger of freezing, under a mixture of water and alcohol). • Used as an igniting charge for lead azide and as an ingredient in priming mixtures for small arms ammunition.
Mercury Fulminate	• White or gray crystals. • Extremely sensitive to initiation by heat, friction, spark or flame, and impact. • Stored under water (or if there is danger of freezing, under a mixture of water and alcohol). • Gradually becomes inert when stored continuously above 100 °F.

Explosive	Description
	• Can be pressed into containers, usually at 3,000 psi, for use in detonators and blasting caps. When "dead pressed" (compressed at greater and greater pressure (up to 30,000 psi)), it can only be exploded by another initial detonating agent.
Nitroglycerin	• Heavy, colorless, oily, explosive liquid. Most commonly produced by treating glycerol with nitric acid under conditions appropriate to the formation of the nitric acid ester. • In undiluted form, is one of the world's more powerful explosives. Detonates at 30 times the speed of sound. • Sensitive to physical shock, heat, and flame (so sensitive that a slight jolt, friction, or impact may cause it to detonate). • Degrades over time to even more unstable forms. • Used as an active ingredient in the manufacture of explosives (mostly dynamite) used in the construction, demolition, and mining industries. Also used as a propellant in firearms.

Visual 11: Secondary (Booster) Explosives

- Less sensitive than primary explosives.
- Used as main charge.
- Intended to be initiated by a shock (detonator).
- Safer to handle and store.
- Examples: TNT, RDX, Semtex.

Key Points

Secondary explosives are less sensitive than primary explosives. As such, they are safer to handle and store. These explosives are used as the main charge and require a detonator to set them off.

Examples of secondary explosives are listed in the following table.

Examples of Secondary Explosives

Explosive	Description
TNT	• Trinitrotoluene (TNT). • Light yellow, brown, or light gray. • A constituent of many explosives, such as amatol, pentolite, tetrytol, torpex, tritonal, picratol, ednatol, and composition B. It has been used under such names as Triton, Trotyl, Trilite, Trinol, and Tritolo. • Relatively insensitive to blows or friction. In a refined form, is one of the most stable of high explosives and can be stored over long periods of time. • Non-water soluble; neither absorbs nor dissolves in water. • Does not form sensitive compounds with metals, but it is readily

Explosive	Description
	acted upon by alkalies to form unstable compounds that are very sensitive to heat and impact. • May exude a flammable oily brown liquid. • Can be used as a booster or as a bursting charge for high-explosive shells and bombs.
RDX	• The name RDX stands for Research Department Explosive. Also known as cyclonite, hexogen, and T4. • Obtained by reacting white fuming nitric acid (WFNA) with hexamine. • Pure, synthesized state is a white, crystalline solid. • One of the most powerful and brisant of the military high explosives. When exploded in air it has about 1.5 times the explosive power of TNT per unit weight. • Often used in mixtures with other explosives, plasticizers, or desensitizers. • Very stable stored at room temperature. It burns rather than explodes and detonates only with a detonator. • Widely used in military and industrial applications. • Also used by terrorists—e.g., 1993 Bombay bombings, 2006 Mumbai train bombings, 2010 Moscow Metro bombings.
Semtex	• General-purpose plastic explosive. • Contains RDX, PETN, plasticizer, binder, and antioxidant. • Used in commercial blasting, demolition, and in certain military applications. • Also used by terrorists—e.g., Pan Am Flight 103.
C-4	• A common variety of Composition C, a plastic explosive. • Off-white solid with a texture similar to modeling clay. • Composed of RDX, plastic binder, plasticizer, a small amount of motor oil. May contain a chemical tag to help detect the explosive and identify its source. • Very stable and insensitive to most physical shocks. Detonation can only be initiated by a combination of extreme heat and a shockwave, such as when a detonator inserted into it is fired. • Can be molded into any desired shape, pressed into gaps, and used in shaped charges.
PETN	• Pentaerythritoltetranitrate (PETN). • One of the strongest known high explosives.

Explosive	Description
	• More sensitive to shock or friction than TNT. • Never used alone as a booster. It is primarily used in booster and bursting charges of small caliber ammunition, in upper charges of detonators in some land mines and shells, and as the explosive core of primacord.

Visual 12: Tertiary Explosives

- Insensitive to shock.
- Require an intermediate explosive booster of a secondary explosive.
- Used in mining and construction operations.
- Used in terrorist attacks because of readily available precursors.
- Example: ANFO (ammonium nitrate and fuel oil).

Key Points

Tertiary explosives, also called blasting agents, are very insensitive to shock. They can't be reliably detonated by practical quantities of primary explosive, so they require an intermediate explosive booster of secondary explosive.

The main users are large-scale mining and construction operations. These materials have also been used for terrorist attacks (e.g., the first attempt on the World Trade Center in 1993 and the 1995 Oklahoma City bombing) because of the sometimes ready availability of large quantities of precursors (e.g., nitrate fertilizers).

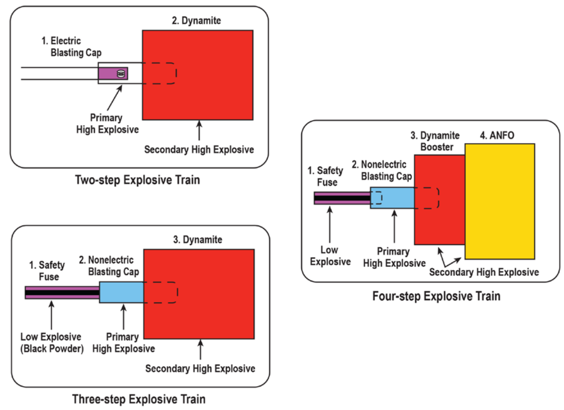
ANFO is an example of a tertiary explosive. (Image source: Halen on Wikimedia Commons)

ANFO

- Ammonium Nitrate/Fuel Oil (ANFO).
- A widely used bulk blasting agent because it is readily available and cheap.
- Contains 94 percent porous prilled ammonium nitrate that acts as the oxidizing agent and absorbent for the fuel oil.
- Is highly stable and insensitive. Under most conditions it cannot be detonated with a #8 blasting cap. It generally requires a booster to ensure continuation of the detonation.
- Decomposes through detonation rather than deflagration with a moderate velocity of about 3,200 meters per second in 5-inch diameter, unconfined, at ambient temperature.
- Requires confinement for efficient detonation and brisance. The optimum blend for ANFO (if properly prepared) could yield greater explosive power than TNT.
- Readily absorbs water from air and is dangerous when stored in humid environments, as any absorbed water interferes with its explosive function.
- Is water soluble.

Visual 13: Explosive Train

- A sequence of events that culminates in the detonation of explosives
- May be 2, 3, or 4 steps



Explosive Train Image Description

Two step explosive train

1. Electric blasting cap (Primary high explosive)
2. Dynamite (secondary high explosive)

Three step explosive train

1. Safety fuse (low explosive [black powder])
2. Nonelectric blasting cap (primary high explosive)
3. Dynamite (secondary high explosive)

Four step explosive train

1. Safety fuse (low explosive)
2. Nonelectric blasting cap (primary high explosive
3. Dynamite booster (secondary high explosive)
4. ANFO (secondary high explosive)

Key Points

An explosive train (also called a triggering sequence or firing train) is a sequence of events that starts with low-level energy followed by a chain reaction to initiate the final explosive material or main charge. **All explosives need a firing train to work. Explosive train=firing train.**

Because most widely used high explosives are difficult to detonate, a primary explosive of higher sensitivity is used to trigger a uniform and predictable detonation of the main body of the explosive. Although the primary explosive itself is generally a more sensitive and expensive compound, it is only used in small quantities and in relatively safely packaged forms.

High-explosive trains can be either two-step (e.g., detonator and dynamite) or three-step (e.g., detonator, booster of primary explosive, and main charge of secondary or tertiary explosive).

Visual 14: Other Important Properties of Explosives

- Brisance
- Density
- Hygrosopicity
- Power, performance, and strength
- Stability
- Toxicity
- Volatility

Key Points

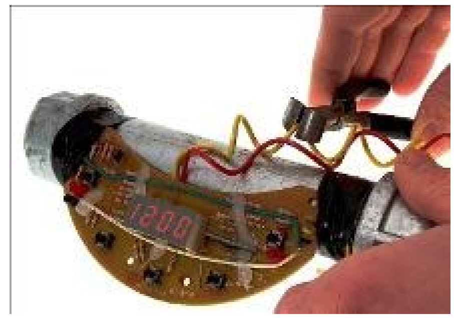
We have talked about two important properties of explosives—velocity and sensitivity. Other important properties of explosive materials are described in the table below.

Property	Description
Brisance	Shattering effect. The rapidity with which an explosive reaches its peak pressure (power) is a measure of its brisance.
Density of load	The mass of an explosive per unit volume. High load density can reduce sensitivity by making the mass more resistant to internal friction. Increased load density also permits the use of more explosive, thereby increasing the available power.
Hygrosopicity	A material's moisture-absorbing tendencies. Moisture promotes decomposition and can cause corrosion. It can also reduce the sensitivity, strength, and velocity of detonation of the explosive.
Power, performance, and strength	Ability to do the work intended (i.e., deliver the needed energy).
Stability	Ability of an explosive to be stored without deterioration. Stability may be affected by chemical constitution, rate of decomposition, storage temperature, exposure to ultraviolet light, and electrical discharge.
Toxicity	The decomposition products of an explosion may be hazardous (e.g., carcinogens). Examples of harmful byproducts are lead,

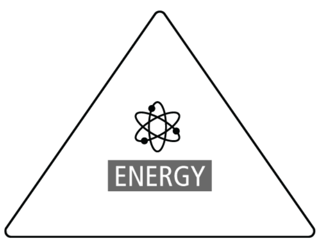
Property	Description
	mercury, and nitric oxides.
Volatility	The readiness with which a substance vaporizes. Too much volatility may affect chemical composition and reduce stability.

Visual 15: Improvised Explosive Devices (IEDs)

- "Homemade" bombs or destructive devices used to destroy, incapacitate, harass, or distract.
- Many forms—from simple pipe bombs to sophisticated devices.
- Many methods of delivery:
  - On persons
  - In delivered packages
  - In vehicles
  - Concealed in public places
  - On aircraft as weapon



This is energy.



Key Points

An improvised explosive device (IED) attack is the use of a "homemade" bomb and/or destructive device to destroy, incapacitate, harass, or distract. The term IED came into common usage during the Iraq War that began in 2003. IEDs are used by criminals, vandals, terrorists, suicide bombers, and insurgents.

Forms: Because they are improvised, IEDs can come in many forms, ranging from a small pipe bomb to a sophisticated device capable of causing massive damage and loss of life.

Delivery: There are many methods of delivery-for example:

- Carried, placed, or thrown by a person (briefcase, book bag, suicide vest, parcel, luggage, etc.).
- Delivered in a package (by mail, delivery service, messenger).
- Carried or delivered in a vehicle (bicycle, street cart, automobile, van, large truck, airplane).
- Concealed in public places (transit systems, public gathering places, public events, on the roadside).

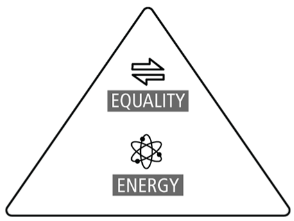
Visual 16: Blast Effects

Key Points

This section will discuss blast effects of explosives on structures and people.

Visual 17: Blast Effects

- **Thermal** - High volume of heat
- **Blast** - Effects of shock wave
- **Fragmentation** - Damage from shrapnel
- **Seismic** - Shaking of the ground by explosion - can destabilize buildings



This is equality and energy.

Key Points

Now that we have seen what happens during the blast process, let’s look at the effects.

There are four main types of effects from an explosion:

- **Thermal:** First there is a high volume of heat generated by the combustion in the chemical reaction.
- **Blast:** Second, there is overpressure-the effects of the shockwave.
- **Fragmentation:** Next, the explosive device itself and objects in the path of the pressure wave fragment, which can cause damage from shrapnel (flying pieces of material). Due to the force of the explosion, shrapnel can fly a great distance.
- **Seismic:** Large explosions can also have a seismic effect. The downward pressure of the air bubble can shake the ground, and if the blast is large enough, this shaking can destabilize buildings.

Because of the supersonic speed of an explosion, all of these effects may appear to happen at once.

Visual 18: Blast Effects on Structures

- An explosion begins with a thermal event, then a violent shock. The shock wave expands, pressure decreases, then it meets surfaces.
- Blast effects on buildings vary with:
  - Explosive properties.
  - Reflected pressure.
  - Location of the blast.
  - Building characteristics.

Key Points

How do these blast effects impact buildings and other structures in the path of the explosion?

An explosion begins with a thermal event, then a violent shock. The shock wave expands, pressure decreases, then it meets surfaces. The energy (blast impulse) from an explosion imparted to a building includes both the negative and positive phases of the pressure-time waveform.

The magnitude and distribution of blast loads on a structure vary greatly with several factors:

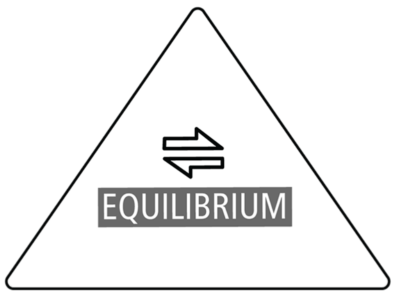
- **Explosive properties**—type of material, energy output, and quantity of explosive. The amount of explosive is usually expressed as TNT equivalent weight.
- **Reflected pressure**—reinforcement of the pressure pulse through its interaction with the ground or structure (reflections).
- **Location** of the detonation relative to the structure-the stand-off distance between the explosive and the building.
- **Building characteristics**—the exterior envelope construction (walls and windows) and the framing or load-bearing system used.

The reflected pressure and the reflected impulse are the forces to which the building ultimately responds. These forces vary in time and space over the exposed surface of the building, depending on the location of the detonation in relation to the building.

Visual 19: Shock Wave—Incident Pressure

- Explosion creates a shock wave, or blast pressure front, which creates most of the damage
- The shock wave moves spherically from the point of the blast
- Pressure drops as the wave moves away from the blast source

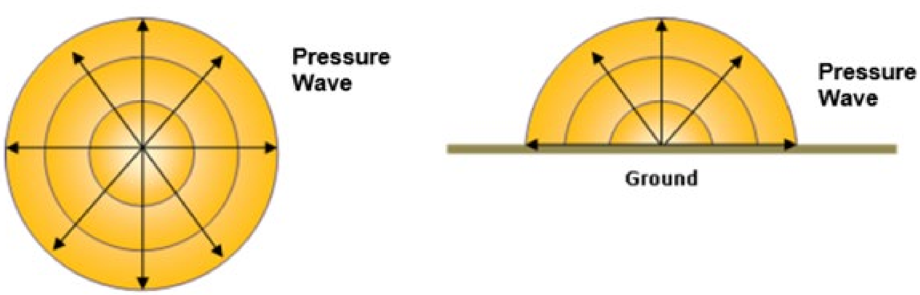
This is equilibrium.



Key Points

In an explosion, about one-third of the explosive material contributes to the detonation. At this point, several things happen:

- **Creation of pressure wave:** Hot expanding gases from the explosion compress surrounding air to form a constant-velocity bubble of air, or shock wave. Heat generated by chemical reactions supports the shock wave.
- **Movement of the pressure wave:** The shock wave, or blast pressure wave, moves spherically away from source of the explosion at supersonic speed at peak pressure. Objects (such as the ground) may alter the shape of the wave.



- **Pressure drop:** As it reaches a point in space, such as a person or building, the pressure of the wave goes rapidly from atmospheric to peak pressure in very little time.

The pressure at this point decays rapidly as the supersonic bubble moves on, its pressure reducing exponentially as the surface area of the bubble increases, expending energy over an ever-increasing area.

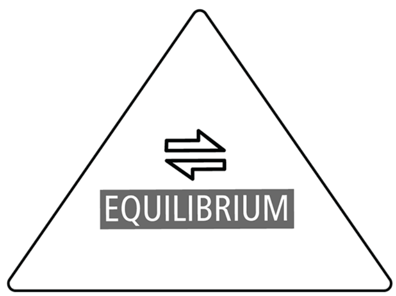
- The pressure also drops off due to the completion of the chemical reaction of the explosive mixture (burning of the remaining two-thirds of the material). If the explosion occurs within a **confined space**, the gases generated by the burning of the explosive are contained and keep the pressure elevated over a longer period of time.

Visual 20: Two Phases

- Positive pressure phase: Wave pushes outward from point of explosion. The force heats and moves the air in front of it, creating a vacuum.
- Negative pressure phase: Air rushes back into the vacuum to equalize the pressure, causing additional damage.

Blast impulse is the peak incident pressure of both the positive and negative phases.

This is equilibrium.



Key Points

There are two phases in the movement of the pressure wave:

- **Positive phase:** The positive phase is the process just described-the shock wave pushing outward from the point of explosion. The force heats and moves the air in front of it, creating a vacuum.
- **Negative phase:** The negative phase of the blast wave is the ambient air rushing in behind the blast wave to return to a stable pressure. Although the negative phase has much less energy than the positive phase, it can hit structures at the most inopportune moment in their vibration, resulting in unexpected consequences-increased damage or having windows blow OUT of the building rather than into it.

Impulse is a measure of the energy from an explosion imparted to a building. Both the negative and positive phases of the pressure-time waveform contribute to impulse.

Visual 21: Positive and Negative Phases

Video description:

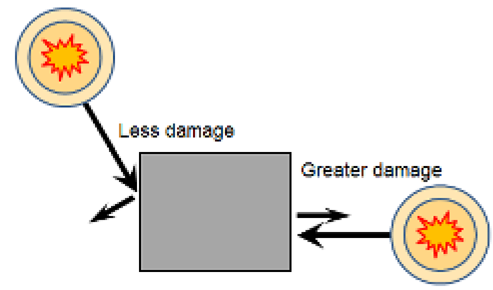
Image of shock wave-This animation depicts the positive and negative phases of a blast wave.

Key Points

This animation depicts the positive and negative phases of a blast wave.

Visual 22: Reflected Pressure

- When the blast wave strikes an immovable surface, it reflects off the surface, resulting in an increase in pressure that enforces the blast wave.
- Reflected pressure is greater than incident pressure.
- Reflected pressure varies with angle (greater when perpendicular).
- In internal explosions, reflected pressures collide, enforce the blast wave, and produce more damage.



Key Points

When the incident pressure wave hits an immovable surface that is not parallel to the direction of the wave's travel, the wave reflects off the surface and is reinforced, resulting in an increase in pressure.

This reflected pressure actually causes the damage to the building. A very high reflected pressure may punch a hole in a wall or cause a column to fail, while a low reflected pressure will try to push over the whole building.

The reflected pressure is always greater than the incident pressure at the same distance from the explosion, and varies with the incident angle.

The worst case is when the direction of travel for the blast wave is perpendicular to the surface of the structure and the incident pressure is very high.

In internal explosions, reflected pressures inside the structure collide, enforcing the blast wave and greatly increasing the pressure. The increase in pressure produces even more damage.

Visual 23: Building Characteristics

- **Brittle materials** respond to peak incident pressure, are less affected by impulse.
- **Ductile materials** respond more to impulse (total push) rather than peak incident pressure (the maximum hit).

What are the implications?

Key Points

Building characteristics relate to the exterior envelope construction (walls and windows) and the framing or load-bearing system used.

- Brittle materials (like glass) respond to peak incident pressure and are less affected by impulse.
- Ductile materials (like most building structures), on the other hand, respond more to impulse (the total push) rather than peak incident pressure (the maximum hit).

Discussion Question: What are the implications of these response tendencies?

In most, but not all cases, the glass is the weakest component of the building envelope. Conversely, the columns, whether concrete or steel, are usually the strongest components of the building envelope.

A direct air blast, especially from a close-in explosion, may result in component failure of walls, windows, columns, and beams/girders. Once the exterior envelope is breached, the blast wave causes additional structural and nonstructural damage inside the building.

Collapse is a primary cause of death and injury if an explosive blast occurs.

- In a **localized collapse**, a load-bearing wall, or portion thereof, on one side of the building may fall to the ground, or a single column may fail causing the surrounding floors to fall with it.
- In a **progressive collapse**, the result is more disastrous. A single component failure, like a wall or column, may result in the failure of more walls and columns so that more of the building falls to the ground than what the explosive initially affected.

Visual 24: Phases of Blast Injuries

- Primary
- Secondary
- Tertiary
- Quaternary

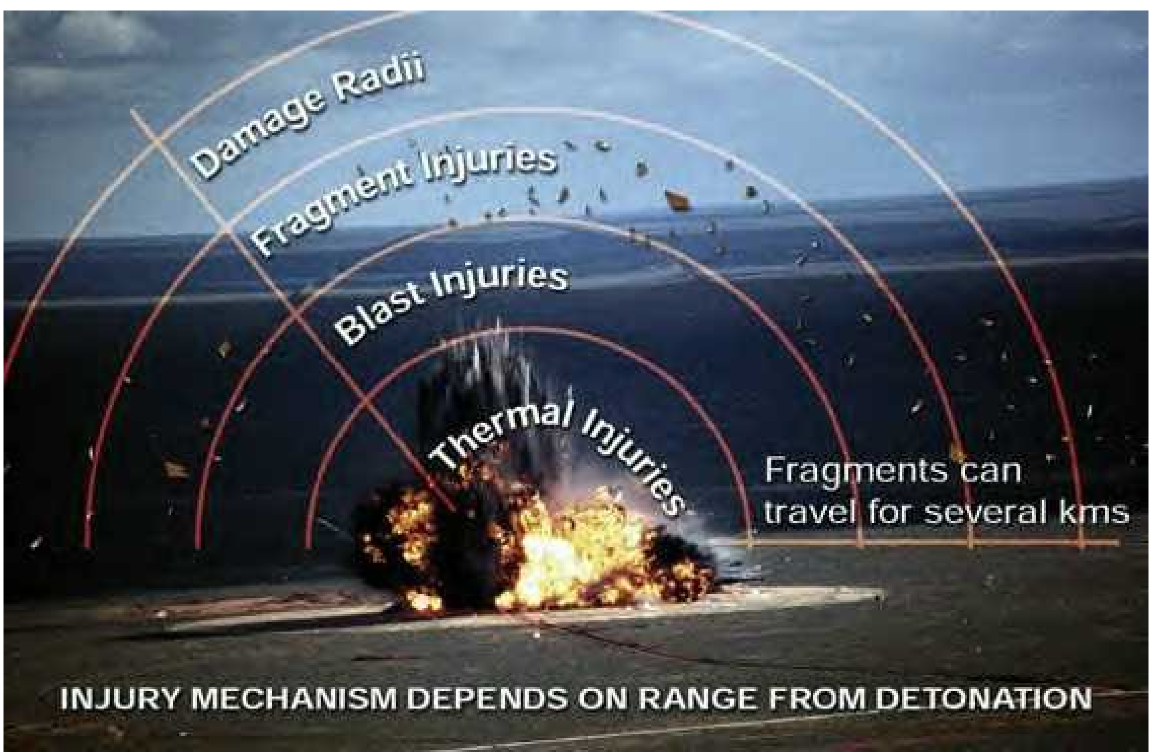
Key Points

A blast injury is a complex type of physical trauma resulting from direct or indirect exposure to an explosion. Blast injuries occur with the detonation of high-order explosives as well as the deflagration of low order explosives. These injuries are compounded when the explosion occurs in a confined space.

Injuries and casualties during an explosive blast vary based on the different phases of the blast. The four phases of blast injuries are:

- Primary
- Secondary
- Tertiary
- Quaternary

The distance from the detonation affects the type of injuries likely to be sustained.



Visual 25: Phases of Blast Injuries

Phase	Cause	Effects
Primary	Due to the overpressure wave from the blast	Impacts/ruptures hollow organs (ears, lungs, GI) *
Secondary	Flying debris strikes victims in the vicinity	Injuries are overt (lacerations, open and closed fractures, burns, impaled objects)
Tertiary	Occurs from the victim being thrown away from the blast.	Injuries such as blunt trauma, crush trauma, fractures, amputation with severity related to distance traveled, and type of material impacted.
Quaternary	Catch-all category for other injures/illness not otherwise specified.	Injuries such as building collapse on the victim, secondary/opportunistic infections, flash burns, Psychological impacts (PTSD)

*The speed of sound is 1,125 feet/second.

Key Points

Primary injuries are caused by blast overpressure waves, or shock waves. These are especially likely when a person is close to an exploding munition, such as a land mine.

Overpressure causes eardrum rupture first, which is normally not lethal. Overpressure can also overdrive the lungs, causing injury or death. The relationship between pressure and impulse is very evident in lung response, where the threshold of lethality for incident pressure is:

- 102 psi for 3 milliseconds
- 23 psi for 18.5 milliseconds

Thermal and blast injuries include burns and injuries sustained when the blast wave picks up and throws a person against a surface or object (translation). The result may be blunt trauma, lacerations, and impalement from the impact.

Secondary injuries are caused by fragmentation and other objects propelled by the explosion. These injuries may affect any part of the body and sometimes result in penetrating trauma with visible bleeding. At times, the propelled object may become embedded in the body, obstructing the loss of blood to the outside. However, there may be extensive blood loss within the body cavities.

Fragmentation from any source can result in blunt trauma, impact, penetration, or laceration injuries.

- More than 80 percent of all injuries from explosive blasts can be attributed to lacerations caused by broken glass. The fragments can come from around the bomb or from the bomb container (e.g., parts of the vehicle used in a car bomb, or shrapnel incorporated into the bomb).
- Objects can be picked up either intact or damaged by the blast wave as it travels along (e.g., street furniture or jersey barriers).
- Building component failure also causes material fragments with sufficient velocity to injure or kill. When portions of a building collapse, people commonly suffer crushing or falling injuries.

Displacement of air by the explosion creates a blast wind that can throw victims against solid objects Injuries resulting from this type of traumatic impact are referred to as tertiary blast injuries. Tertiary injuries may present as some combination of blunt and penetrating trauma, including bone fractures and coup contre-coup injuries. Children are at a particularly higher risk of tertiary injury due to their relatively smaller body weight.

- The quaternary phase is a catch-all category for other injures/illness not otherwise specified:
  - Building collapse on the victim
  - Secondary/opportunistic infections
  - Flash burns
  - Psychological impacts (e.g., neurological damage or PTSD)

Visual 26: Buffer Zones – Lines of Defense

- A layered approach to defense.
    - More rings/layers = increased distance = more protection
- Utilized to protect key infrastructure and high-value targets
- Buffer zones integrate evacuation distances into the engineered layers

Key Points

Buffer zones are engineered protective rings that aid in the prevention of successful bombings. In theory, buffer zones incorporate a ring of engineered protection, often bollards, to force explosive materials away from the primary target at a distance that minimizes the impact.

Bomb Threat Stand-Off Chart (https://www.dni.gov/files/NCTC/documents/features_documents/2006_calendar_bomb_stand_chart.pdf)

Visual 27: Buffer Zones

Key Points

The visual shows a photograph of the headquarters for the Bureau of Alcohol, Tobacco, Firearms, and Explosives. See if you can identify the multiple buffer zones, both overt and disguised, in the engineering.

Discussion Question: Which side the engineers thought was most vulnerable?

Visual 28: Activity 13.1 – Prevention & Mitigation of Explosives

Instructions: Working in groups…

1. Review the scenario
2. Answer the questions provided
3. Select a spokesperson, and be prepared to share your ideas with the class

Key Points

Instructions: Working in groups…

1. Review the scenario.
2. Answer the questions provided.
3. Select a spokesperson and be prepared to share your ideas with the class.

Scenario: You are the emergency manager for a county in your local community. Within your jurisdiction you have two major hospitals, including University Medical Center (UMC), the regional trauma center that has a capacity to bed up to 300 patients.

At 16:30 hours today, county law enforcement received a tip that a family member of recently deceased patient at UMC was angry with the hospital and staff. The tipster informed law enforcement that the family member made threats on social media that he planned to "hunt down" the staff at the hospital for "killing his father." Photos of potential bomb electronics and chemical precursors for explosives were also posted to the site.

A law enforcement officer visited the family member's house and confirmed the presence of Ammonium Nitrate/Fuel Oil, blasting caps, wiring, and other bomb making components. Law enforcement has advised county, state, and federal partners that they believe the threat is credible and there is evidence indicating the family member intends to utilize his Dodge pickup truck as a vehicle-borne IED against the hospital within the next 24 hours.

Questions

1. What agencies, resources, and subject matter experts would you expect in to assist with the investigation?
2. What agencies, resources, and subject matter experts would you request to assist with the response to the threat?
3. Given the threat, what protective actions would you recommend for the hospital and surrounding buildings?
   a. What buffer zone distance might you try to implement? How?
   b. What resources would aid in protecting the hospital?

4. Would you consider evacuating the hospital or sheltering in place?
    a. If so, discuss your strategy:
        i. Who would conduct the evacuation?
        ii. Who would be evacuated and who would shelter in place?

Visual 29: Unit Summary

You should now be able to:

- Describe the formation and movement of an explosive shock wave and factors that affect it.
- Describe how different categories of materials work together in an explosive train.
- Describe blast effects on structures and people.

Key Points

Do you have any questions about the content covered in this unit?

Unit 14: Radiation Hazards

Scope

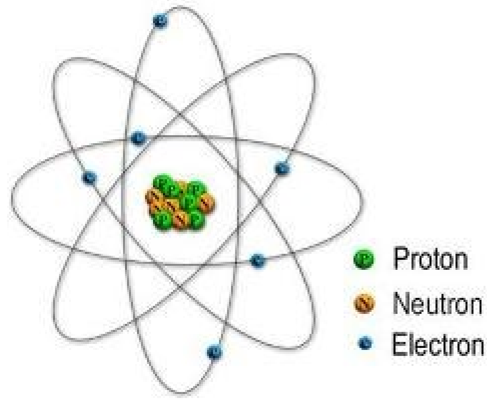
- Introduction
- Radiation Basics
- Exposure and Contamination
- Optional Demo
- Effects of Radiation
    - Activity 13.1 – Goiânia Contamination
- Unit Summary
    - Activity 13.2 – Assessing Radiological Exposure Risk for Your Community

Materials

- PowerPoint visuals
- Instructor Guide
- Student Manual

Visual 1: Unit 14: Radiation Hazards

Unit 14: Radiation



Key Points

This unit will introduce fundamental concepts related to radiation.

Time Plan

A suggested time plan for this unit is shown below.

Topic	Time
Introduction	5 minutes
Radiation Basics	10 minutes
Exposure and Contamination	20 minutes
Optional Demo	5 minutes
Effects of Radiation • Activity 14.1 – Goiânia Contamination	45 minutes
• Activity 14.2 – Assessing Radiological Exposure Risk for Your Community	10 minutes
Unit Summary	5 minutes

Topic	Time
Total Time	**1 hour 40 minutes**

Visual 2: Unit Objectives

- Explain basic concepts related to the atom, isotopes, radioisotopes, radiation, and radioactive material.
- Distinguish between radiation exposure and radioactive contamination.
- Identify the units for measuring radioactivity and exposure.
- Describe the biological effects of ionizing radiation.
- Explain the ALARA principle.

Key Points

Review the unit objectives as shown on the visual.

Visual 3: Topics

Radiation Basics

Biological Effects

Radiological Hazards

Key Points

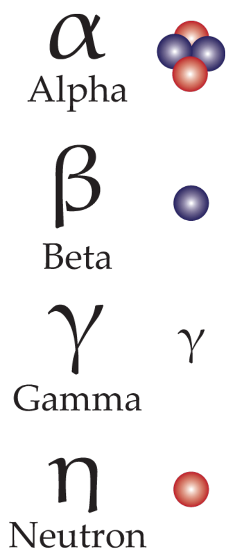
Three main topics will be covered in this module: radiation basics, exposure and contamination, and effects of radiation. We will begin with radiation basics—the underlying concepts of radiation and radioactivity.

Visual 4: Key Points

<u>Discussion Question:</u> When you hear the word "radiation," what do you think of?

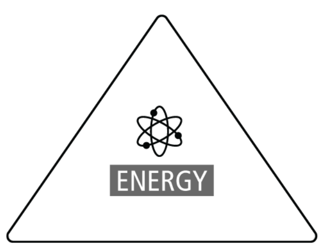
Visual 5: Four Types of Ionizing Radiation

Atoms with an unstable nucleus give off radiation in an effort to become stable.



Ionizing radiation carries enough energy to remove electrons from atoms or molecules causing them to become ionized (electrically charged).

This is energy.



Key Points

The four basic types of ionizing radiation are:

- Alpha radiation
- Beta radiation
- Gamma radiation
- Neutron radiation

These types differ in their penetrating power and the manner in which they affect human tissue.

Next, you will take a closer look at each type of ionizing radiation and its penetrating ability.

Visual 6: X-Rays

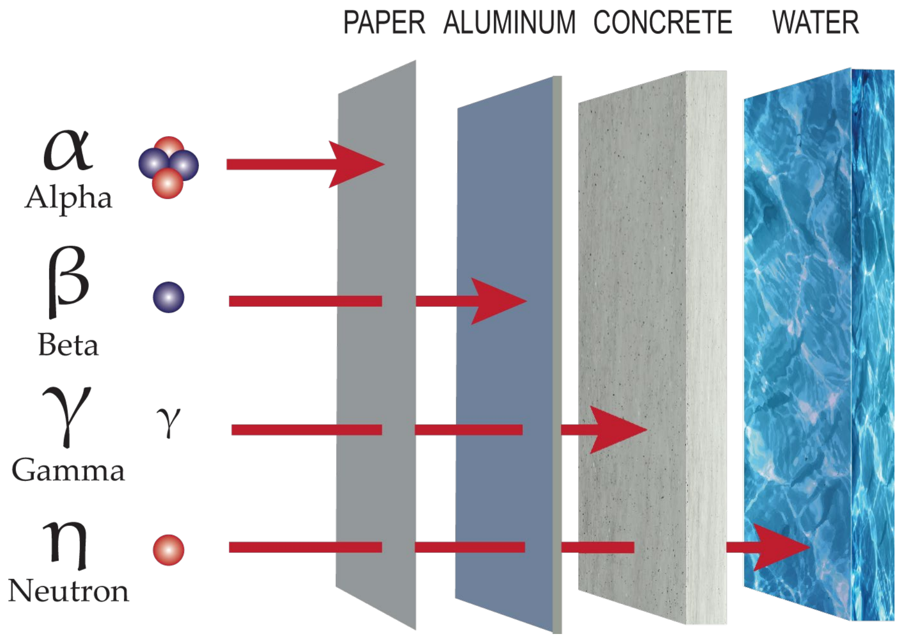
- X-ray machines
  - Do not contain radioactive material
  - Produce ionizing. radiation only when they are energized.
- High voltage is used to accelerate electrons in a vacuum.
- As electrons strike a target, their energy is converted into heat and electromagnetic waves (X-rays).

Key Points

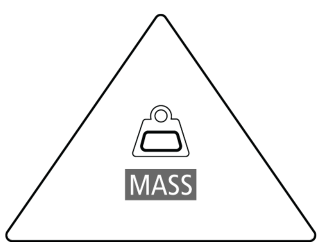
X-rays provide a good example of exposure without contamination.

- X-rays are created by using high voltage to accelerate electrons in a vacuum and stopping them in a target. Electrons have mass, and when they are accelerated they gain kinetic energy—energy from being "in motion."
- When an electron strikes the target it gives up its kinetic energy. Most of that energy ends up generating heat in the target, but some of that energy will generate x-rays. The higher the voltage, the higher the kinetic energy of the electron and the higher the energy of the x-ray generated.
- X-ray machines do not contain a radioactive source. You cannot become contaminated by exposure to x-rays.
- Without high voltage the x-rays cannot be created. Removing the energy source removes the hazard.

Visual 7: Shielding Radiation



This is mass.



Key Points

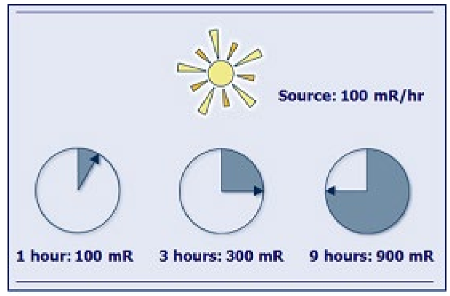
Compare the shielding required for the four types of ionizing radiation discussed:

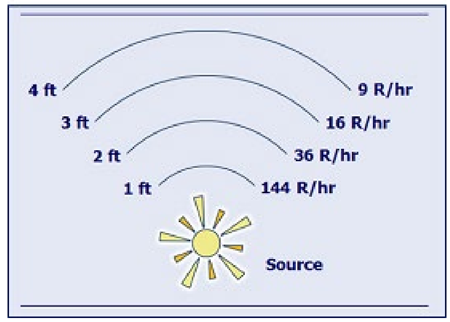
- **Alpha radiation:** Something as thin as a sheet of paper can block the passage of alpha radiation.
- **Beta radiation:** Beta radiation can be shielded with moderately dense materials like aluminum.
- **Gamma radiation:** Because of its high penetrating ability, very dense materials such as concrete are required to shield gamma radiation.

- **Neutron radiation:** The characteristics of neutron radiation make it difficult to shield. Typically, materials with a high hydrogen content (e.g., water) are required to shield neutron radiation. The cooling pools in a nuclear reactor are a good example.

Visual 8: Protection From Radiation

- **Time:** Limit or minimize the exposure time to reduce the dose from the radiation source.
- **Distance:** The intensity of radiation decreases the farther you are from the source of the radiation.
- **Shielding:** Place shielding between you and the radiation source. The types of shielding depend on the radiation.





Visual 9: Measuring Radioactive Decay

- Radioactive decay is measured in half-lives.
- Half-life is unique to each radioactive isotope and varies greatly.
- Radioactivity level is constantly decreasing.

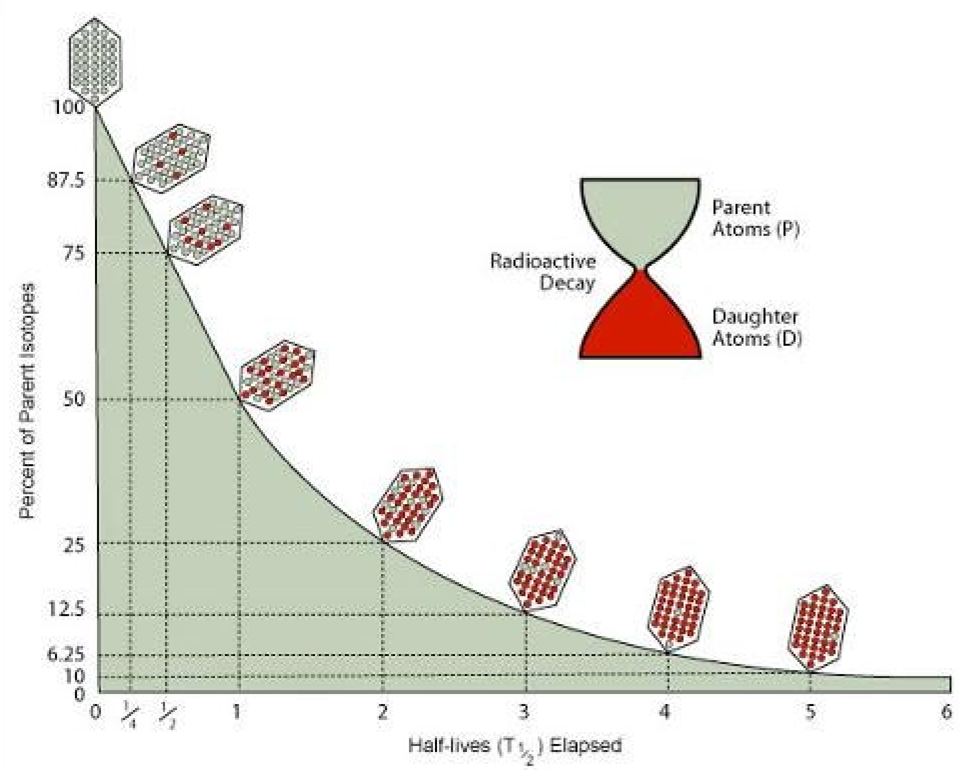
Half-life = the time it takes for half of the radioactive atoms present to decay to another form.

Key Points

Radioactive decay is measured in half-lives.

- Following a transformation the nucleus is usually more stable than it was, but it may not be completely stable. In such cases, another transformation takes place in which the nucleus again emits radiation.
- Each step in the series of transformations results in a distinct reduction in the total mass-energy of the nucleus. As the energy of the nucleus is reduced, the nucleus is said to disintegrate or decay. **Half-life is the time it takes for one-half of the radioactive atoms present to decay to another form.**
- Half-life is unique to each radioactive isotope and can vary greatly from one radioactive material to another. Radioactive pharmaceutical products (called radiopharmaceuticals) typically have half-lives of a few hours or days.
- Regardless of the half-life, the radioactivity level of any given amount of radioactive material is **constantly decreasing** by half during every "half-life."

Visual 10: Radioactive Decay



Key Points

Due to the constant decrease in radioactivity, **after seven half-lives, the activity of the material will be at less than 1 percent of its original activity.**

The curve shown in the graphic represents the same shape common to the radioactive decay of all isotopes through the first several half-lives.

The table below shows several common radioactive materials and their respective half-lives. More information about each of these materials and their uses is provided in the chart that follows.

Radioactive Isotope	Half-Life
Nitrogen-16	7 seconds
Technetium-99m	6 hours
Thallium-201	73 hours

Radioactive Isotope	Half-Life
Cobalt-60	5 years
Cesium-137	30 years
Americium-241	432 years
Uranium-238	4.5 billion years

Information About Selected Radioactive Isotopes

Isotope	Description
Nitrogen-16	• A radionuclide associated with nuclear powerplant operations. • Produced in a process called activation when oxygen in reactor coolant is exposed to neutron radiation. • Formed when Oxygen-16 captures a neutron and emits a proton to form Nitrogen-16.
Technetium-99m	• The most widely used radiopharmaceutical for diagnosing diseased organs. (A small amount of the radioactive isotope is placed in the patient's body, usually injected into the bloodstream, for the purpose of imaging some part of the body.) • One of the things that make technetium-99m so popular for this purpose is its short half-life, which leads to very fast clearing from the body after an imaging process.
Thallium-201	• Widely used in as a radiopharmaceutical for diagnosis of coronary artery disease, other heart conditions such as heart muscle death, and for location of low-grade lymphomas.
Cobalt-60	• Produced in a process called activation, when materials (such as steel) are exposed to neutron radiation in reactors. Can also be produced in a particle accelerator. • In medicine, used for cancer radiotherapy. • Industrial uses include testing of welds and castings, and various measurement and test instruments (e.g., leveling devices and thickness gauges). • Commonly used to sterilize instruments and to irradiate food to

Isotope	Description
	kill microbes and prevent spoilage.
Cesium-137	• A common radionuclide produced when nuclear fission of uranium and plutonium occurs in a reactor or atomic bomb. • Commonly used in hospitals for diagnosis and treatment, as a calibration source, and to sterilize medical equipment. • In industry, used to irradiate food and in industrial instruments.
Americium-241	• A human-made radioactive metal that exists as a solid under normal conditions and is produced when plutonium absorbs neutrons in nuclear reactors and nuclear weapons tests. • Blended with beryllium, is used in various types of test gauges. • Used as a radiation source in medical diagnostic devices and in research. • Commonly used in minute amounts in smoke detectors as an ionization source.
Uranium	• A naturally occurring radioactive metal present in low amounts in rocks, soil, water, plants, and animals that contributes to low levels of natural background radiation in the environment. • Occurs in three forms or isotopes: uranium-234, uranium-235, and uranium-238. About 99 percent of uranium in rock is uranium-238, which decays to form other radioisotopes, including radium-226 and radon-222. • Significant concentrations of uranium occur naturally in some substances such as phosphate deposits and uranium-enriched ores.

Visual 11: Measuring Radioactive Source Strength

The strength of a radioactive source is measured in:

- The traditional unit of curies (Ci), or
- The international system (SI) unit of becquerels (Bq).

Both units measure activity. The Ci is a large amount of activity, while the Bq is a small amount.

Key Points

Radioactive material is not typically measured by its mass, weight, or volume. Rather, radioactivity is measured in the number of nuclear decays or disintegrations that occur in a sample during a specific time. This is known as the **activity** of the sample.

The curie (Ci) is defined as 3.7 x 1010 or 37 billion (37,000,000,000) disintegrations per second (dps). The becquerel (Bq) is defined as 1 dps.

- The traditional unit of activity is the **curie (Ci),** named after Marie and Pierre Curie, physicists who were pioneers in the study of radioactivity.
- The international system (SI) unit of activity is the **becquerel (Bq),** after Henri Becquerel, who shared a Nobel Prize for Physics with the Curies in 1903.

Both the curie and becquerel measure the same thing-activity. One curie is considered to be a large amount of activity, whereas one becquerel is a very small amount of activity.

Because the base unit for measuring activity may be either very large (Ci) or very small (Bq), prefixes (e.g., nano, micro, milli, kilo, mega, giga) are often used to change the size of the unit.

Visual 12: Background vs. Normal Radiation

- Exists naturally in nature and is found all around us
- Cosmic
  - Higher doses at higher elevations and around the poles
- Terrestrial
  - Dose from earth sources can vary widely depending on the types of rocks
- Biological/Internal

Key Points

Background radiation encompasses all natural radiation that is present in the environment. This includes cosmic radiation from the sun and stars, terrestrial radiation from the soil/earth, and internal radiation that exists in all living things. On average, a United States resident is exposed to about 0.3 rem per year.

When taking radiation readings, HAZMAT technicians and scientists must account for background radiation by taking sample/control readings without the materials to be tested:

- Source Radiation = Radiation Sampled by Meter – Background Radiation

Visual 13: Topics (cont.)

Radiation Basics

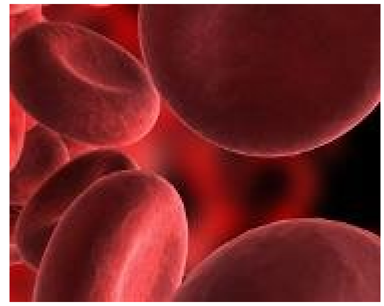
Biological Effects

Radiological Hazards

Key Points

Next, we will look at exposure and contamination—what they mean and how they can occur.

Visual 14: How Radiation Affects the Body (1 of 2)



- Routes of contamination: inhalation, ingestion, absorption (skin/eyes), injection.
- Ionizing Radiation effects occur at the cellular level causing the formation of free radicals. For example, ionization of water molecules inside the cells can produce hydrogen peroxide—a chemical poison.

Key Points

Routes of exposure: Radiation exposure can occur through the same primary routes as we have discussed for other hazards: inhalation, ingestion, absorption (through the skin or eyes), and injection.

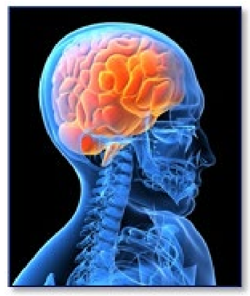
- Gamma radiation can penetrate into your body, delivering a deep dose. The radiation affects the blood and internal organs. Gamma radiation is a significant external and internal health hazard.
- All types of radiation cause health effects through internal contamination, when people swallow or breathe in radioactive materials, or when radioactive materials enter the body through an open wound or are absorbed through the skin. Some types of radioactive materials stay in the body and are deposited in different body organs. Other types are eliminated from the body in blood, sweat, urine, and feces.

Cellular damage: Scientists have determined that the effects of ionizing radiation occur at the cellular level. Each organ of the body is made up of specialized cells, and ionizing radiation can affect the normal operation of these cells.

How damage occurs: Radiation causes damage to any material by ionizing the atoms in that material-changing its atomic structure. When atoms are ionized, the chemical properties of those atoms are altered. If a person receives a sufficiently high dose of radiation and many cells are damaged, there may be observable health effects.

Visual 15: How Radiation Affects the Body (2 of 2)

- Some body parts are more sensitive to radiation-induced damage than others.
- The most sensitive cells are:
    - Immature cells.
    - Less specialized cells.
    - Cells that divide rapidly or are in the process of dividing.



Key Points

Sensitivity: Some parts of the body are more sensitive to radiation-induced damage than others. Radiation damage to the cells of the body depends on how sensitive the cells are to ionizing radiation.

Most sensitive cells: Generally speaking, the most sensitive cells are those that are immature and less specialized, those that divide rapidly, or those that are in the process of dividing. These cells are most vulnerable because it is **difficult or impossible for them to repair damage that occurs during cell division.** Examples of rapidly dividing, immature cells include:

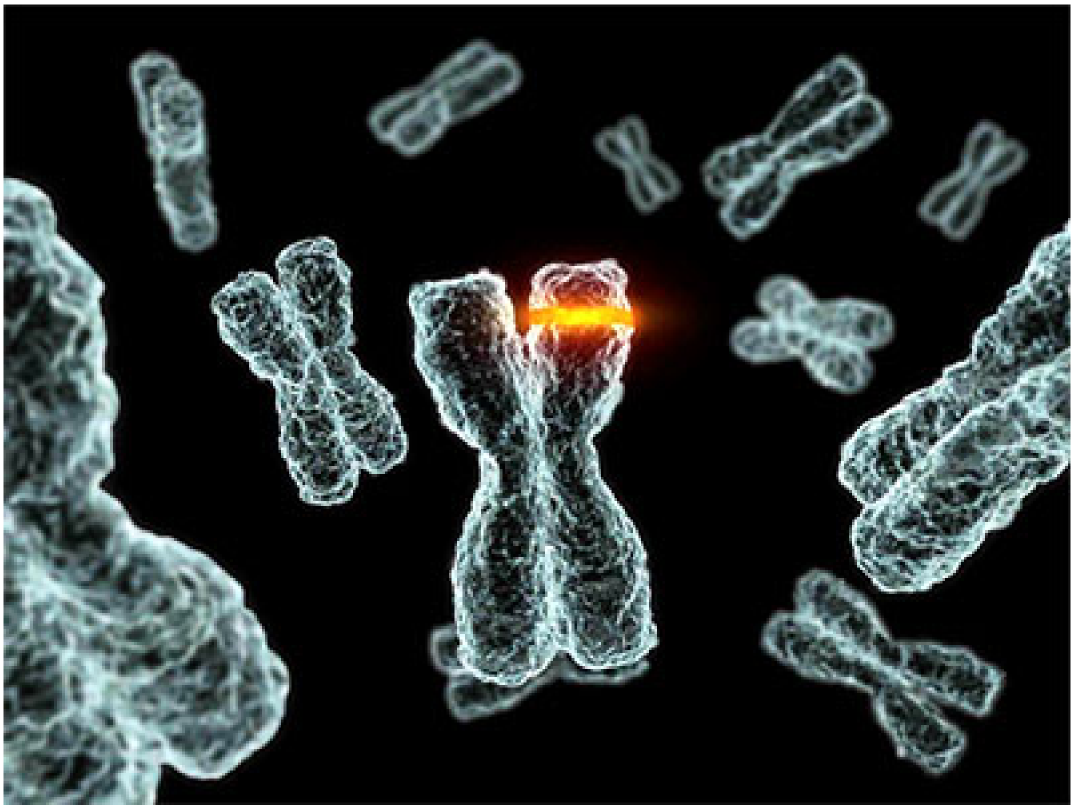
- Blood-forming cells (bone marrow). The more primitive stem cells are more sensitive than the more mature ones.
- Cells lining the intestinal tract. Again, the more primitive crypt cells are more sensitive than the more mature epithelial cells lining the gut.
- Cells in an embryo or fetus.

Cells that divide more slowly and cells that are more specialized are not as easily damaged by ionizing radiation. Examples include:

- Nerve cells.
- Brain cells.
- Muscle cells.

Visual 16: Radiation Exposure – DNA Mutations

- Neutral
- Harmful
- Beneficial



Key Points

Radiation directly interacts with the atoms of the DNA molecule or other components critical to cell survival and may affect the cell's ability to reproduce and survive or destroy the cell by interfering with its life-sustaining system.

Mutations are permanent changes in the DNA. Most mutations are neutral; they either make no change in the expression of genes, or the changes made do not affect the function of any gene product. Of those mutations which do make a difference, most have a negative effect.

- **Neutral** – Most mutations to DNA are neutral and have no negative or beneficial impact to the host organism.
  - This is partly because most DNA has little-to-no known function and is not incorporated in a gene.
  - Not all portions of the DNA are equally important.

- **Harmful**
  - Can modify DNA to a point where protein structures are rendered ineffective, dead, or cancerous
- **Beneficial**
  - While extremely rare, it is possible for DNA mutations to lead to overall positive impacts.

Visual 17: Factor: Dose Rate

Chronic Dose

- Small dose received over a long time.
- Body can repair damage because fewer cells need repair at any given time.
- No observable health effects.
- Examples: Natural background radiation; workers in nuclear and medical facilities.

Acute Dose

- Large dose received in a short time.
- Body can't repair/replace cells fast enough.
- Possible health effects:
  - Reduced blood count
  - Hair loss
  - Nausea, vomiting, diarrhea
  - Fatigue
- Causes Acute Radiation Syndrome (ARS)

Key Points

Often, the biological effects of ionizing radiation depend not only on how much radiation is received but also on dose rate, or **how fast a radiation dose is received.** There are two categories of radiation doses: chronic radiation doses and acute radiation doses.

- **Chronic Dose: A small amount of radiation received over a long period of time.** Examples of chronic radiation doses include the everyday doses we receive from natural background radiation and the doses received by workers in nuclear and medical facilities. The body can repair the damage from chronic doses because fewer cells will need repair at any given time, and it has enough time to replace dead or nonfunctioning cells with healthy ones. Chronic doses do not result in detectable health effects.
- **Acute Dose: A large dose of radiation received in a short period of time.** The body cannot repair or replace cells fast enough after a large acute dose of radiation, so physical effects may be seen. It takes a large acute dose of radiation before people experience any observable physical effects. The physical reaction to an acute dose of radiation is the result of extensive cell damage over a short period of time.

Visual 18: Acute Radiation Syndrome (ARS)

- “Radiation sickness” or “radiation toxicity.”
- Acute illness caused by a large dose of penetrating radiation delivered to most or all of the body in a short period of time, usually minutes to hours.

What historical events have caused significant ARS?

Key Points

An extreme example of the effects of ionizing radiation is ARS.

What is ARS? Acute Radiation Syndrome (ARS) is an acute illness caused by a large dose of penetrating radiation delivered to most or all of the body in a short period of time-usually within a matter of minutes to hours. The major cause of this syndrome is depletion of immature stem cells in specific tissues.

Necessary conditions: The following are required conditions for ARS:

- **Large:** The radiation dose must be large (i.e., greater than 70 rem).
- **External:** The dose is usually external (i.e., the source of radiation is outside of the person's body).
- **Penetrating:** The radiation must be penetrating (i.e., able to reach the major organs).
- **Entire body:** The entire body (or a significant portion of it) must have received the dose. Most radiation injuries are local, frequently involving just the hands, and these local injuries seldom cause classical signs of ARS.
- **Short timeframe:** The dose must have been delivered in a short time (usually a matter of minutes). Fractionated doses are often used in radiation therapy. These large total doses are delivered in small daily amounts over a period of time. Fractionated doses are less likely to induce ARS than a single dose of the same magnitude.

Acute Effects: Symptoms of acute radiation sickness include:

- Changes in blood cells and blood vessels.
- Skin irritation (similar to sunburn but lasting 3 weeks).
- Gastrointestinal system effects.
- Nausea and vomiting.
- Diarrhea.
- High fever.
- Hair loss.
- Dermal burns.
- Severe injury to internal organs.
- Long-term physiological effects.

Symptoms may appear shortly after exposure, then disappear for a few days, and reappear in a much more serious form a week or so later. Later symptoms may include:

- Malaise, fatigue, and drowsiness.
- Weight loss.
- Fever.

- Abdominal pain.
- Insomnia and restlessness.
- Blisters.

Long-Term Effects: The probability of experiencing long-term effects increases as the level of exposure increases. Long-term effects may include various forms of cancer (leukemia, bone cancer, thyroid cancer, lung cancer), cataracts, and shortened life span.

The severity and course of acute radiation sickness depends on how much total dose is received, how much of the body is exposed, and the radiosensitivity of the individual.

Visual 19: Factor: Biological Variability

- Age
- Sex
- Health
- Rate of metabolism
- Size and weight

Discussion Question: Why would children be very susceptible to radiation damage?

Key Points

Individuals also have biological variability factors that impact how they are affected by radiation.

These factors include the exposed person's age, sex, health, rate of metabolism, size, and weight. Children are very susceptible to the damage caused by ionizing radiation.

Discussion Question: Why would children be very susceptible to radiation damage?

Visual 20: Factor: Portion of the Body Exposed

Amount of body exposed:

- Whole body dose
- Localized exposure
- Combination exposure

Extremities can withstand a much higher dose than the rest of the body.

Key Points

The extremities of the body can withstand a much higher dose of radiation than the whole body (head, trunk, arms above the elbow, or legs above the knee). This is because the major blood-forming organs are located in the whole body area.

Whole body dose: When a whole body dose occurs, the radiation dose is delivered to the whole body homogeneously. For example, a person may enter a radiation field (e.g., a sterilizer that uses a radioactive source, or an industrial radiography area) where the entire body is exposed to radiation.

Localized exposure: In the case of localized radiation exposure, the dose is only delivered to a portion of the body, as would occur if a person placed a hand into the path of a radiation beam or picked up a radioactive rod.

Combination exposure: In some cases, the dose may occur as a combination of whole body and localized exposure. For example, in one case a janitor placed an industrial radiography source in his back pocket and sustained severe local injury to his buttock; he also received a whole-body dose sufficient to cause ARS.

Amount of body exposed: The amount of the body exposed to radiation is a factor in determining the biological effect. While many cancer patients receive large doses of radiation to destroy tumors, this radiation is concentrated on a specific portion of the body. Exposing the whole body poses a greater risk because the radiation-induced damage affects a larger area.

Visual 21: Topics

Radiation Basics

Biological Effects

Radiological Hazards

Key Points

The final section of this unit will focus on the effects of radiation on the human body.

Visual 22: Discussion: Exposure vs. Contamination

<u>Discussion Question:</u> Radiation exposure and radiation contamination – what's the difference?

Visual 23: Radiation Exposure

- Exposure means being exposed to ionizing radiation or to radioactive material.
- Exposure does not constitute a hazard at controlled levels.
- Exposure decreases when you move away from the source.

Video description:

Illustrating exposure from an unshielded source and lack of exposure when the source is shielded.

Key Points

Radiation exposure and radioactive contamination are not the same thing.

Radiation exposure means being exposed to ionizing radiation or to radioactive material. A person who has been exposed to radiation has had radioactive waves or particles penetrate the body, like having an x-ray.

We are exposed to low levels of radiation in the natural environment every day. Exposure does not, in and of itself, constitute a hazard at controlled levels. For example, there are many applications in medicine for radiation exposure.

Exposure decreases as soon as the person is moved away from the radiation source. The animation on this visual illustrates the difference between what happens when the source is unshielded and what happens when it is shielded.

Visual 24: Radioactive Contamination

- Is the deposition of radioactive material where it is not wanted—an uncontrolled location
- Can result from release of radioactive material
- May be external and/or internal
- May be:
  - Fixed (measurable but not spreadable)
  - Removable (easily spread through normal contact)

Radioactive Contamination Video Description

Illustrating the deposition of radioactive particles on the body.

Key Points

Radioactive contamination, in short, means the deposition of radioactive material where you don't want it, such as on surfaces, on people, or ingested by living things.

For a person to be contaminated, radioactive material must be on or inside of his or her body. A contaminated person is exposed to radiation released by the radioactive material.

An uncontaminated person can be exposed by being too close to radioactive material or to a contaminated person, place, or thing.

Radioactive contamination can be categorized as either fixed or removable.

- **Fixed contamination** is radioactive material that is not easily transferred to other people or equipment through normal contact. Fixed contamination poses an exposure hazard only to what it is affixed to, whether it be people, places, or things.
- **Removable contamination** is radioactive material that is easily transferred to other people or equipment through normal contact. Removable contamination poses a hazard to everything, and more importantly, everyone.

When contamination is discovered at an incident scene or on a person, it will likely be a combination of both fixed and removable.

	Fact Sheet: Exposure and Contamination
Exposure vs.	• Radiation exposure does not equal contamination.

	Fact Sheet: Exposure and Contamination
Contamination	• Radiation is a type of energy that can pass through people and objects. We are exposed to low levels of radiation every day from common sources like cosmic rays, x-rays, and even the bricks used to make buildings. • Exposure to radiation at controlled levels does not constitute a hazard. • Exposure stops when one moves away from the radiation source. • Radioactive contamination, on the other hand, continues to emit radiation.
Contamination	• Radioactive contamination is, simply stated, radioactive material in a place where it is not wanted—an uncontrolled location. Radioactive material on the ground, in water, or on you, is referred to as contamination. • Should radioactive material be released during an incident, it is possible for anyone or anything present to become contaminated if they come in contact with the material. The possibility of contamination is increased when the material is in the form of a liquid or powder. • Radioactive contamination can be external, internal, or a combination of the two.
External Contamination	External contamination is radioactive material that is *on* something where it is not wanted. • While a short exposure to radioactive material may be safe, prolonged or very close exposure may not be. • As long as the material is on you or your clothing, you are still being exposed to radiation from the material. • People who are contaminated may contaminate others, either directly or by secondary contamination. Secondary contamination occurs when a contaminated person or object touches or is touched by another person.
Internal Contamination	Internal contamination is radioactive material that is *in* something where it is not wanted. • Internal contamination occurs when people swallow or breathe in radioactive material, usually a liquid or powder, or when radioactive material is absorbed through the skin. • Once inside the body, radioactive material may be difficult to remove. • Radioactive material that might not be very dangerous outside

	Fact Sheet: Exposure and Contamination
	the body may be dangerous if allowed to enter the body.
Avoiding Contamination	In the presence of radioactive material, it is important not to eat, drink, smoke, or chew to prevent the possibility of internal contamination. It is also important to use personal protective equipment (PPE) to prevent external contamination.

Visual 25: Measuring Radiation Exposure

Common units for measuring radiation exposure:

- Roentgen
- Radiation Absorbed Dose (rad)
- Roentgen Equivalent Man (rem)

	Exposure	Absorbed Dose	Dose Equivalent
Common Units	roentgen (R)	rad	rem
SI Units	coulomb/ kilogram (C/kg)	gray (Gy)	sievert (Sv)

Key Points

Common units for measuring radiation exposure include the roentgen (R), radiation absorbed dose (rad), and roentgen equivalent man (rem). Each common unit has a corresponding international (SI) unit as shown on the visual.

Roentgen

- **Definition:** The roentgen (R), one of the common units used to measure radiation exposure, is defined as the sum of charge per unit mass of air. 1 roentgen = 2.58 x 10-4 coulombs/kg of air. The SI equivalent is C/kg.
- **What it measures:** It is a measure of the ability of photons (X and gamma) to produce ionizations in air. In the United States, instrumentation (both new and old) will typically be displayed in roentgen. The roentgen does not relate the biological damage done from the radiation.

Radiation Absorbed Dose (Rad)

- **Definition:** The Radiation Absorbed Dose, or rad, is defined as the deposition by any radiation of 100 ergs of energy in one gram of any material. (An erg is a unit of energy.) The SI unit for absorbed dose is the gray (Gy): 1 rad = .01 Gy.
- **What it measures:** The rad is the customary unit for measuring absorbed dose and can be applied to all types of radiation. The rad only measures absorbed dose and does not relate biological damage done from the radiation.

Roentgen Equivalent Man (rem)

- Definition: The rem is the customary unit of dose equivalence. The rem is the quantity of ionizing radiation whose biological effect (in man) is equal to that produced by 1 roentgen of X or gamma radiation. The SI unit is the sievert (Sv):
  - 1 rem = .01 Sv
  - 1 Sv = 100 rem = 100,000 mrem

- What it measures: Because the same amount of absorbed dose of different kinds of radiation causes different degrees of damage, and neither the roentgen nor the rad conveys those differences, we need a way to account for biological damage.

  Each type of radiation is assigned a quality factor (QF) that relates the relative risk from the type of radiation absorbed to the risk from the same dose of X or gamma radiation. The quality factor converts the absorbed dose to a unit of dose equivalence, a common scale that can be added with and compared to damage caused by any kind of ionizing radiation. The rem is calculated as rad x QF.
- Example: Alpha radiation is assigned a quality factor of 20. This means that 1 rad of alpha radiation is equal to 20 rem (1 rad x 20 QF = 20 rem).

Visual 26: ALARA

- Rule for radiation protection: Keep exposure As Low As Reasonably Achievable.
- Based on assumption that any exposure in any amount presents some risk.
- Concept applies in all cases:
  - Radiation workers
  - Emergency workers
  - General public

Use—

- Time
- Distance
- Shielding

Key Points

The rule for radiation protection is to keep exposure "As Low As Reasonably Achievable" (ALARA), based on the assumption that any radiation exposure in any amount presents some risk. The ALARA concept applies in all cases-to radiation workers, emergency workers, and the general public.

Visual 27: Potential for Exposure/Contamination (1 of 2)

Widespread use of radioactive materials in:

- Consumer products (small amounts)
- Research - Academic, medical, pharmaceutical
- Medicine - Diagnosis and treatment
- Industry - Construction, manufacturing, food processing
- Nuclear reactors - Research, energy production

Key Points

Radioactive material is a natural part of our environment and is widely used for industrial and commercial applications. It has specialized uses in consumer products, building materials, research, medicine, industry, nuclear reactors, irradiators, and transportation.

Because of regulations governing the use of radioactive material and the enhanced safety precautions utilized, it presents a low exposure risk to the general public.

Common uses of radioactive materials are summarized in the following table.

Uses/Sources of Radioactive Material

Area of Use	Description
Consumer Products	The following are examples of consumer products that may contain radioactive materials: • Antique items including: ceramic-glaze products in orange, red, or yellow (e.g., antique cups and plates, decorative floor tiles, jewelry, pottery) and "Vaseline" glass (emerald green glass used in some antique tableware) • Older camera lenses and gas lantern mantels (thorium-232) • Radio-luminescent products (using radium paint) including older watches, clocks, and instrument gauges • Low-sodium salt substitutes (potassium-40) • Propane tanker trucks (from radioactive deposits on the tanker's interior walls) Smoke detectors (Am-241) • Thoriated aluminum (an alloy containing Th-233) • Thoriated tungsten arc-welding electrodes (often labeled thoriated welding rods) Uranium ore samples

Area of Use	Description
	• Other materials that contain naturally occurring radioactive material, such as: marble, monazite sand, sandstone, slate and concrete, feldspar, fertilizers, and granite
Research	Radioactive material is commonly used for research by academic and medical institutions, pharmaceutical companies, and small research and development companies. Radioactive isotopes can be chemically incorporated into the molecules that make up DNA. When processed appropriately, the materials can create an image showing where the radioactively labeled genetic material has concentrated. This technique is used in forensic analyses of biological specimens to provide physical evidence in legal proceedings. Research facilities may use a wide variety of isotopes. The activity levels used may be very high or low.
Medicine	Radioactive materials are used for diagnosing and treating cancer and other illnesses. • **Diagnostic imaging** with radiopharmaceuticals involves binding a radioactive isotope to a chemical or drug that is injected, ingested, or inhaled by a patient. The type of isotope and the chemical form vary depending on the type and purpose of the medical procedure being performed. • **Therapeutic treatments** such as brachytherapy and teletherapy use radioactive material to treat cancer and other illnesses. In brachytherapy, radioactive sources are placed in close proximity to a tumor to kill cancer cells. The radioactive material is sealed in specially formed capsules ("seeds") that are implanted into the body. In teletherapy, intense and focused beams of radiation are used to treat cancerous tumor growths. One approach is to use linear accelerators that generate electron beams. Another is to use gamma emitting isotopes like cobalt-60 and cesium-137. These sources may contain thousands of curies of radioactive material.
Industry	**Radioactive** material is used in a variety **of** industrial applications, including: • **Density gauges** for measuring thickness, compaction, density, or moisture content. • **Industrial radiography equipment** used for nondestructive testing and internal inspection of an object—such as checking welds and metal for flaws.

<table>
<tr><th>Area of Use</th><th>Description</th></tr>
<tr><td></td><td>Irradiators used to calibrate instrumentation, sterilize blood, and treat food products to kill harmful bacteria.
Sources commonly used in industry that may be of concern if misused include: American (Am-241)
Cobalt (Co-60)
Barium (Ba-133)
Iridium (Ir-192)
Cesium (Cs-137)
Radium (Ra-226)
Cobalt (Co-57)
Thorium (Th-232)</td></tr>
<tr><td>Reactors</td><td>As of October 2012 there were 104 commercial nuclear powerplants across the United States and an additional 31 licensed research and test reactors operated by universities and national laboratories. Isotopes of major concern for accidental or terrorism-related contamination include:
Plutonium (Pu-239).
Enriched Uranium (U-235).
Uranium (U-233).
Neptunium (Np-237).</td></tr>
<tr><td>Transportation</td><td>Approximately 3 million packages of radioactive materials are shipped each year in the United States by highway, rail, air, and water, opening the possibility of transportation accidents.

However, as with other hazardous materials, the transportation of radioactive material is strictly regulated. Many governmental agencies have jurisdiction over the transfer and shipment of radioactive material from nuclear facilities. The regulatory requirements become more restrictive as the quantity, concentration, and potential hazard of the radioactive material increases. Most of the regulatory restrictions apply to the packaging and the methods of shipment used to transport the package.</td></tr>
</table>

Visual 28: Potential for Exposure/Contamination

Exposure or contamination could result from:

- Accidental contamination:
  - Leaks or spills of radioactive materials.
  - Improper handling of radioactive equipment or inadequate shielding.
  - Transportation accidents.
  - Industrial or nuclear accidents.
- Terrorist use of acquired source materials.

Key Points

With the wide range of radioactive materials in use today, radiation exposure or contamination could result from accidental contamination or from malicious use of acquired source materials.

Accidental contamination can result from leaks or spills of radioactive materials, improper handling of radioactive equipment, inadequate shielding, transportation accidents, or industrial or nuclear accidents. The risks vary with the type of radioactive material, the quantities involved, and whether the material is sealed or unsealed.

- **Unsealed radioactive material** is a potential internal radiation hazard because it can be inhaled, ingested, or absorbed through the skin, leading to dangerous exposure to internal organs. Some isotopes (e.g., P-32, Cs-137) also pose an external radiation hazard, so shielding is required to protect against exposure to the radiation field. Isotopes such as C-14 and H-3 emit such low energy beta radiation that they can be safely handled without concern to external radiation exposure.
- **Sealed source** means radioactive material that is permanently bonded or fixed in a capsule or matrix designed to prevent release and dispersal of the radioactive material under the most severe conditions. An example is the Gamma Knife® unit (pictured on the visual) which uses cobalt-60. A small, pea-sized source is sealed in a small welded capsule, and the capsule is encased in a shield, usually lead, with a small shuttered opening that controls the gamma beam.

In medical facilities, radioactive material may be sealed or unsealed. Research facilities may use a wide variety of isotopes, typically in an unsealed or dispersible form, which increases the potential for radiological contamination. The activity levels used may be very high or low. Incidents that occur at such facilities therefore may require a hazardous materials response.

Visual 29: Radiological Terrorism

- Attack on a nuclear facility or shipments
- Malicious use of a radiological device
- Radiological dispersal device (RDD)
- Radiation emitting device (RED)

Key Points

Background: Not long after their development, nuclear weapons became a symbol of both military and national power, and nuclear testing became a useful tool for sending political messages. Many nations have evaluated the use of nuclear or radiological weapons, but in the aftermath of atomic attacks on Hiroshima and Nagasaki, they have so far concluded that the consequences of using such weapons would outweigh any military gains they might make. These consequences include high civilian casualties, destroyed land and property, and a fierce international backlash, which could include retaliation with nuclear weapons.

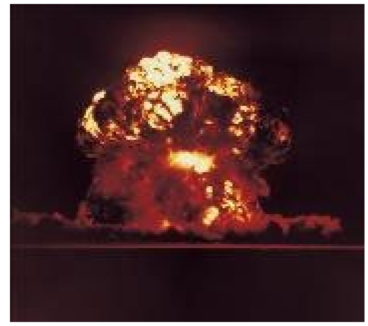
Methods: There are two primary ways to implement radiological terror, and the motives for either action would be the same: to cause injury and ruin property, escalate public fears of radiation, damage the economy, and prompt political changes.

- **Attacks on nuclear facilities and transport:** Attacks on nuclear facilities could be in populated or rural areas. Potential facility targets include nuclear powerplants, cooling pools for spent nuclear fuel rods, nuclear reactors used for research or other non-electricity purposes, nuclear reprocessing facilities, calibration laboratories, and nuclear waste sites. Trucks or railcars carrying nuclear weapons, spent nuclear fuel, and high-level radioactive waste are also potential terrorist targets.

Because of the **robust safeguards** in place for nuclear facilities and nuclear shipments in the United States, the likelihood of a successful attack on a nuclear installation or nuclear shipment is considered remote.

- **Malicious use of a radiological device:** While terrorists would face significant obstacles in the development and deployment of a radiological device, an attack is possible; consequently, responders need to plan and train for a response to a radiological terrorism incident. Radiological devices would most likely be used in large cities.

Visual 30: Weapons of Mass Destruction



- Improvised Nuclear Device (IND): Produces nuclear-yield reaction.
- Detonation of the smallest nuclear weapon would cause:
    - Mass casualties.
    - Extensive damage.
    - Potentially lethal radiation levels from widespread contamination.

Key Points

Definition: Nuclear weapons are defined as:

> "a weapon in which enormous energy is released by nuclear fission (splitting the nuclei of a heavy element like uranium 235 or plutonium 239)."

They are the world's most powerful and destructive weapons. In a nuclear weapon there is enough fissile material for the formation of several critical masses, but prior to detonation it is kept in a "sub-critical" state (that is, the fissile material is arranged so that spontaneous neutrons cannot start chain reactions, or only very short ones, which quickly die out).

Method: Unlike an RDD that disperses radioactive material using conventional explosives, a nuclear attack is the use of a device that **produces a nuclear explosion.** The effect of detonating even the smallest of nuclear weapons in any city would be devastating. Responders would encounter mass casualties, extensive damage, and potentially lethal radiation levels from widespread contamination.

Existing Weapons: According to the Federation of American Scientists, there are more than 17,000 nuclear warheads, with the largest stockpiles in the United States and Russia. Many safeguards are in place to protect nuclear weapons controlled by the United States. While many nuclear weapons in Russia are adequately protected from theft, it is believed that others are not. Many Soviet-era tactical nuclear devices are vulnerable, and given the smaller size of such weapons, would be particularly useful to terrorist groups. Some reports have estimated that several hundred weapons are vulnerable to theft by terrorists or criminals who might sell them to terrorist organizations. While it may be unlikely, it is at least conceivable that a terrorist group could purchase and smuggle a nuclear weapon into the United States or explode one off its coasts, either by construction of a weapon on its own, or by obtaining a weapon from a rogue nation.

Improvised Weapons: There is little doubt among experts that technically competent terrorists could make a device given sufficient quantities of the right radioactive material. Such a device would be called an Improvised Nuclear Device, or IND (sometimes called "dirty nukes"). According to the Department of Defense (DOD), an IND is a:

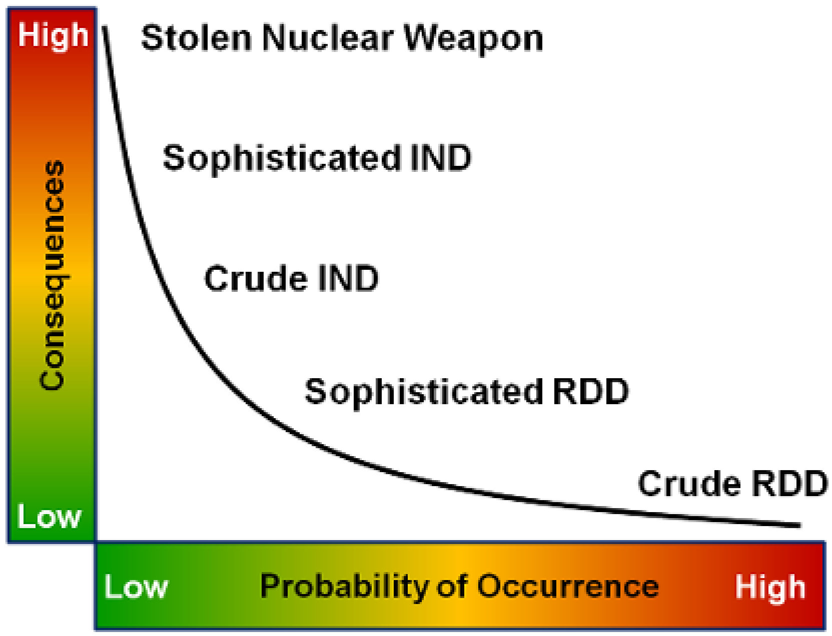
"device incorporating radioactive materials designed to result in the dispersal of radioactive material or in the formation of nuclear-yield reaction. Such devices may be fabricated in a completely improvised manner or may be an improvised modification to a U.S. or foreign nuclear weapon."

Purpose: Like RDDs, one of the primary intents of INDs is to scatter radiological contamination. A key difference between an IND and an RDD, however, is that an IND results in a nuclear yield that can cause widespread destruction whereas an RDD does not.

Impact of a Nuclear Explosion:

- A fireball, roughly spherical in shape, is created from the energy of the initial explosion. It can reach tens of millions of degrees.
- A shockwave races away from the explosion and can cause great damage to structures and injuries to humans.
- The ionization of the atmosphere around the blast can result in an electromagnetic radiation pulse (EMP) that, for ground detonations, can drive an electric current through underground wires causing local damage. For high-altitude nuclear detonations, EMP can cause widespread disruption to electronic equipment and networks.
- A mushroom cloud typically forms as everything inside of the fireball vaporizes and is carried upwards. Radioactive material from the nuclear device mixes with the vaporized material in the mushroom cloud.
- Fallout results when the vaporized radioactive material in the mushroom cloud cools, condenses to form solid particles, and falls back to the Earth. Fallout can be carried long distances on wind currents as a plume and contaminate surfaces miles from the explosion, including food and water supplies.

Visual 31: Potential Weapon Use



Key Points

The chart on the visual illustrates that radiological weapons with the greatest consequences are the least likely to be used, while weapons with lower consequences have a higher probability of occurrence.

Visual 32: Activity 14.1 – Goiânia Contamination

Instructions: Working in groups…

1. Review the scenario synopsis of the Goiânia, Brazil contamination incident
2. Answer the questions in your Student Manual
3. Select a spokesperson and be ready to share your ideas with the class

Key Points

Instructions: Working in groups…

1. Review the scenario synopsis of the Goiânia, Brazil contamination incident.
2. Answer the questions in your Student Manual.
3. Select a spokesperson and be ready to share your ideas with the class.

Activity 14.1 – Goiânia Contamination Synopsis

The **Goiânia accident** was a radioactive contamination [Source: Wikipedia (https://en.wikipedia.org/wiki/Radioactive_contamination)] accident that occurred on September 13, 1987, at Goiânia [Source: Wikipedia (https://en.wikipedia.org/wiki/Goi%C3%A2nia)], in the Brazilian state of Goiás [Source: Wikipedia (https://en.wikipedia.org/wiki/Goi%C3%A1s)], after an old radiotherapy (This link can also be accessed at the following URL: https://en.wikipedia.org/wiki/Radiation_therapy) source was stolen from an abandoned hospital site in the city. It was subsequently handled by many people, resulting in four deaths. About 112,000 people were examined for radioactive contamination, and 249 were found to have significant levels of radioactive material in or on their bodies. [Source: Wikipedia (https://en.wikipedia.org/wiki/Goi%C3%A2nia_accident#cite_note-NYT-2)].

Health outcomes: News of the radiation incident was broadcast on local, national, and international media. Within days, nearly 130,000 people swarmed local hospitals concerned that they might have been exposed. Of those, 250 were indeed found to be contaminated— some with radioactive residue still on their skin— through the use of Geiger counters [Source: Wikipedia (https://en.wikipedia.org/wiki/Geiger_counter)]. Eventually, 20 people showed signs of radiation sickness [Source: Wikipedia (https://en.wikipedia.org/wiki/Acute_radiation_syndrome)] and required treatment.

Fatalities: (Ages in years are given, with dosages listed in Greys (Gy) [Source: Wikipedia (https://en.wikipedia.org/wiki/Gray_(unit)].

- **Leide das Neves Ferreira,** age 6 (6.0 Gy), was the daughter of Ivo Ferreira. When an international team arrived to treat her, she was discovered confined to an isolated room in the hospital because the hospital staff were afraid to go near her.
- She was buried in a common cemetery in Goiânia, in a special fiberglass coffin lined with lead to prevent the spread of radiation. Despite these measures, news of her impending burial caused a riot of more than 2,000 people in the cemetery on the day of her burial, all

fearing that her corpse would poison the surrounding land. Rioters tried to prevent her burial by using stones and bricks to block the cemetery roadway.

Other affected people: Afterwards, about 112,000 people were examined for radioactive contamination; 249 were found to have significant levels of radioactive material in or on their body. Of this group, 129 people had internal contamination. The majority of the internally contaminated people only suffered small doses (< 50 mSv) [Source: Wikipedia (https://en.wikipedia.org/wiki/Sievert)], less than a 1 in 400 risk of getting cancer as a result.

Cleanup: Topsoil [Source: Wikipedia (https://en.wikipedia.org/wiki/Topsoil)] had to be removed from several sites, and several houses were demolished. All the objects from within those houses were removed and examined. Those that were found to be free of radioactivity were wrapped in plastic bags, while those that were contaminated were either decontaminated or disposed of as waste. In industry, the choice between decontaminating or disposing objects is based on only the economic value [Source: Wikipedia (https://en.wikipedia.org/wiki/Value_(economics)] of the object and the ease of decontamination [Source: Wikipedia (https://en.wikipedia.org/wiki/Decontamination)]. In this case, the IAEA recognized that to reduce the psychological impact [Source: Wikipedia (https://en.wikipedia.org/wiki/Psychological_trauma)] of the event, greater effort should have been taken to clean up items of personal value, such as jewelry [Source: Wikipedia (https://en.wikipedia.org/wiki/Jewelry)] and photographs [Source: Wikipedia https://en.wikipedia.org/wiki/Photograph)]. It is not clear from the IAEA report to what degree this was practiced.

Activity 14.1 – Goiânia Contamination Worksheet

- What would you do if this occurred in your community? (Response)
- What resources/partners would be available to help your community? (Preparedness-Planning)
- What are the long-term impacts of an incident such as this? (Recovery)

Visual 33: Goiânia Video

Key Points

Introduction: The 1987 Goiânia radiological incident changed worldwide regulations for radiological waste. More than 200 people were exposed to cesium-137 with four deaths. More than 100,000 people were monitored and screened for radiation exposure.

Transcript:

Speaker: Thank you for staying with CNN. It is a symbol that can save lives. A red triangle with radiation waves and a man running. It was just adopted last year, but there was no such sticker to convey danger when scavengers went routing through debris at a deserted clinic in Brazil over 20 years ago. UN TV has details.

Voiceover speaker: Two families live at this scrapyard at the Brazilian city of Goiania. It is also home to the world's worst accident involving a radiative source. Its lessons still shape actions on nuclear safety and security decades later.

It started in September 1987 when scrap dealers pillaged and then sold a metal canister from an abandoned medical clinic. They had no clue it contained a powerful radioactive source used to treat cancer: Cesium Chloride, a glittering powder that glows blue in the dark.

Dr. Nelson Jose L. Valverde: They took the equipment to his dining room and called the neighbors, relatives, friends to show them that glittering object, and small fragments of the source were taken, were robbed on the scene, were given to other people as souvenirs, and that's the way contamination came to spread.

Voiceover: The powdery cesium spread undetected for over 2 weeks. Almost 250 people were contaminated or died in the first month, including a little girl who lived here. The legacy of a handful of cesium is three thousand cubic meters of contaminated waste. It's buried here. Goiania's plight brought global change. The international atomic energy agency introduced rigorous safety standards for sources. Brazil now requires that each and every source is licensed for lifetime tracking to final disposal.

Didier Louvat: Certainly the public and the environment are better protected now than thirty years ago.

Voiceover: Lessons were learned in Goiania, but worldwide radioactive sources are still dumped and lost. Efforts are underway to assist countries to search and secure abandoned sources, train body guards to detect them, as part of a cradle to grave approach needed to keep radioactive materials secure so that what happened in Goiania is never repeated.

From UN Television, this is Kirsty Hansen, with *CNN World Report.*

Visual 34: Activity 14.2 – Assessing Radiological Exposure Risk for Your Community

Instructions: Working individually…

1. Answer the questions in your IAW
2. Be ready to share your answers with the class in 5 minutes

Key Points

Instructions: Working individually…

1. Answer the questions in your IAW.
2. Be ready to share your answers with the class in 5 minutes.

Visual 35: Unit Summary

You should now be able to:

- Explain basic concepts related to the atom, isotopes, radioisotopes, radiation, and radioactive material.
- Distinguish between radiation exposure and radioactive contamination.
- Identify the units for measuring radioactivity and exposure.
- Describe the biological effects of ionizing radiation.
- Explain the ALARA principle.

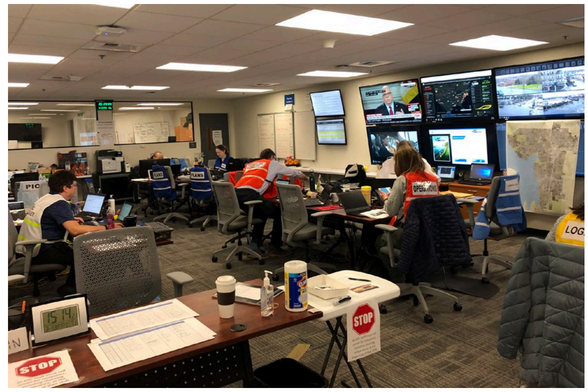
Key Points

Do you have any questions about the material covered in this unit?

Unit 15: Emerging Issues in Science and Technology Affecting Emergency Management

Visual 1: Unit 15: Emerging Issues in Science and Technology Affecting Emergency Management

Unit 15: Emerging Issues in Science and Technology Affecting Emergency Management



Key Points

This unit will introduce emerging issues related to science and technology affecting emergency management.

Time Plan

A suggested time plan for this unit is shown below.

Topic	Time
Introduction	5 minutes
Cybersecurity	10 minutes
Ransomware • Activity 15.1 – Assessing Your Vulnerabilities	10 minutes
Course Wrap-Up • Activity 15.2 – Course Wrap-Up	10 minutes
Unit Summary	5 minutes
Total Time	**40 minutes**

Visual 2: Unit Objectives

- Recognize emerging science and technology hazards and risks affecting our communities.
- Identify sources of information and subject matter experts, and incorporate them in our planning efforts.
- Identify ways that course concepts can be applied on the job.
- Indicate avenues to continue learning about the science of disaster.

Key Points

Review the unit objectives as shown on the visual.

Visual 3: Other Hazards

What are some emerging issues that have not been discussed yet?

Key Points

Beyond class, this is a question for you to ask back home as you start your risk analysis.

In the 103 course, we will talk about hazard/threat vulnerability analysis in the THIRA format, asking the questions:

- What emerging threats and hazards can affect our community?
- If they occurred, what impacts would those threats and hazards have on our community?
- Based on those impacts, what capabilities should our community have?

Visual 4: Other Possible Hazards

- Electromagnetic Pulse (EMP)
- Geomagnetic Pulse (GMP)
- Industrial, Engineering, & Transportation Hazards
- Cyber Threats
- Utility Failure
- Civil Disorder
- Supply Chain Vulnerabilities
- Ecological Hazards Waste Disposal
- Space Weather

We're going to talk about one category—cyber incidents

Visual 5: Cyber Incidents

- Accidental mistakes/human error
- A **cybercrime** is an offense committed with a criminal motive to intentionally harm the victim
- A **cyberattack** is any type of offensive maneuver that targets computer information systems, infrastructures, computer networks, or personal computer devices
  - These attacks can be cyberwarfare and/or cyberterrorism

Key Points

A cybercrime is an offense committed against individuals or groups with a criminal motive to intentionally harm the reputation of the victim or cause physical or mental harm, or loss, to the victim directly or indirectly, using modern telecommunication networks such as Internet (e.g., chat rooms, emails, notice boards, groups) and mobile phones.

Cybercrime may threaten a person or a nation's security and financial health. Includes actions such as:

- Hacking
- Copyright infringement
- Unwarranted mass-surveillance
- Sextortion
- Child pornography
- Child grooming

A cyberattack can be employed by sovereign states, individuals, groups, society or organizations and may originate from an anonymous source.

Depending on context, cyberattacks can be:

- Cyberwarfare: the use of technology to attack a nation causing harm comparable to actual warfare.
- Cyberterrorism: the use of the internet to conduct violent acts that result in, or threaten, loss of life or significant bodily harm, in order to achieve political or ideological gains through threat or intimidation.

Visual 6: Types of Cyber Incidents

Regardless of the cause, the result is often the same.

Employees actions outside of work can put our organizations at risk:

- Physical security issues
- Malware, including ransomware
- Phishing
- Man-in-the-middle
- Denial-of-service
- Others

Key Points

Common types of cyber attacks:

Malware

Malware is a term used to describe malicious software, including spyware, ransomware, viruses, and worms. Malware breaches a network through a vulnerability, typically when a user clicks a dangerous link or email attachment that then installs risky software. Once inside the system, malware can do the following:

- Blocks access to key components of the network (ransomware)
- Installs malware or additional harmful software
- Covertly obtains information by transmitting data from the hard drive (spyware)
- Disrupts certain components and renders the system inoperable

Phishing

Phishing is the practice of sending fraudulent communications that appear to come from a reputable source, usually through email. The goal is to steal sensitive data like credit card and login information or to install malware on the victim's machine. Phishing is an increasingly common cyberthreat.

Source: Cisco - What is phishing? (www.cisco.com/c/en/us/products/security/email-security/what-is-phishing.html).

Man-in-the-middle attack

Man-in-the-middle (MitM) attacks, also known as eavesdropping attacks, occur when attackers insert themselves into a two-party transaction. Once the attackers interrupt the traffic, they can filter and steal data. Two common points of entry for MitM attacks:

1. On unsecure public Wi-Fi, attackers can insert themselves between a visitor's device and the network. Without knowing, the visitor passes all information through the attacker.
2. Once malware has breached a device, an attacker can install software to process all of the victim's information.

Denial-of-service attack

A denial-of-service attack floods systems, servers, or networks with traffic to exhaust resources and bandwidth. As a result, the system is unable to fulfill legitimate requests. Attackers can also use multiple compromised devices to launch this attack. This is known as a distributed denial of service (DDoS). Source: Cisco - What is a DDoS attack? (www.cisco.com/c/en/us/products/security/what-is-a-ddos-attack.html).

SQL injection

A Structured Query Language (SQL) injection occurs when an attacker inserts malicious code into a server that uses SQL and forces the server to reveal information it normally would not. An attacker could carry out a SQL injection simply by submitting malicious code into a vulnerable website search box.

Learn how to defend against SQL injection attacks. Source: Cisco - SQL injection attacks (tools.cisco.com/security/center/resources/sql_injection).

Zero-day exploit

A zero-day exploit hits after a network vulnerability is announced but before a patch or solution is implemented. Attackers target the disclosed vulnerability during this window of time. Zero-day vulnerability threat detection requires constant awareness. Source: Talos Vulnerability Reports (talosintelligence.com/vulnerability_reports).

DNS Tunneling

DNS tunneling utilizes the DNS protocol to communicate non-DNS traffic over port 53. It sends HTTP and other protocol traffic over DNS. There are various, legitimate reasons to utilize DNS tunneling. However, there are also malicious reasons to use DNS Tunneling VPN services. They can be used to disguise outbound traffic as DNS, concealing data that is typically shared through an internet connection. For malicious use, DNS requests are manipulated to exfiltrate data from a compromised system to the attacker's infrastructure. It can also be used for command and control callbacks from the attacker's infrastructure to a compromised system.

To learn more about DNS Tunneling, visit Cisco - DNS Tunneling (learn-umbrella.cisco.com/solution-briefs/dns-tunneling)

Source: Cisco (www.cisco.com/c/en/us/products/security/common-cyberattacks.html).

Visual 7: Ransomware Attacks on Government

Other governments:

- Atlanta, GA;
- Baltimore, MD
- 23 towns in Texas
- Matanuska-Susitna (Mat-Su) & Valdez, AK;
- Oshkosh, WI…. As well as utilities, hospitals, school districts, and transportation authorities.

Ransomware Attacks on Government

Video: Why ransomware attacks target local governments like Atlanta (https://www.pbs.org/newshour/show/why-ransomware-attacks-target-local-governments-like-atlanta).

Other governments:

- Atlanta, GA;
- Baltimore, MD
- 23 towns in Texas
- Matanuska-Susitna (Mat-Su) & Valdez, AK;
- Oshkosh, WI…. As well as utilities, hospitals, school districts, and transportation authorities.

Visual 8: Background (1 of 2)

- Cyber incidents are growing in size and scope
- Requires cooperative effort through:
  - Preparedness (Planning, Training, Exercising)
  - Response Recovery
- It is not just an Information Technology (IT) department problem
  - Lead agencies: IT, EM, Law Enforcement
  - Support agencies: ALL Departments!

Key Points

How often do cyber attacks occur?

Cyber attacks hit businesses every day. Former Cisco CEO John Chambers once said, "There are two types of companies: those that have been hacked, and those who don't yet know they have been hacked." According to the Cisco Annual Cybersecurity Report (www.cisco.com/c/m/en_au/products/security/offers/cybersecurity-reports.html) , the total volume of events has increased almost fourfold between January 2016 and October 2017.

Why do people launch cyber attacks?

Cybercrime has increased every year as people try to benefit from vulnerable business systems. Often, attackers are looking for ransom: 53 percent of cyber attacks resulted in damages of $500,000 or more.

Cyberthreats can also be launched with ulterior motives. Some attackers look to obliterate systems and data as a form of "hacktivism."

What is a botnet?

A botnet is a network of devices that has been infected with malicious software, such as a virus [Source: Cisco - virus differences (www.cisco.com/c/m/en_au/products/security/offers/cybersecurity-reports.html)] . Attackers can control a botnet as a group without the owner's knowledge with the goal of increasing the magnitude of their attacks. Often, a botnet is used to overwhelm systems in a DDoS attack [Source: Cisco - distributed-denial-of-service attack (DDoS) attack (www.cisco.com/c/en/us/products/security/what-is-a-ddos-attack.html) .

Visual 9: Background (2 of 2)

- Requires a Cyber Plan/Annex AND a good Continuity of Operations (COOP) plan
- Many standards exist to assist
- Requires organization-wide training on awareness, recognition, and reporting

Key Points

References

National Cyber Incident Response Plan, Department of Homeland Security, 2016 (www.us-cert.gov/ncirp)

- Computer Security Incident Handling Guide (Revision 2) National Institute of Standards and Technology, 2012 (nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-61r2.pdf)
- Washington State Significant Cyber Incident Annex, Washington Military Department – Emergency Management Division, 2015 (mil.wa.gov/uploads/pdf/PLANS/wastatesignificantcyberincidentannex20150324.pdf)

ISO/IEC 27032 – Information Technology – Security techniques – Guidelines for cybersecurity, International Standards Organization, 2012 (www.iso.org/obp/ui/)

Cybersecurity and Infrastructure Security Agency (CISA) https://www.cisa.gov/

Extra reading:

Cyber:

Cities Speak (https://citiesspeak.org/2019/10/01/how-one-alaskan-borough-stood-up-to-a-cyber-attack/)

Anchorage Daily News "Price tag for cyberattack on Mat-Su Borough now tops $2 million" (https://www.adn.com/alaska-news/mat-su/2018/10/11/price-tag-for-mat-su-cyberattack-now-tops-2-million/)

Secure World "Incident Response: The Alaska Cyber Attack, a State of Emergency, and YouTube" (https://www.secureworldexpo.com/industry-news/incident-response-the-alaska-cyber-attack-a-state-of-emergency-and-youtube)

Washington Post "An Alaskan Borough Turns Typewriters and Handwriting After Its Computers Were Hacked" (https://www.washingtonpost.com/technology/2018/08/01/an-alaskan-borough-turns-typewriters-handwriting-after-its-computers-were-hacked/)

State Scoop "Ransomware attack forces Alaska suburb to revert to typewriters, rebuild email from scratch" (https://statescoop.com/ransomware-attack-forces-alaska-suburb-to-revert-to-typewriters-rebuild-email-from-scratch/)

Valdez (paid the ransom):

ZDNet "City of Valdez, Alaska admits to paying off ransomware infection" (https://www.zdnet.com/article/city-of-valdez-alaska-admits-to-paying-off-ransomware-infection/)

Baltimore:

Baltimore Sun "Baltimore transfers $6 million to pay for ransomware attack; city considers insurance against hacks" (https://www.baltimoresun.com/politics/bs-md-ci-ransomware-expenses-20190828-njgznd7dsfaxbbaglnvnbkgjhe-story.html)

Secure World "Baltimore, $18 Million Later: 'This Is Why We Didn't Pay the Ransom" (https://www.secureworldexpo.com/industry-news/baltimore-ransomware-attack-2019)

Visual 10: Activity 15.1 - Assessing Your Vulnerabilities

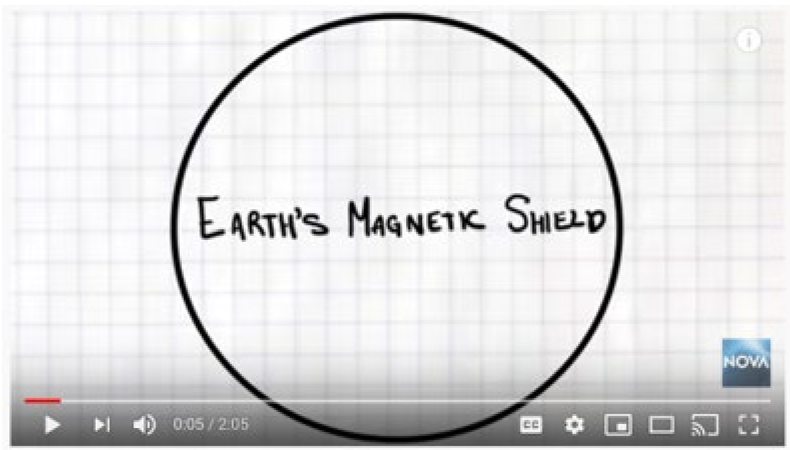
Instructions:

1. Working individually, answer the questions in your IAW.
2. Be ready to share your answers with the class in 5 minutes.

Visual 11: Science and the Practice of Emergency Management (EM)

All of the sciences that we have had discussed in this class are connected because our world is connected…

These next several slides will show some examples of how some of the science that we have discussed over the last three days comes into play as you practice the profession of emergency management.



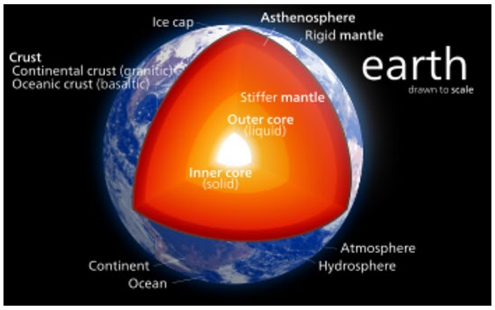
Key Points

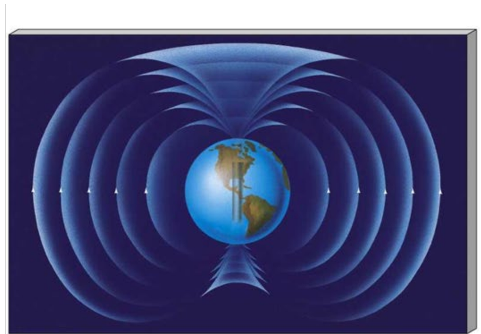
- Electricity and Magnetism are related
- Moving electric charges create magnetic fields
- Changing magnetic fields cause charges to move

Video: Earth's Magnetic Shield (https://www.youtube.com/watch?v=URN-XyZD2vQ)

Visual 12: Example (1 of 7)

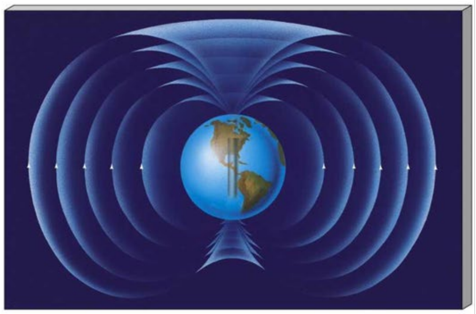
The liquid metal in our outer geological core is in motion, which causes magnetism and creates our magnetosphere.





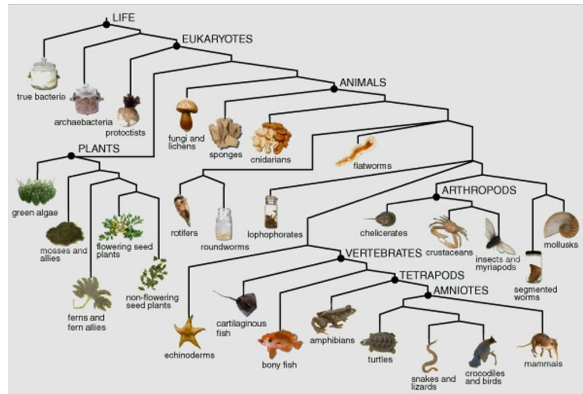
Visual 13: Example (2 of 7)

The magnetosphere plus our atmosphere create a protective blanket that, generally, allows in just enough solar radiation to allow life to exist.



Visual 14: Example (3 of 7)

Too much radiation would scramble our DNA and not allow biological entities to reproduce effectively…but a little powers our dynamic environment, allowing us to evolve at a reasonable rate, over time, in concert with our environment.



Visual 15: Example (4 of 7)

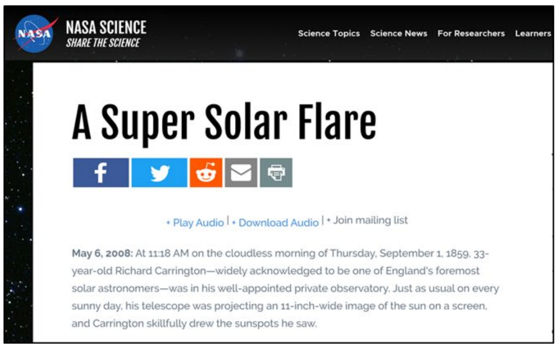
Humans have evolved with and adapted to our environments but now we also have the power (technology) to shape them…

Visual 16: Example (5 of 7)

…to a point. Nature can still exceed our ability to manage it and technology can fail – that is a disaster…

Visual 17: Example (6 of 7)

…and there are new threats emerging as our world changes – both naturally and technologically – and we have to keep up.



…a huge solar flare on August 4, 1972, knocked out long-distance telephone communication across Illinois. That event, in fact, caused AT&T to redesign its power system for transatlantic cables. A similar flare on March 13, 1989, provoked geomagnetic storms that disrupted electric power transmission from the Hydro Québec generating station in Canada, blacking out most of the province and plunging 6 million people into darkness for 9 hours; aurora-induced power surges even melted power transformers in New Jersey. In December 2005, X-rays from another solar storm disrupted satellite-to-ground communications and Global Positioning System (GPS) navigation signals for about 10 minutes.

Key Points

"...a huge solar flare on August 4, 1972, knocked out long-distance telephone communication across Illinois. That event, in fact, caused AT&T to redesign its power system for transatlantic cables. A similar flare on March 13, 1989, provoked geomagnetic storms that disrupted electric power transmission from the Hydro Québec generating station in Canada, blacking out most of the province and plunging 6 million people into darkness for 9 hours; aurora-induced power surges even melted power transformers in New Jersey. In December 2005, X-rays from another solar storm disrupted satellite-to-ground communications and Global Positioning System (GPS) navigation signals for about 10 minutes. That may not sound like much, but as Lanzerotti noted, "I would not have wanted to be on a commercial airplane being guided in for a landing by GPS or on a ship being docked by GPS during that 10 minutes."

Source: NASA (https://science.nasa.gov/science-news/science-at-nasa/2008/06may_carringtonflare/)

Visual 18: Example (7 of 7)

Modern Emergency Management professionals must understand the world around us - how it connects, interacts, and evolves – and how our society is impacted by this dynamism. This class was designed to help you get started…

Visual 19: So What Now?

An Emergency Manager is not expected to be an expert in everything but…

- You should be familiar with existing and emerging issues in our field.
- This requires investing time and effort in ongoing, life-long learning.
- You should also always be expanding your network of Subject Matter Experts (SMEs).

Our breadth of knowledge and our extensive network are an EM’s best assets!

Visual 20: Science Takes Time

- Remember that as you learn and make connections, you need to ensure that your information is scientifically **Credible and Valid**.
- It is also important to remember that the scientific method takes time - time to make the hypothesis, time to test it, time to peer review the test, and time to have others validate it. This is not a failure of science but a logical and methodical system to ensure that good science prevails.
- This increases your value as a professional and ensures that you are providing the best service to your community.

Key Points

The authorized biography by Frank Dyer and T. C. Martin, Edison: His Life and Inventions (the first edition of the book is 1910), quotes Edison's friend and associate Walter S. Mallory about these experiments:

> "This [the research on light bulbs] had been going on more than five months, seven days a week, when I was called down to the laboratory to see him [Edison]. I found him at a bench about three feet wide and twelve feet long, on which there were hundreds of little test cells that had been made up by his corps of chemists and experimenters. I then learned that he had thus made over nine thousand experiments in trying to devise this new type of storage battery but had not produced a single thing that promised to solve the question. In view of this immense amount of thought and labor, my sympathy got the better of my judgment, and I said: 'Isn't it a shame that with the tremendous amount of work you have done you haven't been able to get any results?' Edison turned on me like a flash, and with a smile replied: **'Results! Why, man, I have gotten lots of results! I know several thousand things that won't work!'**"

Visual 21: Activity 15.2 – Course Wrap-Up

Instructions:

1. Answer the following questions:
    a. How you can apply on the job what you learned in this training?
    b. How will you continue learning about the science of disaster?

Remember: You will need to bring your IAW books for the next course!

Key Points

Instructions:

1. Answer the following questions:
    - How you can apply on the job what you learned in this training?
    - How you will continue learning about the science of disaster? Remember: You will need to bring your IAW books for the next course!

Visual 22: Unit 15 Summary

You should now be able to:

- Recognize emerging science and technology hazards and risks affecting our communities.
- Identify sources of information and subject matter experts, and incorporate them in our planning efforts.
- Identify ways that course concepts can be applied on the job.
- Indicate avenues to continue learning about the science of disaster.

Key Points

Do you have any questions about the material covered in this unit?

Unit 16: Course Summary

Visual 1: Unit 16: Course Summary

Unit 16: Course Summary

Key Points

This module provides an opportunity to review key concepts covered in the training and to consider their practical applications.

Time Plan

A suggested time plan for this module is shown below.

Topic	Time
Course Summary	5 minutes
Post-Test	25 minutes
Feedback and Graduation	10 minutes
Total Time	**40 minutes**

Visual 2: Module Objectives

At the end of this module, you will be able to:

- Complete the IAW Wrap-Up activity.
- Complete the Post-Test with a passing score.

Key Points

Review the module objectives as shown on the visual.

At the end of this nodule, you will be able to:

- Complete the Course Wrap-Up activity.
- Complete the Post-Test with a passing score.

Visual 3: Topics Covered in This Course (1 of 2)

- **Unit 1**: Introduction to Class
- **Unit 2**: Relationship Between Science and our Understanding of Disasters
- **Unit 3**: Severe Storms, Tornadoes, and Hurricanes
- **Unit 4**: Other Hazardous Weather
- **Unit 5**: Floods
- **Unit 6**: Earthquakes and Tsunamis
- **Unit 7**: Landslides and Sinkholes
- **Unit 8**: Volcanoes

Visual 4: Topics Covered in This Course (2 of 2)

- **Unit 9**: Science of Human Induced Disasters
- **Unit 10**: Biological Basics
- **Unit 11**: Chemistry Fundamentals
- **Unit 12**: Chemistry Hazards
- **Unit 13**: Explosive Hazards
- **Unit 14**: Radiation Hazards
- **Unit 15**: Emerging Issues in Science and Technology Affecting Emergency Management
- **Unit 16**: Course Summary

Key Points

This course introduced you to scientific concepts and principles in several key areas related to natural and human-caused disasters.

The course focused on common and emerging threats that provide a basis for understanding the science of disaster.

The course was organized as follows:

- **Unit 1**: Introduction to Class
- **Unit 2**: Relationship Between Science and our Understanding of Disasters
- **Unit 3**: Severe Storms, Tornadoes, and Hurricanes
- **Unit 4**: Other Hazardous Weather
- **Unit 5**: Floods
- **Unit 6**: Earthquakes and Tsunamis
- **Unit 7**: Landslides and Sinkholes
- **Unit 8**: Volcanoes
- **Unit 9**: Science of Human Induced Disasters
- **Unit 10**: Biological Basics
- Unit **11**: Chemistry Fundamentals
- **Unit 12**: Chemistry Hazards
- **Unit 13**: Explosive Hazards
- **Unit 14**: Radiation Hazards
- **Unit 15**: Emerging Issues in Science and Technology Affecting Emergency Management
- **Unit 16**: Course Summary

Visual 5: Post-Test Information

Instructions: Working individually …

1. Write your name on the question packet and answer sheet.
2. Tear the Post-Test Answer Sheet off the test packet and use it to record your answers.
3. Once you have completed the test, turn it in to the instructors
4. You have 25 minutes to complete the Post-Test

Passing Grade = 75%

Key Points

Instructions:

1. Write your name on the question packet and answer sheet.
2. Tear the Post-Test Answer Sheet off the test packet and use it to record your answers.
3. Once you have completed the test, turn it in to the instructors.
4. You have 45 minutes to complete the Post-Test.

You must have a score of 75% on the Post-Test to pass.

Visual 6: Feedback

- Any other comments or questions?
- Please complete the course evaluation form.
- Your comments are important!
- Thank you for your participation.

Key Points

Congratulations! You have completed the course Science of Disaster. Thank you for your participation and for your contributions to the discussions.

We value your input. Please provide your feedback on the course evaluation form.