

Could a Tsunami Occur in New York City?

How to Predict and Prepare for These Natural Disasters

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Unit Lesson Objectives:

- Understand what tsunamis are and what causes them
- Understand the warning signs and how tsunamis could be predicted
- Relate this understanding to New York City; understand how to prepare

Target Audience: Regents Earth Science, Grades 8 & 9 - 12

Time: Six class periods

Standards:

National Science Education Standards (Earth and Space Science)

Grades 5-8

- The solid earth is layered with a lithosphere; hot, convecting mantle; and dense, metallic core.
- Lithospheric plates on the scales of continents and oceans constantly move at rates of centimeters per year in response to movements in the mantle. Major geological events, such as earthquakes, volcanic eruptions, and mountain building, result from these plate motions.

Grades 9-12

- The outward transfer of earth's internal heat drives convection circulation in the mantle that propels the plates comprising earth's surface across the face of the globe.
- Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.

New York State (Physical Setting/Earth Science Content Standards)

- 2.1j - Properties of Earth's internal structure (crust, mantle, outer core, inner core) can be inferred from the analysis of the behavior of seismic waves (including velocity and refraction.) Analysis of seismic waves allows the determination of the location of earthquake epicenters and the measurement of earthquake intensity. This analysis leads to the inference that Earth's interior is composed of layers that differ in composition and states of matter.
- 2.1k - The outward transfer of Earth's internal heat drives convective circulation in the mantle that moves the lithospheric plates comprising Earth's surface.
- 2.1l - The lithosphere consists of separate plates that ride on the more fluid asthenosphere and move slowly in relationship to one another, creating convergent, divergent, and transform plate boundaries. These motions indicate Earth is a dynamic geologic system. These plate boundaries are the sites of most earthquakes, volcanoes, and young mountain ranges. Compared to continental crust, ocean crust is thinner and denser. New ocean crust continues to form at mid-ocean ridges. Earthquakes and volcanoes present geologic hazards to humans. Loss of property, personal injury, and loss of life can be reduced by effective emergency procedures.

- 2.1m - Many processes of the rock cycle are consequences of plate dynamics. These include: production of magma (and subsequent igneous rock formation and contact metamorphism) at both subduction and rifting regions; regional metamorphism within subduction zones; and the creation of major depositional basins through down-warping of the crust.
- 2.1n - Many of Earth's surface features are the consequence of forces associated with plate motion and interaction. These include: mid-ocean ridges/rifts; subduction zones trenches/island arcs; mountain ranges (folded, faulted, and volcanic); hot spots; and the magnetic and age patterns in surface bedrock.
- 2.1o - Plate motions have resulted in global changes in geography, climate, and the patterns of organic evolution.

New York State (Physical Setting/Earth Science Process Skills Standards)

- *Standard 1: Analysis, Inquiry, and Design.* Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.
- *Standard 2: Information Systems.* Students will access, generate, process, and transfer information using appropriate technologies.
- *Standard 6: Interconnectedness.* Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design; The grouping of magnitudes of size, time, frequency, and pressures or other units of measurement into a series of relative order provides a useful way to deal with the immense range and the changes in scale that affect the behavior and design of systems.

Benchmarks for Scientific Literacy (Chapter 4: The Physical Setting)

Grades 6-8

- The interior of the earth is hot. Heat flow and movement of material within the earth cause earthquakes and volcanic eruptions and create mountains and ocean basins. Gas and dust from large volcanoes can change the atmosphere.
- Some changes in the earth's surface are abrupt (such as earthquakes and volcanic eruptions) while other changes happen very slowly (such as uplift and wearing down of mountains). The earth's surface is shaped in part by the motion of water and wind over very long times, which act to level mountain ranges.

Grades 9-12

- The solid crust of the earth—including both the continents and the ocean basins—consists of separate plates that ride on a denser, hot, gradually deformable layer of the earth. The crust sections move very slowly, pressing against one another in some places, pulling apart in other places. Ocean-floor plates may slide under continental plates, sinking deep into the earth. The surface layers of these plates may fold, forming mountain ranges.
- Earthquakes often occur along the boundaries between colliding plates, and molten rock from below creates pressure that is released by volcanic eruptions, helping to build up mountains. Under the ocean basins, molten rock may well up between separating plates to create new ocean floor. Volcanic activity along the ocean floor may form undersea mountains, which can thrust above the ocean's surface to become islands.

Part I: What are Tsunamis?

A tsunami is a series of ocean waves, which can be generated by sudden displacements in the sea floor (a certain type of earthquake), landslides, or volcanic activity. The tsunami wave may come gently ashore or may increase in height to become a fast moving wall of turbulent water several meters high, as experienced in Asia in December 2004.

In this part of the unit, students will review what they have learned about natural hazards, and learn how a tsunami could occur.

Time Frame: Two class periods

Materials/Setting Needed:

- Television with video capability
- Video, "The Wave that Shook the World"
- Available computers with internet access

For each group of students, the materials needed include:

- Clear plastic box
- Rubber Mallet

Pre-Assessment:

In order to pre-assess the students' knowledge of natural disasters, have them watch the video entitled "Natural Disasters" on

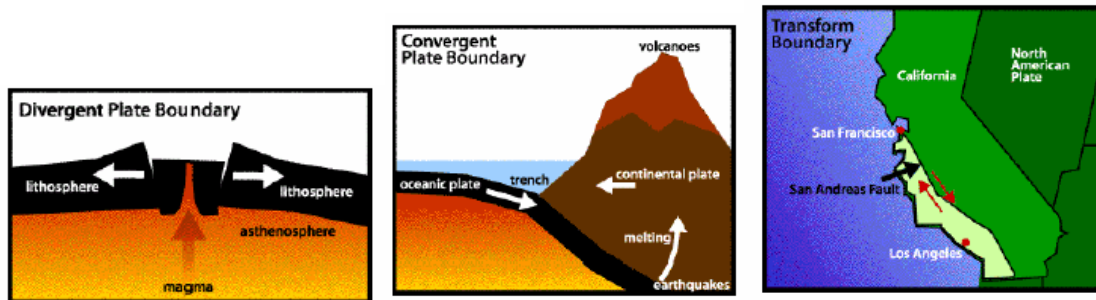
<http://www.brainpop.com/science/naturalhazards/naturaldisasters/>. At the end of the video, have each student take the quiz to test their knowledge and discuss the answers together as a group. Tell the students that they will know learn about one specific type of natural disaster, the tsunami.

Note to Teacher: The "Natural Disasters" video is free. However, there is also one specifically on tsunamis that is available for purchase (once you become a member of www.brainpop.com).

What Will Happen/Instructional Sequence:

1. After discussing the answers to the quiz, review with your students what they have learned about earthquakes and plate boundaries in previous classes. Discuss the location of plate boundaries and fault lines. Point out to the students that tsunamis can be caused by a certain type of earthquake, as seen in the video.

Plate Boundary Summary: There are three types of plate boundaries: 1) Divergent, 2) Convergent, and 3) Transform boundaries. (These images are courtesy of <http://www.cotf.edu/ete/modules/mseese/earthsysflr/plates4.html>.)



Note to Teacher: For more information, please review "Earthquakes and Mid-Ocean Ridge Spreading" Workshop with Dr. Maya Tolstoy on March 12, 2005 (www.earth2class.org).

2. Tell students they are going to do a demonstration to show how earthquakes affect sea waves. Students will work in teams of two or three. This will build off their prior knowledge of earthquakes.
3. Direct each team to fill a clear plastic box halfway with water and place the box on a sturdy tabletop.
4. Have a student from each team lightly strike the tabletop with a rubber mallet on the table's front edge. As student in each team strikes the tabletop, the other team members should observe the water and draw pictures of the waves they see in the box.
5. Instruct students to repeat the procedure two more times, lightly striking the table on its top, then on one of the side edges of the tabletop. Students should take turn using the rubber mallet. Each time the tabletop is struck, students should observe the waves in the box and draw what they see, labeling their drawings "front," "top," and "side," according to where the table was struck with the mallet.
6. Tell students that the three directions in which earthquake waves vibrate determine how large the resulting sea waves will be. The front strike produces a P (primary) wave, the side strike produces an S (secondary) wave, and the top strike produces an L (surface) wave. Students will observe that the L wave is the biggest of the three (Weisel, 2005).
7. Working in groups, have the students complete the following discussion questions:
 - Describe the waves that were produced.
 - Which wave do you think would cause the most damages and set up tsunamis? Why?
 - Using the following website, research to find out how else could a tsunami occur.
8. During the next class period, review the previous activity and discussion questions with the students. Ask the students to name a time when a tsunami occurred because of an earthquake.

9. This discussion will provide the lead-in for the viewing of "The Wave that Shook the World" (NOVA, 2005). This NOVA video investigates that powerful and catastrophic tsunami that occurred on December 26, 2004 in the communities around the Indian Ocean. It presents an explanation and analysis of the tragedy, revealing exactly how the waves were triggered by one of the most powerful earthquakes recorded this century. It also discusses the possibility of an effective early warning system to avoid future catastrophes. The prediction of tsunamis will be discussed in the next class.

Note to Teacher: The video is approximately 56 minutes long, so you may need to adjust according to your class length. Additionally, the DVD is \$19.95 and can be ordered from the following website: <http://www.pbs.org/wgbh/nova/tsunami/shop.html>.

10. After the video, circulate a homework sheet with the following questions for review:

- Define epicenter. Where was it located in the Tsunami of 2004?
- Based on the video, how do you think more lives could have been saved?
- If you were making a movie about tsunamis, how would you show the effects? Would you build a model, draw a picture, or use some other method?
- If a tsunami is imminent, what can people do to be safe when it approaches?
- Research the main differences between tsunamis and wind-driven waves. Include statistics on the average heights of these waves, the average wavelengths, and the average periods of the waves (the time required for successive wave crests to pass a fixed point). The following graphic and website may assist you:

<http://www.ess.washington.edu/tsunami/images/tsunami.pdf>



Optional - The following tsunami simulation can be used to accompany the lesson plan:
http://esminfo.prenhall.com/science/geoanimations/animations/86_Tsunami.html

Part II: How Can We Predict a Tsunami?

Although a tsunami cannot be prevented, the impact of a tsunami can be mitigated through community preparedness, timely warnings, and effective response. What are some of the warning signs? Why is important to know the warning signs?

Note to Teacher: Please review Arthur Lerner-Lam's Earth2Class workshop, entitled "How predictable are natural disasters?" This workshop from January 15, 2000 can be viewed at http://www.earth2class.org/k12/w1_s2000/ws1.htm. It looks at whether or not natural disasters (earthquakes in particular) are predictable. How can appropriate information and warning reach the general public? The workshop provides the chance to find out more about such problems, and develop some ideas about how to present these topics to your students.

Time Frame: Two to three class periods

Materials/Setting Needed:

- Television with video capability
- News segment of the interview with the British middle school student
- Five index cards with the name of a well-known tsunami on each card
- Computers with internet access
- Research materials (encyclopedias, textbooks, etc.)
- Markers or colored pencils
- Poster board or other material for mapping the paths of the tsunamis
- Video, "Can Animals Predict Disaster?" OR copies of the article, "Did Animals Sense Tsunami was Coming?" (one per student)

Note to Teacher: Depending upon time constraints, use either the video or article about animal behavior and the prediction of natural disasters. The DVD is \$19.95, available for purchase at <http://www.pbs.org/wnet/nature/shop/animalspredict.html>. This can tie in nicely with a co-occurring biology lesson plan on animal behavior.

Pre-Assessment:

After students have turned in their homework questions, quickly review the answers and lead into the today's topic, how to predict tsunamis.

What Will Happen/Instructional Sequence:

1. Begin the class by showing the class a brief news segment that interviewed the 10-year-old British girl saved 100 people in Phuket, Thailand. She did this by recognizing the signs of the approaching tsunami that occurred in December of 2004. According to Reuters, an international news agency, the girl had just learned about the science of tsunamis in school. She and her mother quickly warned hotel staff, who evacuated the beach minutes before the devastating tsunami hit. The beach was one of the few on the island where no one was killed.
2. State to the students that they, too, can be like this girl, who is now recognized as a hero. This lesson plan will be reviewing how to predict tsunamis by recognizing the warning signs and plotting where they have occurred in the past.

3. Based on what they have already learned, have the students create a "wordsplash" of what they think could be warning signs. Write the words or phrases on the blackboard, and then discuss each one with the class.
4. Divide the class into groups of five and have the students research tsunamis, either confirming the already established warning signs, or discovering new ones. Instruct them to use the following website: <http://olc.spsd.sk.ca/DE/resources/tsunami.html>
5. While in their groups, pass out one of the five index cards to each group. These cards will have the name of one of the famous tsunamis of the past (the 1960 tsunami in Chile; the 1964 tsunami in Alaska; the 1992 tsunami in Nicaragua; the 1993 tsunami in Hokkaido, Japan; the 1998 tsunami in Papa New Guinea). Using all available resources, each group answers the following questions:
 - What were the geologic trigger events that caused the tsunami?
 - Where was the origin of the tsunami and what path did it take?
 - How did the tsunami behave in the water?
 - How did the tsunami behave after hitting the coastline?
 - What was the extent of the tsunami's damage?
 - Was there a tsunami warning system in place? How did it work?

(Note to Teacher: Group work will continue into the next class period.)

6. After completing their research, have each group prepares a visual representation of the path that their tsunami took. The visual representation could take the form of a poster, a series of maps, or a spherical (global) perspective.
7. After the group work, reconvene as a class. Have the students share their visual representation. Add any additional warning signs to the blackboard. Based on their representations, what similarities do they see? Are there any additional warning signs based on these previous tsunamis?
8. Depending upon the time constraints, either watch the video "Can Animals Predict Disaster?", which explores a variety of science-based explanations for unusual animal behavior prior to natural disasters, or read as a class "Did Animals Sense Tsunami was Coming?". Ask the class to reflect upon:
 - How do these materials connect with our already established warning signs?
 - Have you noticed any strange behaviors in your own pets due to weather?
 - Why do you think many seismologists discount these theories?

Interdisciplinary Connections:

- **Global History-** Write a research paper on how theories about the origins of tsunamis have evolved throughout history. Did certain cultures have specific superstitions about tsunamis? If so, how were these beliefs challenged?
- **Technology-** Imagine you are a scientist of the future. What technological devices do you imagine there will be to help forecast and understand tsunamis? Invent a device and explain what it does and how it is an improvement on current tsunami technology.

Part III: Could a Tsunami in New York City? Preparing for Natural Disasters

Although less likely, tsunamis could occur in the Atlantic Ocean and threaten the entire east coast. In this lesson, students will apply their prediction skills and determine whether or not a tsunami could occur in New York City. They will then prepare appropriately for the natural disaster by creating a family plan and disaster kit.

Time Frame: Two class periods

Materials/Setting Needed:

- Television with video capability
- Available computers with internet access
- Research materials (encyclopedias, textbooks, etc.)

What Will Happen/Instructional Sequence:

1. Working in groups of three, students will determine, based on the previous lessons and new research, whether or not a tsunami could occur in New York City. Students will answer the following questions:
 - Can a tsunami occur in NYC? Why or why not?
 - What volcano could be associated with an east coast tsunami?
 - Can it be predicted when this volcano will erupt? Explain.
 - If it did occur, what effect might this tsunami have?
 - What were your sources?
 - How can you determine if a source is credible?
2. After the groups have finished their work, reconvene as a class and discuss the issue of bioliteracy and credible sources. Discuss the importance of knowing the source of your information, particularly in disaster situations.
3. During the next class period, reflect back on the situation in New York City. Is a tsunami possible? Have the groups look up the New York City Office of Emergency Management website (<http://www.nyc.gov/html/oem/home.html>).
 - Are tsunamis listed as a New York City hazard?
 - Based on your research, should they be?
 - If you think YES, write a letter to Mayor Bloomberg and the Office of Emergency Management requesting that they update their website. In the letter, include reasons why tsunamis need to be included with references.
 - If you think NO, write a short paper stating your reasons for non-inclusion and why the website should remain as it is now.
4. Given the fact that a tsunami is possible in New York City, have students create disaster kits and family plans within their groups. Students could visit the website "Hurricane!" to see what should and should not be placed in a disaster kit. What other preparations, if any, can people take to protect themselves from a tsunami?
(Note to Teacher: Please review the lesson plan "Disaster Plan Preparation" by Bonnie Keller on the Earth2Class website,
<http://www.earth2class.org/er/teachers/lessonplans/Keller%20disaster%20planning.php>*).*
5. Complete the unit on tsunamis by having each student create an actual kit for their own family, and have them bring it to the next class.

Additional Resources:

What are Tsunamis?

- Welcome to Tsunami! <http://www.ess.washington.edu/tsunami/index.html>.
- Tsunami from the National Oceanic and Atmospheric Association (NOAA). <http://www.tsunami.noaa.gov/>.
- *Tsunami: The great waves*. Presented by Unesco Intergovernmental Oceanographic Commission (IOC), International Tsunami Information Centre (ITIC), Laboratoire de Geophysique, France (LDG), U.S. National Oceanic & Atmospheric Administration (NOAA).

Where Can Tsunamis Occur?

- Tsunamis: Can they happen here? *Smithsonian Magazine*, http://www.smithsonianmag.si.edu/smithsonian/issues05/mar05/tsunami_transcript.html.

Preparing for a Tsunami:

- *Surviving a Tsunami—Lessons from Chile, Hawaii, and Japan*. Compiled by Brian F. Atwater, Marco Cisternas V., Joanne Bourgeois, Walter C. Dudley, James W. Hendley II, and Peter H. Stauffer, <http://pubs.usgs.gov/circ/c1187/>.

Tsunami Aftermath:

- Cochrane, J. (2005). Living With Fear. *Newsweek, International Edition*, <http://q.msn.com/OMN2ET7/2?http://www.msnbc.msn.com/id/10507305/site/newsweek/from/ET/&&CM=EmailThis&CE=1>.

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http://www.nytimes.com/learning/teachers/lessons/20020423tuesday.html?searchpv=learning_lessons.

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