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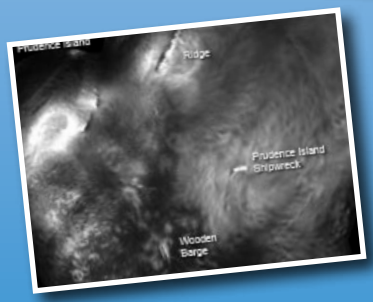
Thunder Bay 2010:
Cutting-Edge Technology and the Hunt for Lake Huron's Lost Ships

The Big Blow



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lesson plan

Focus
Extreme storms in the Great Lakes

Grade Level
9-12 (Anthropology/Earth Science)

Focus Question
What causes extreme storms such as the Great Lakes Storm of 1913?

Learning Objectives
- Students will identify and explain factors that contribute to extreme storm conditions in the Great Lakes region.
- Students will describe the weather systems that produced the Great Lakes Storm of 1913, and explain why extreme storms in the Great Lakes region often occur in November.
- Students will compare and contrast extra-tropical cyclones, tropical cyclones, and hybrid storms.

Materials
- ❑ Overhead transparency or digital image of the eastern Great Lakes region
- ❑ Audio recording of "The Wreck of the *Edmund Fitzgerald*" by Gordon Lightfoot, or copy of the song's lyrics
- ❑ Copies of the *Great Lakes Storm of 1913 Inquiry Guide*, one copy for each student or student group

Audio-Visual Materials
- ❑ Overhead or digital image projector

Teaching Time
One 45-minute class period, plus time for student research

Seating Arrangement
Classroom style or groups of 2-4 students

Maximum Number of Students
32

Key Words
Lake Huron
Great Lakes Storm of 1913

Perfect storm
Nor'easter
Oceanographic data buoy
Trough
Extra-tropical cyclone
Tropical cyclone
Hybrid storm

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

"That good ship and true was a bone to be chewed
When the gales of November came early"
Gordon Lightfoot, "The Wreck of the Edmund Fitzgerald"

While the sinking of the *Edmund Fitzgerald* may be the most famous Great Lakes shipping disaster, the gale that sent the *Fitzgerald* and her crew of 29 to the bottom of Lake Superior was not the worst storm in the Lakes' maritime history. That storm took place in November of 1913, killed more than 250 people, and sank 12 ships. Most of those sinkings occurred in Lake Huron, which is notorious for its dense fog banks, violent storms, and rocky shoreline—hazards that have brought disaster to many ships. A particularly dangerous area surrounding Thunder Bay is so hazardous to shipping that it has earned the nickname Shipwreck Alley.

This area also represents one of the nation's most historically-significant collections of shipwrecks. The Thunder Bay National Marine Sanctuary (TBNMS) was established in 2000 to protect this important cultural resource. The present boundaries of the TBNMS enclose 448 square miles that contain 40 known historic shipwrecks. Plans are well underway, however, to expand these boundaries to include 3,662 square miles (Figure 1). Archival records indicate that the expanded boundaries include more than 100 undiscovered shipwrecks which can provide unique opportunities for historians and archaeologists to study the maritime and cultural history of the Great Lakes region, as well as for recreational explorers. Finding the exact location of these shipwrecks is obviously essential to these kinds of uses, as well as to protecting these resources.

To help meet this need, the Thunder Bay 2010: Cutting-Edge Technology and the Hunt for Lake Huron's Lost Ships Expedition will use state-of-the-art technology that includes a sophisticated underwater robot carrying a one-of-a-kind precision sonar system to survey up to 200 square nautical miles in the proposed expansion area.

Images from Page 1 top to bottom:
Existing (yellow) and proposed (green) boundaries of the Thunder Bay National Marine Sanctuary. Locations of some known shipwrecks are indicated. Source: Thunder Bay National Marine Sanctuary

A crew in a support boat releases the line from the Naval Undersea Warfare Center (NUWC) REMUS 600 unmanned underwater vehicle equipped with the Integrated Precision Underwater Mapping (iPUMA) subsystem in Narragansett Bay during the Autonomous Vehicle Fest in May 2008.
http://www.militaryaerospace.com/index/display/article-display/337291/articles/military-aerospace-electronics/volume-19/issue-8/features/special-report/swimming-robots.html

This image was captured by iPUMA, a wide-swath forward-looking sonar used to identify possible targets. Here we see the two wrecks off Prudence Island, as well as features on the surrounding seafloor. To get a sense of scale, consider that the wooden barge is 120 feet long.
http://oceanexplorer.noaa.gov/explorations/08auvfest/logs/summary/media/ipuma_s2_3_sonar.html

Once a shipwreck has been located on a sonar image, archaeologists don SCUBA gear to "ground truth" the discovery. Dives deeper than about 40 m require the use of special breathing mixtures containing helium, oxygen, and nitrogen to reduce some of the safety hazards that accompany breathing ordinary air during deep dives. Source: Thunder Bay National Marine Sanctuary

Map 1. Great Lakes region, with Thunder Bay National Marine Sanctuary marked with a red dot.

US Army Corps of Engineers, Detroit District. From Wikipedia.

Figure 1. Existing (yellow) and proposed (green) boundaries of the Thunder Bay National Marine Sanctuary. Locations of some known shipwrecks are indicated. Source: Thunder Bay National Marine Sanctuary

Further investigation of shipwrecks located during the survey will be done by marine archaeologists using technical diving procedures. If particularly interesting wrecks are discovered, these "ground truthing" dives may be done during the Thunder Bay 2010 Expedition. Most of these investigations, however, will be done after the expedition's conclusion.

In this lesson, students will research the history of the Great Lakes Storm of 1913.

Learning Procedure

1. To prepare for this lesson:
   (a) Review introductory essays for the Thunder Bay 2010: Cutting-Edge Technology and the Hunt for Lake Huron's Lost Ships Expedition at http://oceanexplorer.noaa.gov/10thunderbay/welcome.html

   If students will be using classroom computers for their research, be sure these computers have the Djvu Browser Plug-In needed to view historic weather maps from the NOAA Central Library's U.S. Daily Weather Maps Project (http://docs.lib.noaa.gov/rescue/dwm/data_rescue_daily_weather_maps.html; you can download the plug-in using the link on the left side of this page).

2. Briefly introduce students to "Shipwreck Alley" and the Thunder Bay 2010: Cutting-Edge Technology and the Hunt for Lake Huron's Lost Ships Expedition. Play a recording of "The Wreck of the *Edmund Fitzgerald*," or show students a copy of the song's lyrics. Ask students to speculate about why the song seems to suggest that November is a particularly hazardous month in the Great Lakes. Briefly introduce the Great Lakes Storm of 1913, and provide each student or student group with a copy of the *Great Lakes Storm of 1913 Inquiry Guide*. Tell students that their assignment is to prepare a written report on the storm that includes answers to the questions on the *Inquiry Guide*.

3. Lead a discussion of students' results. Key points include:
   - Storms can usually be classified into one of two types: extratropical cyclones and tropical cyclones. Extra-tropical cyclones are "ordinary" storms formed by the intersection of warm and cold air masses, and can form over land and water in mid-latitudes at all times of the year. The temperature difference or gradient between the air masses is the major source of energy for these storms. Tropical cyclones include hurricanes and typhoons, and are formed mainly during summer and fall over warm tropical oceans. Warm humid air in these regions is loaded with water vapor that condenses as it rises into cooler air in the atmosphere. Condensation releases latent heat of vaporization, and this heat is the primary source of energy for tropical cyclones.

Occasionally, an extratropical cyclone will develop some of the characteristics of a tropical cyclone. This hybrid storm forms when thunderstorms begin to generate near the storm's center. When this happens, the central core of the storm is warmed as latent heat is released by water vapor condensing in the thunderstorms. Pressure in the core of the storm drops—sometimes very rapidly—and creates gale-force or hurricane force winds. The rapid drop in pressure is called "explosive deepening;" if the pressure steadily falls one millibar per hour for 24 hours or more, the storm is called a "bomb cyclone." At the same time, a tight temperature gradient is maintained on the northern side of the storm (in the northern hemisphere).

- Large storms tend to form over the North American continent during autumn because at this time of the year, cold, dry air moving south from northern Canada converges with warm, moist air moving north from the Gulf of Mexico.

- Particularly intense storms on the Great Lakes during November are the result of converging storm systems; one travelling southeastward from the province of Alberta, and the other travelling northeastward from the eastern side of the Rocky Mountains. When these systems move over the lakes, they are intensified by the jet stream above and energy from the warmer lake waters.

- On November 7 and 8, 1913, a low pressure area was moving from the west across Lakes Superior and Michigan.

- On November 8 and 10, 1913, a low pressure area moved in from the southern Appalachian region, headed northwestward toward the Great Lakes.

- Winds circulating in a counterclockwise direction would cause rapid changes in wind direction as the center of the low pressure area passed over a given location (such as Buffalo, NY).

- The black oval shaped lines on the weather maps are called isobars, and represent areas of equal barometric pressure. When isobars are close together, it signifies that barometric pressure changes sharply over a relatively small geographic area. Steep pressure drops are often associated with severe storm conditions.

- The convergence of the low pressure area from the south with northwesterly winds over Lakes Superior and Huron would be expected to result in wind speed increases severe enough to produce a "bomb cyclone."

- Rotating wind circulation near the center of low pressure areas could explain observations of winds blowing in directions opposite to the direction of the waves.

- At least 25 killer November storms have struck the Great Lakes since 1847.

The BRIDGE Connection

www.vims.edu/bridge/archive1200.html/; http://www.vims.edu/bridge/climate.html– Links to information and activities about shipwrecks and climate, weather and atmosphere, respectively

The "Me" Connection

Have students write a short essay describing how real-time or historical meteorological information might be personally useful.

Connections to Other Subjects

English/Language Arts

Assessment

Students' research reports and class discussions provide opportunities for assessment.

Extensions

Have students visit http://oceanexplorer.noaa.gov/10thunderbay/welcome.html to keep up with the latest discoveries from the Thunder Bay 2010: Cutting-Edge Technology and the Hunt for Lake Huron's Lost Ships Expedition.

Other Relevant Lesson Plans from NOAA's Office of Ocean Exploration and Research

The Robot Archaeologist
(17 pages, 518k) (from AUVfest 2008)
http://oceanexplorer.noaa.gov/explorations/08auvfest/background/edu/media/robot.pdf

Focus: Marine Archaeology/Marine Navigation (Earth Science/Mathematics)

In this activity, students will design an archaeological survey strategy for an autonomous underwater vehicle (AUV); calculate expected position of the AUV based on speed and direction of travel; and calculate course correction required to compensate for the set and drift of currents.

Where Am I?
(7 pages, 264 kb) (from the 2003 Steamship *Portland* Expedition)
http://oceanexplorer.noaa.gov/explorations/03portland/background/edu/media/portlandwhereami.pdf

Focus: Marine navigation and position-finding
In this activity students will be able to identify and explain at least seven different techniques that have been used for marine navigation and position finding, explain the purpose of a marine sextant, and use an astrolabe to solve practical trigonometric problems.

By Land or By Sea or Both?
(14 pages, 1.1 Mb) (from the Exploring the Submerged New World 2009 Expedition)
http://oceanexplorer.noaa.gov/explorations/09newworld/background/edu/media/landsea.pdf

Focus: Watercraft in Paleoamerican Migrations

In this activity, students will describe evidence that supports the idea that the initial settlement of North and South America involved watercraft, discuss types of watercraft that might have been involved in new world settlement, and explain at least three advantages and three disadvantages of coastal settlements compared to inland settlements.

The Ridge Exploring Robot
(27 pages, 1.6 mb) (from the INSPIRE: Chile Margin 2010 expedition)
http://oceanexplorer.noaa.gov/explorations/10chile/background/edu/media/robot.pdf

Focus: Autonomous Underwater Vehicles/Marine Navigation

Students will explain a three-phase strategy that uses an autonomous underwater vehicle (AUV) to locate, map, and photograph previously undiscovered hydrothermal vents, design a survey program to provide a photomosaic of a hypothetical hydrothermal vent field, and calculate the expected position of the AUV based on speed and direction of travel.

X-Storms
(5 pages, 384k) (from the 2003 Steamship *Portland* Expedition)
http://oceanexplorer.noaa.gov/explorations/03portland/background/edu/media/portlandstorm.pdf

Focus: Extreme storms (Earth Science)

In this activity, students identify and explain three factors that contributed to extreme storm conditions during the Halloween

Nor'easter of 1991, discover how to obtain real-time and historical meteorological data, and compare and contrast extra-tropical cyclones, tropical cyclones, and hybrid storms.

Now Take a Deep Breath
(14 pages, 548 Kb) (from the Exploring the Submerged New World 2009 Expedition)
http://oceanexplorer.noaa.gov/explorations/09newworld/background/edu/media/breath.pdf

Focus: Physics and physiology of SCUBA diving (Physical Science/Life Science)

In this activity, students will be able to define Henry's Law, Boyle's Law, and Dalton's Law of Partial Pressures, and explain their relevance to SCUBA diving; discuss the causes of air embolism, decompression sickness, nitrogen narcosis, and oxygen toxicity in SCUBA divers; and explain the advantages of gas mixtures such as Nitrox and Trimix and closed-circuit rebreather systems.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov/10thunderbay/welcome.html – Web site for the Thunder Bay 2010: Cutting-Edge Technology and the Hunt for Lake Huron's Lost Ships Expedition

http://thunderbay.noaa.gov/welcome.html – Web site for the Thunder Bay National Marine Sanctuary with links to Lesson Plans; includes grades K - 2 Boat Builder Activity, grades 3 - 5 Photomosaic Activity, grades 3 - 5 Mapping Activity, grades 6+ Mapping Activities, Steamships and Energy Conversions, and Make Your Own Putt-Putt Boat

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book - A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focusing on the exploration, understanding, and protection of Earth as a whole system

http://www.crh.noaa.gov/dtx/stm_1913.php – "Hell Hath No Fury Like a Great Lakes Fall Storm . . . Great Lakes White Hurricane November 1913" by William R. Deedler, Weather Historian

http://www.nhc.noaa.gov – National Hurricane Center Web site, with historical information on hurricanes

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science

- Motions and forces
- Interactions of energy and matter

Content Standard D: Earth and Space Science

- Energy in the Earth system

Content Standard E: Science and Technology

- Abilities of technological design

Content Standard F: Science in Personal and Social Perspectives

- Natural and human-induced hazards

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle Essential Principle 3.
The ocean is a major influence on weather and climate.

Fundamental Concept b. The ocean absorbs much of the solar radiation reaching Earth. The ocean loses heat by evaporation. This heat loss drives atmospheric circulation when, after it is released into the atmosphere as water vapor, it condenses and forms rain. Condensation of water evaporated from warm seas provides the energy for hurricanes and cyclones.

Fundamental Concept f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water.

Essential Principle 6.
The ocean and humans are inextricably interconnected.

Fundamental Concept a. The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.

Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

Fundamental Concept c. The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.

Fundamental Concept d. Much of the world's population lives in coastal areas.

Fundamental Concept f. Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).
Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.
The ocean is largely unexplored.
Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.
Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

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Student Handout
Great Lakes Storms of 1913 Inquiry Guide

1. What is a tropical cyclone, extratropical cyclone, and hybrid storm?

2. Why do large storms tend to form over the North American continent during autumn?

3. What causes particularly intense storms during November?
   Look at weather maps for November 7 - 10, 1913. You can find these at the NOAA Central Library's U.S. Daily Weather Maps Project (http://docs.lib.noaa.gov/rescue/dwm/data_rescue_daily_weather_maps.html). You may need to install the free Djvu Browser Plug-In linked on the left side of the page.

4. What weather system was affecting the western Great Lakes region on November 7 and 8?

5. What happened between November 8 and November 10?

6. On November 9, weather observers in Buffalo, NY reported rapidly changing wind directions. What do you see on the weather maps that would explain this?

7. What do the black oval shaped lines represent? What does it mean when these lines are close together?

8. In the late evening of November 9, a low pressure area from the south with winds rotating counterclockwise encountered northwesterly winds over Lakes Superior and Huron. What result would you expect from this encounter?

9. Some captains whose ships were on the Great Lakes during the storm reported that the wind was often blowing in directions opposite to the direction of the waves. What would account for these observations?

10. About how many "killer storms" have struck the Great Lakes since 1847?