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2005 Hidden Ocean Expedition

Where Have All the Glaciers Gone?

Focus
Arctic Climate Change

Grade Level
7-8 (Earth Science)

Focus Question
How is the climate of the Arctic region changing, and what impacts are expected from these changes?

Learning Objectives
Students will be able to describe how climate change is affecting sea ice, vegetation, and glaciers in the Arctic region.

Students will be able to explain how changes in the Arctic climate can produce global impacts, and will be able to provide three examples of such impacts.

Students will be able to explain how a given impact resulting from climate change may be considered "positive" as well as "negative", and will be able to provide at least one example of each.

Materials
❒ Copies of "Arctic Climate Change Worksheet," one copy for each student or student group

❒ (Optional) Copies of "ACIA Highlights" and "Climate Change, the Arctic and the United Kingdom: directions for future research;" see "Learning Procedure"

Audio/Visual Materials
❒ None

Teaching Time
One or two 45-minute class periods, plus time for student research

Seating Arrangement
Classroom style if students are working individually, or groups of two to four students

Maximum Number of Students
30

Key Words
Arctic Ocean
Canada Basin
Climate change
Greenhouse gas
Permafrost
Sea ice
Sea level

Background Information
The Arctic Ocean is the most inaccessible and least-studied of all the Earth's major oceans. Although it is the smallest of the world's four ocean basins, the Arctic Ocean has a total area of about 14 million square kilometers (5.4 million square miles); roughly 1.5 times the size of the United States. The deepest parts of the Arctic Ocean (5,441 m; 17,850 ft), known as the Canada Basin, are particularly isolated and unexplored because of year-round ice cover. To a large extent, the Canada Basin

is also geographically isolated by the largest continental shelf of any ocean basin (average depth about 50 meters) bordering Eurasia and North American. The Chukchi Sea provides a connection with the Pacific Ocean via the Bering Strait, but this connection is very narrow and shallow, so most water exchange is with the Atlantic Ocean via the Greenland Sea. This isolation makes it likely that unique species have evolved in the Canada Basin.

The 2002 Ocean Exploration expedition to the Arctic Ocean focussed specifically on the biology and oceanography of the Canada Basin. These explorations included three distinct biological communities:

- The Sea-Ice Realm includes plants and animals that live on, in, and just under the ice that floats on the ocean's surface;
- The Pelagic Realm includes organisms that live in the water column between the ocean surface and the bottom;
- The Benthic Realm is composed of organisms that live on the bottom, including sponges, bivalves, crustaceans, polychaete worms, sea anemones, bryozoans, tunicates, and ascidians.

These realms are linked in many ways, and food webs in each realm interact with those of the other realms.

Sea ice provides a complex habitat for many species that are called sympagic, which means "ice-associated." The ice is riddled with a network of tunnels called brine channels that range in size from microscopic (a few thousandths of a millimeter) to more than an inch in diameter. Diatoms and algae inhabit these channels and obtain energy from sunlight to produce biological material through photosynthesis (a process called "primary production"). Bacteria, viruses, and fungi also inhabit the channels, and together with diatoms and algae provide an energy source (food) for flatworms, crustaceans, and other animals. In the spring, melting ice releases organisms and nutrients that interact with the ocean water below the ice. Large masses of algae form at the ice-seawater interface and may form filaments several meters long. On average, more than 50% of the primary production in the Arctic Ocean comes from single-celled algae that live near the ice-seawater junction. This interface is critical to the polar marine ecosystem, providing an energy source (food) for many organisms, as well as protection from predators. Arctic cod use the interface area as nursery grounds, and in turn provide an important food source for many marine mammals and birds, as well as migration routes for polar bears. In the spring, the solid ice cover breaks into floes of pack ice that can transport organisms, nutrients, and pollutants over thousands of kilometers. Partial melting of sea ice during the summer months produces ponds on the ice surface called polynyas that contain their own communities of organisms. Because only 50% of this ice melts in the summer, ice flows can exist for many years and can reach a thickness of more than 2 m (6 ft).

When sea ice melts, more sunlight enters the sea, and algae grow rapidly since the sun shines for 24 hours a day during the summer. These algae provide energy for a variety of pelagic organisms, including floating crustaceans and jellyfishes called zooplankton, which are the energy source for larger pelagic animals including fishes, squids, seals, and whales. When pelagic organisms die, they settle to the ocean bottom, and become the energy source for inhabitants of the benthic realm. These animals, in turn, provide energy for bottom-feeding fishes, whales, and seals.

The 2005 Hidden Ocean expedition is focused on additional explorations of these realms. A key objective of this expedition is to help establish a marine life inventory and map the physical and chemical environment of the sea-ice, pelagic, and benthic ecosystems of the Canada Basin. These

explorations are increasingly urgent, because the Arctic environment is changing at a dramatic rate. A 2004 report from the Arctic Council states that temperature in the Arctic is increasing at nearly twice the rate of increase as the rest of the world. One visible result is rapid loss of glaciers and sea ice. Less visible are the impacts on living organisms that depend upon glaciers and sea ice for their habitat. Melting sea ice can also have direct effects on human communities. The Greenland Ice Sheet, for example, holds enough water to raise global sea levels by as much as 7 meters. Sea level increases at this magnitude would be sufficient to flood many coastal cities, including most of the city of London.

In this lesson, students will investigate some of the impacts that are expected to result from a warmer Arctic climate.

Learning Procedure

1. To become more familiar with the Hidden Ocean expedition, you may want to visit the expedition's Web page (http://oceanexplorer.noaa.gov/explorations/05arctic/welcome.html) for an overview of the expedition and background essays.

   This lesson is intended to introduce students to some basic information about Arctic climate change. The Arctic Climate Impact Assessment (ACIA) is an international project of the Arctic Council and the International Arctic Science Committee to evaluate and synthesize knowledge on climate variability, climate change, and increased ultraviolet radiation in the Arctic and the consequences of these changes. The full ACIA scientific report is expected to be released in July 2005. Some of the basic information contained in the report is summarized in two reports:
   - "ACIA Highlights"
   - "Climate Change, the Arctic and the United Kingdom: directions for future research"

   Both reports are available on the internet at www.amap.no/acia/highlights.pdf and http://www.scribd.com/doc/42980/Arctic respectively. To prepare for this lesson, review these materials and the "Arctic Climate Change Worksheet." Download and copy these documents if students will not be using the internet to complete their assignment.

2. Briefly review the geography of the Arctic Ocean, highlighting the location of the Canada Basin and the activities of the Hidden Ocean expedition. Do not discuss Arctic climate change at this point. Tell students that their assignment is to answer questions on the "Arctic Climate Change Worksheet. Provide copies of the reports cited above, or direct students to the appropriate Web sites.

3. Lead a brief discussion of students' responses to worksheet questions. The discussion should include the following points:
   - The extent of Arctic sea ice has decreased by 5% in the last 20 years (8% in the last 30 years). In some areas, sea ice thickness has decreased by 40%.
   - The Arctic climate is warming more rapidly than elsewhere on Earth. Reasons for this include:
     – Reduced surface reflectivity caused by snow- and ice-melt allows more solar energy to be absorbed by the Earth's surface;
     – More of the trapped enery goes directly to warming rather than to providing heat for evaporation;
     – Less heat is required to warm the atmosphere over the Arctic because the Arctic atmosphere is thinner than elsewhere;
     – With less sea ice, the heat absorbed by the ocean in summer is more easily transferred to the atmosphere in winter; and
     – Changes in atmospheric and oceanic circulation can cause heat to be retained in the Arctic region.
   - Ice in the Greenland Ice Sheet contains enough water to raise global sea levels by 7 meters.

- Sea ice is melting at an increasing rate over the Greenland Ice Sheet.
- Global average sea level has risen by about 8 cm during the past 20 years.
- The melting trend on the Greenland Ice Sheet was interrupted in 1992 when ash from the Mt. Pinatubo volcano reduced the amount of sunlight reaching the Earth's surface, resulting in a short-term global cooling event.
- Changes in snow, ice, and vegetation lower the reflectivity of Arctic land and ocean surfaces, causing more solar energy to be absorbed and thus accelerate global warming.
- Rising sea level and reduced sea ice allow stronger waves and storm surges to reach shore, increasing coastal erosion; particularly where melting permafrost has weakened the soil structure.
- The Arctic is believed to hold about one-fourth of the world's undiscovered petroleum resources.
- While warmer temperatures were the trend for most of the Arctic region between 1966 and 1995, a cooling trend took place in the northernmost portions of the Arctic during this period.
- At present, primary Arctic industries are fishing, timber production, mineral mining, and petroleum production. In addition, tourism and renewable energy are growing in importance.
- Ultraviolet radiation in the Arctic is increasing due to depletion of stratospheric ozone.
- Glaciers are shrinking throughout the Arctic region.
- Woody plants and scrub vegetation are becoming more widely distributed and are replacing tundra-type vegetation.
- Permafrost is thawing at an increasing rate, causing unstable ground conditions that damage roads, pipelines, and building foundations.
- Travel across ice is being restricted because thinning ice is less stable.
- Warmer climates could cause significant quantities of water, methane, and carbon dioxide to be released from the Arctic. The result of these releases would be rising sea level, and increasingly warm temperatures due to the "greenhouse effect" of methane and carbon dioxide.
- Because many activities in the Arctic are presently hampered by sea ice, reduction in the extent of sea ice could be a stimulus to commercial development.
- Increased economic development could have serious negative impacts on wilderness areas, environmental quality, and indigenous cultures.
- Major reductions in Arctic sea ice could make the Arctic Ocean the shortest sea route between North America and the Orient.

Students should recognize that whether an impact is "positive" or "negative" often depends upon an individual's perspective. If you like polar bears and seals, or belong to an indigenous Arctic culture, then many of the changes resulting from a warmer Arctic climate are devastating. On the other hand, if you are involved in international shipping or petroleum industries, then the same changes could be seen as providing new opportunities.

Students should also understand that while greenhouse gas emissions from human activities are not the sole cause of climate change, they play a significant role in these changes (the ACIA says these emissions "have now become the dominant factor"). Be sure students realize that atmospheric concentrations of greenhouse gases will remain elevated for centuries even if emissions were completely eliminated, but the rate and extent of warming can be reduced if future emissions are sufficiently lowered.

The BRIDGE Connection

www.vims.edu/bridge/ – Enter "greenhouse" in the "Search" box, then click "Search" to display entries on the BRIDGE Web site for global warming and the greenhouse effect.

The "Me" Connection

Have students write a brief essay describing the personal impacts of climate change in the Arctic.

Connections to Other Subjects

Biology, English/Language Arts, Geography

Evaluation

Student reports prepared in Learning Procedure Step 2 and group discussion in Step 3 provide opportunities for assessment.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov/explorations/05arctic/welcome.html to keep up to date with the latest 2005 Hidden Ocean Expedition discoveries.
2. Visit http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_lessonplans.html for more lesson plans and activities related to the 2002 Hidden Ocean expedition.
3. Log onto http://earthednet.org/Ocean_Materials/Mini_Studies/Greenhouse_gases/Greenhouse_gases.html for more information and activities related to the greenhouse effect.

Resources

http://oceanexplorer.noaa.gov/explorations/05arctic/welcome.html – Follow the 2005 Hidden Ocean Expedition daily as documentaries and discoveries are posted each day for your classroom use.

http://www.scribd.com/doc/42980/Arctic – Synopsis of a conference on "Climate Change, the Arctic and the United Kingdom: directions for future research;" 8 May 2002, University of East Anglia

http://www.amap.no/acia/ – Web page for the Arctic Climate Impact Assessment secretariat

http://www.uky.edu/KGS/education/index.htm – Great resources on geological time and major events in Earth's history

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

Content Standard C: Life Science

- Interdependence of organisms

Content Standard D: Earth and Space Science

- Energy in the Earth system

Content Standard E: Science and Technology

- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

For More Information

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http://oceanexplorer.noaa.gov

Student Handout
Arctic Climate Change Worksheet

1. What has happened to Arctic sea ice in the last 20 years?

2. How do climate trends in the Arctic compare with similar trends elsewhere on Earth?

3. How could water in the Greenland Ice Sheet affect global sea levels?

4. What is happening to sea ice in the Greenland Ice Sheet?

5. What has happened to global average sea level during the past 20 years?

6. What happened in 1992 that interrupted the pattern of change on the Greenland Ice Sheet?

7. How could changes in snow, ice, and vegetation in the Arctic affect global warming?

8. How could a warmer Arctic climate affect coastal erosion?

9. How significant are Arctic petroleum reserves?

10. Are climactic trends the same for the entire Arctic region?

11. At present, what are the major industries in the Arctic?

12. What is happening to ultraviolet radiation levels in the Arctic region?

13. What is happening to glaciers in the Arctic region?

14. How are vegetation patterns changing in the Arctic region?

15. How are changes in permafrost affecting human activities?

16. What changes are taking place in travel across Arctic ice?

17. Warmer climates could cause significant releases of what substances from the Arctic. What might be some of the consequences of these releases?

18. What positive and negative impacts might result from a reduction in Arctic sea ice?

19. What changes in sea transportation might result from major reductions in Arctic sea ice?