The NOAA Ship *Okeanos Explorer*

NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site: *http://oceanexplorer.noaa.gov/okeanos/welcome.html*

Where Have All the Glaciers Gone?

(adapted from the 2005 Hidden Ocean Expedition)

An essential component of the NOAA Office of Ocean Exploration and Research mission is to enhance understanding of science, technology, engineering, and mathematics used in exploring the ocean, and build interest in careers that support ocean-related work. To help fulfill this mission, the Okeanos Explorer *Education Materials Collection is being developed to encourage educators and students to become personally involved with the voyages and discoveries of the* Okeanos Explorer*—America's first Federal ship dedicated to Ocean Exploration. Leader's Guides for Classroom Explorers focus on three themes: "Why Do We Explore?" (reasons for ocean exploration), "How Do We Explore?" (exploration methods), and "What Do We Expect to Find?" (recent discoveries that give us clues about what we may find in Earth's largely unknown ocean). Each Leader's Guide provides background information, links to resources, and an overview of recommended lesson plans on the Ocean Explorer Web site (*http://oceanexplorer.noaa.gov*). An Initial Inquiry Lesson for each of the three themes leads student inquiries that provide an overview of key topics. A series of lessons for each theme guides student investigations that explore these topics in greater depth. In the future additional guides will be added to the Education Materials Collection to support the involvement of citizen scientists.*

This lesson guides student inquiry into the key topic of Climate Change within the "Why Do We Explore?" theme. Optionally, this lesson may be extended to include an inquiry into the concept of proxies using conductivity and salinity as an example.

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 Inquiry Guide*, one copy for each student or student group
- (Optional) Copies of *Arctic Climate Impact Assessment (ACIA) Highlights* and *Climate Change, the Arctic and the United Kingdom: Directions for Future Research*; see Learning Procedure, Step 1
- (Optional) Materials for constructing photocubes; the following quantities are for one photocube; kits of these materials are available from http://www.chicaandjo.com/ourstore/
  – 8 - 1.5" wooden cubes
  – 8 - 3" x 3" photos printed on thin photo-quality paper such as HP Bright White Inkjet Paper
  – 2 - 3" x 6" photos, printed on paper described above
  – 2 - 8" x 11" sheets of double-sided tape ("red liner tape")
  – Black felt tip marker
  – Scissors or paper trimmer
  – Sandpaper, 150 grit or finer

Audiovisual Materials

- None

Teaching Time

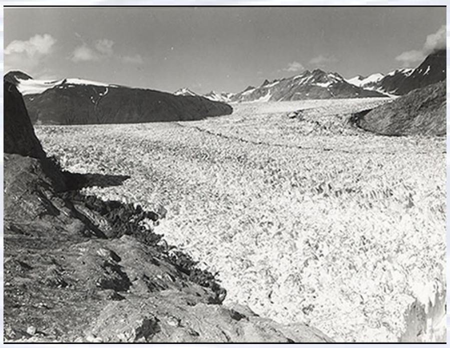
One or two 45-minute class periods, plus time for student research

Seating Arrangement

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

Maximum Number of Students

No limit, if students work individually



The black and white photograph of Muir Glacier was taken on August 13, 1941; the color photograph was taken from the same vantage on August 31, 2004. Between 1941 and 2004 the glacier retreated more than twelve kilometers (seven miles) and thinned by more than 800 meters (875 yards). Ocean water has filled the valley, replacing the ice of Muir Glacier; the end of the glacier has retreated out of the field of view. The glacier's absence reveals scars where glacier ice once scraped high up against the hillside. In 2004, trees and shrubs grew thickly in the foreground, where in 1941 there was only bare rock. Image credit: National Snow and Ice Data Center, W. O. Field, B. F. Molnia.
http://nsidc.org/data/glacier_photo/repeat_photography.html

Key Words and Concepts

Arctic Ocean
Canada Basin
Climate change
Greenhouse gas
Permafrost
Sea ice
Sea level
Sympagic
Polynya

Background Information

Within the world scientific community there is broad consensus that:

- Earth's climate is undergoing a significant warming trend that is beyond the range of natural variability;
- The major cause of most of the observed warming is rising levels of carbon dioxide;
- The rise in carbon dioxide levels is the result of burning fossil fuels;
- If carbon dioxide levels in the atmosphere continue to rise over the next century the warming will continue; and
- The climate change that is expected to result from these conditions represents potential danger to human welfare and the environment.

The consensus on these points is supported by a huge amount of data from many places on Earth. A brief summary of some of the key data is provided in Appendix A; for more details, see references listed under "Other Resources."

Since the late 1800's, average global surface temperatures have increased by about 0.74°C. The word "average" is very important, because some parts of Earth (including the southeastern United States and parts of the North Atlantic) have cooled slightly during this period. The greatest warming has been observed in Eurasia and North America between latitude 40° and 70° N.

Some confusion about the warming trend has recently been generated by assertions that Earth's temperature has been dropping for the last ten years. These statements are based on the fact that 1998 was abnormally hot due to the strongest El Nino event in the last century. The years following 1998 were indeed cooler than 1998, but the long-term trend still shows continued warming. There are many factors that affect global temperatures in a single year, and it is not surprising that one year might be cooler than the preceding year. But the global warming trend is a matter of decades, not just one or two years. The long-term trend is still clear: Seven of the eight warmest years on record have occurred since 2001, and the ten warmest years on record have all occurred since 1995.

These changes are particularly dramatic in the Arctic, where temperature is increasing at nearly twice the rate of increase occurring in the rest of the world. The Arctic Ocean is the most inaccessible and least-studied of all the Earth's major oceans. Its deepest parts (5,441 m; 17,850 ft), known as the Canada Basin, are particularly isolated and unexplored because until recently they were covered by ice for the entire year. 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 America. 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 focused specifically on the biology and oceanography of the Canada Basin. Three distinct biological communities were explored:

- The Sea-Ice Realm, which includes plants and animals that live on, in, and just under the ice that floats on the ocean's surface;
- The Pelagic Realm, which includes organisms that live in the water column between the ocean surface and the bottom; and
- The Benthic Realm, which 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.

The ice-seawater 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. The ice also provides 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 floes 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 focused on additional explorations of these realms. A key objective was 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. This kind of exploration is increasingly urgent, because the Arctic environment is changing at a dramatic rate. 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.

This lesson guides a student inquiry into some of the impacts that are expected to result from a warmer Arctic climate.

Learning Procedure

1. To prepare for this lesson:
   - If you have not previously done so, review introductory information on the NOAA Ship *Okeanos Explorer* at http://oceanexplorer.noaa.gov/okeanos/welcome.html. You may also want to consider having students complete some or all of the Initial Inquiry Lesson, *To Boldly Go…* (http://oceanexplorer.noaa.gov/okeanos/edu/leadersguide/media/09toboldlygo.pdf).
   - To become more familiar with the 2005 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.
   - Review *ACIA Highlights* and *Climate Change, the Arctic and the United Kingdom: Directions for Future Research* (http://amap.no/acia/Highlights.pdf and http://www.scribd.com/doc/42980/Arctic, respectively). You may want to download and copy these documents if students will not be using the internet to complete their assignment.
   - Review questions on the *Arctic Climate Change Inquiry Guide*.
   - Decide whether you want to have student groups make photocubes to show changes in glaciers. These objects can be used very effectively as visual aids for student presentations about climate change to other audiences (other groups of students, parents, etc.); see Learning Procedure, Step 4 and *Photocube Construction Guide*.

2. If you have not previously done so, briefly introduce the NOAA Ship *Okeanos Explorer*, emphasizing that this is the first Federal vessel specifically dedicated to exploring Earth's largely unknown ocean. Lead a discussion of reasons that ocean exploration is important, which should include further understanding of climate change. Show students a graph of global surface temperature trends (e.g., http://www.pewclimate.org/docUploads/images/global-surface-temp-trends.gif), and ask them if they can recognize any trend in the data. Data are variable prior to about 1910, but thereafter there is a distinct trend of increasing temperature. Ask students whether the drop in surface temperature between 1935 and 1945 cancels out the overall trend. Students should

realize that year-to-year fluctuations do not negate trends over longer periods of time.

Briefly review the geography of the Arctic Ocean, highlighting the location of the Canada Basin and the activities of the 2005 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 Inquiry Guide*. 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:
   a. 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%.
   b. 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 energy 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.
   c. Ice in the Greenland Ice Sheet contains enough water to raise global sea levels by 7 meters.
   d. Sea ice is melting at an increasing rate over the Greenland Ice Sheet.
   e. Global average sea level has risen by about 8 cm during the past 20 years.
   f. 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.
   g. 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.
   h. 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.

i. The Arctic is believed to hold about one-fourth of the world's undiscovered petroleum resources.

j. 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.

k. At present, primary Arctic industries are fishing, timber production, mineral mining, and petroleum production. In addition, tourism and renewable energy are growing in importance.

l. Ultraviolet radiation in the Arctic is increasing due to depletion of stratospheric ozone.

m. Glaciers are shrinking throughout the Arctic region.

n. Woody plants and scrub vegetation are becoming more widely distributed and are replacing tundra-type vegetation.

o. Permafrost is thawing at an increasing rate, causing unstable ground conditions that damage roads, pipelines, and building foundations.

p. Travel across ice is being restricted because thinning ice is less stable.

q. 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.

r. 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.

s. Major reductions in Arctic sea ice could make the Arctic Ocean the shortest sea route between North America and Asia.

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.

4. (optional) Tell students that communication is an essential element of the scientific process. Visual aids, particularly if they are three-dimensional, can greatly enhance the interest of an audience and make presentations much more memorable. Provide each student or student group with a copy of the *Photocube Construction Guide*, and materials listed in the *Guide*. You may also want to suggest the following Web site which contains images of glaciers that show changes caused by a warmer climate: http://nsidc.org/cgi-bin/glacier_photos/glacier_photo_search.pl?collection=repeat. This link opens the Search page for the National Snow and Ice Data Center's collection of repeat glacier photography. Click the "Search" button and a new page will open showing thumbnails of the photographs.

The 2006 Tracking Narwhals in Greenland Expedition used satellite-linked time-depth-temperature recorders to track whale movements, diving behavior, and ocean temperature structure during the fall narwhal migration from north Greenland to Baffin Bay. This information is needed to help understand how Arctic climate change may affect the deep-ocean thermohaline circulation, sometimes known as the "global conveyor belt." Image credit: Mads Peter Heide-Jorgensen.
http://oceanexplorer.noaa.gov/explorations/06arctic/background/hires/male_narwhals_hires.jpg

The BRIDGE Connection

www.vims.edu/bridge/ – Scroll over "Ocean Science Topics," then click "Atmosphere" for links to resources atmosphere and climate change.

The "Me" Connection

Have students write a brief essay describing how they might be personally affected by climate change in the Arctic.

Connections to Other Subjects

Biology, English/Language Arts, Geography

Assessment

Students' responses to Inquiry Guide questions and class discussions provide opportunities for evaluation.

Extensions

1. Follow events aboard the *Okeanos Explorer* at http://oceanexplorer.noaa.gov/okeanos/welcome.html.

2. Visit http://earthednet.org/Ocean_Materials/Mini_Studies/Index.html for links to Mini Studies from Earth Education Online, including Greenhouse Gases and Human Influenced Climate Change.

Other Relevant Lesson Plans from the Ocean Exploration Program

Frozen Out
http://oceanexplorer.noaa.gov/explorations/06arctic/background/edu/media/frozenout.pdf
(10 pages, 296 kb) (from the 2006 Tracking Narwhals in Greenland Expedition)

Focus: Impacts of climate change on Arctic predators (Life Science/Earth Science)

In this activity, students will be able to explain the concepts of indicator species and microhabitats; compare and contrast average regional conditions with site-specific conditions; and explain at least three examples of the impacts of climate change on top predators in the Arctic.

Climate, Corals, and Change
http://oceanexplorer.noaa.gov/explorations/05stepstones/background/education/ss_2005_climate.pdf
(14 pages, 441k) (from the North Atlantic Stepping Stones 2005 Expedition)

Focus: Paleoclimatology (Physical Science)

In this activity, students will be able to explain the concept of "paleoclimatological proxies" and describe at least two examples, describe how oxygen isotope ratios are related to water temperature, and interpret data on oxygen isotope ratios to make inferences about the growth rate of deep-sea corals. Students will also be able to define "forcing factor", describe at least three forcing factors for climate change and discuss at least three potential consequences of a warmer world climate.

Meet the Arctic Benthos
http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_benthos.pdf
(8 pages, 492k) (from the 2002 Arctic Exploration Expedition)

Focus: Benthic invertebrate groups in the Arctic Ocean (Life Science)

In this activity, students will be able to recognize and identify major groups found in the Arctic benthos, describe common feeding strategies used by benthic animals in the Arctic Ocean, and discuss relationships between groups of animals in Arctic benthic communities. Students will also be able to discuss the importance of diversity in benthic communities.

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 – Web site for NOAA's Ocean Exploration Program

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.ncdc.noaa.gov/oa/climate/globalwarming.html – "Global Warming Frequently Asked Questions," from NOAA's National Climatic Data Center

http://www.ipcc.ch/ – Home page for the Intergovernmental Panel on Climate Change

http://www.unep.org/climatechange/ – United Nations Environment Programme Climate Change Web page

http://www.epa.gov/climatechange/ – U. S. Environmental Protection Agency Climate Change Web page

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

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.

The Earth has one big ocean with many features.

Fundamental Concept b. An ocean basin's size, shape and features (such as islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates.

Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

Essential Principle 5.

The ocean supports a great diversity of life and ecosystems.

Fundamental Concept c. Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.

Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator- prey dynamics and energy transfer) that do not occur on land.

Fundamental Concept e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

Fundamental Concept f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy." Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

Essential Principle 6.

The ocean and humans are inextricably interconnected.

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 e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.

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 b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

Fundamental Concept c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.

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.

Send Us Your Feedback

We value your feedback on this lesson, including how you use it in your formal/informal education setting.
Please send your comments to: oceanexeducation@noaa.gov

For More Information

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Acknowledgments

This lesson plan was produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: http://oceanexplorer.noaa.gov

Arctic Climate Change Inquiry Guide

The following questions are intended to introduce you to some basic information about climate change in the Arctic.

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

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

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

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

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

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

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

Arctic Climate Change Inquiry Guide - Page 2

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

i. How significant are Arctic petroleum reserves?

j. Are climatic trends the same for the entire Arctic region?

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

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

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

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

o. How are changes in permafrost affecting human activities?

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

Arctic Climate Change Inquiry Guide - Page 3

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

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

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

Photocube Construction Guide - Page 1

These directions are adapted from "Create your own "magic" folding wooden photo cubes" (http://www.chicaandjo.com/2008/05/08/magic-folding-wooden-photo-cubes/), and are used with permission.

Materials

- 8 - 1.5" wooden blocks
- 8 - 3" x 3" photos printed on thin photo-quality paper such as HP Bright White Inkjet Paper
- 2 - 3" x 6" photos, printed on paper described above
- 2 - 8" x 11" sheets of double-sided tape ("red liner tape")
- Black felt tip marker
- Scissors or paper trimmer
- Sandpaper, 150 grit or finer

1. Locate images of glaciers that you want to use for your photocube. There is a great collection at http://nsidc.org/cgi-bin/glacier_photos/glacier_photo_search.pl?collection=repeat. This link opens the Search page for the National Snow and Ice Data Center's collection of repeat glacier photography. Click the "Search" button and a new page will open showing thumbnails of the photographs.

   Select images that can be shown side-by-side in a 3" x 3" space or a 3" x 6" space. You will need a total of eight 3" x 3" image sets and two 3" x 6" image sets. Arrange the images in your photo editor and print them onto thin photo-quality paper.

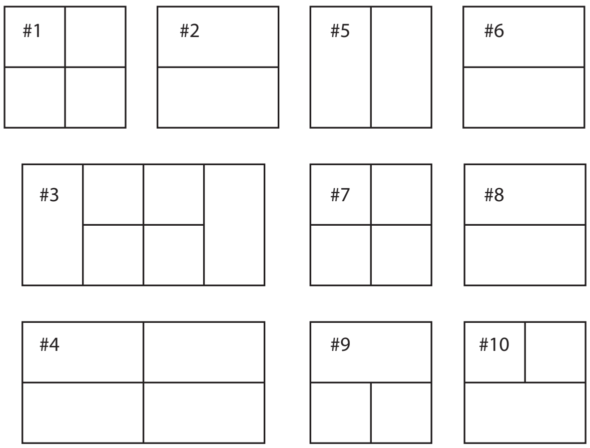
   If the printed images aren't as bright as you'd like, try specifying "Photo/Glossy paper" in your Print dialogue box instead of ordinary paper. This causes your printer to apply more ink, making much bolder images.

2. Cut each image about 1/8" larger on each side than the specified dimensions. You will cut out 8 photos measuring 3 1/8" x 3 1/8" and 2 photos measuring 3 1/8" x 6 1/8".

3. Back each image with double-sided adhesive. Peel off one side of the backing and lay the sheet down, sticky side up. Attach the images to the sticky surface so that the back of each photo is completely covered. Trim the adhesive sheets to match the images. Don't peel off the other adhesive backing layer yet!

Photocube Construction Guide - Page 2

Step 4.



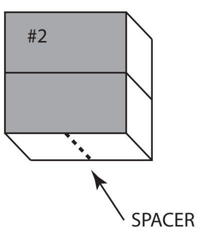
4. Arrange the images as indicated in the diagram. Use a paper trimmer or scissors to cut each photo into squares or rectangles as indicated. Keep the pieces for each image together so they don't get mixed up! Don't throw out the scraps.

5. You will need a spacer to fill the space between blocks that will eventually be taken up by photos. To make a spacer, use the leftover scraps of photo paper and double-sided tape sheets. Start with three pieces of adhesive about 3" long and 1/2" wide. Peel the backing off of both sides of each piece and stack them together. Cover the top and bottom with scraps of your photo paper. Trim the sides to get rid of overhanging edges.

6. Check the edges of all eight cubes. If they are rough, use the sandpaper to smooth them. Using a black felt tip marker, color the edges of the blocks, otherwise, they may show up in the finished product.

7. Begin assembling your photocube by lining up four wooden blocks in a square. Remove the adhesive backing from the four pieces of image #1 and stick them onto the cubes.

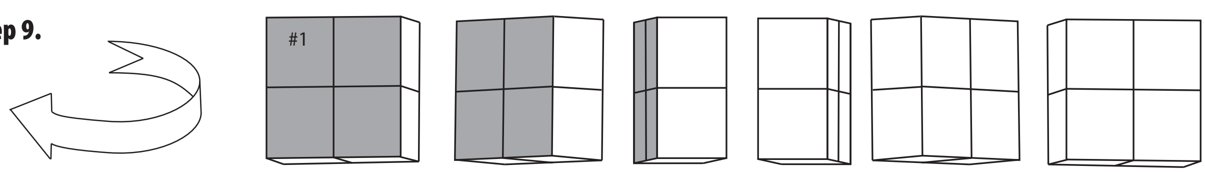
Step 8.



8. Line up the remaining four wooden blocks in a square. Slide your spacer strip between the blocks, so that it sticks out as shown in the diagram. Then stick your two rectangles onto the blocks as shown.

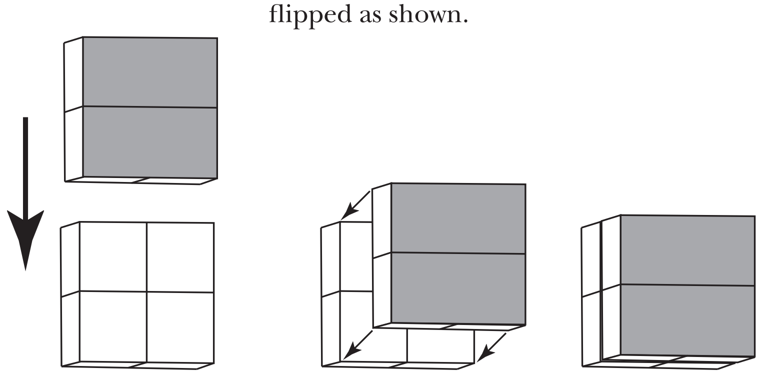
9. Turn over the set of four blocks with image #1 on them as shown below.

Step 9.



10. Place the four blocks with image #2 on them on top of the four you just flipped as shown.

Step 10.



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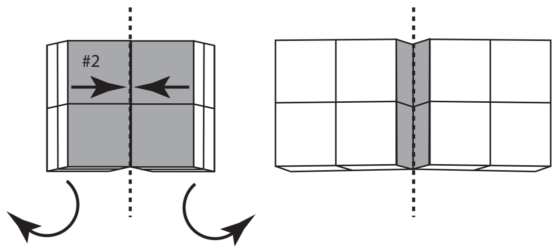
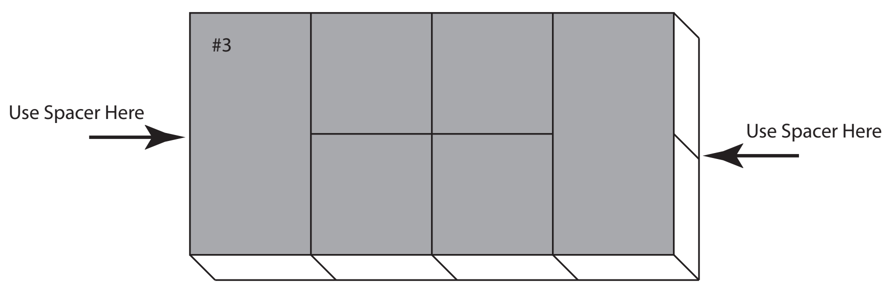
Step 11.



11. Put your hands on the left and right side of your cube, grabbing 4 blocks with each. Lift the sides up so that the top (image #2) folds in on itself, as seen at left, with the pivot being the dotted line in the diagram. The result will be all eight blocks laying in a rectangle.

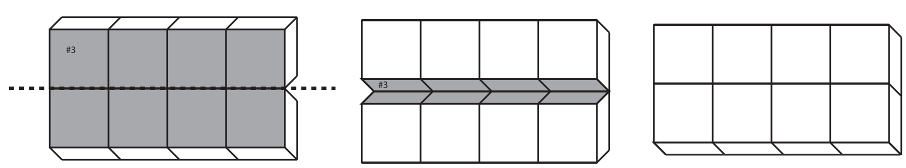
12. Apply the pieces of image #3 to the tops of the eight blocks, taking care to use the spacer whenever covering a span of two blocks, as indicated below.

Step 12.



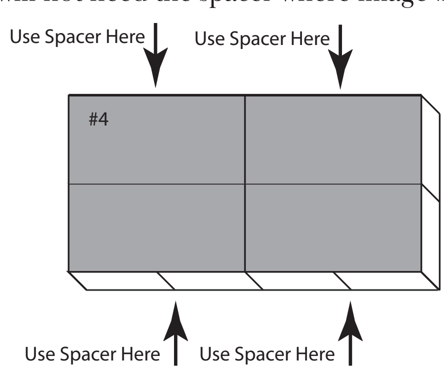
13. Fold the top four blocks down and the bottom four blocks up, with the pivot on the dotted line in the diagram. Your new image #3 that you just attached will fold in on itself and become hidden inside. You'll end up with eight blocks showing in a rectangle.

Step 13.



14. Apply the pieces of image #4 to the tops of the eight blocks, taking care to use the spacer whenever covering a span of two blocks, as indicated below. (You will not need the spacer where image #3 has been placed.)

Step 14.



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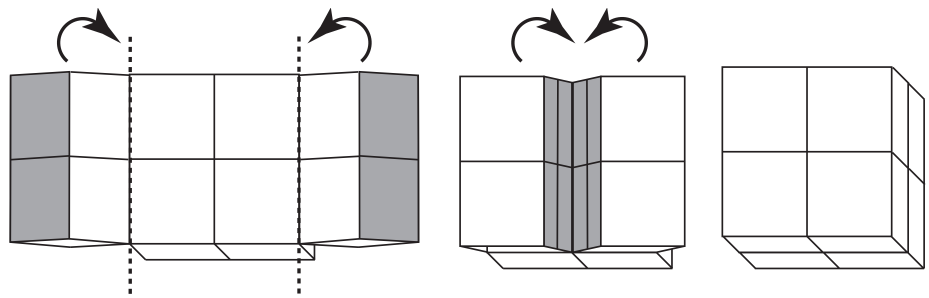
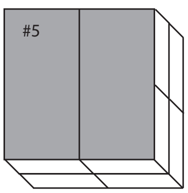
15. Fold the two leftmost blocks and two rightmost blocks up towards the center, pivoting on the dotted lines in the diagram. Your new image #4 that you just attached will become hidden inside. You'll end up with a cube shape.

Step 15.



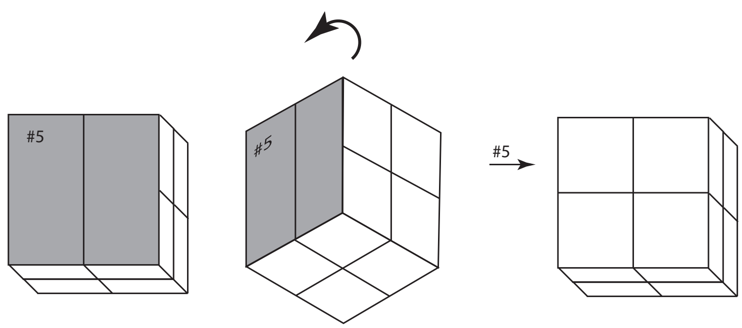
Step 16.



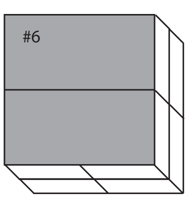
16. Apply the pieces of image #5 to the tops of the four blocks. **You do NOT need the spacer from here on, because the blocks underneath will already have photos attached to them.**

17. Rotate the entire cube to the left, so that image #5 moves from the top side to the left side. You will expose a new surface with no image on it.

Step 17.



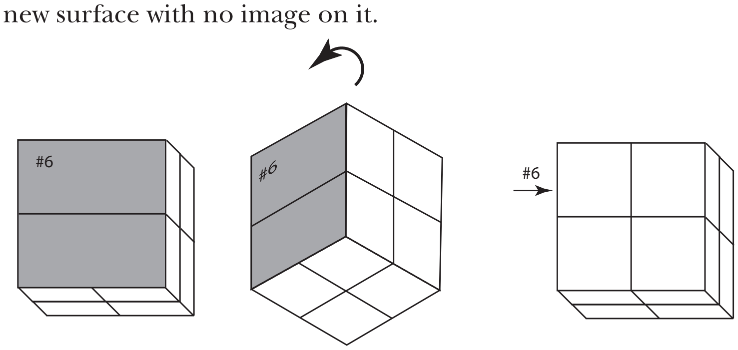
Step 18.



18. Apply the pieces of image #6 to the tops of the four blocks.

19. Rotate the entire cube to the left, so that image #6 moves from the top side to the left side (and #5 is now face-down on the table). You will expose a new surface with no image on it.

Step 19.



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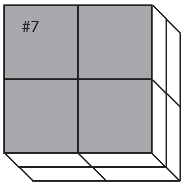
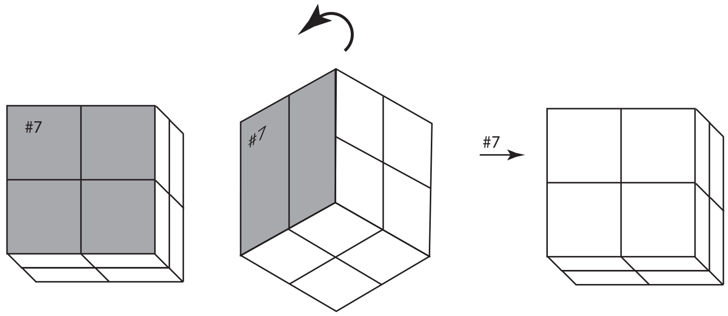
Step 20.



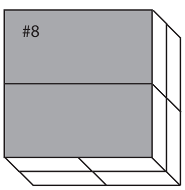
20. Apply the pieces of image #7 to the tops of the four blocks.

21. Rotate the entire cube to the left, so that image #7 moves from the top side to the left side (and #6 is now face-down on the table and #5 is now on the right). You will expose a new surface with no image on it.

Step 21.



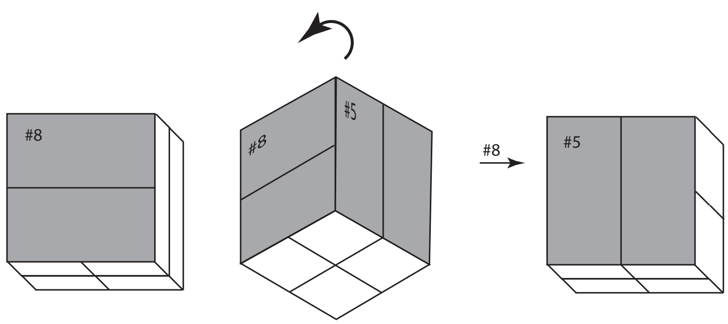
Step 22.



22. Apply the pieces of image #8 to the tops of the four blocks.

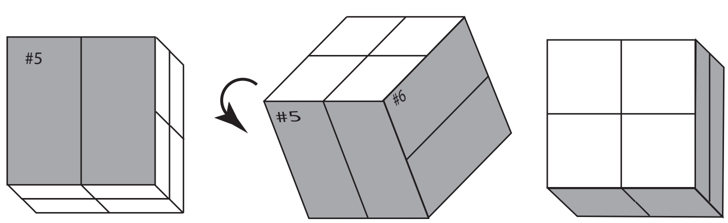
23. Rotate the entire cube to the left, so that image #8 moves from the top side to the left side. You will now have image #5 showing on top.

Step 23.



24. Now rotate again, this time towards you, so that #5 becomes the side closest to you and the top has no photos on it.

Step 24.



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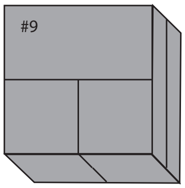
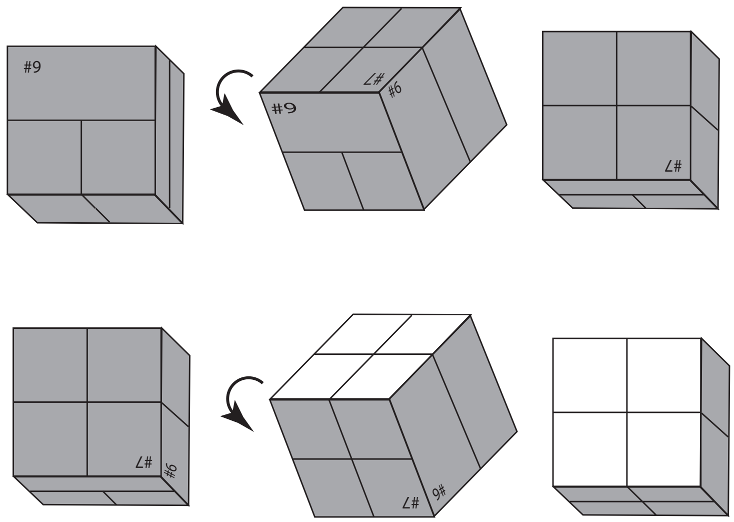
Step 25.



25. Apply the pieces of image #9 to the tops of the four blocks.

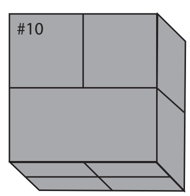
26. Rotate the entire cube towards you, so that image #9 moves from the top side to the side closest to you. You will now have image #7 showing on top. Now rotate again, towards you, so that #7 becomes the side closest to you and the top has no photos on it.

Step 26.



27. Apply the pieces of image #10 to the tops of the four blocks.

Step 27.



You're done!
To view all the images, just fold and unfold the cube, revealing a new side with every twist.
You can display the cube with any of the images showing.

Appendix A

A Brief Review of Some Key Data Concerning Global Climate Change

Within the world scientific community, there is a broad consensus that:

- Earth's climate is undergoing a significant warming trend that is beyond the range of natural variability;
- The major cause of most of the observed warming is rising levels of carbon dioxide;
- The rise in carbon dioxide levels is the result of burning fossil fuels;
- If carbon dioxide levels in the atmosphere continue to rise over the next century the warming will continue; and
- The climate change that is expected to result from these conditions represents potential danger to human welfare and the environment.

The scientific consensus on these points is supported by a huge amount of data from many places on Earth. Following is a brief review of a few key points.

Climate Warming Trend

Since the late 1800's, average global surface temperatures have increased by about 0.74°C. The word "average" is very important, because some parts of Earth (including the southeastern United States and parts of the North Atlantic) have cooled slightly during this period. The greatest warming has been observed in Eurasia and North America between latitude 40° and 70° N.

You may have heard statements such as "Earth's temperature has been dropping for the last ten years. These statements are based on the fact that 1998 was abnormally hot due to the strongest El Nino event in the last century. The years following 1998 were indeed cooler than 1998, but the long-term trend still shows continued warming. There are many factors that affect global temperatures in a single year, and it is not surprising that one year might be cooler than the preceding year. But the global warming trend is a matter of decades, not just one or two years. The long-term trend is still clear: Seven of the eight warmest years on record have occurred since 2001, and the ten warmest years on record have all occurred since 1995.

Cause of the Observed Warming

Earth's climate is affected by a number of factors, including changes in Earth's orbit, solar variability, volcanoes, and the greenhouse effect. But the only factor that coincides with the warming trend of the last century is the observed increase in greenhouse gases, particularly carbon dioxide. There is no scientific debate about this: Since the start of the Industrial Revolution, atmospheric carbon dioxide concentrations have increased from 280 parts per

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million (ppm) to 380 ppm. Today, the global concentration of carbon dioxide is significantly higher than the natural range over the last 650,000 years of 180 – 300 ppm.

Cause of Increasing Atmospheric Carbon Dioxide

There is also no scientific debate about the source of increased atmospheric carbon dioxide. Humans burning fossil fuels release billions of tons of carbon into the atmosphere every year, and the quantity of fuels burned has been increasing for over 150 years (see, for example, http://cdiac.ornl.gov/trends/emis/tre_glob.html).

What about volcanoes? Scientists estimate that volcanoes (including underwater volcanoes) emit 145-255 million tons carbon dioxide into the atmosphere each year. Emissions of carbon dioxide from human activities is estimated at about 30 billion tons per year. So, the amount of carbon dioxide from human activities is more than 100 times greater than the amount of carbon dioxide emitted by volcanoes (http://volcano.oregonstate.edu/education/gases/man.html). Further, if volcanoes had a significant impact, we should see "spikes" on graphs of atmospheric carbon dioxide every time a volcano erupts; but such spikes are not present on these graphs.

What about increases in atmospheric carbon dioxide that happened during pre-human times? It is true that carbon dioxide rose and fell by over 100 ppm at various times in Earth's history, but these rises took place over 5,000 to 20,000 years; the present increase of 100ppm has happened in only 150 years. Additional evidence implicating human activities comes from isotope analyses of the carbon and oxygen atoms that make up atmospheric carbon dioxide molecules. These analyses show that the oxygen atoms in some of these molecules are much younger than the carbon atoms in the same molecule. Older carbon could only come from fossil fuel deposits, and the only way these deposits could become airborne is through combustion.

Effect of Continued Increase in Atmospheric Carbon Dioxide

If atmospheric carbon dioxide concentrations continue to increase, global temperatures are also expected to increase by 2° to 5°C. So, the minimum expected temperature increase under these conditions is nearly three times the increase that has already been observed. The actual increase could be much greater, depending upon the influence of feedbacks. For example, decreasing ice and snow in polar regions means that less solar radiation will be reflected away from Earth's surface. This would result in more radiation being absorbed at the surface, and increased warming.

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Warmer temperatures in the Arctic could also trigger another feedback process. Methane hydrates are a type of ice that contains methane molecules surrounded by a cage of frozen water molecules. Most methane hydrates are believed to exist in ocean sediments, but some are also found in high latitude soils called permafrost. If these soils become warm enough, methane hydrates could melt and release methane gas to the atmosphere. Since methane is a powerful greenhouse gas, and decomposes to form carbon dioxide, increased atmospheric methane could results in an increased greenhouse effect and additional warming of Earth's climate.

A warmer atmosphere could also mean warmer temperatures in Earth's ocean. Since the solubility of carbon dioxide decreases as temperature rises, warmer temperatures could decrease carbon dioxide absorption by the ocean creating yet another feedback mechanism. Temperature has an opposite effect on the atmosphere's capacity for water vapor: Increased temperature can result in increased atmospheric water vapor. Since water vapor is also a greenhouse gas, additional warming might result from a strengthened greenhouse effect. The latter feedback, however, might be moderated if increased atmospheric water vapor caused an increase in cloud cover that could reduce the amount of solar radiation reaching Earth's surface.

Increasing atmospheric carbon dioxide is also having a serious effect on ocean pH. Each year, the ocean absorbs approximately 25% of the CO_2 added to the atmosphere by human activities. When CO_2 dissolves in seawater, carbonic acid is formed, which raises acidity. Ocean acidity has increased by 30% since the beginning of the Industrial Revolution, causing seawater to become corrosive to the shells and skeletons of many marine organisms as well as affecting the reproduction and physiology of others. See *Off Base* (http://oceanexplorer.noaa.gov/explorations/09lophelia/background/edu/media/09offbase.pdf) for additional discussion and references.

Impacts of Expected Climate Change if Trends Continue

The Intergovernmental Panel on Climate Change (the leading provider of scientific advice to global policy makers) has produced a report on some of the impacts that are occurring as a results of climate change as well as impacts that are anticipated if present trends continue (http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg2_report_impacts_adaptation_and_vulnerability.htm). These impacts include:

- Decreased water resources in semi-arid areas such as the Mediterranean Basin, western USA, southern Africa and north-eastern Brazil;
- Decreased availability of fresh water due to sea-level rise;
- Ecosystems such as tundra, boreal forest, mountains, mangroves, salt

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marshes, coral reefs, and sea-ice are highly vulnerable, and are virtually certain to experience species extinctions and major changes;

- A global intensification and expansion of wildfires is likely, as temperatures increase and dry spells become more frequent and more persistent;
- Increased risk of coastal flooding in low-lying areas due to sea-level rise and more intense coastal storms;
- Surface ocean pH is very likely to decrease by as much as 0.5 pH units by 2100, and is very likely to impair shell or exoskeleton formation in marine organisms such as corals, crabs, squids, marine snails, clams and oysters.

Resources

http://www.ncdc.noaa.gov/oa/climate/globalwarming.html – "Global Warming Frequently Asked Questions," from NOAA's National Climatic Data Center

http://www.ipcc.ch/ – Home page for the Intergovernmental Panel on Climate Change

http://www.unep.org/climatechange/ – United Nations Environment Programme Climate Change Web page

http://www.epa.gov/climatechange/ – U. S. Environmental Protection Agency Climate Change Web page