SciGuide lesson: Climate Change and Ocean Currents

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Grade Level: 9–12

Subject Area: Earth and Space Science

SciGuide Lesson Resources:

Weather Underground
http://www.wunderground.com/education/abruptclimate.asp

Shutdown of Thermohaline circulation
http://en.wikipedia.org/wiki/Shutdown_of_thermohaline_circulation

Great Ocean Conveyor Belt
http://www.grida.no/publications/vg/climate/page/3085.aspx

NOAA Paleoclimatology
http://www.ncdc.noaa.gov/paleo/primer.html

How do Human Activities Contribute to Climate Change and How do They Compare with Natural Influences?
http://oceanservice.noaa.gov/.../howhuman.pdf

NOAA Climate Change
www.nws.noaa.gov/om/brochures/climate/Climatechange.pdf

NOAA Paleoclimatology
http://www.ncdc.noaa.gov/paleo/globalwarming/paleo.html

NOAA Earth System Research Laboratory
http://www.esrl.noaa.gov/psd/cgi-bin/data/getpage.pl

Instrumental Temperature Records
http://en.wikipedia.org/wiki/Instrumental_temperature_record

Temperature Record
http://en.wikipedia.org/wiki/Temperature_record
Paleoclimatology: How Can We Infer Past Climates?
http://serc.carleton.edu/microbelife/topics/proxies/paleoclimate.html

Integrated Ocean Drilling Program (IODP) Record-Breaking Expedition
http://iodp.org/index.php?option=com_content&task=view&id=510&Itemid=1162

The Younger Dryas cold interval as viewed from central Greenland
http://www.ncdc.noaa.gov/paleo/pubs/alley2000/alley2000.html

Greenland Ice Sheet Project2 (GISP2)
http://www.gisp2.sr.unh.edu/

European Greenland Ice Core Project (GRIP)
http://www.ncdc.noaa.gov/paleo/icecore/greenland/summit/document/

Standards Addressed:

Earth and Space Science

- **Energy in the earth system**

Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans.

Science in Personal and Social Perspectives

- **Natural resources**

The earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and it depletes those resources that cannot be renewed.

Humans use many natural systems as resources. Natural systems have the capacity to reuse waste, but that capacity is limited. Natural systems can change to an extent that exceeds the limits of organisms to adapt naturally or humans to adapt technologicall

- **Natural and human-induced hazards**

Human activities also can induce hazards through resource acquisition, urban growth, land-use decisions, and waste disposal. Such activities can accelerate many natural changes.

Natural and human-induced hazards present the need for humans to assess potential danger and risk. Many changes in the environment designed by humans bring benefits to society, as well as cause risks. Students should understand the costs and trade-offs of various hazards—ranging from those with minor risk to a few people to major catastrophes with major risk to many people. The scale of events and the accuracy with which scientists and engineers can (and cannot) predict events are important considerations.

Time Required: Three 45-minute class periods.

Lesson Goal: The overall goal for this lesson is for students to learn more about the effect of ocean currents on climate change and determine if the possibility exists that rising atmosphere and ocean temperatures might trigger a massive melt down of the Greenland Ice Sheet which in turn may stall the Great Ocean Conveyor Belt.

Learning Objectives:

- Students will be able to answer basic questions on ocean currents and their effect on climate change.
- Students will be able to discuss what the effects might be if the THC stalls.
- Students will be able to evaluate climate change data and forecast future trends.

Prerequisite Knowledge: The Science of Abrupt Climate Change: Should we be worried?
By Jeffrey Masters, Ph.D. — Director of Meteorology,
Weather Underground, Inc.

Introduction

We generally consider climate changes as taking place on the scale of hundreds or even thousands of years. However, since the early 1990s, a radical shift in the scientific understanding of Earth's climate history has occurred. We now know that that major regional and global climate shifts have occurred in just a few decades or even a single year. The most recent of these shifts occurred just 8200 years ago. If an abrupt climate change of similar magnitude happened today, it would have severe consequences for humans and natural ecosystems. Although scientists consider an abrupt climate change unlikely in the next 100 years, their understanding of the phenomena is still a work-in-progress, and such a change could be triggered instantly by natural processes or by human-caused global warming with little warning.

The National Academy of Sciences--the board of scientists established by Congress in 1863 to advise the federal government on scientific matters--compiled a comprehensive report in 2002 entitled, Abrupt Climate Change: Inevitable Surprises. The 244-page report, which contains over 500 references, was written by a team of 59 of the top researchers in climate, and represents the most authoritative source of information about abrupt climate change available. Most of the material that follows was taken from this report.

The Greenland Ice Sheet: The Key to Understanding Earth's Climate Record

Ice cores hold an amazingly detailed record of Earth's climate. Each year, snow falling on glacial areas accumulates, piling on top of thousands of years of past snow, compressing the snow into yearly layers of ice, like rings inside a tree trunk. Preserved in the ice are tiny bubbles of ancient air that tell us the composition of the atmosphere at that time. The amount of dust in the snow tells us how windy the climate was. The thickness of the layer tells how much precipitation fell that year. Most importantly, the amount of the "heavy" isotope of oxygen, $_{18}O$, lets us infer the average atmospheric temperature, since water vapor with "heavy" $_{18}O$ molecules condenses out of clouds more readily at cold temperatures.

Accessing this treasure-trove of climatic information is a huge undertaking--cores of ice must be drilled miles deep in some of the most inhospitable places on Earth. In 1989 the National Science Foundation funded the $25 million Greenland Ice Sheet Project II (GISP2) to drill an ice core through the entire two mile depth of the Greenland ice sheet. At the same time, a separate European project (GRIP), drilled through the ice just 20 miles away, providing a crucial independent check of the GISP2 data. By 1993, both the GRIP and GISP2 drills had hit bedrock, and two miles of ice cores, preserving 110,000 years of climate history in year-by-year layers, were taken to laboratories for analysis.

What the scientists found was surprising and unnerving. They had known from previous ice core and ocean sediment core data that Earth's climate had fluctuated significantly in the past. But what astonished them was the rapidity with which these changes occurred.

Ocean and lake sediment data from places such as California, Venezuela, and Antarctica have confirmed that these sudden climate changes affected not just Greenland, but the entire world. During the past 110,000 years, there have been at least 20 such abrupt climate changes. Only one period of stable climate has existed during the past 110,000 years--the 11,000 years of modern climate (the "Holocene" era). "Normal" climate for Earth is the climate of sudden extreme jumps--like a light switch flicking on and off.

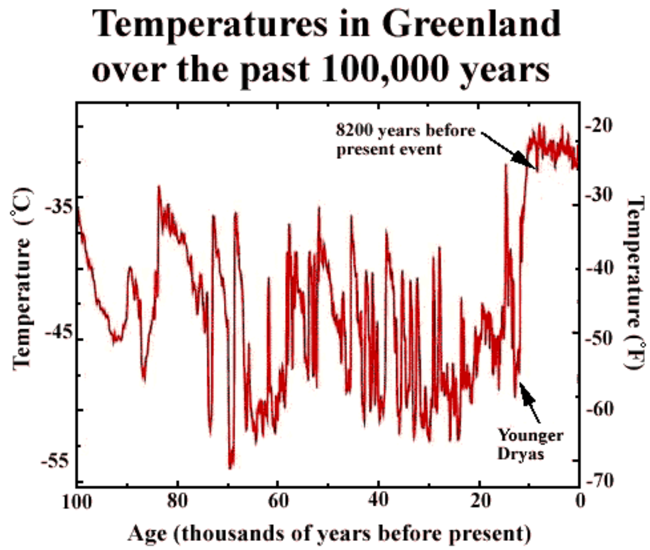

Figure 1. Average Yearly Temperatures in Greenland over the past 100,000 Years as inferred from Oxygen isotope analysis of the GISP2 Greenland ice core. Source: Cuffey, K.M., and G.D. Clow, "Temperature, accumulation, and ice sheet elevation in central Greenland throughout the last deglacial transition", Journal of Geophysical Research, 102, 383-396, 1997.

As seen in Figure 1, the ice core record showed frequent sudden warmings and coolings of 15°F (8°C) or more. Many of these changes happened in less than 10 years. In one case 11,600 years ago, when Earth emerged from the final phase of the most recent ice age (an event called the Younger Dryas), the Greenland ice core data showed that a 15°F (8°C) warming occurred in less than a decade, accompanied by a doubling of snow accumulation in 3 years. Most of this doubling occurred in a single year.

What causes abrupt climate change?

Current theories on the cause of abrupt climatic change focus on sudden shut downs and start-ups of the Meridional Overturning Circulation (MOC) (also referred to as the thermohaline circulation), which is a global network of density-driven ocean currents. The Meridional Overturning Circulation transports a tremendous amount of heat northward, keeping the North Atlantic and much of Europe up to 9°F (5°C) warmer, particularly in the winter. A sudden shut down of this current would have a ripple effect throughout the ocean-atmosphere system, forcing worldwide changes in ocean currents, and in the path of the atmospheric jet stream. Studies of North Atlantic Ocean sediments have revealed that the Meridional Overturning Circulation has shut down many times in the past, and that many of these shut downs coincide with the abrupt climate change events noted in the Greenland ice cores.

How does one shut down the Meridional Overturning Circulation? First, one must examine the MOC itself. The MOC, or Great Ocean Conveyor Belt (Figure 2), is a system of interconnected ocean currents that girdle the planet.

Figure 2. The Great Ocean Conveyor Belt Source: IPCC

At the surface, warmer ocean currents (shown here in orange) are driven by the winds, and so move parallel to the wind direction, except where continental land masses block the way. Water can also move vertically in the ocean. High density water sinks, and low density water rises. Salty water is more dense than fresh water, and cold water is more dense than warm water, so that wherever we find cold, salty water, it tends to sink. Colder currents (shown here in blue) are deeper and have higher salinity.

In the tropical Atlantic, the sun's heat evaporates large amounts of water, creating relatively warm, salty ocean water. This warm, salty water flows westward toward North America, then up the East Coast of the U.S., then northeastward toward Europe, forming the mighty Gulf Stream current. As this warm, salty water reaches the ocean regions on either side of Greenland, cold winds blowing off of Canada and Greenland cool the water substantially (in Figure 2, these regions are marked with white circles labeled, "Heat release to the atmosphere.") These cool, salty waters are now very dense compared to the surrounding waters, and sink to the bottom of the ocean. Thus, the oceanic areas by Greenland where this sinking occurs are called "deep-water formation areas". This North Atlantic deep water flows southward toward Antarctica, eventually making it all the way to the Pacific Ocean, where it rises back to the surface to complete the Great Ocean Conveyor Belt. It takes about 1000 years for the water to make a complete circuit around the globe.

Since the Great Ocean Conveyor Belt is driven in part by differences in ocean water density, if one can pump enough fresh water into the ocean in the key areas on either side of Greenland where the Gulf Stream waters cool and sink, this will lower the ocean's salinity (and therefore its density) enough so that the waters can no longer sink. As a result, the Atlantic conveyor belt and Gulf Stream current would shut down in just a few years, dramatically altering the climate.

http://www.ncdc.noaa.gov/faqs/climfaq23.html

Procedures/Instructional Strategy:

Explain the assignment:

Using the information from all sources including the websites, each group will develop a discussion about the potential of a shut down of the THC.

Period 1: Research data and read the accompanying article on the THC.
Divide the class into small groups of no more than four.

Data sets to be included in evaluation.

1. NOAA instrumental global temperature.
2. European Project for Ice Coring in Antarctica (EPICA), Vostox, and Greenland Ice Sheet Project 2 (GISP2), European Greenland Ice Core Project (GRIP) ice core data.
3. NOAA/IODP (Integrated Ocean Drilling Program) deep sea sediment temperature data.

Period 2:

Students will prepare oral discussions that answer the following questions:

1. What is the THC? Why is it important?
2. How does it affect climate change?
3. How accurate are the data that support this hypothesis?
4. How can instrumental data be used to verify changes in the circulation?
5. Is there any evidence that the THC has stalled in the past, and how severe was the impact?
7. Is the recent rate of climate change unique or was it commonplace in the past?
8. How long might a stall in the THC affect the climate system?

Period 3:

Student groups discuss the evaluation of the data and their determination if a shut down or a stall of the THC is a possibility in the near future and the consequences it might have on modern climate.

Points will be given on the following criteria:

Engagement: (Does your discussion include all the important data?)

Content: (Does it cover the required areas — instrumental and multiple proxy data types,

understanding of the GOCB circulation, rapid climate change events)
Depth of understanding: Do students seem to understand the material and are able to communicate their understanding and evaluate other groups information. Ask students to evaluate each other's presentations.

Lesson goal: Students will create a presentation that addresses all the criteria for an effective discussion about thermohaline circulation and climate change. They will evaluate each others discussion effectiveness and give feedback.

Extensions: Students can create poems, tales or images that share their thoughts, feelings and visions about ocean currents and climate change and incorporate them into their discussions. Multimedia should also be options for displaying information.

Classroom Resources: Computer access for students

Other Teaching Resources Lesson Plan List:
Oceans Effect on Weather and Climate,
Sci Guide- http://www.nsta.org/store/product_detail.aspx?id=10.2505/5/SG-18

SciPack -http://learningcenter.nsta.org/product_detail.aspx?id=10.2505/6/SCP-OCW.0.1

Audio/Video Clips:

University of Arizona Lecture series on Global Climate Change, 2006, 7 lectures
http://www.youtube.com/watch?v=KcuWaa6bn4g
http://www.youtube.com/watch?v=w6axoGfDId0&feature=related