

A Tale of Two Teeth: A Hands-On Discussion about Climate Change

Summary

Using real fossils or plastic models of shark teeth and mammoth teeth, teachers use a story line and the Socratic question-and-answer method to discuss climate change as revealed by changing sea level resulting from glacial and interglacial periods.

Learning Objectives

Students will be able to:

- Describe the nature of historic climate change.
- Name at least two causes of past climate change.
- List at least two kinds of evidence for recent climate change.
- Relate past climate change to present climate and future climate change.

National Science Education Standards

Standard A: Science as Inquiry.

Standard D: Earth and Space Science.

Ocean Literacy Essential Principles

2. The ocean and life in the ocean shape the features of Earth.
3. The ocean is a major influence on weather and climate.
5. The ocean supports a great diversity of life and ecosystems.

Target Age: Grades 5-8

Time: Two to three class periods

Materials

- One large, well-preserved, whole *Carcharodon megalodon* tooth with serrated edges. *Carcharodon megalodon* was the “great white shark” of its day, but was much larger than the modern great white shark. Good tooth specimens (6 inches

long) cost about \$100 and can be purchased at a science outlet such as Ward’s (<http://www.wardsci.com/>). These large teeth are rare because they are easily broken by natural reworking or in the phosphate mining process since they are commonly found in phosphate deposits. Because shark skeletons (not teeth) are made of cartilage and preserve poorly, all that remains of these huge creatures is their teeth.

- Good image of the full jaw set and artistic rendering of the 18-m-long monster, *Carcharodon megalodon*.
- Small sharks’ teeth of other varieties for students to handle.
- One plastic model of a mammoth tooth—real ones are very expensive, heavy and break easily. Ward’s is a good source for this item also.
- Maps showing location of Florida and Stellwagen Bank off Cape Cod.
- An empty bag of lawn or garden fertilizer that clearly has three numbers on it (e.g., 10-10-10 or 28-2-10).
- Large physiographic globe to show the asymmetric distribution of landmasses in the northern hemisphere.
- Models of the sun (use flashlight in darkened room) and Earth (can use globe) to show why we have seasons and how light energy striking the earth changes depending upon the distance between the sun and the earth and the tilt of the earth’s axis of rotation.
- Good images of modern glaciers, sources of greenhouse gasses (CO₂; burning forests, cars/trucks on clogged highways, active smoke stacks).

Background

This lesson is a storytelling activity—a story that has characters (including a villain), a series of mysteries (starting with unexplained recovery of body parts) set in geologic time, clues to help solve the mysteries, a resolution, and finally, a sequel. You will ask your students to solve the final mystery (causes of climate change), but part of this mystery is still unresolved as it relates to future climate change and its effects on human society (the sequel). By actively engaging students in solving the mystery, they use thinking skills to assemble facts and observations to propose their own hypotheses or ideas.

The key idea is to engage your students by keeping a fast-paced, rapid-fire question-answer-question-answer Socratic dialog going with short periods of explanation using hands-on materials and/or imagery that should then lead into another fast-paced question-answer dialog. Teachers are encouraged to call on students who appear reluctant to get into the fray by accepting any answer, however off point. Given an off-point answer, the teacher can bring the student closer to the point by providing clues and asking for elaboration. Teachers should be prepared to ask the same question from different viewpoints to get students back on track.

The use of hands-on samples (rocks and fossils), compelling imagery, and other teaching tools such as maps and a physiographic globe are essential. This exercise cannot be taught effectively using PowerPoint as the primary medium—although some imagery can be projected at appropriate points depending upon where answers to the teacher’s questions have taken the group.

To effectively teach this unit, some essentials of earth history and oceanography must be known by the instructor. This would include glaciations, sea-level changes, geologic time, ocean circulation, seasonality, food chains, extinction, and the basics of Earth orbital variations (Milankovitch-scale cyclicality).

Some resources to assist you:

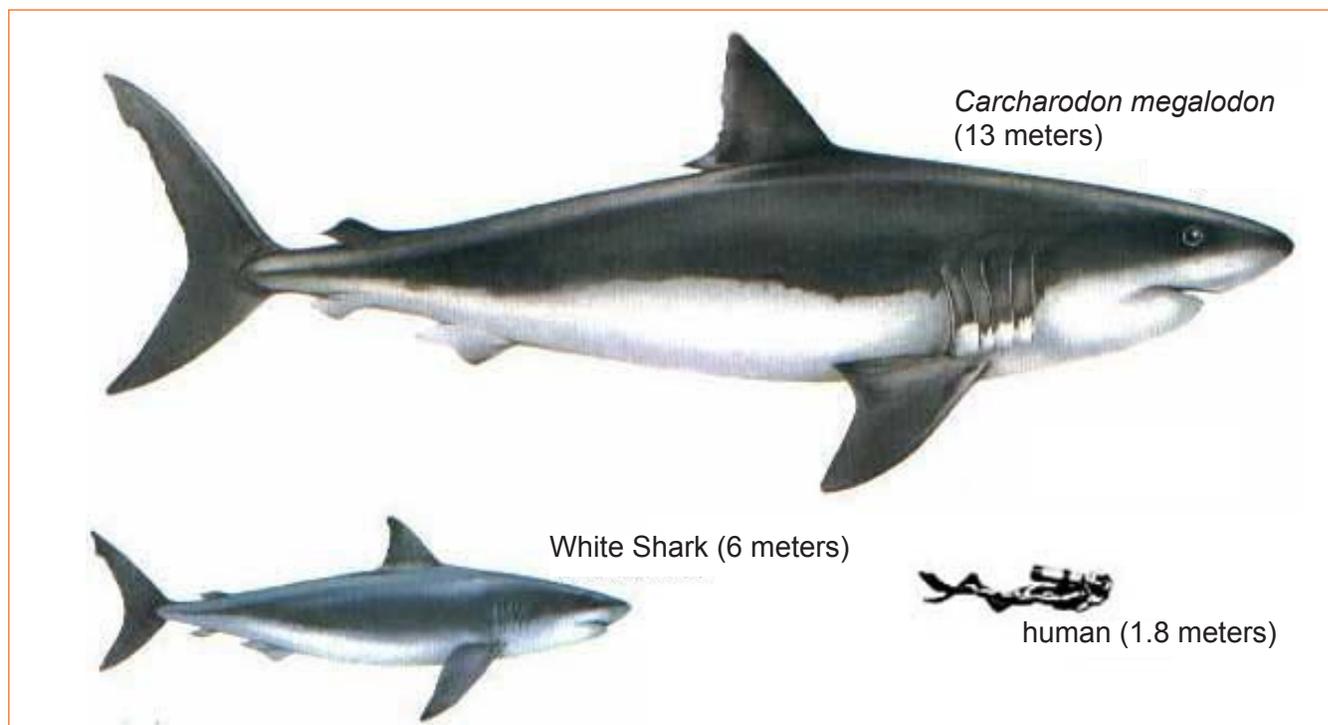
<http://www.oceanleadership.org/education/deep-earth-academy/educators/classroom-activities/>

Press, F., Siever, R., Grotzinger, J., and Jordan, T.H., 2004, *Understanding Earth*; W.H. Freeman and Co. 4th Ed., 567 p.

Stanley, S.M., 2005, *Earth System History*; W.H. Freeman and Company, 2nd Ed., 567p.

Pinet, P.R., 1998, *Invitation to Oceanography*; Jones and Bartlett Publishers, web enhanced edition, 508 p.

Strahler, A., and Strahler, A., 1997, *Physical Geography, Science and Systems of the Human Environment*; John Wiley and Sons, 637 p.



(Image: www.fossilien.de)

What to do

1. Hold up the large shark tooth (*Carcharodon megalodon*) to the class and pass out small shark teeth so they can be touched. Have students take a good look at them.

Note: This ancient “great white shark” was common in the Miocene—a geologic epoch of time lasting from about 22 to 5 million years ago. This species survived for a few more million years and then became extinct in the late Pliocene/early Pleistocene. *Carcharodon megalodon* grew up to 18 m long (60 ft) and weighed ~18,000 kg (20 tons/40,000 lbs). It had to consume about 2% of its weight per day or 360 kg (800 lbs). It ate just about anything except plankton. (Name a marine mammal that eats lots of plankton—baleen whale). Impress the students with the size of this creature. A man could stand up in its mouth between its jaws. If it were lying in the classroom with its belly on the floor, its back would be ~2.5m (8 ft) high and its dorsal fin would extend through the ceiling. At up to 18-m long, it probably would not fit lengthwise into a classroom and much of its tail would stick far out into the hall. Note that there is some debate over the name of this ancient shark. To learn more, visit: http://www.elasmo-research.org/education/evolution/carcharodon_vs_carcharocles.htm

For images, visit:

<http://images.google.com/images?q=Carcharodon+megalodon&hl=en&lr=&rls=GGLR,GGLR:2005-50,GGLR:en&sa=X&oi=images&ct=title>

<http://www.enchantedlearning.com/subjects/sharks/glossary/Megalodon.shtml>

2. Ask students:

- a. What is this? (*Answer: tooth*)
- b. What kind of animal used it? (*Answer: shark*)
- c. Where did it live? (*Answer: coastal & open ocean—but near abundant food sources*)
- d. What did it eat and why? (*Answer: meat—needed sharp serrated edges for tearing flesh*)
- e. What would you call this type of animal? (*Answer: predator; carnivore*)
- f. Did any other creatures threaten it? (*Answer: No, it was a top-of-the-food-chain predator—the villain in our story line.*)

Knowing this, would you say that the ocean where these creatures lived was highly productive or relatively barren of life? (*Answer: Obviously, this ocean had to be teeming with life to keep these creatures fed.*)

- g. Why was this ocean so productive—so filled with food? (*Answer: There must have been a lot of nutrients—from upwelling or land-runoff—rivers, coastal marshes, nursery areas.*)
How/why are some parts of the ocean more productive than others, thus sustaining more life? (*Note: These are peripheral questions that can be set aside for another discussion.*)
- h. What was the base (bottom) of the food chain that supported everything above, including these huge sharks? (*Answer: plankton, primarily phytoplankton—tiny plants needing light to photosynthesize*)
- i. Why did these huge sharks eventually become extinct? (*Answer: probably broad changes in climate, change of habitat such as lower sea level, smaller continental shelves, reduced coastal upwelling that occurred over long periods of time leading to less fertile coastal oceans and reduced food supply—this was not a sudden event*)
- j. How come we never see whole skeletons of fossil sharks—just lots of teeth? (*Answer: The bones of sharks are made of cartilage and not the same resistant material as mammal bones.*)



Carcharodon megalodon tooth. Image: http://commons.wikimedia.org/wiki/File:Carcharodontosaurus_and_Megalodon_teeth.jpg

3. Hold up the mammoth tooth (*Mammuthus primigenius*) and go through some give and take with the students. Try to use a full-scale plastic model. This one is more difficult to identify as a tooth because it is a large molar with a long root that anchored it firmly into the mammal's jaw. Most of the tooth was below the gum line. Many students will have no idea what it is, so some hints might be needed.



Pleistocene mammoth molar tooth, *Mammuthus primigenius*, collected 1937. Dimensions: Centimeters: 35 (length), 27 (width), 10 (height). Image: Royal Ontario Museum, Museum ID Number: 01159, Image Number: ROM2004_1028_18

Note: Woolly Mammoths (scientific name *Mammuthus primigenius*) are extinct herbivorous mammals that had long, dense, dark hair and under-fur, long, curved tusks, a fatty hump, a long proboscis (nose), and large ears. They lived in the tundras of Asia, Europe, and North America. They lived from the Pleistocene to the early Holocene epoch (350,000 to about 10,000 years ago), millions of years after the dinosaurs went extinct. They are closely related to modern-day Indian elephants. They were about 11.5 feet (3.5 m) long, 9.5 feet (2.9 m) tall at the shoulder and weighed about 3 tons. Their tusks were used for protection, in interspecies dominance, and for digging in the snow of the ice ages for grass and other food. Much of our knowledge of mammoths is from cave drawings found in France and Spain and from mummified mammoths found in Siberian ice! (Classification: Family Elephantidae)

<http://www.zoomdinosaurs.com/subjects/mammals/iceagemammals.shtml>

http://news.nationalgeographic.com/news/2001/11/1101_WoollyMammoth_2.html

The functional morphology of the two teeth could not be more different. Tearing and grinding require quite different dental architectures. Dagger-like teeth are not good for picking and eating blueberries, and broad, flat molars don't work well for biting and tearing off large chunks of meat. Note that the ancient "great white shark" and the woolly mammoth were not contemporaries in geologic time. The shark became extinct probably about the same time woolly mammoth ancestors were evolving. This, however, is irrelevant to the main point of this story line.

4. Ask your students:
- What is it? (*Answer: tooth*)
 - What kind of animal used it? (*Answer: land based, elephant like—woolly mammoth*)
 - Where did it live? (*Answer: cold climates—it was woolly for a reason*)
 - What did it eat? (*Answer: plants—grasses*) How can we deduce this from looking at its tooth? (*Answer: large grinding surfaces, rather than sharp, knife-like edges for meat-eaters*)
 - What do you call this type of animal? (*Answer: herbivore*)
 - Did other creatures threaten it? (*Answer: Yes, saber-tooth cats hunted it in packs, as did early humans, most likely.*)
 - In what kind of an environment did this animal live? (*Answer: open grassy areas, periglacial*)
 - Why did this animal become extinct? (*Answer: climate change, overhunted—by humans perhaps, disease*)

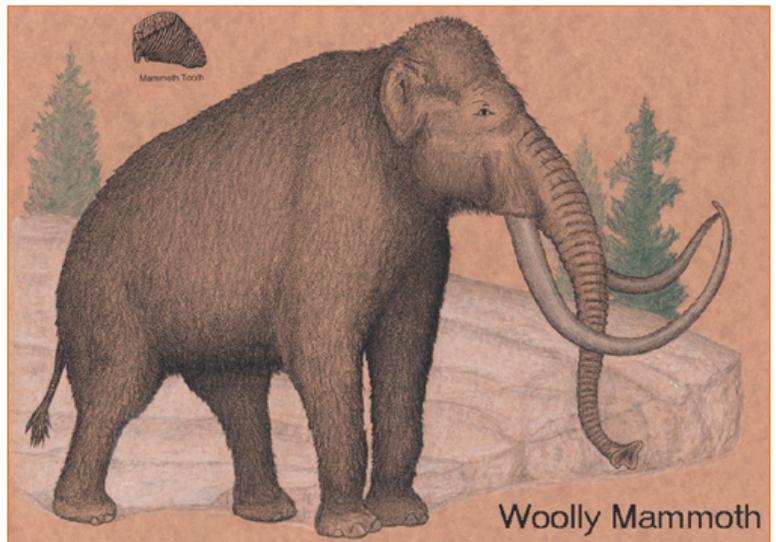


Image: Illinois State Geological Survey (<http://www.isgs.uiuc.edu/education/ice-age-res/mammoth.shtml>)

Setting up the Mystery

- Tell the students where these fossils are commonly found and why. First important fact: In central peninsular Florida, 100 km from the modern ocean on dry land, lies one of the great fossil hunting areas of the world. A famous geologic stratigraphic unit called the Hawthorn Group underlies the land surface there. This unit contains millions of fossils of manatees, alligators, rays, sharks, and other fish.
- Ask students: how come there are so many marine fossils in central Florida? Pose the question here, but answer it later so as not to prematurely reveal the answer to the question towards which you are headed.

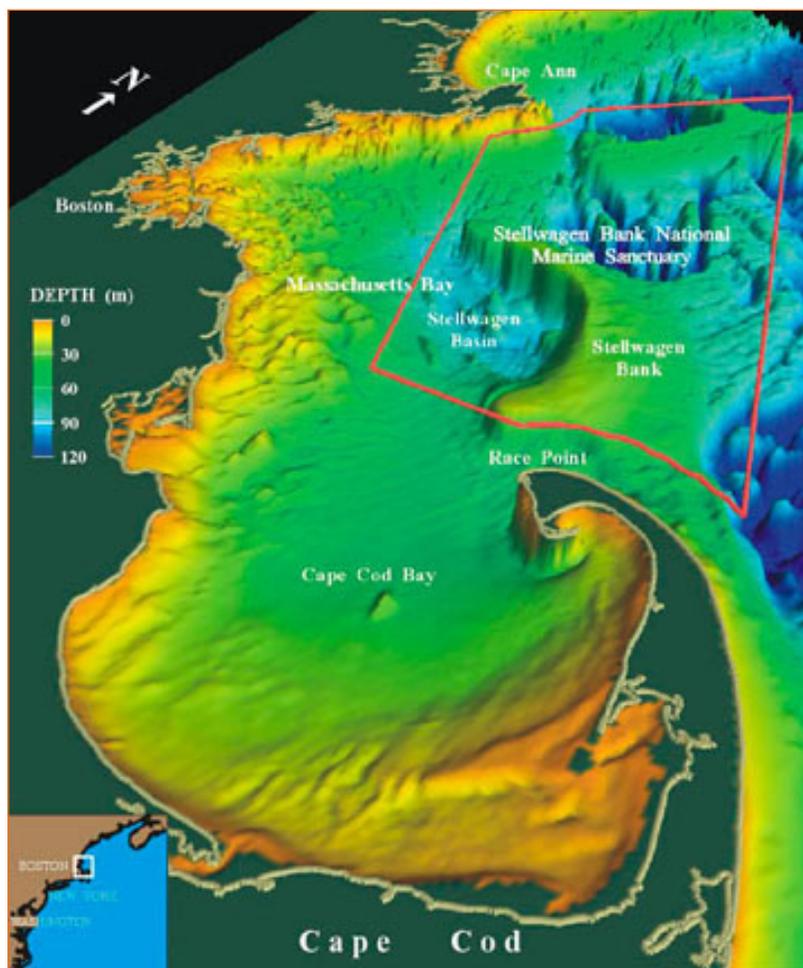
Note: The Hawthorn Group also contains phosphate, a sedimentary mineral formed on the seafloor that is mined for the element phosphorous. Phosphorus is used in making fertilizers along with other primary nutrients—nitrogen (N) and potassium (K) (<http://www.tfi.org/factsandstats/fertilizer.cfm>). Florida produces approximately 30% of the world's phosphate, making it one of the largest exporters of this material worldwide. (<http://www1.fipr.state.fl.us/PhosphatePrimer>). The nitrogen and potassium come from other sources, but when one looks at a bag of fertilizer, there are three numbers that stand out, such as 10-10-10 or 28-2-10. These numbers represent the percent concentration of: (1) nitrogen, (2) phosphorous (P_2O_5), and (3) potassium (K_2O) in that order. People use fertilizers with different concentrations of the elements depending upon what kinds of plants they want to fertilize.

- Tell students the next important fact: For years fisherman dragging nets on the bottom of the ocean off the coast of New England, such as Stellwagen Bank, (<http://stellwagen.noaa.gov/>; <http://www.nesportsman.com/articles/article80.shtml>) would retrieve mammoth teeth in their gear.

SO, here is the mystery: We find the remains (teeth) of sea animals now exposed on land (central Florida). Conversely, we find the remains of land animals on the modern seafloor (Stellwagen Bank). How can we explain this mystery?

Seeking the Answer

- One can expect a whole range of answers once you present students with this dilemma—sharks swimming up rivers to die and mammoths drowning in floods on land with their bodies then washed out to sea. This can go on for some time as students exercise their fertile imaginations. Challenge them with reality, e.g., does it make sense that thousands of sharks swam up river like salmon? Do we know them to do this? *Eventually, someone will latch onto the idea that the level of the sea must have changed. Sea level dropped, exposing the fossilized remains of sea animals. Conversely, sea level rose – covering land on which land animals lived and on which their remains became buried and then exposed via marine erosion.*



This image showing Stellwagen Bank (inside the red line) was developed by the U.S. Geological Survey using computer visualization software to turn bathymetric maps into a three-dimensional image. (Source: <http://stellwagen.noaa.gov/about/settingimage.html>)

9. Adding to the realization of a change in sea level, you can now dig deeper and answer the question posed above, “So, how come there are so many marine fossils located in central Florida?” Again, see what the students come up with. *(Answer: If there are lots of fossils with large predators, then there must have been lots of food to keep this food chain viable.)*
- How do you get lots of food? *(Answer: You need lots of nutrients—hence upwelling.)*
 - How do you get upwelling? *This requires an explanation of topographic upwelling resulting from high sea level and allowing a piece of the Gulf Stream (Loop Current) to move up onto the Florida platform. The moving water is deflected by the topography (topographic steering) thus producing a zone of persistent upwelling. Ultimately, all the fossils and the organic matter to create the phosphate resulted from this process. (Note that this is complicated, but could be tackled by good high school science students as another peripheral lesson.)*



10. Now ask students: So, how does sea level go up and down? *One logical and correct answer is that land goes up and down relative to sea level due to geologic forces—such as plate collision, sediment loading, compaction, etc. Think about New Orleans sinking below sea level over the past 150 years. This is called local, relative sea-level change. (Note: You could get into these processes as a peripheral lesson, but to stay on course towards a climate change discussion, we must consider changing the level of the global ocean—called eustacy.)*
11. Challenge students: How do we make the world’s oceans go up and down? *(Answer: We can actually change the volume of the global ocean basin, again due to plate tectonic activity. Given constant water volume, if the global ocean basin volume increases, sea level will fall, and if the global ocean basin decreases, sea level will rise. This happens on very long time scales—many tens to hundreds of millions of years.)*
- So, how else can we change sea level? *(Answer: We can change the volume of water in the global ocean.)*
 - How do we do that? How can we remove water from the ocean and conversely add water to the global ocean? *(Answer: We build glaciers.)*

So, How Do We Build a Glacier?

12. Actually, we need to build an ice sheet (Greenland, Antarctica), which is a giant glacier. So, what conditions are required? *(Answer: Simply put, part of the snowfall from one winter needs to survive the following summer so that there is a net accumulation each year. Eventually, the snow compacts and becomes ice. With enough mass, the ice begins to flow—even on flat terrain—much like a drop of molasses flows outward on a flat table.)*



Mackay Glacier, Antarctica (www.rosssea.info/glaciers.html)

- So, what do we conclude from this observation? *(Answer: We need cool summers).*
- What else do we need? *(Answer: We need land on which to place the glaciers.)*
- Where is most of the land on the face of the earth? *(Answer: In the northern hemisphere. Examine a physiographic globe to demonstrate this point.)*

So, combine the two ingredients needed to form glaciers. We need cool summers in the northern hemisphere to create the large continental ice sheets that were the hallmark of the last ice age. Use maps depicting the maximum extent and thickness of the ice sheet that covered northern North America and the ice sheet that covered much of northern Europe. Point out that Antarctica was already covered with ice, so there was not much room to place additional ice there.

So, How Do We Create Cool Summers in the Northern Hemisphere?

13. Ask students: Why do we have seasons in the first place? *(Answer: Go through an exercise pointing out the tilt of the earth's axis of rotation with respect to the sun. Demonstrate using a globe and flashlight how the northern and southern hemispheres are illuminated depending on if the North Pole is pointed away or towards the sun as the earth revolves around the sun.)*

Now that we can see why we have seasons, how can we make seasons more or less intense?

Let's consider two extremes:

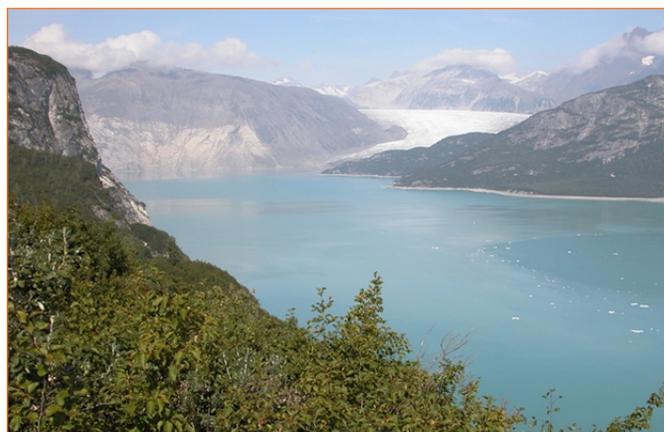
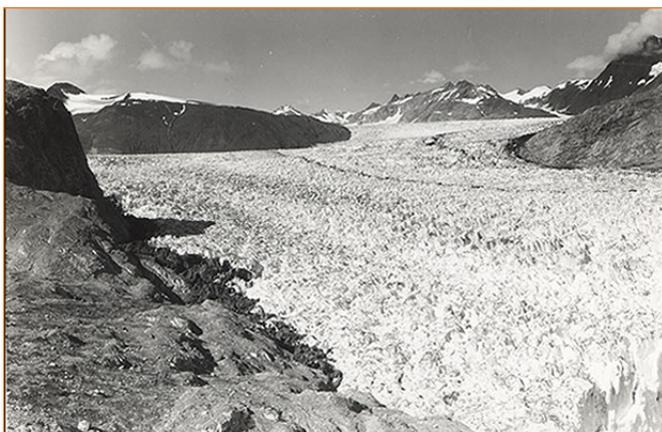
- Would there be any seasons if there were no tilt to the earth's axis of rotation—perpendicular to the plane defined by the earth and the sun (plane of the ecliptic)? *(Answer: If the axis is perpendicular, the climate is the same all the time on the northern and southern hemispheres.)*
- Would there be any seasons if the earth's axis were parallel to the plane defined by the earth and the sun, and the North Pole always pointed toward the sun? *(Answer: The northern hemisphere would be perpetually hot [always facing the sun] and the southern hemisphere would be perpetually cold [always facing away from the sun]. Actually, they would no longer be called the northern and southern hemispheres if this condition ever existed. But this has never happened.)*

As it turns out, Earth's axis of rotation wobbles and the magnitude of tilt varies with time—thus changing the amount of radiation that the northern and southern hemisphere receive. These two variables change or cycle (repeat themselves) on a 23,000 and a 41,000 year time scale. If the North Pole is tilted more towards the sun, the seasons are more severe—hotter in summer and colder in winter—a greater seasonal effect. So, if we want cooler summers in the northern hemisphere, we would require less of a tilt. If we want to make glaciers on the dominant northern hemisphere land masses, we require cool, wet winters with plenty of snowfall and relatively cool summers that prevent all of that snowfall from melting—saving some snow for the following winter's snowfall to add to it.

How Else Can We Change the Heat (Radiation) Arriving From the Sun?

14. The sun's furnace fluctuates—but this works on short time scales (11-year sunspot cycle, not at glacial/interglacial time scales of tens to hundreds of thousands of years). We can vary the orbit of the earth and the sun to make it more elliptical, meaning that there are times when the earth is actually closer to the sun and times when the earth is farther away. This works on a 100,000-year time scale and is called eccentricity.

So, now knowing this information, ask students to create a scenario whereby we can have cool summers in the northern hemisphere. *(Answer: Try a smaller angle of tilt and have the North Pole tilted towards the sun, e.g., northern hemisphere summer, when the earth is furthest away from the sun in an elliptical orbit.)*



Muir Glacier, Alaska, photographed by William O. Field on August 13, 1941 (left) and by Bruce F. Molnia on August 31, 2004 (right). Image Credit: National Snow and Ice Data Center, W. O. Field, B. F. Molnia.

How Do We Melt Glaciers?

15. Just do the opposite. Create a situation whereby we have warm northern hemisphere summers—high angle of tilt of the North Pole toward the sun and have the earth located close to the sun during the northern hemisphere summer.

Explain that the waxing and waning of glaciers is a function of the earth's orbital cycles, combining the tilt and wobble of the axis of rotation and the changing elliptical shape of the earth's orbit around the sun. When these variables augment each other, glacial or interglacial events occur. Right now, the earth is dominated by a ~100,000-year cycle. So, the last major interglacial period similar to the one we are in now was ~125,000 years ago when sea level was actually a bit higher (about 6 m higher).

Ask students: How do we know that sea level was ~6 m higher 125,000 years ago? *(Answer: We see coral reefs that provide radiometric dates of this age at +5 to 6 m elevation—the islands forming the upper Florida Keys consists of elevated fossil coral reefs, for example.)*

- If we are in an interglacial period now, can we expect sea level to rise another 6 m? *(Answer: It is possible to happen again as it did in the past.)*
 - What important factors exist now that did not exist 125,000 years ago? *(Answer: No human agricultural/industrial complex existed back then—most scientists now feel that these human activities provide an unpredictable “wildcard” into the mix that may further aggravate global warming.)*
 - What might happen if sea level rises another 6 m? *(Answer: widespread disruption in human activity in coastal areas)*
16. Conclude with a discussion about what we as humans can do about our own impacts and potential impacts on global climate change. This is really open-ended and leads to a discussion of controlling global warming, reducing greenhouse gas emissions, developing a new energy policy, and many other related topics.