

Cross-Curricular Discussion

After students have had a chance to review the article "[2016 shattered Earth's heat record](#)," lead a classroom discussion based on the questions that follow. You can copy and paste only the questions that apply to your classroom into a different document for your students. Before starting the discussion, you may want to let your students explore some of the additional resources listed on [Blackline Master 4](#). You may also want to show these short videos to preface the discussion questions.

Video Resources:

- Smithsonian.com presents: [Climate Change 101 with Bill Nye the Science Guy](#)
- PBS's NOVA presents: [Climate Change](#)
- The National Oceanic and Atmospheric Administration explains: [What are El Niño and La Niña?](#)

PHYSICAL SCIENCES**Discussion Questions:**

1. How much light, or electromagnetic radiation, from the sun reaches Earth in Watts per square meter? For comparison, how much energy is emitted by a typical light bulb? [*Sun: approximately 1,366 Watts per square meter. Incandescent light bulb: approximately 50 to 100 Watts per square meter, but less for fluorescent and LED bulbs.*]
2. What are the various fates of components of the solar radiation striking Earth's atmosphere and surface? [*Energy is reflected into space by the atmosphere, absorbed and reemitted by the molecules in the atmosphere, reflected into space by the surface and absorbed and reemitted by the surface.*]

Extension Prompts:

3. What is the greenhouse effect? What is the radiative forcing, or the net amount of solar heating retained by Earth, caused by greenhouse gases? [*Sunlight of relatively shorter wavelengths (mainly ultraviolet and visible light) enters through the atmosphere, is absorbed by Earth's surface and is reemitted as thermal radiation of longer wavelengths (in the infrared region). While some of the infrared radiation passes through the atmosphere and is released into space, some is reabsorbed by certain molecules in the atmosphere and is released back toward Earth. Radiative forcing is around 1.5–2 W/m² and rising as the concentration of greenhouse gases in the atmosphere increases.*]
4. Explain how molecules in the atmosphere absorb infrared radiation (IR). Name a few molecules in

the atmosphere that would not be able to absorb IR. Name a few molecules that would likely absorb IR. *[For a molecule to absorb infrared radiation, molecular vibration or rotation must cause a net change in the molecular dipole moment. When the molecule vibrates, the change in dipole moment creates a field that interacts with the electric field of the electromagnetic radiation. When the vibrational frequency of the molecule matches the frequency of radiation, the radiation will be absorbed. Nonpolar molecules such as O₂ and N₂ would not absorb IR. Vibrations in the greenhouse gases such as polar H₂O molecules and asymmetric vibrations in nonpolar CO₂ molecules would absorb IR.]*

5. What sorts of phenomena could cause positive feedback for global warming? *[Because ice is more reflective than water, less ice and more water means more absorption of solar radiation; heating can accelerate the natural decay of plant and animal matter and release greenhouse gases; the loss of polar ice will allow people access to new fossil fuel reserves, for example.]*

Physical Sciences Question Bank

How much light, or electromagnetic radiation, from the sun reaches Earth in Watts per square meter? For comparison, how much energy is emitted by a typical light bulb?

What are the various fates of components of the solar radiation striking Earth's atmosphere and surface?

What is the greenhouse effect? What is the radiative forcing, or the net amount of solar heating retained by Earth, caused by greenhouse gases?

Explain how molecules in the atmosphere absorb infrared radiation (IR). Name a few molecules in the atmosphere that would not be able to absorb IR. Name a few molecules that would likely absorb IR.

What sorts of phenomena could cause positive feedback for global warming?

EARTH SCIENCES

Discussion Questions:

1. What are the major greenhouse gases? *[Carbon dioxide may be considered the most important, due to the amount being produced. Others such as methane, water vapor, nitrous oxide and ozone also have an effect. Methane is a major contributor to global warming and its concentration may increase as the Earth continues to warm.]*
2. How has the atmospheric carbon dioxide concentration changed in recent history? *[Increased from approximately 300 to more than 400 parts per million (ppm) over the last century. It is rising rapidly and could pass 1,000 ppm this century.]*
3. The article states that the global average surface temperature for 2016 was 0.94 degrees Celsius higher than the 20th century average. How is a single temperature calculated to represent the global average surface temperature for a given year? *[To get this figure, temperature is averaged over all areas, land and sea, day and night, throughout the year.]*

4. How has the global average temperature changed in recent history? *[It has risen by about 1 degree Celsius, or about 1.8 degree Fahrenheit, over the last century. It is predicted that it could rise several more degrees this century.]*

Extension Prompts:

5. Based on the graphic titled “Temperature difference in 2016 compared with 1891–2010 average” on Page 9 (also on [Blackline Master 2](#)), what possible reason can you imagine to explain the distribution of areas that are colder than normal? Explain. *[Melting ice, long-frozen in glaciers, is adding cold water to the ocean near Antarctica, Greenland and Siberia/Alaska.]*
6. How does increasing global temperature raise sea level? How has the global sea level changed in recent history? *[Ice melting from land increases the volume of water in the ocean, but water also expands as it warms. Global sea level has risen by about 20 centimeters over the last century. It could increase by one to two meters this century.]*
7. If all the ice on Earth melts, will there still be any land? *[Many islands and low-lying areas will go under, but there will still be a lot of land. Would you like to buy a nice condo in the Rocky Mountains?]*

Earth Sciences Question Bank

What are the major greenhouse gases?

How has the atmospheric carbon dioxide concentration changed in recent history?

The article states that the global average surface temperature for 2016 was 0.94 degrees Celsius higher than the 20th century average. How is a single temperature calculated to represent the global average surface temperature for a given year?

How has the global average temperature changed in recent history?

Based on the graphic titled “Temperature difference in 2016 compared with 1891–2010 average” on Page 9 (also on [Blackline Master 2](#)), what possible reason can you imagine to explain the distribution of areas that are colder than normal? Explain.

How does increasing global temperature raise sea level? How has the global sea level changed in recent history?

If all the ice on Earth melts, will there still be any land?

BIOLOGICAL SCIENCES

Discussion Questions:

1. Why does the global atmospheric level of carbon dioxide oscillate slightly up and down throughout each year? *[The seasonal variation in atmospheric carbon dioxide concentration is shown in the Keeling Curve. There is more plant-covered land area in the Northern Hemisphere than the Southern Hemisphere. When those plants are most active in the spring and summer of the Northern Hemisphere, they absorb some carbon dioxide from the atmosphere, causing the global concentration to dip. But when those plants are less*

active in the fall and winter, then atmospheric concentrations rise.]

2. What could be the effects of continued global warming on animal life at the poles? [*Loss of Arctic sea ice reduces territory. The area becomes less suitable for animals that roam on land and more suitable for aquatic animals. Polar bears will have to seriously rethink their fashion sense :) So will Santa Claus for that matter.*]
3. What could be the effects of continued global warming on life in areas such as southern Louisiana and southern Florida? [*Rising sea levels flood more area and increase water salinity in coastal areas, killing or driving out some plants and animals.*]
4. What could be the effects of continued ocean acidification from carbon dioxide on marine life? [*Ocean acidification can make it difficult for animals shells of alkaline calcium carbonate. Loss of those animals could affect the rest of the food web.*]

Extension Prompts:

5. The article mentions that both human-caused climate change and the strong 2015–2016 El Niño were likely causes of the rise in average global temperature observed for 2016. What is El Niño and how does it affect surface temperature? [*Typically, trade winds travel east to west across the Pacific Ocean near the equator and push warm surface water to the Western Pacific. This causes an upwelling of cold water along the west coast of South America. An El Niño occurs when the trade winds die down or reverse direction, and the upwelling of cold surface water along the west coast of South America is reduced. The overall effect of an El Niño is typically warmer-than-average conditions over parts of North America during the winter season, but it can also have large-scale impacts on global weather patterns.*]
6. How are the effects of human-caused climate change on species similar to or different from the effects of previous climate changes? [*Natural climate change tends to occur slowly over millions of years, allowing species to adapt or relocate. Current climate change is comparatively very sudden, perhaps more comparable with the sudden events that have caused mass extinctions, like the extinction of the dinosaurs and other species 66 million years ago.*]

Biological Sciences Question Bank

Why does the global atmospheric level of carbon dioxide oscillate slightly up and down throughout each year?

What could be the effects of continued global warming on animal life at the poles?

What could be the effects of continued global warming on life in areas such as southern Louisiana and southern Florida?

What could be the effects of continued ocean acidification from carbon dioxide on marine life?

The article mentions that both human-caused climate change and the strong 2015–2016 El Niño were

likely causes of the rise in average global temperature observed for 2016. What is El Niño, and how does it affect surface temperature?

How are the effects of human-caused climate change on species similar to or different from the effects of previous climate changes?

ENGINEERING AND EXPERIMENTAL DESIGN

Discussion Questions:

1. What energy sources produce greenhouse gases and thus contribute to human-caused climate change? What energy sources do not produce greenhouse gases? [*Greenhouse gas-producing energy sources: Burning fossil fuels including coal, natural gas, oil and gasoline refined from oil. Energy sources that do not directly produce greenhouse gases: Nuclear energy, solar energy, wind energy, hydroelectric energy, hamster wheels, etc.*]
2. Do electric vehicles reduce greenhouse gas production? [*Only if they are more efficient than cars with internal combustion engines or are charged using electricity generated by sources that don't include fossil fuels. Some just move the location of greenhouse gas emissions from the tailpipe to the local fossil fuel power plant that produced the electricity.*]

Extension Prompts:

3. How could you reduce global energy consumption? [*Improve efficiency of devices that consume energy, use less energy for heating and cooling, reduce production and consumption, increase recycling, reduce travel or take forms of travel that consume less energy, and so on.*]
4. How could you decrease the amount of carbon dioxide in the atmosphere and ocean? [*Capture it and store it, for example by pumping it underground; decrease the amount produced by humans to begin with; and so on.*]
5. How could you decrease the net amount of solar radiation absorbed by Earth? [*Create space mirrors or space clouds to block some from reaching Earth, scatter reflective particles in the upper atmosphere, increase reflective surfaces on land or on water, and so on.*]
6. If climate change continues, how could civilization try to adapt? [*Decrease population, shift population inland as sea level rises, move underground where it is cooler, head into space, and so on.*]

Engineering and Experimental Design Question Bank

What energy sources produce greenhouse gases and thus contribute to human-caused climate change?
What energy sources do not produce greenhouse gases?

Do electric vehicles reduce greenhouse gas production?

How could you reduce global energy consumption?

How could you decrease the amount of carbon dioxide in the atmosphere and ocean?

How could you decrease the net amount of solar radiation absorbed by Earth?

If climate change continues, how could civilization try to adapt?

February 18, 2017

2016 shattered Earth's heat record

Cross-Curricular Discussion and Activity Resource List

Directions: Use "[2016 shattered Earth's heat record](#)" and the following resources to answer related discussion questions or to research a related topic assigned by your teacher.

Websites:

National Oceanic and Atmospheric Administration gives a Global Analysis by year:

<https://www.ncdc.noaa.gov/sotc/global/201613>

National Center for Science Education presents educational resources about climate change:

<http://ncse.com/climate>

NASA Goddard Institute for Space Studies provides global surface temperature graphs and maps:

<http://data.giss.nasa.gov/gistemp/>

Environmental Protection Agency presents educational resources about climate change:

<https://www3.epa.gov/climatechange/>

Intergovernmental Panel on Climate Change offers numerous online reports:

http://ipcc.ch/publications_and_data/publications_and_data_reports.shtml

RealClimate presents educational resources about climate change:

<http://www.realclimate.org/index.php/archives/2007/05/start-here/>

Woods Hole Research Center offers a Global Carbon Cycle Primer:

<http://whrc.org/publications-data/global-carbon-cycle/>

Woods Hole Research Center offers Understanding Climate Change: A Primer:

<http://whrc.org/publications-data/understanding-climate-change-a-primer/>

NOAA Geophysical Fluid Dynamics Laboratory presents climate change data:

<https://www.gfdl.noaa.gov/climate-change/>

NOAA Geophysical Fluid Dynamics Laboratory presents data on specific climate impacts:

<https://www.gfdl.noaa.gov/climate-impacts/>

NASA Earth Observatory gives a variety of global maps:

<http://earthobservatory.nasa.gov/GlobalMaps/?eocn=topnav&eoci=globalmaps>

American Association for the Advancement of Science describes the consensus of 31 scientific societies about climate change:

<https://www.aaas.org/news/intersocietyclimateletter2016>

Union of Concerned Scientists presents the scientific consensus on global warming:

www.ucsusa.org/ssi/climate-change/scientific-consensus-on.html

Grist proposes responses to the most common skeptical arguments on global warming:

<http://grist.org/series/skeptics/>