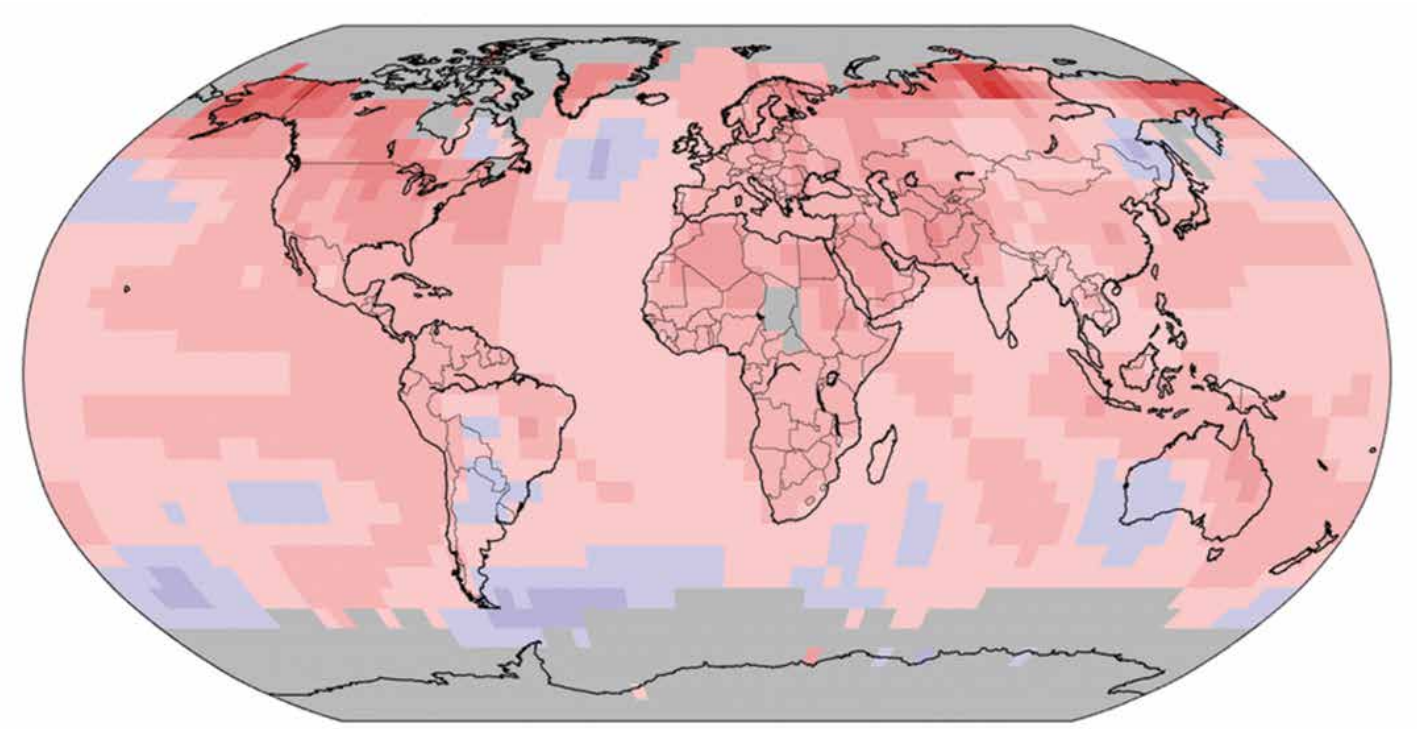
ScienceNews
IN HIGH SCHOOLS | EDUCATOR GUIDE



February 18, 2017

2016 shattered Earth's heat record

SOCIETY FOR
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SN EDUCATOR GUIDE

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About this Issue

The article "2016 shattered Earth's heat record" (9.3 readability score) describes the record high global average temperature and record low global sea ice extent during 2016, and places that data within the larger context of climate change. Students can focus on trends that climate scientists are recording as described in the article, follow connections to earlier articles about climate change, explore cross-curricular connections to other major science topics and work in groups to study and report on various aspects of climate change science. *Science News for Students* provides another version of this article written at a lower Lexile level (7.5 readability score): "Earth breaks heat record for third year straight." *Power Words* are defined at the end of the *Science News for Students* article. Also, *Science News for Students* describes "El Niño and La Niña" (8.2 readability score) and "Global warming and the greenhouse effect" (8.5 readability score) in two brief explainers.

Want to introduce your students to an interesting STEM career related to this article? Check out Cool Jobs: Hunting surprises in thinning glaciers by *Science News for Students*.

Connections to Curricula

- Climate change
- Atmospheric science
- Ocean current science
- Fossil fuels
- Renewable energy sources
- Meteorology
- Infrared spectroscopy
- History of the Earth
- Energy

What's in this Guide?

- Article-Based Observation: These questions focus on reading and content comprehension by drawing on information found in the article "2016 shattered Earth's heat record." Questions focus on observations about Earth's surface temperature over time and reasons behind the changing climate.
- Quest Through the Archives: With Internet access and your school's digital access to *Science News*, your students can use this short section to explore the history of climate change research and technology as reported by *Science News* since 1922.
- Cross-Curricular Discussion: These questions and extension prompts encourage students to think in more detail about scientific areas related to the article. The section is subdivided roughly by science subdiscipline for educators who would like to focus on one particular topic area. The extension prompts are either more topic specific or more conceptually advanced. **Physical Sciences** questions concern the radiant energy coming to and from Earth and the imbalance that causes net warming. **Earth Sciences** questions address the effects of global warming on the atmosphere, land and ocean. **Biological Sciences** questions involve effects on species and their survival. **Engineering and Experimental Design** questions focus on possible methods of averting or adapting to climate change.

- Activity: While working in groups, students can use **Climate Change: Analyze the Data** to explore available data and research various aspects of climate change. Each student group is charged with supporting their claims about a climate change topic with relevant data captured in charts and graphs on suggested sites. Teachers may choose to review best slide-making and presentation techniques before the groups share their findings with the class.

Standards Alignment

Next Generation Science	Common Core
Earth's Systems: HS-ESS1-2, HS-ESS1-4, HS-ESS1-6	ELA Standards: Reading Informational Text (RI): 1, 2, 3, 4, 5, 6, 7, 8
Earth and Human Activity: HS-ESS3-1, HS-ESS3-2, HS-ESS3-3, HS-ESS3-4, HS-ESS3-5, HS-ESS3-6	ELA Standards: Writing (W): 1, 2, 3, 4, 6, 7, 8, 9
Energy: HS-PS3-1, HS-PS3-2	ELA Standards: Speaking and Listening (SL): 1, 2, 3, 4, 5, 6
Ecosystems: Interactions, Energy, and Dynamics: HS-LS2-1, HS-LS2-6, HS-LS2-7	ELA Standards: Reading for Literacy in Science and Technical Subjects (RST): 1, 2, 3, 4, 5, 6, 7, 8, 9
Biological Evolution: Unity and Diversity: HS-LS4-4, HS-LS4-5	ELA Standards: Writing Literacy in History/Social Studies and Science and Technical Subjects (WHST): 1, 2, 4, 6, 7, 8, 9
Engineering Design: HS-ETS1-1, HS-ETS1-2, HS-ETS1-3	

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Article-Based Observation

Directions: Read the recent article "2016 shattered Earth's heat record" and then answer these questions:

1. **What was significant about Earth's surface temperature in 2016?**

2. **The graphic titled "Temperature difference in 2016 compared with 1891–2010 average" on Page 9 (also on Blackline Master 2) compares the temperature in 2016 with the 1891–2010 average. What does the graphic show and how does it lead to the conclusion that 2016 broke the heat record?**

3. **What other record was set in 2016 and early 2017?**

4. **The graph titled "Vanishing ice: 1978–2017" on Blackline Master 2 shows daily fluctuations in global sea ice extent from 1978 to 2017. What general trend occurs over the course of a year? What does the gray-shaded region indicate? How does the global sea ice extent at the beginning of November 2016 compare with the gray-shaded region for that time?**

5. **According to climate scientist Kevin Trenberth, what factors have caused warmer temperatures in 2016?**

6. **What metaphor is used by Kevin Trenberth to describe global temperature changes? Use the metaphor to explain his predictions about future global temperatures.**

7. **Give two examples of supporting data from the article's text that indicate global warming in recent years.**

8. **Come up with another catchy title for the article that summarizes the content.**

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Responses to Article-Based Observation

1. **What was significant about Earth's surface temperature in 2016?** Possible student response: 2016 was the warmest year on record since record-keeping began in 1880.

2. **The graphic titled "Temperature difference in 2016 compared with 1891–2010 average" on Page 9 (also on Blackline Master 2) compares the temperature in 2016 with the 1891–2010 average. What does the graphic show and how does it lead to the conclusion that 2016 broke the heat record?** Possible student response: Blue areas indicate places where the average temperature in 2016 was cooler than the long-term average temperature (from 1891 to 2010), and red areas indicate places where the 2016 average was warmer than the long-term average. There appear to be many more red areas than blue areas (a rough estimate might indicate about 90% red and 10% blue—not including the gray area).

3. **What other record was set in 2016 and early 2017?** Possible student response: Global sea ice extent was at its smallest area in potentially thousands of years, according to data from the National Snow and Ice Data Center and sea ice reconstructions.

4. **The graph titled "Vanishing ice: 1978–2017" on Blackline Master 2 shows daily fluctuations in global sea ice extent from 1978 to 2017. What general trend occurs over the course of a year? What does the gray-shaded region indicate? How does the global sea ice extent at the beginning of November 2016 compare with the gray-shaded region for that time?** Possible student response: Global sea ice extent fluctuates throughout the year in a consistent pattern—sea ice extent is generally lowest in late February and highest in early November. The gray-shaded region shows two standard deviations from the average daily sea ice extent. The global sea ice level at the beginning of November 2016 is a little less than 24 million square kilometers, which is about 2 million square kilometers less than the lowest extent of the gray-shaded region and about 4 million square kilometers less than the highest extent of the gray-shaded region.

5. **According to climate scientist Kevin Trenberth, what factors have caused warmer temperatures in 2016?** Possible student response: Human fossil fuel consumption was partly to blame. But one of the three strongest El Niño occurrences on record also raised global temperatures, by releasing heat from the ocean into the atmosphere.

6. **What metaphor is used by Kevin Trenberth to describe global temperature changes? Use the metaphor to explain his predictions about future global temperatures**. Possible student response: Kevin Trenberth says that "the temperature record is like going up a staircase," and the 2015 and 2016 temperatures have gone up to the next "step." While he thinks oscillations around these new high temperatures are likely, he doesn't think that average global temperature will go back down the stairs to the temperatures of previous years.

7. **Give two examples of supporting data from the article's text that indicate global warming in recent years.** Possible student response: The 2016 global average surface temperature was 0.94 degrees Celsius higher than the 20th century average. The 2015 global average surface temperature was 0.90 degrees Celsius higher than the 20th century average. All 16 years of the 21st century are among the 17 warmest years on record.

8. **Come up with another catchy title for the article that summarizes the content.** Possible student response: "Climbing climate change—the 2016 heat record reports."

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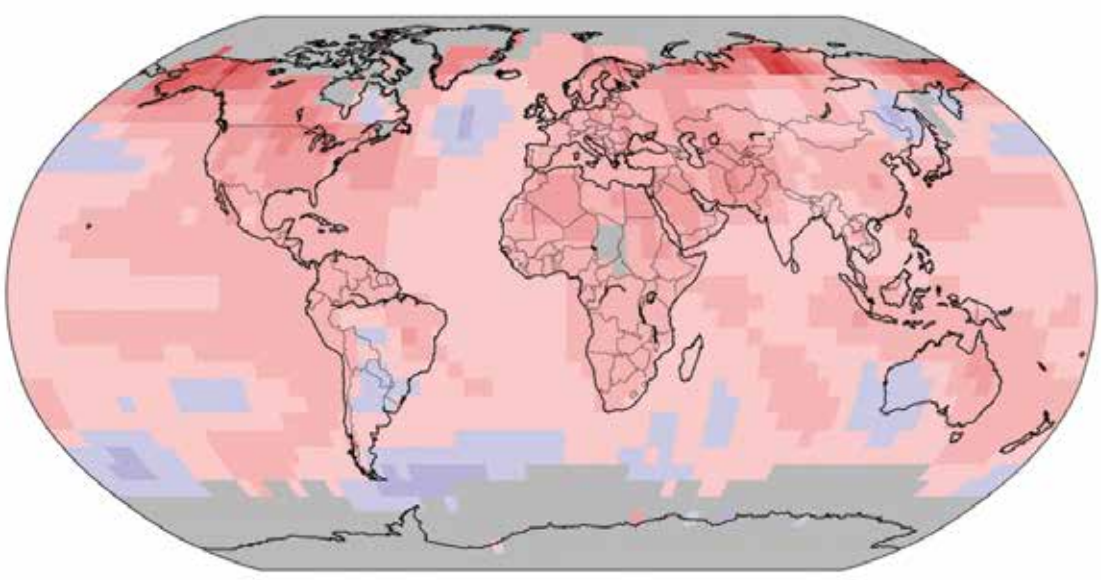
Article-Based Observation

Directions: Use the graphics from "2016 shattered Earth's heat record" to answer the related questions.

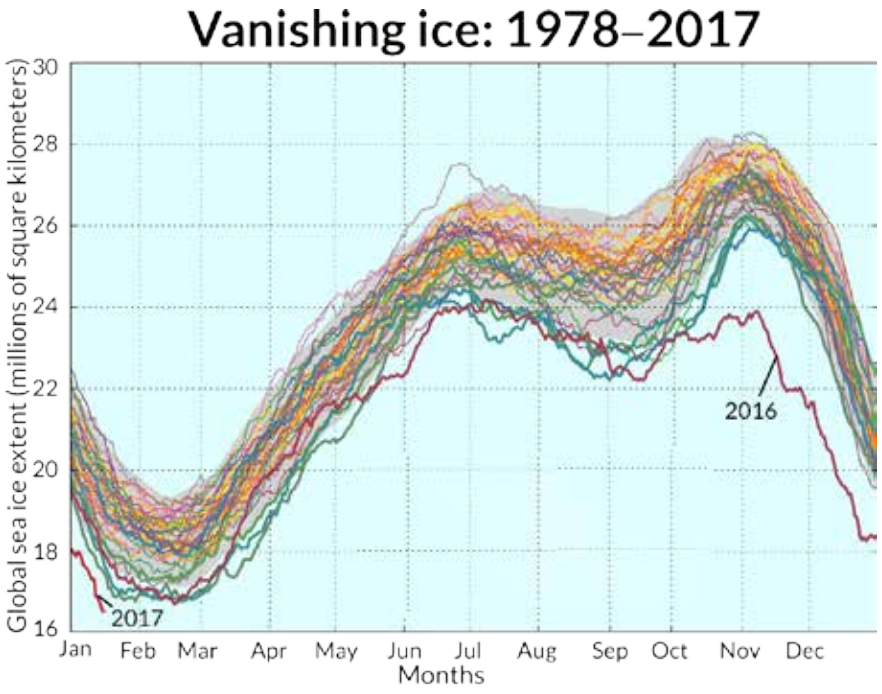


Temperature difference in 2016 compared with 1891–2010 average

−5 −4 −3 −2 −1 0 1 2 3 4 5

Degrees Celsius

SOURCE: NOAA



SOURCE: NSIDC

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Quest Through the Archives

Directions: After reading the article "2016 shattered Earth's heat record," use the archives at www.sciencenews.org to answer these questions:

1. **Search for the earliest published article about factors that affect climate in the *Science News* archives. What is it about?**

2. **Search for the earliest published article you can find that discusses suggested government interventions on climate change in the *Science News* archives. What studies are discussed?**

3. **Find at least two articles that share progress made in scientific research for techniques used to combat climate change. What ideas do they present?**

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Responses to Quest Through the Archives

1. **Search for the earliest published article about factors that affect climate in the *Science News* archives. What is it about?** Possible student response: "Ozone may control world heat supply," published on 11/22/1924, discusses the role that ozone plays in trapping heat in the atmosphere and its effect on climate.

2. **Find at least two articles that share progress made in scientific research for techniques used to combat climate change. What ideas do they present?** Possible student response: "Scientists Advise Congress," published 4/9/1960, outlines the need for government-supported satellite studies to observe energy input and output in Earth's atmosphere. The article goes on to mention that the continued consumption of fossil fuels might be altering the climate and geography, so gathering appropriate data to monitor such changes is important.

3. **Find at least two articles that share progress made in scientific research for techniques used to combat climate change. What ideas do they present?** Possible student response: "Volcanic rocks help turn carbon emissions to stone—and fast," published online 6/9/2016 discusses solidifying excess carbon dioxide emissions by pumping carbon dioxide into basaltic lava rock. Though this is an expensive process, it doesn't require monitoring over time. "There's something cool about Arctic bird poop," published 11/15/2016, discusses how researchers discovered that the ammonia produced by bacteria that consume Arctic bird poop can help form clouds. More cloud surface area reflects a larger percentage of sunlight and helps to keep Earth cool.

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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/m^2 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 O_2 and N_2 would not absorb IR. Vibrations in the greenhouse gases such as polar H_2O molecules and asymmetric vibrations in nonpolar CO_2 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, casuing 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? [T*ypically, 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?

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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/

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Teacher's Guide for Climate Change: Analyze the Data

Class time: 40-120 minutes (or longer depending on your approach)

Purpose: Because there is so much scientific research seeking to understand the past, present and future of climate change, students or groups of students can research some of those aspects in much more detail themselves. They can learn how to analyze and summarize key data and then report their findings as in-class presentations (or written papers, if class time is limited). If time permits, after groups are finished presenting, have students work on a culminating activity that encourages them to summarize the information that they have learned to form a powerful message. Creating a public service announcement, for example, could be an alternative assessment for the project. The University of Kansas Community Tool Box shares information about preparing public service announcements.

Notes to the teacher:
You can adapt this activity based on the number and the level of the students, as well as the amount of available class time. Use Blackline Master 4 as an initial list of resources for your students and Blackline Master 5 for specific questions and resources relating to each group's topic. Also, consider discussing best slide-making and presentation practices with your students before they begin.

Presentation and slide tips:
Dartmouth's Biomedical Library gives PowerPoint: Guides, Tips and Help

Rubric resources:
Ohio University's Rubric for PowerPoint and Oral Presentation
University of Wisconsin-Madison suggests Sample Scoring Rubrics for Presentations
Make your own rubric with iRubric from Rcampus

Directions:

1. Assign different groups of students to research and report their findings on different aspects of climate change. Possible group topics include:
    - Group 1: Causes of climate change
    - Group 2: Current state of the climate
    - Group 3: Potential future climate change scenarios
    - Group 4: Potential methods of limiting or reversing climate change
    - Group 5: Climate change policies and winning over skeptics
2. Discuss effective slide-making and presentation techniques.
3. Provide student groups with recommended resources, such as the questions on Blackline Master 5, and allow them to conduct research during class or as homework.
4. Have the student groups prepare and present slides (about 10–15 slides per group is recommended) summarizing their findings for the class.

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Student Instructions for Group 1: Causes of Climate Change

Your group should research the causes and history of climate change, using the resources list given by your teacher or other resources that you or your teacher find online, in books or in journals. Find the most important data and graphs, put them into approximately 10–15 slides (with notes about sources and explanatory comments of your own) and give a short presentation in class to explain your findings and answer questions from the class. All of your statements and findings should be supported with appropriate data.

Start with the following resource:
Environmental Protection Agency presents educational resources about the causes of climate change: https://www.epa.gov/climate-change-science/causes-climate-change

Then look at as many other sources as you can and gather the best data.

You should especially consider:

- How have global temperatures changed over time?
- How has the concentration of atmospheric greenhouse gases changed over time?
- How has sea level changed over time?
- How has ocean pH changed over time?
- What natural factors have influenced recent climate change, how much of an effect have they had and how do we know?
- What human-caused factors have influenced climate change, how much of an effect have they had and how do we know?

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Student Instructions for Group 2: Current State of the Climate

Your group should research the current state of the climate (compared with conditions druing the 19th and 20th centuries) using the resources below or other resources that you or your teacher find online, in books or in journals. Find the most important data and graphs, put them into approximately 10–15 slides (with notes about sources and explanatory comments of your own) and give a short presentation in class to explain your findings and answer questions from the class. All of your statements and findings should be supported with appropriate data.

Start with the following resources:

NASA Goddard Institute for Space Studies presents graphs on surface temperature analysis: https://data.giss.nasa.gov/gistemp/graphs/

NASA Goddard Institute for Space Studies shows maps on surface temperature analysis: https://data.giss.nasa.gov/gistemp/maps/

Then look at as many other sources as you can and gather the best data.

You should especially consider:

- What are current temperatures (highs, lows and averages globally and for different areas of the world and different times of year)?
- How do those temperatures compare with values from the past?
- How do current concentrations of atmospheric greenhouse gases compare with those of the past?
- How do current sea levels compare with those of the past?
- How do current ocean pH values compare with those of the past?
- How do current precipitation levels compare with those of the past?
- How do current volumes of glaciers, polar ice caps and sea ice compare with those of the past?
- What impact is climate change currently having on the extinction of species?
- What impact is climate change currently having on flooding?
- What impact is climate change currently having on agriculture?
- What impact is climate change currently having on storms and other natural disasters?

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Student Instructions for Group 3: Potential Future Climate Change Scenarios

Your group should research the potential future of the climate (compared with current or past conditions) using the resources below or other resources that you or your teacher find online, in books or in journals. Find the most important data and graphs, put them into approximately 10–15 slides (with notes about sources and explanatory comments of your own) and give a short presentation in class to explain your findings and answer questions from the class. All of your statements and findings should be supported with appropriate data.

Start with the following resources:

Environmental Protection Agency presents resources about the future of climate change:
https://www.epa.gov/climate-change-science/future-climate-change

Intergovernmental Panel on Climate Change offers numerous online reports:
http://ar5-syr.ipcc.ch/topic_futurechanges.php

NOAA Geophysical Fluid Dynamics Laboratory presents climate change data:
http://www.gfdl.noaa.gov/will-the-wet-get-wetter-and-the-dry-drier

Then look at as many other sources as you can and gather the best data.

You should especially consider:

- What are some leading scenarios that could occur as a result of continued greenhouse gas emissions?
- For those different emissions scenarios, how much are temperatures expected to change (global averages, as well as values for different areas of the world and different times of year) by 2050?
- What about by 2100 and beyond?
- For those different emissions scenarios, how much are sea levels expected to change by 2050, 2100 and beyond?
- For those different emissions scenarios, how much are ocean pH values expected to change by 2050, 2100 and beyond?
- For those different emissions scenarios, how much are precipitation levels expected to change by 2050, 2100 and beyond?
- What impact could future climate change have on the extinction of species?
- What impact could future climate change have on flooding of specific areas (especially consider the Louisiana coast, southern Florida, the North Carolina coast and the Chesapeake Bay area)?
- What impact could future climate change have on storms and other natural disasters?
- What impact could future climate change have on agriculture?
- What impact could future climate change have on human famines and wars?

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Student Instructions for Group 4: Potential Methods of Limiting or Reversing Climate Change

Your group should research potential methods of limiting or reversing climate change using the resources below or other resources that you or your teacher find online, in books or in journals. Find the most important data and graphs, put them into approximately 10–15 slides (with notes about sources and explanatory comments of your own) and give a short presentation in class to explain your findings and answer questions from the class. All of your statements and findings should be supported with appropriate data.

Start with the following resources:

Environmental Protection Agency presents educational resources about climate change:
https://www.epa.gov/climatechange/adapting-climate-change

NASA suggests climate changes solutions:
http://climate.nasa.gov/solutions/adaptation-mitigation/

The National Academies offers Climate Intervention Reports and other resources:
https://nas-sites.org/americasclimatechoices/other-reports-on-climate-change/climate-intervention-reports/

Then look at as many other sources as you can and gather the best data.

You should especially consider:

- What would be required to reduce global energy consumption?
- What would be required to switch to energy sources that do not produce greenhouse gases?
- What would be required to decrease solar heating of the Earth?
- What would be required to remove carbon dioxide from the atmosphere and ocean?
- What would be required to adapt human civilization if climate change continues?

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Student Instructions for Group 5: Climate Change Policies and Winning Over

Your group should research some of the major environmental policies involving climate change preventions. Also research the arguments of climate change skeptics and what responses may convince them using the resources below or other resources that you or your teacher find online, in books or in journals. Find the most important data and graphs, put them into approximately 10–15 slides (with notes about sources and explanatory comments of your own) and give a short presentation in class to explain your findings and answer questions from the class. All of your statements and findings should be cited to the appropriate source.

Start with the following resources:

The National Center for Science Education provides resources on climate change and policy:
https://ncse.com/node/16981

Science News writes "Outgoing congressman Rush Holt calls scientists to action":
https://www.sciencenews.org/article/outgoing-congressman-rush-holt-calls-scientists-action#video

Science News writes "Depolarizing climate science":
https://www.sciencenews.org/blog/science-public/depolarizing-climate-science

Science News writes "Changing climate: 10 years after An Inconvenient Truth":
https://www.sciencenews.org/article/changing-climate-10-years-after-inconvenient-truth

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

Then look at as many other sources as you can and gather the best data.

You should especially consider:

- What environmental policies are already in place to help prevent climate change in the United States? In the world?
- What are some of the people and groups that deny or cast doubt on human-caused climate change?
- What are some of the primary arguments of those skeptics?
- How do these arguments relate to the available scientific evidence?
- Do the skeptics seem to be motivated by scientific evidence or by other factors?
- Why is climate change science debated?