EXPLORING the ENVIRONMENT®

Global Climate Change

What Is Climate Change?

- **Climate** – long-term weather patterns that characterize regions of the world.
- **Weather** – short-term, day-to-day climate conditions.
- **Climate change** – changes to long-term weather patterns that have been recorded.

Why Study Climate Change?

- Climate affects every part of your daily life.
- Changes in our climate could have profound, long-lasting effects.
- It is important to be “climate literate” and to understand the connections between Earth’s climate, living organisms, and physical spheres.

Key Indicators

- Scientists use ***key indicators*** to identify possible trends in Earth's climate.

- A key indicator is a measurable factor that can be used to draw conclusions about a problem.

- Key indicators for climate change include: global temperatures, Earth's biodiversity, drought frequency, human health effects, ice caps and sea levels, atmospheric gas levels, and disease occurrence and frequency.

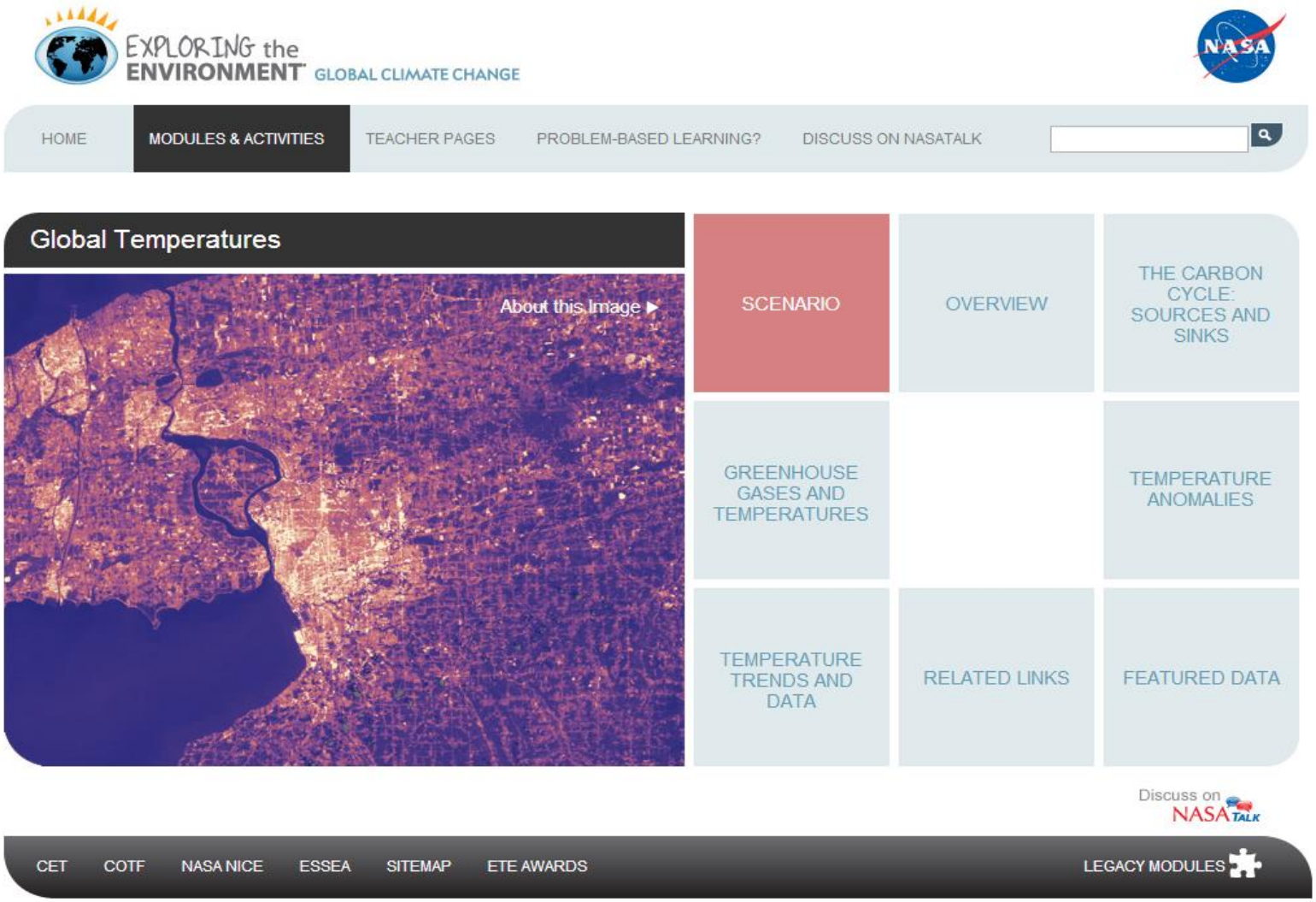
How Will Students Study Global Climate Change?

Students will:

- Take on the role of a scientist studying a global climate change key indicator.
- Use data to investigate and analyze trends in the key indicator.
- Draw conclusions about what is happening to Earth's climate.
- Present findings and conclusions.

Exploring the Environment-Global Climate Change

http://www.cotf.edu/ete/gcc/?/



Using the Website

- Students can access each key indicator from the homepage by clicking on the indicators listed at the bottom of the satellite image or by clicking on the **“Modules and Activities”** button and choosing an indicator. The Global Temperature module is shown in the previous slide.

- Each indicator has topics that help you get started on your research.

Scenario

The scenario introduces the topic and role as a global climate change scientist returning home after many months of research work in remote locations all over the world. Students now must prepare to analyze findings and present their conclusions to an international panel.

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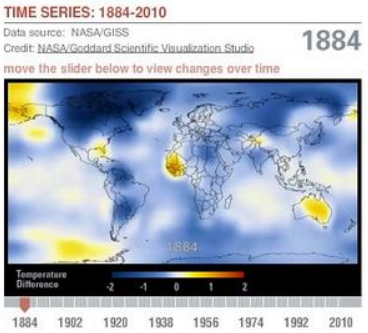
Scenario

As a research scientist working for the U.S. Panel on Global Climate Change Research, you and your colleagues have been collecting data in the field for months. You've studied research on varying aspects of Earth's diverse ecosystems, and your colleagues are now gathering to share their experiences and preliminary findings with the rest of the group.

With a major international conference looming, it's time for all of you to analyze the data to formulate a comprehensive report on global climate change on planet Earth.

This conference requires more than a standard report citing data and displaying results in tables and graphs. Analysis of the data will be required to fully present an accurate picture of the state of the planet's climate and trends that have been the focus of heated controversy and debate for the last decade. As a scientist, you naturally look at the data from purely objective perspectives.

Given the ongoing controversy surrounding the recorded rise in Earth's global mean temperatures, your team will have to provide some concrete analysis of temperature data for the report to the international commission.



Remember: Each research team is analyzing a global climate change indicator. Your indicator, global mean temperatures, will be an important component to the overall climate change picture.

The scenario also details student task descriptions.

For example, for the Global Temperature module:

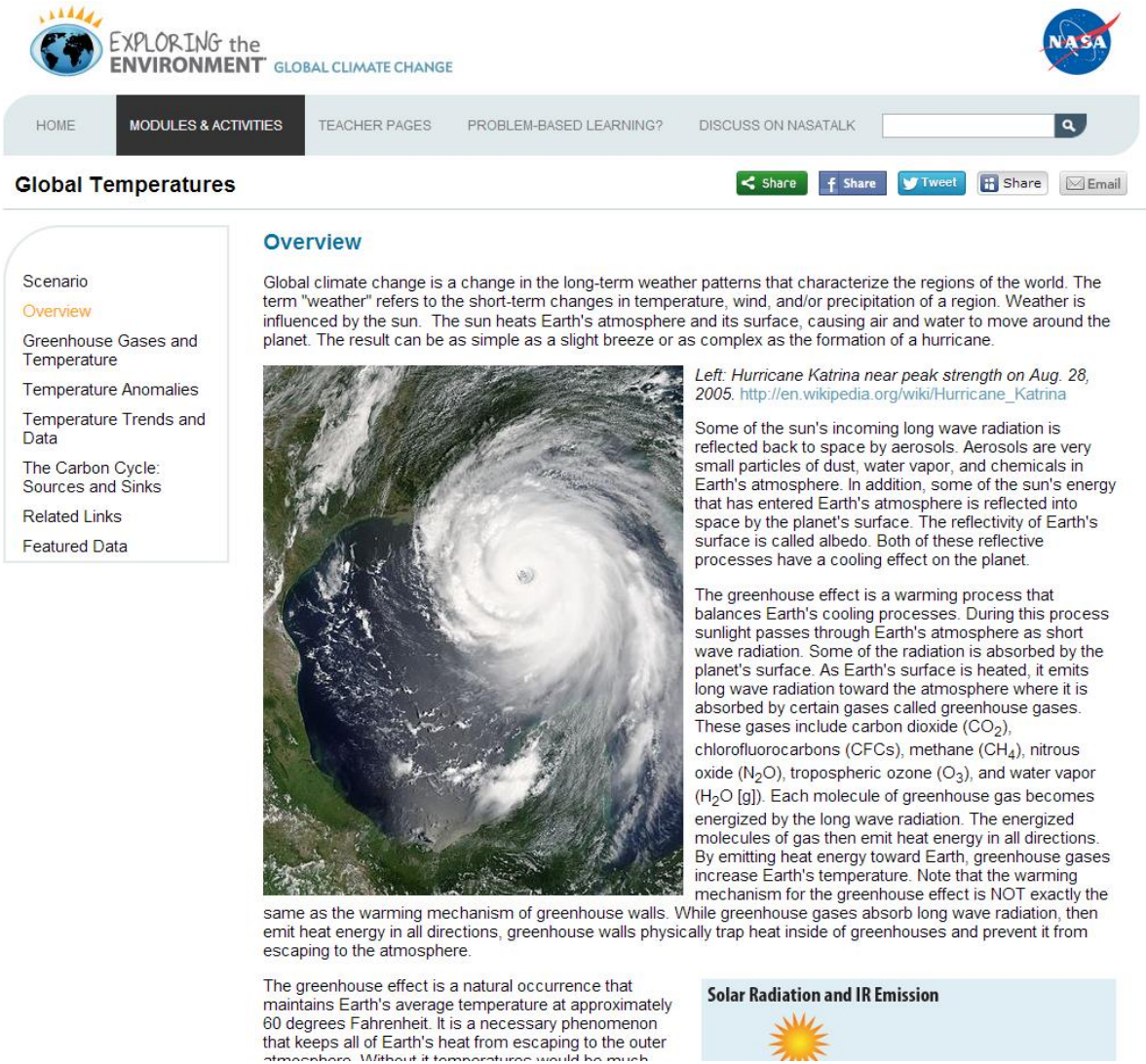
In order to present accurate, complete, and valid findings, you will:

- Analyze data and identify any trends that occurred in global mean temperatures.
- What are the impacts of this change? Remember to report the impacts to humans, wildlife, ecosystems, etc.
- What appears to be the source(s) of the changes? Can you identify a major cause?
- What strategies do you see that could mitigate or lessen the change? How long would they take to make a difference? What are the pros and cons of the approach?

Overview

The Overview presents an introduction to background information on the key indicator. Students gain a basic understanding of the mechanisms at work.

Students use this information to help them get started with their analysis of the data.



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Overview

Global climate change is a change in the long-term weather patterns that characterize the regions of the world. The term "weather" refers to the short-term changes in temperature, wind, and/or precipitation of a region. Weather is influenced by the sun. The sun heats Earth's atmosphere and its surface, causing air and water to move around the planet. The result can be as simple as a slight breeze or as complex as the formation of a hurricane.

Left: Hurricane Katrina near peak strength on Aug. 28, 2005. http://en.wikipedia.org/wiki/Hurricane_Katrina

Some of the sun's incoming long wave radiation is reflected back to space by aerosols. Aerosols are very small particles of dust, water vapor, and chemicals in Earth's atmosphere. In addition, some of the sun's energy that has entered Earth's atmosphere is reflected into space by the planet's surface. The reflectivity of Earth's surface is called albedo. Both of these reflective processes have a cooling effect on the planet.

The greenhouse effect is a warming process that balances Earth's cooling processes. During this process sunlight passes through Earth's atmosphere as short wave radiation. Some of the radiation is absorbed by the planet's surface. As Earth's surface is heated, it emits long wave radiation toward the atmosphere where it is absorbed by certain gases called greenhouse gases. These gases include carbon dioxide (CO_2), chlorofluorocarbons (CFCs), methane (CH_4), nitrous oxide (N_2O), tropospheric ozone (O_3), and water vapor (H_2O [g]). Each molecule of greenhouse gas becomes energized by the long wave radiation. The energized molecules of gas then emit heat energy in all directions. By emitting heat energy toward Earth, greenhouse gases increase Earth's temperature. Note that the warming mechanism for the greenhouse effect is NOT exactly the same as the warming mechanism of greenhouse walls. While greenhouse gases absorb long wave radiation, then emit heat energy in all directions, greenhouse walls physically trap heat inside of greenhouses and prevent it from escaping to the atmosphere.

The greenhouse effect is a natural occurrence that maintains Earth's average temperature at approximately 60 degrees Fahrenheit. It is a necessary phenomenon that keeps all of Earth's heat from escaping to the outer atmosphere. Without it temperatures would be much

Solar Radiation and IR Emission

Background Information

Each key indicator also includes other pages of background information to help students understand the topics that are connected to your indicator. Shown here is a site explaining the carbon cycle and its sources and sinks.

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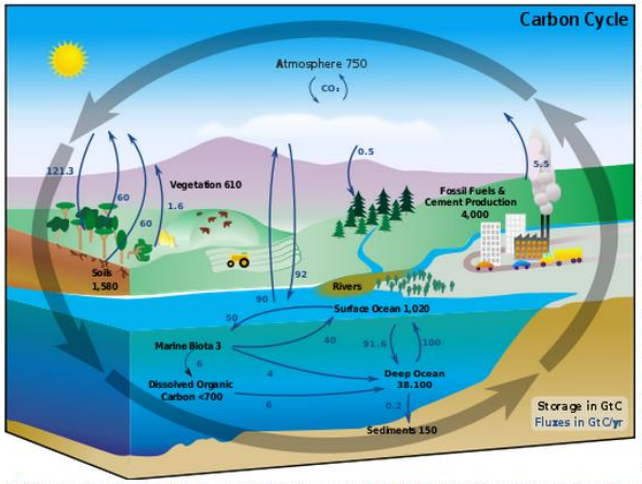
The Carbon Cycle: Sources and Sinks

Compounds that contain the element carbon are referred to as "organic." They are present in all living things. Carbon is continually moving among Earth's lithosphere, hydrosphere, biosphere, and atmosphere in various forms: as carbon dioxide (CO_2) in the atmosphere, sugars or carbohydrates ($C_nH_{2n}O_n$) in living organisms, and calcium carbonate ($CaCO_3$) in rocks and minerals, to name just a few. The movement of carbon among Earth's spheres, as diagrammed below, is known as the carbon cycle.



The black numbers in the diagram indicate how much carbon is stored in carbon sinks (areas of storage) in billions of tons (gigatons—GtC). The arrows show how carbon moves among Earth's spheres.

Green plants play a very important role in the carbon cycle. They absorb carbon dioxide (CO_2) from the atmosphere and produce carbon-containing sugars. This process is called photosynthesis. There are two main steps in photosynthesis. First, plants trap the sun's light energy in a compound called chlorophyll. This energy is converted to a chemical form called adenosine triphosphate (ATP). In the second step plants use the energy from ATP to produce sugar ($C_6H_{12}0_6$). The process of photosynthesis requires water (H_2O). It also produces water as well as oxygen (O_2). The net chemical reaction for the process of photosynthesis is $6\ CO_2 + 6\ H_2O$ + sunlight ------> $C_6H_{12}O_6 + 6\ O_2$.

Animals eat plants to obtain the energy trapped during photosynthesis. As the animals' bodies break down the carbohydrates in the plant tissue, CO_2 is released to the atmosphere. This process is called respiration. The net chemical reaction for the process of respiration is the exact opposite of photosynthesis: $6\ O_2 + C_6H_{12}O_6$ ------> $6\ H_2O + 6\ CO_2$. Plants respire also as they break down the organic molecules in themselves in order to release the stored energy. Plants and animals also release CO_2 to the atmosphere when they decay.

Background Information (cont.) Greenhouse Gases and Temperature

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Greenhouse Gases and Temperature

A greenhouse gas (GHG) is any gas in the atmosphere that absorbs and emits radiation in the thermal infrared range. These are the fundamental cause of the greenhouse effect, which results in increased temperatures on Earth.

The greenhouse effect occurs as the gases reach Earth's surface. As the short wave energy heats the surface, some of the longer wave energy radiates back into the atmosphere and back into space. Greenhouse gases absorb some of the energy and trap it in the lower atmosphere. Less heat radiates into space, and Earth is warmer.

Many greenhouse gases occur naturally. Carbon dioxide, methane, water vapor, and nitrous oxide are naturally present in Earth's atmosphere. Others, such as chorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6), are human made. Because of the Industrial Revolution atmospheric greenhouse gas concentrations have been rising over the last few centuries. Increasing population and dependence on fossil fuels for energy have resulted in a sharp rise in GHG emissions. While some GHGs do occur naturally, other human activity has interfered with the natural cycles that can moderate the effect of the increasing emissions.

Read about the characteristics and implications of some of the major greenhouse gases below. Use the Related Links and other resources in this module to investigate other greenhouse gases and their effects on global climate.

Water Vapor

Water vapor is the most abundant greenhouse gas in Earth's atmosphere. Changes in the concentration of water vapor in our atmosphere are not attributed directly to industrialization but to climate feedbacks related to climate warming. Although the water cycle is well understood, feedback loops connecting the water cycle and climate changes are still poorly understood for the most part.

Carbon Dioxide

Carbon dioxide is perhaps the most widely studied greenhouse gas. Dr. Charles Keeling, an American scientist, began recording

Background Information (cont.) Temperature Anomalies

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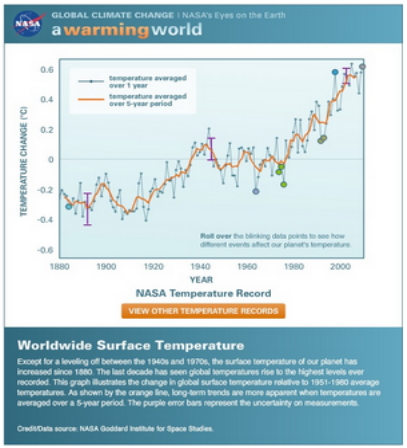
Temperature Anomalies

When researching global climate changes and temperature data, you will often read about the "temperature anomaly." That is the **difference** between the long-term average temperature (sometimes called a reference value) and the temperature that is actually occurring. In other words, the long-term average temperature is one that would be expected; the anomaly is the difference between what you would expect and what is happening.

A positive anomaly means that the temperature was warmer than normal; a negative anomaly indicates that the temperature was cooler than normal.

Why use temperature anomalies and not the actual temperature measurements? Actual temperature measurements are often difficult to gather. Some areas in the world have few temperature measurement stations (for example, remote jungles and deserts), and temperatures must be estimated over large regions.

Using anomalies, the departure from an "average," allows more accurate descriptions over larger areas than actual temperatures and provides a frame of reference that allows easier analysis. You will use anomalies in many of the table and graphs presented in the Data Resource Center.



Activity Practice for Analyzing Data

Look at the table below. The table lists temperature anomalies for different environments (land, ocean, and land and ocean combined) globally and for the Northern and Southern Hemispheres. This table provides some interesting data. Take a closer look and answer the questions below to help you in your temperature analysis:

1. Do the temperature anomalies tend to be positive (warmer than normal) or negative (cooler than normal)?
2. Globally, which environments have warmer anomalies? Which have cooler anomalies?
3. In the Northern Hemisphere which environments have warmer anomalies? Which have cooler anomalies?
4. In the Southern Hemisphere which environments have warmer anomalies? Which have cooler anomalies?
5. Generally, describe how 2010 ranks out of 131 years of temperature data.
6. Generally, describe when the next warmest year for the different environments occurred. Did they occur decades ago or more recently?
7. What conclusions do you make from this table concerning global warming?

Background Information
Temperature Trends and Data

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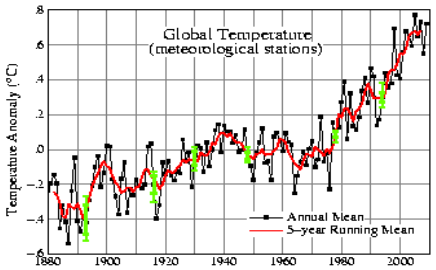
Temperature Trends and Data

Recent evidence from numerous scientific reports draw similar conclusions: Earth is warming. Hundreds of scientists from many countries contributed to studies that confirm that the first decade of the 21st century was the warmest on record and that Earth has been growing warmer for the last 50 years.

Global Mean Surface Temperature Changes—1880-present



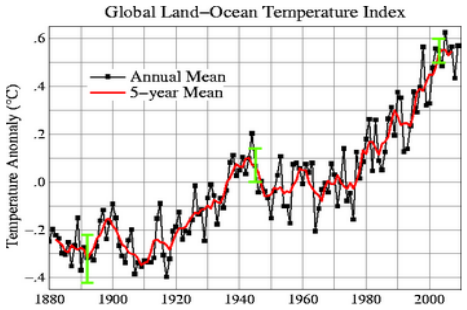
Red line—5-year running averages
Black line—annual (yearly) averages

(Normal seasonal fluctuations cause the variability seen on the graph.)

Note: 5-year running averages are calculated by averaging temperatures over 60 months prior to the date for which they are given.

Hansen et al. (2001)
http://data.giss.nasa.gov/gistemp/graphs/

Global Mean Land-Ocean Surface Temperature Changes—1880-present



Red line—5-year running averages
Black line—annual (yearly) averages

(Normal seasonal fluctuations cause the variability seen on the graph.)

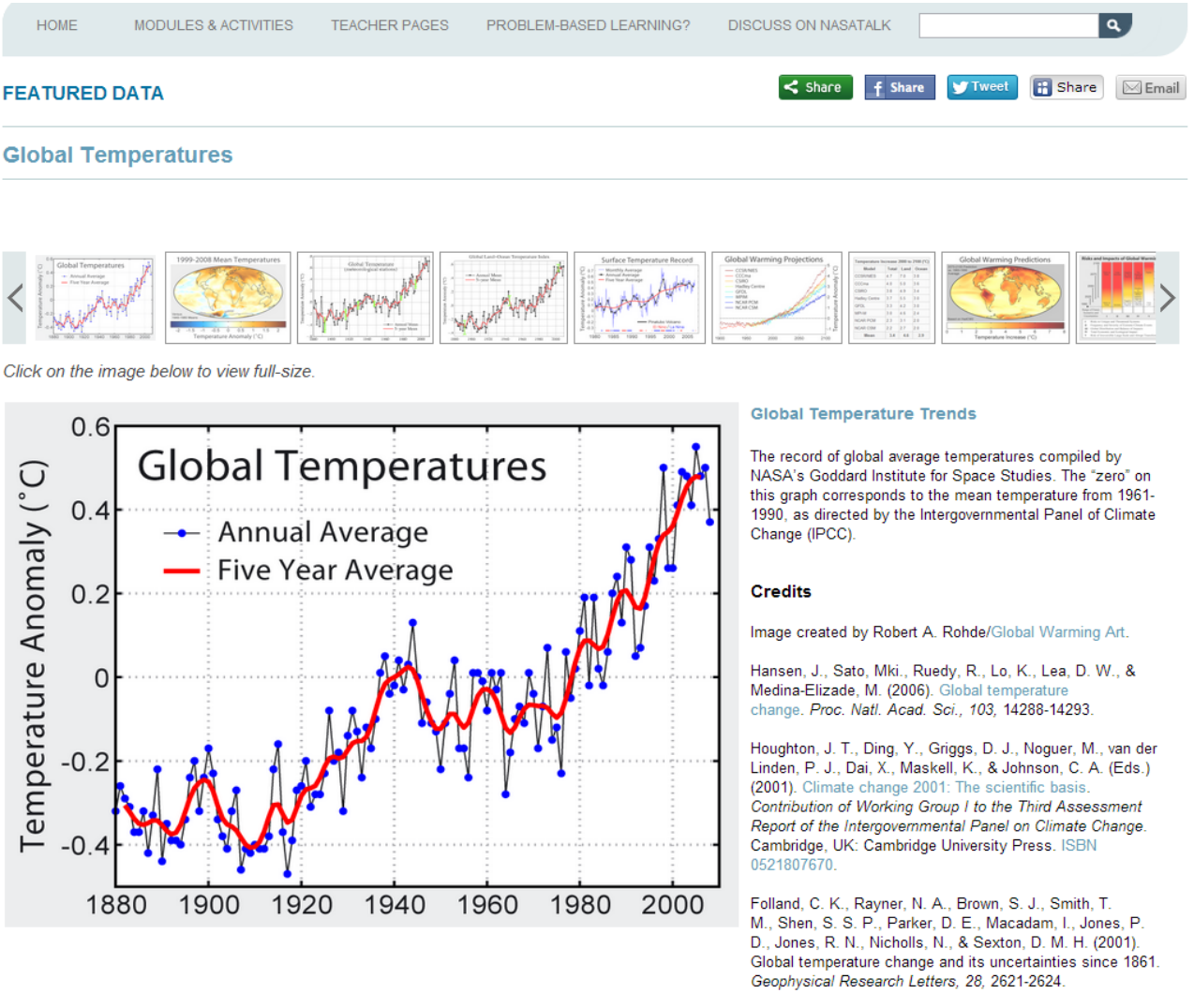
Note: 5-year running averages are calculated by averaging temperatures over 60 months prior to the date for which they are given.

Featured Data

Student conclusions will be based on their analysis of *data*. Each key indicator has a Featured Data resource which provides some data to help them get started with the analysis.

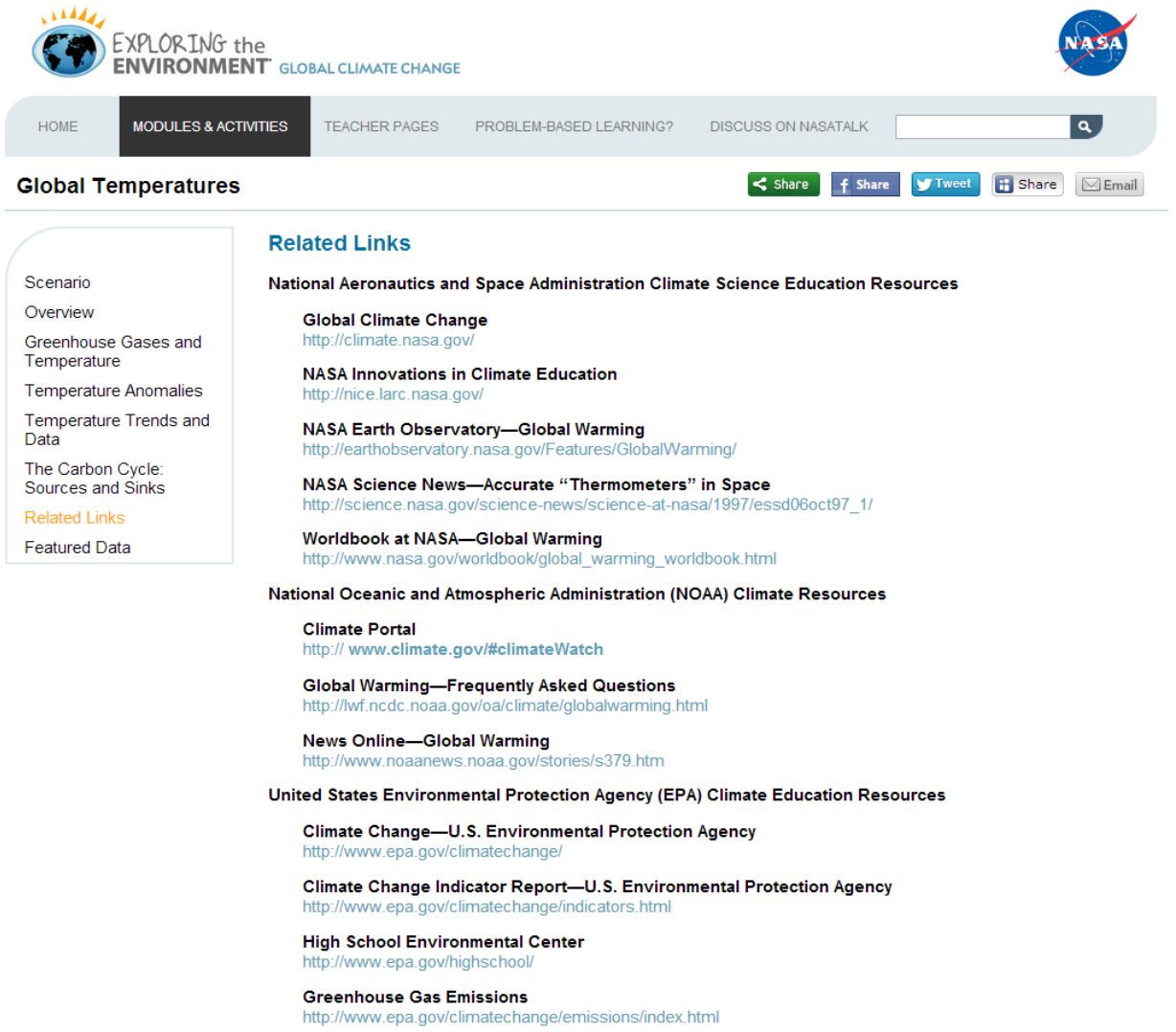
Presentations should include the data used to draw conclusions.

Students scroll through the graphs and images in the bar near the top of the page to find tables, graphs, and images for analysis.



Related Links

Each indicator also has a list of related links to help students find additional data sources and background information.



Presentation

- Provide your students with specific guidelines concerning their presentation requirements and assessment.
- In general, students should continue in their roles as climate change scientists and use their data analysis to present conclusions to their (classroom) climate colleagues.