NATIONAL GEOGRAPHIC

Activity
APPLY

For Educator
45 Minutes | Grades 7-12+ | Ages 12+

Using Models to Make Predictions

How much do humans have to reduce greenhouse gas emissions to prevent major warming?

For the complete activity with media resources, visit:
http://education.nationalgeographic.com/education/activity/using-models-make-predictions/

ACTIVITY OVERVIEW

Students explore how solar radiation, Earth's surface and oceans, and greenhouse gases interact to cause global warming. They can change variables to determine how much greenhouse gas emissions might need to fall to mitigate the temperature increase.

DIRECTIONS

1. Activate students' prior knowledge about greenhouse gases and global warming.

Tell students they will be investigating how much greenhouse gas concentrations need to be reduced to prevent major warming of Earth's atmosphere. Review with students the interactions of greenhouse gases with radiation and temperature and Earth's surfaces and temperature. Ask:

- *How do greenhouse gases cause atmospheric warming?* (Greenhouse gases absorb outgoing infrared radiation and re-emit it, trapping the heat energy in the atmosphere.)

- *How does the level of carbon dioxide in the atmosphere affect the level of water vapor in the atmosphere?* (When there is more carbon dioxide in the atmosphere, there will be more water vapor in the atmosphere. Carbon dioxide increases temperatures, which leads to increased evaporation of water. This leads to more warming, and more carbon dioxide in the atmosphere as it is released from the oceans and more water vapor as more water evaporates. This is a positive feedback relationship.)

- *How does the color of Earth's surfaces affect temperature?* (When the surface is light-colored, solar radiation is reflected, leading to less heating. When the surface is dark-colored, solar radiation is absorbed, leading to more heating.)

- *What is the relationship between water vapor and clouds?* (When there is more water vapor, there are more clouds. The clouds can reflect solar radiation, leading to cooling, which can decrease the amount of water vapor in the air. This is a negative feedback relationship.)

2. Discuss the role of uncertainty in the scientific process.

Science is a process of learning how the world works and that scientists do not know the “right” answers when they start to investigate a question. Tell students they can see examples of scientists' uncertainty in climate forecasting.

Show the **Global Temperature Change Graph** from the 1995 IPCC (Intergovernmental Panel on Climate Change) report. Tell students that this graph shows several different models of forecast temperature changes. Ask: *Why is* *there more variation (a wider spread) between the models at later dates than at closer dates?* (There is more variation between the models at later dates than at closer dates because there is more variability in predicting the far future than in predicting the near future.)

Tell students that the ability to better predict near-term events occurs in hurricane and tropical storm forecasting as well. Project **The Definition of the National Hurricane Center Track Forecast Cone** and show students the “cone of uncertainty” around the track of the storm. Tell students that the cone shows the scientists' uncertainty in the track of the storm, just as the climate models show the scientists' uncertainty in how much Earth's temperature will change in the future.

Ask: *When are scientists most confident in their predictions?* (Scientists are most confident in their predictions when they have a lot of data. This is why the forecast for near-term events is better than forecasts of longer-term events, both in storm forecasting and in climate forecasting.)

Tell students they will be asked questions about the certainty of their predictions and that they will need to think about what scientific data are available as they assess their certainty with their answers. Encourage students to discuss the scientific evidence with each other to better assess their level of certainty with their predictions.

3. Discuss the role of systems in climate science.

Tell students that forecasting what will happen in Earth's climate system is a complicated process because there are many different interacting parts. Scientists think about how one part of the system can affect other parts of the system. Give students a simple example of a system, as described in the scenario below.

On an island, there is a population of foxes and a population of rabbits. The foxes prey on the rabbits. Ask:

- *When there are a lot of rabbits, what will happen to the fox population?* (It will increase because there is an ample food supply.)
- *What happens to the fox population when they’ve eaten most of the rabbits?* (The foxes will die of starvation as their food supply decreases.)
- *What happens to the amount of grass when the fox population is high?* (The amount of grass will increase because there are fewer rabbits to eat the grass.)
- *If there is a drought and the grass doesn’t grow well, what will happen to the populations of foxes and rabbits?* (The rabbit population will decrease because they have a lesser food supply. The fox population should also decrease as their food supply decreases.)

Humans introduce dogs to the island. The dogs compete with the foxes over the rabbit food supply. Ask: What will happen to the populations of foxes, rabbits, and grass after the dogs are introduced? (The foxes will decrease because they are sharing their food supply, the rabbits will decrease because they have more predators, and the grass will do well because of the lowered impact of the smaller rabbit population.)

Tell students that these simple cause-effect relationships can expand into more complex system relationships. Let students know they will be exploring cause-effect and system feedback relationships between carbon dioxide and water vapor in this activity. Ask students to think about how each piece of the system affects other pieces of the system.

4. Introduce and discuss the use of computational models.

Introduce the concept of computational models, and give students an example of a computational model that they may have seen, such as forecasting the weather. Project the NOAA **Weather Forecast Model**, which provides a good example of a computational model. Tell students that:

- scientists use information about the past to build their climate models.
- scientists test their climate models by using them to forecast past climates.
- when scientists can accurately forecast past climates, they can be more confident about using their models to predict future climates.

5. Have students launch the Using Models to Make Predictions interactive.

Provide students with the link to the Using Models to Make Predictions interactive. Divide students into groups of two or three, with two being the ideal grouping to allow students to share a computer work station. Tell students they will be working through a series of pages of models with questions related to the models. Ask students to work through the activity in their groups, discussing and responding to questions as they go. Tell students this is Activity 5 of the lesson **What Is The Future of Earth's Climate?**

6. Have students discuss what they learned in the activity.

After students have completed the activity, bring the groups back together and lead a discussion focusing on these questions:

- *Are models necessary to understand climate change?* (No. The basic cause of Earth's warming is understood without models, but the interactions are complex enough that models help in trying to fully understand all of the relationships between the components in Earth's climate system.)

- *How can you tell that the results from a climate model are valid?* (When a climate model can accurately predict past climates, you can have more confidence in its ability to predict future climates. If the inputs to the model are good enough to predict the past, they should be enough to give a good indication of the future.)

- *In the **Earth system model with human emissions slider (Model 8)**, how much of a decrease in greenhouse gas emissions was needed to keep the temperature from rising too much?* (The model shows that a 50-75% decrease is necessary. There are many factors missing from this model though. It doesn't show the warming effect of clouds or ocean currents, which can affect global temperatures.)

TIPTEACHER TIP

To save your students' data for grading online, register your class for free at the High-Adventure Science portal page.

MODIFICATION

This activity may be used individually or in groups of two or three students. It may also be modified for a whole-class format. If using as a whole-class activity, use an LCD projector or interactive whiteboard to project the activity. Turn embedded questions into class discussions. Uncertainty items allow for classroom debates over the evidence.

INFORMAL ASSESSMENT

1. Check students' comprehension by asking them the following questions:

- What is the relationship between greenhouse gas emissions and Earth's temperature?
- Why does the temperature not decrease immediately after greenhouse gas emissions decline?
- Why do scientists think the warming of the 20th century cannot be explained by natural variability?

2. Use the answer key to check students' answers on embedded assessments.

OBJECTIVES

SUBJECTS & DISCIPLINES

- Science
  - Earth science
  - General science

LEARNING OBJECTIVES

Students will:

- explore the complex interrelationships between Earth's surface and oceans, greenhouse gases, and temperature
- analyze the validity of climate models for predicting future climate conditions

TEACHING APPROACH

- Learning-for-use

TEACHING METHODS

- Discussions
- Multimedia instruction
- Visual instruction
- Writing

SKILLS SUMMARY

This activity targets the following skills:

21st Century Student Outcomes

Information, Media, and Technology Skills

- Information, Communications, and Technology Literacy

Learning and Innovation Skills

- Critical Thinking and Problem Solving

21st Century Themes

- Global Awareness

Critical Thinking Skills

- Analyzing
- Evaluating
- Understanding

NATIONAL STANDARDS, PRINCIPLES, AND PRACTICES

National Science Education Standards

• (5-8) Standard A-1: Abilities necessary to do scientific inquiry
• (5-8) Standard A-2: Understandings about scientific inquiry
• (5-8) Standard B-1: Properties and changes of properties in matter
• (5-8) Standard B-3: Transfer of energy
• (5-8) Standard E-1: Abilities of technological design
• (5-8) Standard E-2: Understandings about science and technology
• (5-8) Standard F-5: Science and technology in society
• (5-8) Standard G-1: Science as a human endeavor
• (5-8) Standard G-2: Nature of science
• (9-12) Standard A-1: Abilities necessary to do scientific inquiry
• (9-12) Standard A-2: Understandings about scientific inquiry
• (9-12) Standard B-2: Structure and properties of matter
• (9-12) Standard B-5: Conservation of energy and increase in disorder
• (9-12) Standard D-1: Energy in the earth system
• (9-12) Standard E-1: Abilities of technological design

- (9-12) Standard E-1: Abilities of technological design
- (9-12) Standard E-2: Understandings about science and technology
- (9-12) Standard G-1: Science as a human endeavor
- (9-12) Standard G-2: Nature of scientific knowledge

Common Core State Standards for English Language Arts & Literacy

- Reading Standards for Literacy in Science and Technical Subjects 6-12:
  Craft and Structure, RST.11-12.4
- Reading Standards for Literacy in Science and Technical Subjects 6-12:
  Key Ideas and Details, RST.9-10.3
- Reading Standards for Literacy in Science and Technical Subjects 6-12:
  Key Ideas and Details, RST.6-8.3
- Reading Standards for Literacy in Science and Technical Subjects 6-12:
  Key Ideas and Details, RST.11-12.1
- Reading Standards for Literacy in Science and Technical Subjects 6-12:
  Key Ideas and Details, RST.6-8.1
- Reading Standards for Literacy in Science and Technical Subjects 6-12:
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- Reading Standards for Literacy in Science and Technical Subjects 6-12:
  Key Ideas and Details, RST.11-12.3

ISTE Standards for Students (ISTE Standards*S)

- Standard 3: Research and Information Fluency
- Standard 4: Critical Thinking, Problem Solving, and Decision Making

Next Generation Science Standards

- Crosscutting Concept 2: Cause and effect: Mechanism and explanation
- Crosscutting Concept 3: Scale, proportion, and quantity
- Crosscutting Concept 4: Systems and system models

- Crosscutting Concept 5: Energy and matter: Flows, cycles, and conservation
- Crosscutting Concept 7: Stability and change
- HS. Earth and Human Activity: HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.
- HS. Earth and Human Activity: HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.
- HS. Earth's Systems: HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.
- HS. Earth's Systems: HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
- HS. Earth's Systems: HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
- MS. Earth and Human Activity: MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
- Science and Engineering Practice 1: Asking questions and defining problems
- Science and Engineering Practice 2: Developing and using models
- Science and Engineering Practice 3: Planning and carrying out investigations
- Science and Engineering Practice 4: Analyzing and interpreting data
- Science and Engineering Practice 6: Constructing explanations and designing solutions
- Science and Engineering Practice 7: Engaging in argument from evidence
- Science and Engineering Practice 8: Obtaining, evaluating, and communicating information

PREPARATION

WHAT YOU'LL NEED

Required Technology

- Internet Access: Required
- Tech Setup: 1 computer per classroom, 1 computer per learner, 1 computer per small group, Projector

Physical Space

- Classroom
- Computer lab
- Media Center/Library

Grouping

- Heterogeneous grouping
- Homogeneous grouping
- Large-group instruction
- Small-group instruction

Resources Provided: Websites

- Global Temperature Change Graph
- Definition of the NHC Track Forecast Cone
- NOAA Weather Forecast Model
- Using Models to Make Predictions Interactive
- Earth System Model—Model 8

Resources Provided: Handouts & Worksheets

- Answer Key—Using Models to Make Predictions

BACKGROUND & VOCABULARY

BACKGROUND INFORMATION

Climate scientists use models to test their predictions about climate change. They test different scenarios by changing their inputs to the model and algorithms for how various factors interact with each other.

When scientists can accurately predict past climates with their inputs and algorithms, they can be more sure that their models will be able to correctly predict future climates. There are many different factors that can affect Earth's atmosphere and temperature, and scientists continually update their models to reflect as many of these interactions as they can.

PRIOR KNOWLEDGE

- None

RECOMMENDED PRIOR ACTIVITIES

- Earth's Changing Climates
- Feedbacks of Ice and Clouds
- Interactions Within Earth's Atmospheres
- Sources, Sinks, and Feedbacks

VOCABULARY

Term	Part of Speech	Definition
absorb	*verb*	to soak up.
atmosphere	*noun*	layers of gases surrounding a planet or other celestial body.
carbon dioxide	*noun*	greenhouse gas produced by animals during respiration and used by plants during photosynthesis. Carbon dioxide is also the byproduct of burning fossil fuels.

climate	*noun*	all weather conditions for a given location over a period of time.
emit	*verb*	to give off or send out.
greenhouse effect	*noun*	phenomenon where gases allow sunlight to enter Earth's atmosphere but make it difficult for heat to escape.
greenhouse gas	*noun*	gas in the atmosphere, such as carbon dioxide, methane, water vapor, and ozone, that absorbs solar heat reflected by the surface of the Earth, warming the atmosphere.
ice core	*noun*	sample of ice taken to demonstrate changes in climate over many years.
infrared radiation	*noun*	part of the electromagnetic spectrum with wavelengths longer than visible light but shorter than microwaves.
model, computational	*noun*	a mathematical model that requires extensive computational resources to study the behavior of a complex system by computer simulation.
parts per million (ppm)	*plural noun*	A unit of measure of the amount of dissolved solids in a solution in terms of a ratio between the number of parts of solids to a million parts of total volume.
radiation	*noun*	energy, emitted as waves or particles, radiating outward from a source.
system	*noun*	collection of items or organisms that are linked and related, functioning as a whole.
temperature	*noun*	degree of hotness or coldness measured by a thermometer with a numerical scale.

FOR FURTHER EXPLORATION

Articles & Profiles

- National Geographic: Daily News: Climate Predictions: Worst-Case May Be Most Accurate
- National Geographic Education: Encyclopedia—Global Warming
- National Geographic Education: Encyclopedia—Climate Change
- National Geographic Education: Encyclopedia—Climate

Images

- National Geographic: Daily News: Pictures: 7 Emergency Climate Fixes: 1. Artificial Volcanoes

FUNDER

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