RESOURCE LIBRARY
ACTIVITY : 45 MINS

Sources, Sinks, and Feedbacks

Students explore the relationships between ocean surface temperature and levels of atmospheric carbon dioxide and water vapor.

GRADES

7 - 12+

SUBJECTS

Earth Science

CONTENTS

3 Links, 1 PDF

OVERVIEW

Students explore the relationships between ocean surface temperature and levels of atmospheric carbon dioxide and water vapor.

For the complete activity with media resources, visit:
http://www.nationalgeographic.org/activity/sources-sinks-and-feedbacks/

Content Created by

The Concord Consortium

DIRECTIONS

1. Activate students' prior knowledge about carbon dioxide in the Earth system.

Tell students that matter cycles throughout Earth's system and that matter is not destroyed as it moves throughout the system. Ask:

- *What are some sources of carbon dioxide?* (Carbon dioxide is emitted when organisms respire and decay, as well as when materials are burned.)
- *Where is carbon stored when it is not carbon dioxide?* (The elements in carbon dioxide came from foods and fuels.)
- *Where does carbon dioxide go after it's released into the atmosphere?* (Carbon dioxide in the atmosphere can be taken up by plants during photosynthesis, or it can be absorbed by the ocean.)

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

Let students know that in this activity they will be asked questions about the certainty of their predictions. Tell them to think about what scientific data are available and the evidence they get from the model 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.

Explain that 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 should think about what scientific and model-based 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 that 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 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 Sources, Sinks, and Feedbacks interactive.

Provide students with the link to the Sources, Sinks, and Feedbacks interactive. Divide students into groups of two or three, with two being the ideal grouping to allow groups to share a computer workstation. Tell students that 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.

NOTE: You can access the Answer Key for students' questions—and save students' data for online grading—through a free registration on the High-Adventure Science portal page.

Tell students this is Activity 4 of the **What Is the Future of Earth's Climate?** lesson.

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:

- Show the **biogeochemical cycle of carbon** (file in media carousel). Ask: *Is there a source that does not act as a sink?* (No. All of the sources of carbon in the Earth system are also sinks for another source.)
- *In the **Earth system model with ocean and water vapor (Model 5)**, how did the level of carbon dioxide affect the amount of water vapor in the atmosphere?* (When the carbon dioxide level is high, the temperature is high, because carbon dioxide is a greenhouse gas. The higher temperature causes water to evaporate from the surface, leading to more water vapor in the atmosphere.)
- *What is the effect of water vapor on temperature?* (Water vapor increases temperature because water vapor is also a greenhouse gas.)
- *What is the feedback relationship between carbon dioxide level and water vapor level?* (It is a positive feedback relationship. When carbon dioxide is high, the temperature is higher, leading to more evaporation of water and lower solubility of carbon dioxide, leading to higher temperatures, leading to more water vapor and still lower solubility of carbon dioxide, leading to higher temperatures, and so on.)
- *Is the **Earth system model with ocean and water vapor (Model 5)** a good model of the Earth system?* (No. This model is not a good model of the Earth system. The temperature keeps going higher and higher, which is not realistic. There is something missing from this model.)

TipTeacher Tip

This activity is part of a sequence of activities in the What Is the Future of Earth's Climate? lesson. The activities work best if used **in sequence**.

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:

- How is the solubility of carbon dioxide affected by temperature?
- How do atmospheric carbon dioxide levels affect ocean temperature?
- What is the effect of water vapor on temperature?
- Why is the relationship between carbon dioxide and water vapor considered a positive feedback relationship?

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

OBJECTIVES

Subjects & Disciplines

Earth Science

Learning Objectives

Students will:

- describe how carbon dioxide travels through Earth's system and identify sources and sinks for carbon dioxide
- explain how temperature affects the ocean's ability to absorb carbon dioxide
- explain the role of water, a greenhouse gas, on Earth's temperature
- explain the effects of temperature on carbon dioxide uptake by the oceans and water vapor in the atmosphere
- describe an example of a positive feedback loop in the Earth's climate system
- explain why it is necessary to consider multiple factors when modeling the climate

Teaching Approach

- Learning-for-use

Teaching Methods

- Discussions
- Multimedia instruction
- Self-paced learning
- 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 D-1:**
Structure of the earth system
• **(9-12) Standard A-1:**
Abilities necessary to do scientific inquiry
• **(9-12) Standard A-2:**
Understandings about scientific inquiry
• **(9-12) Standard D-1:**
Energy in the earth system

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.6-8.3
• **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.11-12.3
• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Craft and Structure, RST.6-8.4
• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Key Ideas and Details, RST.9-10.1
• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Craft and Structure, RST.9-10.4
• **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**:
Key Ideas and Details, RST.11-12.1

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 prediction

• **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-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

• **HS. Earth 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'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-ESS2-2. 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-ESS2-6. 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 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

BACKGROUND & VOCABULARY

Background Information

Like all matter, carbon cycles throughout the Earth system. Carbon dioxide is released into the atmosphere from rocks as they weather. It is taken up by plants and incorporated into proteins, carbohydrates, and fats. It is released when organisms respire, and it is released when fossil fuels are burned. Carbon dioxide is removed from the atmosphere when it dissolves into the ocean.

The oceanic uptake of carbon dioxide is temperature-dependent. Carbon dioxide, like all gases, is less soluble in water as the water temperature warms. So as Earth warms, the oceans are less able to remove carbon dioxide from the atmosphere.

At the same time, the increased temperature resulting from increased levels of atmospheric carbon dioxide causes water to evaporate from the ocean surface. Water vapor is a powerful greenhouse gas. With increased water vapor in the atmosphere, the temperature increases even more. The relationship between atmospheric carbon dioxide and water vapor is a type of positive feedback—an increase in one leads to an increase in the other, leading to a continual increase in temperature.

Prior Knowledge

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Recommended Prior Activities

- Earth's Changing Climates
- Interactions Within Earth's Atmospheres

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.
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.
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.
sink	*noun*	part of a physical system that absorbs some form of matter or energy.
solubility	*noun*	ability of a substance to be dissolved or liquified.
source	*noun*	any thing or place from which something comes, arises, or is obtained.
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.
water vapor	*noun*	molecules of liquid water suspended in the air.

For Further Exploration

Articles & Profiles

- National Geographic: All About Climate
- National Geographic Education: Encyclopedia—Climate Change
- National Geographic Education: Encyclopedia—Global Warming
- National Geographic Magazine: The Case of the Missing Carbon

FUNDER

This material is based upon work supported by the National Science Foundation under Grant No. DRL-1220756. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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