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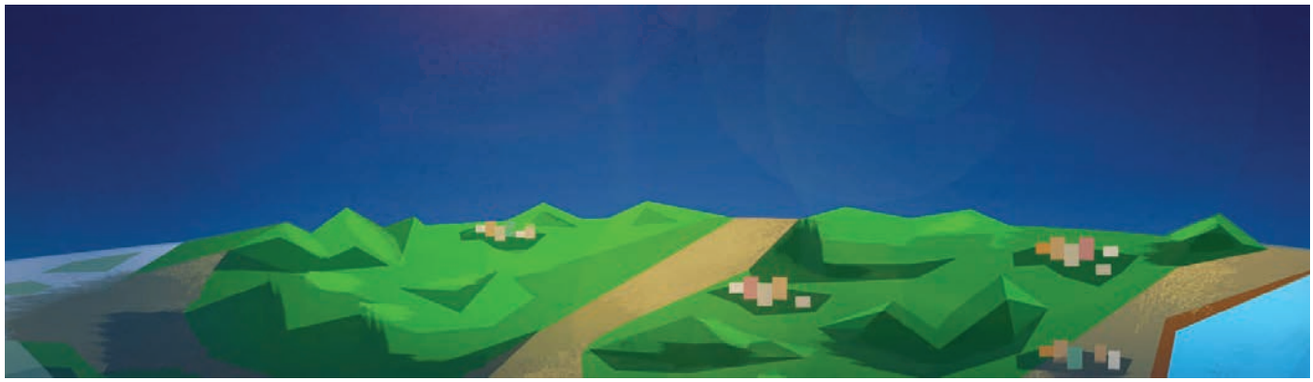

Earth's Changing Climate:

Vanishing Ice

Investigation Notebook with Article Compilation

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Developed by the Learning Design Group at the University of California, Berkeley's Lawrence Hall of Science.

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Earth's Changing Climate:

Vanishing Ice

Investigation Notebook

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Safety Guidelines for Science Investigations

1. **Follow instructions.** Listen carefully to your teacher's instructions. Ask questions if you don't know what to do.

2. **Don't taste things.** No tasting anything or putting it near your mouth unless your teacher says it is safe to do so.

3. **Smell substances like a chemist.** When you smell a substance, don't put your nose near it. Instead, gently move the air from above the substance to your nose. This is how chemists smell substances.

4. **Protect your eyes.** Wear safety goggles if something wet could splash into your eyes, if powder or dust might get in your eyes, or if something sharp could fly into your eyes.

5. **Protect your hands.** Wear gloves if you are working with materials or chemicals that could irritate your skin.

6. **Keep your hands away from your face.** Do not touch your face, mouth, ears, eyes, or nose while working with chemicals, plants, or animals.

7. **Tell your teacher if you have allergies.** This will keep you safe and comfortable during science class.

8. **Be calm and careful.** Move carefully and slowly around the classroom. Save your outdoor behavior for recess.

9. **Report all spills, accidents, and injuries to your teacher.** Tell your teacher if something spills, if there is an accident, or if someone gets injured.

10. **Avoid anything that could cause a burn.** Allow your teacher to work with hot water or hot equipment.

11. **Wash your hands after class.** Make sure to wash your hands thoroughly with soap and water after handling plants, animals, or science materials.

Name: _____ Date: _____

Earth's Changing Climate: Vanishing Ice
Unit Overview

The amount of ice on Earth is decreasing. *Why?* As a student climatologist working for the World Climate Institute, you will investigate changes to Earth's climate and Earth's ice. Using a computer simulation as well as data, physical models, and science articles, you will investigate what can cause climate and ice to change. You'll learn about energy, Earth's atmosphere, volcanic eruptions, and the impact of human activities.

Name: _____ Date: _____

Chapter 1: Climate and the Atmosphere
Chapter Overview

What can make Earth get cooler or warmer? You'll start your investigation of Earth's decreasing ice by exploring relationships between global temperature and changes in Earth's atmosphere.

Name: _____ Date: _____

Lesson 1.2: Introduction to Climate Change

Over the next few weeks, you will take on the role of student climatologists. A climatologist is a scientist who studies the weather (temperature, rain, sun, wind) over long periods of time. Climatologists have been collecting data, and it shows that Earth's climate is changing. For example, the amount of ice near Earth's poles has been decreasing. Today you will learn more about ice melting on Earth and think about how this is related to other changes happening to our planet.

Unit Question

- What causes climate change?

Chapter 1 Question

- Why is the ice on Earth's surface melting?

Vocabulary

- climate
- climate change
- evidence
- fluctuation
- stability
- temperature
- trend

Name: _____ Date: _____

Warm-Up

For each statement in this Anticipation Guide, indicate whether you **agree** or **disagree**. Be prepared to share your explanations with a partner. Don't worry about being right or wrong. This is your chance to think about what you already know about Earth's changing climate. During the unit as you learn more, you will return to this guide to revise and explain your answers.

1. _____ Earth's atmosphere is made of different gases that can affect Earth's climate in different ways.

2. _____ Climate has to do with how much energy is in the Earth system.

3. _____ Earth's atmosphere does not change.

4. _____ There have been times in the past when Earth's climate was very different.

5. _____ Energy from the sun that enters the Earth system does not leave.

6. _____ It is possible for gases in the atmosphere to change the behavior of energy on Earth.

7. _____ Human actions cannot change Earth's atmosphere.

8. _____ Human actions can lead to a decrease in Earth's temperature.

Name: _____ Date: _____

Analyzing Climate Data

Although researchers at the polar station have now concluded that global average temperature has increased and that this is causing ice to melt, some scientists initially disagreed that the ice was melting.

Question: ***Why did some scientists disagree that overall ice was decreasing?***

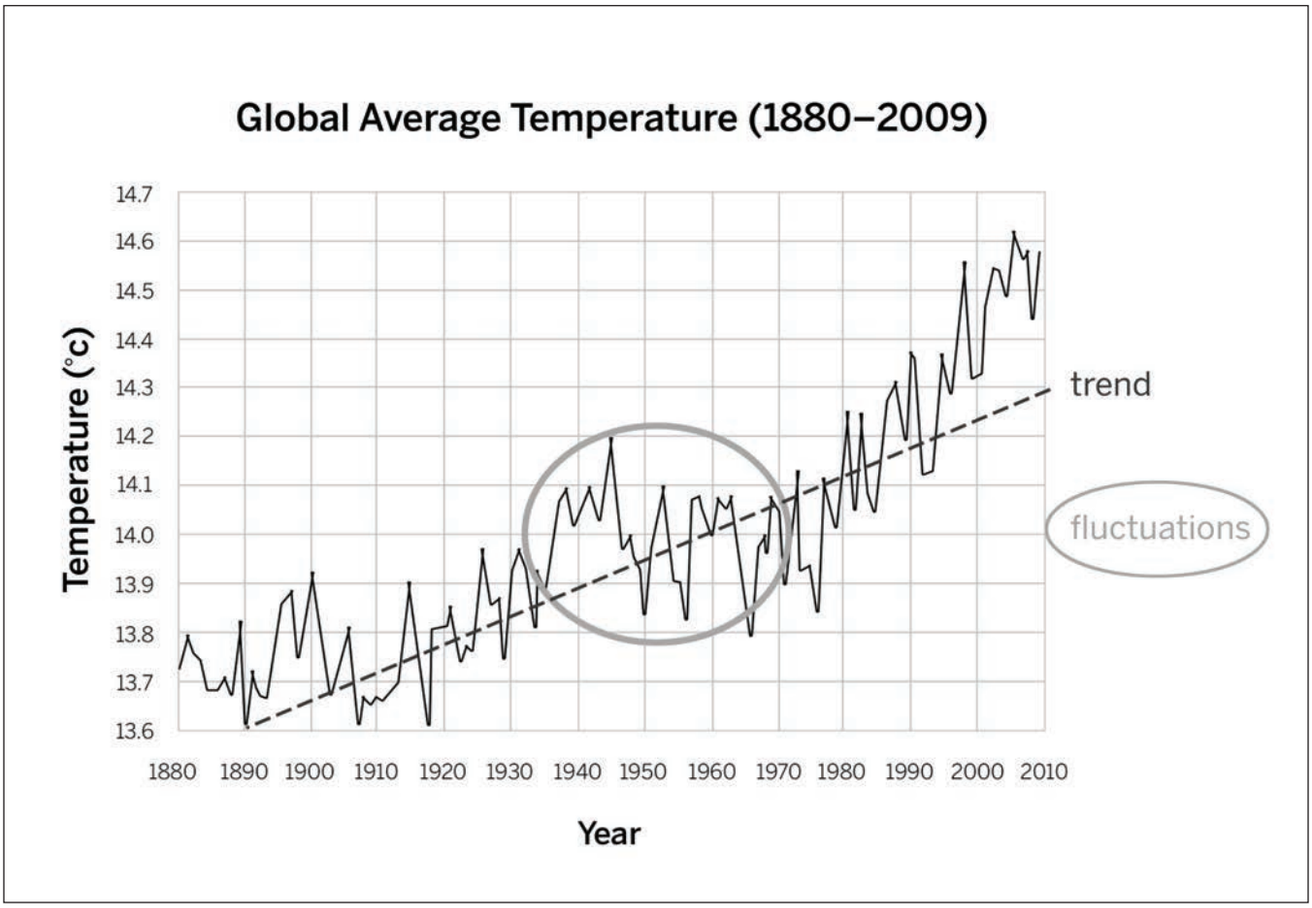
1. **Read all cards.** With your partner, carefully read each Melting Ice Evidence Card. Consider the titles and labels on each card and decide what the data can help you explain about polar ice melting. Pay close attention to the year labels on the graph.

2. **Use the Evidence Gradient to evaluate the evidence.** Place the cards with stronger evidence higher on the gradient. As you place the cards, discuss the following questions with your partner:

   - How is the evidence on each card different?
   - Which evidence would be stronger or more convincing to climate scientists? Why?
   - Where do you think we should place this card? Why?

Name: _____ Date: _____

Trend and Fluctuation in Climate Research



Name: _____ Date: _____

Homework: Reading About the Effects of Climate Change

Of the three articles in *The Effects of Climate Change*, select at least **one** to read. Use your Active Reading skills as you read and annotate the article you chose. After reading, answer the question below.

Rate how successful you were at using your Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ never
- ☐ almost never
- ☐ sometimes
- ☐ frequently/often
- ☐ all the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 1.3: Exploring Energy in the Earth System

How do climatologists study climate change? Today you will use a digital tool, *Earth's Changing Climate* Simulation, to investigate ideas about the relationship between energy in the Earth system and temperature. You'll look at a claim about why Earth's temperature is rising and then get to spend time making your own claims.

Unit Question

- What causes climate change?

Chapter 1 Question

- Why is the ice on Earth's surface melting?

Key Concept

- Although there are many fluctuations, there is a trend toward increasing temperatures and decreasing ice on Earth since about 1880.

Vocabulary

- absorb
- claim
- climate
- climate change
- energy
- evidence
- model
- temperature

Digital Tool

- *Earth's Changing Climate* Simulation

Name: _____ Date: _____

Warm-Up

This snow fell during the night and is now starting to melt.

Why do you think this snow is melting during the day? What does energy have to do with ice melting?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Exploring *Earth's Changing Climate* Simulation

Part 1: Exploring the Sim

Talk with your partner as you explore the *Earth's Changing Climate* Simulation. Share what you both notice.

Part 2: Making Ice Melt in the Sim

Sim Mission: Make ice melt in the Sim.

- Use Earth's System mode.
- Reset the Sim before you begin.

Before: Quickly sketch the starting amount of ice.	**After:** Sketch what it looks like after you made some ice melt.

How did the global average temperature change when you made the ice melt?

_____

_____

How did the energy absorbed by the surface change when you made the ice melt?

_____

_____

Name: _____ Date: _____

Making a Claim About Melting Ice

Part 1: Group Brainstorm

1. In groups of four, brainstorm at least three possible claims that address the question, *Why is the ice on Earth's surface melting?*
2. Record the claims.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Making a Claim About Melting Ice (continued)

Part 2: Individual Claims

1. Choose the strongest claim (in your opinion) from your group's brainstorm. Write this in the space at the top of the Ice Melting Claim.
2. Create a model that shows what you think is happening to cause Earth's ice to melt. Use symbols and labels to explain what you are thinking. If there is time, create a key that explains your symbols.

Why is the ice on Earth's surface melting?

Ice Melting Claim: _____

_____

_____

_____

Model: Draw what you think is causing Earth's ice to melt.

Key:

Name: _____ Date: _____

Lesson 1.4: Testing Changes to the Atmosphere

One possible cause of the current climate change and melting of ice could be a change to Earth's atmosphere. Today you will use the Simulation to test the effects of increasing or decreasing different gases. Do changes to all types of gases affect energy and temperature in the same way?

Unit Question

- What causes climate change?

Chapter 1 Question

- Why is the ice on Earth's surface melting?

Key Concepts

- Although there are many fluctuations, there is a trend toward increasing temperatures and decreasing ice on Earth since about 1880.
- Global average temperature increases when energy absorbed by the surface increases.

Vocabulary

- atmosphere
- carbon dioxide
- claim
- climate
- climate change
- energy
- evidence
- methane
- model
- temperature

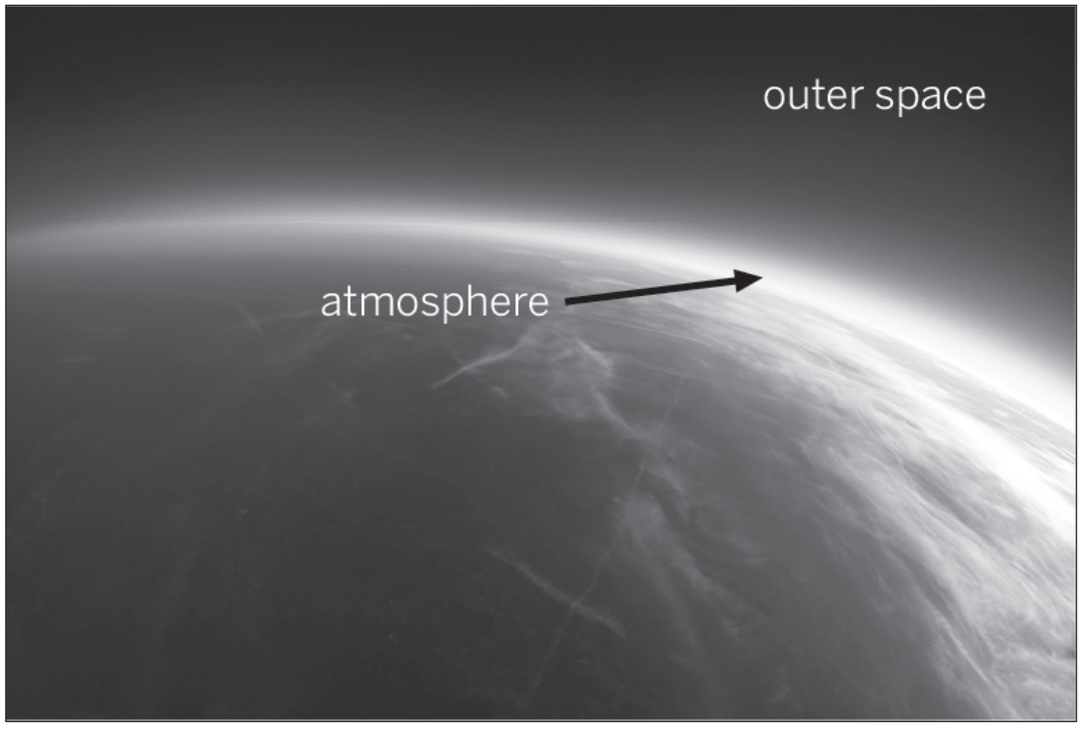
Digital Tool

- *Earth's Changing Climate* Simulation

Name: _____ Date: _____

Warm-Up

The atmosphere is about 480 km (300 miles) thick and surrounds Earth.



What is the atmosphere made of?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Introducing the Claims Chart

Why is the ice on Earth's surface melting?

Name: _____ Date: _____

Testing Changes to the Atmosphere

Use the Simulation to investigate the claim that all gases affect energy absorbed by the surface in the same way. One partner will test nitrogen dioxide and carbon dioxide (Parts 1 and 2); the other student will test sulfur dioxide and methane (Parts 3 and 4). Both students will complete Part 5.

Part 1: Testing Nitrogen Dioxide and Carbon Dioxide

1. Let the Sim run until the timer reaches 20 before beginning a test.
2. Make only one change per test. When increasing, set the gas at 500 ppm; when decreasing, set the gas at 0 ppm.
3. Run the test until the timer reaches 40.
4. Observe the temperature, amount of ice, and glow of absorbed energy.
5. View the graph to observe changes in temperature, surface ice, and absorbed energy.
6. Record your results.
7. Reset the Sim before your next test.

Part 2: Test Results: Nitrogen Dioxide and Carbon Dioxide

1. When I **increased** nitrogen dioxide,
   - energy absorbed by the surface ☐ increased ☐ decreased ☐ did not change.
   - temperature ☐ increased ☐ decreased ☐ did not change.
   - the amount of ice ☐ increased ☐ decreased ☐ did not change.
2. When I **decreased** nitrogen dioxide,
   - energy absorbed by the surface ☐ increased ☐ decreased ☐ did not change.
   - temperature ☐ increased ☐ decreased ☐ did not change.
   - the amount of ice ☐ increased ☐ decreased ☐ did not change.
3. When I **increased** carbon dioxide,
   - energy absorbed by the surface ☐ increased ☐ decreased ☐ did not change.
   - temperature ☐ increased ☐ decreased ☐ did not change.
   - the amount of ice ☐ increased ☐ decreased ☐ did not change.
4. When I **decreased** carbon dioxide,
   - energy absorbed by the surface ☐ increased ☐ decreased ☐ did not change.
   - temperature ☐ increased ☐ decreased ☐ did not change.
   - the amount of ice ☐ increased ☐ decreased ☐ did not change.

Name: _____ Date: _____

Testing Changes to the Atmosphere (continued)

Part 3: Testing Sulfur Dioxide and Methane

1. Let the Sim run until the timer reaches 20 before beginning a test.
2. Make only one change per test. When increasing, set the gas at 500 ppm; when decreasing, set the gas at 0 ppm.
3. Run the test until the timer reaches 40.
4. Observe the temperature, amount of ice, and glow of absorbed energy.
5. View the graph to observe changes in temperature, surface ice, and absorbed energy.
6. Record your results.
7. Reset the Sim before your next test.

Part 4: Test Results: Sulfur Dioxide and Methane

1. When I **increased** sulfur dioxide,
   - energy absorbed by the surface ☐ increased ☐ decreased ☐ did not change.
   - temperature ☐ increased ☐ decreased ☐ did not change.
   - the amount of ice ☐ increased ☐ decreased ☐ did not change.
2. When I **decreased** sulfur dioxide,
   - energy absorbed by the surface ☐ increased ☐ decreased ☐ did not change.
   - temperature ☐ increased ☐ decreased ☐ did not change.
   - the amount of ice ☐ increased ☐ decreased ☐ did not change.
3. When I **increased** methane,
   - energy absorbed by the surface ☐ increased ☐ decreased ☐ did not change.
   - temperature ☐ increased ☐ decreased ☐ did not change.
   - the amount of ice ☐ increased ☐ decreased ☐ did not change.
4. When I **decreased** methane,
   - energy absorbed by the surface ☐ increased ☐ decreased ☐ did not change.
   - temperature ☐ increased ☐ decreased ☐ did not change.
   - the amount of ice ☐ increased ☐ decreased ☐ did not change.

Name: _____ Date: _____

Testing Changes to the Atmosphere (continued)

Part 5: Analyzing Evidence from Sim Tests

Answer the question and provide evidence to support your answer. If you have time, you can use the space at the bottom of the page to sketch or describe the graphs from the Sim tests that provided evidence. As part of your answer, annotate your sketches or describe how the graphs provide evidence.

Do you agree or disagree with this claim?

A change to any gas in the atmosphere affects energy absorbed by the surface in the same way.

- ☐ agree
- ☐ disagree

What is your evidence?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Using the Word Relationships Routine to Reflect

With a partner, use words from the Word Bank to create different sentences that answer the Investigation Question, *What kinds of changes to the atmosphere could affect how much energy is absorbed by Earth's surface?* After you discuss some different ideas, record at least two of your sentences.

Word Bank

carbon dioxide	methane	temperature
energy	increase	decrease
absorb	surface	atmosphere

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Reading "A Hole in Earth's Ozone Layer"

Read "A Hole in Earth's Ozone Layer," and annotate it with your questions and ideas. As you read and use your Active Reading skills, continue to think about the Chapter Question, *Why is the ice on Earth's surface melting?* Could changes to ozone in the atmosphere be related to climate change? After reading, answer the question below.

Rate how successful you were at using your Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ never
- ☐ almost never
- ☐ sometimes
- ☐ frequently/often
- ☐ all the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 1.5: Evidence About Gases in the Atmosphere

What might be causing ice on Earth's surface to melt? Today you'll look at evidence about temperature and different gases in the atmosphere. This will prepare you to help the World Climate Institute scientists create diagrams that will help explain possible causes to the public.

Unit Question

- What causes climate change?

Chapter 1 Question

- Why is the ice on Earth's surface melting?

Key Concepts

- Although there are many fluctuations, there is a trend toward increasing temperatures and decreasing ice on Earth since about 1880.
- Global average temperature increases when energy absorbed by the surface increases.
- When the amount of carbon dioxide or methane in the atmosphere changes, the amount of energy absorbed by the surface also changes.
- When the amount of carbon dioxide or methane increases, energy absorbed by the surface increases.
- When the amount of carbon dioxide or methane decreases, energy absorbed by the surface decreases.

Vocabulary

- atmosphere
- carbon dioxide
- climate
- climate change
- energy
- evidence
- methane
- model

Digital Tools

- *Earth's Changing Climate* Simulation
- *Earth's Changing Climate* Modeling Tool activity: Ice and Temperature

Name: _____ Date: _____

Warm-Up

You read "A Hole in Earth's Ozone Layer" for homework. Answer the following questions about the article. If you need to, you can review the article.

1. Based on what you read, what is true about gases in the atmosphere? (circle one)

   a. All gases in the atmosphere affect energy the same way.

   b. Different gases in the atmosphere affect energy differently.

   c. No gases in the atmosphere affect energy at all.

   d. Ozone is the only gas in the atmosphere.

2. Based on what you read, what is true about the ozone hole? (circle one)

   a. The ozone hole causes warmer global average temperature.

   b. The ozone hole causes cooler global average temperature.

   c. The ozone hole does not affect global average temperature.

Name: _____ Date: _____

Analyzing Gas and Temperature Data

Part 1: Choosing Data

Global average temperature has increased since about 1880. We want to look at data for methane, carbon dioxide, and sulfur dioxide in the atmosphere in order to consider the claim that an increase in those gases has caused this current warming.

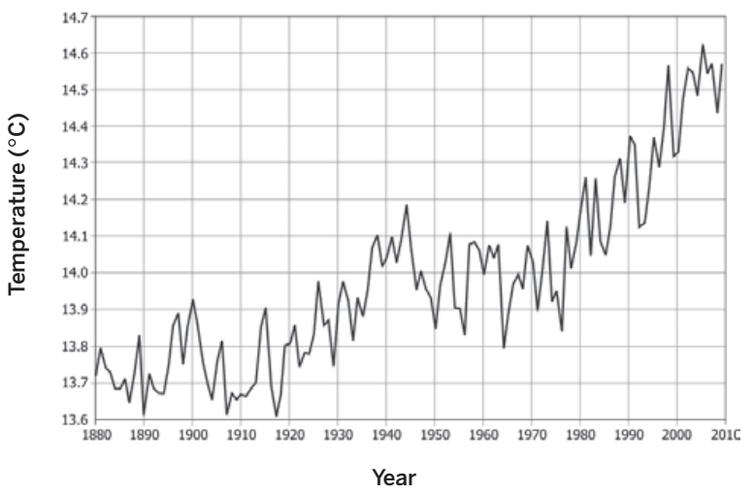
Which time period's data would provide the best evidence? (circle one)

a. data from 1880 to 2014

b. data from 1995 to 2014

c. data from 2013 to 2014

Part 2: Global Average Temperature Trend



For global average temperature, what is the trend or change? (circle one)

a. increasing (getting warmer)

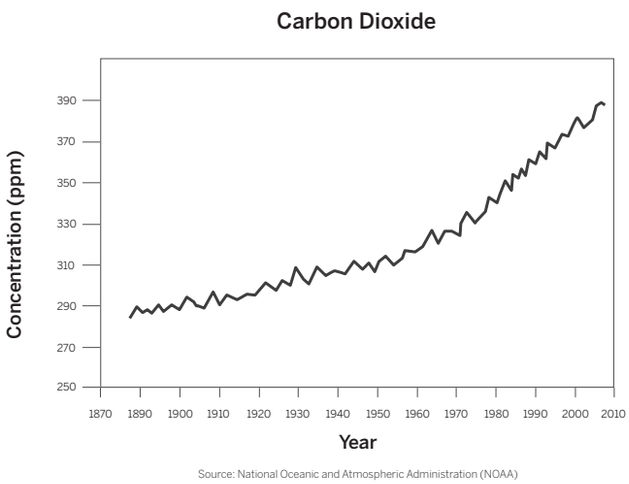
b. decreasing (getting cooler)

c. no trend or change (neither warmer nor cooler)

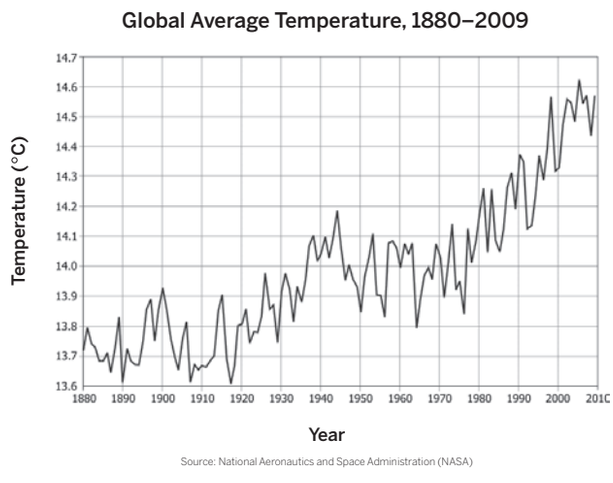
Name: _____ Date: _____

Analyzing Gas and Temperature Data (continued)

Part 3: Carbon Dioxide Trend



Source: National Oceanic and Atmospheric Administration (NOAA)

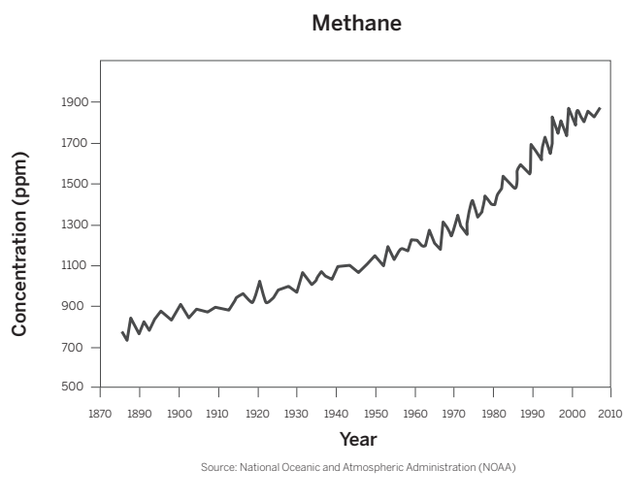


Source: National Aeronautics and Space Administration (NASA)

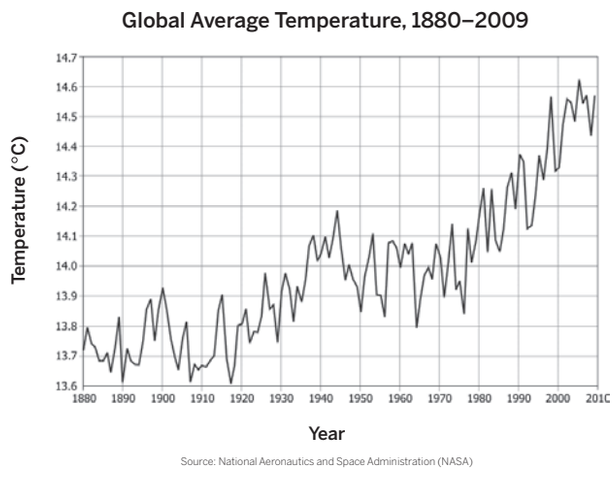
Compare the trends for carbon dioxide and temperature in the graphs above. Do these graphs show the same trend? (circle one)

a. yes b. no

Part 4: Methane Trend



Source: National Oceanic and Atmospheric Administration (NOAA)



Source: National Aeronautics and Space Administration (NASA)

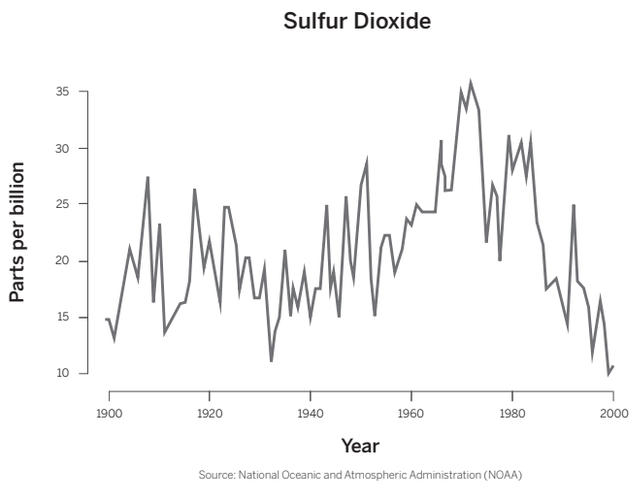
Compare the trends for methane and temperature in the graphs above. Do these graphs show the same trend? (circle one)

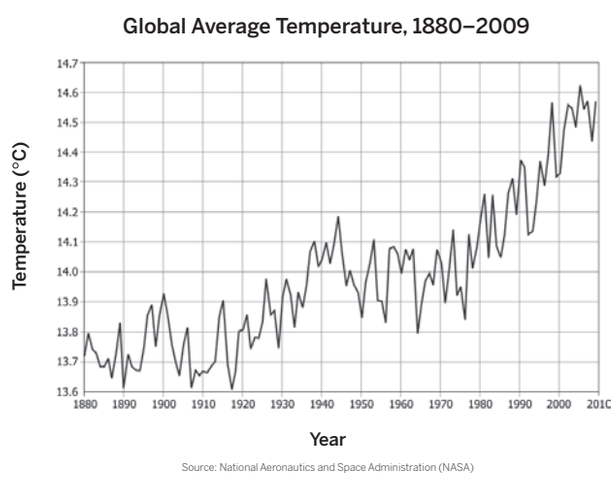
a. yes b. no

Name: _____ Date: _____

Analyzing Gas and Temperature Data (continued)

Part 5: Sulfur Dioxide Trend





Compare the trends for sulfur dioxide and temperature in the graphs above. Do these graphs show the same trend? (circle one)

a. yes b. no

Part 6: Making a Claim Based on Evidence

Which of the following claims do you think might be supported by the graph evidence? (You may circle more than one.)

a. Increasing carbon dioxide is causing temperature to increase and ice to decrease.

b. Increasing methane is causing temperature to increase and ice to decrease.

c. Decreasing sulfur dioxide is causing temperature to increase and ice to decrease.

Explain your thinking.

_____

_____

_____

_____

Name: _____ Date: _____

Introducing the Modeling Tool

When your model is complete, press HAND IN.
If you worked with a partner, write their name here: _____

Part 1: Making a Model to Show Your Ideas

Why is ice on Earth's surface decreasing (melting) and temperature increasing?

Use the Modeling Tool activity, Ice and Temperature, to show one idea about what is causing this to happen. Model an idea that you can support with evidence. If you have time, you can complete a second model in Part 2.

Explain what your model shows.

_____

_____

_____

_____

Part 2: Ice and Temperature Model 2

If you have time, use the Modeling Tool activity, Ice and Temperature 2, and create a second model that shows a different idea about what might be causing ice to melt and temperature to increase.

Explain what your second model shows.

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Sim Mission: Make Earth as Cold as Possible

Using what you learned about gases in the atmosphere and temperature, complete the following mission in the *Earth's Changing Climate* Simulation.

Mission: Without changing the sun and reflectivity, change the atmosphere so Earth's temperature becomes as cold as you can make it.

1. How did you make Earth as cold as possible?

_____

_____

_____

2. When you succeeded in your mission, describe what happened with energy absorbed by the surface.

_____

_____

_____

3. Sketch the results of your mission.

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

Scientists investigate in order to explain their observations. You have been investigating why the climate has been changing. Are you getting closer to understanding what causes climate change?

1. I understand how the atmosphere is related to the ice melting. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

2. I understand what can affect energy entering and exiting the Earth system, and how this affects climate. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

3. I understand what can happen when energy hits gases. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

4. I understand what causes the amount of gases in the atmosphere to change. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

5. What about climate change are you still wondering?

_____

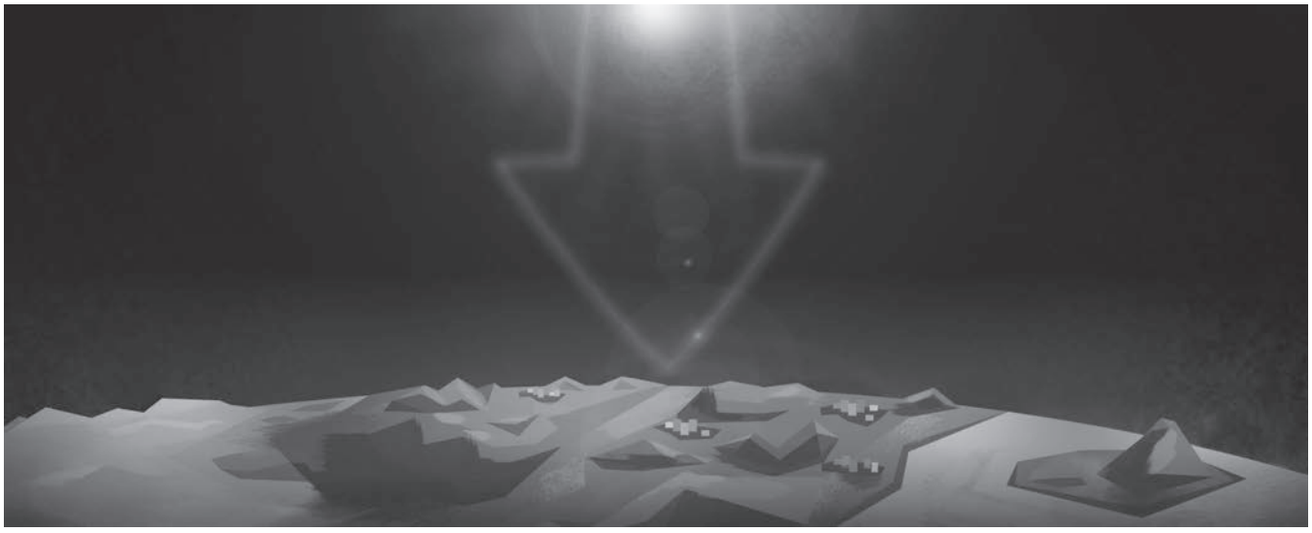
_____

_____

Name: _____ Date: _____

Chapter 2: Energy Entering and Leaving Earth's System
Chapter Overview

You know now that there's a connection between certain gases in the atmosphere and increased global temperature—but why? Your next challenge will be to discover exactly how these gases can affect energy in the Earth system.



Name: _____ Date: _____

Lesson 2.1: Introduction to Energy Entering and Leaving

The research you conducted as student climatologists has shown that at the same time ice is melting on Earth, carbon dioxide and methane are increasing in the atmosphere, and that results in higher temperatures. But why? Temperature is tied to the amount of energy absorbed by Earth's surface. What can affect absorbed energy?

Unit Question

- What causes climate change?

Chapter 2 Question

- Why do temperatures on Earth increase when the amount of carbon dioxide or methane in the Earth system increases?

Vocabulary

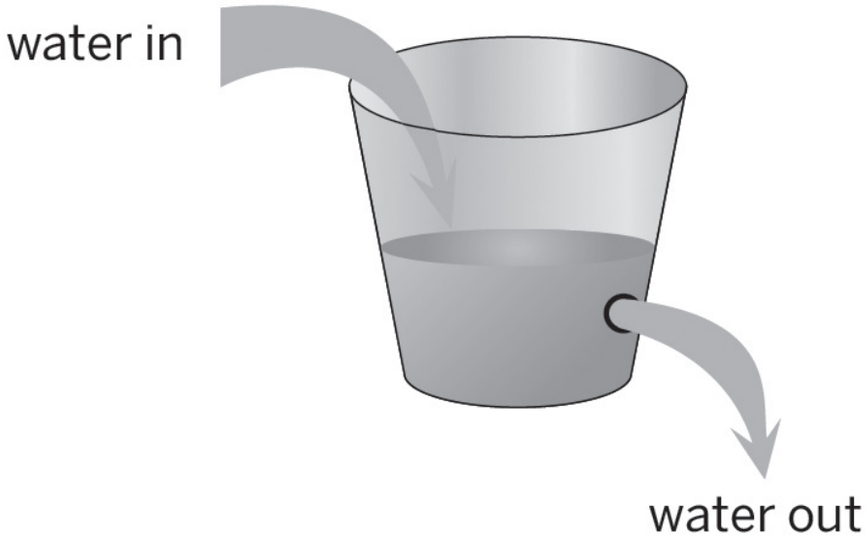
- atmosphere
- carbon dioxide
- change
- claim
- climate
- climate change
- energy
- evidence
- methane
- model
- stability
- temperature

Digital Tool

- *Earth's Changing Climate* Simulation

Name: _____ Date: _____

Warm-Up



Imagine you are filling a bucket with water, but the bucket has a hole in it. What will happen to the level of the water in the bucket?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Energy Token Physical Model

Outer Space

Start with 10 tokens here.

Atmosphere

Earth's Surface

Start with 10 tokens here.

Name: _____ Date: _____

Energy Token Physical Model

What can affect the amount of energy near Earth's surface?

Gather evidence to help answer this question by using the Energy Token Model to test changes to the amount of energy entering and exiting.

Setup

- For every test, start with 10 energy tokens at Earth's surface and 10 in outer space.
- For some tests, you need to decide how much energy enters or exits.

Running the Model

- *Energy enters:* Bring in the correct number of tokens from outer space, down through the atmosphere to Earth's surface.
- *Energy exits:* Bring out the correct number of tokens, up through the atmosphere to outer space.
- Repeat three times.
- Record the final amount of energy at Earth's surface.

Test #1: Run a test where the same amount of energy enters and exits.

Energy entering = 3

Energy exiting = 3

Final energy at Earth's surface = _____

What happened to energy in Test #1?

Energy ☐ increased ☐ decreased ☐ stayed the same.

Test #2: Run a test where more energy enters than exits.

Energy entering = _____ (choose a number greater than 3, but fewer than 7 so you don't run out of tokens)

Energy exiting = 3

Final energy at Earth's surface = _____

What happened to energy in Test #2?

Energy ☐ increased ☐ decreased ☐ stayed the same.

Name: _____ Date: _____

Energy Token Physical Model (continued)

Test #3: Run a test where less energy enters than exits.

Energy entering = 3

Energy exiting = _____ (choose a number greater than 3, but fewer than 7 so you don't run out of tokens)

Final energy at Earth's surface = _____

What happened to energy in Test #3?

Energy ☐ increased ☐ decreased ☐ stayed the same.

Which situation leads to an **increase** in temperature? (circle one)

a. The same amount of energy enters and exits.

b. More energy enters than exits.

c. Less energy enters than exits.

Which situation leads to an **decrease** in temperature? (circle one)

a. The same amount of energy enters and exits.

b. More energy enters than exits.

c. Less energy enters than exits.

Name: _____ Date: _____

Investigating Energy in the Sim

Part 1: Making Predictions

Predict what will happen to temperature and energy entering and exiting the Earth system when you make different changes in the Sim.

Test #1: No Change

1. If you make no changes, temperature will (**increase** / **decrease** / **stay the same**).

2. Predict what will happen to the amount of energy entering and exiting. (circle one)

   a. More energy will enter than exit.

   b. Less energy will enter than exit.

   c. The amount of energy entering and exiting will be equal.

Test #2: Increase Carbon Dioxide OR Methane to 500 (you choose)

1. If you increase (**carbon dioxide** / **methane**),

   temperature will (**increase** / **decrease** / **stay the same**).

2. Predict what will happen to the amount of energy entering and exiting. (circle one)

   a. More energy will enter than exit.

   b. Less energy will enter than exit.

   c. The amount of energy entering and exiting will be equal.

Test #3: Increase Sunlight

1. If you increase sunlight, temperature will (**increase** / **decrease** / **stay the same**).

2. Predict what will happen to the amount of energy entering and exiting. (circle one)

   a. More energy will enter than exit.

   b. Less energy will enter than exit.

   c. The amount of energy entering and exiting will be equal.

Name: _____ Date: _____

Investigating Energy in the Sim (continued)

Part 2: Testing Changes in the Sim

Procedure:

- Run the Sim until the timer reaches 20 before pausing to make a change.
- Make only one change per test:

  Test #1: No Change

  Test #2: Increase Carbon Dioxide OR Methane to 500

  Test #3: Increase Sunlight
- When the timer reaches 40, observe the temperature, the energy entering, and the energy exiting.

Test #1: No Change

1. When you made no changes in the Sim,
   temperature (**increased** / **decreased** / **stayed the same**).
2. What did you observe about the amount of energy that entered and exited? (circle one)
   a. More energy entered than exited.
   b. Less energy entered than exited.
   c. The amount of energy that entered and exited was equal.

Test #2: Increase Carbon Dioxide OR Methane to 500

1. When you increased (**carbon dioxide** / **methane**),
   temperature (**increased** / **decreased** / **stayed the same**).
2. What did you observe about the amount of energy that entered and exited? (circle one)
   a. More energy entered than exited.
   b. Less energy entered than exited.
   c. The amount of energy that entered and exited was equal.

Test #3: Increase Sunlight

1. When you increased sunlight in the Sim,
   temperature (**increased** / **decreased** / **stayed the same**).
2. What did you observe about the amount of energy that entered and exited? (circle one)
   a. More energy entered than exited.
   b. Less energy entered than exited.
   c. The amount of energy that entered and exited was equal.

Name: _____ Date: _____

Reflecting on Energy

more entered than exited

less entered than exited

equal

Between the years 1200 and 1600, global average temperature decreased (Earth got colder). Which do you think is true about the energy that entered and exited the Earth system during that time?

a. More energy entered than exited.

b. Less energy entered than exited.

c. The amount of energy that entered and exited was equal.

Explain your answer.

_____

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 2.2: Reading "Past Climate Changes on Earth"

Earth is always changing and it hasn't always been the way it is today. You will learn about two different times in Earth's past during which the climate was not at all like it is now, and you will begin to discover how these changes can happen.

Unit Question

- What causes climate change?

Chapter 2 Question

- Why do temperatures on Earth increase when the amount of carbon dioxide or methane in the Earth system increases?

Key Concepts

- A system can be stable, even as something flows into and out of the system. If this balanced flow is disrupted, there may be changes to the system.
- A change to either the amount of energy entering or exiting the Earth system affects how much energy is absorbed by the surface.
- Temperature increases if more energy enters than exits.
- Temperature decreases if less energy enters than exits.

Vocabulary

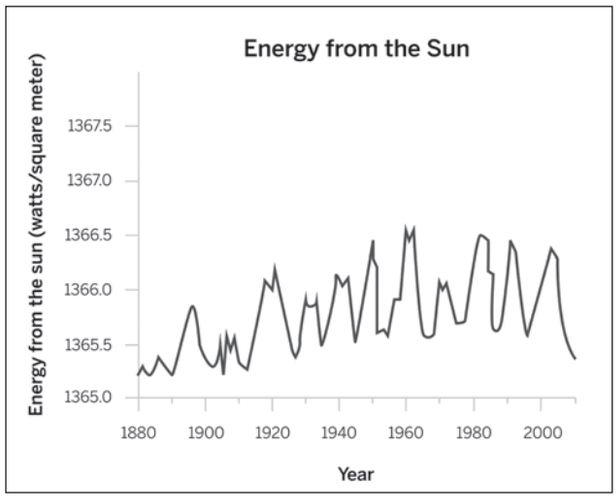
- atmosphere
- carbon dioxide
- climate
- climate change
- energy
- fluctuation
- methane
- temperature
- trend

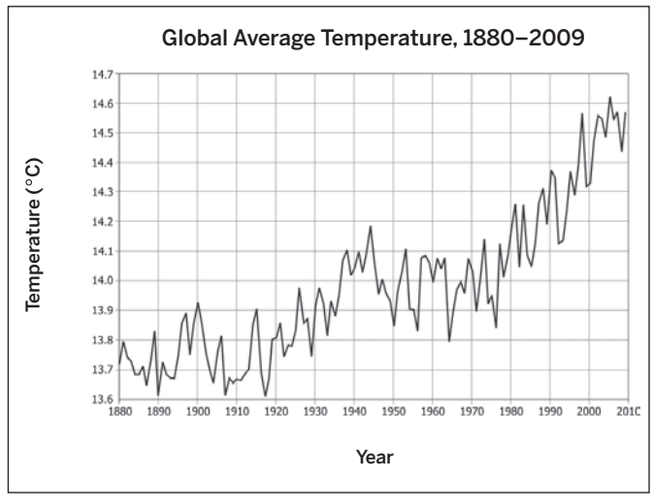
Name: _____ Date: _____

Warm-Up

Could an increase in energy from the sun be the cause of the most recent climate change?

Compare these two graphs from the same time period: one with data about energy from the sun and the other with data about global average temperature, and then answer the question.





Examine the trend for sunlight. Does the sunlight trend mirror the temperature trend? In other words, does sunlight increase at the same time as temperature increases? (circle one)

a. yes

b. no

Do you think an increase in energy from the sun could be the cause of the most recent climate change? What is your evidence?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Reading "Past Climate Changes on Earth"

1. Read and annotate the article, "Past Climate Changes on Earth."
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. After reading, answer the question below.

Rate how successful you were at using your Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ never
- ☐ almost never
- ☐ sometimes
- ☐ frequently/often
- ☐ all the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Homework: Testing Predictions in the Sim

Part 1: Predict

Predict what you think will happen if either carbon dioxide or methane decreases. Then, move on to Part 2 and test your predictions in the Sim.

Decreasing Carbon Dioxide or Methane

1. I will decrease (**carbon dioxide** / **methane**).

2. If I decrease carbon dioxide or methane,
   temperature will (**increase** / **decrease** / **stay the same**).

3. Predict what will happen to the amount of energy entering and exiting.

   a. More energy will enter than exit.

   b. Less energy will enter than exit.

   c. The amount of energy entering and exiting will be equal.

Part 2: Test

Test what happens in the Simulation when you decrease either carbon dioxide or methane.

Procedure:

- Run the Sim until the timer reaches 20 before pausing to make a change.
- Pause and decrease either carbon dioxide or methane.
- Run the test until the time reaches 40.
- Observe the temperature and energy entering and exiting.

Results:

1. When you decreased (**carbon dioxide** / **methane**),
   temperature (**increased** / **decreased** / **stayed the same**).

2. What did you observe about the amount of energy that entered and exited?

   a. More energy entered than exited.

   b. Less energy entered than exited.

   c. The amount of energy that entered and exited was equal.

Name: _____ Date: _____

Lesson 2.3: Learning More About Past Climate Changes

Climate change is not a new thing. There is evidence that this has happened before in Earth's history. Today you will use evidence from the text about warming during the Eocene in order to model the Earth system during this current warming climate. The model you create will help you figure out what types of changes can affect our planet.

Unit Question

- What causes climate change?

Chapter 2 Question

- Why do temperatures on Earth increase when the amount of carbon dioxide or methane in the Earth system increases?

Key Concepts

- A system can be stable, even as something flows into and out of the system. If this balanced flow is disrupted, there may be changes to the system.
- A change to either the amount of energy entering or exiting the Earth system affects how much energy is absorbed by the surface.
- Temperature increases if more energy enters than exits.
- Temperature decreases if less energy enters than exits.

Vocabulary

- atmosphere
- carbon dioxide
- claim
- climate
- climate change
- energy
- evidence
- methane
- model
- temperature

Digital Tool

- *Earth's Changing Climate* Modeling Tool activity: Carbon Dioxide/Methane

Name: _____ Date: _____

Warm-Up

Earth's current climate is changing, but there have been other times in Earth's history when the climate changed. During some of these times in the past, **more energy entered than exited** the Earth system. Explain how this affected energy absorbed by the surface and temperature by making choices that complete the statement below.

If **more energy enters than exits** the Earth system, energy absorbed by the surface would (circle one)

a. increase,

b. decrease,

c. remain stable,

causing global average temperature to (circle one)

d. increase.

e. decrease.

f. remain stable.

Name: _____ Date: _____

Second Read of "Past Climate Changes on Earth"

Effects of Carbon Dioxide and Methane

Today, you will reread part of this article to help you better understand why increased carbon dioxide or methane can cause temperatures to increase. Reread the introduction and the section, "Alligators in the Arctic: The Eocene Period." As you read, highlight any information that helps answer the question, *How do carbon dioxide and methane affect energy entering or exiting the Earth system?* After you read, use your annotations to help you answer the two questions.

1. When more energy enters than exits the Earth system, what happens to temperatures on Earth?

_____

_____

_____

_____

2. Do carbon dioxide and methane affect energy **entering** or **exiting** the Earth system?

_____

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Modeling Tool Activity: Temperature Increase Due to Gases

You've already found that temperature increases when either carbon dioxide or methane increases.

1. Use what you learned about energy entering and exiting to show why temperature increases when the amount of carbon dioxide or methane increases.
2. Launch the Modeling Tool activity: Carbon Dioxide/Methane.
3. Choose either carbon dioxide or methane.
4. When your model is complete, press HAND IN and explain what it shows.

   If you worked with a partner, write their name here: _____

Explain what your model shows.

_____

_____

_____

_____

Name: _____ Date: _____

Revisiting the Anticipation Guide

Turn to page 6 in your Investigation Notebook and review your original response to statement #4 in the Anticipation Guide.

4. _____ There have been times in the past when Earth's climate was very different.

Do you currently agree or disagree with this claim? (circle one)

a. agree

b. disagree

Have your views changed throughout the unit? (circle one)

a. yes

b. no

Describe the evidence you would use to support your current thinking about this claim.

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 2.5: Reviewing Key Ideas in Climate Change

Today you will take a closer look at a special scenario from Earth's history. Working with a partner, you will accurately show your scenario using information from "Past Climate Changes on Earth," *Earth's Changing Climate* Simulation, and *Earth's Changing Climate* Modeling Tool, as well as everything you have learned so far. This deeper investigation into what happened in Earth's past will help you better understand how climate change happens.

Unit Question

- What causes climate change?

Chapter 2 Question

- Why do temperatures on Earth increase when the amount of carbon dioxide or methane in the Earth system increases?

Key Concepts

- Although there are many fluctuations, there is a trend toward increasing temperatures and decreasing ice on Earth since about 1880.
- Global average temperature increases when energy absorbed by the surface increases.
- When the amount of carbon dioxide or methane in the atmosphere changes, the amount of energy absorbed by the surface also changes.
- When the amount of carbon dioxide or methane increases, energy absorbed by the surface increases.
- When the amount of carbon dioxide or methane decreases, energy absorbed by the surface decreases.
- A system can be stable, even as something flows into and out of the system. If this balanced flow is disrupted, there may be changes to the system.
- A change to either the amount of energy entering or exiting the Earth system affects how much energy is absorbed by the surface.
- Temperature increases if more energy enters than exits.
- Temperature decreases if less energy enters than exits.
- If there is an increase in the amount of carbon dioxide or methane, the amount of energy leaving the Earth system decreases, so more energy enters than exits.
- If there is a decrease in the amount of carbon dioxide or methane, the amount of energy leaving the Earth system increases, so less energy enters than exits.

Name: _____ Date: _____

Lesson 2.5: Reviewing Key Ideas in Climate Change (continued)

Vocabulary

- atmosphere
- carbon dioxide
- claim
- climate
- climate change
- energy
- evidence
- methane
- model
- temperature

Digital Tools

- *Earth's Changing Climate* Modeling Tool activity: Revised Model of Carbon Dioxide/Methane
- *Earth's Changing Climate* Modeling Tool activity: Cryogenian Climate Change
- *Earth's Changing Climate* Simulation

Name: _____ Date: _____

Green Group: Warm-Up

What would you say to someone if they said, "The atmosphere hasn't changed during Earth's history because air is always just air."

Refer to the image and use your own words to write a response to this person.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Green Group: Simulating Climate Change from the Article

Part 1: Reviewing Climate Change During the Eocene

In the Eocene, average temperatures rose to over 25°C. Look back at "Past Climate Changes on Earth" and review what changes to the atmosphere caused this climate change, then answer the questions. In the next part of this activity, you will try to model this climate change in the Sim.

1. According to "Past Climate Changes on Earth," what changes to the atmosphere caused temperatures to increase, making the Eocene such a warm time in Earth's history?

_____

_____

_____

_____

2. What changes happened during the Eocene with amount of energy absorbed by Earth's surface? Did absorbed energy **increase**, **decrease**, or **stay the same**? Explain your thinking.

_____

_____

_____

_____

Name: _____ Date: _____

Green Group: Simulating Climate Change from the Article (continued)

Part 2: Simulating Climate Change During the Eocene

Record your partner's name: _____

Model what happened in the Eocene by making changes to the atmosphere in the Sim. Follow the steps to see if you can make the temperature reach 25°C. Try to make the same kinds of changes that caused the Eocene to be such a warm time.

1. Discuss with your partner what changes you will make to try to model the Eocene.
2. Run the Simulation until the timer reaches 20, then pause to make changes.
3. Observe what happens to temperature and energy absorbed by the surface. Remember to check the graph.
4. If you do not reach 25°C, adjust the settings.
5. Make a sketch that shows how your changes affected absorbed energy. You may describe your sketch on the lines below.

_____

_____

_____

_____

Name: _____ Date: _____

Green Group: Simulating Climate Change from the Article (continued)

Part 3: Adding More Details to Previous Answers

After working with the Sim, you may have learned more or found extra details to add to the answers you gave earlier. If possible, add more detail to your answers in Part 1 (on page 52). If you finish early, move to Activity 3 (Revising or Creating Modeling Tool Diagrams on the next page).

Name: _____ Date: _____

Green Group: Revising or Creating Modeling Tool Diagrams

Modeling What Happened During the Eocene

In an earlier lesson, you answered the question of why temperatures on Earth increase when the amount of carbon dioxide or methane increases. You just learned that the atmosphere changed in the same way during the Eocene.

Take a look at your explanation of the Carbon Dioxide/Methane Model on page 47. Show what you learned by using the Modeling Tool to make a new model that is more accurate or more complete. When you are finished with the new model, explain the changes you made and why.

1. What changes did you make to your Carbon Dioxide/Methane Model? Why did you make these changes?

_____

_____

_____

2. How does the energy entering and exiting compare when the amounts of carbon dioxide or methane increase? (circle one)

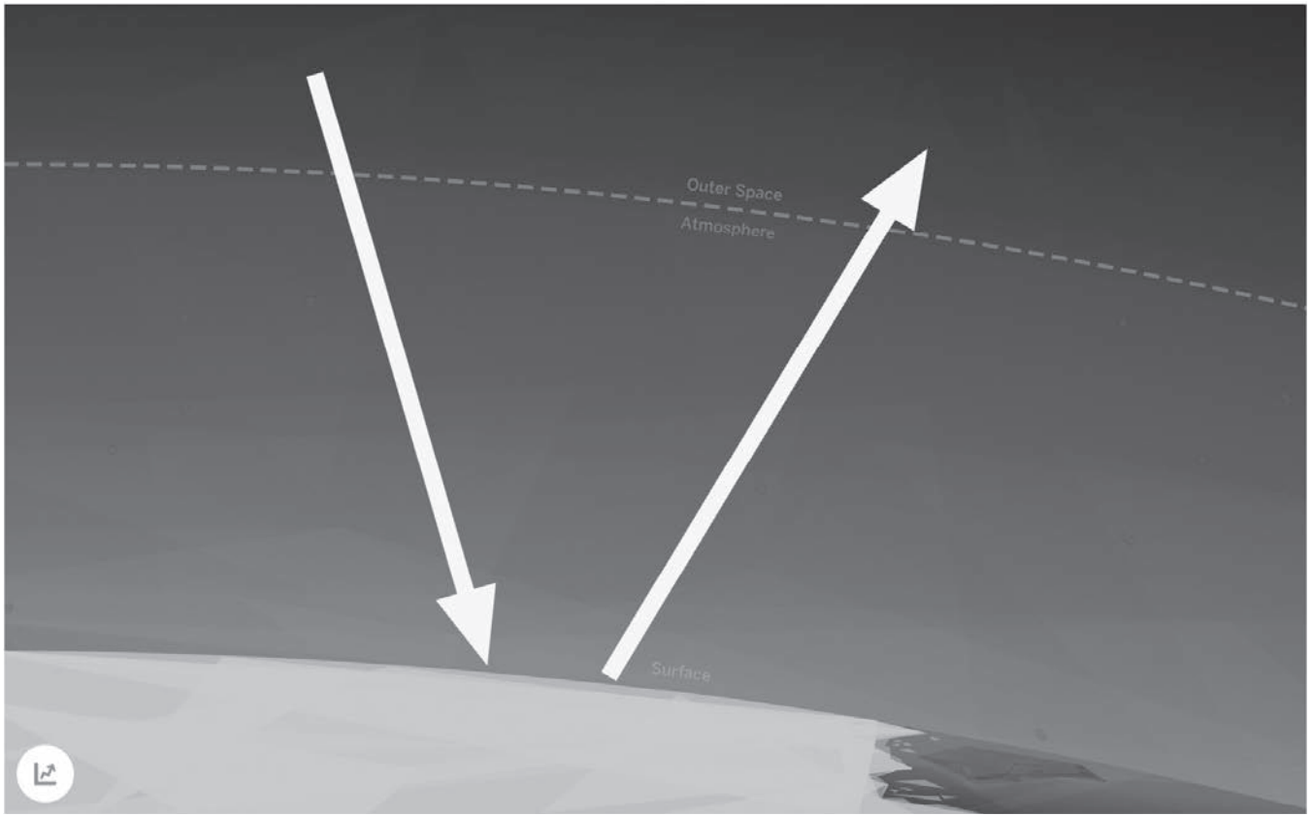
   a. Energy entering was more than energy exiting.

   b. Energy entering was less than energy exiting.

   c. Energy entering was equal to energy exiting.

Name: _____ Date: _____

Blue Group: Warm-Up



What would you say to someone if they said, "Sunlight is what heats Earth, so if sunlight doesn't change, the temperature doesn't change."

Refer to the image and use your own words to write a response to this person.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Blue Group: Simulating Climate Change from the Article

Part 1: Reviewing Climate Change During the Eocene

In the Eocene, average temperatures rose to over 25°C. Look back at "Past Climate Changes on Earth" and review what changes to the atmosphere caused this climate change, then answer the questions. In the next part of this activity, you will try to model this climate change in the Sim.

1. According to "Past Climate Changes on Earth," what changes to the atmosphere caused temperatures to increase, making the Eocene such a warm time in Earth's history?

_____

_____

_____

_____

2. What happened with the amount of energy entering compared with the amount of energy exiting the Earth system as temperatures increased during the Eocene? Did **more** energy enter than exit, **less** energy enter than exit, or **the same** amount of energy enter as exit?

_____

_____

3. Based on your answer to question 2, explain how energy entering and exiting the Earth system is connected to increased temperature during the Eocene.

_____

_____

_____

_____

Name: _____ Date: _____

Blue Group: Simulating Climate Change from the Article (continued)

Part 2: Simulating Climate Change During the Eocene

Record your partner's name: _____

Model what happened in the Eocene by making changes to the atmosphere in the Sim. Follow the steps to see if you can make the temperature reach 25°C. Try to make the same kinds of changes that caused the Eocene to be such a warm time.

1. Discuss with your partner what changes you will make to try to model the Eocene.
2. Run the Simulation until the timer reaches 20, then pause to make changes.
3. Observe what happens to temperature and energy absorbed by the surface. Remember to check the graph.
4. If you do not reach 25°C, adjust the settings.
5. Make sketches that show how energy entering and exiting was affected by your changes. You may describe your sketches on the lines below.

_____

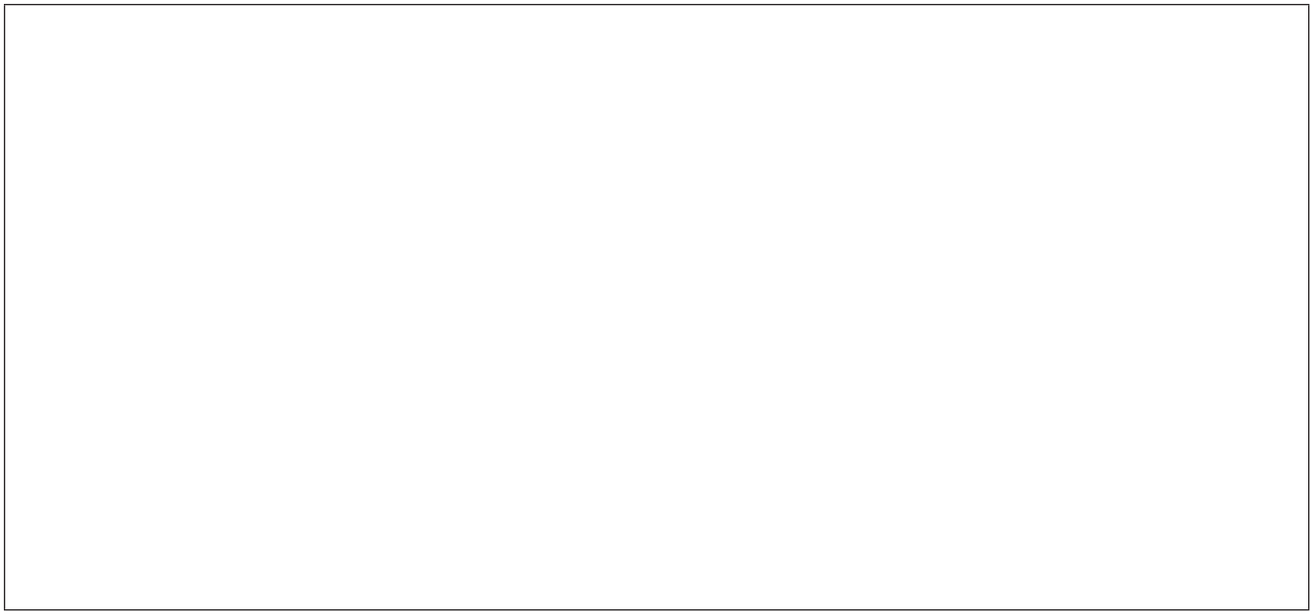
_____

_____

_____

Name: _____ Date: _____

Blue Group: Simulating Climate Change from the Article (continued)



_____

_____

_____

_____

Part 3: Adding More Details to Previous Answers

After working with the Sim, you may have learned more or found extra details to add to the answers you gave earlier. If possible, add more detail to your answers in Part 1 (page 57). If you finish early, move to Activity 3 (Revising or Creating Modeling Tool Diagrams on the next page).

Name: _____ Date: _____

Blue Group: Revising or Creating Modeling Tool Diagrams

Modeling What Happened During the Eocene

In an earlier lesson, you answered the question of why temperatures on Earth increase when the amount of carbon dioxide or methane increases. You just learned that the atmosphere changed in the same way during the Eocene.

Take a look at your explanation of the Carbon Dioxide/Methane Model on page 47 of your Investigation Notebook. Show what you learned by using the Modeling Tool to make a new model that is more accurate or more complete. When you are finished with the new model, explain the changes you made and why.

Explain the changes you made to your Carbon Dioxide/Methane Model. Why did you make these changes?

_____

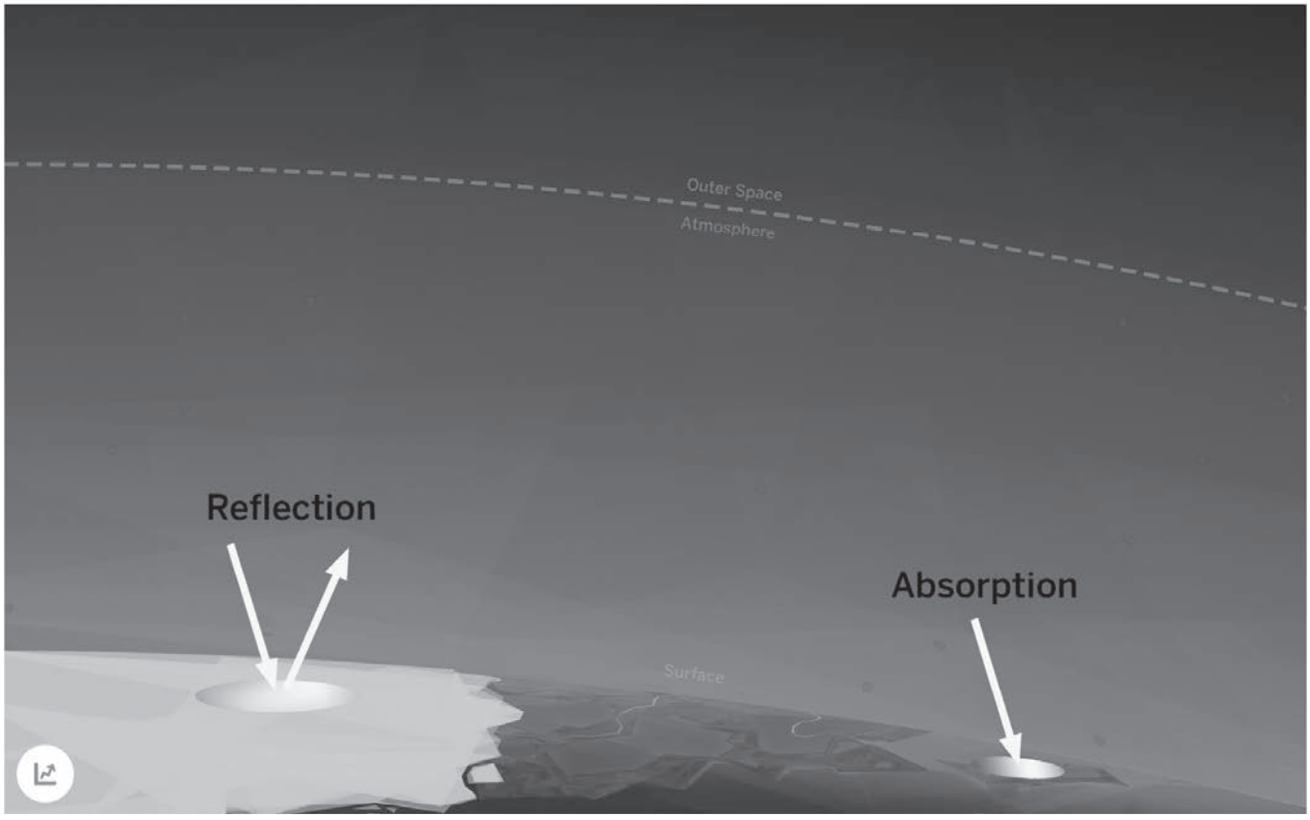
_____

_____

_____

Name: _____ Date: _____

Purple Group: Warm-Up



Light is more likely to reflect off an ice surface. Look at the diagram and explain how temperature might change if reflection increases.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Purple Group: Simulating Climate Change from the Article

Part 1: Reviewing Climate Change During the Cryogenian

In the Cryogenian, average temperatures fell to about -40°C. Look back at "Past Climate Changes on Earth" in the Snowball Earth section, and review the description of this climate change, then answer the questions. In the next part of this activity, you will try to model this climate change in the Sim.

1. According to "Past Climate Changes on Earth," what changes caused temperatures to decrease, making the Cryogenian such a cold time in Earth's history?

_____

_____

2. Describe the connection between reflectivity, energy entering and exiting the Earth system, energy absorbed at the surface, and temperature.

_____

_____

_____

_____

Name: _____ Date: _____

Purple Group: Simulating Climate Change from the Article (continued)

Part 2: Simulating Climate Change During the Cryogenian

Record your partner's name: _____

Model what happened in the Cryogenian by making changes to the atmosphere in the Sim. Try to make the same kinds of changes that caused the Cryogenian to be such a cold time. Note that the Sim is not able to model temperatures quite as cold as those during the Cryogenian.

1. Discuss with your partner what changes you will make to try to model the Cryogenian.
2. Run the Simulation until the timer reaches 20, then pause to make changes.
3. Observe what happens to temperature, energy absorbed at the surface, and energy entering and exiting the Earth system.
4. Make sketches below and on the next page that show how your changes affected temperature, energy absorbed, and energy entering and exiting the Earth system. You may describe your sketches on the lines below.

_____

_____

_____

_____

Name: _____ Date: _____

Purple Group: Simulating Climate Change from the Article (continued)

Part 3: Adding More Details to Previous Answers

After working with the Sim, you may have learned more or found extra details to add to the answers you gave earlier. If possible, add more detail to your answers in Part 1 (page 62). If you finish early, move to Activity 3 (Revising or Creating Modeling Tool Diagrams on the next page).

Name: _____ Date: _____

Purple Group: Revising or Creating Modeling Tool Diagrams

Modeling What Happened During the Cryogenian

Use the Modeling Tool to create a model showing the Cryogenian climate change.

When you are finished, press HAND IN in the Modeling Tool to see a screenshot of your completed model. Make a sketch in the space below and annotate it to explain what your model shows. The Modeling Tool may not allow you to show all the causes of the change, but you can add details when you annotate the model. You can also describe your model on the lines below.

_____

_____

_____

_____

Name: _____ Date: _____

Sharing Results

Reflection

Prepare to share what you learned with the class. Discuss with your partner how you would answer the questions for your group.

- **Green Group:** What changes to the atmosphere caused the Eocene warming? How did energy absorbed by the surface change?
- **Blue Group:** What happened with energy entering and exiting the Earth system during the Eocene warming?
- **Purple Group:** What caused the Cryogenian cooling? How did that affect energy in the Earth system?

Name: _____ Date: _____

Lesson 2.6: Investigating Paths of Energy

During your research as student climatologists, you have gathered evidence to investigate how different gases relate to energy and temperature. You found that an increase in the amount of methane or carbon dioxide in the atmosphere means that more energy is entering than exiting the Earth system. Now you will figure out exactly why this is happening.

Unit Question

- What causes climate change?

Chapter 2 Question

- Why do temperatures on Earth increase when the amount of carbon dioxide or methane in the Earth system increases?

Key Concepts

- A system can be stable, even as something flows into and out of the system. If this balanced flow is disrupted, there may be changes to the system.
- A change to either the amount of energy entering or exiting the Earth system affects how much energy is absorbed by the surface.
- Temperature increases if more energy enters than exits.
- Temperature decreases if less energy enters than exits.
- If there is an increase in the amount of carbon dioxide or methane, the amount of energy leaving the Earth system decreases, so more energy enters than exits.
- If there is a decrease in the amount of carbon dioxide or methane, the amount of energy leaving the Earth system increases, so less energy enters than exits.

Vocabulary

- atmosphere
- carbon dioxide
- claim
- climate
- climate change
- energy
- evidence
- methane
- model
- temperature

Digital Tools

- *Earth's Changing Climate* Simulation
- *Earth's Changing Climate* Modeling Tool activity: Homework Explore

Name: _____ Date: _____

Warm-Up

Turn to page 6 in your Investigation Notebook and review your original response to statement #6 in the Anticipation Guide.

6. _____ It is possible for gases in the atmosphere to change the behavior of energy on Earth.

Do you currently agree or disagree with this claim? (circle one)

a. agree

b. disagree

Have your views changed throughout the unit?

a. yes

b. no

What evidence do you have to support your current thinking about this claim? Please explain.

_____

_____

_____

_____

Name: _____ Date: _____

Investigating Energy Interactions in the Sim

Part 1: Investigating Energy Interactions in the Sim

Use the Simulation to investigate this question: ***What happens when energy interacts with carbon dioxide or methane in the atmosphere?***

1. Discuss with your partner and record your initial claim below.
2. Decide which partner will investigate carbon dioxide and which one will investigate methane.
3. Set the gas you are investigating to MAXIMUM and the other gases to ZERO.
4. Press on the eye icon to make the gas you are investigating visible.
5. Choose an energy arrow that is moving away from Earth. Press on the arrow to activate the tracking function. The other arrows will fade and this arrow's track will be visible.
6. Press PLAY and observe.
7. If your energy arrow leaves Earth's system, choose a new one. Be patient; it may take a few tries before you capture an interaction!
8. If your energy arrow interacts with a gas, continue observing until that energy arrow leaves the Earth system, then pause. Describe what happened and make a sketch of each interaction.
9. Try to capture at least three interactions.

Initial Claim:

_____

Interaction 1	
Describe what you observed.	**Make a sketch.**

Name: _____ Date: _____

Investigating Energy Interactions in the Sim (continued)

Interaction 2	
Describe what you observed.	**Make a sketch.**
_____ _____ _____ _____ _____ _____	
Interaction 3	
Describe what you observed.	**Make a sketch.**
_____ _____ _____ _____ _____ _____	
Interaction 4	
Describe what you observed.	**Make a sketch.**
_____ _____ _____ _____ _____ _____	

Name: _____ Date: _____

Investigating Energy Interactions in the Sim (continued)

Part 2: Summarizing Results from the Sim Investigation

What happens when energy interacts with carbon dioxide and methane in the atmosphere?

Discuss the results of your investigation with your partner. Was your initial claim accurate? Based on your investigation, how would you answer this question now?

_____

_____

_____

Name: _____ Date: _____

Investigating with the Energy Token Model

Part 1: Investigating with the Energy Token Model

Why does an increase in carbon dioxide or methane result in more energy entering than exiting the Earth system?

You used the Sim to observe what happens when energy interacts with carbon dioxide and methane. Now, with your partner, you'll use the Energy Token Model to model how those interactions affect the amount of energy entering and exiting.

1. **Set up the model as follows:**
   - 1 energy token in the Atmosphere (on top of a methane or carbon dioxide symbol)
   - 10 energy tokens in Outer Space
   - 4 energy tokens in Earth's Surface
2. **Each round has three parts:**
   - **Part 1: Energy in the Atmosphere.** If there is an energy token in the Atmosphere, use rock-paper-scissors to decide what happens. If Partner A wins, the energy is reemitted upward (the token moves to Outer Space). If Partner B wins, the energy is reemitted downward (token returns to Earth's Surface).
   - **Part 2: Energy from Outer Space:** Partner A moves an energy token from Outer Space to Earth's Surface. **Hint:** incoming energy, in the form of visible light, can pass THROUGH methane and carbon dioxide.
   - **Part 3: Energy in Earth's Surface.** Partner B moves an energy token from Earth's Surface through the Atmosphere toward Outer Space. If its path crosses a methane or carbon dioxide symbol, leave the token in the Atmosphere to represent that it was absorbed by the gas. Otherwise, place the token in Outer Space.
3. **Repeat!** (You may wish to keep a tally on scratch paper so you remember how many rounds you have completed.) Add more energy tokens from the bag, if you run out.
4. **Count and record the energy in the Earth system.** Every 5 rounds, count the energy (Earth's Surface and Atmosphere) and record your results in the table to the right.

Round	Energy in the Earth System (Surface + Atmosphere)
Start	5
5	
10	
15	
20	

Name: _____ Date: _____

Energy Token Model #2

Outer Space

Start with 10 tokens here.

Atmosphere

Start with 1 token here.

Earth's Surface

Start with 4 tokens here.

Name: _____ Date: _____

Investigating with the Energy Token Model (continued)

Part 2: Summarizing Results from the Model

Why does an increase in carbon dioxide or methane result in more energy entering than exiting the Earth system?

Based on your investigations with the Sim and the Energy Token Model, which of the following statements is the most accurate claim? (circle one)

a. Increased carbon dioxide or methane makes more sunlight enter Earth's system.

b. Increased carbon dioxide or methane holds energy in the atmosphere permanently.

c. Increased carbon dioxide or methane redirects some energy that was leaving back to Earth's surface.

Use the answer you chose to explain why increased carbon dioxide or methane leads to an increase in temperature.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Exploring New Features in the Modeling Tool

When your model is complete, press HAND IN.
If you worked with a partner, write their name here: _____

There are some new things you can do with the *Earth's Changing Climate* Modeling Tool activity: Homework Explore. In this version of the Modeling Tool, the panels don't represent Before and After. Instead, you can use the two panels to show how two different gases affect energy (for example, you could show how energy is affected by nitrogen dioxide in one panel and carbon dioxide in another).

Draw the path of energy and drag out individual gases. Play around with these new features. Use them to draw some different ways you saw energy move and interact with gases in the Sim today.

Goal: Explore the tool.

Tips:

- Drag and drop an Energy arrow into the workspace. Move it around, lengthen or shorten it, or point it in a different direction by dragging the circles at the ends.
- Drag and drop another arrow, and try connecting it to the first arrow.
- Drag and drop a gas into the workspace. Try connecting an arrow to the gas.

Name: _____ Date: _____

Lesson 2.7: Explaining Climate Change

The head climatologist at World Climate Institute has sent a message asking for your help. Today you will make a model and write an explanation to show how increasing carbon dioxide and methane are affecting Earth's temperature. Your explanation will be used to educate the public on this important topic.

Unit Question

- What causes climate change?

Chapter 2 Question

- Why do temperatures on Earth increase when the amount of carbon dioxide or methane in the Earth system increases?

Key Concepts

- A system can be stable, even as something flows into and out of the system. If this balanced flow is disrupted, there may be changes to the system.
- A change to either the amount of energy entering or exiting the Earth system affects how much energy is absorbed by the surface.
- Temperature increases if more energy enters than exits.
- Temperature decreases if less energy enters than exits.
- If there is an increase in the amount of carbon dioxide or methane, the amount of energy leaving the Earth system decreases, so more energy enters than exits.
- If there is a decrease in the amount of carbon dioxide or methane, the amount of energy leaving the Earth system increases, so less energy enters than exits.
- Carbon dioxide and methane stop energy from leaving by redirecting energy that would have exited the system.

Vocabulary

- atmosphere
- carbon dioxide
- claim
- climate
- climate change
- energy
- evidence
- methane
- model
- temperature

Digital Tools

- *Earth's Changing Climate* Modeling Tool activities: Carbon Dioxide Energy Path and Methane Energy Path

Name: _____ Date: _____

Warm-Up

Read the following message, then answer the question.

From: Irene Lee
To: Student Climatologists
Subject: Helping Others Understand Climate Change

World Climate Institute

Thank you for all your hard work on the subject of climate change these last few weeks. Being able to explain why our climate is changing and why Earth's ice is melting is vital.

Today, I'd like you to create a report that explains these climate change ideas to a general audience. Be sure your writing is clear and includes visuals so people who don't know much about this topic will find it meaningful. WCI hopes that if people understand, they will take action and support laws that will help with this serious problem.

Your report is a valuable part of WCI's mission to educate the public so they can better understand this topic. We appreciate your help!

What are some important ideas you'd want to share with people who don't know very much about climate change?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Explaining Climate Change with the Modeling Tool

When your model is complete, press HAND IN.
If you worked with a partner, write their name here: _____

Part 1: Modeling How Gases Affect the Path of Energy

Open the Modeling Tool activity: Carbon Dioxide Energy Path. Create a model that you can add to your report for the World Climate Institute. If you have time, press NEXT and move on to Part 2 of this Activity where you will complete a model that shows the Methane Energy Path.

Goal: Show how the path of energy is affected by carbon dioxide (or methane).

Do:

- Drag and drop an arrow on the Carbon Dioxide (or Methane) panel. Move it and resize the arrow to show what happens when energy hits carbon dioxide (or methane).

Tips:

- The example on the left shows how nitrogen dioxide affects the path of energy.
- Arrows can be connected to other arrows or to gases.
- Incoming energy hitting the surface and carbon dioxide (or methane) have already been placed in the panel on the right.

Complete the following statement using your model of carbon dioxide affecting the path of energy.

When there is an increase in carbon dioxide in the atmosphere,

a. more energy enters than exits,

b. less energy enters than exits,

c. there is no change in energy,

which causes temperatures to (**increase** / **decrease** / **stay the same**).

Part 2: Modeling How Gases Affect the Path of Energy

If you have time, create a model that shows the Methane Energy Path.

Name: _____ Date: _____

Discussing Causes of Climate Change

Word Relationships

Chapter 2 Question: *Why do temperatures on Earth increase when the amount of carbon dioxide or methane in the Earth system increases?*

Word Bank

atmosphere	methane	absorb
carbon dioxide	energy	redirect

1. With your group, use the words from the Word Bank to discuss and answer the Chapter 2 Question.
2. After the discussion, work with your group and record one or two sentences that answer the question on the lines below. Be sure you've included all the words.
3. Be prepared to share your sentences with the class.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Writing About Climate Change for the Public

Part 1: Writing an Explanation of Climate Change

We know that the global average temperature on Earth is increasing and ice is melting. We also know that the amount of carbon dioxide and methane has increased. You may find it useful to refer to your model and use words from the Word Bank as you write your explanation.

Word Bank

atmosphere	methane	temperature
carbon dioxide	redirect	
energy	surface	

Why does temperature increase when the amount of carbon dioxide or methane in the Earth system increases?

_____

_____

_____

_____

_____

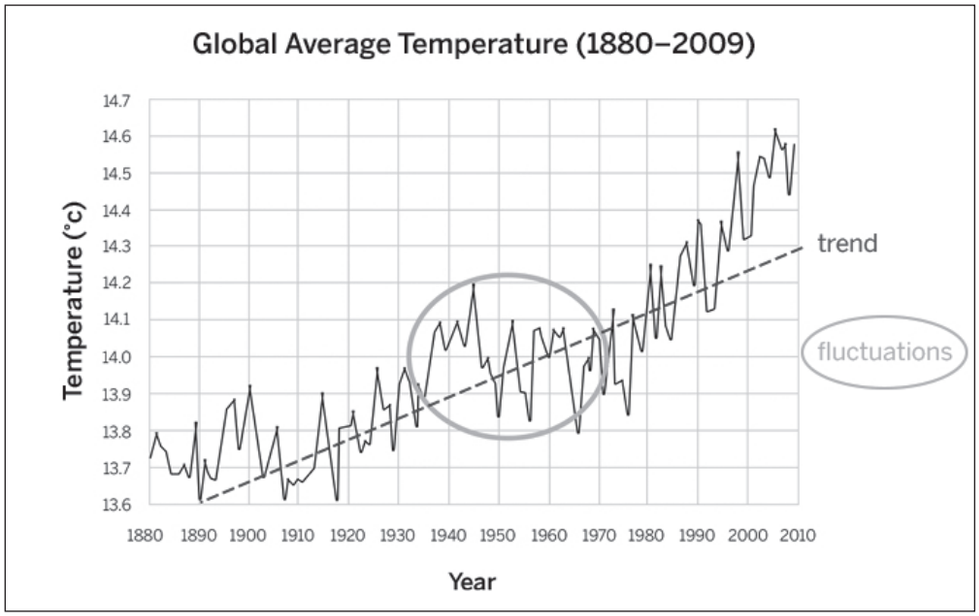
_____

Name: _____ Date: _____

Writing About Climate Change for the Public (continued)

Part 2: Explaining Trend and Fluctuation

This graph shows Global Average Temperature since around 1880. We know that globally, more and more ice is melting because the average temperature on Earth is increasing. Use this graph to explain why we are sure that the data over this time period is showing climate change, not just a temporary change in temperature. Use the terms ***fluctuation*** and ***trend*** in your explanation.



_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

Scientists investigate in order to explain their observations. You have been investigating why the climate has been changing. Are you getting closer to understanding what causes climate change?

1. I understand how the atmosphere is related to the ice melting. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

2. I understand what can affect energy entering and exiting the Earth system, and how this affects climate. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

3. I understand what can happen when energy hits gases. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

4. I understand what causes the amount of gases in the atmosphere to change. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

5. What about climate change are you still wondering?

_____

_____

_____

Name: _____ Date: _____

Chapter 3: Human Activity and Climate
Chapter Overview

Now you understand how increased carbon dioxide and methane in the atmosphere can lead to a warmer Earth. Next, you'll explore how humans affect the amount of these gases in the atmosphere and what we can do to try to reduce global warming.

Name: _____ Date: _____

Lesson 3.1: Investigating Human Activity and the Atmosphere

The head climatologist is calling on you for assistance with another investigation. This investigation is focused on human activities and how they might be impacting the atmosphere. You will use the Sim and evaluate evidence, using the Evidence Gradient, as you discover how human activities are affecting Earth.

Unit Question

- What causes climate change?

Chapter 3 Question

- What can be done to stop the carbon dioxide and methane in Earth's atmosphere from increasing?

Vocabulary

- atmosphere
- carbon dioxide
- change
- claim
- climate
- climate change
- combustion
- energy
- fluctuation
- human activities
- methane
- stability
- temperature
- trend

Digital Tools

- *Earth's Changing Climate* Simulation
- *Earth's Changing Climate* Modeling Tool activity: Climate Change Cause

Name: _____ Date: _____

Warm-Up

We discovered that both carbon dioxide and methane have been increasing in Earth's atmosphere. What ideas do you have about why this might be happening? What could be causing Earth's atmosphere to change?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Investigating Human Activities in the Sim

Part 1: Carbon Dioxide Investigation

Investigate how changes to **Population** and **Combustion per Person** affect the amount of carbon dioxide in the atmosphere. Go to *Earth's Changing Climate* Simulation and select Human Activities mode. **Note:** If you're assigned to the Methane Investigation, only complete Part 2 of this activity.

Select Human Activities mode from the menu on the left. Open the graph by pressing the graph icon in the lower left corner and select carbon dioxide.

Population Testing

1. **No change to Population:** Run the Sim until the time reaches 30. Pause and record your observations.

   With no change to Population,

   _____

2. **Decrease Population to the lowest setting:** Run until the time reaches 60. Pause and record your observations.

   When I decreased Population,

   _____

3. **Increase Population to the highest setting:** Run until the time reaches 90. Pause and record your observations.

   When I increased Population,

   _____

Name: _____ Date: _____

Investigating Human Activities in the Sim (continued)

Combustion Testing

4. **No change to Combustion:** Reset the Sim. Run until the time reaches 30. Pause and record your observations.

   With no change to Combustion,

   _____

5. **Decrease Combustion to the lowest setting:** Run until the time reaches 60. Pause and record your observations.

   When I decreased Combustion,

   _____

6. **Increase Combustion to the highest setting:** Run until the time reaches 90. Pause and record your observations.

   When I increased Combustion,

   _____

Name: _____ Date: _____

Investigating Human Activities in the Sim (continued)

Part 2: Methane Investigation

Investigate how changes to **Population** and **Livestock per Person** affect the amount of methane in the atmosphere. Go to *Earth's Changing Climate* Simulation and select Human Activities mode. **Note:** If you're assigned to the Carbon Dioxide Investigation, only complete Part 1 of this activity.

Select Human Activities mode from the menu on the left. Open the graph by pressing the graph icon in the lower left corner and select methane.

Population Testing

1. **No change to Population :** Run the Sim until the time reaches 30. Pause and record your observations.

   With no change to Population,

   _____

2. **Decrease Population to the lowest setting:** Run until the time reaches 60. Pause and record your observations.

   When I decreased Population,

   _____

3. **Increase Population to the highest setting:** Run until the time reaches 90. Pause and record your observations.

   When I increased Population,

   _____

Name: _____ Date: _____

Investigating Human Activities in the Sim (continued)

Livestock per Person Testing

4. **No change to Livestock per Person:** Reset the Sim. Run until the time reaches 30. Pause and record your observations.

   With no change to Livestock per Person,

   _____

5. **Decrease Livestock per Person to the lowest setting:** Run until the time reaches 60. Pause and record your observations.

   When I decreased Livestock per Person,

   _____

6. **Increase Livestock per Person to the highest setting:** Run until the time reaches 90. Pause and record your observations.

   When I increased Livestock per Person,

   _____

Name: _____ Date: _____

Analyzing Human Activities Data

Evaluating Evidence with the Evidence Gradient

Your teacher will give you and your partner an Evidence Gradient and a set of Human Activities Evidence Cards.

1. Place the Human Activities Evidence Cards on the Evidence Gradient, based on how strong the evidence is.
2. Use the strongest evidence to discuss with your partner and answer the Investigation Question, *Why are carbon dioxide and methane increasing in the atmosphere?*

Name: _____ Date: _____

Homework: Modeling Human Impact

When your model is complete, press HAND IN.
If you worked with a partner, write their name here: _____

Use the Modeling Tool activity: Climate Change Cause to answer the question, ***Why is carbon dioxide or methane increasing in the atmosphere?***

Goal: Show one cause of carbon dioxide or methane increasing in the atmosphere and how this leads to a change in temperature.

Do:

- Select one human activity that could lead to either an increase in carbon dioxide or methane.
- Show whether the selected human activity leads into an increase in carbon dioxide or methane.
- Show the balance of energy entering and exiting in both panels.
- Show the amount of energy absorbed in both panels.
- Show the temperature in both panels.

Tip:

- The Before Change panel should show a time when the temperature is stable.

Name: _____ Date: _____

Homework: Reading "Global Warming: A History of a Hot Debate"

You have learned a lot about how human activity is related to climate change. Read "Global Warming: A History of a Hot Debate" to learn about how scientists explored the role of human activities on climate. As you read, highlight any information that will help you answer the two questions below. After reading, use your annotations to help you answer the questions.

1. What different ideas did scientists in the twentieth century have about the effect of adding carbon dioxide to the atmosphere?

_____

_____

_____

_____

2. What happened that made it easier for scientists to test their ideas about the effect of gases (such as carbon dioxide and methane) on the atmosphere?

_____

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 3.2: Reading "Climate Change Solutions"

Human activities are causing the levels of carbon dioxide and methane in the atmosphere to increase and there are several possible solutions for this serious situation. Today you will learn about some of the creative ways people are trying to combat climate change and protect the Earth system.

Unit Question

- What causes climate change?

Chapter 3 Question

- What can be done to stop the carbon dioxide and methane in Earth's atmosphere from increasing?

Key Concepts

- Carbon dioxide and methane in the atmosphere increase as a result of human activities, such as combustion.

Vocabulary

- atmosphere
- carbon dioxide
- claim
- climate
- climate change
- combustion
- energy
- human activities
- methane
- temperature

Digital Tool

- *Earth's Changing Climate* Simulation

Name: _____ Date: _____

Warm-Up

Earth's climate is getting warmer because more carbon dioxide and methane are being added to the atmosphere from human activities. There are things we can do to put less carbon dioxide and methane into the atmosphere.

What are your ideas about how humans can reduce the amount of carbon dioxide and methane they add to the atmosphere?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Reading "Climate Change Solutions"

1. Read and annotate "Climate Change Solutions."
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. After reading, answer the question below.

Rate how successful you were at using your Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ never
- ☐ almost never
- ☐ sometimes
- ☐ frequently/often
- ☐ all the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Revisiting the Anticipation Guide

Turn to page 6 in your Investigation Notebook and review your original response to statement #7 in the Anticipation Guide.

7. _____ Human actions cannot change Earth's atmosphere.

Do you currently agree or disagree with this claim? (circle one)

a. agree

b. disagree

Have your views changed throughout the unit? (circle one)

a. yes

b. no

Describe the evidence you would use to support your current thinking about this claim.

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Investigating Forest Cover in the Sim

All plants take in carbon dioxide, use it to make food for themselves, and release oxygen. Use the *Earth's Changing Climate* Simulation to find out how forest cover affects the amount of carbon dioxide in the atmosphere.

Predict: If I increase forest cover in the Sim, carbon dioxide will (check one)

☐ increase ☐ decrease ☐ not change

Test your prediction by conducting two tests in the Human Activities mode of the Sim.

Test 1:

1. Decrease the population to 2 billion.
2. Run the Sim until the time reaches 20.
3. Increase Forest Cover to high.
4. Observe carbon dioxide and temperature in the graph. Make and annotate a sketch of the graph.

In Test 1, what happened to carbon dioxide? What happened to temperature?

_____

_____

Name: _____ Date: _____

Homework: Investigating Forest Cover in the Sim (continued)

Test 2:

1. Reset the Sim and leave the population at 7 billion.
2. Run the Sim until the time reaches 20.
3. Increase Forest Cover to high.
4. Observe carbon dioxide and temperature in the graph. Make and annotate a sketch of the graph.

In Test 2, what happened to carbon dioxide? What happened to temperature?

_____

_____

How does forest cover affect the amount of carbon dioxide in the atmosphere?

_____

_____

Why do you think the results were different for these two tests?

_____

_____

Name: _____ Date: _____

Lesson 3.3: Explaining Possible Solutions

The head climatologist is calling on you to help put together a climate change solutions blog. This blog will spread the word and inspire people to make these solutions a reality. Today you will explore one solution in detail and use the Modeling Tool to help you explain this solution and its effect on the climate in your blog post.

Unit Question

- What causes climate change?

Chapter 3 Question

- What can be done to stop the carbon dioxide and methane in Earth's atmosphere from increasing?

Key Concepts

- Carbon dioxide and methane in the atmosphere increase as a result of human activities, such as combustion.
- Some ways to stop the increase of carbon dioxide and methane include decreasing combustion and removing these gases from the atmosphere.
- Humans can take actions in their daily lives that will reduce the amount of carbon dioxide and methane in the atmosphere.

Vocabulary

- atmosphere
- carbon dioxide
- change
- claim
- climate
- climate change
- combustion
- energy
- evidence
- human activities
- methane
- stability
- temperature

Digital Tools

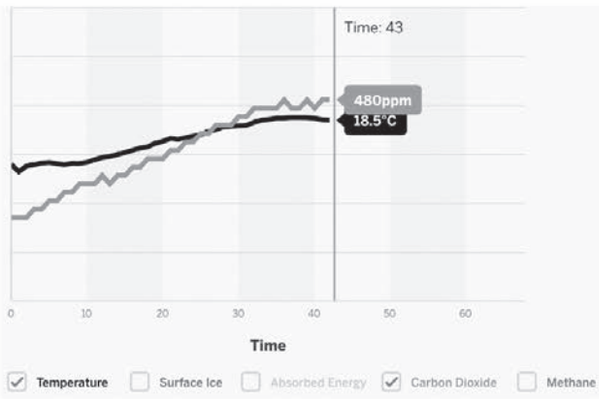
- *Earth's Changing Climate* Modeling Tool activity: Climate Change Solution
- *Earth's Changing Climate* Simulation

Name: _____ Date: _____

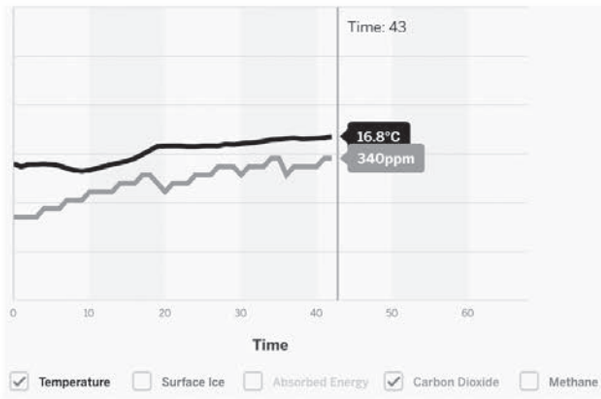
Warm-Up

One of these Sim tests was run with the Combustion per Person set to high; the other one was run with Combustion per Person set to medium. Which is which? Select the setting for each graph.

Combustion set to ☐ medium ☐ high



Combustion set to ☐ medium ☐ high



Explain how you knew which graph was which.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Rereading About One Solution

Analyzing One Solution to Climate Change

Read about ONE possible solution from "Climate Change Solutions." Your partner will read about a different solution. You are rereading part of this article so you can better understand one solution, explain it to your partner, and write about it in your report for WCI.

Highlight helpful information as you read, and then answer the following questions:

1. Which solution did you read about? (circle one)
   a. solar power
   b. bikes and transit
   c. capturing methane from cows
   d. capturing carbon dioxide at power plants
   e. reforestation

2. What kind of solution is it? (circle one)
   a. This solution produces less carbon dioxide.
   b. This solution removes carbon dioxide from the atmosphere.
   c. This solution removes methane from the atmosphere.

3. Explain why the solution is needed.

_____

_____

_____

4. Explain how the solution works.

_____

_____

_____

5. Is this a good solution? Why or why not?

_____

_____

_____

Name: _____ Date: _____

Modeling One Solution

When your model is complete, press HAND IN.
If you worked with a partner, write their name here: _____

Use the Modeling Tool activity: Climate Change Solution to create a diagram that shows how the solution you read about would affect climate. Hand in your finished model and annotate it to help explain what you included.

Goal: Show how one solution would work to stop carbon dioxide or methane in the atmosphere from increasing and how it will affect temperature.

Do:

- Select one solution that will stop either carbon dioxide or methane from increasing.
- Show how this solution would affect energy, carbon dioxide or methane, and temperature.

Tip:

- If the Modeling Tool does not allow you to show all your ideas, complete what you can, press HAND IN in the Modeling Tool to see a screenshot of your model, and add annotations to further explain your ideas.

Name: _____ Date: _____

Stable Temperature in the Sim

Sim Mission: Stable Temperature: Keep the temperature as stable as possible (not increasing or decreasing) until the time reaches 100 or more.

- Use the *Earth's Changing Climate* Simulation and select Human Activities mode.
- Leave population at 7 billion (close to what the world population is today).
- Adjust Combustion per Person, Livestock per Person, Forest Cover, and Gas Capture.
- When you succeed at the mission, make two sketches: (1) the Earth system and (2) graph view showing the stable temperature.
- Do not let the temperature reach 30°C.
- Answer the question.

Sketch: the Earth system	Sketch: graph view

Why do you think these human activity settings resulted in a stable temperature? If it helps you answer, annotate your sketches.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Blog Post: Climate Change Solution

Dr. Lee asked you to write a blog post that describes and explains the solution you read about in "Climate Change Solutions." When you write your explanation, remember that the general public is your audience. Try to be as convincing as possible. Carefully explain the solution, how it would affect climate change, and why it is needed.

Word Bank

absorb	energy	methane
atmosphere	enter	redirect
carbon dioxide	exit	surface

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Reading "What Are We Doing About Sea Level Rise?"

Read "What Are We Doing About Sea Level Rise?" to learn about how people are preparing for a future with higher ocean levels. As you read, highlight any information that will help you answer the two questions below. After reading, use your annotations to help you answer the questions.

1. What are some things that will happen if global sea levels rise?

_____

_____

_____

2. What are the ways coastal cities are preparing for sea level rise?

_____

_____

_____

3. Why is wetland restoration an effective way to prepare for sea level rise?

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

Scientists investigate in order to explain their observations. You have been investigating why the climate has been changing. Are you getting closer to understanding what causes climate change?

1. I understand how the atmosphere is related to the ice melting. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

2. I understand what can affect energy entering and exiting the Earth system, and how this affects climate. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

3. I understand what can happen when energy hits gases. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

4. I understand what causes the amount of gases in the atmosphere to change. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

5. I understand that scientists can only make explanations about things they can observe and gather evidence about. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

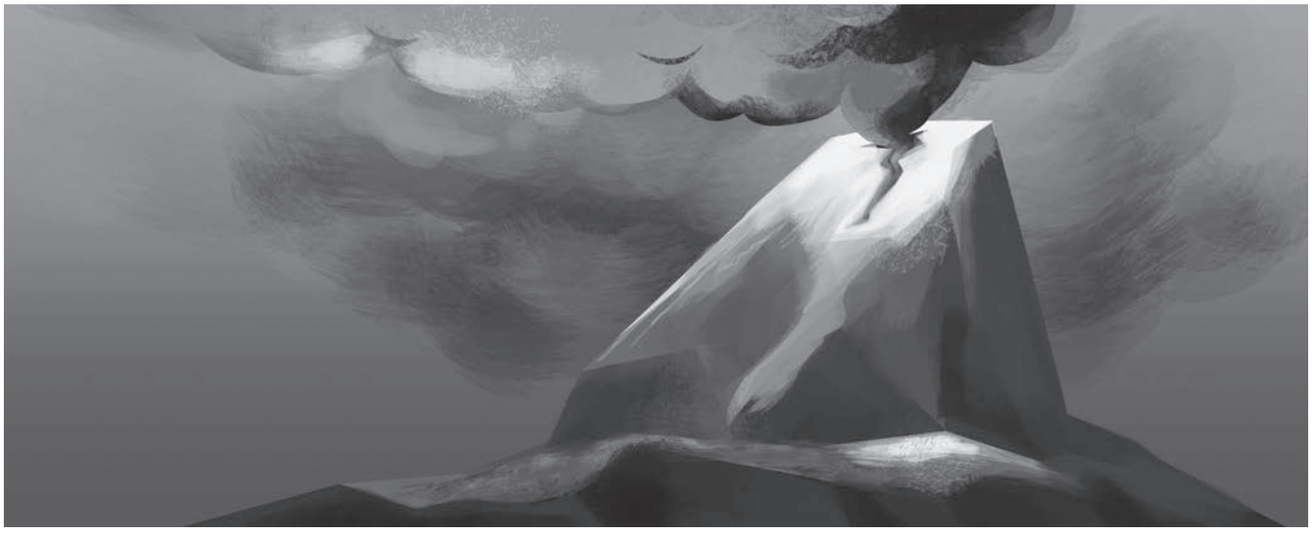
6. What about climate change are you still wondering?

_____

Name: _____ Date: _____

Chapter 4: Volcanic Eruptions and Climate
Chapter Overview

Humans are not the only factor causing climate change; volcanoes can also have a huge impact on the climate! Analyze evidence and decide for yourself what effect volcanic eruptions can have on Earth's atmosphere and climate.



Name: _____ Date: _____

Lesson 4.1: Investigating Volcanic Eruptions

The head climatologist has one final mission for you. Scientists are working to understand the effect of volcanic eruptions on Earth's climate. Volcanic eruptions blast dust, ash, and gases into the atmosphere. Overall, does this cool or warm our planet? While volcanoes are not impacting the climate anywhere near as much as human activities are, understanding their impact is still important for predicting and modeling smaller-scale changes to the climate.

Unit Question

- What causes climate change?

Chapter 4 Question

- How is Earth's climate affected in the five to ten years after a large volcanic eruption?

Vocabulary

- atmosphere
- carbon dioxide
- claim
- climate
- climate change
- energy
- evidence
- fluctuation
- human activities
- methane
- temperature
- trend

Digital Tools

- *Earth's Changing Climate* Simulation
- *Earth's Changing Climate* Modeling Tool activity: Sulfur Dioxide Energy Path

Name: _____ Date: _____

Warm-Up

Read the message from Dr. Irene Lee, the head climatologist, and then answer the question. Don't worry if you're not sure about your answer. You will learn more about volcanic eruptions in the next few days.

From: Irene Lee
To: Student Climatologists
Subject: Effect of Volcanic Eruptions

World Climate Institute

Thank you for your excellent work! You've helped us explain to the public how climate change is happening on a large scale because of human activities. And now, I have a new mission for you.

Please help us research a smaller-scale influence on climate. Major explosive volcanic eruptions affect the atmosphere, and we want to know whether they cause cooling or warming of the planet in the five to ten years following the eruption. You'll examine evidence from several volcanoes, but mostly from Mount Pinatubo (major eruption in 1991), which is located in the Republic of the Philippines in Southeast Asia. Before drawing conclusions, you will discuss your claims and evidence in a few days in a group discussion called a Science Seminar.

Looking forward to an interesting discussion . . .

What do you already know about volcanoes and volcanic eruptions?

_____

_____

_____

_____

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_____

Name: _____ Date: _____

Simulating Effects of Sulfur Dioxide

Part 1: Observe Overall Effects

- Run the *Earth's Changing Climate* Simulation until the time reaches 20, then pause.
- Increase sulfur dioxide to 500 ppm.
- Run the Sim until the time reaches 40.
- Observe changes to (1) energy entering and exiting and (2) temperature.
- Be sure to check the graph.
- Answer the questions below, using your results.

Part 2: Track Individual Energy Arrows

- Continue running the Sim and track incoming energy to see what happens when it hits sulfur dioxide. It may take several tries in order to find energy that hits sulfur dioxide.
- Add to your answers to the questions below, using your observations.

Questions

1. What happened to temperature after you increased sulfur dioxide?

_____

_____

_____

_____

_____

_____

2. What happened to energy entering and energy exiting after you increased sulfur dioxide? (circle one)

   a. More energy entered than exited.

   b. Less energy entered than exited.

   c. The same amount of energy entered and left.

Name: _____ Date: _____

Simulating Effects of Sulfur Dioxide (continued)

3. What happens when incoming energy hits sulfur dioxide?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Evaluating Temperature Evidence

Using the Evidence Gradient to Evaluate Evidence

Your teacher will give you and your partner an Evidence Gradient and a set of Volcano Evidence Cards. Look at and discuss the three evidence cards. Decide which one of the three cards provides the strongest evidence about the effect of the Pinatubo eruption on global average temperature in the five to ten years after the eruption.

Which evidence card (or cards) provides the most useful evidence about temperature? (circle one)

a. Evidence Card A: May 1991–August 1991

b. Evidence Card B: January 1991–December 1995

c. Evidence Card C: 1980–2010

Name: _____ Date: _____

Homework: Modeling the Path of Energy

When your model is complete, press HAND IN.
If you worked with a partner, write their name here: _____

Show how the path of energy is affected by carbon dioxide and sulfur dioxide.

Carbon dioxide and sulfur dioxide are both gases in the atmosphere, but they are different in the way they interact with energy. Using the Modeling Tool, demonstrate the difference between how carbon dioxide interacts with energy and how sulfur dioxide interacts with energy.

Goal: Show how the path of energy is affected by carbon dioxide and sulfur dioxide.

Do:

- In the Carbon Dioxide panel (left), show the path of energy after it hits carbon dioxide.
- In the Sulfur Dioxide panel (right), show the path of energy after it hits sulfur dioxide.

Tips:

- Incoming energy is given in both panels. You may choose to have the incoming energy hit the gas or the surface first.
- The correct gas has already been placed in each panel.

Use your model to explain the effect of sulfur dioxide on energy and temperature. You can annotate your model if it helps you with your explanation.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 4.2: Examining Evidence About Volcanic Eruptions

Today you will get more evidence about two different volcanic eruptions, Pinatubo and Eyjafjallajökull. You will analyze this evidence and then, with a partner, discuss how this new evidence relates to the claims made about how volcanic eruptions affect global average temperature over short periods of time. Does a large volcanic eruption make Earth's temperature warmer? Cooler? You might even decide that you have a different claim based on the evidence you receive today.

Unit Question

- What causes climate change?

Chapter 4 Question

- How is Earth's climate affected in the five to ten years after a large volcanic eruption?

Key Concepts

- While human activities are causing the current long-term trend of increasing temperatures, other factors can have smaller effects on the climate in the short term.

Vocabulary

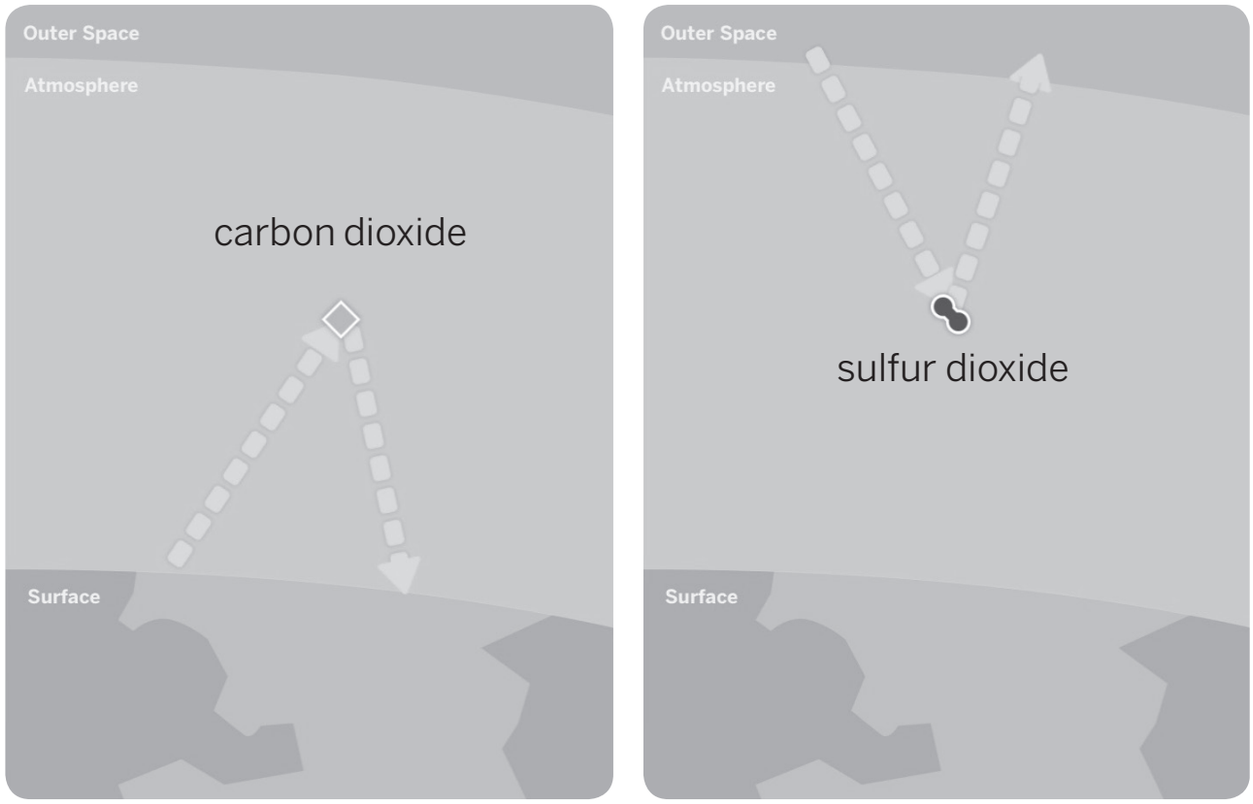
- atmosphere
- carbon dioxide
- claim
- climate
- climate change
- energy
- evidence
- human activities
- methane
- temperature

Name: _____ Date: _____

Warm-Up

For homework, you modeled what happens when incoming energy hits sulfur dioxide. Review the image and answer the question.

Carbon Dioxide and Sulfur Dioxide



How is the effect of energy hitting carbon dioxide different from energy hitting sulfur dioxide?

_____

_____

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_____

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_____

Name: _____ Date: _____

Analyzing More Evidence

You will use the Volcano Evidence Cards you evaluated in the previous lesson. In addition, your teacher will give you some new evidence cards.

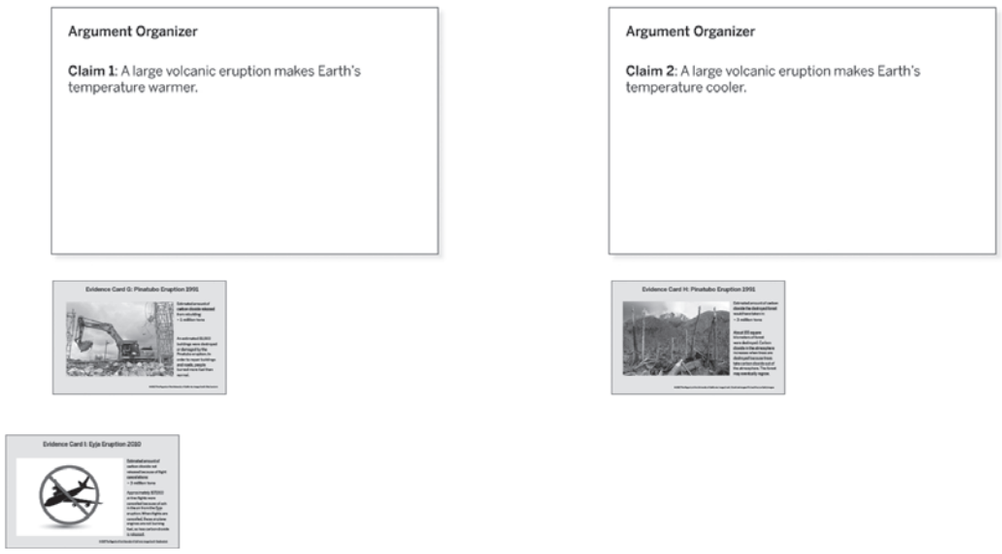
- Carefully read and annotate each evidence card.
- Write connections and questions that you think of as you read.
- If you come across words you don't know, circle those.
- Try to write one short summary sentence on each card.

Name: _____ Date: _____

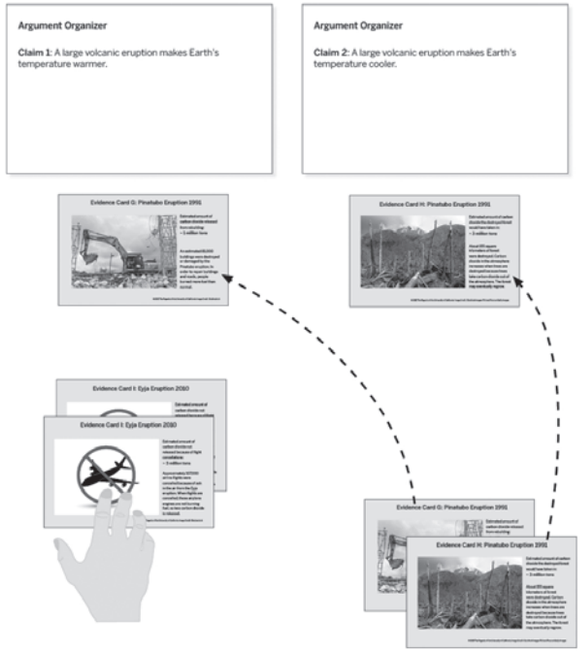
Sort and Organize Evidence Cards

1. Using the illustrations as a guide, discuss and sort one set of evidence cards with your partner.
2. Sort the second set so it matches the first set.
3. Clip each partner's cards to their Argument Organizer.

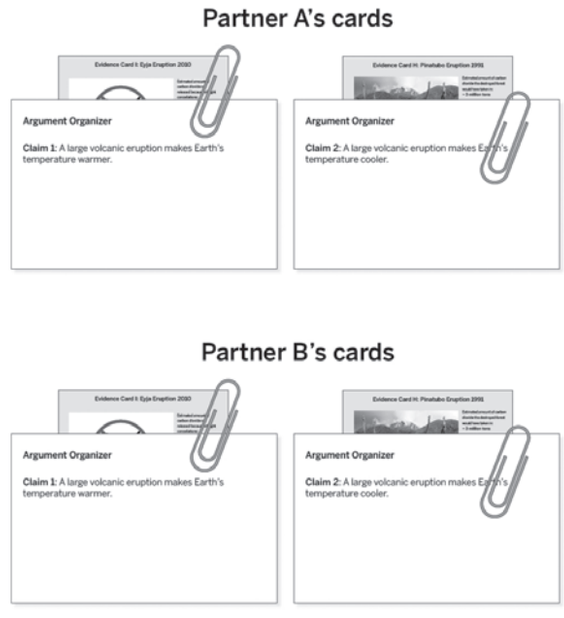
1. Working with a partner, sort one set of cards according to the claim it supports.



2. Place each card from the second set on top of the card it matches.



3. Separate the card pairs so each partner's cards are attached to the appropriate claim.



Name: _____ Date: _____

Homework: Making Climate Change Connections

Think of another science topic you studied earlier. How might considering stability and change be useful when investigating that topic? How is that similar to and different from how the crosscutting concept of stability and change is useful in this unit?

Name: _____ Date: _____

Lesson 4.3: The Science Seminar

Do large volcanic eruptions affect Earth's climate? In today's Science Seminar, you and your classmates will discuss the evidence, listen to each other's ideas, and try to arrive at the best explanation for how large volcanic eruptions affect Earth's temperature. After hearing your classmates and participating in the discussion, you will be ready to write a convincing scientific argument.

Unit Question

- What causes climate change?

Chapter 4 Question

- How is Earth's climate affected in the five to ten years after a large volcanic eruption?

Key Concepts

- Although there are many fluctuations, there is a trend toward increasing temperatures and decreasing ice on Earth since about 1880.
- Global average temperature increases when energy absorbed by the surface increases.
- When the amount of carbon dioxide or methane in the atmosphere changes, the amount of energy absorbed by the surface also changes.
- When the amount of carbon dioxide or methane increases, energy absorbed by the surface increases.
- When the amount of carbon dioxide or methane decreases, energy absorbed by the surface decreases.
- A system can be stable, even as something flows into and out of the system. If this balanced flow is disrupted, there may be changes to the system.
- A change to either the amount of energy entering or exiting the Earth system affects how much energy is absorbed by the surface.
- Temperature increases if more energy enters than exits.
- Temperature decreases if less energy enters than exits.
- If there is an increase in the amount of carbon dioxide or methane, the amount of energy leaving the Earth system decreases, so more energy enters than exits.
- If there is a decrease in the amount of carbon dioxide or methane, the amount of energy leaving the Earth system increases, so less energy enters than exits.

Name: _____ Date: _____

Lesson 4.3: The Science Seminar (continued)

- Carbon dioxide and methane stop energy from leaving by redirecting energy that would have exited the system.
- Carbon dioxide and methane in the atmosphere increase as a result of human activities, such as combustion.
- Some ways to stop the increase of carbon dioxide and methane include decreasing combustion and removing these gases from the atmosphere.
- Humans can take actions in their daily lives that will reduce the amount of carbon dioxide and methane in the atmosphere.
- While human activities are causing the current long-term trend of increasing temperatures, other factors can have smaller effects on the climate in the short term.

Vocabulary

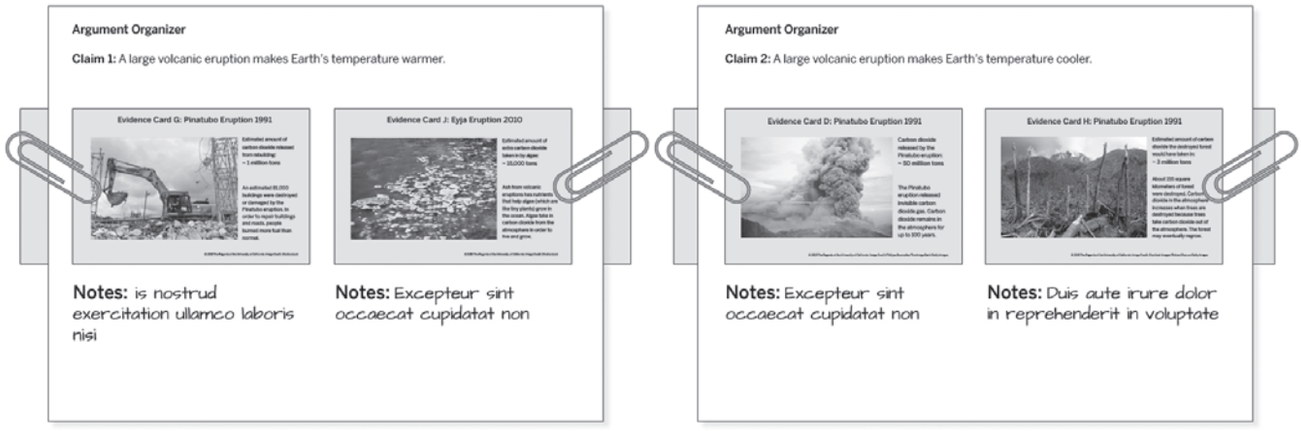
- atmosphere
- carbon dioxide
- claim
- climate
- climate change
- energy
- evidence
- human activities
- methane
- temperature

Name: _____ Date: _____

Warm-Up

Take out your Argument Organizers.

1. Examine each evidence card carefully. Choose the two cards that are most convincing for Claim 1. Clip these on top of the Argument Organizer for Claim 1, with the other cards underneath.
2. Choose the two cards that are most convincing for Claim 2. Clip these on top of the Argument Organizer for Claim 2, with the other cards underneath.
3. Record some notes on the Argument Organizers that will help you remember what you want to say about your most convincing cards.



Name: _____ Date: _____

Science Seminar

You'll be discussing this question in the Science Seminar:

How is Earth's climate affected in the five to ten years after a large volcanic eruption?

Claim 1: A large volcanic eruption makes Earth's temperature warmer.

Claim 2: A large volcanic eruption makes Earth's temperature cooler.

Possible Claim 3: A large volcanic eruption . . .

Science Seminar Observations

Write a check mark in the right-hand column every time you hear one of your peers say or do something listed in the left-hand column. If you hear an interesting idea, write it in the last row of the table.

Observations during the seminar	Check marks
I heard a student use evidence to support a claim.	
I heard a student respectfully disagree with someone else's thinking.	
I heard a student explain how her evidence is connected to her claim.	
I heard a student evaluate the quality of evidence.	
I heard an idea that makes me better understand one of the claims. That idea is	

Name: _____ Date: _____

Homework: Writing an Argument

Write an argument that answers the question, *How is Earth's climate affected in the five to ten years after a large volcanic eruption?*

Part A: Choosing a Claim

Choose one of the two claims below, or create one of your own. (circle one)

a. Claim 1: A large volcanic eruption makes Earth's temperature warmer.

b. Claim 2: A large volcanic eruption makes Earth's temperature cooler.

c. Neither a nor b. I will write my own claim.

If you chose "c" and want to create your own claim, write it here.

_____

_____

Name: _____ Date: _____

Homework: Writing an Argument (continued)

Part B: Choosing Evidence

Choose the evidence cards that will be important to refer to in your argument. Review your evidence cards to help with this step.

- ☐ **Evidence Card A: May 1991–August 1991** temperature data
- ☐ **Evidence Card B: January 1991–December 1995** temperature data
- ☐ **Evidence Card C: 1980–2010** temperature data
- ☐ **Evidence Card D: Pinatubo Eruption 1991** carbon dioxide released
- ☐ **Evidence Card E: Pinatubo Eruption 1991** sulfur dioxide released
- ☐ **Evidence Card F: Pinatubo Eruption 1991** ash and dust released
- ☐ **Evidence Card G: Pinatubo Eruption 1991** rebuilding: carbon dioxide released
- ☐ **Evidence Card H: Pinatubo Eruption 1991** destroyed forests: less carbon dioxide taken in
- ☐ **Evidence Card I: Eyja Eruption 2010** flights cancelled: less carbon dioxide released
- ☐ **Evidence Card J: Eyja Eruption 2010** algae growth: more carbon dioxide taken in

Name: _____ Date: _____

Homework: Writing an Argument (continued)

Part C: Write Your Argument

Write your argument, using the claim and evidence you selected.

- Include the claim (chosen in Part A) that is strongest and you want to support.
- Use evidence (selected in Part B) to support your thinking and to explain why you think the claim you chose is the strongest, most convincing claim about how volcanoes affect the total energy in the system, as well as how this affects temperature.

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

1. What are the most important things you have learned in this unit about what causes climate change?

_____

_____

_____

_____

_____

_____

2. I understand that scientists have criteria for evaluating evidence. (check one)

☐ yes ☐ not yet

Explain your answer choice.

_____

_____

_____

3. What questions do you still have?

_____

_____

_____

_____

_____

_____

Earth's Changing Climate Glossary

absorb: to take in
absorber: traer hacia dentro

atmosphere: the mixture of gases surrounding a planet
atmósfera: la mezcla de gases que rodea a un planeta

carbon dioxide: a molecule made of carbon and oxygen atoms
dióxido de carbono: una molécula hecha de átomos de carbono y oxígeno

change: when something becomes different over time
cambio: cuando algo se vuelve diferente con el tiempo

claim: a proposed answer to a question about the natural world
afirmación: una respuesta propuesta a una pregunta sobre el mundo natural

climate: general weather patterns over a long period of time
clima: patrones atmosféricos generales que ocurren durante un periodo largo de tiempo

climate change: changes in climate over a long period of time that can be caused by natural events or human activities
cambio climático: cambios en el clima durante un largo periodo de tiempo, los cuales pueden ser causados por eventos naturales o actividades humanas

combustion: the process of burning fuels, which produces carbon dioxide
combustión: el proceso de quemar combustibles, que produce dióxido de carbono

data: information collected in an investigation
datos: información recolectada en una investigación

deforestation: the process of clearing trees from land
deforestación: el proceso de despejar un terreno de árboles

energy: the ability to make things move or change
energía: la capacidad de hacer que las cosas se muevan o cambien

eruption: the sudden pushing out of something, such as lava from a volcano
erupción: la expulsión repentina de algo, como la lava de un volcán

evidence: information about the natural world that is used to support or go against (refute) a claim

evidencia: información sobre el mundo natural que se utiliza para respaldar o rechazar (refutar) una afirmación

fluctuation: variations in a set of data

fluctuación: variaciones en un conjunto de datos

human activities: things people do that affect the Earth system

actividades humanas: cosas que hacen los humanos que afectan el sistema Tierra

lux: a measure of how much light is present

lux: una medida de cuánta luz hay

methane: a molecule made of carbon and hydrogen atoms

metano: una molécula hecha de átomos de carbono y hidrógeno

model: an object, diagram, or computer program that helps us understand something by making it simpler or easier to see

modelo: un objeto, diagrama o programa de computadora que nos ayuda a entender algo haciéndolo más simple o fácil de ver

reasoning: the process of making clear how your evidence supports your claim

razonamiento: el proceso de aclarar cómo tu evidencia respalda tu afirmación

redirect: to send to a new or different place

redirigir: mandar a un lugar nuevo o diferente

reflect: to bounce off without absorbing

reflejar: rebotar sin absorber

scientific argument: a claim supported by evidence

argumento científico: una afirmación respaldada por evidencia

stability: when something stays mostly the same over time

estabilidad: cuando algo permanece más o menos igual a lo largo del tiempo

sulfur dioxide: a molecule made of sulfur and oxygen atoms

dióxido de azufre: una molécula hecha de átomos de azufre y oxígeno

temperature: a measure of how hot or cold something is

temperatura: una medida de qué tan caliente o frío está algo

the Earth system: the living and nonliving components of Earth, including the water, land, and atmosphere

el sistema Tierra: los componentes vivientes y no vivientes de la Tierra, incluyendo el agua, el terreno y la atmósfera

trend: overall tendency (for example, a consistent increase) in a set of data over time

tendencia: una propensión general (por ejemplo, un aumento constante) en un conjunto de datos a lo largo del tiempo

volcano: a mountain that has an opening in the land where gas, lava, and/or ash is pushed out

volcán: una montaña que tiene una abertura en el terreno por donde sale gas, lava y/o ceniza

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Earth's Changing Climate:

Vanishing Ice

Article Compilation

Table of Contents: Articles

Even a small rise in global temperature can have a big impact on the entire planet.

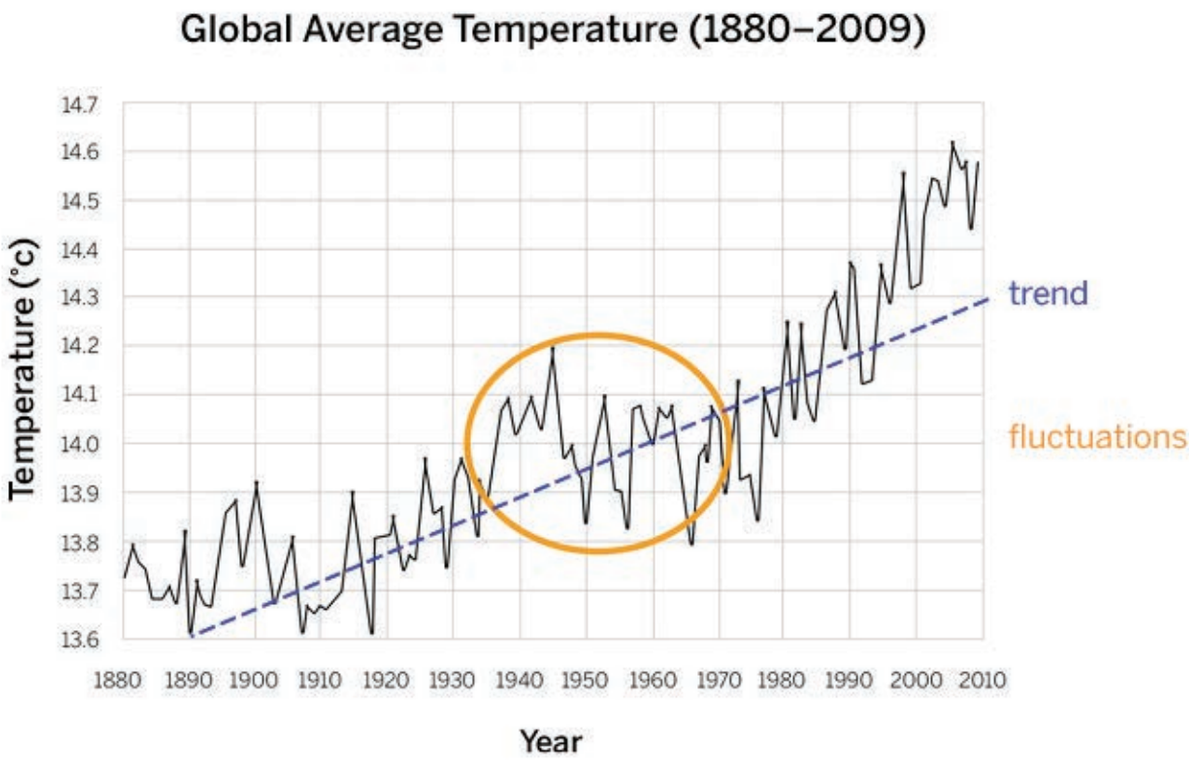
The Effects of Climate Change

Chapter 1: Introduction

Earth's climate is changing. In the last hundred years, the average temperature of our planet has increased by at least 0.8 degrees Celsius (1.4 degrees Fahrenheit), and climate scientists say that global temperature will continue to rise by at least a few more degrees in coming years. That may not sound like much, but even a small change in global temperature has a large effect on the atmosphere, biosphere, geosphere, and hydrosphere on our planet. These changes will affect the resources and conditions people depend on.

A warming climate changes the patterns of where living things on Earth can survive. By

increasing the temperature of the planet, climate change forces many species to move, or risk dying out—and in some cases, species like the polar bear can be left with no habitat at all. A warming climate also melts glaciers around the world, causing sea levels to rise. As the oceans take up more space, some coastal cities may end up underwater. In addition, a warming climate increases the temperature of Earth's oceans and puts more water in the atmosphere, causing more extreme weather around the globe. A wetter atmosphere means more storms, droughts, and flooding, all of which threaten the way humans live. To learn more about the effects of global warming on Earth, choose one of the chapters that follow.



This graph shows the change in global temperature in degrees Celsius between the years 1880 and 2009.

As global temperatures rise and sea ice melts, polar bears have fewer places to live and hunt for food.

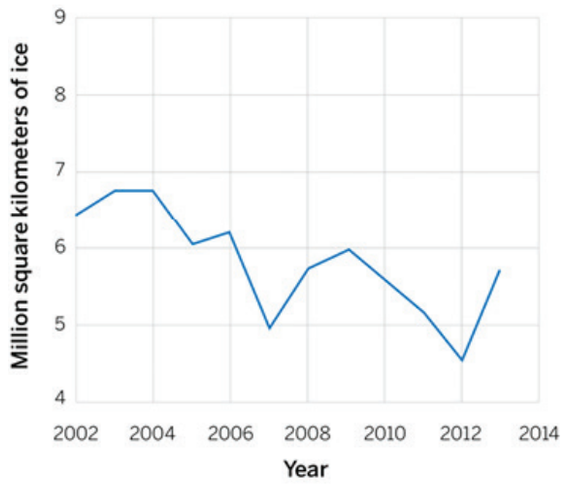
Chapter 2: Warming and Habitat Loss

Changing global temperatures mean changing habitats—and this can be bad news for living things. A living thing's habitat is more than just the place where it lives: habitat includes everything an animal or plant needs for its survival, such as food sources, shelter, and lots of other factors.

It's easy to see how a warming climate trend would cause polar bears to lose their habitat. Warmer temperatures cause more ice to melt. Ice is an essential part of the polar bear habitat: the bears walk out onto ice that covers the Arctic Ocean in winter in order to reach the seals that they kill and eat. Less ice means less habitat for polar bears.

It's harder to understand why a warming climate trend causes habitat loss for other

Amount of Summer Sea Ice in Artic (2002-2013)



This graph compares how much of the Arctic Ocean was covered by ice in different years between 2002 and 2013. The measurements were all taken at the same time of year.

living things, but it does. Temperature is an important part of habitat, and some species are very sensitive to changes in temperature. For example, salmon depend on cold-water streams: young salmon die if the water in a stream becomes too warm for them.

Global warming causes habitat loss in other ways, too. For example, weather patterns change as the climate warms, making some places wetter and others drier. When habitats become wetter or drier than the animals and plants that live in them are used to, the habitats can become unlivable for those species. Climate change benefits some species as well, especially species that reproduce quickly, can survive in a range of habitats, or do well in warmer areas. For example, the populations of some kinds of mosquitoes, bullfrogs, sea stars, jellies, and kudzu plants are increasing.

As their habitats change due to warming, some plants and animals have already begun shifting the areas where they live. Many are moving toward the poles, where temperatures are cooler. Others are moving higher up mountains. However, a mountain is only so high. Once they have reached the top of the mountain, there's nowhere higher to go. Climate change is likely to cause many species to become extinct.

Young salmon need cold stream water to survive.

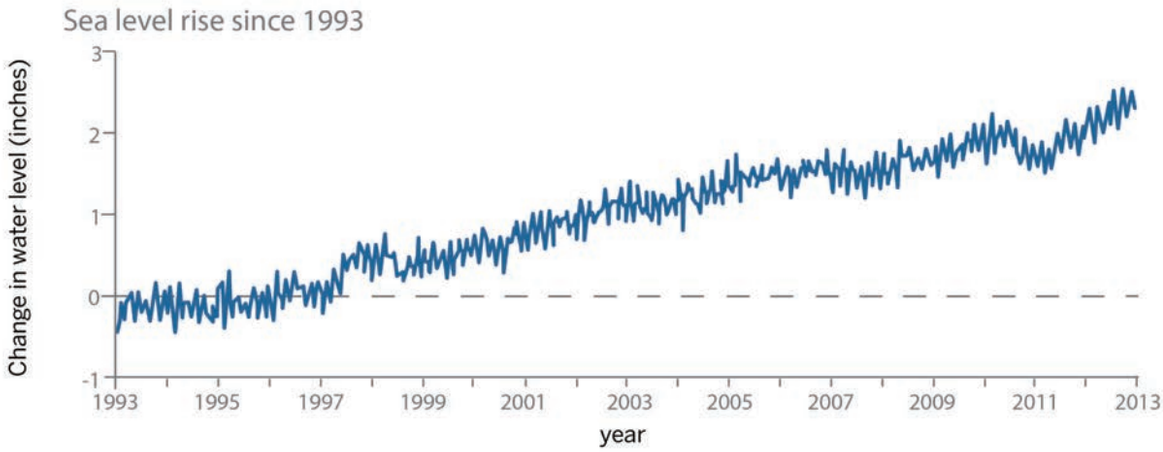
Pikas are small animals related to rabbits. They live in the mountains. As the climate warms, pikas are beginning to move higher up the mountain, where temperatures are cooler.

Chapter 3: Warming and Sea Level Rise

Due to rising sea levels, places where humans live now may be underwater in the future.

One surprising effect of a warming global climate is rising sea levels. Sea level is the line where ocean water meets dry land: as sea level rises, more land becomes covered with water. Over the past hundred years, global sea levels have risen by 10 to 20 centimeters (4 to 8 inches). Rising sea levels can cause major problems for low-lying islands, as well as for coastal cities like Miami and New York. If sea levels rise too high, some places where people now live will end up underwater in the future.

How can warming cause sea levels to rise? The answer has to do with melting ice on land. Glaciers and ice sheets form when ocean water evaporates into the air, forms clouds, and falls on the land as snow. In cold areas, layers of snow build up year after year, compressing the layers below them and forming solid ice. When this ice melts, the water runs down from the

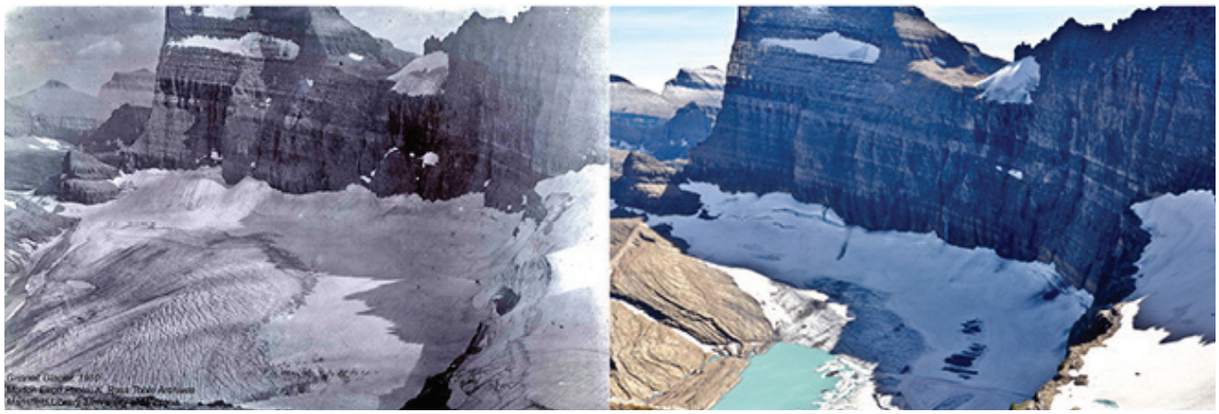


This graph traces the rise of sea levels since 1993.

land and into the ocean again. If glaciers and ice sheets melt faster than they are building up, more water ends up in the ocean. Adding water to the ocean causes sea levels to rise.

In addition, water expands a little bit as it gets warmer. That means that warmer water takes up more space than colder water. As ocean water becomes warmer, it takes up more space and sea levels rise.

You might expect that sea levels would rise the same amount everywhere, but they don't. Because of the shape of the land and other factors, sea levels are rising much faster in some places than in others.

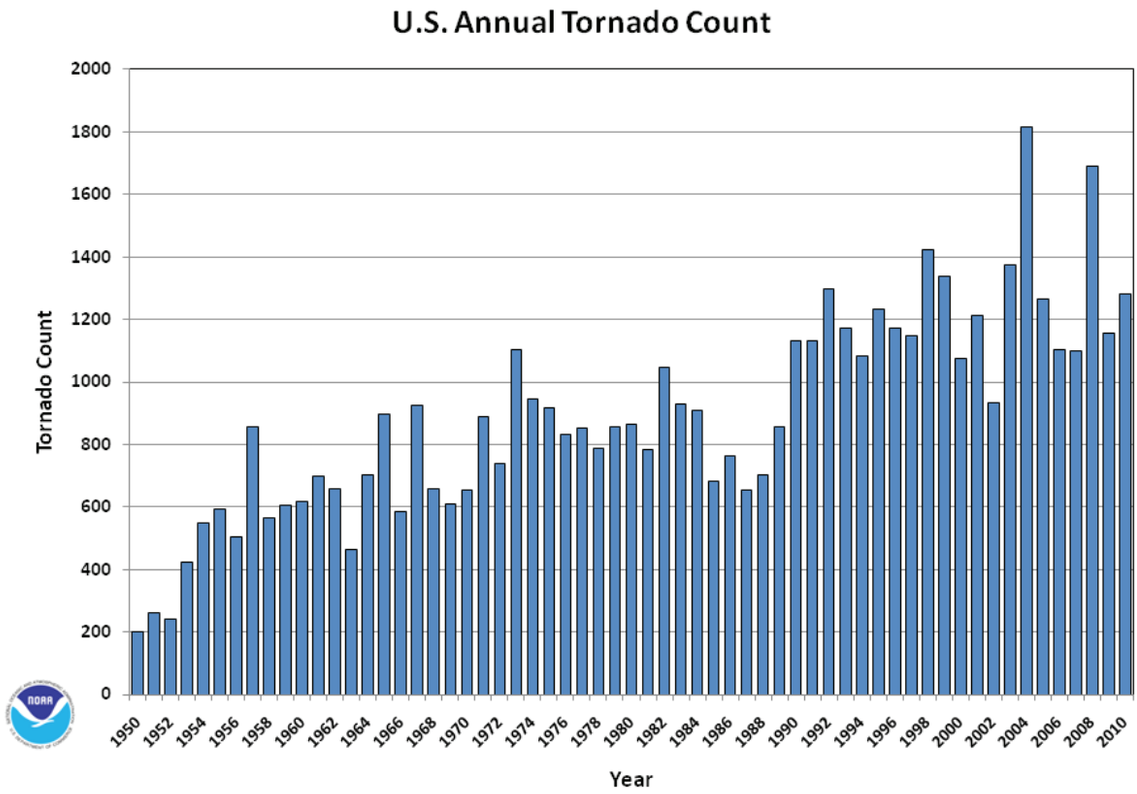


In 1910 (the photo on the left), this glacier was big enough to cover an entire valley. By 2012 (the photo on the right), the same glacier was much smaller. A lot of ice had melted.

Chapter 4: Warming and Extreme Weather

Even the most dire predictions of climate change predict a rise in global average temperature of only 6 degrees Celsius (10.8 degrees Fahrenheit). That doesn't sound like much at first—it may even sound like we can look forward to nicer weather. However, rising global average temperatures lead to all kinds of weather changes...and some are not so nice. In fact, evidence shows that global warming leads to extreme weather: more severe storms, droughts, flooding, and other disasters.

A rise in global temperature makes severe weather events, like tornadoes, more likely.



This graph shows the number of tornadoes in the United States for each year from 1950 through 2010.

As the climate warms, ocean water warms, too. Warm ocean water gives power to big storms such as hurricanes and typhoons. With warmer water, these storms tend to become more severe.

Warming temperatures also cause more water to evaporate, putting more moisture into the air. More moisture in the air leads to more precipitation (rain and snow). It may seem amazing that global warming can cause more snowstorms, but that's what happens. An increase in precipitation (whether rain or snow) can lead to dangerous flooding.

While warming causes more precipitation in some areas, it can also cause droughts— a lack of precipitation. The warming climate changes patterns of wind and water currents, making some areas drier than they were before.

There's no way to look at one particular weather event and put all the blame for it on climate change. Weather is complicated, and lots of factors combine to make events happen. However, it is clear that a warming trend makes extreme weather more likely. Some people have compared extreme weather events to home runs hit by a baseball player taking steroids. You can't say for sure whether steroids made him hit any particular home run, but you CAN say that steroids made home runs more likely. Global warming is like putting our weather systems on steroids, making extreme events more common.

A rise in global temperature increases precipitation of all kinds, including snow.

As global temperatures rise and the patterns of wind and water currents change, droughts may become more common.

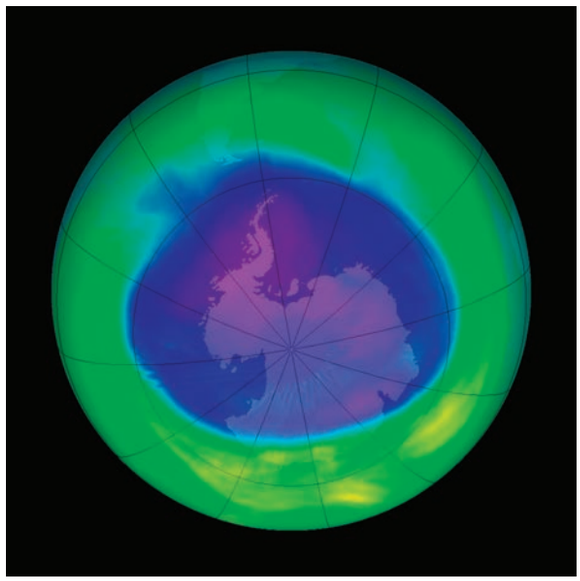
Extreme weather can cause damage to people's homes, schools, and businesses.

Earth's atmosphere is a layer of gases that surrounds the planet. Some of the gases in the atmosphere block energy from getting into the atmosphere, while others let energy pass through.

A Hole in Earth's Ozone Layer

Earth's atmosphere is a layer of gases that surrounds the entire planet. Each gas in the atmosphere interacts differently with energy: each gas may absorb energy, reflect it back to where it came from, or let it pass through.

One of the gases in Earth's atmosphere is called ozone. Ozone allows some kinds of energy to pass through to Earth, but it absorbs a type of energy from the sun called UVB energy. A layer of ozone about 10 km (6 mi) above Earth's surface surrounds the planet, keeping UVB energy from reaching Earth's surface. This layer of ozone protects humans from the harmful effects of UVB energy, such as skin cancer.



In the 1970s, scientists noticed that the amount of ozone in the atmosphere was decreasing all over Earth, but the change was especially noticeable over Antarctica.

Beginning in the 1970s, scientists noticed that the amount of ozone in Earth's atmosphere was decreasing. The change was taking place because of a chemical reaction between the ozone in the atmosphere and certain types of chemicals made by humans and used in refrigerators, aerosol spray bottles, and fire extinguishers. The ozone layer was becoming especially thin over Antarctica. As the ozone layer became thinner, scientists predicted that humans would see increased rates of skin cancer and other diseases.

The hole in the ozone layer has caused an increase in the amount of UVB light that reaches Earth, which has had health effects for humans and other species. However, UVB light is less than one percent of the energy from the sun, so the increase in UVB caused by the ozone hole is not significant enough to raise global temperature. Global climate change is being caused by energy that can't escape Earth's atmosphere, not by extra energy reaching Earth. The hole in the ozone layer is not a cause of global climate change.

There's good news about Earth's ozone layer: after scientists began to study the growing hole in the ozone layer and identified the chemicals that were causing it, many countries agreed to ban the use of those chemicals. Companies were required to invent refrigerators, spray bottles, and fire extinguishers that used different chemicals. People stopped releasing the chemicals that were causing the ozone hole, and that solution is working! The hole in the ozone has shrunk since 1989, when the chemical bans went into effect. The hole in the ozone layer was caused by human activities, but now human activities are causing it to shrink.

The thinning ozone layer was partially caused by the chemicals used in aerosol spray cans. Companies that make those products now use different chemicals to make their spray cans work.

Triceratops and other dinosaurs may have gone extinct because of a change in climate.

Past Climate Changes on Earth

Evidence shows that Earth is getting warmer—the global climate is changing right now. Did you know that Earth's climate has also changed in the past? During some periods in Earth's 4.6 billion-year history, Earth has been much warmer than it is now. During other periods, Earth has been much cooler. In every case, climate changes on Earth have to do with the amount of energy that enters Earth's system compared to the amount of energy that exits.

Energy is always entering the Earth system as light from the sun. This energy is absorbed by Earth's surface and warms the air near the surface. At the same time, energy is always exiting the Earth system, passing through the atmosphere and going out into space. When the energy entering and exiting are in balance, global average temperatures will stay the same. Average temperature keeps its stability as long as the amount of energy entering the system is equal to the amount of energy exiting the system. If either one changes, whether it's the energy entering or the energy exiting, the temperature changes too. In the past, when more energy entered than exited, the climate warmed. When less energy entered than exited, the climate cooled. Scientists study past climate changes to find out what might happen as Earth's climate changes, both now and in the future.

Alligators in the Arctic: The Eocene Period

About 56 million years ago, Earth's temperature rose suddenly. Earth got so warm that water in places that were normally very cold or even frozen, such as places near the Arctic Circle, became warm. During the Eocene Period, landscapes near the poles looked like swamps in Florida do today. Earth had no ice caps, and the water in the Arctic Ocean was warm enough for a pleasant swim. In fact, scientists have found fossils showing that alligators, which are warm-water organisms, lived in the Arctic during the Eocene Period. The global average temperature was about 16°C (28.8°F) warmer than it is today.

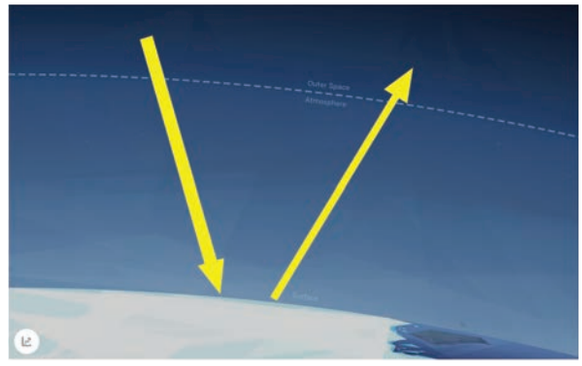
During the Eocene Period, even the Arctic was warm enough to be a comfortable home for organisms that need warm conditions.

Possible Causes of Warming in the Early Eocene

Scientists are still working to figure out what might have triggered extreme warming in the early Eocene Period. Whatever caused the change, the increased temperature tells us that more energy was absorbed by Earth's surface during that time. The balance of energy entering and exiting the Earth system changed in such a way that more energy entered the system than exited. What could have changed the balance? One theory is that the amount of carbon dioxide gas (CO_2) in the atmosphere increased, perhaps because many volcanoes erupted in a short period of time or a huge asteroid hit Earth.

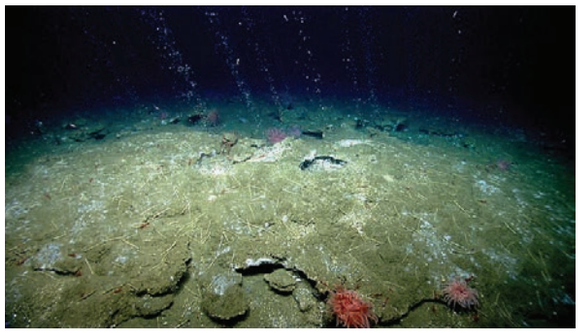
One possible cause of warming in the Eocene Period may have been a large asteroid hitting Earth.

If carbon dioxide increased, the amount of energy coming into the system from the sun wouldn't have changed, because incoming sunlight passes right through carbon dioxide. However, carbon dioxide in the atmosphere stops some outgoing energy from leaving the Earth system. Because of this, an increase in carbon dioxide would mean less energy exiting the system—and higher global temperatures. Gases that affect the Earth system in this way, such as carbon dioxide, are called greenhouse gases.



When more energy enters the Earth system than leaves it, Earth gets warmer.

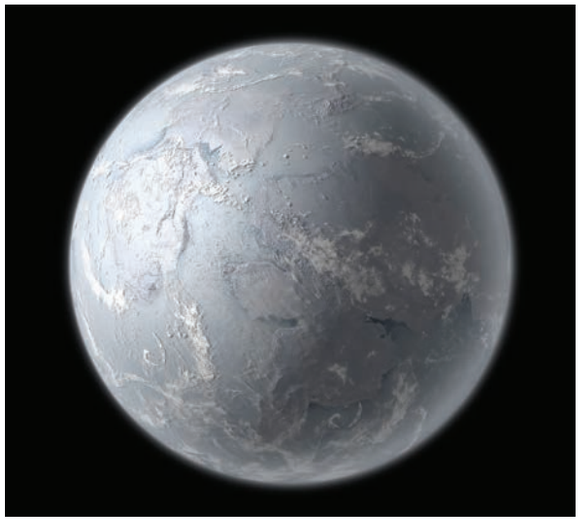
As the climate warmed in the Eocene Period, ocean water warmed as well. Normally, water at the bottom of the deep ocean is very cold—close to freezing temperature. However, in the early Eocene, even the deepest water became warm. This change in temperature released methane gas that had been trapped on the ocean floor. The methane gas bubbled up to the surface and entered the atmosphere. Like carbon dioxide, methane stops some outgoing energy from leaving the Earth system. The increase in methane in the atmosphere made the climate even warmer. According to this theory, the combination of increased carbon dioxide and methane in the atmosphere made Earth a very warm place in the Eocene.



Warming oceans during the Eocene Period released methane gas that had been trapped on the bottom of the ocean. This photo shows methane bubbling up from the ocean floor.

Snowball Earth: The Cryogenian Period

About 800 million years ago, Earth got much colder. Over time, ice covered most of Earth's surface—maybe even all of it! This was the Cryogenian Period. You may have heard of ice ages in Earth's past, but the Cryogenian Period was much colder than any ordinary ice age. During this period, the average global temperature may have fallen as low as -20°C (-4°F)! Even the equator, which today is warm and tropical, experienced freezing temperatures back then. Nothing lived on land at that time—all life was in the ocean, in liquid water beneath the frozen surface. The only living things on Earth at that time were simple sponges, worms, and microscopic creatures such as bacteria and algae. During the Cryogenian Period, Earth's surface was an icy wasteland that scientists have nicknamed "Snowball Earth."



During the Cryogenian Period, Earth was a cold, icy wasteland that scientists now call "Snowball Earth."

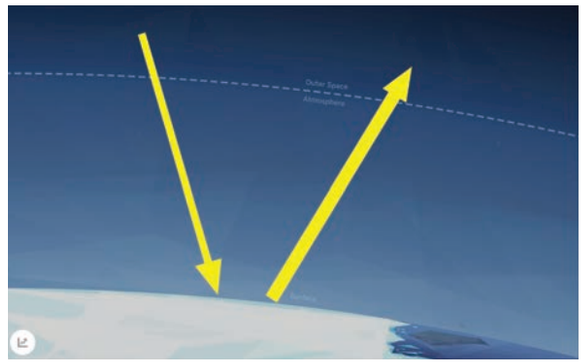
Possible Causes of Cooling in the Cryogenian

Since scientists began finding evidence of Earth's deep freeze, they have been debating what could have caused it. Scientists don't agree about the causes, but there's one thing they do agree on: whatever caused Snowball

Earth during the Cryogenian Period, less energy must have entered Earth's system than exited. This could have been because the amount of energy entering decreased or the amount of energy exiting increased—or both.

Scientists have made models to help them understand what might have caused a Snowball Earth event. Earth sometimes passes through huge clouds of dust floating in space, and according to one theory, one of these dust clouds entered Earth's atmosphere about 800 million years ago. The dust blocked some of the incoming sunlight from reaching Earth's surface without changing the amount of energy exiting the system. When less energy entered the system than exited it, Earth's temperature cooled.

Once the cooling began, more ice formed. Unlike land and liquid water, ice reflects lots of sunlight instead of absorbing it, sending light (and its energy) back out into space. When ice began building up during the Cryogenian Period, the sunlight it reflected caused more energy to leave Earth's system and therefore made temperatures even colder. Colder temperatures led to more ice, which led to even colder temperatures, which led to even more ice, and so on. Once ice covered the entire surface of the planet, a Snowball Earth had formed.



When less energy enters the Earth system than leaves it, Earth gets cooler.

Combustion, or burning fuel, is the process used to power most of our homes, businesses, and cars. Combustion adds carbon dioxide gas to the atmosphere.

Climate Change Solutions

The Problem: Too Much Carbon Dioxide and Methane

Most of the energy sources humans use to power our homes, businesses, and cars involve burning fuel, a process we call combustion. Combustion leads to higher temperatures on Earth—but not because fires are hot. The process of burning almost any fuel puts carbon dioxide (CO_2) into the atmosphere, whether the fuel is coal, oil, natural gas, or wooden logs. It's this increase in carbon dioxide that warms the planet.

Carbon dioxide is not the only gas that affects the Earth's climate. Would you believe that some of the gases that warm the planet come from inside farm animals? Cows and other grass-eating animals, like sheep and goats, produce a gas called methane, which also warms the planet when it gets into the atmosphere. Methane is also produced by industrial sources such as using natural gas to produce electricity. However, of the methane put into the atmosphere by human activities, 35% comes from raising grass-eating animals.

Because they warm the planet, carbon dioxide and methane are known as greenhouse gases. How do we solve the problem of too much carbon dioxide and methane in the atmosphere? Many people have thought of possible solutions, like capturing carbon dioxide at power plants, reducing the amount of methane animals release into the air, and using more solar power. We may need to use all of these solutions together if we want to solve as huge a problem as climate change!

Part of the Solution: Producing Less Carbon Dioxide

Solar Power

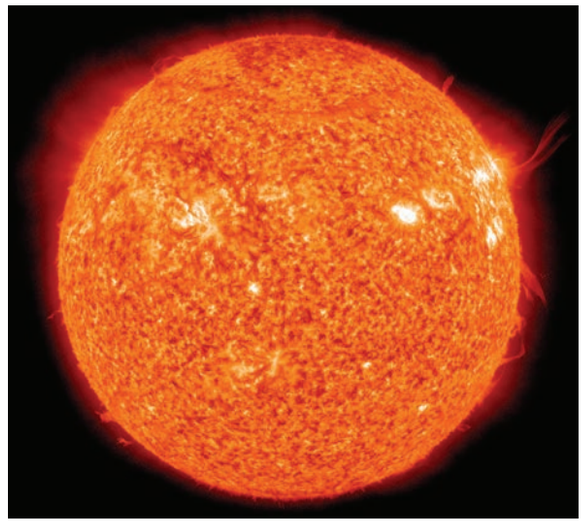
What energy source is about 93 million miles away? The sun, of course! Solar power plants convert light energy from sunshine into electrical energy. Increasing our use of solar power can help reduce the amount of carbon dioxide in our atmosphere. But how? Solar power isn't taking carbon dioxide out of the air. How can solar power affect the amount of carbon dioxide in the atmosphere?

Unlike solar power plants, most power plants produce electricity by burning fuel—that is, combustion. Burning fuel releases carbon dioxide. Solar power plants work differently: instead of burning fuel for power, they use energy from the sun. If we can produce electricity using energy from the sun instead of energy from burning fuel, we can stop putting so much carbon dioxide into the atmosphere.

One drawback to solar power is that it's expensive. However, engineers are working to make solar power cheaper. With smart engineering, they hope to make solar power an even bigger part of the carbon dioxide solution now and in the future.

Bikes and Transit

One way humans can keep carbon dioxide out of the atmosphere is to drive cars less frequently. Driving cars increases carbon dioxide in the atmosphere. Most cars burn fuel through combustion, and burning fuel releases carbon dioxide into the atmosphere. Even electric cars tend to increase the amount of carbon dioxide in the atmosphere because they get energy from being plugged into an electrical outlet. The electricity they get comes from power plants, and most power plants produce electric energy by burning fuel, which releases carbon dioxide into the atmosphere. People can keep some of that



The sun provides energy without adding carbon dioxide to Earth's atmosphere.

Solar panels like these convert light energy from the sun into electrical energy people can use in their homes.

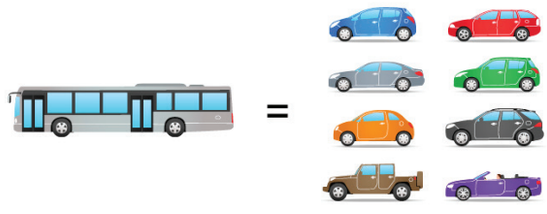
This solar power plant uses energy from the sun's light instead of from the combustion of fuel.

carbon dioxide from being released by driving less, no matter what kind of car they have.

How can people stop driving cars so much? One answer is to find other ways of traveling. For short trips, people can ride bikes or walk instead of driving. For longer trips, people can use public transit—buses, trains, and subways. These vehicles usually burn fuel (or run on electricity generated by combustion), but lots of people can ride them at once. If eight people are riding a bus at one time, that's one engine burning fuel to move eight people. If those same eight people are each riding in a separate car, that's eight engines burning fuel to move eight people. Even though transit vehicles often burn fuel, riding public transit helps reduce the amount of carbon dioxide we put into the air.

Riding bikes instead of driving cars helps reduce the amount of carbon dioxide in the atmosphere.

Subways help people get around without driving cars.



Public transit allows many people to travel using fewer engines and putting less carbon dioxide into the atmosphere.

Part of the Solution: Removing Carbon Dioxide and Methane

Capturing Methane from Cows

Cows are very good at getting energy from plants, but the microorganisms that live in their digestive systems and help them eat grass also produce a lot of methane—and that methane has to get out somehow. In this case, it leaves the cows' bodies through burps and farts! In one year, one cow puts out methane in about the same amount as one car puts out carbon dioxide.

To reduce the amount of methane cows produce, some scientists are working on inventing ways for cows to produce less gas when they digest their food. Some are trying to find out whether different diets for cows might help them put out less gas. Others are trying to change the way microorganisms in the cows' digestive systems process food. If the microorganisms produce less methane, so will the cows.

Another solution would be to eat less beef: if humans ate less meat that comes from cows, farmers would raise fewer cows, and there would be less methane in the atmosphere.

Capturing Carbon Dioxide at Power Plants

We put carbon dioxide into the atmosphere by using electrical devices like lights, phones, and computers. Why is that? Phones and light bulbs don't burn any fuel—they run on electrical energy. However, that electrical energy had to come from somewhere. It traveled through power lines from a power plant. Most power plants generate electricity by burning fossil fuels like coal, oil, or natural gas. Burning those fuels sends carbon dioxide into the atmosphere.

For now, millions of people rely on power plants for electricity, and those power plants nearly always release carbon dioxide. What

Cows produce a lot of methane, which stops energy from leaving the Earth system and causes the planet to warm.

Most of the electrical energy we use in our homes, schools, and businesses comes from power plants that burn fuel.

Big power lines like these carry electrical energy from power plants to places where it is needed.

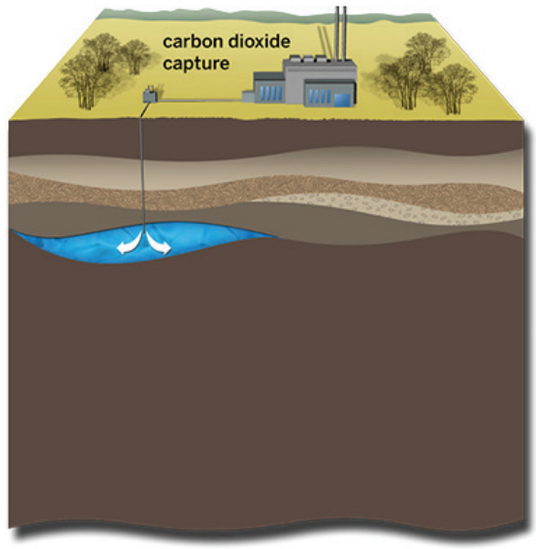
if we could stop that carbon dioxide from reaching the atmosphere? Some power plants use complicated processes to capture the carbon dioxide produced by burning fuel and store it deep underground. Capturing carbon dioxide keeps it out of the atmosphere, which helps stop the planet from warming as quickly. However, capturing carbon dioxide is expensive, and we don't know what the long-term effects might be of burying huge amounts of carbon dioxide underground.

Reforestation

To reduce the amount of carbon dioxide in the atmosphere, we can use less energy and store our carbon dioxide before it reaches the atmosphere—or we can rely on a natural process to absorb carbon dioxide from the air. That natural process involves trees and other plants.

All plants take in carbon dioxide, use it to make food for themselves, and release oxygen. The more plants there are in the world, the more carbon dioxide is removed from the atmosphere. One reason there is so much carbon dioxide in the atmosphere today is that humans have cut down many of the trees on Earth and used them to build buildings and make paper and other materials. There are millions fewer trees on Earth than there once were, which means there is less carbon dioxide being taken in.

One way of solving the problem of too much carbon dioxide in the atmosphere is reforestation, or planting trees. Many tree-planting projects are located in places where people cut down forests in the past. By replacing trees that have been removed and planting new trees (even in places where they never grew before), people can cause the world's forests to take in more carbon dioxide. Reforestation also creates forest habitat, benefiting many kinds of animals and plants that live in forests.



At some power plants, carbon dioxide is buried deep in the ground to keep it from reaching the atmosphere.

Planting trees, or reforestation, is one way to reduce the amount of carbon dioxide in the atmosphere.

When making goods in factories became more common, scientists began to research the effect of burning fuel on the atmosphere and on global temperatures.

Global Warming: A History of a Hot Debate

Today, scientists around the world agree that our planet is warming and that the rise in temperature is due to human activities over the past two hundred years. However, this level of agreement hasn't been around long! For hundreds of years, nobody knew exactly how carbon dioxide was affecting the planet or what kinds of effects humans had on the natural world. Many scientists had competing ideas that took centuries to work out.

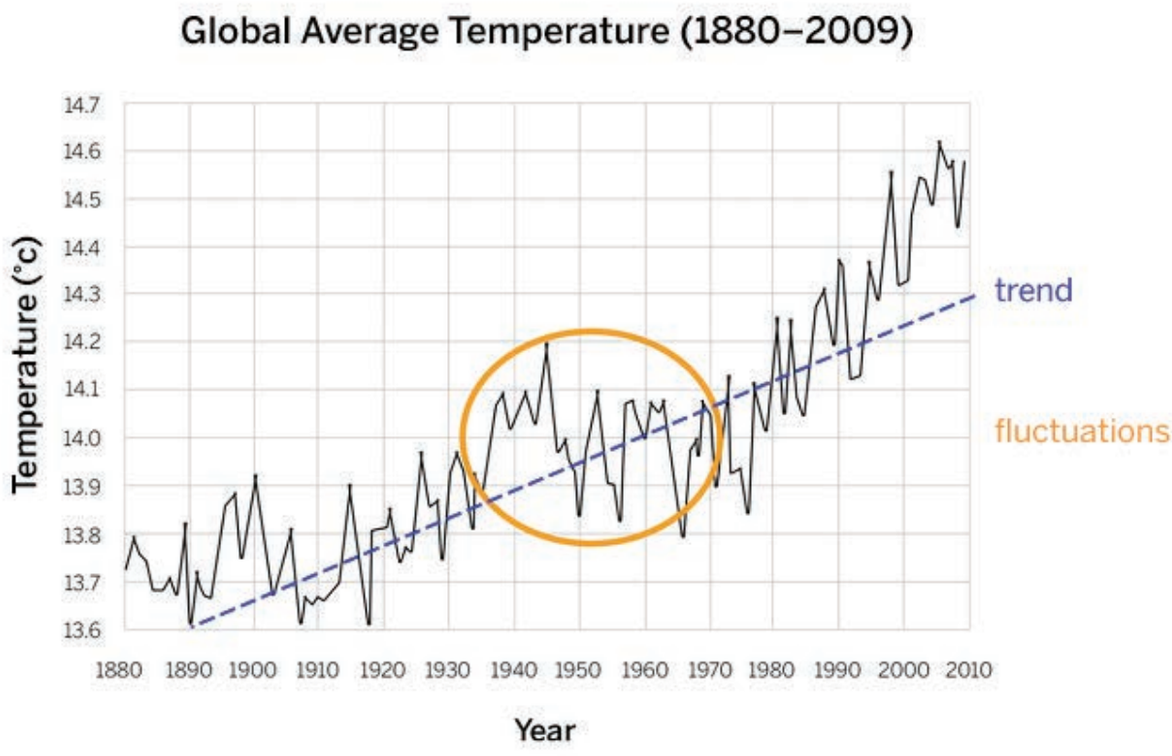
Beginning in the nineteenth century, scientists understood that carbon dioxide and a few other types of gases in the atmosphere affected energy in the Earth system. They took measurements of the air in the atmosphere and Earth's temperature and found that global temperatures went up as the amount of carbon dioxide in the atmosphere increased. In 1896, a Swedish scientist named Svante Arrhenius (SVAN-tuh Ah-RAIN-ee-us) calculated that doubling the amount of carbon dioxide in the atmosphere would cause a temperature temperature increase of 5 to 6 degrees Celsius (9 to 11 degrees Fahrenheit), while cutting the level of carbon dioxide in the atmosphere in half would be enough to cause a new ice age! The relationship between these gases in the atmosphere and global temperatures had become especially important in the nineteenth century as the first large factories began putting much more pollution into the air than before. The growth of factory-made goods and then the automobile meant that the atmosphere contained far more carbon

dioxide than it had in all of human history.

In the twentieth century, scientists around the world studied the relationship between pollution in the atmosphere and Earth's temperature. However, they did not always agree about whether the carbon dioxide added to the atmosphere by humans would have effects on global temperatures, or about what those effects might be. Some agreed with Arrhenius and predicted warming due to carbon dioxide in the atmosphere. Others predicted that other types of pollution might cause the planet to cool rather than heat up: some types of pollution include tiny particles floating in the air, which block some of the sun's energy from reaching Earth's surface. They thought this cooling effect might be stronger than the heating effect of the carbon dioxide.

To determine what was really happening with Earth's atmosphere, scientists around the world needed more precise data. That kind of data became easier to get as computer technology improved and scientists were able to use better models to test their ideas. With the help of computers, the evidence began to show clearly that increases in gases like carbon dioxide and methane in the atmosphere happened at the same time as temperatures around the planet began to rise.

Today, scientists agree that Earth is getting warmer quickly, and that the rise in temperature is due to carbon dioxide and other gases released into the atmosphere by human activities. As technology improves today and in the future, scientists will learn even more about our effects on the planet—how we can solve some of the problems we've created. However, that is not enough to change how humans affect the planet. Scientists can describe the consequences of our actions, but society needs to decide what to do with that knowledge.



This graph shows the change in global temperature in degrees Celsius between the years 1880 and 2009.

As sea levels rise, flooding in coastal cities will become more severe.

What Are We Doing About Sea Level Rise?

As the climate on Earth warms, glaciers and other frozen water sources are melting. All that extra liquid water is going into the ocean, causing the water level to rise and cover up some areas that are currently dry land. Scientists predict that global sea levels will rise between 0.9 and 2.1 meters (3 to 7 feet) by the year 2100. If that happens, places near the ocean that have elevations lower than the rising seas will be covered in water. In some very flat areas on the world's coasts—for example, near Miami, Florida—many people could be forced to find new places to live and work. Rising seas can also affect weather patterns all over the world, causing severe flooding during storms.To prepare for rising sea levels, some coastal cities are already preparing to change and rebuild some areas so that they won't end up underwater as the nearby ocean rises.

As sea levels rise and more intense weather becomes more likely, many coastal cities have water drainage systems that may not be able to handle the amount of water flowing into them. Some cities are already improving their drainage systems so that more water can drain, less water backs up in the system, and flooding becomes less likely. Some cities are doing even more and exploring even bigger projects to prepare for sea-level rise.

Some cities are even building floating architecture that will rise with the sea level. The city of Rotterdam, located in the Netherlands, is already slightly below sea level and very flat, and its residents expect that many areas of the city will be underwater within the next few

decades. To see how well floating buildings would work for their city, they built three buildings that float in the public harbor. The buildings are accessible by boat and floating sidewalks, and are being used as public spaces that show off green ways of designing and building for the future. The buildings worked so well that the city of Rotterdam plans to build more than a thousand floating homes for people to live in as the water around the city rises.

Other coastal cities, like New York City, are looking into wetland restoration to help protect them from storms and flooding. Wetlands are marshy areas where land and shallow water meet, and they can act like sponges, absorbing extra water before it gets to the cities. Wetlands are flexible ecosystems that can store lots of extra water, absorb energy from large waves caused by storms, and keep dirt from eroding and moving around too much. All of these things can help protect cities from flooding. Like New York, many coastal cities already have wetlands nearby. By protecting wetland areas and restoring the health of damaged wetlands, cities hope to protect themselves from the flooding that comes with sea level rise.

Earth's Changing Climate:
Vanishing Ice

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