Examining the Enhanced

INSULATING YOU, INSULATING EARTH

Greenhouse Effect

DESCRIPTION

To model the enhanced greenhouse effect, students conduct an experiment using their own body heat, thermometers, towels, and space blankets.

PHENOMENON

How do greenhouse gases increase the earth's temperature?

GRADE LEVEL

6 – 12

OBJECTIVES

Students will:

- Make a prediction using prior knowledge and experience
- Model the greenhouse effect
- Synthesize the results of an experiment
- Use data and models to forecast the rate of climate change and impacts on Earth

TIME

1 HOUR

COMMON CORE STATE STANDARDS

English Language Arts Standards » Science & Technical Subjects » Grade 6-8

CCSS.ELA-LITERACY.RST.6-8.3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.ELA-LITERACY.RST.6-8.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

English Language Arts Standards » Science & Technical Subjects » Grade 9-10

CCSS.ELA-LITERACY.RST.9-10.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

CCSS.ELA-LITERACY.RST.9-10.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.

English Language Arts Standards » Science & Technical Subjects » Grade 11-12

CCSS.ELA-LITERACY.RST.11-12.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

Grade 6 » Statistics & Probability

CCSS.MATH.CONTENT.6.SP.B.5. Summarize numerical data sets in relation to their context, such as by: CCSS.MATH.CONTENT.6.SP.B.5.C. Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.

NEXT GENERATION SCIENCE STANDARDS

Middle School Performance Expectation

MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

High School Performance Expectation

HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems (MS) Developing and Using Models (MS, HS) Analyzing and Interpreting Data (MS, HS)	ESS2.A Earth Materials and Systems (MS, HS) ESS3.C Human Impacts on Earth Systems (MS, HS) ESS3.D Global Climate Change (MS, HS)	Stability and Change (MS, HS) Systems and System Models (MS, HS)

BACKGROUND

Earth is surrounded by an atmosphere of gases, which remains near the planet because of gravitational force. The atmosphere is composed mostly of nitrogen, oxygen, argon, and carbon dioxide, and it functions to moderate the climate of Earth.

The **greenhouse effect** describes the process by which the climate is regulated by greenhouse gases: carbon dioxide, water vapor, ozone, methane, nitrous oxide, and fluorinated gases. Electromagnetic radiation from the sun, mostly at short wavelengths in the form of light, is able to pass through the atmosphere and is absorbed by Earth. Electromagnetic radiation at longer wavelengths, often called infrared radiation or heat, is re-radiated from Earth up to space. Unlike solar radiation, most long-wave radiation is absorbed by greenhouse gases (or clouds) and re-emitted in all directions. The long-wave radiation re-emitted downward warms the surface. The greenhouse effect effectively traps heat near Earth and ensures that the planet is warm enough to sustain life.

Since the Industrial Revolution, humans have been emitting increasing amounts of greenhouse gases into the atmosphere, especially carbon dioxide, methane, and nitrous oxide, mostly through energy production, transportation, and industry. As additional greenhouse gases are released into the atmosphere, more of the re-radiated heat from Earth is re-emitted back to the planet instead of escaping into space. This **enhanced greenhouse effect** is causing average global temperatures to increase. With this increase in temperature, Earth is experiencing changes in weather, climate, and ocean systems. The effects include increased droughts in some areas, increased flooding in other areas, melting glaciers and ice, rising sea levels, altered timing of stream flows, and ocean acidification.

MATERIALS

- *Insulating You, Insulating Earth* handout [1 per student]
- PowerPoint presentation
- Computer and projector
- Binder clips, size small (¾" wide) [1 per every four students]
- Calculators [1 per every four students or more if available]
- Stopwatches [1 per every four students]
- Hand towels (16" x 26" or larger) [1 per every four students]
  - If working with adults or older students, may also want a few small bath towels (27" x 52" or smaller)
- Mylar space/emergency blanket (Figure 1), cut into rectangles of approximately 20" x 26" or larger if needed [1 per every four students]
- Thermometers,* preferably ones with a probe and separate digital readout, such as the meat thermometer shown in Figure 2 [1 per every four students]
- *Insulating You, Insulating Earth* instructional video, optional introduction to the experiment for the instructor

Figure 1. Example Mylar emergency/space blanket »

« Figure 2. Example meat thermometer with probe and digital readout

***Some notes about thermometers:** A thermometer without a probe and digital readout can be used. However, students will not be able to check the temperature readings every minute as instructed in this activity because, if so, they would have to lift the towel to read the thermometer, which would release the trapped heat. Instead, if using a thermometer without a probe, students should **only** read and record the temperature of the test subject's lap before placing the towel on top and after 5 minutes, immediately after removing the towel.

- If a different type of thermometer is used, an alternative method of fastening the thermometer to the clothing on students' laps may be needed.
- If a different type of thermometer is used, it is recommended that the educator try the experiment using their own lap several times before conducting the activity with students.

Another option is an indoor-outdoor thermometer with a digital readout and wired sensor (such as the one found here: http://www.taylorusa.com/digital-indoor-outdoor-thermometer-hygrometer.html). However, in our testing of an indoor-outdoor thermometer, it seemed slower to respond and register changes in temperature, and students may not see as large of a temperature difference.

PREPARATION

1. If possible, watch the Insulating You, Insulating Earth instructional video for an explanation of how to set up and conduct the experiment.
2. Plan to divide students into teams of four. If necessary, teams of three or five would also be acceptable, as activity tasks can be combined or divided.
3. Plan locations for the appropriate number of stations needed to accommodate the number of student teams in the group. Stations can be simple tables and chairs with enough space for three to five students, and no power source is needed.
4. Place a small binder clip,calculator, stopwatch, thermometer, towel, and rectangle of space blanket at each station.
5. Draw the "Whole Class" table from page 3 of the *Insulating You, Insulating Earth* handout on the board or prepare to show it with a document camera.
6. Set up a computer and projector and display the PowerPoint presentation.

PROCEDURES

Experimental Setup and Greenhouse Effect Introduction

1. Divide students into teams of four and place students at stations.
2. Pass out an *Insulating You, Insulating Earth* handout to each student.
3. Instruct students to read the team member roles on the front page of the handout and choose one role for each student in the group.
4. Display the "Setting Up the Experiment" slide in the PowerPoint presentation (Slide 2). The test subject will use a binder clip to attach the wire of the meat thermometer to the clothing on their lap. Instruct the student to point the metal probe toward their hip, and attach the binder clip approximately halfway down the length of their thigh (Figure 3). Ensure that the thermometer probe is contacting the student's thigh as much as possible. The probe should not be pointed sideways or hanging off of the student's lap.

Figure 3. Meat thermometer set up

5. The meat thermometer can take up to five minutes to accurately display the initial temperature of students' laps. Instruct students to watch the temperature casually and note whether it increases, decreases, or stays the same. Now that students have their thermometers in place, take some time to explain the experiment, have students make a prediction, and give a short introduction to the greenhouse effect.
6. Explain to the class that they will be conducting an experiment to determine which will insulate better: a single towel or a towel plus a space blanket on top. Tell students that they will first place a towel over the thermometer and perpendicular to their thighs while demonstrating with one of the towels. They will record the temperature every minute for five minutes. Then say that they will place the towel back on their lap and put a rectangle of space blanket on top while demonstrating with a towel and space blanket. Explain that the space blanket is made of Mylar, which is a good insulator (and also used for balloons), and it can be used as a blanket in emergencies.
7. Ask students to make a prediction about which trial will result in warmer temperatures and then fill in the blank of the prediction statement on the front page of the handout.
8. Give a short introduction to the greenhouse effect using the PowerPoint presentation.
   a. **Slide 3**: we have gases in our atmosphere that trap heat called greenhouse gases, and they are: carbon dioxide, water vapor, ozone, methane, nitrous oxide, and fluorinated gases.
   b. **Slide 4 (a)**: begin with the diagram on the left. The greenhouse effect ensures that Earth is warm enough for us to inhabit. Our atmosphere contains greenhouse gases, like carbon dioxide, methane, and nitrous oxide. Electromagnetic radiation from the sun, mostly at short wavelengths in the form of light, is able to pass through the atmosphere and is absorbed by Earth. Earth re-radiates some of this energy back toward space as heat, which is long-wave radiation. Most of the heat is able to pass through the atmosphere and escape into space, but some is absorbed by the atmosphere and then re-emitted back to Earth.
   c. **Slide 4 (b)**: now explain the diagram on the right. This is the enhanced greenhouse effect, which is caused by increased greenhouse gases in our atmosphere. As more greenhouse gases are released into the atmosphere, more of the re-radiated heat from Earth is re-emitted back to Earth instead of escaping to space. This is causing the average global temperature to increase.
   d. **Slide 5**: ask students which is the closest planet to the sun in our solar system [answer: Mercury]. Ask students which is the hottest planet in our solar system [answer: Venus]. Ask students if they know why Venus is the hottest planet even though it is not the closest to

the sun. Venus has a very thick atmosphere, comprised mostly of carbon dioxide. Carbon dioxide is a greenhouse gas, which effectively traps the heat within the atmosphere of Venus. High temperatures on the surface of Venus can reach almost 900°F. Venus serves as a natural experiment of the runaway greenhouse effect, demonstrating how high levels of greenhouse gases in the atmosphere result in high temperatures.

e. **Slide 6**: this pie chart shows the percentage of each of the greenhouse gases that humans emit through our activities. Carbon dioxide accounts for more than 75% of the greenhouse gases that we release.
f. **Slide 7**: humans emit carbon dioxide mostly through fossil fuel combustion, i.e. the burning of coal, natural gas, and oil, for the production of electricity and transportation. Many industrial processes rely on fossil fuel combustion as well, and the production of mineral products, such as cement, the production of metals, and the production of chemicals can all result in carbon dioxide emissions.
g. **Slide 8**: since 1958, scientists at Mauna Loa, on a Hawaiian island in the North Pacific, have been collecting atmospheric data. This graph shows the concentration of carbon dioxide in the atmosphere as measured at Mauna Loa. Ask students to describe the trend of this graph [answer: carbon dioxide is increasing]. Ask students why they think scientists would choose to take this measurement at Mauna Loa [answer: to minimize the effects of local surface CO_2 emissions and air pollution so that the measurement is representative of the global atmosphere.]
h. Stop the presentation here to conduct the experiment.

TOWEL TRIAL

1. Ask students to read the current temperature of their thermometers and tell you whether it has increased, decreased, or stayed the same since they clipped it to their clothing. The temperature should have increased initially and then mostly stabilized.
2. Once the temperature has stabilized, direct each team's data recorder to record the temperature in the lap row of the towel temp column. The data recorder is the team member who is responsible for writing down all of the data, but all students must complete the data table as well.
3. Instruct the materials manager to give the towel to the test subject. The test subject lays the towel over the thermometer and across their lap so that its long side is perpendicular to their thighs. Then they tuck the ends of the towel under their legs if possible; if it will not tuck under, just ensure that it is covering the thermometer.
4. As soon as the towel is in place, instruct the timer to press the start button on the stopwatch.
5. Explain to the timer that for each minute that passes, they are to call out the time to the data recorder.
6. Explain to the data recorder that when the timer calls out the time, they are to read the temperature on the thermometer, and record it in the corresponding row of the towel temp column.
7. Tell students to stop recording after 5 minutes. If you would like to extend the data collection time for this activity, have students continue to write temperature data on a separate piece of paper (see the Extensions section).
8. At the conclusion of the measurements, instruct the timer to reset the stopwatch.
9. Quickly ask the test subject to remove the towel from their lap but **leave the thermometer attached**. The goal is to return the thermometer to approximately the same temperature as the beginning lap temperature in the towel only trial. This can take 2-3 minutes. If it takes too long, you can instruct students to fan the metal probe with a piece of paper to speed up the cooling, but be cautious of fanning it for more than 20-30 seconds, which could result in the temperature decreasing too much.
10. While waiting for the thermometer to stabilize and return to the beginning lap temperature in the towel-only trial, ask students to complete the subtraction problem on the third page of the handout (in-between the tables). They fill in the blanks with the temperature of their final measurement (5 min., unless you choose to take measurements for longer) and the temperature of the test subject's lap at the beginning of the trial. They then calculate the difference by subtracting lap temperature from the 5 min. temperature.

TOWEL + SPACE BLANKET TRIAL

1. When the thermometer stabilizes at approximately the same as the beginning lap temperature in the towel trial, begin the second trial. Instruct the data recorder to record the beginning lap temperature in the towel and space blanket temp in the lap row.
2. Ask the materials manager to give the towel and then the space blanket rectangle to the test subject.
3. Instruct the test subject to, first, lay the towel over the thermometer and across their lap, and then place the space blanket rectangle on top. Both should be oriented so that the long side is perpendicular to their thighs. Have them tuck both the towel and the space blanket under their legs together if possible. If they will not tuck under, just ensure that they are covering the thermometer.
4. As soon as the towel and space blanket are in place, the timer

starts the stopwatch.
5. Explain to the timer that for each minute that passes, they call out the time to the data recorder.
6. Explain to the data recorder that when the timer calls out the time, they read the temperature on the thermometer, and record it in the corresponding row of the towel and space blanket temp column.
7. Tell students to stop recording after 5 minutes (unless you would like to extend the data collection time for this activity).
8. The test subject can remove the space blanket, towel, and thermometer.
9. Instruct students to calculate the difference in towel and space blanket temperature.
10. Ask students to report the temperature differences in the towel trial and the towel and space blanket trial to the class. Have students record their differences in the table on the board, or they can call them out to you while you write them on the board. Students must then record them in their "Whole Class" table on their handout and calculate the mean.

RESULTS AND CONCLUSIONS

1. Have students answer the results and conclusions questions.
2. If you would like to discuss evaluation question number 1 with students, return to the PowerPoint presentation.
   a. **Slide 9**: Quickly review the left and right sides of the diagram, explaining the natural greenhouse effect and the enhanced greenhouse effect.
      i. The experiment that students just conducted was a model of the natural greenhouse effect and the enhanced greenhouse effect.
      ii. Ask students to determine which item in the experiment modeled the earth and discuss how it is like the earth [answer: the student's lap modeled the earth because it emits heat].
      iii. Ask students to determine which item in the experiment modeled the atmosphere and discuss how it is like the atmosphere [answer: the towel modeled the atmosphere because the towel absorbed some of the heat and re-emitted it back toward the lap, effectively trapping it and keeping the lap warmer].
      iv. Ask students to determine which item in the experiment modeled the additional greenhouse gases and discuss how it is like additional greenhouse gases [answer: the space blanket because, once it was added, more of the heat from the lap was re-emitted back to the lap instead of escaping to into the room].
3. Use the PowerPoint presentation to explain the concept of climate change and wrap up the activity.
   a. **Slide 10**: the atmosphere influences our climate, and we conducted the experiment to model one aspect of how our climate is changing. Explain that climate is the description of the long-term pattern of weather in a particular area. Long-term usually means approximately 30 years. Make sure that students understand that in order to be considered climate, conditions must be averaged over a long time period. Today's weather in your area (or even this month's or this year's) is not the same as the climate.
   b. **Slide 11**: the climate of Earth is changing. Read the definition for climate change. Tell students that climate change includes global warming (the temperature of Earth is increasing), changes in precipitation patterns, and more severe storms.
   c. **Slide 12**: we have recorded data on Earth temperatures since 1880. Ask students to describe the trend of this graph [answer: temperature is increasing].
   d. **Slide 13**: remind students that you discussed carbon dioxide levels in the atmosphere earlier and that these are shown in the top graph. Temperature is shown in the bottom graph. Ask students to describe the relationship between CO_2 and global temperature [answer: as carbon dioxide increases, global temperature increases].
   e. **Slide 14**: our atmosphere acts like one blanket around the earth and keeps our planet warm enough for us to inhabit. However, when we add greenhouse gases to our atmosphere, we are putting on an additional blanket (click slide forward to display second blanket). This extra blanket results in temperatures that are too warm for species that are adapted for recent historic local temperatures, and is causing changes to atmospheric conditions and weather patterns, which will have large impacts on humans.
4. If you would like to discuss evaluation question numbers 2 - 4 with students, display slide 15.
   a. **Slide 15**: scientists used several models to predict global temperatures by the end of the century, in the year 2100. This graph displays three global temperature projections, shown by the colored lines. The three lines represent different scenarios for the amount of warming that will occur, which depends on the activities of humans. The amount that the temperature will increase depends greatly on human population growth and the amount of greenhouse gases emitted in this century.
   b. Direct students to look at evaluation question 2 and at the scenario with the warmest projected temperatures, shown by the top (red) line of the

approximately 6 - 8 °F].

c. Direct students to look at evaluation question 3 and at the scenario with the lowest projected temperatures, shown by the bottom (blue) line of the graph. Emphasize that they should only be considering the bottom line of the graph. Ask them to estimate the approximate number of degrees Fahrenheit by which the average temperature is projected to increase by 2100 in the lowest temperature scenario [answer: approximately 2 - 4 °F].
d. Ask students to consider question 4 and solicit answers. Although temperature increases of 2 - 8 °F may not sound like much, the impacts are likely to be great. We will continue to experience increases in snow and glacial melt; increased sea levels; less rainfall in the Mediterranean, southwest North America, and southern Africa; and more precipitation in Alaska and other high latitudes of the Northern Hemisphere. These changes will impact humans through increased droughts and wildfires in some areas, increased severe storms and flooding in other areas, and reduction in food production.

EXTENSIONS

1. After students conduct the experiment as outlined, they may have ideas for further research. Students are often interested to investigate what happens under different scenarios. Here are some ideas for additional student-directed inquiry, but feel free to encourage your students to think of more:
    a. Conduct the experiment for a longer time period. The temperature differences are greater and there is a more pronounced difference between the two trials if you allow the experiment to continue for up to 15 minutes.
        i. Record the results on a separate piece of paper. Ask students to determine which variables they will be measuring and how they need to construct their data table.
    b. Add more layers of insulating materials, such as additional towels and space blankets, small blankets, jackets, etc., and conduct the experiment again.
        i. Record the results on a separate piece of paper. Ask students to determine which variables they will be measuring and how they need to construct their data table.
        ii. Ask students to reflect on how their extension experiment relates to the natural and enhanced greenhouse effect.
            1. For example, some additional insulating materials may not result in increased temperatures because they are not as efficient at insulating as space blankets. This is analogous to adding non-greenhouse gases, such as O_2, to the atmosphere.
    c. Carry out the experiment on an object that does not generate heat, such as a rock.
        i. Ask students to hypothesize about the temperature change [answer: insulating a rock will not change its temperature because the rock does not have an internal temperature source like a person does. The rock is in energy balance with the surrounding air.].
        ii. Record the results on a separate piece of paper. Ask students to determine which variables they will be measuring and how they need to construct their data table.
2. Have students research ways to reduce greenhouse gases and create an education campaign for their school or community.

ADDITIONAL RESOURCES

Website with helpful background information:

Environmental Protection Agency (EPA). Climate Change: Basic Information. Published 18 Mar. 2014. Web. Accessed 09 Oct. 2014. <http://www3.epa.gov/climatechange/basics/>.

Examining the Enhanced

INSULATING YOU, INSULATING EARTH

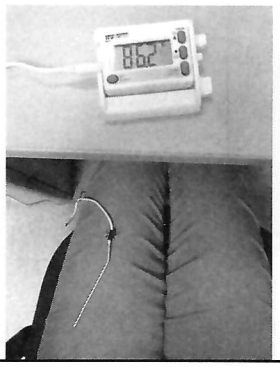
Greenhouse Effect

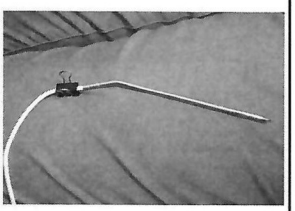
Southwest Regional Climate Hub

Developed by the
Asombro Institute for Science Education (www.asombro.org)

1

Setting Up the Experiment





2

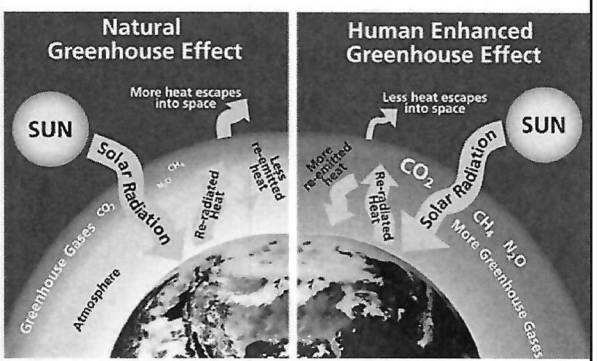
Greenhouse Gases

Gases that trap heat in the atmosphere

- Carbon Dioxide
- Water Vapor
- Ozone
- Methane
- Nitrous Oxide
- Fluorinated Gases

Source: www.epa.gov/climatechange/ghgemissions/gases.html

3



Source: www.nps.gov/goga/naturescience/images/Greenhouse-effect.jpg

4

Venus: Runaway Greenhouse Effect

- Very thick atmosphere, mostly CO_2
- High temps of almost 480°C (900°F)
  - Hotter than Mercury

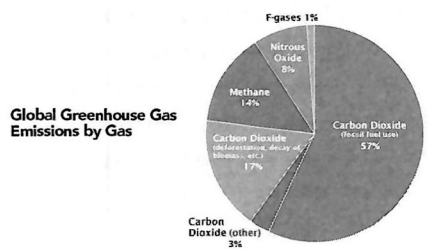
My Very Excellent Mother Just Served Us Noodles

Source: solarsystem.nasa.gov/planets/profile.cfm?Object=Venus

5

Humans & Greenhouse Gases

- Humans produce more carbon dioxide (CO_2) than any other greenhouse gas

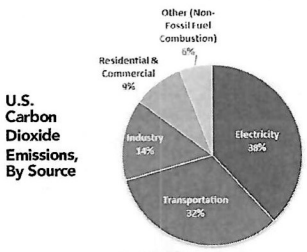


Source: www.epa.gov/climatechange/ghgemissions/global.html

6

How do humans release CO_2?

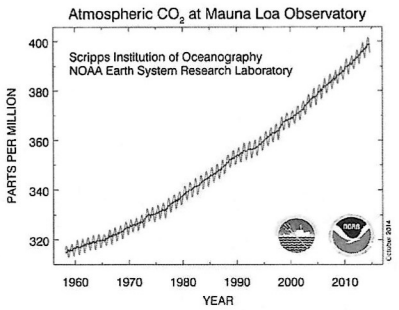
- **Electricity**
  - **Largest source of CO_2 emissions in U.S.**
- **Transportation**
- **Industry**



Source: www.epa.gov/climatechange/ghgemissions/gases/co2.html

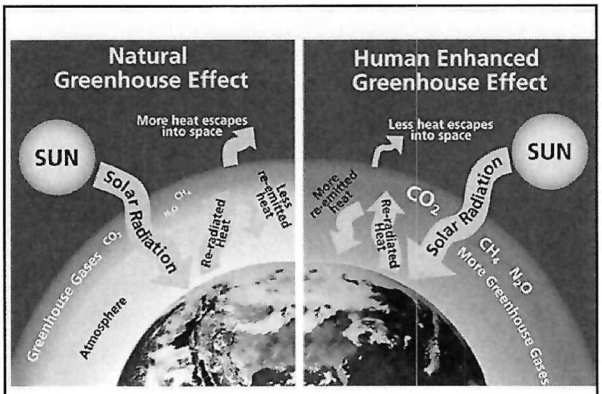
7

CO_2 in the Atmosphere



Source: www.esrl.noaa.gov/gmd/ccgg/trends/

8



Source: www.nps.gov/goga/naturescience/images/Greenhouse-effect.jpg

9

Climate

- **Description of the long-term pattern of weather in a particular area**
  - **Today's (or even this month's or this year's) weather is NOT the same as climate**

Source: www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

10

Climate Change

Refers to any significant change in the measures of climate lasting for an extended period of time

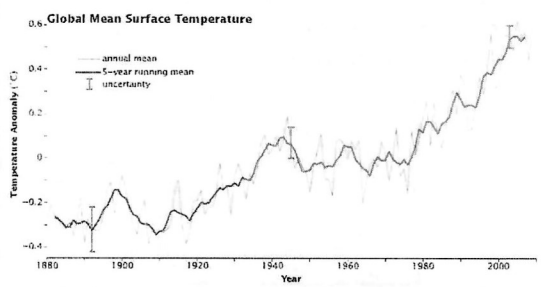
- **Global warming**
  - **Temperature increasing**
- **Precipitation patterns**
- **More severe storms**

Source: www.epa.gov/climatechange/basics/

11

Global Warming

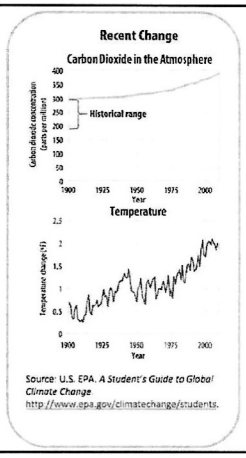
Recorded Data Since 1880



Source: earthobservatory.nasa.gov/Features/GlobalWarming/page2.php

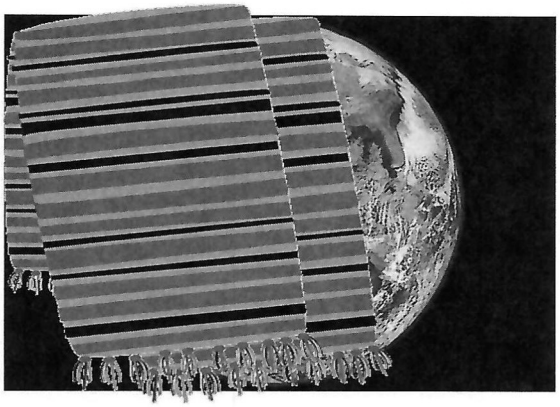
12

Atmospheric CO_2 and Temperature: What is the Relationship?



Source: U.S. EPA. *A Student's Guide to Global Climate Change*
http://www.epa.gov/climatechange/students.

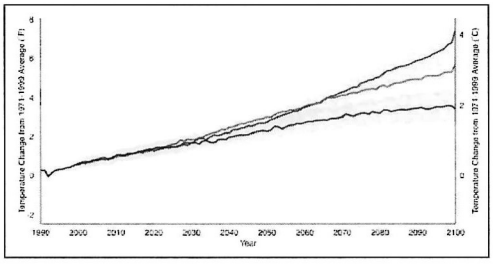
13



Earth photo source: solarsystem.nasa.gov/planets/profile.cfm?Object=Earth

14

Global Temperature Projections



The graph shows the average of a set of temperature simulations for the 20th century (black line), followed by projected temperatures for the 21st century based on a range of emissions scenarios (colored lines). The shaded areas around each line indicate the statistical spread (one standard deviation) provided by individual model runs.

Source: www.climate.gov/news-features/understanding-climate/climate-change-global-temperature-projections

15

Name _____ Date _____

Examining the Enhanced

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Greenhouse Effect

SETTING UP THE EXPERIMENT

1. Please work with your instructor to assemble into teams of 4.
2. Each team member will choose a role from the list of team member roles below.

TEAM MEMBER ROLES
Test subject
Materials manager
Timer
Data recorder

3. **As quickly as possible**, the team member who is the test subject will use a binder clip to attach the thermometer to the clothing on their lap. Attach the binder clip approximately halfway down the length of the thigh, and ensure that as much of the thermometer as possible is contacting the leg (Fig. 1).
4. Complete the prediction and follow the procedures.

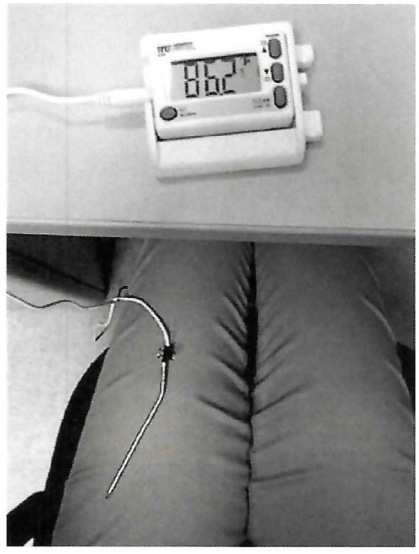


Figure 1. Example thermometer set up

PREDICTION

I predict that the temperature of the _____ trial will be **warmer**.

a. Towel
b. Towel + space blanket
c. Neither (they will be the same)

MATERIALS

- Thermometer
- Small binder clip
- Stopwatch
- Hand towel
- Rectangle of space blanket
- Calculator

PROCEDURES FOR TOWEL TRIAL

1. **Data recorder,** once the temperature reading of the test subject's lap has stabilized, record the temperature in the "Your Group" table. It can take several minutes for the temperature to stabilize. Enter the temperature under the "Towel Temp" column in the "Lap" row.
2. **Materials manager**, give the towel to the **test subject**. Test subject, lay the towel over the thermometer and across your lap so that its long side is perpendicular to your thighs, and tuck the ends of the towel under your legs if possible. **Timer**, press the start button on the stopwatch.
3. **Timer**, every time a minute passes on the stopwatch, call out the time to the data recorder. **Data recorder**, when the timer calls out the time, read the temperature on the thermometer and record it in the corresponding row of the "Towel Temp" column. Stop recording after 5 minutes. **Timer**, stop and reset the stopwatch.
4. **Test subject**, remove the towel from your lap and give it to the materials manager. **Leave the thermometer clipped to your lap.**
5. Everyone in the group will transfer these measurements onto their own data table. Using these data, calculate the difference in towel temperature.

PROCEDURES FOR TOWEL + SPACE BLANKET TRIAL

1. Wait until the thermometer reads approximately the same as the beginning lap temperature in the towel trial.
2. **Data recorder**, record the beginning lap temperature under the "Towel + Space Blanket Temp" column in the "Lap" row.
3. **Materials manager**, first give the towel and then the space blanket rectangle to the test subject. **Test subject**, lay the towel over the thermometer and across your lap, and then place the space blanket rectangle on top. Both should be oriented so that the long side is perpendicular to your thighs. Tuck both the towel and the space blanket under your legs together if possible. **Timer**, press the start button on the stopwatch.
4. **Timer**, every time a minute passes on the stopwatch call out the time to the data recorder. **Data recorder**, when the timer calls out the time, read the temperature on the thermometer, and record it in the corresponding row of the "Towel + Space Blanket Temp" column. Stop recording after 5 minutes. **Timer**, stop and reset the stopwatch.
5. Everyone in the group will transfer these measurements onto their own data table. Using these data, calculate the difference in towel + space blanket temperature.
6. Report the temperature differences in your towel trial and your towel + space blanket trial to the class. Record every group's differences, including your own, in the "whole class" table. Calculate the average differences. Answer the results and conclusions questions.

DATA & ANALYSIS

	YOUR GROUP	
TIME	A. TOWEL TEMP	B. TOWEL + SPACE BLANKET TEMP
LAP	°F	°F
1 MINUTE	°F	°F
2 MINUTES	°F	°F
3 MINUTES	°F	°F
4 MINUTES	°F	°F
5 MINUTES	°F	°F

A. TOWEL DIFFERENCE

_____°F – _____°F = _____°F
5 min. Lap Difference

B. TOWEL + SPACE BLANKET DIFFERENCE

_____°F – _____°F = _____°F
5 min. Lap Difference

	WHOLE CLASS	
GROUP	A. TOWEL DIFFERENCE	B. TOWEL + SPACE BLANKET DIFFERENCE
GROUP 1	°F	°F
GROUP 2	°F	°F
GROUP 3	°F	°F
GROUP 4	°F	°F
GROUP 5	°F	°F
GROUP 6	°F	°F
GROUP 7	°F	°F
GROUP 8	°F	°F
GROUP 9	°F	°F
MEAN		

RESULTS

1. In your group, which trial had the greater temperature difference? (Circle one.)
   a. Towel
   b. Towel + space blanket
   c. Same in both trials

2. In the whole class data, which trial had the greater mean difference? (Circle one.)
   a. Towel
   b. Towel + space blanket
   c. Same in both trials

CONCLUSIONS

1. Turn back to the first page and review your prediction. Was your prediction correct? Use the mean temperature differences from the "Whole Class" table to answer.

   Yes / No

2. Review your answer to the results question #2. Looking at the trial that you circled, why do you think that it had a greater difference in temperature, or if it was the same, why do you think that occurred?

EVALUATION

1. This experiment was a model of the greenhouse effect. Fill in the blanks below to indicate which component in this experiment was modeling the following components of the greenhouse effect. Read the excerpt below for help.

   Earth was modeled by the _____.
   Lap / Towel / Space Blanket

   The atmosphere was modeled by the_____.
   Lap / Towel / Space Blanket

   Additional carbon dioxide was modeled by the_____.
   Lap / Towel / Space Blanket

Think of yourself under a blanket in a cold room. You represent the earth, a warm body giving off energy, what we usually call "heat." The blanket represents the atmospheric layer of greenhouse gases.

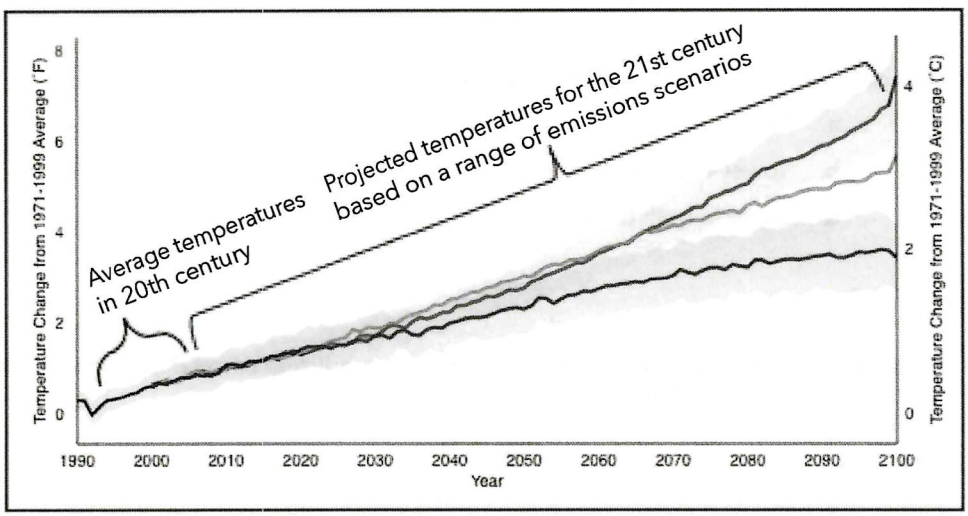
Among the earth's blanket of greenhouse gases, carbon dioxide is the one you probably hear about most often, because it is increasing in the atmosphere as we burn a great deal of coal, oil, and gas for energy.

In our blanket analogy, this is like putting on another blanket, so there are more layers of blanket fibers for the energy to pass through to reach the top.

Excerpted from: American Chemical Society - A Greenhouse Effect Analogy
http://www.acs.org/content/acs/en/climatescience/climatesciencenarratives/a-greenhouse-effect-analogy.html

Figure 2. Global Temperature Projections. The graph shows the average of a set of temperature simulations for the 20th century (single line), followed by projected temperatures for the 21st century based on a range of emissions scenarios (three lines). The shaded areas around each line indicate the statistical spread (one standard deviation) provided by individual model runs.

Source: *www.climate.gov/news-features/understanding-climate/climate-change-global-temperature-projections*



Use the Global Temperatures Projections graph (Fig. 2) to answer the following questions.

2. Examine the scenario with the **warmest** projected temperatures (top line). In the scenario with the **warmest** projected temperatures, by approximately how many degrees Fahrenheit is the average temperature projected to increase over the 21st century, from the year 2000 to the year 2100?

3. Examine the scenario with the **lowest** projected temperatures (bottom line). In the scenario with the **lowest** projected temperatures, by approximately how many degrees Fahrenheit is the average temperature projected to increase over the 21st century, from the year 2000 to the year 2100?

4. How will increasing temperatures affect Earth systems?

ANSWER KEY

Examining the Enhanced

INSULATING YOU, INSULATING EARTH

Greenhouse Effect

SETTING UP THE EXPERIMENT

1. Please work with your instructor to assemble into teams of 4.
2. Each team member will choose a role from the list of team member roles below.

TEAM MEMBER ROLES
Test subject
Materials manager
Timer
Data recorder

3. **As quickly as possible**, the team member who is the test subject will use a binder clip to attach the thermometer to the clothing on their lap. Attach the binder clip approximately halfway down the length of the thigh, and ensure that as much of the thermometer as possible is contacting the leg (Fig. 1).
4. Complete the prediction and follow the procedures.

Figure 1. Example thermometer set up

PREDICTION

I predict that the temperature of the ___*student answers will vary*___ trial will be **warmer**.

a. Towel
b. Towel + space blanket
c. Neither (they will be the same)

MATERIALS

- Thermometer
- Small binder clip
- Stopwatch
- Hand towel
- Rectangle of space blanket
- Calculator

PROCEDURES FOR TOWEL TRIAL

1. **Data recorder,** once the temperature reading of the test subject's lap has stabilized, record the temperature in the "Your Group" table. It can take several minutes for the temperature to stabilize. Enter the temperature under the "Towel Temp" column in the "Lap" row.
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5. Everyone in the group will transfer these measurements onto their own data table. Using these data, calculate the difference in towel temperature.

PROCEDURES FOR TOWEL + SPACE BLANKET TRIAL

1. Wait until the thermometer reads approximately the same as the beginning lap temperature in the towel trial.
2. **Data recorder**, record the beginning lap temperature under the "Towel + Space Blanket Temp" column in the "Lap" row.
3. **Materials manager**, first give the towel and then the space blanket rectangle to the test subject. **Test subject**, lay the towel over the thermometer and across your lap, and then place the space blanket rectangle on top. Both should be oriented so that the long side is perpendicular to your thighs. Tuck both the towel and the space blanket under your legs together if possible. **Timer**, press the start button on the stopwatch.
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5. Everyone in the group will transfer these measurements onto their own data table. Using these data, calculate the difference in towel + space blanket temperature.
6. Report the temperature differences in your towel trial and your towel + space blanket trial to the class. Record every group's differences, including your own, in the "whole class" table. Calculate the average differences. Answer the results and conclusions questions.

DATA & ANALYSIS

	YOUR GROUP	
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2 MINUTES	°F	°F
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4 MINUTES	°F	°F
5 MINUTES	°F	°F

student answers will vary

A. TOWEL DIFFERENCE

_____°F – _____°F = _____°F
5 min. Lap Difference

B. TOWEL + SPACE BLANKET DIFFERENCE

_____°F – _____°F = _____°F
5 min. Lap Difference

	WHOLE CLASS	
GROUP	A. TOWEL DIFFERENCE	B. TOWEL + SPACE BLANKET DIFFERENCE
GROUP 1	°F	°F
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GROUP 6	°F	°F
GROUP 7	°F	°F
GROUP 8	°F	°F
GROUP 9	°F	°F
MEAN		

student answers will vary

RESULTS

1. In your group, which trial had the greater temperature difference? (Circle one.)

   a. Towel
   b. Towel + space blanket ← *this is usually the case*
   c. Same in both trials

2. In the whole class data, which trial had the greater mean difference? (Circle one.)

   a. Towel
   b. Towel + space blanket ← *this is usually the case*
   c. Same in both trials

CONCLUSIONS

1. Turn back to the first page and review your prediction. Was your prediction correct? Use the mean temperature differences from the "Whole Class" table to answer.

   student answers will vary Yes / No

2. Review your answer to the results question #2. Looking at the trial that you circled, why do you think that it had a greater difference in temperature, or if it was the same, why do you think that occurred?

   The trial with the towel and the space blanket had a greater difference in temperature because adding the space blanket provided additional insulation, trapping more heat.

EVALUATION

1. This experiment was a model of the greenhouse effect. Fill in the blanks below to indicate which component in this experiment was modeling the following components of the greenhouse effect. Read the excerpt below for help.

   Earth was modeled by the _____*lap*_____.
   Lap / Towel / Space Blanket

   The atmosphere was modeled by the_____*towel*_____.
   Lap / Towel / Space Blanket

   Additional carbon dioxide was modeled by the_____*space blanket*_____.
   Lap / Towel / Space Blanket

Think of yourself under a blanket in a cold room. You represent the earth, a warm body giving off energy, what we usually call "heat." The blanket represents the atmospheric layer of greenhouse gases.

Among the earth's blanket of greenhouse gases, carbon dioxide is the one you probably hear about most often, because it is increasing in the atmosphere as we burn a great deal of coal, oil, and gas for energy.

In our blanket analogy, this is like putting on another blanket, so there are more layers of blanket fibers for the energy to pass through to reach the top.

Excerpted from: American Chemical Society - A Greenhouse Effect Analogy
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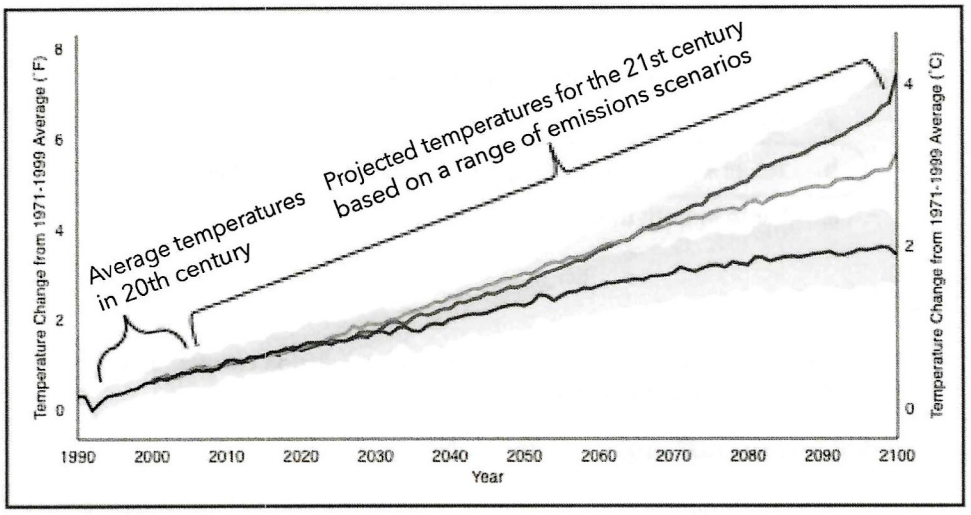
Source: *www.climate.gov/news-features/understanding-climate/climate-change-global-temperature-projections*



Use the Global Temperatures Projections graph (Fig. 2) to answer the following questions.

2. Examine the scenario with the **warmest** projected temperatures (top line). In the scenario with the **warmest** projected temperatures, by approximately how many degrees Fahrenheit is the average temperature projected to increase over the 21st century, from the year 2000 to the year 2100?

   Approximately 6 – 8 °F

3. Examine the scenario with the **lowest** projected temperatures (bottom line). In the scenario with the **lowest** projected temperatures, by approximately how many degrees Fahrenheit is the average temperature projected to increase over the 21st century, from the year 2000 to the year 2100?

   Approximately 2 – 4 °F

4. How will increasing temperatures affect Earth systems?

   Snow and glacial melt, increased sea levels, changes in precipitation patterns (flooding in some areas, drought in some areas), more severe storms