Lab Handout

Lab 17. Factors That Affect Global Temperature: How Do Cloud Cover and Greenhouse Gas Concentration in the Atmosphere Affect the Surface Temperature of Earth?

Introduction

All matter in the universe radiates energy across a range of wavelengths in the electromagnetic spectrum. Hotter objects tend to emit radiation with shorter wavelengths than cooler objects. The hottest objects in the universe, as a result, mostly emit gamma rays and x-rays. Cooler objects, in contrast, emit mostly longer-wavelength radiation, including visible light, infrared (IR), microwaves, and radio waves. The surface of the Sun has a temperature of about 5500°C or about 10000°F. At that temperature, most of the energy the Sun radiates is visible and near-IR light.

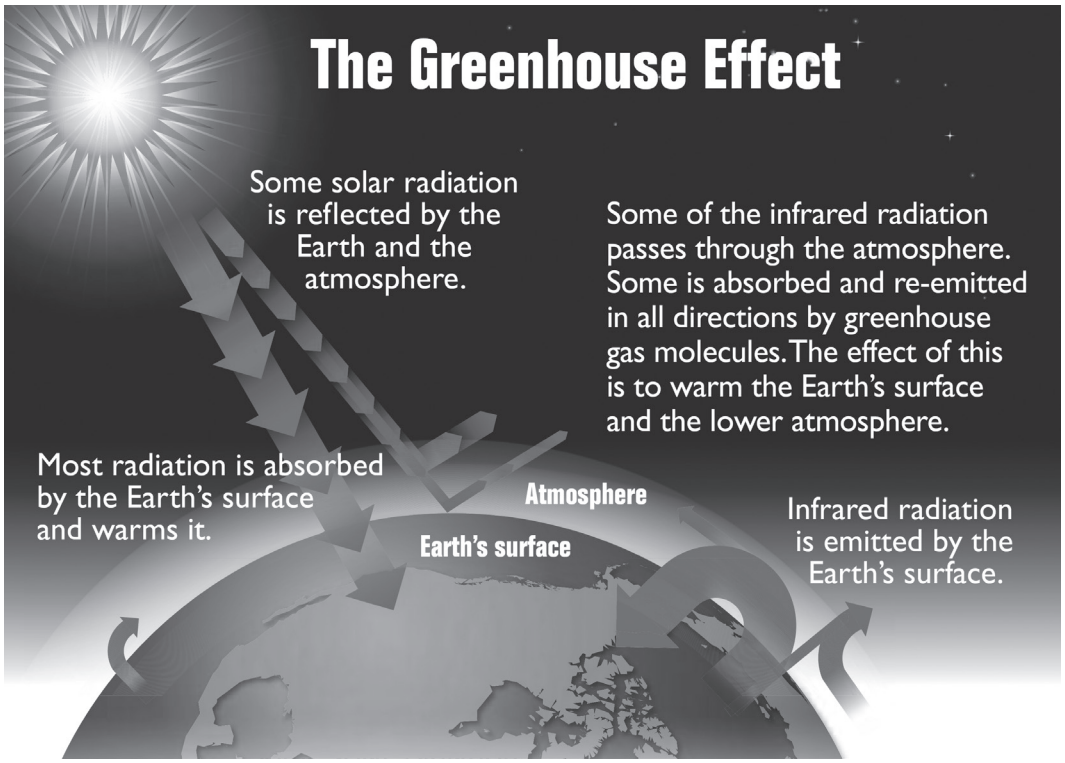
When sunlight first reaches Earth, some of it is reflected back out into space and some is absorbed by the atmosphere. The rest of the sunlight travels through the atmosphere and then hits the surface of Earth. The energy from the sunlight is absorbed by the surface and warms it. All objects, including Earth's surface, emit (or give off) IR radiation. The hotter an object is, the more IR radiation it emits. The amount of IR radiation emitted by Earth's surface therefore increases as it warms. The atmosphere traps some of this IR radiation before it can escape into space. The trapped IR radiation in the atmosphere helps keep the temperature of Earth warmer than it would be without the atmosphere. Scientists call the warming of the atmosphere that is caused by trapped IR radiation the *greenhouse effect* (see Figure L17.1, p. 420). Many gases that are found naturally in Earth's atmosphere, including water vapor, carbon dioxide, methane, nitrous oxide, and ozone, are called greenhouse gases because these gases are able to trap IR energy in the atmosphere.

The amount of energy that enters and leaves the Earth system is directly related to the average global temperature of the Earth. The Earth system, which includes the surface and the atmosphere, currently absorbs an average of about 340 watts of solar power per square meter over the course of the year (NASA n.d.). The Earth system also emits about the same amount of IR energy into space. The average global surface temperature, as a result, tends to be stable over time. However, if something were to change the amount of energy that enters or leaves this system, then the flow of energy would be unbalanced and the average global temperature would change in response. Therefore, any change to the Earth system that affects how much energy enters or leaves the system can cause a significant change in Earth's average global temperature.

The average global surface temperature of Earth has increased approximately 0.8°C (1.4°F) over the last 100 years (NASA Goddard Institute for Space Studies 2016). There are at least two potential explanations for this observation. One explanation is that the

FIGURE L17.1

The greenhouse effect



Note: A full-color version of this figure can be downloaded from the book's Extras page at *www.nsta.org/adi-ess*.

average global surface temperature of Earth normally increases and decreases over time and the current increase in temperature is just a normal part of this cycle. These changes could be to due to differences in the Sun's brightness, Milankovitch cycles (small variations in the shape of Earth's orbit and its axis of rotation that occur over thousands of years), or an increase or decrease in cloud cover (clouds form when water vapor in the air condenses into water droplets or ice). This explanation, however, does not account for the rapid increase in the average global surface temperature. An alternative explanation, which is the consensus view of the scientific community, is that humans have caused the rapid increase in the average global surface temperature of Earth by adding large amounts of greenhouse gases to the atmosphere. The addition of greenhouse gases magnifies the greenhouse effect. The atmosphere, as a result, traps more IR radiation and emits less IR energy out into space.

Before you can evaluate the merits of these two explanations for the observed change in average global surface temperature, it is important for you to understand how energy from the Sun interacts with the surface of the Earth and the various components of the

atmosphere, such as clouds. You will therefore need to learn more about the relationships between surface temperature, cloud cover, and greenhouse gas levels in the atmosphere.

Your Task

Use a computer simulation and what you know about stability and change and the importance of tracking how energy flows into, within, and out of systems to determine how the temperature of Earth responds to changes in the amount of cloud cover and the concentration of carbon dioxide in the atmosphere.

The guiding question of this investigation is, ***How do cloud cover and greenhouse gas concentration in the atmosphere affect the surface temperature of Earth?***

Materials

You will use an online simulation called *The Greenhouse Effect* to conduct your investigation; the simulation is available at *https://phet.colorado.edu/en/simulation/legacy/greenhouse.*

Safety Precautions

Follow all normal lab safety rules.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

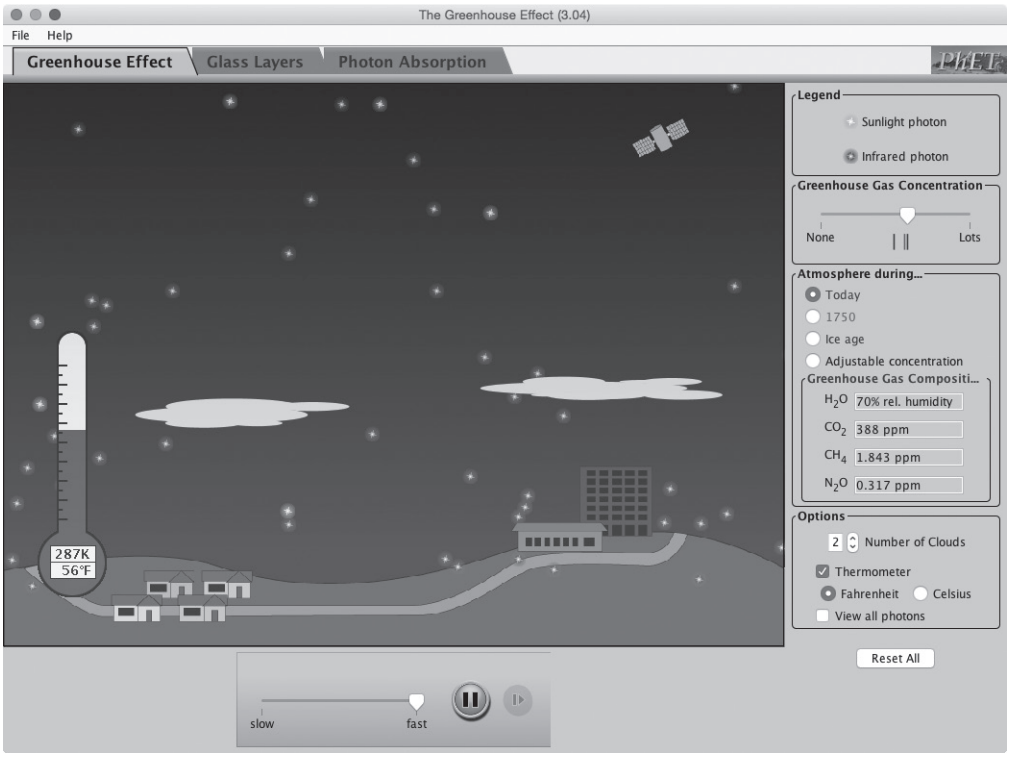
The *Greenhouse Effect* computer simulation models how energy flows into, within, and out of the Earth system and records changes in average global temperature over time (see Figure L17.2, p. 422). It shows the surface of Earth as a green strip. Above the green strip there is a blue atmosphere and black space at the top. Yellow dots stream downward representing photons of sunlight. Red dots represent photons of IR light that are emitted by the surface of Earth and travel toward space. The greenhouse gas concentration in the atmosphere, including amounts of water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), can be changed so it reflects the current level of these gases, the level in 1750, the level during the last ice age, or a level of your choice. Clouds can also be added or removed from the atmosphere. Greenhouse gases block IR light (energy) that is emitted by Earth's surface. Clouds can block sunlight and IR photons.

To answer the research question, you must determine what type of data you need to collect, how you will collect it, and how will you analyze it. To determine *what type of data you need to collect,* think about the following questions:

- What are the boundaries and components of the system you are studying?
- How do the components of the system interact with each other?
- When is this system stable, and under which conditions does it change?

FIGURE L17.2

A screenshot from *The Greenhouse Effect* simulation



Note: A full-color version of this figure can be downloaded from the book's Extras page at *www.nsta.org/adi-ess.*

- Which factor(s) might control the rate of change in this system?
- How can you describe the components of the system quantitatively?
- How could you keep track of changes in this system quantitatively?
- How can you track how energy flows into, out of, or within this system?

To determine *how you will collect your data,* think about the following questions:

- What type of measurements or observations will you need to record during your investigation?
- How often will you need to make these measurements or observations?
- What will serve as your dependent variable?
- What will serve as a control condition?
- What types of treatment conditions will you need to set up?
- How many trials will you need to run in each condition?

- How long will you let the simulation run before you collect data?
- How will you keep track of and organize the data you collect?

To determine *how you will analyze the data*, think about the following questions:

- What types of patterns might you look for as you analyze your data?
- How could you use mathematics to describe a change over time?
- How could you use mathematics to document a difference between treatment and control conditions?
- What type of calculations will you need to make?
- What type of graph could you create to help make sense of your data?

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

As you work through your investigation, be sure to think about

- how scientific knowledge can change over time, and
- the types of questions that scientists can investigate.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence to support your claim, and a justification of the evidence. The *claim* is your group's answer to the guiding question. The *evidence* is an analysis and interpretation of your data. Finally, the *justification* of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L17.3.

FIGURE L17.3
Argument presentation on a whiteboard

The Guiding Question:	
Our Claim:	
Our Evidence:	Our Justification of the Evidence:

Argumentation Session

The argumentation session allows all of the groups to share their arguments. One or two members of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. This is similar to what scientists do when they propose, support, evaluate, and refine new ideas during a poster session at a conference. If you are presenting your group's argument, your goal is to share your ideas and answer questions. You should also keep a record of the

critiques and suggestions made by your classmates so you can use this feedback to make your initial argument stronger. You can keep track of specific critiques and suggestions for improvement that your classmates mention in the space below.

Critiques of our initial argument and suggestions for improvement:

If you are critiquing your classmates' arguments, your goal is to look for mistakes in their arguments and offer suggestions for improvement so these mistakes can be fixed. You should look for ways to make your initial argument stronger by looking for things that the other groups did well. You can keep track of interesting ideas that you see and hear during the argumentation in the space below. You can also use this space to keep track of any questions that you will need to discuss with your team.

Interesting ideas from other groups or questions to take back to my group:

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections. Each section should provide an answer for the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. You should write your report using a word processing application (such as Word, Pages, or Google Docs), if possible, to make it easier for you to edit and revise it later. You should embed any diagrams, figures, or tables into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid.

References

National Aeronautics and Space Administration (NASA). n.d. Earth's energy budget. *https://earthobservatory.nasa.gov/Features/EnergyBalance/page4.php.*

National Aeronautics and Space Administration (NASA) Goddard Institute for Space Studies. 2016. GISS surface temperature analysis. *https://data.giss.nasa.gov/gistemp/graphs_v3.*