What Factors Impact a Greenhouse?

Modified with permission from Global Climates – Past, Present, and Future, S. Henderson, S. Holman, and L. Mortensen (Eds.). EPA Report No. EPA/600/R-93/126, U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC 47 - 52.

Background

The earth's atmospheric "greenhouse effect" is much more complex than the simple greenhouse experiment described in Activity 12. While the earth's temperature is dependent upon the greenhouse-like action of the atmosphere, the amount of heating and cooling are strongly influenced by several factors.

The type of surface that sunlight first encounters is the most important factor. Forests, grasslands, ocean surfaces, ice caps, deserts, and cities all absorb, reflect, and radiate radiation differently. Sunlight falling on a white glacier surface strongly reflects back into space, resulting in minimal heating of the surface and lower atmosphere. Sunlight falling on a dark desert soil is strongly absorbed, on the other hand, and contributes to significant heating of the surface and lower atmosphere. Cloud cover also affects greenhouse warming by both reducing the amount of solar radiation reaching the earth's surface and by reducing the amount of radiation energy emitted into space.

Scientists use the term **albedo** to define the percentage of solar energy reflected back by a surface. Understanding local, regional, and global albedo effects is critical to predicting global climate change. The following are some of the factors that influence the earth's albedo.

- **Clouds:** On a hot, sunny day, we usually welcome a big fluffy cumulus cloud passing overhead because we feel cooler immediately. That's because the top of the cloud reflects sunlight back into space before it ever reaches earth. Depending on their altitude and optical properties, clouds either cool or warm the earth. Large, thick, relatively low-altitude clouds, such as cumulus and cumulonimbus, reflect incoming solar radiation and thereby reduce warming of the surface. The whitewash on plant greenhouses has the same effect on a smaller scale. High-altitude, thinner clouds, such as cirrus clouds, absorb longwave radiation reflected from the earth's surface, causing increased warming.

Cirrus

Cumulus

Nimbus

- **Surface albedo:** Just as some clouds reflect solar energy into space, so do light-colored land surfaces. This surface albedo effect strongly influences the absorption of sunlight. Snow and ice cover are highly reflective, as are light-colored deserts. Large expanses of reflective surfaces can significantly reduce solar warming. Dark-colored land surfaces, in contrast, are strongly absorptive and contribute to warming. If global temperatures increase, snow and ice cover may shrink. The exposed darker surfaces underneath may absorb more solar radiation, causing further warming. The magnitude of the effect is currently a matter of serious scientific study and debate.

- **Oceans:** From space, oceans look much different than adjacent land areas – they often appear darker, suggesting that they should be absorbing far more sunlight. But unlike dry land, water absorbs energy in a dynamic fashion. Some of the solar energy contacting the surface may be carried away by currents, some may go into producing water vapor, and some may penetrate the surface and be mixed meters deep into the water column. These factors combine to make the influence of the ocean surface an extremely complex and difficult phenomenon to predict.

  Water also has the capacity to store heat and transport large amounts of heat energy. In addition, oceans are an important sink (storage site) for atmospheric CO_2, and their ability to absorb CO_2 is strongly related to ocean temperature.

  Because of their enormous size and depth, oceans are extremely important in determining global climate and the future rate of global temperature change.

- **Forested areas:** Like the oceans, the interaction of forests and sunlight is complex. The amount of solar radiation absorbed by forest vegetation depends upon the type and color of vegetation, the time of year, and how well watered and healthy the plants are. In general, plants provide a dark surface, so you might expect high solar absorption. A significant fraction of the solar radiation is captured by the plants and used to make food through photosynthesis (and thus it doesn't re-radiate as heat); some of the energy is dissipated as water evaporates from plant leaves; and some is absorbed and distributed deep within the forest canopy. These complexities make a simple definition of forest influences impossible.

To a lesser extent, the same complexities apply to any relatively continuous-cover ecosystem (for example, grasslands and farmlands).

In this exercise, students will form their own conclusions as to how different surface and cover types affect heating using the model bottle systems introduced in Activity 12.

Learning Goals

1. Students will be able to identify at least three factors affecting the heat-trapping ability of a greenhouse, including the transparency of the greenhouse cover, color of the surfaces inside the greenhouse, and type of surfaces inside.

2. Students will be able to explain the factors important in the atmosphere's heat trapping ability.

3. Students will understand the influence of albedo on earth's temperature.

Alignment to National Standards

National Science Education Standards

- Unifying Concepts and Processes, Grades K to 12, pg. 117: "Models are tentative schemes or structures that correspond to real objects, events, or classes of events and that have explanatory power."

- Physical Science, Transfer of Energy, Grades 5 to 8, pg. 155, Item #2: "Heat moves in predictable ways flowing from warmer objects to cooler ones, until both reach the same temperature."

- Earth and Space Science, Grades 9 to 12, pg. 189, Item #3: "Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents."

Benchmarks for Science Literacy, Project 2061, AAAS

- Common Themes, Models, Grades 6 to 8, pg. 269, Item #1: "Models are often used to think about processes that happen too slowly, too quickly, or on too small a scale to observe directly, or that are too vast to be changed deliberately, or that are potentially dangerous."

- The Physical Setting, Energy Transformations, Grades 6 to 8, pg. 85, Item #3: "Heat can be transferred through materials by the collisions of atoms or across space by radiation. If the material is fluid, currents will set up in it that aid the transfer of heat."

Grade Level/Time

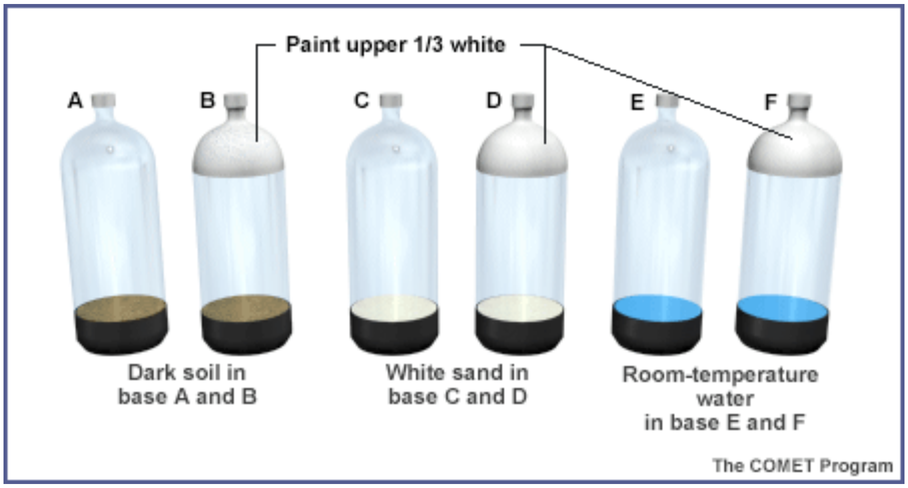
- **Grade level:** 5 to 9
- **Time:**
    - Introduction by teacher: 15 minutes
    - Student activity (assuming bottle construction already done): 60 minutes

Materials for Each Team of Four Students

- Six soda bottle experimental chambers (see materials in Activity 12)
- Six thermometers
- Tape (transparent or light-colored)
- White paint
- Three cups of dark soil (garden or potting soil)
- Three cups of white sand or perlite
- Water and dump buckets
- One 150-watt floodlight bulb
- Portable reflector lamp
- Stand to support lamp set-up
- Graph paper

Procedure

1. To save time, you (or your students) should prepare the model greenhouses prior to class. For each team of four students, you will need six experimental chambers. Paint the upper third of three of the bottles white.



2. Label the bottles A, B, C, D, E, and F with bottles B, D, and F having the white paint.

3. Fill the base of bottles A and B with dark soil, bottles C and D with white sand, and bottles E and F with room-temperature water.

4. Tape a thermometer (using transparent tape or light-colored masking tape) to the inside of each bottle (facing out).

5. Place the bottle tops in the bases. Make sure the bottles are capped.

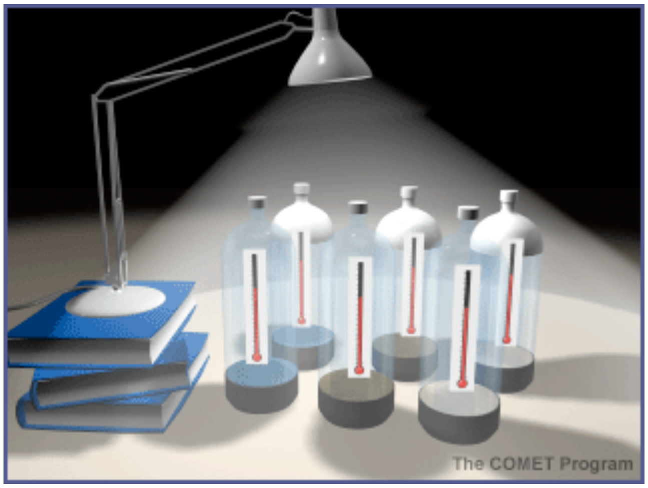
6. Make sure the bulbs of the thermometers are just above the top of the bases. If the bulbs are below the base, the thermometer may record the heat absorbed directly by the soil or water, complicating the results.

7. Ask students to predict which bottle will get hotter. Why? Record predictions.

8. Have each team set up a graph of time (in minutes) vs. temperature to record their observations.

9. Each student should have a specific responsibility during the experiment, either keeping track of the time or recording the temperature for the different bottles.

10. Place the bottles approximately six inches away from the lamp with the thermometer facing away from the light. Record the baseline temperatures.



11. Turn on the light and begin recording the temperatures every two minutes. Continue for at least 20 minutes.

Cautionary Note: If your lamp is not big enough, six bottles may be too many to have under the light at the same time. The ones further from the light may not get the same intensity of heat as the bottles closer to the light thereby compromising the experiment. You may have the students use a sub-set of the bottles at one time. If you make changes in the experiment, make sure you also change the student guide.

Observations and Questions

1. Compare the graphed information from the different bottles.

2. Discuss the results and propose some possible explanations.

3. Relate the factors affecting the model greenhouses to the factors affecting the "global greenhouse." Which factors are the same? Which are different?

Assessment Ideas

- After discussing their findings, ask students to sketch and explain how to set up a model greenhouse (with the light on) with the absolutely coolest possible temperatures. Where might such a condition be found on earth?

- Now ask them to sketch and explain a greenhouse designed to generate the maximum possible heat. Where might such a condition really exist?
