



# Atmospheric Perturbations

High School Grades

## **Lesson Summary**

Students use a soda bottle to explore how changes in temperature, pressure, and amount of particles in the atmosphere affect the formation of clouds. Students will gain an understanding of Earth's feedback mechanisms that help to keep it at a stable temperature.

## **Prior Knowledge & Skills**

- Basic knowledge of clouds

## **AAAS Science Benchmarks**

### **The Nature of Science**

*Scientific Inquiry*

### **The living Environment**

*Interdependence of Life*

### **Common Themes**

*Systems*

*Constancy and Change*

## **NSES Science Standards**

### **Science as Inquiry**

*Abilities Necessary to Do Scientific Inquiry*

### **Life Science**

*Matter, Energy, and Organization in Living Systems*

**Teaching Time:** ~ 1 hour

## **Materials**

- Bottles, 4 two liter clear soda bottles
- Chopsticks
- Liquid crystal thermometer
- Matches
- Tape
- Water

## **Advanced Planning**

**Preparation Time:** ~10 minutes

1. Review the instructions
2. Gather the necessary supplies.

## **Recommended Reading: (attached)**

- Feedback mechanism supplementary information

Institute for Global Environmental Strategies: Discover Earth Program Materials

<http://www.strategies.org/index.aspx>

# The Earth System

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## **Additional Materials**

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**Grade Level:** 8 - 12

## Key Concepts and Terms:

### albedo effect

Albedo is the fraction of solar energy that is reflected back to space. The more reflective a surface, the higher the albedo (the range is 0 - 1). The elements of the climate system that most contribute to Earth's albedo are clouds, surface ice and snow, and aerosol haze. Variations in the albedo of these elements can have a significant impact on global climate. For example, the albedo for fresh snow can be as high as .87 (87% of incoming solar energy is reflected). When the portion of ocean and land that is covered by ice and snow increases, the increased area of high albedo can be a positive feedback that increases cooling and expands the area covered with ice and/or snow, which can increase cooling and further expand the area covered with ice and/or snow. This is known as the ice albedo effect. A decrease in ice and snow--which would damp (reduce) the albedo effect--would increase the amount of solar energy received, resulting in warmer temperatures that would diminish the area covered by ice and snow. This in turn would further damp the albedo effect. This is a negative feedback.

### cloud condensation nuclei (CCN)\*

In the atmosphere, clouds can form at relative humidities of less than 100%. This is due to the presence of minute water-attracting particles. Water vapor will stick to, and condense on, these particles to form clouds. Major sources of naturally occurring CCN are:

- volcanoes - dust and sulfate particles;
- oceans - sea salt and particles;
- phytoplankton - sulfate particles; and
- wildfires - soot and dust.

CCN can also result from man's activities. In particular, CCN occur as a byproduct of any combustion process. This includes motor vehicles emissions, industrial activity, and controlled fires (slash and burn agriculture).

### Earth system science

Science of Earth as a system composed of interacting subsystems. This approach emphasizes the interactive nature of the components and crosses traditional discipline boundaries. The subsystems are the atmosphere, biosphere, geosphere, and hydrosphere (chart on page 9-4); described as follows:

## atmosphere

Thin layer of gas or air that surrounds the Earth. Processes in the atmosphere include winds, weather, and the exchange of gases with living organisms.

## biosphere

The wealth and diversity of living organisms on the Earth. Processes in the biosphere include life and death, evolution, and extinction.

## geosphere

Physical elements of the Earth's surface, crust, and interior. Processes in the geosphere include continental drift, volcanic eruptions, and earthquakes.

## hydrosphere

Water and ice on or near the surface of the Earth. Includes water vapor in clouds; ice caps and glaciers; and water in the oceans, rivers, lakes, and aquifers. Processes in the hydrosphere include the flow of rivers, evaporation, and rain.

## feedback

Any process which amplifies or damps any perturbation to a system-- such as the climate system. An initial change is amplified (a + feedback) or damped (a - feedback). Within the Earth system, feedback may occur in a subsystem(s) other than where the stimulant is located. For example, increased greenhouse gases in the atmosphere-- which may lead to global warming--originate at the Earth's surface and may be ultimately stored in the ocean. See albedo effect for examples of positive and negative feedbacks. Note that all perturbations to a system are not necessarily part of a feedback loop.

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## perturbation

Any change in a system which has an effect on the system.

## turgor

Rigidity of plant due to water content.

\* courtesy of William F. Ryan, University of Maryland at College Park, Department of Meteorology.

## **Background for Teachers:**

Space observations have changed the way we view Earth. Having access to data acquired by satellites that survey the entire planet, at regular intervals, has dramatically enhanced our ability to study Earth and supports the realization that humanity shares a common destiny. Scientists now use a systems view of Earth to understand the processes responsible for the evolution of the Earth on all timescales and the interaction of Earth's subsystems (atmosphere, biosphere, geosphere, hydrosphere). Understanding Earth means using a scientific approach that considers the Earth as a complex, evolving body, characterized by ceaseless change. It means understanding Earth on a global scale by describing how its component parts

and their interactions have evolved, how they function, how they may be expected to evolve.

We are interested in how the Earth system functions, what is "normal," what causes change in the system, and how the system copes with change. The Earth system is sometimes compared to the human body. We are interested in how well our heart/ lungs/muscles/nerves, etc. work--but we are most keenly interested in how well the components work together--our overall health. So it is with Earth.

Disturbances to the Earth system are called perturbations. They can encompass anything from a change in the amount of solar insolation reaching Earth to the amount of carbon dioxide humans are putting into the atmosphere. Any change that has an effect on the Earth system that is either amplified or damped is part of a feedback loop--either positive or negative. Positive feedback reinforces an action or response. For example, an increase of ice or snow in cold climates can encourage cooler temperatures and more ice and snow--a positive feedback. Negative feedback is usually more stabilizing and limits the deviation of the system. For example, if those cold climates had warmer temperatures, that would likely result in less ice and snow, which would encourage the continuation of warmer temperatures. Notice that positive feedback reinforces (amplifies) a behavior but does not mean that the behavior is desirable. See Daisyworld on page 9-13 for a more detailed look at systems.

*Activity 2: Perturbations of the Earth System*

Students will conduct experiments to show examples of perturbations for one of the four parts of the Earth system.

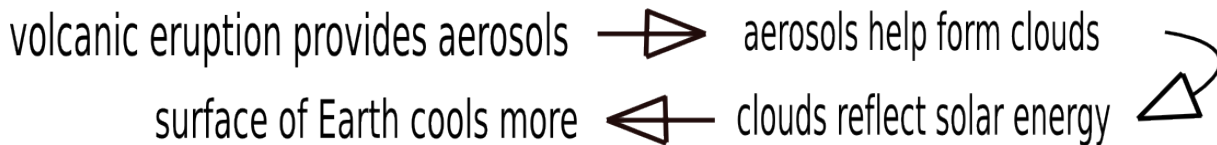
**Atmosphere objective:** Students will investigate cloud formation and disappearance in relation to pressure and temperature changes, and relate this to feedback. See the diagram on page 9-11.

**Materials:**

bottles, 4 two-liter clear soda bottles or gallon milk jugs  
chopsticks  
liquid crystal thermometer (available from NASCO Science Catalog)  
matches  
tape  
water

## Procedure:

1. Divide the class into four groups.
2. Bow the thermometer, use a piece of clear tape to hold it in place. The bowed thermometer will be shaped like the letter "D." Use 2 additional pieces of tape to attach the thermometer inside the bottle. Hint - use a chopstick to insert the thermometer into the bottle and apply pressure to the tape strips.
3. Cap the bottle; squeeze the bottle hard. NOTE: This may require some force. What do you observe?
4. Release the bottle to reduce the air pressure inside the bottle. What do you observe?
5. Place a small amount of water inside the bottle. Repeat steps 3 and 4.
6. Light a match and let it burn for a few seconds, then place it in the bottle while still burning. Repeat steps 3 - 4 to create high and then low pressure inside the bottle.
7. The process in the bottle becomes feedback if you include a perturbation. For example, a volcanic eruption cools because dust in the atmosphere absorbs solar energy. (Factory emissions are an alternate example.)



The initial impact of the volcanic/factory emissions is then amplified. Imagine, too, the opposite effects. See cloud condensation nuclei on page 9-2, and NASA Facts: Clouds and the Energy Cycle [http://eosps0.gsfc.nasa.gov/nasa\\_facts](http://eosps0.gsfc.nasa.gov/nasa_facts) for background.

8. Students note and record what they observe in the bottle.
9. With their groups, students discuss and record examples of feedback involved in cloud formation and disappearance. Give examples of where and why on the Earth this type of feedback might occur.
10. Discuss how the Earth system is affected by increases or decreases in cloud coverage. Some examples of where clouds do and do not form: at the Equator, convergence and low pressure result in clouds and rain. Divergence and high pressure result in deserts at 30 degrees N and 30 degrees S latitudes. Frontal boundaries with their low pressure produce clouds and rain. Orographic uplift (forced lifting along a topographic barrier such as mountains) produces cooling, and clouds if the air is humid. On the leeward side of the mountain, sinking drier air results in noticeably less precipitation.

Note: the cloud in the bottle with thermometer procedure was developed by the American Meteorological Society's Project Atmosphere.

cloud in a soda bottle\*  
see page 9-9

