

Lesson 7

Earth's Albedo



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NYS Intermediate Level Science

Standard 1: Analysis, Inquiry and Design/Scientific Inquiry

- S1.2a Independently formulate a hypothesis.
- S2.1c Design and conduct an experiment to test a hypothesis.
- S2.1d Use appropriate tools and conventional techniques to solve problems about the natural world, including: measuring, observing, describing, classifying, sequencing.
- S2.3c Collect quantitative and qualitative data.
- S3.2c Evaluate the original hypothesis in light of the data.
- S3.2d Formulate and defend explanations and conclusions as they relate to scientific phenomena.
- S3.2h Use and interpret graphs and data tables.

Standard 6: Interconnectedness

- 5.2 Observe patterns of change in trends or cycles and make predictions on what might happen in the future.

Standard 4: The Living Environment

- 7.2d Since the Industrial Revolution, human activities have resulted in major pollution of air, water, and soil. Pollution has cumulative ecological effects such as acid rain, global warming, or ozone depletion. The survival of living things on our planet depends on the conservation and protection of Earth's resources.

Standard 4: The Physical Setting

- 4.4b Light passes through some materials, sometimes refracting in the process. Materials absorb and reflect light, and may transmit light. To see an object, light from that object, emitted by or reflected from it, must enter the eye.
- 2.2j Climate is the characteristic weather that prevails from season to season and year to year.
- 2.2q Hazardous weather conditions include thunderstorms, tornadoes, hurricanes, ice storms, and blizzards. Humans can prepare for and respond to these conditions if given sufficient warning.
- 2.2r Substances enter the atmosphere naturally and from human activity. Some of these are carbon dioxide, methane, and water vapor. These substances can affect weather, climate, and living things.
- 4.5b Energy can change from one form to another, although in the process some energy is always converted to heat. Some systems transform energy with less loss of heat than others.

Next Generation Science Standards

Science and Engineering Practices:

- 2. Developing and using models
- 3. Planning and carrying out investigations.
- 4. Analyzing and interpreting data
- 6. Constructing explanations



Grade 6

PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

Grade 7

ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

Common Core State Standards**ELA in the Content Areas - Grades 6-8**

CCSS.ELA-Literacy.RST.6-8.7

Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

Common Core State Standards - Mathematics**Standards for Mathematical Practice**

CCSS.Math.Practice.MP2

Reason abstractly and quantitatively.

CCSS.Math.Practice.MP4

Model with mathematics.

Grade 6

CCSS.Math.Content.6.NS.C.8

Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate.



Earth's Albedo

*Adapted from the Climate Discovery Teacher's Guide, National Center for Atmospheric Research:
http://eo.ucar.edu/educators/ClimateDiscovery/ESS_lesson4_10.19.05.pdf*

Introduction

Students experiment and observe how the color of materials that cover the Earth affects the amounts of sunlight our planet absorbs.

Background Information

What Is Albedo?

While the Earth's temperature is dependent upon the greenhouse-like action of the atmosphere, the amount of energy retained by the Earth is strongly dependent on the albedo of Earth surfaces. Just as some clouds reflect solar energy into space, so do light-colored land surfaces.

Scientists use the term albedo to define the percentage of solar energy reflected back by a surface. This surface albedo effect strongly influences the absorption of sunlight. Forests, grasslands, ocean surfaces, ice caps, deserts, and cities all absorb, reflect, and radiate solar energy 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 soil or rock is strongly absorbed, and contributes to significant heating of the Earth's surface and lower atmosphere.

Understanding local, regional, and global albedo effects is critical to predicting global climate change. Light colored ice and snow are very weakly absorptive, reflecting 80-90% of incoming solar energy.

Dark-colored land surfaces, are strongly absorptive and contribute to warming, reflecting only 10-20% of the incoming solar energy. 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.

How Much Are Glaciers Melting?

Currently glaciers cover about 10% of the Earth's land surface. In most areas of the world, mountain glaciers are melting. Between 1961 and 1998, small glaciers lost an average of 7 meters of ice thickness. Glaciers in mountainous areas near the equator have been particularly hard-hit.

According to global climate models, all of the glaciers in Glacier National Park in Montana will be gone by the year 2030. Snow and ice cover near the North Pole is currently decreasing at approximately 0.4% per year.

Arctic sea ice has been decreasing at about 2.9% per decade. Since 1974, seven ice shelves, most in Antarctica, have retreated by a total of approximately 13,500 square kilometers.





Bhutan Glacier



Cornell University

About the Image The image used in this activity is of retreating mountain glaciers in Bhutan. It is a satellite image taken by the ASTER instrument aboard NASA's Terra satellite. Visible in the image are several glaciers in the Himalayan Mountains of Bhutan. The glaciers have been melting over the past few decades, and lakes have formed on the surfaces and near the termini of many of the glaciers. Some of the glaciers are white as the ice is covered with snow pack. Other parts are rocky and have the same color as the surrounding land.

Objectives

Students will be able to

- conduct an experiment to examine the heating of different colored materials
- explain how the color of materials affects heat absorption
- support experimental conclusions with evidence
- relate their experiment to warming of Earth materials

Advanced Preparation

- Copy Student Page for all students.
- Make color copies of the Bhutan glacier image (see previous page). Laminate these photos for use with multiple classes.

Materials Required

(for each group of about three students):

- Copies of the Student Page
- 2 Thermometers
- One copy of the Bhutan glacier photo (p.4)
- Tape
- Watch or stopwatch
- Small heating lamps (laboratory lamps or small desk lamps will work fine), alternatively you can conduct the activity outdoors in direct sunlight
- Graph paper

Engage

Ask students if they have ever noticed that different colored materials are hotter in the hot sun than others. For instance,

- Does dark-colored asphalt or light-colored sidewalk feel hotter?
- Do you feel hotter wearing a black or white shirt in the hot sun?

Show students a picture of the Earth from space. Ask:

- What colors do you see?
- What are the lightest colors? The darkest? What Earth features do they represent?
- Where do they expect that most sunlight will be absorbed?
- Where do they expect that the least sunlight will be absorbed?



Show students the photo of the Bhutan glaciers. Explain that this picture was taken from a satellite high above the Earth. Ask students to share what they observe in the picture.

- The dark reddish parts of the picture are land (rocks).
- The white sections are ice and snow.
- This ice and snow is in glaciers. Define glacier. Parts of the glaciers are light blue in color. These are made of blue ice, sand and gravel. The very dark patches are lakes that form from the glacier melt water.

Explore

1. Divide students into groups of 2-4. Provide each group a Student Page and a set of materials. Ask students to designate who in their group is going to record the data, who is going to read the ice thermometer, who is going to read the land thermometer and who is going to be the timekeeper.
2. Ask students to make a hypothesis about which areas of the photograph they think would absorb the most solar energy and which would absorb the least. Remind of them of their prior experiences with the topic, as discussed in the Engage, e.g., wearing a dark shirt, walking on asphalt. Students should write the hypothesis on the Student Page.
3. Instruct students to fix their thermometers to the back of the picture using tape. One thermometer bulb should be under a section of light-colored ice and the other thermometer bulb under a section of dark red land. Remember to place the thermometers so that when you lay the picture down on a table, the thermometers are right side up and can be read.
4. Place the light (not turned on) directly above the picture, about a foot above. Do not turn it on yet!
5. The two students read their thermometers before the light is turned on and give the numbers to the data collector. The thermometer readings should be approximately the same.
6. Once they have the initial readings, groups should turn on their light and the timekeeper begins timing. Students should take temperature readings every 2 minutes for 8 minutes total. Advise students to read the thermometers without shading the light if possible.

Explain

1. Next, students should create a graph and explain what they think their graph shows. You may wish to have students complete this task individually on graph paper.
2. Assign pairs of student teams to compare their graphs with one another and list some similarities and differences between the teams' data.
3. At the same time, compile all data into a table on a computer, blackboard, or overhead transparency so that all groups can see it.
4. Students should then calculate the class averages for land and ice temperatures.
5. Have individual students create a graph of the class data, with two different lines for the ice and land data.



6. Discuss the findings as a class. Important questions to ask students include:
 - a. What overall pattern do you observe?
 - b. Was your hypothesis supported? How do you know?
 - c. Did any groups' findings seem out of line with the rest of the class? If so, why do you think that might have happened?
 - d. What do these findings tell you about Earth materials?

Explain to students that the proportion of light energy that surface reflect is known as **albedo**. If surfaces reflect a lot of the light that they receive, they have high albedo. If they absorb most of the light that they receive, they have low albedo.

Discuss

- a. On Earth, what types of land coverings do you think absorb the most energy? *Ocean, dark soil, dense forest*
- b. Reflect the energy? *Ice, snow, light colored sand*
- c. When energy hitting glaciers, ice caps, and other high albedo surfaces is reflected, where does it go?

Elaborate

Share the following statistics with students (from the Background Information):

- Currently glaciers cover about 10% of the Earth's land surface. In most areas of the world, mountain glaciers are melting.
- Between 1961 and 1998, small glaciers lost an average of 7 meters of ice thickness.
- Glaciers in mountainous areas near the equator have been particularly hard-hit.
- According to global climate models, all of the glaciers in Glacier National Park in Montana will be gone by the year 2030.
- Snow and ice cover near the North Pole is currently decreasing at approximately 0.4% per year. Arctic sea ice has been decreasing at about 2.9% per decade.
- Since 1974, seven ice shelves, most in Antarctica have retreated by a total of approximately 13,500 square kilometers.

Discuss

- What do these statistics tell us? *The overall amount of ice on Earth is decreasing.*
- How will Earth's albedo be different if this trend continues? *The albedo will decrease.*
- If the albedo decreases, what does that mean for Earth? *If the snow and ice melt, there land below has a lower albedo. That is, the land will absorb more energy, causing the Earth to warm.*

Evaluate

Direct students to write two paragraphs in response to the following prompts:

1. Describe what you did in your experiment. What conclusion can you make based on your investigation? Use data from the experiment to support your conclusion.
2. Imagine you were building an outdoor doghouse for your pet to enjoy while playing outdoors. Would you use dark or light-colored materials for the roof? Defend your answer based on what you know about albedo and results from your experiment.



Evaluate Rubric

Component/Score	3 Exemplary	2 Satisfactory	1 Needs Improvement
Procedure	Accurately and completely describes the procedure used.	Description is mostly accurate and mostly complete.	Description contains several inaccuracies or omits important steps
Conclusion	Conclusion is reasonable and well-supported by specific data from the experiment	Conclusion is reasonable with some support from the experiment	Conclusion is not reasonable or not supported by experimental findings
Roof color	Student explains that a dark roof would better heat the doghouse, whereas a light roof would reflect heat, keeping it cooler	Student explains that either a dark roof will absorb heat or a light roof will reflect heat	Student suggests roof color but does not explain why
Support with evidence	Student supports suggestion by describing the concept of albedo and relating their design to the experiment they conducted	Student supports suggestion by describing the concept of albedo OR relating their design to the experiment they conducted	Student does not adequately support suggestion with evidence



Student Activity Sheet Earth's Albedo

Name _____ Date _____ Class _____

Take a look at the photograph of the Bhutan Glacier.
 Place the bulb of one thermometer under the light colored snow and ice part of the photo.
 Place the bulb of the other thermometer under the dark colored land part of the photo.
 (Make sure both thermometers are facing so that you can read them easily.)

What is your hypothesis?
 (What do you think will happen to the thermometers under the ice colored parts of the photo and the land colored parts of the paper?)

Collect the data!
 Use the table below to help you collect the temperature data.

Time	Temperature under ice picture	Temperature under land picture
0 minutes		
2 minutes		
4 minutes		
6 minutes		
8 minutes		

What do YOU think?
 How is this different than the real world?

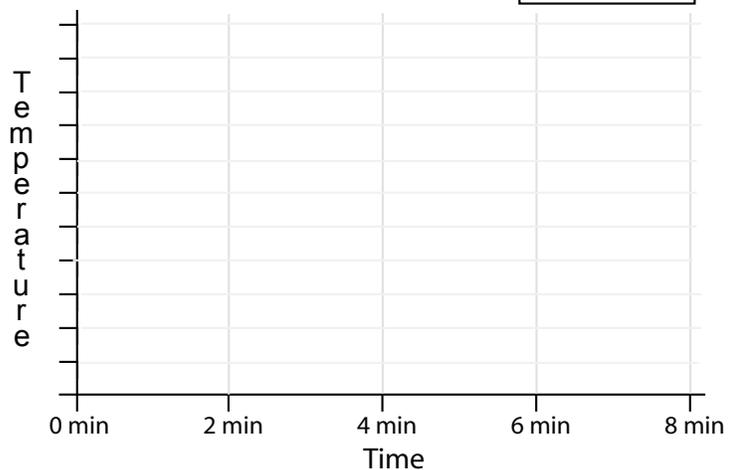
What does the data mean?
 Graph your data by plotting the points and connecting them into two lines:
 One line for the ice photo temperature
 One line for the land photo temperature
 (Remember to fill in the temperature axis and the key.)

Key:

Ice

Land

Explain what you think it shows in the space below.



Hudson River Estuary Climate Change Lesson Project

www.nyseagrant.org
<http://www.dec.ny.gov/lands/>



New York State
Water Resources Institute



Cornell University