ALBEDO

Overview:

Students learn about albedo and the ice-albedo feedback effect as it relates to snow, ice, and the likely results of reduced snow and ice cover on global temperatures.

Objectives:

The student will:
- investigate how different colored surfaces reflect or absorb light energy;
- draw conclusions from his or her model;
- calculate albedo; and
- relate albedo to global temperatures.

Targeted Alaska Performance Measures Tested on the High School Graduation Qualifying Exam

Math

M.6.3.1 Collect, analyze, and display data in a variety of visual displays including frequency distributions, circle graphs, histograms, and scatter plots.

M3.4.1 Use estimation to solve problems and to check the accuracy of solutions; state whether the estimation is greater or less than the exact answer.

M6.3.2 Interpret and analyze information found in newspapers, magazines, and graphical displays.

Targeted Alaska Grade Level Expectations

Science

[9] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating.

[10-11] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, analyzing data, developing models, inferring, and communicating.

Vocabulary

albedo – a measurement of how much solar energy is reflected off a surface

Whole Picture:

Albedo is the measurement of how much solar energy is reflected off a surface. It is common knowledge dark-colored clothing is warmer than light-colored clothing. The scientific property behind this difference is called albedo. When the sun shines on a surface, solar radiation, or solar energy, is either absorbed into or reflected off that surface. Materials that are lighter in color have a higher albedo than the same materials with a darker color. Black jeans have a low albedo; they reflect very little solar energy. White jeans have a high albedo; they reflect a large amount of solar energy.

Albedo affects Earth's environment. Soil, water, and snow also have albedo measurements. Fresh snow reflects 90 percent of the solar energy striking its surface, so its albedo measurement is 0.90. This means that only 10 percent (100-90) of the solar energy that reaches the snow is absorbed. The albedo of a water surface depends on the angle at which the sunlight strikes it and whether the surface is smooth or rough. The average albedo of Earth as a whole is 30 percent. As snow ages and becomes discolored, its albedo changes.

The climate system is characterized by strong positive and negative feedback loops between processes that affect the state of the atmosphere, ocean, and land. A simple example is the ice-albedo positive feedback loop whereby melting snow exposes more dark ground (of lower albedo), which in turn absorbs heat and causes more snow to melt.

or... melting sea ice exposes more dark water (of lower albedo), which in turn absorbs heat and causes more ice to melt.

A feedback effect, also known as a feedback loop, is a cycle within a system that continually increases ("positive feedback") or decreases ("negative feedback") the effects of the system. The climate system is characterized by strong positive and negative feedback loops between processes that affect the state of the atmosphere, ocean, and land. A simple example is the ice-albedo positive feedback loop whereby melting snow exposes more dark ground (of lower albedo), which in turn absorbs heat and causes more snow to melt. In the northern oceans melting sea ice exposes more dark water (of lower albedo), which in turn absorbs heat and causes more ice to melt.

In the Arctic, where snow and ice are present for long periods each year, a change in the albedo of the surface can cause rapid climate changes. Climate models predict far more warming in the polar regions than in the tropics. In the past few decades, temperatures have risen about twice as fast in the Arctic as in the rest of the world. This is largely because of the high albedo of snow and ice. As snow and ice melt, the exposed darker surfaces absorb more heat. This sensitivity to climate makes it more difficult to model climate responses at the poles.

Materials:

- Desk lamp with a 60-watt bulb
- Black construction paper
- White construction paper
- Thermometers (2 for each pair of students)
- Scissors
- Stapler
- A small sheet of foam to insulate each envelope from the table top
- Calculators
- MULTIMEDIA: "Reflections from the Surface" available on the UNITE US website (uniteusforclimate.org)
- STUDENT WORKSHEET: "Albedo Lab"
- STUDENT WORKSHEET: "Putting a Number on Albedo"

Activity Procedure:

1. Explain students will investigate how light affects the temperature of material of different colors.
2. Distribute STUDENT WORKSHEET: "Albedo Lab" and review the worksheet as a class. Have students pair up to complete the investigation.
3. After students have completed their worksheets, review student work as a class.
4. Distribute STUDENT WORKSHEET: "Putting a Number on Albedo" and calculators.

Answers:

STUDENT WORKSHEET: Albedo Lab

Background Information:

1. B. Albedo is the measure of how much radiant energy from the sun is reflected.

Hypothesis:

2. Answers will vary but should reflect an understanding of the lab.

Data:

1. Answers will vary
2. Answers will vary, but should correspond with data in table.
3. Answers will vary, but should correspond with data in table.

Analysis of Data:

1. The thermometer used with the black paper should have registered the warmest temperature.
2. The thermometer used with the black paper

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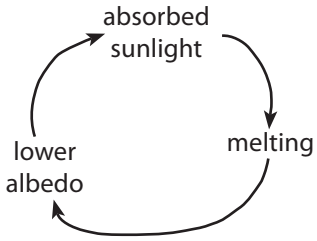
Conclusion:

1. Answers will vary. Check hypothesis to verify.
2. Based on your analysis of data, light colors have high albedos while dark colors have low albedos.
3. Dirt Tundra Fresh snow
4. The albedo would decrease, driving up temperatures.
5. The temperature would increase, and ice would form later in the year.

Further Questions:

1. snow goggles
2. high
3. high
4. red
5. As sunlight melts snow and ice the albedo becomes lower. The lower albedo causes even more sunlight to be absorbed and causes even more melting. See diagram at right



STUDENT WORKSHEET: Putting a Number on Albedo

1. 100 km^2
2. B. The dirt areas are higher elevation because the creek flows in the valley between them and fresh snow is found by one of the areas of dirt.
3. Answers will vary but the average albedo should be close to 0.27.
4. less than
5. lower
6. The glacier has receded and exposed more dirt.
7. Answers will vary but the average albedo should be close to 0.15.
8. The albedo decreased from map A to map B.
9. Answers will vary but should reflect that the area of the glacier shrunk by about 42 km^2.
10. Answers will vary but should reflect that the area of dirt increased by about 43 km^2.
11. The albedo is lower than the average albedo of Earth.
12. Albedo is the amount of light reflected from a surface.
13. Answers will vary but should reflect that Earth's albedo decreases as global temperatures rise. Rising global temperatures also contribute to more melting of snow and sea ice, causing more sunlight to be absorbed..

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ALBEDO LAB

Testable Question:

How does the color of a material placed under a light affect temperature?

Background Information:

Albedo is the measurement of how much solar energy is reflected off a surface. It is common knowledge dark-colored clothing is warmer than light-colored clothing. The scientific property behind this difference is called albedo. When the sun shines on a surface, solar radiation, or solar energy, is either absorbed into or reflected off that surface. Materials that are lighter in color have a higher albedo than the same materials with a darker color. Black jeans have a low albedo; they reflect very little solar energy. White jeans have a high albedo; they reflect a large amount of solar energy.

Albedo affects Earth's environment. Soil, water, and snow also have albedo measurements. Fresh snow reflects 90 percent of the solar energy striking its surface, so its albedo measurement is 0.90. This means that only 10 percent (100-90) of the solar energy that reaches the snow is absorbed. The albedo of a water surface depends on the angle at which the sunlight strikes it and whether the surface is smooth or rough. The average albedo of Earth as a whole reflects 30 percent. As snow ages and becomes discolored, its albedo changes.

Directions: Answer the question below and then work in pairs to complete the lab.

1. What is albedo?
   - A. Albedo is the percentage of radiant energy produced by the sun.
   - B. Albedo is the measure of how much radiant energy from the sun is reflected.
   - C. Albedo is the measure of how much radiant energy from the sun is absorbed.

Hypothesis:

2. Use the background information and the investigation procedure to state a hypothesis. Try to write it in the form of an "If…., then…." statement.

_____

_____

Investigation:

Materials:

- Stapler
- Scissors
- Desk lamp with a 60-watt bulb
- Black construction paper
- White construction paper
- 2 sheets of foam
- Thermometers (2 for each pair of students)

Procedure:

To study albedo, work in pairs to complete the following lab.

Step 1: Cut two 4 ¼" by 5 1/2 " squares; one from black construction paper, one from white construction paper.

Step 2: Fold each square in half twice.

Step 3: Staple two edges of each square to form pockets. Place each pocket on a piece of foam to insulate it from the table top.

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Step 4: Place the bulb end of each thermometer into the pocket.

Step 5: Place the pockets with the thermometers directly under the lamp so that they receive equal amounts of light. The lamp should be pointed straight down.

Step 6: Allow two minutes for the thermometers to reach the temperature of the surrounding air. This will be the initial temperature for the lab. Record this initial temperature on the chart below. Turn on the lamp. Record the temperature of each thermometer every two minutes for the next 20 minutes. Be sure to use the same units (°F or °C) for both thermometers.

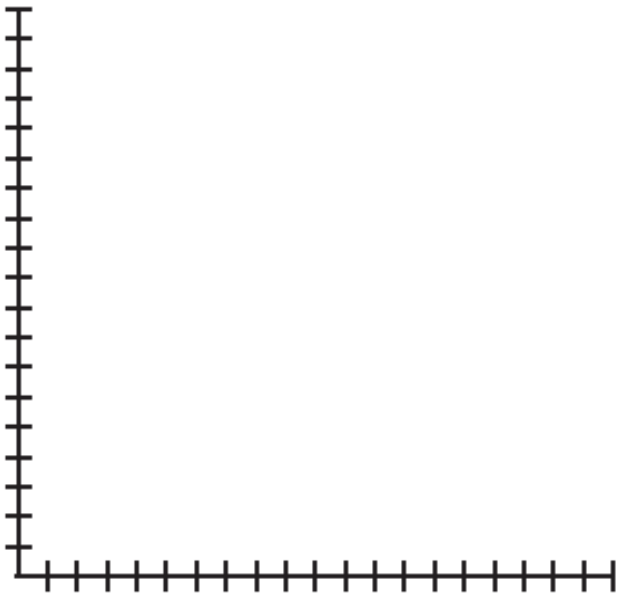
Data:

1. Record data in the table below.

Thermometer	Starting	2 min.	4 min.	6 min.	8 min.	10 min.	12 min.	14 min.	16 min.	18 min.	20 min.
White											
Black											

2. Graph the data on the line graph below. Use a different color pen or pencil for each thermometer. Label the key and the axes of the graph.

KEY
White
Black



3. Subtract the starting temperature from the final temperature for each thermometer.

White: _____ - _____ = _____
(final temperature) (starting temperature) (increase in temperature)

Black: _____ - _____ = _____
(final temperature) (starting temperature) (increase in temperature)

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Analysis of Data:

1. Which thermometer registered the warmest temperature? _____
2. Which thermometer registered the fastest rise in temperature?_____

Conclusion:

1. Was your hypothesis supported? _____
2. Circle your answer. Based on your analysis of data, light colors have ***low*** / ***high*** albedos while dark colors have ***low*** / ***high*** albedos.
3. Classify the following in order of lowest to highest albedo: fresh snow, dirt and tundra.

   Low _____ _____ _____ High
4. If an increase in global temperatures causes interior Alaska to remain snow-free for two additional weeks each year, how will it affect albedo? Why?

   _____

   _____
5. If the albedo of Interior Alaska decreases, how will this affect temperatures and ice formation in the winter? Explain.

   _____

   _____

Further Questions:

Access the MULTIMEDIA: "Reflections from the Surface" on the UNITE US website (uniteusforclimate.org) to answer the following questions.

1. Name the traditional technology used to protect eyes from the high albedo of snow. _____

Directions: Use the map on "Measuring Albedo" to answer the following three questions.

2. Circle one. Compared to the rest of the world, in April 2002, Alaska has a ***low*** / ***high*** albedo.
3. Circle one. According to the map from April 2002, sandy desert areas have a ***low*** / ***high*** albedo.
4. If the satellite was able to measure albedo in northern Greenland, what color do you predict it would be?

   _____
5. Draw a diagram that shows the relationship among "absorbed sunlight," "melting snow and ice," and "lower albedo." Describe what your diagram means.

   _____

   _____

   _____

   _____

   _____

   _____

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PUTTING A NUMBER ON ALBEDO

Background:

Albedo is the amount of light reflected from a surface. Land cover that is light in color has high albedo whereas dark colors have low albedo. The average albedo of Earth is 0.30. Use the attached maps to calculate and compare changes in albedo.

Map A

1. What is the area of this map in square kilometers (km^2)? _____

2. What can you infer about the two areas of dirt that are directly North and South of the lake?
   A. They are areas of mud from the lake.
   B. The dirt areas are higher elevation because the creek flows in the valley between them and fresh snow is found by one of the areas of dirt.
   C. Animals dug up two areas of tundra to expose the dirt.
   D. There were two very small glaciers that have since melted.

3. Complete the steps below to calculate the average albedo of the map.
   Step 1. Estimate the area for each type of land cover and fill in COLUMN A. Hint: the total number of km^2 should equal 100.
   Step 2. Multiply the area for each type of land cover by its albedo measurement in COLUMN B and write the answer in COLUMN C.
   Step 3. After each albedo measurement has been calculated, add all of the calculations and write it in the TOTAL.
   Step 4. Divide the TOTAL by 100 to determine the average albedo measurement for the area.

Land Cover	**COLUMN A** Area (km^2)	**COLUMN B** Approximate albedo measurement	**COLUMN C**
Glacier		**x 0.30**	
Dirt		**x 0.05**	
Tundra		**x 0.25**	
Water		**x 0.12**	
Fresh Snow		**x 0.90**	
		TOTAL	
		÷ 100 for average albedo	

4. Is the albedo for this area greater or less than the average albedo of Earth? _____

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Map B is the same area as Map A, however it shows how warming temperatures have changed the landscape.

5. Predict: Will the albedo be higher or lower on Map B compared to Map A?

_____

6. Describe how the land cover changed from Map A to Map B.

7. Complete the process of the four previously described steps to calculate the average albedo of this total area.

Land Cover	**COLUMN A** Area (km^2)	**COLUMN B** Approximate albedo measurement	**COLUMN C**
Glacier		**x 0.30**	
Dirt		**x 0.05**	
Tundra		**x 0.25**	
Water		**x 0.12**	
Fresh Snow		**x 0.90**	
		TOTAL	
		÷ 100 for average albedo	

8. How did the Albedo measurement change from map A to Map B?

_____

9. How did the area of the Glacier change from Map A to Map B.

_____

10. How did the amount of dirt-covered area change from Map A to Map B?

_____

11. How does the albedo measurement from Map B compare to the average albedo measurement of Earth?

_____

_____

12. What is albedo?

_____

_____

13. How does albedo affect global temperatures?

_____

_____

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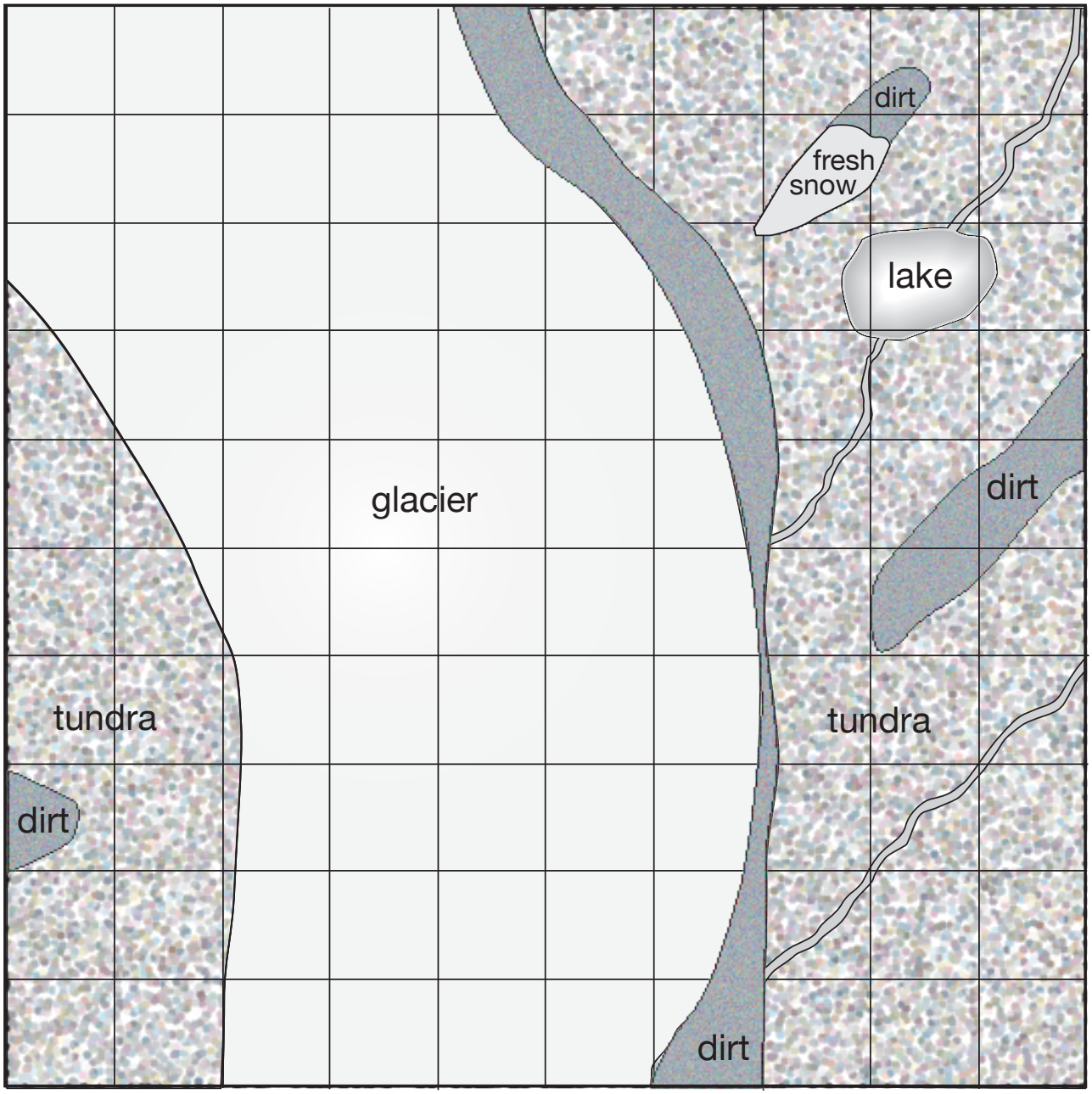
Map A



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Map B