Albedo, Melting Ice and Climate Change

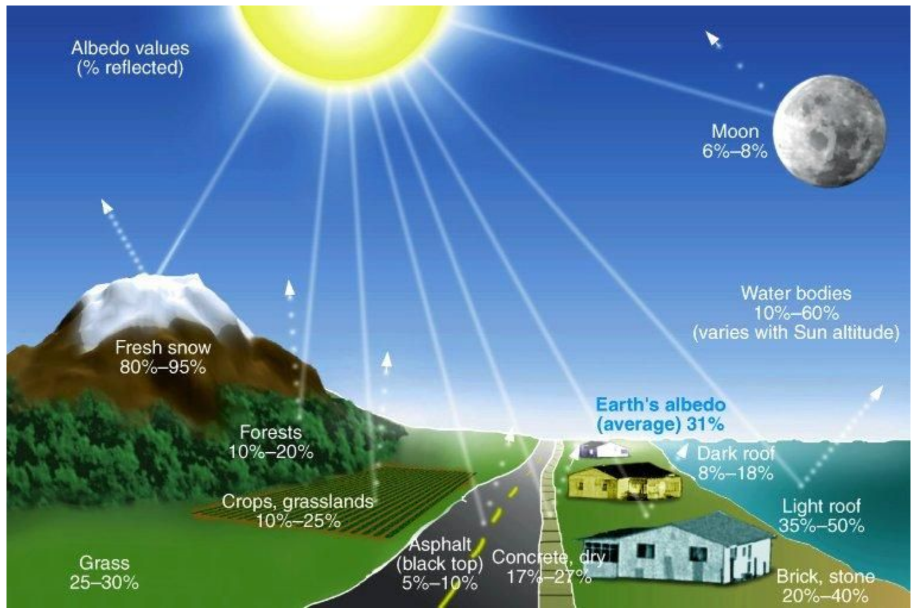
(modified from SERC Earthlabs: Cryosphere Lab 6)

Objectives:

- Students will understand how light reflection and absorption are related to albedo
- Students will explore feedback processes between the cryosphere and atmosphere

Background:

Earth's **radiation budget** is a concept that helps us understand how much energy Earth receives from the Sun and how much it radiates back into space.



Albedo measures the percentage of light that is reflected off a surface. An object that reflects all the light would have albedo of 1 (100%), whereas a completely opaque object would have an albedo of zero.

If Earth was completely covered in ice like a giant snowball, its albedo would be about 0.84, meaning it would reflect 84 percent of incoming sunlight and absorb 16 percent. On the other hand, if Earth was completely covered by a dark green forest canopy, its albedo would be about 0.14, meaning most of the sunlight would get absorbed and our world would be significantly warmer than it is today.

Satellite measurements made since the late 1970s estimate Earth's average albedo to be about 0.30. In other words, about 30 percent of incoming solar radiation is reflected back into space, and 70 percent is absorbed. Earth's radiation budget is balanced when the amount of incoming radiation is equal to the amount of outgoing radiation. If the budget is out of balance, Earth may experience net warming or cooling. Over the past century, there has been a net warming trend, which has caused Earth's temperature to increase by about 0.8°C.

Materials List:

- light source
- 4 plastic containers
- snow, shaved ice or sugar (stand in for snow)
- soil
- gravel
- sand
- plant material (leaves, grass, moss)
- light meter and LoggerPro interface
- printed image of Antarctic sea ice
- two thermometers
- ring stand and clamp
- ruler
- data table or access to Google sheets or Excel
- graph paper or access to Google sheets or Excel

Part 1: Measuring Albedo of Different Surfaces

In this part of the lab, you will explore the feedback process that occurs between the cryosphere and the atmosphere by modeling different surface conditions.

1. Cover the bottoms of each of the four plastic containers with different surface materials found on Earth: snow (sugar), soil, gravel, plant material and sand. Choose any four, but be sure to do snow (or sugar).
2. Open LoggerPro. The probe will measure in units of lux (the SI unit for light intensity). Depending on the intensity of the light source, you may have to adjust the sensitivity switch on the probe.
3. If you are able to conduct this experiment outside, use the sun as your light source. If you are indoors, use a lamp clamped to a ring stand. Make sure that all four containers are receiving the same amount of incident light.
4. Point the sensor at the light source and measure the incident illuminance (I). Record the value on your data table.
5. Hold the light probe sensor 1-2 inches above the first sample with the sensor pointing directly at the material in the container. Avoid shadows from your hand.
6. Record the reflected illuminance (R) on your data table.
7. Repeat for the remaining materials.
8. Calculate the albedo (A) for each material (A = R/I), and record the values in your data table.

Table 1 below shows the accepted albedo values for different surfaces.

Surface	Typical Albedo
Fresh asphalt	0.04
Conifer forest (summer)	0.09-0.15
Deciduous trees	0.15-0.18
Bare soil	0.17
Green grass	0.25
Desert sand	0.40
New concrete	0.55
Sea ice	0.5-0.7
Fresh snow	0.80-0.90

Part 2: Albedo and Antarctic Ice

In this part of the lab, you will be using an image of Antarctica to model feedback between the cryosphere and the atmosphere in Antarctica.

1. Examine the printed image of the Larsen B ice shelf breaking up off Antarctica in 2002: https://drive.google.com/open?id=0B1m76b1pjpjAdkZXcXFYVXF5M2M.
2. Tape the two thermometers to the back of the image so that the bulb of one thermometer is directly beneath a section of the image with bright white ice and the bulb of the other thermometer is directly beneath a section of the image with dark open ocean. Make sure you will be able to read both thermometers easily when the image is lying face up on the table.
3. Position the 150 watt lamp so that it will shine directly over the image, but DO NOT turn it on yet. The lamp should be about 15 cm above the image.
4. On your data table, record the starting temperature (time = 0 min) showing on each thermometer.

5. Turn on the lamp. Record the temperature shown on each thermometer every 2 minutes for 10 minutes. Be careful not to cast any shadows over the image or thermometers when taking your measurements.
6. Using graph paper or Google Sheets or Excel, make a plot of temperature as a function of time for the ice-covered and ocean regions of the image.

<u>Analysis</u>

1. How did your albedo values compare to the typical ones shown in Table 1?
2. Is the ice-albedo feedback loop an example of positive or negative feedback? Draw a feedback loop showing components and couplings to illustrate your answer.
3. How did the temperatures of the two regions of the Antarctic image compare over time?
4. Evaluate how well each of the two activities models the connection between albedo and climate change.

Extension:

5. Watch the video about The White Roof Project at http://whiteroofproject.org/. Explain how the project works, referring to results from your lab.
6. Use the Earth's Albedo and Global Warming Simulation available at Teacher's Domain to review and answer the following questions.
    a. How does soot from pollution and coal burning affect the albedo of ice?
    b. How has Arctic sea ice cover changed in the past 30 years? Be sure to give numbers.
    c. How does melting ice on land affect the ocean?

Albedo, Melting Ice and Climate Change
Data Collection Sheet

Part 1: Measuring Albedo of Different Surfaces

Surface	Incident Illuminance	Reflected Illuminance	Albedo (A) = R/I
Snow (sugar)			

Part 2: Albedo and Antarctic Ice

Time, minutes	Ice temperature, °C	Ocean temperature, °C
0		
2		
4		
6		
8		
10		