Earth's Albedo

Focus Questions:

How do ice and snow help to regulate the overall energy balance on Earth?

What will the impact of climate change be on the Earth's ability to reflect incoming solar energy?

Time

2 class periods or approximately 1.5 hours

Materials

- Yellow popcorn kernels
- Shaker to hold the popcorn (a plastic cup will work)
- 11 x 14 sheet with map of Earth's eco-regions or land surface types
- Copy paper box top to provide a holder with sides for the map
- Printed Key of eco-regions or global biomes
- Ice cube tray or egg carton to sort out sunlight kernels
- Data sheet for recording

Vocabulary (Terms)

Absorb
Albedo
Energy
Insolation
Land Use
Radiation
Reflect

Preview

Now, in your mind's eye, step out onto a paved playground or other dark-colored surface. How does the temperature underfoot change? (Ouch!) Or maybe you have experienced the difference between light and dark-colored sand at the beach. All of these materials have a different albedo, or ability to reflect incoming solar radiation. The more solar radiation that is reflected, the cooler the object or material, because less radiation is absorbed. You may have looked at bright white snow or clouds and wondered why they were so bright; they both have a high albedo, or reflectivity.

Albedo is derived from the Latin word "albus" for white. Albedo is defined as the percentage of solar (shortwave or ultraviolet) radiation reflected by a given surface. The range of albedo on the Earth's surface can be as little as 3% (0.03) for water and as high as 95% (0.95) for fresh snow cover. Scientists have studied the albedo of the surface vegetation and land cover found on Earth. By studying these surfaces it is possible to calculate how much energy will be absorbed by the Earth and how much will be reflected back into space. Knowing this information is critical to calculating Earth's overall energy balance.

In this activity you will use a world map of "global biomes" and "solar energy packets," represented by popcorn kernels, to explore and calculate the average yearly percentage of absorbed and reflected energy. Once you have calculated the present day average albedo, you will predict what will happen as the Earth's snow and ice cover decreases due to climate change.

Activity 1D- Earth's Albedo

Prepare

Activity Steps:

1. Use the map template on the next page. *Note: To save class time, maps can be prepared and printed ahead of time. (Color copies are best.)

2. Place completed map in photocopy paper box lid or similar container. The sides will keep the popcorn kernels from falling off the map.

3. Using the map legend, label the sections of an ice cube tray or egg carton with the different possible land surface types.

4. Place map and container on work surface.

5. Assemble a small plastic cup or shaker of 100 yellow pieces of popcorn to represent solar energy (in watts/ m2) Each kernel represents 1% of the total energy reaching Earth's surface.

Sprinkle the popcorn onto the map. (The goal of this is to distribute the kernels as randomly as possible.)

6. Count and collect the popcorn that lands on each surface type. Then place the kernels in the sorting tray (ice cube tray or egg carton). For kernels that land on more than one surface, choose the land surface that has the majority of the popcorn on it.

7. Count and record in the data table provided for this activity.

8. Return all popcorn kernels to the cup. (This will ensure that the Sun's initial energy remains the same in every round.)

9. Repeat steps 5- 8 three times. Record the results on your data table.

10. Average the number of kernels on each land surface type.

11. Multiply the average number of popcorn by the albedo factor as shown on the data table. Popcorn kernels that land on the map are "absorbed" by earth's surfaces.

12. Complete the calculations and compare how much of incoming solar radiation is absorbed by each type of surface.

Example world map and sorting tray.

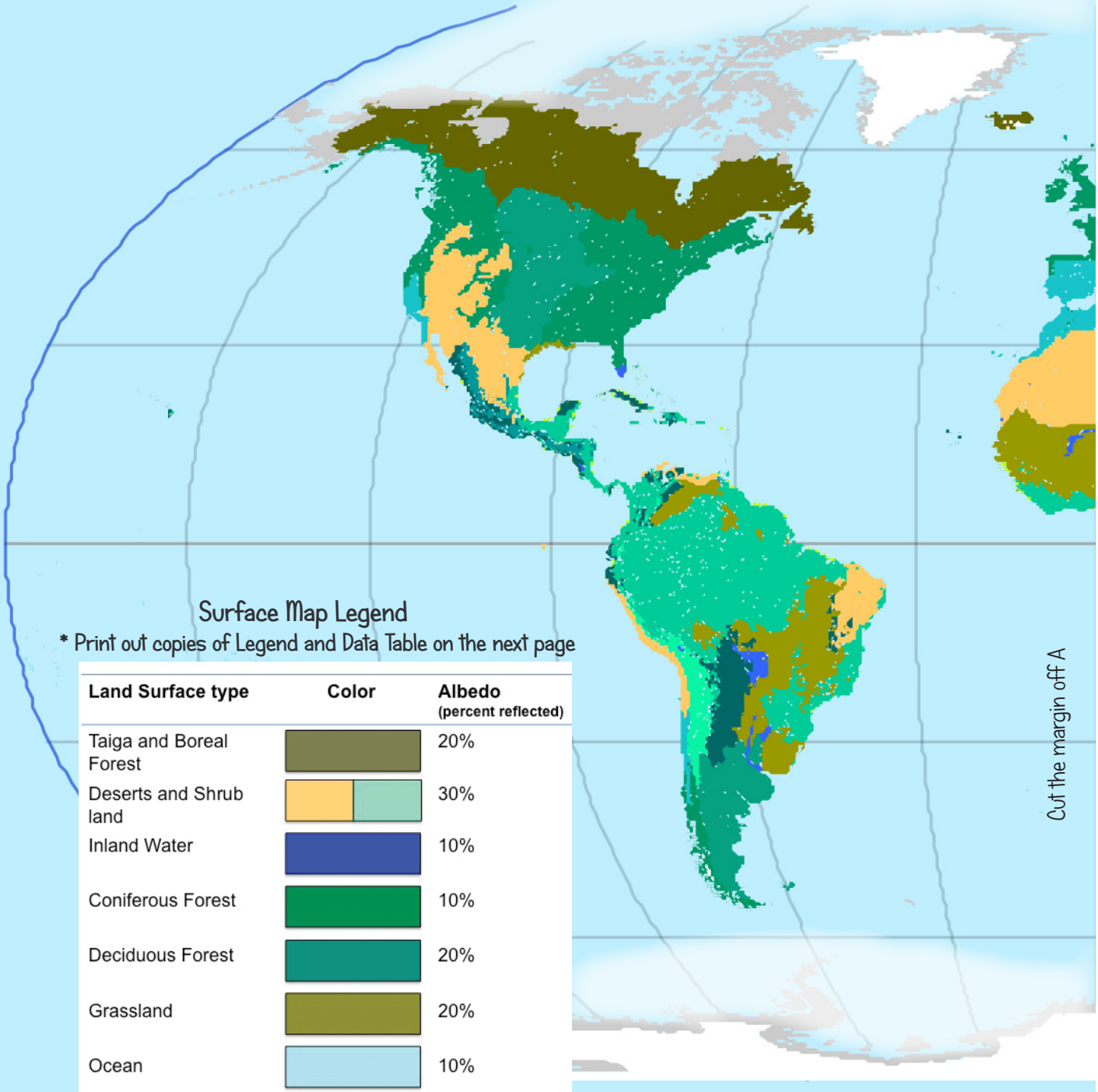
*Note, colored pompoms (found at hobby and craft stores) are shown in the photos, not popcorn kernels.

Extension: Repeat the activity using the map without snow and ice in the polar regions. How does Earth's albedo change with the loss of present-day ice? OR--Have half the class do the activity with the present day map, and half of the class do it with the map of snow and ice in the polar regions. Groups then discuss differences in their results and how the loss of present-day ice affects albedo.

Activity 1D-Earth's Albedo

Present Day Ice and Snow

A.



Surface Map Legend

* Print out copies of Legend and Data Table on the next page

Land Surface type	Color	Albedo (percent reflected)
Taiga and Boreal Forest		20%
Deserts and Shrub land		30%
Inland Water		10%
Coniferous Forest		10%
Deciduous Forest		20%
Grassland		20%
Ocean		10%
Tundra		20%
Ice and Snow		80%

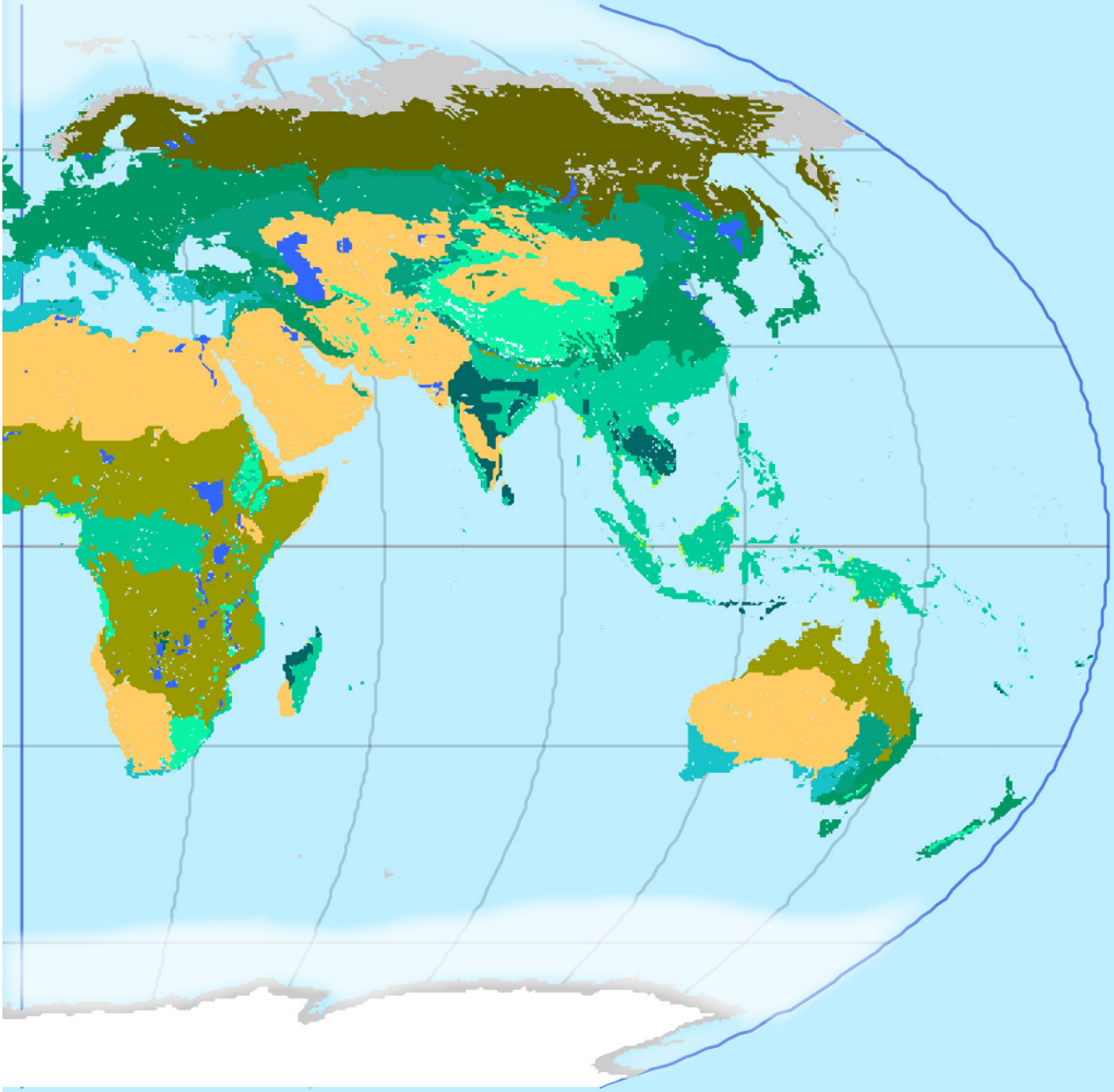
Use the legend provided as a guide when recording your kernels on ecah specific surface area.

Cut the margin off A

Make copies of this map and join the two pieces at the blue line cutting through Africa- you will need to overlap A over B and then fasten with tape.

Unit 1- ENERGY

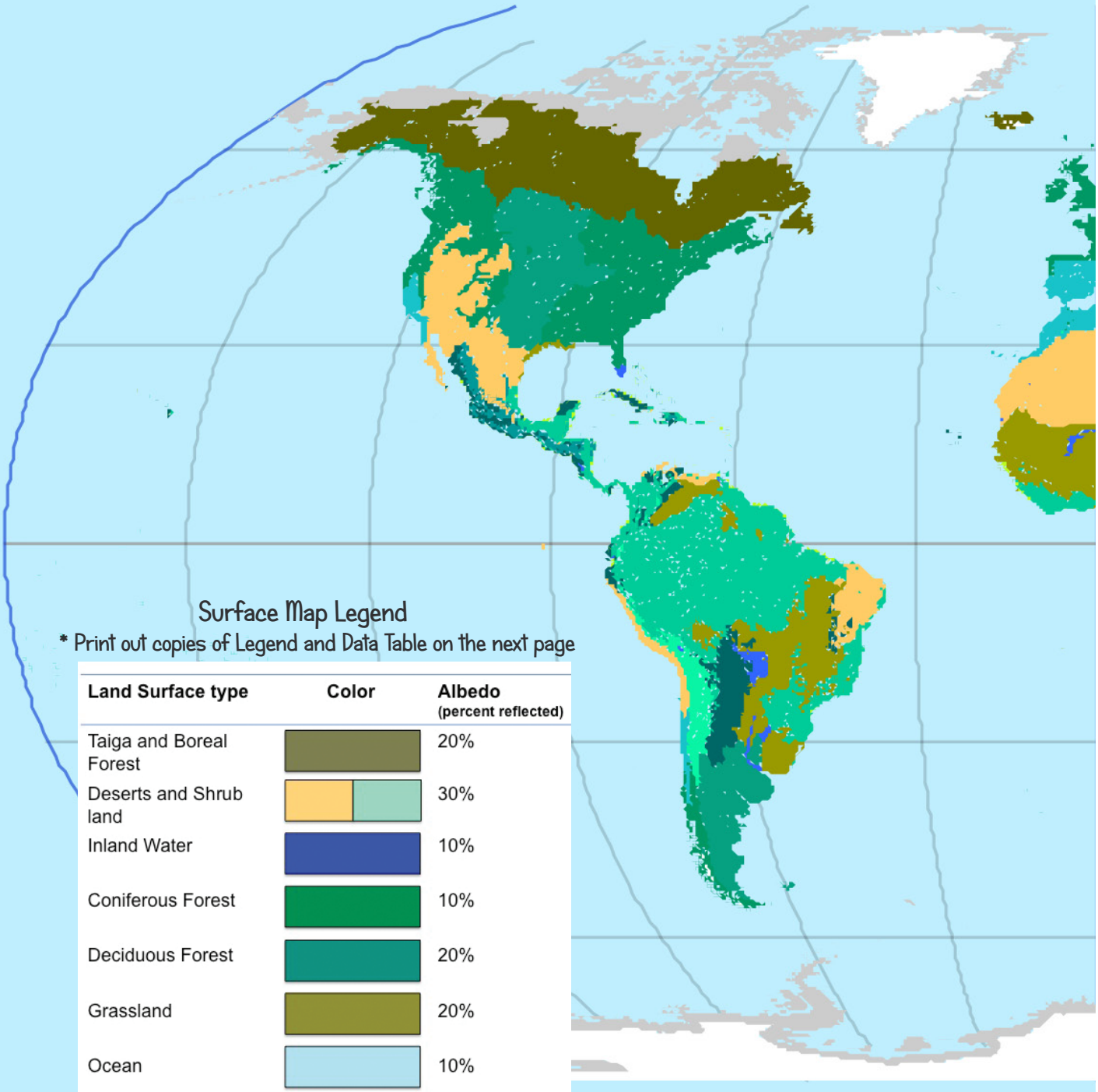
B.



Activity 1D- Earth's Albedo

Earth without Arctic Summer Sea Ice

A.



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Ice and Snow		80%

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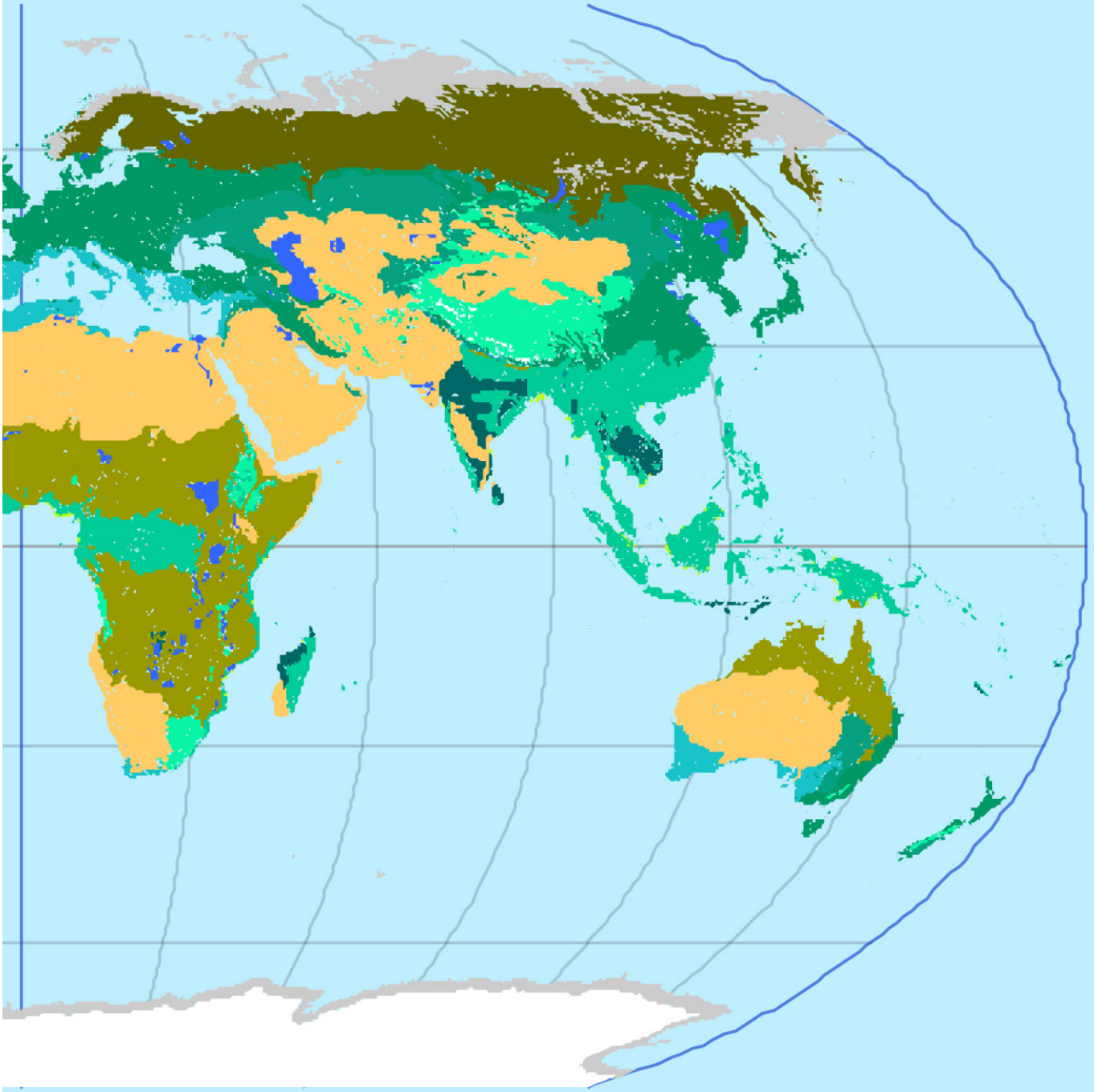
Unit 1- Energy

B.



Activity 1D-Earth's Albedo

Print out a copies for the Albedo activity

Earth's Albedo Data Table							
Land Surface Type	**Round 1**	**Round 2**	**Round 3**	**Average of 3 Rounds**	**Albedo** (Percentage Reflected)	**Reflected** (Average x Albedo)	**Absorbed** (Average – Number Reflected)
Taiga and Boreal Forest					0.20 (20%)		
Deserts and Shrubs					0.30 (30%)		
Inland Water					0.10 (10%)		
Coniferous Forest					0.10 (10%)		
Deciduous Forest					0.20 (20%)		
Grassland					0.20 (20%)		
Ocean					0.10 (10%)		
Tundra					0.20 (20%)		
Ice and Snow					0.80 (80%)		

Activity 1D-Earth's Albedo

Practice

Got the Big Idea?

Ponder

1. What land surface types reflect the most incoming radiation? What land surface types absorb the most incoming radiation?

2. How would the total amount of the Sun's radiation absorbed by the Earth change if all of the Tundra / Taiga was covered with snow as it is in the winter?

3. How would the total amount of the Sun's radiation absorbed by the Earth change if there were fewer forests and more deserts?

4. How will decreasing amounts of snow and ice change the amount of energy absorbed by the Earth's surface? How would this affect Earth's average temperature?

Present

Make several map set-ups with trays and popcorn to use with visitors at this station. Make one map representing the present and one the future, based on the predicted trend of decreasing ice and snow cover in the Northern Hemisphere.

Special preparations for this station

1. Have the maps ready and in box tops to contain the popcorn.

2. Have several cups of 100 popcorn kernels counted and ready.

3. Have ice cube trays labeled with land surface types.

4. Run off data sheets, or make a large poster-sized data table to collect data from many visitors in one place.

Activity 1D-Earth's Albedo

Background Information for the Teacher

Activity	NSES 5-8	CLEP	ELF
In this hands-on activity, learners develop a model to illustrate the relationship between the albedo of various surfaces and the energy balance of the Earth. They propose how the albedo of these surfaces affects climate patterns around the world. **NSES 5-8** **Physical Science Std B:** Energy is transferred in many ways. Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature. Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). The sun is a major source of energy for changes on the earth's surface. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.	**Earth Science Std D:** Clouds, formed by the condensation of water vapor, affect weather and climate. The sun is the major source of energy for phenomena on the earth's surface, such as growth of plants, winds, ocean currents, and the water cycle. Seasons result from variations in the amount of the sun's energy hitting the surface, due to the tilt of the earth's rotation on its axis and the length of the day. **History and Nature of Science Std G:** Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.	**1A:** Sunlight reaching the Earth can heat the land, ocean, and atmosphere. Some of that sunlight is reflected back to space by the surface, clouds, or ice. Much of the sunlight that reaches Earth is absorbed and warms the planet. **1B:** When Earth emits the same amount of energy as it absorbs, its energy budget is in balance, and its average temperature remains stable. **2B:** Covering 70% of Earth's surface, the ocean exerts a major control on climate by dominating Earth's energy and water cycles. It has the capacity to absorb large amounts of solar energy.	**Energy 1:** Solar energy is the driving force for Earth's climate system. **Energy 1c:** Unequal heating of Earth's surface by the Sun causes movement in the atmosphere and ocean, giving rise to circulation patterns in these systems that play an important role in global climate. **Hydrosphere 4b:** Ice and snow reflect as much as 90% of the solar radiation that falls upon them, helping to maintain cooler global temperatures. When ice and snow melt, less solar radiation is reflected by the land or water surface, thus allowing the Earth to warm.

NSES: National Science Education Standards (http://www.csun.edu/science/ref/curriculum/reforms/nses/index.html)
CLEP: Climate Literacy Essential Principles (http://www.climatescience.gov/Library/Literacy/)
ELF: Environmental Literacy Framework (www.andrill.org/education/elf)

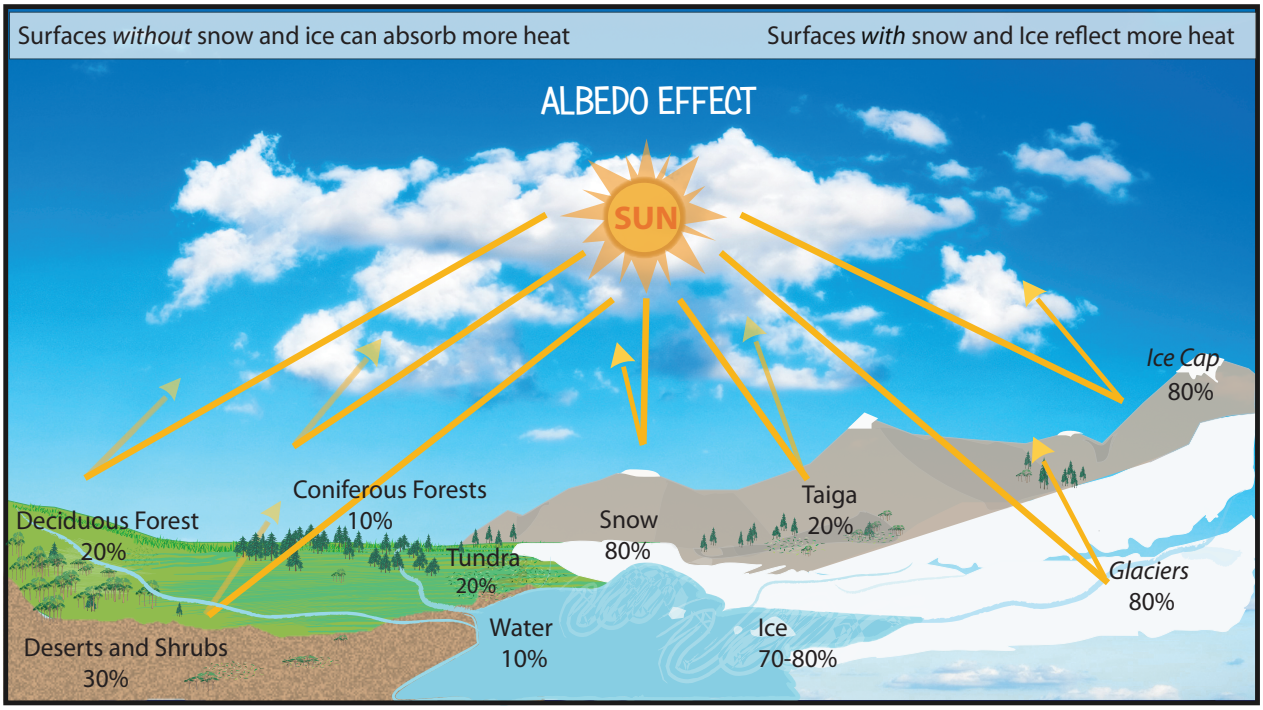
Activity 1D-Earth's Albedo

Background Information for the Teacher

A continuous stream of sunlight bathes Earth's surface. This sunlight provides the energy needed to warm Earth and its atmosphere to a habitable temperature, support life, power our weather, and drive ocean currents.

An average of 342 w/m^2 of solar radiation reaches the top of Earth's atmosphere. Approximately 30% of the incoming radiation is reflected by the atmosphere back into space, without altering weather or climate. The remaining 70% is absorbed by the atmosphere (20%) and Earth's surfaces (50%). Some surfaces are more reflective than others. The fraction or percent of radiation that a surface reflects is known as its albedo. Albedo is derived from the Latin word "albus" for white. The range for albedo on Earth can be as little as 3% for water (when the sun is directly overhead) and as high as 95% for fresh snow cover.

Albedo is important because the reflection of a portion of the incoming radiation helps to keep the planet in energy equilibrium. For example, if the Earth were completely covered in highly reflective materials like ice and snow, whose albedo are 80-90%, the surface would be much more reflective. If this were the case, the average surface temperature on Earth would be much colder. Conversely, if Earth were covered in dark-colored, light-absorbing materials such as dark coniferous forests, pavement or open water, it would absorb more incoming energy and be warmer.



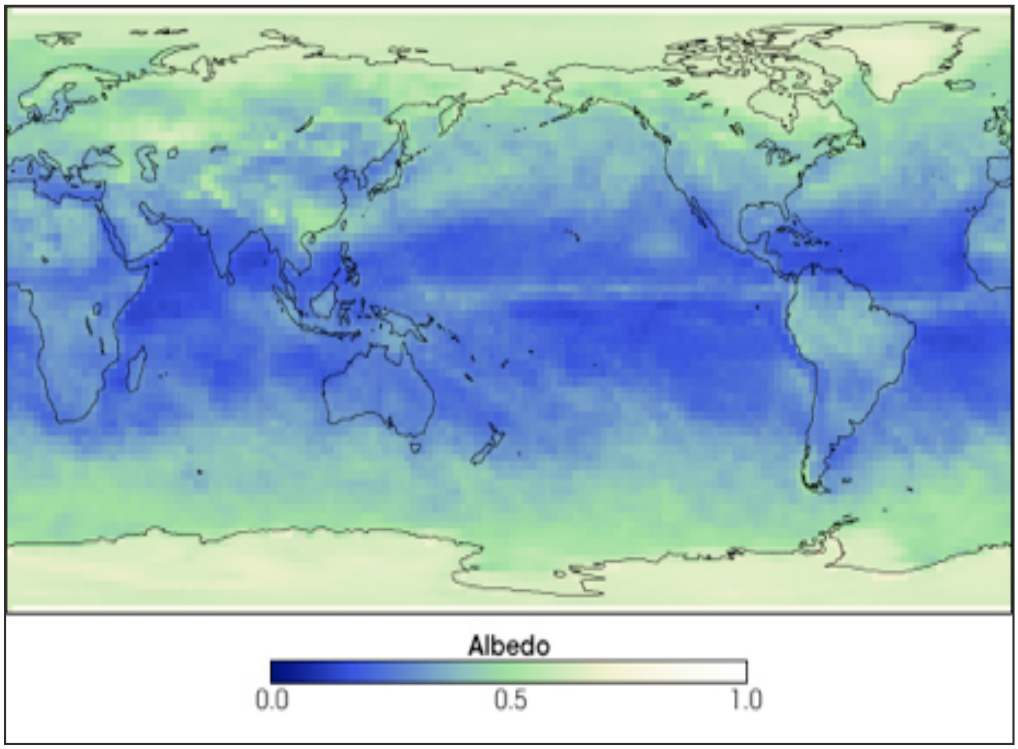
Different surfaces reflect different amounts of energy from the Sun. Light areas (snow and ice) reflect more energy back into space. Dark areas (grass, water, trees etc.) reflect less energy.

Graphic: Rita Thomas, ANDRILL-University of Nebraska

Activity 1D-Earth's Albedo

The image below shows Earth's average albedo for March 2005. Note the high albedo over the Northern hemispehre. This is due to snow and ice cover.

The scale in this graphic is given as a decimal; to convert it to percentage, multiply by 100. Perfectly white areas have an albedo of 1 while perfectly black areas would have an albedo of 0.



Over the past several decades, climate change has caused the winter snow to melt earlier in the season and has increased the snow-free period in the Arctic regions. As the snow-free seasons are longer, there is also a longer period when the exposed land cover type has a low albedo. This change may significantly alter the overall planetary albedo, causing even further warming. This is an example of a "positive feedback" cycle.

Resources:

http://www.eoearth.org/article/Albedo?topic=54300

Climate Studies: Introduction to Climate Science, American Meteorological Society 2010.

Earth Observatory Article 'By Reflecting Sunlight, Greenland Helps Keep the Arctic Cool' http://earthobservatory.nasa.gov/IOTD/view.php?id=40932

Project Learn – learning module Cycles of Earth and Atmosphere www.ucar.edu/learn

Glossary

Unit	Activity	Vocabulary Word	Definition
Energy	Earth's Albedo	Absorb	Enter a body. (E.g., radiation from the Sun is absorbed by the surface of the Earth, water or the atmosphere.)
Energy	Earth's Albedo	Albedo	Ratio of radiation reflected from a surface compared to the total incoming radiation, usually expressed as a percent (E.g., complete reflection from a white surface = 1, or 100%, while no reflection from a black surface = 0, or 0%.)
Energy	Earth's Albedo	Energy	An indirectly observed quantity, it is usually defined as the ability to do work. Energy can be stored or transferred and like mass is considered to be conserved.
Energy	Earth's Albedo	Insolation	The amount of solar radiation received by the Earth in a given area in a given time usually expressed as watts per square meter, W/m^2
Energy	Earth's Albedo	Land Use	Human modification and management of land, such as agriculture, homes or other development
Energy	Earth's Albedo	Radiation	Energy emitted in waves and rays by the Sun. About half of the energy is in the visible short-wave part of the electromagnetic spectrum. The other half is mostly in the near-infrared part, with some in the ultraviolet part of the spectrum
Energy	Earth's Albedo	Reflect	Change the direction of waves (commonly water, sound and light) as they interact with a substance