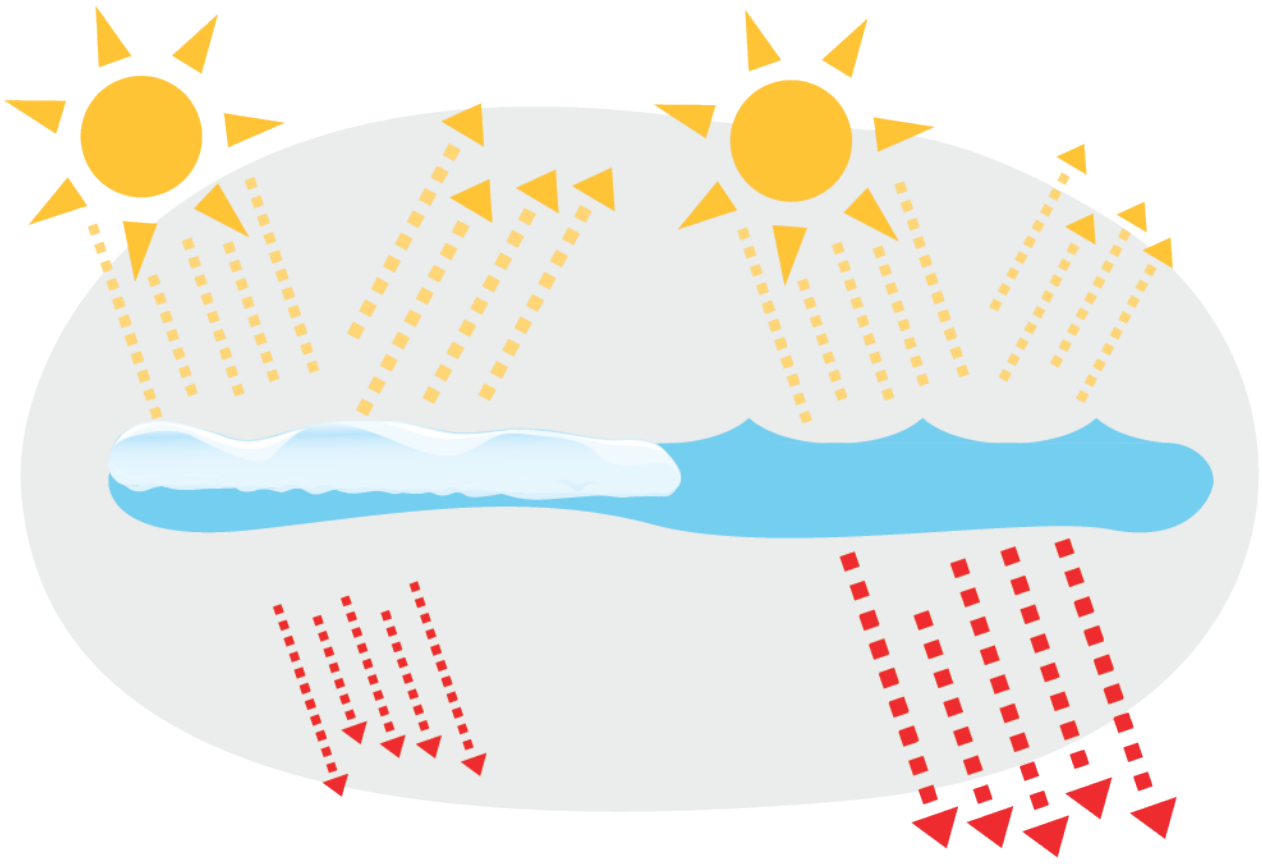
Government of
Northwest Territories

LESSON # 4:

Reflecting on Reflectivity



INTRODUCTION

Experiential Science provides an avenue for students to conduct real world first-hand scientific investigations. With an activity emphasis on Science, Technology, Engineering and Mathematics (STEM) the planning, construction and testing of the Albedo reflectivity apparatus gives students the opportunity to design and construct a working piece of scientific equipment using simple materials while integrating smartphone technology.

Students plan, construct and test a simple albedo testing apparatus to measure the relative reflectivity (albedo) of different surfaces, including ice, snow, soil (light to dark), rock surfaces, water, man-made surfaces and vegetation. They will use the data collected from their test apparatus to determine the relative reflectivity of surface and interpret their findings to consider the implications of changing albedo on the polar environment, the connection with climate change and possible mitigation strategies to bolster albedo.

The Albedo measuring apparatus that students design can be used to gain insight into the effects of albedo on terrestrial, marine and freshwater systems. Once constructed this apparatus can be used to determine the reflective index (lux) of different natural and man-made surfaces. The information gained from these experiments can provide students with the evidence to support their conjectures about the effects of changing albedo on climate change and offer potential mitigation strategies.

As students work through Experiential Science 10, Unit 2: Climatology and Meteorology, Experiential Science 20. Unit 1: Introduction to Oceanography and Experiential Science 30 Unit 2 Introduction to Limnology they can use their Albedo Apparatus to measure the lux of different surfaces. This will provide students with first hand data as well as an opportunity to integrate Traditional Ecological Knowledge to support their understanding of albedo and its effects on northern climate change and heritage practice as well as inform possible mitigation strategies.

LESSON PLAN #4 : REFLECTING ON REFLECTIVITY

Author: Brent Urie, Nunavut

GOAL

Students will construct and use their Albedo apparatus to measure the lux and evaluate the relative reflectivity (albedo) of various surfaces under different conditions to demonstrate, record and make conjectures about their findings for potential impacts on northern environment due to climate change. As an extension they can use this information to propose possible mitigation strategies to reduce the positive albedo feedback loop.

KEYWORD SEARCH

Albedo, Planetary Heat Budget, Arctic Climate Change, thermodynamics albedo, human influences albedo, Albedo mitigation strategies

CURRICULUM MAP

Experiential Science 10, Unit 2, Climate and Climatology
General Learning Outcome:

- Students will investigate the natural cyclical nature of climate change, the human factors and technologies that allow scientists to study and make predictions about climate change.

Specific Learning Outcomes:

- Students will gain an understanding of climate change and climatology by: Investigating, Ice – Albedo feedback mechanisms and its effects on the atmosphere.

Experiential Science 20, Unit 1, Introduction to Oceanography
General Learning Outcomes:

- Students will investigate the marine currents and ocean dynamics.

Specific Learning Outcome:

- Students will gain an understanding of Arctic Ocean dynamics by:
- Describing and demonstrating the albedo effect using simple field or laboratory models to illustrate the qualitative reflective index and heat absorption capacity of representative surfaces, such as: barren land, open water, ice / snow covered surfaces.

Experiential Science 30, Unit 2 Introduction to Limnology
General Learning Outcomes:

- Students will investigate the characteristics of freshwater ecosystems and catchments.

Specific Learning Outcome

- Investigating the effects of climate change on aquatic systems.

Associated Curricular Connections:

- Language Arts: public speaking, presentation skills, technical writing, literature research and social media
- Social Studies & Northern Studies: Citizenship, Traditional Knowledge, self efficacy, networking, using social media and team work

Time

Two to Four Class periods: (construction and testing time 1-2 hours)

Materials And Methods

Materials:

Albedo Apparatus:
Cardboard / boxes, black construction paper (low gloss), Smart Phone LUX app (downloadable android / iPhone), light source (flashlight), hot glue, scissors, box cutter knife, water tight sample tray to fit inside box and ruler.

Test Surfaces:
Freshwater ice (with and without snow cover), snow, light and dark soils, rocks, sand, vegetation (lichens, mosses, grasses), salt water ice, Man-made surfaces (roofing shingles, asphalt), etc.

Method:

1. The basic construction of the Albedo reflectivity apparatus consists of a small light-tight cardboard box with a lid, similar to a shoebox.

2. The interior of the box is securely lined with black construction paper to provide a uniform non-reflective interior.

3. To allow for the light source and lux sensor, two appropriate size holes are cut on opposite ends of the lid. The first hole is the diameter of the flashlight light source and the second is just large enough for the camera sensor of the smartphone. This will give a consistent light source and angle of incidence for the light to reflect off the test surface and reflect onto the sensor of the smartphone. Note: The protractor can be used to help determine the position of the holes in the lid. DETAILS NEEDED

4. The smartphone Lux meter app (downloadable for android / iPhone) will give a measure of lux that can be record for each surface tested. Follow the app procedures for collecting data. Practice experimenting with the light source to make sure the angle of incidence and reflection are optimal for the light sensor. It is important to test and retest the sensor with a known surface (blank white paper) to act as a control prior to using samples.

5. Once constructed this devise can be used to measure and collect first hand data on the relative reflective index, Lux, of various surfaces and materials. This data can organized into tables and used to make conjecture about the effects of albedo as it extends to climate change.

6. Choose the samples to test by place samples in a waterproof tray on the inside bottom of the apparatus and close the lid. The light source can then be focused on the sample and the sensor on the smartphone can measure the reflected light. Note: a protractor can be used to assist with the alignment process.

7. Record the results of each sample in a notebook and present the results using a table.

8. After collecting the data from various samples compare your results with others in the class.

9. Explain each finding as it relates to the potential impact changing albedo would have on the arctic terrestrial, marine and freshwater environments.

10. Make a list of "what if" questions you would like the data to answer, i.e. What if we made all roof surfaces white?

Inquiry Questions

- As a class develop questions that you would pose to help mitigate loss of albedo in an arctic environment?
- What mitigation strategies could be employed to reduce the positive feedback loop of climate change in the polar regions?

Sharing The Message

Students can share their data and conclusions with classmate on social media (closed), to practice presentation, key messaging and debate skills.

Enrichment Activities/Fast Finishers

As a class discuss your finding and look at possible mitigation strategies that could be used to reduce the impact of changing albedo as it relates to climate change. It is important to allow students to engage creative thinking strategies and give all students an equal opportunity to voice their opinions and thoughts. Encourage students to think low cost, low tech practical applications as well as high tech solutions.

Student Handouts

- Backgrounder #1: Climate Change: What's the Big Idea?
- Backgrounder #2: The Green House Effect
- Backgrounder #7: The Changing World of Water and Ice
- Lesson #4 What is Albedo? Reading and worksheet
- Albedo Quiz

Evaluation

Evaluation will be formative in nature, there is a potential for students to discuss their Albedo mitigation strategies with a think pair share exercise entered around the inquiry questions found in the What is Albedo Student Handout. See also the Albedo Quiz as another form of evaluation.

Name:_____

ALBEDO QUIZ

1. Organize the following surfaces from **MOST REFLECTIVE** to **LEAST REFLECTIVE** *(5 pts.)*

Most Reflective

- Fresh snow
- Cloud Cover
- Crops
-Tundra
- Soil, Wet

Lease reflective

Crop Cover
Fresh Snow
Soil (wet)
Cloud Cover
Tundra

2. Draw a diagram illustrating the albedo effect. Points will be given for each element that is correctly labeled and depicted *(5 pts.)*

Name 3 Human Factors that affect the earth's Albedo

1. Poor Agricultural practices
2. Airborne Pollutants making it harder for light to be reflected back into space
3. Climate change leading to less reflective snow and ice at the poles

Name:_____ **Date:**_____

WHAT IS ALBEDO?

Albedo is the ratio of incoming solar energy (shortwave length) reflected from the earth back into space. The concept of albedo allows scientists to quantify the reflectivity of surfaces both on a planetary scale as well as specific types of surfaces (land, water, vegetation, man-made surfaces) on a planet.

Reflective surfaces such as snow, ice and low-level clouds reflect most of the light energy they receive from the sun back into space. However, features such as liquid water, land and high-altitude clouds and aerosols will reflect less energy back into space and instead absorb this energy and retain the energy as heat causes the climate to warm. Therefore, changes in the atmospheric chemistry (water vapour and aerosols) in the lower and upper atmosphere can alter the amount of incoming solar radiation reaching the surface of the earth and or being reflected back into space.

The balance of incoming and outgoing radiation will determine the level of heating or cooling of a planet and ultimately the climate. Scientists study the reflective properties of substances, on the ground as well as using space borne satellites to better understand the effect of these substances on a planets climate.

Planetary albedo is the ratio between incoming and reflected radiation from the upper atmosphere and surface albedo of a planet. This allows scientists to study the reflective properties (light spectrum) of the earth and other planets to determine the chemical composition of the atmosphere and or its surface to better understand its climate.

SURFACE ALBEDO

Surface albedo uses the same principles as planetary albedo as it is the ratio of incoming to reflected radiation, but deals more with the reflective properties of the Earth's surface. The surface albedo is determined by many factors, the wavelength of light, the physical and chemical properties of the reflective surface, the angle of incidence and intensity of the radiation. For example, the reflective properties of a specific types of soil will vary due to moisture content, particle size, organic matter content, surface roughness, mineral composition, time of year and latitude (angles of the sun). Similarly, the reflective properties of vegetation would vary based on the type of plant, leaf size, ground cover, stage of growth, latitude (angle and duration of sunlight) and time of year (seasons). These properties can be extended to other substances as well, such as snow, where its reflectivity varies depending on the crystal size of the snow, its age, compactness, chemical substances dissolved in the ice crystals etc.

Think about the reflective properties of liquid water, scientists have to interpret what they are seeing and what the clues are telling them based on the time of year, location of the water body, its depth, turbidity and concentration of aquatic plants and animals living in the water.

Changes in Albedo

Albedo can vary within and between geographical regions, seasons, latitude and altitude as the reflective properties of the surface change over the short term (season) or longer term (climate change). The seasonal changes in the incoming angle of the sun creates temperature differences between the equatorial tropic and north and south poles which drive the atmospheric wind and oceanic currents as heat energy is transferred between the equator and poles.

Changes in cloud formations, duration, moisture content, chemical composition and height in the atmosphere affect the reflection and absorption of solar energy. When changes happen to the surface albedo it can drastically alter climate on a regional and global scale as the Earths heat budget is altered. We experience this first hand living north of 60o latitude as the angle of the sun between seasons create a seasonal imbalance in the energy we receive from the sun. For example, in the summer there can be 24 hours of daylight while in the winter there may be one, which creates an energy imbalance during the season.

Reflectivity of Clouds

Cloud Type	Percent Radiation Reflected
Cumuliform	70-90%
Stratus (150-350m thick)	59-84%
Altostratus	38-59%
Cirrostratus	44-50%

Source: Albedo wiki

The interpretation of this data can be complex, but scientists use the scientific method to isolate variable to better understand in the impact changes in the environment can make to an environmental system and the climate.

Look at the following Latitude Percent Reflection data and provide possible explanations for the differences that you see between summer and winter at the various latitudes. What does this tell you about the energy budget and the absorption of energy by the water at the different latitudes?

Latitude Percent Radiation Reflection

Winter	Percent Radiation Reflection
0° latitude	6%
30° latitude	9%
60° latitude	21%
Summer	**Percent Radiation Reflection**
0° latitude	6%
30° latitude	6%
60° latitude	7%

Source: Albedo wiki

Make a statement about the changes in reflectivity between summer and winter at 60° Latitude.

Why do we see so much more reflectivity in the winter vs the summer?

The following data represents generalizations of land conditions and soil types. In your groups, beside each of the topics try and explain some of the variable that would affect the reflective properties of the substance. Conduct research on the Internet to find the reflective properties of other substances that may be specific to your community and add this to the table.

Surface Radiation Reflection

Surface Feature	Percent Radiation Reflection	Explanation
Snow, fresh-fallen	75-95%	
Snow, several days old	40-70%	
Sea Ice	30-40%	
Sand dunes, dry	35-45%	
Sand dunes, wet	20-30%	
Soil, dark	5-15%	
Soil, moist grey	10-20%	
Soil, dry clay or gray	20-35%	
Soil, dry light sand	25-45%	
Concrete, dry	17-27%	
Road, asphalt	5-10%	
Desert, sand	25-30%	
Savanna, dry season	25-30%	
Savanna, wet season	15-20%	
Meadows, green	10-20%	
Forest, deciduous	10-20%	
Forest, coniferous	5-15%	
Tundra, summer	15-20%	
Crops	15-25%	

BASED ON THE REFLECTIVITY SEEN IN THE PREVIOUS TABLE, PREDICT THE REFLECTIVITY OF THESE FEATURES.		
Surface Feature	**Percent Radiation Reflection**	**Explanation**
Rooftops?		
Roadways?		
Lakes?		

Source: Albedo wiki

Albedo varies with latitude, altitude, and the season's base on the angle of the sun and the reflection of surface features. The circulation of global wind and water currents move heat and moisture from the tropics to the poles. This, along with the season variation of the angle of the sun causes the changes in the regional albedo due to the state of vegetation, open water, ice and snow. These variables work together to create the planets energy budget and feedback loops.

Changes to regional albedo can cause a positive feedback loop were more energy is absorbed vs. reflected back into space, thereby causing a region to experience more solar energy absorption and more rapid climate warming. For example, the Polar Regions are more susceptible to climate change because during the summer months, 24 hours of daylight allows for more energy to be absorbed per unit time as ice and snow cover decreases. The decrease in the period of snow and ice cover means lower albedo, warmer conditions and shorter winters which affects the normal cycle of marine and terrestrial systems. This is contrasted by equatorial regions, which have a more constant solar input and albedo throughout the year. Ask Elders, how the climate has changed over their life time and how this has affected their cultural heritage, for such practices as hunting and traveling on the on the land.

HUMAN FACTORS ON THE EARTH'S ALBEDO

Scientists have been monitoring climate change for quite some time and suggest that human activities have been altering the planet's albedo on a global scale. In recent years the rates and magnitude of desertification, droughts, floods, and extreme weather events can be mapped back to human activity. Human actions such as deforestation, poor agricultural practices, greenhouse gas emissions and other airborne pollutants have affected the planets albedo thereby changing the Earth's energy budget. With a decrease in planetary albedo a positive feedback loop is established as the rate of energy absorption is greater than energy loss due to reflection thereby causing the planet to get warmer especially at the poles. This not only affects the large-scale ecology and weather of a region but human infrastructure, cultural practices and ways of life. Today, new branches of science are investigating how humans can change their practices to mitigate the effects of decreasing planetary albedo.

INQUIRY QUESTIONS:

1. As a class develop questions that you would pose to help mitigate loss of albedo in an arctic environment?

2. What mitigation strategies could be employed to reduce the positive feedback loop of climate change in the polar regions?