Part C: Exploring the Arctic - Teacher Guide

Setting the Stage

Students conduct hands-on experiments measuring albedo, relative humidity, and soil temperature using simple techniques. In the jigsaw activity, students analyze the collected data in teams and discuss the provided questions. Then, students research and identify scientific instruments at the Eureka Arctic meteorological tower.

Photo Credit: NOAA; Arctic Atmospheric Observatory in Utqiagvik (formerly Barrow)

Lesson Overview

In this lesson sequence, students will collect meteorological data, measuring albedo, relative humidity and temperature.

- ***Data Collection 1*** *– (30 minutes) Albedo*
  Students will use lightmeters to measure and calculate the albedo of different surfaces by comparing incoming and reflected light.
- ***Data Collection 2*** *– (40 minutes) Relative Humidity*
  Students will create a sling hygrometer to measure relative humidity by comparing the temperatures of a dry bulb and a wet bulb thermometer.
- ***Data Collection 3*** *– (40 minutes) Soil Temperature*
  Students will measure soil temperature at different depths and air temperature at various sites to analyze how soil properties and vegetation affect temperature.
- ***Lesson 1*** *– (30 minutes) Thinking Deeper*
  Students will analyze and compare data on albedo, relative humidity, and soil temperature in expert teams to identify patterns and relationships.
- ***Lesson 2*** *– (40 minutes) Eureka Tower*
  Students will research and analyze the instruments used to collect meteorological data at the Eureka flux tower and compare them to their own measurements.

- ***Extension*** *– (70 minutes) Using Smartphone App to Measure Albedo*
  Students will learn how to use digital image processing to measure and analyze albedo.

This project is funded by NSF, Award number 1107428

Instructional Overview	
Grade Level	Middle/High School
Instructional Time	170 minutes *(total time needed plus extension)*
Activity 1 Goals	• Define what the Arctic is • Describe the Arctic environment and life of Indigenous peoples • Describe how feedback loops work, specifically the effect of albedo
Lesson Driving Question	• How do you describe and measure albedo, relative humidity, and soil temperature? • How do you evaluate the collected data for these measurements? • What instruments are used for meteorological observations?
Building Toward	NGSS: ESS2D, LS2C
Three Dimensions	Science and Engineering Practices: • Planning and Carrying Out Investigations • Analyzing and Interpreting Data • Using Mathematics and Computational Thinking Disciplinary Core Ideas: • Earth's Systems Crosscutting Concepts: • Energy and Matter: Flows Cycles & Conservation

Materials	❏ Student Jigsaw Worksheet
	❏ Student Worksheet
	❏ *Albedo Materials:*
	  ❏ 1-3 light meters ($22, for example here)
	❏ *Relative Humidity Materials:*
	  ❏ 2-4 red bulb glass thermometers
	  ❏ wet cloth
	  ❏ cardboard squares, rubber bands
	❏ *Soil Temperature Materials:*
	  ❏ 2-4 soil thermometers
	  ❏ Nail or spike, hammer for pilot hole

Material Preparation	❏ Set up stations outside for three activities
Vocabulary	Albedo is a measure of how much light a surface reflects, with 0 representing no reflection (black) and 1 representing total reflection (white), and it refers to the fraction of sunlight or radiation that is diffusely reflected by a surface.

Instructional Strategies	• The hands-on experiments should be done in groups of no more than four students because the report-out will be done in a jigsaw format. Assign a role to each student to increase accountability, e.g., 1) set up, 2) note taker, 3) measurements, 4) results • An excellent reference on teaching with the jigsaw method (here) • The last part of the activity (Eureka flux tower) encourages students to think about how scientists know what they know. This can also be completed as a homework assignment.

In this Jigsaw activity, students will collect meteorological data, measuring albedo, relative humidity, and temperature, and then compare their collected data..

Jigsaw Data Collection 1: Albedo (modified from EarthLabs) *(30 minutes)*

How does surface material affect albedo and solar radiation reflection?

Background:
Albedo is a measure of reflectivity. It is the ratio of the incoming solar radiation (or shortwave radiation) reflected by a surface to the total incoming solar radiation. Albedo can either be expressed in a ratio (dimensionless number) or as a percentage. The higher the value, the more energy is reflected back to the source. Complete reflection is 1 or 100%, and complete absorption is 0. Surfaces that have a low albedo, such as rocks or water, are dark colored and will absorb more incoming solar radiation. High albedo surfaces are light, such as snow, ice, or sand, and reflect most of the incoming solar radiation back into the atmosphere. Incoming solar radiation is measured in Watt/m^2, and the instrument that is used for the measurement is called a **pyranometer.**

Since pyranometers are very expensive, the following experiment will be done with lightmeters. Lightmeters provide a measure of the light intensity (measured in the unit, **lux**), a good approximation of solar radiation. Photo credit: Amazon

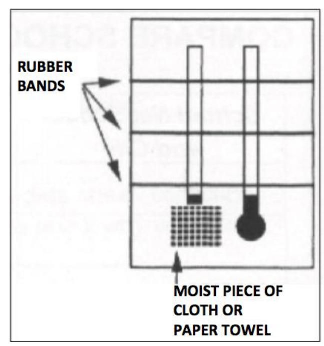
Procedure:
At this station, you will measure the albedo of different surfaces such as grass, sand, dirt, asphalt, snow, or concrete. At each site, you will measure light intensity of your light source and different surfaces with a lightmeter and calculate the albedo for each material.

1) Point the lightmeter directly at the incoming light source (sun or lamp). Avoid measurements if a shadow covers the lightmeter.
2) Record the incoming illuminance on your data sheet.
3) Point the lightmeter directly at the surface that you want to measure.
4) Record the reflected illuminance on your data sheet.
5) Calculate the albedo for the surface by determining the ratio of the outgoing illuminance over the incoming illuminance.
6) Conduct measurements for other surface types. Ensure that you measure the incoming versus reflected illuminance in a short time period.

Jigsaw Data Collection 2: Relative Humidity (modified from Science Giants – Earth and Space): *(40 minutes)*

How does temperature affect relative humidity?

Background:
Relative humidity measures the amount of water vapor that is currently in the air compared to how much water vapor the air can hold at that temperature. Relative humidity can be defined as: Relative humidity % = (Moisture in the air now / Maximum possible moisture air can hold at the current temperature) x 100 The amount of water vapor air can hold is dependent on the air temperature. Warm air can hold more moisture than cold air, so the relative humidity of air is higher on a warm, cloudy day than on a clear, cold day. The relative humidity is stated as a percent. If the relative humidity is 50%, this means that the air contains half of the water vapor that it can hold at that temperature.



Procedure:
At this station, you will create a sling hygrometer to measure relative humidity.

1) Lay two thermometers side by side on a piece of cardboard. Use rubber bands to hold them in place (see image).

2) Wrap the bulb of one thermometer with a moistened piece of cloth or paper towel (=wet bulb thermometer) and keep it moist.

3) Read and record the temperature of the dry bulb and the wet bulb. The dry bulb thermometer simply measures the air temperature.

4) Carefully fan the cardboard with the two thermometers in the air for about 30 seconds or until the wet bulb temperature stops falling and remains constant.

5) Record the temperatures for both thermometers on the worksheet and calculate the difference between the temperatures [dry bulb temperature – wet bulb temperature].

6) On the Relative Humidity chart, find the dry bulb temperature that you measured on the y-axis and the difference between the two measured temperatures on the x-axis. The relative humidity is given as a percentage where the corresponding rows meet.

Jigsaw Data Collection 3: Soil Temperature (modified from GLOBE Soil Temperature Protocol): *(40minutes)*

How does temperature affect relative humidity?

Background:
Soils are a mixture of weathered bedrock or other local rock material ("parent material") and organic matter. The temperature of soil fluctuates over the day and over the year and is affected mainly by variations in air temperature and solar radiation. The water content of the soil plays an important role in the temperature exchange between air and soil temperature since higher water content in the soil increases the thermal conductivity of the soil. A temperature gradient exists if the air and soil temperature are different, and heat will be transferred to reduce the temperature gradient. Soil surface temperatures are usually closer to the air temperature, while deeper soil layers are usually delayed in displaying any changes in air temperature. Thus, soil temperature varies with depth below ground. The degree of shading by plants and trees, as well as a snow cover, affects the temperature profile in the ground due to insolation properties (**insolation = incoming solar radiation**).

The Plan:
At this station, you measure soil temperature by placing the thermometer in the ground at different depths and carefully measuring the temperature. Air temperature measurements will also be conducted at this station.

1. Choose two different sampling sites that appear to have different soil properties (sandy versus clay or different vegetation cover) for each student group conducting a measurement. Note the density of soil and the vegetation cover

2. Measure the air temperature about 30 cm (one foot) above the ground using a thermometer or temperature probe. Make sure not to measure in direct sunlight since that will cause an erroneously high measurement. Record the temperature.

3. Make two pilot holes at each site that have the approximate diameter of your thermometers (by using for example a thick nail and a hammer or a hand-drill). The pilot holes should be about 5 cm (2 inches) deep. Try to disturb the soil as little as possible when pulling out the nail or drill. Twisting as you pull out may help. If the soil cracks or bulges, choose another site and drill new holes.

4. Measure 5 cm (2 inches) from the temperature sensor (not the tip–the sensor is often located about 2 cm above the tip) and mark the two thermometers (this will be the depth to which the thermometers are being inserted in the ground).

5. Gently push the thermometers into the soil down to the mark that you made on the thermometer shaft. Put on safety equipment such as gloves and goggles if working with glass thermometers. Be careful to not break the glass of the thermometer when pushing it in the soil to avoid injuries to your hands. You are measuring the soil temperature at 5 cm depth. Wait 2 minutes. Record the temperature for each thermometer on the worksheet as the 5 cm reading. Remove the thermometers from the holes.

6. Now deepen both holes to 10 cm (4 inches) using the thick nail or spike. Measure 10 cm (4 inches) from the temperature sensor and mark the thermometer shaft.

7. Insert the thermometer in the same hole and gently push it down until the mark on the thermometer shaft is level with the surface, indicating that the temperature sensor is 10 cm below the surface. Wait 2 minutes and record the temperature.

8. Calculate the average of the two measurements for 5 cm depth and 10 cm depth below ground.

9. Compare the measurements from different sites.

How hot is it today? Air temperature is not the only factor that we need to consider when talking about the perceived heat of a day; we also have to take into account the relative humidity. A 100°F day in Montgomery, Alabama, feels much hotter than in Tucson, Arizona, because of the higher relative humidity in Alabama. The human body cannot cool itself as effectively due to the high humidity, causing heat-related issues such as heat stroke. This effect is measured in the so-called Heat Index. You can calculate the Heat Index by using the NOAA Heat Index Calculator http://www.wpc.ncep.noaa.gov/html/heatindex.shtml.

Lesson 1: Thinking Deeper *(30 minutes)*

How do albedo, humidity, and soil temperature affect global climate patterns?

For the debrief, student research groups reorganize into three "expert teams": one for Albedo, one for Relative Humidity, and one for Soil Temperature. Each student research team sends at least one student with the group measurements to one of the three expert teams with their team's corresponding data (i.e., albedo expert team representative brings albedo data only).

Albedo Expert Team:

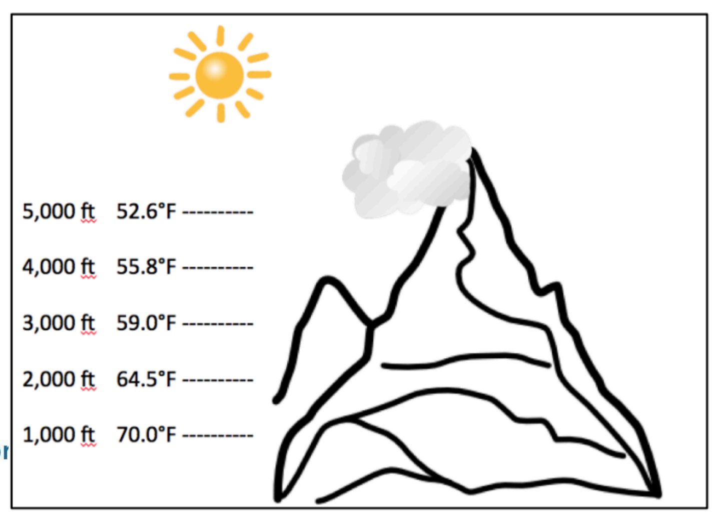
Compare the albedo measurements from the different student research groups by looking at variations of data among the different groups, identifying possible outliers and discussing reasons, emerging patterns, or relationships. Please discuss the following guiding questions:

- Which surface had the highest albedo?
- Which surface had the lowest albedo?
- Which surfaces in the Arctic would have the highest albedo, assuming the sun hits the surface at the same angle: open ocean or sea ice? Explain why.
- Thinking Globally:
    - What is the effect of a large volcanic eruption that reaches the stratosphere (like Mount Pinatubo in the Philippines in 1991) on the albedo in the Arctic?
    - What is the effect of a dust storm on the albedo of ice sheets? Explain why.

Relative Humidity Expert Team:

Compare the relative humidity measurements from the different student research groups by looking at variations of data among the different groups, identifying possible outliers, and discussing reasons, emerging patterns, or relationships. Please discuss the following guiding questions:

- What were the average and the range of relative humidity determined by the groups? What were the average and the range of air temperature measured by all groups?
- Think Globally:
    - Think about the effect that changing air pressure has on relative humidity. Does the relative humidity of an air parcel change if it moves upslope?
    - Which side of a mountain chain receives higher precipitation–the windward facing or the leeward facing side? Why?



Soil Temperature Expert Team

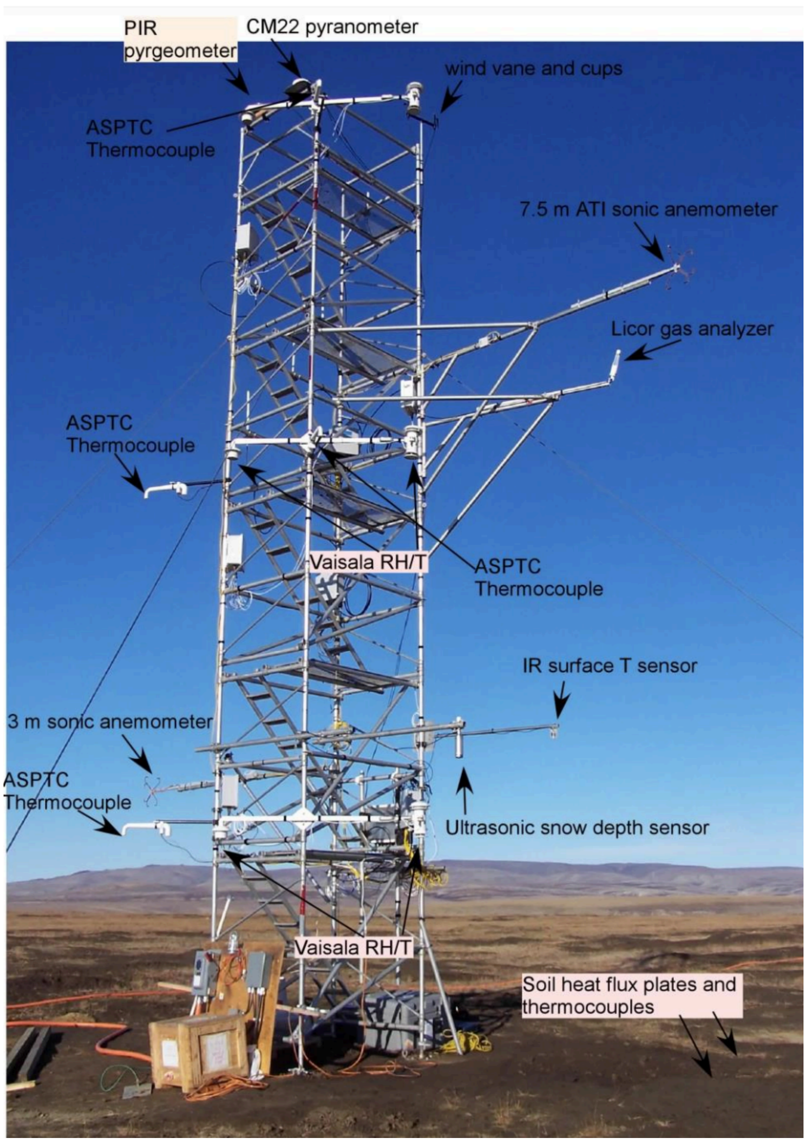
Compare the soil temperature measurements from the different student research groups by looking at variations of data among the different groups, identifying possible outliers, and discussing reasons, emerging patterns, or relationships. Please discuss the following guiding questions:

- At which sampling location did you find the largest difference between air and soil temperatures?
- Can you explain why the difference was largest?
- Which soils would you expect to warm faster with warming air temperatures? Why?
    - At which sampling location did you find the largest difference between air and soil temperatures?
    - Can you explain why the difference was largest?
    - Which soils would you expect to warm faster with warming air temperatures? Why?
- Think Globally: Increasing soil temperature in the Arctic raises important concerns with climate scientists as well as the local population in the Arctic. Can you brainstorm why?

Lesson 2: Scientific Data Collection: Eureka Tower *(40 minutes)*

How does temperature affect relative humidity?

How do scientists conduct measurements? The National Oceanic and Atmospheric Administration (NOAA) and Environment Canada constructed together a 10.5 m tower, called a flux tower, that holds multiple meteorological instruments that record hourly data year-round. This tower is located just outside of Eureka, Nunavut, Canada (you visited the site with Google Earth earlier).



In the previous activity, you conducted measurements of basic meteorological parameters like albedo, soil temperature, and relative humidity. The instruments that you used were simplified versions of the instruments that the scientists use. Research instruments conduct measurements with high precision so that scientists can trust their results.

The meteorological data that you will be using in the following Activities 2 and 3 (Arctic Climate Connections Activities 2 and 3) were collected at the Eureka flux tower in 2010. In order for you to understand how the data was derived, please look in detail at the photograph of the flux tower. Using internet-based research, find out what each of the instruments measures and complete the matrix below.

Thinking Deeper:

- What is precision?
- How is precision different from accuracy? Use the meteorological measurements as an example when explaining the concept.

	What does the instrument measure?	**Unit used to measure parameters**	**Height above/below ground**	**Instrument Direction (facing upward, facing downward, no direction)**
Soil heat flux plates and thermocouples				
Vaisala RH/T				
ASPTC thermocouple				
PIR pyrgeometer				
CM22 pyranometer				
Wind vane and cups				
7.5 m ATI sonic anemometer				
Ultrasonic snow depth sensor				

You have spent time conducting meteorological measurements yourself and explored how scientists measure the same data.

- What is the difference between weather and climate?
- What are these instruments measuring: weather or climate?

Extension Activity: Using Image-Processing Software ImageJ to Measure Albedo *(70 minutes)*

Measure albedo with a smartphone-based app?

Teaching Tips for Extension Activity

Students use the free “Albedo: A Reflectance App” to measure albedo digitally.

Albedo: A Reflection App is a free imaging software package. It is easy to use and allows displaying, editing, analyzing, processing, saving, and printing of images (such as .tif, .gif, .jpg, and other image formats).

Free download is here (website is very basic): https://albedo-a-reflectance-app.soft112.com

See this learning activity from CEEE for instructions on how to conduct the albedo hands-on activity.

Find more curriculum here:
https://ceee.colorado.edu/programs/arctic-climate-connections