Arctic Climate Connections Activity 1 Exploring the Arctic

Part A: What's the big deal about the Arctic anyway? Why are so many scientists studying the Arctic?

The Arctic consists of the large, ice-covered Arctic Ocean surrounding the North Pole and the adjacent land region. It is a unique place–a wide, empty, and spectacular landscape. Arctic species have to be well adapted to the extreme climatic conditions found in this region.

The Arctic is an important area for climate scientists who study global climate, as it is very sensitive to changes in climate. However, the Arctic is a difficult place to study. The main challenges to research in the region are extreme weather conditions, seasonal changes in light conditions (nighttime throughout winter and daylight throughout summer), and remoteness.

In this activity, you will explore the Arctic and research done in the region by examining different research sites.

CONCEPT MAPPING – WHAT IS THE ARCTIC?

Before visiting Arctic research sites, you should document your own understanding of the Arctic. To do this, construct a concept map titled, "What is the Arctic?". Consider the following questions when constructing this individual concept map:

- What do you know about the Arctic?
- What makes the Arctic so unique?
- What do you know about the environment, climate, plant cover, animals, human activity, habitability, natural resources, politics, history, populations, and other aspects that come to mind?

Teaching Tips for Part A:
In this activity, students brainstorm their knowledge about the Arctic and build concept maps of different aspects of the Arctic environment. Students try to define the Arctic and revisit the definition after completing a reading.

If your students have never created a concept map, you might want to give them a brief introduction on concept mapping —see next page for background and resources.

When creating the whole class concept map, you can highlight the facts that seem most widely known as well as unusual facts.

The "crumple and toss" or snowball fight activity is a fun break and allows for anonymous peer review.

The readings and explorations prepare students for the videos that are suggested. Guiding questions help students to focus while watching the videos.

Learning Goals:
After completing this activity students will be able to

- Define what the Arctic is.
- Describe the Arctic environment and life of indigenous people

Materials:

- Student Guide
- Student Worksheet
- White board for class concept map
- "Passport to the Arctic" - background readings
- Video streaming capacity
- Powerpoint with all relevant images

Background readings for teachers:
Arctic Report Card (http://www.arctic.noaa.gov/reportcard/) - Updated annually with latest research on changes in the Arctic
NSIDC Arctic Primer (http://nsidc.org/cryosphere/arctic-meteorology/index.html) - Excellent website by a trusted source
NOAA Arctic FAQ Page (http://www.arctic.noaa.gov/faq.html) - Frequently asked questions

Assessment:

- Concept maps (individual, group, and whole-class concept map)
- Definition of Arctic including revisiting of definitions

In groups, create a group **concept map** to show how the different aspects of the Arctic relate to each other based on the individual concept maps of each group member.

Create a **whole-class concept map** by combining the small group concept maps into one.

Teaching Tips – Concept Mapping

A concept map is a graphical representation to organize knowledge and show connections between different concepts. They are organized in hierarchical nodes that are linked together with directional lines and are arranged from general to specific.

Suggested background readings about concept mapping:

- http://cmap.ihmc.us/Publications/ResearchPapers/TheoryCmaps/TheoryUnderlyingConceptMaps.htm
- http://www.appliedconceptmapping.info/
- http://www.ifets.info/journals/14_3/3.pdf
- http://serc.carleton.edu/NAGTWorkshops/assess/conceptmaps.html
- http://serc.carleton.edu/introgeo/assessment/conceptmaps.html

DEFINITION OF THE ARCTIC:

Using a blank piece of paper, write down a possible definition for the Arctic in your own words.

Crumple up the paper with the definition and toss it to someone else. Everyone tosses the papers until definitions are well mixed, and each student has one definition (that is not his/her own).

Compile all definitions on a shared class sheet. Come to a class consensus about the best definition for the Arctic.

Now, read through the background materials "Passport to the Arctic".

Revisit the definitions on the shared class sheet and the definition in front of you.

- What are the four possible definitions of Arctic?
- Which of the four possible definitions of Arctic are listed on the class sheet?
- Which of the four definitions in the background reading is the closest to the definition you have in front of you?

EXPLORING VEGETATION IN THE ARCTIC

Reading: Landscapes and Vegetation in the Arctic
When thinking about the Arctic, images of snow and ice usually come to mind for many people. However, the Arctic is covered with vegetation and is home to many animals and people.
Read the following background materials on "Landscapes and Vegetation in the Arctic" by the Russian Geographical Society:
http://arctic.ru/geography-population/landscapes-vegetation

Guiding questions for the reading "Landscapes and Vegetation in the Arctic":

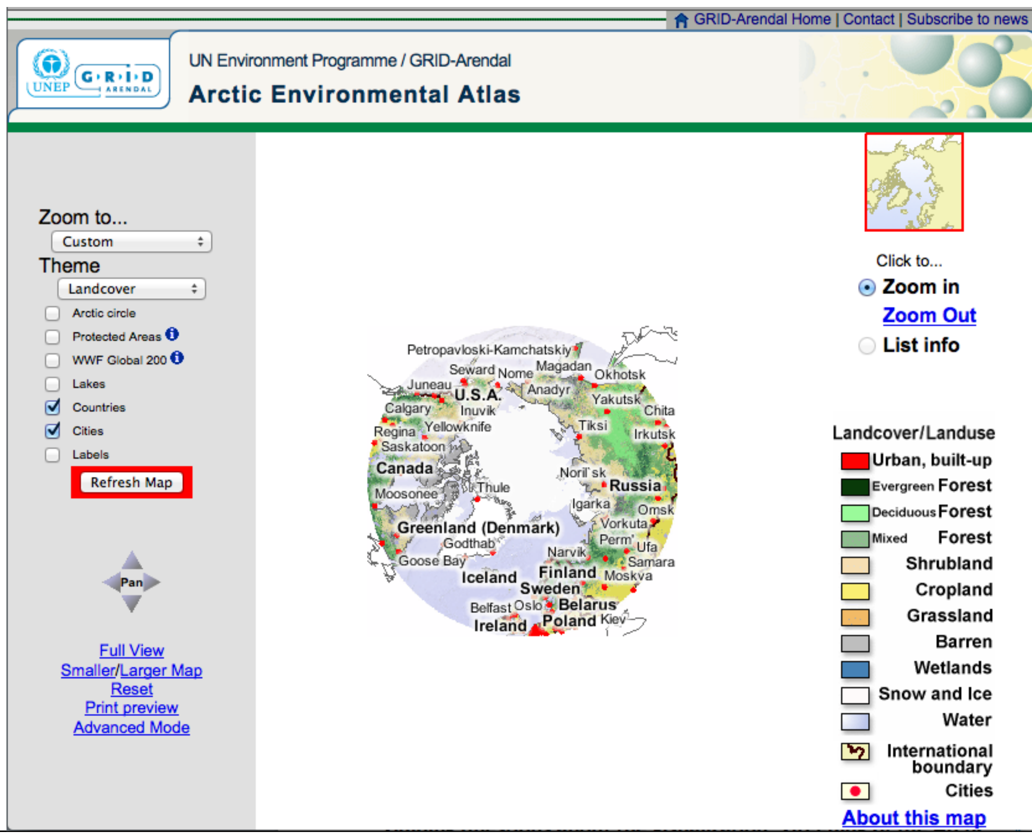
- In which of the four Arctic landscapes are trees found?
- What is permafrost? Where does permafrost occur?
- Why do we care about Arctic vegetation?

Extension: Exploration of Arctic Environmental Atlas
Students can explore the "Arctic Environmental Atlas" by the UN Environmental Program here: http://maps.grida.no/arctic/
Guiding questions for exploring the "Arctic Environmental Atlas":

- In which country/region does forest cover reach furthest north?
- In general, do deciduous or evergreen forests extend further north?

Additional information for using the "Arctic Environmental Atlas":

- On the left menu bar click "Countries" and "Cities" to make orientation easier.
- Click on the map to zoom in and click on the blue hyperlink "Zoom Out" in upper right hand corner to zoom out.
- For further exploration, you can choose in the upper left hand corner to zoom into defined geographic areas or replace the displayed information by choosing a different theme.



Visualization: Greening of the Arctic
View the following visualization about vegetation in the Arctic.

Greening of the Arctic (3:34 minutes)
by American Museum of Natural History
http://www.amnh.org/explore/science-bulletins/%28watch%29/bio/visualizations/greening-of-the-arctic

Guiding questions about the visualization, "Greening of the Arctic":

- How does the Arctic vegetation respond to a changing climate?
- Based on the visualization, how do scientists study vegetation in the Arctic?
- Explain what is meant by a positive feedback loop with respect to climate change and vegetation in the Arctic. Does this mean the feedback is beneficial?

Exploration of Arctic's Indigenous Population:

Read a short article about the "Population of the Arctic" from the Russian Geographical Society:
http://arctic.ru/geography-population/population

Take a look at the map below that shows the population distribution in the Arctic by country.
http://www.grida.no/graphicslib/detail/population-distribution-in-the-circumpolar-arctic-by-country-including-indigenous-population_1282

Guiding questions:

- What percentage of the Arctic population is comprised of indigenous people in Canada, Greenland and Russia, respectively?
- How did people in the Arctic originally adapt to live in the extreme Arctic environment?

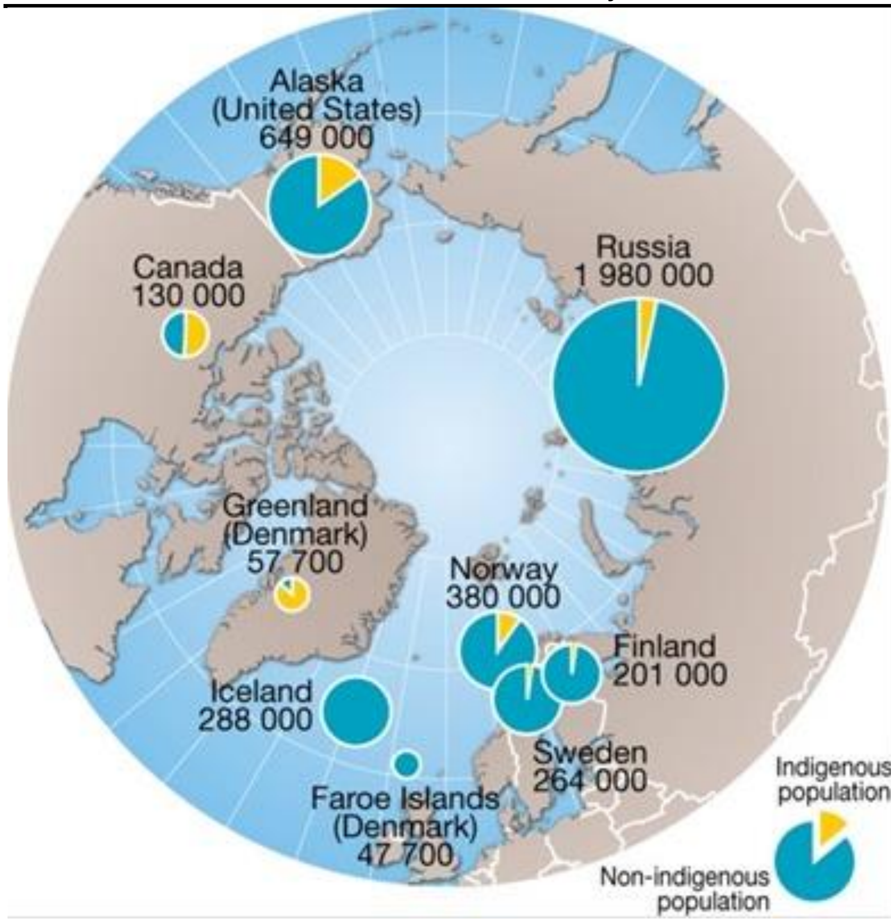
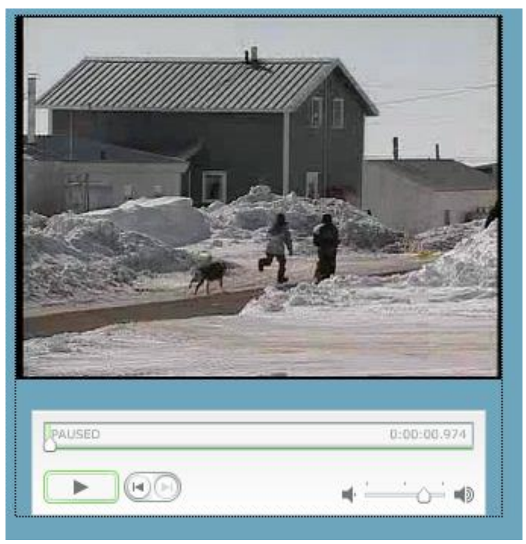


Image source: U*NEP: Population distribution in the circumpolar Arctic, by country (including indigenous population)*

Extension – Documentary of Arctic People and Climate Change:

Watch the following documentary about the Inuits in Sachs Harbor, Canada
Eyewitness of Changes in the Arctic's Climate (5:33 min)
from Smithsonian Institution / National Museum of Natural History:
http://forces.si.edu/arctic/video/eyewitness.html



Guiding questions:

- What effects of climate change are being reported by Inuit people of Sachs Harbor?
- How are scientists working together with these Sachs Harbor citizens?

Part B: A Virtual Trip to the Arctic

The Arctic is politically shared by many nations. The Arctic is sparsely populated and home to many indigenous people. Research is often conducted as international research efforts. One large international research organization that coordinates atmospheric research efforts working in the Arctic is the International Arctic Systems for Observing the Atmosphere (IASOA). They coordinate research conducted in atmospheric observatories around the Arctic.

The following data analysis activities (Arctic Climate Connections Activities 2 and 3) are based on data collected at one of the IASOA observatories. This research was conducted by scientists from the National Oceanic and Atmospheric Administration (NOAA) and University of Colorado's Cooperative Institute for Research in Environmental Sciences (CIRES). This next exploration takes you on a virtual tour of different Arctic research sites using Google Earth.

Exploration of Arctic Research Sites:
Visit the International Arctic Systems for Observing the Atmosphere (IASOA) website at http://www.esrl.noaa.gov/psd/iasoa/, and click on "Observatories". Click through different stations and look at their webcams or images. Then visit the Exchange for Local Observations and Knowledge of the Arctic (ELOKA) website at http://eloka-arctic.org/about/

Guiding questions:

- Who participates in the IASOA?
- What role do Arctic people play in Arctic research efforts?

Teaching Tips for Part B:
Students take a virtual tour of the Arctic and Arctic research sites using Google Earth.
The short tutorial introduces students to all features necessary to complete the activity.
The PowerPoint file includes screenshots of step-by-step description of answers.

Learning Goals:
Students will be able to

- Describe geographic extent of the Arctic.
- Describe differences between mid-latitudes and the Arctic latitudes.
- Locate Arctic research stations using Google Earth.
- Rationalize why people study the Arctic.

Materials:

- Student Guide
- Student Worksheet
- Computers with Google Earth installed and internet connectivity
- Powerpoint file with relevant images and step-by-step description of answers

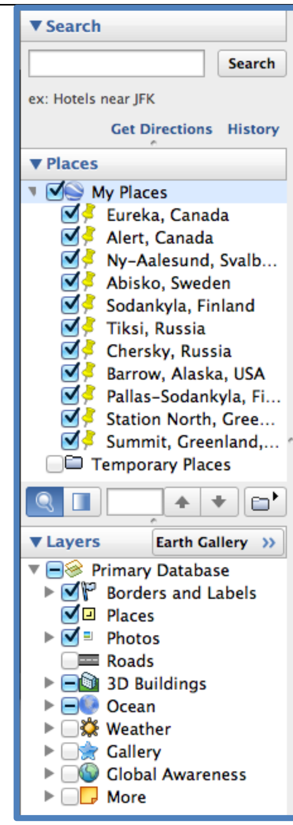
Background readings for teachers:

- Google Earth tutorials https://support.google.com/earth/answer/176576?hl=en
- Google Earth user's guide https://docs.google.com/file/d/0BzmdpKjx5MyDZjc5NzM5ZTUtNGIwMy00MDg1LWE3NWQtYzZhZWU1ODFkZDQz/edit?hl=en_US
- How to teach with Google Earth http://serc.carleton.edu/sp/library/google_earth/how.html

Preparation:
Go to http://www.google.com/earth/index.html.
Download the latest version of Google Earth using the blue "Download Google Earth" button in the upper right hand corner.
Follow the instructions and prompts to install the software onto your computer.

Assessment:

- Google Earth kmz files
- Worksheet questions
- "Thinking Deeper" questions



Brief Google Earth Tutorial

Layers and Featured Content
Note the panels on the left side of the screen (**Search**, **Places**, **Layers**). You can search Google Earth in the **Search** panel, just as you would search any other online mapping software. The **Places** panel is where you can store your own files and folders, and where you can save downloads. Finally, the **Layers** panel allows you to turn on and off other features, such as borders, roads, pictures, and many more. All these layers can be turned on and off by clicking the box to the right of each layer. The little arrow that points to the right shows that there are additional sub-layers available. Clicking this arrow unfolds the additional layers.

Navigation

In the upper right corner of your screen there is a control panel that only appears when you move your cursor over the window. It has three parts:

- The upper control lets you look around (as if you were turning your head) and it indicates where north is relative to your view.
- The middle control panel lets you move around from one place to another.
- The bottom panel is used to zoom in and out. If you zoom in enough, Google Earth automatically tilts your view up toward the horizon, and you can use the top panel to change the direction.

Saving Your Work:
Click on the **Add** menu at the top of the Google Earth window and add a folder. Name this folder with your last name. Once added, you will see the folder in your **Places** panel. Be sure that the folder is inside the **My Places** folder and NOT inside the **Temporary** folder – simply drag and drop to rearrange the folders.

Trouble Shooting:
If Google Earth is not working properly try to close the program and restart it.

START GOOGLE EARTH EXPLORATION CLOSE TO HOME

1) Launch Google Earth on your computer and "fly" to your school by typing the name of the school (and possibly the street address) in the **Search** box at the top. You will see an overview of the neighborhood of the school. You can zoom in further to look at the school buildings, sports facilities, and parking lots. Once you zoom in enough, Google Earth will change to Street View and you can look

at the school in 3D. Can you recognize any landforms like ponds, parks, rivers, streams, lakes, hills, and valleys?

2) Add a “placemark” at your school by clicking on the yellow pin icon at the top of the screen. A pin shows up on the Google Earth image, and you can move the pin while it has a yellow border until it sits right at your front door. Please name the placemark by typing the name you choose in the New Placemark window that appears. If you want to edit your placemark, right click and choose **Get Info**.

3) Use the navigation tools to navigate around your hometown. Make sure to note what vegetation you can see in the images – can you see trees, grass, and shrubs? Describe the vegetation that you can identify.

LET’S VISIT THE ARCTIC

Later in this module, you will use meteorological data that was collected by a research team from Boulder, CO–Andrey Grachev and Ola Persson—who study Arctic weather and climate. They are part of a pan-Arctic IASOA research network that has weather stations located across the Arctic. Using Google Earth, you can “visit” a few of the sites where they collect their data.

1) The first site you will visit is **Eureka** in Canada. Type in your Google Earth search box, “Eureka, Canada.” Add a placemark that you name, “Eureka”.
Now zoom out to see where the placemark (=Eureka) is located relative to your hometown and where in Canada.

2) Explore the settlement. Make a simple hand-sketch on a separate piece of paper that shows the layout of the settlement.

- What type of vegetation do you see around Eureka, Canada?
-
- Describe the physical setting (mountains, rivers, ocean) of Eureka, Canada using cardinal directions (N, S, E, W)?
-
- What does the infrastructure of Eureka, Canada look like (roads, buildings)?
-

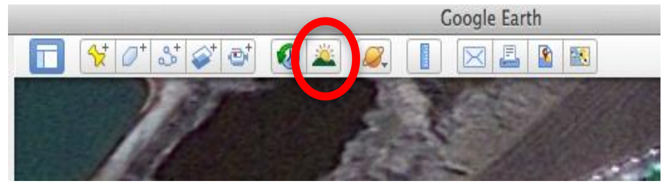
More information about Eureka, Canada

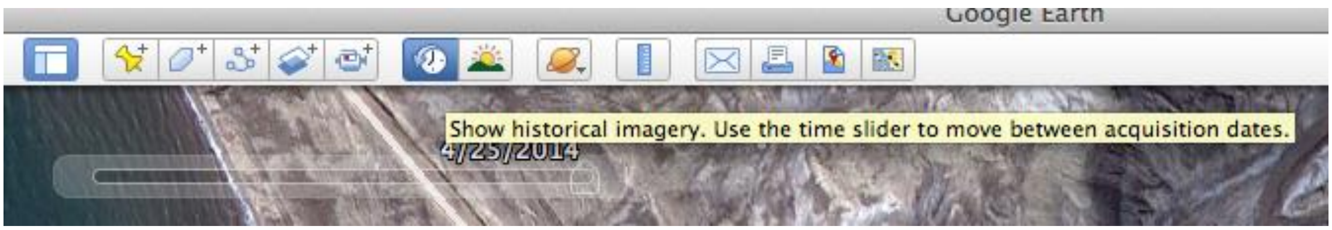
In the following activities students will be working with data collected in Eureka. Eureka is located on Ellesmere Island in Nunavut, the northernmost of Canada's three territories (Nunavut, Northwest Territories, and Yukon).
The Eureka weather station was established in 1947 and has been manned continuously since then. At 80N, Eureka is well north of the treeline where the main biome is tundra. Arctic mammals such as the polar bear, arctic fox, caribou, muskox, narwhale, and walrus frequent Ellesmere Island and its surrounding waters. Geological features in the area include glaciers, low mountains, and the ocean.

Additional materials about Eureka:
http://www.uphere.ca/node/140
http://www.youtube.com/watch?v=UAVUZsNvbtw

3) What is the elevation above sea level of Eureka, Canada?

4) Click on the icon with the sun in the top bar above the image. You will see the amount of daylight in Eureka at the current time. Move the slider to find out when it gets light in Eureka today. You can also play a time slider animation that shows the amount of daylight throughout the year by clicking the “Show historical images” icon that has a globe with a left pointing arrow. That will open the time slider. By clicking on the wrench icon you can choose the time and day but can also just use the time slider function. When does it get light in Eureka today and when does it get dark?





5) Go to http://www.esrl.noaa.gov/psd/iasoa/stations/eureka, then read more details about Eureka’s observatories. Next, look at some images from the settlement by scrolling down the page to “site map”. Click on the image and find the location of the flux tower on the photograph (marked in green). Now go back to Google Earth. Look for the location of the flux tower that you just saw on the IASOA website in Google Earth. You will measure the distance from the NOAA observation tower to the ocean.

- Select the ruler icon in the menu bar above the image.
- Choose a sensible unit of measurement.
- Click the starting point of the measurement (tower).
- Click the end point of the measurement (ocean).

Approximately, how far is the flux tower away from the ocean (make sure to include the unit you used for the measurement)?

6) Now visit the research station **Barrow, Alaska** using Google Earth. The research station is located exactly at 71.325 N 156.625 W outside the town of Barrow. Copy or type the geographic coordinates in the Search field to find the exact location of the station. Set a placemark where the station is and choose an appropriate name for your placemark.

7) Measure the distance (in a straight line) from the station to the airport in the town of Barrow (following the instructions about distance measurements under question 5).

8) Click on the sun icon at the top of the screen to see whether it is light or dark in Barrow (same process as for question 4). Then go to the website from IASOA about the Barrow station: http://www.esrl.noaa.gov/psd/iasoa/stations/barrow and look at the webcam.
Does the webcam show the same light/darkness as you see in Google Earth?
If not, please explain and explore if there is a way to replicate the webcam light conditions.

9) Now visit **Ny Ålesund,** Svalbard in Norway and set a placemark. You can see little image icons around the town. Click on some of the pictures and see what Ny Ålesund looks like. What does the vegetation in Ny Ålesund look like based on the pictures?

10) Now visit **Tiksi** in Russia, another IASOA station. Explore the town using Google Earth and visit the IASOA website: http://www.esrl.noaa.gov/psd/iasoa/stations/tiksi. Set a "placemark".

11) Determine the distance from each of the four stations (see your placemarks) to the Arctic Circle (66° 33′ 44″N or 66.5622°N). Use the ruler and determine the distance between each station and the Arctic Circle–make sure to use a sensible unit:

Eureka – Arctic Circle:
Ny Ålesund – Arctic Circle:
Tiksi – Arctic Circle:
Barrow – Arctic Circle:

12) Save your work: Right-click on the folder that includes the four placemarks that you have created. Choose **Email** and follow the instructions for sending an email. The program will automatically create a .kmz file (zipped version of the .kml file for each placemark) of all your placemarks. Send the .kmz file to your teacher and your school email or save it to a flashdrive for data transfer.

Thinking Deeper:

In these activities you have defined what the Arctic is and explored sites across the Arctic. What effect does the tilt of the Earth's axis have on the Arctic?

Now imagine Earth's axis wasn't tilted. What would the effect be on the Arctic in terms of temperatures, daylight, and vegetation?

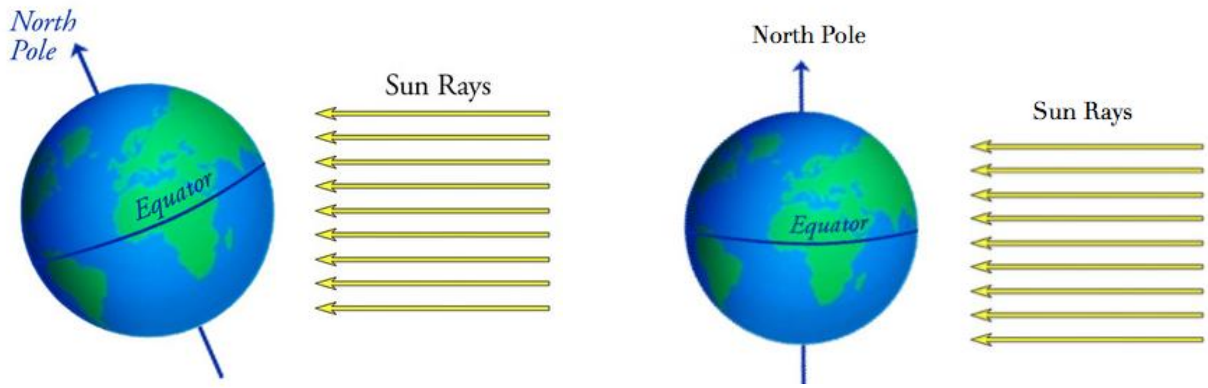


Image: Earth with an axial tilt of about 23.5deg (left) and without a tilt (right). Modified from Illustrative Mathematics

Going back to the four definitions of the Arctic we have provided and the four corresponding maps, can you identify any locations that are being considered part of the Arctic based on one (or more) of the four definitions but not considered part of the Arctic by one of the other definitions? Explain.

	Arctic Circle	Average summer temperature	Polar treeline	Political boundaries
Arctic Circle – Average				
Average summer temperature				
Polar treeline				
Political boundaries				

Part C — Collecting Your Own Meteorological Data

Research scientists like Dr. Andrey Grachev and Dr. Ola Persson measure many climate and weather parameters at research sites across the Arctic. They use automated measurement stations to get continuous data. This means that the measurements are controlled by computers and conducted automatically without the need of a person to be present. Having scientific personnel at each research site around the year would be too expensive and difficult to maintain. Having continuous measurements of Arctic meteorological data allows calibration of climate models and the study of meteorological conditions across the Arctic.

Collect your own data

Before you start analyzing data that was collected by researchers in the Arctic you will get some experience with collecting data yourself. In this activity you will gather the same type of data that scientists collect, only using simpler instruments. In groups of two to four students you will be conducting measurements and recording your data on your data collection worksheets just like scientists do in the field. Make sure that you sketch the experimental set up; note the date, collectors, general conditions, and any other observations and metadata that you might have at the site. This will allow revisiting the data collection conditions. You will rotate through all three stations (albedo, relative humidity, soil temperature).

Data Collection I: Albedo (modified from EarthLabs)

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

Teaching Tips for Part C:
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.

The hands-on experiments have to 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 can be found at:
http://serc.carleton.edu/sp/library/jigsaws/index.html

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.

Learning Goals:
Students will be able to
- Describe and measure albedo, relative humidity, and soil temperature.
- Evaluate collected data.
- Name instruments that are used for meteorological observations.

Materials:
- Student Guide
- Student Worksheet
- *Albedo Materials:*
  - 1-3 light meters ($15, for example here: http://www.amazon.com/dp/B000JWUT6O/ref=pe_385040_30332190_TE_M3T1_ST1_dp_1)
- *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

Preparation:
- Set up stations outside for three activities

Assessments:
- Data collection sheets
- Responses to discussion questions

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**.


Pyranometer (above) Source: NOAA

Lightmeter (above) Source: Amazon

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.

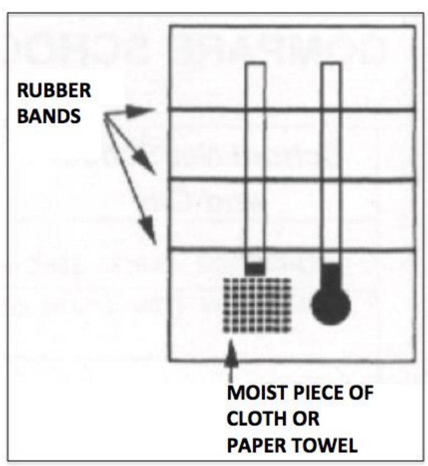
Procedure:
At this station you will measure the albedo of different surfaces such as grass, sand, dirt, asphalt, snow, or concrete. At each site, you will measure light intensity of your light source and different surfaces with a lightmeter and calculate the albedo for each material.

1) Point the lightmeter directly to 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.

Data Collection II: Relative Humidity (modified from Science Giants – Earth and Space):

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. 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.

Data Collection III: Soil Temperature (modified from GLOBE Soil Temperature Protocol):

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 = **in**coming **sol**ar radi**ation**).

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 as effectively cool itself 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.

Thinking Deeper

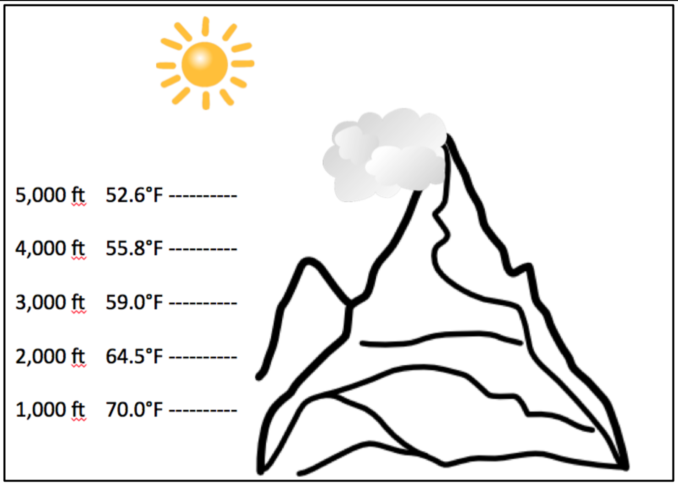
For the debrief, student research groups reorganize into three "expert teams": one for Albedo, one for Relative Humidity, and one for Soil Temperature. Each student research team sends at least one student with the group measurements to one of the three expert teams with their team's corresponding data (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 variation 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 on 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 variation 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?



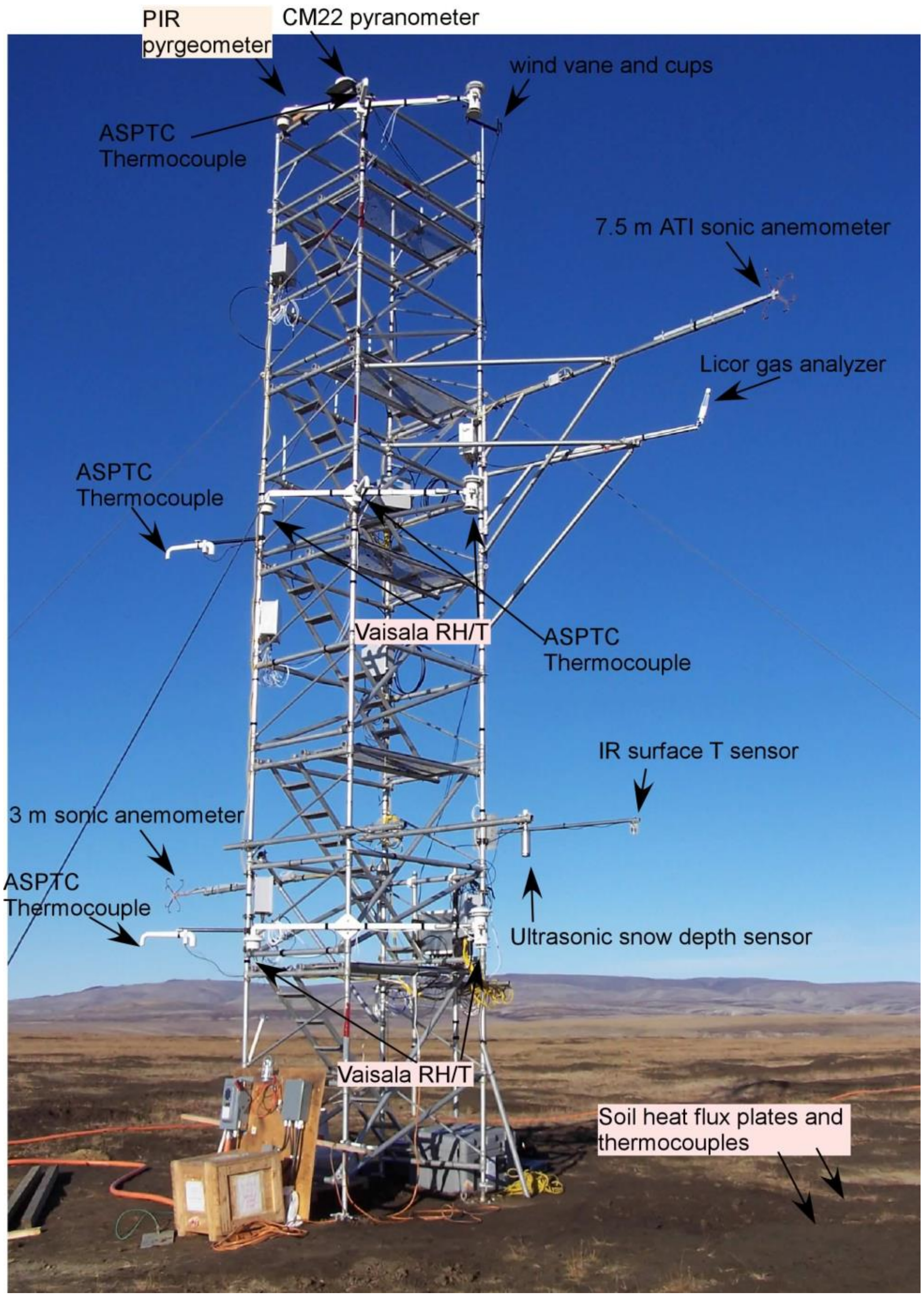
Soil Temperature Expert Team

Compare the soil temperature measurements from the different student research groups by looking at variation 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?
    - Wet soils or dry soils?
    - Snow covered soils or barren soils?
    - Light soils or dark soils?
- Thinking 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?

Scientific Data Collection: Eureka Tower

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) was 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 measure 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 that parameters are measured in**	**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				

Thinking Deeper:

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

Teaching Tips for Extension Activity

Students use ImageJ, a free image-processing program, to measure albedo digitally.

ImageJ is a free imaging software package developed by the National Institutes of Health. 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): http://rsbweb.nih.gov/ij/download.html
More information here: http://rsbweb.nih.gov/ij/docs/index.html or http://en.wikipedia.org/wiki/ImageJ

See https://sites.google.com/site/albedoproject/home/analyzing-the-data/using-imagej-for-albedo-analysis for instructions for how to conduct the activity. Have students either find images online (e.g., of glaciers surrounded by mountains) and use them in the albedo analysis. Have students estimate the albedo before they measure to establish quantitative reasoning skills.

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