Arctic Climate Connections Activity 2
Do you really want to visit the Arctic?

YOUR MISSION:

You have been accepted into CIRES's Arctic intern program to work with scientists, Dr. Andrey Grachev and Dr. Ola Persson on their research project in the Canadian Arctic.

WARM-UP ACTIVITY:

Before scientists undertake new research, they do a lot of reading to learn from what has already been studied, to come up with questions that need to be answered, and to understand methods that have been used to answer similar questions.

So before you dive into your Arctic research, take a moment to read up on Arctic climate and how it is related to the climate worldwide. The data you will be working with is from 2010, so take a look at the State of the Climate report from that year:
http://www1.ncdc.noaa.gov/pub/data/cmb/bams-sotc/2010/bams-sotc-2010-brochure-lo-rez.pdf

Write down 3 questions about the Arctic that you might like to know the answers to. For example, do you want to know about the environment, the landscape, the people, or the weather? Try to phrase your questions so they are specific.

ANALYZING WEATHER DATA

Your team is planning to visit EUREKA on Ellesmere Island in Nunavut, Canada. You need to plan the visit during a time when the conditions will allow your team to be there in relative safety and comfort. You have year-round weather data to use to help you make your decision. Because there is so much data to analyze, your research team will break into smaller groups to examine parts of the data.

Meteorological data collection instruments have been

Teaching Tips for Activity 2

This is a jigsaw activity and is primarily designed for students to become familiar with the Arctic weather data, reading and interpreting graphs before moving on to Activity 3.

The warm-up activity is optional, but it allows students to learn a little about the Arctic and the climate system. Students are prompted to ask questions like scientists do before they start analyzing data. This section may be assigned as homework before engaging in this activity. High-resolution versions of the brochure, supporting slides, and reports from other years can be found at:
http://www.ncdc.noaa.gov/bams-state-of-the-climate/

An excellent reference on teaching with the jigsaw method can be found at:
http://serc.carleton.edu/sp/library/jigsaws/index.html

Learning Goals

Students will be able to:

- Read and interpret Arctic data graphs.
- Articulate seasonal weather patterns in Arctic datasets.
- Synthesize data from four different datasets to determine the optimal time to visit the Arctic.
- Create a measureable definition for "winter."
- Compare Arctic weather to weather in their hometowns.

Activity Format

This activity is designed for 16 students. For more or fewer students, you can alter the number of groups or the number of students in each group. For a class size around 32 students, you can run two parallel sets of groups.

Materials:

- Student guide
- Student worksheet
- Jigsaw worksheet (Each student only needs the one for their assigned Research Group)
- PowerPoint with data graphs (Print so that each student has a graph and data tips for their Research Group assignment.)

Assessment:

- Completed worksheets
- Extension activity or homework assignment: Infographic about weather in Eureka

set up at this research station. To understand what this data means, each group will examine one dataset, and then compare your findings with the other groups. In the meantime, you will also learn about the data and how it is measured and you will discover what the weather conditions are like in this special environment of the Arctic.

THE PLAN

- For Part A, start in *Research Groups* where your group will work together to examine one weather parameter that was measured at Eureka Station.
    - Research Group A – Air Temperature
    - Research Group B – Wind Speed
    - Research Group C – Snow Depth
    - Research Group D – Incoming Solar Radiation

- Next, for Part B, one member from each Research Group will join a *Research Team*.

- Each Research Team has a particular research focus and will need to plan their visit to the Arctic accordingly. Teams will have to combine the needs of their research focus, along with the weather conditions at Eureka to come up with the ideal time to visit.
    - Research Team 1 – Testing a fat-tired bicycle for travel across a snowy surface for field research
    - Research Team 2 – Collecting seeds from Arctic wildflowers
    - Research Team 3 – Astronomy research and photographing the night sky
    - Research Team 4 – Annual visit to maintain the meteorological instruments on the tower

Teaching Tips for Part A.
Guided by questions, student groups examine and describe one of four datasets of the annual record of 2010 at Eureka for air temperature, wind speed, snow depth, and incoming solar radiation.

Arrange students into *Research Groups*.
- Research Group A – Air Temperature
- Research Group B – Wind Speed
- Research Group C – Snow Depth
- Research Group D – Incoming Solar Radiation

Students work together in their Research Groups to answer the questions in Part I. Each student completes their own worksheet for the parameter their group is studying.

- Research Teams will contain one member of each Research Group. Thus each person is an "expert" in the particular parameter that they learned about with their Research Group. Each expert will present a summary of the data they examined. Then, the whole team will consider all of the data to reach a conclusion about when to visit Eureka at a time that makes sense for the purposes of their Research Team.

  Research Team 1 – One member of Research Group A, one member of Research Group B, one member of Research Group C, and one member of Research Group D.

  Research Team 2 – One member of Research Group A, one member of Research Group B, one member of Research Group C, and one member of Research Group D.

Research Team 3 – One member of Research Group A, one member of Research Group B, one member of Research Group C, and one member of Research Group D.

Research Team 4 – One member of Research Group A, one member of Research Group B, one member of Research Group C, and one member of Research Group D.

Part A – Research Groups

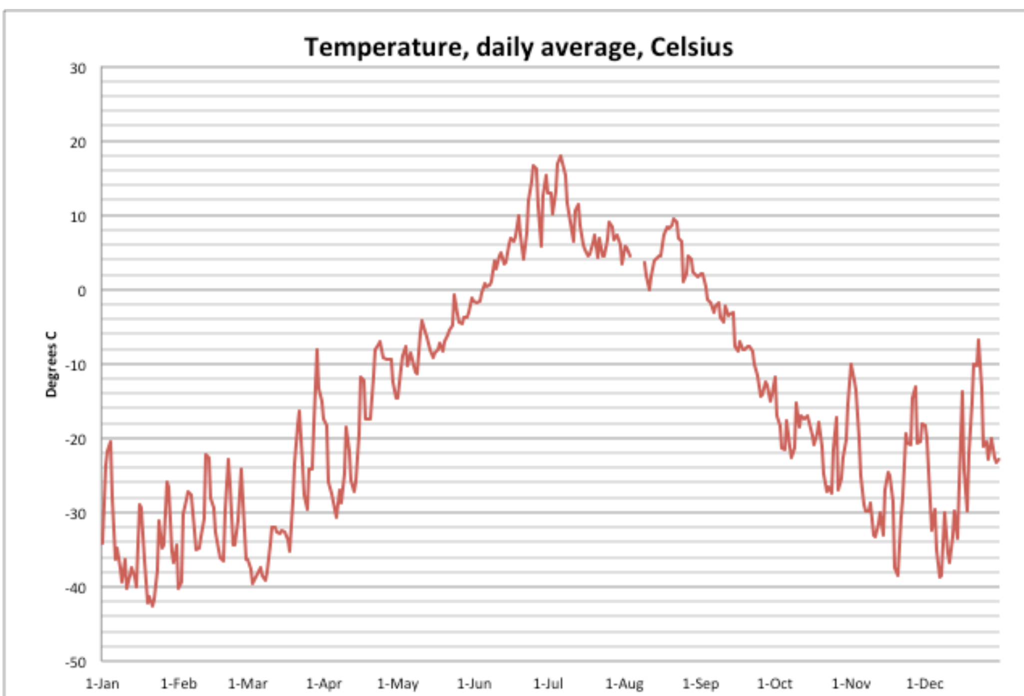
Work in groups of 4 to analyze the data as outlined below.

Research Group A – Air Temperature
Research Group B – Wind Speed
Research Group C – Snow depth
Research Group D – Incoming Short-wave Radiation

Use the graph, 'about the data' and 'analysis tips' to learn about the parameter that is assigned to your research group. (Your teacher will give these materials to each research group.)

Answer the questions on the worksheet for your Research Group only.

Research Group A – Air Temperature



About the data:

Air temperature varies throughout the day in response to direct solar heating and from day to day as weather systems move around the globe. Average air temperature also changes with the seasons. Scientists want to know both the extremes of temperature and the average temperature for some periods ranging from 24 hours to a month, a year, or longer.

The Eureka project measured air temperature at 2, 6, and 10 meters from the ground surface. This data is from 2 meters above the ground surface. This graph shows data collected in 2010.

Analysis tip:

This data is the ***average daily temperature*** from readings taken every minute and then averaged together to give one reading for the day. This means that the high temperature for the day was warmer than this value, and the low temperature was colder than this value.

There was a period from August 4-8 when data was not collected. This is shown as a gap in the line on the graph.

Examine the graph of **air temperature**.

1. What does the x-axis show?

2. What does the y-axis show? What are the units?

3. Draw a vertical line on the graph at the following dates:

    First day of spring
    First day of summer
    First day of autumn
    First day of winter

4. What is the warmest daily average temperature for the year? When did that occur?

5. Temperatures are shown in degrees Celsius. Convert your high temperature reading to Fahrenheit so that you can better relate to what the temperature was.

The formula for conversion °C to °F is: Multiply °C by 9, then divide by 5, then add 32

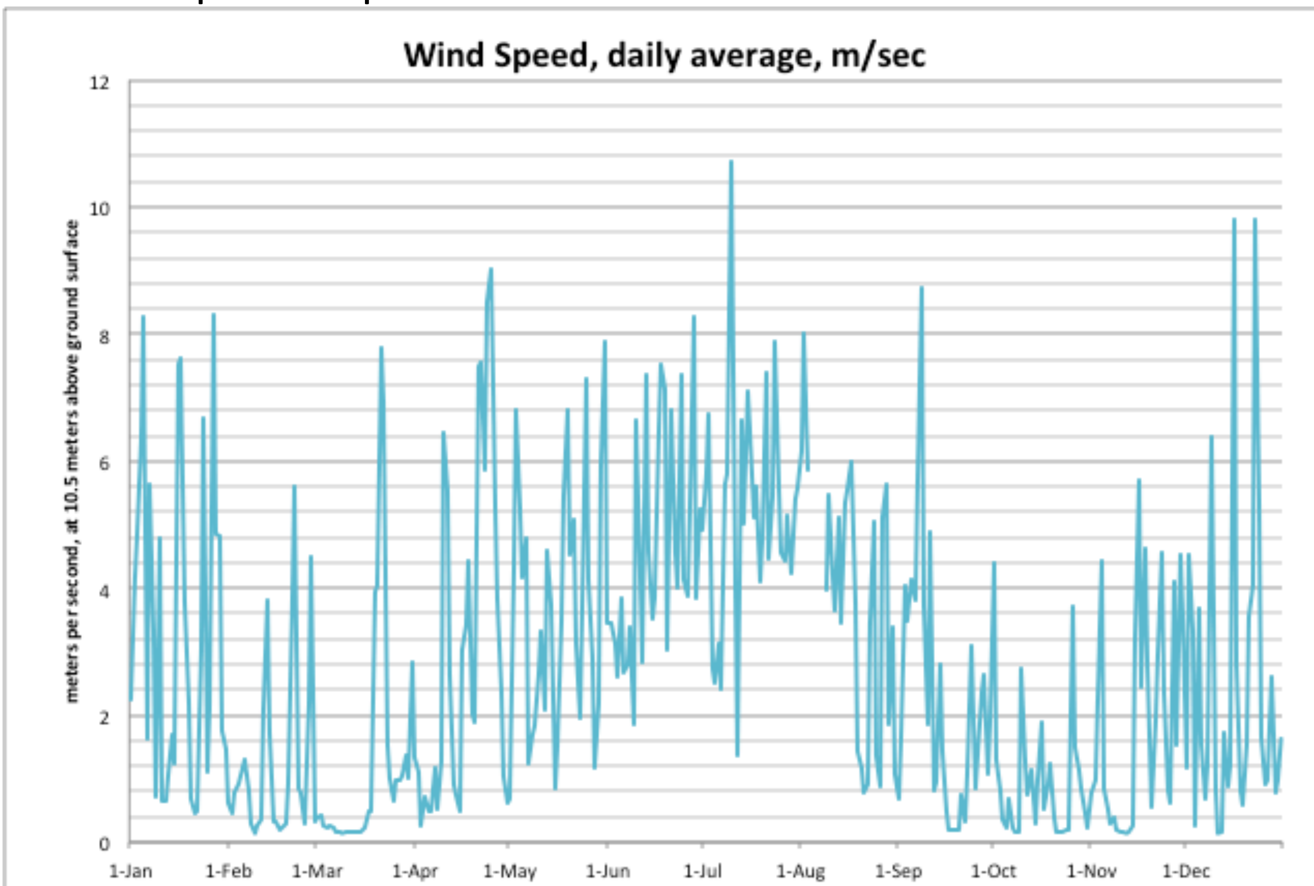
6. What is the coldest daily average temperature for the year? When did that occur?

7. Convert your low temperature reading to Fahrenheit.

8. How do these compare to the temperatures in your own hometown during similar times of the year?

9. During which parts of the year would you consider the temperatures to be habitable?

Research Group B – Wind Speed



About the data:

Winds are a result of uneven heating of Earth's atmosphere. Winds can accompany weather fronts and storms, or they can be steady throughout a number of days.

The Eureka project measured wind speed at a height of 10.5 meters above the ground surface. Wind direction was also measured but is not included here, just to keep things simple. This graph is for data collected in 2010.

Analysis tip:

This data is the ***average daily wind speed*** from readings taken every minute and then averaged together to give one reading for the day. This means that the highest wind speed for the day was greater than this value, and the lowest wind speed was lower than this value.

There was a period from August 4-8 when data was not collected. This is shown as a gap in the line on the graph.

Examine the graph for **wind speed.**

1. What does the x-axis show?

2. What does the y-axis show? What are the units?

3. Draw a vertical line on the graph at the following dates:

First day of spring
First day of summer
First day of autumn
First day of winter

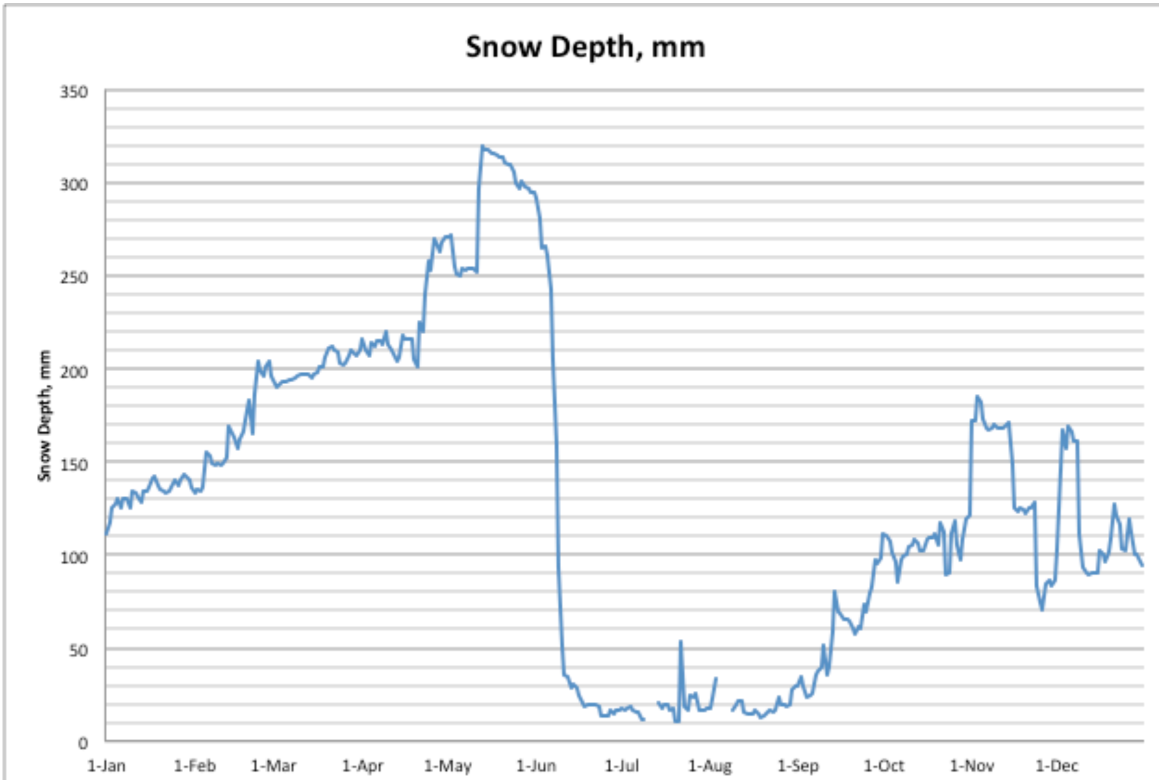
4. What was the maximum daily average wind speed during the year? When did that occur?

5. Convert the maximum wind speed from meters per second to miles per hour, so that the units are easier to relate to.

You'll need to know that there are 1609 meters/mile

6. When were there periods of generally low wind speeds?

7. Can you see any pattern to when the winds were the strongest and when they are quieter?



Research Group C – Snow depth

About the data:

Snowfall and snow depth may vary significantly over distances less than 10 km. In order to understand the local, regional, and global weather patterns, scientists must know how much precipitation falls at many different locations around the world. Topography, winds, and other local effects can create large differences in snow depth. This graph is for data collected in 2010.

Analysis tip:

This data is the ***average daily snow depth*** from readings taken every minute and then averaged together to give one reading for the day.

There were periods from July 10-13 and August 4-8 when data was not collected. These are shown as gaps in the line on the graph.

This dataset has an error in it, which is a normal part of scientific data collection. During the summer months, you can see that the snow depth never goes all the way down to zero. This is partly because of the way the instrument detects snow (by sending sound waves from the tower down to the ground and measuring the response time) and partly because the instrument experienced "drift" where the instrument loses accuracy over time. The instrument was re-calibrated in August. Corrections for these kinds of calibration drifts are often necessary, and this is a good example of real-world decisions scientists have to make when looking at data.

There is a spike of snow depth in late July. To confirm if this is real, other factors need to be considered. In Activity 3, you will look at albedo along with snow depth. But to keep things simple for now, we can safely say that there are no other indications that it snowed in July. Given all of that, question 6 on the worksheet asks you to estimate the snow-free season in Eureka in 2010.

1. What does the x-axis show?

2. What does the y-axis show? What are the units?

3. Draw a vertical line on the graph at the following dates:

   First day of spring
   First day of summer
   First day of autumn
   First day of winter

4. When was the greatest snow depth during the year? How deep was the snow?

5. Convert the value from millimeters to feet and inches so that you can better relate to the depth of the snow.

1 foot = 305 mm

6. Note that the snow depth never reads zero, but instead the data "wiggles" around between 15-30 mm of snow. Upon analyzing the data and re-calibrating the instrument, the scientists working on this project realize that these are erroneous readings from the instrument. (See the data analysis tips for more details.)

Given that, what is your **best estimate** of when the snow-free season was in Eureka?

For Teachers: Further notes about snow depth

The inconsistencies in the summer snow depth data are an important part of the scientific process. Sometimes, data does not seem to make sense. Scientists need to work to understand if there is an unexpected process at work, if the instruments are malfunctioning, or what other cause might underlie the unexpected data.

The curriculum development team asked the scientific research team about the irregularities in the summer snow depth. Their answer is below.

The snow depth measurement at Eureka is made by a Campbell Scientific SR50 Ultrasonic range *finder. It uses the speed of sound to measure the distance between the sensor and the surface, be it soil or snow. Because the speed of sound is partly dependent on temperature, this measurement is corrected for temperature. The accuracy of the Campbell Scientific Sonic Snow Depth Gauge is +/- 1 cm or 0.4% of the reading. Hence, little "wiggles" in the data that fall within this range may not be related to any physical event.*

In converting the electrical signal to distance, there are a couple of calibration coefficients, which are typically set in the factory and also adjusted when the instrument is serviced. Unfortunately, we have noticed that the calibrations for this instrument tend to drift with time, and most likely the servicing and latest calibration adjustment was done the previous summer (typically August). Hence, by the following summer, the calibration has often drifted. There are very few melt-offs as measured by this instrument that go exactly to zero. Some are slightly positive by a few cms, such as this case, and some are negative. Corrections for these kinds of calibrations drifts are often necessary, and this is a good example of real-world decisions scientists have to make when looking at the data.

To correct for this problem, we would need some independent information. I would look at the albedo measurements and identify the hour that the albedo reaches a value typical of soil (wet soil) of about 0.10. I would also verify what the "snow depth" measurement was the previous autumn just before the albedo increased above a dry-soil value (about 0.15) (the first snowfall will rapidly increase the albedo to 0.50 or higher depending on the amount). This autumn snow depth should have been zero. Our best estimate for the snow depth measurement through the winter is then obtained by linearly interpolating in time the drift of the instrument between the previous autumn and the summer onset, and subtract this value from the actual measurements. Your graph suggests that it would be a correction of no more than about 2 cm.

Furthermore, students may find it surprising that the snow depth is so small. The scientists responded to this question as well.

Eureka's location in a u-shaped valley seems to reduce the precipitation there. Clouds are often seen to have a thin spot or even be broken over Eureka while the surrounding mountains are heavily enveloped, suggesting downward motion and hence less cloud and precipitation production. The Arctic bush pilots (at least the one I flew with) refer to Eureka as the "Garden spot of the North", because they can generally depend on being able to land there while weather makes it impossible at other locations. I have done a comparison of conditions at Eureka and Alert, which are both on Ellesmere Island and about 500 km apart, and there is typically much more snow at Alert (2-3X). Snow typically disappears earlier at Eureka and summer temperatures are a bit warmer.

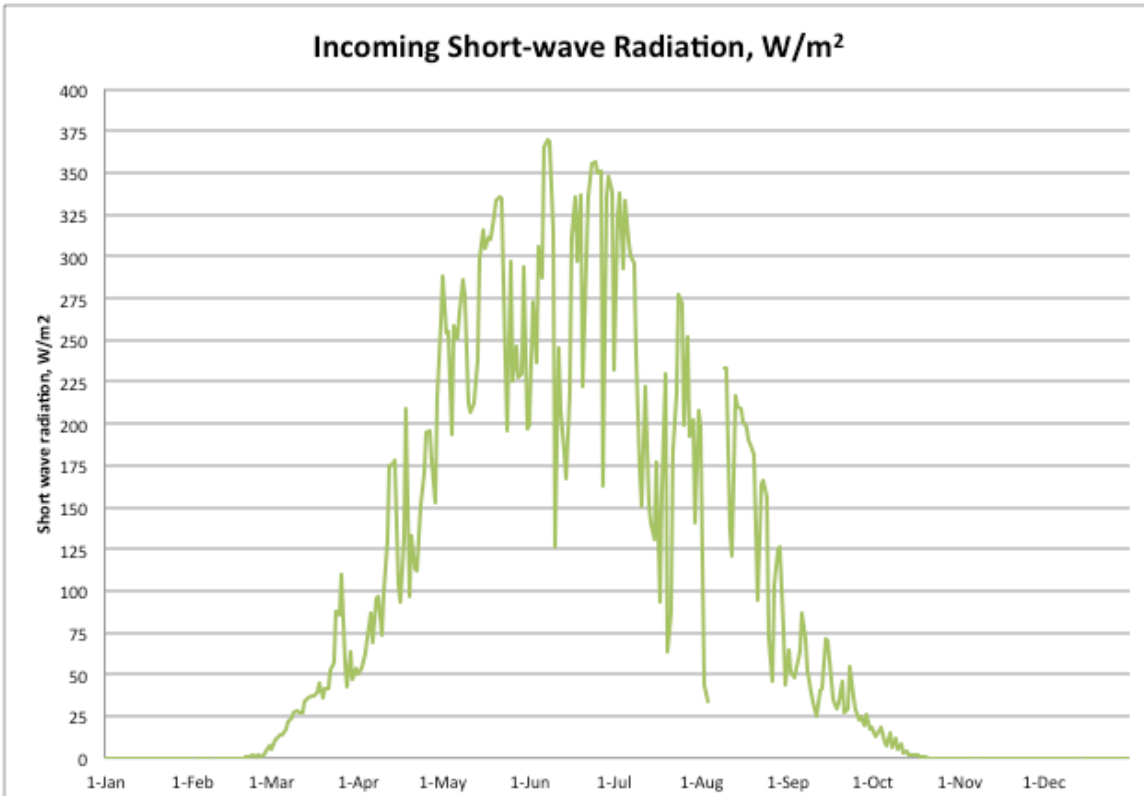
Also, note, however, that many locations in the Arctic are deserts. The amount of precipitation is quite small. That is because at these cold temperatures, the absolute humidity is quite small (the saturation water vapor pressure -- given by the Clausius-Clapyron equation-- increases exponentially with temperature, so is very low at very cold temperatures). For instance, over the sea ice away from any effects of topography, snow depths are believed to be ~ 30 cm at the end of winter (e.g., SHEBA).

Hence, the value at Eureka is not atypical for Arctic regions away from topography (though the year you chose to look at seems to have more snow at Eureka than most years -- some have only ~ 10 cm). The values at Alert show the effect of topography on producing more lifting and more precipitation.

Research Group D – Incoming shortwave radiation

About the Data:

Energy from the Sun reaches Earth as visible light and ultraviolet radiation. These electromagnetic waves have a short wavelength. Some of this inbound energy is reflected or absorbed by the



atmosphere and some makes it all the way to Earth's surface. The amount of incoming solar energy varies by:

Season - Due to the tilt of Earth's axis, more solar energy falls on parts of the Earth that are tilted toward the Sun (this is the definition of summer).

Latitude - More solar energy reaches tropical latitudes compared to the poles.

Weather - Clouds tend to reflect the incoming radiation so that less of it reaches the ground.

Time of day - Solar radiation only hits parts of the Earth that are facing the Sun. Thus, there is no incoming shortwave radiation at night, while that part of the Earth is facing away from the Sun.

Once shortwave radiation hits the surface of the Earth, some of it bounces off, and some of it gets absorbed by the surface of Earth, which warms the surface. Energy in the form of longwave radiation is then re-emitted from the warmed surface. The Earth then radiates much of this longwave radiation back out to space. (Incidentally, the ability of the atmosphere to capture and retain some of this longwave radiation is called the *Greenhouse Effect*.)

Analysis tip:

This data is the ***average daily incoming shortwave radiation*** from readings taken every minute and then averaged together to give one reading for the day. This means that the highest incoming solar energy for the day was greater than this value, and the lowest incoming solar energy was lower than this value. This graph is for data collected in 2010.

There was a period from August 4-8 when data was not collected. This is shown as a gap in the line on the graph.

Examine the graph of **incoming shortwave radiation**. Note that the value for each day is an average throughout the day, with readings taken every hour and then averaged.

1. What does the x-axis show?

2. What does the y-axis show? What are the units?

3. Draw a vertical line on the graph at the following dates:

   First day of spring
   First day of summer
   First day of autumn
   First day of winter

4. What does downward short-wave radiation mean anyway? What is meant by the units of watts per square meter? Explain these concepts in your own words.

5. What was the greatest amount of incoming radiation?

6. On what date did the maximum incoming radiation occur?

7. Why is there zero incoming radiation for a large part of the year?

Part B – Research Teams

Recombine the teams so that each Research Team has one member of each of the four Research Groups. Your newly-formed team assembles experts from each aspect of the Eureka weather conditions. Each team member will contribute information they learned in Part A of this activity to assist in the decision about when to visit Eureka.

Each team has a particular reason they are visiting the Arctic, so they need to combine the purpose of the visit with the conditions at Eureka during different times of the year.

- Research Team 1 – Testing a fat-tired bicycle for travel across a snowy surface for field research
- Research Team 2 – Collecting seeds from Arctic wildflowers
- Research Team 3 – Astronomy research and photographing the night sky
- Research Team 4 – Annual visit to maintain the meteorological instruments on the tower

Step 1 – The team should first consider the purpose of their trip. What are they studying? What time of year would work best for this purpose?

Purpose of trip:

Conditions needed to engage in the research mission:

Teaching Tips for Part B.

To facilitate discussion, the graphs from each Research Group can be printed on transparency film so they can be overlaid and all the data can be seen at once.

Students rearrange into *Research Teams*.
Each team will contain one member from each of the groups, so that there is a representative from each of the datasets the groups studied. Each Research Team has an assigned research focus – thus they need to consider the conditions in Eureka with that focus in mind.

Research Team 1: contains one member of Research Group A, one member of Research Group B, one member of Research Group C, and one member of Research Group D.
Research Team 2: contains one member of Research Group A, one member of Research Group B, one member of Research Group C, and one member of Research Group D, etc.

Once the groups have formed, each member of the *Research Team* gets a few minutes to describe the parameter they studied. All students write a summary of each of the datasets on their worksheet.

The *Research Team* then goes on to synthesize all of the data and then reach a conclusion about the overall best time to visit the Arctic. For most students, they will conclude that the optimal time to visit is when it is warmest, least windy, with sunlight rather than darkness, and a shallow or absent snowpack. But some groups may have a different idea of what constitutes the best time for a visit. The point of the activity is to have students engage in the data and use several datasets to reach a conclusion, and it is far less important that students reach a certain conclusion. Some latitude should be allowed, so long as their answer is well-supported by the data.

Research Team 1 – Testing a fat-tired bicycle for travel across a snowy surface for field research.

Research Team 2 – Collecting seeds from Arctic wildflowers

Research Team 3 – Astronomy research and photographing the night sky

Research Team 4 – Annual visit to maintain the meteorological instruments on the tower

Step 2 – In turn, each team member will describe the highs and lows for the parameter they examined. They will also describe when the best time of year would be to visit Eureka based on their particular variable **and** the research purpose. Everyone should write down the summary for each weather parameter on their own worksheet.

Best time of year to visit and why

Air temperature:

Wind speed:

Snow depth:

Incoming radiation:

Step 2 – After every team member has presented their data summary, the whole group should decide on a time of year that makes the most sense to plan for an Arctic visit. This answer should take into consideration both the research mission of the trip and the meteorological conditions necessary to engage in the research mission.

Best overall time of year to visit Eureka for your Research Team and why:

How does the Eureka weather compare to the weather in your hometown?

(A good place to look is the NOAA Climate Data Online http://www.ncdc.noaa.gov/cdo-web/datasets or for mountain regions of the Western US, you can find data (including snowfall and snow depth) here: http://www.wcc.nrcs.usda.gov/snow/)

Would you, personally, want to take a trip to the Arctic? Why or why not? What time of year would you want to go?

Teaching Tips for Part C.
After working in groups for the first two sections of this activity, students work

Part C – Individual Reflection

Aside from the usual calendar-based definition, how would you define "winter"? Scientists need to come up with measureable ways of defining what they are looking for (otherwise, how do you know if you've found it?). So, create a concrete definition for "winter" that is measureable using the all of the datasets that you have seen today.

Using your definition and the available data for 2010, how long was winter in this location in the Arctic?

Using the same definition, how long is winter in your hometown?

Data about your hometown is available from many sites. A good place to look is the NOAA Climate Data Online http://www.ncdc.noaa.gov/cdo-web/datasets
or for mountain regions of the Western US, you can find data (including snowfall and snow depth) here: http://www.wcc.nrcs.usda.gov/snow/

individually to create a measureable definition for winter. Obviously, the calendar definition of winter is measureable, but here students should be able to reflect on just how long "winter" is in the Arctic, and how much more severe it is compared to most locations in the US. The key is that their definition has to be something that is concrete.

Some possible, measurable definitions for winter:

- The length of time snow is on the ground
- The period during which the sun does not shine
- The period when the daily average temperature is below freezing (0°Celsius)
- The period when the daily average temperature is below 0° Fahrenheit (-18° Celsius)

Students are then asked to apply their definition of winter to their own hometown. Ideally this would be data-driven, and educators can have some local datasets available for comparison.

Some good places to look for climate data are:

NOAA Climate Data Online
http://www.ncdc.noaa.gov/cdo-web/datasets

Natural Resource Conservation Service
http://www.wcc.nrcs.usda.gov/snow/
Data for the mountain regions of the Western US. This data includes snowfall and snow depth.

Extension Activity - Create an Infographic

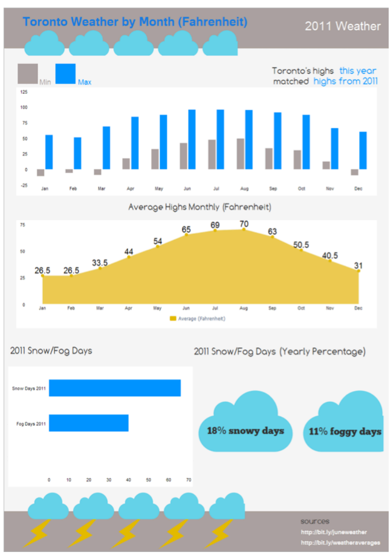
Students work in groups to create an infographic as a means to communicate the weather in Eureka. An infographic is a fun and creative way to organize and express data, but this method also helps develop the ability to synthesize several different types of data in one place. Three examples of infographics are shown below, and many more can be found via web searches.

Teaching Tips for Extension Activity
Here are some starting points. Tools for creating infographics:

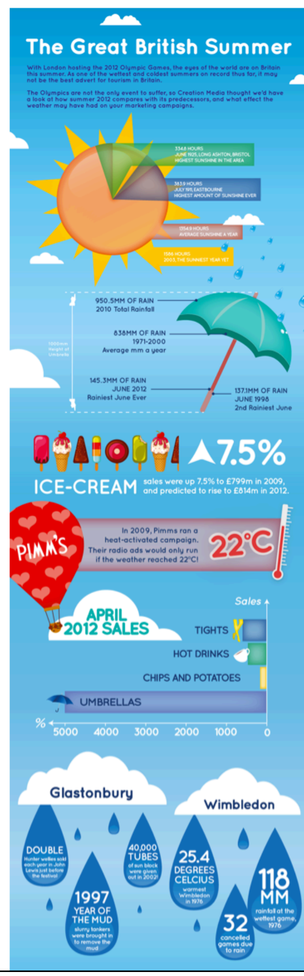
- Google Public Data Explorer www.google.com/publicdata
- Piktochart: piktochart.com
- Infogr.am infogr.am
- Gapminder www.gapminder.org

A rubric for evaluating infographics was developed by Loyola University New Orleans and can be found at http://sites.tufts.edu/tischinstruction/files/2010/11/Rubric-for-Assessing-Information-Literacy-in-Infographics.pdf. This file is also available from the Arctic Climate Curriculum website.

Toronto Weather from Venngage.com
https://venngage.com/blog/index.php/its-getting-hot-in-toronto-infographic/



British Weather from Creation Media UK
http://www.loveinfographics.com/categories/marketing-infographics/the-great-british-weather-infographic



Greenland Albedo from Visual.ly
This example summarizes albedo data from Greenland and is very relevant to Lesson Three.
http://visual.ly/albedo-effect