MEASURING PERMAFROST

UNITE US
INSTRUCTIONS
Grade 9-10

Overview:

Students learn how scientists monitor permafrost temperature as a study of permafrost health in the Arctic, how climate change may contribute to changes in permafrost distribution, and potential consequences of permafrost thaw.

Objectives:

The student will:
- determine what landforms indicate permafrost using satellite imagery; and
- interpret two types of graphs that show data related to permafrost temperature.

Targeted Alaska Grade Level Expectations:

Science

[9]SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating.

[10]SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, analyzing data, developing models, inferring, and communicating.

[9]SE1.1 The student demonstrates an understanding of how to integrate scientific knowledge and technology to address problems by recognizing that the value of any given technology may be different for different groups of people and at different points in time (e.g., different uses of snow machines in different regions of Alaska).

[10]SE1.1 The student demonstrates an understanding of how to integrate scientific knowledge and technology to address problems by identifying that progress in science and invention is highly interrelated to what else is happening in society.

[10]SG4.1 The student demonstrates an understanding that advancements in science depend on curiosity, creativity, imagination, and a broad knowledge base by recognizing the role of these factors on scientific advancements.

Vocabulary:

borehole – a hole that is drilled into the ground for exploratory purposes or to extract a core; a permafrost borehole is dug into frozen soil to monitor temperatures at different depths in permafrost

energy flux – the rate of transfer of energy through a surface

flux – the rate of flow of fluids, particles or energy across a given surface or area

frost tube – device for measuring the depth of freeze or thaw

mass flux – the rate of mass flow across a unit area

permafrost – a subsurface layer of ground (soil or rock, including ice and organic material) that remains below freezing (0˚C or 32˚F) for at least two consecutive years

trumpet curve graph – shows soil temperature range over the course of a year from the surface to a specific depth; the warmest and coldest points appear near the soil's surface; the shape formed by the lines suggests a trumpet

Whole Picture:

It is important to note that in many publications about climate change, writers often state that permafrost is melting. While their intentions are clear, their words are incorrect. Permafrost does not melt, it thaws. Remember that permafrost is any material that remains below freezing (0˚C or 32˚F) for at least two consecutive years. It can be soil, bedrock, organic material, and even a mummified woolly mammoth. Think of frozen salmon in your

freezer. You don't take it out for dinner and set it on the counter to melt, you set it out to thaw. The word melt, by definition, means "the process of changing from a solid to a liquid state." That doesn't apply to permafrost. It only applies to solid ice within permafrost. So remember, permafrost thaws, it doesn't melt.

Excerpt adapted from "*How rapidly is permafrost changing and what are the impacts of these changes?*" by Vladimir E. Romanovsky, Associate Professor, Geophysical Institute University of Alaska Fairbanks

Why does permafrost still exist in areas with such warm summers?

The average temperature during the year is the most important factor for the existence of permafrost. Winters in Interior Alaska are cold and long. The average air temperatures in Fairbanks, for example, are typically between -2 and -5° Celsius. The insulating effect of snow makes the average temperatures in permafrost higher, typically from -0.2 to -2° Celsius, which brings permafrost to the edge of instability. It becomes vulnerable to long-term thawing.

Permafrost gets colder and thicker northward. Within the northern foothills of the Brooks Range permafrost is already -2 to -5° Celsius and about 200 meters thick. On the Alaskan Arctic Plain, permafrost could be as cold as -9 to -11° Celsius and up to 650 meters thick.

Observed and predicted future climatic changes will inevitably change the energy and mass fluxes at the land surface. Things may continue warming. As a result, the near-surface and subsurface physical conditions in the Arctic and subarctic regions will change (the active layer and the permafrost). This will trigger changes in ecosystems and infrastructure because the stability of these systems in the North relies on the stability of ice that, so far, holds these systems together. In losing permafrost, we are losing the stability of systems.

Materials:

- Map of Alaska with clearly marked latitude and longitude lines (classroom size)
- Blank transparency film (one per student)
- Red, blue and black markers (one set per student)
- Ruler (one per student)
- Overhead marker
- MULTIMEDIA: "How to Read a Permafrost Graph" available on the UNITE US website (uniteusforclimate.org)
- VISUAL AID: "Permafrost Distribution in Alaska and Permafrost Observatories Locations"
- VISUAL AID: "Satellite Imagery"
- VISUAL AID: "Long-term Permafrost Data"
- VISUAL AID: "Vegetation Gives Clues to Permafrost Location"
- VISUAL AID: "Pearl Creek School Permafrost Data 2006-2007"
- STUDENT WORKSHEET: "Vegetation and Permafrost"
- STUDENT WORKSHEET: "What Does the Graph Say?"

Language Links:

The local dialect for the words below may differ from the examples provided. Share the words with students to build fluency in local terms related to weather. Include local words in songs, stories and games when possible.

English	Gwich'in	Denaakk'e	Lower Tanana	Deg Xinag	Your Language
Water	Chuu	Too	Tu	Te	
Melt/It's melting	Naaghwan/ neeyahkwaii	Ghaan	Nghan	Ntidlighanh	
Freeze/It's freezing	Datan	Ggats	Ethdetenh		
Ice	Łuu	Ten	Tenh	Tinh	

MEASURING PERMAFROST

UNITE US INSTRUCTIONS

Activity Preparation:

- Bookmark the UNITE US website on student computers (www.uniteusforclimate.org) or write the website address on the board.
- Refer to VISUAL AID: "Permafrost Distribution in Alaska and Permafrost Observatories Locations" and make sure all the data collection locations referred to on OVERHEAD: "Long-term Permafrost Data" are marked on a classroom map of Alaska. (See Materials.)

Activity Procedure:

1. Introduce the lesson on permafrost. Do a knowledge check by asking some review questions. Allow students freedom to brainstorm. Ask questions such as:
   a. What is permafrost? How can you tell the difference between permafrost and ground that freezes and thaws?
   b. Can you name a problem caused by the presence of permafrost?
   c. Can you name a traditional use of permafrost?
   d. What landforms in the area are a result of permafrost?
   e. How do scientists study permafrost? Why?

   Review the vocabulary words in a similar fashion, asking students to define the words as they know them, and assisting, where necessary with the definition.
2. Display VISUAL AID: "Satellite Imagery. "Explain there are many indicators on the land surface to indicate the presence of permafrost. The overhead presents two satellite images. The first is a typical satellite image. The second is the same image, but colorized. Colors have been added to show the different features. The purple areas are black spruce trees on north-facing slopes. The green areas are birch and aspen trees on south facing slopes. Ask students which areas most likely have permafrost. Ask them to explain their reasoning.
3. Show VISUAL AID: "Vegetation Gives Clues to Permafrost Location." Explain the blue areas on the lower map show permafrost distribution for the area in the satellite imagery. From this page note permafrost is present in areas of black spruce. Students should understand black spruce trees tend to grow in areas of permafrost. Birch and aspen trees cannot thrive in those areas, so they grow in non-frozen ground. Ask students to explain the best areas to build a house, based on the map. Hand out STUDENT WORKSHEET: "Vegetation and Permafrost," transparency film, and markers and instruct students to complete the worksheet in small groups.
4. Divide students into pairs. Ask pairs to discuss why they think it is important to determine where permafrost exists in the community and whether it is stable or thawing. Provide five to ten minutes to discuss, then discuss as a class.
5. Explain one way scientists study permafrost is to monitor depth and temperature. This can be done by drilling a borehole. Display VISUAL AID: "Permafrost Distribution in Alaska and Permafrost Observatory Location." Data is recorded at these locations for long-term studies. Remind students the top layer of ground above permafrost is called the active layer. The active layer thaws during the summer and freezes during the winter. Permafrost stays frozen all year. Ask students to view MULTIMEDIA: "How to Read a Permafrost Graph" on the UNITE US website (uniteusforclimate.org). (NOTE: This would be a good activity to display on a multimedia projector and discuss as the class works through it together.)
6. Display VISUAL AIDS: "Pearl Creek School Permafrost Data 2006-2007" and "Long-term Permafrost Data." Hand out STUDENT WORKSHEET: "What Does the Graph Say?" and ask students to complete Section 1 on their own. At teachers discretion, display VISUAL AID: "Long-term Permafrost Data" and work through Section 2 as a class, using a ruler and overhead marker to help students clearly view the data needed to complete the questions.

Extension Idea:

If your school has a permafrost borehole and/or a frost tube installed, take this opportunity to visit and gather data from the site.

MEASURING PERMAFROST

Answers:

STUDENT WORKSHEET: Vegetation and Permafrost:

1. Answers for A, B and C will vary according to the spacing of the grid marks.
2. The ratio would change. Further north the amount of permafrost would increase; further south it would decrease.
3. Aerial photography is one method. Prior to that, however, looking at the vegetation patterns was a good way to locate permafrost. Certain types of vegetation grow in the active layer above permafrost (black spruce and berries, for example). Other types cannot grow in permafrost, so if they are present, it is unlikely that permafrost is present (birch, aspen, etc.).
4. Satellite images help scientists see permafrost terrain, landscape features, etc. over a large area. Satellite imagery also helps monitor changes over time.

STUDENT WORKSHEET: What Does the Graph Say?:

For questions 1– 5 student answers should be very close to those listed below.

1. -10° C to 12° C
2. A. -3° C
   B. -7° C
   C. -6° C
   D. -1° C
   E. 4° C
   F. 0° C
3. A. -1° C
   B. -3° C
   C. -5° C
   d. -1° C
   e. 0° C
   f. 0° C
4. -7° C to 4° C
5. -4° C to 0° C
6. About 1 m depth
7. About 3 m depth
8. Between 68° N and 70° N latitude (see box at right)
9. Between 62° N and 67° N latitude (see box at right)
10. Answers should indicate that the temperature of the permafrost gets colder the farther north you go. Permafrost temperatures are colder near the ocean than they are inland. Some students may also observe the change in temperature of Deadhorse and West Dock are greater than the change of the other three places over the same period of time.
11. A. Deadhorse shows the most change, from about -8.75° C in 1978 to about -6.4° C in 2009 – a change of 2.35 degrees.
    B. 27 percent (the percent change between -8.75 and -6.4).
12. A. Chandalar Shelf or Old Man (Both are correct, see explanation below.)
    B. Chandalar Shelf shows a one degree change, from it's coldest in 1986 of -2.75° Celsius to -1.75° Celsius 2009. Old Man also shows a one degree change if you look at the warmest temp recorded around 2007, but if you use only the start and end marks, it is under one degree of change. Teacher can use discretion as to how to grade if student justifies answer well. (Both are correct.)
13. It took 24 years for it to rise 0.3° C. At the current thawing rate, it will take only 96 years for it to thaw completely.

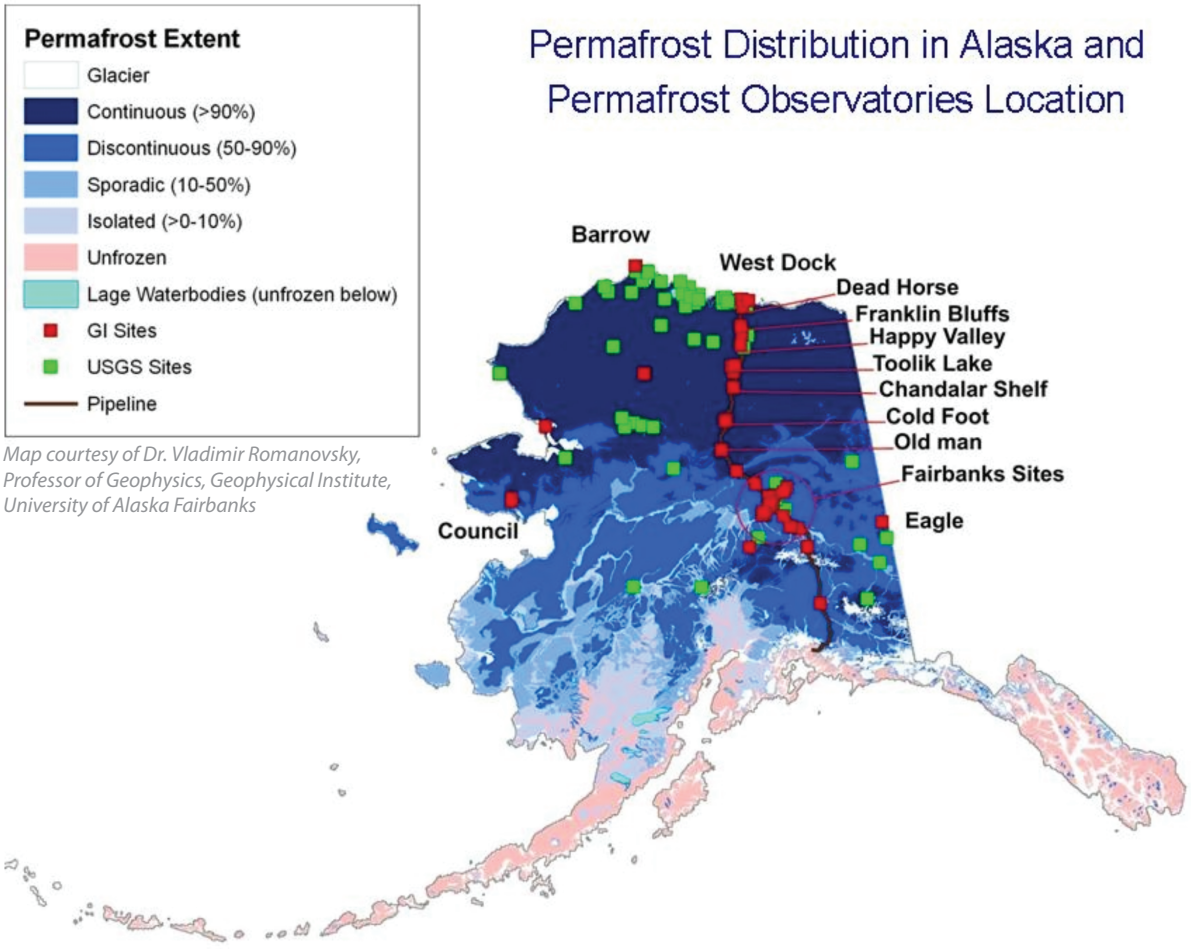
Latitude – North Slope Sites

Happy Valley: 69° N
Galbraith Lake: 68° N
Franklin Bluffs: 69° N
Deadhorse: 70° N
West Dock: 70° N

Latitude – Interior Sites

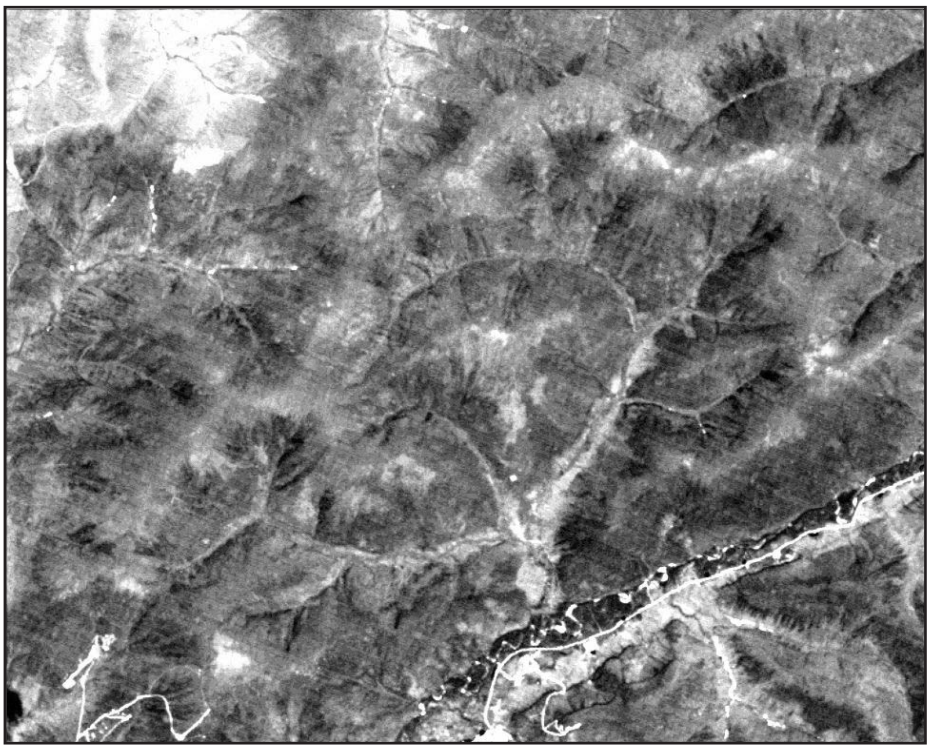
Livengood: 65° N
Gulkana: 62° N
Healy: 63° N
Coldfoot: 67° N
Birch Lake: 64° N
College Peat: 64° N
Chandalar: 68° N
Old Man: 66° N

PERMAFROST DISTRIBUTION IN ALASKA AND PERMAFROST OBSERVATORY LOCATIONS



Map courtesy of Dr. Vladimir Romanovsky, Professor of Geophysics, Geophysical Institute, University of Alaska Fairbanks

SATELLITE IMAGERY



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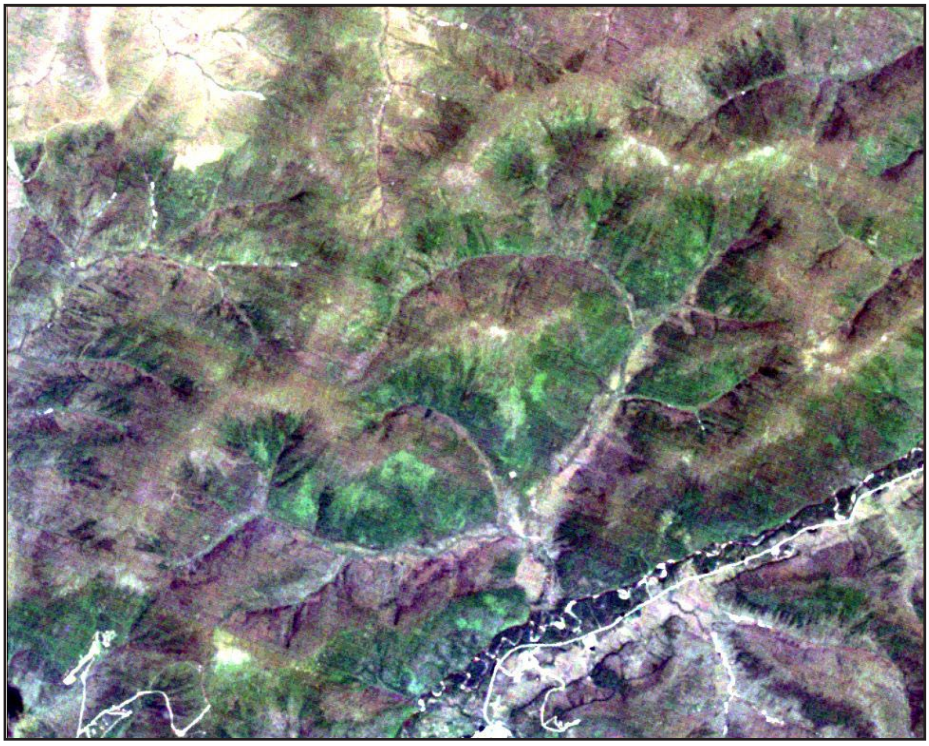

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LONG-TERM PERMAFROST DATA

Dr. Vladimir Romanovsky, Associate Professor of Geophysics at the University of Alaska Fairbanks Geophysical Institute, collects long-term temperature data for permafrost around the state. Long-term data helps scientists understand what is happening to permafrost and provides a clue to how climate change is impacting Alaska.

Learn more about each of these sites by visiting:

http://www.gi.alaska.edu/snowice/Permafrost-lab/projects/projects_active/proj_influences.html#west

Figure 1: Permafrost temperature records for northern Alaska

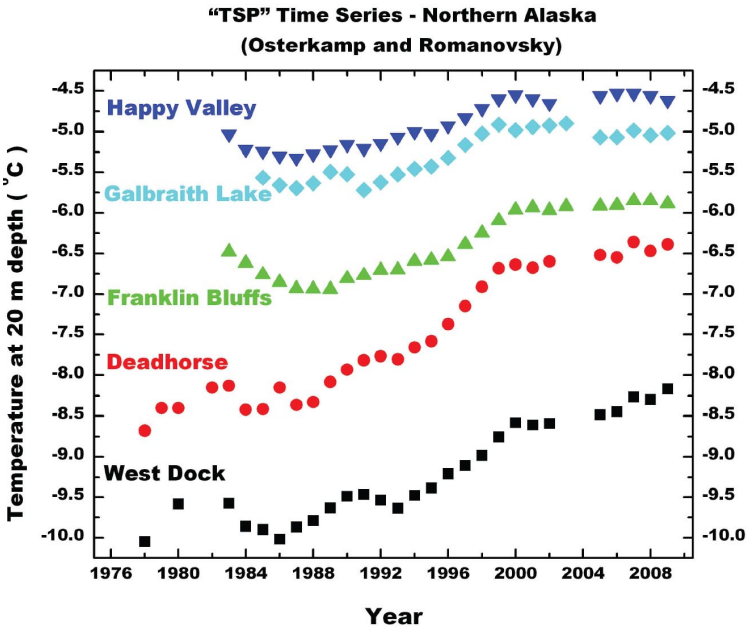
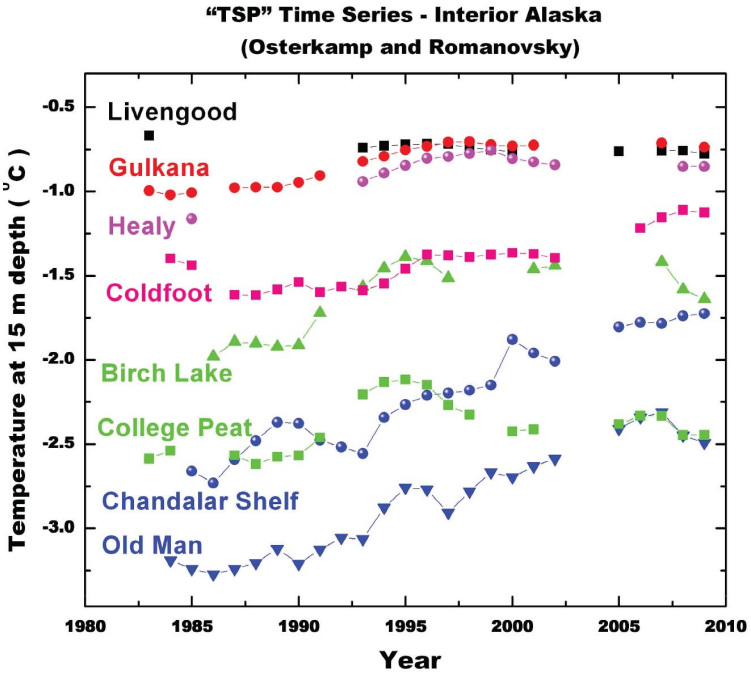
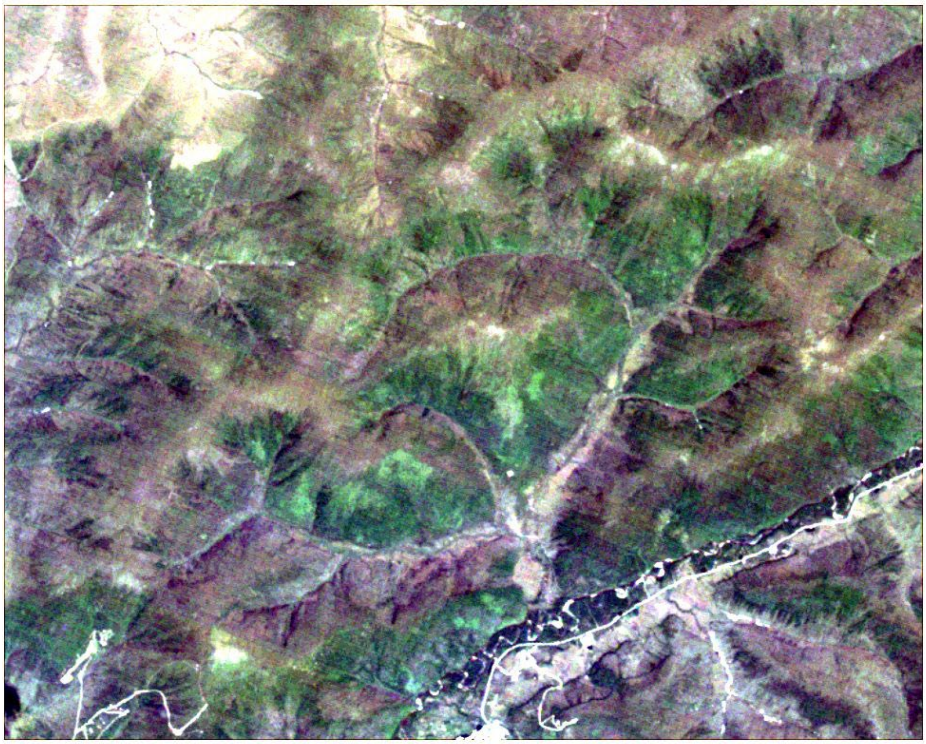


Figure 2: Permafrost temperature records for Interior Alaska



VEGETATION GIVES CLUES TO PERMAFROST LOCATION



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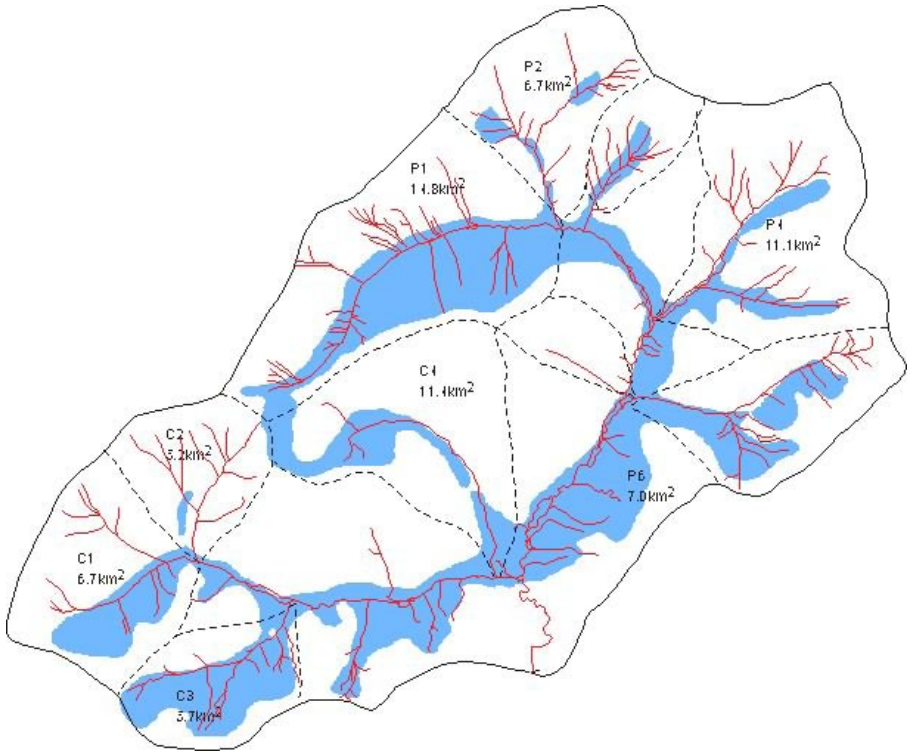

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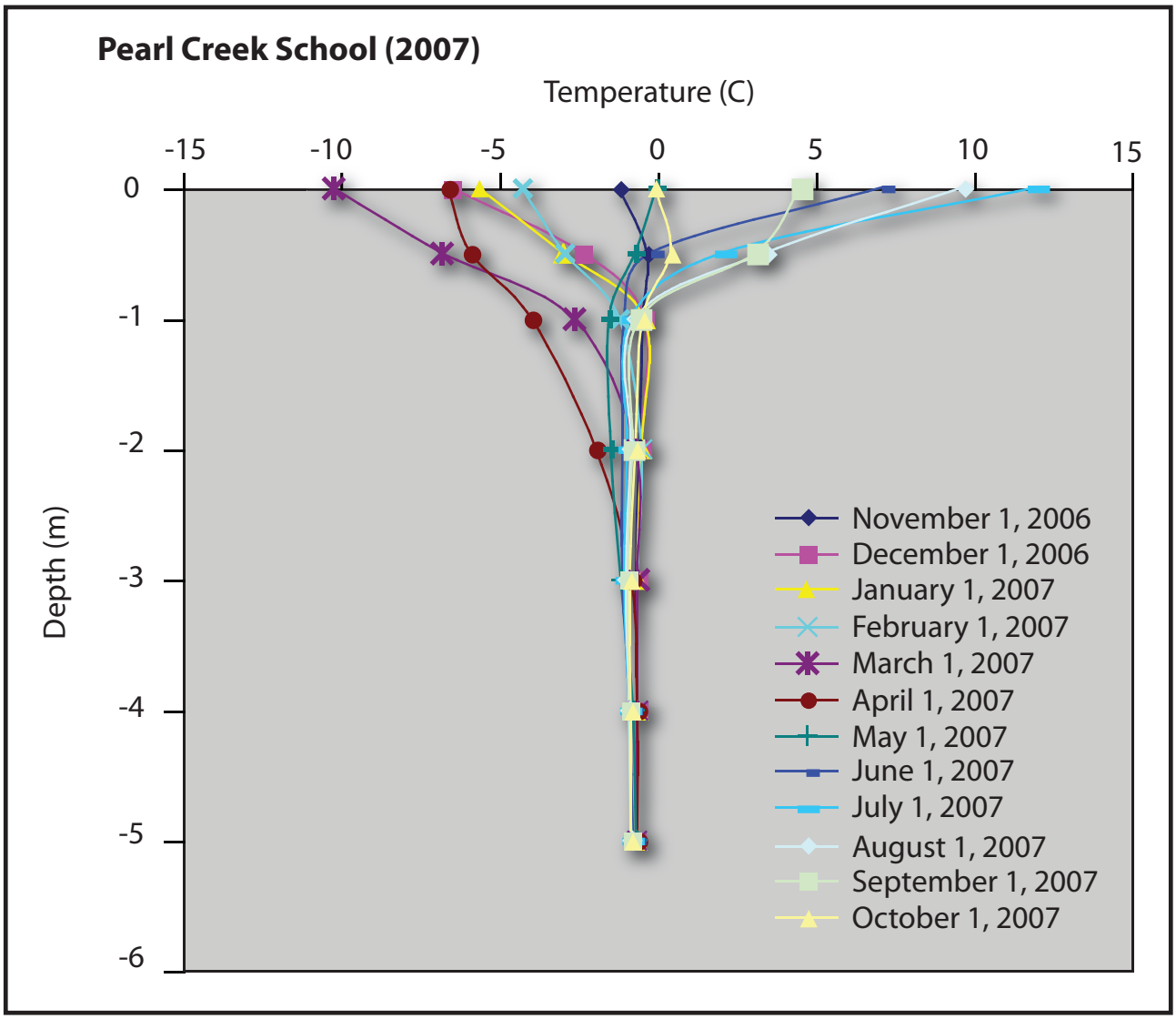
PEARL CREEK SCHOOL
PERMAFROST DATA 2006-2007

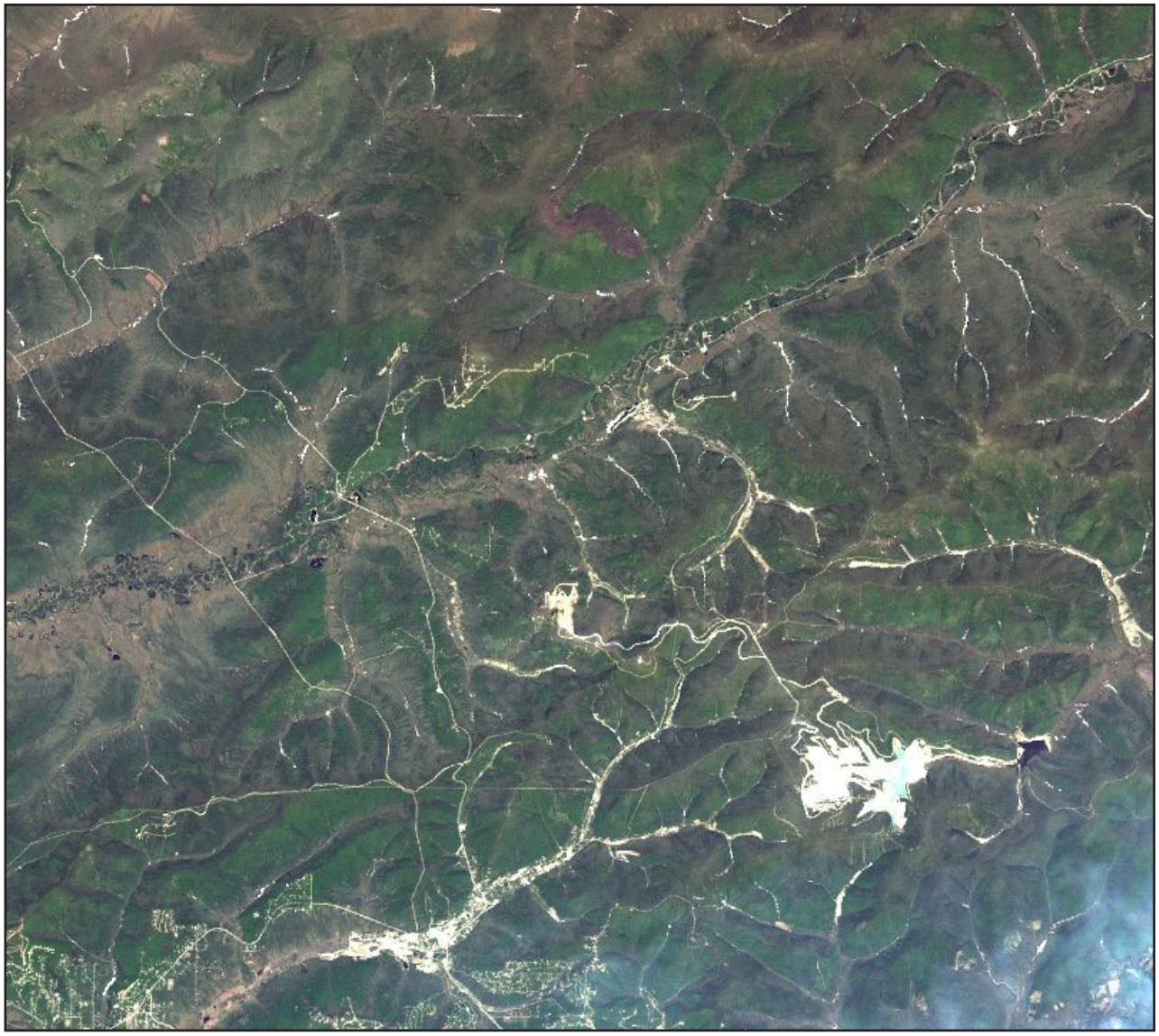


NAME: _____

VEGETATION AND PERMAFROST

Directions: Overlay a sheet of transparency film on top of the image below. Trace the border of the image. In red pen, draw all streams and lakes. In blue, mark the locations of permafrost.

Background Information: Vegetation, or lack of it, is a good indicator of permafrost locations. In Interior Alaska, black spruce trees and areas of little to no vegetation (brown and purple on image) are indicators of soil underlain with permafrost; whereas birch and aspen trees (green on image) are indicators of non-permafrost soil.



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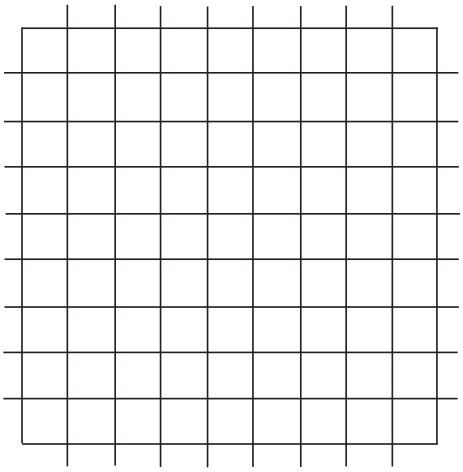
VEGETATION AND PERMAFROST



1. Use a ruler to make grid marks on the transparency overlay. Use centimeters to mark the top and bottom then connect the lines. Do the same on the left and right side to create a grid.

   Mark squares that are mostly permafrost.

   A. How many squares of permafrost ground are there?
   B. How many squares do not have permafrost?
   C. What is the ratio of permafrost to non-permafrost?

Directions: Answer the following questions.

2. Think of the ratio above. Do you think the ratio would change further north or further south of that location? Explain.

_____

_____

_____

_____

3. How do you think permafrost was detected over large areas before satellite imagery?

_____

_____

_____

_____

4. How has the use of satellite imagery improved our knowledge of landscapes and underlying permafrost?

_____

_____

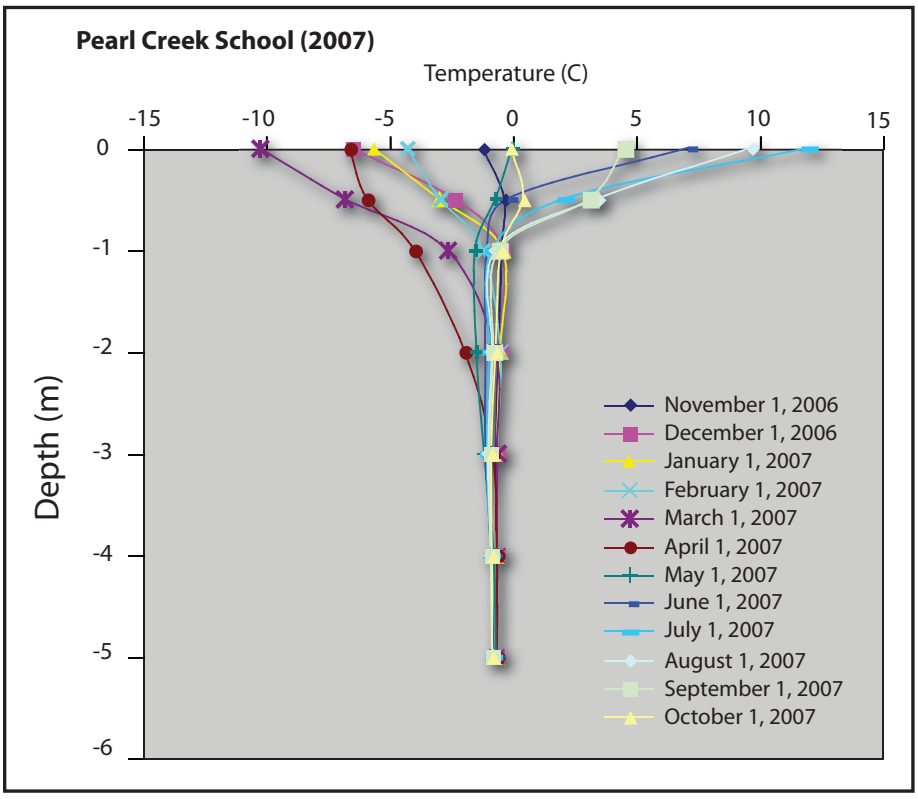
_____

_____

NAME: _____

WHAT DOES THE GRAPH SAY?

Directions: Study the trumpet curve graph below, then answer the questions that follow.



1 m = 3.28 ft

The graph at left represents one year of ground temperature data, from November 1, 2006 to October 1, 2007, taken at Pearl Creek School in Fairbanks, Alaska.

1. What is the temperature range at the surface? _____

2. Write the temperature of the ground 0.5 m below the surface in:
   - A. February _____
   - B. March _____
   - C. April _____
   - D. May _____
   - E. September _____
   - F. October _____

3. Write the temperature of the ground 1 m below the surface in:
   - A. February _____
   - B. March _____
   - C. April _____
   - D. May _____
   - E. September _____
   - F. October _____

4. What is the temperature range at .5 m below the surface? _____

5. What is the temperature range at 1 m below the surface? _____

6. At what depth does the active layer end? _____

7. At what depth does the graph show zero amplitude? _____

NAME: _____

WHAT DOES THE GRAPH SAY?

Directions: Refer to VISUAL AID: "Long-term Permafrost Data," then complete the remaining questions. (NOTE: You will need to refer to a map of Alaska clearly marked with latitude lines.)

8. Refer to your classroom map. What is the range of latitude for the locations of the permafrost data sites listed in Figure 1? _____

9. Refer to a map of Alaska or access Google Earth. What is the range of latitude for the locations of the permafrost data sites listed in Figure 2? _____

10. Look at Figure 1. The sites labeled Deadhorse and West Dock are sites very close to the coast. Franklin Bluffs, Galbraith Lake and Happy Valley are inland. Based on the graph, what are two notable differences between coastal areas and inland areas? Explain.

    A. _____

    _____

    B. _____

    _____

11. Look at Figure 1.

    A. Name the site showing the greatest amount of change: _____

    B. What is the percentage of change? _____

12. Look at Figure 2.

    A. Name the site showing the greatest amount of change: _____

    B. What is the percentage of change? _____

13. Look at the data for Coldfoot. In 1985 the temperature at 15 m depth was about -1.5˚ Celsius. In 2009 the temperature reads about -1.2˚ Celsius. If the permafrost near Coldfoot continues to increase in temperature at the same rate, about how long will it be before the permafrost begins to thaw?

    _____

    _____