

# **FIRE AND FROST: INTERACTIONS OF WILDFIRE AND PERMAFROST**

## **Overview:**

Wild fires burn millions of acres in Alaska every year. Continuous or discontinuous permafrost lies under much of the state. The effects of wild land fire on permafrost can create significant changes in the ecology of the area.

## **Objectives:**

The student will:

- evaluate the cultural significance of wildfires;
- draw the five stages of fire succession; and
- predict potential changes in a typical boreal forest area after a wild fire.

## **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.
- [10] SC3.1 The student demonstrates an understanding that all organisms are linked to each other and their physical environments through the transfer and transformation of matter and energy by relating the carbon cycle to global climate change.
- [10] SD1.2 The student demonstrates an understanding of geochemical cycles by describing their interrelationships (i.e., water cycle, carbon cycle, oxygen cycle).

## **Vocabulary:**

**alter** – to make different without changing into something else

**bedrock** – solid rock that lies beneath the soil and other loose material on Earth's surface

**carbon sink** - a natural or artificial reservoir that accumulates and stores carbon for an indefinite period; permafrost that contains frozen organic material is considered a sink

**cavity-nesting bird** – a bird that lives in a chamber (a hollow space), typically in living or dead wood

**deciduous** – shedding leaves at the end of the growing season and re-growing them at the beginning of the next growing season

**ecosystem** – an ecological community made up of plants, animals and microorganisms together with their environment

**hydrology** – the scientific study of the properties, distribution and effects of water on Earth's surface, in the soil and underlying rocks and in the atmosphere

**insulation** – separation from conducting bodies by means of nonconductors so as to prevent transfer of electricity, heat, or sound

**lichen** – an organism that consists of a fungus and an algae living together in a symbiotic (mutually beneficial) relationship

**lowland/wetland** – a low-lying area of land that is saturated with moisture, especially when regarded as the natural habitat of wildlife

**perennial** – present at all seasons of the year

**sapling** – a young tree

**sedge** – any of a family (Cyperaceae, the sedge family) of usually tufted marsh plants; members of the sedge family have triangular stems (with occasional exceptions), and their leaves are spirally arranged in three ranks (grasses have alternate leaves forming two ranks)

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**silt** – small grains or particles of disintegrated rock, smaller than sand and larger than clay, often found in aeolian (wind blown) deposits

**succession** – the gradual replacement of one type of ecological community by another, involving a series of changes, especially in the vegetation

**terrestrial** – relating to Earth or its inhabitants

**thermokarst** - a geographic area characterized by an irregular land surface, with bogs, pits, and other depressions, formed as ice-rich permafrost thaws

**upland** – ground elevated above the lowlands along rivers or between hills

**vegetation** – plant life or total plant cover (of an area)

### **Whole Picture:**

The interaction of wild fire and permafrost is complex. Effects of fire on permafrost are dependent on vegetation, moisture and fire intensity. Thin permafrost may be thawed by a fire and cause immediate ecological repercussions. Thicker or deeper permafrost may thaw more slowly after insulating vegetation is lost due to fire. Thawing permafrost may result in changes in the ecosystem hydrology depending on the site of the fire. Steeper slopes may result in drying because of increased drainage, while valleys may increase in wetland area and formation of thermokarst lakes as permafrost thaws. Large fires may contribute large quantities of carbon dioxide to the atmosphere and even methane as permafrost thaws. Both greenhouse gases could result in increased air temperatures and subsequent climate change.

### **Materials:**

- Computer access with audio (for Project Jukebox)
- VIDEO: "Fire Succession"
- STUDENT INFORMATION SHEET: "Fire and Frost"
- STUDENT WORKSHEET: "Fire and Frost"
- VISUAL AID: "Fire and Frost"
- VISUAL AID: "Hills and Valleys"

### **Activity Preparation:**

Explore the University of Alaska Project Jukebox Raven's Story site for stories related to wildfire in Alaska. Go to <http://jukebox.uaf.edu/pjweb/pjhome.htm>. Look for the link to **Ravens Story Project Jukebox** (<https://jukebox.uaf.edu/site7/ravenstory>). Click the image on the right to proceed. The following interviews discuss wildfires:

**Huslia:** Lloyd an Amelia DeWilde – Part 2, Numbers 6 and 7

**Koyukuk:** Eliza Jones – Part 1, Number 2

**Galena:** Hazel Strassburg – Number 9

**Galena:** Sidney Huntington – Part 1, Number 5

**Allakaket:** Johnson Moses – Number 4

**Allakaket:** Pollack Simon – Number 11

### **Activity Procedure:**

1. Ask students to share knowledge and experiences about wild fires. Ask about recent fires in the area or the state. Access Raven's Story Project Jukebox (see Activity Preparation) and play two or three clips of Elders talking about fire. Ask students to listen respectfully as though the Elder was in the room. If students have a science journal, have them write the following question and listen for the answer. "How does wildfire impact the community?"



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Does wildfire impact culture?" Students should take notes or draw a picture related to what they hear in the clips. If students don't have a science journal, ask that they write on a blank piece of paper.

2. Show VISUAL AID: "Fire and Frost," page one. Explain wild fires are a part of the natural succession of forestlands. Most fires are started by lightning strikes. Fires help an area "clean up and start over." Lightning strikes in dry areas are responsible for hundreds of fires each summer. Many agencies that track fire data have noted an increase in the number of fires and the amount of land affected. Scientists are watching this trend to see how it may be connected to climate change. (*Warmer temperatures, drier summers contribute to more fires, etc.*)
3. Hand out STUDENT WORKSHEET: "Fire and Frost." Ask students to access the VIDEO: "Fire Succession." The clip shows the succession of a boreal forest after a fire and discusses animal adaptations to fire. Allow students time to review the material, then ask them to complete the worksheet.
4. Show VISUAL AID: "Fire and Frost," page two. Explain fires affect the land and animals that live in an area; they also affect air and water. Ask students if they can determine what has happened in this photo. (*The active layer was likely thin. The fire destroyed the insulating layer and the underlying permafrost became vulnerable to thaw.*)
5. Show VISUAL AID: "Fire and Frost," page three. Divide students into pairs. Hand out STUDENT INFORMATION SHEETS: "Fire and Frost," and STUDENT WORKSHEET: "Fire and Frost." Ask pairs to read the information sheets then complete the worksheet. Students may also refer to the worksheet "Fire and Frost" for help with answers.
6. Discuss the following questions:
  - a. Are recent trends showing an increase or decrease in acreage burned?  
*The trend is toward increasing numbers of acres burned.*
  - b. What type of fire can cause permafrost to degrade?  
*A high intensity fire can cause thin permafrost to degrade.*
  - c. What fire effect may cause long-term permafrost degradation?  
*The loss of insulating vegetation may cause long-term permafrost degradation.*
  - d. What greenhouse gas is released into the air in large quantities during and after a fire?  
*Carbon dioxide is released.*
  - e. What relatively new fire phenomenon are scientists now observing?  
*Tundra fires are becoming more common as temperatures increase and lightning is seen further north than in previous years.*

### Ideas for Filming:

NOTE: Students will complete a short film about permafrost for the final project associated with this UNITE US unit. Each lesson leading to the final project contains ideas about what students might film as they compile clips. Students are not limited to the list and are encouraged to use their imagination and creativity when filming.



If there is a burn area near the community, it provides a great opportunity for student filming. Students could also film interviews with community members, particularly Elders, about fires of the past.

### Answers:

#### STUDENT WORKSHEET: Fire and Frost

1. Black spruce
2. Birch and aspen (leafy, deciduous)
3. Under the valley floor
4. At the bottom of the valley
5. Well drained areas, hills (top, side)

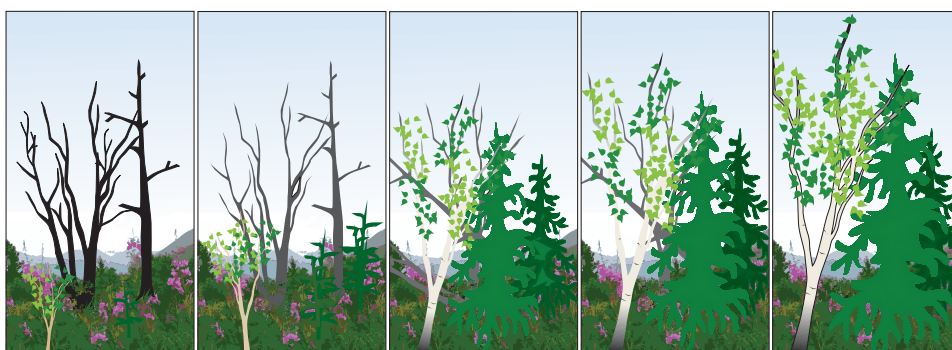


## FIRE AND FROST: INTERACTIONS OF WILDFIRE AND PERMAFROST

6. Responses will vary, but should include information on succession level (herb stage, grasses and sedges), likely erosion on the north facing slope and increased wetlands on valley floor, possibly thermokarst lakes, cavity nesting birds may have nests in the area, bears may be present if berry crops have been replenished, moose may be moving into the area.
7. Responses will vary, but should include succession level, (young forest stage, birch and aspen, shrubs and the beginnings of conifers, particularly on north facing slope,) wetlands on the valley floor will still be present, and possibly thermokarst lakes. Moose will be in the area to feed on shrubs and saplings, beaver may be present in lakes. Bear may be found in the area due to increase in food availability. Grouse will likely be found as well as sparrows. Ducks and geese may be present, especially at nesting time due to increased wetlands.
8. Responses will vary but should include succession level (mature forest stage, much like the area previous to the burn,) moose are less prevalent but caribou may be present, ducks and geese may still be present unless thermokarst lakes and wetlands have drained. Spruce grouse will likely have moved into the area. Porcupine may be present but beaver numbers will likely have decreased.
9. Answers will vary but should include possible long-term effects of initial carbon dioxide emissions on temperature increase.  $\text{CO}_2$  is a greenhouse gas; significant amounts of  $\text{CO}_2$  are emitted during and after a fire. These add to the greenhouse effect and may, over time, contribute to an increase in air temperature.

### STUDENT WORKSHEET: Fire Succession

This is a screen shot of the multimedia students will view. Drawings should indicate similar succession. Answers will vary as students interpret the description but should be in similar ranges:



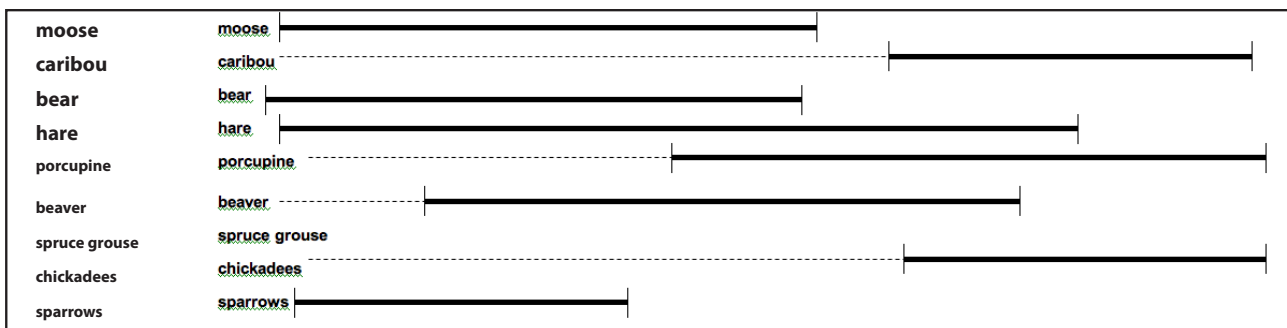
Herb Stage  
(0-5 years)

Shrub Stage  
(6-25 years)

Young Forest Stage  
(26-50 years)

Mature Forest Stage  
(51-150 years)

Climax Forest Stage  
(151-300 years)



## FIRE AND FROST

## STUDENT INFORMATION SHEET (page 1 OF 2)

Wildfires are a part of the natural succession of forests. Fires help an area “clean up and start over.” Lightning strikes in dry areas are responsible for hundreds of fires each summer. Humans generally cause more forest fires than lightning, but lightning fires burn about 90 percent of the total area each year. One reason is that lightning often strikes in remote areas that are hard for fire fighters to reach. Human-caused fires are usually closer to homes and populated areas where they are aggressively fought.

### Some Short-term Effects of Fire

- Fire removes vegetation and blackens soil, so the soil can be warmed by the sun for better plant growth.
- Warming soil increases permafrost thaw.
- Bare, burned soil erodes easily.
- Recent burn areas are good hunting grounds for birds of prey.
- Fire returns nutrients of plants and animals to the soil.
- There is little, if any, food and cover for most wildlife immediately after a fire.
- Food for wildlife and humans is destroyed by fire.
- Burn areas have dead trees (snags) for cavity-nesting birds.

### Some Long-term Effects of Fire

- The shrub stage of a burn area provides abundant cover for small mammals such as mice, which are food for larger mammals such as fox.
- Bare, burned soil erodes easily.
- Some plants, like black spruce, depend on fire to reproduce.
- Fire sometimes helps to prevent insect attacks since it often encourages plant diversity in an area.
- Burn areas have dead trees (snags) for cavity-nesting birds.
- Ash from fires adds to the greenhouse effect.

### What does fire have to do with permafrost?

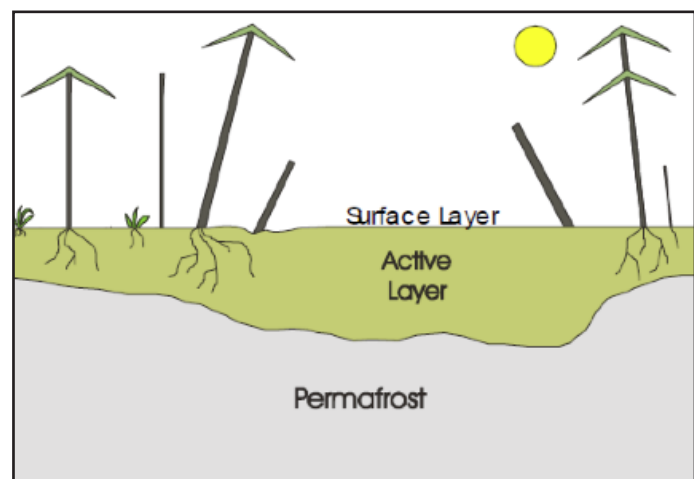
The way fire affects permafrost depends on several factors:

- vegetation
- moisture
- rate (speed) of burning

A rapidly moving fire doesn’t always last long enough to disturb deeper layers of permafrost.

A fire moving through wet surface peat and moss will not destroy all the insulating vegetation, so permafrost may remain undisturbed.

When the surface vegetation is very dry fire burns the layer of insulating material.



## FIRE AND FROST

## STUDENT INFORMATION SHEET (page 2 OF 2)

The surface becomes black and absorbs more heat from the sun. The heat increases on the surface and into the active layer. As the active layer warms, the permafrost layer may begin to thaw. In the discontinuous zone, where many areas of permafrost are thin, a fire can wipe out the permafrost.

This is often the case in areas where wild fire is common. Areas that are well drained with a raised elevation are drier. When a lightning strike starts a fire, it can easily take hold in such conditions. Frequent fires mean permafrost is usually unprotected, therefore cannot remain near the surface.

Areas of low elevation are often not well drained. After a fire disrupts the surface, thawing permafrost can change the hydrology, creating wetlands and ponds.

### Fires, Permafrost and the Carbon Cycle

Fire and the resulting permafrost thaw also impact the carbon cycle and methane emissions. A byproduct of a forest fire is carbon dioxide ( $\text{CO}_2$ ). Permafrost is also considered a carbon “sink.” In other words, permafrost immobilizes the carbon in the frozen organic material, keeping it out of the carbon cycle. When it thaws, it begins to decay and release carbon again. As new plants grow they uptake the excess carbon dioxide, however if the number and intensity of fires increase resulting in excessive permafrost thaw, new vegetation might not handle the load efficiently. More carbon dioxide could end up in the atmosphere, which could impact the greenhouse effect and contribute to climate change.

Even the tree-free Arctic has become more susceptible to dramatic fires. In 2007 the largest tundra fire in recorded history burned near north of the Brooks Range, scorching 1,000 square kilometers of land. Scientists recorded the carbon and energy exchanges between land and atmosphere after the fire and found the blaze itself released 1.9 million metric tons of carbon into the atmosphere. After one year of re-growth the burned tundra continued to emit almost twice as much carbon as unburned land.

If tundra is becoming more susceptible to fire, then fire disturbance could also mean the release of  $\text{CO}_2$  into the atmosphere and that could speed up temperature increase in the Arctic or even globally. Burned tundra is darker, too, and absorbs more solar radiation than undisturbed tundra. That means the permafrost just inches below the surface is susceptible to thaw.

Fire’s interaction with permafrost may have both short and long term impacts on the ecology of the landscape in which it occurs.

NAME: \_\_\_\_\_  
FIRE AND FROST

**Background:** The interaction of fire and permafrost can have both short and long term effects on an area's terrain and ecology. Many of the effects of fire are dependent upon changes in an area's hydrology, which is strongly influenced by permafrost.

**Directions:** Study the VISUAL AID: "Hills and Valleys" displayed by your teacher. The graphic shows terrain common to Interior Alaska. Use a pencil to sketch the graphic in the space below. Include vegetation and sub-surface layers. Draw the compass rose.



Answer the following questions.

1. What type of vegetation is on the north-facing slope? \_\_\_\_\_
2. What type of vegetation is on the south-facing slope? \_\_\_\_\_
3. Where is the largest concentration of permafrost? \_\_\_\_\_
4. Where would runoff from precipitation and snowmelt collect? \_\_\_\_\_
5. What area is likely the most susceptible to fire? \_\_\_\_\_

### Critical Thinking

**Directions:** Refer to VISUAL AID: "Hills and Valleys." Read the following scenario then answer the questions that follow.

A lightning strike started a fire on the north-facing slope of the valley. The fire burned down the north-facing slope, over the valley floor and up the south-facing slope. The fire on the north-facing slope and on the valley floor is of high intensity and burns nearly all the organic layer away. On the south-facing slope the fire jumps around and leaves some areas relatively untouched, some are partially burned at low levels and others are almost completely burned. There is a mosaic of different burn types.

NAME: \_\_\_\_\_  
**FIRE AND FROST**

Consider the fire's short-term and long-term effects on this area. Think about the fire's effect on the permafrost. Consider the effects on plants and animals in the short and long term. Consider the short and long term effects of the fire on global warming, including smoke production and potential release of carbon dioxide.

6. What do you think this area will look like three years after the fire described above?

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7. What do you think this area will look like 40 years year after the fire described above?

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8. What do you think this area will look like 100 years after the fire described above, if there has been no other fire within the hundred years?

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9. What do you think the long term effects of the fire on greenhouse gas emission (carbon) from the area will be?

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**NAME:** \_\_\_\_\_

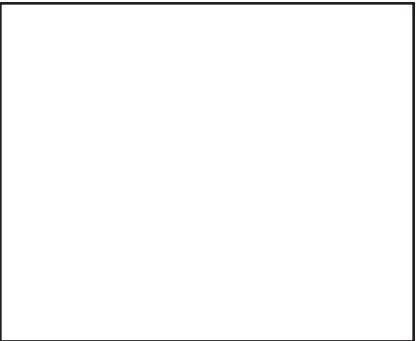
**FIRE SUCCESSION**

**Directions:** Access the multimedia file, "Fire Succession." Review the material then sketch and label the five stages of fire succession of a boreal forest. Note the number of years in each stage. Underneath each one draw a line that indicates the favorite habitat of the animal listed. Two have been done for you.

Stage 1: \_\_\_\_\_



Stage 2: \_\_\_\_\_



Stage 3: \_\_\_\_\_



Stage 4: \_\_\_\_\_



Stage 5: \_\_\_\_\_



moose \_\_\_\_\_

caribou

bear

hare

porcupine

beaver

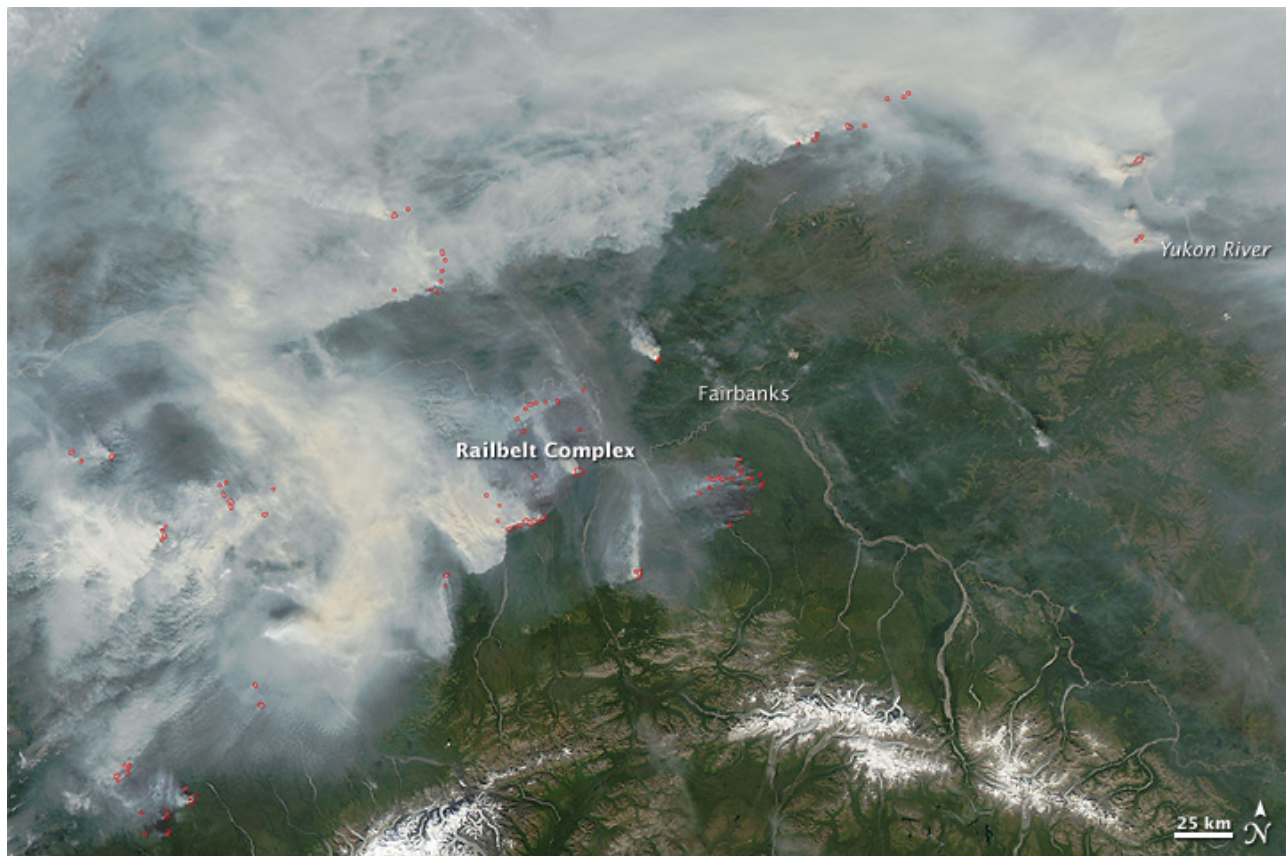
spruce grouse

chickadees

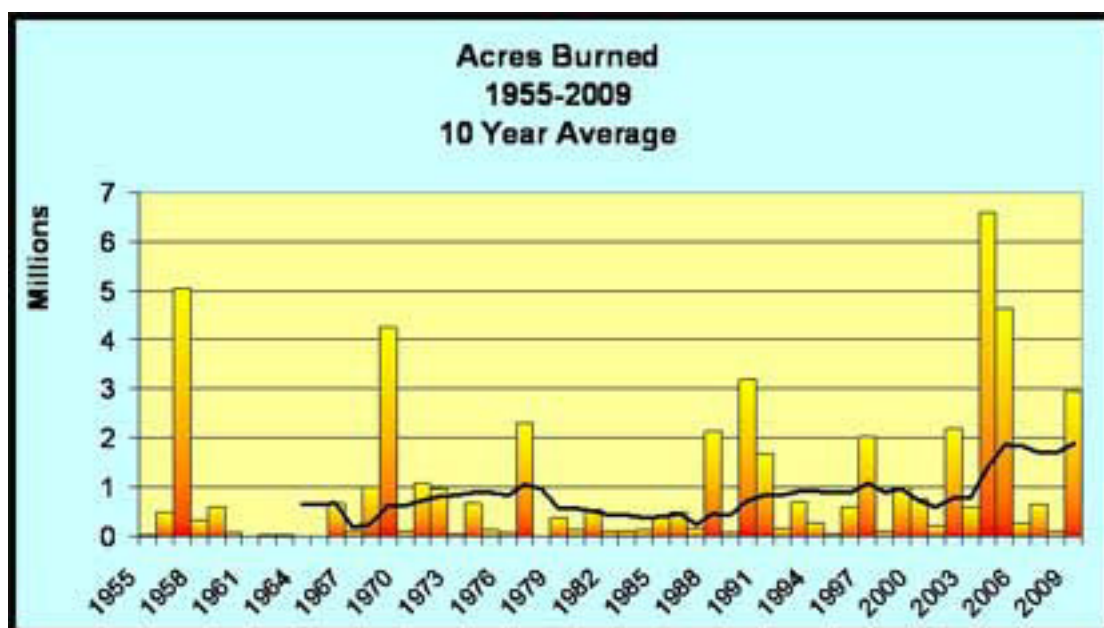
sparrows



## FIRE AND FROST



In 2004, Alaska reported a total of 706 fires that burned 6.6 million acres. In 2005 another 4.6 million acres burned. That is a total of 11 million acres burned in just two seasons! This NASA Earth Observatory photo taken July 3, 2009, shows fires burning in the Interior. Photo courtesy of the Alaska Fire Service.



The graph above shows a trend toward increased acres burned in Alaska over the last half century. Graphic courtesy of Alaska Seasonal Fire Weather/Fire Danger Outlook 2010 AICC Predictive Services.

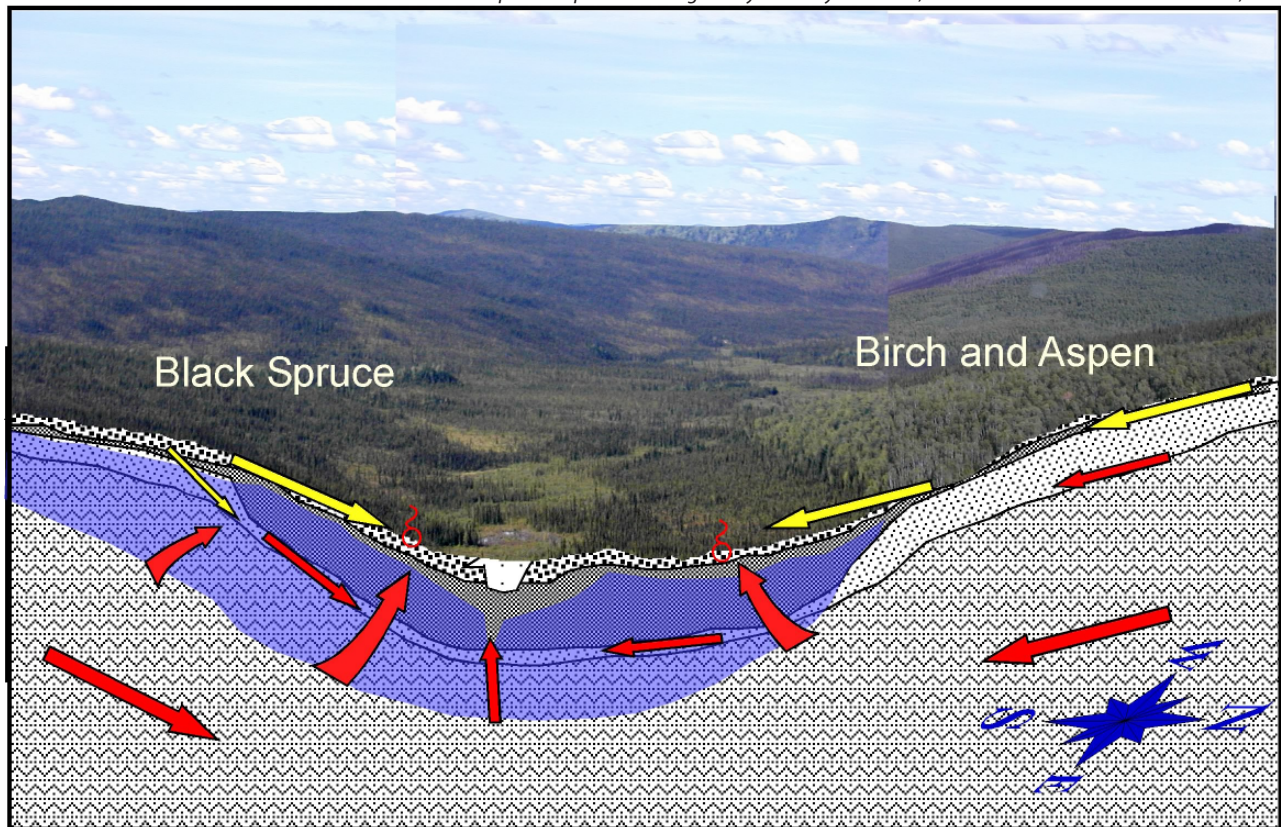












This photo was taken after the Erickson Creek fire along the Dalton Highway, about 60 miles north of Fairbanks. The fire burned for over a month during June and July of 2003. The photo shows permafrost thaw and overland flow over the burned area. Photo by Dr. Merritt Turetsky, University of Guelph, Guelph, Ontario, Canada.

# HILLS AND VALLEYS

Graphic adapted from original by Dr. Larry Hinzman, International Arctic Research Center, UAF



-  Perennial flow
-  Run off
-  Spring
-  Permafrost

-  Organic layer
-  Silt
-  Rocks
-  Bedrock (Schist)