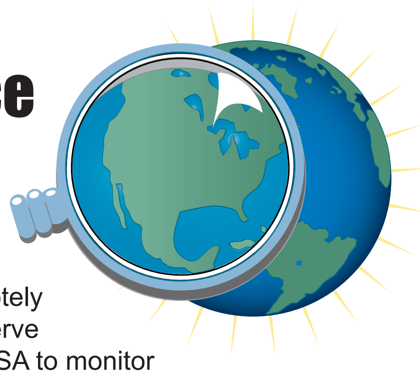
Sensing volcanic effects from space



Investigation Overview

This investigation supplements traditional curriculum materials about volcanoes by focusing on how the effects of volcanic activity can be remotely sensed and monitored. Students observe different types of data gathered by NASA to monitor Mount Spurr in Alaska. By comparing visual data captured in a photograph taken from the Space Shuttle to the remotely sensed signals of the TOMS (Total Ozone Mapping Spectrometer) and AVHRR (Advanced Very High Resolution Radiometer), students begin to see relationships between volcanic eruptions and the global environment. Specifically, students use data to determine if a correlation exists between aerosols and atmospheric temperature. The investigation reinforces graphic skills and evaluation skills.

Time required: Two 45-minute sessions

Materials/Resources

Log (one per student)
Figure 1: Locator map of Mount Spurr in Alaska
Color copies of the following images, or computer access for student groups of two or three:
- Figure 2: Handheld Space Shuttle photograph of Mt. Spurr, 1992 eruption
- Figure 3: AVHRR image of Mount Spurr, 1992 eruption
- Figure 4: TOMS image of Mount Spurr, 1992 eruption
- Figure 5: AVHRR with transect, August 19, 1992
- Figure 6: TOMS aerosol index with transect, August 19, 1992
- Figures 7 and 8: AVHRR image of Mount Spurr aerosol cloud

Ruler (one per student)
World map

Content Preview

Volcanoes provide clues, or *signals,* that help predict their behavior and effects. The focus of this investigation is to identify ways to measure the signals given off by volcanoes. NASA uses a variety of sensors to monitor volcanic signals in order to identify local and global environmental impacts.

In this investigation, three types of figures are used: hand-held Space Shuttle photography, TOMS images, and AVHRR images. The Space Shuttle photo shows the scene as an astronaut saw it from the Space Shuttle. The TOMS instrument measures the amount of aerosol particles in the atmosphere. The AVHRR instrument measures atmospheric temperature. The AVHRR images used in this activity have been processed to highlight the Mount Spurr volcanic ash cloud by comparing the temperature of the ash cloud with that of the surrounding clouds, land, and water. The aerosols produced by volcanic eruptions can be easily detected by AVHRR

Geography Standards

Standard 1: The World in Spatial Terms

How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective

- Evaluate the relative merits of maps and other geographic representations, tools, and technologies in terms of their value in solving geographic problems.

Standard 3: The World in Spatial Terms

How to analyze the spatial organization of people, places, and environments on Earth's surface

- Analyze and explain distributions of physical and human phenomena with respect to spatial patterns, arrangements, and associations.

Standard 7: Physical Systems

The physical processes that shape the patterns of Earth's surface

- Predict the consequences of a specific physical process operating on Earth's surface.

Geography Skills

Skill Set 3: Organize Geographic Information

- Prepare various forms of graphs to organize and display geographic information.

Skill Set 4: Analyze Geographic Information

- Interpret information obtained from maps, aerial photographs, satellite-produced images, and geographic information systems.

because they are significantly hotter than the surrounding clouds and atmosphere.

Classroom Procedures

Beginning the Investigation

1. Introduce the investigation by explaining to students that geographers are interested in learning about changes caused by volcanoes at different scales, from the local effects (*immediately adjacent to volcanoes*) to the global effects (*e.g., world atmospheric conditions*).

2. Have students discuss what they already know about volcanoes and their local to global effects. You may want to prompt them by discussing well-known volcanic eruptions in history (Pompeii, Krakatoa) or any current eruptions. List their ideas on the board.

   - Students will probably be well acquainted with local effects, such as lava and debris flow, ash clouds, and disruption and destruction of plant and animal life. They will likely be less aware of the impact volcanic eruptions can have on the entire Earth system, particularly on global climate patterns. **Investigation 1** provides information on more local environmental effects.

3. Explain that the purpose of this investigation is to study volcanoes through the *signals* they send. NASA is interested in monitoring these signals to understand more about volcanoes and their effects on people and the environment. In this investigation, students use current NASA technologies to monitor volcanoes while learning about the global impacts of volcanic aerosols.

4. Explain that not all volcanoes are alike; there are three distinct types of volcanoes (stratovolcanoes or composite, shield, cinder cone—see bottom of page 4 for further explanations). This module concentrates on composite volcanoes, which erupt and are built differently than cinder cones or shield volcanoes. Other review information you may wish to share with students appears in a graphic in the **Background**. Ensure that students understand that this investigation deals with composite volcanoes, which tend to behave more explosively—what students might consider a "typical" volcanic eruption.

Developing the Investigation

5. Guide students to understand that geographers and vulcanologists study volcanoes through a variety of means. Various sources provide different insights into the processes and effects of volcanoes because they provide information at different geographic scales, from the local to the global.

   Ask students to return to the list of effects of volcanic eruptions and identify how such phenomena could be monitored and evaluated. For example, if a volcano were releasing steam, personal observation would be one way to monitor that. Example responses may include:
   - personal observation—CVO (Cascade Volcano Observatory), AVO (Alaska Volcano Observatory), USGS
   - aerial photographs to observe changes in a region
   - GPS (global positioning systems) to mark positions and observe changes over time, and monitor for earthquakes <http://www.scign.org/>
   - tiltmeters to detect the movement of lava underground
   - lasers to detect micro-movements of the Earth's surface; can signal earthquakes and movement of magma
   - satellite images to study the atmospheric effects of volcanoes around the globe, in addition to observing changes in the local landscape

6. Display **Figure 1: Locator map of Mount Spurr in Alaska**, and use a world map to make sure students know the absolute and relative location of Mount Spurr.

7. Arrange students in small groups. Distribute **Figures 2, 3,** and **4** one image at a time, and ask students to analyze each.

   Figure 2: Handheld Space Shuttle photograph of Mount Spurr, 1992 eruption
   - Ask students how they might distinguish an ash cloud from a "regular" meteorological cloud. (*Whitish clouds are water vapor clouds. The darkish cloud streaming from the lower right corner of the figure is an ash cloud.*)
   - Ask students if they can tell the direction the plume is traveling. Call attention to the concentration of the ash. A darker color indicates the part of the cloud closest to the source. Concentration dissipates as it moves farther away. (*The cloud is moving "toward" the horizon.*)

   Figure 3: AVHRR (Advanced Very High Resolution Radiometer) image of Mount Spurr, 1992 eruption
   - Ask students to study the title, scale, and legend on the figure to focus on what this sensor measures. (*The AVHRR image shows tempera-*

ture difference in degrees. This means that the scale shows how many degrees the plume varies from the surrounding air, land, or water.)

Figure 4: TOMS (Total Ozone Mapping Spectrometer) image of Mount Spurr, 1992 eruption

- Ask students to study the title, scale, and legend on the figure to focus on what this sensor measures. (*The TOMS image shows the amount of aerosols sensed in the atmosphere. The scale index shows aerosol concentration. The similarities between the two scales are coincidental. The gray areas on the images represent a layer of clouds that were detected below the ash plume.*)

- Students should also observe the differences in resolution or detail available on each image. Ask students which figure provides the greatest amount of detail. (*Figure 3: AVHRR image of Mount Spurr, 1992 eruption.*)

8. Distribute the **Log** and ask students to summarize and report their observations in the Log. The Space Shuttle photograph provides an aerial view of the eruption as seen from space. The TOMS data show the concentration of aerosol particles (bits of ash or other tiny particles) in the atmosphere released by the volcano. The AVHRR senses temperature differences between the ash cloud and the surrounding air or underlying land or water.

9. Distribute **Figure 5: AVHRR with transect, August 19, 1992; and Figure 6: TOMS aerosol index with transect, August 19, 1992**. Explain that this is an opportunity to look for a *correlation* or relationship between two types of data. Ask students to hypothesize about the relationship between volcanic aerosols and temperature based on the images.

10. To determine the relationship between aerosols and temperature, students graph the transect (the white straight line) angled across each image to make a profile (side view) of aerosols and temperature. To do this:

    A. Fold a piece of paper in half.
    B. Using rulers, make tick marks along the folded edge for 8 centimeters. The marks should be in 0.5 centimeter increments.
    C. Then, line the folded paper up along the white transect line in Figure 5, with the end tick mark starting at Mount Spurr.
    D. Transfer the image data to the folded paper using the scale. For example, if the image were yellow at a particular tick mark, the student would record an 8 for that point of the transect.
    E. Then, transfer data from each tick mark on the folded paper to the Log graph.
    F. Complete the graph by connecting the dots to make a line graph. The resulting graph represents temperature differences within the plume as it moves away from Mount Spurr.
    G. Repeat the process with Figure 6.

11. After students have created the two profiles, ask them to explain the connection between aerosols and temperature difference using their graphs as illustrations. Students may use their rulers to compare the points in each graph. Ask:
    - Do the graphs rise and fall at the same points? (*Yes, they show the same general trend.*)
    - Are the variations *exactly* the same? (*No, the lines do not match up exactly.*)
    - What might explain the slight differences? (*Possible reasons: variations in students' assigning numbers to the images; the resolution of the two images varies so the TOMS image may have more generalizations; the correlation is not exact because other factors besides the concentration of aerosols affect temperature.*)
    - Is there a correlation or relationship between the temperature difference and the concentration of volcanic ash? (*Students should recognize that although there may be variations and the lines do not match exactly, the general trends of the lines suggest a link between the quantity of volcanic aerosols and temperature difference.*)

Concluding the Investigation

12. Discuss with the class the connection between temperature and the presence of a volcanic ash cloud. Students should now be aware that volcanic ash does affect the temperature of the air. This occurs because the aerosol particles absorb radiation from Earth and reflect solar radiation. This disruption of the radiation balance can last two to three years after the volcanic eruption.

13. Distribute **Figure 7.** Ask students to predict the changes that will occur along the path of Mount Spurr's ash plume and record their predictions in the Log. (*Students should suggest that aerosols will become less dense with distance from the volcano.*)

14. **Figure 8** shows the trail of a second ash plume from Mount Spurr, recorded one month later. Ask

students to speculate about the effects of ash cloud movement occurring regularly across the globe. (*Students should mention possible effects on atmospheric temperatures.*)

15. Scientists measure signals using various sensors designed for specific purposes, but sometimes comparing signals provides even more information. Ask students to explain how scientists who are studying the effects of volcanoes on the global climate system can benefit from exploring the relationships between different types of signals.

Background

Aerosols are very small particles suspended in the atmosphere. They scatter and absorb sunlight, affecting Earth's temperatures. In large quantities, such as volcanic ash clouds, aerosols can damage aircraft (the focus of **Investigation 3**). Some aerosols enable chemical reactions that influence stratospheric ozone, thus producing a long-term environmental effect. A well-known example is 1816, "The Year without a Summer," when the northern hemisphere, particularly New England, experienced record-breaking cold temperatures as a result of aerosols produced by Tambora, an Indonesian volcano. See <http://www.mountwashington.org/notebook/transcripts/1999/06/index.html> for additional information.

Aerosols also influence rainfall, which is another global consequence of volcanism, as well as dust-producing human activities, such as forest burning. The damage volcanoes inflict on humans and the environment is detected and measured through remote sensing. For more information, see <http://eospso.gsfc.nasa.gov/NASA_FACTS/volcanoes/volcano.html>.

For additional information on the TOMS or AVHRR sensors, see the **Sensors Glossary**.

Related NASA Resources

http://earthobservatory.nasa.gov/Study/Volcano DAAC feature on volcanoes and climate change

Related Resources

http://www.gi.alaska.edu/remsense/features/comparativeavhrr.htm This site explains how AVHRR image data is processed. Uses four images of Mount Spurr eruption as an example showing how different processing options produce different results.

http://www.geo.mtu.edu/volcanoes/research/avhrr/images/spurr This site provides individual images that went into the composite images in Figures 7 and 8.

http://vulcan.wr.usgs.gov/Glossary/framework.html

http://vulcan.wr.usgs.gov/Glossary/volcano_terminology.html

http://www.avo.alaska.edu/avo3/atlas/atlindex.htm Alaskan Volcano Observatory, outstanding images and text about all volcanoes in Alaska, the Aleutian Islands, and Kamchatka Peninsula. Regional and local maps. Images of volcanoes, their eruptions, and the effects on the nearby human populations.

	Shield	Composite/ Stratovolcanoes	Cinder Cones
Formation/ Location	Massive fluid lava flows and slowly builds up a gently sloping volcanic shape.	Built from both explosive eruptions and quieter eruptions. Layers of tephra (ash, cinders, and other material blown into the air) alternate with layers of lava to create steep-sided, often symmetrical cones.	Made primarily from explosive eruptions of lava. Blown into the air, the erupting lava breaks apart into the small fragments known as cinders. The fallen cinders accumulate into a cone around the volcano's central vent (the "hole in the ground" from which the lava emerged).
Location	Primarily located along tectonic spreading centers or at "hot spots."	Primarily located along tectonic subduction zones, where two plates of the Earth are slowly colliding.	Not associated with any particular tectonic activity. Some are found near current tectonic boundaries, and others found near old boundaries.
Examples	Kilauea, Mauna Loa (Hawaii)	Mt. Fuji (Japan), Mt. St. Helens (Washington)	Sunset Crater (Arizona), Capulin Mountain (New Mexico)

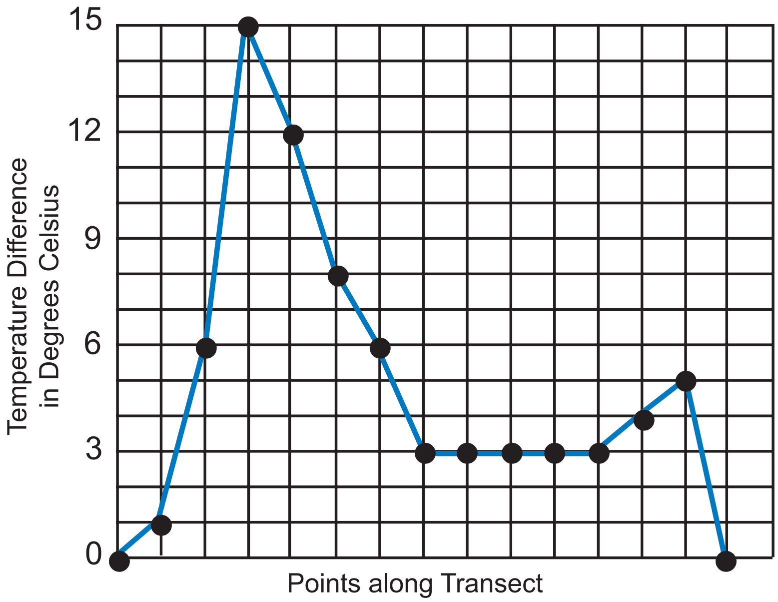
Evaluation

Log

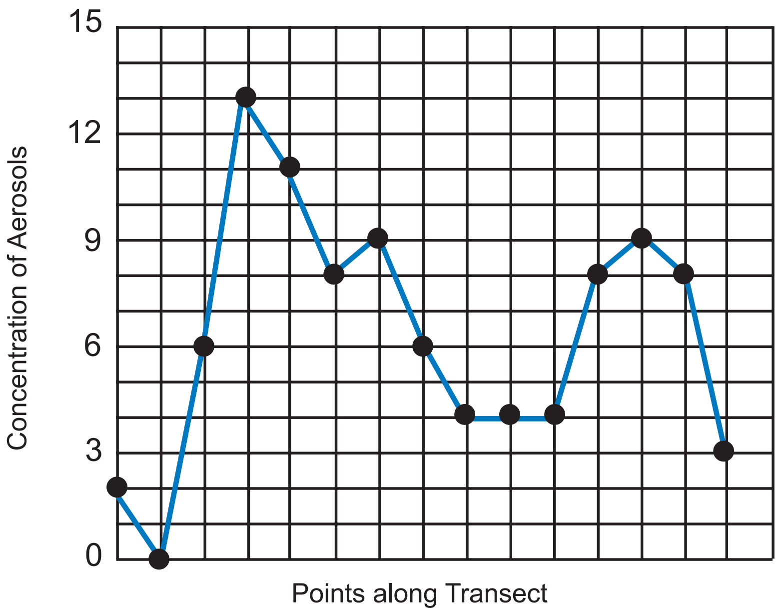
1. Space Shuttle Photo: provides visual data
   AVHRR: provides temperature data
   TOMS: provides data on the concentration of aerosols

2. Graphs

Post-Eruption Temperature along Transect, Mount Spurr, 1992



Post-Eruption Aerosol Concentrations along Transect, Mount Spurr, 1992



3. There is a relationship between the level of aerosols and the temperature of the air. When one line goes up or down, the other generally does the same.

4. Changes in air temperature are expected as the aerosol plume travels around the globe.

5. The August cloud moved more slowly and stayed more concentrated to the west. The September cloud advanced more quickly across Canada and the northern United States. The plume was also more spread out, affecting a larger geographic area in the same number of days.

6. Using multiple sources of data is important because 1) it reveals connections between phenomena; in this case, the full effect of the ash cloud is not clear until a comparison of all available data is reviewed; and 2) it prevents scientists from drawing hasty conclusions.

Module 1, Investigation 2: Log
Sensing volcanic effects from space

Background
Volcanoes are extremely disruptive and destructive to the environment and to the people who live nearby. They may disrupt the entire Earth system. How? Aerosols are tiny particles of dust and ash thrown from volcanoes during eruptions. Clouds of aerosols have far-reaching, Earth-wide impact when they are carried all around the globe by winds. NASA monitors volcanoes using remote sensors mounted on satellites and through other means. In this investigation, you use data from three types of sensors to learn the effect Mount Spurr in Alaska has on the environment.

Objectives
In this investigation, you will:
1. read and interpret information from different types of images,
2. create a profile (line) graph of aerosols and temperature differences from Mount Spurr to look for a correlation,
3. summarize the need for data from a variety of sources, and
4. predict the continued effects of volcanic ash movement.

Procedures for the Investigation
1. There are many ways that NASA monitors volcanoes and the effects of eruptions. Below are three types of instruments used to observe the eruption of Mount Spurr in Alaska. Observe each image carefully and list what you see in each one.

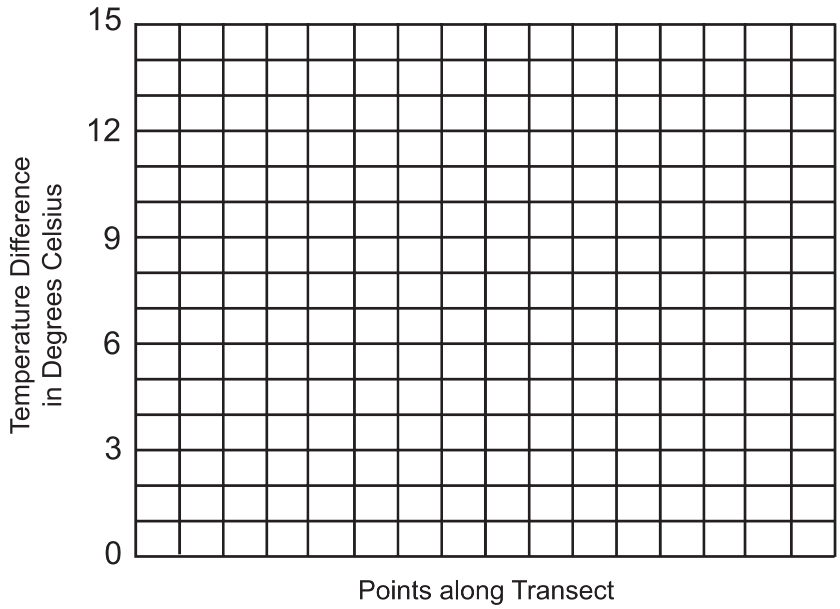
Source	Observations
Figure 2: Space Shuttle photograph	
Figure 3: AVHRR (Advanced Very High Resolution Radiometer) image	
Figure 4: TOMS (Total Ozone Mapping Spectrometer) image	

2. Testing for a correlation:
   Make two graphs of the data supplied by AVHRR and TOMS in Figure 5: AVHRR with transect, August 19, 1992 and Figure 6: TOMS aerosol index with transect, August 19, 1992. Use the numbers along the transect (the line that bisects the image) to create the profile.
   A. Fold a piece of paper in half.
   B. With a ruler, make marks along the folded edge every 0.5 centimeters for 8 centimeters.
   C. Line up the folded paper with the white transect lines in Figure 5 with the first mark at Mount Spurr (the white dot).
   D. Starting at the white dot, transfer the information from the image onto the folded paper using the color scale. For example, if the image is orange at a particular tick mark, record 9 for that segment.
   E. Be sure to check the title of the graphs to record the correct data for each. Then lay the folded paper with the marks along the horizontal edge or bottom of the top graph "Post-Eruption Temperature along Transect, Mt. Spurr, 1992." Transfer the data to the graph by placing a dot for each 0.5 centimeter mark on the number that represents the color on the image. (If the increment on the image is orange, then you would go up to the 9 and make a dot.)
   F. Connect the dots to create a profile. Repeat the process with Figure 6, beginning with Step A.

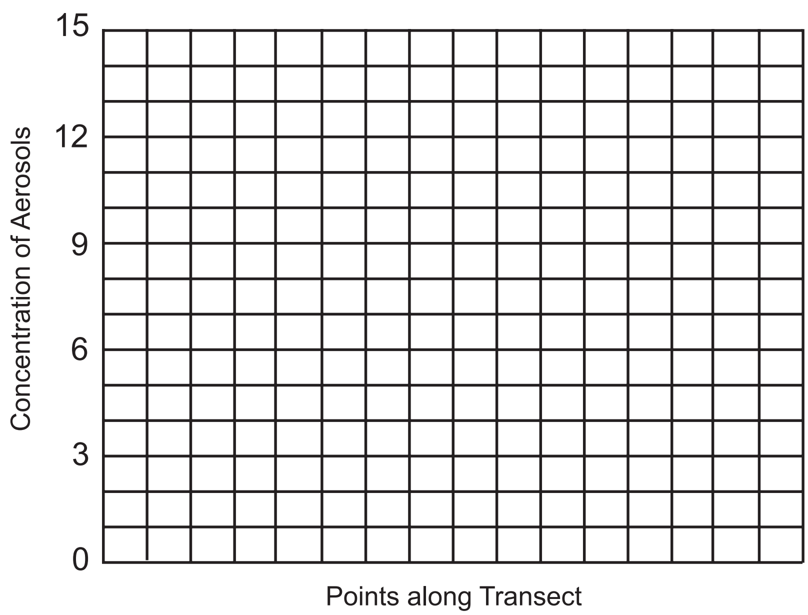
Module 1, Investigation 2: Log

Sensing volcanic effects from space

Post-Eruption Temperature along Transect, Mt. Spurr, 1992



Post-Eruption Aerosol Concentrations along Transect, Mt. Spurr, 1992



Module 1, Investigation 2: Log

Sensing volcanic effects from space

3. Compare the two graphs. Describe the relationship between the two lines.

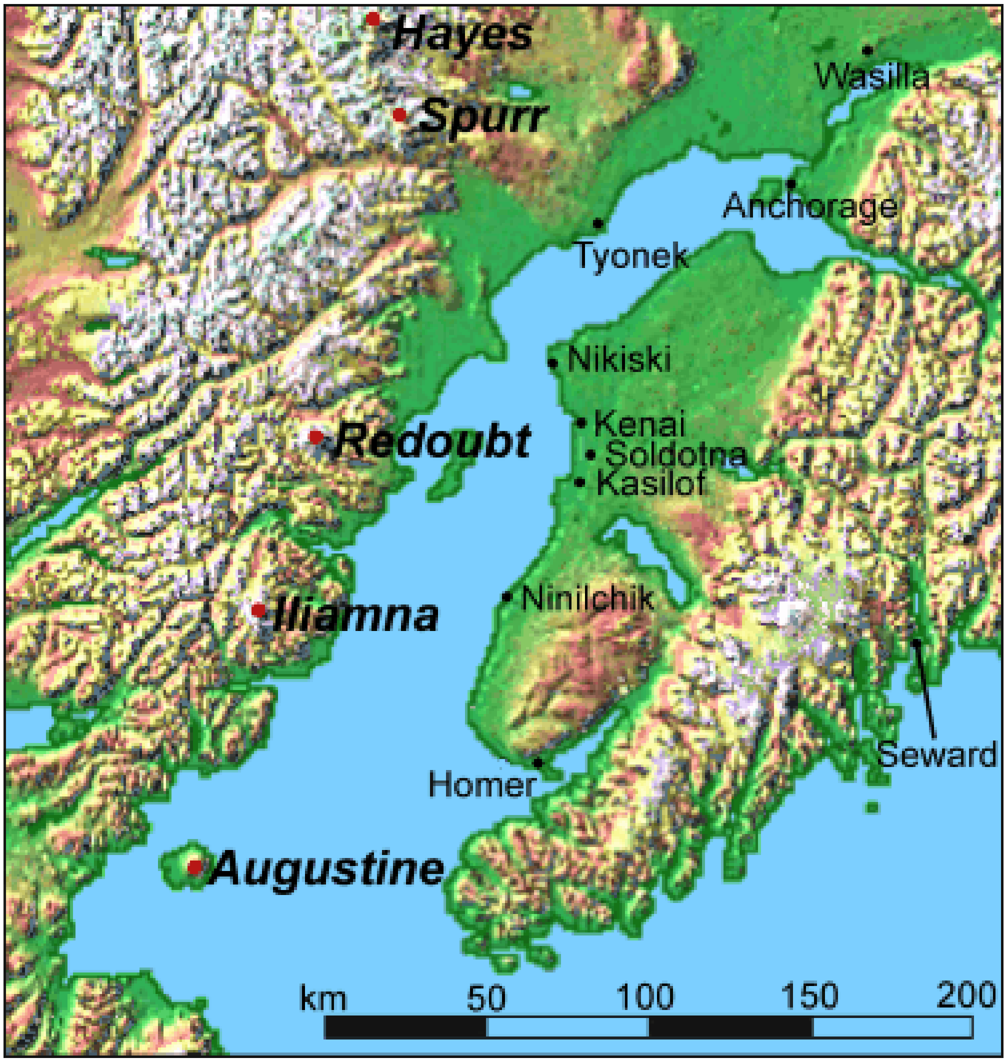
4. Look at Figure 7. Predict the changes that probably occurred along the path of Mount Spurr's ash cloud in August 1992.

5. Figure 8 shows the movement of an aerosol cloud from Mt. Spurr's eruption in September 1992. How did this cloud travel differently than the cloud one month earlier?

6. Explain how scientists who are studying the effects of volcanoes can benefit from exploring the relationships between different types of signals.

Module 1, Investigation 2: Figure 1

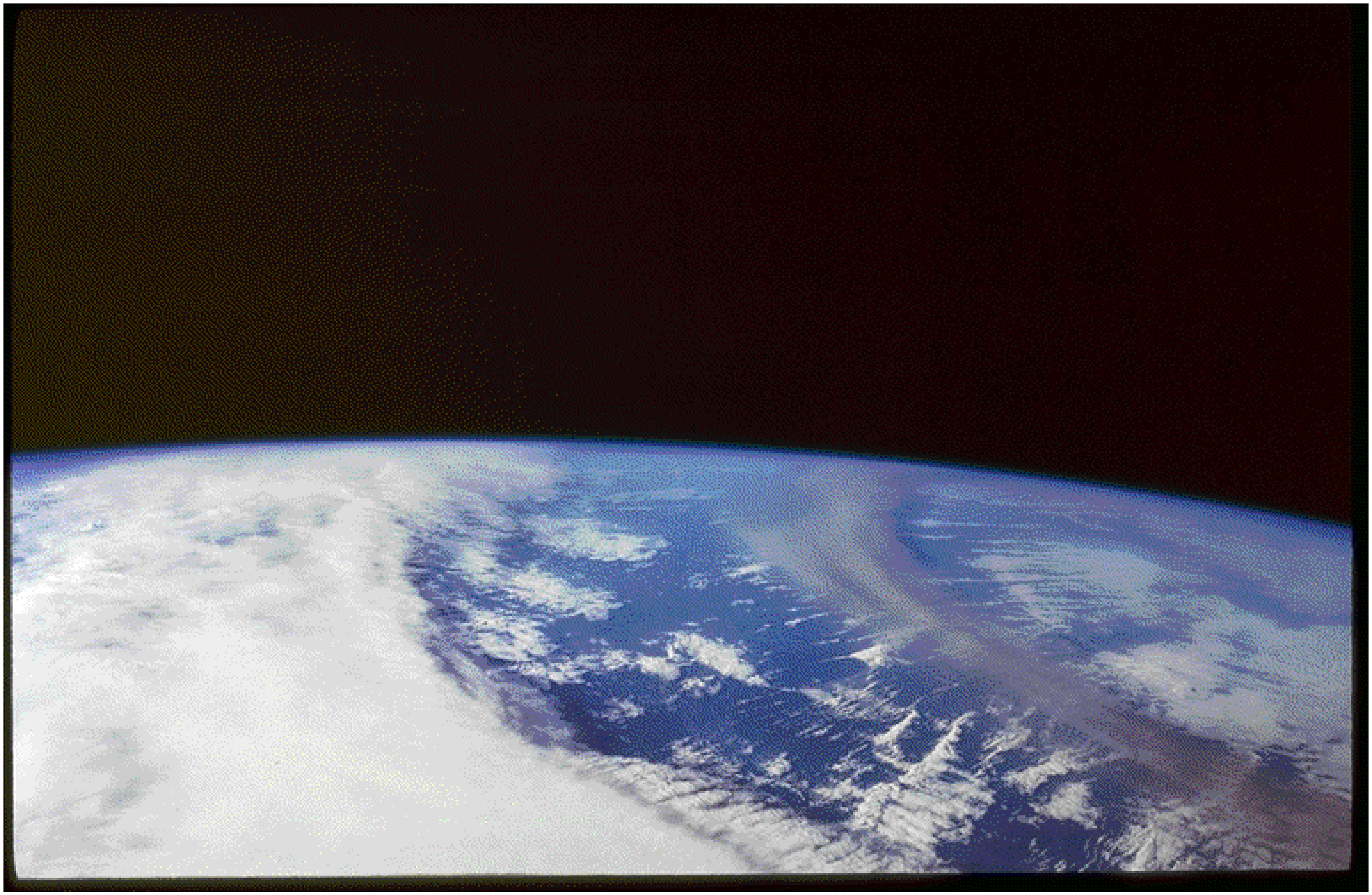
Locator map of Mount Spurr in Alaska



Source: http://www.avo.alaska.edu/avo3/atlas/cookmain.htm

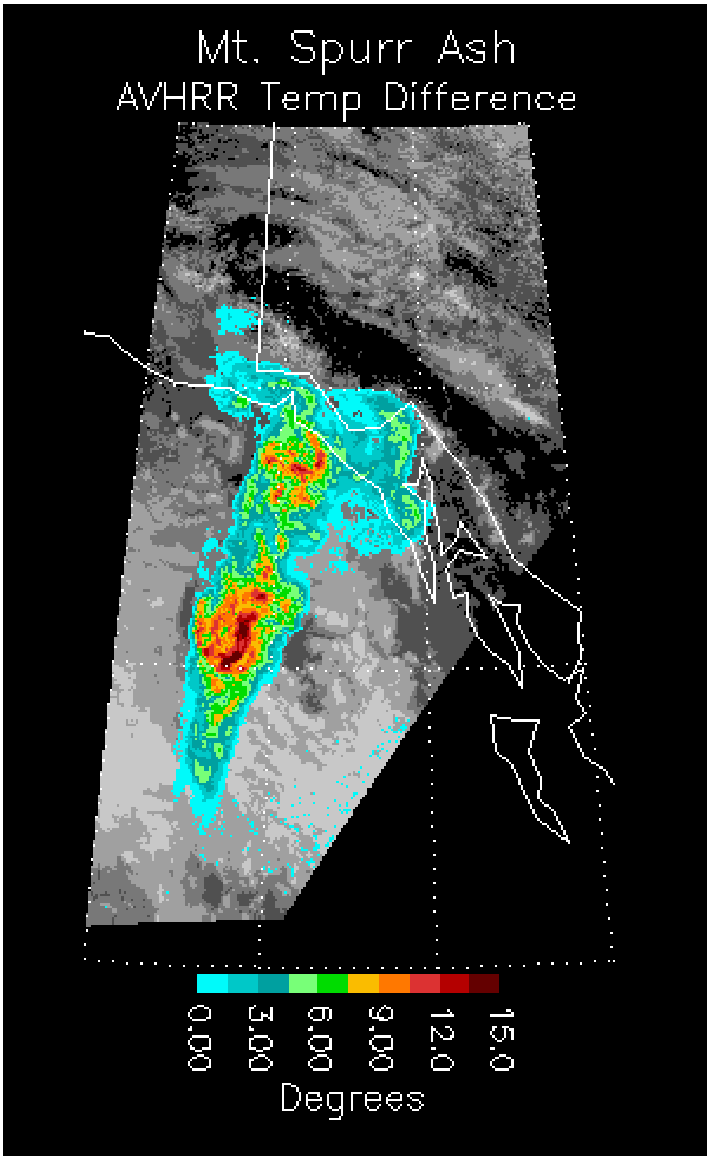
Module 1, Investigation 2: Figure 2

Handheld Space Shuttle photograph of Mount Spurr, 1992 eruption



Module 1, Investigation 2: Figure 3

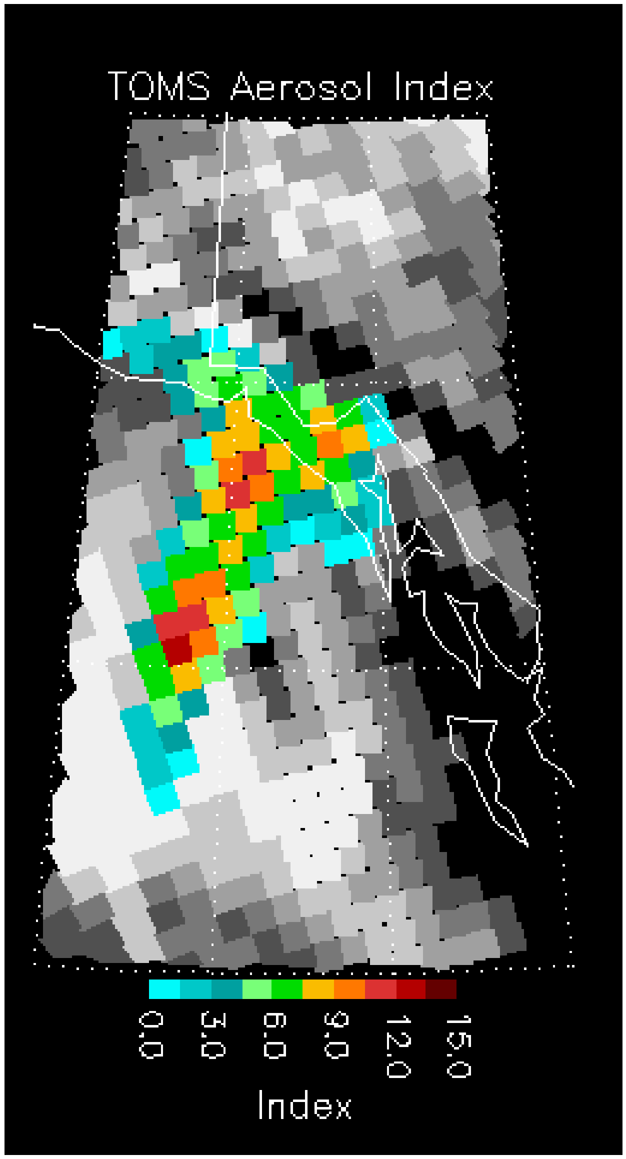
AVHRR image of Mount Spurr, 1992 eruption



AVHRR (Advanced Very High Resolution Radiometer) image of Mount Spurr 1992 eruption, taken August 19, 1992 (degrees in Celsius)

Source: http://jwocky.gsfc.nasa.gov/aerosols/tomsavhrr.html

Module 1, Investigation 2: Figure 4
TOMS image of Mount Spurr, 1992 eruption

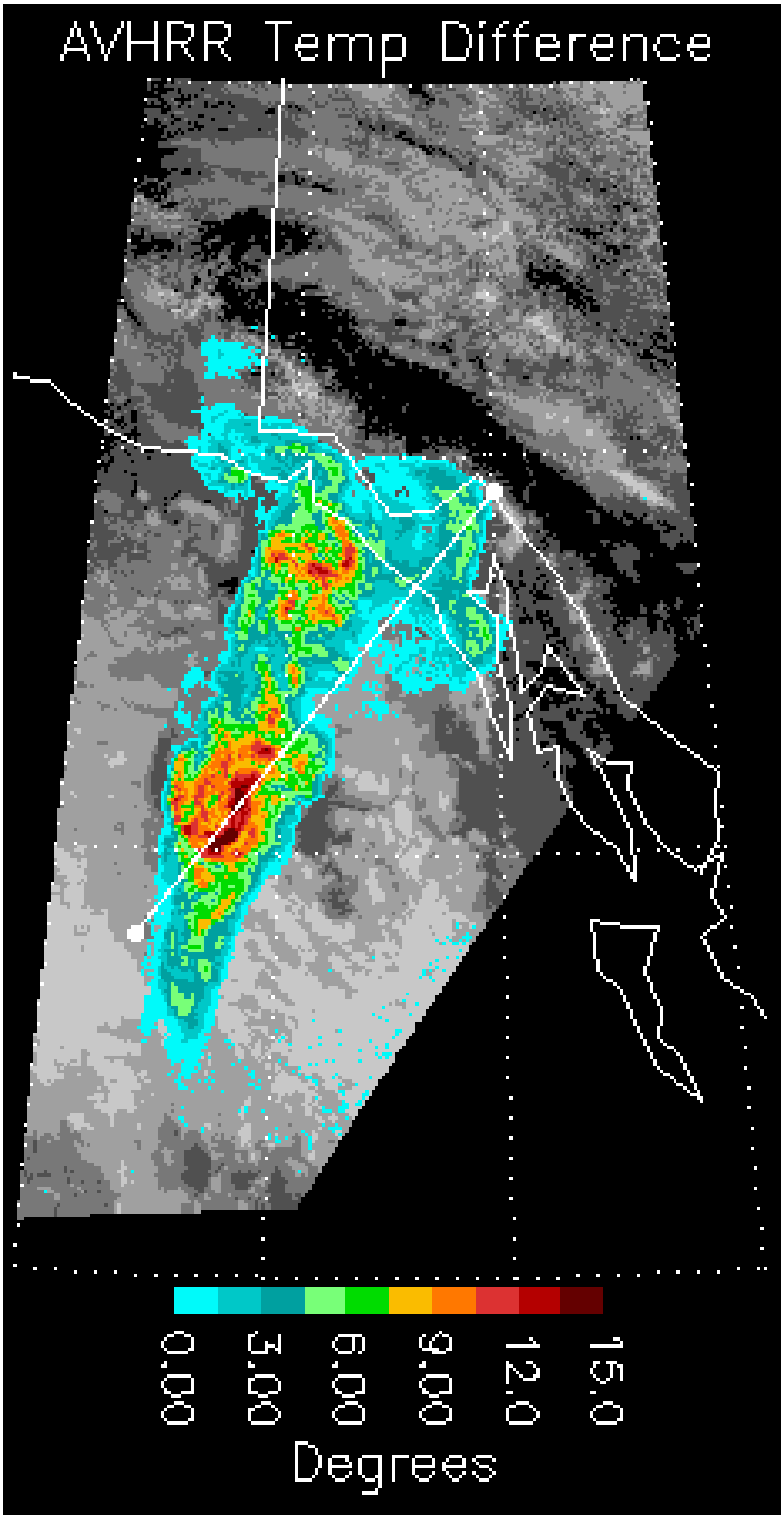


TOMS (Total Ozone Mapping Spectrometer)
image of Mount Spurr 1992 eruption, taken August 19, 1992

Source: http://jwocky.gsfc.nasa.gov/aerosols/tomsavhrr.html

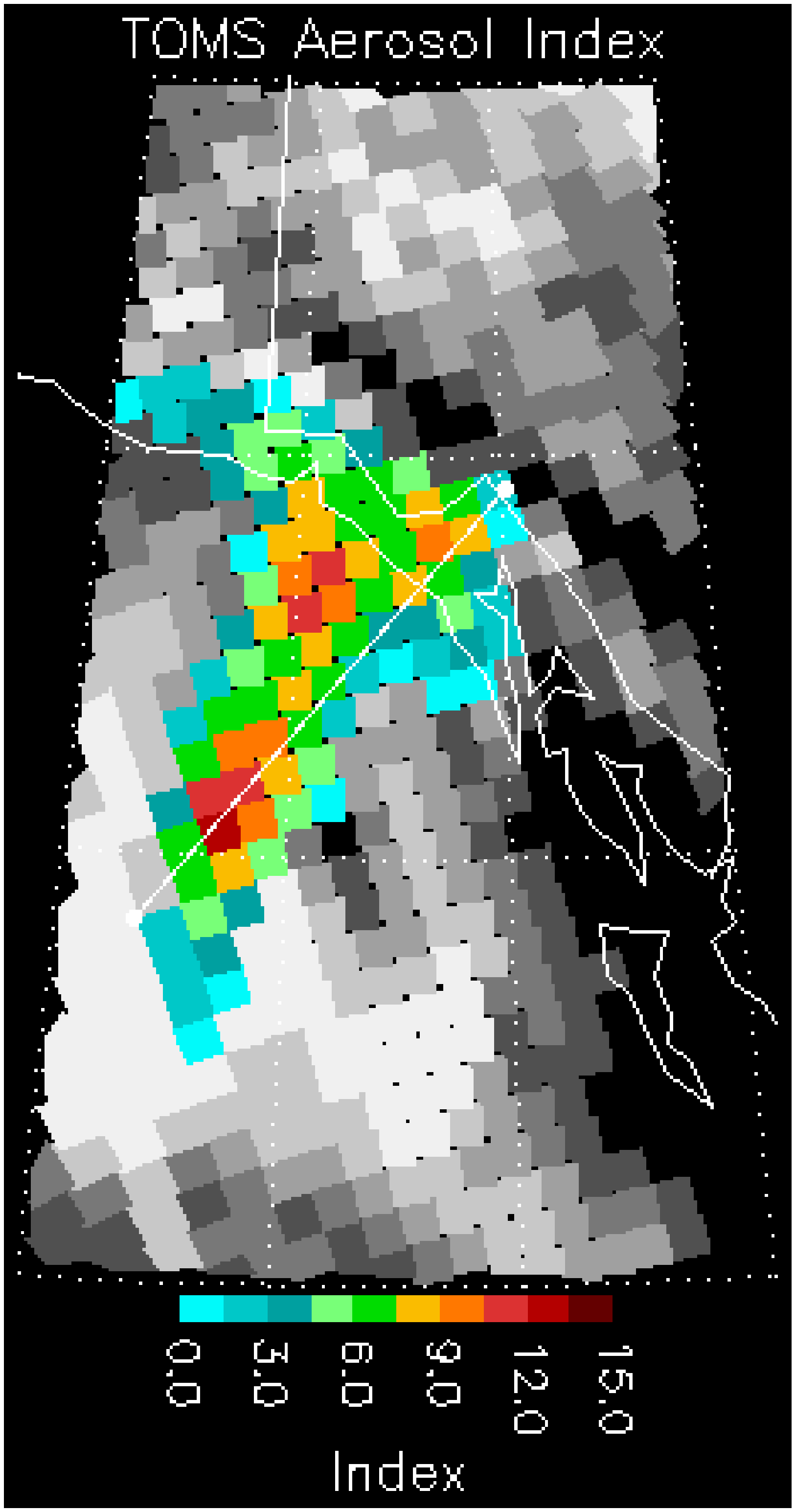
Module 1, Investigation 2: Figure 5

AVHRR with transect, August 19, 1992



Module 1, Investigation 2: Figure 6

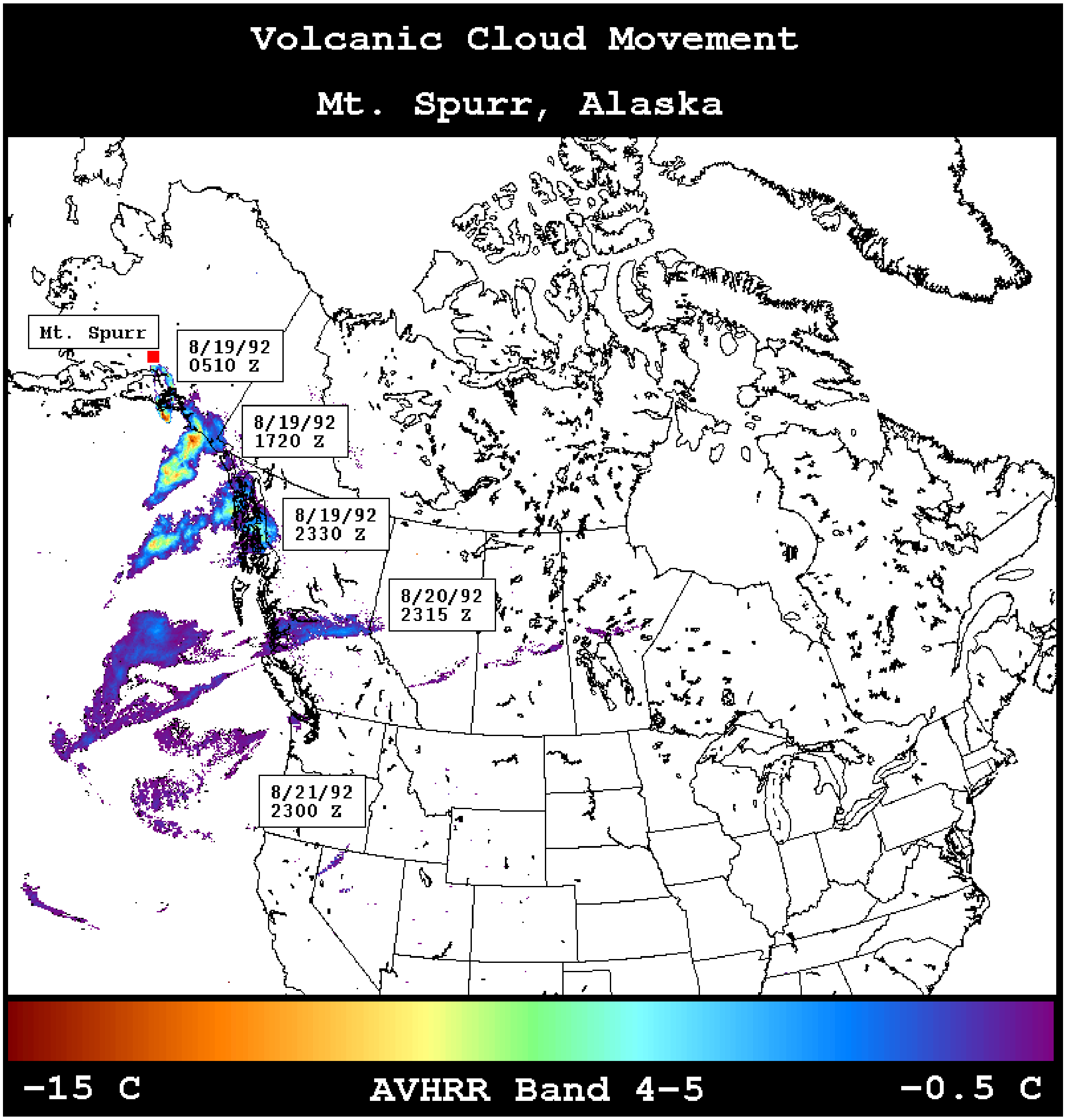
TOMS aerosol index with transect, August 19, 1992



Module 1, Investigation 2: Figure 7

AVHRR image of Mount Spurr aerosol cloud

August 19-21, 1992

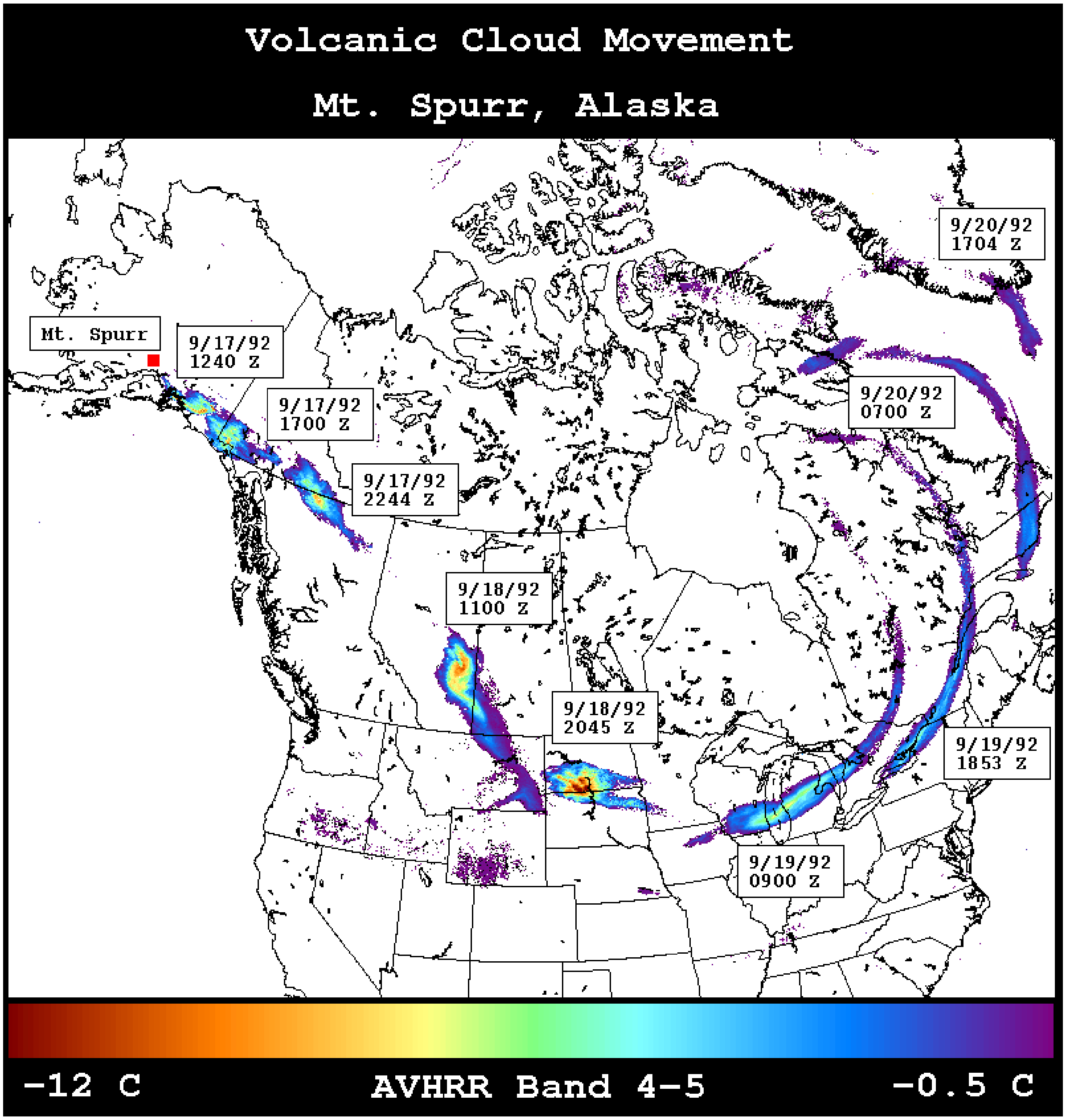


Composite image of Mount Spurr aerosol cloud movement from August 19-21, 1992
Source: http://www.geo.mtu.edu/volcanoes/research/avhrr/images/spurr/

Module 1, Investigation 2: Figure 8

AVHRR image of Mount Spurr aerosol cloud

September 17-20, 1992



Composite image of Mount Spurr aerosol cloud movement from September 17-20, 1992
Source: http://www.geo.mtu.edu/volcanoes/research/avhrr/images/spurr