Volcanoes: Local hazard, global issue

Module Overview

Middle school students are interested in volcanic eruptions because of their dramatic nature and because of the sensational destruction they can cause. The National Geography Standards expect students to understand how physical processes like plate tectonics shape and change patterns in the physical environment, how the characteristics of different environments both encourage and constrain human activities, and how natural hazards affect humans. Detecting change and tracking processes in Earth's systems is an important component of NASA research. This module allows students, like NASA scientists, to explore two ways that volcanoes affect Earth: by directly threatening people and the environments adjacent to them, and by ejecting aerosols into the atmosphere. Through three investigations, students explore issues of volcano hazards at different scales, from their local environment to the global effect of volcanic aerosols on climate and aircraft safety.

Investigation 1: How close is safe? Buffer zone development

This investigation provides an overview of the local effects of volcanism. Students categorize causes, effects, and responses to volcanic hazards. They observe the visible effects of Mount St. Helens' 1980 eruption over time. Based on these observations students identify a buffer zone to prevent development in dangerous locations.

Investigation 2: Sensing volcanic effects from space

The second investigation provides students with basic understanding about volcanoes and aerosols as well as skills in remote sensing. Students learn about volcanic aerosols and how to interpret satellite data. This investigation reinforces skills of comparison as students measure and graph satellite data to compare various satellite signals.

Investigation 3: Tracking world aerosol hazards

In this investigation, students are introduced to a global hazard of volcanic aerosols: aircraft damage. In small groups, students use satellite images to create time series of global aerosol hazards. By collecting and organizing data, students designate global locations with high aerosol dangers. Two methods of observation are used, and students compare the usefulness of each strategy.

Geography Standards

The World in Spatial Terms

- **Standard 1:** How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective
- **Standard 3:** How to analyze the spatial organization of people, places, and environments on Earth's surface

Physical Systems

- **Standard 7:** The physical processes that shape the patterns of Earth's surface

Environment and Society

- **Standard 15:** How physical systems affect human systems

Uses of Geography

- **Standard 18:** How to apply geography to interpret the present and plan for the future

Science Standards

Unifying Concepts and Processes

- Systems, order, and organization
- Constancy, change, and measurement

Science as Inquiry

- Abilities necessary to do scientific inquiry

Life Science

- Structure and function in living systems
- Populations and ecosystems

Earth and Space Science

- Structure of the Earth system

Science and Technology

- Understandings about science and technology

Science in Personal and Social Perspectives

- Natural hazards
- Risks and benefits
- Science and technology in society

Connection to the Curriculum

This module can be used in geography and science classes to extend a study of volcanism and to practice skills in map interpretation, remote sensing, and problem solving. In addition, it provides students with real-world contexts in which to learn about ways humans learn to adapt to hazardous physical systems. This module also reinforces mathematical skills of estimation, graphing, and computation. Students apply many language arts skills through readings.

Time

Investigation 1: Two 45-minute sessions
Investigation 2: Two 45-minute sessions
Investigation 3: Three 45-minute sessions

Module Assessment

At the completion of the unit, students may be given the assignment of preparing a brief to an international organization in which they must address this statement:

> Roughly 28 percent of Earth's surface and over half of its population are directly affected by volcanism. Volcanism has wide effects on world rainfall, temperature, and other atmospheric conditions. Summarize the potential effects of volcanism on the world population based on the material studied in this module. Suggest ways humans can prepare for and adapt to this dynamic aspect of Earth's physical system.

Mathematics Standards

Number and Operation
- Compute fluently and make reasonable estimates

Algebra
- Understand patterns, relations, and functions
- Analyze change in various contexts

Measurement
- Understand measurable attributes of objects and the units, systems, and processes of measurement
- Apply appropriate techniques, tools and formulas to determine measurements

Data Analysis and Probability
- Develop and evaluate inferences and predictions that are based on data

Problem Solving
- Apply and adapt a variety of appropriate strategies to solve problems

Communication
- Communicate mathematical thinking coherently and clearly to peers, teachers, and others

Connections
- Recognize and apply mathematics in contexts outside of mathematics

Representation
- Create and use representations to organize, record, and communicate mathematical ideas
- Use representations to model and interpret physical, social, and mathematical phenomena

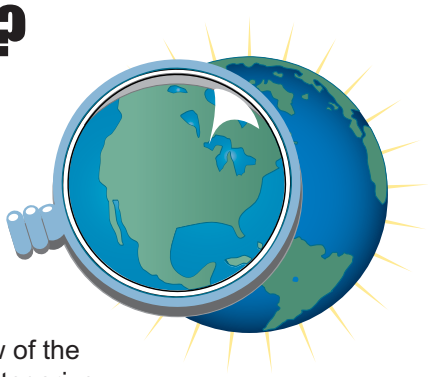
Technological Literacy Standards

Nature of Technology
- **Standard 3:** Relationships among technologies and the connection between technology and other fields

Technology and Society
- **Standard 4:** The cultural, social, economic, and political effects of technology

Abilities for a Technological World
- **Standard 13:** Assess the impact of products and systems

How close is safe? Buffer zone development



Investigation Overview

This investigation provides an overview of the local effects of volcanism. Students categorize causes, effects, and responses to volcanic hazards by focusing on the interdependence of all Earth systems. Using various remotely sensed images, students observe the visible effects of Mount St. Helens' 1980 eruption over time. Based on these observations students identify a buffer zone to designate safer locations for development.

Time required: Two 45-minute sessions

Materials/Resources

Log 1, Briefing, and Log 2 (one copy per student)
One set of Cause and Effect Statements, cut into strips (per group)
Poster paper for categorization (per group)
Images needed (one copy per group)
- Figure 1: Mount St. Helens, March 1980, before the eruption
- Figure 2: Mount St. Helens, June 1980, after the eruption
- Figure 3: Aerial photograph of 1980 damage to Mount St. Helens
- Figure 4: Mount St. Helens in 1999
- Figure 5: Mount St. Helens hazards map

Blank overhead transparency (one per group)
Five different colors of transparency markers
Ruler (one per group)
Masking tape

Content Preview

Geographers conceptualize Earth in terms of physical systems (the lithosphere, the biosphere, the hydrosphere, and the atmosphere) and human systems that are unified in a single, highly interconnected system. Changes in one system lead to changes in other systems, with an impact on a variety of scales, from local to regional to global. Volcanoes provide an outstanding opportunity to highlight the relationships between human and physical systems and how humans deal with natural hazards.

Geography Standards

Standard 15: Environment and Society

How physical systems affect human systems

- Analyze ways in which human systems develop in response to conditions in the physical environment.
- Describe the effect of natural hazards on human systems.

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.

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.

Geography Skills

Skill Set 4: Analyze Geographic Information

- Interpret information obtained from maps, aerial photographs, satellite-produced images, and geographic information systems.
- Interpret and synthesize information obtained from a variety of sources.

Skill Set 5: Answer Geographic Questions

- Make generalizations and assess their validity.

Classroom Procedures

Beginning the Investigation

1. Explain that the purpose of the module is to investigate the effects of volcanoes. Geographers are vitally interested in learning about changes caused by volcanoes at different scales, from the local (immediately adjacent to volcanoes) to the global (world atmospheric conditions affected by volcanic eruptions). Give students time to discuss what they already know about volcanoes and their local-to-global effects.

2. Distribute **Log 1** and have students read the background and objectives. Distribute the **Briefing** and have students read the narrative account of Mount St. Helens' 1980 eruption. You may ask students to take turns reading this dramatic story in a "reader's theater."

3. NASA monitors volcanoes because of their significant effect on people and the environment. Introduce or review the following terms used to describe the environment in Earth-systems terms:
   - Hydrosphere: Earth system dealing with water (hydro-), including surface water systems (lakes, rivers, oceans) and frozen water (glaciers, polar ice caps) as well as water beneath the surface of Earth (aquifers, groundwater, etc.)
   - Lithosphere: Earth system dealing with land (soil, rocks, etc.)
   - Atmosphere: Earth system dealing with air
   - Biosphere: Earth system dealing with plant and animal life (flora and fauna)

   Have students record definitions in the Log.

4. Divide the class into groups of 3-5 and distribute the Cause and Effect Statements, cut into strips, one set per group.

Causes	Effects	Human Responses
Structure of the Volcano The Eruption Event	Effects on... Lithosphere Hydrosphere Biosphere Atmosphere Human Activities	Clean-Up Efforts Responses to Environmental Hazards Monitoring Efforts

   - Review the statements with students to make sure they understand the vocabulary.

   - Ask students to organize the strips into three groups: Causes, Effects, and Human Responses. Some statements may require a fine distinction between "cause" and "effect"; develop working definitions as a class if necessary. (Suggested definitions: Cause—incidents that lead up to or are related to the actual eruption event. Effect—incidents that result from the actual eruption event).

   - Students complete item 3 in the Log.

5. Using large sheets of poster paper and tape, have students classify the statements again, this time into more specific categories shown in **Log 2: Cause and effect organizer**. Be sure that all students understand the categories. Discuss the types of cues they would use to determine a statement's classification. For example, students should identify that statements dealing with the plant and animal life of the area would be placed under "Effects on the Biosphere."

   - Students record their categorizations on **Log 2**.

6. Ask selected groups to share their classifications with the class. If groups disagree about a statement's classification, allow them to explain their underlying thought process. Use points of disagreement to reinforce the concept that Earth systems function interdependently, so it is sometimes difficult to determine which "-sphere" is being affected.

7. Debrief this activity by highlighting that effects and consequences such as the ones listed require considerable lengths of recovery time after an eruption. How people prepare for and respond to volcanic eruptions is vital to the safety and productivity of an area. Explain that NASA images show the extent of damage after an eruption and provide data useful to lessen the human impacts of possible future eruptions.

Developing the Investigation

8. Distribute **Figure 1: Mount St. Helens, March 1980, before the eruption** to each group. Explain that this is a false color Landsat image, which means that the colors on the image are not the same as would appear to the human eye. In this image, vegetation is red.

9. Guide students in interpreting the image using the following questions:
   - What would you look for to identify a river? (*Look for meanders or curves in a line.*)
   - How would you identify the location of the volcano's peak? (*Look for dark gray or black areas surrounded by little vegetation. These represent snow and glaciers that are on top of the volcano.*)
   - How would you find areas of vegetation? (*Look for red areas since this is a false color image and living vegetation is reddish.*)
   - Why might some areas of vegetation have straight boundaries? (*They are probably boundaries for agricultural land or some other managed landscape.*)

   Have students complete item 4 in the Log.

10. Ask students to review the Cause and Effect Statements they organized earlier in the investigation. Have them record in their log three things that they would expect to be able to observe in a false color image taken after an eruption. Allow students to discuss their predictions with the class. They should mention things like:
    - less red color because much of the vegetation was killed by the blast
    - changes in the course of rivers or the development of new lakes as debris obstructed the flow of rivers
    - changes in the shape of the volcano due to landslides

11. Distribute a blank overhead transparency and transparency marker to each group. Instruct students to mark the corners of **Figure 1** on the transparency to aid in lining up other images later.

12. Ask students to locate the summit of the volcano (*in the lower left area of the image*) and then trace the extent of the volcano. Students should create a key at the bottom of the transparency for each color used throughout the investigation.

13. Explain the concept of a buffer. A buffer provides an area to absorb negative consequences of physical or human activities. For example, tree buffers can serve to protect a neighborhood from highway traffic and noise, while an uninhabited buffer area can protect people from some dangers of natural hazards.

    In a different colored transparency marker, ask students to sketch the area they think should be the buffer zone for safety around Mount St. Helens.

14. Distribute **Figure 2: Mount St. Helens, June 1980, after the eruption**.
    - Instruct students to compare this figure to **Figure 1**.
    - Have students discuss their reactions to the changes from **Figure 1** to **Figure 2**. In what ways was the environment disturbed and disrupted by the eruption? In what ways was vegetation altered? The flow of rivers? Students should check to see the changes they predicted. Were their predictions accurate?
    - Have students measure the areal extent of the damage in four directions using a ruler and the scale of the image.
    - Have students place the transparency on **Figure 2**, lining up the corner marks.
    - In another color, have students trace the boundary of the extent of the disruption and devastation brought on by the eruption. Ask how effective their buffer would have been for this particular eruption.

15. Have students review the Cause and Effect Statements again to imagine what the area in this image would look like at ground level. Then, display **Figure 3: Aerial photograph of 1980 damage to Mount St. Helens** to illustrate what the land looked like after the eruption.

16. Ask students to formulate a hypothesis about the present environment around Mount St. Helens. What would it look like today? Using a new color transparency marker, have students draw in with dashed lines how much of the area they think probably still shows effects of the 1980 eruption today.

17. Distribute **Figure 4: Mount St. Helens in December 1999**. Students need to line this image up with the lower right corner of their transparency. Explain that instead of vegetation appearing red, in a true color image vegetation looks green like it does in the real world. Ask students to compare this image with the previous two. How has the local environment changed? Ensure that students notice the vegetation regrowth in some areas. Where has regrowth occurred, and where has it not? Have students look for patterns and explanations for the areas of regrowth. (*Explanations could include: The impact was more severe and lasting in the direction of the blast. The area directly adjacent to the volcano was slowest to grow vegetation. Areas along the river and surrounding Spirit Lake have begun to recover vegetation.*)

18. Using a different color marker, ask students to draw a second safe buffer zone around the volcano applying this new information. Students should record their justification for the boundary by stating which effects are being addressed by their new buffer zone.

Concluding the Investigation

19. Compare the second buffer zone to the buffer they drew originally. Ask how many groups made their second buffer zone bigger.

    Students may assume that the next eruption will affect the same area, which would not necessarily be the case. Ask what other information students or scientists would need to create a buffer zone that took this possibility into account.

20. Remind students that scientists are constantly monitoring changes with volcanoes, hoping that new information will help the area be safer and more prepared for potential eruptions. Using data from several different years allows people to make wiser decisions. If students changed their buffer zone, they understand the need to respond to additional information about dangers.

21. Circulate **Figure 5: Mount St. Helens hazards map** for students to compare their second buffer zone area with the hazard areas identified by the U.S. Geological Survey.

22. Ask students to review the Cause and Effect Statements they used in the beginning of the investigation. Have them identify which effects may have been less of a problem if there had been a sufficient buffer zone in place before the 1980 eruption of Mount St. Helens. Have students record their answers in their Log. Provide time for whole group discussion of the possible effects and limitations of buffer zones.

Background

Volcanoes are dangerous, but they are also very important to humans. Volcanic eruptions contribute substantially to soil fertility. In the Andes, many people live on the flanks or at the foot of active composite volcanoes, largely because of the fertility of the volcanic deposits. The same is true in the Philippines where residents near active volcanoes like Mount Mayon and Mount Taal regularly move away during eruptions, only to move right back when the danger subsides. These two cases present good examples of how people learn to live and adapt to hazardous environments.

Mount St. Helens is one of many composite (strato-volcano) volcanoes in the Cascade Range of the Northwest United States. Mount St. Helens has been one of the most active volcanoes in the Pacific Northwest although before the eruption in May 1980, it had been dormant since 1857.

	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."	Stratovolcanoes are located primarily along tectonic subduction zones, where two plates slowly collide.	Not associated with any particular tectonic activity. Some are found near current tectonic boundaries, and others are near old boundaries.
Examples	Kilauea, Mauna Loa (Hawaii)	Mount Fuji (Japan), Mount St. Helens (Washington)	Sunset Crater (Arizona), Capulin Mountain (New Mexico)

More detailed information about the Cascade Range, Mount St. Helens, and the 1980 eruption can be found at the USGS/Cascade Volcano Observatory web site: <http://vulcan.wr.usgs.gov/Volcanoes/MSH/framework.html>

Evaluation

Statement Categorization

Following are suggested categorizations and justifications. Some statements are listed in more than one category to illustrate the multiple categorizations that may occur.

Causes

Structure of the Volcano

15. Composite volcanoes erupt explosively. (*Statement describes Mount St. Helens' volcano type.*)
16. Composite volcanoes are made of alternating layers of lava, ash, and other volcanic debris. (*This layering of debris from former eruptions gives the volcano its structure as well as providing considerable material to spew during an eruption.*)
18. Magma contains high concentrations of gas that may cause an explosion that breaks magma into pumice and tiny ash particles. (*This statement describes magma behavior in a composite volcano.*)

The Eruption Event

2. The mountain "awoke" with a series of steam explosions and bursts of ash. (*This was a cause leading to the effect of an enormous ash cloud that traveled the globe [10, 14] and the development of global ash monitoring stations [9].*)
3. The mountain shook from a strong, magnitude 4.2 earthquake. (*This statement is associated with activity immediately preceding the eruption.*)
4. The entire face of the mountain broke free and slid downward in a giant rock avalanche. (*Depending on the interpretation, this statement could apply to the conditions surrounding the eruption or an effect of the eruption on the lithosphere. Students could justify placement in either of these categories based on their distinction between a physical cause and effect.*)
5. The lava contained dissolved water that exploded into superheated steam. (*This was a cause leading to the effect of an enormous ash cloud that traveled the globe [10, 14] and the development of global ash monitoring stations [9].*)
19. Within hours of the blast, mixtures of gas, pumice, and ash swept down the north side of the volcano at speeds up to 160 kilometers/hour (100 miles per hour) and at temperatures of over 648˚ C (1200˚ F). (*While this mentions a timeline of "within hours of the blast," the speed and temperature of the materials caused many of the devastating effects listed.*)

Effects

Lithosphere

1. Volcanic deposits literally reshaped the entire region around the mountain. (*The term deposits is key in this statement to suggest actions after the actual eruption.*)
13. Enormous mudflows gushed down the mountain. (*Mudflows are made up of primarily materials from the lithosphere, but students may see this as an interaction between the lithosphere and the hydrosphere.*)
20. A fan-shaped pumice plain developed to the north and directly in front of the crater. (*The deposition of the pumice reshaped the physical landscape in front of the crater.*)
21. Layers of pyroclastic flow (pumice, ash, and gas) were deposited as thick as 20 meters (60 feet) deep along the north side of the volcano. (*Volcanic deposits, again, affecting the landscape.*)

Hydrosphere

22. The Columbia River was closed to freighter traffic for several days to remove debris. (*The reference to freighter [shipping] traffic makes this statement fit better within effects on human activities than effects on the hydrosphere, but students may initially associate the river with the hydrosphere.*)
28. A debris avalanche blocked the natural outlet of Spirit Lake. (*The natural circulation processes of Spirit Lake were affected.*)
29. Several new lakes were formed by debris deposits, but these natural dams were unstable and could fail and flood the streams. (*Students should recognize that actions such as natural or artificial damming have consequences such as potential failures, which ultimately can add considerable stress to the rest of the river system.*)

Biosphere

7. Thousands of deer, elk, bear, and other animals died. (*Fauna are all part of the biosphere.*)
8. Almost 594 square kilometers of forest were destroyed. (*Flora are part of the biosphere.*)

17. Plant growth was severely slowed for years after the eruption. (*The soil must have time to recover for the plant life to return. At first, though, only very short hardy plants will be able to survive.*)
23. Trees were stripped from the hillsides as far as 10 kilometers from the volcano. (*The blast literally tore many trees out of the ground.*)
24. Around the edges of the blowdown zone, trees were killed simply by the intense heat of the blast. These trees are called Standing Dead. (*Beyond the area where trees were torn out of the ground, trees were singed and killed. The Standing Dead resembled deciduous trees during the winter, except that they were not just dormant.*)

Atmosphere

10. Tiny ash particles were thrust 24 kilometers into the sky and continued for about nine hours. (*Material was being added to the atmosphere.*)
14. Small ash particles reached the eastern United States within three days of the blast and circled the globe within two weeks. (*This statement illustrates the global extent of the atmospheric impact. Material from an eruption in the United States traveled around the globe in less than two weeks.*)

Human Activities

6. Shipping channels were blocked. (*Students may place this statement in either the hydrosphere or in human activities. This statement speaks more directly to the human activities on the river rather than effects on the hydrology of the area, so it is better categorized here.*)
11. Many communities and agricultural areas were affected by falling ash. Machinery and crops were damaged. (*The emphasis on agriculture and technology focuses this statement on the effects on human activities.*)
12. A small airplane narrowly avoided disaster when the pilot put the plane into a steep dive to gain speed and turned south, away from the ash cloud. (*This statement refers to human activities in the atmosphere but is better categorized as an effect on human activities.*)
22. The Columbia River was closed to freighter traffic for several days to remove debris. (*The reference to freighter, shipping traffic makes this statement fit better within human activities than effects on the hydrosphere.*)

Human Responses

Clean-Up Efforts

25. From May to September 1980, the U.S. Army Corps of Engineers removed 32 million cubic meters of debris from the Cowling River. (*The Corps was working to free up shipping channels again.*)

Environmental Hazards

26. Levees and retaining structures were built to control sediment and debris deposits. This prevents deposits from clogging the rivers and hindering boat traffic or causing flooding downstream. (*While levees are designed to control floods and manage water resources, it is important for students to remember that these structures sometimes fail just as natural dams sometimes do [29]. Settling outside the floodplain is the safest way to minimize flood damage.*)
27. Flood gates were installed to prevent potential flooding of Spirit Lake caused by future volcanic activity. (*Efforts by humans to control natural environmental hazards.*)
30. A fish transport system was built to help fish get around the sediment-retention structure. This provided safe passage for salmon and steelhead returning from the sea. (*This system was an attempt to reconnect the migration path of fish that had been disrupted by human-built structures. Students should realize that human actions also have effects on the interactions of all the spheres, which should be minimized as much as possible.*)

Monitoring Efforts

9. A global network of Volcanic Ash Advisory Centers was created to observe volcanic eruptions in order to improve aircraft safety. (*The VAAC system was created to address the effects of worldwide volcanic ash hazards.*)
31. Scientists carefully watch the activity of magma under Mount St. Helens. Nonetheless, heat from the magma has led to avalanches (melting snow) and explosions of steam (heated water) without warning. (*Scientists monitor for changes that often lead up to volcanic eruptions to attempt to give some warning before the next one.*)
32. The U.S. Geological Survey and University of Washington are watching for volcanic activity of Mount St. Helens. Information on lahar (mud slides) and flood hazards is now collected by

the USGS and the National Weather Service who then issue warnings. (*This statement reflects the interagency concern with monitoring volcanic activity*).

Suggested Key for Log 1

2. Hydrosphere: Earth system dealing with water
   Lithosphere: Earth system dealing with land
   Atmosphere: Earth system dealing with air
   Biosphere: Earth system dealing with plants and animals, flora and fauna
5. Responses will vary but might include: loss of vegetation, changes in shape of the volcano, changes in the course of the river, formation of additional lakes.
8. Observations will vary.
10. Student estimates will vary but should include reference to changes in the shape of the volcano, lack of trees, debris flow.
12. Students should observe that Figure 4 is true color; thus vegetation is green in this image rather than red.
13. Vegetation regrowth can be seen primarily to the northwest of the volcano. Directly north of the volcano is still gray because the area has not yet recovered.
14. Reasons may vary but should be evaluated for soundness of the reasoning. A sample answer: The area closest to the blast side of the volcano was most severely disrupted by the eruption as shown by loss of vegetation and other items, so it is taking the longest time to recover.
15. Student justifications will vary, but the response should include why they chose to make the new buffer zone larger or smaller than the previous one. Answers should also include consideration for the areas of regrowth. For example, areas that are green now were not "safe" during 1980, so establishing a buffer based only on Figures 1 or 4 would be misleading.
16. Student responses should illustrate reasoning and careful evaluation of the significant issues.
17. The paragraph should address both the importance and limitations of buffer zones. On one hand, buffers protect humans and human activities from direct hazards. However, there are numerous effects of volcanic eruptions that a buffer cannot address such as effects on the various -spheres. By its nature, a buffer zone addresses natural hazards from a human perspective alone, although humans are not the only living things affected by natural hazards. This paragraph can also be evaluated for grammar and composition.

Related NASA Resources

http://volcano2.pgd.hawaii.edu/eos/ Earth Observation System Volcanology Homepage, provides comparative information on a variety of volcanoes under study. Includes eruption data as well as satellite and aerial images of each.

Related Resources

http://vulcan.wr.usgs.gov/Volcanoes/MSH/framework.html Links to information about Mount St. Helens. Includes details of the 1980 eruption, maps and graphics of the Cascades Volcanoes, monitoring efforts, and more.

http://vulcan.wr.usgs.gov/Volcanoes/MSH/May18/summary_may18_eruption.html Summary of the 1980 eruption event, including measurements and extent of damage

http://volcano.und.nodak.edu/vwdocs/msh/msh.html Mount Saint Helens Homepage

http://edcwww.cr.usgs.gov/earthshots/slow/MtStHelens/MtStHelens Landsat progression of images with additional pictures of selected sites

http://volcano.und.nodak.edu/vwdocs/volc_images/img_st_helens_bw.html Dramatic black and white picture of eruption and ash cloud

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

http://volcano.und.nodak.edu/vwdocs/volc_images/volc_images.html Volcano World page with searchable world map. Students can search for volcanoes by region, country, name, etc. Provides useful information and images from a variety of sources.

Module 1, Investigation 1:
Cause and effect statements

1. Volcanic deposits literally reshaped the entire region around the mountain.
2. The mountain "awoke" with a series of steam explosions and bursts of ash.
3. The mountain shook from a strong, magnitude 4.2 earthquake.
4. The entire face of the mountain broke free and slid downward in a giant rock avalanche.
5. The lava contained dissolved water that exploded into superheated steam.
6. Shipping channels were blocked.
7. Thousands of deer, elk, bear, and other animals died.
8. Almost 594 square kilometers of forest were destroyed.
9. A global network of Volcanic Ash Advisory Centers was created to observe volcanic eruptions in order to improve aircraft safety.
10. Tiny ash particles were thrust 24 kilometers into the sky and were airborne for about nine hours.
11. Many communities and agricultural areas were affected by falling ash. Machinery and crops were damaged.

12. A small airplane narrowly avoided disaster when the pilot put the plane into a steep dive to gain speed and turned south, away from the cloud.
13. Enormous mudflows gushed down the mountain.
14. Small ash particles reached the eastern United States within three days of the blast and circled the globe within two weeks.
15. Composite volcanoes erupt explosively.
16. Composite volcanoes are made of alternating layers of lava, ash, and other volcanic debris.
17. Plant growth was severely slowed for years after the eruption.
18. Magma contains high concentrations of gas that may cause an explosion that breaks magma into pumice and tiny ash particles.
19. Within hours of the blast, mixtures of gas, pumice, and ash swept down the north side of the volcano at speeds up to 160 kilometers per hour (100 miles per hour) and at temperatures over 648˚ C (1200˚ F).
20. A fan-shaped pumice plain developed to the north and directly in front of the crater.
21. Layers of pyroclastic flow (pumice, ash, and gas) were deposited as thick as 20 meters deep along the north side of the volcano.
22. The Columbia River was closed to freighter traffic for several days to remove debris.
23. Trees were stripped from hillsides as far as 10 kilometers from the volcano.

24. Around the edges of the blowdown zone, trees were killed simply by the intense heat of the blast. These trees are called Standing Dead.
25. From May to September 1980, the U.S. Army Corps of Engineers removed 32 million cubic meters of debris from the Cowling River.
26. Levees and retaining structures were built to control sediment and debris deposits. This prevents deposits from clogging the rivers and hindering boat traffic or causing flooding downstream.
27. Flood gates were installed to prevent potential flooding of Spirit Lake caused by future volcanic activity.
28. A debris avalanche blocked the natural outlet of Spirit Lake.
29. Several new lakes were formed by debris deposits, but these natural dams were unstable and could fail and flood the streams.
30. A fish transport system was built to help fish get around the sediment-retention structure. This provided safe passage for salmon and steelhead returning from the sea.
31. Scientists carefully watch the activity of magma under Mount St. Helens. Nonetheless, heat from the magma has led to avalanches (melting snow) and explosions of steam (heated water) without warning.
32. The U.S. Geological Survey and University of Washington are watching for volcanic activity of Mount St. Helens. Information on lahar (mud slides) and flood hazards is now collected by the USGS and the National Weather Service who then issues warnings.

Module 1, Investigation 1: Log 1

How close is safe? Buffer zone development

Background

Volcanoes are like good news, bad news jokes. The good news is that they offer humans benefits such as rich soil. The bad news is that they are very destructive when they erupt. Because of this contradiction between productivity and destruction, areas around volcanoes need to be evaluated for safety. Creating a safety zone around a volcano helps to minimize a volcano's effect on humans. Creating a safety or buffer zone, however, requires information about the extent of previous eruptions compared to human settlement patterns. In this investigation you use data at different scales to study the impact of volcanic eruptions on the environment and its inhabitants in order to establish a buffer zone.

Objectives: In this investigation, you

- categorize the causes and effects of volcanic eruptions and human responses to them,
- measure the extent of damage of the Mount St. Helens 1980 eruption, and
- analyze images of a volcano to suggest a settlement buffer zone.

Procedures for the Investigation:

1. Read the account of the Mount St. Helens 1980 eruption.
2. Define the following elements of Earth's physical systems:

hydrosphere: _____

lithosphere: _____

atmosphere: _____

biosphere: _____

3. Categorizing causes, effects, and responses

   Organize the Cause and Effect Statements into three categories. List the strip numbers under each category title.

Causes	Effects	Human Responses

Divide the strips into more specific categories using the headings on Log 2: Cause and effect organizer. Be prepared to explain your choices.

Module 1, Investigation 1: Log 1

How close is safe? Buffer zone development

4. Look at Figure 1. This is a false color image, which means the features in the figure do not have the same color as they do in real life. The volcano is in the lower left corner. In this image, the vegetation (plant life) appears reddish and the water appears dark blue or black. Locate the following.
   - Mount St. Helens volcano
   - Spirit Lake
   - A river
   - Areas of vegetation

5. Go back to the Cause and Effect Statements that you organized earlier in this investigation. Write down three changes that you expect to observe in an image taken after an eruption.

   1) _____

   2) _____

   3) _____

6. Place a transparency over Figure 1. Mark the corners of the image onto the transparency to line up the other images. With a transparency marker, outline the base of the volcano's cone. Create a key at the bottom of your transparency. Label the first colored line as **Volcano** on the key.

7. With a different color transparency pen, draw a line representing the nearest point to the volcano where you think people could safely build houses and businesses. This creates a buffer zone.

8. Look at Figure 2, another false color image of Mount St. Helens. This was taken *after* the 1980 eruption. Compare Figure 1 and Figure 2. Write down three changes that occurred.

   1) _____

   2) _____

   3) _____

9. With another color transparency pen, trace the extent of the disruption caused by Mount St. Helens' 1980 eruption. Add this color to the key and label it **Damage.**

10. Think back to the Cause and Effect Statements. What would the area shown in this image look like from the ground?

11. Do you think the area has recovered to the way it was before the eruption in 1980? What is the extent of damage today? Sketch your predicted area on the transparency using dashed lines. Add the dashed line to your key and label it **Estimate for Today**.

    _____

    _____

    _____

    _____

Module 1, Investigation 1: Log 1

How close is safe? Buffer zone development

12. How is Figure 4 different from Figures 1 and 2?

13. Where has the vegetation around the volcano begun to grow back? Where has it not?

14. Write one reason why some of the areas have recovered from the 1980 blast while other areas still have not.

15. With a different color transparency pen, draw a second buffer zone line based on all three images. Should the area be larger than your last prediction? How should you deal with the areas of regrowth and recovery? Record this color on your key and label it Buffer 2.

16. Review the Cause and Effect Statements from the beginning of the investigation. Which of these statements would be different if an effective buffer zone was in place before the 1980 eruption?

Module 1, Investigation 1: Log 1

How close is safe? Buffer zone development

17. Write a paragraph discussing both the importance and limitations that buffer zones have when dealing with Earth's systems.

References

http://vulcan.wr.usgs.gov/Volcanoes/MSH/framework.html Use this website for more information about Mount St. Helens and other volcanoes in the Cascades Range

http://volcano.und.nodak.edu/vwdocs/volc_images/volc_images.html Use this website to locate additional volcanoes to research

Module 1, Investigation 1: Briefing

Narrative of Mount St. Helens 1980 eruption

A Slumbering Volcanic Giant

Mount St. Helens was once one of the most beautiful mountains in the entire Cascade Range of the American Northwest. In 1805, William Clark in the Lewis and Clark expedition described Mount St. Helens as "perhaps the greatest pinnacle in America."

The serenity of the mountain and its surroundings was misleading. One of the Indian names for Mount St. Helens was "fire mountain." Local Indians were reluctant to approach the mountain despite the abundant game in the area.

To the experienced observer, the cone shape and composition of rocks on the mountain boldly proclaimed Mount St. Helens' true nature—it was a volcano. Lava flows and multiple layers of ash (powdered volcanic rock) lay everywhere under the carpet of trees—abundant evidence of many prior eruptions. Volcanic deposits had reshaped the region around the mountain. Even beautiful Spirit Lake was a volcanic accident created by a giant mudflow that rolled down the mountain 3,000 years ago and backed up a stream.

Mount St. Helens was active between 1832 and 1857 during the early settlement of the area by Easterners. But the eruptions were small, and the mountain then "dozed off" for the next century. Small settlements became towns, and towns became cities like Portland and Seattle. These new neighbors of Mount St. Helens knew the mountain only as a sleeping giant. Its violent past was largely ignored.

The Awakening

The quiet ended abruptly in March 1980, with a series of steam explosions and bursts of ash. The following story of the eruption of Mount St. Helens illustrates the potential dangers of an eruption from Mount Ranier—a volcano about 120 kilometers southwest of Seattle, Washington.

During the months following the initial outbursts, vulcanologists and seismologists watched the mountain closely. Small earthquakes accompanied the bursts and indicated the movement of fresh lava into the heart of the mountain. Enormous cracks appeared in the summit and sides of the mountain, and the entire northern face expanded outward some 137 meters. Locals perceived this initial activity as minor, so in spite of warnings and the designation of the mountain and its surroundings as a dangerous "Red Zone," tourists flocked to the area to get a close view of the fireworks. Residents were strongly advised to move away, but some refused to go. Likewise, logging companies working in the area refused to shut down, claiming to "know the mountain." Vulcanologists established several camps around the mountain to monitor its activity. Some of the camps had to be dangerously close to the mountain to provide the necessary data. The scientists who manned the camps in shifts knew they were at risk.

The Main Eruption

On May 18, a quiet Sunday morning, a few observers were at their stations, watching Mount St. Helens. Tourists and loggers were also nearby. At 8:32 a.m. a small aircraft with two geologists aboard flew directly over the central cone.

Eleven seconds later, a strong earthquake shook Mount St. Helens. The whole north face of the mountain broke free and slid downward as a giant rock avalanche. In seconds, pressure in the mass of hot lava inside the mountain dropped; water that had been dissolved in the lava turned into superheated steam, fragmenting the lava into a fine powder ash. This mass of superheated steam and ash blasted upward and outward over the top of the avalanche, roaring to the north and west at speeds reaching hundreds of miles an hour. The pilot of the small aircraft narrowly avoided disaster by putting the "plane into a steep dive to gain speed" and turning sharply south, away from the expanding ash cloud.

Every living thing within about 16 kilometers of the volcano on the north side—tree or bush, human or animal, scientist or layman—was destroyed. Some of the people took a few quick pictures. Then, realizing their situation, most ran or tried to drive away from the approaching cloud of dust and steam. The near-supersonic blast of rock, ash, and hot gas engulfed the area with enough force to uproot trees. The temperature within the cloud reached 260°C (500°F), more than enough to start fires or burn exposed skin. The rock avalanche

roared over Spirit Lake and the valley of the North Fork of the Toutle River, burying them under layers of rock up to several hundred feet thick.

Moments after the rush of the avalanche and ash cloud, enormous mudflows—formed when glacial ice and snow that had capped the mountain were melted by the intense heat—surged down the mountain. Masses of mud poured down the nearby river valleys, sweeping away buildings, vehicles, trees, and bridges. One flow even blocked the shipping channel of the Columbia River, 88 kilometers downstream.

Millions of tons of fine ash were thrown high into the air and carried hundreds and thousands of miles downwind. These clouds, visible in satellite images, dropped several inches of ash over many communities and agricultural areas, ruining machines and crops.

The Toll

To the nation, and especially to those living nearby, the May 18 eruption was apocalyptic. The crown and heart of a whole mountain had been blasted away, and the surrounding countryside devastated. The energy released by the eruption was estimated at 10 megatons, an explosion thousands of times stronger than an atomic bomb.

- Thousands of deer, elk, bear, and smaller animals perished—in addition to 57 humans.
- Over 593 square kilometers of forest were destroyed, including three billion board feet of timber estimated at $400 million in value.
- Numerous buildings, bridges, roads, and machines were destroyed, and farms and communities up to 1,600 kilometers away were partially buried in ash.
- One hundred sixty-nine lakes and more than 4,800 kilometers of streams had either been marginally damaged or destroyed.
- Losses to property and crops were set at more than $1.8 billion.

Yet, the impact on human life could have been much greater if the main eruption had occurred on a workday or if the blast had been directed southwest toward the Portland/Vancouver metropolitan area (just 72 kilometers away) or if the wind had been blowing toward the southwest.

As large and destructive as the May 18 eruption appeared, it was a relatively small eruption when seen in context. Thick deposits of older volcanic rock around Mount St. Helens attest to much larger eruptions in its past. Mount St. Helens is also only one of many volcanoes that dot the Cascade Range. All of these volcanoes grew in the same geologic setting. Some eruptions at other Cascade volcanoes have been truly huge, such as the explosion nearly 7,000 years ago—100 times larger than the May 18 eruption—that reduced Mount Mazama to Crater Lake. Eruptions ranging in size from the May 18 eruption to the Mazama blast could occur at any time at any of the Cascade volcanoes. For the metropolitan centers of Portland, Seattle-Tacoma, and San Francisco that have grown up among the Cascade volcanoes, this is a serious concern.

Source: *NASA's Classroom of the Future*. http://www.cotf.edu/ete/modules/volcanoes/vnarrative1.html
For an extended discussion of Mount St. Helens, see http://vulcan.wr.usgs.gov/ljt_slideset.html

Module 1, Investigation 1: Log 2

Cause and effect organizer

Causes	Effects	Human Responses
Structure of the Volcano	Effects on the Lithosphere	Clean-Up Efforts
	Effects on the Hydrosphere	
		Responses to Environmental Hazards
	Effects on the Biosphere	
The Eruption Event		
	Effects on the Atmosphere	
		Monitoring Efforts
	Effects on Human Activities	

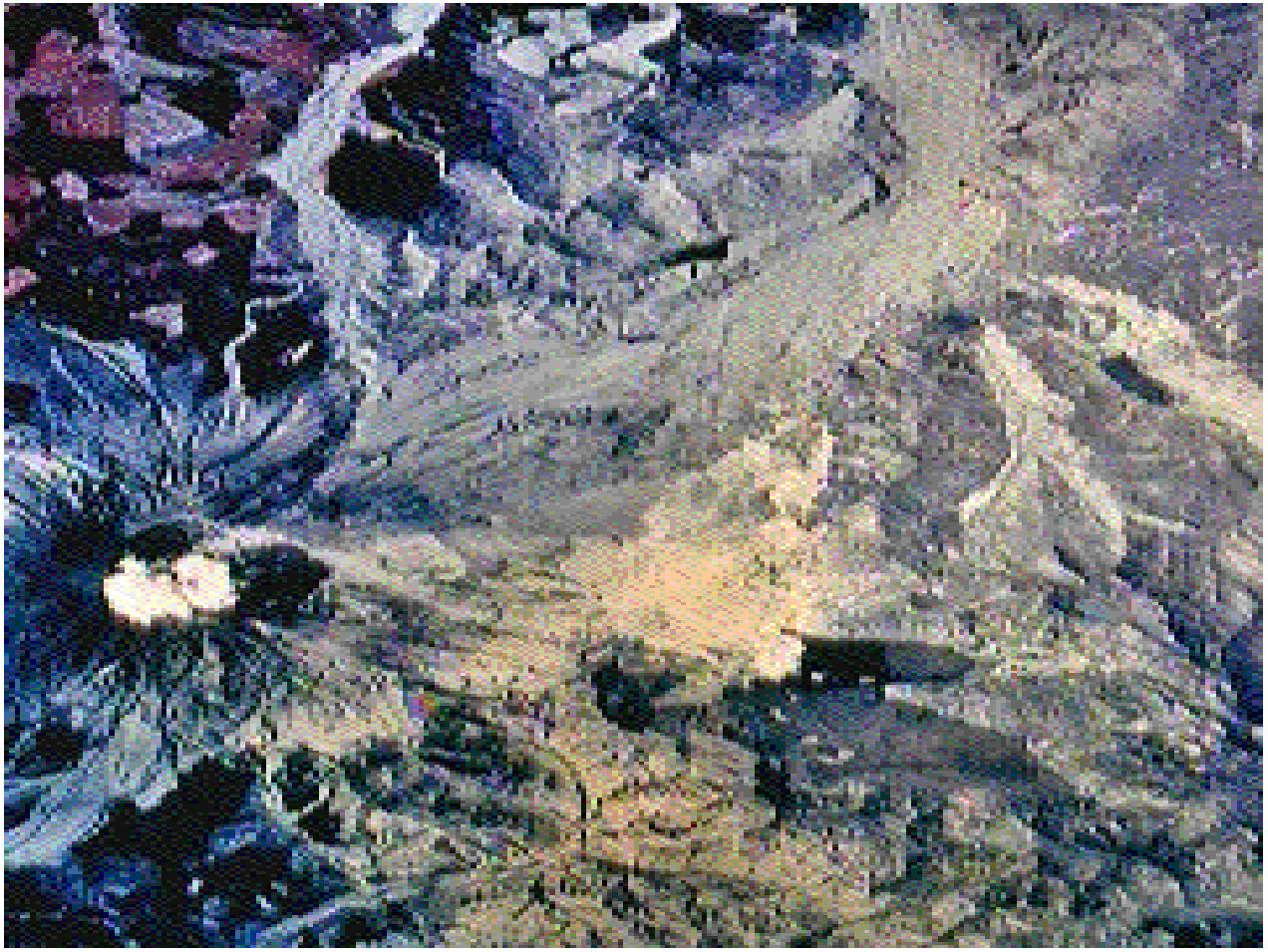
Module 1, Investigation 1: Figure 1

Mount St. Helens, March 1980, before the eruption

Infrared false color Landsat image of Mount St. Helens and the surrounding area in March 1980.
The reddish areas are living vegetation.
Source: LandSat satellite http://volcano.und.nodak.edu/vwdocs/msh/ov/ovs/ovssl.html

Module 1, Investigation 1: Figure 2

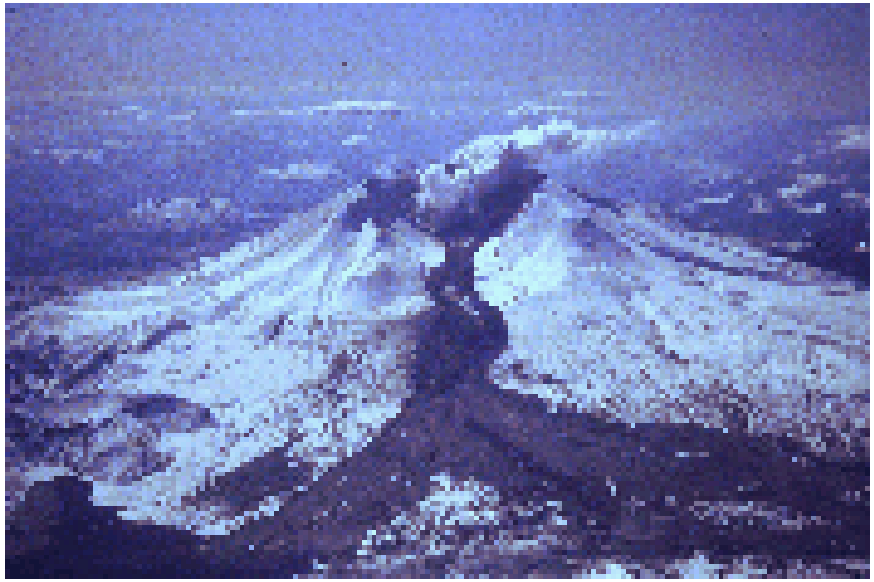
Mount St. Helens, June 1980, after the eruption



Infrared false color Landsat image of Mount St. Helens and the surrounding areas in June 1980.
Orientation: NNE
Source: http://volcano.und.nodak.edu/vwdocs/msh/ov/ovs/ovssl.html

Module 1, Investigation 1: Figure 3

Aerial photograph of 1980 damage to Mount St. Helens



Mount St. Helens' 1980 eruption triggered massive debris flows down the north face of the volcano as seen in this photograph.

Source: Cascade Volcano Observatory by Thomas Casadevall http://denali.gsfc.nasa.gov/research/volc2/volc_top.html

Module 1, Investigation 1: Figure 4

Mount St. Helens in December 1999

True color Landsat image of Mount St. Helens in 1999. Some areas have yet to rebound from the 1980 eruption.

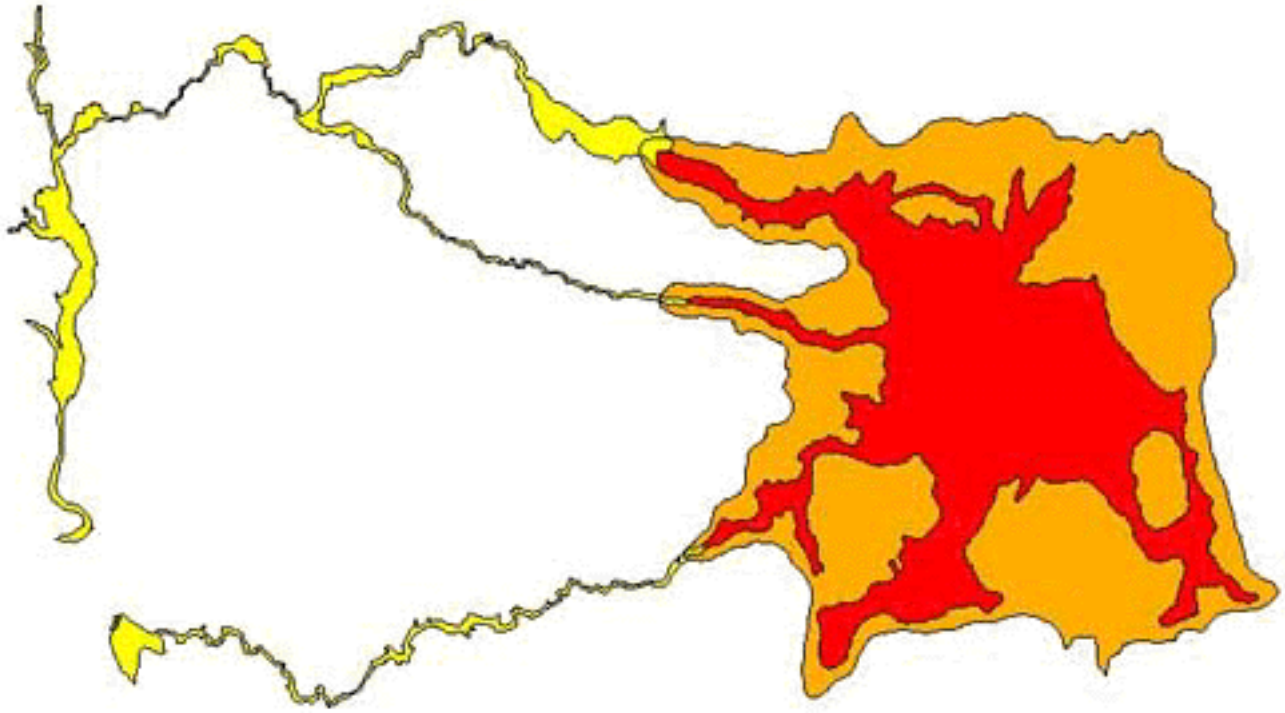
Key: green = forest
white = snow and glaciers
grey = areas destroyed by 1980 debris flow which have not recovered

Orientation: NNE

Source: http://volcano.und.nodak.edu/vwdocs/volc_images/img_st_helens.html

Module 1, Investigation 1: Figure 5

Mount St. Helens hazards map



0 10,000 20,000
kilometers

Hazard Zones

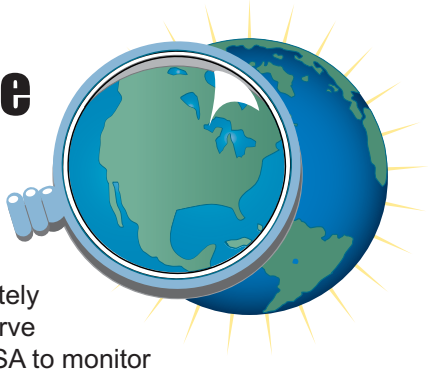
Zone 1: Vulnerable to high-density flows, including pyroclastic flows, lava flows, and parts of lahars

Zone 2: Area that could be overrun by low-density pyroclastic surges

Zone 3: Intermediate and lower reaches of valleys that could be inundated by lahars

Source: E. W. Wolfe and T. C. Pierson. 1995. Volcanic-Hazards Zonation for Mount St. Helens, Washington, 1995. USGS Open-File Report 95-497. http://vulcan.wr.usgs.gov/Volcanoes/MSH/Hazards/OFR95-497/framework.html

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)

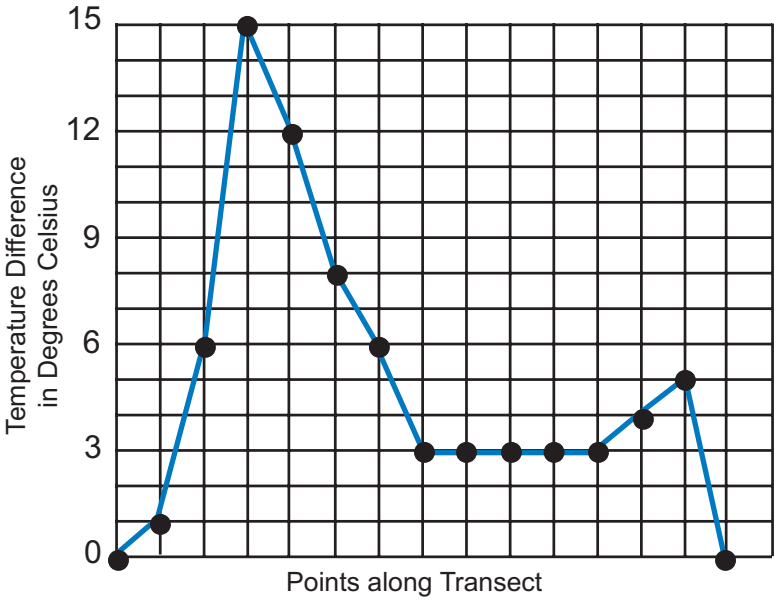
Evaluation

Log

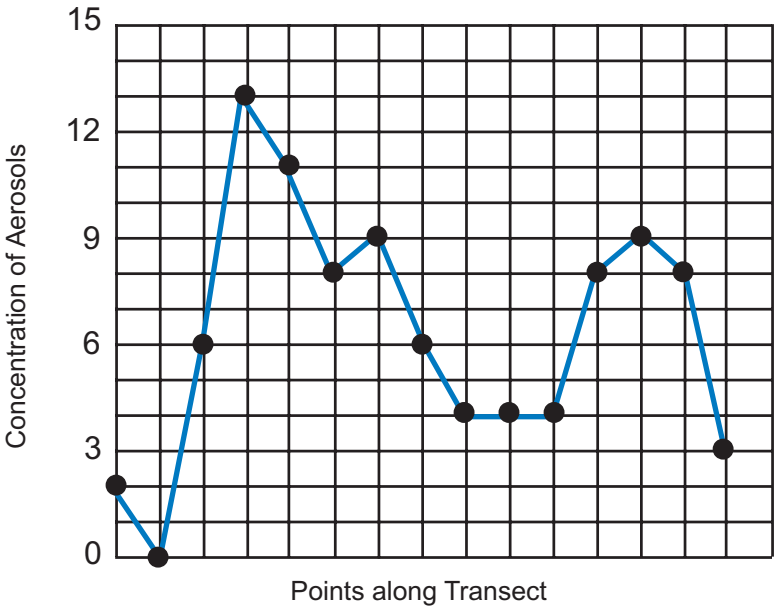
1. Space Shuttle Photo: provides visual data
   AVHRR: provides temperature data
   TOMS: provides data on the concentration of aerosols

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.

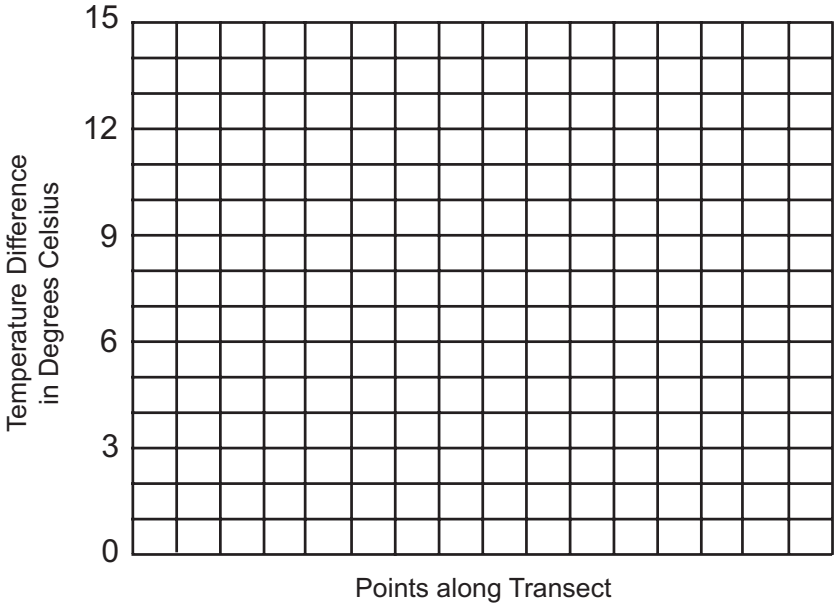
Source	Observations
Figure 2: Space Shuttle photograph	
Figure 3: AVHRR (Advanced Very High Resolution Radiometer) image	
Figure 4: TOMS (Total Ozone Mapping Spectrometer) image	

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.

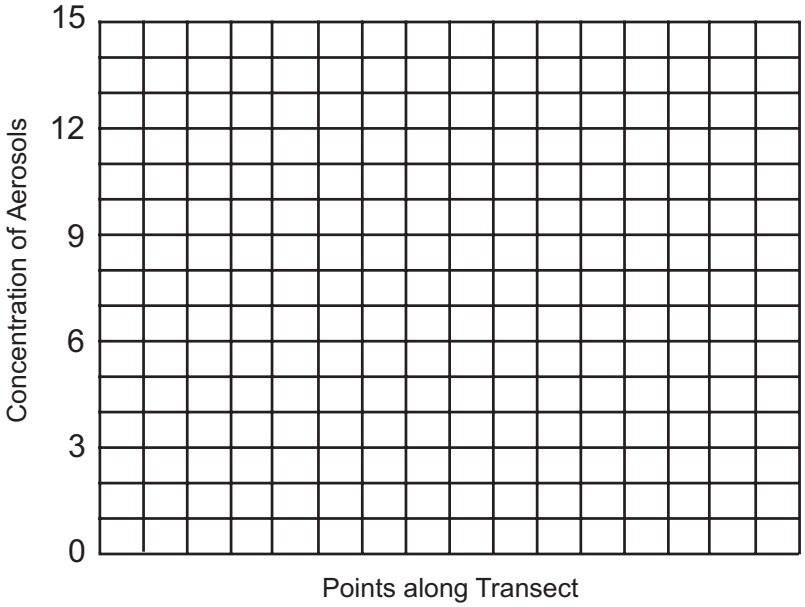
Module 1, Investigation 2: Log

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.

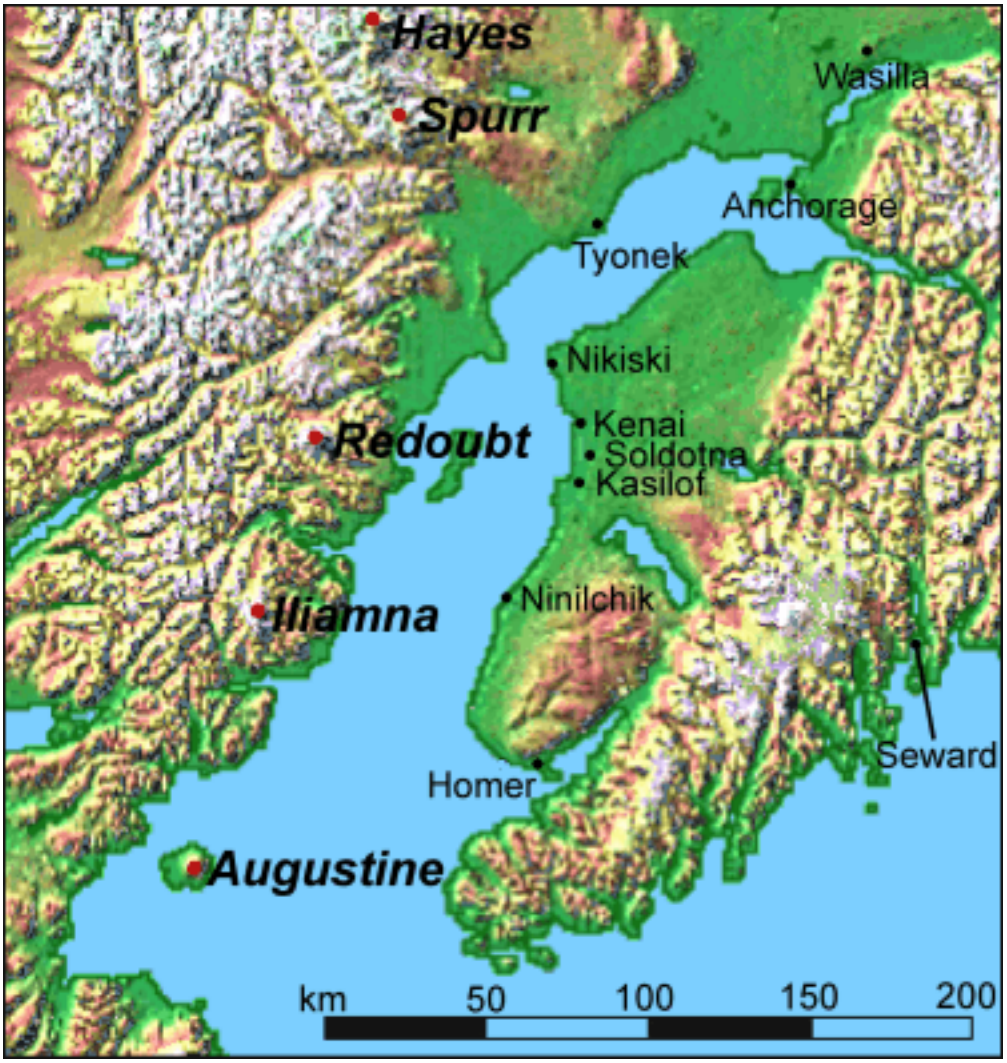
4. Look at Figure 7. Predict the changes that probably occurred along the path of Mount Spurr's ash cloud in August 1992.

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

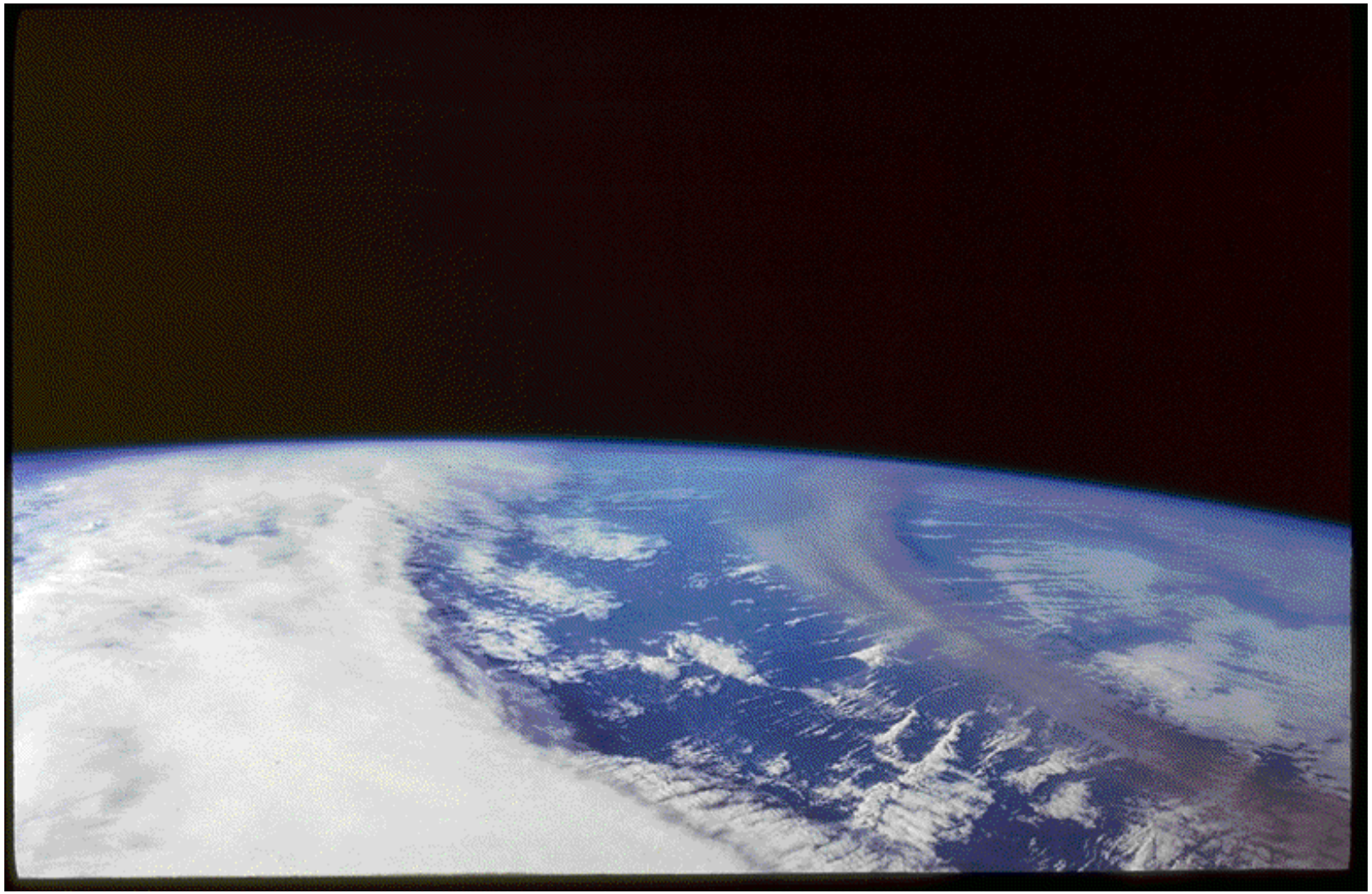
Locator map of Mount Spurr in Alaska



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

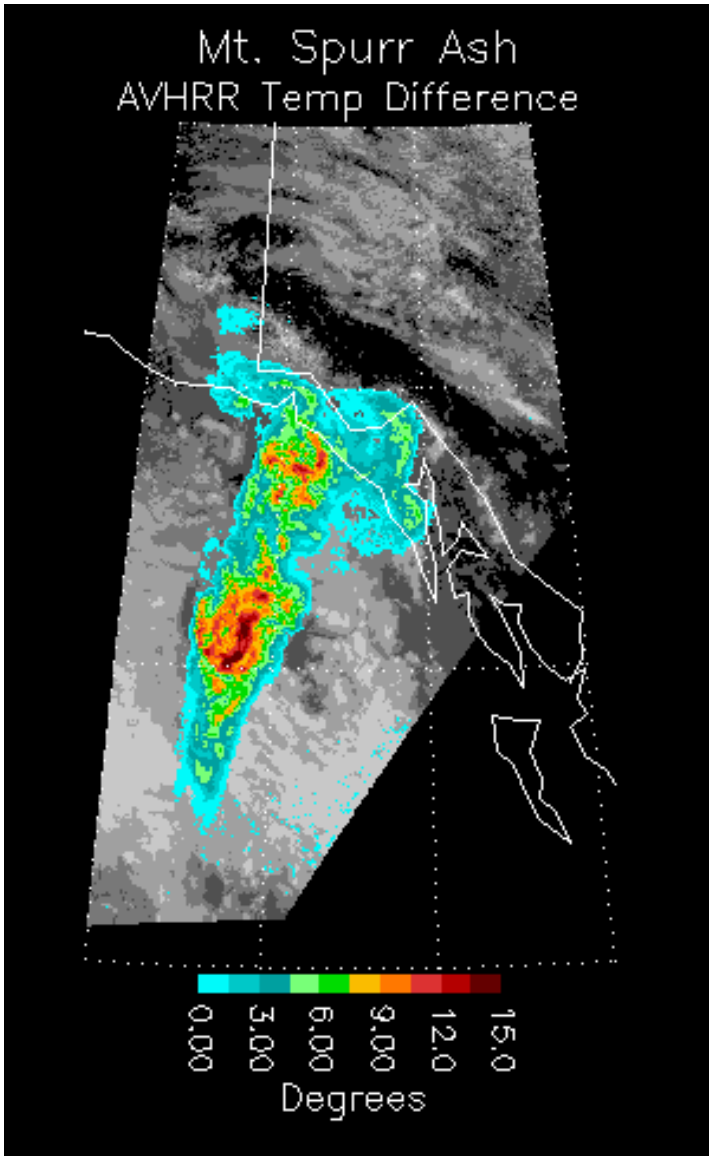
Module 1, Investigation 2: Figure 2

Handheld Space Shuttle photograph of Mount Spurr, 1992 eruption



Module 1, Investigation 2: Figure 3

AVHRR image of Mount Spurr, 1992 eruption

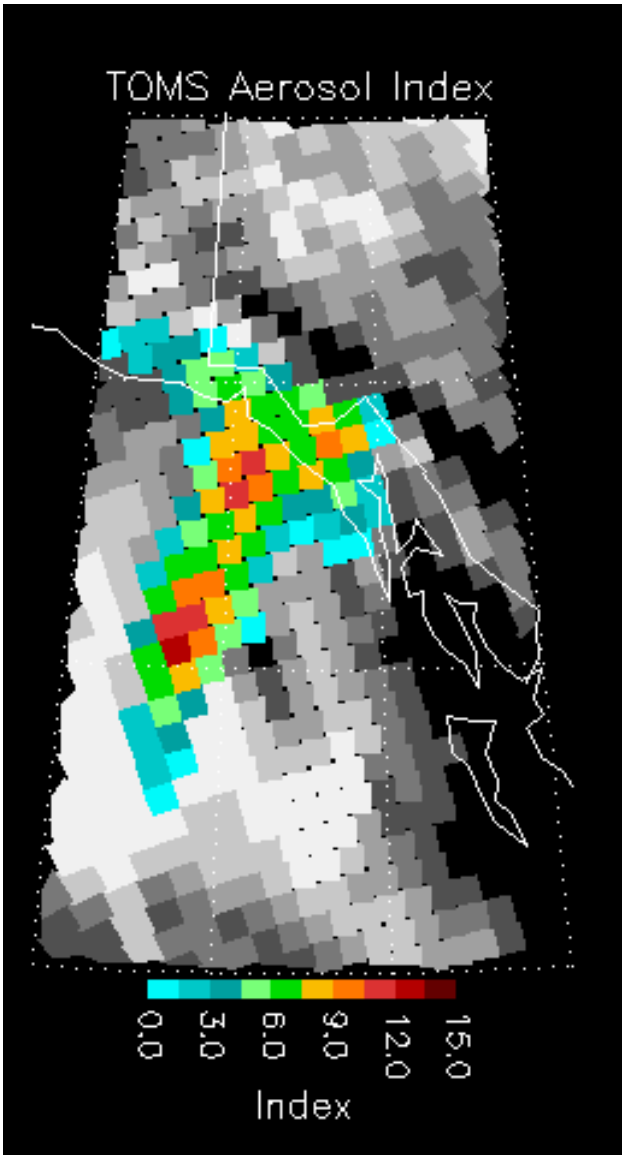


AVHRR (Advanced Very High Resolution Radiometer) image of Mount Spurr 1992 eruption, taken August 19, 1992 (degrees in Celsius)

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

Module 1, Investigation 2: Figure 4

TOMS image of Mount Spurr, 1992 eruption

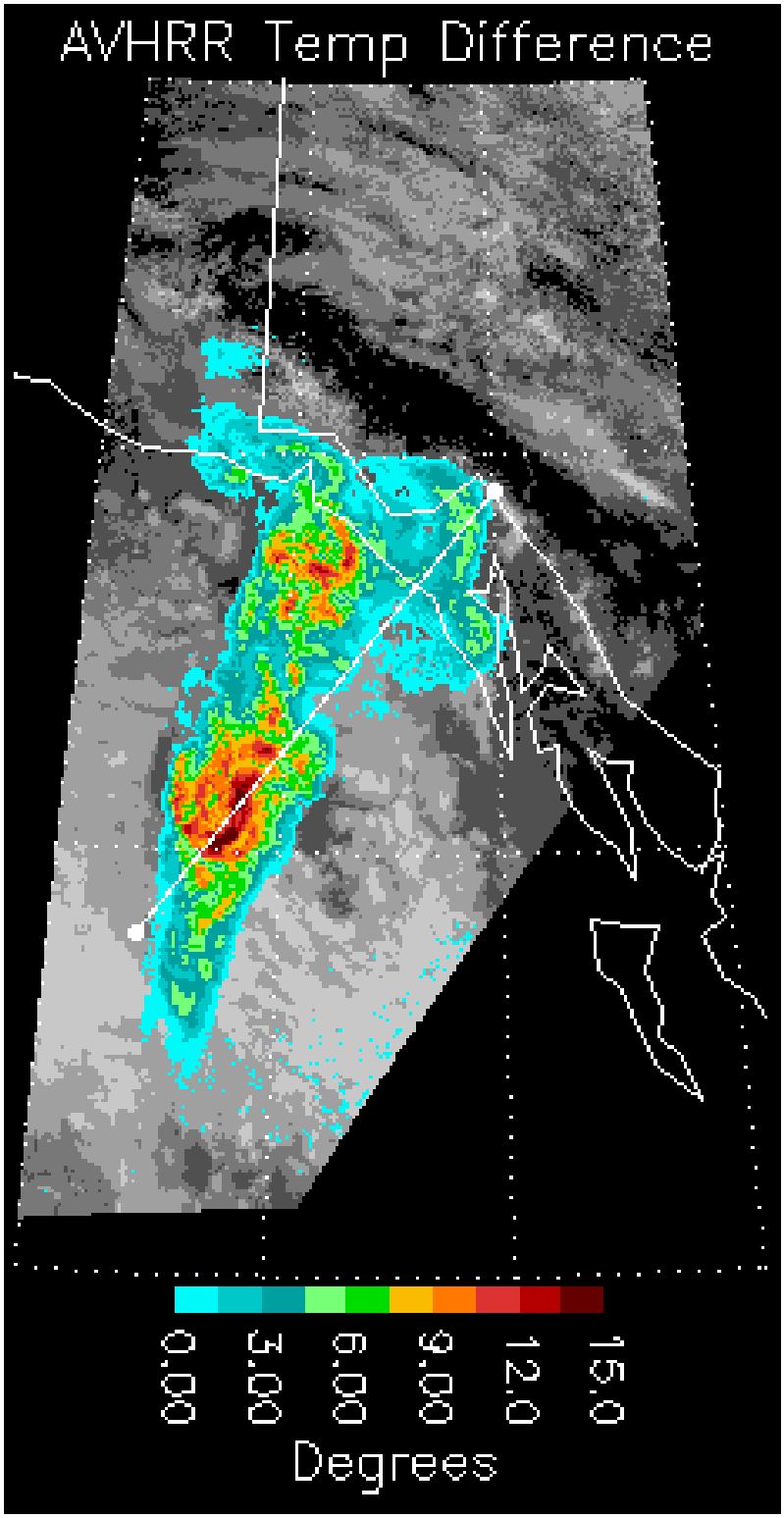


TOMS (Total Ozone Mapping Spectrometer)
image of Mount Spurr 1992 eruption, taken August 19, 1992

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

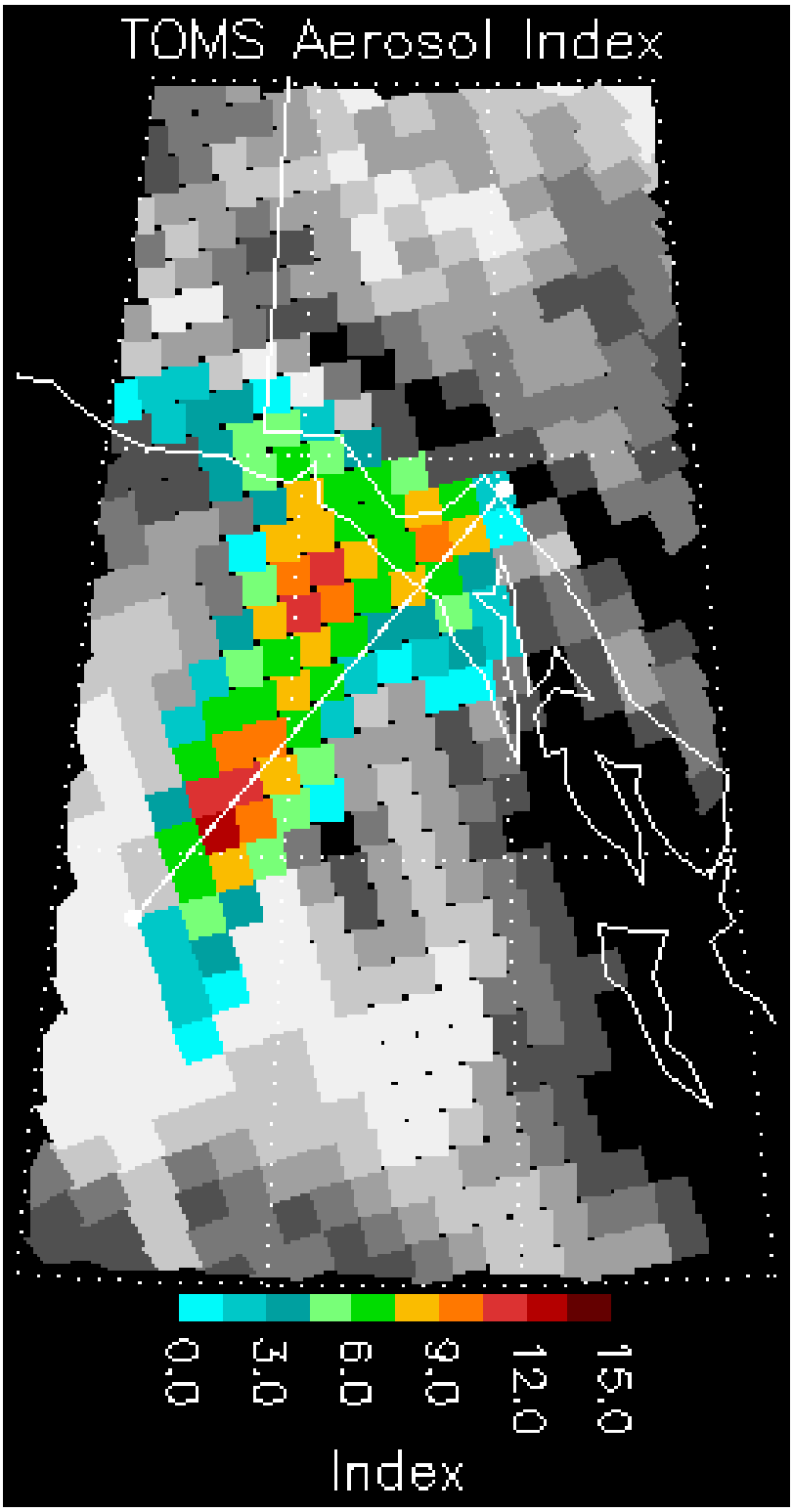
Module 1, Investigation 2: Figure 5

AVHRR with transect, August 19, 1992



Module 1, Investigation 2: Figure 6

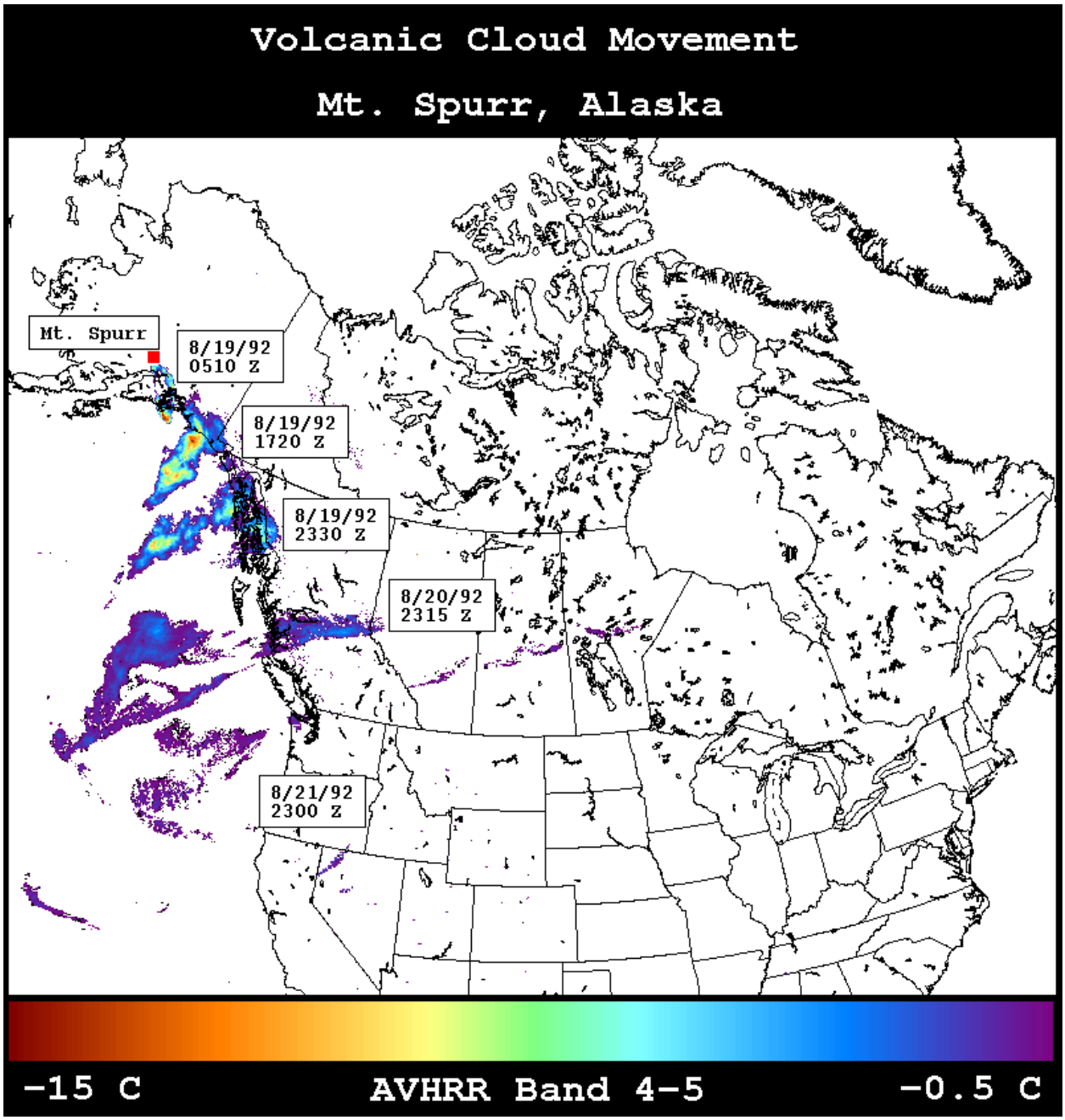
TOMS aerosol index with transect, August 19, 1992



Module 1, Investigation 2: Figure 7

AVHRR image of Mount Spurr aerosol cloud

August 19-21, 1992

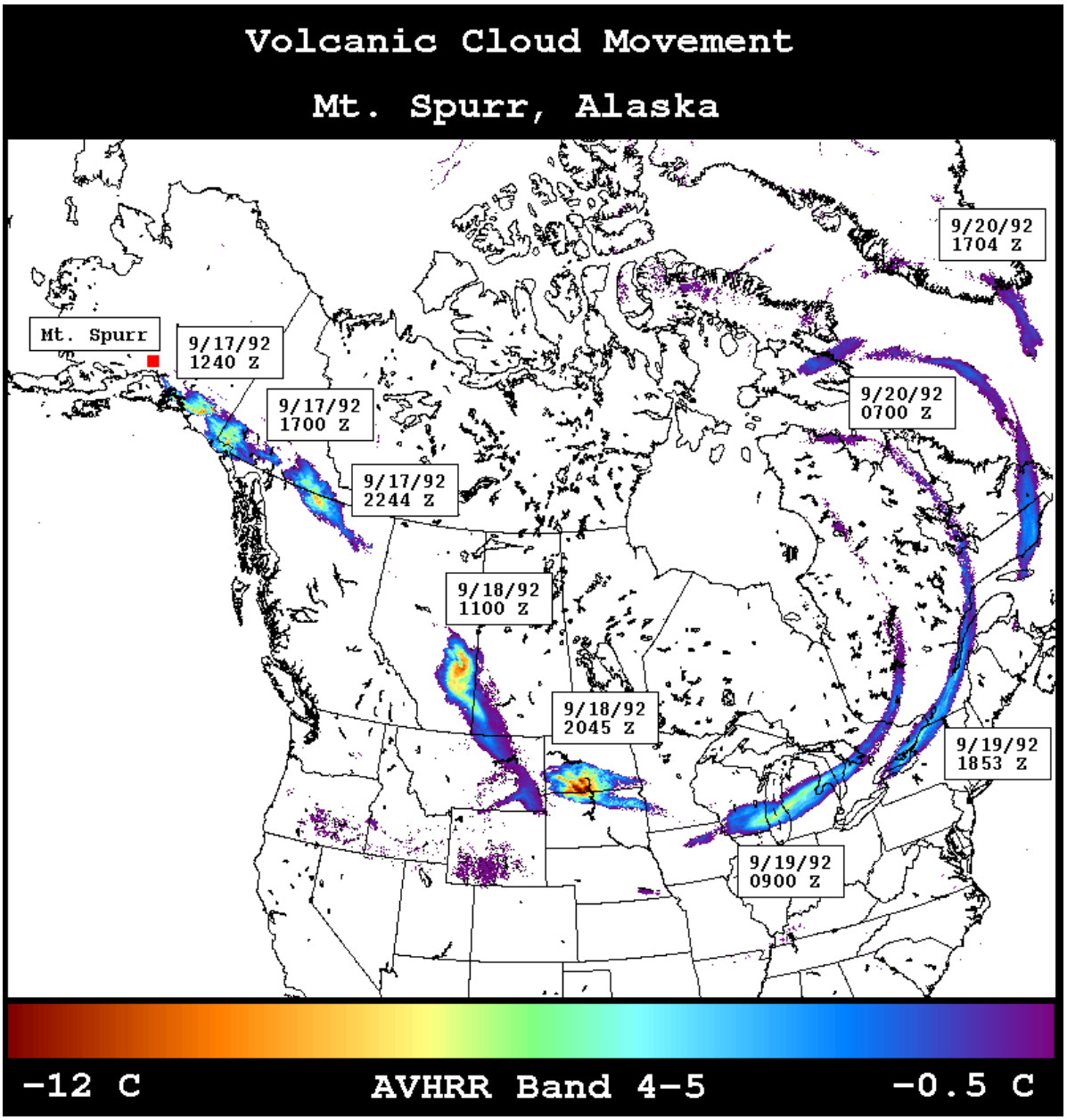


Composite image of Mount Spurr aerosol cloud movement from August 19-21, 1992
Source: http://www.geo.mtu.edu/volcanoes/research/avhrr/images/spurr/

Module 1, Investigation 2: Figure 8

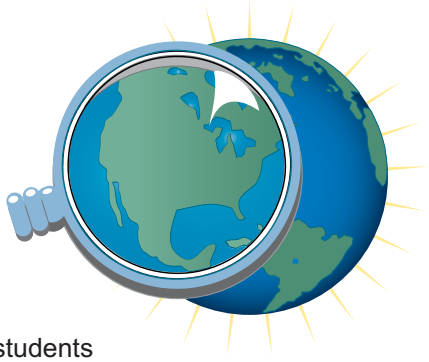
AVHRR image of Mount Spurr aerosol cloud

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

Tracking world aerosol hazards



Investigation Overview

This investigation allows students to see how geography and a spatial perspective are useful in addressing global challenges. Data gathering and organization skills are emphasized as students create maps of global aerosol hazards. In small groups, students collect either long-term or short-term data showing the distribution of global aerosols and convert the data into a map. Groups then compare their maps to identify patterns and sources of aerosols around the world. The investigation is structured to offer two options: one for students with direct access to the web in a lab setting (Option 2) and one for students without such resources (Option 1).

Time required: Three 45-minute sessions

Materials/Resources

Option 1, No Computer Lab Access:

- Transparency: Redoubt ash cloud
- Briefing (one per student or to read as a group)
- Log 1 (one per student)
- Log 2.1 (Make two transparencies per group)
- Log 3: Frequency chart (one per group)
- Log 4: World map (two per group)
- If available, a computer with access to TOMS Aerosol Animation: http://toms.gsfc.nasa.gov/aerosols/aerosols.html
- Copies of eight figures per group

Long-Term Group	Short-Term Group
Figure 1: November 23, 1990	Figure 8: August 14, 2000
Figure 2: March 15, 1993	Figure 9: August 15, 2000
Figure 3: September 15, 1996	Figure 10: August 16, 2000
Figure 4: October 21, 1996	Figure 11: August 17, 2000
Figure 5: May 29, 1997	Figure 12: August 18, 2000
Figure 6: February 14, 1998	Figure 13: August 19, 2000
Figure 7: August 8, 1999	Figure 14: August 20, 2000
Figure 8: August 14, 2000	Figure 15: August 21, 2000

- Two transparency pens per group
- Colored pencils (six per group)

Option 2, Web Access:

- Transparency: Redoubt ash cloud
- Briefing (one per student or to read as a group)
- Log 1 (one per student)
- Log 2.2: Data tally sheet (eight copies per group)
- Log 3: Frequency chart (one per group)
- Log 4: World map (two per group)
- Computer access to TOMS Aerosol Index for small groups: http://toms.gsfc.nasa.gov/aerosols/aerosols.html
- Colored pencils (six per group)

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

- Use geographic tools and technologies to pose and answer questions about spatial distribution and patterns on Earth.

Standard 15: Environment and Society

How physical systems affect human systems

- Analyze ways in which human systems develop in response to conditions in the physical environment.

Standard 18: The Uses of Geography

How to apply geography to interpret the present and plan for the future

- Analyze the interaction between physical and human systems to understand possible causes and effects of conditions on Earth and to speculate on future conditions.

Geography Skills

Skill Set 2: Acquire Geographic Information

- Use maps to collect and/or compile geographic information.

Skill Set 3: Organize Geographic Information

- Prepare various forms of maps as a means of organizing geographic information.

Skill Set 4: Analyze Geographic Information

- Use statistics and other quantitative techniques to evaluate geographic information.

Content Preview

Aerosols are tiny particles in the atmosphere that come from a variety of sources (primarily volcanic ash, dust, and smoke). Volcanic eruptions emit large clouds of ash, which can damage aircraft that fly through them. Desert areas produce dust clouds of sand and other light particles swept up by winds. Smoke aerosols result from burning biomass, primarily forests.

Students compare short-term and long-term observations of aerosols. Isolated sources of aerosols, such as volcanic eruptions or seasonal fires, are best observed through short-term daily observations. Long-term observations reveal areas with consistent aerosol hazards.

Classroom Procedures

Beginning the Investigation

1. Distribute the **Briefing** and display **Transparency: Redoubt ash cloud**, while students read the account of the plane's encounter with an ash cloud from the Redoubt Volcano in 1989. Explain that damage to aircraft like that mentioned in the story contributed to the establishment of worldwide Volcanic Ash Advisory Centers to help inform pilots of volcanic ash dangers. These centers receive information from volcano observatories, air traffic control towers, and meteorological agencies. One source for information about volcanic ash clouds is NASA's TOMS (Total Ozone Mapping Spectrometer).

2. Explain that volcanic ash is a serious concern for aircraft safety, but that there are many aerosols that may damage airplanes, such as ash, dust, and smoke from burning biomass.

3. Divide students into groups of four. **Option 2:** At separate computer stations (or projected for the entire class, if possible in **Option 1**), have students go to <http://toms.gsfc.nasa.gov/aerosols/aermovie.html> to observe an animation about aerosol movement over a two-month period. Assign different groups to watch for potential volcanic activity in different regions of the world.

   Option 1: If no access to the animation is available, this step may be omitted.

4. Allow students to share their observations. Ask:
   - Which region had the greatest aerosol activity during the two-month period?
   - Where did the aerosols in your assigned region travel?
   - Considering what you know about the region that you were observing, what do you think caused the aerosols? Volcanic ash? Smoke from fires? Dust?

   After students have shared their predictions, explain the causes for the aerosols in various regions.

5. Explain to students that this animation showed a two-month period of time. Pose the question: Do you think the patterns of aerosols would be different over a longer period of time?

Developing the Investigation

6. Assign equal numbers of small groups the task of either a short-term or long-term study. Some groups should collect TOMS data for eight consecutive dates (short-term). The other groups should collect TOMS data for eight random dates that they determine within a 10-year time span (long term).

   For Option 1:
   Provide the short-term groups with **Figures 8-15**, two transparency pens, and two transparencies of **Log 2.1**. Provide the long-term groups with **Figures 1-8**, two transparency pens, and two transparencies of **Log 2.1**.

   For Option 2:
   Ask student groups (in smaller subgroups if additional computers are available) to go to the TOMS website <http://toms.gsfc.nasa.gov/aerosols/aerosols.html>. Ask the short-term groups to select a series of eight consecutive dates. Ask the long-term groups to select a series of eight random dates of data. If access is limited to only a few computers, have students print the images for the dates they select.

7. **For Both Options:**
   In order to keep track of the aerosol data, students should "index" each figure by lettering the blocks across and numbering the blocks down so that each square has a reference of A1 to R14 (14 numbers down and 18 letters across).

   For Option 2: This step is more helpful if the images are printed out, but students can use the grid as mental references if printing must be conserved.

8. **Option 1:**
   Students should systematically lay the transparency over each figure, carefully lining up the grid with the grid on the figure. With a transparency marker, students should place a dot in each square that contains aerosols. Using the same transparency, repeat this process for each figure.

   Option 2:
   Each group then inspects each square and records on **Log 2.2** "yes" if aerosols are present or "no" if they are not.

9. **For Both Options:**
   When all data have been recorded, the groups should tally the results from all eight figures for each block and record the data on **Log 3**. How many times were aerosols present in each square?

   Have students calculate the percentage of time aerosols were present in each square of their map by dividing the frequency observed and recorded by the number of observations (eight). If time does not permit, these calculations may be omitted and students may map their raw numbers.

10. In order to map world aerosol hazard zones, have students determine a way to categorize their data by ranking the area hazard levels as follows:
    1—severe hazard area,
    2—moderate hazard area, and
    3—no or low hazard area.

    Directions for determining equal classes are located in the **Background** section. If time does not permit, provide students with one of the following ranking schemes for their maps.

Hazard Level	Percentages	Raw Numbers
Level 3	67-100%	6-8
Level 2	34-66%	4-5
Level 1	0-33%	0-3

    For example, if students observed aerosols in a particular grid cell in five of their images, they would categorize that square as a Level 2 hazard because aerosols were found 62.5 percent of the time. If aerosols were observed in seven of the images, students would label that square a Level 3 hazard because aerosols were found 87.5 percent of the time.

11. Distribute **Log 4**. Have all groups create two identical maps of their data using three colored pencils. Students should include all appropriate map elements on their maps: title, orientation, authors, dates. An appropriate title would identify the map as a *long-term* or a *short-term* aerosol study.

    Note: Maps are easiest to interpret when colors are carefully chosen to reflect the data being presented. For example, a light color should signify a low risk, while a darker color should signify a high hazard risk. When students begin to analyze their maps, the patterns for high aerosol risks will be more evident.

Concluding the Investigation

12. Ask each group to analyze their maps and prepare answers to the following questions:
    - What patterns do you observe on your map? Are there concentrated areas that have high/medium/low aerosol hazards?
    - Considering what you know about global environments (locations of deserts, forests, and volcanoes), what is probably causing the patterns that you observed (volcanoes, dust, smoke from biomass burning)?

13. Ask each group to share their maps and analysis with the class.

14. Have the long-term and short-term groups compare maps. Split each group into pairs (each with a copy of the group's map) and match them with pairs from the other group. The new groups of four should consist of two students from both long-term and short-term groups.

15. In the new groups, ask students to compare the maps created by the two groups:
    - What are the pattern similarities and differences?
    - Are there areas that are shown to be dangerous on one map but not on the other?
    - Explain any differences that your group observes.

16. Provide students time to process the benefits and limitations of their research and analysis by asking the following questions:

- Which data collection method is better for identifying isolated, episodic sources of aerosols? (*Short-term or daily data collection is better because isolated sources such as volcanic events, fires, and other local aerosol-producing activities may not be identifiable if observation dates are not consecutive.*)
- Which data collection method is better for identifying persistent sources of aerosols? (*Long-term data collection is better because it minimizes the impact of isolated sources of aerosols and exaggerates the areas that consistently produce aerosols, such as dust storms and large-scale burning of forests.*)
- In which category (isolated episode or persistent source) would volcanic eruptions be considered? (*Isolated episode, although the ash ultimately travels around the globe.*)
- What type of observation of aerosols would be needed to minimize the *immediate* dangers to aircraft? (*Daily observations to quickly identify local sources of aerosols.*)
- What would be the potential benefit of each type of observation technique to the safety of airplanes? (*Daily observation can help to identify localized hazards for aircraft to avoid. Long-term observation and trend information can help to develop safe flight paths that avoid high-hazard areas.*)

Background

Determining Equal Class Ranking Scheme

Step	Example
1. Subtract the lowest possible value from the highest possible value.	100%-0% or 8-0
2. Divide the answer by the number of categories needed. Round as desired. This is the unit size.	100/3 = 33.333 (33%) 8/3 = 2.67 (3)
3. Determine the divisions for each class by starting with the lowest possible. For the second class, add one to the unit size so that any number falls into only one class.	Percentages 0-33 34-66 67-100
4. Adjust classes, if necessary, to better reflect the data to be mapped.	Raw Numbers 1-3 4-5 6-8 (Here, 6 is added to the highest class rather than being the upper boundary of the second class. This emphasizes the significance of observing aerosols 75% of the time.)

Related Resources

http://toms.gsfc.nasa.gov/aerosols/aerosols.html Images and data on aerosol index

http://capita.wustl.edu/Databases/UserDomains/SaharaDust2000/ Additional resources about the effects of dust storms from Africa using SeaWiFS data

http://volcanoes.usgs.gov/Hazards/What/Tephra/tephra.html USGS source for information on airborne volcanic hazards

http://volcanoes.usgs.gov/Hazards/Effects/Ash+Aircraft.html USGS information on volcanic ash and aircraft

http://www.avo.alaska.edu/genrl_info/pdfs/usgsfs030_97_ash.pdf USGS fact sheet on the interaction of airplanes and ash. In .pdf format.

http://www.geo.mtu.edu/department/classes/ge404/gcmayber/ Volcanic ash clouds and aircraft safety

http://www.geo.mtu.edu/department/classes/ge404/gcmayber/historic.html Narrative of an aircraft encounter with an ash cloud from Redoubt

Transparency: Redoubt ash cloud

Aerial view of Redoubt Volcano during a continuous, low-level eruption of steam and ash
December 18, 1989
Source: photo by W. White, USGS, http://www.avo.alaska.edu/avo3/volc/redou/photo.htm

Module 1, Investigation 3: Log 1

How can airline damage from volcanoes be minimized?

Background

When volcanoes erupt, they spew tiny particles, called aerosols, into the air. Aerosols get swirled around in the atmosphere and can cause significant damage to airplanes flying through these clouds. Between December 1989 and February 1990, five commercial airplanes were damaged because they encountered volcanic ash from Redoubt Volcano, an active volcano in Alaska. The volcanic ash caused more than $80 million in damages to just one of the airplanes! Please help to identify areas in the world where aerosols can present a hazard to aircraft safety.

Objectives

In this activity, you will

1. identify the sources of aerosols worldwide,
2. develop a time series for global aerosols, and
3. prepare a world map that ranks regions by hazard potential based on any images and data you collect.

Procedures for the Investigation

1. To get an idea about the dangers associated with volcanic ash, read the story of a plane that encountered an ash cloud from the Redoubt Volcano in Alaska. This 1989 eruption encouraged the formation of a group of nine Volcanic Ash Advisory Centers (VAACs) that use information from NASA's Total Ozone Mapping Spectrometer (TOMS) sensors, weather data, and air traffic control towers to warn pilots of ash clouds in their flight path.
2. You will be gathering, organizing, and analyzing TOMS aerosol data for eight dates to identify hazardous areas for airplanes.
3. Follow your teacher's directions to collect and record the data. Divide the work evenly among your group members so everyone has a chance to contribute.
4. After all the dates have been analyzed, total up the information from all eight of the dates and record your answers on Log 3: Frequency chart.
5. Make each tally into a percentage by dividing the number of times the square contained aerosols by the number of dates that you checked (eight). Fill in the following chart to convert days to percentages more quickly.

Dates aerosols were observed in the square		Percentage of time aerosols were present
1	1/8=	
2	2/8=	
3	3/8=	
4	4/8=	
5	5/8=	
6	6/8=	
7	7/8=	
8	8/8=	

Module 1, Investigation 3: Log 1

How can airline damage from volcanoes be minimized?

6. Based on the data, rank the regions of the world by aerosol hazard: Level 1—no or low hazard area, Level 2—moderate hazard area, Level 3—severe hazard area.

7. Create two identical world maps showing these hazard areas. Color areas according to the rating that you gave; for example, use yellow for the low hazard regions, orange for the moderate hazard regions, and red for the severe hazard regions.

   Be sure to include all appropriate map elements on the front of both the maps. The map title should be descriptive so that people know what data you mapped.

8. Share your maps with the class. Prepare an explanation of the maps using these questions to guide you.

   - What patterns do you observe on your map? Are there concentrated areas that have high, medium, and low aerosol hazards?
   - What is probably causing the patterns that you observed? Think about what you know about the locations of aerosol sources (deserts, volcanoes, and forests).

9. Divide your group into two teams. Join members from another team to analyze the two different maps. Use the following questions to guide your analysis.

   - What are similarities of and differences between the patterns on the two maps?
   - Are there areas that are shown to be dangerous on one map but not on the other?
   - Explain any differences that your group observes.

10. Based on your map comparison, which type of map (short-term or long-term) would be most helpful in identifying aerosol hazards from volcanoes? Explain your answer.

_____

_____

_____

_____

_____

_____

_____

_____

References:

http://toms.gsfc.nasa.gov/aerosols/aerosols.html

E. E. Campbell. Recommended flight-crew procedures if volcanic ash is encountered, pp.151-156

Module 1, Investigation 3: Briefing

Volcano's ash kills 747's engines en route to Anchorage

ANCHORAGE, AK—Redoubt Volcano, near Anchorage, Alaska, began erupting on December 14, 1989. On the following day, a 747-400 airplane entered an ash cloud at 7,620 meters (25,000 feet) and experienced flameouts on all four engines.

During descent to 7,620 meters (25,000 feet), the airplane entered a thin layer of clouds when it suddenly became very dark outside. The crew also saw lighted particles pass over the cockpit windshields. At the same time, brownish dust with a sulfurous smell entered the cockpit. The captain commanded the pilot flying to start climbing to attempt to get out of the volcanic ash. One minute into the high-power climb, all four engines flamed out. Due to the volcanic ash and dust in the cockpit, the crew donned oxygen masks.

The pilot flying noticed the airspeed descending, initially at a normal rate but suddenly very fast. All airspeed indications were then lost due to volcanic dust contamination in an instrument. The pilot flying rather firmly put the nose of the aircraft down to avoid a stall and initiated a turn to the left in a further attempt to get out of the volcanic ash.

The crew noticed a "Cargo Fire Forward" warning and decided that the fire warning was caused by the volcanic ash, so no further action was taken. As the engine slowed down, the generators tripped off and all instruments were lost except for instruments powered by the batteries.

During the time the engines were not working, the cabin pressure remained within limits and no passenger oxygen masks deployed. The crew elected not to deploy the masks because the passenger-oxygen-mask system would have been contaminated by volcanic dust in the cabin air.

An emergency was declared when the airplane passed through approximately 5,181 meters (17,000 feet). The crew stated that a total of seven or eight restart attempts were made before engines 1 and 2 finally restarted. Initially, the crew maintained 3,962.4 meters (13,000 feet) with engines 1 and 2 restarted, and after several more attempts, engines 3 and 4 also restarted.

After passing abeam and east of Anchorage at 3,352.8 meters (11,000 feet), the airplane was given clearance for a wide right-hand pattern to runway 06 and further descent to 609.6 meters (2,000 feet). The captain had the runway continuously in sight during the approach; however, vision through the windshields was impaired due to "sandblasting" from the volcanic ash in such a way that the captain and the first officer were only able to look forward with their heads positioned well to the side.

Finally, the airplane did land safely, but approximately $80 million was spent to restore the plane, which included replacing four engines. The in-depth account of this incident helped researchers devise a procedure of what a crew should do when they encounter an ash cloud.

Source: http://www.geo.mtu.edu/department/classes/ge404/gcmayber/historic.html

Module 1, Investigation 3: Log 2.1

Data-gathering grid

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		

Module 1, Investigation 3: Log 2.2

Data tally sheet

Date _____

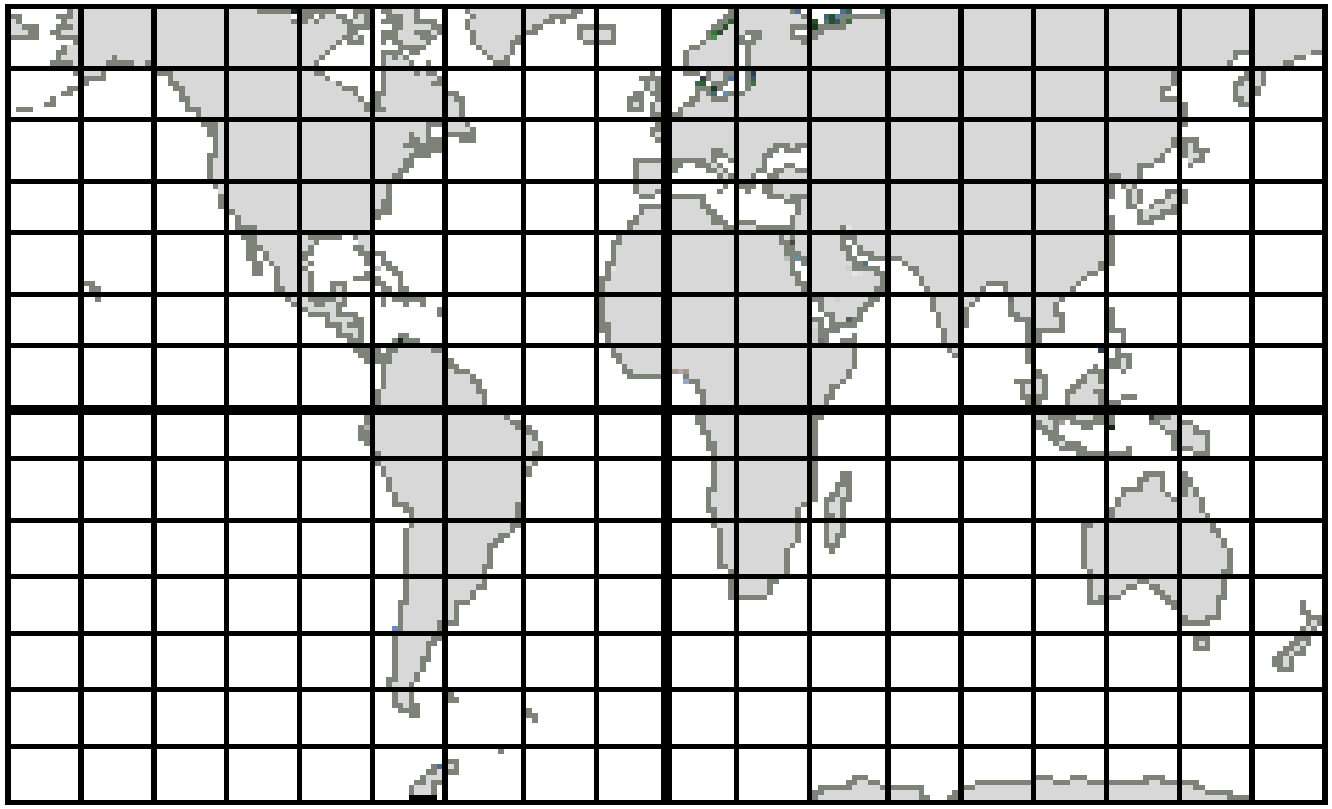
Module 1, Investigation 3: Log 3

Frequency chart

Directions: Tally each square. Then figure the percentage of time that each square contained aerosols.

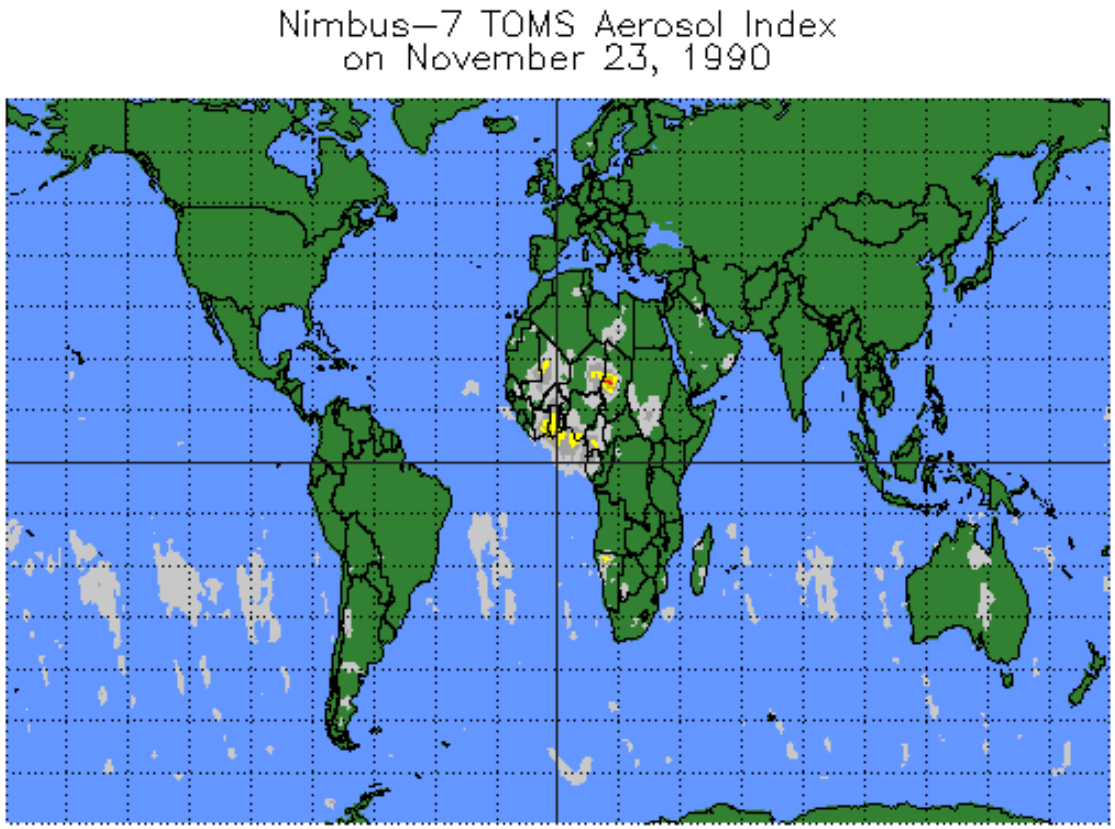
Module 1, Investigation 3: Log 4

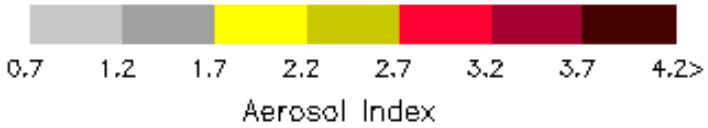
World map



Module 1, Investigation 3: Figure 1

November 23, 1990





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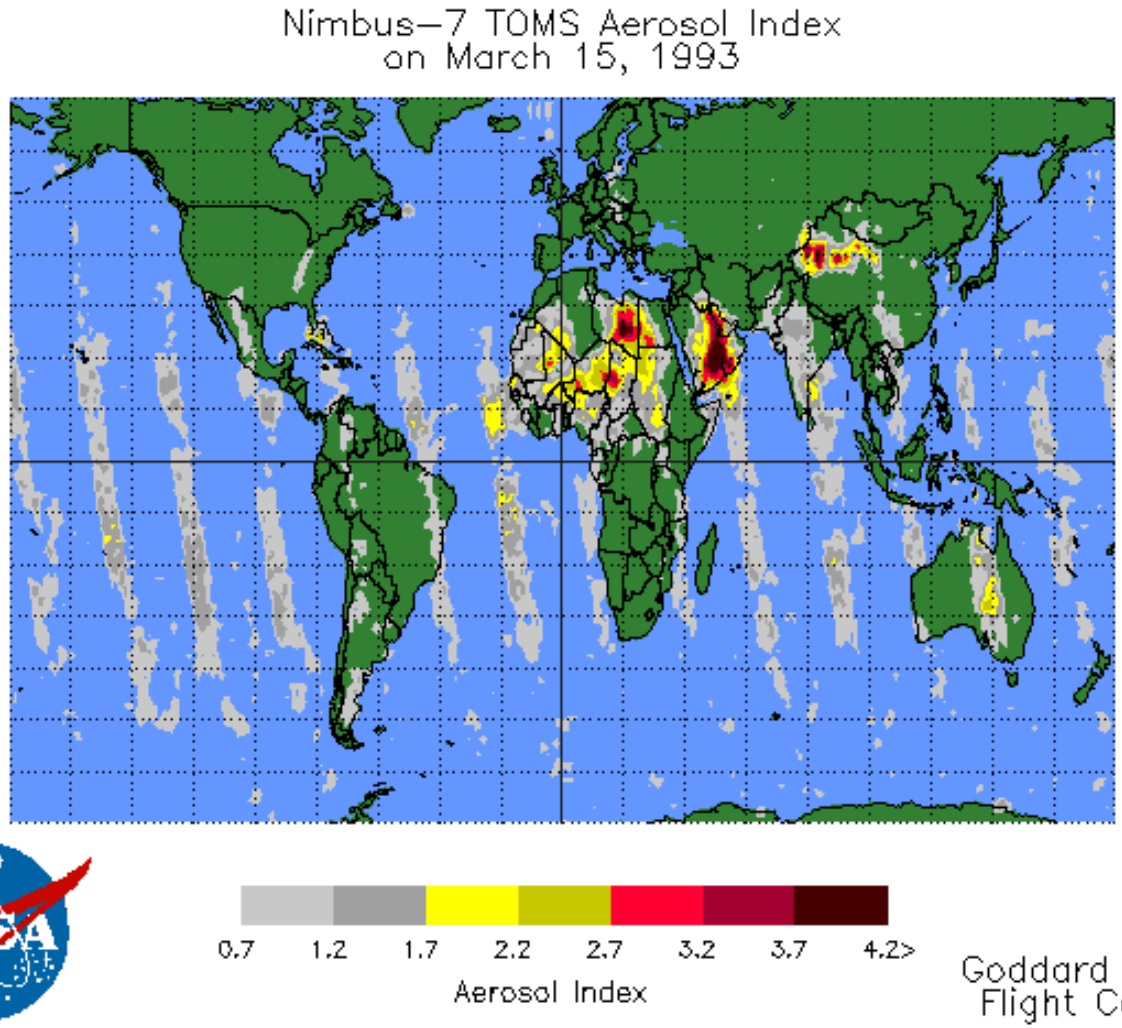
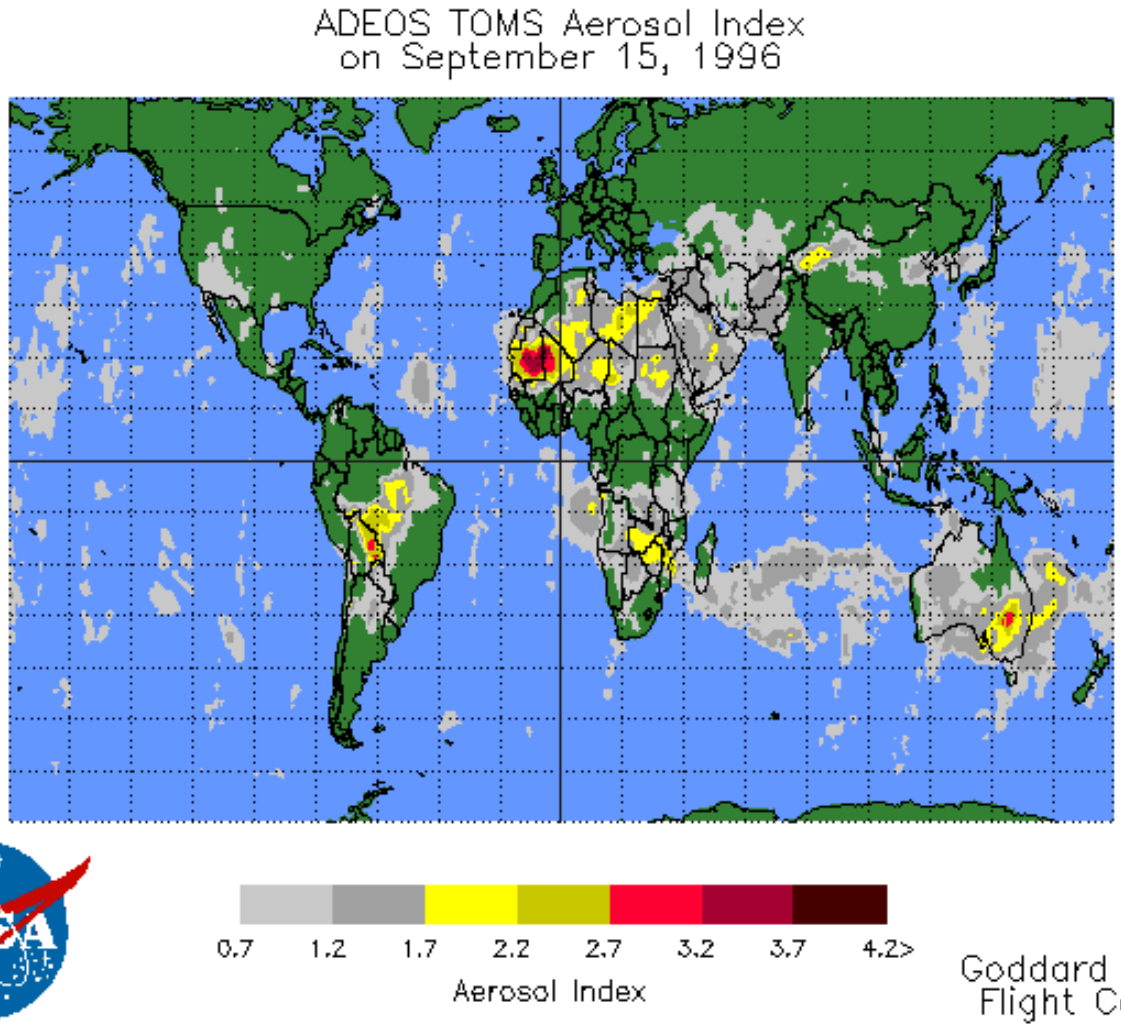
Module 1, Investigation 3: Figure 2

March 15, 1993



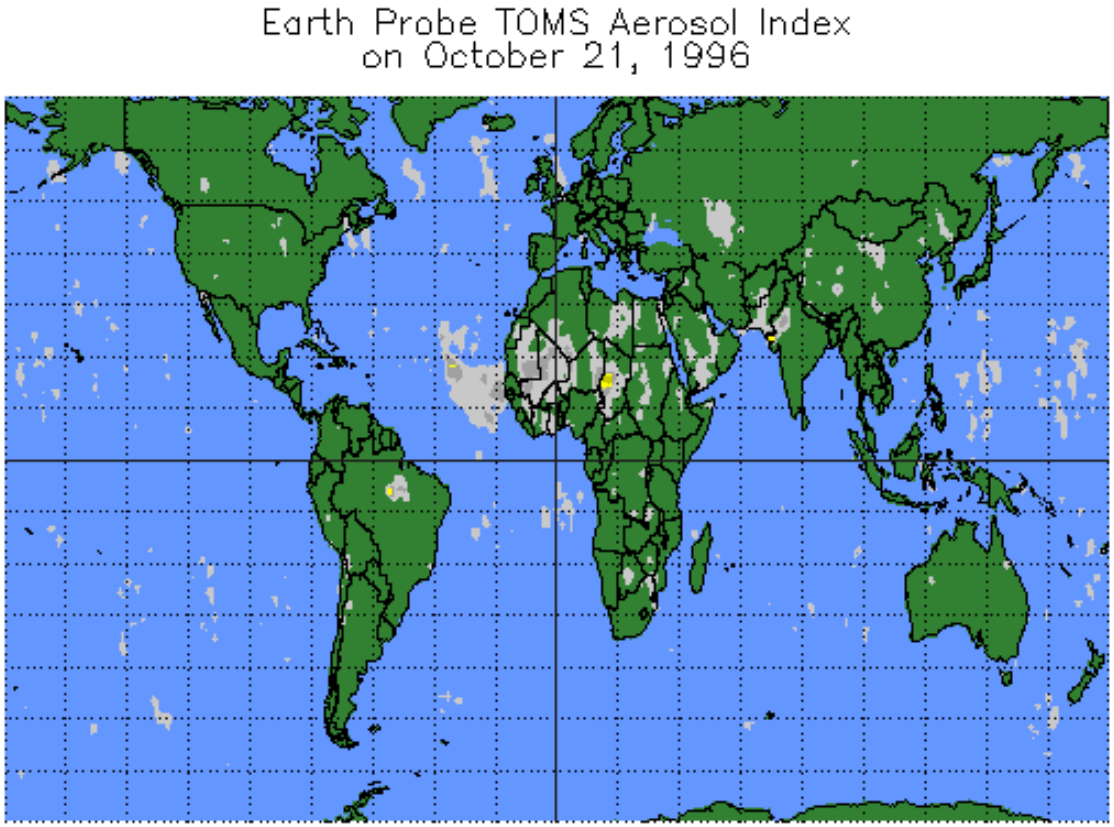
Module 1, Investigation 3: Figure 3

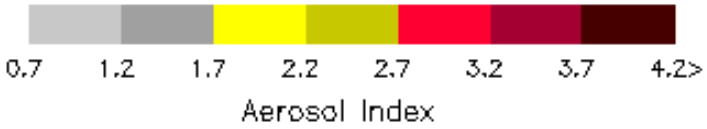
September 15, 1996



Module 1, Investigation 3: Figure 4

October 21, 1996





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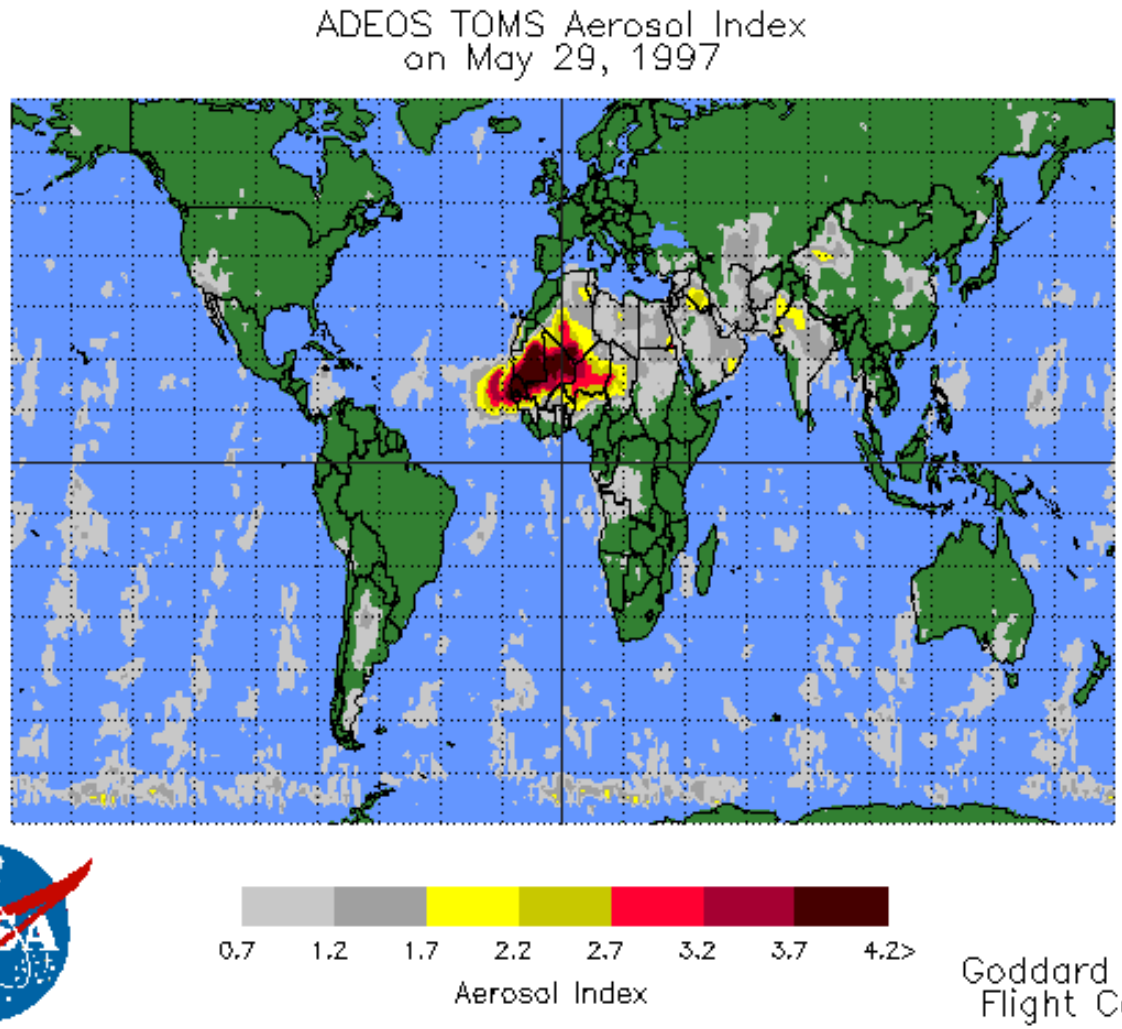
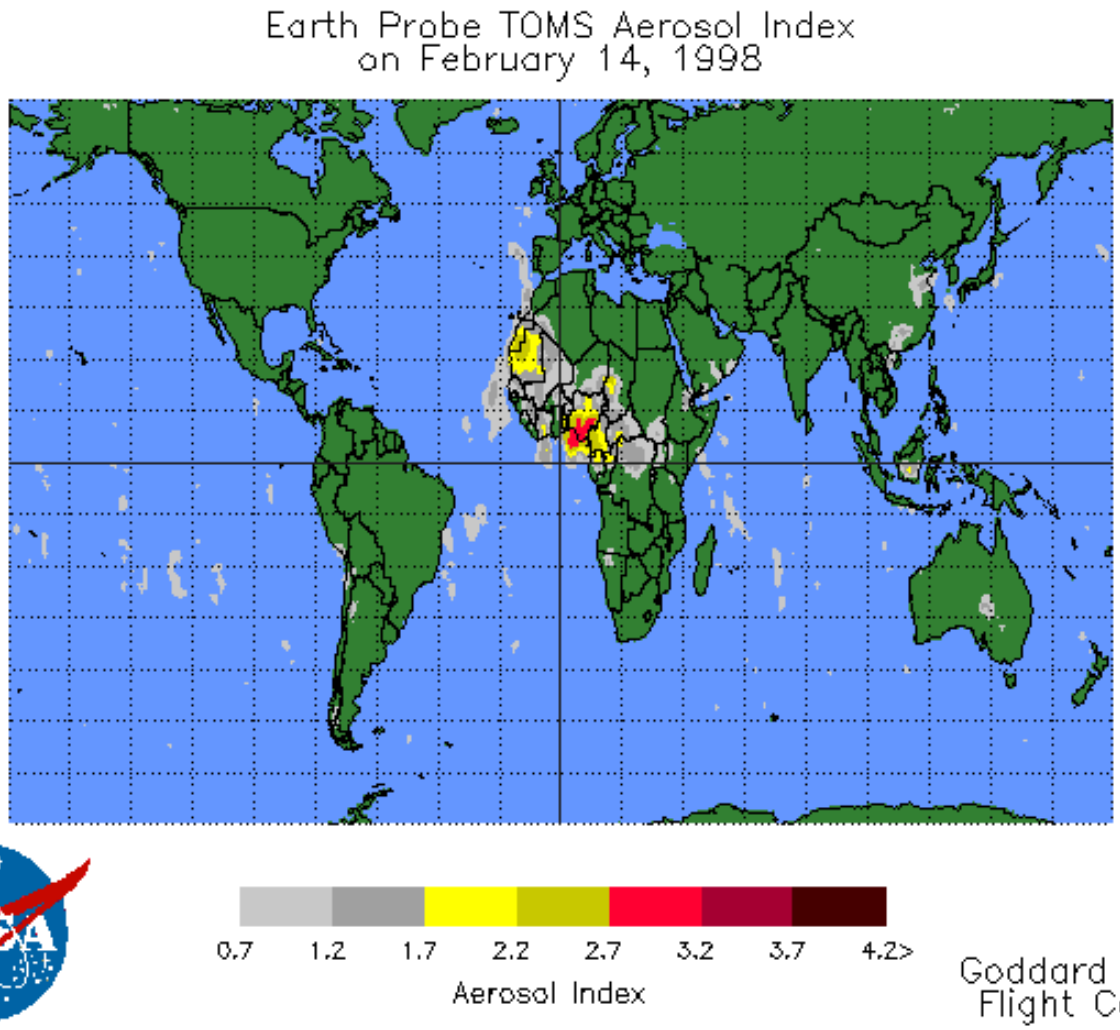
Module 1, Investigation 3: Figure 5

May 29, 1997



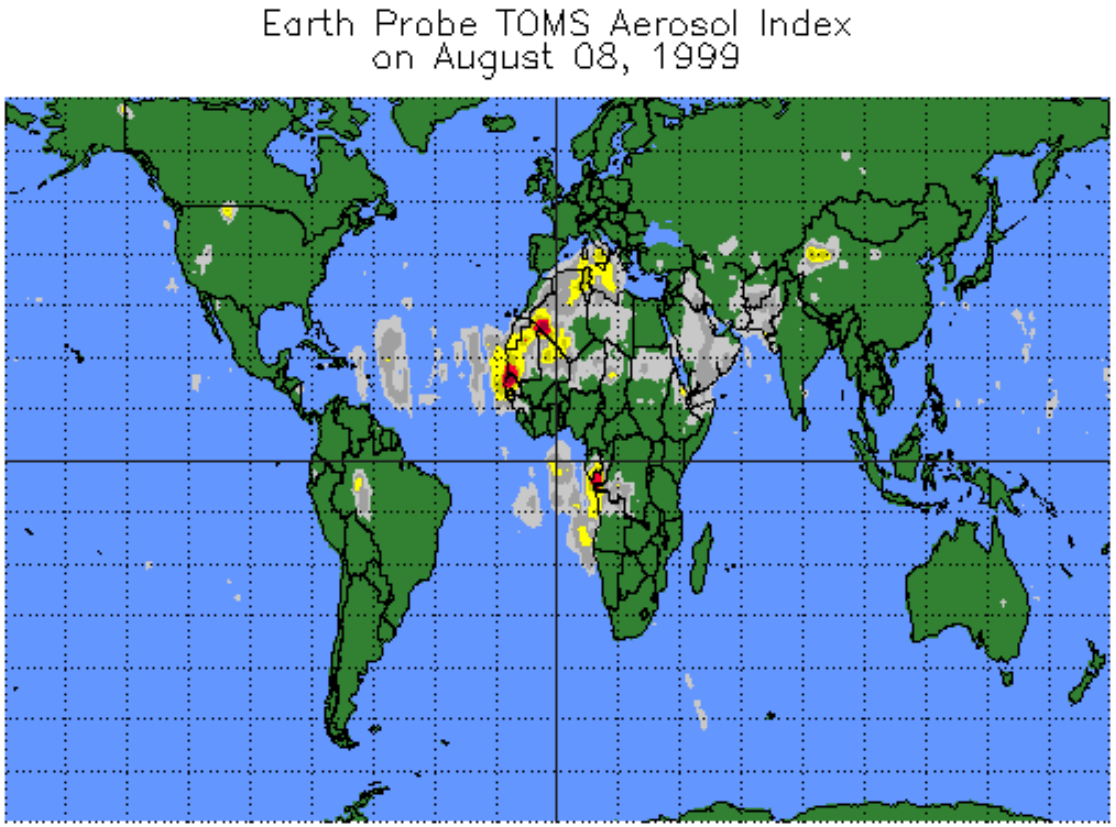
Module 1, Investigation 3: Figure 6

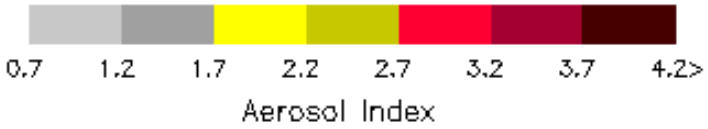
February 14, 1998



Module 1, Investigation 3: Figure 7

August 8, 1999





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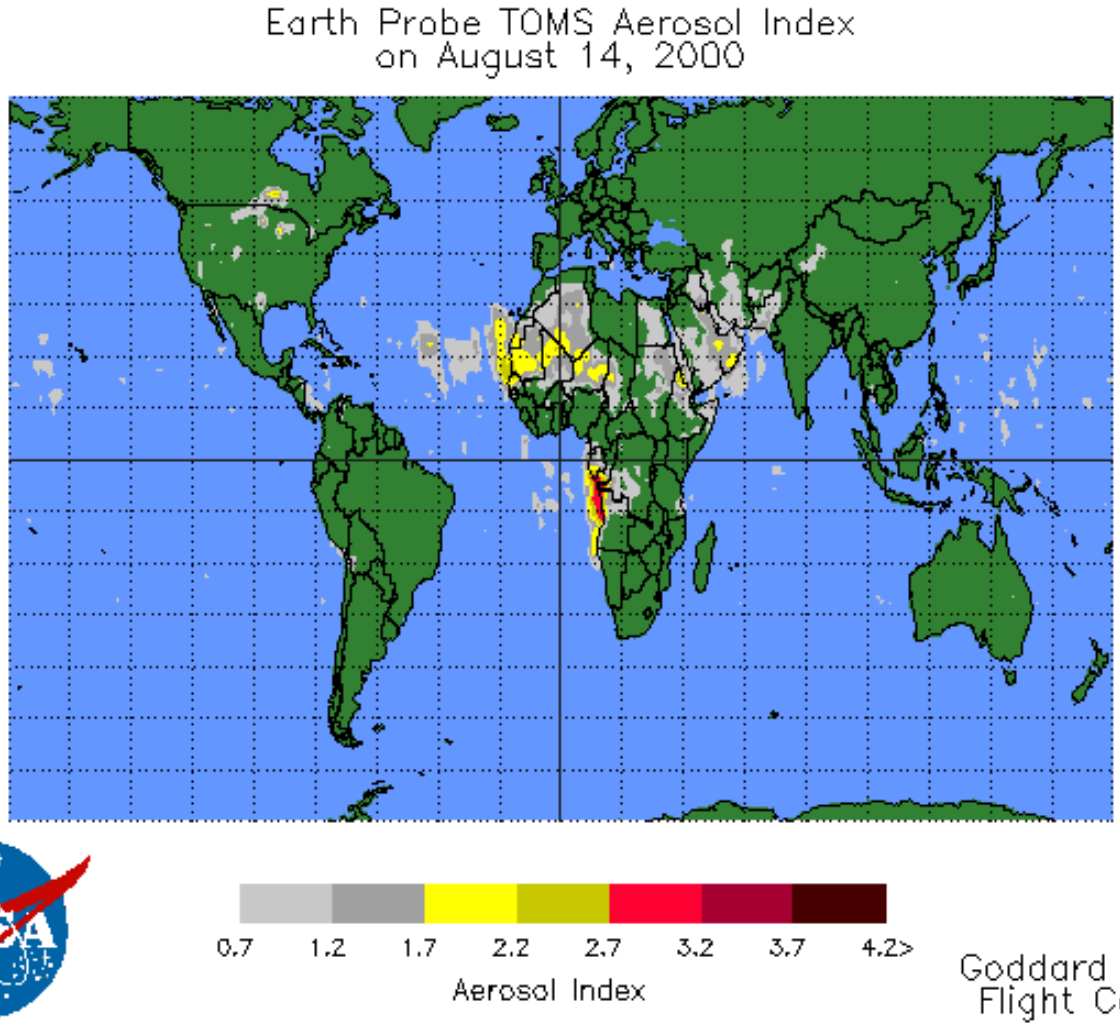
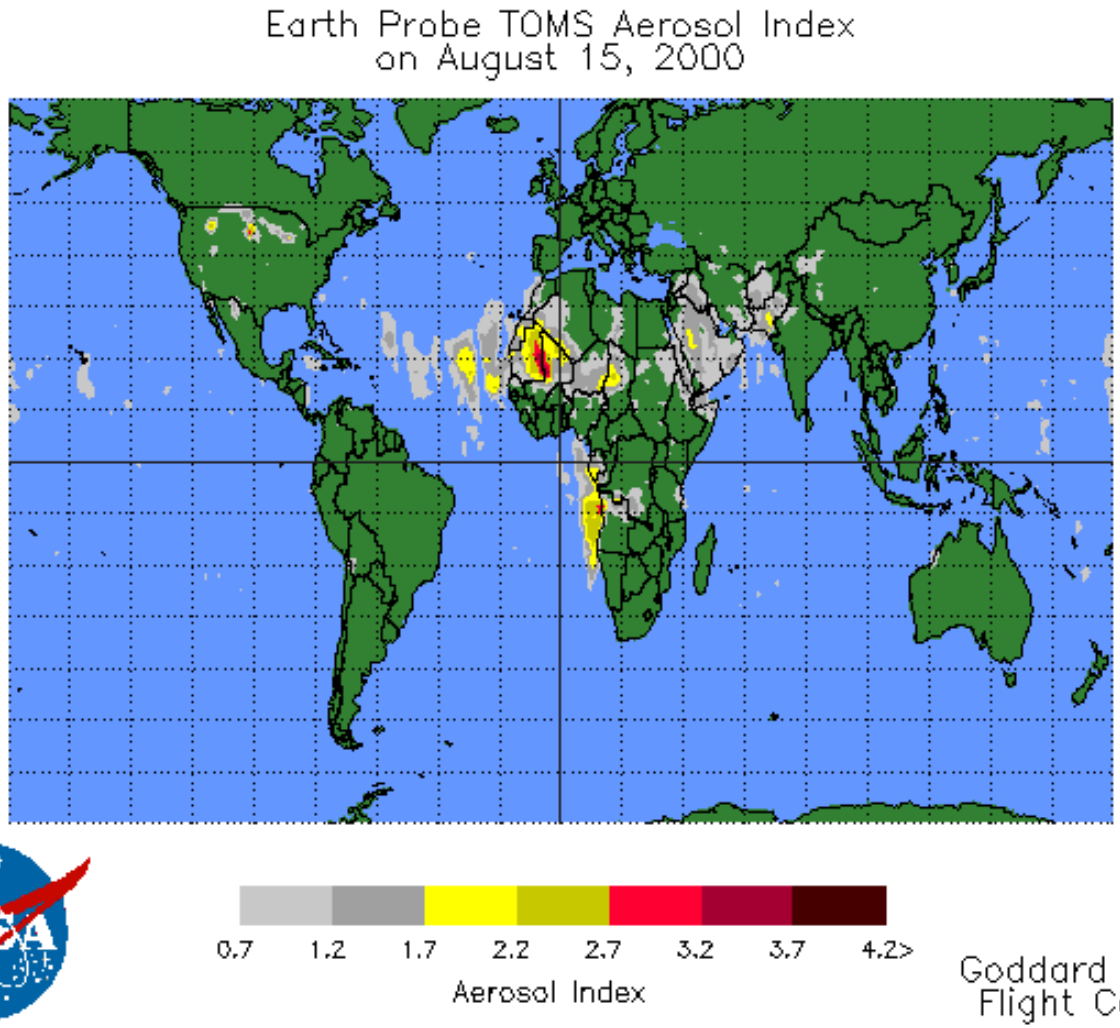
Module 1, Investigation 3: Figure 8

August 14, 2000



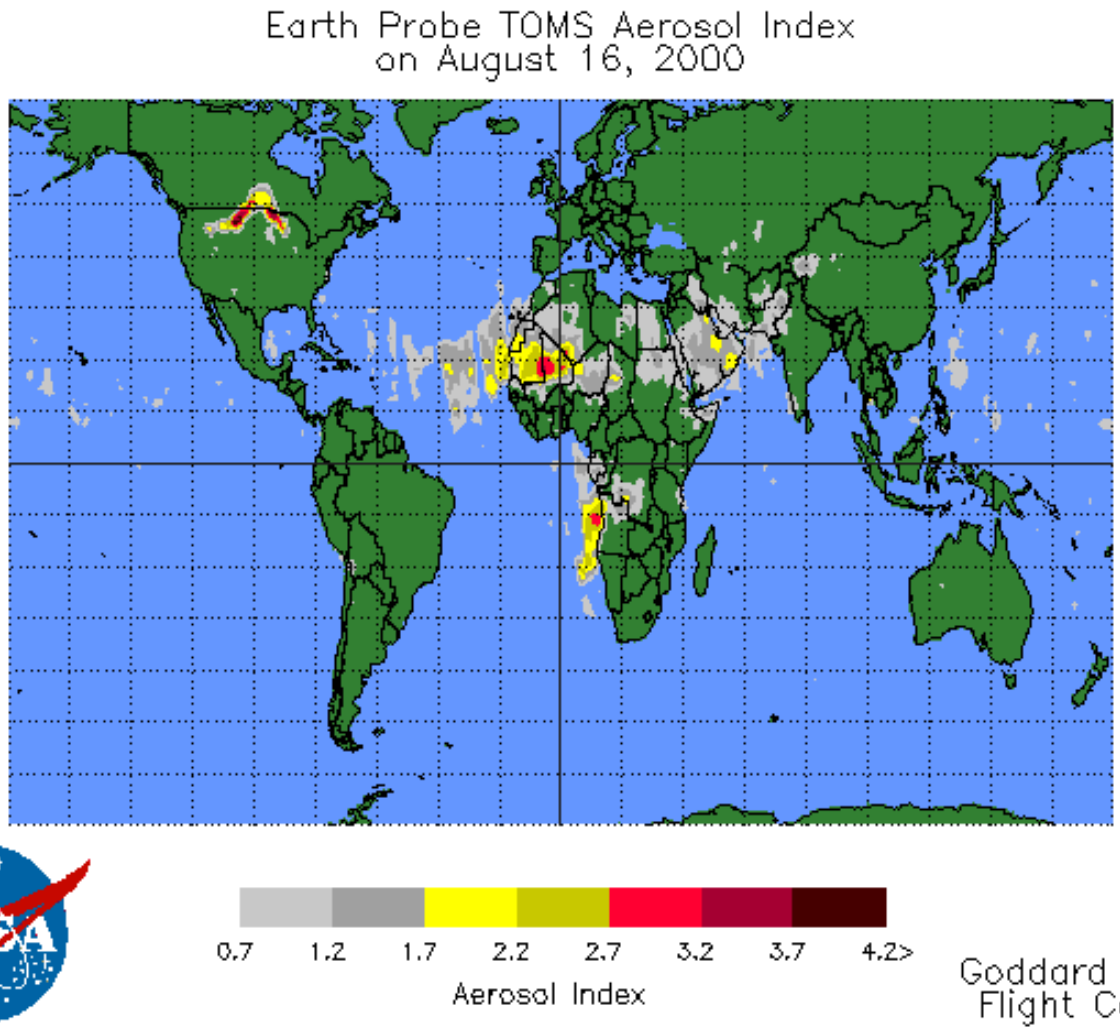
Module 1, Investigation 3: Figure 9

August 15, 2000



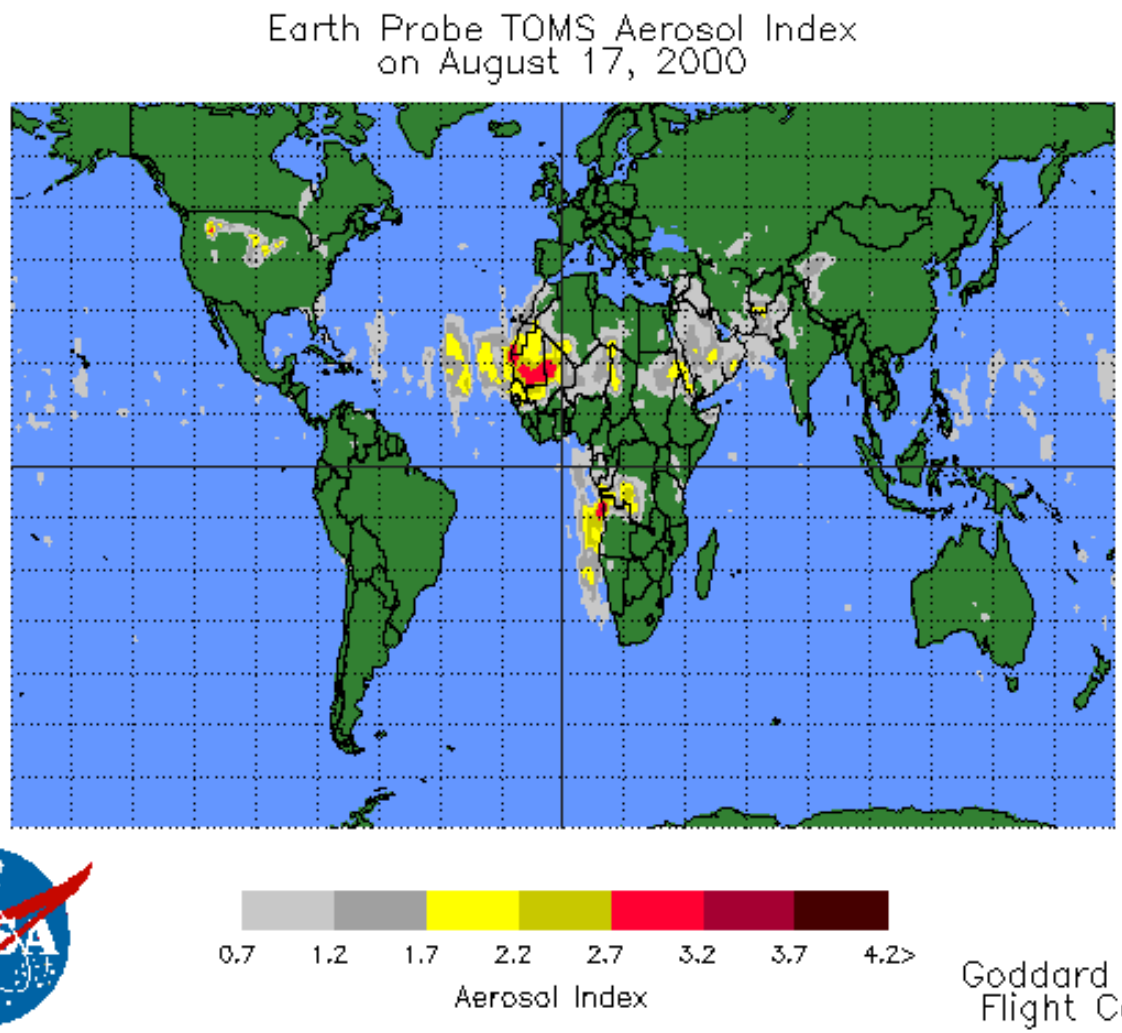
Module 1, Investigation 3: Figure 10

August 16, 2000



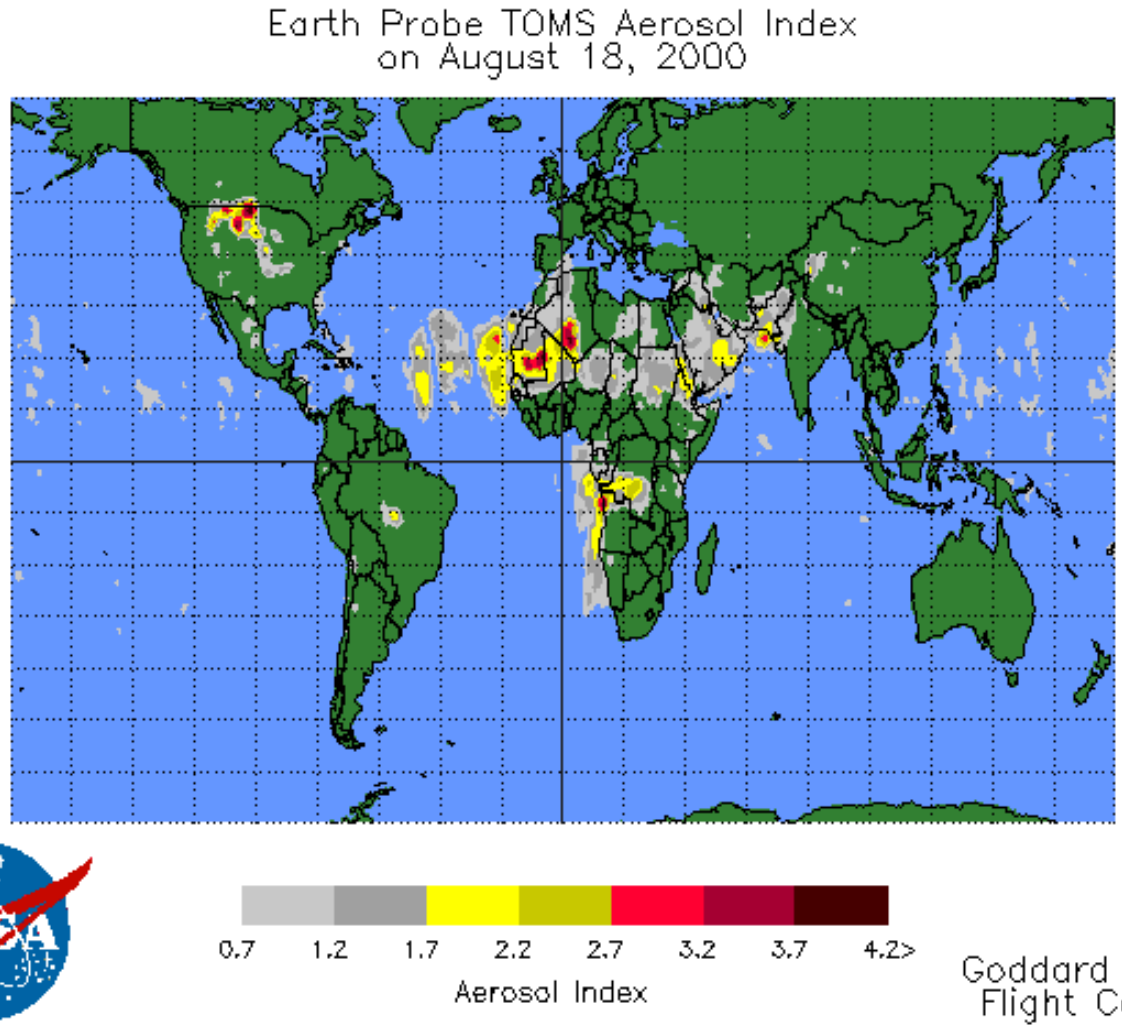
Module 1, Investigation 3: Figure 11

August 17, 2000



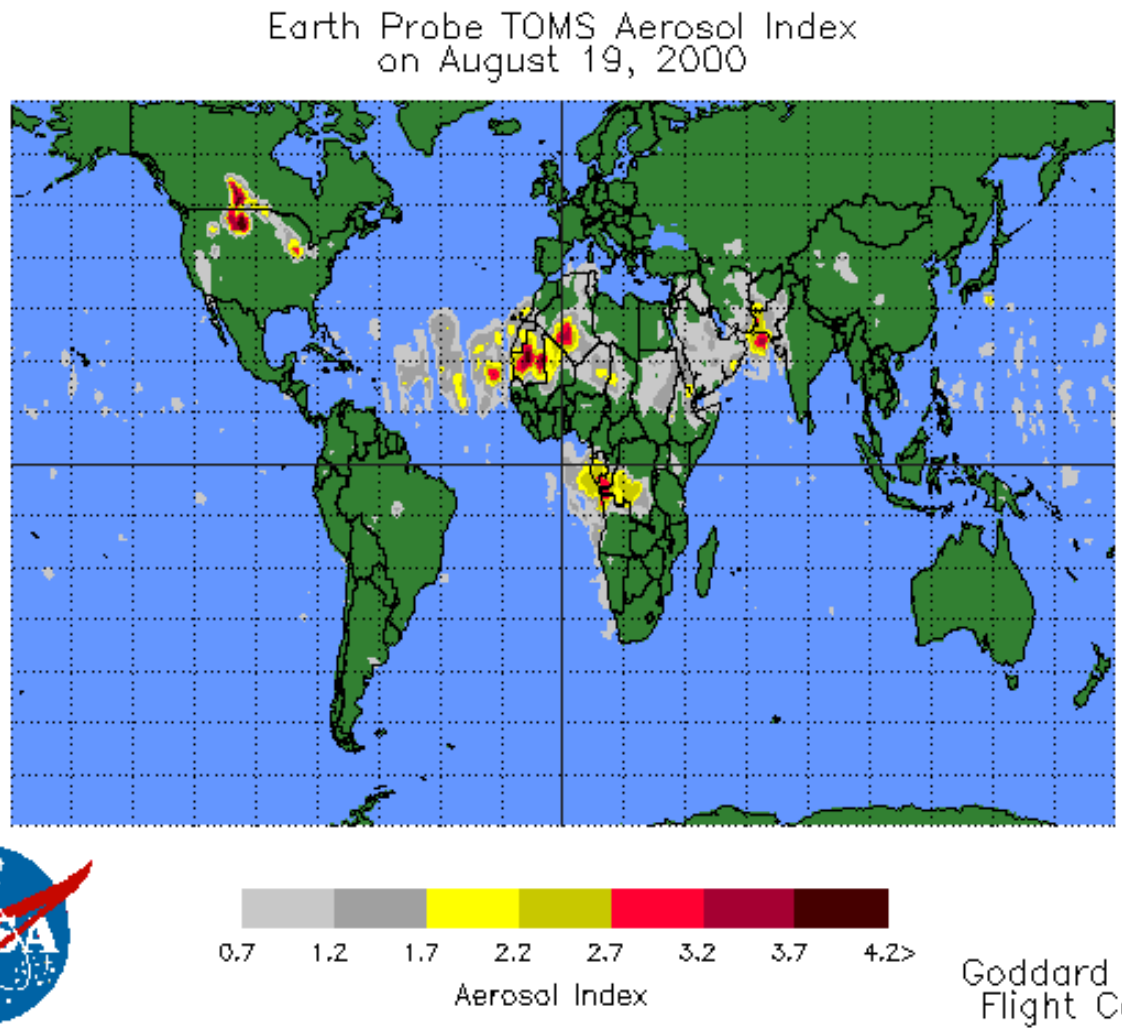
Module 1, Investigation 3: Figure 12

August 18, 2000



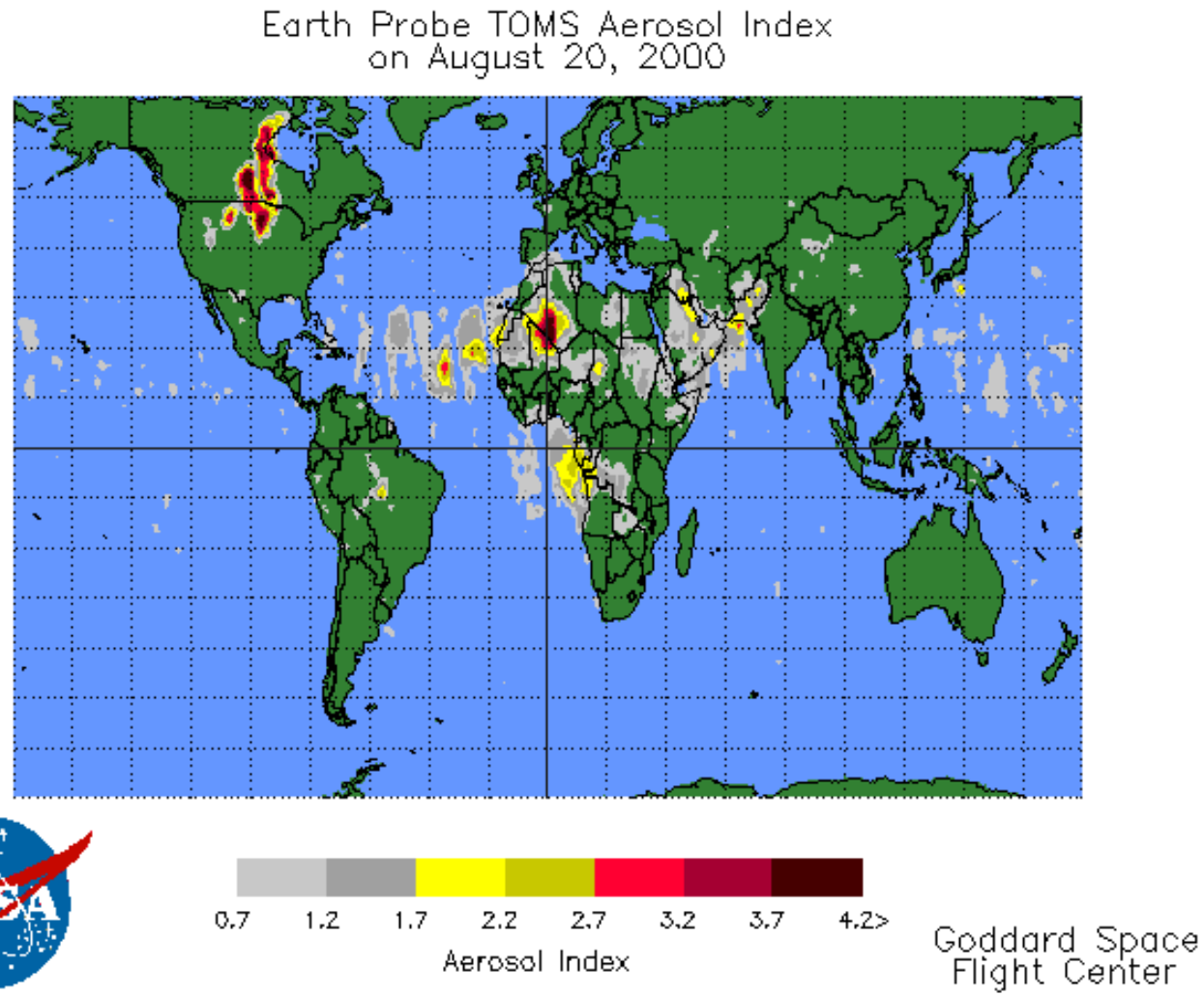
Module 1, Investigation 3: Figure 13

August 19, 2000



Module 1, Investigation 3: Figure 14

August 20, 2000



Module 1, Investigation 3: Figure 15

August 21, 2000