Paths

Module Overview

This module looks at many different kinds of paths and considers why paths are where they are and how they look from space. Paths are usually not arbitrary ways to reach a destination. People and animals make paths that take into account the terrain and other features of the landscape. Rivers, lava, smoke, and other natural phenomena follow paths. The Space Shuttle and satellites follow paths. Are some paths only visible from satellite or aerial images? Are there paths that can only be seen by remote sensing and not by the eye? What do these images tell us about links between the past and present? Paths imply movement: movement of people, goods, animals, ideas, matter, and energy. How is movement influenced by the environment and how does it affect the environment?

***Investigation 1:* Paths—What are they and who makes them?**
Students use their immediate environment to determine what kinds of paths are visible, who makes these paths, where the paths are located, and why the paths are located where they are. This investigation develops field excursion skills and introduces students to the need for "ground truthing." Students are introduced to the skill of locating a variety of human-made paths in satellite images.

***Investigation 2:* How do paths look from different perspectives?**
This investigation uses literature about paths to help students understand how the world looks from different heights. Students also identify natural and human-made paths in satellite images.

***Investigation 3:* Paths—Usual or unusual?**
NASA images introduce students to some unusual physical and human-made paths. These include ancient camel caravan tracks, lava flows, ship channels, and smoke paths. The investigation introduces the idea of one-way or two-way paths. It provides an opportunity for students to work together to study images of paths and to pose and answer many questions about them.

***Investigation 4:* How do disaster paths affect people's lives?**
Four scenarios illustrate natural disaster paths. Letters from imaginary pen pals describe how the disaster paths affected their lives. Students match satellite images with the locations of the pathways described by the pen pals. They learn about the importance of satellite imagery in alerting people to possible natural disasters.

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 2:** How to use mental maps to organize information about people, places, and environments in a spatial context

Environment and Society
- **Standard 14:** How human actions modify the physical environment
- **Standard 15:** How physical systems affect human systems

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

Science Standards

Unifying Concepts and Processes
- Evidence, models, and explanation
- Constancy, change, and measurement

Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Earth and Space Science
- Properties of Earth materials

Connection to the Curriculum

This module can be used in geography, social studies, and science classes to study the connections between and among places. Students develop skills in reading and interpreting maps and images as well as comparing different communities and world regions. They learn to use maps as a means of communication as well. Students practice language arts skills by reading to be informed, by honing their listening skills, reading to learn to perform a task, and by expanding their vocabulary and comprehension skills. They organize information and practice expository writing. The topic of paths would make an ideal focus for an interdisciplinary unit.

Time

Investigation 1: Two 45-minute sessions
Investigation 2: One or two 45-minute sessions
Investigation 3: One 45-minute session
Investigation 4: One 45-minute session

Mathematics Standards

Geometry

- Use visualization, spatial reasoning, and geometric modeling to solve problems

Measurement

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

Technological Literacy Standards

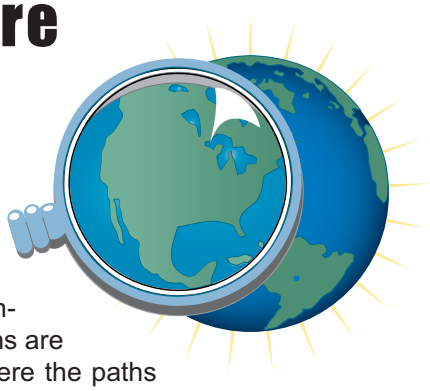
Nature of Technology

- **Standard 1:** The characteristics and scope of technology

Technology and Society

- **Standard 6:** The role of society in the development and use of technology

Paths—What are they and who makes them?



Investigation Overview

Students use their immediate environment to determine what kinds of paths are visible, who makes these paths, where the paths are located, and why the paths are located where they are. The investigation develops field work skills and introduces students to the need for "ground truthing." Students are introduced to the possibilities for locating a variety of human-made paths in satellite images.

Time required: Two 45-minute sessions

Materials/Resources

NASA images (Make overhead transparencies):
- Figure 1: Boston, Massachusetts
- Figure 2: Paris, France
- Figure 3: Houston, Texas

World Map
Log 1: Paths
Log 2: A favorite path
Log 3: An imaginary path
Satellite image of your community, if available. You may be able to download it from www.terraserver.com. Use a map of the community if no satellite image is available.

Content Preview

A path is any visual connection between two points. Paths are visible in many ways including from remotely sensed images. When scientists compare features on the surface of Earth to the images obtained from satellites it is called ground truthing—does what really exists on the ground confirm the remotely sensed image? Five geographic skills can be used to organize field research for young students: asking geographic questions, acquiring geographic information, organizing geographic information, analyzing the geographic information, and answering geographic questions.

Classroom Procedures

Beginning the Investigation

1. With the class, brainstorm answers to some of the questions in **Log 1** and have them complete it in small groups. Then have them compare their responses. Younger students can do the exercise as part of a class discussion with the educator listing their responses on the chalkboard.

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

- Identify and describe the characteristics and purposes of geographic representations, tools, and technologies.

Standard 14: Environment and Society

How human actions modify the physical environment

- Identify ways in which humans alter the physical environment.

Geography Skills

Skill Set 2: Acquiring Geographic Information

- Make and record observations about the physical and human characteristics of places.

2. Have students describe their pathways from home to school. Older students can draw a map that shows important places along this path.

Developing the Investigation

3. Have students form small groups to talk about paths they have taken, either in the immediate area or at some other location. Encourage students to describe the landscape or setting around the paths and to talk about obstacles that may have diverted the path. Share this information with the class. For kindergarten and grade 1, this can be done as a class rather than in groups.

4. Ask students to draw a map of a favorite path that they have taken. The maps should include landmarks, features of the terrain, and the reason for taking the path. Encourage the students to describe the paths to answer the following questions:

   - Was the path straight or curved? Why?
   - Were there features in the environment that made the path less direct?
   - Did the path cross water, cross a street, etc.?
   - How long was the path?
   - How long did it take to get from the starting to the finishing point?

5. Ask students to talk with a family member about a pathway he or she has taken. Use **Log 2** for this activity. Have students show the map drawn by a family member or read their reports to the class. Emphasize the landscape along the path.

6. Ask students if they would like to see how paths look in images from space. Tell the students that they will be examining satellite images of three cities and talking about what they see. Project transparencies of **Figures 1**, **2**, and **3** and have the students point out streets, roads, bridges, runways, rivers, and any other paths they can find.

7. Compare the paths of Paris with those of Boston and Houston. How are they different? (*Many streets radiate from the center of the city outward. The Seine River forms a major path through the city. A big highway circles much of the city. See* ***Background*** *for more information about the images.*)

8. Talk about why it is important to look at paths from aerial photos and satellite images. What can you see that you can't see from the ground?

9. Ask students to think about good ways to verify that the images show what students think they show. Talk with students about "ground truth." (*Images are important to the study of Earth. However, locations must be observed on the ground to verify that the information gleaned from images is correct. See* ***Background*** *for additional information. Only selected images can be verified in this way. Regular ground truthing helps to determine what kinds of information is reliable and what kinds of information may require more careful interpretation.*)

10. If you have access to a satellite image of your community (It may be available on www.terraserver.com), students can do their own ground truthing. Ask them to identify specific paths shown in the image (bridges, roads, rivers) that they can visit on the ground. Visit those locations to verify the information in the image. It is important to check the dates on images for ground truthing.

11. If a satellite image is not available, the class can explore the concept of ground truthing using a local map. Explain that maps also need to be verified by the same process. Select a feature on the map that is likely to change over time and visit it to verify that it still is the way it is shown on the map. (*It could be an old bridge, a park, a shopping center.*) If possible, select a feature that *has* changed since the map was made so that students can update the map.

12. Take a walk outside the school and look for signs of paths. Look for paths that lead to the play area or other sites. Have students make maps of the paths they observe and label the important items on each map. On the back of the map, have them write a couple of descriptive sentences about the paths. Answer questions such as, "Is the path straight or crooked? Why? Does the path go directly to the destination?" In an urban environment, ask students to look for signs of heavily used pathways: litter, street lights, etc. Discuss the findings. These skills can organize the outdoor field excursion. The first two can be answered outdoors, and the last three can be completed as a group indoors.

    Ask geographic questions: Where is the path located? Why is it there? What is the place like?
    Acquire geographic information: What is the description of the path? Where does it go? Who uses the path? (This information can be acquired through looking at photographs, talking to people, in addition to observing the path.)
    Organize the geographic information: This can be done through drawing maps and making

graphs. Geography has been called "the art of the mappable." Making maps should be a common activity for all students.

Analyze geographic information: Look for patterns on the maps, draw inferences, and identify relationships.

Answer geographic questions: Generalize and conclude based on the above four skills. Why *is* the path where it is?

Concluding the Investigation

13. Have students write a journal page or draw a picture describing an imaginary path from the beginning to the end on **Log 3**. Set the scene for either an urban, suburban, or rural area depending on students' locale.

Background: Satellite Images

Figure 1: Boston <http://southport.jpl.nasa.gov/pio/srl2/sirc/boston.html> This image is of the area surrounding Boston, Massachusetts. The bright white area at the right center is downtown. The wide river below and to the left of the city is the Charles River. The bridge across the north end of Back Bay connects the cities of Boston and Cambridge. Ponds are shown as dark irregular spots. Many densely populated urban areas show up as red in the image due to the alignment of streets and buildings to the incoming radar beam.

Figure 2: Paris <http://svs.gsfc.nasa.gov/imagewall/LandSat/paris.html> This LandSat scene shows Paris from above, facing (roughly) south, looking across the city and the Seine River which snakes through the center of Paris. Features such as concrete buildings and roads appear as dark gray/black, water as dark blue, while green spaces are vegetation such as grass and trees. Note the radial street pattern and the highly visible highway that encircles Paris.

Figure 3: Houston <http://southport.jpl.nasa.gov/pio/sr12/sirc/sr12-jsc.gif> This image shows Houston. North is toward the upper left. Black areas are bodies of water, including Galveston Bay. Clear Lake is the dark body of water in the middle right of the image. Interstate 45 runs from the top to the bottom through the image. The dark cross in the upper center is Hobby Airport. The green square just north of Clear Lake is Johnson Space Center, home of Mission Control and the astronaut training facilities.

Background: Ground Truthing

When scientists compare features on the surface of Earth to the signals or pictures from satellites or other remote sensing devices, it is called "ground truthing." There are three main purposes of ground truthing. The first is simply to check or confirm the accuracy of the images. The second is identification—sometimes it is difficult to interpret features in an image without checking them out on the ground. The third purpose of ground truthing is to develop relationships between ground features and the signals detected by remote sensors. For example, by measuring soil moisture in a field and comparing it to remote sensing measurements taken at the same time, we can use remotely sensed information to monitor soil moisture. In short, ground truthing involves comparing remotely sensed images (or data sets) with actual on-site observation.

Related Resources

http:edu.larc.nasa.gov/connect. Online Road Rally using images

http//www.TOPOZONE.com Excellent topographic maps of local areas

NASA's Student Involvement Program, Earth systems in my neighborhood, educators' resource guide, pp. 2-5

Module 4, Investigation 1: Log 1

Paths

Directions: Talk in your group about different types of paths. Be creative! Fill in all the blanks and then have each person in your group put her/his name beside her/his favorite path.

Name some paths	Who makes paths?	Where are paths located?	Why are paths where they are?

Module 4, Investigation 1: Log 2

A favorite path

Homework: Interview a family member or a friend. Tell the person that you are studying pathways and you would like to ask her/him questions about a pathway that is important to her/him. You may fill in the blanks or ask for help in doing this project. You will report back to your class about your findings.

Name of family member: _____ Age (optional): _____ Date: _____

Type of path: _____

Location of path: _____

Why was the path important or special? _____

_____

_____

_____

Describe the path (estimate length, time it takes to walk or ride it, what it is made of, what is special about it, what its surface is, etc.).

_____

_____

_____

_____

What special things do you see on the path?

_____

_____

_____

_____

Ask the person you interview to draw a map of the path and to label important landmarks (trees, houses, signs, waterways, etc.) on the back of this page.

Module 4, Investigation 1: Log 3

An imaginary path

Describe the setting surrounding the path. _____

Who made the path? _____

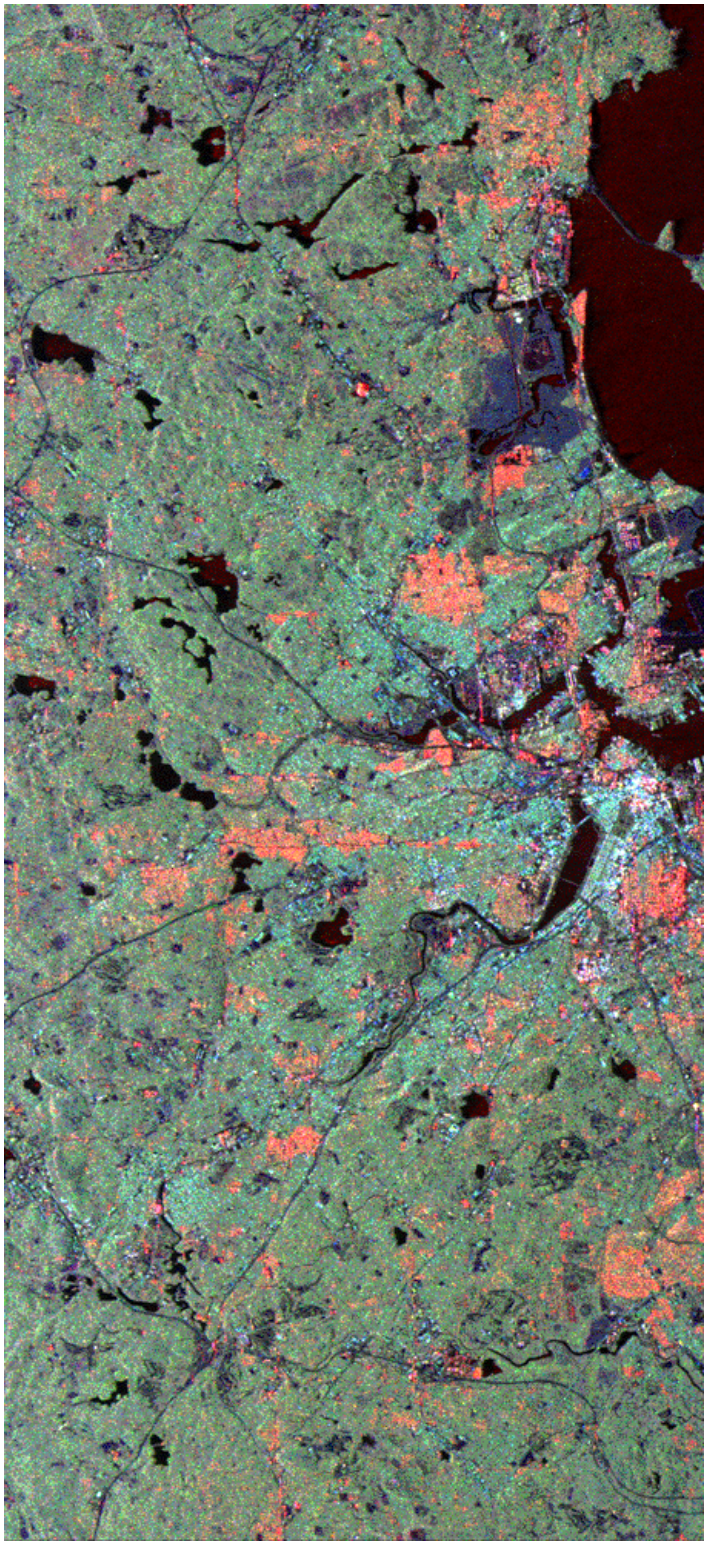
Where does it begin? _____ Where does it end? _____

Why was the path made? _____

Draw your path and label things that you see along the path.

Module 4, Investigation 1: Figure 1

Boston, Massachusetts



Source: http://southport.jpl.nasa.gov/pio/srl2/sirc/boston.html

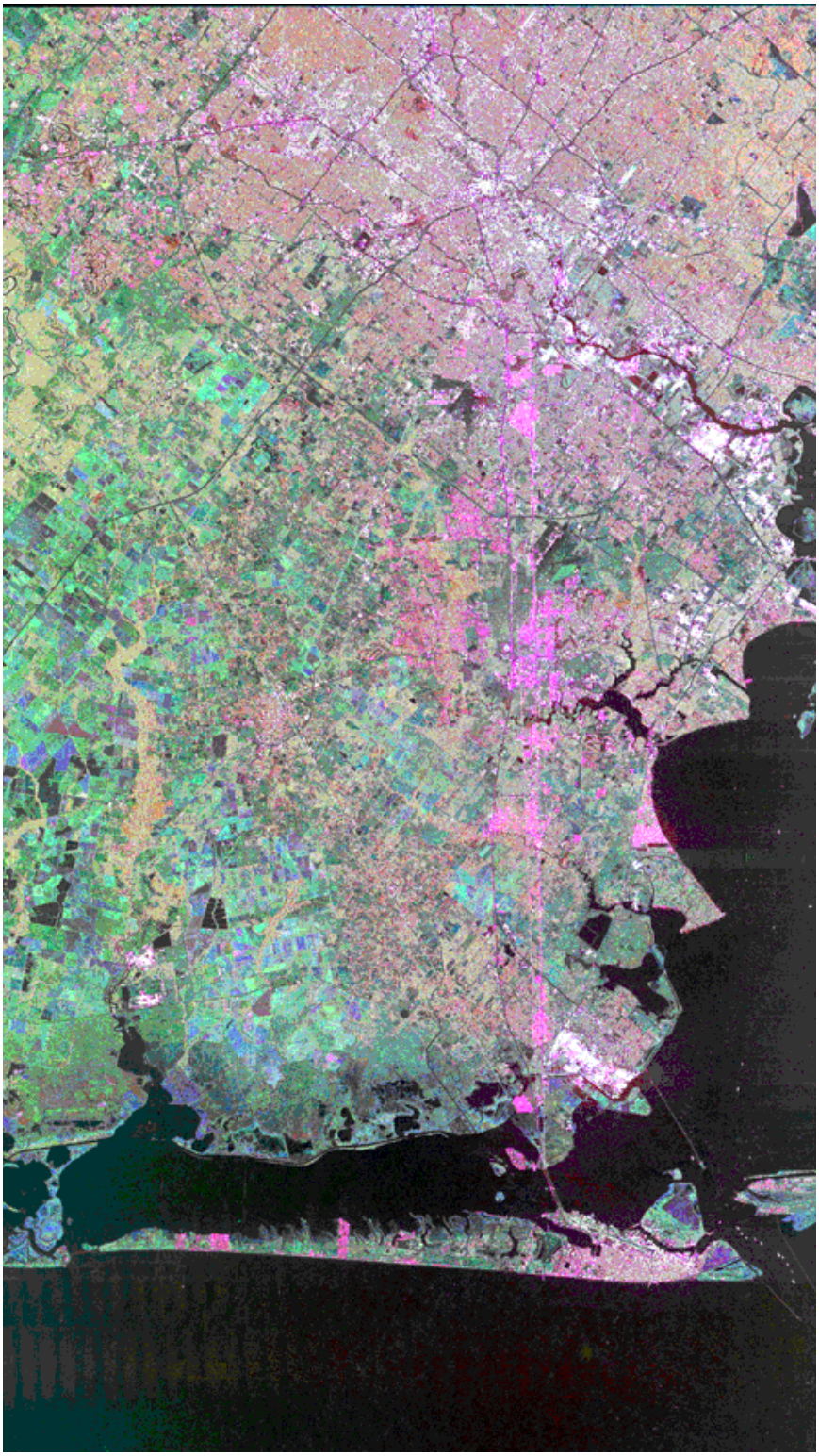
Module 4, Investigation 1: Figure 2

Paris, France

Source: http://svs.gsfc.nasa.gov/imagewall/LandSat/paris.html

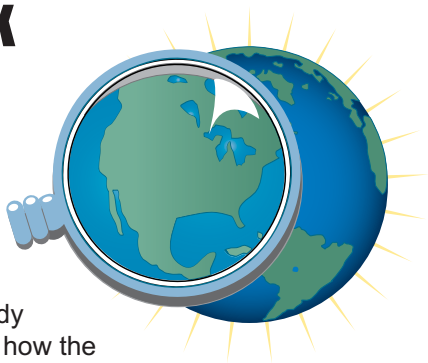
Module 4, Investigation 1: Figure 3

Houston, Texas



Source: http://southport.jpl.nasa.gov/pio/srl2/sirc/srl2-jsc.gif

How do paths look from different perspectives?



Investigation Overview

This investigation uses literature to study paths and to help students understand how the world looks from different elevations. Students also identify natural and human-made paths in satellite images. A local or state map is the basis for an activity in which a flashlight beam from different distances demonstrates the possible view at different altitudes. The investigation concludes with an examination of satellite images of three cities. Students identify natural and human-made pathways in the images.

Time required: One to two 45-minute sessions

Materials/Resources

Flashlights, penlight suggested
Large map of students' community or state, laminated or covered with clear acetate
Erasable magic marker for the laminated map
NASA images (make overhead transparencies):
- Figure 1: New Orleans, Louisiana
- Figure 2: San Francisco, California
- Figure 3: New York City, New York

Books
- *The Ultimate Field Trip* <http://eol.jsc.nasa.gov/uft/uft.html>
- *Little Red Riding Hood, Over the River,* or *Hansel and Gretel*
- *Alice in Wonderland* or *Big Bad Bruce*
- *Jack in the Beanstalk* or *Gulliver's Travels*
- *Me on the Map, Ily,* or *Around the World in 80 Days*

Content Preview

Satellite images, because of their breadth and scope, can help people make decisions about how to use, maintain, and build paths. They can also help people to see natural paths such as fault lines. Detailed descriptions of paths in New Orleans, San Francisco, and New York City point out the number of paths in urban areas.

Classroom Procedures

Beginning the Investigation

1. Review with students why pathways are important to them and to other family members. Tell students that many authors have written about paths. Ask them to think about books in which paths are very important. Some leads may be, "Do you know who . . . "
   - followed "The Yellow Brick Road?" (*Dorothy and friends in* The Land of Oz.*)*

Geography Standards

Standard 2: The World in Spatial Terms

How to use mental maps to organize information about people, places, and environments in a spatial context

- Identify major physical and human features at a variety of scales using maps, globes, and other sources of graphic information.

Standard 14: Environment and Society

How human actions modify the physical environment

- Identify ways in which humans alter the physical environment.

Geography Skill

Skill Set 4: Analyzing Geographic Information

- Use texts, photographs, and documents to observe and interpret geographic trends and relationships.

- went to Grandmother's house with a basket of baked goods? (Little Red Riding Hood.)
- went "Over the River and Through the Woods?" (*Grandchildren in the song with the same name.*)
- spread crumbs on a pathway leading home? (Hansel & Gretel.)
- followed the North Star to freedom? (*Slaves in* Follow the Drinking Gourd.)

Developing the Investigation

2. Read from one of the books listed below. (For the youngest children, *Little Red Riding Hood*, *Over the River,* and *Hansel and Gretel* are appropriate. Visit web site: <http://spaceplace.jpl.nasa.gov/eo1_1.htm> for activities for *Little Red Riding Hood* on the path.)

3. Talk about how the paths would look different:
   - from the view of an ant. (Read *Big Bad Bruce* [grades K-3] or portions of *Alice in Wonderland.)*
   - from the view of a giant. (Read *Jack in the Beanstalk* or portions of *Gulliver's Travels*.)
   - from an air balloon or plane. (Read *Me on the Map, Ily,* or portions of *Around the World in 80 Days*.)
   - from a space craft or satellite. (Read NASA's publication *The Ultimate Field Trip.* For younger students, this book can be told rather than read.)

4. Do the following activity to help students understand how paths look from various heights and how much of the area can be seen from these altitudes.

   A. Put a large map of the students' community or state on the floor or wall. If possible, laminate the map or cover the map with a clear sheet of acetate if it is to be used again.

   B. Trace paths (roads, railroads, bridges) leading into the city/town/community. Talk about where the roads go, their purposes, and whether the paths are straight or curved and why. (*Because of obstacles, both human and natural.*)

   C. Direct a flashlight (a small penlight is best) very close to the map. Use an erasable magic marker to draw a circle around the area that is directly lighted. Talk about how much of the paths can be seen at this level. Compare this with a helium balloon view.

   D. Move the flashlight farther from the map in the same spot. Draw a circle around the area directly lighted. Have students talk about the area lighted and the intensity of the light. (*The area lighted will be larger; however, the intensity of the light will decrease as the flashlight is farther from the map.*) Continue at levels that simulate a view from an airplane, a Space Shuttle, and a satellite. Observe the paths and talk about how much more is seen as the flashlight is pulled father away.

   E. Talk about the ways satellites can be used to observe large parts of Earth's surface from space. (*Monitoring land use change, weather, vegetation patterns, etc.*)

Concluding the Investigation

5. Project transparencies of **Figures 1**, **2**, and **3**. (See **Background** and share the information about each satellite image, as appropriate.)

6. Have the students take turns identifying the paths made by people: roads, railroads, bridges, etc. Why were the paths made and how did they change the environment?

7. Ask students to find paths that were not built by people. (*Rivers are the most obvious in **Figures 1 and 3**. In **Figure 2**, fault lines can easily be detected. See **Background**.*) Tell students that these are "natural" pathways. Have students trace them on the transparency.

8. Have students talk about the benefits of having these satellite images. (*We can see how things are connected, where to put new human-made paths, and the changes in natural and human paths. The images help people make decisions about how to use, maintain, and build paths.*)

Background: Images

Figure 1: Area around New Orleans <http://southport.jpl.nasa.gov/pio/sr12sirc/sr12-neworleans.gif> This image shows the area surrounding New Orleans, Louisiana. It is an excellent site for identifying bridges and roads. The dark area in the center is Lake Pontchartrain. The thin line running across the lake is a causeway. The Mississippi River appears as a dark, wavy line in the lower left. The white dots on the Mississippi are ships. Note the New Orleans Airport. It is the bright spot near the center, jutting out into Lake Pontchartrain.

Figure 2: San Francisco <http://southport.jpl.nasa.gov/pio/srl2/sirc/srl2-sfc.gif> This image shows San Francisco, California. Downtown San Francisco is at the center, and the city of Oakland is at the right across San Francisco Bay. Some city areas, such as South of Market,

called the SOMA district, appear bright red due to the alignment of streets and buildings to the incoming radar beam. Various bridges in the area are visible, including the Golden Gate Bridge (left center) at the opening of San Francisco Bay, the Bay Bridge (right center) connecting San Francisco and Oakland, and the San Mateo Bridge (bottom center). All the dark areas on the image are relatively smooth water: the Pacific Ocean to the left, San Francisco Bay in the center, and various reservoirs. Two major faults bounding the San Francisco-Oakland urban areas are visible on this image. The San Andreas fault, on the San Francisco peninsula, is seen in the lower left of the image. The fault trace is the straight feature filled with linear lakes which appear dark. The Hayward fault is the straight feature on the right side of the image between the urban areas and the hillier terrain to the east.

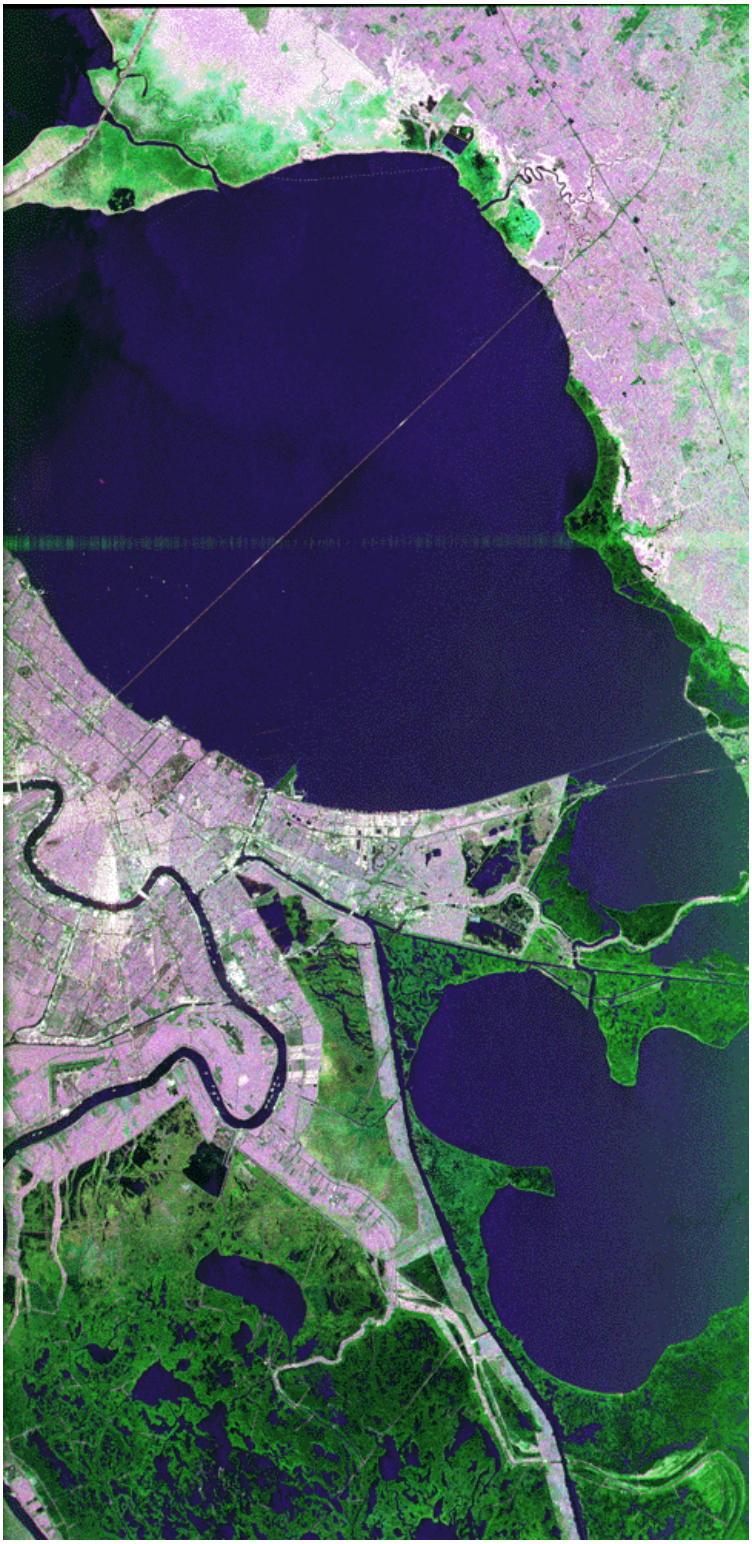
Figure 3: New York Metropolitan Area <http://southport.jpl.nasa.gov/pio/srl2/sirc/srl2-nyc.gif> This is a radar image of the New York metropolitan area. North is toward the upper right. In general, light blue areas correspond to dense urban development, green areas to moderately vegetated zones, and black areas to bodies of water. The Hudson River is the black strip that runs from the left edge to the upper right corner of the image. It separates the states of New Jersey and New York. The Atlantic Ocean is at the bottom of the image where two barrier islands along the southern shore of Long Island are also visible. John F. Kennedy International Airport is visible on the mainland, across from these islands. Long Island Sound, separating Long Island from Connecticut, is the dark area right of the center of the image. Many bridges are visible in the image. From south to north along the Hudson River are the Verrazano Narrows, George Washington, and Tappan Zee bridges. Manhattan is south of the George Washington Bridge, to the east of the river. Central Park is a large rectangle in Manhattan. The radar illumination is from the left of the image; this causes some urban zones to appear red because the streets are at a perpendicular angle to the radar pulse.

Related Resources

http://spaceplacejpl.nasa.gov/facts.htm NASA relief maps
http://www.erc.nasa.gov/ Writing an essay describing a flight and view from a plane
Looking Down by Steve Jenkins (Houghton Mifflin Co., New York, 1995)
As the Crow Flies, a First Book of Maps by Gail Hartman (Aladdin Books, Maximillan Publishing, 1991)
Oh, the Places You Go by Dr. Seuss
http://www.usgs.gov/ Educator lessons on map adventures
Figure 1: http://southport.jpl.nasa.gov/pio/srl2/sirc/srl2-neworleans.gif
Figure 2: http://southport.jpl.nasa.gov/pio/srl2/sirc/srl2-sfc.gif
Figure 3: http://southport.jpl.nasa.gov/pio/srl2/sirc/srl2-nyc.gif

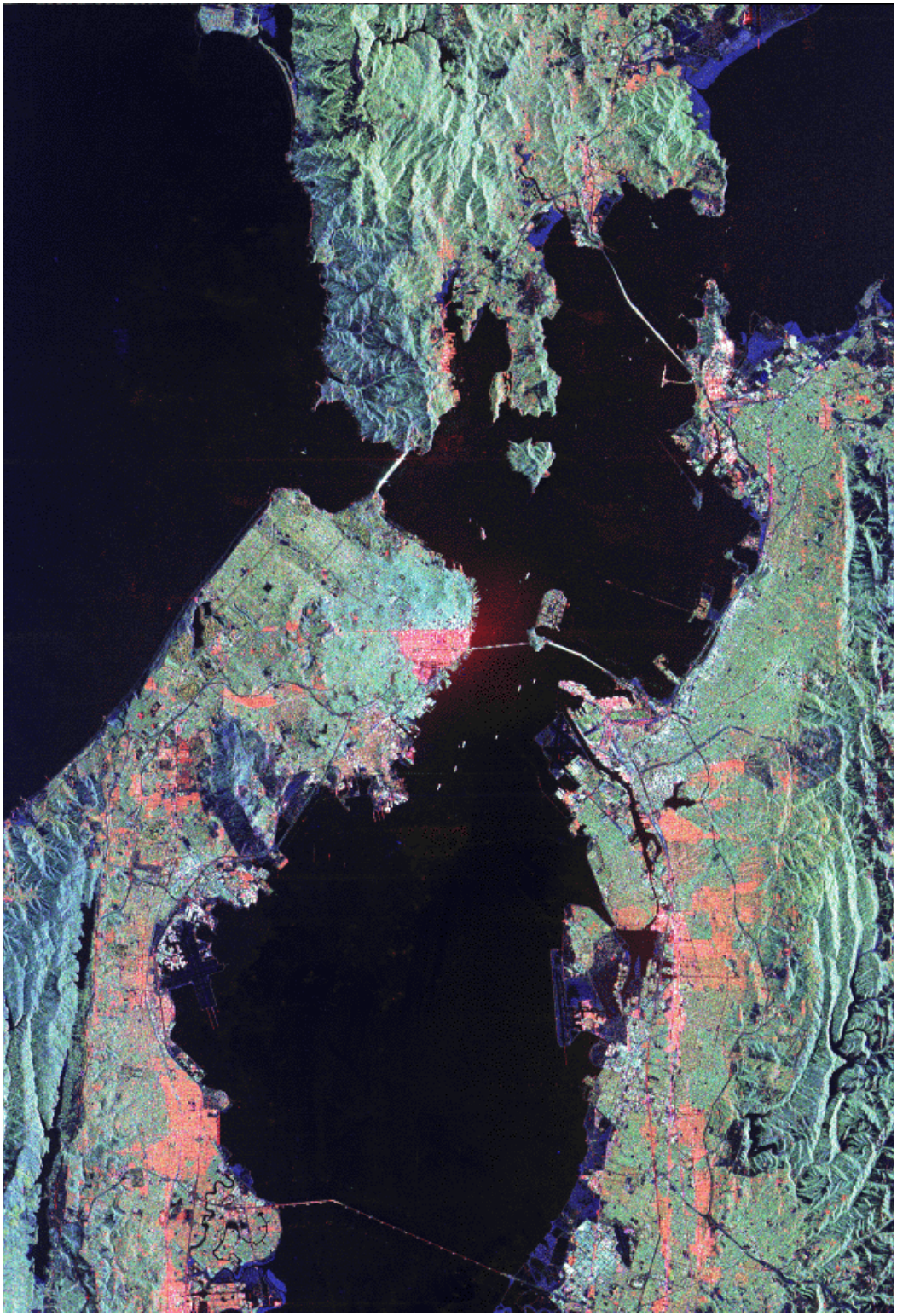
Module 4, Investigation 2: Figure 1

New Orleans, Louisiana



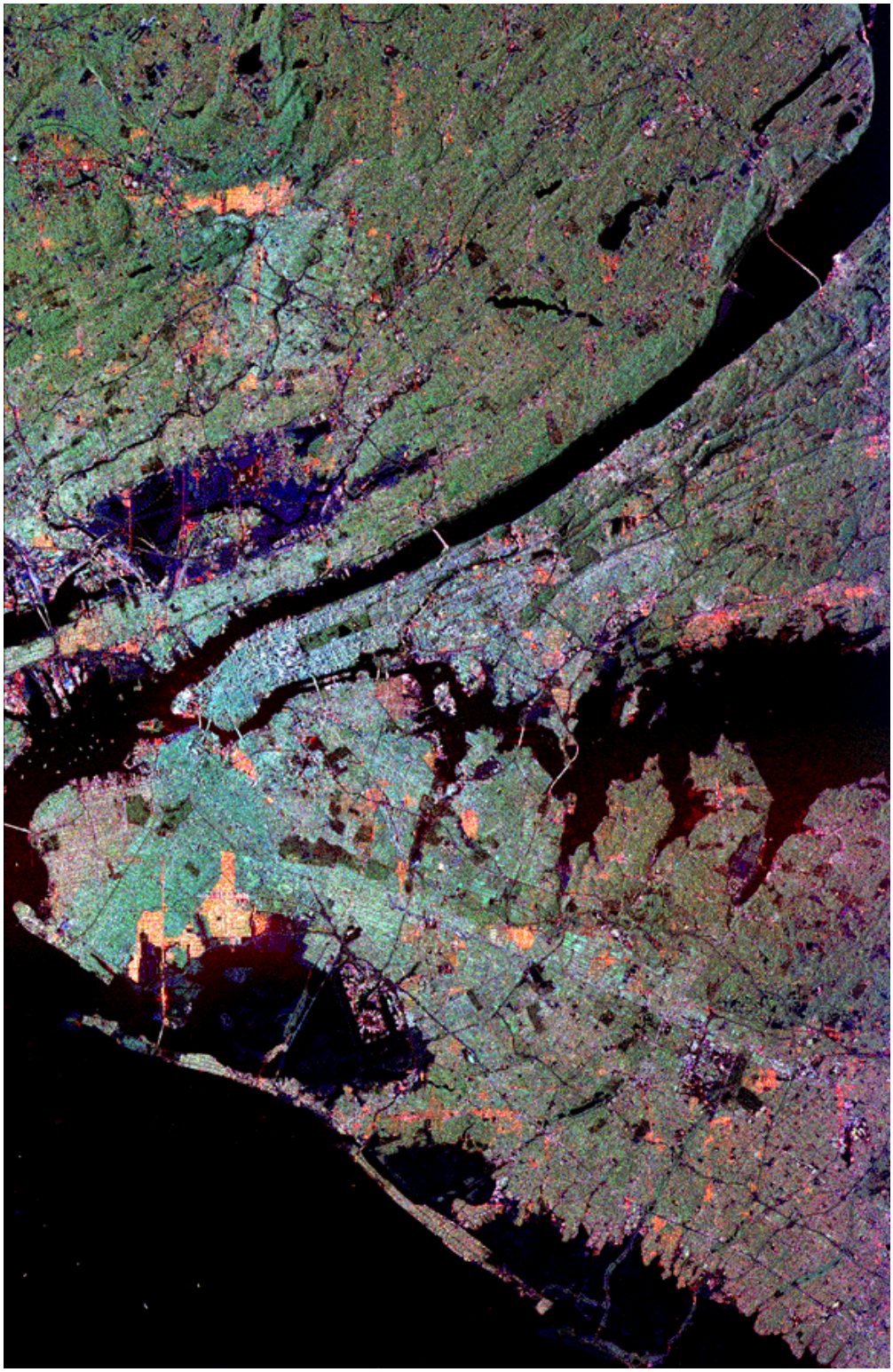
Module 4, Investigation 2: Figure 2

San Francisco, California

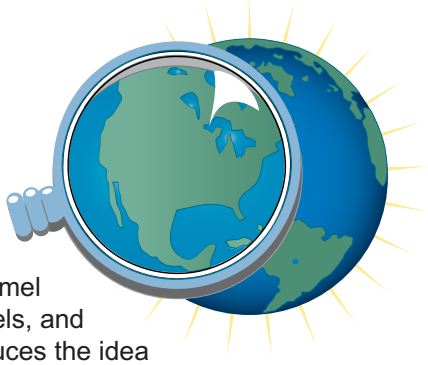


Module 4, Investigation 2: Figure 3

New York City, New York



Paths—Usual or unusual?



Investigation Overview

NASA images can introduce students to some unusual natural and human-made paths. These include ancient camel caravan tracks, lava flows, ship channels, and smoke paths. The investigation introduces the idea of one-way and two-way paths. It provides an opportunity for students to work together to study images and to pose and answer many questions about paths. They record their observations and draw conclusions about the origins and nature of these pathways. They also match the images with descriptions of the paths and use maps to gather more information about the environments illustrated in the images.

Time required: One 45-minute session

Materials/Resources

NASA images (make overhead transparencies and one copy for each group of students):

Figure 1: Mozambique
Figure 2: Ubar
Figure 3: Teide volcano, Canary Islands
Figure 4: Mississippi River delta

Log 1: Looking at new paths
Log 2: Reading about the images
Atlases (or wall maps showing world vegetation and landform patterns)

Content Preview

Paths come and paths go. Some paths are visible from space but not from the ground. Geographers and other scientists use remote sensing to learn about different paths because they affect people and their activities. Paths also give clues about past places and peoples. This technology is especially useful in remote regions of the world or to see paths that extend over long distances. Detailed descriptions of images of Mozambique, Ubar, the Teide volcano, and the Mississippi River delta show paths that are significant for a variety of human endeavors.

Classroom Procedures

Beginning the Investigation

1. If the class has done **Investigation 1**, review the list of paths that students developed in **Log 1**. If they have not done **Investigation 1**, begin this investigation by talking about the various kinds of paths and making such a list on the chalkboard. (See **Investigation 1, *Beginning the Investigation***.)

2. Look at the list of paths and ask the following questions:
   - Can paths disappear, and what would make them disappear? (*Rivers change courses, rainwater or snow may cover paths, natural*

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

- Identify and describe the characteristics and purposes of geographic representations, tools, and technologies.

Standard 15: Environment and Society

How physical systems affect human systems

- Identify ways in which human activities are constrained by physical environment.

Geography Skills

Skill Set 2: Acquiring Geographic Information

- Make and record observations about the physical and human characteristics of places.

Skill Set 4: Analyzing Geographic Information

- Use texts, photographs, and documents to observe and interpret geographic trends and relationships.

Skill Set 5: Answering Geographic Questions

- Use methods of geographic inquiry to acquire geographic information, draw conclusions, and make generalizations.

disasters can obliterate paths, people may no longer use pathways and they may become overgrown, etc.)

- Can images from space tell us what happened to pathways that existed long ago? (*Yes, pathways that seem obscure on the ground can be more apparent from a distance.*)
- Why would we be interested in knowing about these pathways? (*To learn about people and their movements in the past and how they have changed.*)
- What kinds of pathways could more easily be studied in images from space than on the ground? (*Paths that are in remote places or extend over long distances.*)

Developing the Investigation

3. Tell students that they will work in small groups to look for some unusual paths in images taken from the Space Shuttle.

4. Form groups of three or four students. Give each group a copy of **Log 1**. Go over the directions. Project transparencies of **Figures 1-4** and give each group a copy of each image. Note that the number of each image should correspond to the numbers on the worksheet.

   Use information in **Background** to tell the class enough about each image so that they will be able to figure out the answers. When showing **Figure 1**, explain that this is a photograph taken by an astronaut. Explain that **Figures 2-4** were produced by radar signals from a sensor on the Space Shuttle. Explain that radar signals can go through clouds and darkness. The signals give information about the ground to computers that use it to create images. These images can look like photographs. Scientists determine the colors shown in the image according to what will help them interpret it.

5. Have students work together in their groups after completing the first image together as a class.

6. After the groups have completed the task, show each image again and have the groups report what they have observed.

7. Distribute **Log 2** and have the groups decide which description in **Log 2** goes with each image, in **Figures 1 to 4**. Have students read the descriptions that match the images. Share additional information in the **Background** section with the students. Ask students to point out the pathways and features that are mentioned.

8. Find the locations of the images on a world map or in atlases. Describe the physical features of the locations.

Concluding the Investigation

9. Show the images again and discuss the significance of the pathways in each image.

   - Smoke paths: *People downwind may be affected by the smoke in adverse ways.*
   - Camel tracks: *Old caravan tracks show the movement of people across the desert in ancient times. They can lead archeologists to ancient settlement sites that might otherwise be difficult to find.*
   - Lava flow path: *Historic flow patterns may help predict future volcanic activity, indicating areas of danger to human settlements.*
   - Mississippi River delta paths: *Sediment deposits change the delta and affect river traffic.*

Background: Images

Figure 1: Mozambique <http://eol.jsc.nasa.gov/newsletter/smoke/page1.htm>. The image STS070-717-027 shows bush fires in southern Mozambique in Africa. The easterly winds from the Mozambique Channel blow the smoke from many large fires into the country of Zimbabwe on the African plateau. This image shows winter, the dry season in southern Africa. People set fires to hasten the greening of the grass shoots for cattle grazing.

Figure 2: Ubar <http://observe.ivv.nasa.gov/nasa/exhibits/ubar/ubar_3.html> This is a radar image of the region around the site of the lost city of Ubar in southern Oman, on the Arabian Peninsula. The ancient city was discovered in 1992 with the aid of remotely sensed data. Archeologists believe Ubar existed from about 2800 B.C. to about 300 A.D. It was a remote desert outpost where caravans assembled to transport frankincense across the desert. Frankincense is a sweet-smelling incense used as a fragrance, for medicinal purposes, and for embalming. This image was acquired by the Space Shuttle *Endeavour* on April 13, 1994. The image covers an area about 50 by 100 kilometers. The prominent magenta-colored area is a region of large sand dunes. The prominent green areas are rough limestone rocks, which form a rocky desert floor. A major wadi, or dry stream bed, runs across the middle of the image and is shown largely in white. The actual site of the fortress of the lost city of Ubar, currently under excavation, is near the wadi close to the center of the image. The fortress is too small to be detected in this image. However,

tracks leading to the site, and surrounding tracks, appear as prominent, but diffuse, reddish streaks. These tracks have been used in modern times, but field investigations show many of these tracks were in use in ancient times as well. Mapping of these tracks on regional remote sensing images was a key to recognizing the site as Ubar in 1992. This image, and ongoing field investigations, will help shed light on a little-known early civilization.

Figure 3: Teide volcano, Canary Islands <http://southport.jpl.nasa.gov/volcanopic.html> This radar image shows the Teide volcano on the island of Tenerife in the Canary Islands. The Canary Islands, part of Spain, are located in the eastern Atlantic Ocean off the coast of Morocco. Teide is the third highest volcano on Earth. Teide erupted only once in the 20th century, in 1909, but is considered potentially threatening due to its proximity to the city of Santa Cruz de Tenerife, shown in this image as the purple and white area on the lower right edge of the island. The summit crater of Teide, clearly visible in the left center of the image, contains lava flows of various ages and roughnesses that appear in shades of green and brown. Color enhancement of the image makes it easier to see the lava flows and the vegetation. Different vegetation zones, both natural and agricultural, are shown as areas of purple, green, and yellow on the volcano's flanks. Scientists are using images such as this to understand the evolution of the structure of Teide, especially the formation of the summit caldera and the potential for collapse of the flanks. The volcano is one of 15 identified by scientists as potentially hazardous to local populations, as part of the international "Decade Volcano" program. The image was acquired onboard the Space Shuttle *Endeavour* on October 11, 1994.

Figure 4: Mississippi River delta <http://southport.jpl.nasa.gov/pio/srl2/sirc/srl2-delta.gif> This is a radar image of the Mississippi River delta where the river enters into the Gulf of Mexico along the coast of Louisiana. The main shipping channel of the Mississippi River is the broad red stripe running northwest to southeast down the left side of the image. The bright spots within the channel are ships. This image was acquired aboard the Space Shuttle *Endeavour* on October 2, 1995. The image is centered on latitude 29.3 degrees North latitude and 89.28 degrees West longitude. The area shown is approximately 63 kilometers by 43 kilometers. North is towards the upper right of the image. As the river enters the Gulf of Mexico, the water slows down and dumps the sediment that it has eroded from the land. This sediment accumulates over the years and forms new land in the delta. Most of the delta in the image consists of mud flats and marsh lands. There is little human settlement in this area due to the instability of the sediment.

Background: One- and Two-Way Paths

One-way paths are ones in which movement is overwhelmingly in one direction. For example, rivers and glaciers flow downhill, and prevailing or constant winds and currents such as the jet stream and gulf stream flow in a consistent direction. Movement on two-way paths can be in either direction. There are many human examples such as roads and railroads. Animal paths, bird flyways, and some environmental flows (for instance land breeze/sea breeze patterns), or flows in tidal channels, are examples of two-way paths.

Evaluation

***Log 1**

What are the paths in the image?	Made by natural forces, people, or animals?	One-way or two-way path?	Can it change? How/why?
1. smoke	natural/ people	1	yes, wind changes
2. caravan routes	people/ animals	2	yes, people change routes
3. lava flows	natural	1	yes, lava erupts elsewhere
4. river channel	natural	1	yes, channels change course

***Log 2**

1. Ubar
2. Teide volcano
3. Mozambique
4. Mississippi River delta

Related Resources

http://observe.ivv.nasa.gov/nasa/ootw/1999/ootw_990512/ob990512_more7.html Japan, good images of lava flows

Module 4, Investigation 3: Log 1

Looking at new paths

Directions: Scientists use images from space to study events on Earth. You can do the same thing. Work in your group to answer the following questions about each image in Figures 1, 2, 3, and 4. Be sure to match the image with the number on your sheet.

What kind of path is in the image?	Is the path made by natural forces, people, or animals?	Is the path a one-way or two-way one? Explain your thinking.	Can the pathway change? How and why?
1.			
2.			
3.			
4.			

Module 4, Investigation 3: Log 2

Reading about the images

1. This is an image of ancient camel caravan paths. The paths lead to a place where there was once a city called Ubar. The ancient city was discovered in 1992 with the aid of images from space. For years, archaeologists have looked for the lost city of Ubar. Ubar is believed to have been in southern Oman, on the Arabian Peninsula. Archaeologists believe Ubar disappeared about 1700 years ago. Ubar probably was a desert outpost where caravans met while they were carrying goods across the desert. Frankincense was an important trade item. Frankincense was used as a medicine, as perfume, and in preserving dead bodies.

   The fortress is too small to be seen in this image. However, ancient camel tracks leading to the site, and surrounding tracks, appear as reddish streaks. This image and field investigations will help us to learn more about this little-known early civilization.

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2. This is an image of the pathways of lava. This volcano is called Teide and is located on the island of Tenerife in the Canary Islands. The Canary Islands, part of Spain, are located in the eastern Atlantic Ocean off the coast of Morocco. This is the third highest volcano on Earth. Teide last erupted in 1909. The city of Santa Cruz de Tenerife may be damaged by lava flows.

   Scientists are using images like this one to understand how Teide developed and what paths future lava flows might take. The volcano is one of fifteen that scientists have listed as possibly dangerous for local populations.

Module 4, Investigation 3: Log 2

Reading about the images

3. This is an image of the pathway of smoke. The image is from Mozambique in Africa. Winter is the dry season in southern Africa. Many cattle are raised in this area. Fires are set to speed up the greening of the grass shoots for cattle grazing.

   The easterly winds from the Mozambique Channel blow the smoke from these many large fires. The smoke is carried by the wind to the southern part of this island. The wind carries the smoke into the country of Zimbabwe.

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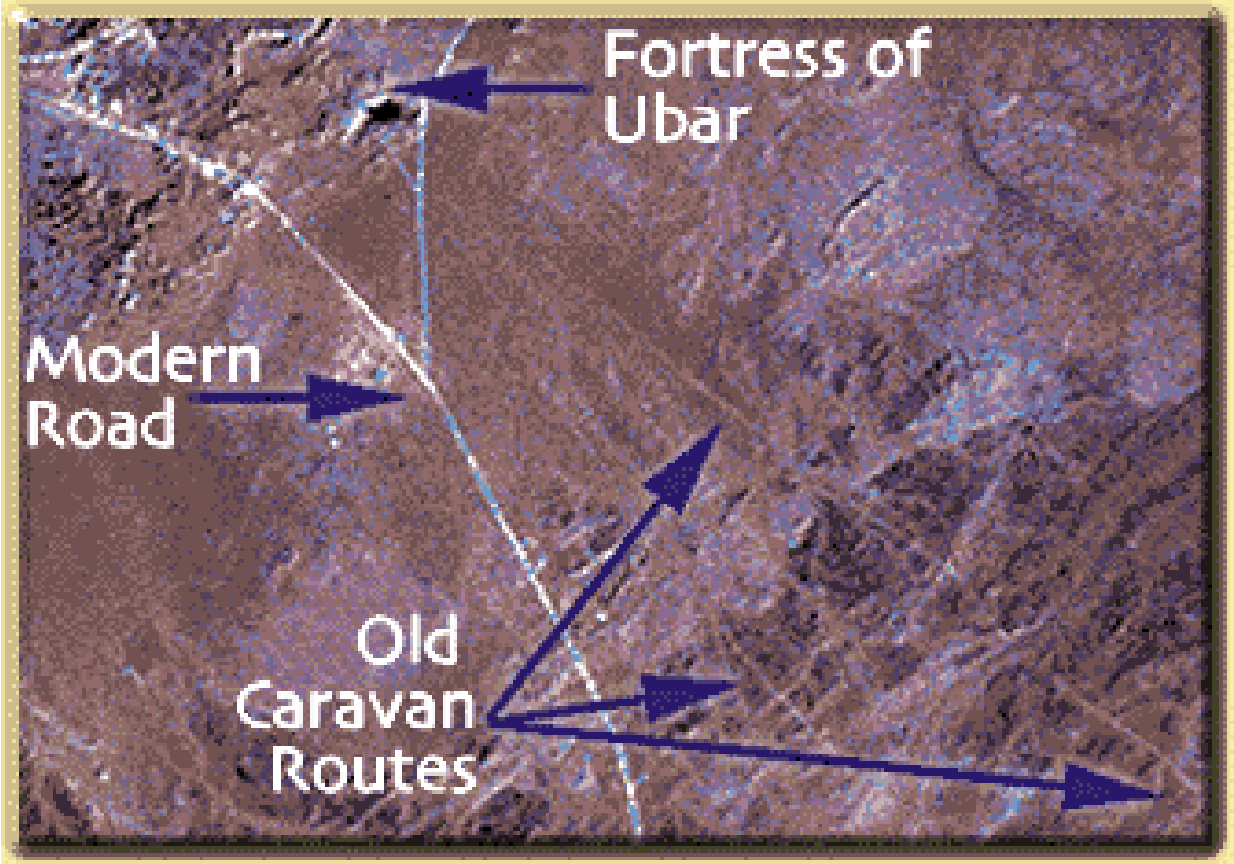
4. This is an image of the Mississippi River Delta on the Louisiana coast. It shows the channels that ships take through the delta as they enter or leave the river. The main shipping channel of the Mississippi River is the broad red stripe.

   As the river enters the Gulf of Mexico, it dumps most of the sediment (mainly mud, clay, and sand) that it has eroded from the land. This sediment can pile up over the years, adding new land to the delta and making the channels find new paths as the old ones become clogged.

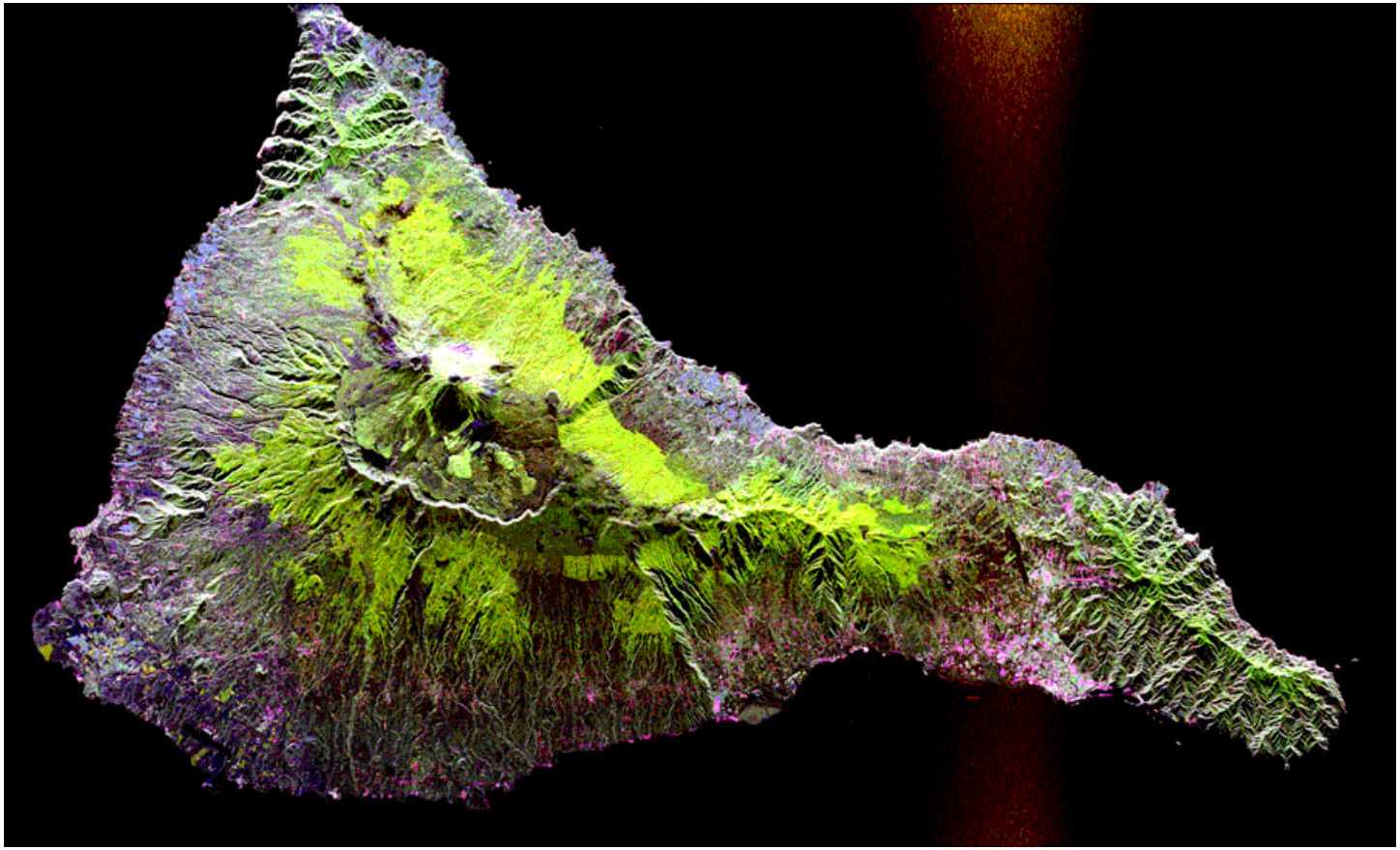
   Most of the land in the delta is made up of mud flats and marsh lands. There is little human settlement in this area because it is not safe to build on sediment that keeps shifting.

Module 4, Investigation 3: Figure 1

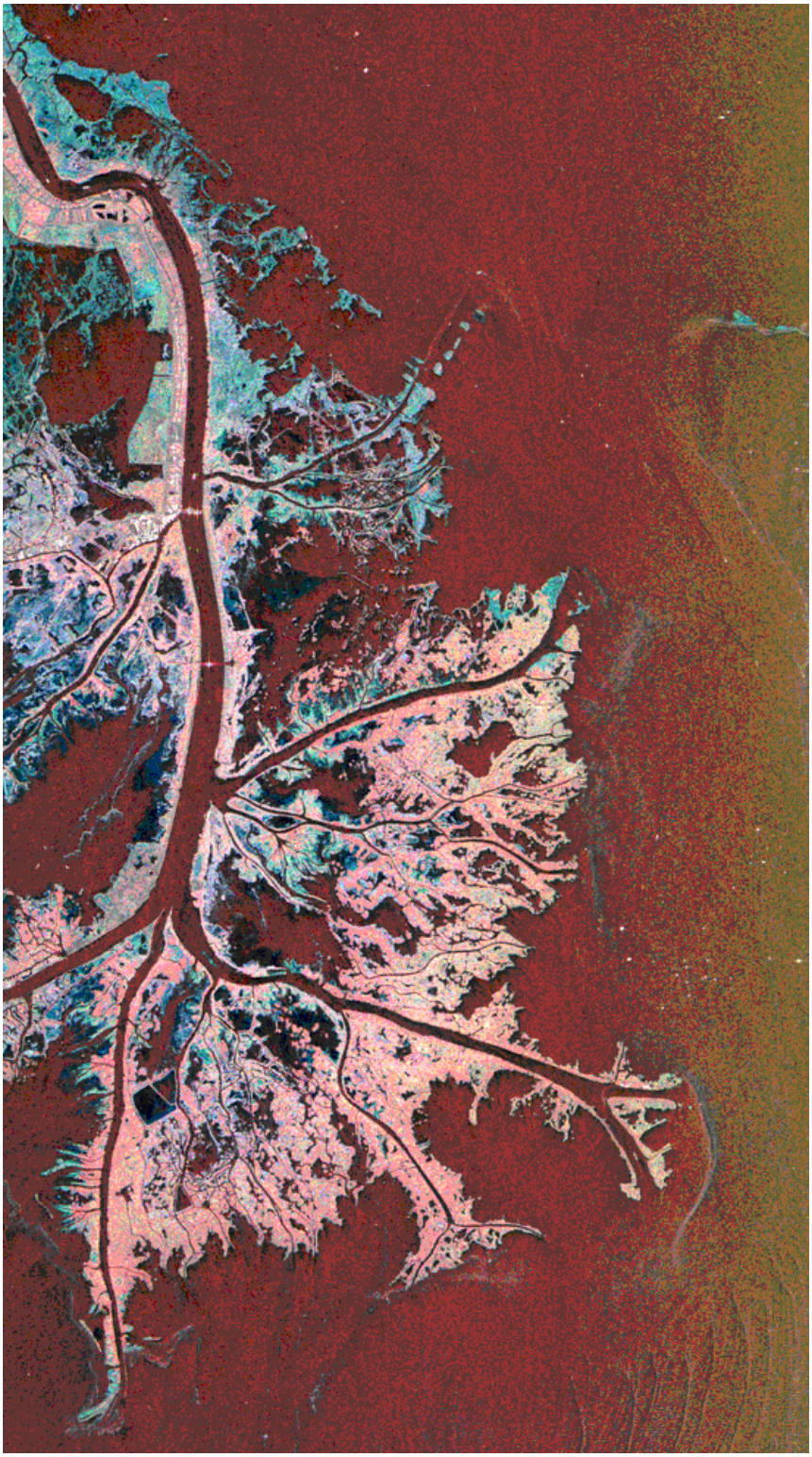
Module 4, Investigation 3: Figure 2



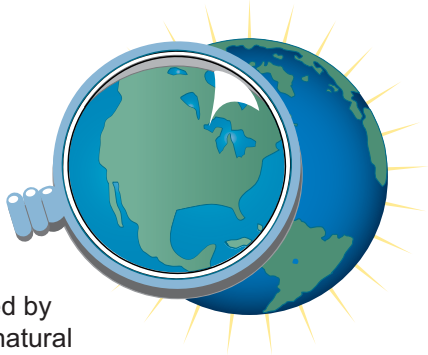
Module 4, Investigation 3: Figure 3



Module 4, Investigation 3: Figure 4



How do disaster paths affect people's lives?



Investigation Overview

Four scenarios illustrate paths produced by natural disasters. Students learn that natural disasters can be observed and analyzed using remotely sensed images. Working in groups, students read letters from imaginary pen pals describing specific natural disasters, examine NASA images of the locations of these events, report on the events, and write a response to pen pals.

Time required: One 45-minute session

Materials/Resources

Atlases or world wall map
NASA images (one copy for each group of students)
- Figure 1: Hawaii
- Figure 2: Russia
- Figure 3: Hurricane Georges
- Figure 4: Mississippi River flood path

Log 1: Pen pal letters

Content Preview

Events such as hurricanes, volcanic eruptions, and floods are aspects of physical systems that have immediate and disastrous effects on human systems as well as physical systems. Remotely sensed images can be used to assist reducing social and economic disruptions from such natural disasters by contributing to the scientific understanding of Earth processes. The effects of a lava flow, aerosols and smoke from a volcano, a hurricane, and a flood can be seen on images.

Classroom Procedures

Beginning the Investigation

1. Write *Natural Disasters* on the chalkboard. Ask students to brainstorm different types of disasters. List each in a column under this heading. Write *Effects on the Environment* and *Effects on People* as additional headings. Go down the list of natural disasters and talk about how people and natural environments are affected by each disaster. A table can be made on the chalkboard that resembles the following:

Natural Disaster	Effects on the Environment	Effects on People
Hurricanes Earthquakes Tornadoes Floods ...		

Geography Standards

Standard 15: Environment and Society

How physical systems affect human systems
- Describe and locate natural hazards in the physical environment.

Standard 18: The Uses of Geography

How to apply geography to interpret the present and plan for the future
- Identify ways in which geographic conditions change.

Geography Skills

Skill Set 3: Organizing Geographic Information
- Prepare maps to display geographic information.

Skill Set 4: Analyzing Geographic Information
- Use texts, photographs, and documents to observe and interpret geographic trends and relationships.

Skill Set 5: Answering Geographic Questions
- Present geographic information in the form of both oral and written reports accompanied by maps and graphics.

Developing the Investigation

2. Tell students that they will see pathways that can best be seen from above Earth. Talk about ways to view natural disasters from different levels and the advantages and disadvantages of each (airplane, Space Shuttle, satellites). *(Refer back to the list of natural disasters and talk about why it is important to see the disasters from above:*

    - *helps to see how large an area the disaster is affecting.*
    - *helps to predict the direction of the disaster or the pathway that it is taking.*
    - *helps to warn people before the disaster reaches them.)*

3. Talk about NASA's mission in studying natural disasters. (*See* ***Background.***)

4. Share with students that they will see four images of disaster pathways. Project transparencies of **Figures 1-4** (or distribute copies) and ask students to try to identify what they are seeing. Spend time on the images; talk about possible locations for the images, any outstanding features in the landscape that they see, and any other observations that students want to share.

5. Tell students that they will read letters from imaginary students in other parts of the world who have experienced a natural disaster that was shown in one of the images. Tell students that the imaginary letter writers would like to have a response from students in this class.

6. Have the students work in groups and give each group a page from **Log 1** (letter) and a **copy of the image** that goes with their letter, and an atlas (or use a wall map). In a small class, this can be done with four groups of students, each group with a different image and letter. A larger class would require eight groups, with two groups receiving the same pen pal letter and image. Ask students to read their letters and to use both the image and their atlases (or a wall map) to respond to their pen pal with one letter from the group (or individual letters from the groups' members). Encourage students to be sure that each member of the group contributes to the project.

Concluding the Activity

7. Bring the class back together and have each group

    - read the original pen pal letter,
    - show their image,
    - trace the pathway on the image and point out any important features,
    - locate the disaster event on the world map, and
    - read the letter or letters they are sending to their pen pals.

8. Project **Figure 3: Hurricane Georges** and talk about possible paths that could be used for evacuation. Look at the other images and have students talk about possible ways to escape the disaster. If students are in a geographic area that experiences natural disasters, locate regional maps showing pathways for evacuation purposes.

9. Review how images from space can help people deal with natural disasters.

Background

Natural hazards are inevitable manifestations of Earth processes but need not be inevitable disasters. Images from space can assist society in reducing social and economic disruptions from future natural disasters by contributing to the scientific understanding of Earth processes and conditions that lead to natural disasters.

Figure 1: Hawaii <http://hvo.wr.usgs.gov/gallery/kilauea/erupt/2553002_caption.html> In this radar image, produced by a sensor on the Space Shuttle, the city of Hilo is seen at the top. Different types of lava flows around the crater Pu'u O'o are evident. Ash deposits which erupted in 1790 from the summit of Kilauea volcano show up as dark in this image, and fine details associated with lava flows which erupted in 1919 and 1974 can be seen to the south of the summit in an area called the Ka'u Desert. In addition, the other historic lava flows created in 1881 and 1984 from Mauna Loa volcano (out of view to the left of this image) can be easily seen despite the fact that the surrounding area is covered by forest. This information is used to map the extent of the lava flows which can pose a hazard to the subdivisions of Hilo. Highway 11 is the linear feature running from Hilo to the Kilauea volcano. The Kilauea volcano has been almost continuously active for more than 11 years. Field teams that were on the ground specifically to support these radar observations report that there was vigorous surface activity about 400 meters inland from the coast. A moving lava flow about 200 meters in length was observed at the time of the shuttle overflight, raising the possibility that subsequent images will show changes in the landscape.

Figure 2: Russia <http://images.jsc.nasa.gov/images/pao/STS68/10117628.jpg> Shortly after the launch of the Space Shuttle on September 30, 1994, the crew reported thick black smoke over the Kamchatka Peninsula in northeast Russia. On the next orbital pass, the crew took photographs of the eruption of Klyuchevskaya. This is the most active volcano on the peninsula, and this eruption has been its largest in 40 years. The eruption cloud reached 19,000 meters above sea level, and the winds carried the volcanic ash as far as 1025 kilometers southeast from the volcano. The ash cloud interfered with the heavily traveled north Pacific air routes for 48 hours, diverting up to 70 flights carrying about 10,000 passengers per day.

Figure 3: Hurricane Georges <http://rsd.gsfc.nasa.gov/rsd/images/Georges/GeorgesThree_md.jpg>
This satellite image shows Hurricane Georges at three different times on its path toward the Gulf of Mexico. During late September 1998, Hurricane Georges cut a path of destruction through Puerto Rico. Its strong winds, heavy rains, storm surge, and tornadoes resulted in an estimated $2 billion in damage on the island. The hurricane's powerful thunderstorms spawned tornadoes, flooded hotels, and exploded shop and car windows. Georges forced tens of thousands of people into shelters and left hundreds of thousands without water or power. The hurricane prevented rescuers from immediately responding to calls for help. The center of the storm passed just south of the Puerto Rican capital of San Juan. Georges unleashed a landslide in Tao Alta, near San Juan, that killed three people. As it moved westward across southern Puerto Rico, Georges spawned tornadoes. Wind gusts reached 287 kph. More than 80 percent of Puerto Rico's 3.8 million people lost electricity, and more than 70 percent had no water. Countless roads and highways were choked by fallen trees and poles, dangling power lines, antennas, awnings, tin roofs, and other debris. More than 20,000 people huddled in shelters in San Juan, Arecibo, Mayaguez, and other Puerto Rican cities, and President Clinton declared Puerto Rico and the U.S. Virgin Islands disaster areas, authorizing immediate release of federal recovery aid.

Figure 4: Mississippi River flood path
<http://observe.ivv.nasa.gov/nasa/exhibits/flood/flood_2.html> <http://observe.ivv.nasa.gov/nasa/exhibits/flood/flood_3.html> These Space Shuttle photographs, with river and state boundaries overlaid, show the Midwestern United States during the flood of 1993. The Mississippi, Illinois, and Missouri Rivers converge just north of St. Louis. For over a month torrential rains, which had begun in the spring of 1993, began again in June and continued to fall on the already saturated fields. The waters of the Mississippi, Missouri, and Illinois Rivers and their tributaries soon spilled over once-protective levees, causing billions of dollars in damage and destruction. Tens of thousands of acres of farmland and crops were destroyed, water treatment plants were closed, roads and bridges were severely damaged or destroyed, and entire communities were inundated, leaving many thousands homeless.

Related Resources

Students as scientists
http://dns.kilauea.k12.hi.us/sas/
Images and information on hurricanes
http://rsd.gsfc.nasa.gov/rsd/images/
Hurricane and extreme weather impact studies
http://coastal.er.usgs.gov/hurricanes/
Hurricane and other storms information
http://www.aomi.noaa.gov/hrd/Storm_pages/
Japan, good images of lava flows
http://observe.ivv.nasa.gov/nasa/ootw/1999/ootw_990512/ob990512_more7.html
The Weather Dude, The Weather Channel
http://www.wxdude.com
Hurricane basins
http://www.usatoday.com/weather/whurbasn.htm

Module 4, Investigation 4: Log 1a

Pen pal letters

Dear students in the United States,

I am so glad that I will be your pen pal. I would like to learn more about your country, and I will tell you more about mine. My name is Olga, and I am 10 years old. I know that you are studying about pathways, so I wanted to share an experience with you.

I live on a peninsula in northeast Russia. Do you know what a peninsula is? It is a stretch of land that juts out into water and is nearly surrounded by water. Do you have any peninsulas in the United States? In September of 1994, a volcano erupted near my town. The name of the volcano was Klyuchevskaya. This volcano is our peninsula's most active volcano. This was the **biggest** eruption in 40 years. I am very glad that I live to the west of the volcano and farther north on the peninsula.

A huge amount of volcanic ash erupted from the top of the volcano. The snow on the volcano and on the nearby mountains turned blackish brown. Winds were blowing toward the southeast, and the volcanic ash covered the ground from the volcano to places over 960 kilometers (600 miles) to the southeast. We are very lucky that the winds blew the ash away from us.

Write back and tell me more about yourself and your country. Do you have any active volcanoes in the United States?

Your friend,
Olga from Russia

P.S. You can find out more about what happened in my country by visiting <http// www.earthkam.ucsd.edu>, <http://earth.jsc.nasa.gov>, or <http://spacelink. nasa. gov>.

Your jobs:

1. Write back to Olga and answer her questions about peninsulas and active volcanoes.
2. Send her a map of the United States, labeling the peninsulas and active volcanoes.
3. Visit the web sites that Olga mentioned and let her know what you found out about the eruption. Mention at least three facts.
4. Draw a map of the Kamchatka peninsula, locate the volcano, and draw a picture of the path that the ash clouds took.

Module 4, Investigation 4: Log 1b

Pen pal letters

Dear students on the “mainland,”

I am so glad that I will be your pen pal. My name is Kuloo, and I am 10 years old. I would like to learn more about the U.S. mainland. The mainland, as my family calls the continental United States, seems so far away.

I heard that you are studying about pathways, and I want to share an experience with you. It is an experience that my family and I had. It was very frightening. But we are all OK. We just had to move.

My family and I live in the state of Hawaii. All of our islands have their own names, beautiful Hawaiian names. My island is called Hawaii. So I really live on the island of Hawaii in the state of Hawaii. People often call our island The Big Island, and that makes it less confusing.

We live on the newest island of all the islands here, on the slopes of the Kilauea volcano. Our island sometimes shakes, rattles, and pours out lava. We lived in a place called Royal Gardens, but we had to move. In 1998, the volcano began pouring out lava from its side. The lava came down the slopes in a path toward Royal Gardens. We had plenty of time to pack up and leave our homes. It was sad to watch our houses burn. This path was called a flow from Pu’u O’o. (The Hawaiian language only has 13 letters in it.)

Write and tell me about the place where you live.

Your pen pal,
Kuloo from Hawaii

P.S. You can find out more about the lava path on <http://earth.jsc.nasa.gov/Images> or <http://southport.jpl.nasa.gov/imagemaps/html/srl-kilauea.html>.

Your jobs:

1. Visit the web sites that Kuloo mentioned.
2. Write back to Kuloo and let him know what you found out about the lava flow on the web site.
3. Draw a map of the island of Hawaii that shows the Kilauea volcano. If you can find the location of Royal Gardens, show it on your map, and draw the laval flow that reached the town.

Module 4, Investigation 4: Log 1c

Pen pal letters

Dear pen pals,

I am so glad that I will be your pen pal. My name is Elizabeth, and I am 10 years old. I would like to learn more about your part of the United States.

I heard that you were studying about pathways. Did you know that some paths change a lot? In my state, Missouri, we talk a lot about the paths of the rivers around us. Sometimes the paths get **very wide** because of heavy rain. And that is when we have floods. Do you have floods where you live? Please write and tell me if you have streams, rivers, or lakes where you live. I like to find out about other places. I want to be a geographer when I grow up.

Back to my story . . . My family and I had to move from our house in St. Louis when the River Des Peres began to overflow its banks. I was only four years old then. We waited until the last minute to leave. The water was already covering the living room floor. When we returned, after the waters went down, our house was filled with mud. My family is very lucky because no one was hurt. Our pets are fine too. But cleaning up that mud was TERRIBLE.

Goodbye for now.

Your pen pal,
Elizabeth from Missouri

P.S. You can find out more about the flooded river path at <http://observe.ivv.nasa.gov/nasa/exhibits/flood/flood_2.html> and <http://observe.ivv.nasa.gov/nasa/exhibits/flood/flood_3.html>.

Your jobs:

1. Visit the web sites that Elizabeth mentioned.
2. Write back to Elizabeth. Let her know what you found out about the flood of 1993 from the web site.
3. Send her a map of your state. Label any rivers, lakes, and waterways, and tell her about them.
4. Draw a map of Missouri and the river system, and label the rivers.

Module 4, Investigation 4: Log 1d

Pen pal letters

Dear pen pals,

I am so glad that I will be your pen pal. My name is José, and I am 10 years old. I would like to learn more about your part of the United States since I have never visited there.

I heard that you were studying about pathways. Did you know that some paths are **huge**? The path of a hurricane can start off the western coast of Africa and continue across the Atlantic Ocean and north along the coast of the United States. There are many islands that can be in the hurricane path, and my island is sometimes one of them. I live in Puerto Rico. It is a beautiful island.

My family and I watch the weather on television very closely when a hurricane is coming. If it is heading toward Puerto Rico, we cover our windows with boards. We take our bikes, swings, and porch furniture inside so that they won't get blown away. The winds can get very strong. In 1998, a hurricane hit my island, and our house was flooded. The winds were very strong. It was very scary. The hurricane was called "Georges." Most of us lost our electricity. The president said that the U.S. government would send help to the people in Puerto Rico because of the damage.

Have you ever tracked a hurricane's pathway? Do you get hurricanes where you live? If you don't get hurricanes, do you get other strong winds?

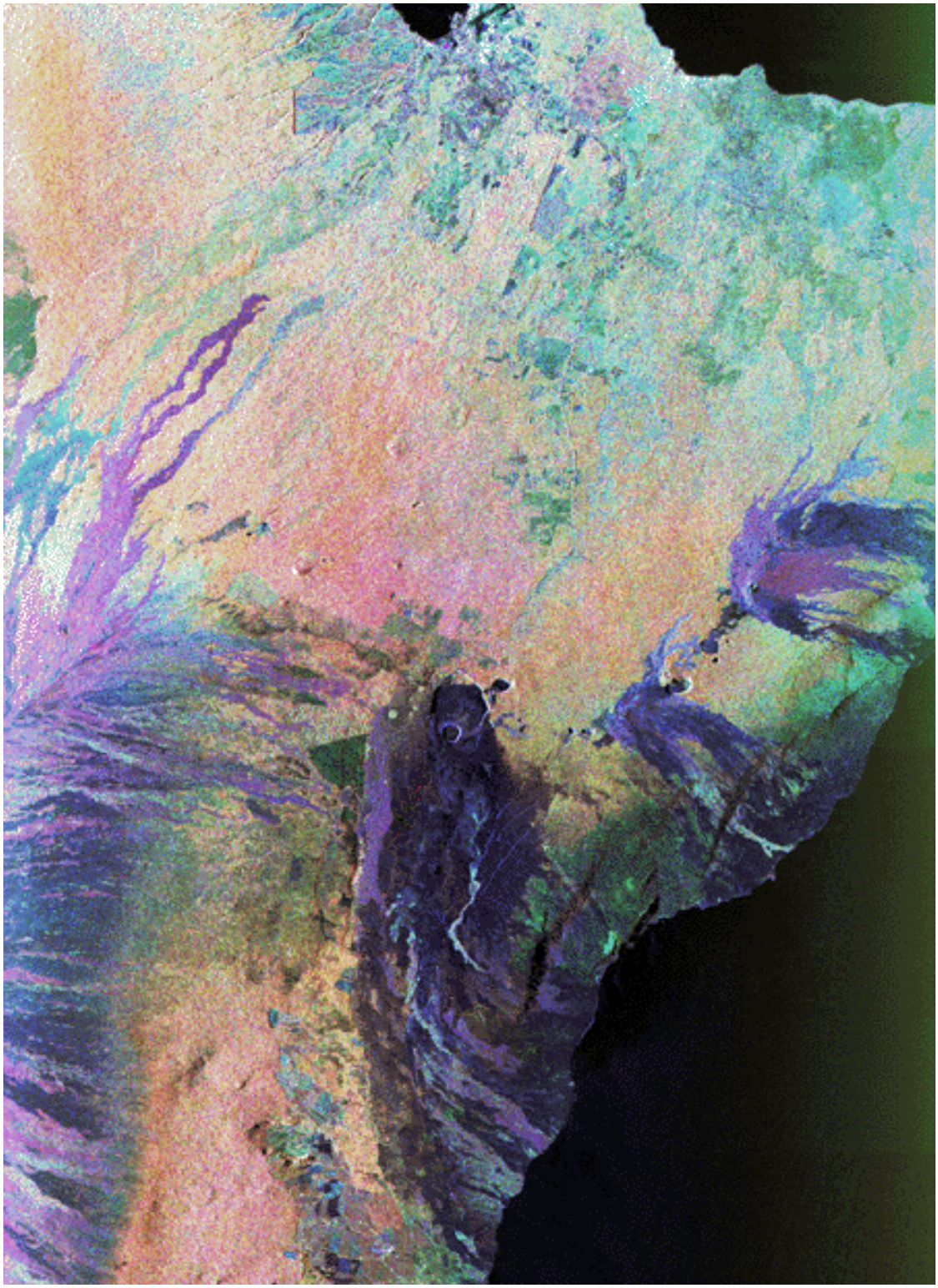
Goodbye for now.

Your pen pal,
José from Puerto Rico

P.S. You can find out more about hurricanes at <http://rsd.gsfc.nasa.gov/rsd/images/Georges/Georges19980921_lg.jpg> and <http://dprsj35.er.usgs.gov/public/hurricane.html>.

Your jobs:
1. Visit the web sites that José mentioned.
2. Write back to José and let him know what you found out about hurricanes. Answer his questions about your state.
3. Send him a map of your state labeling important features or places.
4. Draw a map of Puerto Rico and label the water around it.
5. Research the definitions of "hurricanes."
6. Search for more images of hurricanes in other places.

Module 4, Investigation 4: Figure 1
Hawaii



Source: http://southport.jpl.nasa.gov/imagemaps/html/srl-kilauea.html

Module 4, Investigation 4: Figure 2
Russia

Source: http://images.jsc.nasa.gov/images/pao/STS68/10117628.jpg

Module 4, Investigation 4: Figure 3
Hurricane Georges

Source: http://rsd.gsfc.nasa.gov/rsd/images/Georges/GeorgesThree_md.jpg

Module 4, Investigation 4: Figure 4
Mississippi River flood path

Before

After

Source: http://observe.ivv.nasa.gov/nasa/exhibits/flood/flood_2.html (before)
http://observe.ivv.nasa.gov/nasa/exhibits/flood/flood_3.html (after)