Water, water almost everywhere?

Module Overview

The presence of water in solid, liquid, and gaseous forms is one of the primary factors that distinguishes Earth from its neighbors in the solar system. In this module, students compare the amount of land and water on Earth; consider craters as evidence of a lack of water on other planets; define and locate water bodies found on Earth; and identify changes that occur in these water bodies.

Investigation 1: Why is Earth called the "water planet"?
Students use NASA photographs and hands-on activities to compare the amounts of land and water on our planet.

Investigation 2: How can we tell if other planets have water?
Students learn that the presence of craters is an indication of a dry planet. They demonstrate how craters are formed and how craters are concealed or obliterated in wet climates. Students also use satellite images to assess the presence of water on two other planets.

Investigation 3: Water bodies, where are they?
This investigation introduces and defines different kinds of water bodies and examines their locations. The activity focuses on oceans, seas, gulfs, bays, straits, lakes, and rivers. Students use NASA satellite images and maps to study these water bodies, and they compare their state's water bodies to those of other states.

Investigation 4: How do water bodies change over time?
Students explore how water bodies change in response to changes in weather and climate. They do experiments to demonstrate the effect of rising sea level on coastlines. They also use NASA images to examine dramatic changes in water levels in a river system in the United States and a lake in Africa.

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
- **Standard 3:** How to analyze the spatial organization of people, places, and environments on Earth's surface

Places and Regions
- **Standard 4:** The physical and human characteristics of places

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

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

Earth and Space Science
- Properties of Earth materials
- Structure of the Earth system

Technological Literacy Standards

Technology and Society
- **Standard 5:** The effects of technology on the environment

Connections to the Curriculum

This module can be used in geography, social studies, and science classes in the study of Earth's physical characteristics and relations with the solar system. In addition, it provides a good case study to examine human impact on the environment. The world's oceans are an excellent focus for interdisciplinary units. The investigations strengthen science and social studies skills of observation, prediction, inference, and classification. Students are given many opportunities to practice measurement and estimation skills. The ratio of land to water on Earth is a topic. Students practice language arts skills by reading to be informed, by reading to learn to perform a task, and by expanding their vocabulary and interpretation skills.

Time

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

Mathematics Standards

Number and Operations

- Compute fluently and make reasonable estimates

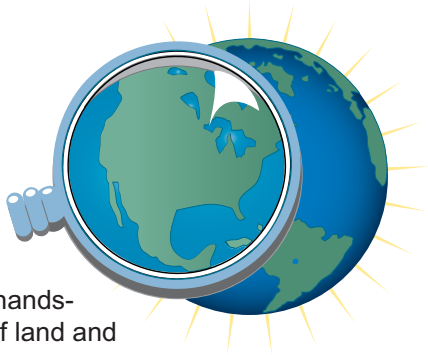
Geometry

- 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

Why is Earth called the "water planet"?



Investigation Overview

Students use NASA photographs and hands-on activities to compare the amounts of land and water on our planet.

Time required: One or two 45-minute sessions

Materials/Resources

NASA Images: (Show on large monitor or project as transparencies)
- Figure 1: Earthrise
- Figure 2: The "blue planet" from space
- Figure 3: Earth without shadows or clouds

Blue and brown crayons (one set per pair of students)
Inflatable or otherwise soft-sided globe
Outline world maps (one per pair of students)
Log: Our watery planet
Clay
Chart paper or transparency of Globe Toss Game, page 6

Content Preview

NASA monitors Earth from space to investigate human impact on the environment (erosion, deforestation, water pollution, biomass burning), to monitor natural hazards (volcanoes, hurricanes, floods), and to be able to make predictions related to natural phenomena (weather, ENSO, climate, Antarctic ice melt). They also monitor the world ocean, 70 percent of Earth's surface, because it affects the entire Earth system. The world's water mass is divided into four oceans: the Pacific, the Atlantic, the Indian, and the Arctic. Beneath the ocean lie landforms like those above the surface.

Classroom Procedures

Beginning the Investigation

1. Read the following description to the class.

   "Suddenly from behind the rim of the Moon . . . there emerges a sparkling blue and white jewel, a light, delicate blue sphere laced with slowly swirling veils of white, rising like a small pearl in a thick sea of black mystery. It takes more than a moment a fully realize this is Earth . . . home."

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

- Show spatial information on geographic representations.

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

- Explain how physical processes help to shape features and patterns on Earth's surface.

Geography Skills

Skill Set 2: Acquire Geographic Information

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

Skill Set 4: Analyze Geographic Information

- Use tables and graphs to observe and interpret geographic trends and relationships.

Skill Set 5: Answer Geographic Questions

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

2. Ask students to try to identify who might have described Earth in these words. (*They are the comments of an astronaut, Edgar Mitchell, who saw Earth from the Moon in 1971.*) Project **Figure 1** and ask the following questions.

   - What is Astronaut Mitchell seeing that is a "delicate blue"? (*Earth's oceans.*)
   - What are the "swirling veils of white"? (*Cloud cover.*)
   - What is the "thick sea of black mystery"? (*Space appears black because it cannot reflect any light from the Sun.*)
   - Why can't we see the lower half of Earth? (*It is the nighttime side of Earth.*)

3. Have students draw a picture of Earth as Mitchell saw it.

4. Have students look at the photo again and ask how many have heard Earth called the "blue planet?" Why is Earth sometimes called this? (*From space, Earth looks blue because so much of its surface is water. Oceans cover about 2/3 of Earth's surface, and more still is covered by large seas and lakes.*)

5. Have the students use a globe to identify the four oceans. Discuss where they are located in relation to the continents. Then, project **Figures 2** and **3** and ask students to identify the oceans they can see in each photograph. Explain that **Figure 3** was created from many different images. Clouds are always present in the atmosphere, and it would be impossible to get one photo that showed no clouds. Compare the amount of land and water visible in each image. Note the Arctic and Antarctic ice caps and explain that they contain so much ice that if it were to melt, the level of the oceans would rise and flood the present coastlines.

Developing the Investigation

6. Explain the directions for a globe toss game and ask students to predict whether the final tally of the game will have more points for the land or water. *(For older students, have them predict which ocean will receive more points.)*

   - Students sit or stand in a circle.
   - An inflatable (or other soft-sided) globe is tossed or rolled to a student across the circle. The student receiving the globe will look at his/her right thumb to see where it has landed, either on water or land, and give the information to the tally person.
   - The student tallying the results will record the thumb landings on water or land on a tally sheet (sample above). Students in grades 2–4 can also give the names of the oceans and continents on which their thumbs land, to be recorded on the tally sheet. Make the tally sheet on large chart paper or on the chalkboard or make a transparency of the table on page 6 of this Educator's Guide.
   - Discuss the findings with the students. Were the results what they expected?

Globe Toss Game, Grades K-1

Water	Land

Globe Toss Game, Grades 2-4

Water		Land	
Atlantic Ocean		Africa	
Arctic Ocean		Antarctica	
Indian Ocean		Asia	
Pacific Ocean		Australia	
Other		Europe	
		North America	
		South America	

Concluding the Investigation

7. For a more visual comparison of land and water, have the students make a bar graph of the tally sheet and complete the **Log**. Read the directions together. For K–2 students, the bottom section of the **Log** may be eliminated. Discuss their answers and guide them to understand that they have demonstrated that about 1/3 of Earth's surface is covered with land and about 2/3 with water.

8. Form groups of two or three students. Distribute outline world maps and clay. Ask the students to locate and label the oceans on the map. Then have them roll the clay into a "snake" long enough to contain the Pacific Ocean and place the "snake" around its borders. Use more clay to outline the other oceans. Describe the shapes made by the clay. Compare the sizes of the oceans.

Background

The Pacific Ocean is by far the largest and deepest of the four oceans. It covers nearly 1/3 of the globe, an area approximately 165,760,000 square kilometers. This area can contain all the world's continents with room to spare. The average depth of the Pacific Ocean is 3,962 meters.

The Atlantic Ocean has an hourglass shape and covers more than 20 percent of Earth's surface. It is the second largest ocean. It covers 1/5 of Earth's surface. It reaches from the North Pole to the continent of Antarctica. The average depth is 3,657 meters. The Atlantic is less salty than other oceans because many rivers carry fresh water into it.

The Indian Ocean has a triangular shape and is bordered by Africa, Asia, Antarctica, and Australia. It is smaller than the Atlantic Ocean and less than half the size of the Pacific Ocean. It contains almost 1/5 of Earth's water surface, and many island nations are found within its boundaries.

The Arctic Ocean is centered approximately on the North Pole. It is the world's smallest and shallowest ocean. Its average depth is 1,205 meters. It is surrounded by North America, Eurasia, and Greenland. It is covered by ice year-round.

Draining the oceans would reveal that Earth's solid surface is divided into highlands and lowlands. The highlands are the landmasses that form the continents, and the lowlands form the ocean basins. The ocean floor contains mountain chains, isolated peaks, and deep valleys.

Evaluation

***Log**

1. Earth has much more water than land.
2. 2/3 water, 1/3 land
3. Oceans: Atlantic, Pacific, Indian, Arctic
   Continents: Africa, Antarctica, Asia, Australia, Europe, North America, South America

Resources

Image Sources:
Figure 1: http://images.jsc.nasa.gov/images/pao/AS8/10074963.jpg
Figure 2: http://pds.jpl.nasa.gov/planets/gif/ear/earthspn.gif
Figure 3: http://www.fourmilab.ch/cgi-bin/uncgi/Earth

http://www.ess.ucla.edu/hypermap/Vmap/top.html
http://seawifs.gsfc.nasa.gov/SEAWIFS.html *Life in the Oceans: Studying Global Ocean Color from Space*
http://earthrise.sdsc.edu Earthrise, large database of photos of the Earth from space
http://www.seaspace.com
http://www.sierraclub.org/books/598.html *Water, Water Everywhere*
Ladybird First Facts about the Earth, Caroline Arnold, Ladybird Books, Auburn, ME 04210
The Earth's Surface, Colin Walker, Modern Curriculum Press, Inc., 13900 Prospect Road, Cleveland, OH 44136

Globe Toss Game

Water		Land	
Atlantic Ocean		Africa	
Arctic Ocean		Antarctica	
Indian Ocean		Asia	
Pacific Ocean		Australia	
Other		Europe	
		North America	
		South America	

Module 2, Investigation 1: Log

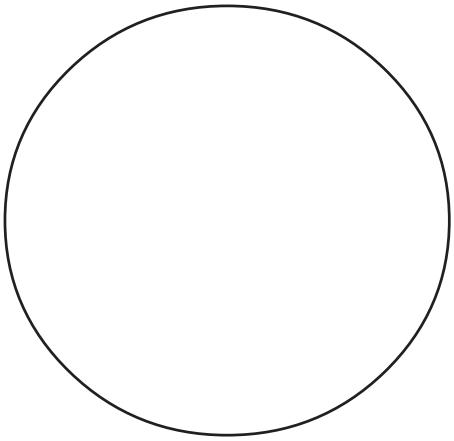
Our watery planet

1. You have looked closely at Earth and compared the amount of land and water on its surface. What did you discover?

_____

_____

2. If all the land was moved together, to the top of the globe, how much of Earth's surface would be left to be covered by water? Your job now is to color with your blue crayon how much of Earth is covered by water.



3. Write the names of the oceans and continents on the lines below. Your teacher will help you.

Water	**Land**
Oceans	Continents
1. _____	1. _____
2. _____	2. _____
3. _____	3. _____
4. _____	4. _____
	5. _____
	6. _____
	7. _____

Module 2, Investigation 1: Figure 1

Earthrise

Source: http://images.jsc.nasa.gov/images/pao/AS8/10074963.jpg

Module 2, Investigation 1: Figure 2

The “blue planet” from space

Source: http://pds.jpl.nasa.gov/planets/gif/ear/earthspn.gif

Module 2, Investigation 1: Figure 3

Earth without shadows or clouds

Source: http://www.fourmilab.ch/cgi-bin/uncgi/Earth

Globe Toss Game

Water		Land	
Atlantic Ocean		Africa	
Arctic Ocean		Antarctica	
Indian Ocean		Asia	
Pacific Ocean		Australia	
Other		Europe	
		North America	
		South America	

Module 2, Investigation 1: Log

Our watery planet

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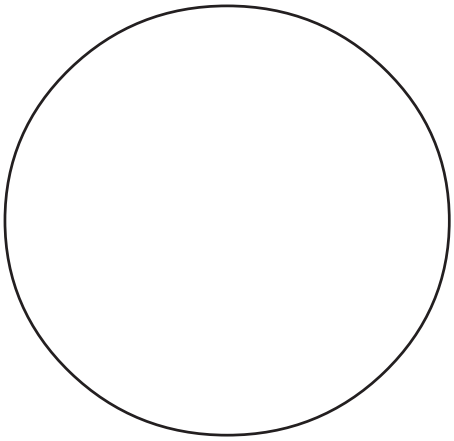

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4. _____	4. _____
	5. _____
	6. _____
	7. _____

Module 2, Investigation 1: Figure 1

Earthrise

Source: http://images.jsc.nasa.gov/images/pao/AS8/10074963.jpg

Module 2, Investigation 1: Figure 2

The “blue planet” from space

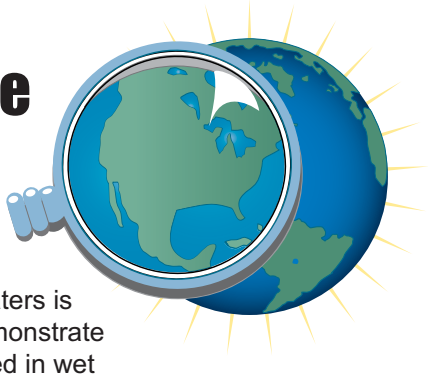
Source: http://pds.jpl.nasa.gov/planets/gif/ear/earthspn.gif

Module 2, Investigation 1: Figure 3

Earth without shadows or clouds

Source: http://www.fourmilab.ch/cgi-bin/uncgi/Earth

How can we tell if other planets have water?



Investigation Overview

Students learn that the presence of craters is an indication of a dry planet. They demonstrate how craters are concealed or obliterated in wet climates. Students also use satellite images to assess the presence of water on two other planets.

Time required: Two 45-minute sessions

Materials/Resources

NASA images (transparencies of each)
- Figure 1: The planets in our solar system
- Figure 2: Craters on Mercury
- Figure 3: Mars
- Figure 4: Earth
- Figure 5: Chesapeake Bay
- Figure 6: Mars in 1977
- Figure 7: Mars in 2000

Two trays with at least a 2 inch deep lip
Damp sand
About 30 marbles
Log 1: Our experiment
Log 2: The Chesapeake Bay crater
United States map (showing Chesapeake Bay)

Content Preview

A crater is a saucer-shaped pit or depression on a planetary surface. Craters are formed by the impact of meteorites and asteroids, pieces of space debris that strike a planet or other body. Erosion obscures and destroys most of the craters on Earth.

Classroom Procedures

Beginning the Investigation

1. Project a transparency of **Figure 1**. Have students name the planets and tell or write what they know about them. Talk about similarities and differences among and between the planets, distance from the Sun, vegetation, water availability, etc. A student or the educator should record the comments.

Developing the Investigation

Craters and Water

2. Project transparencies of **Figures 2** and **3**. **Figure 2** is Mercury, and **Figure 3** is Mars. Brainstorm about the surfaces of these planets while looking at the NASA images. Have students point out the craters by

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.

Standard 4: Places and Regions

The physical and human characteristics of places

- Describe and compare the physical characteristics of places.

Standard 7: Physical Systems

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

- Explain how physical processes help to shape features and patterns on Earth's surface.

Geography Skills

Skill Set 2: Acquire Geographic Information

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

Skill Set 4: Analyze Geographic Information

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

marking them on the overhead. Ask the students to define "crater."

Crater: A saucer-shaped pit or depression on a planetary surface.

3. Ask the following questions and list the students' responses on the chalkboard.

   - What causes craters? (*The impacts of meteorites and asteroids create craters. Scientists can determine the relative age of the surface of the Moon by the number of craters.*)
   - Why does Earth have so few visible craters compared to the Moon and some other planets? Is it because Earth is struck less often? (*No, it is because on the other bodies there is little or no water to obscure or destroy the craters.*) Meteorites may disintegrate in Earth's atmosphere.

   Project **Figure 4** of Earth. Look for signs of craters.

   - How would water cover up or destroy craters? (*Rain, flowing water, and moving ice erode them and/or fill them with sediment. And where there is moisture there may also be vegetation, which can obscure craters. Other erosion processes such as wind erosion or plate tectonics also change the shape of the Earth's surface.) If asteroids or meteors strike large water bodies, no crater would be formed.*

4. Do the following experiment to show how a planet's surface is impacted by meteors.

   A. Place two sand trays filled with damp sand on the floor, with sand surface smoothed. Label the trays 1 (older) and 2 (newer). Have students drop a marble every 10 seconds into Tray 1. Each drop will create a crater. Continue the experiment for four minutes with Tray 1, and for two minutes with Tray 2. Carefully remove the marbles to expose the craters. Explain that when meteorites strike a planet, they land with such force that they usually disintegrate. Have the students count the number of craters in each tray. The "old" four-minute tray will have more craters. This illustrates the idea that, when craters persist, scientists can use their number to determine the relative age of the surface. Follow up by identifying older and younger sections of Martian crust in **Figure 3**, with obvious differences in the number of craters. The newer crust is generally the result of lava flows.

   B. Take the older, four-minute tray (Tray 1) and gently sprinkle water on it. The craters will soon be worn away. This illustrates the effect of water—rain, rivers, waves, etc. in wearing away evidence of craters on Earth.

   C. Smooth out the other sand tray (Tray 2), and form a hole or depression in the middle. Fill the depression with water. Have students drop marbles on the sand and in the water. This will illustrate how an impact in the oceans is much less likely to leave a crater than one on land. Thus, an ocean-covered planet will have fewer craters.

5. Have students write about their experiment and findings on **Log 1** and share their responses.

6. Show a transparency of **Figure 5** and ask a student to read **Log 2** about the Chesapeake Bay bolide crater. Share additional information from **Background** on the Chesapeake Bay crater.

7. Find the location of the impact site on a map showing the Chesapeake Bay area and circle the site on the transparency. (The site is under the southern part of the bay. The narrow extension of the peninsula to the east of the bay covers part of the crater. The peninsula formed from sediments deposited over the crater.) Tell the students that NASA Langley Research Center in Hampton, Virginia, sits on the edge of this 30 kilometer wide impact crater. (Hampton is marked by a red dot in the image.)

8. Return to a sand tray and create a sloping valley. Add water to make a river and watch the flow of water. Make a crater by dropping a large ball of clay onto the river. Carefully remove the ball of clay. Add more water and predict what will happen. (*The river will fill the crater.*)

Concluding the Investigation

9. Tell the class that NASA's increasing ability to explore outer space is rapidly providing new information about other planets. When Mars was visible only by telescopes, the most easily distinguished features were large craters. Therefore, it was assumed that the planet had always been very dry. In 1977, NASA's Viking Orbiter spacecraft reached Mars and sent back images that showed large canyons similar to the canyons formed by water on Earth. That made scientists think that Mars may have had a great deal of water on its surface in its ancient past. But until recently,

detailed images of Mars' surface were not available to search for more evidence of water.

10. Show the students the transparency of **Figure 6** and explain that this is one of the Viking Orbiter images. Ask them to find the canyons and have one of the students mark several of them on the transparency. Ask how many craters the students can see and have another student circle some of them. Point out the small white square in the image and explain that this marks the area that the class will see close up. Note that one of the canyons runs through this square.

11. Explain that the Mars Global Surveyor spacecraft has been in orbit over Mars since 1997, and that in its first three years in orbit it produced over 80,000 detailed images of the planet's surface. Show **Figure 7** and tell the class that this is an image from Surveyor of the area inside the square in the previous image.

12. Ask if the students can figure out what they are looking at. Explain that this is the side of the canyon. The top of the image shows relatively flat land. The irregular band from left to right shows the top of the cliff that forms one side of the canyon. Under the top of the cliff is a dark band, which is a shadow made by overhanging rock. In this area, water has seeped out and eroded the rock below it, making the cliff recede and creating gullies down the slope. Ask the students if they can see the gullies.

13. Have one student draw a line on the transparency along the top of the cliff. Ask the class to use the scale on the image and figure out how far below the top of the cliff the water seeped out. (*About 100 meters.*) Have another student make a circle around one of the gullies. Ask the class to estimate the length of the gullies. (*100–200 meters.*)

14. Explain that the most interesting thing about this erosion is that it is so recent that it is probably still going on. Scientists can tell by their appearance that the gullies were formed within the last few decades. This tells us that enough water has been seeping out onto parts of Mars' surface in recent years to erode the land. Mars is not as dry as we once thought!

Background

Liquid water is a rare commodity in our solar system. Only on a planet of the right mass and chemical composition, and the right distance from a neighboring star, can liquid water be found. As far as we know, Earth is the only planet in our solar system that has large water bodies. Some other planets have significant amounts of frozen water. Jupiter's moons appear to have liquid water that is trapped under thick surface ice. On Mars underground water appears to seep out onto the surface in places, but it apparently vaporizes before it can accumulate.

Planets can be struck by comets or asteroids (also called bolides). The depressions made by the impact can fill up with water to make lakes or bays. The Chesapeake Bay bolide helped to create the Chesapeake Bay.

Background: Chesapeake Bay Crater

A spectacular geological event took place on the Atlantic margin of North America about 35 million years ago. Sea level was unusually high everywhere on Earth, and the ancient shoreline of the Virginia region was somewhere in the vicinity of where Richmond is today. Tropical rain forests covered the slopes of the Appalachians.

Suddenly, with an intense flash of light, from the far reaches of space, a bolide (comet or asteroid), 3–5 kilometers in diameter, swooped through the atmosphere and struck Earth, creating an enormous crater approximately 200 kilometers southeast of Washington, D.C. It is buried 300–500 meters beneath the southern part of Chesapeake Bay and the southern part of the Delmarva Peninsula (which developed after the crater was formed).

The Chesapeake Bay crater was recently identified by the U.S. Geological Survey (USGS), which has assembled an international team to investigate its characteristics. Evidence of the crater comes from two sources: (1) cores drilled by the USGS and the Virginia State Water Control Board and (2) marine seismic-reflection profiles collected by Texaco, Inc., the USGS, and the National Geographic Society.

Analysis of the profiles shows that the crater is 85 kilometers in diameter and 1.3 kilometers deep, an excavation twice the size of Rhode Island and as deep as the Grand Canyon. It is three times larger than any other U.S. crater and is the sixth largest known crater on the planet. A rubble bed fills the crater and forms a thin halo around it.

Discovery of the giant crater has completely revised our understanding of Atlantic Coastal Plain evolution. Several consequences of the ancient cataclysm still affect the land around Chesapeake Bay today: land subsidence, river diversion, disruption of coastal aquifers, and ground instability. (See http://marine.usgs.gov/fact-sheets/fs49-98/ for more information.)

Evaluation

Log 1

1. A round depression on the surface of a planet
2. Asteroids, comets, or meteors collide with a planet
3. Answers will vary
4. Answers will vary
5. Mercury, Mars, Earth
6. They have been covered by water and vegetation, eroded away, buried under sediment.

Additional Resources

http://www.ess.ucla.edu/hypermap/Vmap/top.html
http://mars3.jpl.nasa.gov/mgs/realtime/groupd-pds.html Shows real-time images with good contrast
http://spaceart.com/solar. Links to other sites. Planetary images including satellite and close-ups showing cratered and noncratered surfaces
http://nssdc.gsfc.nasa.gov/image/planetary/moon/gal_moon_color.jpg. A good shot of the Moon
Venus, http://spaceart.com/solar/raw/venus/venus.gif Doesn't show craters well due to Venus' thick atmosphere. Does show how an oceanless planet looks very different.
http://pds.jpt.nasa.gov/planets/gif/ven/golubnew.gif Venus's surface
www.challenger.org - Challenger Center classroom programs, Mars City
CD-ROM, *Visit to an Ocean Planet*, NASA educational product
Poster of Solar System, NASA educational product
Solar System Lithography Set for Space Science, NASA educational product

Module 2, Investigation 2: Log 1

Our experiment

Dear Family:
We did a very interesting experiment about craters today.

1. A crater is _____

   _____

   _____

2. Here is what causes craters.

   _____

   _____

   _____

3. Here are two drawings of craters.

Module 2, Investigation 2: Log 1

Our experiment

4. This is the experiment that we did to demonstrate what causes craters. Here are three pictures and sentences telling you what we did.

A.

A. _____

_____

_____

B.

B. _____

_____

_____

C.

C. _____

_____

_____

5. We looked at images of these planets.

_____ _____

_____

6. We cannot see as many craters on the surface of Earth because

_____

_____

Module 2, Investigation 2: Log 2

The Chesapeake Bay crater

What is the smallest state in the area? (Rhode Island)

Double the state's size and you have the area that we are talking about.

What is the deepest canyon in the United States? (Grand Canyon)

Now you have it . . . an area twice the size of Rhode Island and as deep as the Grand Canyon. What is it and where is it?

It is the giant crater caused by a spectacular event that happened where the Chesapeake Bay is located today. It happened about 35 million years ago.

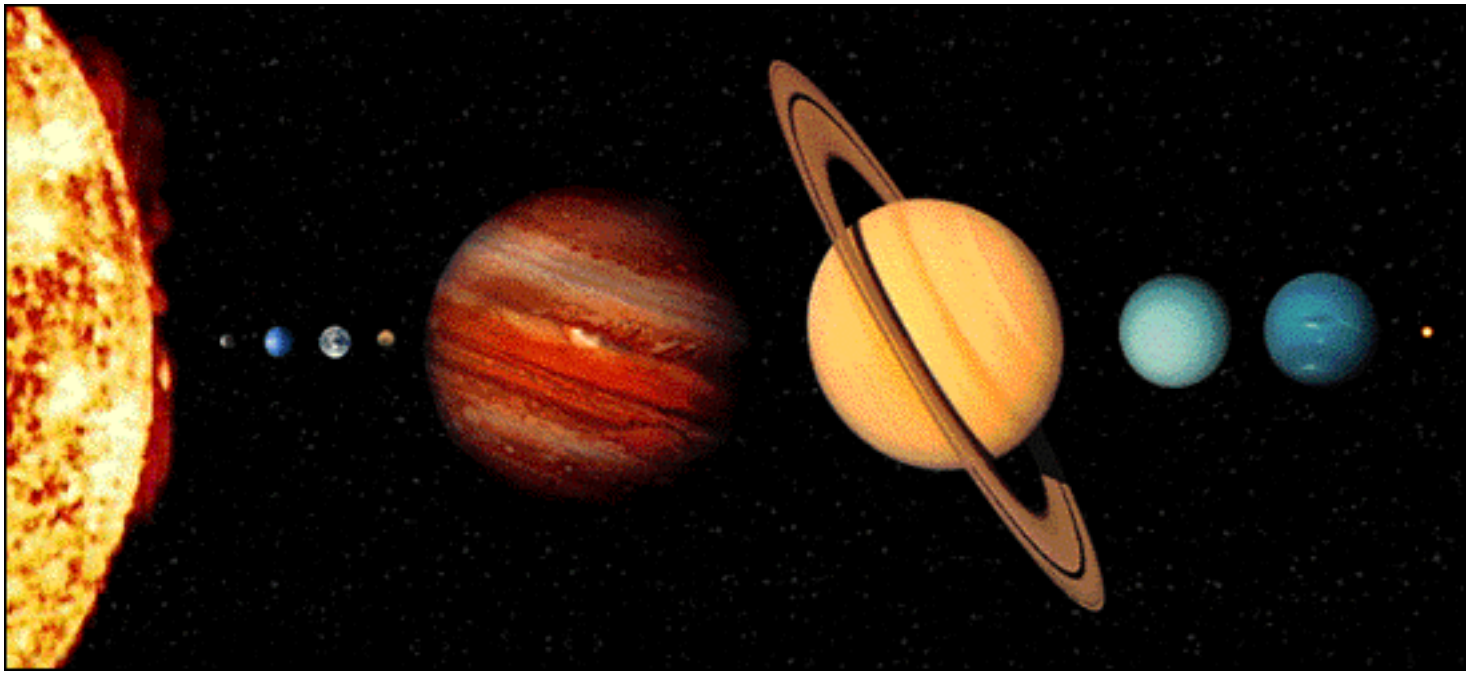
When a comet or asteroid swooped through the atmosphere and hit Earth, it created a huge crater. The crater is now buried beneath the southern part of Chesapeake Bay.

This crater is three times larger than any other in the United States. It is also the sixth largest in the world.

Craters on other planets are easier to see than the ones on Earth. So much of Earth is covered by water and vegetation that most of our craters are hidden.

Module 2, Investigation 2: Figure 1

The planets in our solar system



Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto

Source: http://pds.jpl.nasa.gov/planets/index.htm

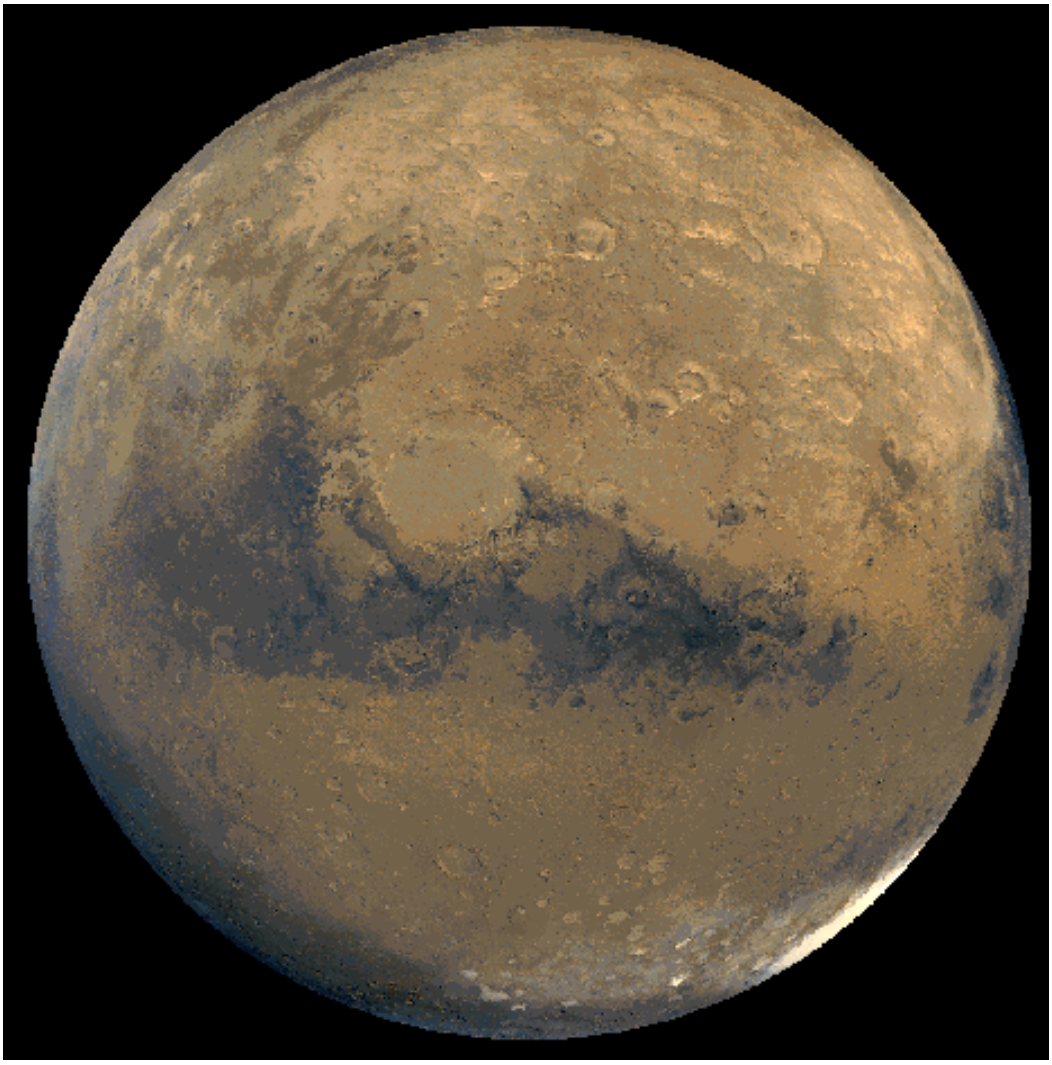
Module 2, Investigation 2: Figure 2

Craters on Mercury

Source: http://pds.jpl.nasa.gov/planets/gif/mer/mercury1.gif

Module 2, Investigation 2: Figure 3

Mars



Source: http://pds.jpl.nasa.gov/planets/gif/mar/schiap.gif

Module 2, Investigation 2: Figure 4

Earth

Source: http://www.fourmilab.ch/cgi-bin/uncgi/Earth

Module 2, Investigation 2: Figure 5

Chesapeake Bay

Hampton, Virginia is marked by the red dot.
Source: http://modis.gsfc.nasa.gov/MODIS/IMAGE_GALLERY/MODIS1000017_md.jpg

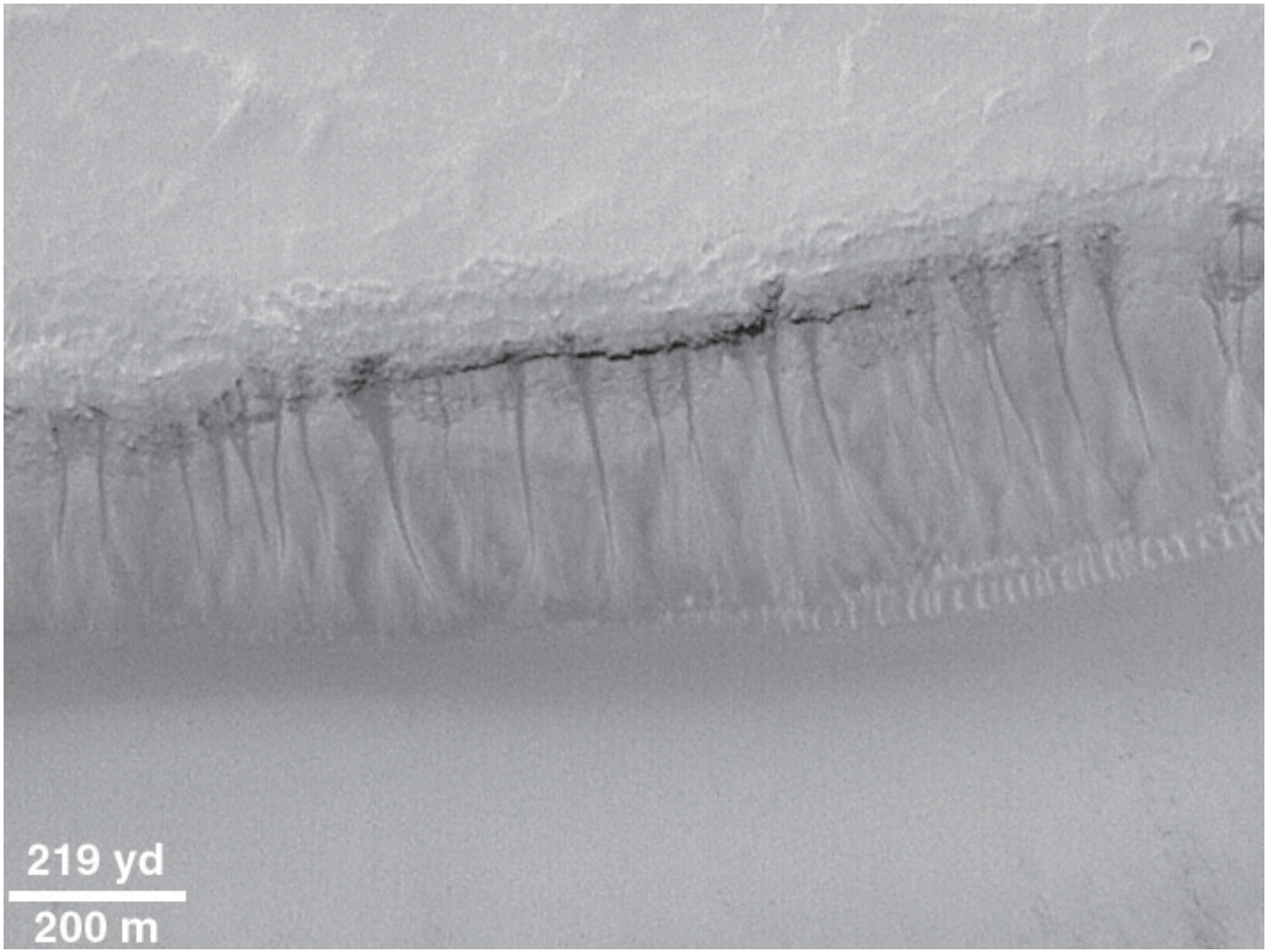
Module 2, Investigation 2: Figure 6

Mars in 1977

Source: http://www.msss.com/mars_images/moc/june2000/weeping/weeping_cntx_100.jpg

Module 2, Investigation 2: Figure 7

Mars in 2000



Source://www.msss.com/mars_images/moc/june2000/weeping/weeping_100.jpg

Module 2, Investigation 2: Log 1

Our experiment

Dear Family:
We did a very interesting experiment about craters today.

1. A crater is _____

   _____

   _____

2. Here is what causes craters.

   _____

   _____

   _____

3. Here are two drawings of craters.

Module 2, Investigation 2: Log 1

Our experiment

4. This is the experiment that we did to demonstrate what causes craters. Here are three pictures and sentences telling you what we did.

A.

A. _____

_____

_____

B.

B. _____

_____

_____

C.

C. _____

_____

_____

5. We looked at images of these planets.

_____ _____

_____

6. We cannot see as many craters on the surface of Earth because

_____

_____

Module 2, Investigation 2: Log 2

The Chesapeake Bay crater

What is the smallest state in the area? (Rhode Island)

Double the state's size and you have the area that we are talking about.

What is the deepest canyon in the United States? (Grand Canyon)

Now you have it . . . an area twice the size of Rhode Island and as deep as the Grand Canyon. What is it and where is it?

It is the giant crater caused by a spectacular event that happened where the Chesapeake Bay is located today. It happened about 35 million years ago.

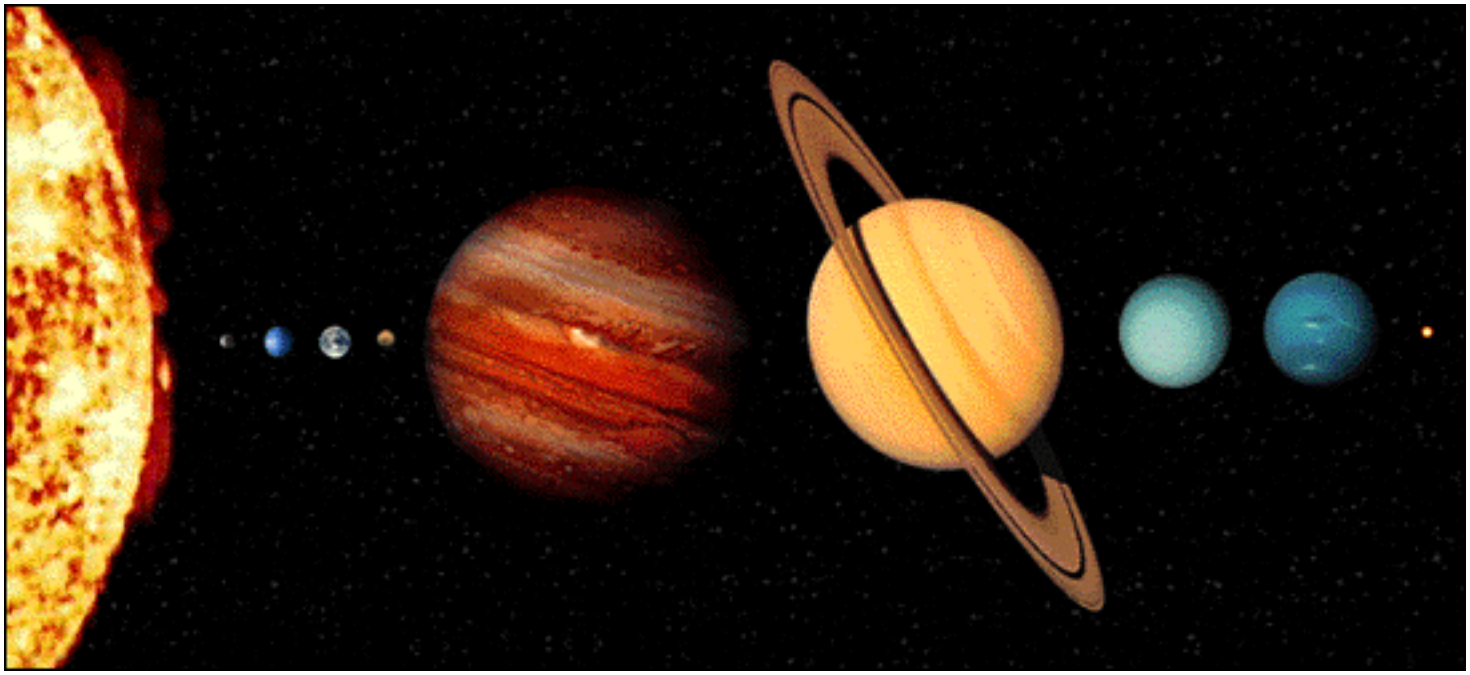
When a comet or asteroid swooped through the atmosphere and hit Earth, it created a huge crater. The crater is now buried beneath the southern part of Chesapeake Bay.

This crater is three times larger than any other in the United States. It is also the sixth largest in the world.

Craters on other planets are easier to see than the ones on Earth. So much of Earth is covered by water and vegetation that most of our craters are hidden.

Module 2, Investigation 2: Figure 1

The planets in our solar system



Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto

Source: http://pds.jpl.nasa.gov/planets/index.htm

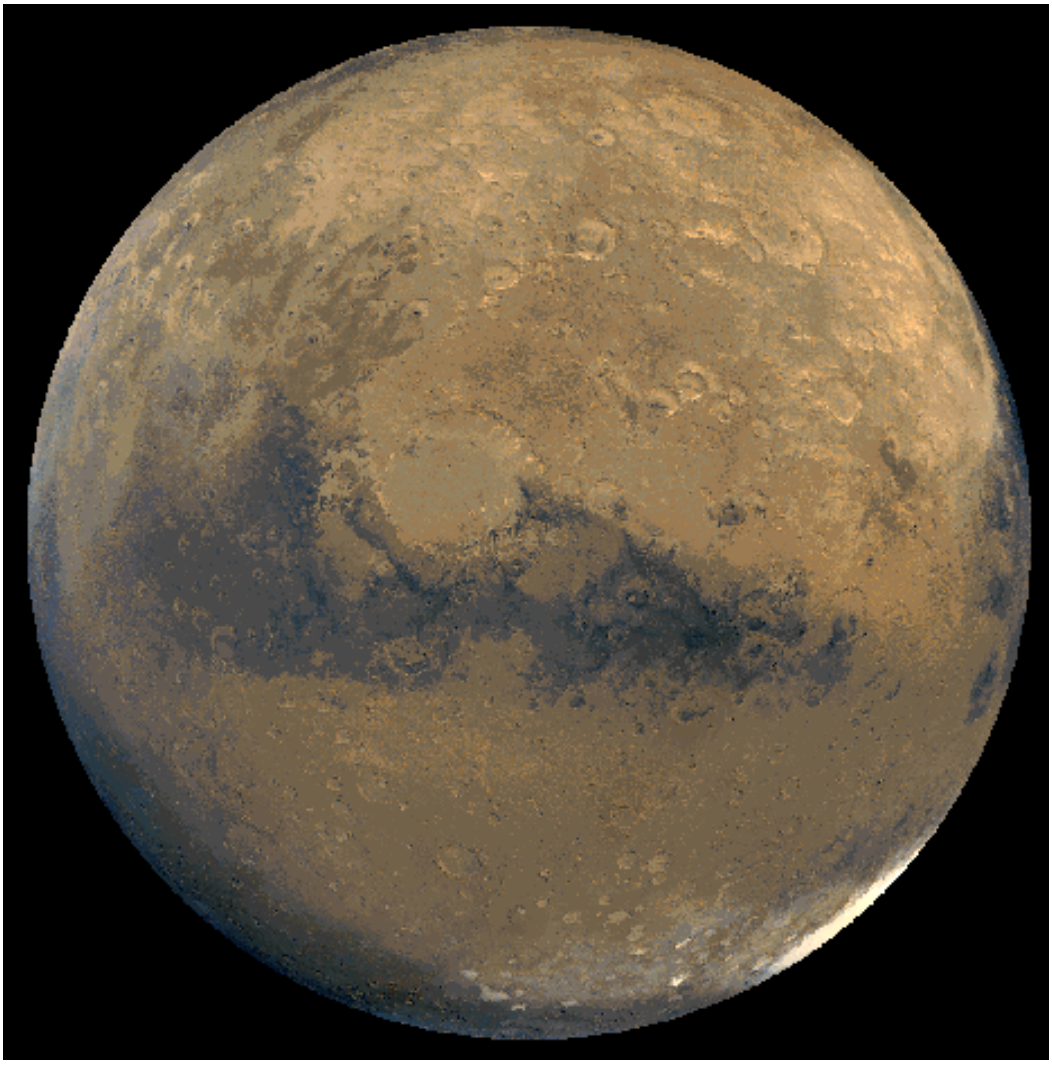
Module 2, Investigation 2: Figure 2

Craters on Mercury

Source: http://pds.jpl.nasa.gov/planets/gif/mer/mercury1.gif

Module 2, Investigation 2: Figure 3

Mars



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Module 2, Investigation 2: Figure 4

Earth

Source: http://www.fourmilab.ch/cgi-bin/uncgi/Earth

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Module 2, Investigation 2: Figure 6

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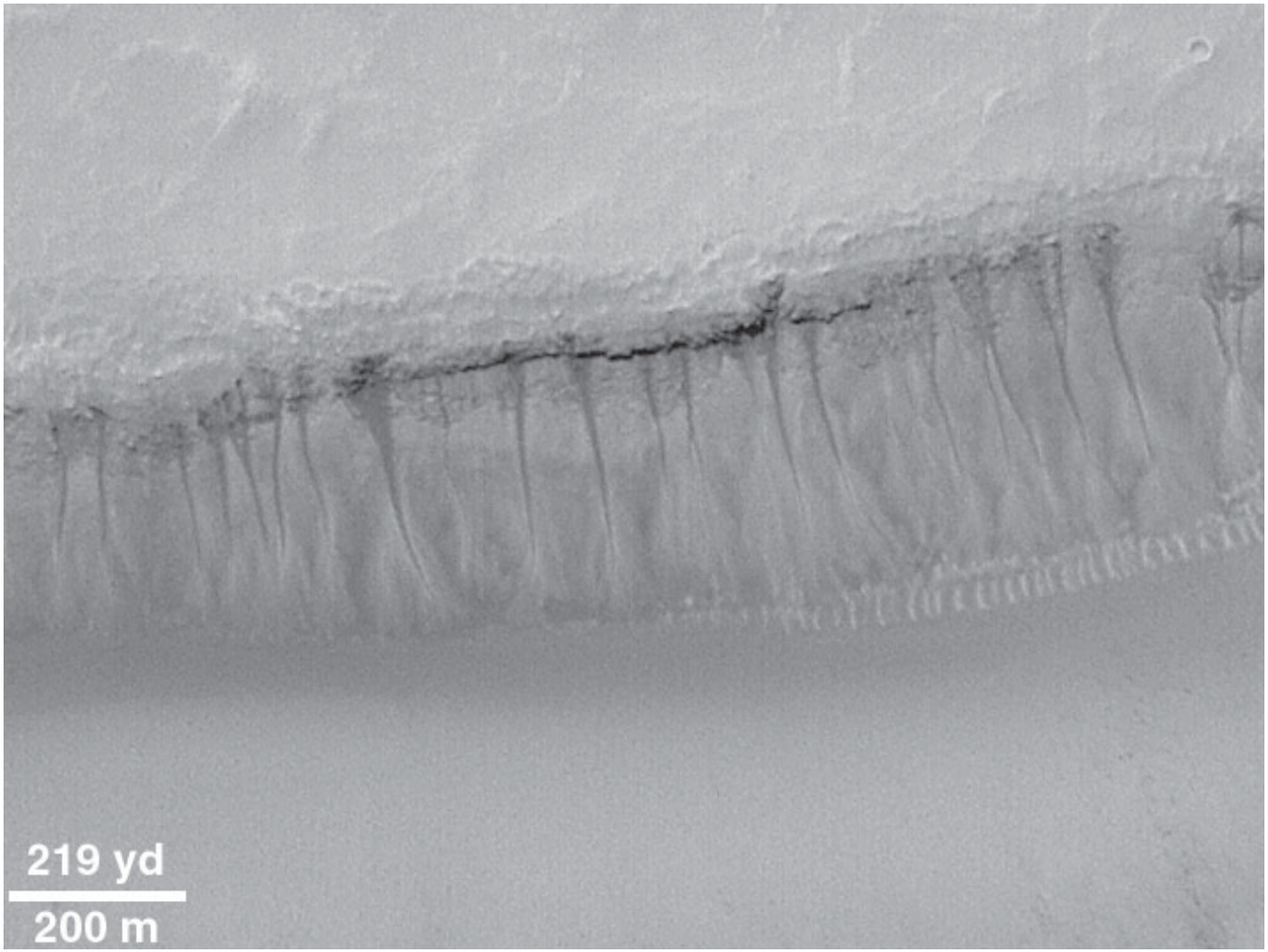
Source: http://www.msss.com/mars_images/moc/june2000/weeping/weeping_cntx_100.jpg

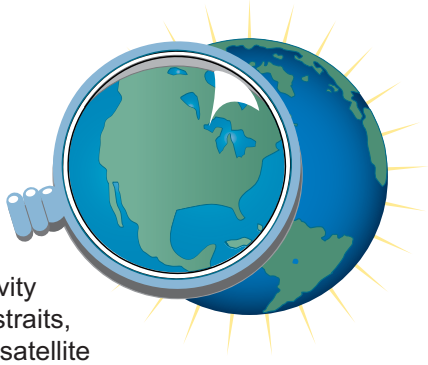
Module 2, Investigation 2: Figure 7

Mars in 2000



Source://www.msss.com/mars_images/moc/june2000/weeping/weeping_100.jpg

Water bodies, where are they?



Investigation Overview

This investigation introduces and defines different kinds of water bodies and examines their locations. The activity focuses on oceans, seas, gulfs, bays, straits, lakes, and rivers. Students use NASA satellite images and maps to study these water bodies, and they compare their state's water bodies to those of other states.

Time required: Two 45-minute sessions

Materials/Resources

NASA Images: (transparency or six copies of each)
- Figure 1: Pacific and Atlantic Oceans
- Figure 2: Mediterranean Sea
- Figure 3: Gulf of Mexico
- Figure 4: Chesapeake Bay
- Figure 5: Susquehanna and West Branch Rivers, Pennsylvania
- Figure 6: Lake Victoria

World outline map (six copies)
6 atlases
Globe
CD-ROM: *Visit to the Ocean Planet*, NASA educational product, optional
Log 1: Images of water bodies (one copy for each student)
Log 2: Water bodies (one copy for each student)
Log 3: Looking at the world's water (one copy for each student)
Log 4: Comparing our state (one copy for each student)

Content Preview

Geographers divide Earth's water bodies into three types: oceans, flowing water, and lakes. All three types are vulnerable to human impact such as oil spills, other pollution, and lessened flow; however, those water bodies close to large population concentrations are the most affected by human activities.

Classroom Procedures for Day 1

Beginning the Investigation

1. Have the students list as many types of water bodies as they can. Do this in small groups or as a class. If done in small groups, share with the class. Put the types on a chart or chalkboard and add types as the lesson progresses.

2. Tell the students that the world's water bodies can be divided into three major groups. Have them look at the list on the chalkboard and predict

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 features at a variety of scales using maps, globes, and other sources of graphic information.

Standard 7: Physical Systems

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

- Explain how physical processes help to shape features and patterns on Earth's surface.

Geography Skills

Skill Set 1: Ask Geographic Questions

- Ask geographic questions—Where is it located? Why is it there? What is significant about its location? How is its location related to the locations of other people, places, and environments?

Skill Set 2: Acquire Geographic Information

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

Skill Set 4: Analyze Geographic Questions

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

what three groups that could be. Have students justify their choices. Write "Oceans, Flowing Water, and Lakes" on the chalkboard and share information from **Background** with the group.

Developing the Investigation

3. Refer to the list above and circle the following water bodies. Tell the students that the project that they will be doing will focus on these: oceans, seas, gulfs, bays, lakes, and rivers. Give the definitions to the class, either verbally or on a slip of paper and ask them what water body is being defined. Use the following definitions.

   ocean: a vast body of salt water that separates or surrounds continents
   sea: a smaller division of the ocean, partially enclosed by land (or sometimes a very large lake)
   gulf: arm of the ocean that reaches into land
   bay: a body of water that is partly enclosed by land, smaller than a gulf
   lake: a body of fresh water, surrounded by land
   river: water that flows downhill in a natural channel

4. Place one set of **Figures 1-6** and an atlas on each of six tables. Divide the students into six groups and give each student a copy of **Log 1**. Review the directions and note the definitions at the bottom of the page. (Alternative: Show transparencies of these figures instead of distributing copies. In this case, project two transparencies at a time on two projectors so that the students can move ahead at their own pace.)

5. Ask each group to use the atlas to find the names of the water bodies in the images. Have each student record these names on **Log 1**, along with an interesting observation about the image.

6. Have the students remain in their six groups and give each student a copy of **Log 2**. Explain that because most water bodies change over time, images taken from space in different years can be important tools that help us monitor the changes. Ask what kinds of changes such images might show. (*More or less water in lakes and rivers, flooding, changing sea level, etc.*)

7. Have each group work with a different water body:

   oceans, seas, gulfs, bays, rivers, or lakes.

8. Distribute atlases for the students to use. Have students complete the response sheet and share their choices with the group. Distribute a world outline map to each group and have them find and label the locations of their water bodies.

Concluding the Investigation

9. Review reasons for monitoring changes in water bodies over time. Ask the following questions:

   Which water bodies may experience oil spills? (*Those nearest oil reserves, pathways of tankers, port cities.*)
   Which water bodies may experience pollution from fertilizers used on farms? (*Those near farm land and downstream from farmland.*)
   Which water bodies may decrease or increase size? (*Those being dammed or diverted, near the seacoast with rising or receding water levels, in places with decreasing or increasing precipitation.*)

Classroom Procedures for Day 2

Beginning the Investigation

10. Begin by having students look at the globe, if possible. Maps can be used if globes are not available.

    Have students locate the Equator and the northern and southern hemispheres. Write the following question:

    - Is more of Earth covered by water in the southern or northern hemisphere?

11. Have the students answer the question and tell them that they will be doing an activity that examines the distribution of land and water.

Developing the Investigation

12. Cut a world outline map into six sections, horizontally, along the equator and the lines of latitude at 30 degrees and 60 degrees north and 30 degrees and 60 degrees south. Write the latitude at the top and bottom of each section. (For example, the southernmost section in the northern hemisphere would be marked 0 degrees at its lower edge and 30 degrees north at its upper edge.)

13. Divide students into six groups. Give each group a section of the map and an atlas. Give each student a copy of **Log 3**. Read the instruction on **Log 3** together and have students complete the information.

14. Have the groups put the map back together, starting from either the North or South Pole. Have each group report from **Log 3** as the map is put back together.

Concluding the Investigation

15. Keep the students in their six groups. Have them use the atlas to find their state on a map large enough that it shows the main rivers. Assign each group another state with a significantly different climate. Have each group find a map of this state that shows a similar level of detail as the map of their own state. Distribute **Log 4** and have each student fill in the answers. Then discuss their findings with the class. List each state on the board and compare its water characteristics with those of the students' own state. Have the students draw conclusions about the impacts of water availability and water scarcity on people, animals, and plants.

Background

Earth supports a large and fascinating variety of water bodies. They can all be grouped into categories. The first, largest, and most important are the oceans. There is really only one, huge, interconnected body of ocean water. We divide it up into different oceans for descriptive purposes. The relative proportion of the globe covered by the sea varies only a little over geologic time, but the size, shape, and location of the ocean basin(s) is determined by the tectonic movements of the continental plates. The global ocean configuration is therefore dynamic over geologic time, but these changes can only be observed in human lifetimes with very sensitive instruments.

The second general type of water body is flowing water—rivers and streams. These channel water downhill to estuaries and oceans, or into lakes. The amount of flowing water in any region changes with changes in climate, land use, or vegetation. Rivers and streams are extremely dynamic. They erode their channels in some places and deposit sediment in other places. Their channels sometimes flood, and they shift their locations over time.

The third general type of water body is lakes. Any kind of depression on Earth's surface that collects water can form a lake, including huge depressions excavated by glaciers (the Great Lakes), and river or stream valleys dammed by humans. Any process that can create depressions on Earth's land surface, or affect the amount of water and sediment entering or leaving them, can cause changes in the sizes of lakes. Very small lakes are called ponds; very large lakes are sometimes called seas.

Why is there more water in the southern hemisphere? Most of Earth's land is concentrated in the northern hemisphere, so a disproportionately large amount of the ocean water is in the southern hemisphere. This is simply the result of the current location of Earth's moving tectonic plates. About 240 million years ago, most of the continental land masses were concentrated in the southern hemisphere, and most of the water in the northern. As the tectonic plates shifted, they carried most land masses northward, reversing the hemispheric allocation of land and water.

Evaluation

***Log 1**

1. Pacific Ocean
2. Mediterranean Sea
3. Gulf of Mexico
4. Chesapeake Bay
5. Susquehanna River
6. Lake Victoria

Additional Resources

http://pds.jpl.nasa.gov/planets/gif/ear/earthspn.gif A nice "blue planet" photo from space

http://images.jsc.nasa.gov/images/pao/AS8/10074963.jpg One of the famous "earthrise" images from the Moon (in this case from Apollo 8), showing the lighted portion of Earth as blue and white from ocean and clouds

http://images.jsc.nasa.gov/images/pao/AS4/10074815.jpg A photograph from Apollo 4 showing Earth about half in darkness. The light portion is almost entirely blue water and white clouds

http://www.fourmilab.ch/cgi-bin/uncgi/Earth Images of Earth as though you were seeing it from the Moon, Sun, or an orbiting satellite, no portion of Earth in shadow or obscured by clouds

http://fermi.jhuapl.edu/states/states.html Climate, vegetation, the color landform atlas of the U.S. site

www.fs.fed.us/land/wfas Vegetation maps, greenness maps (produced from satellite images) at the forest service's wildfire assessment site

http://www.cgrer.uiowa.edu/servers/servers_references.html *Maps of the World*, glossary of map terms; Grolier Educational, Danbury, CT

Make It Work! Rivers: World Book, Chicago, 1996

Make It Work! Oceans: World Books, Chicago, 1997

Module 2, Investigation 3: Log 1

Images of water bodies

Your teacher will show you some NASA images of water bodies. Look at the water and the land surrounding it. Use an atlas or wall map to identify each water body.

Here are the directions:

1. Look at the water body and write down what type it may be. Be sure to match the number of the image with the number on your worksheet.
2. Write a definition for each water body after looking carefully at the image. Definitions are at the bottom of this paper.
3. Write an interesting observation that you made while looking at the image.

Image Shows a/an...	Definition of Water Body	Interesting Observation about the Image
1.		
2.		
3.		
4.		
5.		
6.		

bay: a body of water that is partly enclosed by land, smaller than a gulf

gulf: arm of the ocean that reaches into land

lake: a body of fresh water, surrounded by land

ocean: a vast body of salt water that separates or surrounds continents

sea: a smaller division of the ocean, partially enclosed by land (or sometimes a very large lake)

river: a long body of water that flows downhill in a natural channel

Module 2, Investigation 3: Log 2
Water bodies

You are scientists who will help NASA to identify water bodies that will be photographed from the Space Shuttle every year in order to monitor how they change. You will work in teams, and your teacher will assign each team a type of water body. Use an atlas to select five examples of your water body for NASA to study. Work together as a team to make your selections.

Your group's water body is a/an _____

Define your water body. _____

_____

Names of the Water Bodies We Selected	Location (Continent or Country)
1.	
2.	
3.	
4.	
5.	

What kinds of changes might show up in the NASA images of your water bodies if rainfall decreases over the next several years?

_____

_____

How would these water bodies be affected if rainfall increases?

_____

_____

Module 2, Investigation 3: Log 3

Looking at the world's water

Directions:
1. Look carefully at your part of the map.
2. Answer the questions below. Use an atlas to identify the water bodies.
3. Plan to report your findings to the class.

Latitudes of our section: from _____ to _____ degrees.

Hemisphere of our section: (north or south) _____

Names of important water bodies: _____

_____

_____

Circle the most accurate: 1. more water than land 2. more land than water 3. about the same

Amazing discoveries: _____

_____

Module 2, Investigation 3: Log 4

Comparing our state with _____

Your job is to compare water in your state with water in another state. Your teacher will assign you a state. Write its name and the name of your state at the top of the chart. Your mission is to look at the maps and images of water features in both states. Compare, as closely as possible, the availability of water in the two states. Good luck.

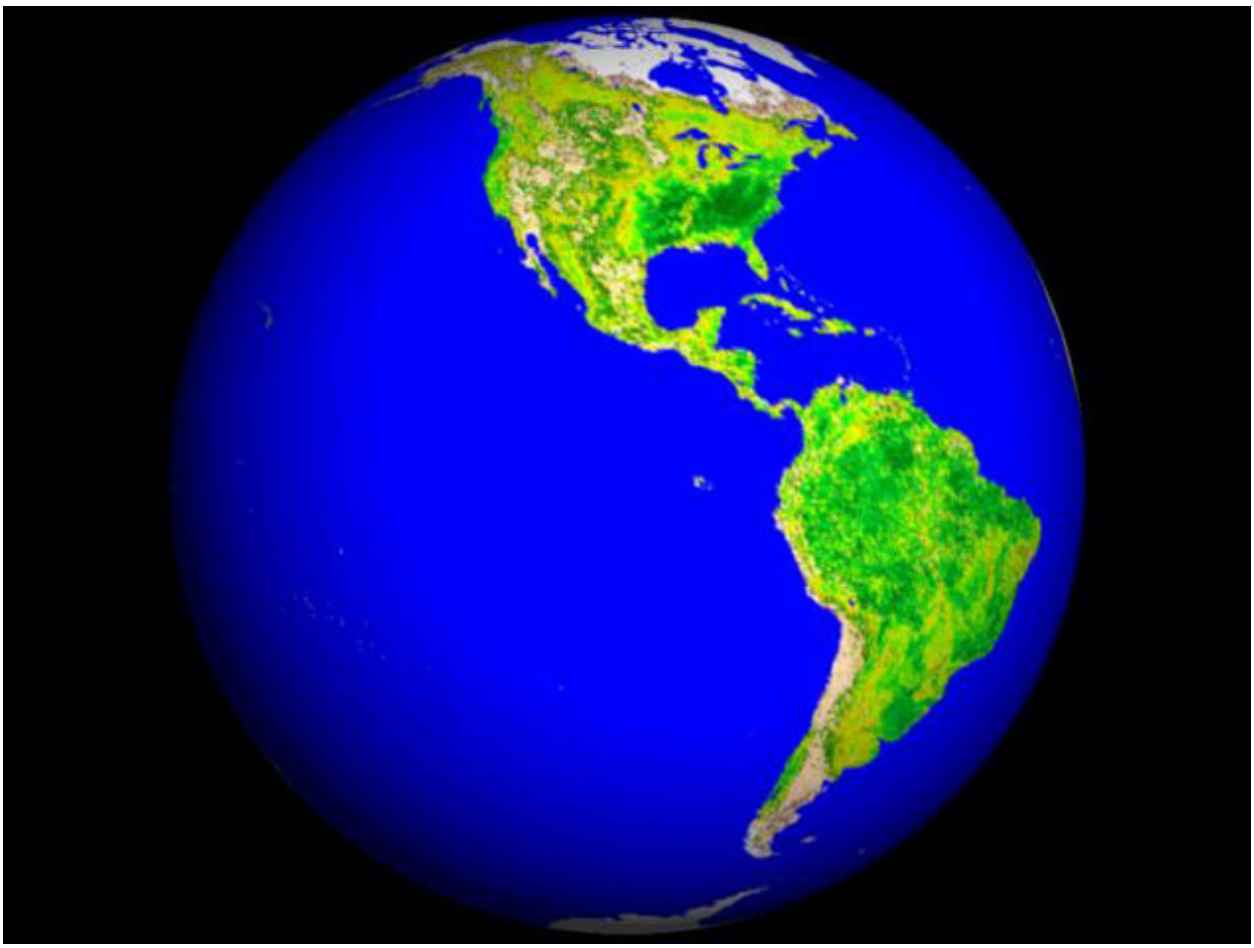
	Our State: _____	**Other State:** _____
Borders ocean?	Yes _____ No _____ If yes, which ocean?_____	Yes _____ No _____ If yes, which ocean?_____
Rivers	My state has more___ fewer___ . Name two rivers: 1. _____ 2. _____	This state has more ___ fewer___. Name two rivers: 1. _____ 2. _____
Lakes	My state has more___ fewer___ . Name two lakes: 1. _____ 2. _____	This state has more ___ fewer___. Name two lakes: 1. _____ 2. _____
Bays	My state has more___ fewer___ . Name two bays: 1. _____ 2. _____	This state has more ___ fewer___. Name two bays: 1. _____ 2. _____
Other waterways (canals, creeks)	My state has more___ fewer___ . Name two waterways: 1. _____ 2. _____	This state has more ___ fewer___. Name two waterways: 1. _____ 2. _____

Conclusions after comparing states: _____

_____

_____

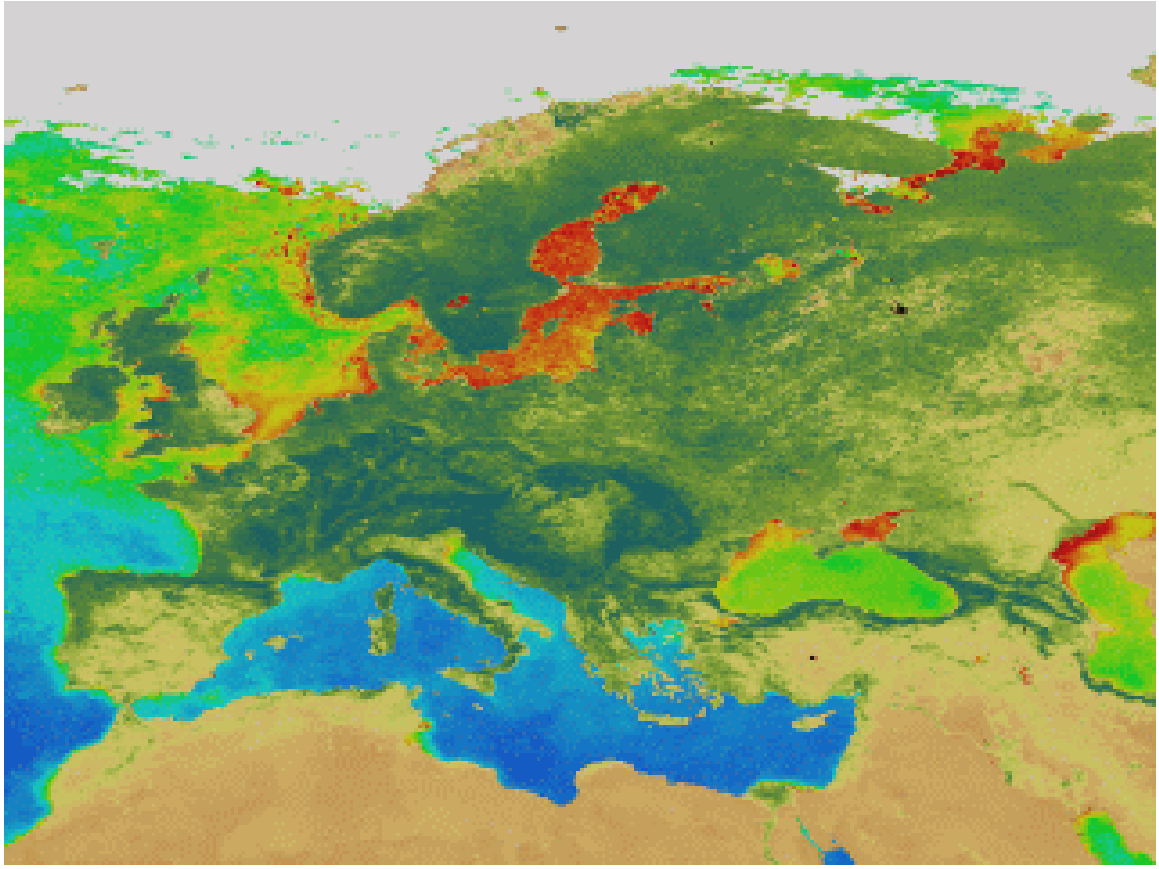
Module 2, Investigation 3: Figure 1



Source: http://www.nasm.si.edu/earthtoday/ndvilg.htm

Which ocean can you see on the western half of this view of Earth?

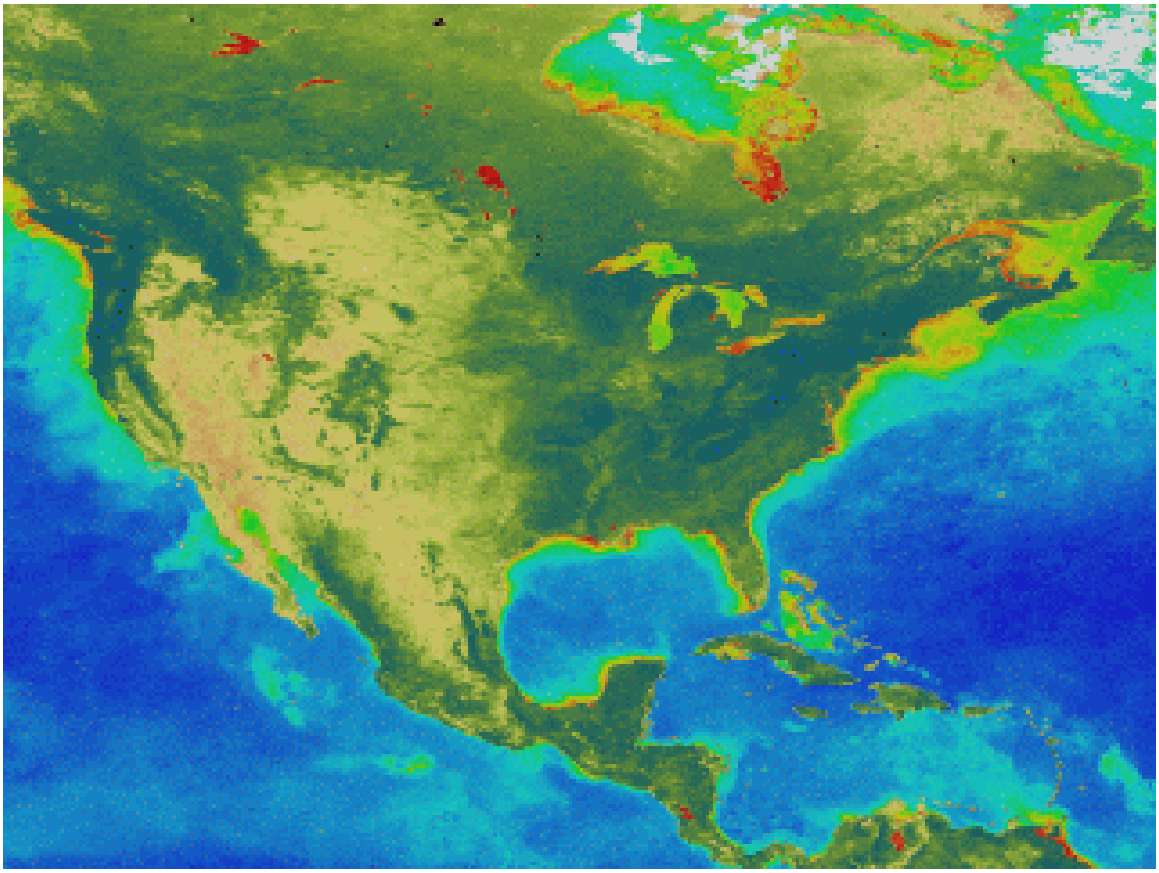
Module 2, Investigation 3: Figure 2



Source: http://svs.gsfc.nasa.gov/imagewall/SeaWiFS/europe.html

This is a sea between Europe and Africa. Can you name it?

Module 2, Investigation 3: Figure 3



Source: http://modis.gsfc.nasa.gov/MODIS/IMAGE_GALLERY/MODIS1000017_md.jpg

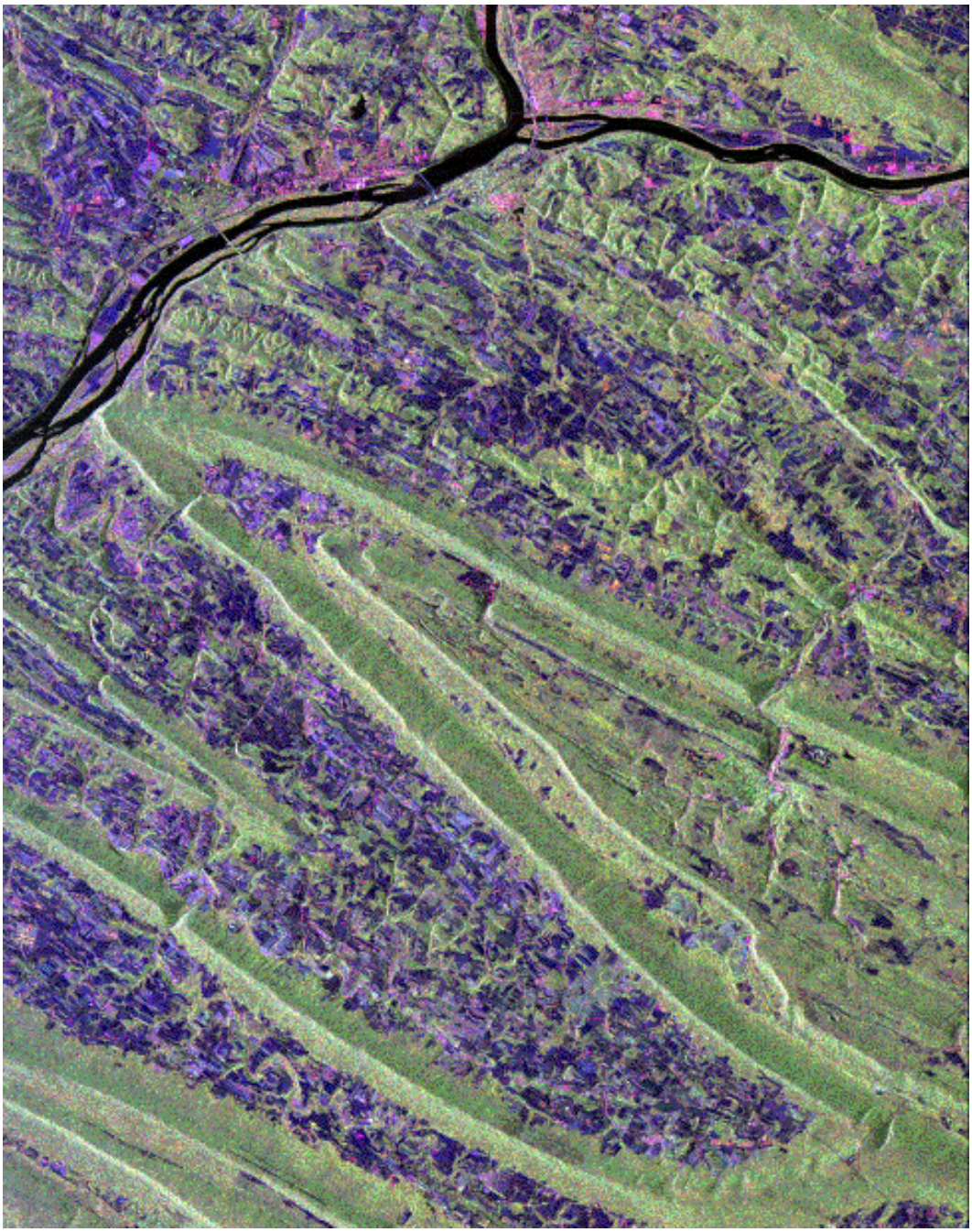
Can you identify the largest gulf in this image?

Module 2, Investigation 3: Figure 4

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

This is a bay on the east coast of the United States. It extends from Virginia into Maryland. Can you name it?

Module 2, Investigation 3: Figure 5



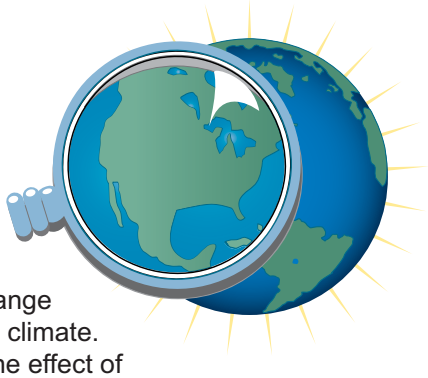
Source: http://www.nasm.si.edu/earthtoday/trclrlg.htm

This is a famous river that flows through the Appalachian Mountains in Pennsylvania and empties into the Chesapeake Bay. Can you find it on a map and name it?

Module 2, Investigation 3: Figure 6

Can you see the rectangular lake in eastern Africa? Find it in an atlas and name it.

How do water bodies change over time?



Investigation Overview

Students explore how water bodies change in response to changes in weather and climate. They do experiments to demonstrate the effect of rising sea level on coastlines. They also use NASA images to examine dramatic changes in water levels in a river system in the United States and a lake in Africa.

Time required: Three 45-minute sessions

Materials/Resources

NASA images (transparency of each and four copies each of Figures 5, 6, and 7)

- Figure 1: Mountainous coastline in California
- Figure 2: Flat coastline in the Eastern United States
- Figure 3: Greenland
- Figure 4: Map of Midwestern flooding
- Figure 5: The Mississippi River System in 1988
- Figure 6: The Mississippi River System during the 1993 floods
- Figure 7: Lake Chad, 1973 and 1997 (Note: hard copies must be in color)
- Figure 8: Grid (one transparency to project and one transparency for each group of students)

Two preferably clear, rectangular baking pans, any size,
Clay
Water
Sand or soil
Two blocks of ice frozen in a full sandwich-size Ziploc bag
For each group of 2 to 4 students:

- One sheet tracing paper
- A fine black marker
- A sharp pencil
- A sharp light blue crayon
- An atlas (with U.S. landform map)

Log 1: Our coasts
Log 2: Greenland
Log 3: Flooding in the Midwest—Background
Log 4: Flooding in the Midwest
Log 5: Lake Chad is shrinking
Two overhead projectors
NASA background information: DAAS, "Distributed Active Archive Centers" "Meltdown," "Ramping Up," "Eye on the Ocean," optional

Geography Standards

Standard 7: Physical Systems

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

- Explain how physical processes help to shape features and patterns on Earth's surface.

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 4: Analyze Geographic Information

- Use texts, photographs, and documents to observe and interpret geographic trends and relationships.
- Use simple mathematics to analyze geographic data.

Skill Set 5: Answer Geographic Questions

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

Content Preview

Like everything else on Earth, bodies of water change. NASA monitors such changes using remote sensing. Water bodies change because of global warming, erosion, drought, human modifications (e.g., diverting water and building dams that result in a depletion of water supplies), and natural events such as floods and hurricanes. As Earth's temperature warms and ocean levels rise, large population concentrations may be affected. Related climate change and seasonal differences in precipitation affect water bodies like Lake Chad in Africa.

Classroom Procedures for Day 1

Beginning the Investigation

1. Ask students to think about change that they can see. What changes and why? List their responses on the chalkboard. (*Changes in people, in the landscape during different seasons, in the position and phases of the Moon, etc.*)

2. Write the phrase "Earth Changes" on the chalkboard and refer back to the list made in #1. Find the changes that were described that affect Earth and discuss how we can find out about changes that occur at different scales: local, national, and global. (*Written information, aerial photographs, satellite images, etc.*) Tell students that part of NASA's mission is to monitor changes on Earth to help us understand changes in our environment.

3. Discuss with the class the ways in which water bodies may change over time and the reasons for such changes. Be sure that the following causes are addressed:

   - Warming trends during which ocean water expands and glaciers melt
   - Erosion caused by national forces and human/environmental modifications
   - Drought
   - Human modifications such as diverting water, building dams, depleting water supplies
   - Natural disasters, hurricanes, floods

   Tell students that this lesson will focus on changes in water and water bodies and on the impacts of such changes.

Developing the Investigation

4. Project **Figure 1** and explain that this NASA image shows the coast of southern California. Ask students which ocean borders this coast. (*Pacific.*) Can they tell if the coast is mountainous or flat? NASA has helped us see the mountain ranges by adding shading and color to the image.

5. Project **Figure 2** and explain that this is an image of the east coast of the United States. Ask students to identify the ocean in this image. (*Atlantic.*) If the class has completed **Investigation 2** in this module, they should be able to identify Chesapeake Bay.

   Ask the students if this coastline is flat or mountainous. How can they tell? The Coastal Plain is a lighter shade than the Piedmont region (the foothills between the Coastal Plain and the Appalachian Mountains). Have a student draw a line on the transparency marking the western edge of the Coastal Plain. Have the class identify beaches and barrier islands.

6. Speculate about how changes in sea level would affect these two coastlines, and lead students to realize that the mountainous coast would experience less flooding because of the higher elevations and steeper sloping coastline.

7. Do the following experiment to demonstrate how the change in water level can affect the coastline. This can be done as a class project or in smaller groups.

   A. Put a layer of clay at the bottom of a baking pan. Ask students to mold mountains from clay and to create a coastline of mountains. Arrange the mountains along half of the clay bottom. Tell the students that the clay bottom represents the land that is covered by the ocean.

   B. Have a student pour some water into the bottom of the baking pan. Talk about what will happen to the shoreline as sea level rises. Mark a line in the clay mountains to show sea level after this first application of water. Have two more students add water to the pan and make new lines in the clay to show the changing sea level. Ask students to give reasons why water level might rise. (*Ice caps may melt as Earth warms.*)

   C. Create a different landscape in the second baking pan. Have students cover the bottom of the baking pan with a gently sloping layer of clay. Add another gently sloping layer of clay in half of the pan. Ask students to talk about this landform. Have a student pour water in the lowest part of the pan. Mark a line in the clay

coast at the water level. Ask students to predict what will happen as sea levels rise. Pour more water into the "ocean" and watch the flooding when the sea begins to cover the landscape. Save the two landscapes for concluding activity for Day 1.

8. Distribute **Log 1** and have a student read the information on coastlines to the class. (This information can be read to younger students.) Ask the following questions.

   - What are coastlines? (*Where oceans or other large water bodies meet land.*)
   - What causes coastlines to change? (*Force of waves and currents, lava entering the sea from land, depositing of sediment, sea level rising and falling.*)
   - How much has the sea level risen in the past 100 years? (*30 centimeters.*)
   - What portion of the world's people live within 80 kilometers of a coast? (*More than half.*)
   - How will the rise of sea level affect coastal cities? (*Lowland cities will be flooded.*)

   Have students work in groups to answer the questions in **Log 1**. Each group will:
   1) locate a landform map of the United States in the atlas,
   2) identify two cities on mountainous coastlines and two cities on flat coastlines,
   3) assess the impact of a significant rise in sea level on the region in which each city is located. It is important to stress that they are looking at the region rather than the city itself. A city could be in a mountainous area but still be located entirely on a narrow and flat coastline.

   Then ask each group to report their findings to the class.

9. Share with students that NASA scientists are concerned about sea level rising and that Greenland is being studied to track changes in the melting ice sheet. Locate Greenland on a map, then project **Figure 3**. For grades K–2, discuss the information in **Log 1** while examining this photo, taken by an astronaut on the Space Shuttle.

   For grades 3 and 4, discuss the photo, pointing out the extent of the ice cover. Make sure students can tell the difference between the ice and the clouds. Distribute **Log 2** and have students work in pairs to read the background information and answer the questions. Share responses.

   With all grades, talk about what impact continued melting of Greenland's ice sheet could have on coastal areas.

Concluding the Investigation

10. Show the ice in Ziploc bags. Ask students to predict what would happen to the two coastline landscapes that they created if some of the ice melted into the ocean. Take the ice out of the bag and put it on the clay landscapes. Mark the water level on the coastline with a line. Have the landscapes sit overnight and measure changes in the sea level at the next class.

Classroom Procedures for Day 2

Beginning the Investigation

1. Look at the changes in the coastline clay activity and talk about why it is important to look at images of the same location over time. Project a transparency of **Figure 4**. Explain that the map has been drawn on a satellite image to give a realistic view of the land. Have students read the names of the rivers and the states. Leave the transparency on the screen for the rest of this activity. Explain that an unusual amount of rain made these rivers flood their banks in 1993, causing a great deal of damage to the surrounding land. Many farms and towns were flooded, and many people lost their homes.

Developing the Investigation

2. Project **Figure 5** and **Figure 6** using two projectors. Help students figure out 1) that these are satellite images taken before and after the flooding, and 2) that such images can help us calculate the extent of the flooding and predict the downstream movement of the floodwaters.

3. Divide the class into groups of four. Give each group a copy of **Log 3** and **Log 4** and a hard copy of **Figure 5** and **Figure 6**. Have students take turns reading the background information in **Log 3**, then have each group discuss the questions in **Log 4** and come to some agreement on the answers. Students can take turns recording the answers. Go over the questions with the class and ask the groups to share their responses. Question 4 should lead to some speculation about measuring the width of the flooded area with a ruler and comparing it with the width of the river channel.

4. Locate the region on a physical map of the United States. Note the relatively flat landscapes surrounding the rivers. Raise questions about what causes rivers to rise (*heavy rainfall*) and what types of landscapes would more easily be flooded (*flat land*).

5. Give each group tracing paper, a fine black marker, a sharp pencil, and a light blue crayon. Explain that they will work together to make a map that shows how much of the land along the rivers was flooded in the Midwest in 1993. Have each group follow these instructions:

   A. Tape the tracing paper over **Figure 5**.
   B. Take turns using the pencil and a ruler to draw a box around the area in the image, following the edges of the image.
   C. One student will make a circle with the black marker to show the location of St. Louis, and then draw a very fine line with the same marker along the Mississippi River south from St. Louis.
   D. Each of the other three students will use the marker to draw fine lines along the Mississippi River north of St. Louis, the Illinois River, and the Missouri River. Do not label the rivers yet.
   E. Now move the tracing paper to **Figure 6**, line up the box and the rivers on the tracing paper with the image, and tape the tracing paper in place.
   F. Each student will return to his/her part of the river system and use a sharp pencil to outline the flooded areas. This will produce a map that shows the original channels in black marker and the edges of the flooded areas, on either side of the rivers in most cases, in pencil. Students can complete the map by very lightly coloring the flooded areas with a blue crayon. They should be sure that the black line marking the original channel shows clearly. Then they can label their parts of the river system and the city of St. Louis.

Concluding the Investigation

6. Keep students in their groups and give each group a copy of **Figure 7**. Project the transparency of this figure. Explain that these are satellite images of an important lake in Africa that many people depend on for water. It is on the border of the Sahara Desert in a region that is very dry.

7. Have students find Africa, the Sahara Desert, and Lake Chad on appropriate maps. Ask them to identify the countries that border the lake. Explain that the water in Lake Chad comes mainly from a river named the Chari, which flows from places to the south that receive more rainfall than the region around the lake. Point out the Central African Republic on the map as the source of the Chari River. In the Central African Republic, most of the rain falls in the summer and little falls in the rest of the year. If the summer is wet in the Central African Republic, Lake Chad fills up with more water in the fall. Why in the fall? Have the students figure out that it takes that much time for the rainwater to drain into the river and for the river to carry it north to Lake Chad.

   What happens when summers are drier than usual in the Central African Republic? Lead the students to conclude that there is less water in the Chari River and that less water comes into Lake Chad in the fall. This has been the case for the past three decades because in this part of the world the climate has become drier. In addition, water has been diverted from the river for irrigation, further reducing the flow into the lake.

   Water evaporates from the lake all year because of the hot, dry climate, and if the water is not replenished during the fall to compensate for the evaporation, the lake becomes smaller and smaller. As the water becomes shallower along the shores, plants appear on the emerging lake bottom, creating large marshes, or wetlands, that gradually become dry land as the lake becomes smaller.

8. Have the class examine the images of Lake Chad in the transparency. Point out that the blue areas are water and that the speckled areas are wetlands. Plants that are very lush and green are shown here as red to make it easier to see where the vegetation is. In this dry environment, the only plants that can grow well are in the wetlands around the lake. Why is this? (*They have plenty of water. Farther from the lake, the wetlands are drying out as the lake shrinks.*)

9. Discuss the change between 1973 and 1997 in the amount of water in the lake and in the amount of wetlands. Lead the class to conclude that much of the area that was under water in 1973 is now wetland. As the wetlands gradually turn into dry land, local farmers use it to grow crops. Younger students should conclude the investigation at this point, while fourth graders may continue.

10. Divide the class into groups and give each group a copy of **Figure 7** and a transparency of **Figure 8**. Remind the class that satellite images made at different times can be used to measure changes in the environment. Explain that they themselves can figure out how much smaller Lake Chad was in 1997 than in 1973, and how much the wetlands expanded during that time. Make sure that they understand the following procedure.

Each image contains a square that is 20 kilometers on each side, or 400 square kilometers. Help students understand this concept. You can measure the size of the lake by seeing how many of these 400 square kilometer squares you can place on it. The easiest way to do this is to place a grid of squares over the images. Demonstrate this to the students by placing the transparency of **Figure 8** (Grid) over that of **Figure 7** (Lake Chad), so that the grid covers the image of the lake in 1973. Point out that they can count the number of squares that are on water. Then move the grid to the 1997 image and show the class that far fewer squares are on water.

If the area under the square is more water than wetland, they will count it as water, and if it is more wetland than water, they will count it as wetland.

11. Distribute **Log 5**, and help each group to follow the directions to calculate the change in the size of the lake and the wetlands. The interpretations will vary, given the necessarily gross estimates and the students' lack of experience interpreting images, but the final conclusion should be that there was a drastic reduction in the surface area of the lake. This is a useful measuring procedure that can be refined as students are able to handle more complex interpretations.

Background

Glaciated terrain

Glaciers are large masses of ice that are usually 200 meters or more thick. Because they move so slowly, you cannot see them move, but these big heavy masses flow and shape the landscape. There are two types of glaciers, valley glaciers and continental glaciers. Valley glaciers form high in mountains, filling in narrow mountain valleys and widening them as the ice moves slowly downhill. If a valley glacier reaches the sea, parts may break off and form icebergs.

A continental glacier is a thick dome of ice that covers a large area, the size of part of a continent. Continental glaciers are also called ice caps or ice sheets. The weight of the ice causes it to flow very slowly from where it is deepest toward the margins of the ice sheet. When continental glaciers melt, they leave behind altered landscapes. The moving ice takes with it soil, rocks, boulders, and anything else that it can pry loose and move across the landscape. All this loose material is deposited as the ice stops moving and begins to melt near the margins of the ice sheet. In mountainous areas, continental glaciers erode the mountain slopes in much the same way valley glaciers do.

Evaluation/Key

Log 2: Greenland

1. 1/5
2. By comparing older and newer satellite images.
3. It causes the sea level to rise.

Log 5: Lake Chad is shrinking

Note that there are no "correct" answers. They will vary depending on how the squares are initially positioned and how the vegetation is interpreted.

Additional Resources

http://southport.jpl.nasa.gov/pio/srl/sirc/srl-patagonia.gif Patagonia

http://sdcd.gsfc.nasa.gov/GLACIER.BAY/glacierbay.story.html Glacial changes, work done by NASA geographer, Dorothy Hall

http://www.nasm.edu/ceps/RPIF/LANDSAT/LIMG/24_37.gif Landsat image north of Vicksburg, Mississippi, showing Mississippi River floodplain

http://observe.ivv.nasa.gov/ *Educator's guide to Earth—The ever-changing planet*, images of Earth to identify and illustrate ways that Earth changes

http://www.nasm.si.edu/earthtoday/quakelg.htm Western Hemisphere quake zone

Make It Work! Rivers: World Book, Chicago, 1996

Make It Work! Oceans: World Books, Chicago, 1997

CD-ROM, *Visit to the Ocean Planet,* NASA educational product

Module 2, Investigation 4: Log 1

Our coasts

The coast is where the ocean meets land. Coastlines are always changing their shape. They are being worn away in some places and built up in others. Coasts can wear away due to the force of waves and currents. Coasts can build up when sediment (sand, gravel, etc.) is carried from one spot to another. They can also be built up when lava enters the sea from land.

Coastlines also change as the sea level rises and falls. Average sea level has risen about 30 centimeters in the last 100 years. Earth's atmosphere has warmed up slightly, causing some of the ice in the polar regions to melt. Meltwater has returned to the oceans, and sea level has risen. Another reason for the rising sea level is that the oceans are also warmer, and as the water becomes warmer it expands.

More than half of the people in the world live within 80 kilometers of a coast. Many large cities are near the coast. London, New York, and New Orleans are examples. What will happen to these coastal cities if sea levels continue to rise?

1. Look in your atlas and find two large U.S. cities that are on flat coastlines and two that are on mountainous coastlines.

2. Name the cities and the oceans that they border.

   Flat Coastlines:
   City 1: _____ Ocean_____

   City 2: _____ Ocean _____

   Mountainous Coastlines:
   City 3: _____ Ocean_____

   City 4: _____ Ocean _____

3. Think about how the *region* around each city would be affected by a rise in sea level of several feet. Which two *regions* would have the most widespread flooding?

   The regions around _____ and _____.
   Write a sentence to explain your answer.

   _____

Module 2, Investigation 4: Log 2

Greenland

In much of the world, sea level is slowly rising. One important reason for this seems to be that some of the world's ice is melting and adding water to the oceans.

Most of our planet's ice is found in thick sheets that cover the land in places where the climate is cold. The largest ice sheets are in Antarctica and Greenland. If these ice sheets melt, they will add so much water to the oceans that most of the world's coastlines will be flooded.

About 4/5 of Greenland is covered by ice that is up to 3,000 meters thick. Some of the ice always melts in the summer. But summers are short there, and winters are long. During the winter, the falling snow packs down to form new ice. If the amount of ice that melts in the summer is the same as the amount of ice that forms in the winter, the ice sheet stays about the same size. If the amount of ice that melts is greater than the amount that forms each year, the ice sheet shrinks.

NASA scientists discovered that some of the ice along Greenland's coastline disappeared during the last few years. How did they find this out? They compared satellite images from 1993 with images from 1999. By measuring the changes in the ice sheet, they could tell how much of the ice had melted.

Does this mean that the ice will continue to melt? We cannot be sure yet. But the scientists will continue to compare new satellite images with older ones. Over time, they will see if the ice sheet keeps melting. If it does, the images will help them figure out how fast it has been melting. Then they can use that information to predict how fast the ice will melt in the future.

Use the information about Greenland's ice sheet to answer these questions.

1. If 4/5 of Greenland is covered by ice, how much is not covered by ice?

   _____

2. How can scientists tell if the ice sheet is melting?

   _____

3. Why is it important to know if Greenland's ice sheet is melting?

   _____

   _____

Module 2, Investigation 4: Log 3

Flooding in the Midwest—Background

Directions: Read this information to learn more about river flooding. Answer the questions on Log 4. You will share this information with the class.

Satellite images were used to help people during serious flooding in 1993. In the Midwest, heavy rains caused the waters of the Mississippi, Missouri, Illinois, and several smaller rivers to overflow their banks. Communities and farms along the rivers were in danger of being flooded.

Officials in the city of St. Louis, Missouri, needed a plan to evacuate people and property as the waters of the Mississippi River rose toward the top of the river bank. Mr. Lee Blackmore, who worked for the city, used satellite images and maps to help plan the evacuation.

"The water is rising fast," said the frantic voice on the telephone. "Can you help with the evacuation? We're losing our race against the river." Mr. Blackmore went to work. He knew the city was running out of time and that homes and businesses along the river would soon be flooded.

The St. Louis police department had been ordered to start evacuating neighborhoods that might be in danger. But these areas had seldom flooded, so many residents remained in their homes, believing they were safe.

Mr. Blackmore helped make a map from satellite images of the flooding. It clearly showed the police where the flood waters were rising fast. The successful evacuation began within four hours after Mr. Blackmore received the call for help.

Many people were affected by the flood waters, but no lives were lost.

Figure 5 shows the St. Louis area during the dry summer of 1988. The river, in black, is narrow and runs in its normal channel. Vegetation is in green; dry soil and urban areas are shown as red and brown. Figure 6 shows the river system in full flood in July 1993.

Can you see just where the river went over the banks?

http://observe.ivv.nasa.gov/nasa/exhibits/flood/flood_2.html

Module 2, Investigation 4: Log 4

Flooding in the Midwest

Directions: Look at your two images very carefully. How are they different? Read the information about the images and answer the following questions.

1. Titles of the images

   Figure 5 _____

   Figure 6 _____

2. In which year was each image made? Figure 5 _____ Figure 6 _____

3. What changes can you see in Figure 6? _____

   _____

   _____

4. How could you measure these changes? _____

   _____

5. What could happen to people, animals, and the rest of the environment because of these changes? _____

   _____

   _____

6. Why do you think the changes occurred? _____

   _____

   _____

7. Look at a map to find the location of your images. Which states are shown in the images?

   _____

   _____

8. Which two rivers join in the Mississippi River just north of St. Louis?

   _____ _____

Module 2, Investigation 4: Log 5

Lake Chad is shrinking

Directions: Your group will use satellite images of Lake Chad to figure out how the lake changed in size between 1973 and 1997.

Place the grid (Figure 8) over the 1973 satellite image of Lake Chad (Figure 7). Take turns counting the number of squares that are on water in each numbered row. If the square falls partly on water and partly on wetland or dry land, use the following rule: If more than half of the square is on water, count it as water. If less than half the square is on water, do not count it as water. Remember that wetland is not water!

Take turns placing this information on the tally sheet below. Then do the same for the 1997 image.

Tally Sheet (Row)	**1973 Image**	**1997 Image**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

1. How many water squares did you count in 1973? _____ In 1997? _____

2. Each square represents 400 square kilometers. How many square kilometers

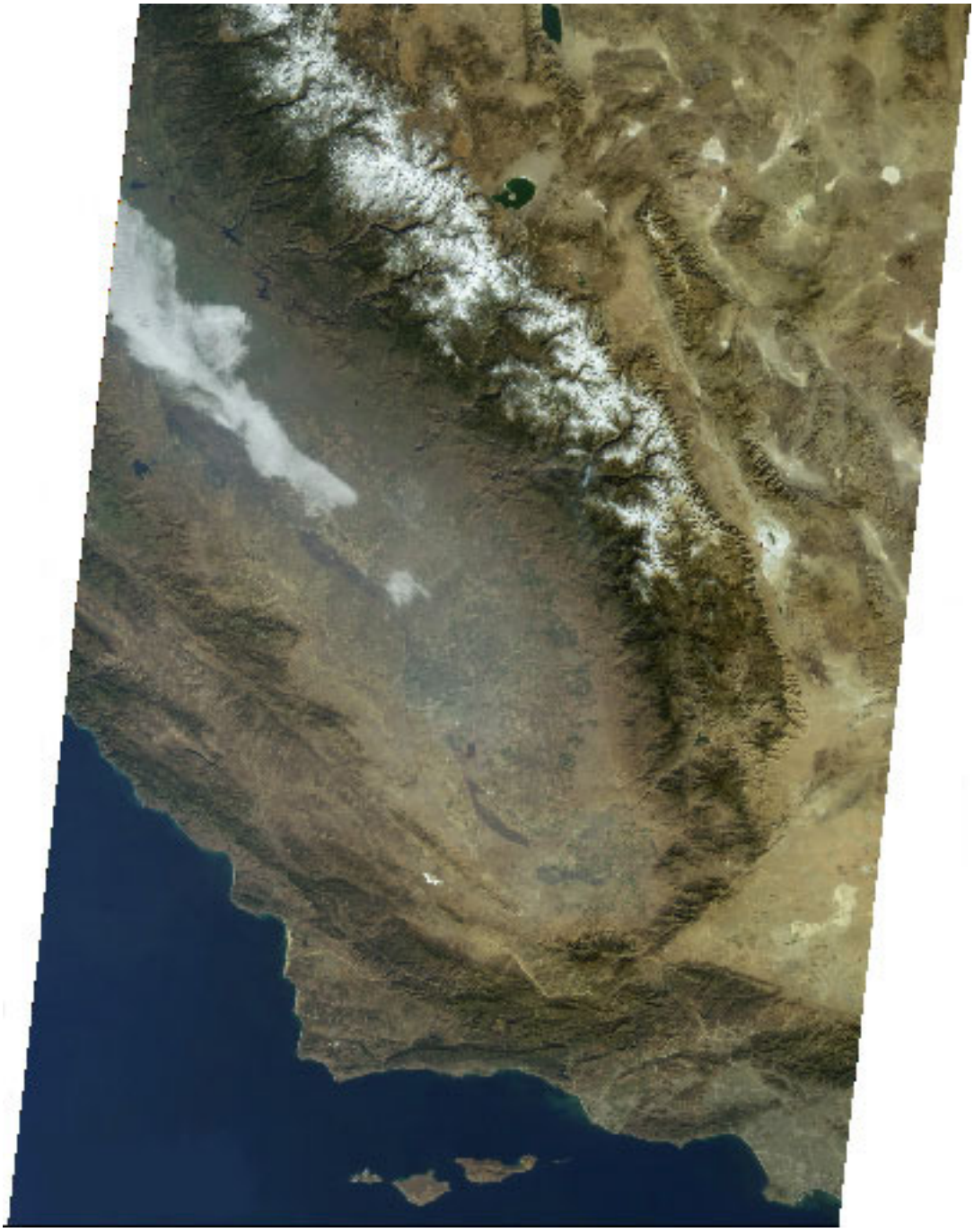
   was Lake Chad in 1973?_____ In 1997? _____

3. How much smaller was Lake Chad in 1997 than in 1973?

   _____square kilometers

Module 2, Investigation 4: Figure 1

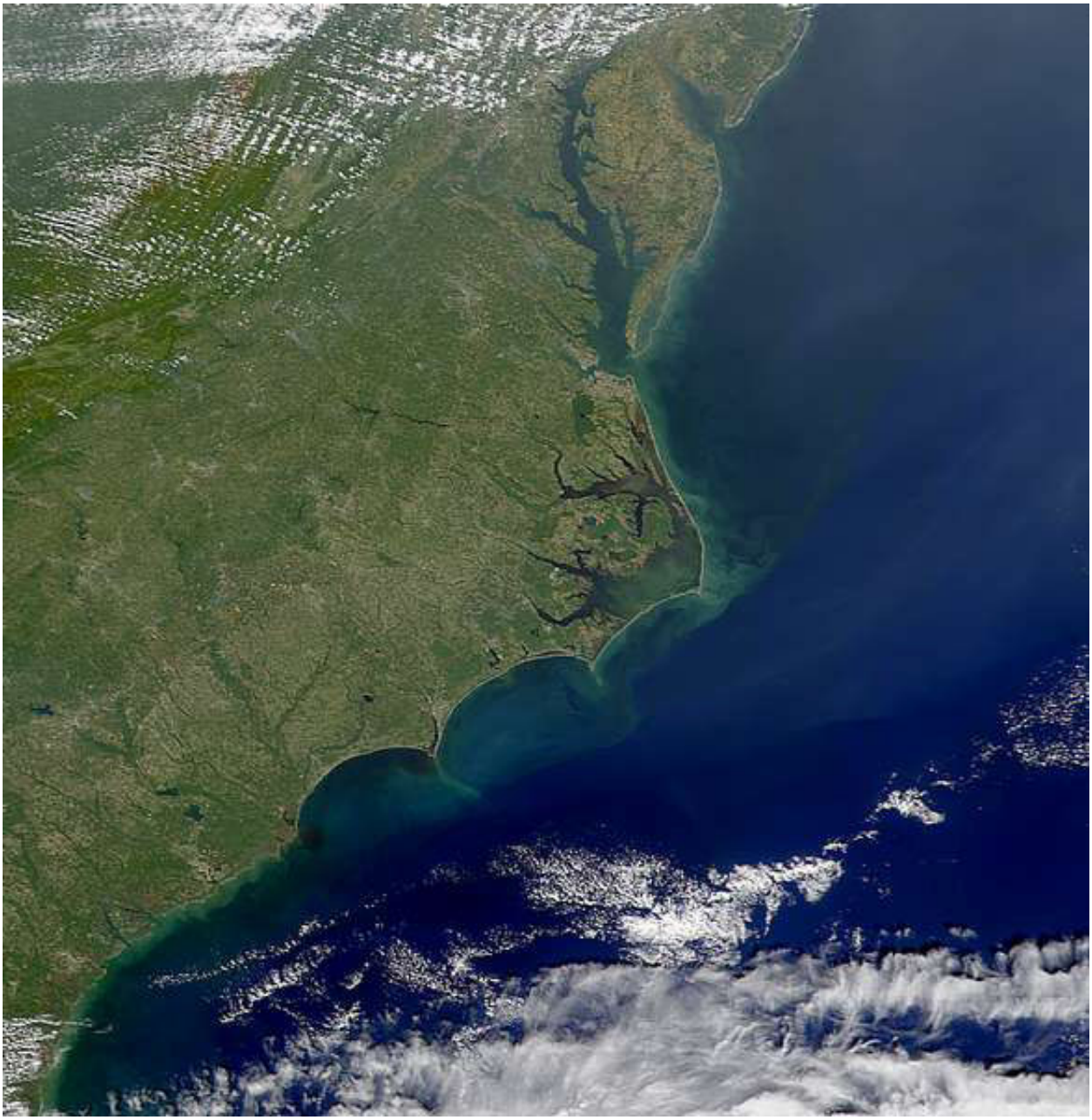
Mountainous coastline in California



Source: http://visibleearth.nasa.gov/cgi-bin/viewrecord?7546

Module 2, Investigation 4: Figure 2

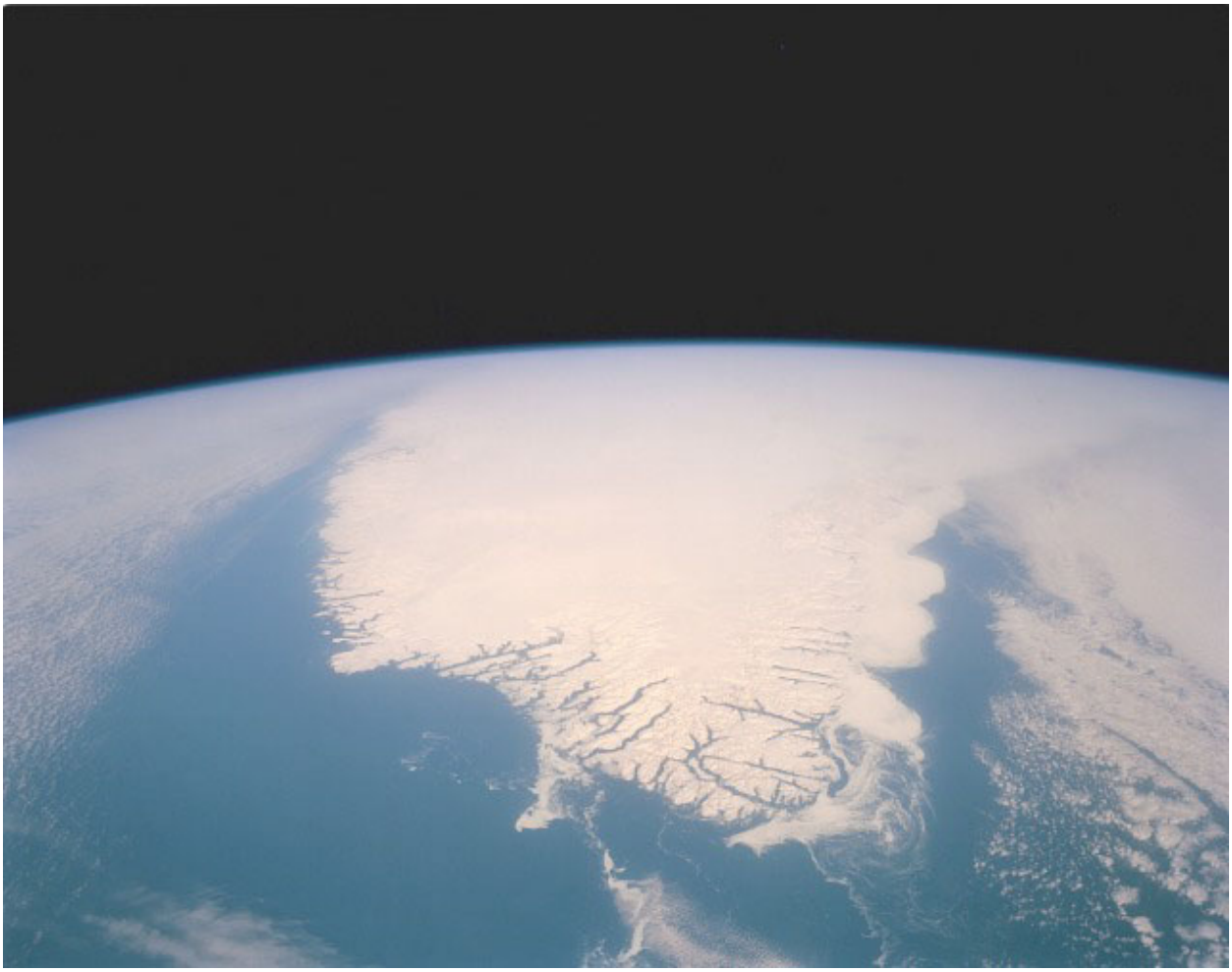
Flat coastline in the Eastern United States



Source: http://visibleearth.nasa.gov/data/ev51/ev5144_S2000277172549_md.jpg

Module 2, Investigation 4: Figure 3

Greenland



Source: earth.jsc.nasa.gov/photoinfo.cgi?PHOTO+STS045-152-105

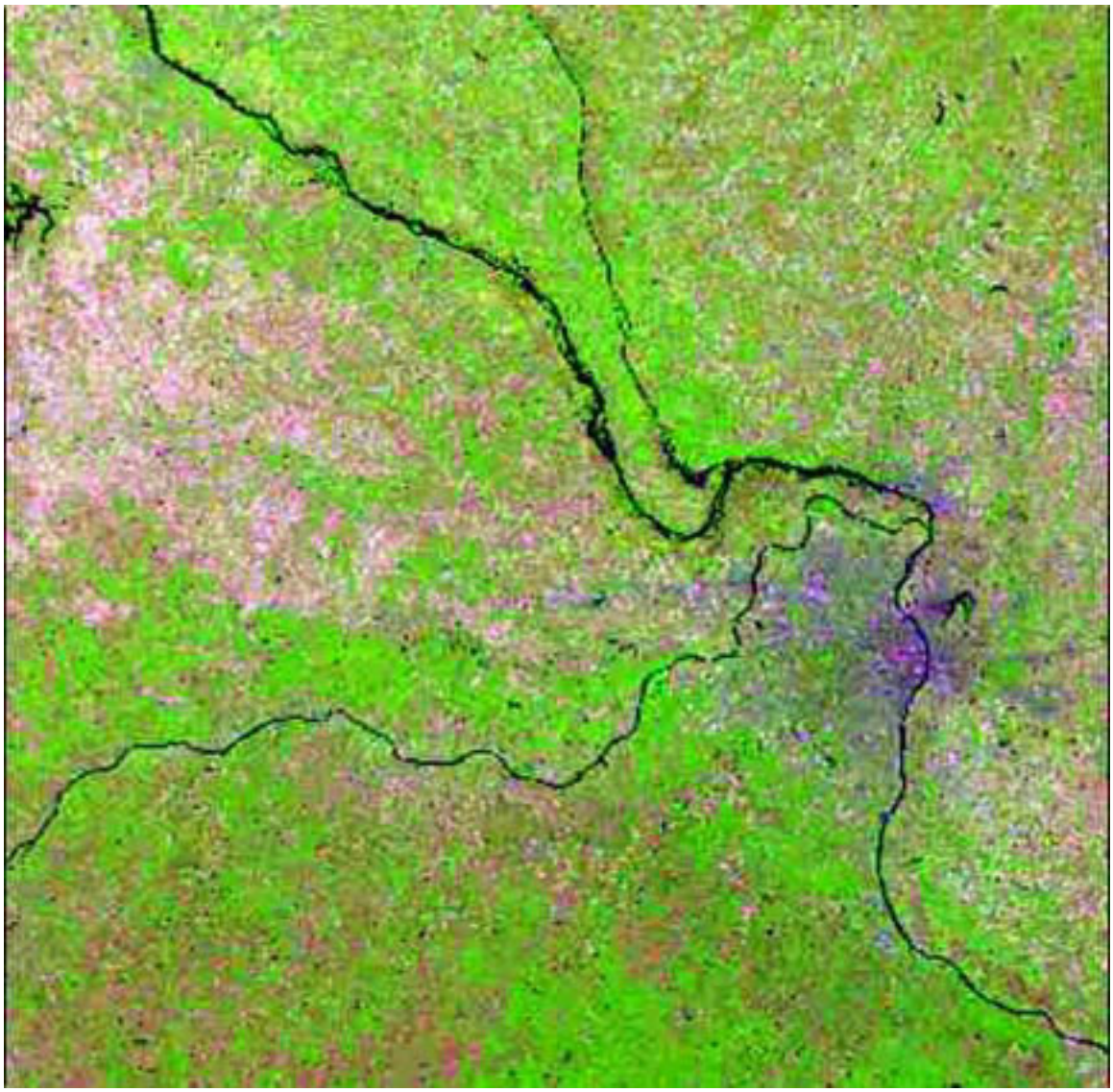
Module 2, Investigation 4: Figure 4

Map of Midwestern flooding

Source: http://observe.ivv.nasa.gov/nasa/exhibits/flood/flood_2.html

Module 2, Investigation 4: Figure 5

The Mississippi River System in 1988



Source: http://observe.ivv.nasa.gov/nasa/gallery/world/graphics/flood1.jpg

Module 2, Investigation 4: Figure 6

The Mississippi River System during the 1993 floods

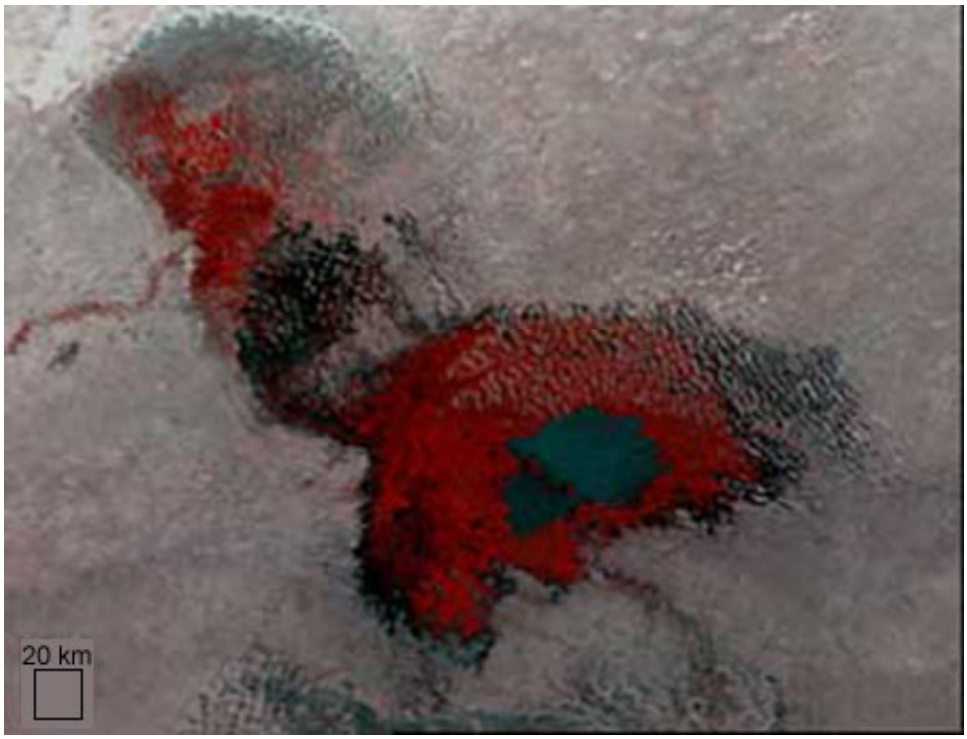
Source: http://observe.ivv.nasa.gov/nasa/gallery/world/graphics/flood2.jpg

Module 2, Investigation 4: Figure 7

Lake Chad, 1973 and 1997

Image 1: January 1973

Image 2: January 1997



Source: http://www.gsfc.nasa.gov/gsfc/earth/environ/lakechad/chad.htm

Module 2, Investigation 4: Figure 8

Grid