Activity: A Satellite Puzzle

Introduction

Satellites provide unique views of Earth. The imagery acquired by these space platforms reveal weather systems and broad-scale circulation patterns that can be seen in their entirety. Sensors aboard satellites scan the Earth line by line in narrow strips and measure signal strengths generated by reflected sunlight or infrared (heat) radiation for small blocks within each strip. Each block segment, called a pixel, is the smallest picture element in the image. A series of numbers indicating pixel signal strengths is transmitted to receiving stations on Earth where computers reassemble the values into lines of shaded or colored blocks. The lines are added together in sequence to complete the picture. The weather satellite views seen on television weathercasts are examples of such images.

After completing this activity, you should be able to:

- Describe how information is acquired by satellites, sent to Earth, and interpreted to construct images.

- Explain how pixel size influences the detail (resolution) on weather satellite images.

Method

This activity explores the process by which satellite imagery is produced. Imagine that two different sensors scan the same scene and that both sensors measure <u>reflected sunlight</u>. Scanning of the scene produced the two sets of data presented in the accompanying figure. Grids to the right of each data set show the size of the pixels resolved by the two satellite sensors. One sensor is able to resolve pixels whose side-length is one-half that of pixels detectable by the other sensor.

A scale from 0 to 3 is used to indicate the signal strength of the light received by the satellite sensors. The value of 0 indicates no detection of light while 3 indicates the receipt of the most intense light.

Reconstruct the scene based on the sensed pixel values appearing to the left of each grid. The values are in the same relative positions as the pixels they represent. A value of “0” indicates no light being detected, while a “3” indicates the most intense receipt of reflected sunlight from Earth below.

SHADING KEY

0 1 2 3

By referring to the Shading Key, shade in the left grid according to the data given. Then use the same procedure to fill in the right grid with the smaller pixels.

DATA		1	2	3
2 0 2	A			
0 2 2	B			
0 1 0	C			
2 0 2	D			

DATA		1	2	3	4	5	6
3 2 1 0 1 2	A						
2 0 0 0 0 1	B						
1 0 2 2 2 2	C						
0 0 3 3 3 3	D						
0 0 3 0 0 0	E						
1 0 2 2 0 1	F						
2 0 0 0 0 1	G						
3 2 1 0 1 2	H						

Questions

1. What do you guess the original was? (Hint: the scene scanned in this activity was a particular letter or number.) In which of the two views is there greater detail? Why?

   ____

   ____

2. Assume that the two weather satellite sensors used in this activity produce pixels that represent Earth-surface areas 2 kilometers and 1 kilometer on a side, respectively. Assuming that the U.S. mainland is approximately 5,000 km from west to east and 3,000 km north to south, how many pixels would need to be scanned to obtain an image of the U.S. mainland by the:

   2-km pixels? ____________ pixels W-E, ____________ pixels N-S

   1-km pixels? ____________ pixels W-E, ____________ pixels N-S

3. What are some of the possible problems of producing weather satellite pictures with far greater detail than currently available? Consider such aspects as engineering, design, cost, politics, time, and other considerations.

   ____

   ____

   ____

Real World Applications

Figure 3 on the following page shows three satellite images sensed at the same time, 1815Z or UTC (2:15 pm EDT) on 26 August 2011. At that time generally fair weather was experienced by most of the coterminous U.S. A cold front was advancing southeastward from Canada into the north-central U.S. The major feature seen in the images was Hurricane Irene located off the Georgia and South Carolina coast heading northward. Irene made landfall the following morning on North Carolina's Outer Banks as a Category 1 hurricane on the Saffir-Simpson scale.

The top visible image in Figure 3 shows the small fair-weather cumulus clouds in a broad band from New York State to the Texas Gulf Coast and northern Mexico. Small cumulus clouds are also seen over the Rocky Mountains in the western states. The broad curving band of cumulus and higher cirrus clouds forming an arc from north of Lake Superior to southern Nebraska marked the region ahead of the advancing cold front. A deck of stratus clouds hugs the West Coast from Oregon to Baja California of Mexico. A couple of thunderstorms can be seen as bright white dots with wispy cirrus blowing off their tops in the Gulf of Mexico west of Florida.

The left infrared image display the coldest cloud surfaces as bright white shadings. These cold cloud tops are typically associated with thunderstorms as make up Hurricane Irene, the Gulf dots and the band of the cold front over Lake Superior and in Iowa. Lower clouds are located where the atmosphere is warmer and appear darker gray in shading. They can be seen over the southwestern mountains, in northern Mexico, and off the southern California coast. The lowest and warmest clouds are dark gray and close to the shade of the land surfaces whose temperatures they are near. The cumulus band from New York to Texas and the stratus deck along the West Coast.

The right water vapor image shows the concentrations of water vapor in the middle troposphere, typically between 13,000 and 30,000 feet (4000 to 9000 meters). Bright white shades are high cloud tops as seen with Hurricane Irene and along the cold frontal band. Middle gray shades are relatively large water vapor concentrations in the middle atmosphere, but perhaps without clouds present. Dark gray or black shades are relatively dry layers. One can see the high water vapor concentrations across the Gulf of Mexico and northern Mexico. There is also a plume or "river" of vapor arcing over the southwest U.S. and above the cold frontal location of ground level. From central Texas to the Northeast, relatively dry air exists. Shading waves over the Northwest show how water vapor images display atmospheric motions that are evident in animations.

1. In visible satellite images, all clouds **[(*__are__*)(*__are not__*)]** seen as generally equally white.

2. Small fair-weather cumulus clouds appearing in visible satellite images **[(*are*)(*are not*)]** readily visible in infrared or water vapor images.

3. Low clouds along the West Coast seen in visible images **[(*are*)(*are not*)]** readily seen in infrared images.

4. Visible and infrared images **[(*do*)(*do not*)]** detect the broad flows of water vapor in the atmosphere over the western and north-central U.S.

5. Being sensitive to the high, thin, cold cloud tops (infrared image) and the upper atmospheric water vapor (water vapor image) of Hurricane Irene, the extent of the hurricane structure is **[(*more*)(*less*)]** expansive than seen by the visible image.

6. The visible image shows that there was no significant cloud cover over the northwestern portion of Mexico. The darkness of shadings in the infrared image of the Baja California peninsula of Mexico and the Gulf of California to its east shows that, at the time of the satellite views, the land surface of Baja was **[(*cooler*)(*warmer*)]** than the water surface of the Gulf.

Types of Satellite Images

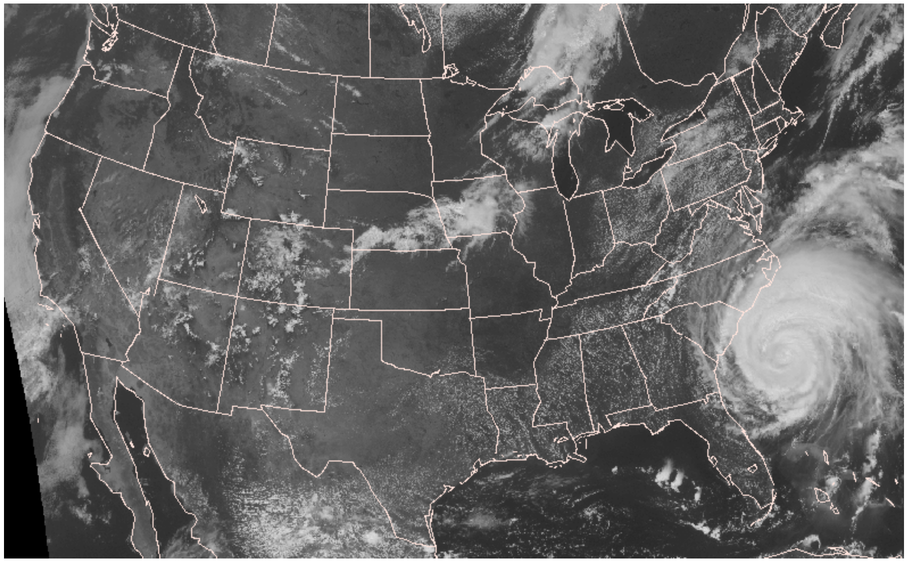
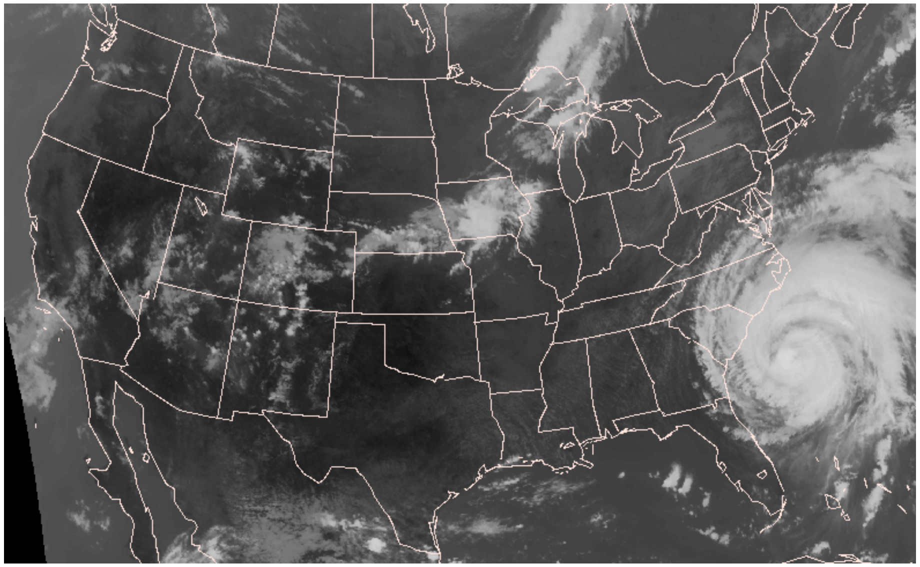
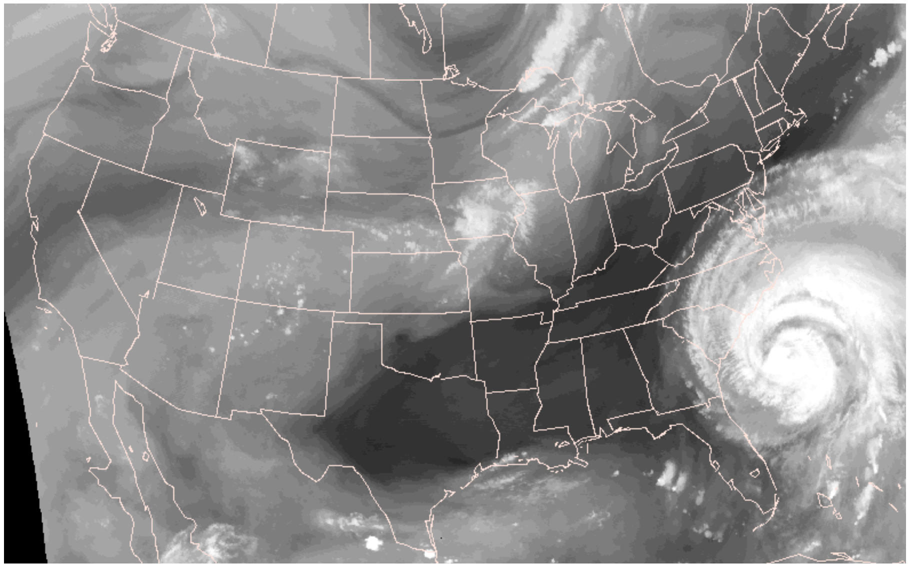


Figure 3. Visible satellite image at 1815 UTC, 26 AUG 2011.



Infrared satellite image at 1815 UTC 26 AUG 2011.



Water vapor satellite image at 1815 UTC 26 AUG 2011.