ACTIVITIES

The following classroom activities are organized by grade level.

ACTIVITIES

USING THE ACTIVITIES

The activities presented here were developed by pre-college science teachers for use in their own classrooms. The contributing teachers are all participants in a NASA-sponsored project to enhance science education through expanded knowledge of Earth system science and the use of satellite technology and remote-sensing techniques. The NASA series, *Looking At Earth From Space*, was published to provide a comprehensive resource for educators who want to utilize data from environmental satellites in their classroom. Refer to the other publications in this series for additional information.

These innovative activities reflect creative approaches to specific classroom needs, yet they have virtually universal application. The activities enable multi-disciplinary learning, engage higher-level thinking skills, and present real-life applications. The activities suggest appropriate grade levels; minor adjustments for ability and time constraints will broaden their use.

We advocate the excitement that is generated by using ground stations in the classroom. However, the lessons can be used with the satellite imagery contained in this publication, and/or supplemented with imagery from the Internet. Many of the images that accompany the activities have *answer* pages, that is, images with additional information to assist you with analysis. These images are all labeled with an *a*, such as image 1 and 1a. Some of the lessons have visible and infrared image pairs (indicated by *v* and *i*). See pages 94, 95, and 192 for more information about these two types of images.

Satellite imagery may be both a new resource and new frontier for you. The following notes should help.

- The activities were developed by teachers from Maryland and Washington, D.C. and emphasize local weather conditions, topography, and in the one case, the home team. You are encouraged to make these lessons equally relevant for your students by substituting local scenery and focusing on weather (good and bad) common to your area.

- You are encouraged to duplicate and use the worksheets and other materials in the lessons. Some of the illustrations will make effective transparencies.

- Satellite imagery doesn't always duplicate well. When multiples of the images are needed, copies made on a high-resolution copy machine (type commercial copying companies use) may prove adequate. Photographing the images in the book to obtain slides may be more effective than copying. Classrooms with ground stations and/or Internet access can print appropriate images in needed quantities.

- Tap local and electronic resources for support. Local Weather Service Field Offices, weather forecasters, and newspaper and television predictions can assist with and confirm your interpretations of the imagery. The Internet allows access to both satellite imagery and experts who can help with image analysis.

- The weather symbols and cloud abbreviations used in the activities are listed in the glossary at the back of this publication.

- A complete citation of the references listed with individual activities can be found in the bibliography.

Imagery from Environmental Satellites

Environmental (also known as meteorological or weather) satellites are unmanned spaceships that carry a variety of sensors to observe Earth. Two types of meteorological satellite systems are used to ensure comprehensive coverage. The two types of satellites are named for their orbit paths—geostationary and polar-orbiting.

Both types of satellites carry remote-sensing equipment to obtain visible and infrared images of Earth. The images can be captured and displayed with a direct readout ground station (direct readout is the ability to obtain information directly from satellites). Satellite images can also be obtained via the Internet.

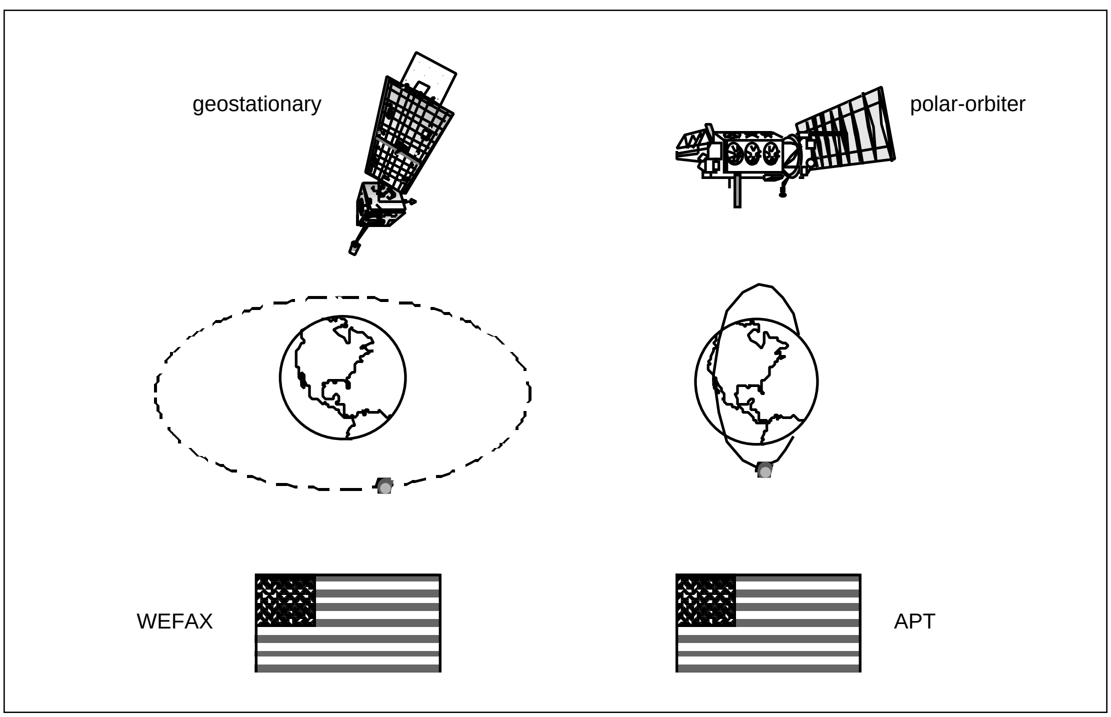
It is important to note that satellite imagery should be used in conjunction with other data. Satellite imagery was not intended to serve as either an isloated or comprehensive resource.

The U.S. launched the world's first environmental satellite, and continues to operate both geostationary and polar-orbiter systems. Direct readout from U.S. geostationary satellites is called Weather Facsimile (WEFAX). Direct readout from U.S. polar-orbiting satellites is called Automatic Picture Transmission (APT). Both WEFAX and APT* are essentially *brand names*, referring specifically to U.S. satellite data. Direct readout from other nations' satellites is correctly referred to as either geostationary or polar-orbiting satellite data.

The following activities specify whether geostationary or polar-orbiter data (images) will be used, and whether visible or infrared images are needed.

* The terms WEFAX and APT refer to low-resolution satellite imagery. High resolution (more detailed) data is available, but requires more expensive equipment than is usually found in the pre-college classroom.

figure 62.



USING WEATHER SYMBOLS

Authors:
Russ Burroughs, Harford Day School, Bel Air, Maryland
Edward Earle, Norwood School, Bethesda, Maryland
Sue McDonald, Canton Middle School, Baltimore, Maryland

Grade Level: 4–6

Objectives:
Students will be able to recognize relationships between weather symbols and weather patterns indicated by satellite images. Note that clouds may indicate weather activity (such as a thunderstorm) but may be present without producing any such activity. Note also that forecasts are developed by assessing a variety of data—it will be advisable to utilize other data with the imagery (TV and newspaper forecasts, information from National Weather Service and/or obtained from the Internet, etc.).

Rationale:
Students will gain experience in creating a weather map using satellite imagery, and will learn some of the symbols commonly used on weather maps.

Relevant Disciplines:
Earth science, language arts, geography

Time Requirement:
Two 45-minute periods

Image Format:
GOES visible image

Prerequisite Skills:
Knowledge and comprehension of different forms of precipitation, clouds, and fronts.

Vocabulary:
front, precipitation, satellite imagery

Materials:
1. Large classroom map of North America
2. GOES satellite image (photocopies or overhead)
3. Copies of weather symbols and weather symbols key for distribution
4. U.S. map with symbol keys
5. Category chart (for symbols)
6. Scissors and glue

Activities

Day One

1. Distribute (or project) the satellite image and discuss the information represented on the image.
2. Lead the class in a discussion regarding the importance of using weather symbols.
3. Divide the class into groups of four, for cooperative learning.

4. Distribute the sets of symbols, and instruct each group to cut the symbols apart and categorize them into three groups. Each group of symbols should be somehow related, and should be given a name that describes its meaning or function. Each team of students will then present their three categories of symbols, and explain their reasoning for their classification.

Day Two

1. Divide the class into groups of four.
2. Distribute the U.S. maps with symbol keys, and the satellite image.
3. Groups will draw as many symbols on the map as seem appropriate.
4. Each group will complete five maps, one for each student and a combined group map.
5. Check work by having jigsaw groups, four members from four different groups, gather to compare their group's weather map.

Conclusion:

Display group weather maps wherever appropriate

Questions:

1. What are we able to observe from a satellite image?
2. How are weather symbols useful?
3. How are weather symbols categorized, and why?
4. How do we use weather symbols to transfer what is observed from a satellite image onto a weather map?

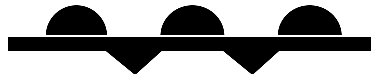
Extension:

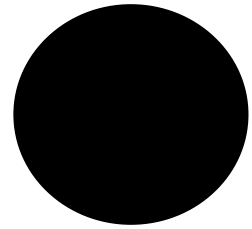
Have students develop or discover other weather symbols.

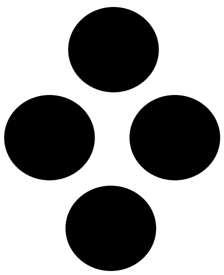
References:

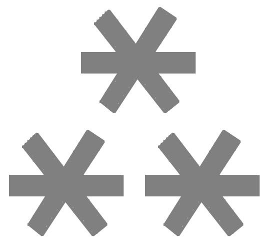
Ahrens, Donald C. *Meteorology Today: An Introduction to Weather, Climate, and the Environment*
GOES satellite image

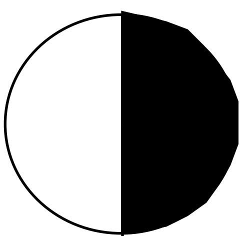
Weather Symbols

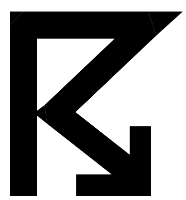


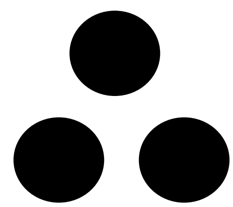


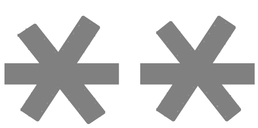


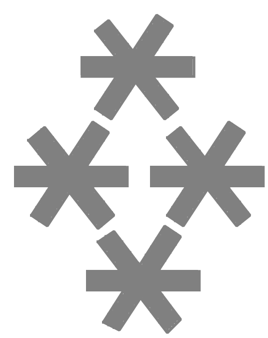


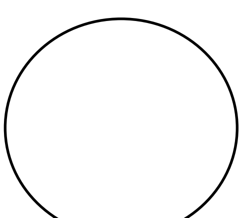


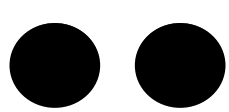


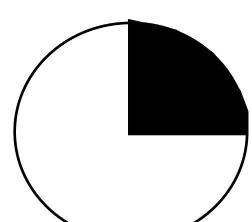












Weather Symbols Classification

Group Members:

____________________ ____________________

____________________ ____________________

Category #1: " ____________________ "

Category #2: " ____________________ "

Category #3: " ____________________ "

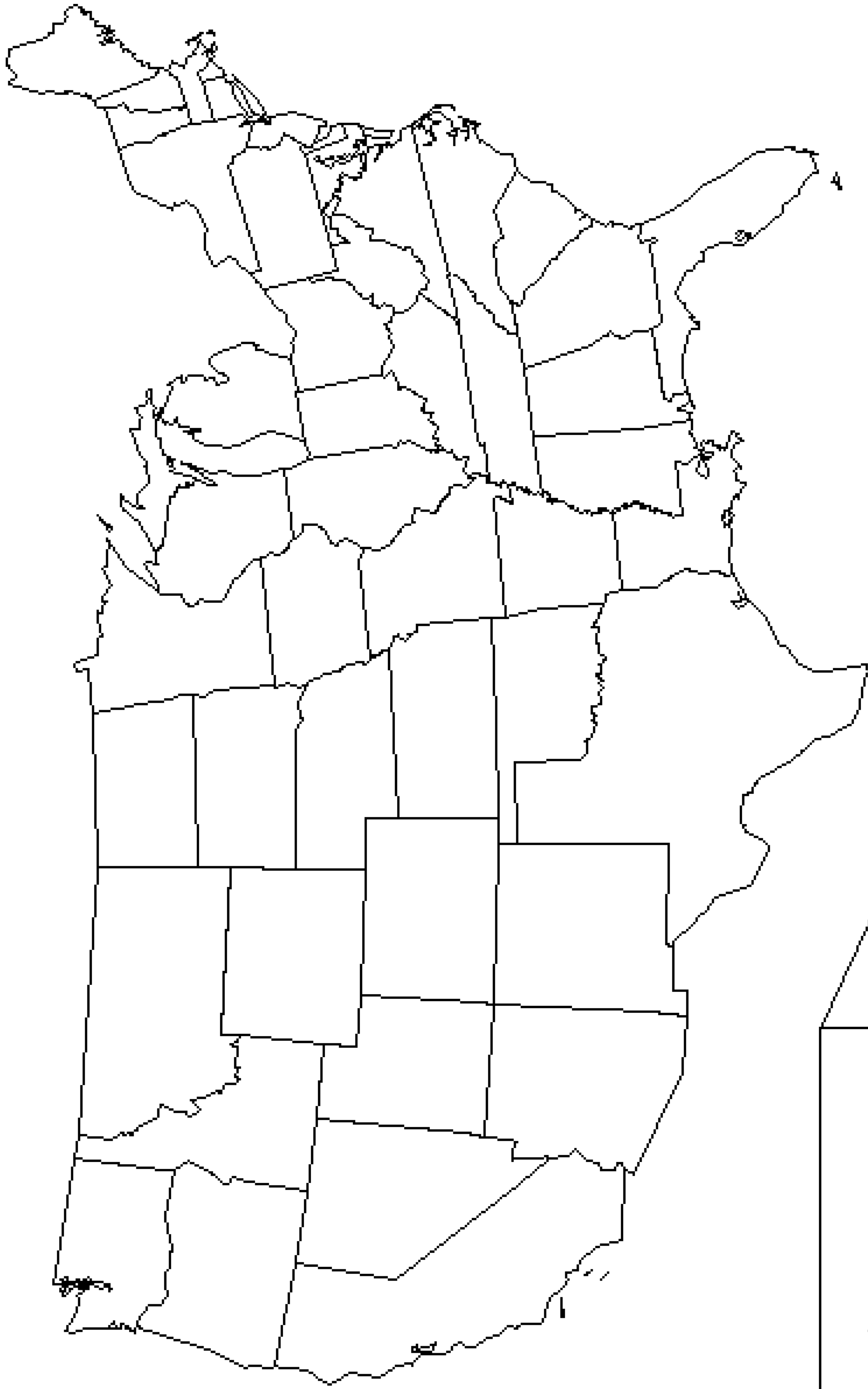
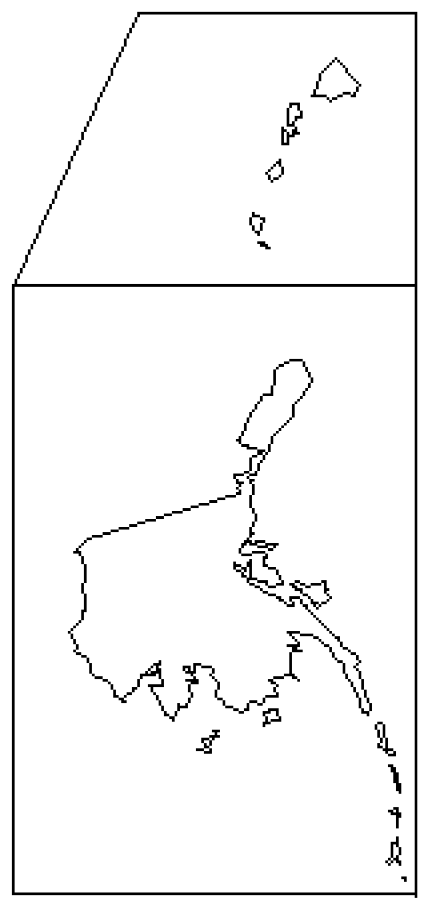



figure 63.

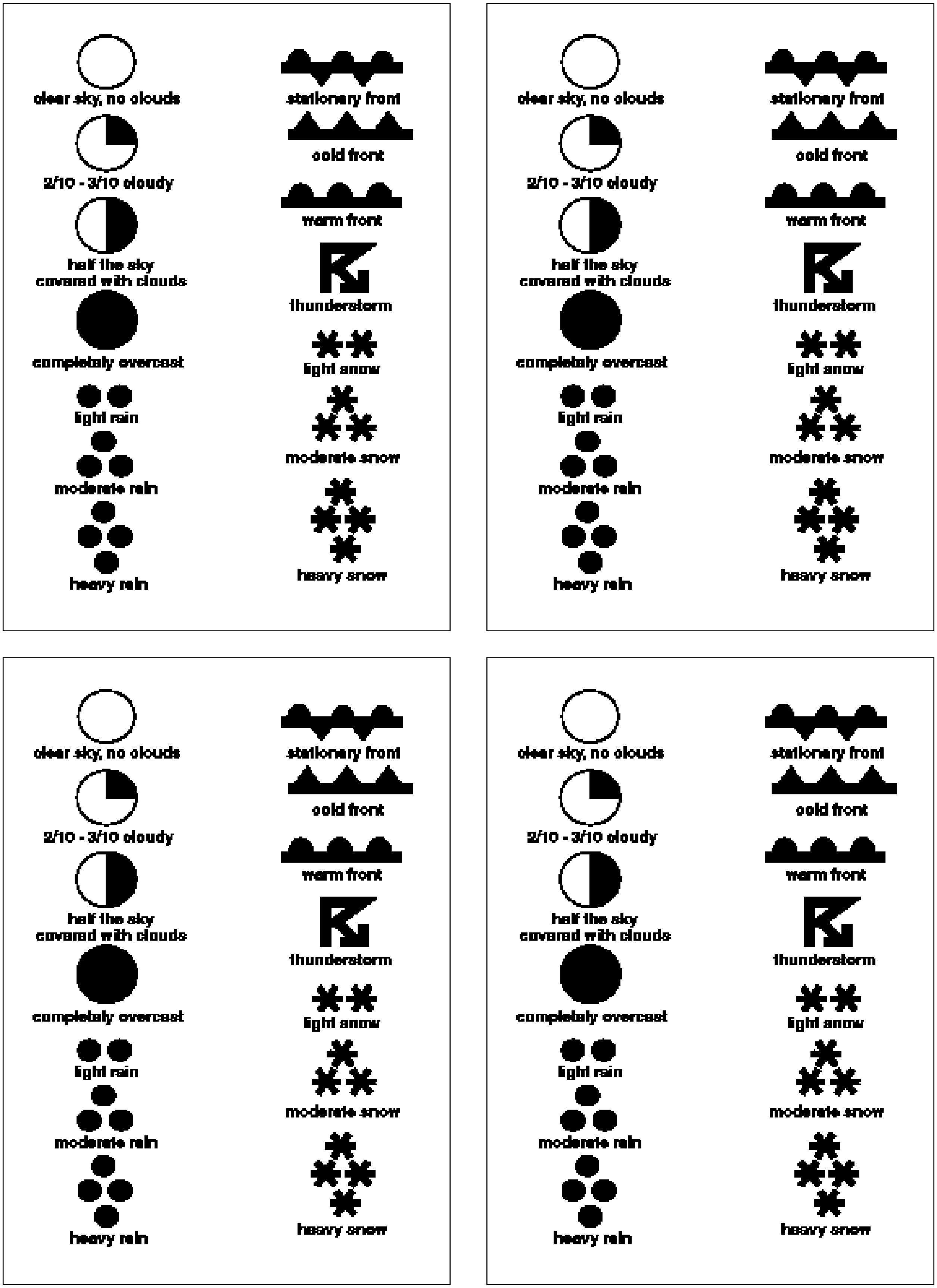


figure 64. Key: Weather symbols (Copy keys and distribute on day two)

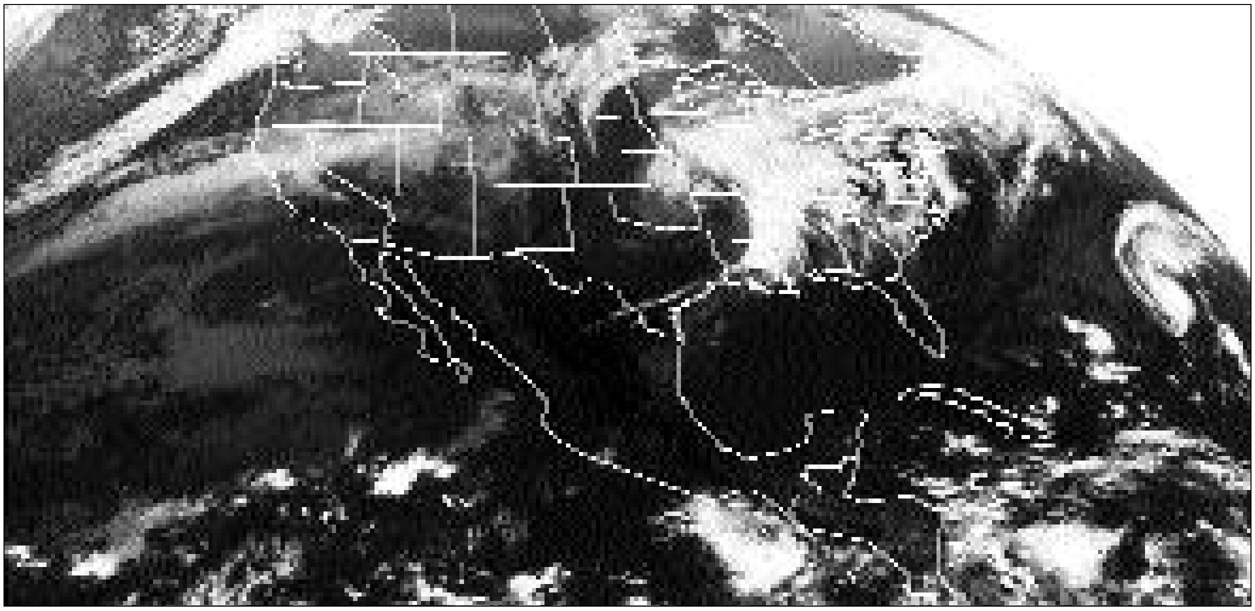


figure 65. GOES infrared image, November 5, 1994
image courtesy of M. Ramamurthy, University of Illinois, Urbana/Champaign

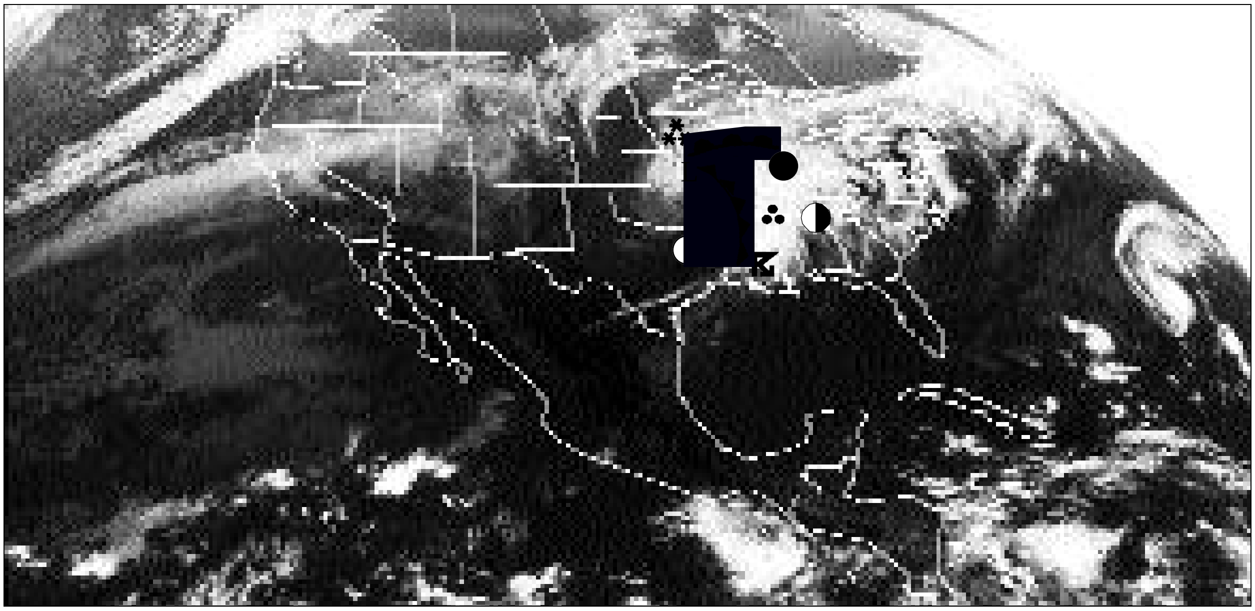


figure 65a. GOES infrared image, November 5, 1994
image courtesy of M. Ramamurthy, University of Illinois, Urbana/Champaign

Information in addition to the satellite image is necessary to determine whether the precipitation is rain or snow, and how heavy the precipitation is (which symbol to use).

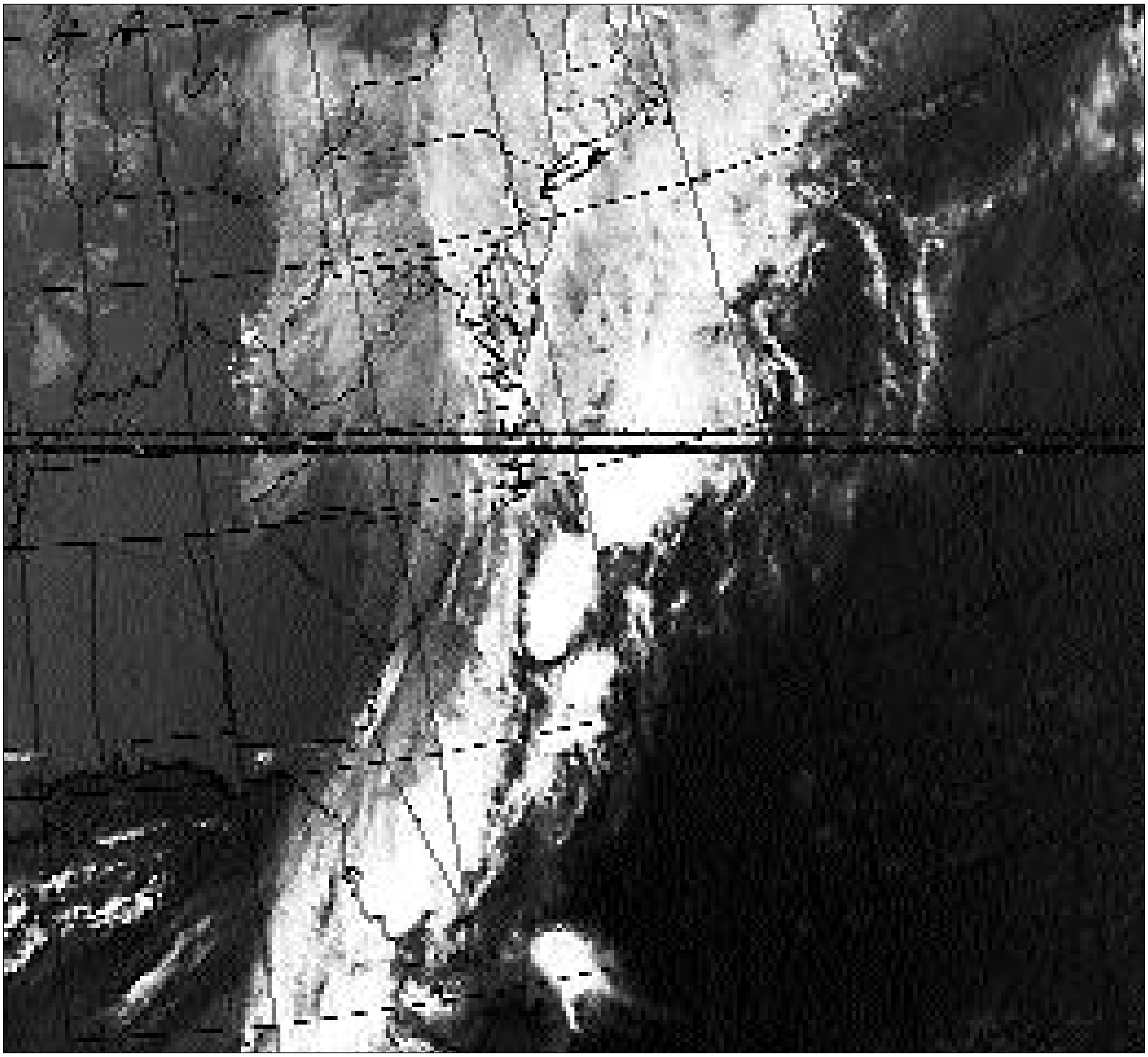


figure 66. NOAA 10, March 29, 1994 morning satellite image courtesy of D. Tetreault, University of Rhode Island

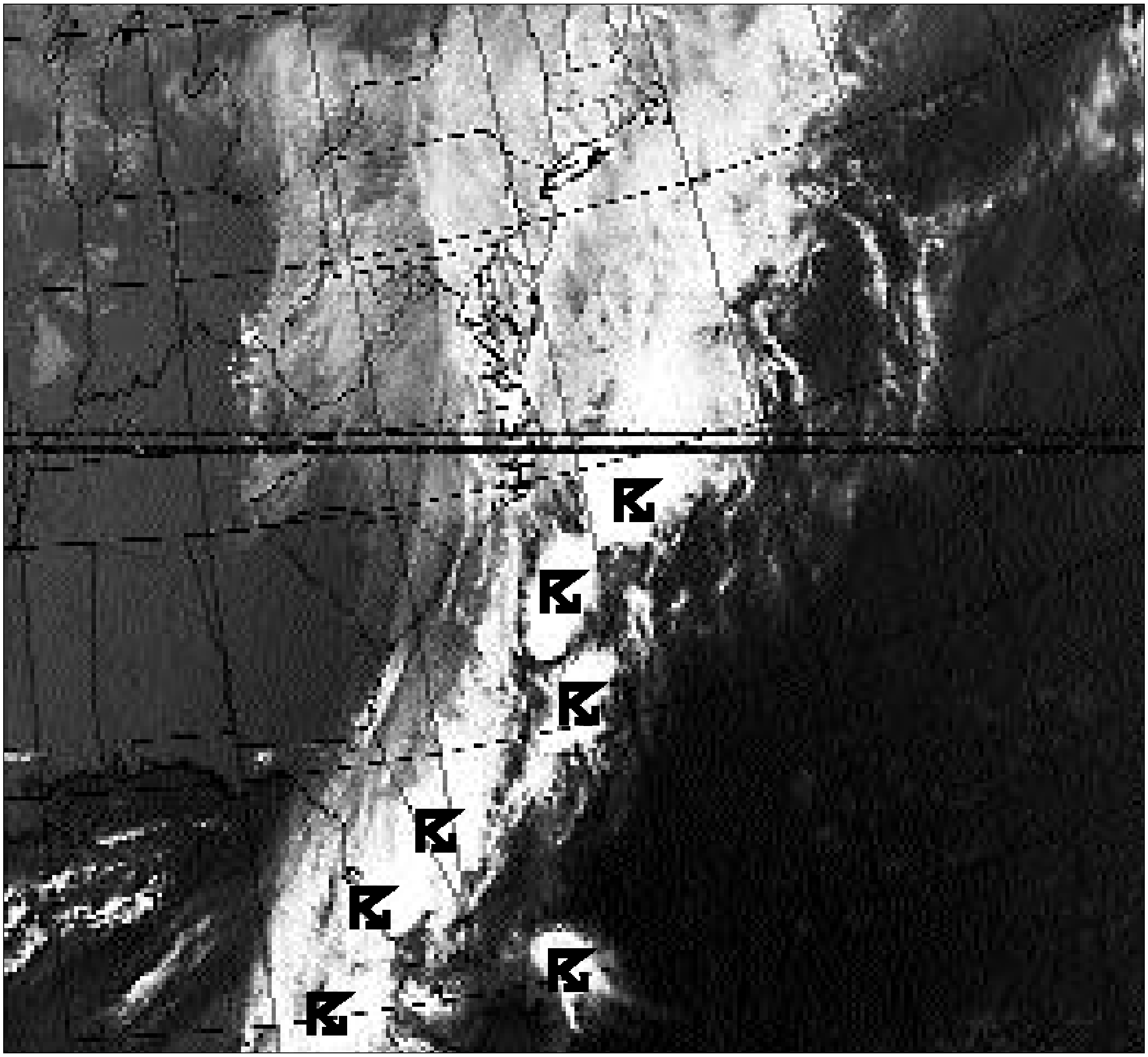


figure 66a. NOAA 10, March 29, morning satellite
image courtesy of D. Tetreault, University of Rhode Island

Forecasting the Weather: Satellite Images & Weather Maps

Authors:
Russ Burroughs, Harford Day School, Bel Air, Maryland
Edward Earle, Norwood School, Bethesda, Maryland
Sue McDonald, Canton Middle School, Baltimore, Maryland
Linda Webb, Jarrettsville Elementary School, Jarrettsville, Maryland

Grade Level: 4–6

Objectives:
Students will use satellite images and weather (outcome) maps to forecast weather for the Maryland region.

Rationale:
Students will be able to see the relationship between satellite images, weather maps, and forecasting.

Essential Learnings:
1. Weather across the Northern Hemisphere can follow recognizable patterns.
2. Satellite images show the movements of air masses that affect weather.
3. Cloud movement and types are related to the weather in a region.
4. The presence of clouds does not necessarily indicate any weather activity.

Relevant Disciplines:
Earth and Space Science, geography of North America, math (movement measurements, scale, temperature differences), language arts (predicting and writing a weather forecast report)

Time Requirements:
Allotted 45 minute classes will be used as follows:
- one 15-minute class
- two to three 30-minute classes
- one 45-minute class

Image Format:
GOES and APT, visible images

Prerequisite Skills:
1. Knowledge of weather symbols
2. The ability to recognize cloud masses on a satellite image and associated weather maps
3. An understanding of the use of weather instruments to collect data on temperature, wind, etc.

Vocabulary:
forecast, front, imagery, precipitation, stationary, temperature

Materials:
1. Weather maps from local papers (several days in succession)
2. GOES or APT satellite images for the same days as the accumulated weather maps
3. Student map of the United States
4. Student weather forecast sheet

Activities

Day 1

1. Divide the class into cooperative learning teams of four students each.
2. Distribute day-00 weather map and the matching satellite images.
3. Compare the satellite image and weather map, and match features relating to cloud cover and weather events.
4. Report team findings and discuss (whole class).

Day 2

5. Distribute day-01 weather map and satellite image.
6. Compare the image and the weather map, and relate it to the previous day.
7. Record and report any differences. Discuss.

Days 3–4

8. Distribute the third set of weather maps and images.
9. Compare them, and report any differences.
10. In individual groups, look for patterns that are occurring on the maps and images.
11. Discuss as a class.
12. In teams, use the patterns from the maps and images to predict the weather for the next day.
13. Each team member completes a weather map and forecast for the next day.
14. Share and post forecasts and maps.
15. Use a satellite image and weather map for the next day to compare the actual weather to the forecasted weather.

note: Daily comparison of the images and weather maps could be done in one or two 40-45 minute classes instead of daily, for four or five days.

Questions:

1. How are the satellite images and the weather maps the same?
2. How are temperature, clouds, and precipitation related?
3. How does the movement of cloud patterns help us to find weather fronts?
4. How did the satellite images and weather maps change each day?
5. What patterns could you find in the changes each day?
6. How can finding these patterns help us to predict (forecast) the weather?

Extensions:

1. Continuation of daily weather forecasting from maps and images by each group in rotation.
2 Exploration of the factors that might have caused the forecast not to match the actual weather.
3. Investigation into weather forecasting: history, tools, benefits.

References:

Ahrens, Donald C. *Meteorology Today: An Introduction to Weather, Climate, and the Environment*

Berman, Ann E. *Exploring the Environment Through Satellite Imagery.*

For Spacious Skies. Sky Watcher's Cloud Chart.

Summary of Forecast Rules by Cloud Types.

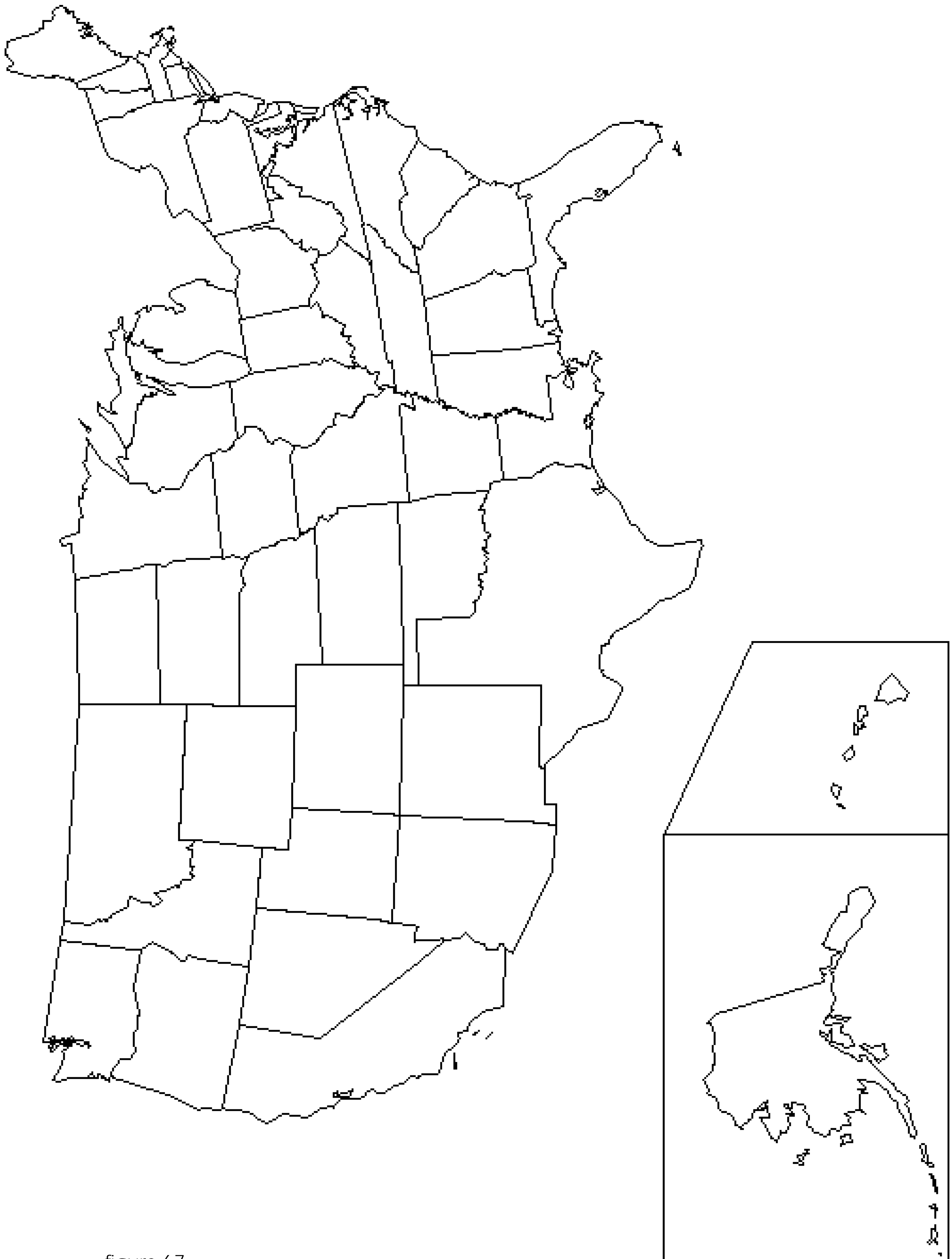


figure 67.

Weather Observations

name ______________________________

day and date: ______________________________

temperature: ______________________________ humidity: ______________________

barometer: ______________ rising/falling high wind direction: ______________

cloud type: ______________________________ wind speed: fast, slow __________

cloud cover ______________________ %

general conditions:

____

____

____

____

____

____

predictions:

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____

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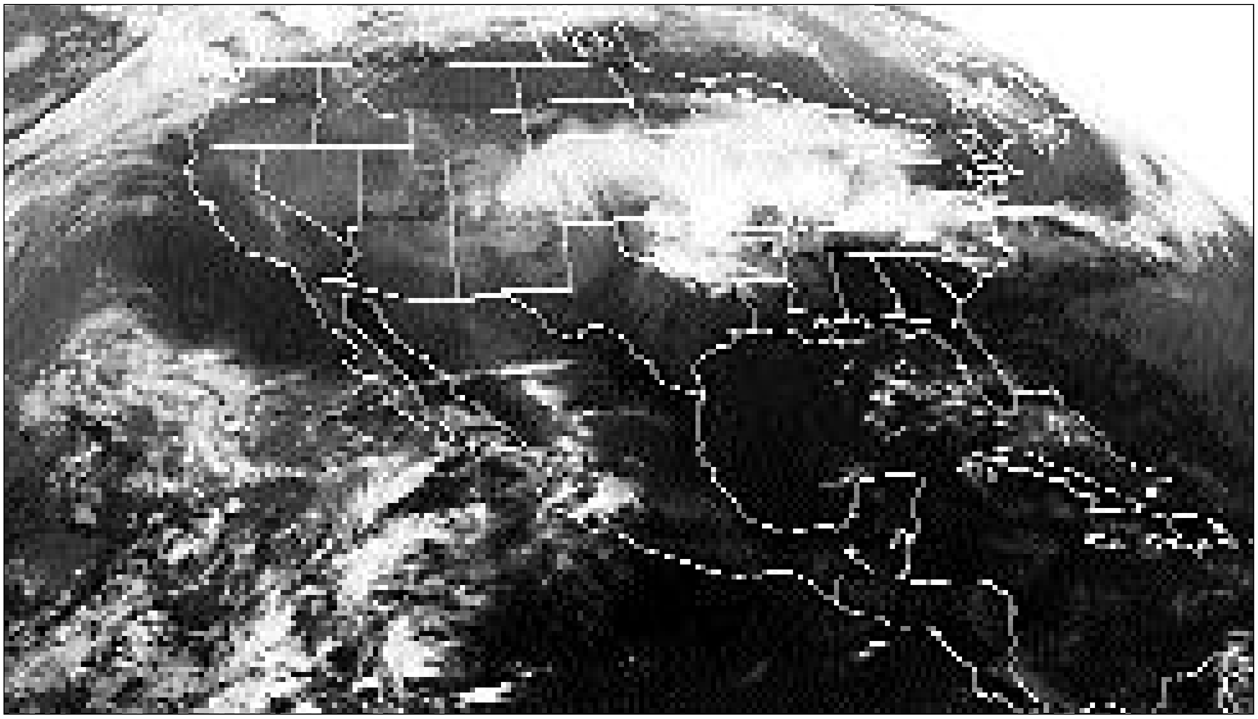


figure 68. GOES image, April 11, 1994, 0900 CDT
image courtesy of M. Ramamurthy, University of Illinois, Urbana/Champaign

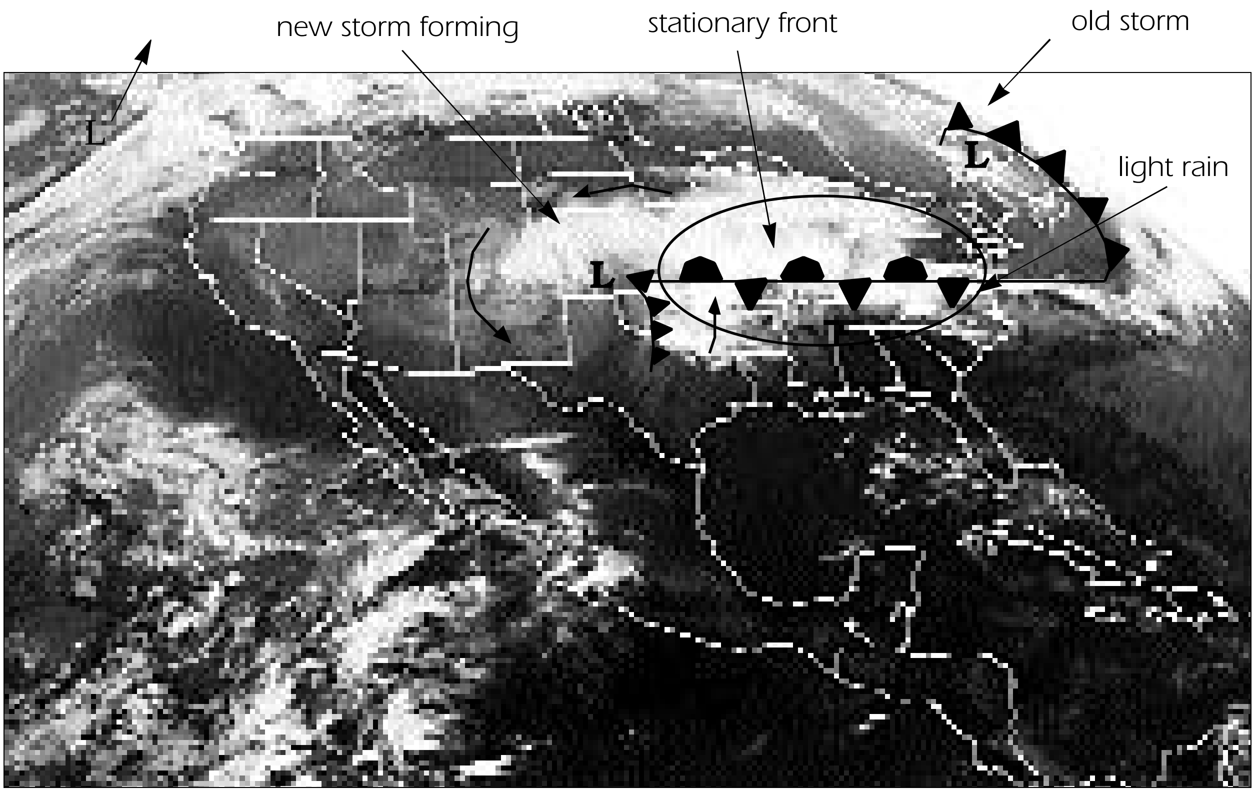
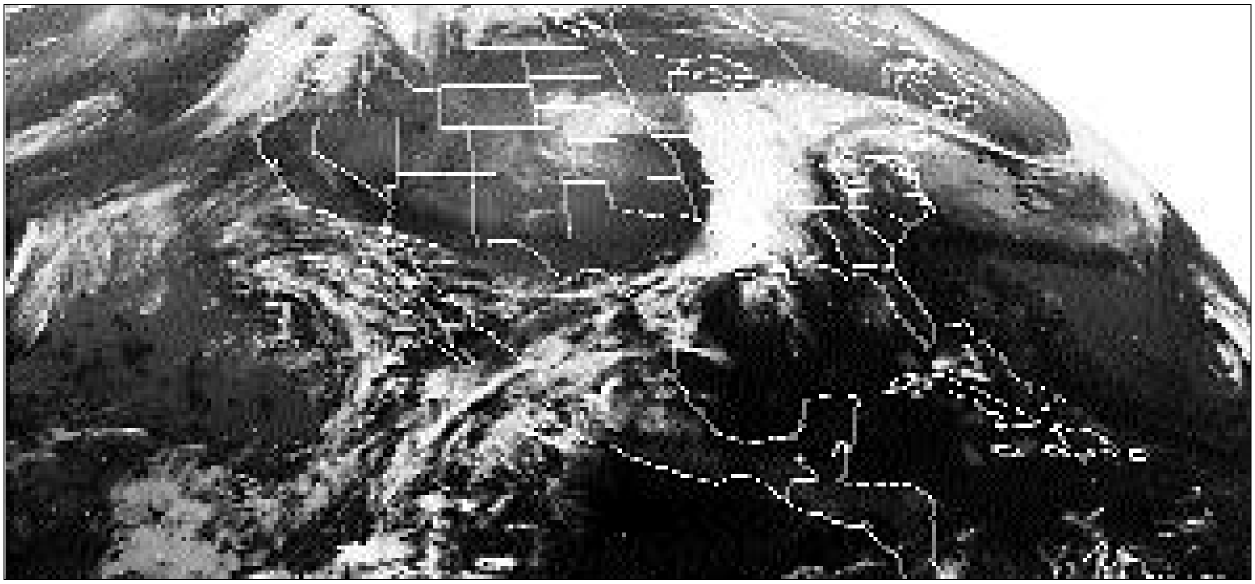


figure 68a. GOES image, April 11, 1994, 0900 CDT
image courtesy of M. Ramamurthy, University of Illinois, Urbana/Champaign

Old storm is producing rain. Arrows indicate wind direction. Images 1–3 for this activity appear in the chapter entitled *Weather Systems and Satellite Images* as figures 27c,



27d, and 27f (pages 40, 41, and 43).

figure 69. GOES image, April 12, 1994, 0100 CDT
image courtesy of M. Ramamurthy, University of Illinois, Urbana/Champaign

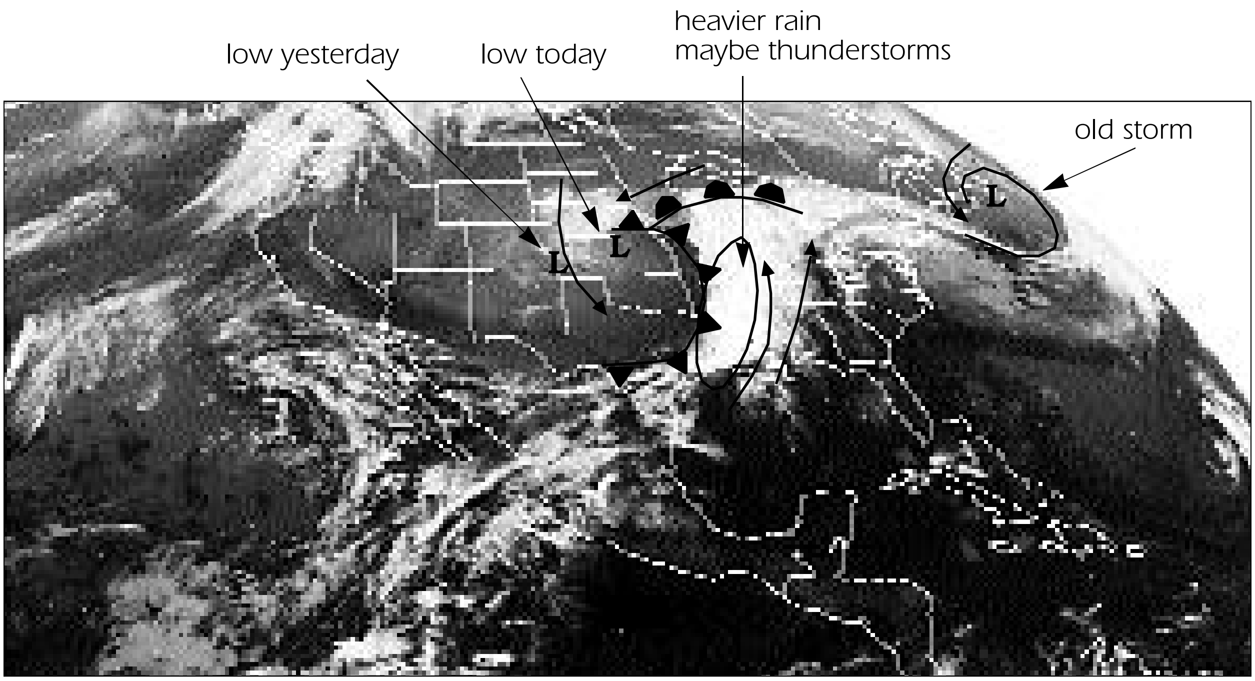


figure 69a. GOES image, April 12, 1994, 0100 CDT
image courtesy of M. Ramamurthy, University of Illinois, Urbana/Champaign

Compare position of low and cold front to their locations on April 11. Note that storm is strengthening and moving East.

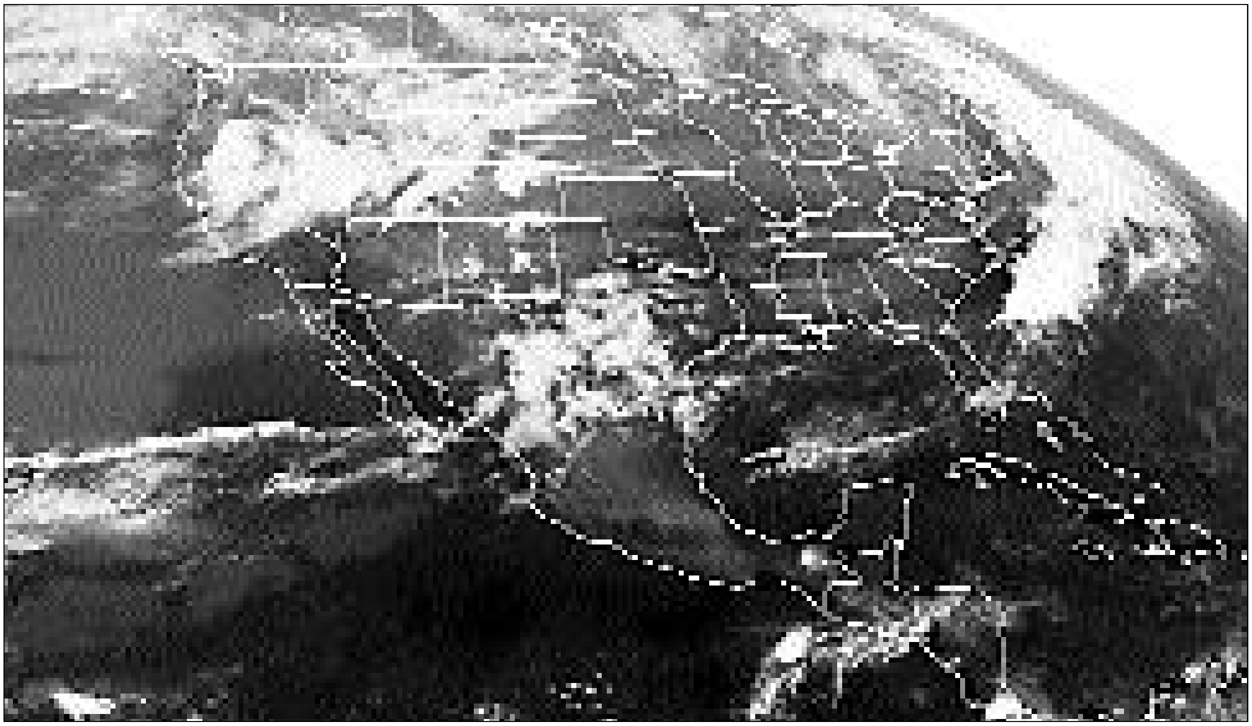


figure 70. GOES image, April 14, 1994, 0600 CDT
image courtesy of M. Ramamurthy, University of Illinois, Urbana/Champaign

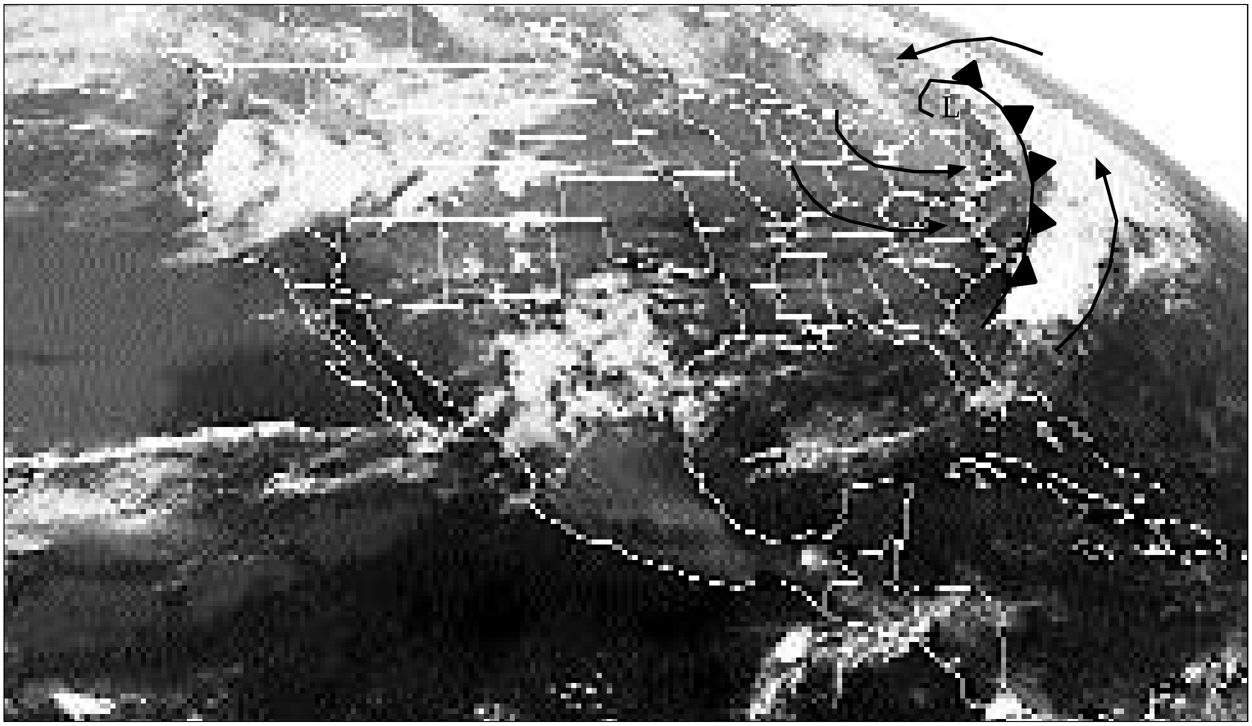


figure 70a. GOES image, April 14, 1994, 0600 CDT
image courtesy of M. Ramamurthy, University of Illinois, Urbana/Champaign

Note that the weather is clear over the Eastern United States, and that the storm is gone. Have students determine location of the low on April 13. Have students compare the location of the low in this figure with the location of the old storm on day 1 (April 11).

Cloud Families

Authors:
Angeline Black, Kenmoor Middle School, Landover, Maryland
Renee Henderson, Forestville High School, Forestville, Maryland
Karen Mattson, Ballenger Creek Middle School, Frederick, Maryland
Allen White, New Market Middle School, New Market, Maryland

Grade Level: 6–8

Objectives:
Students will be able to:
1. Identify and describe the four major cloud families: high, middle, low, and vertically developed; and
2. Associate cloud families and satellite images with daily weather patterns.

Relevant Disciplines:
Earth and space science, meteorology, photography, art, computer science

Time Requirement:
2–4 class periods

Image Format:
APT and GOES

Prerequisite Skills:
Students should be able to:
1. Identify cloud families they can see from the ground;
2. Identify cloud families from visible and infrared satellite images;
3. Identify typical weather associated with cloud families;
4. Operate a camera; and
5. Access a satellite image from the computer bank.

Vocabulary:
alto, cirrus, cumulonimbus, cumulus, stratus

Materials:
1. 35mm camera and/or Polaroid camera
2. Satellite cloud identification chart
3. Poster board
4. Construction paper
5. Glue, scissors, cotton, markers
6. Satellite images - computer bank
7. Photos of clouds - camera or magazines
8. Telex or slides of satellite images (20 or more)
9. Worksheet: *Cloud Families*

Preparation:
Before beginning the student activities the teacher should:
1. Obtain visible and infrared satellite images (about 20) illustrating a variety of low, middle, high and vertically developed clouds.

2. Organize materials into stations:
    a. Computer with software and stored images;
    b. Camera to photograph images once accessed;
    c. Camera to take outside photos and/or magazines as sources of cloud photos;
    d. Materials to assemble display: posterboard, glue, scissors, etc.;
    e. Materials to create 3-D clouds: cotton, glue;
    f. Reference materials: cloud charts, weather maps.

Note that current conditions may be cloudless or offer only uninteresting clouds. Also note that morning and afternoon sessions may observe very different types of clouds. Cloud observation schedules should be sensitive to these concerns; requiring students to observe clouds early in the morning and before sunset can offset predictable daily patterns.

Activities

1. Take students outside to discuss, view, and identify current cloud formation. Review weather associated with the current formation.
2. Review cloud families via satellite images using slides or telex.
3. Review directions for assignment - see Cloud Families worksheet.
4. Divide students into groups of four (cooperative learning groups).
5. Day 1: Have students plan/outline in their groups how they will organize their cloud families (chart, book etc.).
6. Day 2: Organize groups into rotating stations so that each group has an opportunity to access materials for each activity.
7. Day 2–4: Have groups rotate stations and complete activities.
8. Final Day: Display and have groups present their final projects.

Questions:
1. What cloud type would be associated with thunder?
2. What cloud type is made up of ice crystals?
3. What cloud type is associated with fair weather?
4. Compare/contrast a satellite image and ground image of the same cloud.

Extensions:
1. Require older students to break cloud families into specific cloud types.
2. Add cloud symbols as an additional identifier in the activity.
3. Have students obtain real data and record dates on their cloud charts. Save finished cloud charts and have students compare previous year(s) to current year.

References:
Loebl, Thomas S. *View From Low Orbit*
Cloud identification charts

Cloud Families Student Worksheet

Objectives:

1. To identify and describe the four major cloud families: high, middle, low, and vertically developed.

2. To construct a display identifying cloud families.

Criteria:

1. Each group will construct a display identifying the major cloud families: high, middle, low, and vertically developed.

2. Each cloud family must include the following:
   a. Cloud family name
   b. Photo or magazine picture of each cloud family (from Earth looking up)
   c. Satellite image of each cloud family with the cloud identified (from space looking down).
   d. A brief description of each of the cloud families that includes typical weather associated with the cloud family.
   e. A 3-D model of each cloud family using cotton.

3. Each display must :
   a. Be titled
   b. Have group members identified
   c. Be accurate
   d. Be neat/colorful

sample format

Location	Cloud Type	Description	Satellite Name	Ground Image	3 Dimensional	Type Weather
High						
Middle						
Low						
Vertically Developed						

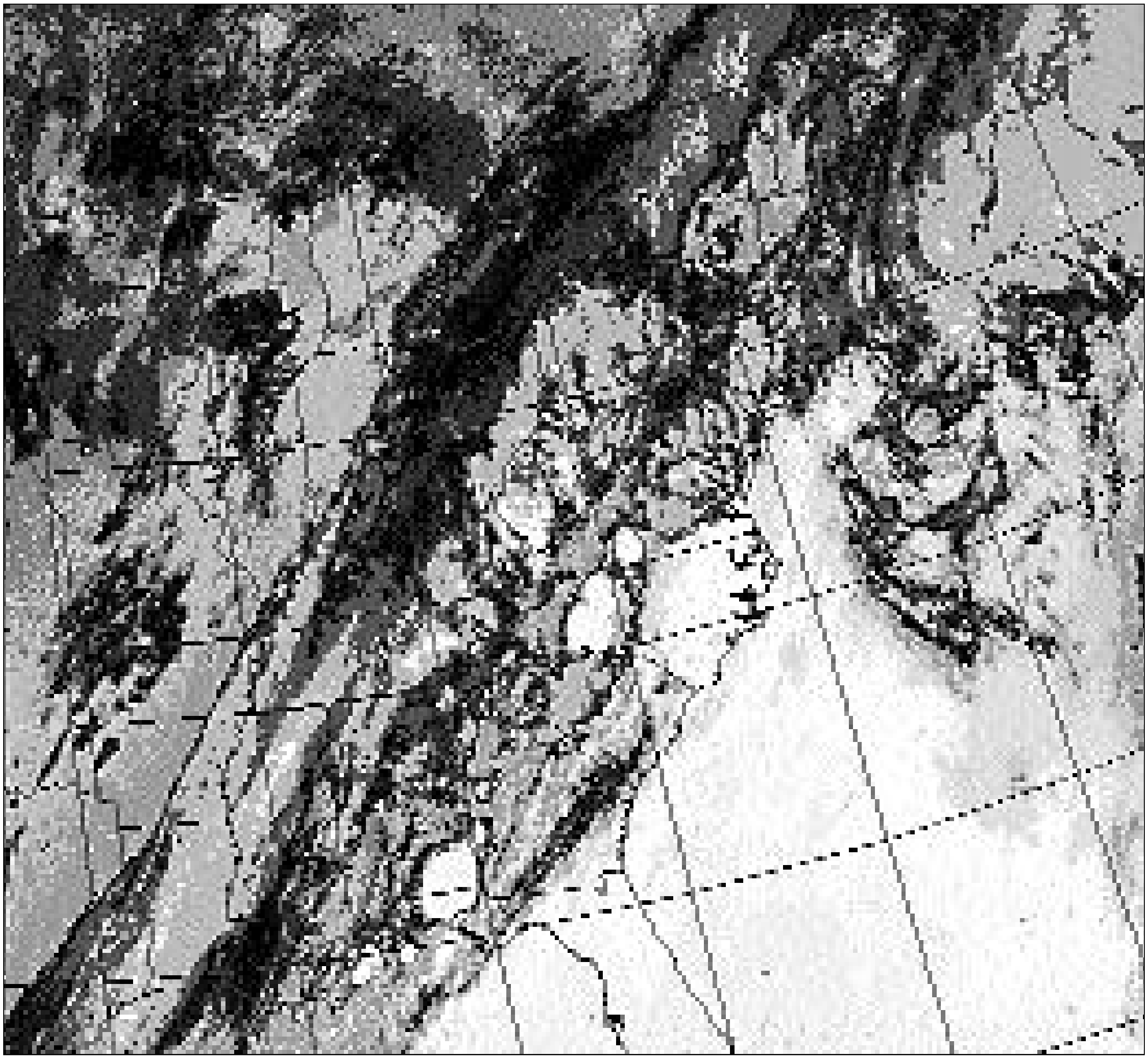


figure 71. NOAA 10, March 28, 1994, infrared
image courtesy of G. Chester, Smithsonian Institution, Albert Einstein Planetarium

Have students use this in conjunction with figure 71b (the visible version of this image) to help identify clouds.

little thunderstorms

cumulus congestus or towering cumulus
mid-level, vertically developed clouds

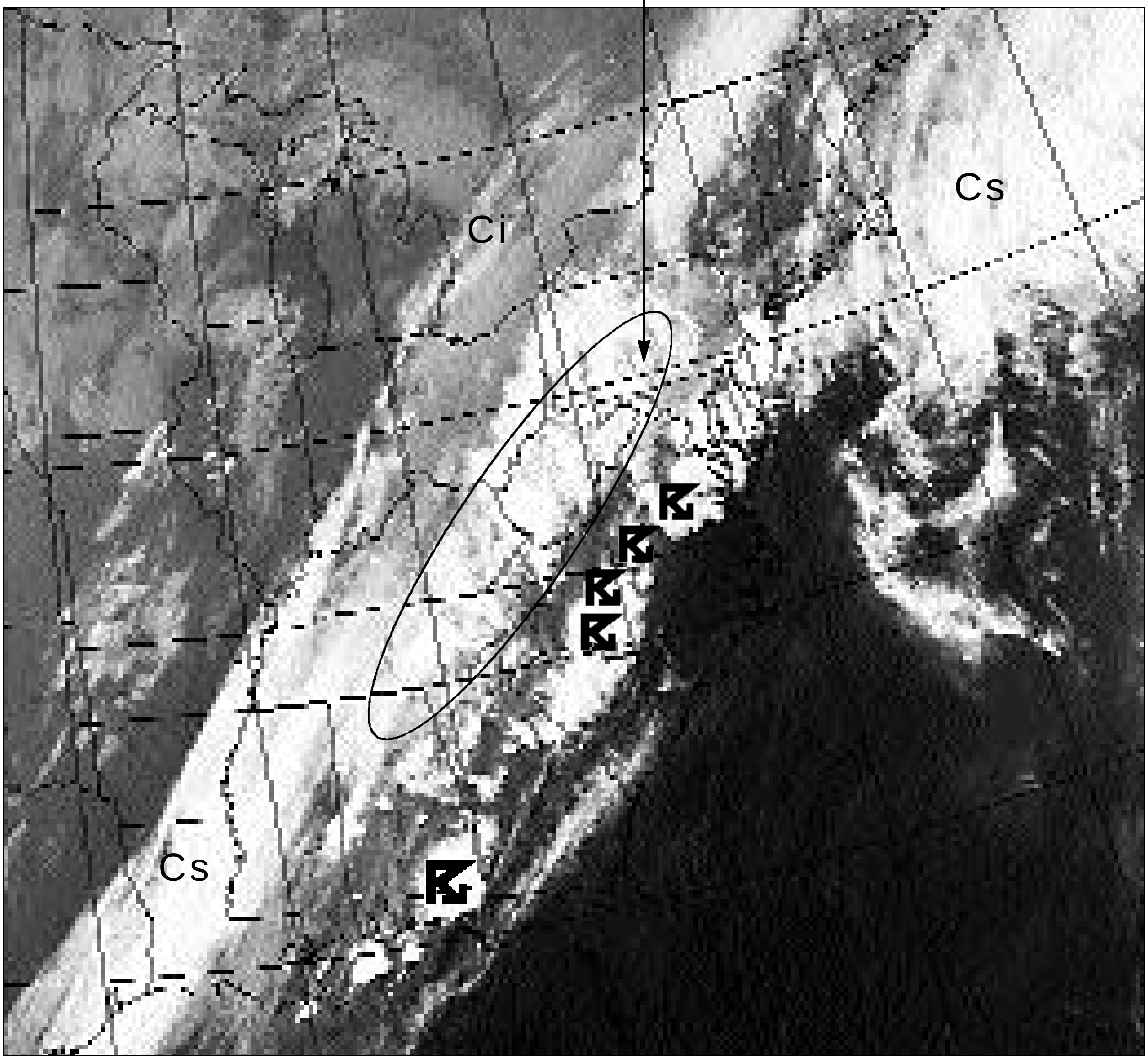


figure 71a. NOAA 10, March 28, 1994
image courtesy of G. Chester, Smithsonian Institution, Albert Einstein Planetarium

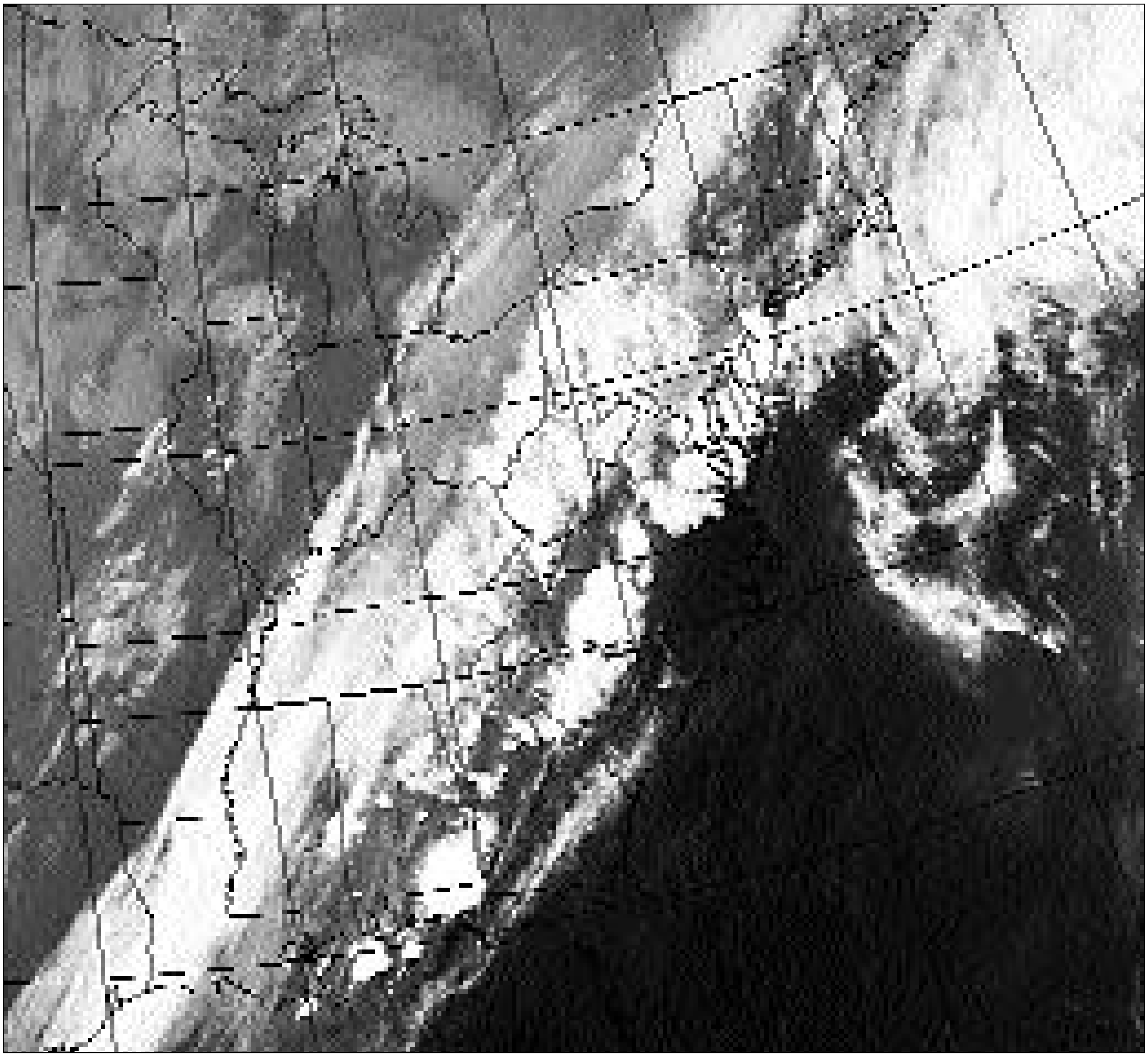


figure 71b. NOAA 10, March 28, 1994
image courtesy of G. Chester, Smithsonian Institution, Albert Einstein Planetarium

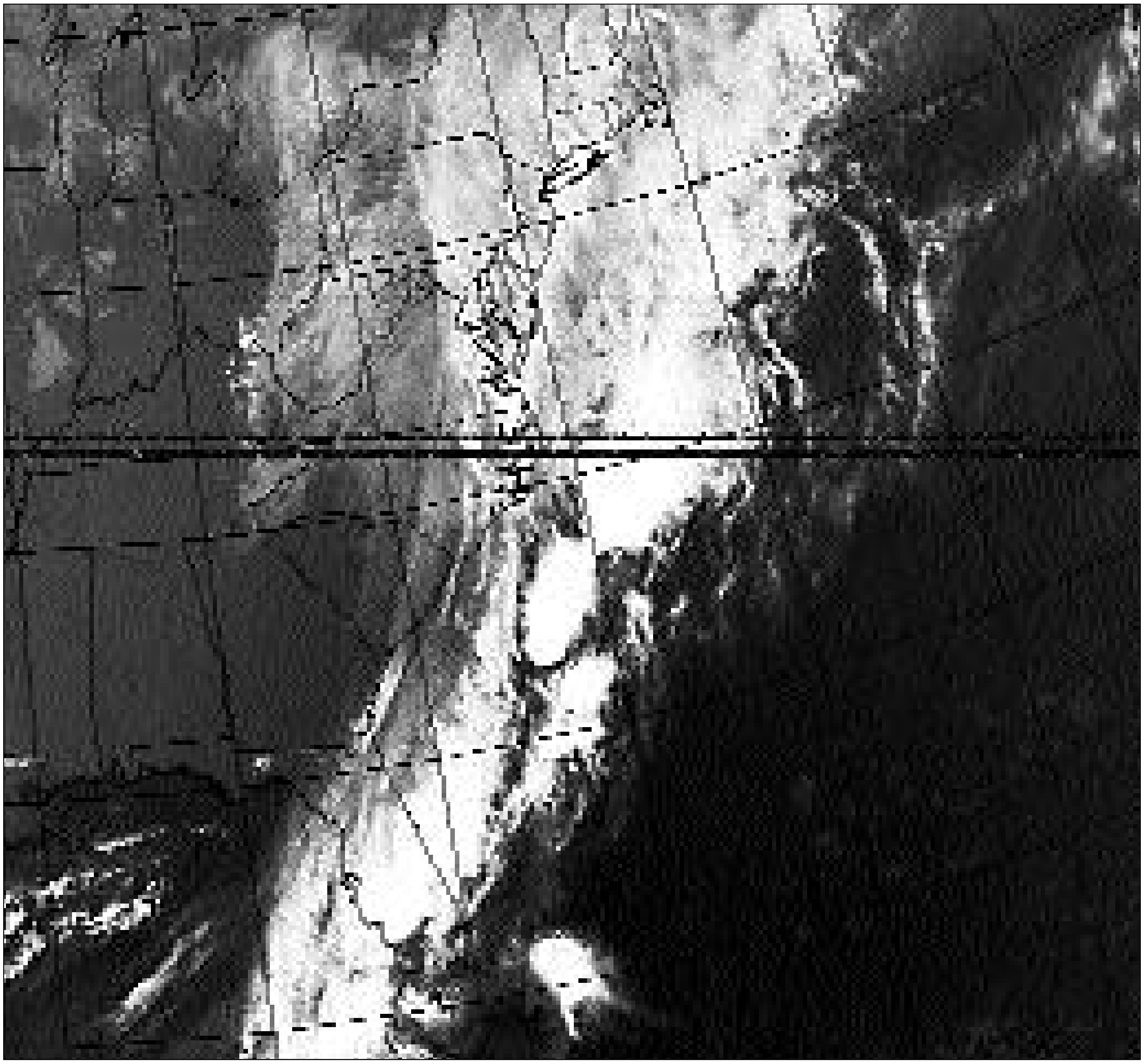


figure 72. NOAA 10, March 29, 1994
image courtesy of G. Chester, Smithsonian Institution, Albert Einstein Planetarium

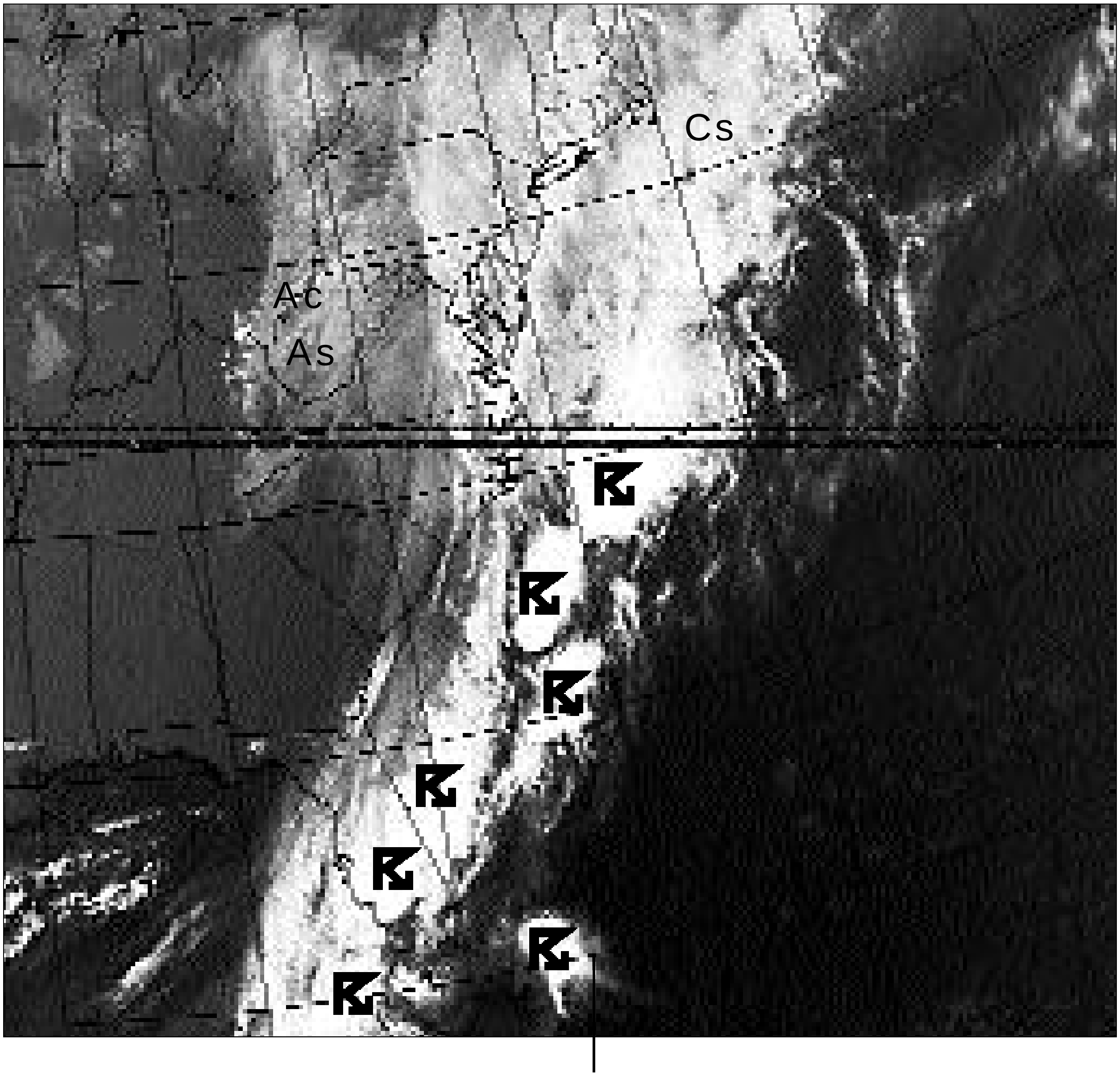


figure 72a. NOAA 10, March 29, 1994
image courtesy of G. Chester, Smithsonian Institution, Albert Einstein Planetarium

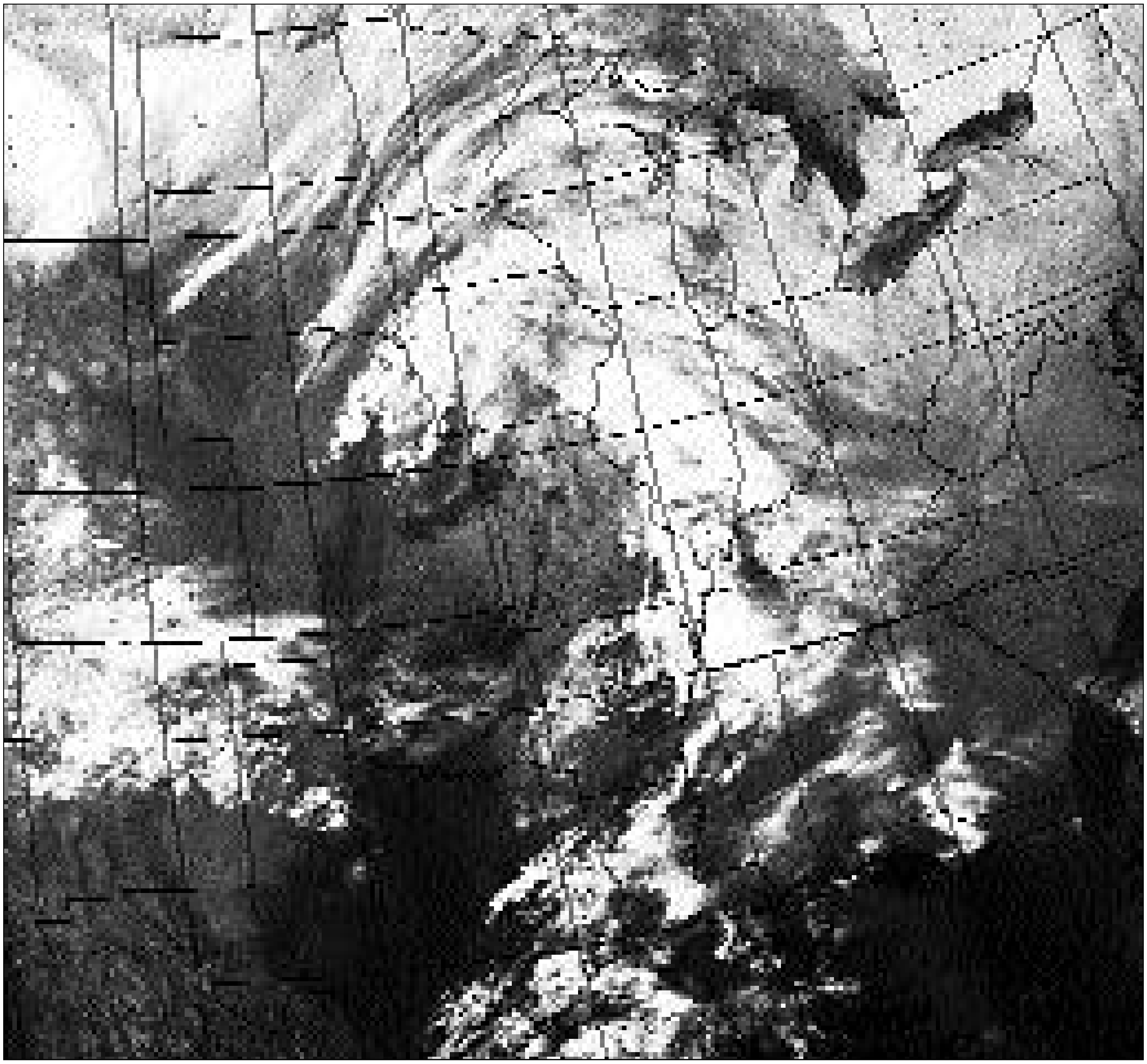


figure 73. NOAA 10, January 10, 1994
image courtesy of G. Chester, Smithsonian Institution, Albert Einstein Planetarium

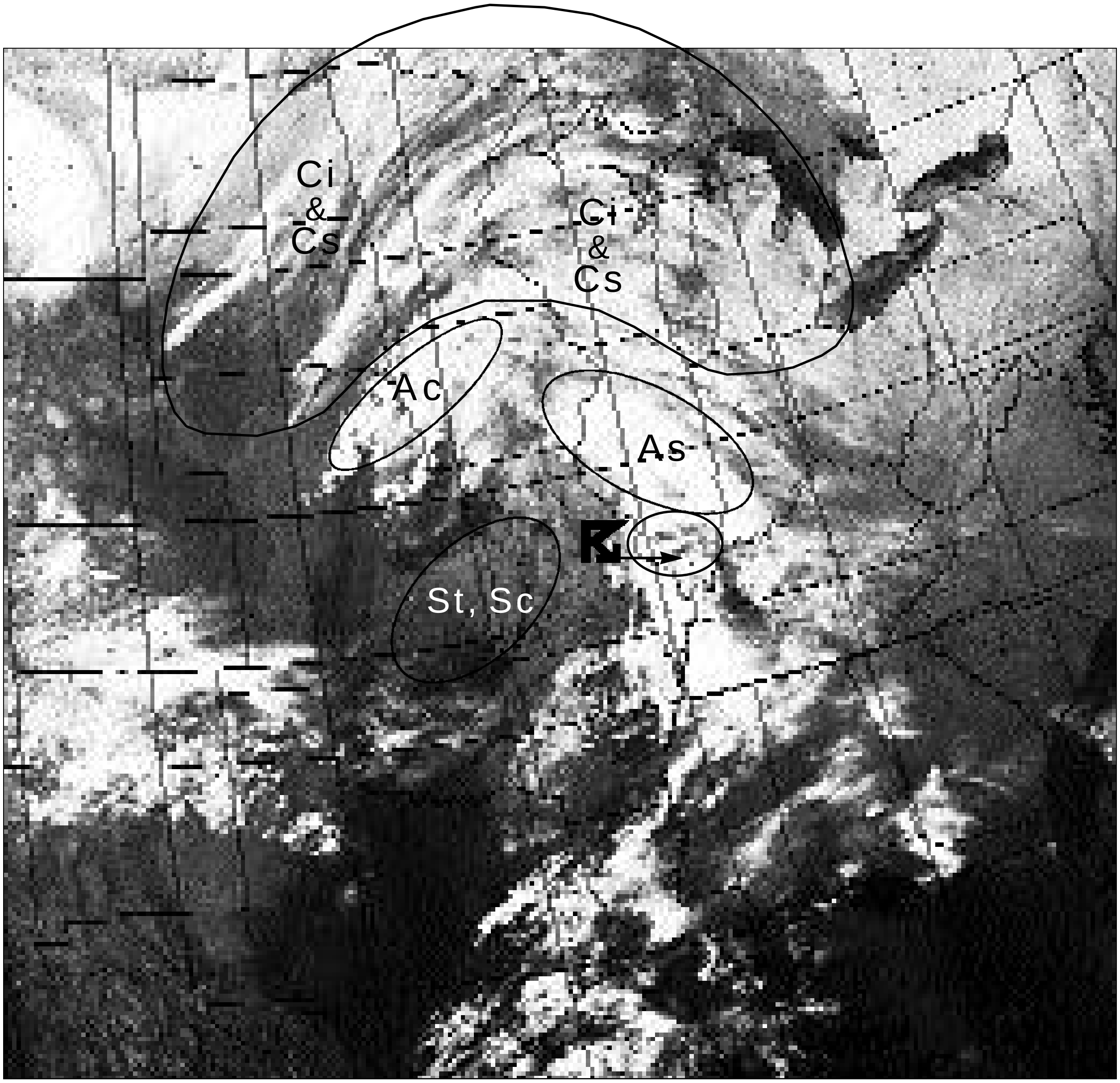


figure 73a. NOAA 10, January 10, 1994
image courtesy of G. Chester, Smithsonian Institution, Albert Einstein Planetarium

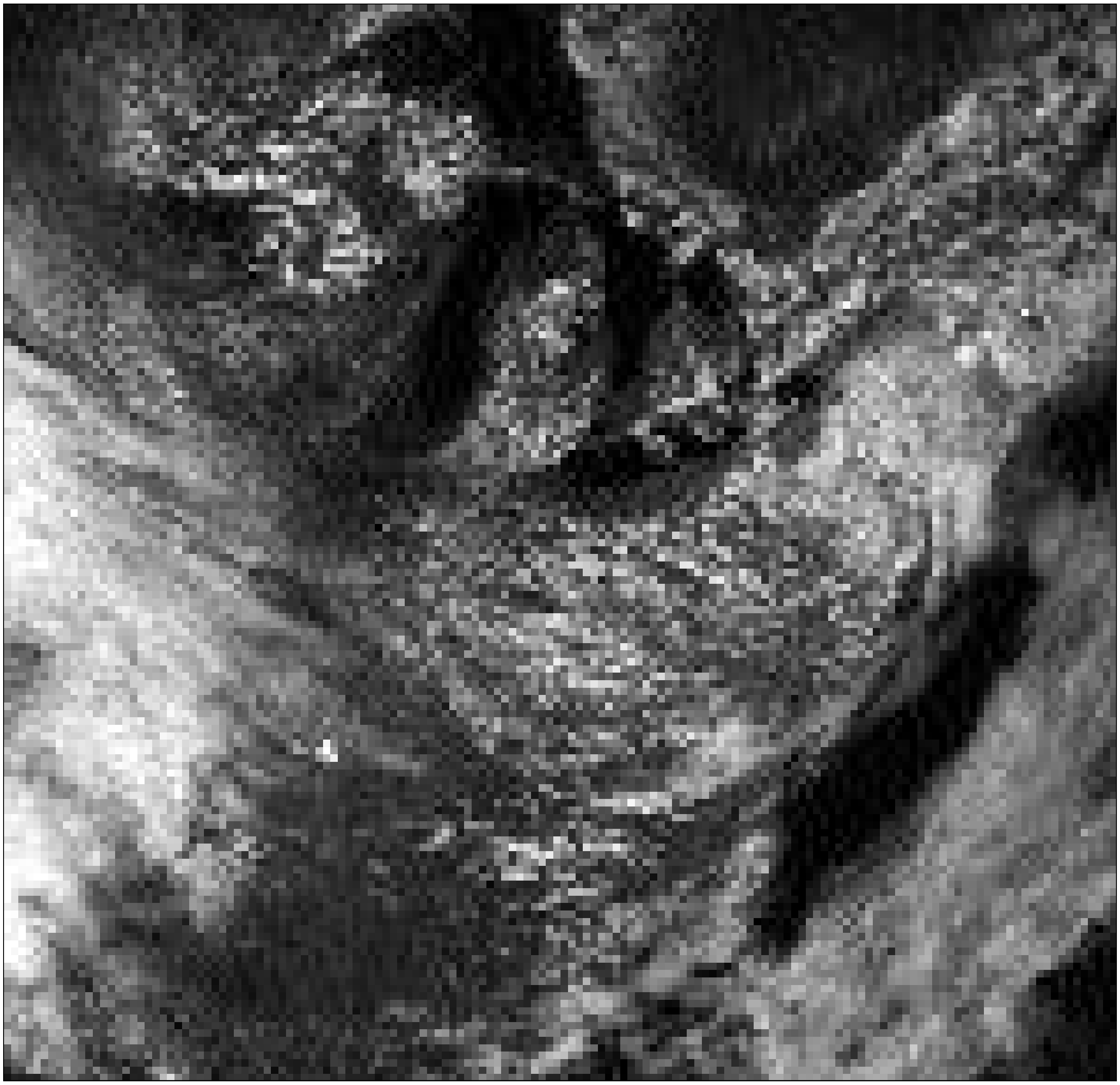


figure 74. NOAA 11, May 27, 1992
image courtesy of C. Davis, Hampstead, Maryland

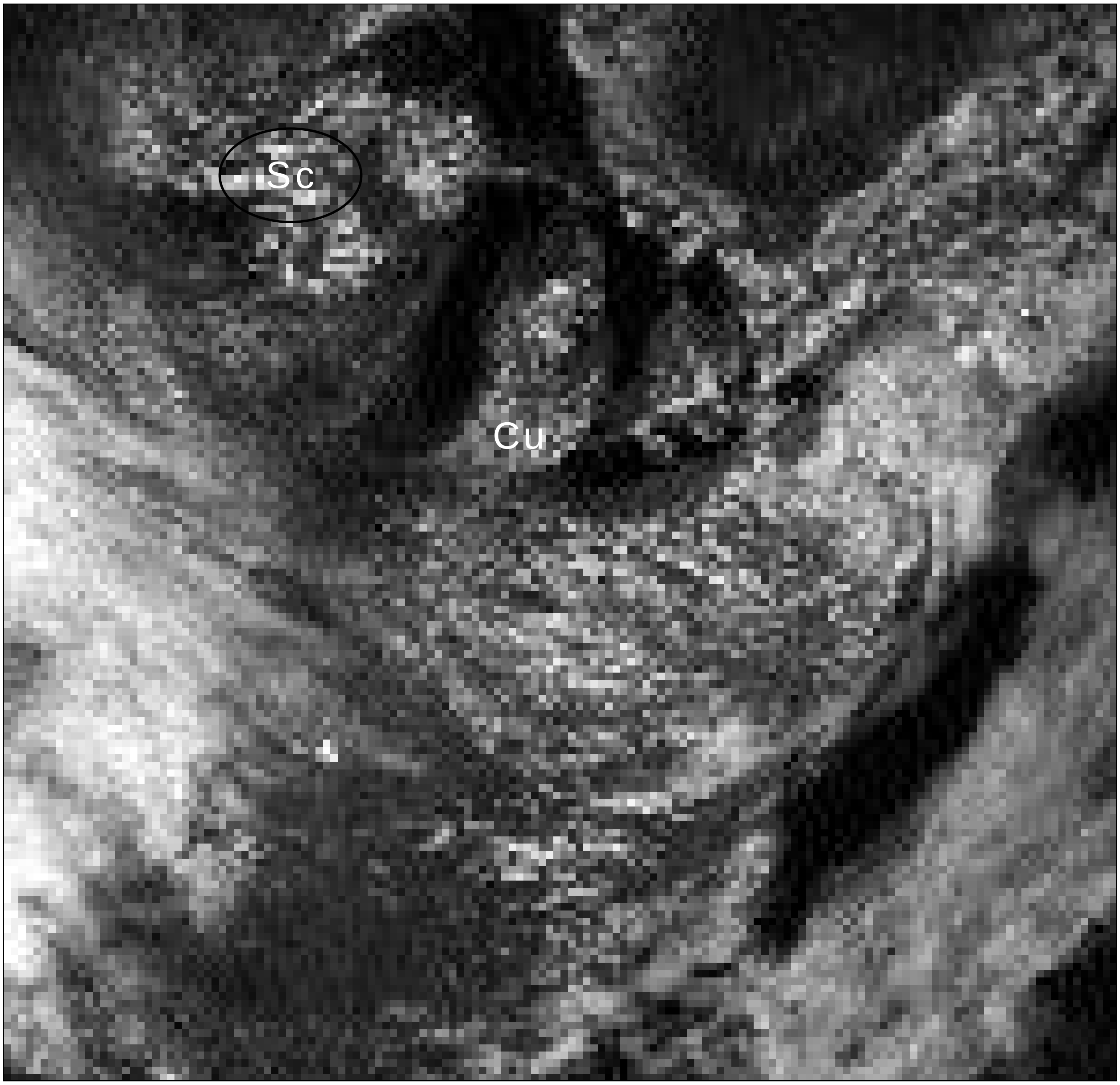


figure 74a. NOAA 11, May 27, 1992
image courtesy of C. Davis, Hampstead, Maryland

Cloud Identification

Authors:
Angeline Black, Kenmoor Middle School, Landover, Maryland
Renee Henderson, Forestville High School, Forestville, Maryland
Karen Mattson, Ballenger Creek Middle School, Frederick, Maryland
Allen White, New Market Middle School, New Market, Maryland

Grade Level: 6–8

Objectives:
1. Students will become familiar with identifying clouds on satellite images.
2. Student will be able to predict weather using satellite images, weather maps, and other weather data over a series of four days as a low pressure area passes north or south of two predetermined locations.

Rationale:
To associate cloud types and satellite images of clouds with daily weather patterns.

Relevant Disciplines:
Earth and space science, meteorology, computer science

Time Requirement:
One 40–50 minute period

Image Format:
APT

Prerequisite Skills:
Students should be able to:
1. Identify cloud types they can see from the satellite images;
2. Identify typical weather associated with cloud types;
3. Access a satellite image from the computer bank; and
4. Identify cloud types associated with fronts.

Vocabulary:
air pressure (millibar/inches), clouds (alto, cirrus, cumulonimbus, cumulus, nimbostratus, stratus), cold front, erosion, precipitation, stationary front, temperature, warm front, wind

Materials:
1. Series of satellite images for four consecutive days stored in a computer bank, or photographs of visible and infrared satellite images for four consecutive days
2. Cloud identification chart
3. *Cloud Identification* student worksheet
4. Newspaper weather maps for four consecutive days or a video of four consecutive days of weather maps from the Weather Channel

Preparation:
Before beginning the student activities the instructor should:
1. Obtain visible and infrared satellite images and newspaper or television weather maps on video for four consecutive days. The images and weather maps should show a typical comma cloud formation; and
2. Label point A to the north of the low pressure area on the images and maps, and label point B to the south of the low pressure area on the images and maps.

Activities

1. With student discussion, the teacher will model the current day's weather relative to the previously identified locations (point A and point B).
   a. Display the satellite image of current day on the overhead/computer screen.
   b. Discuss the current day's weather associated with cloud types.
   c. Relate the current day's newspaper or a video of a television weather map to the satellite image.

2. Divide students into groups (cooperative learning).

3. Distribute *Cloud Identification* worksheet, review the directions, and have students complete the worksheet.
   a. Discuss and draw hypothesis about four consecutive days of satellite images.
      1. Have the clouds moved?
      2. Have clouds dissipated or have more clouds developed?
      3. What kinds of clouds are at points A and B?
      4. What type of weather currently exists at points A and B?

   b. Distribute weather maps or show weather maps saved on video for four consecutive days. How does the actual weather relate to your hypothesis when you discussed the satellite images?

   c. Have students, working in groups, complete the *Cloud Identification* worksheet.

   d. Discuss trends observed over the four consecutive days that were observed in the satellite images and on the weather maps.

   e. As a class, review possible responses to the worksheet.

Extension:

This activity can be completed in cooperative groups or as a whole class discussion. Some teachers may want students to write their responses for graded evaluation.

1. You are a farmer living at point B.
   a. How would the weather affect your crops over the four days?
   b. Would you be concerned about surface erosion of your fields over the four day period? Why or why not?
   c. How would your farming activities be affected?
   d. Compare/contrast the affects of the weather on farms at points A and B.

2. You are planning a camping trip to point A.
   a. Which day would be the best for your trip?
   b. What type of clothing should you take?
   c. How would your camping activities (hiking, sleeping, cooking) be affected?
   d. Compare/contrast points A and B as sites for a camping trip based on the weather.

References:

Cloud identification charts
"The Weather Channel"
Local or national newspapers

Cloud Identification Worksheet

name ______________________

Point A	Point B
DAY 1	DAY 1
Cloud type: Weather conditions: precipitation: wind: speed/direction: front type: temperature: air pressure:	Cloud type: Weather conditions: precipitation: wind: speed/direction: front type: temperature: air pressure:
DAY 2	DAY 2
Cloud type: Weather conditions: precipitation: wind: speed/direction: front type: temperature: air pressure:	Cloud type: Weather conditions: precipitation: wind: speed/direction: front type: temperature: air pressure:
DAY 3	DAY 3
Cloud type: Weather conditions: precipitation: wind: speed/direction: front type: temperature: air pressure:	Cloud type: Weather conditions: precipitation: wind: speed/direction: front type: temperature: air pressure:
DAY 4	DAY 4
Cloud type: Weather conditions: precipitation: wind: speed/direction: front type: temperature: air pressure:	Cloud type: Weather conditions: precipitation: wind: speed/direction: front type: temperature: air pressure:

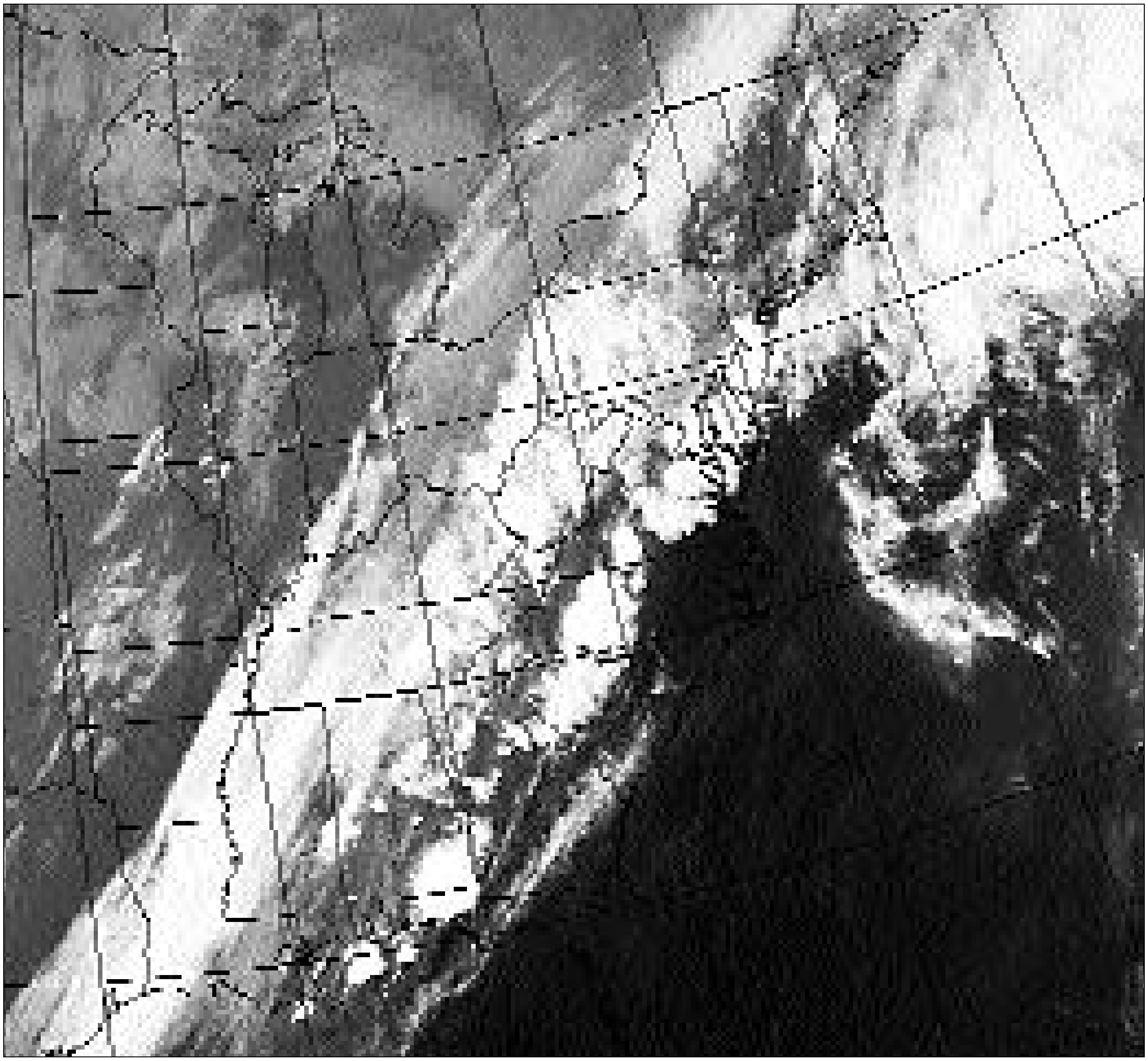


figure 75v. NOAA 10, March 28, 1994
visible image courtesy of G. Chester, Smithsonian Institution, Albert Einstein Planetarium

Note: See figure 71a (page 175) for additional information about figures 75v and 75i.

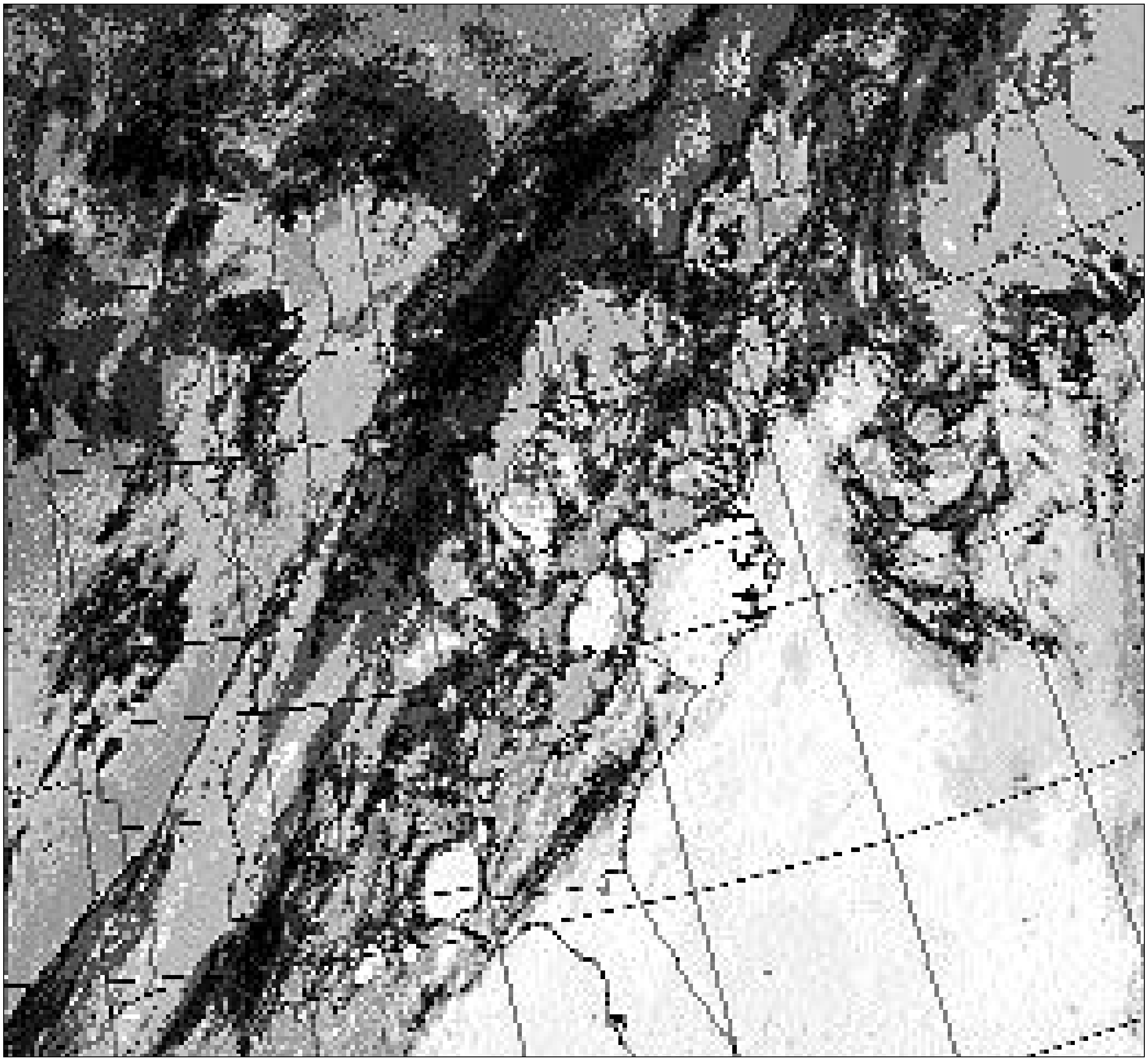


figure 75i. NOAA 10, March 28, 1994
infrared image courtesy of G. Chester, Smithsonian Institution,
Albert Einstein Planetarium

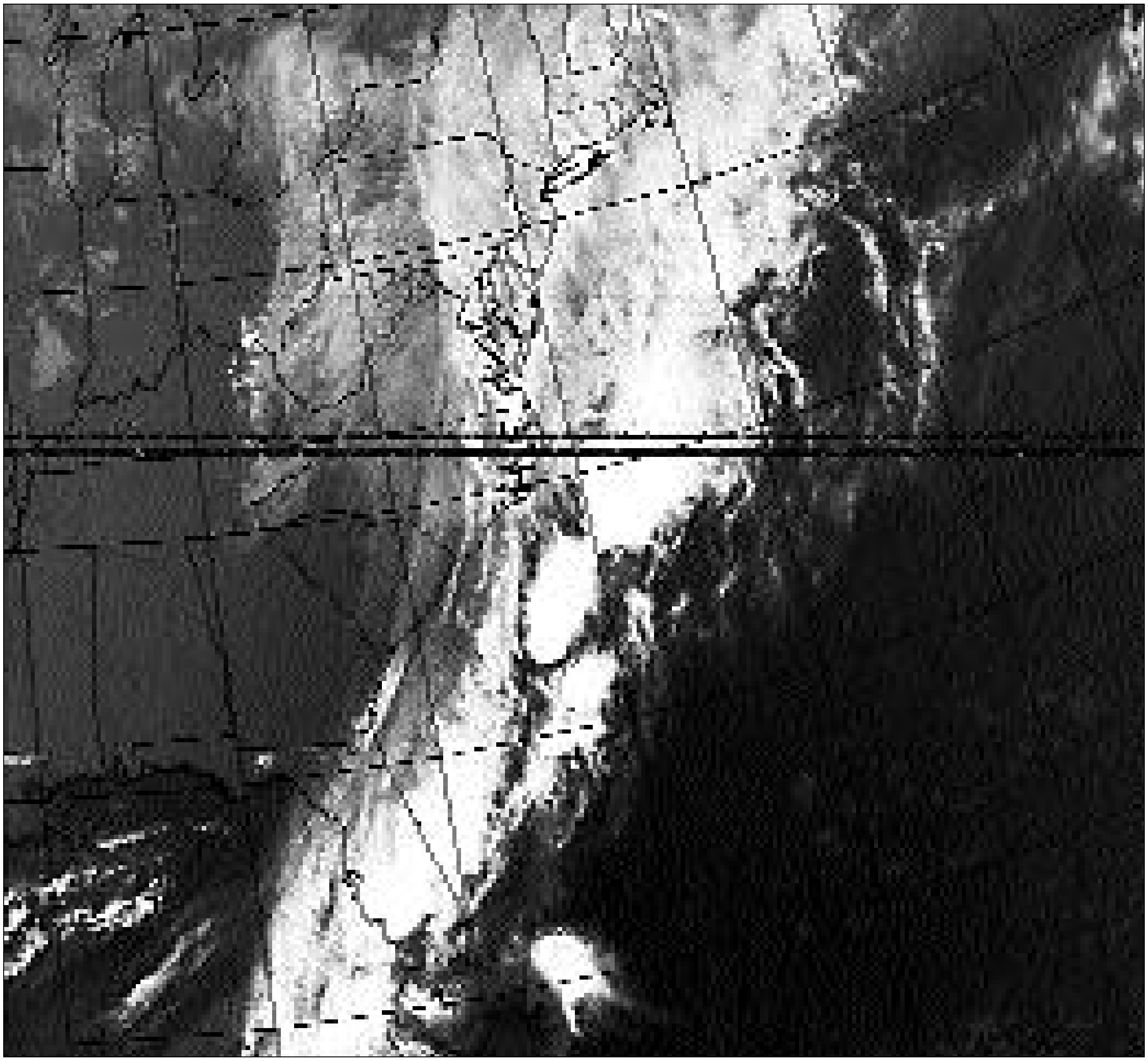


figure 76v. NOAA 10, March 29, 1994
visible image courtesy of G. Chester, Smithsonian Institution,
Albert Einstein Planetarium

Refer to figure 72a, page 178 for additional information abouth this image.

Reception of satellite images is often affected by local sources of interference—**noise**. On satellite images, interference typically appears as horizontal stripes, as in this image. Common sources of interference are household appliances, motors (heating and cooling, vacuum cleaners, etc.), radio and aircraft transmissions, automobiles, and fluorescent lights. The higher the frequency, the less susceptible the receiving equipment is to noise (geostationary reception is less affected than polar-orbiting satellite reception).

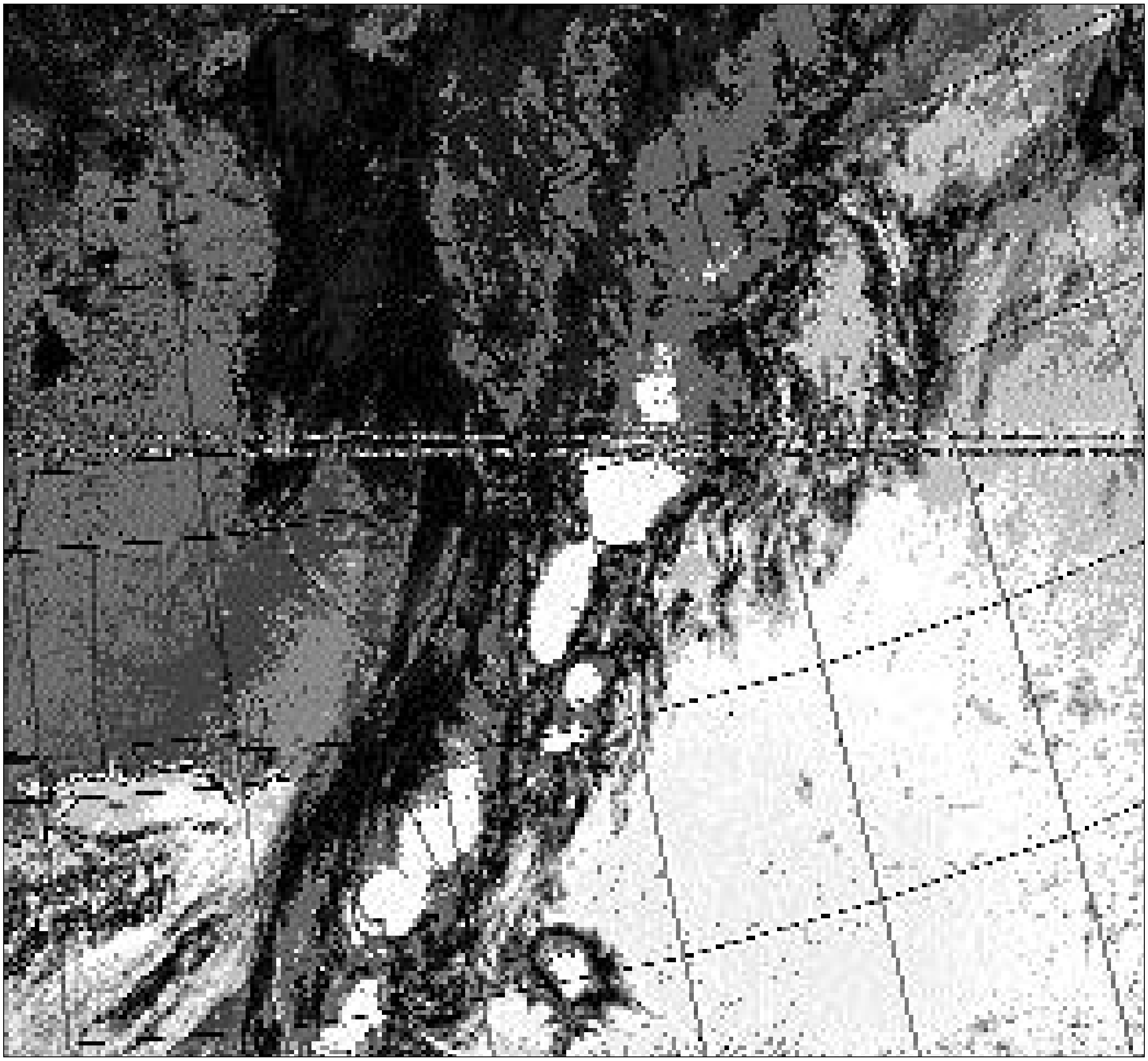


figure 76i. NOAA 10, March 29, 1994
infrared image courtesy of G. Chester, Smithsonian Institution, Albert Einstein Planetarium

Classification of Cloud Types Through Infrared APT Imagery

Authors:
Stu Chapman, Southampton Middle School, Bel Air, Maryland
Bill Davis, DuVal High School, Lanham, Maryland
Tony Marcino, Margaret Brent Middle School, Helen, Maryland

Grade Level: 5–8

Objectives:
Students will be able to:
1. Use statistical methods to analyze and display direct readout APT infrared (thermal) imagery;
2. Communicate experimental procedures through mapping and computer simulation;
3. Classify clouds into three types according to the altitude of the cloud tops using infrared APT imagery photographs; and
4. Use cloud classification data to predict possible locations where precipitation may be forecast.

Science Thinking Skills:
Categorizing, classifying, constructing, contrasting, decision-making, defining, describing, discussing, generalizing, identifying, identifying the main idea, justifying, observing, organizing, sequencing, summarizing, visualizing

Relevant Disciplines:
Earth and space science, geography, mathematics, art

Time Requirement:
Three science periods on successive days:
day 1 - warm-up exercise, classifying clouds
day 2 - classifying clouds on infrared APT images
day 3 - simulating computer imaging software

Image Format:
APT infrared imagery

Materials:
1. 35 mm slides depicting at least nine major cloud types. If slides are unavailable, substitute textbook pictures.
2. Four to five sets of cloud cards displaying various cloud types and classifications (pages 199–201).
3. Student worksheets and *Cloud Type Survey*, U.S. outline map, one student scanner map, and the computer simulation worksheet, all enclosed.
4. APT groundstation(s), images obtained via internet, or photographs of satellite images.
5. One infrared APT image of the local geographic area - **large enough to display to the whole class** - which clearly displays local topographic surface features (such as the Great Lakes), and all three of the major cloud types as classified by height.
6. APT infrared images - at least three per group - showing at least two of the major cloud types (high, middle, low). These may be supplied on disks for available ground stations, or as photographs of satellite images.

Preparation:

Prior to the first lesson, divide the class into cooperative working groups of four or five and have each group cut out a set of six cloud cards (included). Each card will display the following information:

1. Picture of the cloud with its name
2. Altitude range (0–2 km, 2–6 km, 6–12 km) for each type - some altitudes may be supplied in meters or feet to encourage student conversion of units
3. Composition of the cloud (water, water and ice, or just ice)

You may want to add to the cards provided by making additional cards for altostratus, altocumulus, cirrostratus, cirrocumulus, and nimbostratus.

Reference:

Berman, Ann E. *Exploring the Environment Through Satellite Imagery.*

Background: Clouds

Clouds may be classified by shape, content, or cloud height. For day 1, students will classify clouds by height, based on the appearance of cloud types in the polar-orbiter imagery. Infrared imagery is thermally sensitive, so areas of different temperatures display as different intensities on a gray scale (white is coldest, black is warmest, middle temperatures are shades of gray).

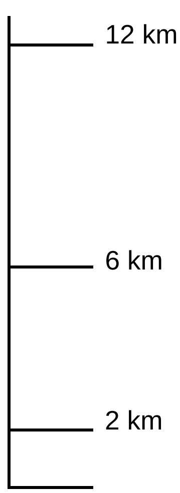
The two basic shapes under which clouds may be classified are:
stratus - layered and sheetlike and cumulus - puffy and heap-like
Many clouds exhibit combinations of both traits. Cloud content may include water droplets only, a mixture of water and ice, or just ice. Cloud heights are generally described as low (under 2 km), medium (2–6 km), or high (6–12 km); these are average cloud heights for the mid-latitudes.

The temperature of the atmosphere generally decreases with height. The rate of decrease in air temperature with elevation is called the environmental lapse rate. An average value for this lapse rate is about 7 degrees Celsius per kilometer. The direct relationship is **adiabatic** (page 48)—moisture helps control and decrease temperature.

In an infrared (thermal) image, temperature provides a quantitative measurement of cloud-top temperature with the coldest areas appearing to be the brightest. Low-level clouds, which are closest to the ground and therefore the warmest, appear dark gray and may be hard to distinguish from the ground. Mid-level clouds appear in medium (brighter) shades of gray due to their cooler temperature. High level clouds, the coldest, appear very pale gray or bright white on thermal images.

If you have an APT groundstation, you may wish to demonstrate how image processing can be used to help identify areas of differing temperature. Each pixel in the image represents a temperature value. *Stretching* the pixels (increasing the contrast) will make temperature variations more discernible. Students can readily see how the tops of cumulonimbus clouds appear dark on a white background, though they would appear all-white without the software manipulation of the image.

figure 77.



High Clouds
These clouds are generally found between 6 and 12 kilometers. Composed primarily of ice, they appear bright white on infrared imagery. Two examples are towering cumulonimbus and cirrus. Cumulonimbus appear as bright white splotches and are often associated with thunderstorm activity. Cirrus clouds appear as bright white streaks — as if they had been painted by a brush.

Middle Clouds
Heights are generally between 2 and 6 kilometers. On infrared images, they appear as a lighter shade of gray than the surface or low-level clouds. Two examples are altocumulus and altostratus. The former will have a mottled texture while the latter will appear more sheet-like. Be aware that the middle level clouds are usually the hardest to determine because they are often shielded by higher level clouds.

Low clouds
Heights generally do not exceed 2 kilometers. Two of the lowest clouds are stratus and fog. On the image, they appear a uniform dark gray shade and lack any texture. Often they are hard to distinguish from the ground because of similarities in temperature and the resulting similarity of the gray shades.

Classification of Cloud Types Through Infrared APT Imagery

Activities

Day 1 - Warm-up

Explain to the students that you will be assessing their prior knowledge of the characteristics of cloud types. To do this, you will show them slides or illustrations of various types of clouds. Be sure not to present the clouds in any sort of order. Describe each cloud as you present them with phrases such as "puffy or heap-like" for cumuliform or "layered or sheet-like" for stratiform clouds.

- After all slides have been viewed, assign each cooperative group to a workstation and distribute the set of index cards with the cloud information. Instruct students to classify the cards into two or more groups, based upon criteria they choose.
- After each group has completed their classification, have them share their classification criteria with the class.
- Have students answer the first two questions on the worksheet, *Classifying Cloud Types Through Infrared APT Imagery.* After they have answered questions (1) and (2), explain to students that they will classify clouds on the basis of their cloud height because the imagery provides temperature information which is directly related to cloud height. (Cloud temperature decreases as the altitude increases.)
- To see how the temperature varies with cloud height, ask students to use the standard atmosphere data provided on their worksheets to make a graph of the decrease in temperature with altitude. These temperature differences can be detected on infrared photographs. They should sketch the different cloud types found in each of the three layers, described as simply low, medium, or high on their *Cloud Type Survey*. Their completed should resemble figure 1.

Display one infrared APT image - large enough for the entire class to see - that contains examples of all three cloud types as classified by height.

Point out the relatively dark and warmer surfaces along with the familiar geographic feature you've included (such as the Great Lakes, Chesapeake Bay estuary, or the Baja peninsula). If you are working with an image at an active ground station, use the imaging software to reveal surface temperatures at various points on the image. Then point out the low, middle, and high cloud types and their resulting appearance on APT infrared imagery.

Day 2 - Classifying clouds on infrared APT images

For procedure, see student worksheet entitled *Cloud Classification*. For the answer to question 1, see 1st paragraph of *Background: Clouds*

Day 3 - Simulating Computer Imagining Software

Procedure on Day 3: Activities, student worksheet titled *Computer Simulation,* and student scanner map, included.

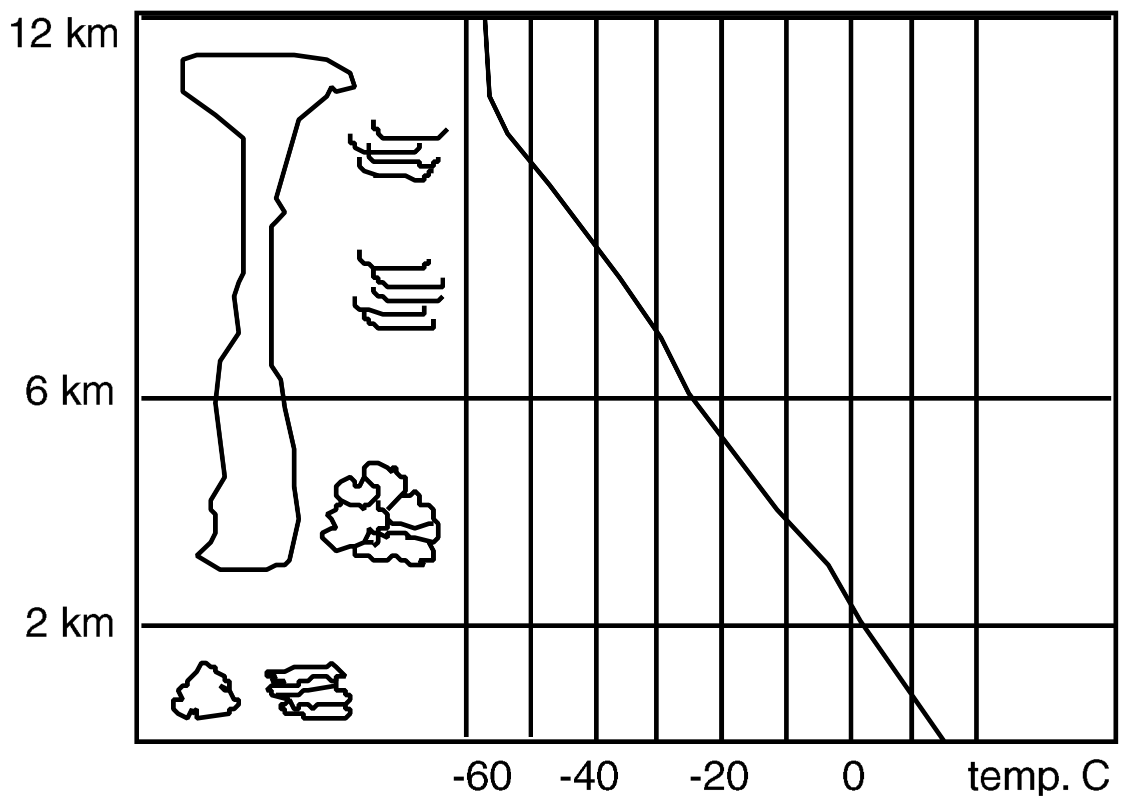


figure 78.

Classifying Cloud Types Through Infrared APT Imagery

name ______________________

Your teacher will provide your group with a set of cards containing information about clouds. Lay each card on the desk. Look at the illustrations of each cloud and the information contained.

1. Divide your cloud cards into at least two - or more - groups based on the information and pictures with which you have been provided. Give each of your cloud-groups a name. How did your science group classify the clouds? List each group and describe how your group made its decisions.

2. Name some other ways that the same clouds could have been classified. Do you think any one way of classification is better than any other? Why or why not?

3. The temperature of the air in the atmosphere changes with its altitude above the surface. Your teacher will provide you with a worksheet entitled *Cloud Type Survey.* To understand how this change occurs, plot a graph on the worksheet that indicates air temperature at several different altitudes. Assume that the temperature of the surface is about 15 degrees Centigrade (about 59 degrees Fahrenheit). Use the data provided in the table, *standard atmosphere, altitude and temperature,* to plot your graph.

name ______________________

altitude in meters	temperature° C
0	15
1000	8.5
2000	2
3000	- 4.5
4000	-11
5000	-17.5
6000	- 24
7000	- 30.4
8000	- 36.9
9000	- 43.4
10,000	- 49.9
11,000	- 56.4

Table 1. standard atmosphere, altitude and temperature

3a. Using the graph you have plotted, estimate the temperature of the air at each of the following altitudes:

a. 6,500 meters ______________________

b. 9.5 kilometers ______________________

c. 1,250 meters ______________________

d. 0.5 kilometers ______________________

e. 1 mile (5,280 feet) [1 meter = 3.28 feet] ______________________

4. The Earth's atmosphere is believed to extend to about 120 kilometers (120,000 meters). Using the graph you have constructed, explain in your own words how the temperature of the air is related to the altitude. (*hint: Do you have enough data from your graph to answer this question with certainty?*)

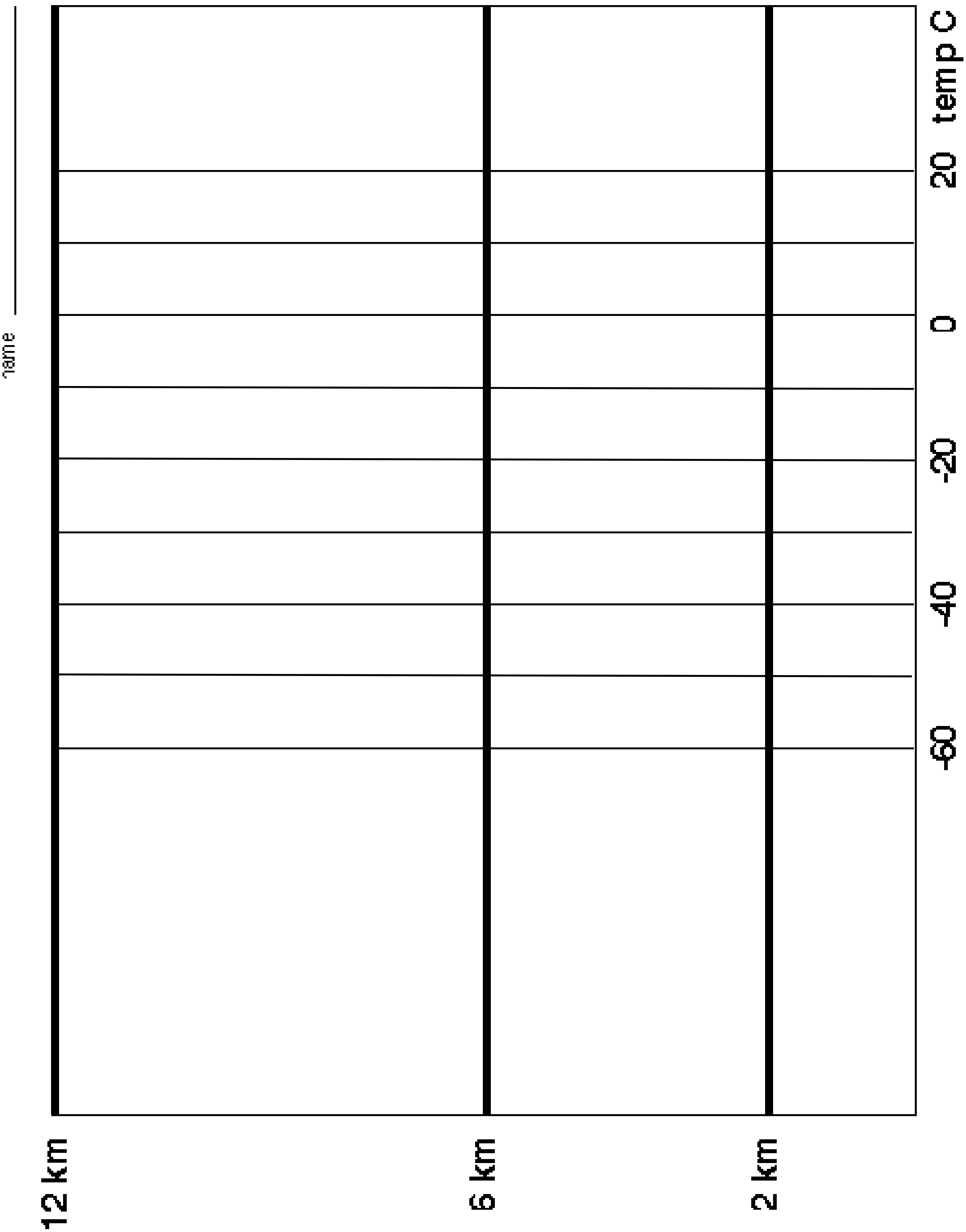
____

____

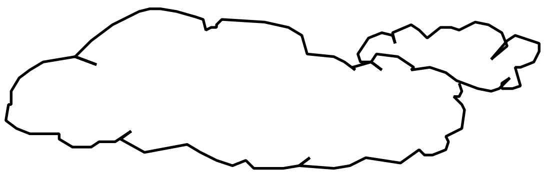
____

5. On the left-hand section of the *Cloud Type Survey*, sketch at least two of the different kinds of clouds which can be found in the low, middle, and high levels of the weather-producing part of the atmosphere (the troposphere).

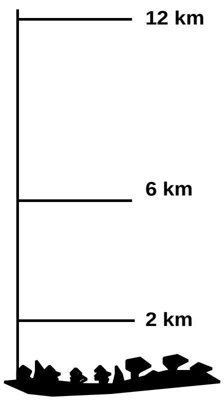
Cloud Type Survey



Cloud Classification



Your group will be provided with two or three polar-orbiting satellite images and a corresponding number of US outline maps. If you have a ground station, your teacher will help you locate images stored on the computer. Use the following criteria to help you in your classification of clouds.



HIGH CLOUDS
These clouds are generally found between 6 and 12 km. They are composed primarily of ice, and appear bright white on infrared imagery. Two examples are towering cumulonimbus and cirrus. Cumulonimbus appear as bright white splotches, and are often associated with thunderstorm activity. Cirrus clouds appear as bright white streaks - as if they had been painted by a brush.

MIDDLE CLOUDS
Heights are generally between 2 and 6 km. These appear as a lighter shade of gray than the surface or low-level clouds on infrared images. Two examples are altocumulus and altostratus. The former will have a mottled texture while the latter will appear more sheet-like. Be aware that the middle level clouds are usually the hardest to determine since they areoften shielded by higher level clouds.

LOW CLOUDS
Heights generally do not exceed 2 km. Two of the lowest clouds are stratus and fog. On the infrared image, they appear in a uniform dark gray shade and lack any texture. Often they are hard to distinguish from the ground because of similarities in temperature.

a. At the top of one of your outline maps, write the name of the satellite and its pass date - information shown on the computer screen or provided by your teacher.

b. Work with your group members to determine the positions of low, medium, and high clouds on the image.

c. Use a color code and color in portions of your three maps as follows:

dark color	low level clouds, identify them by name on your map
gray	mid level clouds, identify them by name on your map
red or yellow	high level clouds, identify them by name on your map

d. Repeat this process with each map and image.

1. In this activity, clouds are classified according to height (low, medium, high). Why is this classification method used instead of another?

____

____

____

2. Are there any areas on your maps where precipitation may be occurring? Which map, and in what states? How do you know?

____

____

3. Sometimes the images can be processed by computer software. One of many possible enhancements of an image is called ***stretching*** (increasing pixel contrast). You have probably seen stretched cloud images by a weather forecaster on television. To illustrate the process of stretching, choose a colored pencil which has not been used in your color code, such as blue or green. On one of your maps, color over all of the mid-level clouds with your blue or green pencil. Using the graph you made yesterday, what temperatures correspond to the areas that you have stretched?

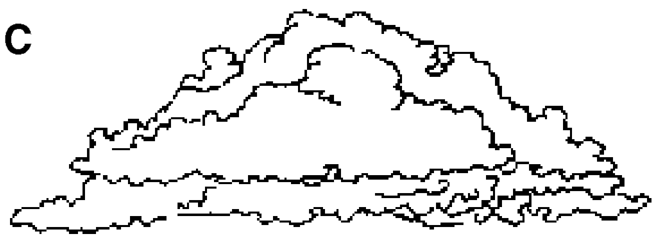
____

Name: **Cumulus**

Altitude: < **2 km**

Composition: **Water**

Temperature: **5° to 15° C**



Name: **Fog**

Altitude: < **5000 ft.**

Composition: **Water**

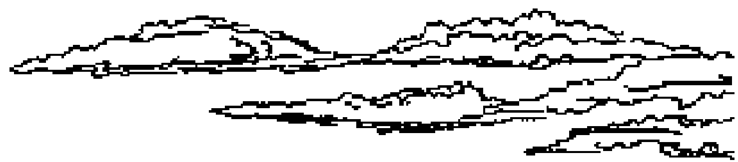
Temperature: **10° to 20° C**

Name: **Stratus**

Altitude: < **2 km.**

Composition: **Water**

Temperature: **5° to 15° C**

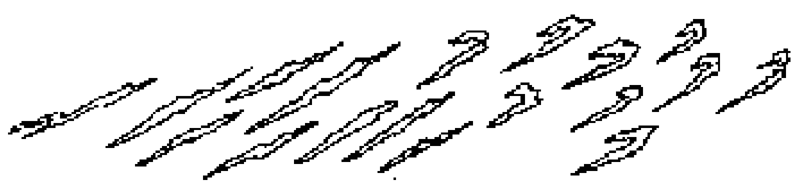


Name: **Cirrus**

Altitude: < **6 km.**

Composition: **Ice Crystals**

Temperature: **-50° to -60° C**

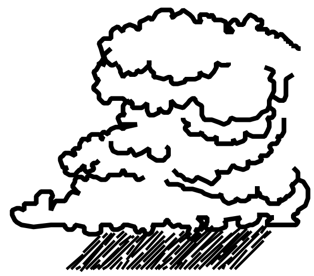


Name: **Cumulus congestus**

Altitude: **6 km**

Composition: **Water**

Temperature: **-10° to -20° C**

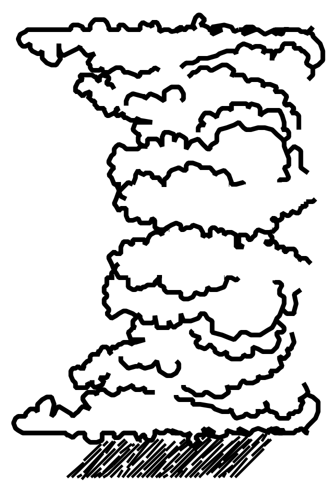


Name: **Cumulonimbus**

Altitude: **12 km**

Composition: **Water and Ice**

Temperature: **-50° to -60° C**



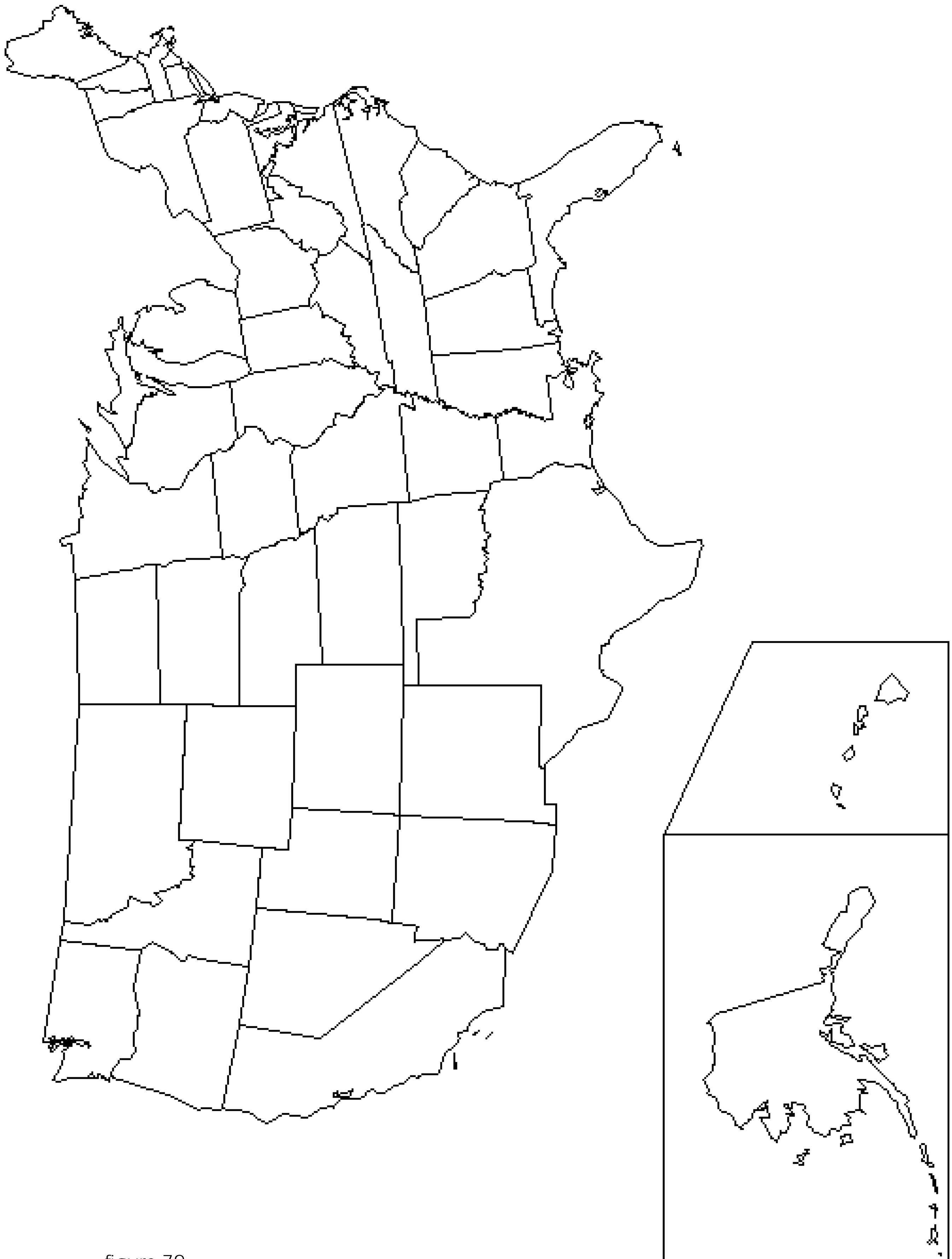


figure 79.

SIMULATING COMPUTER IMAGING SOFTWARE

Activities

Day 3

In this exercise, the method for producing a satellite-generated image will be studied. The concept of computer enhancement will be introduced, but instead of using a computer, the student will generate an image on a piece of graph paper superimposed upon a map of the eastern U.S. seaboard.

Students should imagine a broadcast of infrared data from a NOAA satellite on a descending orbit from the North Pole in the morning hours. An area is observed by the satellite as a series of temperatures, the information is encoded, and sent as radio signals. When the signal is received by an Earth station, the radio signals are decoded and displayed on a computer monitor. The image (this is not a photograph) produced is actually made up of thousands of tiny squares called picture elements or ***pixels***.

Each pixel is assigned a number value between 0 and 255. The number assignments are determined by the temperatures that were measured by the NOAA satellite sensors during its pass. In this system:

0 represents pure black (warmest)
255 represents pure white (coldest)
all values in between are shades of gray.

The value of each pixel is electronically transferred as a byte. A ***byte*** is a unit of eight bits of data or memory in microcomputer systems. ***Bit*** is a contraction of binary digit, which is the basic element of a two-element (binary) computer language.

Provide each student with:

- a Computer Simulation worksheet
- the Scanner Map Shading Chart
- a Student Scanner Map composed of 26 squares by 34 lines to represent 884 pixels

Students will use colored pencils to shade in each square (pixel) according to the suggested color code on the map and on the shading chart. They should note their start and completion times to enable them to calculate their rate and compare it with a NOAA satellite rate. It is important that they shade in one row of the image at a time, beginning at the top, since they are simulating a satellite descending from the North Pole. When the image is completed (p. 207) students should observe the familiar geographical features of the United States with a large cold front and its associated *comma cloud* formation over the Ohio Valley. A comma cloud is a band of cumuliform clouds that look like a comma on a satellite image. Make several transparency copies of the East coast map on the preceding page to help students locate the weather patterns.

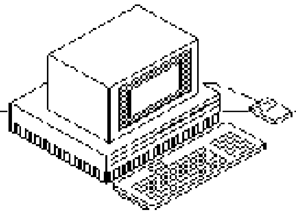
Answers for Computer Simulation Worksheet

1. 640 pixels x 480 pixels = 307,200 pixels
2. 24 pixels x 36 pixels = 864 bytes = 6912 bits

Answer for extension

The binary code equivalent of 80 is 01010000.

Computer Simulation



name ____________________

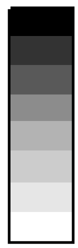
Imagine a broadcast of infrared data from a NOAA satellite descending from the North Pole in the morning hours. The observed image must be encoded and then sent as a radio signal. The entire image seen is actually made up of tiny squares called picture elements or **pixels**.

The brightness of each pixel is assigned by a number value between 0 and 255. In this system,

0 represents pure black (warmest)

255 represents pure white (coldest)

all values in between are shades of gray



1 pixel = 1 byte = 8 bits

1 pixel is electronically transferred as 1 byte
1 byte equals 8 bits of data

1. The APT images you have been working with are rectangular, 640 pixels wide by 480 pixels long. How many pixels compose the image? __________

2. Pretend that you are a computer that will analyze several bytes of information. You will be presented with a table of 24 x 36 pixels. How many bytes of data is this? __________ How many bits of data? __________

   To determine your transmission rate per minute, enter your start time. __________

3. Shade the figure according to the information on page 205. When acquiring an image from a NOAA satellite in descending orbit, the satellite image will appear one line at a time from top to bottom. That is, all 26 pixels in the top row are colored in first. Then the second row is completed, and so on.

   Write the time when you completed the shading. __________

4. What is your bit rate? (How many squares–pixels–could you fill in per minute multiplied by eight bits per pixel.) __________

5. NOAA satellites transmit data at 120 lines per minute. How does this compare with your personal transmission? Remember, you have 34 lines by 26 pixels.

   ____

6. What cloud patterns might be detected from your observations?

   ____

   ____

7. From your map, can you determine if any precipitation might be occurring?

   ____

   ____

Scanner Map Shading Chart

Shade the scanner map as shown in the box below.

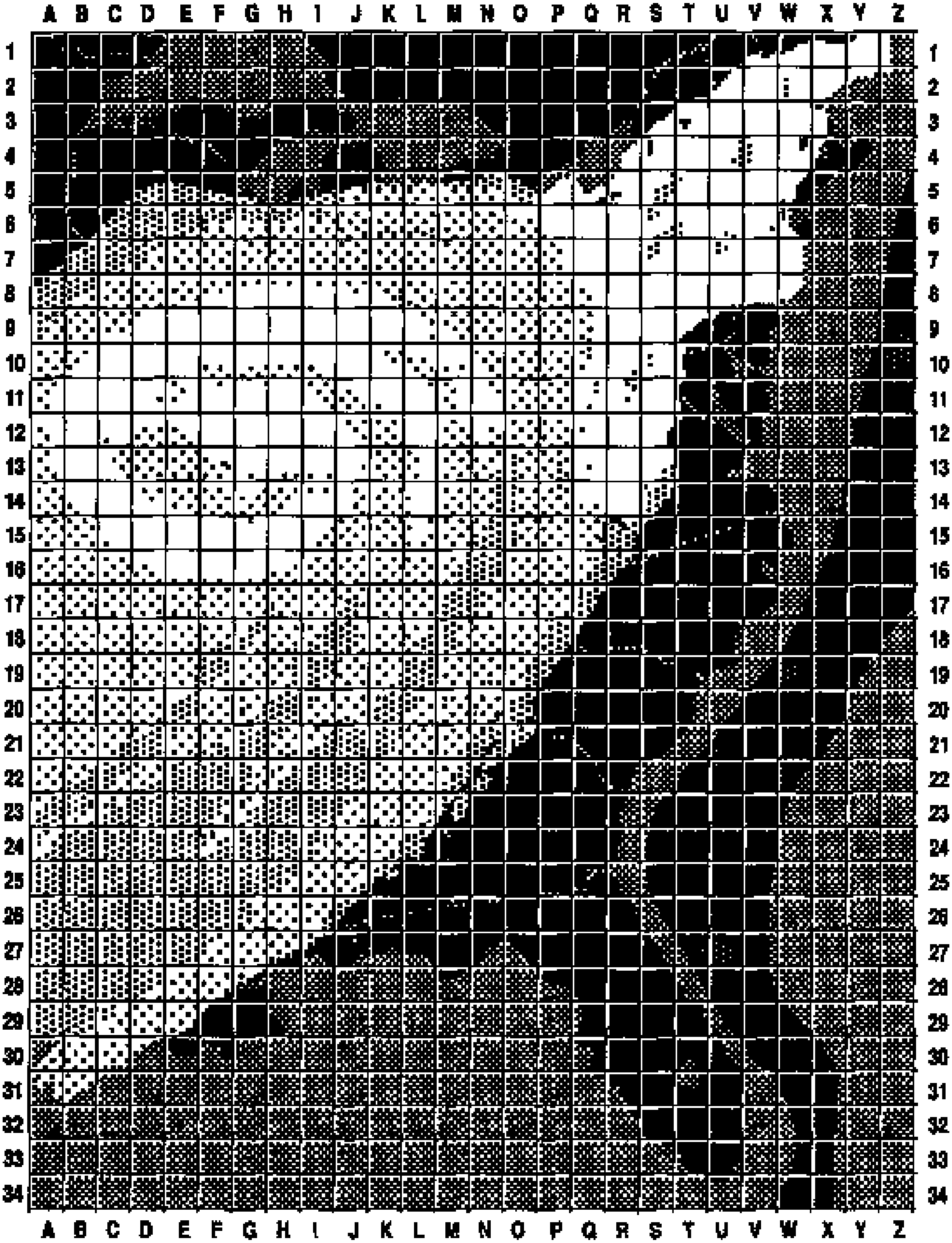
Decimal Equivalent	Temperature Range	Color
0–45	> 15 ° C	black
46–90	between 10° C and 14° C	dark blue
91–135	between 5° C and 9° C	light blue
136–180	between 2° C and 4° C	orange
181–225	between -22° C & + 1° C	yellow
131–255	colder than - 22° C	white

STUDENT SCANNER MAP

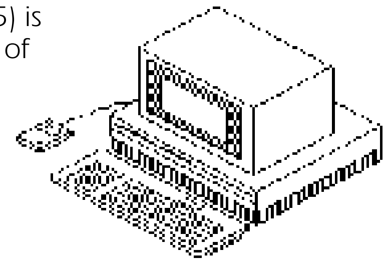
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	23
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	27
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	28
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31
32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	32
33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	33
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	34

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Completed Student Scanner Map



EXTENSION



How does the computer know which number (0 to 255) is being encoded? It receives the information in the form of computer information storage called a ***byte***. The byte itself is actually sent as a number in ***binary code*** - the binary system describes all numbers with combinations of 0 and 1. Each digit of the binary code is called a ***bit***. So each bit is either a 0 or a 1.

Examine the chart below and you will see that the binary number code system is very much like the decimal system that we use, except that ones, tens, hundreds, and thousands places are replaced by ones, twos, fours, eights, sixteens, and so on.

figure 80.

128	64	32	16	8	4	2	1	place
1	1	1	1	1	1	1	1	= 255
0	0	1	0	0	1	0	1	= 37
1	0	0	0	0	0	0	0	= 128
1	1	0	0	1	0	1	1	= 203
								= 80

The example above shows how only four of the pixels in a picture are encoded. Each of the three signals is called a ***byte***, composed of eight ***bits***.

In the bottom row (or byte), see if you can provide the binary code which would provide the value of 80.

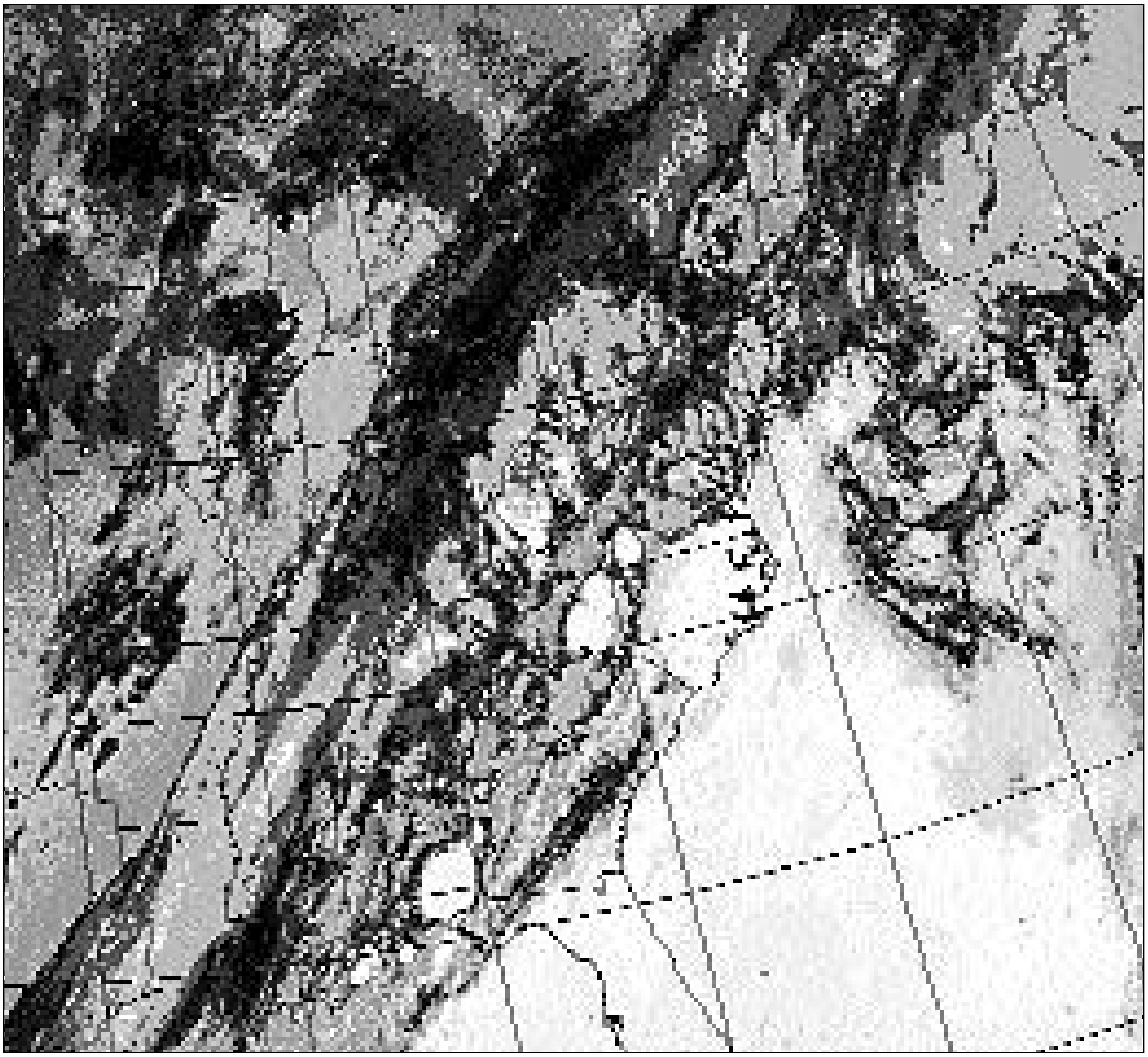


figure 81. NOAA 10, March 28, 1994
infrared image courtesy of G. Chester, Smithsonian Institution,
Albert Einstein Planetarium

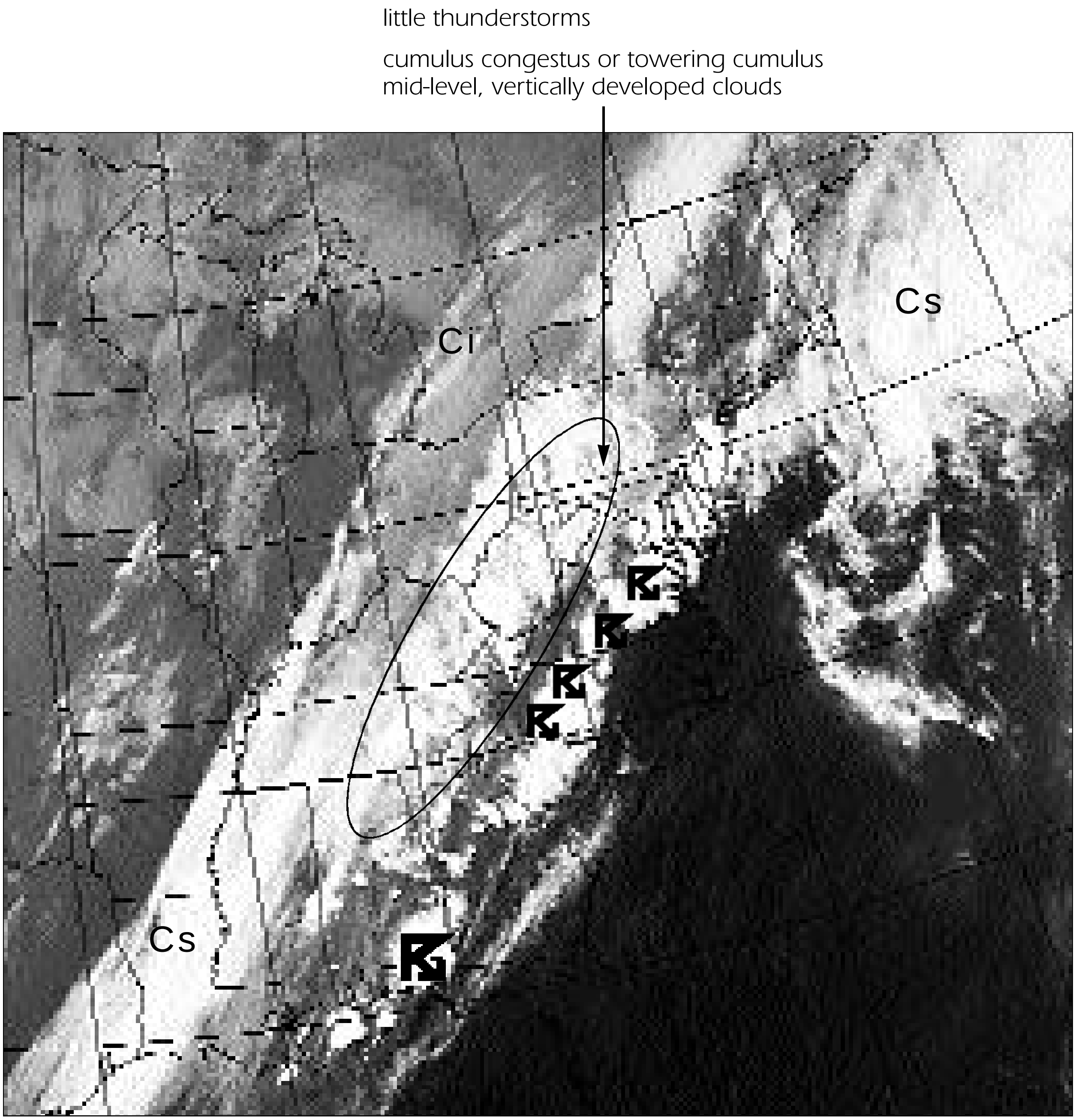


figure 81a. NOAA 10, March 28, 1994
image courtesy of G. Chester, Smithsonian Institution, Albert Einstein Planetarium

Visible image - counterpoint to figure 81

Images on computer will more clearly display temperature gradients and facilitate assessment of the infrared image.

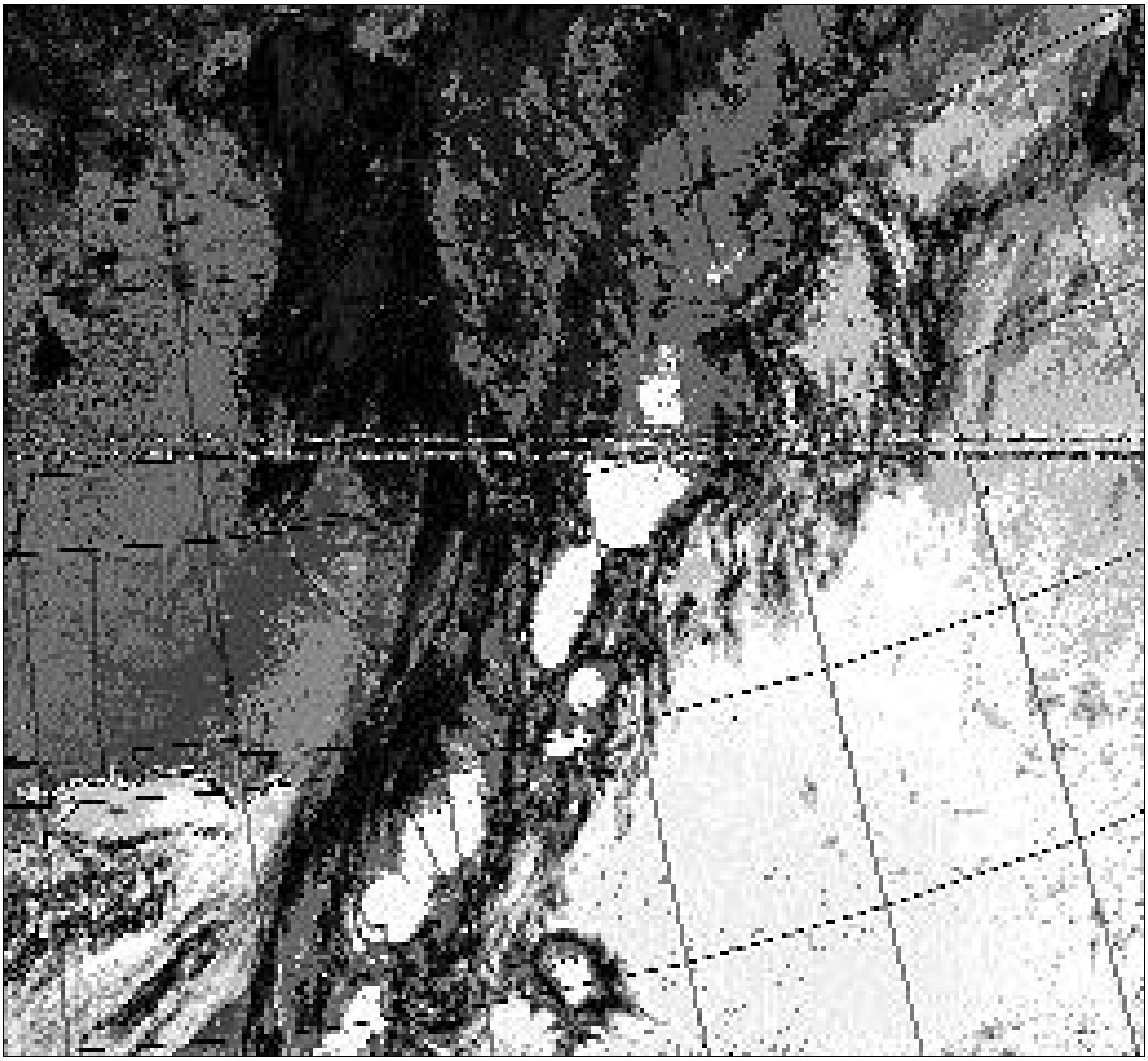
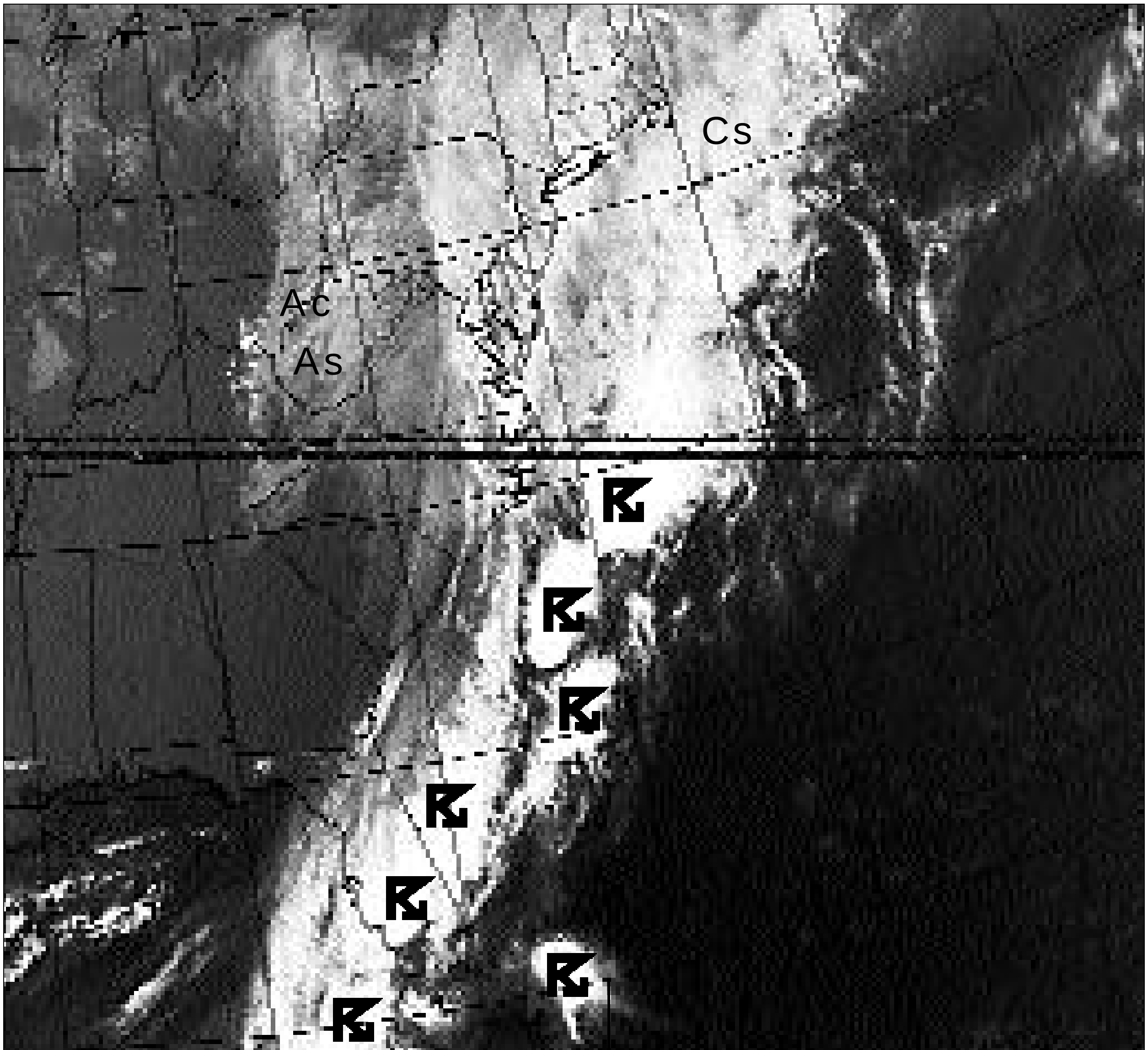


figure 82. NOAA 10, March 28, 1994
infrared image courtesy of G. Chester, Smithsonian Institution,
Albert Einstein Planetarium



Ci on edges of thunderstorm

figure 82a. NOAA 10, March 28, 1994
image courtesy of G. Chester, Smithsonian Institution, Albert Einstein Planetarium

Visible image - counterpoint to figure 103.

Images on computer will more clearly display temperature gradients and facilitate assessment of the infrared image.

A Comparison of Visible and Infrared Imagery

Authors:
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Bill Davis, DuVal High School, Lanham, Maryland
Tony Marcino, Margaret Brent Middle School

Grade Level: 5–8

Objectives:
Students will compare APT visible and infrared imagery to demonstrate:
1. Organizing and presenting data; and
2. Interpreting evidence and inferring.

Relevant Disciplines:
Earth and space science, geography, art, oceanography

Time Requirement:
At least two science periods, one for lab, the other for assessment. Additional lab time may be provided to ensure student success.

Image Format:
APT, visible-infrared image pairs

Materials:
1. World atlas
2. Student worksheets, including outline maps of the areas described below
3. Colored pencils
4. APT visible and infrared images in pairs, large enough to display to the entire class, or as slides for projection
5. APT image pairs of visible and infrared images of:
   - Eastern USA containing low, middle, and high clouds
   - Southern Great Lakes region - preferably images recorded from an evening pass during the summer months
   - Gulf stream area - preferably taken during the winter months
   - Assorted images for assessment. The images should include several cloud types in thermal and visible images, as well as other objects such as a gulf stream on an infrared image

note: These images may be supplied as prints if an Earth station is not available.

Advance Preparation:
1. Divide the class into cooperative groups of at least 4 students.
2. Provide each group with at least three image pairs (infrared and visible images).

Activities

Warm-up:

Place a visible-infrared APT image pair on the screen for the entire class to view. The pair should contain at least two of the differences between the types listed in the Teacher Background, which can be readily pointed out to the students. Explain, using specific examples, some of the differences between infrared (IR) and visible imagery.

Procedure:

Pass out the visible-IR image pairs (listed under materials) to each cooperative group. Hand out worksheets. Ask students to examine the images and determine which are IR and which are visible. After students confer, you may wish to check with each group before allowing them to proceed.

As you walk about the room to monitor the students' success, the following points about the images will be helpful:

1 The warmer waters of the Gulf Stream will be readily distinguishable from the colder waters of the North Atlantic on the IR image. This differentiation will not be noticeable on the visible image.

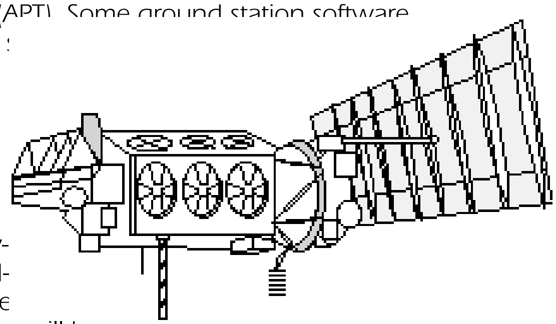
2. Clouds will look white on the visible image because they show reflected sunlight. Shadows will be readily apparent. If the shadows point westward, it is a morning image (sun in the eastern sky). If the shadows point eastward, it is an evening image (sun in the western sky). Clouds on the IR image will appear in differing shades of gray depending upon their temperature (related to their height).

3. A July IR image of a hot day will easily distinguish cities from their surroundings. The warm asphalt and concrete are radiating more infrared energy than the surrounding vegetation. The following are some of the cities that should be easily distinguished by students—with the help of a student gazetteer (a book containing geographical names and descriptions). This list is applicable when using imagery of the Southern Great Lakes region.
   - Detroit, Michigan
   - Milwaukee, Wisconsin
   - Toledo, Ohio
   - Indianapolis, Indiana
   - Dayton, Ohio
   - Columbus, Ohio
   - Fort Wayne, Indiana

4. On the following day, you may wish to give your students an assessment of their individual ability to identify visible and infrared images. Student instructions are on page 218. Using additional image pairs and practice will help ensure their success.

Background: APT Imagery

National Oceanic and Atmospheric Administration (NOAA) polar-orbiting satellites provide both visible and infrared imagery of Earth in a low-resolution format called Automatic Picture Transmission (APT). Some ground station software is able to display both types of images s the comparison process.



The visible images display see-able topography, and are dependent upon sunlight to illuminate features. Consequently, it is productive to acquire visible images only during day-time. Only visible images contain shad-ows. Those shadows fluctuate with the day—shadows early and late in the day will be more pronounced than shadows in mid-day images.

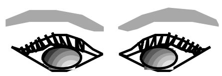
Infrared images display gradients in temperature, with the warmest temperature appearing dark gray or black, and the coldest temperatures displayed as very pale gray or white. Infrared images are not limited by daylight, and provide equally informative images at noon or midnight. Large urban areas will appear on the image as a dark spot — indicating the concentration of concrete and other building materials that retain heat, as well as heat-producing inhabitants (people, cars, utilities, etc.). Such an area is called a heat island and is distinguishable from less developed areas that more quickly react to nature (heating up during daylight, cooling off at night, etc.).

The dominant feature in each image will be clouds.

- In the visible image, almost all the clouds will appear bright white—because reflected light is being observed.
- In the infrared image, the same clouds will appear as varying shades of gray depending upon their temperature (determined by their altitude above the Earth).
- Shadows appear only in visible images.
- Another distinguishing feature between two types of images is that shades of gray may appear in infrared images where little or no contrast is seen in visible images. For example, an image pair of the North Atlantic in winter will display far more shading of the Gulf Stream meshing with the cold Atlantic in the infrared image, than will the visible image.

Comparing Visible and Infrared Imagery

Student Activity Worksheet

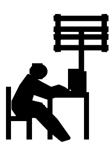


name ______________________

1. Your teacher provided your group with three pairs of APT images. Work with your group to determine which of the pairs are visible and which pairs are infrared. After class discussion, write some of the differences between visible and infrared images.

2. Find the image pair of the Eastern seaboard. Locate some specific geographic features such as capes, bays, estuaries, or peninsulas. Use your world atlas to help. Write the names of some of the features you have located.

3. On your infrared image, you should be able to easily see the warmer waters of the Gulf stream. On your worksheet map, color the waters of the Atlantic ocean light blue. Use a dark blue pencil to draw in the location of the Gulf stream, based on what you see in the infrared image.



If you have a direct readout ground station, have your teacher show you how to determine the temperatures of the water in the Gulf stream and the water surrounding it. Place these temperatures in several locations on your map.

4. Now locate the image pair which shows the mid-Atlantic region. The clouds on the visible image should appear mostly white, while the clouds in the infrared image are various shades of gray and white, depending upon their temperature. On the infrared image, the whites clouds are the highest in altitude (coldest) and the darkest gray clouds are the warmest because they are closest to the ground. Mid-level clouds will appear as a variation between gray and white, if they are visible at all. The whitest clouds are the highest in altitude (coldest).

Use your map of the mid-Atlantic region and three colored pencils to color in at least two different regions. One region should show the location of low-altitude clouds.

Comparing Visible and Infrared Imagery

Student Activity Worksheet

name ______________________

How does the appearance of the low-altitude clouds differ on each of the mid-Atlantic regions?

5. Which of the two images readily shows shadows? Locate some shadows on the image. Sketch the clouds and their shadows on your map. What time of day do you think this image was recorded—morning or evening? (circle one)

   Hint: Which way do shadows point in the morning?

6. Place the final pair of images in front of you. This should be a pair of images taken of the Great Lakes region during the summer months. On your map of the Great Lakes region, label the Great Lakes, using your atlas if necessary. On the infrared images, why does Lake Michigan appear as a different shade of gray than Lake Superior?

7. The image you are using was captured on a hot summer day. On the infrared image, dark areas indicate regions of higher temperature. Locate the city of Chicago, Illinois on your infrared image. Why would Chicago appear warmer than its surroundings?

8. How does the Chicago, Illinois area look different in the visible than in the infrared image?

9. Use your world atlas. Find as many different cities as you can. Mark those cities names and locations on your Great Lakes region map. Can you find more than six?

Comparing Visible and Infrared APT Imagery

Please complete each of the tasks individually.

1. Write the word visible under the visible image. Write the word infrared under the infrared image.

2. Locate a specific geographical location. This should be very general, such as Southern Asia or Northwestern North America. Write the name of the area at the top of both images. You may use the atlas to help you.

3. Locate a region of very high clouds (low temperature) on your pair. Place a few snowflake symbols (⁂) on this region.

4. Locate a region of very low clouds (higher temperature). Mark on of these with an X.

5. Do either (a) or (b), depending on which features are available on your image.

   a. Identify a region of warm water (such as an ocean current) and mark this region with the words warm $H_2$0.
   b. Identify a specific city on your infrared photo. Mark the name of the city directly on the photo.

Comparing Visible and Infrared APT Imagery

Please complete each of the tasks individually.

1. Write the word visible under the visible image. Write the word infrared under the infrared image.

2. Locate a specific geographical location. This should be very general, such as Southern Asia or Northwestern North America. Write the name of the area at the top of both images. You may use the atlas to help you.

3. Locate a region of very high clouds (low temperature) on your pair. Place a few snowflake symbols (⁂) on this region.

4. Locate a region of very low clouds (higher temperature). Mark on of these with an X.

5. Do either (a) or (b), depending on which features are available on your image.

   a. Identify a region of warm water (such as an ocean current) and mark this region with the words warm $H_2$0.
   b. Identify a specific city on your infrared photo. Mark the name of the city directly on the photo.

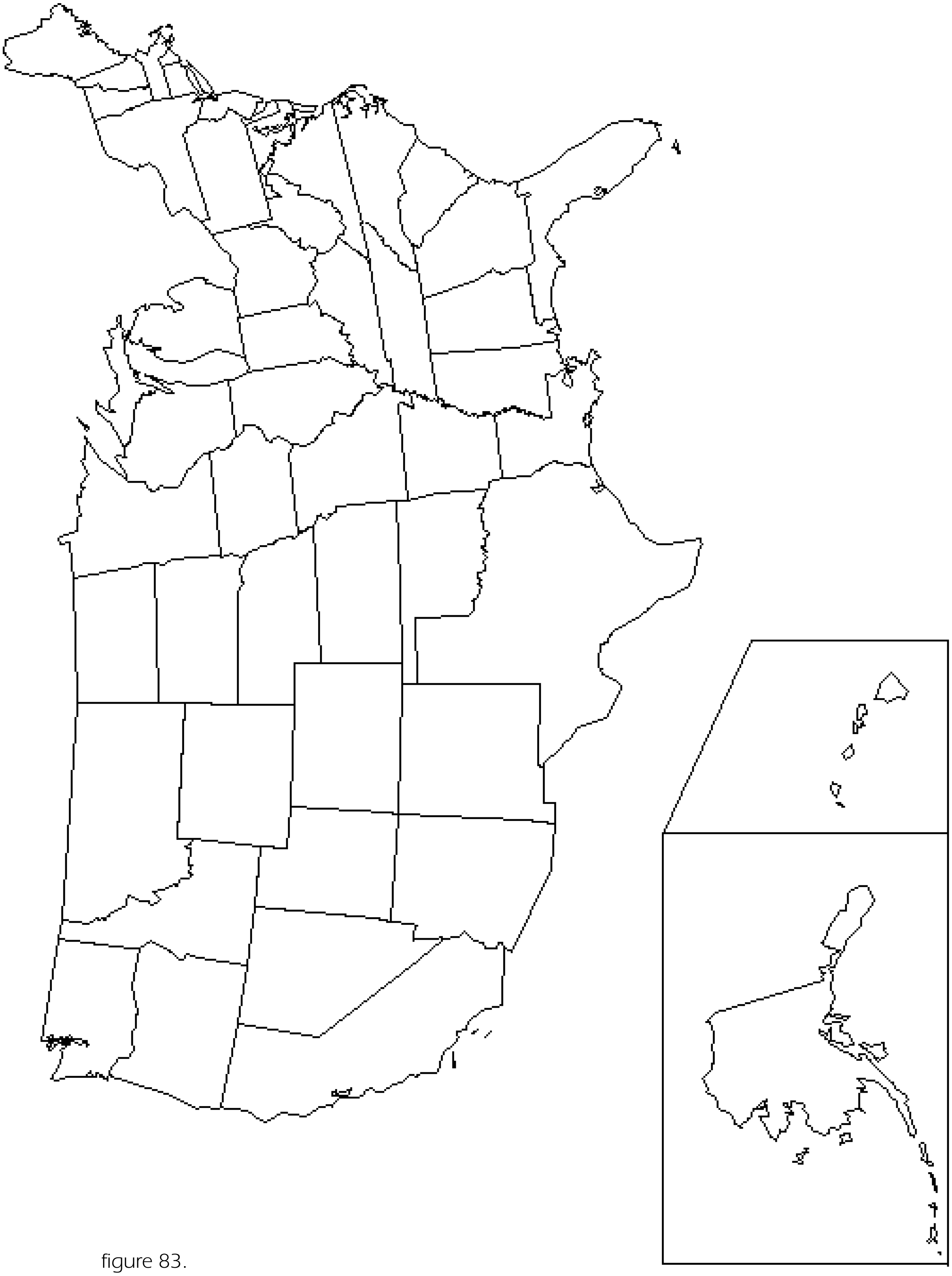


figure 83.

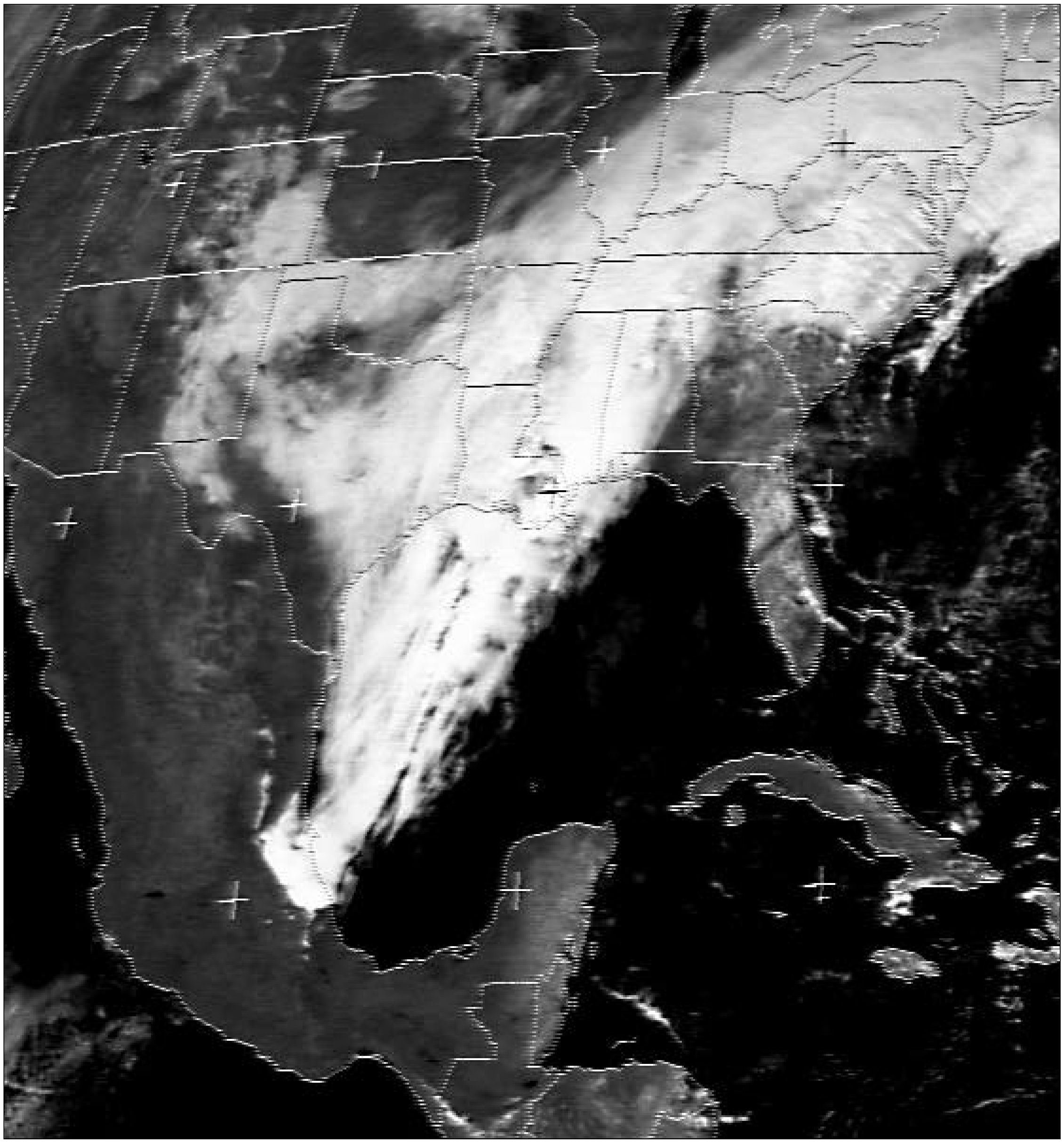


figure 84v. GOES visible image, March 9, 1994
image courtesy of D. Peters, Linganore High School, Frederick, Maryland

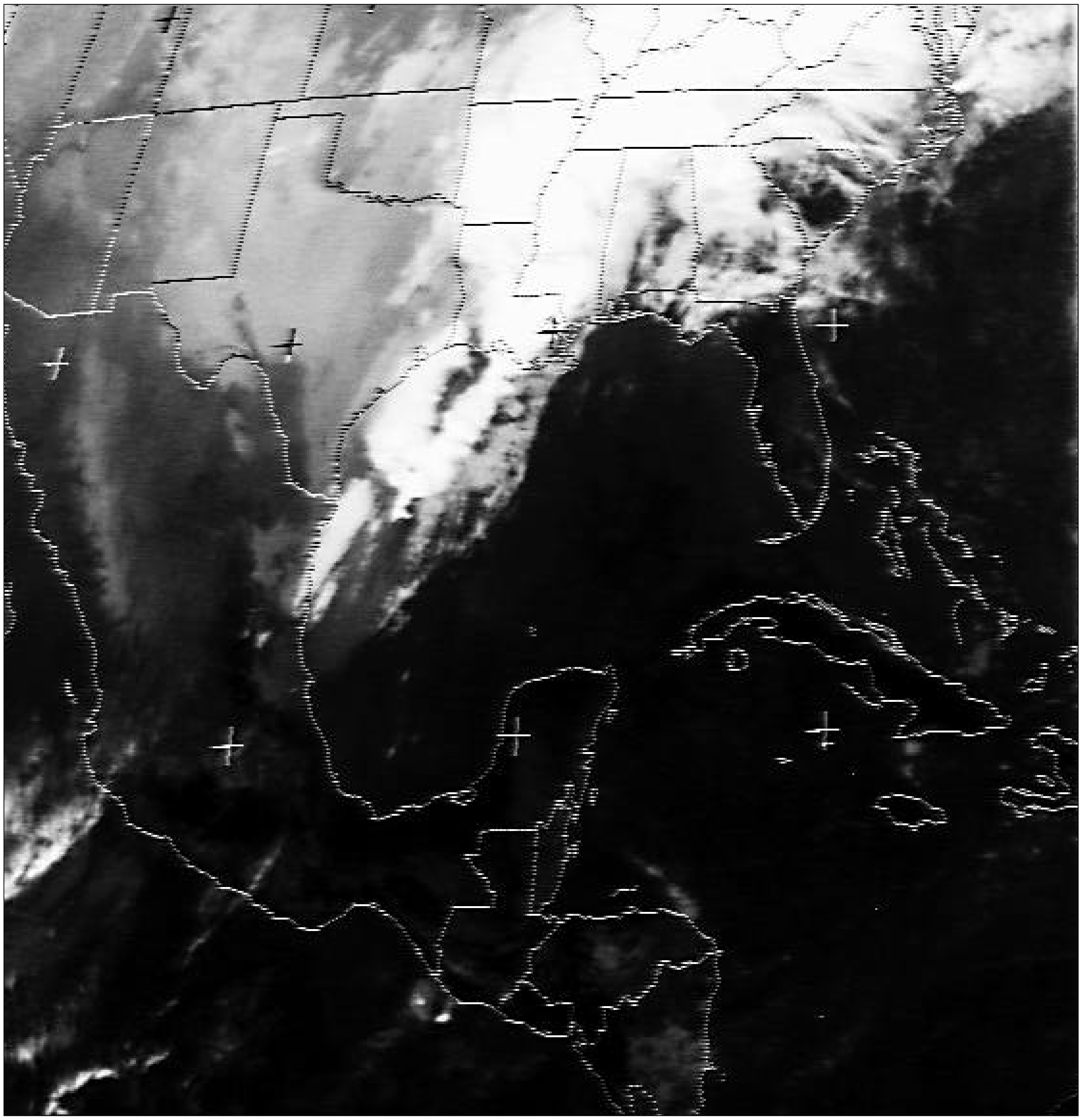


figure 84i. GOES infrared image, March 9, 1994
image courtesy of D. Peters, Linganore High School, Frederick, Maryland

low clouds (see IR image)
but appear to be high on this visible image

mid- to upper level clouds

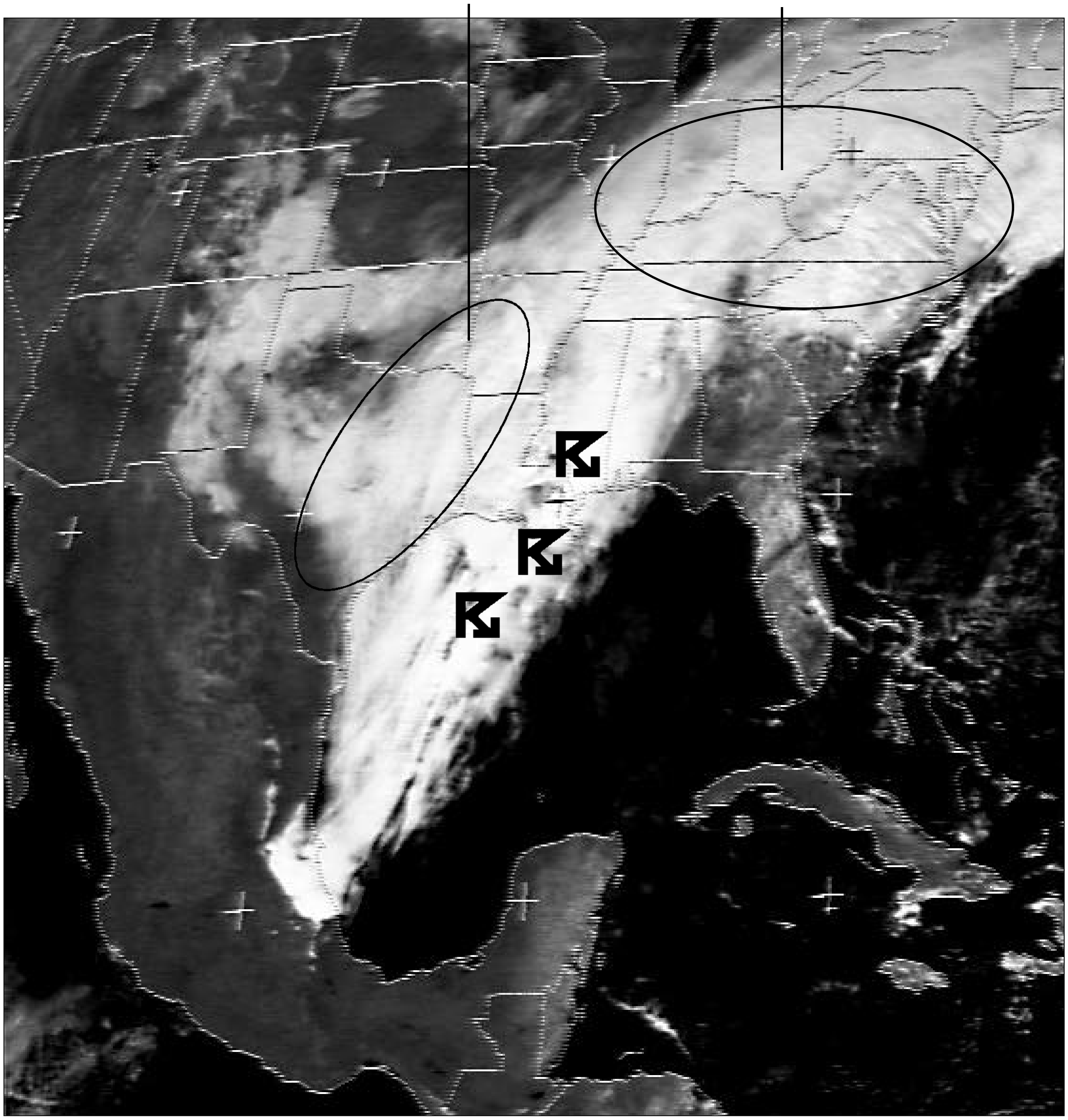


figure 84a. GOES visible image, March 9, 1994
image courtesy of D. Peters, Linganore High School, Frederick, Maryland

Right Down the Line: Cold Fronts

Authors:
Gayle Farrar, Southern Middle School, Oakland, Maryland
Eileen Killoran, Glenelg Country Day School, Glenelg, Maryland
Stacey Mounts, Ballenger Creek Middle School, Frederick, Maryland

Grade Level: 8

Objectives:
Students will discover that a cold front is a boundary between air masses of different temperatures by:
1. Using a table of cities with temperatures and correctly labeling a blank U.S. map,
2. Differentiating between the coolest and warmest cities, and
3. Utilizing the satellite image and the map to draw in the location of the cold front.

Relevant Disciplines:
Earth and space science, geography

Time Requirement:
One class period

Prerequisite Skills:
Students should have:
1. A working knowledge of air masses, and
2. A brief introduction to frontal systems.

Materials:
1. Classroom map of North America with states and cities
2. Satellite image of the United States, taken at the time (or same day) as an approaching severe storm
3. Blank U.S. outline map
4. Weather page from *USA Today* or other newspaper
5. Student activity sheet

Activities

Warm-up:

1. Think of a time a strong storm occurred. What can you remember about it? Write down key words.
2. Now, pair with another student and share your "storm memories."
3. Note similarities to share with the class.

Give students an overview of the task. Then:

- Distribute blank U.S. maps
- Tell students to find the temperature for each city listed on the activity sheet. Temperatures can be found on the USA Today (or other newspaper) weather page.
- On your map, indicate the location of each city with its temperature. (Note: Be sure you have cities on each side of the front and that temperature differences are easily distinguished)
- Circle the six coolest in blue, the 6 warmest in red.
- Have the students work through the student activity sheet.

Note: The lesson warm-up for the following day could include a viewing of AM Weather from public television or other weather forecast. Be sure to videotape it the day of and after the storm.

RIGHT DOWN THE LINE: COLD FRONT

name ______________________

period ______________________

date ______________________

Student Activity Sheet

Step 1:
On your blank map, locate the positions of the cities listed below, use an atlas if needed. At the point on the map where each city is located, write the temperature in degrees Fahrenheit. Obtain the data from the newspaper.

Cities:

Cincinnati, OH	Albany, NY	Norfolk, VA
Columbus, OH	Baltimore, MD	Philadelphia, PA
Buffalo, NY	Cleveland, OH	Washington, DC
Richmond, VA	Pittsburgh, PA	Wiilmington, DE

Step 2:
a. Circle the six coolest temperatures with a blue crayon or pencil.
b. Circle the six warmest temperatures with a red crayon or pencil.

Step 3:
Look at your satellite image of the United States.

Questions

1. What do you notice about the locations of the coolest and warmest temperatures?

____

____

2. Why do you think the temperatures are separated the way they are?

____

____

3. Now observe the satellite image of the eastern United States, taken the same day as the temperatures.

   A. Temperatures have been given for the various cities. According to the satellite image, are there any atmospheric features over these areas? Describe them (if any). ______________________

   ____

   B. Is there anything visible on the satellite photo which could explain the greatest temperature differences? Describe. ______________________

   ____

   C. Now, sketch this feature (from B) on your map of the United States.

   D. This feature forms at the boundary of two very different air masses. This feature is called a ______________________ .

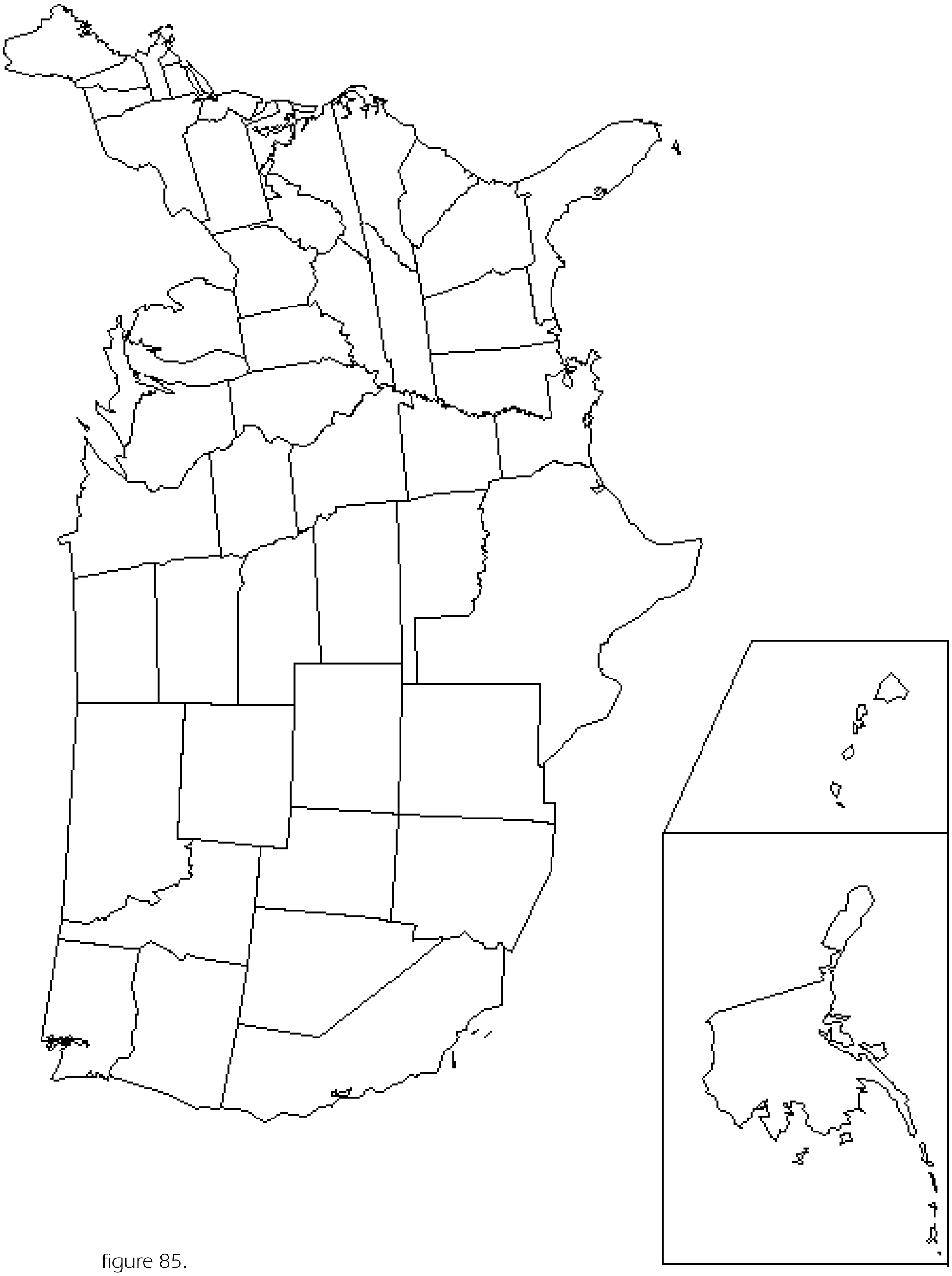


figure 85.

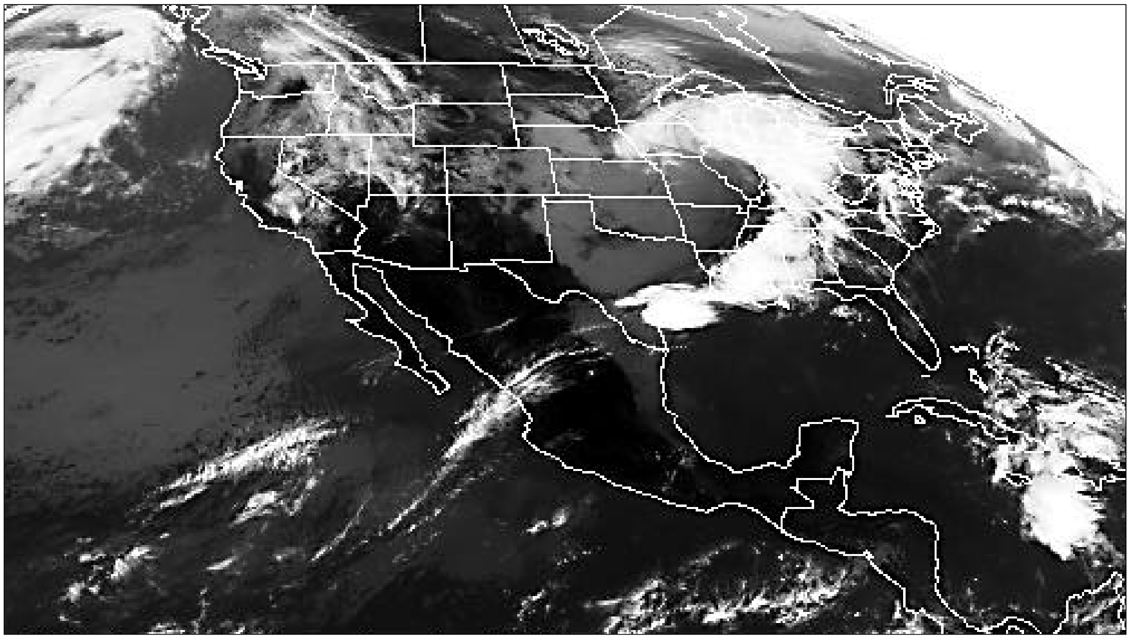


figure 86. GOES, April 30, 1994
image courtesy of M. Ramamurthy, University of Illinois, Urbana/Champaign

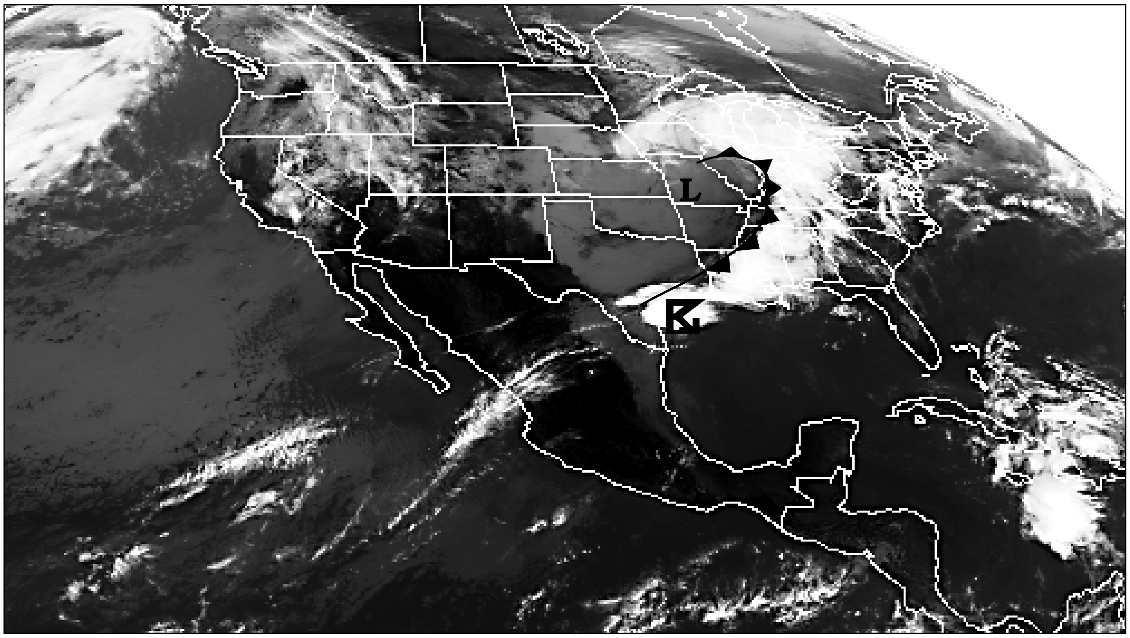


figure 86a. GOES, April 30, 1994
image courtesy of M. Ramamurthy, University of Illinois, Urbana/Champaign

To Ski or not to Ski

Authors:
Gayle Farrar, Southern Middle School, Oakland, Maryland
Eileen Killoran, Glenelg Country Day School, Glenelg, Maryland
Stacey Mounts, Ballenger Creek Middle School, Frederick, Maryland

Grade Level: 8

Objectives:
Students will apply the interpretation of satellite imagery to a “real life” situation by:
1. Interpreting a satellite image, and identifying features (land, water, snow) on the image;
2. Compiling data for five potential winter ski resorts on a chart; and
3. Selecting the best ski resort site and supporting the choice with written statements.

Relevant Disciplines:
Earth and space science, geography, economics, language arts

Time Requirement:
One class period

Image Format:
Polar-orbiter image

Prerequisite Skills:
Basic knowledge of how to identify features such as ice, snow, water, and mountains on a visible satellite image.

Vocabulary:
albedo

Materials:
1. Globe and a variety of maps of North America
2. Satellite image of the Great Lakes region (winter image, with snow cover and minimal clouds)
3. Student activity sheet

Activities

Warm-up:

1. **Think** about what things must be present for a winter ski resort to be successful (list individually).
2. **Pair** with another student.
3. **Share** ideas together with the class.

Give students an overview of the task:

Group cooperative learning

1. You will be given a satellite image of an area of the U.S.
2. First, identify the region using maps and globes.
3. Identify specific features by name (numbers).

Individual effort

4. Examine the potential ski resort sites (letters) and complete the data table.
5. Select the best winter ski resort site and support your answer. (Note: responses may vary with student abilities)

Extensions:

1. What other features can you identify?
2. Can you name them specifically?
3. Give the latitude and longitude of each potential ski resort site.

Divide students into cooperative learning groups

To Ski or not to Ski

name ____________________

period ____________________

date ____________________

S tudent Activity Sheet

Questions:

1. This satellite image shows the __________ __________ region of the United States.

2. Identify the numbered features by name.

   #1 ____________________

   #2 ____________________

   #3 ____________________

   #4 ____________________

   #5 ____________________

Data Table:

Winter Ski Site	COLORS			POSSIBLE TERRAIN					NOTES
	white	black	gray	mts.	water	ice	snow	low land	
A									
B									
C									
D									
E									

To Ski or not to Ski

name ______________________

Student Activity Sheet

Conclusion:

1. If you were financing the construction of a winter ski resort, which location would you support?

____

2. In your own words, explain why you would support one ski resort over all the others. Remember, your data table is full of information for you to use...be specific!

____

INFRARED AND VISIBLE SATELLITE IMAGES

Authors:
Bob Mishev, DuVal High School, Lanham, Maryland
Wayne Rinehart, North Hagerstown High School, Hagerstown, Maryland
Lonita Robinson, Suitland High School, District Heights, Maryland
Nancy Wilkerson, Prince George's County Public Schools, Maryland

Grade level: 9

Objectives:
Students will be able to:
1. Distinguish between visible and infrared energy on the electromagnetic spectrum, and
2. Compare and contrast visible and infrared satellite images.

Relevant Disciplines:
Earth and space science

Time Requirement:
One-two class periods

Image Format:
Geostationary and/or polar-orbiting, visible and infrared

Prerequisite Skills:
Map reading, graphing skills

Vocabulary:
crest, electromagnetic spectrum, infrared radiation, trough, visible radiation, wavelength

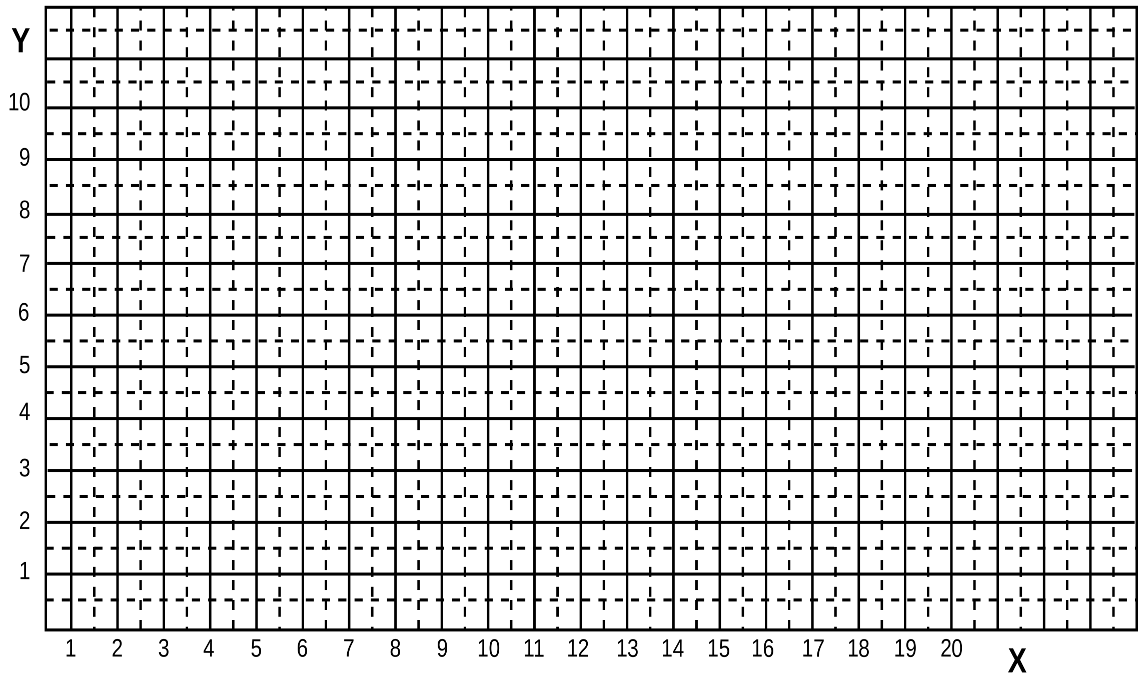
Materials:
1. Map of United States
2. Graph paper
3. Textbook
4. Chart of electromagnetic spectrum
5. Visible and infrared satellite imagery

Activities

1. Plot values on *Activity 1* to show waves of varying lengths. Identify parts of a wave using vocabulary: crest, trough and wavelength.
2. Use textbook and chart to gather information on electromagnetic spectrum. Answer questions on *Activity 2.*
3. Use infrared and visible satellite imagery to complete *Activity 3.*

Infrared and Visible Satellite Images

Activity 1



PLOT:

X	Y
.5	8
1.3	5
2	2
2.7	5
3.5	8
4.3	5
5	2
6	5
7	8
8	5
9	2
10	5
11	8
12.5	5
14	2
15.5	5
17	8
19	5

label point (3.5, 8) **A**
label point (5, 2) **B**
label point (7, 8) **C**
label point 11, 8) **D**
label point (17, 8) **E**

Questions

1. **A** is called the ________________ of a wave.
2. **B** is called the ________________ of a wave.
3. The distance between **C** & **D** is called________________ .
4. The distance between **D** & **E** is called________________ .
5. How are **C** & **D** and **D** & **E** the same ________________ ?
6. How are **C** & **D** and **D** & **E** different ________________ ?

THE ELECTROMAGNETIC SPECTRUM

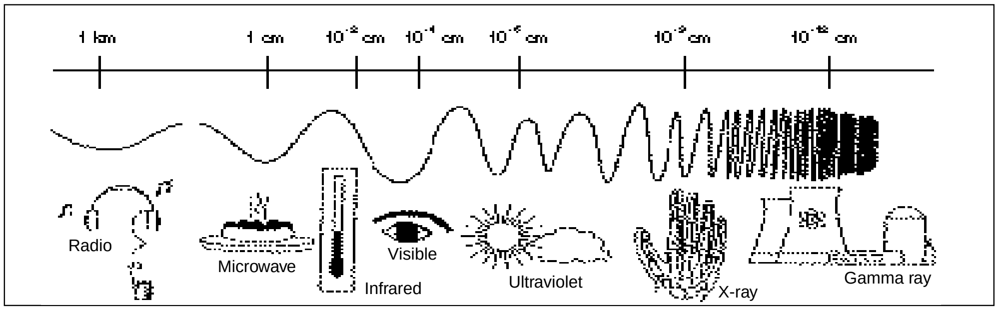


figure 87.

For hundreds of years, scientists believed that light energy was made up of tiny particles which they called “corpuscles.” In the 1600’s, researchers observed that light energy also had many characteristics of waves. Modern scientists know that all energy is both particles—which they call **photons**—and waves.

Photons are **electromagnetic** waves. These waves oscillate at different **frequencies**, but all travel at the speed of light. The **electromagnetic spectrum** is the range of wave frequencies from low frequencies (below visible light) to high frequencies (above visible light).

The **radio wave** category includes radio and television waves, and cordless and mobile telephone waves. These low-energy waves bounce off many materials including the ionosphere, a characteristic that enables radar applications. Radio waves are received and retransmitted by satellites for long-distance communication.

Microwaves pass through some materials but are absorbed by others. In a microwave oven, the energy passes through the glass and is absorbed by the moisture in the food. The food cooks, but the glass container is not affected.

Infrared or heat waves are more readily absorbed by some materials than by others. Dark materials absorb infrared waves while light materials reflect them.

Visible light waves are the very smallest part of the spectrum and the only frequencies to which the human eye is sensitive. Colors are different frequencies within this category.

The atmosphere protects Earth from dangerous **ultraviolet** rays from the Sun. Ultraviolet and extreme ultraviolet radiation are absorbed in Earth’s atmosphere, although some longer ultraviolet wavelengths (UVB) penetrate to the ground. UVB can cause sunburn and is linked to most cases of skin cancer.

X-rays can penetrate muscle and tissue, making medical and dental X-ray photographs possible.

Gamma-ray waves, the highest frequency waves, are more powerful than X-rays and are used to kill cancerous cells.

Humans’ limited senses are extended by technology. Technology that utilizes the full electromagnetic spectrum enable the most comprehensive investigation of Earth.

this lesson contains excerpts from Astro 1, Seeing in a New Light, Teacher’s Guide With Activities, NASA

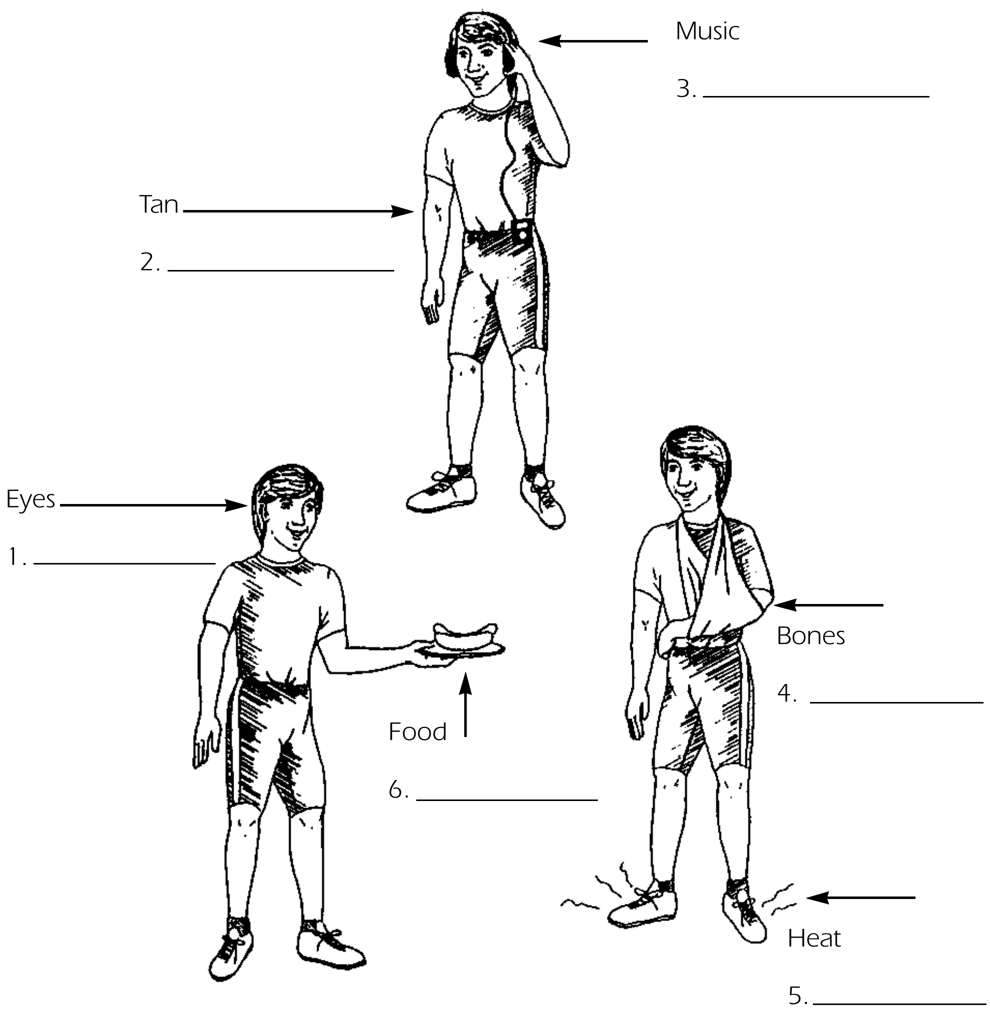
INFRARED AND VISIBLE SATELLITE IMAGES

Activity 2

Light and other kinds of radiation consists of photons that travel in waves.

The Spectrum and You

Different radiation wavelengths are part of your everyday life. Write the name of the wavelength in the blank the way that it affects your life.



microwaves	infrared	visible light
radio waves	ultraviolet	X-ray

Activity 3

Visible Radiation

Seen because of light reflected from objects such as land, clouds, etc.

Light areas indicate very reflective surfaces or colors; dark areas may be shadows, or indicate an area of refraction or the absorption of light.

Infrared Radiation

Seen because of the temperature or heat energy contained in an object.

Light areas indicate objects with lower temperatures while dark areas indicate warmer or more intense heat radiation.

Advantages/Disadvantages of visible vs infrared images

Visible Images	Infrared Images
Daylight use only*	Day or night use
Students familiar	Students unfamiliar

Use infrared and visible satellite imagery of same area to complete Activity 3. Divide each image into four quadrants.

Visible Image 1

1A	1B
1C	1D

Infrared Image 2

2A	2A
2A	2A

Questions

1. What distinguishing features can be identified?
   a. In sections 1A and 2A?
   b. In sections 1B and 2B?
   c. In sections 1C and 2C?
   d. In sections 1D and 2D?

2. Based upon your knowledge of visible and infrared radiation, identify sectors that show visible or infrared radiation.

3. In sections 1D and 2D, what differences can be seen?

4. In section 2D, why do we see differences in shades of gray?

* *The Defense Meteorological Satellite Platform (DMSP) does provide night-time (low light) imagery, however access to the data is limited.*

Infrared and Visible Satellite Images—part 2

Authors:
Bob Mishev, DuVal High School, Lanham, Maryland
Wayne Rinehart, North Hagerstown High School, Hagerstown, Maryland
Lonita Robinson, Suitland High School, District Heights, Maryland
Nancy Wilkerson, Prince George's County Schools, Maryland

Grade level: 9–12

Objectives:
Using weather satellite images, students will:
1. Identify areas of cooler or warmer surfaces on land and water;
2. Use currents to show some magnitude and direction of weather vectors (movements); and
3. Use water currents and cloud formations to identify some temperature differences.

Relevant Disciplines:
Earth and space science

Time Requirement:
1–2 class periods

Image Format:
Geostationary and/or polar-orbiting, visible and infrared

Materials:
1. Direct readout station or computer equipped to display imagery
2. Picture displays or a television that can interface with and display a computer screen

Procedure:
1. Display model images on the screen or bulletin board with identifiable features of: land masses, water bodies, clouds and/or currents.
2. Use a data display (liquid crystal display—LCD) or other display method to enable all students to see imagery.
3. Entire class interacts with imagery displayed.

Activities

Hands-on student identification of:
- Land masses e.g., Florida, Baja
- Water bodies e.g., Great Lakes, Chesapeake
- Cloud formations (small storms, thunderstorms, cyclones, hurricanes)
- Currents (air or water, jet streams)

Note: Some events, such as hurricanes, are seasonal. Timing is critical when using real-time imagery. Developing an archive of files will provide flexibility.

Extensions:
1. Practice, practice, practice
2. Follow a storm, make predictions

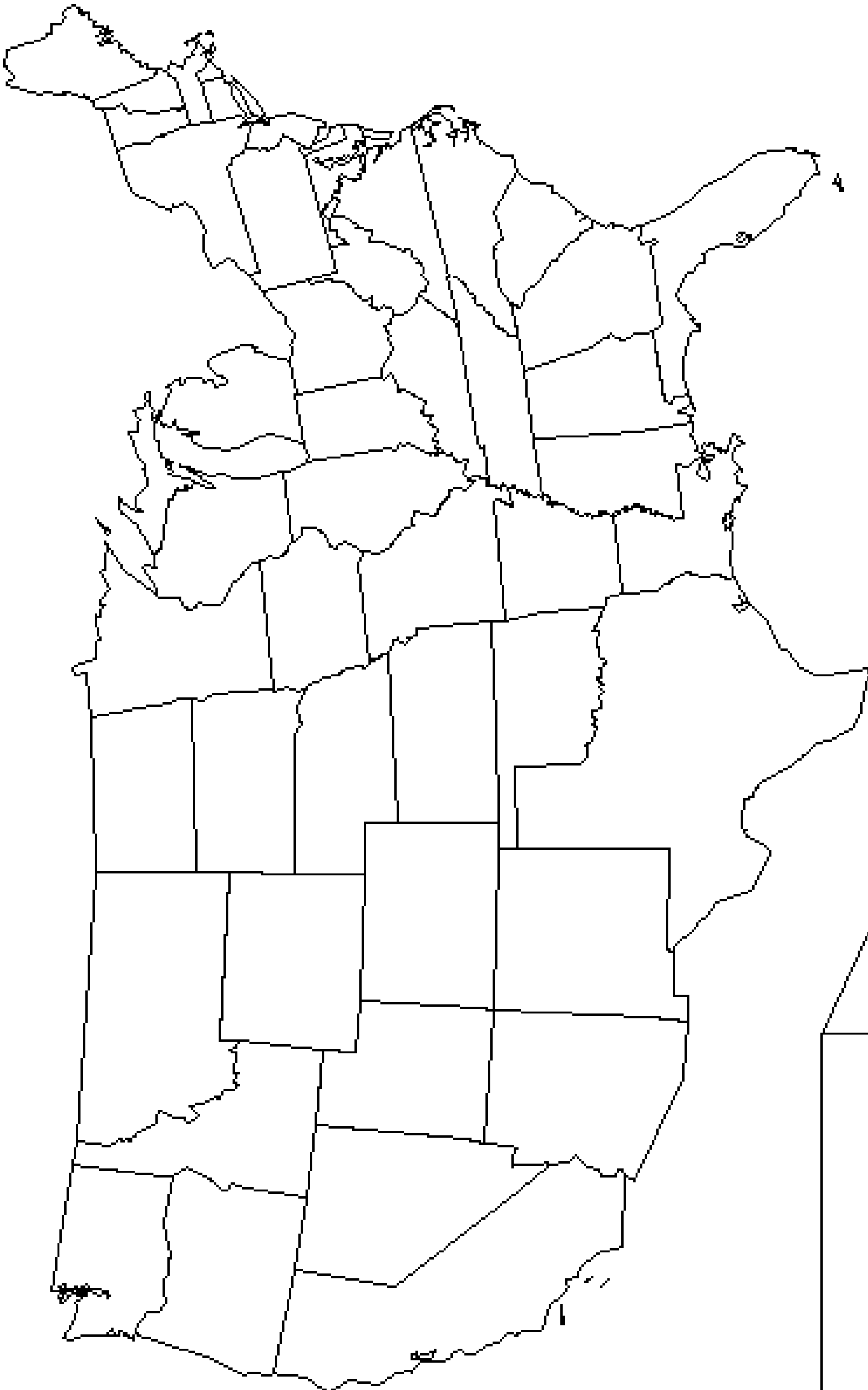
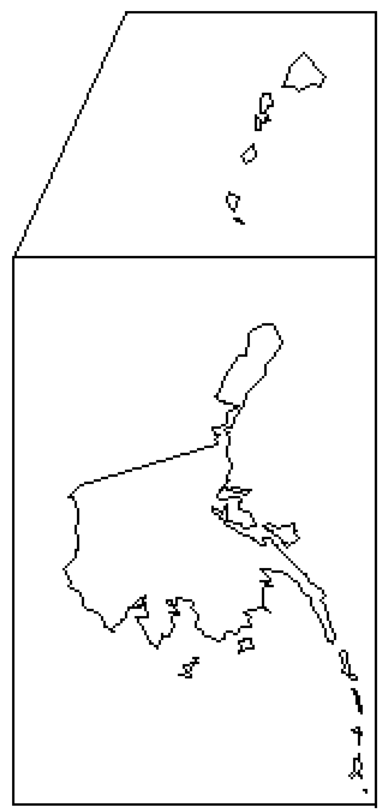



figure 88.

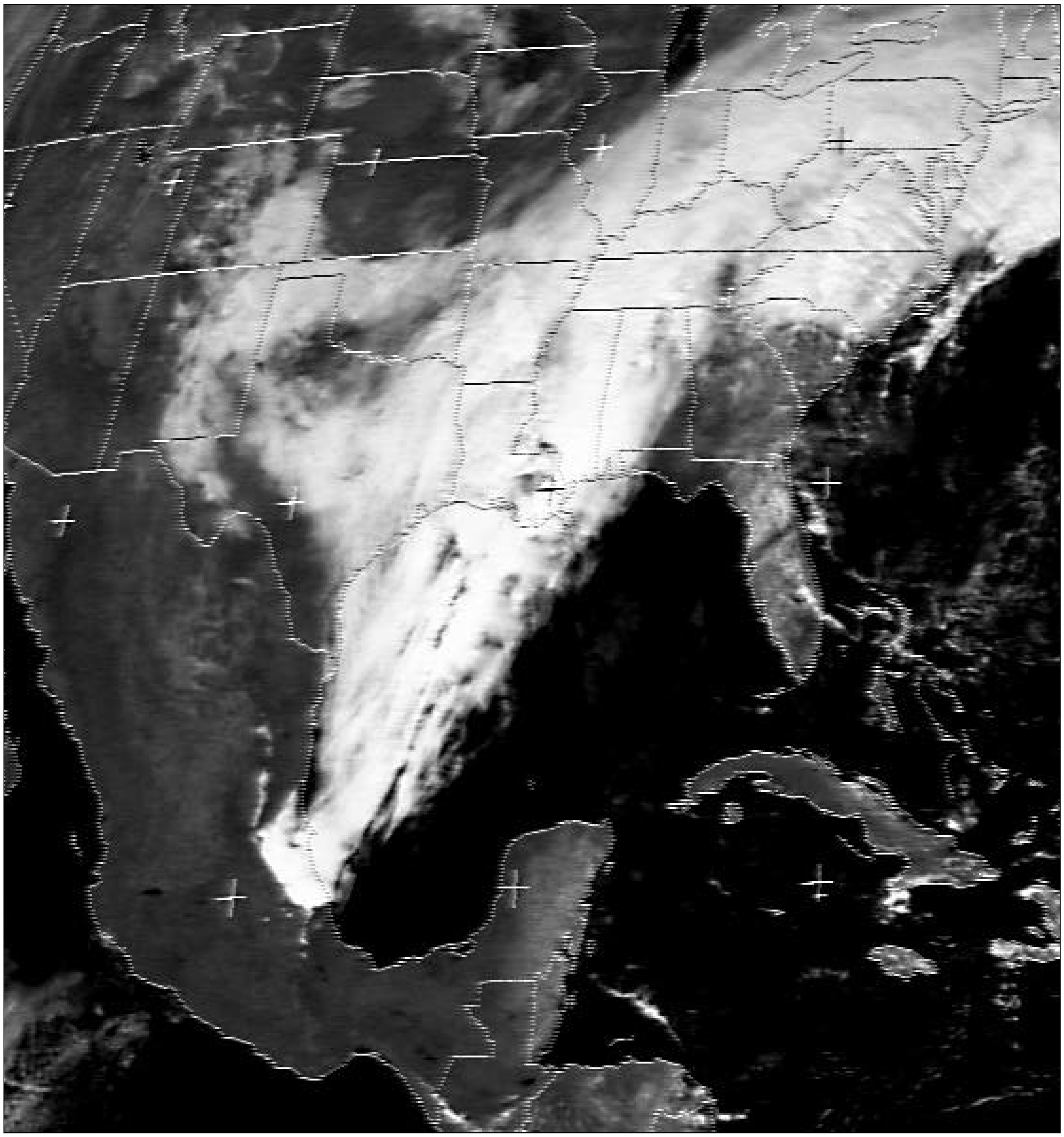


figure 89v. GOES visible image, March 9, 1994
image courtesy of D. Peters, Linganore High School, Frederick, Maryland

Refer to page 222 for additional information about the image.

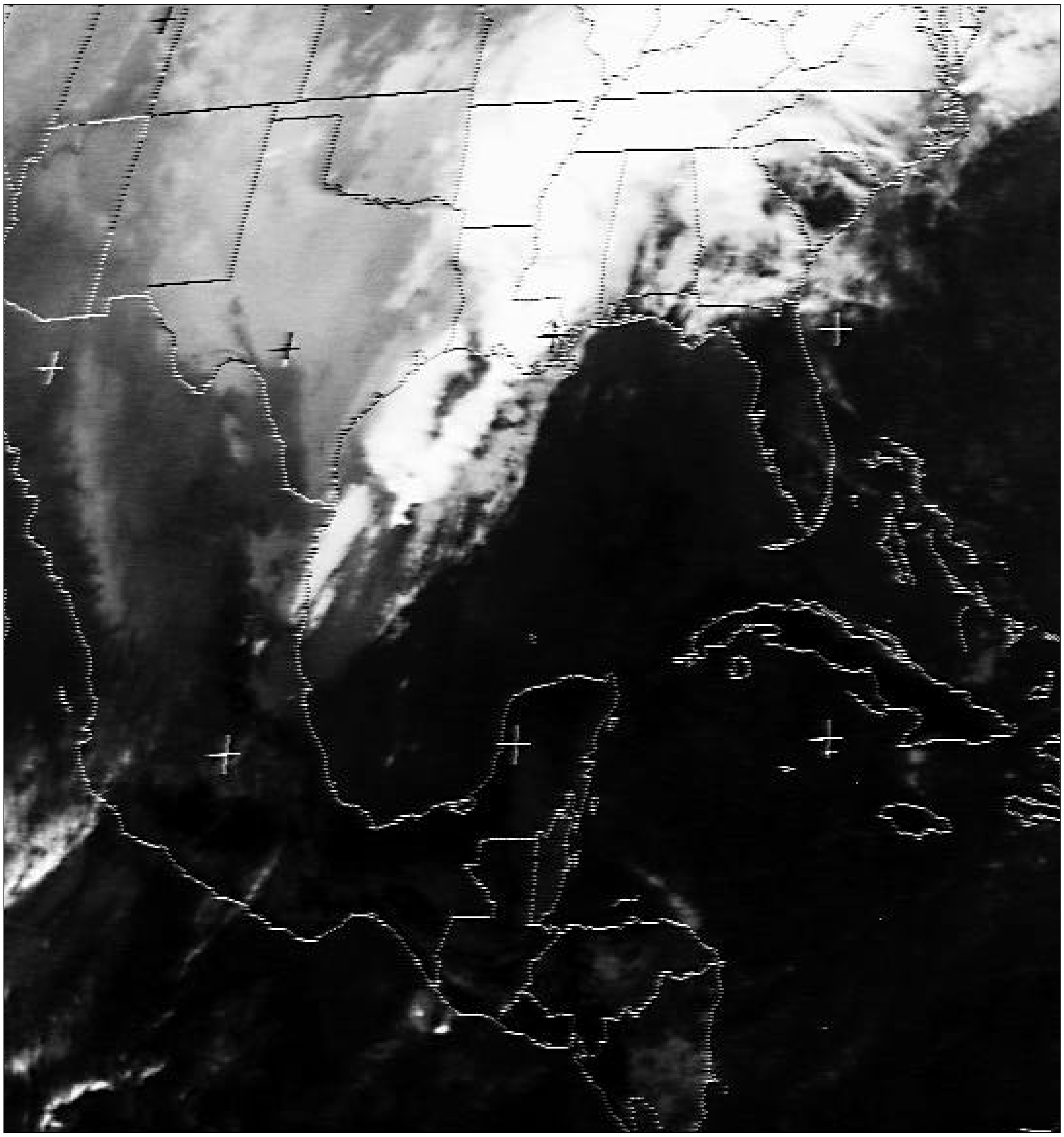


figure 89i. GOES infrared image, March 9, 1994
image courtesy of D. Peters, Linganore High School, Frederick, Maryland

Understanding a Thunderstorm-Development Through Expiration

Authors:
John Entwistle, Damascus High School, Damascus Maryland
Carolyn Ossont, DuVal High School, Lanham, Maryland
Hans Steffen, DuVal High School, Lanham, Maryland
John Webber, Aberdeen High School, Aberdeen, Maryland

Grade Level: 9

Objectives:
Students will be able to:
1. Identify the features, patterns, and stages of a thunderstorm; and
2. Explain how the thundercloud evolves.

Relevant Disciplines:
Earth science, meteorology, computer science

Time Requirement:
Two to three periods

Image Format:
APT, visible and infrared

Prerequisite Skills:
1. Knowledge of how clouds form
2. Ability to analyze satellite images

Materials:
1. APT images (visible and infrared pairs preferable, one per group) with a particular cloud type circled for identification
2. Thunderstorm reference sheet
3. Data sheet
4. Cloud fact cards, cut apart (pages 246–248)
5. Teacher-provided reference materials about clouds and satellite imagery
6. *Thunderstorm Reference Sheet* (page 245) for each cooperative learning group

Preparation:
The teacher should spend at least one period preparing the class for this activity. During this preparation time, discuss with the class why and how clouds form. Once students understand the dynamics of cloud formation, go into specific detail concerning the evolution of a thunderstorm—from cumulus cloud through dissipation stage.

Note that this activity describes *standard* thunderstorms. The development of multi- and super-cell thunderstorms won't match what is described here.

Reference:
Ahrens, Donald C. *Meteorology Today: An Introduction to Weather, Climate, and the Environment.*

Activities

1. Divide students into cooperative learning groups (each group has five roles to fill).

2. Pass out one *Data Sheet* to each group.

3. Each group divides up the tasks listed at the bottom of the data sheet (chairperson, recorder, traveler, reporter, researcher).

4. Teacher randomly gives one satellite image to each group as well as a *Thunderstorm Reference Sheet.*

5. After analysis of the satellite image, the group decides which five cloud facts they should receive from the teacher. Making multiple sets of the cards will ensure that each group decides which cards they want, rather than choosing by default. The card types describe: appearance, temperature, source card, associated weather, and vertical development.

6. After reviewing their five cloud fact cards, the group must decide which, if any, of the fact cards pertain to the cloud indicated on their satellite image. Do research from provided materials, allow ten minutes for research.

7. When it is determined which cards are needed or not needed, students may choose to trade cards with other groups through the traveler — to obtain the cards they need.

8. The traveler may approach other groups which have determined the cards they need and make trades for cards to complete the data sheet.

9. When all fact cards are collected, the recorder should complete the data sheet and arrange the fact cards in the order on the data sheet.

10. The reporter for each group, in turn, names the group's cloud and reads each cloud fact card (start with cumulus and go through each stage, ending with dissipating cumulonimbus).

11. Data sheets and fact cards are turned into the teacher for grading.

Extensions:
On the day following this activity, discuss in detail with the class the formation of lightning, tornadoes, hail, and the damage they inflict.

Investigate multi-cell and/or super-cell thunderstorms.

DATA SHEET

Group Number ______

Cloud type indicated on your satellite image ______________________________
Cloud Facts: MUST pertain to your cloud

Source ______________________________

Temperature ______________________________

Appearance ______________________________

Vertical Development ______________________________

Associated Weather ______________________________

Satellite Image, describe what you see. ______________________________

____

____

Names

______________	**Chairperson:** Controls discussion, directs research.
______________	**Recorder:** Completes data sheet compiled by group.
______________	**Traveler:** Moves efficiently through other groups to trade for needed cloud facts.
______________	**Reporter:** Reports results of groups conclusions.
______________	**Researcher:** Optional depending on size of group.

Thunderstorm Reference Sheet

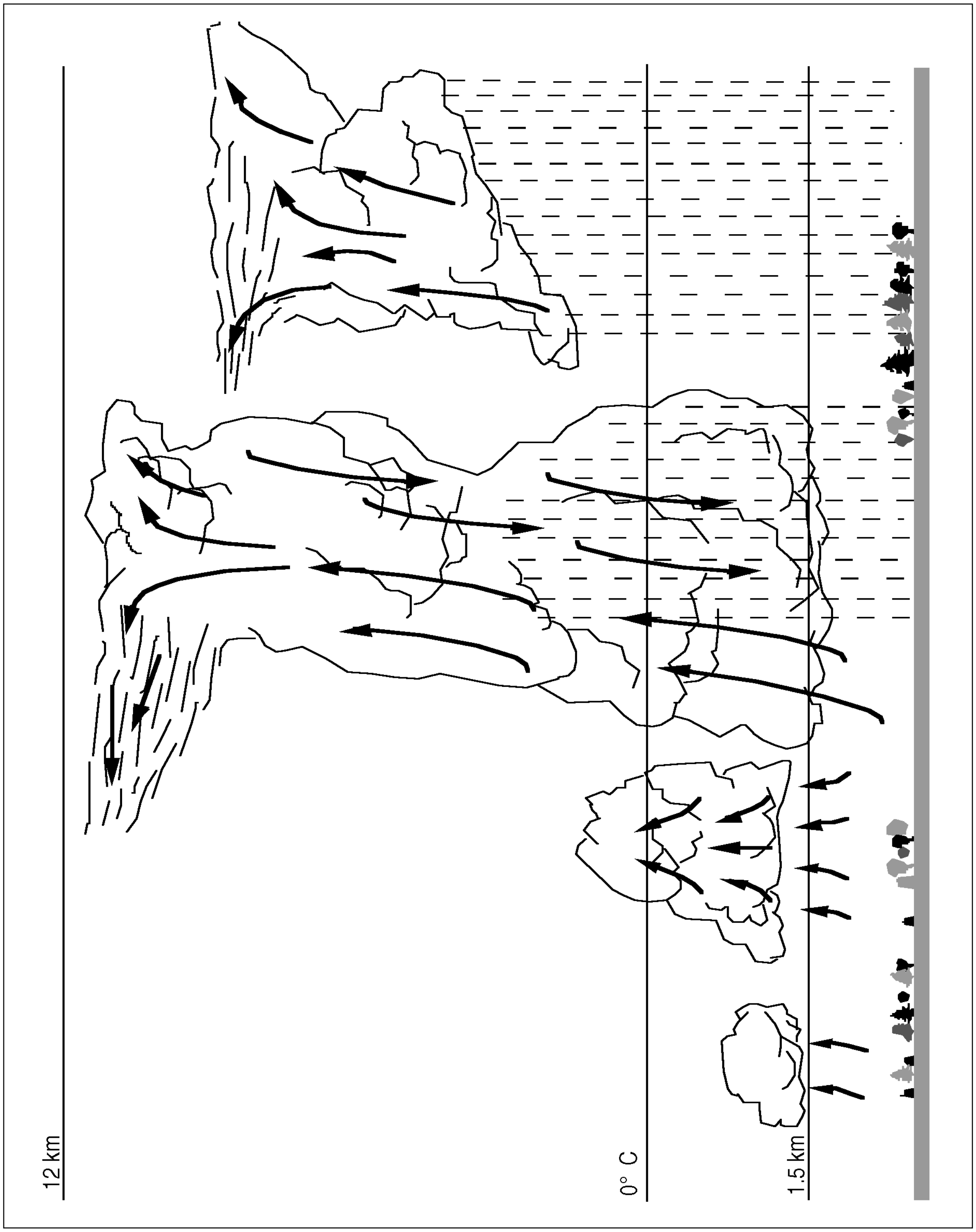
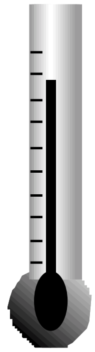
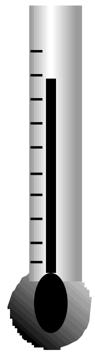
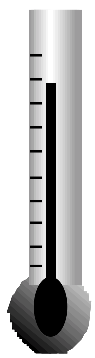
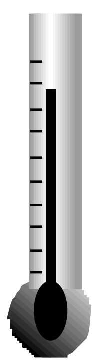


figure 90.

Appearance Card Towering Cumulus Resembles head of cauliflower	 Temperature -50° C top 0° C base
Appearance Card Cumulus Puffy, floating cotton	 Temperature -10° C top 24° C base
Appearance Card Mature Cumulonimbus (thunderhead) Top - ice crystal Mid - ice crystal/water droplets Low - water droplets	 Temperature -15° C top 20° C base
Appearance Card Dissipating Cumulonimbus Cirrus anvil cloud remains	 Temperature -60° C top 24° C base

Source Card	Associated Weather
Evaporation continued due to increase in temperature	Occasional showers
Source Card	**Associated Weather**
Evaporation from lakes, oceans, or other bodies of water	Light showers Increased clearing Cooler temperature
Source Card	**Associated Weather**
Evaporation causes air to become more moist. Rising air is now able to condense at higher levels and the cloud grows taller. The freezing cloud particles become too heavy to be supported by rising warm air and it rains. Lightning develops when the cloud becomes unstable and experiences turbulance.	Moderate thermals Fair
Source Card	**Associated Weather**
Downdrafts occur throughout the cloud. Deprived of its rich supply of warmed humid air, cloud droplets no longer form. Light showers below and upper level winds dissipate the cloud.	Possibility of hail, rain, lightning, thunder—some or all of each. Strong winds

Vertical Development top 12 km base 1 km	Vertical Development top 1.5 km base 1.0 km
Vertical Development top 11 km base 5 km	Vertical Development top 6.0 km base 1.5 km

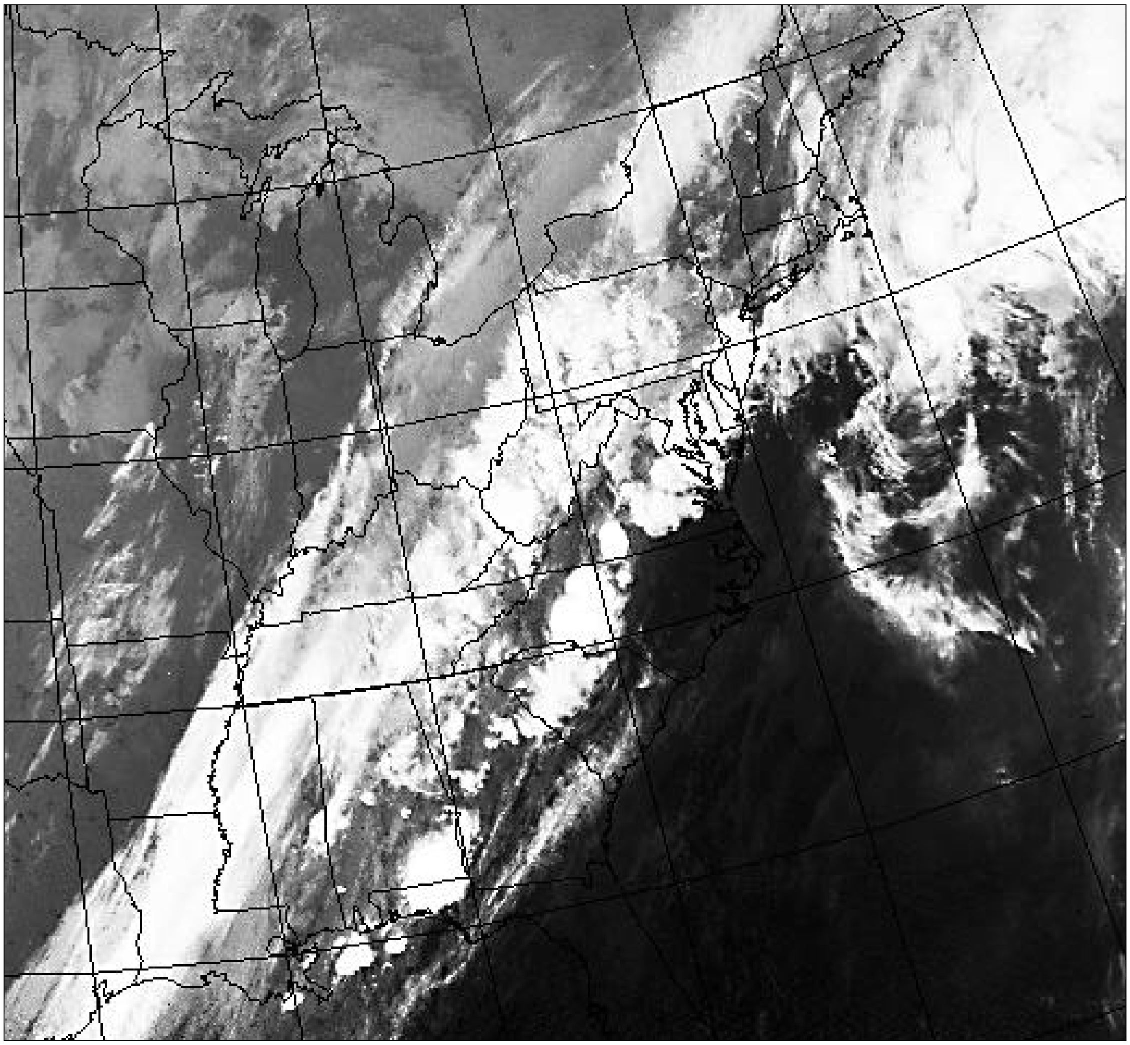


figure 91v. NOAA 10, March 28, 1994
visible image courtesy of G. Chester, Smithsonian Institution, Albert Einstein Planetarium

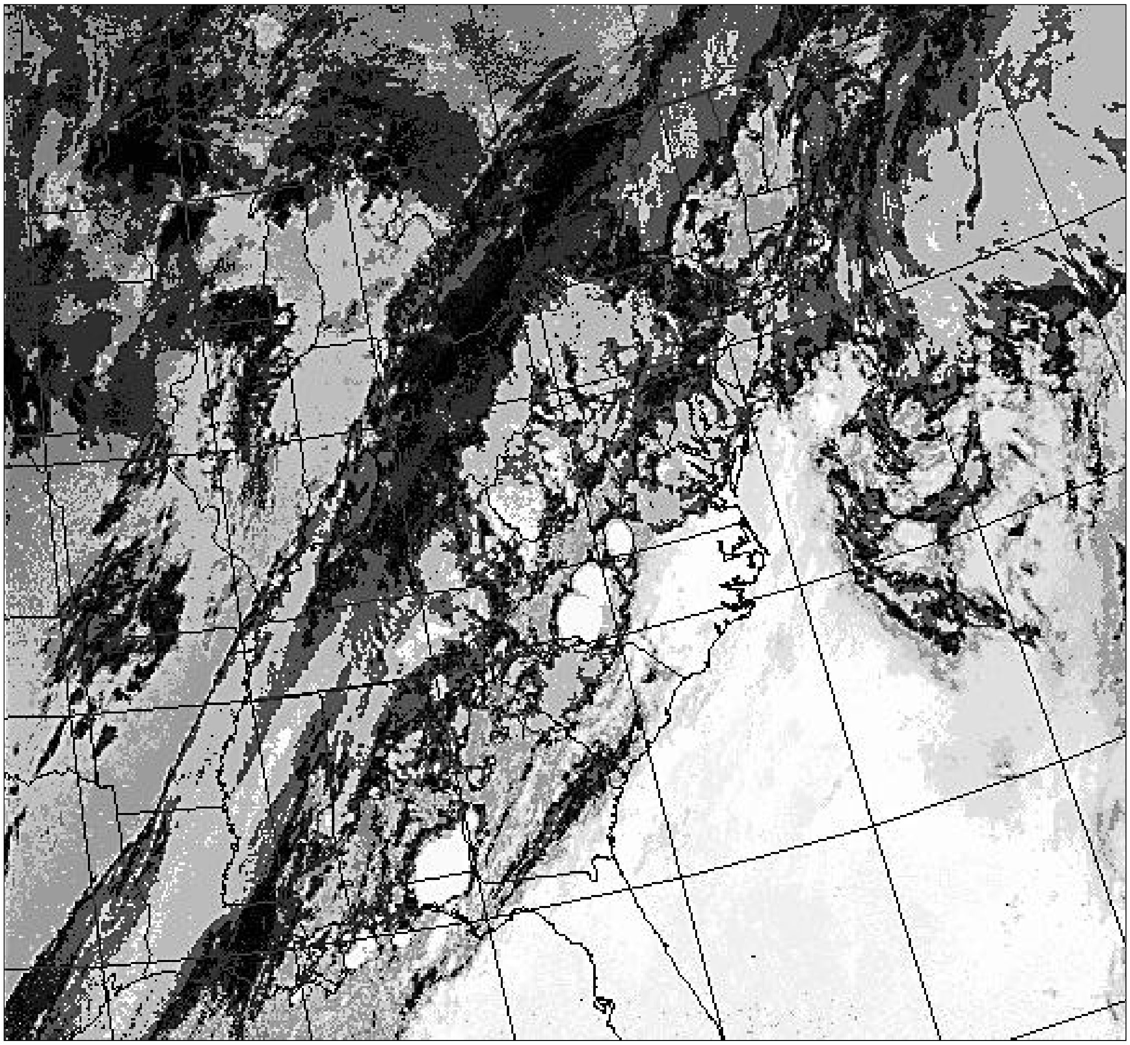


figure 91i. NOAA 10, March 28, 1994
infrared image courtesy of G. Chester, Smithsonian Institution,
Albert Einstein Planetarium

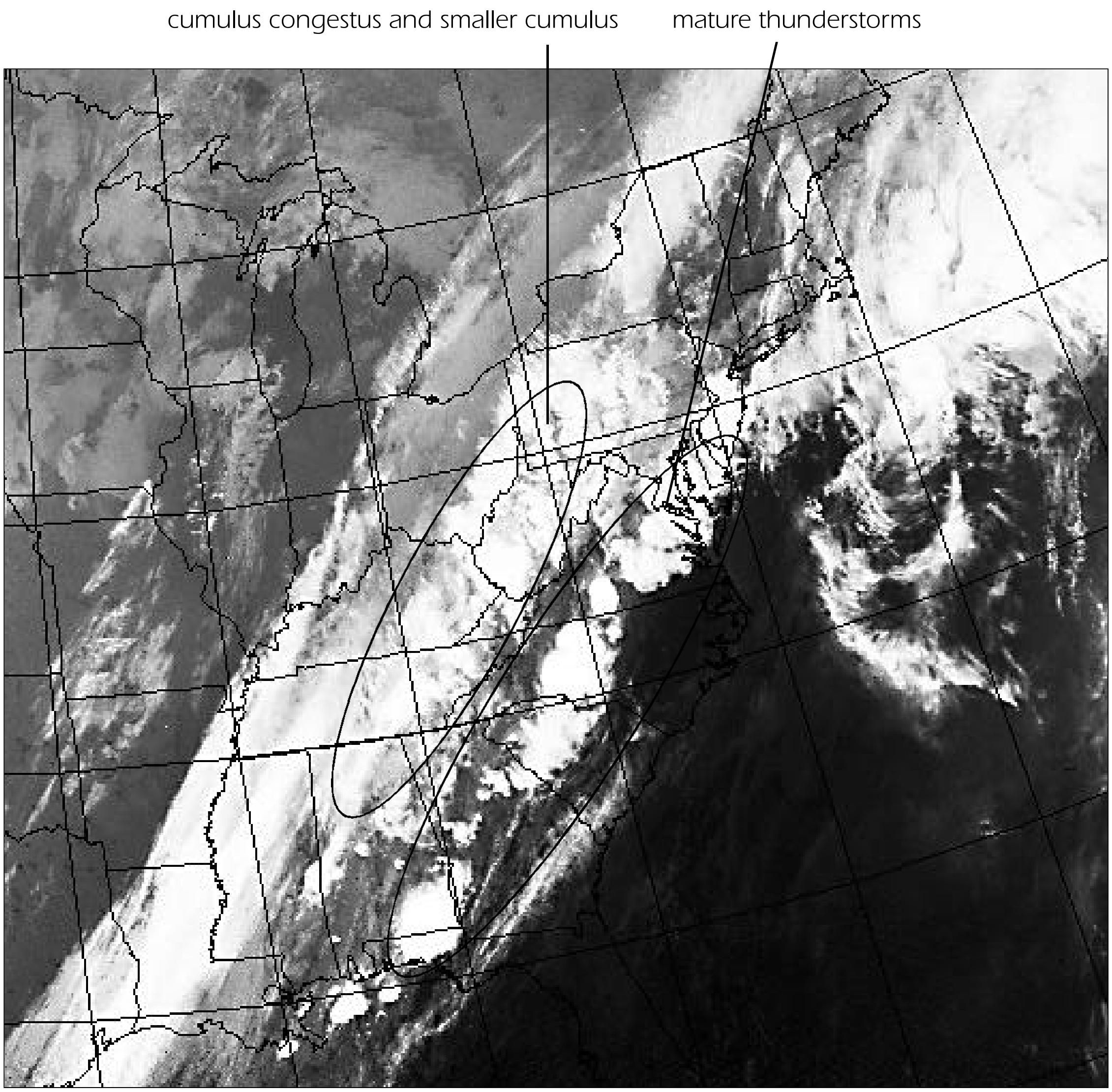


figure 91a. NOAA 10, March 28, 1994
visible image courtesy of G. Chester, Smithsonian Institution, Albert Einstein Planetarium

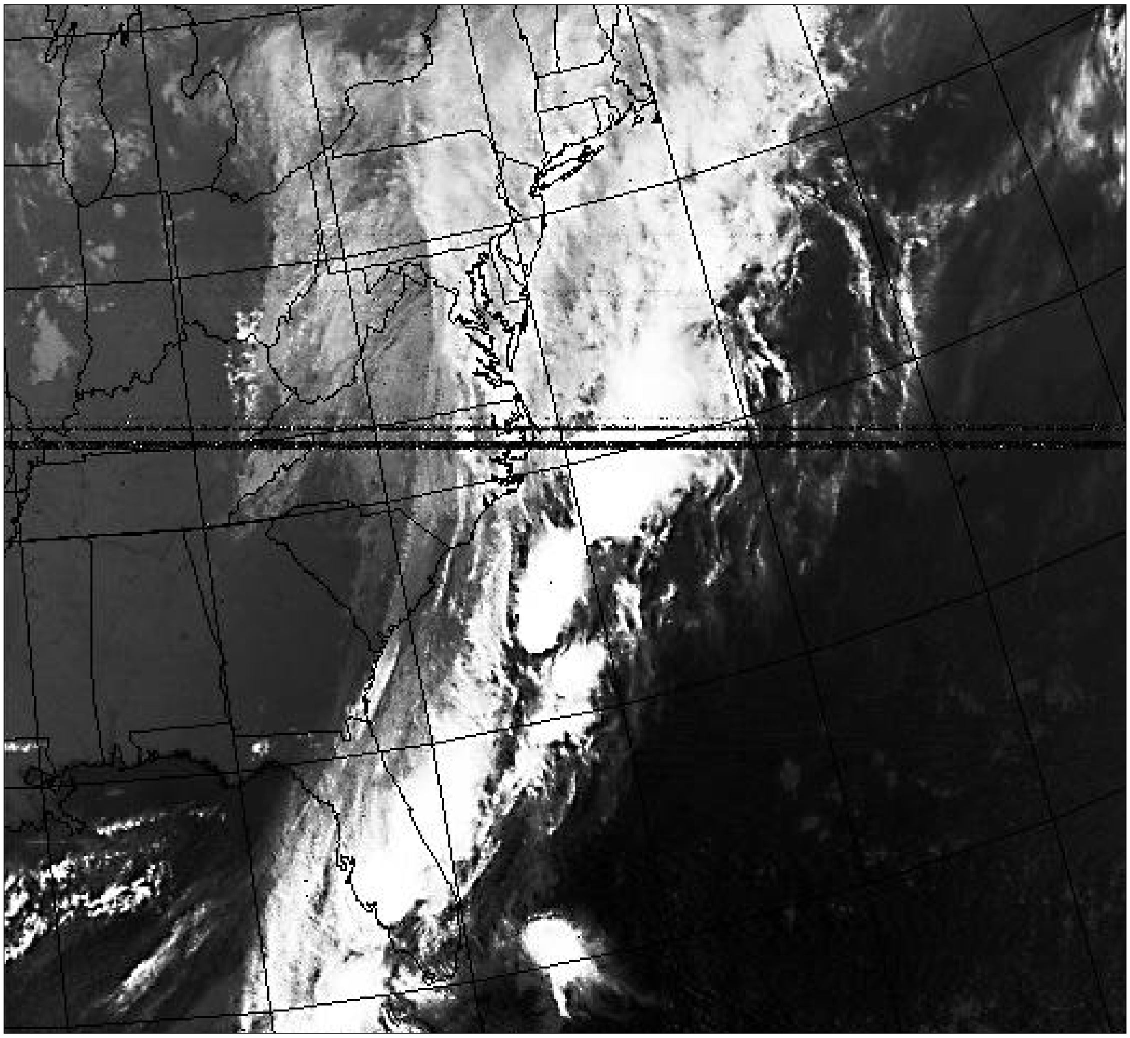


figure 92v. NOAA 10, March 29, 1994
visible image courtesy of G. Chester, Smithsonian Institution, Albert Einstein Planetarium

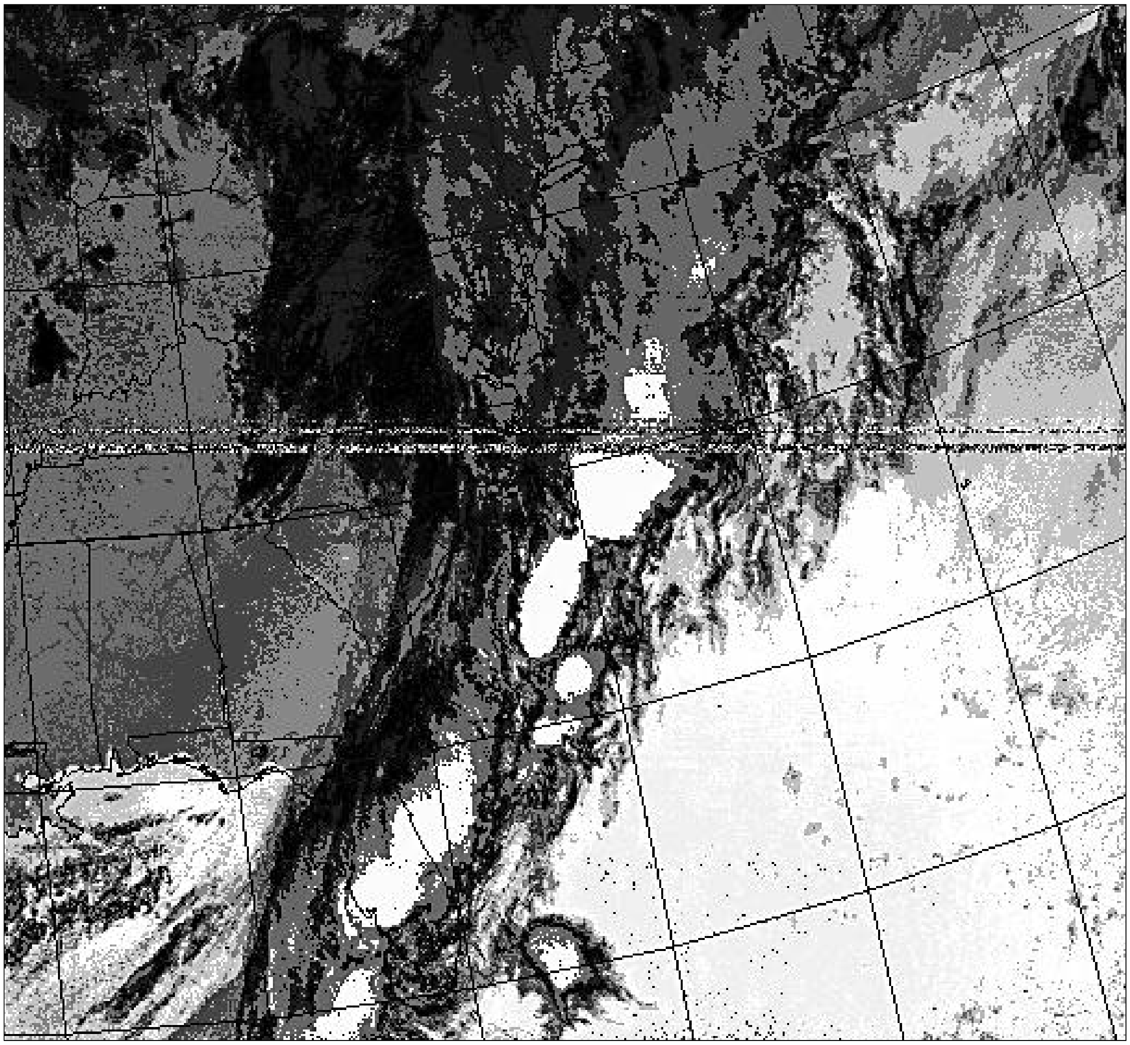


figure 92i. NOAA 10, March 29, 1994
infrared image courtesy of G. Chester, Smithsonian Institution,
Albert Einstein Planetarium

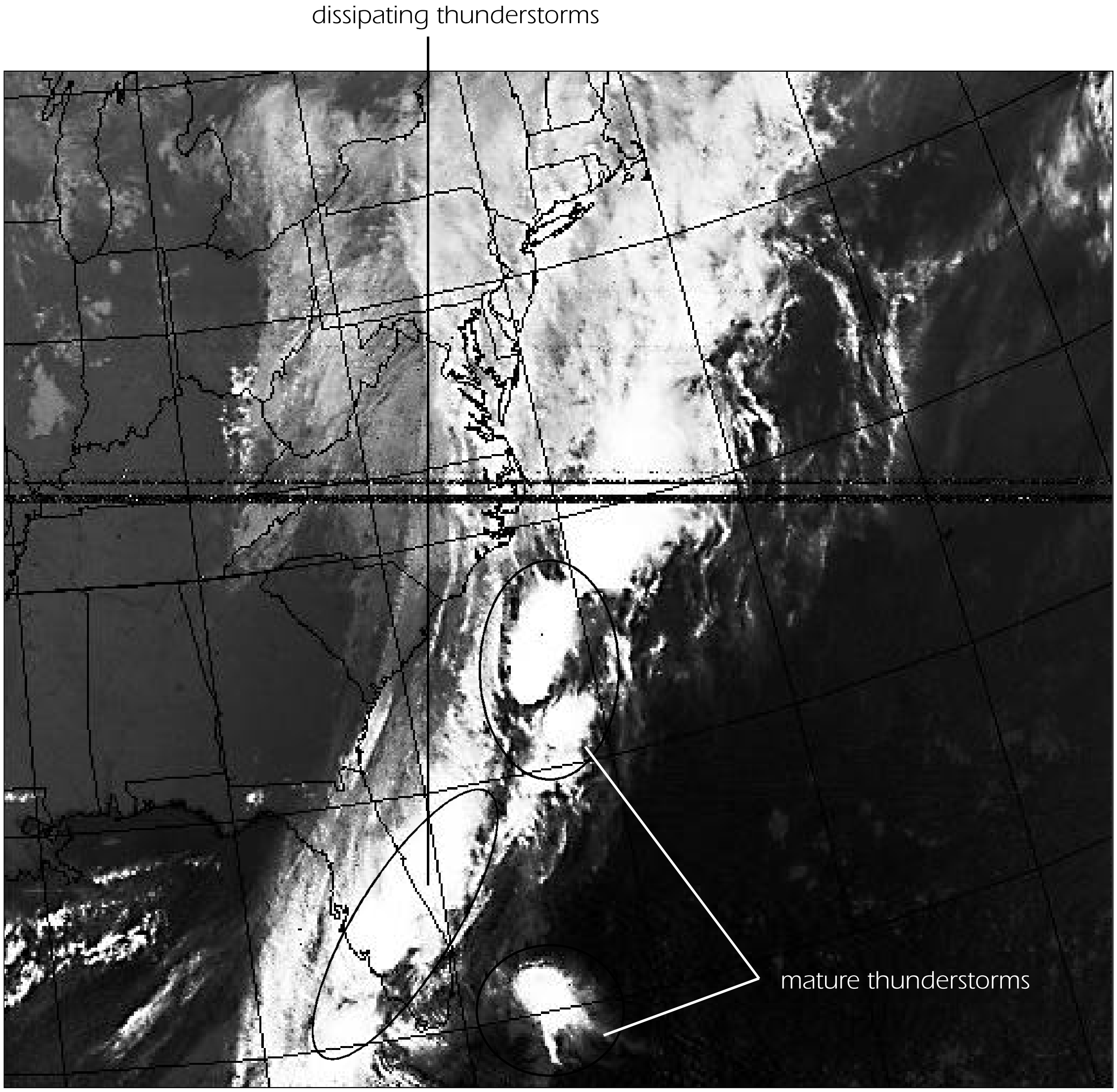


figure 92a. NOAA 10, March 29, 1994
visible image courtesy of G. Chester, Smithsonian Institution, Albert Einstein Planetarium

See page 188 for information about image noise.

ANIMATION CREATION

Authors:
John Entwistle, Damascus High School, Damascus, Maryland
Carolyn Ossont, DuVal High School, Lanham, Maryland
Hans Steffen, DuVal High School, Lanham, Maryland
John Webber, Aberdeen High School, Aberdeen, Maryland

Grade Level: 7–12

Objective:
To create a computer animation of a sequential series of WEFAX images which will assist in identification of fronts, clouds, hurricanes, and storm movement.

Materials:
1. IBM/compatible computer system
2. Romeo file * (see page 256)
3. A collection of visible or infrared WEFAX satellite images on computer disk in .GIF format. The images should have been obtained at consistent time intervals.

Background:
1. Two programs are needed to create the animation. *ANIMATE* creates the animation, and *PLAY* displays the animation file created by ANIMATE.
2. The programs must be run from a hard disk drive.
3. The animation is smoother if run on a computer with a fast microprocessor.
4. Only .GIF format image files can be animated using these programs.

Procedure:
1. Make a new directory on your hard drive using the following command.

   M D R O M E O ENTER

2. Change to the new directory using the following command.

   C D R O M E O ENTER

3. Copy the file named "ROMEO.ZIP" from the directory/drive where ROMEO.ZIP has either been downloaded, or the drive on which ROMEO.ZIP is located, using the following command:

   C O P Y R O M E O . Z I P T O R O M E O ENTER

4. Unzip ROMEO.ZIP using the following command (this command assumes that you have PKUNZIP on your hard drive and in your path. If you don't have PKUNZIP, download it from a bulletin board system [BBS] such as those listed on the following page. The newest version of PKUNZIP and associated files is called "PKZ204G.EXE).

   P K U N Z I P R O M E O . Z I P ENTER

Note: You must have at least 2.5 MB of free hard drive space in order to unzip and run this program. Additional information on the PATH statement in your AUTOEXEC.BAT file may be found in your DOS manual. A sample PATH statement looks like this:
PATH = C:\;C:\DOS;C;\ARCFILE

Procedure (con't):

5. Collect your sequential WEFAX image files.

6. Place the image files in the ROMEO subdirectory. Be sure the image files are listed in the subdirectory in chronological order. The closer together the chronological files are obtained, the smoother the animation. Images collected every hour work best, although images collected every two, four, or six hours also give good results. Animation works well with 10 or more image files.

7. To animate the files, be sure you are in the subdirectory containing the file DTA.

8. To create the animation file, type:

   D T A \ * . G I F / S D / S W ENTER

   where the path is the path to the image files. This will create the file ANIM.FLI, the more images in the animation, the longer this process will take.

9. To show the animation, type

   P L A Y A N I M . F L I ENTER

10. The file, ANIM.FLI should be renamed since each subsequent animation created by DTA will be called ANIM.FLI.

11. Additional, in-depth information about the programs DTA and PLAY are found in their .DOC or .TXT files.

References:

Mason, David K., *DTA (Dave's.TGA Animation Program) 1.8f*

Mason, David K., *Animate, 1992.*

* The Romeo file may be obtained from:

NASA Spacelink via modem at (205) 895-0028
Internet at spacelink.msfc.nasa.gov.

BorderTech Bulletin Board (410) 239-4247 no charge to educators except long distance phone cost.

Dallas Remote Imaging Group (DRIG) Bulletin Board System
There is a fee to use this BBS. (214) 394-7438

The animation software is shareware, meaning that it is not free, Trilobyte will support the product and send you new versions as they become available. To register, send $39 to Trilobyte, PO Box 1412, Jacksonville, Oregon 97530.

There are two animation files and 9 individual frame files on the disks. The file, ROMEO, contains 10 images, taken by GOES West. This animation covers 5 hours in the life of the hurricane.
The file ROMEO.ALL contains the original 10 images plus an additional number of frames that extend the animation to over a day's period of time.

PKUNZIP may be downloaded from Spacelink, or the Border Tech or DRIG BBS.

WHEREFORE ART THOU, ROMEO?

Authors:
John Entwistle, Damascus High School, Damascus, Maryland
Carolyn Ossont, DuVal High School, Lanham, Maryland
Hans Steffan, DuVal High School, Lanham, Maryland
John Webber, Aberdeen High School, Aberdeen, Maryland

Grade Level: 7–12

Objectives:
Students will be able to follow the path of a Pacific Ocean hurricane and be able to:
1. Identify a hurricane by its properties, as shown in a series of sequential, animated GOES images;
2. Determine actual size, velocity, and direction of movement of a hurricane; and
3. Predict the path that a hurricane will take.

Time Requirement:
2 to 4 class periods

Image Format:
Geostationary infrared images

Background:
1. Read *U.S. Geostationary Environmental Satellites and Background: Hurricanes*
2. Collect a series of infrared GOES satellite images on computer disk (images acquired at one hour intervals).
3. Download the files described in the previous lesson, *Animation Creation.* Included are two animation files and 9 individual frame files. The file, ROMEO, contains 10 images, each taken from GOES West, covering 5 hours in the life of the hurricane. The file ROMEO.ALL contains the original 10 images plus an additional number of frames that extend the animation to over a day's period of time.

Materials:
1. Computer
2. Romeo files*
3. Metric ruler
4. 1 piece of acetate and marking pen per student group

Preparation:
1. Review background information
2. Set-up the computer system
3. Distribute 1 sheet of acetate and marking pen per student group
4. Distribute student data sheet

References:
Ahrens, Donald C. *Meteorology Today: An Introduction to Weather, Climate, and the Environment.*
Risnychok, Noel T. *"Hurricane!" A Familiarization Booklet.*
Williams, Jack. *The Weather Book.*

* See the lesson *Animation Creation* regarding software.

U.S. GEOSTATIONARY ENVIRONMENTAL SATELLITES

Background

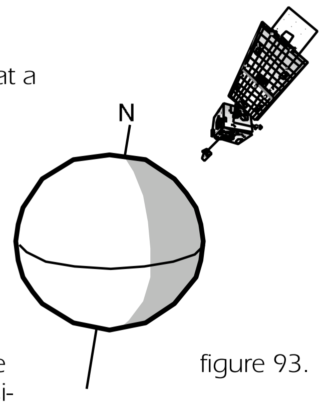


figure 93.

Geostationary or geosynchronous satellites orbit the Earth at a speed and altitude (approximately 22,240 miles) that allow them to continuously hover over one area of the Earth's surface and provide constant coverage of that area. The U.S. Geostationary Operational Environmental Satellites (GOES) view almost a third of Earth's surface and provide continuous western hemisphere coverage.

GOES provides low-resolution direct readout service called Weather Facsimile (WEFAX). WEFAX transmissions include visual reproductions of weather forecast maps, temperature summaries, cloud analyses, etc. via radio waves. WEFAX visible images have a resolution of eight kilometers, meaning each pixel represents an area eight kilometers on a side. Infrared images have a resolution of 4 kilometers. WEFAX is formatted in a 240 lines-per-minute transmission rate.

GOES

- Provides continuous day and night weather observations
- Monitors weather events such as hurricanes and other severe storms
- Relays environmental data from surface collection points to a processing center
- Performs facsimile transmission of processed weather data to users (WEFAX)
- Provides low-cost satellite image services; the low resolution version is called weather facsimile (WEFAX)
- Monitors the Earth's magnetic field, the energetic particle flux in the vicinity of the satellite, and x-ray emissions from the sun

GOES I-m Primary Sensor Systems:

Imager is a five-channel (one visible, four infrared) imaging radiometer that senses radiant energy and reflected solar energy from the Earth's surface and the atmosphere. The imager also provides a star-sensing capability, used for image navigation and registration purposes.

Sounder is a 19-channel discrete-filter radiometer that senses specific radiant energy for vertical atmospheric temperature and moisture profiles, surface and cloud-top temperature, and ozone distribution.

Communications Subsystem includes weather facsimile (WEFAX) transmission and the search and rescue (SAR) transponder.

Space Environment Monitor (SEM) consists of a magnetometer, x-ray sensor, high-energy proton and alpha detector, and an energetic particles sensor, all used for in-situ surveying of the near-Earth space environment. The real-time data is provided to the Space Environment Services Center—which receives, monitors, and interprets solar-terrestrial data and forecasts special events such as solar flares or geomagnetic storms.

Hurricanes

Background

Hurricanes are severe tropical cyclones with pronounced rotary circulation whose winds consistently exceed 74 mph or 64 knots (1 knot = 1.15 miles/hour). One beneficial quality of hurricanes is serving as a source of rain to land in their path, although the rain is often delivered in devastating quantities. A mature hurricane orchestrates more than a million cubic miles of atmosphere, typically has an 8 to 12 day cycle, and averages about 300 miles in diameter. Winds may exceed 150 knots, and generate waves of 50 feet or more over deep ocean.

Hurricane winds are produced, as all winds are, by differences in atmospheric pressure. The hurricane's energy is derived from the latent heat of condensation. The maximum strength that a storm can achieve is determined by the temperature difference between the sea surface and the top of the storm. Water below 80 degrees Fahrenheit does not contribute much energy to a hurricane so all storms are doomed once they leave warm tropical waters. However, the remnants of some large hurricanes may travel for days over cold ocean before dissipating.

Hurricanes form over tropical waters where the winds are light, the humidity is high, and the surface water temperature is warm (typically 79 degrees F or greater) over a vast area. All hurricanes develop an eye. Within the eye, an average of 20 to 50 kilometers in diameter, clouds are broken and winds are light with very low surface air pressure. Hurricane strength is generally unrelated to overall size, however very strong hurricanes usually have small eyes (less than 10 miles or 16 kilometers in diameter), which has the effect of concentrating the hurricane's energy. Hurricane Gilbert's (1988) eye displayed the lowest sea-level pressure ever recorded in the Western Hemisphere with 26.22 inches (888 millibars) of mercury—compared to the standard 29 inches of mercury in North America, and 30 inches in the tropics. Surrounding the eye is the eye wall, a ring of intense thunderstorms that whirl around the storm's center and extend upward to almost 15 km above sea level.

Although the high winds of hurricanes inflict a lot of damage, it is the waves and flooding associated with the storm surge that cause the most destruction. High winds generate waves over 10 meters (33 feet high), and an average hurricane brings six to twelve inches of rain to the area it crosses. Storm surge claims nine of ten victims in a hurricane.

While a hurricane lives, the release of energy within its circulation is immense. The condensation heat energy released by a hurricane in one day, converted to electricity, could supply the United States' electrical needs for about six months. Hurricane season in the Northern Hemisphere normally lasts from June through November, more hurricanes occur in the Pacific than in the Atlantic Ocean.

storm surge The combined effect of high water and high winds that produce a rise in ocean level that drenches low-lying coast.

storm tide The combination of high tide and storm surge.

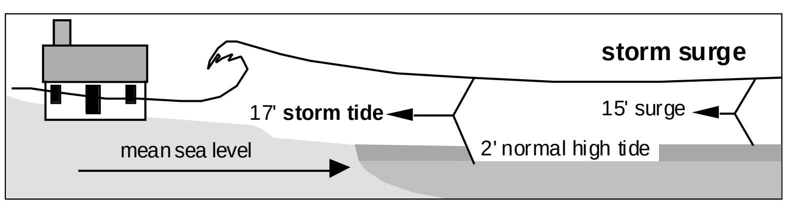


figure 94.

TEACHER NOTES FOR ACTIVITIES 1 & 2

Activity 1

1. Run the computer animation by typing: P L A Y R O M E O ENTER
2. Slow the animation by typing: 9
3. Observe the animation, identify the hurricane.
4. Answer the observation questions.

Hurricane Pattern Types Chart is from NOAA Technical Report NESDIS 11, listed in bibliography.

Questions

1a. Which direction is the hurricane moving? How do you know?
1b. Which direction are the clouds in the hurricane moving?
1c. Using a copy of *Cloud Pattern Types used in Intensity Analysis* chart, locate the shape of the hurricane and identify the strength of the hurricane.

"scale" was not included on disk at time of writing so there was no response to that command.

Activity 2

1. Before beginning the activity, the teacher should set-up the computer system and display the picture "SCALE" from the Romeo disk by typing:
   P L A Y S C A L E ENTER
2. Tape a piece of acetate to the computer monitor.
3. Students need to copy the distance scale from the screen onto the acetate.
4. View the individual hurricane sequence by typing:
   P L A Y R O M E O . 1 ENTER
5. Mark the center of hurricane Romeo.
6. Trace the coastline onto the acetate.
7. Repeat procedures 4 & 5 for frames Romeo.2, ...Romeo.9.
8. Remove the acetate from the computer screen.
9. Connect the points marking the center of the hurricane.

The activity should employ a scale of about 1 centimeter equals 136 km. This proportion was developed using a CRX monitor and may be adjusted for monitors of different size by the following method:

Play Romeo 1 to display a still frame of hurricane. Enhance image to view pixels. Measure from hurricane center to southern edge by counting the number of pixels. Multiply that number by 8 (there is an 8 km resolution per pixel for the image). Restore image to default size on screen. Using a center of the hurricane to the southern edge. The metric distance can then be placed in ratio to actual distance.*

Example: On CRX monitor there were 17 pixels between center and edge (remember frame is enlarged) 17 x 8 km - 136 km. Standard frame measured 1 centimeter from center to edge, resulting in a 1 cm = 136 km scale.

* The GOES image is distorted by the curve of the Earth. That has been ignored for the purpose of this activity, but should be considered for higher level work.

Record the Following Information on Your Data Sheet

2a. Using the scale, determine the distance between each point.
2b. Determine the total distance hurricane Romeo traveled.
2c. Determine the speed the center of the hurricane moved between each dot.
2d. Determine the average speed the hurricane moved.

WHEREFORE ART THOU, ROMEO? STUDENT ACTIVITIES

A ctivity 1

1. Run the computer animation by typing:
   P L A Y R O M E O ENTER
2. Slow the animation by typing: 9
3. Observe the animation, identify the hurricane.
4. Answer the observation questions.

Q uestions

1a. Which direction is the hurricane moving? How do you know?
1b. Which direction are the clouds in the hurricane moving?
1c. Using a copy of *Cloud Pattern Types used in Intensity Analysis* chart, locate the shape of the hurricane and identify the strength of the hurricane.

A ctivity 2

1. Before beginning the activity, set-up the computer system and display the picture "SCALE" from the Romeo disk by typing:
   P L A Y S C A L E ENTER
2. Tape a piece of acetate to the computer monitor.
3. Students need to copy the distance scale from the screen onto the acetate.
4. View the individual hurricane sequence by typing:
   P L A Y R O M E O . 1 ENTER
5. Mark the center of hurricane Romeo.
6. Trace the coastline onto the acetate.
7. Repeat procedures 4 & 5 for frames Romeo.2, ...Romeo.9.
8. Remove the acetate from the computer screen.
9. Connect the points marking the center of the hurricane.

R ecord the Following Information on Your Data Sheet

2a. Using the scale, determine the distance between each point.
2b. Determine the total distance hurricane Romeo traveled.
2c. Determine the speed the center of the hurricane moved between each dot.
2d. Determine the average speed the hurricane moved.

STUDENT ACTIVITIES (CONTINUED)

Activity 3

1. Return to the computer and tape the acetate onto the computer screen, aligning the center of the hurricane images with the dots on the acetate.

2. Load ROMEO.1.

3. Draw a line (radius) from the center of the hurricane to the southern edge of the spiral bands.

4. Repeat procedures 2 & 3 for each frame.

5. Remove the acetate from the computer screen.

6. Determine the diameter of hurricane Romeo for each image. Record this information on your data sheet.

Questions for Activities 2 & 3

3a. Describe the circulation pattern of the clouds around hurricane Romeo.
3b. Compare the distances traveled between each of the images. Is there a pattern? Explain your answer.
3c. Compare the diameters of the hurricane images. Is there a pattern? Explain your answer.
3d. Based on your drawing and the data collected, predict a possible location for Romeo in the next 3, 6, 9, 12, 24 hours. Check to see if your hurricane movement prediction was correct by typing:

P L A Y   R O M E . A L L   ENTER

3e. Predict what will happen to the shape of Romeo over the next 3, 6, 9, 12, 24 hours.
3f. Based on your drawing, what might be one reason that a hurricane would lose strength?
3g. If you were a meteorologist in Hawaii, would you issue a hurricane warning? Explain your answer.

Extensions:

1. Collect GOES images and animate a sequence.

2. Using ROMEO.ALL, compare the movement of hurricane Romeo to the clouds in the north-central and the central parts of the U.S.

References:

Ahrens, Donald C. *Meteorology Today: An Introduction to Weather, Climate, and the Environment.*
"A.M. Weather for Teachers."
Dvorak, Vernon F. "Tropical Cyclone Intensity Analysis Using Satellite Data."
Mason, David K. "DTA, Dave's/TGA Animation Program 1.8f." 1992.
Mason, David K. "Animate." 1992.
Williams, Jack. *The Weather Book.*

Hurricane Romeo Activities Data Sheet

name ______________________

Image	Distance Between Hurricane Image Centers (cm)	Actual Distance Between Hurricane Centers (km)	Hurricane Image Diameter (cm)	Actual Hurricane Diameter (km)
Romeo 1	X	X		
Romeo 2				
Romeo 3				
Romeo 4				
Romeo 5				
Romeo 6				
Romeo 7				
Romeo 8				
Romeo 9				
Total Distance			X	X

Cloud Pattern types used in Intensity Analysis

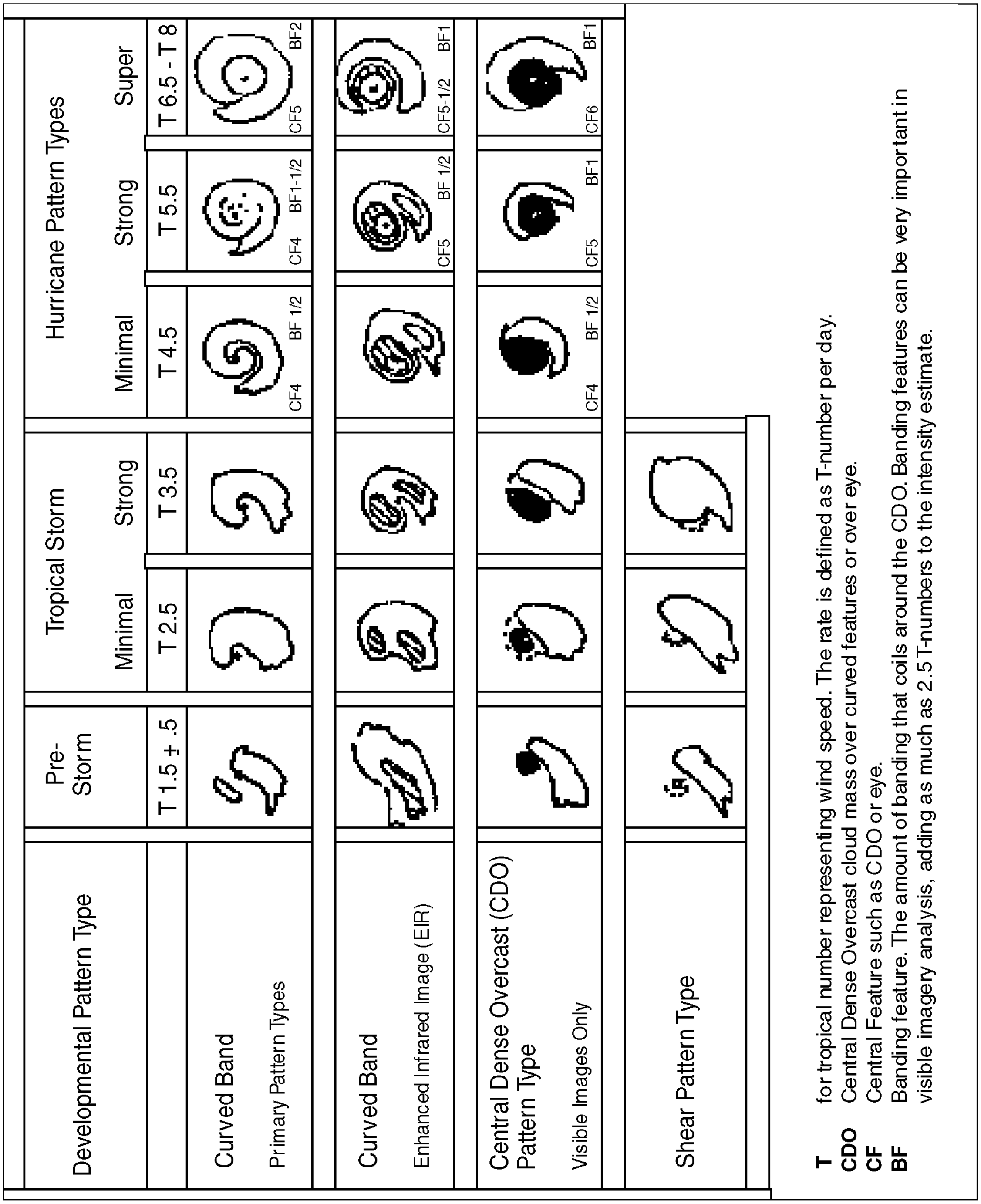


figure 95. excerpt from NOAA Technical Report —see bibliography

A Cold Front Passes

Authors:
Sarah Clemmitt, Montgomery Blair High School, Silver Spring, Maryland
Onyema Isigwe, Dunbar High School, Washington, DC

Grade Level: 9–12
Can be adapted for other grade and ability levels.

Objectives:
At the conclusion of this project, the students will be able to:
1. Identify satellite-viewed features associated with a cold front,
2. Identify surface data trends associated with the passing of a cold front,
3. Track the movement of a cold front, and
4. Predict the arrival of the cold front.

Rationale:
To enable students, in groups of four, to apply the information they have learned about cold fronts to analyze satellite images and synoptic data they have collected.

Relevant Disciplines:
Earth and space science, computer science, mathematics, English

Time Requirement:
One-and-a-half to two weeks

Image Format:
APT or GOES, visible and/or infrared

Prerequisite Skills:
This lesson is not intended as an introductory activity.
1. The students should be familiar with manipulating and enhancing satellite images.
2. The students should be familiar with weather patterns, including cold fronts, and the variables inherent in their passing.
3. The students should have experience in using a thermometer, a barometer, an anemometer, and a sling psychrometer.

Vocabulary:
air mass, clouds (cirrus, cumulonimbus) cold front, dew point, velocity

Materials:
1. access to images
2. anemometer
3. barometer
4. sling psychrometer
5. thermometer

Activities

Introduction:

At this point students have already learned quite a bit about weather patterns. They know what a cold front is, as well as the variables that will change as a front passes. In this activity that knowledge will be used to:

1. Identify satellite features associated with a cold front,
2. Identify surface data trends associated with the passing of a cold front,
3. Track the movement of a cold front, and
4. Predict the arrival of the cold front.

Student instructions are on page 268 and can be copied and distributed to the class. Students are expected to turn in a written report that includes the following sections:

1. Title page - names of group members and dates of study
2. Introduction - summary of what you know about cold fronts (include citations) and a statement about the objective of your report
3. Materials and methods
4. Data
   - Information collected from the satellite images including the position of a cold front
   - Predicted velocity of the front
   - Table of surface data
   - Graphs demonstrating ground data trends
5. Discussion
6. Citations

1. Pull up the day's satellite image of your location.

   Depending on the computer facilities available, this can be done a number of ways. Most likely you will need to save the image on discs for the students to use during their class periods.

2. Using the satellite image, indicate the position of the cold front. Also, note the types of clouds you see and their positions relative to the cold front (are they on the leading edge? trailing edge? middle?).

   Because the students need to include this information in their report, you may wish to use the "Position of a Cold Front" worksheet on page 267, or allow each group to devise their own presentation format. In order for the students to indicate the position of the cold front, they may need a printout of the image to trace, or a map to transfer the location onto.

3. Step #2 should be repeated for 2 or 3 images in order to get a good idea of the movement associated with this front.

   The front may be moving quickly, so it may be best to do this with a few images captured on the same day. Otherwise the cold front may pass before the students have made their predictions.

4. Based on the images you have analyzed thus far, calculate the average velocity of the cold front. There are a number of ways to do this. Students should decide on a method, then show all their steps to illustrate how they have chosen to proceed.

Decide how much information about velocity to give your students. Distances can be determined in a number of ways, such as counting pixels or creating a scale based upon known distances. More advanced students should be made aware that the distance between the fronts does not necessarily follow the boundaries of the pixel. To be accurate, they may need to find the corner-to-corner distance across the pixel. Also, beware that a derived distance scale may be distorted due to the Earth's curvature.

5. Using your velocity calculations, predict when this cold front will pass through your area. Show your work.

6. For the next few days (in some cases, hours), until the cold front passes through, do two things:
   a. Record the following information in the table on page 266:
      - cloud type - sketches or photos may be included
      - date
      - dew point (relative humidity if hygrometer is available)
      - time
      - pressure
      - precipitation
      - temperature
      - wind direction and speed
      - any other observations
   b. Continue to analyze the daily (or more frequent) satellite images. Prediction of the arrival time for the cold front should be adjusted if the velocity of the cold front varies with time. Include all of the predictions in the final report.

7. After the front has passed, write a discussion section that includes the following:
   a. A summary of the satellite observations.
      - General location and movement of the front (latitude and longitude)
      - Velocity and arrival predictions made (discuss any adjustment made to the prediction)
   b. A summary of the trends seen in the surface data collected.
      - General trends seen in each variable.
      - Does the data match what is expected when a cold front passes?
      - Can you explain the variables that do not match a cold front?
   c. A discussion of the similarities and differences between *a* and *b*.
      - Was your prediction accurate? Why or why not?
      - Do the cloud types seen in both data sets correlate? Why or why not?
      - How accurate is this method of prediction?
      - What could be done to ensure a more accurate prediction (discuss at least two options)?

Variations on this Lesson:

1. Limit the study to just one or two variables, as appropriate to grade level.
2. Stagger the due dates for the reports to ensure that the students do not fall behind and become overwhelmed.
3. Require peer editing of a rough draft of the report.
4. Use other phenomena in place of a cold front, e.g., a tropical storm turning into a hurricane.
5. Have students from period to period collaborate their surface data to obtain a more accurate picture of surface activity.

Student Activities

Written Report

Students are expected to turn in a written report that includes the following sections:

1. Title page - names of group members and dates of study

2. Introduction - summary of what you know about cold fronts (include citations) and a statement about the objective of your report

3. Materials and methods

4. Data
   - Information collected from the satellite images including the position of a cold front
   - Predicted velocity of the front
   - Table of surface data
   - Graphs demonstrating ground data trends

5. Discussion

6. Citations

Observation of the Front

1. Obtain the day's satellite image.

2. Using the image, indicate the position of the cold front and complete the chart on page 271. Also, note the types of clouds you see and their positions relative to the cold front (are they on the leading edge? trailing edge? middle?).

3. Step #2 should be repeated for 2 or 3 images in order to get a good idea of the movement associated with this front.

4. Based on the images you have analyzed thus far, calculate the average velocity of the cold front. There are a number of ways to do this. Decide on a method, then show all your steps so your teacher knows how you have chosen to proceed.

5. Using your velocity calculations, predict when this cold front will pass through your area. Show your work.

6. For the next few days (in some cases, hours) until the cold front passes through, do two things:
   a. Record the following information in the table on page 270:
      - cloud type - sketches or photos may be included
      - date
      - dew point (relative humidity if hygrometer is available)
      - pressure
      - precipitation

- temperature
- time
- wind direction and speed
- any other observations

b. Continue to analyze the daily (or more frequent) satellite images. Prediction of the arrival time for the cold front should be adjusted if the velocity of the cold front varies with time. Include all of the predictions in the final report.

Analysis

After the front has passed, write a discussion section that includes the following

1. A summary of the satellite observations.
   - General location and movement of the front (latitude and longitude).
   - Velocity and arrival predictions made (discuss any adjustment made to the prediction).

2. A summary of the trends seen in the surface data collected.
   - General trends seen in each variable.
   - Does the data match what is expected when a cold front passes?
   - Can you explain the variables that do not match a cold front?

3. A discussion of the similarities and differences between a and b.
   - Was your prediction accurate? Why or why not?
   - Do the cloud types seen in both data sets correlate? Why or why not?
   - How accurate is this method of prediction?
   - What could be done to ensure a more accurate prediction (discuss at least two options)?

A Cold Front Passes
Table of Surface Data

names ______________________________

____

date	time	dew point	pressure	precipitation	temperature	wind direction	wind speed	cloud types and coverage	other observations

Position of the Cold Front

place image here

date	names
time	
satellite	
cloud type	
other observations	

Will There be a Rain Delay?

Authors:
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Sandra Steele, Pikesville High School, Baltimore, Maryland
Sushmita Vargo, Washington International School, Washington, DC

Grade Level: 9–12

Objectives:
Using satellite images, students will be able to:
1. Identify general cloud types,
2. Identify areas of precipitation based on the locations of appropriate cloud types,
3. Identify areas of low pressure and frontal boundaries based on cloud patterns, and
4. Predict weather based on analysis of visible satellite images and other weather information.

Relevant Disciplines:
Earth and space science, geography, meteorology, marketing, business

Time Requirement:
One class period

Image Format:
APT or GOES images. Use images from different time periods so student predictions will vary.

Prerequisite Skills:
Students should be familiar with elements of mid-latitude cyclone development. This could be the culminating activity for a weather unit.

Vocabulary:
cloud types, cold front, pressure systems, warm front, weather symbols

Materials:
1. APT or GOES visible images (1 visible image per pair of students)
2. Outline map of the United States
3. Student handout

Activities

1. Distribute to each pair of students: 1 visible satellite image, 1 political map, 1 student worksheet

2. Explain that the first game of the world series will be played in Baltimore (or your city or nearest city with a team) tomorrow and that they are the meteorologists responsible for predicting the weather. Note: you may wish to reword the activity to reflect your location and team.

3. Allow the students 20–25 minutes to discuss and answer the worksheet questions in pairs.

4. Have students share their predictions with the class. Insure that each group can back up their predictions by asking questions concerning cloud identification, front location, etc. Allow other students to ask questions.

5. Instead of forecasting game day weather, have students forecast weather over a holiday (will it snow on Thanksgiving, rain on Memorial Day, etc.?).

6. Verify the forecasts by using weather information from newspapers or TV.

Extension:
Track and compare *Farmer's Almanac* forecasts with local weather.

Will There be a Rain Delay?

Student Worksheet

Objective:

The Orioles have won the American League Championship. The series will be played in Baltimore at Camden Yards. Your objective is to predict the cloud cover and precipitation condition for the World Series game that will be played tomorrow by analyzing the satellite image.

Materials:

1. Visible satellite image
2. Outline map of the United States

Activities

Observe the satellite image and complete the following questions:

1. What large scale cloud type is associated with a low pressure system?

2. Can you find this cloud shape on the image, and determine its location on your outline map? Label this location with the symbol for low pressure (L).

3. What image patterns are associated with thunderstorm activity? Comment on the characteristic gray shade and shape.

4. Find these thunderstorm images on the satellite image and label them on your out line map using the thunderstorm symbol ( ).

5. Shade in the area on your outline map which contains a concentration of ( ) symbols.

6. On the outline map you have just labeled, and using the satellite image, identify a geographic location of a cold front. Label this on your map with the symbol for a cold front ( ).

7. Locate Baltimore on the outline map. Label it with a dot (•).

8. Comparing the satellite image on your labeled map, predict the cloud cover and precipitation in Baltimore for tomorrow, World Series Day.

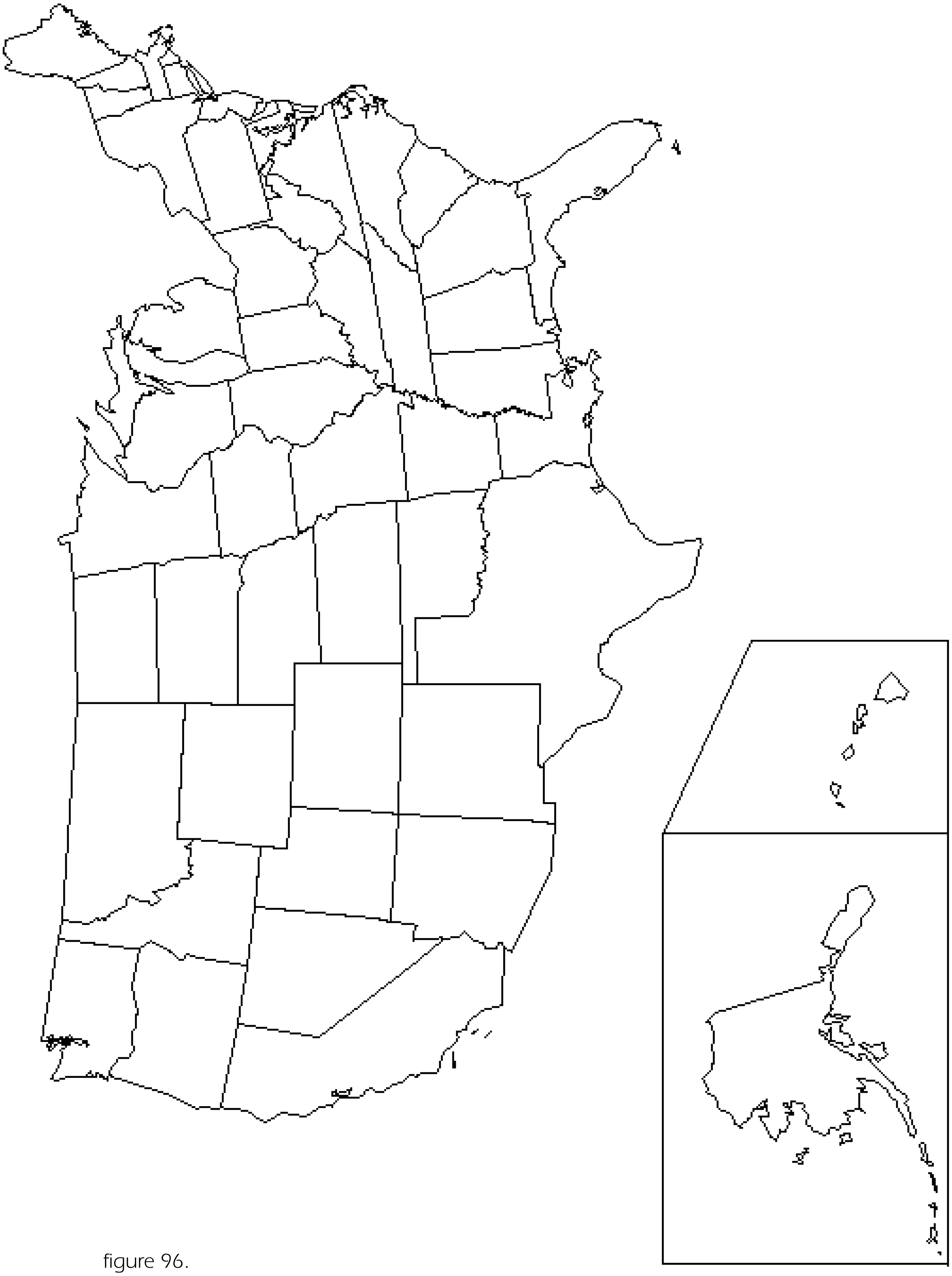

figure 96.

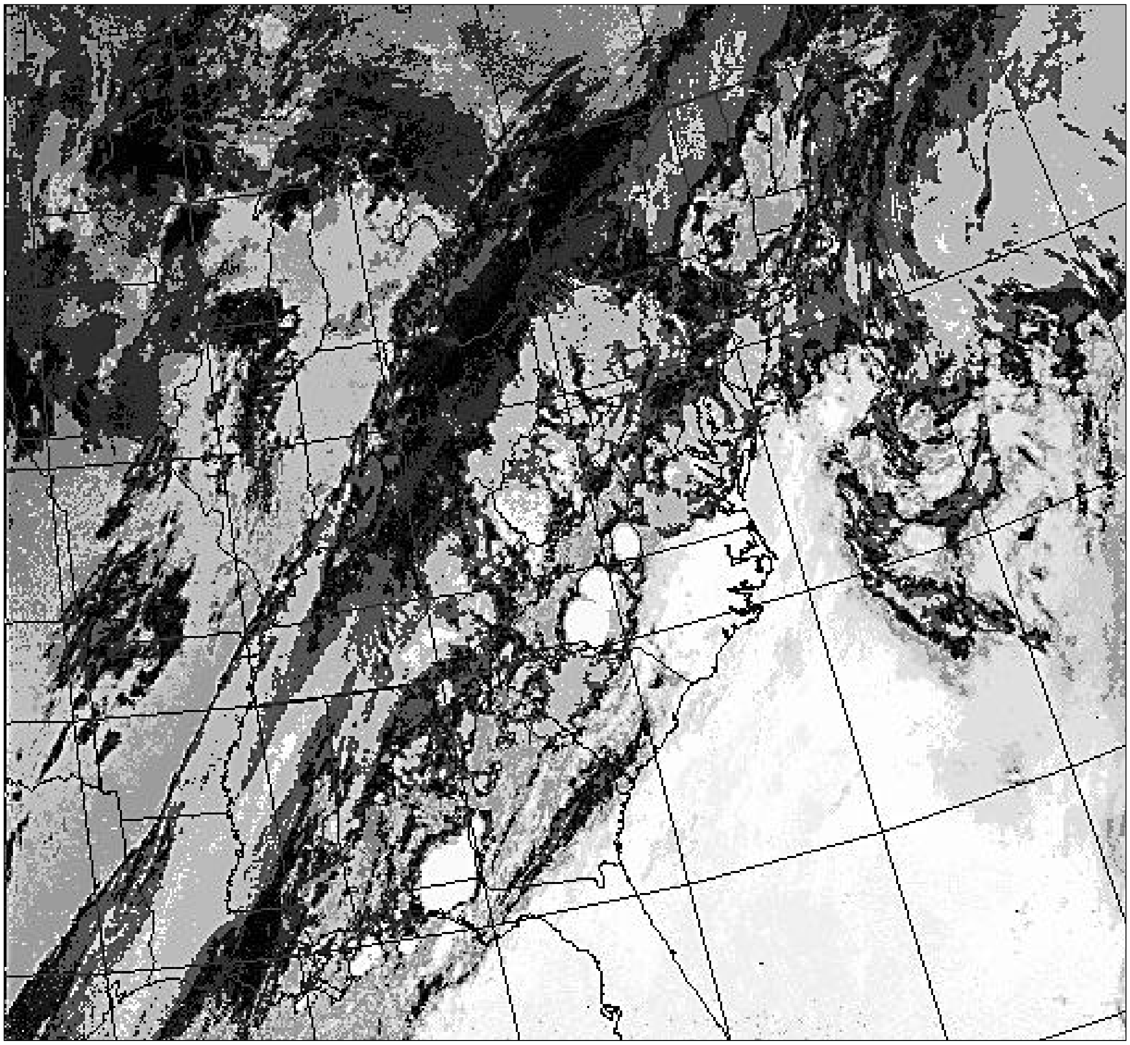

figure 97i. NOAA 10, March 28, 1994
infrared image courtesy of G. Chester, Smithsonian Institution,
Albert Einstein Planetarium

little thunderstorms

cumulus congestus or towering cumulus
mid-level, vertically developed clouds

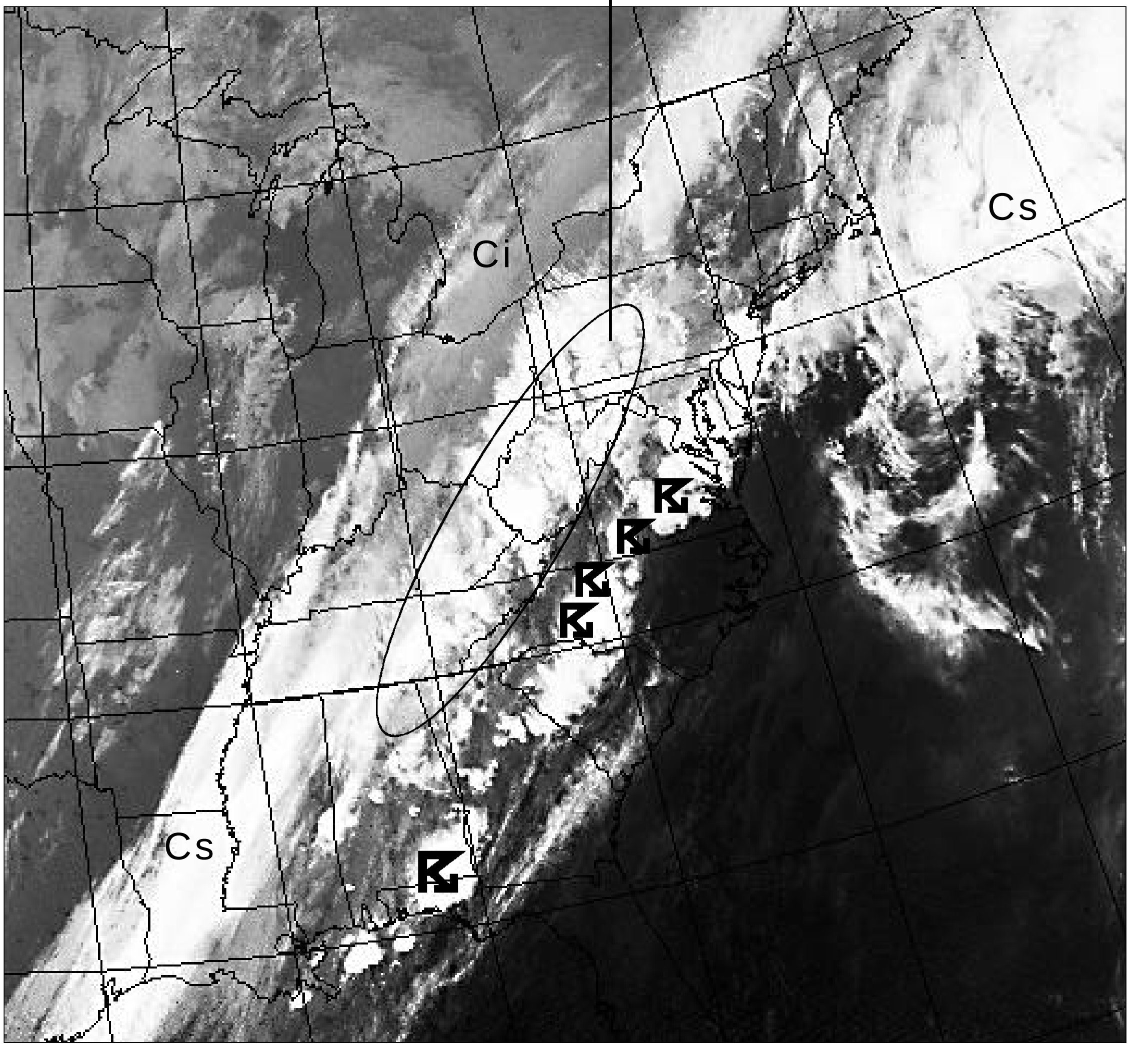

figure 97a. NOAA 10, March 28, 1994
image courtesy of G. Chester, Smithsonian Institution,
Albert Einstein Planetarium

visible image - counterpoint to figure 97i

Images on computer will more clearly display temperature gradients and facilitate assessment of the infrared image.

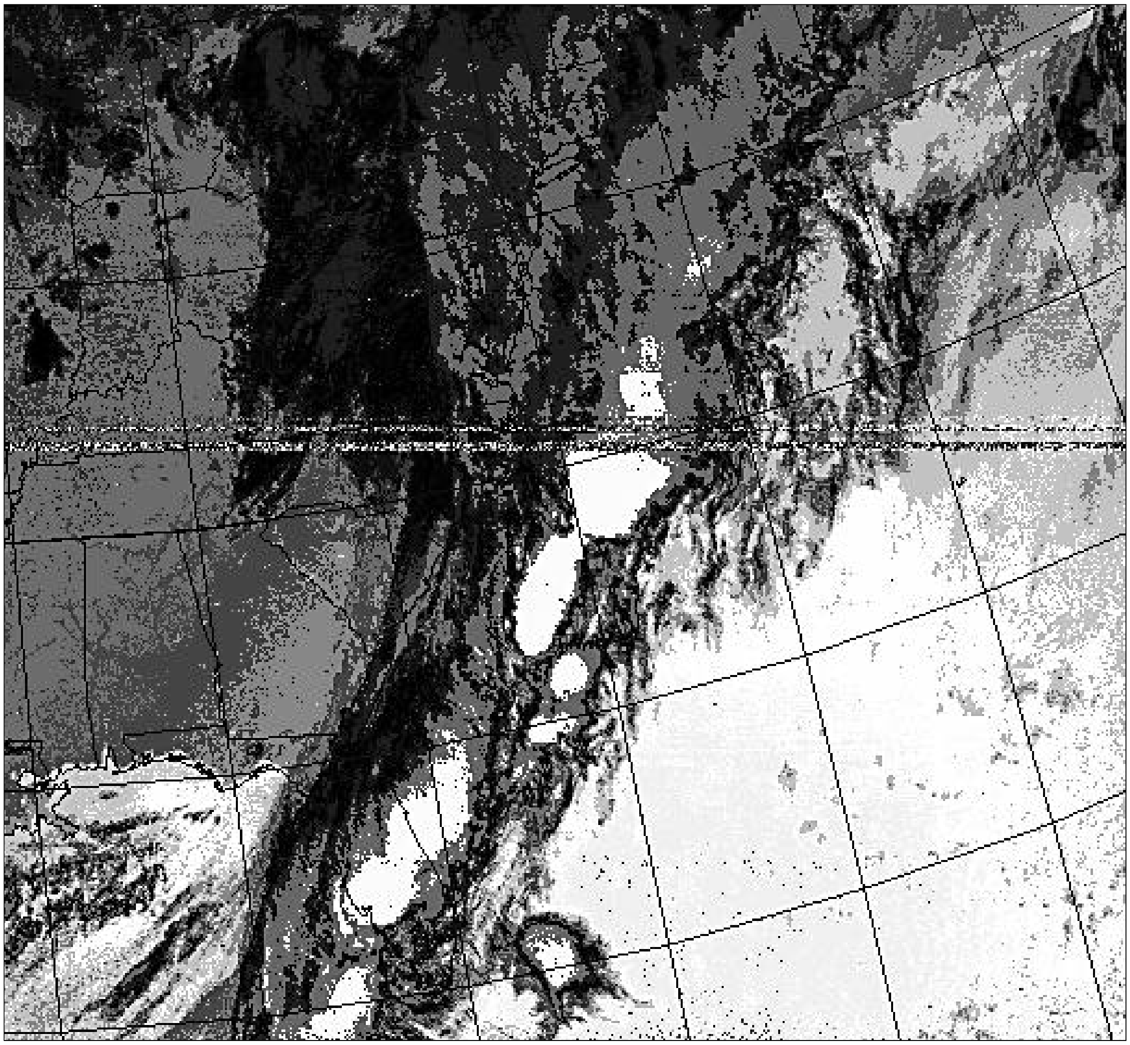

figure 98i. NOAA 10, March 29, 1994
infrared image courtesy of G. Chester, Smithsonian Institution, Albert Einstein Planetarium

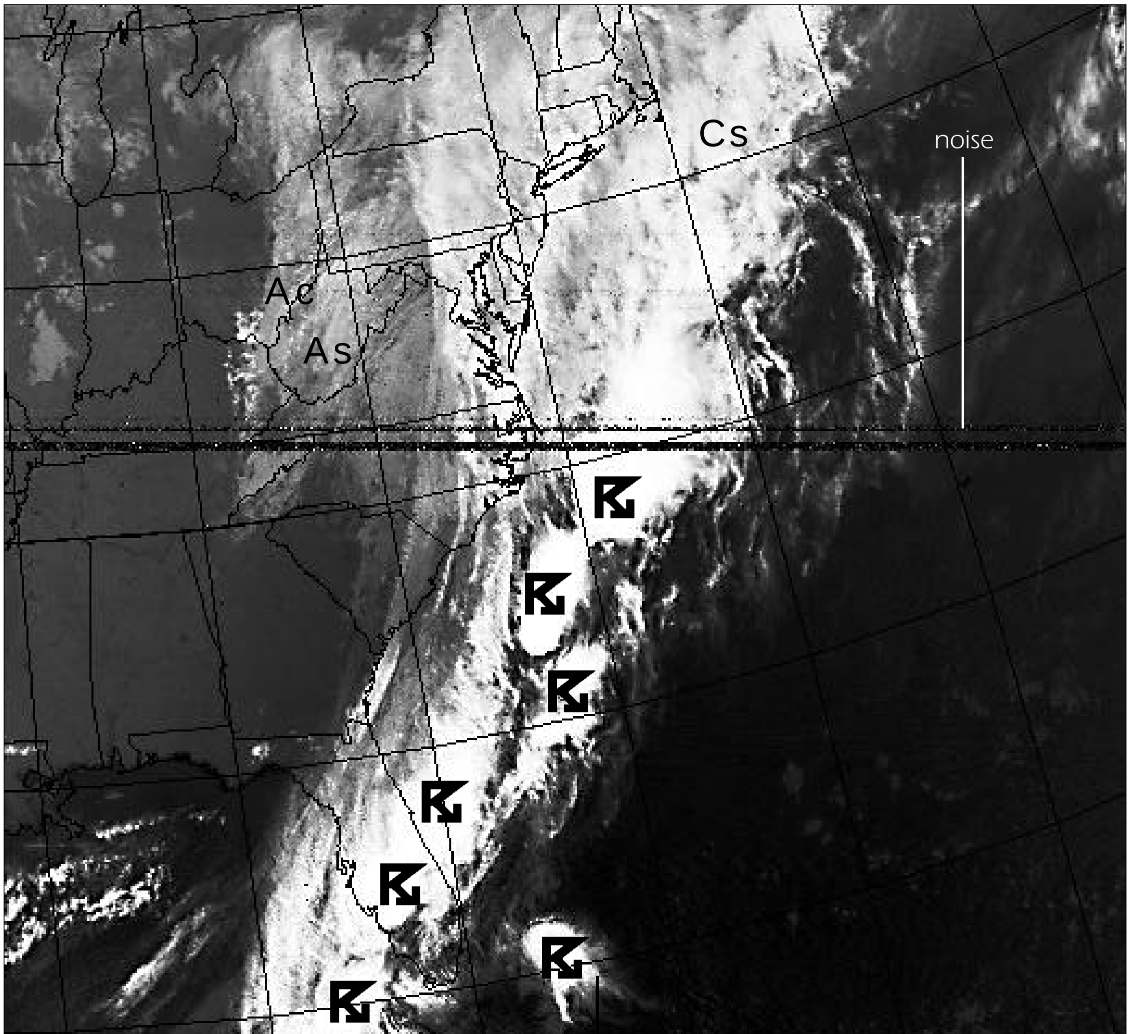

figure 98a. NOAA 10, March 29, 1994
image courtesy of G. Chester, Smithsonian Institution,
Albert Einstein Planetarium

visible image - counterpoint to image 2

Images on computer will more clearly display temperature gradients and facilitate assessment of the infrared image.

Seasonal Migration of the ITCZ

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Grade Level: 9–12

Objectives:
Students will be able to:
1. Identify the ITCZ on a satellite image,
2. Describe the fluctuation of the ITCZ, and
3. Hypothesize why the ITCZ shifts in position.

Relevant Disciplines:
Earth and space science, meteorology, geography

Time Requirement:
One class period

Image Format:
GOES

Prerequisite Skills:
Students should have knowledge and understanding of the following:
1. Latitude
2. Global wind patterns
3. Process of cloud formation
4. Seasonal shifts in the sun's direct rays

Vocabulary:
cloud, convection, convergence, equator, intertropical convergence zone (ITCZ), latitude, thunderstorm, the Tropic of Cancer, the Tropic of Capricorn

Materials:
1. GOES infrared images showing the ITCZ at different times of the year
2. World map
3. Blank transparencies
4. Colored transparency pens
5. Rulers
6. Paper towels
7. Water

Activities

1. Organize the class into groups of two for a pair-share activity.
2. Review the global wind patterns by asking students what they would expect to see on a satellite image at areas of convergence and divergence.
3. Distribute to each group of two the following materials: GOES image and two blank transparencies, world map, two different colored transparency pens, work sheet. Alternating groups should have GOES images for opposite seasons of the year.
4. Direct the students to complete steps #1–3 on their worksheet.
5. Pair each group with another group that has a GOES image for the opposite season of the year.
6. Complete steps #4 and #5 of the procedure with the class.

Extension:
Compare seasonal rainfall data for cities in the ITCZ.

Observing the ITCZ

P air-Share Worksheet

Objectives:

1. Review the location of major lines of latitude.
2. Locate the intertropical convergence zone by observing where and when thunder-storms occur in the tropics.

Materials:

(per groups of two)

1. GOES image and two transparencies
2. World map
3. Two colored transparency pens

Procedure:

1. Label one transparency sheet #1 and the other #2.

2. On the transparency sheet labeled #1, use one colored transparency pen to do the following:
   a. Draw lines to identify and then label the equator, the Tropic of Cancer, and the Tropic of Capricorn. Be sure to move transparency sheet #2 out of the way when your marking on sheet #1.
   b. Mark the location of the compass points (N, S, E, W).
   c. Mark your geographical location (home) with an "x."

3. Answer the following questions:
   a. What latitude receives direct sunlight all year?
   b. What impact will this heating have on the surface air?
   c. What will happen to this air?
   d. Is this air moist or dry? Explain why.
   e. On the satellite image, what cloud patterns do you observe in the area of the ITCZ?
   f. Does the position of the ITCZ change over a year? If so, within which latitudes is it usually located?

4. Label the ITCZ on transparency sheet #2 using a different color transparency pen.

5. Work with a group that has a different GOES image from yours to answer the following questions:
   a. Compare your image and your conclusions. Do you see any similarities? Differences?
   b. Suggest reasons for the similarities and/or differences

6. Choose a spokesperson from your group of four to explain your conclusions to the class.

Key, Question 3, a–f, page 282

Pair-Share Worksheet

3a. the tropical latitudes, especially 0°

3b. Year-round direct heating of the equatorial regions causes the air to expand over the equatorial regions and the warmed air to rise.

3c. When the moist air reaches the "ceiling" of the troposphere (imposed by the stratosphere), it will be forced to diverge—moving poleward. As it moves away from the equator, the air cools—becoming more dense and sinks back toward Earth.

3d. moist—as a result of strong surface evaporation

3e. tall thunderstorms, that is, cumulonimbus clouds

3f. yes. 10°N–10°S

THE INTERTROPICAL CONVERGENCE ZONE (ITCZ)

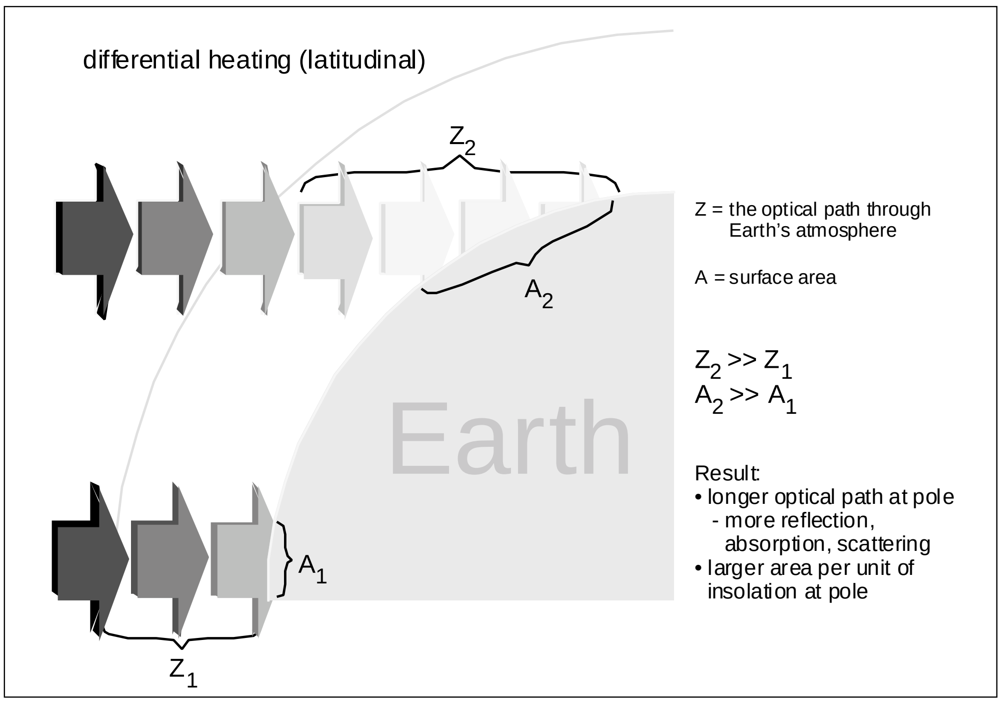
Background

William F. Ryan, University of Maryland, College Park, Department of Meteorology

The general circulation of the atmosphere—the average motion of the winds around the globe—is driven by the differential heating of the Earth. In the simplest terms, excess heating near the equator causes the air to expand or swell over the equatorial regions. Upward motion associated with this heating is typically concentrated in a relatively narrow band named the **Inter-Tropical Convergence Zone** (ITCZ). The satellite signature of the ITCZ is a band of clouds, usually tall thunderstorms (cumulonimbus), that circles the globe near the equator. The position of the ITCZ varies seasonally, moving northward during the northern summer and moving south during the northern winter.

The ITCZ forms as a result of moist air rising under the influence of strong surface heating. Upward motion along the ITCZ is limited to approximately 15 kilometers by the presence of the stratosphere.

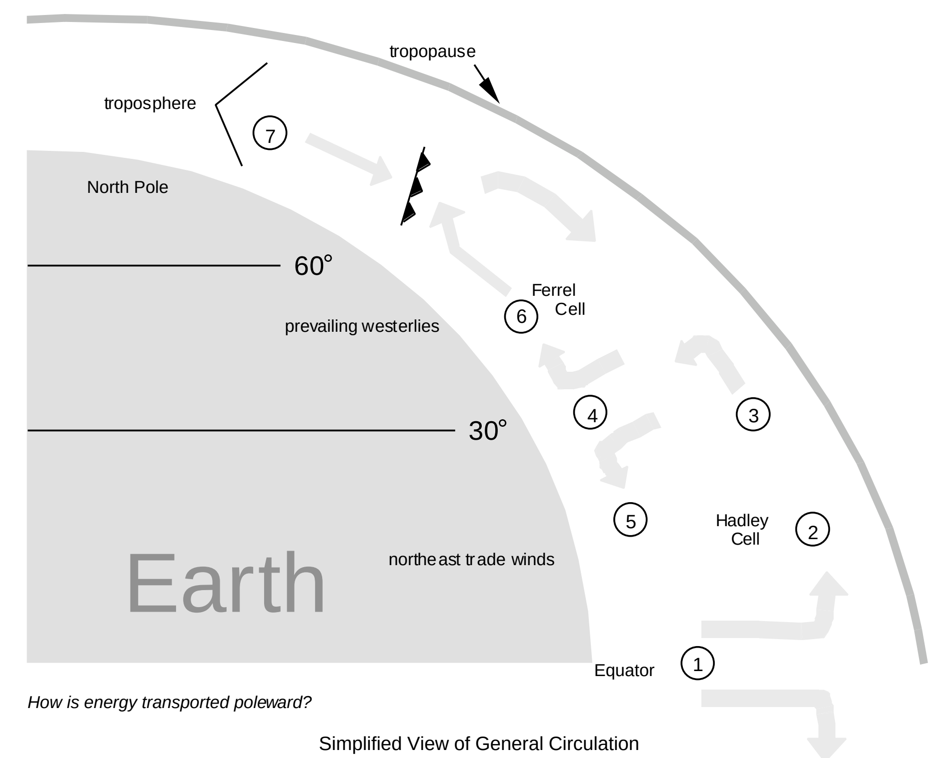
figure 99.



The stratosphere, which is kept very warm by its abundance of ozone efficiently absorbing solar radiation, acts as a lid on the lowest portion of the atmosphere—the troposphere. For practical purposes, all the weather that we experience occurs in the troposphere.

The air that rises in the vicinity of the ITCZ must spread out, or diverge, at the top of the troposphere. We might initially believe that the Earth has a one-cell circulation in which the air lifted at the ITCZ travels north until it reaches the cold polar regions and then sinks. This would be a direct way to restore the system to balance. However, due to complex effects, the circulation associated with the differential heating of the atmosphere is not a simple one-cell circulation from equator to pole. Instead, a more complex multi-cell structure acts to transport heat energy from the equator to the poles. A simplified version of the Earth's general circulation is shown in figure 100, the ITCZ is located at point 1.

figure 100.



How is energy transported poleward?

Simplified View of General Circulation

The rising air near the ITCZ 1 diverges at the top of the troposphere and some portion travels north 2. As the air moves north it radiates energy into space and cools. As it cools it becomes more dense and sinks 3. The area of sinking motion, or subsidence, occurs near 30°N. A region with strong subsidence is typically very clear and warm with light winds. The subsiding air reaches the surface and branches outward 4 with the northern branch traveling north 6 and the southern branch traveling south to complete Hadley cell circulation 5. The northern branch collides with cold, dense polar air moving south 7. This area, marked by the cold front symbol ( ) is often the location of frontal zones and cyclonic disturbances.

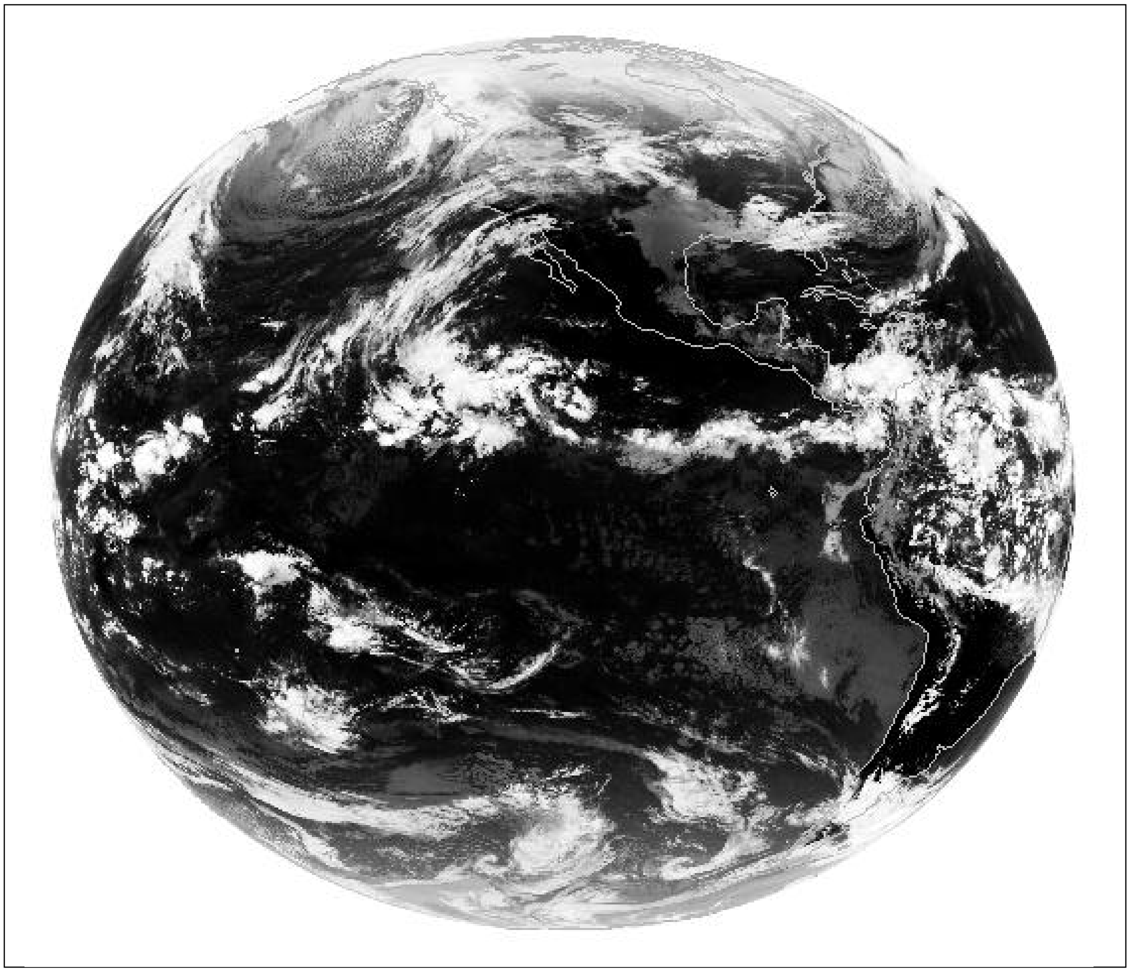


figure 101. GOES infrared image, November 24, 1994
image courtesy of SSEC, University of Wisconsin-Madison

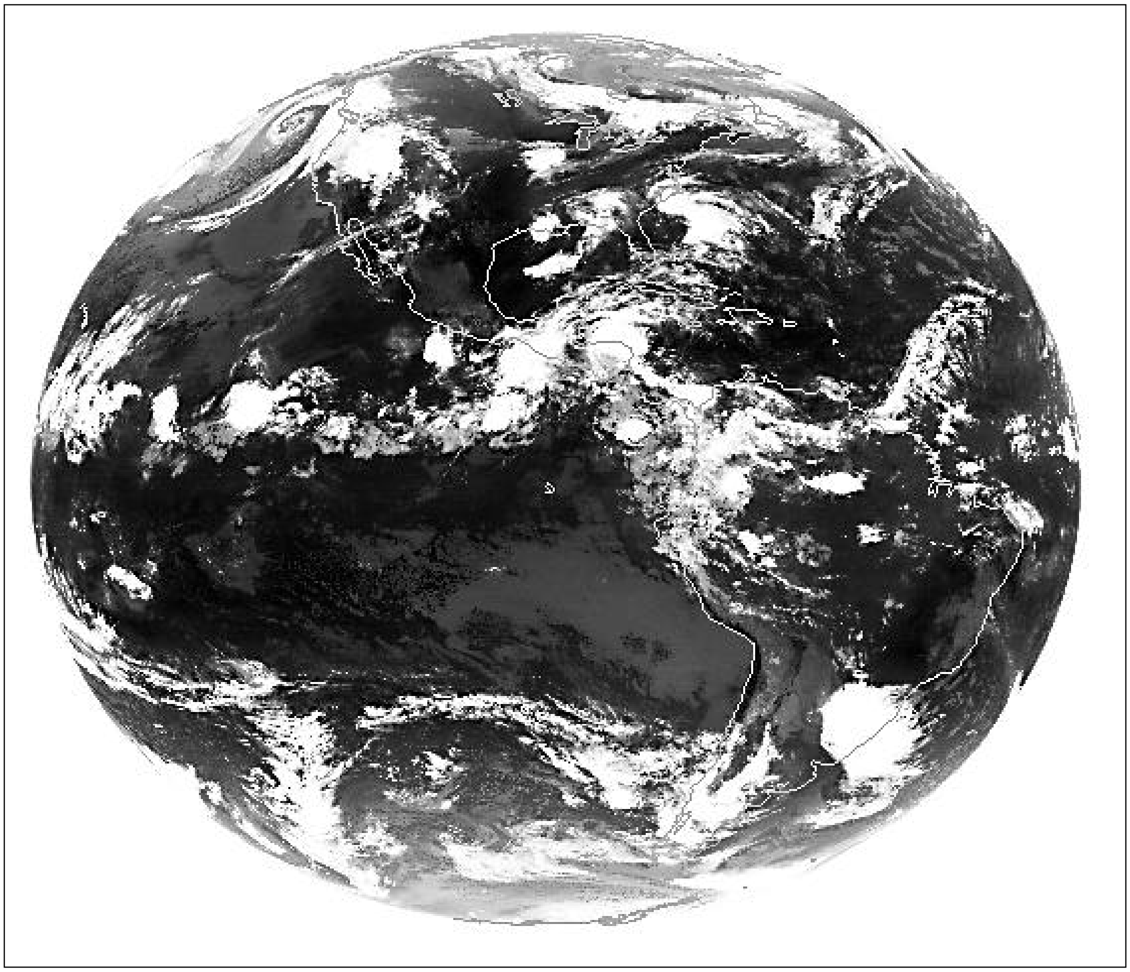


figure 102. GOES infrared image, May 31, 1994
image courtesy of SSEC, University of Wisconsin-Madison

USING WEATHER SATELLITE IMAGES TO ENHANCE A STUDY OF THE CHESAPEAKE BAY

Authors:
Donald Allen, Hancock High School, Hancock, Maryland
Dale E. Peters, Linganore High School, Frederick, Maryland

Grade Level: 9–12

Objectives:
Students will be able to:
1. Demonstrate an understanding of the relationship between environmental parameters of an ecosystem and organism behavior,
2. Demonstrate the ability to use basic math functions,
3. Identify various geographic features of the eastern U.S. using weather satellite images, and
4. Explain the differences in land and water surface temperatures obtained from weather satellite images.

Rationale:
To show students how weather satellite images can be used in studying various environmental interactions.

Relevant Disciplines:
Biology, Earth science, environmental science, mathematics, English, social studies

Time Requirement:
2–3 class periods

Image Format:
APT (infrared), GOES

Prerequisite Skills:
1. Students should be familiar with using metric units.
2. Students should have some experience using information obtained from weather satellite images.
3. Students should be able to calculate area and find the average of a data set.
4. Students should have a basic understanding of Polar-orbiting and GOES satellites and the images they produce.
5. Students should have a basic understanding of energy absorption and emission by land and water.
6. Students should have a basic understanding of the properties of water.
7. Students should be familiar with the Gulf Stream.

Vocabulary:
albedo, APT, ecosystem, geosynchronous, GOES, infrared, NOAA, parameter, salinity, sun synchronous, water properties (heat capacity, specific heat)

Materials:
1. Metric rules
2. Cloud identification chart
3. Balance
4. Scissors
5. Colored pencils
6. String
7. Student activity answer sheet
8. Spring and fall satellite images of the eastern U.S. for each pair of students
9. Supplementary satellite images of the eastern U.S.
10. Map of the eastern U.S.
11. Map of the Chesapeake Bay drainage area for each student
12. 3 maps of the Chesapeake Bay for each student
13. Copies of “Blue Crab” and “Striped Bass” articles for each student
14. Cloud chart

Activities

note: The day before this lesson is to be started, distribute the GOES weather satellite images and the cloud identification charts. Discuss with the class the basic features illustrated in these images and the properties of water. The distinction between visible and infrared images should be made at this time.

Warm-Up:
As a class, have students identify the major tributaries of the Chesapeake Bay on their individual maps.

note: It is suggested that a wall map of the eastern U.S. be available to help the students identify the major tributaries of the Bay.

Students should work in pairs for the remaining activities

1. Using the map on page 294, calculate the area of the Chesapeake Bay watershed.

2. Using one of the maps of the Chesapeake Bay, calculate the surface area of the Bay.

note: One possible way to calculate the area of the Bay is to weigh the piece of paper the bay map is on. Have students cut out the outline of the Bay and weigh this piece of paper. Calculate the area of the Bay using the following formula.

$$\frac{\text{area of whole piece of paper}}{\text{mass of whole piece of paper}} = \frac{\text{area of the Bay}}{\text{mass of cut-out peice of paper}}$$

or

Students could follow the perimeter of the Bay with a peice of string, reshape it into a rectangle, and then determine the Bay’s area.

Have students explore other ideas they may have.

3. Using the satellite images containing temperature readings, calculate the average temperature of the land surface, the surface of the Chesapeake Bay, and the Atlantic coast water surface.

4. Using the information from the salinity charts, the article on the blue crab, and the satellite images with temperature readings:
   - Color the area on the Chesapeake Bay map where you would expect to find blue crabs in the early spring;
   - Using a different color, indicate where the blue crabs would be found in the fall; and
   - Make a color key on your map.

5. Repeat step FOUR for the striped bass population, replacing the blue crab article with the article on the striped bass.

Extension:

1. Determine the basic cloud types from the satellite images you have been given. Use a cloud chart and briefly discuss the possible weather conditions associated with cloud type.

2. Write a letter of request seeking more information on the blue crab, striped bass, or other threatened species living in the Chesapeake Bay.

References:

Chase, Valerie. *The Changing Chesapeake.*
Chesapeake Bay: *Introduction to an Ecosystem.* U.S. EPA
Lee and Taggart. Adapted from *"A Satellite Photo Interpretation Key."*
Blue Crab. U.S. Fish and Wildlife Service.
Striped Bass. U.S. Fish and Wildlife Service.

Additional Resources:

Berman, Ann E. *Exploring the Environment Through Satellite Imagery*
Chesapeake Bay Restoration: U.S. Fish and Wildlife Service,
"Mission to Planet Earth." *Aviation Week & Space Technology*
National Oceanic and Atmospheric Administration (NOAA) Education Affairs Division
Reports To The Nation On Our Changing Planet, The Climate System. UCAR

A STUDY OF THE CHESAPEAKE BAY

name ______________________
period ______________________
date ______________________

Activity Sheet

Please answer all of the following, except number three, with complete sentences.

1. What is the area of the Chesapeake Bay drainage area (km^2)?

2. What is the area of the Chesapeake Bay (km^2)?

3. Average the following temperatures obtained from satellite images:

	spring	fall
land surface		
Chesapeake bay		
Atlantic Coast		

4. Explain you and your partner's selection of locations with blue crab in spring and fall (the areas you colored in). Be sure to consider salinity and temperature differences in your answer.

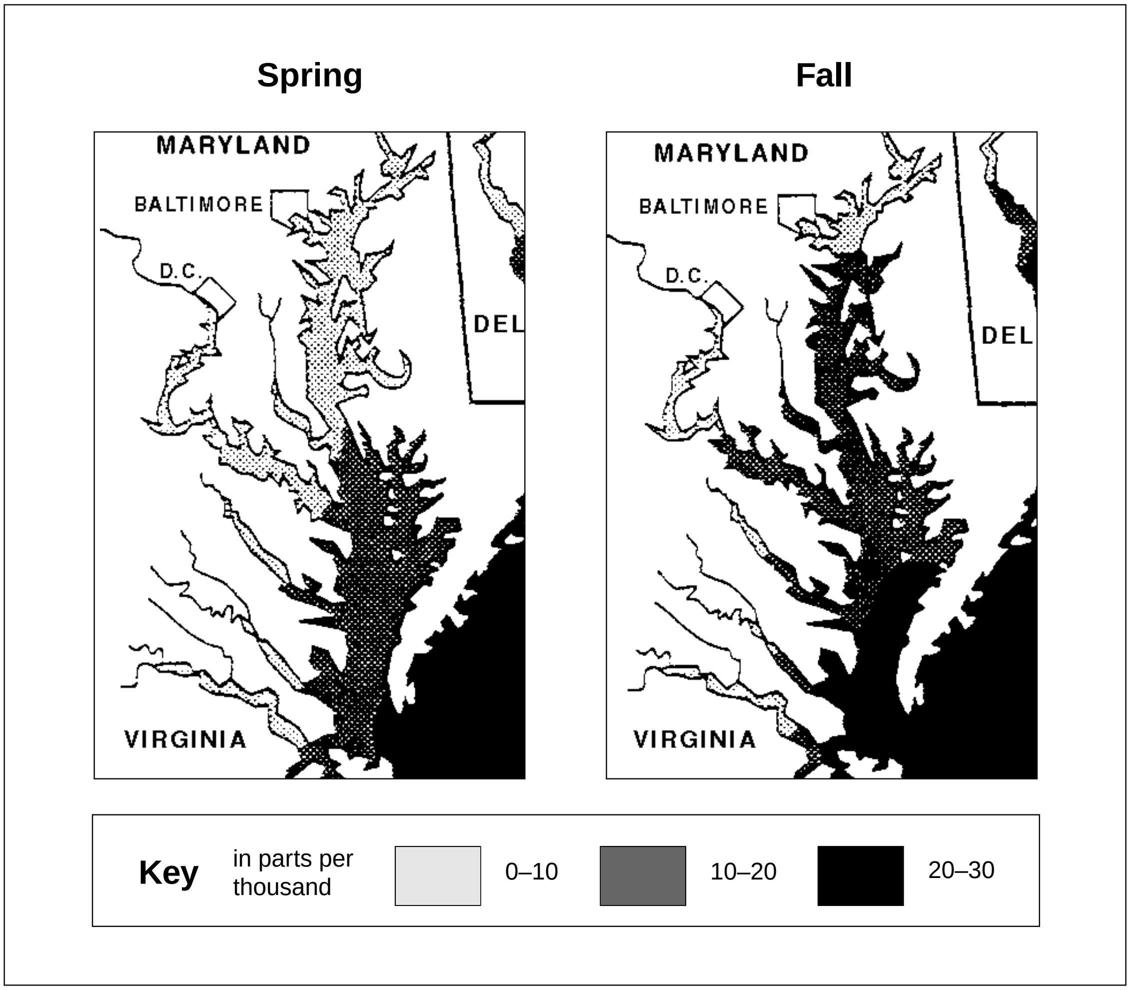
5. Explain you and your partner's selection of locations with striped bass for spring and fall (the areas you colored in). Be sure to consider salinity and temperature differences in your answer.

6. Discuss why the Chesapeake Bay has a greater temperature gradient between land and water surfaces in the fall than in the spring.

7. Typically, deeper water is cooler than shallow water. Why then, do the surface temperatures of coastal waters get warmer farther from shore, as indicated on the weather satellite images?

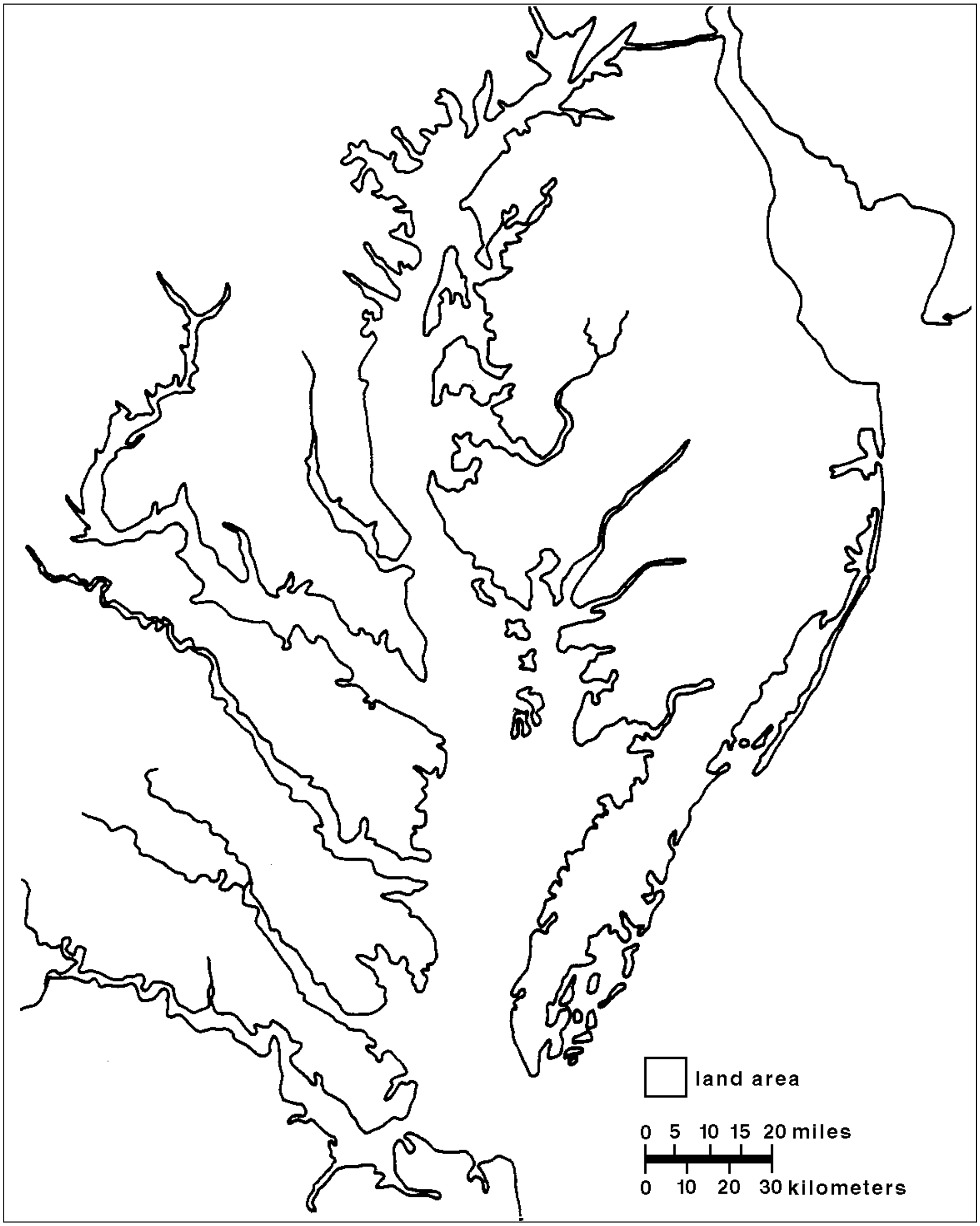
8. What possible explanations may account for the readings of -1° C for land surface temperature on the fall weather satellite image?

Chesapeake Bay Salinity

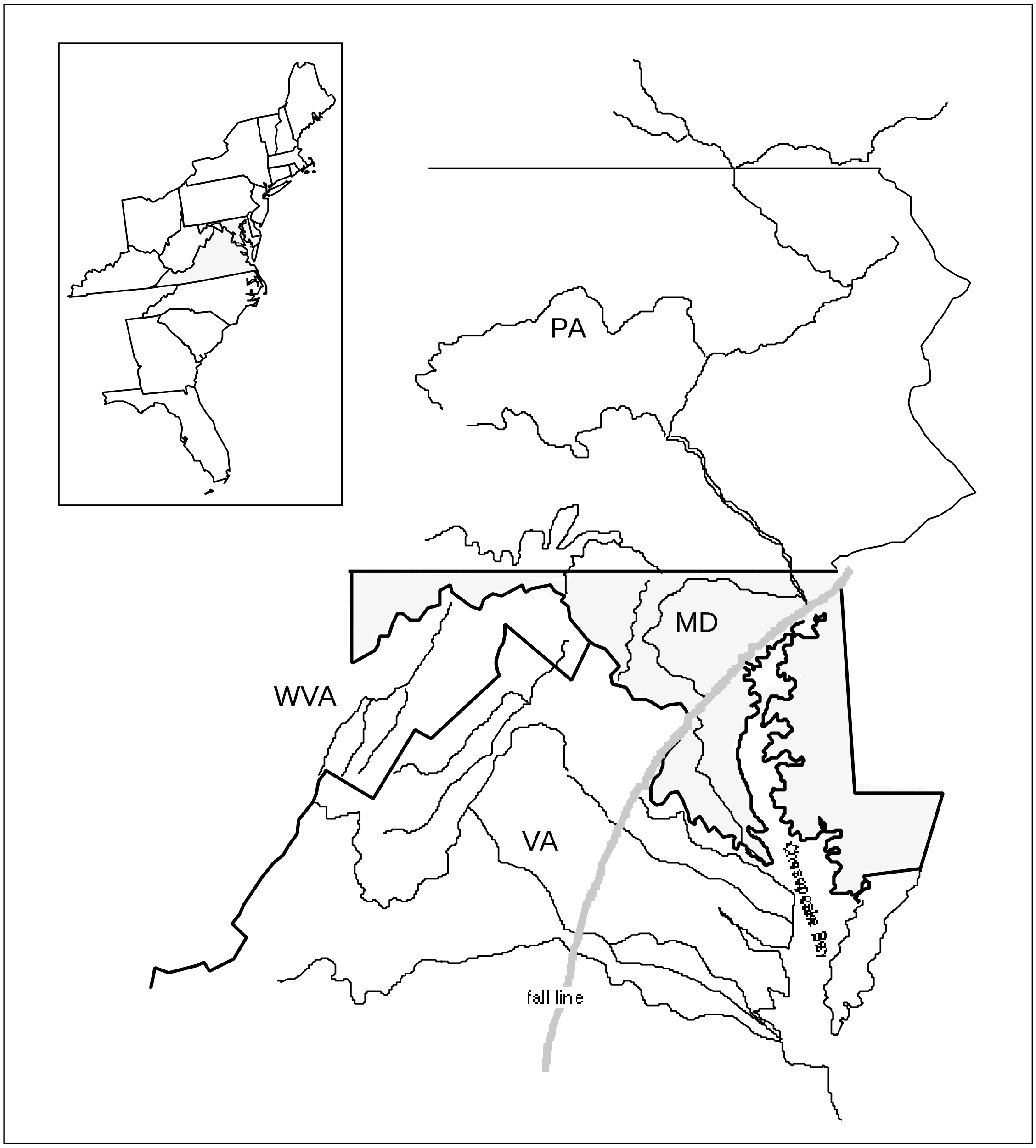


Salinity: Spring and Fall: Higher river flows in spring (left) push back the ocean's saltier influence. In autumn, drier weather diminishes river flow and the ocean marches up the estuary. Adapted from Cronin, *The Biology of the Estuary*, and White, *Chesapeake Bay: A Field Guide*.

Map of the Chesapeake Bay



EAST COAST MAP



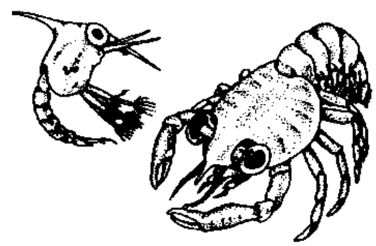
BLUE CRAB (CALLINECTES SAPIDUS)

The Bay's Best

One can hardly say Chesapeake Bay without a picture of the blue crab coming to mind. This pugnacious creature has been the honored center of attention at many feasts over the years. Close your eyes and you can almost smell the spicy seasoning. Commercial crabbers harvest roughly 80 million pounds annually and recreational crabbers take nearly as much. Blue crabs have a place of importance in the ecosystem. They help regulate the abundance of benthic (bottom) populations by feeding upon living and dead organisms. They serve as food for cownose rays, striped bass and bluefish. When small, or in its softshelled stage (after molting), the crab is a source of food for wading birds and some mammals.

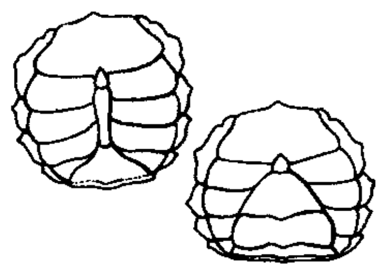
Life History

The blue crab (Callinectes sapidus) is a crustacean, one of a large group of animals characterized by a hard external shell and many jointed appendages. Other familiar crustaceans include lobsters, cray-fish, and shrimp. Blue crabs belong to a group known as "swimming crabs," identified by the paddle-like back legs. The scientific name Callinectes is a Greek word meaning beautiful swimmer. The second part of the blue crab's scientific name, sapidus, is Latin, meaning tasty or savory. Blue crabs are omnivorous, meaning that they will eat just about anything, dead or alive, including other crabs. Living or decaying vegetation also comprises part of their diet.



Zoea and Megalops

The shell of the adult crab is dark green on top and white underneath. A deep blue coloring on the top of the large claw gives this crab the common name "blue crab." A crab's sex can be determined by the shape of the abdomen or "apron" on the underside of the crab. A male crab has an apron which is shaped like an inverted "T." An adult female's is broad and rounded, while an immature female's is more triangular. Red tips on the claws also indicate that the crab is a female. A female carrying a cluster of orange eggs beneath her apron is known as a "sponge crab" and is nearing spawning time.



Male and Female

A crab increases in size through periodic molting or shedding of its shell. The hard shell is incapable of expanding and must be shed in order for the new, soft, slightly larger shell to be exposed. The crab pumps water into its body to enlarge the new shell and within a few hours, the shell hardens. In its first stage of life, the microscopic young blue crab is known as a "zoea" and lives a planktonic or free-floating existence. After molting about seven times, the zoea reaches a second larval stage known as a "megalops," looking like a cross between a crab and a lobster. After one more molt, however, the "first crab," no bigger than a "BB " is revealed. The "first crab" begins migrating from its birthplace in the southernmost part of the estuary to tidal rivers and throughout the Bay.

In 12 to 18 months, the juvenile crab reaches maturity and measures about 5 inches from point to point across the back. The mating of the crab starts as the male crab struts about, posturing with his claws and walking on tip-toes. At the end of the courtship, the female turns her back to the male and may try to back underneath him. The male crawls on top and cradles her between his walking legs until she molts, at which time mating occurs. Cradling insures proper timing for mating and protection of the female while she is soft and vulnerable during and after molting. After the female's shell hardens again, the crab couple go their separate ways. The male crabs remain in the fresher reaches of the Bay and its tributaries until fall, then move to deeper water. The female crabs migrate to spawning areas near the mouth of the Chesapeake Bay by the end of fall where the eggs will hatch the following summer.

Shedding Blue Crab

Crabs and Watermen

Blue crabs provide a commercial resource that many watermen and seafood enterprises depend on for their livelihood. Starting in late April and often continuing through December, watermen set out in the pitch-black morning in search of the blue crab. As dawn breaks, the watermen, clad in oilskin aprons and rubber gloves, mark the beginning of a new day by kicking their hydraulic "pot-pullers" into motion. With gaffs in hand, they pull in the crab pots filled with the adult female that prevail in the southern Bay. Moving to deeper waters the watermen harvest the larger male crabs. As winter approaches, the blue crabs conceal themselves in the bottom mud. In the southern Bay, the most determined watermen then resort to dredging the bottom for the succulent treasure because scarcity brings higher prices.

Watermen

Resource at Risk

Starting in the 1930's, the harvest of crabs steadily increased for many years, due in part to increased fishing. In 1970, however, a downward trend began and the blue crab catch dropped throughout the Bay. In 1980, the trend again changed and the blue crab harvest increased. No one knows for certain what conditions influence a record-setting year or a poor-catch year. The temporary bounty of this species does not indicate that it or the Bay has no problems.

Biologists are now studying the blue crab to understand how its numbers are affected by a deteriorating Bay environment. One factor which has been found to have a definite impact on the crab's habitat is nutrient pollution. High discharges or runoff of phosphates and nitrates from sewage plants and farm fields causes overfertilization of water which, in turn, leads to massive algal blooms. When these free-floating, microscopic plants die, they decompose, leaving the water low in dissolved oxygen. Areas of low dissolved oxygen are increasing in the Bay. When water containing a low amount of dissolved oxygen is pushed toward shore by winds, crabs will avoid it, even to the extent of running onto land, a phenomenon known as a "crab war."

The blue crab population is not in serious jeopardy at this time, as are populations of American shad and oyster. This treasure of blue crabs, however, may suffer adverse consequences if overharvesting occurs or the quality of its water habitat deteriorates further.

For more information on Chesapeake Bay restoration, contact:

U.S. Fish and Wildlife Service Chesapeake Bay Estuary Program
180 Admiral Cochrane Drive, Suite 535
Annapolis, MD 21401
(301) 224-2732

Blue Crab Facts

- Other common names for the blue crab include edible crab, sally crab (young females), sook (adult females), and jimmy, jimmy dick, or channeler (large male crabs).
- Female blue crabs mate at the time of their final molt from the immature to the adult stage, and then migrate toward the lower Bay.
- The female blue crab stores the male's sperm in specialized sacs, where it can survive for up to a year before fertilization takes place.
- The female crab's orange egg mass may contain 2 million eggs!
- Out of this amazing number of eggs, less than one percent will reach maturity.
- All Maryland blue crabs begin their lives in Virginia. The larvae are carried out of the bay by surface currents soon after hatching. Salinities on the continental shelf that range from 28 to 34 parts per thousand are optimum for the tiny larvae. After 6 weeks or so, megalopae return to the Bay.
- After reaching maturity, crabs live an average of l year and rarely more than 2 years.
- While they are in their vulnerable softshell stage, blue crabs find protection in underwater grass beds or in shallow water from predators such as fish, cownose rays, and even other blue crabs.
- The soft-shell crab industry began in Crisfield, Maryland in the 1870's.
- More blue crabs are harvested from Chesapeake Bay than anywhere else.

U.S. Fish and Wildlife Service

The Chesapeake Bay is the largest estuary in North America. Its waters provide food and habitat for an abundance of fish and wildlife. It serves as a highway for commerce, a playground, a storehouse of food, and a home for the 13.6 million people who live in its vast watershed. But in recent years the Chesapeake has become less able to support the fish and wildlife it once did. Increasing amounts of excess nutrients, sediment, and toxic substances are causing serious ecological problems in the Bay. Studies show alarming declines in species of fish and wildlife and in the habitat available to them.

The U.S. Fish and Wildlife Service is one of many Federal, State, and local agencies and private organizations engaged in the Chesapeake Bay restoration program to reverse the damage already done, to arrest further degradation and to restore the Bay—as nearly as time, technology and resources allow— to its former productivity.

As one of the primary Federal stewards of the nation's living natural resources, the U.S. Fish and Wildlife Service provides leadership in habitat and wetlands protection, fish and wildlife research, technical assistance, and in the conservation and protection of migratory birds, anadromous fishes certain marine mammals. and threatened and endangered species. The Service also manages more than 450 National Wildlife Refuges and 70 National Fish Hatcheries across the country, including more than a dozen in the Bay area.

Take Pride in Chesapeake Bay!

STRIPED BASS (MORONE SAXATILIS)

Resource at Risk

Since colonial days, East Coast fisherman have delighted in the striped bass, a migratory fish known for its size and fighting ability. Striped bass, often called rockfish in Chesapeake Bay, have long been an important commercial and game fish from North Carolina to Maine. During the 1970s and 1980s, striped bass declined alarmingly, especially in the Chesapeake, once the spawning and nursery, ground for nearly 90 percent of the Atlantic population.

From a record commercial catch of 14.7 million pounds in 1973, the harvest dropped to 1.7 million pounds just 10 years later. Sport fishermen report an equally severe drop in their harvest. The decline translated into a loss of about 7,000 jobs and $220 million in 1980.

Causes for the decline were numerous and interwoven. They included overfishing, pollution, and the degradation or loss of habitat. Recently, due to improved management techniques, a hatchery, program and increased public awareness, the striper population has improved.

Life History

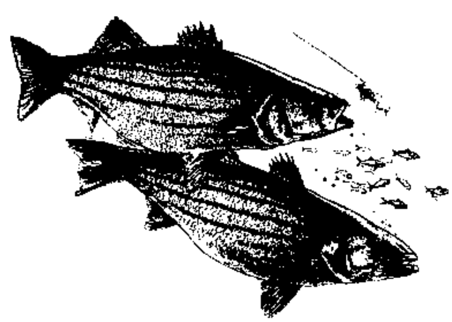
The silvery, striped bass gets its name from the 7 or 8 dark, continuous lines along the sides of its body. Most striped bass weighing more than 30 pounds are female. The fish can weigh up to 100 pounds and reach nearly five feet in length!

Striped bass spawn in fresh water but spend most of their adult lives in the ocean. On the Atlantic coast they range from the St. Lawrence River in Canada to Florida's St. Johns River. although they are most prevalent from Maine to North Carolina.

After about 3 years, at the juvenile stage, the females begin to migrate to the ocean where they mature. The males tend to remain in the estuary longer than the females. After 5 to 7 years, females return to spawn for the first time. It takes several years for spawning females to reach full productivity. An average 6 year-old female produces half a million eggs while a 15 year-old can produce three million.

When water temperature begins to rise in the spring, mature fish begin their spawning runs. Most Atlantic Coast striped bass spawn in freshwater rivers and streams of Chesapeake Bay. Other important areas include the Hudson River, Delaware River and rivers along the North Carolina coast.

Once the female deposits her eggs, they arc fertilized by milt (sperm) ejected from the males. Because they are only semibuoyant, the eggs require enough water flow to stay suspended for 2 or 3 days until they hatch.



Larval striped bass obtain nutrients from the yolk sac for about 5 days after hatching. The larvae are particularly vulnerable to pollution, starvation, and predators during this stage.

C ause for Concern

The decline of Atlantic striped bass was so alarming that Congress enacted an Emergency Striped Bass Act in 1979. Under the Act, a study was initiated to assess the size of the migratory stock, investigate the causes of decline, calculate its economic importance and recommend measures for restoration.

From this research, scientists from the U.S. Fish and Wildlife Service, state agencies and universities discovered new information about striped bass to assist them in restoration. Careful assessment of the present stock showed that, because of overfishing, the striped bass population was much more susceptible to natural stresses and pollution. They also discovered that fluctuation of water temperatures at spawning grounds is the most significant natural stress the fish face.

Research conducted in the Chesapeake's Nanticoke and Choptank Rivers indicated that highly acidic rain reacts with aluminum in the soil, causing it to dissolve in the water The combination of high acidity and aluminum is lethal to newly hatched stripers. Larval striped bass are also very susceptible to toxic pollutants like arsenic, copper, cadmium, aluminum, and malathion, a commonly used pesticide. Studies showed that chlorination of effluent from sewage plants and electric power stations adversely affects zooplankton, leading: ding to starvation of newly hatched striped bass that feed on it.

The study team also concluded that reducing fishing pressure would have an immediate positive effect by enabling females with eggs to spawn. An Atlantic Stares Marine Fishery Commission management plan, based party on recommendations of this study. set size and pound limits to reduce the catch.

In 1985, Maryland imposed a total moratorium on striped bass. Virginia followed by banning striped bass fishing in spawning areas. Four years later. Virginia also imposed a total ban on striped bass fishing. However. fishery managers knew that harvest restrictions alone would not permanently restore striped bass to the Bay.

B ringing the Striper Back

Under the Emergency Striped Bass Restoration Act, Congress designated the Fish and Wildlife Service as the lead federal agency to determine the cause of the fishery's decline. Striped bass restoration began in 1980. Water quality problems on spawning grounds were evaluated. By 1985, a coast-wide striped bass tagging and hatchery program was initiated to determine the rates of exploitation and natural morality, and determine if hatchery-reared fish could supplement wild stocks in severely depleted rivers.

Fishery managers and biologists from the Fish and Wildlife Foundation, National Marine Fisheries Service, state agencies from Massachusetts to North Carolina and universities continue to participate in the striped bass tagging program. A central database, designed and managed by the Service, stores stocking information, migrarory data from tag returns and other information upon which management decisions are based.

Anchor or "spaghetti" tags are inserted into juvenile striped bass.

Since 1985, more than 190,000 hatchery-reared and wild striped bass have been tagged with external anchor or “spaghetti” tags. Anglers returned more than 30,000 of these tags by 1993. In addition, all hatchery-reared striped bass, more than 9 million fish in all, are tagged with tiny micro-encoded pieces of wire that anglers cannot see but researchers can read with specialized equipment. These hatchery-reared striped bass provide managers with information about population dynamics, growth and migratory patterns.

In 1988, hatchery fish comprised nearly 50 percent of Maryland, Iand juvenile striped bass in some rivers like the Patuxent. Today, as hoped, wild fish far outnumber hatchery fish. Evaluations continue on the potential contribution of hatchery fish to depleted stocks.

During the years of the moratorium in Maryland, fishery managers continued to monitor striped bass populations in Chesapeake Bay. In particular, the juvenile index survey was closely watched. Conducted annually since 1954, this survey of the young-of-the-year reflects the success of spawning. The striped bass management plan set a goal for loosening restrictions based on this index. The juvenile indices averaged from 1987 to 1989 met the management plan goal.

In 1989, both Virginia and Maryland lifted their moratoriums on striped bass. Limited commercial and recreational striped bass fishing resumed.

The Future of the Fishery

Striped bass stocks continue to gradually increase. The 1993 juvenile index was the highest since the survey first began. Besides the young-of-the-year index, managers have noted an increase in adult striped bass and in the proportion of spawning females, age 8 or older. This information is critical to establishing fishing seasons, minimum fish lengths, daily catch limits and harvest quotas.

Since Chesapeake Bay is the primary, spawning and nursery area for 70–90 percent of Atlantic stock of striped bass, restoration depends on protecting and improving habitat and water quality. We have much to gain from restoring striped bass and Chesapeake Bay; we have much more to lose if we decline the challenge. Through harvest restrictions, pollution control, stocking and commitment, we can restore the striped bass to Chesapeake Bay.

For more information contact:

U.S. Fish and Wildlife Service Chesapeake Bay Estuary Program
177 Admiral Cochrane Drive
Annapolis, MD 21401
(410) 224-2732

Striped Bass Facts

- 70–90 percent of the striped bass in Atlantic coast waters spawn in Chesapeake Bay tributaries.
- At one time striped bass were used to fertilize fields, so great were their numbers.
- Maximum weight recorded for a striped bass is 125 pounds; age is 31 years.
- Older striped bass produce more eggs than younger fish and the eggs are of higher quality.

U.S. Fish and Wildlife Service

The Chesapeake Bay is the largest estuary in North America. Its waters provide food and habitat for a great variety of fish and wildlife. It serves as a highway for commerce, a playground, a storehouse of food, and a home for the 13.6 million people who live in its vast watershed. But in recent years the Chesapeake has become less able to support the fish and wildlife it once did. Increasing amounts of nutrients, sediment, and toxic substances are causing serious ecological problems in the Bay. Studies show alarming declines in populations of fish and wildlife and in the habitat available to them.

The U.S. Fish and Wildlife Service is one of many federal, state, and local agencies and private organizations engaged in the Chesapeake Bay restoration. Nationally, the Service provides leadership in habitat and wetlands protection, fish and wildlife research, technical assistance, and in the conservation and protection of migratory, birds, anadromous fishes, certain marine mammals, and threatened and endangered species.

The Service also manages more than 500 national wildlife refuges and 75 national fish hatcheries across the country, including more than a dozen in the Bay area.

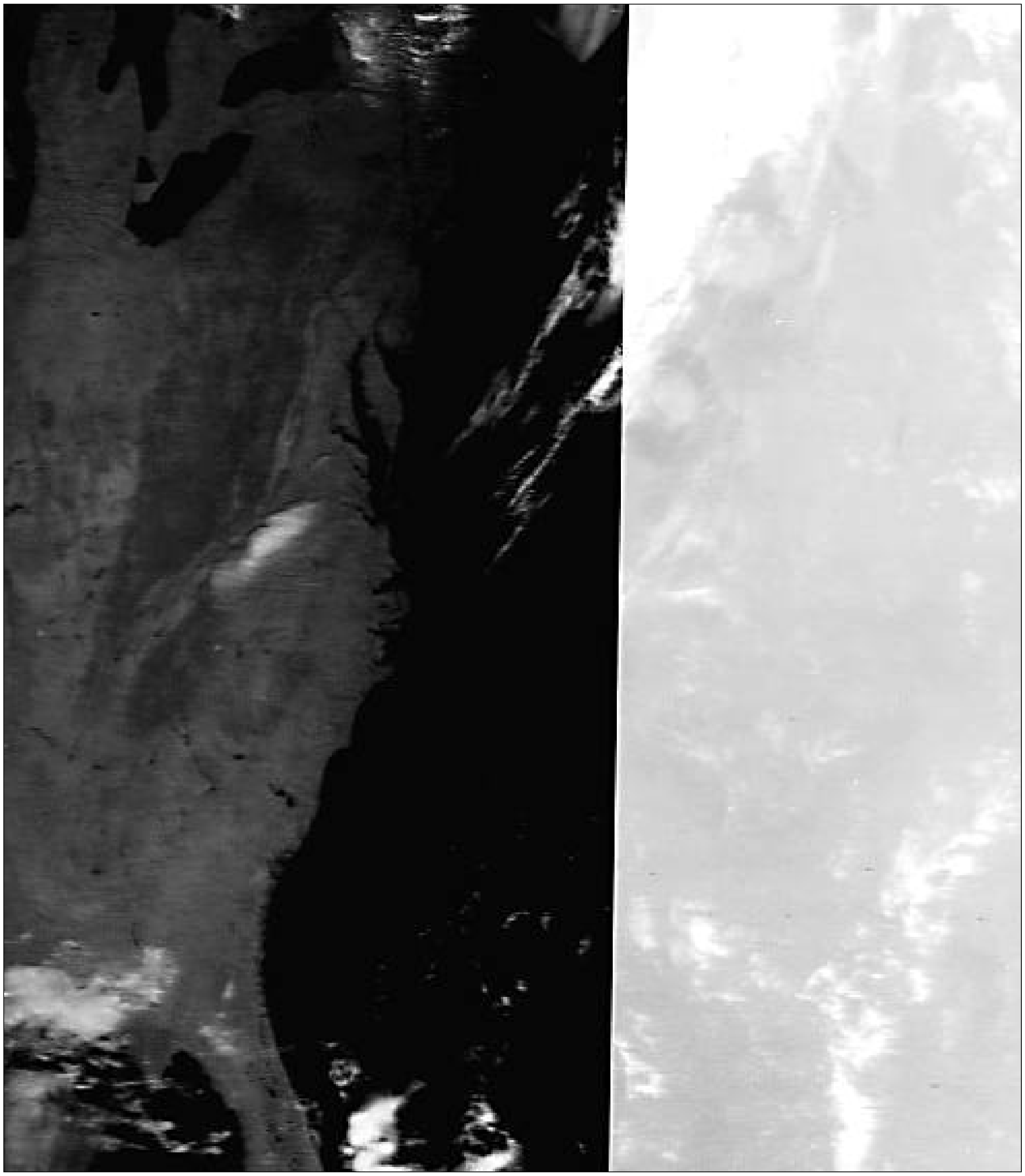


figure 103. NOAA 12, Chesapeake Bay on April 20, 1994
image courtesy of D. Peters, Linganore High School, Frederick, Maryland

figure 104. NOAA 12, Chesapeake Bay on May 3, 1994
image courtesy of D. Peters, Linganore High School, Frederick, Maryland

figure 104a. NOAA 12, Chesapeake Bay on May 3, 1994, with temperatures
image courtesy of D. Peters, Linganore High School, Frederick, Maryland

figure 105. NOAA 12, Chesapeake Bay on September 1, 1993
image courtesy of D. Peters, Linganore High School, Frederick, Maryland

figure 106. NOAA 12, Chesapeake Bay on November 7, 1994, showing hurricane
image courtesy of D. Peters, Linganore High School, Frederick, Maryland

Glossary

adiabatic
Process without transfer of heat, compression results in warming, expansion results in cooling.

advection
Horizontal transfer of any atmospheric property by the wind.

air mass
Large body of air, often hundreds or thousands of miles across, containing air of a similar temperature and humidity. Sometimes differences between masses are hardly noticeable, but if colliding air masses have very different temperatures and humidity values, storms can erupt.

air pressure
The weight of the atmosphere over a particular point, also called barometric pressure. Average air exerts approximately 14.7 pounds (6.8 kg) of force on every square inch (or 101,325 newtons on every square meter) at sea level. See *millibar.*

albedo
The ratio of the outgoing solar radiation reflected by an object to the incoming solar radiation incident upon it.

alto
From the Latin *altum* (height), the prefix is used to describe some middle height clouds. See *clouds.*

apogee
The point on an orbital path where the satellite is farthest from the Earth's center.

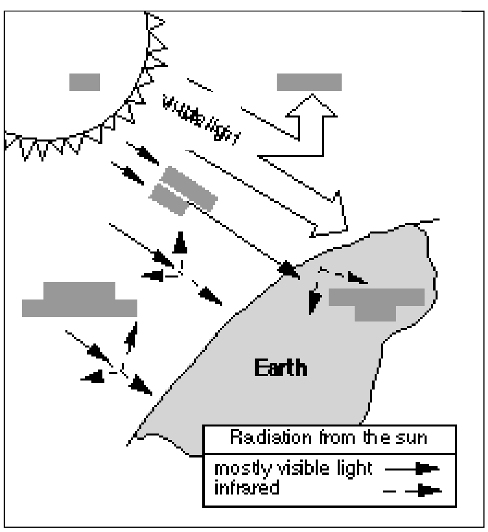


figure 107. albedo

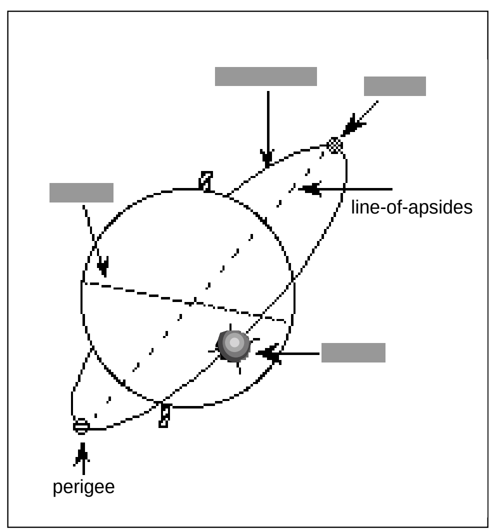


figure 108. apogee

APT, Automatic Picture Transmission
System developed to make real-time reception of satellite images possible whenever an APT-equipped satellite passes within range of an environmental satellite ground station. APT images are transmitted by U.S. polar-orbiting TIROS-N/NOAA satellites which orbit 500–900 miles above the Earth and offer both visible and infrared images.

argument of perigee (ω)
One of six *Keplerian elements*, it describes the rotation of the satellite on the orbit. The argument of *perigee* is the angle from the *ascending node* to perigee. The angle is measured from the center of the Earth. For example, when $\omega = 0$ degrees, *apogee* would occur at the same place as the descending node.

ascending node
The point in an orbit (longitude) at which a satellite crosses the equatorial plane from south to north.

azimuth
The angle measured in the plane of the horizon from true north clockwise to the vertical plane through the satellite.

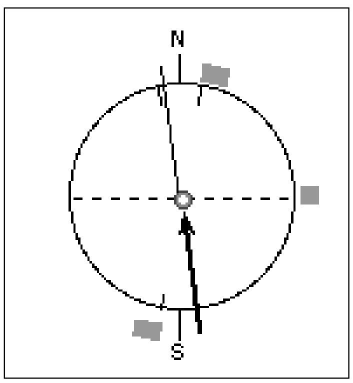


figure 109. ascending node

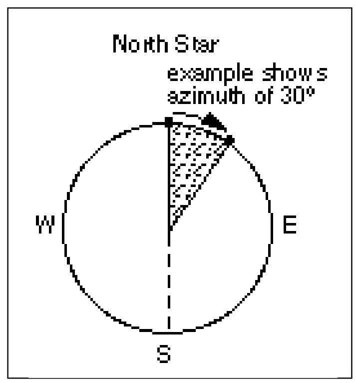


figure 110. azimuth

baroclinic
Instability in the atmosphere arising from a meridional temperature gradient. Extratropical cyclones are associated with strong baroclinicity.

bit
A contraction of "binary digit." The basic element of a two-element (binary) computer language.

byte
A unit of eight bits of data or memory in computer systems.

catalog (object) number
A five-digit number assigned to a cataloged orbiting object. This number is found in the NASA Satellite Situation Report and on the *NASA Prediction Bulletins.*

centrifugal
An apparent force present in a rotating system which deflects an object outward from the axis of rotation.

cirrus
See *cloud.*

Clarke Belt
A belt 22,245 miles (35,800 kilometers) directly above the equator where a satellite orbits the Earth at the same speed the Earth is rotating. Science fiction writer and scientist Arthur C. Clarke wrote about this belt in 1945, hence the name.

cloud
A visible mass of water droplets or crystals suspended in the atmosphere above Earth's surface. Clouds form in areas where air rises and cools. The condensing water vapor forms small droplets of water(0.012 mm) that, when combined with billions of other droplets, form clouds. Clouds can form along warm and cold fronts, where air flows up the side of the mountain and cools as it rises higher into the atmosphere, and when warm air blows over a colder surface, such as a cool body of water.

Clouds fall into two general categories: sheet-like or layer-looking stratus clouds (stratus means layer) and cumulus clouds (cumulus means piled up). These two cloud types are divided into four more groups that describe the cloud's altitude.

High clouds form above 20,000 feet in the cold region of the troposphere, and are denoted by the prefix CIRRO or CIRRUS. At this altitude water almost always freezes so clouds are composed of ice crystals. The clouds tend to be wispy, are often transparent, and include cirrus, cirrocumulus, and cirrostratus.

Middle clouds form between 6,500 and 20,000 feet and are denoted by the prefix ALTO. They are made of water droplets and include altostratus and altocumulus.

cloud groups and abbreviations	
high clouds	*low clouds*
cirrus (Ci)	stratus (St)
cirrostratus (Cs)	stratocumulus (Sc)
cirrocumulus (Cc)	nimbostratus (Ns)
middle clouds	*vertical clouds*
altostratus (As)	cumulus (Cu)
altocumulus (Ac)	cumulonimbus (Cb)

figure 111.

Low clouds are found up to 6,500 feet and include stratocumulus, nimbostratus, and stratus clouds. Nimbostratus clouds are low, thick, dark gray clouds that produce steady rain or snow. They are actually the lowering and thickening of altostratus clouds, and are composed of water droplets and ice crystals. When stratus clouds contact the ground they are called fog. Vertical clouds, such as cumulus, rise far above their bases and can form at many heights. Cumulonimbus clouds, or thunderheads, can start near the ground and soar up to 75,000 feet.

cloud deck
See *satellite signature.*

cloud shield
Vernacular term for cloudy area associated with a weather disturbance such as an extratropical cyclone or hurricane. In the case of the extratropical cyclone, the cloud shield is typically a *comma* form.

cold front
See *front.*

comma cloud
The shape of the cloud pattern associated with mature mid-latitude cyclones.

convection
The rising of warm air and the sinking of cool air. Heat mixes and moves air. When a layer of air receives enough heat from the Earth's surface, it expands and moves upward. Colder, heavier air flows under it which is then warmed, expands and rises. The warm rising air cools as it reaches higher cooler regions of the atmosphere and begins to sink. Convection produces local breezes, winds, and thunderstorms.

convergence
Over a period of time, more air flows into a given region than flows out of it.

coordinated universal time (UTC)
Also known as Greenwich Mean Time (GMT) and Zulu time, it is the local time at zero degrees longitude at the Greenwich Observatory, England. UTC uses a 24-hour clock, i.e., 2:00 pm is 1400 hours, midnight is 2400 or 0000 hours.

Coriolis effect
An apparent force present in a rotary system such as the Earth.

crest
The highest part of a wave. Radiant energy and weather features can be described mathematically as waves.

culmination
The point at which a satellite reaches its highest position or elevation in the sky relative to an observer. Also known as the closest point of approach.

cumulonimbus
See *cloud.*

cumulus
See *cloud.*

decay or period decay
The tendency of a satellite to lose orbital velocity due to the influences of atmospheric *drag* and gravitational forces. A decaying object eventually impacts the surface of the Earth or burns up in the atmosphere. This parameter directly affects the satellite's *mean motion*. It is a real number measured in terms of revolutions per day per day (REV/DAY/DAY).

declination
The angular distance from the equator to the satellite measured positive north and negative south.

density

$$\frac{\text{mass of a substance}}{\text{volume occupied by a substance}}$$

Usually expressed in grams per cubic centimeter or kilograms per cubic meter.

dew point
The temperature to which air must be cooled for saturation to occur, exclusive of air pressure or moisture content change. At that temperature dew begins to form, and water vapor condenses into liquid.

drag
A retarding force caused by the Earth's atmosphere. Drag will act opposite to the vehicle's instantaneous velocity vector with respect to the atmosphere. The magnitude of the drag force is directly proportional to the product of the vehicle's cross-sectional area, its drag coefficient, its velocity, and the atmospheric density, and inversely proportional to its mass. The effect of drag is to cause the orbit to decay, or spiral downward. A satellite of very high mass and very low cross-sectional area, and in a very high orbit, may be very little affected by drag, whereas a large satellite of low mass, in a low altitude orbit may be affected very strongly by drag. Drag is the predominant force affecting satellite lifetime.

eccentricity (e)
One of six *Keplerian elements,* it describes the shape of an orbit. In the Keplerian orbit model, the satellite orbit is an ellipse, with eccentricity defining the shape of the ellipse. When $e = 0$, the ellipse is a circle. When e is very near 1, the ellipse is very long and skinny.

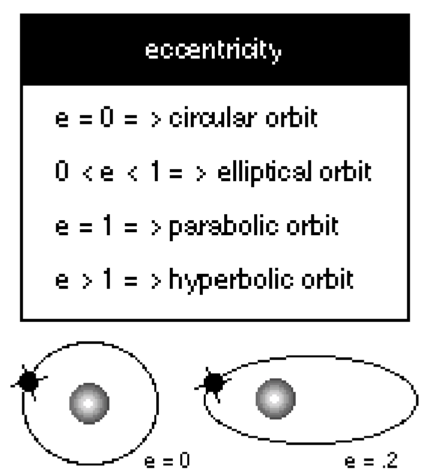


figure 112. eccentricity

ecosystem
Entity including living and non-living parts that interact to produce a stable system through the cyclic exchange of material.

eddy
A small volume of fluid, embedded within a larger fluid, that exhibits motion different from the average motion of the fluid. An example of eddy motion are the circular swirls observed in rapid river flow.

electromagnetic spectrum
The entire range of radiant energies or wave frequencies from the longest to the shortest wavelengths—the categorization of solar radiation. Satellite sensors collect this energy, but what the detectors capture is only a small portion of the entire electromagnetic spectrum. The spectrum usually is divided into seven sections: radio, microwave, infrared, visible, ultra-violet, x-ray, and gamma-ray.

element set
Specific information used to define and locate a particular satellite. See *Keplerian elements*.

ephemeris
A series of points which define the position and motion of a satellite.

epoch
A specific time and date which is used as a point of reference; the time at which an element set for a satellite was last updated.

epoch day
Epoch specifies the day and fraction of day for the particular description of a satellite orbit. This number defines both the *Julian day* (whole number part of the value) and the time of day (fractional part of the value) of the data.

epoch year
Epoch specifies the day and fraction of day for the particular description of a satellite orbit. This number defines the year that the *epoch day* describes.

erosion
The wearing away of the Earth's surface by any natural process, such as rain, wind, waves, and floods.

equator
An imaginary circle around the Earth that is everywhere equally distant (90°) from the North Pole and the South Pole. The equator is a great circle and defines 0° latitude.

extratropical cyclone
A closed circulation—characteristic of non-tropical regions in the northern hemisphere—which rotates counter clockwise about a center of low pressure.

Ferrel cell
The middle cell of the three-cell general circulation model. In the Northern Hemisphere, the Ferrel cell exhibits downward motion at roughly 20°–30° north, and upward motion at roughly 40°–50° north.

forecast
prediction

front
A boundary between two different air masses. The difference between two air masses sometimes is unnoticeable. But when the colliding air masses have very different temperatures and amounts of water in them, turbulent weather can erupt.

A cold front occurs when a cold air mass moves into an area occupied by a warmer air mass. Moving at an average speed of about 20 mph, the heavier cold air moves in a wedge shape along the ground. Cold fronts bring lower temperatures and can create narrow bands of violent thunderstorms. In North America, cold fronts form on the eastern edges of high pressure systems.

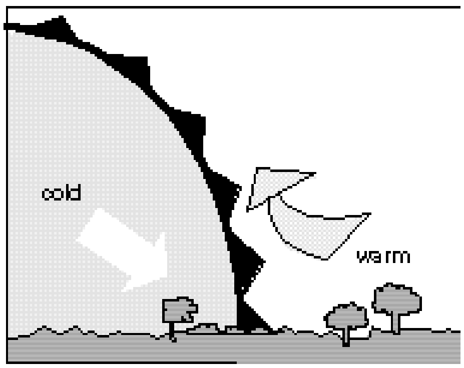


figure 113. warm front

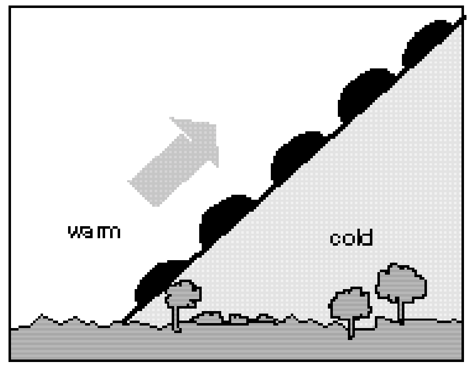


figure 114. cold front

A warm front occurs when a warm air mass moves into an area occupied by a colder air mass. The warm air is lighter, so it flows up the slope of the cold air below it. Warm fronts usually form on the eastern sides of low pressure systems, create wide areas of clouds and rain, and move at an average speed of 15 mph.

When a cold front follows and then overtakes a warm front (warm fronts move more slowly than cold fronts) lifting the warm air off the ground, an occluded front forms.

A front that is nearly stationary with winds blowing almost parallel and from opposite directions on each side of the front is a stationary front.

geostationary

Describes an orbit in which a satellite is always in the same position (appears stationary) with respect to the rotating Earth. The satellite travels around the Earth in the same direction, at an altitude of approximately 35,790 km (22,240 statute miles) because that produces an orbital period equal to the period of Earth's rotation (actually 23 hours, 56 minutes, 04.09 seconds).

Geostationary Operational Environmental Satellite (GOES)

NASA-developed, NOAA-operated series of satellites that:

- provide continuous day and night weather observations;
- monitor severe weather events such as hurricanes, thunderstorms, and flash floods;
- relay environmental data from surface collection platforms to a processing center;
- perform facsimile transmissions of processed weather data to low-cost receiving stations;
- monitor the Earth's magnetic field, the energetic particle flux in the satellite's vicinity, and x-ray emissions from the sun.

GOES observes the U.S. and adjacent ocean areas from geostationary vantage points approximately 35,790 km (22,240 miles) above the equator at 75° west and 135° west. GOES satellites have an equatorial, Earth-synchronous orbit with a 24-hour period, a resolution of 8 km, an IR resolution of 4 km, and a scan rate of 1864 statute miles in about three minutes.

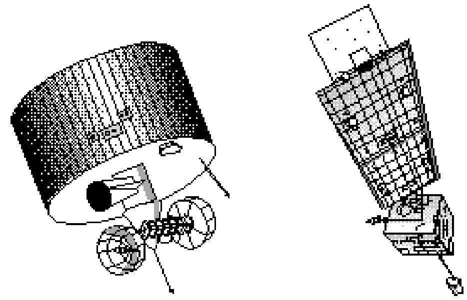


figure 115. GOES 7 (left) and GOES 8 (right)

The transmission of processed weather data (both visible and infrared) by GOES is called weather facsimile (WEFAX). GOES WEFAX transmits at 1691+ MHz and is accessible via a ground station with a satellite dish antenna.

geostrophic wind (Vg)
Horizontal wind velocity present when the Coriolis force is balanced by the pressure gradient force. This is approximately true of air flow above the Earth's surface.

geosynchronous
Synchronous with respect to the rotation of the Earth. See *geostationary*.

Hadley cell
Single-cell model of circulation that assumes Earth is uniformly covered with water, that the Sun is always directly over the equator, and that the Earth does not rotate. Circulation consists of a closed loop with rising air over the equator and sinking air over the poles.

horse latitudes
Latitudes 30°–35°N (or south) over the oceans, characterized by light winds and warm, dry conditions.

hydroscopic
Water-attracting.

inclination (*i*)
One of the six *Keplerian elements*, it indicates the angle of the *orbit plane* to the central body's equator. The *orbital plane* always goes through the center of the Earth but may be tilted at any angle relative to the equator. Inclination is the angle between the equatorial plane and the orbital plane measured counterclockwise at the *ascending node*. A satellite in an orbit that exactly matches the equator has an inclination of 0°, whereas one whose orbit crosses the Earth's poles has an inclination of 90°. Because the angle is measured in a counterclockwise direction, it is quite possible for a satellite to have an inclination of more than 90°. An inclination of 180° would mean the satellite is orbiting the equator, but in the opposite direction of the Earth's rotation. Some sun-synchronous satellites that maintain the same ground track throughout the year have inclinations of as much as 98°. U.S. scientific satellites that study the sun are placed in

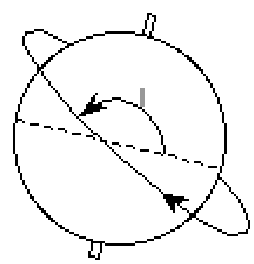


figure 116. inclination

orbits closer to the equator, frequently at 28° inclination. Most weather satellites are placed in high-inclination orbits so they can oversee weather conditions worldwide.

infrared radiation (IR)
Infrared is electromagnetic radiation whose wavelength spans the region from about 0.7 to 1000 micrometers (longer than visible radiation, shorter than microwave radiation). In the far infrared, emissions from the Earth's atmosphere and surface offer information about atmospheric and surface temperatures and water vapor and other trace constituents in the atmosphere. Since IR data are based on temperatures rather than visible radiation, the data may be obtained day or night.

insolation
The rate of solar radiation reaching the surface of the Earth.

international designator
An internationally agreed upon naming convention for satellites. Contains the last two digits of the launch year, the launch number of the year and the piece of the launch, i.e., A-indicates payload, B-the rocket booster, or second payload, etc.

Intertropical Convergence Zone (ITCZ)
Area near the equator where the northeast trade winds converge with the southeast trade winds. Narrow bands of thunderstorms and persistent cloudiness typifies this area.

isobars
Lines of equal pressure, usually a feature of surface weather maps.

jet stream
Ribbons of strong winds found in the upper troposphere.

Julian day
Calendar system that consecutively numbers days from the beginning of the year. January 1 has a Julian count of 1, February 28 is 59. This number may range from 1.0 to 366.999999999 (on leap years).

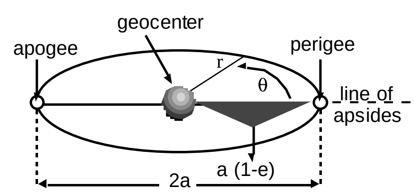
Keplerian elements
(aka orbital elements)
Also called classical elements, satellite elements, *element set*, etc. Includes the *catalog number* (*epoch year*, day, and fraction of day); period of *ascending node, mean anomaly, mean motion;* revolution number at *epoch*; and *element set* number.

knot
Unit of speed of one nautical mile (6076.1 feet) per hour.

figure 117.

Keplerian elements

- a semi-major axis, gives the size of the orbit
- e eccentricity, gives the shape of the orbit
- i inclination angle, gives the angle of the orbit plane to the central body's equator
- Ω right ascension of the ascending node, which gives the rotation of the orbit plane from reference axis
- ω argument of perigee gives the rotation of the orbit in its plane
- θ true anomaly gives the location of the satellite on the orbit



2a is major axis

latitude
The angle between a perpendicular at a location, and the equatorial plane of the Earth. Latitude is measured in degrees north or south of the equator (the equator is 0°, the North and South Poles are 90° N and 90° S, respectively).

latitudinal temperature gradient
See *temperature gradient.*

line-of-apsides
(aka major axis of the ellipse)
The straight line drawn from the *perigee* to the *apogee*. See figure 108.

line-of-nodes
The line created by the intersection of the equatorial plane and the *orbital plane*.

longitude
The angular distance from the Greenwich (zero degree) meridian, along the equator.

loop
A series of images connected to form a movie-like view of the atmosphere.

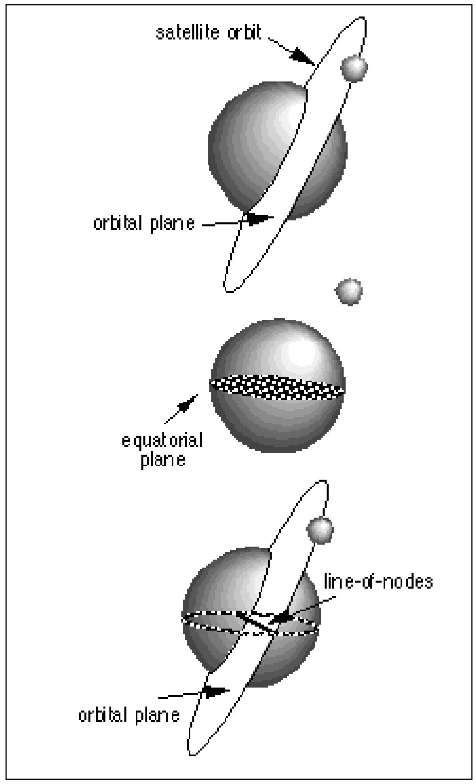


figure 118. lines-of-nodes

mean anomaly
Specifies the mean location (true anomaly specifies the exact location) of a satellite on an orbit ellipse at a particular time, assuming a constant *mean motion* throughout the orbit. Epoch specifies the particular time at which the satellite's position is defined, while mean anomaly specifies the location of a satellite at epoch. Mean anomaly is measured from 0° to 360° during one revolution. It is defined as 0° at perigee, and hence is 180° at apogee.

mean motion
The averaged speed of a satellite in a non-circular orbit (i.e., *eccentricity* > 0). Satellites in circular orbits travel at a constant speed. Satellites in non-circular orbits move faster when closer to the Earth, and slower when farther away. Common practice is to compute the mean motion (average the speed), which is measured in revolutions per day. The number may be greater than 0.0 and less than 20.0.

meridional flow
Airflow in the north-south direction, that is motion along meridians.

mesoscale
Scale of atmospheric motion that covers the range from a few kilometers to several hundred kilometers—in the horizontal. Examples of meteorological effects that occur in the mesoscale are: squall lines, tornadoes, and sea breeze fronts.

mid-latitude
Region of the Earth between 30°–50° latitude.

millibars (mb)
One thousandth of a bar, a unit of atmospheric pressure. The average atmospheric pressure at sea level is 1.01325 bars or 1013.25 mb.

National Aeronautics and Space Administration (NASA)
U.S. Civilian Space Agency created by Congress. Founded in 1958, NASA belongs to the executive branch of the Federal Government.

NASA's mission to plan, direct, and conduct aeronautical and space activities is implemented by NASA Headquarters in Washington, D.C., and by ten major centers spread throughout the United States. Dozens of smaller facilities, from tracking antennas to Space Shuttle landing strips to telescopes are located around the world. The agency administers and maintains these facilities; builds and operates launch pads; trains astronauts; designs aircraft and spacecraft; sends satellites into Earth orbit and beyond; and processes, analyzes, and distributes the resulting data and information.

NASA Prediction Bulletin
Report published by NASA Goddard Space Flight Center providing the latest orbital information on a particular satellite. This report gives information in 3 parts:
1. the two line orbital elements,
2. longitude of the south to north equatorial crossings, and
3. longitude and heights of the satellite crossings for other latitudes

National Oceanic and Atmospheric Administration (NOAA)
NOAA was established in 1970 within the U.S. Department of Commerce to ensure the safety of the general public from atmospheric phenomena and to provide the public with an understanding of the Earth's environment and resources. NOAA includes the National Ocean Service, the National Marine Fisheries Service, the NOAA Corps (operates ships and flies aircraft), and the Office of Oceanic and Atmospheric Research. NOAA has two main components: the National Weather Service (NWS) and the National Environmental Satellite, Data, and Information Service (NESDIS).

nimbostratus
See *cloud.*

occlusion or occluded front
In a mature cyclonic disturbance, occlusion occurs when the cold front overtakes the leading warm front. The warm air that was ahead of the cold front is lifted above the surface by the cool, dense air associated with the front. On weather maps, the occlusion is denoted by a line that contains both warm and cold front symbols on the same side.

orbital plane
An imaginary gigantic flat plate containing an Earth satellite's orbit. The orbital plane passes through the center of the Earth.

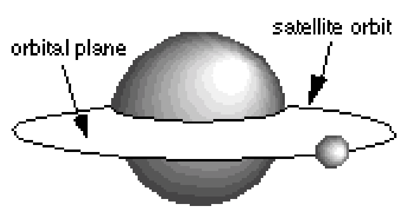


figure 119. orbital plane

parameter
An arbitrary constant used as a reference for determining other values.

perigee
The point in the satellite's orbit where it is closest to the surface of the Earth. See figure 108.

polar orbit
An orbit with an orbital inclination of near 90°, where the satellite ground track will cross both polar regions once during each orbit. The term is used to describe the near-polar orbits of spacecraft such as the USA's NOAA/TIROS satellite.

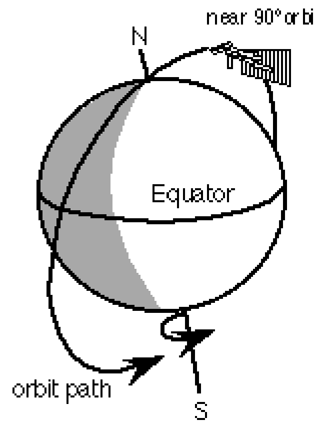


figure 120. polar orbit

precipitation
Moisture that falls from clouds. Although clouds appear to float in the sky, they are always falling, their water droplets slowly being pulled down by gravity. Because their water droplets are so small and light, it can take 21 days to fall 1,000 feet and wind currents can easily interrupt their descent.

Liquid water falls as rain or drizzle. All raindrops form around particles of salt or dust. (Some of this dust comes from tiny meteorites and even the tails of comets.) Water or ice droplets stick to these particles, then the drops attract more water and continue getting bigger until they are large enough to fall out of the cloud. Drizzle drops are smaller than raindrops.

In many clouds, raindrops actually begin as tiny ice crystals that form when part or all of a cloud is below freezing. As the ice crystals fall inside the cloud, they may collide with water droplets that freeze onto them (when the water vapor changes directly into ice—without becoming liquid first—it is called deposition). The ice crystals continue to grow larger, until large enough to fall from the cloud. They pass through warm air, melt, and fall as raindrops.

When ice crystals move within a very cold cloud (10 °F and -40 °F) and enough water droplets freeze onto the ice crystals, snow will fall from the cloud. If the surface temperature is colder than 32 °F, the flakes will land as snow.

Precipitation Weights:

- one raindrop .000008 lbs
- one snowflake .0000003 lbs
- one cumulus cloud 10,000,000 lbs
- one thunderstorm 10,000,000,000 lbs
- one hurricane 10,000,000,000,000 lbs

pressure gradient force (PGF)
Forces exerted by differences in pressure within a fluid. In the atmosphere, the force is directed from high pressure regions toward low pressure regions.

radiation
Energy transfer in the form of electromagnetic waves or particles that release energy when absorbed by an object.

radiosonde
A balloon-borne instrument that measures pressure, temperature, and moisture in the atmosphere, and transmits these data back to Earth.

remote sensing
Remote-sensing instruments work by sensing radiation that is naturally emitted or reflected by the Earth's surface or from the atmosphere, or by sensing signals transmitted from a satellite and reflected back to it. In the visible and near-infrared regions, surface chemical composition, vegetation cover, and biological properties of surface matter can be measured. In the mid-infrared region, geological formations can be detected due to the absorption properties related to the structure of silicates.

resolution
The ability to separate observable quantities. In the case of imagery, it describes the area represented by each picture element (pixel) of an image. The smaller the area represented by a pixel, the more detailed the image.

retrograde orbit
Satellite motion which is opposite in direction to the rotation of the Earth.

revolution number
The number of revolutions the satellite has completed at the *epoch* time and date. This number is entered as an integer between 1 and 99999.

ridge
An area of relatively high atmospheric pressure generally associated with a clockwise (anticyclone) curvature of the troposphere.

ridge axis
A line perpendicular to the center, or area of maximum curvature, of a ridge.

right ascension of ascending node (Ω)
One of the six *Keplerian elements*, it indicates the rotation of the orbit plane from some reference point. Two numbers orient an *orbital plane* in space; *inclination* is the first, this is the second.

After specifying inclination, an infinite number of orbital planes are possible. The intersection of the equatorial plane and the orbital plane (see diagram, line-of-nodes) must be specified by a location on the equator that fully defines the orbital plane. The line of nodes occurs in two places. However, by convention, only the ascending node (where the satellite crosses the equator going from south to north) is specified. The descending node (where the satellite crosses the equator going from north to south) is not. Because the Earth spins, conventional latitude and longitude points are not used to separate where the lines of node occur. Instead, an astronomical coordinate system is used, known as the right-ascension/declination coordinate system, which does not spin with the Earth. Right ascension of the ascending node is an angle, measured at the center of the Earth, from the vernal equinox to the ascending node. For example, draw a line from the center of the Earth to the point where the satellite crossed the equator (going from south to north). If this line points directly at the vernal equinox, then $\Omega = 0°$. Ω is a real number with a range of degrees 0.0 to 360.0 degrees.

salinity
A concentration (as in a solution) of salt.

satellite imagery
Pictorial representation of data acquired by satellite systems, such as direct readout images from environmental satellites. An image is not a photograph. An image is composed of two-dimensional grids of individual picture elements (pixels). Each pixel has a numeric value that corresponds to the radiance or temperature of the specific ground area it depicts.

satellite signature
The cloud shape, or cloud deck associated with a particular weather phenomena, as observed by satellite. For example, the comma cloud is the characteristic signature for an extratropical cyclone.

satellite situation report
Report published by NASA Goddard Space Flight Center listing all known man-made Earth orbiting objects. The report lists the *catalog number, international designator,* name, country origin, launch date, orbital period, *inclination,* beacon frequency, and status (orbiting or *decayed*).

stationary front
See *front.*

stratus
See *cloud.*

subsidence
Descending air motion.

subtropical latitudes
Region of the Earth between roughly 20°–35° latitude.

sun-synchronous
Describes the orbit of a satellite that provides consistent lighting of the Earth-scan view. The satellite passes the equator and each latitude at the same time each day. For example, a satellite's sun-synchronous orbit might cross the equator twelve times a day, each time at 3:00 p.m. local time. The orbital plane of a sun-synchronous orbit must also precess (rotate) approximately one degree each day, eastward, to keep pace with the Earth's revolution around the sun.

synoptic scale
Scale of atmospheric motion that covers the range of hundreds of kilometers to several thousand kilometers in the horizontal. An example of synoptic scale meteorological phenomena are: extratropical cyclones and high pressure systems. Compare with *mesoscale.*

temperature
A measure of the heat energy in a substance. The more heat energy in the substance, the higher the temperature. The Earth receives only one two-billionth of the energy the sun produces. Much of the energy that hits the Earth is reflected back into space. Most of the energy that isn't reflected is absorbed by the Earth's surface. As the Earth's surface warms, it also warms the air above it.

temperature gradient
Rate of change of temperature. In this text, the gradient is assumed to be horizontal.

thunderstorm
Local storm resulting from warm humid air rising in a continually unstable environment. Air may start moving upward because of unequal surface heating, the lifting of warm air along a frontal zone, or diverging upper-level winds (these diverging winds draw air up beneath them).

The scattered thunderstorms that develop in the summer are called air-mass thunderstorms because they form in warm, maritime tropical air masses away from weather fronts. More violent severe thunderstorms form in areas with a strong vertical wind shear that organizes the updraft into the mature stage, the most intense stage of the thunderstorm. Severe thunderstorms can produce large hail, forceful winds, flash floods, and tornadoes.

trade winds
Persistent winds that blow toward the *ITCZ* at an angle determined by the Coriolis force.

tropical cyclone
Closed circulation's that rotate counter-clockwise in the Northern Hemisphere around low pressure centers and originate over the tropical oceans. This category includes tropical depressions, tropical storms, and hurricanes.

tropopause
Marks the limit of the troposphere and the beginning of the stratosphere.

troposphere
The lowest layer of the atmosphere, extending from the surface of Earth to 10–15 kilometers above.

trough
An area of lower pressure. On weather charts, a trough is the southern most portion of a wave.

trough axis
A line perpendicular to the center, or area of maximum curvature, of a trough.

true anomaly
One of six *Keplerian elements,* it locates a satellite on an orbit. True anomaly is the true angular distance of a satellite (planet) from its *perigee* (perihelion) as seen from the center of the Earth (sun).

velocity
Rate of motion; speed in a particular direction.

vernal equinox
Also known as the first point of Aries, it is the point where the Sun crosses the Earth's equator going from south to north in the spring. This point in space is essentially fixed and represents the reference axis of a coordinate system used extensively in astronomy and astrodynamics.

visible
That part of the electromagnetic spectrum to which the human eye is sensitive, between about 0.4 and 0.7 micrometers.

warm front
See *front*.

warm sector
Region bounded by cold front to west, warm to the north and east, and characterized by fair weather with warm and moist conditions.

wavelength
The physical distance of one wave repeat.

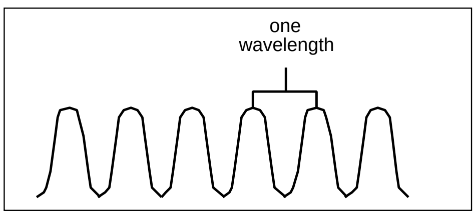


figure 121.

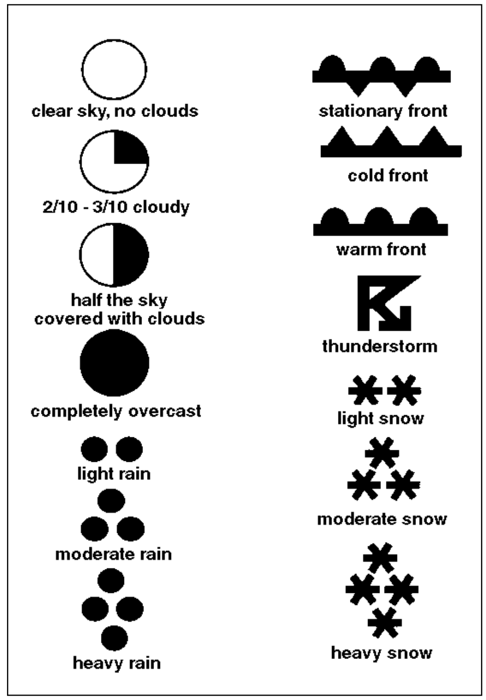


figure 122. weather symbols

weather symbols
Symbols used in the text are illustrated in the chart.

wind
A motion of the air, especially a noticeable current of air moving in the atmosphere parallel to the Earth's surface. Winds are caused by pressure differences—as modified by such effects as the Coriolis force, the condensation of water vapor, the formation of clouds, the interaction of air masses and frontal systems, friction over land and water, etc. Large scale pressure differences are driven by unequal heating and cooling of the Earth and atmosphere due to absorbed, incoming solar radiation and infrared radiation lost to space.

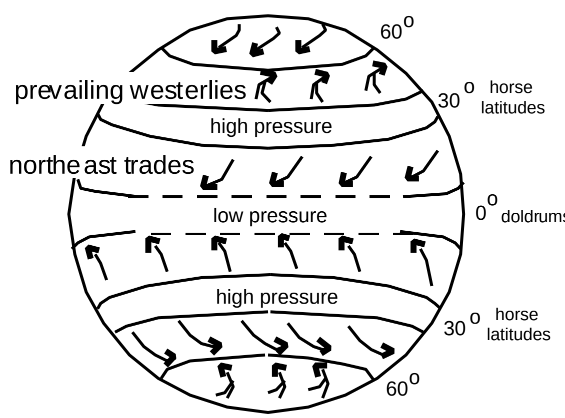


figure 123.

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Skywatchers Cloud Chart
Bushnell Spectacu-Learn Skywatcher's Weather Set
300 North Lone Hill Avenue
San Dimas, CA 91773
(800) 423-3537

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