ACTIVITY 1 A Satellite Puzzle

After completing this activity, you should be able to:

- Describe how information is acquired by satellites, sent to Earth, and interpreted to construct images.
- Explain how pixel size influences the detail (resolution) on weather satellite images.

Introduction

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

Method

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

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

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

Use a pencil to fill in the Shade Key below as follows:

0 - black

1 - medium grey

2 - light grey

3 - no shading

Shading Key

0	**1**	**2**	**3**

By referring to the Shading Key, shade in the grid below according to the data given. Then use the same procedure to fill in the grid on the next page with the smaller pixels.

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

DATA

3	2	1	0	1	2
2	0	0	0	0	1
1	0	2	2	2	2
0	0	3	3	3	3
0	0	3	0	0	0
1	0	2	2	0	1
2	0	0	0	0	1
3	2	1	0	1	2

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

Questions

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

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2. Assume that the two weather satellite sensors used in this activity produce pixels that represent Earth-surface areas 2 kilometres and 1 kilometre on a side, respectively. Assuming that Canada is approximately 5,000 km from west to east and 5,000 km north to south, how many pixels would need to be scanned to obtain images of Canada by each of the two sensors?

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

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ACTIVITY 2 What Can You See?

After completing this activity, you should be able to:

- Explain how satellite pictures can be made with reflected sunlight (visible radiation) and with the heat (infrared radiation) given off by the Earth.
- Describe the advantages and disadvantages of visible-light weather satellite pictures.
- Describe the advantages and disadvantages of infrared-radiation weather satellite pictures.

Introduction

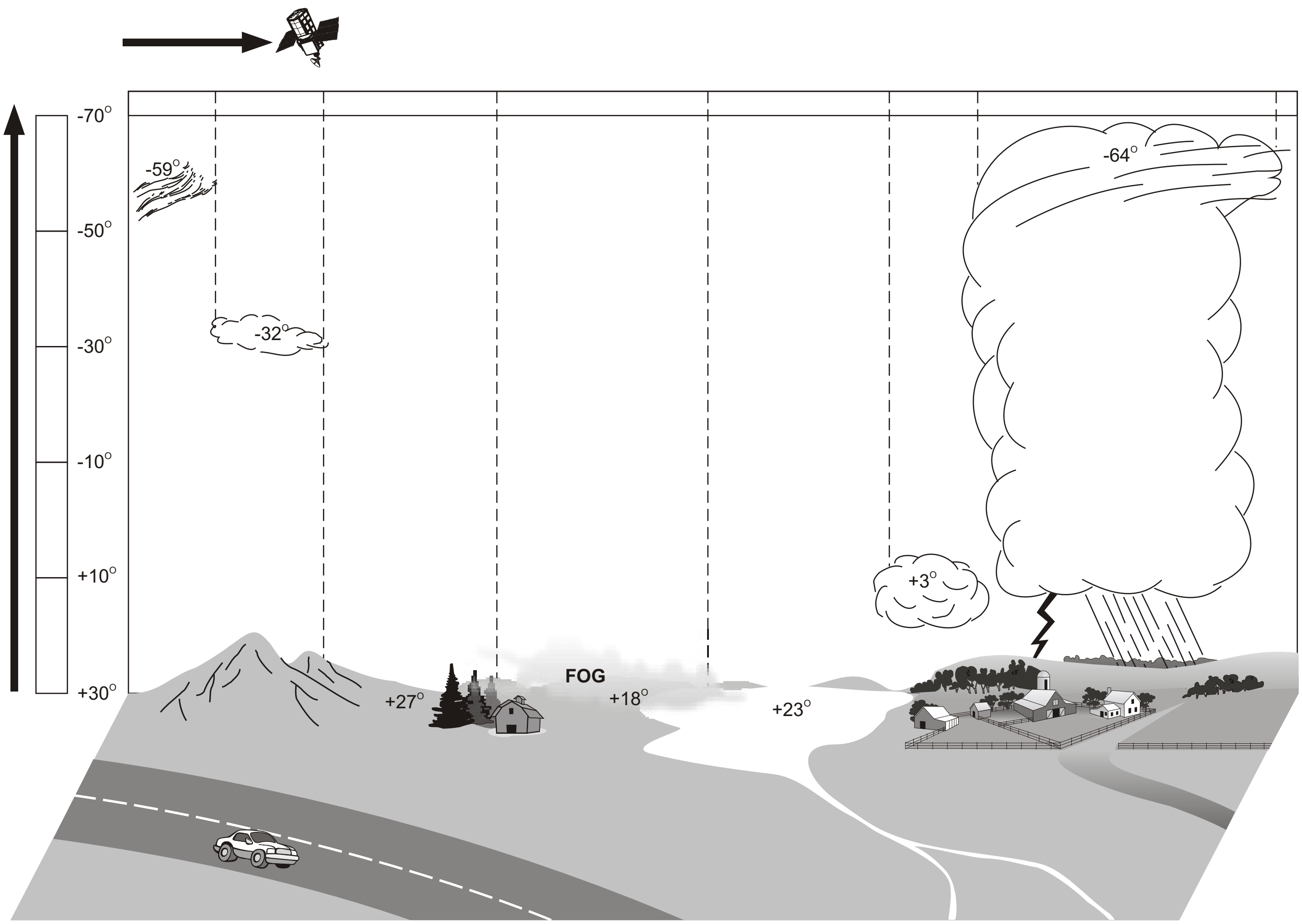
Weather satellites have sensors aboard that detect both visible light and infrared or heat radiation. The sensors providing views of reflected sunlight are engineered to be more detailed than infrared, so that smaller objects can be seen. However, visible images are only available during the day, limiting their continuous monitoring of weather conditions. Although less detailed, infrared views are temperature maps of surfaces viewed from the satellite's vantage point, whether land, water or clouds. The temperature variations of the surfaces may be enhanced to highlight certain features of interest to meteorologists.

Method

The accompanying drawing shows an earth surface and atmospheric cross-section. A temperature scale at the left shows the decrease in temperature with an increase in height in the atmosphere. Shade in the temperature-scale blocks with your pencil. Start by making the bottom block darkest, the next one up lighter, the next lighter, and so on. Leave the top block white.

The numbers in the drawing indicate temperatures of various surfaces. For example, the lake surface is at +23°C, the upper surface of the fog bank is +18°C and the thunderstorm top is at a very cold -64°C.

The rates of infrared (heat) radiation from objects are related to their surface temperatures. The higher the surface temperature, the greater the radiation. The lower the temperature, the less the radiation. Because of this, the cold tops of high clouds appear white while the tops of warmer low clouds appear grey in infrared pictures (unless the images have been enhanced).



Questions

1. What does a satellite "see" when it senses the Earth in reflected sunlight (visible radiation)? Imagine yourself <u>looking straight down</u> from a satellite moving across the top of the drawing. Your direction of travel is shown by the arrow. List the sequence of things you would see as you make the trip across the field of view. Could you see this same scene at night?

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2. What does a satellite "see" when it senses the Earth by infrared radiation? Imagine yourself making the same scan but now you sense the heat or infrared radiation given off by the upper surfaces of objects.

   a) Select your own shading (or colour enhancement) scale for the temperatures at the left of the cross-section. Now, using the shading (or colour enhancement) scale you selected for temperature as a guide, shade (or colour) in the strip at the top of the picture based on the temperatures of surfaces directly below.

b) List the sequence of "things" you would see as you scan across the field of view. Could you see as many different things as you saw with visible light? Can you distinguish between land, fog, and water? Were there some things you could "see" better in the infrared scan than in the visible light view? Which are whiter, low or high cloud surfaces? Can you see this temperature scene day or night?

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3. In the list below, place a ☑ in the appropriate column to indicate which kind of satellite view (visible or infrared) is better suited to provide the information requested:

	Visible	Infrared
a) 24-hour coverage of atmosphere		
b) finer details of cloud surfaces		
c) temperatures of cloud tops (and indirectly, their heights)		
d) distinguishing fog from surrounding Earth surfaces		
e) determining extent of snow cover on ground		
f) detecting small fair-weather clouds		
g) the colour-coding of cloud tops		

ACTIVITY 3 Comparisons of Satellite Imagery for Storm Analysis

After completing this activity, you should be able to:

- Explain how different formats of satellite imagery can assist in weather analysis.
- Describe the advantages and disadvantages of the various satellite imagery formats.

Introduction

This activity includes examples of visual, infrared and water vapour (GOES) images taken at approximately the same time on November 6th, 2000. Also included with the images is a surface weather map depicting the location of the weather systems at that time. As discussed each of these images see things differently and the correct analysis as to what's going on requires careful consideration and data assimilation.

Data Analysis and Assimilation

1. Review the following analyses of the visible and infrared satellite images for March 28, 1998:

   The GOES visible image for 00Z March 28, 1998 (Figure 1) shows a broad swirl of clouds associated with a storm system whose centre is over northern Michigan. The comma-shaped cloud mass is typical of a mature cyclone. The clouds are uniformly white but shapes suggest cloud type. Streams of small, low cumulus clouds have formed over southern Michigan and northern Indiana in the cold air following the cold front that has passed east into Ohio. The uneven appearance in the clouds from central Ohio into southern Ontario indicates the convection in the storm system.

   The GOES enhanced infrared image for 13Z March 28, 1998 (Figure 2) shows the high, cold cloud tops of the storm from near Toronto to Sault Ste. Marie by the bright white colour. The imbedded shadings have been chosen (enhanced) to draw visual attention to those locations. Enhancement starts with the warmest temperatures detected in the image being depicted with the darkest shading. Cooler surfaces are shown in successively lighter shades of grey. High, cold thunderstorm cloud tops exist in a line across central Ohio (bright white line surrounded by darker shadings). Much of the rest of Ontario is under medium grey shading of lower level, warmer clouds. Much of Wisconsin and northwestern Ontario (west of Thunder Bay) are dark grey due to cool land surfaces. The warmest temperatures occur in extreme eastern Ontario, eastern New York and Pennsylvania, shown by the dark shades in this cloud-free area.

2. Recognizing the time difference in the images, identify any commonalities noted with each image and then reflect on the unique aspects of each image which

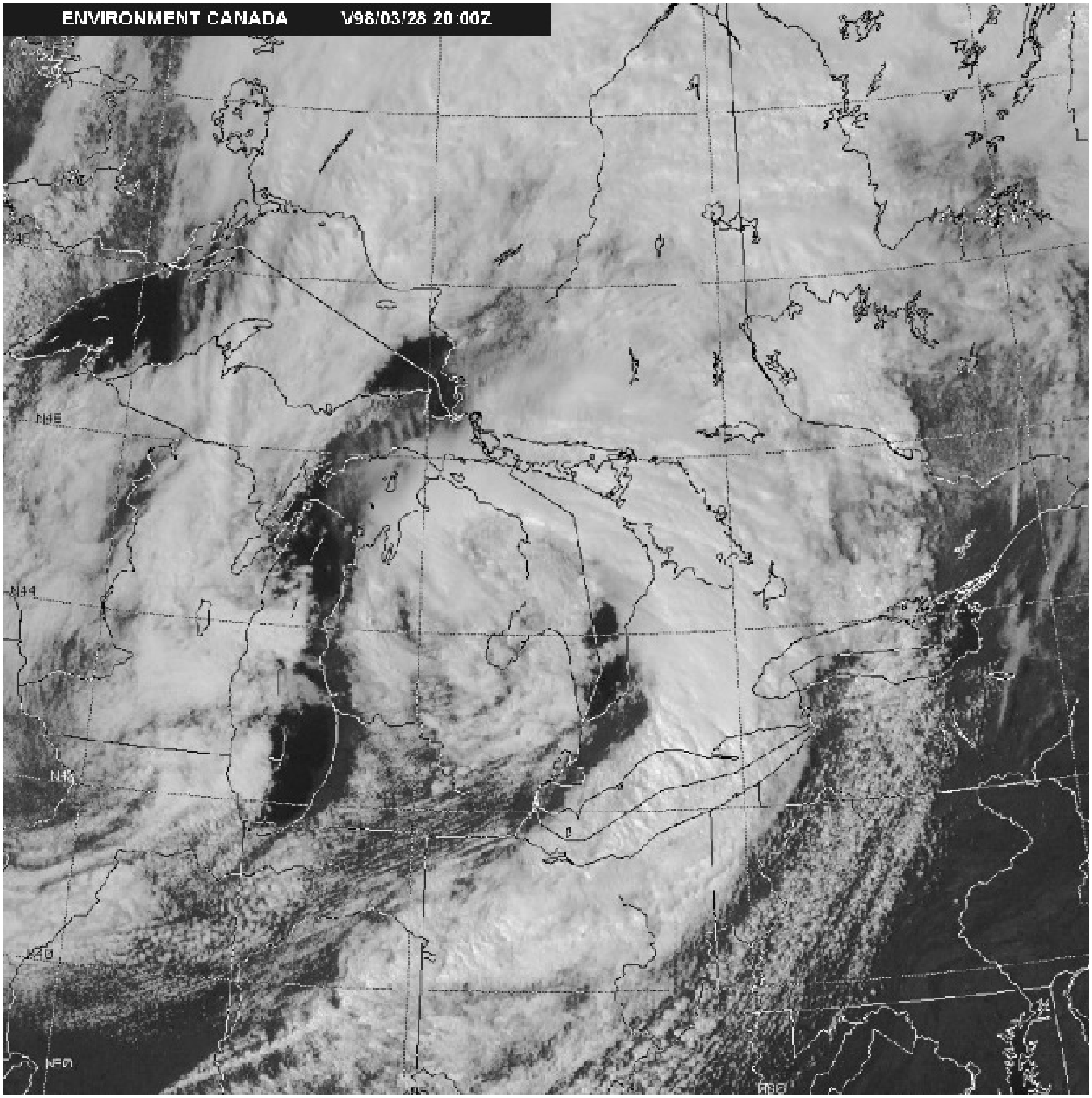

Figure 1 - US National Oceanic and Atmospheric Administration (NOAA) GOES visible satellite image for 00Z March 28, 1998

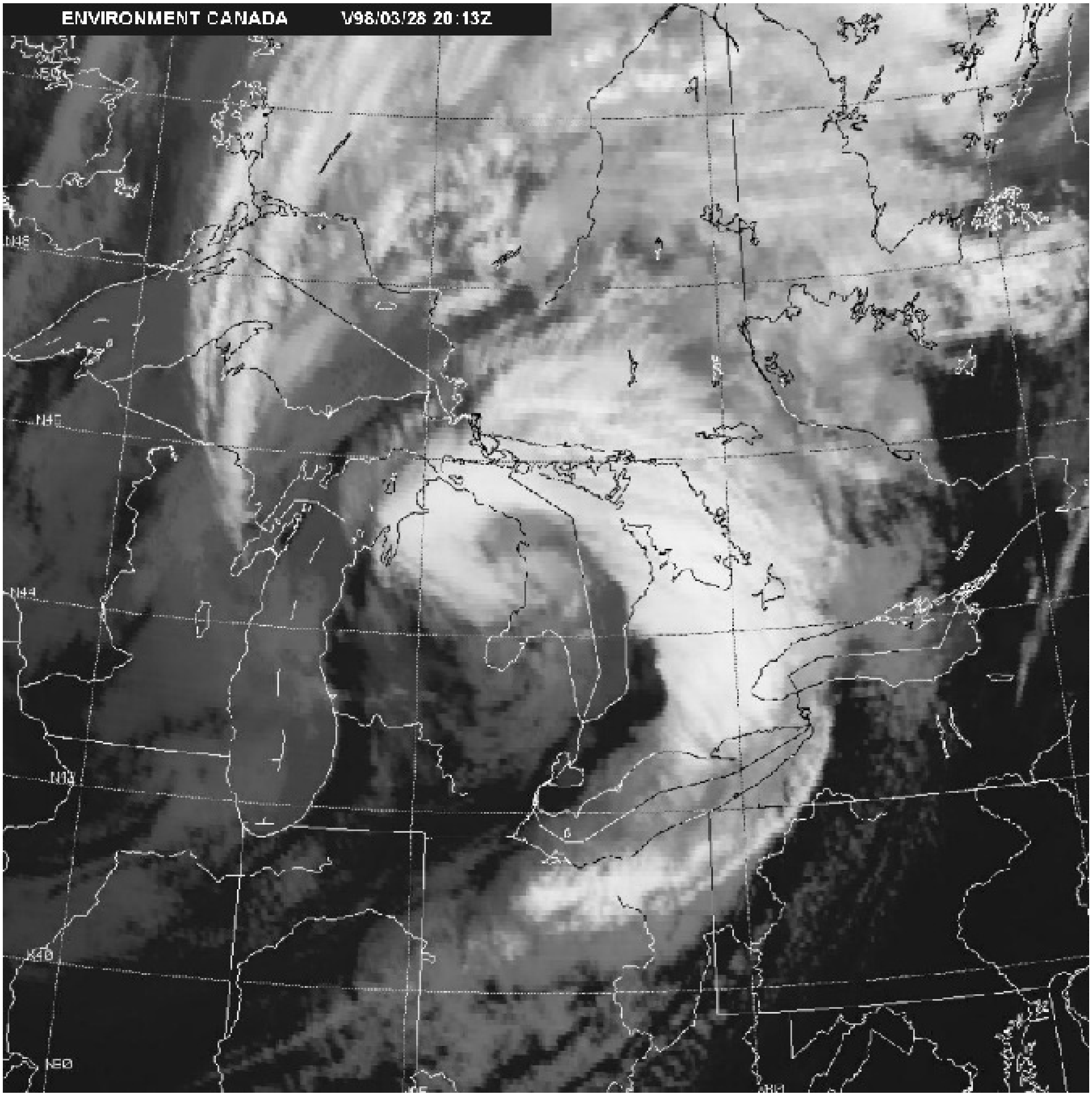

Figure 2 - US National Oceanic and Atmospheric Administration (NOAA) GOES infrared satellite image for 13Z March 28, 1998

might cause one to change their interpretation of various elements identified during the analysis process.

3. Review the next set of satellite images from November 6th, 2000 and the analyses of the infrared and water vapour images.

   The GOES infrared image (Figure 3) shows a well-defined low-pressure system centered over Iowa. Associated with this low is a spiral of cloud extending in a comma pattern from northwestern Ontario (IR image) to the southern U.S. As with the previous infrared image (Figure 2), the high, cold tops are coloured in a brighter shade.

   The GOES water vapour image (Figure 4) indicates the thick cloud cover of the storm system by the bright white shading in an arc from northwestern Ontario to the Gulf of Mexico. Interestingly, there is a darker shading immediately west of the brightest colours showing little water substance. There are some low clouds present in this zone which are apparent in the grey-white shading on the infrared image. The satellite water vapour sensor detects humidity primarily at middle and upper levels of the troposphere, above the low clouds.

4. Using the CMC Environment Canada surface map analyses (figure 5), depicting the storm system at 18Z November 6, 2000, just prior to the satellite images, identify the connections a meteorologist might make between the satellite images and individual weather systems as well as the complementary ways the images are used to decipher atmospheric conditions.

5. Based on the understanding of the conditions shown and motions from succeeding satellite images, meteorologists can produce more accurate general forecasts and severe weather warnings when needed. Using the November 6, 2000 data sets provided, i.e. satellite images and surface analysis, what would be in your forecast for Winnipeg, Toronto and Indianapolis, Indiana for the next 24 hours?

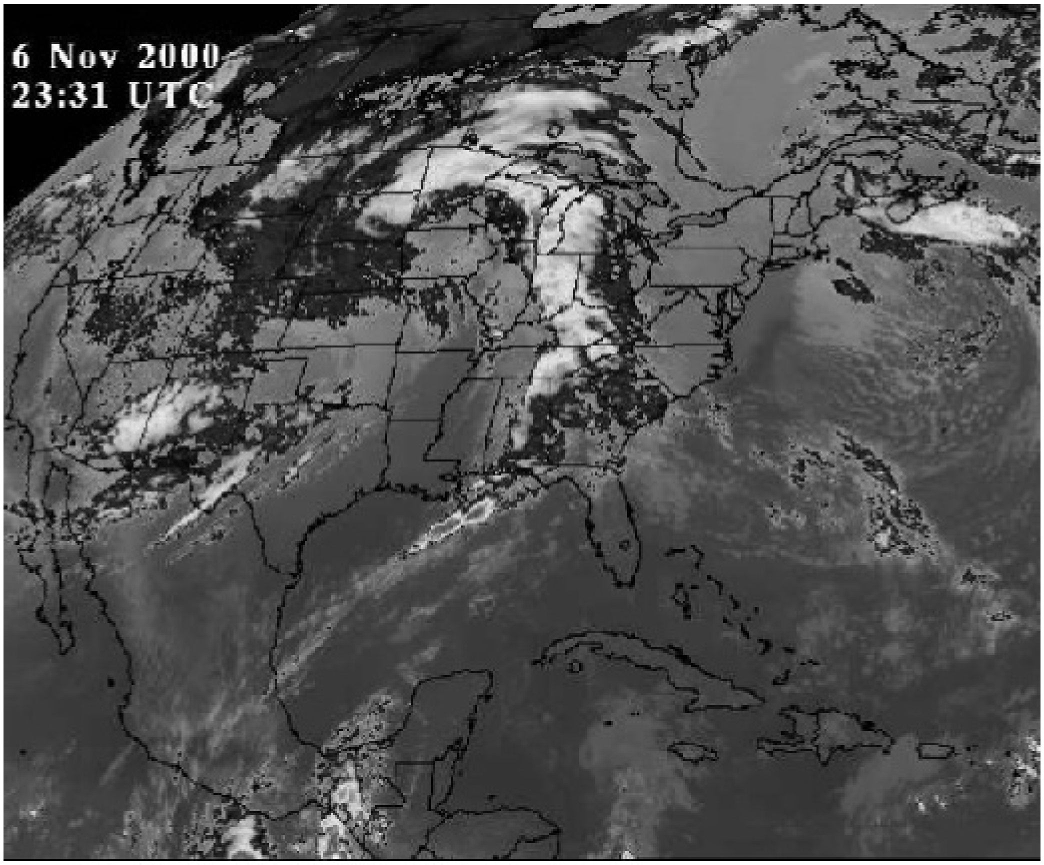

Figure 3 - GOES infrared image for 2331Z on November 6, 2000

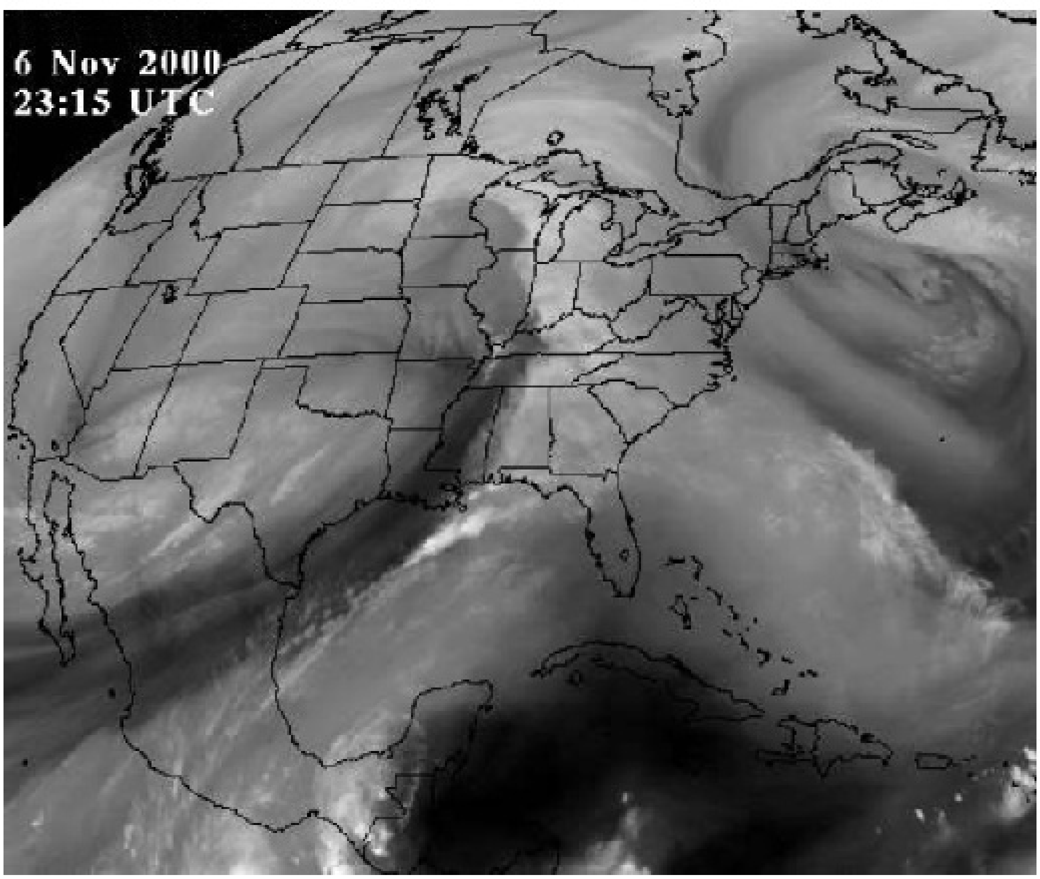

Figure 4 - GOES water vapour image for 2315Z on November 6, 2000

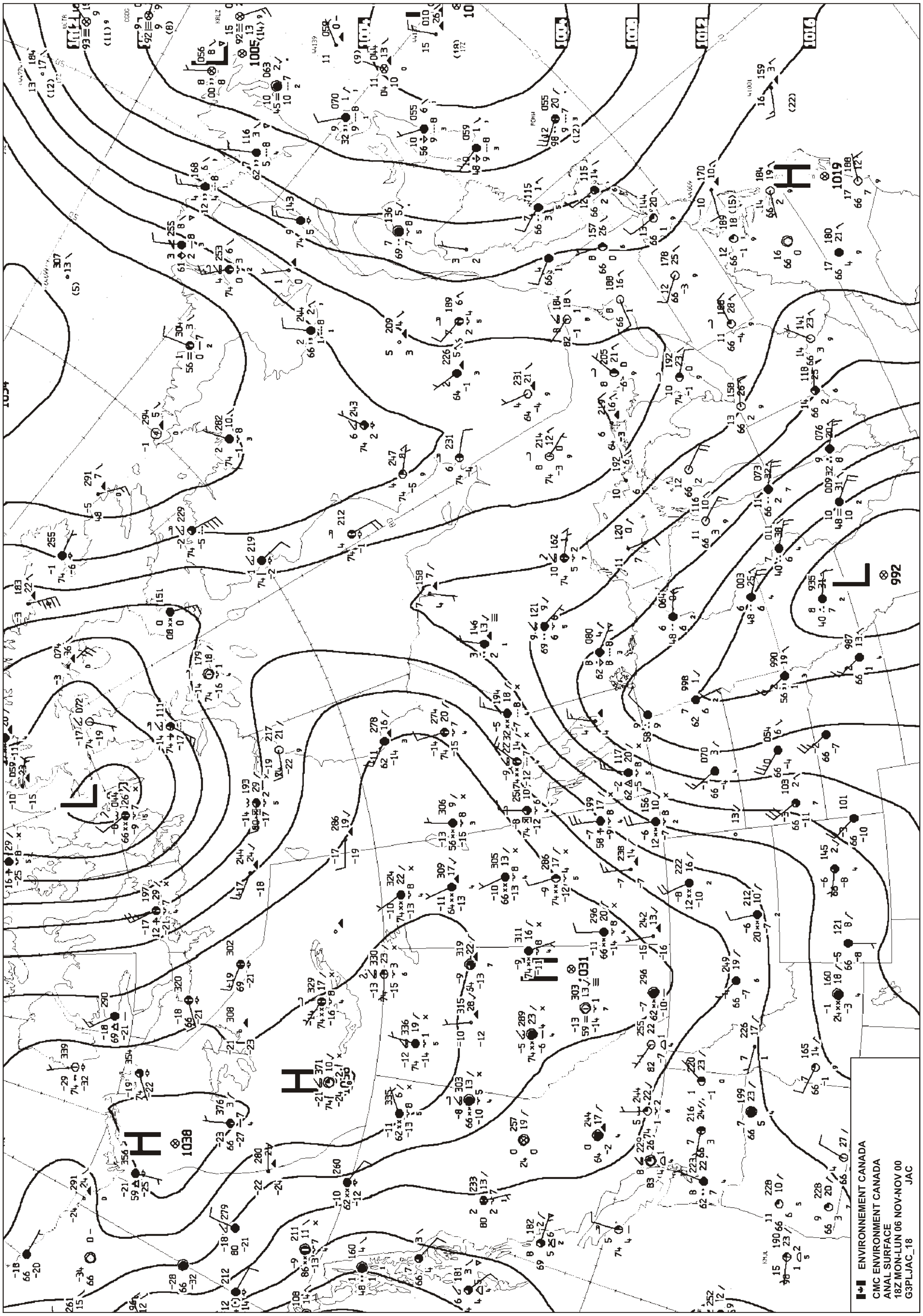

Figure 5 - CMC Environment Canada surface map analyses for 1800Z on November 6, 2000