BASIC UNDERSTANDINGS — Winter Storms

Winter Storm Development

1. Winter storms are large-scale disturbances associated with low-pressure areas called mid-latitude cyclones.
2. Winds blow counterclockwise as seen from above (in the Northern Hemisphere) around the centre of the low pressure system.
3. Winter storms occur when warm, humid air interacts with colder air along the frontal boundary separating the two air masses. The two contrasting air masses provide energy, which permits the storm to intensify.
4. Winds speeds increase as the storm strengthens. The warm, moist air is lifted upward, producing widespread areas of cloudiness and precipitation along the frontal surfaces in the vicinity of the developing cyclone.
5. The normal lifetime of a winter cyclone is about three to five days.
6. Steered by the direction of the upper air flow, winter storms tend to move from west to east.

Winter Storm Hazards

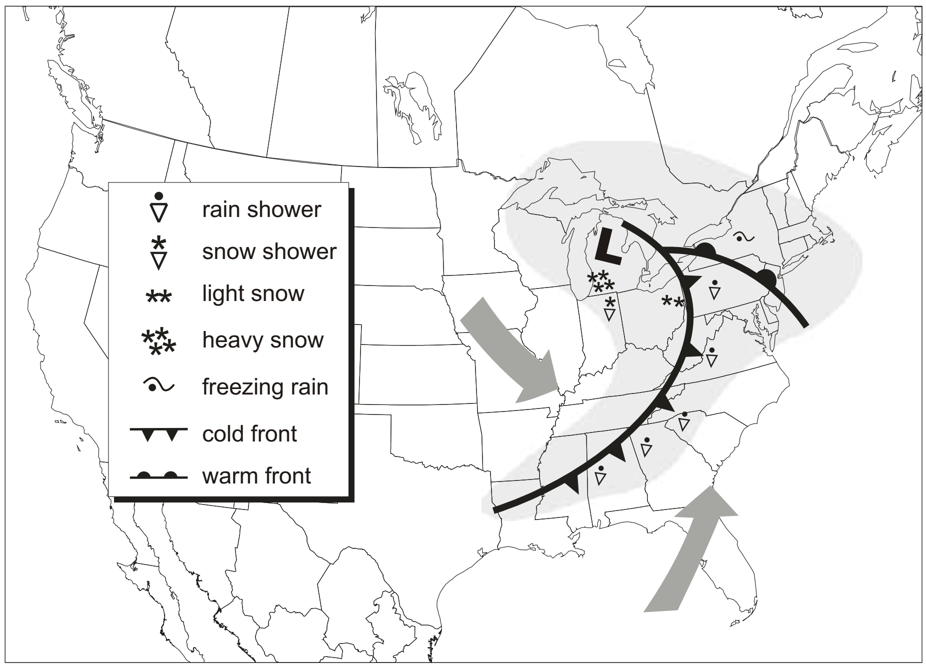
7. Winter storms produce strong winds, heavy precipitation (rain, freezing rain, or snow) and cold temperatures. Hazardous winter weather includes freezing rain, snow, blizzards, and bitterly cold temperatures.
8. Cold temperatures feel more extreme when there is wind. The wind chill factor combines the effect of both temperature and winds to determine the cooling rate and the equivalent temperature with no wind.
9. Environment Canada issues a variety of severe winter weather watches and warnings to alert the public to the approach of winter storm conditions.
10. Winter storm dangers include being stranded outside while exposed to the elements, having breakdowns in transportation systems due to accidents, and losing access to basic necessities and services.

NARRATIVE Winter Storms

What is a Winter Storm?

A winter storm is a large-scale disturbance, often hundreds of kilometres across, associated with a low-pressure system (called a cyclone) that develops along a front during the cooler part of the year. Winter storms can produce strong winds, heavy precipitation (rain, freezing rain, ice pellets or snow) and cold temperatures.

What Causes Winter Storms?



Surface map depiction of a winter storm system, showing the low pressure centre (L), cold and warm fronts, and a accompanying weather (legend gives explanation of symbols)

Winter storms occur when relatively warm, humid air interacts with colder air along the frontal boundary separating the two air masses. Initially, the front is slow-moving or stationary. The formation and evolution of a deep low pressure centre and the associated circulation is referred to as cyclogenesis. It is a complex process involving upper level divergence as well as near-surface processes. The two contrasting air masses provide energy to this rotating system, permitting the storm to intensify with time. Wind speeds increase as the storm strengthens. The warm, moist air is lifted upward, producing widespread areas of clouds and precipitation along the frontal surfaces in the vicinity of the developing cyclone.

Structure and Movement of a Winter Storm

The figure on page 23 displays the structure of a mature stage of a winter storm, with major features noted at both the surface and at upper levels (6 to 10 km). The primary storm is associated with the surface position of the low (L) centre and the accompanying cold and warm fronts. At upper levels, the storm normally is associated with an upper level trough, a low pressure region which forms a distinct southerly "dip" in the upper air flow, which generally lags the surface low pressure centre. The surface high (H) pressure behind the cold front brings colder temperatures, clear skies and fair weather. The entire storm system moves(arrow on surface chart labelled Movement) with the upper level steering wind currents (noted by the direction of the arrow of the jet stream).

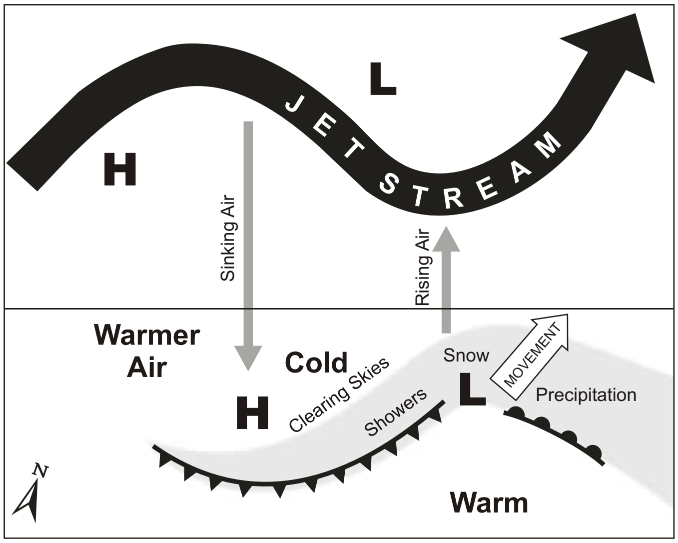


Illustration of the vertical structure of a winter storm. The bottom view depicts the surface features, and the top view shows upper level features of the system (adapted from Ahrens)

Weather Accompanying Winter Storms

Some of the hazardous weather conditions that accompany winter storms area:

Heavy snow — snowfalls greater than 15 cm in 12 hours usually cause significant problems.

Blowing Snow — wind-driven snow that reduces visibility and causes significant drifting

Blizzards — winds exceeding 50 km/h with snow and blowing snow reducing visibility to near zero; high wind chills.

Snowsqualls — narrow bands of very heavy snow that blow in off the Great Lakes, Gulf of St. Lawrence, and other bodies of water. Heavy snow and near zero visibilities are generally associated.

Ice pellets — raindrops that freeze before reaching the ground. This normally occurs when the rain forms along a warm front and descends through a layer of air with temperatures just below freezing.

Freezing Rain — rain falls through a layer or onto a surface with a temperature just below freezing, causing a layer of ice to form on the surface.

Most of the hazardous weather associated with winter storms occurs in the vicinity of the low pressure centres and along the frontal systems. Warmer, moister air is lifted over the frontal systems producing widespread areas of cloudiness and precipitation. Freezing rain is often observed just ahead of the warm front, as the rain falls through colder air below. Snow occurs further north of the freezing rain area and especially in the area to the north of the cyclone where there is a deeper layer of colder air through which the precipitation falls. The prime area for blizzard conditions occurs in the immediate vicinity of the cyclone where there often is heavy snow and the strong winds rotate about the storm centre.

Winter Weather Advisories and Warnings

Environment Canada issues a variety of special weather statements, advisories, watches and warnings to alert the public to the approach of winter storm conditions.

A special weather statement / winter weather advisory is issued when winter weather conditions are expected to cause significant inconveniences.

A winter storm watch is a “heads up” that winter severe weather is expected in the near future.

A winter storm warning is issued when severe winter weather conditions have begun or are about to begin in a given area.

A blizzard warning is issued when snow and strong winds wi11 combine to produce blinding snow (near zero visibility), deep drifts, and life-threatening wind chill.

What is Wind Chill and the Wind Chill Index?

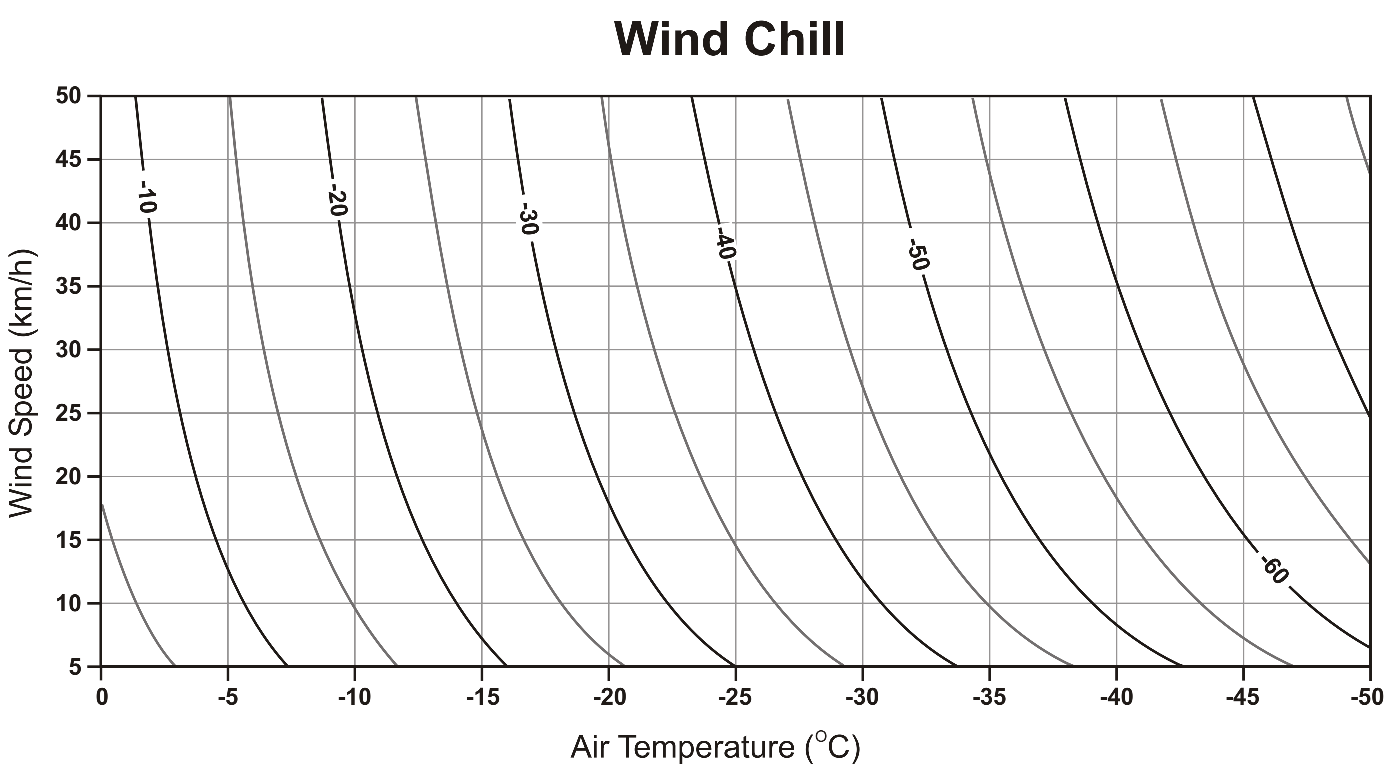
Wind chill is the cooling effect of the wind in combination with low temperatures. When it is windy, we *feel* colder because our skin temperature is lower. This *sensation* of cold is what the wind chill index quantifies: as such, the index is *not* a real temperature and is expressed without units, even though it is based on the Celsius temperature scale.

Environment Canada's wind chill index estimates the temperature which, with a wind of about 5 km/h, would give your face a sensation of cold similar to that caused by the actual temperature with the wind. Wind chill also estimates the risk of your getting frostbite (a severe injury caused by cold), according to these approximate thresholds:

- Wind chill below -25: risk of frostbite in prolonged exposure.
- Wind chill of -35: frostbite possible in 10 minutes (warm skin, suddenly exposed; shorter time if skin is cool at the start).
- Wind chill of -60: frostbite possible in less than 2 minutes (warm skin, suddenly exposed; shorter time if skin is cool at the start).

Major Health Hazards

The major health problems associated with winter storms are overexposure and overexertion. Overexposure implies that parts of the body are not properly protected from the cold temperatures and/or strong winds, leading to frostbite or hypothermia. Overexertion results from the strain of working too hard in cold temperatures, and can lead to heart failure.



ACTIVITY Major Winter Snowstorm

Upon completing this activity, you should be able to:

- analyse the snowfall pattern of a winter storm
- track the path of the cyclone
- determine the relationship between the major storm and corresponding hazardous weather it produced

Introduction

During the period of 25-27 January 1987, a major winter storm moved across the mid-Atlantic States. This particular storm brought heavy snowfalls to the area, with Washington, D.C. receiving about ten inches or 25 cm of snow during this period.

Major snowstorms are generally associated with winter storm systems that move across the country. The purpose of this exercise is to demonstrate the relationship between the areas of heavy snowfall and the track of the winter cyclone.

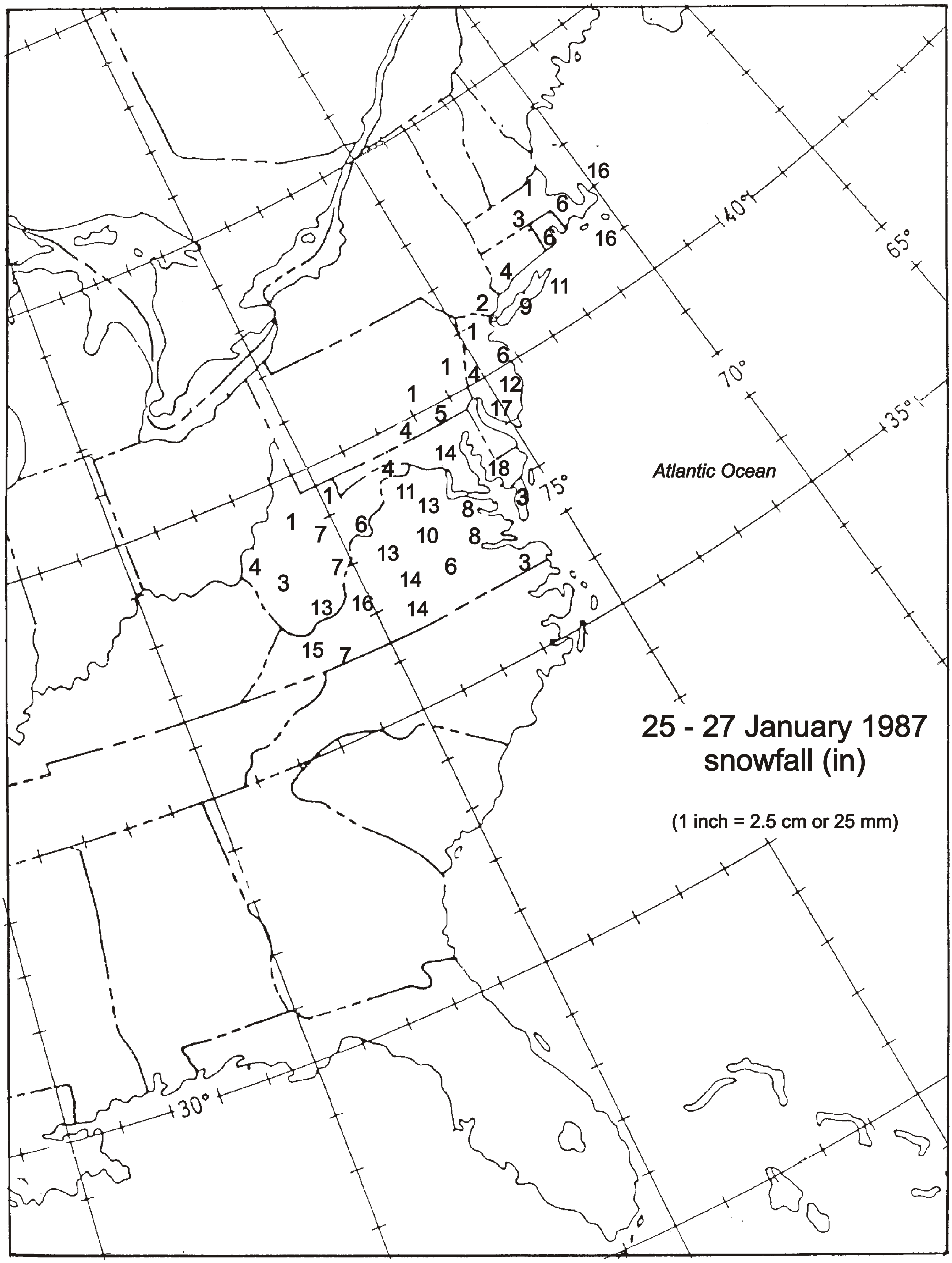
Activity

1. On the snowfall map provided, draw lines connecting points with 5 inches of snow. Where a 5 is not shown, interpolate between the values provided to locate the line. Next draw the line for 10 inches of snow and finally the line for 15 inches of snow.

2 Observe the three isolines which you have just drawn with a contouring interval of 5 inches and note where the heaviest snowfalls occurred. Also note the amount of change in the snowfall between locations that are very close together. (Remember those times when the weather forecast was for heavy snowfall and there was barely a light dusting? Perhaps the snow was quite heavy only 80 kilometres away!)

3. Examine the four panels of surface weather analyses on page 27. Locate the positions of the surface low pressure centres (L) in each panel. On the snowfall chart, plot the positions of each low pressure centre by placing an "L" with the date and time.

4. What relationship do you note between the track of the cyclone centre and the heaviest snowfall? Why would you expect this relationship to occur? (Keep in mind the necessary conditions for snow to occur.)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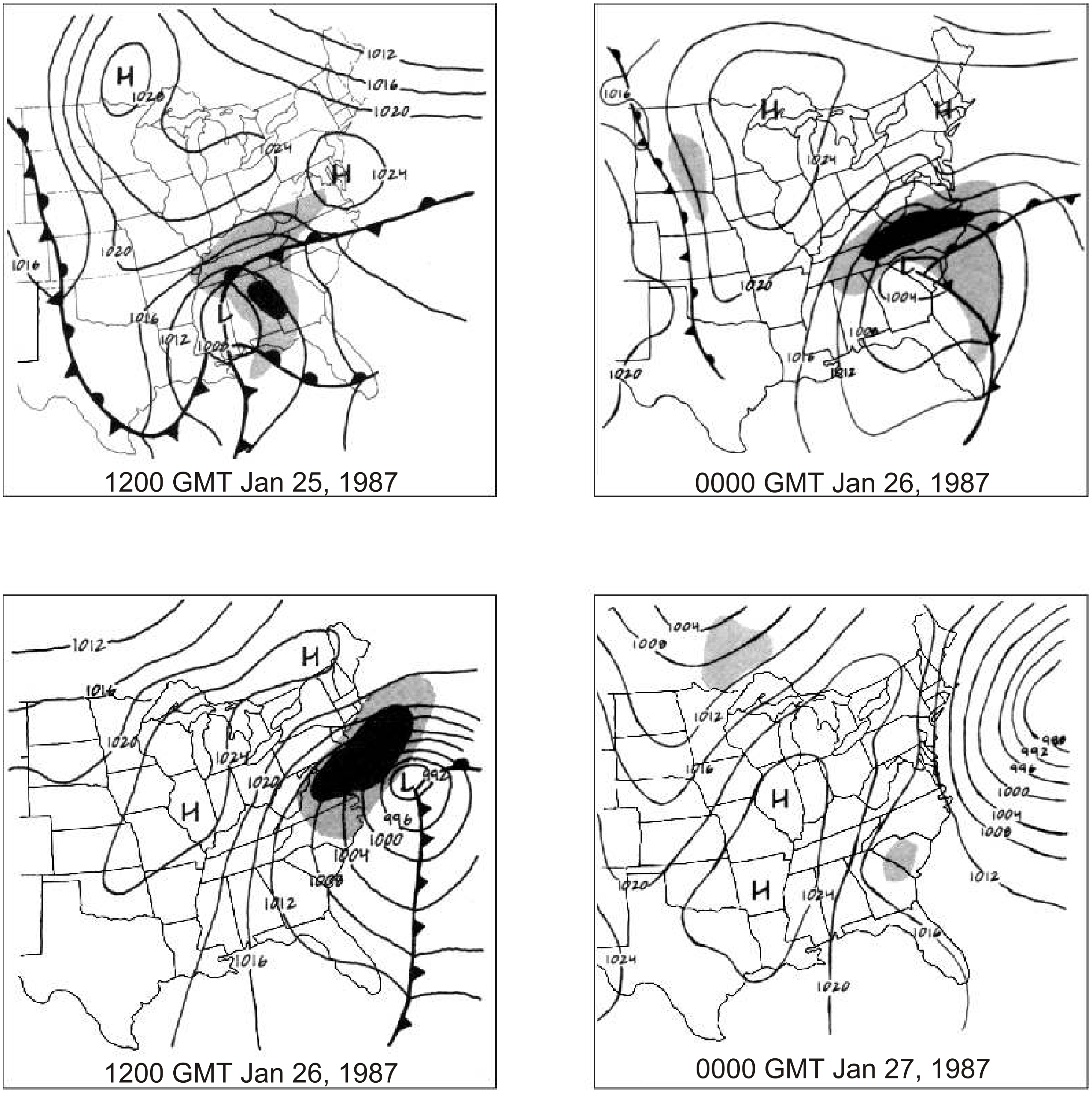
Atlantic Ocean
140°
65°
70°
35°
75°
30°
25 - 27 January 1987
snowfall (in)
(1 inch = 2.5 cm or 25 mm)



Four panels of surface weather analyses of winter storm on January 27, 1987 (Adapted from Kocin and Uccellini, 1990)

ACTIVITY Operation Icestorm

Upon completing this activity, you should be able to:

- describe the atmospheric conditions that can result in freezing rain
- trace the life history of freezing raindrops

Introduction

In January 1998 a series of storms passed through Eastern Ontario, Southern Quebec and the northeastern United States. Over a six-day period, freezing rain resulted in 5 to 10 centimetres of ice accumulating on everything. Millions of trees, thousands of power and telephone poles were downed by the weight of the ice. Millions of people were without electricity for prolonged periods, lasting for several weeks in some rural areas. The great ice storm of 98 will be long remembered.

Ice storms occur when a unique set of atmospheric temperatures and moisture conditions come together to produce freezing rain. Freezing rain differs from ordinary rain in a very important way. When drops of freezing rain strike a surface, some of the water immediately freezes. Quickly, freezing rains make roads and sidewalks slick and dangerous. Coatings of ice silently thicken on objects, adding weight as the glaze builds. Gradually, tree limbs and wires bend and droop from their increasing burdens. Should icing continue, tree limbs begin to break and fall while electric and telephone wires snap, lights go out, furnaces stop, and many people find themselves in threatening situations.

The atmospheric data used in this activity to investigate freezing rain were collected by weather instruments carried aloft by balloons. These instrument packages,called radiosondes, rise through the atmosphere and take temperature, humidity, and other measurements. These observations are then transmitted back to the Earth's surface. The humidity measurement they make is reported as dew point. Dew point is the temperature to which the air must be cooled to become saturated. Whenever the air temperature and the dew point have identical values, the air is saturated. Saturation is a condition which has to be met in order for a cloud to exist. In turn, clouds must be present in order for precipitation to occur.

Activity

The radiosonde data appearing on page 30 are representative of the atmospheric conditions during the January 98 ice storm. Plot the values on the accompanying graph. Place a dot (·) to show temperature at a particular altitude. Use a cross (x) to show the dew point at the same height. If the temperature and dew point values are the same, draw a small circle around the dot (⊙). After plotting all the data, connect adjacent temperature values with solid straight lines to show the temperature pattern with altitude, and use dashed straight lines for adjacent dew point values. The combination of temperature and humidity patterns that results is termed a "sounding". It depicts atmospheric conditions in the atmosphere above the reporting station at the time the data were collected.

Use the graph with plotted data to answer the following questions:

1. Were there clouds above the area when these data were collected? What assumption must you make in interpreting the data to answer this question? (Refer back to the Introduction section if you need help answering this).

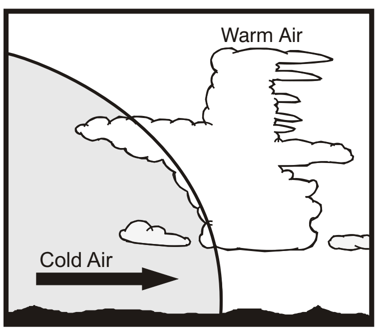
2. Locate the top and bottom of any existing cloud layer. Draw on the graph horizontal lines that cut across the sounding at the highest and lowest points at which saturated air was reported, i.e., temperature and dew-point values were the same. Since precipitation typically falls from relatively thick layers of cloud at least a few hundred metres thick, were the clouds thick enough to produce precipitation?

3. Shade lightly with your pencil the area enclosed by the vertical 0-degree line on the graph and that part of the plotted sounding showing temperatures of 0 degrees and higher. This shading highlights a layer of air in which temperatures are above freezing. Label the layer, "WARM". Describe in your own words the conditions above the area in terms of layers of air with above-freezing and freezing temperatures.

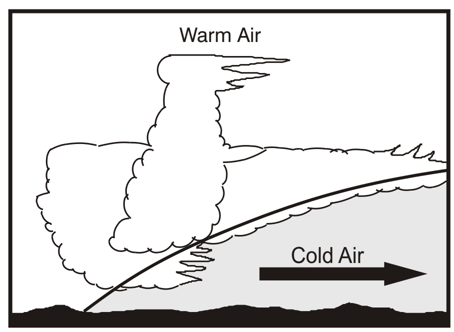
4. Assume that precipitation was occurring and that it originated as ice particles in the upper reaches of the existing cloud layer. What will prevent these particles from reaching ground level as snow?

5. For freezing rain to occur as it was in Eastern Ontario at the time of observation, raindrops must fall through a relatively shallow layer of freezing air immediately above the Earth's surface. According to the table of data given to you, how thick was this layer above Eastern Ontario ?

COLD FRONT



WARM FRONT



The slope of a cold front is steeper than that of a warm front because of the friction between the cold air and surface.

Answer Key

1. One has to assume that cloud is present when the upper air data indicates the presence of saturated air aloft (layers where the temperature and dew-point are the same). The data provided clearly indicates saturation aloft and therefore cloud aloft.

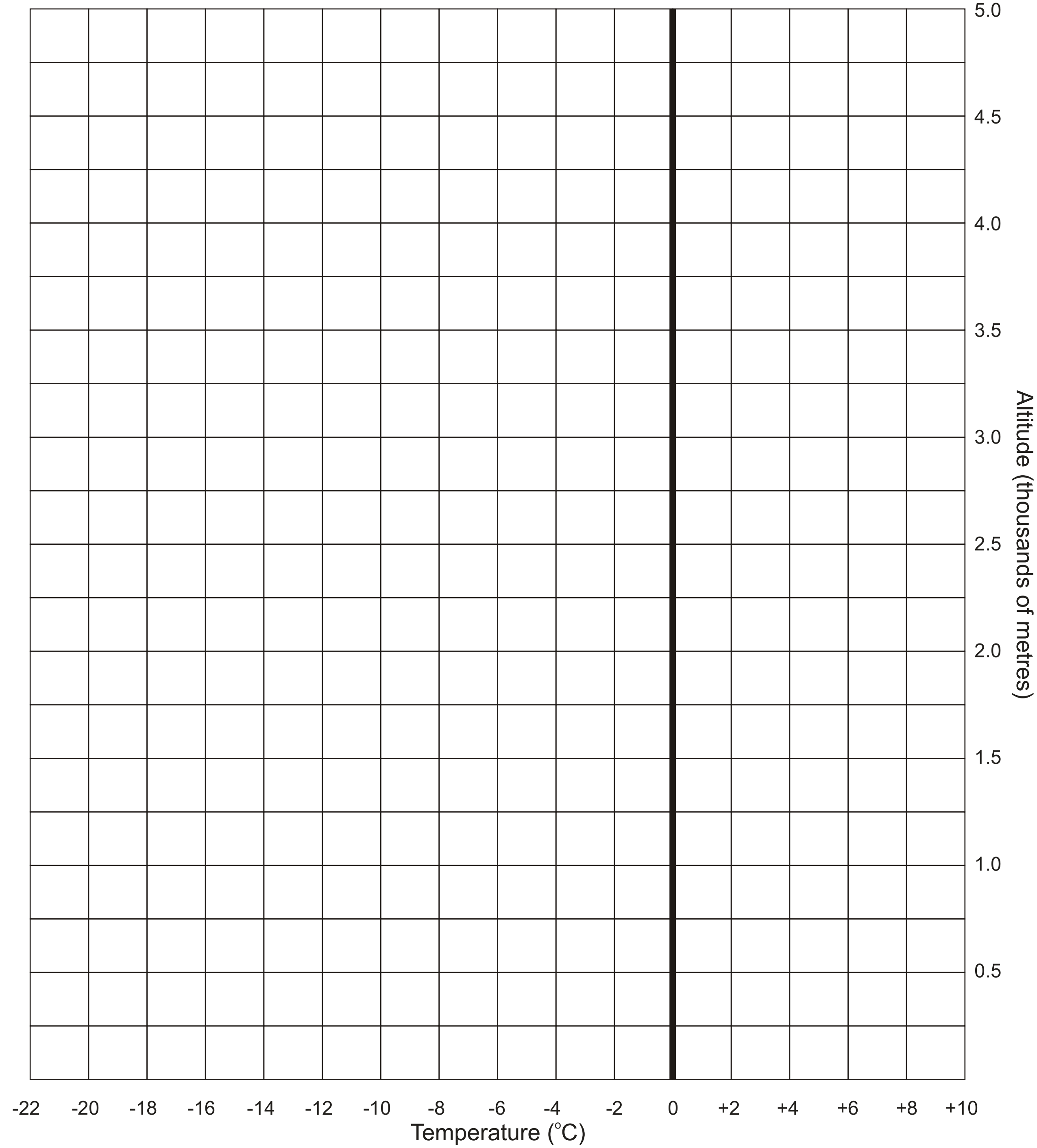
2. The upper air reports indicate that the clouds were about 3 km thick, therefore definitely thick enough to produce precipitation.

3. The saturated air was below freezing above 2.2 km, as well as below .4 km. Between these two levels the temperature was above freezing.

4. When these ice particles fall into the above freezing layer, they will melt and turn to rain before reaching the ground.

5. The layer of below freezing temperatures near the ground was about 500 metres.

Temperature-Altitude Diagram



Eastern Ontario Southern Quebec
January 7, 1998

Altitude (km)	Temperature (°C)	Dew Point (°C)
5.0	-16.5	-19.5
4.2	-9.5	-11.8
3.0	-3.5	-3.5
2.0	+0.4	+0.4
1.5	+4.2	+4.2
0.9	+6.4	+6.4
0.6	+3.8	+3.8
0.4	-0.5	-0.5
0.2	-0.1	-0.1
0.1	-2.1	-2.1
0 (Surface)	-3.5	-4.8