HAZARDOUS WEATHER

WINTER STORMS

TEACHER'S GUIDE

Project ATMOSPHERE

This guide is one of a series produced by Project ATMOSPHERE, an initiative of the American Meteorological Society. Project ATMOSPHERE has created and trained a network of resource agents who provide nationwide leadership in precollege atmospheric environment education. To support these agents in their teacher training, Project ATMOSPHERE develops and produces teacher's guides and other educational materials.

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Foreword

This guide has been prepared to introduce fundamental understandings about the guide topic. This guide is organized as follows:

Introduction

This is a narrative summary of background information to introduce the topic.

Basic Understandings

Basic understandings are statements of principles, concepts, and information. The basic understandings represent material to be mastered by the learner, and can be especially helpful in devising learning activities in writing learning objectives and test items. They are numbered so they can be keyed with activities, objectives and test items.

Activities

These are related investigations. Each activity typically provides learning objectives, directions useful for presenting and completing the activity and questions designed to reinforce the learning objectives.

Information Sources

A brief list of references related to the guide topic is given for further study.

Overview

Weather is variable, from the gentle breezes of a balmy evening to the heavy wind and rain of a late afternoon thunderstorm. Hazardous weather, such as thunderstorms, hurricanes, and winter storms — covered in this and related guides — can cause property damage, bodily injury or even death. With the necessary information, proper preparation, and sensible reactions, most people can protect themselves and to some extent their property from the ravages of most kinds of hazardous weather.

Hazardous weather may affect anyone, anywhere in the world at any time. The table below shows the annual approximate numbers of various types of severe weather for several countries worldwide. The United States actually has the greatest variety and occurrence of threatening weather conditions.

Comparison of Weather Risks[1]

Country	Severe Thunderstorms	Tornadoes	Severe Winter Storms	Hurricanes, Tropical Cyclones, Typhoons	Flash Floods
U S A	10,000/yr	1000/yr	10/yr	10/yr	1000/yr
Australia	500	< 100	0	10	100
Canada	500	10	20	0	10
France	100	< 10	10	0	10
Germany	100	< 10	10	0	10
Japan	500	< 10	10	10	50
United Kingdom	100	10	10	0	10
Russia/former USSR	5,000	10	20	0	100
China	10,000	< 10	5	20	500

[1] Data courtesy of NOAA, NWS.

Hazardous weather in the United States result in hundreds of lives lost each year with total property losses typically reaching into the billions of dollars. These are ample reasons why everyone should keep track of the weather and understand what to do if severe weather occurs.

The U.S. National Weather Service, an office of the National Oceanic and Atmospheric Administration, has the responsibility of warning people in the country of the possible impact of a severe weather-related event. Warning programs have been developed to inform the public of the weather hazard and to help initiate appropriate adaptive measures. Prompt response to such information can save lives, reduce injuries, and lessen property damage.

Suggested Activities:

1. Plot the numbers appearing in the table on a world map to highlight the types and numbers of weather threats around the globe. Does there appear to be any particular geographical pattern to the frequency of the different kinds of weather risks?

2. Which country listed has the greatest variety of hazardous weather and need for timely weather forecasts, watches and warnings?

3. Of the threats listed, which is of greatest concern in your local area? What should you, your family, and your community do to try to adequately prepare and respond to the threat or threats?

4. What was the most recent hazardous weather you and/or your community faced? What was done or could have been done to lessen its effects?

5. Does your family, school, and community have a plan for all types of hazardous weather that might occur? What has been done or should be done? Who should do it?

6. What are the basic safety rules individuals should follow in facing the different kinds of hazardous weather? (Find information from your local National Weather Service office or local chapter of the American Red Cross for safety rules and hazardous weather preparedness and response.)

Hazardous Weather Watches and Warnings

The National Weather Service has terminology to alert the public to weather conditions that may require action to save lives and protect property. These terms accompany the specific type of severe weather to be encountered such as thunderstorms, tornadoes, high winds, floods and flash floods, and hurricanes.

A ***watch*** is issued when there is a threat of that weather developing in a specified area over a certain period of time.

A ***warning*** is issued when that weather threat has been observed (visually or by radar) in a given location. One should take immediate steps to avoid imminent danger.

Basic Understandings: Winter Storms

Winter Storm Development

1. Winter storms are large-scale disturbances associated with low-pressure areas called cyclones.

2. Winds blow counterclockwise as seen from above (in the Northern Hemisphere) around the center 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. Wind speeds increase as the storm strengthens. The warm, moist air is lifted upward, producing widespread areas of cloudiness and precipitation along the frontal surface 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 or sleet (ice pellets), 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 equivalent temperature with no wind.

9. The National Weather Service issues a variety of severe winter weather advisories 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.

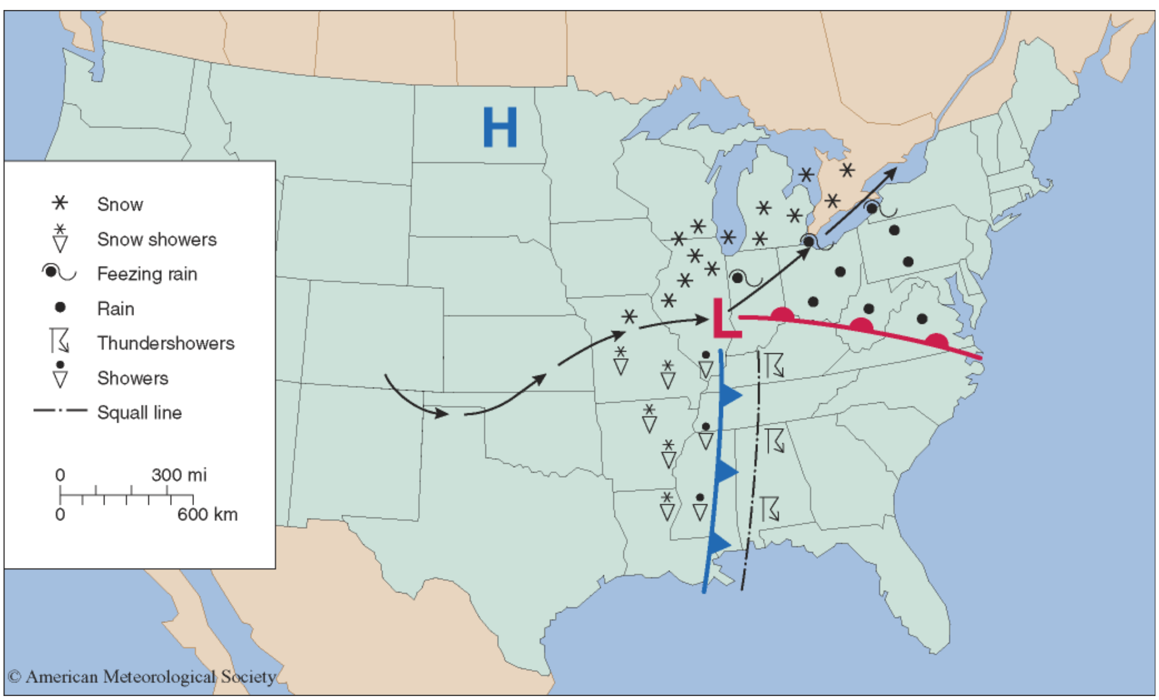
Introduction: Winter Storms

What is a Winter Storm?

A winter storm is a large-scale disturbance, often hundreds of miles 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, sleet, or snow) and cold temperatures.

What Causes Winter Storms?

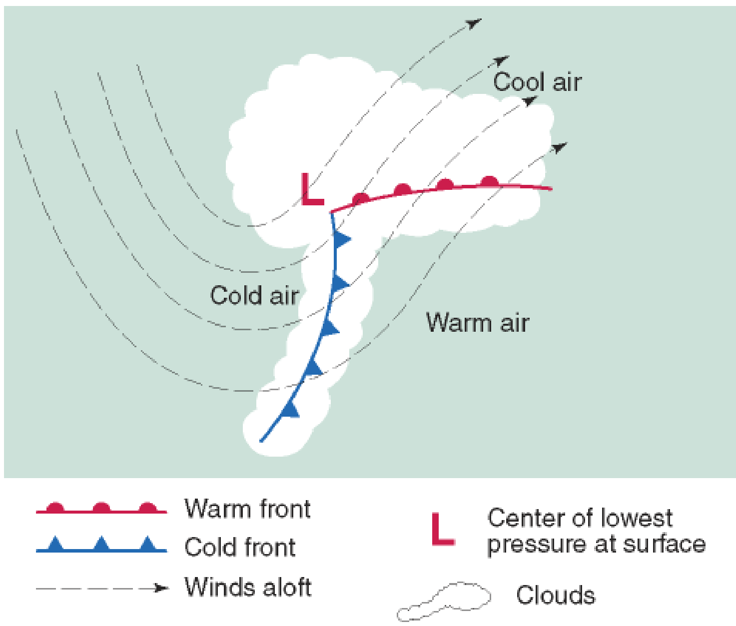
Winter storms occur when relatively warm, humid air interacts with colder air along the frontal boundary separating two air masses. Initially, the front is slow-moving or stationary. As the warm air intrudes into the colder region, the air density decreases, so the surface pressure falls in this area. This results in the formation of a *cyclone* — the circulation about a low pressure region. The two contrasting air masses provide energy to the 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.



Map depiction of a winter storm system, showing the low pressure center (**L**), fronts and accompanying weather. Arrows denote the movement of the low pressure center.

Structure and Movement of Winter Storms

The figure below displays the structure of a mature stage of a winter storm, with major features noted at both the surface and at upper levels (18,000 to 30,000 ft). The primary storm is associated with the surface position of the low (***L***) center 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 center. The surface air flow behind the cold front brings colder temperatures, clear skies and fair weather. The entire storm system moves with the upper level steering wind currents (noted by the direction of the arrows of the winds aloft).



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Weather Accompanying Winter Storms

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

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

Blizzards – winds exceeding 35 mph with snow and blowing snow reducing visibility to near zero.

Sleet (**ice pellets**) **–** raindrops that freeze into ice pellets 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 onto a surface with a temperature just below freezing, causing a layer of ice to form on the surface. Temperatures are slightly warmer than in the situation responsible for sleet.

Most of the hazardous weather associated with winter storms occurs in the vicinity of the low pressure centers and along the frontal systems. Warmer, moister air is lifted over the frontal systems producing widespread areas of cloudiness and precipitation. Freezing rain and sleet often are just ahead of the warm front, as the rain falls through the 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 is often heavy snow and the strong winds rotate about the storm center.

Winter Weather Advisories and Warnings

The National Weather Service issues a variety of severe winter weather advisories and warnings to alert the public to the approach of winter storm conditions.

A *frost/freeze warning* is issued when below freezing temperatures are expected that can cause damage to plants, crops, or trees.

A *winter weather advisory* is issued when winter weather conditions are expected to cause significant inconveniences, which may be hazardous.

A *winter weather 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 will combine to produce blinding snow (near zero visibility), deep drifts, and life-threatening wind chill.

What is the Wind Chill Factor?

Cold temperatures feel more extreme when there is wind. As wind speed increases the rate of heat loss by the body, especially exposed skin, is also increased, hence body temperature decreases. The *wind chill factor* combines the effect of temperature and winds to determine the equivalent cooling by temperature alone.

Wind-Chill Factor: The numbers in the table below show the equivalent temperature in still air. For example, an actual temperature of zero degrees Fahrenheit in a 20 mph wind is equivalent to –22 degrees Fahrenheit in still air.

NWS Windchill Chart

Temperature (ºF)

Wind (mph)	Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
	5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
	10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
	15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
	20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
	25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
	30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
	35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
	40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
	45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
	50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
	55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
	60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes | 10 minutes | 5 minutes

Effective 11/01/01

Major Health Hazards

The major health problems associated with winter storms are overexposure and overexertion. Overexposure implies tat 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

Introduction

"The "Blizzard of '96" will rank as one of the most significant snowstorms of the 20th century since many of the largest population centers within the Northeast urban corridor were buried under more than 20 in. (50 cm) of snow. This was the most significant storm during the snowiest winter of the 20th century for much of the area from Virginia through southern New England." [Kocin and Uccellini, p. 599]

Two smaller snowstorms followed the Blizzard and finally rain and milder weather in later January led to severe flooding in New York, Pennsylvania and Maryland. This was an extreme example of winter weather hazards.

Paul Kocin and Louis Uccellini of the National Oceanic and Atmospheric Administration (NOAA) have developed the Northeast Snowfall Impact Scale (NESIS) to compare snow storms based on their societal impacts. This included the area covered by varying depth of snow and also the number of people in the region that were affected. These NESIS values are then scaled into categories from 1–5 to be comparable with the impact scales associated with hurricanes and tornadoes.

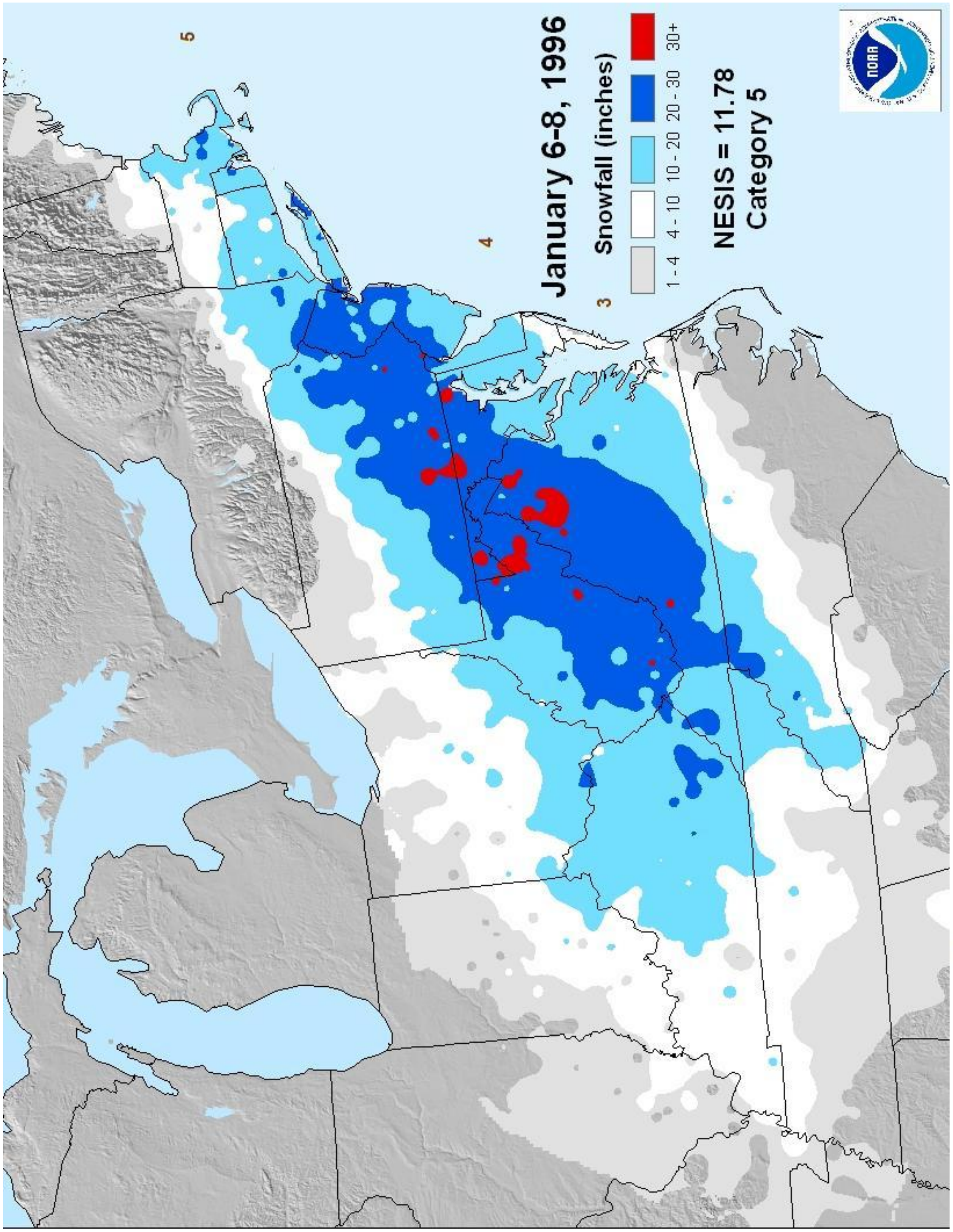
After completing this exercise, you should be able to:

- analyze 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.

Activity

1. On the snowfall map provided from NESIS, the snowfall amounts are given in inches for the *shaded categories* according to the scale on the right for the Category 5 snow storm of January 6-8, 1996. The red shading indicates areas where snowfall amounts were **[(*1-4 in.*)(*4-10 in.*)(*10-20 in.*)(*20-30 in.*)(*30 in. or more*)]**.

Observe the shaded category boundaries. 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 a few tens of miles away!)


January 6-8, 1996
Snowfall (inches)
1 - 4
4 - 10
10 - 20
20 - 30
30+
NESIS = 11.78
Category 5
1
2
3
4
5

2. The table below indicates generally where the centers of lowest atmospheric pressure were at the times listed.

Plot Number	Time/Day
1	00Z 1/7
2	12Z 1/7
3	00Z 1/8
4	12Z 1/8
5	00Z 1/9

   At the position numbers (in brown) labeled on the snowfall map, place a bold (**L**) and label its time and day beneath the L. Connect the Ls with a dashed curve from earliest (western most location) to latest (eastern most). Your dashed curved represents the storm's track.

3. What relationship do you note between the track of the cyclone center and the heaviest snowfall? Why would you expect this relationship to occur? (Keep in mind the necessary conditions for snow to occur.)

Ref: Kocin, Paul J. and Louis W. Uccellini, *Northeast Snowstorms*, Am. Meteor. Soc., Boston, 2004, Vol. I, II, 818 pp.

Activity: Operation Ice Storm

Introduction

A winter storm passed through western New York and raised havoc. Over half of the trees in the area received major damage, electric and telephone lines were ripped down, and residents in a major urban center lost electrical power for up to a week and more. Deaths and injuries occurred. Schools and businesses were closed as people tried to cope with a major winter hazard — an ice storm.

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 increased burdens. Should icing continue, tree limbs begin to break and fall while electric, cable and telephone wires snap. Lights go out, furnaces stop, and many people find themselves in threatening situations.

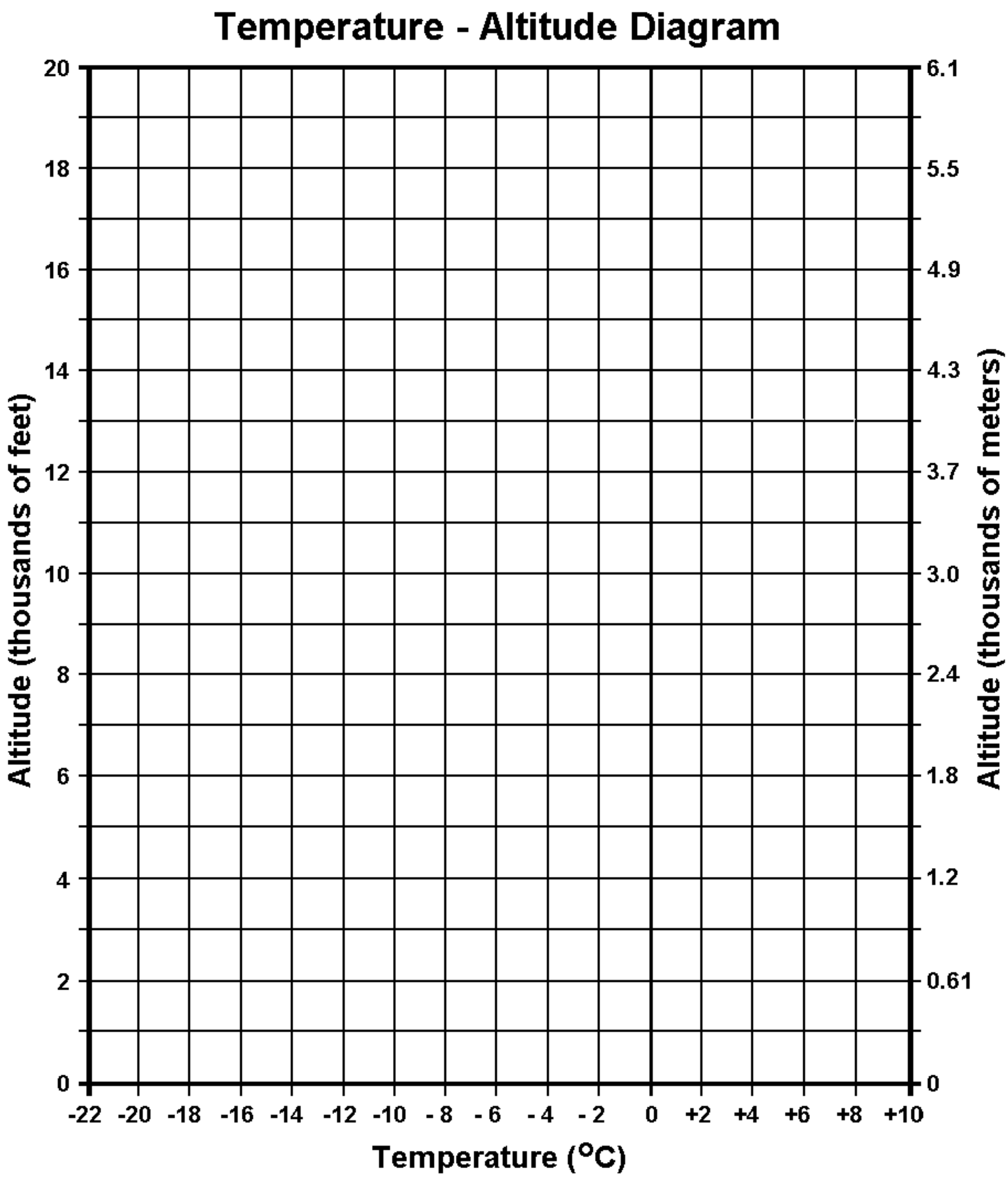
The atmospheric data used in this activity to investigate freezing rain were collected by weather instruments carried aloft by balloons. These instrument packages, called radiosondes, rise through the atmosphere and take temperature, humidity, and other measurements. These observations are then transmitted back to Earth's surface. The humidity measurement they make is reported as dewpoint. Dewpoint is the temperature to which the air must be cooled to become saturated. Whenever the air temperature and the dewpoint 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.

After completing this exercise, you should be able to:

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

Activity

The radiosonde data appearing in the following table were recorded in Albany, New York on an early February morning when a freezing rain episode was in progress. Plot the values on the accompanying graph. Place a dot (•) to show temperature at a particular altitude. Use a cross (×) to show the dewpoint at the same height. If the temperature and dewpoint 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


Temperature - Altitude Diagram
Altitude (thousands of feet)
20
18
16
14
12
10
8
6
4
2
0
Altitude (thousands of meters)
6.1
5.5
4.9
4.3
3.7
3.0
2.4
1.8
1.2
0.61
0
-22 -20 -18 -16 -14 -12 -10 - 8 - 6 - 4 - 2 0 +2 +4 +6 +8 +10
Temperature (°C)

dewpoint values. The combination of temperature and humidity patterns that results is termed a “sounding”. It depicts conditions in the atmosphere above the reporting station at the time the data were collected.

Albany, NY – 7 AM EST – 2 February

Altitude (ft)	Temperature (°C)	Dewpoint (°C)
18,270	– 18.3	– 21.6
13,940	– 9.5	– 11.8
9,770	– 3.5	– 3.5
6,670	+ 0.4	+ 0.4
4,660	+ 4.2	+ 4.2
2,980	+ 6.4	+ 6.4
2,050	+ 3.8	+ 3.8
1,190	– 0.5	– 0.5
570	– 0.1	– 0.1
340	– 2.1	– 2.1
(surface) 0	– 3.5	– 4.8

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

1. Were there clouds above Albany when these data were collected? What assumption must you make in interpreting the data to answer this question?

2. Locate the top and bottom of any existing cloud layer over Albany. 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 dewpoint values were the same. Since precipitation typically falls from relatively thick layers of cloud at least a few thousand feet thick, were the clouds above Albany thick enough to produce precipitation?

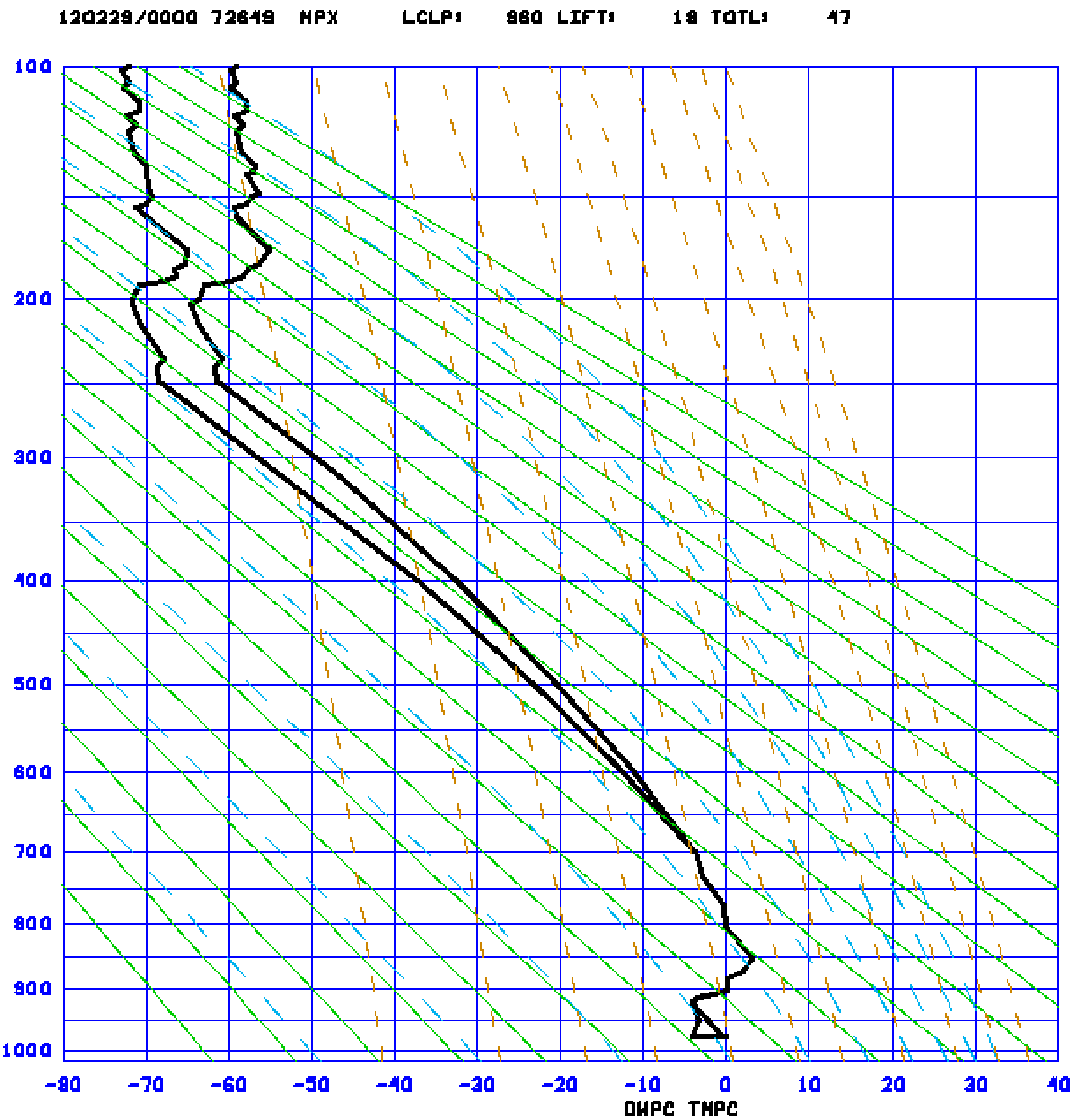
3. Shade lightly with your pencil the area enclosed by the vertical 0-degree line on the graph and that part of the plotted sounding showing temperatures of 0 degrees and higher. This shading highlights a layer of air in which temperatures are above freezing. Label this layer, “*WARM*”. Describe in you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

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

5. For freezing rain to occur as it was in Albany 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 of sub-freezing air above Albany?

6. A common place for freezing rain to occur is in advance of an approaching warm front in a winter storm system. Locate this region on a surface weather map showing a winter storm if such a map is available. Explain, based on this activity and a side-view model of warm front if it is available, why this is so.

Real World Applications



The above figure is a radiosonde sounding from Minneapolis, Minnesota at 0000Z 29 February 2012 (6 PM CST Tuesday evening).

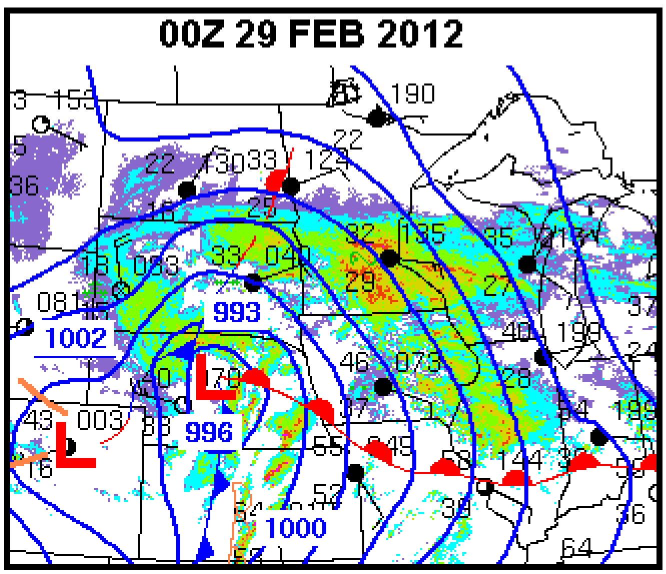
The heavy curve to the right on the Stüve diagram (atmospheric chart used here) is the temperature while the curve to the left is the dewpoint. Temperatures are along the horizontal axis in degrees Celsius, the vertical axis is pressure in millibars, decreasing upward as in the atmosphere.

1. Is the atmosphere above Minneapolis saturated, i.e. clouds probably existed? How can you tell using the temperature and dewpoint relationship?

2. Is there saturated air aloft that would be a cloud possibly producing precipitation? Is the temperature cold or warm, i.e. below or above freezing (0 °C) , producing snow or rain?

3. Is there a warm layer where any solid precipitation could melt to rain?

4. Is the surface temperature at or below freezing such that falling precipitation could freeze on the surface?



The surface map segment from the time of the radiosonde plot shows precipitation occurring at Minneapolis, MN, as detected by radar. The surface temperature at Minneapolis at this time was 32 0 °F, freezing, and the weather symbol indicated that freezing drizzle was happening.

Information Sources

Books

Moran, Joseph M. Weather Studies: Introduction to Atmospheric Science, 5th Ed. Boston, MA: American Meteorological Society, 2012.

Periodicals

Weatherwise. Bimonthly magazine written in association with the American Meteorological Society for the layperson. Weatherwise, 1319 Eighteenth St., NW, Washington, DC 20036.

USA Today. National newspaper with extensive weather page. Available at local newsstands and by subscription.

Radio and Television

NOAA Weather Radio. The voice of the National Weather Service and All Hazards Emergency Alert System. Local continuous broadcasts from over 1000 transmitting stations nationwide.

The Weather Channel. A continuous cable television program devoted to reporting weather. Includes frequent broadcast of local official National Weather Service forecasts.

Internet

DataStreme Atmosphere (*www.ametsoc.org/amsedu/dstreme/*). Atmospheric education distance-learning website of the AMS Education Program.

JetStream – Online School for Weather (*www.srh.noaa.gov/jetstream/*). Background weather information site from the National Weather Service.