DOCUMENT RESUME

ED 372 955 SE 054 654

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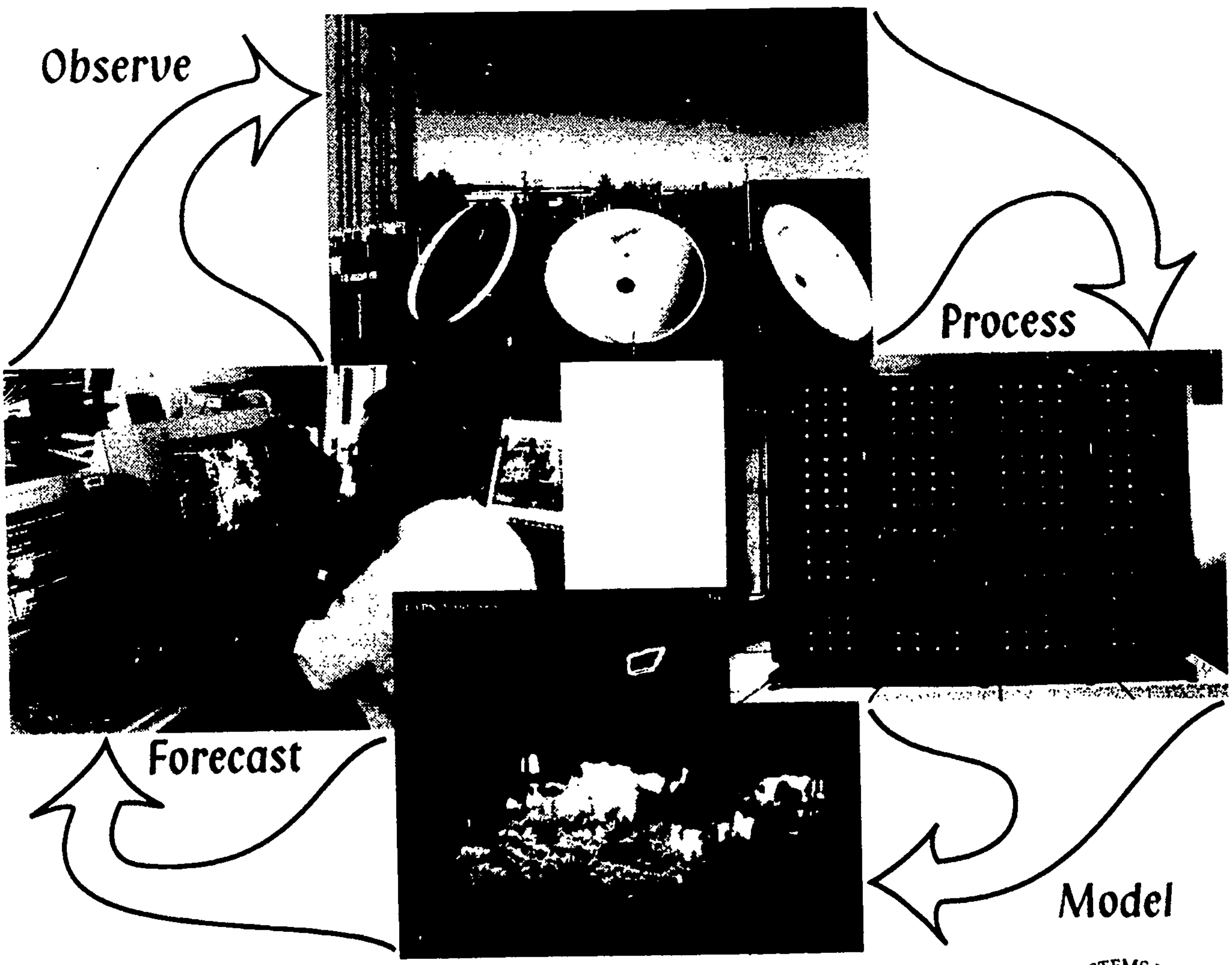
TITLE	Student Activities in Meteorology: SAM. Version 2.
INSTITUTION	National Oceanic and Atmospheric Administration, Boulder, CO. Environmental Research Labs.
PUB DATE	[93]
NOTE	84p.
PUB TYPE	Guides - Classroom Use - Teaching Guides (For Teacher) (052)
EDRS PRICE	MF01/PC04 Plus Postage.
DESCRIPTORS	*Air Pollution; Earth Science; Elementary Secondary Education; *Greenhouse Effect; *Meteorology; *Science Activities; *Science Education; Technology Education; Vectors (Mathematics); *Weather; Wind (Meteorology)
IDENTIFIERS	*Hands on Science

ABSTRACT

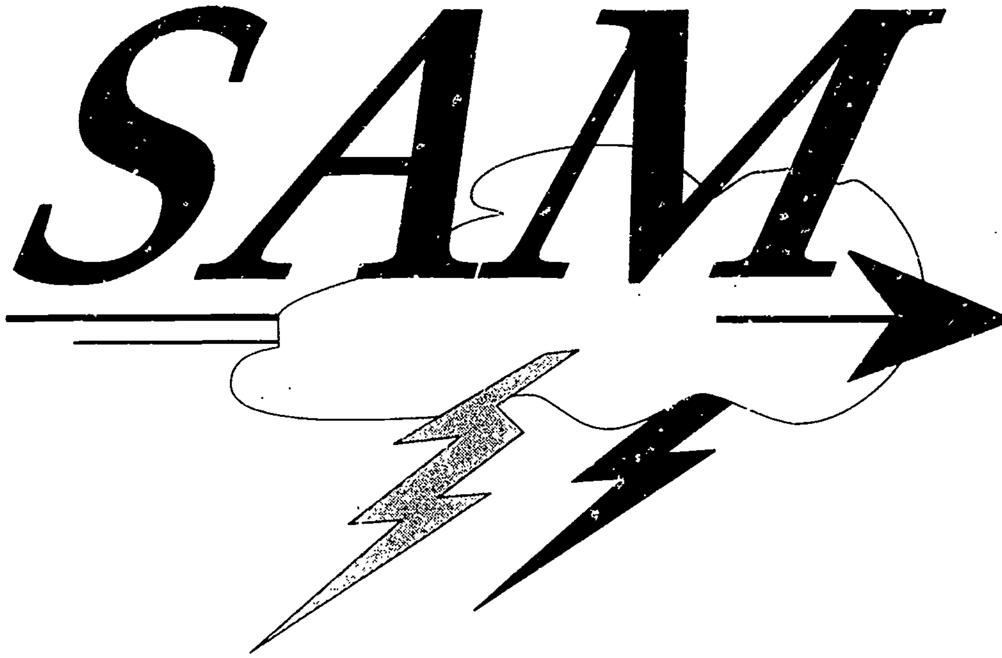
The task of providing hands-on as well as minds-on activities for students in science is one of concern to many scientists and educators. In an effort to inspire student interest in science and technology, scientists from the Forecast Systems Laboratory, a laboratory within the National Oceanic and Atmospheric Administration's (NOAA) Environmental Research Laboratories, and classroom teachers from the Boulder Valley School District collaborated to produce a series of Student Activities in Meteorology (SAM). The following SAM activities are included: (1) "Tracking Severe Weather with Doppler Radar"; (2) "Wind Profiler: Doppler Radar in a Vertical Direction"; (3) "Looking at Severe Weather: Lightning and Tornadoes"; (4) "Wind Chill"; (5) "Greenhouse Effect: Too Much, Too Little, or Just Right?"; (6) Volcanoes: Ozone Depletion and Atmospheric Cooling"; (7) "Using Statistics to Analyze Climate Data"; (8) "Carbon Monoxide Pollution, Wind Speed, and Wind Direction"; (9) "Air Traffic, Weather, and Vectors"; and (10) "Sunspots: Space Weather Monitoring." Each activity contains: (1) statement of the problem; (2) materials needed; (3) background information; (4) description of the procedures; and (5) a list of questions. (A glossary of 85 terms is included along with an answer key.) (ZWH)

Student Activities in Meteorology

SAM



Student Activities in Meteorology



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Version 2 - *Unofficial*

Contents

Acknowledgments

August 31, 1992
Boulder, Colorado

We wish to thank the many individuals who helped us prepare the *Student Activities in Meteorology*. A unique combination of knowledge, time, and effort on the part of many National Oceanic and Atmospheric Administration's (NOAA) Environmental Research Laboratories' employees enabled us to create the *SAM* series. We hope that both students and teachers learn as much as we did, and have as much fun doing the activities as we had creating them.

We owe a special note of gratitude to the project coordinator, Barbara McGehan, for her inspiration and guidance.

We thank and acknowledge the contributions of the following people.

Audrene Brown
Betty Close
Tom Conway
Steve Dent
Ed Dlugokencky
Wyn Eberhard
Wayne Fischer
Dick Fritz
Chris Grund
Seth Gutman
Rich Jesuroga
Rhonda Lange
Raul Lopez
Sandy MacDonald
Brooks Martner
Phil Mc Donald
John Osborn
Frank Pratte
Josephine Race
Bob Rilling
Doron Shalvi
Mel Shapiro
Greg Shaw
Lynn Sherretz
Dorothy Skinner
Ellen Steiner
Tony Tafoya
Chris Thomas
Taniel Uttal
Doug van de Kamp
Will von Dauster
Randy Wasser
Audrey Williams

Finally, we would like to acknowledge three students, Melissa Borego, Mariah Carbone, and Jennifer Pierpont, whose comments helped us improve the readability of the technical information presented in the activities.

Beverly L. Meier
Elisa Passarelli

Acknowledgments (continued)

August 31, 1993
Boulder, Colorado

I owe a debt to many scientist colleagues and teachers who helped me to revise, update, and add to the *Student Activities in Meteorology*. To those who took time to critique the *SAM* manual, I thank you for your detailed assessment. Many of your suggestions appear in the current version of *SAM*.

Once again, scientists from NOAA's Environmental Research Laboratories (ERL) have provided not simply information, but an aesthetic enjoyment that accompanies the thrill of discovery and a sense of excitement that emerges from the search for explanations. I sincerely hope that our enthusiasm reaches students who use the *SAM* series.

In addition to those who contributed to the original *SAM* activities last summer, and who contributed again this summer, I thank the following people for their knowledge and assistance.

John Ball
Roger Brown
Larry Combs
Kathryn Jones
Matt Kelsch
Patrick McIntosh
Tom Schlatter
Christopher Wilson
Robert Battjes
Helen Coffey
Bill Glover
Joann Joselyn
Virginia Lincoln
Bob Munger
Janet Stellema

I would also like to thank two former students and summer employees at ERL, Scott Geertgens and Tonya Reed.

Finally, to John Osborn, I owe a special note of thanks for his design and layout suggestions, as well as for his patience and support in helping me to meet many deadlines in a short period of time.

Beverly L. Meier

Letter to Colleagues in Science and Teachers

August 31, 1993
Boulder, Colorado

Dear Colleagues In Science and Teachers,

In an effort to inspire student interest in science and technology, scientists from the Forecast Systems Laboratory, a laboratory within the National Oceanic and Atmospheric Administration's (NOAA) Environmental Research Laboratories, and classroom teachers from the Boulder Valley School District collaborated to produce a series of classroom science activities on meteorology and atmospheric science. We call this series ***Student Activities in Meteorology***, or *SAM*.

Our goal is to provide activities that are interesting to students, and at the same time convenient and easy to use for teachers. The activity topics chosen are to incorporate trend setting scientific research and cutting edge technology. Several of the activities focus on the meteorological concerns of Denver metropolitan area because many of NOAA's research labs are located in Boulder, where much of the research and testing for the region is performed.

We believe that these activities are versatile and can be easily integrated into your current science, environmental studies, health, social studies, and math curriculum. Although each *SAM* activity can be used alone, the series is designed to supplement your established curriculum. Further, these activities are designed to span a wide range of grade and ability levels. The reading level is aimed at the middle school age group. However, the questions that follow each procedure vary in difficulty and can challenge even high school age students. A serious attempt was made to incorporate math into the procedures and follow-up questions. We hope that you find these activities flexible enough to adapt to your teaching and classroom style.

Your opinion and evaluation of the science activities in this packet are vital to us. We plan to update and improve *SAM* based on your comments and hope to continue to add to the series in the future. An evaluation form is included in the "Information for Teachers" Section of your document. Please complete the form after you have used one or more of the activities, and return it to us so that we can implement your suggestions for improvement.

We hope that these activities prove to be interesting and motivational, and provide a springboard to lively classroom discussions.

Sincerely,

Barbara McGehan
NOAA/ERL/FSL

Beverly L. Meier and Elisa Passarelli
Science Teachers, Boulder Valley School District

SAM Answer Key SAM

Activity # 1. Tracking Severe Weather With Doppler Radar

1. East; south; west
2. From the north or slightly northwest
3. Red +15m/sec and violet -18 m/s (Negative indicates motion toward the radar.)
4. 19.4 miles/hour
5. Diameter = 40 km or 24 miles; yes

Activity # 2. Wind Profiler: Doppler Radar in a Vertical Direction

Part A

1. 65 knots
2. 15 knots; SW
3. From SW to almost northerly; speed increases slightly
4. Cooling

Part B

1. About 11-12 km (Higher wind speeds at other levels are probably anomalous and should be ignored.)
2. From about 9 to 13.5 km (or about 4.5 km)
3. Decreasing
4. Surface winds increase as time progresses.

Activity # 3. Looking at Severe Weather: Lightning and Tornadoes

1. July
2. Summer; People are outside more in the summer and thunderstorms happen more often in the spring and summer.
3. 813 people
4. 7 miles
5. See the safety information (use cordless phone).
6. 2 possible answers: No, lightning deaths occur most often in non-severe thunderstorms because people take shelter less promptly. Yes, both are spawned by thunderstorms.
7. November. In November, tornadoes are more likely to occur in the southeastern U.S. where there is less tornado awareness than in the mid U.S. Also, forests, haze, hills, and night time occurrences make tornadoes more difficult to see. Be sure to make the point that data in this activity are anomalous. Students should wrestle with the problems of drawing conclusions from a limited amount of data, as deliberately presented in this activity.

Answer Key (continued)

Activity 4. Wind Chill

Temperatures for the Wind Chill Table blanks, left column to right column, are -5, -15, -60.

1. Wind speed, relative humidity, sunshine, type of clothing worn, state of health, amount of body fat, individual metabolism
2. a. -18° F
   b. -46° F
   c. 8° F
3. Very cold—cover exposed skin.
4. See safety information about hypothermia.
5. See safety information about frostbite.

Activity 5. Greenhouse Effect: Too Much, Too Little, or Just Right?

Part A

1. Northern Hemisphere winter
2. Southern Hemisphere winter
3. Less vegetation in the Southern Hemisphere, further from sources and sinks.
4. To avoid local contamination and to find an air average over large areas.

Part B

1. Increase
2. CH_4
3. No, Trace gas concentration is only one component of global warming. Need more information over a longer period of time, for example, "Is the global average temperature actually rising compared to natural variability?"

The rate of change for CO_2 is 1.4 ppm/year.
The rate of change for CH_4 is 11.1 ppb/year.

Activity 6. Volcanoes: Ozone Depletion and Atmospheric Cooling

1. SO_2
2. 19 km
3. Stratosphere
4. Increased; Increased aerosols formed from the SO_2 propelled into the stratosphere by the eruption of Mt. Pinatubo.
5. 971 backscatter units; 1790 backscatter units

Answer Key (continued)

6. Stratosphere
7. Moved higher into the stratosphere by 3 km , from 16 km to 19 km.
8. Aerosol particles that travel around the Earth in the stratosphere are less likely to fall to the Earth and, therefore, remain aloft for a longer period of time than particles in the troposphere.
9. It takes more time for material to spread into the stratosphere of the Northern Hemisphere, where the backscatter was measured, than into the stratosphere above the tropics, where the volcanic eruption occurred.

Activity 7. Using Statistics to Analyze Climate Data

1. Mean: July Max 92° F - Min 63° F, Jan Max 45° F - Min 19° F.
2. Median: July Max 93° F - Min 63° F, Jan Max 46° F - Min 19° F.
3. Mode: July Max 96° F - Min 61° F and 65° F, Jan 39° F and 50° F - Min 19° F.
4. Cloudy and cold; Because the temperature is so low compared to other temperatures.
5. Jan 15 colder than normal; Jan 24, 28, and 31, warmer than normal.
6. 13° F
7. July 28 and 29.
8. January is much colder because it is winter in North America.
9. A large amount of data over a long period of time. Global warming is a complex issue, temperature is not enough evidence.

Activity 8. Carbon Monoxide Pollution, Wind Speed, and Wind Direction

1. 6 hours; 0 hours
2. Max = 7 knots; Min = 0 knots
3. Max = 10 knots; Min = 0 knots
4. Denver range is 7 knots; Boulder range is 10 knots.
5. Denver is N, NE; Boulder is W
6. Denver: As wind speed increases, CO level decreases.
   Boulder: Wind speed is low to moderate and CO level is low.
7. 2:00 am; It is not the time of the usual rush hour maximum.
8. See student graphs which should coincide roughly with AM and PM rush hour.
9. CO pollution follows river valleys, therefore, prevailing westerly winds disperse pollution in Boulder more than in Denver. Furthermore, in Denver, winds from the N and NE hold CO pollution against the foothills.

Activity 9. Air Traffic, Weather, and Vectors

1. Approximately 150 miles
2. Yes; one

Answer Key (continued)

3. Almost three times as fast
4. 27,000 ft; 430 miles/hour; 1 hr 45 minutes
5. 30 - 40 minutes; No, new planes will replace existing.
6. LAX (Los Angeles International); Boeing 727
7. Approximately 30 miles
8. 1797.4 miles; 752.5 miles
9. There is severe weather ahead, including lightning.
10. Going around and flying at altitudes above the weather.
11. Vectors, to predict where planes will be so there are not too few or too many planes in one area. Weather, to forecast weather for maximum safety and efficiency.
12. See background information.

Activity 10. Sunspots: Space Weather Monitoring

Part A

Sample data for Table 10-1 (Accept a reasonable range of answers. Officially, at the equator, rotation is less than 27 days; two thirds of the way to the pole, rotation slows to about 30 days.)

Sunspot Number	Sunspot Latitude	Longitude March 11, 1989	Longitude March 12, 1989	Difference in Longitude (Distance Traveled in One Day)	360^0 Divided by Difference in Longitude (Number of Days for Sun's Rotation at each Sunspot)
5397	N 39°	E 28°	E 15°	13°	27.6
5398	S 11°	E 33°	E 18°	15°	24

Table 10-1. Answer Key

Answer Key (continued)

1. Group #5398
2. Approximately North 40°
3. No; Uneven rotation; Faster near the equator
4. Using sample data: Group #5397; East 2°; Group #5398; East 3°

Part B

Sample data for Table 10-2 (Accept a reasonable range of answers.)

Number of Sunspots	Local Sunspot Group Number	Type	Magnetic Class	Area	Extent	SESC Sunspot Group Number	Location
2	001	Bxo	B	20	10	5392	N 31° W 31°
7	003	Bxo	B	70	9	5394	S 27° E 04°
24	004	Fkc	B	2500	18	5395	N 40° E 00°
6	006	Cso	B	70	7	5397	N 39° E 15°
5	007	Dao	B	180	9	5398	S 10° E 17°
2	009	Axx	B	40	1	5400	N 18° E 43°
1	010	Axx	A	20	0	5401	S 14° W 04°
1	013	Axx	A	80	2	5403	S 13° E 80°
2	015	Bxx	B	20	1	1008	S 32° E 13°

Table 10-2. Answer Key

SAM

Answer Key (continued)

1. Group #5395
2. Bipolar
3. Approximately 2500 millionths (accept a reasonable range of answers)
4. Group #5395
5. Group #5395; North 39°; Fkc sunspot group (a long bipolar sunspot group with penumbra on both ends; large; asymmetric; compact); area of approximately 2200 millionths; extent at about 18°; bipolar; likely to be active

SAM Evaluation SAM

Dear Colleagues In Science and Teachers,

We want your feedback on the activities. Please duplicate this form and complete one evaluation for each activity or simply write your comments on a copy of the activity and send them in. Your comments are important to us and will be gratefully received. Please return your assessment to:

Barbara McGehan
NOAA/ERL/FSL
R/E/FS
325 Broadway
Boulder, CO 80303

Optional Teacher Name:______________________

School Name:______________________

Address:______________________

____

Phone: (____) ______________________

Activity Title:______________________

Circle your response to each statement or question according to the scale provided.

		Low				High
1.	Length of activity.	1	2	3	4	5

COMMENT:

2.	Students read background information with ease.	1	2	3	4	5

COMMENT:

3.	Students followed the procedure(s) with ease.	1	2	3	4	5

COMMENT:

Evaluation (continued)

		Low 1	2	3	4	High 5
4.	Students answered questions with ease.	1	2	3	4	5

COMMENT:

5.	Students could draw a conclusion to the problem(s) with ease.	1	2	3	4	5

COMMENT:

6.	Students seemed interested in the activity.	1	2	3	4	5

COMMENT:

7.	Students learned from the activity.	1	2	3	4	5

COMMENT:

8.	Probability that you will use the activity again.	1	2	3	4	5

COMMENT:

(Circle one)

9. Would you recommend this activity to a colleague? Yes No

COMMENT:

(Circle one)

10. Do you want to test future activities? Yes No

If you circle yes, then you must fill in your name, school, address, and phone at the beginning of this evaluation.

Evaluation (continued)

11. What did you like about this activity?

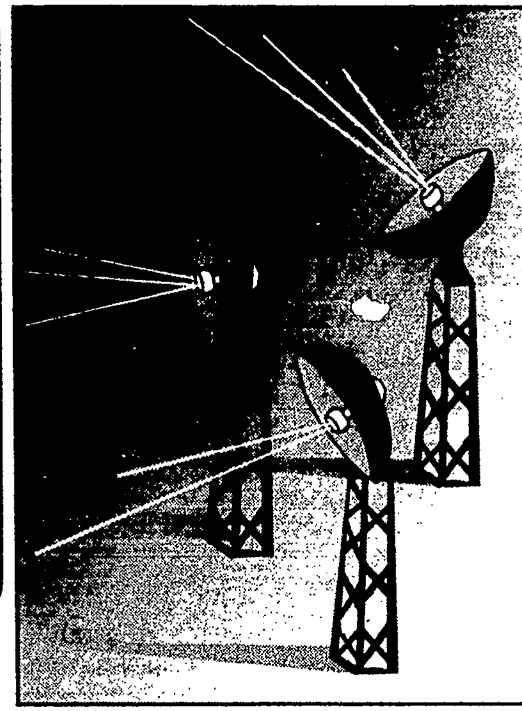
12. How would you improve this activity?

Other comments?

Tracking Severe Weather with Doppler Radar

Problem: How does Doppler weather radar help to locate storms and estimate storm intensity? How does Doppler weather radar measure wind speed and direction?

Materials: Rulers and colored pencils (recommended: purple, blue, green, yellow, brown, red)



Background Information:

Doppler radar is a valuable tool for weather forecasters, research scientists, and air traffic controllers. Doppler weather radar differs from conventional weather radar because it can detect not only where a storm is located, but also how fast air inside the storm is moving. National Weather Service Doppler radars transmit pulses of radio waves at a wavelength of approximately 10 cm (centimeters), about the same as those used to cook food in a microwave oven. Water droplets in the air reflect the pulses. Some of the radio energy returns to the Doppler radar, where it creates a picture of a storm and how it is moving.

More than 150 years ago, a young scientist named Christian Doppler explained this effect. Doppler was studying the motion of waves and predicted that the frequency of a wave (for example, the pitch of a note) would change depending on whether the source of the sound moved toward or away from you. To test the idea, an engineer blew the whistle on a railroad train while an observer standing by the side of the tracks listened to the whistle's pitch as the train approached, passed, and moved away. What Doppler predicted, and the observer confirmed, was that the frequency (pitch) of the source (the whistle) increased or rose as the train approached and decreased or fell as it moved away. More than 50 years later, Albert Einstein demonstrated that this phenomenon, called the Doppler Effect, was also true for electromagnetic waves.

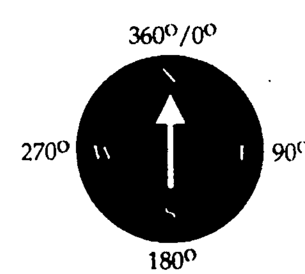
The antenna of a Doppler radar is called a "dish" because of its shape. The radar dish constantly moves (or scans) in a circle at angles between 1° and 20° above the horizon. While it scans, the radar sends out radio pulses and listens for the returned signal reflected from airborne particles.

The Doppler radar can detect small changes in the frequency of the returned signal as precipitation moves either toward or away from the radar. Droplets moving with the air are a good indicator of wind speed in a storm. When the air moves away from the radar, the frequency of the returned signal is lower than the transmitted signal, just as the pitch of a train whistle appears to fall as the train moves away from you. When the air moves toward the Doppler radar, the frequency of the returned signal is higher. Try to imagine how the frequency and wavelength of the reflected radar signal changes depending on how the storm in Figure 1-1 is moving. Police traffic radars work in the same way.

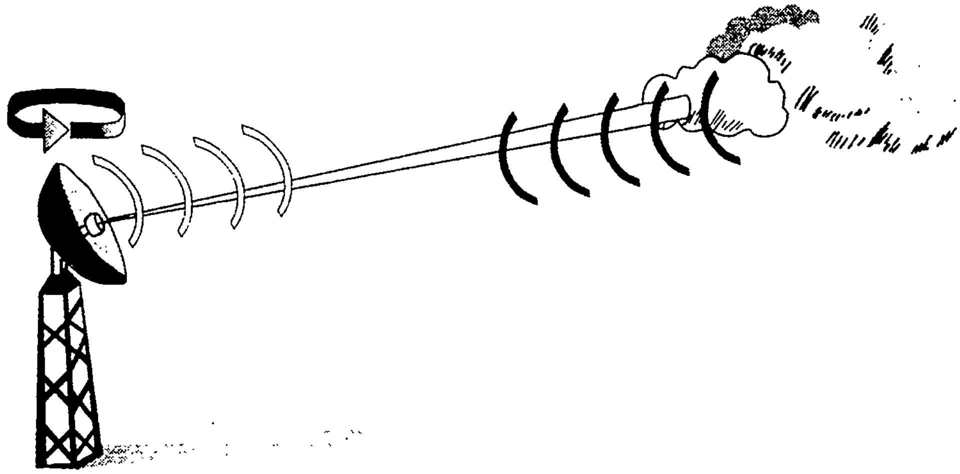
The location of a storm or cloud is detected by the strength or intensity of the radar signal reflected from the water in it. The higher the moisture content in a region of a storm or cloud, the greater its intensity, or reflectivity. Therefore Doppler radar not only shows the location of the storm, but it can also show where in the storm most of the moisture is located. For these reasons, Doppler radar is especially good at detecting severe weather such as hail storms or tornadoes. On the radar screen, hail appears as the most dense, rain is less dense, and snow is least dense. Airplanes and swarms of insects also reflect radar waves, but experienced forecasters can easily tell the difference.

The data for this activity were collected from the Mile High Doppler Radar site east of Stapleton International Airport in Denver, Colorado. The radar image shown in the worksheet was generated by analyzing the Doppler pitch of a winter storm that occurred on March 9, 1992, at 9:45 pm. The storm dropped large amounts of snow on Denver and the surrounding area. In the worksheet for this activity, you are looking at the motion of the snowflakes as recorded by the Doppler radar. This view is different from the view of storm intensity broadcast during daily television weather reports, because it can detect storm movement.

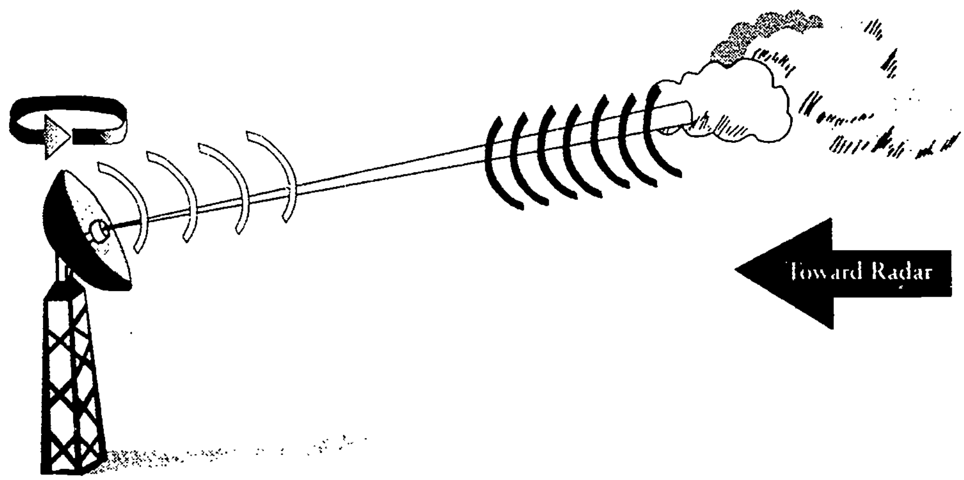
Meteorologists, as well as astronomers and other physical scientists, use the color blue or violet to indicate movement toward the radar and the color red to indicate movement away from the radar. The accompanying worksheet provides the pattern of Doppler velocities that covers a radius of approximately 20 km around the Mile High Doppler Radar site.



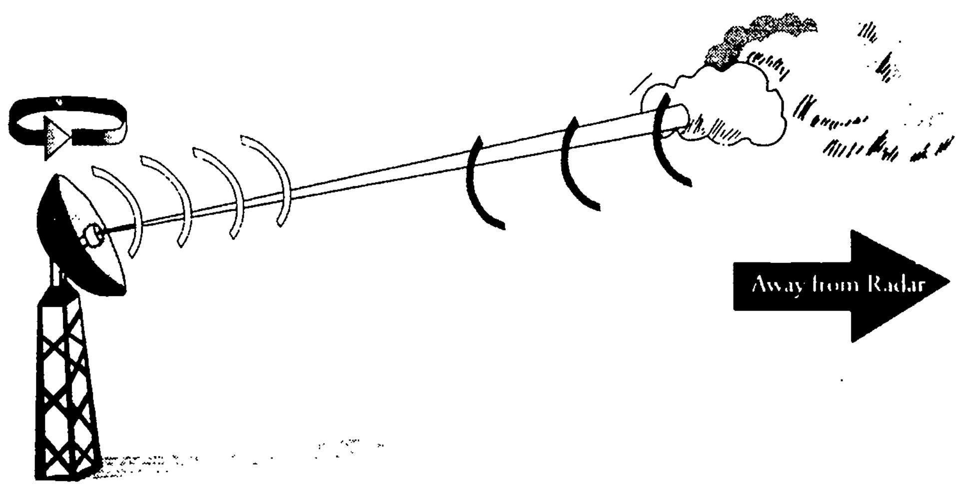
Azimuth and Cardinal Directions



Stationary Storm: transmitted wavelength = reflected wavelength
(frequency or pitch stays the same)



Storm Moving Toward Radar: transmitted wavelength > reflected wavelength
(frequency or pitch increases)



Storm Moving Away from Radar: transmitted wavelength < reflected wavelength
(frequency or pitch decreases)

Figure 1-1. Doppler Radar in Three Weather Situations

Procedure:

1. Color the scale at the bottom of the Mile High Doppler Radar Worksheet as follows:

   Section A = Dark purple or violet (**The greatest negative Doppler pitch indicates a storm moving towards the Radar.)**
   Section B = Light purple or violet
   Section C = Light blue
   Section D = Dark green
   Section E = Light green
   Section F = No color or white
   Section G = Yellow
   Section H = Brown or orange
   Section I = Light red
   Section J = Dark red **(The greatest positive Doppler pitch indicates a storm moving away from the Radar.)**

2. Note that there are letters assigned to each area of the radar image indicating the wind speed range in that area. Using these letters and your completed scale as a key, fill in the colors corresponding to the wind velocity in each area of the worksheet. For example, areas marked with an "A" should be colored dark purple or violet. Ignore the concentric circles and radius lines of the radar screen.. It is OK if your boundaries between colors blend together because that is how a real radar screen would look. The velocities of the winds do not suddenly change in one spot, but change over a distance.

3. Place an "X" on the Doppler transmitter station (Mile High Doppler Radar).

Doppler Radar Worksheet

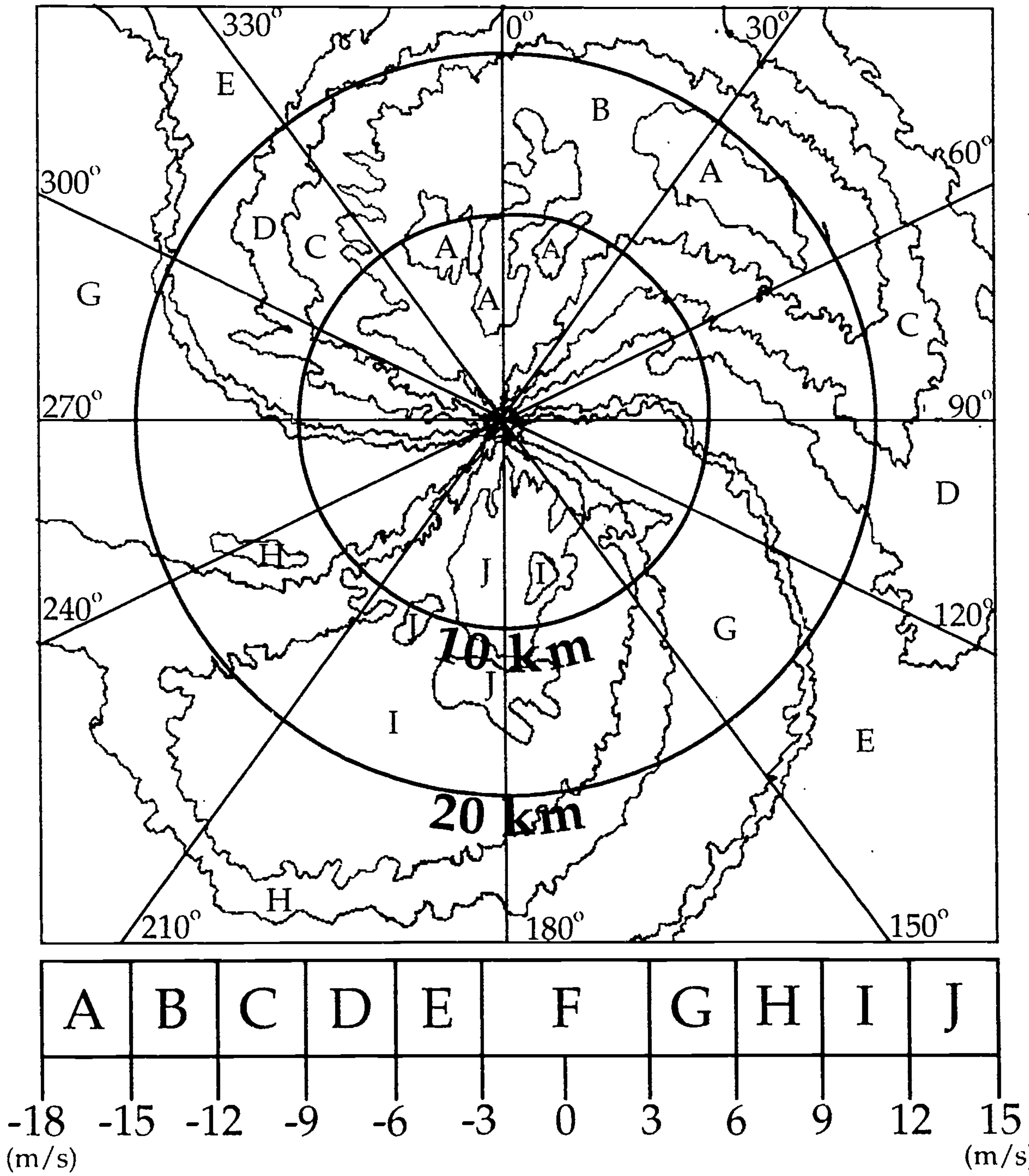


Figure 1-2. Doppler Radar Display of Wind Velocity in meters/second, observed at the Mile High Radar, Denver, CO, on March 9, 1992, 9:45 pm.

(Negative numbers indicate motion toward the radar, while positive numbers indicate motion away from the radar.)

Questions:

1. If the 0° azimuth on the radar screen is North, what direction is
   90°? _____ 180°? _____ 270°? ____

2. Place a ruler on the part of the zero velocity line that runs through the radar station. The wind blows perpendicular to this line. What direction is the wind coming from? ________

3. What two colors represent the fastest air velocities, and what are their speeds in meters per second?

4. Change the wind velocity from 9 m/s to m.p.h. Use the unit analysis technique set up below.

$$\_\_\_\_ \ \frac{\mathbf{m}}{\mathbf{s}} \times \frac{\mathbf{1\ km}}{\mathbf{1000\ m}} \times \frac{\mathbf{0.6\ mi}}{\mathbf{1\ km}} \times \frac{\mathbf{60\ s}}{\mathbf{1\ min}} \times \frac{\mathbf{60\ min}}{\mathbf{1\ hr}} = \_\_\_\_ \ \frac{\mathbf{mi}}{\mathbf{hr}}$$

5. What is the diameter of the outer ring of the radar screen in miles? _____
   (Hint: Range rings measure distance **from the radar**. Therefore, the diameter of the outer range ring is 40 km or two times the 20 km radius.) Show your work here.

   Does the storm cover this entire area?

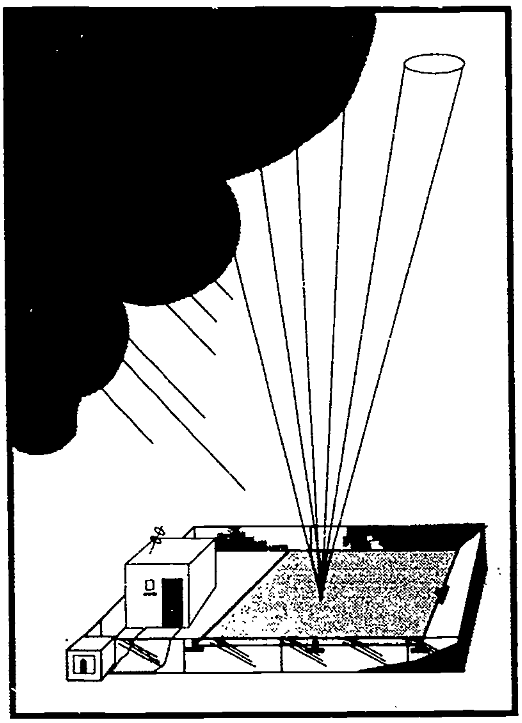
Conclusions:

Review the problem stated on the first page (screen) and write your conclusions here.

Wind Profiler: Doppler Radar in a Vertical Direction

Problem: How is a wind profiler plot used in weather forecasting to identify wind speed, wind direction, the jet stream, and weather fronts?

Materials: Rulers and colored pencils (recommended: yellow, red, blue, green, violet)



Background Information:

What clothes should I wear today? Should I walk, bike, or get a ride to school or work? Will it rain or snow, or will the sun shine? The answers to these questions, asked by young and old, depend on current and future weather conditions.

Weather also affects aviation, agriculture, fishing, shipping, and recreation. Forecasters believe that information on upper air wind speed and direction are the most important data to have when they are preparing a forecast. For example, the ability to predict wind shear and precipitation is a key element in preventing aviation disasters.

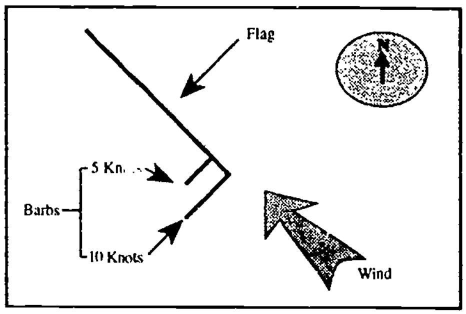
The wind profiler is a Doppler radar which measures upper level winds. It operates in nearly all weather conditions. The National Oceanic and Atmospheric Administration (NOAA) has installed a network of 32 wind profilers mostly in the central United States where much of the dangerous weather occurs. Data on wind speed and direction are gathered by each profiler every six minutes vertically up to about 50,000 feet (15 km). These data are processed and given to forecasters every hour as hourly averages.

The weather balloon, which for many decades has been used to track wind, typically gathers information only once every 12 hours. The wind profiler, with its hourly averages, provides forecasters with more accurate wind information much more frequently than the weather balloon, and may in fact replace them.

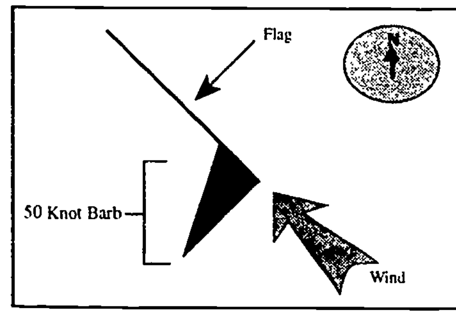
Profiler data are recorded on a graph called a wind profiler plot. The wind profiler plot shows how winds change with time above a specific location on the Earth's surface.

Wind profiler plots indicate wind speed in knots and wind direction at different heights and pressures in the atmosphere. Profiler plots indicate wind speed in knots where 1 mile per hour is equivalent to 0.8684 knots. Notice that profiler plots use UTC (Coordinated Universal Time) - also called Greenwich Mean Time (GMT) as the time increment.

The wind profiler plot is a computer printout with flags and barbs that indicate wind direction and speed. A flag is simply a line (\ ). This flag can have long and short lines called barbs. These are used to indicate the wind speed and direction for each flag. Each long barb indicates a recorded wind speed of 10 knots and each short barb indicates 5 knots.



Using this notation, the flag shown here represents a wind speed of 15 knots.



A symbol shaped like a triangle attached to the flag represents 50 knots, so the flag shown in this figure indicates a recorded wind speed of 50 knots.

Wind is always identified by the direction from which it blows. The end of the flag attached to the barbs points to the direction the wind comes from. In these diagrams, the wind is blowing from the southeast, where north is at the top of the paper.

A wind profiler plot is a series of wind barbs stacked one on top another to indicate wind speed and direction at increasing altitudes. There is a stack for each hour and there are usually 12 hours on each plot.

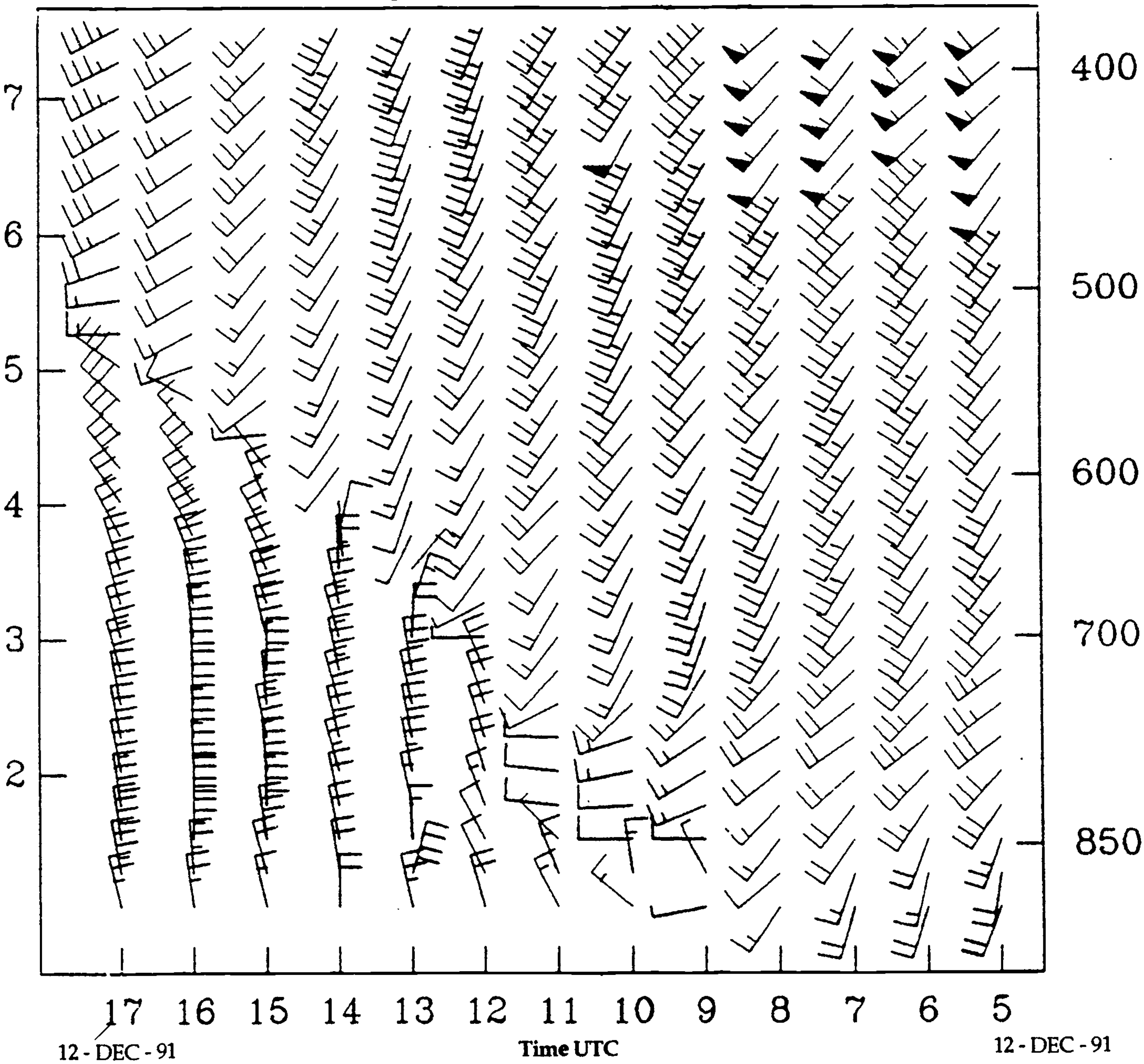
In the following procedure, you will use profiler plots to develop a general body of information about the winds at the profiler site over time. The profiler plots included in this activity are actual data used by meteorologists and researchers at the National Oceanic and Atmospheric Administration (NOAA) Forecast Systems Laboratory, in Boulder, Colorado.

Part A:

Procedure:

1. On the Neligh, Nebraska Profiler Plot worksheet, circle the wind barb that represents the maximum (highest) wind speed. Print the label "max" on the circled wind barb. Refer to Figure 2-2 at the end of this activity for the location of Neligh, Nebraska.

Neligh, Nebraska Profiler Plot Worksheet



2. A weather front is a zone of weather change over a relatively short distance. Wind usually changes across a front. When the wind changes direction, or speed, or both, the weather is changing. Knowing this information helps forecasters predict weather.

   On the worksheet above, beginning at hour 5 and ending with hour 17, draw a heavy dark line along the path where the wind abruptly changes speed and direction. This is the location of a front. Label this line "front."

Sometimes the wind barbs overlap. Do not try to look at each wind barb individually but look for wind direction patterns that can be grouped together.

3. A line connecting points of equal wind speed is called an *isotach*. In this part of the procedure you will draw isotachs on the Neligh Profiler Plot worksheet.

   On the previous page's worksheet, draw a curved isotach that encloses all wind barbs at or below 20 knots in velocity. Color the area limited by this line violet. Next, draw the isotachs that contain all barbs at and between 25 and 45 knots in velocity. Color this area blue. Repeat this process for the isotachs enclosing all barbs at or between 50 and 75 knots in velocity, and color this area green. Finally, complete the plot by repeating the process for the isotachs containing barbs in the 80 to 100 knot velocity range. Color this area yellow.

Questions:

1. What is the highest wind speed?

2. What is the wind speed and wind direction at the lowest height at 8 hours (0800 UTC)?

3. As the front passes from 5 to 17 hours (1700 UTC), what change in wind direction is likely at ground level?

   In wind speed?

4. What effect might the passing of the front have on surface temperature?

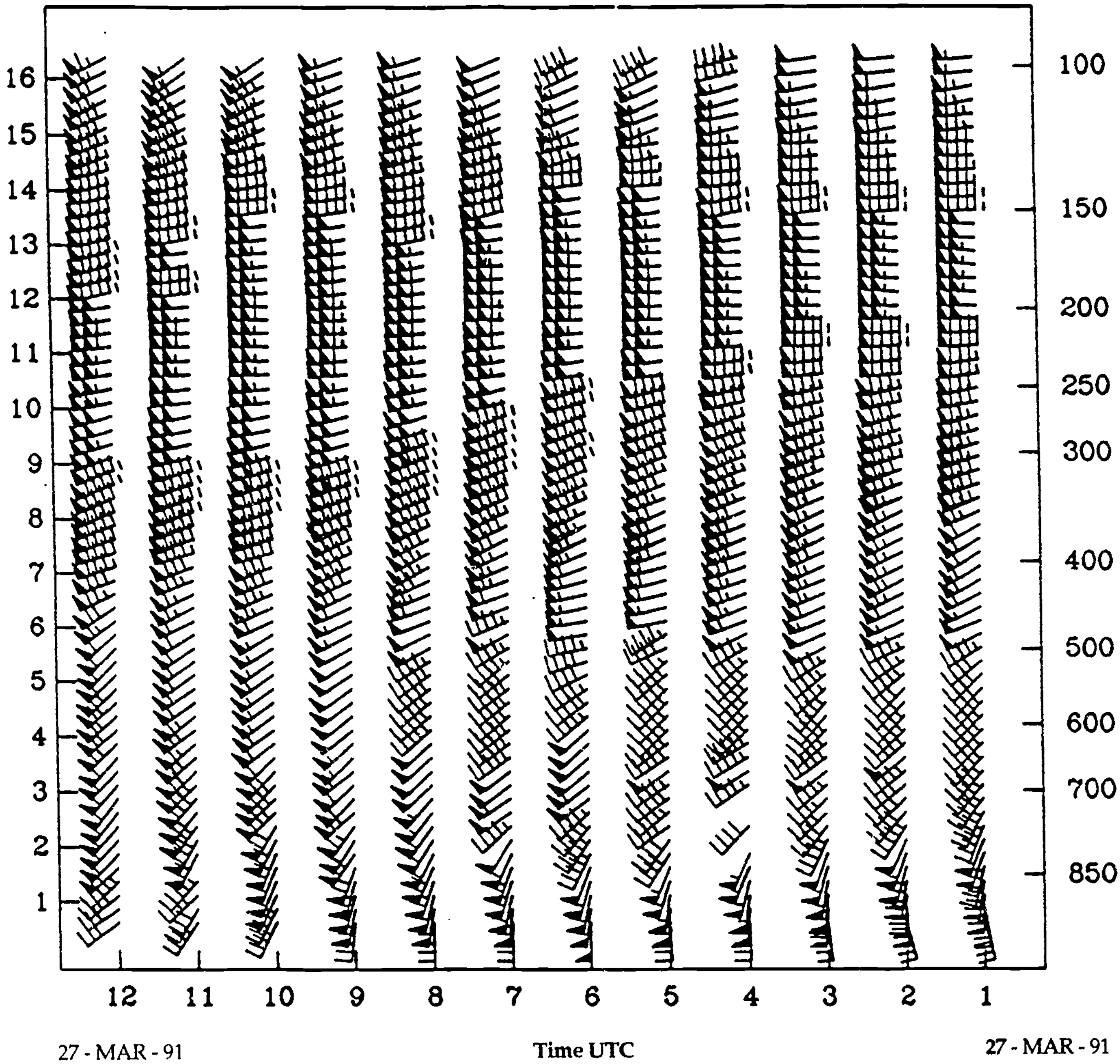
Part B

Procedure:

1. On the Palestine, Texas Profiler Plot worksheet, circle the wind barb(s) that represent the maximum (highest) wind speed. Print the label "max" on each circled wind barb. Refer to Figure 2-2 at the end of this activity for the location of Palestine, TX.

2. In this step of the procedure you will draw the isotachs and color each velocity range as in Procedure A. When drawing your isotachs, be sure to include the extreme values of each wind velocity range presented in this part of the activity. After you draw the isotachs for a given velocity range, color the area limited by the isotachs with the color assigned to that velocity range.

Palestine, Texas Profiler Plot Worksheet



Velocity Range (knots)	Color
5 - 20	violet
25 - 45	blue
50 - 75	green
80 - 100	yellow
> 100	red

Questions:

1. At what height in kilometers does the maximum wind speed occur?

2. The jet stream is a high-speed ribbon of air that meanders through the Earth's upper atmosphere. On the Palestine, Texas Profiler Plot, the jet stream is located between the two 100 knot isotachs.

   What is the range for the height of the jet stream? (Hint: Subtract the lowest height from the highest height between the two isotachs.)

3. What is happening to the height of the jet stream as time passes from 1 to 12 hours UTC?

4. What effect might this height change have on local weather at ground level?

Conclusions:

Review the problem stated on the first page (screen) and write your conclusions here.

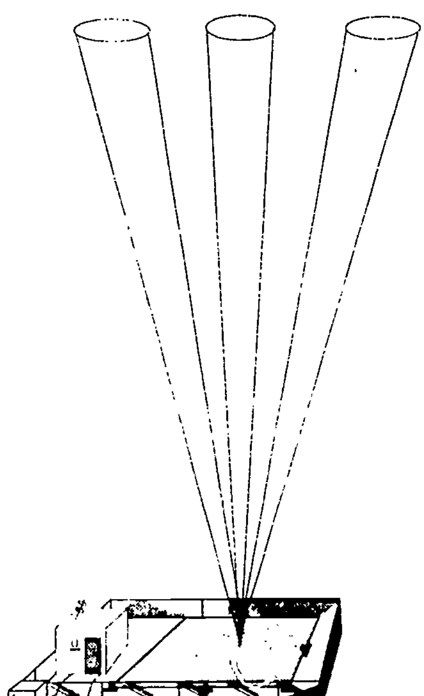


Figure 2-1. Wind Profiler Site

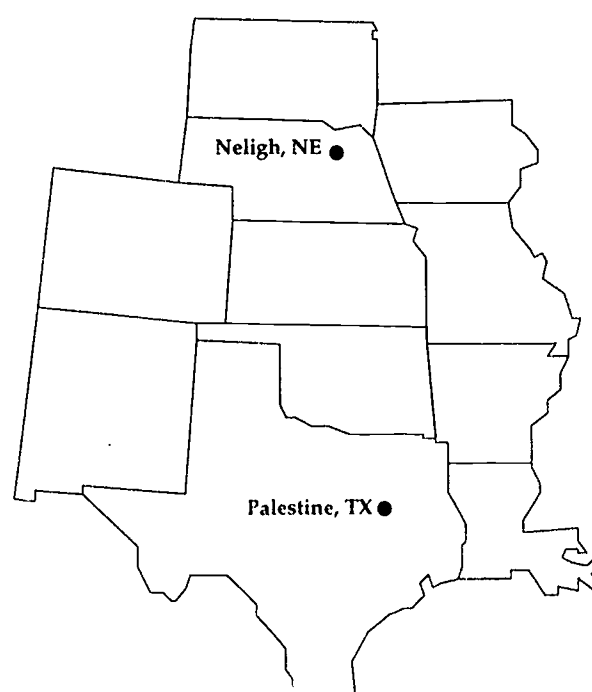


Figure 2-2. Profiler Site Map - Neligh, NE and Palestine, TX

Looking At Severe Weather: Lightning And Tornadoes

Problem: What is the relationship between the month of the year and fatalities caused by lightning and tornadoes?

Materials: Ruler, two colored pencils

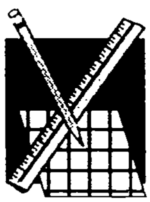
Background Information:

In July 1990, an 18-year-old male was struck and injured by lightning while attending a concert at an amphitheater 14 miles south of Birmingham, Alabama. While chatting with a friend near a mulberry tree, a 35-year-old woman was knocked to the ground by lightning in San Manuel, Arizona. She had first and second degree burns, coins in her pockets were partially melted, and rivets on her jeans also were melted. A 17-year-old girl was shocked and burned while talking on the telephone when lightning struck near the back of her house in Canton, Illinois. When lightning struck a tree north of Kokomo, Indiana, it killed one person and injured four people who were seated in metal lawn chairs under the tree. Lightning is a sudden electrical discharge that is formed in a way similar to the spark that flashes when you touch an object after walking across a carpet. In lightning, electrons flow between the oppositely charged parts of a cumulus cloud or between the cloud and the ground. As a thunderstorm passes overhead, the ground below becomes positively charged compared to the bottom of the cloud that is negatively charged. Since opposite charges attract one another, the stage is set for the huge outdoor spark that we call lightning.

During 1990 there were 1132 tornadoes in 181 days, which killed 53 people and injured 11. A tornado is the wildly spinning column of air, called a vortex, that extends downward from a cumulonimbus cloud and moves along the ground. Low air pressure within the vortex causes air near the Earth's surface to rush into the vortex carrying dust and debris. Winds that can reach well over 200 miles per hour circulate counterclockwise around the center of the tornado. Known as the most powerful storms in the world, tornadoes can destroy almost anything in their paths.

Although most people realize that both lightning and tornadoes are spawned by thunderstorms, few people realize that lightning causes more deaths than tornadoes. One explanation for this misconception comes from our method of reporting tragedies. Lightning deaths tend to occur singly with little property damage and, therefore, are deemed less news worthy. On the other hand, multiple deaths and extensive property damage from a tornado frequently make headline news. Furthermore, lightning deaths often occur in weak thunderstorms when people remain outside, not during severe thunderstorms when people take shelter.

In the procedure for this activity we will look at deaths caused by lightning and tornadoes to see if there is a relationship.



Procedure:

1. Complete the plots provided on page 3, by generating *bar* graphs that plot the number of deaths caused by lightning and tornadoes in each month for a given year. Use one color bar for lightning deaths and a different color bar for tornadoes. Use the statistics presented in Table 3-1 for the data points. Note that time in months is on the horizontal axis, and number of deaths is on the vertical axis. Label these axes on your graph. Before you start plotting data points, be sure to complete the scale on the vertical axis, numbering by fives. Write a title for the series of graphs.

Data

National Deaths By Year For 1988-1990

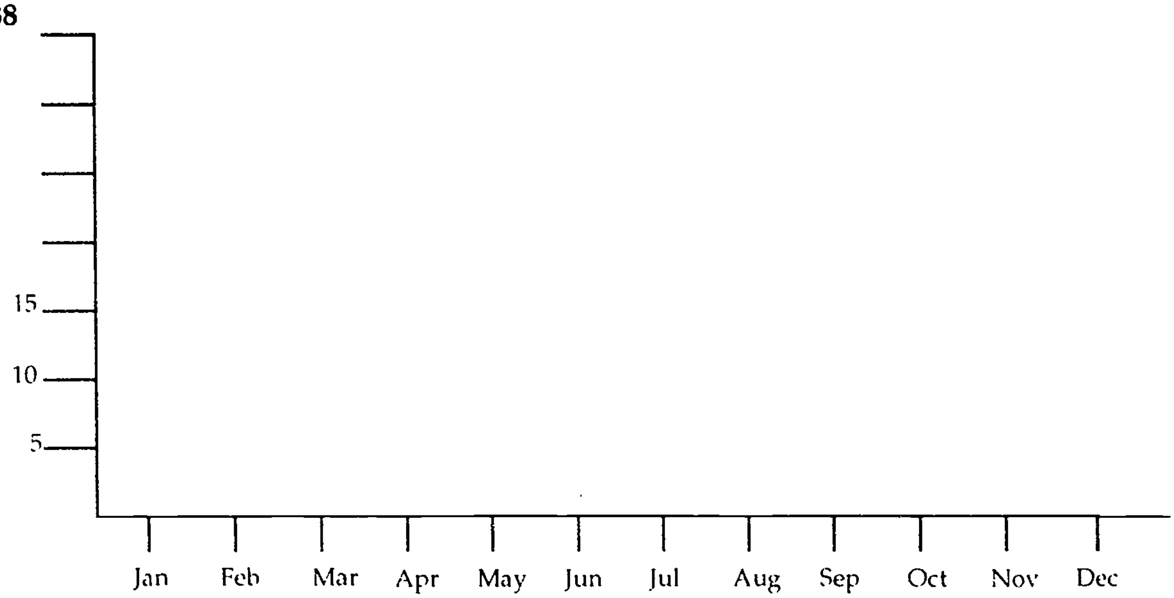
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1988												
Tornadoes	5	0	1	4	3	0	0	3	1	0	14	1
Lightning	0	0	0	3	9	17	21	14	2	1	2	0
1989												
Tornadoes	0	0	1	0	9	5	0	0	0	4	31	0
Lightning	0	0	1	1	9	14	19	18	4	1	0	0
1990												
Tornadoes	0	1	3	0	7	11	0	29	0	2	0	2
Lightning	1	0	3	1	3	18	22	15	10	0	0	1

Table 3-1.

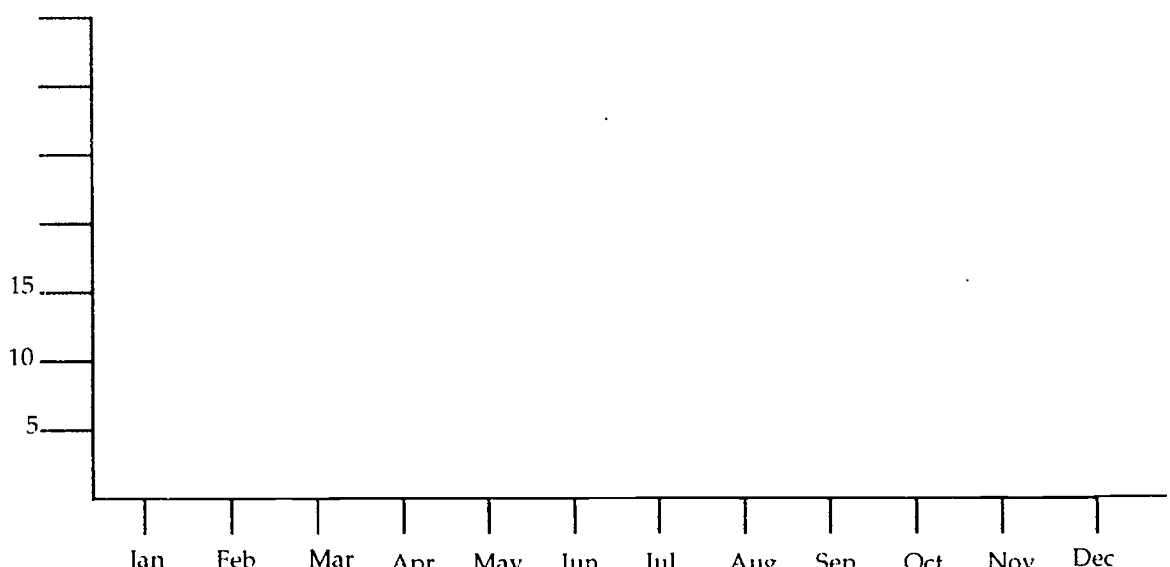
The tornado season for the U.S. never really ends. In general, tornadoes for the entire U.S. peak between April and June. In July, the polar jet stream moves north, and with it, the tornado season will peak in North Dakota and in southern Canada. Tornado numbers will decline, then peak again in the southeastern U.S. during November.

Title: ____

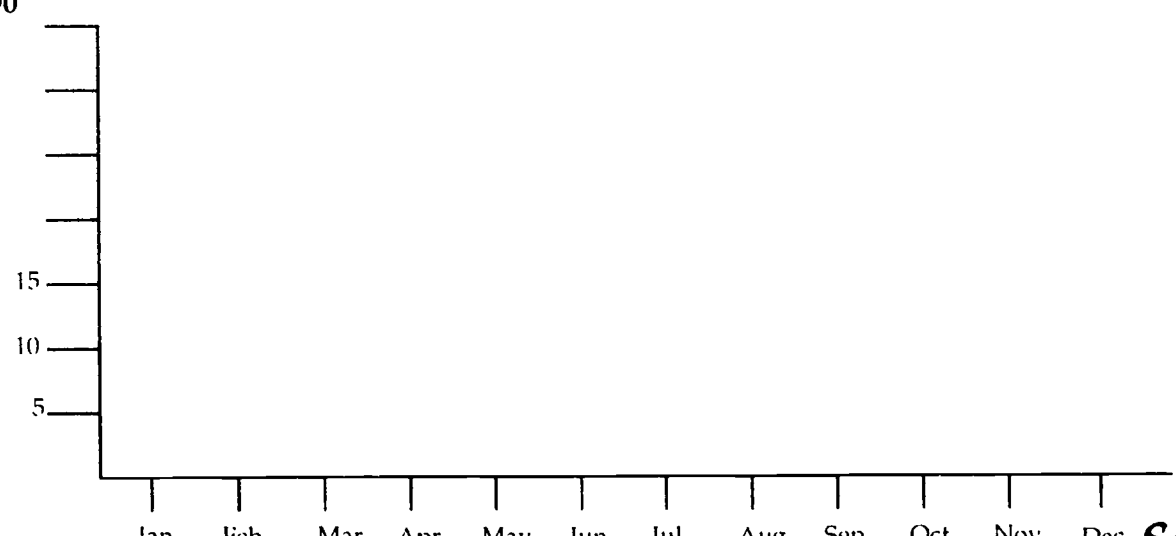
1988



1989



1990



Questions:

1. During what month do most deaths caused by lightning occur?

2. What season has the highest number of deaths caused by lightning?

   Why does this make sense?

3. Approximately 3011 people died from lightning strikes from 1959 to 1990: 27% died in open fields and ball parks, 17% were under trees, 13% were boating or involved in water related activities, 6% were near tractors or heavy road equipment, 4% were on golf courses, 1% were on telephones, and 31% were in other locations. How many people were killed in open fields or ball parks? Show your work here.

4. Lightning is approximately one mile away for each five seconds it takes the sound to travel that distance. If you hear thunder 35 seconds after you see the lightning, how far away is the lightning? Show your work here.

5. Based on your experience and the information in this activity, make a set of lightning safety rules that apply to you in a specific situation. For example, list all of the precautions that you would take to protect yourself and others if you were on a ball field which is not close to home, or if you were baby-sitting for several children, or if you needed to use the telephone for an emergency. Write a title above your list of safety rules.

6. Are tornado deaths and lightning deaths related?

   Why or why not?

7. Most U.S. tornadoes occur between April and June. According to the data presented in this activity, during what month do most deaths caused by tornadoes occur?

   Explain.

Conclusions:

Review the problem stated on the first page (screen) and write your conclusions here.

Safety Information:

Tornado Safety:

- If a tornado WARNING has been issued, this means that a tornado has been spotted or is about to strike (tornadoes can happen so rapidly you may not get a warning). SEEK SHELTER IMMEDIATELY. Go to the basement, the lowest floor if there is no basement, or an interior hallway on the lowest floor in the center of the building.

- Stay away from windows.

- Get under something sturdy (work benches, pool tables, and staircases are good examples), and protect your head.

- On the street or in a car: LEAVE YOUR CAR. If there is no large building nearby, then lie flat in a ditch or low-lying area. (Be alert for flash floods.)

- It is a good idea to have a battery-operated radio or television to listen for warnings issued by the National Weather Service.

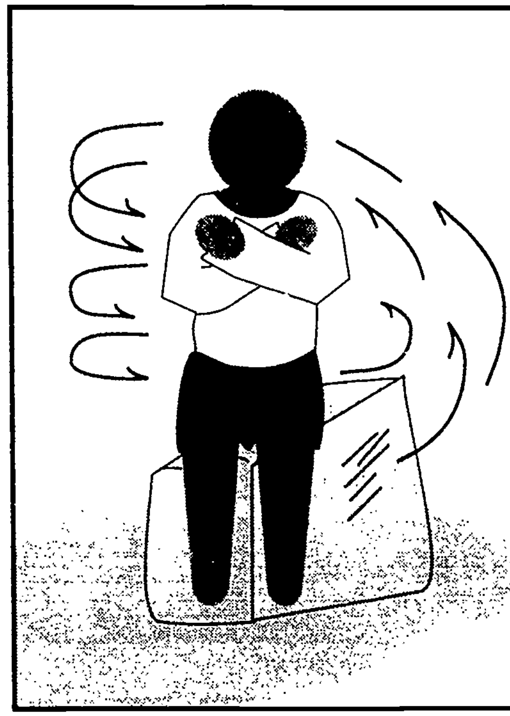
Lightning Safety:

- GET INSIDE OR STAY INSIDE! Stay inside homes, buildings, and automobiles. Automobiles can be lightning shelters because the current in the lightning stroke passes through the metal of the car and into the ground. Avoid touching any metal parts inside the car.
- Don't use the telephone (lightning can travel down phone wires), or any plug-in electrical equipment like hair dryers, televisions, or computers.
- Get out of and away from open water (don't take a bath or shower).
- Don't stand underneath natural lightning rods such as large trees or isolated sheds in open fields.
- Get away from tractors and other metal equipment such as fences, golf clubs and bicycles.
- Stay off exposed rocks and ridges on hills and mountains.
- When you feel an electrical charge — if your hair stands on end or your skin tingles — lightning may be about to strike you. Crouch low to the ground, with your head down, IMMEDIATELY!

Wind Chill

Problem: How is the wind chill temperature table made and how is it used?

Materials: Ruler and pencil



Background Information:

The temperature of the air in winter is not always a reliable indicator of how cold you will feel outdoors. Wind speed, relative humidity, and sunshine also have an effect. What you are wearing, how healthy you are, and your metabolism all affect how cold you feel. "Coldness" is related to the loss of heat from exposed flesh. Hypothermia, a life-threatening condition caused by the lowering of a person's core body temperature, can be prevented by understanding the chilling effect of wind.

In 1939, Paul Siple coined the term "wind chill" to describe the relative discomfort caused by a combination of wind and temperature, but his index did not work for temperatures above freezing or for high wind speeds. In 1941, Siple and Charles Passel developed a new formula to determine wind chill from experiments made at Little America, Antarctica.

Experiments could not be conducted on human skin without permanent injury, so Siple and Passel measured how long it took to freeze 250 grams of water in a plastic cylinder during different combinations of wind and temperature. They assumed that the rate of heat loss was proportional to the difference in temperature between the cylinder and the temperature of the surrounding air. They plotted results in kilogram calories per square meter per hour (kg cal/m^2/h) against wind speed in meters per second to create a nomogram. A nomogram is a graph that has several lines arranged so an unknown value can be read from the intersection of one of these lines and a known value. From the Wind Chill Index Nomogram, scientists create a wind chill table.

The wind chill index or equivalent temperature is based on a neutral skin temperature of 33° C, or 91.4° F. It represents how cold the air feels to the skin, not how cold it is! Furthermore, the wind chill effect applies only to human flesh, not houses, cars, or clothing. The index does not take into account all possible heat losses of the body. With physical exertion, body heat production rises, perspiration begins, and evaporation removes heat from the body. A body can lose heat by contact with cold surfaces and by breathing cold air, which removes heat from the lungs.

The next time you want to know how cold it is outdoors, check the thermometer. But keep in mind that other things, such as wind speed, body fat, individual metabolism, and protective clothing, all help to determine how "chilly" you feel.

In the procedure for this activity, you will use the Wind Chill Index Nomogram to find the temperatures needed to complete a wind chill table. The line at 4 mph on the nomogram approximates the wind speed generated by someone walking briskly under calm conditions. **This is the standard wind speed chosen for calculating wind chill equivalent temperatures.** Wind Chill refers to the temperature which, at a four mph wind speed, cools the skin at the same rate as the observed (ambient) temperature and wind speed.

Procedure:

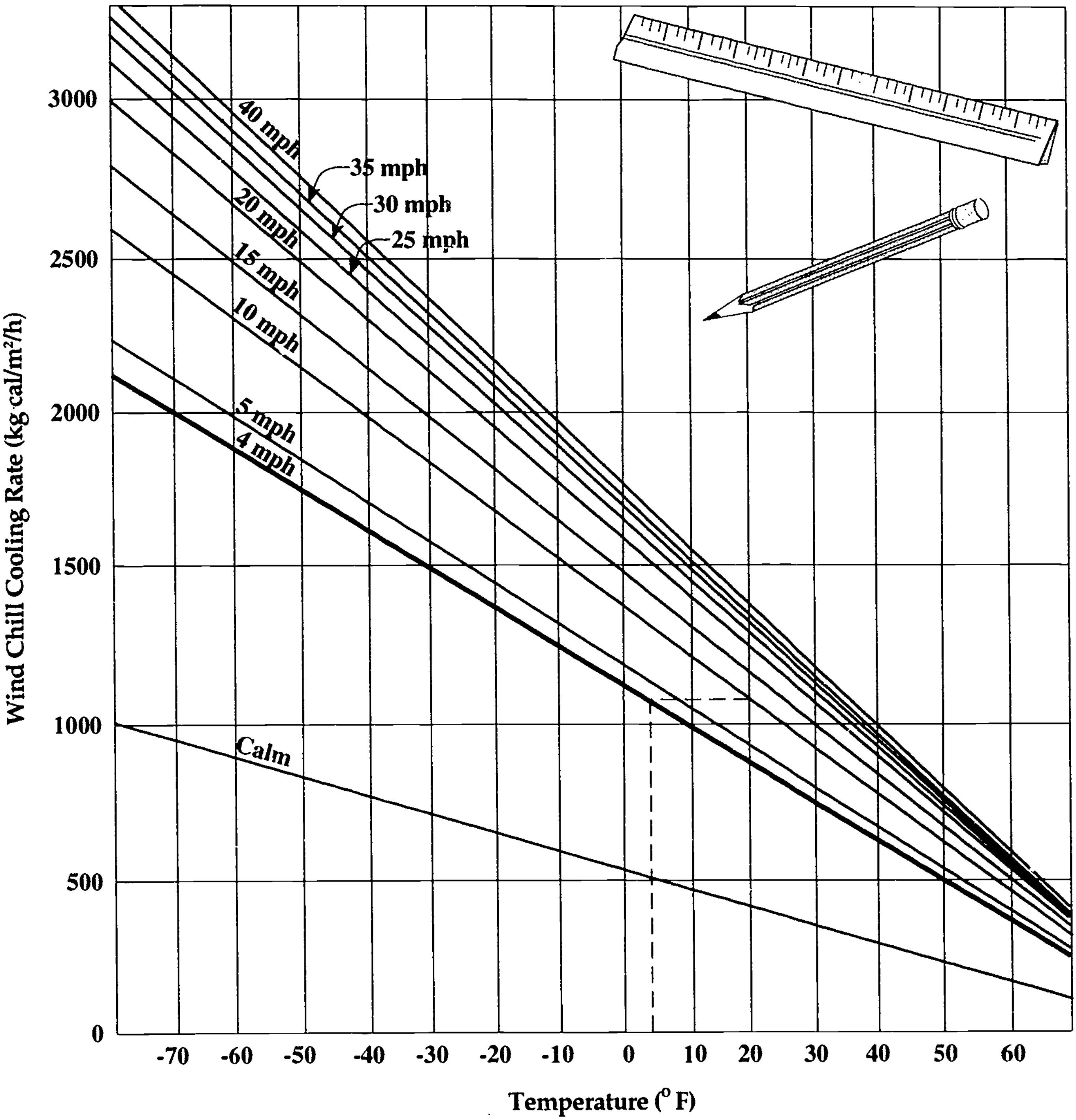
Assume that the air temperature is 20° F, and the wind speed is ten mph. You are walking to school. What temperature would you actually feel? To answer this question perform the following steps.

1. On the Wind Chill Index Nomogram, locate 20° F on the X (horizontal) axis. Follow the vertical line that starts at 20° F up until it intersects the ten mph wind speed line.

2. Draw a dashed horizontal line from this intersection over to the four mph wind speed line and stop. From the point where you stopped, draw a dashed vertical line down to the horizontal axis. Read the temperature where your line intersects the X axis. This is the wind chill equivalent temperature. If you read 3° F, then you followed the procedure correctly.

3. The Wind Chill Table on page 4 of this activity indicates the wind chill equivalent temperatures for different combinations of wind speed and air temperature. Notice there are four blank values in the table. Using the same process outlined in steps one and two above, determine the missing values in the wind chill table using the wind speed and air temperature pair for each blank.

Wind Chill Index Nomogram



Note: [illegible]

Wind Chill Table
Indicates the Wind Chill Index
(equivalent in cooling power on exposed flesh)

Cold — Very Cold — Bitter Cold — Extreme Cold

Wind Speed (miles per hour) \ Air Temperature °F	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
4	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	32	27	22	16	11	6	0	-5	-10	-15	-21	-26	-31	-36	-42	-47	-52
10	22	16	10	3	-3	-9		-22	-27	-34	-40	-46	-52	-58	-64	-71	-77
15	16	9	2	-5	-11	-18	-25	-31	-38	-45	-51	-58	-65	-72	-78	-85	-92
20	12	4	-3	-10	-17	-24	-31	-39	-46	-53		-67	-74	-81	-88	-95	-103
25	8	1	-7		-22	-29	-36	-44	-51	-59	-66	-74	-81	-88	-96	-103	-110
30	6	-2	-10	-18	-25	-33	-41	-49	-56	-64	-71	-79	-86	-93	-101	-109	-116
35	4	-4	-12	-20	-27	-35	-43	-52	-58	-67	-74	-82	-89	-97	-105	-113	-120
40	3		-13	-21	-29	-37	-45	-53	-60	-69	-76	-84	-92	-100	-107	-115	-123
*45	2	-6	-14	-22	-30	-38	-46	-54	-62	-70	-78	-85	-93	-102	-109	-117	-125

* Wind speeds greater than 40 mph have little additional cooling effect.

Example: A 30 mph wind, combined with a temperature of 30° F (-1° C), can have the same chilling effect as a temperature of -2° F (-19° C) when it is calm.

Questions:

1. What factors, other than temperature, determine how "chilly" you feel?

2. Using the Wind Chill Table, find the wind chill equivalent temperature for the following wind speeds and temperatures.

   a. On a cold winter day on your way to school or work: The air temperature is 10° F and the wind speed is 15 mph.

   b. While skiing with friends: The air temperature is -5° F and the wind speed is 20 mph, while you are standing still, waiting to start down the slope.

   c. Riding your bike downhill on a cool, calm autumn morning: The air temperature is 35° F and your bike speed is 25 mph.

3. Although the wind you feel in Question 2c is due to your bike's motion, you will still feel the effect of wind chill. What will it feel like?

4. Read "Safety Information" about hypothermia. What precautions should you take to prevent hypothermia?

5. Although frostbite and hypothermia are not directly related, you should know what frostbite is and how to prevent it. Read "Safety Information" about frostbite. What precautions should you take to prevent frostbite?

Conclusions:

Review the problem stated on the first page (screen) and write your conclusions here.

Safety Information

Hypothermia

It is important to be aware of hypothermia's symptoms when spending time outdoors. Hypothermia is the rapid, progressive, mental and physical collapse that occurs as the inner core of the human body becomes chilled. The internal body temperature slides downward. This slide can lead to stupor, collapse, and death. Most hypothermia occurs when the air temperature is between 30° F and 50° F. Because most people consider these temperatures to be normal, the effects of hypothermia catch them off guard. **Hypothermia can occur in warm weather!** Furthermore, hypothermia occurs even more rapidly when the person is in water. Often, drowning victims succumb to hypothermia before drowning. Whether in air or water, victims of hypothermia frequently do not realize what is happening. Everyone must be aware of hypothermia and help each other.

These are symptoms of hypothermia:

- **shivering;**
- **vague, slow, slurred speech;**

- **memory lapses;**
- **fumbling hands;**
- **stumbling, lurching walk;**
- **drowsiness;**
- **inability to get going after a short rest.**

To avoid hypothermia, follow these guidelines.

- Dress appropriately. Wear a hat. Major heat loss occurs through the scalp.
- Stay dry. Wet clothes lose their insulating value and water robs heat faster than air at the same temperature.
- Beware of the wind. A slight breeze carries heat away from the skin faster than motionless air.
- Never ignore shivering. Seek help.

Even mild symptoms should be treated immediately.

- Get out of the wind, rain, snow, sleet, or hail.
- Remove wet clothes.
- Bundle up in blankets, coats, sleeping bags, or other available covers.
- Drink warm nonalcoholic beverages.
- Stay awake.

Frostbite

If the skin becomes cold enough, it can freeze. Freezing usually occurs on exposed skin such as fingertips, nose, ears, and cheeks. Toes of climbers are often frostbitten, due to the lack of sufficient blood flow to keep them warm.

- To avoid frostbite, stay indoors during cold windy weather.
- If you must be outside, cover all exposed skin and keep your circulation going in your extremities.
- If injured skin changes color, get medical help.

FYI

For Your Information

The nomogram is based on a general formula for heat loss. Heat loss occurs by means of radiation, conduction, and convection. Combining all effects, the general formula for heat loss (H) is,

$$H = (A + Bv^{1/2} + C_V) T \quad \text{[Note that } v^{1/2} = \text{square root of v],}$$

where H is the heat loss in kg cal/m^2/h, v is the wind speed in m/s, and T is the difference in °C between 33° C (neutral skin temperature) and air temperature. The constants A, B, and C are 10.45, 10.00, and -1.00, respectively.

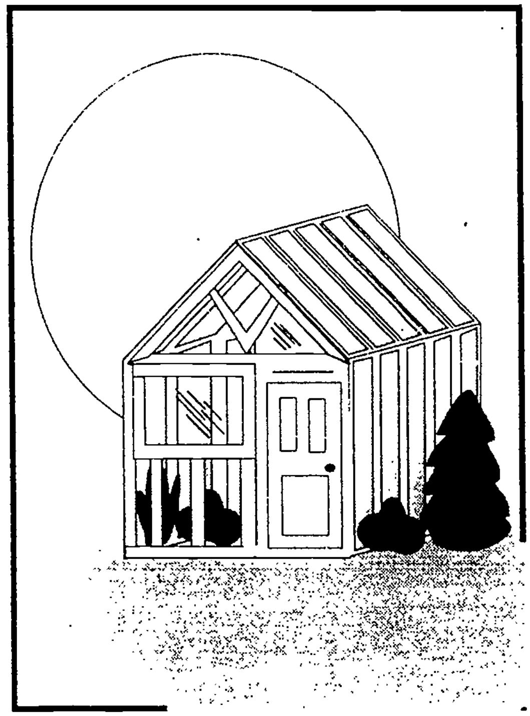
The values of A, B, and C vary widely in formulas presented by different investigators. This is to be expected since heat loss (H), depends on certain properties of the body being cooled. This formula measures the cooling power of the wind and temperature in complete shade and does not consider the gain of heat from incoming radiation, either direct or diffuse. Under conditions of bright sunshine, the heat loss should be reduced by about 200 kg cal/m^2/h.

SAM 6

Greenhouse Effect: Too Much, Too Little, or Just Right?

Problem: What is the seasonal variation in the amount of atmospheric carbon dioxide at two different locations on Earth's surface? What is the annual increase in the amount of global atmospheric carbon dioxide and methane?

Materials: Ruler, colored pencils



Background Information:

Venus and Earth are about the same size and so close that they are frequently called the "twin planets" of our solar system. Yet, Venus is so hot that lead will melt on its surface! A runaway greenhouse effect makes Venus this hot. The greenhouse effect occurs when the atmosphere of a planet acts much like the glass in a greenhouse. Like the greenhouse glass, the atmosphere allows visible solar energy to pass through, but it also prevents some energy from radiating back out into space. The greenhouse effect insures that the surface of a planet is much warmer than interplanetary space because the atmosphere traps heat in the same way a greenhouse traps heat. Certain gases, called greenhouse gases tend to reflect radiant energy from the Earth back to the Earth's surface, improving the atmosphere's ability to trap heat. All greenhouse gases are trace gases existing in small amounts in our atmosphere. Greenhouse gases include carbon dioxide, methane, nitrous oxide, some chlorofluorocarbons, and water vapor.

We know that the greenhouse effect is necessary for survival. Without it, the Earth would be cold, so cold that life as we know it could not exist. However, scientists still have questions that must be answered. What kinds and amounts of greenhouse gases are necessary for survival? Are the amounts of greenhouse gases increasing, decreasing, or remaining the same? To answer these questions, scientists monitor the amounts of greenhouse gases in the Earth's atmosphere.

The atmospheric gas most responsible for the warming effect on both Venus and Earth is carbon dioxide (CO_2). On both planets, a primary source of CO_2 is volcanic eruptions. The difference between these two planets is that on Venus, 97% of the atmosphere is CO_2, whereas on Earth, much less than one percent of the atmosphere is CO_2. Why is there so much less CO_2 on Earth? The carbon cycle holds the answer.

In the natural cycle of carbon, plants take in CO_2 and give off oxygen, whereas animals take in oxygen and emit CO_2. Further, CO_2 dissolved in seawater is used by plants during photosynthesis and by other seawater organisms such as clams and coral to produce calcium carbonate ($CaCO_3$) shells. These processes help control the amount of CO_2 in our atmosphere.

Human beings complicate the natural carbon cycle because they increase the amount of CO_2 in Earth's atmosphere by burning fossil fuels. Driving automobiles, heating buildings, and producing consumer goods---all add to the concentration of CO_2 in Earth's atmosphere.

Methane (CH_4) is another greenhouse gas. It is produced in swamps, bogs, and rice paddies, as well as in the intestinal tracts of most animals, including cattle, sheep, and humans. Coal, oil, and gas exploration also contribute to the accumulation of methane in the atmosphere. However, methane concentrations are much less than CO_2 concentrations.

Nitrous oxide, (N_2O) or "laughing gas," is another greenhouse gas accumulating in the atmosphere, although not as fast as CH_4. Fertilizer decomposition, industrial processes that use nitric acid, and small amounts from automobile emissions all contribute to increasing atmospheric N_2O.

In the procedure for this activity, you will plot curves for the CO_2 (ppm) and CH_4 (ppb) concentrations found in the atmosphere over a period of time. In much the same way a scientist would monitor concentrations of gases in the atmosphere, you will look for changes and trends, as well as maximum and minimum concentrations during that same time period. Data in the tables were provided by the National Oceanic and Atmospheric Administration (NOAA), Climate Monitoring and Diagnostics Laboratory.

Note:
[illegible]

Part A

Procedure:

1. Using Table 5-1, plot the points corresponding to the monthly mean CO_2 concentration at Point Barrow, Alaska. Use a colored pencil to connect the points.

2. Using Table 5-2, plot the points corresponding to the monthly mean CO_2 concentration at South Pole, Antarctica. Use a different colored pencil to connect the points.

3. Print a title at the top of your graph.

4. Place a color-coded legend on your graph in the space provided.

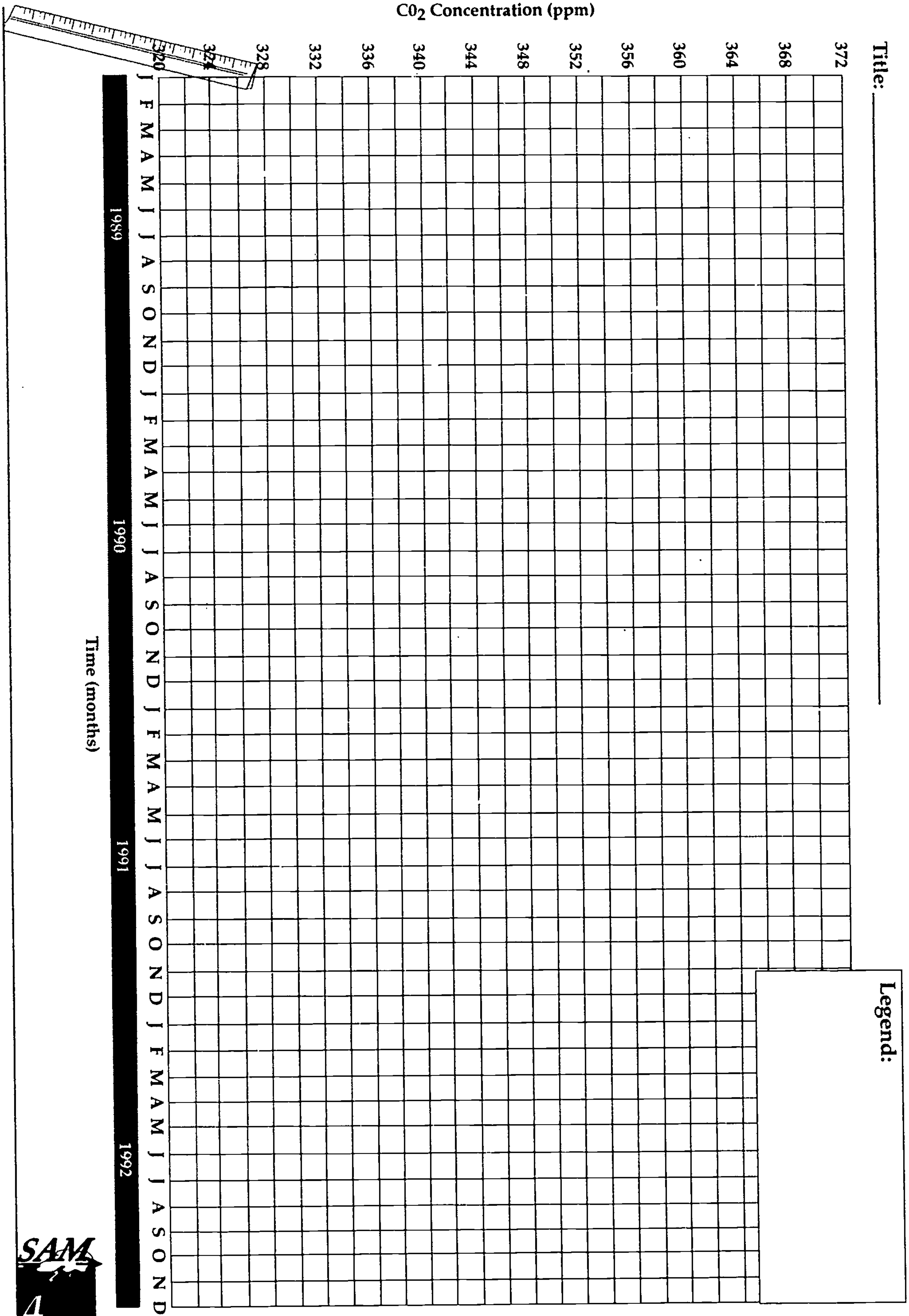
Data:

Month	1989	1990	1991	1992
Jan	360.88	359.81	360.82	361.62
Feb	358.16	359.85	362.09	362.21
Mar	359.15	361.24	361.16	362.48
Apr	359.27	361.04	361.73	362.55
May	358.74	360.48	361.52	362.77
Jun	357.04	356.77	359.80	360.42
Jul	349.34	349.49	353.69	353.58
Aug	344.48	345.74	347.44	347.09
Sep	346.18	346.37	348.28	347.69
Oct	351.19	353.87	356.21	353.66
Nov	355.81	356.63	358.34	357.24
Dec	358.29	359.21	360.87	361.05

Table 5-1. Monthly Mean CO_2 Concentration (ppm), Point Barrow, Alaska

Month	1989	1990	1991	1992
Jan	349.62	350.76	351.97	353.05
Feb	349.68	350.57	351.66	352.80
Mar	349.60	350.64	351.50	352.68
Apr	349.68	350.91	351.77	352.90
May	349.92	351.25	352.03	353.25
Jun	350.22	351.58	352.38	353.65
Jul	350.58	352.06	352.81	354.09
Aug	351.00	352.40	353.22	354.47
Sept	351.08	352.70	353.37	354.66
Oct	351.24	352.74	353.32	354.67
Nov	351.29	352.74	353.46	354.49
Dec	350.87	352.30	353.33	354.22

Table 5-2. Monthly Mean CO_2 Concentration (ppm), South Pole, Antarctica


CO_2 Concentration (ppm)
320 324 328 332 336 340 344 348 352 356 360 364 368 372
Title:
Legend:
Time (months)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1989
1990
1991
1992

Questions:

1. During what season is the monthly mean CO_2 concentration greatest in Point Barrow, Alaska?

2. If you were in the Southern Hemisphere, during what season would the monthly mean CO_2 concentration be greatest in South Pole, Antarctica?

3. Why do CO_2 concentrations vary less at the South Pole location than at Point Barrow?

4. Why do scientists collect CO_2 data at such remote, isolated locations such as Alaska and Antarctica?

Part B

Procedure

1. Using Table 10-3 on the following page, plot data points for the globally averaged annual mean concentration of CO_2. Connect the points with a colored pencil.

2. Using Table 10-3, plot data points for the globally averaged annual mean concentration of CH_4. Connect the points with a different colored pencil.

3. Calculate the rate of change for global annual mean concentration of CO_2. Subtract the lowest concentration from the highest concentration shown on your graph. Then subtract the oldest year from the most recent year on the graph. Divide the concentration from your first subtraction by the number of years elapsed, the result of your second subtraction. Your result is the change in concentration per year. Enter your result in the box next to the graph.

4. Repeat this procedure to find the rate of change for CH_4.

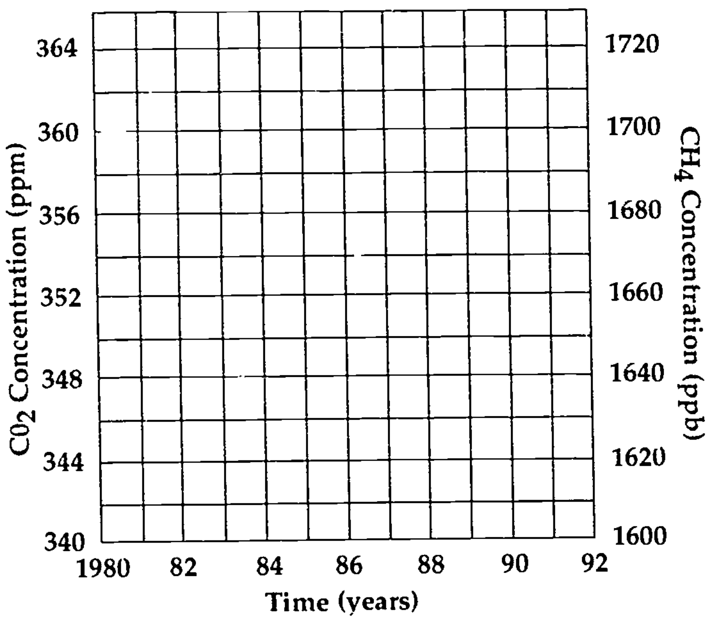
5. Print a title in the space provided above the graph.

6. Draw a color-coded legend for your graph in the space provided.

Year	CO_2 (ppm)	CH_4 (ppb)	Year	CO_2 (ppm)	CH_4 (ppb)
1981	339.86	-	1987	348.50	1662.79
1982	340.62	-	1988	350.96	1673.05
1983	342.13	1614.30	1989	352.57	1684.28
1984	343.83	1625.04	1990	353.69	1693.75
1985	345.36	1637.62	1991	355.00	1703.49
1986	346.63	1650.89	1992	355.59	1714.1

Table 10-3. Globally Averaged Annual Mean CO_2 Concentration (ppm) and CH_4 Concentration (ppb)

Title: ______________________



CO_2 Rate of Change:

CH_4 Rate of Change:

Legend:

Questions:

1. What happened to the CO_2 and CH_4 concentrations between 1983 and 1991?

2. Does CO_2 or CH_4 show the greatest rate of change relative to each other?

3. Do these data alone support the idea of global warming? Explain.

Conclusion:

Review the problem stated on the first page (screen) and write your conclusions here.

Volcanoes: Ozone Depletion and Atmospheric Cooling

Problem: How are aerosols dispersed through the atmosphere after a volcanic eruption?

Materials: Ruler, pencil, and colored pencils

Background Information:

Volcanic eruptions can increase the risk of skin cancer, even when the erupting volcano is a hemisphere away. Beside this personal risk, there is a larger, global risk. Volcanic eruptions may *cool* the Earth. This is a dramatic twist that would complicate efforts to conclusively determine whether or not greenhouse gases contribute to global warming. A close look at the June 1991 eruption of Mt. Pinatubo, in the Philippines, may help to explain this seemingly remote connection between health, the environment, and volcanoes.

When Mt. Pinatubo erupted in the early summer of 1991, it sent clouds of smoke, ash, sulfur dioxide, and water into the atmosphere. Most of the heavier ash settled to the Earth within the first several weeks. By mid-August, however, satellite measurements showed that a band of sulfuric acid droplets in the stratosphere had spread around the Earth in a path on both sides of the equator. Sulfuric acid is formed when sulfur dioxide, a gas, combines with water. In this case, the tiny sulfuric acid droplets are called aerosols. Aerosol particles that travel around the Earth in the stratosphere are less likely to fall to the Earth and, therefore, remain aloft for a longer period of time than particles in the troposphere.

Note [illegible]

The larger aerosol particles will settle out of the atmosphere within about three years. The smallest particles could remain suspended for decades. Some computer models of atmospheric chemistry suggest that a huge increase in sulfuric acid aerosols could thin the protective ozone layer, allowing harmful ultraviolet (UV) radiation to reach the Earth's surface. This increase in surface UV could increase health risks, including skin cancer. In addition to thinning the protective ozone layer, atmospheric aerosols may affect the Earth's temperature. Since more light from the sun is reflected *back into space* by the increased amount of aerosol particles in the stratosphere, the Earth's lower atmosphere is likely to cool. This cooling effect will complicate efforts to determine whether or not there is a net global warming due to the greenhouse effect.

Atmospheric scientists are studying the effects of Mt. Pinatubo's eruption using *lidar*, a type of radar that uses pulses of laser light instead of pulses of radio waves. The short pulse of light bounces off particles, molecules, and even insects in the atmosphere. Some of the scattered light returns to its source. Measuring the amount of time it takes for the scattered laser light to return allows us to calculate the distance to the object (in this case, aerosols). The light that returns to the source is called "backscatter." The amount of backscatter indicates the amount of sulfuric acid aerosols in the atmosphere.

Procedure:

1. Number the horizontal axis, from zero to 3600, by 100s.
2. Number the vertical axis, from zero to 30, by ones.
3. Using the data provided, plot the data points corresponding to the units of backscatter for each time period. Connect the points with a smooth line. Use a different colored pencil for each time period.
4. Draw a horizontal dashed line across the graph at 10 kilometers. Label the area beneath the line "Troposphere." Draw a horizontal dashed line across the graph at 11 kilometers. Label the area beneath the line "Tropopause." Label the upper part of the graph, "Stratosphere."
5. Print a title at the top of the graph.
6. Place a color coded legend on your graph in the space provided.

Data:

These data tables are a shortened version of the data collected at the National Oceanic and Atmospheric Administration (NOAA), Wave Propagation Laboratory, Boulder, Colorado.

January - June 1991

Altitude (km)	Backscatter
4.0	2970
5.5	893
7.0	170
8.5	95
10.0	225
11.5	119
13.0 and above	*

*For this period, since the amount of backscatter at 13 km and above is too small to measure, it can be plotted as zero.

August 1991

Altitude (km)	Backscatter
4.0	18900
5.5	3100
7.0	333
8.5	130
10.0	97
11.5	101
13.0	272
14.5	636
16.0	971
17.5	482
19.0	217
20.5	340
22.0	116
23.5	38

October 1991

Altitude (km)	Backscatter
4.0	10900
5.5	505
7.0	129
8.5	120
10.0	176
11.5	339
13.0	506
14.5	864
16.0	1020
17.5	975
19.0	901
20.5	830
22.0	416
23.5	150

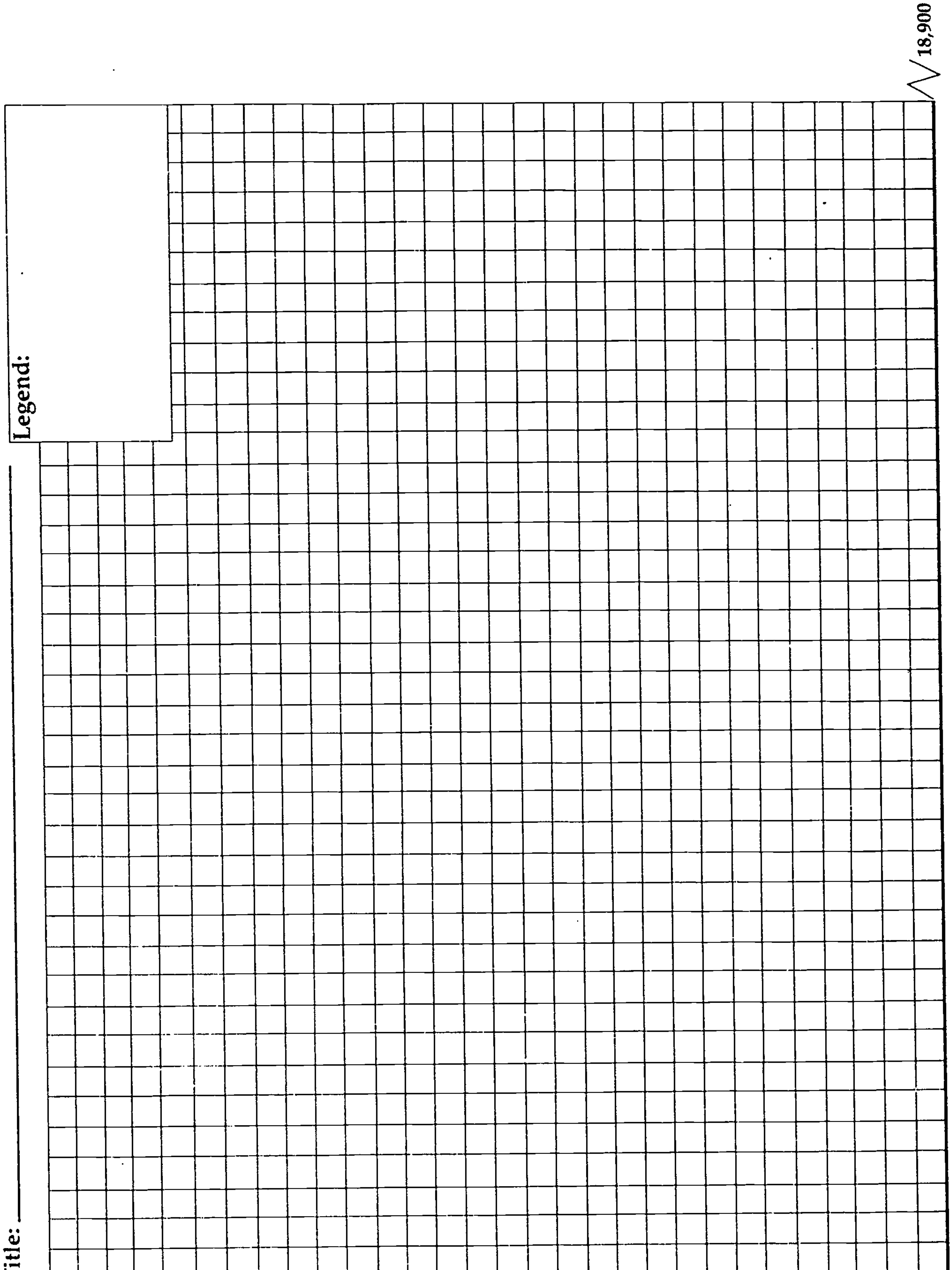
January 1992

Altitude (km)	Backscatter
4.0	201
5.5	44
7.0	34
8.5	42
10.0	63
11.5	250
13.0	425
14.5	485
16.0	682
17.5	1140
19.0	1790
20.5	1340
22.0	215
23.5	151
25.0	88
26.5	57
28.0	43

March 1992

Altitude (km)	Backscatter
4.0	9650
5.5	3580
7.0	1100
8.5	426
10.0	412
11.5	845
13.0	972
14.5	999
16.0	1180
17.5	1420
19.0	1660
20.5	1230
22.0	395
23.5	136
25.0	35
26.5	16
28.0	11

Table 6-1. Backscatter Data


18,900
Legend:
Title:
Backscatter Units
Altitude (km)

Questions:

1. What gas combines with water from a volcanic eruption to form sulfuric acid aerosols?____________________

2. At what altitude above the troposphere, is the most backscatter from aerosols located? ____________________

3. What layer of Earth's atmosphere above 10 kilometers has the most aerosol backscatter? ____________________

4. From January 1991 to August 1991 what happened to the amount of backscatter above an altitude of 10 kilometers?

   Why?

5. What is the maximum (highest) amount of backscatter in the stratosphere for August 1991? ____________________

   For January 1992? _____

6. In what layer of the Earth's atmosphere, above the troposphere, is the largest amount of backscatter located for January 1992 and March 1992?

   ____

7. Between August 1991 and January 1992, what change in altitude, above the troposphere, occurred for the maximum amount of backscatter?

8. Why is the change in altitude significant for the maximum amount of backscatter between August 1991 and January 1992?

9. Why does the maximum amount of backscatter occur in January 1992, when the eruption of Mt. Pinatubo occurred in June 1991, <u>six months earlier</u>? (Hint: Think of our location on the globe compared to Mt. Pinatubo.)

Conclusions:

Review the problem stated on the first page (screen) and write your conclusions here.

FYI

For Your Information:

The original backscatter data have been multiplied by 10^{12} to make the numbers easier to manipulate. The actual unit of backscatter is called the backscatter cross section (m^{-1} sr^{-1} x 10^{-9}) where "sr" is a solid angle called a steradian. To simplify this term, we call it a backscatter unit.

Figure 6-1 gives you information on the various levels and layers in the atmosphere.

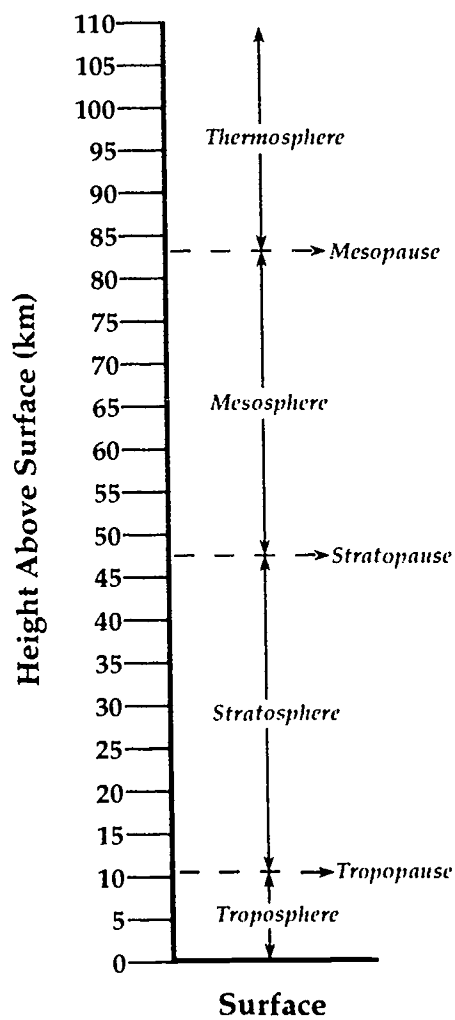


Figure 6-1. Names and Heights of the Different Atmospheric Layers (heights are representative values)

SAM 6

Using Statistics To Analyze Climate Data

Problem: What are the mean, median, and mode temperatures for the warmest and coldest months in Denver, Colorado?

Materials: Ruler, two colored pencils, and calculator

Background Information:

The National Oceanic and Atmospheric Administration (NOAA) collects large amounts of data to examine the local climate and weather of almost every city in the nation.

Climate is the sum of all statistical weather information that helps describe a place or region over a specified period of time (usually decades). Many years of data are required to indicate a trend in the climate. Even when there appears to be a trend, scientists can disagree about the meaning and causes of the trend. Travelers may need to know what kind of weather and temperatures to expect in a region along their route. Meteorologists can use statistics to give expected averages for travelers, but each day's weather can vary considerably. During the weather report of the local news you can expect to hear statistics about the local temperature.

Range is the difference between the maximum and minimum temperatures. *Mean* is the average temperature; the sum of all temperatures divided by the number of observations made. *Median* is the middle number in the range of temperatures arranged in order from the highest to the lowest. *Mode* is the temperature that occurs most often.

Procedure:

1. Complete the temperature scale on the vertical axis of your plot, numbering by 5's. On the horizontal axis, number each day of the month from 1 to 31. In the first part of this exercise, you will be plotting four curves on the SAME graph, two for July, and two for January. Use one color for the July curves, starting at Day 1, and use a different colored pencil to draw the January curves, also starting at Day 1.

2. The daily maximum and minimum temperature range includes all temperatures at and between the lowest and highest values observed for each day. Using the Temperature Summary data table (Table 7-1), calculate the temperature range, then plot the observed daily temperature *range* for each day in July. Connect the points to make a line graph. Repeat the process for each day in January, using a different colored pencil. All data used in this procedure were collected for NOAA by the National Weather Service at Stapleton International Airport in Denver, Colorado.

3. For each day in July, plot the maximum and minimum temperatures for the day. Then connect the maximum and minimum temperature for the same day with a straight vertical line on your graph. Repeat this process for each day in January, using a different color.

4. For each day in July, find the average daily temperature and mark it with an "x" on the vertical line for that day. (Hint: you can read this temperature from the data table.) When you finish, place a title on your graph.

Data:

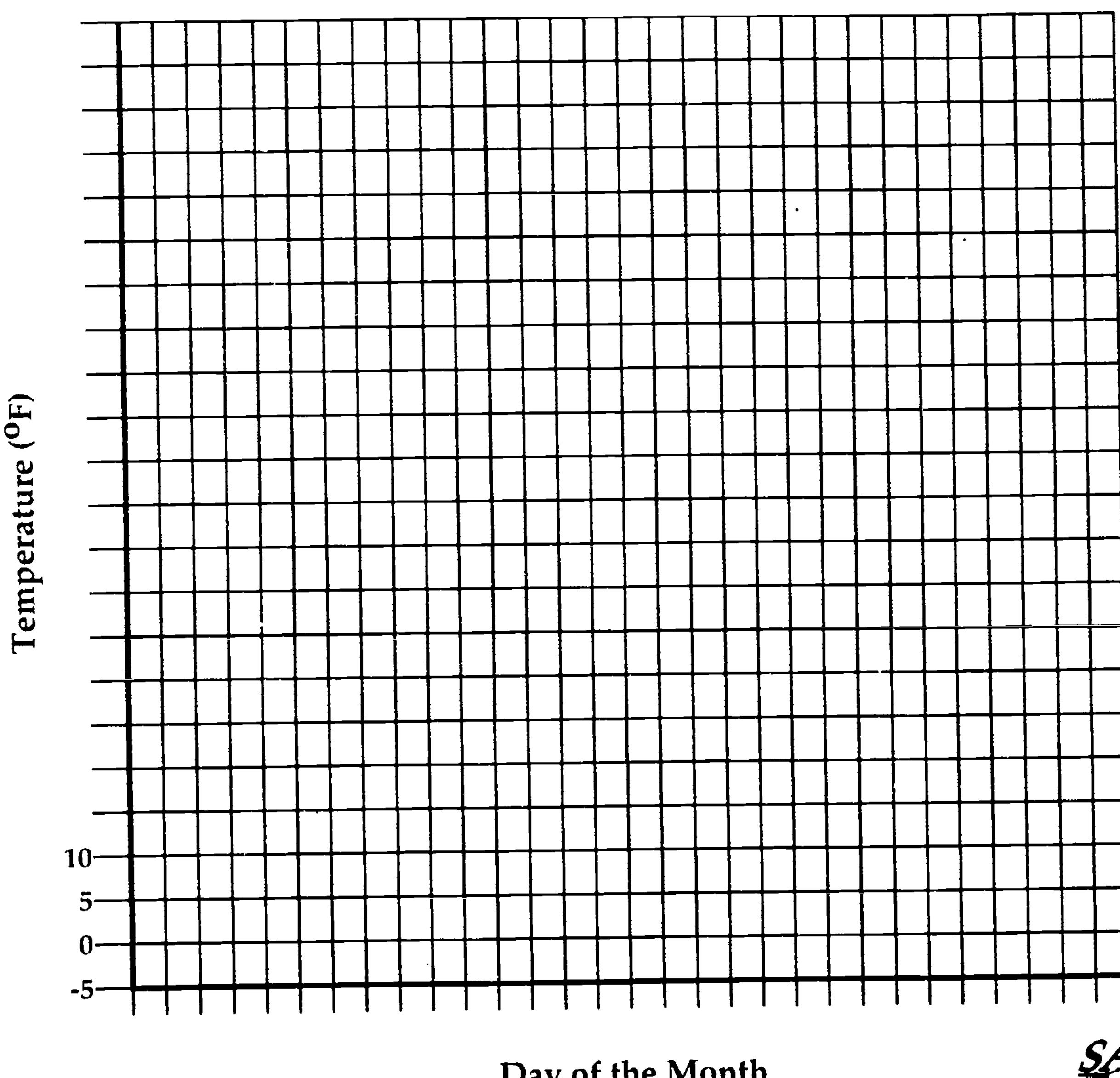
	JULY 1991				JANUARY 1992			
DAY	MAX	MIN	AVE	DEPARTURE FROM NORMAL	MAX	MIN	AVE	DEPARTURE FROM NORMAL
01	91	57	74	-3	41	17	29	-1
02	93	65	79	2	53	20	37	7
03	95	65	80	3	48	28	38	8
04	96	61	79	1	39	19	29	-1
05	100	61	81	3	46	19	33	4
06	101	66	84	6	47	22	35	6
07	98	70	84	6	35	18	27	-2
08	86	65	76	-2	33	14	24	-5
09	88	61	75	-4	35	7	21	-8
10	84	61	73	-6	50	9	30	1
11	88	56	72	-7	50	26	38	9
12	94	61	78	-1	32	17	25	-4
13	93	67	80	1	39	7	23	-6
14	98	67	83	4	39	10	25	-4
15	95	67	81	2	30	-5	13	-16
16	99	66	83	4	52	20	36	7
17	96	68	82	3	36	15	26	-3
18	93	65	79	-1	34	6	20	-9
19	89	66	78	-2	48	16	32	3
20	75	60	68	-12	49	19	34	5

Table 7-1. Temperature Summary for July 1991 and January 1992
***All temperatures are in degrees Fahrenheit.**

	JULY 1991				JANUARY 1992			
DAY	MAX	MIN	AVE	DEPARTURE FROM NORMAL	MAX	MIN	AVE	DEPARTURE FROM NORMAL
21	86	56	71	-9	54	15	35	6
22	94	58	76	-4	42	16	29	0
23	91	63	77	-3	44	25	35	5
24	91	64	78	-2	55	32	44	14
25	89	56	73	-7	45	24	35	5
26	87	60	74	-5	46	22	34	4
27	91	57	74	-5	45	21	33	3
28	96	62	79	0	59	30	45	15
29	95	62	79	0	50	25	38	8
30	96	68	82	3	54	27	41	10
31	96	65	81	2	66	32	49	18

Table 7-1 (continued). Temperature Summary for July 1991 and January 1992
*All temperatures are in degrees Fahrenheit.

Title: ______________________________



Questions:

1. What is the *Mean* temperature for each month?

JULY 1991
Maximum__________
Minimum__________

JANUARY 1992
Maximum__________
Minimum__________

2. What is the *Median* temperature for each month?

JULY 1991
Maximum__________
Minimum__________

JANUARY 1992
Maximum__________
Minimum__________

3. What is the *Mode* temperature for each month?

JULY 1991
Maximum__________
Minimum__________

JANUARY 1992
Maximum__________
Minimum__________

4. What was the weather like on July 20 and 21? Why?

5. On what day(s) in January is (are) the temperature(s) *not* typical?

How is (are) it (they) different from the other temperatures?

6. What is the average temperature for January 15? _____

7. On what days in July are the temperatures exactly normal?

8. How do the temperatures during January compare or contrast to the overall temperatures of July?

Why?

9. If we wanted to look at a topic such as global warming, what climactic evidence would we need to examine?

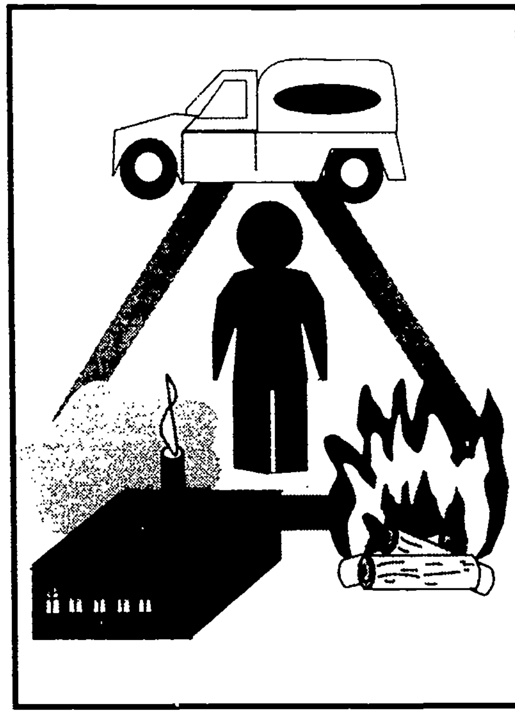
Conclusions:

Review the problem stated on the first page (screen) and write your conclusions here.

Carbon Monoxide Pollution, Wind Speed, and Wind Direction

Problem: What effect does wind speed and wind direction have on carbon monoxide levels in the cities of Denver and Boulder, Colorado?

Materials: Ruler and pencil



Background Information:

Carbon monoxide (CO) is a poisonous gas that damages the central nervous system and, in high enough concentrations, causes death. It is a colorless, odorless, tasteless gas that enters the body through the lungs, where it is absorbed by the bloodstream and combines with the hemoglobin that supplies oxygen to all organs of the body. Since CO combines with hemoglobin more readily than oxygen does, the body is deprived of its oxygen supply. The result is a weakened heart and a reduced blood supply to the rest of the body. The severity of carbon monoxide induced health effects depends on the concentration being inhaled and the length of time a person is exposed.

Carbon monoxide occurs naturally in the air from such processes as forest fires and the decomposition of methane gas. Natural concentrations range from 0.05 to 0.15 parts per million (ppm). This range is very small compared to concentrations found in most cities, which contain about 100 times as much CO. In urban areas, CO is produced primarily by motor vehicles, whose emissions increase carbon monoxide concentrations during morning and evening rush hours.

The Environmental Protection Agency has developed a standard for CO concentrations. Averaged over an eight-hour period, concentrations may not exceed 9 ppm more than once per year in a given location. Denver and Boulder, as well as other U.S. cities have reduced their CO concentration levels by reducing emissions from automobiles, wood burning stoves and fireplaces, and industry.

In the following procedure, you will complete three time series plots. A time series is a plot of time against some other variable. You will use data collected on January 1, 1989, in the cities of Denver and Boulder, Colorado. When plotting Denver data points use the labeled graphs shown under the title "Denver Carbon Monoxide Time Series."

When plotting Boulder data points, use the labeled graphs shown under the title "Boulder Carbon Monoxide Time Series."

In both the Denver and Boulder time series plots, Plot 1 shows time versus CO concentration, Plot 2 shows time versus wind speed in knots, and Plot 3 shows time versus wind direction in degrees. In Plot 3, wind direction is indicated by the azimuth direction in degrees as well as in cardinal directions for north, south, east, and west. Azimuth is the direction measured clockwise from the north through 360°. To better understand the meaning of azimuth direction, examine the diagram "Azimuth and Cardinal Directions" next to Plot 3. Data in Table 8-1 was provided by the Colorado Air Pollution Control Division Daily Pollutant Standard Index Report.

Procedure:

1. On Plot 1 of the Denver Carbon Monoxide Time Series, draw a horizontal line at 9 ppm that extends from hour zero to hour twenty-four. Label this line "Recommended Maximum CO Level." Repeat this procedure for Plot 1 of the Boulder Carbon Monoxide Time Series.

2. Using data provided in Table 8-1, plot the curves on the grids provided for the CO level in ppm, wind speed in knots, and wind direction for Denver. Repeat this procedure for Boulder.

Data

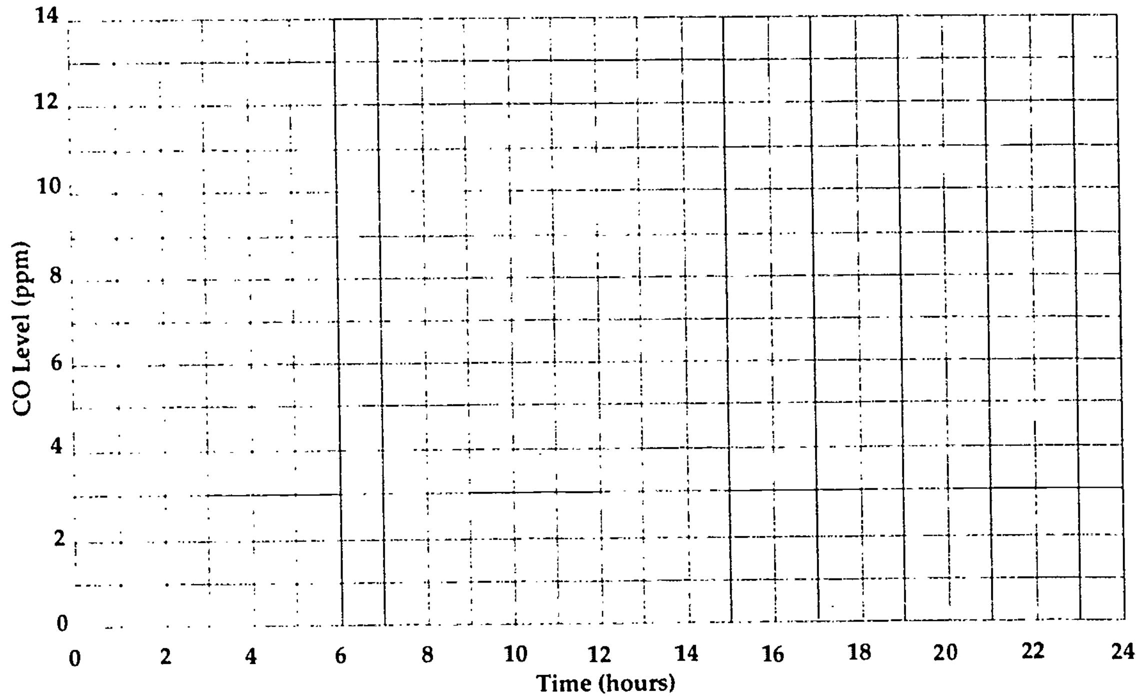
Note:
A wind speed of zero knots has no direction. There is simply no wind.

Hour	CO Level (ppm) Denver	CO Level (ppm) Boulder	Wind Speed (Knots) Denver	Wind Speed (Knots) Boulder	Wind Direction (0° - 360°) Denver	Wind Direction (0° - 360°) Boulder
01	12	01	02	04	20	150
02	13	01	01	02	40	260
03	12	01	01	01	20	270
04	11	01	01	03	90	280
05	10	01	01	01	170	310
06	09	01	01	04	220	230
07	07	01	01	01	260	190
08	07	01	01	00	20	250
09	05	01	01	01	10	100
10	05	01	01	03	40	60
11	04	01	01	04	90	290
12	03	01	00	10	270	270
13	03	01	04	10	40	270
14	02	01	07	09	40	270
15	02	01	05	06	60	270
16	02	01	02	06	70	240
17	03	01	01	04	50	190
18	03	01	01	04	100	180
19	03	01	02	04	120	160
20	04	00	02	06	10	200
21	05	00	02	04	30	210
22	05	01	01	01	330	360
23	06	01	01	00	110	350
24	06	01	01	01	20	10

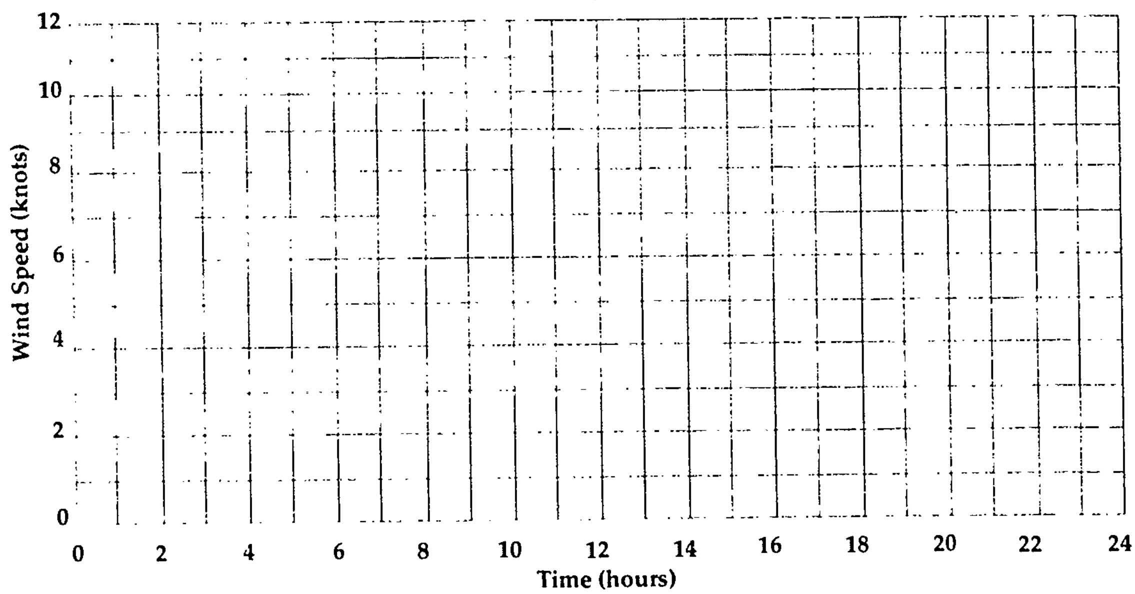
Table 8-1. Observed CO Level, Wind Speed, and Wind Direction for the Cities of Denver and Boulder, Colorado, January 1, 1989

Denver Carbon Monoxide Time Series

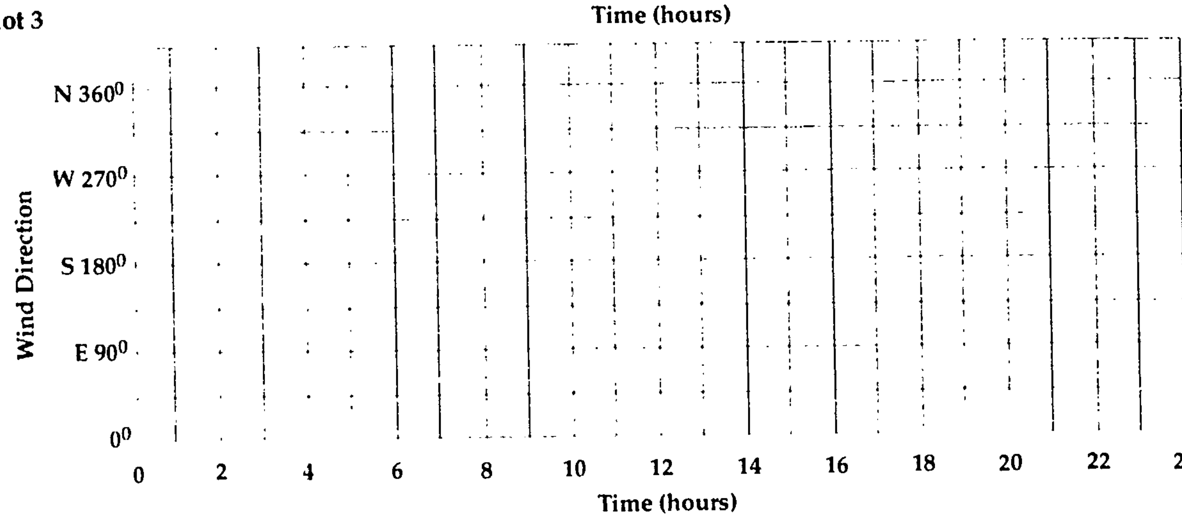
Plot 1

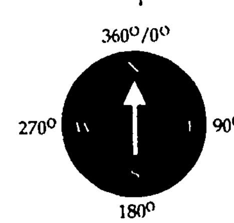


Plot 2



Plot 3

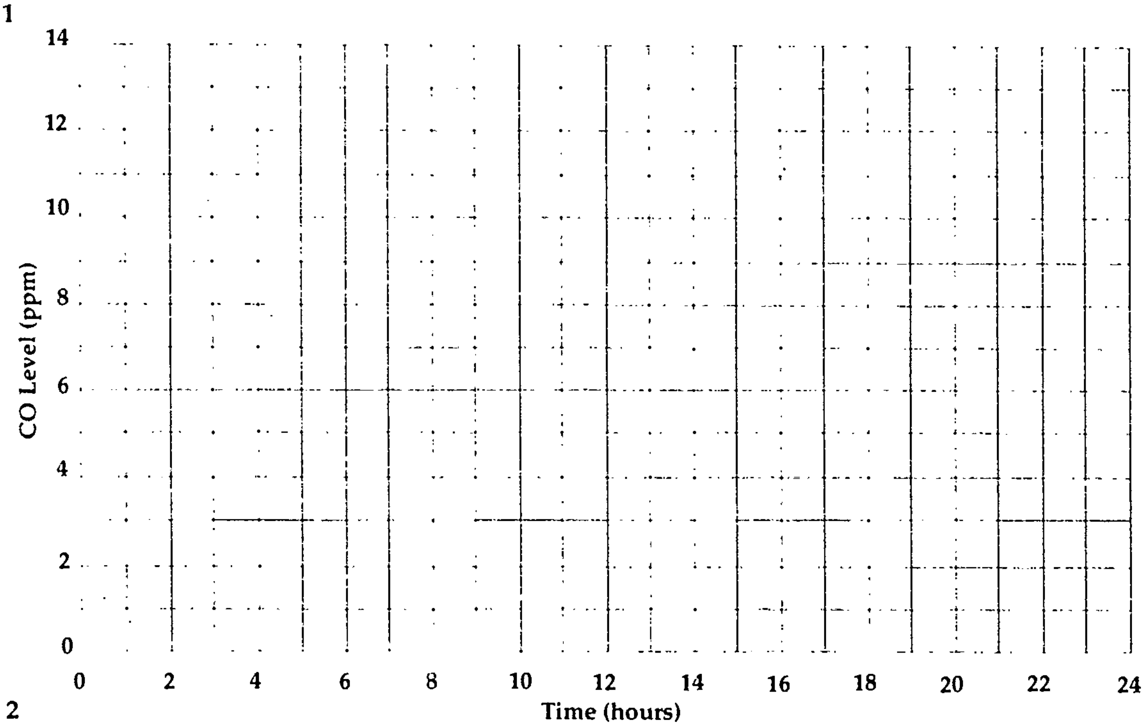




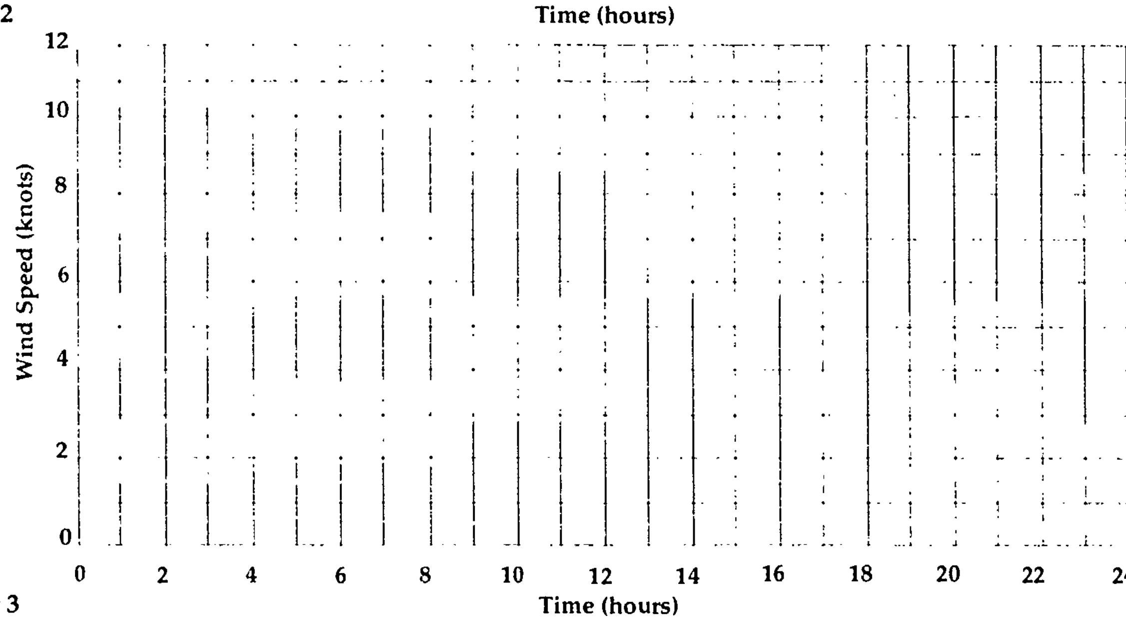
Azimuth and Cardinal Directions

Boulder Carbon Monoxide Time Series

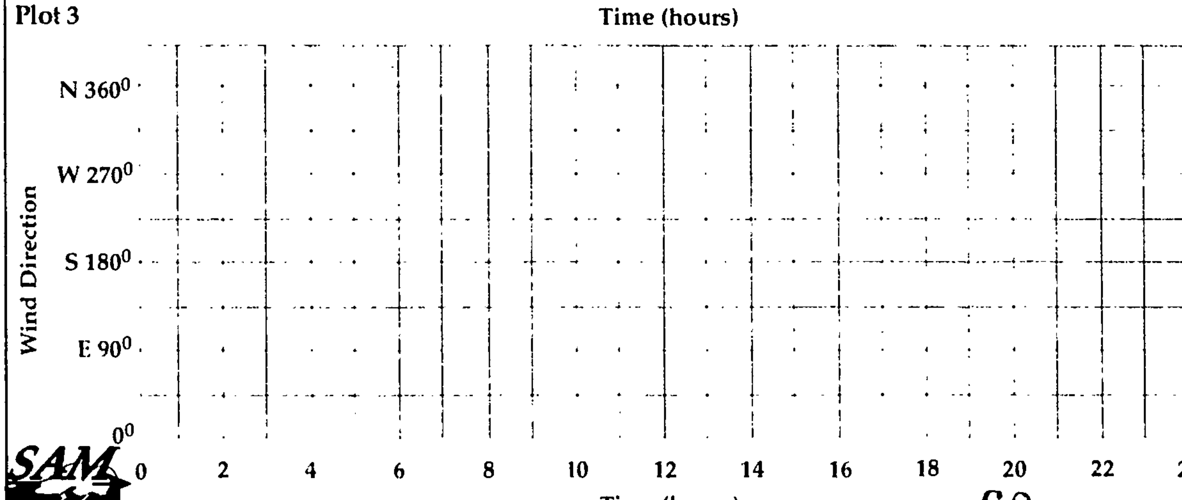
Plot 1

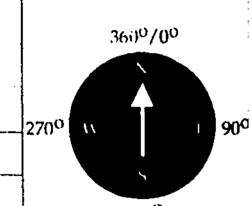


Plot 2



Plot 3





Azimuth and Cardinal Directions

Questions:

1. For how many hours did the CO level equal or exceed the recommended maximum level in Denver?_____

   In Boulder? _____

2. What are the maximum and minimum wind speeds for Denver?

   Maximum = _____

   Minimum = _____

3. What are the maximum and minimum wind speeds for Boulder?

   Maximum = _____

   Minimum = _____

4. What is the range (subtract the minimum from the maximum) for the wind speed in Denver? _____

   In Boulder? _____

5. From what direction did the wind blow most often in Denver? _____

   In Boulder? _____

6. What relationship is there between CO level and wind speed for Denver?

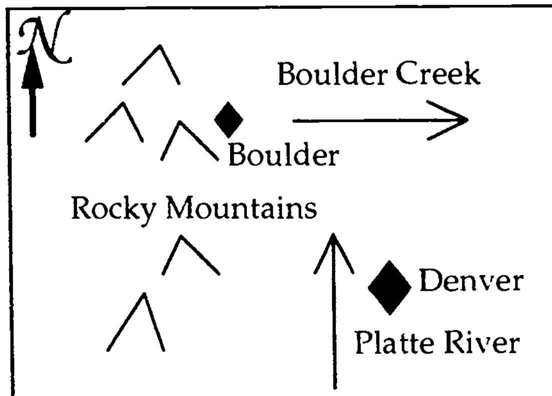
   For Boulder?

7. At what time of the day was the CO maximum for Denver ? _____

   Why is this unusual? (Hint: New Year's Day)

8. Using a dashed line (---), draw a curve on the Denver graph which would illustrate the CO level on a typical working day.

9. As shown in the accompanying diagram, the city of Denver is located in the Platte River Valley. Near Denver, the Platte River flows from south to north. Boulder Creek flows through Boulder from west to east. To the west of both cities are the foothills of the Rocky Mountains. How does the topography affect the wind direction in both locations? Write your answer below.



Relative direction of flow for the Platte River and Boulder Creek

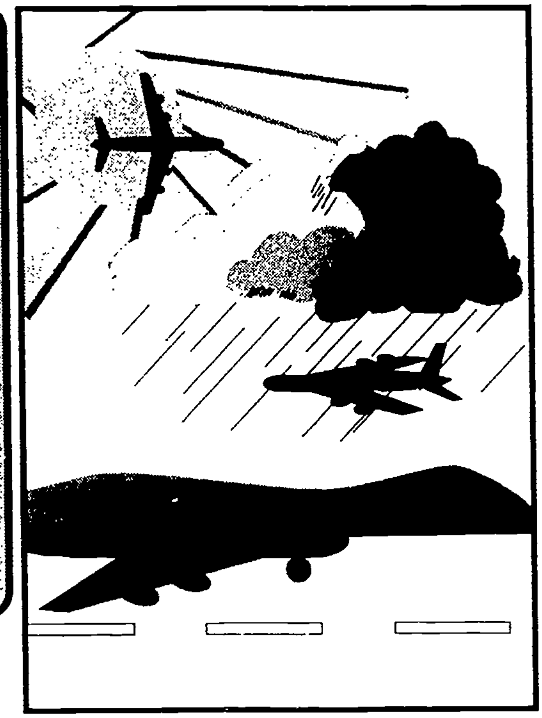
Conclusions:

Review the problem stated on the first page (screen) and write your conclusions here.

Air Traffic, Weather, and Vectors

Problem: How is information on air traffic and weather used by air traffic managers?

Materials: Ruler, pencil, and two colored pencils



Background Information:

"Will my plane arrive safely?" "Will it be on time?" These questions are often on the minds of travelers. In recent years, our skies have become increasingly crowded. Airways are congested with commercial airliners as well as private and military planes.

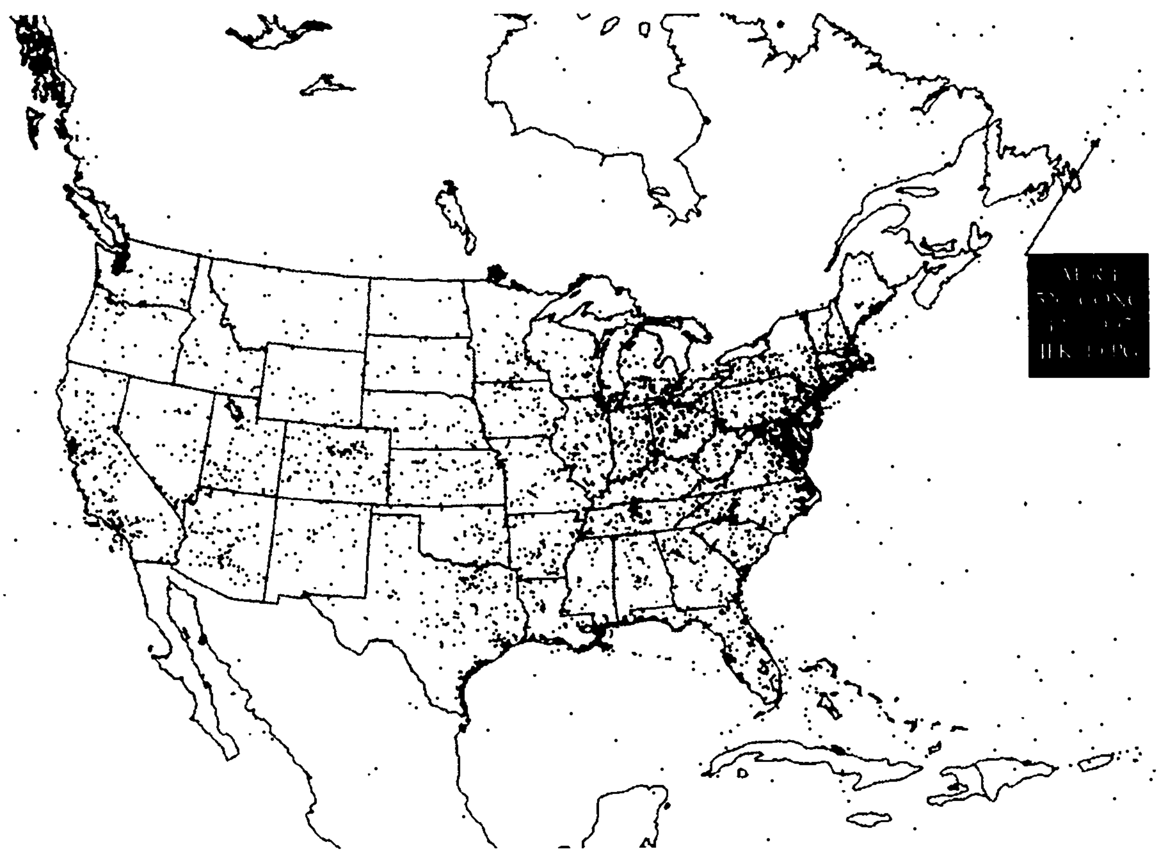
Congested airways cause concern for safety and the number of delays travelers can expect. Fortunately, new technology allows air traffic managers in 22 traffic control centers around the United States to track flights, provide flight information, and look at the weather around the country that can affect flight patterns. This information helps keep our airways safe and makes them more efficient for pilots and their passengers.

Air traffic controllers and air traffic managers are responsible for the safety and efficiency of the airways. Although they work closely together, their jobs are quite different. Air traffic controllers are responsible for keeping a safe separation between aircraft over a particular airspace. Air traffic managers, on the other hand, are concerned with the most efficient use of the airspace.

The air traffic manager must minimize congestion of the airways, as well as delays on the ground and in the air. Weather plays an important role in the management of air traffic. If weather closes a busy airport and slows down air traffic, then airports and air traffic throughout the country can be affected. The ability to predict and track severe weather helps air traffic managers guide air traffic efficiently.

Pilots save fuel by using the jet stream (high speed westerly winds found in the upper troposphere) to help propel the plane when traveling in the same direction as the jet stream, or by avoiding the jet stream when traveling in the opposite direction. Air traffic managers try to anticipate how pilots will request to use the air space in order to save fuel.

Map 1 of the United States is called an Aircraft Situation Display. This display is generated by the Advanced Traffic Management System (ATMS) computer using flight and weather information. Flight information consists of radar tracking data for aircraft in flight, and the pilot's flight plan. The flight plan, filed with air traffic managers before take-off, consists of the pilot's intended route. This is updated during the flight when the pilot communicates with air traffic controllers.



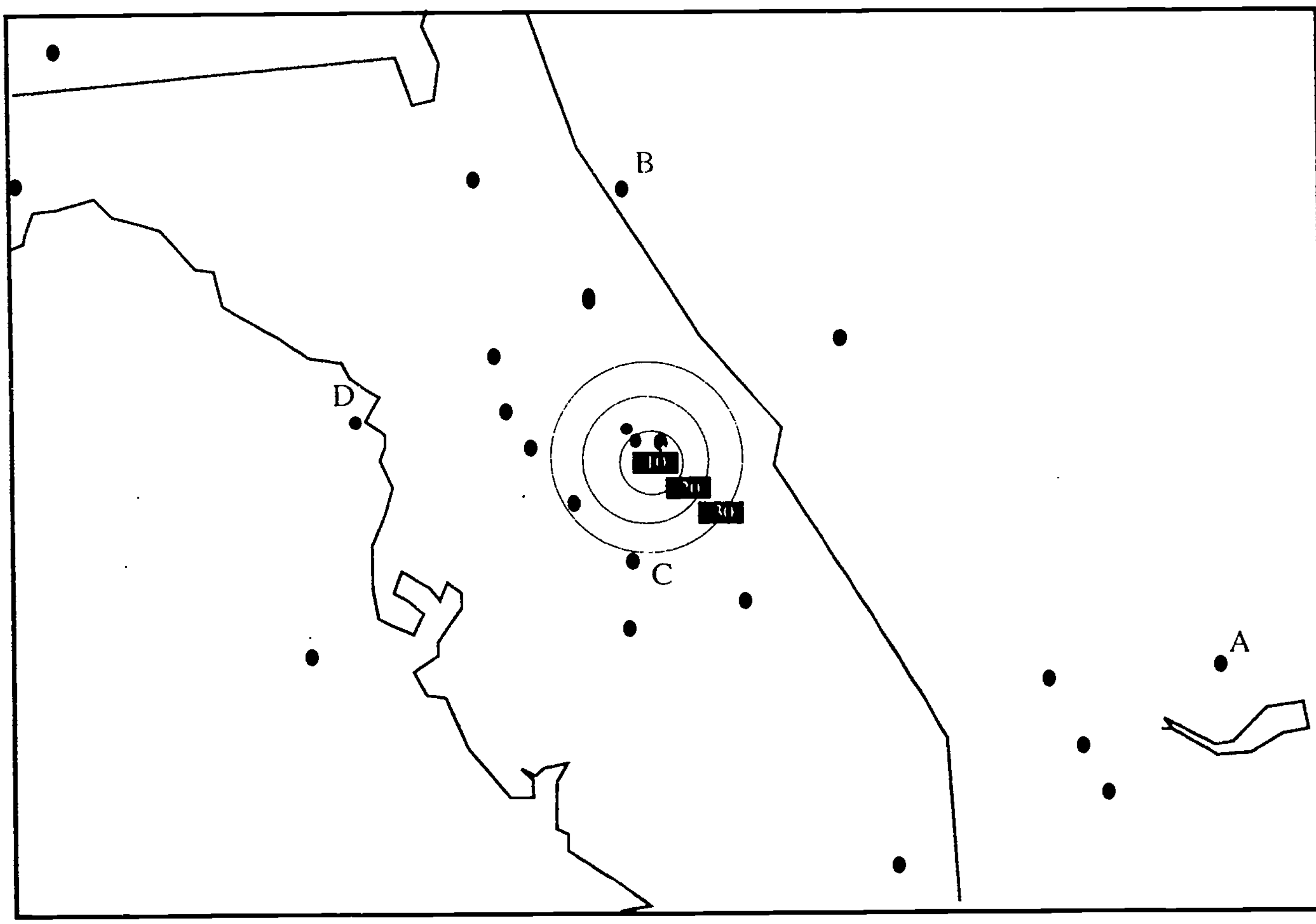
Map 1. Aircraft Situation Display from Tuesday July 28, 1992 3:30 EDT/12:30 PDT

The flight information for the ATMS displays is updated every 3 minutes, and the weather radar every 5 minutes. Air traffic managers and NOAA (National Oceanic and Atmospheric Administration) use the displays to track air traffic and weather throughout the country. The Aircraft Situation Display in Map 1 represents all the commercial flights in the air at 3:30 PM Eastern Daylight Time (12:30 PM Pacific Daylight Time) on Tuesday, July 28, 1992. Flight tags on the Maps like the one shown here give us information about a specific flight.

AFR 1
520 / CONC
125 / 1197
JFK / LFPG

The first line of the flight tag, is the name of the airline and the flight number. In this example, AFR 1 indicates Air France Flight 1. The second line shows the flight level and type of airplane. Multiply the level by 100 to get flight altitude in feet. The flight level in this example is 52,000 feet, and the make of the aircraft is a Concord. The third line indicates the estimated number of minutes until arrival, and the current air speed of the plane. For the flight in this example 125 minutes to arrival, at a speed 1197 miles per hour is recorded. Finally, the last line of the label indicates the departure and destination airports. These were JFK (New York) to Paris, France for this flight.

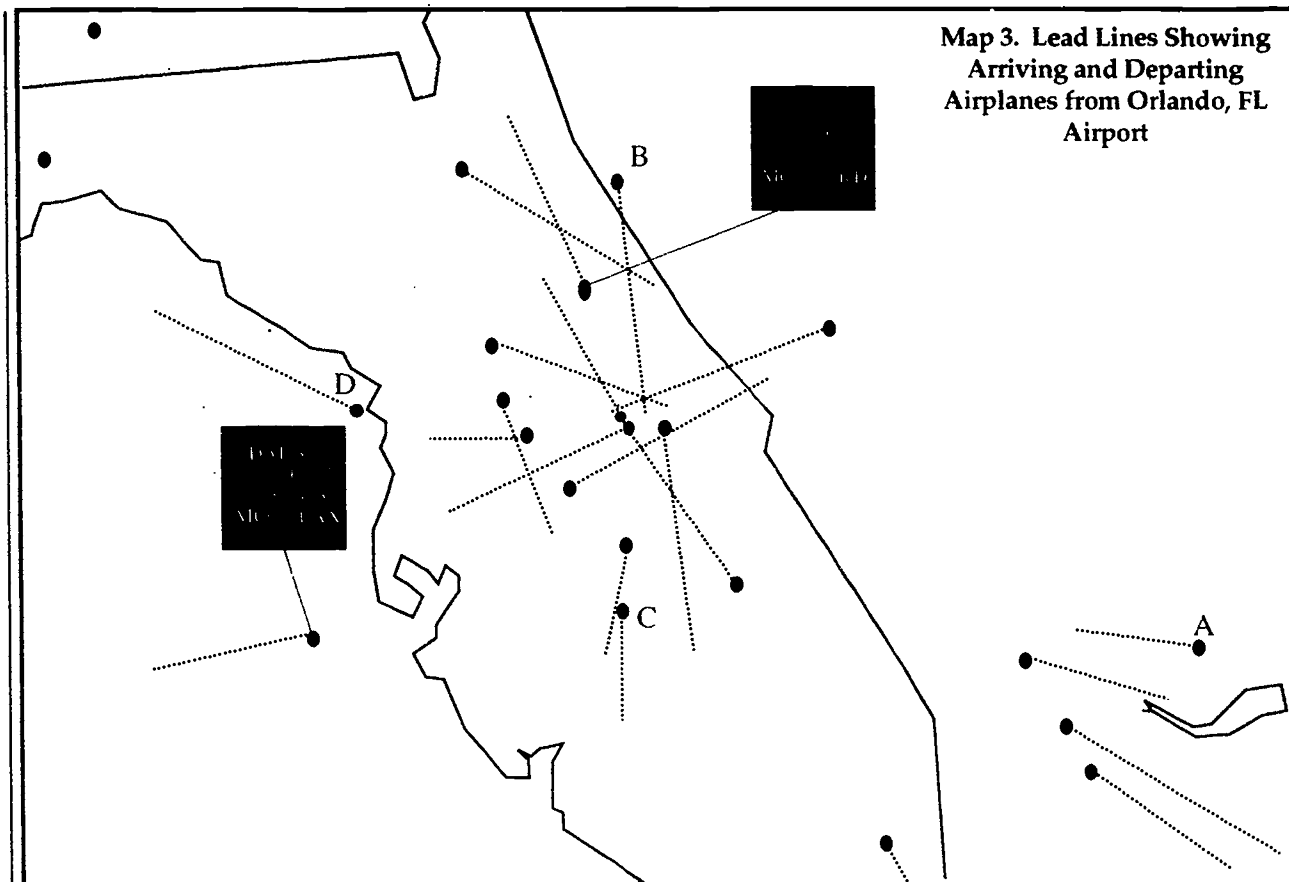
Map 2 displays a portion of Florida and the flights arriving and departing from the Orlando airport (MCO). The range rings on the map are set at 10 mile intervals from the airport.



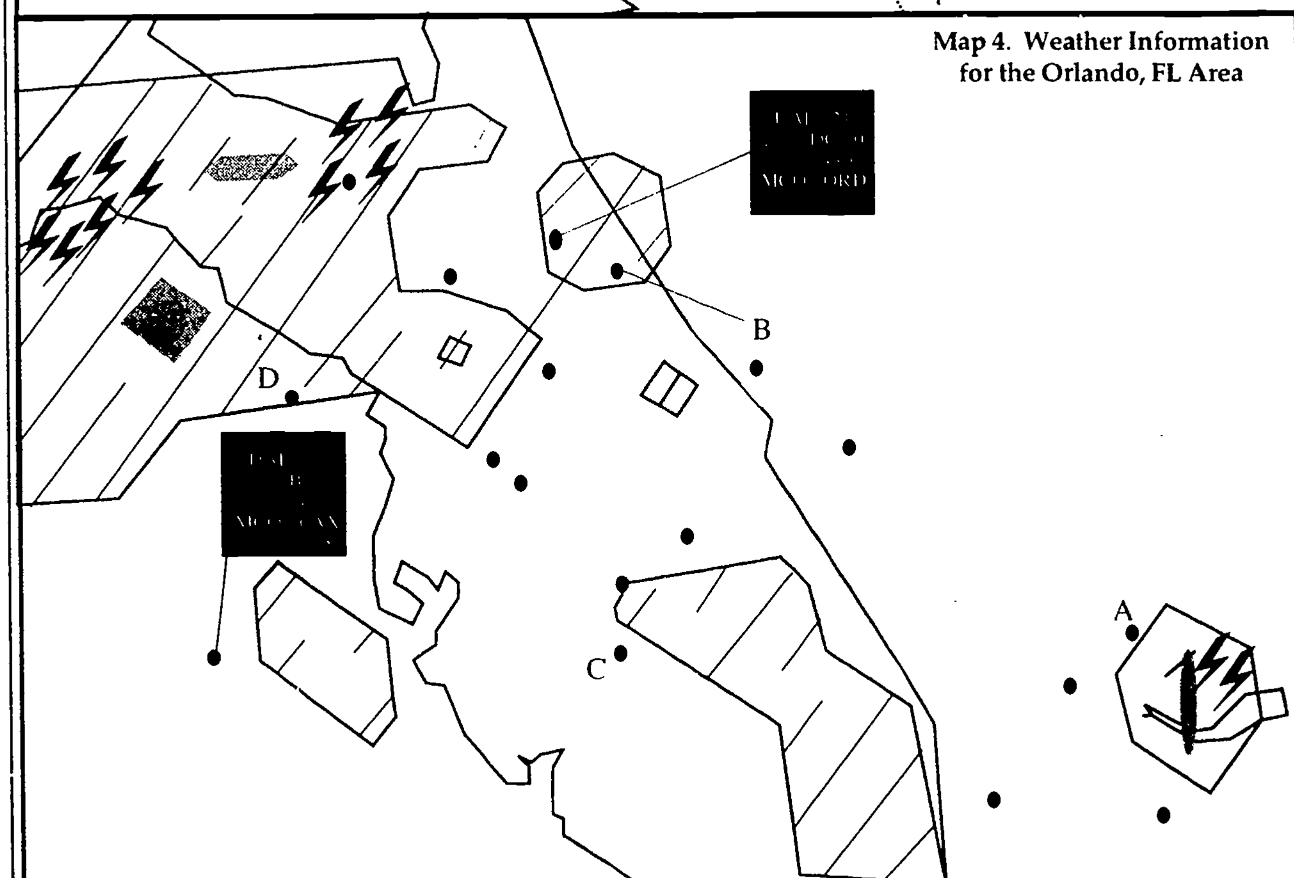
Map 2. Orlando, FL Airport Display with Range Rings in Miles

Map 3 shows the lead lines of airplanes that are arriving and departing from Orlando. Lead lines are vectors. Vectors are lines that give the magnitude and direction of a force. In this case, the lead lines that project from the noses of the airplanes are a type of vector that projects where the airplane can expect to be in 10 minutes while traveling at the indicated speed.

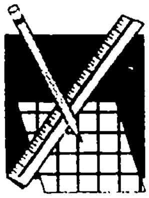
Map 4 overlays weather information for the Orlando area, showing areas of precipitation and lightning strikes. Heavy rain is indicated by gray shaded areas on the map. Notice that light rain, indicated by slash marks, surrounds areas of heavy rain. Lightning strikes are indicated by lightning bolts on your map.



Map 3. Lead Lines Showing Arriving and Departing Airplanes from Orlando, FL Airport



Map 4. Weather Information for the Orlando, FL Area



Procedure:

1. On Maps 3 and 4, place an "X" where the Orlando airport is located.

2. On Map 2 draw an arrow pointing to the airplane (Dot) that represents the plane traveling from MCO (Orlando) to LAX (Los Angeles).

3. Use Map 3 to measure the vectors (lead lines) for the labeled airplanes A, B, C, and D, and for the two planes with flight tags. Map 2 shows the same planes at a different point in time. On Map 2, draw vectors or lead lines projecting where each labeled airplane will be in 20 minutes of flight time. (Hint: These will be twice as long as the original lead lines on Map 3 for the same planes.)

4. On Map 4, color areas of light precipitation with a light colored pencil and areas of heavy precipitation (the shaded area) with a darker colored pencil.

Questions:

1. Using the range rings on Map 2, estimate the distance across Florida in miles, and write your answer here.

2. On Map 2, you drew 20 minute lead lines for all the labeled planes. Are any of these aircraft going to land at the Orlando Airport within 20 minutes? _____

   If so, how many? _____

3. About how many times faster is the Concord on Map 1 traveling than the two planes over Florida in Map 3? _____

4. At what altitude is the United Airlines - Flight 121 in Map 3 traveling? _____

   How fast is it traveling? _____

   The label "ORD" in Map 3 stands for Chicago O'Hare. How long will it take for Flight 121 to arrive in Chicago? _____

5. Estimate how much time will elapse before most of the planes on Map 3 leave the screen? _____

   Will the screen then be totally clear? _____

SAM 5

6. Where is the Delta Airlines Flight 301 in Map 3 headed?

   What kind of plane is it?

7. How far is plane C in Map 2 from the Orlando airport, MCO? _____

8. Using the formula, distance = velocity x time, how far is the Delta airplane from its destination? _____

   The United Airlines flight? _____

9. If you were an air traffic controller, what information about the weather might you give to the pilot of plane D on Map 4?

10. What two methods can pilots use to avoid severe weather?

11. How are vectors and weather information used in air traffic management?

12. Based on your knowledge and experience, as well as this activity, what information does an air traffic manager need to efficiently manage the airways?

Conclusions:

Review the problem stated on the first page (screen) and write your conclusions here.

Sunspots: Space Weather Monitoring

Problem: How can the difference in the speed of rotation between the sun's equator and poles be determined? How do observers record sunspot data? How are sunspots classified?

Materials: Pencil and either a transparent plastic overlay or sheet of tracing paper, 10 cm x 10 cm

Background Information:

Although the average distance from Earth to the sun is a whopping 149,600,000 km., careful observation from the Earth reveals a surprising array of visible features. The most conspicuous and best known feature is the sunspot. Sunspots were first observed by Chinese astronomers more than 2,800 years ago. With the invention of the modern optical telescope during the early 1600's, sunspot observation became more common. Galileo not only observed sunspots, but inferred from the movement of the sunspots that the sun rotated. He observed that sunspots occur in groups, and in two bands above and below the sun's equator.

It was not until 1843 that the next significant development toward understanding sunspots occurred. A German pharmacist, whose hobby was astronomy, discovered that sunspots occur in cycles: the number of sunspots increases then decreases in an eleven year cycle. We now also know that the sun has a magnetic field much like the magnetic field that surrounds a bar magnet. This general magnetic field gradually reverses polarity during each sunspot cycle, like the north and south poles of a bar magnet are switched when the magnet is turned end over end. The result is that the sun has a 22 year magnetic cycle as well as an eleven year sunspot cycle. Furthermore, sunspots themselves have strong magnetic fields that reverse after each eleven year cycle to conform to the 22 year magnetic cycle.

In fact, sunspots are huge magnetic field bundles that break through the surface of the sun. These magnetic fields create cooler, darker regions, which we see as sunspots. The dark center of the sunspot is called the "umbra." The light area around the spot is the "penumbra." Refer to Figure 10-1.

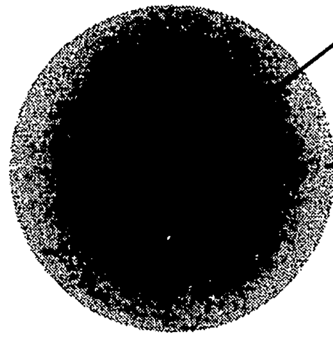


Figure 10-1. Umbra/Penumbra

Sunspots occur in groups and have many possible shapes: round, oval, oblong, raindrop, and almost every other shape in-between. Frequently, sunspots occur in pairs. The two spots have opposite magnetic polarities, like the north and south poles of a horseshoe magnet.

Spots grow in clusters over several days or weeks, then gradually disappear. In the early years of a sunspot cycle, sunspots tend to be smaller and form at higher latitudes, both north and south. As the cycle proceeds toward the maximum number of sunspots in the eleven year cycle, the spots generally become larger and form closer to the equator. During the maximum period of the sunspot cycle, spots form at latitudes of 10 - 15 ^{o}.

As the number of sunspots increases during the sunspot cycle, so does solar activity. Sunspots are sources of solar flares, the most violent events in the solar system. In a matter of minutes, a large flare releases a million times more energy than the largest earthquake.

Sunspots and the resulting solar flares affect us, here on Earth. In fact, the more we learn about sunspots and solar flares, the greater their influence on Earth appears to be. Solar flares emit radiation that includes x-rays and ultraviolet rays, charged particles called protons and electrons, and powerful particles with no electric charge, called neutrons. This radiation surge may damage electrical power systems, interfere with telecommunications, wreck high-tech ship navigation systems, harm an astronaut in space, or create the spectacular aurora (Northern and Southern lights). In 1989, Quebec suffered a blackout because a transformer was destroyed by the charged particles from a solar flare. If astronauts had been either outside a space station or on the Moon's surface in September, 1989, they would have received a lethal dose of radiation. Passengers flying on the Concorde supersonic jets would have received the equivalent of a chest x-ray without being aware of their exposure.

Exposure to radiation from solar flares occurs without our being aware of it. Fortunately, a sudden surge in radiation on Earth caused by a solar flare, may be predicted by an increase in the number and complexity of sunspots. Scientists at the Space Environment Laboratory, in Boulder, Colorado, conduct research in solar-terrestrial physics and develop techniques for forecasting solar disturbances. Also, they provide real-time monitoring and forecasting of solar activity. The Space Environment Services Center is the national and world warning center for disturbances that can affect people and equipment in the space environment.

Although solar forecasters use sophisticated satellite and computer technology to improve space weather monitoring and analysis, researchers continue to observe sunspots using the same centuries old technique developed during the time of Galileo. Simply aim the telescope at the sun, project the magnified image onto a surface, and draw the spots.

In this exercise, you will use techniques similar to those that solar observers use to record data based on sunspot observations at the Space Environment Laboratory in Boulder, Colorado.

Part A:

Procedure: **Refer to Figure 10-2, March 11 and 12, 1989, Boulder Sunspot Observation (page 4 of this activity). Note that groups of sunspots are identified together with only one number.**

1. Locate sunspot number 5397 on the March 11, 1989 diagram. Place an "X" at its estimated center. To find the center, use the grid on your diagram to estimate the longitude of the eastern-most sunspot and the western-most sunspot. Subtract these two longitude numbers, then divide by two and add the result to the lower longitude value. This number is the center of the sunspot group's longitude. Repeat this procedure for March 12, 1989.

2. Locate sunspot number 5398 on the March 11, 1989 diagram. Place an "X" at its estimated center. Repeat this procedure for March 12, 1989.

3. Estimate the latitude for sunspot number 5397 on the March 11, 1989 sunspot diagram. Record your estimate in Table 10-1 on page 5 of this activity. Repeat this procedure for sunspot number 5398.

4. For sunspot number 5397, estimate its longitude on March 11, and again for March 12. Record these data in Table 10-1. Subtract the smaller longitude from the larger to determine the distance it traveled between March 11, at 1620 UT (GMT) and March 12, at 1610 UT, approximately one day. Record the difference on Table 10-1. Repeat this procedure for sunspot number 5398.

5. For sunspot number 5397, divide 360 degrees by the difference in degrees when you subtracted longitudes on March 11. The result is the number of days it takes for the sun to make one complete rotation on its axis. Record your results in Table 10-1. Repeat this procedure for sunspot number 5398.

Questions:

1. Which sunspot group is closest to the sun's equator?

2. What is the latitude of the northernmost sunspot group?

3. Do both sunspot groups travel at the same speed?

   What does this suggest about the sun's rotation?

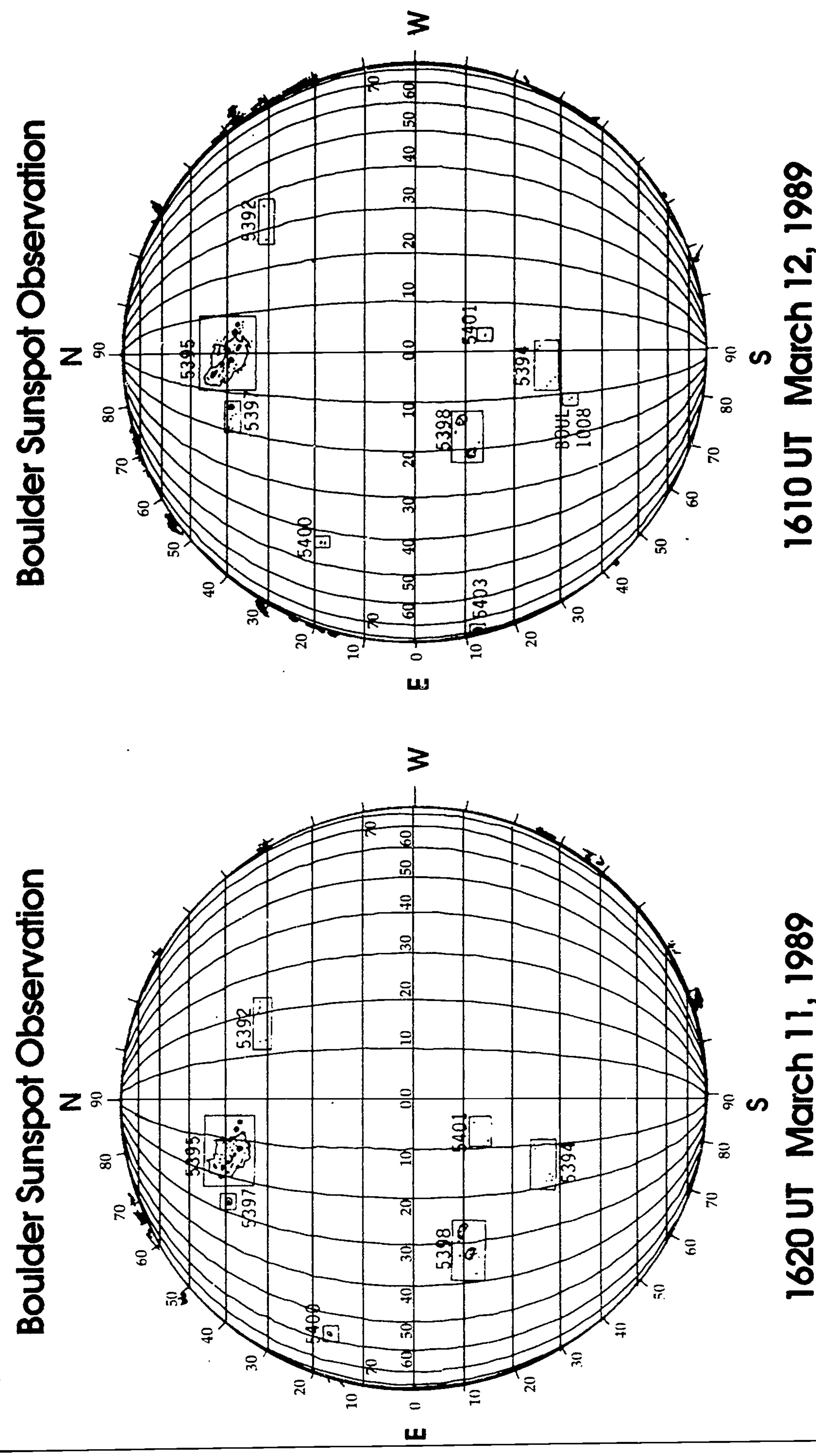


Figure 10-2. Sunspot Observations

4. Use Figure 10-2, the March 12, 1989 Boulder Sunspot Observation to predict where sunspot number 5397 will be at 1620 UT, on March 13, 1989. Place a "*" on the March 12 diagram for that location. Label the sunspot with its number. Repeat the process for sunspot number 5398. What is the predicted longitude for each sunspot group on March 13?

Sunspot Number	Sunspot Latitude	Longitude March 11, 1989	Longitude March 12, 1989	Difference in Longitude (Distance Traveled in One Day)	360^0 Divided by Difference in Longitude (Number of Days for Sun's Rotation at each Sunspot)

Table 10-1. Sunspot Data - A ↑

Table 10-2. Sunspot Data - B →

Number of Sunspots	Local Sunspot Group Number	Type	Magnetic Class	Area	Extent	SESC Sunspot Group Number	Location
2	001	Bxo	B	20	10	5392	N 31° W 31°
	003					5394	
24	004	Fkc		2500		5395	
	006					5397	
	007	Dao				5398	
	009	Axx				5400	
	010				0	5401	
1	013	Axx	A	80	2	5403	S 13° E 80°
	015		B			1008	

Part B:

Procedure: **Refer to Figure 10-2, March 12, 1989, Boulder Sunspot Observation (page 4 of this activity)**

You will record sunspot information in Table 10-2 on this page in much the same way that a solar observer records information for scientists to interpret. The local serial number, the Space Environment Services Center serial number, and some information to be used as examples or that is difficult to determine, has been entered in Table 10-2. (If your initial results do not agree with the observer's results, then try again, and again until you get it right.)

1. Locate sunspot group number 5392. Count the number of spots in the group. Check Table 10-2 to see if your number agrees with the official number. If your total is the same, then you have counted correctly.

   Repeat this procedure for all sunspot groups and record your data in Table 10-2 under the column heading, "Number of Sunspots."

2. If a sunspot stands alone, it is called unipolar and its magnetic class is "A." If there are two or more spots, then it is bipolar and its magnetic class is "B." Identify the magnetic class for sunspot group number 5392. If you identified number 5392 as "B," then you are correct.

   Repeat your observations for all sunspot groups and record your data in Table 10-2 under the column heading, "Magnetic Class."

3. Use the grid on your diagram to estimate the degrees of longitude covered by sunspot group number 5392. Check Table 10-2 to see if your estimate agrees with the official estimate of extent.

   If you are correct, then repeat this process for all sunspot groups and record your data in Table 10-2 under the column, "Extent."

4. Place an "X" on the approximate center of each sunspot. To find the center, use the grid on your diagram to estimate the longitude of the eastern-most sunspot and the western-most sunspot. Subtract these two longitude numbers, then divide by two and add the result to the lower longitude value. This number is the center of the sunspot group's longitude. Place an "X" on the approximate center for sunspot group number 5392. Check Table 10-2 to see if your estimate agrees with the observer's estimate of location.

   If you are correct, then repeat this process for all sunspot groups and record your data in Table 10-2 under the column, "Location."

5. Trace Figure 10-4, the USAF/NOAA Sunspot Area Overlay, located on page 7 of this activity, onto a transparent plastic overlay or sheet of tracing paper. Place this tracing over any sunspot in group number 5392 to find the best fit. Read the number to the left of the best fit circle or oval. This is its area in millionths of a solar hemisphere. Repeat this process for each sunspot in the group. Add the area of each sunspot to find the total area for the sunspot group. Check Table 10-2 to see if your total agrees with the official estimate of area.

   If you are correct, then repeat this process for all sunspot groups and record your data in Table 10-2 under the column, "Area." Refer to Figure 10-3 for help in determining an area count.

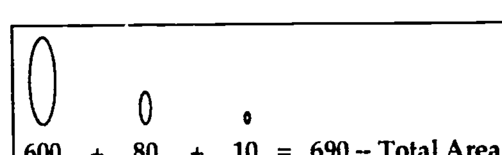


Figure 10-3. Sample Sunspot Area Count

6. Use the information in Table 10-3, located on page 8 of this activity, to determine the type of sunspot for group number 5397. Check Table 10-2 to see if your type agrees with the official type.

   If you agree, then you have correctly determined the type of sunspot.

   Repeat this procedure for all sunspot groups and record your data in Table 10-2 under the column heading, "Type."

Questions:

1. Which sunspot group contains the most spots?

2. In this activity, are most sunspots unipolar or bipolar?

3. What is the area in millionths of a solar hemisphere of the largest spot group?

4. Which sunspot group is more likely to produce a geomagnetic storm?

5. Describe the largest sunspot group using the information in Table 10-3.

USAF/NOAA Sunspot Area Overlay

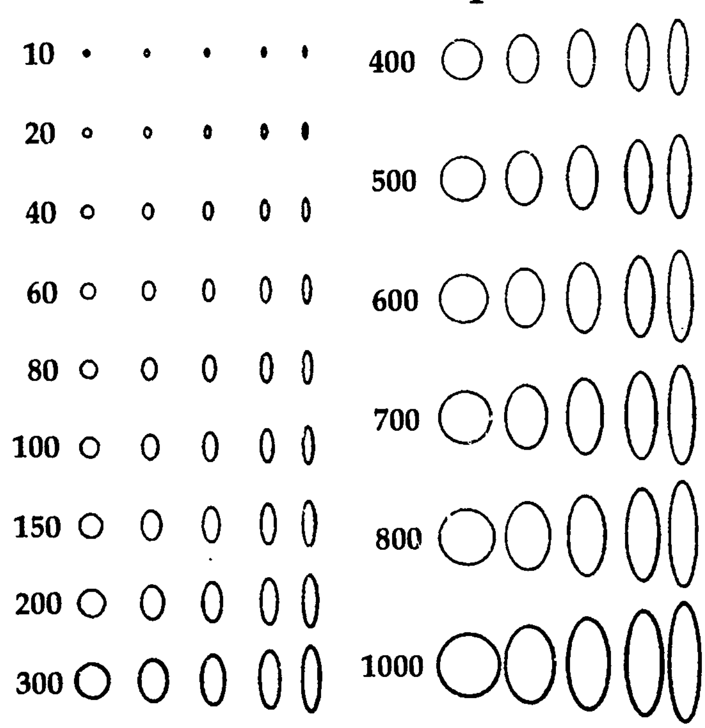
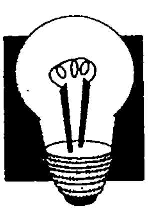


Figure 10-3. USAF/NOAA Sunspot Area Overlay

Note: Sunspot classification is a three letter code. One letter is chosen from each of the three categories listed in Table 10-3. For example, two sunspots with no penumbra and a space between that is greater than 2^{o} would be "Bxo," as in sunspot group 5392.

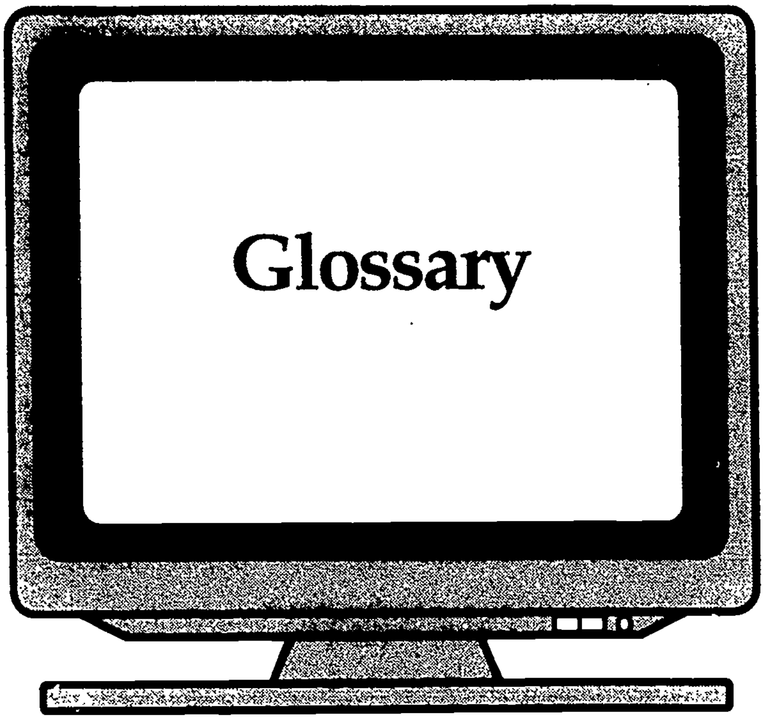
Category	Code	Description
Category "Z" (General Class of the Group)	A	A small single sunspot or very small group of spots with the same magnetic polarity, without penumbra.
	B	Bipolar sunspot group with no penumbra.
	C	A long bipolar sunspot group. Only one sunspot with penumbra.
	D	A long bipolar sunspot group with penumbra on both ends of the group; longitude is more than 5°, but less than 10°.
	E	A long bipolar sunspot group with penumbra on both ends. Longitude of is greater than or equal to 10°, but less than 15°.
	F	A long bipolar sunspot group with penumbra on both ends. Longitude of the sunspot extent is greater than or equal to 15°.
	H	A unipolar sunspot group with penumbra.
Category "p" (Penumbra Type of the Largest Spot in the Group)	x	No penumbra
	r	Beginning of penumbra forming
	s	Small (≤2.5° north-south diameter), symmetric (balanced proportions)
	a	Small, asymmetric
	h	Large (>2.5° north-south diameter), symmetric (balanced proportions
	k	Large, asymmetric
Category "c" (Compactness of the Group)	x	A single spot
	o	Open - few if any spots between the leader and follower; interior spots are small
	i	Intermediate - numerous spots between the leading edge and the following parts of the group, but none has a penumbra
	c	Compact - area between leading and following ends of the spot group is populated with many strong spots, at least one interior spot has a mature penumbra

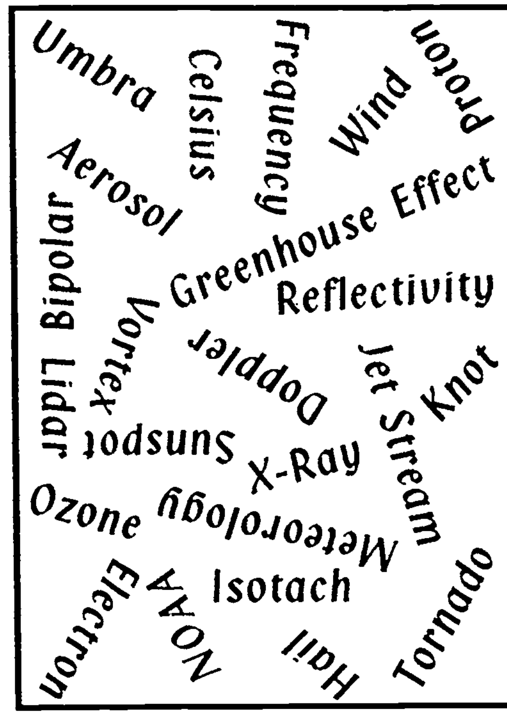
Table 10-3. Sunspot Classification Categories



Conclusions:

Review the problem stated on the first page (screen) and write your conclusions here.





Aerosol — Liquid or solid particles distributed in a finely divided state through a gas, usually air; aerosols play an important roll in the formation of precipitation providing the nucleus upon which condensation or freezing takes place.

Air Traffic Controller — Person who supervises and guides the movement of an aircraft both in the air and on the ground.

Air Traffic Manager — Person who is responsible for the most efficient use of time and space for aircraft both in the air and on the ground.

Aurora — Called Borealis in the northern hemisphere and Australis in the southern hemisphere; a colored illumination of the night sky caused by particles from the sun, guided and accelerated by the Earth's magnetic field, that react with Earth's air molecules.

Azimuth — The horizontal direction measured clockwise along the horizon from a fixed direction (north) through 360°.

Backscatter — The portion of energy emitted by a radar that is reflected (or redirected) back toward the radar.

Bipolar (Sunspot) — A magnetic region of the sun containing at least two areas of opposing polarity.

Carbon Cycle — The progress of carbon (carbon dioxide) from air in the atmosphere as it passes through the biosphere, oceans, and sediments, then ascends back into the atmosphere in the form of carbon dioxide and methane.

Carbon Monoxide	Highly toxic, colorless, odorless, flammable gas; present in exhaust gases of internal combustion engines and furnaces; a product of incomplete combustion.
Cardinal Points	The four principal compass points: north, south, east, and west.
Celsius Temperature	A temperature scale with zero degrees as the melting point and 100 degrees as the boiling point of pure water at standard atmospheric pressure, which is considered sea level.
Chlorofluorocarbons (CFCs)	A group of chemicals used as propellants for aerosol sprays, in production of some plastics, as cleaning solvents, and in air conditioning and refrigeration equipment. Under special conditions, chlorine atoms from CFCs are involved in the removal of ozone from the stratosphere.
Climate	The sum of all statistical weather information that helps describe a place or region over a specific period of time (usually decade .
Cumulonimbus	A towering, bulging cloud, anvil-shaped at the top, containing water droplets, ice crystals, ice pellets, and sometimes hail accompanied by thunder and lightning.
Doppler Effect	An apparent change in the frequency of light or sound waves when the observer and the source are in motion relative to each other. As the source approaches, the frequency increases; as the source moves away, the frequency decreases.
Doppler Radar	A weather radar used to detect the motion within a storm relative to the radar, based on the Doppler Effect; air approaching the radar causes an increase in frequency, receding air causes a decrease in frequency. It can detect rotary motion within a storm, for example, a tornado.
Electromagnetic Radiation	Energy moving through space, includes all wavelengths (or frequencies): infrared, ultraviolet, visible light, radio waves, x-rays, and gamma rays.
Electron	One of three subatomic particles; orbits the atom's nucleus; has a negative electrical charge.
EPA	Environmental Protection Agency.
Extent (Sunspots)	The length of a sunspot or a sunspot group measured by the easternmost to westernmost points in degrees longitude.

Flight Tag	Information on airplane flight situation maps about specific flights, for example, airline name, flight number, altitude, destination, and distance to destination.
Frequency	The number of waves that pass a fixed point in a unit of time.
Frostbite	A freezing of living tissue that impedes blood circulation and can result in gangrene and tissue death.
Global Warming	Increase in global average surface temperature.
Greenhouse Effect	The process by which some of the heat radiated from Earth's surface is trapped and re-radiated back to Earth by gases in the atmosphere.
Greenhouse Gases	Water vapor, carbon dioxide, methane, nitrous oxide, some chlorofluorocarbons and other trace gases in the atmosphere trap some of the heat radiated from the Earth's surface and re-radiate it back to Earth in the Greenhouse Effect. Greenhouse gases allow solar radiation through to Earth's surface where it is absorbed then re-emitted as long wave radiation.
Hail	A form of precipitation made of round or irregular lumps of ice, usually produced in cumulonimbus clouds.
Hemoglobin	Protein in blood of animals (including humans) that transports oxygen to tissues.
Hypothermia	Subnormal inner body temperature that can result in cardiorespiratory failure and death.
Isotach	A contour line of constant wind speed.
Jet Stream	A strong, narrow, meandering stream of air in the westerly winds of the high troposphere.
Knot	A unit of speed equal to one nautical mile per hour. One knot equals 1.15 statute miles per hour.
Latitude	Distance north or south of the equator measured in degrees.
Lidar	(Light Detection and Ranging) - used to determine the amount of dust in the air. A transmitter sends a pulse of light into the air. Dust particles scatter a small part of the light back to a telescope which directs the light to a detector.
Lightning	A flash of light generated by the flow of electrons between oppositely charged parts of a cumulonimbus cloud or between the cloud and the ground.

Longitude	Distance east or west of the prime meridian, expressed in degrees.
Magnetic Class (Sunspot)	Classification of the magnetic character of sunspots according to rules set by the Mount Wilson Observatory in California; most common classifications are unipolar and bipolar.
Magnetic Field	Region where magnetic forces are observable.
Mean (Arithmetic)	The average. For example, the sum of all temperatures divided by the number of observations made.
Median	The middle number in a range of numbers.
Meteorologist	A scientist who studies weather conditions, draws weather maps, forecasts weather, and warns of severe weather.
Meteorology	The study of the atmosphere, its processes and weather.
Mode	The number in a list that occurs most often.
Neutron	One of two particles that make up the nucleus of an atom; it has no electric charge.
NOAA	National Oceanic and Atmospheric Administration
Nomogram	A two dimensional plot, usually consisting of curved lines with labels on them, that expresses a relationship between some variable and two values that it depends upon. For example, the wind chill equivalent temperature may be read from a nomogram by entering the value of temperature along one axis and the value of wind speed along the other.
Ozone	A molecule of oxygen containing three atoms of oxygen.
Ozone Layer	A layer of the stratosphere that contains ozone; it absorbs ultraviolet radiation from the sun, thereby protecting the Earth from ultraviolet radiation.
Parts Per Billion	Units for expressing the relative amount of a trace gas to a total of a billion parts; a ratio of the volume of a dissolved substance to the sum of the volume of dissolved substance plus the volume of dissolving substance.
Parts Per Million	Units for expressing the relative amount of a trace gas to a total of a million parts; a ratio of the volume of a dissolved substance to the sum of the volume of dissolved substance plus the volume of dissolving substance.

Penumbra	The lighter, outer portion of sunspots.
Photosynthesis	For green plants, the conversion of water, carbon dioxide, sunlight, and minerals into oxygen and carbohydrates.
Proton	One of the two particles that make up the nucleus of an atom; it has a positive electric charge.
Radar	An electronic instrument used to detect and compute the distance to objects by reflecting radio energy. On certain frequency bands, radar can detect precipitation and clouds and tell if the moisture is moving toward or away from the radar.
Radiation	Transfer of energy by electromagnetic waves that can travel through space and some materials. (See electromagnetic radiation)
Range	The difference between the maximum and minimum in a list of numbers.
Reflectivity (Radar)	Measure of the efficiency of a radar target in intercepting and returning radio energy; in meteorology, large droplets, melting snow and hail are highly reflective.
Relative Humidity	The ratio of the amount of water vapor in the air at a given temperature compared to the maximum amount that could exist at that temperature, usually expressed in percent.
Solar Flare	A sudden eruption of energy in the solar atmosphere associated with sunspots. Solar flares cause powerful electromagnetic disturbances in the space environment surrounding Earth.
Solar Forecaster	A scientist who forecasts disturbances on the sun that can affect people and equipment on Earth and who warns users in government, industry, and the private sector of solar and geomagnetic activity.
Stratosphere	The atmospheric layer above the troposphere showing a slight increase in temperature with increasing altitude, low moisture content, and near absence of clouds. Earth's ozone layer is in the stratosphere.
Sulfur Dioxide	A compound of sulfur and oxygen; heavy, colorless, poisonous gas with a pungent irritating odor much like that of a just struck match; occurs in nature in volcanic gases and in some warm springs.
Sunspot	A dark, cool spot on the sun's surface that is formed by a magnetic field bundle that breaks through the surface of the sun.
Thunderstorm	A local storm produced by a cumulonimbus cloud and always accompanied by lightning and thunder.

Tornado	A violently rotating column of air that extends downward from a cumulonimbus cloud and moves in a narrow path along the ground.
Troposphere	The lowermost layer of the atmosphere in which we live, where clouds and weather occur and where temperature decreases with increasing altitude.
Type (Sunspot)	A type of three letter designation for the type of a sunspot or sunspot group.
Ultraviolet Radiation	Electromagnetic radiation at the short wavelength (violet) end of the visible light range, emitted from the sun.
Umbra	The darkest, inner portion of a sunspot with penumbra or a sunspot lacking a penumbra.
Unipolar (Sunspot)	A magnetic region of the sun having one polarity.
Upper Air Wind	Air flowing horizontally above the surface of the Earth.
UTC	Coordinated Universal Time; also known as Greenwich Mean Time
Vector	A quantity that has magnitude and direction, commonly represented by a directed line segment whose length represents the magnitude and whose orientation in space represents the direction. A vector can represent the speed and heading of an airplane.
Vortex	In meteorology, any rotating flow in the atmosphere.
Wavelength	The distance between a point on one wave and the identical point on the next wave; for example, the distance between two crests or two troughs.
Weather Balloon	A balloon that carries electronic equipment to relay meteorological data to receiving stations on Earth; a typical balloon filled with helium, rises from the surface to 60,000 feet in about an hour.
Weather Forecaster	A person who tries to predict the weather using principles of physics, computer models, and a variety of statistical and empirical techniques.
Weather Front	A boundary that is a zone of weather change between two air masses of different densities. Fronts move, but sometimes remain still, or stationary.

Wind Flowing air that is in motion relative to the Earth's surface; named after the direction from which it blows.

Wind Chill A measure of apparent temperature that uses the effects of wind and temperature on the cooling rate of the human body. The wind chill table shows the equivalent cooling power of the atmosphere with wind on exposed flesh.

Wind Direction The direction *from* which wind is blowing.

Wind Profiler A Doppler Radar pointing successively in a mostly vertical direction. The wind profiler measures upper level wind speed and wind direction.

Wind Shear Change in direction or speed of the wind; usually horizontal.

X-Ray Electromagnetic waves having very short wavelengths; they can penetrate many materials.

Zero Velocity (Radar) Air that has no velocity relative to the radar.