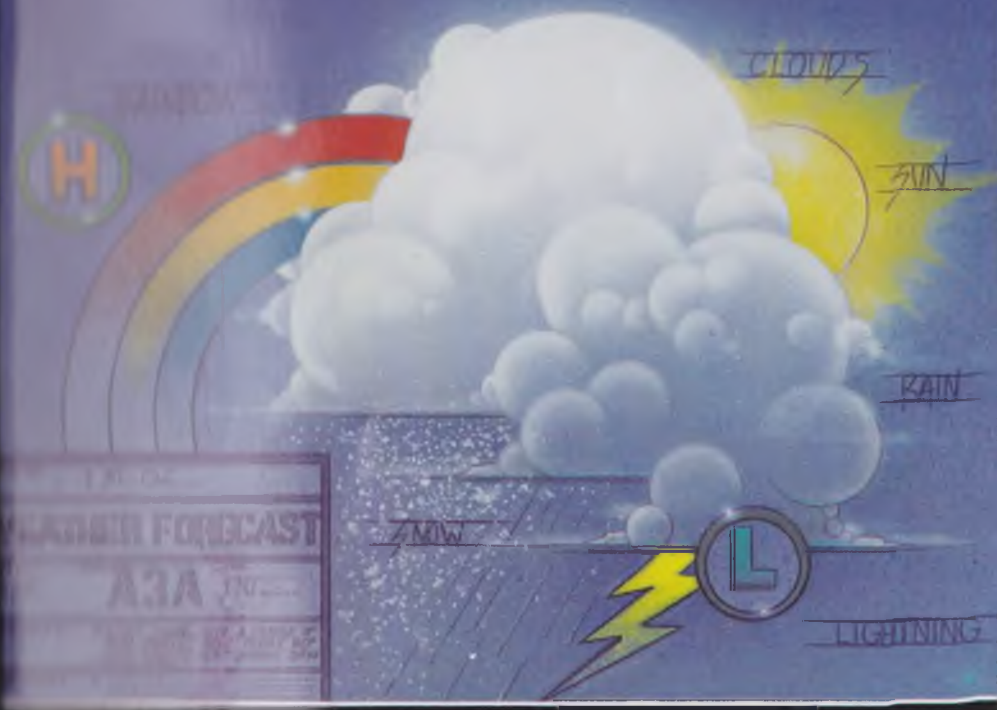
FORECAST!™

Your At-Home Weather Station

By Irv Gikofsky, Tore Jakobsen, Neal Townsend and Jim Witt

PROGRAM GUIDE



CBS SOFTWARE

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CBS Software, A Unit of CBS Inc., Greenwich, Connecticut

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CONTENTS

SETTING UP YOUR COMPUTER

FOR APPLE® II+/IIe/IIc COMPUTERS

1. Following manufacturer's instructions, connect your computer and disk drive to a monitor or TV.
2. Insert the program disk into the disk drive and close the drive door.
3. Turn on your computer and monitor. Adjust the volume.
4. The title screen will appear, followed by the program menu.

FOR COMMODORE 64™ COMPUTERS

1. Following manufacturer's instructions, connect your computer and disk drive to a monitor or TV.
2. Insert the program disk into the disk drive and close the drive door.
3. Turn on your computer and monitor. Adjust the volume.
4. Type: **LOAD "CBS", 8** and press RETURN. Then type **RUN** and press RETURN again.
5. The title screen will appear, followed by the program menu.

FOR IBM® PERSONAL COMPUTERS AND PCjr.

You will need your DOS disk each time you run the program.

If your IBM PC has 64K, you must use DOS 1.1. If your IBM PC has 128K, you may use DOS 1.1, DOS 2.0 or DOS 2.1.

On the IBM PCjr., you must use DOS 2.1. The optional BASIC cartridge is also required.

1. Place the DOS disk in Drive A and turn on your computer. *PCjr. users: Make sure BASIC cartridge is plugged into the left cartridge port.*
2. When the request to enter the date and time appears, press ENTER twice.
3. When the A> appears, type: **BASICA** Then press ENTER.
4. When "OK" appears, remove the DOS disk and place the program disk in Drive A. Type: **RUN "CBS"** Then press ENTER.
5. The title screen will appear, followed by the program menu.

PRINTER OPTION

Some activities allow you to print out copies of your data. If you have a printer, be sure it is connected and follow the instructions that appear on the computer screen for receiving a printout.

HOW TO USE FORECAST!

Get set to unlock the mysteries behind weather prediction with FORECAST!, your at-home weather station! This program guide has been designed to introduce you to the program and explain the scientific principles used by professionals to predict the weather.

The program itself is self-explanatory. Just load it into your computer and you'll be well on your way to becoming an amateur weathercaster. FORECAST! is divided into five activity tools:

The Weather Forecaster

Input daily weather data and you'll be able to predict the weather for this afternoon, tonight and tomorrow often with amazing accuracy.

The Weather Calculator

Convert temperature from Fahrenheit to Celsius, wind speed from miles per hour to knots, and atmospheric pressure from inches of mercury to millibars.

The Weather Keeper

Your own daily log of what Mother Nature has been up to that allows you to store and print out your own weather data.

The Weather Traveller

National weathercast data based on 10 years of compilations provides weather information for every region of the nation, any time of the year.

The Weather Tracker

Follow the patterns of hurricanes and predict where they'll strike next!

Some of these activities require the use of a blank *formatted* disk to record your data on. Keep one on hand so you're ready to log your observations when the computer asks you to do so.

So don't wait for a rainy day! Now is the time to get into FORECAST!

INTRODUCTION

In order for the program to produce an accurate weather forecast, you must observe present weather conditions accurately and input them properly into the computer.

If you establish a routine of observing the weather at the same time each day, you will gain certain advantages. First, you will be able to see the weather changes in a 24-hour period. Second, the entries into the *Weather Keeper* section and your observations will be more consistent.

Let's start observing the weather!

SKY CONDITIONS

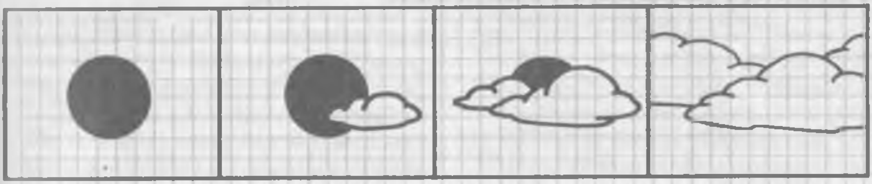
Report skies as follows:

1. CLEAR: If the sky is cloudless or less than 1/10 of the sky contains clouds.

2. PARTLY CLOUDY: If the sky is 1/10–1/2 covered by clouds.

3. MOSTLY CLOUDY: If the sky is 6/10–9/10 covered by clouds.

4. OVERCAST: If the entire sky is covered by clouds.



1. Clear 2. Partly Cloudy 3. Mostly Cloudy 4. Overcast

PRECIPITATION

Once the cloud condition has been recorded, check to see if it is raining, snowing or if there is some other form of *precipitation* such as sleet, freezing rain, drizzle or hail. Then determine the intensity of precipitation.

The intensity of *rain* is determined in the following manner:

1. LIGHT RAIN:
Scattered drops that do not completely wet an exposed surface (regardless of duration) to a condition where individual drops are easily seen; slight spray is observed over pavements; puddles form slowly; sound on roofs ranges from slow pattering to gentle swishing; steady small streams may flow in gutters and downspouts.

2. MODERATE RAIN:
Individual drops are not clearly identifiable; spray is observable just above pavements and other hard surfaces; puddles form rapidly; downspouts on buildings seem 1/4 to 1/2 full; sound on roofs ranges from swishing to gentle roar.

3. HEAVY RAIN:
Rain seemingly falls in sheets; individual drops are not identifiable; heavy spray to height of several inches is observed over hard surfaces; downspouts run more than 1/2 full; visibility is greatly reduced; sound on roofs resembles roll of drums or distant roar.

The intensity of *snow* is determined by visibility and by rate of accumulation. If there are no other obstructions to visibility such as fog, smoke, haze, etc., then report visibility as follows:

1. LIGHT SNOW:
Visibility during falling snow is ⅝ statute mile or more.

2. MODERATE SNOW:
Visibility during falling snow is less than ⅝ statute mile, but not less than 5⁄16 statute mile.

3. HEAVY SNOW:
Visibility during falling snow is less than 5⁄16 statute mile.

Report snow intensity by rate of accumulation as follows:

1. LIGHT SNOW:
accumulates at a rate of one inch every 2-3 hours.

2. MODERATE SNOW:
accumulates at a rate of one inch every 1½ hours.

3. HEAVY SNOW:
accumulates at a rate of over one inch per hour.

TEMPERATURE

After you complete the sky condition and precipitation observations, check the thermometer to determine the outdoor temperature. If possible, the thermometer should be placed in an instrument shelter. This is a box-like structure that protects the thermometer from exposure to direct sunshine, precipitation and condensation, and it also provides adequate ventilation.

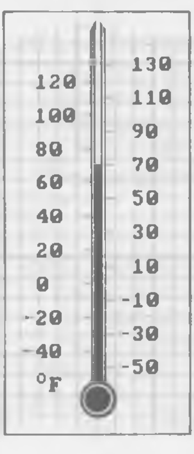
If you do not have an instrument shelter—and many observers do not—place the thermometer on the north side of your home approximately five to eight feet above the ground. Protect it from precipitation and sunshine with any type of inexpensive shelter.

It's easy to read the thermometer. Example 1 indicates a temperature of 70°F.

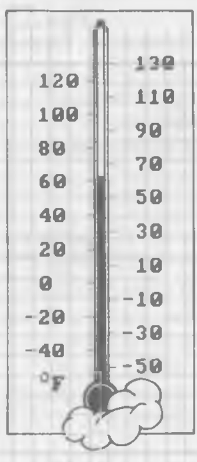
You also can read temperatures with a Celsius thermometer.

You will need a *wet-bulb temperature* to calculate relative humidity and dewpoint temperatures. To get this temperature, make a *wet-bulb thermometer.*

Take a wet cloth or a piece of wet cotton and wrap it around the bulb of your thermometer. Let the wind blow on the thermometer for a few minutes or fan the thermometer if there is no wind. Then read the temperature. In example 2, the *wet-bulb temperature* is 62°



Example 1
Thermometer
reading 70°F.



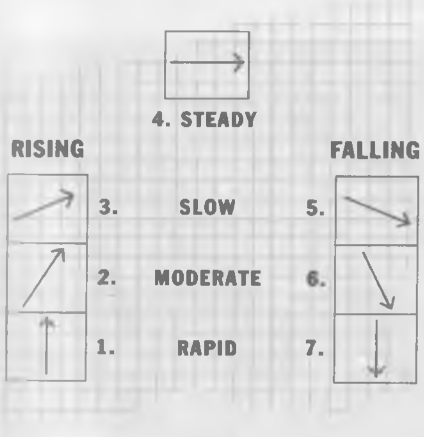
Example 2
Wet-bulb
Temperature 62°F.

AIR PRESSURE

You need a barometer to determine the air pressure at your location.

Air Pressure
inches of Mercury

This barometer indicates air pressure in inches of mercury: however, other barometers may indicate air pressure in units of millibars (mb). Here, the air pressure is between 29.50 inches and 30.00 inches and closer to 29.50 inches. Thus the estimated air pressure is about 29.60 inches of mercury. Most barometers have exact markers and no approximations are necessary when you wish to record air pressure.



Pressure Tendency

Although the actual air pressure is very important, the tendency to rise or fall—the *pressure tendency*—at the time of observation is even more important.

Most amateur weather observers do not follow the rules "exactly." You should record the pressure every hour or at least every three hours. Most barometers have a "set dial." Three hours prior to inputting pressure data into your computer, line this dial up with the air pressure. Observe the pressure again when you are ready to input the data. Record the difference in pressure. If this is impractical, at least tap the barometer lightly at the time of data input. Record which way the needle moved (toward higher or lower pressure) and how much it moved.

To assist you in determining the pressure tendency, use the following rules:

1. PRESSURE RISING RAPIDLY:
Whenever the pressure is rising at the rate of 0.06 of an inch or 2.0 mb. or more per hour.

2. PRESSURE RISING MODERATELY:
Whenever the pressure is rising at approximately the rate of 0.04 inch or 1.4 mb. per hour.

3. PRESSURE RISING SLOWLY:
Whenever the pressure is rising at approximately the rate of 0.02 inch or 0.7 mb. per hour.

4. PRESSURE IS STEADY:
Whenever the pressure changes 0.01 inch or less or 0.3 mb. per hour.

5. PRESSURE FALLING SLOWLY:
Whenever the pressure is falling at approximately the rate of 0.02 inch or 0.7 mb. per hour.

6. PRESSURE FALLING MODERATELY:
Whenever the pressure is falling at approximately the rate of 0.04 inch or 1.4 mb. per hour.

7. PRESSURE FALLING RAPIDLY:
Whenever the pressure is falling at approximately the rate of 0.06 inch or 2.0 mb. or more per hour.

For those who want to be more precise, another factor must be included when reading air pressure. This factor is known as *diurnal variation*. The air pressure normally rises slightly, about 0.01 inch per hour, from 4:00 A.M. to 10:00 A.M. and again at 4:00 P.M. to 10:00 P.M. It falls the same amount from 10:00 A.M. to 4:00 P.M. and from 10:00 P.M. to 4:00 A.M. Each variation totals 0.06 inch.

Here's how to use the factor of *diurnal variation:*

If you observe the pressure at 7 A.M. and there has been no change in the last three hours, then the pressure has actually fallen slightly since the barometer should have risen about .03 inch during the three-hour period. Likewise, if you observe the pressure at 1 P.M. and it shows no change in the past three hours, then the pressure has actually risen slightly because the pressure should have fallen about 0.03 inch during this time period.

Sound confusing? With a little practice it will become simple to include diurnal variation when you observe air pressure.

WIND DIRECTION AND SPEED

The final weather elements that must be observed to produce a forecast are **wind direction** and **speed**.

To determine wind direction, first decide which direction is north. If you do not possess a compass, determine north as follows:

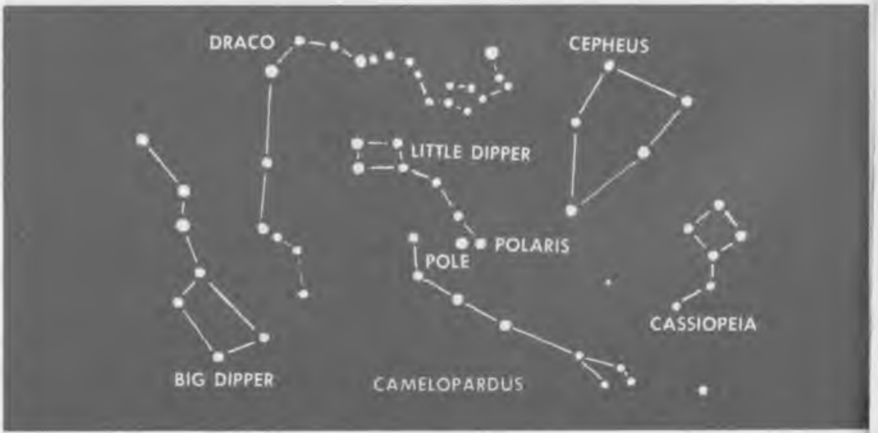
At night, the position of the North Star (Polaris) gives you north almost exactly. If you locate the Big Dipper in the sky, the "pointer" stars in the bowl point to the North Star.

During the day, north can be found by observing the sun at twelve noon standard time or 1:00 P.M. daylight saving time. At that time the shadow of any vertical post will run true north and south.

If you don't want to wait till noon, aim the hour hand of a watch directly at the sun. The point midway between the hour hand and 12 noon is south. Ancient sundials operated on the same principle.

Finally, the sun rises approximately in the east and sets approximately in the west. This is especially true around March 21 and September 21.

When you have decided north, you can select other compass directions. For example, if you face north, south is to the rear, east is to the right, and west is to the left.



Wind directions can be determined by observing smoke from chimneys or flying flags, feeling wind on the body or, best of all, looking at a wind vane. Do not use moving clouds to determine wind directions because winds high in the sky do not come from the same direction as surface winds.

Remember: When you record wind directions, winds are named for the direction *from which* they come. A north wind blows *from the north*.

Wind speed is measured by an instrument called an *anemometer.* If you don't have one, use the chart below. Then record the wind speed. By this time you should be familiar with the elements you will need to record and input into the *Weather Forecaster* section of the program in order to forecast the weather. You also should understand *how* to record them. Now you are all set to become a first-rate amateur weather forecaster. The information in the chapters that follow will help you. Have fun and good luck!

THE BEAUFORT SCALE FOR WIND

BEAUFORT SCALE NUMBER	STATUTE MILES PER HOUR (MPH)	KNOTS (NAUTICAL MILES)	EXPLANATORY TERMS	OBSERVABLE DESCRIPTION
0	Less than 1	Less than 1	Calm	Calm; smoke rises vertically
1	1-3	1-3	Light air	Direction of wind shown by smoke drift but not by wind vanes
2	4-7	4-6	Light breeze	Wind felt on face; leaves rustle, ordinary vane moved by wind
3	8-12	7-10	Gentle breeze	Leaves and small twigs in constant motion; wind extends light flag
4	13-18	11-16	Moderate breeze	Raises dust and loose paper; small branches are moved
5	19-24	17-21	Fresh breeze	Small trees in leaf begin to sway; wavelets form on inland water
6	25-31	22-27	Strong breeze	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty
7	32-38	28-33	Moderate gale	Whole trees in motion; inconvenience felt when walking against wind
8	39-46	34-40	Fresh gale	Breaks twigs from trees; impedes progress generally
9	47-54	41-47	Strong gale	Slight structural damage occurs; chimneys and slates carried away
10	55-63	48-55	Whole gale	Seldom experienced inland; trees uprooted; considerable structural damage done
11	64-72	56-63	Storm	Very rarely experienced; accompanied by widespread damage
12	73-82	64-71	Hurricane	Violence and destruction
13	83-92	72-80	"	" " "
14	93-103	81-89	"	" " "
15	104-114	90-99	"	" " "
16	115-125	100-108	"	" " "
17	126-136	109-115	"	" " "

WHAT IS METEOROLOGY?

Meteorology is defined as the study of the atmosphere, with emphasis on weather and weather forecasting. Mark Twain once said, "Everyone talks about the weather but no one does anything about it." That is no longer true. Modern day meteorologists, with the use of computers, satellites, radar and high speed telecommunications are improving forecast accuracies year by year.

In the following chapters we will attempt to show why different places and seasons have such differences in temperatures, air pressures, winds, humidity, rainfall and snowfall. It is hoped that you will better understand the difficulties a meteorologist encounters preparing his or her daily forecasts.

The *atmosphere* is a cover of gases that surrounds the earth and rotates with it. The outer limits of the atmosphere are about 22,000 miles above the earth, but most weather occurs in the lower 10 miles. It is in this layer of the atmosphere that we will concentrate our attention.

CHAPTER 1
TEMPERATURE: A Vital Factor In Weather

It's no secret that the earth and its atmosphere get their warmth from the sun. However, the relationship of the sun to the earth is such that the earth and its atmosphere are heated unevenly, resulting in a variation of temperatures. This heating is the fundamental cause of winds, storms, clouds, rain and snow.

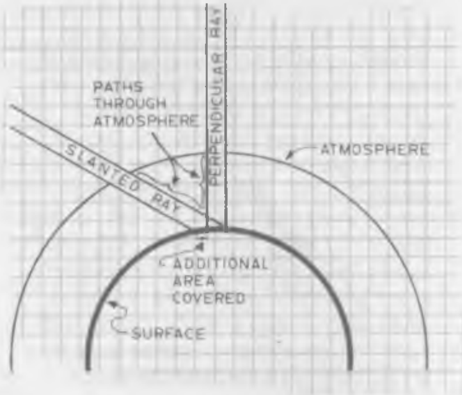
The temperature of air affects air pressure, determines the amount of water vapor a specific volume of air can hold and is responsible for rising and descending air currents. Since temperature is such a vital factor in these weather conditions, it is helpful to thoroughly understand it and its effects.

THE MOST VERTICAL RAYS OF THE SUN ARE THE HOTTEST!

We can determine this from several observations. First, the sun's rays are hotter at noon, when they are most vertical or perpendicular to the earth's surface, than at sunrise or sunset when they are slanted. Second, it is hotter at the equator than at the north and south poles. Rays of the sun are most vertical at the equator and least vertical at the poles. In the northern hemisphere, the sun's rays are strongest in June when they are most vertical and much weaker in December when they are least vertical.

There are two reasons why the sun's rays are strongest and therefore warmest when they are most vertical. These can be seen in the diagram shown.

First, perpendicular or vertical rays pass through less atmosphere than slanted rays. As a result, they pass through less energy-absorbing impurities, such as dust, and arrive at the earth's surface with more energy. Second, the energy from the rays concentrates in a limited area, like the beam of a flashlight that is directed at the floor. If the rays are slanted (or the flashlight tilted), the same energy is spread over a much larger surface area. Each given area then receives a smaller portion of the total energy.



WHAT HAPPENS TO THE SUN'S ENERGY?

The sun's rays do not always heat the objects they encounter. For example, the sun's rays go right through a transparent material, such as glass, without heating it. When the sun's rays strike shiny surfaces, such as mirrors, the rays are reflected. Those objects also are not heated. Only when the rays of the sun are absorbed are they converted into heat.

In general, solids are better heat-absorbers than liquids, while dark rough objects absorb heat better than light-colored, smooth objects. This explains why sand (a solid) at the beach gets hotter than the ocean (a liquid) in the afternoon, and why people wear light-colored clothing in the summer and darker clothing in the winter.

GOOD ABSORBERS ARE GOOD RADIATORS

Easy come, easy go. Objects that heat up quickly also cool off quickly. At the beach, the sand heats up quickly during the afternoon while the water heats up very slowly. At night, the sand quickly loses the heat it gained during the afternoon and is much cooler than the adjacent water. Consequently, on a hot summer day, it is a good idea to head for water in order to cool off. Since it takes water a long time to heat and cool, the ocean or lake remains cool from the previous winter. During the winter, though, coastal sections and locations near a lake have milder weather, since the water retains some of the heat acquired during the previous summer. This explains why coastal sections get rain during the winter while inland areas, away from the warm influence of the ocean waters, get snow. Likewise, easy come, easy go means inland sections generally have hotter summers and colder winters, while coastal locations adjacent to an ocean or large lake have cooler summers and milder winters.

AIR CLOSEST TO THE EARTH'S SURFACE IS WARMEST

Generally the "bottom" air of the atmosphere is warmest since it receives heat from the earth's surface. Remember that the sun's rays are absorbed by dark, solid objects such as soil. This heat is transferred to the air just above it. Also, since the atmosphere is more dense (more molecules of air per unit of space) near the earth's surface, it absorbs the sun's rays more than the thinner, upper levels of the atmosphere. This explains why the mountains also are good places to cool off during summer heat waves. Generally, air temperatures drop approximately 3½°F for every 1000 feet of elevation. These cooler mountain temperatures also produce more snow than at lower elevations, where temperatures may be warm enough to produce rain.

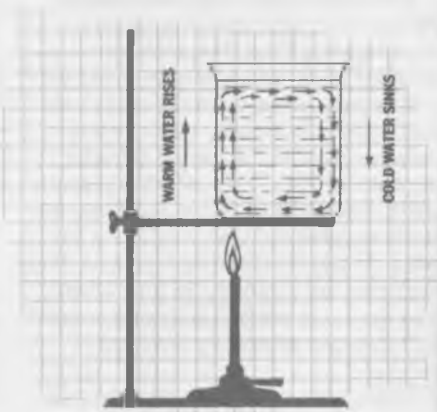
HEAT CAN BE TRANSFERRED

Heat is transferred through the atmosphere in three ways.

1. RADIATION:
Rays of the sun pass through space or transparent objects (e.g. energy from the sun to the earth).

2. CONDUCTION:
Heat is transferred by actual contact. Hot objects touching other objects will pass heat to them. If the ground is hot, the air immediately above it will become hot by coming into contact with the heated ground.

3. CONVECTION:
Heat is actually "carried" from one part of the atmosphere to another. This transfer is accomplished by currents within the heated material as shown in the diagram below.



Heat is applied at the bottom. The heated material above the flame rises. Colder fluid sinks on the opposite side, then flows toward the candle side to replace the rising fluid. A "convection current" is formed. Later we will show how rising and sinking air currents are responsible for much of our weather—both good and bad.

FORECASTING TEMPERATURE: WHAT FACTORS MUST BE CONSIDERED

1. CLOUDS:
When the sun's rays hit clouds, they are reflected back into space, never reaching the ground. Thus, cloudy days are cooler than sunny days. However, at night clouds act as a "blanket" preventing heat loss from the earth. As a result, cloudy nights generally are warmer than clear nights. The *temperature range,* the difference between the highest and lowest temperature in any day, is smallest during cloudy periods.

2. WINDS:
When winds are very light or calm, the air molecules near the earth's surface move very little and are able to remain in contact with the ground below. On a sunny day the ground absorbs the sun's rays and heats up, so the air in contact with the ground is heated. At night, since the ground cools off quickly, air in contact with the cold ground cools rapidly also. Thus, during periods with nearly calm winds and clear skies, daytime temperatures are warm and nighttime temperatures are cold. A larger temperature range occurs. During windy weather, daytime temperatures do not climb as high, and, more importantly, nighttime readings do not drop as low, making for smaller daily temperature ranges.

3. MOISTURE AND CARBON DIOXIDE:
The term *humidity* is generally used to refer to the moisture condition of the atmosphere. If the atmosphere contains a great deal of moisture (high humidity) nighttime temperatures remain mild. This is so because water retains its heat. Therefore, temperature ranges between day and night are greatest when the air is dry (low humidity) and least when the air is moist.

Although it is only a tiny fraction of the earth's atmosphere, carbon dioxide decisively influences the heat balance. Since it possesses a property similar to that of glass, it is transparent to radiation coming from the sun. However, it traps radiation or heat given off by the earth. This captured heat warms the lower atmosphere, preventing strong nighttime cooling. Carbon dioxide levels are highest near industrial sections since carbon dioxide is the by-product of combustion, a common manufacturing process. The atmosphere surrounding large cities contains higher concentrations of carbon dioxide, thus nighttime cooling in large cities is less than in surrounding areas.

4. SNOW COVER:
Daytime temperatures are lower in areas of snow cover since some of the sun's rays are reflected back into space when they encounter this smooth, white surface. At night, snow radiates rapidly whatever heat it has gained. As a result, nighttime temperatures can drop significantly in areas covered by snow.

To sum up:
Coldest nights often occur with cloudless skies, little or no wind, low humidity, and snow cover. *Warmest days* normally occur with cloudless skies, little wind, low humidity, and the ground free of snow cover.

TEMPERATURE INVERSIONS

We discussed earlier that it is normal for "bottom air" near the ground to be warmest. Temperatures normally get colder higher in the atmosphere. However, there are occasions when the bottom air is cooler than the air above. When this happens we have a *temperature inversion.* It occurs most commonly on nights that are clear, calm, and dry. The ground cools off rapidly by radiation, subsequently cooling the air near the ground by conduction. The cold air near the ground, being denser and heavier, stays where it is. The warmer air above, being less dense and lighter, does not sink and make contact with the cold ground. The result is a lack of vertical movement. Convection cannot take place! Under these circumstances, pollutants are trapped near the surface and unhealthy air-quality conditions may result.

Temperature inversions are broken when the sun's rays are able to heat the earth's surface, which in turn heats the bottom air that begins to rise. A convection current is established. As we will show later, temperature inversions often are responsible for certain types of precipitation.

HOW IS TEMPERATURE MEASURED?

We all know that the instrument used to measure temperature is the *thermometer*. But there are several types of thermometers. The liquid version uses mercury or alcohol in a glass column. These liquids expand at a uniform rate as heat increases. Alcohol is used in extremely cold climates since mercury freezes at −39°F and would be useless at temperatures below that. The freezing point of alcohol is −200°F. No place on earth ever gets that cold! (Record worldwide low temperature is −127°F, Vostok, Antarctica.)

Thermometers also can be composed of a dual metallic strip that expands and contracts at varying degrees, causing the strip to bend up or down as the temperature rises or falls. Modern digital thermometers use solid-state electronics to indicate air temperature.

TEMPERATURE SCALES

Temperature can be expressed either in degrees Fahrenheit or degrees Celsius. These simple formulas convert one scale to the other.

To convert a Fahrenheit reading to Celsius, use the formula:

$$°C = \frac{5}{9}(°F - 32°)$$

°F = Fahrenheit Temperature
°C = Celsius Temperature
A Fahrenheit reading of 77° = 25°C

$$°C = \frac{5}{9}(77° - 32°)$$
$$°C = \frac{5}{9} \times 45° = 25°C$$

To convert a Celsius reading to Fahrenheit, use the formula:

$$°F = \frac{9}{5}°C + 32°$$

To convert 25°C back to degrees Fahrenheit:

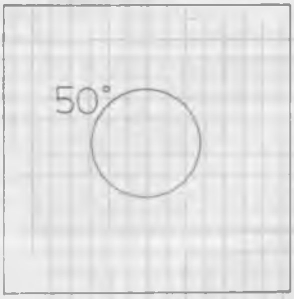
$$°F = \frac{9}{5} \times (25°) + 32°$$
$$°F = 45° + 32° = 77°F$$

To make these calculations easily, use the *Weather Calculator* section of your program.

INDICATING TEMPERATURES ON WEATHER MAPS

1. THE STATION MODEL

Weather observations are taken hourly in all large cities and airports and relayed via high-speed teletype circuits to computers in Washington, D.C., and Kansas City, Missouri. From here they are transmitted nationwide and worldwide. Meteorologists and computers then can record this data on appropriate *station models* shown on a large map. A station model is a circle on a map representing a weather station, usually identified by three letters or numerals. Weather conditions are shown with numbers or symbols at specific locations around this circle. For example, in the diagram below, temperature is placed next to the upper left-hand area of the circle.



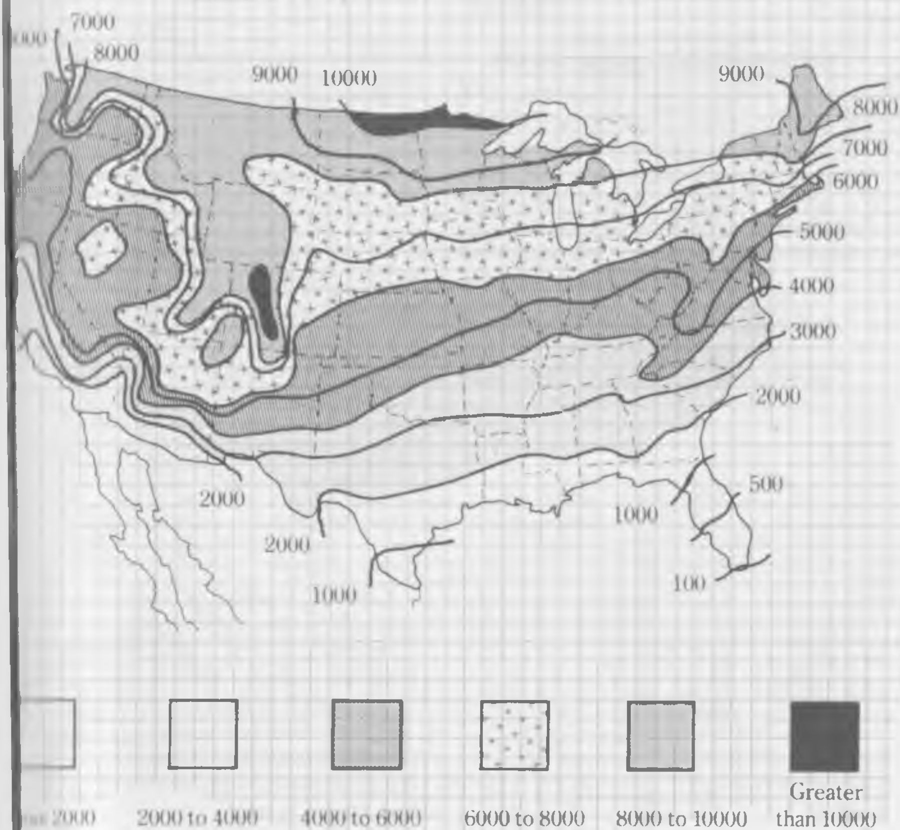
2. KEEPING TRACK

Meteorologists use *heating degree days* to determine how cold a winter is, compared with the previous winter. Heating degree days are calculated for days having a mean temperature below 65°F. Such days are considered to require indoor heating. Degree days are calculated by subtracting the daily mean temperature (the daily high + the daily low ÷ 2) from 65°F. Mean temperatures 65°F or higher are listed as zero.

If on a particular day the temperature ranged from 30°F to 60°F, the mean temperature for the day would be (30° + 60°)/2 = 45°F. Such a day is said to have 20 degree days (65 − 45 = 20). Colder days result in more degree days and more fuel consumption.

The following map indicates the average annual number of degree days across the United States.

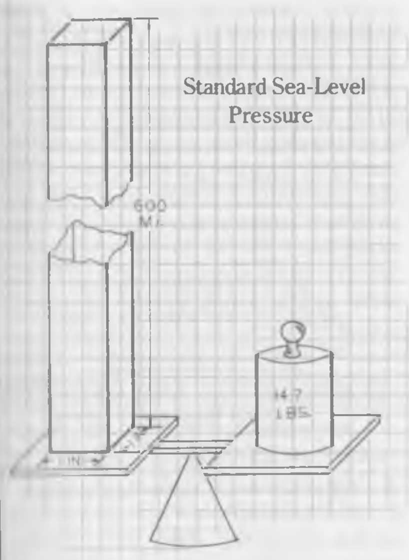
Again, the *Weather Calculator* in your program will make figuring easy. In fact, your degree-day calculations can be stored in the *Weather Keeper*.



Average Annual Heating Degree Days (base 65°F)

CHAPTER 2
AIR PRESSURE: Highs And Lows And Their Influence On Weather

The earth's atmosphere is composed of a mixture of gases. Each molecule of gas in the atmosphere is held to the rotating earth by *gravity*. Being matter, air molecules have weight. It is this weight that causes *air pressure*.

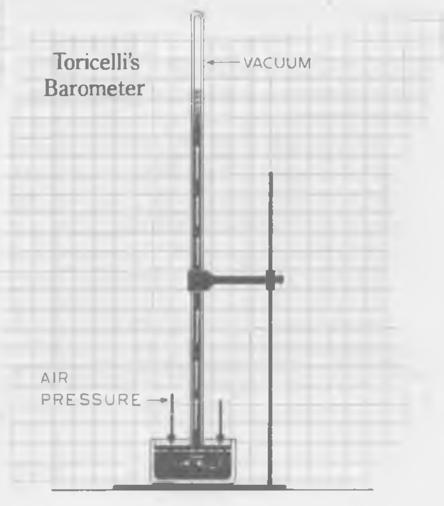


The atmosphere extends 22,000 miles into space. Molecules at the top of the atmosphere exert pressure on the molecules below, creating the most pressure at the surface of the earth. Standard, or average, sea-level pressure is 14.7 pounds per square inch. It is equal to the weight of all the molecules present in a column of air one-inch square in an area 22,000 miles high. Increasing the number of molecules in this column either at the top, middle, or bottom will increase the weight and, subsequently, the pressure at the surface. Likewise, decreasing the number of molecules will decrease the pressure at the surface of the earth. How and when the molecules are increased or decreased will be discussed later in this chapter.

MEASURING AIR PRESSURE

The instrument that measures air pressure is a *barometer* There are two types of barometers, *mercury* and *aneroid*. In 1643, Toricelli invented the mercury barometer when he inserted a glass tube in a dish of mercury and observed the day-to-day variations in the height of the mercury column.

When the atmospheric pressure was high, the greatest pressure was exerted on the mercury in the dish,

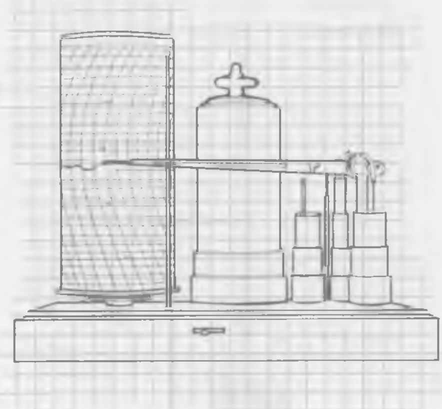


causing the mercury in the glass tube to rise. When the pressure was low, the mercury in the glass tube fell.

The contemporary aneroid barometer employs a vacuum chamber sensitive to external pressure changes. Contraction and expansion of the vacuum chamber, linked mechanically to an indicator needle, move the needle clockwise when the pressure rises and counterclockwise when the pressure falls. A model of a simple aneroid barometer is shown below.

A Simple Aneroid Barometer

A *barograph* is a recording aneroid barometer. It uses a rotating drum with a daily, weekly, or monthly chart attached. The chart shows hours of the day and days of the week as well as a pressure scale.



Barograph

This instrument is extremely helpful in determining pressure changes or pressure "tendencies."

UNITS OF AIR PRESSURE

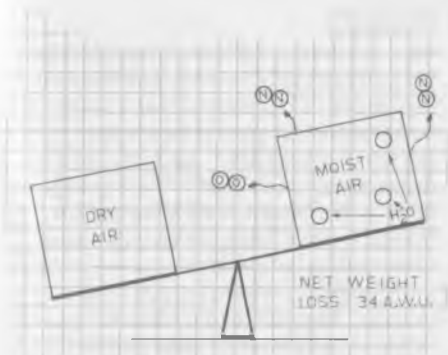
In meteorology, air pressure is commonly expressed in units of "inches of mercury" or "millibars." Each can be converted into the other. Earlier, we mentioned that standard sea-level pressure is 14.7 pounds per square inch. This is the same as 29.92 "inches of mercury," or 1013.2 "millibars."

On modern weather charts the millibar is the unit most commonly used to measure barometric pressure. In order to convert inches of mercury to millibars, simply multiply by a factor of 33.86. For example, a pressure reading of 29.10 inches is equivalent to 29.10 × 33.86 or 985.3 millibars. This reading is considered quite low, which means that there probably is a well-developed low-pressure storm system nearby. On the other hand, should the barometer read 30.80 inches, equivalent to 1042.9 millibars, a very strong high-pressure area exists.

TEMPERATURE AND MOISTURE —HOW THEY AFFECT AIR PRESSURE

Air pressure is dependent upon two factors, *temperature* and *moisture*. Cold air is heavier than warm air and thus exerts higher pressure. In areas where cold air persists for several days, barometer readings are high. On the other hand, low pressure develops where warm air persists.

Another important component of our atmosphere is *water vapor*, or moisture. In order for water vapor to "fit" into the atmosphere, it must replace some of the nitrogen and oxygen. Water vapor is much lighter than either the nitrogen or oxygen whose place it takes, so humid air is lighter than dry air and thus exerts less pressure.

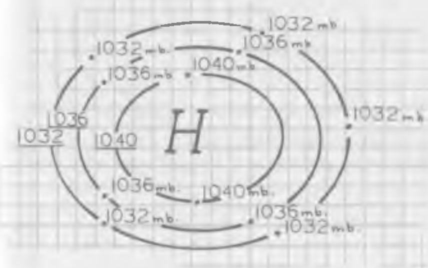


Humid Air is Lighter than Dry Air

The diagram above illustrates how the heavy nitrogen and oxygen molecules are replaced by the lighter H_2O molecules. As water vapor is added, air becomes lighter and pressure decreases. We can determine then that dry air, being heavier than moist air, creates high pressure, while lighter, moist air creates low pressure.

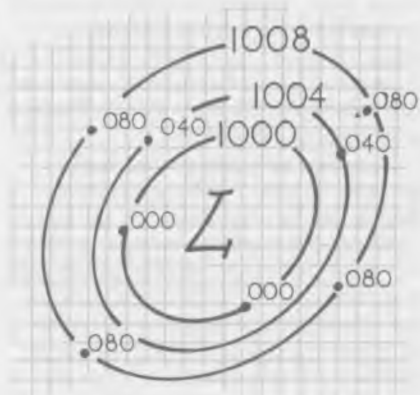
DEVELOPMENT OF PRESSURE SYSTEMS

An area of high pressure should be thought of as a "mountain" of cool, dry air. At the center of the high-pressure system, the highest barometer readings are found. By observing barometric readings at different stations and locating the stations with the highest readings, we can find the center of a "high" and label it with an "H."



A High-Pressure System

High-pressure systems generally form over cool, dry surfaces. Therefore, most high-pressure areas do indeed take shape over land areas, such as Canada and the Arctic.



A Low-Pressure System

An area of low pressure should be thought of as a "valley" of warm, moist air. At the center of the low-pressure systems the lowest barometer readings are found. By observing barometric readings at different stations and locating stations with the lowest readings, we can find the center of a "low" and label it with an "L."

In summary:
High pressure develops where the air is cold and dry, as in central Canada, while low pressure takes shape where the air is warm and moist, as in the Gulf of Mexico. Barometer readings are important because falling pressure indicates the air is getting either warmer and/or more moist, while rising pressure indicates the air is getting either cooler and/or drier.

DRAWING ISOBARS

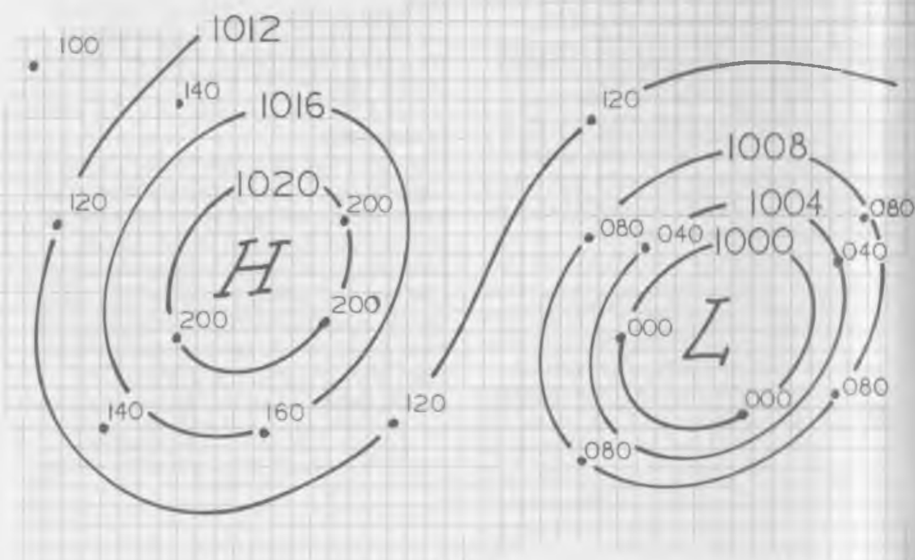
Pressure readings are taken hourly throughout the United States at hundreds of weather stations and relayed to the forecaster via high-speed teletype printers. This data is then plotted on maps. Next, *isobars* are drawn to locate the high-pressure areas and the low-pressure areas. *An isobar is a line that connects all places that have the same pressure readings at the same time.* A finished drawing is shown below.

Note that all stations reporting a pressure of 1008.0 millibars (abbreviated as *080* by recording only the last 3 digits of 1008.0 and removing the decimal point) have one common isobar running through them. The same goes for stations reporting multiples of 4 millibars above and below 1008.0 millibars. On the right side, we are able to analyze a low-pressure system ("L") because pressures decrease towards the center of the low. On the left side, pressure readings increase towards the center, to a maximum of 200 or 1020.0 mb. So we can label the center of the 1020.0 mb. isobar with an "H" for high.

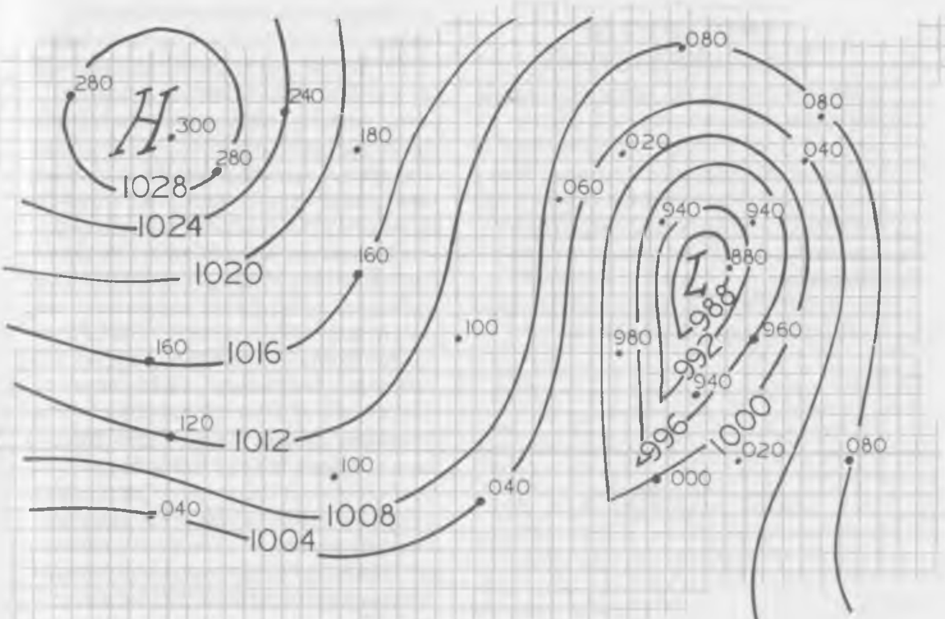
In this illustration only certain isobars are drawn. Isobars are needed for pressures of 1012.0, 1016.0 and 1020.0. We cannot draw an isobar for 1024.0, because there are no pressures reported that high here. Also, we have drawn isobars for 1008.0, 1004.0 and 1000.0. We cannot draw an isobar for 996.0 because there are no pressures observed to be that low.

In summary, isobars are normally drawn at intervals of 4 millibars. In order to keep track of which isobars to draw, simply use one of them, such as the even figure of 1000.0 millibars, then add or subtract consecutive intervals of 4 millibars. Remember to draw isobars only for the data given on the map you have plotted. Be sure to draw all the isobars you can for the data given. The map on page 19 shows another simple isobaric analysis.

Note again that a pressure of 1004.0 mb. is plotted as 040 by recording only the last three digits of the pressure and dropping the decimal point. If the pressure reading is below 1000 mb., such as 996.0 mb., it is plotted as 960. 960 can never be interpreted as 1096.0 mb.,



Isobars



Surface Pressure Map

because barometric pressures never get that high. Also, the plotted value 040 can never be interpreted as 904.0 mb., because surface pressures never get that low. Therefore, 040 must be equivalent to a pressure of 1004.0 mb. Worldwide, surface pressures range from the high 900s to the low 1000s.

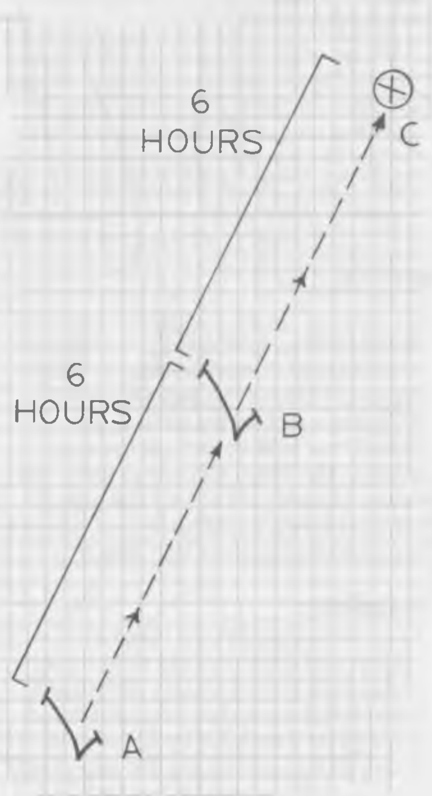
Here's a simple rule to follow: if the plotted value of the pressure begins with a *6, 7, 8, or 9,* place a *9* in front of the plotted digits to obtain the actual pressure, and place a decimal point between the last two digits. If the plotted value of the pressure begins with any other number, place a *10* in front of the plotted digits, and, place a decimal point between the last two digits.

Often there are few stations to work with in analyzing a surface pressure map. Yet, all the isobars in intervals of 4.0 millibars should be drawn for values ranging from the highest pressure to the lowest pressure observed on the particular map. Note that on our map above, the highest reading in the center of the high is 300 (1030.0 mb.); yet, we do not draw an isobar of 1030.0 mb. since it is not evenly divisible by the numeral 4. However, we can draw the 1028.0 mb. isobar, the 1024.0, the 1020.0, the 1016.0, etc., all the way down to the 988.0 (plotted as 880), the lowest plotted pressure on the map. 880 is also exactly divisible by 4, so we are permitted to draw that isobar.

In summary:
Draw smooth isobars in intervals of *4* millibars to accommodate all of the data available to you on a particular map. If the value of any isobar you have drawn is *not* exactly divisible by 4, you have drawn the wrong isobar. It is important that the final analysis be *smoothed out* to eliminate all bumps or sharp corners in the isobars. You may even have to disregard a pressure reading or two to avoid what seems to be an "out-of-the-question" configuration. Pressure systems generally are smooth in nature, and that is of utmost importance in surface analyses. This skill can be achieved only through constant practice.

MOVEMENT OF PRESSURE SYSTEMS

Even this early in the game, it is possible to introduce a commonly used method of forecasting the movement of high- and low-pressure systems. This method is known as *extrapolation.* If the center of a low were at Point A 6 hours ago, and it is at Point B now, we can extrapolate or forecast the storm to move at its current speed and direction to Point C 6 hours from now.

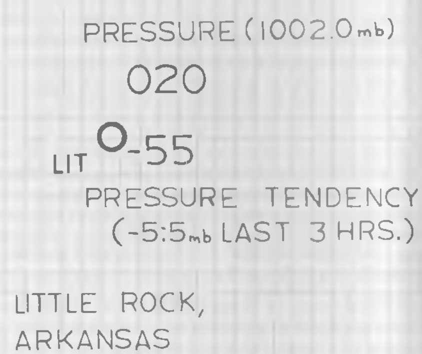


Extrapolation

By using the *extrapolation method,* the low should be at Point C 6 hours from now, assuming that the low continues at the same rate of speed. If it speeds up, the low will be past Point C after 6 hours. If the low slows down, it will not reach Point C after 6 hours.

The *pressure tendency technique* is employed daily by forecasters to help them decide where lows and highs will move. *Pressure tendency* is just what it says, what the tendency of the barometer has been at any given location. Has the pressure fallen, or risen, and, if so, how much? In addition to recording the pressure at the time of observation, each observer records what the pressure has done in the past 3 hours. This is known as the *3-hour pressure tendency.* For example, if the pressure at LIT (Little Rock, Arkansas) were 1008.5 mb. three hours ago, and it is now 1002.0 mb., LIT would report a 3-hour pressure tendency of (1008.5 – 1002.0) or a pressure fall of 5.5 millibars. This is recorded on the weather map as -55. (Note that the decimal point again has been dropped.)

This is how the *pressure* and *pressure tendency* would look plotted on a map at LIT.



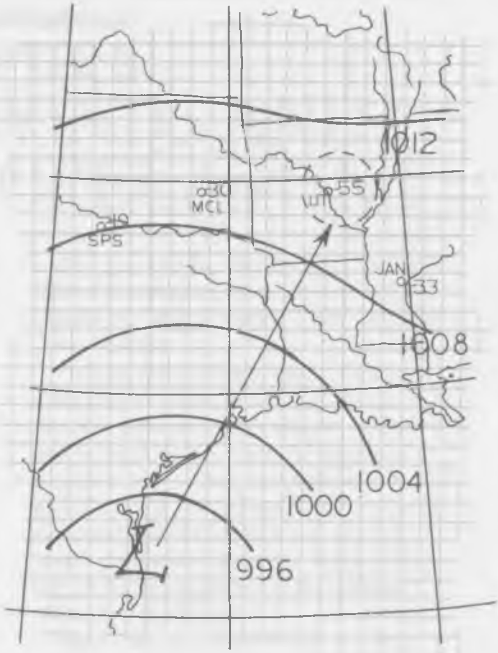
Pressure

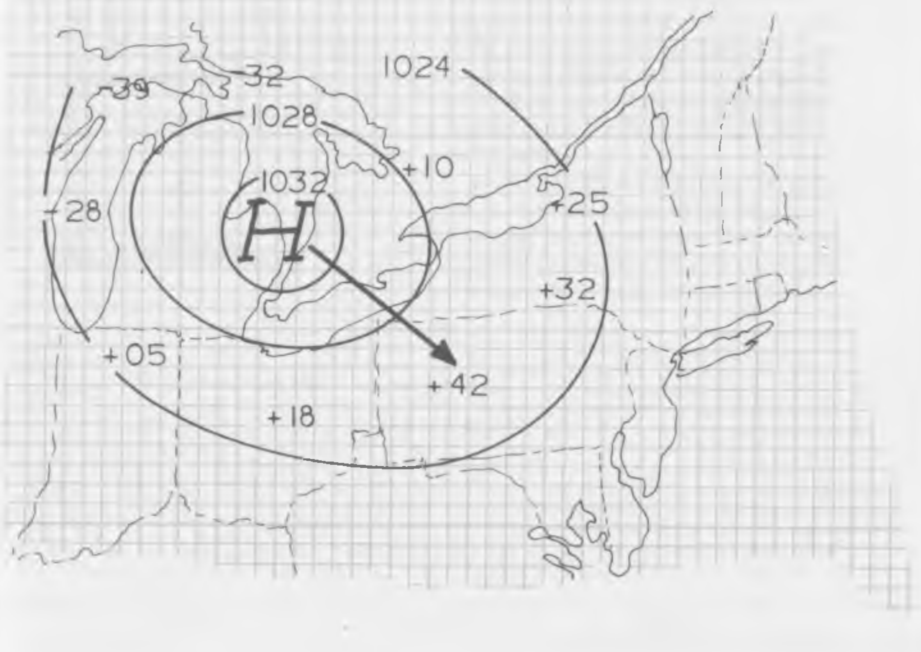
If we know that the pressure at LIT has dropped as much as 5.5 mb. in the past 3 hours, we can come up with two plausible explanations for the effect. Either a low-pressure system is moving toward LIT, or a high-pressure system is moving away from LIT. By studying the isobars on the map, we can decide what is causing the rapid fall. Let us assume that a low is centered near BRO (Brownsville, Texas).

It must be moving in the direction of LIT because all other pressure tendencies are not falling as much as at LIT. Therefore, we forecast the low to move *Northeastward* towards LIT.

Precisely the same technique can be used with a high-pressure area as shown below. Here, the greatest pressure falls are evident north and west of the high, indicating that the high is moving away from those areas. However, there are strong pressure rises south and east of the high. Therefore, the high will move on a line directly toward the area where the pressures are rising the most rapidly. The two forecasting methods of *extrapolation* and *pressure tendency* are extremely important.

If the forecaster can accurately predict both the direction and speed of movement of pressure systems, his/her forecasts will have a high degree of accuracy.

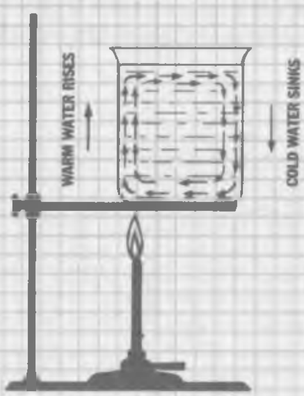




CHAPTER 3
SURFACE WINDS AND WEATHER FORECASTING

Wind is another meteorological element that is extremely important in the study of weather. It can be defined as the horizontal movement of air. Wind is nature's way of correcting unequal pressures across the earth's surface.

The cause of a wind can be explained by comparing our atmosphere with a beaker of water. When heat is applied to the left side of the beaker below, the water is heated, becomes less dense,

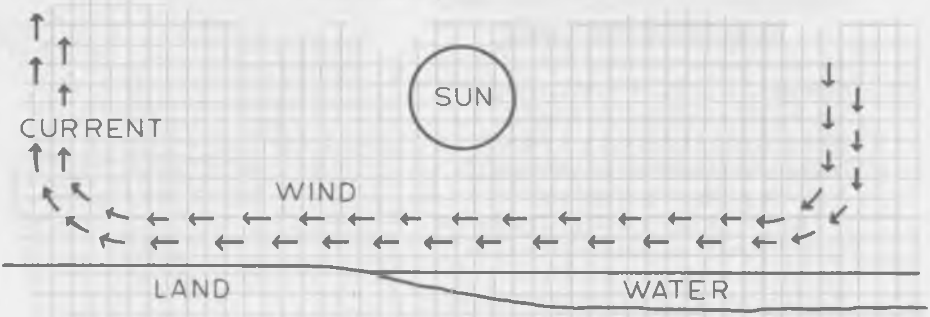


and begins to rise. Water from the right side of the beaker moves to the left to replace the rising water. Thus water is set in motion.

During the daytime, land heats up more quickly than water and the air over the land becomes an area of low pressure. This air, heated from below, begins to rise. The cooler air over the water rushes toward the land, replacing the rising air. At the same time, the cooler air above the water sinks. Thus the air is set in motion and a wind circulation is produced.

Note that winds always blow from regions of cooler temperatures (high pressure) to regions of warmer temperatures (low pressure). The greater the differences in temperatures or pressures, the higher the wind speed. This means that winds that blow from regions of higher pressure to regions of lower pressure are strong, while gentle pressure differences create weak winds.

Our atmosphere reacts in the same manner as the water in the beaker. Unequal heating of the surface causes unequal pressures, which in turn initiate movement of air as shown below.

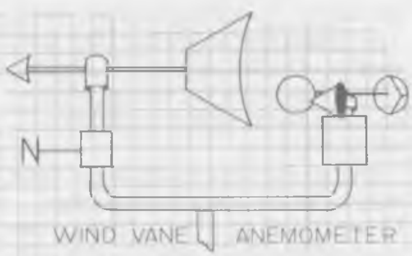


INSTRUMENTS FOR MEASURING WIND

The instrument used to indicate the direction of the surface wind is the *wind vane.* The simplest wind vane consists of an arrow and "feather," balanced and mounted horizontally on a vertical shaft. The shaft usually is set in ball bearings or some other low-friction device to allow the vane to respond to the slightest breeze.

As the wind blows against the "feather," it turns the arrow *into the wind* so that the *arrow points into the direction from which the wind is coming.*

The *anemometer* indicates the *speed of the wind.* The cup anemometer consists of a set of metal cups or hollow cones, all mounted to face the same way. These cups are attached to spokes that, in turn, are mounted on a shaft set in bearings to allow free movement. The cups catch the wind on their open sides. The stronger the wind, the faster the cups turn; subsequently, the higher the reading of the instrument.



WIND NAMES, DIRECTIONS, AND RESULTING WEATHER

A wind is named according to the direction from which it blows. A wind coming *from* the west is a *west wind;* a wind or breeze coming from the sea is a *sea-breeze;* a wind blowing up a mountain from the valley is a *valley breeze.*

There is usually a definite connection between the direction of the wind and the resulting weather conditions. Winds generally transport the weather characteristics of the regions from which they blow. For example, in the United States, winds with a northerly component come from higher latitudes and bring colder weather. Southerly winds, on the other hand, bring warmer weather. Along the east coast of the United States, easterly winds bring moisture onshore. In the wintertime, easterly winds bring warmer temperatures; in the summer, these same easterly winds bring cooler weather. Westerly winds along the east coast of the United States produce dry weather because they are coming from the interior of the continent. During the winter, westerly winds can be quite cold; during the summer, they are generally warm or hot. Along the west coast of the United States, the opposite is true. Westerly winds can bring moisture-laden air since they blow in from the Pacific Ocean.

Winds from the northwest generally bring cooler and drier weather to the

eastern United States, while southwesterly winds bring warmer and drier weather. During the winter months, southeasterly winds produce rainy, but warmer, weather along the east coast. Using these basic rules, it is possible to predict future weather if location and time of year are considered.

DECODING AND PLOTTING WINDS

Wind directions are shown on weather maps with arrows or "sticks" attached to station models that *point into the direction from which the wind is coming.* For example, wind directions would be indicated as follows:

1. Northerly wind: 

2. Southerly wind: 

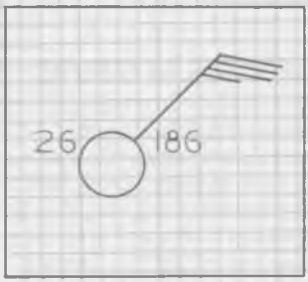
3. Easterly wind: 

4. Westerly wind: 

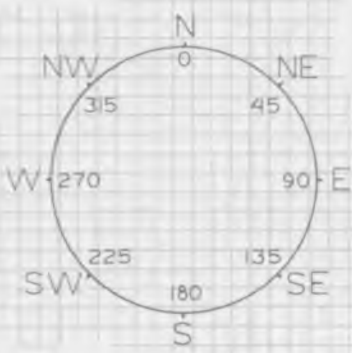
5. Northwesterly wind: 

Speeds are represented by "feathers" or "flags" placed on the "clockwise" side of the shaft. Each full feather represents a speed of about 10 knots while a half-feather indicates about 5 knots. A "flag" with 5 feathers represents a speed of 50 knots.

Below is a station model showing a temperature of 26°F, an air pressure of 1018.6 mb. and a northeast wind of 35 knots. A circle around the station model would indicate calm winds.



Weather data transmitted to weather stations around the country via teletype is in coded form. This information must be decoded before it is plotted on weather maps. The direction of winds is given in "degrees from north"; thus the compass points below must be understood.



CODE FOR SURFACE WINDS

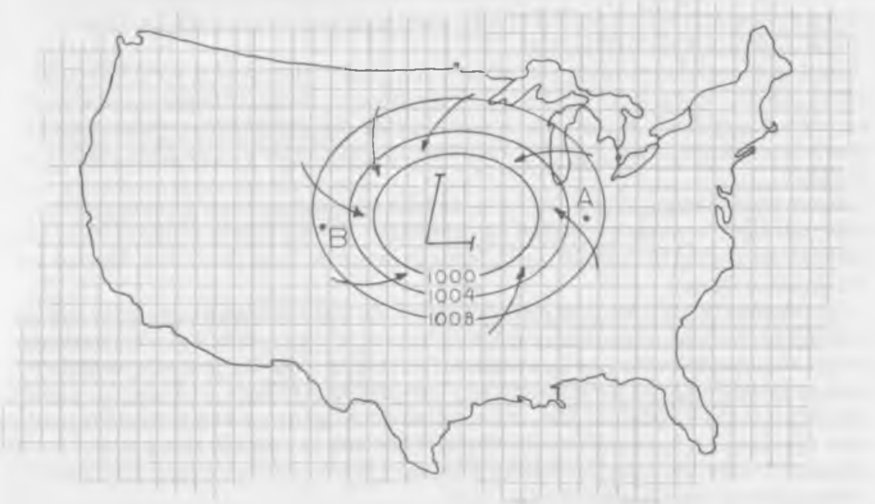
CODED MESSAGE	DECODING	PLOT	EXPLANATION
A. 2715	270° = West 15 = Knots		First two numbers represent direction: 27. A zero must be added. 270 = West, as shown above. Last two numbers represent speed: 15 = 15 knots
B. 0425	040° = N.E. 25 = Kts		
X. 0000	Calm winds no direction		

DIRECTION OF SURFACE WINDS AROUND PRESSURE SYSTEMS

Winds around surface high-pressure systems rotate *clockwise* in the northern hemisphere and are deflected *away from the center,* as shown below. In the center of a high-pressure system, the winds are light and variable in direction or even stable. Cities, such as Indianapolis, Indiana (A), located in the eastern sections of this high-pressure system, would experience northwesterly winds. These winds would sweep colder and drier air into the region. Locations to the west of the high-pressure center, such as Denver, Colorado (B), would experience southeasterly winds. Southeasterly winds would eventually bring warmer and wetter weather into the area. Wind directions can be determined for all areas affected by this high-pressure system.

In low-pressure systems, winds rotate *counterclockwise* and are deflected *toward the center* by friction.

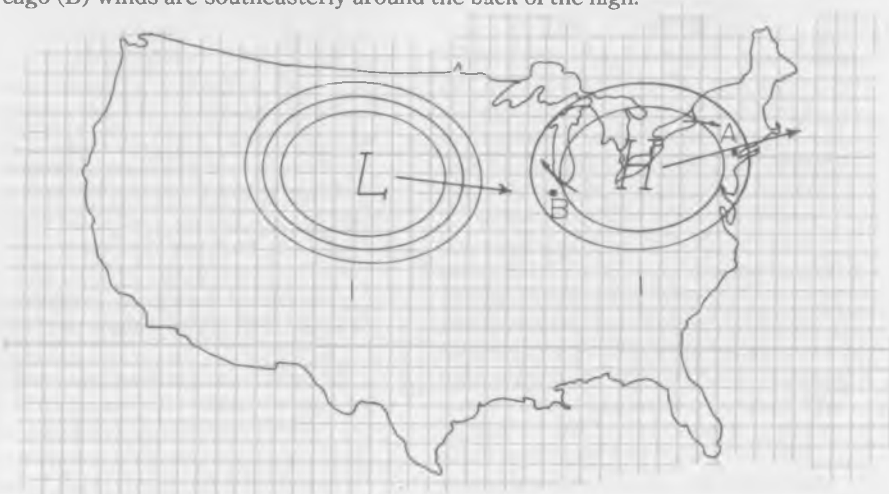
In the map below, cities such as Indianapolis, Indiana (A), located in the eastern sections of this low-pressure system would experience southeasterly winds. These winds would bring warmer and wetter weather into the region. In the western sections of the low-pressure system, such as Denver, Colorado (B), the winds would be northwesterly. Colder and drier weather would sweep into the region. Wind directions can be determined for all areas affected by this low-pressure system.



WIND DIRECTIONS CHANGE AS SYSTEMS MOVE

High-pressure systems and low-pressure systems do not remain stationary. They are usually on the move across the country. This movement of systems is the major cause of shifting wind directions.

The map below shows pressure systems advancing across the country from west to east. The northeastern part of the United States is being dominated by high-pressure. The wind direction in New York City (A) is northwesterly. In Chicago (B) winds are southeasterly around the back of the high.



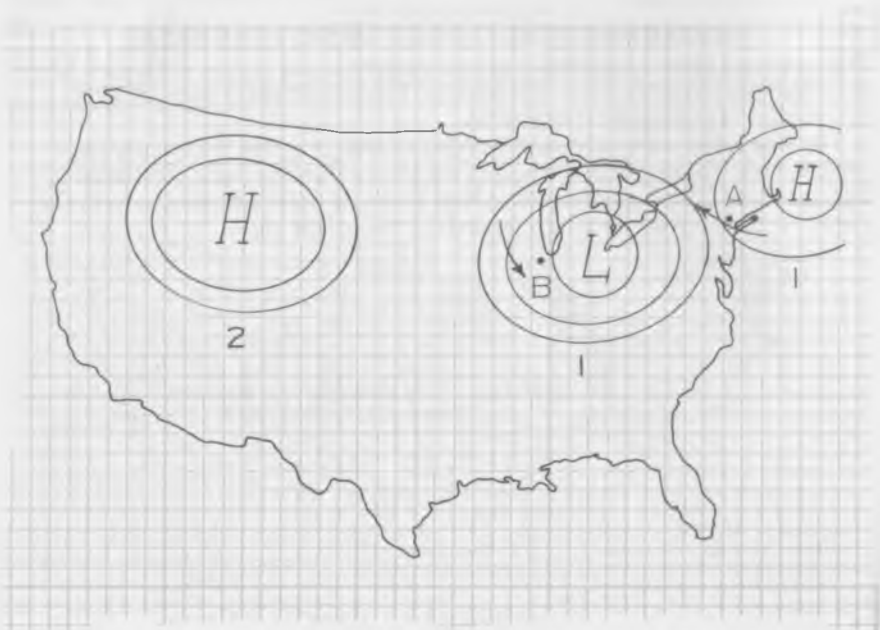
On the following day, as shown in the map below, high-pressure system #1 has moved off the east coast. The wind direction in New York City has shifted from the northwesterly direction of yesterday to a southeasterly direction today. This is the result of the high-pressure system moving out and the low-pressure system moving in. Meanwhile Chicago (B) has had a wind shift from southeasterly yesterday to northwesterly today as a result of low-pressure system #1 moving east.

Accurate weather forecasts can be made only when one knows *in what direction* pressure systems will move and *at what speed* they will travel. Only then can one correctly forecast wind directions.

An experienced meteorologist can tell, at a glance, the present wind directions and those that will result after the pressure systems move. In addition, he/she can estimate the speed of the wind by measuring the distance between the isobars. So now it is possible for you to understand how the forecaster in a weather station works!

From the following map we can see, as high-pressure system #1 moves off to the east, surface winds blow from the southeast. Southeasterly winds in many sections of the United States eventually bring in moisture from the Gulf of Mexico and the Atlantic Ocean.

Notice also that the air pressure would be falling as the high moves away and the low approaches. As a result, when falling barometric pressures and southeasterly winds are input into the weather station, the station indicates that a fair-weather system is moving from the area and/or a low-pressure system is moving in. Clouds and rain would be forecast. Also, if the isobars are tightly packed around the pressure systems, strong winds would result. When you key rapidly rising and/or falling pressure tendencies into the *Weather Forecaster*, you'll find that strong winds will show up in the resulting forecast.

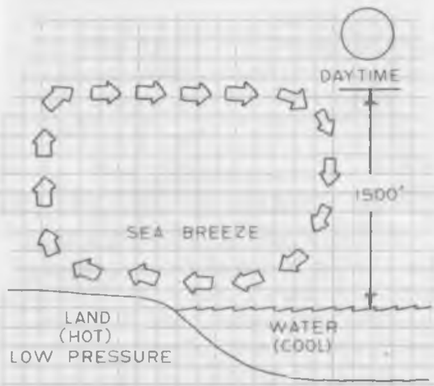


LOCAL WIND SYSTEMS

Local pressure differences because of uneven heating of surfaces in adjacent areas are responsible for local winds. Land and sea breezes as well as mountain and valley breezes are all classified as local winds.

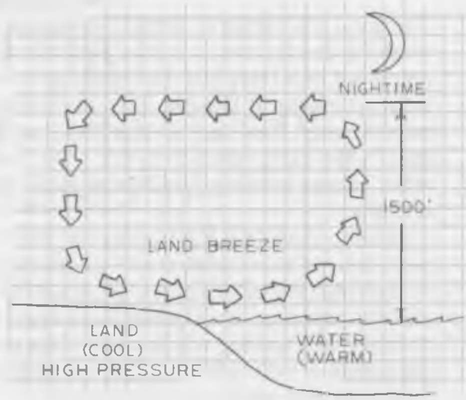
LAND AND SEA BREEZES

During the daytime hours, land areas begin to warm up more rapidly than adjacent water areas as illustrated below.



By approximately 11 A.M., an area of lower pressure is created by surface heating and a gentle breeze begins to blow toward the land. The air over the water, being cool, remains an area of high-pressure. This breeze, blowing from higher pressure (water) to lower pressure (land) increases in velocity until mid-afternoon. During summer afternoons this is known as a *sea breeze.* As the sun dips closer to the horizon during the late afternoon hours, the land begins to cool and the breeze slackens, usually dying down around sunset.

Sea breezes bring relief from the heat on those sunny days, dropping the temperatures as much as 15°-20°. Of course, the greatest cooling is experienced along the immediate shoreline, with decreased cooling further inland, but their cooling effects are diminished as they pass over the warm land.



Land breezes occur at night, as shown above. Rapid nocturnal cooling, or radiation, of the land causes high-pressure to develop over land. The air over ocean waters, retaining its heat, becomes warmer than adjacent air over land areas and develops relatively lower pressure. A gentle flow of air from the land to the ocean commences, usually around midnight, dying down toward sunrise. Land breezes are not as strong as sea breezes.

THE JET STREAM

The Jet Stream is a narrow, meandering belt of high-speed winds, snaking through the sky at altitudes of 30,000–40,000 feet. The Jet Stream is erratic in speed, direction and altitude but usually can be found meandering from west to east. Speeds up to 400 mph have been recorded. Much turbulence is experienced along its "edges," making the Jet Stream important in aviation. Since the Jet Stream exists where cold polar air meets warm tropical air, it is also important to the meteorologist since this zone is one where storms often develop. The Jet Stream will be discussed in greater detail in Chapter 5 in connection with storm development and intensification.

WIND CHILL FACTOR

The wind chill factor is simply a measure of how cold you may feel—no matter what the thermometer shows. For instance, if the temperature is 0° with still air, we do not lose body heat as rapidly as we do when the temperature is 20° and the wind is blowing at 18 mph. This illustrates how wind adds to the chilling effect of temperature. However, it must be remembered, that all people do not experience exactly the same reaction to this type of exposure. Obviously, there are many other factors involved, such as physical condition, individual metabolism, and clothing.

Studies show that the heat lost by the surface of the body due to wind and temperature can be estimated by multiplying a factor for the wind (which gets higher as the wind increases) and a factor for temperature (which gets higher as the temperature decreases). The resulting Wind Chill Index number is a good guide to decide what clothing will be needed for protection against the cold. To help in evaluating the Wind Chill Index, the following scale compares a 20°F temperature with different wind speeds.

Wind (mph) with Temperature 20°F (actual conditions)	Wind Chill Index Equivalent (feels much colder because of wind)	Weather Forecaster's Descriptive Term
10 mph	2°F	Very Cold
20 mph	−9°F	Bitter Cold
35 mph	−20°F	Extreme Cold

The Wind Chill Table below is an excellent tool for practical use. For instance, if a weather broadcast reports the temperature of 30°F with a 10 mph wind, the chart shows that this is equivalent to 16°F and you should dress accordingly. With the same 30°F temperature but with a 20 mph wind, the equivalent effect would be down to 3°E Only in a still atmosphere would the 30°F feel like 30°F

As you can see, the winds are a very important factor in the study of weather. Directional changes can turn warm summerlike weather into bitter cold in a matter of hours. Meteorologists constantly watch the direction and speed of winds as they prepare forecasts for a period of several days. You will see in the following chapters how winds are used to locate fronts on weather maps and locate storm systems around the world.

WIND CHILL TABLE

	°F Dry bulb temperatures															
MPH	35	30	25	20	15	10	5	0	−5	−10	−15	−20	−25	−30	−35	−40
Calm:	35	30	25	20	15	10	5	0	−5	−10	−15	−20	−25	−30	−35	−40
5	33	27	21	16	12	7	1	−6	−11	−15	−20	−26	−31	−35	−41	−47
10	21	16	9	2	−2	−9	−15	−22	−27	−31	−38	−45	−52	−58	−64	−70
15	16	11	1	−6	−11	−18	−25	−33	−40	−45	−51	−60	−65	−70	−78	−85
20	12	3	−4	−9	−17	−24	−32	−40	−46	−52	−60	−68	−76	−81	−88	−96
25	7	0	−7	−15	−22	−29	−37	−45	−52	−58	−67	−75	−83	−89	−96	−104
30	5	−2	−11	−18	−26	−33	−41	−49	−56	−63	−70	−78	−87	−94	−101	−109
35	3	−4	−13	−20	−27	−35	−43	−52	−60	−67	−72	−83	−90	−98	−105	−113
40	1	−4	−15	−22	−29	−36	−45	−54	−62	−69	−76	−87	−94	−101	−107	−116
45	1	−6	−17	−24	−31	−38	−46	−54	−63	−70	−78	−87	−94	−101	−108	−118
50	0	−7	−17	−24	−31	−38	−47	−56	−63	−70	−79	−88	−96	−103	−110	−120

Wind Chill Index *(Equivalent temperature) Equivalent in cooling power on exposed flesh, under calm conditions.*
Wind speeds greater than 40 MPH have little additional chilling effect. Source: National Weather Service.

CHAPTER 4
MOISTURE: An Important Ingredient Of Weather

The availability of water vapor in air is probably the single most important factor in weather.

Development of all clouds and precipitation depends on the moisture content of the air. Will it rain? Will it snow? When? How much? Will the roads become slippery? Common questions on the minds of everybody.

TRANSPIRATION, EVAPORATION, AND EVAPORATIONAL COOLING

Moisture gets into our atmosphere through the process of *evaporation* from bodies of water and *transpiration* from vegetation. Transpiration is a process whereby moisture is evaporated from the undersides of plant leaves into the surrounding air.

However, evaporation from the oceans is the major source of moisture in our atmosphere. In our atmosphere, water constantly changes its state through evaporation. Evaporation is the process whereby liquid water is converted into water vapor. Evaporation is often referred to as a cooling process.

Since all moisture sources are located at the earth's surface, it follows that the atmosphere's moisture is concentrated in the lower *troposphere,* the atmosphere layer closest to the earth's surface. But water vapor in the troposphere can be transported great distances by winds before it is eventually "allowed" to drop out as liquid or solid precipitation.

In weather forecasting, *evaporational cooling* may mean the difference between a heavy rainstorm and a paralyzing snowstorm. Here's how it works: Sometimes snow begins to fall when surface temperatures are as high as 40°F or more. Upon reaching the ground, the snowflakes immediately melt. However, after an hour or so, snow may begin to "stick" on the grass and then slowly spread to the edge of roads and sidewalks. The falling snow continues to cover all surfaces and, depending on the duration of the snowfall, a storm that started out as wet and slushy now poses a threat of heavy snow accumulations. By this time, temperature readings may have dropped to 32°F or below. This drop is the result of evaporational cooling. As the snow began to fall into relatively dry air, some of the flakes "evaporated," thus cooling the surrounding air. This evaporation and cooling process will continue until the air becomes *saturated,* or full of moisture. At that time, the temperature will cease to drop.

It is possible to determine whether falling snowflakes will create either a wet or white "happening." When the snow begins to fall, place a wet cloth around the bulb of a thermometer and put the thermometer in an exposed area outdoors. Water molecules will begin to evaporate, lowering the temperature of the wetted bulb. This evaporation and cooling will continue until no more evaporation takes place from the wet-bulb thermometer. The air is saturated at this temperature. Hence, no more cooling can occur. At this point, the temperature of the wetted thermometer is known as the wet-bulb temperature. The temperature of the air will be the same as this wet-bulb temperature a short time after the onset of the snow. *If the wet-bulb temperature is at or below 32°F, expect the snow to stick eventually,* even though it may not do so at first.

FORECAST HINT:
IF THE WET-BULB TEMPERATURE IS 32°F OR BELOW, EXPECT FALLING SNOW TO STICK EVENTUALLY.

CONDENSATION

In order to fully understand a process called *condensation,* several terms must first be discussed. (Condensation is the process whereby water vapor is changed back to liquid water.) The first term is *capacity.* The capacity of air is the amount of water vapor that it is capable of holding. This depends only on the temperature of the air. The warmer air is, the greater its capacity. The chart below lists some temperatures along with the capacity of the air at that temperature.

CAPACITY OF AIR

TEMPERATURE *Degrees F.*	**CAPACITY** *Grains H_2O Vapor Per Cu. Ft.*
10	0.8
20	1.3
30	2.0
40	3.0
50	4.0
60	6.0
70	8.0
80	11.0
90	15.0
100	20.0

Another term is *absolute humidity.* The amount of water vapor present in the air at any one time is called the absolute humidity. When the absolute humidity is equal to the capacity, the air is said to be *saturated.* For example, if the air temperature is 50°F, it is capable of holding 4.0 grains of water vapor per cubic foot. If the amount of water vapor present at this time is 4.0 grains of water vapor per cubic foot, the air is holding all that it is capable of holding and, therefore, is saturated.

The *relative humidity,* which is the amount of water vapor in the air as compared to what it can possibly hold, is 100%. This is determined by the following formula:

$$\text{RELATIVE HUMIDITY} = \frac{\text{ABSOLUTE HUMIDITY}}{\text{CAPACITY}} \times 100$$

$$\text{R.H.} = \frac{4.0}{4.0} \times 100 = 100\%$$

If the temperature of the air is 60°F and the absolute humidity is 3.0 grains of water vapor per cubic foot, the relative humidity would be 50%. Since air at 60°F is capable of holding 6.0 grains of water vapor per cubic foot, in this case it is holding only one-half that amount.

$$\text{R.H.} = \frac{\text{A.H.}}{\text{CAP}} \times 100 \qquad \text{R.H.} = \frac{3}{6} \times 100 = 50\%$$

The temperature at which air becomes saturated is known as the *dew point.* If the air temperature cools to the dew point, any further cooling will cause the air to release all the water vapor in excess of its capacity, and condensation occurs.

Dew point is a true measure of moisture in the air. High dew point temperature indicates an abundance of water vapor in the air, while low dew point readings indicate dry air. On a weather map, the dew point temperature is indicated near the station as follows:

TEMPERATURE—74°
DEW POINT———74°

When the dew point temperature approaches the air temperature, the relative humidity is high. When the dew point temperature reads the same as the air temperature, as in this case above, the relative humidity is 100%.

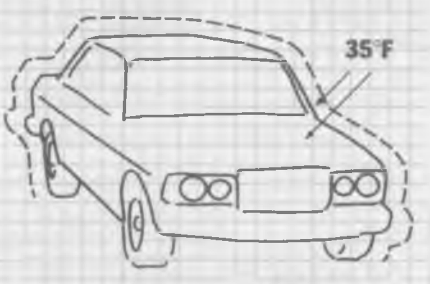
FORECAST HINT:

MINIMUM TEMPERATURES RARELY GO BELOW THE DEW POINT TEMPERATURE OBSERVED AT SUNSET. (When condensation begins, heat is released and warms the atmosphere, preventing temperatures from falling further.)

DEW AND FROST

The dew point temperature is extremely important when forecasting the formation of dew and frost.

Dew is made up of tiny droplets of water that form on blades of grass, cars, ground, or on any surface that has cooled below the dew point temperature of the air.



The air temperature on the night this car was parked was 42°F, and the dew point temperature of the air was 38°F. Since the air temperature was not at the dew point, condensation did not occur. However, solid objects, such as cars, grass etc., cool more rapidly than the air. By night, the temperature of the car was much lower than the temperature of the surrounding air. If the air remained in contact with the cold car for any length of time, and this could have occurred if there was little or no wind, the temperature of the layer of air surrounding the car would drop to the temperature of the car, 35°F. Since the dew point of the air was 38°F, the air temperature dropped "below the dew point," and the water vapor in the air condensed on the surface of the car. However, only the water vapor in the thin layer of air surrounding the car condensed into droplets that clung to the car's surface.

Frost forms in the same way as dew. The only difference is that the dew point temperature must be below 32°F.

Dew and frost form on nights that are clear and calm. This is true because clouds act as a blanket. Cooling would be prevented, so the dew point would not be reached. Wind would keep the air in motion, not allowing air molecules to remain in contact with the solid object long enough to cool. Dew and frost "disappear" when the sun heats the water droplets sufficiently to evaporate them.

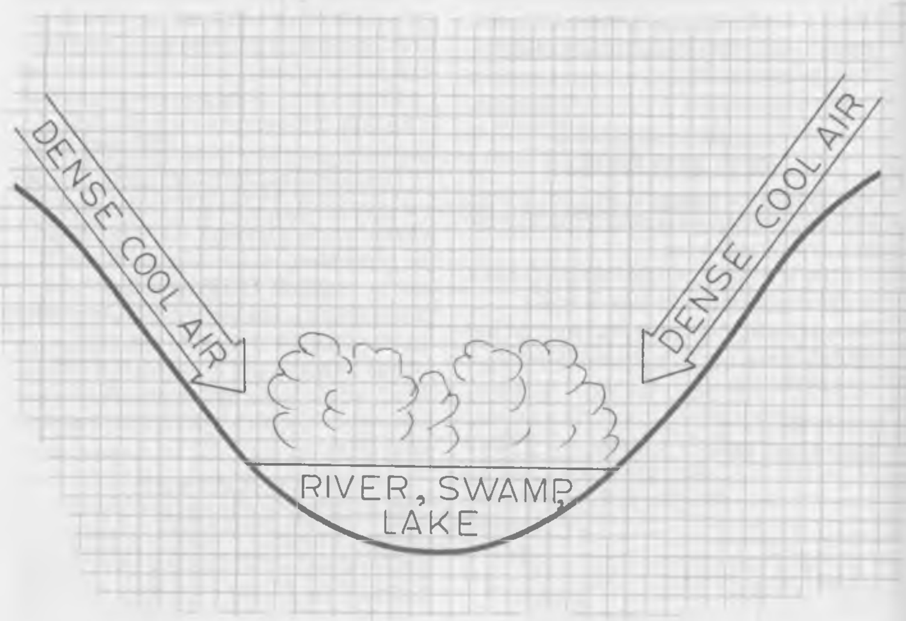
FORECAST HINT:

EXPECT DEW OR FROST TO FORM AT NIGHT WHEN A HIGH-PRESSURE SYSTEM IS CENTERED DIRECTLY OVER THE AREA.

FOG

Although the formation of fog is similar to the formation of dew and frost, there is one major difference. Dew and frost form when the temperature of the air immediately adjacent to a cold surface drops "below the dew point." On the other hand, fog forms when the temperature of an *entire* layer of air drops below the dew point, and water vapor throughout this layer condenses into tiny water droplets.

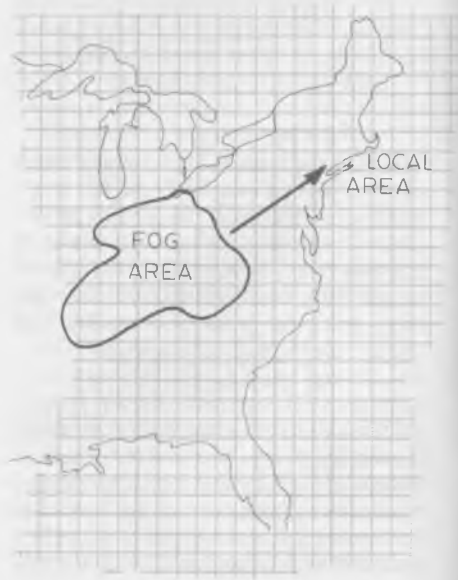
The most common type of fog is *radiation fog*. It forms when the skies at night are clear and the ground rapidly loses heat by the process of radiation. Air, in contact with this cold ground, cools rapidly and temperatures drop "below the dew point." Radiation fogs (also called ground fogs) are most common in valleys, not only because cold air tends to settle in valleys but also because streams and ponds are often found there. These can add water vapor to the air, raising the dew point. As the morning sun begins to heat the air, the fog "burns" away as illustrated below.



FORECASTING FOG

Several factors must be considered when making a fog forecast. First, how much moisture is present in the air? (The dew point temperature indicates the moisture content.) Second, how much cooling will occur in the air? Generally, if the air temperature and dew point temperature are within 5°F at sunset and the skies are clear, the formation of radiation fog is probable.

Weather maps also can aid in making a fog forecast. For example, if weather systems are moving from west to east on a particular day, and your local area is in the east, a glance at fog conditions to the west can be helpful. If visibilities are greatly restricted to the west, and you expect that "parcel of weather" to be in your area during the early morning hours, it is likely that local visibilities will be restricted by fog.



CLOUDS

Clouds are formed when air is cooled, condensing the water vapor already present in the air into tiny water droplets. Generally, the mechanism responsible for cooling the air and forming clouds is rising parcels of air. The manner in which the air rises determines the cloud formation. Air can rise vertically or at a slant. Parcels of air that rise fairly rapidly in the vertical, form *cumuliform* clouds, clouds showing extensive vertical development. Air parcels rising rather slowly and obliquely form *stratiform* clouds. These will be discussed in more detail later.

CLOUDS ON WEATHER MAPS

The amount of clouds in the sky over a particular station is indicated in the station model for the airport, as follows:

○ = **CLEAR:** Less than .1 sky cover

⦶ = **SCATTERED:** 1.1-0.5 sky cover

◫ = **BROKEN:** 0.6-0.9 sky cover

⊕ = **OVERCAST:** More than 0.9 sky cover

NAMING CLOUDS

There are three basic cloud types, *cirrus, cumulus,* and *stratus.* All other clouds are derived from these; thus it is important to know their characteristics.

1. CIRRUS CLOUDS:
High, thin, wispy clouds composed of ice crystals. They are found most often at elevations of 25,000—35,000 feet. The names of all high clouds contain the word CIRRUS.

2. CUMULUS CLOUDS:
White, puffy masses. These clouds are formed from rapidly rising air currents and, thus, exhibit extensive vertical development. Under normal conditions they have flat bases and rounded tops.

3. STRATUS CLOUDS:
Low clouds, forming a blanket-like layer in the sky.

By combining these cloud names and characteristics, a new cloud is named, possessing the characteristics of both parent clouds. For example, *cirrostratus* clouds are high clouds, composed of ice crystals. However, they are lower than cirrus and generally cover the sky in sheet-like fashion.

Two other words must be introduced in order to complete the cloud story. *Alto* means high, but not as high as *cirrus* and *nimbus* generally means precipitation. If you combine these words with the name of a parent cloud, you can name a new cloud.

From all of this information, we can list the names and characteristics of cloud types as well as the weather commonly associated with them. Of course, variations in the described weather are possible.

1. Cirrus Clouds

2. Cumulus Clouds

3. Stratus Clouds

HIGH CLOUD FAMILY: (20,000-30,000 feet)

1. CIRRUS:
They are the highest clouds in the sky. They are composed of ice crystals.

Phenomena: They usually bring fair weather for 36 hours. However, if they thicken in the southwest and become lower, forming cirrostratus clouds, they could foretell rain or snow in 12-24 hours, especially if the surface winds are blowing from the northeast, east, or southeast.

2. CIRROSTRATUS:
These clouds appear as a thin, whitish veil or tangled web in the sky. They are composed of ice crystals.

Phenomena: They produce the *halo* or ring around the sun or moon. They foretell rain or snow in 12-24 hours. However, if the surface winds are from the southwest, cirrostratus clouds usually mean cloudy, warmer weather.

3. CIRROCUMULUS:
These clouds are patches of small globular ice crystals that often look like rippled sand (small, white puffs, flakes, or streaks).

Phenomena: Precipitation is possible in 12-24 hours if the surface winds are blowing from the northeast, east, or southeast.

MIDDLE CLOUD FAMILY: (6,500-20,000 feet)

4. STRATUS:
These form a low gray, uniform layer, resembling fog but not resting on the ground.

Phenomena: They are often associated with drizzle.

5. ALTOSTRATUS:
Clouds that look like a fibrous veil or sheet, gray or bluish in color. The sun or moon is visible through them but they appear as if seen through frosted glass.

Phenomena: If surface winds are from the northeast, east, or southeast, these clouds foretell rain or snow. (Snow or rain generally begins 2-4 hours after the sun or moon disappears completely behind the clouds.) If the surface winds are from the southwest, expect continued cloudy, but milder weather.

6. ALTOCUMULUS:
These are separate little, white or gray rounded "packs of wool." They are not as high as cirrocumulus, thus, "packs of wool" appear larger because they are closer to the ground.

Phenomena: A "mackerel" sky sometimes foretells oncoming precipitation in 12-24 hours if the surface winds are blowing from the northeast, east or southeast.

7. STRATOCUMULUS:
These are long, parallel, gray or whitish rolls of globular masses, often covering the entire sky. Many times they follow the passage of a cold front and may appear more threatening than the weather they produce.

Phenomena: They often indicate strong winds and turbulence.

8. NIMBOSTRATUS:
These are low, gray stratus clouds.

Phenomena: This cloud formation usually produces long, steady, periods of rain or snow. It is a chief precipitation producer.


1. Cirrus Clouds


2. Cirrostratus


3. Cirrocumulus


4. Stratus


5. Altostratus


6. Altocumulus


7. Stratocumulus


8. Nimbostratus

CLOUDS OF VERTICAL DEVELOPMENT: (1,500-50,000 feet)

9. CUMULUS:
These appear as puffs of cotton, usually in the afternoon.

Phenomena: Generally they indicate fair weather for 24-36 hours. However, if they grow larger and larger, forming cumulonimbus, thunderstorms can be expected during the next several hours.

10. CUMULONIMBUS:
(Thunderhead) These are towering clouds that develop from simple, cumulus clouds.

Phenomena: They indicate strong convection with violent up and down drafts. They are often associated with heavy rainshowers and even hail, lightning, thunder, and strong winds.


9. Cumulus

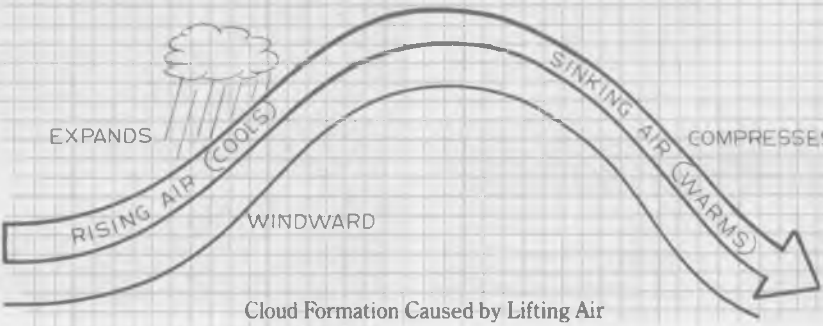

10. Cumulonimbus

PRECIPITATION

Precipitation is the process whereby moisture, in the form of cloud droplets, reaches the ground. The first step in obtaining precipitation is to cool a parcel of air to the dew point. This cooling, necessary for the eventual formation of water droplets or ice crystals, occurs in two ways.

As we said earlier, the first mechanism, and by far the most important one, is *cooling brought about by rising parcels of air.* As a parcel of air rises, it reaches levels where the surrounding air pressure is lower. This allows the parcel of rising air to expand. Any gas that is allowed to expand will cool. This *adiabatic cooling* condenses the water vapor in the rising air into tiny water droplets, forming a cloud.

As air is forced to rise (known as *lifting*) over a mountain range, clouds tend to form on the windward slopes.

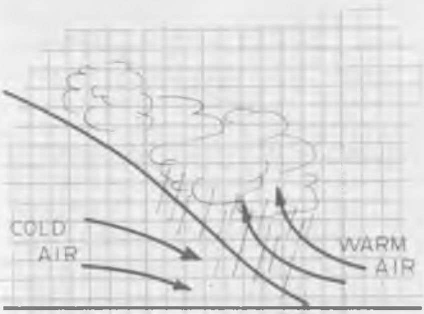


Cloud Formation Caused by Lifting Air

Water droplets in the clouds often cling together around microscopic impurities (such as a grain of dust) in the cloud and eventually get heavy enough to fall as a drop.

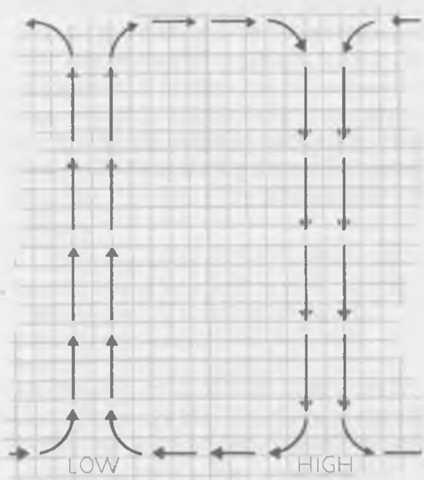
However, on the leeward side of the mountain, the air descends and is warmed by compression. This warming dries parcels of air descending the leeward slopes, creating cloudless skies on the leeward side of high mountains. As the parcels of air reach the valley floor, they are warm and dry, thus, creating a desert climate on the lee of high mountain ranges. Death Valley is a perfect example of this phenomenon.

Precipitation is very common along fronts (cold, warm, stationary, and occluded). Warm air is forced to rise over cold air near the ground. The intensity and amount of precipitation depends on the moisture available in the air as well as the extent to which the air is lifted and subsequently cooled.



Precipitation Caused by Warm Air Lifted Over Cold Air

Excessive and often heavy precipitation occurs in low-pressure systems. Obviously, air must be rising somehow. A cross-sectional view of a low-pressure system shows that low-pressure causes air to flow into the center of a low near the ground, and then upwards, creating rising parcels of air and subsequent cloudiness and precipitation. In a high-pressure system, the opposite effect takes place. Air flows out of the center of the high near



Airflow in High- and Low-Pressure Systems

the ground, allowing air to descend from higher altitudes. Since descending air dries, skies are nearly cloudless in a high-pressure system.

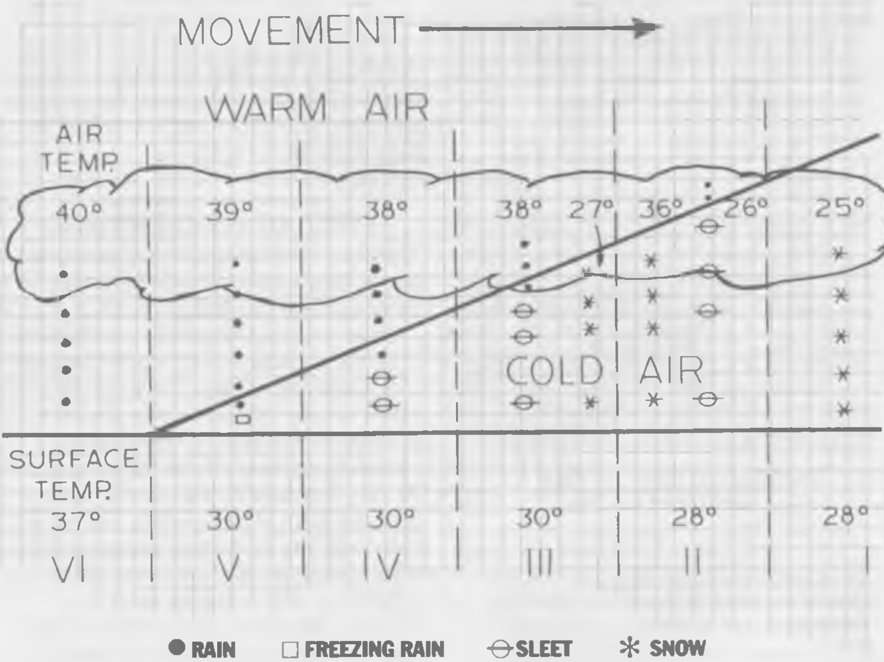
TYPES OF PRECIPITATION

There are five basic forms of precipitation—rain, snow, sleet (ice pellets), freezing rain, and hail.

Rain is simply drops of water falling from the clouds, at least a few thousand feet above the ground. Very fine drops, called *drizzle,* fall from lower clouds such as stratus clouds. The classic *snowflake* consists of a six-sided crystal. At very low temperatures, snow may take the form of ice needles. *Sleet* or ice pellets are formed when raindrops fall through below-freezing layers of air, solidifying into pellets of clear ice. *Freezing rain* forms when drops of rain come in contact with below-freezing surfaces on the ground. This condition, if prolonged, may create an ice storm, causing hazardous driving conditions along with severe damage to trees, shrubs, and telephone and electric wires. Finally, *hail* can be described as alternating layers of snow and ice that resemble an onion in structure. Hailstones, oddly enough, are usually associated with severe summer thunderstorms and are rarely experienced during the winter. Severe thunderstorms are rare during winter because the air is not warm enough to support the very strong updrafts necessary.

Hailstone

The type of precipitation that strikes the ground depends on the vertical and thermal structure of the atmosphere. Following is a diagram depicting the varying vertical conditions that form the different types of precipitation.



Notice that the atmosphere is divided vertically into cold air at the bottom and warm air on the top (Temperature Inversion). The diagram is also divided into six areas. On the following page is a description of each area and its corresponding types of precipitation.

AREA I
The clouds are located completely in the cold air (below 32°F). Since the temperature of the dew point is below freezing, snow forms. As it falls through the air and hits the ground, it does not melt, since the ground temperature is also below freezing. In this case, the snow "sticks."

AREA II
The clouds are located in both the cold air (below 32°F) and warm air (above 32°F). Raindrops are formed. However, as these raindrops in the warm air fall into the colder air below, they eventually freeze and form solid pellets of ice that we call sleet or ice pellets. These pellets reach the ground as sleet, which some people mistakenly call hail. Notice also that a large portion of the cloud is located in the cold air. Since the temperature is below 32°F, snowflakes are formed and fall to the ground and stick. Therefore in area II, a mixture of snow and sleet is falling.

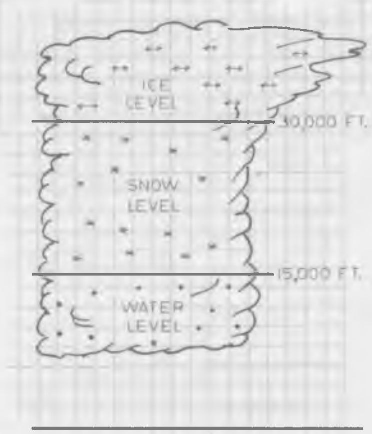
AREA III
This area is similar to area II except that a greater portion of the cloud exists in the warm air. The greater proportion of the precipitation would be ice pellets rather than snowflakes.

AREA IV
The entire cloud exists in the above-freezing warm air. It is no longer possible to have snowflakes falling. However, since the air near the surface is below 32°F, sleet still is the form of precipitation reaching the ground.

AREA V
Again, the entire cloud is located in the warm air. Therefore, raindrops are formed. However, examine the depth of the cold air in area IV compared to area V. The cold air is much "deeper" in area IV. A raindrop has sufficient time to freeze as it falls through the cold air in area IV, but since the cold air is so shallow in area V, the raindrop passes through it before turning into a pellet of ice. Therefore, it strikes the ground as a raindrop. However, since the ground temperature in area V is 30°F, the rain freezes on contact with the ground, forming freezing rain or *glaze*.

AREA VI
The entire cloud is located in the warm air. This causes raindrops to form. Since the surface temperature is above freezing, "ordinary" rain hits the ground.

The movement of the weather system shown is from left to right. If you were located at a station in area I, it would be snowing. As the entire weather system moves over, the snow would become mixed with sleet (area II), would become almost entirely sleet (area III), would eventually turn to all sleet (area IV). The precipitation would then change to freezing rain (area V) and finally to rain in area VI. **Remember the sequence—it is very important! Snow, to sleet, to freezing rain, to rain.** Later you will learn that this diagram represents precipitation associated with the passage of a typical winter warm front.



Hail in a Thunderstorm

As we said earlier, hail is formed only in thunderstorms. In these storms, shown above, strong updrafts and downdrafts of air occur. A raindrop is carried from the water level to the snow level by an updraft. Here the raindrop freezes, forming a pellet of ice, which at this moment is sleet. However, the updraft carries it further up in the cloud to the ice level. Downdrafts of air then carry this growing piece of ice to the bottom of the cloud (water level). If the updrafts are strong enough, the up-and-down journey repeats itself. In violent thunderstorms, strong updrafts may repeatedly throw the hailstone into the higher reaches of the cloud. Each trip adds another layer of snow and ice to the stone, causing it to grow larger and larger. Finally, when the updrafts can no longer support the weight of the hailstone, it falls to the ground.

During very severe storms, hailstones have been found to have circumferences of up to 10-15 inches, weighing as much as 1½ pounds. However, on a hot day in September, 1970, in Coffeyville, Kansas, hailstones 17.5 inches in circumference, weighing 1.67 pounds each were recovered. They were immediately crushed, made into snow-cones, and enjoyed by the residents of Coffeyville.

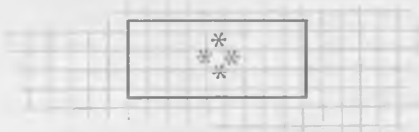
INTENSITY OF PRECIPITATION

PRECIPITATION FORM	INTENSITY	TELETYPE SYMBOL	PLOTTED FORM
Rain	Very Light	R--	•
	Light	R-	• •
	Moderate	R	•˙•
	Heavy	R+	⁘
Snow	Very Light	S--	*
	Light	S-	* *
	Moderate	S	*˙*
	Heavy	S+	⁘ (*)
Rain Showers	Very Light	RW--	•▽
	Light	RW-	••▽
	Moderate	RW	∴▽
	Heavy	RW+	⁘▽

PRECIPITATION AS CODED ON TELETYPE

TELETYPE SYMBOL	WEATHER MAP SYMBOL PLOTTED FORM
R = Rain	•
S = Snow	*
TRW = Thundershowers	☈
L = Drizzle	,
ZR = Freezing Rain	∾
SW = Snow Showers	*▽
RW = Rain Showers	•▽
A = Hail	△▽
IP = Ice Pellets	△

If a station were reporting heavy snow showers, for example, it would be indicated on the station model as follows:



FORECASTING ACCUMULATIONS OF SNOW

As a snowstorm approaches an area, expected snow depths can be forecast by examining the station models for the areas that will affect the region. The following intensities will produce the indicated snowfalls.

1. Very light snow (S--)
1″ of snow every 6-12 hours.

2. Light snow (S-)
1″ of snow every 2-3 hours.

3. Moderate snow (S)
1″ of snow every 1½ hours.

4. Heavy snow (S+)
Over 1″ of snow per hour.

With heavy snow it is possible to accumulate 2-3 inches of snow per hour.

By calculating how long it will snow and how hard it will snow, it is possible to determine how many inches of snow will accumulate.

FORECASTING SNOW VS. RAIN

Perhaps one of the most exciting and challenging aspects of weather forecasting is determining what form winter precipitation will take. If the public is told to expect rain, and heavy snow falls instead, mammoth traffic tie-ups and other snow-related problems crop up. However, if snow is forecast and it rains instead, millions of dollars may be spent on unnecessary precautions. Here are some important parameters to aid the forecaster in determining the type of precipitation that will occur.

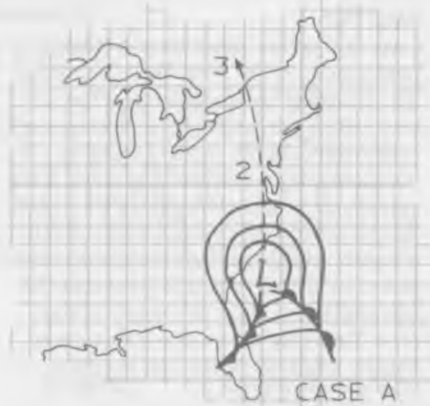
STORM MOVEMENT

The exact movement of the storm system, as well as the locations of other pressure systems, are major concerns in determining which form of precipitation will fall.

In essence, these rules apply for all areas of the country. Storms passing over or to the west of a certain location usually bring rain to that area. Storms traveling just east or south of an area are potential snow "dumpers." Storms too far to the east usually pose no threat of heavy snow. Several examples will illustrate these rules. In each case, a storm develops and moves along the east coast.

CASE "A"

A developing Carolina storm begins moving northward. In the New York City area, winds will become easterly and increase in speed. During the winter season, coastal waters are relatively warm. As a result, winds blowing from these waters will have a warming effect on the lower atmosphere along the immediate coastline. In this case, rain or snow will begin in New York City, depending on present temperature conditions. As the storm reaches point "2", winds in the New York City area will be southeasterly. A southerly component enhances the inflow of warmer air from the south into the area. If the precipitation from the storm did begin as snow in New York City, it would quicky change to rain as the center of the storm passed to the west of the city. Southerly winds would prevail in the New York City area as the storm reached point "2", completely negating the possibility of significant snowfall for the area and creating a nearly all-rain situation.



CASE "B"

Case "B" shows the Carolina storm passing directly over the New York City area. Again, as in Case "A", snow or rain may fall at the outset of the storm, but as the storm approaches the region precipitation will change to rain.

This is because of the warming effect of easterly winds and the fact that the storm center itself is composed primarily of warm air.

CASE "C"

Case "C" is the "ideal" storm track for heavy snow in the New York City area. The Carolina storm moves northeastward along the coast. Precipitation generally starts in the form of snow as northeasterly surface winds pump cold enough air into the New York City area. As the storm reaches point "2", northeasterly winds continue and so does the snow. In fact, it is at this point that the snowfall often becomes heavy in the New York City area since moisture is usually most abundant just in advance

of the center of the storm. When the storm reaches point "3", the winds will change back to northwesterly in New York City. The northerly component pulls down colder, yet drier air, bringing an end to the steady snow. Later, a more westerly component strengthens the drying trend and the skies begin to clear.

CASE "D"

Case "D" produces no significant snow in the New York City area. Here, the storm system and its precipitation shield pass too far to the east of the city. Northwesterly winds pull cold dry air into the area. There may be a few snow flurries however, as colder, less stable air invades the city.

In critical snow-versus-rain situations, elevation above sea level is often the difference between a heavy rain storm and a paralyzing snowstorm. So, nearness to the ocean and elevation are important factors to consider when making a snow-versus-rain forecast. Generally, the surface temperature that separates rain from snow is 35°F.

In the immediate vicinity of the above rain-snow line, more often than not, the precipitation will be mixed. On the cold side of the line, precipitation will be snow, while on the warm side, it will be rain.

CHAPTER 5
AIR MASSES, FRONTS AND STORMS: Nature Shows Its Force

NAME OF AIR MASS	DESIGNATION	SOURCE	CHARACTERISTICS
Continental Polar	**cP**	Central Canada Northern U.S.	Dry and Cold
Continental Tropical	**cT**	Southwest U.S. Mexico	Dry and Warm
Maritime Polar	**mP**	North Atlantic Pacific Ocean	Wet and Cold
Maritime Tropical	**mT**	Gulf of Mexico Tropical Atlantic Pacific Ocean	Wet and Warm

AIR MASSES

An *air mass* is a large section of the lower atmosphere in which temperature and humidity are approximately the same at any given level. Air masses form when large masses of air remain stagnant over a surface, either land or water, for long periods of time. In time the mass of air takes on the characteristics of the surface it is over. If over land, the air becomes dry. Over water, it picks up moisture. If the land is cold, the air gets cold. If the land is warm, the air heats up. So the characteristics of an air mass depend on where it originates—the source region.

In order to distinguish among different air masses, the meteorologist uses a simple classification system shown in this table.

Eventually air masses move from their source regions, bringing their characteristic weather with them. Polar air masses generally move south; tropical air masses move northward and eastward. Most air masses are modified as they encounter different land surface characteristics. The degree of modification will depend on the speed at which the air mass travels as well as the nature of the surface over which the air mass moves.

What type of weather do these air masses produce?

cP:
This air mass produces weather that is cold in winter, cool in summer, with low humidities throughout the year. Cumulus-type clouds are present; yet there are often clear skies. On the leeward side of the Great Lakes and on the windward slopes of the Appalachians, snow flurries may occur. Visibility is generally quite good.

mP:
This air mass produces cool weather in summer, cold in winter, with low humidities throughout the year. The air

mass is often carried long distances from the source region and may dry out when traveling over land areas. On the west coast it produces low cloudiness and fog, and sometimes, heavy rains — even snow in the higher elevations of the Rockies. As it passes over the mountains and descends into the plains, mP warms and dries and is often very pleasant by the time it reaches the east coast. When this occurs, temperatures are mild and cloudiness is at a minimum. There is also good visibility. The mP air from the Atlantic affects only the east coast. It is cold and moist in the winter, often producing layered cloudiness along with sleet or freezing rain, fog, and very cool temperatures, especially during the summer months. Visibility is generally poor.

mT:
This air mass produces very warm weather in summer, mild in winter, with high relative humidities throughout the year. It often has low clouds and fog with poor visibilities during the early morning hours, then hazy sun into the afternoon as clouds develop. Some of these cumulus clouds may build into cumulonimbus clouds, commonly known as *thunderheads*. This air mass brings most of the moisture into the nation.

cT:
This air mass produces warm and dry desert conditions, with good visibility. It has broad temperature ranges between night and day and generally cloudless skies.

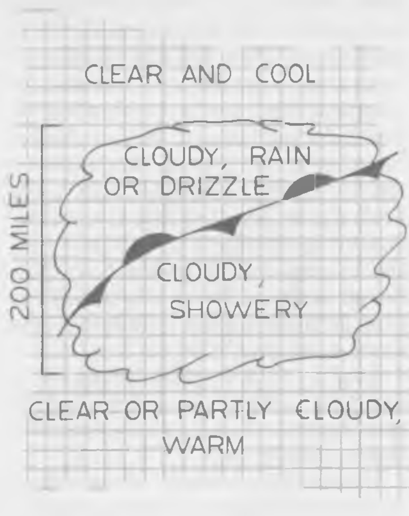
FRONTS

A front is the boundary between two air masses. The greater the difference in characteristics between the two air masses, the stronger the front. Fronts are important for two reasons. First, they are usually accompanied by clouds and precipitation. Second, they usually bring about a change in the weather.

There are four basic types of fronts.

1. STATIONARY FRONT

With a stationary front, cloudiness is prevalent along the entire frontal boundary with most of it occurring in the cold air north of the front, where *over-running* is occurring. Over-running occurs when warm, moist air from the south flows northward, riding up and over the cooler, drier air north of the stationary front. This happens because cold, dry air is heavier than warm, moist air. Such conditions create not only dense cloudiness but often precipitation as well. The extent and intensity of the precipitation is dependent upon *how great a temperature differential exists* across the stationary front. Very cold air to the north and very warm air to the south would result in widespread and heavy precipitation. Low clouds, fog, and drizzle are common, and thunderstorms may occur if the temperature of the warm air is 60°F or higher. These conditions are found all along the stationary front. Any area in which a stationary front lies may see dreary, rainy weather for days, however, several hundred miles north or south of the front, skies are generally clear.

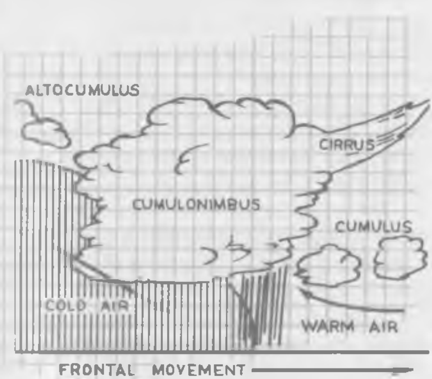


1. Stationary Front

2. COLD FRONT

When the cold front begins sweeping southeastward, most of the cloudiness is thrown out ahead of the front, into the warm air. The illustration below shows a vertical profile of an advancing cold front. Note that the frontal boundary slopes to the left. As a result, the colder air at the surface leads the colder air aloft. Frontal slopes vary. The strongest cold fronts have the most perpendicular slopes. The wedge-like action of a moving cold front forces the warm, humid air in advance of the front to rise. This is the mechanism that creates cloudiness and showers in advance of a cold front. Scattered showers are common with most cold fronts, with thunderstorms limited generally to the warmer months of the year. Severe thunderstorms may develop in advance of rapidly moving or steep-sloped cold fronts, especially in very warm, humid air. These severe thunderstorms often produce hail, along with damaging surface winds sometimes in excess of 50 knots. With the strongest cold fronts—rapidly moving, steep-sloped, strong temperature differential, very warm and humid air ahead of front—tornadoes may occur.

Directly behind the cold front, winds shift to the northwest and skies are clear. If the cold front is moving rather rapidly, skies clear quickly with its passage. A slower-moving front causes cloudiness to linger.

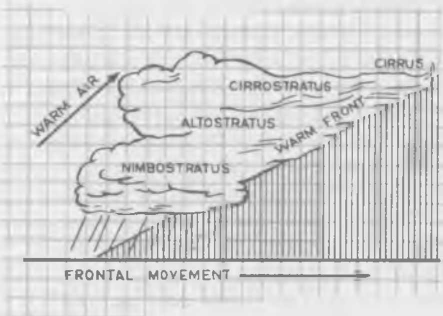


2. Cold Front

3. WARM FRONT

Cloudy, wet conditions prevail ahead—or north—of a warm front. The illustration below shows a vertical profile of a warm front. If the air north of the warm front is cold enough (below-freezing from cloud to ground), precipitation may be snow, then change in to sleet, freezing rain, and, finally, rain as temperatures rise above freezing closer to the warm front.

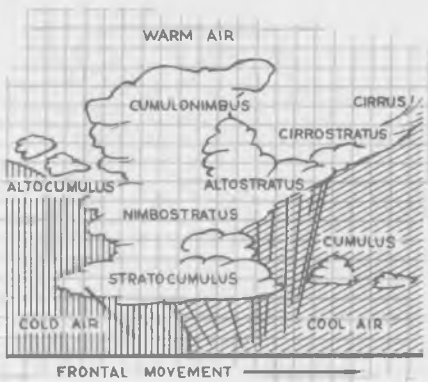
In the warm sector, between the warm and cold fronts, skies are generally partly cloudy, depending upon the moisture present in the warm air.



3. Warm Front

4. OCCLUDED FRONT

Weather associated with an occluded front is similar to that of a cold front. Clouds and showers are evident ahead of the front, with clearing behind the front. A vertical profile of an occluded front is shown below.



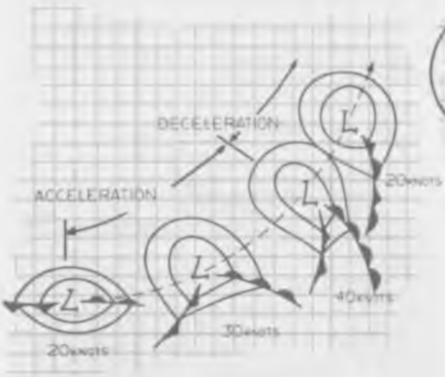
4. Occluded Front

FORECASTING THE MOVEMENT OF LOWS AND FRONTS

There are several very important methods that may be used to forecast the movement of lows and associated fronts. Fronts are associated with and move along with highs and lows. By forecasting the movement of the pressure systems we also forecast the movements of the fronts.

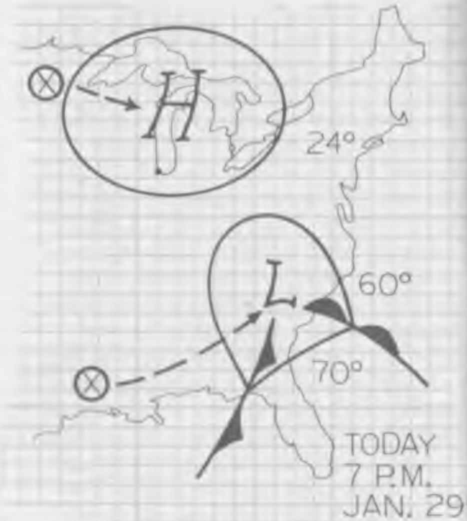
1. EXTRAPOLATION

As we said earlier, extrapolation is commonly used in short-range forecasts. For example, if we know the low has moved 150 miles towards the east in the past 6 hours, chances are that if we forecast the low to continue moving in the same direction for the next 6 hours, we wouldn't be too far off. Extrapolation can also be used if the storm is taking on a curved track towards the northeast. Merely continue the trend for the low to curve more and more towards the north. This tendency for a deepening low occurs in nearly every case. At first, a weak low on what was originally a stationary front scoots eastward, or even south eastward. Then, as it intensifies, the low turns more towards the northeast, speeding up as it goes. The example below illustrates this effect.

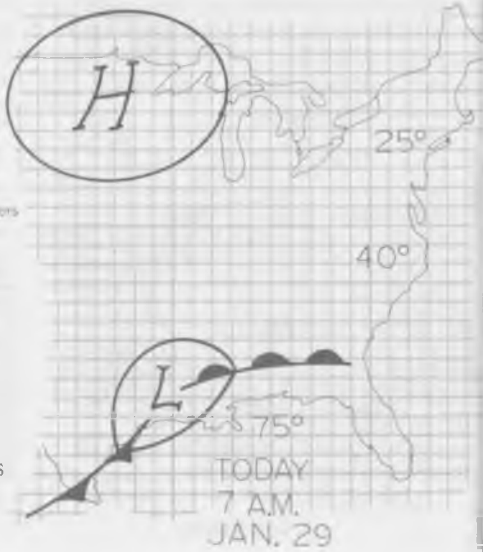


As long as we know the present positions of the low and its fronts, as well as a previous position, we can use the extrapolation technique.

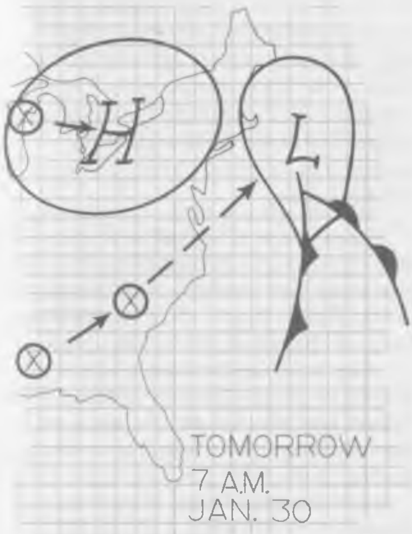
Let's assume it is January 29, 7 P.M. The weather map below has been plotted. We find a high centered over northern Lake Michigan with a low over the western Carolinas. How will the storm move, and how will it affect New York City?



In order to use the extrapolation technique, we take an earlier map, such as the one below for 7 A.M., January 29. It shows the high over Wisconsin with the low back over Louisiana.

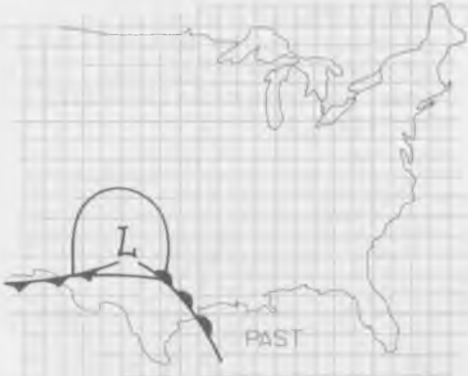


First, draw the position of the systems 12 hours ago on the 7 P.M. map. By looking at the 12-hour movement of the system, we may extrapolate for the next 12 hours, forecasting the high to move to a position near Buffalo and the low to a position southeast of Nantucket Island. We have assumed a steady movement, with no acceleration and not too much northward curvature. If these assumptions hold true, our forecast positions for January 30, as well as our weather forecast, will be accurate.



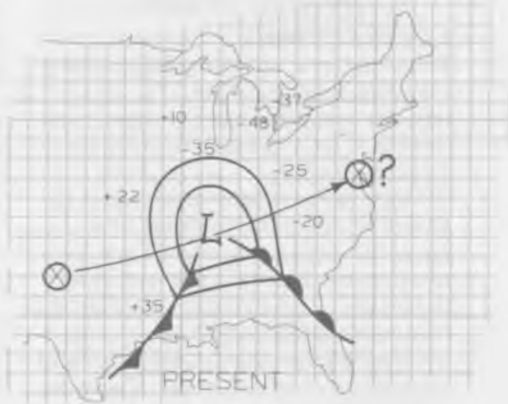
2. PRESSURE TENDENCY

As mentioned before, the other important technique for forecasting movement of systems is by *pressure tendency.* A low will move *toward* an area of pressure *falls* and *away* from an area of pressure *rises.* The method of pressure tendency should be considered as superior to the extrapolation technique, as it often clues the forecaster to new trends regarding a storm's movement. For example, in Map #2, we find a developing low in western Tennessee, while in Map #1 the same low was located in the Texas panhandle. By extrapolation, we forecast the low to be near the Delaware coast in another 12 hours. This, however, would be a grave forecasting



Map #1

error. Because pressure tendencies now show that the greatest pressure falls are occurring, *not east* of the storm as the extrapolation technique would have one believe, *but north* of the storm in the Ohio Valley. This tells the forecaster that the storm is veering sharply to the north as shown on map #3.



Map #2

Significant pressure tendencies must never be ignored and should always take precedence over extrapolation. In terms of the forecast, an error in a situation such as the one just described could mean the difference between a little light snow over the Great Lakes (which would have been the case had the low continued eastward off the mid-Atlantic coast) and the actual forecast of heavy snow and gale force winds from Illinois across the western Great Lakes.

Map #3

STORMS—MOTHER NATURE'S VIOLENT MOODS:

1. THUNDERSTORMS

Thunderstorms are formed when the atmosphere becomes unstable. An unstable condition develops when relatively cold air overruns relatively warm air at the surface.

Most thunderstorms observed in the United States in the course of a year are of the *air mass* variety. That is to say, they are formed in hot, humid air during the afternoon hours, drenching a relatively small area with heavy rain.

Other thunderstorms form just ahead of rapidly moving cold fronts. These are called pre-frontal thunderstorms. The most severe thunderstorms may have hail 1-inch or more in diameter along with wind gusts in excess of 70 mph. Thunderstorms also are observed with the passage of some warm fronts. However, these tend to not be as severe as the ones developed by the wedge-like action of rapidly advancing cold fronts.

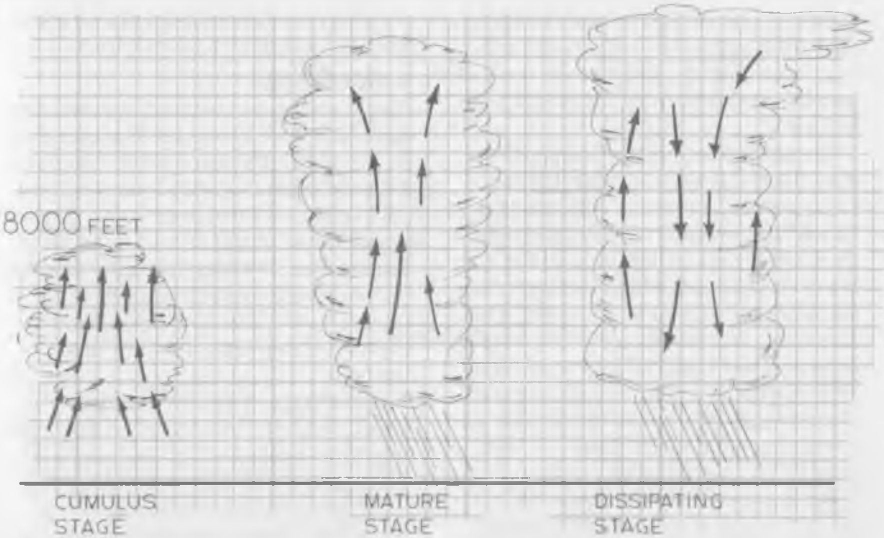
The typical thunderhead or cumulonimbus cloud takes shape when warm, rising air currents build a puffy cumulus cloud. In the cumulus stage, the cloud, as viewed from the ground, darkens, and light, showery precipitation is observed beneath the cloud. If warm air continues to feed into the cloud from the ground, it builds rapidly. Once the cloud towers above 30,000 feet or so, it is capable of producing bolts of lightning and thunder. When the cloud builds to its maximum height, it is termed "mature." At this point, it is releasing heavy precipitation, often hail, lightning, thunder, and strong wind gusts, along with severe turbulence. The storm diminishes during the dissipating stage. The three stages (cumulus, mature and dissipating) are shown on the next page.

The *lightning* observed with thunderstorms is a discharge of static electricity that has built up on cloud particles. This is the result of tremendous frictional forces set up by the severe turbulence in the cumulonimbus cloud. The more severe thunderstorms exhibit violent lightning discharge, along with the resulting "sonic-boom," commonly known as *thunder.*

In the thunderstorm, the greatest danger is from lightning. When lightning discharges take place from the cumulonimbus cloud to the ground, the bolt of lightning often strikes the highest and most convenient point. Lightning striking a tree can cause it to disintegrate or explode. Many people are hit by lightning each year and killed.

During a thunderstorm, it is foolish not to take shelter. Head for shelter immediately if the sky appears threatening in the west, and force yourself to move even more quickly if thunder and vigorous lightning flashes are already occurring in the distance. In particular, a lake or the ocean is one of the worst places to be caught in a thunderstorm.

One simple method of calculating how far away a thunderstorm is located is to count the seconds between the



lightning discharge and the audible thunder. We see the lightning flash almost instantaneously, but sound only travels at *1100 feet per second.* Using this knowledge, you can take several different readings and determine how far away the storm is and whether it is coming closer or moving farther away. For example, if there is a time lag of 8 seconds between the lightning and the thunder, the distance to the cloud from where you are should be about 8,000 feet, or about 1½ miles. A few minutes later, if the time lag has diminished to 4 seconds, this means the thunderstorm is less than a mile away and moving closer.

Many buildings in thunderstorm-prone, open areas, are equipped with lightning rods, which conduct lightning discharges directly into the ground to prevent damage. Occupants of automobiles as well as airplanes are generally safe in the vicinity of thunderstorms; yet, no pilot should ever fly into a cumulonimbus cloud where severe turbulence is prevalent since severe damage may occur, possibly causing loss of control of the aircraft.

Intense, gusty winds are associated with more severe thunderstorms. They are the result of strong downdrafts of cold air that hit the ground, often creating wind gusts of 70 mph! These winds seldom last for more than a few minutes in any one location, since they are directly associated with a certain thunderstorm often barreling along at 40-50 mph. However, just one gust of wind is enough to cause severe damage, broken tree limbs, and downed power lines, creating temporary local blackouts.

2. TORNADOES

Tornadoes are the most severe examples of Mother Nature's wrath currently known. Most tornadoes occur in an area having severe thunderstorms and form as a result of the tremendous instability that can be caused by warm, muggy air on the surface and very cold, dry air aloft. Most tornadoes occur just ahead of rapidly moving, strong cold fronts. Tornado-spawning grounds in the United States are the midwest, the southern plains from Texas to Missouri, and the deep south, from Arkansas to Mississippi and Florida. This is because these areas are often affected by very warm, humid air masses, which are replaced rapidly by cold, dry air from the north and west. Most tornado activity occurs in the spring when the greatest temperature differentials are set up between the warm air flowing up from the Gulf of Mexico and the still-cold polar outbreak racing south and east from Canada. The two air masses usually involved are cP air pushing into mT air.

Tornadoes are most often sighted visually or tracked on radar. On the radar screen, a tornado appears as a "hook" in the midst of several severe thunderstorms. Winds around the center of the cyclonic whirl have been estimated as strong as 500 mph! The diameter of a tornado may vary from as little as a few hundred feet to as much as a quarter of a mile. A tornado most often begins as a *funnel cloud.* That is, a whirling pitch-black mass that dips out of a turbulent cumulonimbus cloud, lowering itself until it reaches the ground where it rips a path of violent destruction.

A severe tornado can completely demolish everything in its path, including steel beams and concrete. A tornado can throw a railroad car several hundred feet, pick up a house and put it down a quarter of a mile down the road. Very low pressure in the center of the tornado often creates a vacuum over the path it travels, causing houses in its way to explode. Nothing is safe, unless it is underground. If the Weather Service issues a *tornado warning,* this means that a tornado has been sighted in the area, and immediate shelter should be sought. Most homes and businesses in tornado-prone areas of the country provide storm cellars for protection.

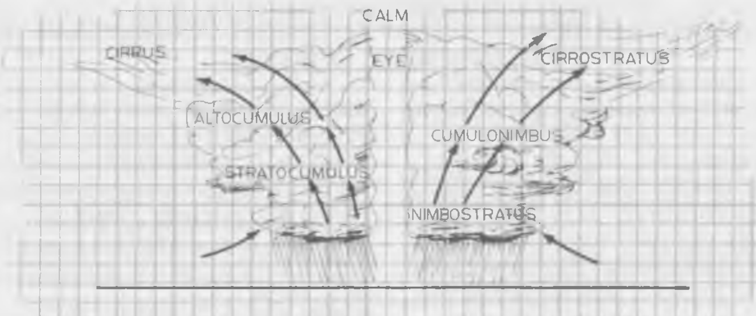
Today, all severe weather forecasting is handled nationwide by the Weather Service's Severe Weather Center located in Kansas City, Missouri. All *severe thunderstorm watches* as well as *tornado watches* and *warnings* are issued by Kansas City and immediately relayed to local Weather Service offices, where the information is disseminated to the public by radio and television. The art of forecasting severe weather has reached the stage today where it is quite unusual for a tornado to occur in an area that has not been placed under a tornado watch by Kansas City.

3. HURRICANES

The hurricane is the most severe *large-scale* storm we know. Its diameter may range up to a thousand miles, but most are only several hundred miles across. All hurricanes form over warm, tropical ocean water, north as well as south of the equator. In order to qualify as a hurricane, winds must be clocked at 75 mph or more. The illustration below shows a cross-sectional view of a hurricane.

A hurricane may develop from a weak, westward-moving disturbance in the trade-winds belt. These weak disturbances are known as *easterly waves.* Associated with easterly waves are numerous thunderstorms and gusty winds along with locally heavy downpours. Some easterly waves never intensify beyond heavy downpours, yet some, especially during the months from June through October, intensify into *tropical storms.* To classify as a tropical storm, winds must be greater than 40 mph. The tropical storm generally moves toward the west or northwest at about 5-15 mph. Should it continue to intensify, it may become a hurricane.

Easterly waves that make it to full hurricane intensity are of great concern to the forecaster. On the oceans, hurricane-force winds produce tremendous seas, 30-50-feet high near the storm's center, making navigation hazardous. If these tropical monsters reach land, greater problems arise. Hurricane-force winds cause widespread damage, heavy rains create flooding, and high tides associated with the advance of the hurricane are often as high as 20 feet above normal! The forecast center handling most hurricane and tropical storm forecasts is located in Miami. Tropical disturbances are tracked at sea by the use of satellite photography. As the disturbances come within range of aircraft reconnaissance, pilots actually fly a plane right into the eye of the storm. These famed *Hurricane Hunters* inves-



Cross-Sectional View of a Hurricane

tigate the ingredients of the storm, i.e., central pressure, wind speeds, and movement. When a tropical storm comes within reach (usually 200-250 miles) of land-based weather radar, it can be tracked by the minute as it nears the coast.

Heavy thunderstorms occur in spiral bands around the hurricane's center. Many of the thunderstorms are severe, with cloud heights in excess of 40,000 feet. In addition, tornadoes can be spawned from hurricanes, creating even more severe damage than the overall effect of hurricane-force winds, high tides, and copious rains.

The areas most affected by tropical storms and hurricanes are those coastal sections bordering on the western sides of the tropical oceans. A tropical storm may affect the Leeward Islands first, as well as those farther north in the Caribbean chain, such as the Virgin Islands, Puerto Rico, and Cuba. While some tropical storms head westward into the Gulf of Mexico and make landfall anywhere from Mexico to Florida, about half of these make a northward curve, often affecting eastern Florida and the east coast up to Cape Hatteras. Few manage to hit land areas north of the Virginias since they get caught in upper-level westerly winds that tend to push them out to sea into the North Atlantic shipping lanes north of Bermuda. Once they get this far north, they no longer have warm water from which to draw their energy. Then the tropical storm either dissipates or, as is most often the case, loses all tropical characteristics and becomes an *extra-tropical* cyclone, or a low.

Once a tropical storm makes landfall, it can no longer intensify because it has lost its source of energy—warm, ocean water. It will dissipate gradually over a 24-48 hour period, losing its ferocious winds, but heavy rains may persist and spread north and west inland, perhaps thousands of miles away from the storm's spawning grounds.

In the years ahead, research will continue in the field of tropical meteorology. Not only will emphasis be placed on forecasting the movement and intensity of these storms but also taming the violent winds. Maybe someday scientists will be able to steer hurricanes. A tall order indeed! Controlling the movement of such storms poses many problems. For example, where do you allow such a storm to strike? Do you turn a hurricane away from land areas thereby losing the valuable water that such a storm drops? Many legal and moral questions arise. So far though, we have not had to face these problems as Mother Nature has kept her secrets well protected.

It is hoped that these few chapters on weather have given you some background into the very complicated field of meteorology. With constant use of your program, your knowledge should continue to grow. Perhaps someday you might even want to make a career of trying to solve some of the problems invented by Mother Nature.

COLLEGES AND UNIVERSITIES WITH DEGREE PROGRAMS IN THE ATMOSPHERIC SCIENCES

ALASKA, UNIV. OF, Fairbanks, AK 99701. Depts. of Geosciences, Space Physics & Oceanography. B.A., B.S., M.S., Ph.D.

ARIZONA, UNIV. OF, Tucson, AZ 85721. Dept. of Atmospheric Sciences. M.S., Ph.D. Summer course in elementary meteorology.

ARIZONA, NORTHERN UNIV., Flagstaff, AZ 86011. Depts. of Physics & Atmospheric Sciences. B.S., M.A., M.S. Selected summer and evening courses.

CALIFORNIA STATE UNIV., Northridge, CA 91330. Depts. of Geography & Geosciences. B.A., M.A., B.S., M.S. Occasional undergraduate evening courses.

CALIFORNIA, UNIV. OF, at Davis, CA 95616. Dept. of Land, Air & Water Resources. B.S., M.S., Ph.D.

CALIFORNIA, UNIV. OF, Los Angeles, CA 90024. Depts. of Atmospheric Sciences and Earth & Space Sciences (Program in Geophysics & Space Physics). B.S., M.S., Ph.D.

CALIFORNIA, UNIV. OF, San Diego, La Jolla, CA 92093. Dept. of the Scripps Inst. of Oceanography. M.S., Ph.D.

CHICAGO, THE UNIV. OF, Chicago, IL 60637. Dept. of the Geophysical Sciences. B.A., M.S., Ph.D.

COLORADO STATE UNIV., Ft. Collins, CO 80523. Dept. of Atmospheric Sciences, Fluid Mechanics & Wind Engr. Program; Dept. of Civil Engineering. M.S., Ph.D.

COLORADO, UNIV OF, Boulder, CO 80309. Depts. of Astro-Geophysics & Geography. M.A., M.S., Ph.D. Summer and evening courses in introductory astronomy.

COLUMBIA UNIV., New York, NY 10027. Dept. of Geological Sciences & Lamont-Doherty Geological Observatory of Columbia Univ., Palisades, NY 10964. B.A., M.A., Ph.D.

CONNECTICUT, THE UNIV. OF, Avery Point, Groton, CT 06340. Dept. of Marine Sciences. M.S., Ph.D.

CORNELL UNIV., Ithaca, NY 14853. Dept. of Agronomy, Div. of Atmospheric Sciences Unit. B.S., M.S., Ph.D.

DELAWARE, UNIV. OF, College of Marine Studies, Newark, DE 19711. Physical Oceanography Program. M.S., Ph.D.; also Univ. of Delaware, Newark, DE 19711. Dept. of Geography. B.A., M.A., M.A., Ph.D.

DENVER, UNIV. OF, Denver, CO 90208. Depts. of Physics, Geology & Geography. B.S., M.S., M.A., Ph.D. Summer courses in astronomy.

DREXEL UNIV., Philadelphia, PA 19104. Dept. of Physics & Atmospheric Science. M.S., Ph.D.

DUKE UNIV., Durham, NC 27706. School of Forestry & Environmental Studies. M.E.M., M.S., Ph.D.

FLORIDA INST. OF TECHNOLOGY, Melbourne, FL 32901. Dept. of Oceanography & Ocean Engineering. B.S., M.S., Ph.D. Some evening courses at beginning M.S. level.

FLORIDA STATE UNIV., Tallahassee, FL 32306. Dept. of Meteorology. B.S., M.S., Ph.D. Correspondence course in elementary meteorology.

GEORGIA INST. OF TECHNOLOGY, Atlanta, GA 30332. School of Geophysical Sciences (Atmospheric Sciences Program). M.S., Ph.D.

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GLOSSARY

ADVECTION FOG: A type of fog formed when warm, moist air flows horizontally over a colder surface.

ANEMOMETER: An instrument that measures and indicates the momentary velocity of the wind.

BAROMETER: An instrument that measures atmospheric pressure.

CELSIUS SCALE: A scale on which the fixed points of freezing and boiling of water are 0° and 100° respectively at standard atmospheric pressure.

COLD FRONT: The leading edge of an advancing mass of relatively cold air.

CONDENSATION: The process whereby water vapor is reformed into water or solid ice crystals.

CONTINENTAL AIR MASS: An air mass that originates over a land area and is relatively dry.

CUMULIFORM CLOUDS: Refers to clouds having dome-shaped upper surfaces with horizontal bases.

CYCLONE: Any area of low air pressure in which winds spiral into the center. All hurricanes and tornadoes are cyclones but not all cyclones are hurricanes or tornadoes.

DEW POINT: The temperature to which air must be cooled in order to become saturated. Cooling below this temperature results in condensation.

DRIZZLE: Precipitation in the form of very fine drops of water falling very slowly from stratus clouds. It is the same as mist.

FAHRENHEIT SCALE: A scale on which the fixed points of freezing and boiling of water are 32° and 212° respectively at standard atmospheric pressure.

FRONT: A definite boundary or mixing zone (a few miles wide) occurring between two adjacent air masses.

GREENHOUSE EFFECT: The phenomenon whereby air is able to absorb long heat waves from the Earth after allowing the Sun's short wave radiation to pass through it.

HAIL: A form of precipitation. It consists of irregular balls or lumps made of concentric layers of ice and snow. Hail is associated with thunderstorms.

HUMIDITY: The water vapor content of the air.

HURRICANE: A violent disturbance that develops over the oceans in the tropics. It has wind speeds of 75 miles an hour or greater.

HYGROMETER: An instrument that measures relative humidity.

ISOBAR: A line, drawn on a weather map, that connects all places which have the same air pressure at the same time.

ISOTHERM: A line, drawn on a weather map, that connects all places that have the same temperature at the same time.

JET STREAM: A narrow band of very intense winds blowing along a relatively narrow "tube" at high levels in the middle latitudes. The wind velocity in the "stream" may be 150 knots.

KNOT: The speed of one nautical mile per hour. It is equal to 1⅙ statute miles per hour.

MARITIME AIR MASS: An air mass that originates over water areas and is relatively moist.

METEOROLOGY: The science of the atmosphere.

MILLIBAR: The unit used by meteorologists to measure air pressure; 34 millibars equal 1 inch of mercury.

NIMBUS CLOUD: A rain cloud.

OCCLUDED FRONT: The front formed when one front overtakes another, forcing one front upward from the surface of the earth.

PRESSURE GRADIENT: The rate at which air pressure changes on the shortest path between two isobars. If the pressure gradient is steep, the isobars are close together indicating strong surface winds.

PSYCHROMETER: An instrument that measures relative humidity by using wet and dry bulb thermometers.

RADIATION FOG: Fog that is formed during a calm, clear night when moist air near the ground is cooled by the process of radiation. It is also known as ground fog.

RELATIVE HUMIDITY: The ratio of the amount of moisture in the air compared to the amount it could hold at a given temperature.

SMOG: A combination of smoke and fog.

SQUALL LINE: A line of thunderstorms usually associated with a fast-moving cold front.

STRATIFORM CLOUDS: Clouds forming unbroken, horizontal layers or sheets.

THERMOGRAPH: An instrument used to make a continuous record of temperature.

TROPOSPHERE: The zone of the atmosphere that extends from the earth's surface to the stratosphere. Its height ranges from 5 miles at the poles to approximately 11 miles at the Equator. All weather occurs in the troposphere.

TYPHOON: A tropical cyclone in the Indian Ocean and the western Pacific Ocean.

UPSLOPE FOG: Fog formed when moist air cools as it rises along hillside or mountain slopes.

VISIBILITY: The greatest horizontal distance at which prominent objects can be recognized by the unaided eye.

WARM FRONT: The leading edge of an advancing mass of relatively warm air.

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