

INTERNATIONAL WEATHER WATCHERS

OBSERVER HANDBOOK

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Weather Graphics Technologies

INTRODUCTION

This handbook represents the pinnacle of work that I did in 1984 through 1995 to develop a set of standard observation routines to help the amateur hobbyist. This incorporates many time-tested procedures and techniques used at official weather stations, and introduces some important information that is largely unavailable (such as using equations to get properly compensated readouts from a home barometer).

I offered my initial versions of the manual to the Association of American Weather Observers (AAWO, dissolved several years ago) in 1988, however ambiguous interest among the organization's leadership stalled the project. I continued to tweak the files from time to time, and several years later I resurrected and edited the manual for the energetic International Weather Watchers, who quickly adopted it until lack of member support led to their demise in 1997. Therefore it is now being provided at no cost via the Internet to assist amateurs in observing the weather. It is in its original unedited condition, and no attempt yet has been made to bring it "up to date". This manual may be freely distributed and reprinted under the strict condition that it is not altered, edited, or offered for sale.

I would like to thank Russ Hobby of Laconia, NH for his helpful inputs and reviews during the 1993-94 time frame. Also helpful to this effort was writer Debi Iacovelli of Cape Coral, FL for her sharp and thorough reviews, meteorologist Steve Ambrose of Dunkirk, MD for his editorial expertise, and business owner Buddy Potts of Bradenton, FL for expediting this manual into the hands of amateurs through the IWW.

Comments and suggestions should be made to me at tim@weathergraphics.com . If there is enough interest, I might put it through another editing cycle.

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contributing material

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INTERNATIONAL WEATHER WATCHERS

OBSERVER HANDBOOK

the official observer manual of the
International Weather Watchers
Release 1.0

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Chapter One

OBSERVING THE WEATHER

The observer steps out into the back yard. Snow cascades lightly to the ground, a stiff January wind is blowing, and one thing is for certain — it's cold! The observer looks at the thermometer, not realizing that his frosty breath has landed on the glass. Forty-two degrees. A little warm — strange! He then looks in the rain gage, discovering that only a few flakes have entered. And there's a foot of accumulation on the ground! Oh well, it doesn't matter. Patiently, he removes the overflow can and brings it inside. He inserts the stick into the can, and measures 0.02 inch of precipitation.

Who would want the records from this observer to become part of their research project or legal case? How accurately would these records compare to that of other stations?

Whatever the case, the public as well as other weather enthusiasts always put their faith in the observer for accuracy. It depends on those little "extras" that determine the accuracy of an observation. The only way that accuracy can be ensured is to establish procedures and standard techniques. Many are based on common sense, while others are time-tested solutions to difficult problems. And when the observer follows them diligently and faithfully, discipline becomes ingrained into the observation procedure, leading to highly accurate and valuable weather records. And that's often reward enough for many hobbyists!

Observation Forms

Observations would be useless if they were entrusted to the brain. Do you remember what the weather was on July 16, 1983? So it's not surprising that every observer uses a form to record their observations, and a good many amateurs even draft their own! The different categories that are on the form vary between observers and their needs. It is not our purpose to present a

universal, cover-all observation form, but instead, to ensure that the many different forms which observers use and their techniques are standardized.

There are two basic types of observations, which will be referred to throughout this manual collectively as "weather observations". Sometimes, these two types of observations are combined onto one form.

Weather Records

Weather records, or "spot" observations, are observations taken at certain times of the day where instantaneous weather variables are measured and recorded. This includes data such as the temperature, wind speed, weather, snow depth, and visibility. The amateur should observe and record these parameters as often as possible, preferably at least once a day. A suggested time for observation is at 0000 UTC or 1200 UTC (1700 or 0700 EST, respectively). While you may not always be aware of significant events taking place in the area, spot weather records during a major catastrophe or weather situation can become very valuable to meteorologists and researchers. For example, when a Delta Airlines L-1011 airliner crashed at Dallas-Fort Worth International Airport in August, 1985, government researchers scavenged for weather records, including those of amateurs, showing conditions around the city at the exact moment of the crash. This helped piece together a microscale weather map of the weather conditions that might have influenced flight safety.

Climatological Records

Climatological records, on the other hand, are observations taken at the end of the day where climatic variables are recorded. Such data includes the high temperature, the low temperature, rainfall, snowfall, and prevailing winds. They are vital in determining overall long-term weather conditions at the station. You should select a preset time during the calendar day to take your observations, and stick to standard rather than daylight saving time. Pick

a time, use it, and stick to it! The preferred time for taking climatological observations is at midnight standard time. If this is impractical, take it as late as possible, but no earlier than 1800 Local Standard Time (LST).

Your Observation Program

Which type of observations you will take depend entirely upon your preferences and needs. Climatological records are almost universal with amateurs, for example, but only the serious add weather records to their program. Weather records are often useful in weather watcher groups for meteorologists. Their intrinsic value when taken at preset times is priceless. Trends which do not show up on climatological records show up instantly on weather records, especially those of moisture and combined weather conditions leading up to weather events.

Elements having the greatest rate of change are evaluated last. When conditions are changing little, evaluate outdoor elements first, then check those items that can be observed indoors. Always check pressure last. When taking observations outdoors at night, the observer should allow time for the eyes to adjust to the dark before judging sky condition, visibility, and visual features.

Units of Measurement

It is important to ensure that the units of measurement are marked clearly. If a stranger was asked to read your form, would they be able to tell if your winds were in miles per hour or knots? Which time zone was in use? What about daylight saving time? The location of the station? Whether temperature was Fahrenheit or Celsius? Clarification of your units of measure are very important.

Writing Instruments

When possible, the same type of writing instrument should be used throughout a particular form, preferably a black inked ballpoint pen, to ensure legible copies can be made.

Avoiding Errors

Errors occasionally creep up in weather observations, either occurring when the entry was recorded or when an instrument was read. Perhaps the most common error is misreading of an analog thermometer by 5 or 10 whole degrees. Try to get in the habit of checking twice before recording the reading. Likewise, it is also easy to misread the rain gage by a whole tenth of an inch. Other errors are attributed to forgetfulness. Has the hail size been recorded on your weather record form? What about the new precipitation in the rain gage? It is a good idea to check over blank entries to see if something has been forgotten.

Designing a Form

If you are experienced in running a weather station, you may prefer to use your own form. If you don't have any forms, you are encouraged to use one of the blank ones provided in the appendix. Also, you may design your own master form, and make copies for your own use. This can be done with a ruler, pen, and typewriter, or if you have a computer that supports desktop publishing, you can design your own form. Some print shops will even let you design your own form on such a computer for about \$10 to \$20.

Chapter Two

THE WEATHER STATION

Each weather station differs, depending on the function of the station and the type of equipment. Some observers, particularly those at climatological stations, will take and record only one observation per day. A few dedicated amateurs may record several observations per day. Others, such as some television weather watcher networks, don't actually record any observations but are on "watch" to report changing conditions.

Whatever the case, before any observations can be taken, an observing station must be physically established. Technically, its precise geographical location is defined as the point (or points) at which measurements are taken of the various elements in the observation. Its exact altitude, by international convention, is represented by the height of the ivory point of the mercury barometer, the base of the aneroid barometer instrument, or if no barometers are available, the base of the rain gage.

When the location is established, use topographic maps to determine the altitude and location of the site to the nearest foot and minute of degree, respectively. Some fine topographic maps are produced by the national government in many countries. For example, American observers can get such maps for about \$3 per copy. Write to the U.S. Geological Survey, Reston, Virginia 22092 for further information about the 1:12,500 topographic chart series. Canadian observers should write the Canada Map Office, Surveys and Mapping Branch, Department of Energy, Mines and Resources, Ottawa, Ontario K1A 0E9, and inquire about the 1:50,000 map series, which cost about \$4 (Canadian) per copy.

Weather instruments are critical for the quantitative measurement of the elements. A typical observer can only guess at parameters such as temperature and wind speed, but weather instruments pinpoint exactly what these unknowns are, and are part of maintaining an accurate record. All instruments should be

exposed and maintained properly if they are to provide any reliable data. When setting up equipment, always follow the instructions supplied by the manufacturer, and ensure that recommended cleaning procedures are observed on a regular basis.

Thermometer

Simple Thermometers

The cheapest type of maximum-minimum thermometer is the Six's design, shaped like the letter 'U'. It can be found in many good hardware stores. The mercury sits in the lower half of the "U", and moves through the tube depending on the temperature. Depending on whether the temperature is falling or rising, it pushes up an metal index marker enclosed within the tube on each side. To read the thermometer, the observer notes the location of the markers against the graduated scale, then with a small magnet, lowers the index marker down to the mercury to reset the thermometer. The Six's thermometer has an accuracy of within one degree, and can be bought for about \$25 from a weather instrument supply company, or even a hardware store or engineering supply company.

Precision Thermometers

For the more dedicated observer, a set of precision maximum-minimum thermometers may be the answer, although costs may approach \$100. They are the same type that are used by most weather agencies. Before you make such an investment, be sure that your instrument shelter is set up right, because the thermometer readings will be only as accurate as your shelter design and placement.

Digital Thermometers

Digital thermometers are becoming increasingly popular with

both amateurs and weather services. These thermometers rely on microprocessor technology and the thermistor, a small device which changes its electrical resistance as the temperature changes. Most electronic units are considered to be reasonably accurate, but if you intend to use your observations for serious research, you should instead consider obtaining precision electronic thermometers from scientific supply companies, or opt for a set of precision thermometers. Never forget that all electronic thermometer sensors must be sheltered properly.

Exposure Problems

It's often tempting to mount the thermometer someplace convenient, such as on a porch post or near a window. This does not provide the instrument adequate exposure! In addition to being exposed to evaporative cooling from precipitation, the thermometer becomes the target of many sources of extraneous radiation, from the house as well as from pavements, which can seriously affect readings.

Proper Exposure

The observer is urged to consider the purchase of a standard weather shelter (described several sections ahead). The weather shelter takes on the critical task of ventilating the instruments without allowing them to become wet or dirty. If a weather shelter cannot be obtained, then the thermometer should be mounted on the north side of a thick white post over a grassy area, away from buildings. It should be mounted in a way in which it does not absorb heat from the post itself. Such a crude setup will suffice, at least until wet or wintry weather strikes. At that time, the observer must attempt to keep the thermometer as dry as possible. Evaporation of precipitation from the thermometer normally degrades the accuracy of readings. If readings are questionable, the observer should not hesitate to record all readings as "estimated".

Accuracy

When possible, the thermometers should be checked against that of a properly calibrated instrument. If there is no access to a calibrated thermometer, a crude way of checking the instruments is to mix a half-and-half combination of ice and water in a large container, and quickly replace all ice that melts. A thermometer placed in this slushy mix should soon read a temperature of 32 degrees F.

Psychrometer

A psychrometer measures the strength of evaporative cooling present in the atmosphere. This reveals many important statistics about moisture in the atmosphere, including dewpoint and relative humidity values. For accurate measurement of moisture, you should invest in a sling-type psychrometer, which will cost between \$40 and \$100. An aspirated psychrometer can be built by using a 110-volt blower motor to draw in air past the wet-bulb thermometer wick into a reversed funnel, with an outlet leading out of the shelter.

Wicks

Wicks for sling psychrometers should be purchased from the manufacturer, a distributor, or a weather supply company to insure a proper fit and optimum performance. If this is not possible, you can use a piece of muslin or bootlace that has been boiled for at least 15 minutes with a little detergent, rinsed in tap water, and boiled again for 10 minutes. Wicks must be handled with clean hands, and as little as possible, since body oils and

contaminants will alter the observed rate of evaporation. The wick should be tied both above and below the thermometer bulb, and should extend about an inch up the stem. The wick of a non-aspirated psychrometer should dip into a small, narrow-necked container, with no slack.

Water

Water used to moisten the wick should be distilled water, which can be purchased from any supermarket. An acceptable substitute is water obtained while defrosting a refrigerator. Never use tap water. Tap water causes a mineral deposit to build up on the bulb, which will cause false readings and can be difficult to remove without breaking the thermometer. A handy procedure is to keep your water supply in a squirt bottle, kept near your sling psychrometer. Wet the bulb thoroughly, and you're ready to sling!

Soil Thermometer

Observers may wish to keep record of the temperature of the soil. It can provide unique information on how warm the ground is, how much heat will conduct into transient air masses (affecting their modification and stability), and how fast ice or snow will melt once fallen.

Exposure

A simple setup can be made for less than \$10 by placing an indoor/outdoor thermometer in the weather shelter and routing its probe through a conduit into the soil. To obtain the soil temperature, just read the 'outdoor' bulb of the thermometer. There are also more expensive soil thermometers similar to meat thermometers which are read while they remain in their burrow.

Standard Depths

Standard depths are 5, 10, 20, 30, and 100 cm (2, 4, 8, 12, and 39 inches, respectively). A good depth to use is 30 centimeters.

Rain Gage

The accuracy of a rain gage quite often depends more upon its placement rather than the workmanship. For example, a cheap rain gage placed out in the open will easily surpass the performance of an eight-inch rain gage placed under a tree.

Varieties

When it comes to shopping for a rain gage, there is a very simple, basic rule of thumb. The larger the diameter of the gage, the more accurate the catch. This is because a larger gage receives a more representative volume of precipitation falling from the sky. Larger gages are also better at catching drizzle and snow, whose fall can be disturbed by eddies around the edges of the gage.

Eight-inch Gage

The best accuracy is obtained with a standard eight-inch diameter rain gage. It consists of a large overflow can containing a measuring tube and capped with a funnel, which covers the measuring tube loosely. The funnel catches precipitation and dispenses it into the measuring tube. If the measuring tube overflows, it "leaks" under the funnel into the overflow can.

To measure the precipitation, the observer removes the funnel, dips an absorbent, calibrated stick (usually made of plastic or redwood) into the measuring tube, withdraws it, and reads the amount.

Four-inch Gage

The four-inch gage is not as accurate as an eight-inch gage, but is sufficient for most observing purposes. It is built similar in construction to the eight-inch gage. However the entire assembly is usually transparent, and the observer can read the rainfall amount in the measuring tube against marks on its side.

Wedge Gage

Small wedge-gages, named for their slender appearance, are readily available in department stores, and are considered marginally accurate. Proper exposure is critical. The observer carefully reads the meniscus (lowest portion of the visible water level) against the marks, which are less precise and require a little patience and good eyesight. When snow falls, wedge gages are considered completely unsuitable and demand the use of different instruments for obtaining liquid equivalent amounts. Observers who own wedge gages must construct a snow board (as described below) which is cleaned daily. Then during snowfall episodes, these snow boards are used exclusively to determine rainfall equivalent and snowfall.

Tube Gages

The tiny test-tube size gages are inaccurate and should be avoided altogether. If you do use them, all readings from them must be considered "estimated".

Exposure

The rain gage should be placed at least ten feet away from the instrument shelter, and kept completely away from buildings, and especially trees. A general rule of thumb dictates that it should be located at a minimum distance of twice the height of nearby obstructions (i.e. keep it 40 feet away from a 20-foot tall house). This prevents splash-in and rain-shadowing effects during windstorms. If you have the choice of placing it near a hard surface or on grass, choose the grassy area. If rain gages are installed in grassy areas, placing a circle of gravel or pebbles around it will help prevent accidental damage when the grass is being mowed. Never place rain gages at a low height above concrete or other hard surfaces, as splash-in will occur.

Wind Screens

Wind screens may be erected to minimize the loss of precipitation. These are large boards which shield the rain gage from winds. They must be placed at least a foot from the gage, otherwise they could create eddy currents that will interfere with the catch. Losses due to winds are much greater during snowfall than rainfall, so they are recommended at locations where at least 20 percent of the annual precipitation falls in the form of snow.

Avoiding Debris

To keep bird droppings, insects, and leaves out of the gage, it is advisable to cut a window screen and bend it in the shape of a funnel. This funnel is then wedged into the gage so that precipitation can drip into it. Such a screen must always be removed before snowfall events, since it interferes with the catch of solid precipitation.

Barometer

A barometer is used to measure atmospheric pressure, which is the weight of a vertical column of air through the atmosphere upon the instrument. When divergence occurs in the upper troposphere due to jet stream patterns or upper-level disturbances, atmospheric mass is removed, which lowers the weight of the atmosphere above a station at the surface. Winds rush in to fill the void, converge, and rise to fill the void aloft. Sometimes these winds rushing together can increase the thermal contrasts at the surface and, as a result, further intensify the patterns and divergence aloft. In any case, this rising motion produces rain and clouds, and is why low pressure is associated with bad weather. The reverse happens with high pressure.

Mercury Barometer

The mercury barometer consists of an evacuated vertical glass tube, with its open end dipping into a reservoir of mercury. Atmospheric pressure forces the mercury into the tube; the greater the pressure, the higher up the mercury can be forced. The height of the mercury is then measured using a scale and a vernier (a sliding scale used for measuring tiny distances), and the result is the station pressure, which is literally the pressure at the station itself. Most mercury barometers have an accuracy of one one-thousandth of an inch of mercury. Mercury barometers are considered much more stable than aneroid barometers, but they, too, can fall out of calibration with time. Pollution of the mercury from the atmosphere, leakage of gas into the evacuated mercury tube, and slippage of the height scale can introduce small errors which grow with time. It is a good idea to perform a remote comparison (see under "calibration") on the mercury barometer occasionally, ideally at least once a year.

Aneroid Barometer

An aneroid barometer works by measuring the expansion of a metal cell or capsule that contains a partial vacuum. When pressure is high, the cell is squeezed by the atmosphere and forced to contract, and a connecting pointer is bent toward the high pressure reading on the face of the instrument. Accuracy of aneroid barometers range from a poor 0.20 of an inch on cheap wall decoration models, down to 0.01 inch on expensive calibrated units. Since the aneroid barometer uses a mechanical assembly to measure pressure, its readings have a tendency to drift from accurate values over a period of months. It must be standardized often (ideally, once a month) using any of the calibration techniques found below.

Digital Barometers

Digital barometers often use a "linear variable differential transformer", which connects a precision aneroid cell to a motion sensing transducer. The manufacturer hooks this device up to electronic circuitry, allowing pressure to be electrically or digitally indicated. These barometers are very expensive, but the accuracy of the unit normally is consistently within 0.01 inch.

Exposure

Keep all barometers indoors, away from air conditioning ducts and vents. Your work desk or a heavy table is a perfect spot.

Calibration

When an aneroid or electronic barometer is first installed at a weather station, it must be calibrated. If no reliable barometers are already on hand, one of the following techniques must be

used. Choose the latter ones only if you have no other option. Never take an instrument to a weather station and set it to their reduced sea-level barometric pressure!

Take the instrument to a weather station. If the aneroid or electronic barometer is to be calibrated to show station pressure (i.e. the bona fide air pressure value without regard to sea level), you may take it to a federal weather station and set it to match their own station pressure. Be sure you ask for their station pressure, not the altimeter setting. It's always a good idea to ask them to eliminate the instrument's removal correction (a value that forces the instrument to estimate all readings at the elevation of the runway, not that of weather station). This can be mathematically subtracted, or done by temporarily changing their instrument's airfield elevation settings to match that of the sensor elevation.

Use an aircraft altimeter. These are highly accurate instruments, engineered with precision. Maintenance facilities at smaller airports may arrange to let you borrow one. Bring one that is known to be accurate to your station, then set the altimeter adjustment knob until the hands on the altitude scale indicate your station's elevation to the nearest 10 feet (determine this carefully from topographic maps or property surveys). Lightly tap the instrument to eliminate any lag due to friction, then recheck it. The value in the calibration window is your official barometric pressure, reduced to sea level.

Remote Comparison. This is the easiest way of doing it, and is sufficient for most hobbyists. Wait for a fair day with light winds, and obtain the current pressure (altimeter setting) from a station within 100 miles. Avoid using this technique during the early afternoon, since diurnal pressure oscillations are at their strongest. The best time, by contrast, is during the late night hours.

Pressure Reduction Basics

Observers at higher elevations are often puzzled why their pressure readings never quite match the official reports. This is not due to a defect in the barometer. Rather, it can be blamed on the physical makeup of the atmosphere, and the way we measure pressure.

Pressure is a measure of the weight of the atmosphere. It follows that pressure changes at higher elevations are naturally weaker than changes at lower elevations. For example, we can use a tall stack of fifty soup cans to simulate a vertical column of air above a barometer. If we simulate a pressure drop, we must pull ten percent of them evenly throughout the entire height of the stack. Now consider a weight scale at the bottom ("sea level"). It would indicate a much greater total drop in weight, compared to a scale placed somewhere in the middle ("ground level"). After all, there are soup cans disappearing below the scale which aren't getting measured. We would have to turn to math to estimate the new weight of the entire column.

Pressure changes with elevation. Figure 1 below shows the variation of pressure with altitude. For example, assume the National Weather Service reports an official barometric pressure (altimeter setting) of 29.92 inches. This is always a pressure that is reduced to sea level. If a off-the-shelf aneroid barometer also showed 29.92" at sea level and was lifted in a hot-air balloon to 2,000 feet, it would register 27.82". This raw value is called the

station pressure, the true pressure of the air at a given elevation and location. Meanwhile, if the official pressure at the ground rose to 30.50", the barometer aloft would jump to 28.37". This represents an increase of 0.55 inches, however, if the same barometer was sitting on the ground, it would have also rose from 29.92 to 30.50", a change of 0.58 inches. This is because barometers at higher altitudes are less sensitive to pressure changes. All barometers at high elevations must have their pressures mathematically reduced to sea-level before they will give a proper sea-level pressure reading.

How the National Weather Service does it. National Weather Service stations use devices called altimeter-setting indicators. Altimeter-setting indicators are instruments programmed with the site elevation which automatically reduce the measured pressure readings to sea level. This yields the official barometric pressure. Unfortunately these devices are generally too expensive for most amateur observers. Some weather stations have mercury barometers, which show the station pressure (the raw, true pressure). An observer must then use mathematics to reduce this station pressure to sea-level pressure. This is often done with prepared tables or a pressure conversion wheel, a circular slide ruler.

How you can do it. Most observers at low elevations (below about 1,000 feet MSL) need not worry about correcting their barometers, because the error is so minute. However, those at higher elevations should use a correction to bring their pressures in line with official readings. Those at high altitudes (above 4,000 feet) are strongly encouraged to use some sort of correction. Observers in Denver, Flagstaff, and Salt Lake City, for example, will get completely inaccurate readings off of ordinary barometers. To remedy the problem, here are some techniques to try.

Gross error correction. When you initially calibrate your barometer, mark that pressure on or near the instrument. Look at Figure 2-1, noting your station elevation, and determine your

Figure 2-1. STATION PRESSURES. The different indicated station pressures at various official barometer (altimeter setting) pressures are shown below. With increasing altitude, station pressure changes become smaller, which means that barometers become less sensitive to change. This error is shown as a percentage of the pressure change, and the recalibration factor to correct the change is given.

Elevation	Barometric Pressure			Gross Error	Recalibration Factor
	30.50"	29.92"	29.50"		
Sea Level	30.50"	29.92"	29.50"	0%	1
1000 feet	29.42"	28.85"	28.45"	3%	1.03
2000 feet	28.37"	27.82"	27.43"	6%	1.06
3000 feet	27.35"	26.82"	26.43"	8%	1.09
4000 feet	26.36"	25.84"	25.47"	11%	1.12
5000 feet	25.39"	24.89"	24.53"	14%	1.16
7500 feet	23.12"	22.65"	22.32"	20%	1.25
10000 feet	21.00"	20.58"	20.27"	27%	1.37

recalibration factor. Then whenever you read the instrument, calculate the difference between the indicated pressure and the initial reading, and multiply this difference by the recalibration factor. This artificially "expands" the change to compensate for the decreased sensitivity of the instrument. Then either add to or subtract from the initial pressure (obviously, subtract if your indicated pressure is lower than the initial pressure). The result is your official barometric pressure. For example, if you are in Dodge City, Kansas, elevation 2,500 feet, your recalibration factor is about 1.07. If you initially set your instrument when the pressure was 29.77 inches and you're now seeing 30.24 inches, this is a difference of 0.47 inches. Multiply it by the recalibration factor to get 0.50 inches. This is how much the barometer should have changed. Add it to the initial calibration, and you'll get your "official" pressure of 30.27 inches. You may wish to make up a reference table to solve all possible readings in advance, so that you can read the instrument, look it up on your sheet, and see the corrected barometric pressure instantly.

Station pressure calibration. Another technique is to calibrate your barometer to show station pressure. This will be your only choice if you own a mercury barometer, which always shows station pressure. If you are setting an aneroid barometer, get the official pressure for your area and convert it from an altimeter setting to a station pressure, based on your station elevation. When you read the instrument, convert your station pressure readings back to altimeter settings using the given formula in the appendix each time you take a reading. This will properly correct the readings. Since station pressure is the only variable in the equation (with elevation a constant), it's a great idea to take a moment to sit down with a calculator and write a reference table for your station, or even write a simple computer program, to help speed your conversions up. Every time you read the barometer and look up the value in your table, you'll have your own accurate "official barometric pressure" or "altimeter setting" for your station.

Snow Board

Every station should have a snow board. This device is nothing more than a readily-available flat platform for snow to fall upon. The snow board is lifted and brushed off daily, allowing the observer to determine the amount of new snowfall and to take core samples, as will be described later. The snow board is especially recommended for owners of small wedge rain gages, for whom the direct measurement of daily snowfall becomes even more critical.

Snow Board Material

The perfect snow board will be light enough to keep from settling into the snow, but heavy enough or anchored, so that it does not blow away. It should be large enough to permit two or three core samples (cut with the overflow can of the rain gage), a size of 16 by 16 inches is perfect. The snow board can be constructed using thin lumber or styrofoam (anchored to the ground). Paint it white, and place it in an open area, away from buildings, trees, and areas where drift may occur.

Dual Snow Boards

If the only available measuring terrain is rough or sloping, the observer may want to consider building a second snow board, which remains buried in the snow permanently. It is used

exclusively for taking measurements of "standing" snow depth. It is never brushed off or disturbed.

Snow Stake

The snow stake is used in geographical areas which frequently experience deep snowfalls, where the use of a yardstick would be impractical. Stations in the Rocky Mountains and areas along the southern shores of the Great Lakes, for example, should maintain a snow stake as part of their weather equipment.

Construction

Snow stakes are graduated in whole inches, with numerals inscribed at ten-inch intervals. The stakes should be sturdy, water resistant, and painted white to minimize snow melt by contact.

Exposure

If possible, they should be located on level ground where the snow depth is most representative of the area. In hilly areas, choose a northerly exposure, which will be least subject to melting by direct sunlight. The area around the stake should be away from trees, buildings, and other obstructions which could cause drifting around the stake. The presence of low, leafless bushes near the stake often helps reduce drifting.

Anemometer

The anemometer is an expensive but very useful addition to the weather station. The goal of a wind observation is to find the most representative sample of wind motion in the low levels of the atmosphere, free of local effects.

Varieties

Anemometers range in price from \$120 to \$4,000, and most operate using cups that spin a DC generator.

Exposure

Believe it or not, the anemometer is often one of the most poorly-placed weather instruments. Keep them clear of buildings and rooftops! All buildings create wind shear problems which significantly affect readings. If it is necessary to use a rooftop exposure, try to install the equipment at least 15 feet above the roof. The British Meteorological Office has a handy rule of thumb for deciding whether an anemometer is properly exposed. Sensors should be installed at a distance of twice the height of a nearby obstruction. For instance, if a 30-foot tree is in the vicinity, the wind equipment should be located at least 60 feet away from the tree. If there are no significant airflow obstructions, the equipment should be mounted at a height of 10 meters (33 feet), which is the internationally accepted anemometer height as prescribed by the World Meteorological Organization and used by the National Weather Service.

Weather Shelter

One problem with temperature data is trying to establish a "standard exposure". Ideally, temperature equipment is exposed to a free-flowing source of air. The weather shelter fulfills this need by housing the thermometer in such a way that sunlight and precipitation do not affect the measurement of air temperature. It is painted white to keep from absorbing heat. The shelter has a double top, and its walls are louvered, with slats sloping downward from the inside to the outside of the shelter.

Varieties

Standard National Weather Service shelters can be purchased from several manufacturers or built to government specification. However, the cost of such an effort is usually expensive, running from \$110 just for the wood and hardware to \$800 for a fully certified and assembled model from the manufacturer.

Lighting

At night, use a flashlight or a permanently-installed, low power lantern bulb. Never use matches, cigarette lighters, or standard house-current light bulbs to illuminate the shelter. During cold weather, avoid breathing condensation on instruments in the shelter.

Exposure

If a choice of a location can be made, the shelter should be erected on a level area of ground which is covered with short grass, at least 100 feet away from any paved or concrete surface. The site should be located on representative terrain, not on hills, creekbeds, hollows, and so forth. The shelter should be as far away from air-conditioned structures as possible, and as a rule of thumb, it should not be closer than four times the height of any building in the area. For example, a shelter should be kept 60 feet away from a 15-foot tall building. Shelters must be elevated so that the thermometers rest about five feet above the ground. Also, the shelter structure should be mounted securely to avoid jarring the instruments and the indices of the maximum and minimum thermometers. Orient the shelter's door so that it opens to the north. This will keep stray sunshine out of the shelter's interior.

Visibility Chart

A visibility chart should be maintained at every observing station. Topographic maps and aerial photos will show landmarks, buildings, towers, and wind mills, as well as natural objects such as hills, mountains, and ravines. Locate other visible objects by determining their location on a map, and then measuring the distance to the object.

Daytime Charts

To construct the chart, obtain a large sheet of paper. Use a drawing compass to mark concentric circles from the center of the paper, and then label each circle with distance values exponentially (where each successive radii represents twice that of the previous one, i.e. 1/8, 1/4, 1/2, 1, 2, 4, 8, 16, 32 miles). Then plot the selected visibility objects on the chart in their appropriate directions and distances from the station. On exceptionally clear days, look for very distant objects and add them to your chart as needed.

Nighttime Charts

At night, a separate visibility chart should be drawn, or the nighttime chart may be added to the daytime chart by using a different marking color. Objects which can serve as visibility markers include green or red light airway beacons, red TV and radio tower obstruction lights (not pulsing high intensity lights on tall masts), red collision lights on buildings, and street lights. Allow time for the eyes to adjust to the darkness before observing visibility, and don't look for daytime markers at night.

Pilot Balloons

Some observers who have a source of helium or hydrogen may want to experiment with using pilot balloons to determine the height of cloud layers. The balloons can be those purchased in any department store. After determining the individual ascent rate of the balloon, the observer can release it toward a cloud layer and time its vertical velocity in feet per minute. Red colors are normally used for thin clouds and blue or black for thicker clouds.

Snow Cans

Snow cans can be used to catch large volumes of snow for accurate measurement. Like rain gages and snow boards, they must be exposed away from obstructions. Snow cans are made from three one-gallon cans. The tops and bottoms are cut out of two, and the top is cut out of the bottom can. These cans are then soldered together to make one tall can. It is best to make two in a matched set. A snow can holder is made from wood to fit the height of the cans, and painted white. It is usually mounted on a post. It is advisable to put a smaller can in the bottom of the holder to prevent sticking. When the cans are changed at the observation, the can holding snow is brought indoors and weighed. The total weight minus the weight of the dry cans in pounds multiplied by 0.052 equals the number of inches of precipitation. If a yard stick is used, the snowfall inside the cans can be measured.

Clock

An accurate clock should be maintained at the station and used to determine the observation times. In accordance with federal procedures, observers should record observations using either LST (Local Standard Time). Regardless of your preference, the time that is chosen must be clearly indicated on all forms and used consistently, if not, it sets the stage for a world of confusion for people using your records.

Local Standard Time

Local Standard Time (LST) is simply the time within your time zone. It is abbreviated on records by using the appropriate standard time zone ("PST", "MST", "CST", "EST", etc.) on the observation record. It must be remembered that daylight saving time (or Local Daylight Time, "PDT", "MDT", "CDT", "EDT", etc.) will disrupt the continuity of your scheduled observations and create confusion, so you may prefer to abandon local time

designations and base all of your scheduled observations off of UTC time, just as the National Weather Service does.

Universal Coordinated Time

UTC (the abbreviation for the French phrase "Universal Temps Coordonné"), is preferred by many observers. It avoids the headaches of daylight saving time conversions. It also allows quick comparison with official weather records and research studies. UTC is simply the standard time in London, England. Since it is a standard time, England's summer time (daylight saving time) has no effect on it. Observers on Eastern Standard Time will need to add 5 hours to their local standard time to get UTC. Six hours is added to Central Standard Time, seven to Mountain Standard Time, and eight to Pacific Standard Time.

24-Hour Time

Express all times using the 24 hour clock (see Figure 2). For instance, 1:32 a.m. is written as 0132, and 2:16 p.m. is 1416. A midnight hour observation will use the new day's date and be considered 0000. The 24 hour clock clears up many problems with the a.m./p.m. system. For example, noon is usually considered to equal 12 p.m., but according to federal recommendation (and even attempted regulation) it is also defined as 12 a.m. Observers are encouraged to stay away from this system.

Using "Midnight"

In written reports, you should always use the complete words "noon" and "midnight". If midnight is used, give the two dates between which it falls (for example, "midnight of April 14/15" is more clear than "midnight of April 15").

Time Checks

How many observers call up the phone company's time & temperature to check the accuracy of their thermometers? Would you trust their time to set your clock, too? There are much more reliable sources of accurate time which are available to the typical amateur.

Shortwave Time Checks. Those that own shortwave radios can tune to the atomic clock operated by the National Institute of Standards and Technology (formerly the National Bureau of Standards) in Fort Collins, Colorado, and Kekaha, Hawaii. The time signals are broadcast at the frequencies of 2.5, 5, 10, 15, and 20 MHz on radio stations WWV (Colorado) and WWVH (Hawaii), at a signal of 10 kW and a reception range of about 4,000 miles. The Canadian government also provides a high-quality source of time information which can be received at 3.33, 7.335, and 14.67 MHz (a 3 kW broadcast).

Electronic Time Checks. There are some electronic clocks which can automatically lock onto these radio broadcasts and correct themselves. These units cost about \$300 but can be a unique addition to the station. One manufacturer of such clocks is Heath.

Telephone Time Checks. If there is no access to a shortwave radio, the U.S. Naval Observatory in Washington, D.C. allows you to listen in on their atomic clock via telephone number (202) 653-1800.

Figure 2. 24-HOUR TIME. This chart will allow you to quickly convert time between the familiar 12-hour system and the 24-hour system.

12 midnight	0000	12 noon	1200
1 a.m.	0100	1 p.m.	1300
2 a.m.	0200	2 p.m.	1400
3 a.m.	0300	3 p.m.	1500
4 a.m.	0400	4 p.m.	1600
5 a.m.	0500	5 p.m.	1700
6 a.m.	0600	6 p.m.	1800
7 a.m.	0700	7 p.m.	1900
8 a.m.	0800	8 p.m.	2000
9 a.m.	0900	9 p.m.	2100
10 a.m.	1000	10 p.m.	2200
11 a.m.	1100	11 p.m.	2300

Figure 3. WORLD TIME ZONES. To use this chart, locate your time zone. Move right to your current local time, then move up to read the UTC time. To see the time in another time zone, move right from your time zone to your current local time, then move up or down to the desired time zone. For example, if it is 0600 EST, this yields a time of 1100 UTC.

UTC (GMT)	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
Azores	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200
South Georgia Isl.	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100
Greenland, Brazil	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
Atlantic/EDT	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
Eastern/CDT	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800
Central/MDT	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700
Mountain/PDT	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600
Pacific/ADT	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500
Alaskan	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400
Hawaiian	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300
Bering	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200
New Zealand	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100
Magadan, Noumea	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000
Sydney, Canberra	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900
Japan, Korea	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800
China, Philippines	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700
Thailand, Jakarta	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600
Bangladesh	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500
Pakistan	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400
Oman	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300
E. Africa, Moscow	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200
Central Africa	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100
European	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000

Chapter Three

TEMPERATURE

Temperature is perhaps the second most popular element observed among amateur hobbyists. When a monthly mean temperature is calculated for a set of years, it is a factor that overwhelmingly describes the climate of a particular place. For example, a tropical climate is considered to have a mean temperature of greater than 18°C (64.4°F) during its coolest month. By contrast, a polar climate has a mean temperature of less than 10°C (50°F) during its warmest month.

It's important to be careful when taking readings around thermometers. When near a sheltered thermometer in cold conditions, conduct readings as quickly as possible so that body heat does not affect the instrument. If any moisture (such as dew or rain) has formed on the bulb, wipe it off briskly with a dry cloth, and wait for the mercury to stabilize before taking a reading.

Logging the Observation

Air Temperature

Temperature, in general, refers to the ambient temperature of the air. This is also called the dry-bulb temperature. Always obtain the dry-bulb temperature from the dry-bulb thermometer on the sling psychrometer whenever it is in use.

Wet-Bulb

Wet-bulb temperature is considered the lowest temperature a wet psychrometer wick reaches during aspiration. Using the psychrometric tables in the back of this book, relative humidity and dewpoint can be calculated. Wet-bulb temperature is not a parameter that needs to be logged on observation forms.

Dewpoint

Dewpoint is the temperature at which the air will saturate and vapor in the air will begin condensing. It's a very important

value to calculate if you have the means, because it's a direct reflection of the actual moisture amount present in the atmosphere. You will often find a direct correlation with the surface dewpoint and the types of weather that take place. If a direct dewpoint readout is not available, use the psychrometric tables in the back of this book to calculate it.

Relative Humidity

Do not use indoor relative humidity instruments, because they will not tell you the relative humidity outside. Relative humidity sensors are built with varying degrees of workmanship. If you doubt the accuracy of your sensor, you should find alternate means of computing moisture.

Wind Chill Index

The wind chill is defined as the cooling effect of any combination of temperature and wind, expressed as the loss of body heat in kilogram calories per hour per square meter of skin surface. Canada uses this system. The wind chill index, used in the United States, is based on the cooling rate of a nude body in the shade. It is only an approximation because variables such as individual body shape, size, and metabolic rate will affect the index. The wind chill and wind chill index may be used to determine the effect of wind on livestock and animals, but is not applicable to plants, water pipes, engine blocks, and radiators. The formula for calculating the wind chill index is provided in the appendix.

Degree Days

Degree days are used primarily for engineering purposes to determine the importance of an air conditioner or heater, or the effect of temperature on crops. The greater the number from zero, the more the air conditioner or heater must be used. The cooling degree day is calculated by subtracting 65 from the day's mean temperature. The heating degree day is calculated by subtracting the day's mean temperature from 65. Finally, the

growing degree day is calculated by subtracting 50 from the day's mean temperature. If any of these results are negative, they are considered to be zero.

Heat Index

Heat index is a measure of how hot it "feels like". It is based mathematically on estimated convection from the skin, the effects of clothing on radiation, the vapor pressure, and a number of other factors. The heat index equals the temperature whenever the dewpoint is 57°F (a vapor pressure of 1.6 kPa), however, the more moist and warm the air is, the higher the heat index. For example, if the temperature is 86°F and the dewpoint is 75°F, this equates to a heat index of 95°F, which accurately describes the sultriness of the air. Heat index may be entered on your observation form. If dewpoint and temperature are known, calculate it using Table 11.

Statistics

An average of temperatures can be calculated by adding the temperatures mathematically, then dividing by the number of readings used. Do not mix Celsius with Fahrenheit temperatures within a calculation. By adding the minimum and maximum temperature, then dividing by 2, the day's mean temperature can be obtained.

Chapter Four

PRECIPITATION

Precipitation is considered by climatologists to be the single most important measurement a weather station can produce. It describes the type of climate that a station has. For example, a wet, tropical climate is considered to have at least 60 mm (2.4 inches) of precipitation during its driest month. When compared with other stations, precipitation readings can illustrate anomalies in the climate across a region. Many studies are conducted on such effects every year. In fact, the United States relies on a network of about 10,000 gages across the country to accurately describe the various rainfall patterns.

This section doesn't merely tell you how to read a rain gage. It describes the careful measurement of snowfall, snow depth, and ways of accurately catching solid precipitation in a gage. It is important to integrate these procedures into your observation routine and follow them carefully.

Liquid Precipitation

Small amounts of rain should be measured as soon as possible, especially in relatively dry weather, to avoid false readings caused by evaporation. If precipitation falls again later, simply add this amount to the amount already measured, then log the total amount at the end-of-day observation.

Wedge gages

Simply read the meniscus of the water level against the marks on the outside of the gage. Try to estimate to the nearest hundredth of an inch.

Four-inch gage

The tube in the four-inch gage normally holds an inch of rain, but any overflow is held in an overflow cylinder. To obtain the precipitation amount, simply read the meniscus of the water level

against the marks etched in the measuring tube. If more than the amount in the tube has fallen, empty the tube, carefully pour the contents of the overflow cylinder into the tube, measure it, and add to the amount originally in the measuring tube, repeating as necessary until the overflow can is empty.

Eight-inch gage

The tube in most eight-inch gages usually holds two inches of precipitation. Overflow is held in an overflow can. When measuring precipitation, remove the funnel and insert the measuring stick into the bottom of the measuring tube. Hold it there long enough for the water to absorb into the stick, and then withdraw and read the amount directly at the water mark.

Full Measuring Tubes

If the measuring tube is full, measure it, then carefully remove the tube and empty the contents completely. Then pour the contents of the overflow can into the measuring tube. Add that to the measurement. To avoid spilling rainwater, the observer should attach the funnel to the measuring tube before emptying the overflow can. However, the observer must also be very careful not to accidentally overfill the tube. Repeat as necessary, until the overflow can is completely emptied, and ensure that each amount in the measuring tube is added before dumping its contents.

Frozen or Mixed Precipitation

Once in the gage, snow should be measured as soon as possible. Timeliness is the key, so if a major snowstorm has just moved out of the area, get out there and measure the precipitation! Any precipitation that occurs afterward can always be measured later.

Anytime mixed precipitation (especially freezing rain) is ex-

pected, the observer should pour a known quantity of antifreeze into the overflow can, then subtract this amount when melting and measuring. A small quantity of antifreeze helps prevent the gage from warping and melts precipitation contained within. Be careful when dumping antifreeze since small animals are attracted to its scent and may try to drink it, often with fatal consequences. Also, be aware that antifreeze may opaque transparent plastic gages.

Wedge and Four-inch Gages

Those who own small gages must dump the snowfall and ignore it. Then a core sample or the estimation procedure should be followed to estimate precipitation. If snow has fallen along with considerable liquid or freezing precipitation, then melt the contents instead using the gage meltdown or hot water flood technique and consider the amount as estimated. Keep in mind that freezing precipitation may damage plastic gages.

Eight-inch Gages

Owners of metal eight-inch gages should remove the funnel and measuring tube during the time of year when snowfall is expected. This will allow snow to collect in the gage unhindered. This procedure does not affect the accuracy of rain measurement; the liquid rain will simply need to be poured into the measuring tube first.

Tipping Gages

Many recording gages measure precipitation by weighing it (such as tipping gages). As a result, the readings already indicate the liquid equivalent of the precipitation. However, be aware that since the tipping gage has moving parts, it can seize during any frozen or freezing precipitation. Also, precipitation may accumulate on the sensor. Observers who love to tinker may want to find a way to keep the sensor warmed. Using an alternate precipitation measurement method is suggested, however.

Core Sample

The most accurate method of determining the liquid equivalent of snowfall is to use a "core sample". This takes a sample of snow on the ground equal to the gage's diameter, simulating its entry into the gage. It eliminates the effects of turbulent wind flow over the gage, so this method is valuable whenever prevailing winds during the day have averaged above 15 knots, because high winds have a tendency to decrease the "catch" in the rain gage.

Prerequisites for core samples. The prerequisites for a core sample include the possession of an eight-inch gage, precipitation which has consisted entirely of snow, and a snow board with new snow only, or flat, level ground containing no old snow from a previous day. Core samples from wedge gages must be considered as estimated, but if any inaccuracy is suspected, abandon the core sample and use the estimation procedure.

Taking a core sample. To take the core sample, completely empty the gage and overflow can of its contents. Turn it upside down, and press it downward into the snow until it reaches the ground. Then carefully withdraw it. All snow in the burrow cut must enter the gage, if there are problems, start again and slide a piece of sheet metal or wood underneath to help lift the sample. You may also remove the remaining snow in the burrow by hand and place it in the can. After the core sample has been taken, melt the contents to a liquid equivalent using the gage meltdown

or hot water flood technique below.

Gage catch meltdown. If precipitation has stopped, you may bring the rain gage or overflow can indoors to melt the catch. For smaller amounts, wrap the gage in a hot cloth. Don't forget to put the gage back outside when you're done!

Gage catch hot water flood. If an ice storm or mixed precipitation is forecast, this is a valuable technique. What you are doing is mixing a known amount of water into the gage. The purpose of this water is to help melt the contents. Once you take your measurement, the water is mathematically subtracted from the total amount.

How to do it. In an unused gage before precipitation starts, put some water in the gage. Measure this as a precipitation amount, then pour it into a container and seal it to keep it from evaporating. Keep this water at room temperature, and put the gage back outside. When you are ready to measure the precipitation, pour the room-temperature water into the active rain gage and wait for it to melt. Then measure the total amount and subtract the amount of water that you added. If the gage is full, introduce the water slowly and carefully. Do not heat this water. If some of it is lost to steam, you will overestimate the precipitation.

Caught unprepared? If you are caught unprepared and have no way of measuring how much water you will be pouring into the gage, fill a container (a glass, for instance) up to a precisely marked level with water (you may use hot tap water), and pour it into the gage. After the contents melt and you obtain your reading, dump everything. Then refill the container to the exact same level, pour this into the empty gage, then measure it and subtract this amount from the total.

Estimation technique. Observers who own wedge gages will be required to estimate precipitation whenever it is frozen. This technique can also be used as a last resort by owners of four and eight-inch gages when no method gives a reliable measurement. First, determine the snowfall (new snow) as described in the section on the next page. Then divide by the following values to obtain the estimated liquid precipitation amount:

- 35, for very dry snow. Common over Canada and the Northern Plains, especially when temperatures are below 10 degrees F. The snow appears crystalline and is very fluffy. It usually falls in small amounts and can be swept off sidewalks with a broom.
- 20, for dry snow. Dry snow usually occurs with "Alberta Clipper" systems or in mountainous areas, and is usually easy to shovel.
- 10, for average snow. This is an average meltdown ratio and should be used when you are sure that the other types do not apply.
- 5, for wet snow. Common during the late winter or spring months. This snow is difficult to shovel, and even sticks to the shovel, but it makes great snowballs and snowmen.
- 2, for sleet or mixed precipitation;
- 1.5 for freezing precipitation or pure ice.

Snowfall

Snowfall refers to the day's total accumulation of snow, ice pellets, glaze, hail, and sheet ice on the ground. It does not include snowfall which has occurred on previous days. Snowfall is rounded to the nearest tenth of an inch, and amounts below 0.05 inch are considered a "trace".

The most accurate way of determining snowfall is to use a yardstick or ruler and take several measurements on the snow board to obtain a representative reading. At the end of the observation, pick the snow board up, brush it off, and place it back on the snow so that its top remains flush with the snow surrounding it. A snow can may also be used to measure the snowfall amount.

If all else fails, try to determine the total amount of new snow on the ground. It is possible that the old snow has settled or partially melted enough to develop a crust or to be noticeably denser than the new snow. When the yardstick is inserted, try to determine where it meets the greater resistance of the crust of old snow. Also, pollution or partial melting sometimes gives the old snow a darker color. If so, cut the snow down to the ground where a cross-section is visible, and inspect the accumulation. If winds have been light, you may also check the amount of snow in the rain gage.

Frequently, observers will see a heavy snowfall which melts as it falls. The definition of "snowfall" still stands; measure only what is on the ground. However, if there has been no accumulation whatsoever, the observer may consider a trace of snowfall to have occurred from the situation. In certain cases, the National Weather Service estimates the snowfall, marking the amount with the phrase "melted as it fell".

Snow Depth

Snow depth takes into account any snowfall that has occurred on other days but has not yet sublimated or melted. It includes not only snow. By definition, it is the total accumulation of all snow, ice pellets, glaze, hail, and sheet ice on the ground. It is done only once a day, and rounded to the nearest whole inch. Amounts below 0.5 inch are considered a "trace". Where the terrain near the observing station is rather flat and no trees are obscuring the sky, use a yardstick or a thin piece of wood marked off in whole inches. Take about ten readings on level earth away from drifts and trees, and then average them (by adding up the readings and dividing by the number of readings). The result is considered the average snow depth.

Logging the Observation

Liquid Precipitation

The amount of precipitation or melted precipitation that fell during the calendar day is entered to the nearest hundredth of an inch. Zero is entered for none observed, and a "T" for trace amounts (less than 0.005 inch). Enter a dash for days which were not observed. Estimated amounts should be preceded with an "E", or enclosed in parentheses.

Snowfall

The amount of new snowfall that occurred during the calendar day is entered. Note that this does not correspond to snow depth, since old snow may still be present on the ground. Zero is entered for none observed, and a "T" for trace amounts (less than 0.05 inch). Enter a dash for days which were not observed. Estimated amounts should be preceded with an "E", or enclosed in parentheses.

Snow Depth

Rounded to the nearest whole inch. Amounts below 0.5 inch are considered a trace ("T").

Times

A unique method of recording precipitation times is to provide a linear graph in each row of this column, with the beginning, middle, and end of the graph representing midnight (early morning), noon, and midnight (late night) of the calendar day, respectively. This time graph indicates the periods during which any precipitation fell. If none occurred, the graph is left blank. However, when precipitation occurred, the abbreviation for the precipitation type is entered or a line is drawn on the graph at the appropriate times.

Number of Days with Measurable Precipitation

Days which receive more than a trace of precipitation are included in the count.

Chapter Five

WIND

Wind measurements tell you where the airmass that is over your station is coming from. It also describes how dynamic the circulation is, and can be an indicator of what is happening aloft. Keeping records of wind is most useful to spot weather records, where it can be drawn up with other spot weather observations to compose a weather map.

Measurement Techniques

The observer's goal is to measure the wind in a way that will represent the surface weather patterns most accurately. Measurements and estimations should be done in an unsheltered area, away from the influence of trees and buildings.

Direction and Speed

Wind is measured in terms of velocity, a vector that includes direction and speed (in miles per hour, knots, kilometers per hour, or sometimes meters per second). Watch the wind speed and direction for two minutes, and determine an average value (this is called a two-minute average). When winds temporarily lull or gust, try to wait for a more representative condition before determining the average. If there is no motion of air, the entire reading may be considered calm.

Gusts

Gusts are defined as the maximum instantaneous wind speed which occurred during the 10-minute period preceding observation time.

Squalls

A wind squall is defined as an event in which the mean wind speed suddenly increases by 15 knots to equal or exceed 20 knots for at least one minute before diminishing. Wind squalls are usually associated with thunderstorm outflow or hurricane winds.

Estimation

When instruments are not available, estimate the wind as accurately as possible. Face into the wind in an unsheltered area, or observe the movement of trees, smoke, leaves, etc. Never obtain the wind direction by observing cloud movement. Use the Beaufort wind scale to estimate wind speeds.

Keeping Records

Direction and Speed

Wind direction is entered in degrees relative to true north, always using three digits (e.g. 40 degrees is 040, and 260 degrees is 260). In like manner, wind speed is always recorded using two digits (e.g. 12, 54, etc.). The unit of measure, whether knots or miles per hour, must be clearly marked on the form to avoid confusion.

Prevailing Wind Direction

A set of wind directions during the day cannot simply be averaged to determine a mean, since wind direction is comprised of two vectors. There are two ways of solving this problem statistically. The most common method requires a set of numerous observations during the day; the mode is selected (by picking the most frequent direction that occurred). This is considered the prevailing wind direction. The second method involves trigonometrically breaking each wind into a north-south vector and a west-east vector using sines and cosines, then averaging them and reassembling the vectors into a direction.

Additional notes. Most observers will find that the easiest and most realistic unit of measurement in statistical averages will be a qualitative term, such as: N, NW, W, SW, S, SE, E, NE. (See Figure 5-1 for conversion of degrees to compass points). In the case of a major wind shift, the two major wind directions during

the day are listed, separated by a slash, and writing the original wind direction first. An example is "S/NW" in the case of a classic cold front passage. If the wind is light and variable, a "V" is entered by itself. Some computerized weather stations can summarize wind conditions for the day, but for most observers, wind conditions must be manually calculated.

Prevailing Wind Speed

An estimate of the average wind speed during the day in miles per hour is given. If a major wind shift was indicated in the "Prevailing Wind Direction" column, two estimates of the average wind speed during each wind direction regime should be given, and separated by a slash (although the National Weather Service does not do this, it might enhance your records). For example, if a classic cold front moved through the station bringing strong winds, one might enter "10/35" to indicate winds averaged 10 mph from the south, and 35 mph from the northwest.

Figure 5-1. Conversion of degrees to compass points.

Direct	16-point degrees	8-point degrees
N	350, 360, 010	340, 350, 360, 010, 020
NNE	020, 030	
NE	040, 050	030, 040, 050, 060
ENE	060, 070	
E	080, 090, 100	070, 080, 090, 100, 110
ESE	110, 120	
SE	130, 140	120, 130, 140, 150
SSE	150, 160	
S	170, 180, 190	160, 170, 180, 190, 200
SSW	200, 210	
SW	220, 230	210, 220, 230, 240
WSW	240, 250	
W	260, 270, 280	250, 260, 270, 280, 290
WNW	290, 300	
NW	310, 320	300, 310, 320, 330
NNW	330, 340	

Chapter Six

PRESSURE

Pressure falls are caused by thermal heating and/or upper-air disturbances, which in turn cause surface winds to converge, rise, and produce clouds and precipitation. Forecasters often watch for strong pressure falls during severe storm situations, because the low-level winds over a small region can be disrupted and shifted in a way that increases tornadic potential. On the other hand, pressure rises are produced by cold, dense air masses, as well as convergence in the upper troposphere. This often causes subsidence (sinking of air through the atmosphere) and causes low-level clouds to dry out. Surface winds diverge and air masses tend to modify and stagnate in an area of pressure rises.

Diurnal Pressure Tides

Pressure rises and falls caused by weather are important, but they are affected, sometimes even cancelled out, by the diurnal pressure oscillation, an effect of atmospheric tides. This is a significant daily fluctuation of the barometer that may range over 0.20 inches in a matter of hours, and is particularly observable in the temperate latitudes (30 to 60 degrees). The pressure oscillations cause barometers to reach their highest levels at around 10 A.M. local time, and to drop to their lowest levels around 5 P.M. Observers may want to chart the pressure readings on several calm, clear days to see the effects of the diurnal oscillation on their station. By using these results and comparing readings from 24 hours previously, the effects of the oscillation in noting trends can be reduced considerably.

Observation

Since there is usually a slight lag in the response time of a barometer, the pressure readings comprise the last observed element in the observational routine. Barographs should not be used unless they are considered to be a precision instrument (such as a microbarograph). Barometric computations are normally based on station pressure. Station pressure equals the actual weight of the atmosphere at the weather station which,

depending on the elevation, can be much lower than the usual 30-inch sea-level equivalent. Strong surface winds can cause unusual pressure patterns to develop in and around the building, which can affect the barometer significantly. Therefore, pressures should be indicated as being estimated whenever the wind speed is 25 knots or greater.

Barometric Pressure

The official barometric pressure, also known as the altimeter setting, is considered by the public to be the universal value of measurement for pressure. Technically, it represents the pressure value to which an aircraft altimeter subscale must be set so that the instrument pointer will indicate the actual aircraft altitude. Barometric pressure is recorded to the nearest hundredth of an inch of mercury (in Hg).

Calculation

Low altitude stations (below about 1,000 feet MSL). Read the aneroid barometer, which should be preset to indicate altimeter setting directly. This is the altimeter setting. If a mercury barometer is used, determine the station pressure, then convert to altimeter setting using the Altimeter Setting formula provided in the appendix.

High altitude stations. Use one of the techniques shown in the section on Barometer Calibration to obtain barometric pressure. In other words, if the instrument is set to display station pressure, convert it to altimeter setting using your prepared tables or the Altimeter Setting formula in the appendix. If your barometer is already reading barometric pressure, apply the recalibration factor as shown earlier.

Sea-Level Pressure

Sea-level pressure is similar to the official barometric pressure, but it is the theoretical value of pressure which would be exerted by the atmosphere at a station at a given time and with a standard atmosphere, if that station were at sea-level. Pressures reduced downward in this manner must assume that similar temperature properties exist below the station, so the calculation of sea-level pressure requires a 12-hour mean temperature. Sea-level pressure calculations are complex and they are used most frequently for comparison and analysis purposes between a large number of weather stations. Therefore it is not of much concern to weather hobbyists, since most observers prefer to use altimeter settings exclusively.

Calculation

Stations at or below 50' MSL. The column of air below the station has a negligible effect on the result, so the station may use a pressure reduction constant. Determine the mean 12-hour temperature (average the current temperature with the temperature 12 hours earlier, or estimate an average based on the 12-hour trend). Use it to compute the pressure reduction factor. Multiply the reduction constant by the station pressure in millibars to obtain the sea-level pressure in millibars.

Higher stations

The IWW has not yet located sufficient documentation for accurately computing sea-level pressures above 50 feet MSL. Observers are encouraged to instead calculate altimeter settings.

Chapter Seven

VISIBILITY

The clarity of the atmosphere is an important element of the observation. It helps the observer determine the intensity of weather types and obstructions to vision. It tells the forecaster the character of moisture and particulates in the atmosphere, and gives clues to the thermal structure of the lower atmosphere. It's well worth logging these observations on your forms.

Finding a Position

If possible, the observation should be made from a position where you have an uninterrupted view of the horizon. If this is not possible, change viewpoints until the entire horizon has been viewed and assessed. The observation should be made at ground level if possible, not from high buildings.

Visibility Definition

Visibility is defined as the greatest horizontal distance at which selected objects can be seen and identified. If a visibility object has sharp outlines and little blurring of color, the visibility is much greater than the distance to it. However, if an object can barely be seen and identified, the visibility is about the same as the distance to the marker. If you live in a valley or area where there are few distant visibility markers, try to estimate the visibility based on the clarity of the objects you can see.

Prevailing Visibility

Prevailing visibility is different. It is an "average" visibility value in all directions. More specifically, it is specifically defined as the greatest visibility equalled or exceeded throughout at least half of the horizon circle, which may or may not be continuous. The prevailing visibility should be part of all weather records. If the prevailing visibility is less than 3 miles and intermittently decreases and increases by one or more reportable values,

the visibility is then defined as the average visibility of these fluctuations, and is suffixed with "V". Using Figure 7-1, determine your visibility with the reportable values indicated. If the visibility is halfway between two reportable values, use the lower one.

Figure 7-1. Standard visibility values.

Increments of Separation (miles)						
$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{4}$	1	1	5
Visibility Values						
0	$\frac{3}{8}$	$1\frac{1}{4}$	2	3	10	15
$\frac{1}{16}$	$\frac{1}{2}$	$1\frac{3}{8}$	$2\frac{1}{4}$	4	11	20
$\frac{1}{8}$	$\frac{5}{8}$	$1\frac{1}{2}$	$2\frac{1}{2}$	5	12	25
$\frac{3}{16}$	$\frac{3}{4}$	$1\frac{5}{8}$	$2\frac{3}{4}$	6	13	30
$\frac{1}{4}$	$\frac{7}{8}$	$1\frac{3}{4}$	3	7	14	35
$\frac{5}{16}$	1	$1\frac{7}{8}$		8		40
$\frac{3}{8}$	$1\frac{1}{8}$			9		etc.

Chapter Eight

WEATHER

Observable weather can manifest itself in several different ways. It can consist of water particles, such as rain, snow and fog. It can also be made up of electrical phenomena, such as lightning or a thunderstorm. Other weather, like haze and dust, simply obscures visibility, and is regarded as an "obstruction to vision". Definitely track these elements and log them on both your weather and climatological forms! They help define the character of the weather at your location.

Lithometeors

A lithometeor is a weather phenomenon that consists of solid material suspended or falling through the atmosphere. According to federal standards, a lithometeor is not considered as occurring at the station unless it restricts the visibility (i.e. reduces the prevailing visibility to below 7 miles). Intensity is not listed for lithometeors except in the case of a severe duststorm or sandstorm.

Haze

A suspension of extremely small, dry particles invisible to the naked eye and sufficiently numerous to give the air an opalescent appearance. Haze casts a uniform veil over the landscape which subdues all colors.

Composition: Submicroscopic dust, soil, pollen, or a buildup of various pollutants.

Distant Objects: Dark objects tend to have a bluish tinge while bright objects may take on a dark yellowish hue.

Sky: The midday sky may have a silvery tinge.

Sun: In thick haze, the sun may become dirty yellow, and reddish at sunrise or sunset.

Smoke

A suspension in the air of small particles produced by combustion. It can occur either at the surface or in layers aloft.

Composition: Ash, carbon monoxide, etc.

Distant Objects: May appear dark gray or dark red.

Sky: Light gray or blue.

Sun: Orange. During sunrise or sunset, it may be very red.

Dust

Fine particles of dust or sand suspended in the air by a duststorm or sandstorm that may have occurred at great distances from the observing site.

Composition: Tiny dust or sand particles.

Distant Objects: Often take on a tan or grayish tinge.

Sky: Pale to a pearly color, or tan.

Sun: Pale and colorless. Sometimes may have a yellow tinge.

Shadows may disappear.

Duststorm/Sandstorm

Dust or sand raised by the wind to great heights above the ground, restricting the visibility to less than 5/8 of a mile. A SEVERE DUSTSTORM / SEVERE SANDSTORM occurs when visibility falls below 5/16 of a mile.

Blowing Dust/Blowing Sand

Dust or sand raised by the wind to heights great enough to affect the visibility at eye-level. When the visibility becomes less than 5/8 of a mile, a duststorm or sandstorm is occurring.

Dust Devil

A small, vigorous whirlwind made visible by dust, tumbleweed, or other debris picked up from the surface. Dust devils are normally recorded only in the remarks of an observation.

Hydrometeors

A hydrometeor is a weather phenomenon caused by water suspended or falling through the atmosphere. Clouds listed in these descriptions are those which are directly associated with the precipitation. There may be other clouds present, or the clouds may not even be seen due to obscuration by the precipitation. With the exception of blowing snow, all hydrometeors are recorded, regardless of the actual visibility value.

Rain

Precipitation in the form of drops larger than 0.02 inches (0.5 mm), or smaller drops, which, in contrast to drizzle, are widely separated.

Cloud: Rain falls primarily from nimbostratus, but light and moderate falls can originate from altostratus or stratocumulus, and on rare occasions, from altocumulus castellanus. Rain which falls from cumulus or cumulonimbus is classified instead as a rain shower.

Intensity: The rate of fall determines the intensity of precipitation. It is not necessary to wait one hour before reading the rain gage, for example, you may use a six-minute total and multiply the amount of new precipitation by ten to estimate the amount of fall per hour. If you cannot determine a rate of fall, then the descriptions listed below should be used.

Light Rain — 0.10 inches per hour or less. Can range from a condition where exposed surfaces are not completely wet, regardless of duration; to a condition where individual drops are easily seen. Slight spray may be 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.

Moderate Rain — 0.11 to 0.30 inches per hour. 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 a gentle roar.

Heavy Rain — More than 0.30 inches per hour. Rain seemingly falls in sheets; individual drops are not identifiable; 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.

Rain Showers

A fall of rain from cumuliform clouds. The precipitation tends to start and stop abruptly.

Cloud: Showers originate from cumulus and cumulonimbus.

Intensity: Use the guidelines for RAIN to determine rain shower intensity.

Freezing Rain

Rain which falls in liquid form, and then freezes upon impact. See guidelines for RAIN for cloud types and a guide to intensity estimation.

Drizzle

Fairly uniform precipitation composed exclusively of a dense fall of fine drops (diameter less than 0.02 inch). Sometimes it appears to move with air currents, although unlike fog droplets, it falls to the ground. The droplets usually do not cause or affect water puddles.

Cloud: Drizzle falls exclusively from stratus clouds.

Intensity: The prevailing visibility determines the intensity of drizzle. The criteria are listed below.

Light Drizzle occurring alone — Prevailing visibility 5/8 mile or greater. Accumulation rate is a trace to 0.01 inch per hour.

Moderate Drizzle occurring alone — Prevailing visibility 5/16 to 1/2 mile. Accumulation rate is greater than 0.01 inch per hour to 0.02 inch per hour.

Heavy Drizzle occurring alone — Prevailing visibility less than 5/16 mile. Accumulation rate is greater than 0.02 inch per hour.

Drizzle occurring together with other obscuring phenomena — Estimate the intensity based on personal experience. Once you have judged visibility, you should find that your estimated intensity will fall either within or below the visibility limits specified in the criteria above. If not, estimate a weaker intensity.

Freezing Drizzle

Drizzle which falls in liquid form, and then freezes upon impact. See drizzle, for an explanation of cloud types and estimation of intensity.

Snow

Precipitation of snow crystals, mostly branched in the form of six pointed stars. At temperatures higher than 23 degrees F, the crystals are usually agglomerated into snowflakes.

Cloud: Snow falls from the same clouds as rain (nimbostratus, altostratus, and stratocumulus), but can also fall from stratus.

Under certain conditions it may fall from altocumulus castellanus.

Intensity:

Light Snow — Prevailing visibility is 5/8 mile or greater.

Moderate Snow — Prevailing visibility is 5/16 to 1/2 mile.

Heavy Snow — Prevailing visibility is less than 5/16 mile.

Snow occurring together with other obscuring phenomena — estimate the intensity based on personal experience. Once you have judged visibility, you should find that your estimated intensity will fall either within or below the visibility limits specified in the criteria above. If not, estimate a weaker intensity.

Snow Showers

Precipitation of snow from cumuliform clouds. The precipitation tends to start and stop abruptly.

Cloud: Snow showers are associated exclusively from cumulus and cumulonimbus.

Intensity: Estimate intensity in exactly the same manner as snow.

Snow Pellets

Precipitation of white, opaque grains of ice. The grains are round or sometimes conical. Diameters range from about 0.08 to 0.2 inches. They are brittle and easily crushed. When they fall on hard ground, they bounce and often break up.

Cloud: Snow pellets are produced by stratocumulus, cumulus, and cumulonimbus clouds.

Intensity: Intensities are determined qualitatively.

Light Snow Pellets — Few pellets falling with little, if any, accumulation.

Moderate Snow Pellets — Slow accumulation.

Heavy Snow Pellets — Rapid accumulation.

Snow Grains

Precipitation of very small, white, opaque grains of ice, similar in structure to snow crystals. However, they do not bounce or shatter when hitting hard ground. They usually fall in small quantities and never in the form of showers.

Cloud: Snow grains fall exclusively from stratus clouds.

Intensity: Determined qualitatively.

Light Snow Grains — Few grains falling with little, if any, accumulation.

Moderate Snow Grains — Persistent, but light fall of snow grains.

Heavy Snow Grains — Fairly constant fall with appreciable accumulation.

Ice Pellets

Also known as "sleet". Precipitation of transparent or translucent pellets of ice, which are round or irregular, rarely conical, and which have a diameter of 0.2 inches or less. The pellets make a noise and rebound when striking hard ground.

Clouds: Ice pellets can fall from either altostratus or nimbostratus clouds.

Intensity: Determined qualitatively.

Light Ice Pellets — Few pellets falling with little, if any, accumulation.

Moderate Ice Pellets — Slow accumulation.

Heavy Ice Pellets — Rapid accumulation.

Hail

Precipitation of ice in the form of small balls or pieces (hailstones). Hailstones normally fall separately or frozen together in clusters. They consist of alternate layers of opaque and clear ice in most cases. Hail is usually associated with thunderstorms, and can fall in temperatures exceeding 80 or 90 degrees F (above 30 deg C). The main factor in whether hail will reach the ground is the average wet-bulb temperature in the low levels of the atmosphere.

Clouds: Hail originates exclusively from cumulonimbus.

Intensity: Hail is not assigned an intensity.

Ice Crystals

Also known as "ice prisms", and "diamond dust". A fall of unbranched ice crystals in the form of needles, columns, or plates. They are often so tiny that they appear to be suspended in the air. They may fall either from a cloud or from clear air. The crystals are visible mainly when they glitter in the sunshine or other bright light, and can then produce a sun pillar or other optical phenomena. Ice crystals are common in polar regions, and occur within very stable air masses at very cold temperatures.

Clouds: Ice crystals may be associated with any sky condition, including clear conditions.

Intensity: Ice crystals are not assigned an intensity.

Fog

A visible aggregate of minute water particles (droplets) based at the earth's surface. By definition, fog occurs over a sizable area, has a depth of more than 20 feet and restricts both horizontal and vertical visibility. It occurs when the dewpoint depression is 5 degrees F or less.

Ground fog (see below) represents a more shallow fog condition.

Clouds: Fog is a cloud based at the earth's surface. Since it develops in humid, stratified conditions, it may be associated with higher stratus layers.

Ground Fog

Fog, which has a depth of less than 20 feet. It restricts horizontal visibility, but at the same time the observer may be able to see stars, higher clouds, or the sun quite clearly.

Ice Fog

A suspension of numerous minute ice crystals in the air, based at the earth's surface and restricting horizontal visibility. It is similar to fog, but occurs at extremely cold temperatures (usually -20 degrees F and below), and does not produce rime or glaze on cold, exposed objects. Sometimes, ice fog may occur simultaneously with fog. Such a condition usually persists for a few hours, while the normal fog changes to ice fog and dissipates due to drying of the air (even though temperatures continue to fall). Dewpoint depressions of as much as 8 degrees F can be observed in ice fog.

Blowing Snow

Snow particles raised from the ground to six feet or more by a strong, turbulent wind. Visibility is restricted, and the sky may become obscured when the particles are blown to great heights.

Drifting Snow

Snow particles raised by the wind no higher than six feet. Objects on the ground may appear veiled. Drifting snow is recorded only in the remarks of an observation.

Funnel Cloud

A violent, rotating column of air which does not touch the ground. In a matter of minutes it may extend to the surface and produce a tornado or a waterspout (see below).

Cloud: Cumulonimbus clouds spawn most funnel clouds, but weak ones sometimes develop from cumulus clouds.

Tornado

A violent, rotating column of air, forming a pendant, which touches the ground. It usually starts as a funnel cloud.

Cloud: Tornadoes originate from cumulonimbus clouds, and are often attached to wall clouds or lowerings under the cumulonimbus base. Very weak tornadoes (known technically as landspouts) are seen occasionally from cumulonimbus and large cumulus clouds.

Waterspout

A violent, rotating column of air which touches a body of water.

Cloud: Most waterspouts come from cumulonimbus clouds, but in tropical and subtropical regions such as Okinawa (Japan), Texas, and Florida, they are frequently associated with cumulus clouds.

Photometers

Photometers are not normally included on government weather records since they have no impact on aviation or commerce.

However, they are frequently of interest to others, and should be included whenever they occur.

Halo Phenomena

This term in general refers to the optical effects that are produced by ice-crystal clouds. They are, from most common to most rare:

Small Halo. A luminous ring centered on the sun or moon, with a radius of 22 degrees. It is the most common type of photometer.

Sundog ("parhelion", "mock sun"). The sundog occurs just outside the small halo, or more rarely, outside the large halo. It

is a bright spot of light at the same altitude as the sun. They are caused by refraction of light through vertically-aligned ice crystals.

Large Halo. A very wide, luminous ring centered on the sun or moon, with a radius of 46 degrees.

Sun Pillar. Seen during sunrise or sunset, it is a tall pillar of light which rises through and above the sun (or rarely, sundogs). The sun pillar forms due to repeated reflection of light off the faces of plate hexagons which are standing upright.

Tangent Arc. Small arcs of light which intersect the top or bottom of the halo. They occur due to the refraction of light through the faces of horizontally-aligned ice crystals.

Infralateral Arc. A tangent arc occurring on the bottom of the halo.

Circumzenithal Arc. A ring centered on the zenith which intersects the top of the 46-degree halo while the sun is low. It is highly colorful but short lived and rare, and occurs when light enters the tops of plate hexagons and leaves through the prism face.

Parry Arc. An arc centered on the sun, positioned just above the 22-degree halo. It is extremely rare, and requires horizontally-aligned ice crystals which have two vertical or two horizontal faces.

Lowitz Arc. An extremely rare arc which seems to connect the sundog to the halo. It is produced by the vibrations in the tiny vertical ice crystals that produce sundogs. These arcs slope downward from the sundog and touch the small halo. This phenomenon is only seen when the sun's altitude is high.

Corona

A small colored disk centered on the sun or moon. With a radius normally of 10 degrees or less, it is smaller than the halo. The corona is occasionally colored; red predominates on the outside. It occurs when the sun or moon shines through a thin layer of clouds containing water droplets.

Rainbow

A group of concentric arcs produced on a "screen" of falling precipitation by sunlight or moonlight. It is centered directly opposite of the sun or moon. The colors usually include violet on the inside and red on the outside. When the precipitation droplets are large, the colors are often more intense.

Fog Bow

A primary rainbow consisting of a white band which appears on a screen of fog. It is usually fringed with red on the outside and blue on the inside.

Mirage

An optical phenomenon which modifies, multiplies, or displaces the images of distant objects. They are produced by the refraction of light in the layers of air closest to the earth's surface. The refraction is caused by sharp changes in the temperature (density) of the lower troposphere with height.

Superior (Upper) Mirage. The light rays are bent downward from a layer of warm air which is resting on a cold lower layer. Since the bending occurs through a large air mass, the images tend to be more stable and clear. Superior mirages are normally seen resting above the horizon. On occasion, they can convey images past the horizon and many hundreds of miles away; such mirages are known as looming mirages. Rarer forms of superior mirages have the ability to magnify across great distances through the atmosphere. They are called telescopic mirages.

Inferior (Lower) Mirage. Light rays are bent upward from a shallow layer of hot air near the surface. This layer is often only a few feet thin, so the images normally waver and flutter. Lower mirages usually occur below the horizon (as opposed to against the sky). The most common example of an inferior mirage is the ghostly "lakes" seen on hot road surfaces, desert sand, and plowed fields.

Alpine Glow

A series of phenomena seen in mountainous regions at dusk and dawn. The alpine glow occurs when the sun is just above the horizon. In the opposite direction, snow covered mountains take on a yellowish tint. As the sun sets, it changes from yellow to pink to purple, and colors extinguish when the shadow of the earth rises above the mountain. The afterglow occurs when the sun is 3 or 4 degrees below the horizon. A diffuse light is seen on the mountain with no sharp boundary, occurring when a purplish tint is seen in the sky. A reversal of the color changes occurs at dawn.

Green Flash

A green flash seen at the upper edge of the sun just as it disappears below or rises above the horizon. It may sometimes be seen against the moon or a planet. They tend to occur mostly in clear air when the horizon is very low in elevation and a long distance away, thus, they are seen chiefly at sea. The colors are not limited to green; blue and violet have also been observed. Explanations hold that occasionally light waves refract over the horizon while the sun is physically below it. The blue and green waves are refracted more intensely than the red waves. Most of the time, however, atmospheric scattering tends to wipe out the bluer colors, leaving the green waves which results in a green flash.

Bishop's Ring

A pale ring, centered on the sun or moon, with a slightly bluish tinge on the inside and reddish-brown on the outside. The inside of the ring is at a radius of about 10 degrees from the sun, while the outside is at 20 degrees. They are rare, and occur due to diffraction through fine dust in the high atmosphere. They have been observed after the eruption of Krakatoa, the Mt. Pelee eruption, the Tunguska meteor strike in 1908, during the passage of Halley's Comet in 1910, and after the 1991 eruption of Mount Pinatubo in the Philippines.

Iridescence

Known as "irisation" in the United Kingdom. It causes unusual colors to appear on clouds near the sun, often in the form of bands. These colors are often made up of green, pink, and pastel shades. Iridescence is caused by optical interference within the cloud. It is common on thin altocumulus, cirrocumulus, and stratocumulus layers, and can often be seen better with the use of sunglasses.

Shimmer

A very common phenomena, shimmer is the apparent fluttering of distant objects toward the horizon. It is more frequent with a bright sun, and is caused by the stirring of air with different temperatures, which continuously changes the refractive index over distance slightly and causes all sorts of subtle bending of the light ray. Shimmer can reduce the visibility noticeably.

Scintillation

Also known as "twinkling". This term refers to the rapid variations in the light from stars or terrestrial sources, and owes its cause to the same basic process as shimmer.

Electrometeors

An electrometeor is considered to be any meteorological phenomenon resulting from electrical causes.

Lightning

A flash of light from a sudden electrical discharge which occurs within a cumulonimbus cloud or near it. It is caused by the creation of zones of strong electrical charge within a thundercloud due to the production of ice particles. Lightning may originate from structures on the ground or from mountains. Lightning intensity is considered occasional (OCNL) when there is less than 1 flash per minute, frequent (FQT) from 1 to 6 flashes per minute, or continuous (CONT) when lightning is greater than 6 flashes per minute, or based on the observer's best judgement.

Cloud discharge (IC). Lightning which takes place within the cloud. It is the most common type of lightning and usually is responsible for the first strikes within a growing storm.

Cloud to ground lightning (CG). Lightning occurring between the cloud and ground, common with all thunderstorm types.

Cloud to cloud discharge (CC). Streaks of lightning reaching from one cloud to another. This type of lightning is typically associated with lines of thunderstorms.

Air discharge (CA). Streaks of lightning which pass from a cloud to the air, but do not strike the ground. Air discharges are normally associated with larger, decaying severe storms.

Thunderstorm

A local electrical storm produced exclusively by a cumulonimbus cloud. It is always accompanied by lightning and thunder, and usually occurs with strong gusts of wind, heavy rain, and sometimes, with hail.

Severe thunderstorm

A thunderstorm which is associated with hail 3/4" in diameter or greater and/or if winds reach 50 knots (58 mph) or greater.

Aurora

A luminous phenomenon which appears in the high atmosphere in polar latitudes (usually greater than 50 degrees north or south). It appears in the form of arcs, bands, draperies, or curtains, which are often white, but can take on other colors. The lower edges of the arcs or curtains are usually well-defined,

but the upper edges are not. Aurorae are created by electrically-charged particles ejected by the sun and acting on the rarified gases of the ionosphere. They are channeled by the Earth's magnetic field, causing them to be seen mostly near the magnetic poles in northern Canada and Antarctica.

Logging the Observation

Observers are encouraged to adhere to the internationally-recognized METAR code as closely as possible. Almost the entire world, including the United States, will be using this code by 1996, and it will be presented in this manual. See Figure 8-1 for a breakdown of these codes.

METAR, however, is designed to serve the aviation community. Amateur observers should make variations in the code, without altering the basic rules and abbreviations, in an effort to make their own observations easy and meteorologically useful. For example, the IWW suggests a set of symbols for photometeors, which currently have no recognition in the existing observing network but are meteorologically important. List any occurring photometeors in the remarks of the observation. Although the aurora borealis is actually an electrometeor, it has been grouped with photometeors to allow more flexibility for observing them.

If two or more conditions are occurring, use multiple abbreviations. Spaces are placed between major precipitation groups and between obstructions to vision. Some examples of multiple abbreviations, if a thunderstorm and heavy rain showers are occurring at the same time, enter "+TSSHRA". If light snow and fog are occurring simultaneously, enter "-SN FG". And if light freezing rain, moderate ice pellets, and fog are occurring, enter "-FZRA SHPE FG". Combine abbreviations according to the following order of entry (when two conflict, the more intense item is listed first):

- a. Tornado, funnel cloud, or waterspout;
- b. Thunderstorm;
- c. Liquid precipitation, in order of decreasing intensity;
- d. Freezing precipitation, in order of decreasing intensity;
- e. Frozen precipitation, in order of decreasing intensity;
- f. Obstructions to vision, in order of decreasing predominance, and only if the prevailing visibility is restricted to under 7 miles.

Figure 8-1. ABBREVIATIONS FOR WEATHER AND OBSTRUCTIONS TO VISION.

METAR Abbreviation	Condition	Category
RA SHRA FZRA DZ FZDZ SN SHSN SG GS PE SHPE GR FG IC FZFG MIFG BCFG BLSN DRSN * * * SQ	Rain Rain Showers Freezing Rain Drizzle Freezing Drizzle Snow Snow Showers Snow Grains Snow Pellets Ice Pellets Ice Pellet Showers Hail Fog Ice Crystals Freezing Fog Shallow Fog Patchy Fog Blowing Snow Drifting Snow Tornado Waterspout Funnel Cloud Wind Squall	WEATHER
HZ DU FU VA PY BLDU BLSA DS SS PO	Haze Dust Smoke Volcanic Ash Spray Blowing Dust Blowing Sand Duststorm Sandstorm Dust Devils	OBSTRUCTIONS TO VISION
GFLA MIRA SPIL IRID CORO 46HA SDOG 22HA RBOW	Green Flash Mirage (superior) Sun Pillar Iridescence Corona 46-degree Halo Sundog 22-degree Halo Rainbow	PHOTOMETEORS (no standard codes for photometeors exist; these codes are suggestions)
TS AURBO	Thunderstorm Aurora borealis	ELECTROMETEORS
Spelled out		OTHER PHENOMENA
* indicates the abbreviation is always spelled out <i>INTENSITY SUFFIXES (where applicable)</i> - Light (no suffix) Moderate + Heavy		

Chapter Nine

CLOUDS

Sky condition tells us about moisture aloft. It clues the weather observer in on what type of precipitation to expect. It gives the forecaster an idea of how much sunshine will provide heating for the day, and at night has a significant impact on the atmospheric radiation balance, which controls nighttime temperatures.

A cloud's definition is a visible aggregate of minute particles of water or ice, or both, in the free air. This aggregate may include larger particles of water or ice and particles, such as those present in fumes, smoke, or dust.

Cloud Appearance

The appearance of a cloud is determined by the nature, sizes, number, and distribution in space of its constituent particles. It also depends on the intensity and color of the light received by the cloud and on the relative positions of the observer and the source of light with respect to the cloud.

Luminance

The luminance of a cloud is determined by the light reflected, scattered, and transmitted by its constituent particles. The light may come from the earth's surface as well as the sun or moon, especially when snow cover is present. Haze affects the luminance of a cloud, also. On a moonlit night in rural areas, clouds are visible generally when the moon is more than a quarter full.

Ice crystal clouds are usually more transparent because of their thin composition and the sparseness of the ice particles. When the sun is low, they show sharp contrasts in luminance, but are otherwise white. Because of this effect, a cirrostratus layer may be mistakenly identified as altostratus during sunset, because of

the apparent thickness.

Color

Clouds do not generate their own colors. Color depends on the color of the incident light. Haze may make distant clouds look yellow, orange, or red, while colors can also be influenced by special luminous phenomena. Colors at night are generally black to gray, except those illuminated by the moon, which are whitish. Nighttime colors may be influenced by street lights, aurorae, fires, or simply by a colorful sunset or sunrise.

Nighttime observation

When observing clouds at night, the principle of continuity should be kept in mind. The observer should check the sky at dusk to get an idea of what to expect during the night. If precipitation falls at night, the descriptions associated with the precipitation will help distinguish cloud types. If the sky is clear, stars and planets will be visible, but only the brightest objects are visible through thin cloud veils. Variation of contrast or luminance may help to determine whether there are multiple layers of cloud. If the observer is located on a hill, lower clouds should be ignored. They may be noted in a remark, however.

Cloud Amount

Layer amount is defined as the total coverage of a specific layer of clouds (for example, a specific altocumulus layer). If that layer is the only one in the sky, then obviously the layer amount will equal the total sky coverage. Layer amount is estimated in oktas (eighths). What use this will be to you is discussed in the "Logging the Observation" section a few pages ahead, but here, we will simply discuss how the estimation technique should be done.

In judging cloud amounts, first determine if the layer in question covers the entire sky. If so, the amount is automatically 8 oktas. If not, the observer should ask themselves, "does this layer, altogether, obscure more or less than half of the entire sky"? If it is difficult to decide either way, it likely obscures 4 oktas exactly. If it obscures more than half of the sky, it covers between 5 and 7 oktas, and if not, it obscures 1 to 3 oktas. Deciding on a number should then be rather easy. If not, then the observer must "mentally" push all the clouds to one area of the sky and make the estimate that way.

The observer must judge the coverage of any visible higher cloud layers as if no others existed. To do this, watch the sky for a few moments, observing the extent of higher layers through breaks in the lower layer as the clouds move across the sky. At night, this can be difficult, but a general knowledge of the existing state of the sky and the weather patterns can help to arrive at a sufficiently accurate number.

A "packing" effect is frequently seen when the sky is filled with tall cumulus clouds. It occurs to the distance where the sides of the clouds obscure the view beyond. Observers should not count the blocking by these clouds as part of the layer amount. Instead, the sky above the observer should be looked at for a more representative number. However, if the distant clouds have grown into cumulonimbus towers, then the sides of the cloud will be added into the layer amount.

Cloud Heights

The layer height is defined by the World Meteorological Organization as the "lowest zone in which the type of obscuration perceptibly changes from that corresponding to clear air or haze to that corresponding to water vapor or ice crystals". Simplified, it indicates that layer height is the height of the lowest part of the cloud base. Layer height is always expressed in feet above ground level (AGL), not above mean sea level (MSL).

Although larger airports and weather stations make use of ceilometers to determine heights, they don't always detect the cloud, and station observers find themselves making "eyeball" estimates quite frequently. For the hobbyist, cloud height



Figure 9-1. Stratus.

estimation is both challenging and rewarding, but is not by any means a mandatory part of the observation. It can be done quite accurately with a little practice, and adds a new dimension to the information in your observation.

Estimation Techniques

Many times, the height of clouds will be readily apparent. When they obscure part of a hill, mountain, skyscraper, or tower, the height of the object can be used to guess the layer height. Also, observers who experiment with pilot balloons can release a balloon of known ascent rate into the layer to estimate its height. When the layer height must be eyeballed, identify the cloud type first, and based on this, make a guess of the height. Suggested heights accompany the text on each cloud type listed below. They can serve as a first guess for novice observers. Once a rough height estimate is made, the observer should refine and adjust the initial estimate. By looking at the general appearance, size of the elements, and comparing the cloud to past situations in memory, the observer can determine whether the layer is unusually low or high, and from that, which level it might be at. The observer can also consult layer heights reported by official reporting stations. Such reports can be downloaded from computer information services, or even checked on The Weather Channel's Local Forecast display.

Nighttime Techniques

At nighttime, heights can be estimated based on the effect of city and street lights on the cloud base. Small towns can illuminate layers as high as 5,000 feet, while large cities can easily cause high cirrus clouds at 35,000 feet to glow. By estimating the layer height before sunset and observing the effect of lighting on the cloud base, the observer can build a sense of good judgement when taking nighttime observations.

Units of Measurement

Consistent with international standards, the cloud base height must be rounded to the nearest: 100 feet when the cloud base is 0 to 5,000 ft high; 500 feet when the cloud base is 5,000 to 10,000 ft high; 1000 feet when the cloud base is over 10,000 ft high. For example, a stratus layer scraping the top of a 926-foot building is considered to be 900 feet high.

Cloud Types

There are ten main cloud types. These consist of the classic cumuliform (puffy) and stratiform (layered) types. There are also two stratospheric and mesospheric clouds that are occasionally observed in the polar regions. They have traditionally been ignored from government observations since they have no direct impact on commerce or aviation. In addition to them, there are obscurations which may be observed aloft and must be accounted for whenever they obscure the sky. For example, haze obscuring the lower horizon will need to be listed, as well as smoke over the station. Abbreviations for these cloud types and obscurations are in Table 9-1.

Stratus

Stratus (also known as "scud" and "pannus") is an amorphous, very low cloud, with a fairly uniform base. It may precipitate drizzle, snow, or snow grains. Rain may be present, but it is always caused by other clouds in conjunction with the stratus.

When the sun is visible through stratus, its outline is clearly discernible. Stratus is Latin for the past participle of the verb *sternere*, which means "to extend", "to spread out", "to flatten out", "to cover with a layer".

Origin. Stratus usually results from the widespread ascent or condensation of a layer of air close to the surface. It is often associated with areas of strong moisture advection. Stratus of bad weather (scud, or pannus) results from the saturation of the rain-cooled layers of air under a nimbostratus, altostratus, or cumulonimbus base.

Height. The base of stratus, typically at 1500 feet, is rarely over 3000 feet above ground level (AGL).

Stratocumulus

Grey or whitish, or both grey and whitish, patch, sheet or layer of cloud which almost always has dark parts, composed of tessellations, rounded masses, or rolls, which are non-fibrous (except for virga), and which may or may not be merged. Stratocumulus may sometimes be confused with altocumulus. In very cold weather, stratocumulus may produce abundant ice crystal virga. The word *stratocumulus* is a combination of the Latin words *stratus*, which means "to flatten out", and *cumulus*, which means "heap".

Origin. Stratocumulus results from the widespread ascent of unstable air.

Height. Stratocumulus heights are highly dependent on the type of weather situation present, but average 4000 feet. A layer above 6500 feet constitutes altocumulus.

Cumulus

Detached clouds, generally dense and with sharp outlines, developing vertically in the form of rising mounds, domes, or towers, of which the bulging upper part often resembles a cauliflower. The sunlit parts of these clouds are mostly brilliant white; their base is relatively dark and nearly horizontal. Sometimes cumulus is ragged. The word *cumulus* is Latin for "accumulation", "a heap", "a pile".

Origin. Convection of low-level air, normally from solar heating.



Figure 9-3. Cumulus.

Height. Heights are directly related to the humidity in the atmosphere. Cloud bases rise as the day progresses and humidity lowers. In the tropics early in the morning, the base can be as low as 1,500 feet and rise to only 2,500 feet. In desert regions, they often start as high as 7,000 feet and rise to 10,000 feet later in the day. The height at which cumulus clouds form is largely determined by the humidity of the surface air which is entrained into the convective updrafts. Furthermore, there is a formula which can determine their approximate height. Simply subtract the dewpoint from the temperature (in degrees F), and multiply by 4.5. The result will be the approximate height in thousands of feet. The formula cannot be used reliably in mountainous areas, nor will it indicate the height of other clouds.

Cumulonimbus

A heavy and dense cloud, of considerable vertical extent, in the form of a mountain or huge towers. By convention, it exclusively produces thunder, lightning, and/or hail. At least part of its upper portion is usually smooth, fibrous, or striated, and often spreads out in the shape of an anvil or vast plume. Under the base of this cloud, which is often very dark, there are frequently low ragged clouds either merged with it or not, and precipitation, sometimes in the form of virga in dry air. The word *cumulonimbus* comes from the combination of the Latin words *cumulus*, which means "heap", and *nimbus*, which means "rainy cloud".

Origin. Cumulonimbus clouds, which form due to deep convection in unstable air, almost always develop from large cumulus. The change from large cumulus with dome tops and a hard outline (produced by water drops) to a top with a softer fibrous outline (produced by ice crystals) marks the change from cumulus to cumulonimbus. Shortly afterward, this is often followed by the spreading of the highest part, leading to the formation of an "anvil". Often, strong upper-level winds blow the anvil downwind in the shape of a half anvil or vast plume.

Observing Cumulonimbus. Any part of a thunderstorm, except the portions of the anvil not over the storm itself, is considered cumulonimbus, regardless of the height. Anvil clouds immediately surrounding a thunderstorm do not have a definite base, and will be considered cumulonimbus. However, a detached roll cloud may be given a separate stratus designation, and an



Figure 9-4. Cumulonimbus.

extensively-spreading anvil cloud may be given a cirrostratus or cirrus designation.

Height. Normally cumulonimbus bases occur between 2,000 and 4,000 feet AGL. Even in the desert, its base rarely exceeds 7,000 feet. The top of the storm is normally between 15,000 and 35,000 feet above sea level, but exceeds 45,000 feet in severe storms and has been known to approach 80,000 feet.

Nimbostratus

Dense, grey cloud layer, often dark, the appearance of which is diffused by more or less continuously falling rain or snow which, in most cases, reaches the ground. It is thick enough throughout to block the sun. Nimbostratus is generally an extensive cloud, the base of which is frequently partially or totally hidden by ragged scud clouds (pannus). Care must be taken not to confuse these with the base of the nimbostratus. Scud clouds and the nimbostratus may or may not merge. Also, nimbostratus can be distinguished from thick stratus by the type of precipitation it produces (see chart). If hail, thunder, or lightning are produced by the cloud, it is then classified as cumulonimbus. The word *nimbostratus* is from the Latin word *nimbus*, which means "rainy cloud", and *stratus*, which means "to spread out".

Origin. Nimbostratus is produced by large-scale rising motion (typically from isentropic lift), as is usually seen along warm fronts and in upslope flow conditions.

Height. Typical base height is 2,000 to 4,000 feet, with shreds of stratus below. The cloud thickness can vary from 8,000 feet during light rain, to 20,000 during constant, heavy rain.

Altostratus

Greyish or bluish cloud sheet or layer of striated, fibrous, or uniform appearance, totally or partially covering the sky, and having parts thin enough to reveal the sun at least vaguely, as if through ground glass. Altostratus prevents objects on the ground from casting shadows. If the presence of the sun or moon can be detected, this indicates altostratus rather than nimbostratus. If it is very thick and dark, differences in thickness may cause relatively light patches between darker parts, but the surface never shows

real relief, and the striated or fibrous structure is always seen in the body of the cloud. At night, if there is any doubt as to whether it is altostratus or nimbostratus when no rain or snow is falling, then, by convention, it is called altostratus. Altostratus is never white, as thin stratus may be when viewed more or less towards the sun. The word *altostratus* is from the Latin *altum*, which means "height", and *stratus*, which means "to spread out".

Origin. Stable stratification of saturated mid-level air.

Height. Altostratus heights span through the entire limits of the middle cloud category heights, but are commonly seen at 10 to 15 thousand feet. When an altostratus sheet lowers into nimbostratus, it can be quite difficult to detect the height change. The observer must carefully watch the changes in the appearances of irregularities on the base of the cloud.

Altostratus

White or grey, or both white and grey, patch, sheet, or layer of cloud, generally with shading, and composed of laminae, rounded masses, rolls, etc. which are sometimes partially fibrous or diffuse and which may or may not be merged. Most of the regularly arranged small elements usually have a visual width or between 1 and 5 degrees. Altostratus sometimes produces descending trails of fibrous appearance (*virga*). The word *altostratus* is a combination of the Latin words *altum*, which means "height", and *stratus*, which means "heap".

Origin. Saturation or convection in marginally unstable middle levels of the troposphere.

Height. The height of altostratus is highly variable but most commonly it is seen at 12,000 feet.

Cirrus

Detached clouds in the form of white delicate filaments, or white or mostly white patches or narrow bands. These clouds have a fibrous appearance, or a silky sheen, or both. Cirrus is whiter than any other cloud in the same part of the sky. With the sun on the horizon, it remains white, while other clouds are tinted yellow or orange, but as the sun sinks below the horizon the cirrus takes



Figure 9-5. Nimbostratus.



Figure 9-6. Altostratus.

on these colors, too, and the lower clouds become dark and/or grey. The reverse is true at dawn when the cirrus is the first to show coloration. The word *cirrus* is Latin for "a lock of hair".

Origin. Saturation of upper-level moisture.

Height. Typical heights range from 25,000 feet in winter to 35,000 feet in summer, and up to 40,000 feet when directly associated with thunderstorm activity. The most common height year round is 25,000 feet, although this figure tends to be widely overused in official weather reports. In polar regions, the cold atmosphere often allows cirrus to descend to 10,000 feet.

Cirrostratus

Transparent whitish cloud or veil of fibrous or smooth appearance, totally or partially covering the sky, and generally producing halo phenomena. The cloud usually forms a veil of great horizontal extent, without structure and of a diffuse general appearance. It can be so thin that the presence of a halo may be the only indication of its existence. The word *cirrostratus* is a combination of the Latin words *cirrus*, which means "lock of hair", and *stratus*, which means "to spread out".

Origin. The stratification of widespread upper-level moisture.

Height. Cirrostratus is seen most often at 25,000 feet.

Cirrocumulus

Thin, white patch, sheet, or layer of cloud without shading, composed of very small elements in the form of grains, ripples, etc. merged or separate, and more or less regularly arranged. Most of the elements have a visual width of less than 1 degree. A rare cloud, cirrocumulus is rippled and is subdivided into very small cloudlets without any shading. It can include parts which are fibrous or silky in appearance but these do not collectively constitute its greater part. The word *cirrocumulus* is a combination of the Latin words *cirrus*, which means "lock of hair", and *cumulus*, which means "heap".

Origin. Convective cells in marginally unstable upper-tropospheric regions.



Figure 9-7. Altocumulus.

Height. Typical heights range from 20,000 feet to 40,000 feet. The most common height is about 30,000 feet.

Nacreous Cloud

Clouds resembling cirrus or altocumulus lenticularis, with strong iridescence, and showing brilliant colors when the sun is below the horizon. They occur at heights between 15 and 20 miles. Nacreous clouds are usually reported from arctic locations such as Scandinavia, Scotland, Alaska, and north Canada. The clouds are lenticular in form and delicate in structure. Colors seen are orange, pink, and dark pink, to black as the evening progresses and the sun becomes lower. They show strong iridescence. Even two hours after sunset, they can be seen as grey patches, and in moonlight they can be seen through the dawn. Nacreous clouds look like pale cirrus during the day. If a high cloud is still bright after cirrus turns grey, then it may be a nacreous cloud. The word *nacreous* is a form of the Latin word *nacrum*, which means "mother-of-pearl", the iridescent substance forming the inner layer of certain shells.

Origin. Diffraction equations suggest that the cloud consists of spherical ice particles. Nacreous clouds show little or no movement, and this suggests that they are in the nature of wave clouds. The clouds require a temperature of about -130°F to form, which occurs only in the polar stratosphere during the winter months. In the lower latitudes, such occurrences are more than likely the result of a thunderstorm, which can push a cirrus shield temporarily as high as 80,000 feet.

Height. They occur at heights between 70 and 100 thousand feet.

Noctilucent Cloud

Resembles thin cirrus, but with a blue, silver, or orange color. The cloud, which normally occurs at heights of about 50 miles, is unmistakable, it stays brilliantly lit long after sunset, usually retaining a blue tinge, while cirrus clouds rapidly turn gray by this time. The cloud usually appears in long streaks, much like cirrus. Coverage can range from a few streaks to a large mass



Figure 9-8. Cirrus.

Table 9-1. STANDARD CLOUD TYPE AND SKY OBSCURATION ABBREVIATIONS

CLOUD TYPES							
ST	Stratus	NS	Nimbostratus	CI	Cirrus	CB	Cumulonimbus
SC	Stratocumulus	AS	Altostratus	CS	Cirrostratus	NA	Nacreous Cloud
CU	Cumulus	AC	Alto cumulus	CC	Cirrocumulus	NL	Noctilucent Cloud
OBSCURATIONS							
RA	Rain	SN	Snow	DZ	Drizzle	IP	Ice Pellets (sleet)
IC	Ice Crystals	FG	Fog	BS	Blowing Snow	BY	Blowing Spray
SA	Dust	HZ	Haze	SA	Sand	FU	Smoke
<p>NOTE: Nacreous and noctilucent clouds aren't recognized by international weather networks; their abbreviations here are nonstandard.</p>							

resembling an altocumulus deck. Weaker forms look like decayed cirrus or a featureless, cirrostratus like mass. So far, they have been observed only in latitudes higher than 45°N. They are most commonly seen in the middle summer months at about latitude 55°N. The word *noctilucent* is from the Latin *nox*, which means "night", and *lucere*, which means "shining".

Origin. Sounding rockets have revealed a composition of ice crystals.

Height. Noctilucent clouds are normally seen between 250,000 and 300,00 feet.

Cloud Species

A cloud species describes a peculiarity in the cloud's shape and internal structure. An individual cloud may not belong to more than one species.



Figure 9-9. Cirrocumulus.

Fibratus — Ci, Cs

Detached clouds or a thin cloud veil, consisting of nearly straight or more or less irregularly curved filaments which do not terminate in hooks or tufts. From the Latin *fibratus*, which means "fibrous", "possessing fibres", "filaments".

Uncinus — Ci

Cirrus often shaped like a comma, terminating at the top in a hook, or in a tuft, the upper part of which is not in the form of a rounded protuberance. From the Latin *uncinus*, which means "hooked".

Spissatus — Ci

Cirrus of sufficient optical thickness to appear greyish when viewed towards the sun. From the Latin *spissatus*, past participle of the verb *spissare*, which means "to make thick", "condense".

Castellanus — mostly Ac, sometimes Ci, Cc, Sc

Clouds which present, in at least some portion of their upper part, cumuliform protuberances in the form of turrets which generally give the cloud a crenellated appearance. The turrets, some of which are taller than they are wide, are connected by a common base and seem to be arranged in lines. The castellanus character is especially evident when the clouds are seen from the side. The presence of altocumulus castellanus during the morning hours is often considered by thunderstorm forecasters to be a sign of strong instability aloft that may be realized during the day. From the Latin *castellanus*, derived from *castellum*, which means a castle or the enceinte of a fortified town.

Floccus — Ci, Cc, Ac

A species in which each cloud unit is a small tuft with a cumuliform appearance, the lower part of which is more or less ragged and often accompanied by virga. From the Latin *floccus*, which means "tuft of wool", "fluff", or "nap of a cloth".

Stratiformis — Ac, Sc, occasionally Cc

Clouds spread out in an extensive horizontal sheet or layer. From the Latin *stratus*, past participle of the verb *sternere*, which means to extend, to spread out, to flatten out, to cover with a layer, and *forma*, which means form, appearance.

Nebulosis — Cs, St

A cloud like a nebulous veil or layer, showing no distinct details. From the Latin *nebulosis*, which means "full of mist", "covered with fog", "nebulous".

Lenticularis — Cc, Ac, Sc**Lenticular Clouds**

Clouds having the shape of lenses or almonds, often very elongated and usually with well-defined outlines. They occasionally show iridescence (coloring). Such clouds appear most often in cloud formations of orographic origin, but may also occur in regions without marked orography. From the Latin *lenticularis*, derived from *lenticula*, diminutive of *lens* meaning a lentil.

Fractus — St, Cu

Clouds in the form of irregular shreds, which have a clearly ragged appearance. From the Latin *fractus*, past participle of the verb *frangere*, which means to shatter, break, snap, fracture.

Humilis — Cu**Fair-weather Cumulus**

Cumulus clouds of only a slight vertical extent, generally appearing flattened. From the Latin *humilis*, which means "near the ground", "low", "of small size".

Mediocris — Cu**Moderate Cumulus**

Cumulus clouds of moderate vertical extent, the tops of which show fairly small protuberances. From the Latin *mediocris*, which means "medium", "keeping to the middle".



Figure 9-10. Pileus, atop a growing cumulonimbus cloud.

Congestus — Cu**Towering Cumulus**

Cumulus clouds which are markedly sprouting and are often of great vertical extent. Their upper bulging part frequently resembles a cauliflower. From the Latin *congestus*, past participle of the verb *congere*, which means "to pile up", "to heap up", "to accumulate".

Calvus — Cb

Cumulonimbus in which at least some protuberances of the upper part are beginning to lose their cumuliform outlines but in which no cirriform parts can be distinguished. Protuberances and sproutings tend to form a whitish mass, with more or less vertical striations. From the Latin *calvus*, which means "bald", and in a wider sense, is applied to something stripped or bared.

Capillatus — Cb

Cumulonimbus characterized by the presence, mostly in its upper portion, of distinct cirriform parts of clearly fibrous or striated structure, frequently having the form of an anvil, a plume, or a vast, more or less disorderly mass of hair. Cumulonimbus capillatus is usually accompanied by a shower or by a thunderstorm, often with squalls and sometimes with hail. It frequently produces very well-defined virga. From the Latin *capillatus*, which means "having hair", derived from *capillus* which means "hair".

Cloud Varieties

A cloud variety describes special characteristics, related to the arrangement of the cloud elements and to their transparency.

Intortus — Ci

Cirrus, the filaments of which are very irregularly curved and often seemingly entangled in a capricious manner. From the Latin *intortus*, past participle of the verb *intorquere*, which means "to twist", "to turn", "to entangle".

Vertebratus — mainly Ci

Clouds, the elements of which are arranged in a manner suggestive of vertebrae, ribs, or a fish skeleton. From the Latin *vertebratus*, which means "having vertebrae", "in the form of vertebrae".

Undulatus — Cc, Cs, Ac, As, Sc, St

Clouds in patches, sheets, or layers, showing undulations. These undulations may be observed in fairly uniform cloud layers or in clouds composed of elements, separate or merged. Sometimes a double system of undulations is in evidence. From the Latin *undulatus*, which means "having waves", "waved"; from *undula*, diminutive of *unda*, which means "wave".

Radiatus — Ci, Ac, As, Sc, Cu

Clouds showing broad, parallel bands or arranged in parallel bands, which, owing to the effects of perspective, seem to converge towards a point on the horizon, or, when the bands cross the whole sky,

towards two opposite points on the horizon, called "radia-

tion points". From the Latin *radiatus*, derived from the verb *radiare*, which expresses the idea of having rays, being radiant.

Lacunosus — Cc, Ac, sometimes Sc

Cloud patches, sheets, or layers, usually rather thin, marked by more or less regularly distributed round holes, many of them with fringed edges. Cloud elements and clear spaces are often arranged in a manner suggestive of a net or a honeycomb. From the Latin *lacunosus*, which means "having holes" or "furrows".

Duplicatus — Ci, Cs, Ac, As, Sc

Superposed cloud patches, sheets, or layers, at slightly different levels, sometimes partly merged. From the Latin *duplicatus*, past participle of the verb *duplicare*, and expressing the idea of "doubled", "repeated", "something double".

Translucidus — Ac, As, Sc, St

Clouds in an extensive patch, sheet, or layer, the greater part of which is sufficiently translucent to reveal the position of the sun or moon. From the Latin *translucidus*, which means "transparent", "diaphanous".

Perlucidus — Ac, Sc

An extensive cloud patch, sheet, or layer, with distinct but sometimes very small spaces between the elements. The spaces allow the sun, the moon, the blue of the sky, or overlying clouds to be seen. This may be observed in combination with translucidus or opacus. From the Latin *perlucidus*, which means "allowing light to pass through it".

Opacus — Ac, As, Sc, St

An extensive cloud patch, sheet, or layer, the greater part of which is sufficiently opaque to completely mask the sun or the moon. From the Latin *opacus*, which means "shady", "shadowy", "thick", "bushy".

Supplementary features

The definition of a supplementary feature is a peculiarity attached to the main body of a mother cloud.

Incus — Cb

The upper portion of a cumulonimbus cloud spread out in the shape of an anvil with a smooth, fibrous, or striated appearance. From the Latin *incus*, which means "anvil".

**Mamma — mostly Cb, sometimes Ci, Cc, Ac, As, Sc
Mammatus Clouds**

Hanging protuberances, like udders, on the undersurface of a cloud. They are formed by cloud moisture that subsides into dry air, mixes, and rises again, causing a series of cells. Contrary to popular belief, mammatus clouds are not directly associated with tornadoes, nor do they occur anywhere near the tornado itself. However, severe thunderstorms often do produce mammatus clouds. From the Latin *mamma*, which means "udder" or "breast".

Virga — Cc, Ac, As, Ns, Sc, Cu, Cb

Vertical or inclined trails of precipitation (fallstreaks) attached to the undersurface of a cloud, which do not reach the earth's surface. From the Latin *virga*, which means "rod", "stick", or

"branch".

Praecipitatio — As, Ns, Sc, St, Cu, Cb

Precipitation (rain, drizzle, snow, ice pellets, hail, etc) falling from a cloud and reaching the earth's surface. Although this phenomenon is a hydrometeor, it is treated here as a supplementary feature because it appears as an extension of the cloud. From the Latin *praecipitatio*, which means "a fall" (down a precipice).

Arcus — Cb, sometimes Cu

A dense, horizontal roll with more or less tattered edges, situated on the lower front part of certain clouds and having, when extensive, the appearance of a dark, menacing arch. From the Latin *arcus*, which means "bow", "arch", "arcade", "vault".

Tuba — Cb, sometimes Cu

Tornado, Waterspout, Funnel Cloud

Cloud column or inverted cloud cone, protruding from a cloud base; it constitutes the cloudy manifestation of a more or less intense vortex. From the Latin *tuba*, which means "trumpet", and in a wider sense, "tube", "conduit".

Wall Cloud — Cb

A pronounced, organized lowering on the flat base of a very large cumulonimbus cloud. It may or may not have distinct rotation or motion. A tornado, waterspout, or funnel cloud may form beneath it. The word is derived from its appearance by Dr. Theodore Fujita.

Flanking Line — Cb

An organized line of more or less discrete cumulus towers growing alongside and connected to cumulonimbus cloud. Each cloud individually grows into a cumulonimbus cloud and dissipates, causing the thunderstorm activity to shift down the line. Fairly common with organized cumulonimbus clouds. The word is derived from its appearance; its origin is unknown.

Accessory Clouds

The definition of an accessory cloud is a peculiarity that is not attached to the mother cloud.

Pileus — Cu, Cb

An accessory cloud of small horizontal extent, in the form of a cap or a hood above the top or attached to the upper part of a cumuliform cloud, which often penetrates it. Several pileus may often be observed in superposition. From the Latin *pileus*, which means "a cap".

Velum — Cu, Cb

An accessory cloud veil of a great horizontal extent, close above or attached to the upper part of one or several cumuliform clouds, which often pierce it. From the Latin *velum*, which means "sail of a ship", "flap of a tent".

**Pannus — As, Ns, Cu, Cb
Scud Clouds**

Ragged shreds sometimes constituting a continuous layer, situated below another cloud and sometimes attached to it. These clouds are considered stratus clouds. From the Latin *pannus*, which means "piece of cloth", "piece", "shred", "rag", "tatter".

Logging the Observation

Although the world is moving towards the new METAR code, it is designed primarily for aviation interests, and does not adequately serve the weather community. It does not provide for cloud recognition or a specific cloud amount. Therefore, the IWW suggests using the old METAR code.

Code Breakdown

Each cloud layer is encoded in the form NTTHHH, where N is the amount of cloud in eighths, TT is the abbreviation of the cloud type (see Table 8), and HHH is the cloud height in hundreds of feet. This group is repeated as necessary for each cloud layer, in ascending order. An example is 4/8 of stratocumulus at 4,000 feet and 2/8 of cirrus at 20,000 feet. This would be encoded as "4SC040 2CI200".

Most amateurs may wish to use simply NTT, completely omitting cloud height. Using the above example, an observer would enter "4SC 2CI".

Obscuring phenomena

Obscuring phenomena with indefinite heights, such as haze, rain, and fog, are to be given heights of a triple slash, such as 2FG///, and will constitute the first layer group. If the obscuring phenomena completely obscures the sky, then indicate a coverage of 9 eighths, and enter a cloud height which equals the vertical visibility into the obscuration (such as 9RA010). Obscuring phenomena floating aloft, such as a smoke cloud, can be assigned the height of its lowest feature.

Handling cloud layers

When more than one layer is present, the observer will try to estimate the physical coverage of each higher layer as if no lower ones existed. If this cannot be done, then presume that higher, unseen layers are totally present behind all lower clouds. When the amount of lower and higher layers are added up, the result will often exceed eight oktas. This is because the layers, which can consist of any amount of coverage, are judged independently. Observation forms which take advantage of sky condition observations should accordingly be provided with three or four semi-separated entry blanks for three layer groups. If additional layer groups need to be listed, they can be placed on the next line or in the "remarks" entry blank.

APPENDIX

Computer Entry

A majority of weather observers have their own computer systems. However, not many realize that with a little time and effort, the computer can be the perfect tool for entering, printing, and analyzing weather records.

Spreadsheets allow the user to set up, for example, a monthly summary form and make daily entries. The spreadsheet can then be programmed to make all sorts of calculations to derive means, averages, totals, and even graphs. Quality output of the form or graph to a printer is often quick and simple.

There are also computer programs which are specifically tailored for weather recordkeeping. They are not as flexible as spreadsheets, but are easier to use and have their advantages. Many such programs can be found in the classified advertisements of weather periodicals.

Weather Observation Equipment/Supplies

Various weather instruments and weather observation information can be obtained from the following companies.

Abbeon Cal, Inc., 123 Gray Ave., Santa Barbara, California 93101 (805) 966-0810

American Weather Enterprises, P.O. Box 1383, Media, Pennsylvania 19063 (610) 565-1232

Belfort Instrument Company, 727 S. Wolfe Street, Baltimore, Maryland 21231. (301) 342-2626. Weather instrument manufacturer.

Bendix Environmental Science Division, 1400 Taylor Avenue, Baltimore, Maryland 21204. (301) 321-5200.

Berkshire Meteorological Services, Hunt Club Road, Old Chatham, New York 12136. (518) 766-5694.

Bureau Technique Wintgens s.a., Edgar Wintgens, President, Neustr. 7-9 B-4700, Eupen, Belgium. Fax (32) 87-743721. Weather instruments for observers in Europe.

Campbell Scientific, Inc. 815 West 1800, North Logan, Utah 84321-1784. Voice (801) 752-3268. Fax (801) 753-2342. Weather instrument manufacturer.

Cape Cod Wind & Weather Instrument, 625 Main Street, Harwichport, Massachusetts 02646. Weather instrument manufacturer.

Captain's Nautical Supplies, 138 N.W. 10th Ave., Portland, Oregon 97209 (503) 227-1648

Charles Dispenza, Box 4400-103, Tehachapi, California 93561. (805) 821-2617.

Colorado Scientific Instruments, 900 Broadway, Denver, Colorado 80203. (303) 832-2811.

Climatronics, 140 Wilbur Place, Airport International Plaza, Bohemia, New York 11716-2419. Voice (516) 567-7585. Fax (516) 567-7300. Weather instrument manufacturer.

Climet Instrument Company, 1320 West Colton Avenue, P.O. Box 151, Redlands, California 92373. (714) 793 2788.

Davis Instrument Manufacturing Corporation, Inc., 4701 Mount Hope Drive, Baltimore, Maryland 21215. Voice (410) 358-0252, (800) 368-2516. Fax (410) 358-3900, (800) 433-9971. Weather instrument manufacturer and retailer.

Downeaster, 574 Route 6A, P.O. Box 925, Dennis, Massachusetts 02638. (508) 385-8366. Weather instrument manufacturer.

Earth & Atmospheric Sciences, 2277 Maue Road, P.O. Box 986, Miamisburg, Ohio 45342. Voice (513) 859-7930. Fax (513) 859-1316. Weather instrument manufacturer.

Edmund Scientific Company, 101 E. Gloucester Pike, Barrington, New Jersey 08007-1380. Voice (609) 573-6295. Fax (609) 573-6250.

EG & G Sierra Misco, Inc., 151 Bear Hill Road, Waltham, Massachusetts 02154. (617) 890-3710.

Eppley Laboratory, 12 Sheffield Avenue, Newport, Rhode Island. (401) 847-1020.

Goodman's Meteorological Services, 275 Eve Street, Manchester, New Hampshire 03104-1558. Voice (603) 669-1990, (800) 497-0571. Internet 76350,627@compuserve.com.

Great Divide Weather Instrument Co., P.O. Box 4303, Englewood, Colorado 80155. (303) 773-2142.

Hinds International, Inc., P.O. Box 429, Hillsboro, Oregon 97123-0929. (503) 648-1355.

L'Softworks Limited, 803 12th Ave. NW, New Brighton, Minnesota 55112-2666. (612) 636-5538.

Maximum, Inc., 30 Barnet Blvd., New Bedford, Massachusetts 02745. Voice (508) 998-5359. Fax (508) 995-2200. Internet 75110.2422@compuserve.com. Weather instrument manufacturer.

Mountain States Weather Services, 904 East Elizabeth Street, Fort Collins, Colorado 80524. (303) 484-WIND.

The Nature Company Stores. Nationwide retail chain.

Novalynx Corporation, 3235 Sunrise Blvd., Suite 2, P.O. Box 240, Rancho Cordova, California 95724. Voice (916) 477-8339, (800) 321-3577. Fax (916) 477-5226. Internet 100145.3141@compuserve.com. Weather instrument manufacturer.

NRG Systems, Inc., 110 Commerce Street, P.O. Box 509, Hinesburg, Vermont 05461. Voice (802) 482-2272, (800) 448-9463. Fax (802) 482-2255. Weather instrument manufacturer.

Qualimetrics, Inc., 1165 National Drive, Sacramento, California 95834. Voice (916) 928-1165. Fax (916) 928-1000. Weather instrument manufacturer.

Rainwise, Inc., 25 Federal Street, P.O. Box 443, Bar Harbor, Maine 04609. Voice (207) 288-3477. Fax (207) 288-5169. Weather instrument manufacturer.

Science Associates, Inc., P.O. Box 230, Princeton, New Jersey 08540. (609) 924 4470.

Scientific Sales, 3 Glenbrook Court, P.O. Box 6725, Lawrenceville, New Jersey 08648. Voice (609) 844-0466, (800) 788-5666. Fax (609) 584-1560.

Sensor Instruments Co, Inc., 41 Terrill Park Drive, Concord, New Hampshire 03301. Voice (603) 224-0167, (800) 633-1033. Fax (603) 224-0167. Weather instrument manufacturer.

Simerl Instruments, 238 West Street, Annapolis, Maryland 21401. (301) 849-8667. Weather instrument manufacturer; known for its portable wind sensor equipment.

Storm Watch, 89 Mansfield Road, Framingham, Massachusetts 01701.

Taylor Scientific Instruments, 95 Glenn Bridge Road, Arden, North Carolina 28704.

Texas Electronics Inc., 5529 Refield Street, P.O. Box 7225, Dallas, Texas 75209. Voice (214) 631-4218. Fax (214) 631-2490.

Texas Weather Instruments, 5942 Abrams Rd. #113, Dallas, Texas 75231. (800) 284 0245.

Vaisala, 100 Commerce Way, Woburn, Massachusetts 01801. Voice (617) 933-4500. Fax (617) 933-8029. Weather instrument manufacturer; known for its rawinsonde equipment.

Viking Instrument and Photo, 532 Pond Street, South Weymouth, Massachusetts 02190. Voice (617) 331-3795, (800) 325-0360.

Weatherama Weather Instruments. Valley Park, 7395 162nd Street, West Rosemont, Minnesota 55068. (612) 432-4315.

Weather Dimensions, Inc., 4058 Orme Street, Palo Alto, California 94306. P.O. Box 846, Hot Springs, Virginia 24445. (800) 354-1117.

Weather Measure / Weatheronics, P.O. Box 41039, Sacramento, California 95984. (916) 923 5737.

WeatherTrac, 1625 Merner Avenue, P.O. Box 122, Cedar Falls, Iowa 50613. (319) 266-7403.

Robert E. White Instruments, 34 Commercial Wharf, Boston, Massachusetts 02110. (617) 742-3045, (800) 992-3045.

Wind and Weather, P.O. Box 1012, The Albion Street Water Tower, Mendocino, California 95460-2320. (707) 937-0323, (800) 922-9463.

R.M. Young Company, 2801 Aero Park Drive, Traverse City, Michigan 49684. Voice (616) 946-4772. Fax (616) 946-3980. Weather instrument manufacturer.

Non-Profit Publications and Organizations

International Weather Watchers

P.O. Box 77442, Washington, DC 20013

A non-profit organization serving amateur weather enthusiasts. Sponsors many different committees and projects.

Publishes the bi-monthly Weather Watcher Review.

Weatherwise

Heldref Publications, 4000 Albemarle Street, N.W., Washington, DC 20016

Six issues annually. A longtime, colorful weather magazine for the amateur.

National Weather Association

4400 Stamp Road, Room 404, Temple Hills, MD 20748

A professional trade magazine mainly for forecasters, published quarterly, with the newsletter issued eight times per year. It occasionally has material of interest for amateurs.

American Meteorological Society

45 Beacon Street, Boston, MA 02108

Professional society for meteorologists and researchers. Several journals are published.

Storm Track

c/o Tim Marshall, 1313 Brazos Blvd., Lewisville, TX 75067

An informal bi-monthly publication for amateur and professional storm chasers and severe thunderstorm enthusiasts, with information about thunderstorms, summaries, tips, chases, and cartoons.

Meteorological Units

Many observers enjoy computerizing their observations or working up conversion tables, and this manual would be incomplete without the math that goes into them. In this section, "exp" means "raise to the exponent of", and log indicates "take to base-10 logarithm". Always use standard algebraic rules when performing calculations; that is, perform operations within parentheses first, then remember that an exponential/root term has precedence over multiplication/division, which in turn has precedence over addition/subtraction. For instance, $2 + 4 / 2$ equals 4, not 3. However, $(2+4) / 2$ equals 3.

Temperature

An absolute temperature value is expressed in "degrees Fahrenheit", whereas a temperature change is indicated in "Fahrenheit degrees". For example, an observer can mention that the current temperature is 85°F, a rise of 40°F from the morning low (note the position of the degree symbol). Conversion of *temperature change* is the same as computing change in temperature values, however, 32 should not be added or subtracted.

Standard sea level temperature is 288.15 degrees Celsius.

Celsius = (Fahrenheit - 32) x 0.5555

Celsius = Kelvin - 273.16

Fahrenheit = (1.8 x Celsius) + 32

Kelvin = Celsius + 273.16

Rankine = (1.8 x Celsius) + 491.69

Mean Daily Temperature = (Day's High Temperature + Day's Low Temperature) / 2

Heating Degree Day = 65 - Mean Daily Temperature (°F) (a negative result is zero)

Cooling Degree Day = Mean Daily Temperature (°F) + 65 (a negative result is zero)

Growing Degree Day = Mean Daily Temperature (°F) - 50 (a negative result is zero)

Vapor Pressure

Normally expressed in millibars. Used in calculating mixing ratio. There are two different formulae in use.

Goff-Gratch Formula

More accuracy, more complicated.

When $T > 273.16$ degrees Kelvin,

$$e = 10 \exp [23.832241 - 5.02808 \times \log (T_d) - 1.3816 \times (10 \exp (-7)) \times (10 \exp (11.334 - 0.0303998 \times T_d)) + 8.1328 \times (10 \exp (-3)) \times (10 \exp (3.49149 - 1302.8844 / T_d)) - 2949.076 / T_d]$$

where

T_d = dewpoint temperature in degrees Kelvin.

When $T < 273.16$ degrees Kelvin,

$$e = 10 \exp [3.56654 \times \log (T_d) - 0.0032098 \times T_d - 2484.956 / T_d + 2.0702294]$$

where

T_d = dewpoint temperature in degrees Kelvin.

Teten's Formula

Less accuracy, simpler.

$$e = 6.11 \times 10 \exp [(a \times T_d) / (T_d + b)]$$

where

$a = 7.5$, $b = 237.3$ for $T_d > 0$ degrees C, or

$a = 9.5$, $b = 265.5$ for $T_d < 0$ degrees C

T_d = dewpoint temperature in degrees Celsius.

Saturation Vapor Pressure

Usually expressed in millibars. Used in calculating saturation mixing ratio. Calculate in the same manner as Vapor Pressure, except replace T_d with T within the calculations.

Mixing Ratio

Expressed in grams per kilogram. Used in calculating relative humidity and virtual temperature.

$$r = 1000 \times 0.622 \times e / (P - e)$$

where

e = Vapor pressure in millibars

P = Station pressure in millibars

Check value: when $T_d = 20$ deg C and $P = 990$ mb, $r = 15.04$ g/kg.

Saturation Mixing Ratio

Used in calculating relative humidity.

$$r_s = 1000 \times 0.622 \times e_s / (P - e_s)$$

where

e_s = Saturation vapor pressure in millibars

amateurs are prepared to pay. The mere conversion of hydrostatic formulas can be rather complicated without the use of a programmable calculator or a computer. Instead, we will supply a set of official psychrometric charts, used with permission of the National Weather Service, in a future update of this manual.

Virtual Temperature

Indicates density of the air. Usually expressed in degrees Celsius. Can be used to obtain a sea-level pressure reduction constant.

$$T_v = T + (r / 6)$$

where

T = Temperature in deg Celsius, and

r = Mixing ratio in grams per kilogram.

Relative Humidity

Expressed as a ratio, usually in percent.

$$RH = r / r_s \times 100$$

where

r = Mixing ratio

r_s = Saturation mixing ratio

Pressure

Standard sea level pressure is 1013.246 mb or 29.921 inches of mercury (inches Hg).

$$\text{Inches Hg} = \text{Millibars} \times 0.02953$$

$$\text{Millibars} = \text{Inches Hg} \times 33.86389$$

Altimeter Setting

This is the "official barometric pressure" as observed by the surface reporting network. To properly compute altimeter setting, the barometer must be calibrated to read station pressure. You may want to create a table to convert readings.

$$AS = (P_s/n + K \times H_p)^{1/n}$$

where

P_s = Station pressure in inches of mercury

H_p = Station elevation in feet

n = 0.190263 (1/n equals 5.255882647)

K = 1.31260 x 10⁻⁵ (0.000013126)

Check value: when P_s = 24.00 and H_p = 5548 then AS = 29.46

Station Pressure

The barometer should be set to this pressure, which is the actual, existing weight of the atmosphere on the barometer without any corrections. It can be determined by use of a mercurial barometer, or it can be estimated using an approximate altimeter setting for the region as follows:

$$P_s = (AS - K \times H_p)^{1/n}$$

where

AS = Altimeter setting in inches of mercury

H_p = Station elevation in feet

n = 0.190263

K = 1.31260 x 10⁻⁵

Sea Level Pressure

Similar to the altimeter setting, this is a reduced pressure which uses a temperature correction to diminish the effects of atmospheric heat on the barometer readings. Sea level pressure is used almost exclusively in surface analysis.

Stations above 50' MSL elevation.

$$P_0 = r \times P_s$$

where

P_s = Station pressure in millibars, and

r = Reduction ratio.

Stations at or below 50' MSL elevation. Sea level pressure for such stations may be calculated using a reduction constant.

$$P_0 = P_s + c$$

where

P_s = Station pressure in millibars, and

c = Reduction constant.

Reduction ratio

The International Weather Watchers is presently working with the National Weather Service and the World Meteorological Organization to research these formulae. All relevant technical information is currently out of print.

Reduction constant

For stations at or below 50' MSL only. It is negative for stations below sea-level.

Based on climatological data, determine the annual mean temperature, and the extreme low and extreme high temperature. Convert each to degrees Celsius, then calculate the virtual temperature for each value, and convert back to degrees Fahrenheit, rounding to the nearest 0.1 degree. When finding the mixing ratio, use the typical dewpoint value which might be representative of each reading (use the psychrometric tables to help determine any wet-bulb readings for the mixing ratio equation). Also, use a normal station pressure for the station (convert an altimeter setting of 29.92 inches to station pressure). Then consult the Sea-Level Pressure Reduction Constant Table in the back of this book to convert each virtual temperature to a reduction constant (use the absolute elevation value if the station is below sea-level).

If either extreme reduction constant differs from the mean reduction constant by more than 0.2 mb, then the station cannot use a reduction constant, it must instead use a reduction ratio. Otherwise, round the mean reduction constant to the nearest 0.1 millibar and establish it as being the "official" reduction constant for the station.

Heat Index

Heat index, also known as apparent temperature, was introduced in 1979 by R.G Steadman of Colorado State University. The heat index replaces the antiquated temperature-heat index (THI) by providing more realistic, accurate numbers to measure the effects of humidity and heat. The result is a somewhat arbitrary measure.

A heat index of 90 degrees or higher signals the threat of heat exhaustion with prolonged exposure, while a heat index of 105 degrees or higher introduces the threat of heat stroke. Heat stroke is likely with continued exposure in heat indices of 130 degrees or above.

Table A-1 is used to calculate heat index. The associated formula is very complex and is beyond the scope of this manual.

Table A-1. HEAT INDEX.

TEMP (F)	DEWPOINT (Degrees F)												
	58	60	62	64	66	68	70	72	74	76	78	80	82
68	69	70	70	70	70	70							
70	70	71	71	72	72	72							
72	72	72	72	73	73	73	74						
74	73	73	74	75	75	75	76	77					
76	76	76	77	78	78	78	79	80	80				
78	78	78	78	80	80	80	81	82	82				
80	80	80	80	82	82	82	83	84	85	86	87		
82	82	83	84	84	85	86	87	88	89	90	91	93	97
84	84	85	86	86	87	88	89	90	91	93	94	95	99
86	86	87	88	88	89	90	91	91	93	95	96	98	100
88	88	89	90	90	91	91	93	94	95	97	99	100	103
90	90	91	91	91	92	93	95	97	98	100	101	103	106
92	91	92	93	94	95	96	97	99	100	102	104	106	109
94	94	95	96	98	99	100	101	102	104	106	108	110	114
96	96	97	98	100	100	101	103	104	106	109	111	113	117
98	98	99	100	102	103	104	105	107	109	112	114	116	120
100	100	102	103	106	107	108	109	111	113	116	119	122	126
102	102	103	105	108	109	110	112	114	116	119	122		
104	104	105	107	109	111	113	115	117	118	122	124		
106	106	107	109	111	113	115	117	118	121	123			
108	108	109	110	113	115	117	118	120	123				
110	109	110	112	115	117	118	120	122	124				
112	112	113	115	118	119	121	123						
114	114	115	117	119	121	123							
116	116	117	118	121	122								
118	118	119	121	124									

P = Station pressure in millibars
Check value: when $e_s = 20$ mb and $P = 980$ mb, $r_s = 12.958$.

Dewpoint

The cost of circular-slide psychrometric calculators used in weather service offices can approach \$100, a price that not many

Wind Speed

Knots = Miles per hour x 1.15
Miles per hour = Knots x 0.8696

Wind Chill Index

When the wind speed is under 4 mph, the wind chill index should be made to equal the temperature.

$$WC = 0.0817 \times ((3.71 \times \text{square root } (V)) + 5.81 - (0.25 \times V)) \times (T - 91.4) + 91.4$$

where

T = Temperature (degrees F)

V = Wind speed (MPH)

Hail Size

The following hail sizes are officially recognized by the National Weather Service.

¼" Pea	2"	Hen Egg
½" Marble, Mothball	2½"	Tennis Ball
¾" Dime, Penny	2¾"	Baseball
1" Quarter, Nickel	3"	Tea Cup
1¼" Anthony or Half-dollar	4"	Grapefruit
1½" Walnut	4½"	Softball
1¾" Golf Ball		

Getting Involved

For the amateur seeking ways of disseminating reports and observations, there are a number of ways of doing so. Here is just a small sample.

Cooperative Observing

Across the nation are thousands of climatological stations run by individual persons or companies. The data are sent primarily to the National Climatic Data Center (NCDC) and used in climatological studies and filed in archives.

Being a cooperative observer demands a long-term commitment to observing at that particular location. If it is expected that the observer will be moving away within a few years, the participation of the station is usually discouraged. Most cooperative observing stations have been in place for twenty years; sometimes as many as eighty or ninety, and are often run by successive generations of the family at that household.

Amateur Organizations

The thousands of observers affiliated with amateur weather organizations without a doubt make up the freshest, most diverse and resourceful weather stations in existence. Many of these observers are not necessarily trying to build up a climatological record, but instead enjoy observing for the fun and challenge of it. Observers share their data, strive for accuracy, and learn from each other through discussions, mistakes and experiments.

The largest non-profit association of amateur weather

observers in the world is the International Weather Watchers (IWW), P.O. Box 77442, Washington, DC 20013. This organization seeks to bring new opportunities, activities, and education to the amateur weather hobbyist. Their official bi-monthly publication *Weather Watcher Review* contains summaries of monthly and annual data, as well as informative and entertaining articles for its readers and reports covering ongoing IWW projects.

All amateurs shouldn't hesitate to look into joining regional groups, such as the Atlantic Coast Observer Network (ACON), Long Island Weather Observers (LIWO), and the North Jersey Weather Observers (NJWO).

Television News Networks

Many television weathercasts pride themselves on their network of organized "weather watcher teams", and rightfully so. These dedicated volunteers help give a local perspective on rainfall and temperature in specific communities and across different parts of town. An advantage to being part of a TV weather watcher team is that it requires no great commitment. The only thing expected of observers is that they disseminate their reports regularly to the TV station. Just before a newscast, the observer simply calls an unlisted number and relays the amount to a secretary or a special answering machine. Then, the observer gets to experience the thrill of seeing his or her observation live on the airwaves. There are some larger radio stations that head weather watcher teams, but they are few and far between.

Skywarn

Skywarn teams are groups of volunteer amateur radio operators in individual cities and communities who act as the National Weather Service's eyes and ears during severe thunderstorms and flooding. Directed by a net control person, the Skywarn participants drive strategically to areas around a thunderstorm and observe winds, cloud features, and weather that might be indicative of tornadoes, hail, damaging winds, and floods. A representative at a nearby National Weather Service office usually listens in on the reports and gives feedback and the current forecast thinking.

Skywarn participants are encouraged to have an amateur radio license and their own 2-meter or half-meter radio gear, usually a \$200 to \$400 investment. The Morse Code test requirement on amateur licenses was lifted recently, so qualifying for a license is now much more easier than it was ten years ago.

When severe weather breaks, the Skywarn emergency net is called into action. A special tone sounds, triggering alarms on radio gear and calling all volunteers to action. The net control person takes count of all those available, and then describes the weather situation, the game plan, and starts taking reports. Although Skywarn participants are encouraged to be "mobile" when possible during the storm episode, reports from home or work are always welcomed.

Annually, many Skywarn personnel attend a seminar or class given by officials and weather service personnel. The latest photographs, films, and techniques for identifying severe storms are presented.

And when the storms are gone? The radio net is open for idle chit-chat and socializing with other radio buffs. And many amateurs find another "family" with their Skywarn friends.

Computer Bulletin Boards

Dedicated amateurs in larger cities may wish to establish a computer bulletin board, which is accessible by anyone with a computer and a modem. A computer bulletin board requires an investment of at least several hundred dollars, but the rewards sometimes overshadow the cost. Amateurs can also talk to system operators (sysops) of existing boards to discuss the possibilities of expanding their systems into weather subjects.

A computer bulletin board offers hobbyists the ability to leave public messages and electronic mail to other hobbyists. Station data and summaries can be posted or exchanged, or users can simply chat about the latest hurricane that hit the coast. And for the thousands of computer hobbyists who hop from board to board, it might offer them the perfect excuse to cultivate their own interest in weather.

Career Opportunities

Most weather observation positions are steps through the weather career field to positions of higher responsibility, such as forecasting and management.

A major employer of civilian weather observers at airports is the Federal Aviation Administration. Pay can range anywhere between minimum wage to \$10.00 per hour. The certification process is usually comprised of on-the-job training.

The U.S. Air Force and the U.S. Navy both have an extensive weather program and make use of hundreds of enlisted weather observers at bases in the United States and worldwide. Officers are normally not assigned to observing positions. After graduating from basic training, observers are assigned to an intensive technical training program, and then supplement the training at their new duty station with on-the-job training and career development studies. Most military observers remain in their position for about 3 to 6 years, and upon reenlistment are required to upgrade their skills by attending forecasting school. Recently the Navy

has had to cope with a surplus of enlisted weather people, whereas the Air Force has a shortage and is always looking for those interested in weather.

References and Suggested Reading

The following references indicate sources of information that were consulted in the creation of this manual and are recommended for the amateur observer.

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Figure A-1. The National Weather Service can provide one of the best employment opportunities for those with meteorology degrees. This public service forecaster at the Fort Worth, Texas forecast office is preparing to send out a weather bulletin.