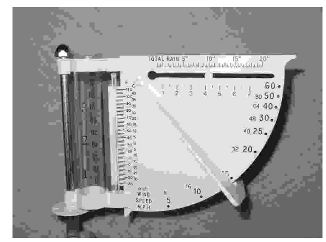
A Naturalists and Teachers Guide to Weather Forecasting by John Guyton, Ed. D.

"Some people are weather wise, some are otherwise" – Ben Franklin

The purpose of teaching a weather unit should be to help students learn a little about forecasting, adapting to its eventualities and preparing for its extremes. The easiest way to teach meteorology is to start making forecasts and watching for impending meteorological changes. We will focus on three interrelated techniques for forecasting the weather in this and the next two newsletters.

Where Weather Comes From

Weather is about air masses. Cold dry air masses come from the polar regions and warm moist air masses from nearer the equator. Winds arrive with moisture and temperature characteristic of where they originate. Wind arriving from over land is dry and wind from over water is moist. Wind direction and speed can be used to forecast the arrival of these masses. A flag, wind vane, wind sock or a piece of yarn on a fence post in a field outside a window, allowing for routine observations, is a good place to start.



If the prevailing winds have been from the north and begin shifting to the west and then southwest, a warm air mass is coming to town. If on the other hand the prevailing winds have been from the southwest and they begin shifting through west to northwest, then a colder air mass is on its way. Rain often accompanies both, but weather from the southwest brings more moisture, hence more rain and it usually last longer. Changes in wind direction alone provides a useful forecasting tool. Of course you must know your cardinal directions and regularly notice wind direction to know when there is a change. The very useful and inexpensive weather station shown measures wind direction and speed, rain, and temperature.

We can increase the precision of our forecast by using barometric pressure and a chart developed by the National Weather Service. Digital weather stations that display a graph of the barometric pressure for the past 12 to 18+ hours, are very useful. Cold dry air is more dense, or heavier, and hugs the ground. Warm moist air is lighter. The barometer measures subtle changes in air pressure or the weight of the air. When the barometric pressure is falling (low pressure) warm moist air is moving into the area and when the barometer is rising (high pressure) cooler dryer air is foretold. High pressure can be thought of as a hill and low pressure as a trough or valley. Air, in general, flows from high pressure to low, as water would do. Rain is more often forecasted with the arrival of low pressure and high pressure is associated with clear days. To use the Forecaster Chart read the forecast where the wind direction (direction wind is coming from) and the barometric pressures and trend (rising or falling) intersect. Now we have two forecasting tools, changes in wind direction and barometric pressure.

Winds are the product of the uneven heating of earth's surface and atmosphere. Air above areas heated by the sun, rises and spreads out causing areas of low pressure. This is like stepping onto a chair from the bathroom scales. Air is sucked into low pressure areas to replace the air that has risen causing wind. Air pulled into the low pressure area from the southwest is typically warm and moist and called a warm front. Air pulled in from the northwest is typically colder and dry and is referred to as a cold front. The ascending air twists in a counterclockwise direction as it rises, the result of the earth's spin on its axis. The jet stream, a band of high speed winds in the upper atmosphere moving from west to east, pulls low pressure areas along its path. What goes up must come down and when air has given up enough of its heat it begins to descend, spiraling down clockwise creating high pressure areas (stepping back down onto the bathroom scales). Barometers are useful in determining the approach of high and low pressure areas.

Record Keeping – By now, you should be making good forecasts and it is time to start keeping records. Use a weather chart, similar to the one included. In the note box record the accuracy of each forecast and think about how you can improve your accuracy. As your skill in forecasting improves, compare your forecasts with a local meteorologist's.

A weather unit should be started early in the school year so there will be numerous warm fronts and cold fronts to study and a year to reinforce the learning. Encourage students to continually watch for shifts in the wind direction and barometric pressure changes. The direction of barometric pressure changes and the magnitude of the change are very important; how much did it rise, or fall, and how quickly.

Fronts form at the boundary of warm and cold air masses. Fronts usually arrive in pairs with the warm front preceding the cold. Fronts typically bring wet weather. As you monitor the passage of fronts watch for trends in temperature, pressure, wind direction, rain and cloud type and height.

Weather Forecaster Chart									
Minimum of 2 observations/ day		N	NE	E	SE	S	SW	W	NW
Barometer Falling	Above 30.2 falling slowly	Unsettled probably cloudy	Summer - light winds; Winter rain		Cloudy & warmer	Increasing clouds	Fair & warmer	Rising temp. & fair	
	Above 30.2 falling rapidly	Cloudy rain probably warmer	Rain, increasing winds		Cloudy & rain	Rain	Cloudy & warmer	Increasing clouds	Unsettled, rain if winds continue
	30.0 to 30.2 falling slowly	Unsettled probably cloudy	Rain or Snow		Rain & warmer		Unsettled warmer	Fair & warmer	Unsettled
	30.0 to 30.2 falling rapidly	Rain & colder	Increasing wind & rain		Increasing wind, rain & warmer	Increasing wind & rain	Rain & colder	Rain	Increasing cloudiness
	Below 30.0 falling slowly	Unsettled	Rain & cooler	Rain			Unsettled & cloudy	Unsettled	
	Below 30.0 falling rapidly	Severe gale, heavy rains; in winter cold wave		Severe storm, rain	Severe storm imminent	Stormy; in winter colder	Rain		Unsettled
Barometer Rising or Steady	Above 30.2 steady	No change or Continued Fair							
	Above 30.2 rising	Fair & cooler	Fair	Fair & cooler	Fair				Fair, much colder
	30.0 - 30.2 steady	No change						Fair	
	30.0 - 30.2 Rising	Fair & cooler	Fair	Fair; colder in winter	Fair & warmer	Fair		Fair & cooler	
	Below 30.0 steady	No change							
	Below 30.0 Rising	Fair & cooler		Clearing then Fair				Fair & colder	

Pressure change in 12 hours: 0.2" and above is a rapid change; 0.05" to 0.2" is a slow change; 0" to .05" is considered steady.
Forecast begins 12 to 24 hours after observation. Barometric Pressure in inches of Hg.
Table from the National Weather Service

Try This!

Place a small glass jar of hot water with red food coloring in the bottom of an aquarium. A piece of plastic with a few holes in it secured over the top of the bottle with a rubber band will allow the warm red water to rise to the surface spreading out just as warm air rises and spreads out.

Hot humid air is less dense, or lighter, than cold dry air. Hot air rises and flows over cooler dry more dense, or heavier, air. If you are reading carefully that likely sounds wrong, but it isn't. Humid air is lighter than dry air because the water molecule has a lower molecular weight than the nitrogen and oxygen in dry air. Further, hot air is also made less dense through thermal expansion (heated air rises, expands and spreads out).

Warm Fronts

- Warm air advances from the southwest rising over the cooler air in a wedge shape and pushing out the cooler air. As the warm air is forced up it expands, cools and moisture condenses into a liquid that often freezes into ice crystals forming cirrus clouds.
- As a warm front approaches the first clouds are very high cirrus, followed by lower altocumulus and altostratus. Rain comes from dark nimbostratus clouds. A warm front usually passes with light rain of long duration, often bringing a few warm days.

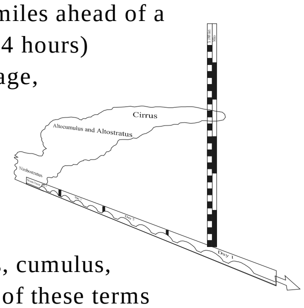
Cold Fronts

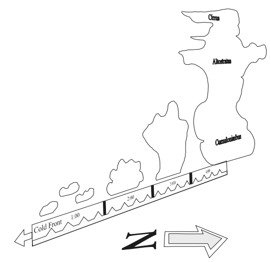
- Cold fronts move rapidly and warning is frequently only a few hours. Cumulus clouds rapidly grow in number and height becoming altocumulus, and are followed by dark bottomed cumulonimbus and thunderstorms.
- Cold fronts typically arrive from the northwest every 5 to 7 days during the winter.
- Cold fronts have greater energy and momentum due to their greater density.
- As the dense cold air pushes the warm moist air up the warm air expands, cools, moisture condenses, and precipitation occurs.

Long Foretold Long Last, Short Notice Soon Will Pass

Clouds
Watch the local weather forecast to determine when the next cold or warm front will be arriving – this is the time to begin teaching about clouds. Before the first tell-tale clouds arrive find a chart illustrating the clouds associated with the different fronts. Charts showing the clouds associated with warm and cold fronts are available in text books or on the Internet. Teachers should consider asking a handy parent to build models of cold and warm fronts for the outdoor classroom. Pictures and patterns are available from the author. Models of the fronts in the school garden serve as ongoing reinforcement as students monitor the weather. The warm and cold fronts are best arranged in the direction from which they typically arrive (warm fronts from the southwest and cold fronts from the northwest). Scale sticks for estimating cloud height and frontal speed across the ground and incorporating appropriate front symbols make the models more useful.

The high cirrus clouds preceding the warm front can be 4 days and 600 miles ahead of a slow, drizzly rain. Mounting cumulus clouds can foretell the rapid (1 to 4 hours) approach of a cold front and a hard, but short duration, rain. The old adage, "Long foretold, long last; short notice, soon will pass" is useful in remembering the type of precipitation associated with each front. Incorporating clouds observations into your forecasts gives you a third forecast technique.





Minimize the number of cloud names and master the basic forms (stratus, cumulus, cirrus and nimbus) and the weather associated with each. Combinations of these terms result in more descriptive cloud types: high cirrus clouds - cirrus, cirrocumulus and cirrostratus; middle level clouds - *alto*cumulus and *alto*stratus; and low clouds - cumulus, stratocumulus, nimbostratus and stratus. The Internet contains many excellent photos and descriptions of cloud types so I have not elaborated on them here.

Lets Make a Cloud. Try these two demonstrations of cloud formation. The first involves a drop in pressure, the second cooling of warm moist air. Note, water vapor is invisible and liquid water is visible. Therefore, clouds are composed of liquid water.

- Pour a few ounces of water into a 5 gallon water bottle and shake to create a humid atmosphere. Drop a lighted match into the bottle to simulate the dust or smoke particles in the atmosphere. Clouds require water vapor and dust or smoke particles to form, hence the small dust spots on the car top after light showers. These small particles of dust are cooler that the surrounding atmosphere and cool the air around them condensing the moisture. Rain removes a lot of dust from the atmosphere. Drill a hole in the water bottle top and insert an air pump nozzle. Hold the top on the bottle to prevent it from popping off too quickly and pump it up, using a bicycle pump. When the top pops off, note the cloud that quickly fills the bottle. Replacing the top and increasing the pressure will cause the cloud to dissipate, typical of an approaching high pressure area.
- Drop a lighted match in a glass containing a half inch of hot water and quickly cover it with a bowl of ice. The bowl of ice will cool the air below causing the water vapor to condense into a cloud. Continue watching and water will collect on the bottom of the bowl and soon drip (rain).
-

Weather Observations and Forecasts Chart

Date/Day	Time	Temperature	Relative Humidity	Barometric Pressure Trend	Wind Direction & Speed	Cloud Type	% Cloud Cover	Rainfall	Dew	Forecast	Notes

Relative Humidity is the ratio of the amount of water vapor in the air to the amount it can hold at that temperature. A glass of ice tea is an indicator of relative humidity. Moisture in the air that comes in contact with the cold glass condenses, leaving drops of water on the outside of the glass. A pine cone is also an indicator of relative humidity. Moist air tightens the scales to protect the seeds. A fresh pine cone on a window ledge is fun to watch as the humidity changes. Increasing humidity is often a sign of rain.

The hygrometer is used to determine the amount of water vapor in the air relative to the amount it can hold. Warm air can hold more water than cool air, and air containing water vapor is lighter than dry air (this also influences barometric pressure - air containing water vapor is lighter so the barometric pressure is less).

When the indoor humidity drops below 30%, breathing can become uncomfortable and furniture creaks. Humidity in excess of 60% can contribute to mold and mildew problems. When the humidity is less than 40%, air pulls, or absorbs, water from any available source. Dry air can make you feel cold in a warm room. Moisture evaporating from the skin leaves a feeling of chilliness, even when the temperature is 75° F or more. A humidity higher than 60% makes people feel their environment is warmer than it really is. An area at 72° F and 60% relative humidity, or greater, feels warmer than 72° F with a relative humidity of 40%. The evaporative cooling of the body (perspiration) is reduced as relative humidity increases. If the thermostat indicates it is 75° F and you are still cold, turn on the humidifier!

The science involved in determining the amount of moisture in the air is rather interesting. The dryer the air the more quickly water will evaporate. Water must absorb heat to evaporate. When you dip your finger in a glass of water and spin it around you notice it becoming cooler. The water is scavenging heat from your finger in the process of evaporating. Think of temperature as a measure of molecular motion - the greater the molecular motion the higher the temperature. Some of your finger's molecular motion is transferred to the evaporating water. A wet/dry bulb hygrometer compares the temperature of a thermometer with a wet wick over its bulb to a dry bulb on another thermometer. The wet bulb temperature will typically be lower because of the evaporative cooling of the water on the wick. Tables are used to interpret the readings from the hygrometer. Direct reading digital hygrometers are also found on many digital weather stations.

Dew Point is the temperature at which atmospheric water vapor starts to condense as the air is cooled. As air heats up it can hold more water vapor. When the air mass begins to cool down it must give up some of its moisture. When the relative humidity reaches 100% and the temperature continues to drop, water vapor will begin condensing into liquid water in the form of dew, clouds, fog or rain. When the ground cools off very rapidly at night, the water vapor in the air touching blades of grass condenses directly onto the grass. When you shower, the warm water increases the humidity and the dew point temperature. The cooler mirror condenses some of the moisture. If the shower is hot enough and the air humid enough, a light fog may form in the bathroom. If the humidity is high and the temperature is falling you are headed for dew point and can expect dew, fog or precipitation.

Forecasting Frost – The closer the sunset temperature to freezing the better the chance for frost. Strong breezes discourage frost formation. Wind shifting to the north or the arrival of a cold front overnight can cause frost. Warm soil discourages frost. If the local terrain is in a bowl or depression, cold air may puddle contributing to frost formation. Land heats faster and cools quicker than water so wet soil or proximity to a lake may inhibit frost formation. And finally, if the dew point is above 45°F at sunset frost is less likely but if the dew point is below 40°F a frost warning may be in order.

Try This

A delicious way to teach the concept of **dew and frost** is to make ice cream in a can. Seal ½ pint (250ml) light cream, a small can of condensed milk, 1-2 teaspoons vanilla extract in a small clean dry coffee can. Place this can in a larger clean coffee can filled with ice and salted liberally, then cap. Gently roll this can around on a non-carpeted floor (accidents happen). Soon moisture will begin to condense on the outside of the larger can. Allow the can to stand for a few minutes and the moisture (dew) might freeze forming frost. The air touching the can has been chilled below the dew point forcing the air to give up some of the water it contains and then in a simulation of the ground giving up a lot of heat energy during a clear night (getting cold) the dew freezes. Air conditioned rooms and the dry air characteristic of cold fronts may reduce the available moisture and cause this activity to perform poorly - but it will

Thunderstorms and Lightning – The distance to a thunderstorm can be determined by counting the seconds between the flash and thunder. Five seconds is about a mile. Lightning travels at 186,000 miles per second (almost instantaneous) and sound travels at 1,100 feet per second. If the flash and thunder are almost simultaneous it is very close. **If you can hear thunder you are within striking distance. Seek shelter immediately!** During the past 30 years, lightning has killed an average of 73 people per year in the United States. The National Weather Service reports that lightning injures 325 to 500 people per year. This is not surprising with about 21,746,000 cloud-to-ground strikes each year. There are approximately 1800 thunderstorms occurring at any given moment with about 100 strikes per second. Many casualties occur **before** a thunderstorm arrives by people ignoring the early warning signs. A person struck by lightning can sometimes be revived by mouth-to-mouth resuscitation.

A thunderstorm can lasts for 2 hours, however, peak activity typically last for only about 15 to 30 minutes. Since most weather arrives from a westerly direction, lightning north or south of your position is passing you by. Lightning west of you is headed your way.

As lightning passes through air it heats the air to around 15,000 degrees C (over twice the temperature of the sun's surface) causing it to rapidly expand! As the air expands and contracts explosively pressure pulses are generated along the path of the lightning strike. The peals of thunder originate at different points along the path of the lightning and thus arrive at different times causing its rolling sound. The sound of thunder can be simulated by lining up a couple of classes of students outside and having each student, in turn, pop an inflated paper bag. Be sure to warn others so as to unduly alarm them!