

<< A SUMMARY OF WEATHER FUNDAMENTALS >>

Instructions: Study these concepts until you not only KNOW them, you also UNDERSTAND them. When you do, you'll be ready to learn METEOROLOGY.

1. Pressure in the atmosphere varies inversely with altitude.

The average pressure of the atmosphere at sea level is approximately 1000 millibars (mb) or 14.7 lbs./in.² Atmospheric pressure is due to the weight of the air above you. As you ascend, there is less air above you and hence lower pressure.

2. The sun's intensity varies with latitude and with the seasons.

The *directness* of the sun's rays (sun overhead means direct) and the length of the daylight period determine the total heat input to the earth and atmosphere. This heat input (intensity) is far greater near the equator (at low latitudes) where the sun is nearly overhead than at the poles (high latitudes) where the sun is low in the sky (Fig. 1). In addition, the sun is higher in the sky in summer (July for the Northern Hemisphere [NH]; January for the Southern Hemisphere [SH]) than in winter (NH - January; SH - July). Finally, the sun's heat also varies from place to place because of irregularities (e.g. mountains) on the surface of the earth.

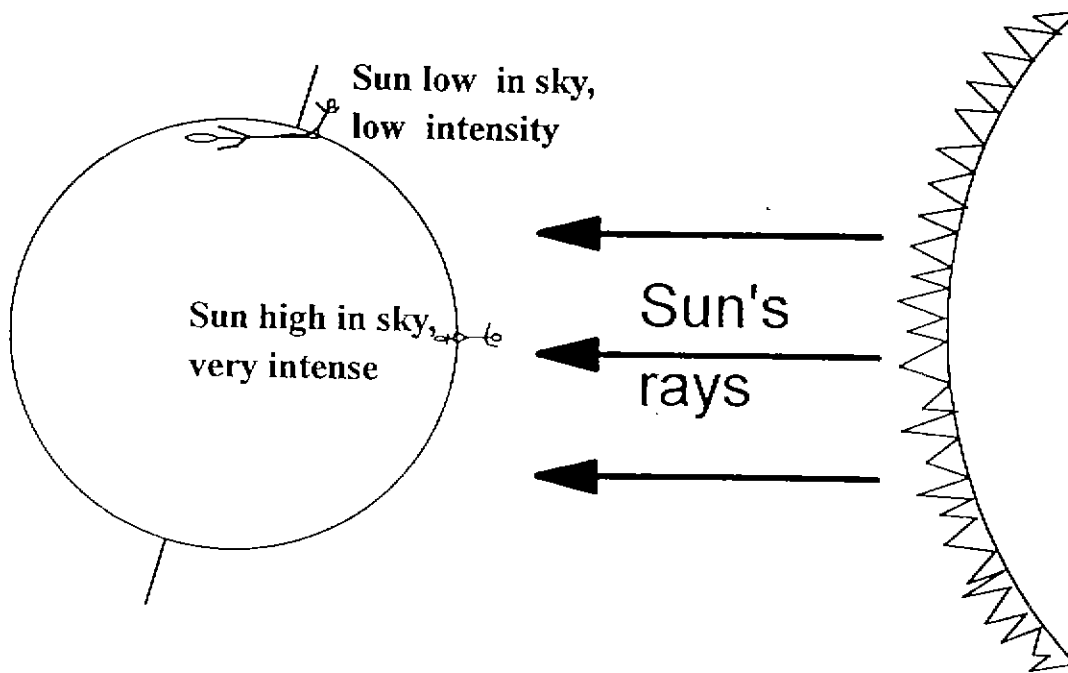


Figure 1. The intensity of the sun's rays varies with latitude. Throughout the year the sun's rays are most direct over the tropics.

3. Increasing temperature causes air pressure to decrease [T↑P↓], whereas decreasing temperature causes pressure to increase [T↓P↑]. This is known as an inverse relationship.

Around the tropics, solar heating of air at the Earth's surface causes that air to expand, decreasing air pressure. This expansion causes the air to be lighter than the surrounding air and so it is buoyed upward in a process known as **convection**. Air that is cooled (in any one of several ways) contracts, increasing

air pressure, and becomes denser, causing the air to **subside**. These activities and other associated processes have many implications for creating and influencing weather and are crucial to a thorough understanding of meteorology.

4. Decreasing air pressure causes the temperature to decrease [P↓T↓]. This is called a direct relationship. You must ALWAYS remember, however, that it is the relative change (increasing or decreasing) that is important, NOT the absolute measure (high or low).

When you pump up a tire or a basketball the pump gets very hot. A general rule is that when air pressure is increasing the temperature rises. Conversely, when air pressure is decreasing the temperature drops. However, you must be careful.

Warning: This does *not* mean that the air in high pressure (HP) areas is warm and the air in low pressure (LP) areas is cold. In fact some of the coldest air is found in HP areas! High or low pressure implies almost nothing about temperature; but the *process of increasing pressure* implies that the temperature of a particular blob or parcel of air is increasing, and the *process of decreasing pressure* implies that its temperature is decreasing.

5. Differences in air temperature over the earth cause winds.

Temperature varies over the globe as a result of unequal solar heating. Generally, air at the equator is much warmer than air at the poles, as indicated in No. 3. Warm air expands, is therefore less dense (lighter), and so tends to rise (**convects**); cold air contracts, is more dense (heavier) and so tends to sink (**subsides**). Winds, which are primarily horizontal, are nature's way of redistributing air molecules -- "filling the void." You might envision a simple, idealized pattern of global winds, *on a non-rotating Earth*, as follows: heated, less dense (lower pressure) air near the equator rises and spreads out toward the poles, while the cold, more dense (higher pressure) polar air sinks and spreads out along the ground, moving back toward the equator (Fig. 2).

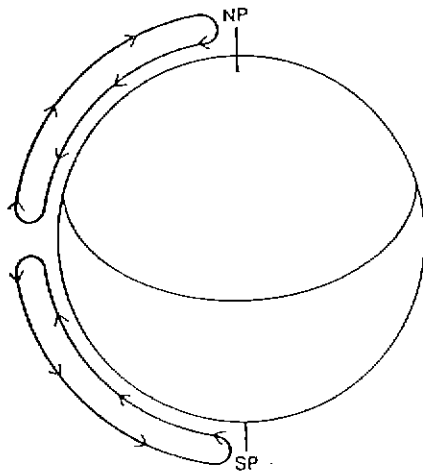


Figure 2. Idealized wind system on a uniform Earth that does not rotate. To produce this wind system, the sun would have to revolve around the Earth.

6. Winds always blow from areas of higher pressure to areas of lower pressure. All else being equal, the shorter the distance (or the higher the pressure difference) between adjacent lows and highs, the stronger the wind.

Two factors control near-surface wind speeds: a) the pressure gradient and b) friction. The pressure gradient is the difference in pressure between two locations divided by their distance. The higher the

pressure gradient, the stronger (faster) the wind. Friction, on the other hand, resists the movement of air molecules, and so acts to slow winds down. There are also two controls on wind direction: a) the Coriolis force (see below), and b) the relative locations of highs and lows (see No. 8).

7. The rotation of the earth disturbs the simple wind pattern referred to above (No. 5). Instead, large-scale wind "belts" with predictable, curved flow paths are produced by the *Coriolis Force*. These winds originate in global "belts" of high pressure.

Once anything moves on the *rotating earth* it is subjected to a force that steers it to the right (clockwise - CW) of its intended path in the NH and to the left (counterclockwise - CCW) in the SH (Fig. 3). This effect is known as the **Coriolis force (CF)** and is caused by the difference in the Earth's rotational speed at different latitudes. The air that rises above equatorial regions and spreads poleward is turned by the CF so that it cools, grows heavy, and sinks in subtropical latitudes long before it reaches the poles. This creates areas of HP at the surface, which are the source of strong prevailing surface winds (Fig. 4).

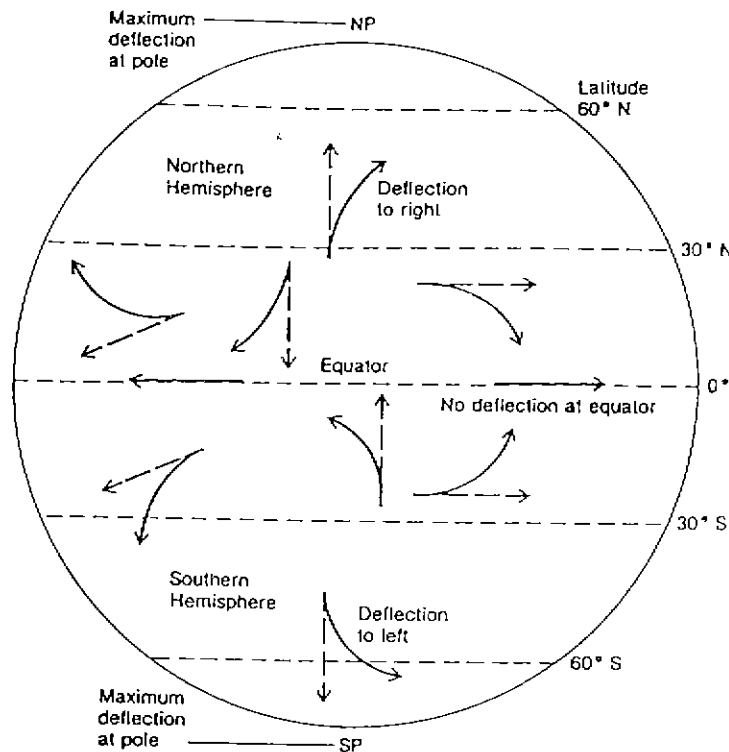


Figure 3. Large scale winds are deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. This deflection is due to the Coriolis effect.

8. Wind spirals, known as cyclones and anticyclones are common in midlatitudes (30°-60°). Winds are so strongly affected by the CF at these latitudes that a series of cyclones and anticyclones are nearly always found there.

The CF increases with increasing wind speed and latitude. Therefore, midlatitude winds are strongly affected by the CF. In the NH, air in LP areas (cyclones) spirals CCW and inward to the center near ground level, whereas air in HP areas (anticyclones) spirals CW and outward from the center near ground level (Fig. 5). For the SH, air in low pressure areas spirals CW, but still inward near ground level. Guess which way the air spirals in high pressure areas in the SH! Cyclones and anticyclones are typically 600 miles (1000 km) or more in diameter.

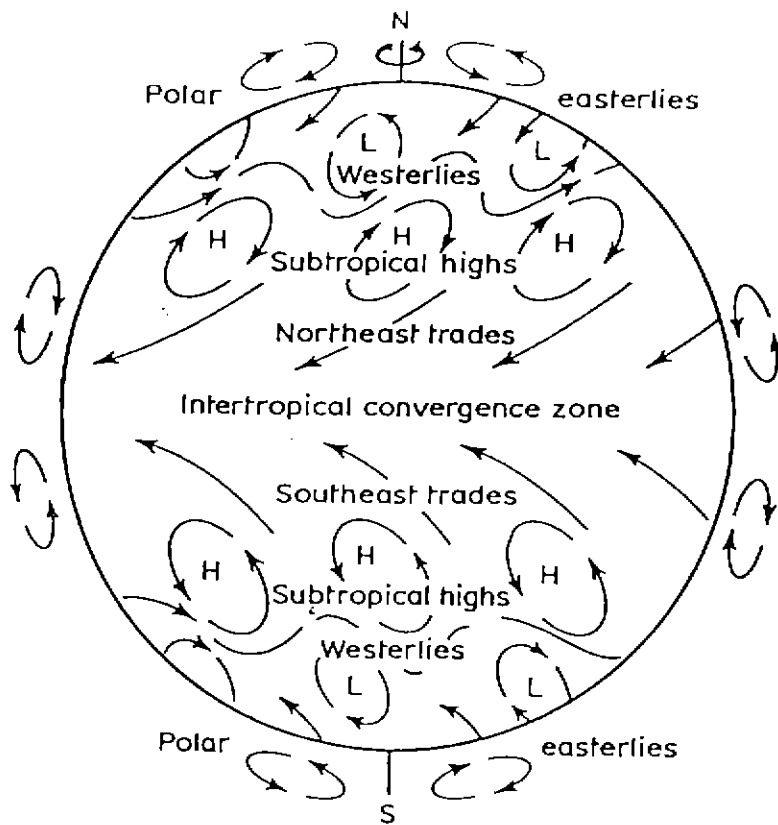


Figure 4. The global atmospheric circulation set in motion by the heat of the sun and the rotation of the Earth produces latitudinal bands dominated by either high or low pressure, or by the trade winds. These are the basic climatic zones of our planet.

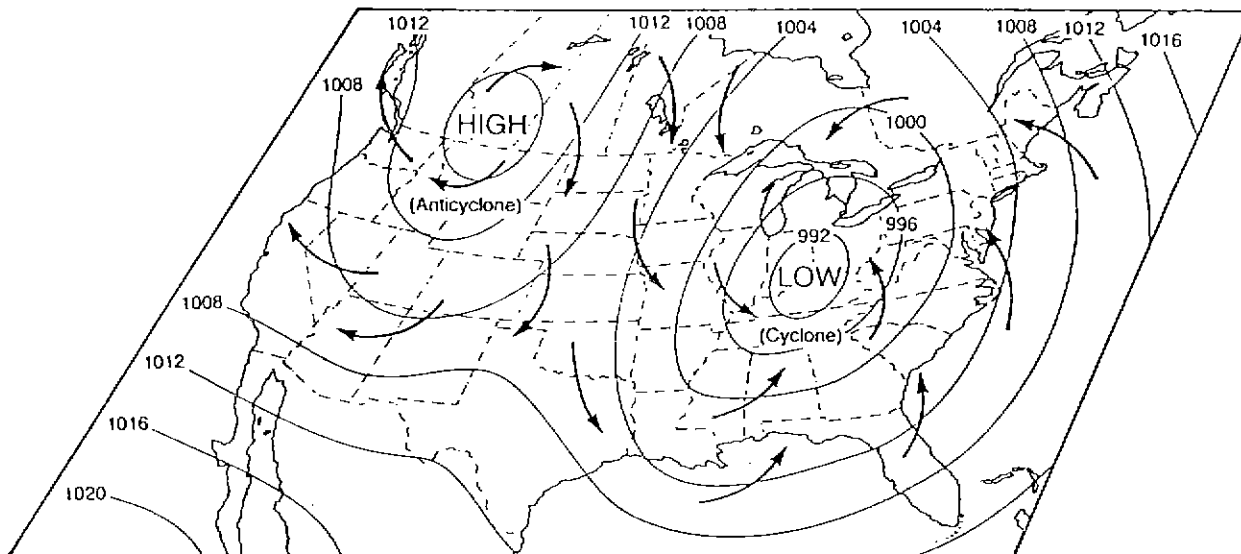


Figure 5. Cyclonic and anticyclonic winds in the Northern Hemisphere. Arrows show the winds blowing in and counterclockwise about a low and out and clockwise about a high.

9. For any air parcel, there is a specific temperature at which the air will become saturated with water vapor. This is the dew point temperature.

When the ambient (surrounding) temperature is higher than the dew point temperature, a parcel of air is said to be **undersaturated**, and **evaporation** outpaces **condensation**. When the temperature has dropped to the dew point, the rates of evaporation and condensation are equal and the air is said to be **saturated** or to have reached its **capacity** with respect to water vapor. At temperatures below the dew point, the air is **supersaturated** and condensation outpaces evaporation. The **carrying capacity** of air with respect to water vapor is dependent upon its temperature. The higher the temperature, the greater the carrying capacity; that is the more water vapor it can carry.

10. Since cool air can carry less water vapor than warm air, rain and other forms of precipitation are caused by cooling the air.

When surface air is warm, water on the ground will evaporate. A great deal of water vapor can remain in the air if the air is warm, but only a small amount if the air is cold. Therefore, **precipitation** (rain, snow, hail, etc.) occurs when air is cooled sufficiently to make some of the vapor **condense** back to its liquid form (water) or be **deposited** in its solid form (ice) and fall to the ground.

This is basically the same process that causes freezers to need to be defrosted periodically. Warm air holding much vapor rushes into the freezer when the door is opened. Inside the freezer the air is cooled considerably, and the vapor sublimates to ice or frost on the freezer walls.

11. Clouds and precipitation are caused by rising air; clear weather is caused by sinking air.

The most efficient way to cool a large parcel of air rapidly is to lower its pressure. This is done by lifting the air (convection) since as it rises the pressure decreases. As a result, the temperature decreases and so does the amount of water vapor that the air can hold. The water vapor rapidly condenses into billions of tiny water droplets (or ice crystals), forming clouds. Sometimes, precipitation results as well.

Virtually all clouds as well as precipitation are due to rising air. On occasion, air can be cooled sufficiently by other processes to form clouds or fog, but it rarely leads to precipitation. Conversely, when air sinks its temperature rises so that its capacity for holding water vapor increases. Any cloud droplets would then tend to evaporate and the clouds would disappear.

12. Rising air creates sustained low pressure areas with clouds and precipitation; sinking air creates sustained high pressure areas with sunny, cloudless skies.

Since the air near the ground spirals inward toward the center of low pressure areas (#6; Fig. 5), the pressure would rapidly increase if the air didn't leave the center by rising. When the pressure remains lower than that of the surroundings, the air which spiraled in toward the center of the low must also have risen and therefore cooled. This leads to clouds and precipitation (Fig. 6a).

On the other hand, air near the ground spirals out of high pressure areas (#6; Fig. 5) and, if the high pressure is to be maintained, air from above must sink to take its place. The sinking air warms and the air clears (Fig. 6b). Now that you know the "secret" of meteorology, never forget it: High pressure areas result from sinking air which causes clear weather; low pressure areas result from rising air which causes cloudy, wet weather (Fig. 7).

Many people ask just how high the pressure has to be in order to have a high pressure area. The answer is that there is *no* specific number. High and low pressure areas are determined in a relative manner. Any time the pressure in a certain region is higher than the pressure of the surrounding areas, it is a high pressure area. Any time the pressure in a certain region is lower than that of the surroundings, it is a low pressure area.

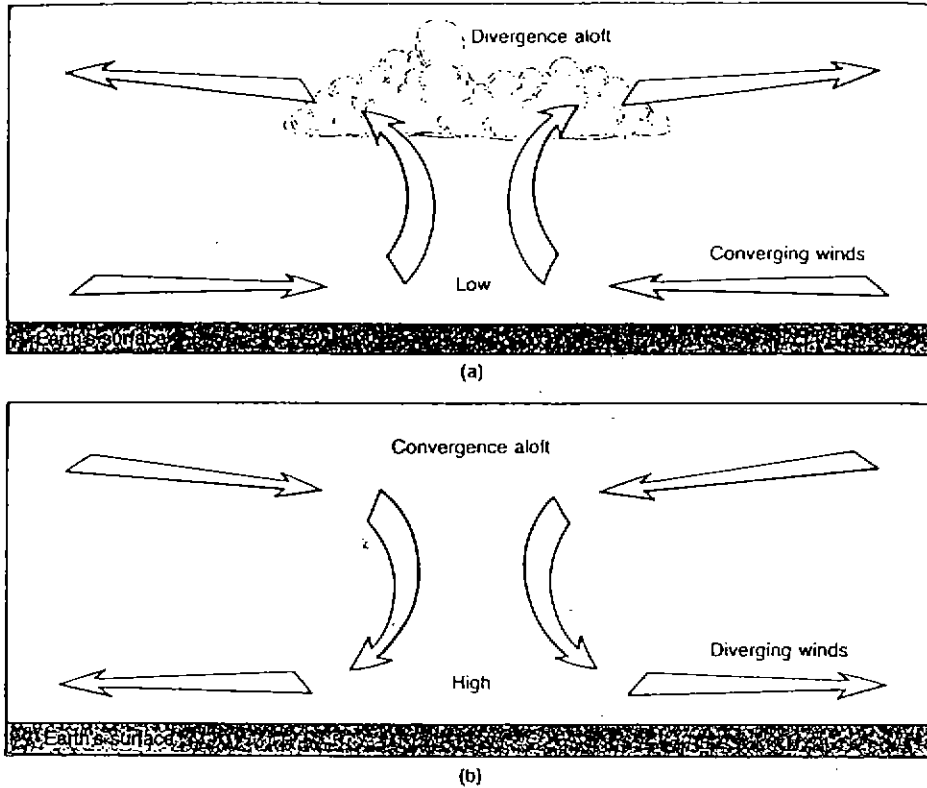


Figure 6. Schematic of airflow associated with cyclones and anticyclones.

(a) converging winds and rising air are associated with a low, or cyclone.

(b) Highs, or anticyclones, are associated with descending air and diverging winds.

13. Air masses are large-scale (regional) air parcels that have fairly consistent temperature and humidity throughout. They are responsible for most weather on a day-to-day basis.

Air masses are formed over large, continental sized areas with stable conditions and subsiding air. The nature of these **source regions** dictates the temperature and humidity characteristics of the air masses that form there (Tbl. 1; Fig. 8). In terms of humidity, there are continental source regions (c) which are dry and maritime source regions (m) which are humid. Source region temperatures range from tropical (T) which is warm, to polar (P) which is cold, to arctic (A) which is very cold. These source region characters, when combined, provide for five different types of air masses. Note that there can be no mA air mass, as no ocean can remain ice free in arctic temperatures. In addition, very cold air can carry very little moisture. Hence a moist, very cold air mass is not possible.

Air masses transport their characteristics from place to place in response to strong **upper-air winds**, such as the jet stream. As air masses move, they cause the weather to change and slowly change their own character as well. Therefore, our weather is a product of the character of the air mass(es) immediately around us.

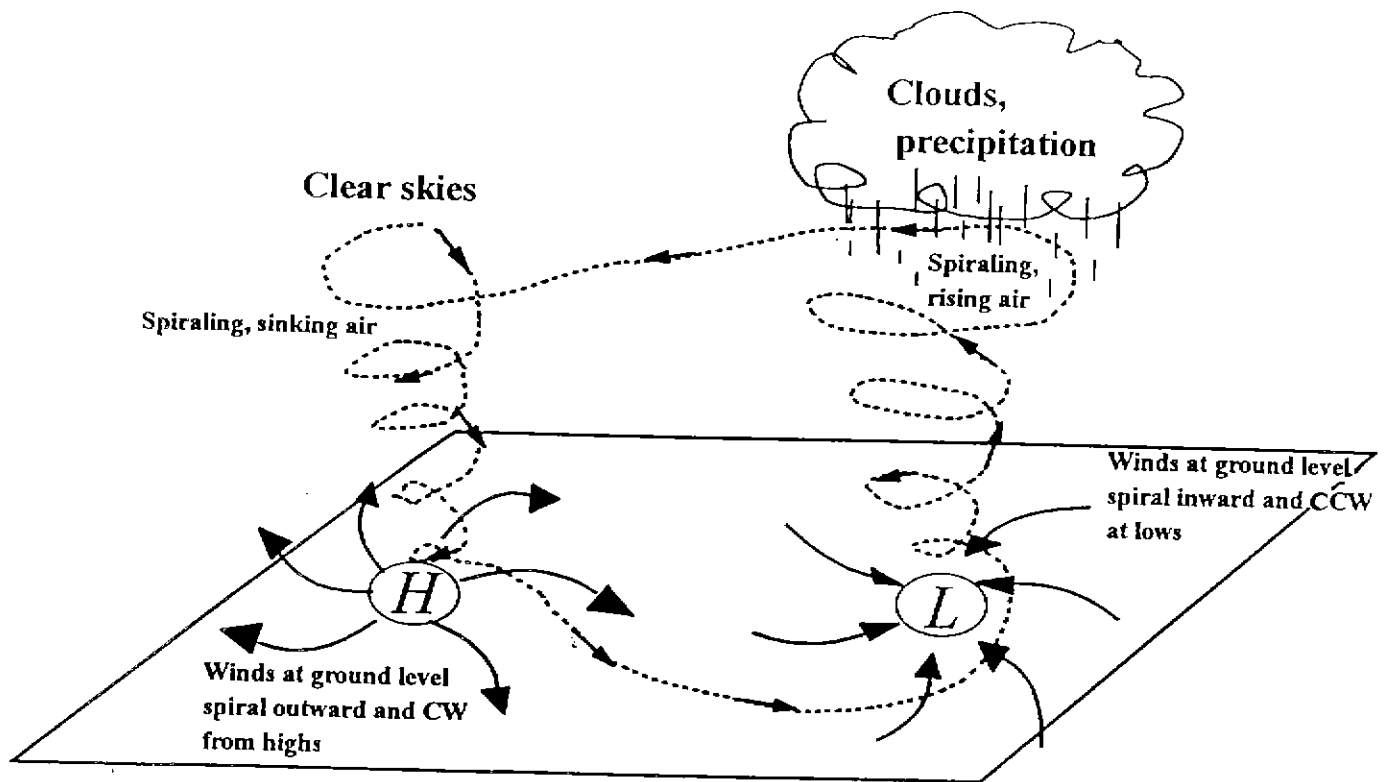


Figure 7. A simplified drawing of the spiraling winds and vertical motions in high and low pressure areas. Air near the ground spirals counterclockwise, converging into low pressure areas where it then rises, producing clouds and rain or snow. Air near the ground spirals clockwise, diverging outward from highs. Thus, sinking air and mostly clear weather dominates in highs.

| | Warm | Cold | Very cold |
|---------------|------|------|-----------|
| Dry (land) | cT | cP | cA |
| Humid (water) | mT | mP | -- |

Table 1. Air mass classification based on humidity and temperature characteristics of the source region. For the abbreviations: c = continental, m = maritime, T = tropical, P = polar, and A = arctic.



Figure 8. Air mass source regions for North America. Air masses originate in areas of stable, subsiding air. The frequency of frontal activity in the mid-latitudes prohibits air mass formation over the United States. As a result, our air masses come to us from other regions at higher and lower latitudes.

14. As you travel from the tropics to the poles, the temperature will naturally become colder. However, temperatures will *not drop steadily*, but rather will fall in an *abrupt and irregular* manner. This is due to the presence of weather fronts.

In meteorology, a *front* is a narrow zone across which the temperature, humidity, and wind direction change abruptly. A front is formed by the collision of two air masses with differing temperature and humidity (Fig. 9). How sharp must the temperature contrast be before the transition zone between two air masses is called a front? Temperature contrasts vary dramatically from one front to another so there is no simple answer to this question. Over land in midlatitudes a typical temperature difference might be 7-10°F across 100-150 miles. Temperature differences tend to be much smaller across fronts in the subtropics or anywhere out at sea.

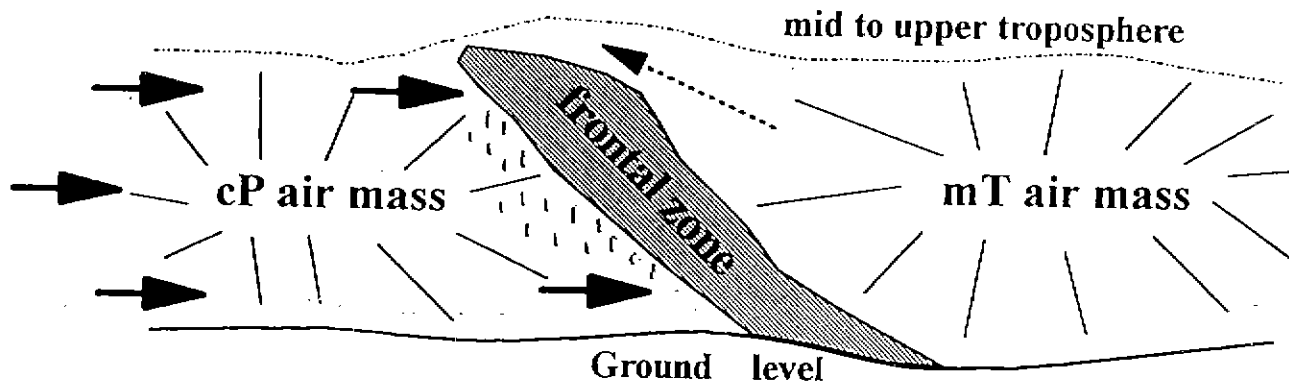


Figure 9. A simplified cross-sectional drawing through a cold front. A front is a zone of contact (and mixing) between two air masses with differing temperature characteristics. In the setting depicted here, a cold, dry air mass is advancing on a warm, moist air mass, forcing the less dense warm air upwards. Precipitation would originate in the frontal zone.

15. A cold front is a front along which a cold air mass is overtaking a warm air mass. A warm front is a front along which a warm air mass is overtaking a cold air mass. Weather in the midlatitudes is dominated by an ongoing battle between cold air masses from the north (cP) and warm air masses from the south (mT). That is why the weather often changes so rapidly.

As any type of front approaches, air pressure falls. Cold fronts are associated with more intense rainfall and destructive forces (hail, strong winds, lightning and tornadoes) but usually pass more quickly than warm fronts. As a result, temperatures will often rapidly drop as a cold front approaches; whereas, they will slowly rise when a warm front passes through. Warm fronts usually are associated with one or more days of light rain and calmer winds. In either case, rainfall is more concentrated over the cold air mass at a front (Fig. 9).

Almost all regional low pressure areas found outside the tropics (the so-called **extratropical cyclones**) have fronts running right through their centers (they are, in fact, a product of the front). Fronts also tend to skirt between high pressure areas (Fig. 10).

The midlatitudes are well-known for their rapidly changing weather conditions. This can be attributed to the frequency of frontal activity. When our weather is a product of frontal activity, we have what is known as **frontal weather**. Otherwise, we have **air mass weather**. Air mass weather tends to be stable, more predictable, and generally more fair than frontal weather.

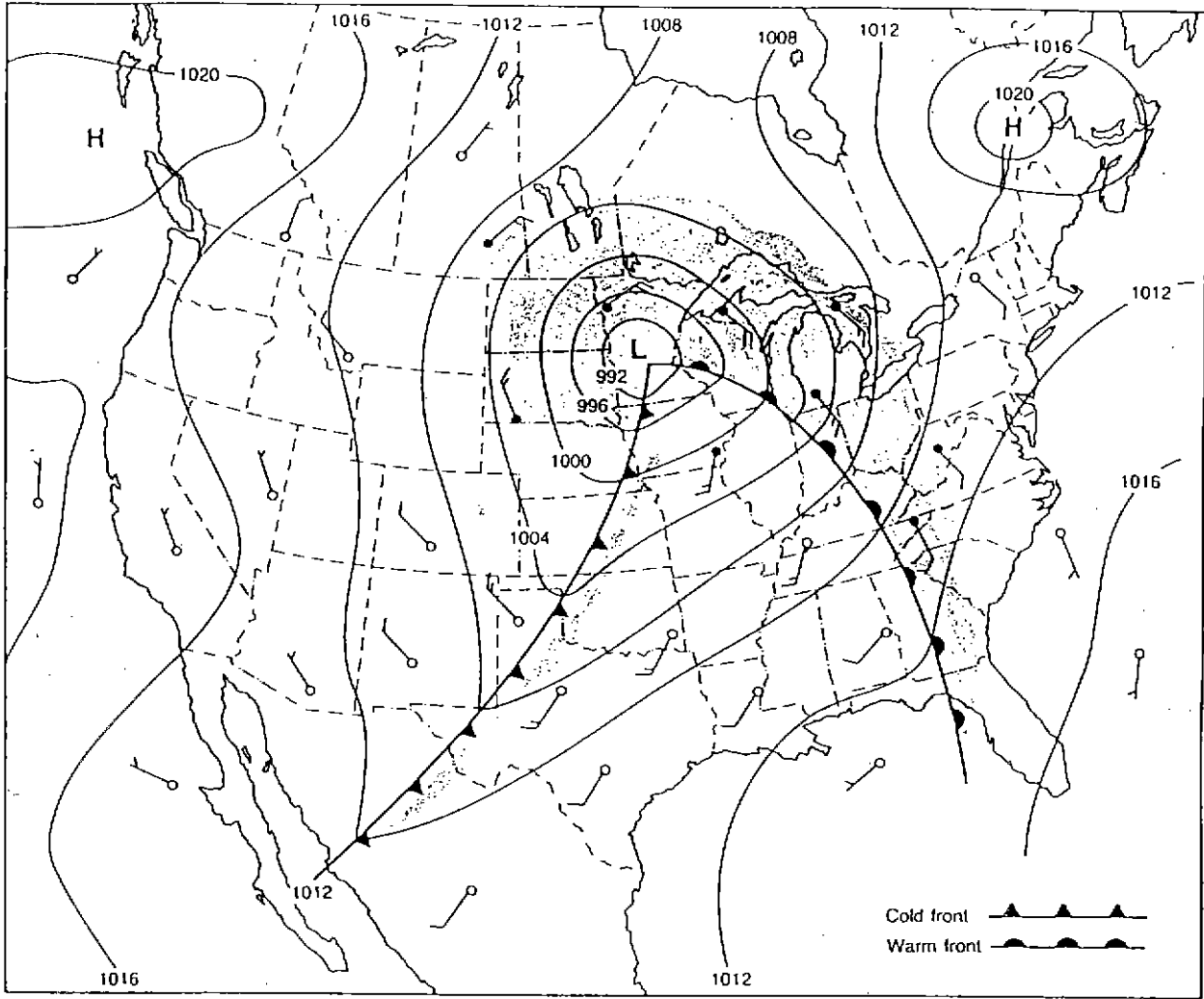


Figure 10. Simplified weather map showing the presence of a low along a frontal line. Note the presence of high pressure areas to the northeast, northwest, and southeast (Atlantic) that help to steer the low.