

The Atmosphere in Motion

Wind is perhaps the most common (and in some places, constant) of all weather phenomena. But what causes the wind to blow? There are several reasons. Differences in air pressure result in large-scale movement of air from areas of high pressure to areas of low pressure. The rotation of the earth causes motion in the atmosphere which results in wind. Winds are often found along frontal boundaries or associated with topographic features. Perhaps the most basic reason that the wind blows is to redistribute energy within the atmosphere. In this chapter we will begin to explore the complex interaction of the solar energy and pressure variations within the atmosphere that result in wind.

Air pressure, density, and temperature are all related. In general, the warmer an unconstrained parcel of air is, the less dense it is and the lower its pressure. Consider two homogeneous columns of air, one warm and the other of cold. Observers are positioned beneath each column to measure the surface air pressure. The column of cold air does not have to be nearly as tall as the column of warm air to exert the same air pressure because of its greater density. If one were to move upward through each column of air, one would observe the density of the air decreasing more rapidly with height in the cold column than in the warm column of air. Atmospheric pressure, therefore, decreases more rapidly in cold air than in warm. A corollary to this is that warm air aloft normally corresponds to regions of high atmospheric pressure while cold air aloft is related to low atmospheric pressure.

A *pressure gradient* is a difference in pressure between two regions. The steeper this gradient (the greater the difference in air pressure between two regions) the faster the wind will blow. As air flows from an area of high pressure to

an area of low pressure, the pressure in the high-pressure area falls and the pressure in the low-pressure area rises.

Air Pressure readings are taken by an instrument known as a barometer. Two common types of barometers used are mercury and aneroid barometers. In mercury barometers, mercury in a sealed column is displaced upwards by the pressure of the air pressing downward on the fluid surrounding the sealed column. The height of the mercury in the sealed column is related to the atmospheric pressure. Aneroid barometers contain no fluid. Instead, a partially evacuated aneroid cell inside the barometer is used to detect small changes in atmospheric pressure.

Station pressure is the atmospheric pressure measured at a specific site. All things being equal, stations at different altitudes will record different atmospheric pressure readings due to the difference in altitude alone. The pressure in the atmosphere changes much more rapidly with height than it does horizontally even if large horizontal pressure gradients are present. In order to correct for differences in altitude, station pressures are adjusted to mean sea level or 0 meters. This *adjusted pressure* is sea level pressure plus the additional atmospheric pressure due to heating, cooling, etc., of the atmosphere at that station. The adjustment that is used is 10 millibars per 100 meters. This is a standard rate based on average values and is added to the pressure recorded for each station. If, for example, a station is 500 meters above sea level, 50 millibars are added to the station pressure to correct for the altitude.

An *isobar* is a line of equal pressure on a weather map. Contours of 4 millibars are commonly used with a 1000 millibar base value. Two common types of pressure charts are *surface charts* and *upper level charts*, both of which are *constant height charts*. Constant height charts are used to show pressure

variations at a constant height in the atmosphere. In addition to constant height charts, charts of constant pressure or *isobaric charts* are also commonly used. Here altitude variations are shown along surfaces of equal pressure. Isobaric charts are widely used in meteorology. A commonly used isobaric chart is a 500 millibar (upper level) chart. The bending of a constant pressure surface on such a chart forms a pattern of ridges and troughs. Ridges correspond to warm (high-pressure) air, and troughs correspond to cold (low-pressure) air. Ridges and troughs from isobaric charts are often shown superimposed over surface weather charts on TV and in newspaper weather forecasts.

There are four forces that affect the magnitude and direction of the wind. The first is the *pressure gradient force*, or PGF. Next is the *Coriolis Force* generated by the earth's rotation. A *Centripetal force* is any center-seeking force that causes the wind to follow a curved path. The Coriolis force acts as a centripetal force. Lastly, *frictional forces* exerted on air moving in close proximity to the ground have the effect of slowing the wind down.

The PGF is caused by a difference in air pressure between two regions. Air flows from regions of high pressure to regions of low pressure under the influence of the PGF. A numerical value for the PGF may be obtained by computing the amount of pressure change over a given distance or:

$$PGF = \Delta_{\text{pressure}}/\text{distance}$$

The direction of the PGF is always at right angles to pressure isobars.

The Coriolis Force is an apparent force that results from the spin of the earth. The C.F. plays a large role in shaping large-scale weather systems. In

essence, large-scale winds undergo an apparent deflection to the right (in the northern hemisphere) due to the spin of the earth as they move along. In general, the higher the wind speed the greater the deflection. The Coriolis Force increases with latitude.

Wind Flow Aloft

Geostrophic winds are winds that blow parallel to isobars. Normally, one would expect winds to blow perpendicular to isobars due to the presence of the PGF. In the upper levels of the troposphere, where the wind blows without restraint, the Coriolis Force modifies the direction that the wind blows by deflecting it to the right. As this occurs, the Coriolis force (which is always directed perpendicular to the flow) changes direction with the wind. When Coriolis Force is equal in magnitude to the PGF but oppositely directed, geostrophic flow results. Since, in this case, the sum of the forces is zero there is no acceleration (Force = mass x acceleration). Strong Pressure Gradients produce strong geostrophic winds. A *gradient wind* is one that blows parallel to curved isobars.

For upper level winds, direction of flow may be determined from the position of isobars and wind speed may be determined from their spacing. This is true for upper level winds because frictional forces are minimal. Near the earth's surface (below 1000 meters), however, frictional forces begin to slow the wind down. As the wind speed is reduced so is the magnitude of the Coriolis Force. The Coriolis Force, in this case, may no longer balance the PGF and the winds will not blow exactly parallel to isobars.

The combination of the Coriolis Force and the PGF is responsible for the rotations of high and low pressure systems. Winds at the surface flow into low

pressure systems and are deflected to the right by the Coriolis Force as they move toward the center of the low. This movement, viewed on a large scale, appears as a *cyclonic* or counterclockwise rotation of air about the center of the system. High-pressure systems (anticyclones) rotate clockwise because surface air flows away from the center of a high and is deflected to the right as it moves outward.

Winds on Upper Level Charts

Zonal Flow is wind flow that runs parallel to lines of latitude (east west). *Meridional flow* is wind flow that runs parallel to lines of longitude (north south). Winds aloft in the winter are usually more intense than in the summer due to increases in temperature gradient. This results in stronger upper level flow during the winter months.