

Chapter 4

WIND

Differences in temperature create differences in pressure. These pressure differences drive a complex system of winds in a never ending attempt to reach equilibrium. Wind also transports water vapor and spreads fog, clouds, and precipitation. To help you relate wind to pressure patterns and the movement of weather systems, this chapter ex-

plains convection and the pressure gradient force, describes the effects of the Coriolis and frictional forces, relates convection and these forces to the general circulation, discusses local and small-scale wind systems, introduces you to wind shear, and associates wind with weather.

CONVECTION

When two surfaces are heated unequally, they heat the overlying air unevenly. The warmer* air expands and becomes lighter or less dense than the cool* air. The more dense, cool air is drawn to the ground by its greater gravitational force lifting or

forcing the warm air upward much as oil is forced to the top of water when the two are mixed. Figure 18 shows the convective process. The rising air spreads and cools, eventually descending to com-

*Frequently throughout this book, we refer to air as *warm*, *cool*, or *cold*. These terms refer to relative temperatures and not to any fixed temperature reference or

temperatures as they may affect our comfort. For example, compare air at -10°F to air at 0°F ; relative to each other, the -10°F air is *cool* and the 0°F , *warm*. 90°F would be *cool* or *cold* relative to 100°F .

plete the convective circulation. As long as the uneven heating persists, convection maintains a continuous "convective current."

The horizontal air flow in a convective current is "wind." Convection of both large and small scales accounts for systems ranging from hemi-

spheric circulations down to local eddies. This horizontal flow, wind, is sometimes called "advection." However, the term "advection" more commonly applies to the transport of atmospheric properties by the wind, i.e., warm advection; cold advection; advection of water vapor, etc.

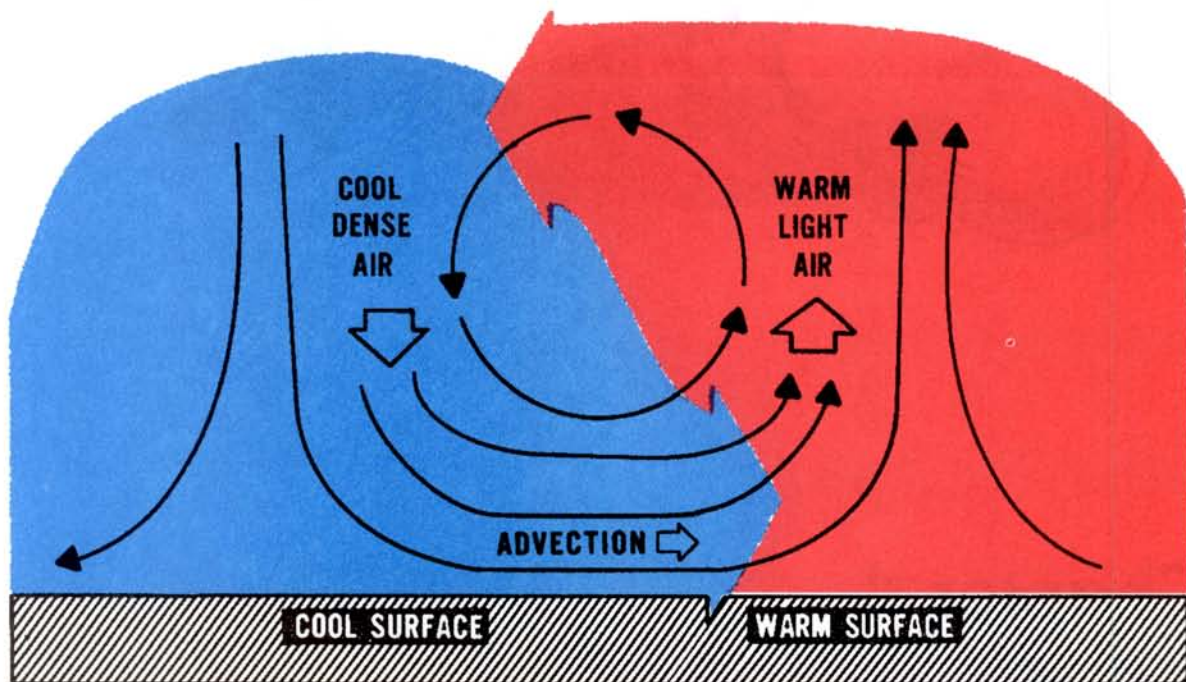


FIGURE 18. Convective current resulting from uneven heating of air by contrasting surface temperatures. The cool, heavier air forces the warmer air aloft establishing a convective cell. Convection continues as long as the uneven heating persists.

PRESSURE GRADIENT FORCE

Pressure differences must create a force in order to drive the wind. This force is the *pressure gradient force*. The force is from higher pressure to lower pressure and is perpendicular to isobars or contours. Whenever a pressure difference develops over an area, the pressure gradient force begins moving the air directly across the isobars. The closer the spacing of isobars, the stronger is the pressure gradient force. The stronger the pressure gradient force, the stronger is the wind. Thus, closely spaced isobars mean strong winds; widely spaced isobars mean lighter wind. From a pressure analysis, you can get a general idea of wind speed from contour or isobar spacing.

Because of uneven heating of the Earth, surface pressure is low in warm equatorial regions and high in cold polar regions. A pressure gradient develops from the poles to the Equator. If the Earth did not rotate, this pressure gradient force would be the only force acting on the wind. Circulation would be two giant hemispheric convective currents as shown in figure 19. Cold air would sink at the poles; wind would blow straight from the poles to the Equator; warm air at the Equator would be forced upward; and high level winds would blow directly toward the poles. However, the Earth does rotate; and because of its rotation, this simple circulation is greatly distorted.

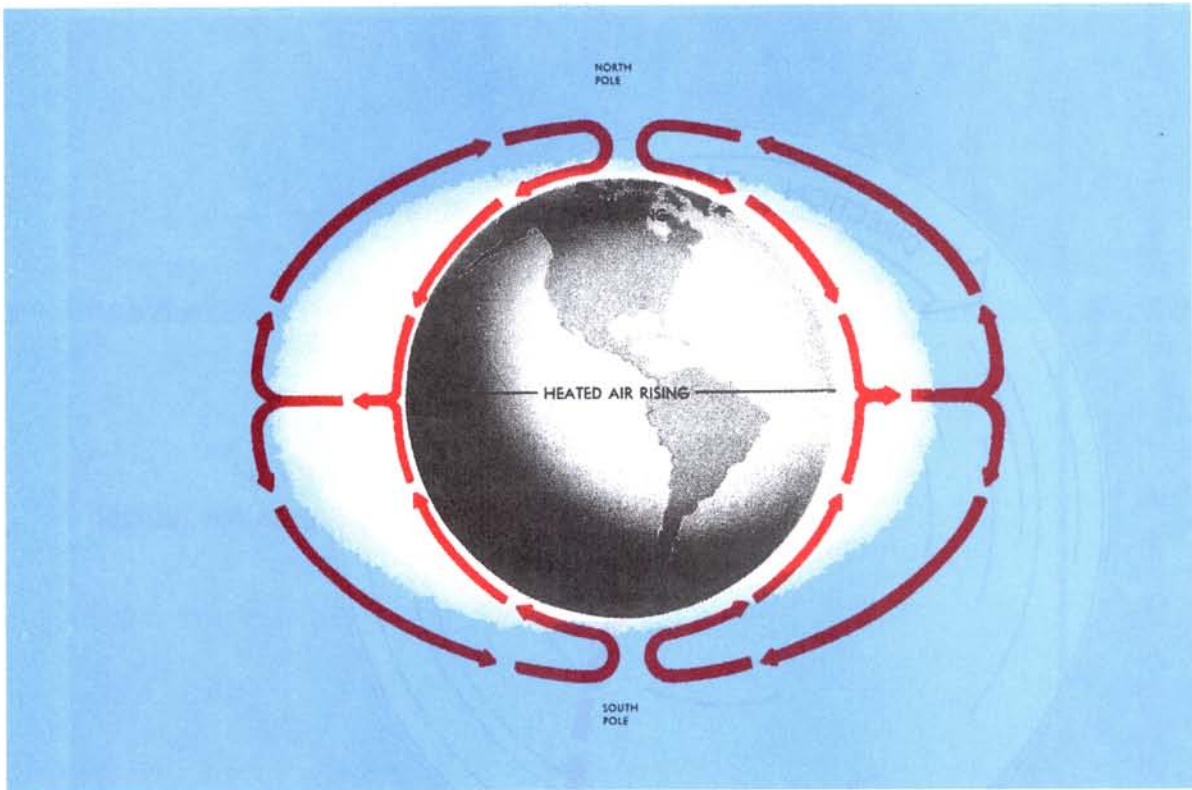


FIGURE 19. Circulation as it would be on a nonrotating globe. Intense heating at the Equator lowers the density. More dense air flows from the poles toward the Equator forcing the less dense air aloft where it flows toward the poles. The circulation would be two giant hemispherical convective currents.

CORIOLIS FORCE

A moving mass travels in a straight line until acted on by some outside force. However, if one views the moving mass from a rotating platform, the path of the moving mass relative to his platform appears to be deflected or curved. To illustrate, start rotating the turntable of a record player. Then using a piece of chalk and a ruler, draw a "straight" line from the center to the outer edge of the turntable. To you, the chalk traveled in a straight line. Now stop the turntable; on it, the line spirals outward from the center as shown in figure 20. To a viewer on the turntable, some "apparent" force deflected the chalk to the right.

A similar apparent force deflects moving particles on the earth. Because the Earth is spherical, the deflective force is much more complex than the simple turntable example. Although the force is termed "apparent," to us on Earth, it is very real. The principle was first explained by a Frenchman, Coriolis, and carries his name—the Coriolis force.

The Coriolis force affects the paths of aircraft; missiles; flying birds; ocean currents; and, most important to the study of weather, air currents. The force deflects air to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. This book concentrates mostly on deflection to the right in the Northern Hemisphere.

Coriolis force is at a right angle to wind direction and directly proportional to wind speed. That is, as wind speed increases, Coriolis force increases. At a given latitude, double the wind speed and you double the Coriolis force. Why at a given latitude?

Coriolis force varies with latitude from zero at the Equator to a maximum at the poles. It influences wind direction everywhere except immediately at the Equator; but the effects are more pronounced in middle and high latitudes.

Remember that the pressure gradient force drives the wind and is perpendicular to isobars. When a pressure gradient force is first established, wind be-

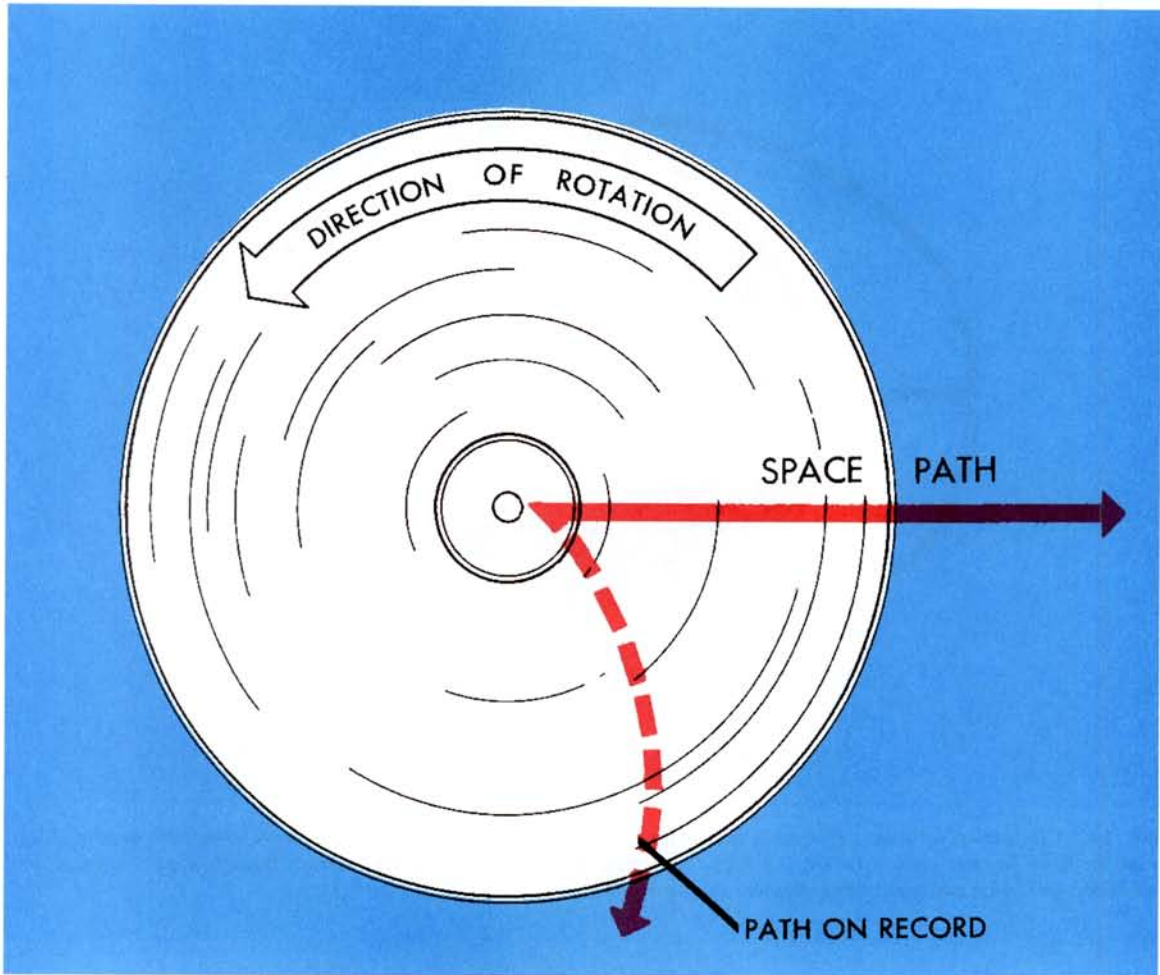


FIGURE 20. Apparent deflective force due to rotation of a horizontal platform. The "space path" is the path taken by a piece of chalk. The "path on the record" is the line traced on the rotating record. Relative to the record, the chalk appeared to curve; in space, it traveled in a straight line.

gins to blow from higher to lower pressure directly across the isobars. However, the instant air begins moving, Coriolis force deflects it to the right. Soon the wind is deflected a full 90° and is parallel to the isobars or contours. At this time, Coriolis force exactly balances pressure gradient force as shown

in figure 21. With the forces in balance, wind will remain parallel to isobars or contours. Surface friction disrupts this balance as we discuss later; but first let's see how Coriolis force distorts the fictitious global circulation shown in figure 19.

THE GENERAL CIRCULATION

As air is forced aloft at the Equator and begins its high-level trek northward, the Coriolis force turns it to the right or to the east as shown in figure 22. Wind becomes westerly at about 30° latitude temporarily blocking further northward movement. Similarly, as air over the poles begins

its low-level journey southward toward the Equator, it likewise is deflected to the right and becomes an east wind, halting for a while its southerly progress—also shown in figure 22. As a result, air literally "piles up" at about 30° and 60° latitude in both hemispheres. The added weight of the air in-

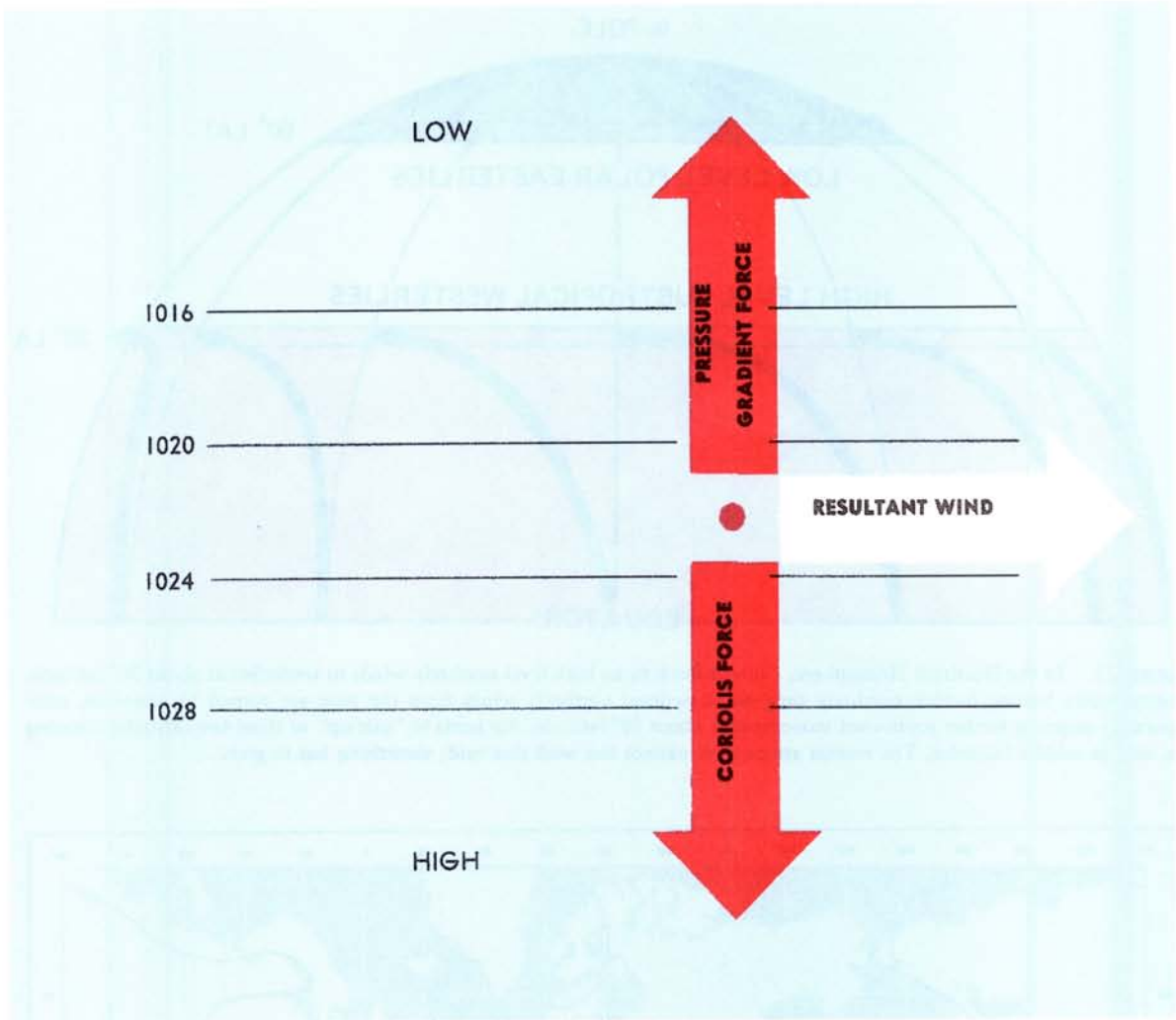


FIGURE 21. Effect of Coriolis force on wind relative to isobars. When Coriolis force deflects the wind until it is parallel to the isobars, pressure gradient balances Coriolis force.

creates the pressure into semipermanent high pressure belts. Figures 23 and 24 are maps of mean surface pressure for the months of July and January. The maps show clearly the subtropical high pressure belts near 30° latitude in both the Northern and Southern Hemispheres.

The building of these high pressure belts creates a temporary impasse disrupting the simple convective transfer between the Equator and the poles. The restless atmosphere cannot live with this impasse in its effort to reach equilibrium. Something has to give. Huge masses of air begin overturning in middle latitudes to complete the exchange.

Large masses of cold air break through the northern barrier plunging southward toward the Tropics. Large midlatitude storms develop between cold

outbreaks and carry warm air northward. The result is a midlatitude band of migratory storms with ever changing weather. Figure 25 is an attempt to standardize this chaotic circulation into an average general circulation.

Since pressure differences cause wind, seasonal pressure variations determine to a great extent the areas of these cold air outbreaks and midlatitude storms. But, seasonal pressure variations are largely due to seasonal temperature changes. We have learned that, at the surface, warm temperatures to a great extent determine low pressure and cold temperatures, high pressure. We have also learned that seasonal temperature changes over continents are much greater than over oceans.

During summer, warm continents tend to be