Surface Winds

Earlier, we saw that winds on a surface weather map do not blow exactly parallel to the isobars; instead, they cross the isobars, moving from higher to lower pressure. The reason for this behavior is **friction**.

In Fig. 9.27a, the wind aloft is blowing at a level above the frictional influence of the ground. At this level (typically above 1000 meters), the wind is approximately geostrophic and blows parallel to the isobars, with the *PGF* on its left balanced by the Coriolis force on its right. At the earth's surface, the same pressure gradient will not produce the same wind speed, and the wind will not blow in the same direction.

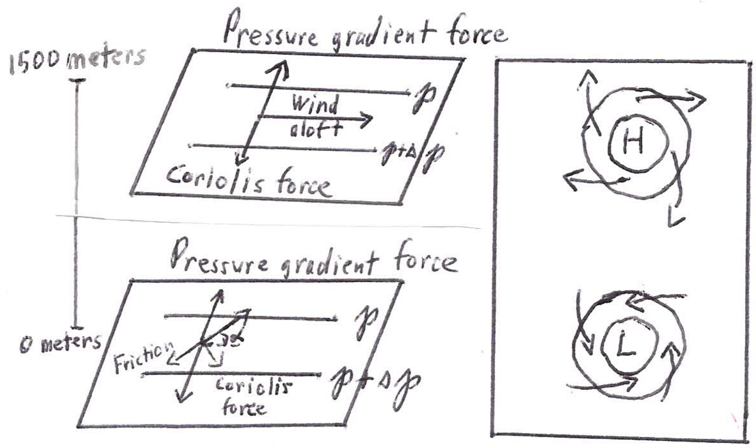
Near the surface, *friction reduces the wind speed, which in turn reduces the Coriolis force.* Consequently, the weaker Coriolis force no longer balances the *PGF*, and the wind blows across the isobars toward lower pressure. The *PGF* is now balanced by the sum of the frictional force and the Coriolis force. Therefore, in the Northern Hemisphere, we find surface winds blowing counterclockwise and *into* a low; they flow clockwise and *out* of a high (see Fig. 9.27b).

In the Southern Hemisphere, winds blow clockwise and inward around surface lows; counterclockwise and outward around surface highs. See the surface weather map and the general wind flow pattern for South America (Fig. 9.28). (We know that the winds aloft in the middle latitudes of the Northern Hemisphere tend to blow from west to east. The Coriolis force in the Southern Hemisphere causes moving air to bend to the left. Does this mean that the upper-level winds in the Southern Hemisphere blow from east to west? If you are not sure of the answer, read the Focus section on p. 240.)

In Fig. 9.27a, the angle (α) at which the wind crosses the isobars to a large degree depends upon the roughness of the terrain. Everything else being equal, the rougher the surface, the larger the angle. Over hilly land, for example, the angle might average between 35° and 40°, while over an open body of relatively smooth water it may average between 10° and 15°. Taking into account all types of surfaces, the average is near 30°. This angle also depends on the wind speed. Typically, the angle is smallest for high winds and largest for gentle breezes. As we move upward through the friction layer, the wind becomes more and more parallel to the isobars.

So far, we have seen that, because of friction, surface winds move more slowly than geostrophic winds with the same pressure gradient. Surface winds also blow across the isobars toward lower pressure. The angle at which the winds cross the isobars depends upon surface friction, wind speed, and the height above the surface. As we have seen, *if we stand with the wind aloft to our backs, lower pressure will be to our left and higher pressure to our right in the Northern Hemisphere* (see Fig. 9.29a). The same rule applies to the surface wind but with a slight modification due to the fact that here the wind crosses the isobars. Look at Fig. 9.29b and notice that, at the surface, *if we stand with our backs to the wind, then turn clockwise about 30°, lower pressure will be to our left.* (In the Southern Hemisphere, if we stand with our backs to the wind, then turn counterclockwise about 30°, lower pressure will be to our right.) This relationship between wind and pressure is often called **Buys-Ballot's law**, after the Dutch meteorologist Christoph Buys-Ballot (1817–1890), who formulated it.

FIGURE 9.27
The effect of surface friction is to slow down the wind so that, near the ground, the wind crosses the isobars and blows toward lower pressure. This phenomenon produces an outflow of air around a high and an inflow around a low.



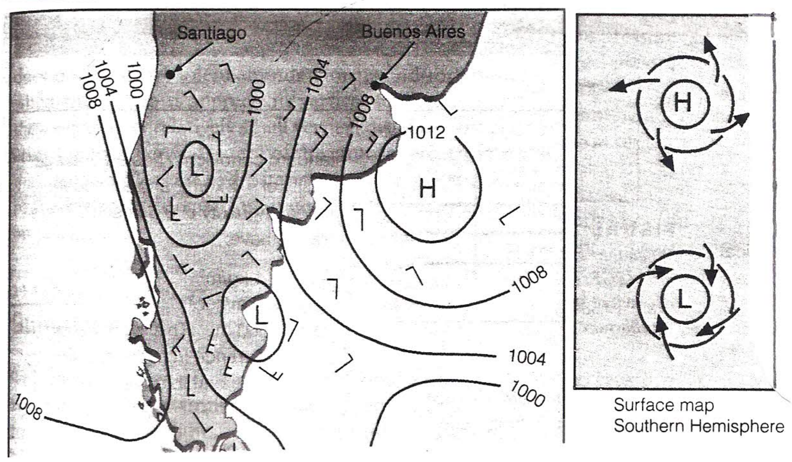


FIGURE 9.28
Surface weather map showing isobars and winds on December 20, 1971, in South America. The boxed area shows the idealized flow around surface pressure systems in the Southern Hemisphere.

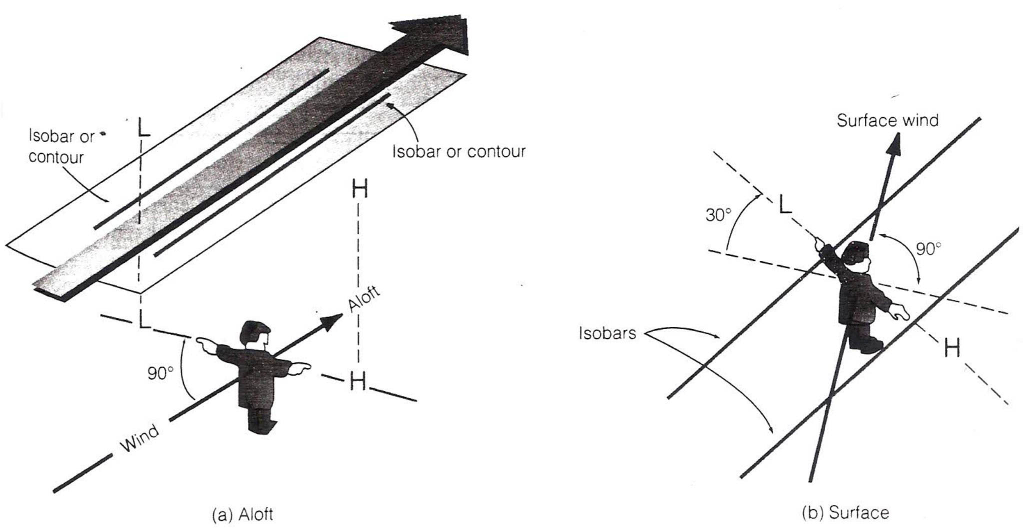


FIGURE 9.29
In the Northern Hemisphere, if you stand with the wind aloft at your back, lower pressure aloft will be to your left and higher pressure to your right (a). At the surface, the same relationship holds if, with your back to the surface wind, you turn clockwise about 30° (b).