Global Wind Systems

General Circulation of the Atmosphere

Although the global scale circulation of the earth's atmosphere is influenced by several factors, the most fundamental process driving general circulation is uneven heating of the earth's surface by solar radiation. Although the energy received by the earth as a whole is balanced by energy radiated back into space, this is not true for every specific location. Some locations receive more heat energy than they emit, some receive less. The tropics, for instance, receive much more heat from the sun than is radiated back into space. The Polar Regions receive much less energy than they emit. Global circulation patterns are a way of redistributing energy from areas of the earth with an energy surfeit to areas with an energy deficit, through the atmosphere. The oceans have very similar patterns that exist for the same reasons. In an attempt to better understand general circulation, scientists have developed computer models of global-scale atmospheric circulation. When these models are combined with ocean current models they are referred to as *coupled* models.

The *single-cell model* is the most basic model of general atmospheric circulation. The single-cell model assumes a non-rotating earth covered entirely by water (such a uniform surface would insure even heating for each point at a given latitude) and that the sun is always at equinox. This model predicts an enormous pattern of circulation from the equator to the poles. This circulation is called a *Hadley Cell* (after British meteorologist George Hadley). In a Hadley cell air rises from the equatorial regions, spreads pole ward at the tropopause, converges and sinks near the Polar Regions, then moves back toward the equator at the earth's surface. Although this simple model has some utility, it fails to describe observed large-scale circulation accurately, largely because it fails to take into account the rotation of the earth.

The *three-cell model* is a variant of the single-cell model that assumes a rotating earth. The predictions of the three-cell model correspond much more closely with observation than those of the one-cell model.

In the three-cell model, the atmosphere above latitudes from the equator to 30^0 N is dominated by air circulating in the first of the three cells. In this region the air over the equator is warm and horizontal pressure gradients are weak. Little wind exists in this region known as the *doldrums.* This region has an unstable atmosphere resulting in towering cumulus clouds known as hot towers. Rising air reaches the tropopause and is deflected to the north and south. The Coriolis Force begins to deflect the northward moving air to the right producing westerly winds aloft. Air converges as it moves northward and cools (due to increasing latitude).

At latitudes of about 30 degrees north, cooling and convergence produce a large, heavy mass of air piled above the earth's surface. As this large, heavy mass of air sinks it produces a widespread, semi-permanent high-pressure system known as a *subtropical high*. While sinking the air warms by compression producing clear skies and warm, dry climates. This region, known as the *Horse Latitudes*, is characterized by weak surface winds because of the weak horizontal pressure gradients. At the surface some of the descending air moves back toward the equator and is deflected to the right as it moves. The *trade winds* are northeasterly winds in this region of the world.

Near the equator, northeasterly winds from the Northern Hemisphere converge with southeasterly winds from the Southern Hemisphere. This is known as the *intertropical convergence zone* or ITCZ. The convergence further aids the ascent of air in the equatorial regions resulting in a widespread area of low pressure known as the *equatorial low.* This cell, characterized by ascent at the equator, northward movement along the tropopause, convergence and descent at 30 degrees north, and southward movement toward the equator along the surface is known as the Hadley Cell in the three-cell model.

At 30 degrees north, the air descending to the surface that does not move south toward the equator begins to move north and is deflected right by the Coriolis force. This results in a SW or WSW prevailing surface wind in much of the Northern Hemisphere known as *Westerlies*. Mild air moving north and east along the earth's surface encounters much cooler air moving south and west (*north* or *polar easterlies*) from the Polar Regions. These air masses of greatly differing temperature and density do not readily mix, resulting in the formation of the *polar front* along the boundary where the air masses meet. The polar front is a zone of strong convergence and rapidly rising air that results in a widespread surface low pressure system known as the *subpolar low*. This region of rapid, widespread ascent produces conditions ripe for storm formation. Some of the rising air, upon reaching the tropopause, moves back southward towards the region of convergence above 30^0 N. This circulation, northward along the surface, upward at the polar front, back to the south along the tropopause, and sinking toward the surface at the Horse Latitudes is known as a *Ferrel Cell*. Polar air, being cooler and denser than the air moving up from the south, can push the location of the polar front further south, especially in the wintertime, producing a cold polar outbreak over the continental U.S. This is known in the "Weather Channel" vernacular as "an outbreak of arctic air."

The portion of the air aloft that does not move south above the polar front moves north and east toward the poles where it converges and sinks. This circulation, which results in high pressure at the pole (the *polar high*), is known as the *polar cell* and is the weakest of the three cells.

The three-cell model, while not perfect, does accurately describe most of the large-scale patterns of circulation observed in the atmosphere, especially those patterns associated with surface flow.

Jet Streams

Jet streams are narrow, meandering bands of high-speed wind that form along boundaries between warm and cold air, usually near the tropopause. Jet Streams are many thousands of kilometers long and may be up to a few hundred kilometers wide but only a few kilometers thick. Wind speeds range from 100 to 200 knots. Over North America the *polar jet* is found in the vicinity of the polar front and the *subtropical jet* forms further south near the horse latitudes.