

Wind - Small-Scale and Local Systems

There are four different scales used to describe both the spatial (area) and temporal (lifetime) the sizes of weather events. The scales are *microscale*, *mesoscale*, *synoptic scale*, and *macroscale*. A *microscale* event is short-lived (lasting only a few minutes maximum) and only few meters of extent. A dust devil on a hot summer day is an example of a microscale event. Mesoscale events are from 1 to 100 kilometers across and last from several hours up to a day. Weather events occurring over the Snake River plain in Idaho are a good example of mesoscale events. *Synoptic* scale is the scale used in most weather maps; hundreds to thousands of kilometers across and with a time frame lasting for many days. Macroscale, as you might expect, is global scale.

Friction and Turbulence in the Boundary Layer

Frictional forces are not confined to interactions between solid objects. The friction of fluid flow is known as *viscosity*. When a fluid moves calmly and smoothly it is said to exhibit *laminar flow*. Eddies are a departure from laminar flow and result from *turbulence*. Eddies are formed in the atmosphere just as they are in rivers and streams. Within an eddy, wind direction and speed can change quickly resulting in wind *gusts*. In large eddies these gusts can be disastrous (e.g. wind shear). Eddies are found both near the surface and aloft. Normally, turbulent air aloft is associated with cumulonimbus clouds or other phenomena that are readily seen from a distance. Wind shear, however, sometimes occurs in the form of *clear air turbulence*, which is not visible from a distance. Clear air turbulence is dangerous because aircraft may encounter it without warning.

Mechanical turbulence results from the air being stirred by objects on the ground such as buildings, trees, hills, etc. Mechanical turbulence also results from friction due to the interaction between the air and the ground itself. Since friction between the ground and air decreases with height, wind speeds tend to increase with altitude, often rapidly. The wind speed at 10 meters above the ground, for example, may be as much as twice the wind speed at the ground. The *friction layer* or atmospheric *boundary layer* is generally considered to be the level of the atmosphere from 0 to 1000 meters above the surface. Above the boundary layer, the effect of mechanical turbulence is normally minimal.

Thermal turbulence results from heating the earth's surface. As pockets of warm air (thermals) rise the air is stirred resulting in turbulence. The more intense the heating, the steeper the lapse rate and the more intense the stirring. Thermal turbulence is most prominent on warm, sunny summer days and poses a hazard to flight.

Microscale Winds

No matter how hard the wind blows, wind speeds are usually zero within about 0.1mm of the ground. As a result, wind, by itself, can not move small particles on the ground. Dust is kicked up into the air on windy days by a process known as *saltation*. Saltation occurs when particles large enough to protrude above the 0.1mm level are picked up by the wind. As these particles hit the ground, they impact smaller particles, knocking them into the air where they are carried off. In desert regions, where a lack of vegetation leaves the soil exposed to the wind, smaller particles are completely removed after a period of time leaving only the larger pieces of gravel and sand. This is known as *desert pavement*.

The wind can act as a powerful abrasive. If the wind comes consistently from a given direction, and the rocks in an area are soft enough to be easily abraded by airborne particles, the windward sides of these rocks can become flattened and pitted. These rocks are called *ventifacts*.

Windblown material is deposited behind objects in the wind's path. These deposits are called *aeolian* deposits. Sand dunes and sand ripples are common aeolian deposits.

The wind can also create *wind-sculpted trees*. These exist in high altitude, open places that are windy such as mountain slopes, high plateaus, etc. High winds also increase the rate of transpiration resulting vegetation that dries quickly and a consequent high fire danger.

When vegetation is removed for farming or other purposes and a drought follows, it is easy to see how the land can be stripped of its topsoil. This is exactly what happened in the dust bowl of 1930's in the Great Plains. To prevent this from happening again farmers often plant *shelterbelts*. Shelterbelts help protect crops from the wind, and are usually formed from a mixture of both deciduous and coniferous trees planted perpendicular to the prevailing wind direction.

Wind causes waves to form in bodies of water. The length (but not the amplitude) of the waves depends on wind speed, the length of time the wind blows over the water, and the *fetch* or distance over the water the wind blows.

A *prevailing wind* is the name given to the wind direction that is most common during a given time period. Over North America, for example, the prevailing winds are out of the west.

Local Wind Systems

Movement of air may be brought on by diurnal changes in air temperature that causes air above warm areas to rise and air above colder areas to sink. If two such areas are conterminous, a circulation pattern may result. This phenomenon is known as a *thermal circulation*. Shallow low and high-pressure systems created by atmospheric heating or cooling are called *thermal lows* or *thermal highs*.

In coastal regions, for example, intense heating of the land under clear, sunny skies warms the air above the ground creating a thermal low. Over the adjacent body of water, less intense heating results in cooler air above the water and a shallow thermal high. The interaction between the two air masses results in a circulation pattern that produces an onshore wind called a *sea breeze*. At night, the situation is usually reversed and an offshore wind known as a *land breeze* results.

Wind can change both direction and speed when crossing a large body of water. As wind moves from land over the water it experiences less friction and subsequently speeds up. The Coriolis force (which is related to wind speed) may cause the wind to change direction. As the air speeds up it spreads out or *diverges*. As the air diverges it sinks, producing clear skies. This is why the regions around some large inland bodies of water are associated with perennially sunny skies. When the wind moves back onto land, it slows down (due to friction), and converges. Convergence forces the air to rise and results in cloud formation.

When strong, steady winds blow over a lake the water begins to slowly "slosh" back and. The resulting waves are called *seiches*.

Daytime heating on mountain slopes produces rising air that moves upslope. This type of wind is known as a *valley breeze*. As the air rises to the LCL clouds are formed which is why cumulus clouds are often observed over mountain ranges in the summertime. At night, radiational cooling results in downsloping winds called a *mountain breeze*. Mountain breezes are accompanied by clear skies due to sinking air.

Katabatic winds are downslope winds that are much stronger than mountain breezes. They are formed in much the same manner as mountain breezes but require a high plateau surrounded by hills or mountains to act as a reservoir for very cold, dense air. When enough air has accumulated on the plateau, it begins to spill through low spots in the surrounding hills or mountains and rushes downhill with much more force than an ordinary downslope breeze. Some examples of famous katabatic winds are the *bora* in Yugoslavia, the *mistral* in France, and the *Columbia Gorge* wind, in the Pacific Northwest.

The *Chinook (foehn)* wind is a warm, dry wind that runs down the eastern slope of the Rockies. Recall that as air sinks it warms by compression. The longer the distance that air moves downslope, the greater the warming. Chinook winds can cause a sharp rise in temperature. Chinooks are sometimes referred to as "snow eaters" because of the way that they melt snow rapidly in places like Denver and Cheyenne.

As regions of high-pressure develop over the Great Basin in the Southwestern United States strong winds race towards the Pacific. As these winds are funneled through the valleys and canyons of Southern California they can reach high speeds. These *Santa Ana* winds are responsible for carrying dust and debris out of the canyons and drying out the vegetation. Santa Ana winds are responsible for many wildfires in Southern California.

A *monsoon* is a wind that changes direction with the seasons. For example, a strong high-pressure system usually dominates the region over southern Asia during the winter months resulting in offshore winds. In the summertime, this high is replaced by low pressure and there is a resulting onshore wind. A weak monsoonal flow is associated with the weather patterns over the Southwestern United States.