

UNIT VI--LOCAL AND GENERAL WINDS

This unit addresses winds, both local and general, and what firefighters should know about them. Before starting the unit, read the instructions to students on page 2; then the unit objectives on page 2 of your workbook. When you have finished, return to this text.

See page 3. What is wind? By simple definition, wind is air in motion, especially horizontal, relative to the earth's surface. We are concerned with winds of two major scales in the atmosphere--the larger scale general wind and the smaller scale local wind. Collectively, these winds are measured at three levels in the atmosphere--the winds aloft, the 20-foot surface winds, and the winds at midflame height. See figure 1.

The general winds or winds aloft are caused by broad scale circulation patterns high above the earth. This circulation of air throughout the atmosphere is the result of large-scale convective circulation between the equator and the polar regions, and of the earth's rotation on its axis. These are sometimes called the gradient winds. In the contiguous United States and Canada, high- and low-pressure patterns mostly move from west to east due to the prevailing westerlies. Winds aloft are measured at 1,000-foot intervals, since they can vary considerably at various altitudes.

As the general air flow nears the earth's surface, it gradually becomes affected by the shape of the topography and by local heating and cooling over large areas. Frictional drag produced by the terrain usually slows the larger scale winds and can modify their direction. Next, consider the smaller scale, local winds. These are produced locally due to heating and cooling or temperature differences at the earth's surface.

The general winds and the local winds may combine to produce the winds that we experience at the surface. The measurement of surface winds has been standardized at 20 feet above the ground in a clearing, or 20 feet above any vegetation.

As surface winds drop closer to the ground, their speeds are reduced primarily due to friction. In doing calculations of fire behavior, we are concerned with the wind speeds at the level of the flames. This is referred to as the "midflame windspeed". This unit will discuss how each of these wind levels are measured and predicted.

All of these wind levels can affect, either directly or indirectly, the behavior of wildfires, although we are generally not concerned with higher level winds unless fire intensities and convection columns are very high and long-range spotting becomes a problem. Most weather forecasts available to firefighters address the general and surface winds because these are more appropriate to fire danger predictions. Some special fire weather forecasts may predict midflame (usually eye level) winds, in which case the forecaster has reduced the surface windspeeds for you.

First, we'll discuss surface or 20-foot winds. These affect the intensity, direction, and rate of spread of wildland fires by angling the flames to preheat fuels by radiation; angling convection currents to preheat fuels ahead of the fire; providing a fresh supply of oxygen to the fire;

speeding up moisture exchange between the air and the fuels; carrying burning embers and firebrands to cause short range spotting; and causing fire to burn erratically.

How much effect does wind really have on fire spread? Let's look at figure 2 on page 4. This chart shows the rates of spread for two fuel types under the same moisture and topography conditions, but for a range of 20-foot windspeeds. In this example, the rate of spread for timber with grass and understory is 3 chains per hour when there is no wind, and about 90 chains per hour when the local wind is 20 miles per hour. When 20-foot windspeed doubles to 40 miles per hour, the rate of spread increases to about 310 chains per hour, an increase of over three times. Notice that increasing windspeed affects the grass fuel type more than it affects the slash fuel.

General winds at various levels above the surface also have direct effects on fires with respect to convection column development, smoke transport, and spotting distance and direction. These processes will be discussed in more detail in later units.

In this course, we stress the importance of the various weather elements to fire behavior. Of these, wind is the most variable, often changing from moment to moment; thus it is the most difficult element of weather to predict. It is also one of the most critical fire behavior factors.

Because wind is so critical to fire behavior, we try to obtain the best wind observations and forecasts possible. Predicting what the winds will be at various times and places is no easy task, even for the experienced meteorologist. This is why the firefighter usually relies on wind predictions from weather forecasts. There are times, however, that by being especially observant of the terrain and past weather patterns, the firefighter is in a good position to adapt a wind forecast to his site. This is especially true where local winds repeat themselves under similar weather conditions. An example of this could be the slope and valley winds in a large valley.

There are other weather situations in which personnel in the field, by recognizing the indicators, are able to anticipate wind changes and take appropriate action. It is not our intent to make you a forecaster of winds, but you should be aware of situations when certain winds can occur.

The next portion of this unit, starting on page 5, will deal with general winds. It is important that you understand more about general winds and how they produce or influence local weather. First, we can generalize by stating that all winds are the result of temperature differences which cause pressure gradients between different areas. This can be on a very large scale, such as over many hundreds of miles, or on a very small scale, such as a few inches.

In figure 3, on the left, we see the general wind blowing across the terrain from an area of high pressure to an area of lower pressure. Close to the terrain, the general air flow will become modified by the roughness of the surface.

On the right-hand side of figure 3, we see that upslope local winds, produced by warm air rising over the terrain, meet and mix with the general winds. The general winds in the lower layers of the atmosphere will be further modified by locally induced convective winds.

To better understand general winds, we should discuss the general circulation of air around the earth. This mass of moving air is our atmosphere--a gaseous mantle encasing the earth, held there by gravity, and rotating with the earth. See figure 4, on page 5. Several natural forces interact to produce continual movement of this air, thus producing wide and varied weather patterns.

The surface of the earth is not heated uniformly by the sun, and the resulting unequal heating of the atmosphere causes compensating air motions which tend to reduce the horizontal temperature differences. As the air moves from the equatorial regions toward the polar regions, it is affected by the earth's rotation. In the Northern Hemisphere, the air is deflected to the right as the earth rotates on its axis. This deflection force-is called the Coriolis force.

The uneven heating and cooling at all latitudes, due to seasonal and day-night cycles, modifies the large-scale circulation pattern. Uneven heating and cooling, due to the distribution of land and sea areas, is another important factor. These and other factors are responsible for producing a series of wind belts that circle the earth at various latitudes. One of these wind belts is called the prevailing westerlies. Closer to the North Pole, high pressure is maintained, and easterly winds occur. We are primarily concerned with latitudes between 30 degrees and 60 degrees North. In figure 4, arrows indicate air flowing out of the south and west. This is the region where we have the prevailing westerlies.

At some latitudes the air tends to "pile up" to cause belts of high surface pressure. These belts are never uniform, but instead consist of a series of rather large pressure cells. Some of the pressure cells are relatively fixed, such as the polar high, while others are migratory. Our weather is closely related to the location and movement of these primary pressure cells and other smaller scale pressure patterns.

On page 6, figure 5 illustrates a surface pressure map over the United States for a particular time. There are cells of high pressure and cells of low pressure on this weather map. The lines that you see on the map are called isobars which are drawn through points of equal air pressure. These isobars outline the areas of high and low pressure.

Typically, pressure cells move from west to east across the United States. However, at times they move in other directions, which further complicates weather patterns. The circular isobars over Mississippi indicate a low pressure cell, or in this case, a hurricane that has moved inland from the Gulf of Mexico.

A line with barbs is shown arching southward from a low-pressure cell in Canada. This designates the boundary between- two air masses or different temperatures and other characteristics. The boundary is called a weather front- The figure shows both a short warm front extending to the east coast and a longer cold front extending into Texas. We will discuss the weather associated with weather fronts a little later.

We need to make one more point regarding pressure cells. Air in a high-pressure cell moves clockwise and outward from the cell; air in a low-pressure cell moves counterclockwise and toward the center of the cell. See figure 6. Remember, clockwise in areas of high pressure,

counterclockwise in areas of low pressure. This has a direct effect on the winds that occur at the surface.

What have you learned about general winds to this point? It's time now to do question 1 on page 7; mark your choice or choices.

In question 1, you should have marked choices 1, 2, and 4. These are all true. In number 3, the general winds may drop very close to the earth's surface in some areas; however, these winds are usually modified by terrain. The resulting surface winds can be considerably different from the general winds.

We'll give you a series of illustrations on how general winds are modified to help produce surface winds. Figure 7 illustrates the lee slope, eddy effects on a much larger scale. Tall mountain ranges can modify strong winds aloft to create waves and large eddies on the lee side of the mountains. Winds dip down due to the difference in pressure on the lee side, thus initiating wave actions in those strong winds. Lens-shaped clouds (altocumulus lenticularis) may develop in the tops of these waves. These clouds can easily be formed on the lee side of mountain ranges that are perpendicular to winds of 40 knots or more. The clouds are usually high, and the resulting winds may not be felt at the surface. However, occasionally these strong winds aloft may dip to the surface, or eddy winds may reverse the direction of usual winds. Depending on your location, surface winds can be significantly modified by this process.

Friction and air turbulence generated at the surface slow low level winds. There are two sources of turbulence--mechanical and thermal. The roughness of surfaces, usually due to vegetative cover, causes friction and results in mechanical turbulence. Surface heating during the day causes thermal turbulence as heat convection currents rise from the surface and mix with the air flowing over the surface.

Let's look at some effects of channeling and mechanical turbulence. Figure 8, on page 8 illustrates a general wind blowing through a pass or saddle in a mountain range. Wind velocities might increase as they pass through the constricted area; then the air spreads out on the lee side with probable eddy actions.

Winds on the lee sides of ridges can shift in direction and speed, making them difficult to predict. We usually term eddy winds as gusty and erratic.

Another factor which has a great deal of effect on low level wind is thermal turbulence caused by surface heating. See figure 9, on page 8. Different land surfaces absorb, reflect, and radiate varying amounts of heat. Warm air rises and mixes with other air moving across the terrain. This mixing action has differing effects on surface winds, but often makes them gusty and erratic.

We have given you a very brief explanation of what general winds are, how they develop, and how they are affected by terrain. There are excellent publications listed in the references for this course which give a much more detailed description of general circulation, pressure systems, and weather fronts.

Now let us turn our attention to the fact that air in the atmosphere is constantly moving, and its speed can vary by heights into the atmosphere. Winds aloft are measured at weather observation stations throughout the world by using radiosonde balloons. See figure 10 on page 9. An instrument package is suspended from the lighter-than-air balloon. These instruments are released at regular intervals by observers. The balloon is tracked by the radio signals transmitted from the instrument package and by other devices. Meteorologists are thus able to calculate wind direction and speeds at various altitudes in the atmosphere. The illustration on the left shows a wind profile with arrows to indicate direction. Notice how wind speeds vary and wind directions change. Occasionally, a band of air will be moving at a much higher rate of speed than adjacent air, as is illustrated in the wind profile on the right. The transition area is called a wind shear. A wind shear at 10,000 feet could have pronounced effects on a smoke convection column and its potential for long-range spotting.

The measuring and predicting of general winds are usually beyond the capability of the firefighter in the field. He or she must rely on the meteorologist to provide this data and to interpret the effects of these winds near the surface.

The firefighter can observe and measure surface winds and, to some extent, should be able to anticipate changes in those winds. Under persisting atmospheric conditions, wind patterns can often be recognized, so that diurnal wind changes can be anticipated or predicted from day to day.

The next portion of this unit, starting on page 10, will address local winds with the aim of making you more aware of what influences these winds, and what can be expected in various topographic situations.

We define local winds as small-scale convective winds of local origin caused by temperature differences. We use the term convective winds in the definition. Actually their meanings are quite similar. Convective winds are all winds--up, down, or horizontal that develop as a result of local temperature differences. Local terrain has a very strong influence on local winds, and the more varied the terrain, the greater the influence. Here are some ways in which local winds develop. Note the following on page 10 under item A: Convection from daytime heating; unequal heating and cooling of the surface; and gravity, including downdrafts. We will discuss and illustrate each of these in this portion of the unit.

Winds of local origin, convective winds, can be as important in fire behavior as the winds produced by the large-scale pressure patterns. In many areas, they are the predominant winds in that they overshadow the general winds. If their interactions are understood and their patterns known, local convective winds can be predicted with reasonable accuracy.

We're going to discuss some common local convective winds. Please turn to page 11. Under item B, list the following: Land and sea breezes, slope and valley winds, thunderstorm downdrafts, and whirlwinds.

Figure 11 illustrates the land and sea breezes. In unit 4, we discussed the surface properties that cause land surfaces to become warmer than water surfaces during the daytime. As a result of this

local-scale temperature and pressure difference, a sea breeze begins to flow inland from over the water, forcing the warm air over the land to rise and to cool adiabatically. In the absence of strong general winds, this air flows seaward aloft to replace air which has settled and moved toward shore, and thus completes the circulation cell. The surface sea breeze begins around midmorning, strengthens during the day, and ends around sunset.

The land breeze at night is the reverse of the daytime sea breeze circulation. At night, land surfaces cool more quickly than water surfaces. Air in contact with the land then becomes cooler than air over adjacent water. Again, a difference in air pressure develops over the land and the water causing air to flow from the land to the water. The air must be replaced, but return flow aloft is likely to be weak and diffuse and is diminished in the prevailing general winds. The land breeze begins 2 to 3 hours after sunset and usually ends shortly after sunrise.

Another combination of convective winds results in slope winds. See figure 12. Slope winds are local diurnal winds present on all sloping surfaces. They flow upslope during the day as the result of surface heating, and downslope at night because of surface cooling. Slope winds are produced by the local pressure gradient caused by the difference in temperature between air near the slope and air at the same elevation away from the slope.

During the daytime, the warm air sheath next to the slope serves as a natural chimney and provides a path of least resistance for the upward flow of warm air. The layer of warm air is turbulent, increasing in depth as it progresses up the slope. This process continues during the daytime as long as the slope is receiving solar radiation. When the slope becomes shaded or night comes, the process is reversed.

A short transition period occurs as a slope goes into shadow: the upslope winds die, there is a period of relative calm, and then a gentle, smooth downslope flow begins. Downslope winds are very shallow and may not be represented by a 20-foot surface windspeed. The cooled denser air is stable, and the downslope flow tends to be quite smooth and slower than upslope winds. The principal force here is gravity. Downslope winds usually continue throughout the night until morning, when slopes are again warmed by solar radiation. The times during which winds change from downslope to upslope and vice versa can depend on aspect, time of year, slope percent, current weather conditions, and other lesser factors.

Now please do question 2 on page 12.

In question 2, you should have marked choices 2, 3, and 4. If you remember these statements, you should have little problem understanding slope and valley winds.

Figure 13 on page 12 illustrates the valley winds. During the day, air in mountain valleys and canyons tends to become warmer than air at the same elevation over adjacent plains or larger valleys, thus creating a pressure gradient and resulting in upvalley winds. The main difference between upslope winds and upvalley winds is that the upvalley winds do not start until most of the air mass in the valley becomes warmed. Usually this is middle or late forenoon, depending largely on the size of the valley. These winds reach their maximum speeds in early afternoon and continue into the evening.

The transition from upvalley to downvalley flow takes place in the early night. The transition is gradual: first the downslope winds, then a pooling of cool, heavy air in the valley bottoms. The cool air in the higher valley bottoms will flow to lower elevations and increase in velocity as the pool of cool air deepens. This continues through the night and diminishes after sunrise.

The velocities of the slope and valley winds vary considerably by terrain and current weather conditions. For example, slope and valley winds develop better under clear skies when the heating and cooling processes are more pronounced.

We can give you some broad ranges to indicate typical windspeeds in mountain topography. Upslope winds usually range from 8 to 12 miles per hour, while downslope winds are somewhat less; 2 to 7 miles per hour. Upvalley winds typically are stronger, 12 to 20 miles per hour, while downvalley winds can be 8 to 14 miles per hour.

The illustrations of slope and valley winds to this point might suggest that upslope and upvalley winds occur on all slopes at the same time. This is not usually the case. For one example, see figure 14 on page 13. Let's suppose we have a ridge line and canyon parallel to each other running north and south. In the morning, the east aspects will be heated by the sun, but the west aspects are shaded. Upslope winds can occur on the east slopes, while downslope winds occur on the west slopes. As the sun passes overhead and into the afternoon positions, the west slopes become heated and the east slopes become shaded. The slope winds can reverse from those of the morning.

Now do question. 3 on page 13; mark your choice or choices.

In question 3, you should have marked statements 1, 2, and 4. If you have problems understanding the diurnal wind processes in mountainous terrain, we suggest that you go to one of several weather references listed for this course, all of which give more details and background.

Local slope winds are often influenced and modified by the general winds. See figure 15 on page 14. It gives three examples of how local winds and general winds may predominate and produce the resultant surface winds.

In the upper example, the general wind at 1000 feet is west at 10 miles per hour. As this wind drops closer to the surface, its speed is reduced to 7 miles per hour by frictional drag. We will refer to this windspeed as the general wind component. The upslope wind or the local wind component is 5 miles per hour. We can add the two components together to arrive at the surface wind speed of 12 miles per hour.

In the middle example, the general wind is blowing in the opposite direction and opposing the east slope wind. At the anemometer, the general wind component is stronger than the local slope wind component. The surface wind at that point would probably be the difference between the two opposing windspeeds, or a west wind at 8 miles per hour.

The lower example shows a nighttime situation where an inversion layer has developed in the valley. Here the general wind is confined to levels above the inversion by the stable air and therefore affects surface winds only at higher elevations. The surface wind at the anemometer will be the same as the downslope wind component.

From these examples, you can see how surface winds are dependent on time of day, position on slope, and the strength and direction of the various wind components.

Move on to page 15 and do exercise 1 on slope and valley winds. It will refer you to the topographic map on page 16. Please do this exercise; then check your answers and return to the text.

The wind conditions that we have covered so far may, or may not, be considered problem winds to the firefighter. These are normal, everyday winds with which the firefighter must deal. Moderate to strong winds present a particular concern because fire behavior is so reactive to wind. Firelines are most often lost, large acreages burned, and property and lives are lost when strong winds fan a fire out of control. This is why we have named the next portion of this unit, "Winds of Most Concern to Firefighters."

See page 17. We will now discuss four kinds of winds that produce severe fire weather conditions. Under item C, list the following: Cold front winds, foehn winds, thunderstorms downdrafts, and whirlwinds. Whirlwinds can be either dust devils or firewhirls.

First let's look at cold front winds. We said earlier that a weather front is the boundary layer between two air masses of different temperatures. Weather fronts center out of an area of low pressure, and they acquire movement as the low-pressure cell moves across the country. Figure 16 on page 17 illustrates a very simple weather map with both a cold front and a warm front. The arrows show the usual direction of winds in relation to these weather fronts. Wind direction is always the direction from which the wind is blowing. As such fronts move through a region, the winds will shift in a clockwise direction. Ahead of a warm front, winds will be out of the northeast and east. Winds ahead of a cold front usually shift from southeast to south, to southwest. As a cold front passes through, winds shift to west, then northwest. The reason for the wind shifts is that air is always flowing in a counterclockwise direction around a low and is crossing the isobars into the center of the low-pressure cell. Winds will be strongest when the frontal boundaries pass through your area, since the strongest pressure gradient exists in these zones. Both types of weather fronts often are not present at the same time. Warm fronts are more common in winter and are seldom seen in the Western United States during summer. Cold fronts are much more common and may be spaced from 1 day to 2 weeks apart. Remember, winds always shift clockwise in direction with the passage of a weather front. They increase in velocity as the fronts pass through an area, and their consistency, strength, and gustiness may vary greatly.

Cold fronts frequently bring thunderstorm activity with possible precipitation. However, during the summer months in the West, cold fronts are often dry, but bring cooler and stronger winds. Cold front winds can easily reach 15 to 25 miles per hour or higher close to the front but blow less strongly well ahead of and behind the front. Typical pre-cold frontal winds would be from

10-14 miles per hour while post frontal winds would be 12-18-miles per hour. If thunderstorms are associated with the front, winds can be much stronger, up to 50 miles per hour, and can rapidly change the usual wind directions.

Now do question 4 on page 18; mark your choice or choices.

In question 4, you should have marked statements 2 and 3. In number 1, winds immediately after the frontal passage will usually be from the west. In number 4, winds immediately ahead of the front are usually from the southwest. It's -very important that you remember the winds associated with a cold front. This understanding could save your life on a fire some day.

Another kind of wind that causes firefighters great concern is the foehn wind. Foehn winds represent a special type of local wind associated with mountain range systems. They occur as heavy, stable air pushes over a mountain range and then descends the slopes on the leeward side as warmer, drier air.

Figure 17 on page 18 gives examples of two commonly known foehn winds. The two foehn winds shown are blowing in opposite directions, but they have similar origins. The chinook occurs on the east slopes of several large mountain ranges in the Western United States. Chinook winds are most prevalent on the east side of the Rocky Mountains during fall and winter.

In the case of the chinook wind, air pushed up on the windward side is cooled adiabatically to the point that clouds and precipitation may occur. As that air passes over the mountains and descends on the lee side, it is warmed adiabatically at 5-1/2 degrees per 1,000 feet of fall. It also gains velocity as it passes through the constricted topography and accelerates as it flows downslope. The resulting foehn or gravity winds on the lee side of mountain ranges can be warm and dry, with moderate to high velocities.

The Santa Ana creates the most critical fire weather situations in areas of Southern California during fall and winter. Foehn winds are produced when the large-scale circulation is sufficiently strong and deep to force air completely across a major mountain range in a short period of time. In many cases, there is a large stationary cell of high pressure over the land.

Subsidence or heavy air lowering within the pressure cell may push up against the mountain range. This heavy or stable air speeds up as it flows through passes and saddles, then down the lee slopes by gravity and pressure gradients.

On page 19, please do question 5.

The true statements in question 5 are 1, 3, and 4. In number 2, foehn winds are associated with areas of high pressure, but their winds are flowing toward lower pressure.

Figure 18 on page 19 shows the more common and better known foehn winds in the Western United States. All shown can cause serious fire control problems, as these winds often reach 25 to 50 miles per hour. Some have been measured in excess of 100 miles per hour.

If you know of foehn or local gravity wind conditions existing in your locality, you should talk to a meteorologist or some other knowledgeable individual about them. There are likely to be peculiarities for each area, and knowing these can help you in recognizing or anticipating the effects of foehn winds.

Next, we will discuss a local wind condition that is important to all regions of the country. This is the thunderstorm downdraft. See page 20. Cumulonimbus clouds, called thunderheads, can build over an area at any time there is adequate moisture in the atmosphere and a lifting mechanism to force air to rise. Generally, there are four lifting mechanisms. These will be discussed in the next unit on atmospheric stability and instability. The most usual lifting mechanism for thunderstorms is convection, which is caused by heating from below. Thunderheads begin as small, fluffy cumulus clouds. Moist air that is lifted will cool to its dew point at some altitude to form cumulus clouds. The greater the lifting, the greater the cloud development. The release of latent heat by the condensation of water provides additional energy to develop the cloud.

Towering cumulus clouds may reach to 20,000 feet of thickness. When their tops reach high in the atmosphere, icing of cloud particles can occur. A fully developed cumulonimbus cloud can reach 30,000 to 40,000 feet or more in the west, and to 60,000 to 70,000 feet in the east. Such clouds have stored vast amounts of energy. Not only are there strong indrafts into the base of the cloud, but strong downdrafts occur with the release of its energy. Violent local storms are produced, accompanied by thunder and lightning, perhaps rain, and strong winds.

When discussing cumulus buildups, we usually categorize their development by stages. Figure 19 illustrates the first three stages. Under item D, we will describe the stages of cumulus cloud development. Stage 1 is most often called fair weather cumulus. These are clouds with horizontal bases, rounded surfaces, and with little vertical development. The winds associated with this stage are light indrafts into the base of clouds-

The second stage is towering cumulus. These are clouds of vertical development, towering and cauliflower like in appearance, with clear-cut tops. These have stronger indrafts into the base of the clouds, perhaps affecting the surface winds.

Stage 3 is the Cumulonimbus or thunderstorm. These clouds have high vertical development and anvil-shaped tops composed of ice crystals. The bases of mature thunderstorms are ragged from downdrafts and virga. Downdrafts that reach the ground result in cool, gusty surface winds that can be experienced within about 5 to 6 miles or so of a thunderhead. Surface wind velocities will often be 25 to 35 miles per hour but can reach as high as 50 to 70 miles per hour. When you observe cumulus clouds near your fire, you should recognize and report them as being in one of these stages.

Go to page 21. Question 6 deals with thunderstorms. Mark your choice or choices.

There is one true statement in question 6. This is number 3. In number 1, rain may not reach the ground but evaporates in the lower atmosphere. This we call a dry thunderstorm. In number 2,

you may experience the downdrafts within 5 miles, but not necessarily. This depends on the strength of the downdrafts, other surface winds at the time, and on terrain features.

In number 4, thunderstorm downdrafts will be cooler and somewhat moister than surrounding air. This is not to say that the relative humidity will be high, but merely higher than otherwise.

Let's take another look at the mature thunderhead. See figure 20. Thunderstorms may remain stationary or move with or across prevailing winds. The top of the cloud may fracture and drift in the direction of winds aloft. Indrafts can continue into the base on the windward side, as downdrafts are pouring from the base elsewhere. Downdrafts will usually reach the ground and flow in all directions; however, local and general winds tend to mix and modify the downdraft winds. Thunderstorm winds will be experienced for greater distances on the ground if they are combined with a prevailing surface wind.

There are several things to watch for that will indicate when downdrafts from a thunderstorm have begun. First, you may see a small roll cloud developing on the downwind side of the cloud base. You may see virga hanging from a ragged, dark base. Virga is actually rain that falls part way to the ground. Then you might observe a dust cloud, as the first gusts spread out over the countryside. Depending on your proximity to a thunderstorm you may experience varying weather conditions. The important thing is that you be prepared for the worst, should it occur. Remember, thunderstorm winds can easily reach 30 to 60 miles per hour.

See page 22. The fourth problem wind is the whirlwind. The most common whirlwind, the dust devil, occurs on hot days over dry terrain when skies are clear and general winds are light. Whirlwinds are an indicator of intense local heating. Strong convection currents or updrafts develop in the areas of intense heating. It is probable that nearly all updrafts have some whirling motion, but usually this is weak and invisible. The stronger the updraft, the stronger the whirl. The whirl becomes visible if the updraft becomes strong enough to pick up dust and other surface materials.

Whirlwinds may remain stationary or move with the surface wind. If it breaks away from its heat source, it may die out, and another whirlwind may develop nearby. In very light wind situations whirlwinds that move, show a tendency to move toward higher ground.

Whirlwinds vary in size from just a few feet to over 100-feet in diameter, and to heights of nearly 4,000 feet. On fires, dust devils are common in an area that has just burned over, since the blackened ash and charred materials are good absorbers of solar radiation and thus encourage local heating.

The firewhirl, which carries flames and burning materials up into its column, is usually caused by very high fire intensities in local areas. Firewhirls are usually considered more dangerous than dust devils, but both can scatter fire, cause spotting across control lines, and generally increase fire intensity in local areas.

Remember that in order for whirlwinds to develop, certain environmental conditions must be present. See figure 21. These conditions usually include mostly clear, sunny skies; light surface

winds; heating with extreme instability of the air near the surface; and on the back side of a shallow ridge, or on lee slopes from the prevailing wind.

Now please do question 7.

In question 7, you should have marked all of the statements as being true. This concludes our discussion of whirlwinds for now; however, whirlwinds and extreme fire behavior will be discussed in Unit 9 of this course.

On page 23 is an exercise on three kinds of problem winds on fires. Read the instructions; then complete the exercise. When you have finished, return to the text.

You should have checked your answers with those on page 30. On page 24, exercise 3 is on matching various kinds of winds with their definitions. We have discussed each of these winds in this unit. Now please complete this exercise.

The last portion of this unit, starting on page 25, is on wind inputs for fire behavior calculations. Wind is a crucial input into fire spread models and calculations, and we need to have the best possible estimates of wind to obtain reasonably accurate results. You on the fireline are often in the best position to provide estimates of windspeed and direction.

In figure 22, we illustrate two instruments for measuring wind. Both of these are carefully located at field weather stations to give readings of the winds 20 feet above the vegetative cover. Windspeeds in miles per hour are determined by the anemometer, and by averaging them over a 2-minute to 10-minute period. Wind direction is observed on a wind vane and is recorded to the nearest 8 cardinal points on a compass--N, NE, E, SE, etc. Unless you have a mobile weather unit on your fire, you probably will not have such instruments. A small belt weather kit, which should be available on any fire, contains all the instruments needed to take good weather observations. Here wind measurements will normally be taken at eye level. The use of the belt weather kit will be covered in Unit 8 of this course.

Now please do question 8 on page 25.

You should have marked statements 2, 3, and 4 as being true. In number 1, winds that are blowing toward the south are north winds. This may seem very elementary, but surprisingly, there can be confusion in describing wind directions. When you hear the wind described as "to the south," or "northerly," this should mean the winds are from the north. If you are facing into the wind, name the wind from that direction. Be sure all parties interpret the direction in the same manner, because it could save someone's life.

We mentioned that anemometers at field weather stations are used to take wind measurements at the 20-foot level. This is standard for all stations, and wind predictions in most regular weather forecasts are for the 20-foot winds. However, wind velocities at 20 feet above the vegetation are not the same as those affecting a fire on the surface. When doing fire spread calculations, we need to use windspeeds measured or estimated at the mid-height of the flames. These are called

midflame windspeeds. The difference between the two is due to friction with the surface vegetative cover and topography.

Figure 23 on page 26 illustrates some midflame winds in relation to the 20-foot winds. On the left, a fire is burning in brush and the midflame windspeed will be less than half of that at 20 feet. On the right, the surface fire under timber will experience midflame wind of only a small fraction of those at 20 feet above the canopy. A fire reaching into the canopy will still not receive the full velocity of the 20-foot winds. Why is this?

Before continuing our discussion of determining midflame speeds, please do question 9 on page 26.

In question 9, you should have marked statement 4 as being true. In number 1, wind measurements taken on fires are usually taken at eye level with a handheld wind meter. In number 2, generally midflame windspeeds will be less than the 20-foot windspeeds except in cases where downslope winds under a canopy occur when the 20-foot wind is calm. In number 3, some spot weather forecasts give midflame windspeeds. For number 4, eye level wind measurements can be used as midflame windspeeds if the measurements are taken under the same sheltering conditions as the fire.

Go to page 27. The present state of the science requires that fire behavior calculations be confined to surface fires. If there are trees present, open or closed canopy, the midflame windspeeds will be considerably less than the 20-foot winds. This reduction in windspeed will depend on how sheltered the surface fuels are. See figure 24. It illustrates how surface fuels may be exposed, partially sheltered, or fully sheltered from the 20-foot winds based on tree canopy and position on the slope. We will be adjusting the 20-foot windspeed based on these conditions. Please study this illustration and note the descriptions below the horizon line. When you have finished, return to the text.

On page 28 you will find a wind adjustment table. This table can be used to estimate midflame windspeeds from 20-foot windspeeds. The adjustment factor depends on how sheltered the surface fuels are from the wind. This sheltering depends on canopy closure and position on the slope. The adjustment factor for exposed fuels also depends on fuel model. The midflame wind is obtained by multiplying the 20-foot windspeed by the appropriate wind adjustment factor. Read the notations at the bottom of the page; then study the table until you become familiar with its use.

The last exercise on page 29 will require that you use the wind adjustment table to determine midflame windspeeds. This will help you to meet a key skill objective for this course. After completing the exercise, check your answers; then prepare for the unit test.