Weather Elements that Affect Fire Behavior

What is weather? It is the state of the atmosphere surrounding the earth at a certain area. The atmosphere is a gaseous mantle (mostly oxygen and nitrogen) encasing the earth and rotating with it in space. Weather is never static. It is dynamic, changing day-by-day, hour-by hour and even minute-by-minute.

Of the three major components making up a fire◆s environment (Fuel, Weather and Topography), weather is the most important, yet it is continuously changing. This unit will deal with the role weather plays in the start and spread of wildfires and in the use of prescribed Fires.

There are several elements of weather that must be considered. They are:

- **Temperature**
- **Wind**
- **Stability of the atmosphere**
- **Relative humidity**
- **Precipitation**
- **Cloud development**

In addition **drought**, a result of certain weather conditions, must be considered.

TEMPERATURE

Air temperature has a direct influence on fire behavior because of the heat requirements for ignition and continuing the combustion process. We discussed radiant heat in the previous unit. Heat from the sun is transferred to the earth by radiation. This heat warms up the surface of the earth and the atmosphere close to the surface is in turn warmed by heat reflecting from the surface. This is the reason that the temperature above the surface is cooler than at the surface of the earth. These temperatures generally decrease about 3.5 degrees per thousand feet in altitude. This decrease is known as the adiabatic lapse rate.

Forest fuels receive heat by radiation from the sun. As a result, less heat is required for ignition. The differential heating of the earth◆s surface is the driving force behind most of the influences on the atmosphere. The sun emits short-wave energy rays (radiation). When striking a solid object such as trees or grass, it is warmed. The surface absorbs some of the heat and reflects some in long-wave radiation that is absorbed by the water vapor in the air thus raising its temperature as well.

Arguably, temperature, is the single most important weather factor affecting fire behavior. Some might say that relative humidity is most important but we will learn that temperature drives relative humidity

Fuel temperatures also affect a fire◆s rate of spread. Warm fuels will ignite and burn faster because less heat energy is used to raise the fuels to their ignition temperature. Fuels exposed to sunlight will be warmer than the fuels in shade. They will also be drier. For this reason, fuels not shaded by an overstory will generally be warmer and drier resulting in a more intense fire.

Fires also have influence on the atmosphere. The temperature is the highest at that time resulting in the greatest amount of fire. High winds will cause heat is needed to raise the fuel to its ignition temperature. At the same time rising temperatures result in decreasing relative humidity and fuel moisture.

The type of surface will also affect the temperature. The temperature at the surface of a body of water will be cooler because the heat will readily penetrate and spread throughout the water. On the other hand, bare soil will be higher because heat will not penetrate. Instead, it will be concentrated at the surface. In forested areas, the trees will absorb most of the heat. For this reason, fuel in the shade will be cooler than in the sun.

We will be discussing other reasons later.

WIND

Wind has a strong effect on fire behavior due to the fanning effect on the fire. Wind can change direction and intensity throughout the day. This change can be very abrupt surprising the burner that is not alert. Abrupt changes generally occur during the afternoon when atmospheric conditions are most unstable. We will discus stability later.

Wind is important to the prescribed burners fire fighter because of three influences it has on fire behavior:

- Supplying oxygen for the combustion process
- Reducing fuel moisture by increasing evaporation
- Exerting pressure to physically move the fire and heat produced closer to fuel in the path of the fire increasing radiation including in some cases pitching burn embers, firebrands

Wind increases the supply of oxygen, which results in the fire burning more rapidly. It also removes the surface fuel moisture, which increases the drying of the fuel. Air pressure will push flames, sparks and firebrands into new fuel. By pushing the flames closer to the fuel in front of the fire, the fuel is preheated quicker because of the increased radiant heat discussed previously. More of the fuel becomes available for combustion since it is dryer and can reach ignition temperature quicker.

Wind may presents the most persistent problem. It can change speed, direction, or become quite gusty. Wind influences the rate of spread and intensity of the fire. High winds will cause the head of a fire to increase spread rapidly. It may cause the fire to crown into the top of the trees and to jump barriers that would normally stop a fire. Wind can carry sparks and firebrands ahead of the main fire causing spotting. Wind generally increases evaporation from any surface by carrying away moist air and bringing in dryer air.

In addition wind strongly influences prescribed fire smoke dispersal, a critical consideration. The National Weather Service, NOAA NWS, normally reports wind speed in fire weather reports at 20◆ elevation in the open (for instance at an air port). NWS also reports the transport wind speed, the average wind speed from the surface to the mixing height. As a general rule prescribed burn planners prescribe surface winds at flame level or eye level between 1 and 5 MPH and transport wind speeds between 9 and 20 MPH depending on the circumstance and prescribed burn objective.

Effect of Wind on Vegetation

- Friction slows down speed next to the surface
- Causes turbulence and eddies
- Fire is more intense at edge of openings
- Increases evaporation by moving away the moist air next to fuel

General Types of Winds

Pressure or Gradient Winds

Air always moves as a result of temperature differences. It moves from high pressure areas to low pressure areas in an attempt to balance out the differences in temperature. Due to the movement of the earth, this is not a straight line. Wind from a "high" will spiral outward in a clockwise direction in the northern hemisphere. The wind flow toward a "low" will spiral in a counter clockwise direction toward the center. These highs and lows are generally shown on weather maps.

On a rotating earth with a uniform surface, the pressure gradient force in the northern hemisphere would be composed of the northeast trade winds, prevailing westerlies, and polar easterlies.

Frontal Winds

A weather front is the boundary layer between two air masses of different temperatures. Fronts start from an area of low pressure. Winds will be the strongest at the frontal boundaries. Wind direction will also shift in a clockwise direction as the front passes.

Local Types of Winds

General winds are winds that are included in the weather forecast. Local factors will also affect the wind in an area that is too small to be included in the forecast. These are known as "local winds". There are two that are important to fire behavior in the southeast.

Land and Sea Breezes

As discussed earlier, land surfaces become warmer than water surfaces during the day. As a result, the air adjacent to the land surface, being warmer, begins to rise and the cooler air (thus heavier) flows inland to take its place. This local wind begins around 2 to 3 hours after sunrise and ends around sunset.

At night, the reverse is true because the land surface cools more quickly than the water surface causing airflow from land to the water. This shift generally occurs around 2 am.

While these winds are normally strongest in coastal areas they may occur around large bodies of water.

Eddies

Eddy winds form around large objects and along tree lines. Eddie winds can strongly influence fire behavior at the edge of stands and open fields or along roads

Slope Winds

Over large, flat areas, it is difficult for the air mass to mix even though the air next to the surface is warmer, thus lighter. However on a slope, the lighter air can rise along the slope with cooler air filling in from below. Local winds will flow upslope during the day and down-slope at night. This is true even on the slightest slope unless the general wind is strong enough to overcome this phenomenon.

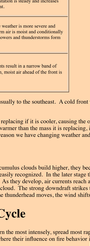
STABILITY OF THE ATMOSHPERE

Atmospheric stability is the resistance of the atmosphere to vertical motion. If the atmosphere is unstable, vertical movement of air is encouraged and this tends to increase fire activity. If the atmosphere is stable, vertical movement of air is discouraged and this decreases fire activity. Parcels of air masses with different temperatures are continually mixing trying to reach the same temperature, much as boiling water. The more difference in the temperatures in the atmosphere, the more unstable the conditions and the more movement--both vertical and horizontally. More unstable conditions result in more vertical movement in the atmosphere. Such conditions act like opening the damper on a stove. A fire will burn more intensely because of the unrestricted updraft of the atmosphere and convective currents. Under stable conditions, fires will burn slowly and the smoke column will not rise very far.

The earth◆s surface is not heated uniformly by the sun and this results in unstable conditions. The warmer air next to the ground (heated from the ground) is lighter, since it expands, and tends to rise. Cooler air from an area not heated as much and heavier, will flow in replacing the warmer air--thus, wind. Forested areas will not heat up the adjacent air as much as a cleared field or highways. Water will not heat up as much as land because a larger percent of the radiant heat is readily absorbed into the lower levels of the water.

Cumulus clouds are an indicator of vertical movement. The higher they rise, the more unstable the atmosphere is and with higher vertical movement. The air in the atmosphere mixes readily with updrafts and downdrafts. Winds will be gusty and tend to change direction. With dry conditions, there may be no cumulus clouds to show the unstable conditions. Other indicators are, strong, gusty winds, tall smoke columns, good visibility and dust devils or small whirlwinds.

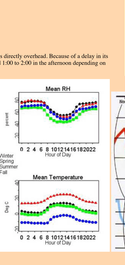
Because of the radiant heat of the sun, stability changes much the same as the temperature and relative humidity during a 24-hour period. Conditions are usually very stable at night and can become very unstable during the day.



The most important method of cooling air to saturation is adiabatic cooling because of lifting. Lifting may be thermal, orographic, or frontal.

An **inversion** is a layer in the atmosphere where the temperature increases with altitude instead of decreasing. With warmer, less dense air, it acts as a lid on updrafts. It is the most stable condition that exists, especially when close to the surface. In the southeast, such conditions occur almost every night. They are close to the surface and with calm winds, high humidity and low temperature, fires seldom start and those still burning at night will be drastically reduced in intensity. Smoke will only rise to the inversion and then flatten out and spread horizontally.

When the sun rises and begins to warm the earth◆s surface, the lower atmosphere is warmed and the inversion rapidly dissipates.



Stable Conditions	Unstable Conditions
• Clouds in layers • Stratus type clouds • Low clouds • Poor visibility • Steady winds • Fog • Limited rise on smoke plumes	• Clouds growing vertically • Little or no clouds • Cumulus type clouds • Smoke lifting high • Gusty winds • Good visibility • Dust devils

RELATIVE HUMIDITY

Moisture in the form of water vapor is always present in the atmosphere. And - the amount of moisture that is in the atmosphere affects the amount of moisture that is in the fuel.

Relative humidity is the term used in prescribed burning to express the amount of moisture in the atmosphere. It is the ratio of actual water vapor in the atmosphere compared to the amount of water vapor that would saturate the atmosphere at that temperature. When the relative humidity is 40 percent, it means that the atmosphere contains 40 percent of the moisture that it could contain at that same temperature.

The lower the relative humidity, the more readily a fire will start and burn; the more vigorously a fire will burn. As will be discussed in more detail later, moisture in the fuel absorbs heat and reduces the fire◆s intensity before it is converted to steam and driven off. When the relative humidity is low, the moisture in the fuel is readily evaporated as it rises to the surface of the fuel. When the humidity is high, it◆s harder for the moisture to evaporate into the air. Consequently, high humidity acts like a damper on a stove. If the humidity is 100 percent or close to it, the fuel will not dry. On the other hand, the lower the relative humidity, the quicker the moisture will evaporate.

Relative humidity fluctuates widely during each 24-hour period. It will generally be the highest in the early morning hours before daylight and the lowest during the early afternoon; the diurnal cycle. This is because relative humidity is changed by temperature. When air is warmed, it expands and as a result, will hold more moisture. The actual amount has not changed but it is spread out over a larger area, consequently the percent is less. As temperature changes, relative humidity changes but in the opposite direction. As temperature goes up, relative humidity goes down and vice versa.

◆Rule of Thumb: Relative Humidity doubles with each 20◆F drop in temperature ◆ and halves with each 20◆F increase in temperature.◆

PRECIPITATION

Precipitation (rain or snow) has a direct and immediate effect on fuel moisture and relative humidity. Temperature usually drops as well and the winds become calm. When the atmosphere becomes saturated, precipitation usually occurs if more moisture is added. Precipitation will quickly dampen the surface of fuels to the point that fires cannot ignite and no wildfires will occur.

The pattern of rainfall is a big factor in determining the fire season (the period when wildfires occur). In the South the fire season starts in the fall and generally slacks off during December and possibly January as the climate turns cold, with numerous rains, calm winds and overcast skies. Knowing typical weather patterns in an area is essential for the accomplished prescribed burn planner. Typically the last two weeks of February and the first two weeks of March are suitable for late dormant season burns in the deep South. As the rains lessen in the early spring and the winds increase, the fire season again ◆picks-up◆ and middle or late April. The last two weeks of March and first two weeks of April is generally a good period to plan early growing season burns depending on bud swelling and break of target species.

As the vegetation ◆greens-up◆ prescribed burning conditions may deteriorate. If, however, a winter drought occurs and continues into the spring, fires will readily burn on into the summer because of the larger amount of dead, dry fuel and low fuel moisture. There may be more difficult to control and do more damage due to burning deeper into the litter and consuming larger size fuel. During long periods of dry weather, drought, moisture that is toward the center of larger fuels and deeper in surface litter is able to work its way to the surface and evaporate into the dry atmosphere. As a result, a larger percent of the total fuel becomes **available fuel**, available to burn.

CLOUD DEVELOPMENT AND FRONTS

When moisture is added to the atmosphere or the air temperature is lowered, the relative humidity increases. When it increases to the saturation point, the moisture begins to combine into droplets. As this process continues, the droplets become visible--as clouds. When the atmosphere is very dry, saturation may not be reached, and ◆ no clouds are formed.

Clouds are formed when there is a lot of **surface heating** from the sun and a lot of moisture is present. As the air close to the surface is heated, it rises to be replaced by cooler air. The heated air can rise until it is saturated and clouds form. As it rises the warmer air cools until it reaches the temperature of the surrounding air. At this altitude puffy type cumulus clouds will form. If they continue to build up, they become cumulonimbus and rain may occur.

Clouds are also caused by **fronts**. Fronts and the associated clouds are important because fronts mean changing weather. Clouds are visible indicators of fronts and other weather phenomenon. Cumulus clouds indicate vertical movement in the atmosphere. Clouds are moisture. The more clouds available, the more moisture available and relative humidity will be higher. ◆Overcast skies shade the surface of the earth and less radiant heat is received. Temperatures are lower and winds are more moderate.

Clouds and precipitation cover a wide band and extend some distance behind slow moving cold fronts. If the warm air is moist and stable, stratus type clouds and steady rain occur. If the warm air is conditionally unstable, showers and thunderstorms are likely.

If the warm air above a warm front is moist and conditionally unstable, altocumulus and cumulonimbus clouds form. Often, thunderstorms will be embedded in the cloud masses.

Lifting of warm, moist air as it is forced up the slope of a warm front, produces widespread cloudiness and precipitation.

If the warm air above a warm front is moist and stable, clouds are of the stratus type. The sequence of cloud types is cirrus, cirrostratus, altostratus, and nimbostratus. Precipitation is steady and increases gradually with the approach of a front.

With rapidly moving cold fronts, the weather is more severe and occupies a narrower band. If the warm air is moist and conditionally unstable, as in this case, scattered showers and thunderstorms form just ahead of the cold front.

The steepness and speed of cold fronts result in a narrow band of cloudiness and precipitation as warm, moist air ahead of the front is lifted.

In the South **cold fronts** usually travel in a west to easterly direction--usually to the southeast. A cold front will generally change the direction of the wind from a southerly direction to the west and on around to the northwest.

When one mass of air is moving, it will push under the mass of air it is replacing if it is cooler, causing the other mass to lift. If lifted high enough, clouds will form and rain may occur due to cooling. If the air mass is warmer than the mass it is replacing, it will be pushed up over the other mass. In either case, one air mass is lifted causing clouds. This is the reason we have changing weather and possibly rain when a front comes through.

Thunderheads

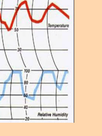
One type of cloud can spell trouble even though of short duration. As cumulus clouds build higher, they become more turbulent. Such clouds are called thunderheads. Their towering, turbulent appearing head can be easily recognized. In the later stage the towering top may become anvil-shaped with the point facing the direction the thunderhead is traveling. As they develop, air currents reach a critical height and precipitation begins. The falling rain or hail indicates a strong downdraft below the cloud. The strong downdraft strikes the ground and spreads in all directions producing strong, gusty winds of up to 70 mph in a few seconds. As the thunderhead moves, the wind shifts rapidly.

The 24-hour Cycle, The Diurnal Cycle

Early afternoon is generally the peak burning period when fires will burn the most intensely, spread most rapidly and tend to exhibit erratic fire behavior. This is because all of the weather elements are at the point where their influence on fire behavior is the greatest.

- Temperature is the highest
- Relative humidity is at its lowest point
- Wind speed is at its maximum
- Wind direction is most variable
- The atmosphere is the most unstable
- Fuel will be the driest

Radiation from the sun is at its maximum when the sun is directly overhead. Because of a delay in its effect, the peak of the burning period is generally around 1:00 to 2:00 in the afternoon depending on latitude and daylight savings time.



DROUGHT

Days since the last rain and seasonal soil moisture deficit have an influence on fuel moisture and fire behavior. The drier the soil, generally, the drier the litter, duff, and organic matter in the soil will be. It is generally inadvisable to burn the organic matter out of the soil. .

(see Drought doc for drought indicator discussion.)