

# Pre-Course Study Material

## Weather

### Introduction

The weather principles learned in S-290 should prepare students for S-390. The main emphasis of the weather instruction in S-390 will be to expand upon what was previously learned regarding atmospheric stability and wind, how to assess stability and wind in an operational environment, and how both affect wildland fire behavior. This pre-course work will include a cursory review of material from S-290, as well as the introduction of one new concept that will be further expanded upon by the S-390 instruction. The suggested reference material provides more comprehensive information on stability and wind and may be appropriate for those who took S-290 some time ago and require additional review.

### Objectives

- Review and understand the basic concepts of atmospheric stability and wind taught in S-290.
- Gain a basic understanding of midflame wind and how it is calculated.

### Suggested Reference Material

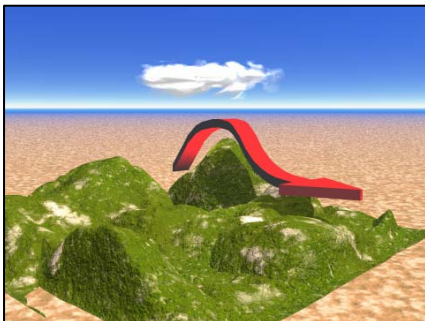
- Wind and stability lessons from S-290 Student Workbook (NFES 2378).
- Chapters 4, 6 & 7 from “Fire Weather,” Agriculture Handbook 360 (NFES 1174 & PMS 425-1).

### Stability Review

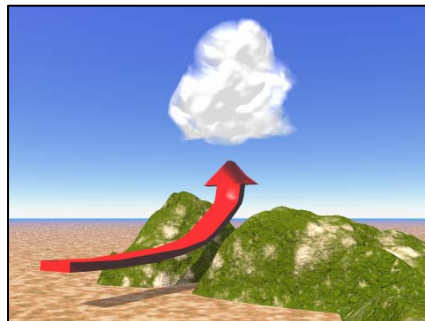
**Stability Definition:** The degree to which vertical motion in the atmosphere is enhanced or suppressed.

Stability is directly related to the potential for vertical motion in the atmosphere, both upwards and downwards. This has implications for fire behavior in terms of the potential for growth of the convection column, and also for stronger winds aloft in the atmosphere to be translated to the surface.

### **Three types of stability conditions:**



**STABLE**



**UNSTABLE**



**NEUTRAL**

Stable: A stable atmosphere resists vertical motion. Air forced to move vertically will want to return to its original level.

Unstable: An unstable atmosphere promotes vertical motion. Air forced to move vertically will continue to accelerate until it encounters air that is at the same temperature.

Neutral: A neutral atmosphere neither promotes nor resists vertical motion. Air forced to move vertically will stay at the level it is moved to.

### Determining stability using lapse rate:

Lapse Rate is defined simply as the change in temperature with altitude. Lapse Rate is usually negative, as temperature decreases with increasing altitude, but it may also be positive, such as with an inversion. For the purpose of this review, we will refer to Lapse Rate as an absolute value and assume it shows a temperature decrease with altitude unless otherwise noted.

Stability is determined by the vertical distribution of temperature in the atmosphere. This distribution is referred to as the Environmental Lapse Rate, which generally ranges from +/- 15° F per 1,000 feet. Stability is determined by comparing the Environmental Lapse Rate to the rate at which a parcel of air would cool if it were lifted. The fastest that air can cool through lifting is 5.5° F per 1,000 feet, which is called the Dry Lapse Rate. For this reason, Dry Lapse Rate is the benchmark for determining stability:

- If the environmental lapse rate is  $> 5.5^{\circ}$  F per 1000 ft, the atmosphere is *unstable*.
- If the environmental lapse rate is  $< 5.5^{\circ}$  F per 1000 ft, the atmosphere is *stable*.
- If the environmental lapse rate is  $= 5.5^{\circ}$  F per 1000 ft, the atmosphere is *neutral*

If the Environmental Lapse Rate exceeds 5.5° F per 1,000 ft, the atmosphere is unstable because air being lifted would always remain warmer than the environment and would be encouraged to continue to rise on its own. Consider the following example:

The Environmental Lapse Rate is 10° F per 1,000 feet, 70° F at 5,000 feet elevation, and 60° F at 6,000 feet. Air <u>lifted</u> from the lower surface at an initial temperature of 70° F would cool (at the Dry Lapse Rate) to only 64.5° F at 6,000 feet. At 6,000 feet, with the lifted air being at 64.5° F and the environmental temperature at 60° F, the lifted air (being warmer than the environment) would want to continue to rise.		
	<b>Environment</b>	<b>Lifted Air (Unsaturated)</b>
<b>° F at 6,000 feet</b>	60° F	64.5° F
<b>° F at 5,000 feet</b>	70° F	70° F

## Effect of Stability on Wildland Fire Behavior:

### Stability and the Wildland Fire Environment

Effects on Fire Behavior


- **Stable Atmosphere**
  - Less potential for extreme fire behavior
  - Poor ventilation
  - Reduced ability to detect other fires




### Stability and the Wildland Fire Environment

Effects on Fire Behavior

- **Unstable Atmosphere**
  - Strong potential for extreme fire behavior
  - Good ventilation
  - More complete fuel consumption

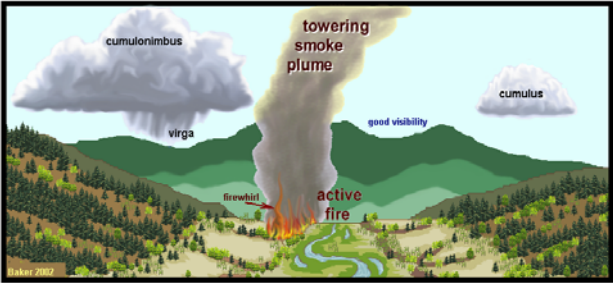


## Indicators of Stability:



1. Smoke columns drift apart after limited rise.
2. Clouds are in layers with little vertical motion, i.e., stratus clouds.
3. Poor visibility at lower levels of the atmosphere due to an accumulation of smoke and haze.
4. The presence of fog.
5. The wind is often light and variable or calm on valley floors.
6. The wind may also be strong and gusty on mountain slopes, i.e., a foehn wind.

### STABLE ATMOSPHERE



1. Clouds grow vertically to great heights, i.e., cumulus, towering cumulus, altocumulus castellanus and cumulonimbus.
2. Well developed updrafts and downdrafts within cumulus type clouds often produce gusty and erratic surface winds.
3. Good visibility due to a well "mixed" atmosphere.
4. Smoke columns rise to great heights. Columns also are well defined with rapidly rising turrets.
5. Dust devils and firewhirls may form particularly in areas strongly heated by the sun or by the fire.

### UNSTABLE ATMOSPHERE

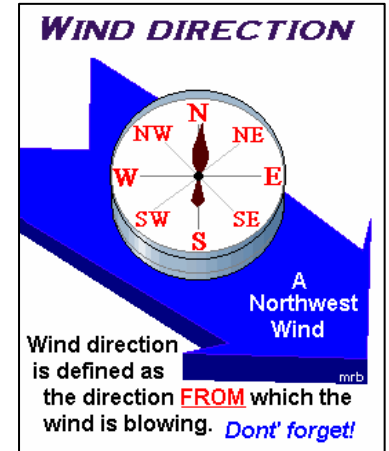
**In summary**, stability dictates the potential for vertical motion in the atmosphere and has direct implications for fire behavior. Stable conditions suppress vertical motion and fire behavior potential, while unstable conditions enhance vertical motion and the potential for extreme fire behavior. Stability is determined by the vertical distribution of temperature in the atmosphere, or Environmental Lapse Rate, and can be assessed by comparing this to the benchmark Dry Lapse Rate of 5.5°F/1000 feet. Stability can also be assessed by directly observable indicators such as vertical development of clouds and/or smoke columns and the nature of the wind (steady vs. gusty or erratic).

## Wind Review

**Wind Definition:** The horizontal movement of air caused by differences in pressure.

Wind has some rather obvious impacts on wildland fire behavior, including the following:

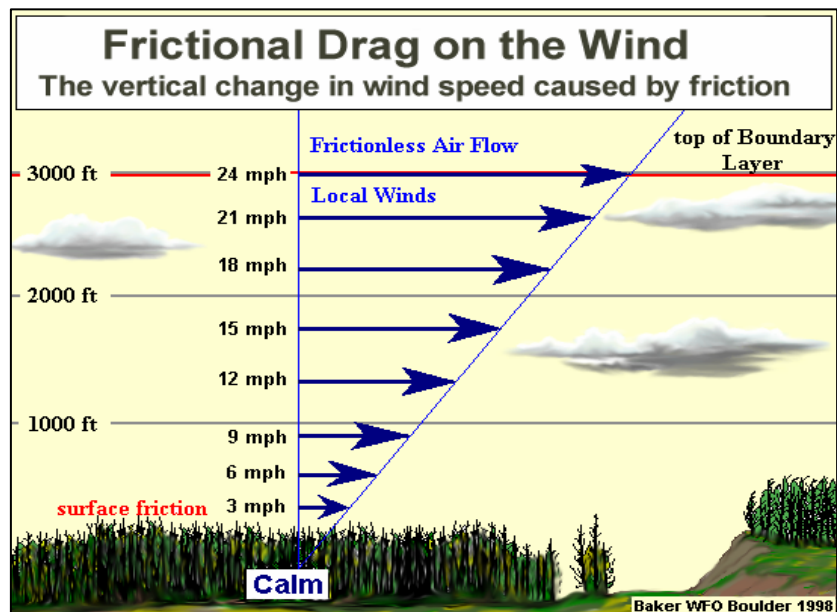
- Wind carries away moisture and hastens the drying of wildland fuels.
- Once a fire ignites, wind aids combustion by increasing the supply of oxygen.
- Wind increases fire spread by carrying heat and burning embers to new fuels – spotting.
- Wind bends the flames closer to the unburned fuels, thus preheating the fuels ahead of the fire front.
- Finally, the DIRECTION of the fire spread is determined mostly by direction of the wind.



**Wind Direction:** The direction the wind is blowing from.

### **Winds Affecting Wildland Fire Behavior:**

Since pressure differences in the atmosphere occur on various scales, there are different types of winds that are relevant to the wildland fire environment. One generality is that air wants to flow from high pressure to low pressure or, in the case of temperature, from colder locations to warmer locations. Another important generality is that wind speeds generally decrease from the upper atmosphere to the surface due to frictional effects of terrain and vegetation.

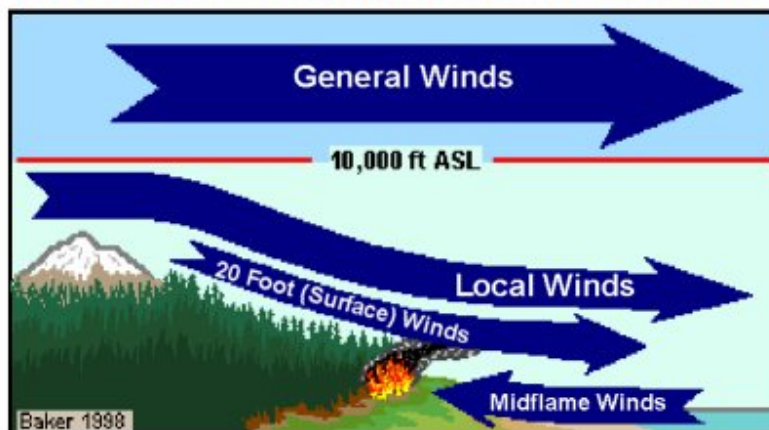


**Friction slows winds higher in the atmosphere as they approach the surface.**

The four types of winds we are interested in are:

- General Winds – Winds caused by large scale pressure (hundreds of miles) differences that are mainly unaffected by surface friction. Counter-clockwise flow of air around a low pressure system is an example of a General Wind.
- Local Winds – Winds caused by small scale (tens of miles or less) pressure differences caused by local temperature contrasts. Upslope winds caused by direct heating of a slope are an example of Local Winds.
- Surface or 20 Foot Winds – Winds measured 20 feet above the ground or the average height of the vegetation. These winds are affected by surface friction and are a combination of components of the General Wind and the Local Wind. RAWS measure 20 foot winds.
- Midflame Winds – Winds measured at one-half the flame height along the flaming front of a fire. Midflame Winds are a portion of 20 Foot Winds after additional frictional effects caused by vegetation are accounted for. Eye-level winds measured on the fireline are Midflame Winds in many cases (more on this later).

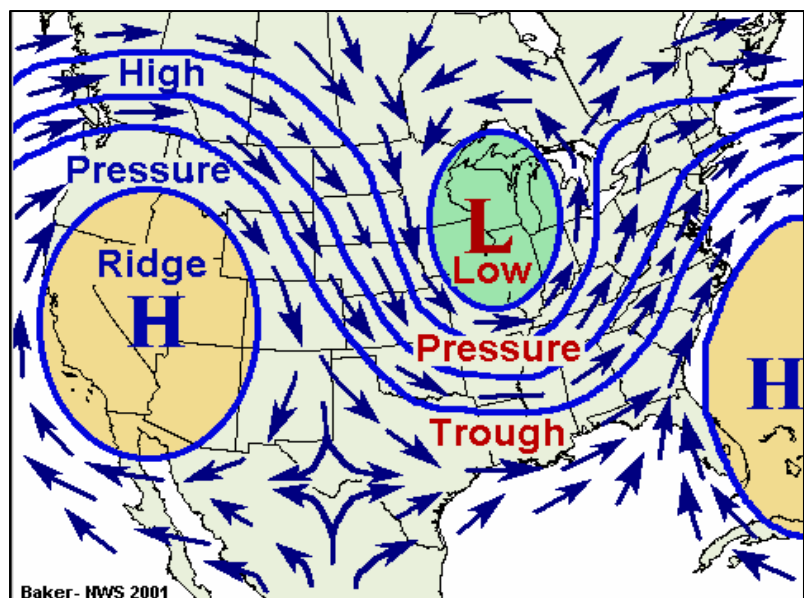
### Winds that Influence Wildland Fire Behavior



Four basic winds that affect wildland fire behavior.

#### General Winds:

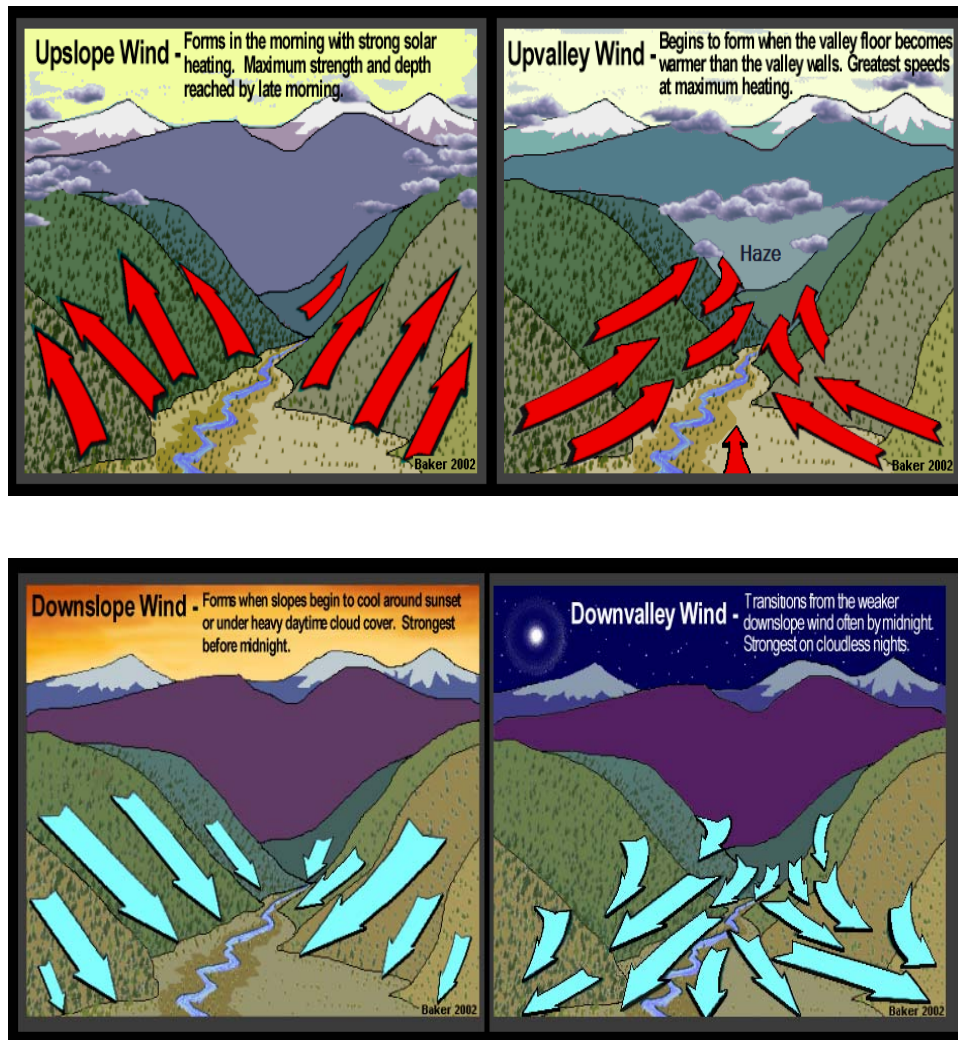
General winds include the Jet Stream and those caused by large-scale high and low pressure systems, such as those depicted on a general weather map. For the purposes of wildland fire behavior calculations, we will consider General Winds to be those just above the layer of friction caused by the earth's surface.

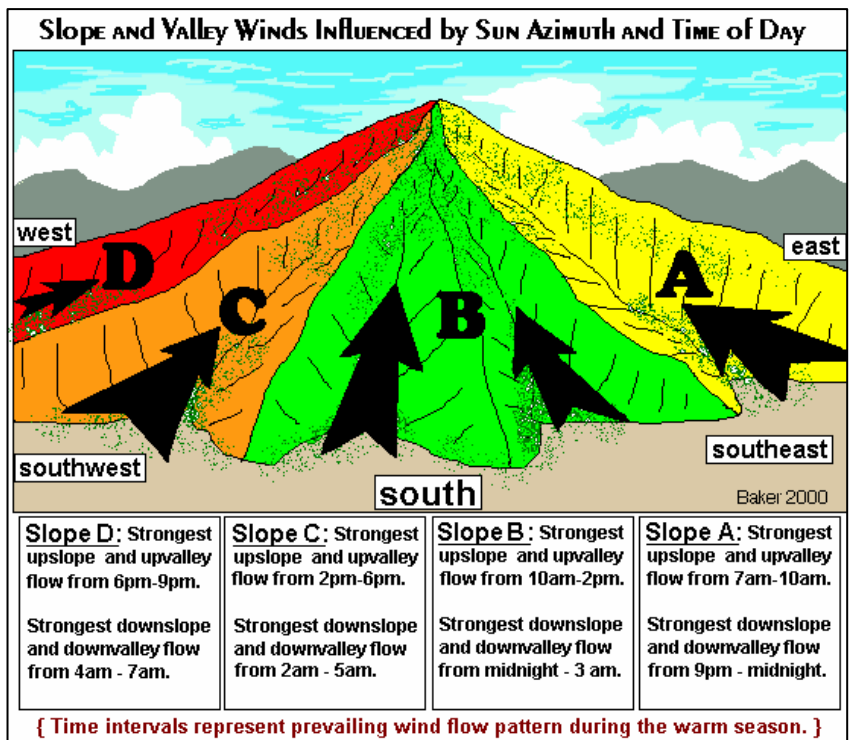


## Local Winds:

As previously stated, Local Winds are caused by small scale pressure differences caused by local temperature contrasts. In the context of wildland fire behavior, the main Local Winds to be considered are the slope and valley wind systems caused by temperature contrasts in complex terrain, and land and sea breeze systems caused by the temperature differences between bodies of water and adjacent land masses.

Slope and Valley Winds – Upslope and upvalley winds are caused by direct heating of the surface and by the resulting rising temperatures in valley locations respectively. Upslope winds are controlled by the amount of solar radiation received and thus are affected by time of year, time of day, aspect, slope and latitude. Upvalley winds are similar with regard to the need for solar radiation, but are dependent on the resulting surface temperatures within a valley. Upslope winds start earlier in the day and are relatively weak, while upvalley winds lag behind upslope winds by several hours and are relatively strong. Downslope and downvalley winds are caused by the exact opposite mechanism, namely radiational cooling at night. Anything which promotes rapid cooling, such as clear skies, aids the development of downslope/downvalley winds. There is a similar relationship to upslope/upvalley winds with regard to time of development and strength.





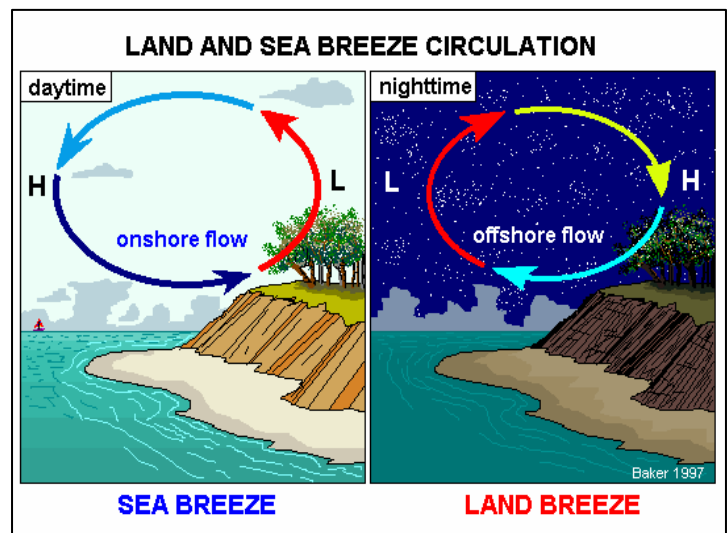
**Range of Slope and Valley Windspeeds**

Typical windspeeds for <u>upslope winds</u> in mountainous terrain: <b>3 to 8 mph</b>
Typical windspeeds for <u>downslope winds</u> in mountainous terrain: <b>2 to 5 mph</b>
Typical windspeeds for <u>upvalley winds</u> in mountainous terrain: <b>10 to 15 mph</b>
Typical windspeeds for <u>downvalley winds</u> in mountainous terrain: <b>5 to 10 mph</b>

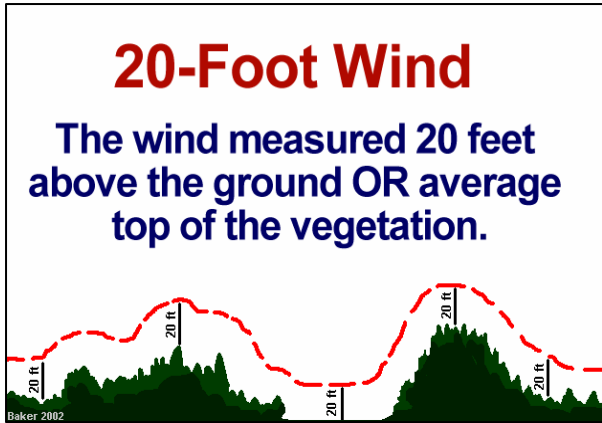
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Land and Sea (Lake) Breezes

Land and sea breezes are caused by the differences in temperature between the water and the land. During the day, when the land warms and the water remains relatively cool, a circulation develops with cool air blowing in off the water towards the adjacent warmer landmass. The opposite occurs at night, when the land becomes relatively cool compared to the water. The strength of these circulations and how far inland they penetrate are directly related to the magnitude of the land-water temperature difference. Typical speeds for sea breezes are 10-20 mph, but sometimes as high as 20-30 mph along the west coast. Land breezes are less, generally from 3-10 mph.

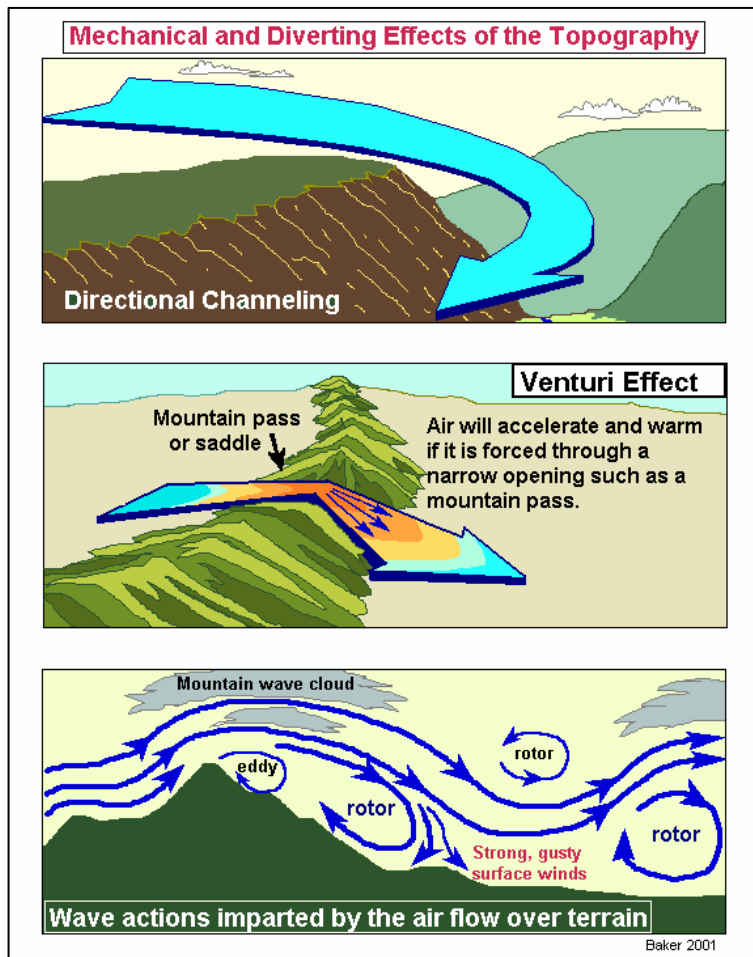


Surface or 20 Foot Winds:



= General Wind Component + Local Wind Component

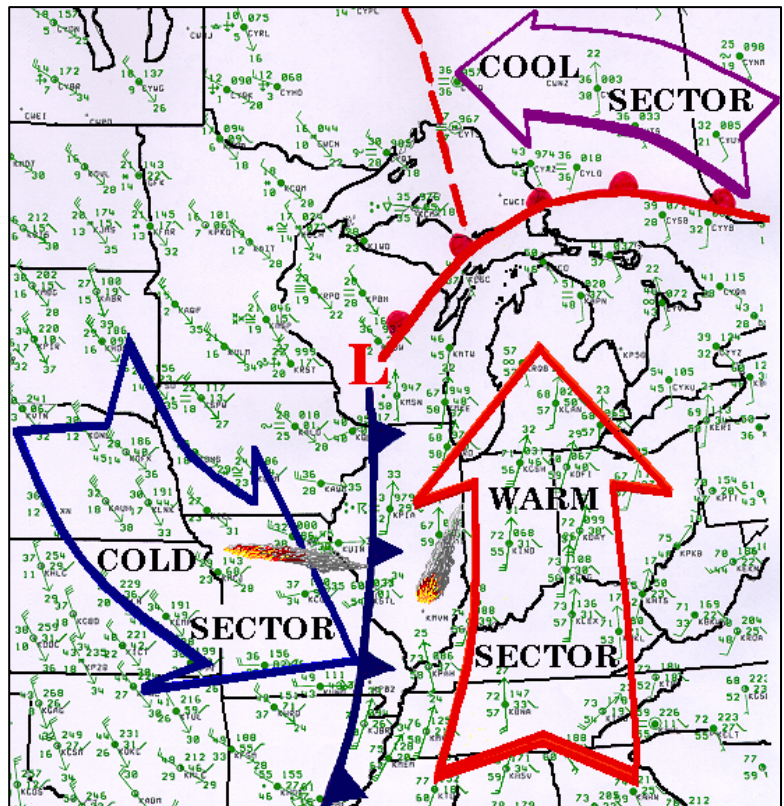
Simply stated, the 20 Foot Wind is the combined effect of the General and Local Winds measured 20 feet above the ground or average vegetation height. The Local Wind Component is essentially just whatever Local Wind is applicable for a given location. The General Wind Component is a portion of the General Wind after it has been altered and/or slowed by topography and surface friction. The frictional slowing of the General Wind will be quantified and covered in detail in S-390, but here are a few ways that terrain can alter the flow of the General Wind and impact the 20 Foot Wind:



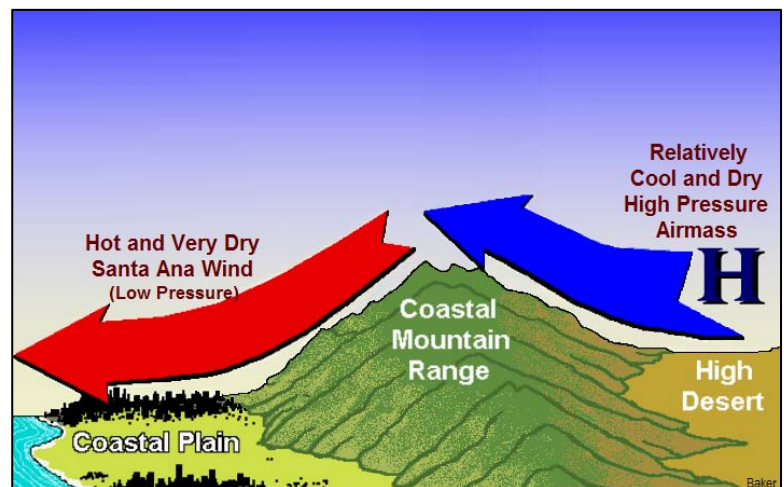


There are special circumstances under which 20 Foot Winds are completely dominated by especially strong or erratic General or Local Winds. These winds which dominate the fire environment are known as Critical Winds. When Critical Winds exist, the 20 Foot Wind becomes the Critical Wind. Critical Winds most applicable to the wildland fire environment are as follows:

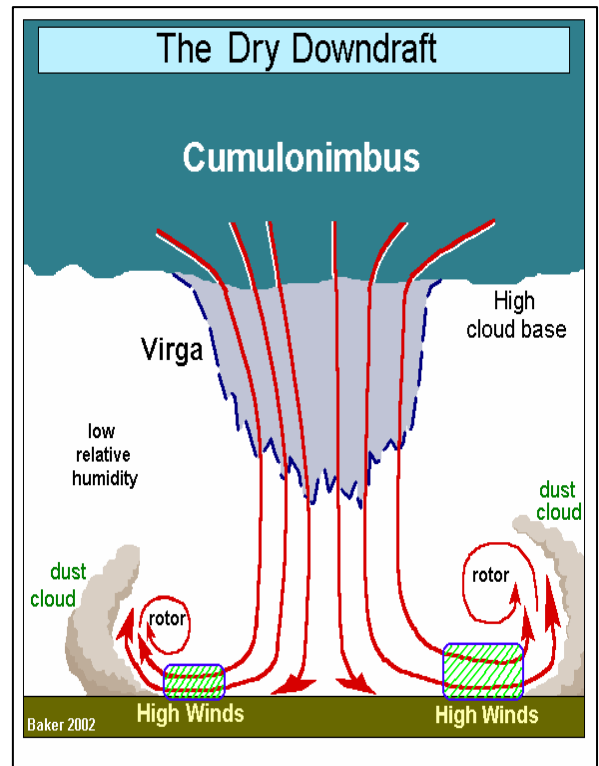
- Cold Frontal Winds – Strong and shifting General Winds associated with cold fronts. Strong southerly winds ahead of an approaching cold front rapidly shift to the west or northwest with the front’s passage.



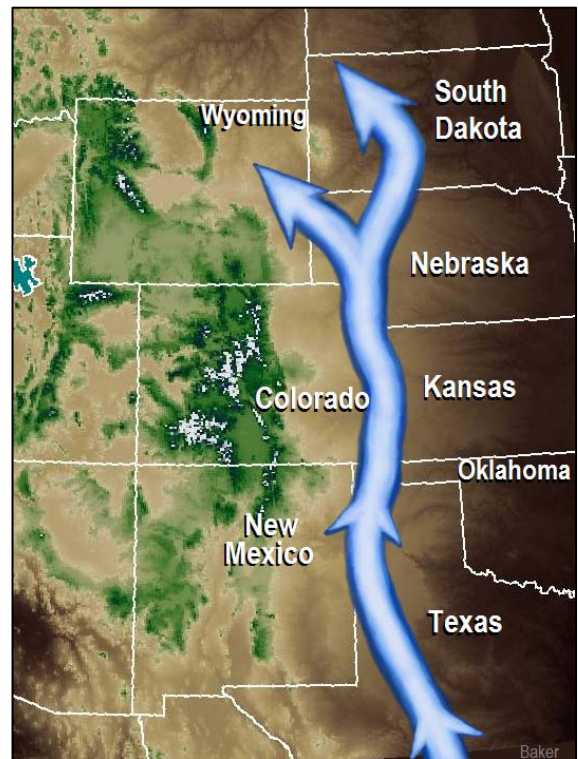
- Foehn Winds – Strong downslope General Winds that occur on the lee side of mountain ranges when high pressure is building on the windward side of the range. These winds are warm, dry and can persist for up to a few days.



- Thunderstorm Winds – Strong Local Winds which are caused by descending bubbles of cool air beneath thunderstorms when they impact the ground and spread horizontally.



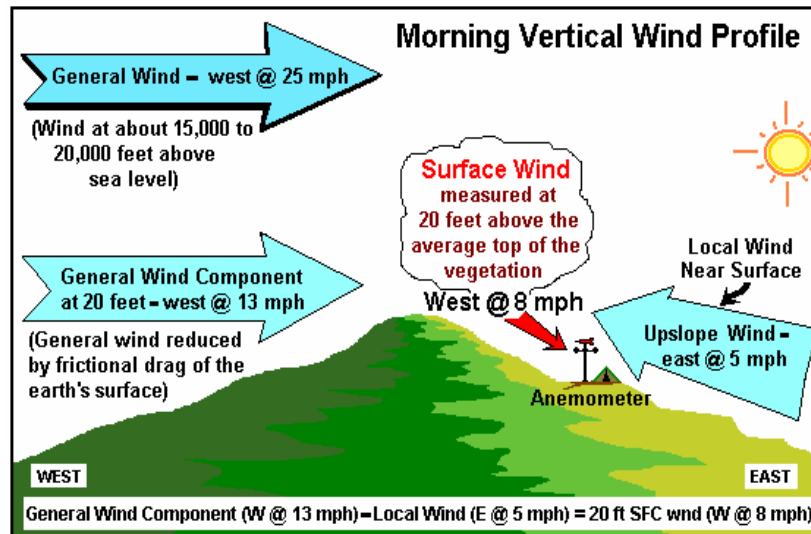
- Low-level Jet / Reverse Wind Profile – This is a situation where General or Local Winds at or near the surface are notably stronger than those aloft, which allows a going fire to potentially develop a strong convection column. The General Wind version of this usually occurs east of the Rockies in association with lee-side troughs or cold frontal passages. The Local Wind version occurs in the intermountain west when, for example, particularly strong valley winds dominate the fire environment. This entire concept will be discussed in detail in S-390.

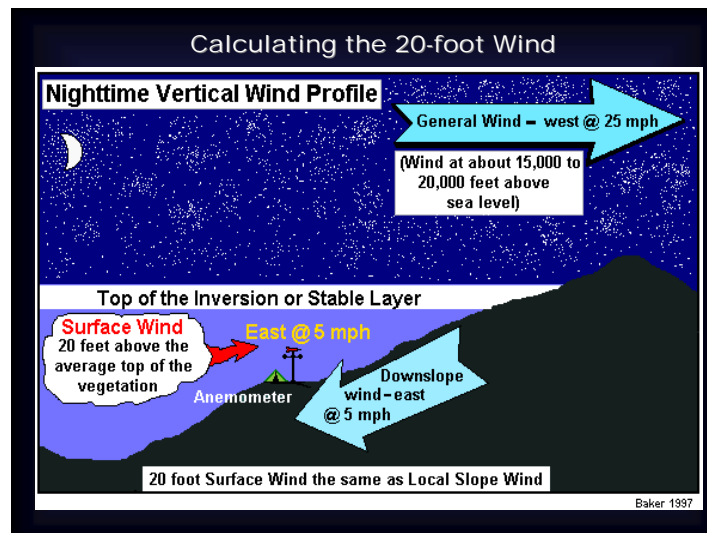
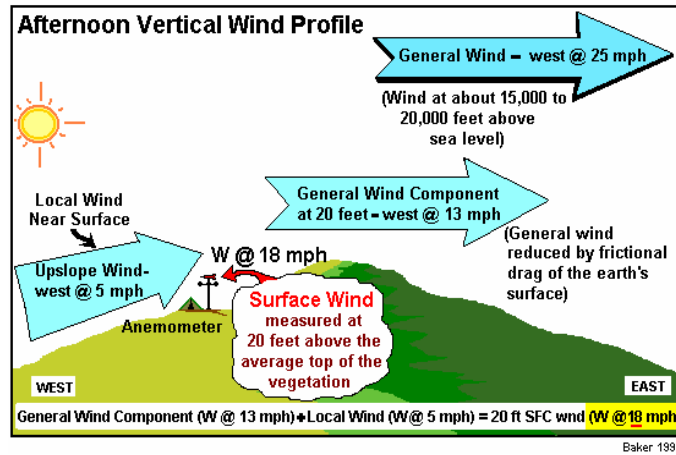


- Whirlwinds – Including Dust Devils and Firewhirls, these Local Winds occur on hot, unstable days with light winds. They are the result of intense, localized convection currents that develop rotation. Burned areas are especially susceptible to whirlwinds due to the dark surface which maximizes absorption of solar radiation. Whirlwinds can extend to hundreds or even thousands of feet in the extreme and can cause prolific spotting and extreme and erratic fire behavior.



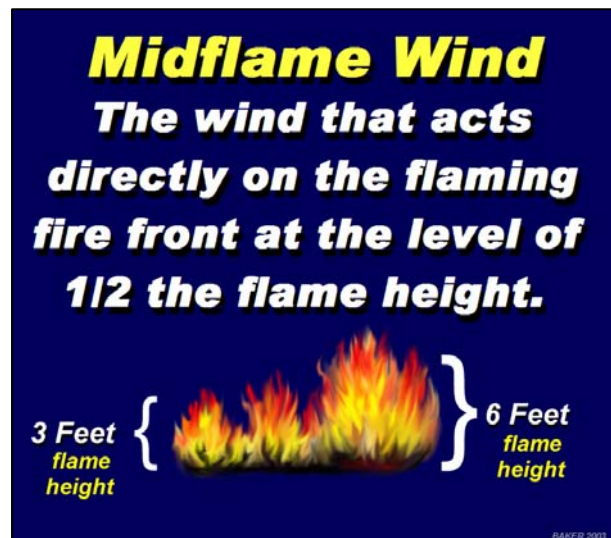
Critical Winds aside, below are a few examples of how the General and Local Wind components combine to produce the 20 Foot Wind. Note how the impact the General Wind has on 20 Foot Wind varies from day to night. This ultimately is related to atmospheric stability and will be discussed in detail in S-390.





### Midflame Winds:

Midflame Winds are measured at one-half the flame height along the flaming front of a fire, and are basically a portion of 20 Foot Winds after additional frictional effects caused by vegetation are accounted for. Eye-level winds measured on the fireline are similar in many cases to Midflame Winds, except when there is extreme fire behavior and overly large flame lengths.



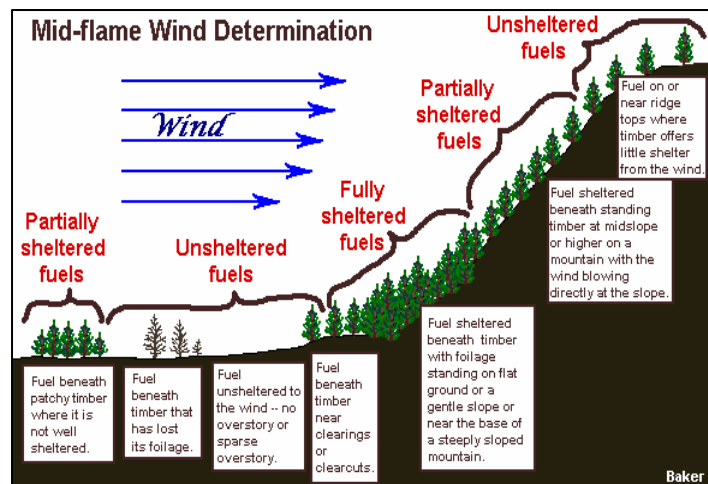
Midflame Winds are direct inputs into the US Fire Behavior Prediction System (USFBPS). In practice, you will have access to observed, forecast, or estimated 20 Foot Winds and will have to calculate Midflame Winds using wind adjustment tables. The mechanics of doing this will be covered in S-390, but it is important to have a basic understanding of how and why this is being done. The information needed to figure Midflame Wind is: 20 Foot Wind, Fuel Model, and the degree of sheltering.

The degree of sheltering is a rather subjective term used to assess the role that friction plays in reducing the 20 Foot Winds to Midflame. The concept is that lighter fuels in more open terrain will be less subject to frictional effects, while heavier fuels with more continuous canopies and in more sheltered locations will experience maximum frictional effects. The degrees of sheltering ranges from unsheltered to partially sheltered to fully sheltered, per the graphic to the right. What is missing to complete the picture here are the actual wind reduction factors for each fuel type and degree of sheltering. The reduction factors are ultimately multiplied by the 20 Foot Wind speed to calculate the appropriate Midflame Wind speed value for use in the USFBPS.

## Inputs Needed to Calculate the Midflame Wind

- 20-foot winds
- fuel type
- degree of sheltering

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### Winds – Summary:

In summary, winds affecting the wildland fire environment are created by pressure differences on various scales and generally decrease in velocity closer to the ground due to frictional effects. General Winds are caused by large-scale pressure systems, while Local Winds are caused by small-scale temperature contrasts (which induce pressure differences). General and Local Winds together comprise Surface or 20 Foot Winds, which in turn can be translated to Midflame Winds for a specific location with knowledge of fuel type and the degree of sheltering.

