



S-190 Unit 5: Atmospheric Stability, Winds, and Clouds

Summary:

Surface winds, temperature, and relative humidity are the most commonly considered and easy to measure elements in the fire environment. Less obvious, but equally important, is atmospheric stability, and related vertical air movements that influence fire behavior.

Incident Position Description (IPD) Alignment:

This unit aligns with the following FFT2 IPD specific duties

(<https://www.nwcg.gov/positions/fft2/position-ipd>):

- Apply the knowledge of fuels, terrain, weather, and fire behavior to decisions and actions.

Objectives:

Students will be able to:

- Describe atmospheric stability and discuss the effects on fire behavior.
- Describe wind and its effects on fire behavior.
- Explain cloud classifications and their impact on fire behavior.
- Explain the similarities between smoke layers and clouds in relation to impact on fire behavior.

Unit at a Glance:

Topic	Method	Duration
Unit Introduction	Presentation	5 Minutes
Atmospheric Stability	Presentation	15 Minutes
Wind	Presentation	15 Minutes
Clouds	Presentation	15 Minutes
Smoke Layers	Presentation	10 Minutes
Total Unit Duration		60 Minutes

Materials:

- *Incident Response Pocket Guide (IRPG)*, PMS 461, <https://www.nwcg.gov/publications/461>.
- *NWCG Glossary of Wildland Fire*, PMS 205, <https://www.nwcg.gov/glossary/a-z>.
- *Fire Weather Cloud Chart*, PMS 438, <https://www.nwcg.gov/publications/438>.
- Notebooks for participants.
- Ability to display images and video on large screen.
- White board or easel access for group breakout.

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Slide 1



Unit 5: Atmospheric Stability, Winds, and Clouds

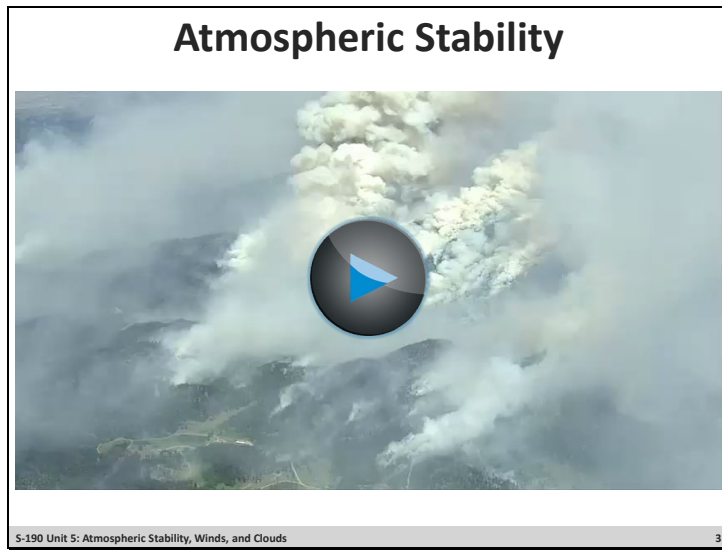
Slide 2

Objectives
<p>Students will be able to:</p> <ul style="list-style-type: none">• Describe atmospheric stability and discuss the effects on fire behavior.• Describe wind and its effects on fire behavior.• Explain cloud classifications and their impact on fire behavior.• Explain the similarities between smoke layers and clouds in relation to impact on fire behavior.
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- ☐ Review unit objectives.

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☐ Play Video

Title Introduction to Atmospheric Stability

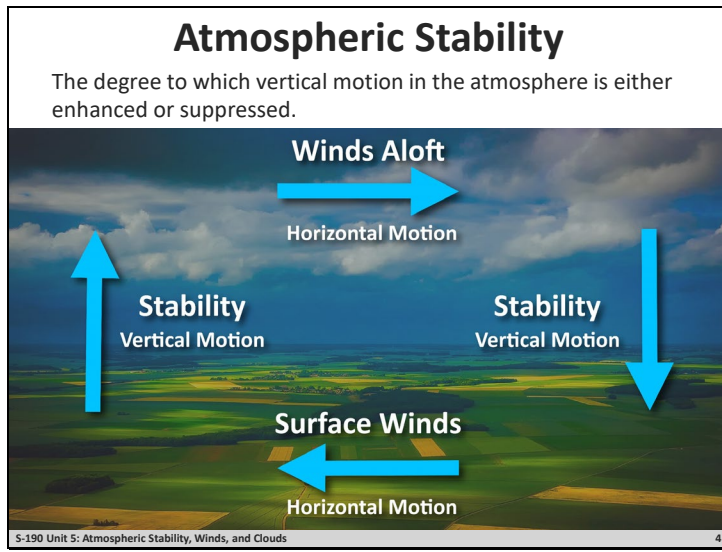
Summary Introduces the way atmospheric stability can affect wildland fire.

Time (00:45)

Audio

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Slide 4



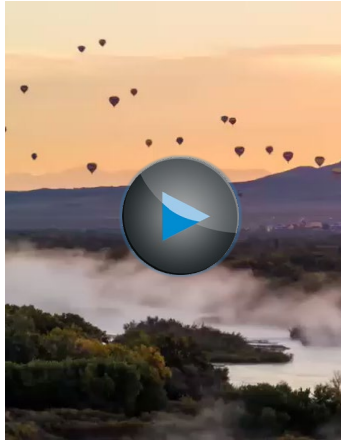
- Environmental temperature structure of the atmosphere determines whether the atmosphere will enhance or suppress vertical motion.

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Slide 5

Example of Atmospheric Stability

- Hot air inside the balloon is less dense than the environmental air outside, causing the balloon to rise.
- As temperatures warm, the density of the environmental air rises, air in the balloon becomes less dense in comparison, and the balloon descends.



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Pre-Video Discussion

- When heated, air parcels become less dense and rise in the atmosphere.
- Using a hot air balloon as an example helps firefighters grasp the basic concepts of atmospheric stability. The hot air balloon can be thought of as an air parcel.

☐ Play Video

Title Hot Air Balloons

Summary The time-lapse video of hot air balloons in flight shows a stable layer of air at the surface, indicated by the low-level stratus cloud (fog) over the river.

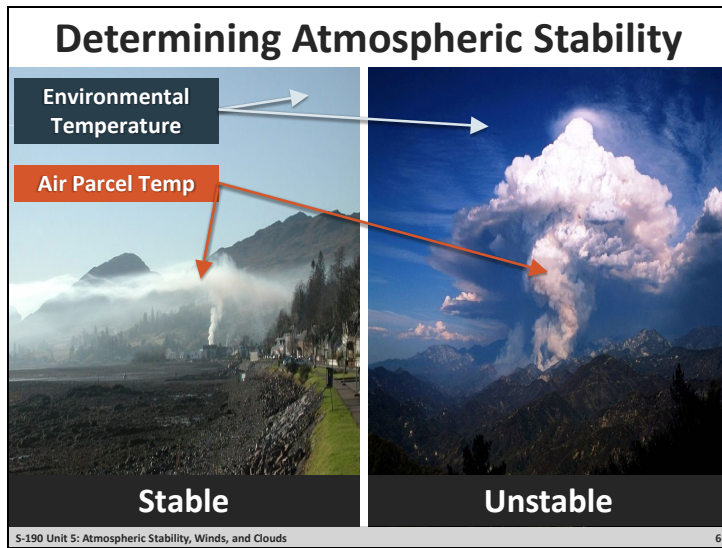
Time (00:10)

No Audio

- ☐ Inform participants the same concept applies to smoke columns, cumulus clouds, and thunderstorms, as heat from solar radiation or fires can decrease the stability in the atmosphere.

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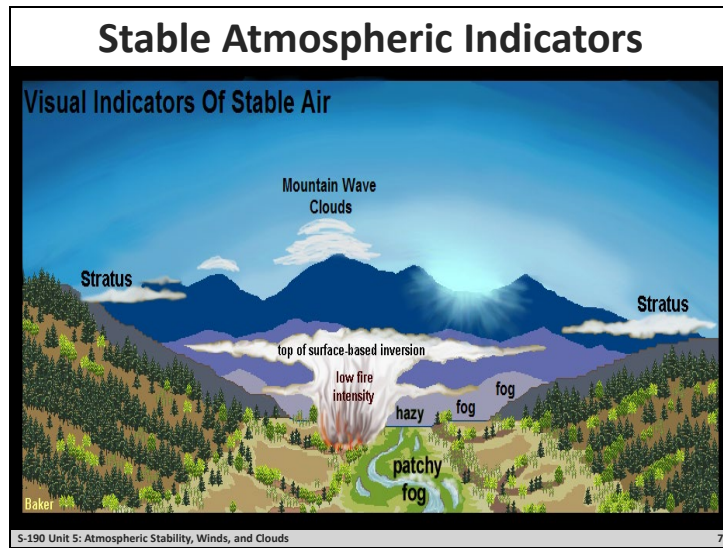
Slide 6



- Atmospheric stability is determined by comparing the temperature of an air parcel or smoke column to the environmental temperature – the air temperature outside the parcel or smoke column.
 - Stable: If the parcel temperature is equal to or cooler than the environmental temperature, it will stay at its current level or sink.
 - Unstable: If the air parcel temperature is warmer than the environmental temperature, it will rise.
- ☐ Reference Haines Index (HI) in the *Incident Response Pocket Guide (IRPG)*, PMS 461, <https://www.nwcg.gov/publications/461>.

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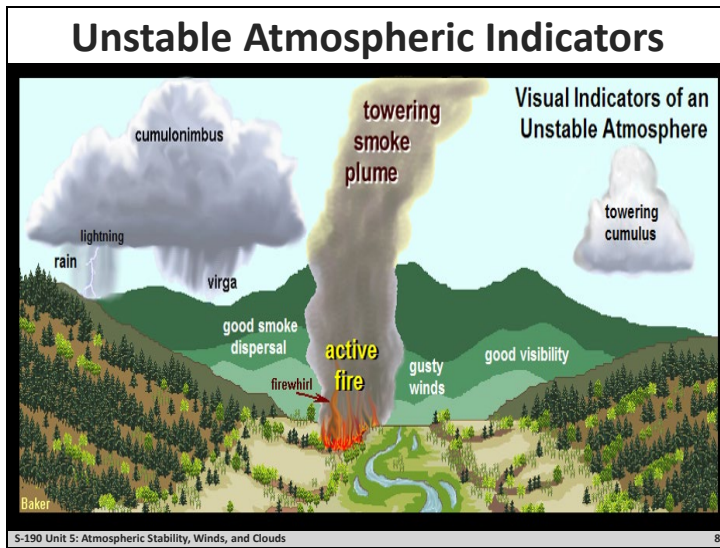
Slide 7



- Visual indicators of stable atmospheric conditions:
 - Smoke layer.
 - Stratus clouds or fog.
 - Low intensity fire as a result of suppressed vertical motion and weak inflow wind to feed fire new oxygenated air.
 - Mountain wave clouds occur, which indicate strong winds aloft that could surface on the lee side of a mountain range that day.
- Effects of stable atmospheric conditions on fire behavior:
 - Limited rise of smoke columns, resulting in poor smoke dispersion and visibility.
 - Reduced inflow of fresh air, thereby limiting fire growth, and intensity.
 - Lower surface wind speeds and fire spread rates, except in mountainous, and hilly terrain – refers to foehn winds.

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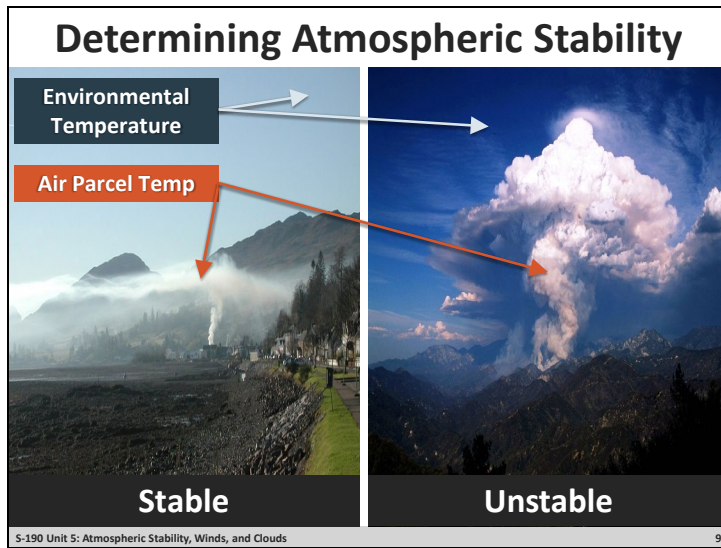
Slide 8



- Visual indicators of unstable atmospheric conditions:
 - Towering smoke plume.
 - Cumulus clouds – these are from rising air parcels.
 - Cumulonimbus clouds – these are from rising air parcels.
 - High intensity fire as a result of increased vertical motion and sufficient, sometimes intense, inflow wind feeding the fire new oxygenated air.
 - Gusty winds – a result from mixing of the lower atmosphere.
 - Good visibility.
- Effects of unstable atmospheric conditions on fire behavior:
 - Increased likelihood of fire whirls and dust devils.
 - Increased likelihood for gusty and erratic surface winds.
 - The height and strength of convection and smoke columns often increase significantly.
 - Increased likelihood of fire brands being lifted to great heights.

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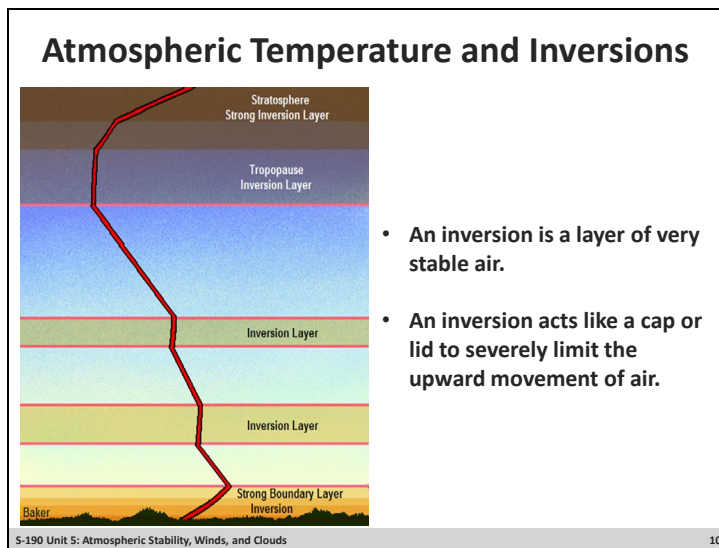
Slide 9



- Atmospheric stability is determined by comparing the temperature of an air parcel or smoke column to the environmental temperature – the air temperature outside the parcel or smoke column.
- ☐ **Stable:** If the parcel temperature is equal to or cooler than the environmental temperature, it will stay at its current level or sink.
- ☐ **Unstable:** If the air parcel temperature is warmer than the environmental temperature, it will rise.
- ☐ Reference Haines Index (HI) in the *Incident Response Pocket Guide (IRPG)*, PMS 461, <https://www.nwcg.gov/publications/461>.

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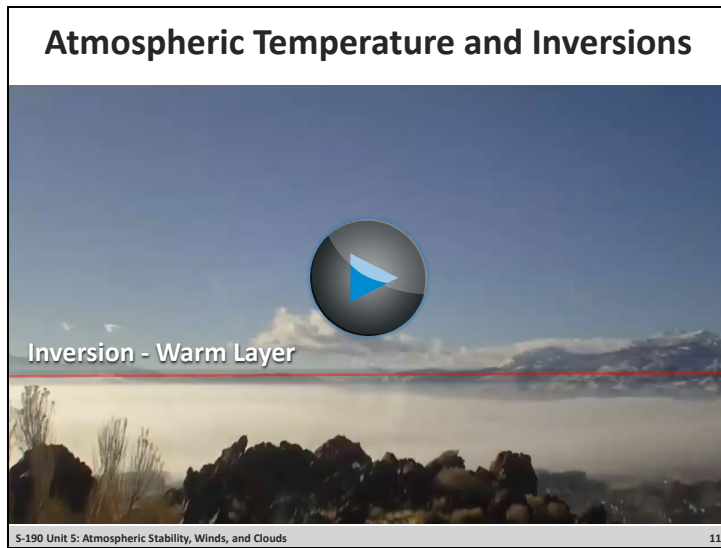
Slide 10



- ☐ Extend the discussion on atmospheric temperature and inversions using the image:
- Warm layers exist at different levels of the atmosphere. Meteorologists use weather data and atmospheric models to determine the strength and level of the inversions.
 - Once the level and strength of the inversion is measured and analyzed, the meteorologist can determine the impacts on the fire environment.

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Pre-Video Discussion

- ☐ Extend the discussion on atmospheric temperature and inversion using the video example of a low-level inversion:
 - The video shows an inversion that is preventing upward vertical motion, noted by the fog layer.
 - Surface heating or temperature changes above the inversion can erode and break the inversion.
 - Heat from fire activity can erode and break the low-level inversion.
- ☐ **Play Video**

Title Atmospheric Temperature and Inversions

Summary Time-lapse of a valley with an inversion filling the valley floor. The inversion is preventing upward vertical motion, indicated by the fog layer.

Time (00: 08)

No Audio

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Recognizing a Developing Inversion



- Stable conditions develop.
- Surface temperatures decrease.
- Relative humidity increases.
- Winds may become light.
- Smoke flattens after limited rise (layers).
- Fire behavior typically decreases.

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Pre-Video Discussion

- Wind may increase and change direction.
 - Temperature increases and relative humidity decreases.
 - The air mass becomes unstable (changing smoke behavior).
 - Smoke begins to loft and develop a column.
 - Fire behavior increases.
- ☐ Reference Look Up, Down and Around in the *Incident Response Pocket Guide (IRPG)*, PMS 461, <https://www.nwcg.gov/publications/461>.
- ☐ **Play Video**

Title

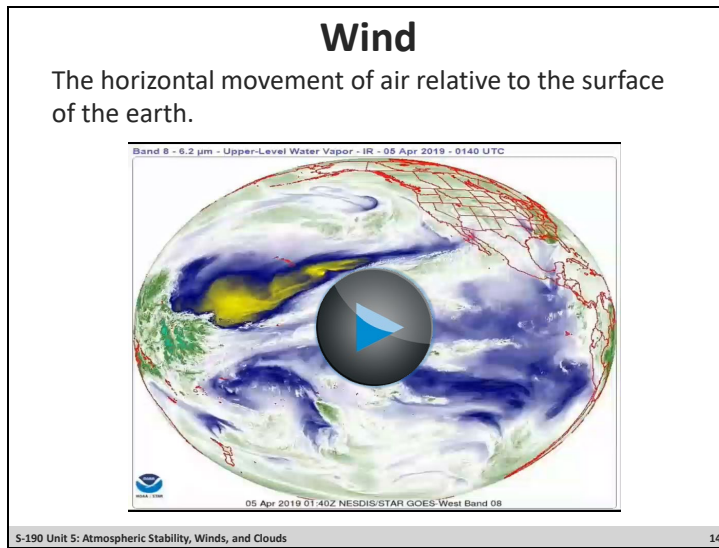
Summary Time-lapse of a valley with an inversion leaving the valley floor.

Time (00:25)

No Audio

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Pre-Video Discussion

Importance of wind and its impact on fire behavior:

- Most critical factor affecting fire behavior.
 - Difficult to predict, especially in complex terrain.
 - Most variable in time and space.
 - Poses safety and control problems, but can support tactics if accurately measured and forecasted.
- ☐ Reference Important Winds to Firefighters in the *Incident Response Pocket Guide (IRPG)*, PMS 461, <https://www.nwcg.gov/publications/461>.

☐ Play Video

Title Wind

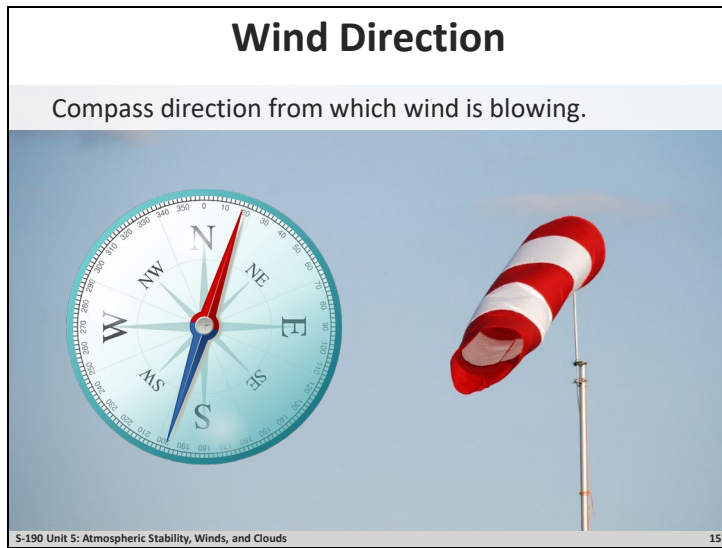
Summary Introduction to wind and its effect on the fire environment.

Time (01:04)

Audio

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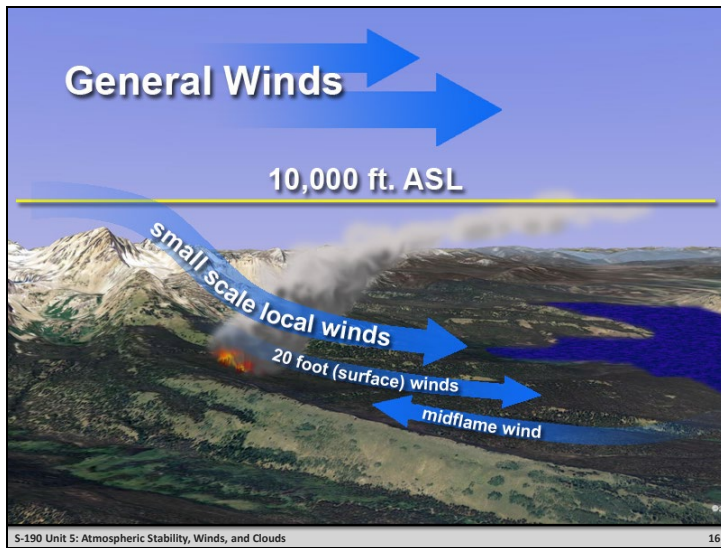


Question: A northeast wind is coming from what direction?

Answer: The northeast.

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- Large scale winds caused by high- and low-pressure systems but generally influenced and modified in the lower atmosphere by terrain.
- ☐ Instruct participants on the concept of general winds and their characteristics:
- Winds driven by large scale high- and low-pressure systems.
 - Winds typically found at mid- and upper-levels of the troposphere.
 - Winds responsible for transporting weather systems around the world.

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☐ Play video

Title General Winds

Summary Time-lapse of a fire and the sky above showing the impact of general winds.

Time (00:16)

No Audio

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Local Winds

Winds which are generated over a comparatively small area by local terrain and weather. They differ from those which would be appropriate to the general pressure pattern.



Pre-Video Discussion

- Winds found at lower levels of the troposphere.
- Induced by small-scale differences in air temperature and pressure.
- Influenced by terrain; the more varied the terrain, the greater the influence.
- Influenced by the difference in sea and land surface temperatures.
- Local winds may be the only wind impacting a fire, or it could be a combination of general and local winds.

☐ Play Video

Title Local Winds

Summary Time-lapse of fire on a mountain side and the effects of local winds on the fire.

Time (00:16)

No Audio

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Pre-Video Discussion

- Small-scale convective winds that occur due to local heating and cooling of a natural incline of the ground.
- A result of slopes or valleys cooling at night. The cooler air will sink down a slope or valley.

☐ Play Video

Title Downslope and Down-Valley Winds

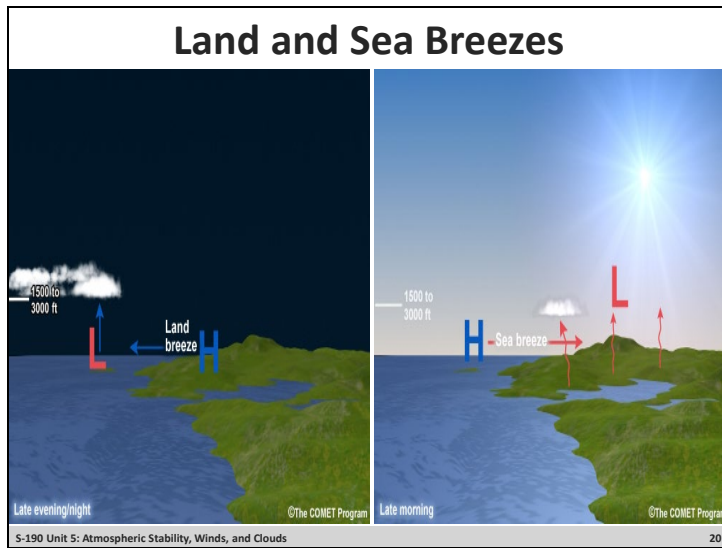
Summary Animation of a valley at night with a fire on a nearby slope and arrows showing the movement of air.

Time (00:21)

No Audio

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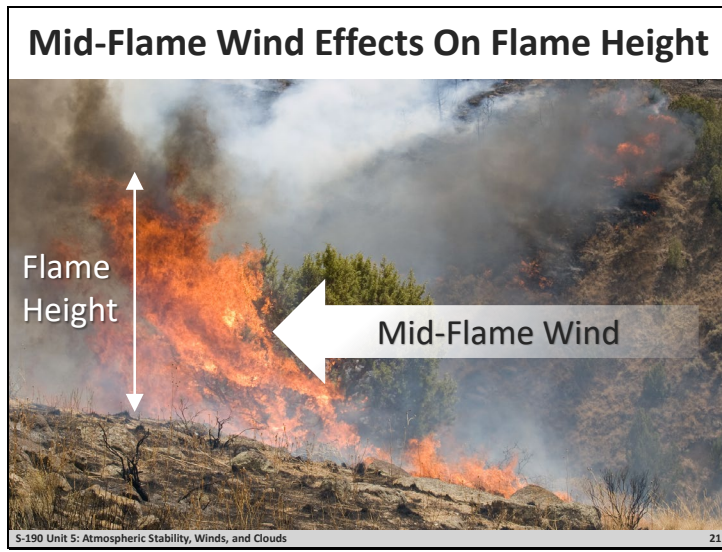
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- Land and sea breezes are common winds in coastal regions. Firefighters should anticipate wind shifts when working near large bodies of water (lake or ocean).
- Land Breeze: During the evening and overnight hours, the land mass becomes cooler than the air over the large body of water. Air over the land becomes stable and the air over the body of water becomes unstable. The rising air over the water is replaced by the air over the land.
- Sea Breeze: During the late morning and early afternoon, the land mass becomes warmer than the air over the large body of water. Air over the land becomes unstable and rises (low pressure). The rising air over the land is replaced by the air over the body of water.

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- ❑ Reference Beaufort Scale in the *Incident Response Pocket Guide (IRPG)*, PMS 461, <https://www.nwcg.gov/publications/461>.
- General or local winds, or components of both, contribute to wind speed and direction, including 20-foot and mid-flame winds.
- Mid-flame wind is the wind that acts directly on the flaming fire front at the level of half the flame height. An excellent approximation of the mid-flame wind is the eye-level wind.
- Eye-level wind can be measured by the firefighter with the Belt Weather Kit wind meter or a handheld electronic weather meter.

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Wind Effects on Fire Behavior



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Pre-Video Discussion

- Wind carries away moisture-laden air 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, pre-heating the fuels ahead of the fire front.
- Changes in wind direction and speed can rapidly change fire behavior from inactive to active.
- The direction of the fire spread and smoke transport are determined mostly by wind direction.

☐ Play Video

Title Wind Effects on Fire Behavior

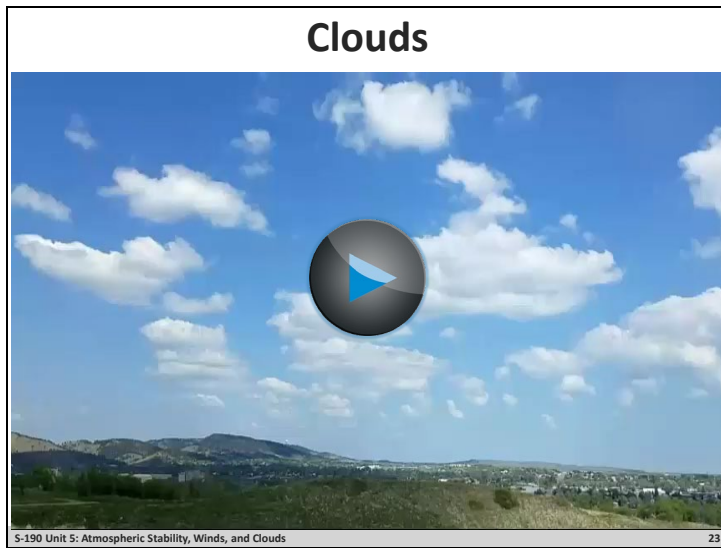
Summary Time-lapse of wildfires on varying landscapes and the effects of wind on fire behavior.

Time (00:17)

No Audio

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Pre-Video Discussion

- ☐ Reference Look Up, Down and Around in the *Incident Response Pocket Guide (IRPG)*, PMS 461, <https://www.nwecg.gov/publications/461>.

☐ Play Video

Title Clouds

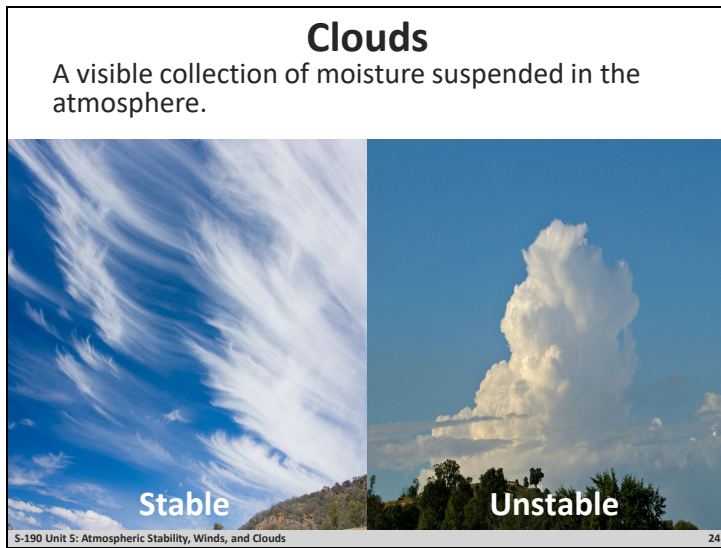
Summary Introduction to how clouds can change fire behavior.

Time (00:39)

Audio

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- Clouds form under stable or unstable atmospheric conditions, and not all clouds produce precipitation.
- There are numerous cloud types. This course only covers some of the basic, important clouds to firefighters.

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Cloud Impacts on Fire Environment

Clouds can modify the fire environment by changing:

- Temperature
- Relative Humidity
- Atmospheric Stability
- Wind
- Fuel Temperature
- Fuel Moisture
- Fire Behavior



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Pre-Video Discussion

- Clouds can reflect incoming solar radiation and, therefore, affect fire weather conditions by:
 - Creating cooler temperatures.
 - Increasing relative humidity.
 - Changing wind and stability.
- Changes in fire weather conditions directly impact:
 - Fuel moisture.
 - Decreases in fire behavior.
- Once clouds move away from the environment, fire behavior can increase.

☐ Play Video

Title Campfire

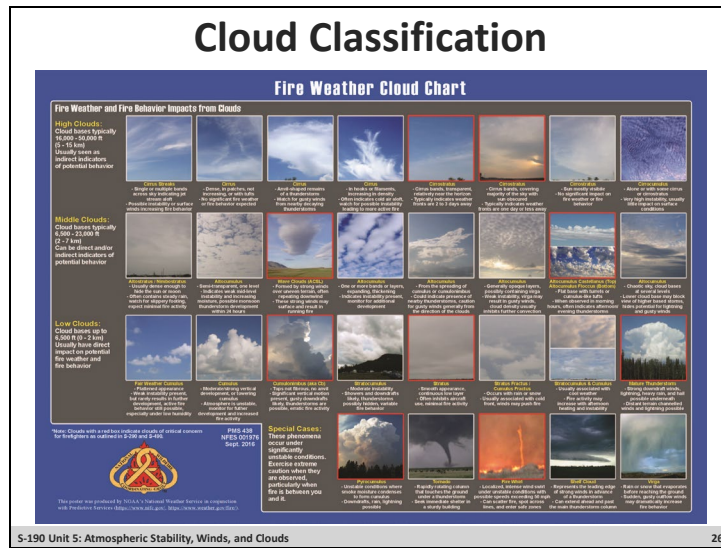
Summary An animation of a campfire burning and clouds moving in, creating cooler temperatures.

Time (00:17)

No Audio

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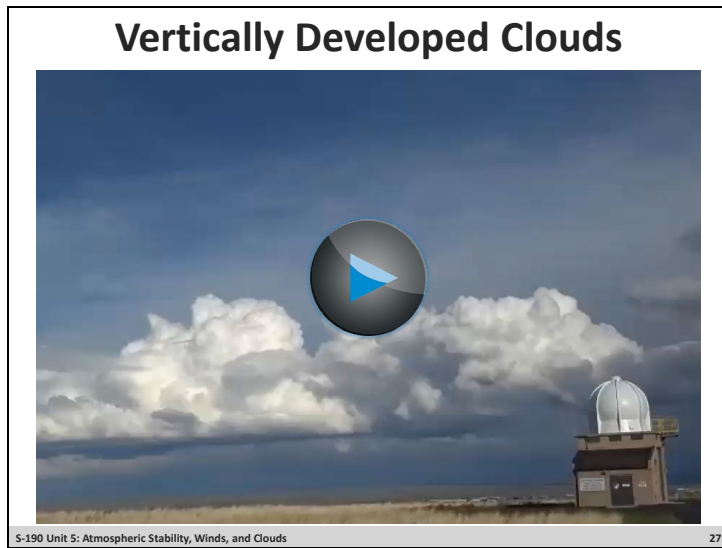
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- ☐ Refer participants to the *The Fire Weather Cloud Chart*, PMS 438, <https://www.nwcg.gov/publications/438>, printout that each participant was provided.
- ☐ Lead participants in a discussion of basic cloud classification:
 - Clouds are classified by height.
 - **High:** 6,000-50,000 feet. Usually pure white in color and made up of ice crystals.
 - **Middle:** 6,500-23,000 feet. Usually a combination of white and gray in color and made of water droplets and ice crystals.
 - **Low:** 0-6,500 feet. Usually gray in color and made of water droplets.
- ☐ Task participants with locating the clouds of critical concern for firefighters outlined in red boxes.
- ☐ Lead participants in a discussion on the information provided for the following clouds of critical concern:
 - Altocumulus castellanus / altocumulus floccus
 - Cumulonimbus
 - Mature thunderstorm

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Pre-Video Discussion

- Made up of water and ice and indicate unstable atmospheric conditions.
- An unstable atmosphere can result in an increase in fire behavior. Identifying this type of cloud is important when predicting changes to the fire environment.
- Cumulus clouds could result in cumulonimbus clouds (thunderstorms), which could result in gusty and erratic winds.
- Bases can range from 1,500 to 10,000 feet, depending on air mass conditions in different parts of the country.
- For example, cumulus clouds or thunderstorms typically have higher bases compared to the same cloud types in southern and eastern sections of the United States.

☐ Play Video

Title Vertically Developed Clouds

Summary Time-lapse of cumulus cloud being formed over land.

Time (00:14)

No Audio

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Smoke Layers

Smoke layers mimic clouds in modifying the fire environment by changing:

- **Temperature**
- **Relative Humidity**
- **Atmospheric Stability**
- **Wind**
- **Fuel Temperature**
- **Fuel Moisture**
- **Fire Behavior**



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- ☐ Inform participants of the similarities between smoke layers and clouds on the fire environment.

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Knowledge Check	
Stable or Unstable?	
1. Clouds or smoke columns that grow vertically indicate a(n) <u>unstable</u> atmosphere.	2. A smoke column that spreads out after limited rise indicates a(n) <u>stable</u> atmosphere.

☐ Evaluate instruction using the knowledge check.

Instructor can choose to have questions answered by individuals or in groups.

Question 1: Clouds or smoke columns that grow vertically indicate a(n) _____ atmosphere.

Answer: Unstable

Question 2: A smoke column that spreads out after limited rise indicates a(n) _____ atmosphere.

Answer: Stable

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Knowledge Check

Fill in the blanks.

1. Wind direction is the direction from which the wind is blowing.
2. General wind is a large scale wind associated with high and low pressure.
3. Local wind is a small scale wind.
4. (True or False). Wind is the most critical factor affecting fire behavior. **True**
5. The direction of the fire spread and smoke transport are mostly determined by direction of wind.

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☐ Evaluate instruction by using the knowledge check.

Instructor can choose to have questions answered by individuals or in groups.

Question 1: Wind direction is the direction _____ which the wind is blowing.

Answer: from

Question 2: General wind is a _____ scale wind associated with high and low pressure.

Answer: large

Question 3: Local wind is a _____ scale wind.

Answer: small

Question 4: True or False. Wind is the most critical factor affecting fire behavior.

Answer: True

Question 5: The direction of the fire spread and smoke transport are mostly determined by.

Answer: direction of wind

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Knowledge Check

The smoke column in the image indicates _____.

A. Stable Atmosphere

B. Unstable Atmosphere

C. Neither



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☐ Provide explanations for the answer, if required.

Question: The smoke column in the image indicates _____.

Answer: Unstable Atmosphere

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Knowledge Check

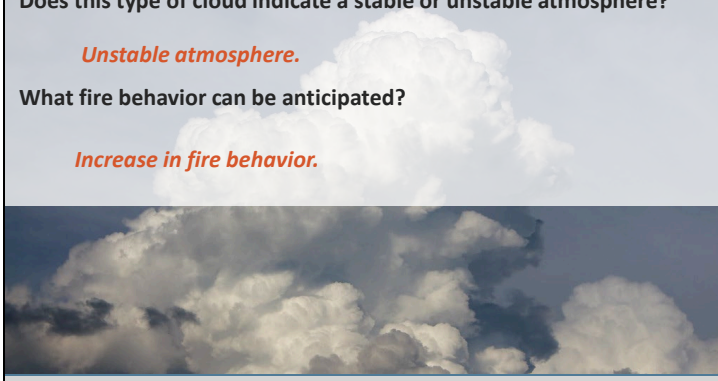
The cloud in this image is a towering cumulus.

Does this type of cloud indicate a stable or unstable atmosphere?

Unstable atmosphere.

What fire behavior can be anticipated?

Increase in fire behavior.



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☐ Provide explanations for the answers if required.

Question: Does this type of cloud indicate a stable or unstable atmosphere?

Answer: Unstable atmosphere.

Question: What fire behavior can be anticipated?

Answer: Increase in fire behavior.

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Objectives

Students will be able to:

- Describe atmospheric stability and discuss the effects on fire behavior.
- Describe wind and its effects on fire behavior.
- Explain cloud classifications and their impact on fire behavior.
- Explain the similarities between smoke layers and clouds in relation to impact on fire behavior.

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- ☐ Review unit objectives.