Effects of Weather on Small UAS

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Goals of This Lecture

According to the FAA's UAS Airman Certification Standards, a Remote PIC should be able to demonstrate knowledge of:

- Weather factors and their effects on performance.
  - Density altitude.
  - Wind and currents.
  - Atmospheric stability, pressure, and temperature.
  - Air masses and fronts.
  - Thunderstorms and microbursts.
  - Tornadoes.
  - Icing.
  - Hail.
  - Fog.
  - Ceiling and visibility.
  - Lightning.

Definitions of Altitude

- **Absolute Altitude** — the height above ground level (AGL)
- **True Altitude** — the height above mean sea level (MSL)
- **Density Altitude** — how we measure the density of air
- **Indicated Altitude** — the height your altimeter shows you (when you're at sea level under standard conditions, indicated altitude is the same as true altitude)
- **Pressure Altitude** — the indicated altitude when the barometric pressure scale is set to 29.92 inHg (inches of mercury)

Density Altitude

The density of air is defined by the pressure altitude and ambient temperature and can have a significant effect on your aircraft's performance. When the density altitude is high, you'll experience reduced aircraft performance.

Density Altitude Attributes

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<u>HIGHER</u> Density Altitude
OCCURS AT
• Higher elevations
• Lower atmospheric pressures
• Higher temperatures
• Higher humidity

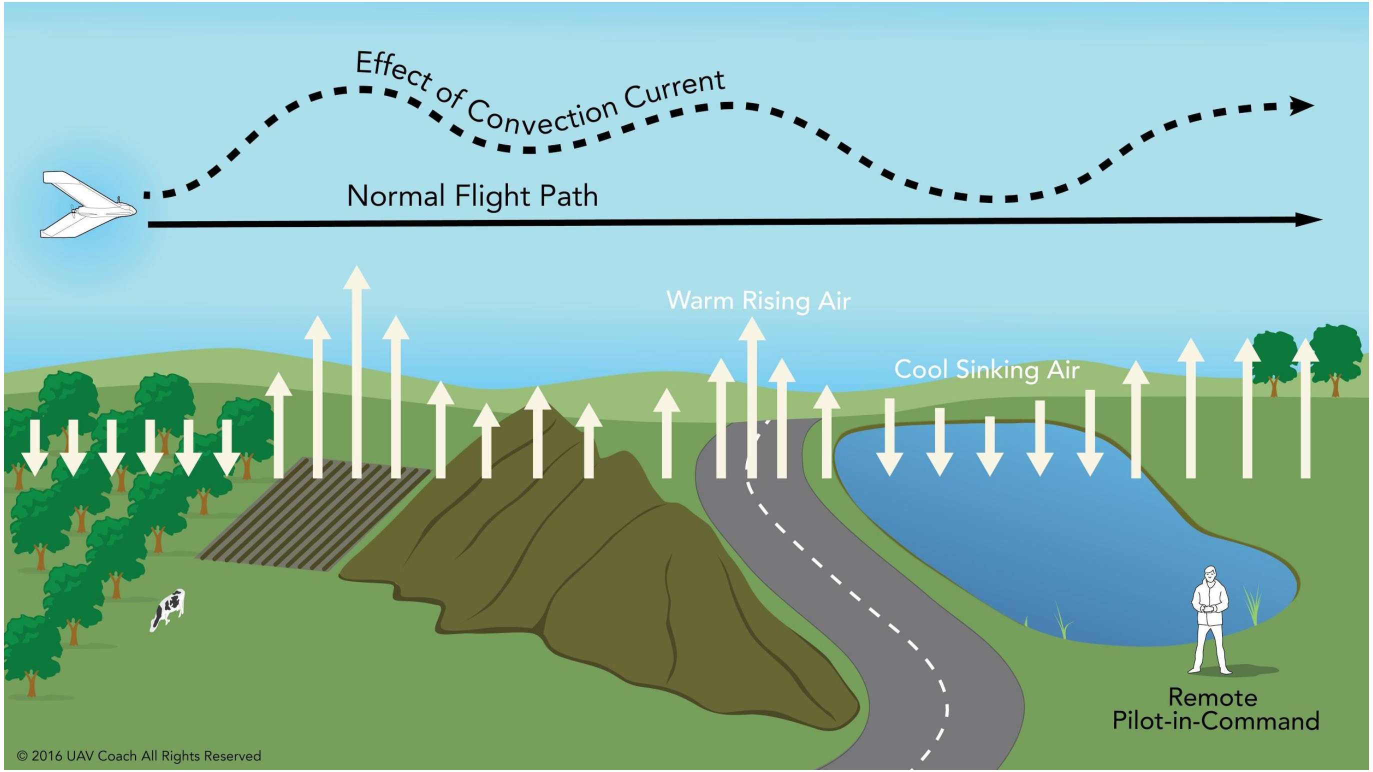
Leads to <u>thinner air</u> & <u>reduced aircraft performance</u>.

<u>LOWER</u> Density Altitude
OCCURS AT
• Lower elevations
• Higher atmospheric pressures
• Lower temperatures
• Lower humidity

Leads to <u>thicker air</u> & <u>stronger aircraft performance</u>.

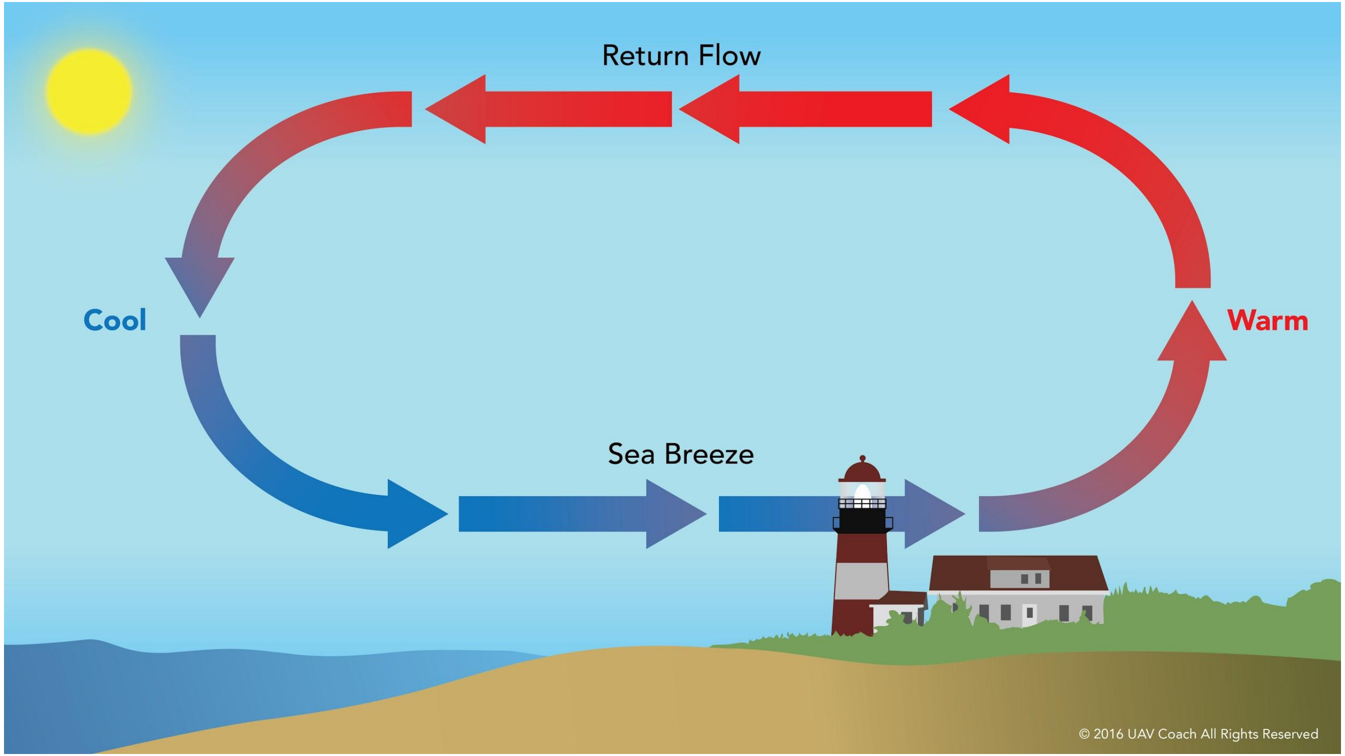
Wind and Currents

Convective Currents



Different types of surfaces radiate heat upwards in different amounts.

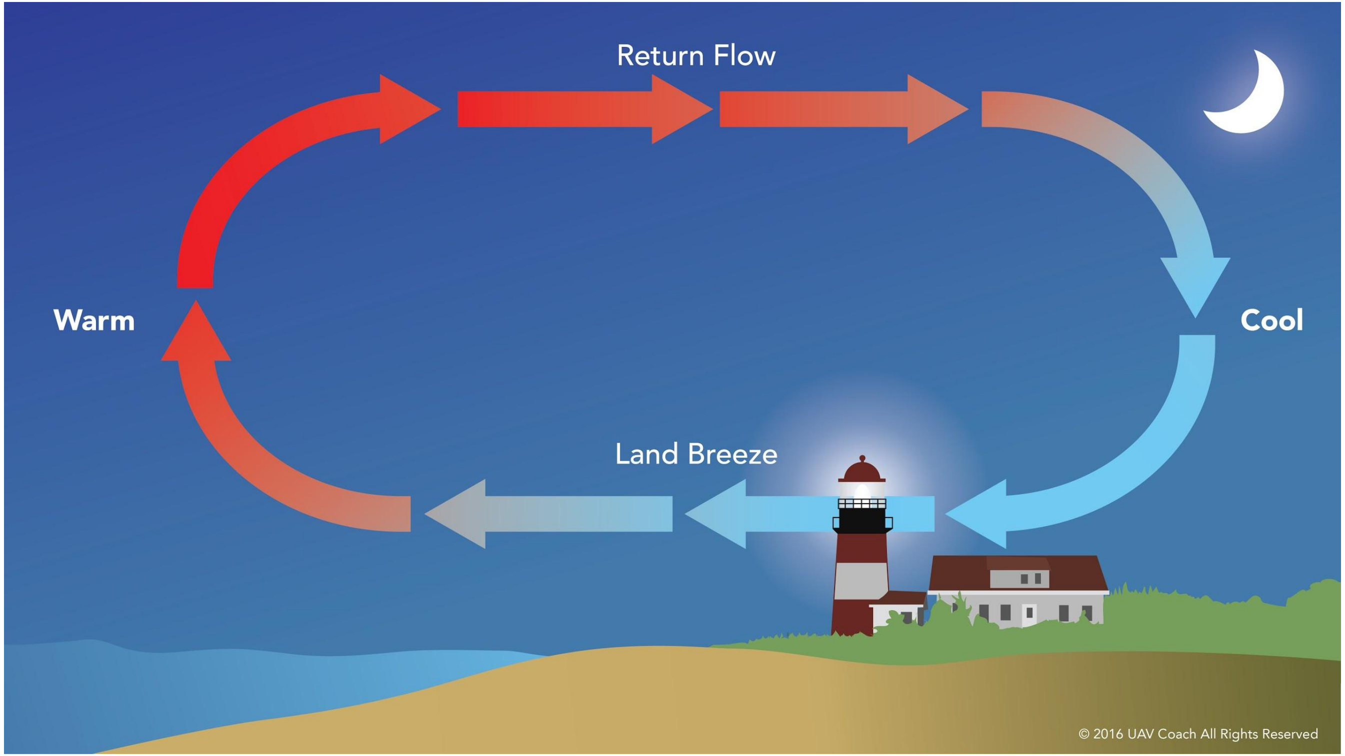
Sea Breeze



The land will heat up faster than the water, so the air over the land becomes warmer and less dense.

It rises and is replaced by cooler, denser air flowing in from over the water.

Land Breeze



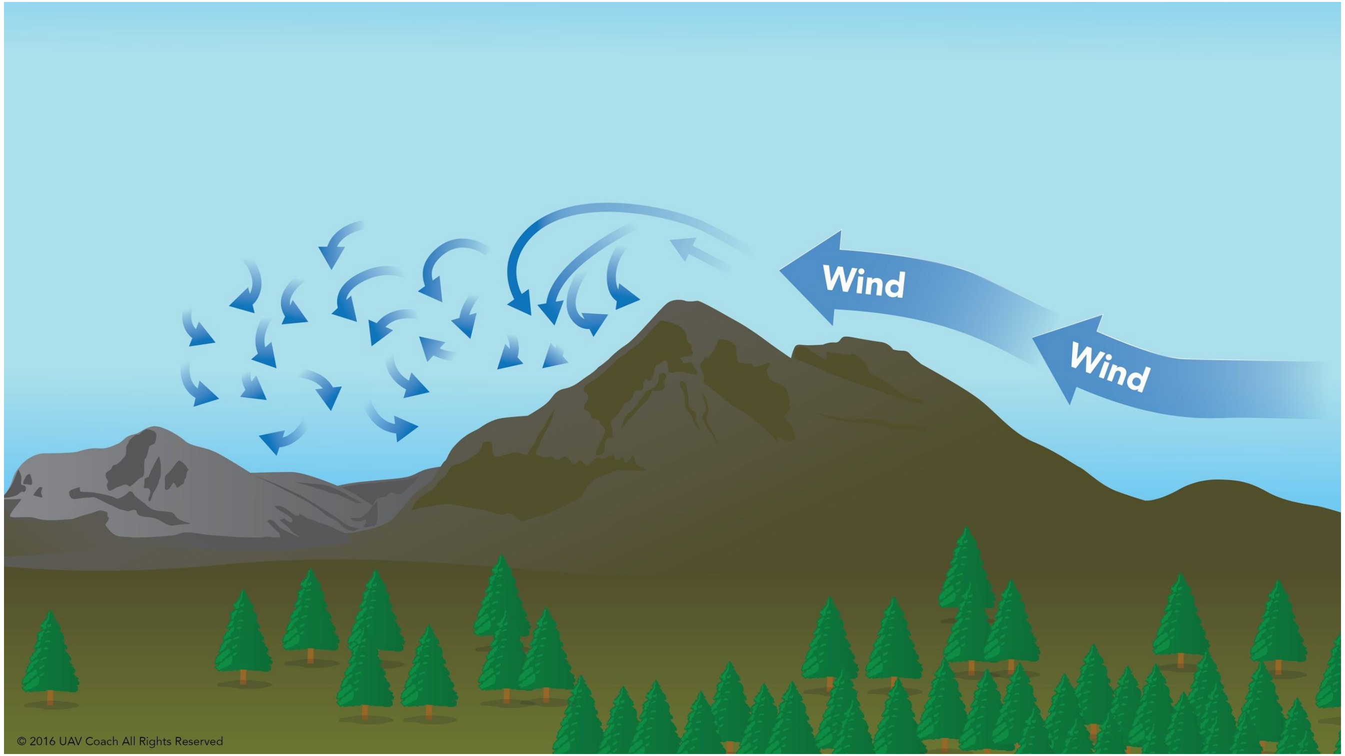
At night, the opposite happens.

The land cools faster than the water, so the warmer air over the water rises and is replaced by the cooler, denser air from the land.

Effects of Obstructions on Wind

Obstructions on the ground can affect the flow of wind, and this can be an unseen danger for a Remote PIC.

Katabatic Wind



In a mountainous environment, you've got wind that flows smoothly up the windward side of the mountain, but on the other leeward side, the wind follows the contour of the terrain and can be quite turbulent.

Wind shear is a sudden, drastic change in wind speed and/or direction over a relatively small area.

Wind shear can occur at all altitudes, in all directions, and it’s typically characterized by directional wind changes of 180° and speed changes of 50 knots or more.

Wind Shear

Wind shear is commonly associated with:

- Passing frontal systems
- Thunderstorms
- Temperature inversions with strong upper level winds (greater than 25 knots)

Microburst

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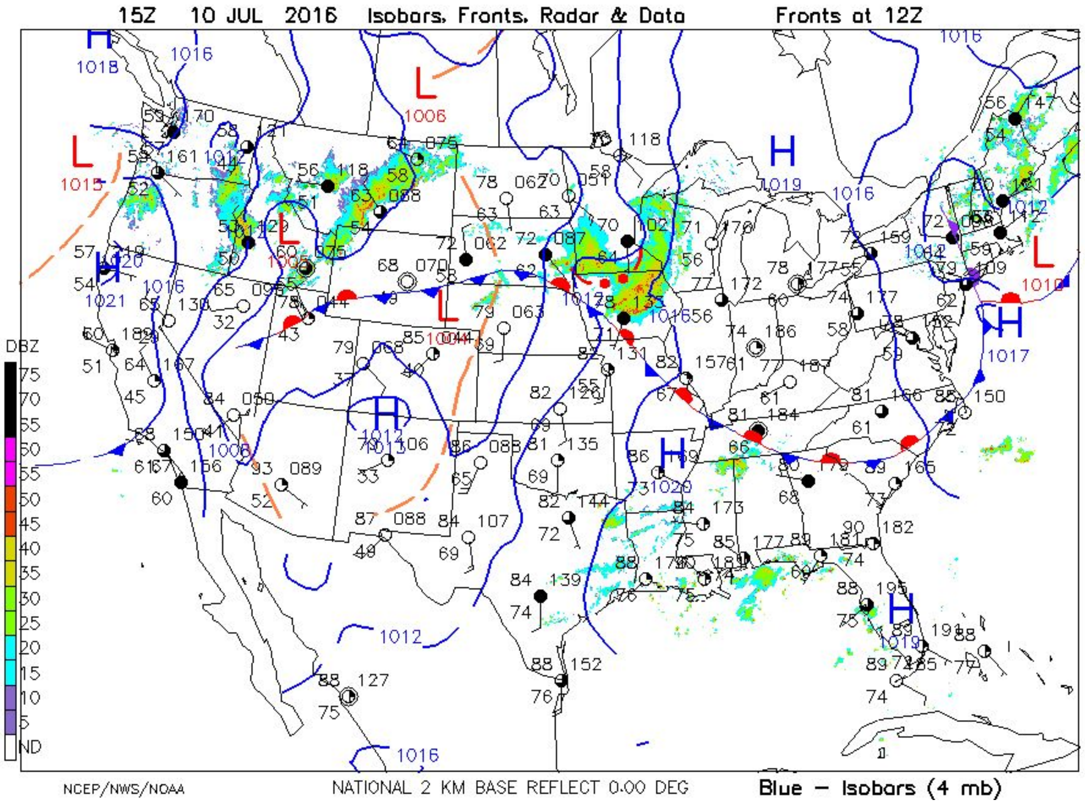
One type of wind shear is a microburst:

- Short and intense precipitation.
- Typically occurs in a space of less than 1 mile horizontally and within 1,000 feet vertically for about 15 minutes.
- Can produce severe downdrafts of up to 6,000 feet per minute.
- Can also produce a hazardous wind direction change of 45 degrees or more, in a matter of seconds.

Expect wind shear in a temperature inversion whenever wind speed at 2,000 to 4,000 ft. AGL is 25 knots or more.

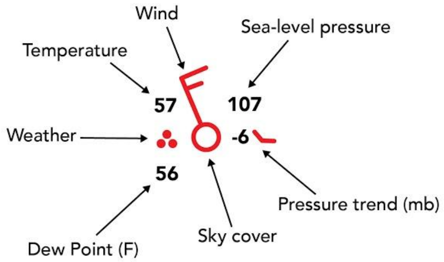
Surface Weather Maps



Each of the circles represents a station model and reveals to us information about the temperature, the sky cover, the wind speed, the wind direction, and some other observations.

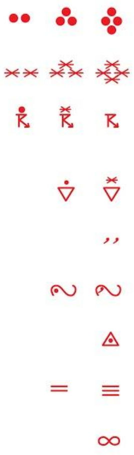
Winds are described by the direction from which they blow, thus a *northwest wind* means that the wind is blowing from the northwest toward the southeast.

Sample Station Plot



WEATHER

A weather symbol is plotted if, at the time of observation, there is either precipitation occurring or a condition causing reduced visibility. Below is a list of the most common weather symbols:



Rain (light, moderate, heavy)

Snow (light, moderate, heavy)

Thunder (with rain, snow, no percipitation

Shower (rain, snow)

Drizzle

Freezing rain, Freezing drizzle

Ice pellets/Sleet

Fog (thin, thick)

Haze

WIND

Wind is plotted in increments of 5 knots (kts), with the outer end of the symbol pointing toward the direction from which the wind is blowing. The wind speed is determined by adding up the total of pennants, lines, and half-lines, each of which has the following individual value:

Pennant: 50 kts
Line: 10 kts
Half-Line: 5 kts

If there is only a circle depicted over the station with no wind symbol present, the wind is calm. Below are some sample wind symbols:

Wind blowing from the west at 75 knots

Wind blowing from the northeast at 25 knots

Wind blowing from the south at 5 knots

Calm winds

PRESSURE

Sea-level pressure is plotted in tenths of millibars (mb), with the leading 10 or 9 omitted. For reference, 1013 mb is equivalent to 29.92 inches of mercury. Below are some sample conversions between plotted and complete sea-level pressure values:

410: 1041.0 mb
103: 1010.3 mb
987: 998.7 mb
872: 987.2 mb

PRESSURE TREND

The pressure trend has two components, a number and symbol, to indicate how the sea-level pressure has changed during the past three hours. The number provides the 3-hour change in tenths of millibars, while the symbol provides a graphic illustration of how this change occurred. Below are the meanings of the pressure trend symbols:

Continuously falling

Continuously rising

Falling, then steady

Rising, then steady

Falling before a lesser rise

Falling before a greater rise

Rising before a greater fall

Rising before a lesser fall

Steady

SKY COVER

The amount that the circle at the center of the station plot is filled in reflects the approximate amount that the sky is covered with clouds. Below are the common cloud cover depictions:

Clear

Few clouds
(less than 12% cloud cover, but sky is not clear)

Scattered clouds
(approximately 25% cloud cover)

Parly cloudy
(approximately 50% cloud cover)

Mostly cloudy
(approximately 75% cloud cover)

Overcast

Sky Obsured

Sky Cover Missing

Isobar Lines

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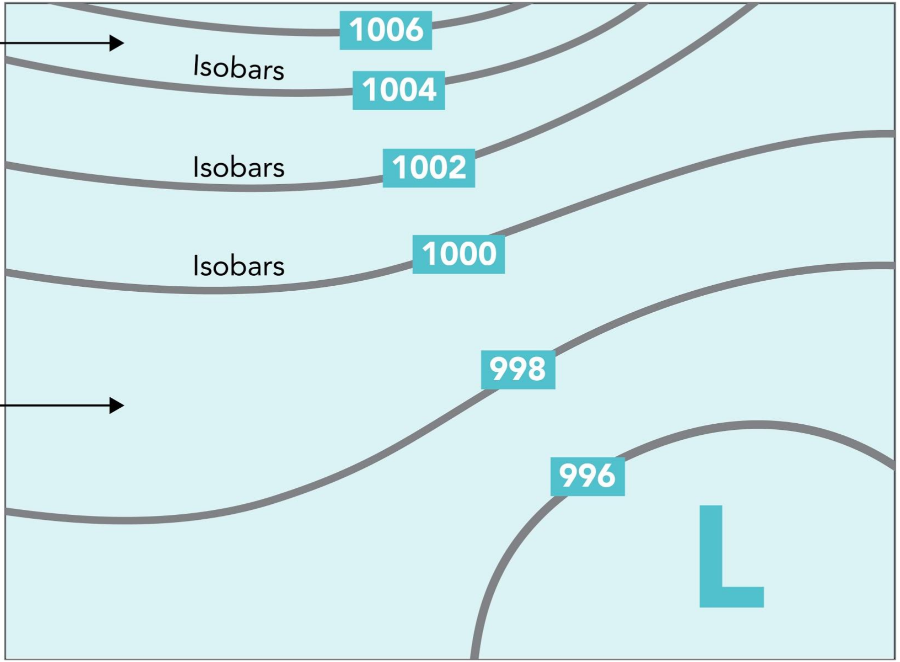
Closely spaced isobars mean a steep pressure gradient and strong winds.

Widely spaced isobars mean a shallow pressure gradient and relatively light winds.



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Isobars are lines drawn on the chart to depict areas of equal pressure.

These lines result in a pattern that reveals the pressure gradient or change in pressure over distance.

Atmospheric Stability, Pressure, & Temperature

Things to Keep in Mind

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- Every physical process of weather is accompanied by (or is the result of) a heat exchange.
- The stability of the atmosphere correlates with its ability to resist vertical motion. A stable atmosphere makes vertical movement of air difficult. An unstable atmosphere allows an upward or downward disturbance to grow into a vertical (or convective) current.
- Instability, as you might imagine, can lead to significant turbulence, extensive vertical clouds, and severe weather.

Adiabatic Heating & Cooling

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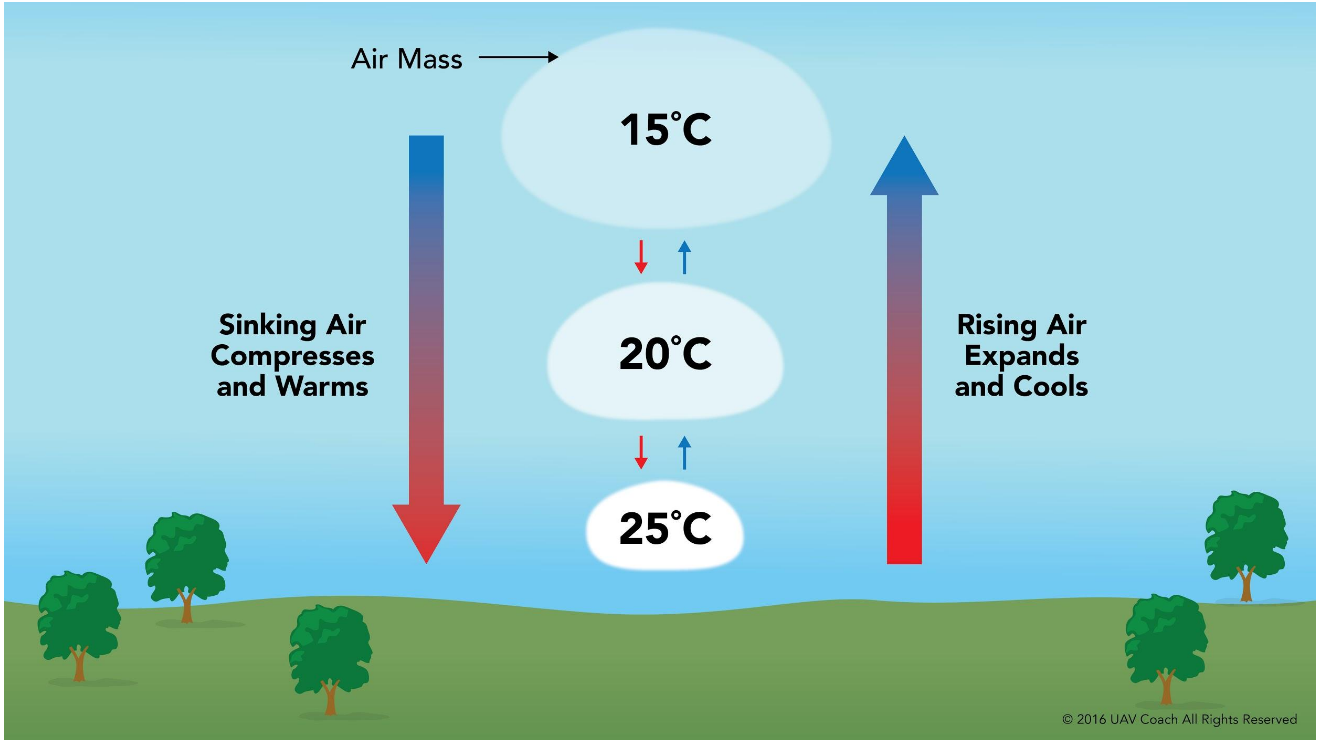

The average rate of temperature change, or lapse rate, is how you can determine the stability of the atmosphere.

Atmospheric Stability

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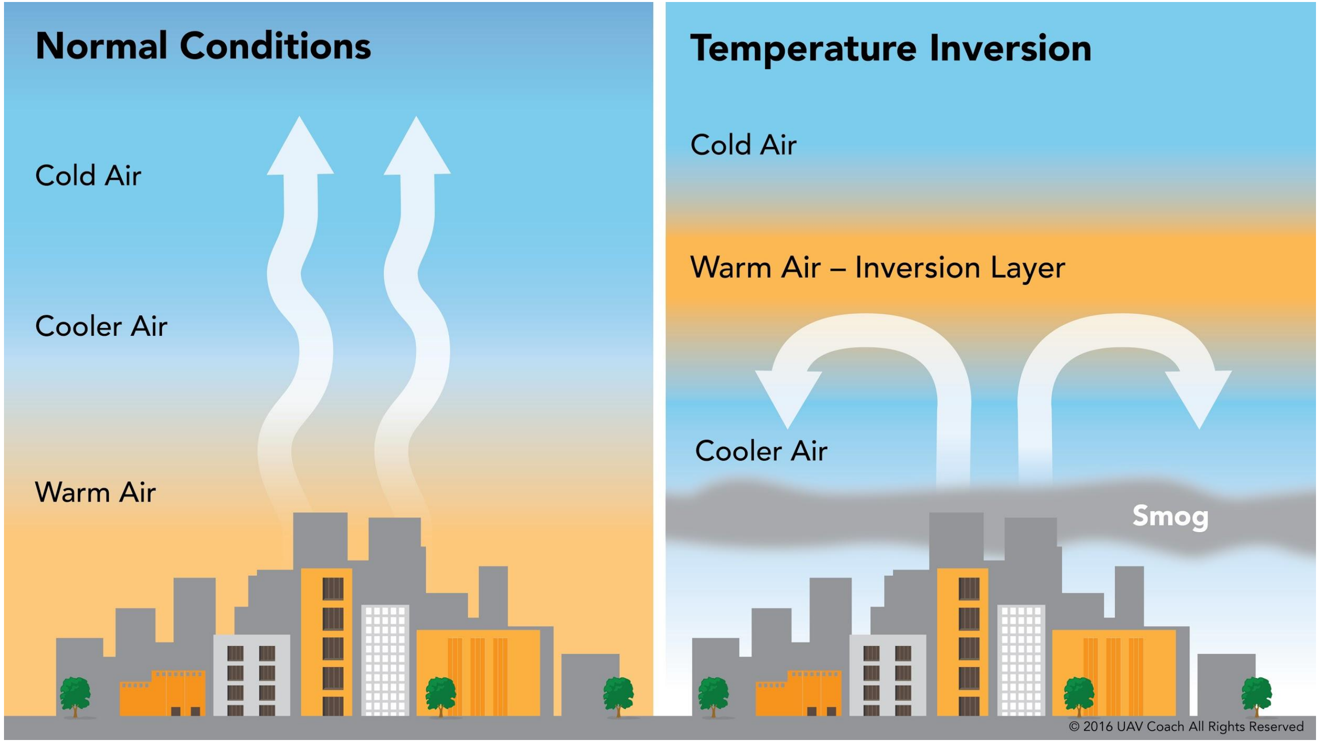
The combination of temperature and moisture determine the stability of the air and the resulting weather.

Cool, dry air is very stable and resists vertical movement, which leads to good and generally clear weather. Stratiform clouds may be present in this case.

The greatest instability occurs when the air is warm and moist, as it is in the tropical regions in the summer. Turbulence and showery precipitation are prevalent. Typically, thunderstorms appear on a daily basis in these regions due to the instability of the surrounding air.

Temperature Inversion



Surface based temperature inversions occur on clear, cool nights when the air close to the ground is cooled by the lowering temperature of the ground.

Moisture & Temperature

By nature, the atmosphere contains moisture in the form of water vapor. The amount of moisture present in the atmosphere is dependent upon the temperature of the air.

- Every 20°F increase in temperature doubles the amount of moisture the air can hold.
- Conversely, a decrease of 20°F cuts the capacity in half.

Water Vapor & Atmosphere

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The only ways water vapor is added into the atmosphere is through evaporation or sublimation.

- **Evaporation** is the changing of liquid water to water vapor.
- **Sublimation** is the changing of ice directly to water vapor, completely bypassing the liquid stage. If you've ever seen dry ice, you've seen sublimation at work.

Relative Humidity

- Humidity refers to the amount of water vapor present in the atmosphere at a given time.

- **Relative humidity is the actual amount of moisture in the air compared to the total amount of moisture the air could hold at that temperature.**

For example, if the current relative humidity is 65 percent, the air is holding 65 percent of the total amount of moisture that it is capable of holding at that temperature and pressure.

Temperature & Dew Point

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- The dew point, given in degrees, is the temperature at which the air can hold no more moisture.

- Typically, when the temperature and the dew point converge, you will have fog.

For example, if the outside air temperature is 64°F and the dew point is 59°F, AND it is dusk (i.e., temperature is falling), you will most likely have fog or low clouds as the temperature and dew point converge.

How to Calculate a Cloud Base

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How do you calculate a cloud base?

- Find the difference between the surface temperature and the dew point. This value is known as the "spread".
- Divide the spread by 4.4 (if temperatures are in °F) or 2.5 (if temperatures are in °C), then multiply by 1000.
- This will give you the cloud base in feet AGL (Above Ground Level).

How to Calculate a Cloud Base

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As an example, let's say that the surface temperature is 75 °F and the dew point is 71 °F.

- 75°F - 71°F = 4°F (that's your spread)
- (4 / 4.4) x 1,000 = 909
- So your cloud base is 909 feet AGL (Above Ground Level)

The pilot can be greatly affected by the cold. Numb fingers are bad!

Also, batteries can be greatly affected by the cold. This is very important to keep in mind for those who time flights rather than keeping an eye on battery voltage.

Air Masses & Fronts

An air mass is a large body of air.

When air masses stagnate in (or move really slowly over) an area that has pretty uniform temperature and moisture characteristics on a day-to-day basis, the air mass takes on those temperature and moisture characteristics.

Air Mass Categories

- Air mass stagnation happens in places like polar regions, tropical oceans, and dry deserts.
- Categorized by temperature characteristics (polar or tropical) and moisture content (maritime or continental).

Examples:

- Continental polar air mass — forms over a polar region and brings cool, dry air with it.
- Maritime tropical — forms over warm tropical waters and brings warm, moist air with it.

Where Air Mass Gets Interesting

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Air mass passes over a warmer surface:

- Convective currents form.
- This creates an unstable air mass with good surface visibility.
- Causes turbulence, cumulus clouds, and showers.

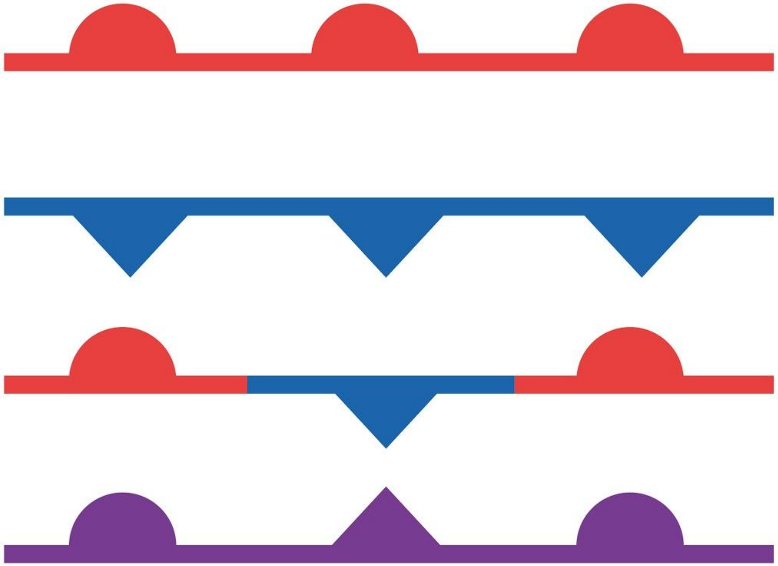
Air mass passes over a colder surface:

- Convective currents do NOT form.
- This creates a stable air mass with poor surface visibility.
- Causes steady precipitation, low stratus clouds and fog.

A front is the boundary layer between the two different air masses or areas of pressure as they get closer to each other.

An approaching front of any type always means that weather changes are imminent. Within a front, there will always be a change in the wind direction (shifting wind) and also in the temperature.

Symbols for surface fronts and other significant lines shown on the surface analysis chart



Warm front (red)*

Cold front (blue)*

Stationary front (red/blue)*

Occluded front (purple)*

*Note: Fronts may be black and white or color depending on their source.
Also, fronts shown in color code do not necessarily show frontal symbols.

Source: FAA-H-8083-25B

Warm Front

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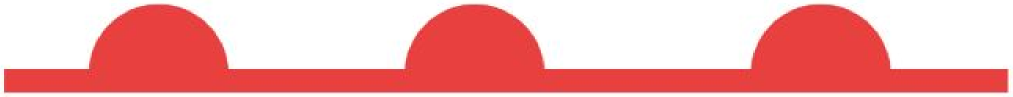
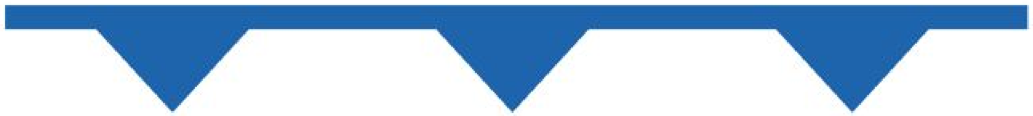
- Occurs when a warm mass of air advances and replaces a body of colder air.
- As the warm air is lifted, the temperature drops and condensation occurs.
- A warm front often has high humidity. Also, warm fronts move SLOWLY, typically 10-25 mph.



Warm front (red)

Cold Front

- Occurs when a cold, dense, mass of stable air advances and replaces a body of warmer air.
- Cold fronts move twice as fast as warm fronts, usually progressing at a rate of 25-30 mph.



Cold front (blue)

Warm & Cold Fronts

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Weather Activity:

- Warm fronts bring low ceilings, poor visibility, and rain.
- Cold fronts bring violent weather.

Approach Speed:

- Warm fronts provide advance warning of their approach and can take days to pass through a region.
- Cold fronts are fast approaching with little or no warning, and they make a complete weather change in just a few hours.

Stationary Front

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- When the forces of two air masses are relatively equal, the boundary or front that separates them remains stationary and influences the local weather for days.

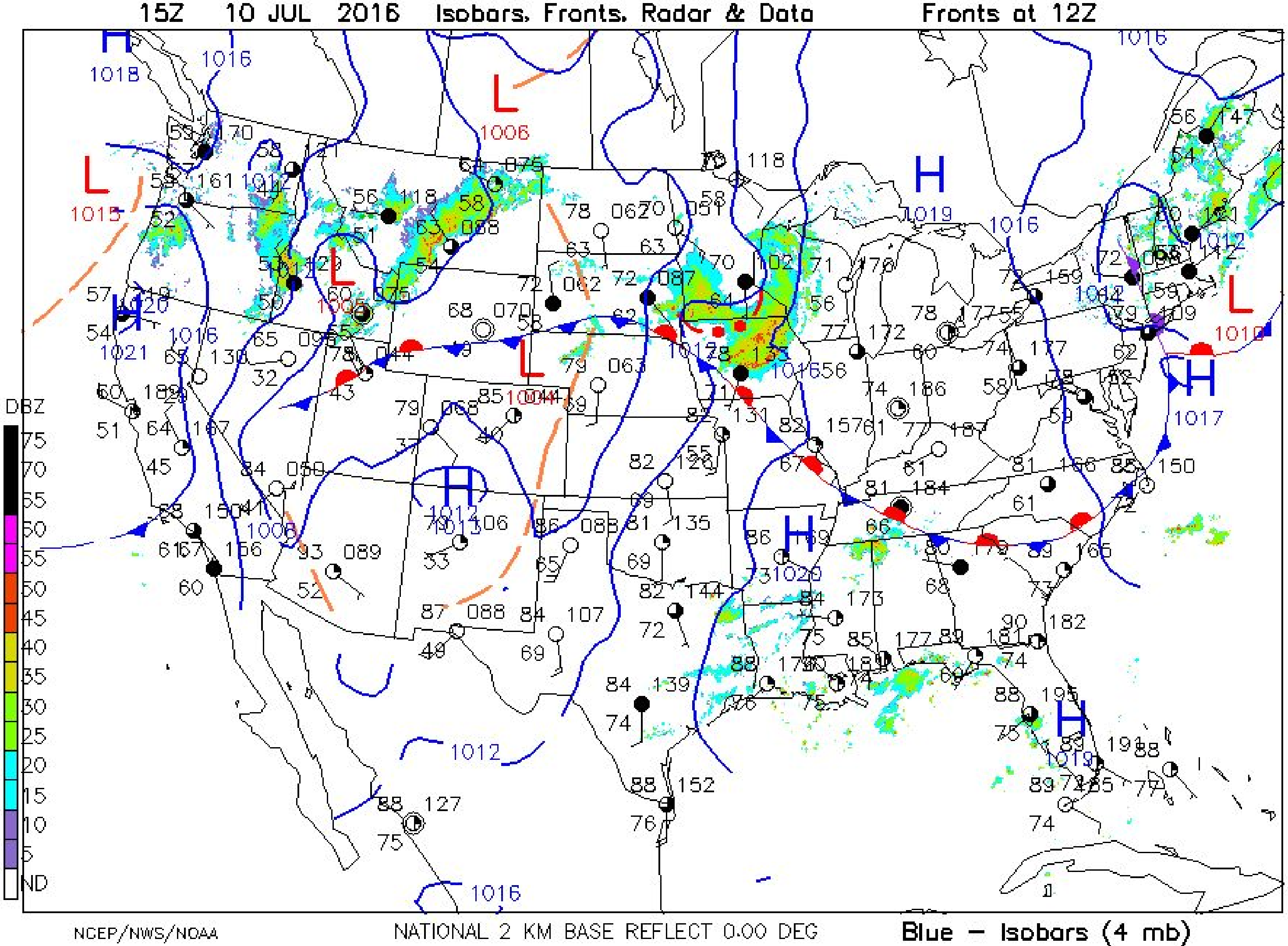
- The weather associated with a stationary front is typically a mixture that can be found in both warm and cold fronts.

Stationary front (red/blue)

Occluded Front

- An occluded front occurs when a fast-moving cold front catches up with a slow-moving warm front.

Occluded front (purple)


15Z 10 JUL 2016 Isobars, Fronts, Radar & Data Fronts at 12Z
DBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
ND
NCEP/NWS/NOAA
NATIONAL 2 KM BASE REFLECT 0.00 DEG
Blue – Isobars (4 mb)

Thunderstorms

Thunderstorms

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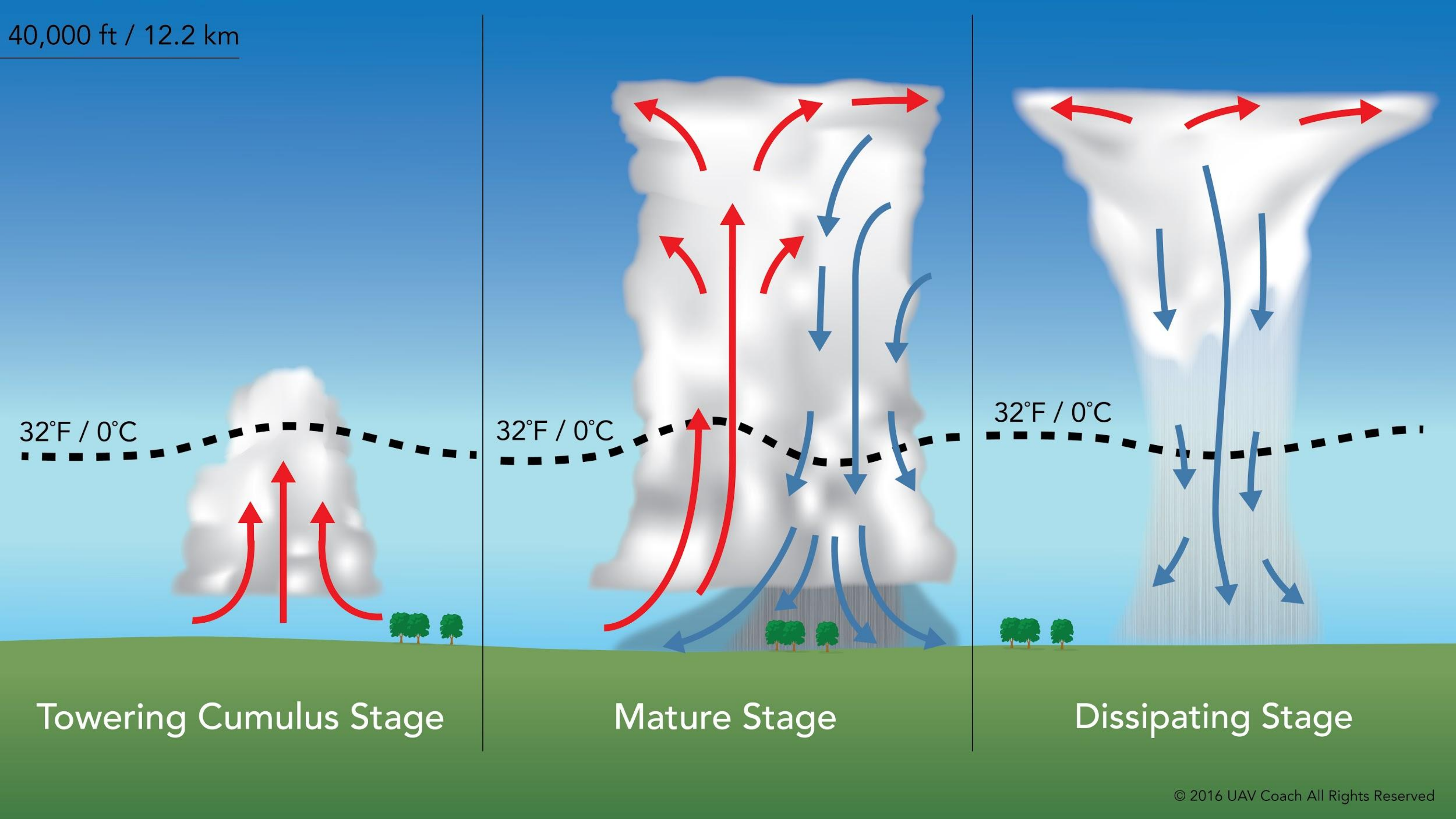
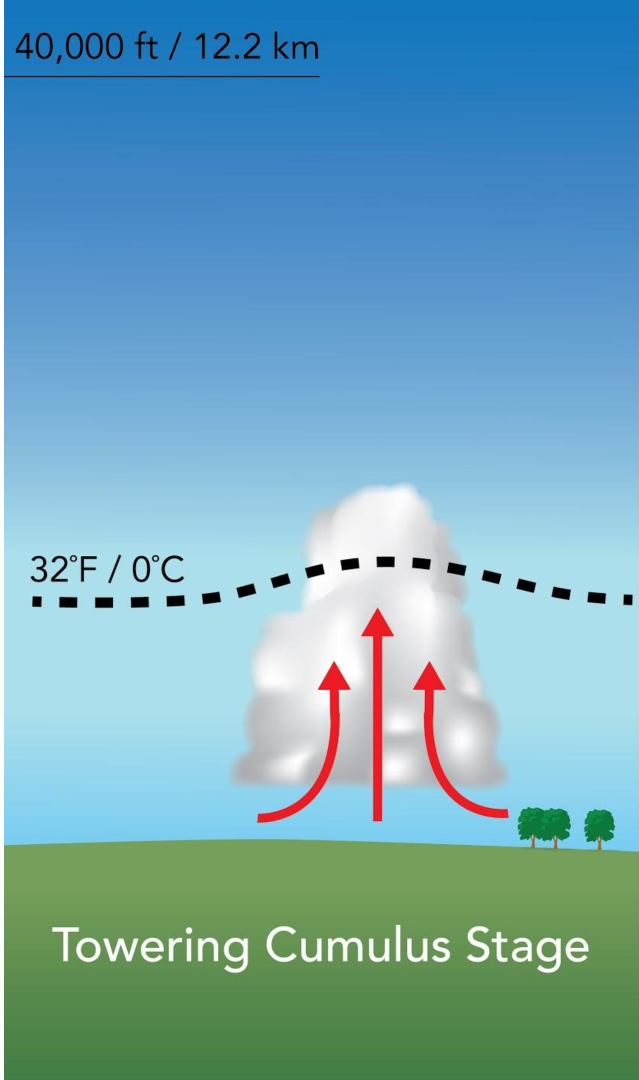
Thunderstorms are produced by cumulonimbus clouds.

They form when there is:

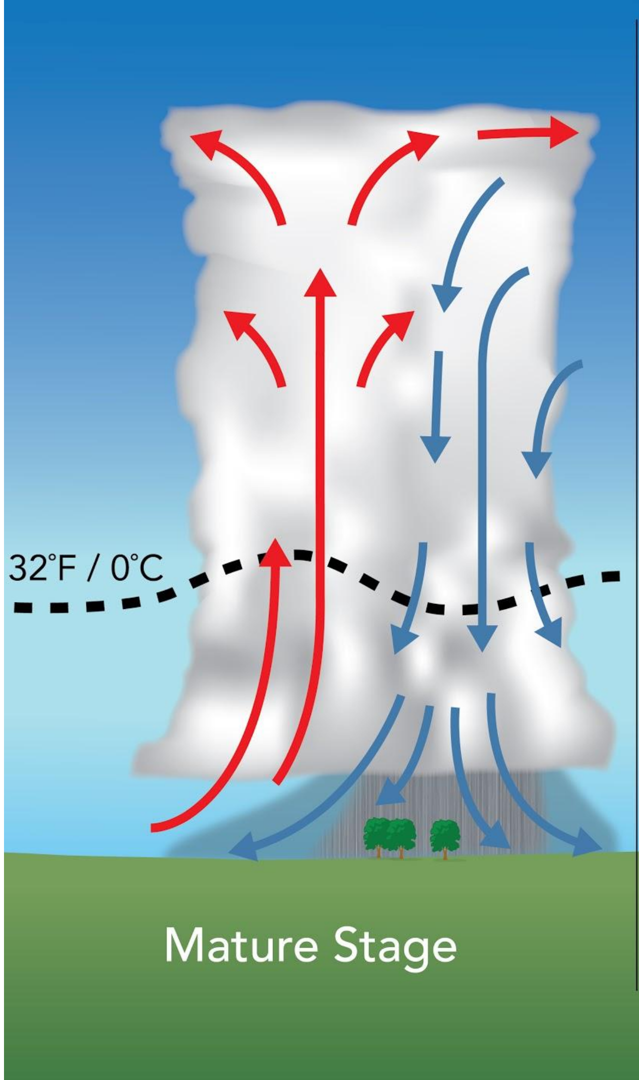
- Sufficient water vapor or moisture.
- An unstable lapse rate (remember, the lapse rate describes the rate of change of the temperature as the air increases in altitude).
- An initial upward boost to start the process (heat).


40,000 ft / 12.2 km
32°F / 0°C
32°F / 0°C
32°F / 0°C
Towering Cumulus Stage
Mature Stage
Dissipating Stage

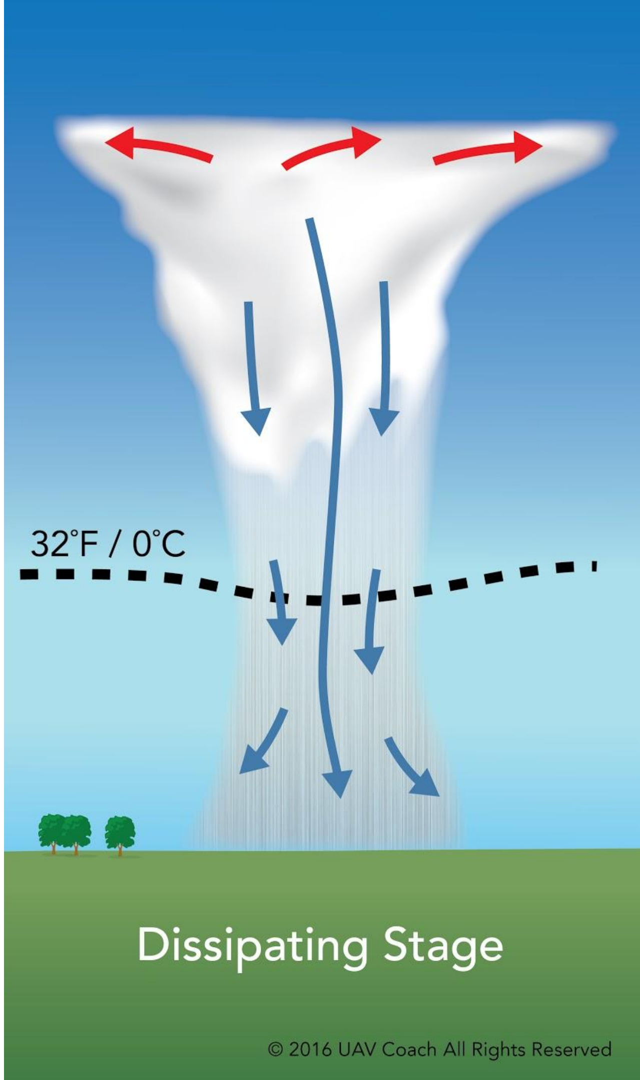
Vertical development always means windshear and turbulence, which is almost always more than an sUAS can handle. Continuous, strong updrafts prohibit moisture from falling.



Within 15 minutes, the thunderstorm reaches the mature stage, which is the most violent time period of the thunderstorm's life cycle.



Once the vertical motion near the top of the cloud slows down, the top of the cloud spreads out and takes on an anvil-like shape. This is when the storm dissipates.



Other Extreme Weather

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- **Tornadoes** — Any cloud connected to a severe thunderstorm could spawn a tornado.
- **Icing** — Be alert for icing anytime 1) the temperature approaches 0°C and 2) there's visible moisture in the air.
- **Hail** — Can be encountered in clear air several miles from thunderstorm clouds.
- **Lightning** — Can induce permanent errors in a magnetic compass and disrupt radio communications.

Fog

Fog Basics

- Begins within 50 feet of the surface.
- Typically occurs when the temperature of air near the ground is cooled to the air’s dew point.
- Not advisable to operate an UA in fog conditions.
- Classified according to the manner in which it forms.

Radiation Fog

- Typically forms in low-lying areas like a mountain valley.
- Happens when the ground cools rapidly due to terrestrial radiation, and the surrounding air temperature reaches its dew point.
- Forms on clear nights, with relatively little to no wind present.

Advection Fog

- Common in coastal areas where sea breezes can blow moist air over cooler land masses.
- Likely to form when a layer of warm, moist air moves over a cold surface.
- Wind is required for advection fog to occur. Winds of up to 15 knots allow the fog to form and intensify; above a speed of 15 knots, the fog usually lifts and forms low stratus clouds.
- Can persist for days.

Upslope Fog

- Occurs up a slope, when moist, stable air is forced up sloping land features like a mountain range.

- Like advection fog, requires wind for formation and continued existence.

- Unlike radiation fog, which can burn off with the sun, upslope fog can persist for days.

Steam Fog

- Common over bodies of water during the coldest times of the year, and because of that it's also known as sea smoke.
- Forms when cold, dry air moves over warm water. As the water evaporates, it rises and resembles smoke.
- Low-level turbulence can occur (and icing can become hazardous) with the presence of steam fog.

Ice Fog

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- Occurs in cold weather when the temperature is way below freezing, and water vapor forms directly into ice crystals.
- Conditions favorable for the formation of ice fog are low-lying areas where the temperature is really cold, usually –25°F or colder.
- Happens mostly in the arctic regions, but during winter seasons, ice fog can also form at middle latitudes.

Ceiling & Visibility

Ceiling & Visibility

A **ceiling** is the lowest layer of clouds reported as being broken or overcast, or the vertical visibility into an obscuration like fog or haze. Current ceiling information is calculated by the temperature and the dew point and is reported by the aviation routine weather report (METAR) and automated weather stations of various types.

Visibility refers to the greatest horizontal distance at which prominent objects can be viewed with the naked eye. Current visibility is also reported in METAR and other aviation weather reports, as well as by automated weather systems.