UAS Standards, Reg, Law & Exam

FAA Regulations: Part 107

Lesson 3b – Weather Conditions

Objectives of Weather

- To determine that the applicant is knowledgeable in sources of weather information
- To determine that the applicant is knowledgeable of the effects of weather on performance

What is Weather?

- Short term atmospheric conditions for a specific area

Elements of Weather and Climate

- Temperature
- Pressure
- Wind
- Moisture

Moisture and Temperature

- Water in the atmosphere can occur in any of its three phases or states:
  - Solid
  - Liquid
  - Gas (water vapor)
- Most of the water in the atmosphere is in the form of water vapor

Moisture and Temperature

- 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
- As water changes from one state to another, an exchange of heat takes place; these changes occur through the processes of
  - Evaporation (liquid water to water vapor)
  - Sublimation (changing of ice directly to water vapor)
  - Condensation (water vapor to liquid water)
  - Melting (ice to liquid water)
  - Freezing (liquid water to ice)
  - Deposition (e.g., frost, dew, etc.)
- The only ways water vapor is added into the atmosphere is through evaporation or sublimation

Water Vapor in the Atmosphere – Temperature / Dew Point

- The dew point, given in degrees, is the temperature at which the air can hold no more moisture as water vapor
- As moist, unstable air rises, clouds often form at the altitude where temperature and dew point reach the same value
- At this point, the air is completely saturated, and moisture begins to condense out of the air in the form of fog, dew, frost, clouds, rain, hail, or snow
- Typically, when the temperature and the dew point converge near the ground, 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.

Water in the Atmosphere – Clouds

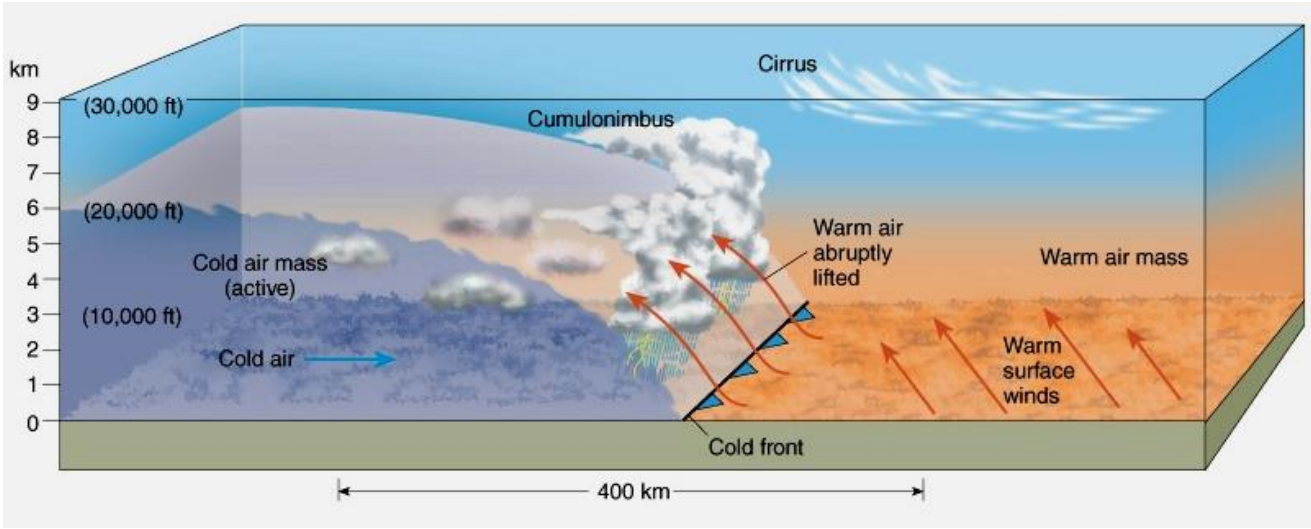
- Clouds are not water vapor
- Clouds are liquid water or ice crystals
- Some clouds can be turbulent
  - Cumulonimbus clouds are very turbulent; associated with thunderstorms
  - Lenticular clouds indicate high winds

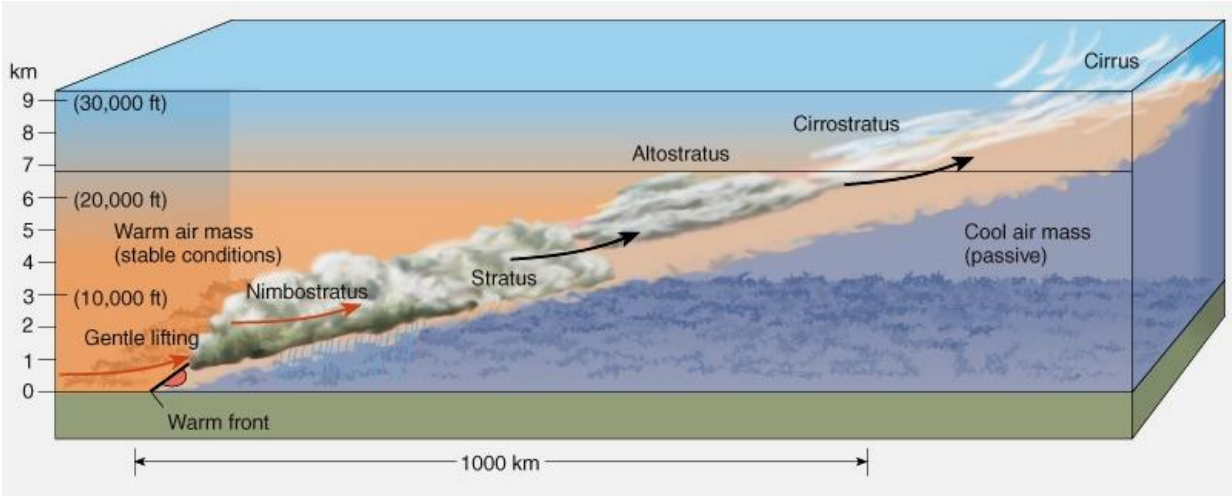
Cumulonimbus clouds.
Source: whatsthiscloud.com

Lenticular cloud above Skaftafell glacier in Iceland.
Source: https://en.wikipedia.org/wiki/Lenticular_cloud

Clouds Associated with Fronts

Cold Front





Warm Front

Characteristics of Unstable Air

- When an air mass passes over a warmer surface, that air mass is warmed from below; and this causes convective currents to form, which causes the air to rise; when the air rises, this creates an unstable air mass with good surface visibility
- Moist, unstable air has good visibility, but it also causes turbulence, cumulus clouds, and showers
- Unstable air tends to display the following characteristics:
  - Cumuli-form clouds
  - Turbulent air
  - Good visibility
  - Showery precipitation

Characteristics of Stable Air

- When an air mass passes over a colder surface, convective currents do not form; instead, you get a stable air mass with poor surface visibility
- Dry stable air has poor visibility, lacks significant turbulence, stratus clouds, and widespread precipitation
- Stable air tends to display the following characteristics:
  - Strati-form clouds
  - Smooth air
  - Fair-to-poor visibility in haze and smoke
  - Continuous precipitation

Characteristics of Stable Air

- Because there are no convective current, there is no air rising which results in smoke, dust, and other particles being trapped near the surface resulting in reduced visibility
- Stable air masses with poor surface visibility can produce:
- Stable air tends to display the following characteristics:
  - Steady precipitation
  - Low stratus clouds
  - Fog

Unstable vs. Stable Air

Unstable Air	Stable Air
Cumuliform clouds	Stratiform clouds and fog
Showery precipitation	Continuous precipitation
Rough air (turbulence)	Smooth air
Good visibility (except in blowing obstructions)	Fair to poor visibility in haze and smoke

Weather Factors and Performance – Air Masses and Fronts

- As an air mass moves across bodies of water and land, eventually it comes in contact with another air mass that has different characteristics
- A front is the boundary layer between two different air masses or areas of pressure
- 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 temperature
- Fronts are named according to the temperature of the advancing air relative to the temperature of the air it is replacing
- Why do we care? – because fronts are responsible for weather

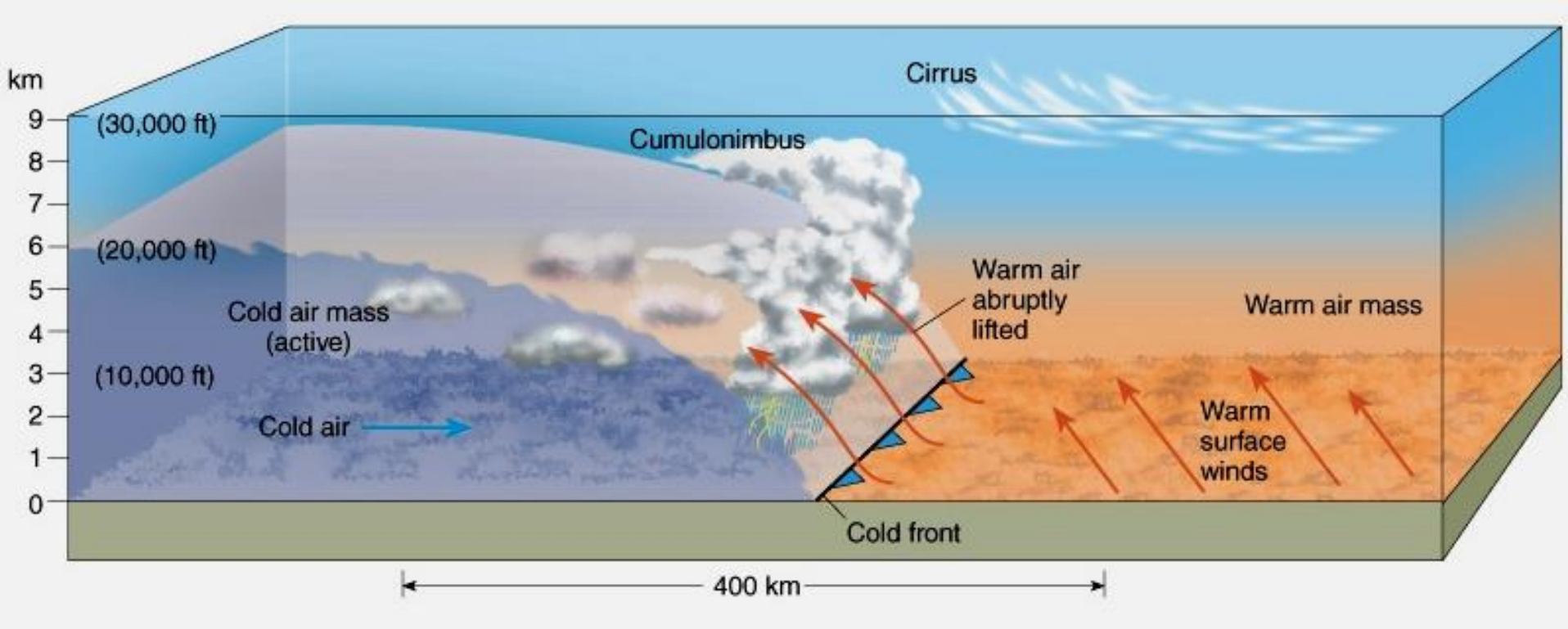
Types of Fronts

- Warm Front – a warm front happens 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 to 25 miles per hour (mph)
- Cold Front – a cold front happens 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 to 30 mph; however, extreme cold fronts have been recorded moving at speeds of up to 60 mph
- Usually, a cold front moves in a manner opposite that of a warm front; this cold, stable air is really dense, so it stays close to the ground and acts kind of like a snowplow, sliding under the warmer air and forcing the less dense air aloft

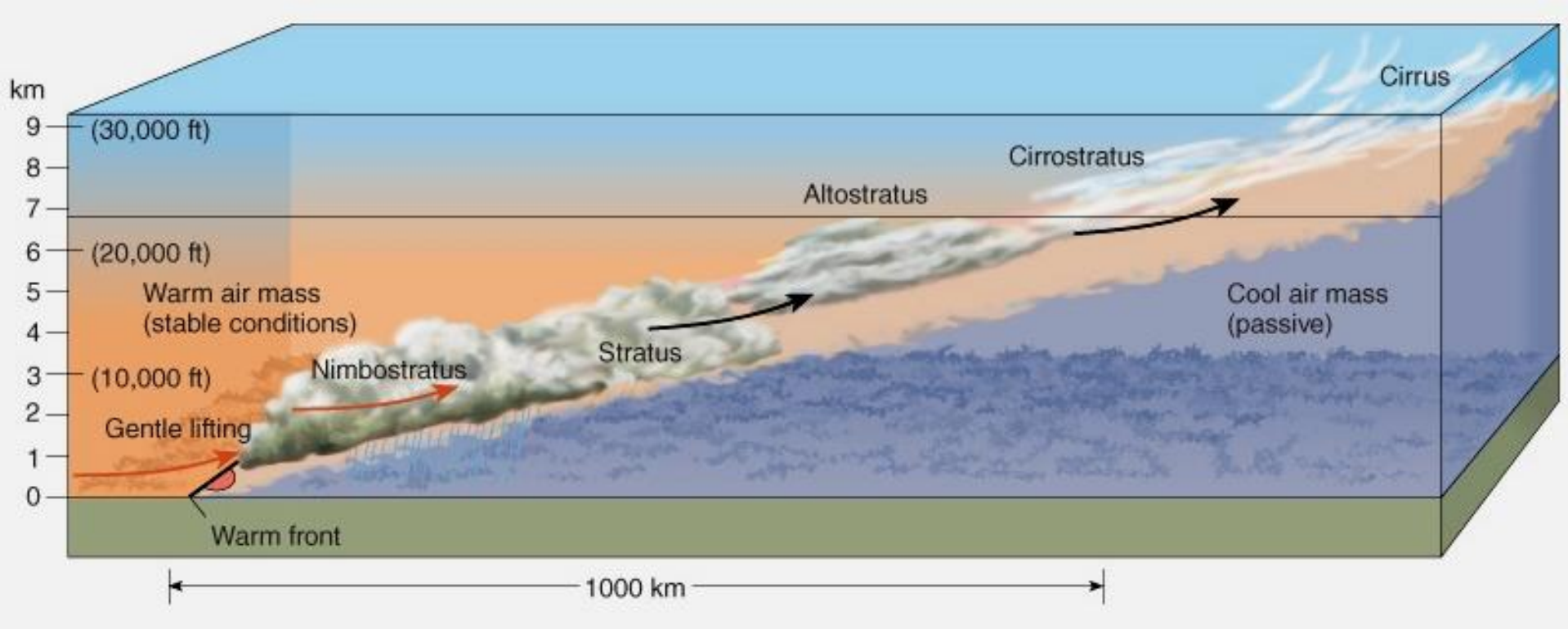
Warm vs. Cold Fronts

- Weather Activity – while warm fronts bring low ceilings, poor visibility, and rain, cold fronts bring sudden storms, gusty winds, turbulence, and sometimes hail or tornadoes; a cold front can be characterized by its shifting wind conditions and 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

Cold Front


km
9
8
7
6
5
4
3
2
1
0
(30,000 ft)
(20,000 ft)
(10,000 ft)
Cirrus
Cumulonimbus
Warm air
abruptly
lifted
Warm air mass
Cold air mass
(active)
Cold air
Warm
surface
winds
Cold front
400 km

Warm Front

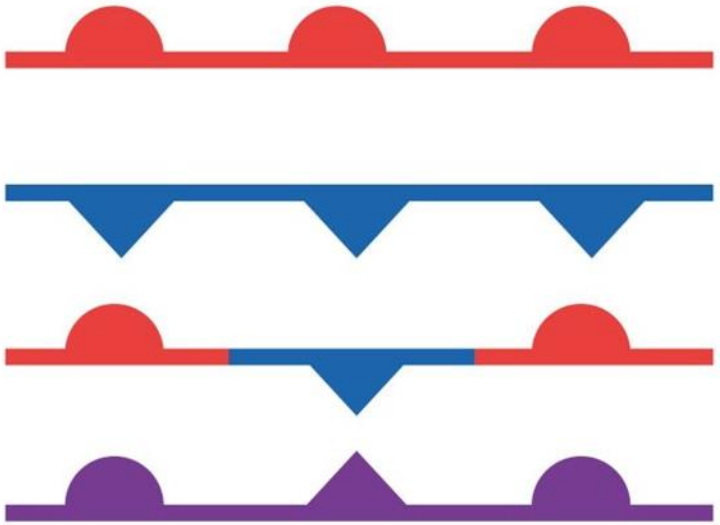

km
9
8
7
6
5
4
3
2
1
0
(30,000 ft)
(20,000 ft)
(10,000 ft)
Warm air mass
(stable conditions)
Gentle lifting
Nimbostratus
Stratus
Altostratus
Cirrostratus
Cirrus
Cool air mass
(passive)
Warm front
1000 km

Other Types of Fronts

- Stationary Front – 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; this front is called a stationary front; the weather associated with a stationary front is typically a mixture that can be found in both warm and cold fronts
- Occluded – an occluded front occurs when a fast-moving cold front catches up with a slow-moving warm front; there are two types of occluded fronts that can occur, and the temperatures of the colliding frontal systems play a large part in defining the type of front and the resulting weather

Fronts on Weather Maps

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

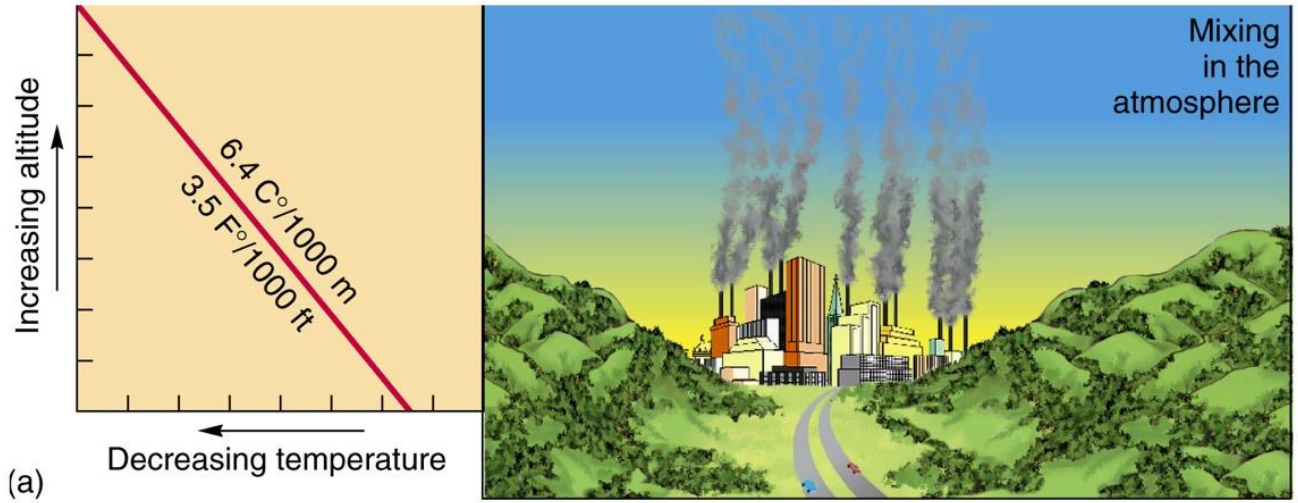
Atmospheric Stability

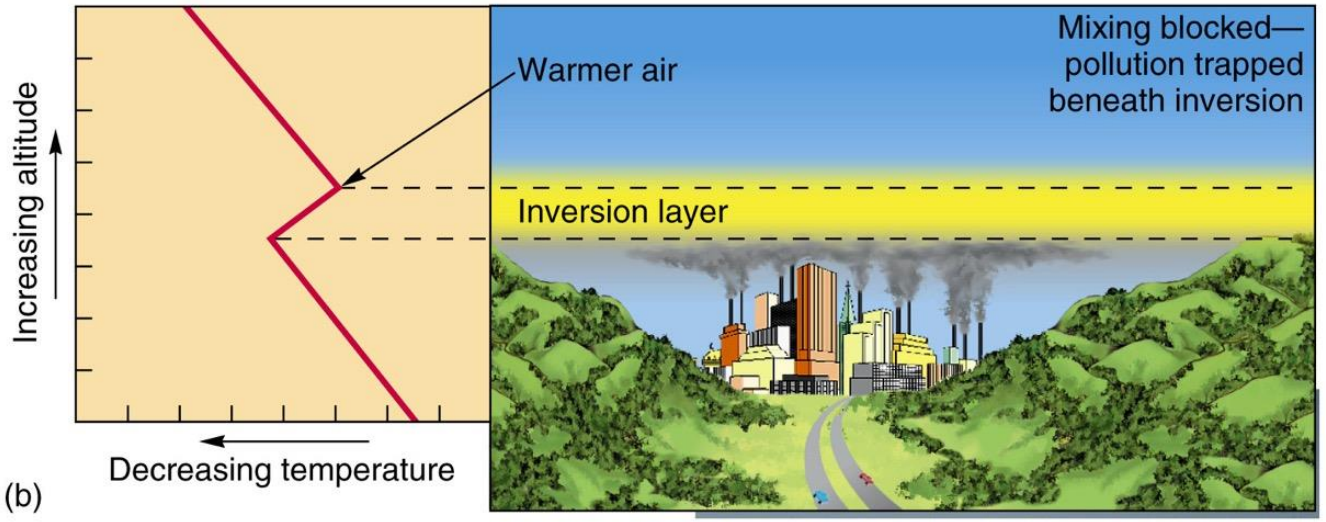
- The combination of temperature and moisture determine the stability of the air and the resulting weather; cool, dry air is very stable and resists vertical movement
  - Results in good and generally clear weather
  - Strati-form clouds may be present in this case
- Warm, moist air has the greatest instability, such as 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

- As air rises and expands in the atmosphere, the temperature decreases; however, an atmospheric anomaly called a temperature inversion can occur where the opposite happens
- When the temperature of the air RISES with altitude, this is called a temperature inversion
- Inversion layers are typically these layers of smooth, stable air close to the ground; the temperature of the air increases with altitude to a certain point, and that is the top of the inversion

Temperature Inversion

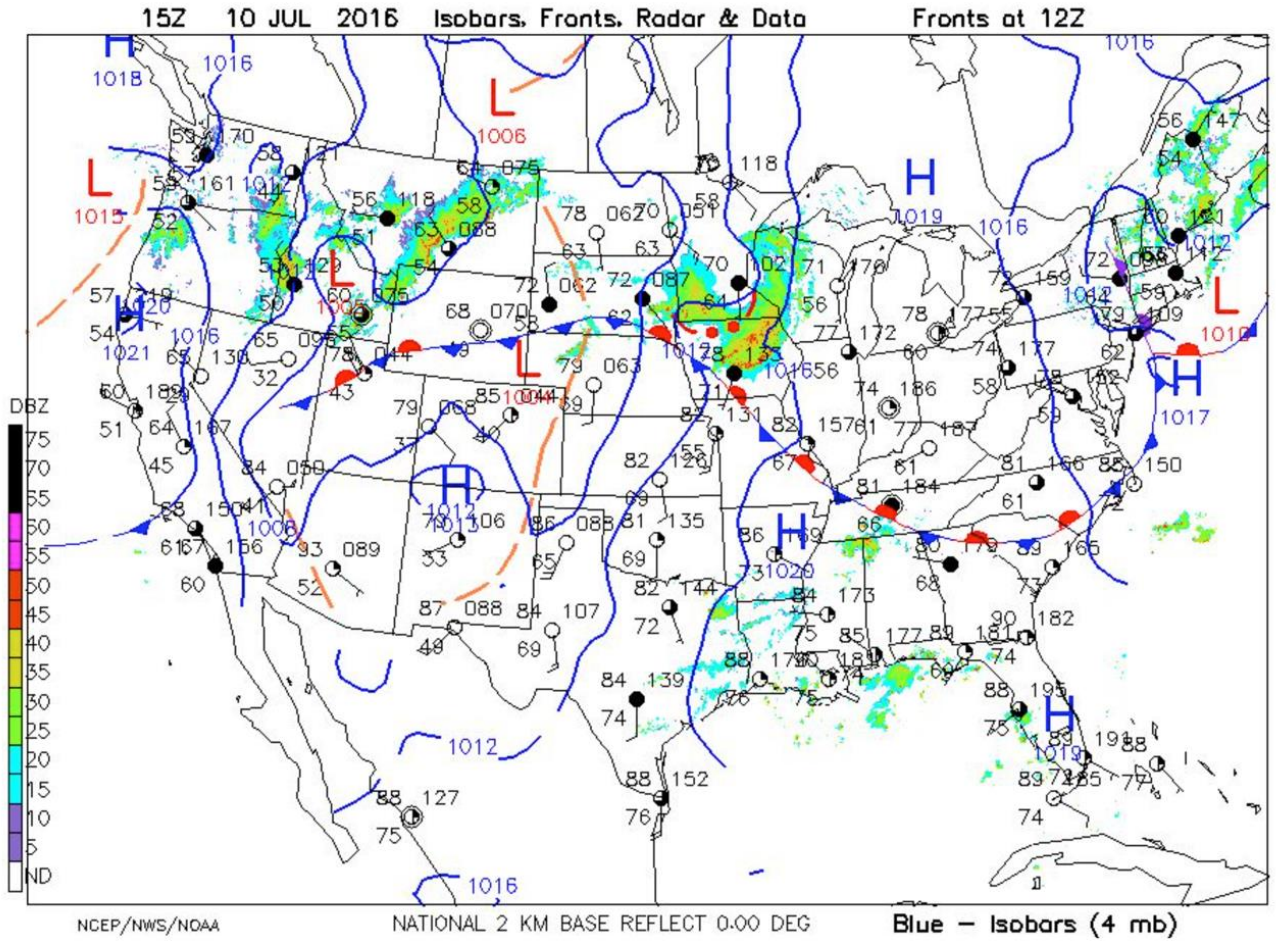




Temperature Inversion

- The air at the top of the inversion layer acts as a kind of lid, keeping weather and pollutants trapped below; if the relative humidity of the air is high, it can contribute to the formation of clouds, fog, haze, or smoke, resulting in diminished visibility in the inversion layer
- 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; the air within a few hundred feet of the surface becomes cooler than the air above it

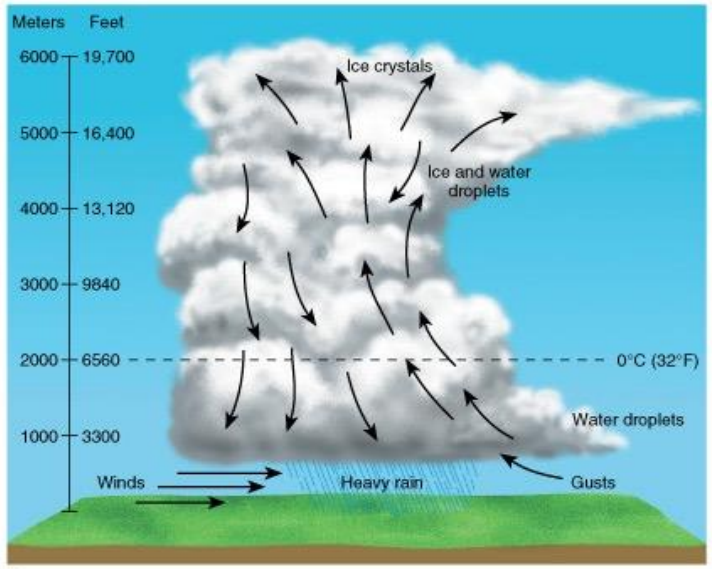
Weather Map – July 10th, 2016



Thunderstorms

- Very dangerous for UAS flight
- Thunderstorms can produce updraft and downdraft that exceed 3,000 feet per minute
- The most severe thunderstorm conditions (those with destructive winds, tornadoes, heavy hail, etc.) are associated with squall line thunderstorms
- A squall line is non-frontal, narrow band of thunderstorms usually ahead of a cold front

Cumulonimbus Clouds Development



(a)


(b)


(c)

Thunderstorm Phases

- Thunderstorms are produced by cumulonimbus clouds that form when there is:
  - Sufficient water vapor or moisture
  - An unstable lapse rate
  - An initial upward boost to start the process (heat)
- Thunderstorms develop through three distinct stages before dissipating:
  - First stage – cumulus stage
  - Second stage – mature stage
  - Third stage – dissipating stage

Life Cycle of A Thunderstorm

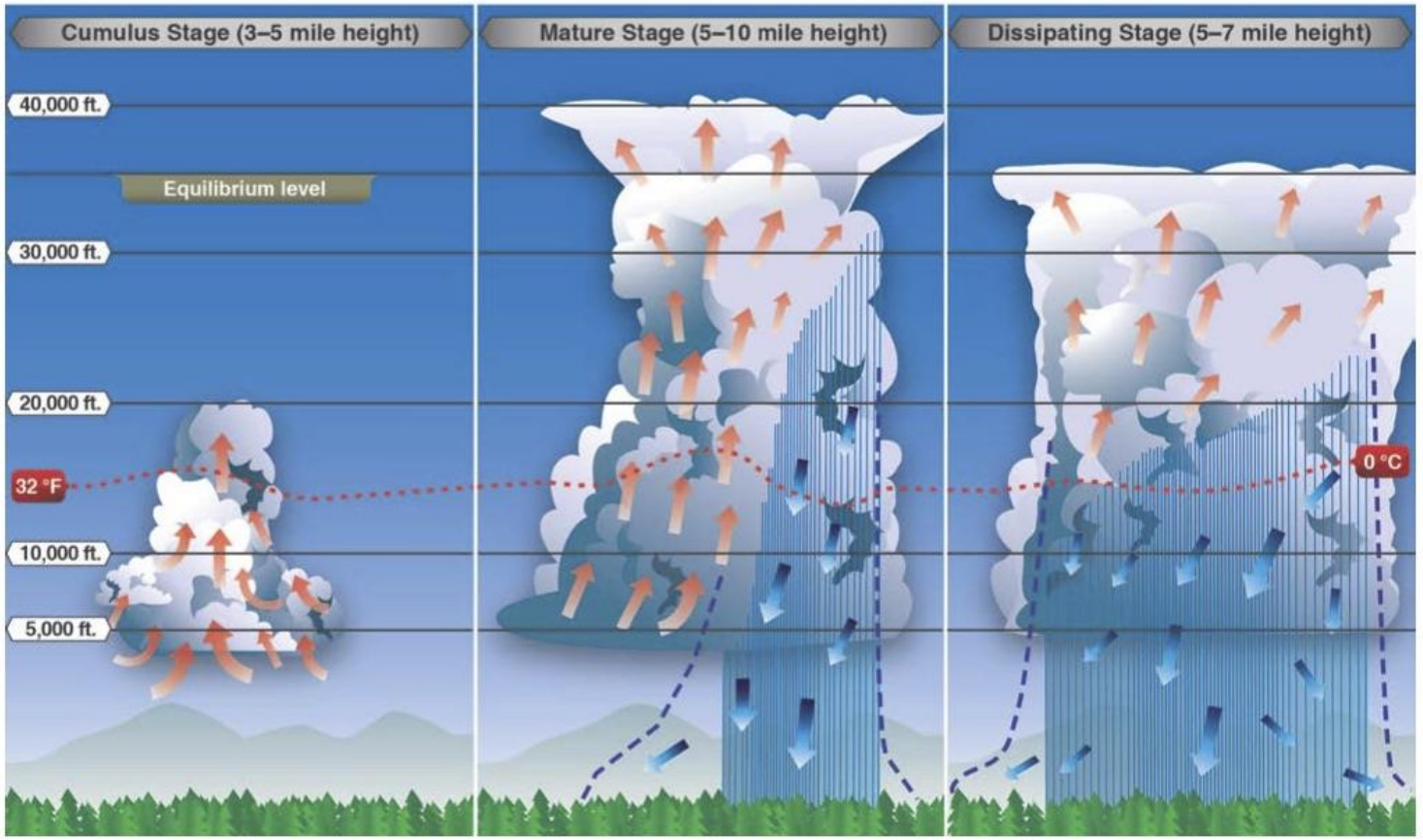


Figure 3-4. *Life cycle of a thunderstorm.*

Source: Remote Pilot Study Guide

Thunderstorm Phases

- The cumulus stage occurs when the lifting action of the air begins; if sufficient moisture and instability are present, the clouds continue to increase in vertical height; **vertical development always means wind shear and turbulence**
  - Continuous, strong updrafts prohibit moisture from falling
  - The updraft region grows larger than the individual thermals feeding the storm
- The mature stage occurs within approximately 15 minutes, when the thunderstorm reaches the most violent part of its life cycle
  - At this point, the moisture condensing or freezing within the cloud, as rain or ice are too heavy for the rising/turbulent air in the cloud to support;
  - This results in precipitation in the form of rain or hail;
  - This creates a downward motion of the air; warm, rising air; cool, precipitation-induced descending air; and violent turbulence all exist within and near the cloud
  - Below the cloud, the down-rushing air increases surface winds and decreases the temperature
- The dissipating stage occurs once the vertical motion near the top of the cloud slows and the top of the cloud spreads out, taking on the characteristic anvil-like shape; during this stage the downdrafts spread out and replace the updrafts needed to sustain the storm

Thunderstorms – Notes

- Not all thunderstorms are visible
- An embedded thunderstorm is obscured by other clouds, this is frequent in New Mexico
- A good rule of thumb is to not operate an unmanned aircraft within 20 nautical miles of a thunderstorm, since hail may fall for miles outside of the clouds
- This may not be possible at some times of the year so the RPIC must be extra vigilant when thunderstorms are present in the area

Wind Shear and Microbursts

- Wind Shear
  - 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 is typically characterized by directional wind changes of 180° and speed changes of 50 knots or more
  - Low-level (low-altitude) wind shear can be particularly hazardous for remote pilots, due to the proximity of your UA to the ground; wind shear can cause violent updrafts and downdrafts, and due to increased wind speed, it can push your aircraft around horizontally with sudden, unforeseen force
  - Wind shear is commonly associated with passing frontal systems, thunderstorms, and temperature inversions with strong upper level winds (greater than 25 knots)
- Microburst
  - One type of wind shear is a microburst; a microburst is associated with convective precipitation, which is shorter and more intense; a microburst typically occurs in a space of less than one mile horizontally and within 1,000 feet vertically for about 15 minutes; it can produce severe downdrafts of up to 6,000 feet per minute (fpm)
  - It can also produce a hazardous wind direction change of 45 degrees or more, in a matter of seconds

Wind Shear and Microbursts

- Wind shear can occur at any altitude
- Always be alert to the possibility of wind shear, particularly when flying in and around thunderstorms and frontal systems
- Expect wind shear in a temperature inversion whenever wind speed at 2,000 to 4,000 ft. AGL is 25 knots or more

Clouds and Part 107

- Must fly 500’ below AND 2,000’ laterally from clouds
- So how do you know how far below clouds you can fly
- You need to know what the “Cloud Base” is for where you are flying; this is easily calculated from the surface air temperature and dew point temperature

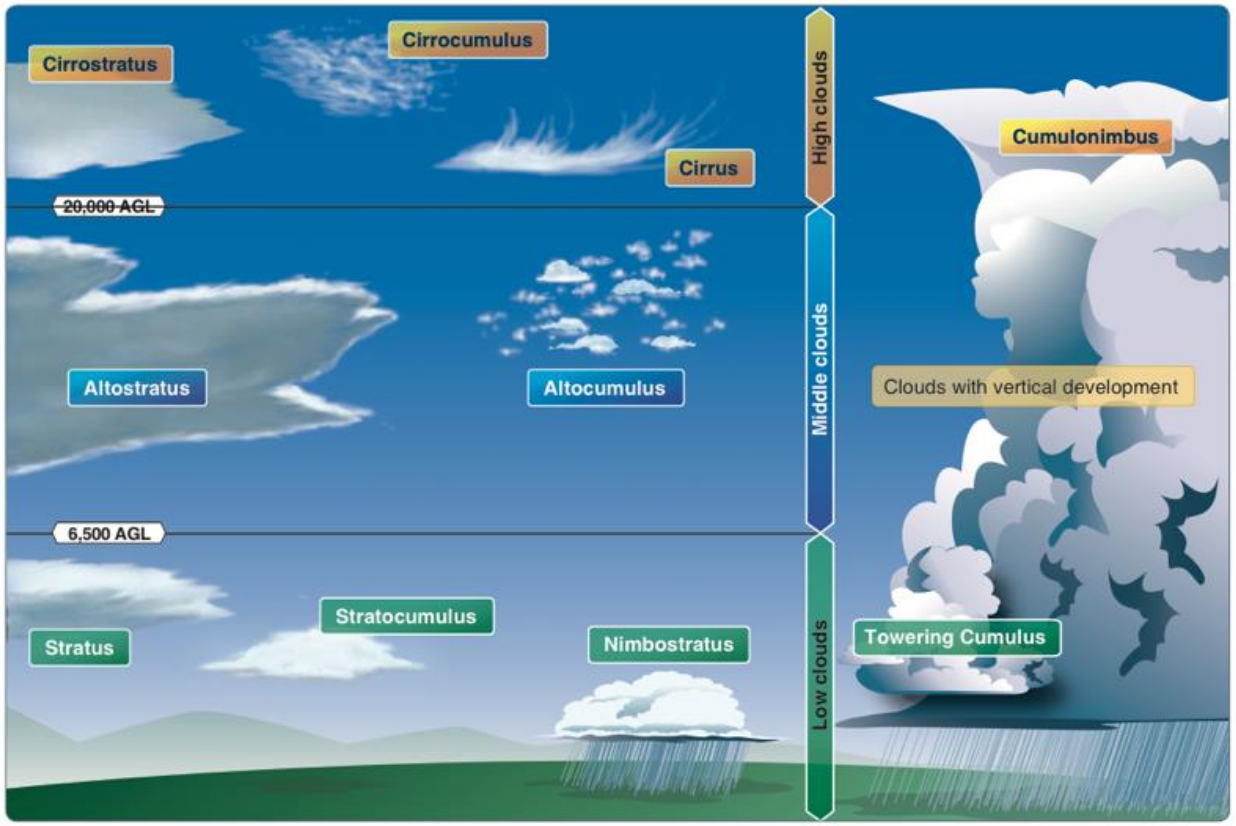


Figure 12-22. *Basic cloud types.*

Aviation Weather Calculating the Cloud Base

- As moist, unstable air rises, clouds often form at the altitude where temperature and dew point reach the same value
- When lifted, unsaturated air cools at a rate of 5.4 °F per 1,000 feet and the dew point temperature decreases at a rate of 1 °F per 1,000 feet; this results in a convergence of temperature and dew point at a rate of 4.4 °F; apply the convergence rate to the reported temperature and dew point to determine the height of the cloud base
  - Given:
    Temperature (T) = 85 °F
    Dew point (DP) = 71 °F
    Convergence Rate (CR) = 4.4°
    T – DP = Temperature Dew Point Spread (TDS)
    TDS ÷ CR = X
    X × 1,000 feet = height of cloud base AGL
  - Example:
    85 °F – 71 °F = 14 °F
    14 °F ÷ 4.4 °F = 3.18
    3.18 × 1,000 = 3,180 feet AGL
    The height of the cloud base is 3,180 feet AGL

Tornadoes

- Any cloud connected to a severe thunderstorm can spawn tornadic activity, even if it is miles away from the main thunderstorm cloud
- So if there is threating weather that is likely to produce tornadoes DON'T FLY

Icing

- Pilots should be alert for icing anytime
  - The temperature approaches 0°C, and
  - There is visible moisture in the air
- Specifically, airframe icing would be when ice builds up on your UAS and it can no longer sustain flight
- In the same way that frost can change the aerodynamic qualities of the propellers, ice can do the same thing; any presence of frost or ice will dramatically and negatively affect the UAS' ability to fly

Drone Operation in Freezing Weather

- Don’t do it!
- Numb fingers may accidentally bump controls
- Batteries are less efficient in cold weather

Hail

- Hail should be anticipated with any thunderstorm, especially beneath the anvil of a large cumulonimbus cloud
- Hail can be encountered in clear air several miles from thunderstorm clouds. So be aware of possible hail and check local weather alerts and forecasts
- Even small hailstones can damage an unmanned aircraft, so exercise extreme caution if there is thunderstorm activity in your area, even if it is distant

Fog

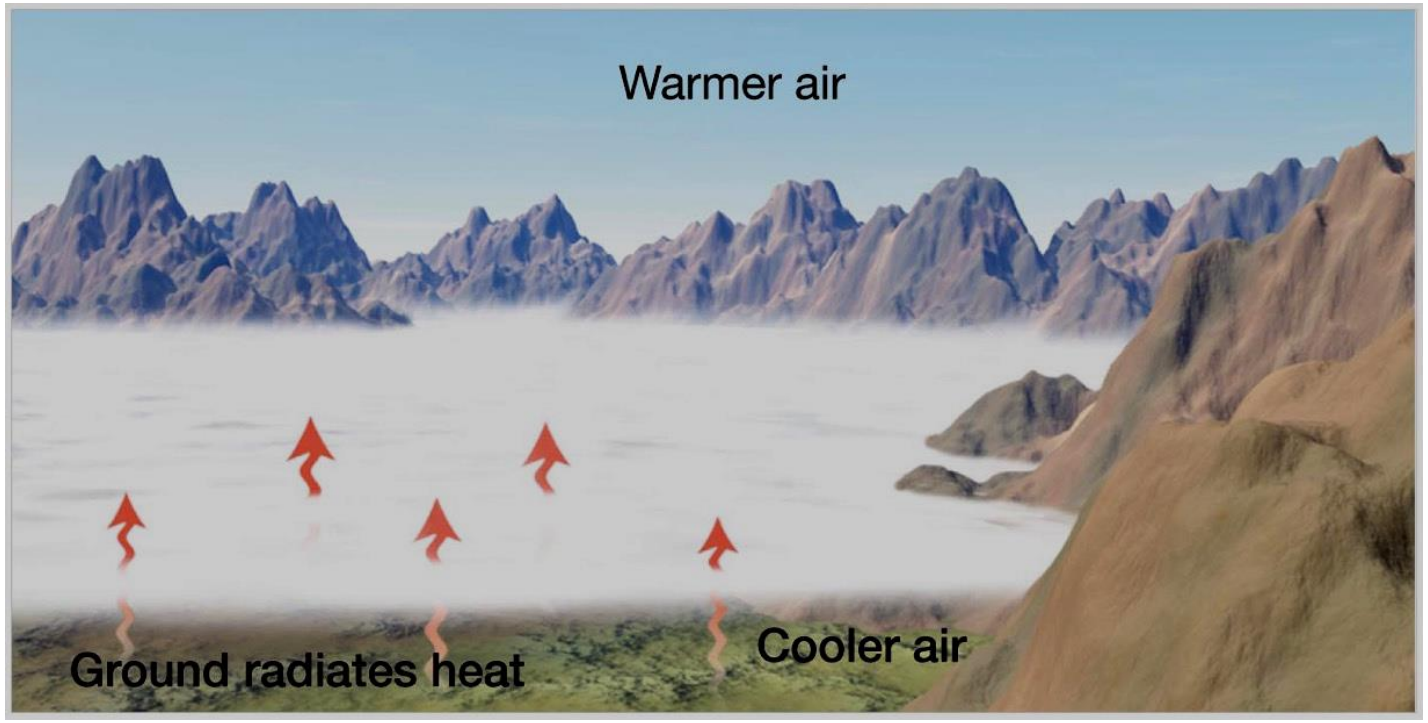
- Fog is a cloud that begins within 50 feet of the surface
- Fog typically occurs when the temperature of air near the ground is cooled to the air's dew point. The dew point is the temperature at which the air will have 100% humidity – it is fully saturated with water vapor; at this point, the water vapor in the air condenses and becomes visible in the form of fog
- Clouds, dew, and fog will always form when water vapor condenses
- DON'T fly in Fog! Because it may prevent you from maintaining visible-line-of-sight with your aircraft
- Since fog is a cloud you cannot legally fly anyway because you cannot remain 500 feet below fog

Types of Fog

- As aforementioned, fog is a cloud that is on the surface
- It typically occurs when the temperature of air near the ground is cooled to the air's dew point; At this point, water vapor in the air condenses and becomes visible in the form of fog
- Fog is classified according to the manner in which it forms and is dependent upon the current temperature and the amount of water vapor in the air
  - Radiation fog
  - Advection fog
  - Upslope fog
  - Steam fog
  - Ice fog

Radiation Fog

- Radiation fog typically forms in low-lying areas like a mountain valley
- Radiation fog happens when the ground cools rapidly due to terrestrial radiation, and the surrounding air temperature reaches its dew point. It'll form on clear nights, with relatively little to no wind present
- As the sun rises in the morning and the temperature increases, radiation fog lifts and eventually burns off; an increase in wind speed can speed up the dissipation of radiation fog

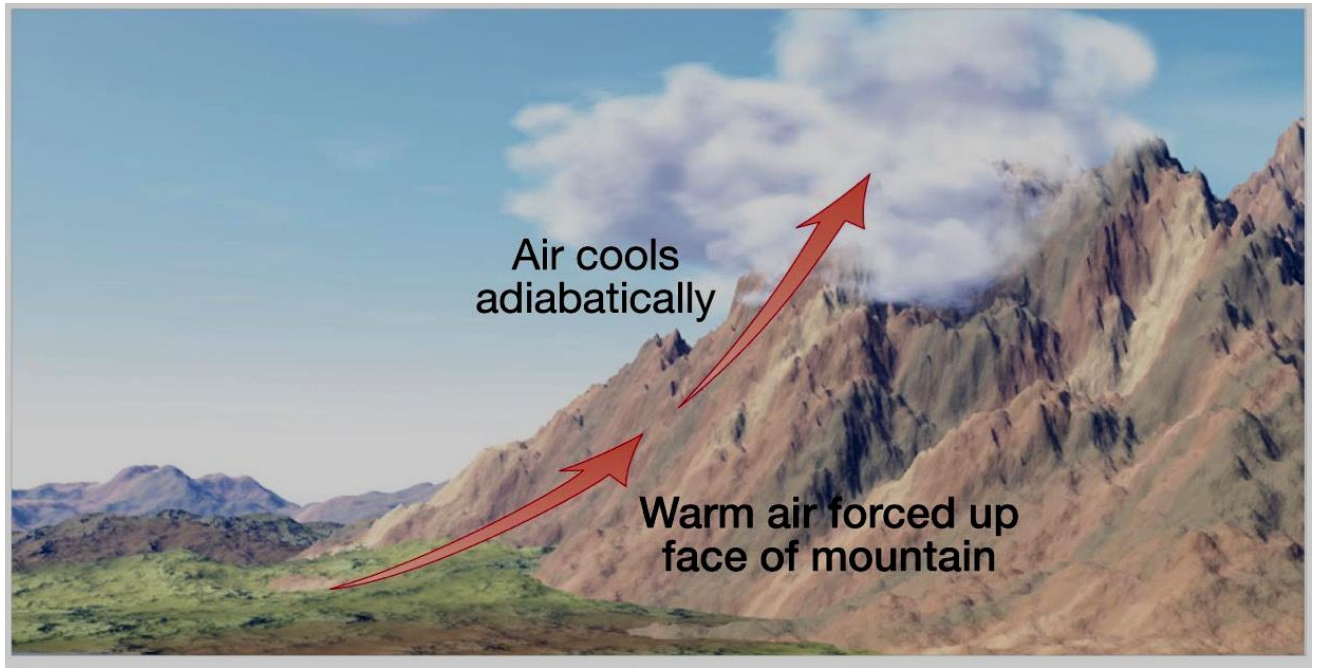


Advection Fog

- Advection fog is common in coastal areas where sea breezes can blow moist air over cooler land masses
- Advection fog is likely to form when a layer of warm, moist air moves over a cold surface
- Unlike radiation fog, 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
- This type of fog can persist for days

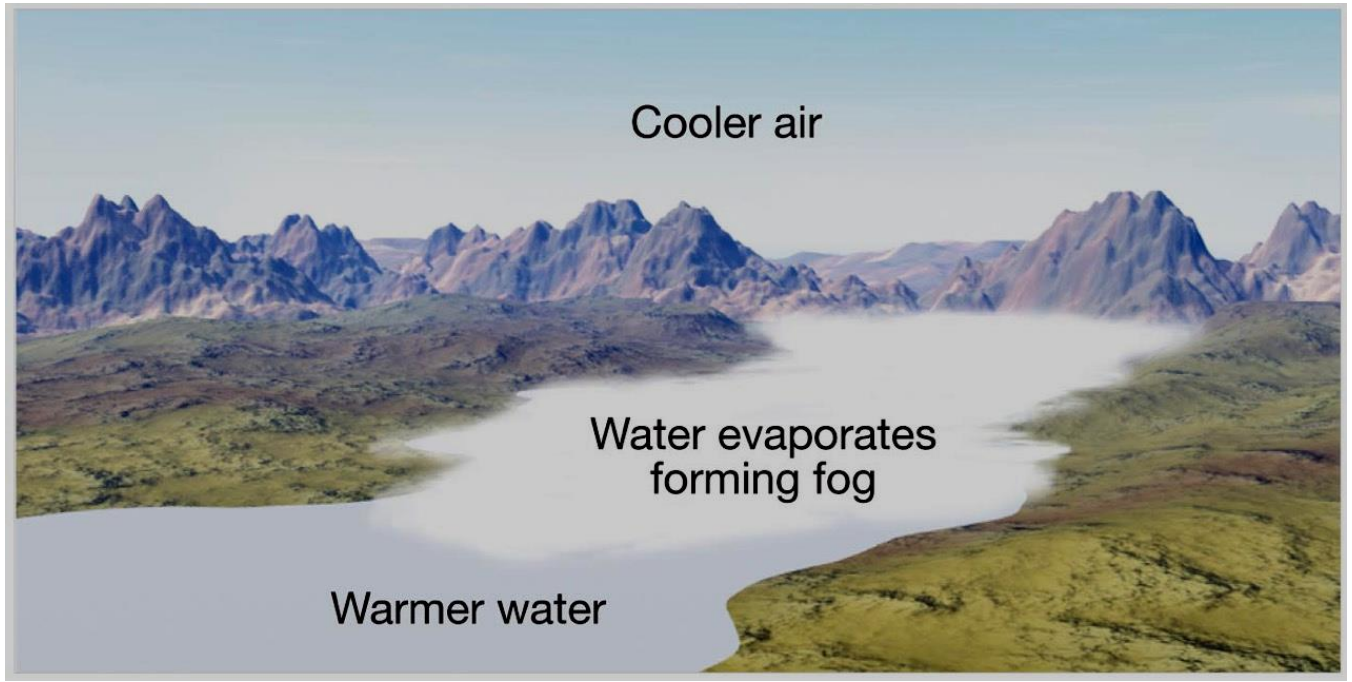
Upslope Fog

- Upslope fog occurs when moist, stable air is forced up sloping land features like a mountain range
- Like advection fog, upslope 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/Evaporation Fog

- Steam fog is common over bodies of water during the coldest times of the year, and because of that, it is also known as sea smoke
- Steam fog 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

- Ice fog occurs in cold weather when the temperature is well below freezing, and water vapor forms directly into ice crystals
- It is unlikely that you would be operating an unmanned aircraft in this environment
- Conditions favorable for the formation of ice fog are low-lying areas where the temperature is really cold, usually –25°F or colder
- Ice fog happens mostly in the arctic regions, but during winter seasons, ice fog can also form at middle latitudes

Ceiling and Visibility

- FAA regulations require that remote pilots must keep their UAS at least 500 feet below clouds and 2,000 feet horizontally away from clouds
- RPIC cannot fly if the minimum flight visibility is less than 3 statute miles
- In aviation, 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

Lighting

- It goes without saying…lightning is dangerous
- A lightning strike can not only damage your flight controller and other electronic equipment, but it can also induce permanent errors in the magnetic compass
- Lightning discharges, even if they're somewhat distant, can also disrupt your radio communications

Atmospheric Stability

- 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
  - Results in good and generally clear weather
  - Strati-form clouds may be present in this case
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