Private Pilot (ASEL) Ground School Course

Lesson 18 | Weather Theory

Lesson Overview

Lesson Objectives:

- Develop knowledge of aviation weather theory.
- Develop an understanding of how to handle weather hazards and make appropriate decisions.

Lesson Completion Standards:

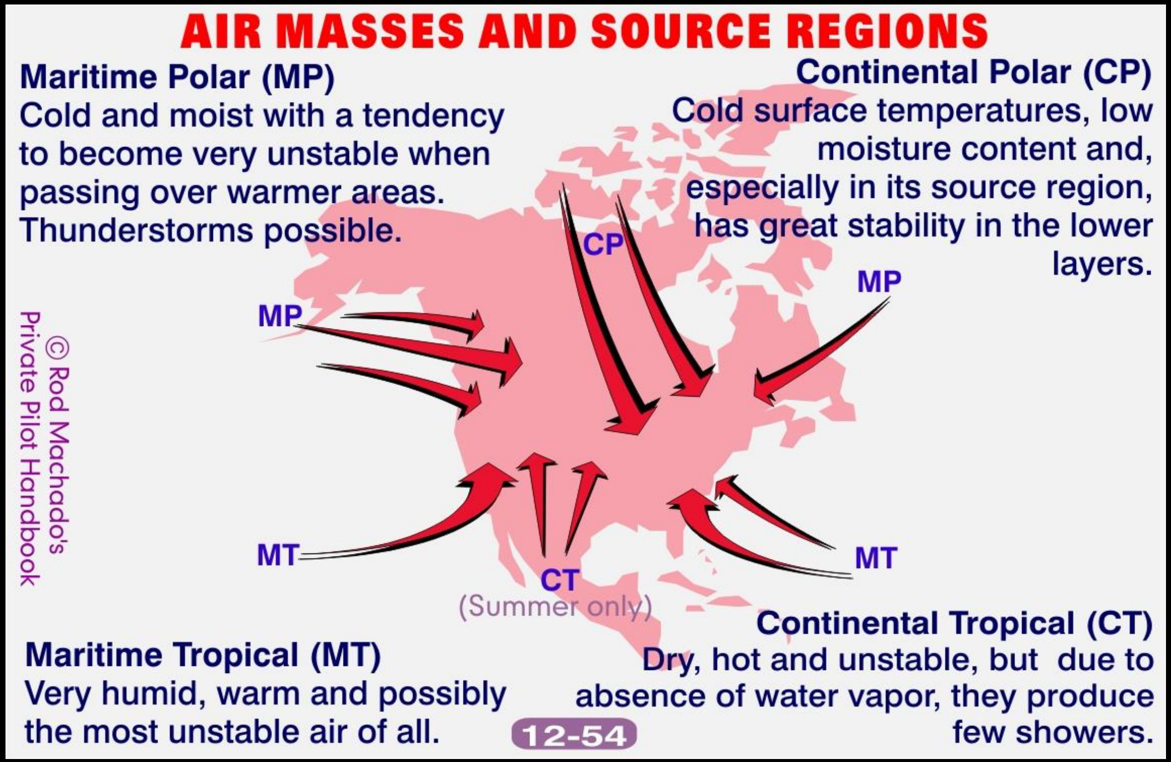
- Student demonstrates satisfactory knowledge of weather theory by answering questions and actively participating in classroom discussions.

Air Masses

Weather Theory

Air Masses and Source Regions

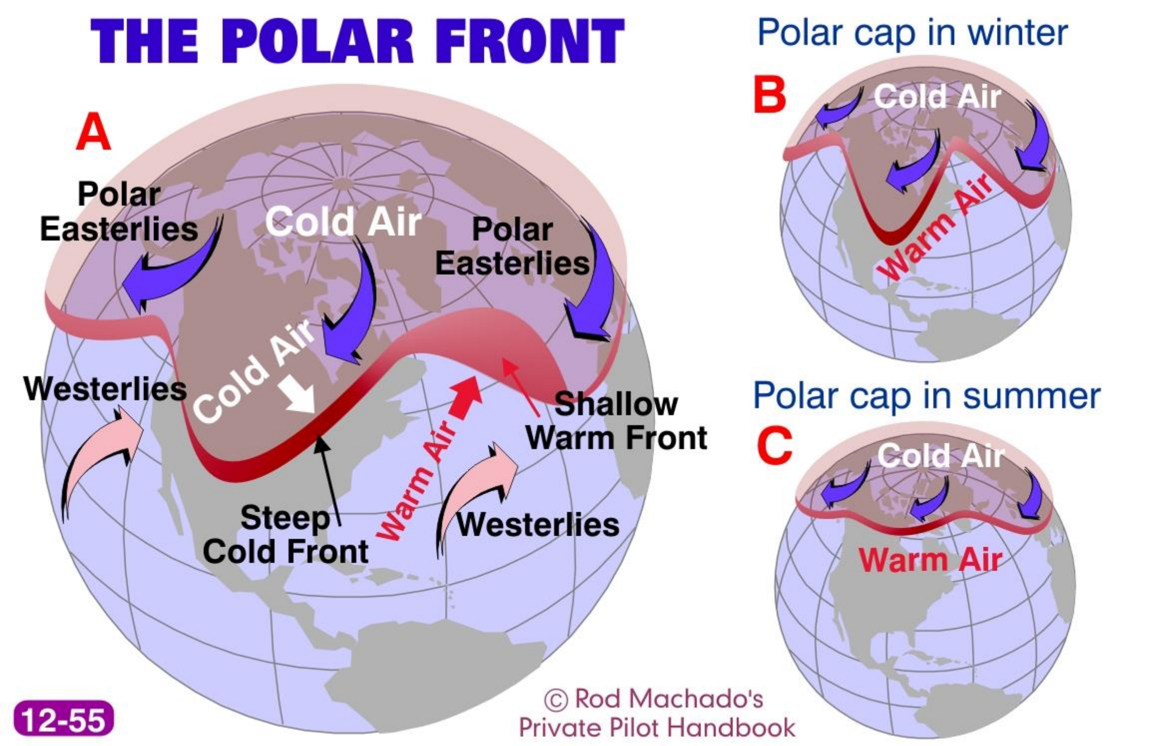
- These masses of air take on the characteristics of their source region (the land or water over which they form and originate)
- Frontal systems start with large air masses



Frontal Systems

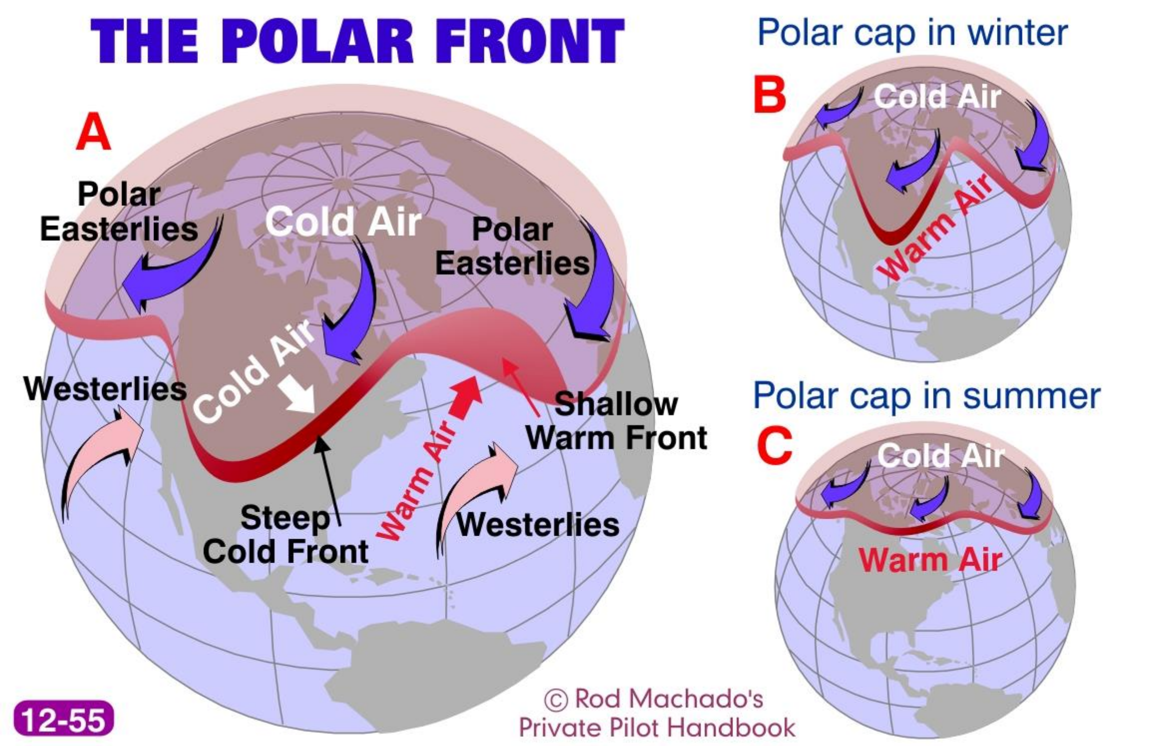
- Highs and lows are associated with more than the horizontal flow of air
- They attract or repel massive moving wedges of air known as frontal systems
- Air masses of different densities that bump into one another cause a confrontation
- The differences in temperature result in a difference in density which don’t mix readily
- The zone of transition between air masses of different densities is called a front

Polar Front



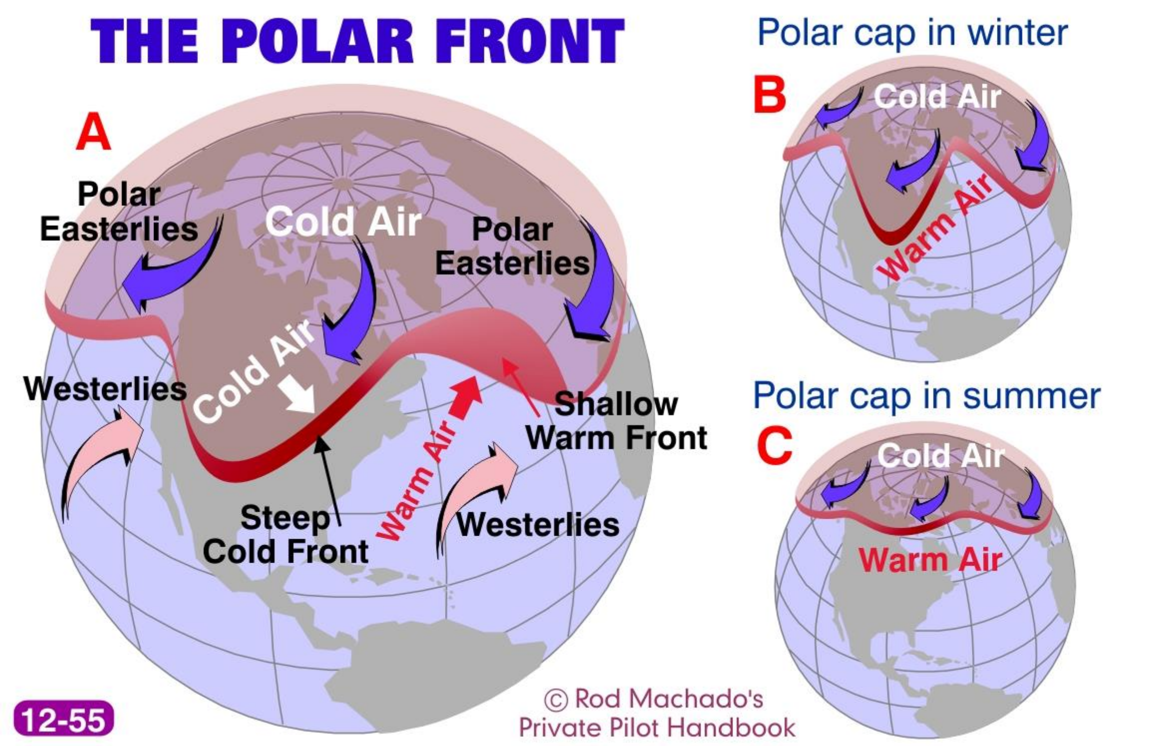
- A cap of dense, cold air sits over the north polar region
- This mass of cold air comes from the cool air descending at the poles
- Moving southward, this cap of cold air flows from the east, forming a band of winds known as the polar easterlies
- The polar front is the zone between the cold polar easterlies and the warmer prevailing westerlies

Polar Front



- Several waves of cold air occur along this frontal zone
- There can be three to seven long waves existing globally at any one time
- Plunging and retreating, these waves advance southward in one area and retreat northward in another
- The advance and retreat is frontal movement

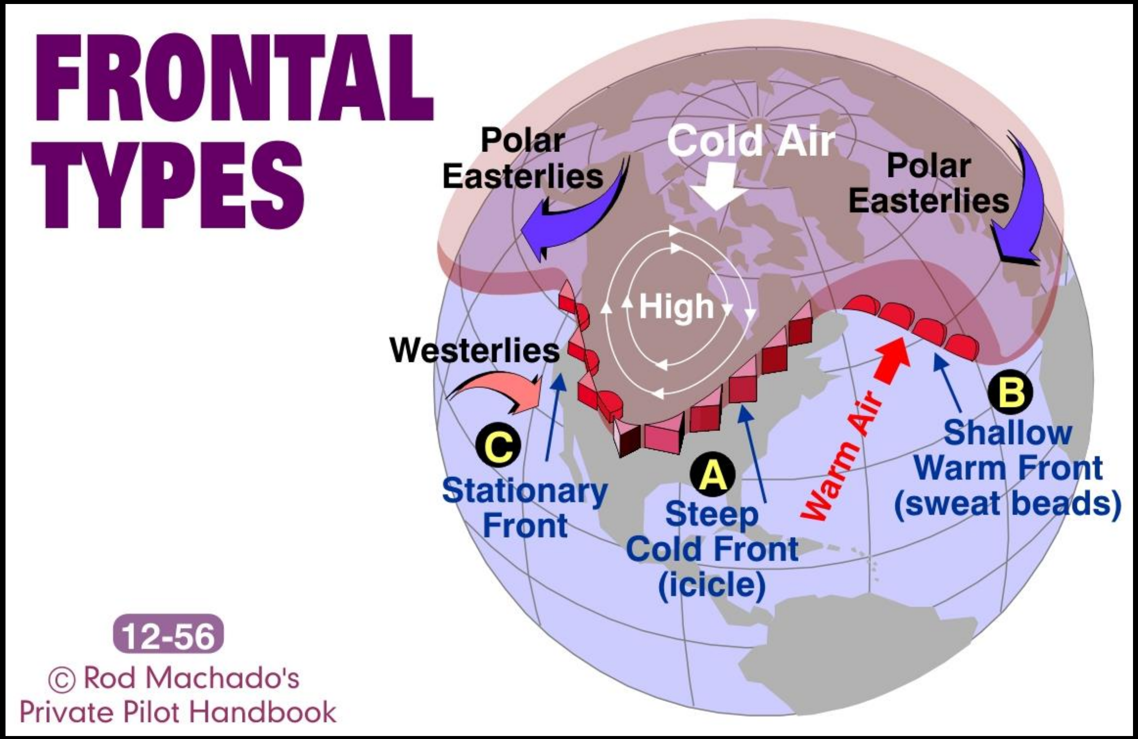
Polar Front



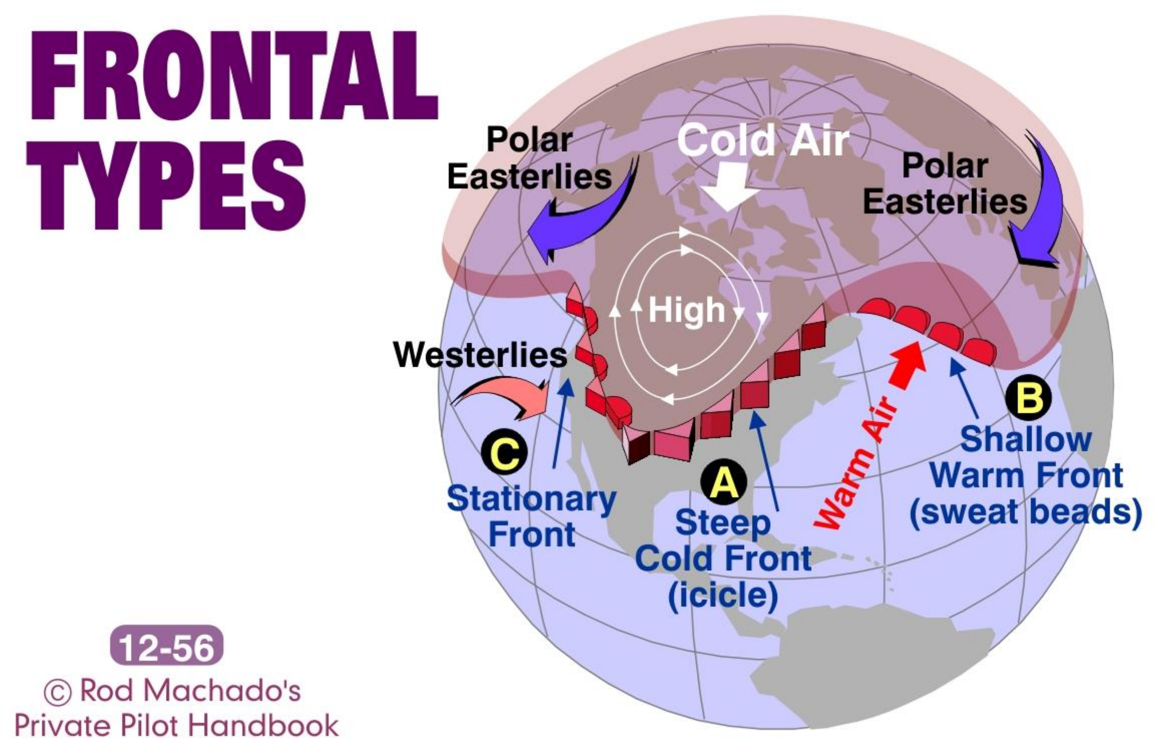
- During winter, a long cold wave of this air can plunge down into the tropics
- A cold wave advancing southward in one area can allow the introduction of warm tropical air moving northward
- Winter weather is characterized by a longer, more protruding polar front (B)
- The polar front is less wave-like in the summer (C)

Frontal Types

- As a wave of cold air moves southward, it overtakes warmer, moister air
- Icicles (triangles) represent the cold front and point in the direction it's moving (A)
- Warm tropical air fills in the receding side of the long cold wave, forming a warm front
- Beads of sweat (B), represent the warm front and point in the direction it moves



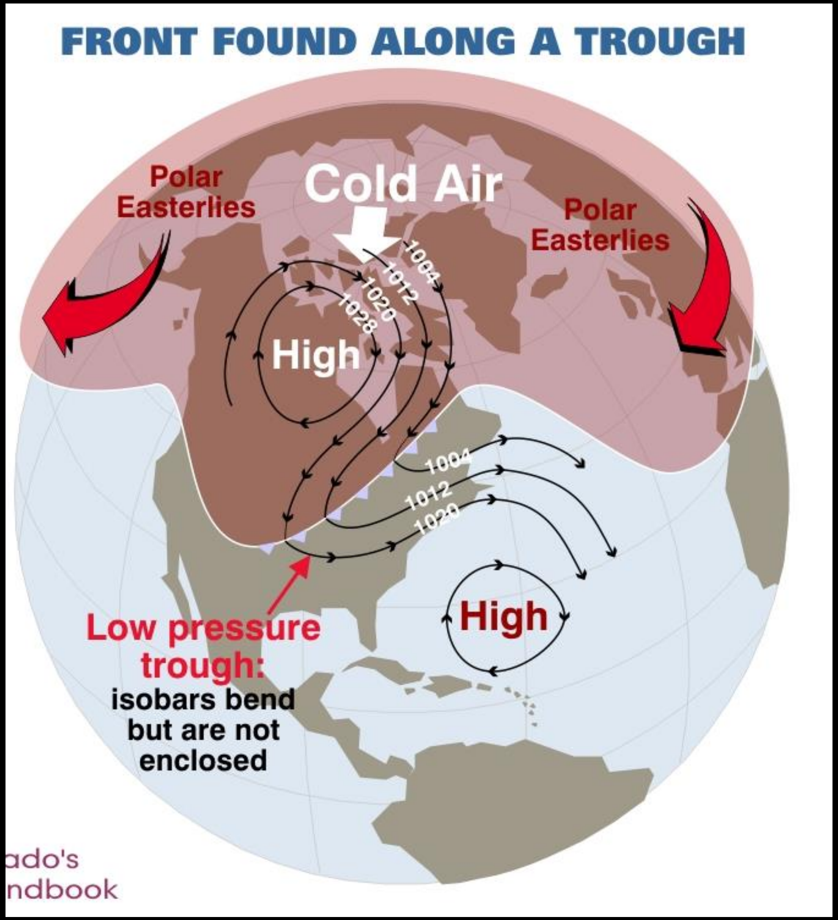
Frontal Types



- Warm and cold air butt up against one another and neither moves
- Stationary front is indicated by icicles and beads of sweat on opposite sides of a frontal line (C)
- Beads of sweat and icicles pointing in the same direction indicate that the faster moving cold front has overtaken and lifted the slower moving warm air
- This is called an occluded front

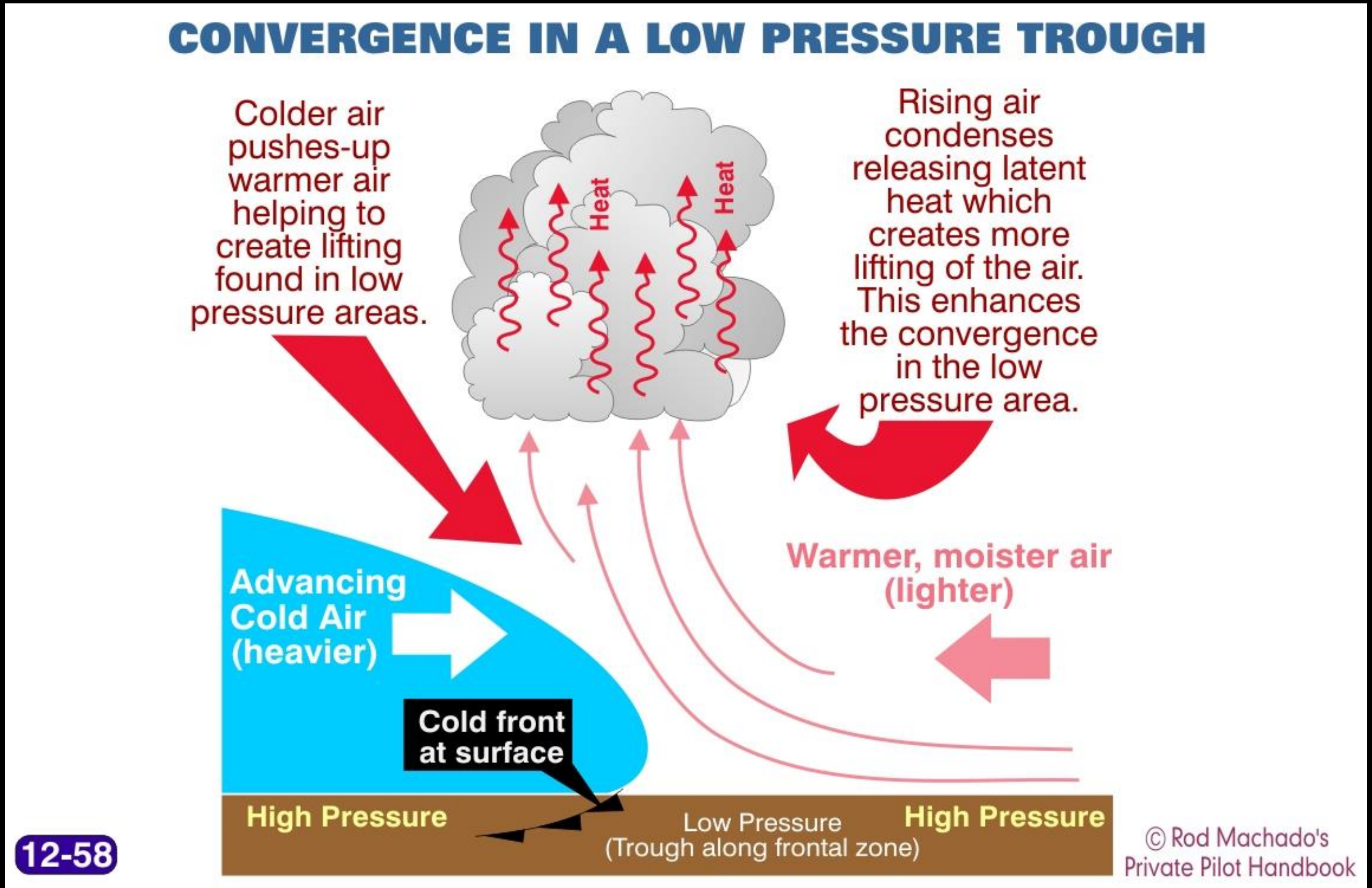
Front Within Trough

- Pressure falls as fronts approach because fronts are often found along low pressure troughs
- Cold front lies along the border between two high pressure areas
- As the front approaches, the pressure falls
- It increases after frontal passage since a high pressure area lies behind the front



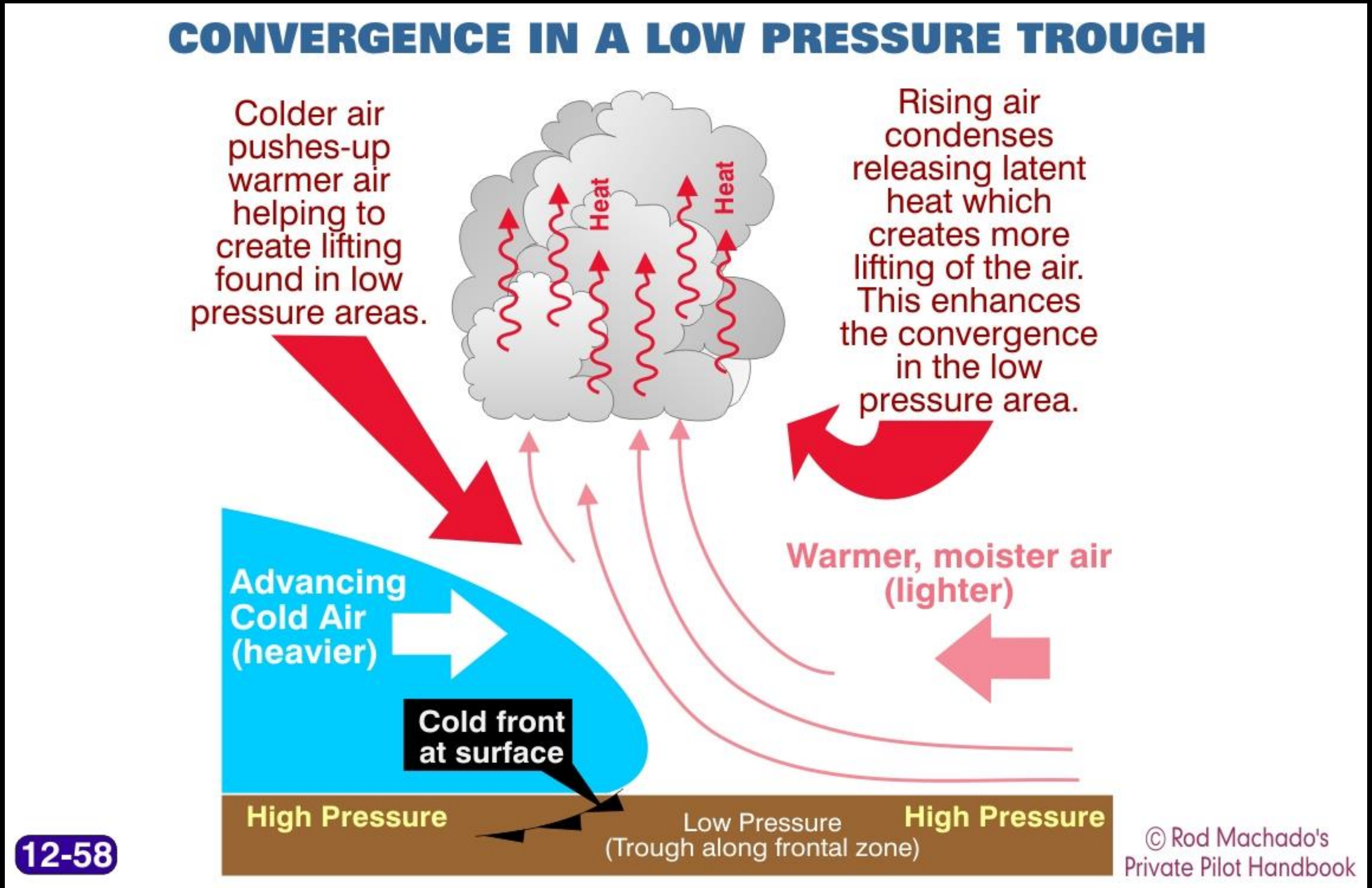
Convergence In Trough

- Cold front air mass approaching a warmer air mass
- Cold air is heavy, so it easily slips under the warmer air
- As it does, it lifts the warmer air (which usually contains a lot of moisture)



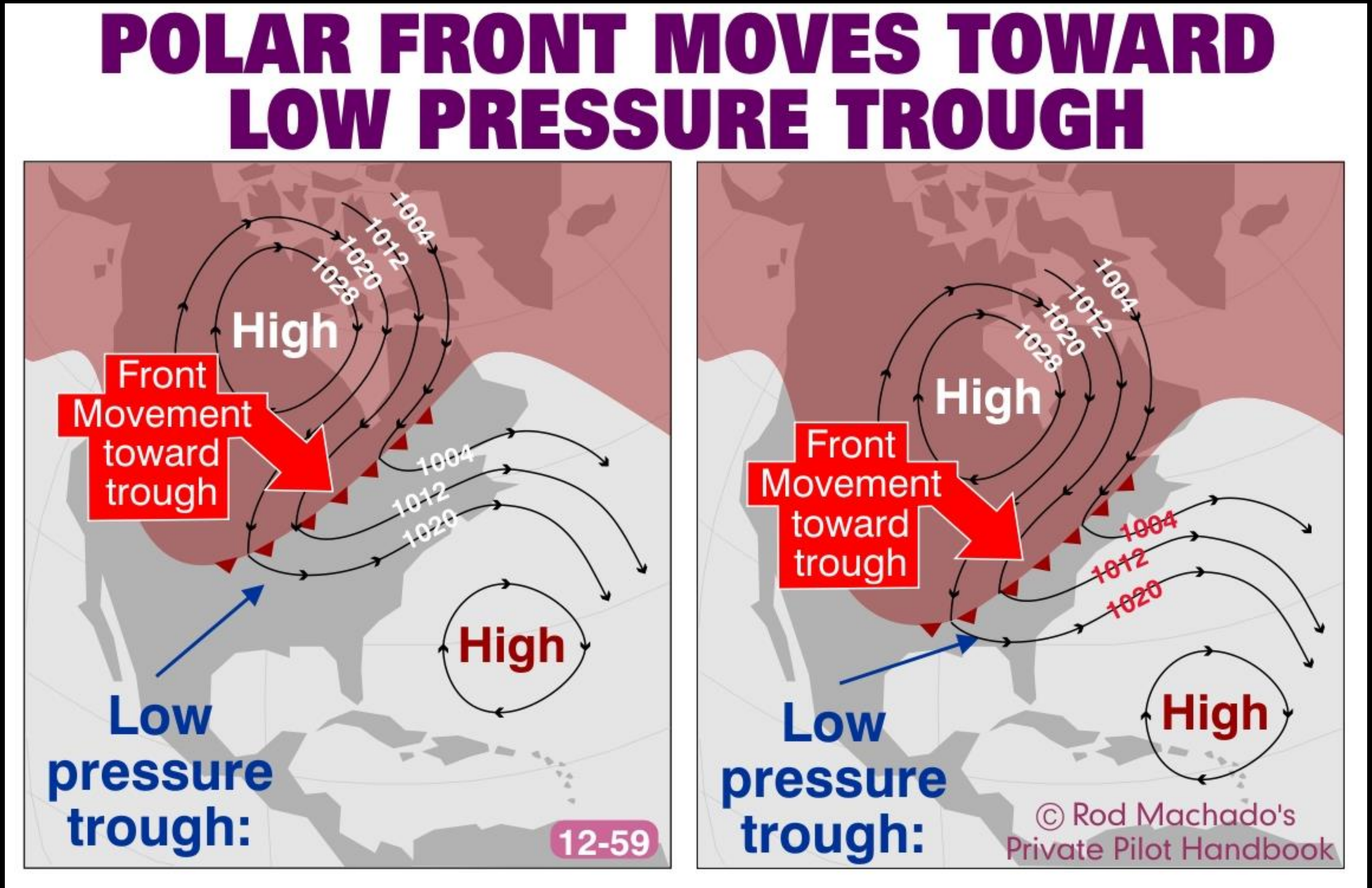
Convergence In Trough

- Given sufficient lift and lapse rate, it condenses and releases its latent heat
- Heat released into the air enhances upward movement, intensifying the trough's low pressure along the front
- Because of the convergence in a trough, it's usually associated with bad weather



Polar Cold Front

- Polar cold fronts tend to move toward the low pressure trough
- High and low pressure centers move, so their associated troughs move
- The front is being drawn along with the trough

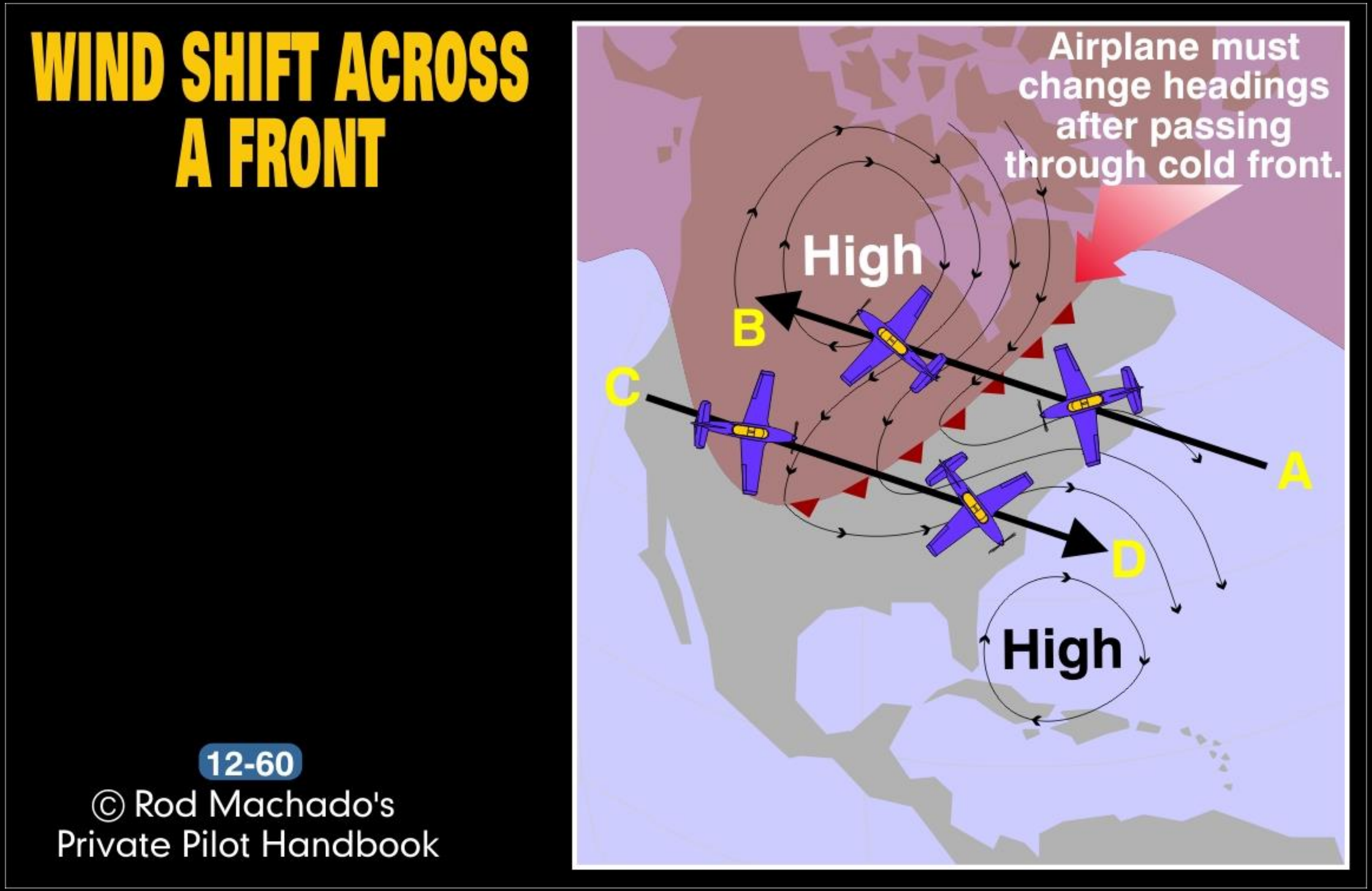


Discontinuities Across a Front

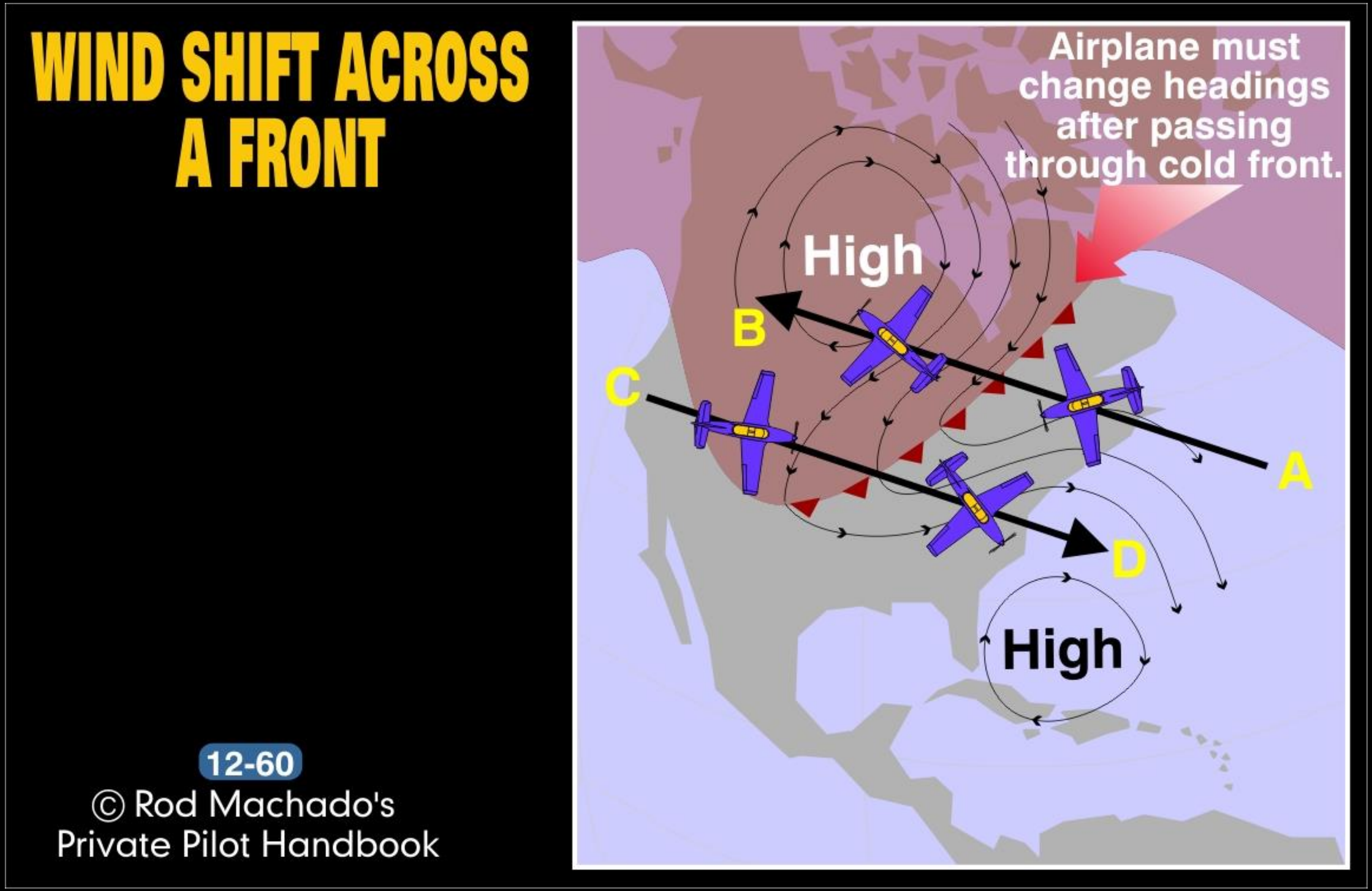
- A front is a boundary or transition zone separating air masses having different properties
- As you cross a front, these properties change
- Temperature is the most easily recognized discontinuity across a front
- Pilots flying across a front are likely to notice a sharper temperature change at lower altitudes than higher ones where air tends to become more homogenous
- Since relative humidity varies with the moisture content of the air, as well as the temperature of the air, expect changes in dew point with frontal passage

Wind Shift Across Front

- A change in wind direction and intensity is an indication of frontal passage
- On the east side of the front the wind is from the left, requiring a left crab to maintain a straight ground track



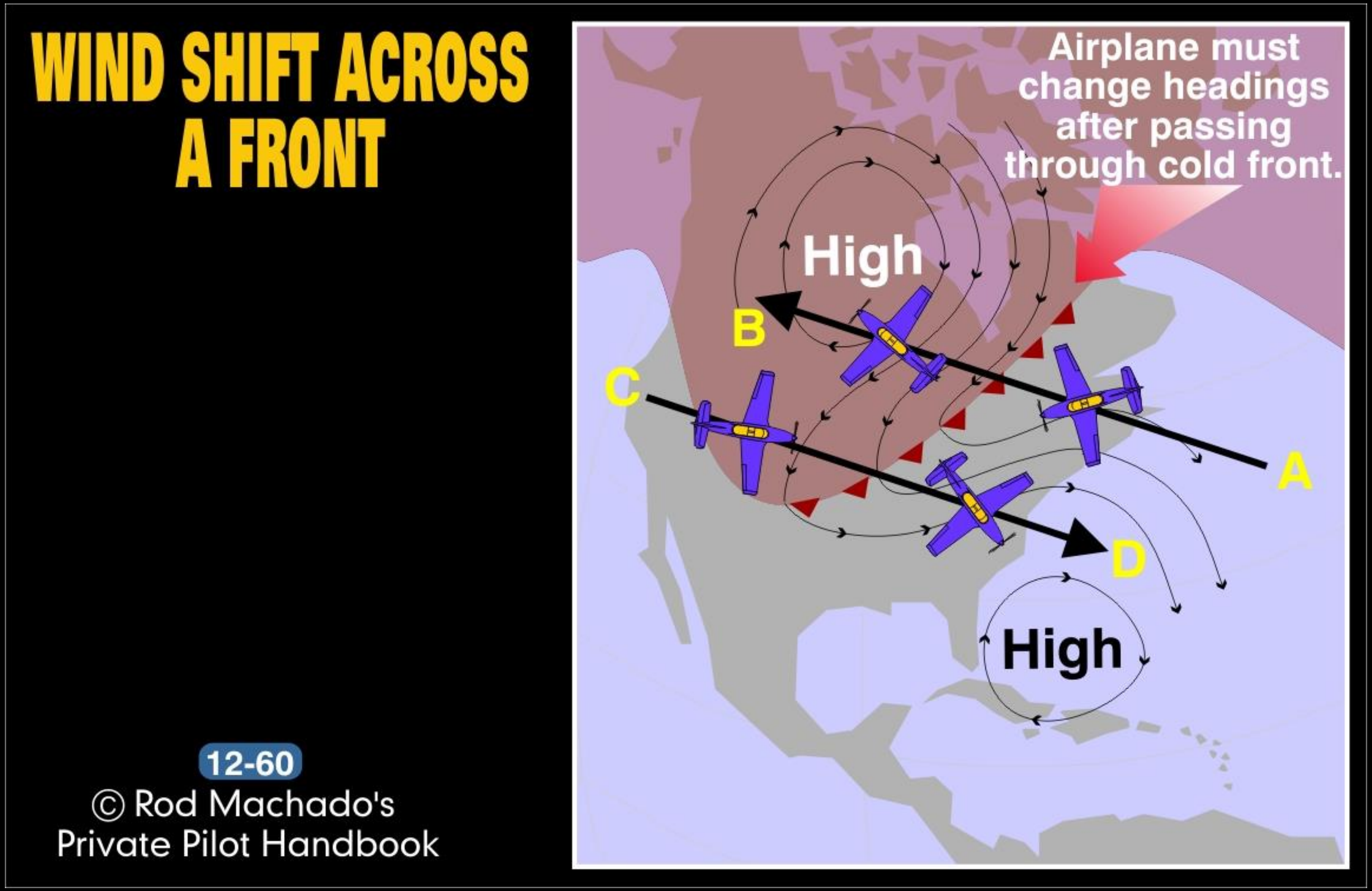
Wind Shift Across Front



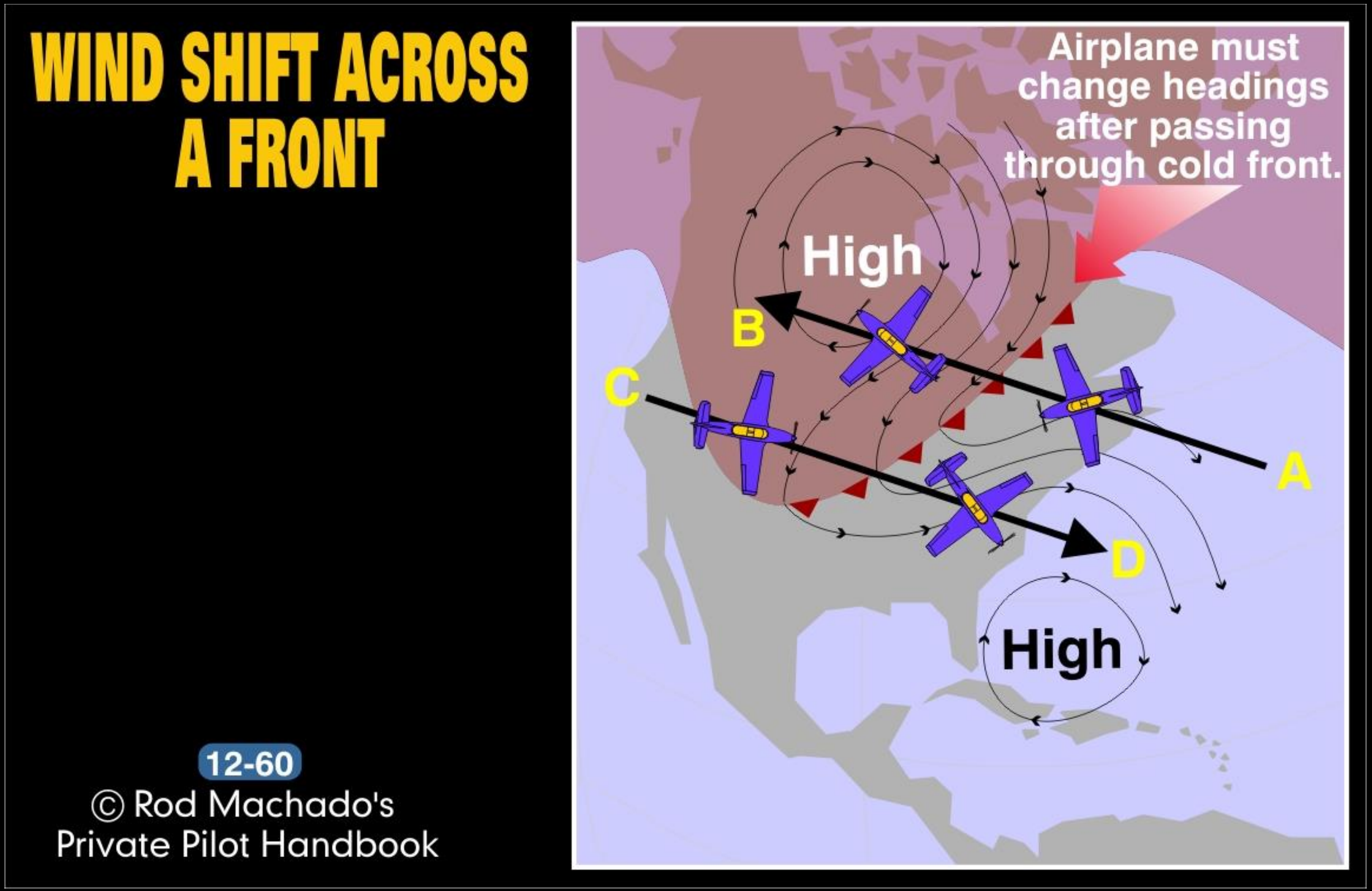
- On the west side of the front the wind is from the right, requiring a right crab to maintain a straight ground track
- Wind shifts from left to the right are an additional way pilots know they are crossing a frontal area

Wind Shift Across Front

- A stationary observer on the ground will notice a shift in wind with frontal passage
- The wind will shift from a southerly to a northwesterly direction



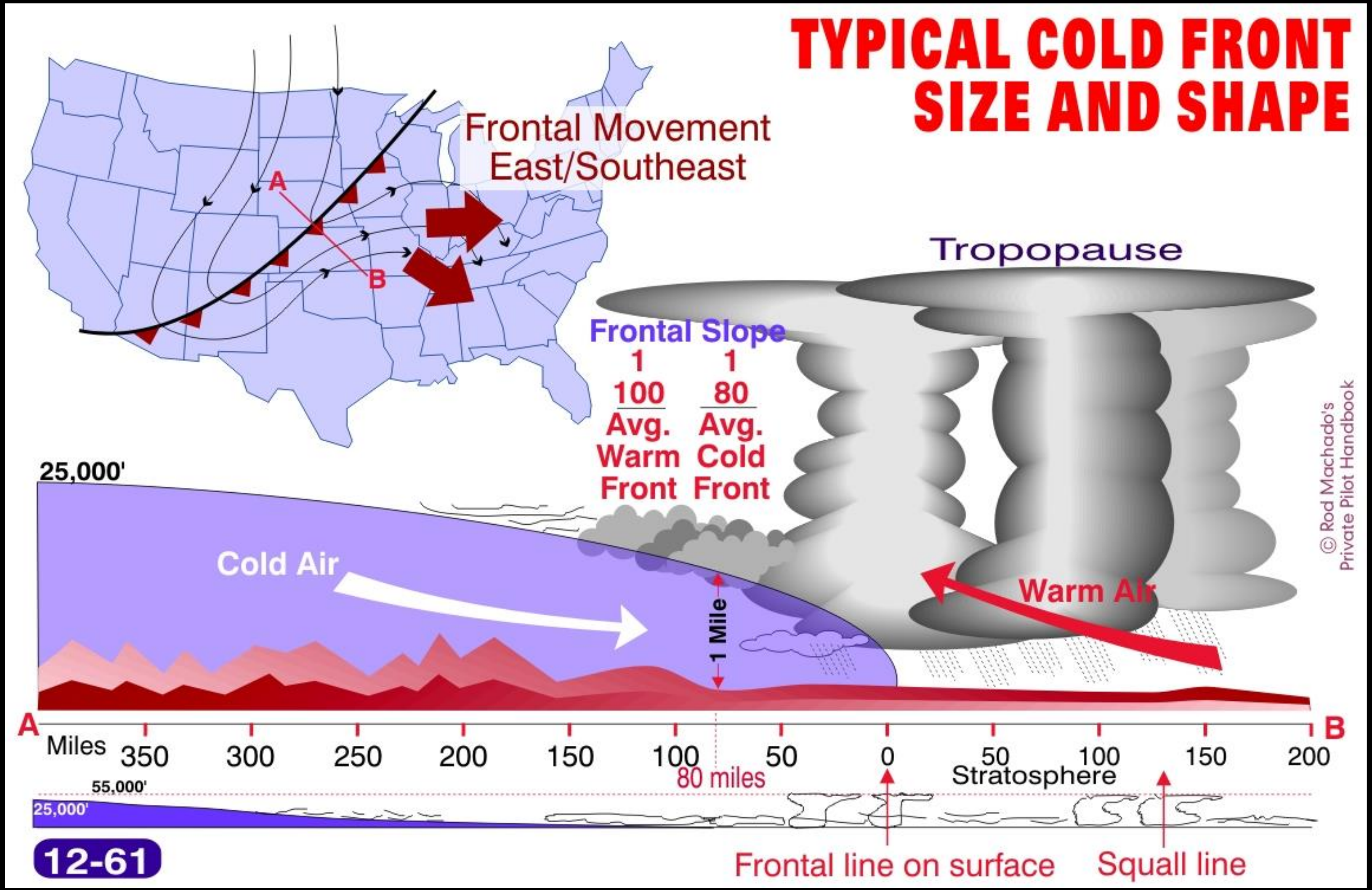
Pressure Change Across Front



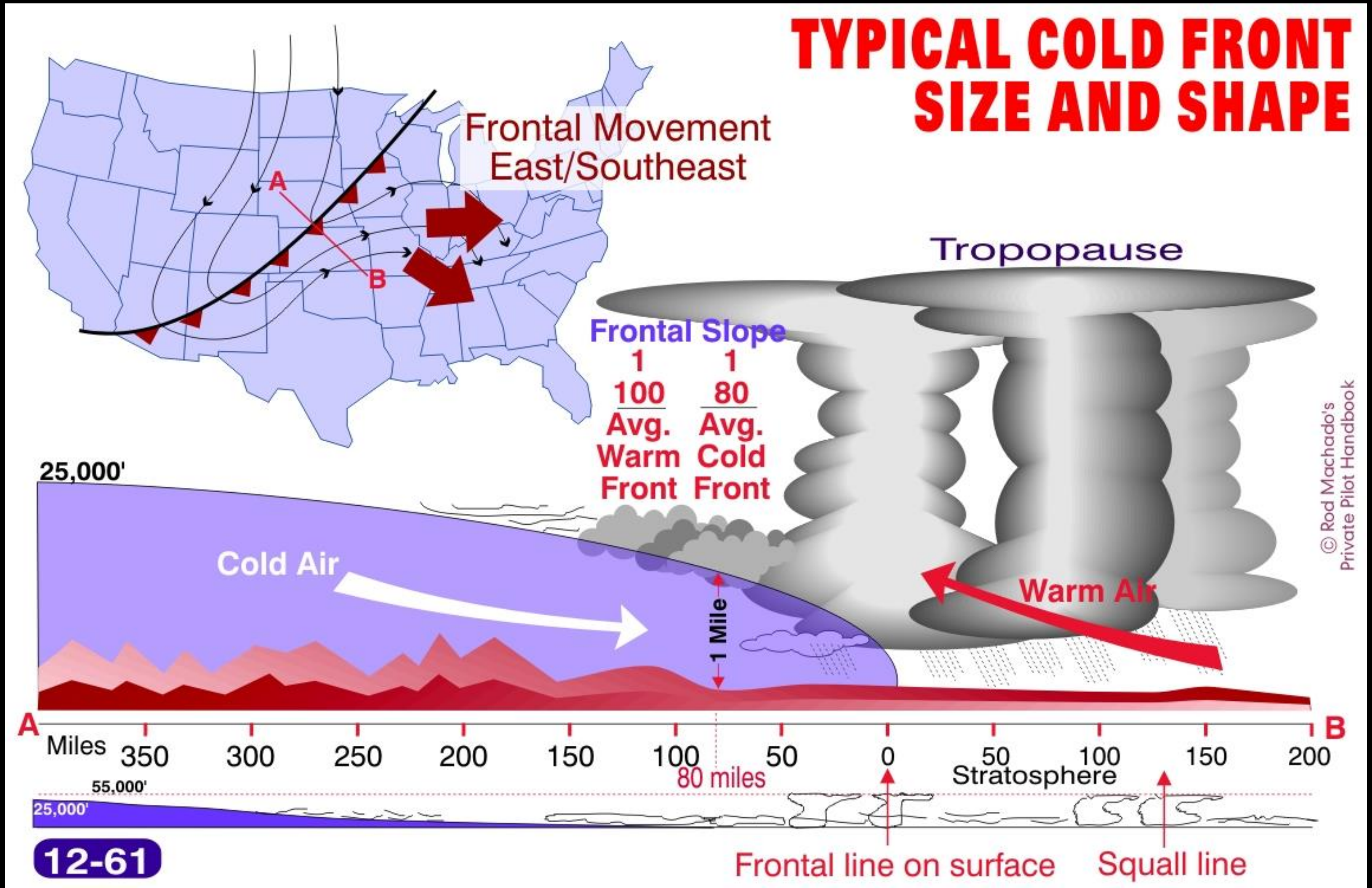
- A falling then rising barometer is another indication of frontal passage
- As the front approaches, barometric pressure lowers
- Altimeter settings for local airports report consistently lower altimeter settings
- Altimeter settings rise as the high pressure air behind the front approaches

Cold Fronts

- A cold air mass overtaking a warm air mass is a cold front
- Cold air (heavier than warm air) moves along the surface
- Pushes warmer air up in a snowplow type action



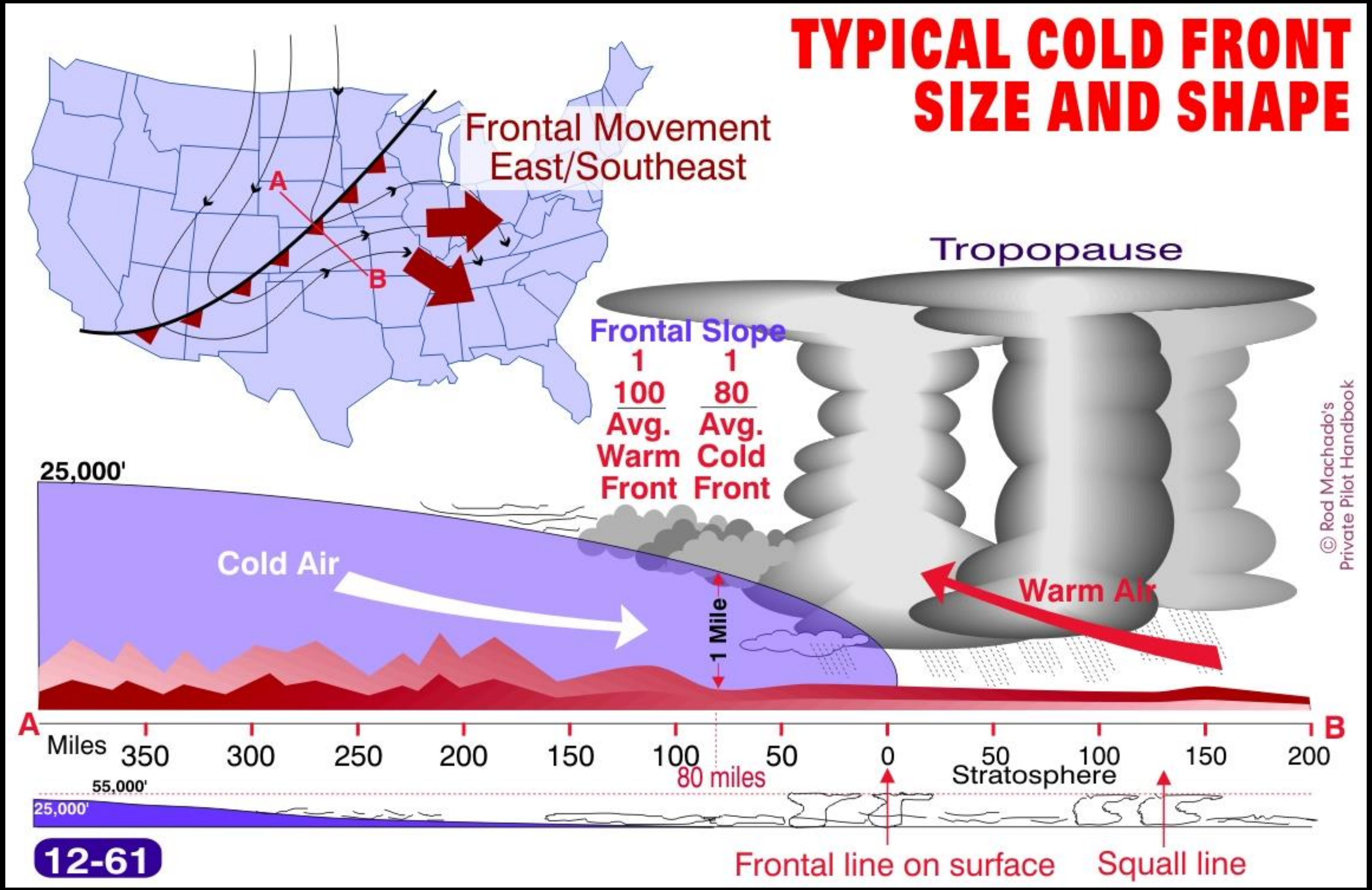
Cold Fronts



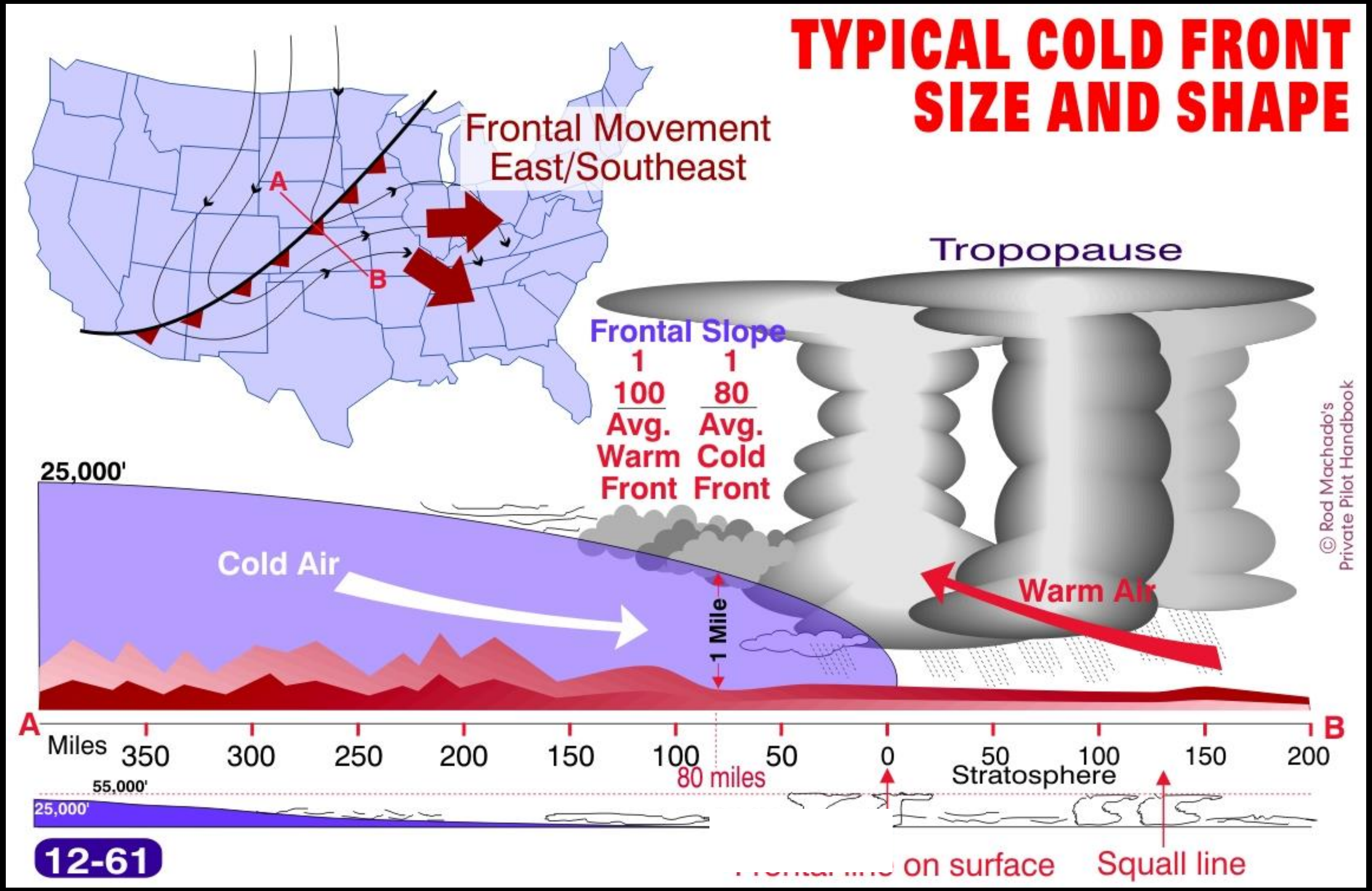
- The leading edge of the cold air sticks to the surface because of its weight and surface friction
- Forms a steeply sloped frontal edge
- Faster moving cold fronts have steeper frontal slopes than slower ones
- Frontal slopes range from 1/50 (steep) to 1/150 (not too steep) and average about 1/80

Cold Fronts

- Cross sectional view of the cold front is exaggerated for clarity
- A more realistic vertical versus horizontal view is shown on bottom diagram



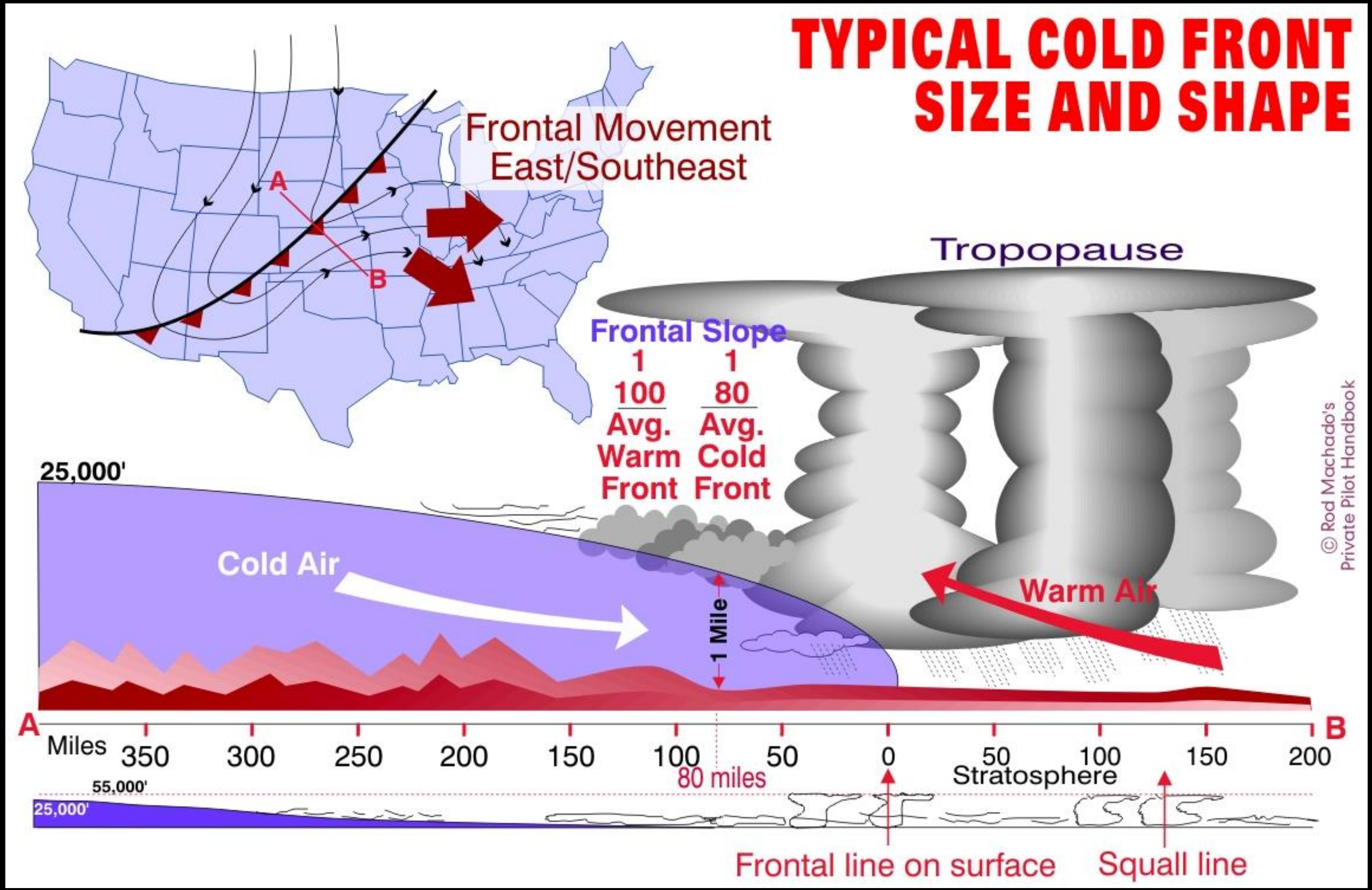
Cold Fronts



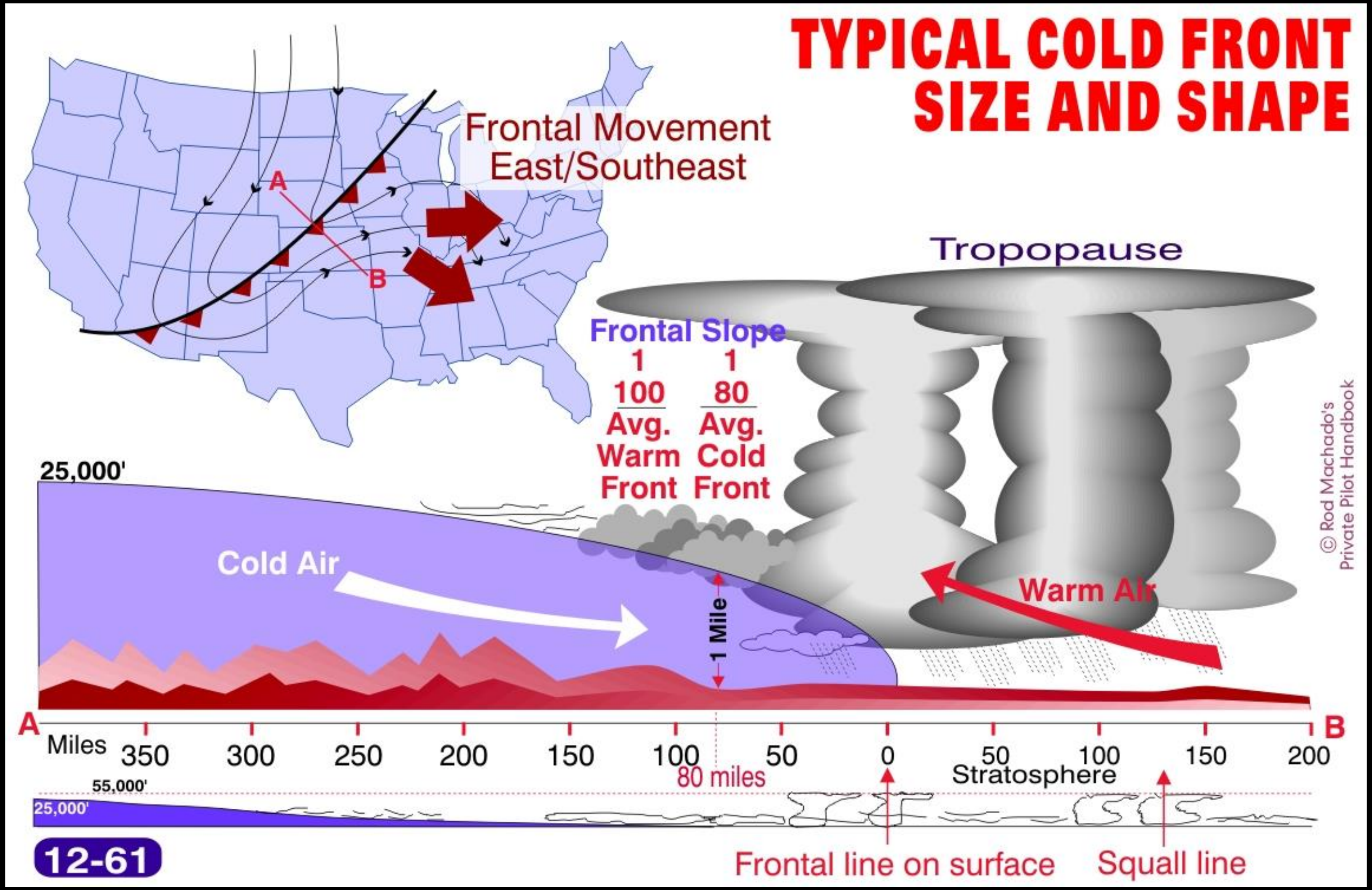
- Strong cold fronts are usually oriented in a northeast to southwest direction
- Movement is toward the east and southeast

Cold Fronts

- They are often followed by colder and drier weather
- The cloudiness and weather associated with the front depends on the degree of stability and moisture content of the air mass ahead that's being lifted by the front



Cold Fronts



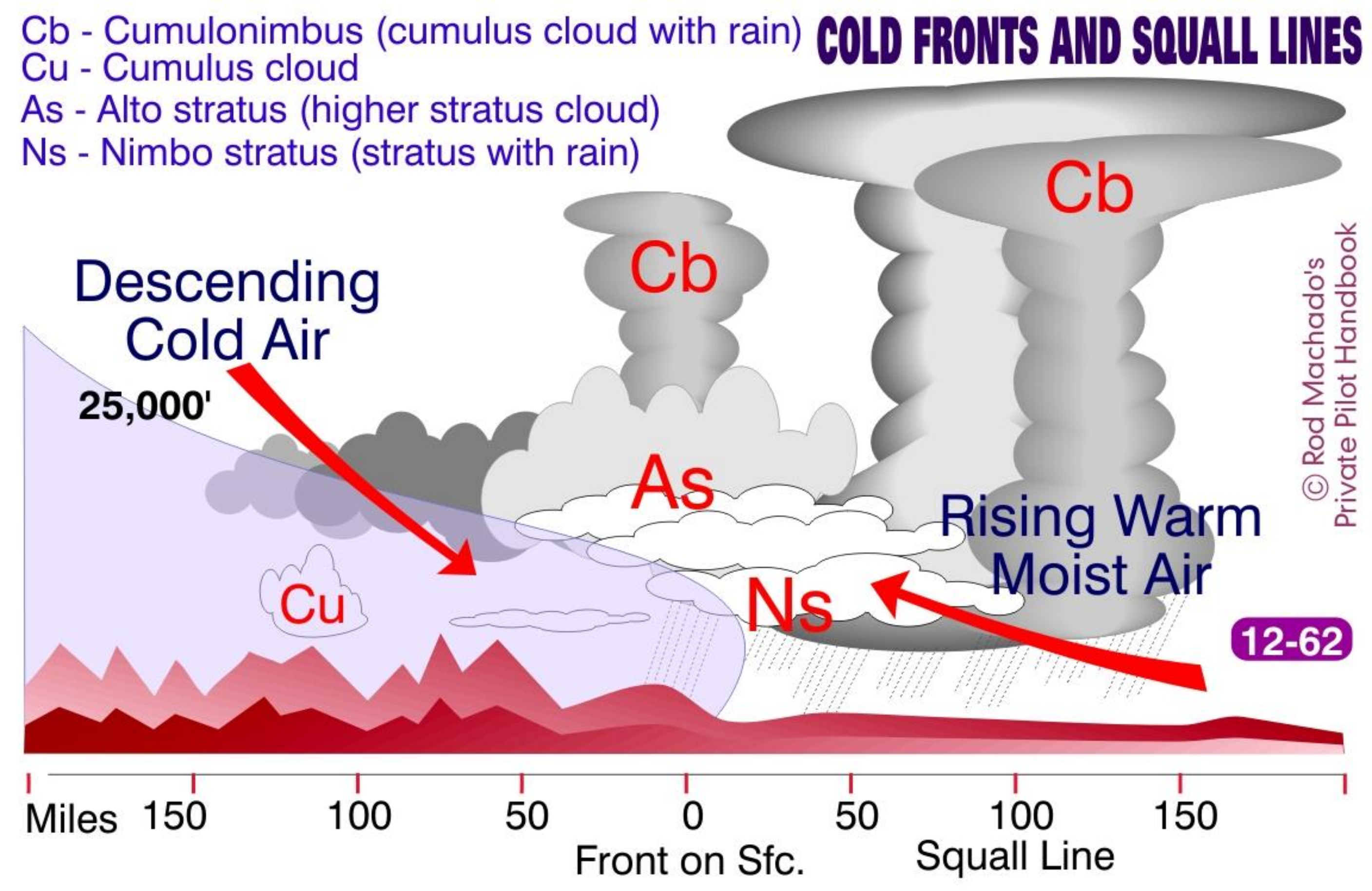
- Parcels of air are lifted within their environment
- Cold fronts provide an excellent means of lifting these parcels
- The longer and steeper the front, the larger the number of parcels lifted
- Therefore, the effects of stability or instability of the air are more widespread

Two Types of Cold Fronts

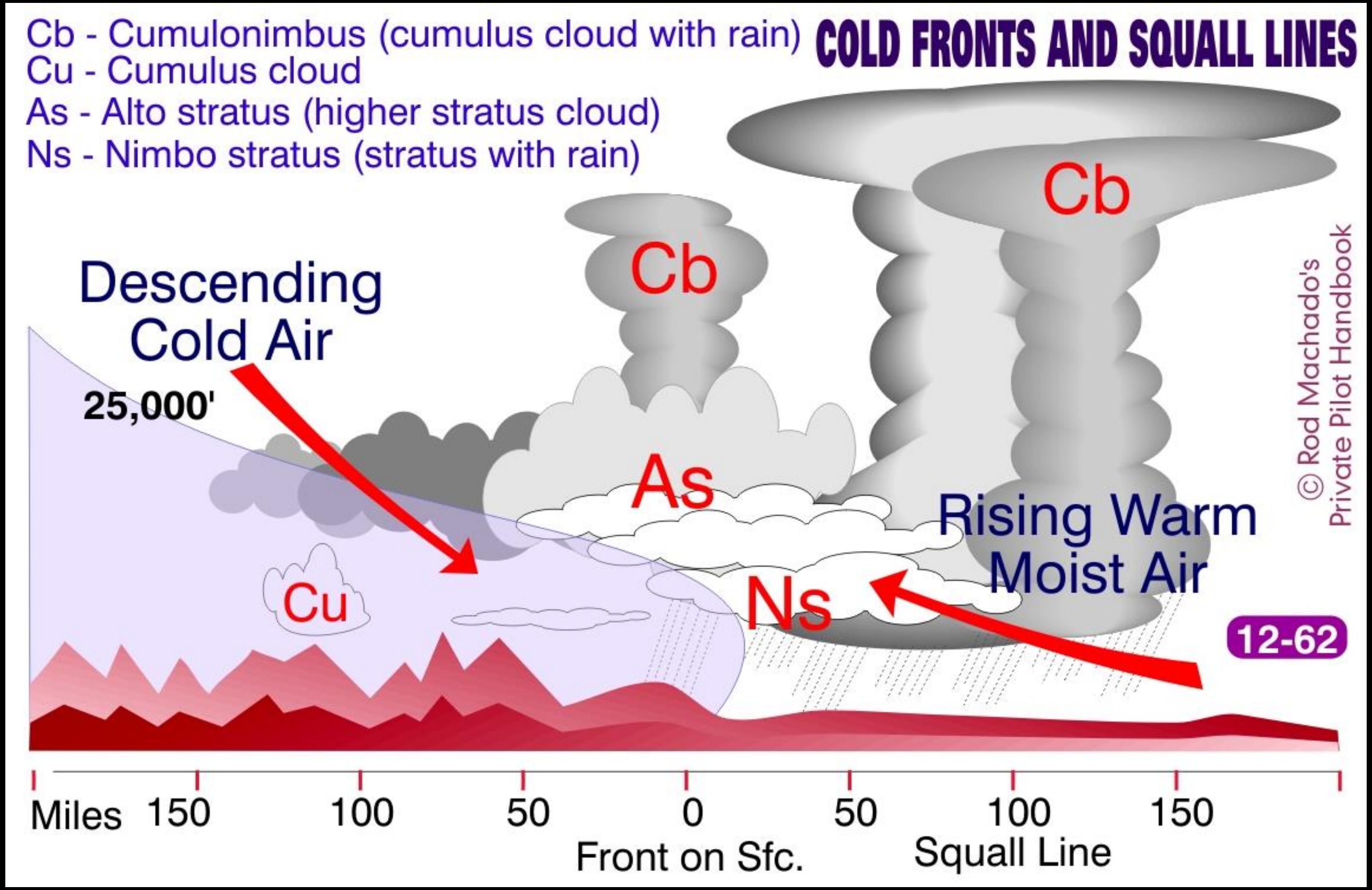
- Cold fronts can be divided into two general types: fast-moving and slow-moving
- Fast moving cold fronts have been clocked in excess of 60 MPH
- On average, they usually move at half that speed
- Their speed is generally faster in winter than in the summer months

Cold Fronts

- Most of the cold front cloudiness and precipitation is located along and ahead of the area where warm and cold air meet
- Because of the cold front's high speed, this weather is often the most hazardous that pilots encounter

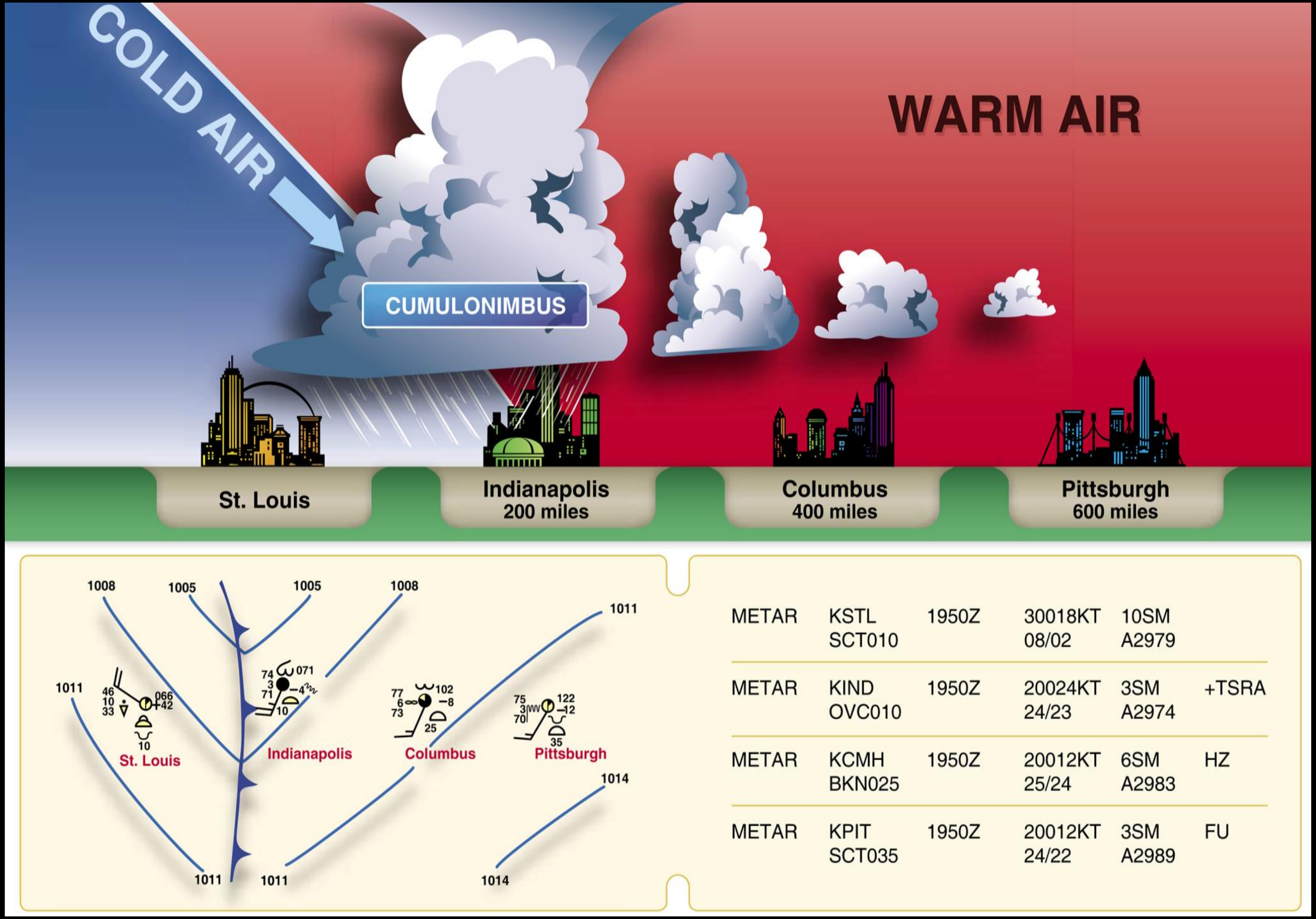


Cold Fronts



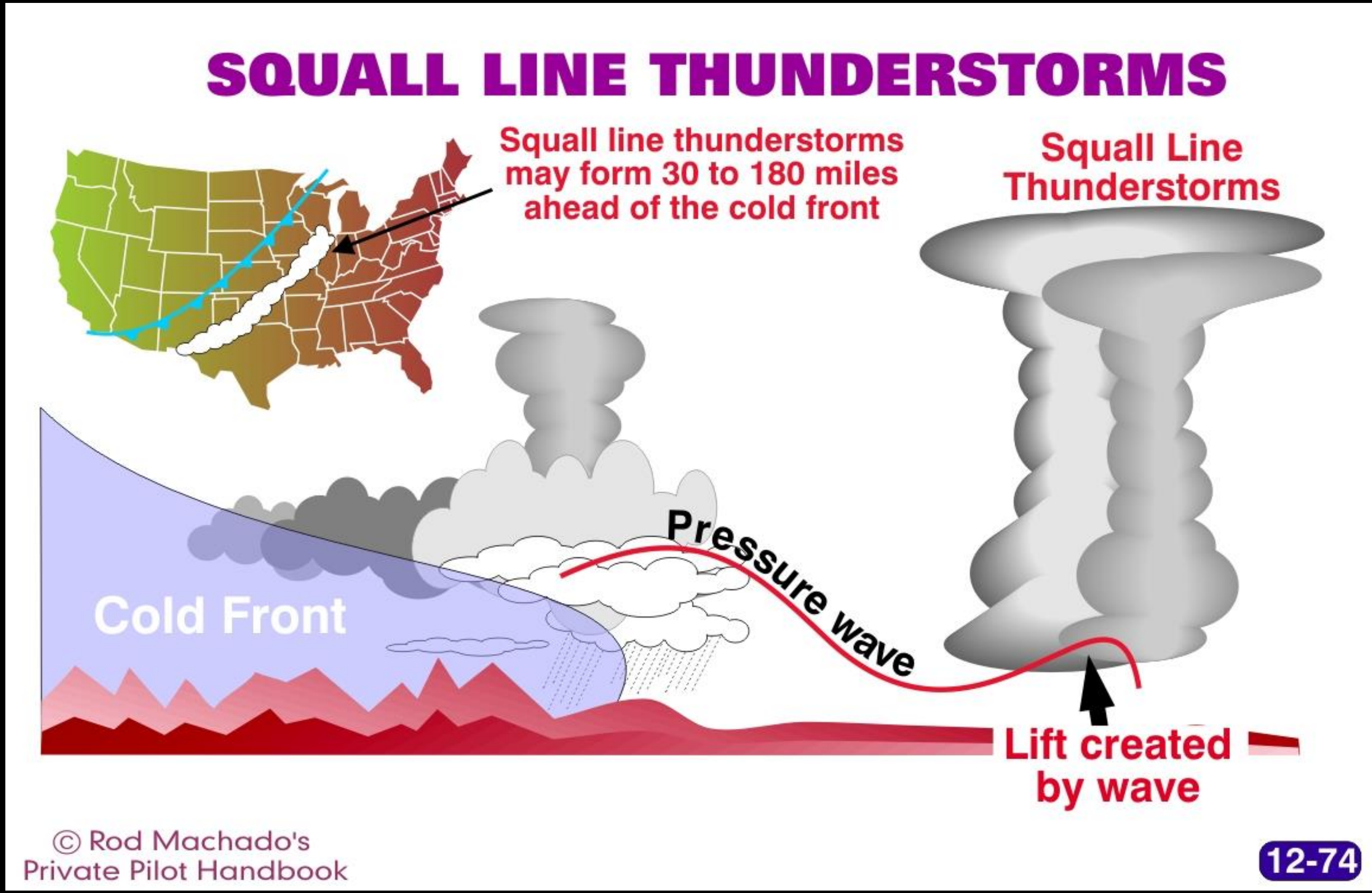
- Combine a fast moving, steep-sloped cold front with unstable, moist air and you have the possibility for cumulonimbus (nimbus means rain) clouds, scattered thunderstorms, and rain showers in advance of the front

Cold Front

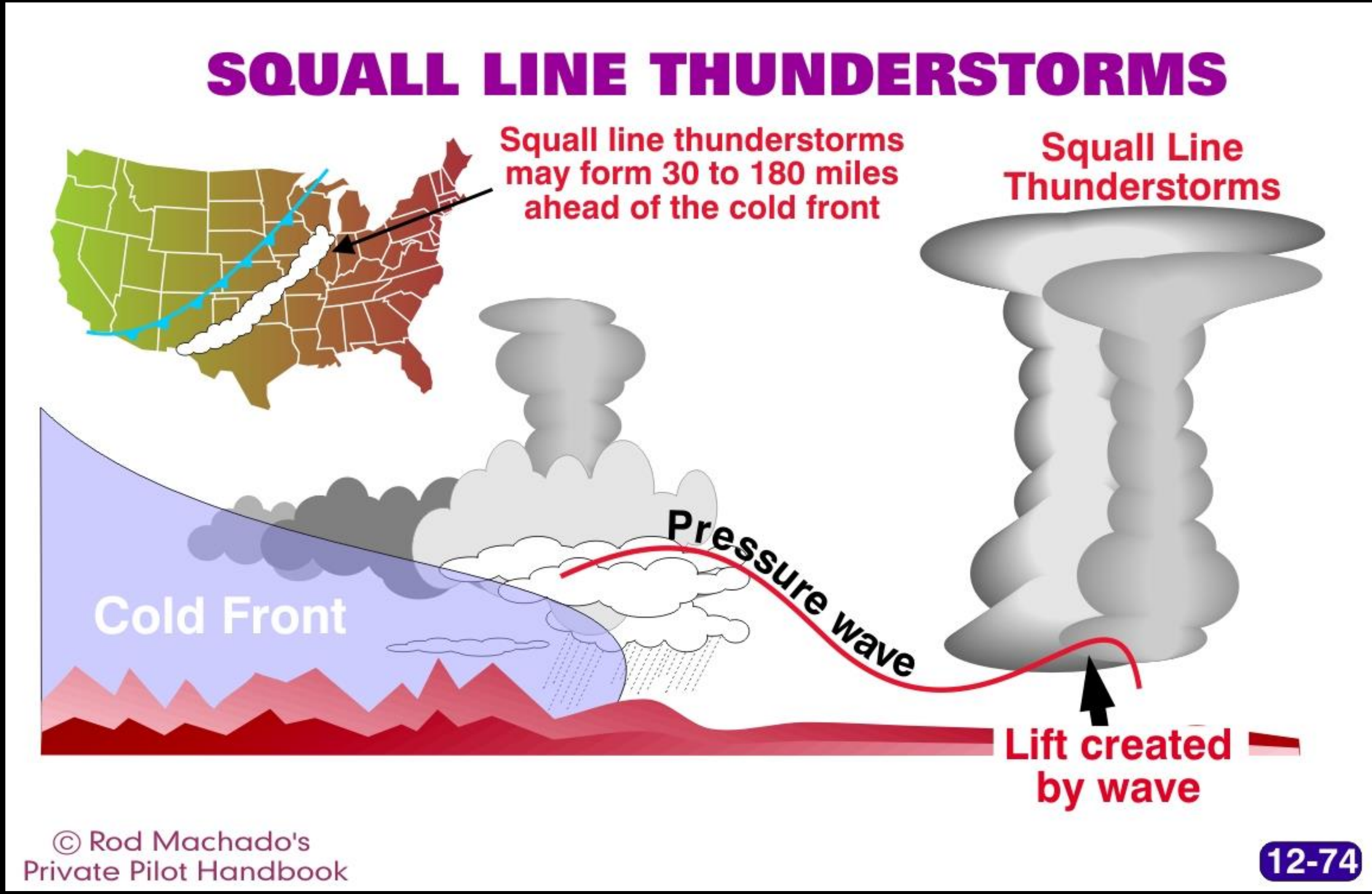

COLD AIR
WARM AIR
CUMULONIMBUS
St. Louis
Indianapolis
200 miles
Columbus
400 miles
Pittsburgh
600 miles
1008
1005
1005
1008
1011
1011
1011
1011
1014
1014
St. Louis
Indianapolis
Columbus
Pittsburgh
METAR KSTL 1950Z 30018KT 10SM SCT010 08/02 A2979
METAR KIND 1950Z 20024KT 3SM +TSRA OVC010 24/23 A2974
METAR KCMH 1950Z 20012KT 6SM HZ BKN025 25/24 A2983
METAR KPIT 1950Z 20012KT 3SM FU SCT035 24/22 A2989

Squall Lines

- Fast-moving cold fronts can generate squall lines 30 to 180 miles in advance of and parallel to the front
- Squall lines are lines of thunderstorms containing some of the most turbulent weather known to pilots



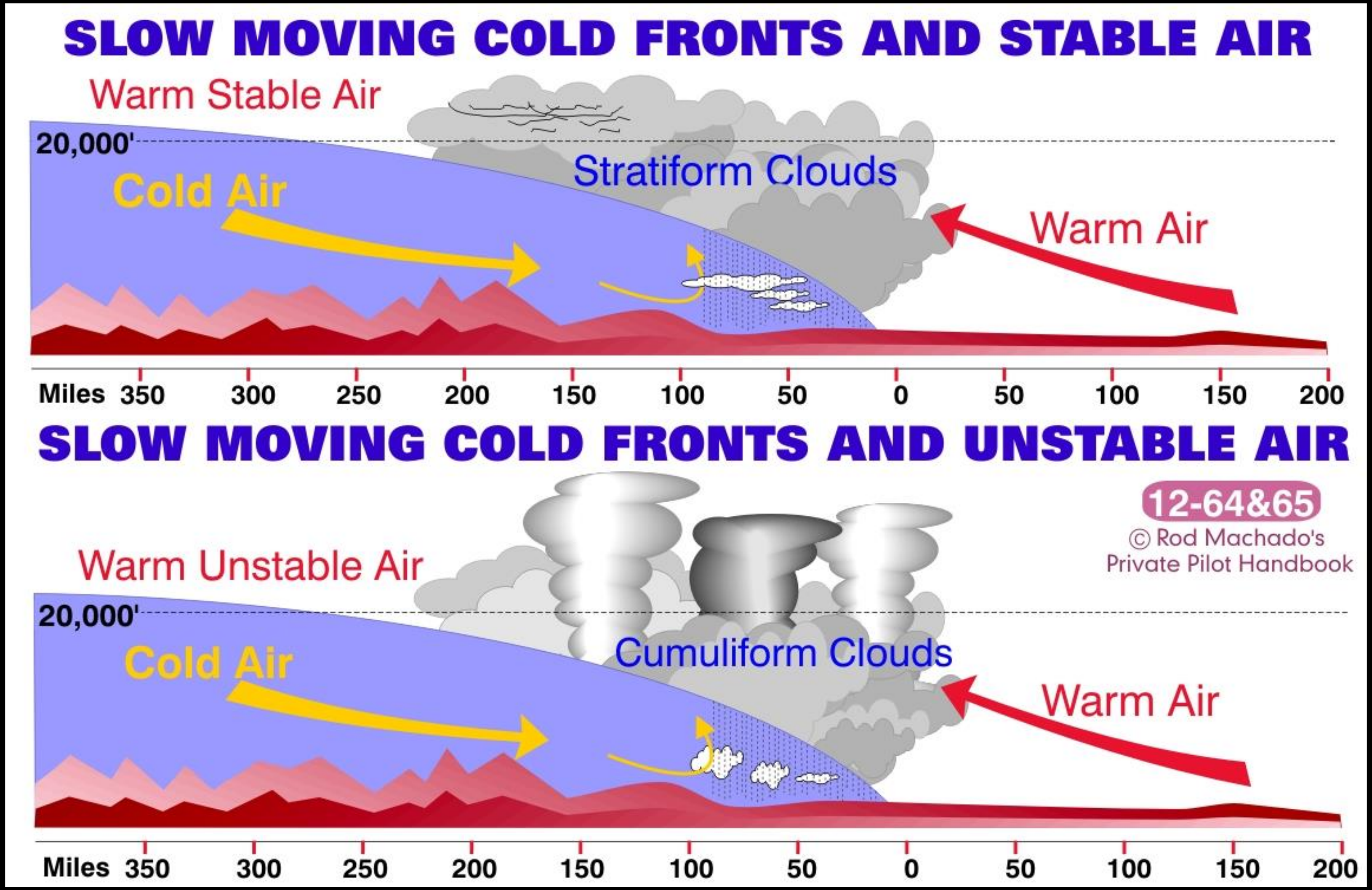
Squall Lines



- An isolated wave forms causing prefrontal lifting in the warm, moist air preceding the cold front
- This prefrontal gravity wave can generate enough prefrontal lifting (lifting in advance of the actual front) to create squall line thunderstorm weather

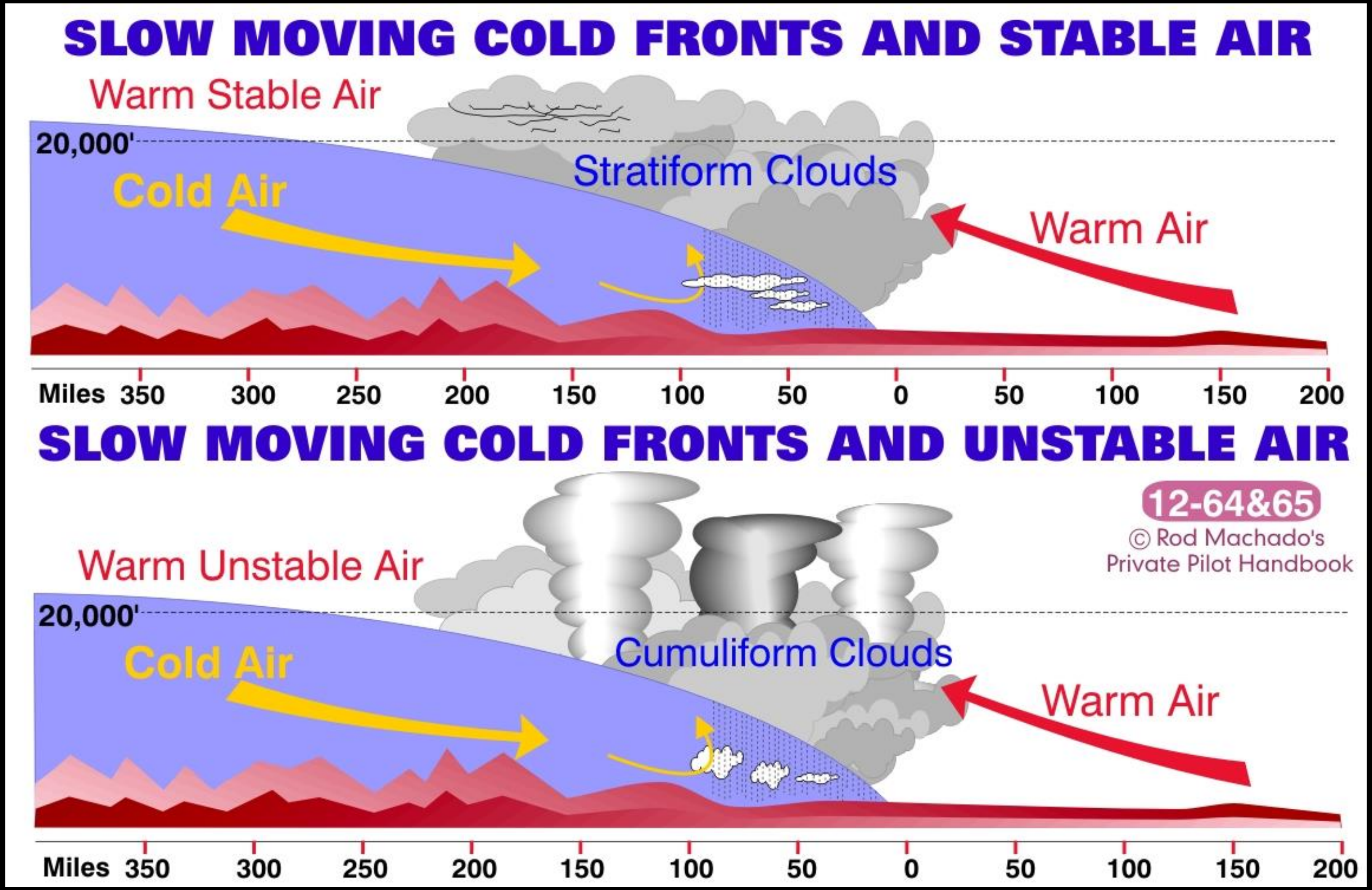
Slow Moving Cold Fronts
Stable Air

- Usually generate less hazardous weather
- Forms a shallower slope with less intense lifting of air
- Precipitation and cloud formation occurs in a broad band behind the front's surface position
- Stratiform clouds are more likely to form if the air is relatively stable
- Fog can also form in the rainy area

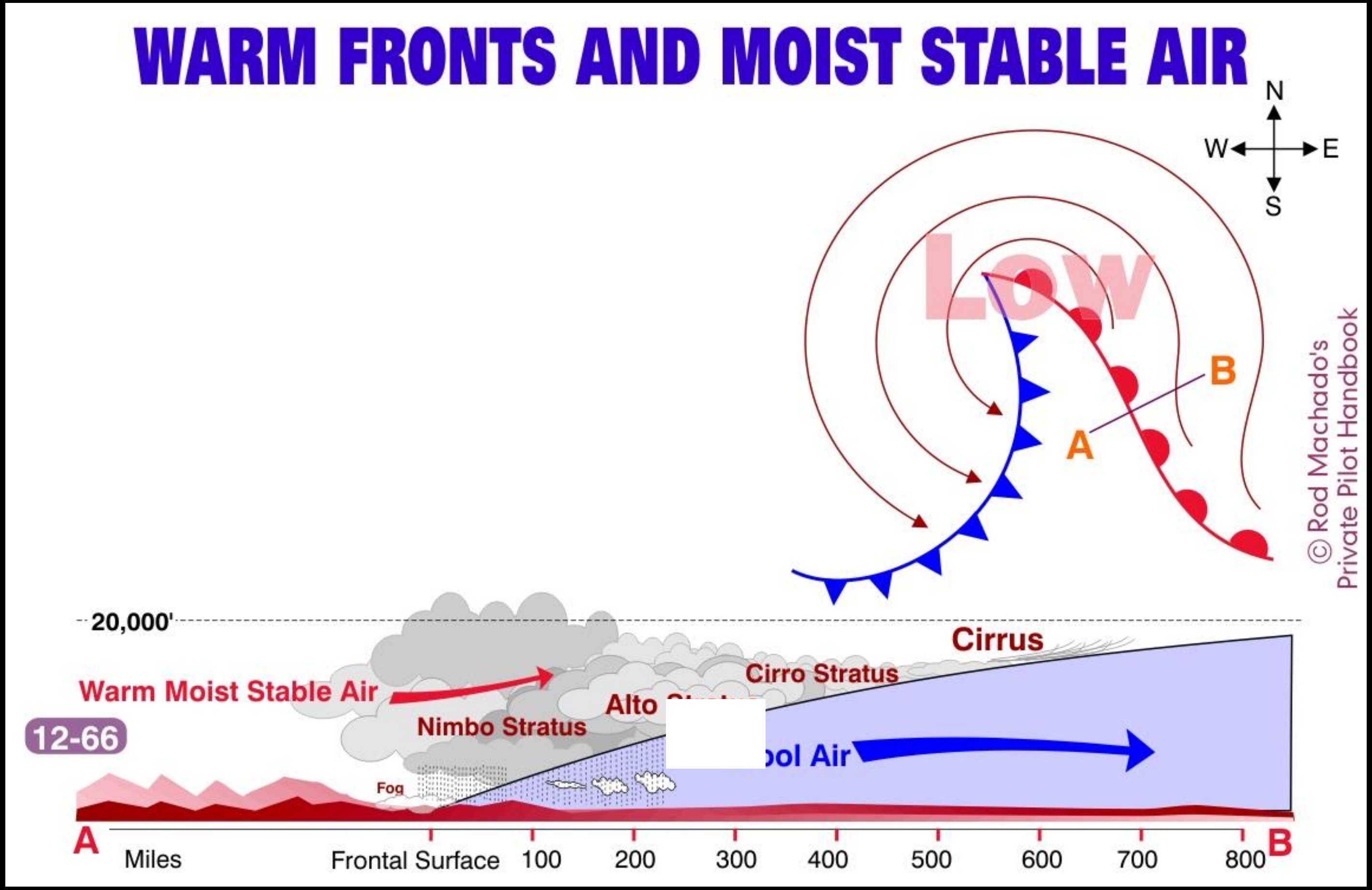


Slow Moving Cold Fronts
Unstable Air

- Unstable air forms cumulus clouds and thunderstorms
- The weather is confined to a narrow band along the front

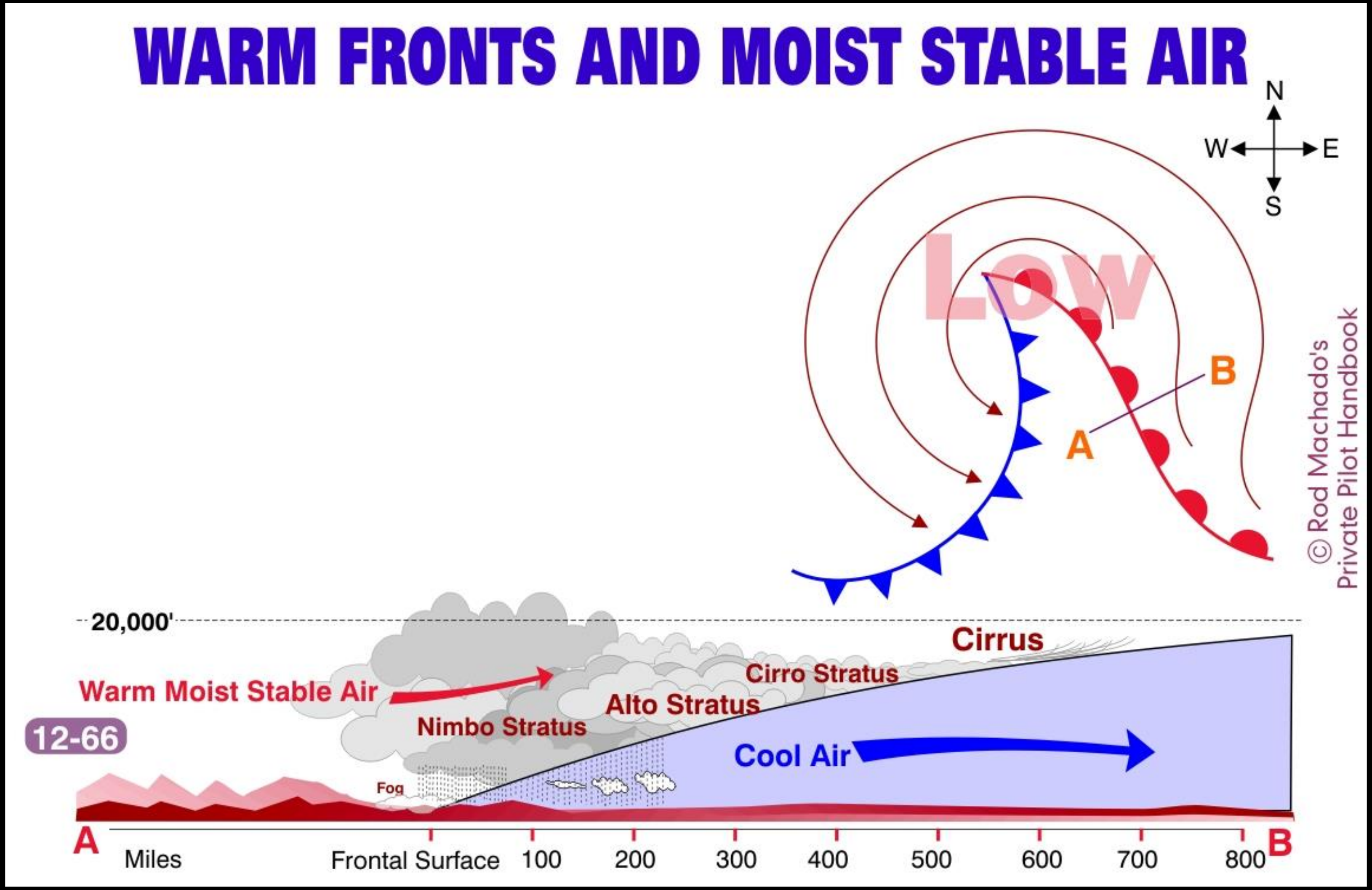


Warm Fronts
Stable Air



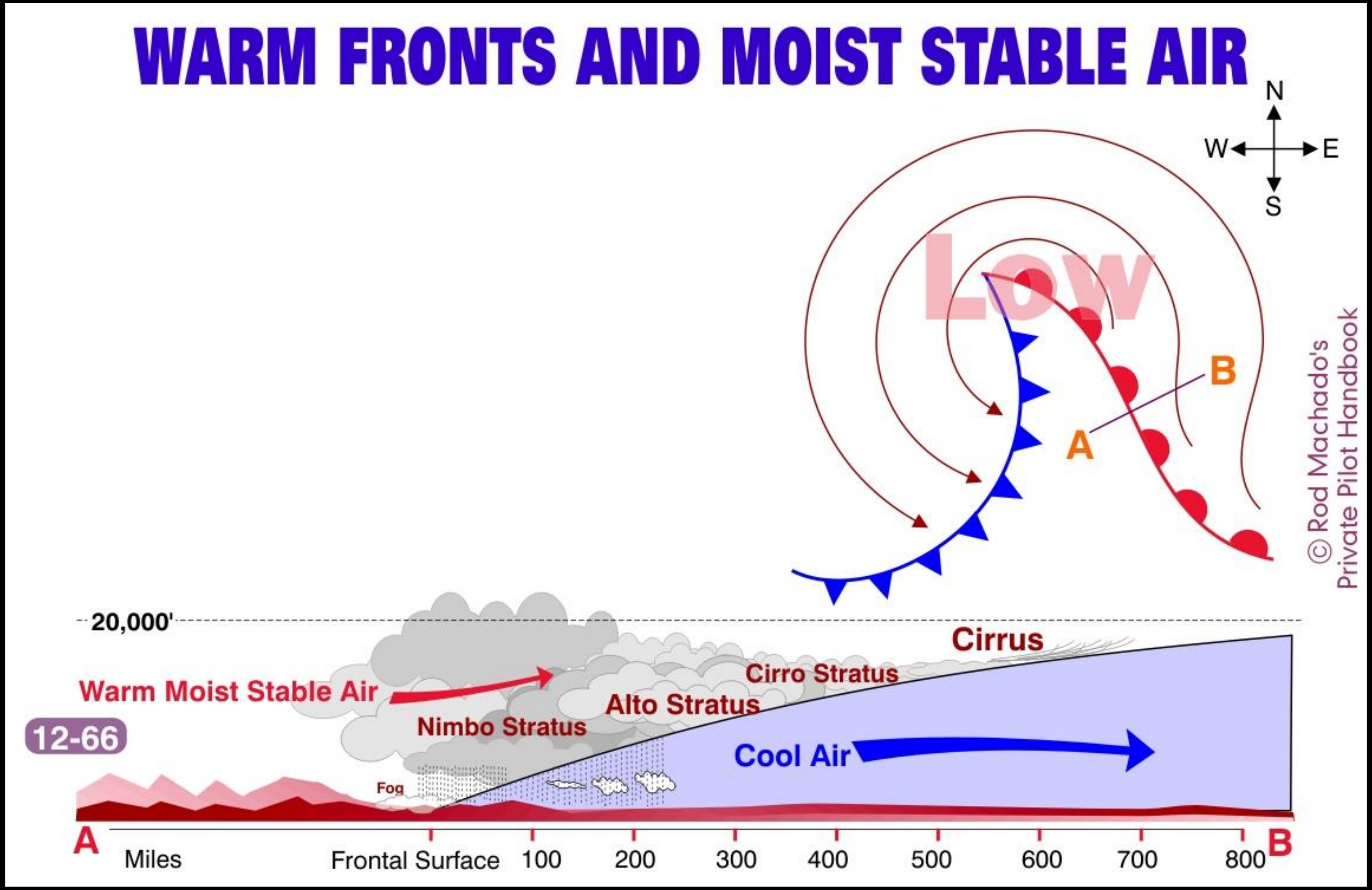
- Follow the small wave patterns moving along the polar front
- Retreating cool air in the upper part of a wave is replaced by warmer, moister air from the south
- Being heavier and denser, the retreating cool air is tugged by surface friction as it moves

Warm Fronts
Stable Air



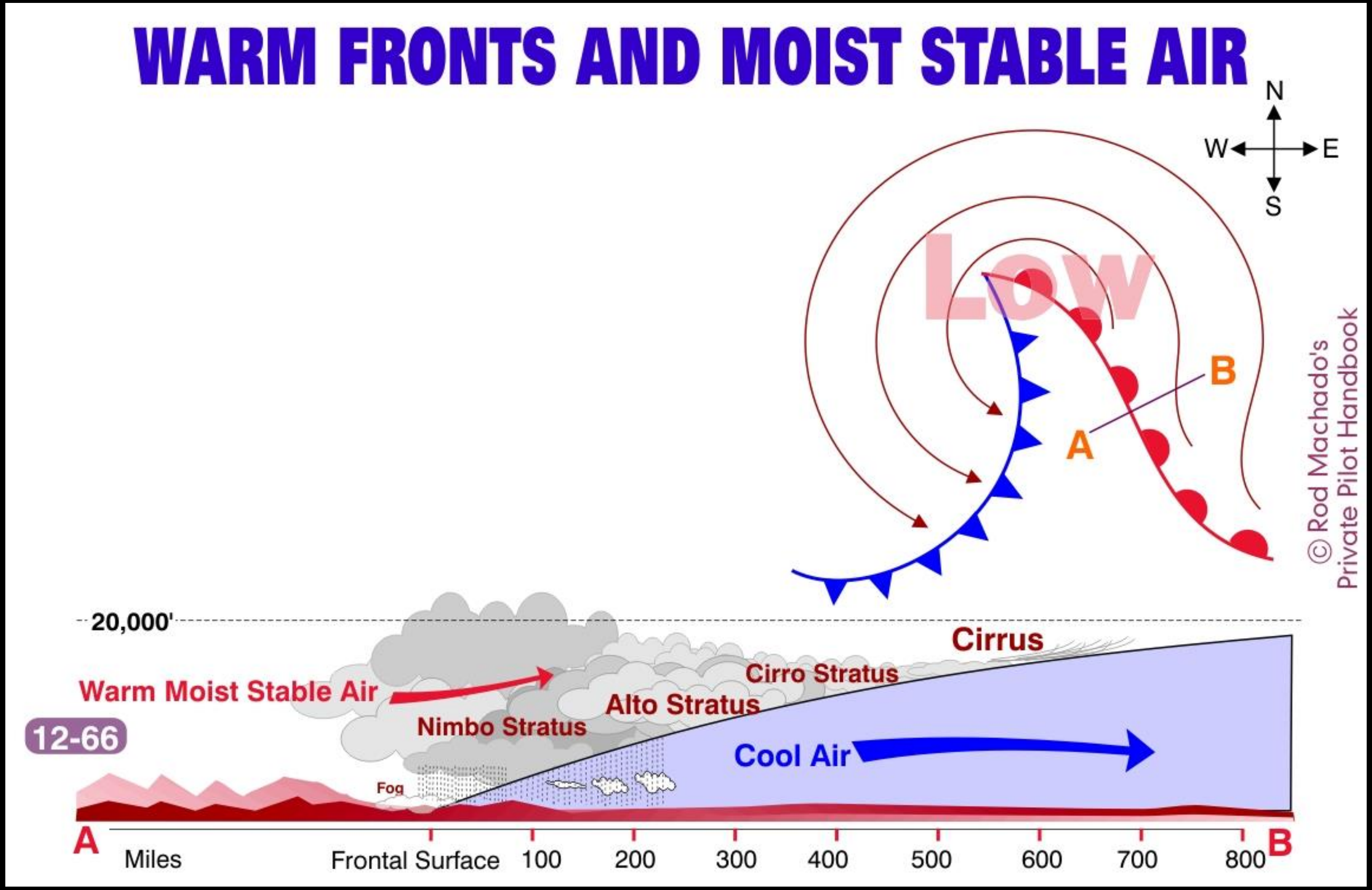
- Tugging creates a long shallow slope over which warm air rises gradually as it replaces the cooler air
- Cool air is reluctant to give way to lighter, warmer air
- Orientation is more N-S or NW-SE, with the front moving in a NE direction

Warm Fronts
Stable Air



- Usually move at 15 MPH or half the speed of the average cold front
- Slopes range between 1/50 to 1/200 with an average of 1/100
- A shallower slope means that warm frontal weather is distributed over a larger horizontal area than that of a cold front

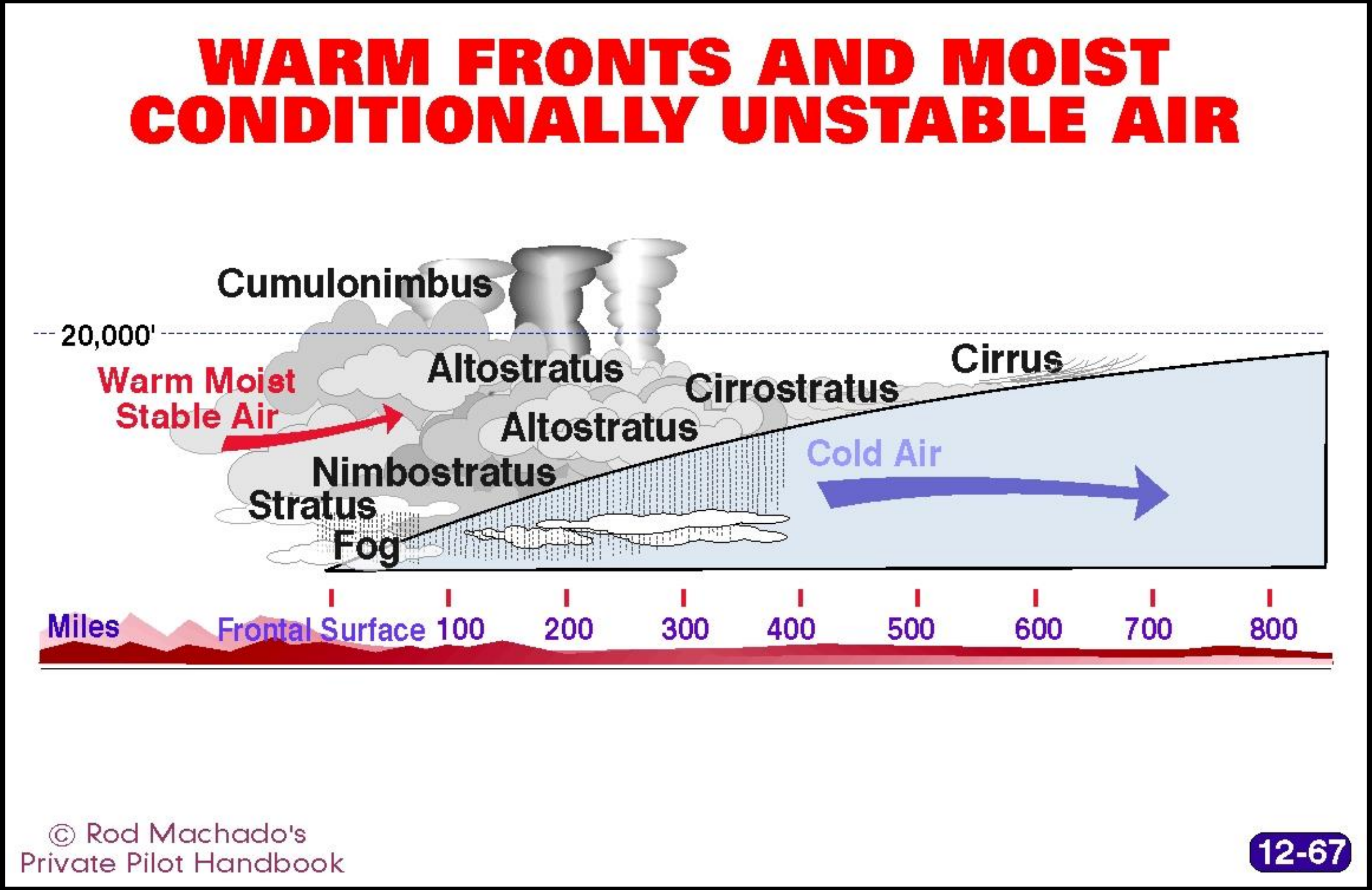
Warm Fronts
Stable Air



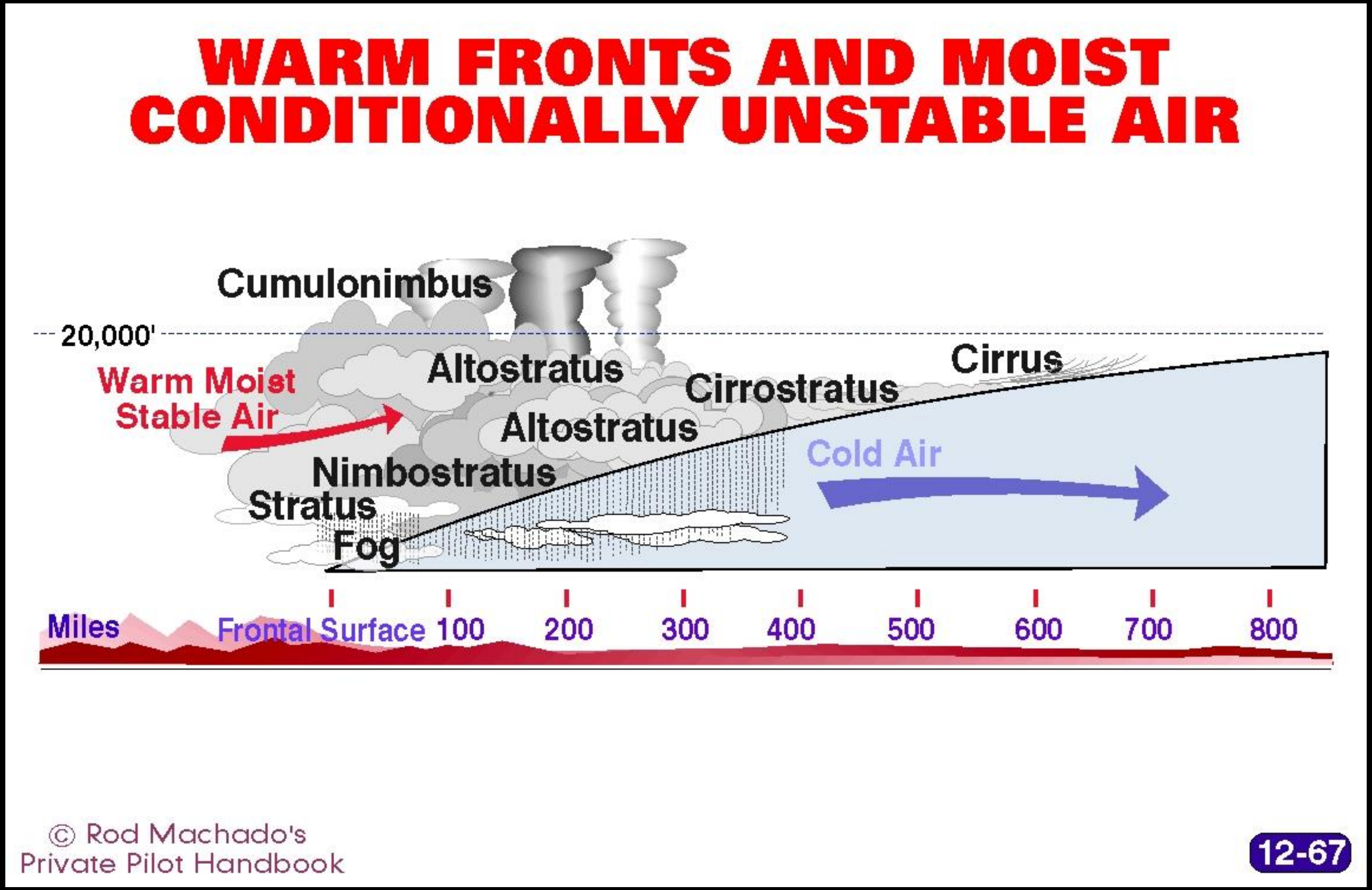
- If the rising warm air is moist and stable, stratiform-type clouds develop in the warm front
- Sequence of cloud formation encountered in advance of the warm front is cirrus, cirrostratus, altostratus, and nimbostratus
- Precipitation increases gradually with the approach of the warm front and continues until it passes

Warm Fronts
Unstable Air

- Embedded thunderstorms are likely in the stratus cloud mass if the air being lifted by the warm front is warm, moist, and conditionally unstable
- Widespread precipitation ahead of a warm front often causes low stratus and fog to form



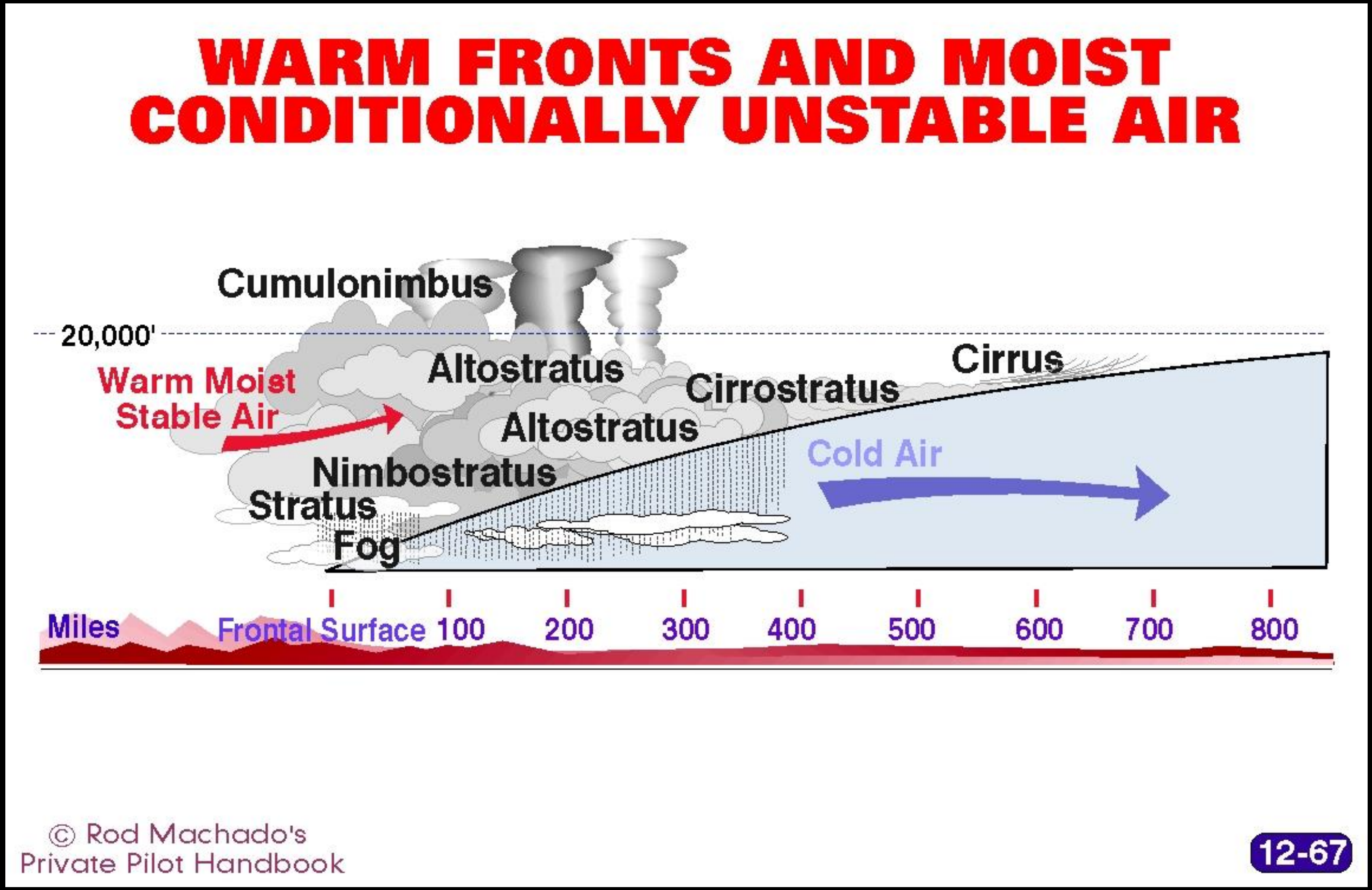
Warm Fronts
Unstable Air



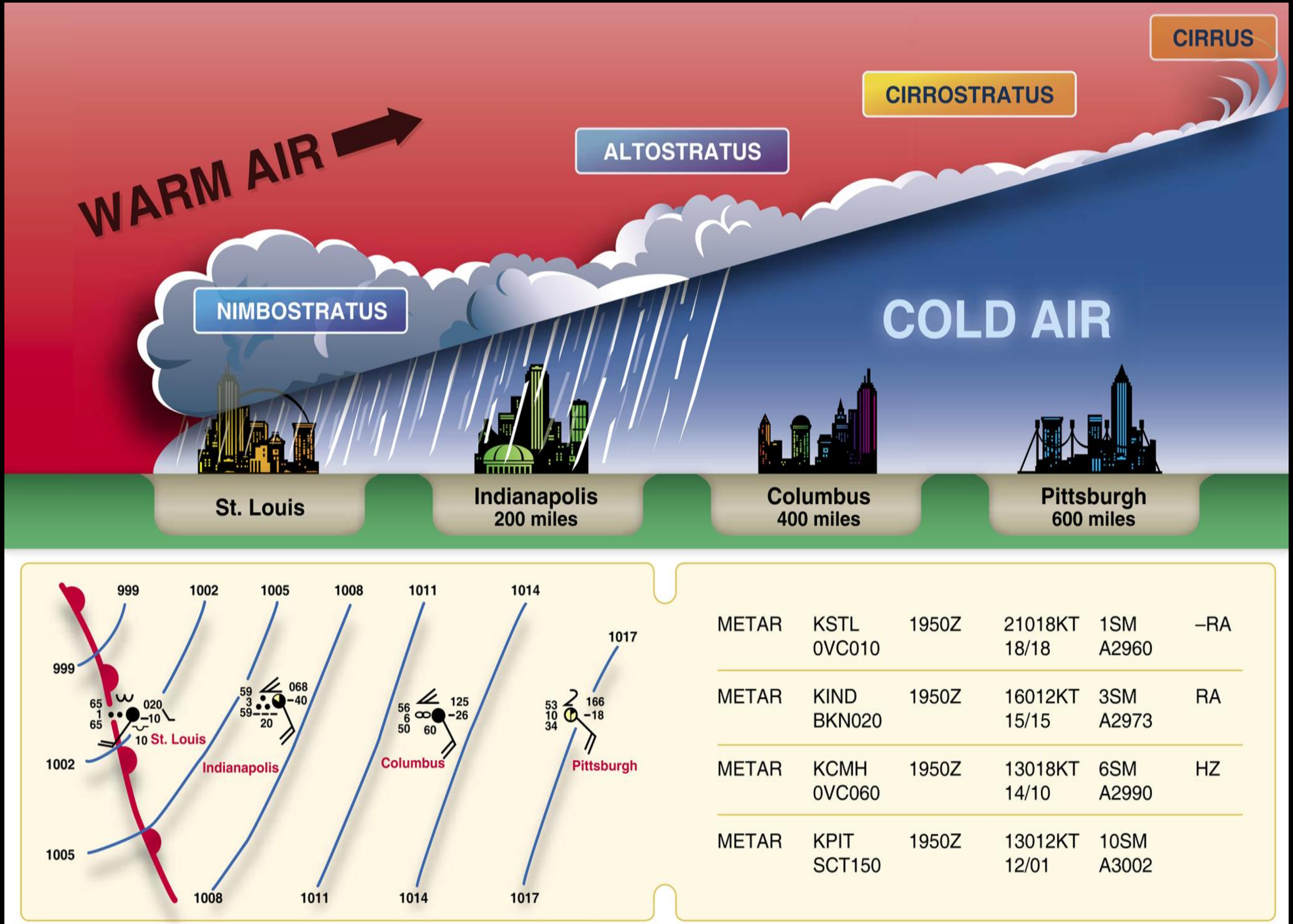
- The precipitation raises the humidity of the cold air to saturation
- This produces low ceilings and poor visibilities over a wide area

Warm Fronts
Unstable Air

- If the retreating cold air has below freezing temperatures, the precipitation can take the form of freezing rain or ice pellets
- Raindrops from the warmer air aloft freeze as they fall into the colder air below
- Freezing rain or ice pellets are usually good indicators that there's warmer air aloft



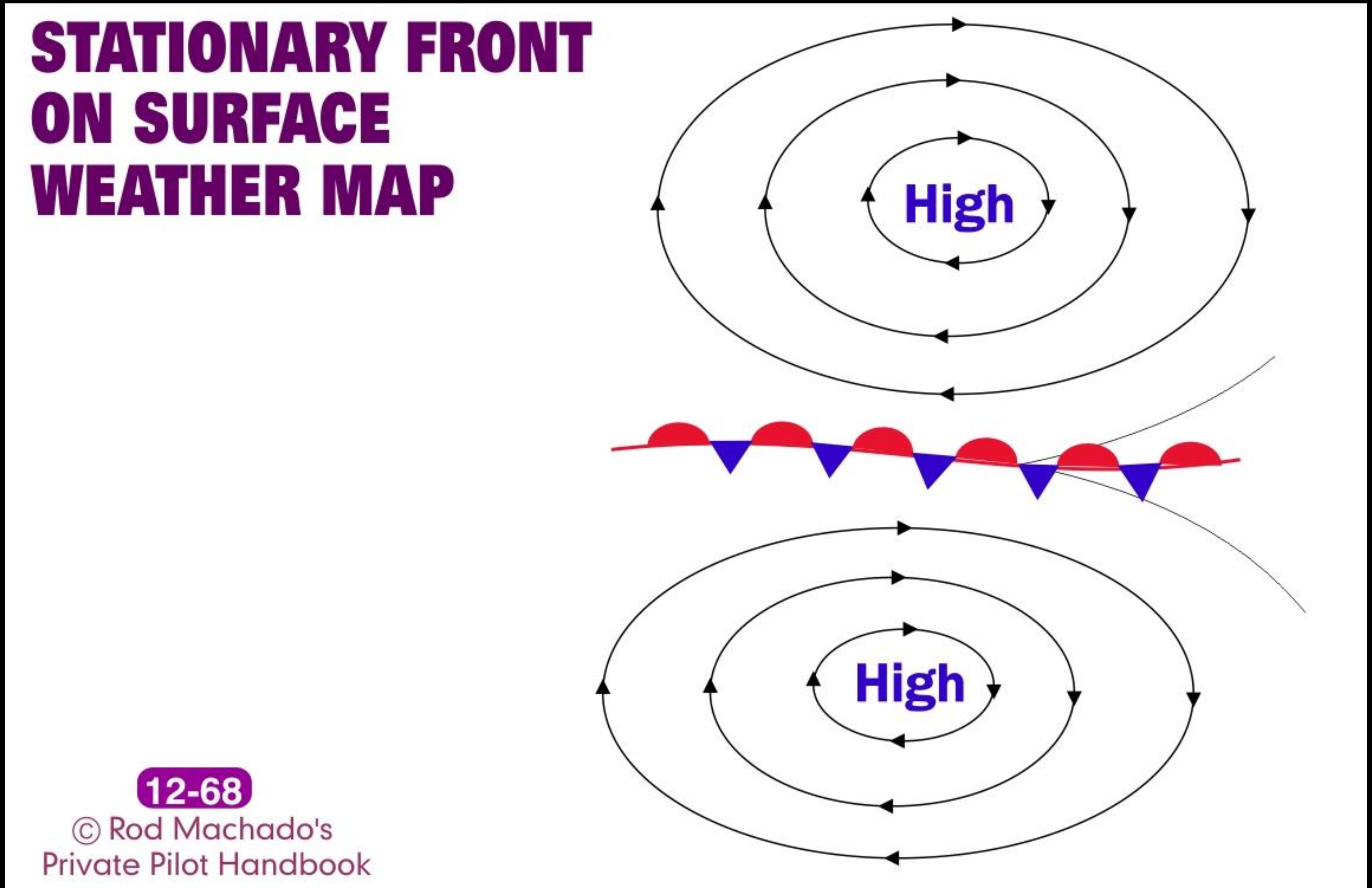
Warm Front



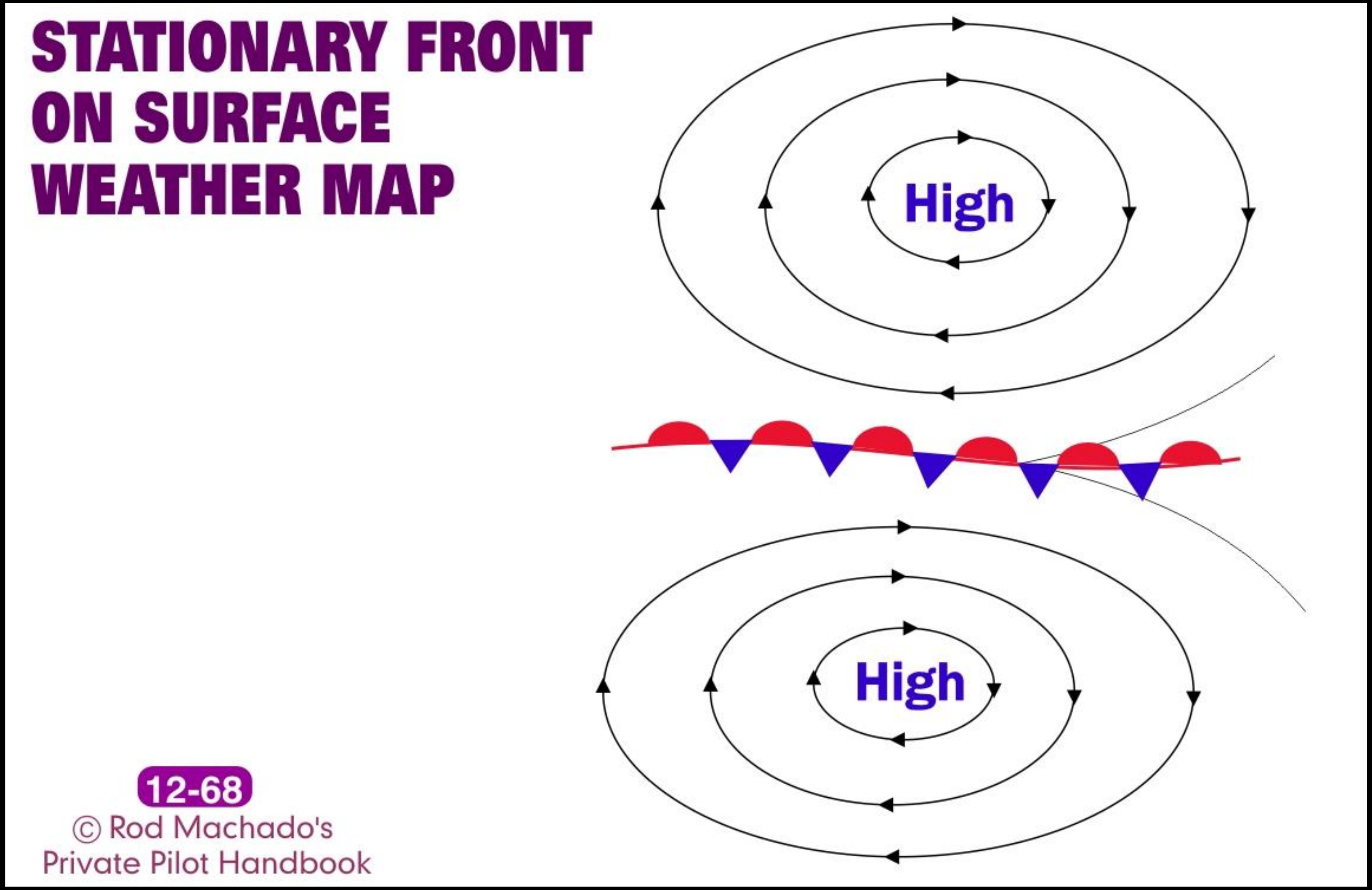
WARM AIR
CIRRUS
CIRROSTRATUS
ALTOSTRATUS
NIMBOSTRATUS
COLD AIR
St. Louis
Indianapolis 200 miles
Columbus 400 miles
Pittsburgh 600 miles
999 1002 1005 1008 1011 1014 1017
St. Louis
Indianapolis
Columbus
Pittsburgh
METAR KSTL 1950Z 21018KT 1SM –RA 0VC010 18/18 A2960
METAR KIND 1950Z 16012KT 3SM RA BKN020 15/15 A2973
METAR KCMH 1950Z 13018KT 6SM HZ 0VC060 14/10 A2990
METAR KPIT 1950Z 13012KT 10SM SCT150 12/01 A3002

Stationary Fronts

- Sometimes the opposing forces exerted by air masses of different densities are of similar strength and little or no movement occurs between them
- With little or no movement at the air mass boundary, a stationary front forms
- Wind on either side of the boundary blows parallel to the front rather than across it



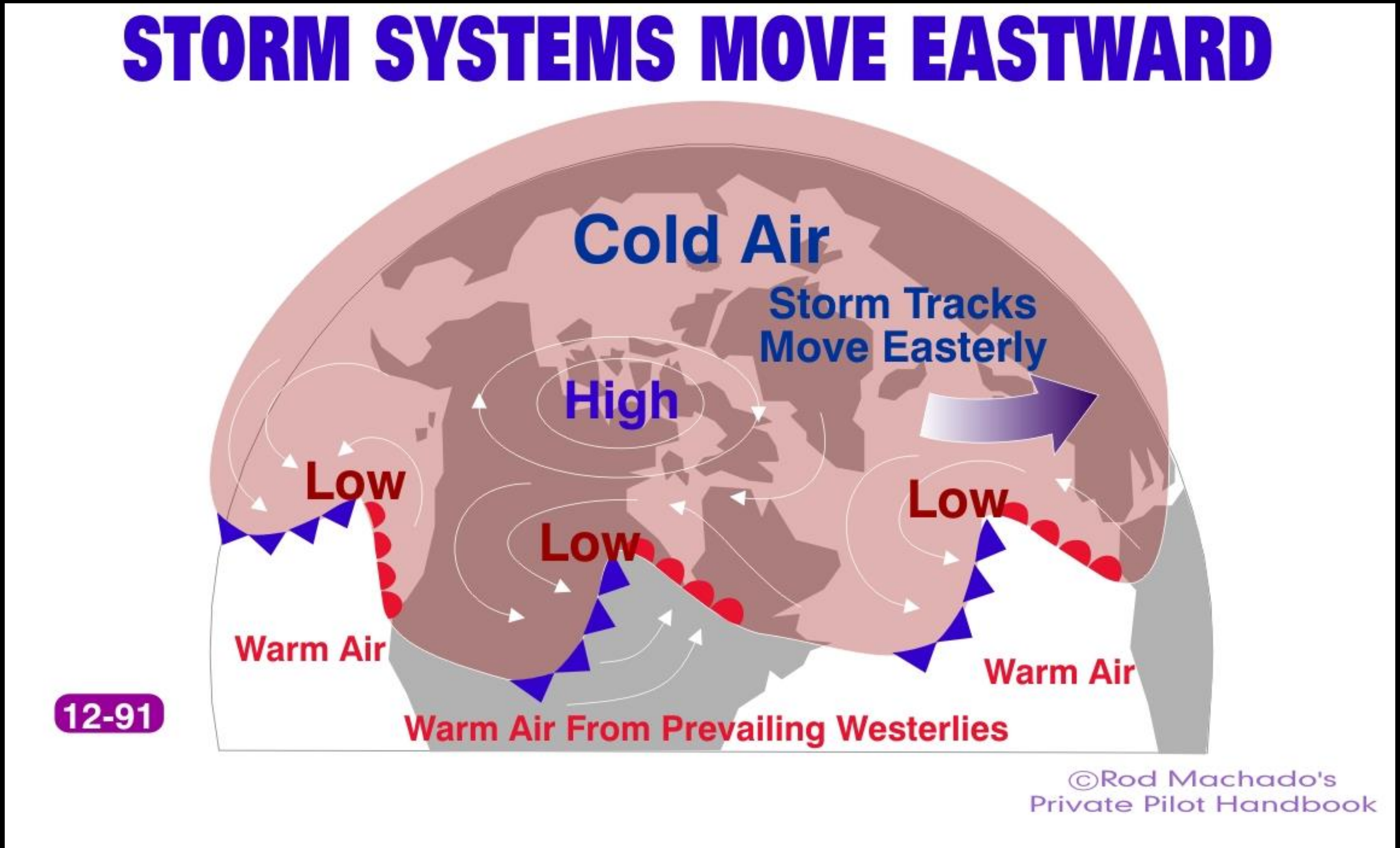
Stationary Fronts



- While stationary fronts are seldom (precisely) stationary, they usually move at a rate of less than 5 knots
- Weather that forms is similar to a warm front, but less intense because very little lifting of warm air over cold occurs
- Their weather patterns usually persist for several days

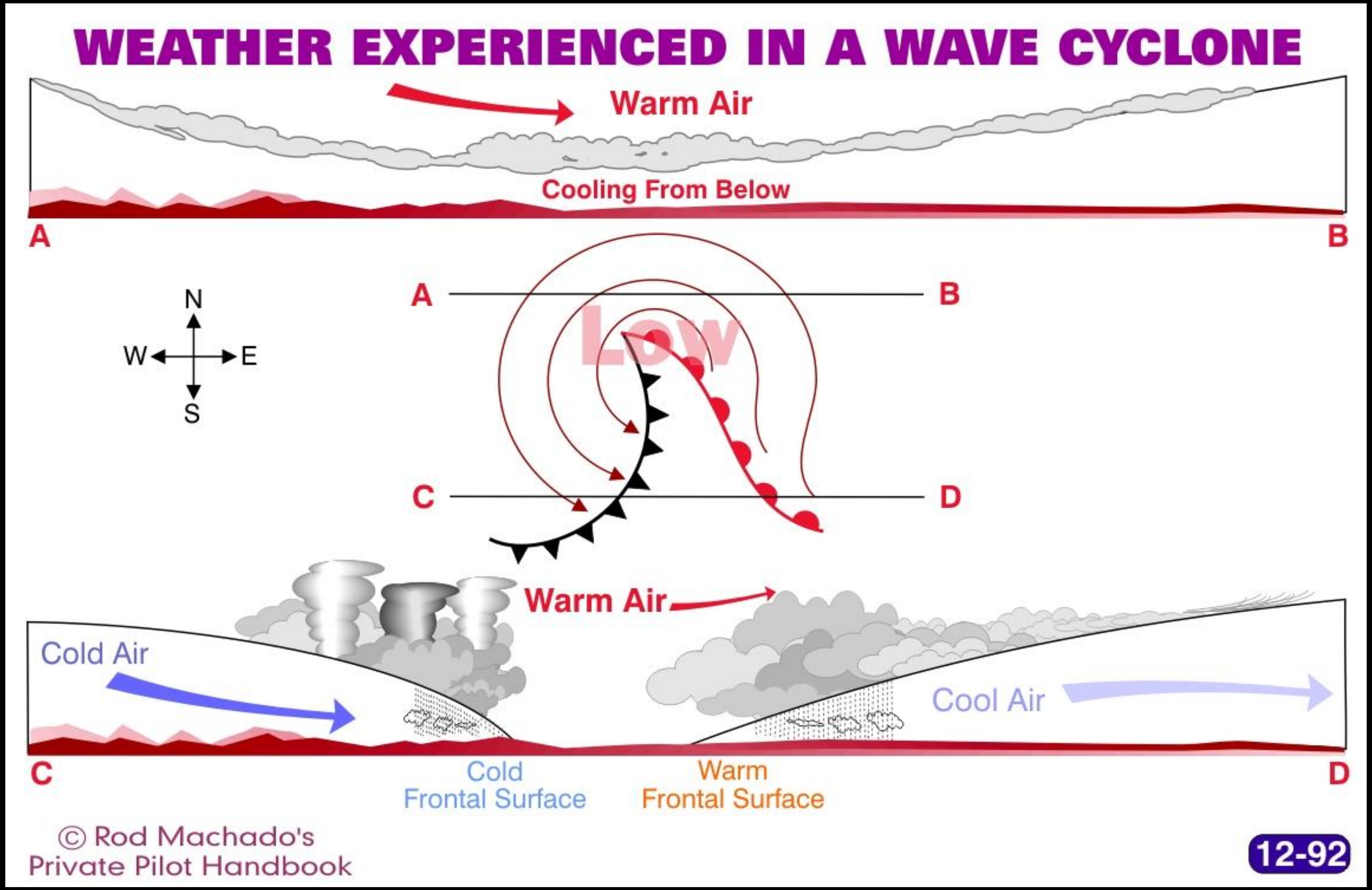
Wave Cyclone Weather Patterns

- A wave cyclone is a storm system that typically contains fronts, a low pressure system, and counterclockwise circulation
- Storm Systems Move Eastward



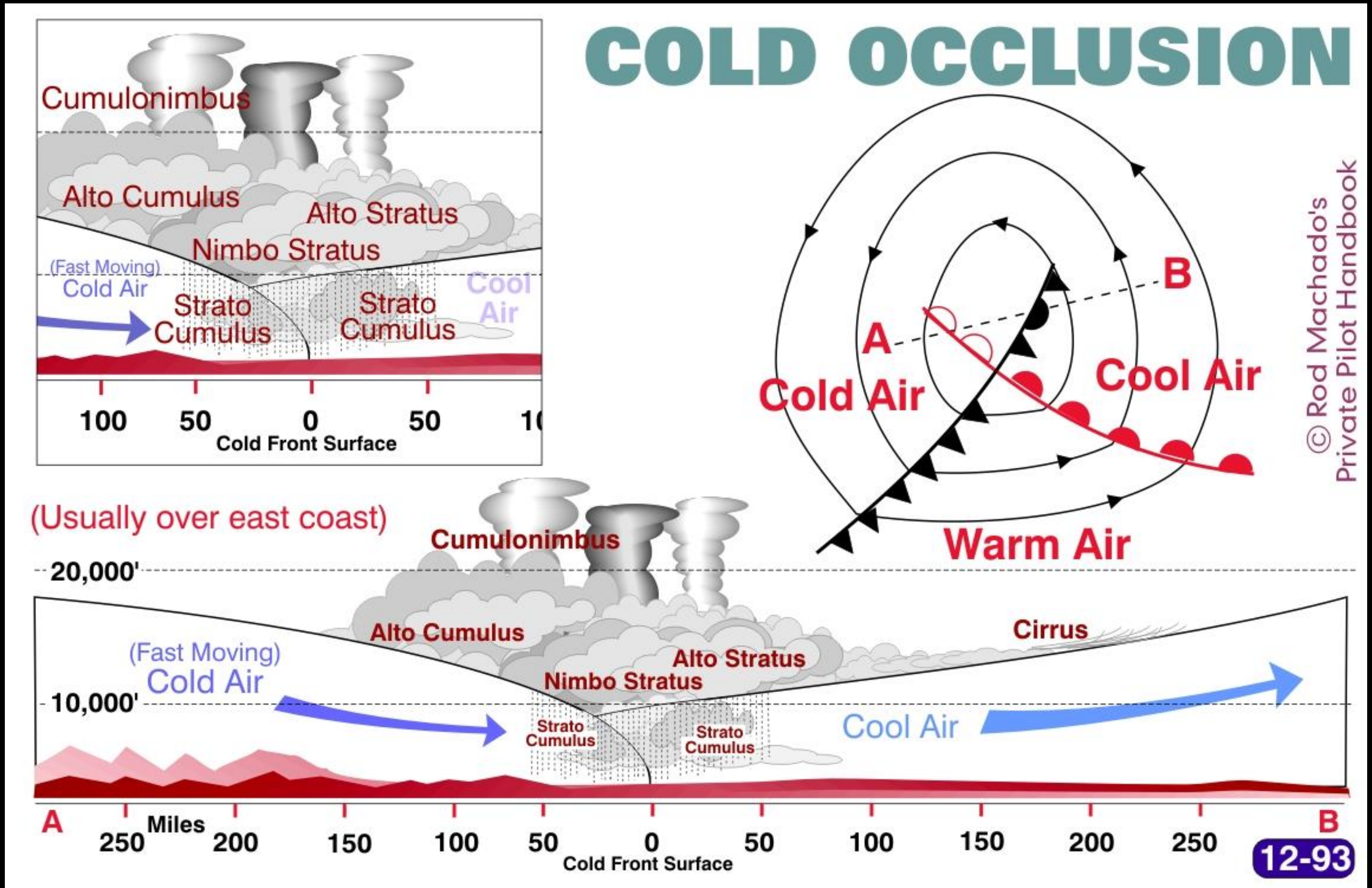
Wave Cyclone Weather

- South of the low a warm front approaches with lowering stratus and nimbostratus
- With passage of the warm front, the weather clears and the air warms up
- Finally the cold front arrives, bringing cumulonimbus clouds and thunderstorms
- Following the cold front is cold air, clearing skies, and gusty winds



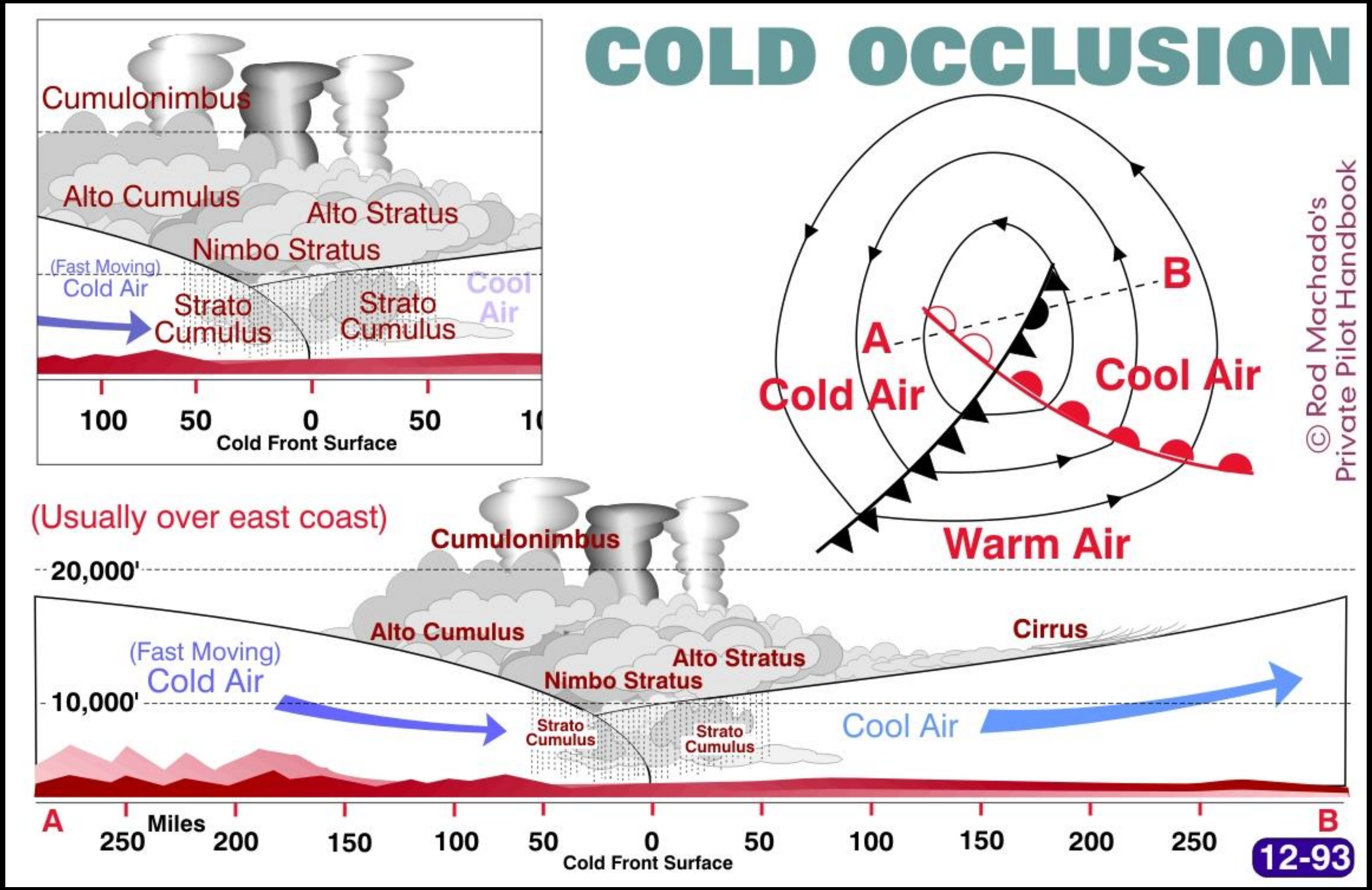
Cold Occlusion

- In wave cyclones, cold fronts usually catch up to and overtake slower moving warm fronts
- This overtaking produces a cold occluded front

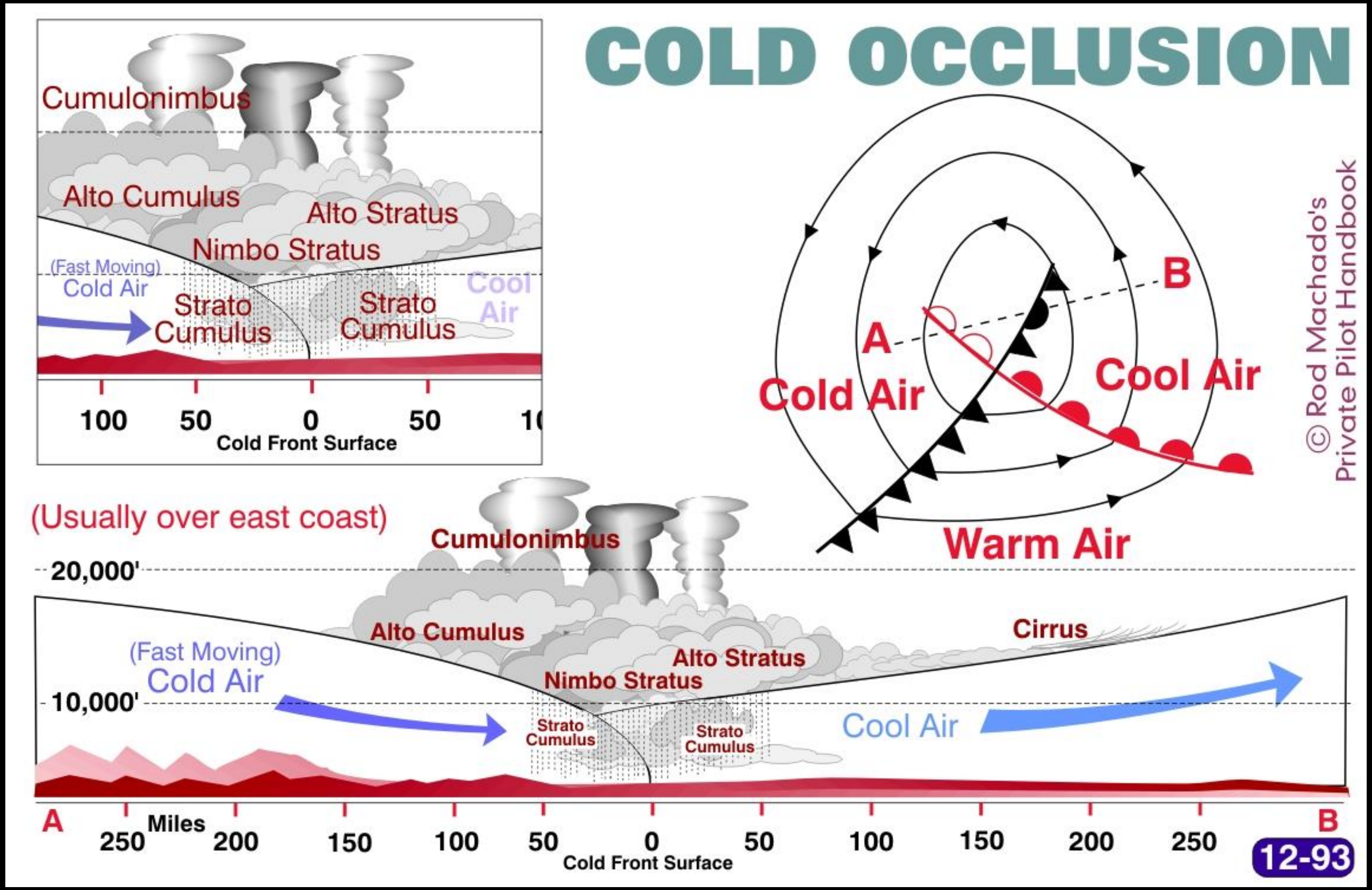


Cold Occlusion

- Cold occlusions occur when the air ahead of the warm front is less cold than the air behind the overtaking cold front
- The cold front overtaking the warm front lifts the warm air up and over the retreating cool air
- The warm front is lifted entirely off the surface by the undercutting cold front



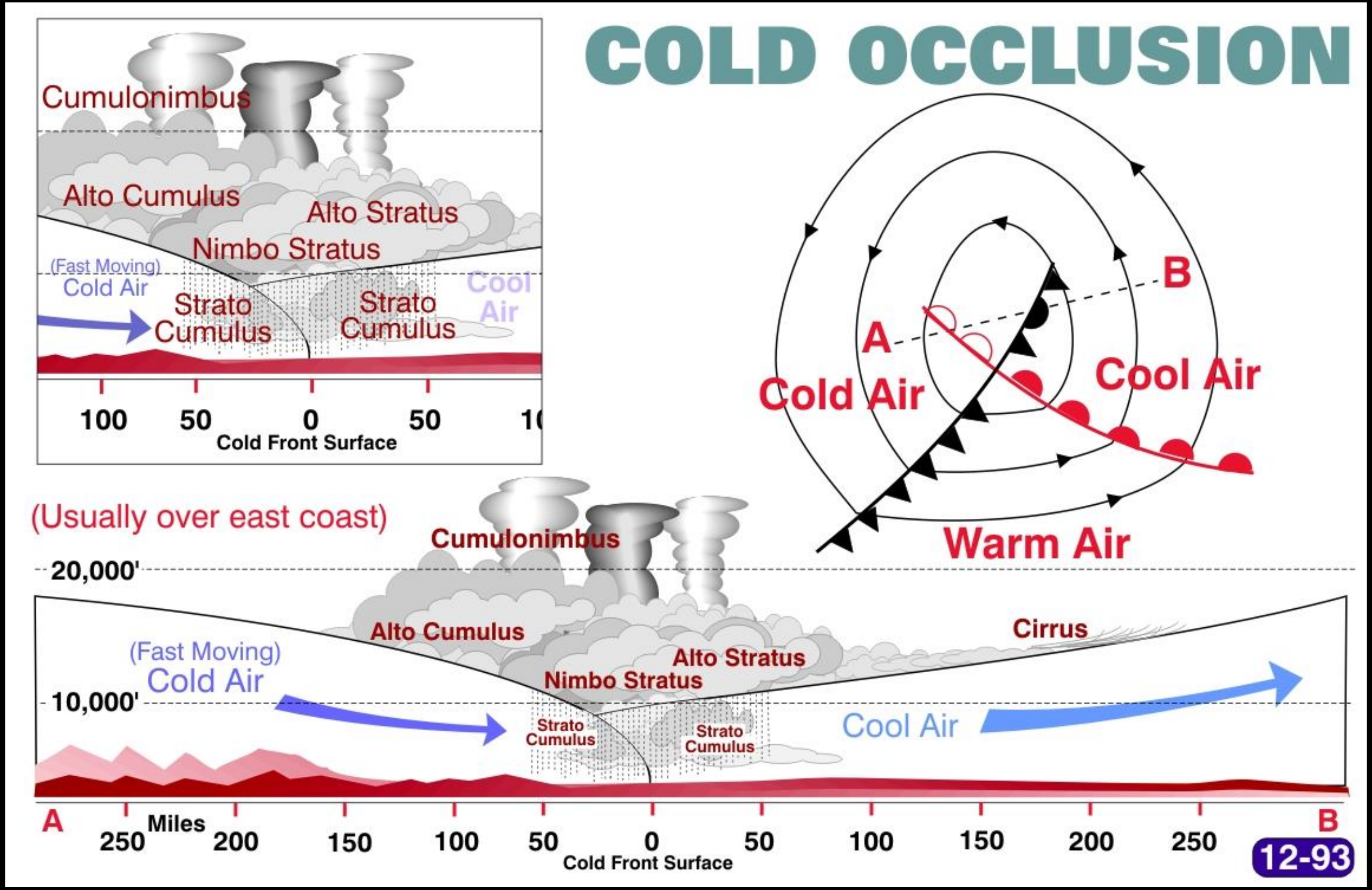
Cold Occlusion



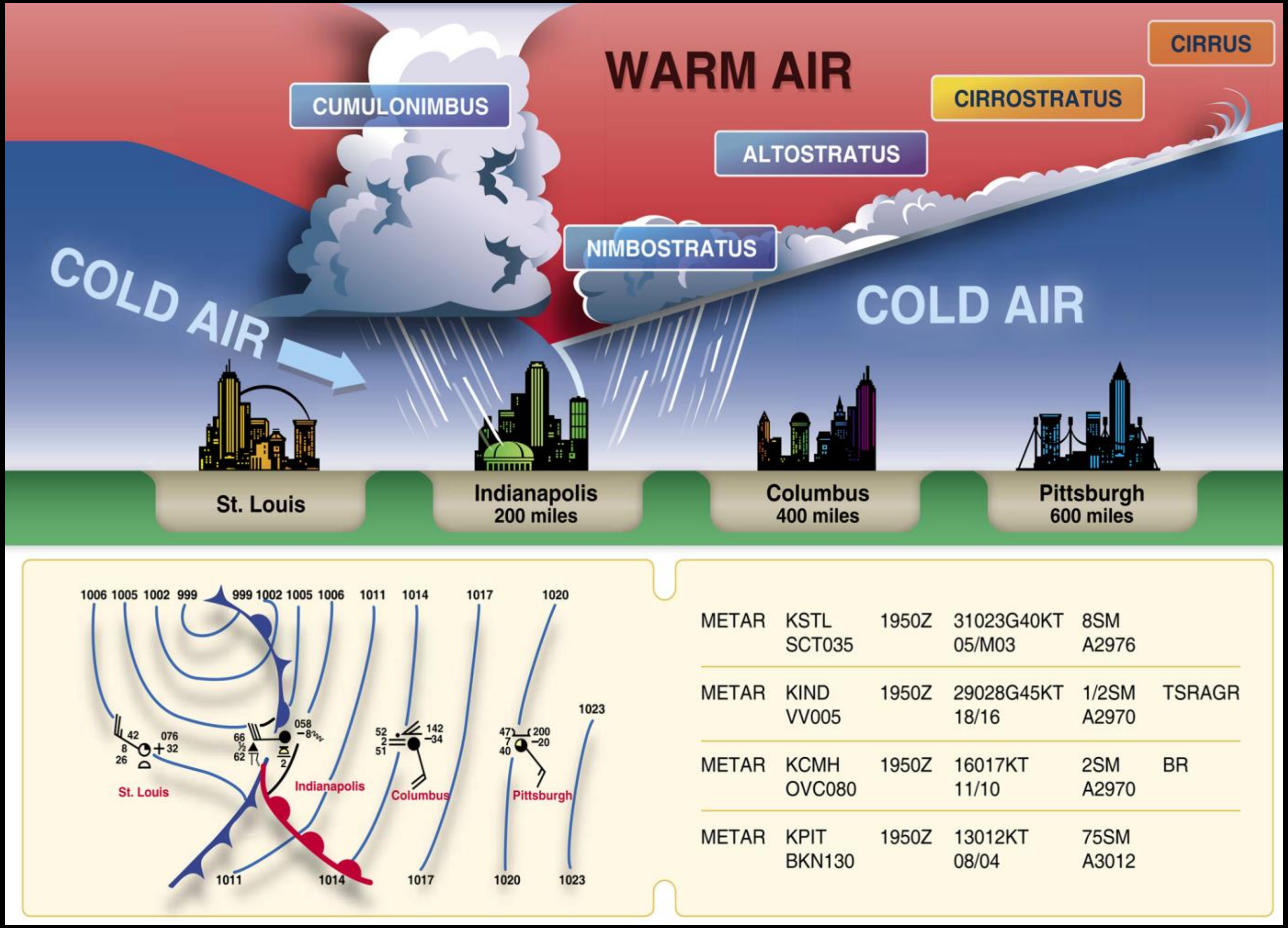
- Weather ahead of the occlusion is similar to that of warm fronts
- The weather near the surface position is similar to that of cold fronts

Cold Occlusion

- As the occlusion develops, warm air is lifted higher and higher
- Finally the cloud system associated with the warm front disappears
- The weather and cloud system now resembles a cold front
- Form predominantly over continents or along the east coast and are more common than warm occlusions

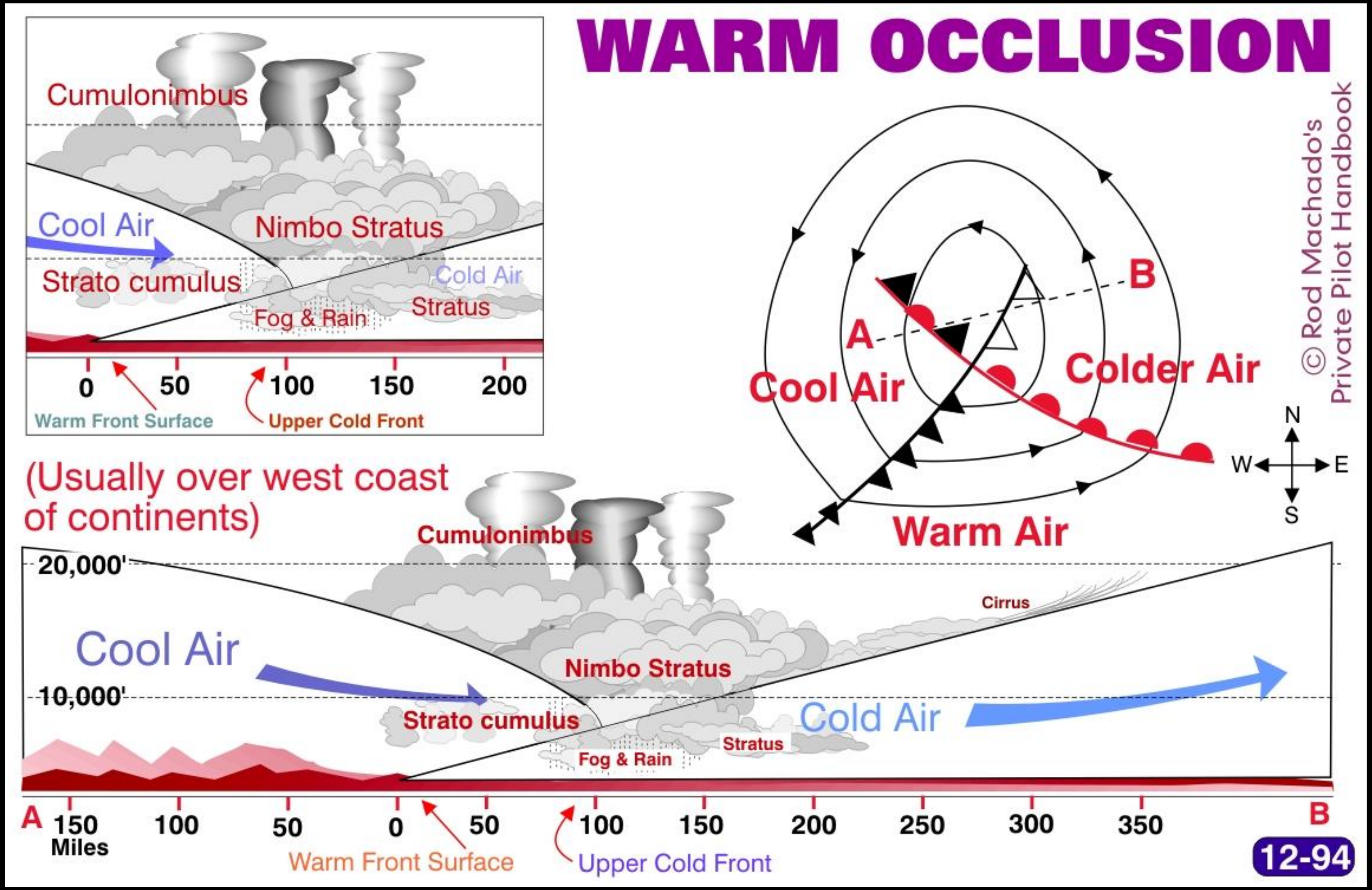


Cold Occlusion



Warm Occlusion

- Usually found in the NW US
- Occurs when the Pacific cold front pushes the warmer air up and over the retreating Arctic air mass
- The Pacific air mass is not as cold as the Arctic airmass and moves up the same slope
- Weather is similar to a warm front to the east
- Cold front weather occurs near the upper cold front boundary



Weather Hazards

Weather Theory

Thunderstorms

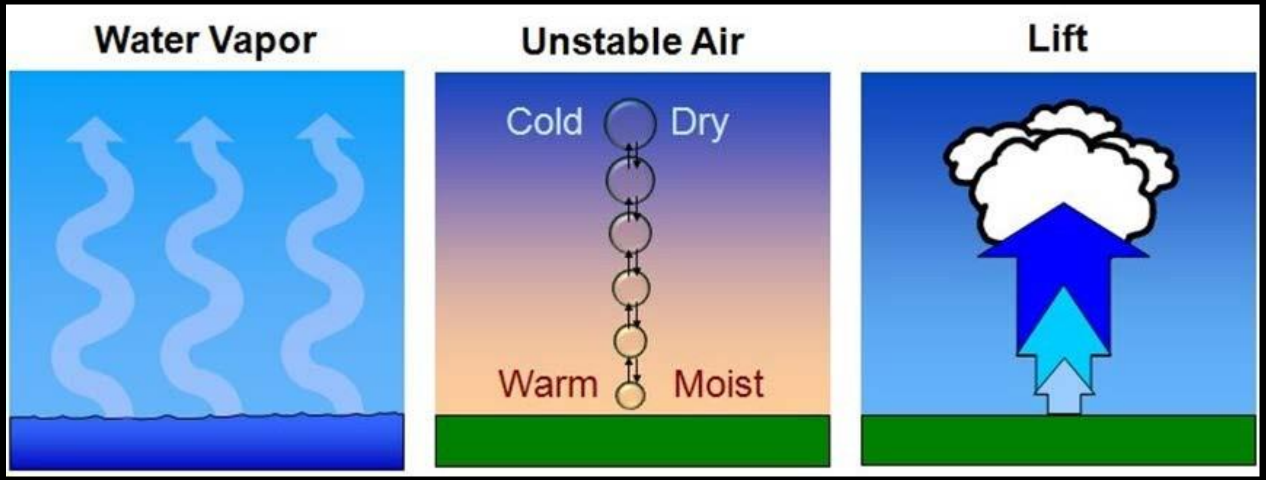
- A thunderstorm is a local storm, produced by a cumulonimbus cloud
- Always accompanied by *lightning and thunder*, usually with strong gusts of wind, heavy rain, and sometimes with hail
- The total life cycle is typically about 20 – 90 minutes
- Thunderstorms are barriers to air traffic because they are usually too tall to fly over, too dangerous to fly through or under, and can be difficult to circumnavigate

Necessary Ingredients for Thunderstorm Cell Formation

- Sufficient water vapor (measured using dewpoint) must be present to produce unstable air
- Virtually all showers and thunderstorms form in an air mass that is classified as conditionally unstable
- A conditionally unstable air mass requires a lifting mechanism strong enough to release the instability

Necessary Ingredients for Thunderstorm Cell Formation

- Thunderstorm cell formation requires three ingredients:
- *Sufficient water vapor*
- *Unstable air*
- *A lifting mechanism*



Lifting Mechanisms

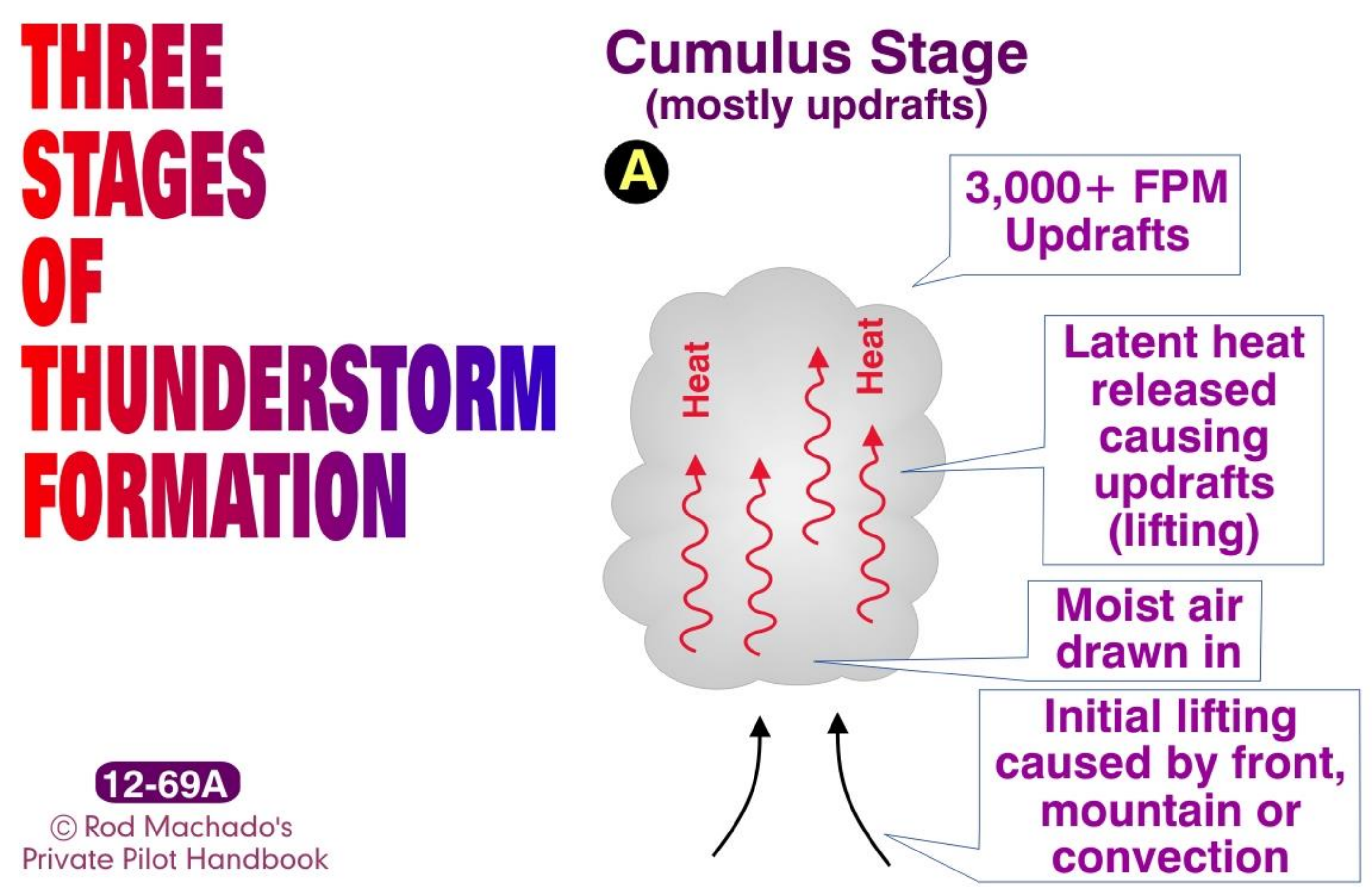
- Converging winds around surface lows and troughs
- Fronts
- Upslope flow
- Local winds (sea breeze, lake breeze, land breeze, and valley breeze circulations)

Three Stages of Thunderstorm Formation

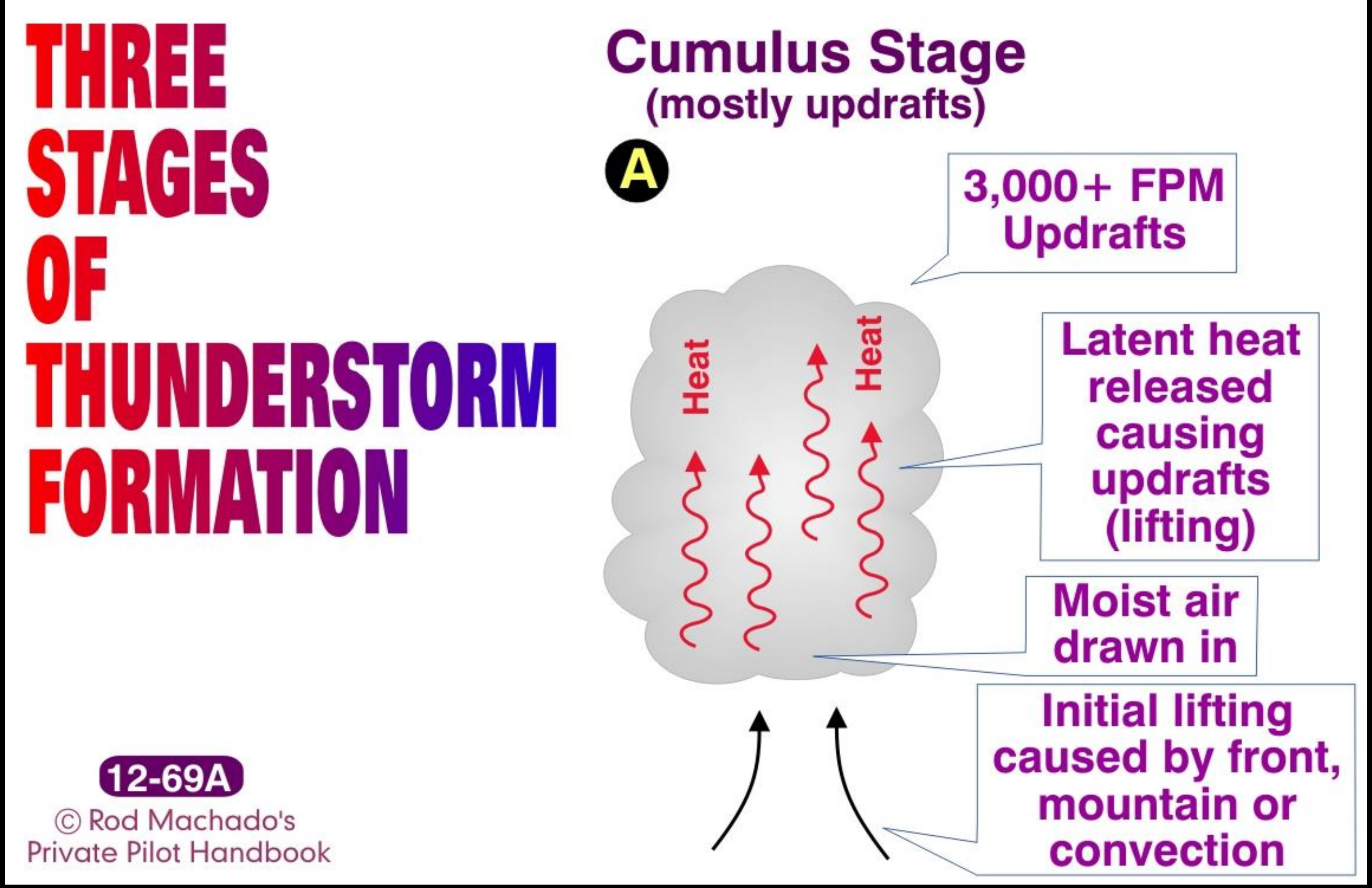
- Cumulus Stage
- Mature Stage
- Dissipating Stage

Cumulus Stage

- The first stage of a potential thunderstorm is always a cumulus cloud
- Air parcels, given an initial shove by a lifting force a small cumulus cloud in the unstable air.
- As the cumulus cloud grows updrafts draw in more moist air from below



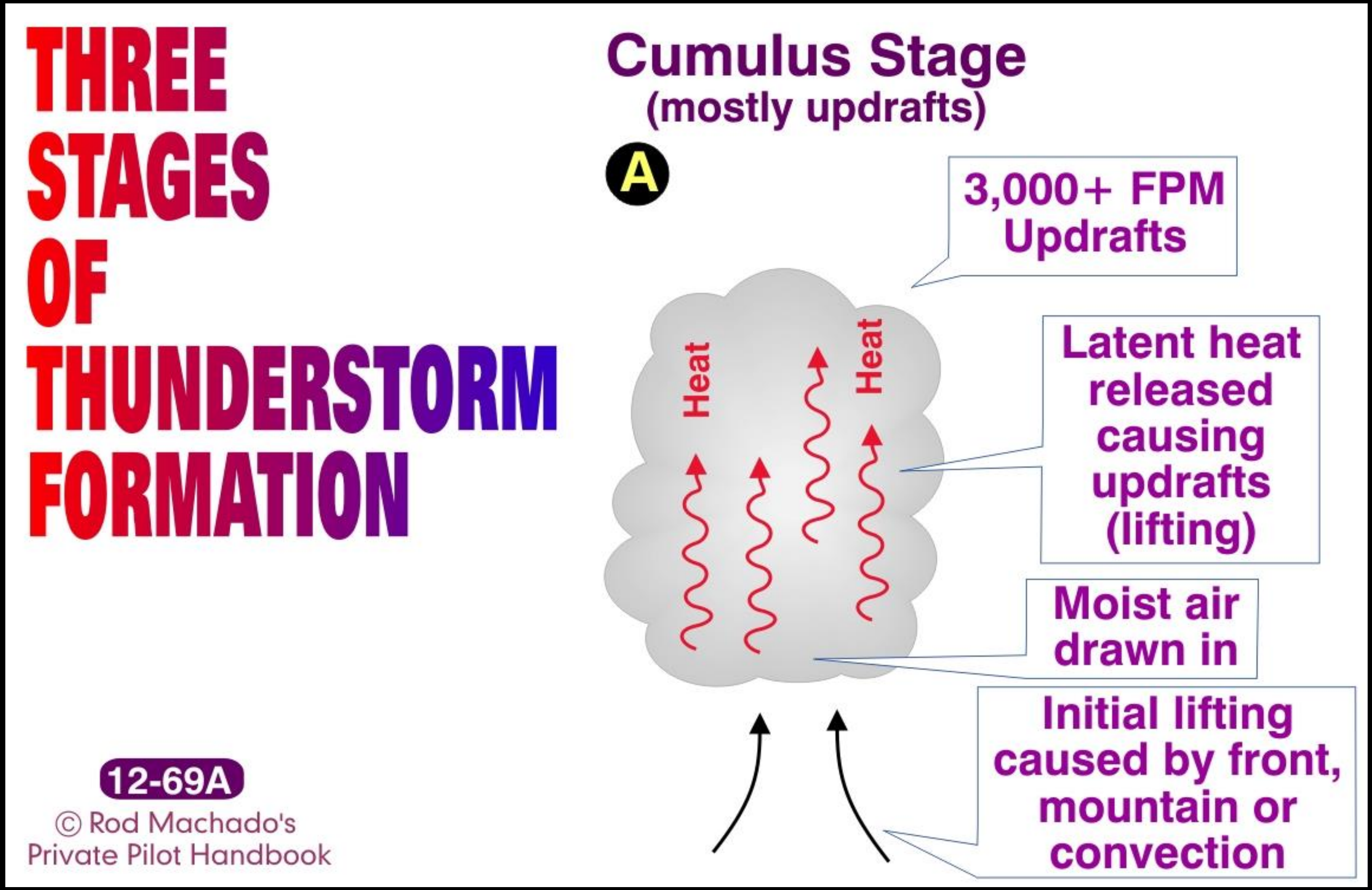
Cumulus Stage



- Latent heat is released as this moisture condenses making the cloud warmer and accelerates its growth
- As more moisture-laden air is drawn into the cloud, the condensation process continues producing additional cloud droplets in the updrafts
- The cloud droplets begin bumping into each other and start combining, growing larger

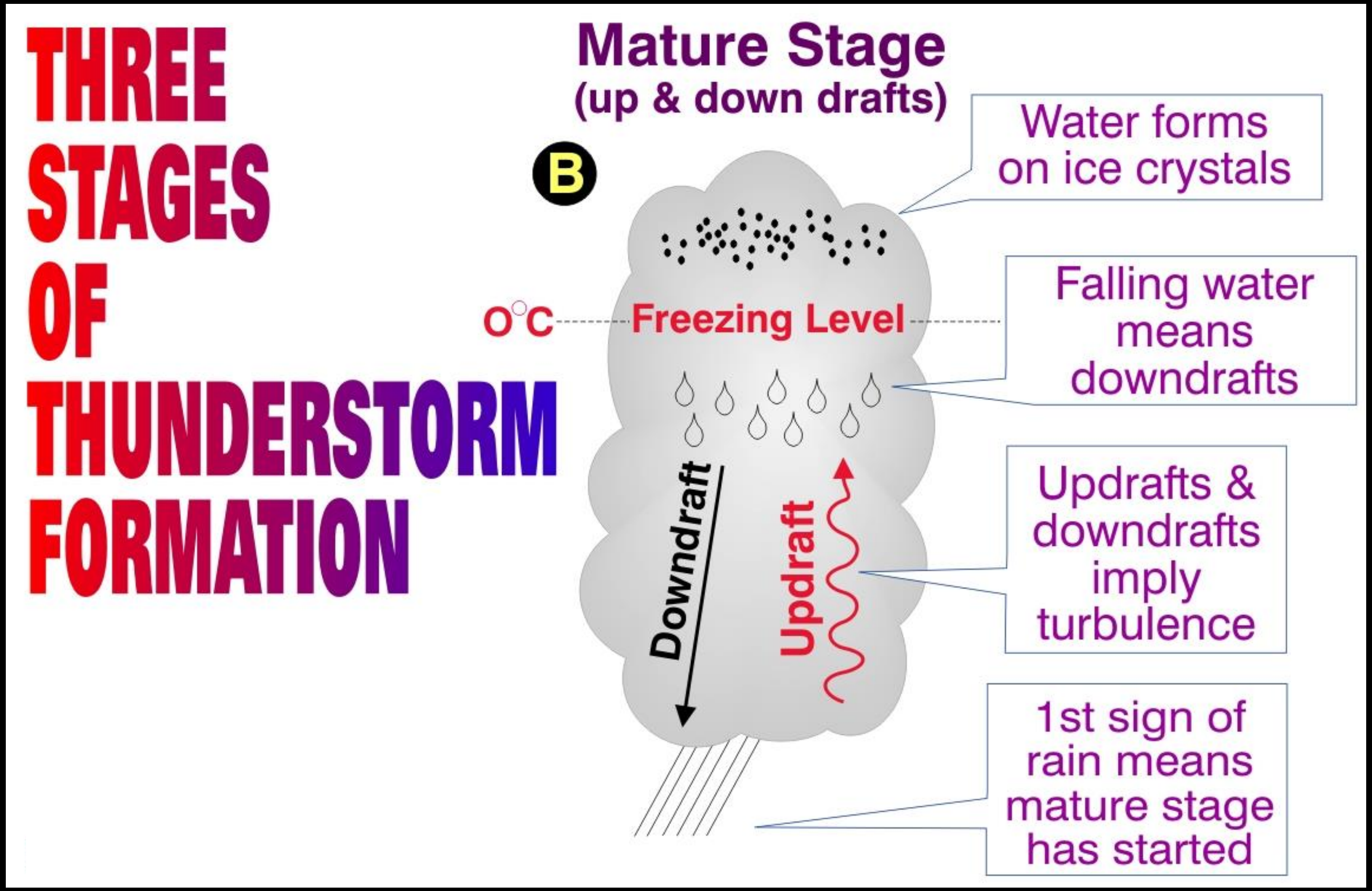
Cumulus Stage

- The only thing keeping the raindrops aloft is the updraft
- As long as they are not too heavy, they are held aloft
- The faster the updraft velocity, the larger the raindrops
- Characterized by updrafts that can be in excess of 3,000 feet per minute

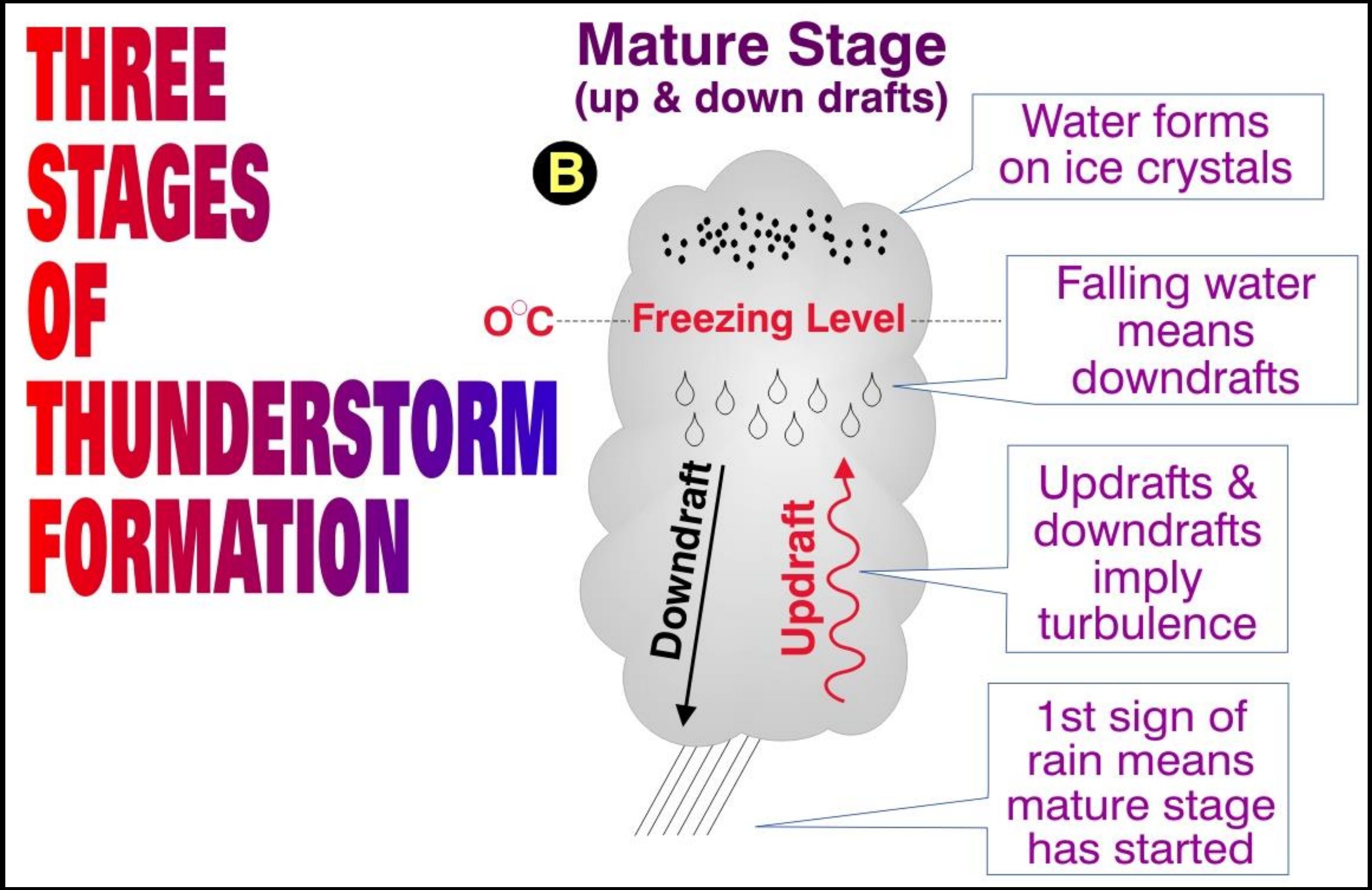


Mature Stage

- Characterized by updrafts, downdrafts, turbulence, low level windshear, hail, ice, rain and lightning
- Most dangerous stage of a thunderstorm's life cycle
- Eventually the raindrops become so heavy the updraft can no longer support their weight and they begin to fall
- Raindrops are still growing as they collide with other cloud droplets



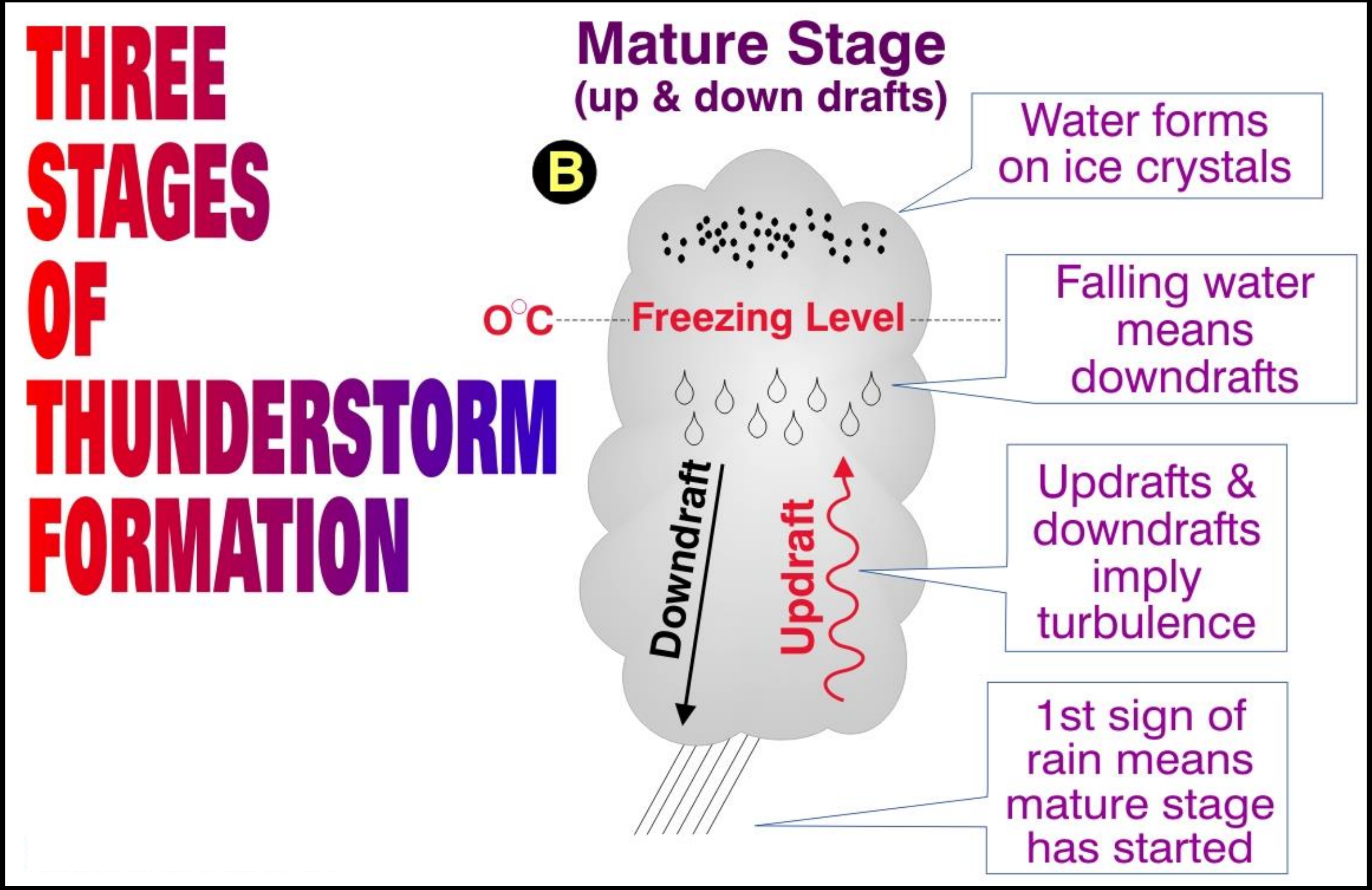
Mature Stage



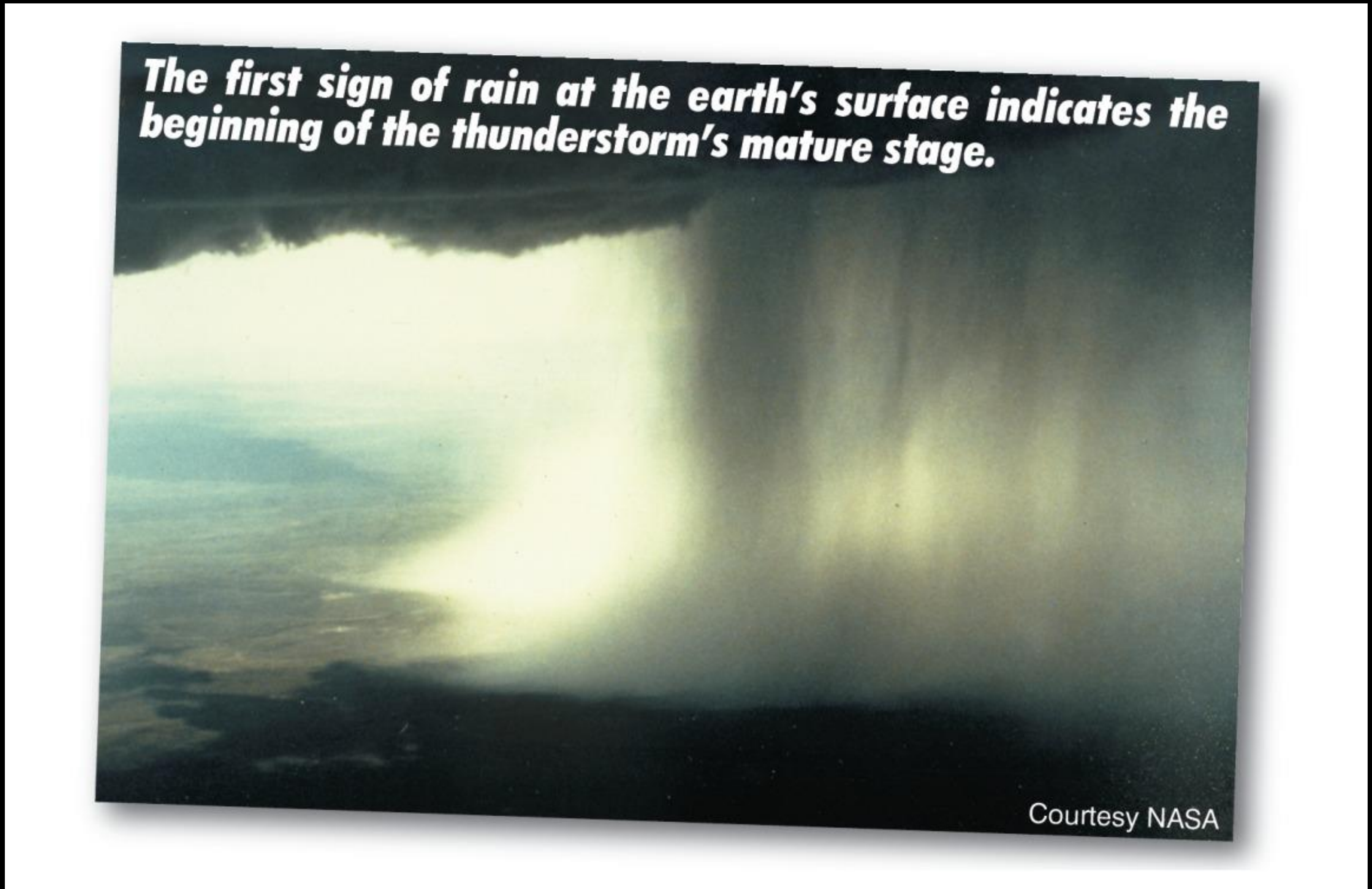
- The first sign of rain at the earths surface indicates the beginning of the mature stage
- Rain descends through the cloud and drags the adjacent air downward, creating a strong downdraft alongside the updraft
- The greater the rainfall rate, the greater the downdrafts

Mature Stage

- With a combination of updrafts and downdrafts the mature stage offers the greatest amount of turbulence and windshear
- Hail is most likely to occur during this stage
- Thunderstorms can grow to 50,000 to 60,000 feet, extending into the tropopause

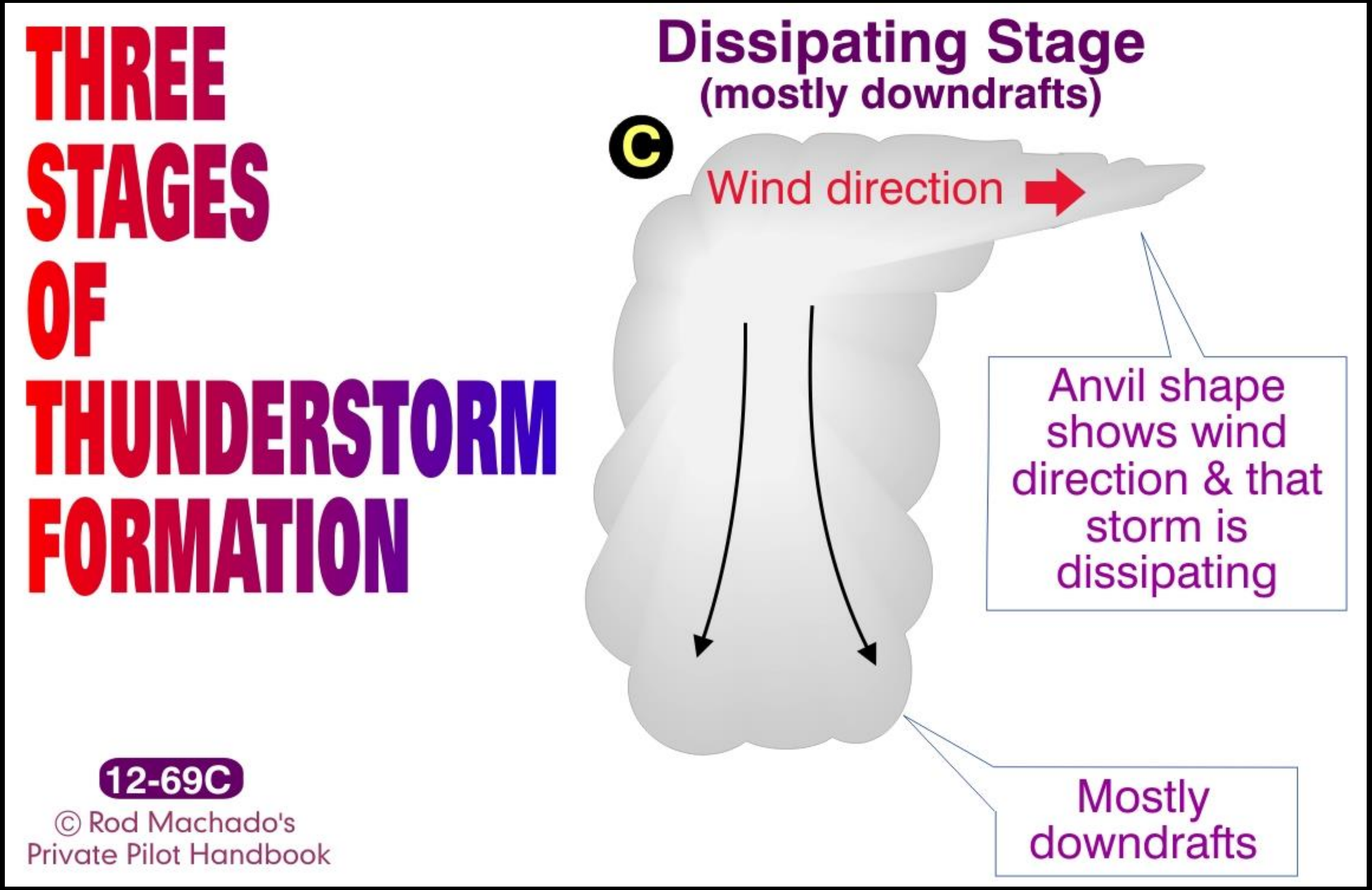


Mature Stage



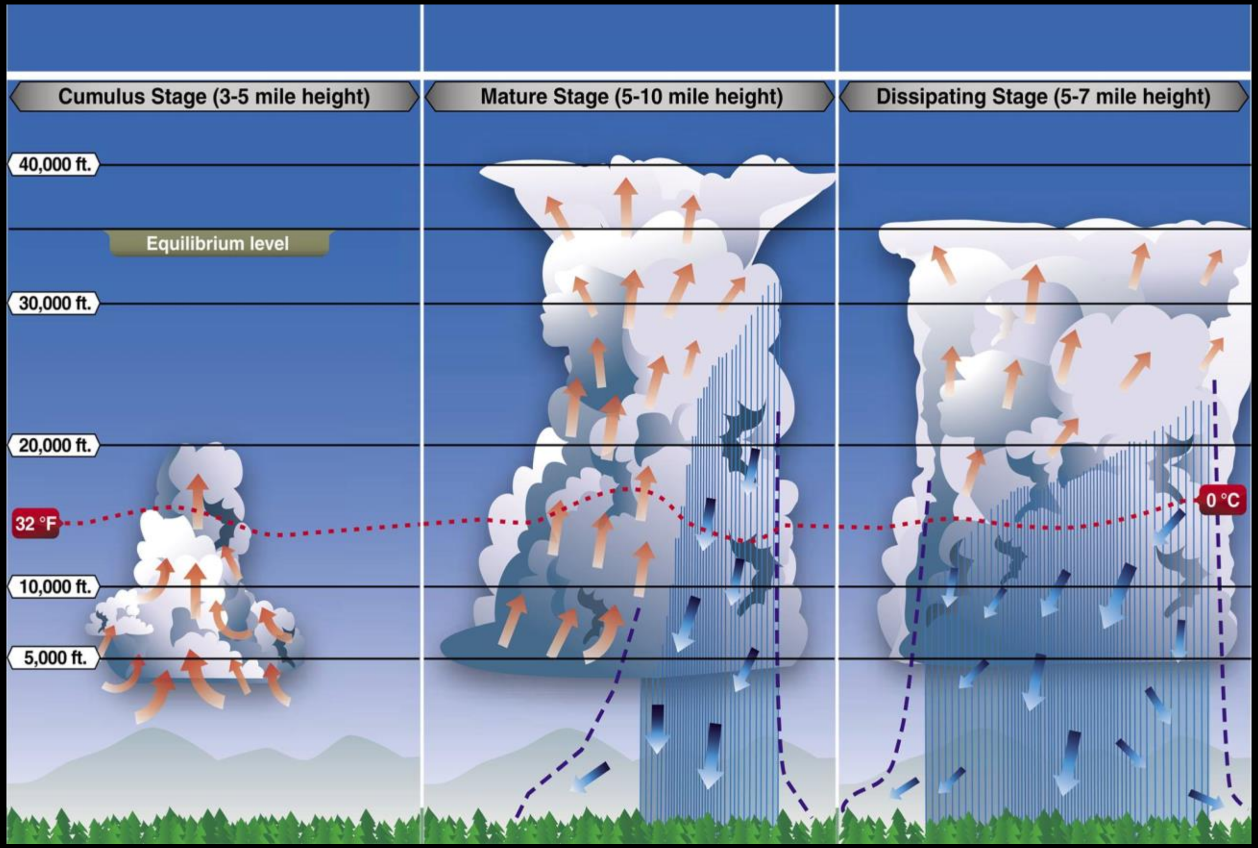
Dissipating Stage

- Throughout the mature stage, downdrafts develop, and updrafts weaken
- Ultimately, downdrafts are all that's left in the thunderstorm cell
- The dissipating stage is often characterized by an anvil top
- Without continued vertical development the thunderstorm's top is blown over by high altitude winds



Thunderstorm Cell Life Cycle

- A thunderstorm undergoes three distinct stages during its life cycle:
- *Cumulus (Towering)*
- *Mature*
- *Dissipating*

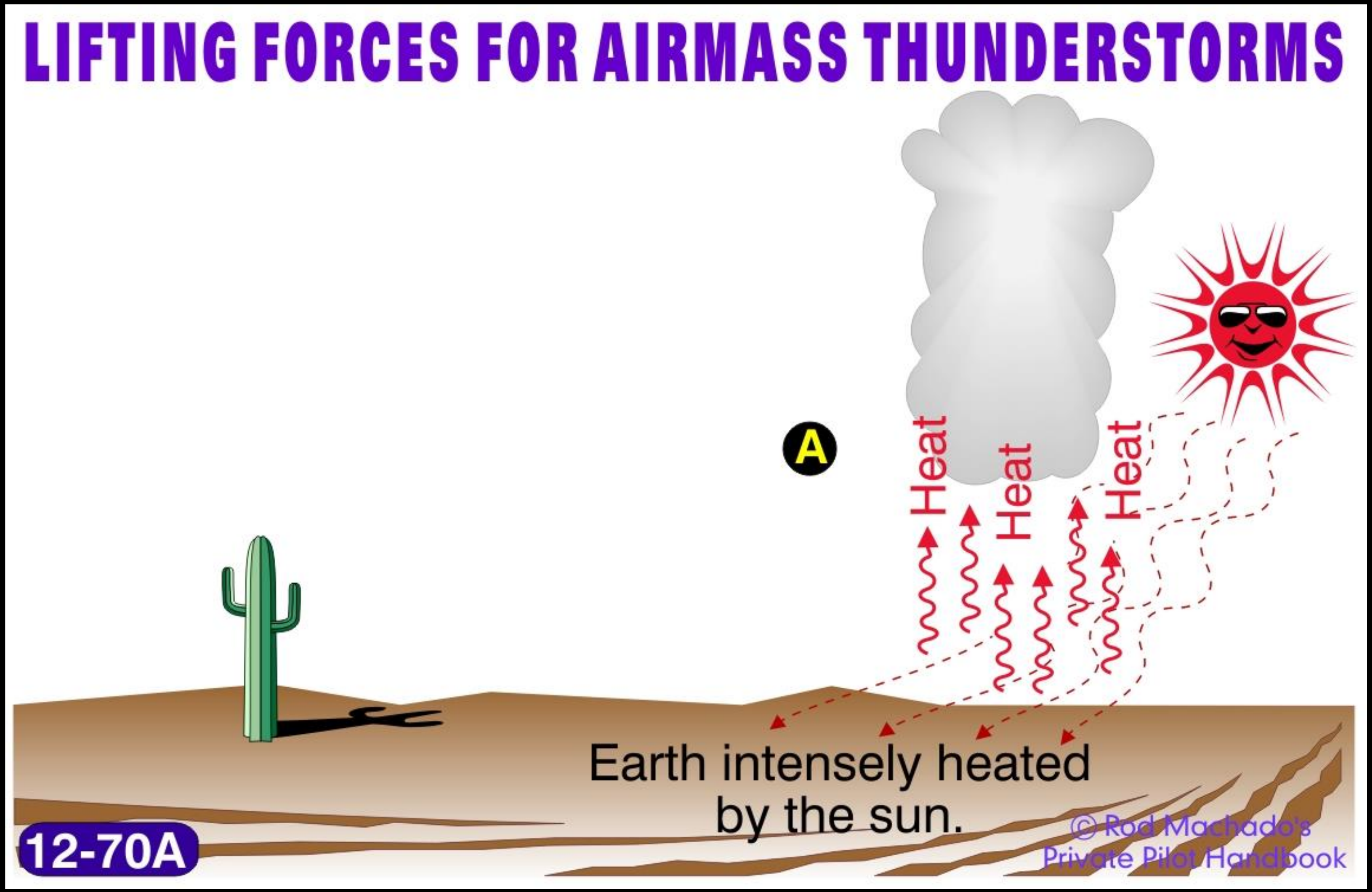


Lifting Actions

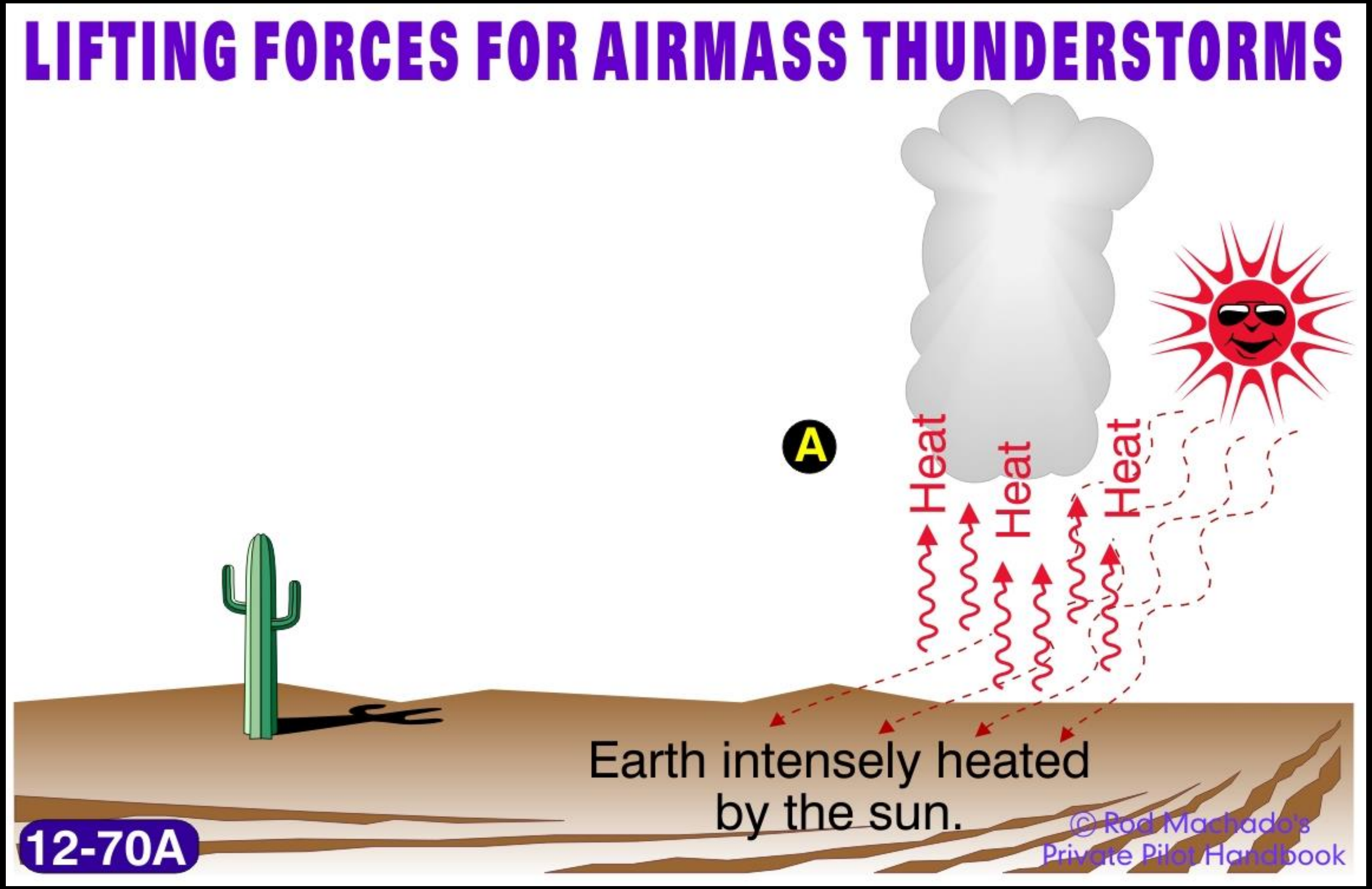
- Lifting action required for thunderstorm formation can be furnished by any of four sources:
  - Heating from below (creating convective currents),
  - Lifting by a front
  - Air movement up a mountain, or
  - Convergence of air
- Typically, thunderstorms form in air masses, in fronts, or over mountains

Air Mass Thunderstorms

- Form within a warm, moist air mass and are not associated with fronts
- Classified as convective (heated from below) thunderstorms
- Usually isolated and widely scattered enough that pilots can safely navigate around them
- Move very slowly, making them relatively easy to avoid



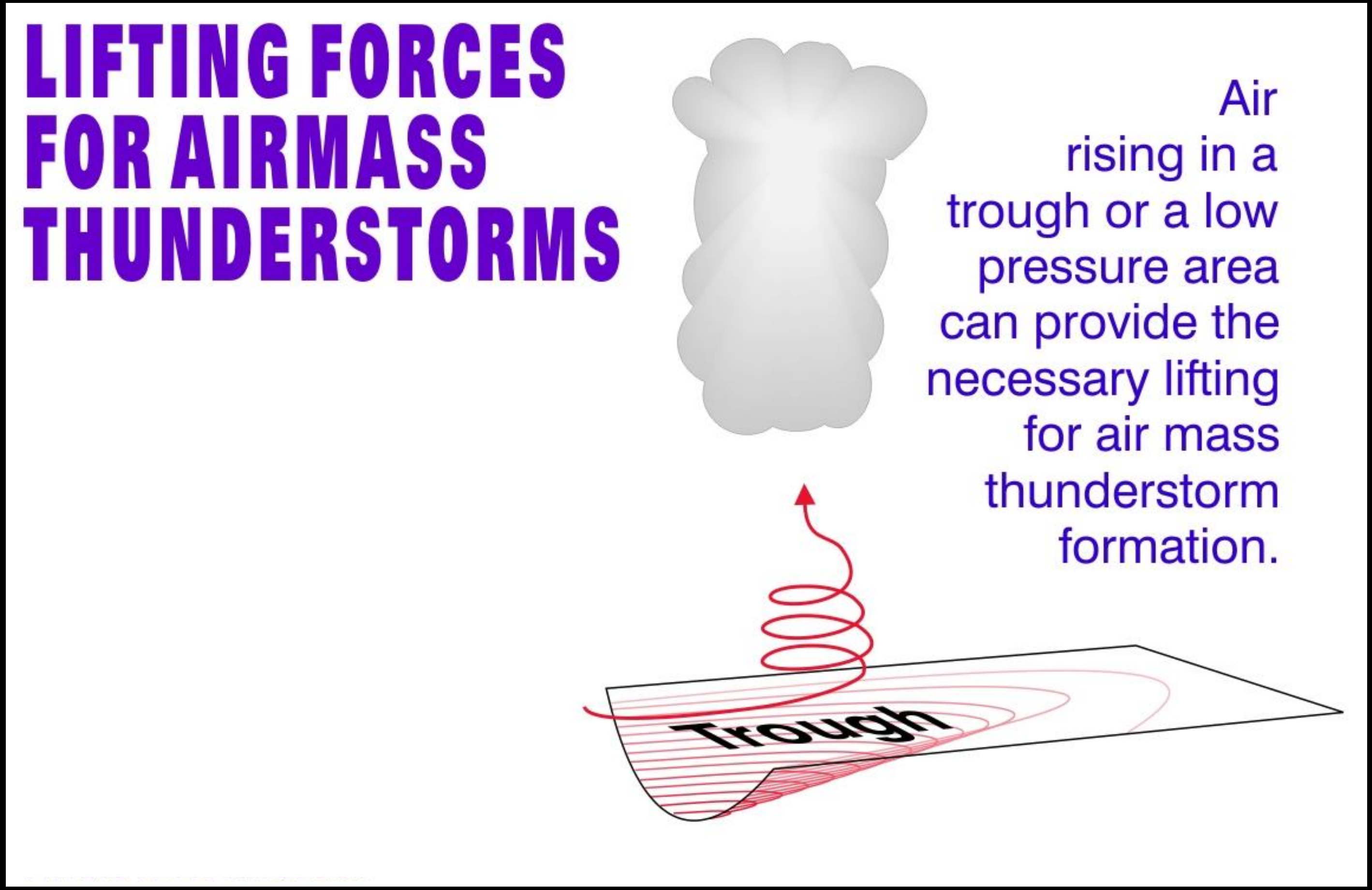
Air Mass Thunderstorms



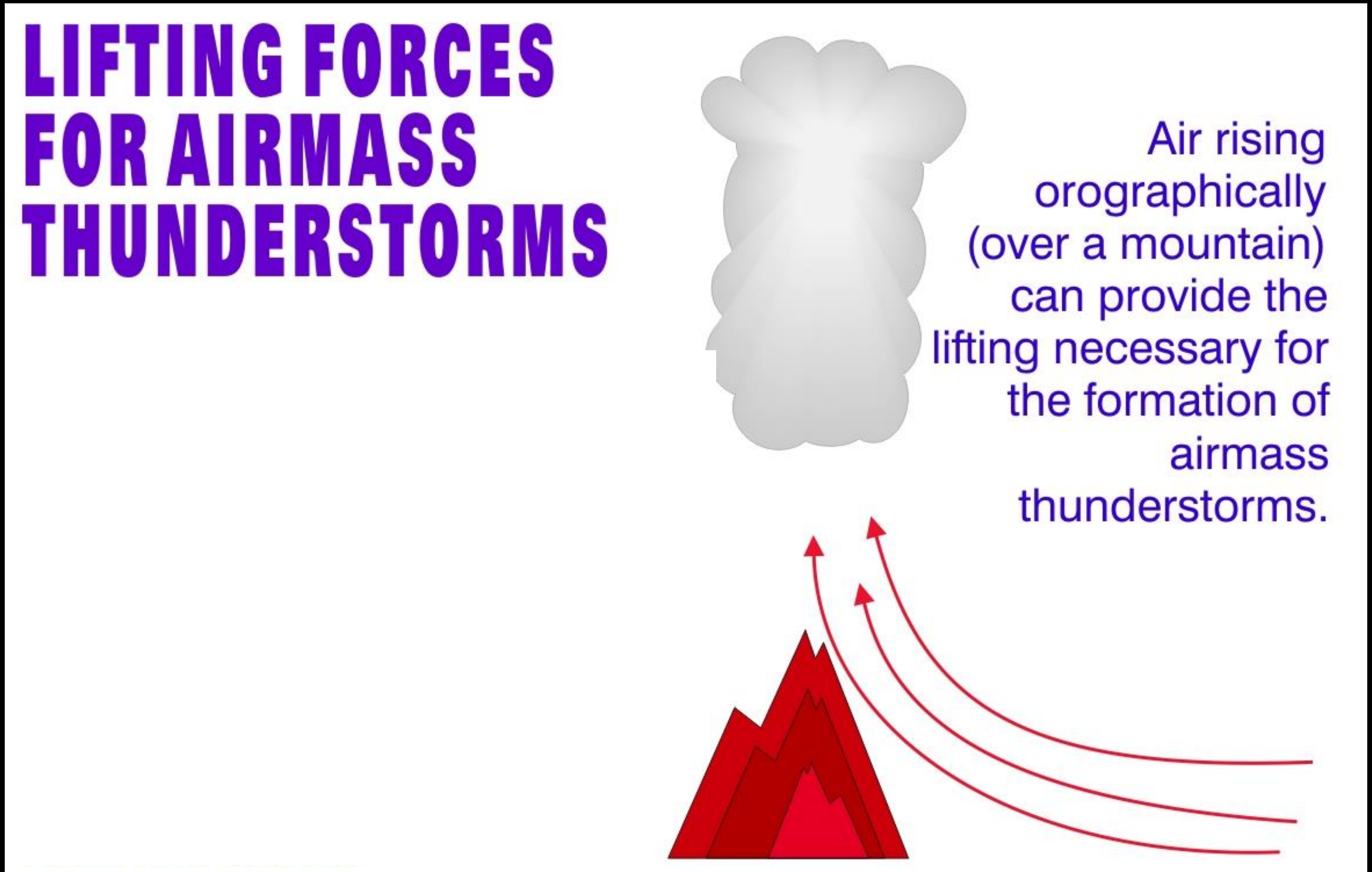
- During afternoon or early evening, land masses provide enough heating for air to begin rising and condensing
- With enough moisture and instability, thunderstorms form

Air Mass Thunderstorms

- Troughs or areas of decreasing pressure can also provide the necessary lifting for thunderstorm formation

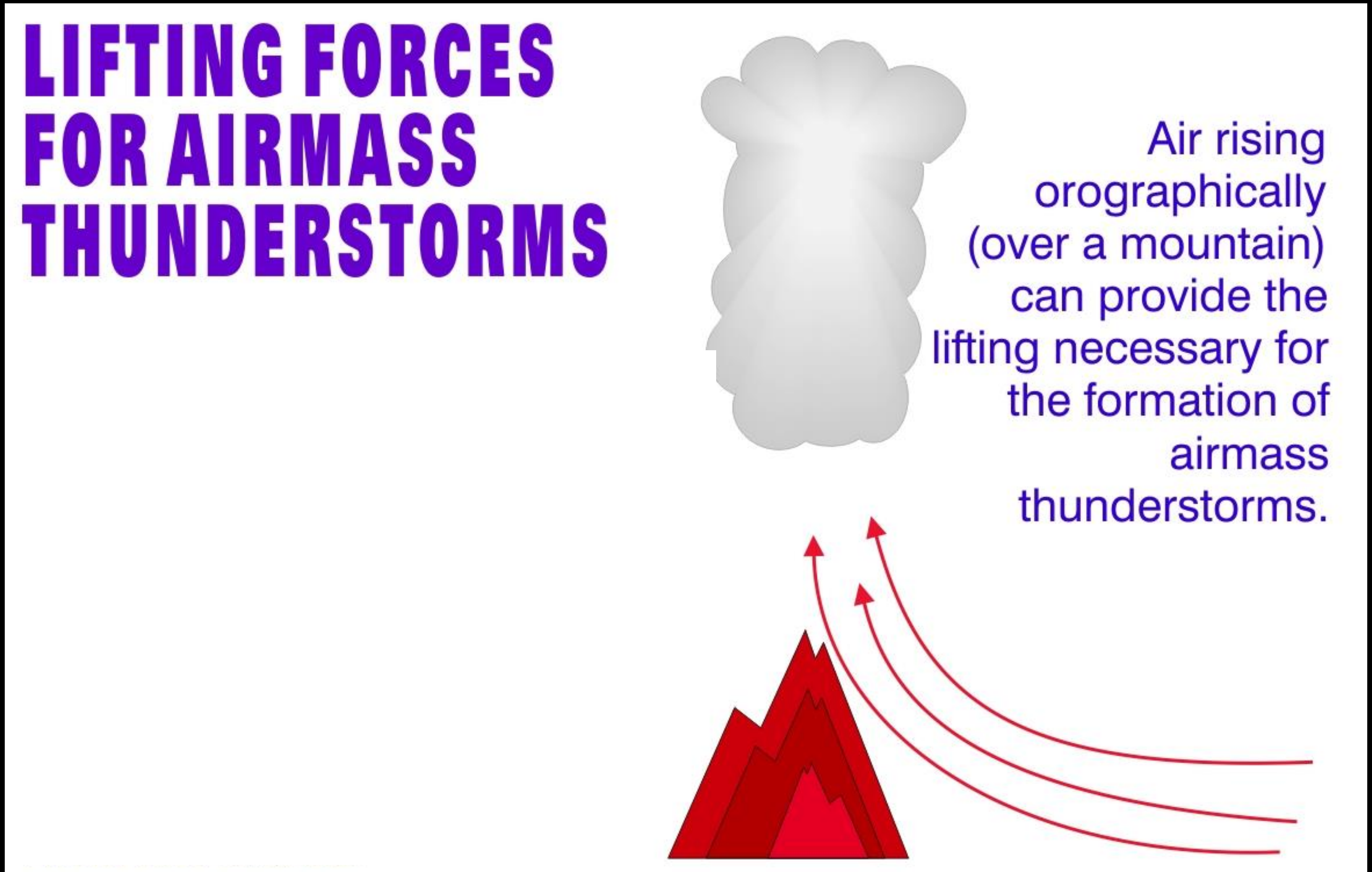


Orographic Thunderstorms



- Occur when moist, unstable air is forced up mountain slopes
- When heating from below works in conjunction with other lifting forces (orographic) air mass thunderstorms increase in frequency

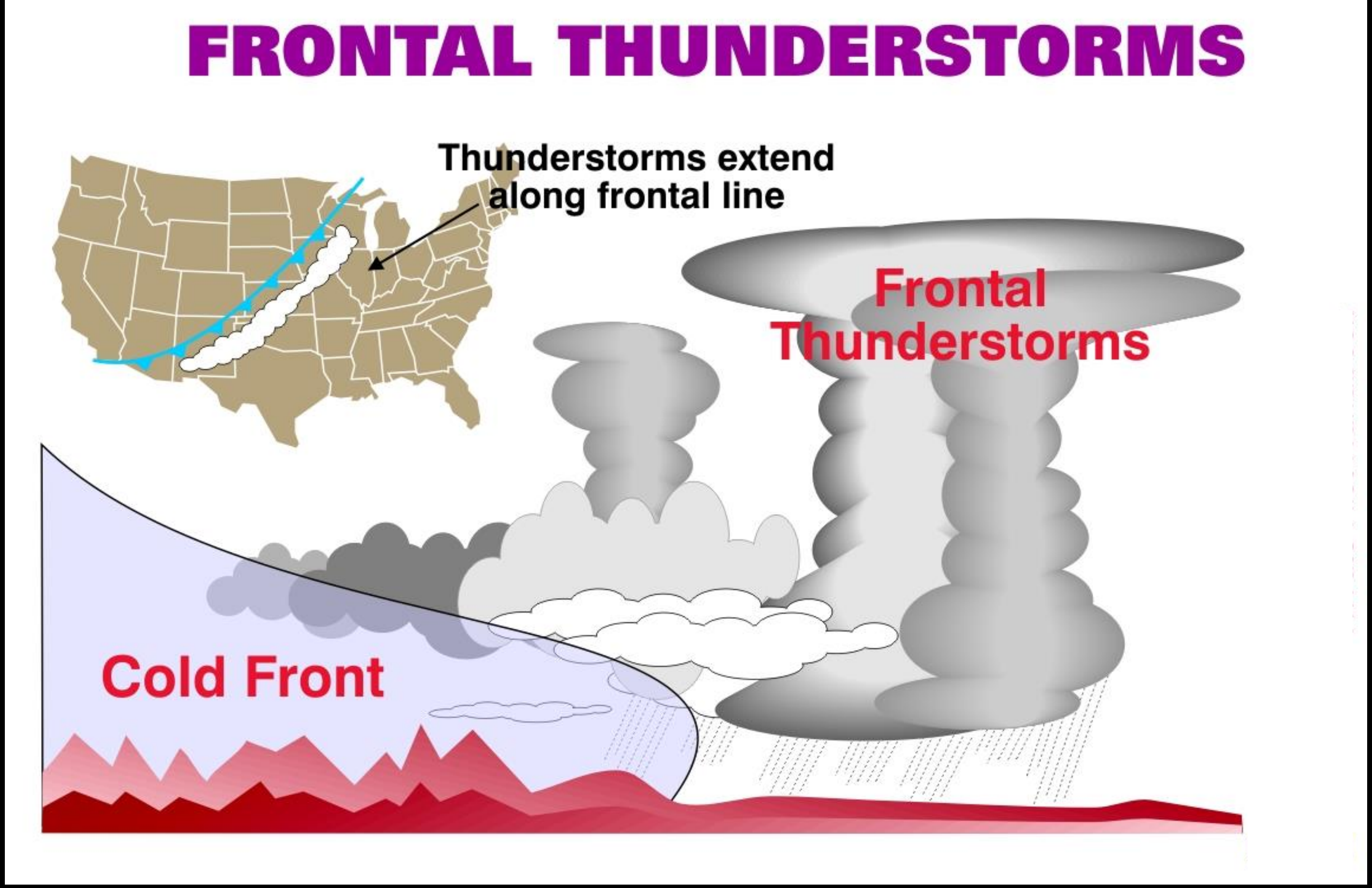
Orographic Thunderstorms



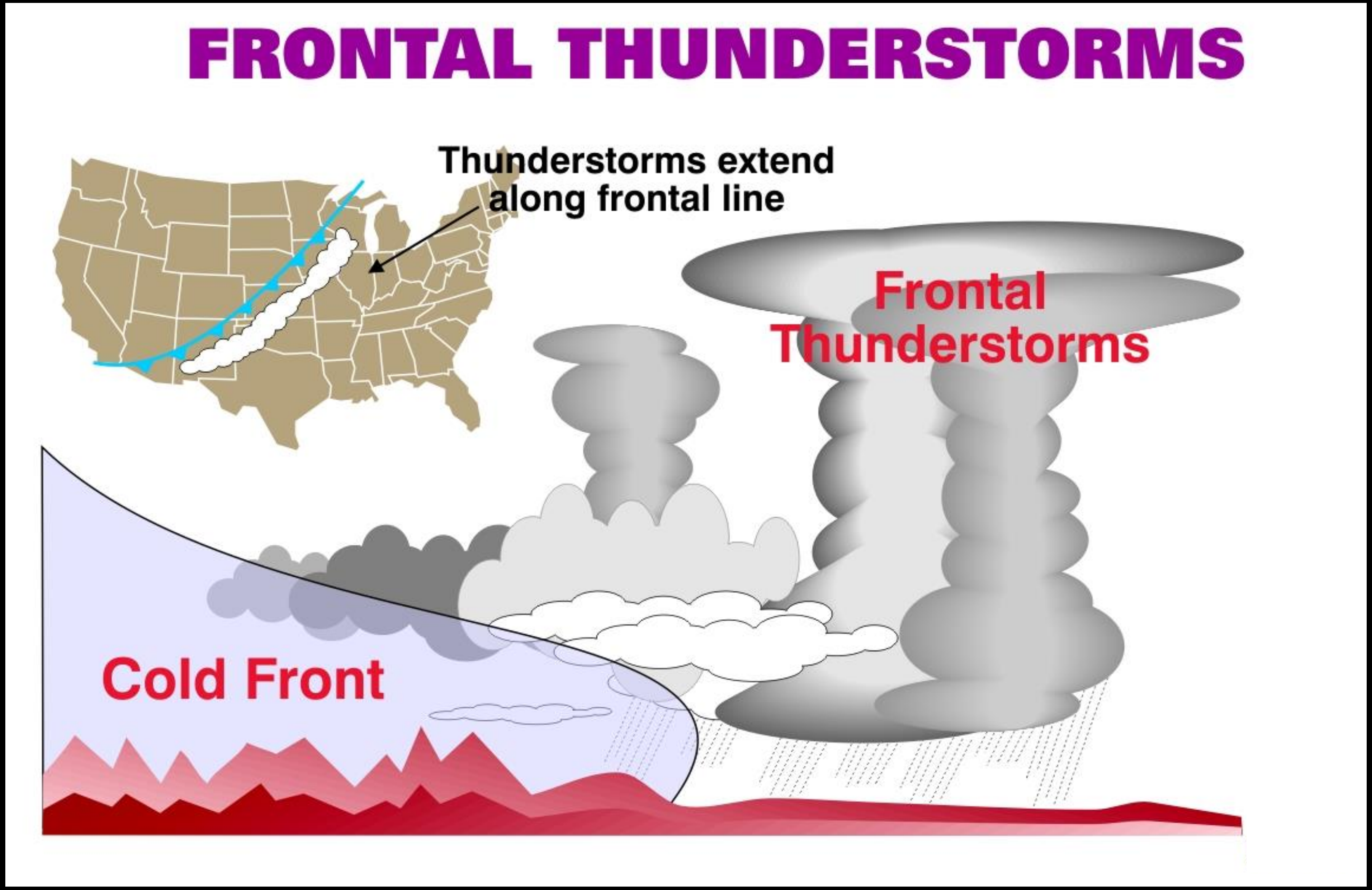
- Sometimes thunderstorms are scattered along mountain peaks and safe passage around them is possible
- Other times entire mountain ranges are obscured by orographic thunderstorms

Frontal Thunderstorms

- Because fronts vary in slope and speed, thunderstorms associated with them vary in intensity
- Faster moving fronts usually produce the most severe thunderstorms
- Thunderstorms associated with cold fronts are normally the worst, except for those found in squall lines



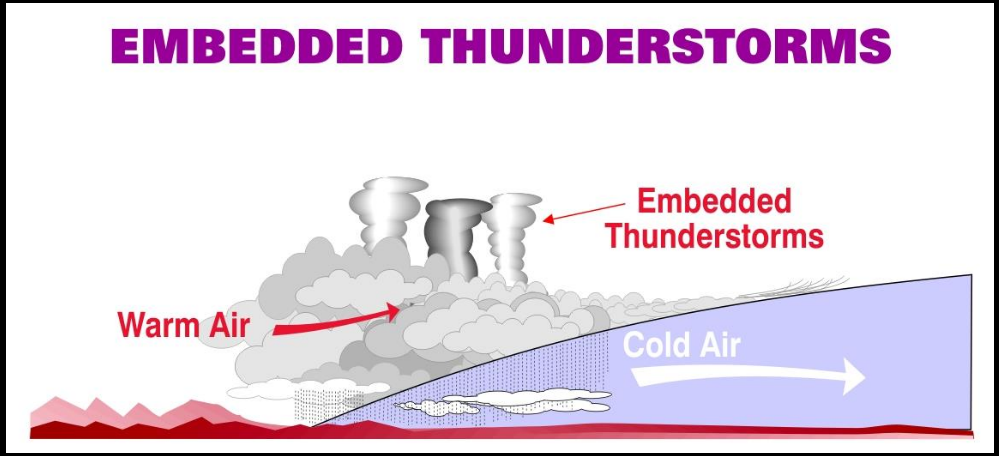
Frontal Thunderstorms



- Frontal thunderstorms usually form in continuous lines
- Problems arise for pilots when thunderstorms extend along the frontal line
- Circumnavigation is often impossible since the frontal line can extend several hundred miles and be packed with thunderstorms

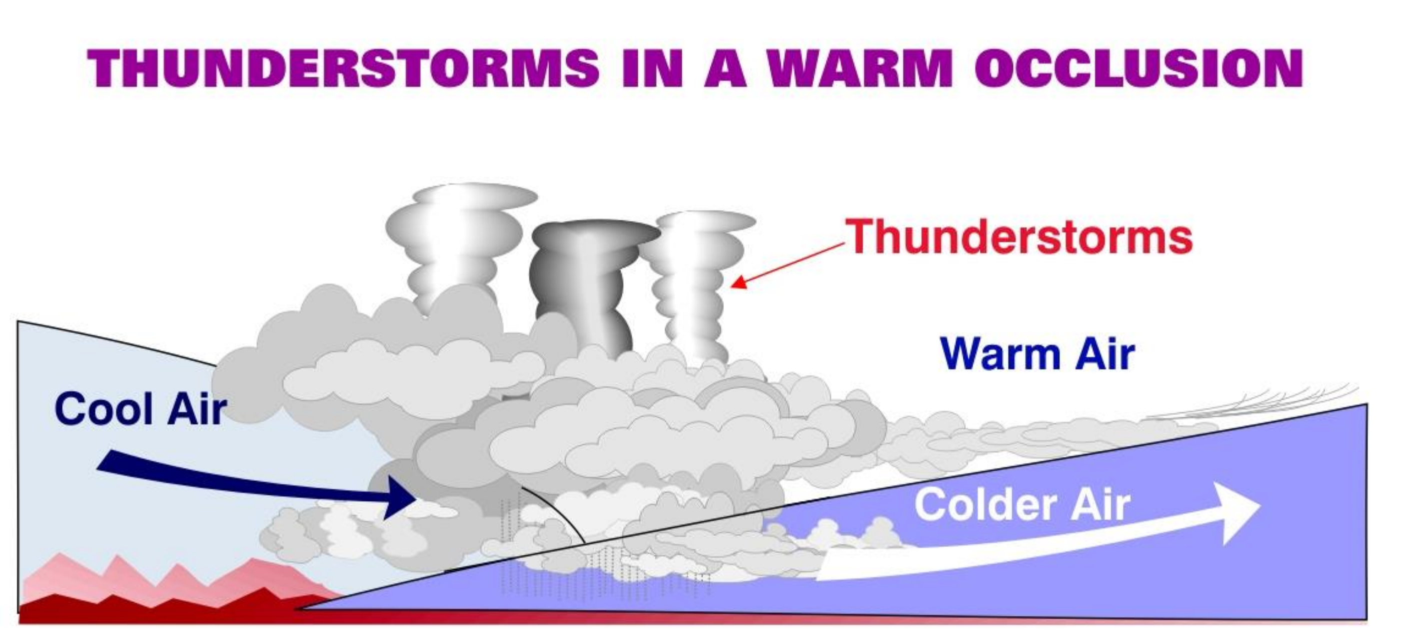
Warm Front Thunderstorms

- The gentleness of warm frontal lifting produces stratiform type clouds
- These clouds can hide thunderstorms
- Embedded thunderstorms are not easily visible to pilots
- Thunderstorms associated with warm fronts are usually the least severe of all frontal-type thunderstorms



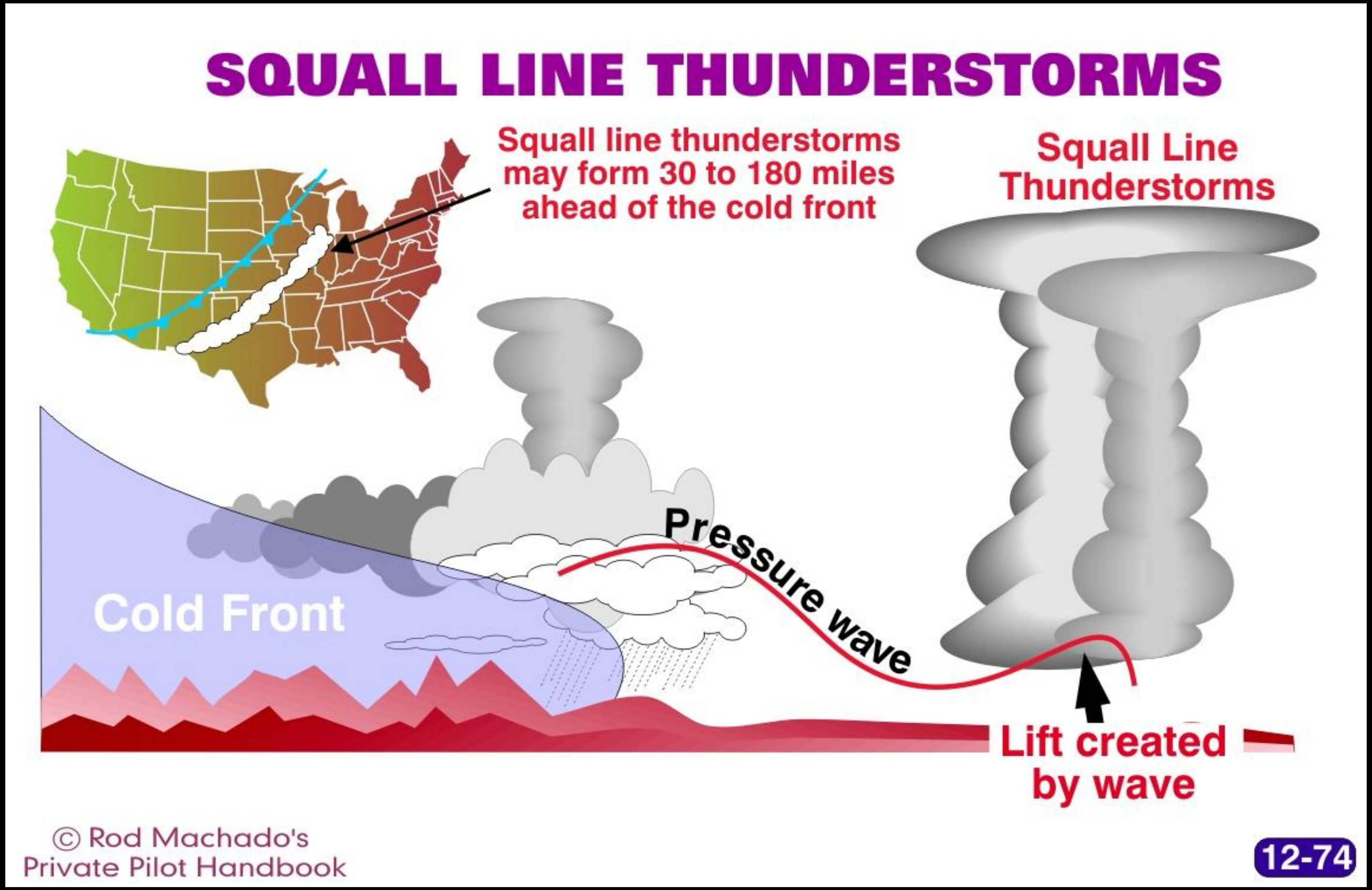
Warm Occlusion Thunderstorms

- Rapid lifting of warm air occurs along the upper cold front, which sets off thunderstorm development
- Usually more severe than those found in warm fronts and are usually embedded in stratiform clouds



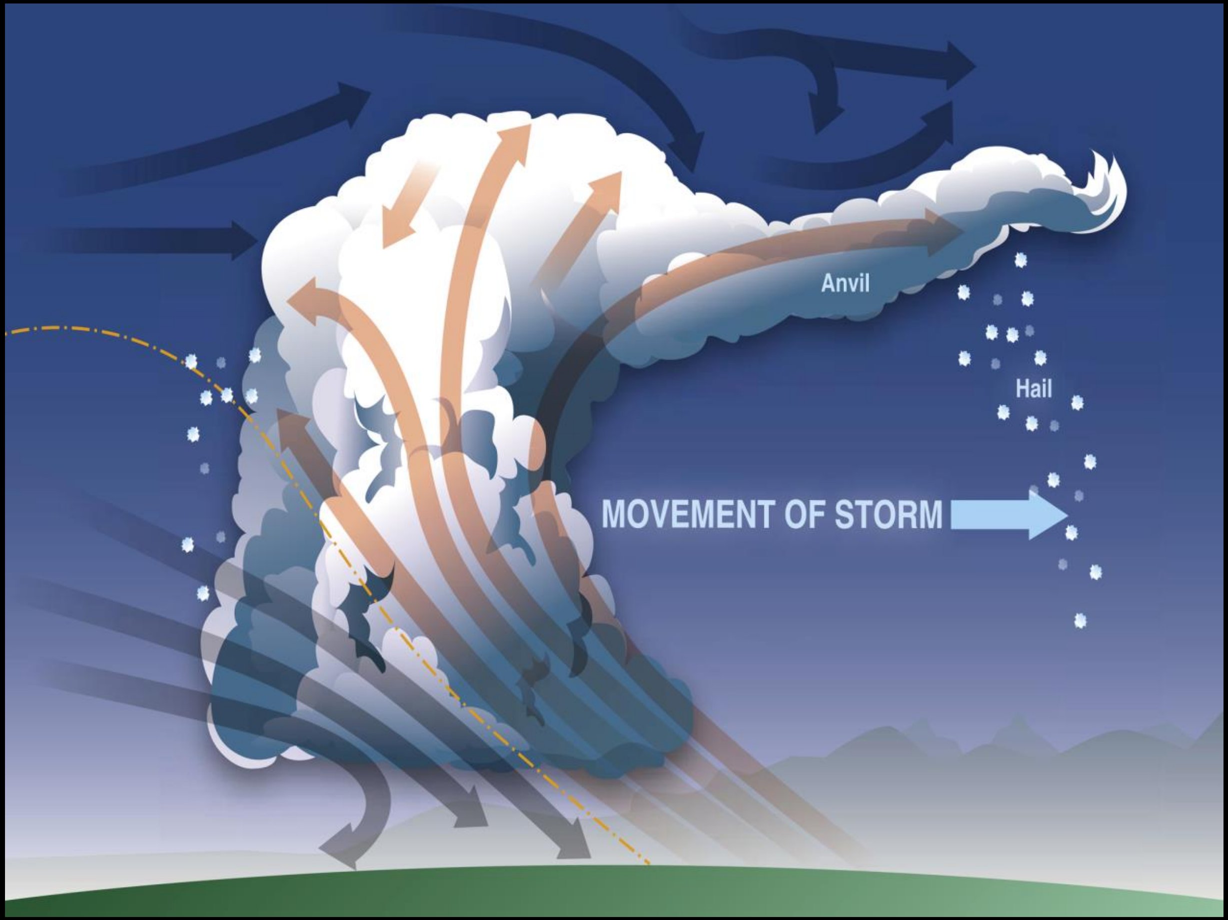
Squall Lines

- Most severe of weather conditions: large hail, destructive winds, tornadoes
- Develop 30 to 180 miles ahead of and parallel to a fast-moving cold front
- Frequently accompany cold fronts, but a cold front is not an absolute requirement for their existence
- Low pressure troughs, easterly waves, or atmospheric convergence can also produce squall lines



Squall Line Thunderstorms

Thunderstorm Movement

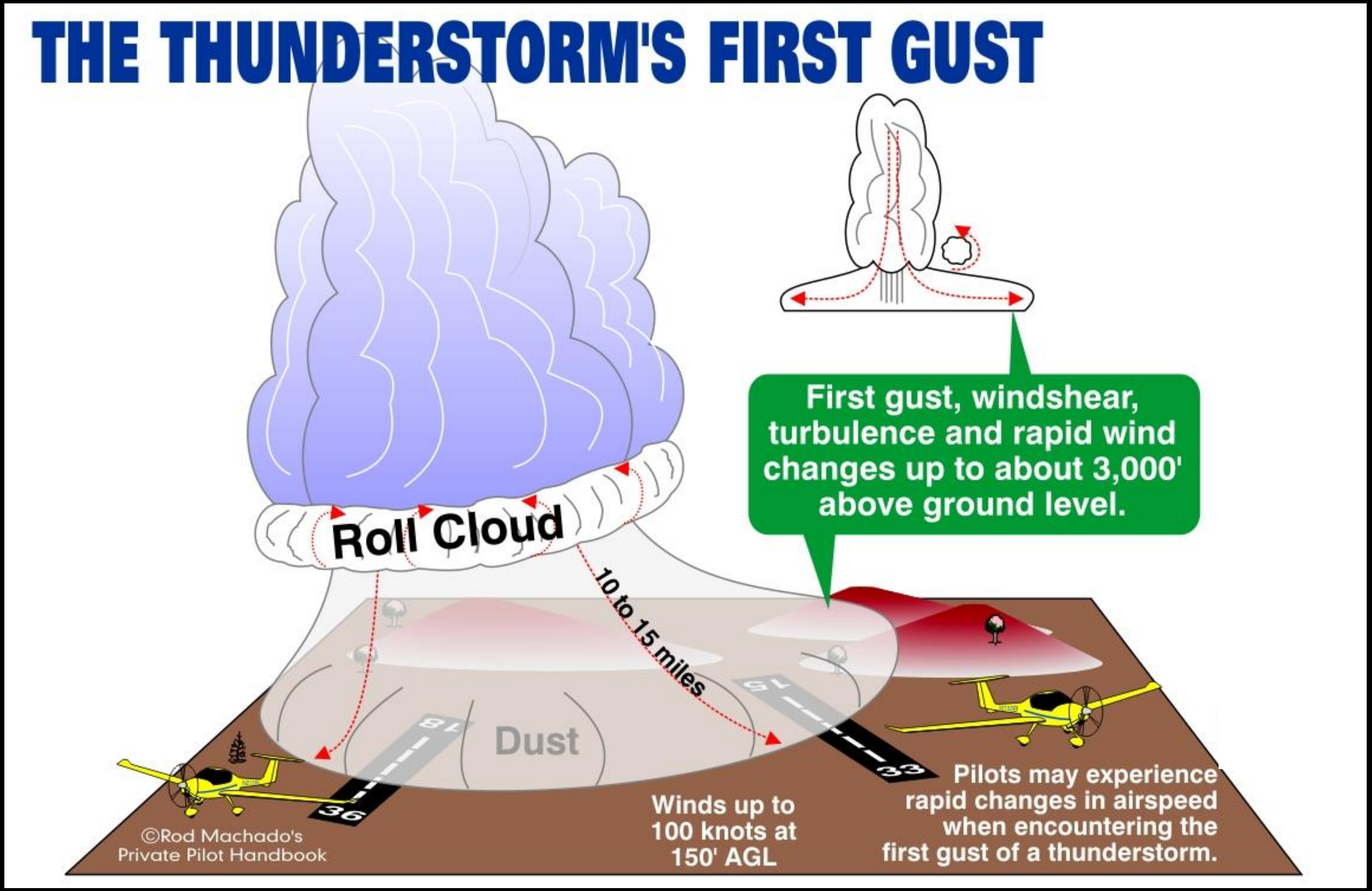


Thunderstorm Turbulence

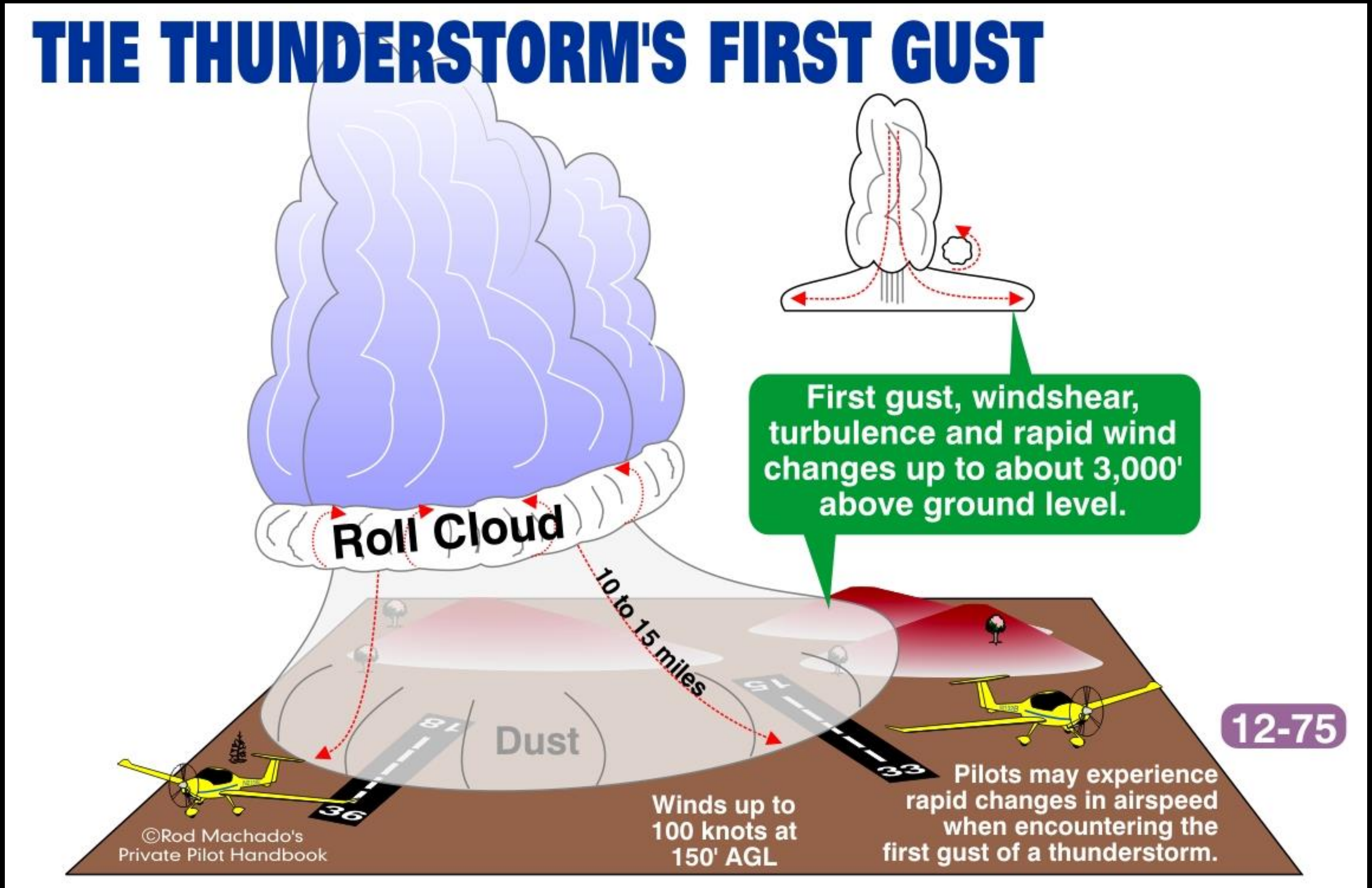
- Most thunderstorms have the capability to produce extreme turbulence
- Contain up and downdrafts that far exceed the capability of most light aircraft to cope

First Gust

- One of the significant hazards produced by thunderstorms
- During the mature stage rain begins falling from beneath the cell
- A massive gust of cold air shoots down to ground level and spreads out in a horizontal direction



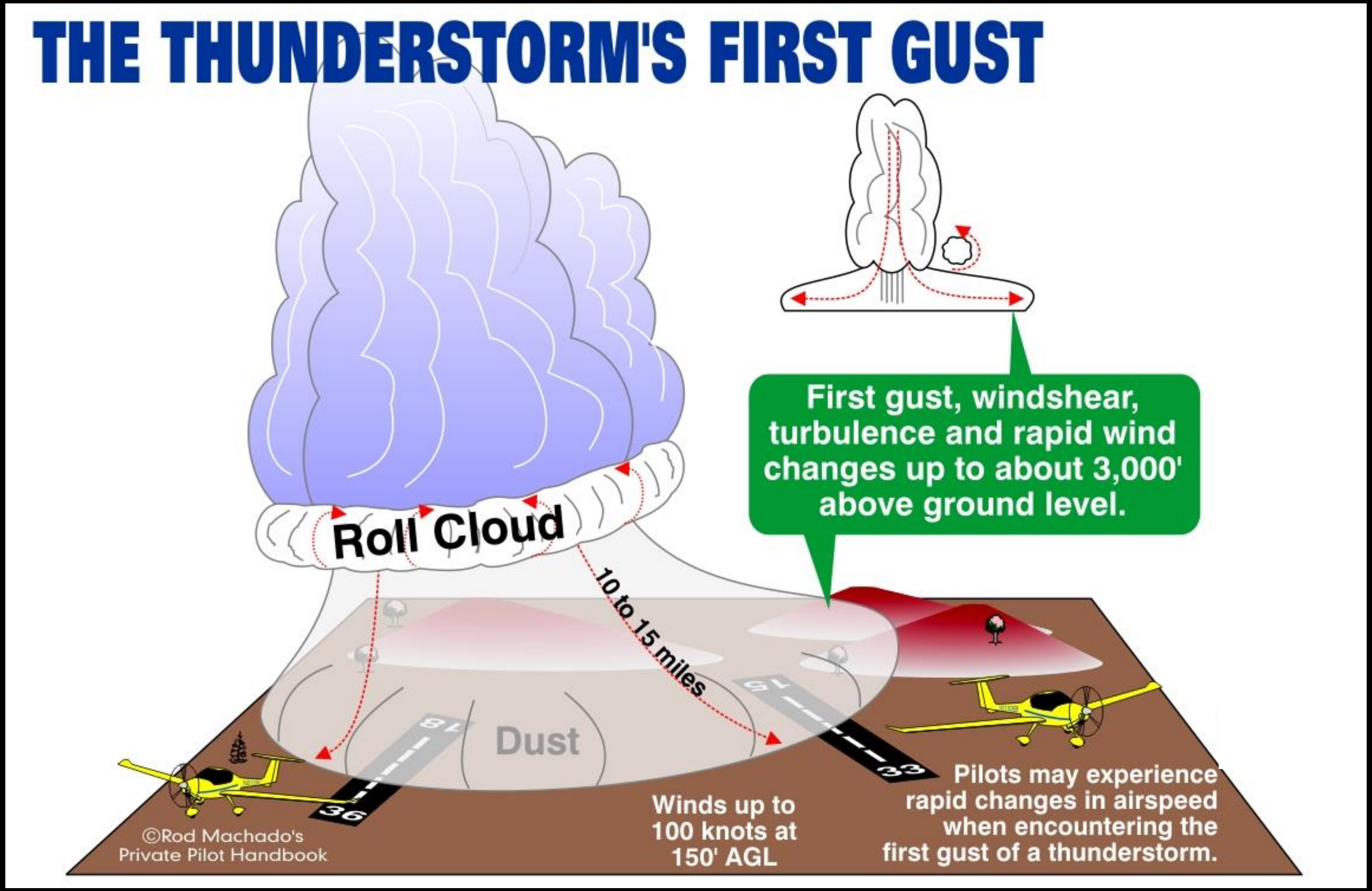
First Gust



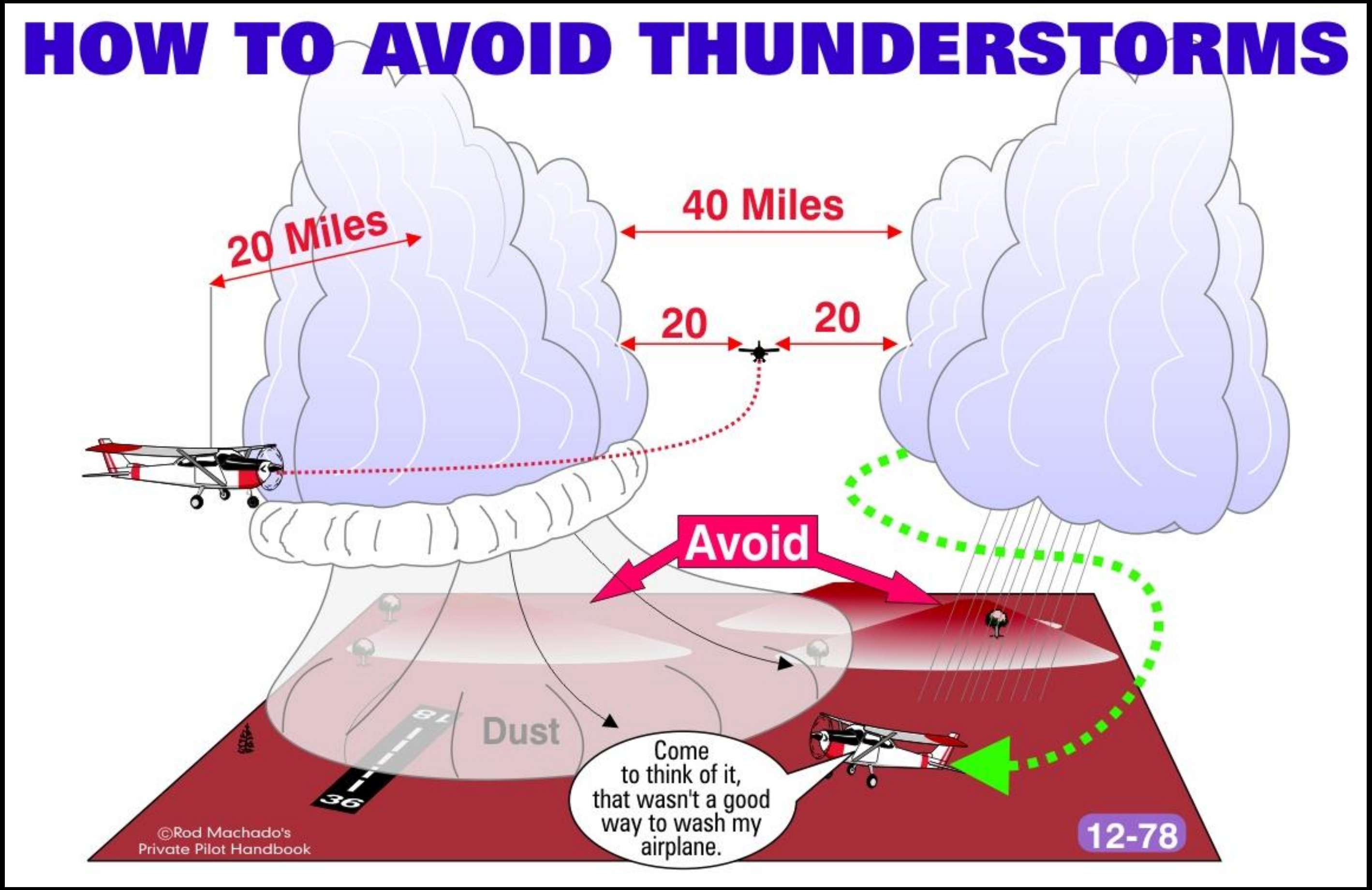
- Winds of 20 to100 knots and higher within 150 feet of the ground have been reported
- Most intense within 10 to 15 miles from the storm
- Effects of these winds have been known to travel distances of 50 miles from the generating cell

First Gust

- On the ground the passage of a gust front resembles a miniature cold front
- As it passes, the wind shifts becoming strong and gusty; temperatures drop sharply
- Because the air in the downdraft is cold and heavy, surface pressure rises



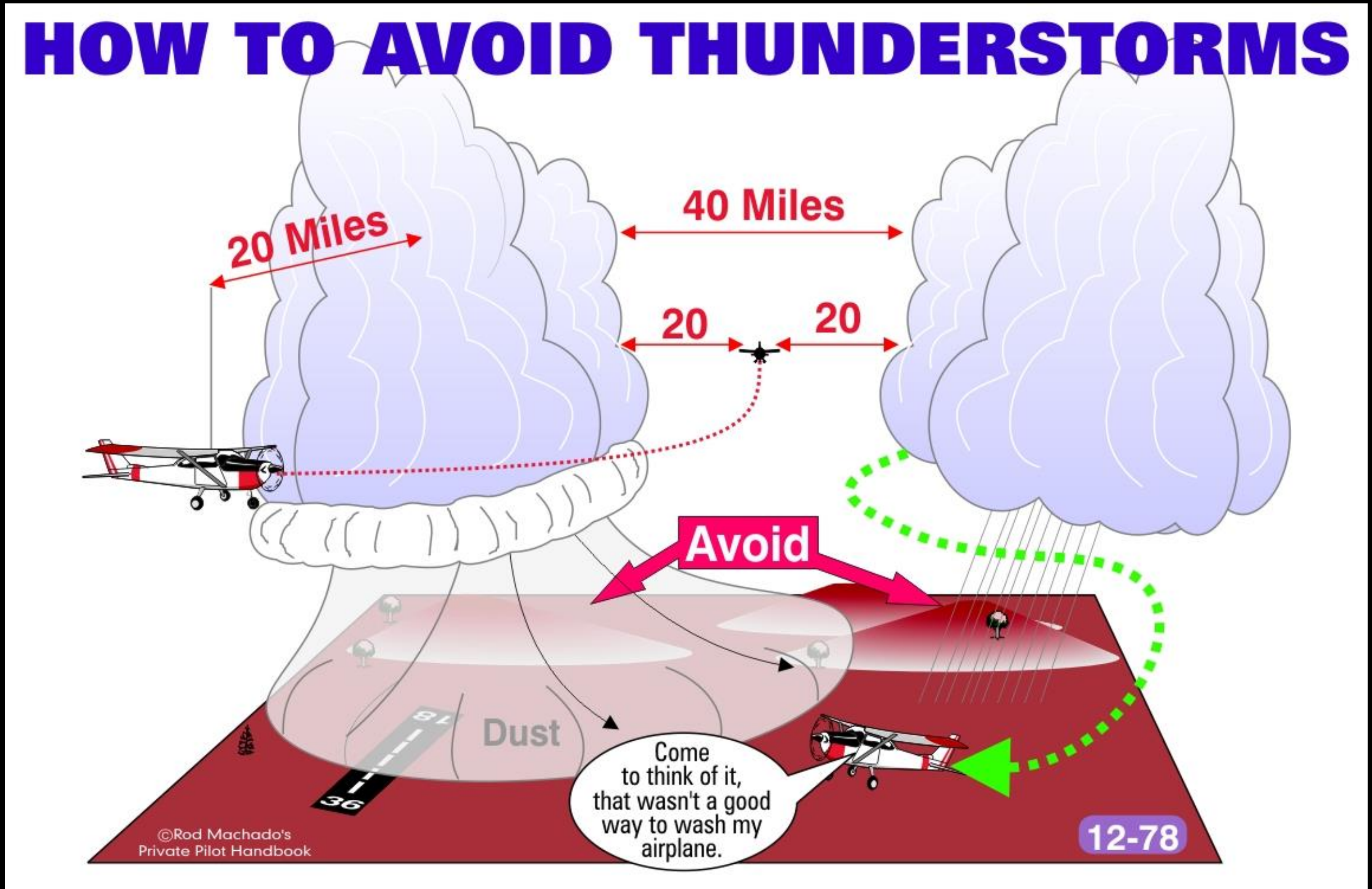
Thunderstorm Avoidance



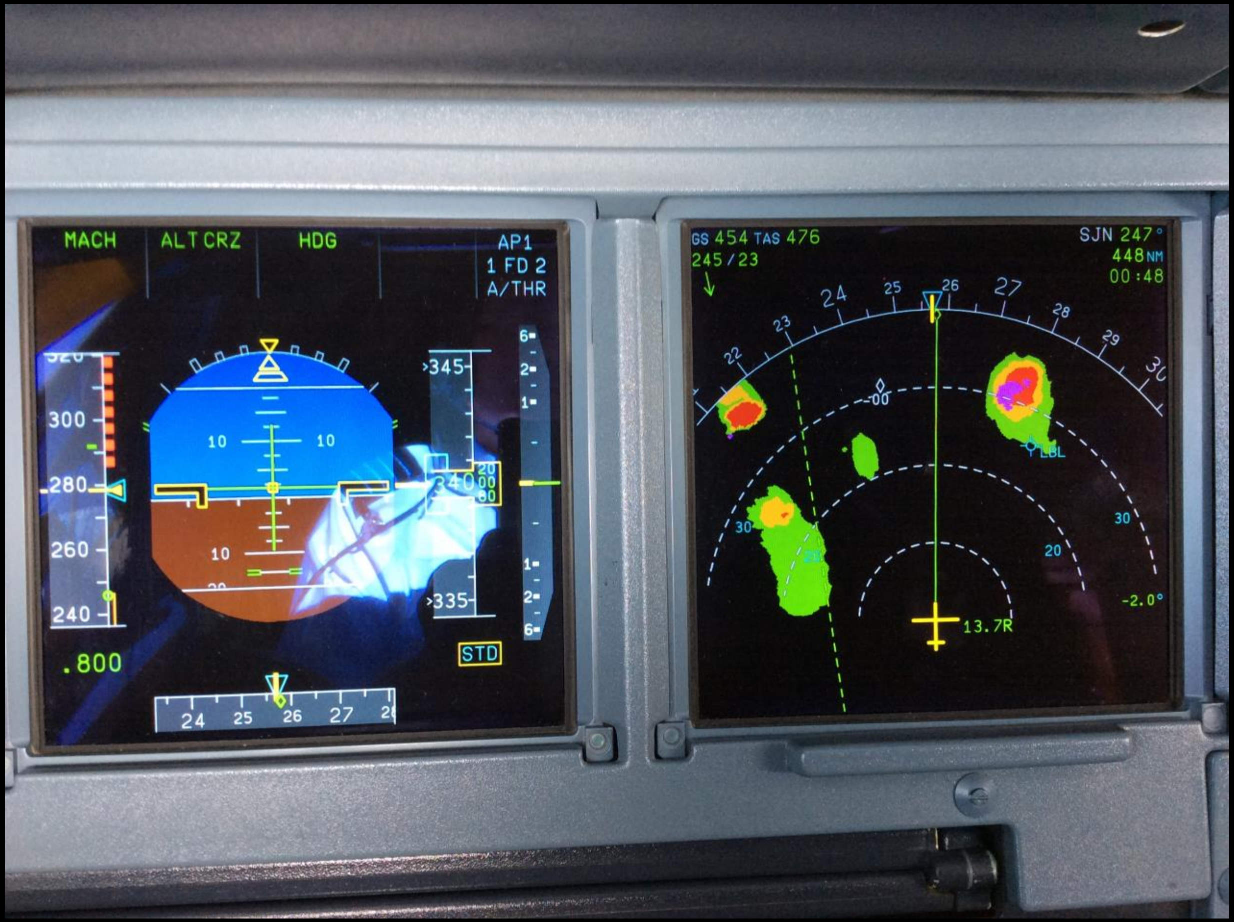
- Avoid thunderstorm cells by at least 20 miles
- Cells have turbulence reaching out many miles
- Flying between two cells is recommended only if enough distance separates them
- FAA recommends a minimum of 40 miles separation between big cells

Thunderstorm Avoidance

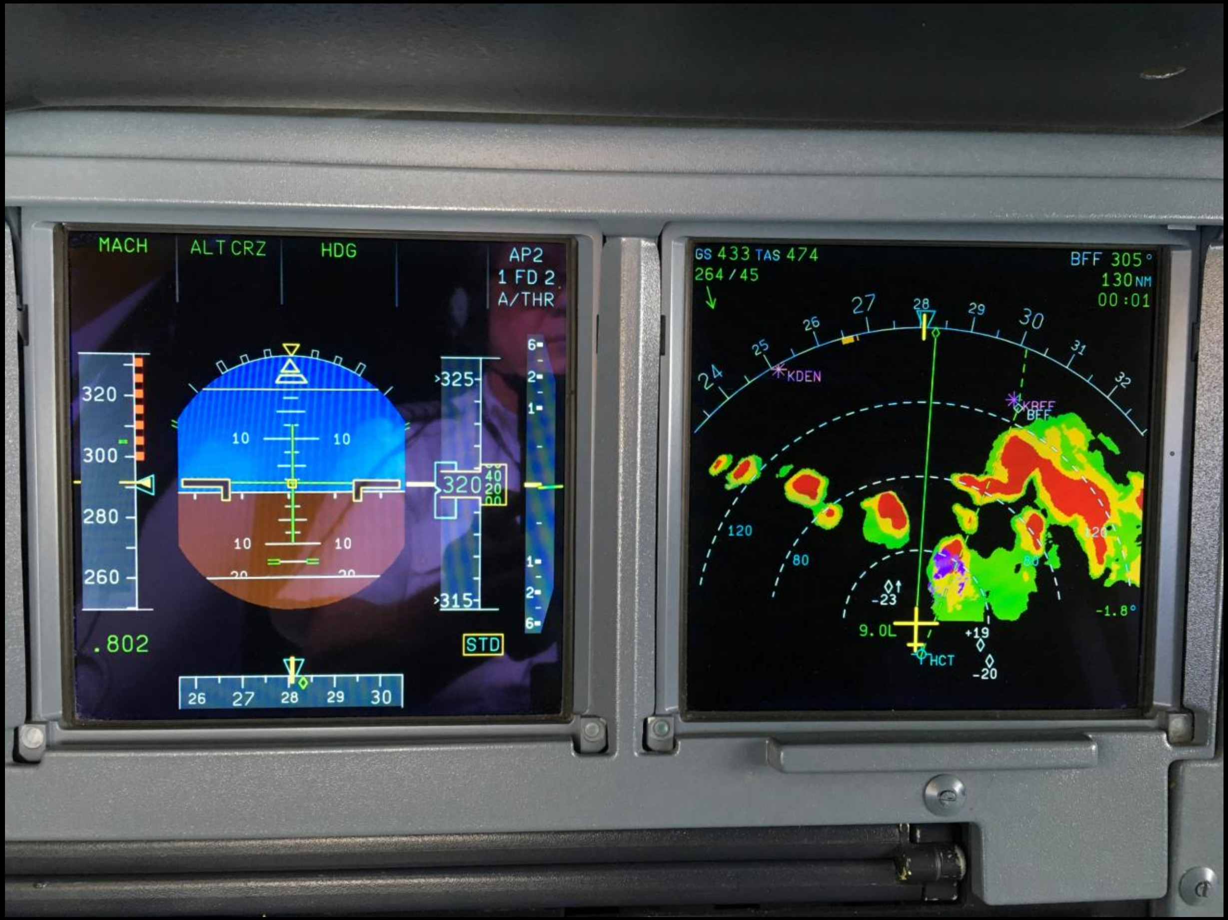
- Avoid flying directly underneath a thunderstorm cell
- Once the cell becomes mature and rain falls, you can expect substantial downdrafts in the core of the rain shaft
- Most airplanes don't have sufficient power to out-climb these downdrafts



Cockpit Weather Radar



Cockpit WX Radar



Cockpit WX Radar

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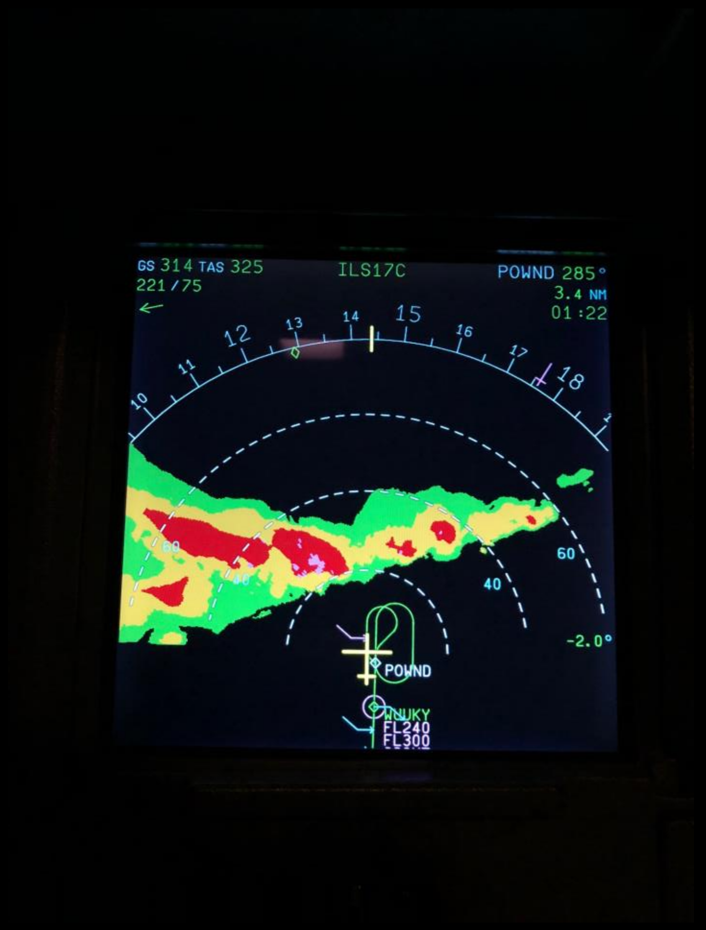
Cockpit WX Radar

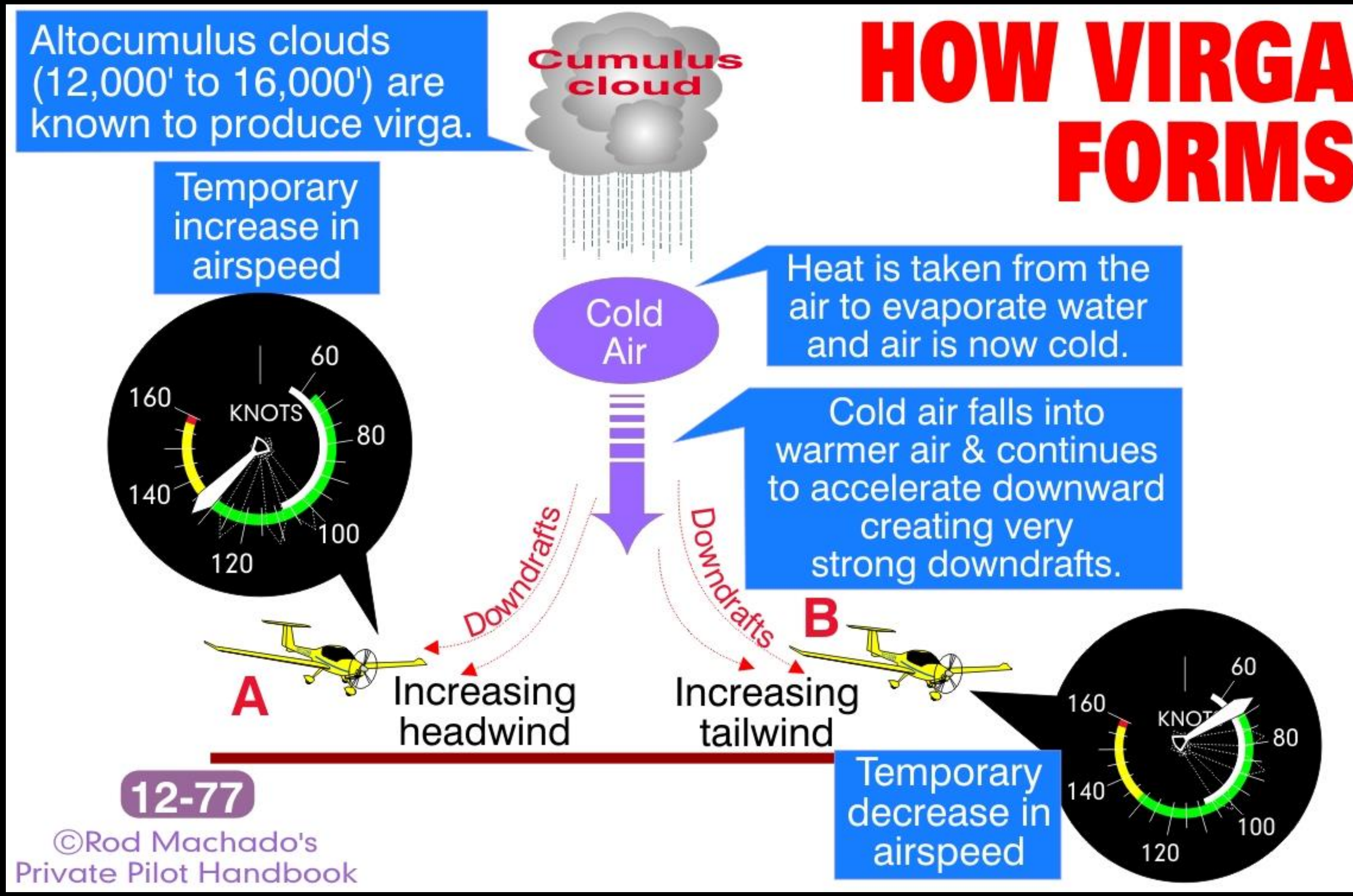


Virga

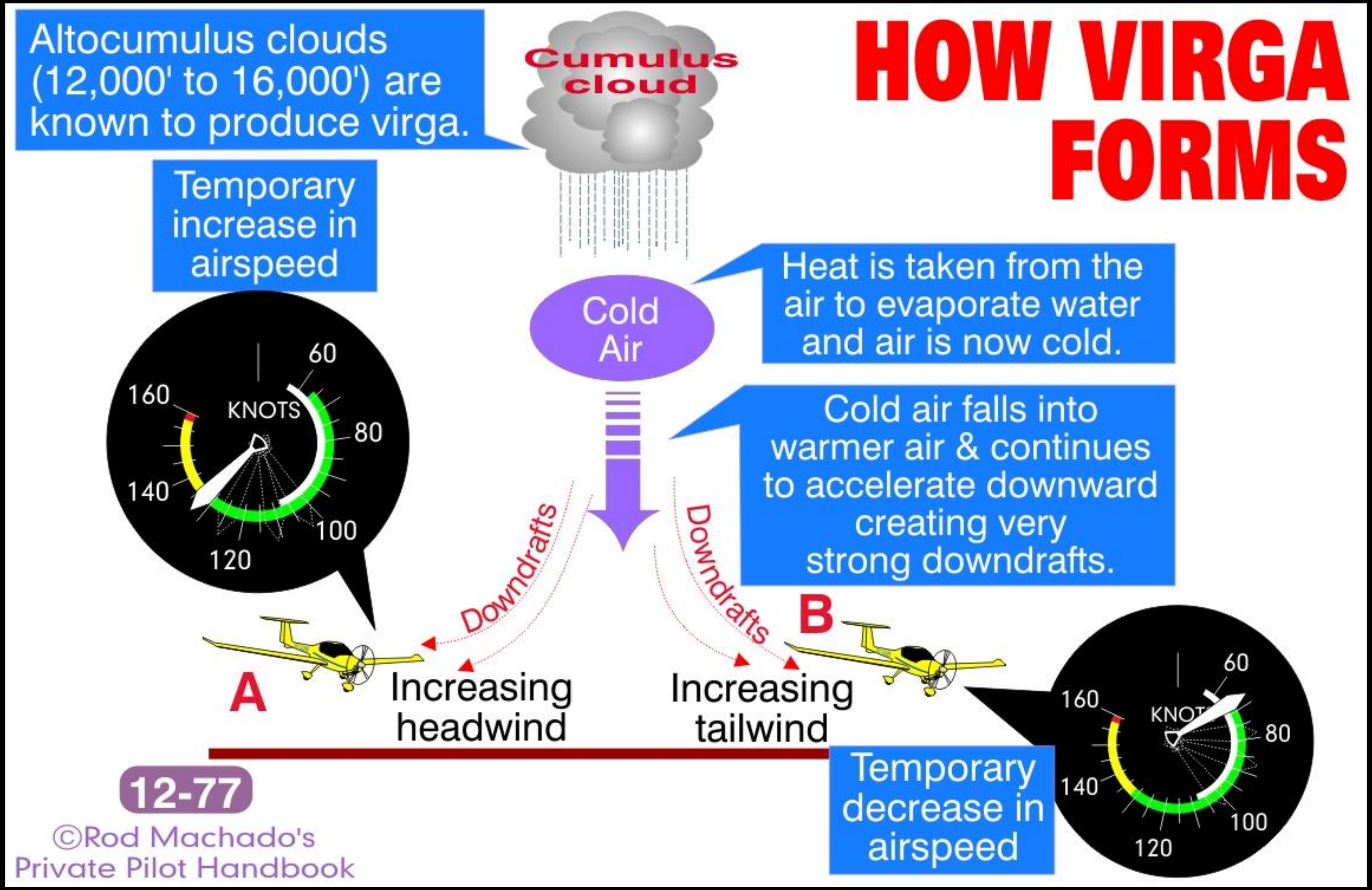
- Variable Intensity Rain Gradient Aloft
- Called virgin rain because the rain doesn't touch the ground
- Occurs when rain falls from a cumulus cloud (usually altocumulus) and evaporates before hitting the surface

Virga

- As rain falls into the drier and warmer air beneath the cloud it evaporates
- It takes heat to evaporate water, which comes from the air the rain falls through
- This makes the air cold and heavy, which falls picking up speed as it descends
- Moderate turbulence and high-velocity downdrafts occur beneath virga



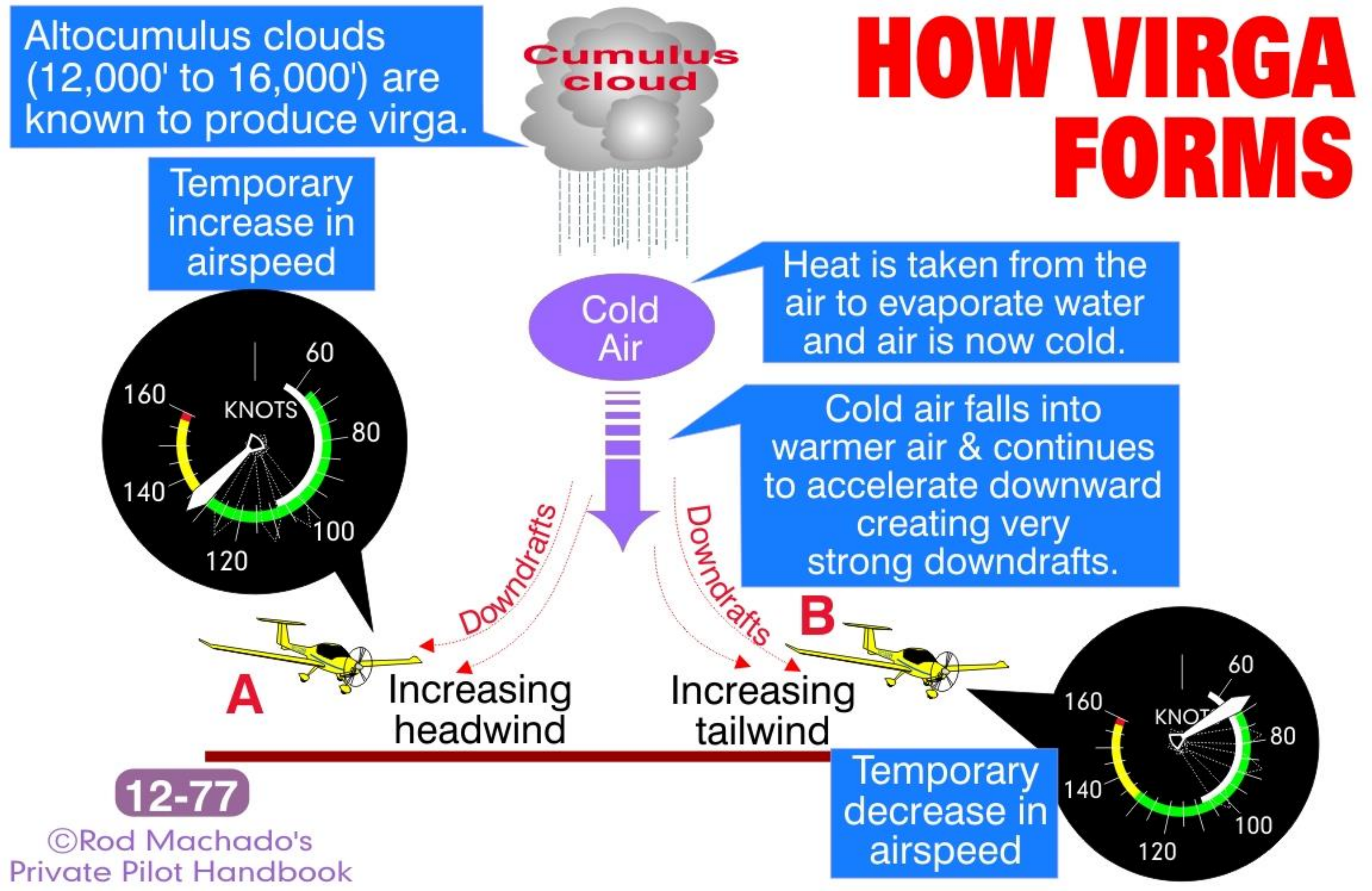
Virga



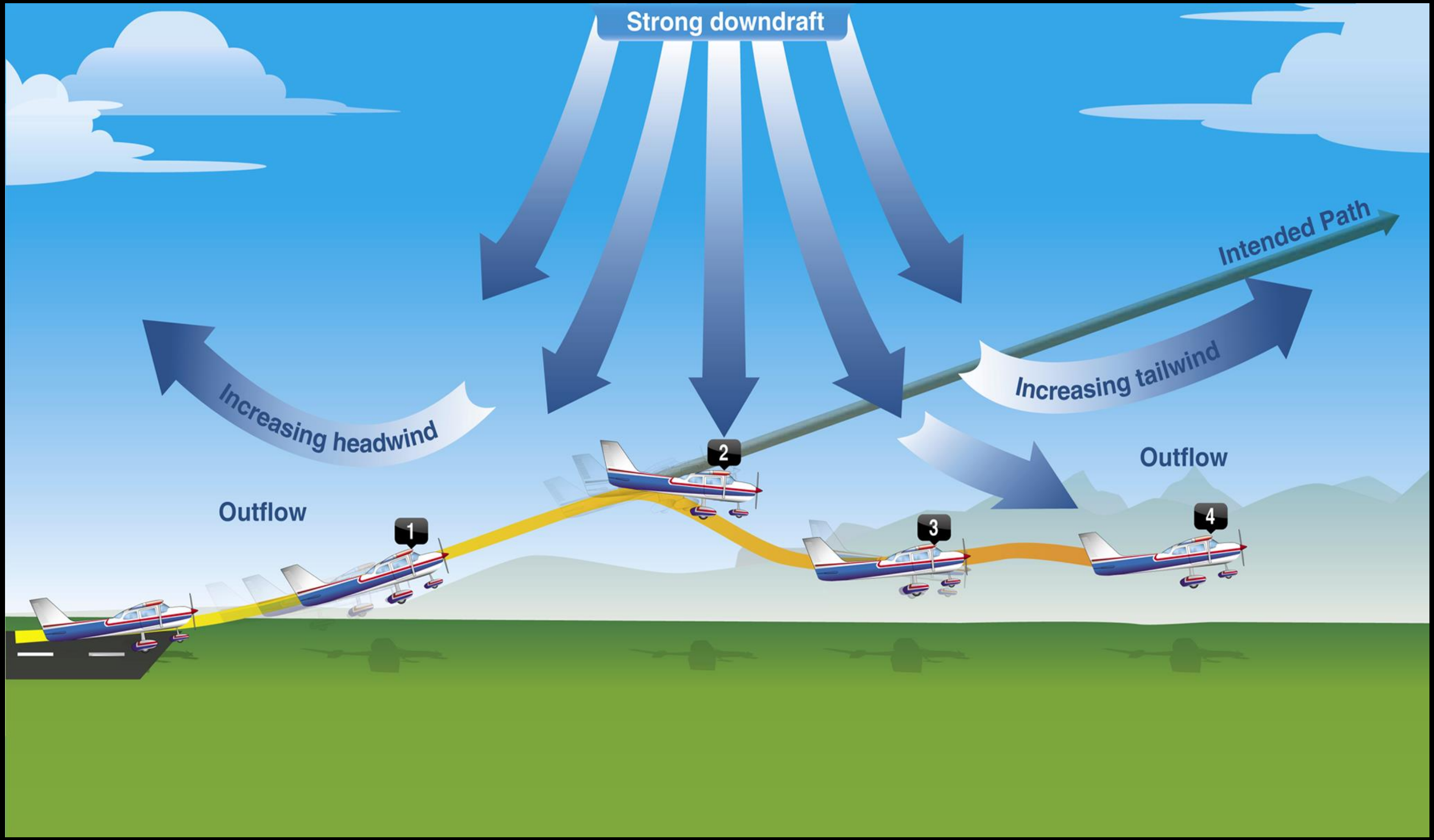
- Sometimes associated with a severe downdraft phenomenon known as a microburst
- Microbursts produce downdrafts containing winds up to 150 knots that typically last from two to five minutes
- Usually covers an area less than two and a half miles at the surface

Virga

- An airplane attempting to take off into or land into a microburst might experience a temporary increase in indicated airspeed (A) as it flies into an increasing headwind
- As it flies through the core of the microburst it may experience an increasing tailwind (B) which temporarily lowers its indicated airspeed

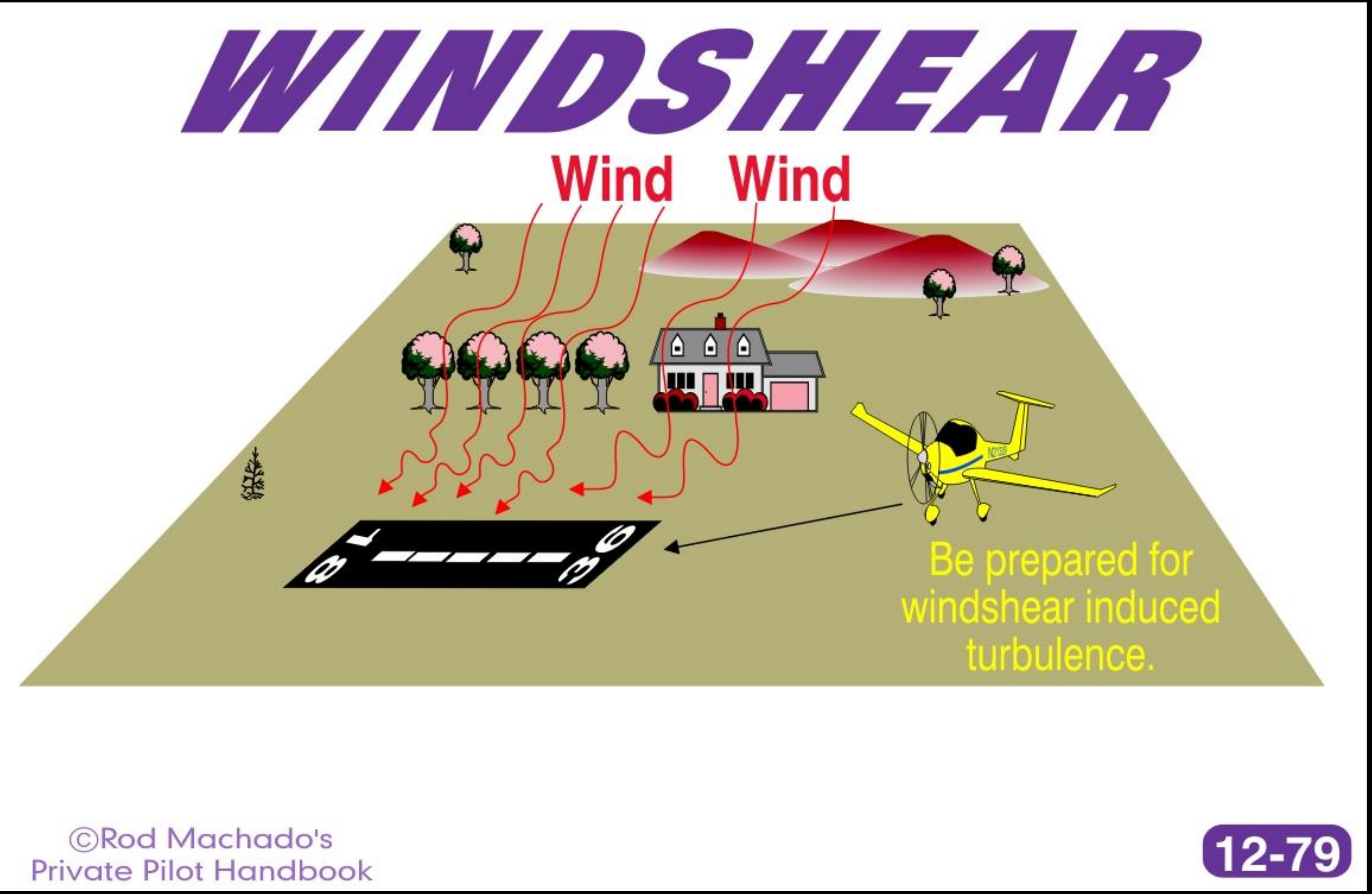


Thunderstorm Windshear



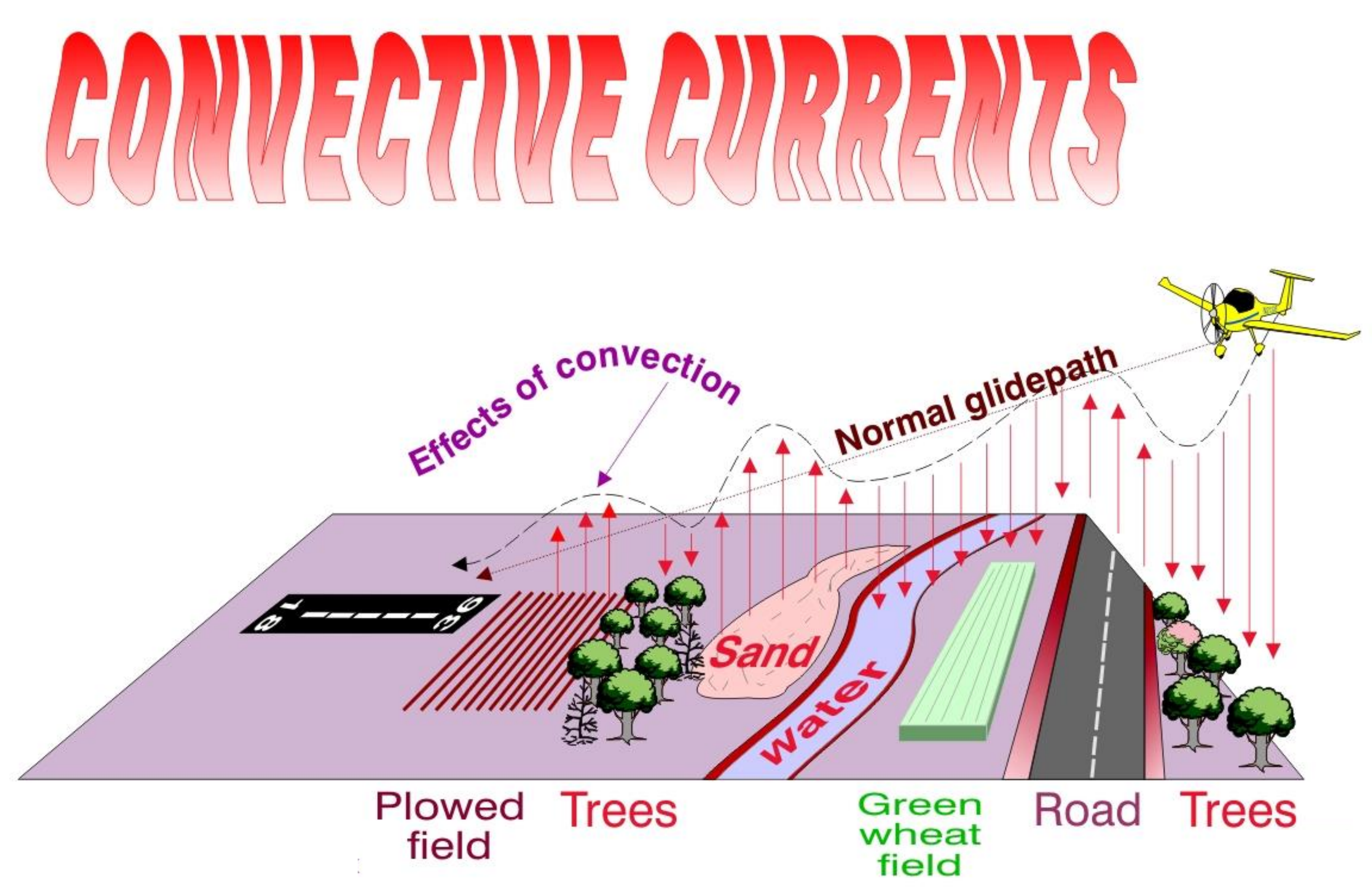
Turbulence and Windshear

- Windshear occurs when wind makes a rapid change in direction or velocity (or both)
- Expect windshear and its associated turbulence when wind flows over uneven terrain, buildings and trees
- If you suspect windshear while on approach, increase your approach speed a few knots above normal for better controllability



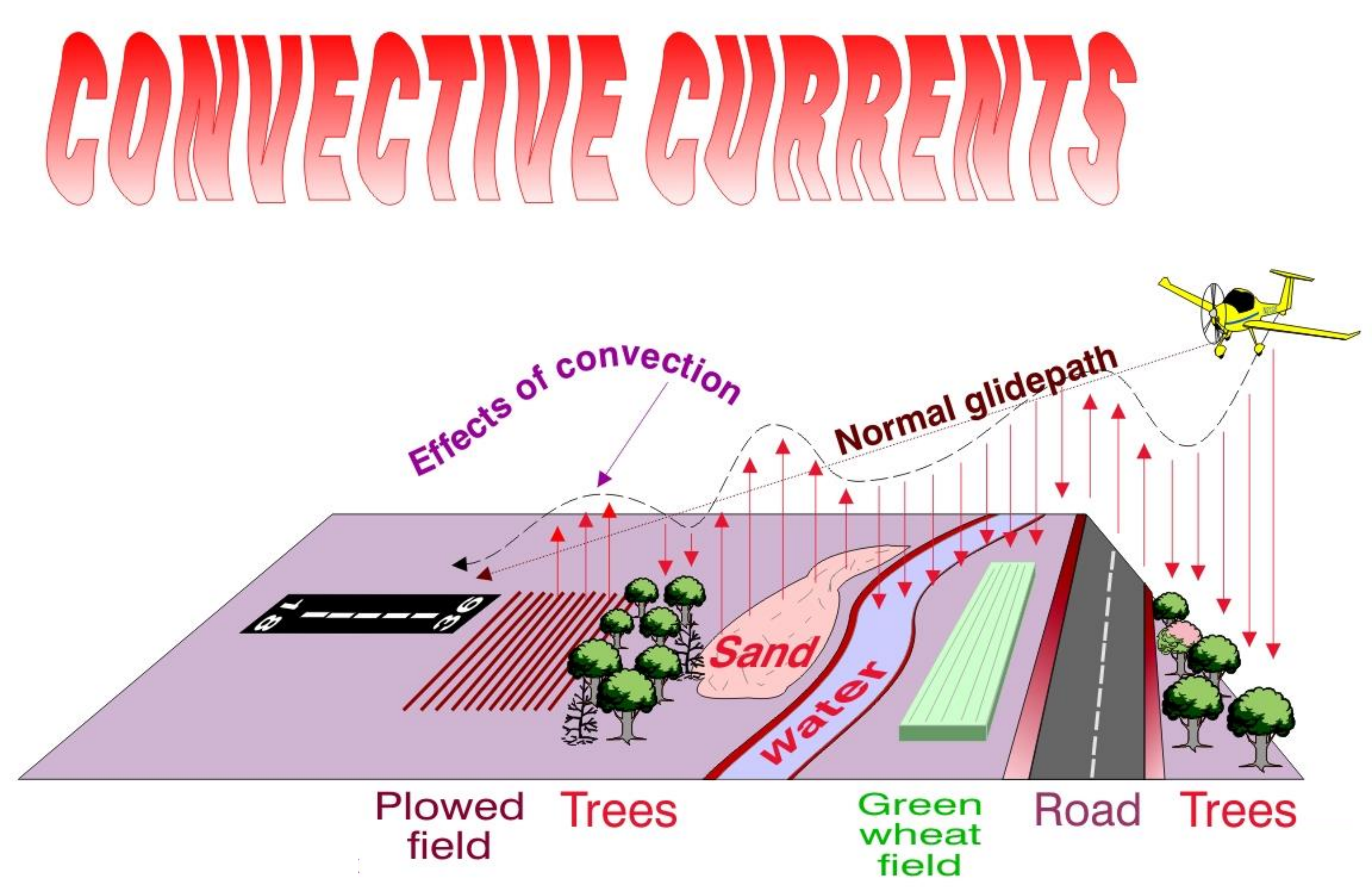
Convective Turbulence

- Quite noticeable at low altitudes during approach to landing
- Uneven heating of land along causes variable concentrations of heated air near the surface
- Heated air parcels rise, creating vertical currents of air
- Air parcels cool as they rise, eventually falling back to earth



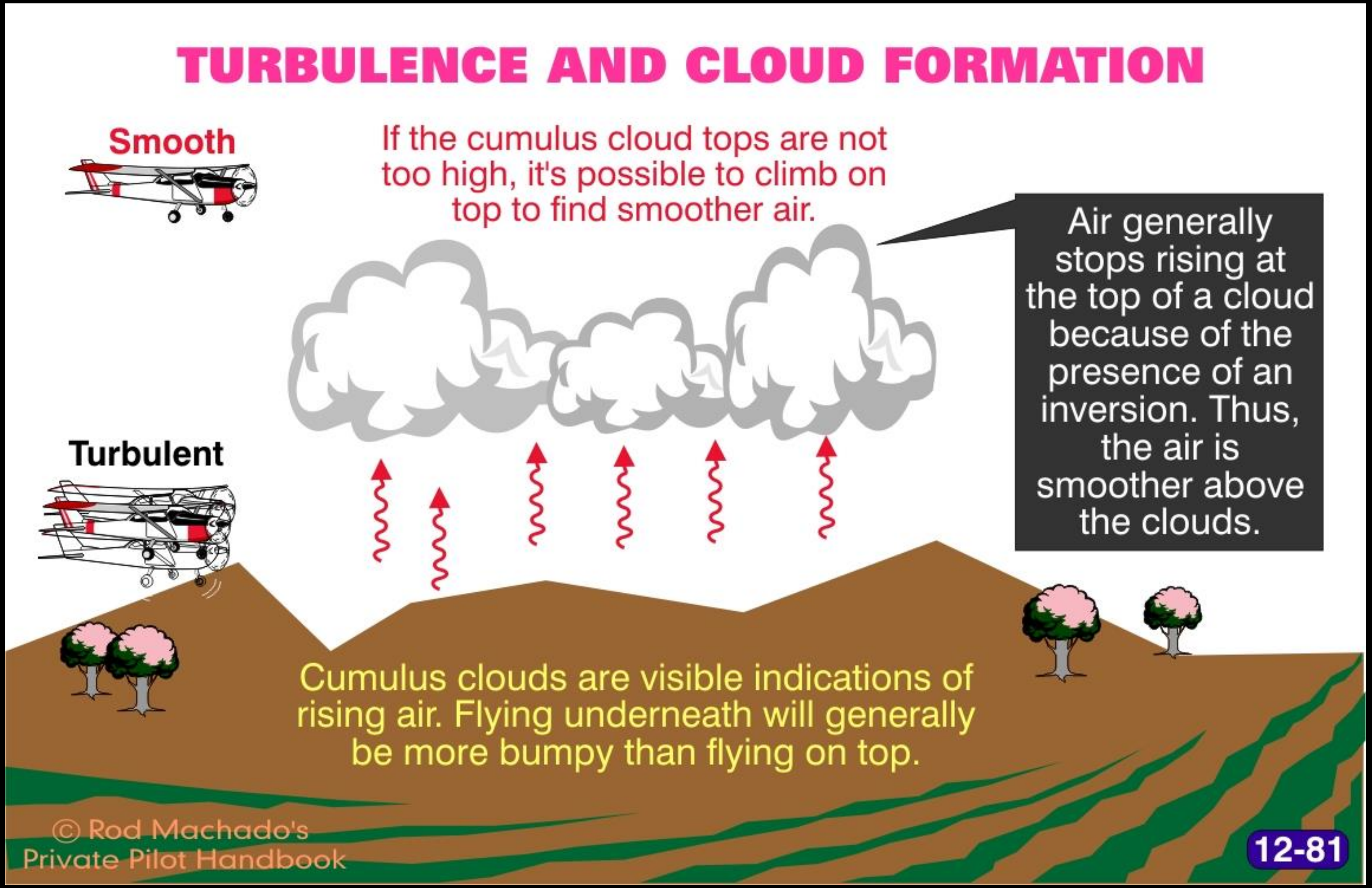
Convective Turbulence

- Darker surfaces (plowed fields and paved roads) warm up quickly and produce rising currents of air
- Green fields and small bodies of water remain cooler, creating downward currents of air
- On approach, maintaining the glidepath requires noticeable changes in pitch and power



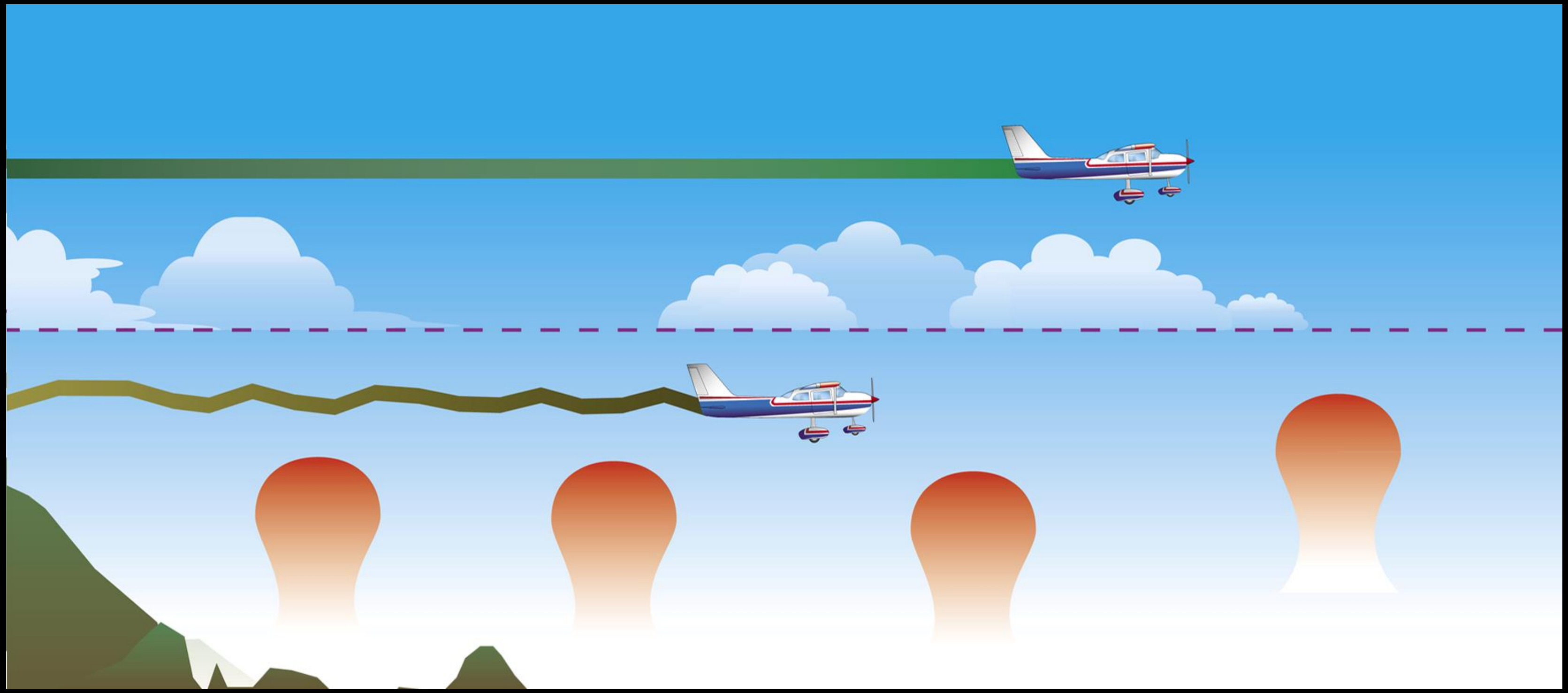
Turbulence Below Cumulus Clouds

- Fair weather cumulus clouds are visible indications of rising and condensing air
- Turbulence occurs beneath these clouds
- The smoothest ride is generally found above these clouds



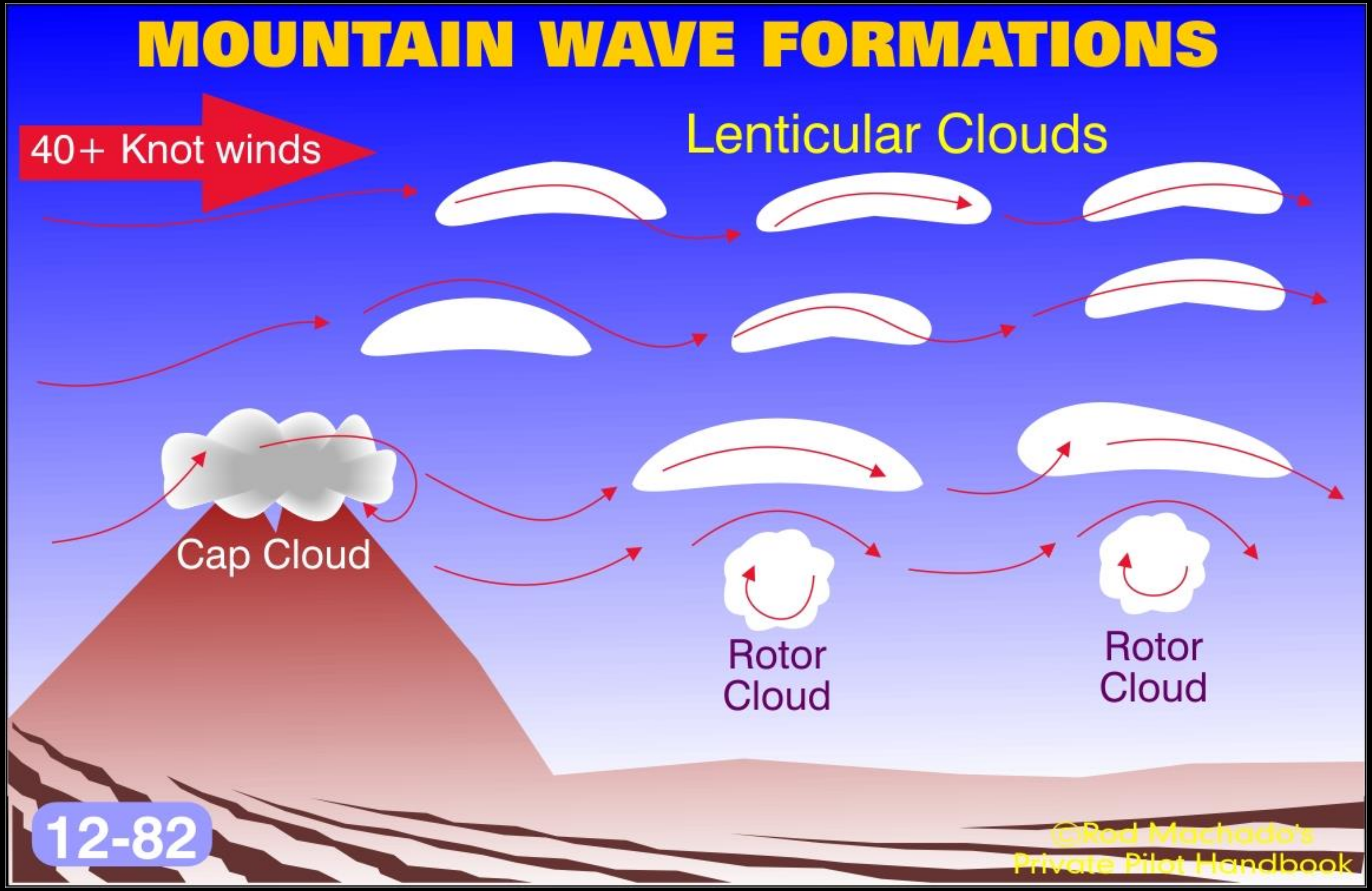
Smooth Air Above Cumulus Clouds

- Turbulence occurs beneath these clouds
- The smoothest ride is generally found above these clouds

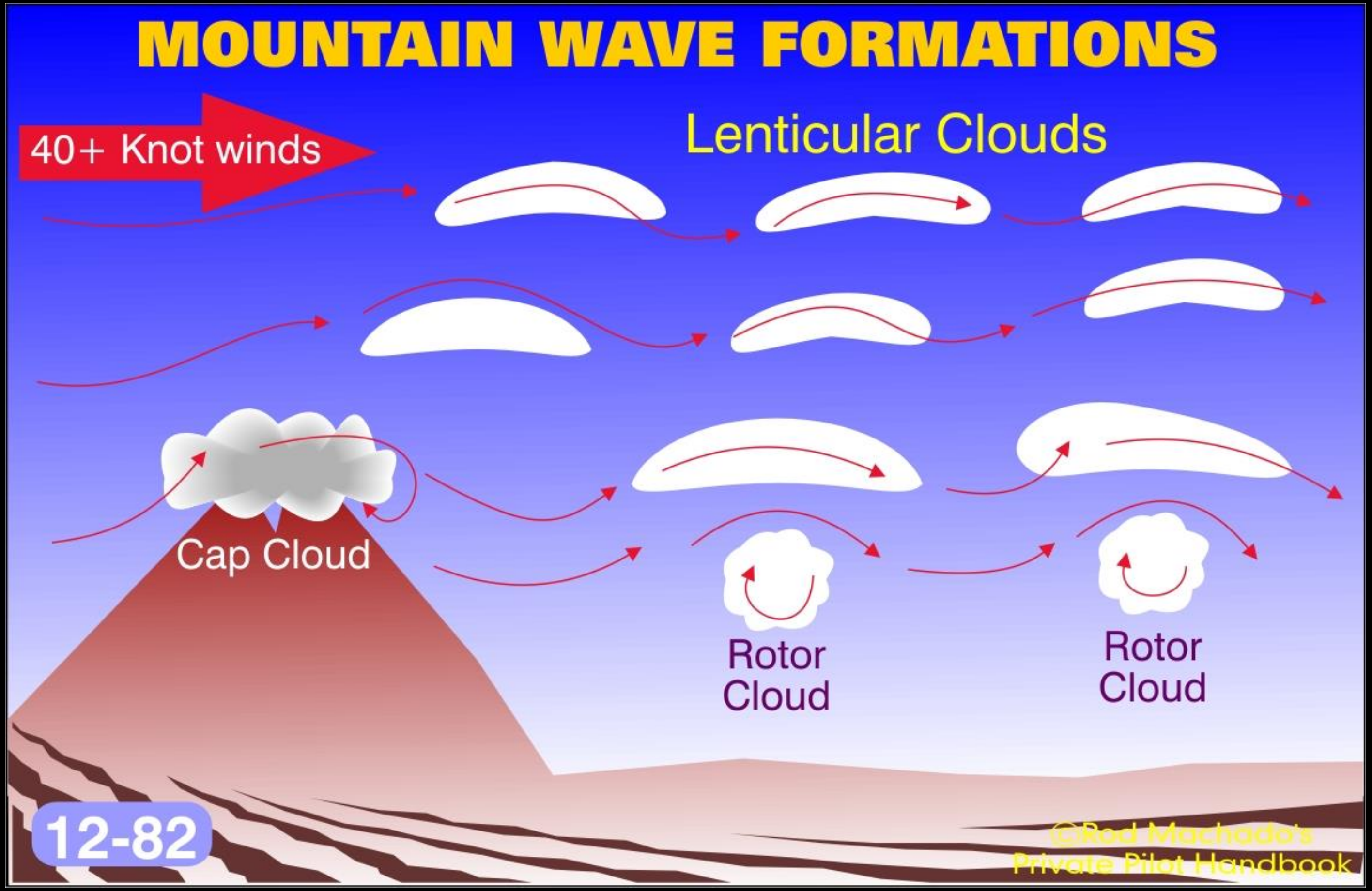


Mountain Waves

- When air moves over a mountain range a curve a is added to its motion
- With large wind speeds and mountains, these wave patterns can travel hundreds of miles from their source



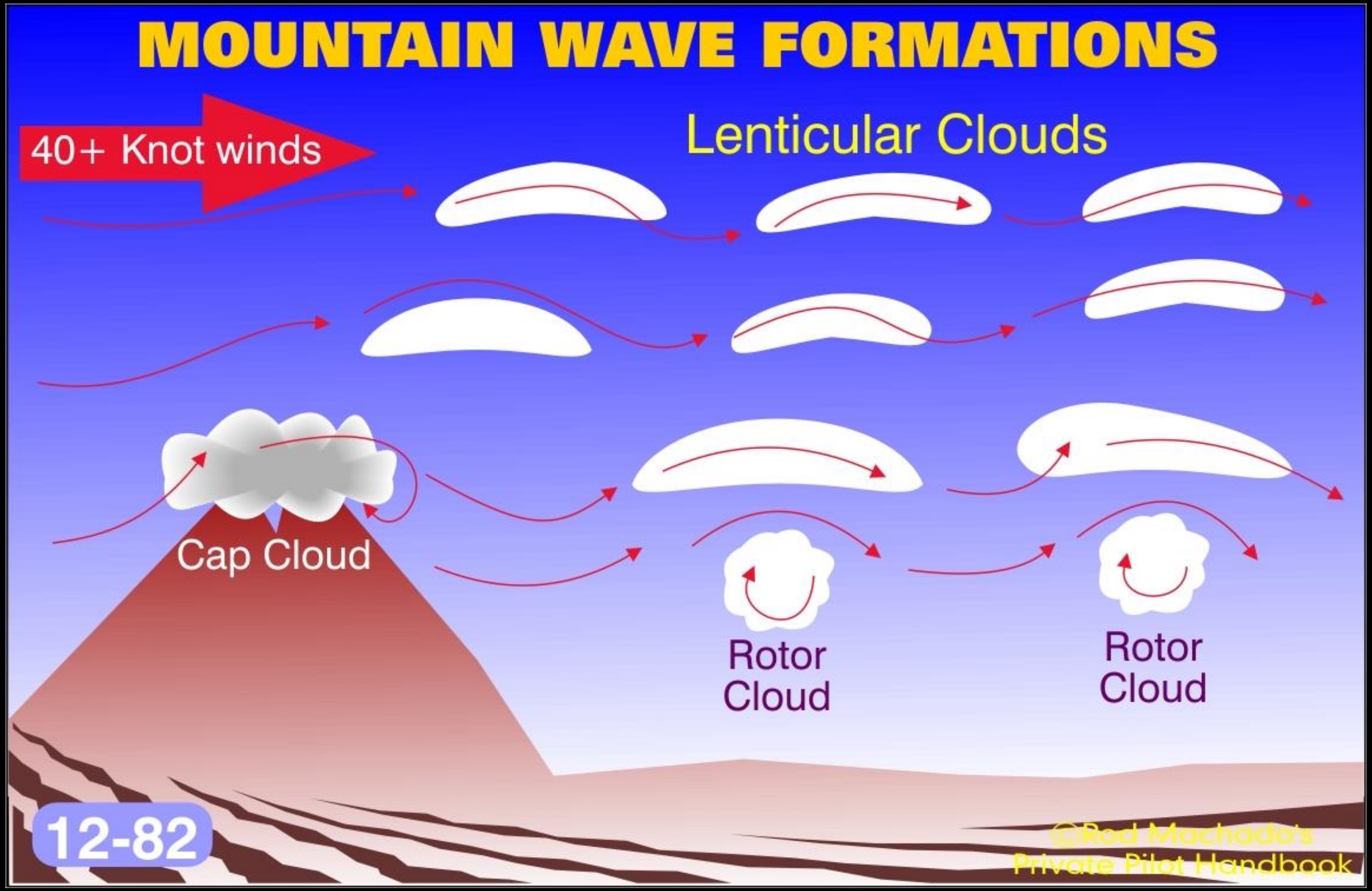
Mountain Waves



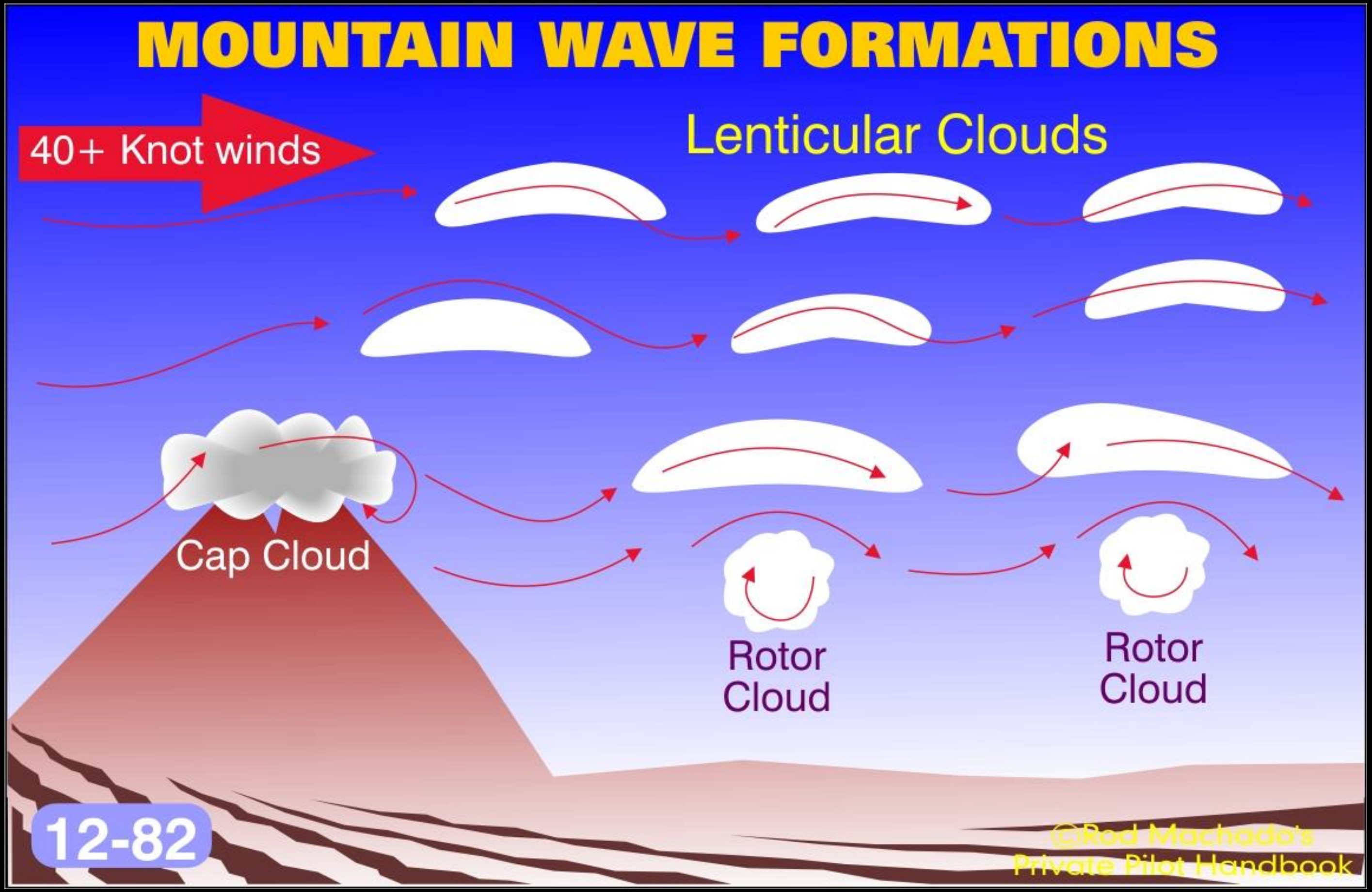
- Stable air moving above the level of surface friction usually flows in a smooth, layered pattern
- When the air encounters a large enough obstacle (mountain range) a standing or mountain wave pattern is established in the mass of moving air

Mountain Waves

- When winds of 40 knots or more encounters a large mountain, a wave pattern is induced
- This pattern sets up a series of waves in the downwind direction, with valleys and peaks that remain stationary
- With enough moisture in the stable air, condensation (from air cooling as it rises) occurs at the peaks of these waves
- A pileus or cap cloud occurs over the mountain top



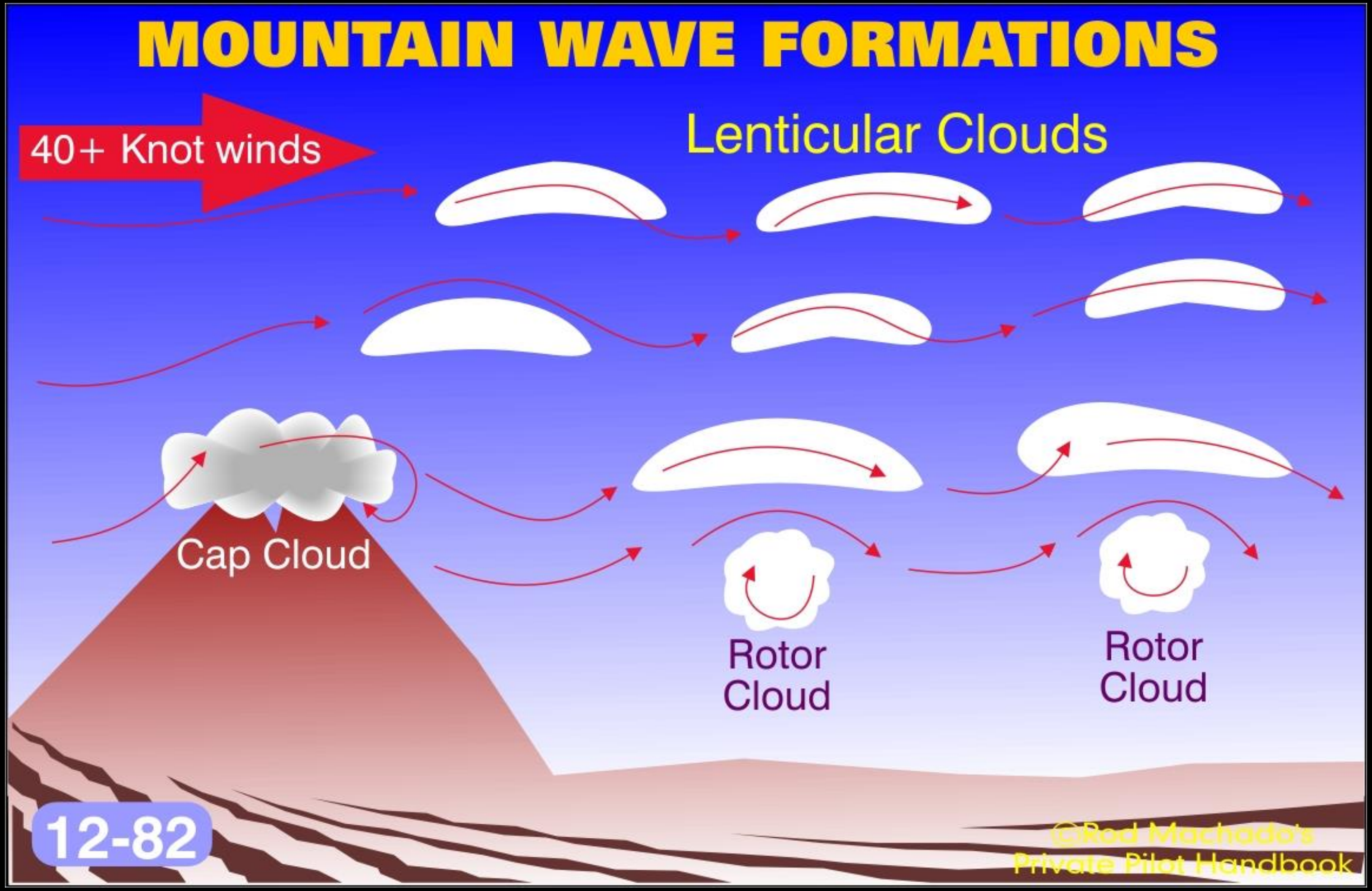
Mountain Waves



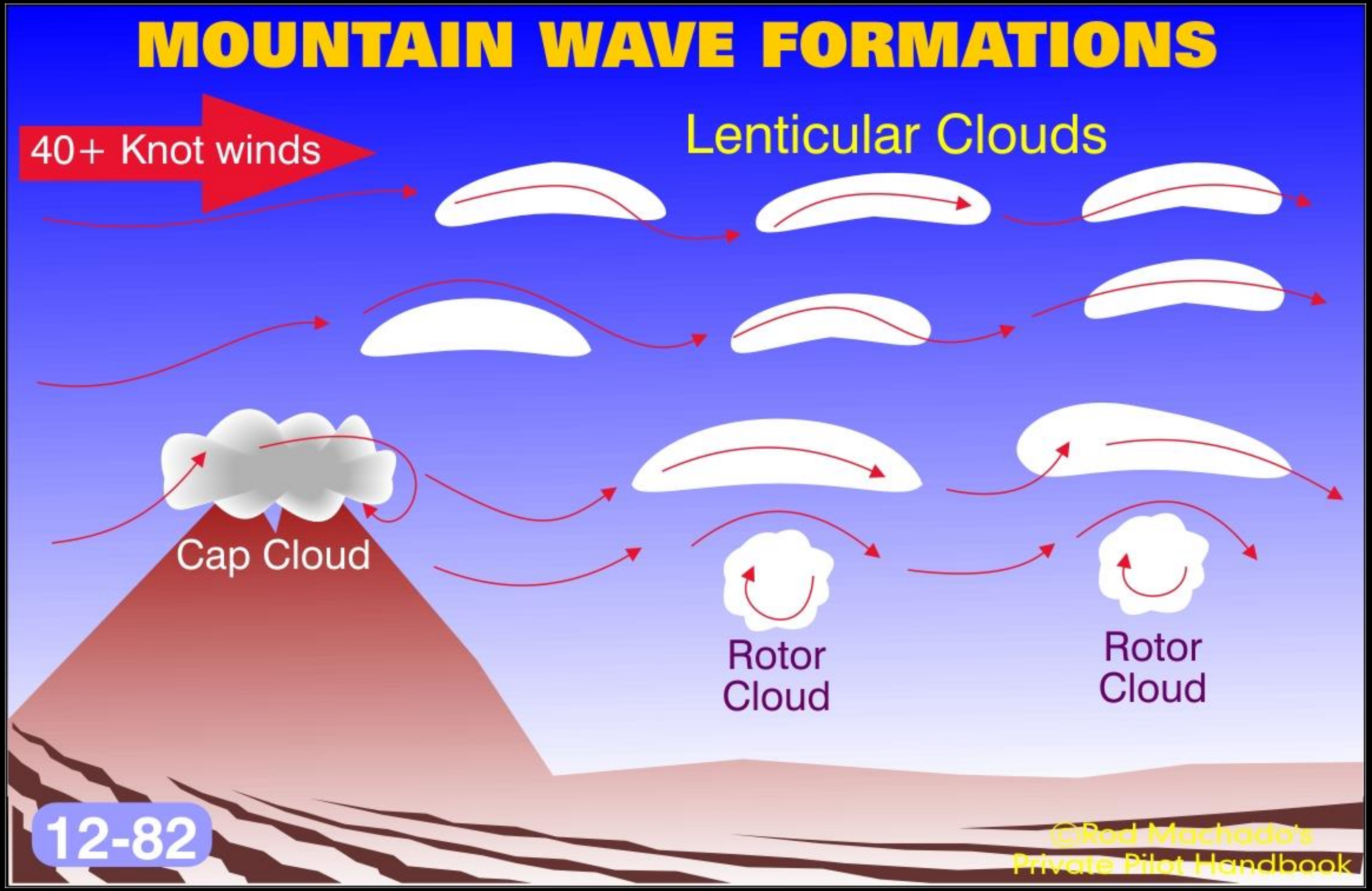
- Farther downwind almond or lens-shaped clouds form at the wave crests
- These clouds are called lenticular clouds because of their lens shape
- As moist air rises on the upwind side of the wave it cools and condenses producing a cloud
- On the downwind side of each wave crest the air sinks and warms, resulting in the cloud droplets evaporating

Mountain Waves

- Standing lenticular wave clouds appear not to move
- Air is rushing through them as they continually form on their western edges and evaporate away on their eastern edges
- Severe turbulence occurs in the up and downdrafts associated with lenticular clouds
- Mountain waves can form 100 miles or more downstream from the mountain barrier

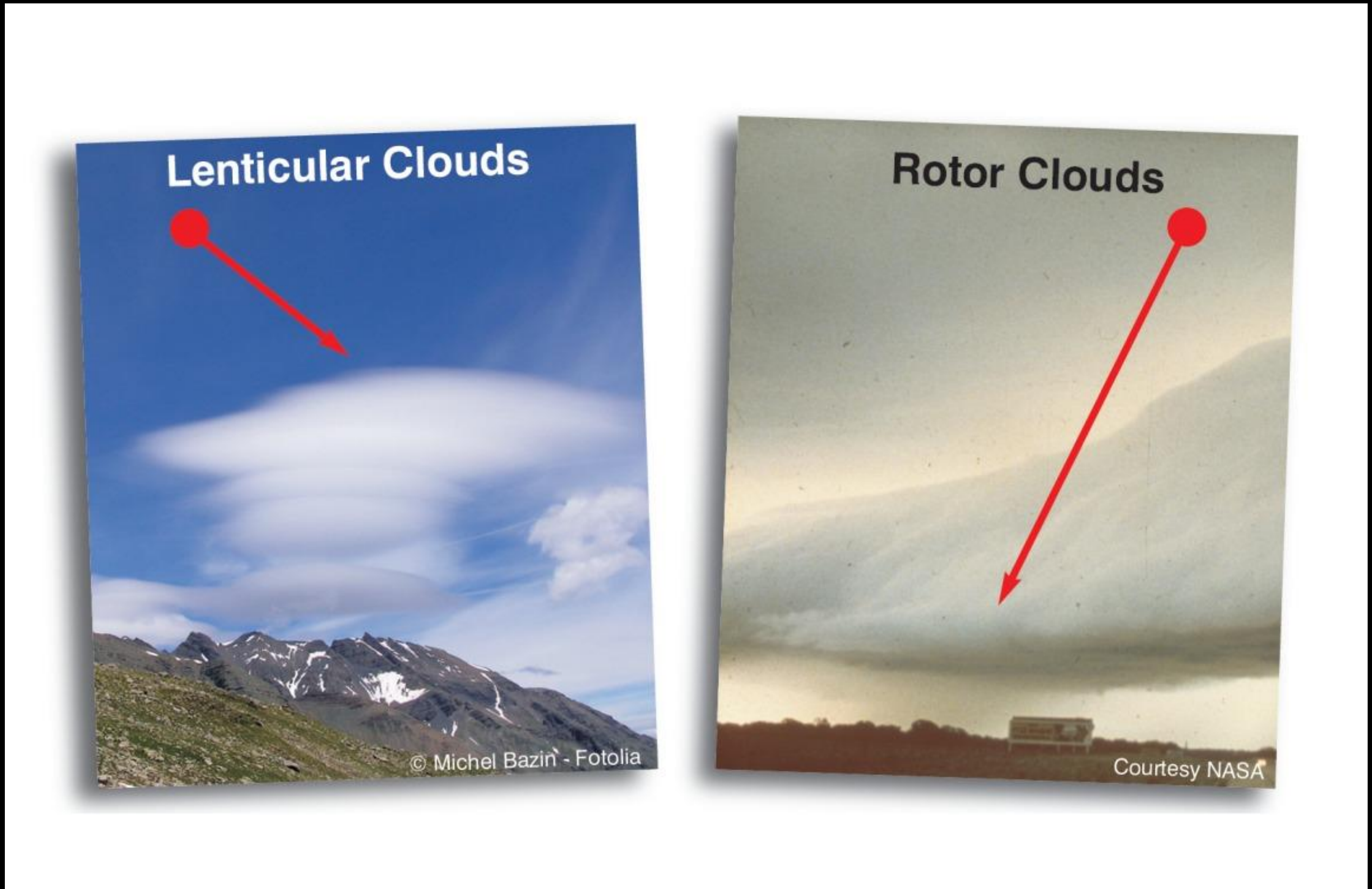


Mountain Waves



- Rotor clouds can frequently be found directly underneath the lenticular clouds at altitudes lower than the peaks over which the air flows
- Rotor clouds contain severe turbulence

Mountain Wave Generated Clouds



Mountain Wave Clouds

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Lenticular Clouds

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Mountain Wave Clouds

Rotor Cloud

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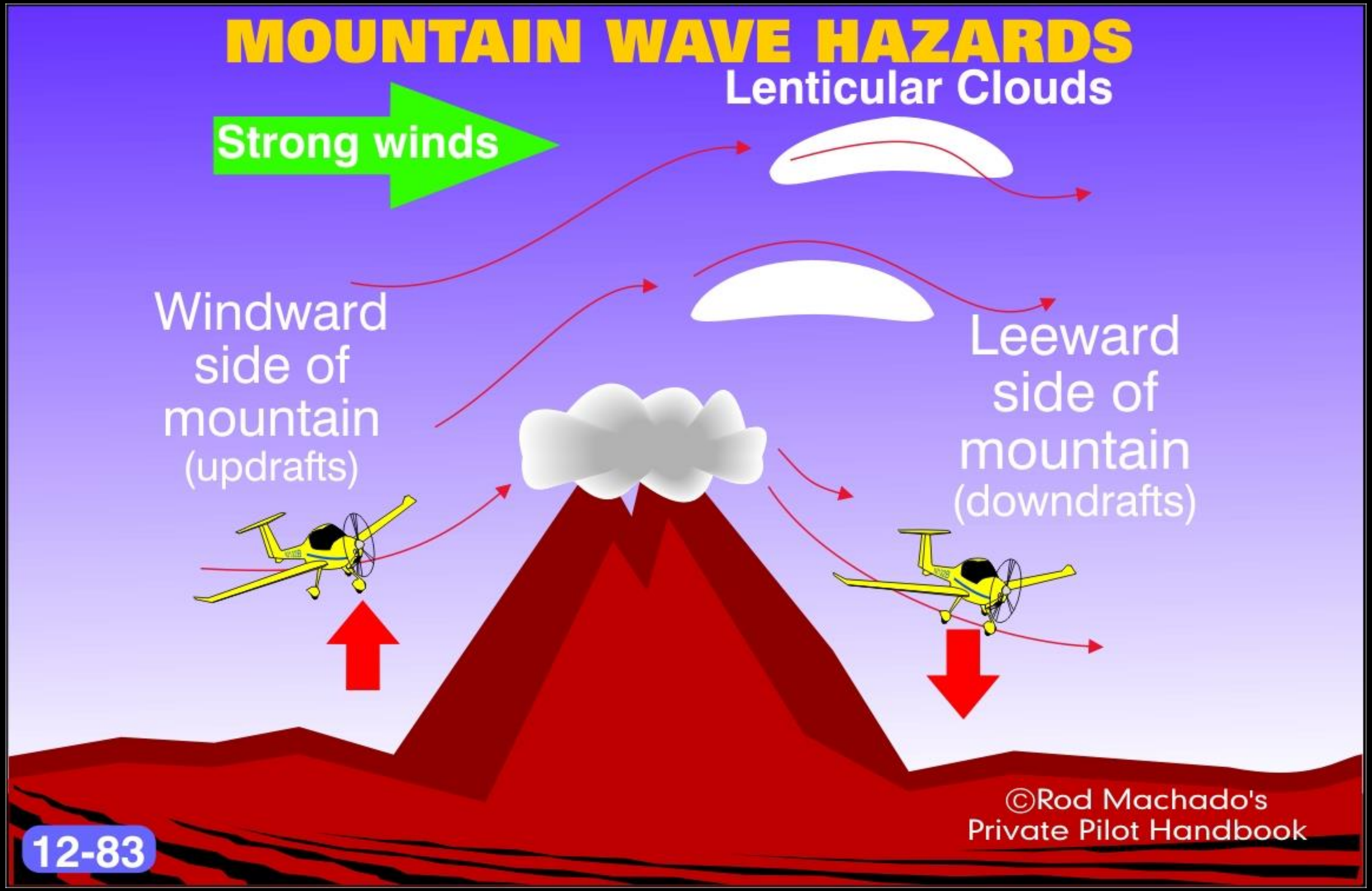
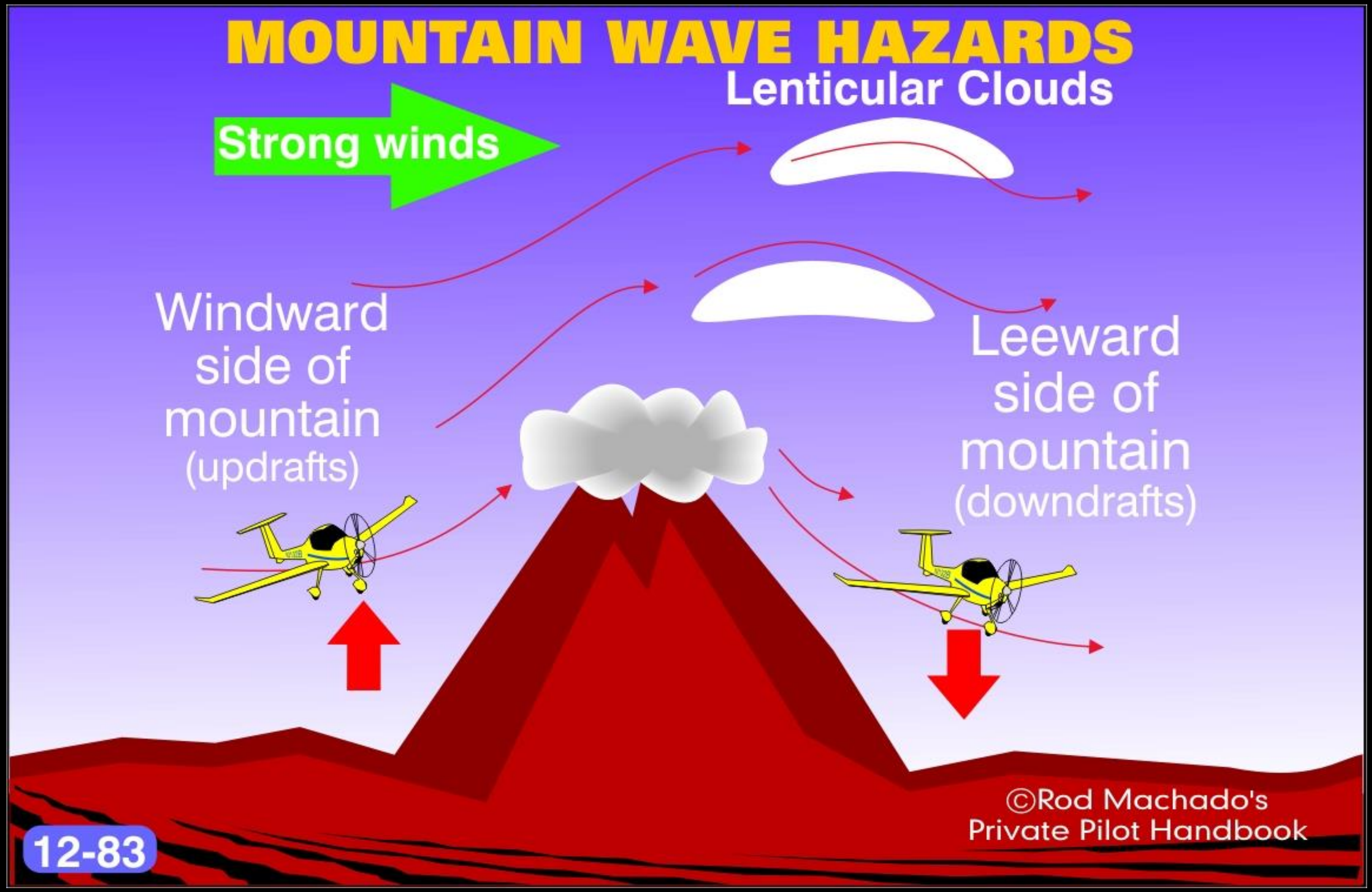
Mountain Wave Hazards

- Pilots must be especially cautious when flying near or around mountain waves
- Mountain waves can form in dry air which are not visible
- Winds in excess of 25 knots at mountaintop altitudes will likely have some degree of turbulence as well as up and downdraft hazards



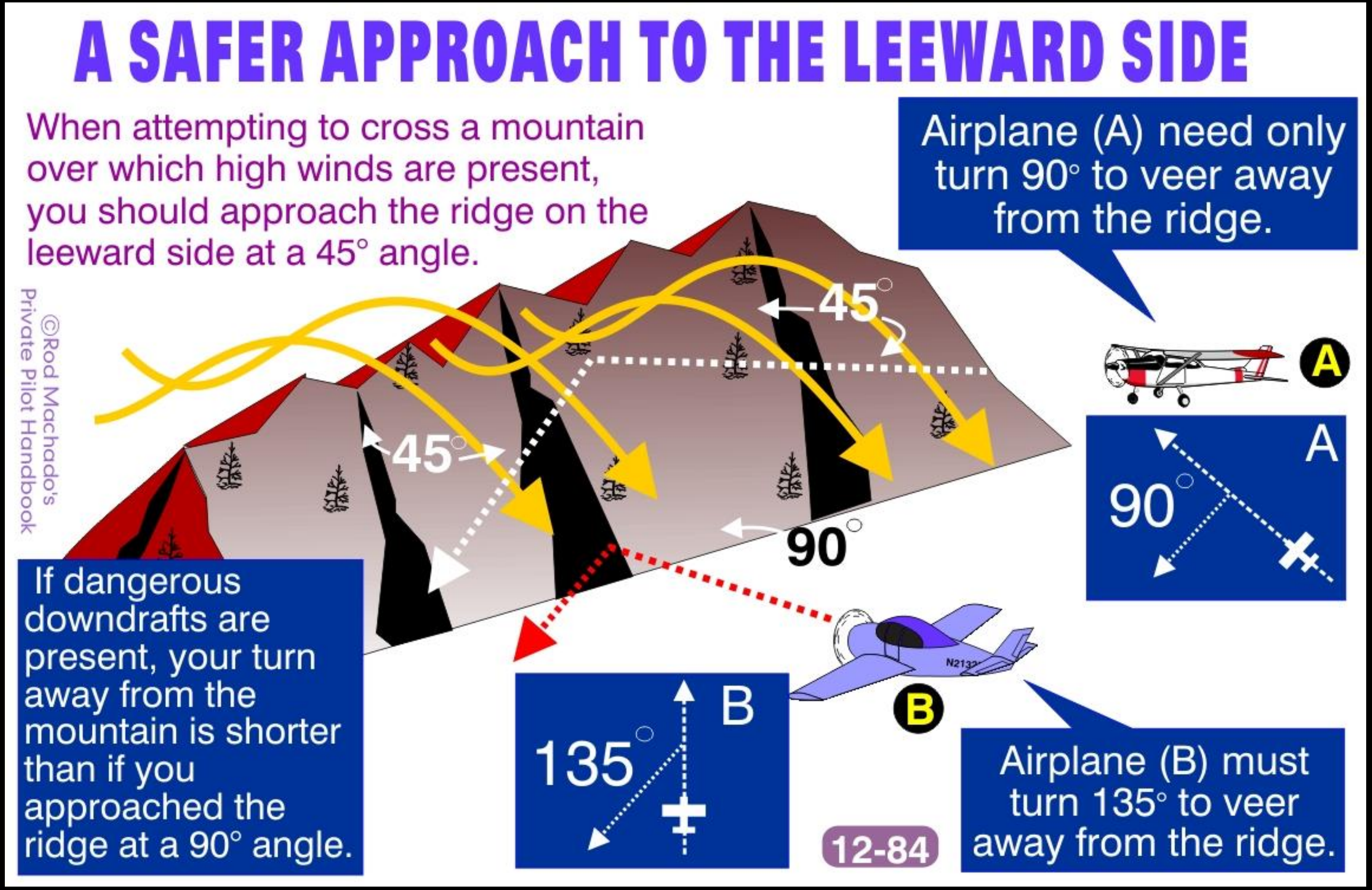
Mountain Wave Hazards



- When approaching the mountain on the windward side (the upwind side) you could encounter strong updrafts
- On the leeward side (the downwind side) it's possible to encounter strong downdrafts that exceed the ability of a light airplane to climb

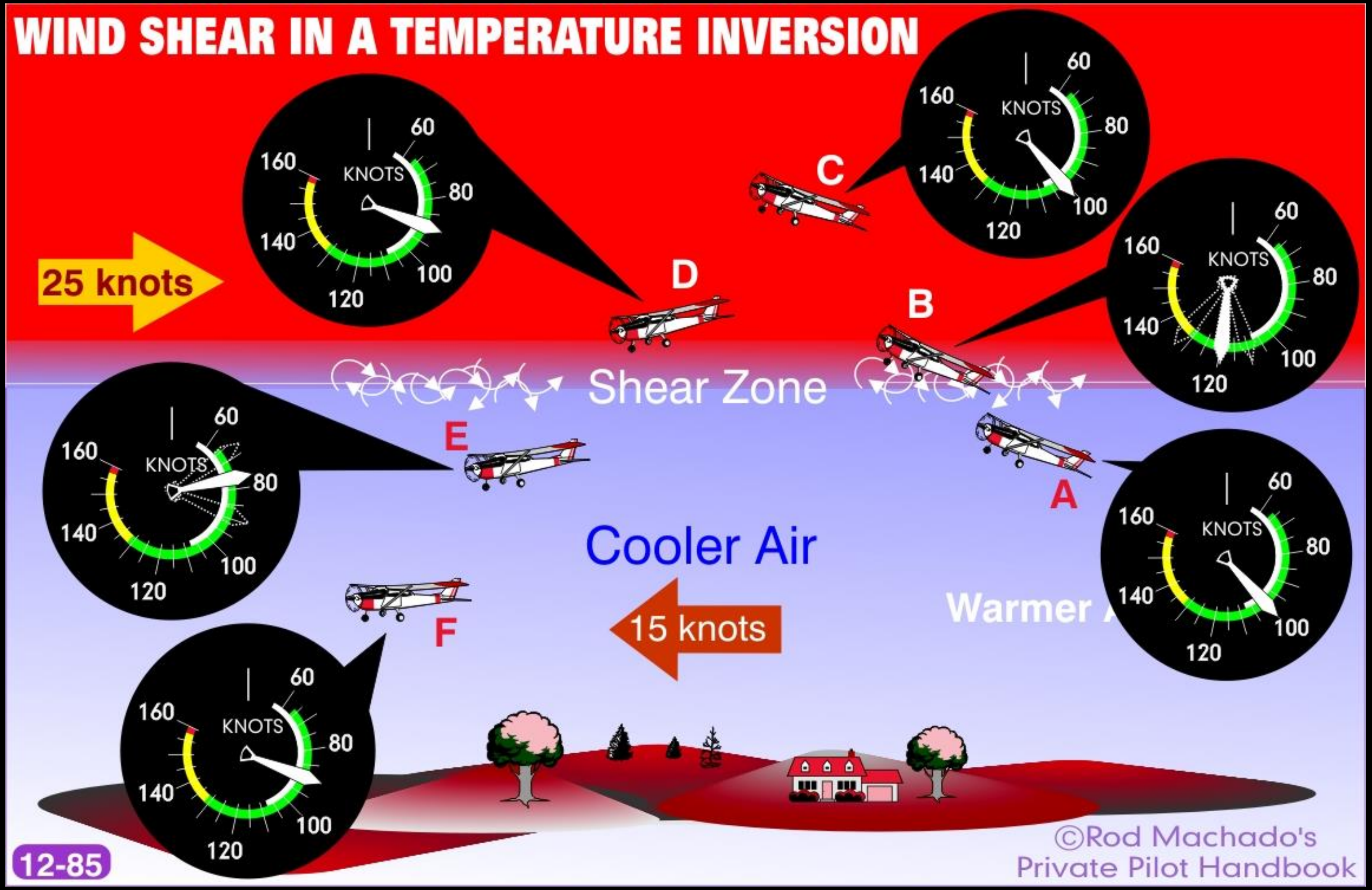
Crossing Mountains

- To minimize the risk if you are uncertain of conditions is to approach the ridge at a 45 degree angle
- If downdrafts are encountered, you need only make a 90 degree turn to avoid the mountain instead of a 135 degree turn

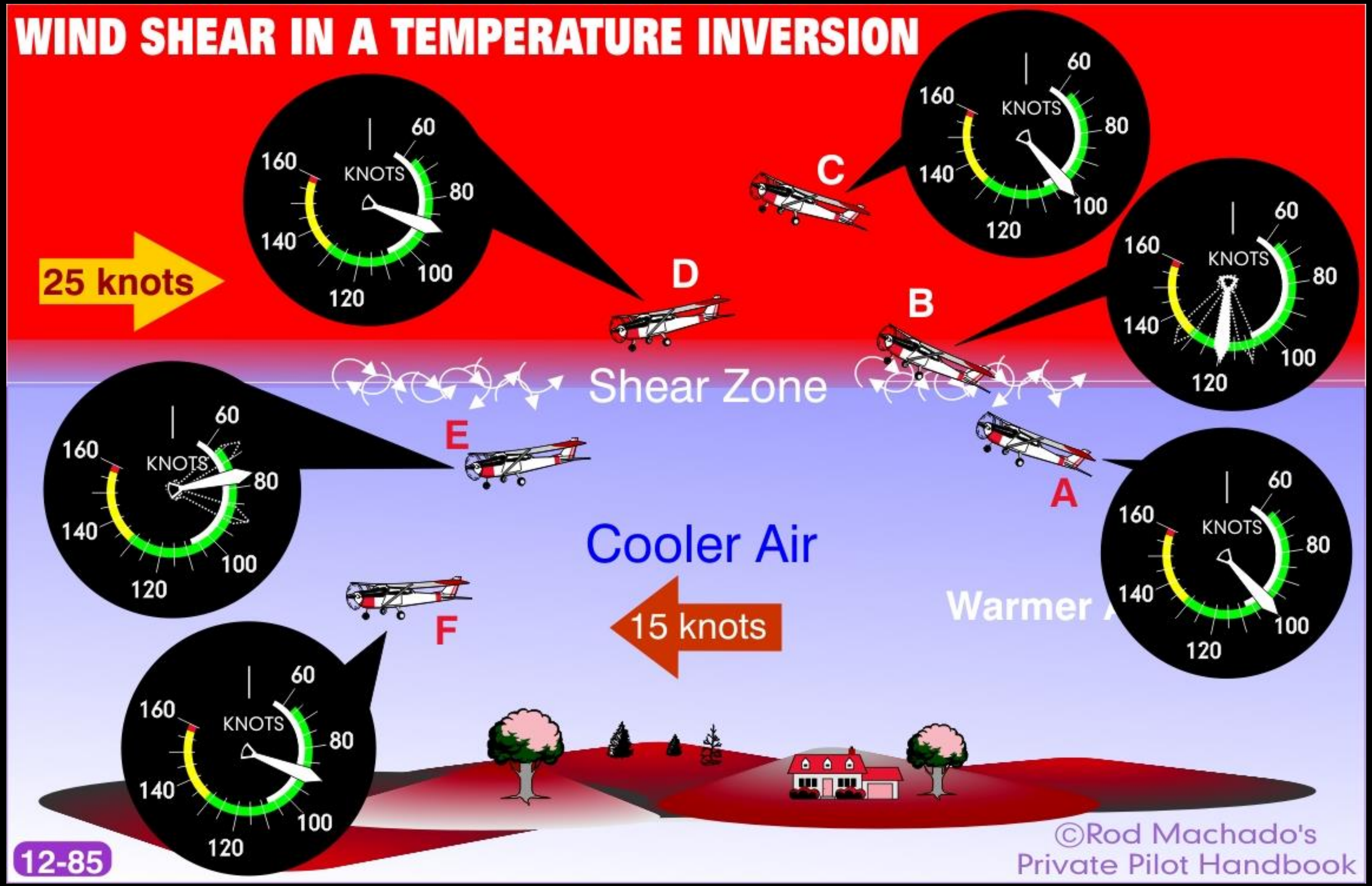


Temperature Inversions And Windshear

- Temperature inversions occur on the surface during clear, calm nights with little or no surface winds
- Strong winds can exist just above the inversion



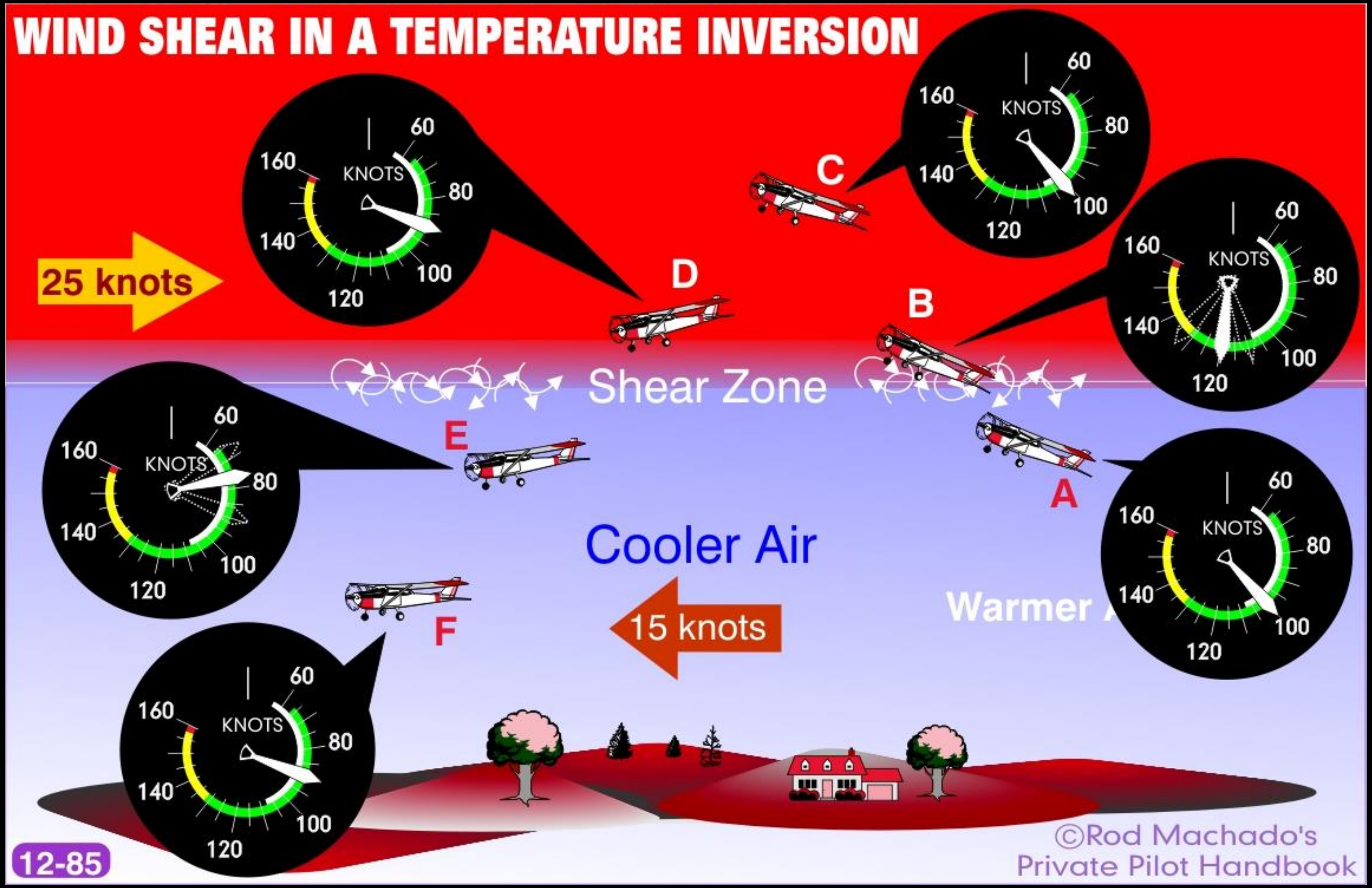
Temperature Inversions And Windshear



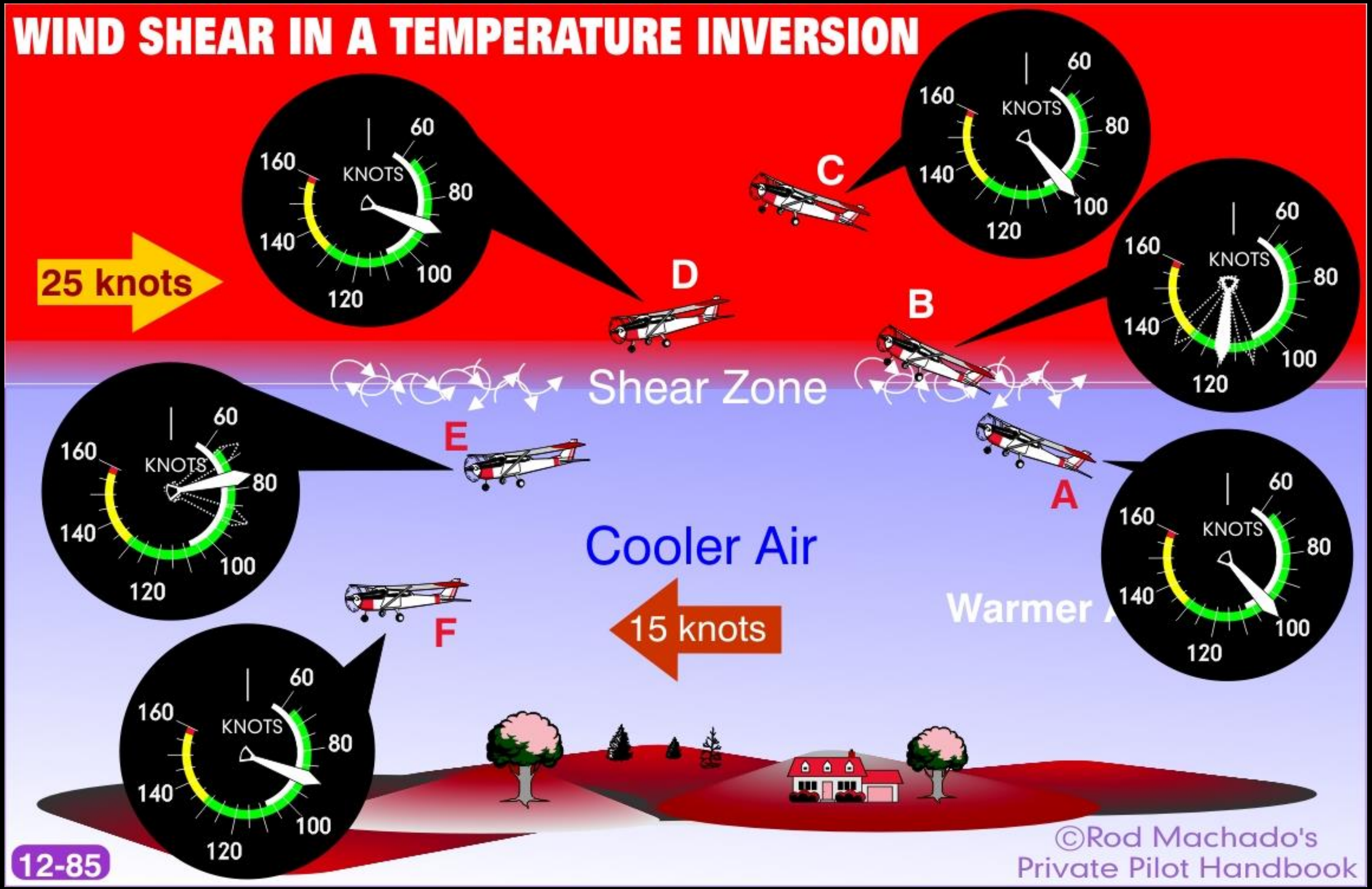
- Because air of different temperatures doesn't mix the warmer air on top slides over the colder air below
- This sliding becomes even more apparent when strong pressure differences exist, causing high wind speeds in the warmer air aloft

Temperature Inversions And Windshear

- Winds over 25 knots at 2,000 to 4,000 feet AGL causes windshear in the zone where the warm and cold air meet
- Differences in wind velocities cause tearing or churning of the air, producing eddies or turbulence in the shear zone
- Pilots climbing or descending at slow speeds may find the windshear bad enough to induce a stall at low altitudes close to the ground



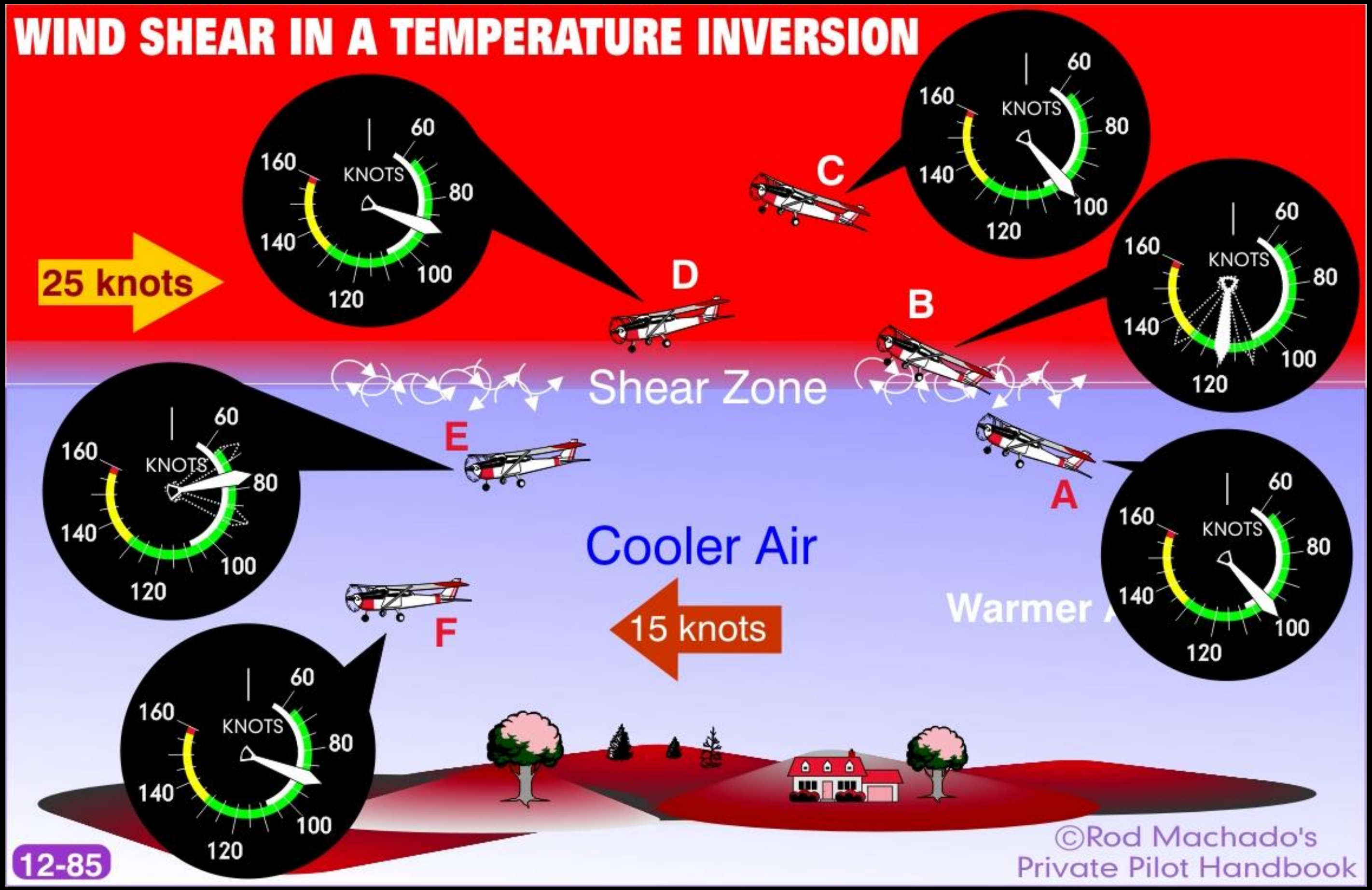
Temperature Inversions And Windshear



- Windshear in an inversion can cause sudden changes in the indicated airspeed
- Airplane A is climbing through the inversion into an increasing headwind
- At position B the indicated airspeed temporarily increases
- As the airplane adjusts to the new wind direction, the indicated airspeed returns to normal at position C

Temperature Inversions And Windshear

- Airplane D is descending into an increasing tailwind
- At position E the indicated airspeed temporarily decreases, then returns to normal at position F
- This event becomes more serious when the airplane is close to its stall speed and the inversion is close to the surface



Fog

- Fog is a cloud that touches the ground
- One of the most frequent causes of reduced surface visibilities
- Presents a serious problem because it can form in a very short time

Fog

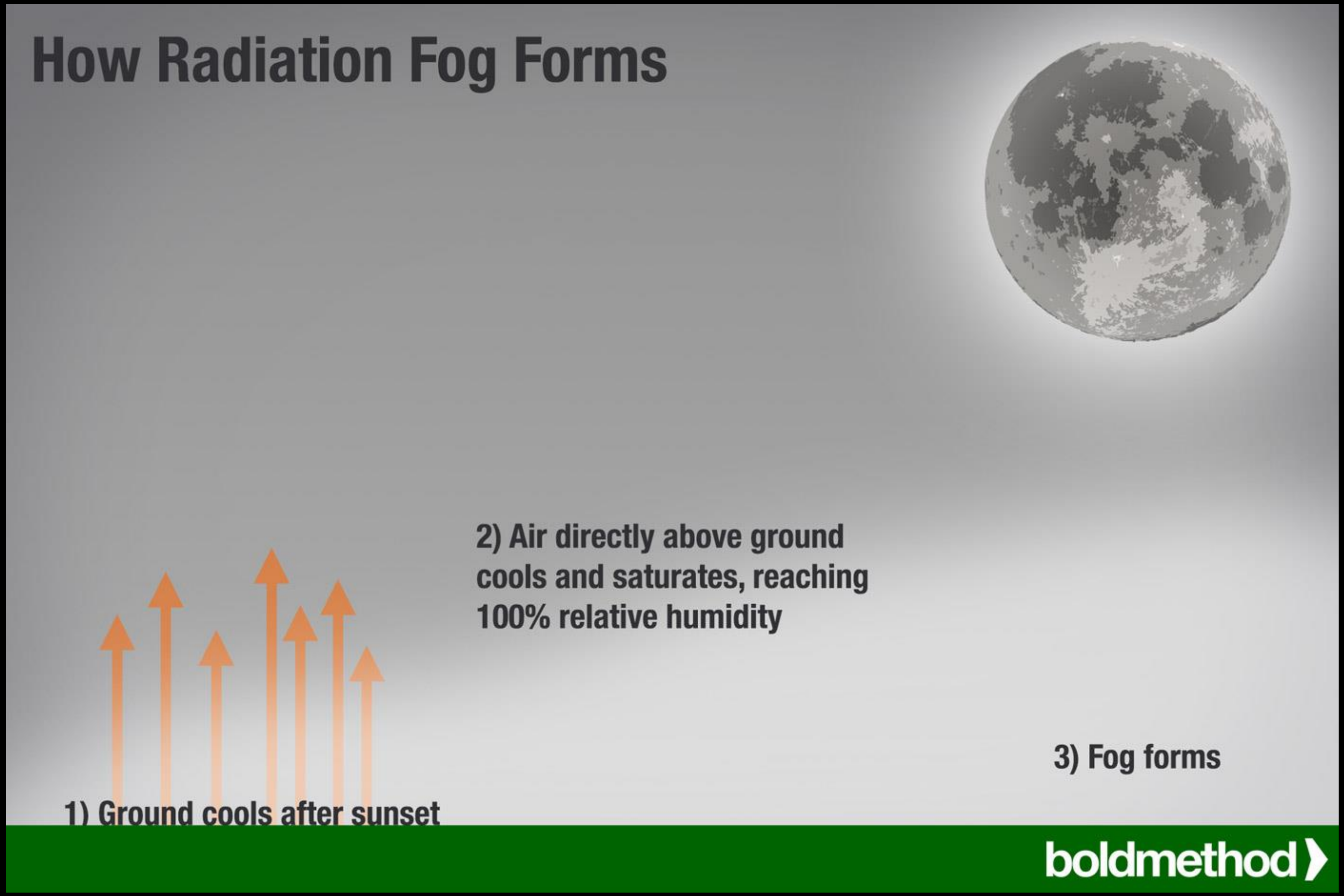
- Dew point is the temperature at which water will condense out of the air
- Small temperature-dew point spreads are conducive to fog formation
- Common in colder months, but can form any time the air contains enough moisture, condensation nuclei, and cooling temperatures

Fog

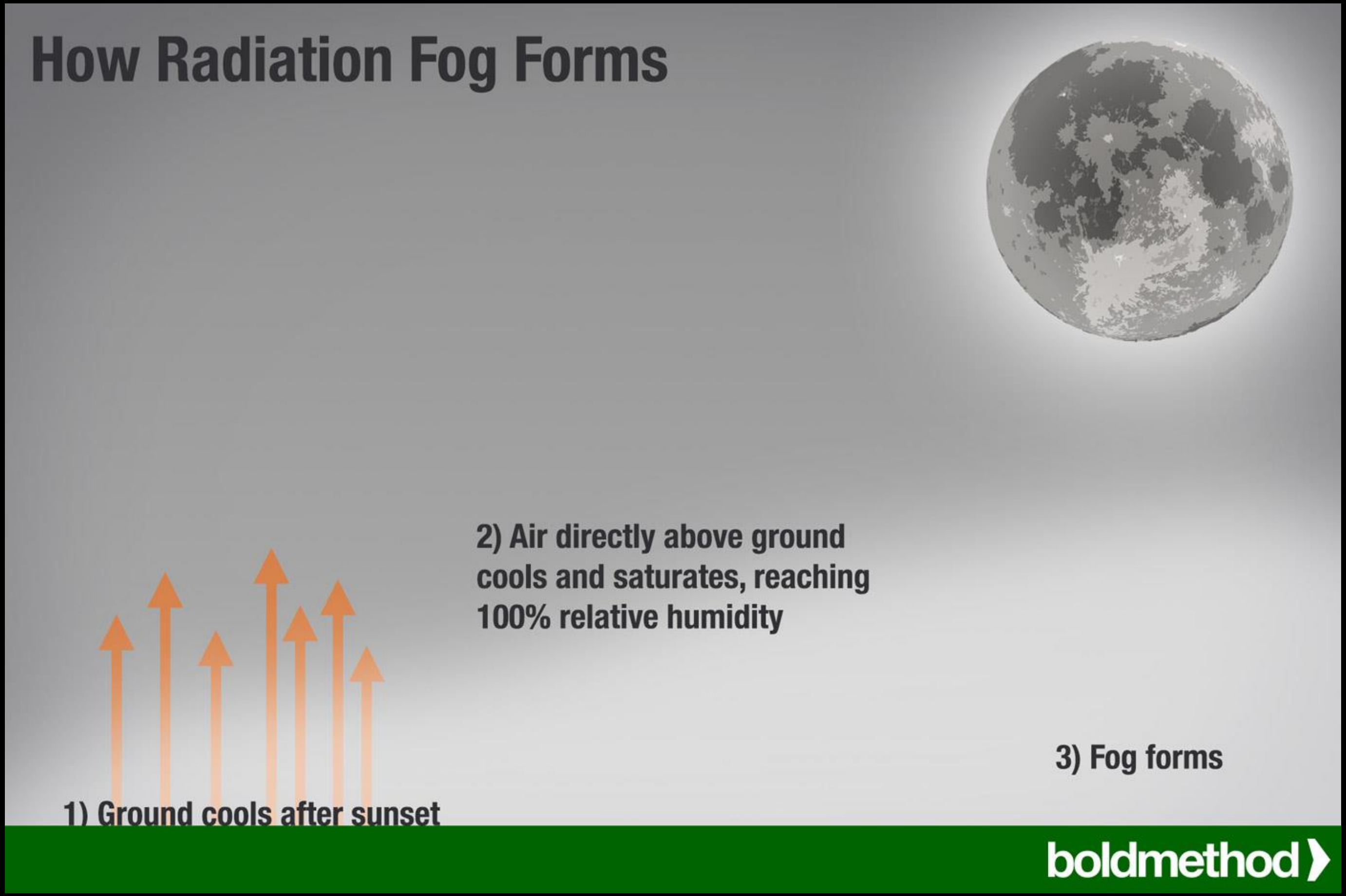
- Cooling the air to its dew point is the most common means of fog production
- Adding moisture to air near the surface also aids in fog formation
- Precipitation from fronts is a common way moisture is added to the air
- Fog is classified by the way it forms

Radiation Fog

- Radiation fog is what happens when the ground radiates its heat away
- On clear, calm nights, terrestrial radiation of heat cools the ground
- This allows the air resting next to the surface to cool quickly



Radiation Fog



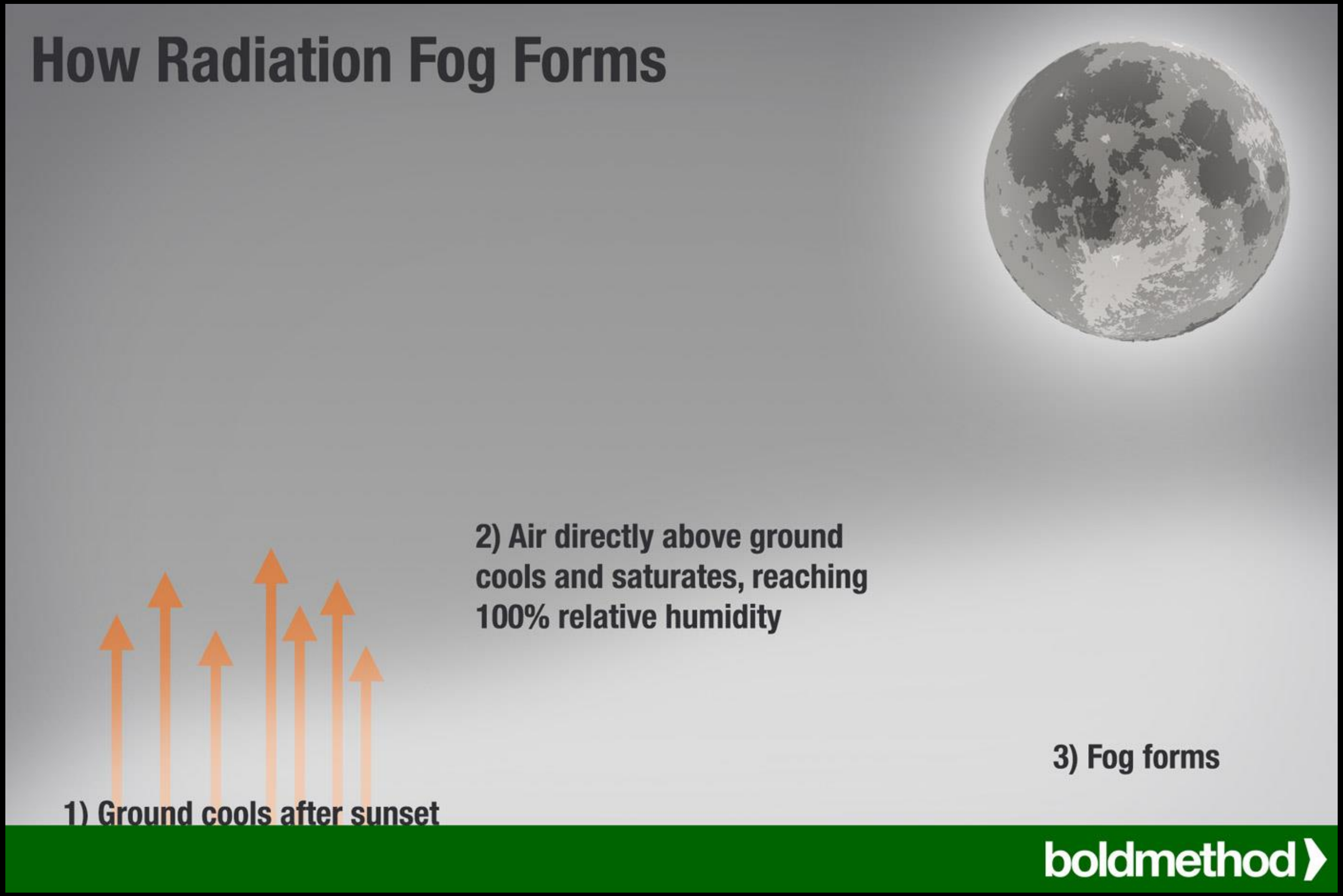
- As air is cooled and approaches its dew point, water vapor condenses and forms a shallow layer of fog
- Radiation fog is very common at night and early morning hours

Radiation Fog

- Areas of high humidity (rain soaked ground, snow melt, and vegetation) are especially conducive to the formation of radiation fog
- Bodies of water aren’t a likely place for radiation fog to form because they don’t cool as quickly at night

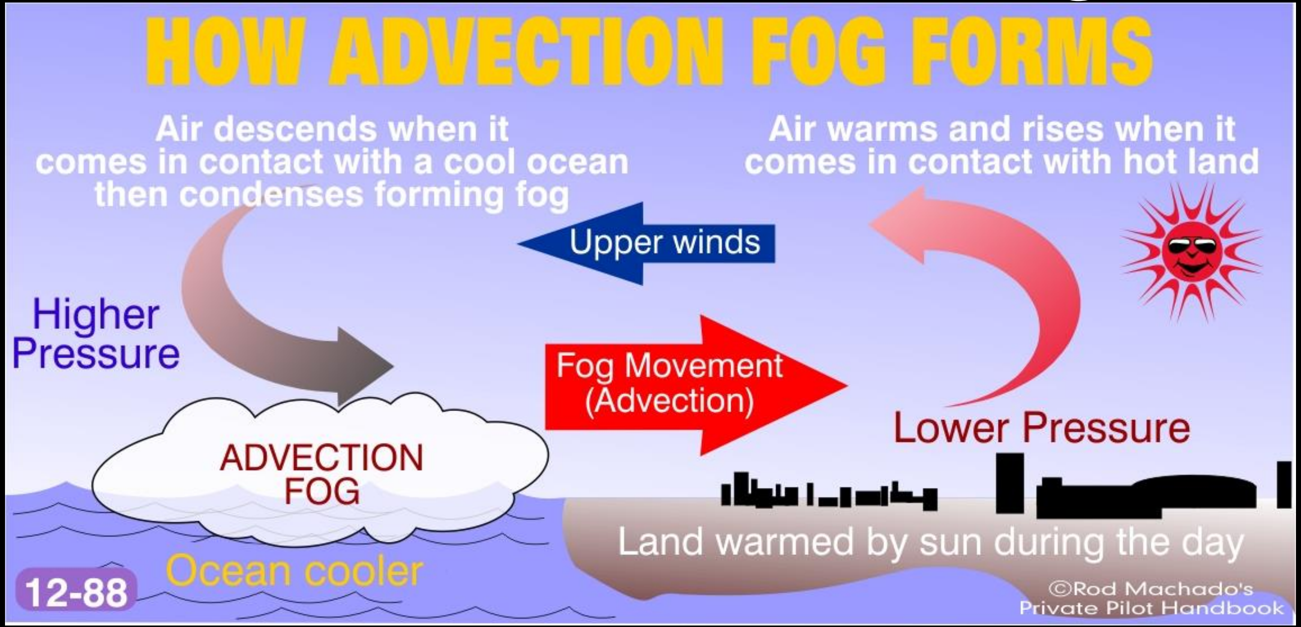
Radiation Fog

- Winds up to about 5 knots tend to mix and deepen the layer of fog
- Higher winds tend to disperse radiation fog
- Solar heating of the earth after sunrise tends to dissipate radiation fog



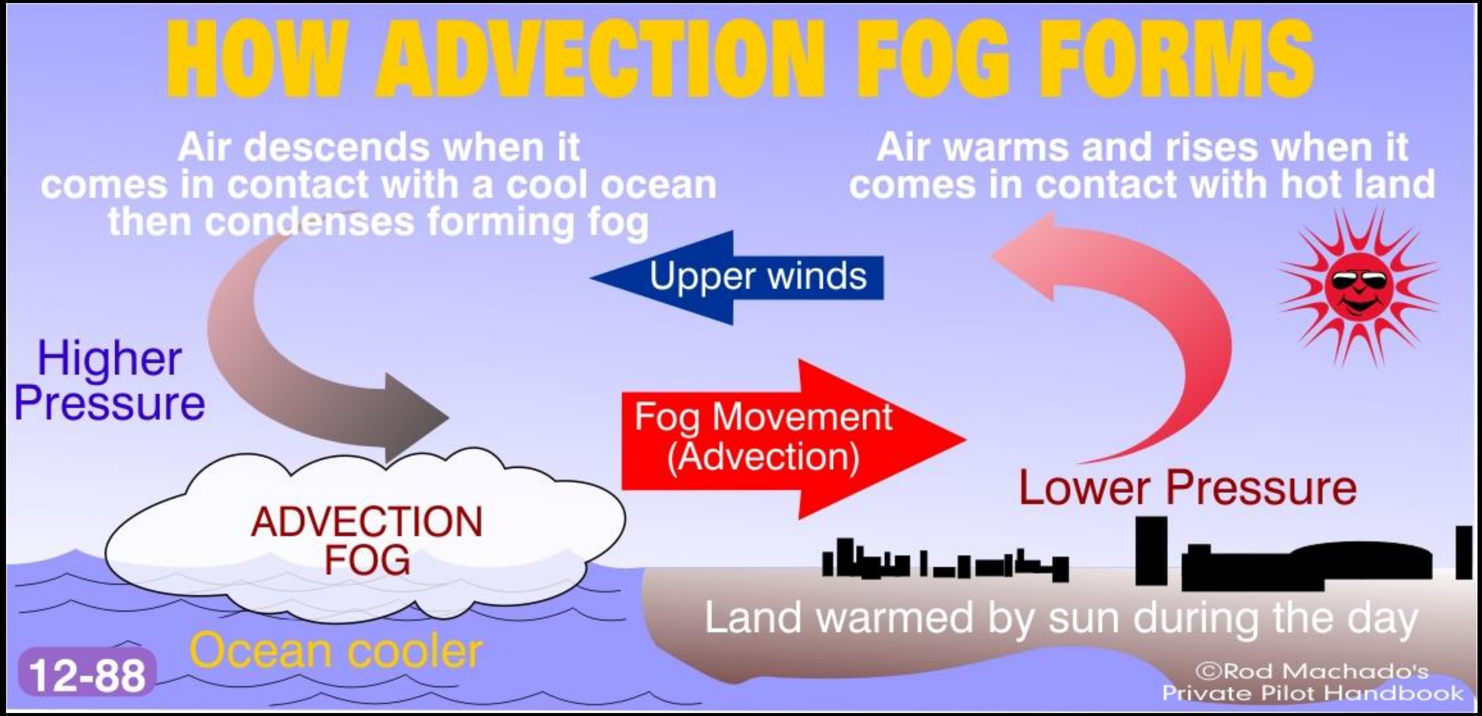
Advection Fog

- Convection means to move something vertically; advection means moving it sideways
- As warmer, moist air comes in contact with the ocean's surface, air temperatures decrease and water vapor condenses
- With slight heating, the pressure over land lowers, drawing advection fog inland



Advection Fog

- Advection fog deepens when winds increase to about 15 knots
- Winds above this speed tend to lift fog layers into low stratus or stratocumulus type clouds

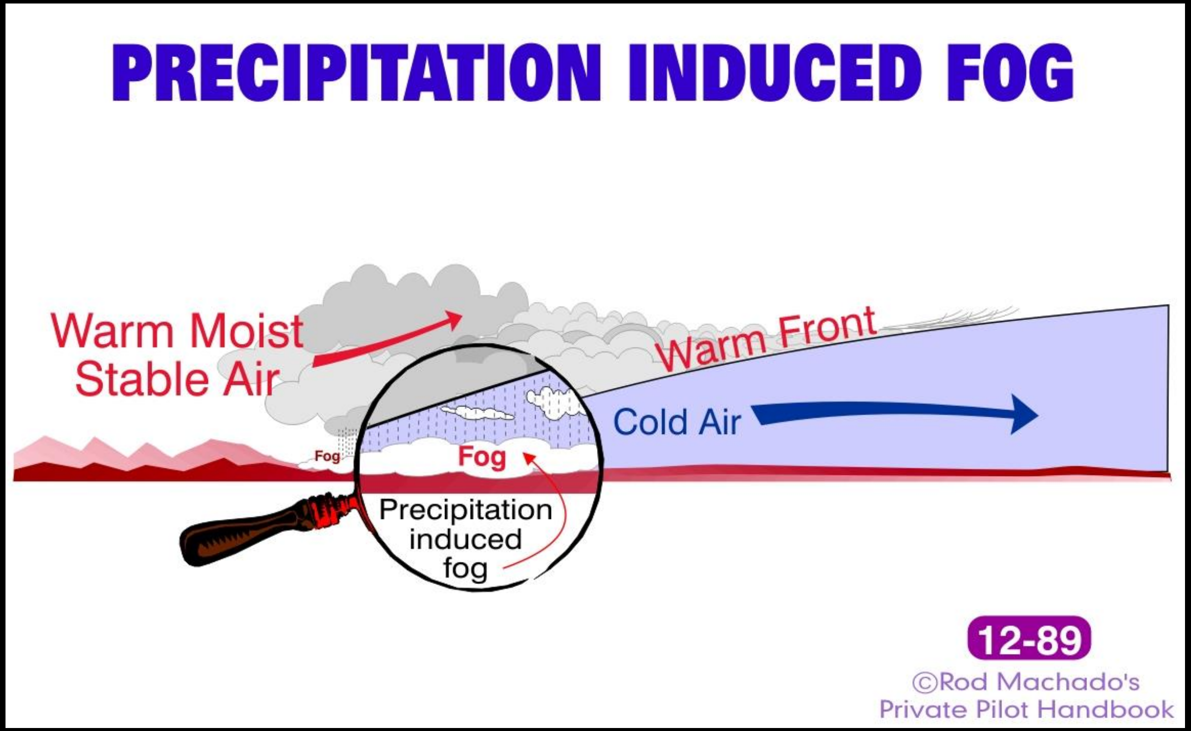


Advection Fog

- Advection fog can form quite rapidly and cover extensive areas

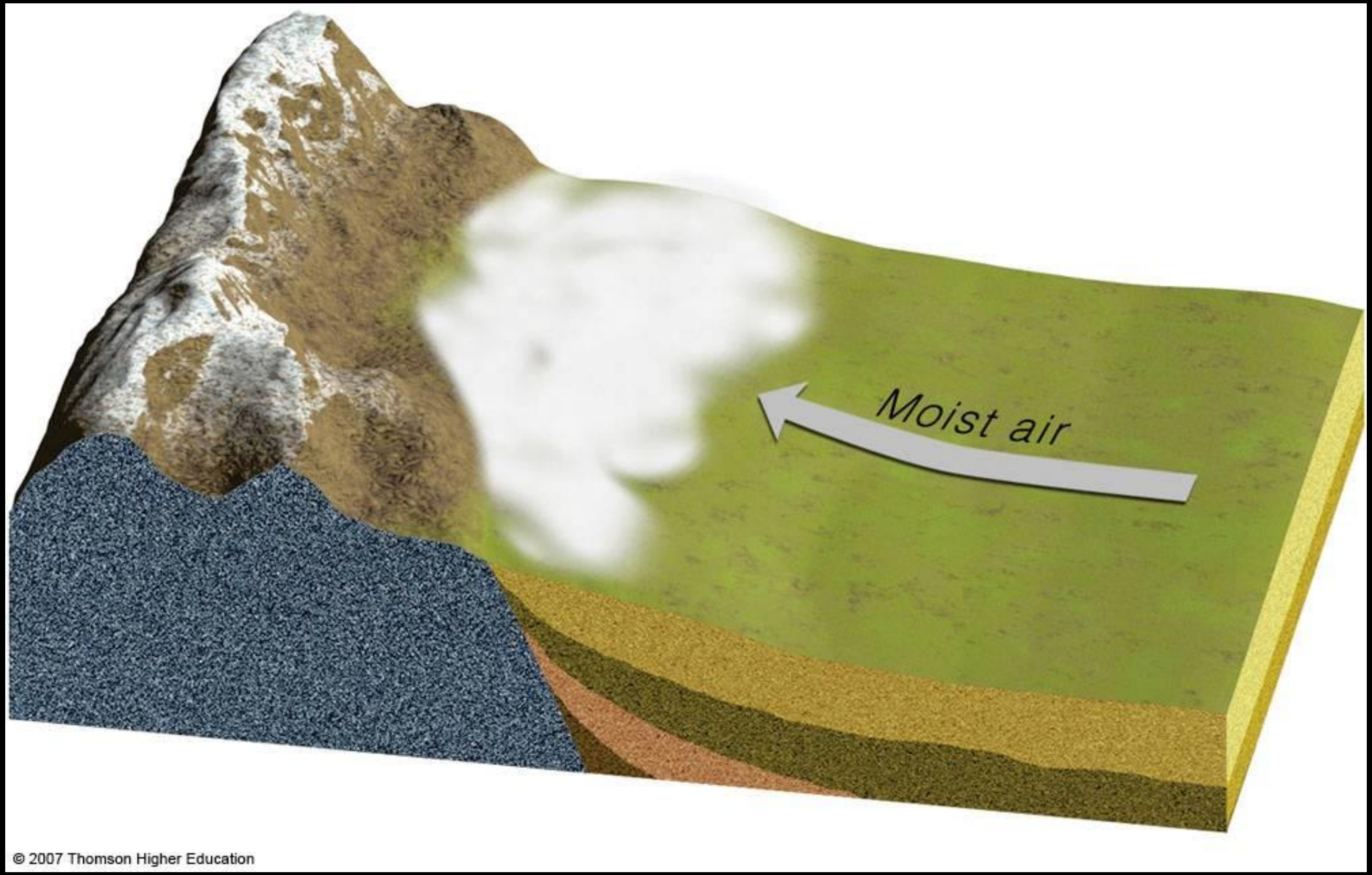
Precipitation Induced Fog

- Warm rain, falling through cooler air can bring the air to the point of saturation, forming fog
- Commonly associated with warm fronts, it can occur in slow moving cold fronts and stationary fronts



Upslope Fog

- When warm, moist air is forced up the slope of a mountain and condenses, it forms upslope fog
- Upslope fog depends on wind for its existence
- Unlike radiation fog, it can form under cloudy skies

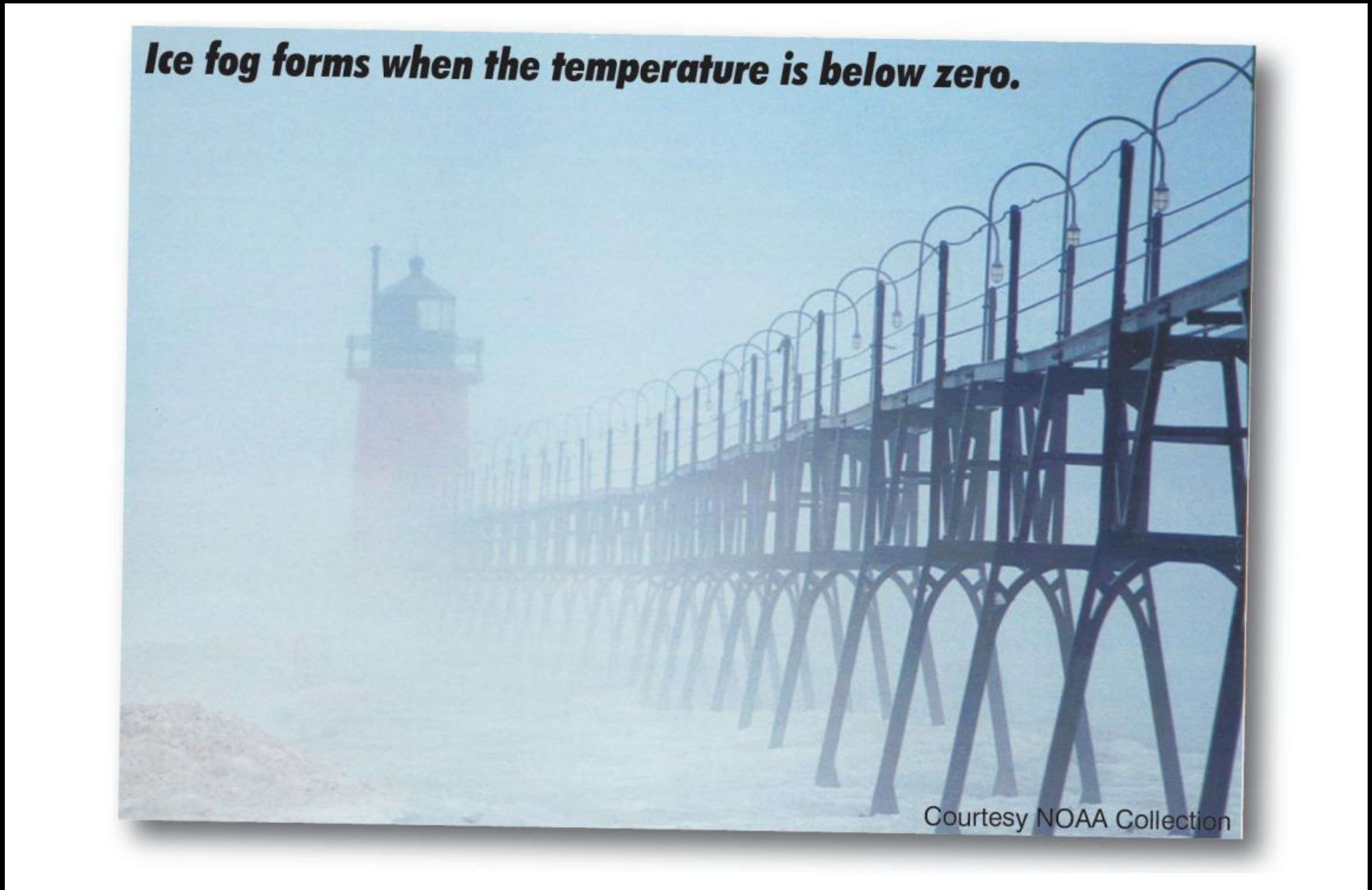


Steam Fog

- As dry, cold air passes over a body of warm water, moisture evaporates rapidly from the surface
- Condensation takes place as the cold air is quickly saturated

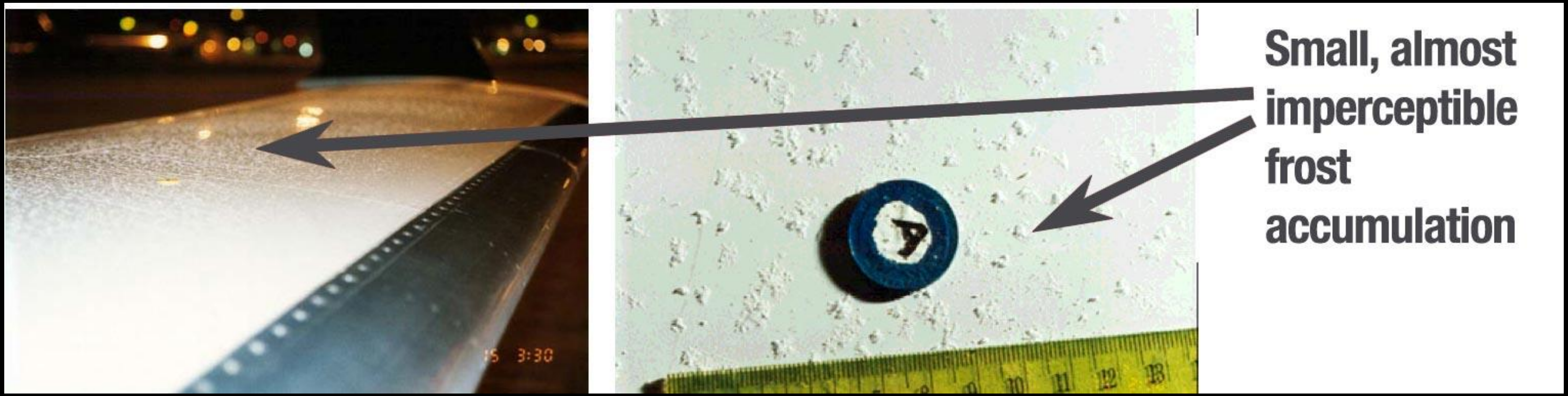
Ice Fog

- Forms under conditions similar to those that cause radiation fog except the air temperature is way below freezing
- Water sublimates directly into the air as ice crystals
- Temperatures around -25 degrees F are favorable for its formation



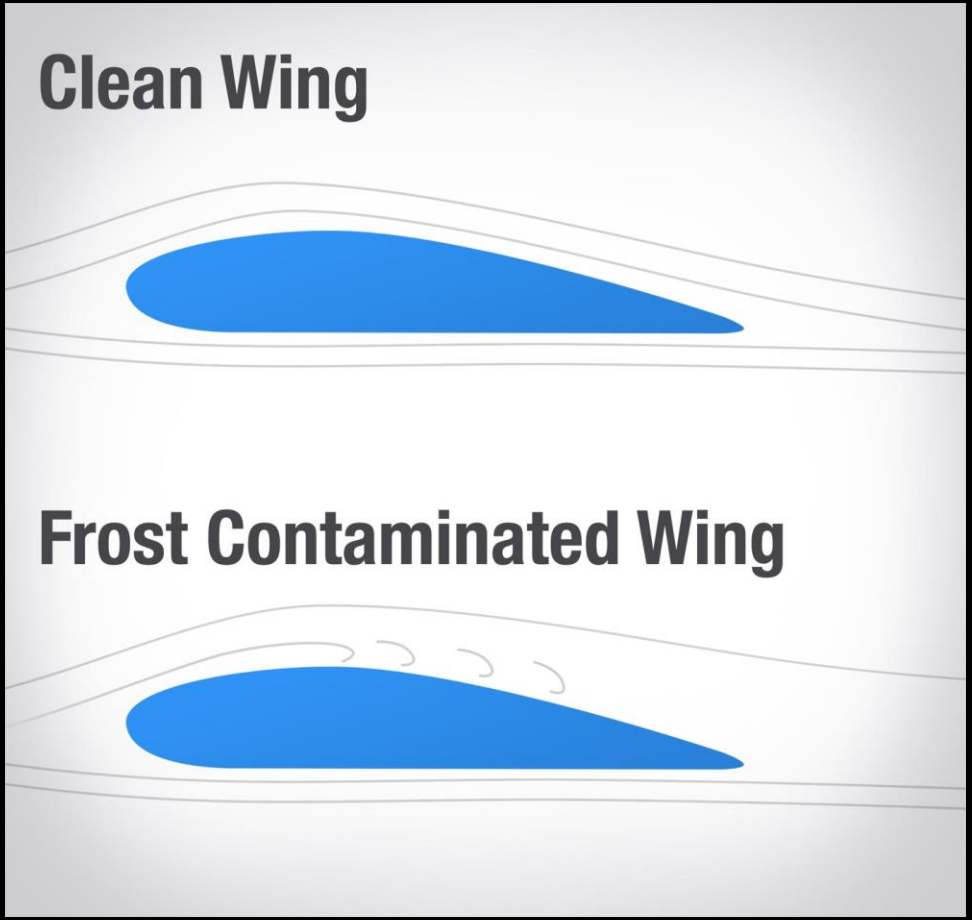
Frost

- Frost forms in much the same way as dew
- Difference is that the dew point of surrounding air must be colder than freezing
- The temperature of the collecting surface is at or below the dew point of the adjacent air and the dew point is below freezing



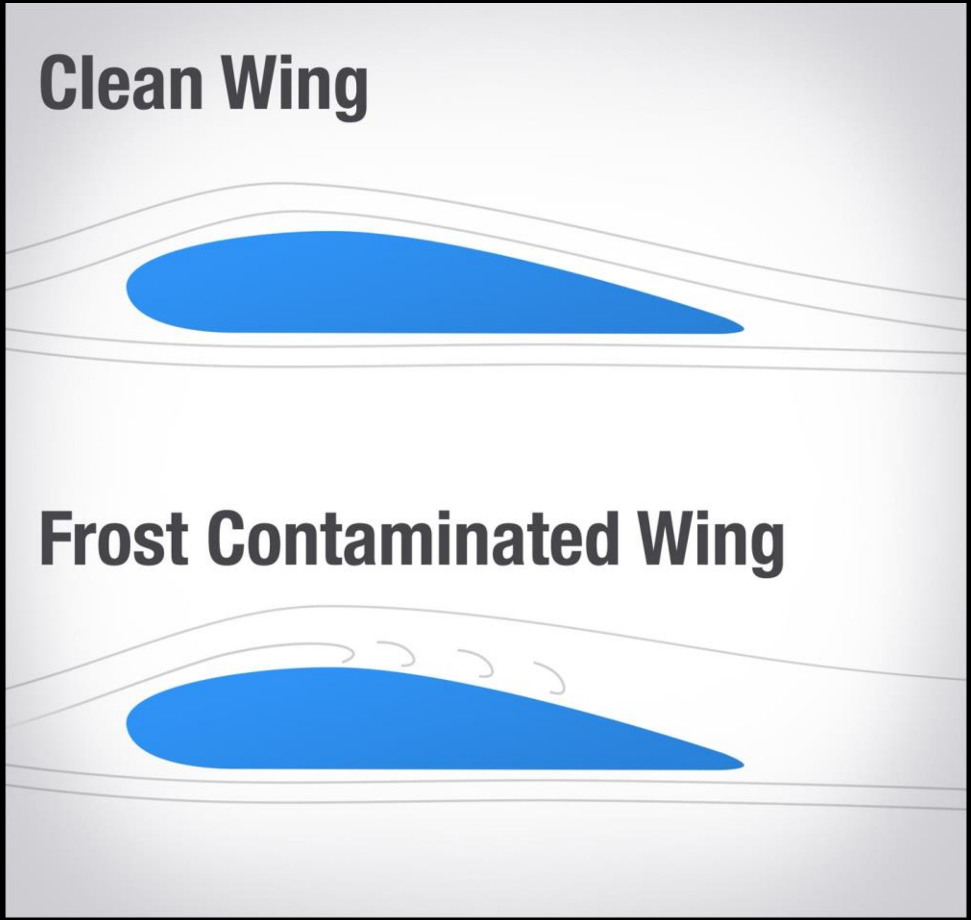
Frost

- Ice, snow, or frost having a thickness and roughness like medium or coarse sandpaper on the wing's leading edge or upper surface can reduce lift by as much as 30% and increase drag by as much as 40%
- Even a mere hint of frost can disrupt the airflow over the wings, creating loss of lift



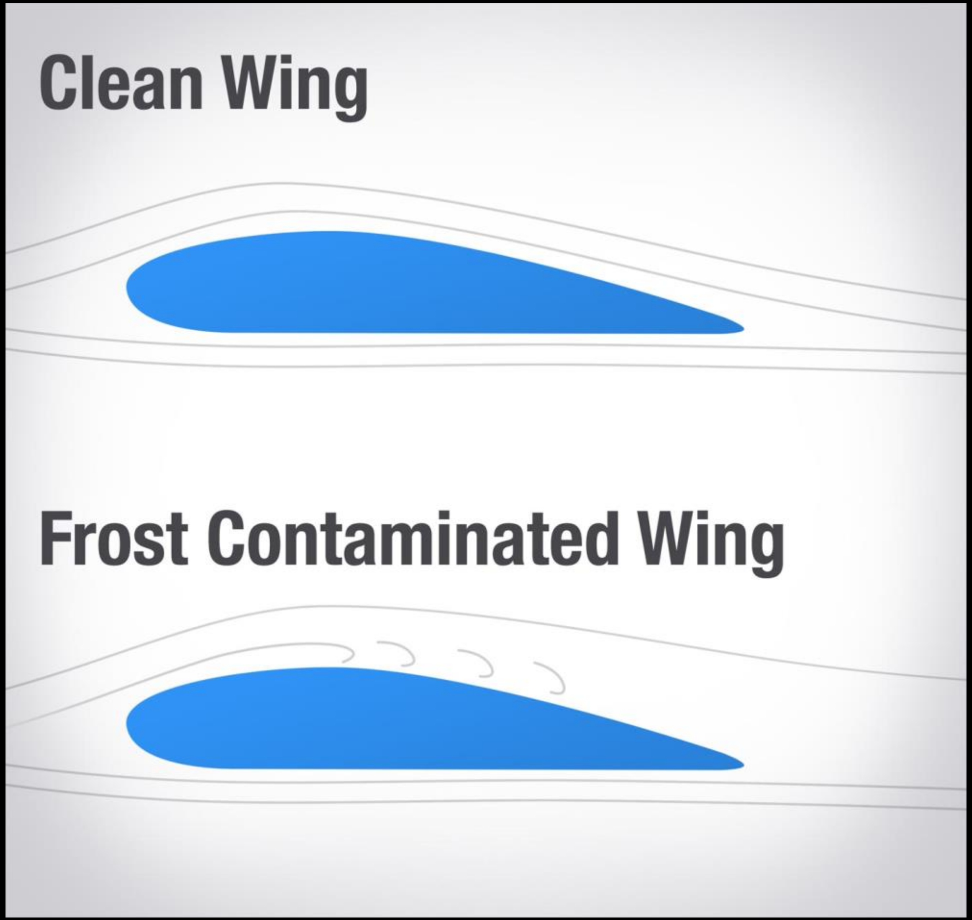
Frost

- Frost spoils the smooth flow of air over the wings, decreasing lifting capability
- The roughness of the surface of frost spoils the smooth flow of air, causing a slowing of the airflow
- This slowing of the air causes early air flow separation over the affected airfoil, resulting in a loss of lift



Frost

- Even a small amount of frost on airfoils may prevent an aircraft from becoming airborne at normal takeoff speed
- Must be removed before flight



Icing

- Except for freezing rain, it’s unlikely you’ll experience inflight icing as a VFR only pilot
- For structural icing to form, you must be in some form of ***visible moisture*** (IFR) and the OAT must be 0°C or colder

Icing

- The one exception to structural icing for VFR pilots occurs in freezing rain
- This can result in the greatest accumulation of structural icing any pilot might experience
- The presence of ice pellets at the surface is evidence that there is a temperature inversion with freezing rain at a higher altitude
- If you encounter freezing rain, you must get out of it fast
- Making an immediate 180-degree turn or turn toward the area where the precipitation stops

Ice Accumulation

- Accumulates unevenly on the airplane
- Adds weight and drag, and decreases thrust and lift
- Landing approaches should be made with a minimum wing flap setting and with an added margin of airspeed
- Avoid sudden and large configuration and airspeed changes

Knowledge Check

Radiation fog needs which of the following to from?

A. Clear night
B. Warm surface
C. Calm winds
D. All of the above

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~~C. Calm winds~~

D. All of the above

Knowledge Check

The most sever weather can be found in what?

A. Airmass thunderstorm
B. Squall Line
C. Frontal Thunderstorm
D. None of the Above

Knowledge Check

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