Aviation Weather

Course designed by Aaron Schoolcraft and Brock Hindman

Course Objectives

Student will be able to:

- Identify weather conditions that may adversely affect the safety of aviation operations.
- Describe mitigations that can be applied when working in unfavorable weather conditions.
- List at least two aviation weather resources that can assist in making informed decisions.

Aviation Weather

- General Weather Overview
- Mitigations
- Aviation Weather Resources

We Will Learn About

- Weather Basics
- Wind/Wind Shear
- Visibility
- Clouds
- Fog
- Inversions
- Thunderstorms
- Icing
- Frontal Systems
- Fire
- Topographic Influences
- Density Altitude
- Wake Turbulence
- Weather as a Contributing Factor in Aircraft Mishaps.

Proceed to the AOPA Weather Wise training program And complete lesson on “Air Masses and Fronts”

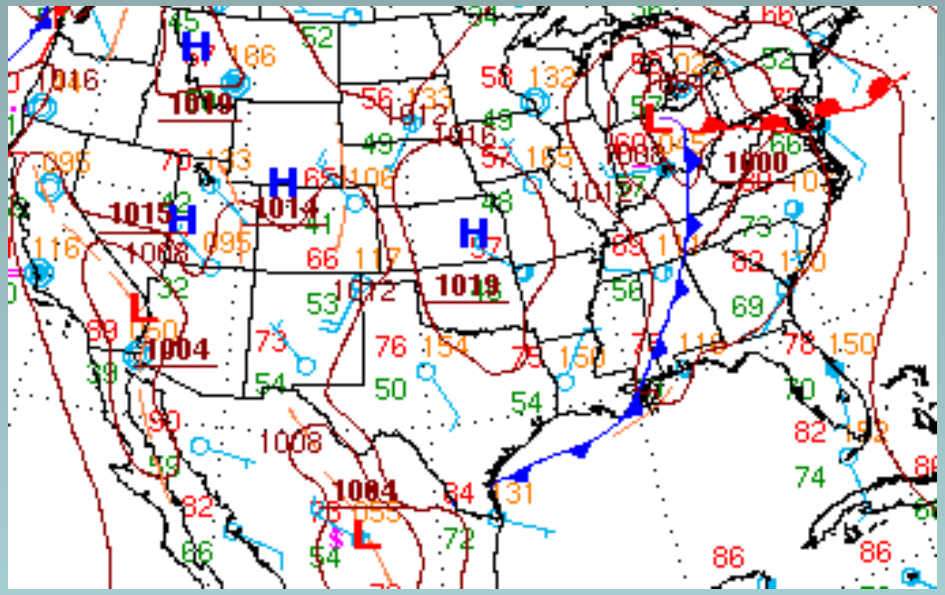
http://flash.aopa.org/asf/wxwise_fronts/wxwise_fronts.cfm?

What is the Atmosphere?

- The earth's atmosphere is like a fluid by the way it moves and is affected by objects on the surface. It can however be expanded and contracted due to the pressures of the gasses.

- Only one to four percent of the atmosphere is moisture, fundamentally speaking, everything that happens in the atmosphere is a function of temperature and moisture.

Atmospheric Flow



A Surface Analysis Chart Depicts High Pressure and Low Pressure systems Warm and Cold Fronts.

Air masses are large bodies of air that have the same moisture and temperature characteristics.

These characteristics will determine the kind of weather that can be expected and produce interactions with other

Aviation Weather
Based On

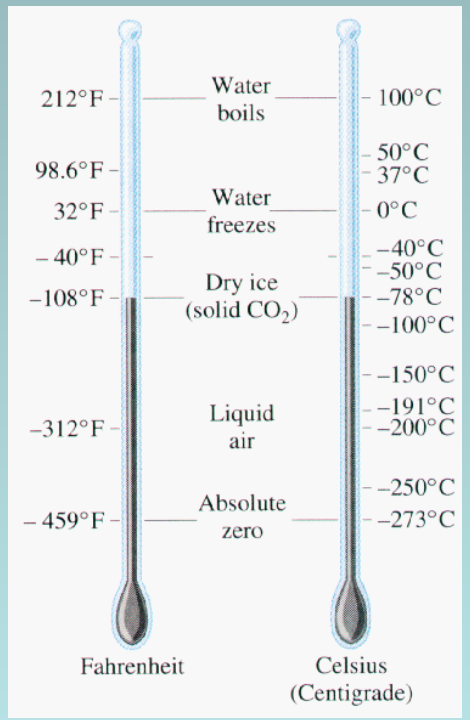
- Temperature
- Density
- Pressure
- Moisture

Temperature

- Measured in both degrees Celsius or Fahrenheit.

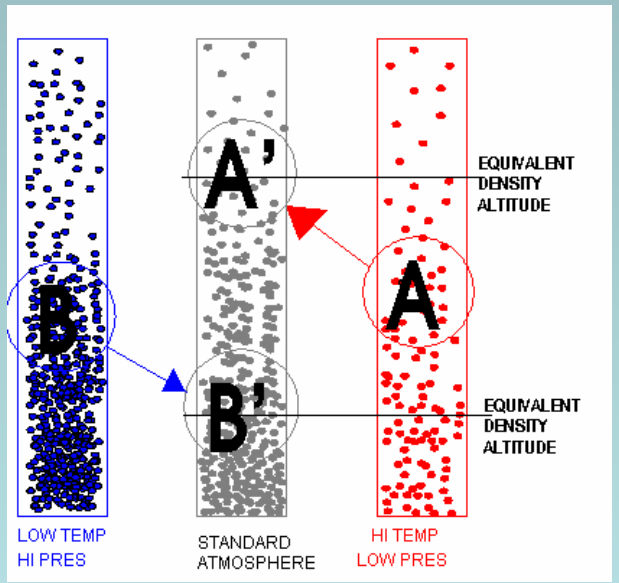
- For every 1 degree Celsius change there is an corresponding 1.8 degree Fahrenheit change. The conversion from Celsius to Fahrenheit is (Celsius Temp. X 1.8+32=Fahrenheit Temperature).

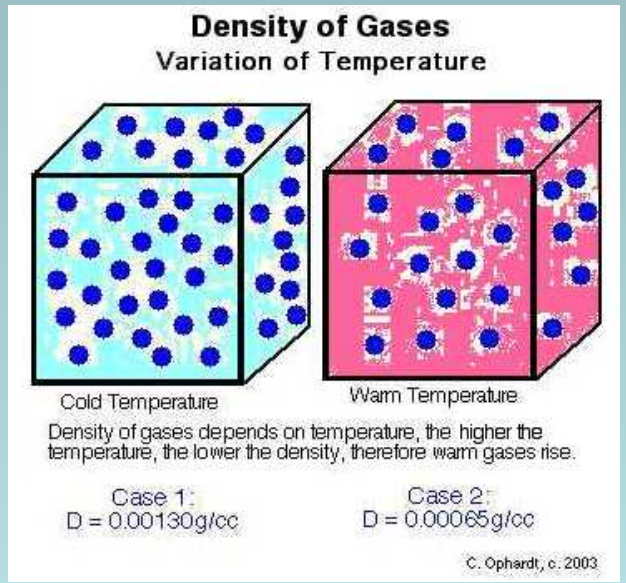
Example-(5°C X 1.8+32=41° F)



Air Density

- Density is defined as the mass of the molecules in a given volume.
- Air density varies with both temperature and altitude.



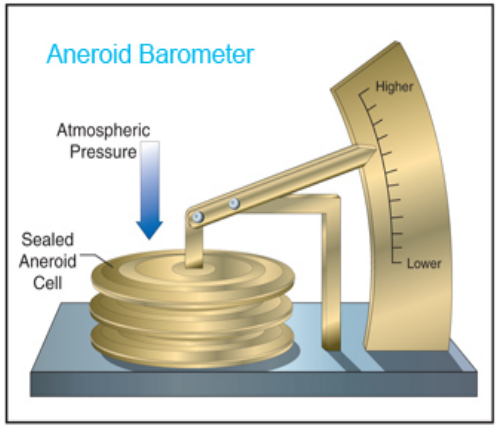


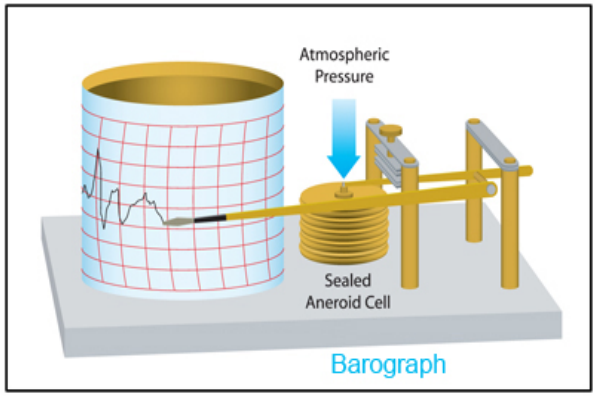
Pressure

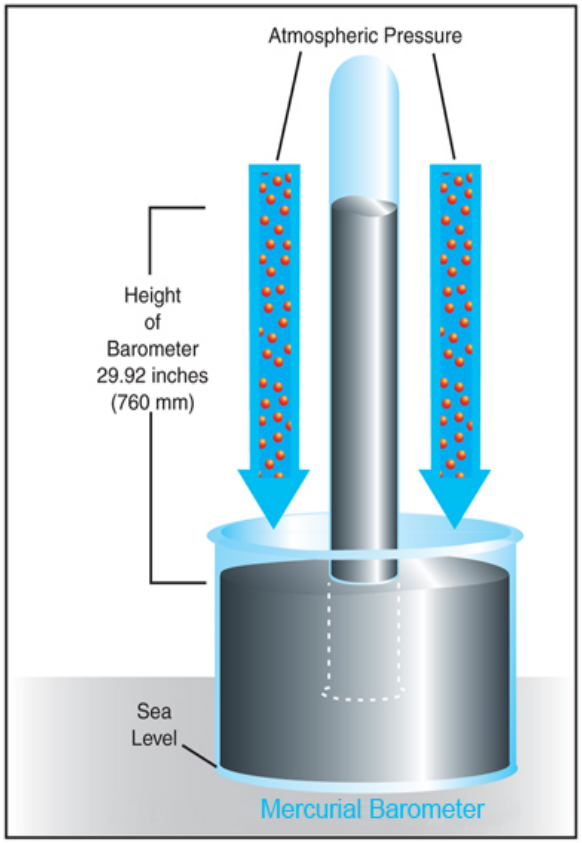
- The force exerted by the moving molecules of the gas on a given area (a square inch or square foot).
- Standard atmospheric pressure at sea level is 14.7 pounds per square inch or 29.92 inches of mercury.
- Standard pressure decreases one inch of mercury per thousand feet in elevation gain.

Pressure

Measuring Atmospheric Pressure

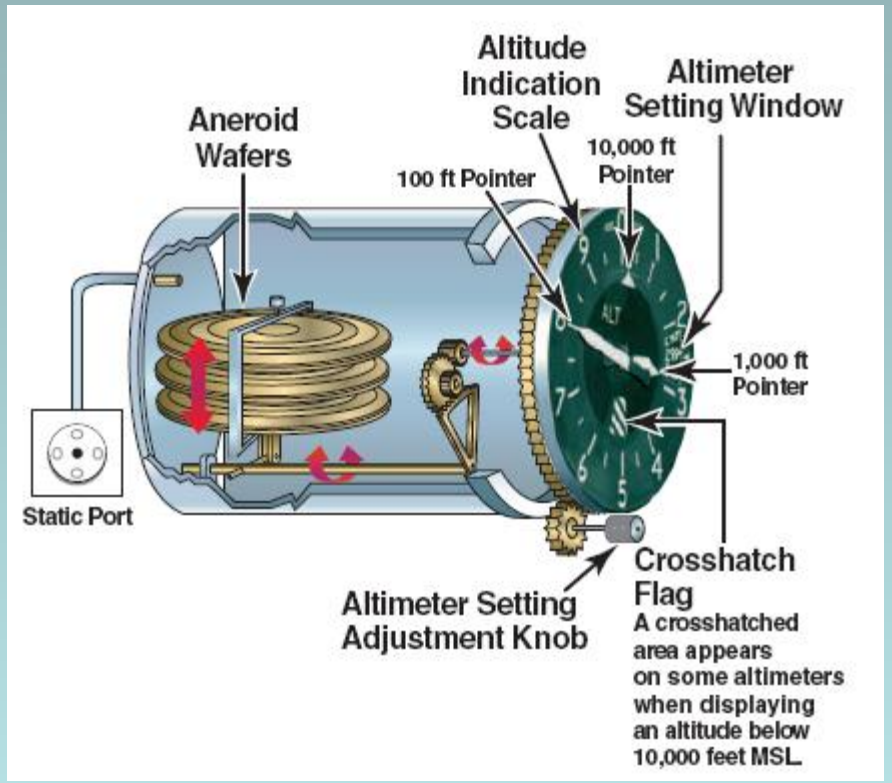






Pressure Altimeter

- An aneroid barometer that reads units of altitude instead of pressure based on the altimeter setting.
- This setting is the value to which the barometric pressure scale on the altimeter is set so the altitude indicates true altitude at field elevation.



Moisture

- Visibility is affected by a combination of Moisture and Temperature.
- When air is cooled to the point that it is completely saturated with water, you will be at Dew Point.
- When enough moisture is present (humidity) and the temperature falls close to dew point, visibility will decrease.

Visibility

- Visibility is how far you can see in statute miles (SM = 5280').

- Obstructions are:
  - Fog
  - Haze
  - Smoke
  - Blowing dust
  - Heavy precipitation
  - Clouds
  - Snow

Wreckage from airtanker impact of terrain
While flying in reduced visibility and low ceilings.

Visibility Obstructions

- Fog:
  - Forms rapidly
  - Can be very unpredictable
  - Forms in all parts of the country
- Haze:
  - Concentrations of very fine dust particles
  - Occurs in stable atmospheric conditions and relatively light wind

Visibility Obstructions

- Smoke:
  - Suspension of combustion particles in the air
  - Travels up to 25 miles or more
  - Reddish-colored sky as sun rises and sets
  - Orange-colored sky when the sun is well above the horizon

Inadvertent IMC Crash due to smoke inversion

Visibility Obstructions

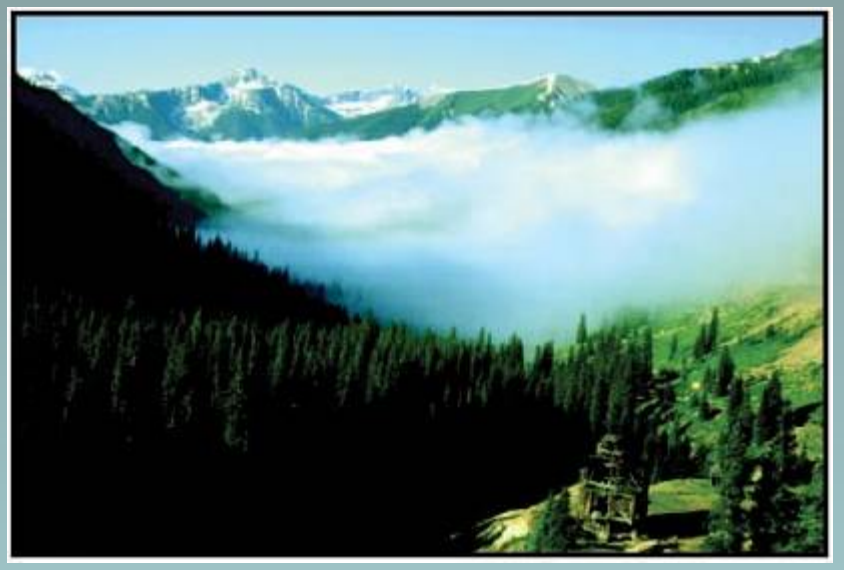
- Blowing Dust:
  - Fine particles of soil suspended in the air
  - May be blown for hundreds of miles
  - Common where dry land farming is extensive
- Heavy Precipitation:
  - Associated with cumulus clouds
  - May deposit on windshield at a rapid rate
  - Falling precipitation may saturate the cool air causing precipitation-induced fog

Visibility

- **Fog**
  - **Advection fog** occurs as lower layer of warm, moist air moves over a cooler surface
  - **Upslope fog** forms when moist, stable air is forced up a sloping land mass
  - **Steam fog** occurs as cool, dry air moves over warmer water or moist land

Fog and Inversions

- Visibility can be reduced to dangerous levels by fog under stable conditions with light winds.
- An inversion is defined as a condition where air temperature increases with altitude. Most aviation-related inversion concerns occur due to surface cooling.



Fog and Inversions

- Fog can become concentrated beneath the marine inversion caused by cool onshore winds, then disperse when the surface warms in the day or winds become offshore

- Fog is common when the temperature and dew point are close together or the same

- **Mitigation:**
  - **Wait until temperatures and/or winds increase to disperse the fog.**

Additional Visibility Concerns

- Visibility may be extremely different at the incident or worksite compared to the airport.
- Marginal VFR conditions may still present some hazards that may be unsafe to fly around.
  - High Antenna Towers.
  - Less margin for changing weather patterns

Visibility Requirements

Typical Visual Flight Rules (VFR) Requirements

Airplane:

- 3 miles visibility
- 500-2000’ from clouds

Helicopter:

- clear of clouds

Wind

What are the main forces that effect wind?

1. **Pressure Gradient Force**
   - The difference in pressure between two points

2. **Coriolis Force**
   - It affects all objects moving across the face of the earth

3. **Frictional Force**
   - The force that resists relative motion. Experienced mainly in the lower 2,000 feet of the atmosphere

Wind Measurements & Concerns

- Wind velocity or speed is often given in nautical miles per hour (knots) and compass direction determined from which the wind is blowing. (Example 270 degrees at 15 knots).

- One knot is equal to 1.152 miles per hour.

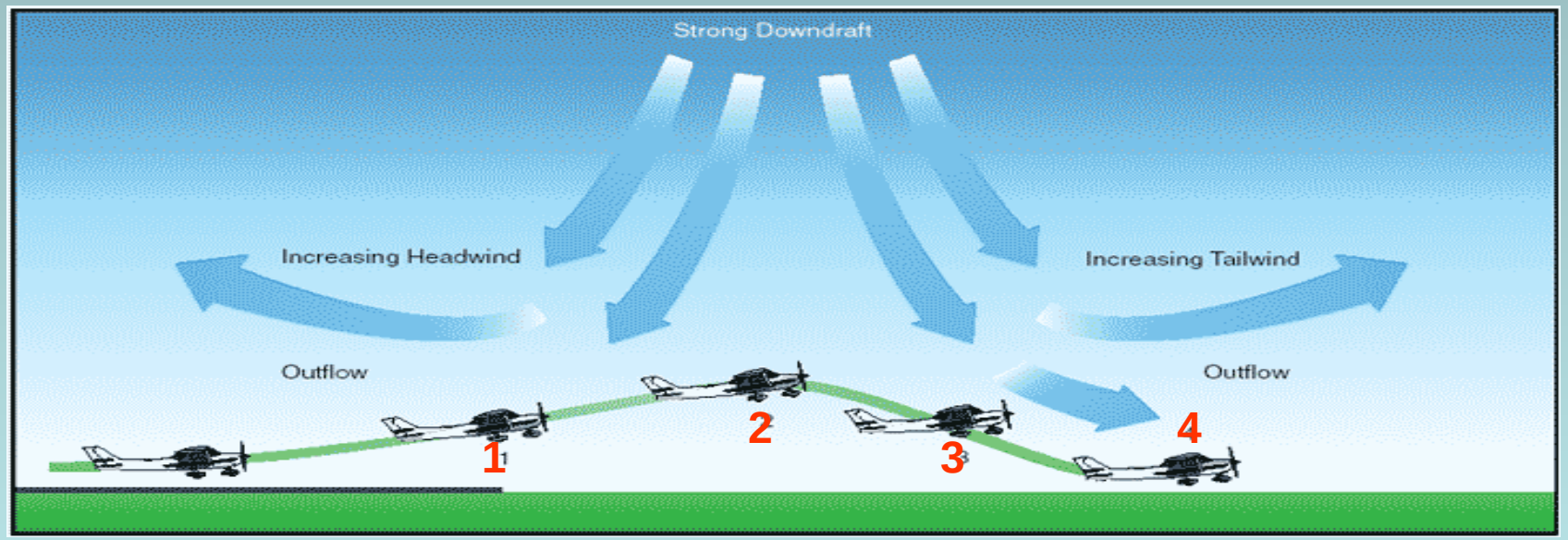
- Safety issues may relate to factors which impact control and performance of aircraft:
  - Excessive wind speeds and or gust spread
  - Sharp changes in speed and/or direction (shear)
  - Turbulent wind eddies
  - Flight planning concerns

Wind Shear

- Rapid change in wind speed and/or direction with distance can negatively impact lift and control of aircraft.

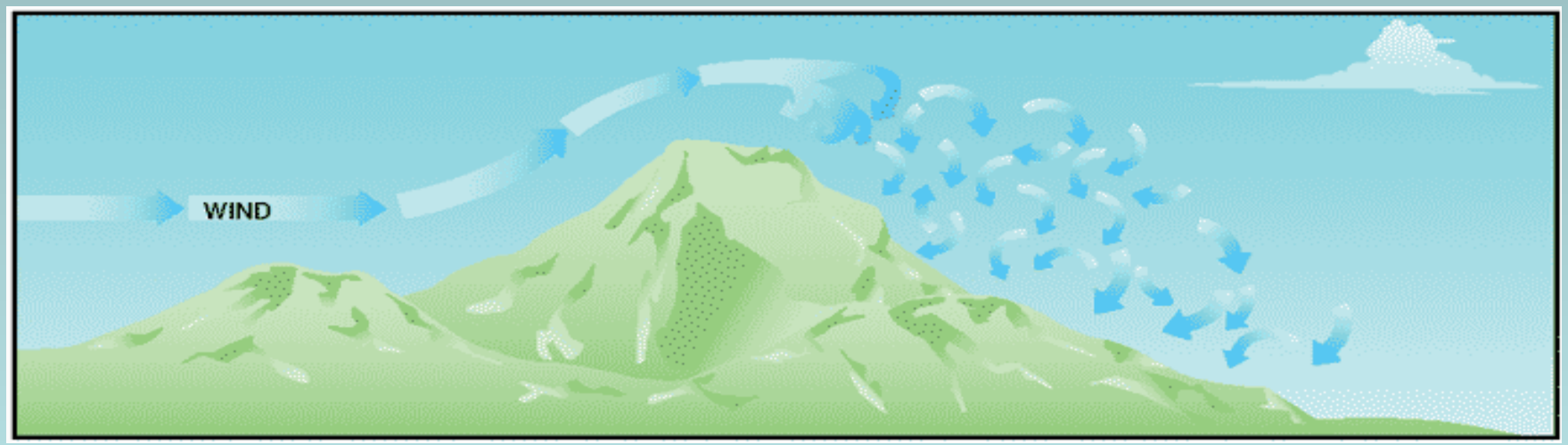
Micro Burst/ Wind Shear

1. Increased headwind
2. Decreased headwind and severe downdraft
3. Tailwind and severe downdraft
4. Increased tailwind



Turbulent Wind Eddies

- Mountain waves can create significant turbulence particularly along the lee slopes of the mountains.
- Possible as stable air moves across a ridge at 20 kts or greater.

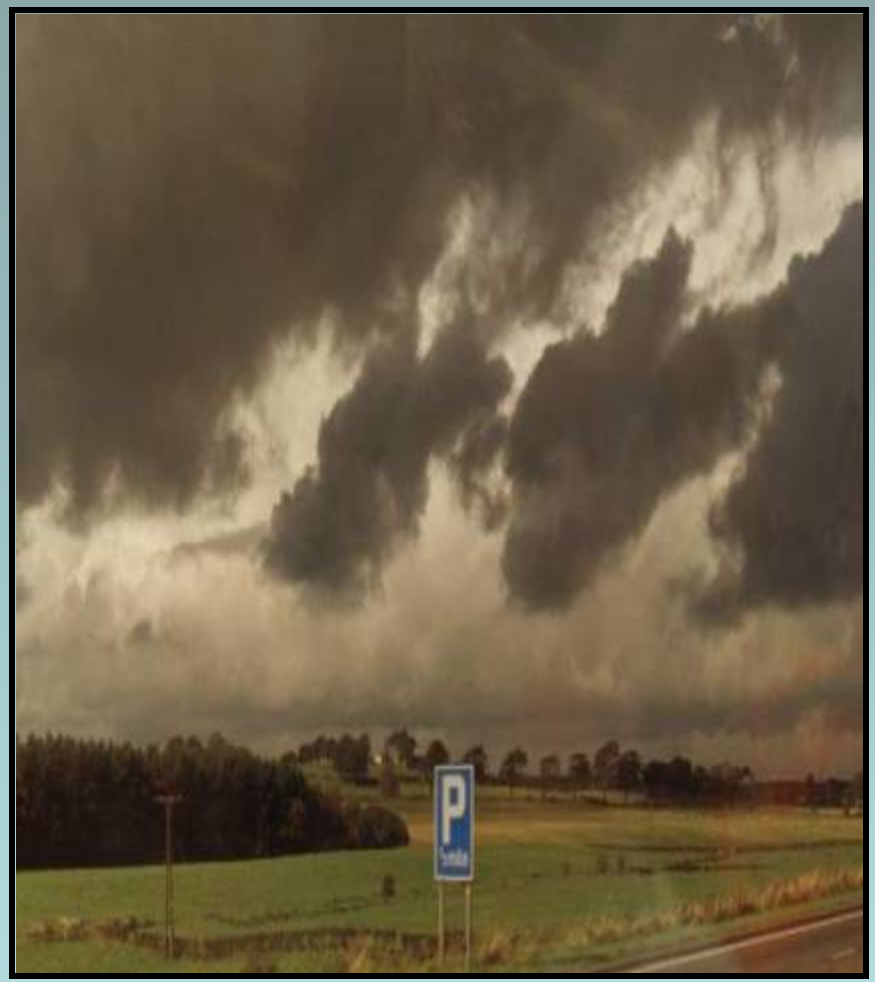


Clouds

- Cloud types:
  - Low clouds
  - Middle clouds
  - High clouds

Cloud Types

- **Low Clouds**
  - Surface to 6,500’ AGL
  - Stratus clouds
  - Fog is considered a low cloud.
- Fog
  - **Radiation fog** occurs on calm, clear, humid nights.



Cloud Types

- **Middle Clouds**
  - Range from 6,500’ to 20,000’ AGL
  - May contain moderate turbulence and potentially severe icing
  - Predominantly consist of stratus type clouds

Cloud Types

- **High Clouds**
  - Range begins at 20,000’ AGL
  - Are composed mainly of ice crystals
  - Seldom pose serious turbulence or icing hazards
  - Are often light cirrus type clouds

Clouds as Indicators

- Stratiform Clouds 
  - General atmospheric stability
  - Often poor visibility
  - Winds steady, but can be strong
  - Ceiling and visibility concerns if clouds thicken and lower or produce precipitation

- Cumuliform Clouds 
  - General atmospheric instability
  - Good visibility
  - Erratic winds, shear and turbulence
  - Thunderstorm potential

Clouds of Concern

- Lenticular – Form over and downwind of mountains and are indicative of very strong winds and stable conditions aloft. These clouds will have a washboard look about them.
  - Usually occur as storm systems are either approaching or freshly departed
  - Winds aloft 75 to 150 kts
  - Possible strong general shear zone between ground and elevation of Lenticular cloud base

Clouds of Concern

- Strong shear and turbulence in vicinity of cloud and associated mountain feature, as well as up to 100 plus miles downwind from the mountain waves.

- **Mitigation: Avoidance and navigating on the upwind side of the feature.**

Clouds of Concern

- Altocumulus Castellanus or floccus
  - Indicative of mid-level instability
  - Strong indicator of thunderstorms and aviation concerns later in the day if seen in the morning

Mitigation: Awareness

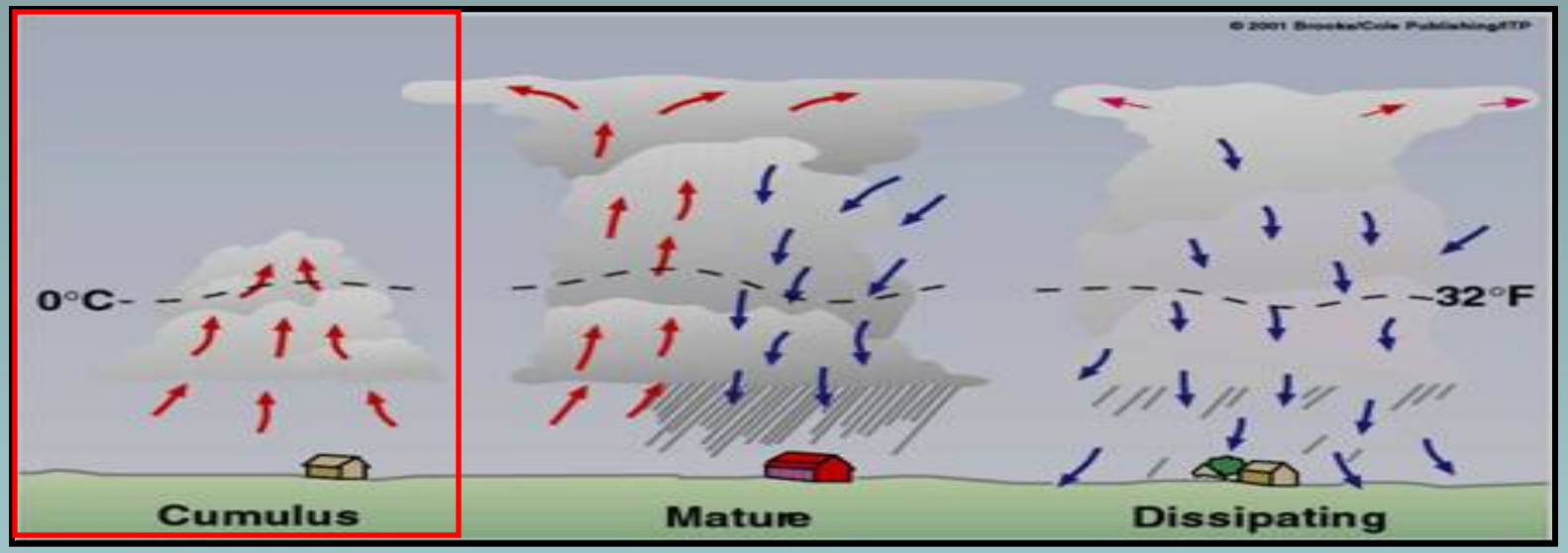
Clouds of Concern

- Cumulonimbus – Fully developed thunderstorm
  - Lightning
  - Strong winds, shear & turbulence, clear ice potential
  - Low ceilings and visibility due to heavy precipitation
  - Damaging hail and tornado potential
  - All factors are immediate aviation safety concerns!

Thunderstorms

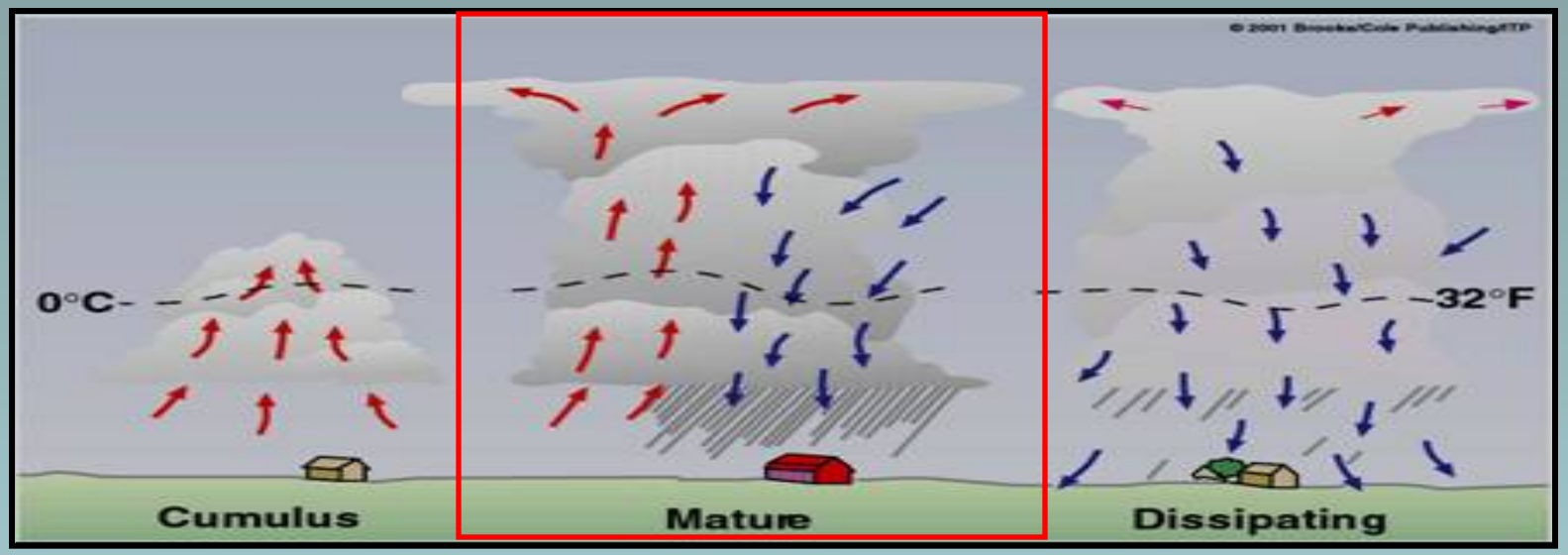
- Arguably the single greatest threat to aircraft operations.
- Thunderstorm formation requires:
  - Unstable conditions
  - Lifting force
  - High moisture levels

Thunderstorm Life Cycle



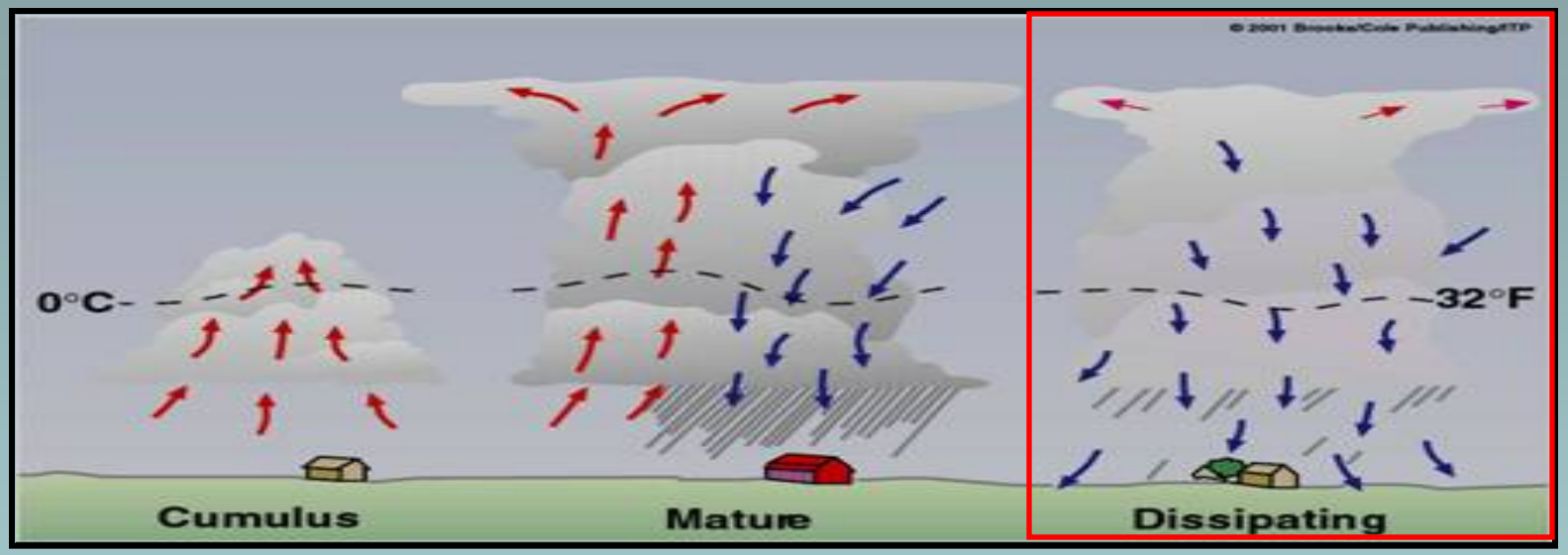
- **Cumulus Stage:**
  - Lifting action and vertical movement
  - Air rises and cools to its dew point, water vapor condenses into small water droplets or ice
  - Updrafts can be up to 3000 feet per minute

Thunderstorm Life Cycle



- **Mature Stage:**
  - Rain drops grow too large to support and precipitation falls
  - Cell is organized and at the most violent stage
  - Produces gust fronts

Thunderstorm Life Cycle



- **Dissipating Stage:**
  - Generally reaches the dissipating stage 15 to 30 minutes after it reaches the mature stage
  - Thunder cell begins to weaken

Thunderstorm Hazards

- Several elements directly associated with a thunderstorm can be extremely hazardous to aircraft.
- Virga
- Lightning
- Hail
- Icing
- Extreme Turbulence

Virga

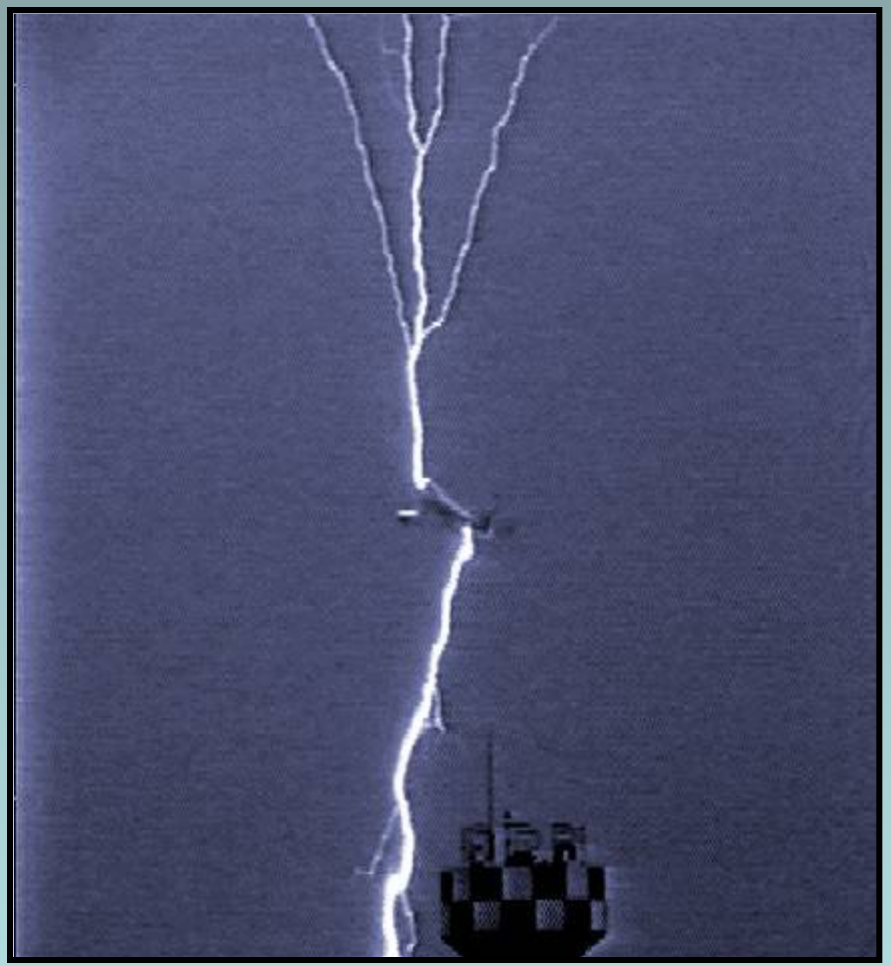
- Streaks of rain which evaporate before reaching the ground.
- Often have strong downdrafts and may precede a microburst.
- Common in desert and temperate climates.

Mitigation: Avoidance

Lightning

- Can strike in clear air in the vicinity of thunderstorms.
- Most likely to strike airborne aircraft when flight level temperature between 24 F and 40 F.
- Usually a minimal hazard to airborne aircraft due to charge dispersion along metal skin.

Lightning



- Greatest risk is for aircraft and personnel on the ground when refueling.

Mitigation: Avoid thunderstorms & don't fuel aircraft when storms are in the area.

Thunderstorms

Mitigation:

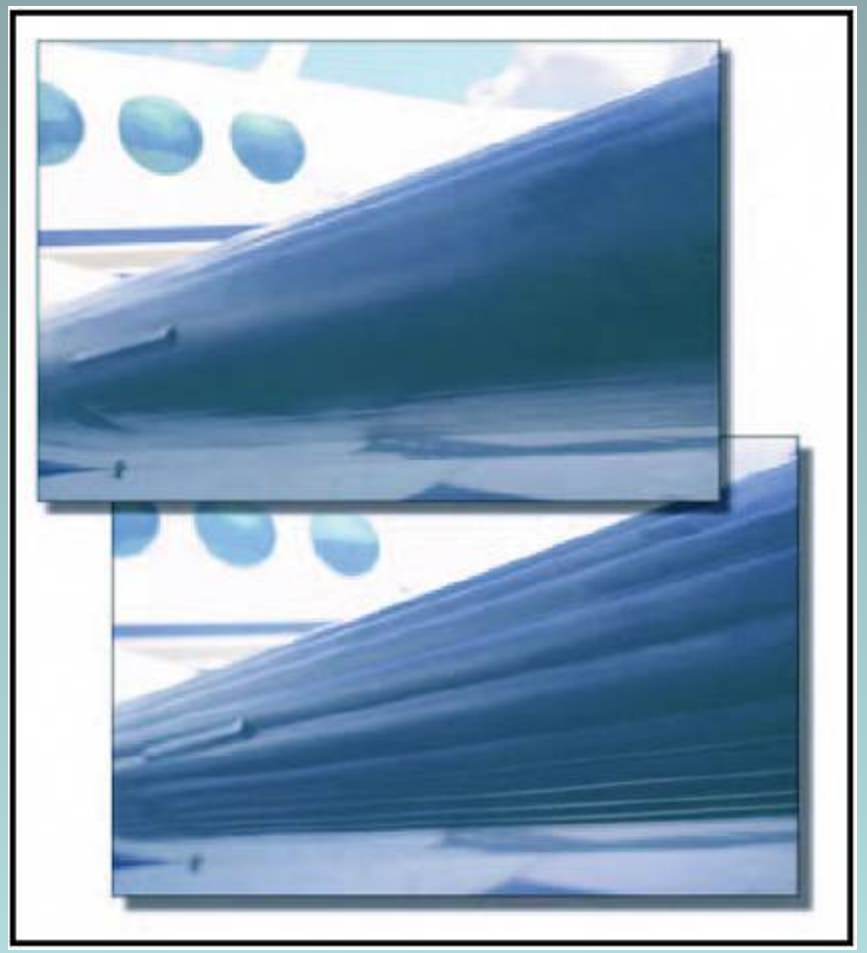
Avoid single storms or areas with 6/10 or more coverage of storms by 10 to 20 miles

Icing

- Rime icing can occur in stratiform clouds
- Clear icing can occur in cumuliform clouds.
- Impact: Increased weight, decreased lift, and aircraft control
- Icing can occur under VFR conditions
- Visible moisture must be present

Icing

- **Mitigation:**
  - **Assure aircraft is equipped for known icing**
  - **Check route and terminal forecast**
  - **Check METARs and PIREPs**
  - **Assess escape routes into warmer or colder air.**



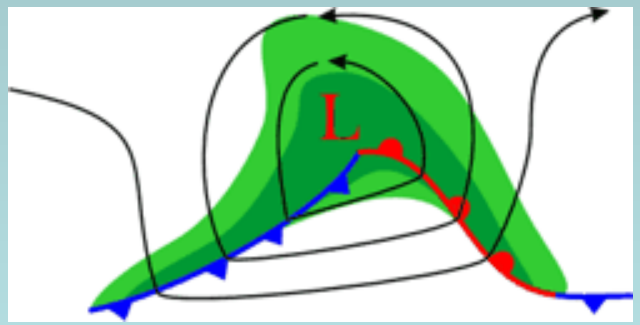
Turbulence

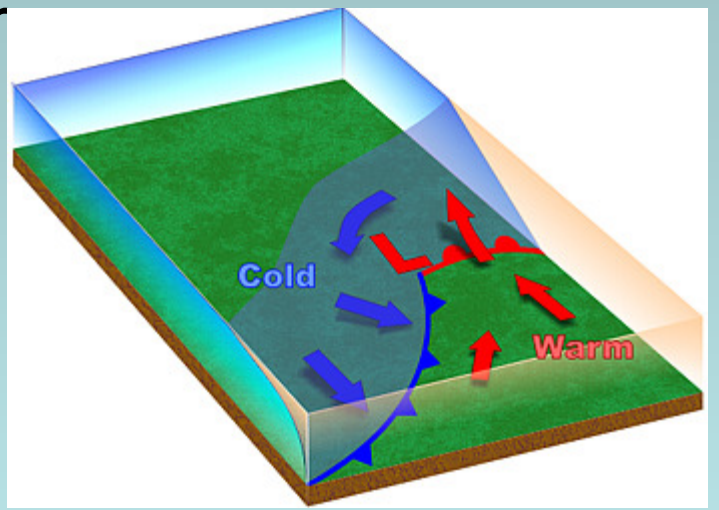
- Extreme Turbulence and wind shear can be encountered in a Thunderstorms.
- Moderate to severe turbulence and wind shear can still be encountered in frontal activity regardless of presence of Thunderstorms

- Moderate turbulence - Changes in altitude/attitude occur. Aircraft remains in control at all times. Variations in indicated air speed.
- Severe turbulence - large, abrupt changes in altitude/attitude. Large variation in indicated airspeed. Aircraft may be temporarily out of control.
- Extreme turbulence - aircraft is violently tossed about and is impossible to control. May cause structural damage.

Storm Fronts

- Frontal systems are areas of changeable weather caused by the clash of air masses of differing characteristics due to the circulation around low pressure systems.
- **Warm Fronts** – Warm air advancing into and overriding (being lifted by) colder air.
- **Cold Fronts** – Cold air advancing into and displacing (lifting) warmer air



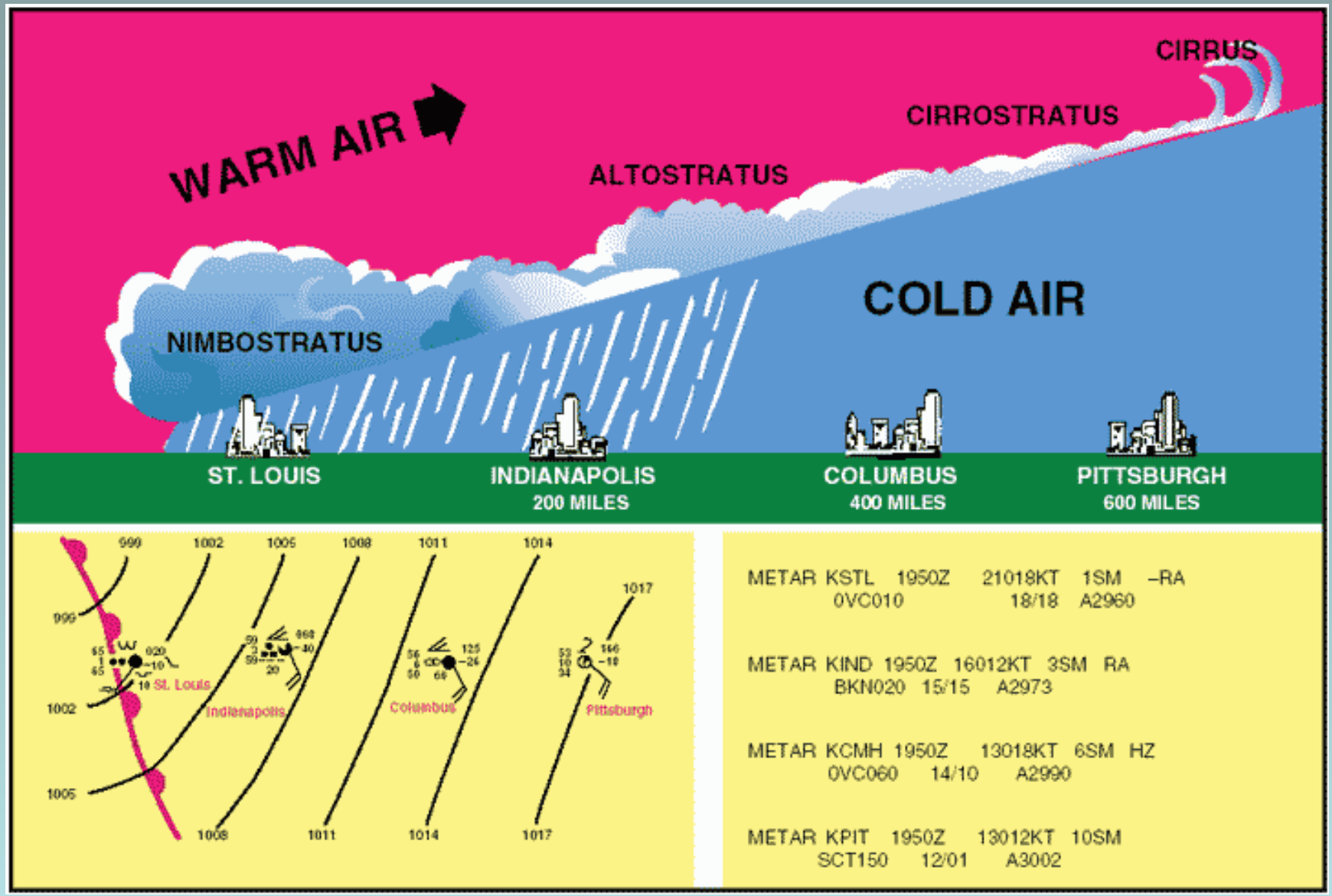


Warm Fronts

- Weather associated with warm fronts is generally more expansive, longer lasting and less erratic in comparison to that associated with cold fronts.
  - The gradual thickening and lowering of stratiform clouds as front approaches will eventually lead to reduced ceilings and visibility due to low clouds, fog, and light steady precipitation (VFR to IFR)
  - Strong/erratic winds and shear not a big issue
  - Passage of front brings clearing, a wind shift in direction and speed, warmer temperatures and greater instability

Mitigation: Wait until frontal impacts lessen.

Warm Front and Aviation Impact

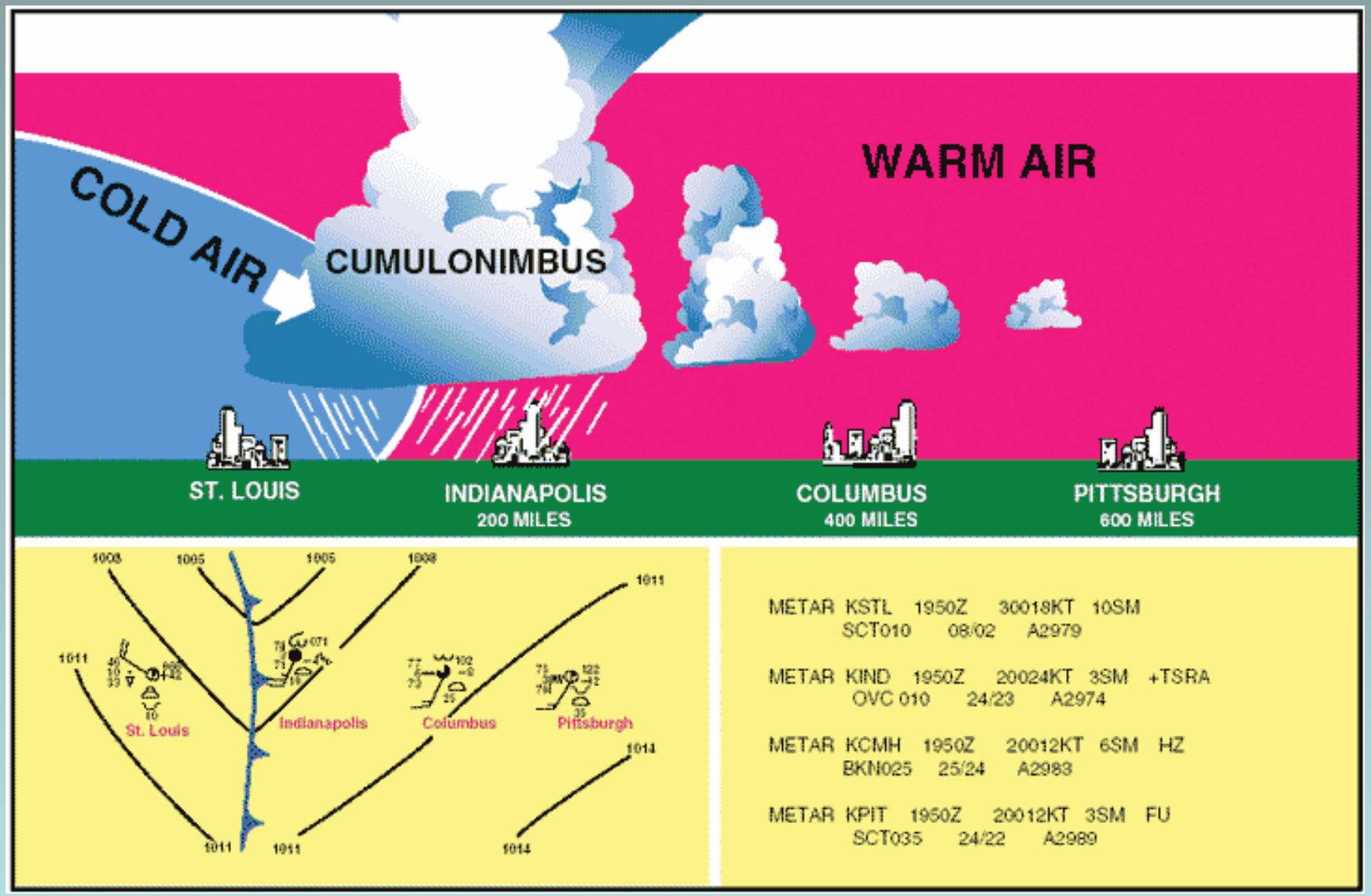


Cold Fronts

- Weather associated with cold fronts is generally less expansive, shorter lived and more violent in comparison to that associated with warm fronts.
  - Strong winds and isolated thunderstorms in advance of front
  - Strong & shifting winds, shear, turbulence and thunderstorm potential with frontal passage. Visibility and ceiling issues related to thunderstorm coverage and intensity
  - Notable wind shift after frontal passage
  - Rapid end to thunderstorm related issues after frontal passage, but strong winds could continue for 12 plus hours

Mitigation: Wait until frontal impacts lessen.

Cold Front and Aviation Impact



Fire Effect on Weather

- Fires can generate their own weather.
- Limited visibility
  - Smoke
  - Inversions
- Extreme updrafts
  - Hot air rising
- Extreme downdrafts
  - Column collapsing

Fire Effect on Weather

- Hail
- Precipitation
- Erratic winds
- Turbulence

Topographic Influences: Mountains

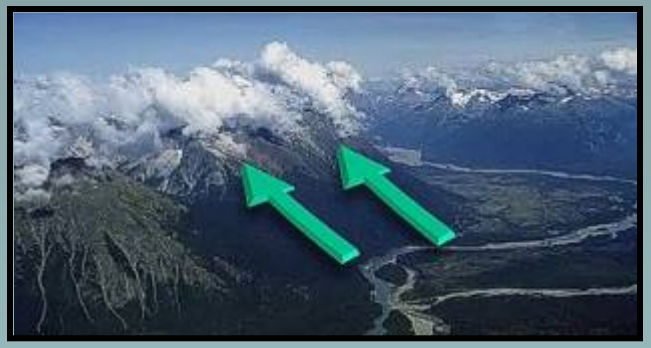
Eurocopter AS-350 rolled over from high wind gust
Alaska

Topographic Influences

- Topographic features create and/or modify weather to produce conditions which can be highly variable in both time and space.
  - **Mountains** – Create their own local weather as well as substantially modify ambient weather conditions, usually resulting in more erratic winds and also the potential for lower ceilings and visibilities.
  - **Coastlines** – Create local weather conditions associated with the sea breeze and marine layer which have a more profound impact on ceiling and visibilities than on winds.

Topographic Influences: Mountains

- Winds:
  - Drainage winds, updrafts, and channeling or disturbance of ambient winds often lead to erratic winds, shear, and turbulence.



- Ceilings and Visibilities:
  - Creation and enhancement of clouds and precipitation can create ceiling, visibility, and icing issues.

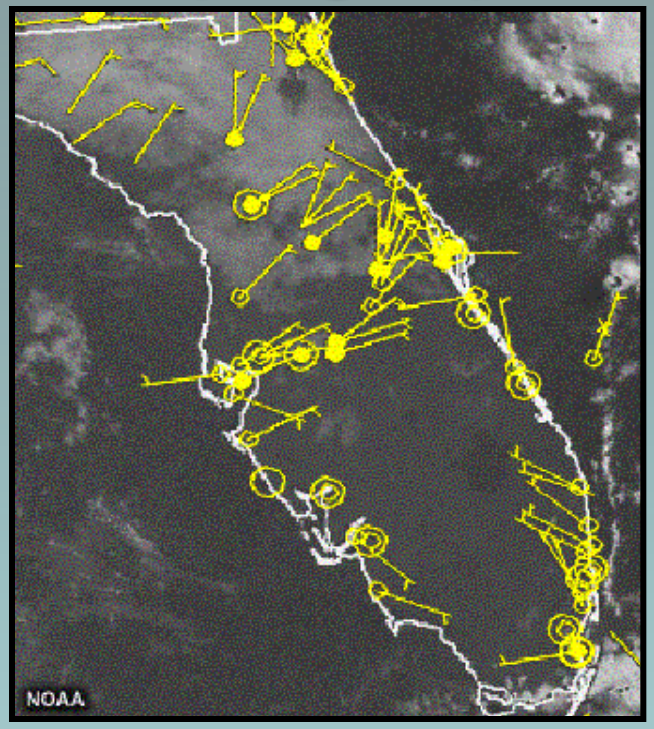
Topographic Influences: Mountains

- Thunderstorms can develop over mountains during the summer, especially in the western U.S.

Mitigation:

Avoidance, strong knowledge of local influences, real-time weather information.

Topographic Influences: Coastlines



- Winds:
  - Interaction between sea breeze and ambient winds can create highly variable winds on either side of the sea breeze front, but speeds are usually low
- Ceilings and Visibilities:
  - Low clouds, fog and/or drizzle often associated with the marine layer can create significant ceiling and visibility restrictions. Nearby higher terrain and areas just inland may not be impacted

Topographic Influences: Coastlines

- Thunderstorms can develop along the sea breeze front in the summer, especially along the Gulf and Atlantic coasts.

Mitigation:

Avoidance, strong knowledge of local influences, real-time weather information.

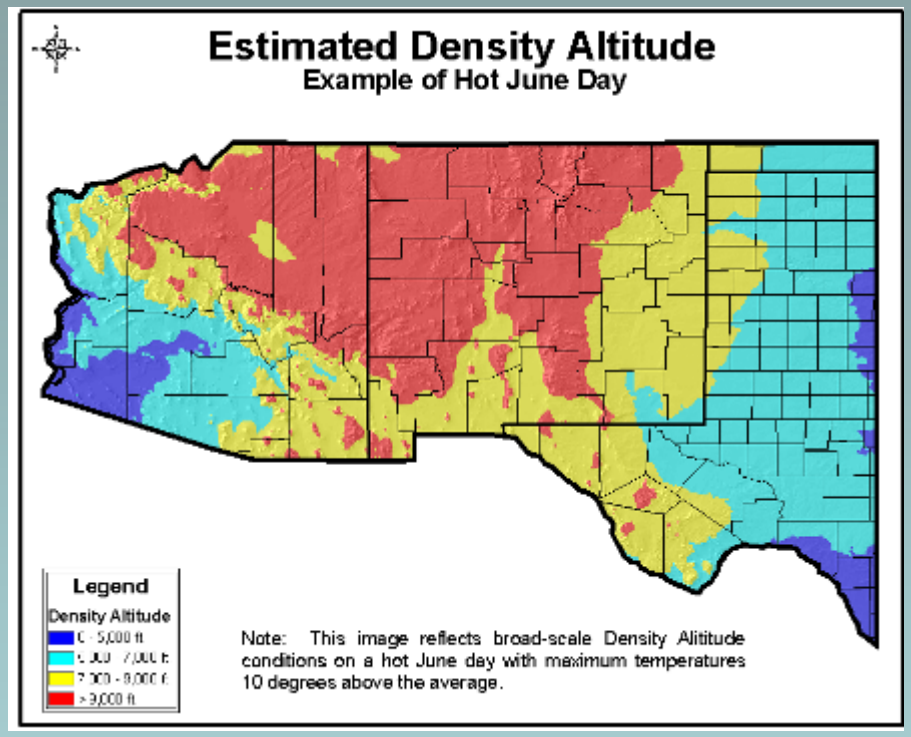
Density Altitude (DA) - Definition

- Air density directly impacts the amount of lift generated by an airfoil and is a major factor in aircraft performance.
- DA is a correction to account for lower air density caused by warmer temperatures.
- Example: A station at 6000 ft. with a temperature of 90 F would have a DA ~ 9200 ft. Aircraft operating from this station would have lift and performance similar to that at 9200 ft. under standard atmospheric conditions.

ELEV/TEMP	8O deg. F	90 deg. F	1OO deg. F	11O deg. F	120 deg. F	130 deg. F
Sea Level	1,200'	1,900'	2,500'	3,200'	3,800'	4,400'
2,000'	3,800'	4,400'	5,000'	5,600'	6,200'	6,800'
4,000'	6,300'	6,900'	7,500'	8,100'	8,700'	9,400'
6,000'	8,600'	9,200'	9,800'	10,400'	11,000'	11,600'
8,000'	11,100'	11,700'	12,300'	12,800'	13,300'	13,800'

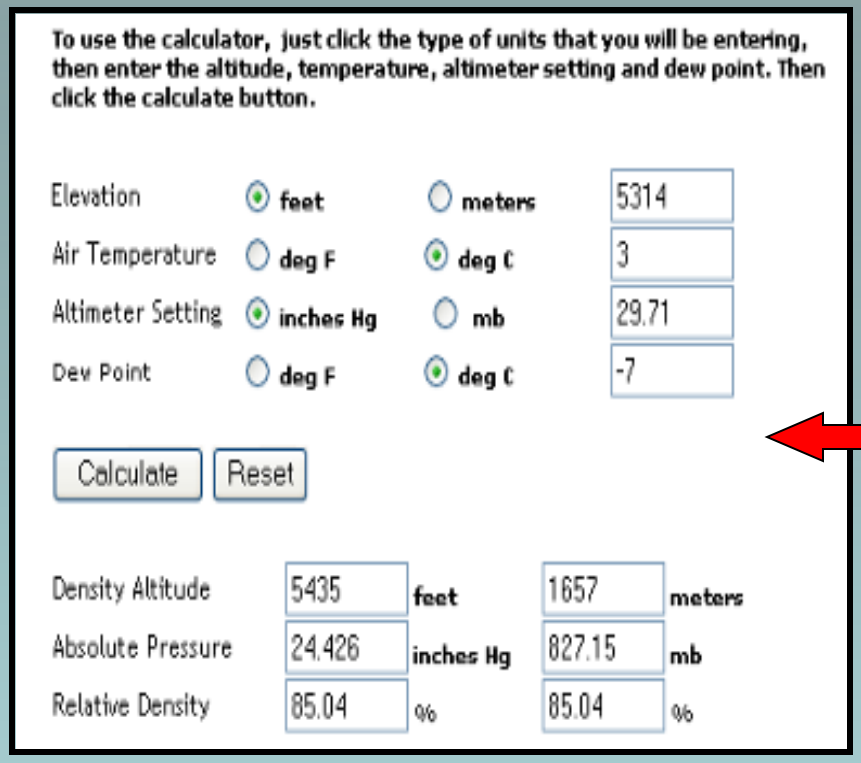
Density Altitude (DA) - Impact

- High DA values are prevalent across the mountainous west in the summer, where already elevated areas can be subjected to hot temperatures.
- Cargo weight capacity, takeoff speed & distance, acceleration, maneuverability and service ceiling can be adversely impacted.



Mitigation: Awareness of DA values vs. aircraft constraints. If impacted, wait for cooler temperatures, operate during cooler time of day, lighten load or obtain higher performance aircraft.

Density Altitude Calculators & Forecasts



KABQ 232356Z 27021G31KT 10SM SCT040 03/M07 A2971 RMK AO2 PK WND 27035/2333 SLP042 VIRGA SE-SW AND NW MTNS OBSC NE AND SE T00331067 10072 20033 53023

KABQ (ALBUQUERQUE, NM, US) observed
2356 UTC 23 December 2008

3.3°C (38°F)

-6.7°C (20°F) [RH = 48%]

29.71 inches Hg (1006.2 mb)
[Sea-level pressure: 1004.2 mb]

Wake Turbulence

- Chaotic airflow that develops behind both fixed and rotor wing aircraft.
- Most important component are wingtip vortices, which linger up to three minutes as they sink to the ground.

Wake Turbulence

- Greatest hazard is during takeoff & landing
  - Low aircraft speeds and higher wing angle maximize formation of vortices
  - Aircraft are operating closest to ground and stall speed

- **Mitigation:**
  - **Land beyond the touchdown point of landing aircraft**
  - **Wait three minutes prior to departing**

Aviation Weather Resources

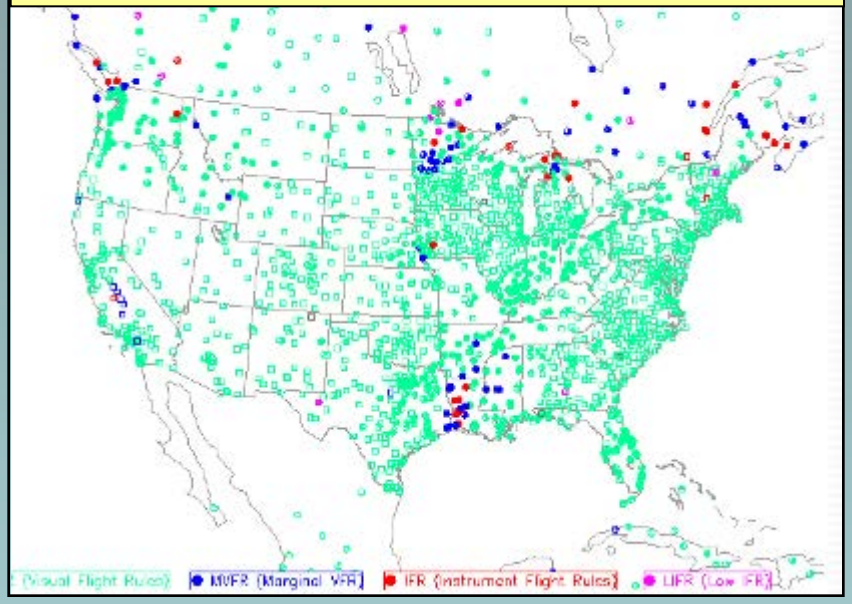
- Aviation routine weather reports (METARs) & forecasts (TAFs)
- Remote Automated Weather Stations (RAWS)
- Audible aviation weather service outlets

Aviation Weather Resources

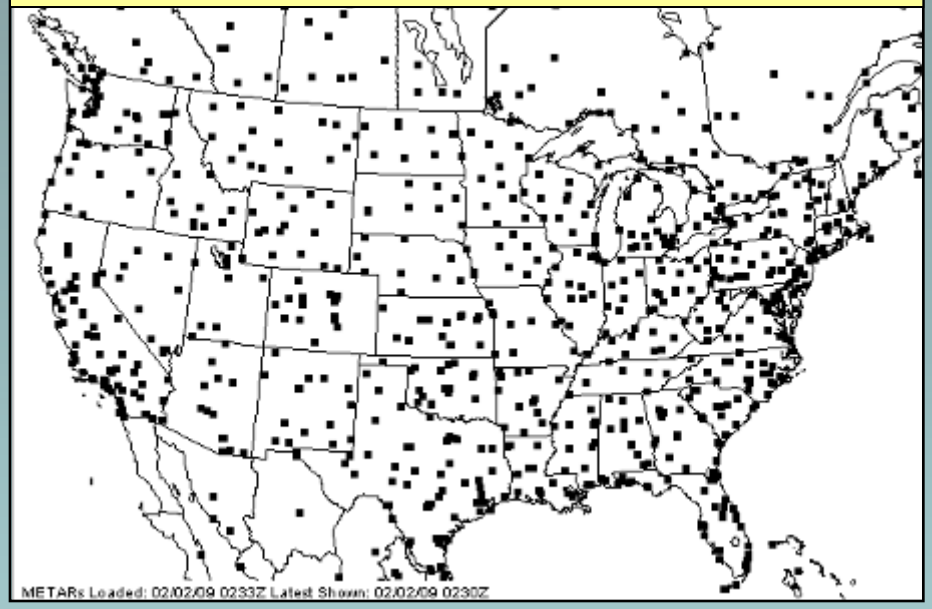
- Incident Forecasts
- Density Altitude calculators & forecasts
- Aviation Digital Data Service (ADDS)
  - Radar, satellite, surface & pilot observations
  - Turbulence, icing and convection advisories
  - TAFs and METARs

Aviation Routine Weather Reports (METAR's) & Terminal Aerodrome Forecasts (TAF's)

METAR Locations



TAF Locations



- METAR = airport observation, taken at least hourly
- TAF = 30 hour forecast for many METAR locations, issued four times per day
- Both use same standard worldwide format, which is not very friendly to the layperson (**see decoding sheet**).
- Focus on using decoded versions of these resources!

METAR Observation

METAR KPIT 201955Z 22015G25KT 3/4SM R28R/2600FT TSRA OVC010CB 18/16 A2992 RMK SLP013 T01760158

Where: **KPIT**

When: **201955Z** 20th day of month at 1955Z

Wind: **22015G25KT** 220 degrees at 15 gusting to 25 knots

V: Variable direction e.g., 20015KT 220V280

VRB: Variable direction when speed is less than or equal to 6 knots

Visibility: **3/4SM** 3/4 statute miles, typical: 2 3/4SM, 1SM

RVR: **R28R/2600FT** Runway 28 Right visibility 2600 feet

M: Used for RVR less than lowest reportable sensor value (e.g. **M0600FT**)

P: Used for RVR greater than highest reportable sensor value (e.g. **P6000FT**)

V: Variable

Significant Weather: **TSRA** thunderstorm/moderate rain (See Abbreviations)

Sky Condition: **OVC010CB** overcast clouds at 1000 feet consisting of cumulonimbus

Typical: **SKC, FEW, SCT, BKN, VV004** indefinite ceiling (Vertical Visibility) 400 feet

Temperature/Dew Point: **18/16** 18 degrees Celsius/dew point 16 degrees Celsius

M: Minus (below zero)

Altimeter: A2992 inches of mercury and preceded by an "A"

RMK SLP013 T01760158 10142 20012 401120084 At selected stations, Sea Level Pressure is reported as the last three digits in hectoPascals (milibars) (e.g., 1001.3 is reported as **SLP013**). Codes such as T01760158 10142 20012 and 401120084 are climate temperature information.

- **Where, When, Wind**
- Visibility
- Runway Visual Range
- Prevailing weather
- Sky condition & cloud levels AGL
- Temp/dewpoint (C)
- Altimeter setting
- Sea Level Pressure
- Remarks

Obs. taken within 15 min. of the top of the hour or immediately when significant changes occur (often changes from VFR>MVFR>IFR).

TAF - Terminal Aerodrome Forecast

- **Where, When, Wind**
- Visibility
- Prevailing weather
- Sky condition & cloud levels AGL
- optional: wind shear
- Tempo, PROB40 and PROB30 indicate significant non-prevailing conditions
- Issued every six hours and updated when significant changes occur.
- 5 miles from airport

KPIT 091730Z 091818 22020KT 3SM -SHRA BKN020 WS015/30045KT

FM2030 30015G25KT 3SM SHRA OVC015 TEMPO 2022 1/2 TSRA OVC008CB

FM2300 27008KT 5SM -SHRA BKN020 OVC040 PROB40 0407 00000KT 1SM -RA BR

FM1000 22010KT 5SM -SHRA OVC020 BECMG 1315 20010KT P6SM NSW SKC

Where: **KPIT**

When: **091730Z** issuance day and time: 9th day at 1730Z
091818 valid period: 9th day at 1800Z to next day (10th) at 1800Z

Wind: **22020KT** 220 degrees at 20 knots

Visibility: **3SM** 3 statute miles, typical - **2 3/4SM, 1SM**,
P6SM: Greater than 6 statute miles

Significant WX: - **SHRA** light rain showers (See Abbreviations)

Sky Condition: **BKN020** broken clouds at 2000 feet

Typical: **FEW, SCT, BKN, OVC**.

VV004 indefinite ceiling (Vertical Visibility) 400 feet. **CB** and **TCU** clouds noted when present.

Wind Shear: **WS015/30045KT** low level wind shear at 1500 feet forecast to be 300 degrees at 45 knots (only nonconvective, low level, wind shear is forecast)

Sequence of Wind, Visibility, Significant Weather and Sky Condition repeats preceded by:

FM2030: From 2030Z

TEMPO 2022: Temporarily between 2000Z and 2200Z.

FM2300: From 2300Z

PROB40 0407: There is a 40 percent probability between 0400Z and 0700Z

FM1000: From 1000Z

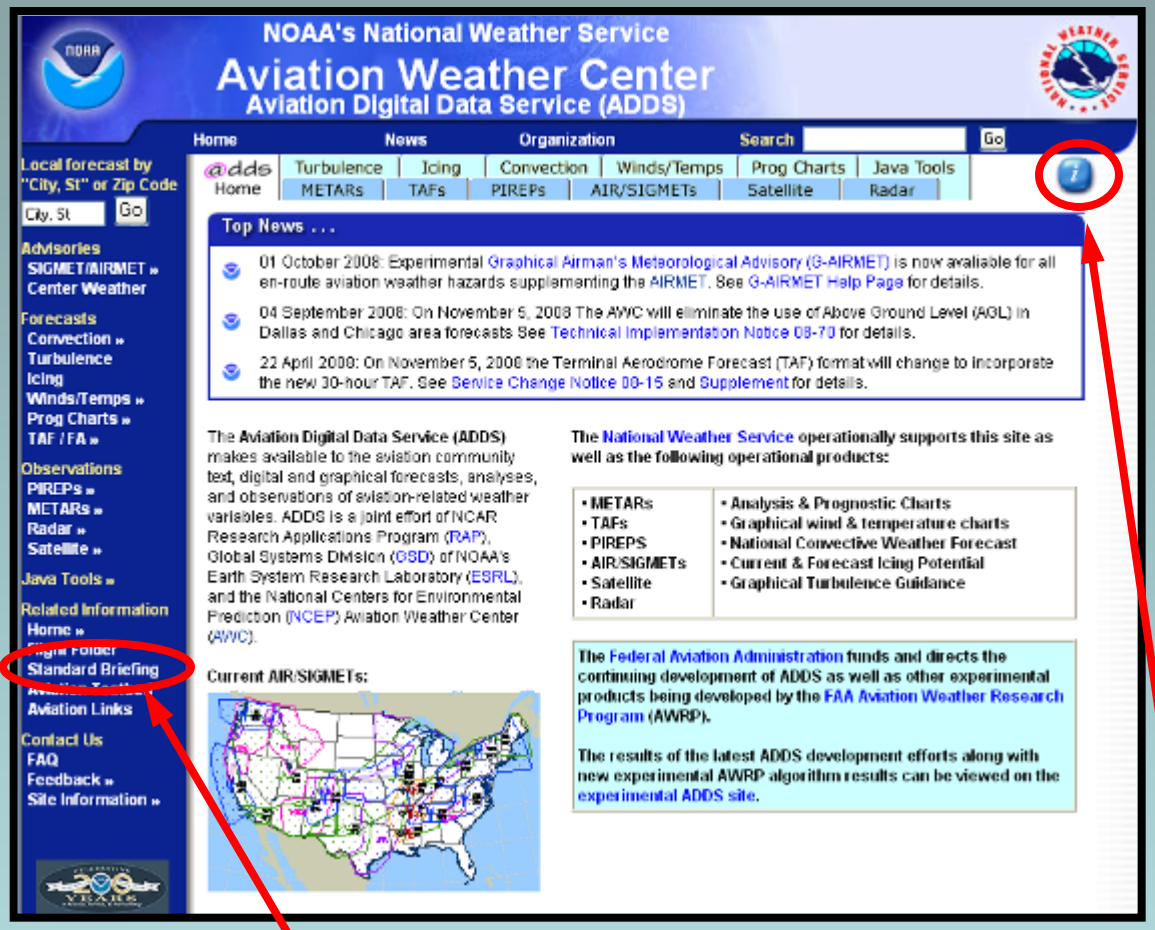
BECMG 1315: Becoming between 1300Z and 1500Z

Note: Weather conditions such as wind and sky condition may be omitted **after PROB40, TEMPO, and BECMG** if no change is expected from those same conditions given in the previous time block.

Audible Aviation Weather Service Outlets

- En route Flight Advisory Service (EFAS) designed for in-flight updates
- **122.0** MHz for aircraft between 5,000 ft. AGL & 17,500 ft. MSL (available 0600-2200)

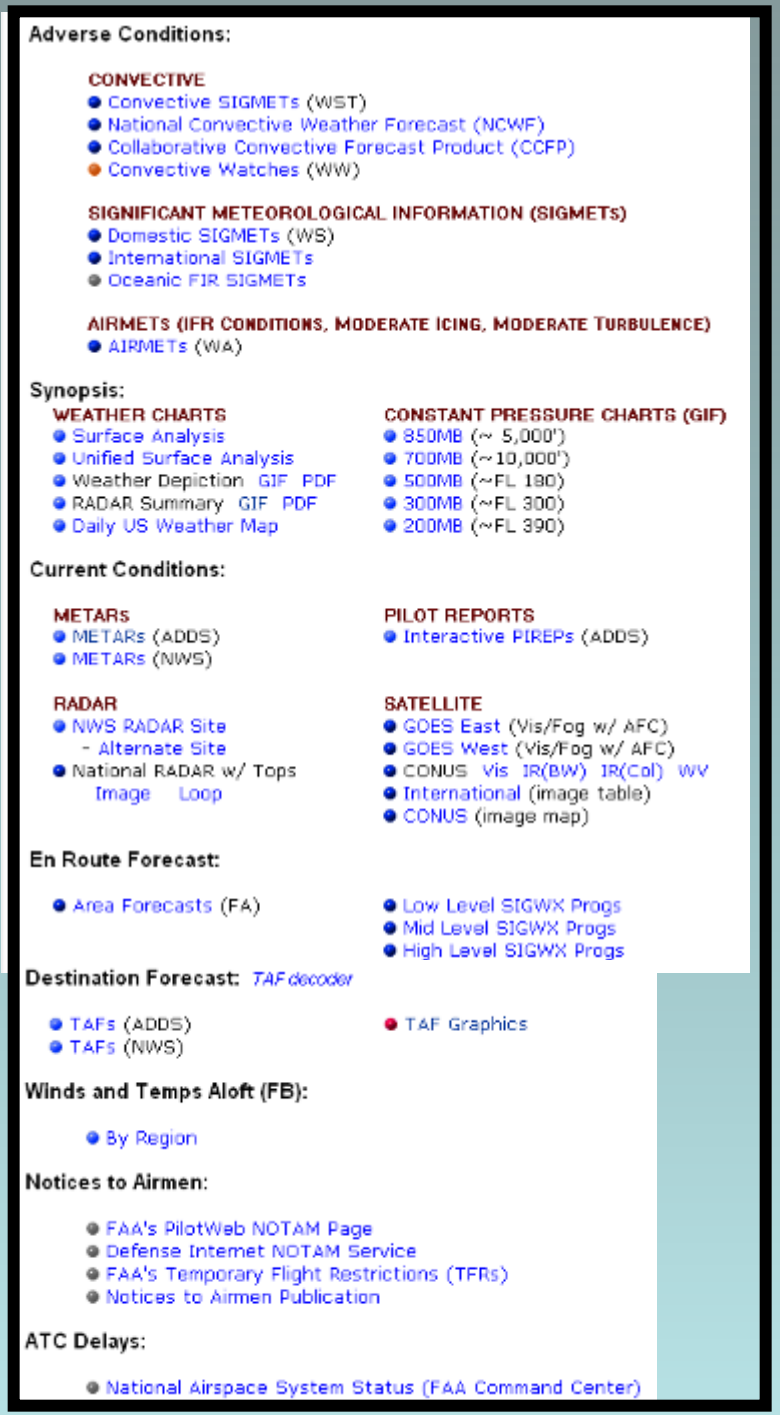
Aviation Digital Data Service (ADDS)



- First-stop resource for aviation weather
  - Turbulence, icing and convection advisories and observations
  - Radar & satellite
  - Pilot and surface obs
  - METARS & TAFs
  - Various tools in development
- Help/Info button for every page

Standard Briefing!

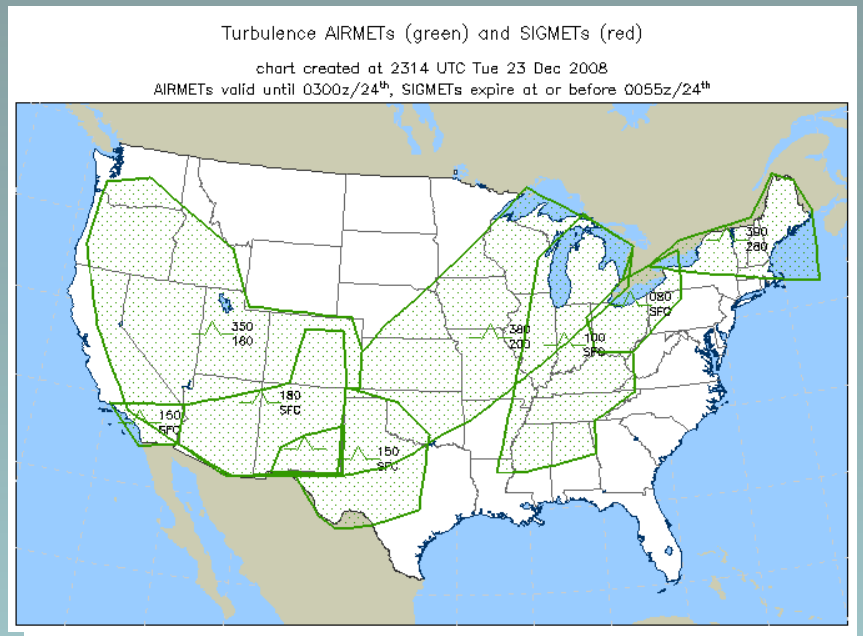
- http://adds.aviationweather.gov/

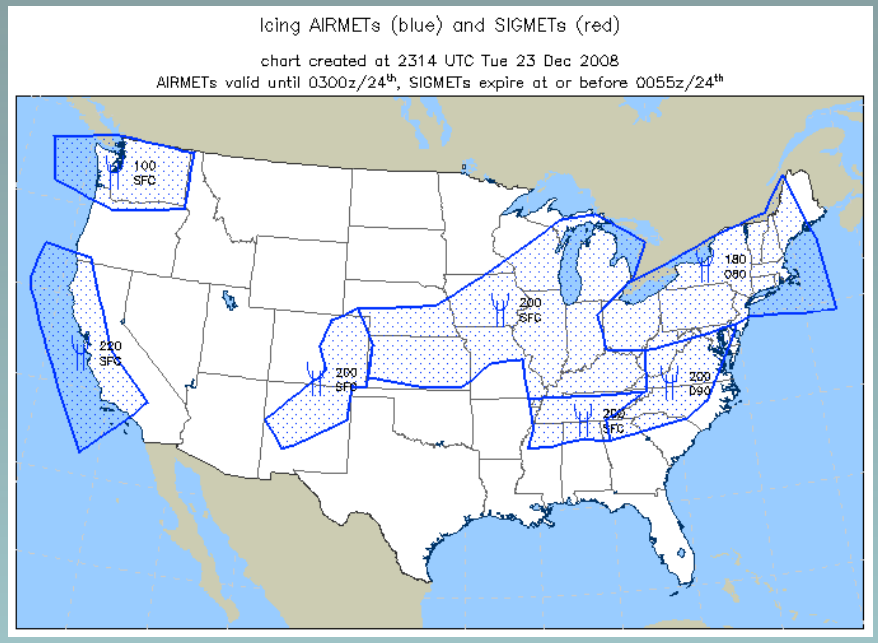


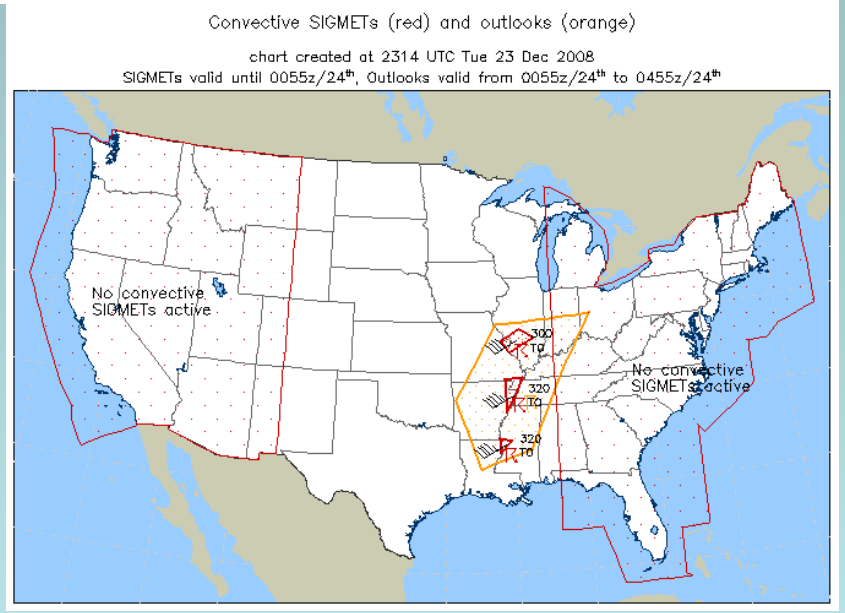
ADDS Standard Briefing

- Follow top to bottom, or pick and choose
- **DOES NOT** replace the pilot standard briefing, but provides information which is more than suitable for non-pilots
- Try it out, find what you like, use it!

ADDS – Adverse Conditions

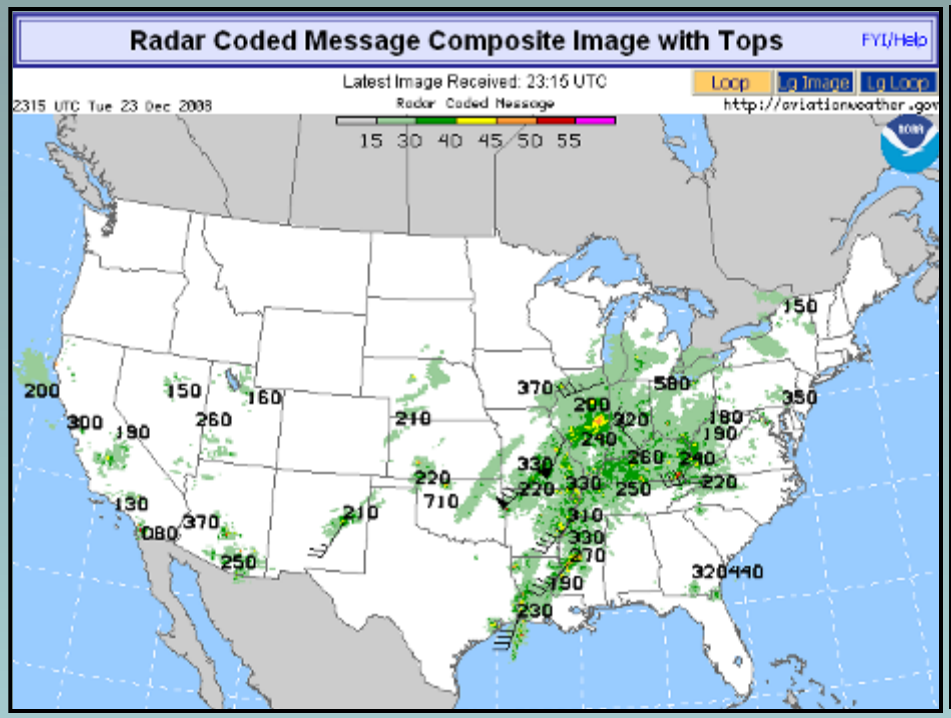


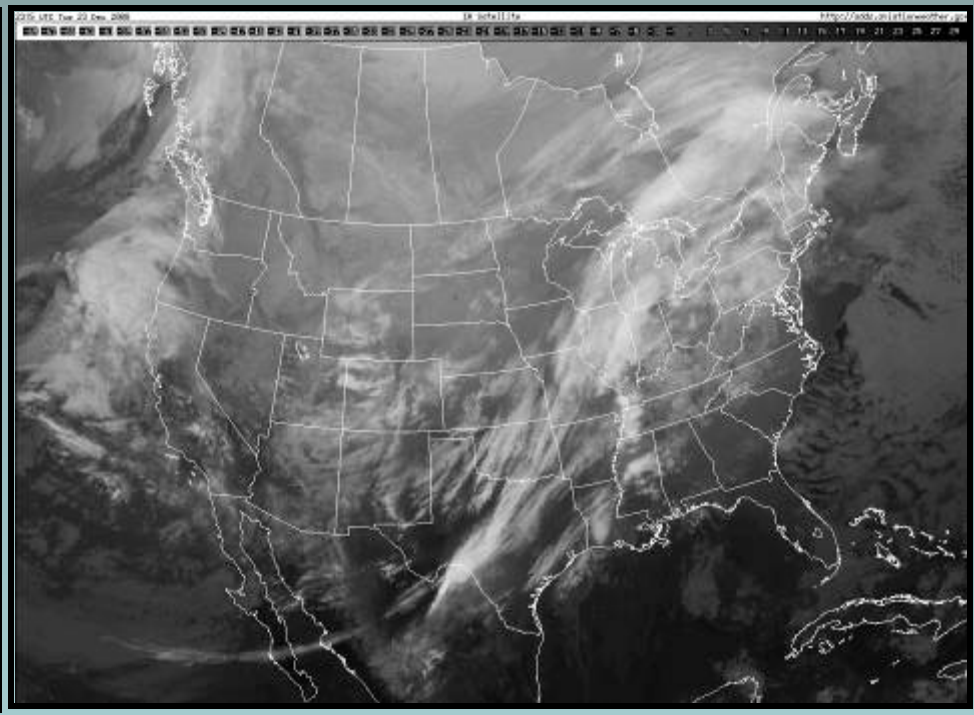




- Can rapidly assess areas of significant turbulence, icing and convection.
- Pilot reports available for each type of hazard in same interface.

ADDS – Synopsis/Current Weather





- Real-time radar and satellite data in various formats, scales, resolutions and time frames for enhancement of situational awareness.
- Scales ranges from international to local in size.

Additional Aviation Weather Sources

- Gleim Aviation Weather & Weather Services
- Aviation Weather by Peter F. Lester
- Weather Flying by Robert N. Buck

General Weather Sources

- Internet
  - www.intellicast.com
  - www.weather.com
- Newspaper
- Television

Flight Planning Concerns

- Time en route
- Fuel planning
- Time on station for mission

Summary

- Weather is an obvious and ever-present factor in aviation safety.
- The main factors which cause concern are fairly well identified & predictable, and thus avoidable.
- An array of weather resources are available to identify and predict these factors, giving us the opportunity to take action to mitigate weather-related aviation safety concerns.

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Course Objectives

Student will be able to:

- Identify weather conditions that may adversely affect the safety of aviation operations.
- Describe mitigations that can be applied when working in unfavorable weather conditions.
- List at least two aviation weather resources that can assist the user in making informed decisions.