Aviation Weather

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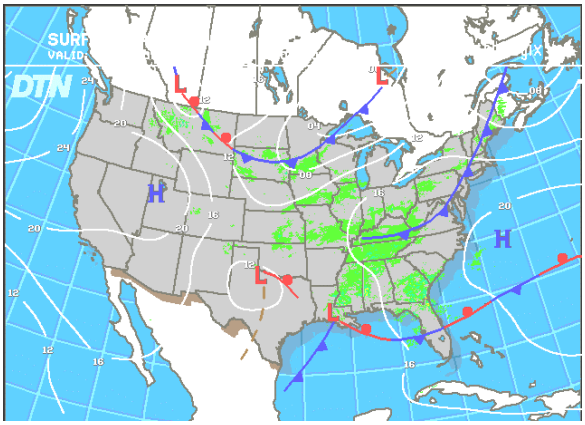
Gleim sections 7.1-7.11

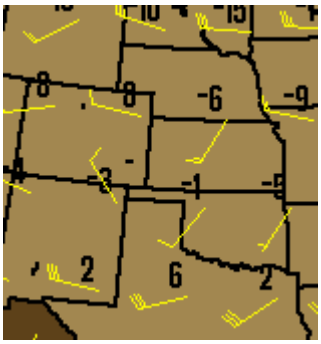
Fundamental Weather Concepts

- Air has several attributes that contribute to weather:
  - Temperature
  - Pressure
  - Humidity (moisture content)



Pressure Differences and Wind

- **Fundamentally, all weather is caused by, or is the result of, heat exchanges**
- **Unequal solar heating of the Earth's surfaces causes differences in pressure and thus differences in altimeter settings. This is because warm air rises and exerts less pressure, and cold air falls and exerts more pressure.**
- An area of relatively low pressure is called a *low*, and an area of relatively high pressure is called a *high*, and these areas are frequently plotted on weather maps
- Air generally wants to travel from higher pressure to lower pressure, and the greater the difference in pressure, the greater the speed of the air
- If the Earth stood still, air would travel directly from highs to lows. However, the Earth's rotation causes wind to deflect to the right in the Northern Hemisphere. This is called the Coriolis Effect.
- Because of the Coriolis Effect, wind moves perpendicular to the direction it would normally travel. It moves clockwise around a high, and counterclockwise around a low, following the isobars.



- **Wind flowing close to the Earth's surface encounters friction, which causes the wind to move slower. At the same time, the Coriolis Effect is lessened, so wind moves more directly from a high to a low close to the Earth's surface. Wind usually changes strength and direction a few hundred to a few thousand feet above the ground.**
- ***Wind shear* is a dramatic change in wind speed or direction across a relatively short distance. Wind shear can occur at any altitude, and in any direction (horizontal or vertical).**
- ***Wind shear* may be associated with *clear air turbulence, frontal zones, or low-level temperature inversions (see below)***

Convective Currents

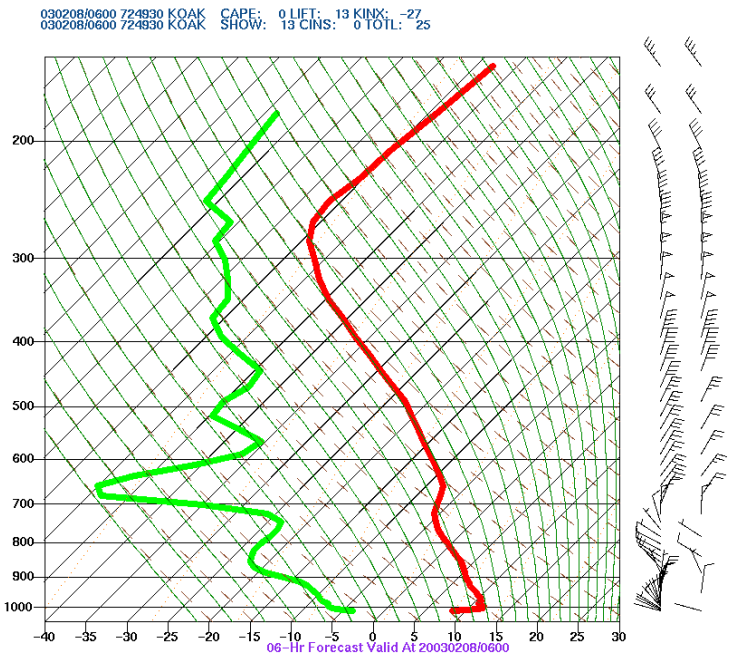
- **Wind can also be caused by solar heating causing air in one place to rise, and thus air in neighboring locations to move in to fill the resulting "hole". This is called a *thermal.***
- **A *sea breeze* is caused by cool, dense air moving inland from over the water when the land is warmer than the ocean (such as during the day), or moving towards the ocean when the water is warmer than the land (such as at night)**

Humidity and Dew Point

- Warm (less dense) air can hold more moisture than cold air
- *Relative humidity* is a measure of how much moisture the air is holding compared to the maximum that could be held at the current temperature
- When the relative humidity is 100%, the air is said to be *saturated*
- **If a constant amount of moisture is assumed, and the air is cooled, eventually a temperature will be reached where the air is saturated. This temperature is called the *dew point.***
- **If moist air is cooled to its dew point, and condensation nuclei are present, clouds or fog will form because the water vapor condenses into visible water droplets**

Stability

- As altitude increases, pressure and density decrease
- If a parcel of air is raised in altitude and allowed to expand, its temperature will decrease (this is why aerosol cans at room temperature, which are under high pressure, can spray a really cold mist when the pressure is released). The temperature drops at a standard rate with altitude. This is called the *dry adiabatic lapse rate*, and is 5.4 degrees F per 1,000 feet.
- At a given pressure, air density is determined by temperature (and a little by humidity)
- Lower density air will rise when placed with higher density air
- The actual distribution of temperatures in the atmosphere (the *environmental lapse rate*) may be different from the adiabatic lapse rate: either the temperatures get colder, quicker, with altitude, or they don't get cold as quickly with altitude, or maybe the temperature even increases with altitude



- If the actual temperatures get colder, quicker, with altitude, then a heated parcel of air on the ground will tend continue to rise because it will always be warmer, and thus less dense, than the surrounding colder air. The air is called *unstable*.
- If the actual temperatures get colder more slowly than the adiabatic lapse rate, stay constant, or get warmer, then a heated parcel of air on the ground will tend to stay put because as it tries to rise it will be colder, and thus denser, than the surrounding air. The air is called *stable*.
- **The environmental lapse rate can be used to determine the stability of the air**
- **When air is warmed from below, it tends to become unstable (it is warmer that the surrounding air as it continues to ascend)**
- **Because stable air resists vertical movement, its characteristics include:**
  - **Stratiform clouds**
  - **Smooth air**
  - **Fair-to-poor visibility with haze**
  - **Continuous precipitation**
- **Because unstable air encourages vertical movement, its characteristics include:**
  - **Cumuliform clouds**
  - **Turbulent air**

  - **Good visibility**
  - **Showery precipitation**

Clouds

- Clouds are visible moisture
- **Clouds are classified according to their height and vertical development**
  - **High clouds (cirrus)**
  - **Middle clouds (alto)**
  - **Low clouds (no prefix or suffix)**
  - **Clouds with extensive vertical development**
- ***Nimbus* means a rain cloud**
- *Stratus* means a flat, smooth cloud layer (e.g. cirrostratus, altostratus, nimbostratus)
- *Cumulus* means a cloud with vertical development (e.g. cirrocumulus, altocumulus, cumulus, cumulonimbus)
- **When moist, stable air is forced upward, such as by wind flowing up a mountain slope, stratus clouds may form**

Thunderstorms

- Saturated air behaves a little differently from dry or non-saturated air. The water vapor in saturated air contains a latent heat of condensation that is released if the vapor condenses into water droplets. If saturated, unstable air is forced upwards so that clouds begin to form, the heat released from the condensation will cause the air to want to move even higher, thus becoming even more unstable. This is called *conditional instability*.
- Towering cumulus clouds have extensive vertical development because strong updrafts are lifting the clouds higher in the atmosphere, and the water vapor is releasing heat to feed the process
- **When moist, unstable air is forced upward, cumulus or cumulonimbus (thunderstorm) clouds will form**
- Strong downdrafts surround the updrafts. The air under towering cumulus clouds will alternately contain strong updrafts followed by strong downdrafts.
- Turbulence is caused by the relative motion of air, and may be caused by updrafts or downdrafts (called convective turbulence)
- **Thus, cumulus clouds and the area below them are likely to contain moderate or higher levels of turbulence**
- **Cumulonimbus clouds contain the worst turbulence**
- **When downdrafts contact the ground, they cause potentially severe horizontal wind shear**
- **A nonfrontal, narrow band of active thunderstorms that develops ahead of a cold front is called a squall line. These thunderstorms generally produce the most intense hazards to aircraft.**
- **The life cycle of a thunderstorm is:**
  - **Cumulus – the building stage when updrafts predominate and moisture is held in the air**
  - **Mature – the middle stage, with the greatest intensity, when both updrafts and downdrafts are present and cause severe wind shear, and rain begins to fall**
  - **Dissipating – the final stage when downdrafts predominate and rain falls to the Earth. This stage is often characterized by an anvil top to the cloud.**
- Different types of thunderstorms are air mass (moist air heated from below), orographic (moist unstable air listed by a mountain slope), frontal (a warm air mass moving over a cold air mass), or squall lines (from a fast-moving cold front)
- Thunderstorms should be avoided by at least 20 miles
- **By definition, a thunderstorm is always accompanied by lightning**

Cloud Height Determination

- When lifted by a convective current, air cools at the rate of 5.4 degrees F per 1,000 feet. The dew point also decreases at the rate of 1.0 degrees F per 1,000 feet. Thus the temperature/dew point spread decreases by 4.4 degrees F per 1,000 feet.

- **By taking the temperate/dew point spread on the ground, dividing by 4.4, and multiplying by 1,000, the approximate base of cumuliform clouds above ground level can be estimated**

Cloud Coverage

- *Clear* refers to no clouds visible
- *Few* refers to cloud coverage between 0/8 and 2/8 of the sky
- *Scattered* refers to cloud coverage between 3/8 and 4/8 of the sky
- *Broken* refers to cloud coverage between 5/8 and 7/8 of the sky
- *Overcast* refers to complete cloud coverage
- The *ceiling* is the lowest cloud level aloft that is reported as broken or overcast

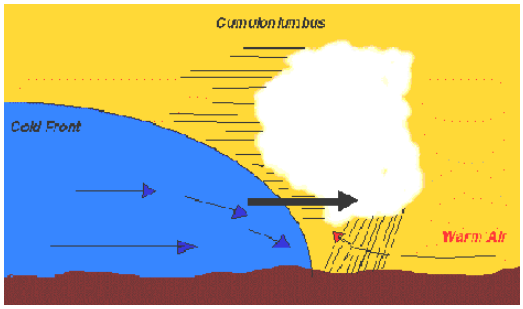
Fog and Frost

- Fog is simply a cloud at ground level
- **Fog is caused when the temperature/dew point spread of moist air at ground level approaches zero and condensation nuclei are present**
- The temperature/dew point spread can be reduced by lowering the temperature (and thus reducing the amount of moisture that can be held), or adding moisture to the air
- **Moisture can be added to the air through evaporation or sublimation**
- **Frost is formed when the temperature of the surface is below the dew point of the surrounding air, and the dew point is below freezing. It is the direct sublimation of water vapor into ice crystals.**
- There are five types of fog:
  - ***Advection fog* is formed when moist air moves over a colder surface, such as air coming inland from a body of water at night or in winter**
  - ***Steam fog* is formed when cold, dry air moves over a warmer, moist surface, such as air moving seaward in the winter. Ice crystals and low-level turbulence can be present because the warm surface causes instability.**
  - ***Upslope fog* is formed when a moist air mass is cooled by being blown upward over rising terrain**
  - ***Radiation fog* is formed when the Earth's surface cools at night by radiating away its energy. This happens in flat, low areas on clear, calm nights.**
  - Precipitation-induced fog is caused by the evaporation of warm precipitation in cold air causing saturation

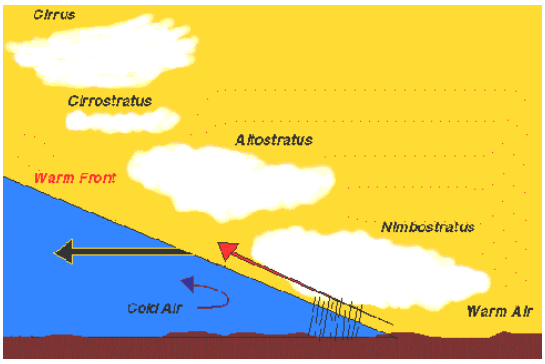
Temperature Inversions

- **A *temperature inversion* is when the air becomes warmer as altitude increases, instead of getting colder**
- Temperature inversions may occur at the surface or aloft
- **Because the warm lapse rate resists the upward movement of air, the air below the inversion layer is stable**
- The location of the inversion layer is often marked by a layer of haze or smoke which rises until the lapse rate prevents further motion
- **If the air under the inversion is humid, the stable air will also be hazy or contain fog or low clouds**
- **A common cause of a surface-based temperature inversion is surface cooling on a clear, still night**
- Surface winds of 7 KTS or greater will tend to break up a surface-level temperature inversion
- Temperature inversions can be caused by a warm air mass moving over a cold air mass. The warm air mass can have strong winds unimpeded by surface friction because the warm and cold air masses don't want to mix.
- **When there is a temperature inversion, and wind speeds at 2,000 to 4,000 feet AGL are at least 25 KTS, wind shear can be expected**

Fronts

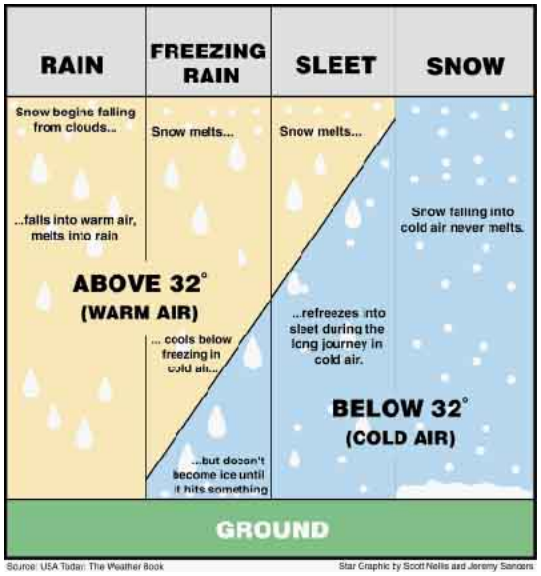


- Air in different locations can have very different properties: temperature, pressure, and humidity
- Air masses with different temperature tend not to mix easily
- **The boundary between two air masses is called a *front***
- **Flying across a front will always be accompanied by a change in wind direction**
- **Because of the change in wind direction, frontal zones frequently contain hazardous wind shear**
- **Flying across a front will also usually be accompanied by a significant change in temperature**
- A cold front consists of a cold air mass moving under a warmer air mass
- If the warmer air mass is moist and unstable, thunderstorms will result along the front. If the warmer air mass is moist and stable, stratiform clouds will result.
- The slope of a cold front is usually fairly steep
- A warm front consists of a warm air mass moving over a cold air mass
- If the warm air mass is moist and unstable, thunderstorms will result. If the warm air mass is moist and stable, stratiform clouds will result.
- The slope of a warm front is usually fairly shallow, resulting in bad weather in an extended area



Precipitation

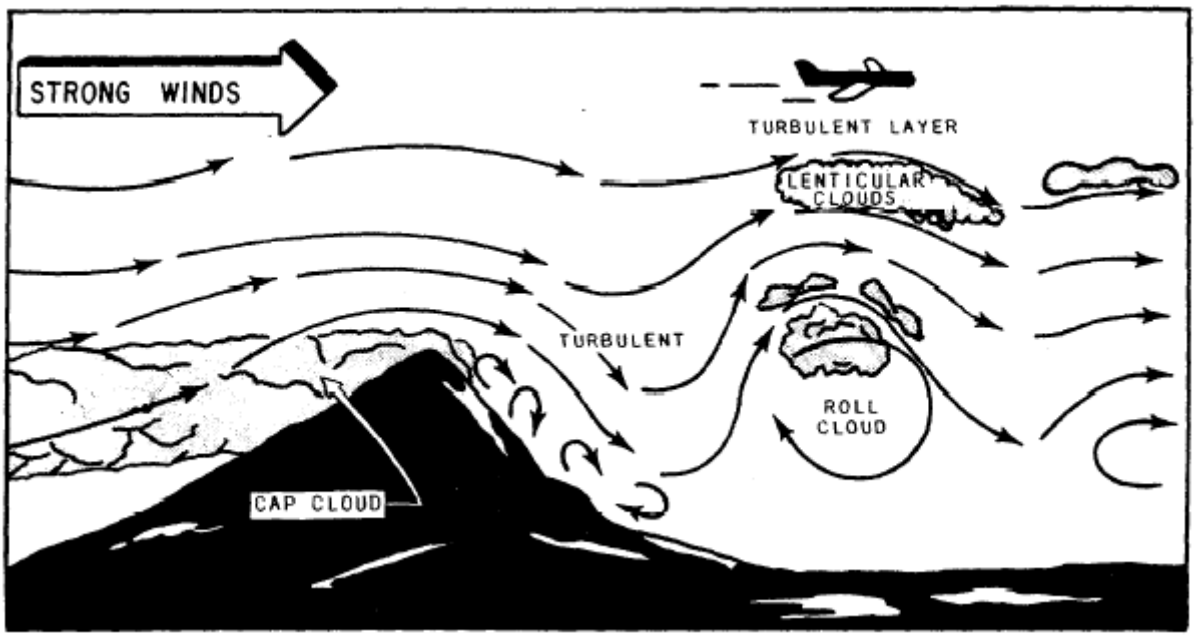
- The various types of precipitation include:
  - Rain
  - Snow
  - Hail
  - Ice pellets or grains
  - Freezing rain
- Freezing rain is caused by warm water falling through a cold layer that is below freezing. The water droplets become supercooled, and turn to ice upon striking a surface. This is very bad news for an airplane!
- **The presence of ice pellets on the surface is an indication of a temperature inversion with freezing rain at a higher altitude**



Icing

- **Ice can form on a surface whenever the temperature is at or below freezing and there is visible moisture**
- **The accumulation of structural icing is most severe in freezing rain**

Mountain Waves



- Mountain waves are caused by wind moving over a ridge or mountain peak and causing a series of waves on the lee side
- As the air is raised and cooled, water may condense, and as the air descends, water may no longer condense. This can cause a cloud to appear at the crest of the wave.
- **This almond or lens-shaped cloud, called a *lenticular* cloud, may contain winds of 50 KTS or greater even though it appears to be standing still**
- **Mountain wave turbulence should be expected when winds of 40 KTS or greater are blowing across a mountain ridge and the air is stable**
- Rotor or roll clouds on the lee side of a mountain may contain extreme turbulence and should be avoided

