AVIATION WEATHER

SYST 460/560

http://virtualskies.arc.nasa.gov/weather/tutorial/
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1 Introduction

• Weather has large influences over our lives
  – we have absolutely no control over.

• Most of the weather that occurs on our planet happens below 15,000 feet.
  – commercial jetliner at a high altitude (>30,000 feet) there is hardly any significant weather.

• Weather is the utmost consideration of all pilots when planning a flight.
Atmosphere

- Earth is a the bottom of an ocean of air.
- Dynamic layers of air interact with the Earth's surface and the Sun's energy to produce the phenomenon of weather.
- The atmosphere is classified into layers based upon the characteristics each layer exhibits.
  - Thermosphere
  - Mesosphere
  - Stratosphere (flying)
  - Troposphere (flying)

- Atmosphere is comprised of air.
  - Air is mixture of gases.
    - 80 percent nitrogen
    - 20 percent oxygen.
    - Water vapor and many other gases constitute the remainder of the gas mixture.
  - Air is made up of matter and has weight.

- Air is gaseous -> it is compressible.
  - Air pressure nearer the surface of the Earth is greater than the air pressure in the stratosphere.
  - At the Earth's surface the pressure is 14.7 pounds per square inch.
  - Increase the air pressure and the air's density is increased.
Atmosphere – Compressibility of Air

- Air compressibility changes flight conditions depending on altitude
  - This is due to air density.
    - More molecules in the air will generate greater lift with less thrust.
    - Fewer molecules in the air will require greater thrust to generate adequate lift.
- Air compressibility affects human performance
  - Decrease in air density with increase in altitude also affects people physiologically.
    - Decrease the air pressure and the oxygen pressure is also decreased.
    - The rate at which our lungs absorb oxygen depends on the partial pressure exerted by the amount of oxygen in the air.
    - Since our atmosphere is about 1/5 oxygen, the oxygen pressure at any given altitude will be about 1/5. Under normal conditions our lungs function under 3 pounds per square inch of oxygen pressure. As an airplane climbs higher into the troposphere, it will encounter less oxygen. Without supplemental oxygen the people on board such a flight will suffer from hypoxia, a deficiency in oxygen. The symptoms of hypoxia are a feeling of acute exhaustion with an immediate impairment in vision and judgment resulting in unconsciousness and death if the proper amount of oxygen is not soon administered. Prolonged flights at or above 10,000 feet and even short flights above 12,000 should use auxiliary oxygen.
Atmosphere - Temperature

• Ocean of air can be calm, warm and pleasant or turbulent and rainy (e.g. thunderstorm, hurricane or tornado).

• Air temperature varies from below -100 Celsius to above 1500 Celsius (-150 Fahrenheit to 2700 Fahrenheit).
  – Variations caused by the uneven heating of the Earth's surface by the sun's energy as well as how the Earth reacts to this energy.
  – The characteristics of a substance (for example water or land) affects the amount of heat absorbed or released by that substance.
    • Land surface becomes hotter at a much faster rate than the water surface.
    • Under equal heat loss the land will become colder at a faster rate than the water.
Atmosphere – Temperature Variation

• Differences in amount of solar energy received by the various regions of the Earth throughout a day or year cause temperature variations that power our dynamic atmosphere.

1. diurnal variation
2. seasonal variation
3. latitudinal variation
4. topographical variation
5. altitude variation
Temperature Variations - Diurnal

- Diurnal variation = change in air temperature that occurs from day to night brought about by the Earth's rotation.
- Exchange takes place on the Earth's surface in regards to solar and terrestrial (from or on Earth) radiation.
  - Sun gives off energy to the Earth in the form of solar radiation.
    - Fifty-five percent of the solar radiation received by the earth and its atmosphere is reflected while the remaining 45% is absorbed and converted into heat.
  - Earth gives off radiation (terrestrial radiation)
Temperature Variations - Diurnal

• Exchange is worldwide and maintains a delicate balance in the Earth's atmospheric temperature
  – Average amount of heat gained through solar radiation is roughly equal to the amount of heat lost through terrestrial radiation.
  – During day - terrestrial radiation is exceeded by the solar radiation and the Earth's surface becomes warmer.
  – During night - the part of the Earth facing away from the sun receives no solar radiation and the Earth's surface cools.
    • The cooling of the Earth's surface continues until about 1 hour after sunrise
      – cause the formation of fog shortly after the sun is above the horizon
  – Shortly after sunrise, the solar radiation of the next day exceeds that of the terrestrial radiation, and the temperature increases.
Temperature Variations - Seasonal

- Seasonal variation occur due to:
  1. Earth's tilt +/-23.50 degree
  2. position relative to sun during its revolution

- Hemisphere that receives more direct rays of sunlight will have warmer temperatures.
  - opposite hemisphere, at same time of year, will have colder temps
Temperature Variations - Latitudinal

- Shape of Earth directly affects the amount of solar radiation received during certain segments of its revolution around the sun.
- Equatorial regions receive more direct rays of the sun, thus more solar radiation.
- Farther south or north of the equator changes angle at which the rays strike the Earth
  - decreasing the amount of solar radiation received at that latitude.
Temperature Variations - Topographical

- Water absorbs and radiates energy with temperature changes that are less than land.
- Topographical Variation
  - Large, deep bodies of water minimize temperature changes while large continents incur greater temperature changes
  - Wet soil (marshes, swamps) minimize temperature changes nearly as much as water bodies
  - Areas of thick vegetation tend to ensure against abrupt temperature changes because it insulates against heat transfer between the ground and the atmosphere
  - The greatest temperature changes occur over areas of arid, barren surfaces (rocky or sandy deserts)
  - Abrupt temperature changes occur along lakes and shorelines
  - Most islands experience fairly constant temperatures
- Topographical variations influenced also by diurnal and seasonal variations and can cause a change in wind direction or wind strength
Temperature Variations - Altitudinal

- Troposphere - temperature decreases as the altitude increases.
  - known as the "lapse rate"
  - average temperature decrease (or average lapse rate) in troposphere is usually given as 2.0 Celsius per 1,000 feet.
- There are times when the temperature actually increases with height.
  - Inversions
    - Ground-based inversion
      - occurs near the ground on cold, clear nights.
      - ground radiates and cools much faster than the air above it, air in contact to the ground becomes cold while just a few hundred feet above it that temperature has changed very little
      - Traps fog or smoke close to the ground and decrease visibility
    - Inversion aloft:
      - occurs a little higher in the atmosphere than ground-based inversions.
      - A current of warm air overruns a large patch of cold air trapping it next to the Earth’s surface.
      - If rain clouds in the warm air current drop rain, it will pass through the colder air and freeze
      - This can develop into icing on an aircraft's wings drastically reducing the aircraft's lift force
Atmosphere - Altimetry

- Temperature affects an aircraft's performance and is perhaps most crucial when making altimetry readings.
- The altimeter is basically an aneroid barometer that is graduated to use increments of height.
- The standard used for graduating the altimeter is that of standard atmosphere.
- Standard atmosphere was developed by engineers and meteorologists who needed a fixed standard with which they could reference for aircraft performance and weather, respectively.
  - standard atmosphere average conditions throughout the atmosphere for all latitudes, seasons and altitudes
  - specific sea-level temperature, pressure and rates of change of temperature and pressure with height.
    - pressure falls at a fixed rate upward through the atmosphere unlike the actual atmosphere
- standard atmosphere is a measuring stick to which pilots compare their altitude based upon other factors (density, pressure and temperature).
- So, why is a standard atmosphere necessary? The altimeter measures altitude (that is vertical distance above a level plane, such as sea level), so at any time a pilot should know the aircraft's distance from sea level, right? The airplane's altimeter measures the atmospheric pressure at flight level. In other words it is measuring the weight of the air pressing down on it from above. What the altimeter cannot measure is the air density and the air temperature, both of which affect the flight characteristics of the aircraft. An airplane performs differently in different temperature and air density situations. By establishing a standard atmosphere, pilots can compare their airplanes performance under certain conditions to this standard. Pilots can then make adjustments accordingly to their instruments and flight plan.
Atmosphere - Altimetry

- When an aircraft measures altitude using pressure
- standard atmosphere - airplane flies at 10,000 feet given a standard sea level pressure of 29.92 inches of mercury or 1013.2 millibars.
- When the air is warmer than the standard, the altimeter reads lower than the airplane's true altitude.
- When the air is colder than the standard, the altimeter reads higher than the airplane's true altitude.
2. Wind

- Horizontal movement of the air is known as wind.
- Wind is derived from convection process
  - hemispheric circulations
  - local airflows.
- Convection is the result of variation in the temperature
  - comes from uneven heating of the Earth's surface by the Sun
- Warmer air expands becoming less dense than the cooler air around it
- The cooler air (which has greater density) moves toward the ground
- The rising air spreads out above, becomes cooler and eventually descends while the cooler air below warms and rises.
Wind – Convection Process

• Convection process causes changes in the air density
• Changes in air density cause winds.
• Winds flow out of higher air density areas into lower air density areas
• Coriolis effect in the Northern Hemisphere, causes wind to flows clockwise around higher air density areas, called a "high," and counterclockwise around lower air density areas or a "low."
  – Highs bring clear weather (in general)
  – Lows bring stormy weather (in general)
Wind – Jet Stream

- Jet stream weaves through high and low pressure areas high in the troposphere (near the tropopause).
- On the average, winds tend to increase speed with height in the troposphere culminating in maximum speeds near the tropopause.
- Jet stream winds concentrated, narrow bands that wind their way through the atmosphere.
- The jet stream varies from:
  - 100 to 400 miles wide
  - usually found above 30,000 feet.
  - motion is from west to east
  - speed range of 150 to 300 miles per hour
  - Seasonal migrations within the United States.
Wind and Terrain

• Terrain features (mountains, valleys and shorelines) generate local wind patterns
  – Land breeze, sea breeze
• Friction occurs between the wind and the terrain surface acting in opposition to the wind's direction.
  – slows the windspeed
  – rougher the terrain the greater the friction
  – greater the windspeed, the greater the friction
Wind - Mountains

- Mountain and valley breezes are diurnal
  - Radiated ground heats air next to a mountain slope in the daytime
  - Colder, denser air farther away from the mountain slope located at the same altitude as the warmer air settles down upon the warmer air forcing it to move up the mountain slope (= “valley wind”)
  - At night, the opposite movement occurs, air on the mountain slope is cooled, becomes heavier than the surrounding air and follows the mountain slope down into the valley (= mountain winds)
  - Note: Mountain winds are usually stronger than valley winds.
Wind – Air Currents

- Rising and descending air currents affect local air circulation
- Planted fields, meadows and water retain heat and cause descending air currents
- Rocky or sandy terrain, plowed fields and barren land reflect heat and cause ascending air currents
Wind - Shear

- Wind shear is encountered in an area where two winds moving in opposite directions "rub" or mix together

- Shear zone creates small eddies and whirling masses of air that move in various directions.
  - generates tremendous turbulence

- Some wind shears are predictable, but others may occur unexpectedly

- Getting caught in wind shear can be devastating to an aircraft, especially if the wind shear occurs close to the ground.
4. Moisture

- Water in the atmosphere is measured by:
  - relative humidity
  - dew point (temperature-dew point spread)

- Relative humidity relates the actual amount of moisture in the air (in the form of a percent) to what total amount of moisture could be held in the air
  - Relative humidity expresses the degree of saturation

- Cold air holds fewer water molecules than warmer air holds

- Air completely saturated with water molecules the humidity is 100%.
5. Clouds

- After air begins to cool and then becomes saturated, sublimation or condensation starts the cloud-forming process.
- Air within the newly formed cloud layer is either stable or unstable - determines the type of cloud structure
  - stable air resists convection
  - unstable air prefers convection
- Cloud formation in stable air develops horizontally in uniform, sheet-like layers called "strata".
- Cloud formation in unstable air - air is forced upward by convection, cloud forms vertically.
  - Height depends on depth of the unstable layer
  - pile up in a heap or "cumulus."
- 4 types clouds:
  - high clouds, middle clouds, low clouds and vertically advanced clouds
Clouds

- **Low Clouds**
  - Cumulus
  - Fractocumulus
  - Stratocumulus
  - Stratus
  - Fog
  - fractostratus

- composed of water, and sometimes the water is supercooled.
- Low clouds at temperatures below freezing can also hold snow and ice particles.
- near the surface to about 6,500 feet
Clouds

- **Middle Clouds**
  - Altocumulus
  - Altostratus
  - Lenticular
- Composed of water, most of which is supercooled
- 6,500 to 23,000 feet.
Clouds

• High Clouds
  – Cirrus
  – Cirrocumulus
  – Cirrostratus

• Consist almost entirely of ice crystals

• 16,500 to 45,000 feet.
Clouds

- Vertically Advanced Clouds
  - Nimbostratus
  - towering cumulus
  - Cumulonimbus
- Contain supercooled water above the freezing level.
- As a cumulus cloud grows to great heights, water in the upper part of the cloud freezes into ice crystals forming a cumulonimbus.
- 1,000 feet (or lower) to a towering 10,000 feet or higher.
Thunderstorm

CROSS-SECTION OF A THUNDERSTORM

- Turbulence
- Storm Movement
- Wind Shear Turbulence Zone
- Roll Cloud
- Wind Shear Turbulence Zone
- Precipitation
- First Gust
## Clouds

<table>
<thead>
<tr>
<th>Cloud Type</th>
<th>Effects on Flight</th>
</tr>
</thead>
<tbody>
<tr>
<td>cirrus</td>
<td>no significant icing; turbulence in dense, banded cirrus</td>
</tr>
<tr>
<td>cirrocumulus</td>
<td>may contain highly supercooled water droplets resulting in some turbulence and icing</td>
</tr>
<tr>
<td>cirrostratus</td>
<td>little if any icing; no turbulence; restricted visibility</td>
</tr>
<tr>
<td>altocumulus</td>
<td>small amounts of icing; some turbulence</td>
</tr>
<tr>
<td>altostratus</td>
<td>moderate amounts of icing; little to no turbulence; restricted sunlight</td>
</tr>
<tr>
<td>altocumulus castellanus</td>
<td>unstable air; rough turbulence with some icing</td>
</tr>
<tr>
<td>standing lenticular altocumulus clouds</td>
<td>very strong turbulence</td>
</tr>
<tr>
<td>nimbostratus</td>
<td>very little turbulence; can pose serious icing problems if temperatures are near or below freezing</td>
</tr>
<tr>
<td>stratus</td>
<td>little or no turbulence; hazardous icing conditions if temperatures are near or below freezing; when associated with fog or precipitation can create conditions of greatly reduced visibility</td>
</tr>
<tr>
<td>stratocumulus</td>
<td>some turbulence; possible icing at subfreezing temperatures; ceiling and visibility better than with low stratus clouds</td>
</tr>
<tr>
<td>cumulus</td>
<td>shallow layer of unstable air will give some turbulence, but no significant icing</td>
</tr>
<tr>
<td>towering cumulus</td>
<td>very strong turbulence with rain showers; some clear icing above freezing level</td>
</tr>
<tr>
<td>cumulonimbus</td>
<td>unstable air throughout; violent turbulence; strong possibility for icing</td>
</tr>
</tbody>
</table>
6. Weather Briefings

- CCFP