Mountain Flying Qualification Course

Civil Air Patrol

Auxiliary of the United States Air Force

Mountain Weather

Slopes

Most U.S. mountain ranges are oriented north-south, while the prevailing winds are from the west. This causes wind to rise over the ranges then descend on the other side.

On these ranges, the west side is the "*upslope*" or "*windward*" side, while the east side is the *"downslope"* or *"leeward"* side.

Wind

Visualize moving air as you would flowing water, passing over and around obstacles. Learn to predict updrafts, downdrafts, and turbulence based upon the predictable movement of air in relation to peaks, valleys, passes, and other obstructions.

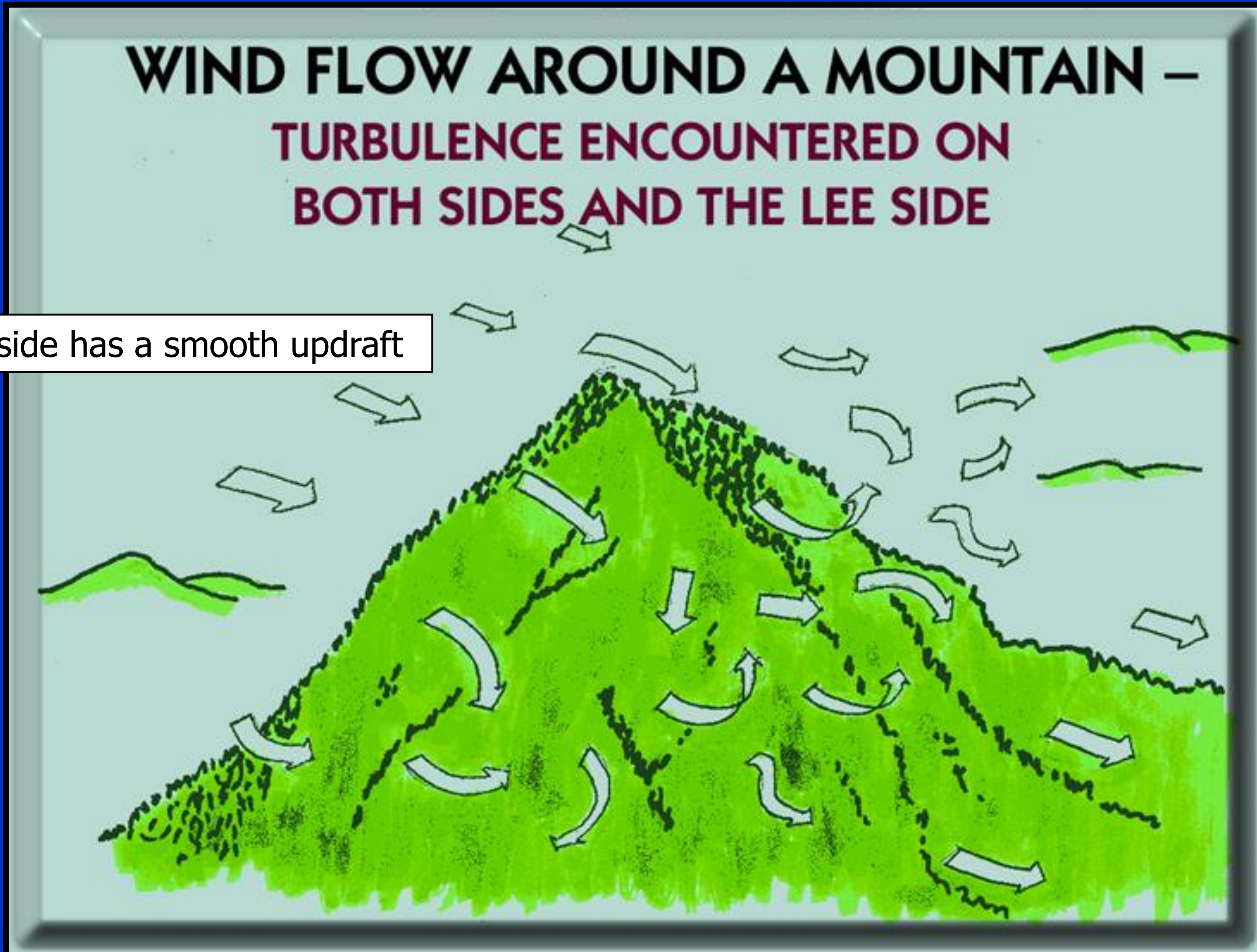
- Upwind slopes and updrafts tend to be relatively stable and smooth
- Downwind slopes and downdrafts tend to be more random and turbulent
- Wind channels and accelerates through valleys and mountain passes, also causing turbulence

Wind Acceleration

Wind will often accelerate when passing over or through mountains. Ridgeline winds in excess of 20 knots indicate that the pilot should proceed with caution.

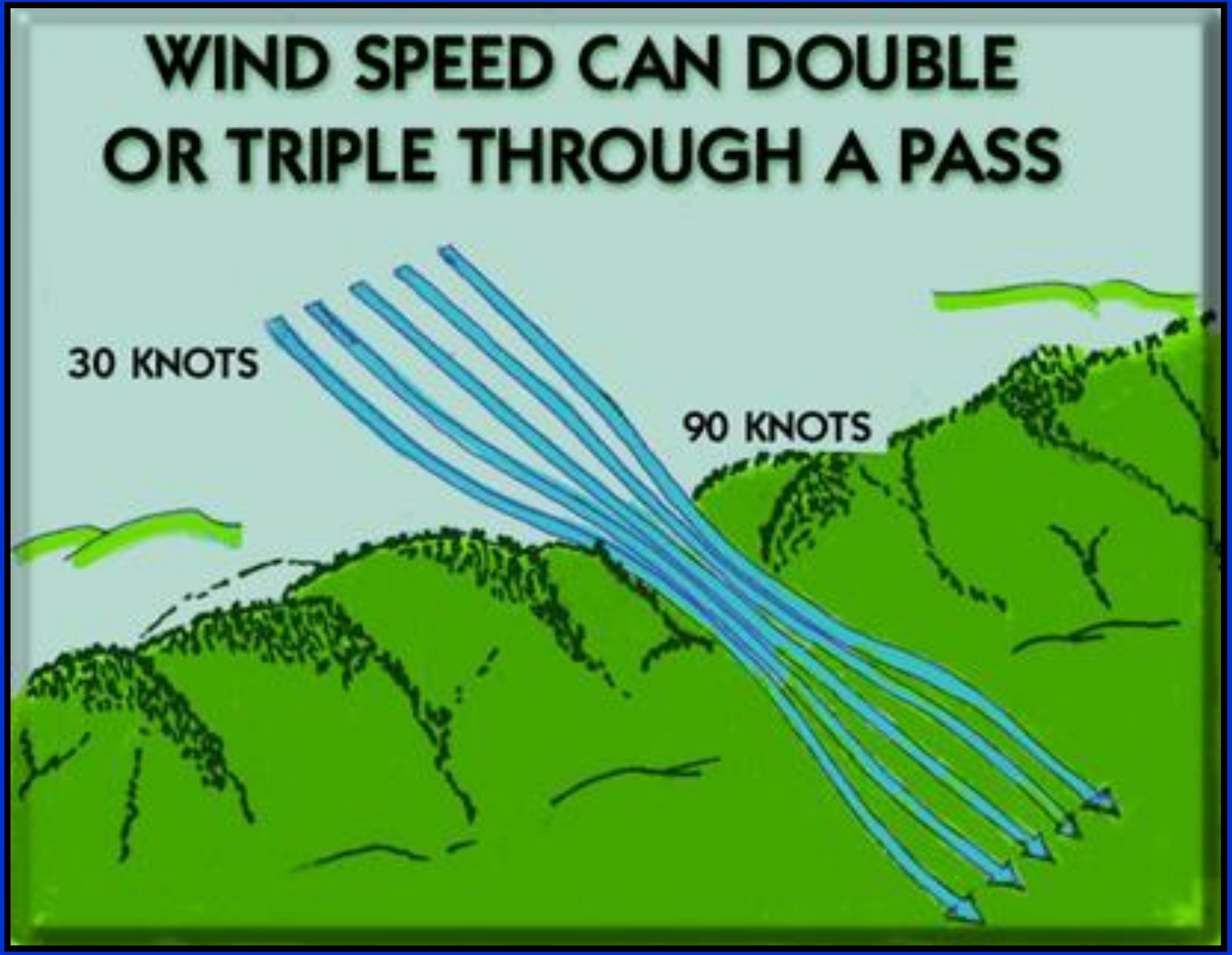
Especially in the presence of an inversion layer, rising air will be "squeezed" between the mountain ridges and the overlying air mass, causing a venturi effect which can double or triple the wind velocity.

Winds aloft at the mountain peak level that are thirty knots or greater produce severe turbulence and are a good indicator that a flight should be postponed.



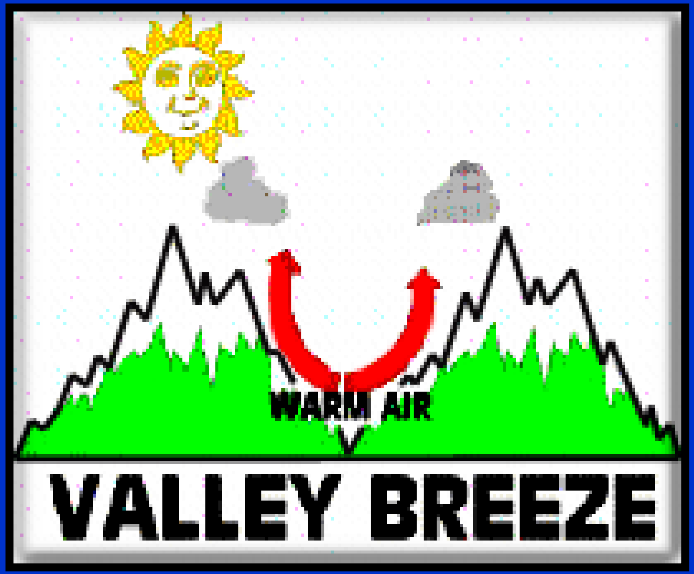
The windward side has a smooth updraft

A venturi effect occurs when wind blows through a mountain pass or valley



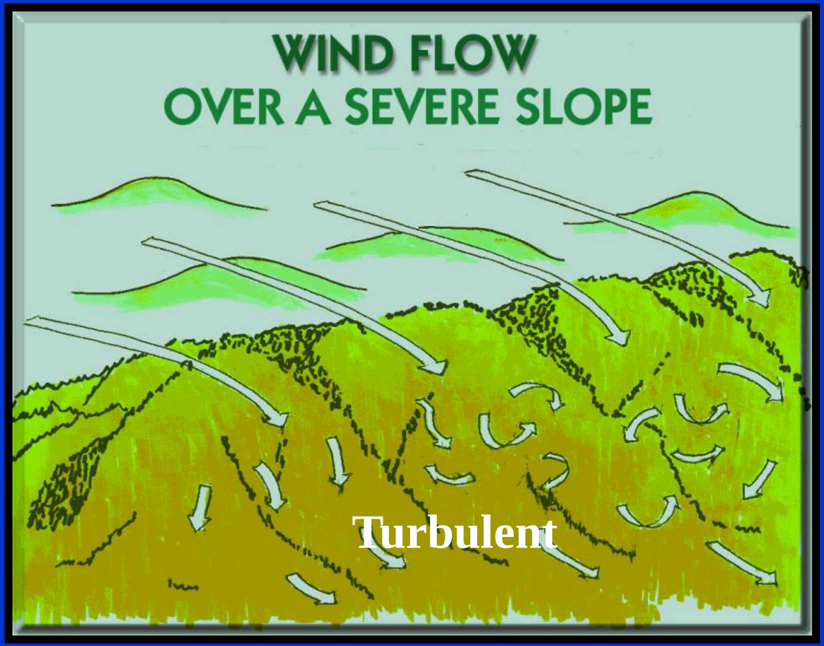
Diurnal Wind Flow

Convection causes wind to flow up valleys in the morning *(Valley Breeze)*, then flow down valleys in the afternoon and evenings *(Mountain Breeze)*. In the late evening, a downflow pattern may exist due to rapid cooling of the air near the mountaintops.



Turbulence

- Turbulence in the mountains is usually the result of airflow over, around, or between obstructions
- Severity is often proportional to wind velocity
- Location is usually predictable
- Shaded and forest areas usually produce sink
- Rocks and light colored areas produce lift
- Usually strongest on leeward side. Depends on the steepness of the downslope

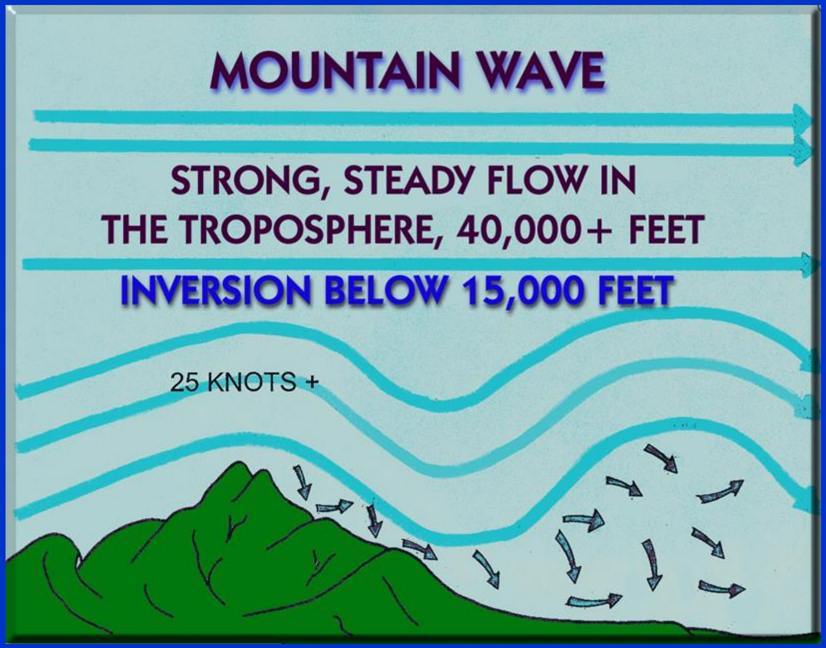


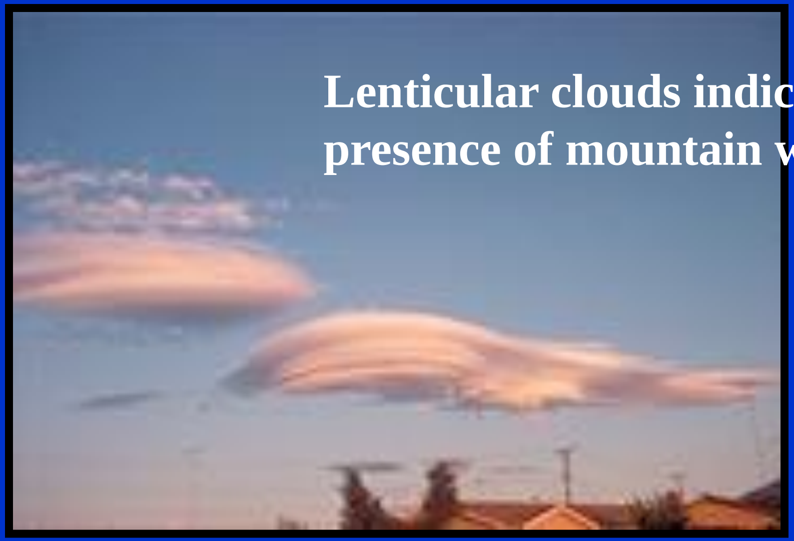
Standing Wave/Mountain Wave

When airflow over mountainous terrain meets certain criteria, a “Standing Wave” may result. In such cases, moving air is forced up by terrain and “bounced” off the overlying airmass, after which it descends to bounce off the flat ground and then continues in this manner, sometimes for a hundred miles on the lee side of a mountain range.

Because the air is accelerated over the mountains and because strong rotor clouds and turbulence often form below this moving airmass on the downwind side of the mountains, extreme caution is indicated when flying in the presence of a standing wave.

Meteorologists are able to forecast standing waves with a high degree of accuracy, so be sure to ask for this information during your weather briefing.

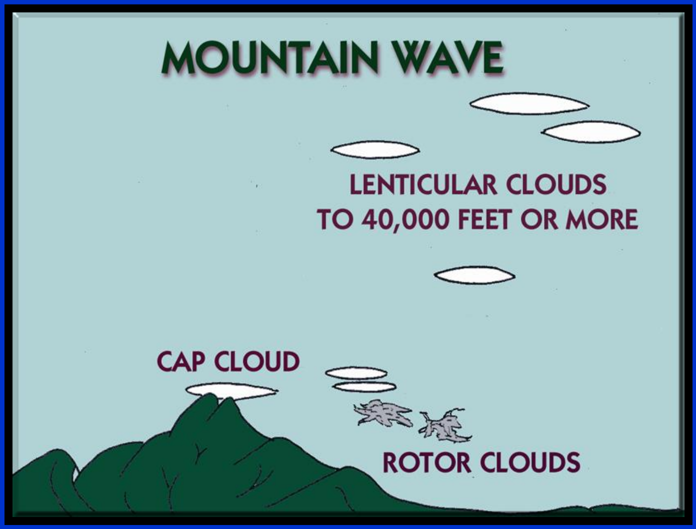


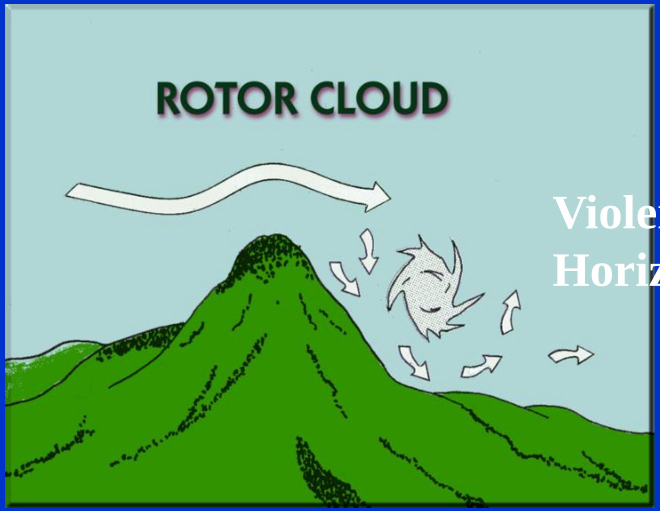


Lenticular clouds indicate presence of mountain wave

Clouds

- Formed from moisture present in the airmass
- Useful in visualizing wind and weather patterns
- The greatest icing potential in cumulus clouds is found in the lower third.
- Lenticular clouds unique to the mountain environment
  - Smooth, lens-shaped clouds above peaks and ridges
  - Indicate strong winds flowing up and through that area
  - There may bean area of severe to extreme turbulence beneath a lenticular cloud.
- Cap clouds form mostly on the windward side of a mountain and dissipate on the leeward side, where air descends.
  - Appear as stationary, but actually reflect strong winds
- Rotor clouds form downwind of a ridgeline
  - Indicate strong, violent winds moving in a rotary motion





Violent Winds
Horizontal Tornado


Lenticular clouds at sunset
with rotor turbulence evident


Standing wave cap cloud

Cloud Ceilings

Ceilings are reported above ground level; in the mountains, this usually means above the valley floor. Surrounding terrain often extends into the ceiling, and valley floors cans rise into the ceiling.

All aircraft forced to fly in valleys and through passes. VOR signals may be lost or become unreliable. Radio communication will be degraded. There is an increased potential for mid-air collisions.

Ceiling heights have been known to drop as much as 2000 fpm in certain sections of the mountain west.

CAP minimum ceiling for VFR flight is 1,000 feet AGL. A higher ceiling may be appropriate for mountain flying.

Visibility

Reduced visibility is dangerous in the mountains

- Obstructions can appear quite quickly. Power lines, towers, rock outcroppings, other aircraft
- Situational awareness can be lost
- Inadvertent IMC can be encountered

Use caution when flying near rain and show showers

- Tend to move and appear in previously-clear areas
- Creates visual illusion of excess altitude

CAP minimum for VFR flight is three miles. Greater visibility appropriate in unfamiliar terrain.

Ground Fog

Ground Fog

Typical ground fog with an inversion layer aloft. Need to know what is causing fog.

Typical ground fog during the morning hours in a valley.

Morning Fog - Usually improving situation. Evening Fog – A deteriorating situation.

Airmass Stability

The normal flow of air is horizontal. If this flow is disturbed, a stable atmosphere will resist any upward motion. Stable air tends to rise over obstructions and then return to its original level in an orderly manner.

An unstable atmosphere favors vertical motion that will allow the upward disturbances to amplify and create convective activity and turbulence, especially if it’s moist.

A comparison of temperatures from one level to another indicates the degree of the atmosphere’s stability. The actual decrease of temperature with height in a real atmosphere is called the "Lapse Rate”, expressed in degrees per thousand feet.

An "adiabatic process" occurs when an air temperature change takes place without the aid of cooling or heating. Visualize rising air as a balloon. The air inside the balloon is separate from the general atmosphere. As the balloon is lifted aloft (e.g. forced up a mountain side) it expands due to the reduced exterior atmospheric pressure. The energy needed to expand the balloon comes from the air in the balloon. Removing energy from the balloon air cools the air in the balloon, and is referred to as expansion cooling. Likewise when the balloon is lowered it contracts due to increasing exterior atmospheric pressure and air in the balloon is warmed. This is compression heating.

Airmass Stability

When unsaturated air is forced up a mountain slope, its temperature decreases at the rate of 3°C (5½°F) per 1,000 feet. When it descends on the other side of the mountain its temperature rises at 5½°F per 1,000 feet. This theoretical cooling/heating rate of unsaturated air is known as the "Dry Adiabatic Rate of Temperature Change."

When saturated air is forced to ascend, condensation occurs, and the heat released as the result of condensation is absorbed by the air. This causes the air to cool at a slower rate than that of unsaturated air. This theoretical rate of temperature change is called the “Moist Adiabatic Rate of Temperature Change”. It varies from approximately 1.1°C to 2.8°C (2°F to 5°F) per 1,000 feet, depending on air temperature and moisture content.

Now apply these concepts to mountains. The warm, dry "chinook “is an example of the difference between the moist and dry adiabatic changes. In winter, moist air from the Pacific Ocean is forced over the Rockies by on-shore winds. The rising air cools, by expansion, and eventually some or all of the water vapor in the air will condense. A cloud will form at the mountain peak and it will rain or snow. The air continues to flow over the mountain range and descends on the other side. Since the air has lost much of its moisture through precipitation, it warms, due to compression. The air is now drier and warmer that it was before it encountered the mountain range.

Airmass Stability

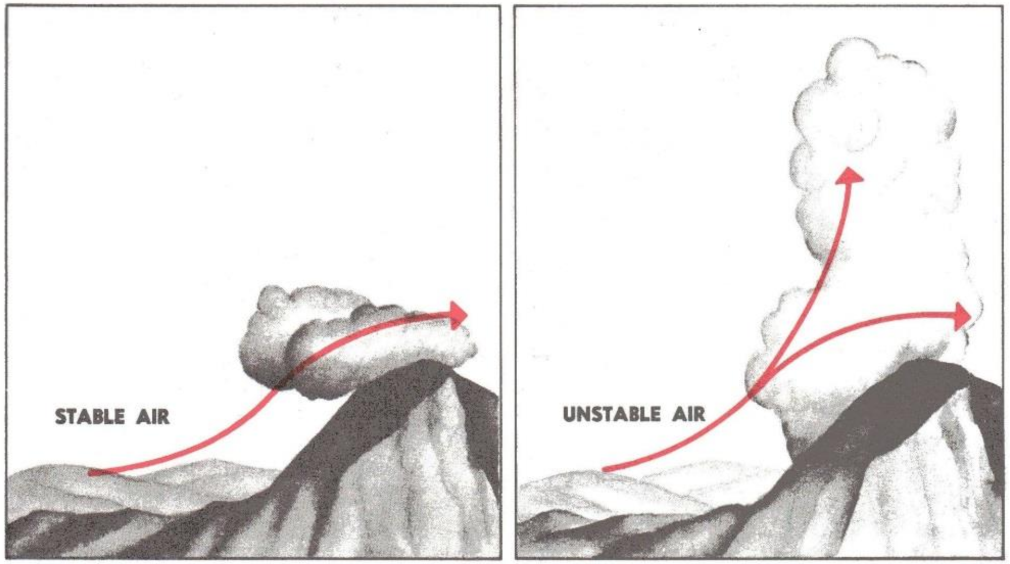
The average rate at which the atmosphere cools with increasing altitude is 2°C (3½ºF) per 1,000 feet, and is referred to as the “Standard Rate of Temperature Change”. It is determined by evaluating thousands of atmospheric soundings from various parts of the world.

Atmospheric stability can be determined by comparing the actual lapse rate to the Dry Adiabatic Rate of Temperature Change, 3ºC/1,000’. A lapse rate greater than 3ºC indicates unstable air, and less than 3ºC is stable air.

To evaluate atmospheric stability calculate the actual lapse rate utilizing surface temperatures available from the Aviation Weather Center (www.aviationweather.gov/adds). For example, the surface temperature at 2235 UTC on 19 March was 14ºC. According to the Winds Aloft Forecast (FBWinds), the temperature at 9,000 feet MSL was 6ºC. A temperature difference of 9ºC between the surface, at 1,617 feet MSL, and 9,000 feet MSL. The actual lapse rate is 1.22ºC per 1,000 feet (9x1,000)/(9,000-1,617), less than 3ºC/1,000 feet, indicating stable air.

EFFECTS and SIGNS of STABILITY and INSTABILITY

- The degree of stability of the atmosphere helps to determine the type of clouds, if any, which form. For example, if very stable air is forced to ascend a mountain slope, clouds will be layerlike with little vertical development and little or no turbulence. Unstable air, if forced to ascend the slope, would cause considerable vertical development and turbulence in the clouds.
- The degree of stability also affects the type of clouds that will appear. Stratus-type clouds represent stability, whereas cumulus-type clouds represent the height of instability.
- Convective turbulence below cloud bases occurs in unstable air.
- Flight in stable air is smooth, but low ceiling and poor visibility may be present requiring IFR.
- Dust devils are a sign of dry, instable air, usually to a considerable height.
- When air near the surface is warm and moist, suspect instability. Surface heating, cooling aloft, converging or upslope winds, of or an invading mas of colder air nay lead to instability and cumuliform clouds.



When stable air (left) is forced upward, the air tends to retain horizontal flow, and any cloudiness is flat and stratified. When unstable air is forced upward, the disturbance grows, and any resulting cloudiness shows extensive vertical development.

Frontal Thunderstorms

- Adequately forecast
- Lines break up when encountering mountains
  - Rarely encounter imbedded thunderstorms
  - Diminish due to interruption of moist air inflow
- Squall lines do not normally occur near mountains because necessary downflow of cool air is interrupted.
- Dangerous when present, consider canceling flight in these conditions.

Orographic Thunderstorms

- Formed when air is forced up by terrain
- Requires moist, unstable air to form
- Usually isolated or scattered
- Can build rapidly
- Can occur at any time when conditions are present

Convective Thunderstorms

- Result from rising, unstable air. Forced upward by solar ground heating.
- Formative stage in mid-morning; billowing cumulous clouds; light to moderate turbulence beneath bases.
- Rapid development by early afternoon with towering and thickening cumulous clouds and increasing turbulence.
- Mature thunderstorms produce severe turbulence, hail, lightning, downdrafts. Remain well clear… at least 20 miles.

Thunderstorms & Downbursts

Heavy rainstorm, note the outflow area.

Beginning of a downburst thunderstorm cell.

Trees downed by a severe downburst

Weather Forecasts

- Not as accurate as in the flatlands
  - Fewer reporting stations
  - More localized weather phenomena
- Weather information for planning a mountain flight will come from AWOS, ASOS, and pilot reports along the intended route.
- As a general rule, weather best during the morning
- Weather can change quickly in the mountains
- Always have a good escape plan

END