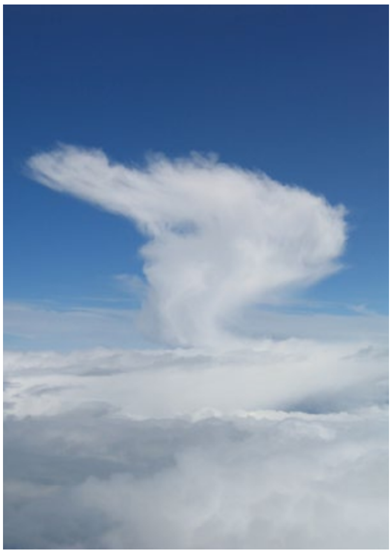
AVIATION REFERENCE MATERIAL

Vertical Stability of the Atmosphere



Vertical motion of air is an important driver of weather. Sometimes rising air is made visible by the development of clouds or by the rising dust in dust devils. Violent vertical motion can be seen in tornadoes. At other times rising air may occur in the absence of any visual clue. Subsiding air is normally relatively gentle and associated with clear conditions (except in association with mountain waves and downburst activity from convective clouds).

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Vertical motion in the atmosphere is largely responsible for turbulence and cloud formation.

The strength of vertical motion is mostly determined by the vertical stability of the atmosphere. A stable atmosphere will tend to resist vertical motion, while an unstable atmosphere will assist it. When the atmosphere neither resists nor assists vertical motion it is said to have neutral stability.

Adiabatic Processes and Lapse Rates

To explain the concept of stability in the atmosphere, it is useful to consider what happens to an imaginary parcel of air displaced vertically from one level to another. During such displacement it is assumed that the parcel undergoes an adiabatic process, i.e. no heat from the external environment is added to, or subtracted from, the parcel (adiabatic heating is demonstrated when using a bicycle pump - compression heats the air and thus the outer casing of the pump; the reverse occurs when air escapes from a tyre - it cools due to rapid expansion). Some mixing with the air outside the parcel normally occurs, and heat may also be lost or gained through radiation, however assuming adiabatic processes is useful in explaining how the atmosphere behaves.

An air parcel will expand and become less dense and will thus cool when it moves to lower pressure (higher altitude); and will contract and become more dense and will thus warm when it moves to higher pressure (lower altitude).

The rate of change of temperature for a vertically displaced parcel of air is termed the adiabatic lapse rate. Two different rates apply - the dry adiabatic lapse rate (DALR) and the saturated adiabatic lapse rate (SALR).

The DALR is the rate at which the temperature of a dry (unsaturated) air parcel changes as it ascends or descends through the atmosphere.It is approximately 3°C per 1000 feet.

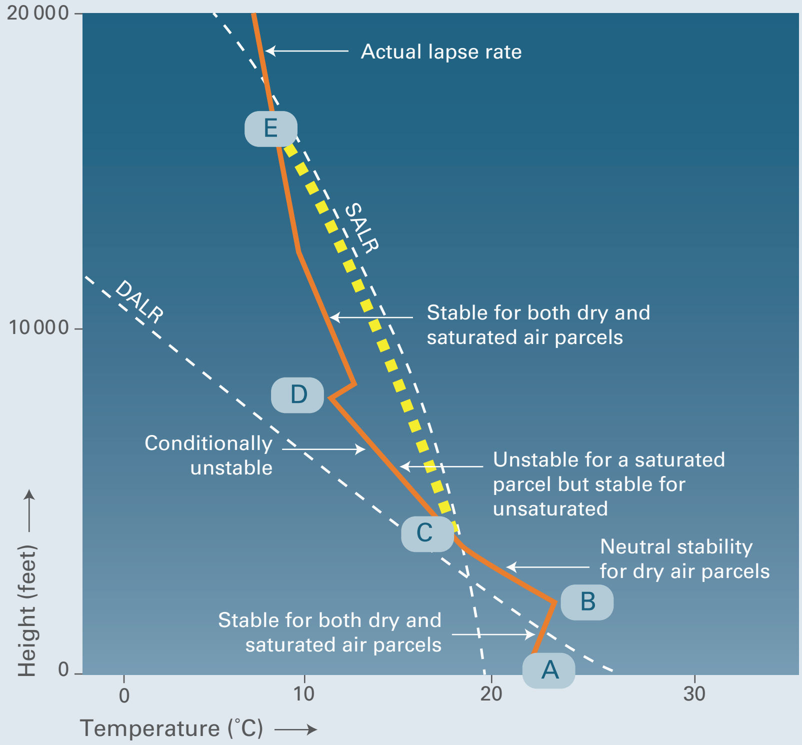
The SALR is the rate at which the temperature of a moist (saturated) air parcel changes as it ascends or descends through the atmosphere. The SALR is often taken as 1.5°C per 1000 feet, although the actual figure varies according to the amount of water vapour present and also the temperature of the air parcel (an air parcel at a higher temperature can contain more water vapour than when at a lower temperature).

The SALR is less than the DALR because as a parcel of saturated air ascends and cools, water vapour condenses into water droplets, releasing latent heat into the parcel, which slows the cooling (and helps to maintain the air parcel's bouyancy). Conversely, if a saturated parcel descends and warms, water droplets will evaporate causing heat (latent heat of evaporaration) to be absorbed from the parcel, thus reducing the rate of warming (generally termed evaporative cooling).

Determining Stability

Air rises if it is warmer than its surroundings. Technically air doesn't rise because it is warmer; it rises because warm air is less dense than cold air, and thus more buoyant.

The vertical temperature profile of the atmosphere changes as different air masses dominate a region. If the temperature profile is known, the rate of change of temperature with height (the environmental lapse rate), and thus the stability of the atmosphere, at that point in time can be determined. Temperature profiles are plotted on aerological diagrams to determine the stabilty of the atmosphere or layers thereof.



A simplified aerological diagram, on which the temperature profile (and thus the environmental lapse rate) of the air mass is displayed by the orange line.

The temperature decreases with height except for the inversion layer D to E. In the layer A to B, the temperature lapse rate is superadiabatic, i.e. it is greater than the DALR.

The DALR and SALR are depicted by the white dashed lines.

The yellow dashed line depicts the cooling of a saturated air parcel displaced from point C and rising to E along the SALR. It would stop rising at E because its temperature at this point is the same as the environmental temperature and thus the air parcel loses its bouyancy.

An air mass is considered to be stable, unstable, neutral or conditionally unstable as follows:

- if a lifted parcel of air is cooler, and therefore denser, than the surrounding atmosphere, the parcel will tend to sink once the lifting mechanism ceases. Such an environment is defined as being STABLE;
- if a lifted parcel is warmer and less dense than the surrounding atmosphere, the lifted parcel will continue to rise once the lifting mechanism ceases. In this case the environment is defined as being UNSTABLE;
- if a lifted parcel is the same temperature as the surrounding air, the conditions are said to be NEUTRAL;
- in some situations the atmosphere is stable for unsaturated parcels of air but unstable if saturated. This is called CONDITIONAL INSTABILITY.

Referring to the diagram above, stable, unstable, neutral and conditionally unstable layers in the air mass can be determined by comparing the temperature lapse rates (orange line) of the air mass with the DALR and the SALR:

- any parcel (dry or saturated) forced to rise (by, for example, convection) between A and B, and cooling at either the DALR or SALR, will remain cooler than the environmental temperature and would therefore sink once forcing had ceased. The layer is therefore stable, as is the inversion layer above D;
- a dry parcel forced to rise through the neutrally stable layer between B and C will continue to rise only if forcing continues, because the parcel would be neither warmer or cooler than the environment;
- a saturated parcel rising through the conditionally unstable layer from C to D, and cooling at the SALR, would be warmer than the environment and thus continue to rise unaided. On the other hand, an unsaturated parcel forced to rise would cool at the DALR and be cooler than the environment, and therefore sink once any forcing had been removed;
- like the layer from A to B, all parcels, saturated or unsaturated rising between D and E would only continue to rise if they were forced upward, since the layer is stable.

In general, when the lapse rate of the air mass:

- is between the DALR and the SALR, the atmosphere is considered to be conditionally unstable;
- is steeper than the SALR, the atmosphere is considered to be absolutely stable;
- is the same as the DALR, the atmosphere is considered to be neutrally stable;
- is less steep than the DALR, the atmosphere is considered to be absolutely unstable.

For more information on lapse rates and atmospheric temperature profiles, readers can refer to the companion brochure in this series, *The Skew T -*

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