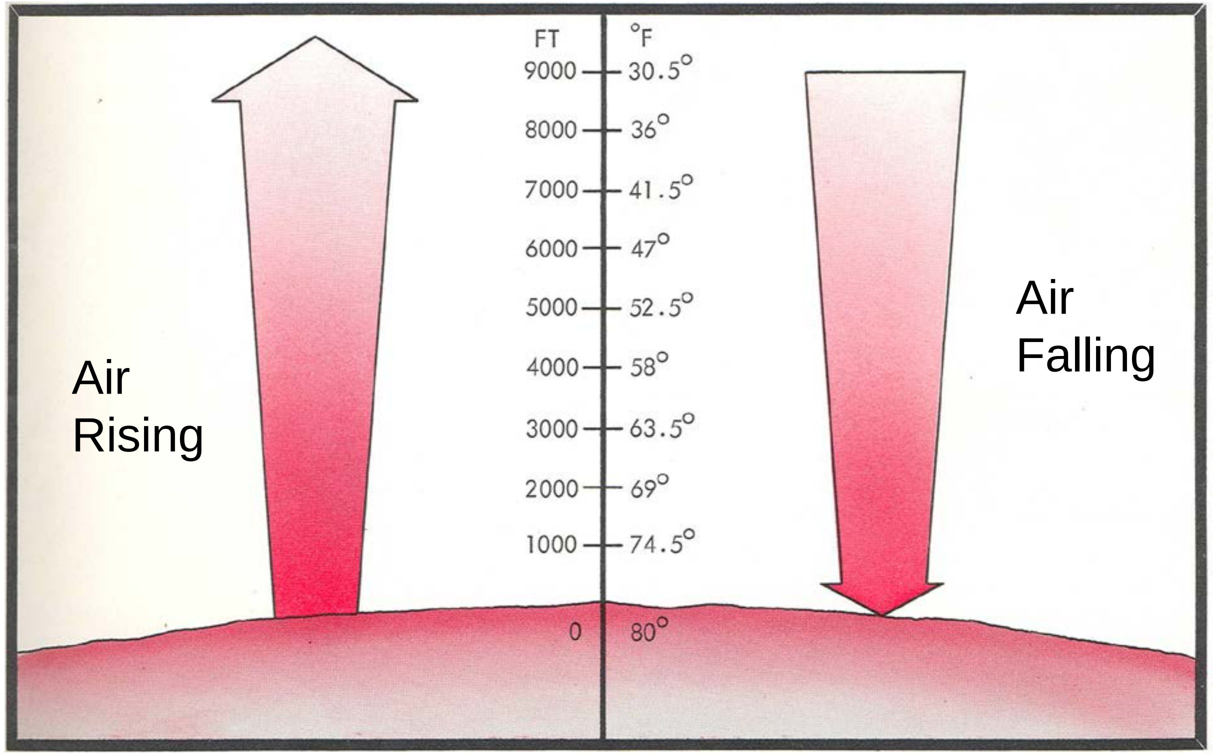
Principles of vertical motion and Atmospheric stability

Atmospheric Stability

- The resistance of the atmosphere to vertical motion.

- Stable air resists vertical motion
- Unstable air encourages vertical motion

↓ pressure
(expansion)
↑ volume
= cooling



↑ pressure
(compression)
↓ volume
= warming

Stable and Unstable Air

Characteristic	Stable Air	Unstable Air
Lapse Rate	Shallow	Steep
Cloud Type	Stratus Type	Cumulus Type
Precipitation	Uniform Intensity including drizzle	Showers
Visibility	Poor low level (Fog may occur)	Good, except in precipitation
Wind	Steady winds which can change with height	Gusty (Windy)
Turbulence	Generally smooth flying conditions	Turbulence may be moderate to severe

Vertical Motion & Stability

- Section A – Vertical Motions
- Section B – Stability
- Section C – Stability and Vertical Motions

Section A – Vertical Motions

- **Section A: Vertical Motions –** when an air parcel moves from one location to another, it typically has a horizontal component (wind) and a vertical component (vertical motion)
  - **Causes –** air may move upward or downward for a number of reasons
    - the most frequent causes are convergence and divergence, orography, fronts and convection

Vertical Motion & Stability

- **Convergence / Divergence**
  - **Convergence –** corresponds to a net inflow of air into a given area
    - it may occur when wind speed slows down in the direction of flow and/or when opposing airstreams meet
    - **Divergence –** the net outflow from a given area
    - winds may diverge when the wind speed increases in the direction of the flow and/or when an air stream spreads out in the downstream direction

Vertical Motion & Stability

- **Embedded thunderstorms are obscured by massive cloud layers and cannot be seen**

Vertical Motion & Stability

- **Orography –** air can be forced upward or downward when it encounters a barrier in Fig
- a simple example is orographic lifting
    - when wind intersects a mountain or hill, it is simply pushed upward
    - on the down-wind or lee side of the mountain, air moves downward

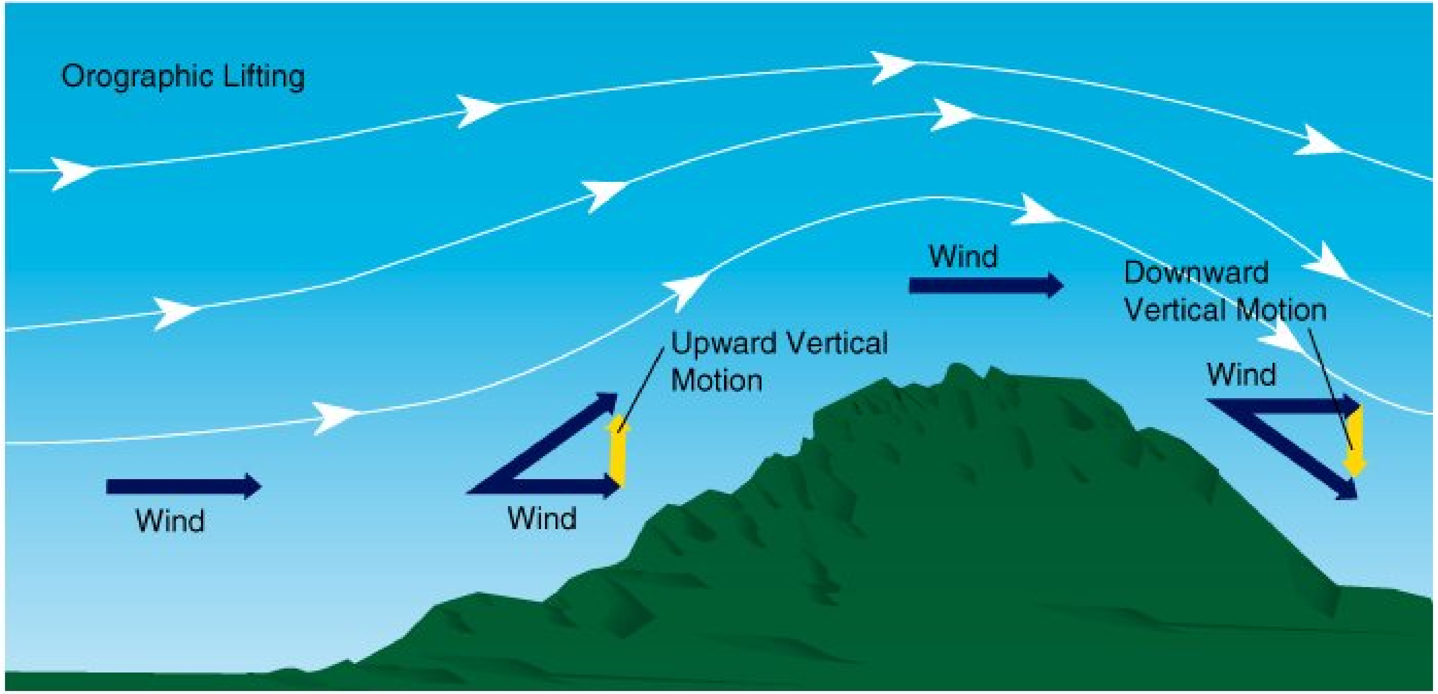


FIG 5-04

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Vertical Motion & Stability

- **Fronts –** when the atmosphere itself creates an obstacle to the wind, a barrier effect similar to a mountain can be produced
  - when a cold air mass is next to a warm air mass, a narrow, sloping boundary is created between the two called a front
- **Frontal lifting –** if either air mass moves toward the other, the warm air moves upward over the cold, dense air mass in a process called frontal lifting or in some special cases overrunning

Vertical Motion & Stability

- **Convection**
    - **Convective lifting –** as bubbles of warm air rise in the convective lifting process, the surrounding air sinks; and occurs under unstable atmospheric conditions

Vertical Motion & Stability

- **Mechanical Turbulence –C**haotic eddies are swept along with the wind, producing downward motions on their downwind side and upward motions on their upwind side Following Fig
  - rough air experienced when landing on windy days is caused by these small scale circulations

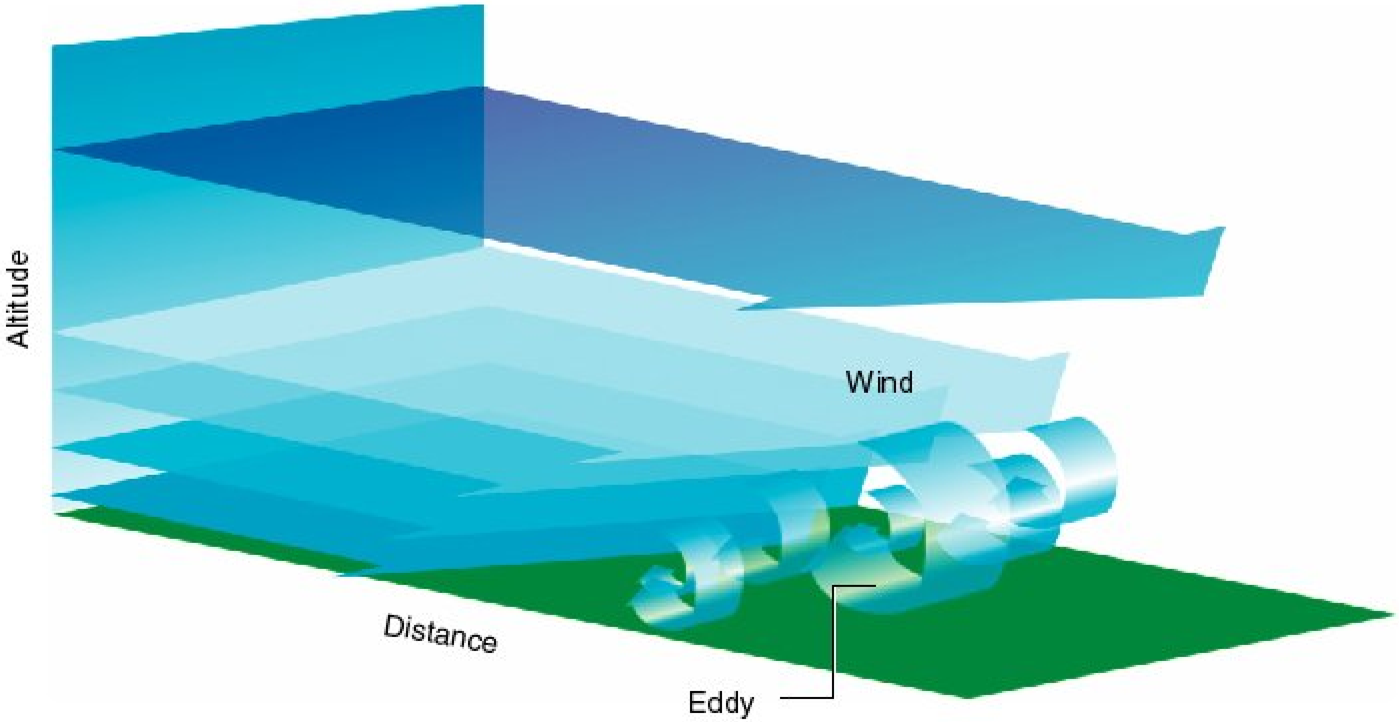

FIG 5-07

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Vertical Motion & Stability

- **Gravity Wave Motions –** under certain circumstances, air may be disturbed by small scale wave motions
  - that is, parcels of air may be caused to oscillate vertically
  - such oscillations that move away from the source of the disturbance are called atmospheric gravity waves because the earth’s gravity plays an important role in producing them
  - a mountain wave is one type of gravity wave

Section B – Stability

- **Section B: Stability –** a stable system may be defined as one that, if displaced or distorted, tends to return to its original location and/or configuration
  - an unstable system is one that tends to move away from its original position, once it has been displaced or distorted
  - a system with neutral stability remains in its new position if displaced or distorted

Vertical Motion & Stability

- **Atmospheric Stability –** a condition that makes it difficult for air parcels to move upward or downward
  - atmospheric instability is a condition that promotes vertical motions

Vertical Motion & Stability

- **Buoyancy –** the property of an object that allows it to float on the surface of a liquid, or ascend through and remain freely suspend in a compressible fluid such as the atmosphere

Vertical Motion & Stability

- **Archimedes' Principle –** when an object is placed in a fluid (liquid or gas), it will be subjected to a positive (upward) or negative (downward) force depending on whether the object weighs more or less than the fluid it displaces
    - can be thought of as the bowling ball / balsa wood-in-the-bucket-of-water concept

Vertical Motion & Stability

- **Positively buoyant –** if a parcel of air is displaced upward and becomes warmer than its surroundings, it is positively buoyant
  - it will accelerate upward (away from its original position); it is unstable
- **Negatively buoyant –** if a parcel of air is displaced upward and is colder than its surroundings, it is negatively buoyant
  - it will be accelerated downward (back to its original position); it is stable

Vertical Motion & Stability

- **Determining Atmospheric Stability –** there are three basic concepts that help determine stability
  - the dry adiabatic process, atmospheric soundings and lapse rates
    - **Dry adiabatic process –** cooling by expansion and warming by compression

Vertical Motion & Stability

- **Adiabatic cooling –** pressure always decreases with height
  - adiabatic cooling will always accompany upward motion
- **Adiabatic heating –** adiabatic heating will always accompany downward motion
  - the rate of temperature change associated with a dry adiabatic process is a constant: 3 degrees Celsius per 1,000 feet (5.4 degrees Fahrenheit per 1,000 feet)

Vertical Motion & Stability

- **Understand (cloud-free) air flowing upslope will cool at the rate of approximately 3 degrees Celsius per 1,000 feet**

Vertical Motion & Stability

- **Soundings –** a measurement of meteorological conditions between the ground and some higher level in the atmosphere
- **Radiosondes –** the most common meteorological soundings are made via freely rising, unmanned, instrumented balloons called radiosondes or rawinsondes

Vertical Motion & Stability

- **Lapse Rates –** an important stability measurement that can be determined from a sounding
    - the change of temperature with altitude for a given atmospheric layer
  - Lapse rate (LR) = T (bottom) – T (Top) / DELZ
    - T (bottom) = temperature at the bottom of the layer
    - T (top) = temperature at the top of the layer
    - DELZ = thickness of the layer

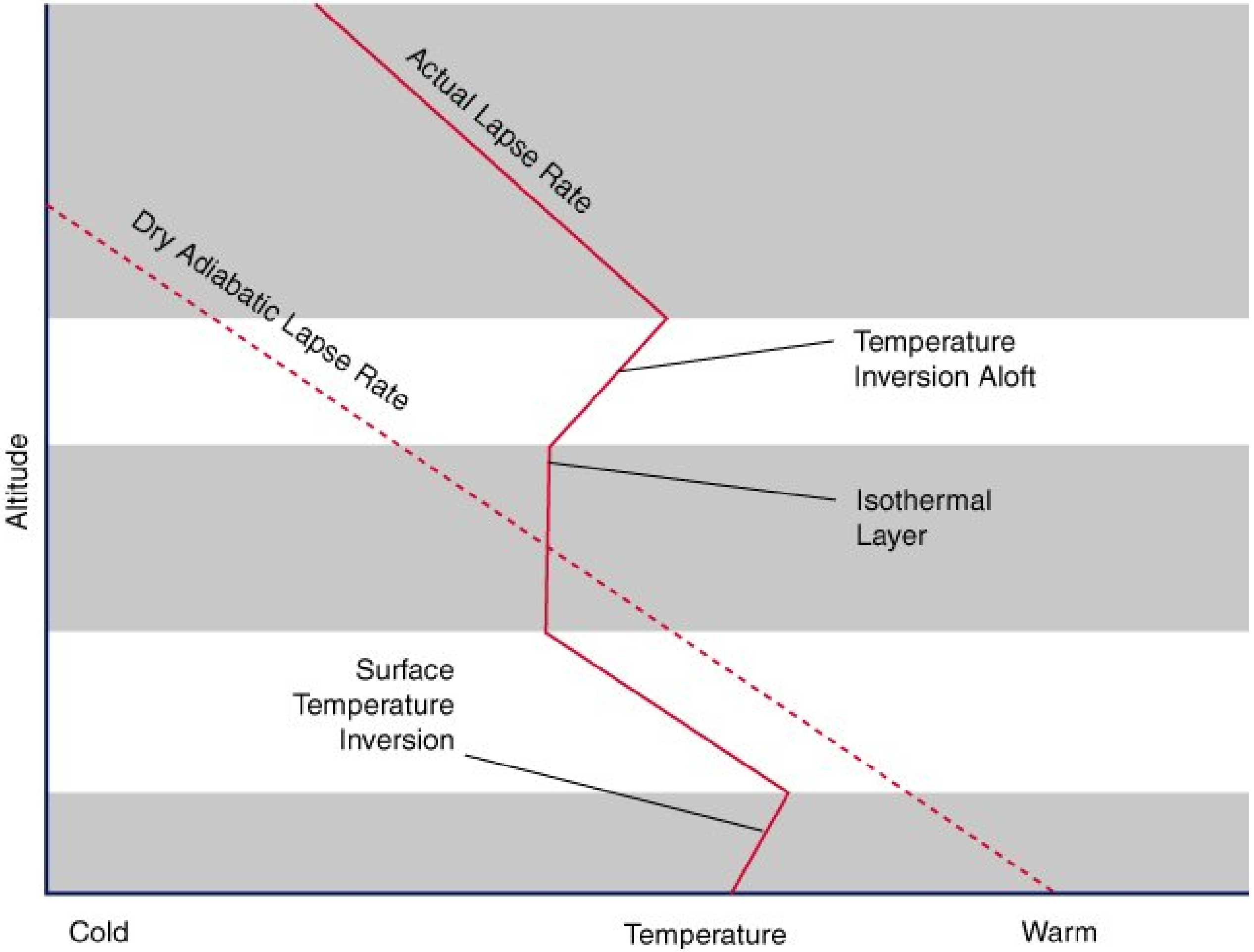

FIG 5-14

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Vertical Motion & Stability

- **Dry adiabatic lapse rate (DALR) –** the rate at which the temperature of a dry parcel of air decreases as it ascends is also a useful reference in stability determinations
  - equal to 3 degrees C per 1,000 feet

Vertical Motion & Stability

- **Isothermal layer –** no change in temperature with height (LR = 0)
- **Inversion layers –** temperature increases with height (LR < 0)
- **Surface-based inversions –** often form at night and may be the source of wind shear problems

Vertical Motion & Stability

- **Stability Evaluation**
    - **Stability criteria; following Fig**
    - select the layer in the sounding in which you are interested
  - within the layer, compare the actual LR and DALR
  - determine which of the following stability criteria are satisfied
    - LR > DALR – absolutely unstable
    - LR = DALR – neutral
    - LR < DALR – stable

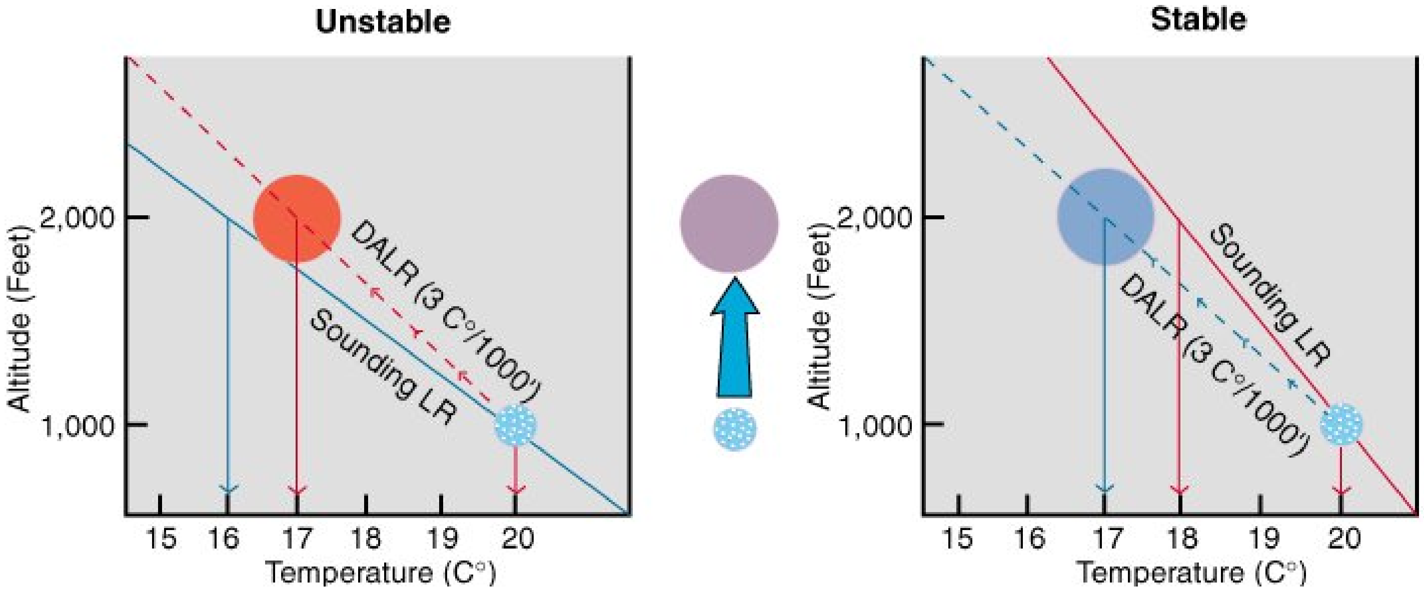

FIG 5-17

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Section C – Stability and Vertical Motions

- **Section C: Stability and Vertical Motions**
  - **A stable air mass is more likely to have smoother air than an unstable air mass**
  - **The formation of either predominantly strati form or predominately cumuliform clouds depends upon the stability of the air being lifted**

Vertical Motion & Stability

- **Conditions favorable for the formation of a surface-based temperature inversion are clear, cool nights with calm or light winds**
- **The stability of an air mass is decreased by heating it from below**

Summary

- Vertical motions in the atmosphere are critical for aviation because of their role in the production of turbulence, clouds, and associated phenomena.
- Upward and downward motions are forced by fronts, mountains, warm surfaces, and converging and diverging airstreams (Lester, 2006).