8. ATMOSPHERIC STABILITY

Reading Assignment:
• A&B: Ch. 5  (p. 118-132)
• LM:   Lab# 8

1. Lapse Rates

Lapse rate: - rate at which temperature decreases with height.
- in [K / km] or [°C / km]
- a positive value indicates decrease of T with height

• Troposphere - general decrease in T with height

• Three types of lapse rates:
  a) ELR - Environmental Lapse Rate
  b) DALR - Dry Adiabatic Lapse Rate
  c) SALR - Saturated (wet) Adiabatic Lapse Rate

a) Environmental Lapse Rate
• Actual air T we measure: i.e. Observed air T at any height
• Varies in space and with time
• Upper air T sounding
  http://weather.unisys.com/upper_air/skew/skew_KILN.html
b) **Dry Adiabatic Lapse Rate**

- Rate which a non-saturated air parcel cools as it rises
- Rate:

\[
\frac{-10 \, K}{1000 \, m} = \frac{-1 \, K}{100 \, m} = \frac{-10 \, K}{1 \, km}
\]
Why does this decrease in $T$ occur?

Recall:

- **Adiabatic Process** - a physical change of the state of the air parcel that does not involve exchange of energy with the air surrounding the air parcel.
- Pressure and density decreases with height
  $\Rightarrow$ As air parcel rises - expands & cools

**c) Saturated Adiabatic Lapse Rate**

- Air is saturated - condensation occurs
  $\Rightarrow$ Release of latent heat of vaporization ($L_v$)
  $\Rightarrow$ Keeps the parcel warmer than it would otherwise
  $\Rightarrow$ Decrease in $T$ with height is not as great
- Dependent on the amount of moisture in the atmosphere
- More moisture in the atmosphere the greater will be the release of $L_v$ $\Rightarrow$ warmer the air will remain
- Range: 4 to 9 K km$^{-1}$
  More moisture Less moisture
• When air cools to the $T_{dew}$ (saturation!), then convert from DALR to SALR

• At base of clouds $T_{air} = T_{dew}$ = Lifting condensation level
2. Atmospheric Stability

- Talked about air parcels moving up & down in the atmosphere but have not talked WHY

**Stability:** Tendency of an air parcel to move vertically following an initial dislocation (up or down)

Atmospheric stability is dependent on $T$ and $\rho$  
- The thermal stratification of the air: vertical temperature profile, environmental lapse rate, ELR
- To determine stability, vertical motions of air parcels are assumed to be adiabatic processes

**Principle:**

- Temperature differences between an air parcel and its surrounding lead to density differences and thus to buoyancy forces in upward (positive) or downward (negative) direction.

  ➔ Air warmer than its surroundings will tend to rise (because of its lower density)

  ➔ Air cooler than its surroundings will tend to sink (because of its greater density)

  ➔ Air at the same temperature as its surroundings will tend to remain at the same height (because there is no density difference)
**In Practice:**

- Can use the lapse rates to determine:
  - Which direction the air will move?
  - How far the air will move?

**Method**

- Compare the environmental air $T$ (given by the ELR) with the DALR or SALR
- Move along the dry (or saturated adiabat)
- If $T$ on the adiabat is **less** than ELR - **STABLE**

![Diagram showing stability conditions](image1)

- If $T$ on the adiabat is **greater** than ELR - **UNSTABLE**

![Diagram showing stability conditions](image2)
• If T on the adiabat is **same** than ELR - **Neutral**

• Conditionally unstable or conditional instability: stable or unstable depends on whether the air is saturated or dry
ELR is not normally just a simple line (see Lab 8)

- Air pollution will get trapped under an inversion
  - Inversion - $T$ increases with height
  - Lapse - $T$ decrease with height
If there are unstable conditions and the air rises
  • Cools as it rises
  • May cool down to the dew point $T$
  • Condensation - clouds

Where air sinks - warms up
  • $T$ moves away from $T_{dew}$ - so no clouds will form
  • Clear air

![Diagram showing zones of rising and sinking air](image-url)
Problem:

An air parcel at the surface is not saturated and has a Temperature of 30°C and $T_{dew}=25°C$. Assuming it moves adiabatically and the SALR is $-8.5 \, ^\circ C \, km^{-1}$ what will the air T be at 3000 m?