Air Parcel

- To demonstrate stability, a parcel of air is used
- Expands and contracts freely
- Always has uniform properties throughout

Air Parcel Movement:
Why does rising air expand and cool?

- Lift parcel: pressure lowers ⇒ air molecules push outward ⇒ EXPANDS
  - Energy is used to expand so molecules slow down ⇒ COOLS
- Lower parcel: pressure increases ⇒ COMPRESSES parcel
  - Compressing increases molecular energy ⇒ WARM
Adiabatic Process

- **Adiabatic Process**: when a parcel expands and cools or compresses and warms WITHOUT exchange of heat with the surrounding environment.
- In *unsaturated* air, a parcel of air cools or warms at the *Dry Adiabatic Rate* (about $10^\circ$C/km)
- The dew point also decreases as a parcel is raised “Dry Adiabatically”
  - Dew Point Lapse Rate: $2^\circ$C/km

Moist Adiabatic Process

- As the parcel rises, temperature and dew point get closer together and are eventually equal $\Rightarrow$ condensation
  - $T_d$ decreases at a slower rate than $T$
- Since latent heat is released inside the parcel during condensation, the temperature will now decrease at a slower rate
  - Moist Adiabatic Lapse Rate: $\sim6^\circ$C/km

Stability

- **Stable Equilibrium**: if the ball is displaced it will return to its original position
- **Unstable Equilibrium**: if the ball is displaced it will accelerate away from the equilibrium point
- **Neutral Equilibrium**: if the ball is displaced it will stay in its new location.
Stability in the Atmosphere

- At any height, if the temperature of the parcel is greater than the environment, the parcel will rise (and vice versa).
  - Temperature profile of the environment is received from radiosonde data.
- We can look at the lapse rate of the environment to see what an air parcel will do if it is displaced.
- In a stable atmosphere: a displaced parcel will return to its initial position.
- In an unstable atmosphere: a displaced parcel will continue to move in the initial direction of motion.

Conditions for Stability

- Absolutely Stable
  - Environmental lapse rate is less than moist adiabatic lapse rate.
  - Lapse rate < 6°C/km
- Absolutely Unstable
  - Environmental lapse rate is greater than dry adiabatic lapse rate.
  - Lapse rate > 10°C/km
- Conditionally Unstable
  - Environmental lapse rate lies between moist and dry lapse rates.
  - Lapse rate between 6-10°C/km

Stable Atmosphere

- The parcel of air is colder than the environment since its lapse rate is greater.
- Therefore, a displaced parcel will return to its original position: vertical motion is suppressed.
- What conditions produce a stable atmosphere?:
  - Air aloft warms (by warm advection) and surface air cools (by radiative cooling at night or cold advection)
  - Subsiding air (frequently associated with a ridge of high pressure)
  - Inversions represent very stable air.
  - Tropopause is often very stable, as the stratosphere is warmed due to ozone.
Unstable Atmosphere

- Buoyant parcels are accelerated upward
  - As parcels rise and cool, they are still warmer than the environment since the environment is cooling faster than the adiabatic lapse rate
- Larger instabilities lead to larger updrafts
- Large updrafts lead to the formation of cumulonimbus clouds and thunderstorms

Causes of Instability

- Cooling of the air aloft:
  - Winds bringing in colder air (cold advection)
  - Clouds (or the air) emitting IR radiation to space (radiational cooling)
- Warming of the surface air:
  - Daytime solar heating of the surface
  - Winds bringing in warm air (warm advection)
  - Air moving over a warm surface

Conditionally Unstable

- Environmental lapse rate is between moist and dry adiabatic lapse rates (common in atmosphere)
  - Ex: environmental rate of 7°C/km
- Conditional instability means that if unsaturated air (stable) could be lifted to a level where it becomes saturated, instability would result
- Figure on next slide demonstrates conditional instability
Conditional Instability

Skew-T/Log-P Diagram

Stability on a Skew-T
Examples

Layer between 700mb and 800mb is absolutely stable
Layer between 850mb and 950mb is absolutely unstable

Examples

Layer between 600mb and 700mb is conditionally unstable

Lifting a Parcel

- Initially, a parcel being lifted will cool at the Dry Adiabatic Lapse Rate
- When the dry adiabat from the surface temperature meets the saturating mixing ratio line from the surface dew point, the parcel will have reached saturation and condensation can occur
- This is called the Lifted Condensation Level (LCL)
Lifting a Parcel

- Once a parcel has reached the LCL, it will continue to rise, but instead cool at the Moist Adiabatic Lapse Rate.
- Often the temperature of the parcel at the LCL is still cooler than the temperature of the environment (negative area).
- If the parcel is lifted further it will reach its Level of Free Convection (LFC), the point at which the parcel becomes warmer than the environment and will be accelerated upward by buoyancy (positive area).
- As it continues to rise it will eventually reach a point where it is cooler than the environment again. This is the Equilibrium Level (EL).

Sources of Lift

- 4 ways to lift a parcel to the LCL
  - Frontal Boundary
  - Orographic
  - Convergence
  - Convection
CAPE

- CAPE = Convective Available Potential Energy
- CAPE is the energy available to a rising parcel to accelerate it
- On a Skew-T, CAPE is proportional to the area between the parcel’s temperature and the environment’s when the parcel is warmer
- CAPE gives an upper limit on how high updraft speeds can get in a severe storm
- High values of CAPE are associated with the possibility of strong convection
  - Large hail requires very high CAPE values

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CIN

- CIN = Convective Inhibition
- This is the energy the must be overcome in order to lift a parcel to its LFC
- On a Skew-T, CIN is proportional to the area between the parcel’s temperature and the environment’s when the parcel is colder
- Large values of CIN will prevent the formation of storms, but often the presence of some CIN can add strength to a storm if this energy is overcome
CAPE and CIN

• Finding cloud levels
• Forecasting precipitation type
• Forecasting max/min temperatures
• Forecasting the possibility of microbursts

More Uses for Skew-T's

• Finding cloud levels – useful for aviation

Clouds are most likely present at 3 layers in this skew-T. Can you find them?
More Uses for Skew-T’s

- Forecasting precipitation type

The 0°C isotherm in this skew-T shows that the precipitation will fall through a layer which is above freezing, thus implying that freezing rain is possible.

More Uses for Skew-T’s

- Forecasting maximum/minimum temperature

- Forecasting the possibility of microbursts

The “inverted V” shape is a sign of possible dry microbursts (isolated pockets of strong winds associated with thunderstorms).
A few skew-T reminders:
- Plot the temperature (or dew point) ON the pressure line that is given.
  - i.e. 25°C at 900mb
- When plotting temperature, remember the temperature lines (isotherms) are slanted.
  - i.e. 25°C at 300mb is NOT going to be directly above 25°C at 1000mb
- The parcel of air begins at the surface temperature but follows either the dry or moist adiabatic lapse as it rises in the atmosphere (NOT the plotted temperature profile = environmental lapse rate)