Hydrostatic Stability

Assumptions on a meteorological parcel

1. Temp changes occur adiabatically
   \[ dq = 0 \]
   \[ q = \text{amt. of heat taken up by or released from parcel} \]

2. \( p_{\text{env}} = p_{\text{par}} \)

3. \( \rho_{\text{env}} \neq \rho_{\text{par}} \)

4. \( w_{\text{par}} \text{ is small so that } KE_{\text{par}} \text{ is small} \)

5. parcel mass = 1 kg
Characteristics of a Parcel (Dry-Moist)

- Precipitation loading due to condensation mass
- Moisture condenses
- Heat released within evaporation cooling on edges
- Mixing with env.
Effects in Cloud/Convection not addressed by Parcel Theory (From AF Manual)

1. **dynamic entrainment** – mixing of convection element with environment (reduces LWC and buoyancy).

2. **vertical mixing** – interaction of top of convection element with environment

3. evaporative cooling by falling precipitation

4. skin friction and form-drag between rising thermal/cloud element and the ambient environmental winds
More Effects...

5. compensatory subsidence in the environment around the rising thermal/convective cloud element

6. buoyancy reduction due to weight of condensed water

7. drag of falling precip on UVM
And Even More Effects...

8. Radiation to and from cloud boundaries

9. Internal viscous friction (very small)

10. Different effects for coalescence vs. ice-crystal precip processes
Skew-T Info

- "process contours" - maintain tenets of parcel theory
  - ignore detraction effects

\[ \Gamma_d = \text{dry adiabatic, 1st law of thermo} \]
\[ \text{lifting} = \text{expansion} = \text{cooling} \]
\[ \text{sinking} = \text{compression} = \text{warming} \]

\[ \Gamma_s = \text{pseudoadiabatic, accounts for latent heat of condensation} \]
Skew-T Info

- Buoyancy and Stability

- Displace a parcel upward
  - If $T_{vp} > T_{ve} \rightarrow$ parcel has positive buoyancy force and accelerates upward.
  - If $T_{vp} < T_{ve} \rightarrow$ parcel has negative buoyancy force and returns to equilibrium position.
Skew-T Info

We Test Parcels Against Observed Environmental Data
Skew-T Info

Testing for static stability:

1. Stable

- Layer between A and B is stable for dry and moist
2. Absolutely Unstable

- layer between A and B is absolutely unstable for moist and dry
Skew-T Info

3. Conditionally Unstable

- layer between A and B is unstable for moist and stable for dry
Skew-T Info

- Lapse Rate: the change of temp with height
  - $\gamma = \frac{dT}{dz}$
  - Dry Adiabatic Lapse Rate = 9.78°C/km
Skew-T Info

- **Stability in Dry Environment**

\[
\begin{align*}
\Gamma_d &> \gamma \\
\Gamma_d &= \gamma \\
\Gamma_d &< \gamma
\end{align*}
\]

- stable
- neutral
- unstable
Skew-T Info

- Stability in Moist Environment

\[ \Gamma_s > \gamma \quad \text{absolutely stable} \]

\[ \Gamma_s = \gamma \quad \text{saturated neutral} \]
Skew-T Info

Γ_d > γ > Γ_s  conditionally unstable

Γ_d < γ  absolutely unstable
Skew-T Info

- Thickness of a Layer
  - Equal area of $T_v$ curve
  - In fact, $\Delta z = \frac{R_d \bar{T}_v}{g} \ln \left( \frac{P_L}{P_u} \right)$
Equal Area Determination

- thickness calculations
- Mean T and q for Lifted Index
Convective Available Potential Energy

\[
\text{CAPE} = R_d \int_{P_{LFC}}^{P_e} [T_p(p) - T_e(p)] d\ln p
\]

- \(P_e\) = pressure at equilibrium level
- \(P_{LFC}\) = pressure at LFC
- \(T_p(p)\) = temp. of parcel
- \(T_e(p)\) = temp. of ambient environment
Convective Inhibition (CIN)

- CIN = amount of energy needed to overcome stability in atm.

\[
\text{CIN} = R_d \int_{P_o}^{P_{\text{LFC}}} [T_p(p) - T_e(p)]d\ln p
\]

- $P_o$ = surface pressure

- $< 10 \text{ J kg}^{-1}$ convection too early
- $\sim 15 \text{ J kg}^{-1}$ early development prevented
- $> 150 \text{ J kg}^{-1}$ convection prevented entirely