

Atmospheric Stability/Skew-T Diagrams

Meteorology 3110

Air Parcel

- Consider a parcel of infinitesimal dimensions that is:
- Thermally isolated from the environment so that its temperature changes adiabatically as it sinks or rises.
- Always at the same pressure as the environmental air at the same level, assumed to be in hydrostatic equilibrium.
- Moving slowly enough that its kinetic energy is a negligible fraction of its total energy.

Stability

- Stability describes how air parcels react to an initial vertical push by some external force.
- Forced to return to its original position: stable.
- Continues to accelerate away from its original position without outside help: unstable.
- Continues to move away from its original position without accelerating: neutral.

Stability cont.

- Consider a small disturbance from equilibrium....
 - Note: Primed values refer to the PARCEL.
- $P = P'$
- Adiabatic, displacements on small time scales.

Lapse Rates

- Dry adiabatic lapse rate
 - Rate at which “dry” parcel changes temperature if raised or lowered in the atmosphere.
 - 10°C/km
- Moist adiabatic lapse rate
 - Rate at which “moist” parcel changes temperature if raised or lowered in the atmosphere.
 - 6°C/km
- Environmental lapse rate, Γ
 - Temperature structure of the environment.

$\Gamma < \text{Parcel Lapse rate}$

- Buoyant acceleration < 0 .
- Buoyant force is opposite the displacement (negatively buoyant).
- Positive restoring force.
- Hydrostatically stable or positive stability.

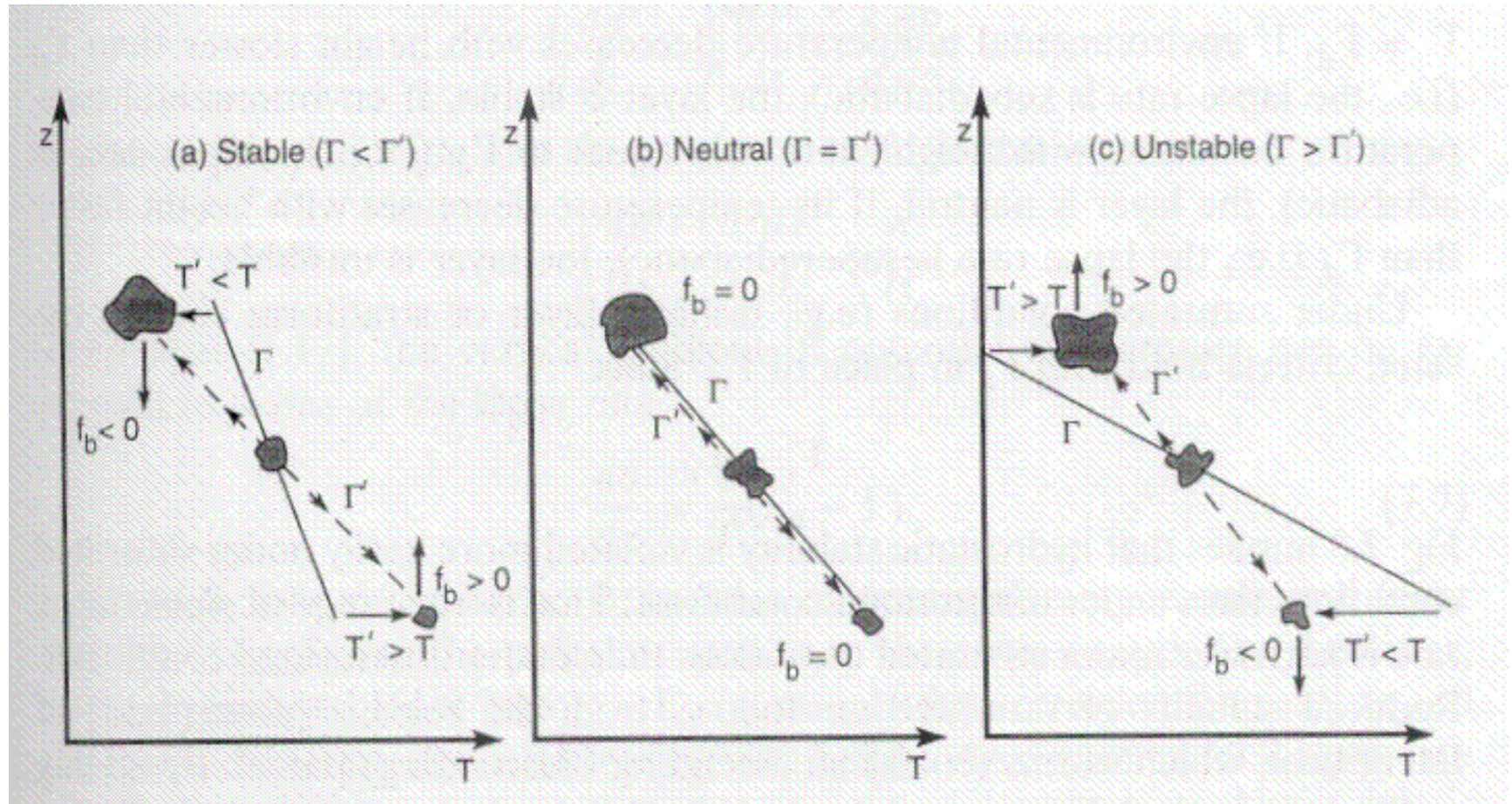
Γ = Parcel Lapse Rate

- Buoyant acceleration = 0.
- No restoring force.
- Displacements are met without opposition.
- Hydrostatically neutral or neutral stability.

$\Gamma >$ Parcel Lapse Rate

- Buoyant acceleration > 0
- Buoyant force in direction of displacement.
- Negative restoring force.
- Hydrostatically unstable or negative stability.

Stability - Visually



Stability – Visual cont.

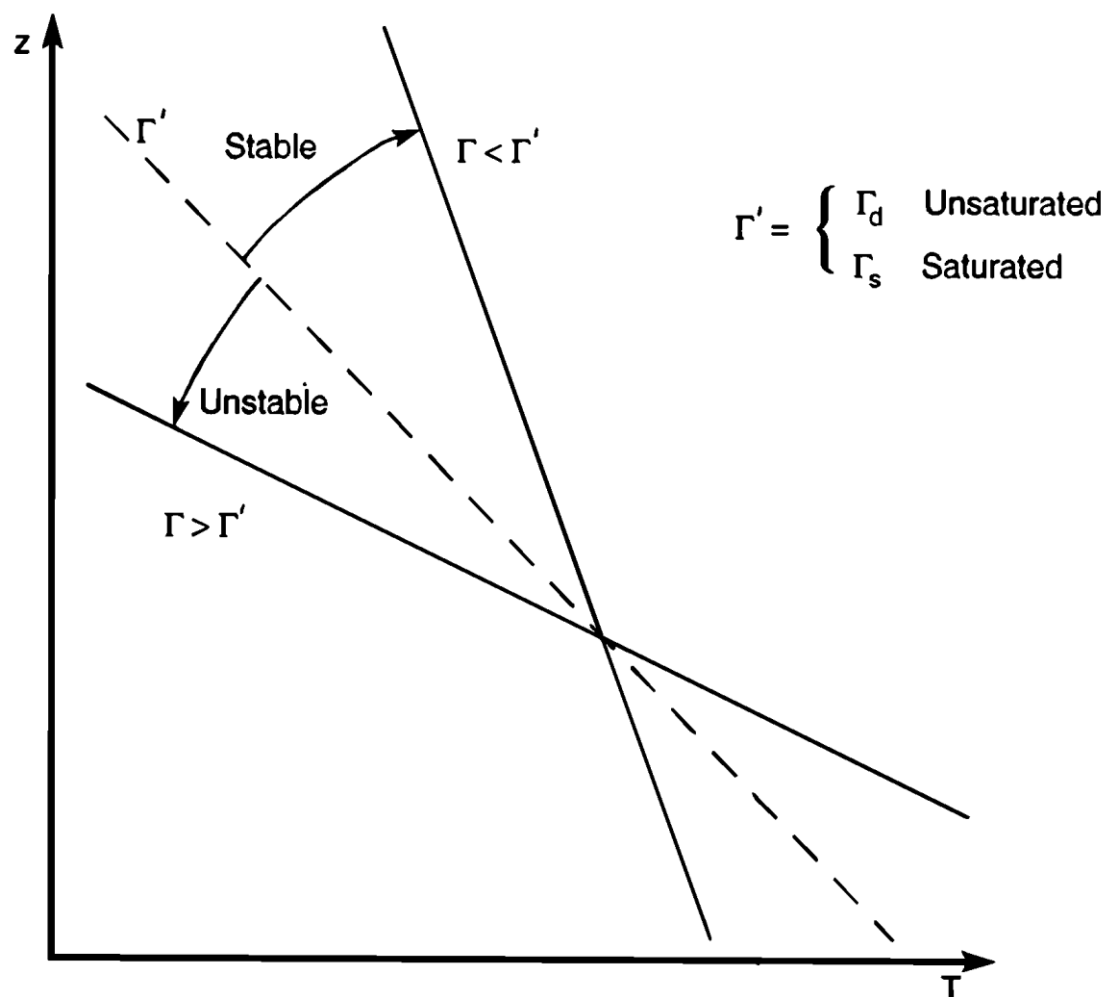
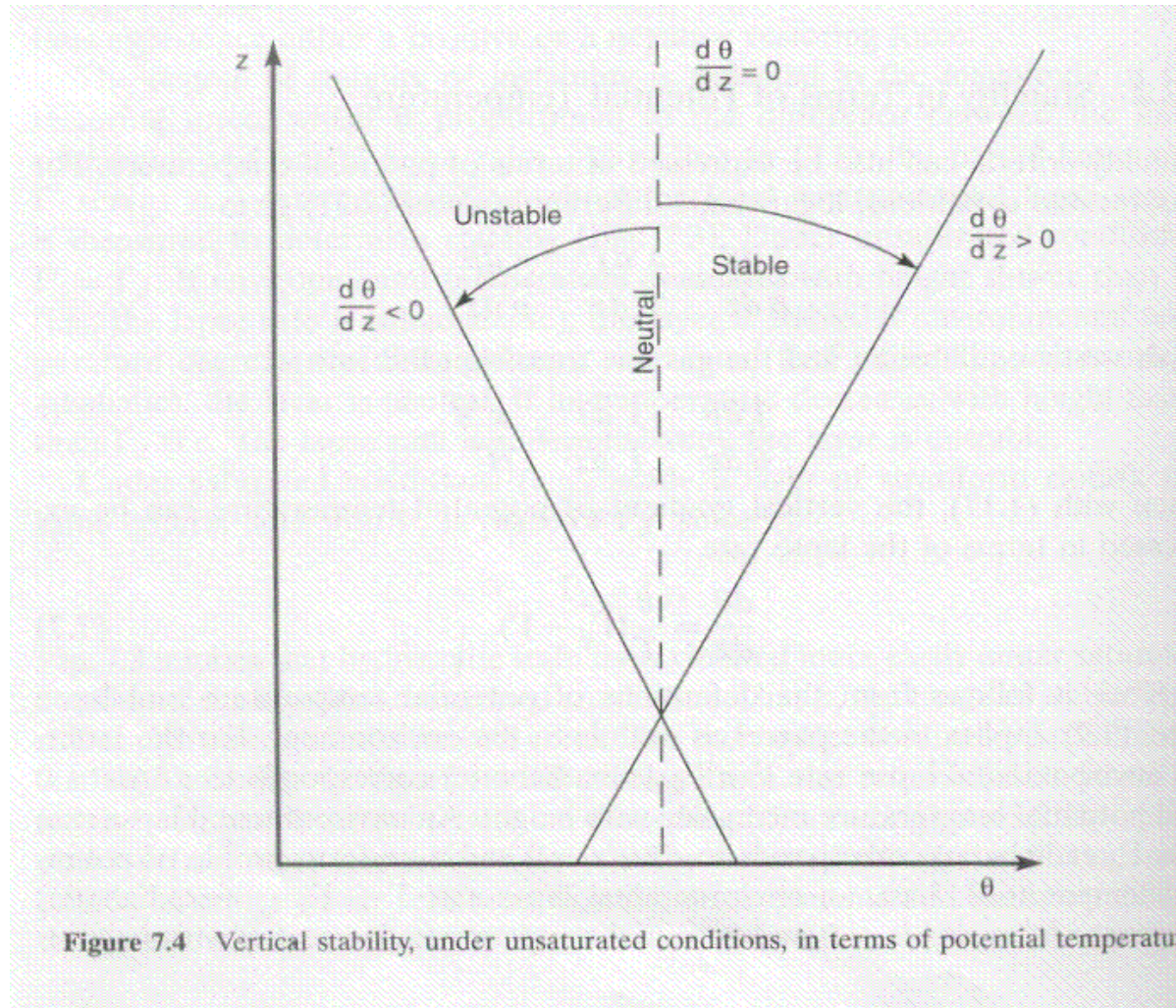


Figure 7.3 Vertical stability in terms of temperature and the environmental lapse rate Γ .

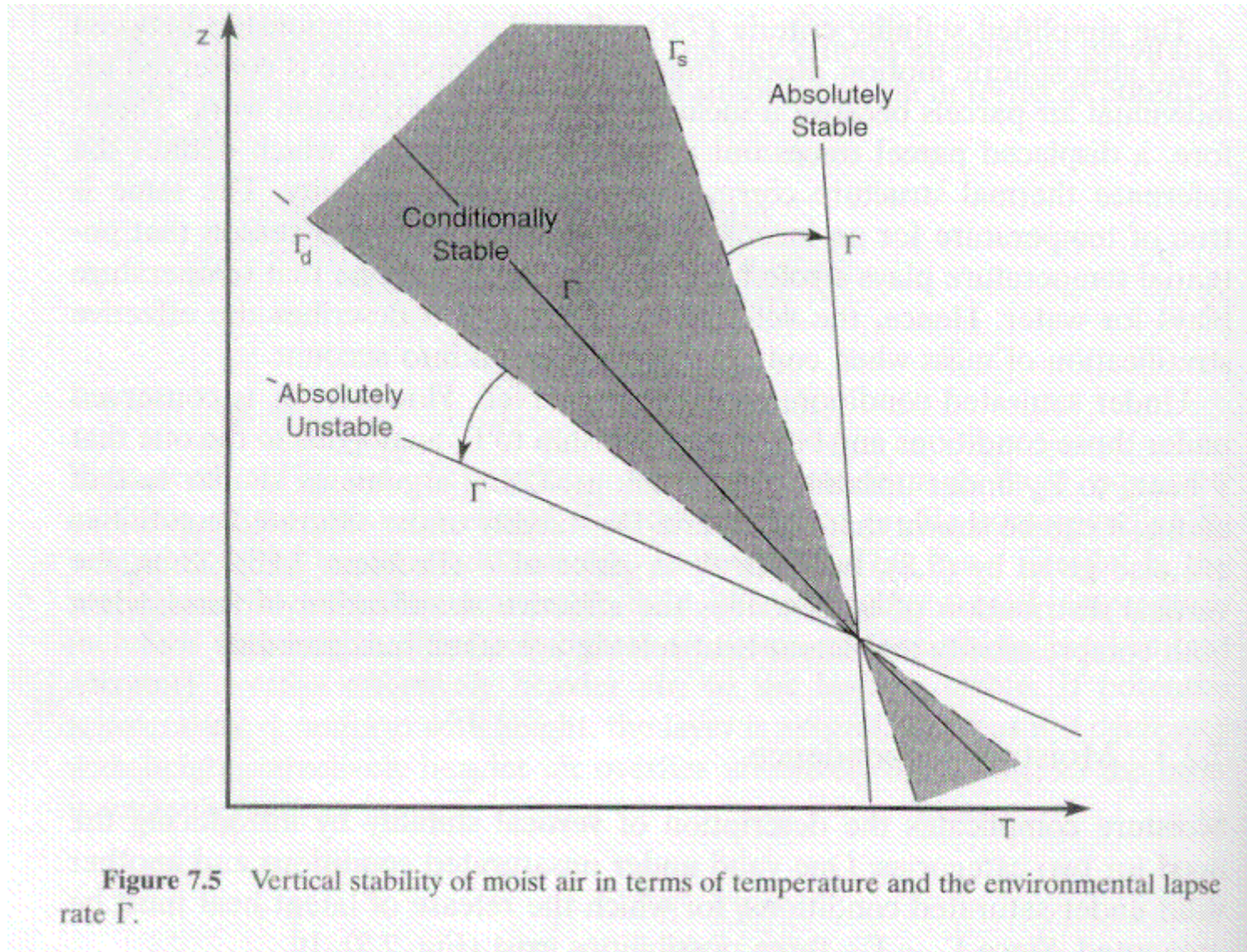
Stability - Theta



Moisture

- $\Gamma < \Gamma_m < \Gamma_d$
 - Absolutely stable.
- $\Gamma > \Gamma_d > \Gamma_m$
 - Absolutely unstable.
- $\Gamma_m < \Gamma < \Gamma_d$
 - Conditionally unstable.
 - Stable for unsaturated conditions.
 - Unstable for saturated conditions.

Conditional Stability



Vertical Motion

- Stability determines a layer's ability to support vertical motion and transfer of heat, momentum, and constituents.
- How do you get vertical motion?
 - Frontal boundaries (airmass differences)
 - Topography
 - Convergence (continuity equation)
 - Differential heating

Changes in Lapse Rate

- Environmental Lapse Rate can change over time.
- Non-adiabatic heating and cooling
- Solid advection
- Differential advection
- Vertical motion

Thermodynamic Diagrams

- Let us plot the vertical structure of the atmosphere.
- Tephigram
- Stuve Diagram
 - Pseudo-adiabatic chart
- Skew-T, log P diagram
 - Most used operationally by forecasters.

Skew-T Diagram

- Y-Axis is logarithmic in pressure.
- Isotherms are “skewed” 45° from lower left to upper right.
- Dry adiabats: slope from upper left to lower right. Label in degrees Celcius.
- Saturation or “moist” adiabats – curved
 - (green on official charts)
- Mixing ratio lines: dashed and slope a little from lower left to upper right (g/kg).

Movement

- If air is dry (not-saturated), θ is conserved.
 - Adiabatic, move along a dry adiabat or line of constant θ .
 - Mixing ratio does not change.
- If air is saturated, moisture condenses or evaporates, heat released impacts the temperature.
 - θ_e and θ_w keep the same value.
 - Mixing ratio changes.

Temperatures

- Potential temperature
 - Conserved in an adiabatic process
 - Dry adiabat
- Wet-bulb temperature
 - Conserved in a moist adiabatic process
 - Moist adiabat
- Equivalent potential temperature
 - Raise parcel until all moisture has condensed out and bring parcel back to 1000mb.
 - Used to compare parcels with different moisture contents and temperatures.

Important Variables

- Mixing ratio (w)
 - Use w line through T_d .
- Saturated mixing ratio (w_s).
 - Use w line through T .
- $RH = 100\% (w/w_s)$
- Vapor pressure (e)
 - Go from T_d up isotherm to 622mb and read off mixing ratio in mb.
- Saturation vapor pressure
 - Use T , not T_d .

More Variables

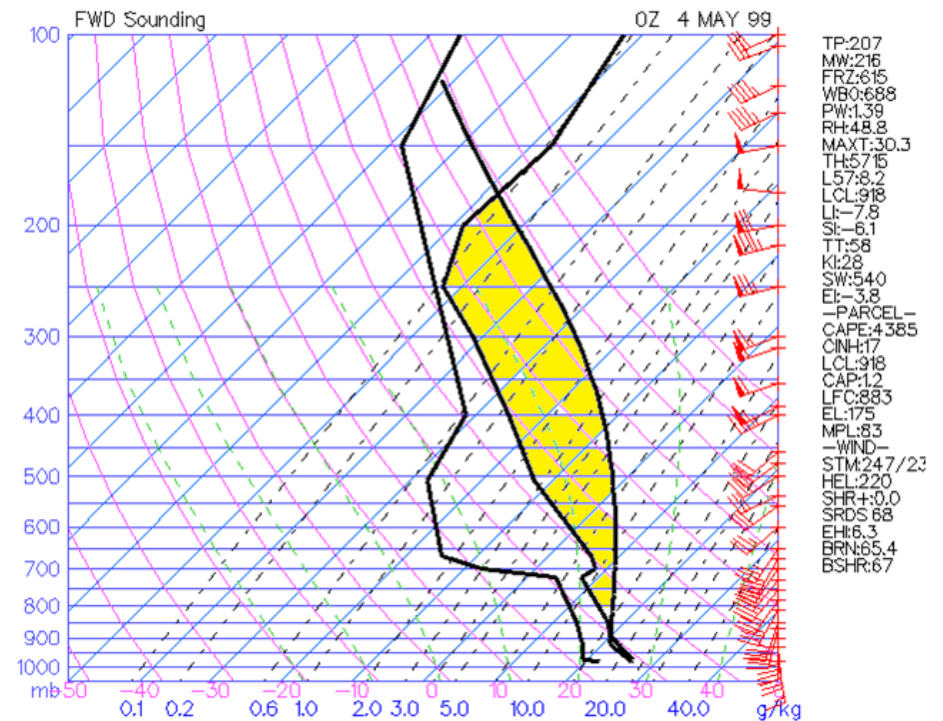
- Wet-bulb temperature (T_w).
- Wet-bulb potential temperature (θ_w).
- Equivalent temperature (T_e).
- Equivalent potential temperature (θ_e).

Important Levels

- LCL – lifting condensation level
 - Where lifted air becomes saturated.
- LFC – level of free convection
 - Where lifted air becomes positively buoyant.
- EL – Equilibrium level
 - Where lifted air becomes negatively buoyant up high.
- CCL – Convective condensation level.
 - Height to which a parcel of air would rise adiabatically to saturation from surface heating.

CAPE

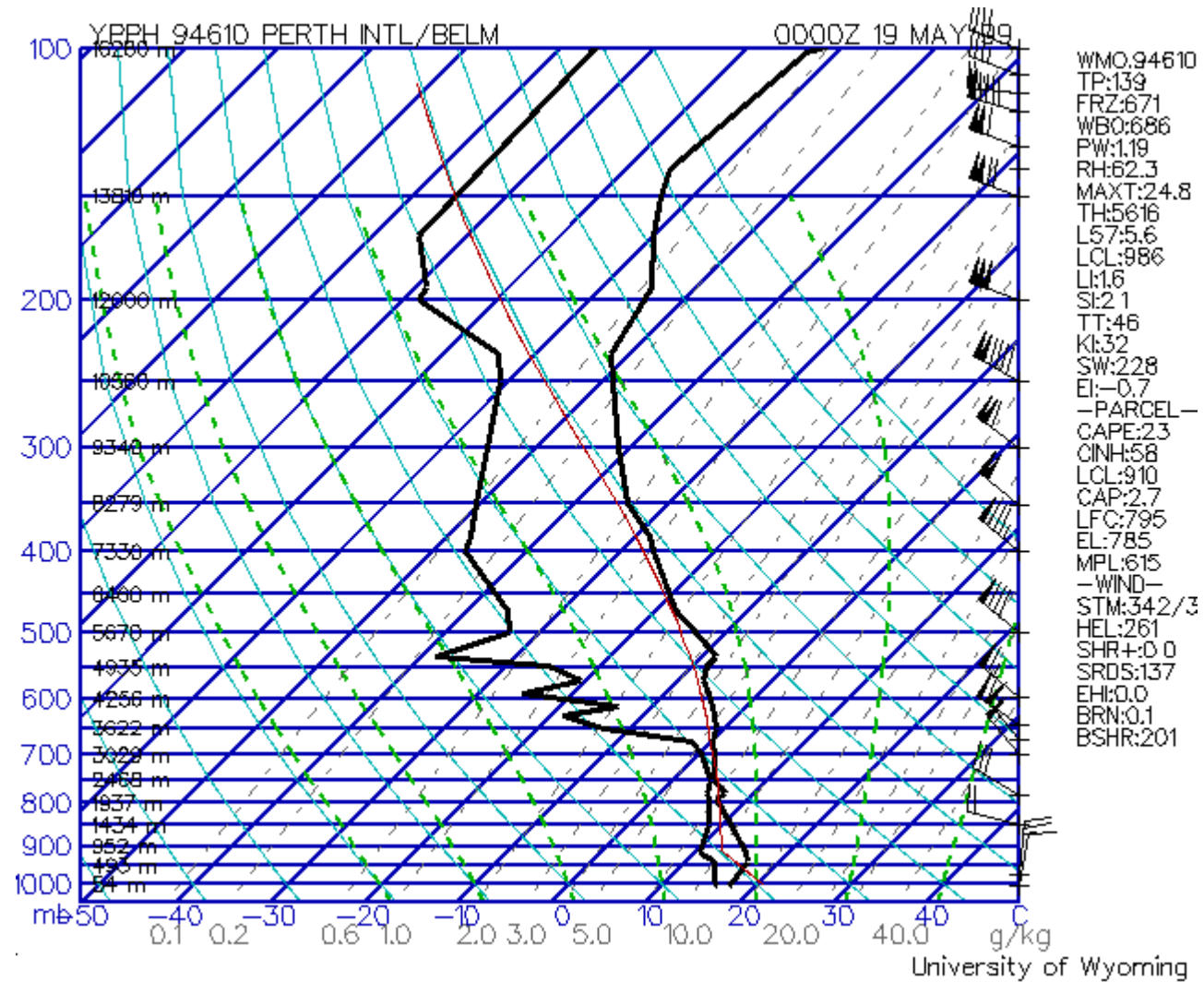
- CAPE = Convective Available Potential Energy
- Positive area between parcel path and environmental profile.
- Gives energy available to be converted to kinetic energy and upward motion.



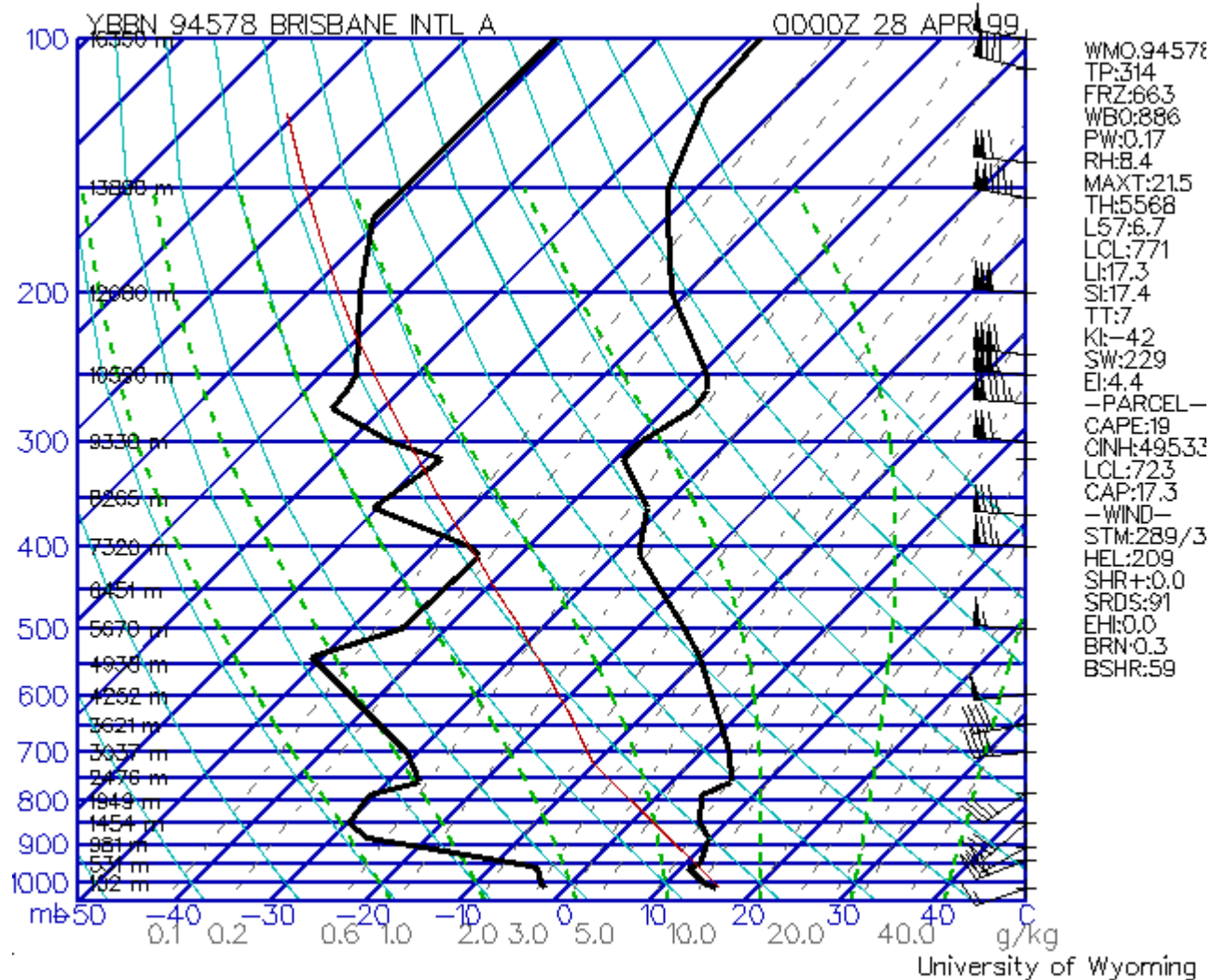
Stability Indices

- LI – Lifted Index
- SI – Showalter Index
- K Index
- TT – Total totals
- SWEAT – Severe WEATher Threat index
- Precipitable water

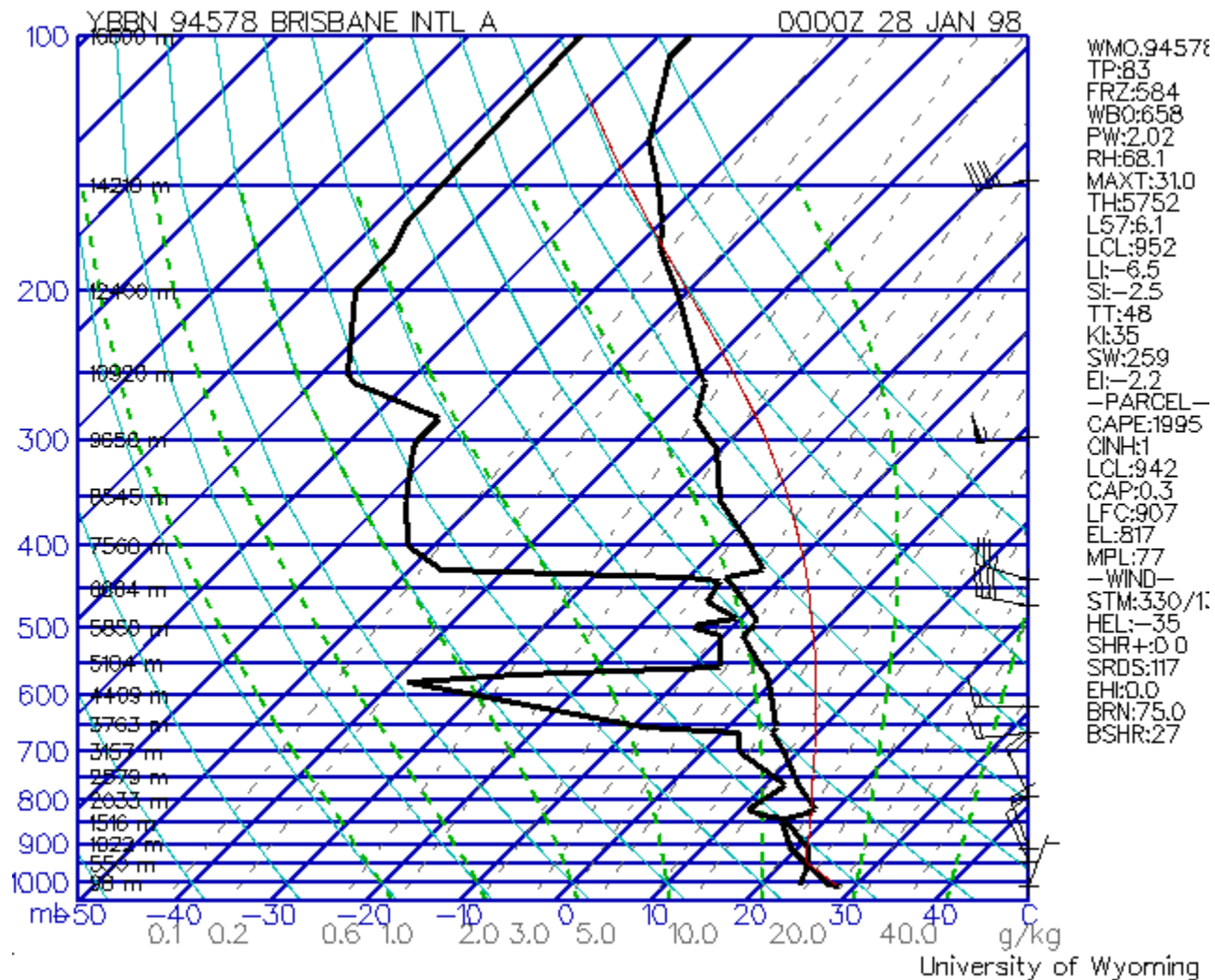
Example #1



Example #2



Example #3



Example #4

