THE UNIVERSITY OF UTAH

ATMOS 5130

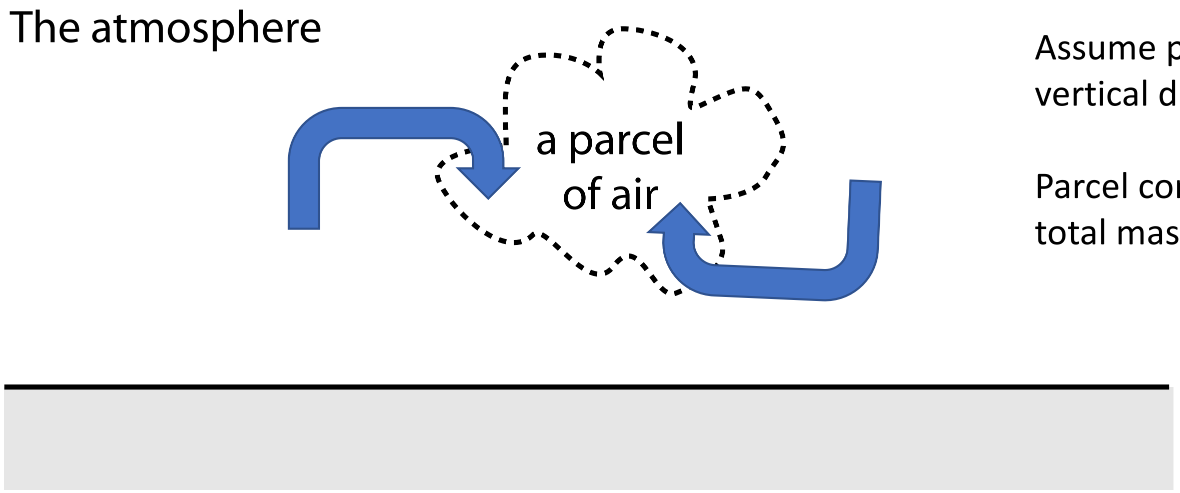
Lecture 14

- Atmospheric Stability
    - Parcel Stability and Atmospheric Convection
    - CIN
    - CAPE
    - Stability Indices

Larger Parcel Displacement

- Relative to deeper atmospheric convection
- Example – Thunderstorm with intense convective updrafts
- Use Parcel stability to reveal when free convection and energy to drive thunderstorms/hail/tornadoes possible.

Add More Reality



Assume parcel is large compared to vertical distance traveled

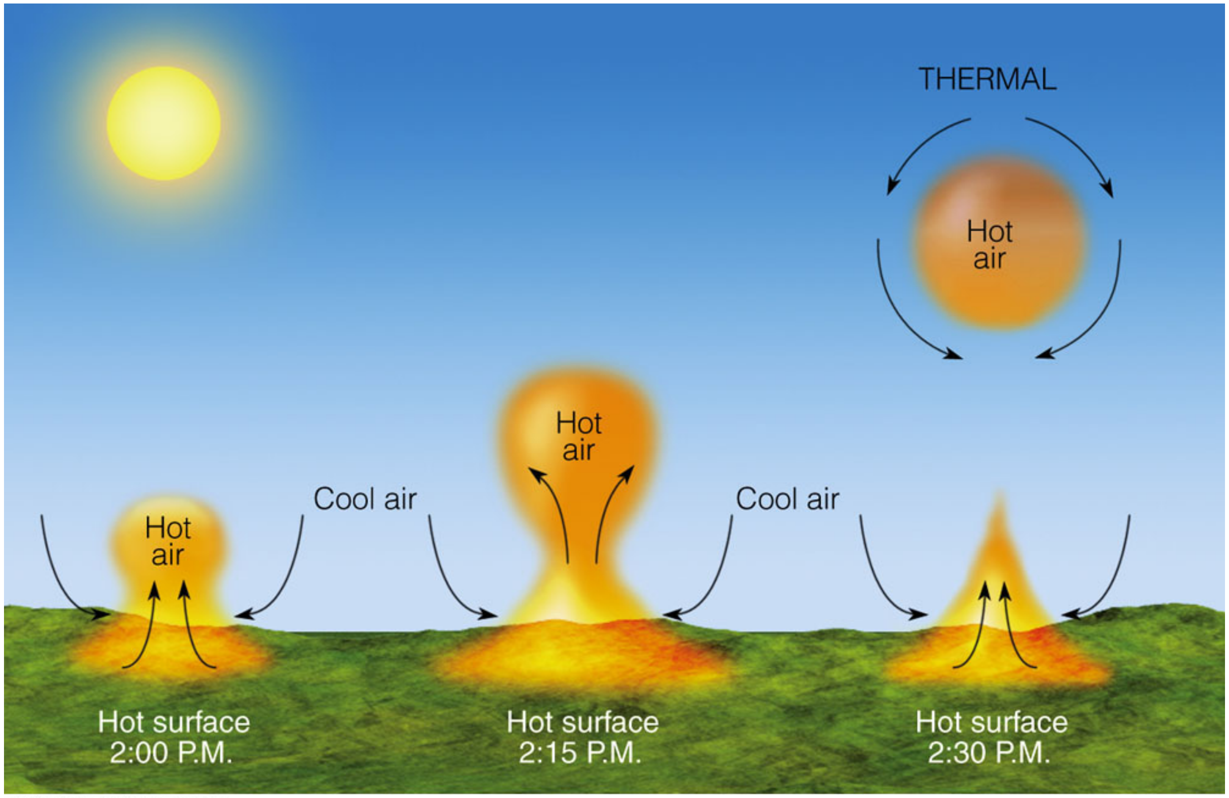
Parcel constitutes a small fraction of the total mass of the layer

Review from Lecture 13

Non-ideal processes in the real atmosphere serve to **reduce** the effects of instability and **dilute** the properties of a moving parcel of air.

Thus, parcel method yields a theoretical **upper limit** on energy

Thermal Example



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Thermal will continue to rise until

$$T = T'$$

At equilibrium level
(also called level of neutral buoyancy)

Recall

$$f_B = \left[\frac{T_v - T_v{}'}{T_v'}\right] g$$

When Rising Thermals have humidity

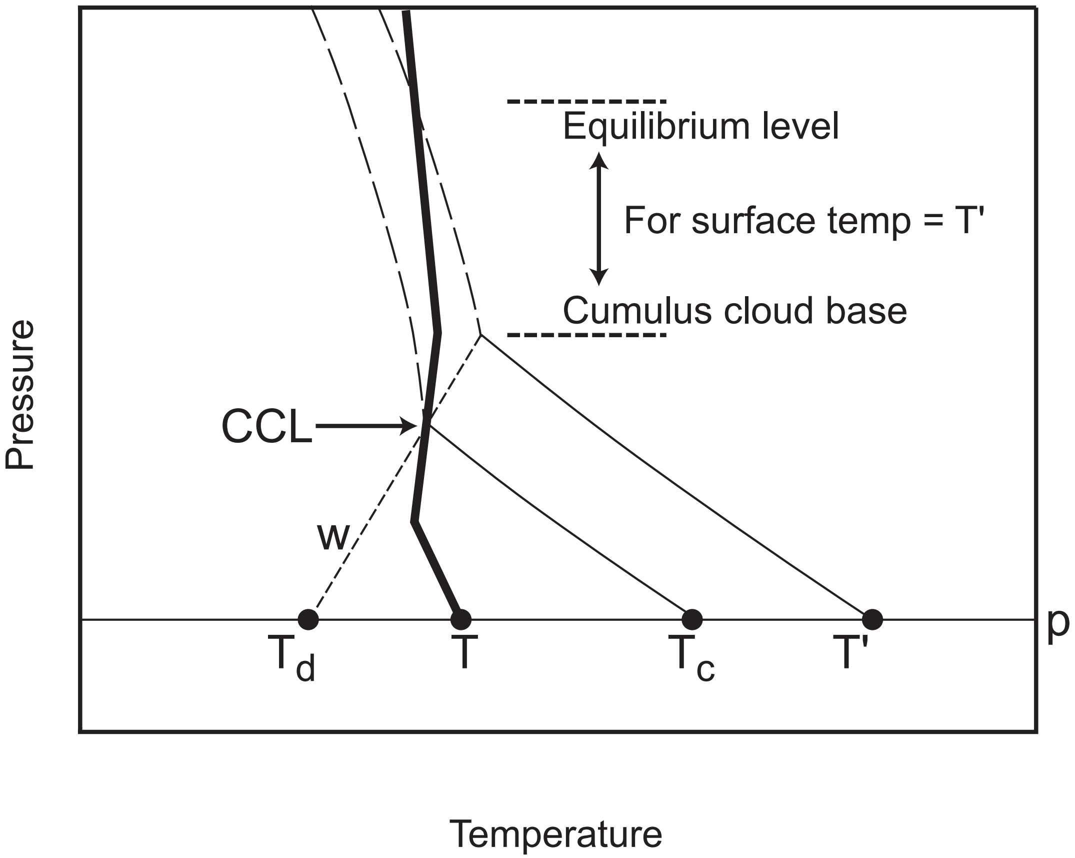
Then you get visible condensation

Define this as:

Convection condensation level (CCL)

Lowest level at which a heated parcel from the surface an rise via free convection to achieve saturation.

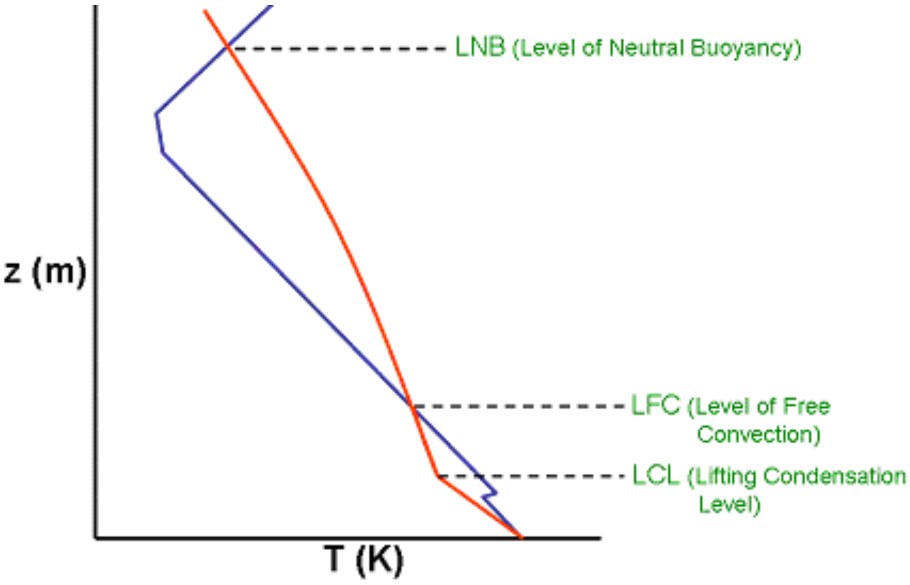
Convective Temperature = T_c = Temperature to which the parcel must be heated in order to reach CCL



Absolute state environment
in the vicinity of the CCL

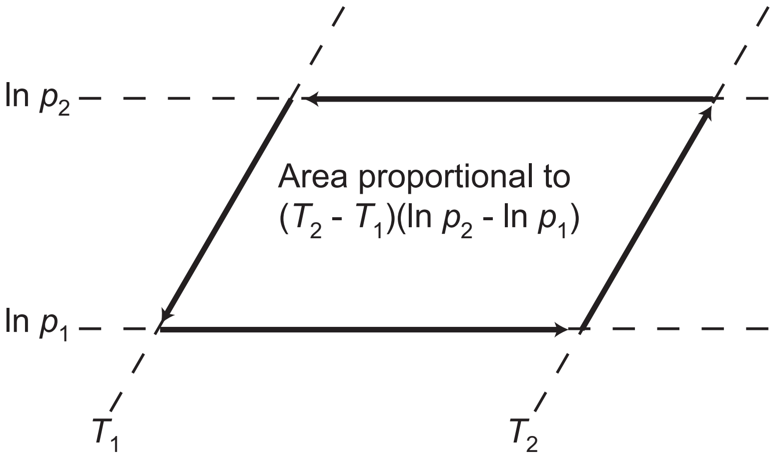
Level of Free Convection

- Altitude in the atmosphere where the temperature of the environment decreases faster than the moist adiabatic lapse rate of a saturated air parcel at the same level.
- Occurs when the moist adiabat being followed by a parcel crosses from the cold side of the environmental profile to the warm side



Work and Energy on skew-T

Review



Recall

$$\boxed{w = \int \delta w \equiv \int_{\alpha_0}^{\alpha_1} p\, d\alpha}$$

Isobaric $\quad w = \pm \int_{\alpha_0}^{\alpha_1} p\, d\alpha = \pm R_d (T_2 - T_1)$

Isothermal $\quad w = \pm \int_{\alpha_0}^{\alpha_1} p\, d\alpha = \pm R_d T \int_{\alpha_0}^{\alpha_1} \frac{1}{\alpha}\, d\alpha = \pm R_d T \ln\left(\frac{p_1}{p_2}\right)$

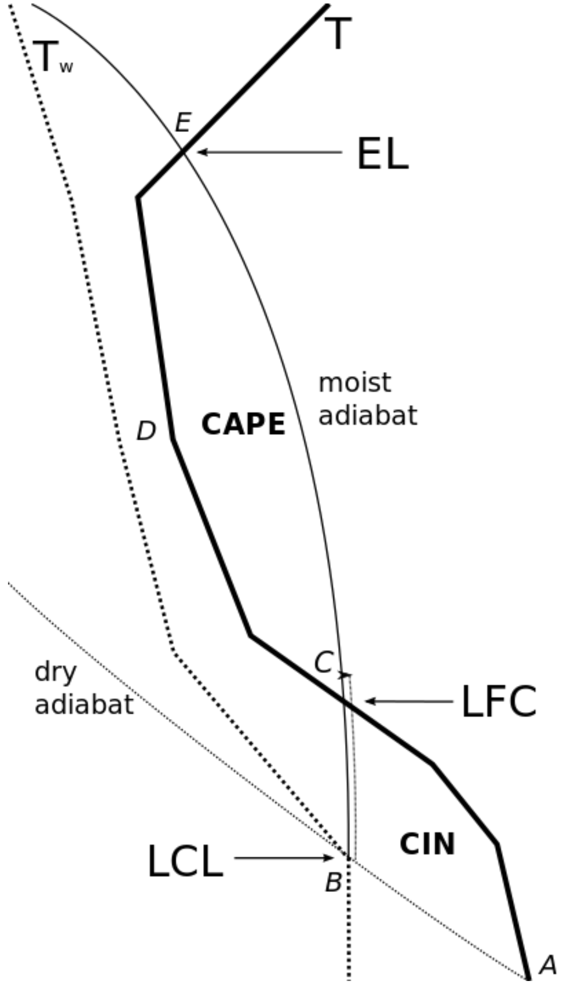
Add up all the leg to get net work

$$\boxed{w_{net} = R_d (T_1 - T_2) \ln\left(\frac{p_1}{p_2}\right) \propto Area}$$

Energy budget of Thunderstorm

- Mere existence of a Level of Free Convection (LFC), and much higher Equilibrium Level (EL) - does not guarantee a thunderstorm or tell you about the intensity of the storm.

- Need to understand the energy budget
  - CIN – Convective Inhibition
  - CAPE - Convective Available Potential Energy



CIN = Convective Inhibition

Mechanical energy required for the surface parcel to reach its Level of Free Convection (LFC)

$$w = \pm \int_{\alpha_0}^{\alpha_1} p \, d\alpha$$

CIN = Convective Inhibition

$$\text{CIN} = -\int_0^{z_{LFC}} f_B\,(z)dz$$

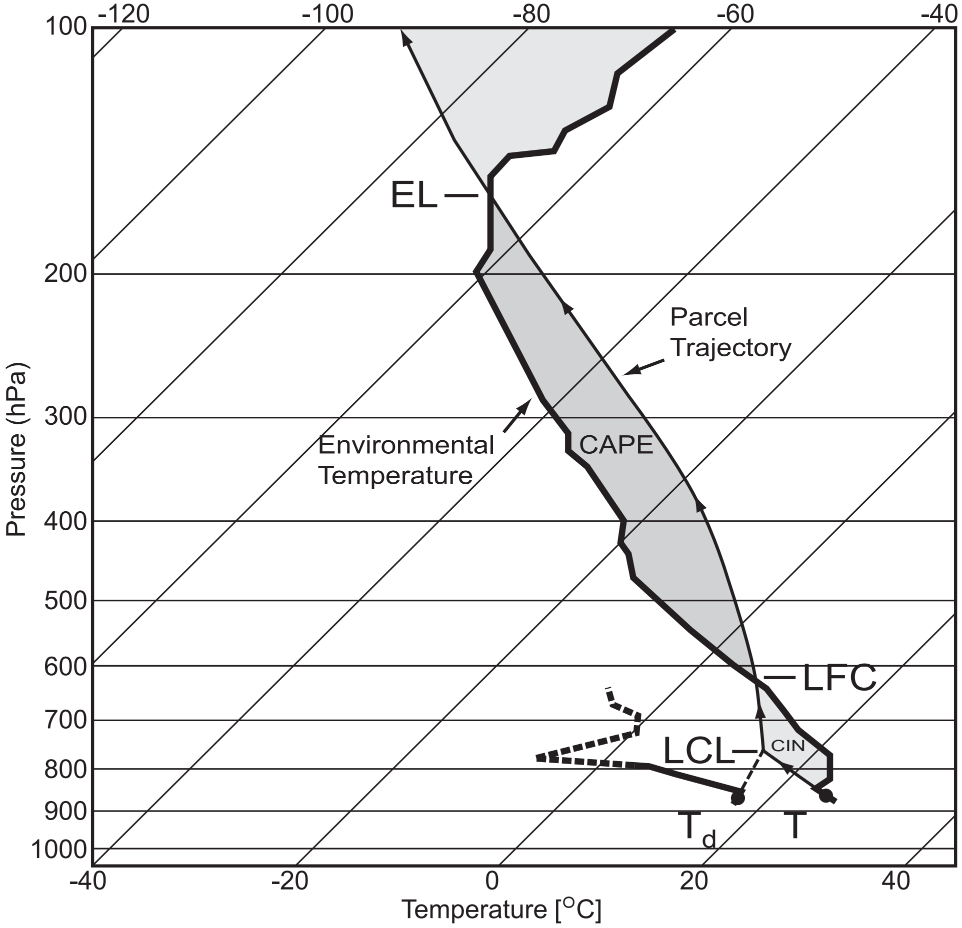
$$\text{CIN} = -\int_0^{z_{LFC}} \left[\frac{T_v - T_v{}'}{T_v'}\right] gdz$$

But we can not get T_v from Skew-T diagram, instead use T

$$\text{CIN} = -\int_0^{z_{LFC}} \left[\frac{T - T'}{T'}\right] g\;dz$$

Substitute in the ideal gas law, to put in terms of pressure (again to use Skew-T diagram)

$$\boxed{\text{CIN} = R_d \int_{p_0}^{LFC} [T(p) - T'(p)]\;dlnp}$$


-120
-100
-80
-60
-40
100
200
300
400
500
600
700
800
900
1000
Pressure (hPa)
EL
Parcel Trajectory
Environmental Temperature
CAPE
LFC
LCL
CIN
T_d
T
-40
-20
0
20
40
Temperature [°C]

CIN = Convective Inhibition

- The larger the negative area, the higher the CIN value, and the lower the likelihood of convective storms.
- One caveat is that if the CIN is large but storms manage to form, usually due to increased moisture and/or heating overcoming the CIN, then the storms are more likely to be severe.
- CIN is usually the result of a capping stable layer or inversion, with values of over 200 J/kg significantly inhibiting convective potential.

CAPE = Convective Available Potential Energy

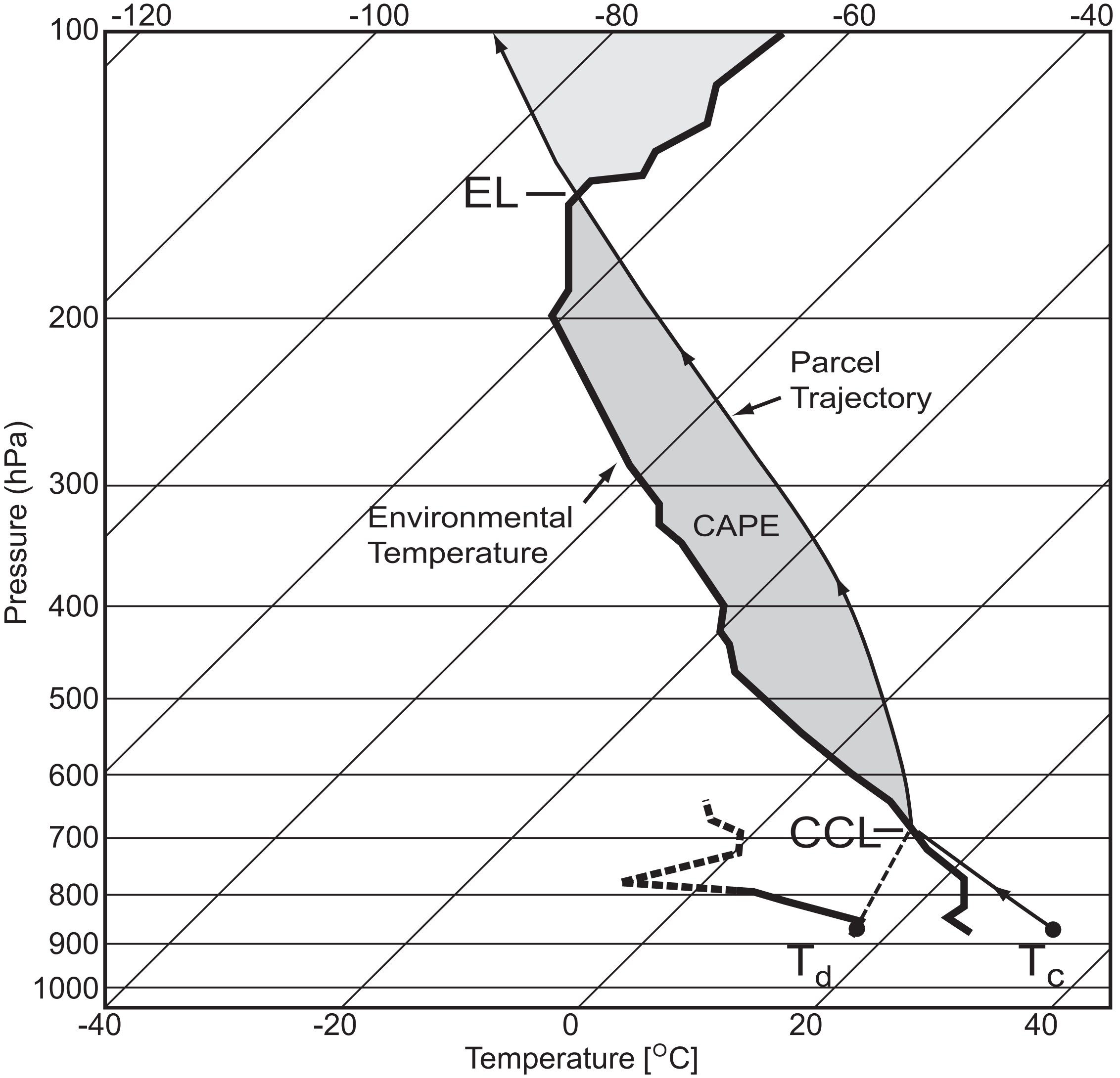
- Represented by the area on a skew-T enclosed by the environmental temperature profile and the saturation adiabat running from the LFC to the EL.
- Indicates the amount of buoyant energy available as the parcel is accelerated upward.

CAPE = Convective Available Potential Energy

$$\boxed{\text{CAPE} = R_d \int_{LFC}^{EL} [T'(p) - T(p)]\, dlnp}$$

CAPE = Convective Available Potential Energy

$$\boxed{\text{CAPE} = R_d \int_{LFC}^{EL} \underbrace{[T'(p) - T(p)]}_{\text{Notice Change in Sign from CIN}} \, dlnp}$$


-120
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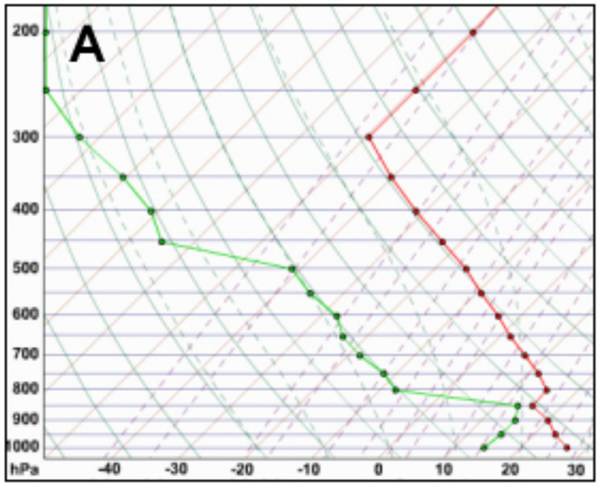
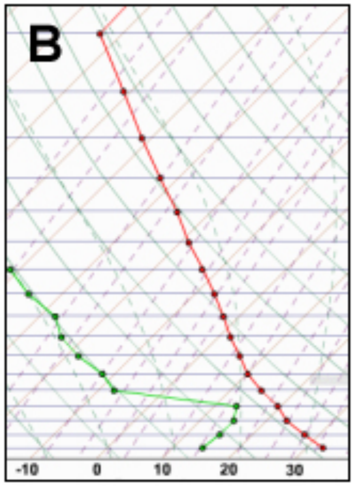
Pressure (hPa)
EL
Parcel Trajectory
Environmental Temperature
CAPE
CCL
T_d
T_c
-40
-20
0
20
40
Temperature [°C]





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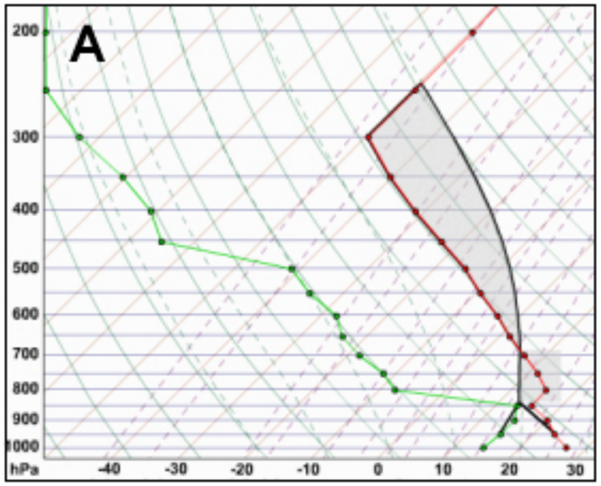
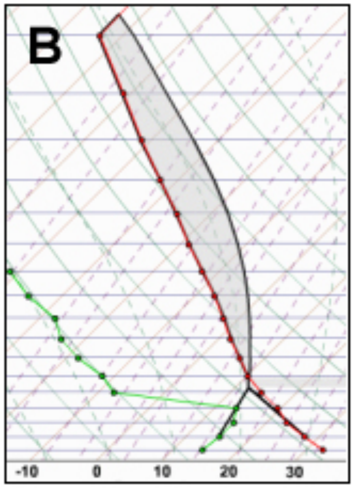
Which of these two soundings has greater CAPE?

A
B
Neither, CAPE same for both





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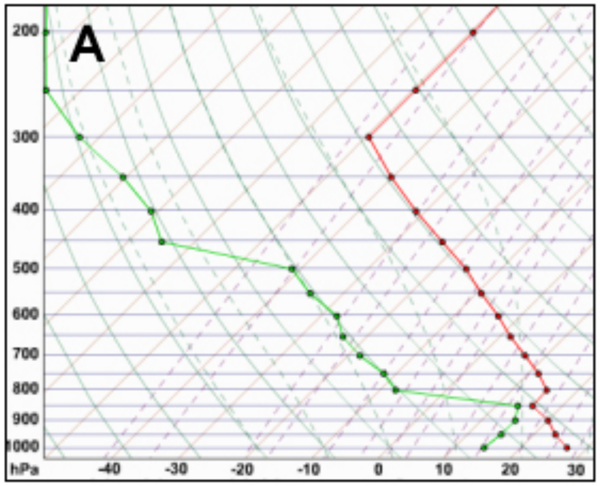
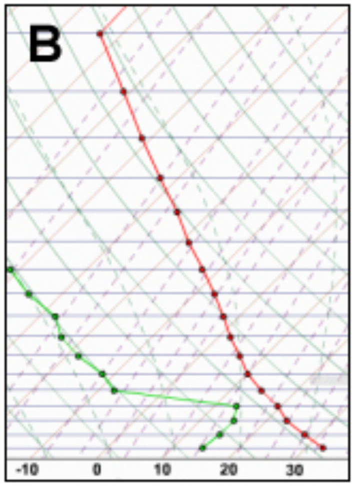
Which of these two soundings has greater CAPE?

Neither, CAPE is the same in both" is correct. The shaded area in both soundings is about the same. In fact, while one CAPE area is tall and narrow and the other is short and wide, both soundings have CAPE values of about 2330 J/kg.





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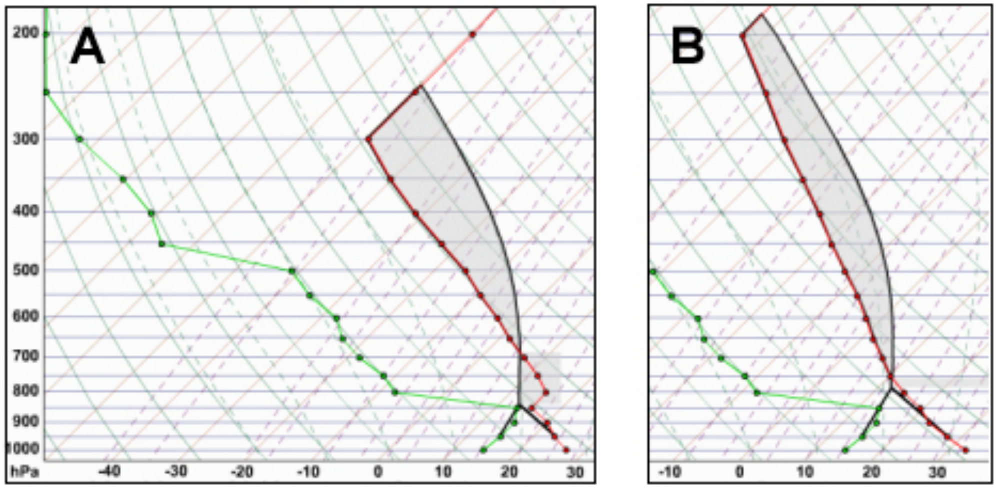

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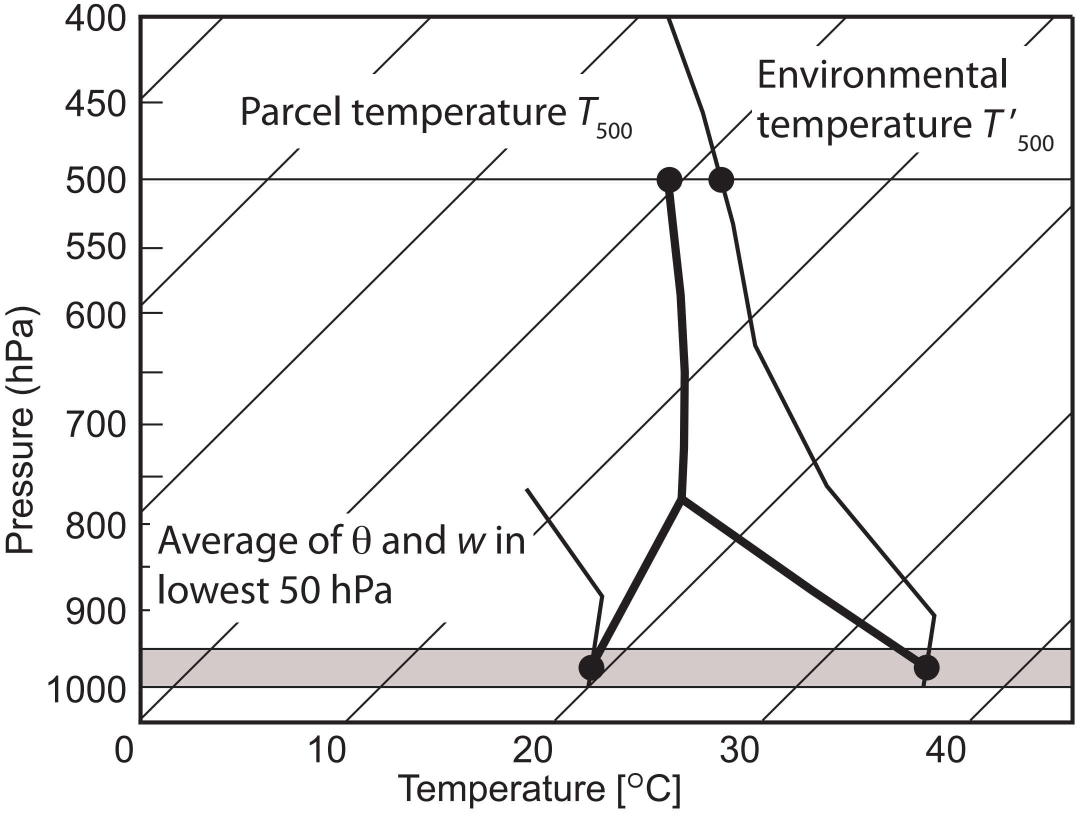
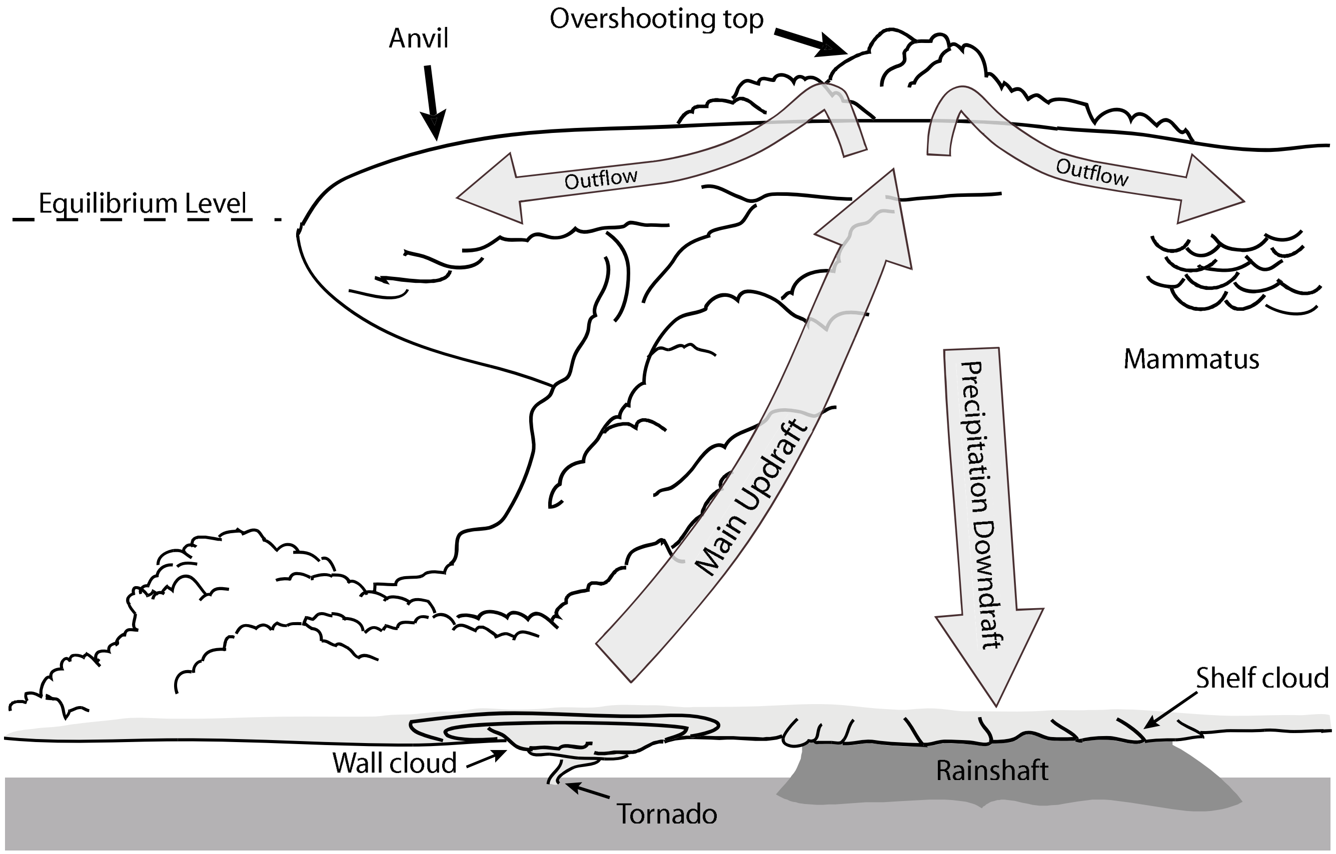
Which of these two soundings has greater CIN

A is correct. CIN is substantially larger in sounding A. This results primarily from the isothermal layer at 850–800 hPa.

Lifted Index = $T'_{500} - T_{500}$




Overshooting top
Anvil
Outflow
Outflow
Equilibrium Level
Mammatus
Main Updraft
Precipitation Downdraft
Shelf cloud
Wall cloud
Rainshaft
Tornado