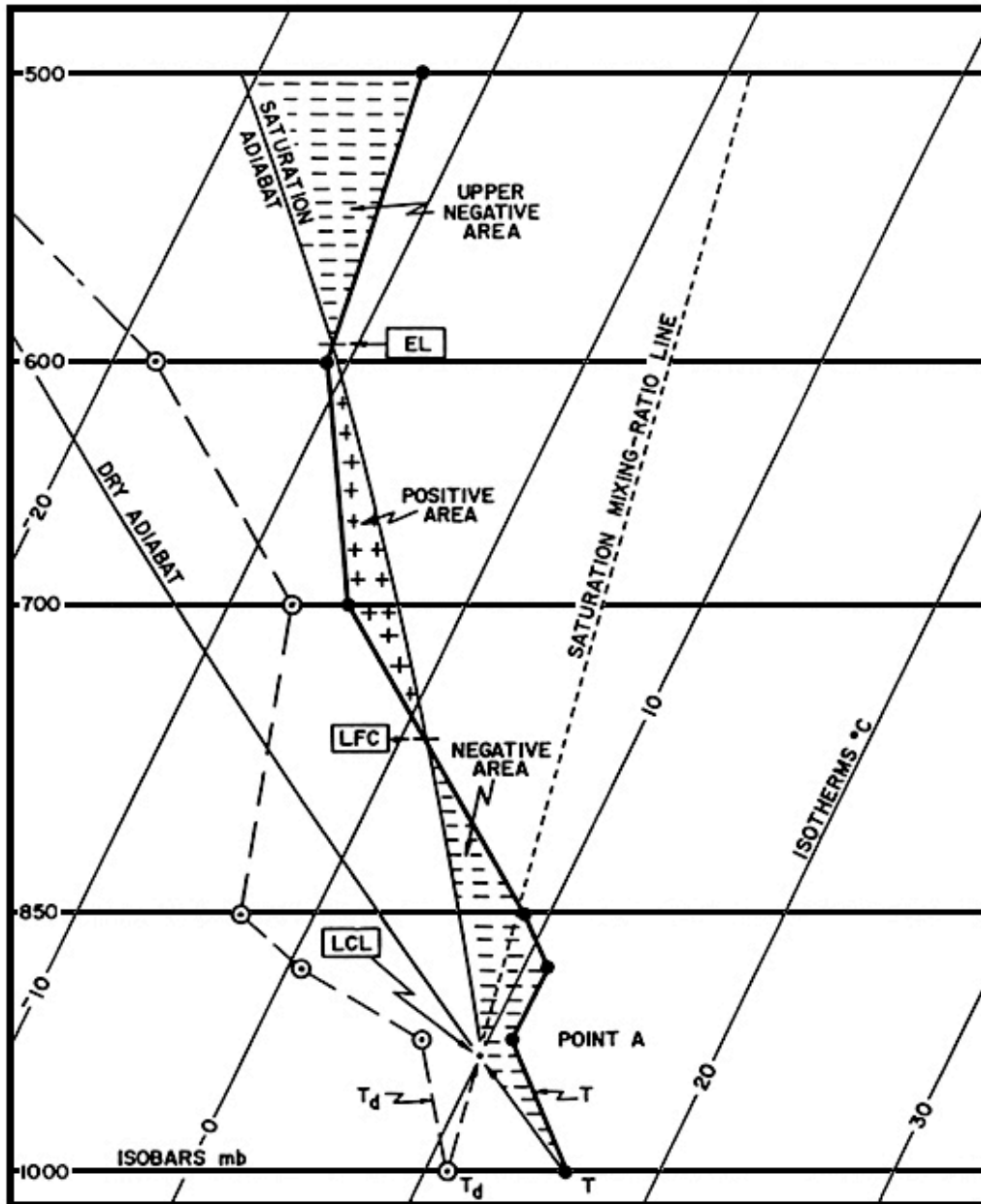


### CAPE: Convective Available Potential Energy

When an air parcel is lifted, it cools adiabatically and its saturation vapor pressure decreases and relative humidity increases. If the air comes from the boundary layer (so that it contains plenty of CCNs), once the relative humidity of the air parcel reaches 100%, water begins to condense out, releasing latent heat causing the temperature of the air parcel to follow a moist adiabat as it rises further (assuming it doesn't entrain any environmental air).

4 basic categories of lifting: thermal heating of surface air (buoyancy), air flow over topography, convergence down low, divergence aloft.



### Lifting Condensation Level (LCL)

This is the vertical level where the air parcel's relative humidity reaches 100% and water begins to condense out. Above this level, the air parcel's temperature follows the moist adiabat as it rises. Remember the LCL is the altitude where the parcel temperature and dew point are equal. Remember the air parcel temperature cools approximately as the dry adiabat below the LCL.

### Level of Free Convection (LFC)

At this level, the temperature of the air equals that of the environment. Above this level, the air parcel temperature is higher than that of the environment such that if the air rises above the LFC, it will continue to rise on its own.

### Vertical acceleration due to differences between the lifted air parcel and the environment

The environment is in hydrostatic equilibrium or very, very close to hydrostatic equilibrium. The mass of the air parcel is  $\rho_{parcel} V$  so the vertical acceleration of the air parcel is

$$a = \frac{F}{m} = -\frac{g\Delta\rho V}{\rho_{parcel} V} = -\frac{g\Delta\rho}{\rho_{parcel}} \quad (3)$$

The fractional density difference between the air parcel and the environment is

$$\frac{\Delta\rho}{\rho_{parcel}} = \frac{\rho_{parcel} - \rho_{env}}{\rho_{parcel}} = -\left(\frac{T_{v,parcel} - T_{v,env}}{T_{v,env}}\right) \quad (4)$$

where  $T_v$  is the virtual temperature of the air which takes into account that water is lighter than dry air. (see the virtual temperature handout).

Once the parcel rises above the *LFC*, the work,  $W$ , per unit mass done on the parcel as it rises is

$$\frac{W}{m} = \int_{LFC}^{z_{max}} \frac{F}{m} dz = \int_{LFC}^{z_{max}} a dz = -\int_{LFC}^{z_{max}} g \frac{\Delta\rho}{\rho} dz = \int_{LFC}^{z_{max}} g \frac{T_{parcel} - T_{env}}{T_{env}} dz \equiv CAPE$$

This quantity is known as *CAPE*.  $z_{max}$  is the altitude at which the rising parcel is no longer warmer than the environment. For deep convection, this is typically near the tropopause (be careful of the definition of the tropopause).

Remember that the acceleration associated with work creates kinetic energy. So if the parcel has an initial upward velocity when it hits the *LFC*, then its final  $w$  at  $z_{max}$  will be

$$\frac{1}{2} m w^2(z_{LFC}) + W = \frac{1}{2} m w^2(z_{max})$$

Generally the vertical velocity at *LFC* is small so it is ignored and

$$W = \frac{1}{2} m w^2(z_{max})$$

such that

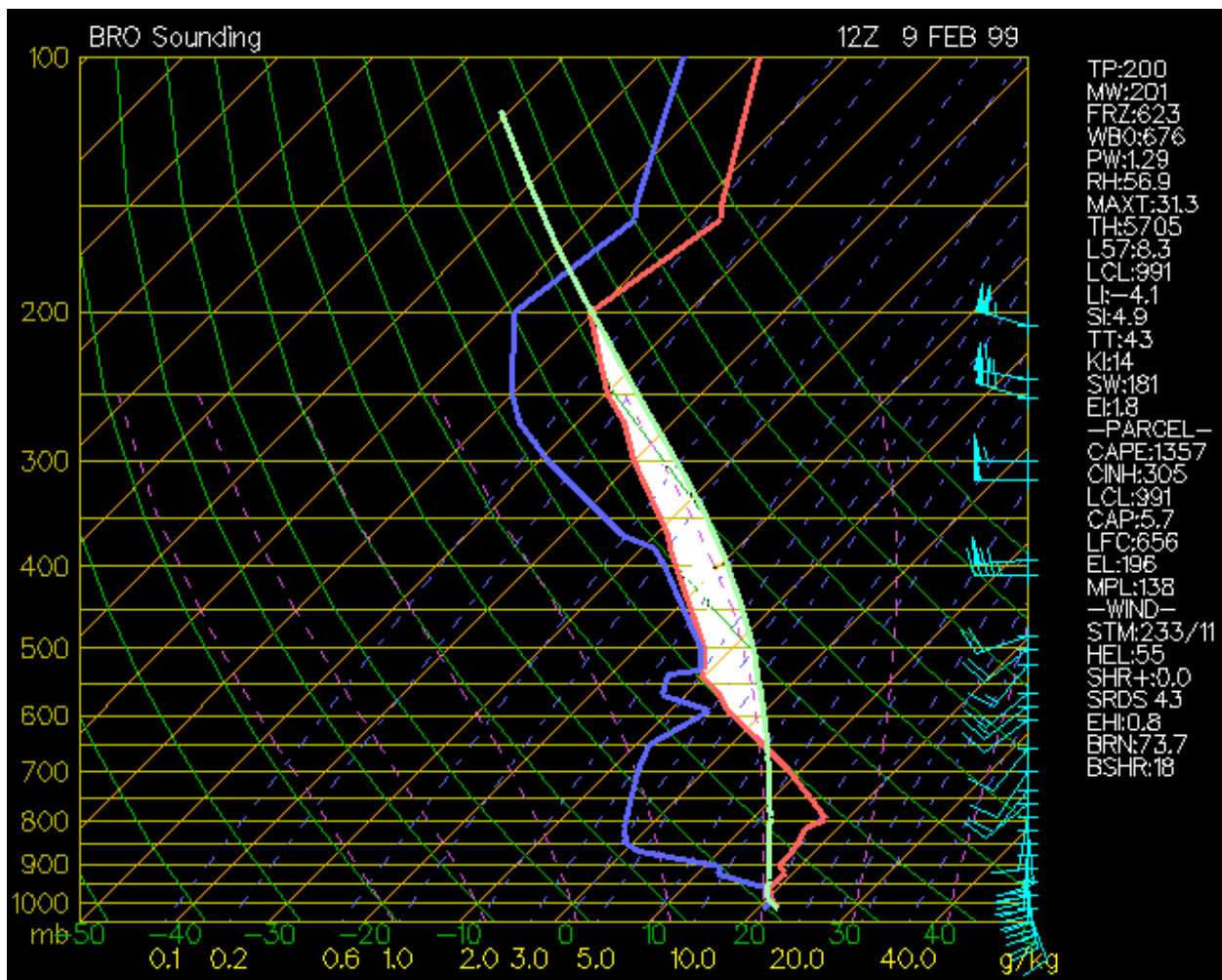
$$\frac{W}{m} = \frac{1}{2} w^2(z_{max}) = CAPE$$

therefore

$$w(z_{\max}) = \sqrt{2 \text{CAPE}}$$

Thus *CAPE* provides a measure or prediction of how violent the afternoon's convection will be. *CAPE* can be estimated from the morning radiosonde profile.

CAPE value (J)	Updraft velocity (m/sec)	Convective potential
0	0	Stable
0-1000	0-43	Marginally Unstable
1000-2500	43-70	Moderately Unstable
2500-3600	70-84	Very Unstable
3600 +	>84	Extremely Unstable



So what increases CAPE?

- Moving cold air in aloft
- Add moisture below
- Add warmer air below

**Convective inhibition energy (CIN)**

$$CIN \equiv \int_{z_{ML}}^{z_{LFC}} g \frac{T_{v,parcel} - T_{v,env}}{T_{v,env}} dz$$

where  $z_{ML}$  is the mixed layer depth.

**Issues with this treatment:**

- Entrainment of environmental air during uplift
- Dryness of the environment
- Where or at what altitude is the parcel initially before it get lifted?
- Drying of the boundary layer surface air during daytime in Tucson.

**Convective Downdrafts**

When rain falls into the air below the cloud, the air is sub-saturated and the rain evaporates on the way down. This causes the temperature of the air through which the rainfall is falling to decrease and the air sinks.

Under what conditions does the air fall all the way to the surface? There must be enough rain for the rain to extend all the way to the surface. The descending air follows a moist adiabat.

A higher cloud base means potentially more severe downdrafts. Bob Maddox claims Southeast Arizona has the most severe downdrafts in the world. Severe downdrafts called microbursts, can knock planes of the sky.