$c_pT + gz$ = dry static energy

Adiabatic process = no heat gained or lost by system

$0 = du + dW$ Simplification of first law.

<u>Concept of "parcel of air"</u>

- Volume expands / contracts freely
- Does not break apart
- Does not interact with surrounding environment and remains single unit
- Pressure in parcel = pressure outside

Figs. from NATS lectures.

1st law as applied to air parcel

Energy exchange with enviroment	=	Change in parcel volume (Work)	+	Change in parcel temp. (Int. energy)
↓		↓		
0		Expansion or Compression		Cooling or Warming

Dry Adiabatic lapse rate: (Γ_d)

Using 1st law for hydrostatically balanced atmosphere.

$$dq = c_p\,dT + g\,dz = 0 \quad \text{Adiabatic}$$

$$\boxed{-\frac{dT}{dz} = \frac{g}{c_p} = \Gamma_d}$$

$$\Gamma_d = 9.8\ \text{K/km}$$

Rate of temperature decrease with height absent heat sources/sinks.

Why does Γ_{obs} almost always less than Γ_d?

Potential temperature (θ)

Physically: Temperature a parcel of air would have if expanded or compressed adiabatically, as compared to a standard pressure (1000 mb)

Conserved quantity for adiabatic process, so greatly simplifies conservation of energy eqn.

$$\frac{d\theta}{dt} = S_\theta \quad (\text{or } dQ)$$

↑ sources/sinks of energy

What comprises S_θ? → Radiation and water phase transition.

Θ derivation

$$c_p\, dT - \alpha\, dp = 0$$ Adiabatic, 1st law, enthalpy form

Ideal gas law $p\alpha = RT$

$$\alpha = RT/p$$

$$c_p\, dT - RT\frac{dp}{p} = 0$$

$$\frac{c_p}{R}\frac{dT}{T} = \frac{dp}{p}.$$

Integrating downward to some ref level

$$\int_T^{T_{ref}} \frac{dT}{T} = \frac{R}{c_p}\int_p^{p_{ref}} \frac{dp}{p}.$$

$$\ln \frac{T_{ref}}{T} = \frac{R}{c_p} \ln \frac{P_{ref}}{P}$$

By rules of logs

$$\frac{T_{ref}}{T} = \left(\frac{P_{ref}}{P}\right)^{R/c_p}$$

Define $T_{ref} = \theta$ = Potential temperature

$P_{ref} = p_0 = 1000\text{ mb}$,

$$\boxed{\theta = T\left(\frac{P_0}{P}\right)^{R/c_p}}$$

Poisson's equation

A "Parcel" of Air

In the case of the atmosphere, our "object" is not a rock but a parcel of air.

<u>Characteristics of air parcel</u>

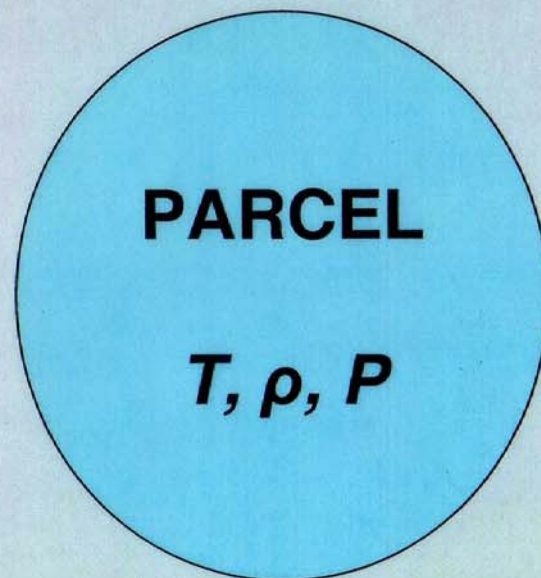
Volume which expands and contracts freely

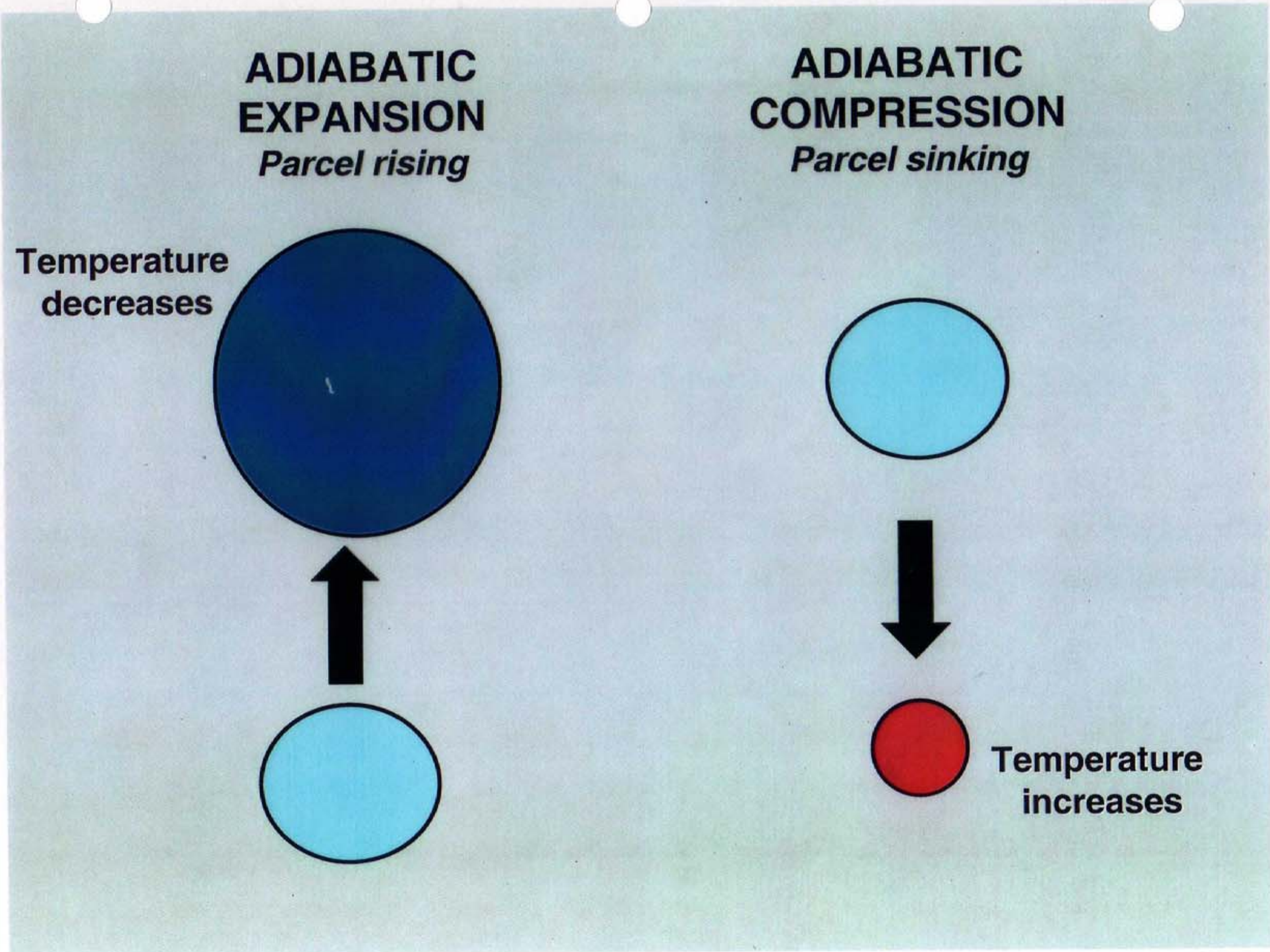
Does not break apart

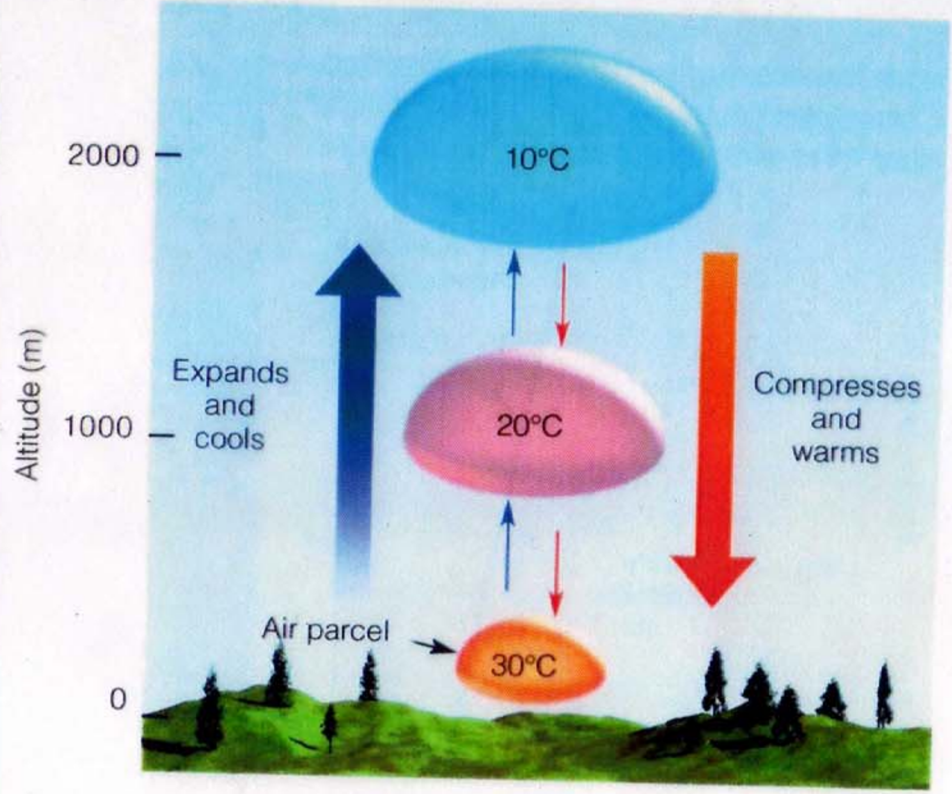
Does not interact with the surrounding environment and remains a single unit.

Parcel has temperature (T), density (ρ), and pressure (P)

Pressure in the parcel is equal to the pressure outside.

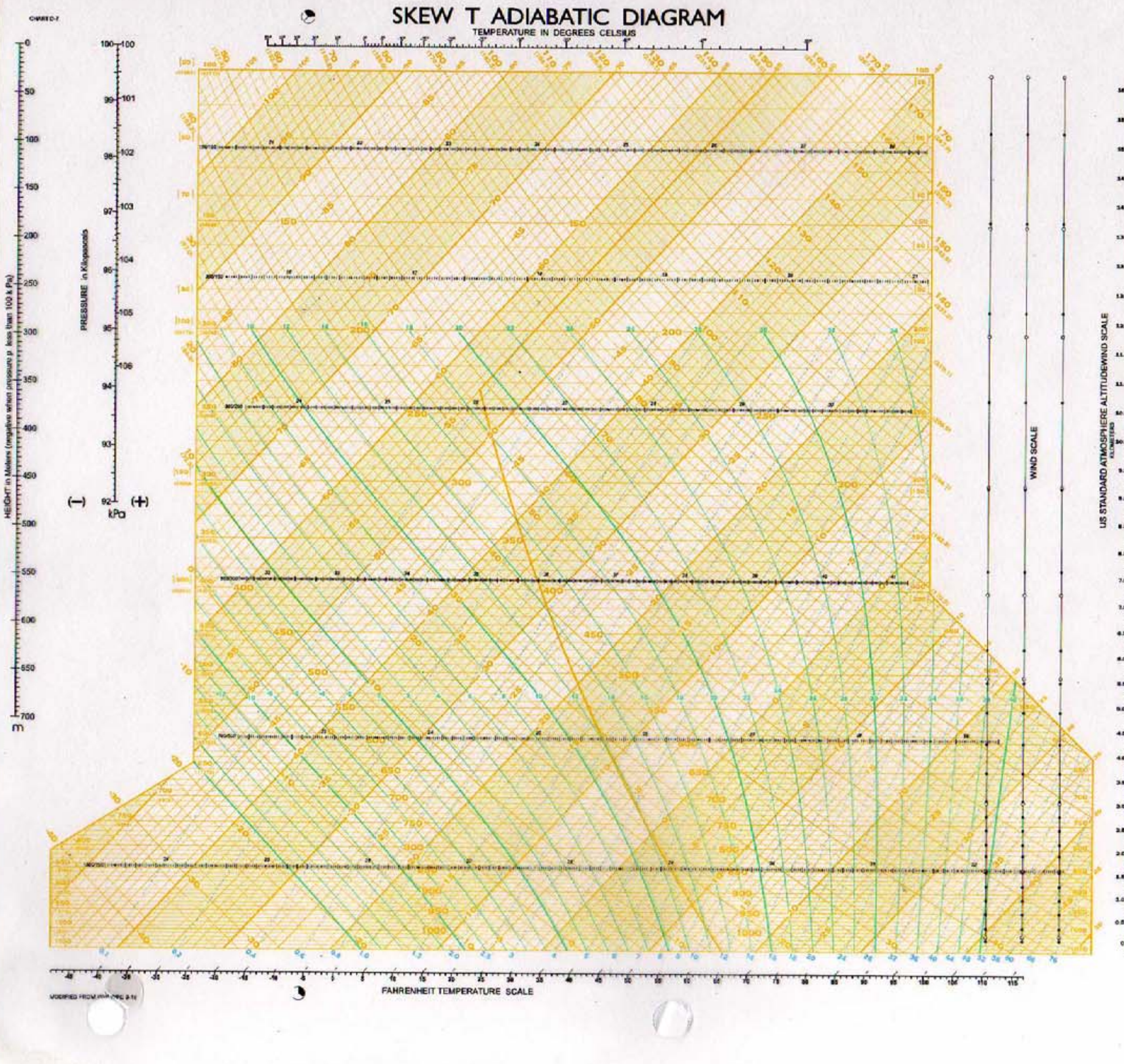



ADIABATIC
EXPANSION
Parcel rising
Temperature
decreases
ADIABATIC
COMPRESSION
Parcel sinking
Temperature
increases



• FIGURE 6.2
The dry adiabatic rate. As long as the air parcel remains unsaturated, it expands and cools by 10°C per 1000 m; the sinking parcel compresses and warms by 10°C per 1000 m.

SKEW T ADIABATIC DIAGRAM



EXPLANATION

SKEW T ANALYSIS

STATION ID	STATION ID	STATION ID
DATE	DATE	DATE
TIME (GMT)	TIME (GMT)	TIME (GMT)

CHART 2-7

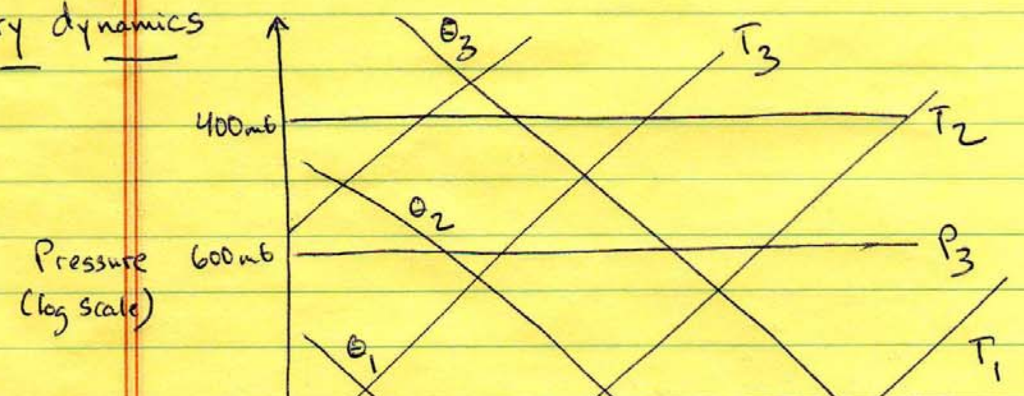
MODIFIED FROM

Introduction to Thermodynamic Diagrams

Idea → A graphical way to display meteorological information from sounding (i.e weather balloon) in relation to its thermodynamic behavior (moist & dry)

Skew-T, Log-P (standard in U.S)

Dry dynamics



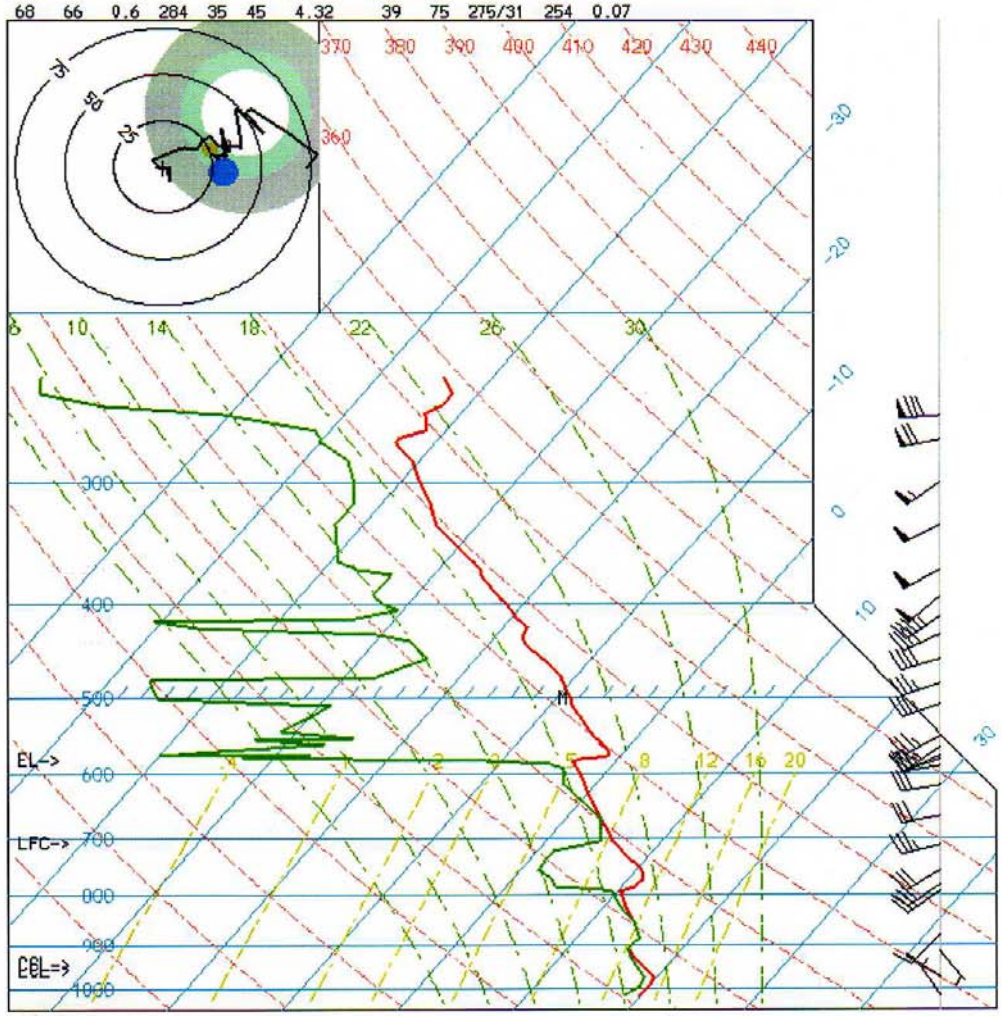
Need figure of skew-T, log-P.

Isobars: Lines of constant pressure
horizontal lines

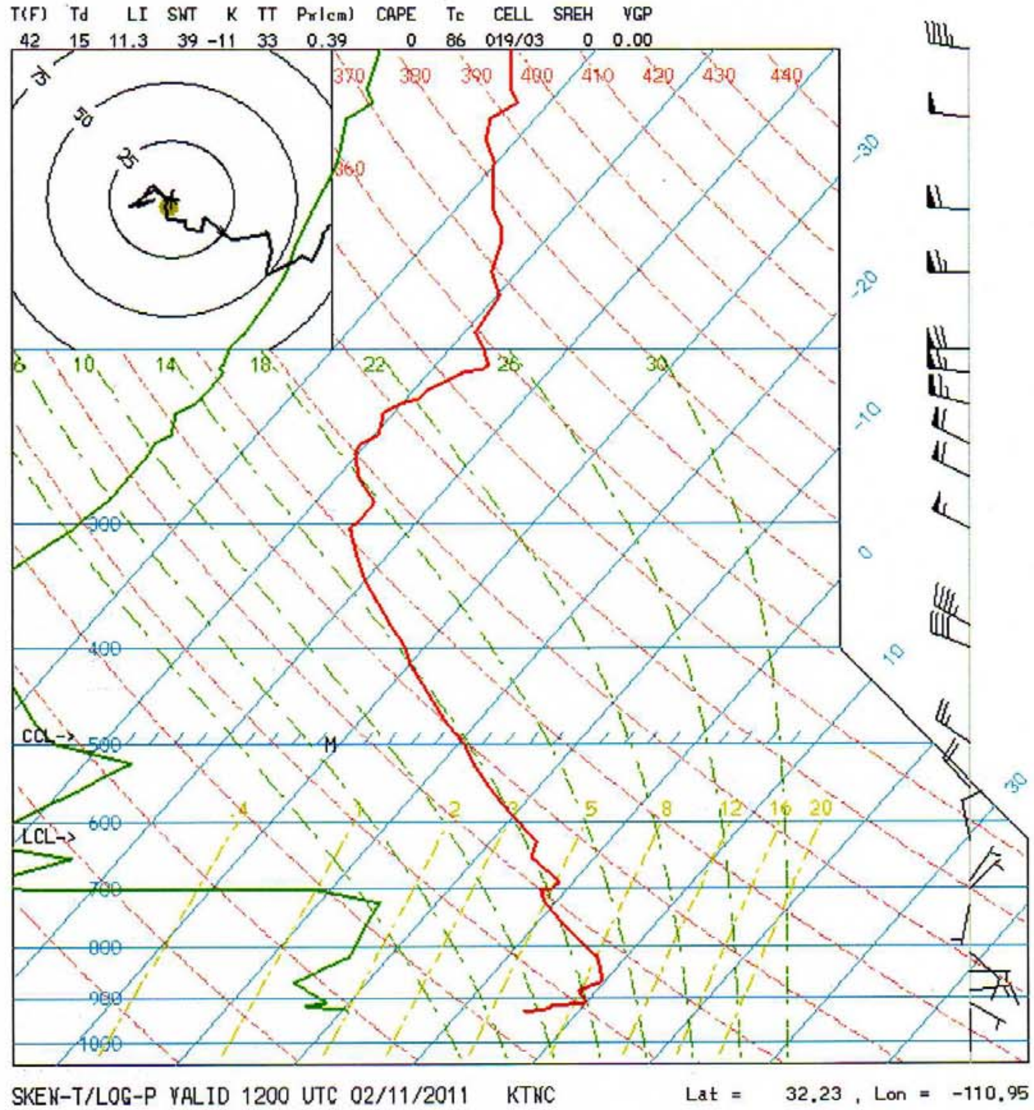
Isotherms: Lines of constant temperature
positive slope

Dry adiabats: Lines of constant potential temperature (θ) $du + dw = 0$.

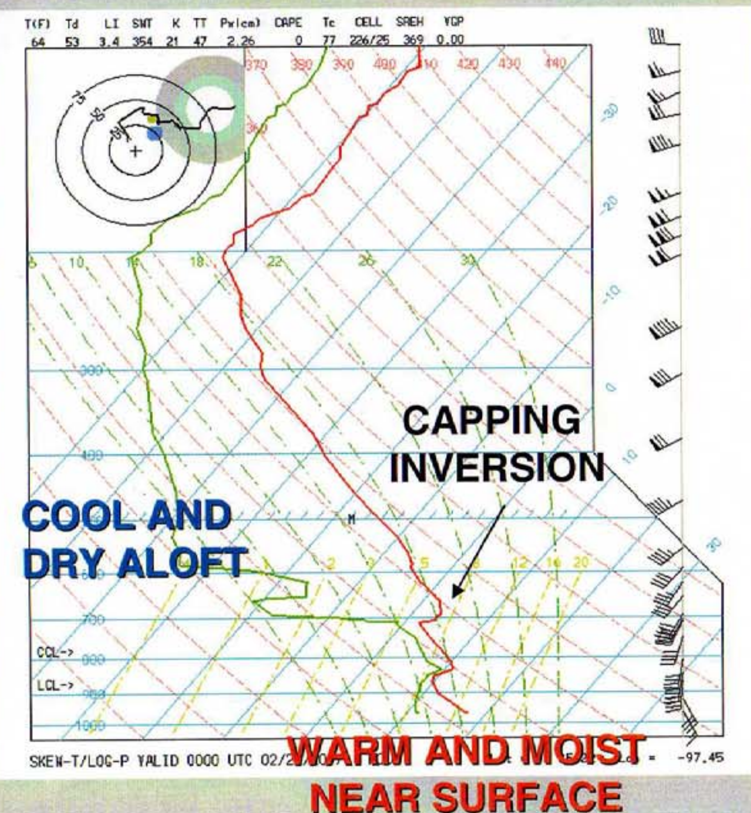
T(F)	Td	LI	SWT	K	TT	Pw(cm)	CAPE	Tc	CELL	SREH	VGP
68	66	0.6	284	35	45	4.32	39	75	275/31	254	0.07



SKEW-T/LOG-P VALID 1200 UTC 02/11/2011 KMFL Lat = 25.75 , Lon = -80.37


T(F) Td LI SWT K TT Pw(cm) CAPE Tc CELL SREH VGP
42 15 11.3 39 -11 33 0.39 0 86 019/03 0 0.00
CCL->
LCL->
SKEW-T/LOG-P VALID 1200 UTC 02/11/2011 KTWC Lat = 32.23 , Lon = -110.95

THE "LOADED GUN" SOUNDING
THE SIGNATURE FOR SUPERCELLS!



WIND DRASTICALLY CHANGES IN SPEED AND DIRECTION WITH HEIGHT

What does traveling along dry adiabat mean?
→ Potential temperature is conserved.

"Up" → Parcel expansion, cooling
"Down" → Parcel compression, warming.

Other lines on chart used if moisture present.

Atmospheric Moisture Measures

1) Mixing ratio (w) = mass of $H_2O(v)$ / mass of dry air

2) Specific humidity (q) = mass of $H_2O(v)$ / total mass air.

3) Vapor pressure (e) = Partial pressure due to $H_2O(v)$

4) Vitual temperature (T_v) = Apparent temp. accounting for $H_2O(v)$

Public measure → 5) Dewpoint (T_d) = Temp to chill air to reach saturation (at const. pressure)

6) Wet bulb (T_{wb}) = Related to heat required to evaporate water at given T & T_d

Public measure →

7) Relative humidity (RH) = $\frac{\text{Vapor pressure}}{\text{Saturation vapor pressure}}$

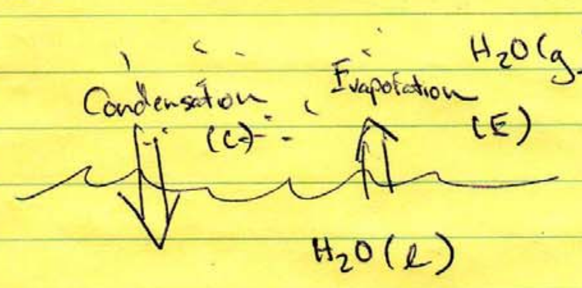
$$= \frac{e}{e_s}$$

8) Equivalent potential temp (θ_e) = Potential temp. air would have if all $H_2O(v)$ condensed out.

Excercise p.80

Show $e = \frac{w}{w+\varepsilon} P$ and $T_v = (1+0.61w)$

Concept of saturation



Water vapor molecules above flat plane of liquid water.

Condensation = $H_2O(g)$ molecules convert from gas to liquid phase

Evaporation = $H_2O(l)$ molecules convert from liquid to gas phase

Balance of C and E depends on the vapor pressure

1) Saturation C = E

- No net change in water vapor molecules
- Air holds as much $H_2O(v)$ as possible
- Vapor pressure (e) = Saturation vapor pressure (e_s)
- RH = 100%

2) Undersaturation C < E

- Vapor pressure < saturation vapor pressure
  (e) < (e_s)
- Liquid water evaporates over time, more the drier the air is.
- RH < 100%

3) Supersaturation : C > E

(Lots of $H_2O_{(g)}$) molecules

- Surplus of $H_2O(g)$ will cause water to start condensing (if condensating sfc.)
- $e > e_s$
- Occurs at dewpoint temperature.

Note the range in of water vapor pressure here…

It approximately is between 0 mb and 70 mb.

Compared to the average mean sea level pressure (1013 mb), water vapor can potentially contribute between 0 and 7% of the total atmospheric pressure.

We'll derive this formally later…

Clausius-Clapeyron equation.