Soundings and Adiabatic Diagrams for Severe Weather Prediction and Analysis

Review

Atmospheric Soundings Plotted on Skew-T Log P Diagrams

- Allow us to identify stability of a layer
- Allow us to identify various air masses
- Tell us about the moisture in a layer
- Help us to identify clouds
- Allow us to speculate on processes occurring

Why use Adiabatic Diagrams?

- They are designed so that area on the diagrams is proportional to energy.
- The fundamental lines are straight and thus easy to use.
- On a skew-t log p diagram the isotherms(T) are at 90^{o} to the isentropes (θ).

The information on adiabatic diagrams will allow us to determine things such as:

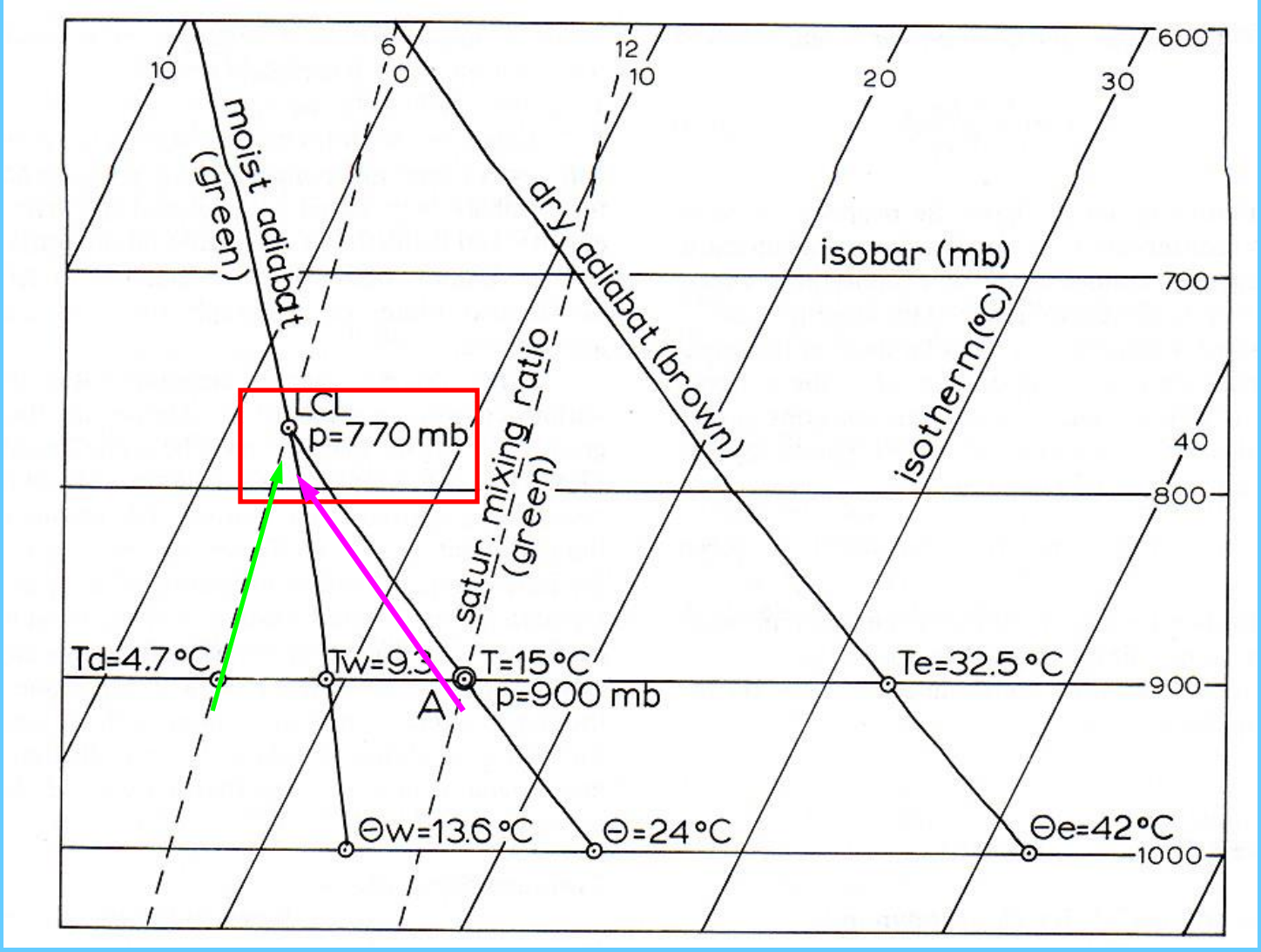
- CAPE (convective available potential energy)
- CIN (convective inhibition)
- DCAPE (downdraft convective available potential energy)
- Maximum updraft speed in a thunderstorm
- Hail size
- Height of overshooting tops
- Layers at which clouds may form due to various processes, such as:
  - Lifting
  - Surface heating
  - Turbulent mixing

Critical Levels on a Thermodynamic Diagram

Lifting Condensation Level (LCL)

- The level at which a parcel lifted dry adiabatically will become saturated.
- Find the temperature and dew point temperature (at the same level, typically the surface). Follow the mixing ratio up from the dew point temp, and follow the dry adiabat from the temperature, where they intersect is the LCL.

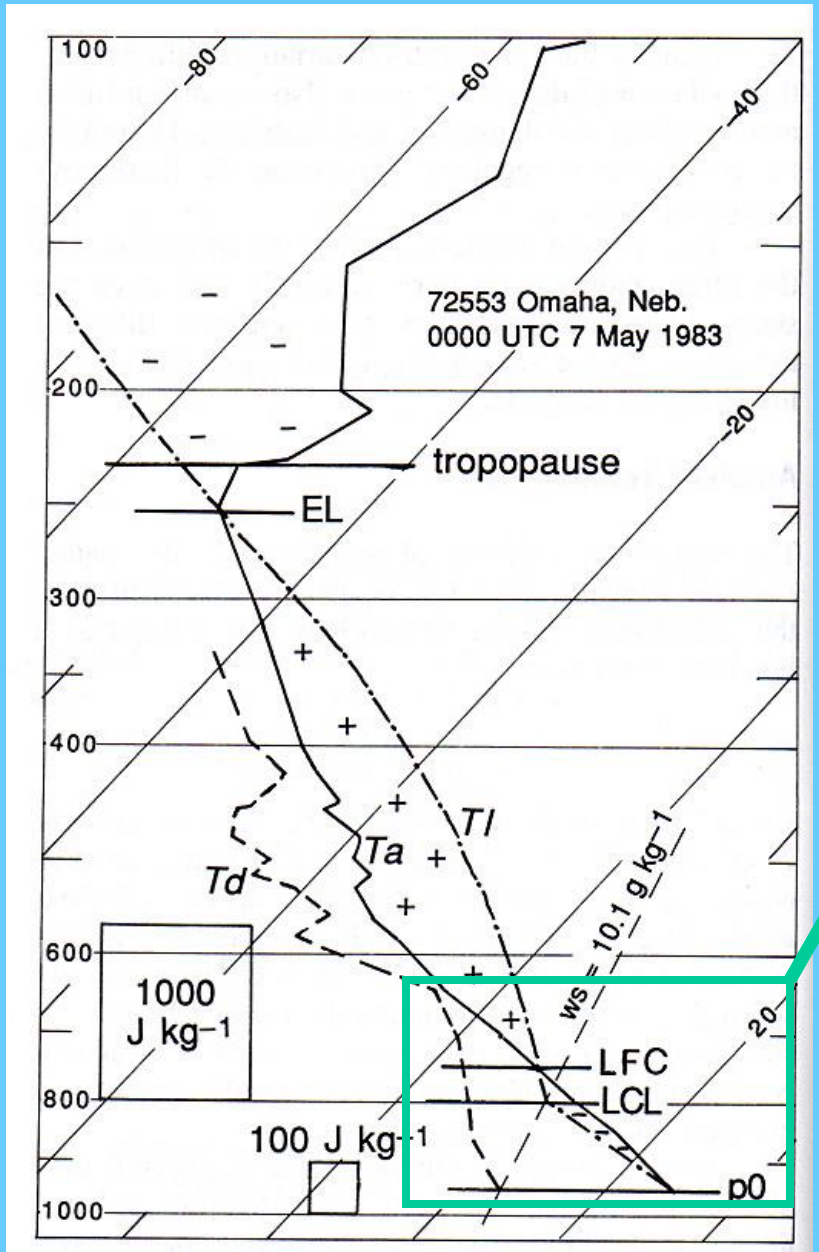
Finding the LCL

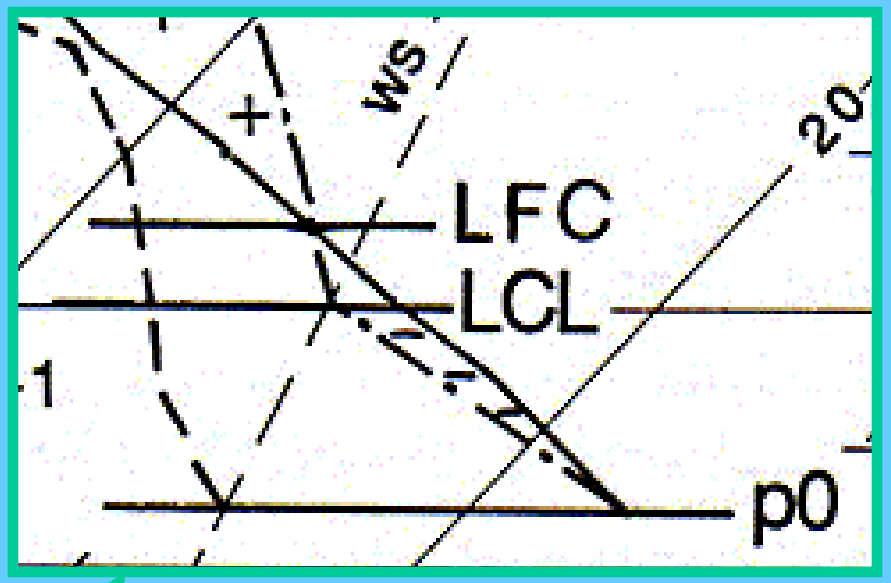


Level of Free Convection (LFC)

- The level above which a parcel will be able to freely convect without any other forcing.
- Find the LCL, then follow the moist adiabat until it crosses the temperature profile.
- At the LFC the parcel is neutrally buoyant.

Example of LFC

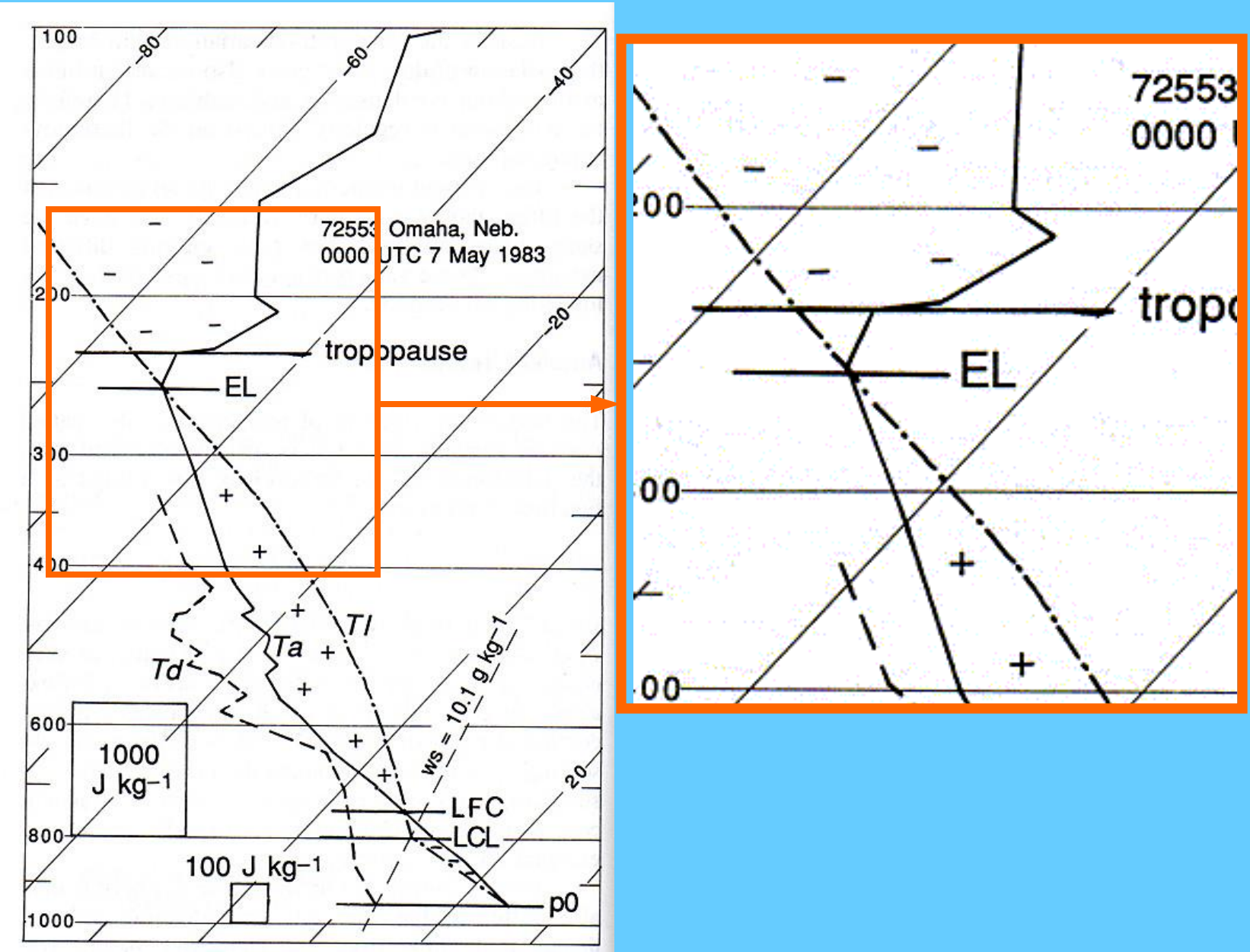




Equilibrium Level (EL)

- The level above the LFC at which a parcel will no longer be buoyant. (At this point the environment temperature and parcel temperature are the same.)
- Above this level the parcel is negatively buoyant.
- The parcel may still continue to rise due to accumulated kinetic energy of vertical motion.
- Find the LFC and continue following the moist adiabat until it crosses the temperature profile again.

Example of finding the EL



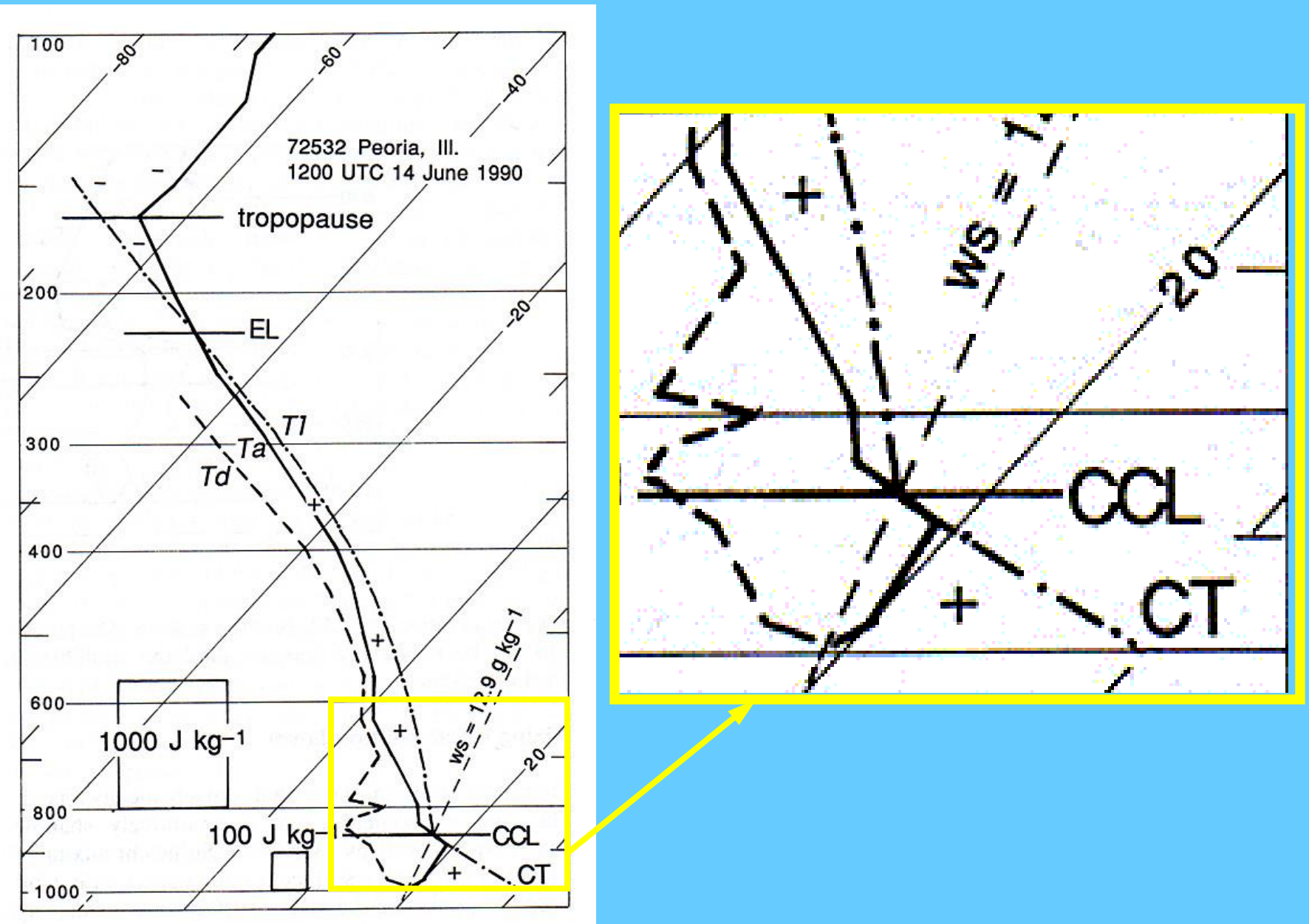
Convective Condensation Level (CCL)

- Level at which the base of convective clouds will begin.
- From the surface dew point temperature follow the mixing ratio until it crosses the temperature profile of sounding.

Convective Temperature (CT)

- The surface temperature that must be reached for purely convective clouds to develop. (If the CT is reached at the surface then convection will be deep enough to form clouds at the CCL.)
- Determine the CCL, then follow the dry adiabat down to the surface.

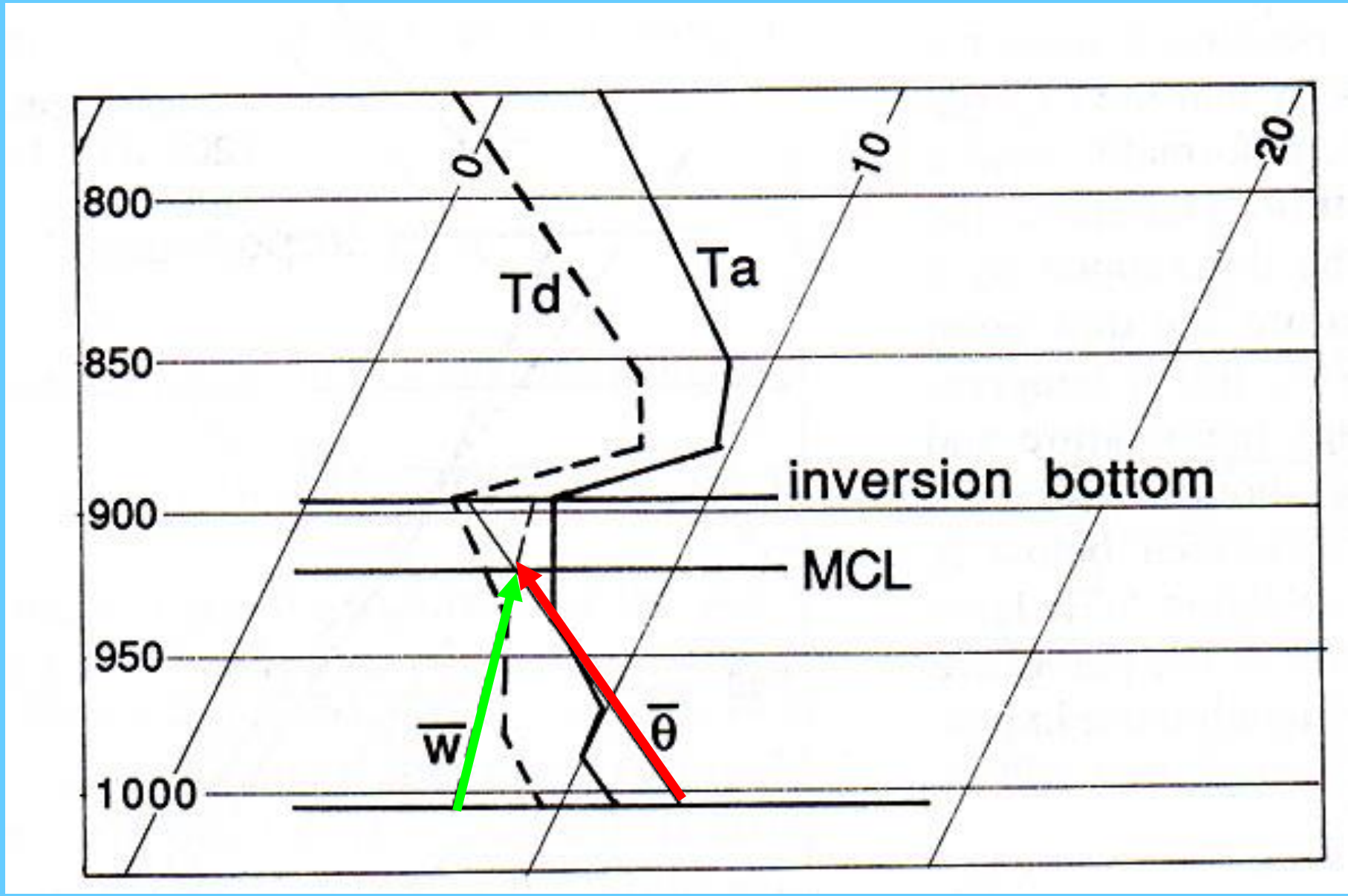
Finding the CCL and CT



Mixing Condensation Level (MCL)

- This represents the level at which clouds will form when a layer is sufficiently mixed mechanically. (i.e. due to turbulence)
- To find the MCL determine the average potential temperature (θ) and average mixing ratio (w) of the layer. Where the average θ and average w intersect is the MCL.

Finding the MCL



Thermodynamic Diagrams and Severe Weather

What is Severe Weather?

Tornado

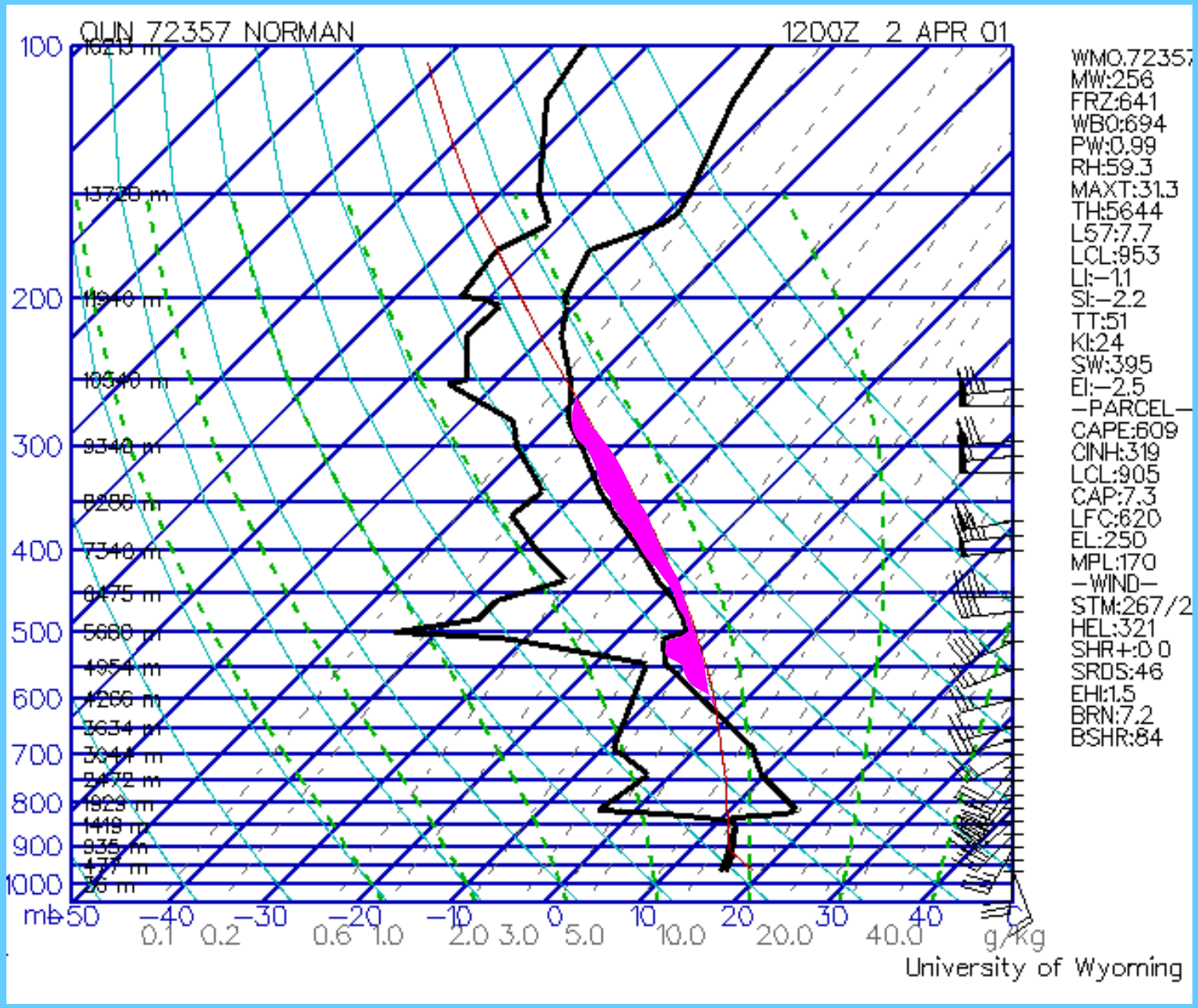
Hail > or = 3/4inch

Wind > 50 knots

Convective Available Potential Energy (CAPE)

- Remember: Area on a thermodynamic diagram is proportional to energy.
- CAPE is also called buoyant energy.
- CAPE on a thermodynamic diagram is the area between the parcel and the environment temperatures from the LFC to the EL
- CAPE is a measure of instability

CAPE


OUN 72357 NORMAN
1200Z 2 APR 01
WMO:72357
MW:256
FRZ:641
WB0:694
PW:0.99
RH:59.3
MAXT:31.3
TH:5644
L57:7.7
LCL:953
LI:−1.1
SI:−2.2
TT:51
KI:24
SW:395
EI:−2.5
−PARCEL−
CAPE:609
CINH:319
LCL:905
CAP:7.3
LFC:620
EL:250
MPL:170
−WIND−
STM:267/2
HEL:321
SHR+:0 0
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EHI:1.5
BRN:7.2
BSHR:84
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g/kg
University of Wyoming

CAPE

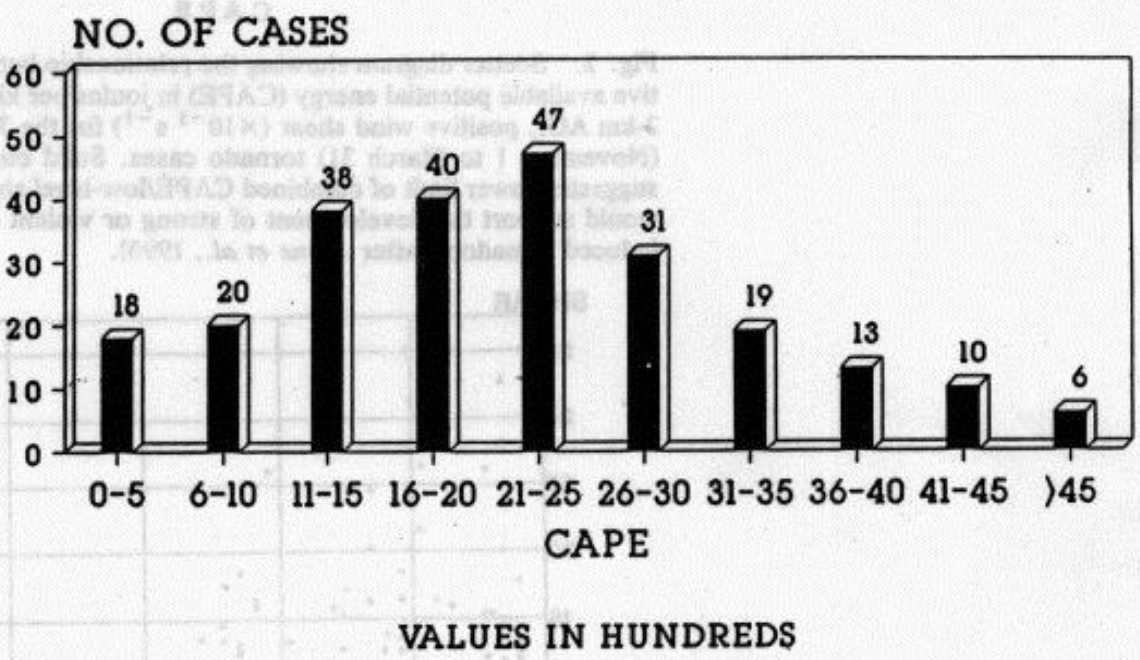


Fig. 1. Distribution of the convective available potential energy (CAPE) values associated with the 242 strong and violent tornado cases in the data set. Number above each bar is the number of cases in that particular range of CAPE values.

Maximum Updraft Speed

- If we convert the potential energy of CAPE to a kinetic energy, we can get the maximum speed of any updraft that may develop.

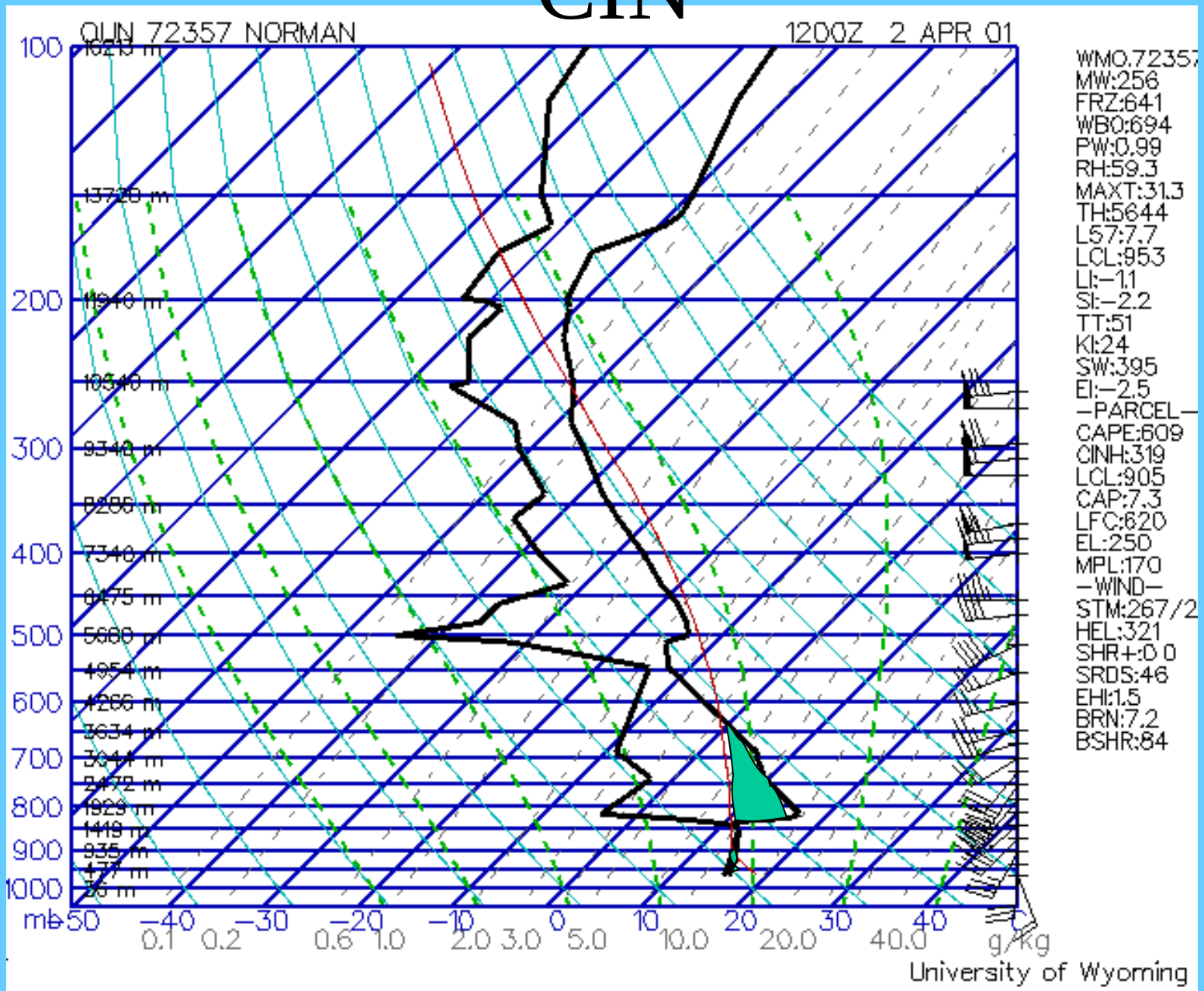
$$CAPE = PE = KE = \frac{1}{2}mv^2$$

$$w_{max} = \sqrt{2CAPE}$$

Convective Inhibition (CIN)

- CIN is NOT negative CAPE!!!!!!
- CAPE integrates from the LFC to the EL, CIN integrates from the surface to the LFC
- Is a measure of stability
- Reported as an absolute value

CIN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LI:−1.1
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STM:267/2
HEL:321
SHR+:0 0
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20.0
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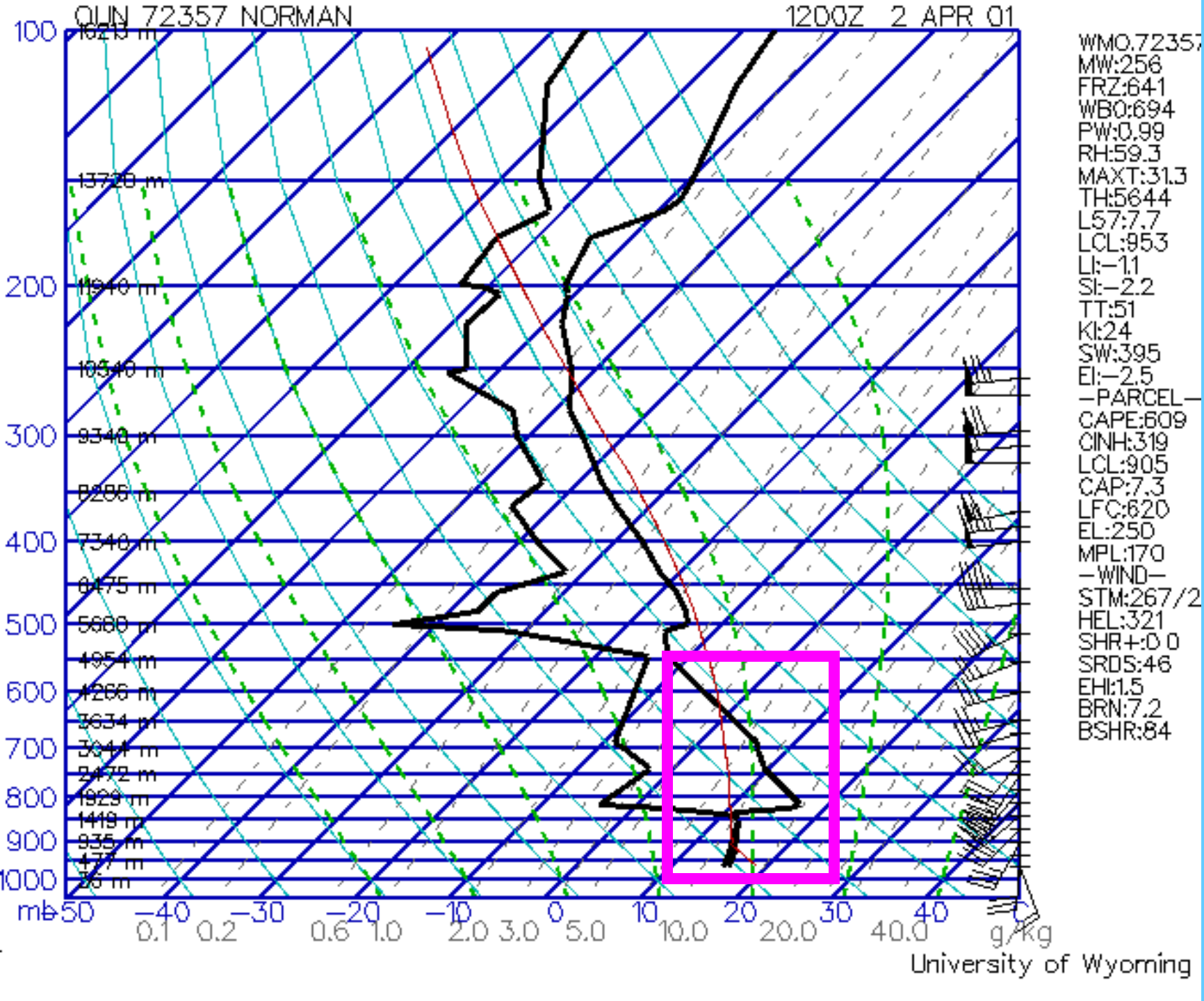
g/kg
University of Wyoming

Overcoming Convective Inhibition

- A convective outbreak rarely occurs from surface heating alone!
- Triggering Mechanisms for T-Storms
  - fronts
  - dry lines
  - sea-breeze fronts
  - gust fronts from other thunderstorms
  - atmospheric buoyancy waves
  - mountains

Cap Strength

- Very important for severe weather to develop
- Too little or no cap: happy little cumulus everywhere
- Too strong of a cap: nothing happens
- Just the right amount of a cap: Severe Weather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1200Z 2 APR 01
WMO:72357
MW:256
FRZ:641
WBO:694
PW:0.99
RH:59.3
MAXT:31.3
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EHI:1.5
BRN:7.2
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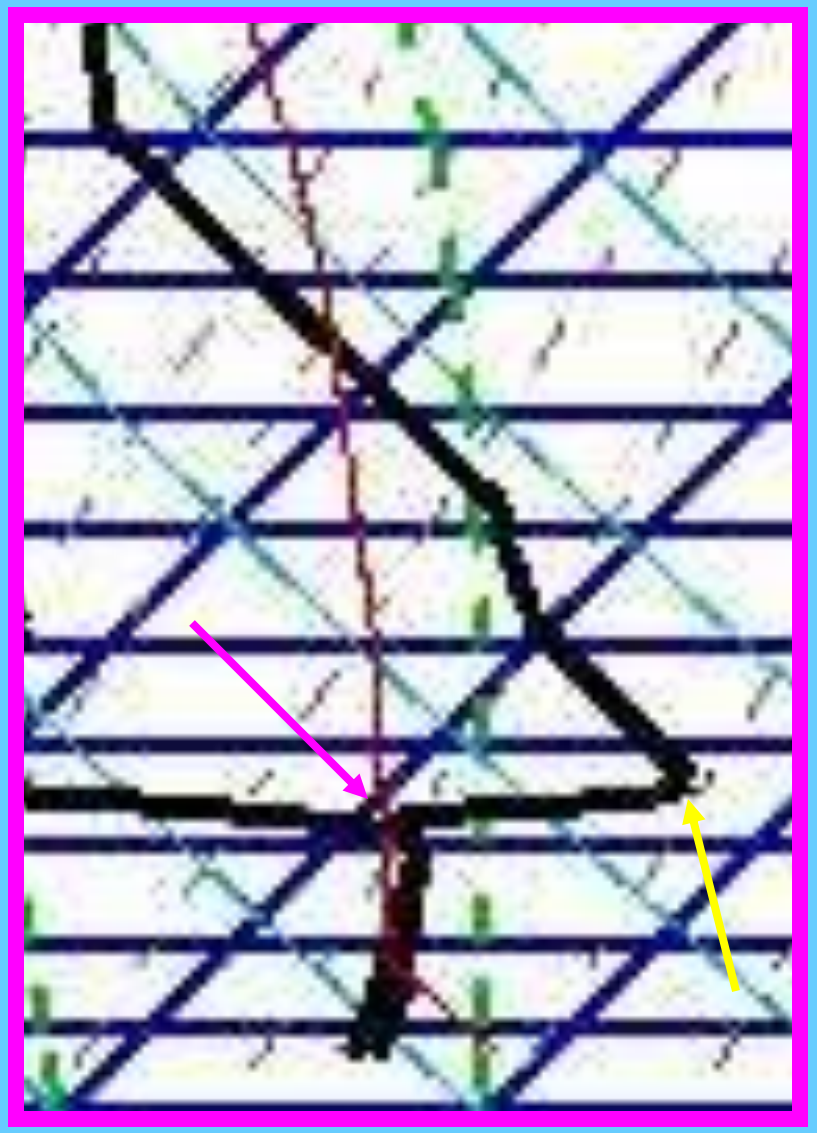
g/kg
University of Wyoming



- At the inversion* look at the temperature difference between the parcel and the environment.

Shear vs. CAPE

- Need a balance between Shear and CAPE for supercell development
- Without shear: single, ordinary, air mass thunderstorm which lasts 20 minutes
- If shear is too strong: multicellular t-storms

  (gust front moves too fast)

CAPE and Shear

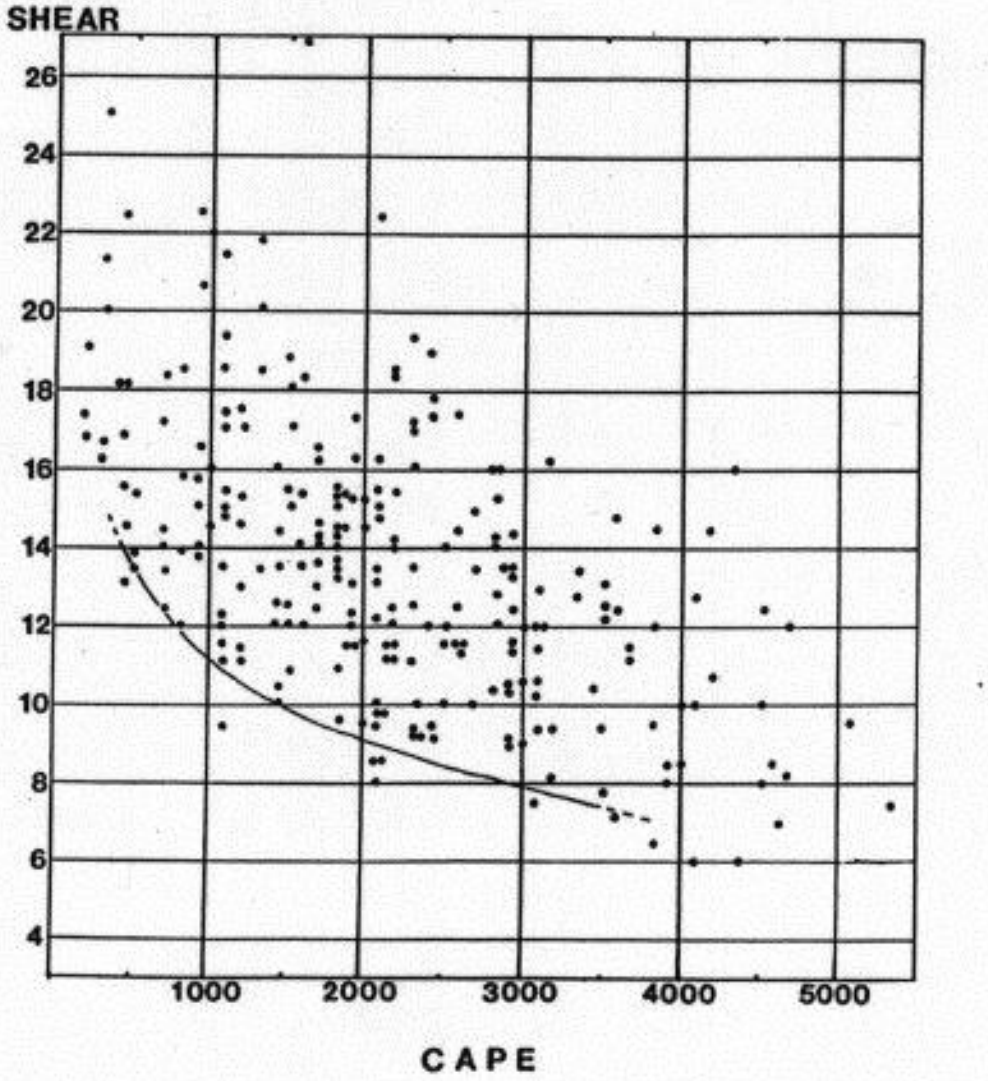
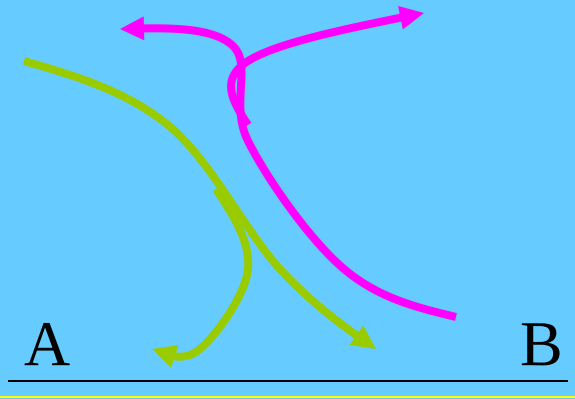
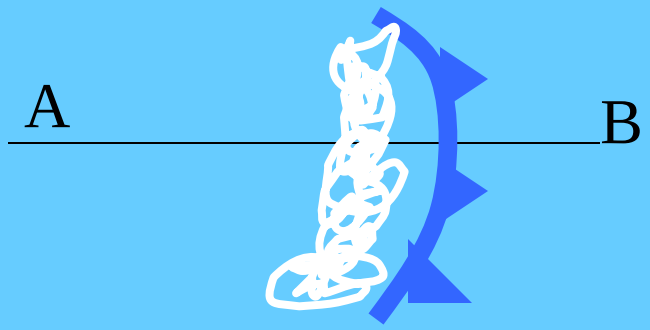


Fig. 6. As in Figure 2 except for all 242 cases in the data set [after *Johns et al.*, 1990].

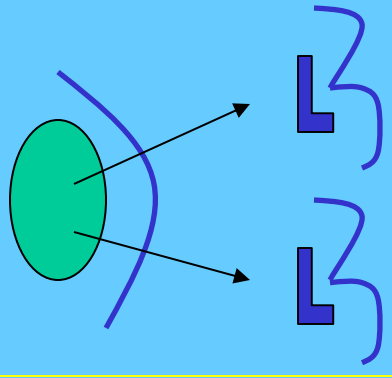
Shear Just Right

- 2-D equilibrium: squall line develops

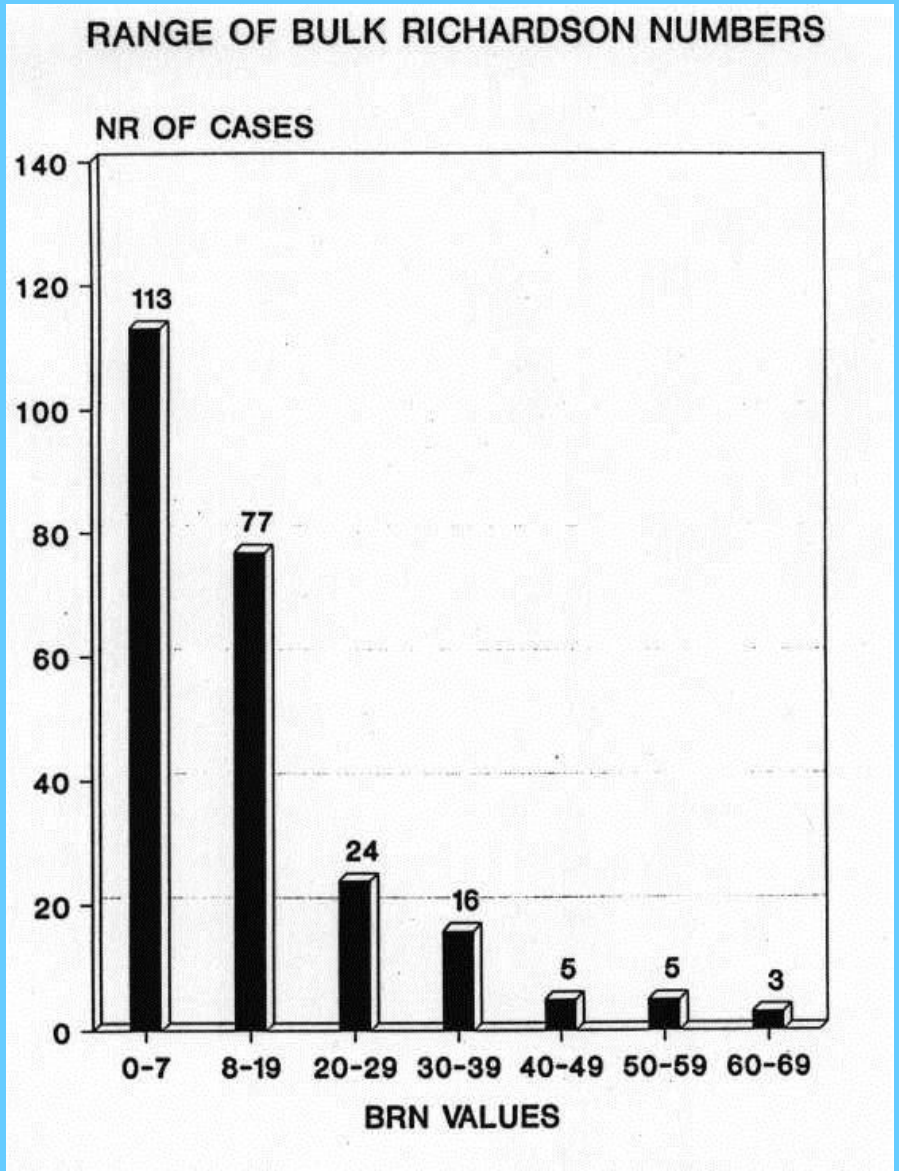




- 3-D equilibrium: right moving and left moving supercells



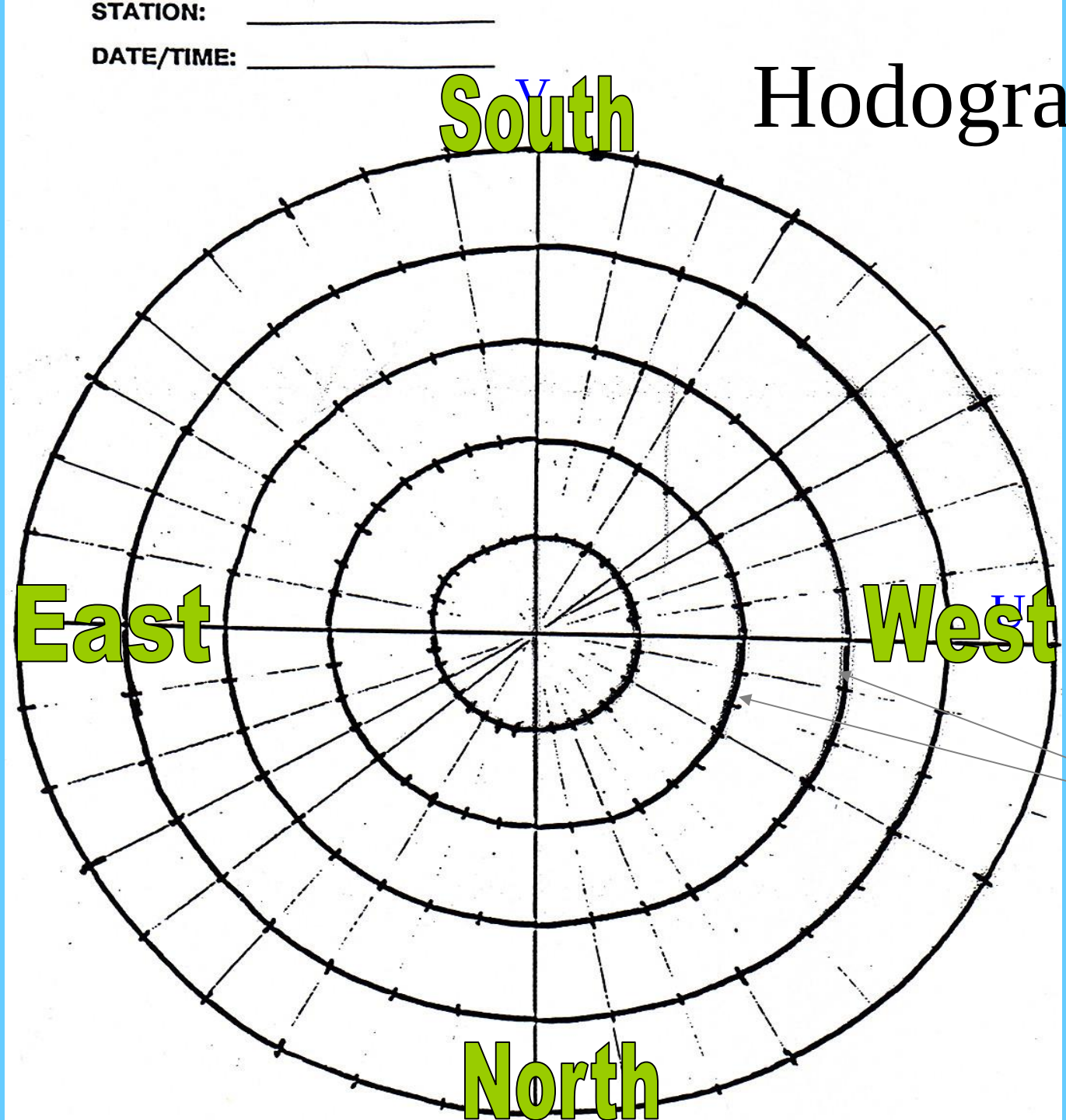
Bulk Richardson Number (BRN)



$$BRN = \frac{CAPE}{{}^{1}/_{2}U_{z}^{2}}$$

(where U_z is a measure of the vertical wind shear)

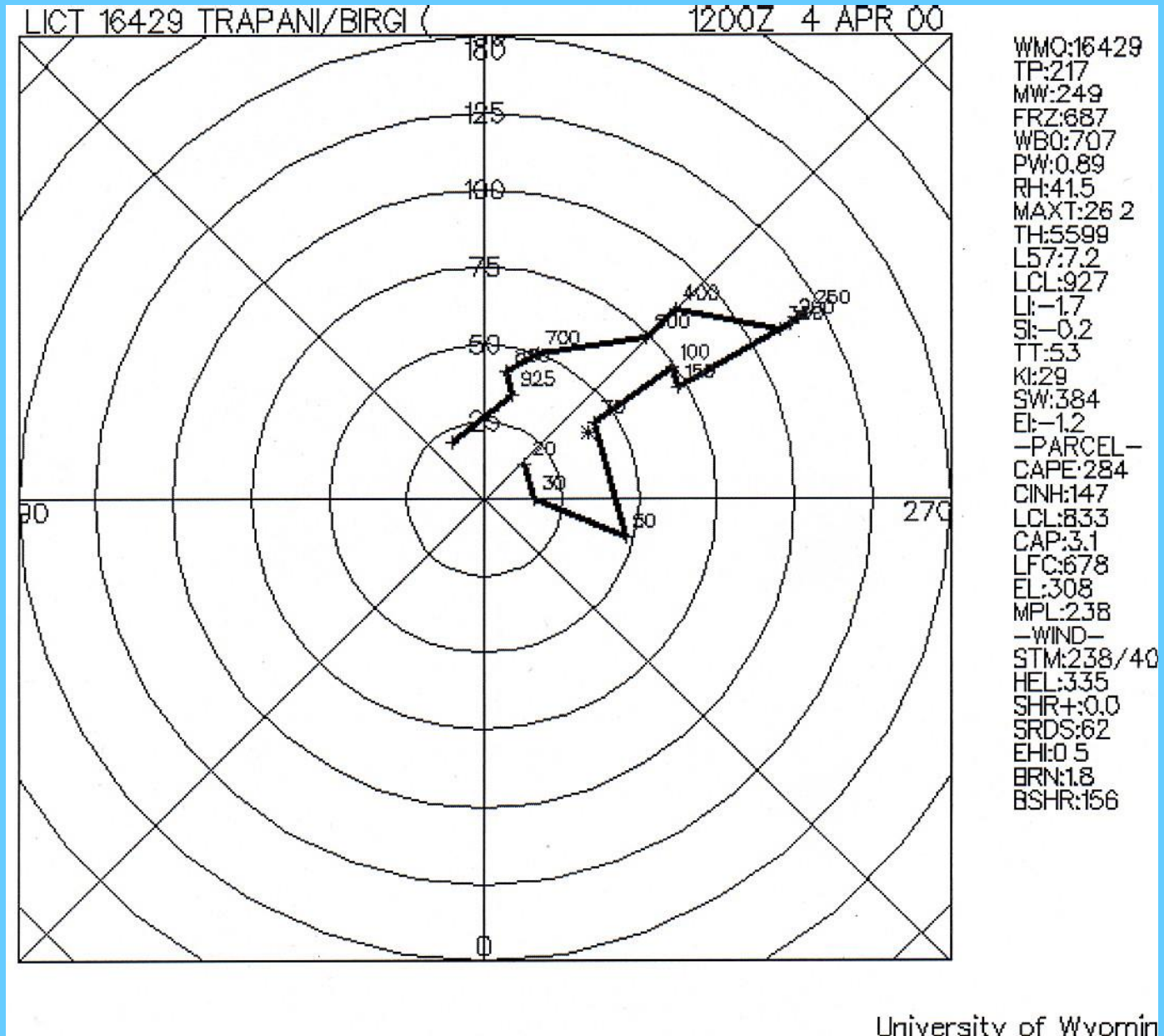
Hodographs



- Draw wind vectors in direction they are going
- This is opposite of how the wind barbs are drawn

Wind speed

Example


LICT 16429 TRAPANI/BIRGI (
1200Z 4 APR 00
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100
75
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TP:217
MW:249
FRZ:687
WB0:707
PW:0.89
RH:41.5
MAXT:26 2
TH:5599
L57:7.2
LCL:927
LI:−1.7
SI:−0.2
TT:53
KI:29
SW:384
EI:−1.2
−PARCEL−
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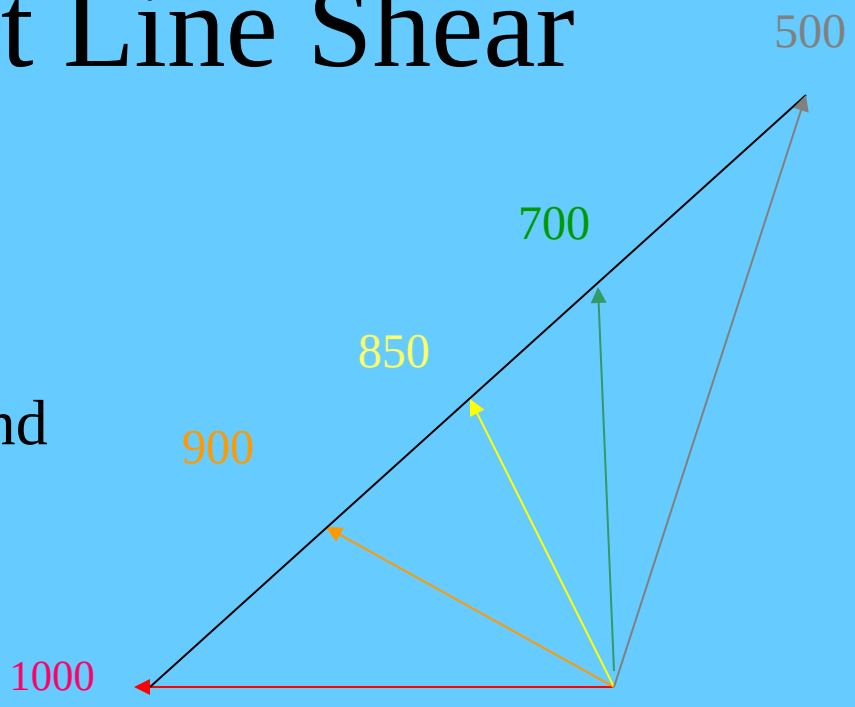
CINH:147
LCL:833
CAP:3.1
LFC:678
EL:308
MPL:238
−WIND−
STM:238/40
HEL:335
SHR+:0.0
SRDS:62
EHI:0 5
BRN:1.8
BSHR:156
University of Wyomin

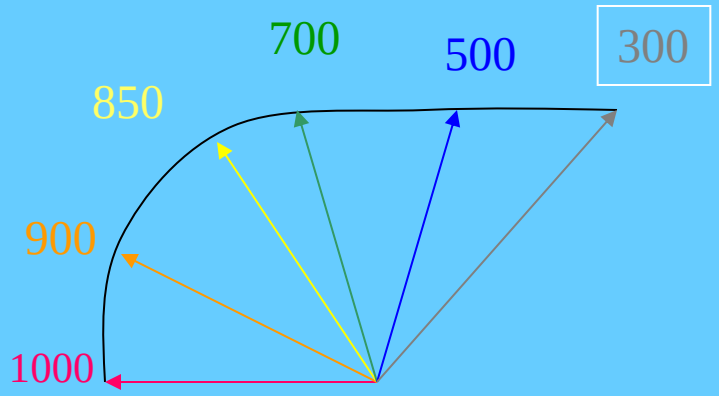
Straight Line Shear

- Storm Splitting:
  - R and L storm cells move with mean wind but drift outward

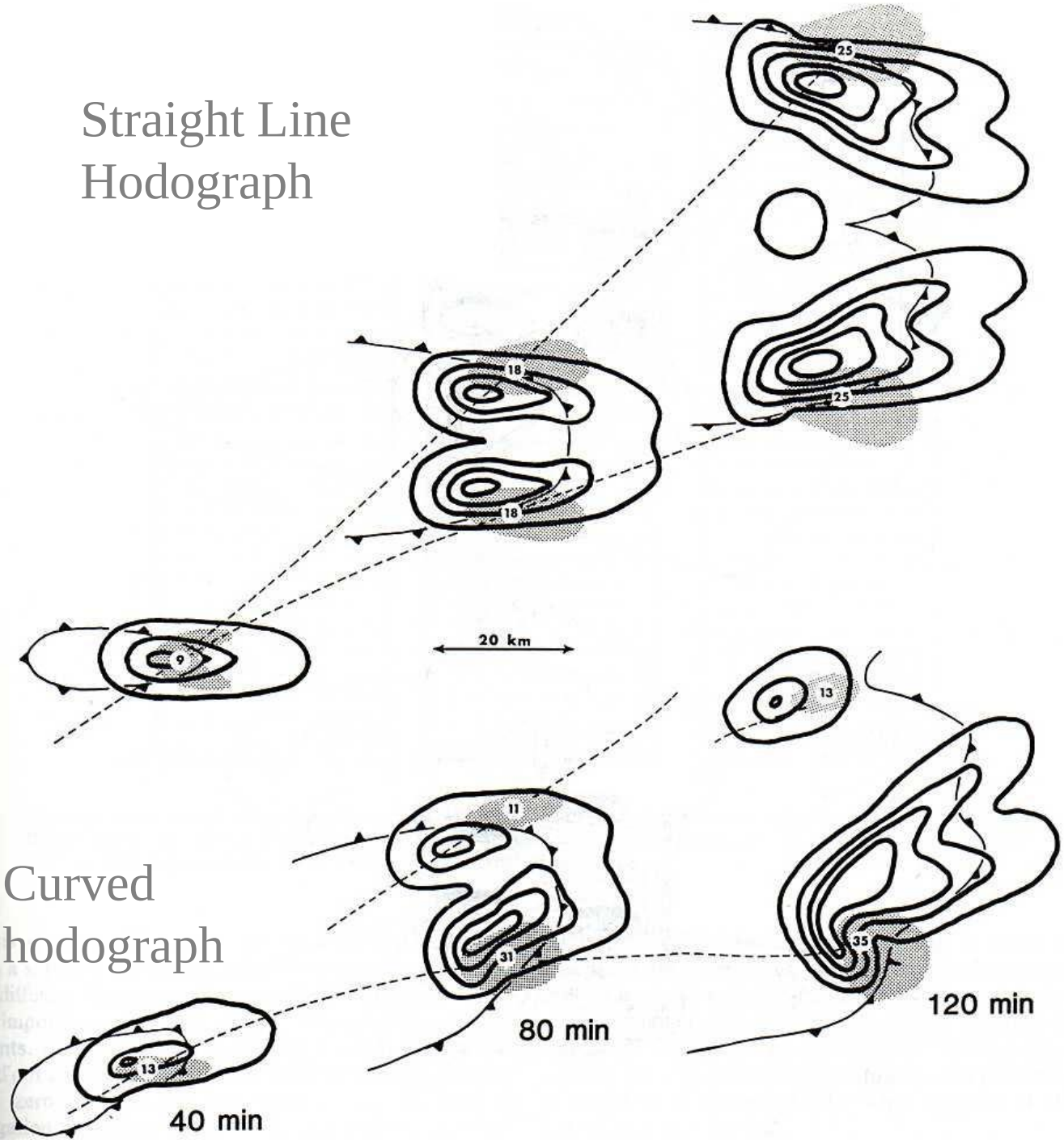


Curved Hodograph

- Emphasizes one of the supercells
  - Veering (clockwise curve):
    - right moving supercells
    - warm air advection in northern hemisphere
  - Backing (counter clockwise curve):
    - left moving supercells
    - warm air advection in southern hemisphere



Straight Line Hodograph



Curved hodograph

Helicity

- Can be thought of as a measure of the “corkscrew” nature of the winds.

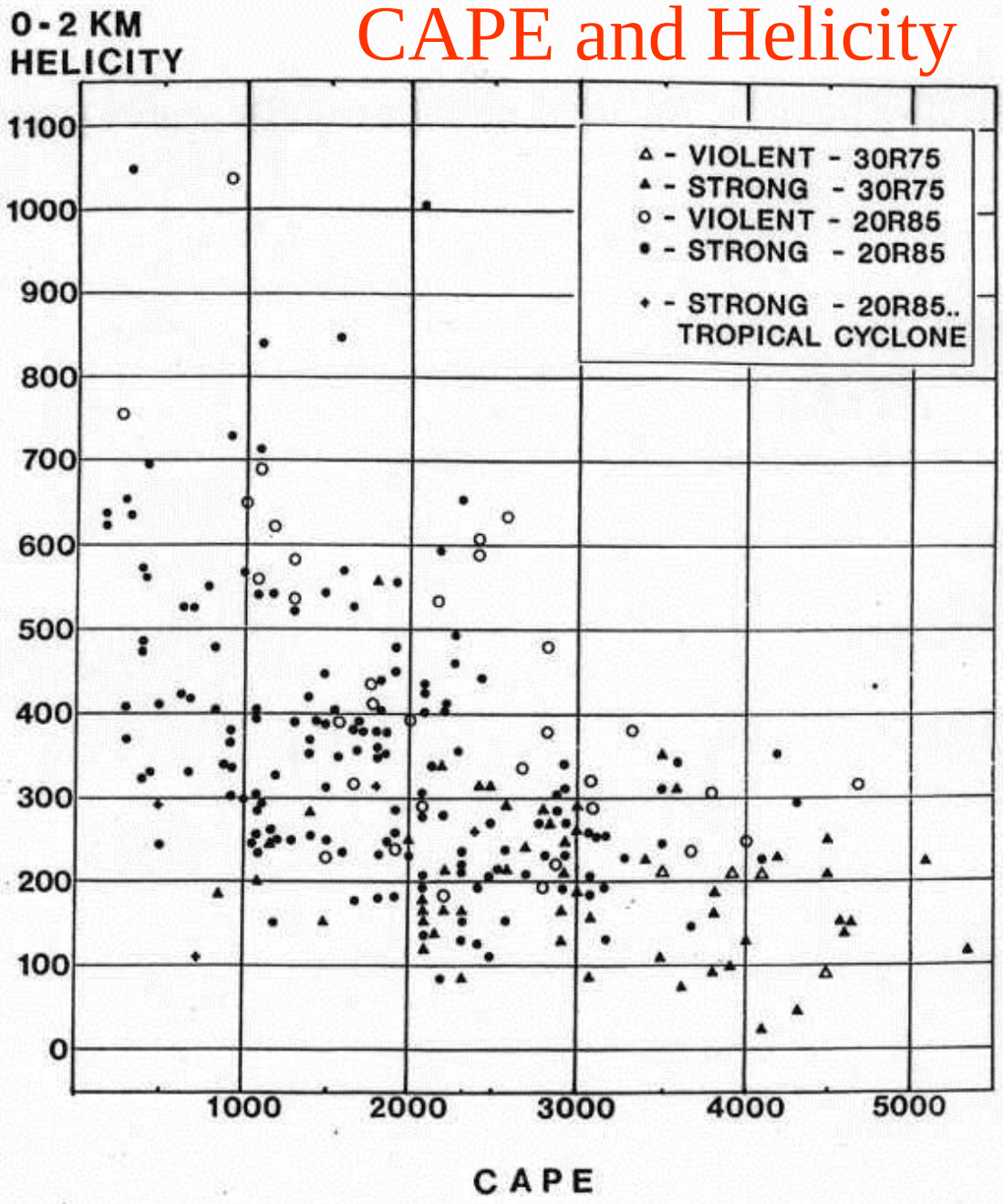
H = velocity dotted with vorticity

$= V \bullet \zeta$

$= u (d_y w - d_z v) - v (d_x w - d_z u) + w (d_x v - d_y u)$

- Higher helicity values relate to a curved hodograph.
  - large positive values--> emphasize right cell
  - large negative values--> emphasize left cells
- Values near zero relate to a straight line hodograph.

CAPE and Helicity



- Plainfield, IL tornado:

CAPE=7000

Helicity=165

Energy Helicity:

160,000

Stability Indices

K Index

- This index uses the values for temperature (t) and dew point temperature (t_d), both in ^oC at several standard levels.

$$K = t_{850} - t_{500} + t_{d850} - t_{700} + t_{d700}$$

K value	T-Storm Probability
<15	0%
15-20	<20%
21-25	20-40%
26-30	40-60%
31-35	60-80%
36-40	80-90%
>40	>90%

Vertical Totals

$$VT = T_{850} - T_{500}$$

- A value of 26 or greater is usually indicative of thunderstorm potential.

Cross Totals

$$CT = T_{d850} - T_{500}$$

CT	T-Storm Potential
18-19	Isolated to few moderate
20-21	scattered moderate, a few heavy
22-23	scattered moderate, a few heavy and isolated severe
24-25	scattered heavy, a few severe; isolated tornados
26-29	scattered to numerous heavy, few to scattered severe, a few tornados
>29	numerous heavy, scattered showers, scattered tornadoes

Total Totals (TT)

$$TT = VT + CT$$

$$= T_{850} + T_{d850} - 2\,T_{500}$$

TT	T-Storm Potential
44-45	Isolated to few moderate
46-47	scattered moderate, a few heavy
48-49	scattered moderate, a few heavy and isolated severe
50-51	scattered heavy, a few severe; isolated tornados
52-55	scattered to numerous heavy, few to scattered severe, a few tornados
>55	numerous heavy, scattered severe, scattered tornadoes

SWEAT (severe weather threat) Index

$$SWI = 12D + 20(T - 49) + 2f_8 + f_5 + 125(S + 0.2)$$

where: D=850mb dew point temperature (^oC)
(if D<0 then set D = 0)
T = total totals (if T < 49 then set entire term = 0)
f_8=speed of 850mb winds (knots)
f_5= speed of 500mb winds (knots)
S = sin (500mb-850mb wind direction)

And set the term 125(S+0.2) = 0 when any of the following are **not** true

1. 850mb wind direction is between 130-250
2. 500mb wind direction is between 210-310
3. 500mb wind direction minus 850mb wind direction is positive
4. 850mb and 500mb wind speeds > 15knots

SWEAT (severe weather threat) Index

$$SWI = 12D + 20(T - 49) + 2f_8 + f_5 + 125(S + 0.2)$$

<300	Non-severe thunderstorms
300-400	Severe thunderstorms possible
>400	Severe thunderstorms, including possible tornados

Lifted Index (LI)

- Compares the parcel with the environment at 500mb.

$$LI = (T_{env} - T_{parcel})_{500}$$

Lifted Index	Thunderstorm Potential
>+2	No convective activity
0 to +2	Showers probable, isolated thunderstorms possible
-2 to 0	Thunderstorms probable
-4 to –2	Severe thunderstorms possible
< -4	Severe thunderstorms probable, tornados possible

- Best Lifted Index
  - Uses the highest value of θ_e or θ_w in the lower troposphere.
  - Use the highest mixing ratio value in combination with the warmest temperature.
- SELS Lifted Index
  - Use the mean mixing ratio and mean θ of the lowest 100mb
  - If using a 12z sounding add 2^o
  - Start parcel at 50mb above the surface

Showalter Index (SI)

- Compares a parcel starting at 850mb with the environment at 500mb.

$$SI = (T_{env} - T_{parcel})_{500}$$

SI	Thunderstorm Possibility
> +3	No convective activity
1 to 3	Showers probable, isolated thunderstorms possible
-2 to 1	Thunderstorms probable
-6 to –2	Severe thunderstorms possible
< -6	Severe thunderstorms probable, tornados possible

Bulk Richardson Number

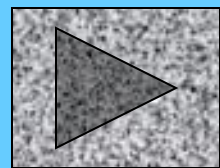
$$BRN = \frac{CAPE}{\frac{1}{2}(U_z^2)}$$

Where U_z = the vertical wind shear (averaged over 3-6km layer)

- In general: 15-40 favors supercell development
  >40 favors multicellular type storms
- Explains the balance between wind shear and convective energy

Supercell Index

- Weights various parameters which are indicative of possible supercell development



Important Points to Remember

- Severe weather is more dependent on dynamical forcing than instability!
- No one parameter tells the full tale!
- 12z soundings usually predict afternoon convection better than 00z soundings predict evening convection.

Links

- http://www.geocities.com/weatherguyry/swx2.html
- http://avc.comm.nsdlib.org/cgi-bin/wiki.pl?Severe_Weather_Indices
- http://www.theweatherprediction.com/severe/indices/
- http://www.theweatherprediction.com/habyhints/315/
- http://www.spc.noaa.gov/exper/mesoanalysis/
- http://mocha.meteor.wisc.edu/table.12z.html