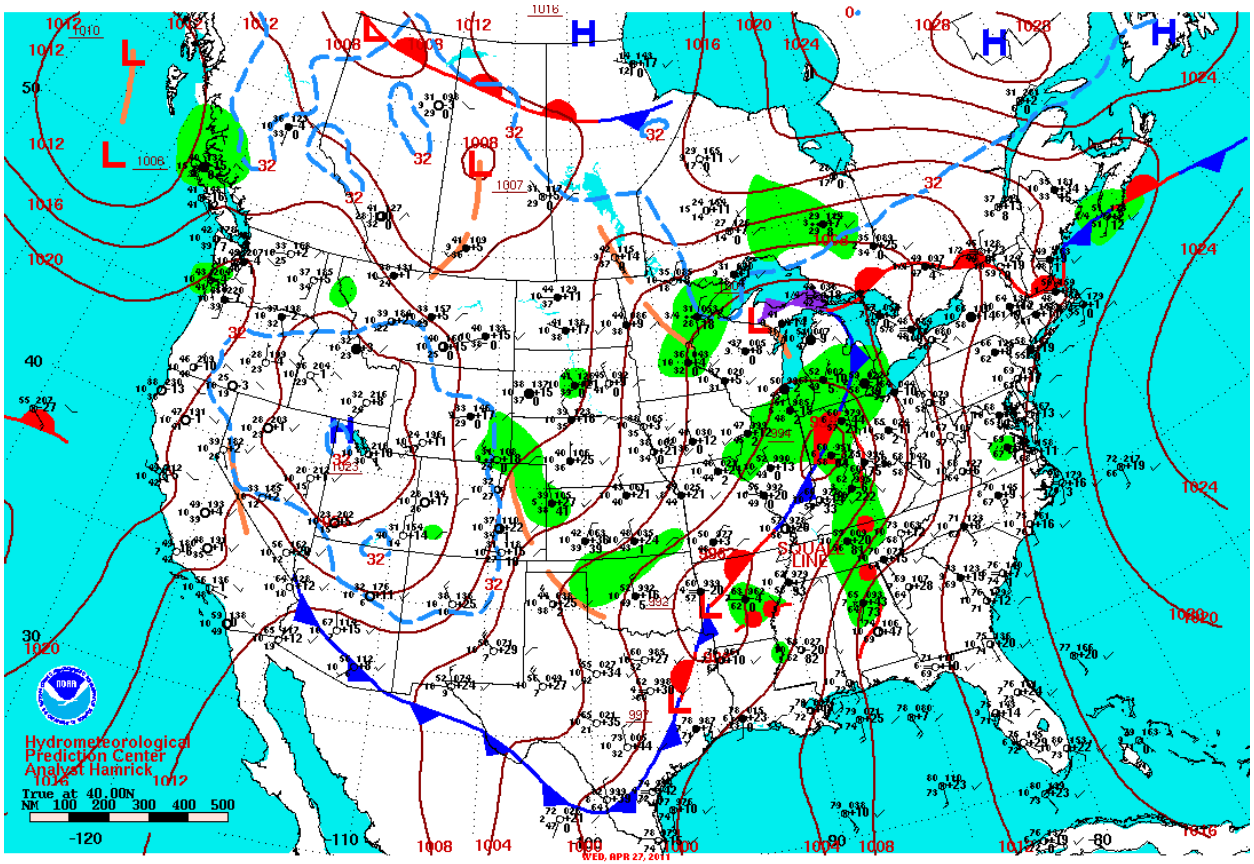
Homework #4 Key
100 points total

Part I
Surface and upper-air analyses
30 points

Acceptable to consider 00 UTC 28 April 2011 and previous six to twelve hours



Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.

Surface low pressure located in western Arkansas. Should probably be analyzed as a cold front that extends from the Great Lakes region to Texas. Front is identifiable on the surface map by weak pressure trough, wind shifts, temperature and dew point contrasts. Some precipitation (rain) along the front at various places.

Alabama is located in the warm sector, with very high dew points (60-70 degrees F), and this would be a favored location for severe weather in a mid-latitude cyclone.

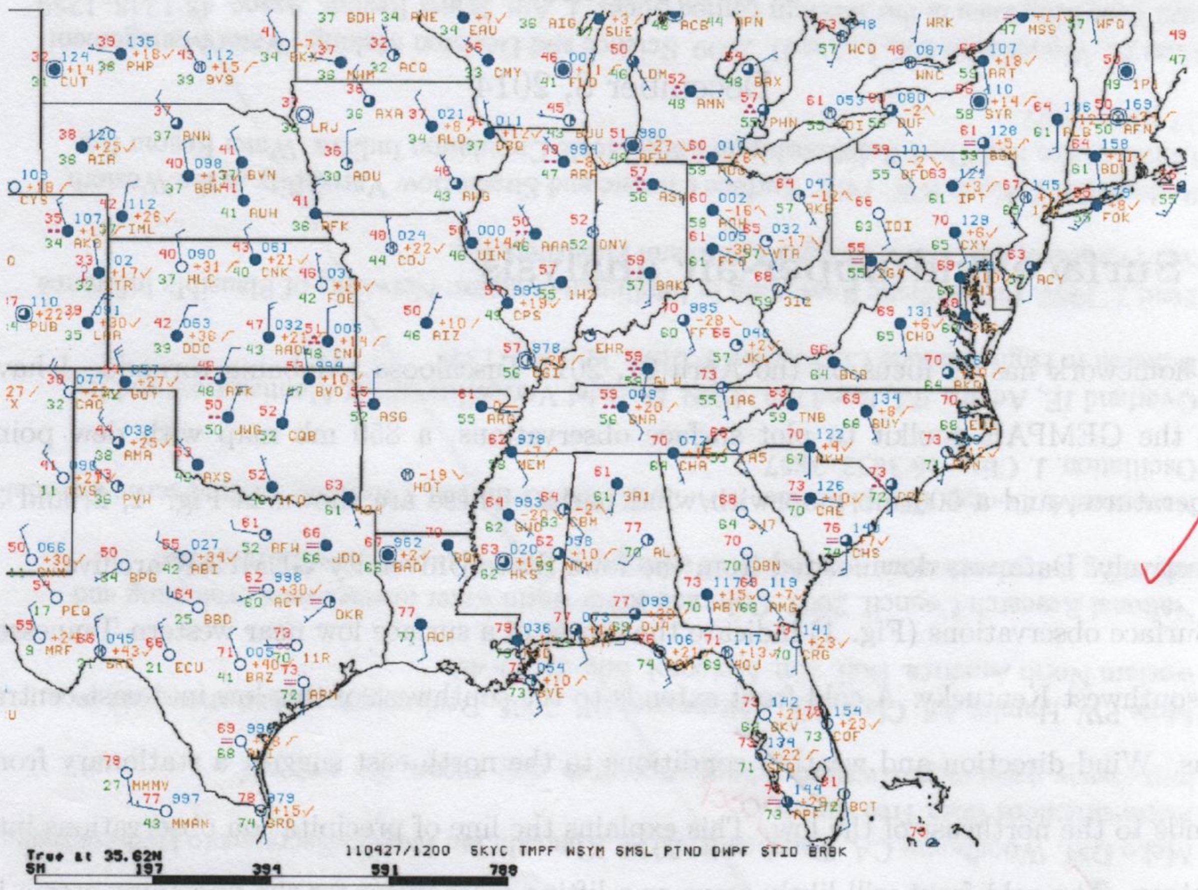


Figure 1: Surface observations from 2011-04-27 1200Z.

Considering the morning surface analysis…a critical factor in the development of severe weather is that it is not completely overcast, so that the convective temperature can be reached in the afternoon. Where the severe weather occurs in central Alabama, there is partly cloudy conditions in the morning, which would be favorable for this to happen.

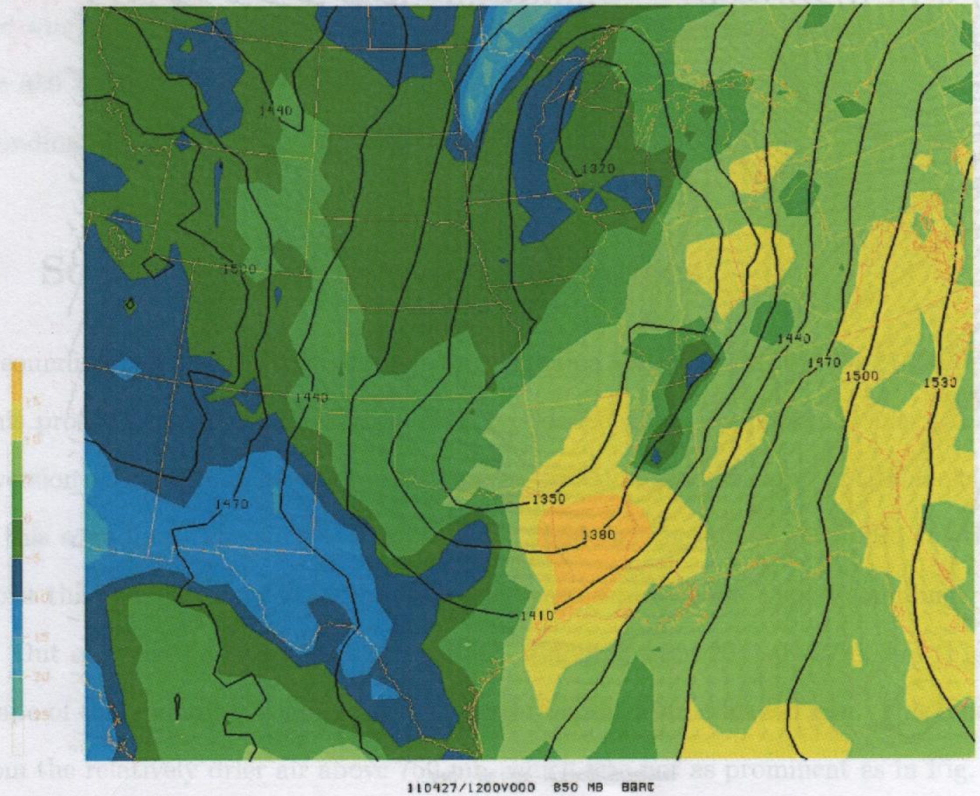


Figure 2: Map with 850 mb geopotential height contours and filled contours giving dew point temperature (in °C). Data is from the NAM analysis for 2011-04-27 1200Z.

Highest dew point temperatures are located south and west of Alabama in Mississippi and Louisiana. As winds in low levels (surface to 850-mb) are from the southwest, even more moist air will be advected into Alabama during the day. This will help increase the equivalent potential temperature even more, thereby making the atmosphere even more favorable for severe weather.

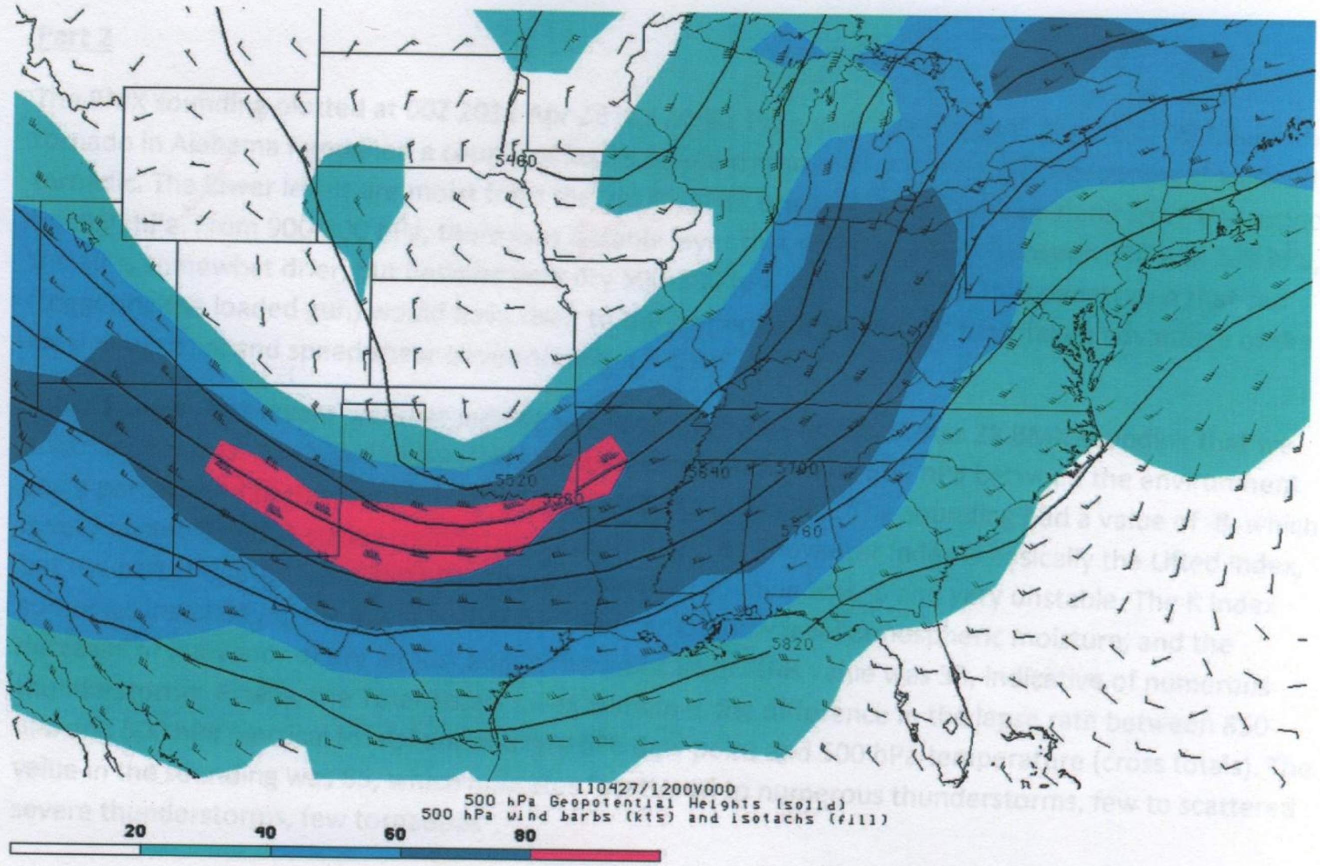
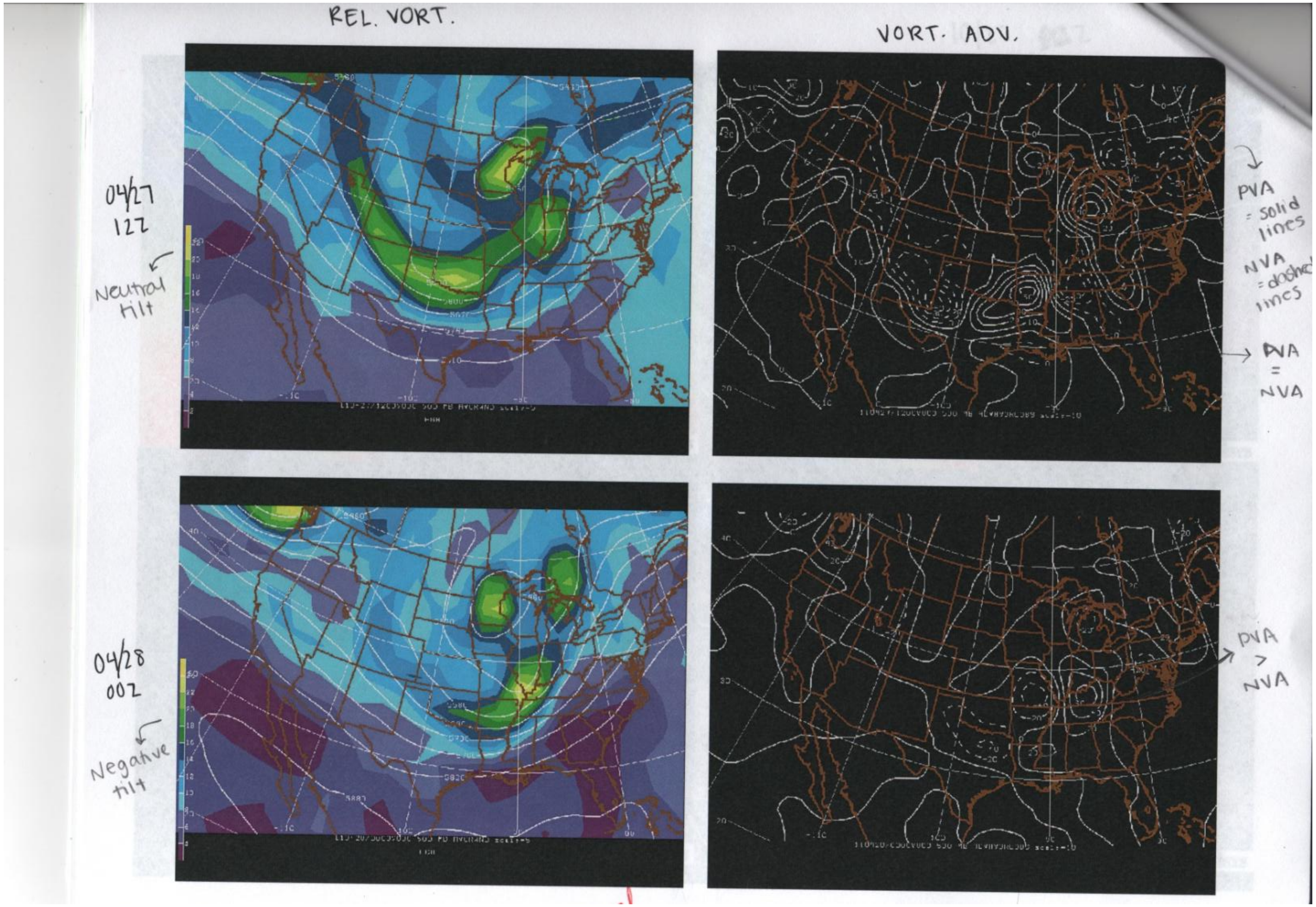
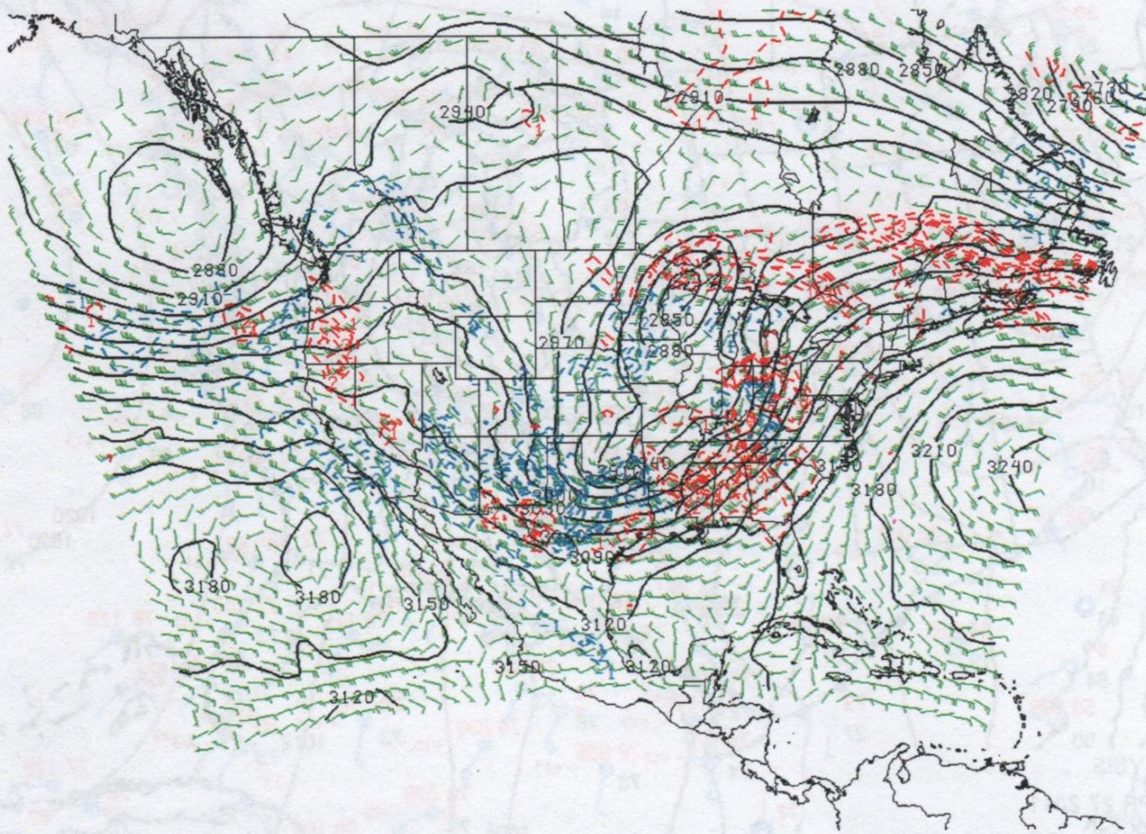


Figure 3: 500 hPa heights, wind barbs (kts) and isotachs at 1200 UTC 2011 Apr 27

Jet streak located to the west of the region. If the trough is digging, this may place Alabama in the left exit region of the jet streak later, which would be most favorable place for strongest rising motion in a mid-latitude cyclone. Upper-level trough located northwest of the surface low, so system is still strengthening.



Considering the 500-mb vorticity and vorticity advection from 12 UTC to 00 UTC, the trough is digging as the day proceeds. By the time the tornado occurs, positive vorticity advection is occurring over Alabama.



Good

Figure 4: 700 mb warm air advection (red contour) and cold air advection (blue contour), and geopotential height (black).

Warm air advection is occurring throughout the Southeastern states during the day, and this is probably the most important contributing factor to synoptic scale vertical motion.

Some additional comments per convective organization on the mesoscale…

Thermodynamics: There is high theta e air near the surface, that is increasing during the day. All that is needed is some surface heating to get the convection going. Exactly where some direct sunshine is observed in the morning ahead of the cold front is where the severe weather will occur later.

Dynamics: From the surface and upper air analyses it is clear that winds are changing speed and direction with height over Alabama (i.e. there is helicity), which would be favorable for development of supercell thunderstorms. Southwesterly winds at surface becoming more westerly aloft is a veering wind profile = warm air advection + favors supercells that would move to the right of the mean steering flow.

Part II
Sounding Analysis
30 points

Acceptable to consider 00 UTC 28 April 2011 and previous six to twelve hours

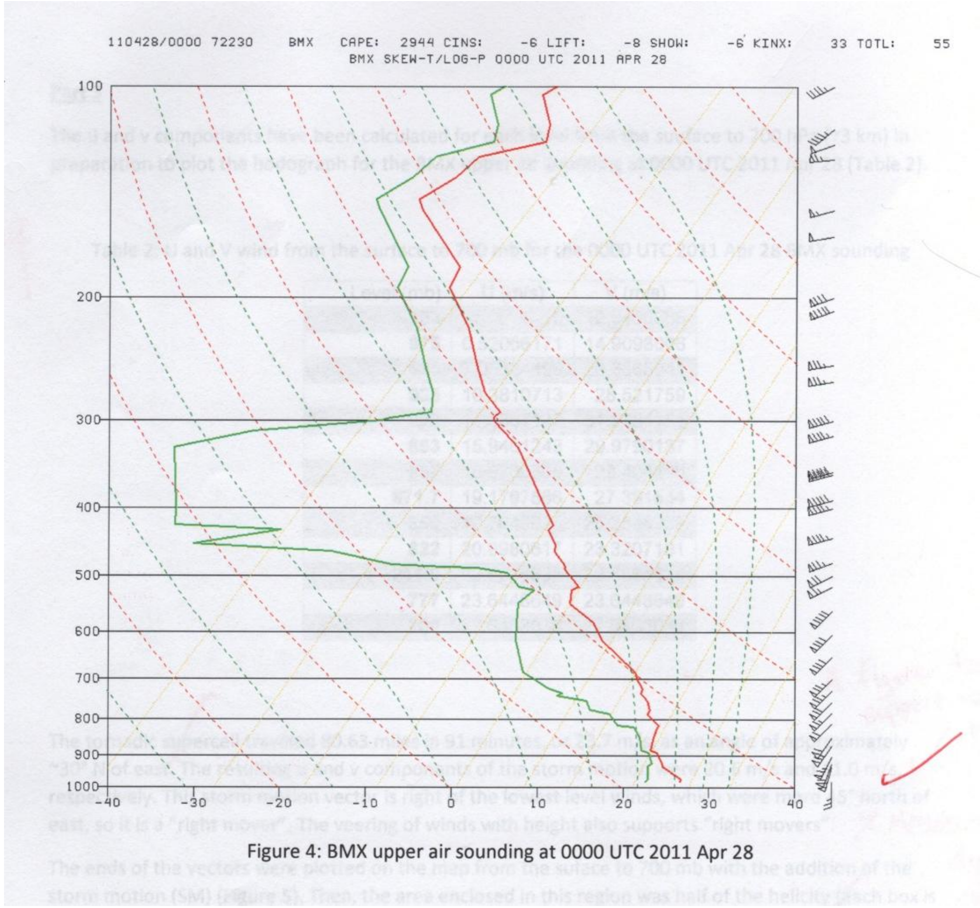


Figure 4: BMX upper air sounding at 0000 UTC 2011 Apr 28

At the time nearest to when the tornado actually occurs, the sounding is closest to Miller type 1, or the loaded gun. Warm moist air in the PBL (up to 850-mb), weak temperature inversion above PBL, then cold and dry above the level of free convection (about 750-mb). Also changes in wind speed and direction with height. Strong winds associated with the approaching jet streak are especially important for supercell thunderstorm. development.

The indices for convection and their projection for thunderstorm formation are shown here:

Index	**Value**	**Indication**
Showalter Index	-6.26	Extremely unstable, strong t-storms likely
Lifted Index	-8.05	Very unstable, heavy to strong t-storms
K Index	33	Probability of scattered t-storms
Bulk Richardson	14	Tendency for supercell/tornadic storms
CAPE	2944 J/kg	Moderate to strong convection

The CAPE, Showalter Index, and Lifted Index performed well to quantify the high atmospheric instability and sever weather outbreaks – the values were at their most extreme levels for these severe outbreaks. The K Index and Bulk Richardson number both indicated severe weather, but because they didn't classify this day at the far extreme end of their ranges, these numbers may have indicated to a forecaster to be more reserved in issuance of warnings.

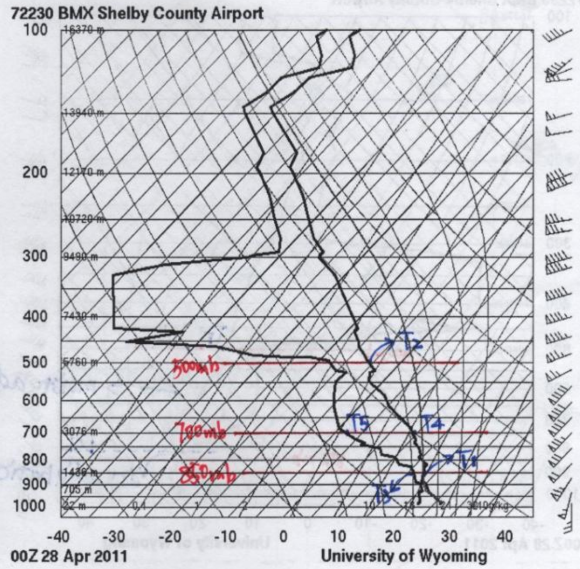
Maximum potential vertical velocity:

$$w_{max} = \sqrt{2 * CAPE}$$
$$w_{max} = \sqrt{2 * 2944} = 76.7 m/s$$

X Some comment about how these indices physically computed in relation to how they inform for this case.

Basic point…multiple convective indices tell the same story in terms of favorability for severe weather. Not surprising since they are designed to work best in the central and eastern U.S. See class notes for specific information on computing indices from the soundings!

(a)



$T_1 = 18°C$

$T_2 = -11°C$

$T_3 = 16°C$

$T_4 = 9°C$

$T_5 = -3°C$

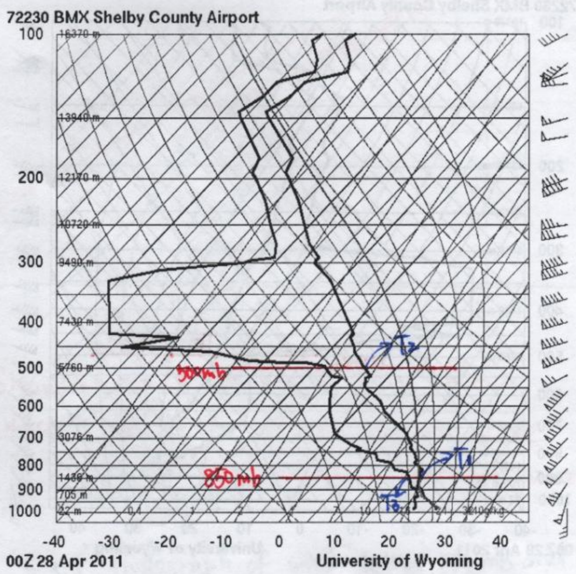
"K" Index

$= T_1 - T_2 + T_3 - (T_4 - T_5)$

$= 18 + 11 + 16 - 12$

$= 33°C.$

(b)



$T_1 = 18°C$

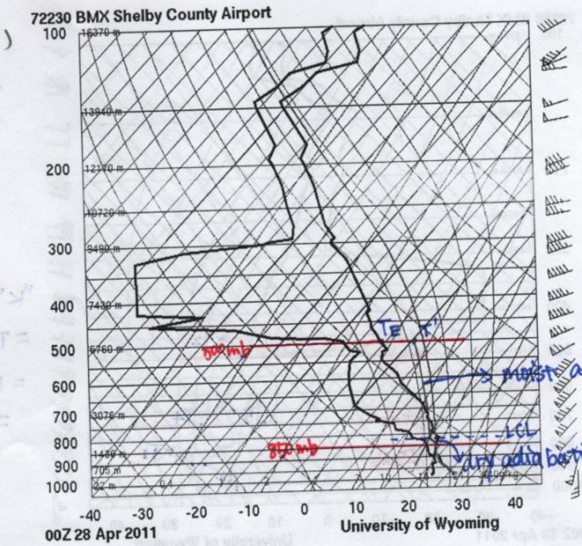
$T_2 = -11°C$

$T_3 = 16°C$

$TT = (18 + 11) + (16 + 11) = 56°C.$

Fig. 8. Sketches to compute four indices.

(c)



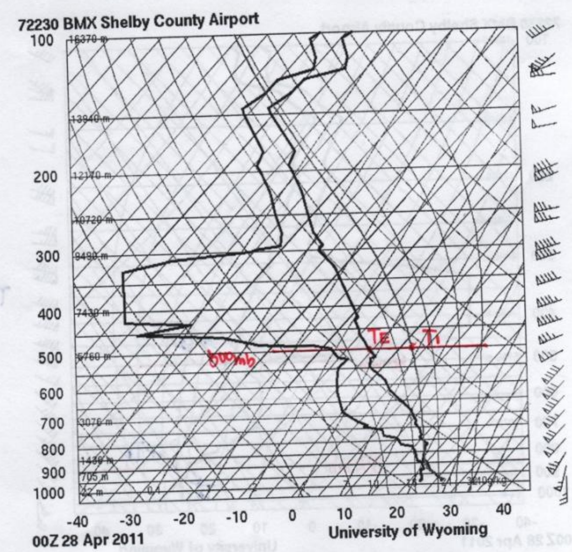
$T' = -5°C$

$T_E = -11°C$

Showalter Index

$= -11 - (-5) = -6°$

(d)



$T_1 = -3°C$

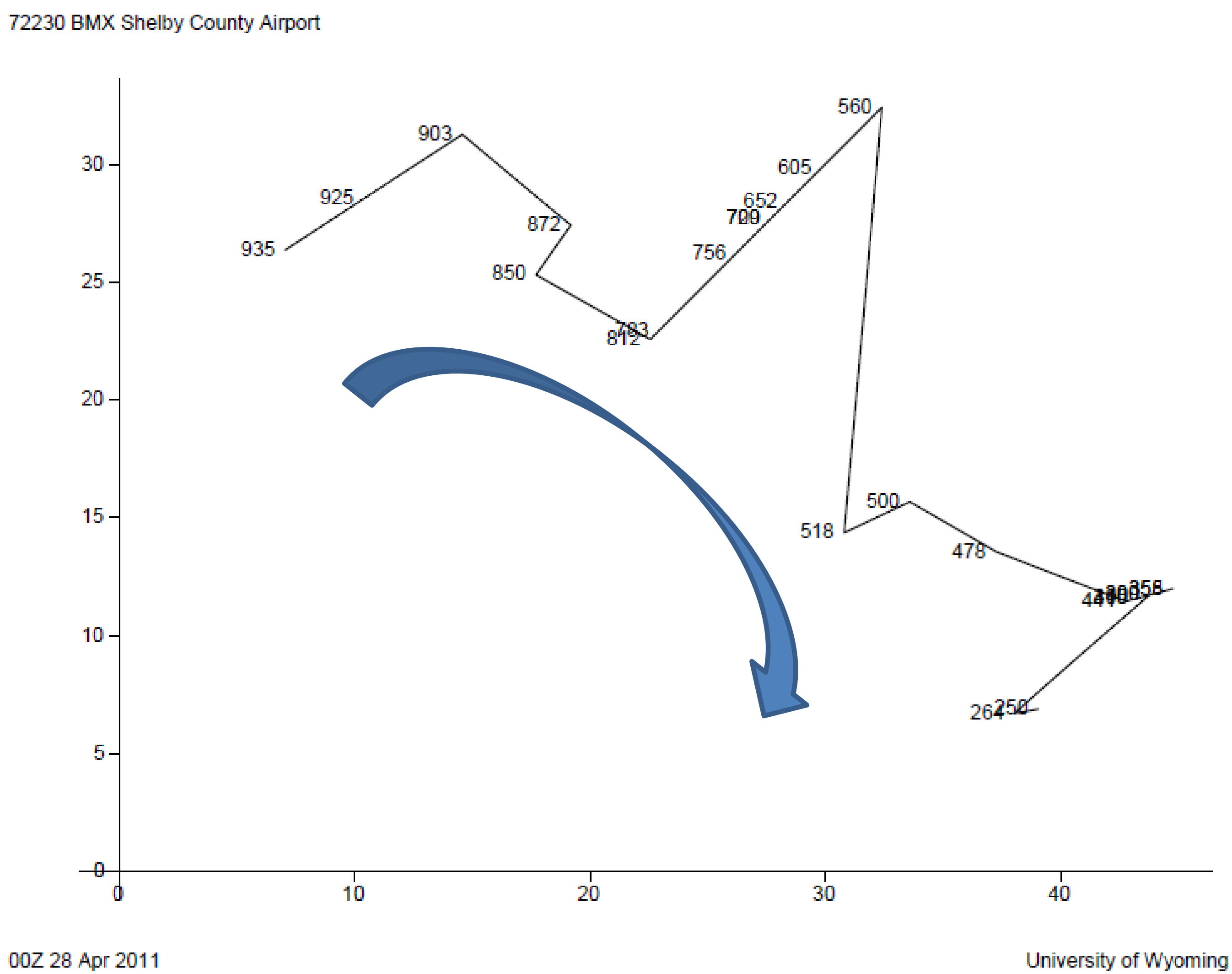
$T_E = -11°C$

Lift Index

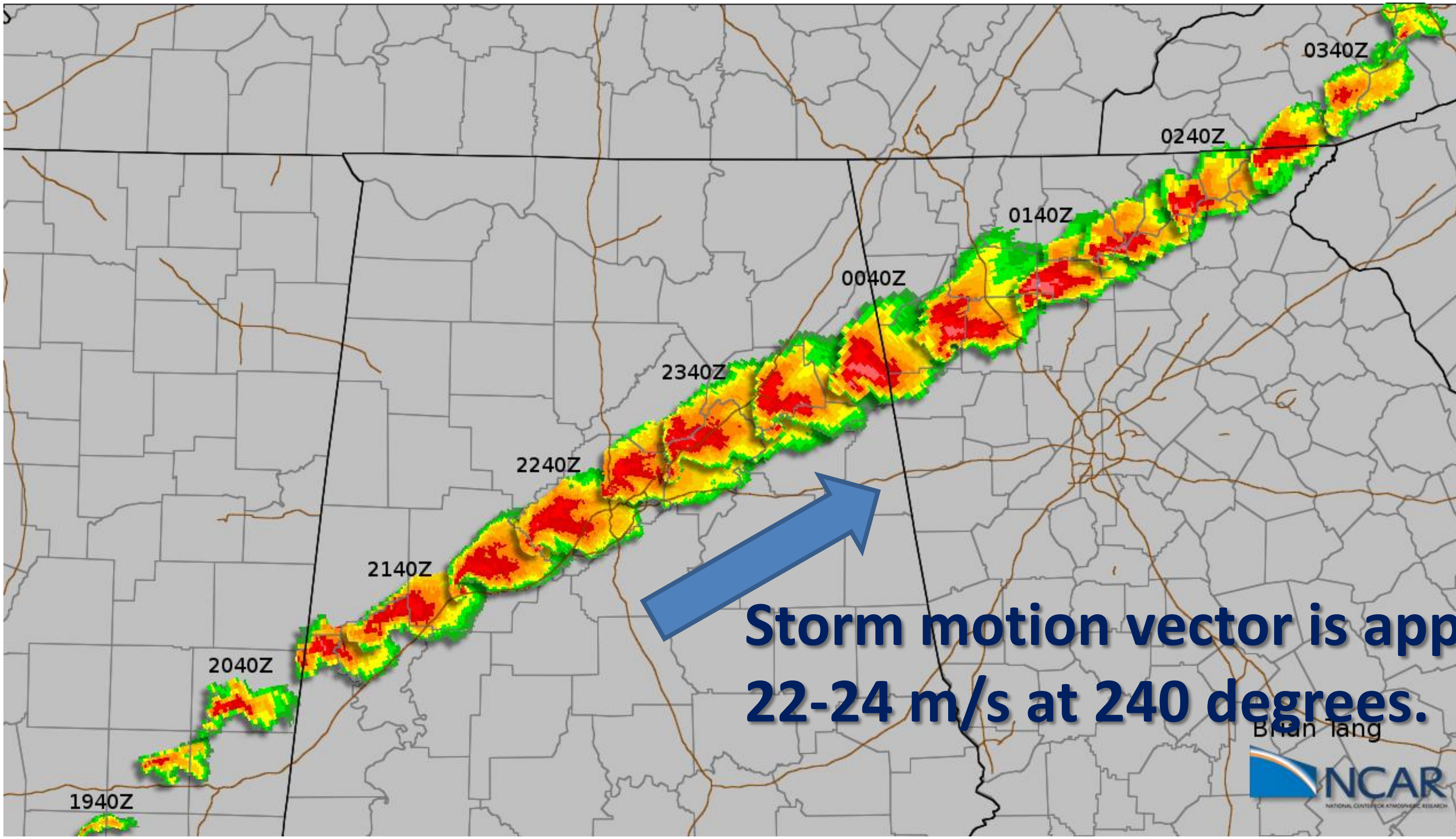
$= -11 - (-3) = -8$

Fig. 8. continued.

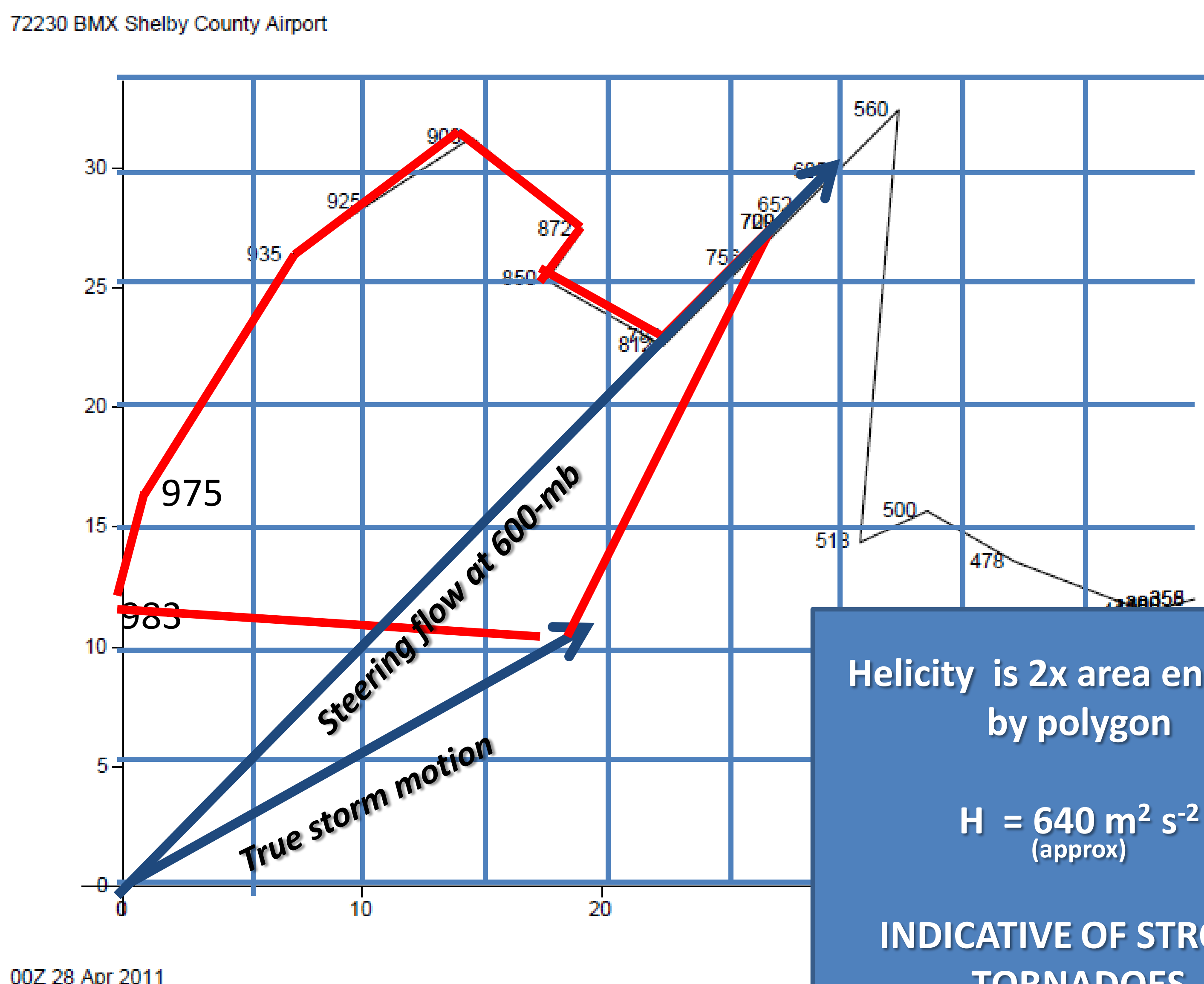
Part III
Hodograph and helicity computation
40 points



Clockwise turning hodograph, which in mid-latitudes in northern hemisphere corresponds to warm air advection and favors the development of right moving supercell thunderstorms if the thermodynamic conditions are favorable.



Storm motion vector is approx. 22-24 m/s at 240 degrees.



Helicity is 2x area enclosed by polygon

H = 640 $m^2\ s^{-2}$
(approx)

INDICATIVE OF STRONG TORNADOES

True storm motion vector about 7 m/s to right of mean steering wind , very much in line with what would be estimate using Bluestein's suggestion!

PART 3

The estimated storm motion vector indicates a right-moving supercell thunderstorm. This is caused by the interaction of the environmental shear with updraft vertical velocity.

The non-linear pressure effects can create an environment in which storm splitting is likely: Horizontal vorticity (caused by vertical wind shear) tilts upward due to the updraft, becoming vertical vorticity. The strongest rotation occurs at mid-levels in the storm flanks, with weaker rotation near the surface. Non-linear shearing terms dictate that this area of mid-level vorticity induced by the updraft will experience low perturbation pressures, while the surface experiences higher pressure and smaller vorticity. This results in an upward directed pressure gradient force, tending to sustain updrafts at the sides of the storm. A downdraft in the center of the storm weakens the updraft and the strongest vertical motion is favored at the flanks, resulting in storm splitting. The separate storms propagate perpendicular to the shear vector.

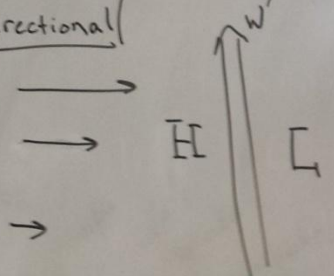
The linear pressure effects cause the right-mover to be favored: For a unidirectional shear environment, a pressure gradient force balances the vertical advection by an updraft of horizontal momentum associated with environmental shear, resulting in a positive pressure perturbation on the up-shear side of the updraft and a negative pressure perturbation on the down-shear side of the updraft. For a directional shear environment, the location of the positive and negative pressure perturbation rotates with height in the direction of the shear rotation (remaining in the up-shear or down-shear location as the wind direction changes), with the result that upward motion is favored on one flank over the other. When the storm splits according to the non-linear pressure effects, the favored flank will persist and the unflavored flank will diminish.

You got it.. outstanding!

Here, the vertical wind profile indicates a clockwise-rotating directional shear profile. In this case, upward directed pressure gradients are favored on the right flank of the storm, resulting in storm motion to the right of the steering flow.

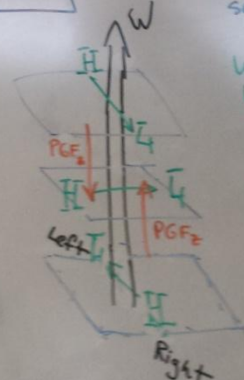
Linear dynamic pressure effects:
Updraft interacting with environmental shear

$\boxed{\text{Unidirectional}}$



High pressure upwind of updraft, low pressure downwind of updraft.

$\boxed{\text{Directional}}$



Typical US
severe Wx profile ... WAA, clockwise turning hodograph.

Upper levels northerlies

Mid-levels westerlies

Low levels Southerlies

Net result:
Upward directed PGF_z on RIGHT side of storm
Downward PGF_z on left side.

Non-linear
Updraft
creating

Non-linear dynamic pressure effects:

Updraft tilts vortex tubes in vertical, creating meso vortices ...

kwise

hodograph.

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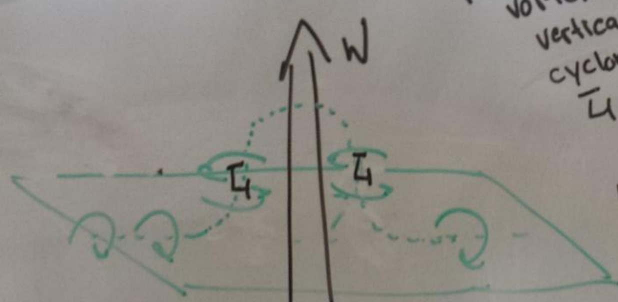
HΓ

orm

PGF_z

ide.

Updraft tilts vortex tubes in vertical, creating cyclonic, anticyclonic $\overline{\zeta}$ (independent of spin)



Vertical wind shear creates vorticity in x-z, y-z planes