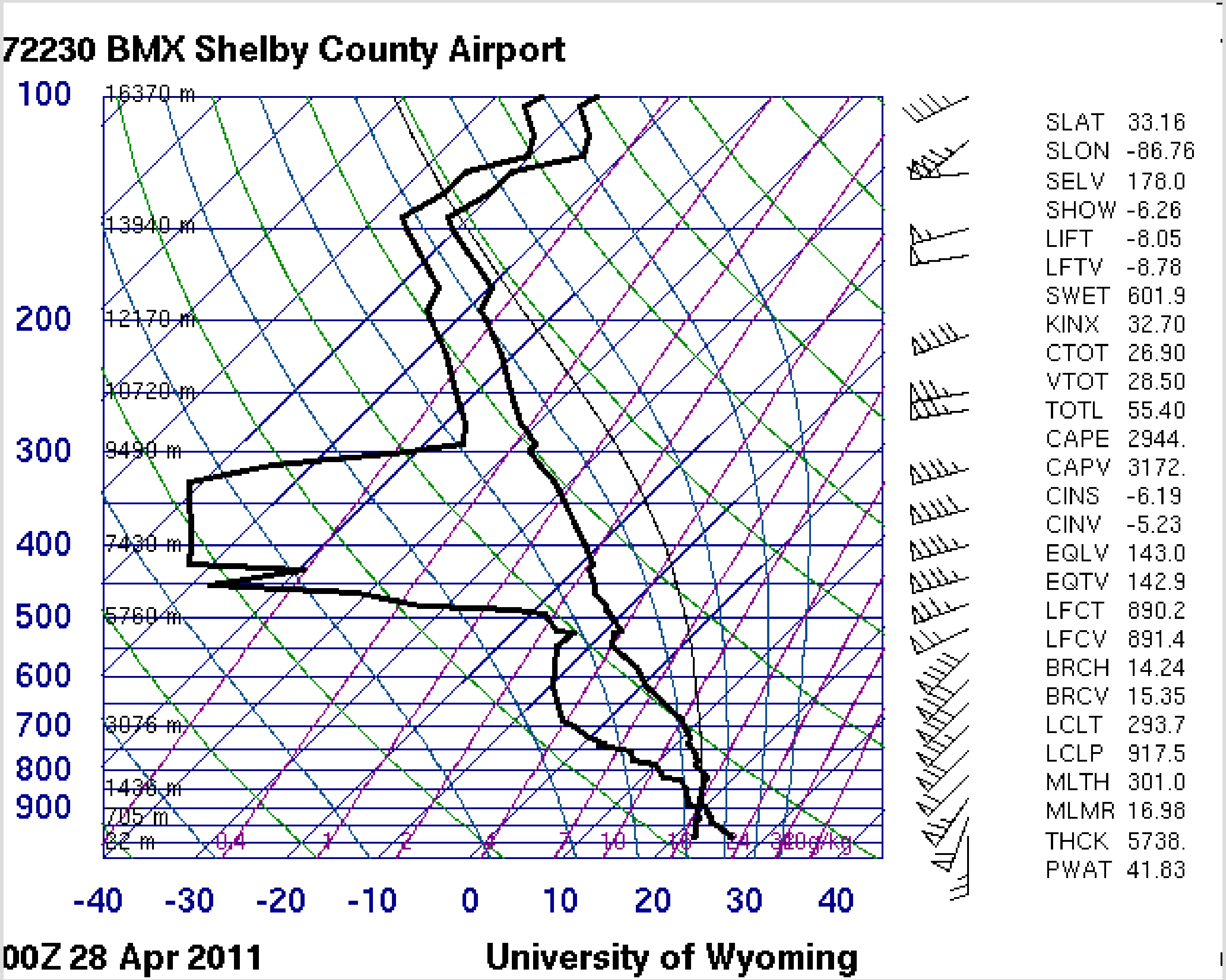
Introduction to hodographs

Primer on diagnosis of severe, organized convection


72230 BMX Shelby County Airport

00Z 28 Apr 2011

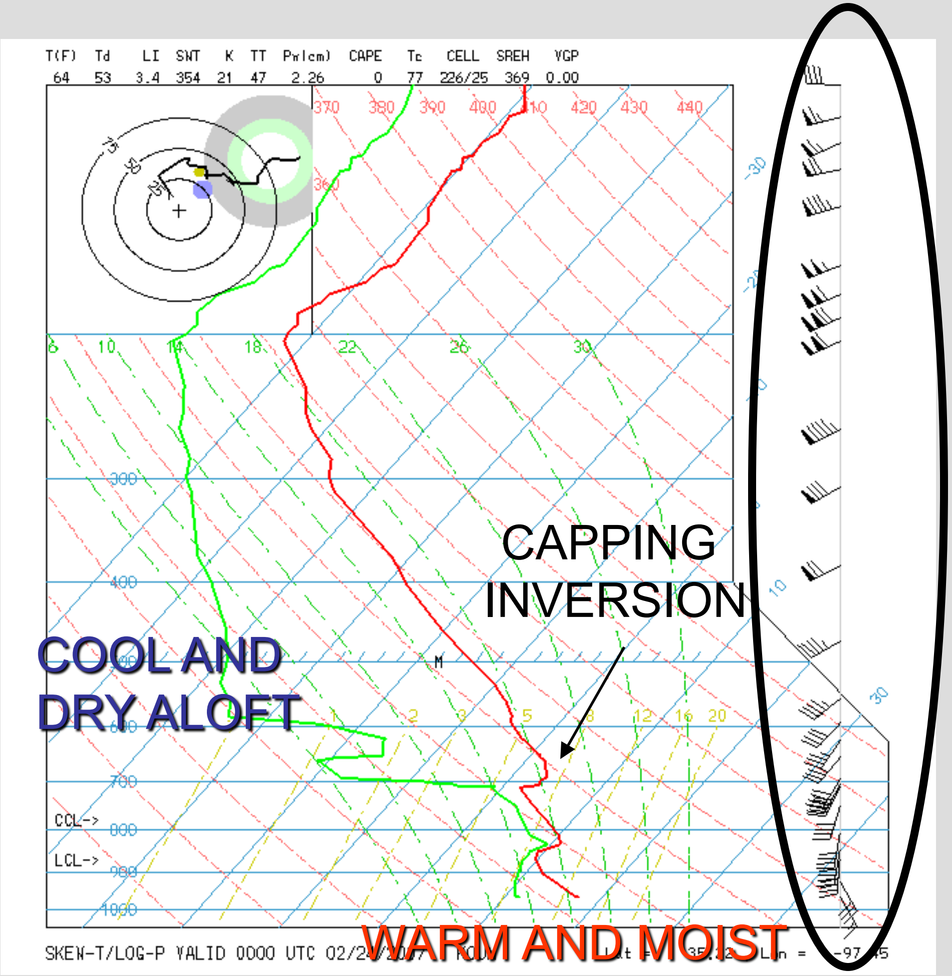
University of Wyoming

SLAT	33.16
SLON	-86.76
SELV	178.0
SHOW	-6.26
LIFT	-8.05
LFTV	-8.78
SWET	601.9
KINX	32.70
CTOT	26.90
VTOT	28.50
TOTL	55.40
CAPE	2944.
CAPV	3172.
CINS	-6.19
CINV	-5.23
EQLV	143.0
EQTV	142.9
LFCT	890.2
LFCV	891.4
BRCH	14.24
BRCV	15.35
LCLT	293.7
LCLP	917.5
MLTH	301.0
MLMR	16.98
THCK	5738.
PWAT	41.83

https://www.weather.gov/bmx/event_04272011

https://www.youtube.com/watch?v=sA7TKSHJ_wM

THE “LOADED GUN” SOUNDING
THE SIGNATURE FOR SUPERCELLS



COOL AND DRY ALOFT

CAPPING INVERSION

WIND DRASTICALLY CHANGES IN SPEED AND DIRECTION WITH HEIGHT

WARM AND MOIST NEAR SURFACE

CAPE in the 'loaded gun' sounding example

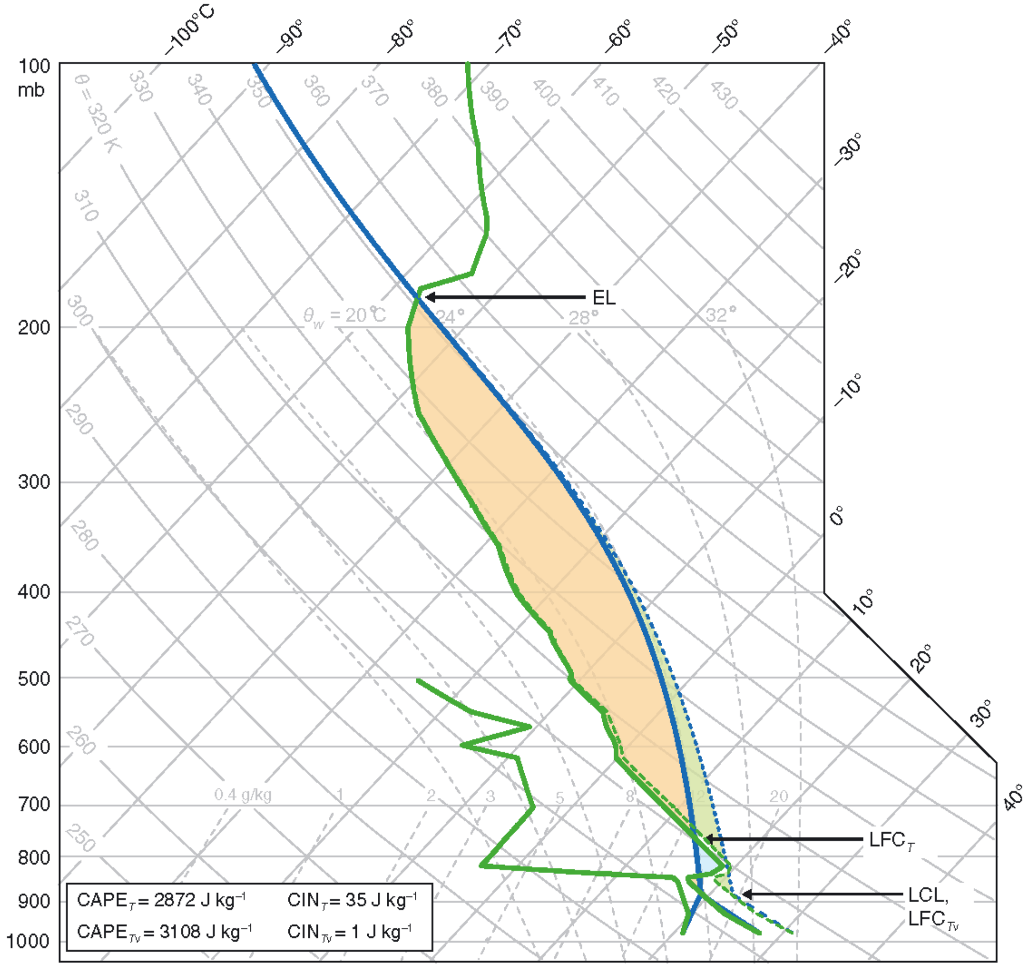


Figure 2.9 Skew T–log p diagram obtained from the Del Rio, Texas, sounding at 1800 UTC 14 May 2008. The temperature and dewpoint profiles are solid green (dewpoints are not plotted above 500 mb because they were unreliable above 500 mb). The virtual temperature profile is indicated with the dashed green line. The solid blue line indicates the temperature of a parcel of air lifted from the surface to its lifting condensation level (LCL), level of free convection (LFC), and equilibrium level (EL). The dashed blue line indicates the virtual temperature of the parcel. The LFC, CAPE, and CIN computed by including virtual temperature effects are LFC$_{Tv}$, CAPE$_{Tv}$, and CIN$_{Tv}$, respectively. The LFC, CAPE, and CIN based on temperature alone (the effect of moisture on buoyancy is neglected) are LFC$_T$, CAPE$_T$, and CIN$_T$, respectively. The positive and negative areas for the solid blue parcel trajectory (proportional to CAPE$_T$ and CIN$_T$, respectively) are shaded light orange and light blue, respectively. The positive area for the dashed blue parcel trajectory (proportional to CAPE$_{Tv}$; the negative area is virtually nonexistent) encompasses both the orange area and the area that is shaded light green.

Conceptualizing downdraft CAPE (DCAPE)

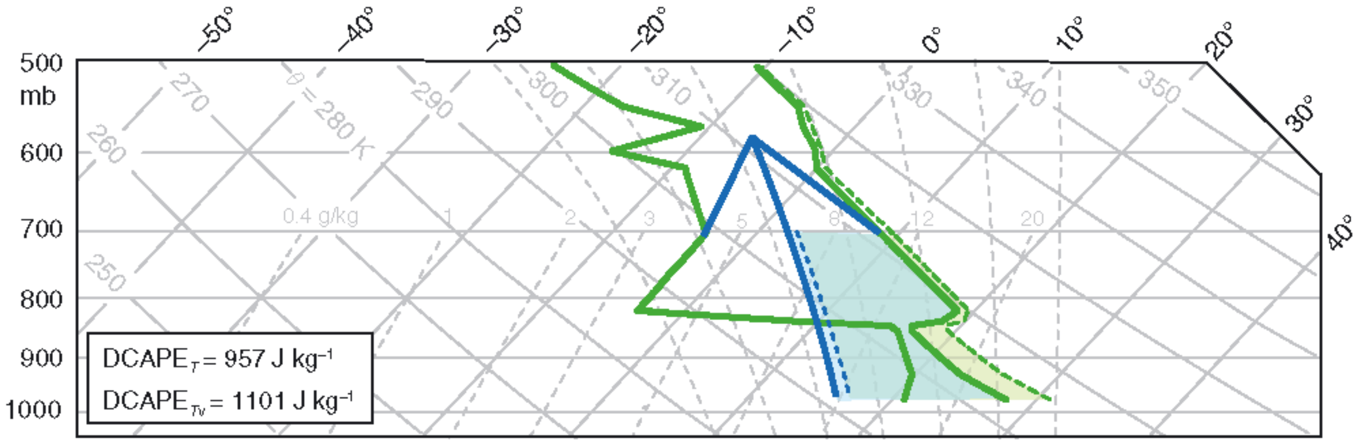
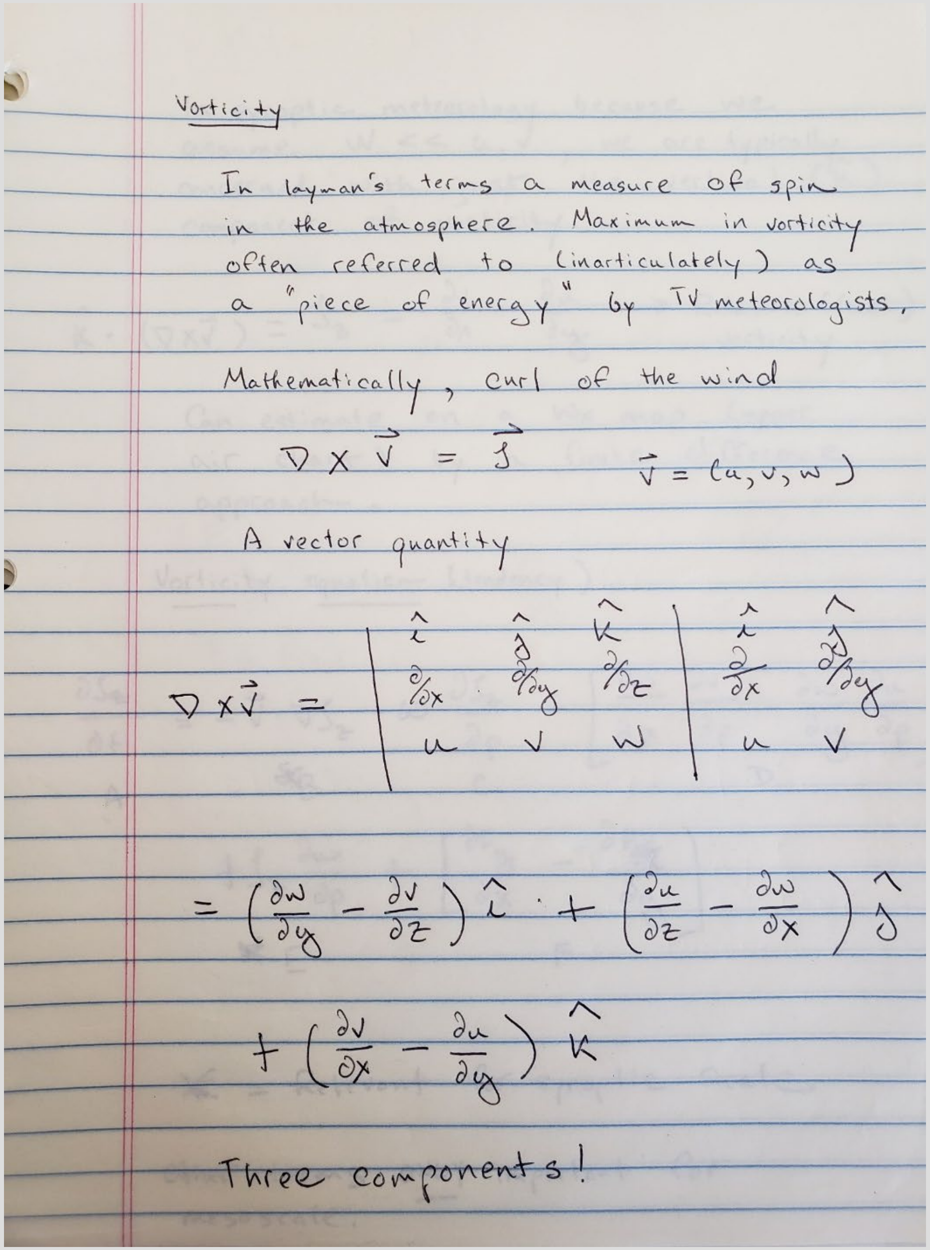


Figure 2.10 Skew T–log p diagram obtained from the Del Rio, Texas, sounding at 1800 UTC 14 May 2008 (this is the same sounding as appeared in Figure 2.9). The temperature and dewpoint profiles are solid green. The virtual temperature profile is indicated with the dashed green line. The solid blue line indicates the temperature of a parcel descending moist adiabatically from 700 mb, and the dashed blue line indicates the virtual temperature of the descending parcel. DCAPE_T and $\mathrm{DCAPE}_{T\mathrm{v}}$ are the DCAPE values computed based on temperature alone and including the effects of both temperature and moisture on buoyancy, respectively. The negative area for the solid blue parcel trajectory (proportional to DCAPE_T) is shaded light blue. The negative area for the dashed blue parcel trajectory (proportional to $\mathrm{DCAPE}_{T\mathrm{v}}$) encompasses both the light blue area and the area shaded light green.

Flashback to definition of vorticity from WAF I



Vorticity

In layman's terms a measure of spin in the atmosphere. Maximum in vorticity often referred to (inarticulately) as a "piece of energy" by TV meteorologists.

Mathematically, curl of the wind

$$\nabla \times \vec{V} = \vec{\zeta} \qquad \vec{V} = (u, v, w)$$

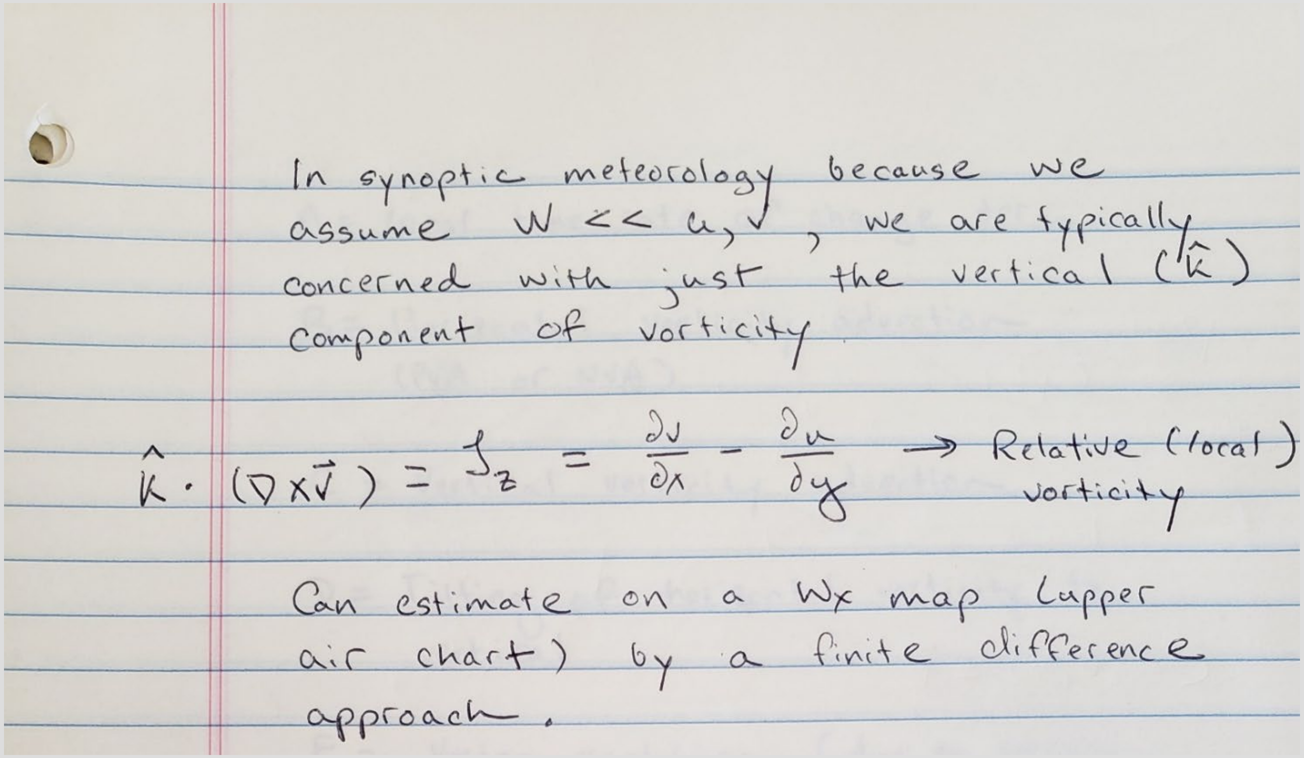
A vector quantity

$$\nabla \times \vec{V} = \left| \begin{array}{ccc} \hat{i} & \hat{j} & \hat{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ u & v & w \end{array} \right| \begin{array}{cc} \hat{i} & \hat{j} \\ \frac{\partial}{\partial x} & \partial/\partial y \\ u & v \end{array}$$

$$= \left(\frac{\partial w}{\partial y} - \frac{\partial v}{\partial z} \right) \hat{i} + \left(\frac{\partial u}{\partial z} - \frac{\partial w}{\partial x} \right) \hat{j}$$

$$+ \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} \right) \hat{k}$$

Three components!

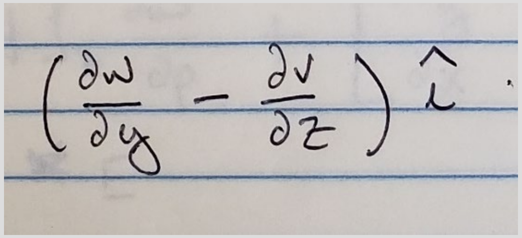


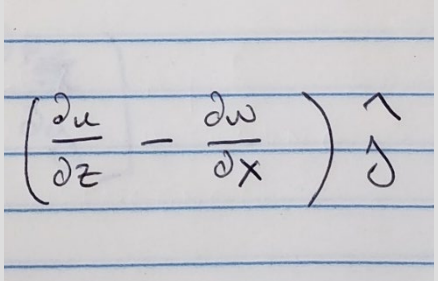
In synoptic meteorology because we assume $w << u, v$, we are typically concerned with just the vertical ($\hat{k}$) component of vorticity

$$\hat{k}\cdot(\nabla \times \vec{V}) = \zeta_z = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} \rightarrow$$ Relative (local) vorticity

Can estimate on a Wx map (upper air chart) by a finite difference approach.

What is different for mesoscale is that the horizontal components of vorticity are now (very) relevant





$$\omega_h = \left(\frac{\partial w}{\partial y} - \frac{\partial v}{\partial z}\right)\hat{i} + \left(\frac{\partial u}{\partial z} - \frac{\partial w}{\partial x}\right)\hat{j}$$

Introduction to Hodographs

Plots the vertical wind profile as a 2-D diagram, usually in (u,v) space

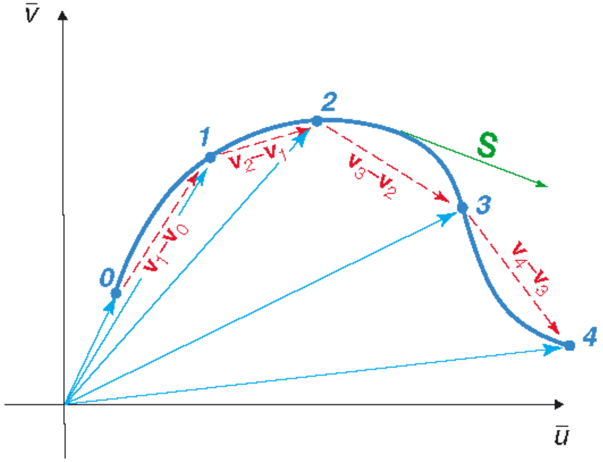


Figure 2.11 A hodograph (blue curve) and its relationship to the horizontal winds (blue vectors), which are drawn at five different levels (the labels along the hodograph indicate heights above ground level in kilometers). The point on the hodograph labeled "0" is the lowest altitude where the wind is measured, which typically is a few meters above the ground rather than $z = 0$ m (the horizontal wind goes to zero at $z = 0$). The vector wind difference between the winds at the top and bottom of each layer also are shown (red vectors). The shear vector at a *point* between 2 and 3 km also is shown (green vector); it lies tangent to the hodograph.

Hodograph curve (dark blue) connects the tips of the point of the wind vectors (light blue)

Tangent line to the hodograph curve defines the wind shear vector (**S**) at a given height

$$\mathbf{S} = \Delta\mathbf{V} / \Delta Z$$

The hodograph provides information about how wind changes with height that may be quickly interpreted.

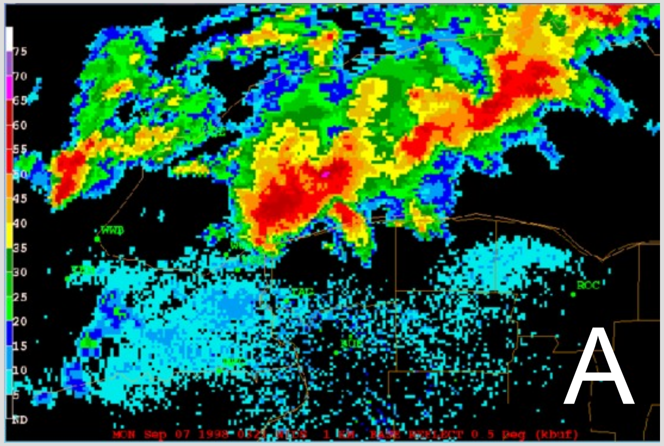
Skew-T: provides insight into the favorability of the mesoscale thermodynamic environment for convection.

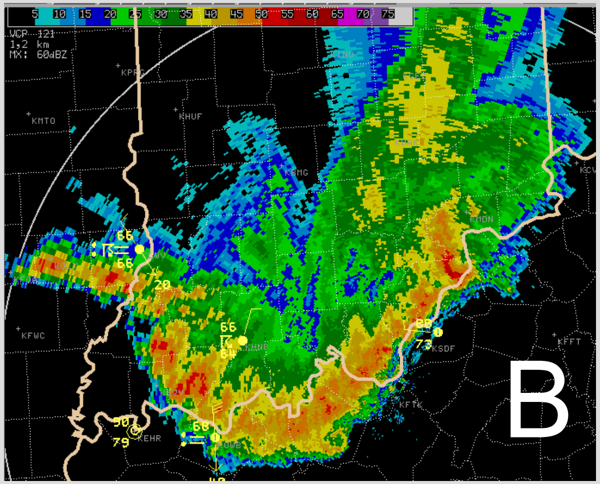
→ *Is convection going to happen?*

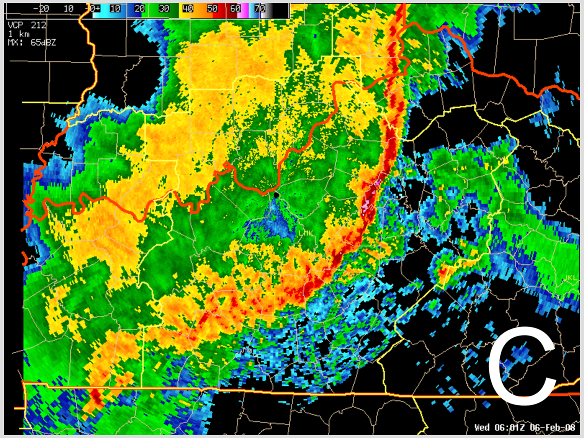
Hodograph: provides complementary insight into mesoscale dynamic environment which governs how convection is likely to evolve over time.

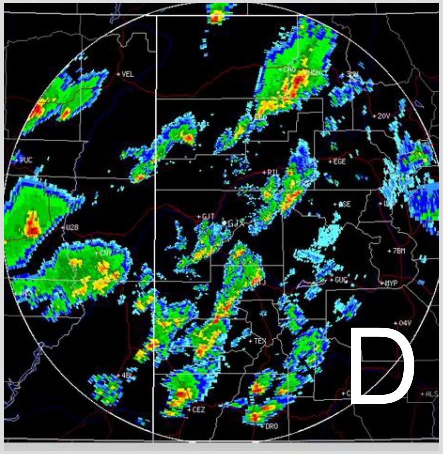
→ ***Will that convection become organized and severe?***

REFLECTIVITY



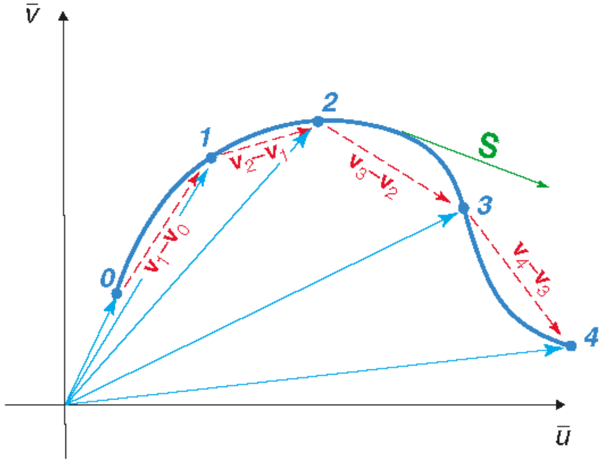






We WILL cover the particulars of radar measurements soon…but radar imagery 'pictures' are fine for now as a primer

Length vs. curvature



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Length: related to vertical wind shear magnitude

The speed shear

Curvature: How the vertical wind shear changes direction with height

The directional shear

Note: This is a different concept than the change in wind direction (e.g. related to backing and veering) as we talked about in WAF I.

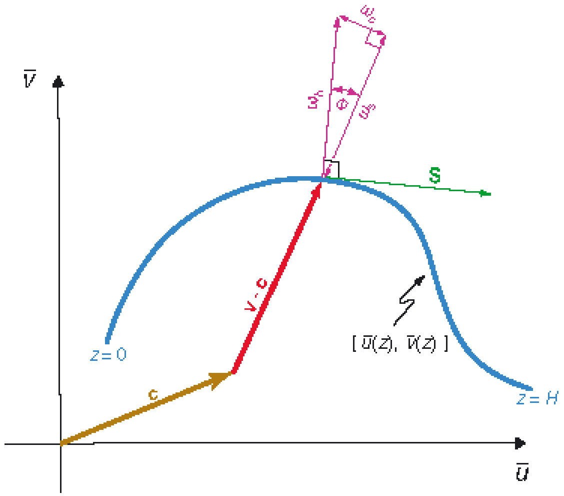


Figure 2.12 Diagram of a hodograph $[\overline{u}(z), \overline{v}(z)]$ depicting the storm motion vector $\mathbf{c}$, storm-relative wind vector $\mathbf{v} - \mathbf{c}$, shear vector $\mathbf{S}$, and environmental horizontal vorticity vector $\boldsymbol{\omega}_\mathrm{h}$. When $\mathbf{S}$ is a good representation of the thermal wind (i.e., when winds are close to geostrophic), $\boldsymbol{\omega}_\mathrm{h}$ points toward the cold air and $\mathbf{v} \cdot \boldsymbol{\omega}_\mathrm{h}$ is porportional to temperature advection. The streamwise and crosswise vorticity components, ω_s and ω_c, respectively, are also indicated.

$$\boldsymbol{\omega}_\mathrm{h} \approx \left(-\frac{\partial v}{\partial z}, \frac{\partial u}{\partial z} \right) = \mathbf{k} \times \mathbf{S};$$

What are hodographs useful for?

1. Estimate the mean wind speed within a given layer
Mid-level steering flow that would be associated with the (initial) movement of a thunderstorm

2. Diagnose speed shear and directional shear
Respectively inform as to cross-wise and stream-wise horizontal vorticity
- *Cross-wise vorticity =* ω_h *perpendicular to storm motion*
- *Stream-wise vorticity =* ω_h *parallel to storm motion*

Both are ultimately related to forecasting of severe convective storms:
- **Movement and organization**
- **Likely storm type (supercell, squall line, MCS, etc.)**

You can determine MOST of that from just looking at the hodograph! More on all that later…

Visualizing stream-wise horizontal vorticity associated with directional shear

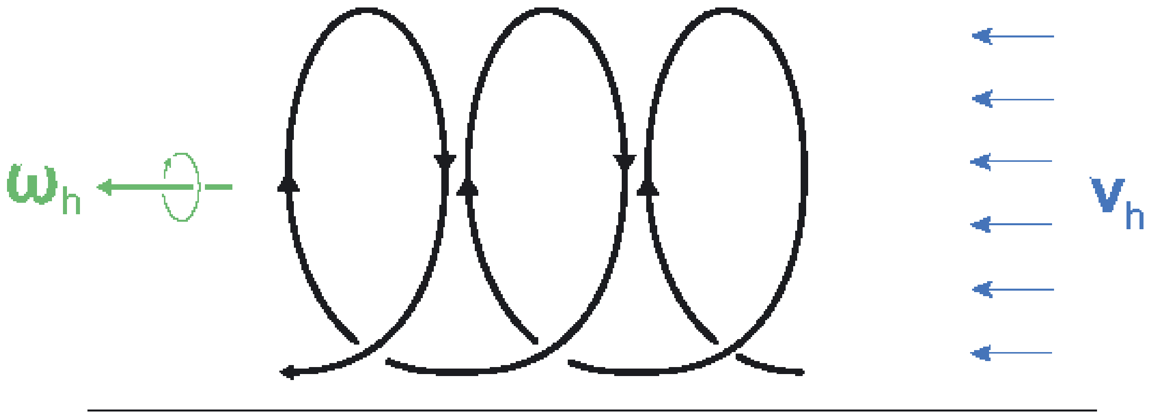


Figure 2.15 Schematic showing how the superposition of horizontal vorticity parallel to the horizontal flow produces a helical flow and is associated with streamwise vorticity. (Adapted from Doswell [1991].)

Directional shear is characterized by the metric of *helicity*.

Where high directional shear, potential for thunderstorm updrafts to tilt this horizontal vorticity in the vertical, creating rotating mesocyclones.

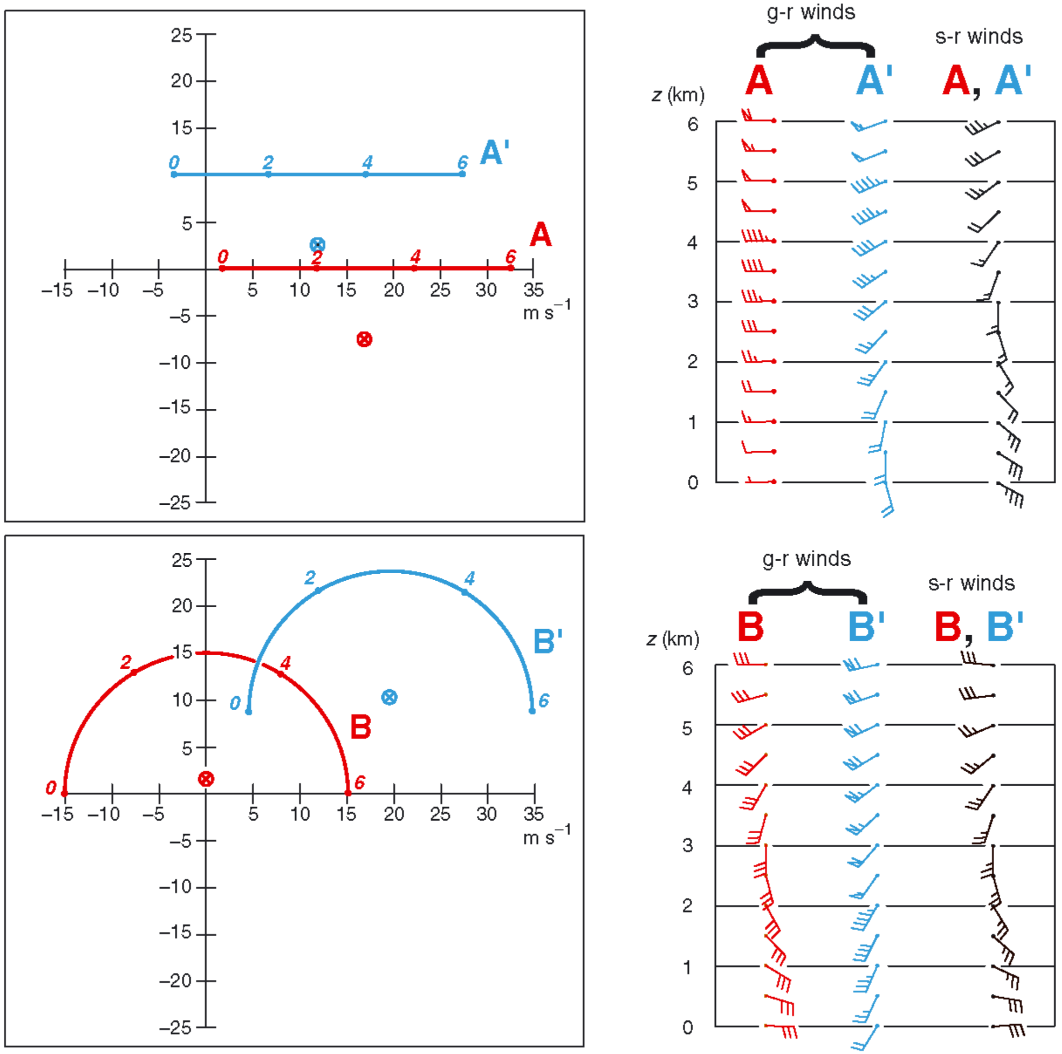


Figure 2.13 Idealized straight (top left) and curved (bottom left) hodographs and their corresponding ground-relative (g-r) and storm-relative (s-r) wind profiles (top and bottom right; half barb — 2.5 m s^{-1}, full barb — 5 m s^{-1}, flag — 25 m s^{-1}). Labels along the hodographs indicate heights above ground level in kilometers. The ⊗ symbols indicate the assumed storm motions (a mature convective storm would likely have a motion to the right of the mean wind in these environments, as we shall later find in Chapter 8). Hodographs A and A′ are identical, but hodograph A′ has been shifted by adding −5 m s^{-1} (10 m s^{-1}) to the zonal (meridional) wind components of the points comprising hodograph A. Hodographs B and B′ are identical, but hodograph B′ has been shifted by adding 20 m s^{-1} (8 m s^{-1}) to the zonal (meridional) wind components of the points comprising hodograph B. The storm-relative wind profiles are identical for the A and A′ hodographs and the B and B′ hodographs. (Adapted from Markowski and Richardson [2006].)

Straight hodograph:
Unidirectional shear
Cross-wise vorticity

A → Zero degrees veering of wind
A'→ 90 degrees veering of wind.

Vertical shear direction is westerly at all levels

Curved hodograph
Directional shear
Steam-wise vorticity

B → 180 degrees veering of wind
B'→ 45 degrees veering of wind

Vertical shear changes direction through profile

Severe weather hodographs: More characteristic of eastern U.S.

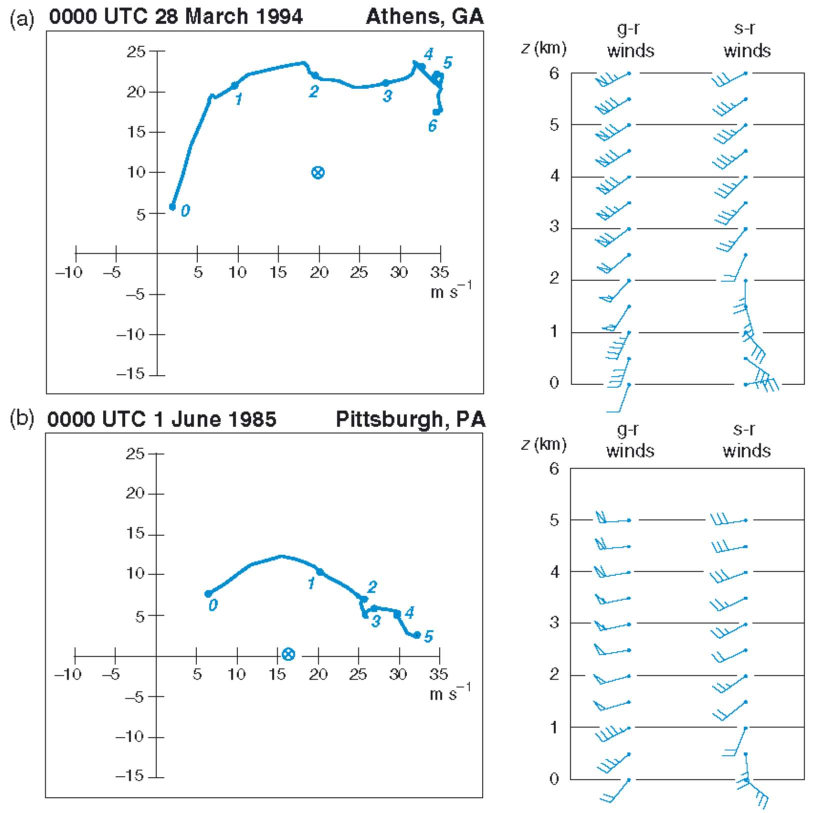


Figure 2.14 (a)–(d) Hodographs observed in relative proximity to outbreaks of severe convection and tornadoes having a wide variety of mean wind velocities and deep-layer shear (thermal wind) orientations. Labels along the hodographs indicate heights above ground level in kilometers. The ⊗ symbols indicate the approximate average storm motions observed on each day. Profiles of ground-relative (g-r) and storm-relative (s-r) winds (half barb — 2.5 m s^{-1}, full barb — 5 m s^{-1}, flag — 25 m s^{-1}) are displayed to the right of each hodograph. (Although wind data in only the lowest 6 km are plotted [the winds are missing above 5 km in (b)], it is not implied that the winds above 6 km are unimportant.) (Adapted from Markowski and Richardson [2006].)

Both u,v tend to be positive throughout the vertical profile (in these examples)

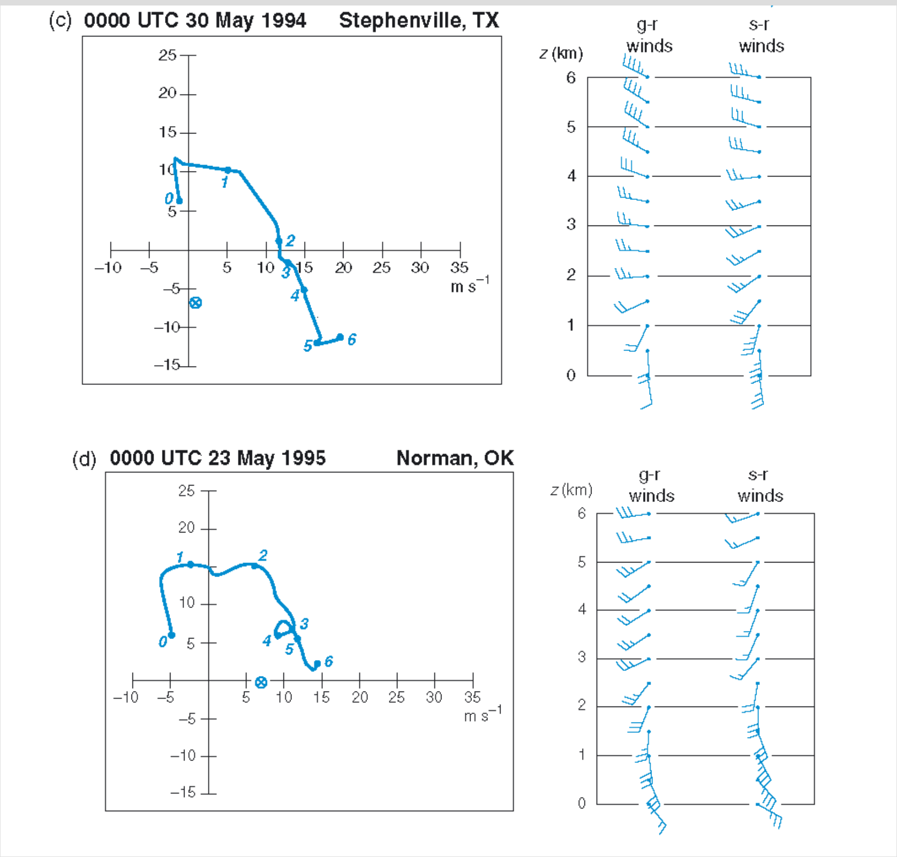
Indicative of generally Southwesterly flow at surface and aloft

Note that the shear tends to be more unidirectional aloft (i.e. the hodograph follows a straight line)

Horizontal vorticity more cross-wise relative to storm motion

More characteristic of squall lines, mesoscale convective systems (stay tuned...)

Severe weather hodographs:
More characteristic of Central U.S., Great Plains



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Change in sign of u or v

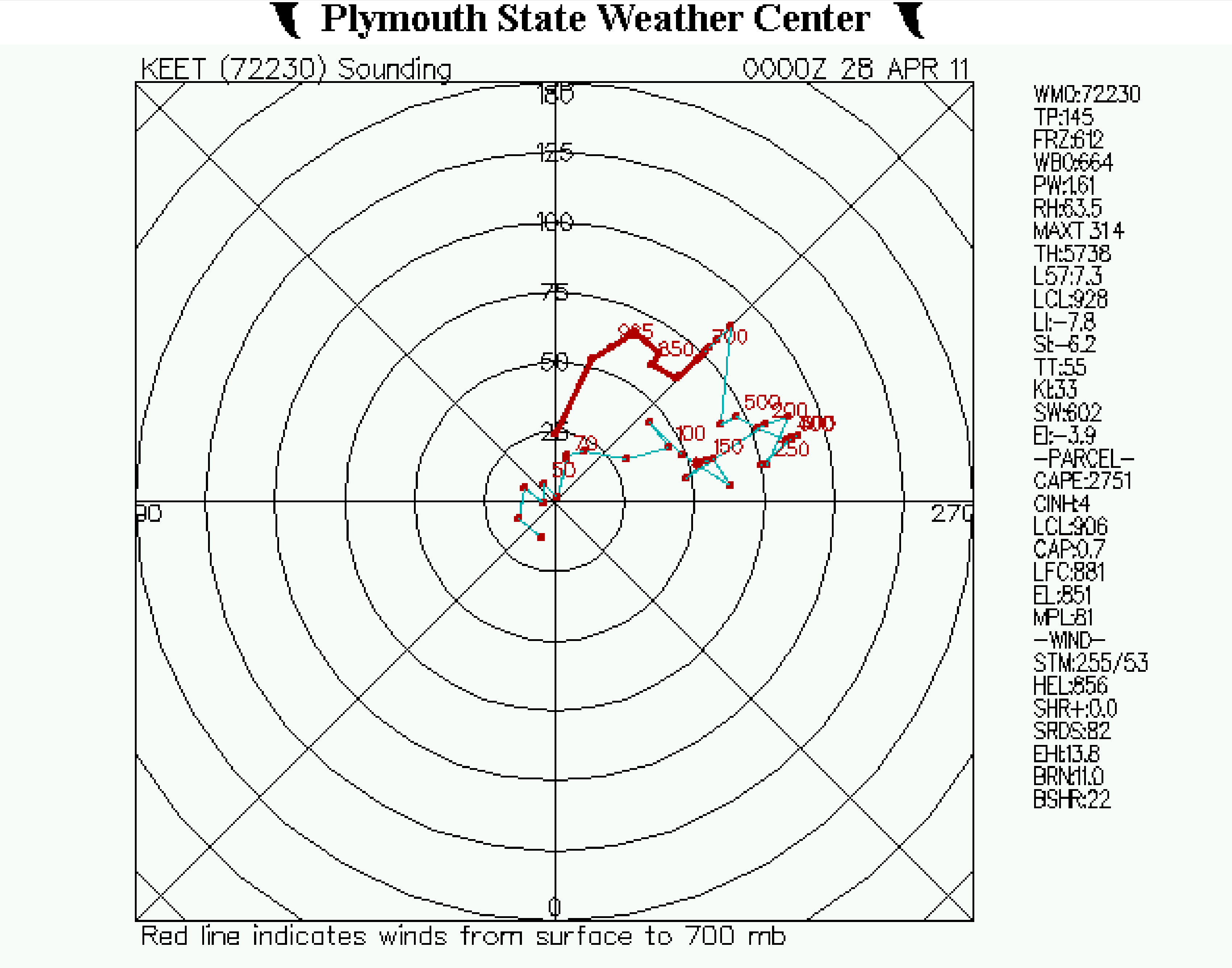
Generally southerly at low levels transitioning to more southwesterly to northwesterly winds aloft.

Strong southerly winds likely indicative of low-level jet.

Note that the shear tends to be more directional, especially for the Norman, OK case!

Horizontal vorticity more steam-wise relative to storm motion

More characteristic of isolated supercellar convection (i.e. tornadic thunderstorms.
(Again, stay tuned…)



Plymouth State Weather Center

KEET (72230) Sounding 0000Z 28 APR 11

Red line indicates winds from surface to 700 mb

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WMO:72230
TP:145
FRZ:612
WBO:664
PW:161
RH:63.5
MAXT 314
TH:5738
LS7:7.3
LCL:928
LI:-7.8
SI:-6.2
TT:55
KI:33
SW:602
EI:-3.9
-PARCEL-
CAPE:2751
CINH:4
LCL:906
CAP:0.7
LFC:881
EL:851
MPL:81
-WIND-
STM:255/53
HEL:856
SHR+:0.0
SRDS:82
EHI:13.8
BRN:11.0
BSHR:22
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