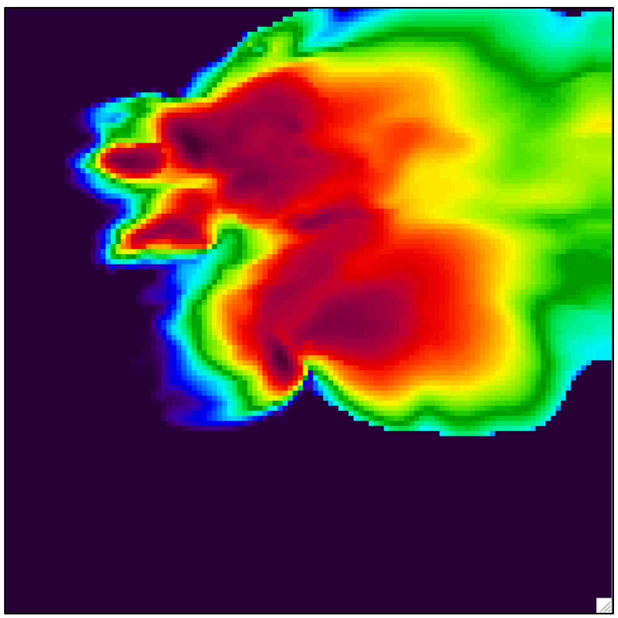
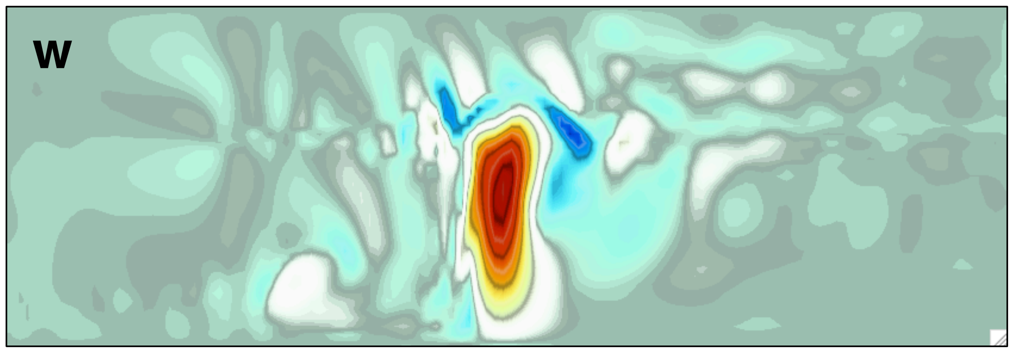
CM1 notes

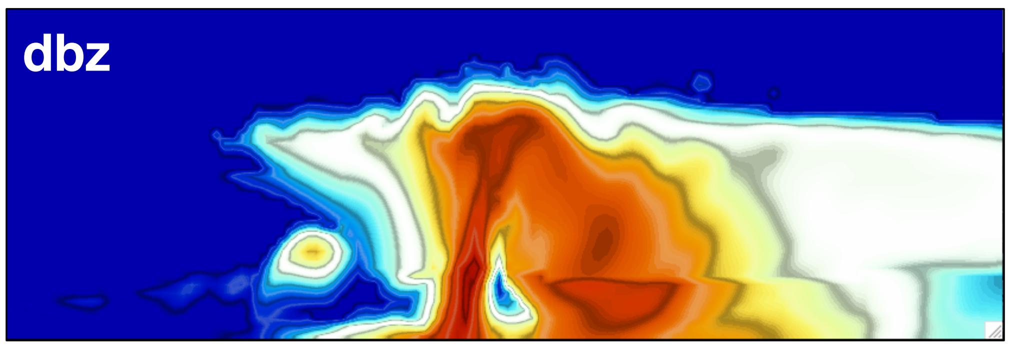
output_format = 2 (for netcdf)
output_filetype = 1 (all in a single file)

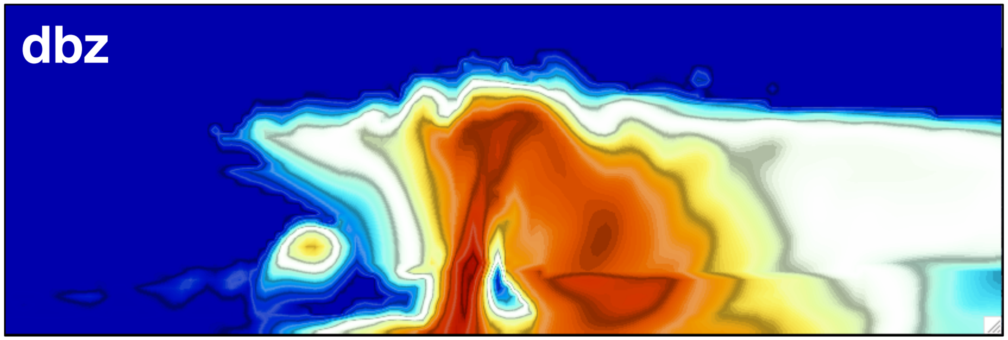
There are **two** reflectivity variables:
dbz (look for `calc_refl10cm` function in ./src/morrison.f90)
cref (column max of dbz array)

'dbz' at lowest model level









Model

Reality

CM1 notes

Can use SAM (http://sam.ucar.edu) to look at job history (updated overnight).

Username	Job Id	Job Name	Queue Name	Submit Time	Start Time	End Time	# Nodes	Adjusted Core Hours
jweber6	4305614	cm1run	share	2018-02-07 12:20:04	2018-02-07 12:20:07	2018-02-07 12:24:19	1	0.07
jweber6	4306321	cm1run	share	2018-02-07 12:46:39	2018-02-07 12:46:42	2018-02-07 12:50:53	1	0.07
jweber6	4310012	cm1run	share	2018-02-07 14:35:41	2018-02-07 14:35:50	2018-02-07 14:40:04	1	0.07
brookez	4310038	cm1run	share	2018-02-07 14:45:35	2018-02-07 14:45:42	2018-02-07 14:45:43	1	0.00
brookez	4310057	cm1run	share	2018-02-07 14:52:05	2018-02-07 14:52:08	2018-02-07 15:14:00	1	0.36
caoswald	4310312	cm1run	share	2018-02-07 15:18:00	2018-02-07 15:18:04	2018-02-07 15:41:14	1	0.39
brookez	4310455	cm1run	share	2018-02-07 15:27:12	2018-02-07 15:27:17	2018-02-07 15:49:33	1	0.37
jweber6	4310571	cm1run	share	2018-02-07 15:35:29	2018-02-07 15:35:34	2018-02-07 15:58:49	1	0.39
brookez	4311578	cm1run	share	2018-02-07 16:10:53	2018-02-07 16:11:02	2018-02-07 16:34:07	1	0.38
codap	4314168	cm1run	share	2018-02-07 19:48:48	2018-02-07 19:48:55	2018-02-07 20:10:02	1	0.35

(1 of 1) 1 20

Total: 2.45

Impacts of vertical wind shear on convection

If we substitute, (mean + perturbation) for u, v, w (e.g., $u = \bar{u} + u'$), we can write p' as,

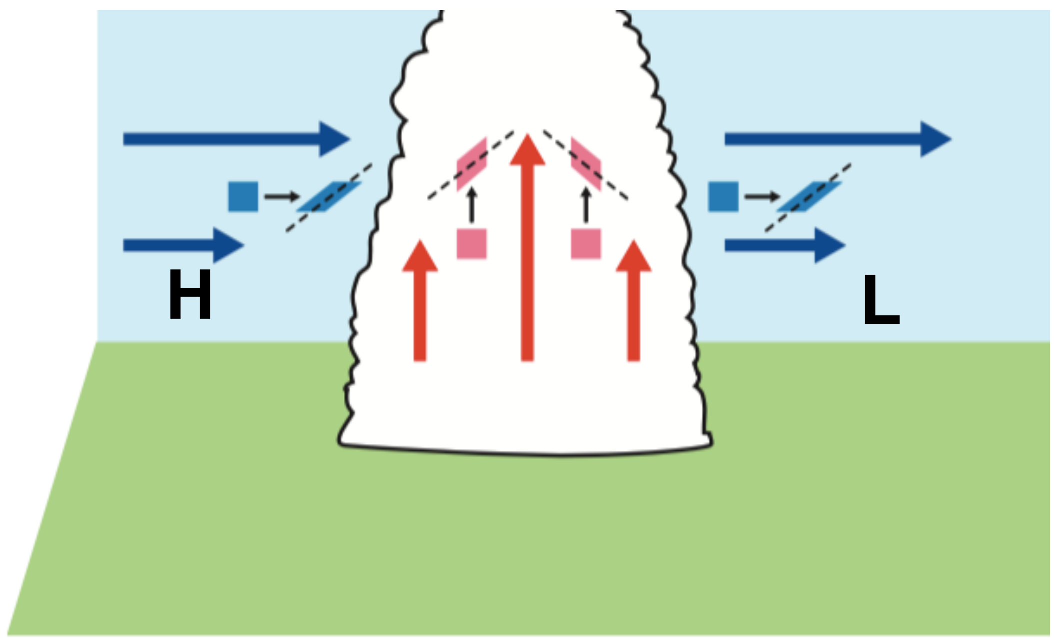
$$p' \propto \underbrace{e_{ij}'^2 - \frac{1}{2}|\boldsymbol{\omega}'|^2}_{\text{nonlinear dynamic pressure perturbation}}$$

$$\underbrace{+2\left(\frac{\partial w'}{\partial x}\frac{\partial \overline{u}}{\partial z} + \frac{\partial w'}{\partial y}\frac{\partial \overline{v}}{\partial z}\right)}_{\text{linear dynamic pressure perturbation}} \underbrace{-\frac{\partial B}{\partial z}}_{\text{buoyancy pressure perturbation}} \qquad (2.137)$$

Where the linear dynamic pressure perturbation (**$p_{D,L}$**) can be written as,

$$2\left(\frac{\partial w'}{\partial x}\frac{\partial \overline{u}}{\partial z} + \frac{\partial w'}{\partial y}\frac{\partial \overline{v}}{\partial z}\right) = 2\mathbf{S}\cdot\boldsymbol{\nabla}_{\mathrm{h}} w'$$

Impacts of vertical wind shear on convection

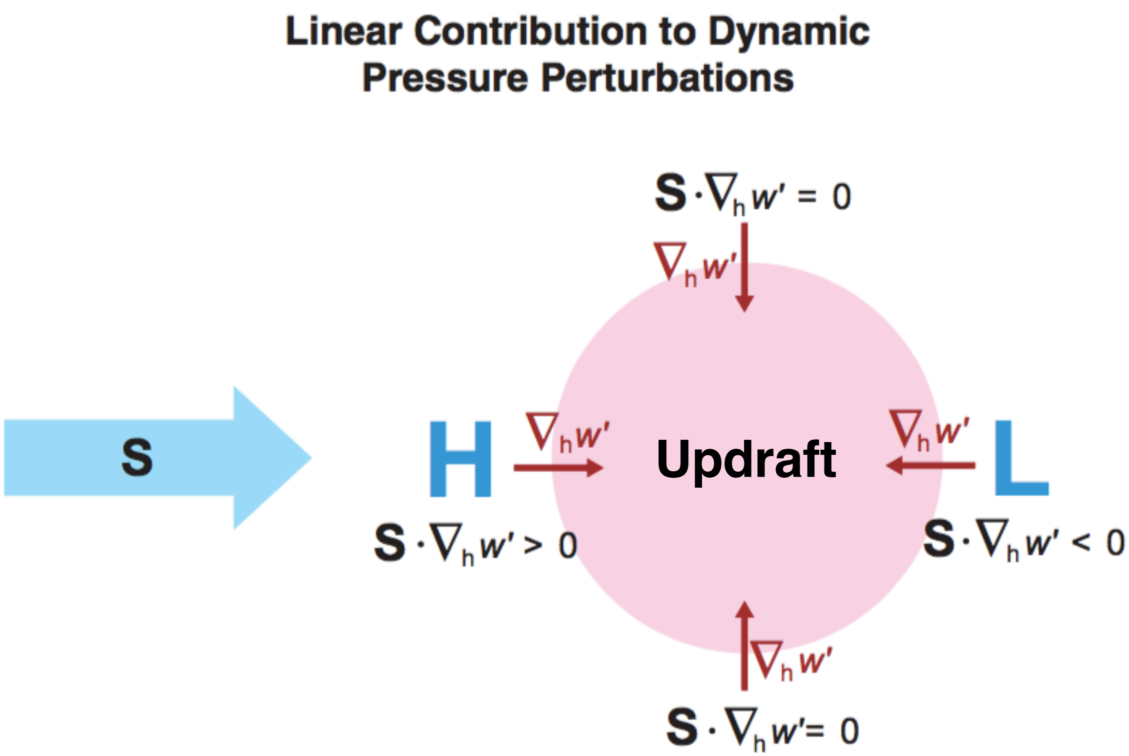


Linear dynamic perturbation pressure produces high pressure *upshear* (not upwind) of the updraft and low pressure *downshear* (not downwind) of the updraft.

Couplets of high and low pressure are aligned with the shear vector at that level.

If shear vector constant with height (unidirectional shear), pressure perturbations are vertically stacked.

Impacts of vertical wind shear on convection

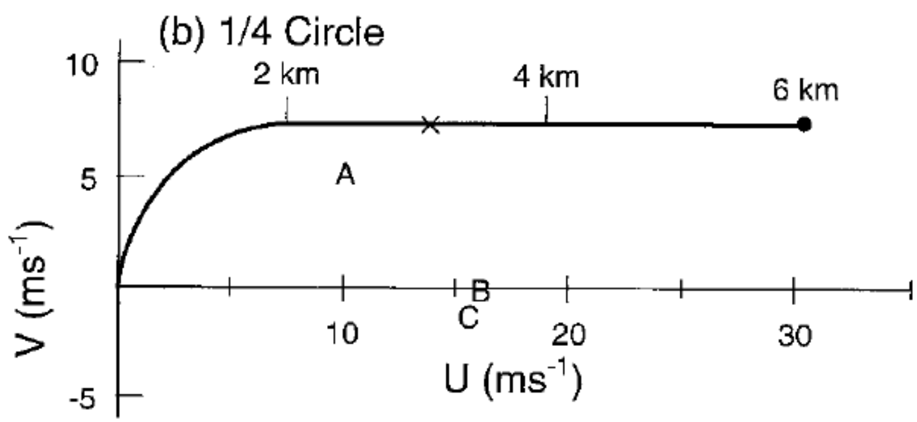


$$p'_{D,L} = 2\mathbf{S} \cdot \nabla_h w'$$

Magnitude of $p'_{D,L}$ proportional to horizontal w' gradient and the strength of the vertical wind shear.

Strong updrafts tend to have large $\nabla_h w'$

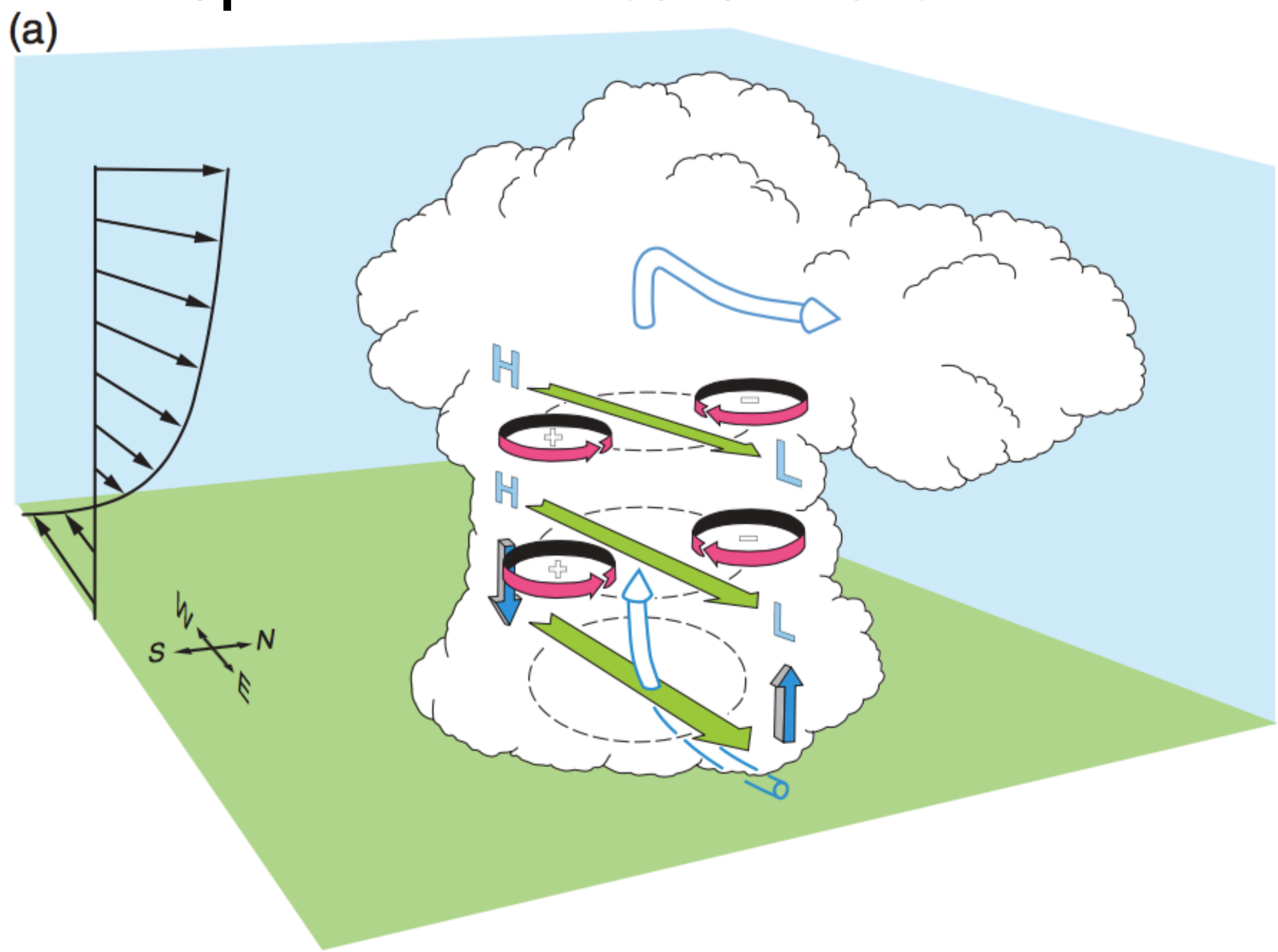
Impacts of vertical wind shear on convection



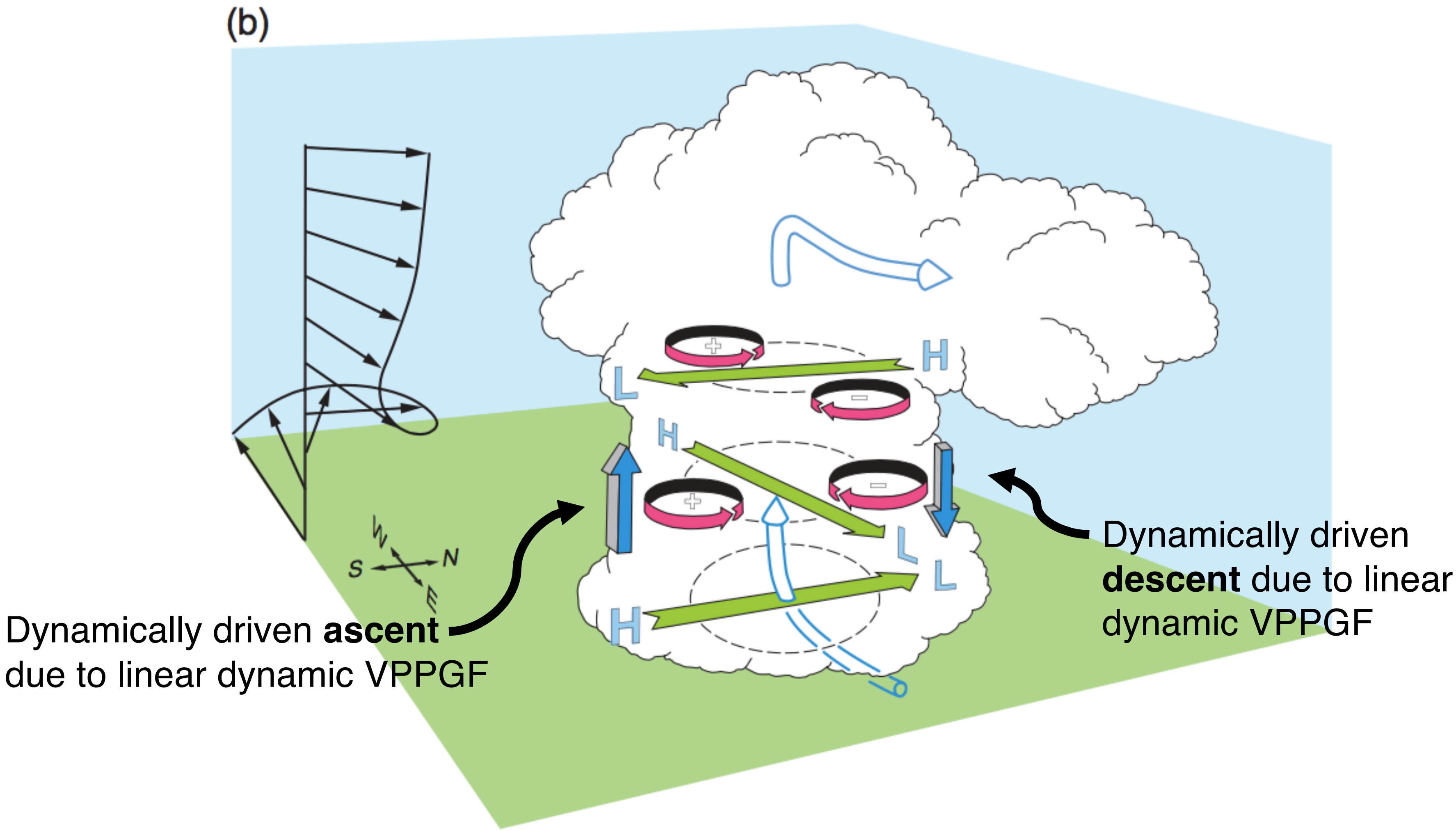
If shear vector veers with height (e.g., with hodograph on the left), vertical $\mathbf{p'}_{D,L}$ gradients are produced.

High/low couplets can be become "stacked" with height along flanks of an updraft, resulting in *dynamically driven ascent or descent* along certain flanks of storm.

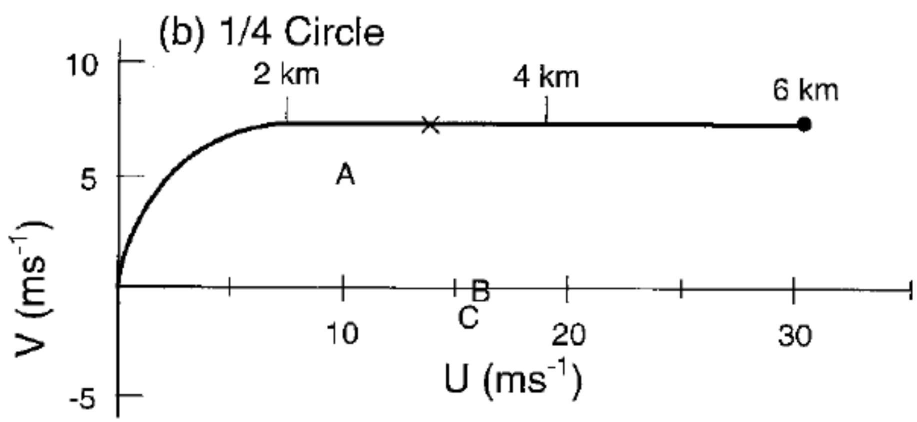
Updraft in unidirectional shear



Updraft in vertically-varying shear



Impacts of vertical wind shear on convection



Clockwise turning hodograph produces ascent on right-flank (relative to storm motion) and descent on left-flank.

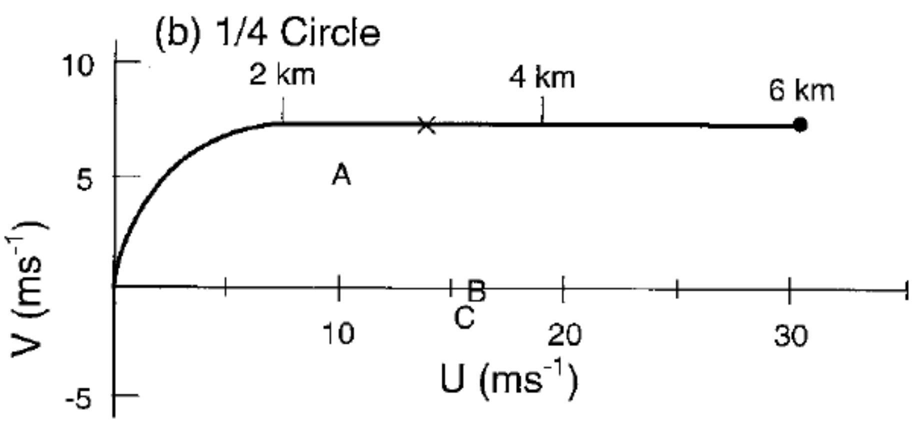
Counterclockwise turning hodograph produces ascent on left-flank and descent on right-flank.

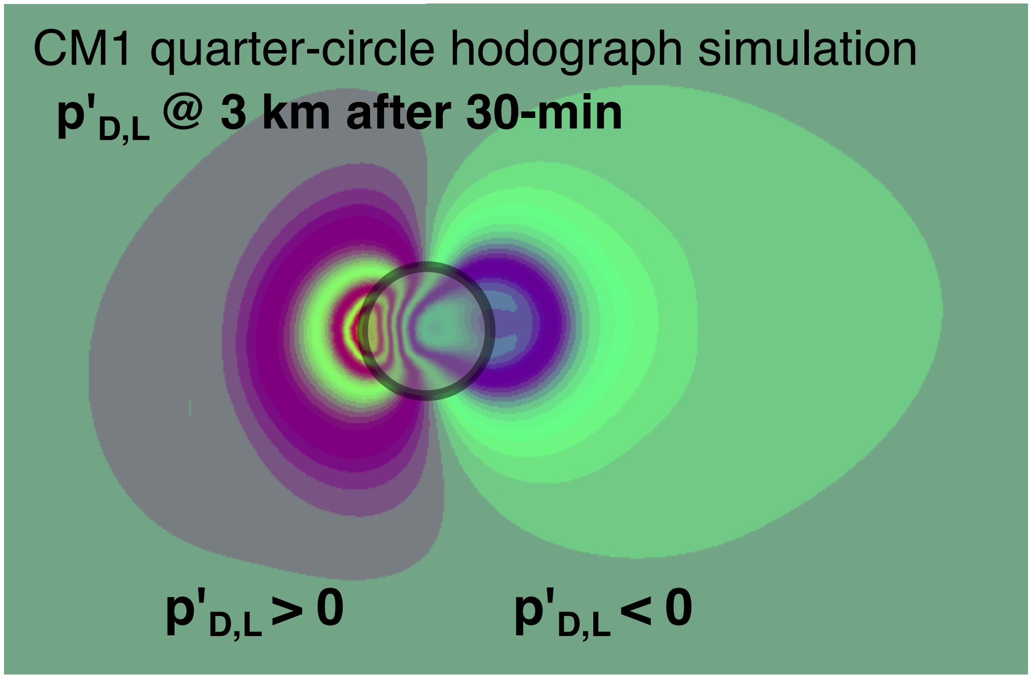
In both cases, hodograph produces stronger vertical gradients of $\mathbf{p'_{D,L}}$, compared to straight hodograph.

Impacts of vertical wind shear on convection

$$2\left(\frac{\partial w'}{\partial x}\frac{\partial \overline{u}}{\partial z} + \frac{\partial w'}{\partial y}\frac{\partial \overline{v}}{\partial z}\right) = 2\mathbf{S}\cdot\nabla_{\mathrm{h}} w'$$

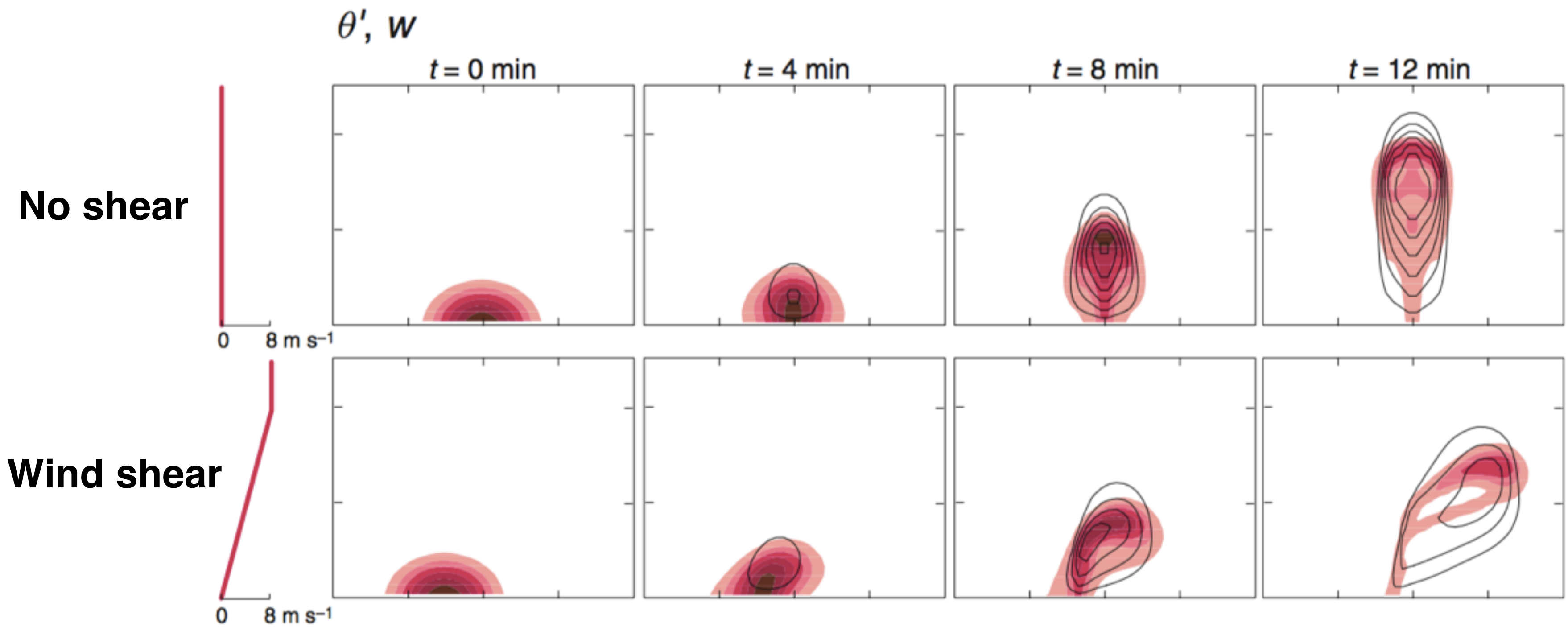
Effects of updraft in shear…





Impacts of vertical wind shear on convection

Vertical wind shear can also be detrimental to convection, especially during initiation.



What causes environmental shear?

Updrafts in environments of appreciable wind shear behave differently than those in environments lacking shear (for more reasons to be explained later…)

Two sources of environmental shear:

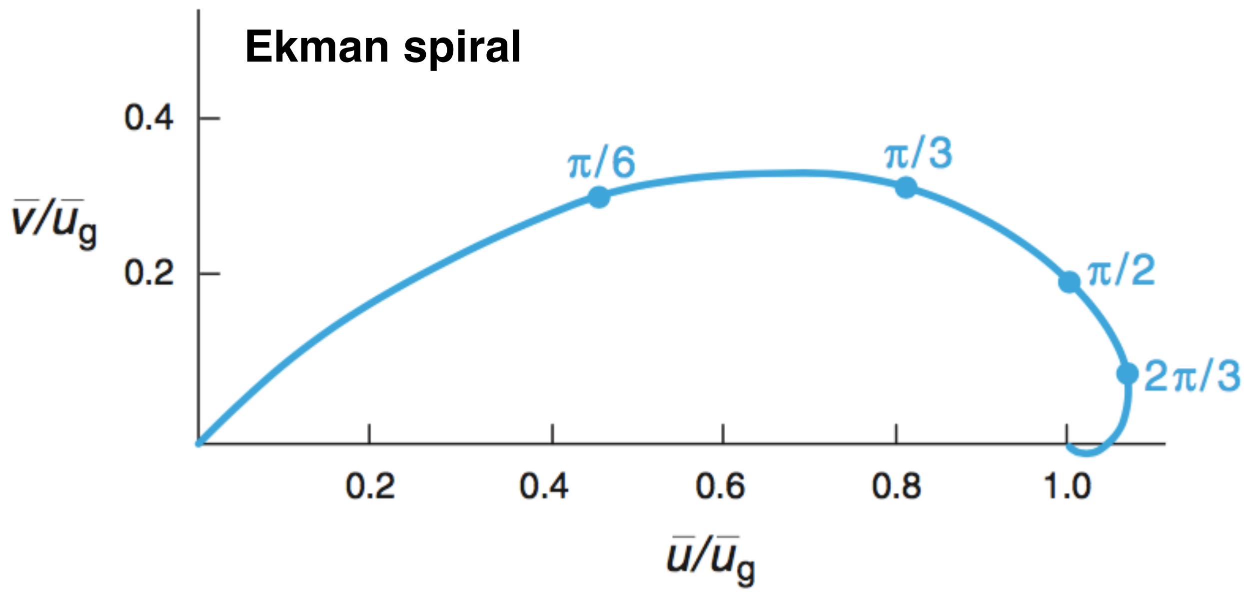
1. **Thermal wind** – when geopotential height gradient changes direction and/or magnitude with height (i.e., baroclinicity exists), geostrophic wind will vary with height.

$$-\frac{\partial \mathbf{v}_g}{\partial p} = -\frac{\partial}{\partial p}\left(\frac{1}{f}\mathbf{k} \times \nabla_p \Phi\right) = \frac{R}{fp}\mathbf{k} \times \nabla_p T,$$

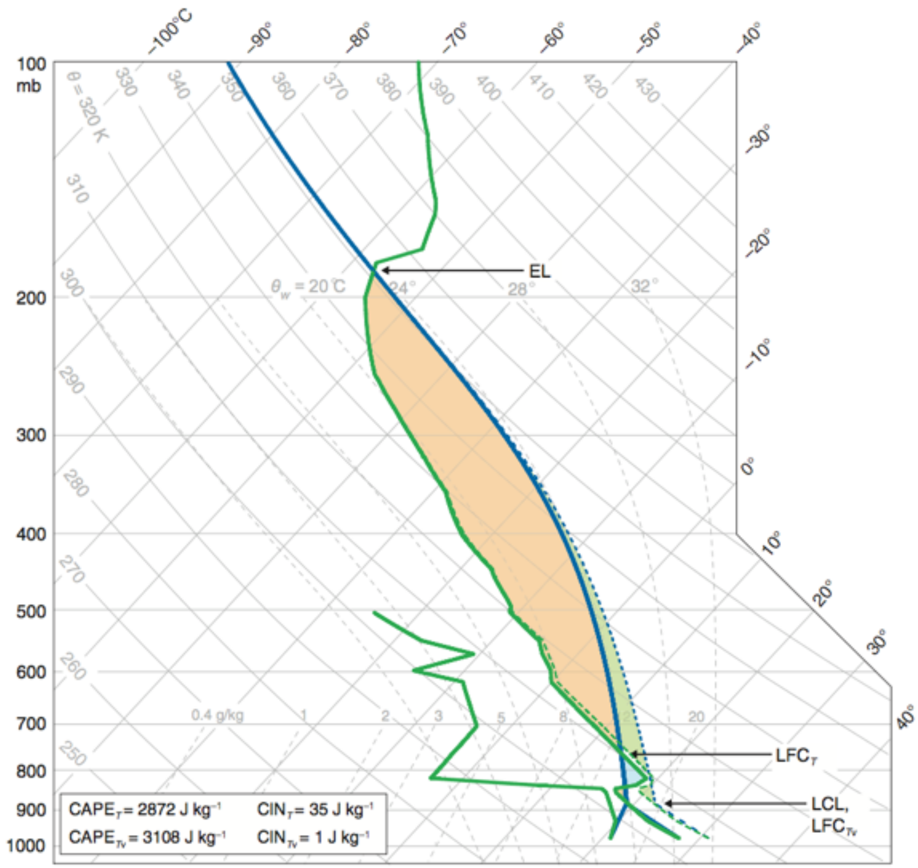
Wind shear is function of horizontal temperature gradient

What causes environmental shear?

2. **Boundary layer processes** – friction plays a large role in wind speed/direction in the boundary layer, largest impact near surface.



Large-scale impacts on environmental thermodynamics



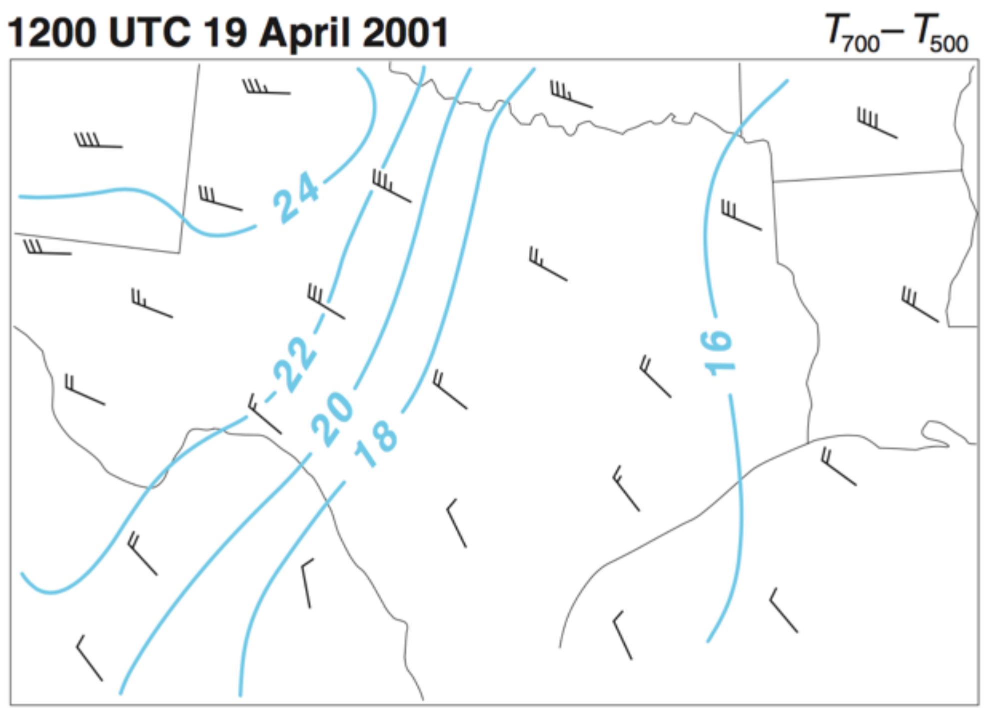
For deep, moist convection (convection that extends through an appreciable depth of the atmosphere) need CAPE and little-to-no CIN.

Buoyancy profile determined by environmental lapse-rate.

What processes generate favorable lapse-rates to produce large CAPE and minimal CIN?

Read M&R Chapter 7

Large-scale impacts on environmental thermodynamics

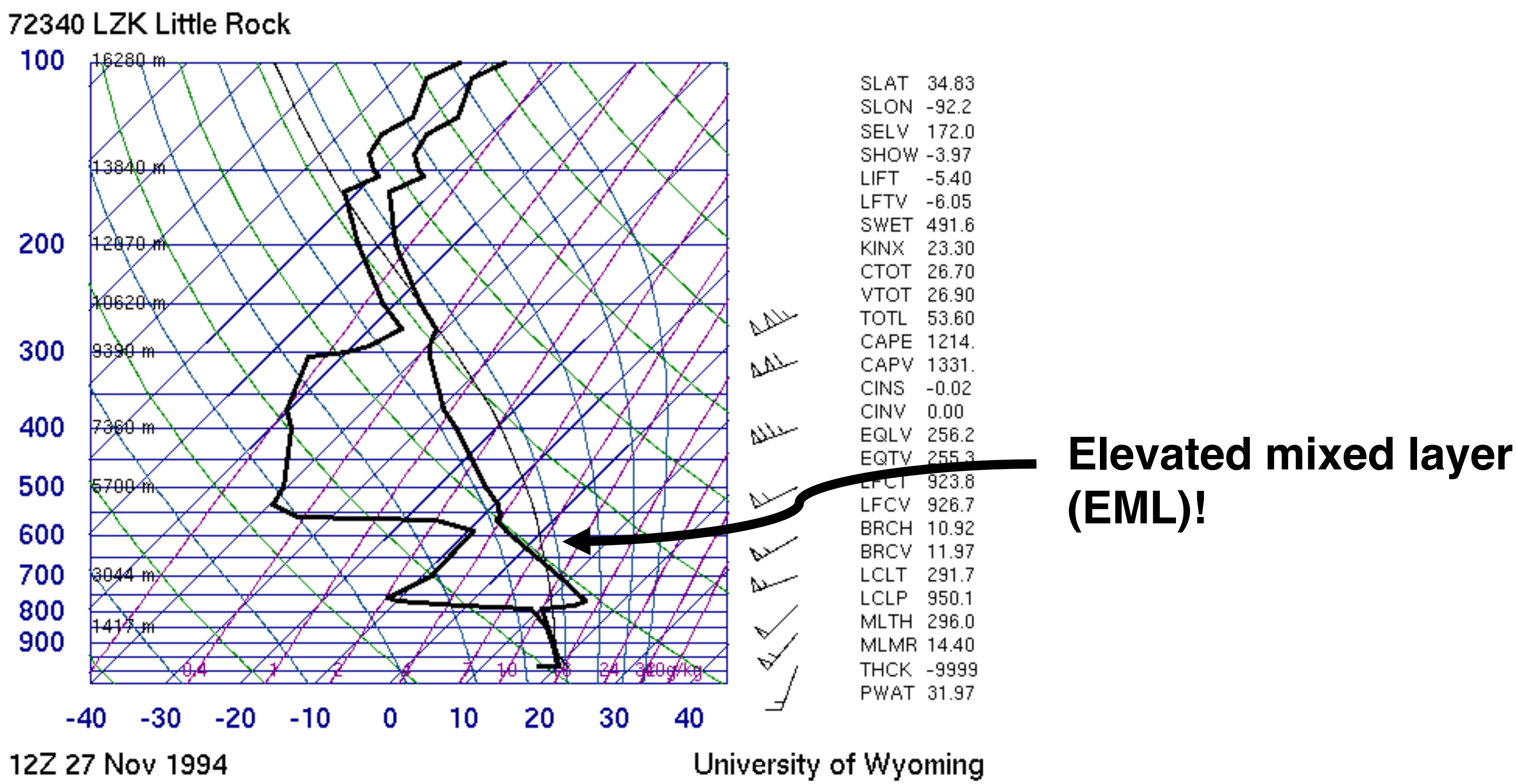


Lapse-rates between 700 mb and 500 mb are referred to as the "**mid-level lapse rate**".

Greater mid-level lapse rates usually result in larger CAPE. Advection of large mid-level lapse rates are especially important over central U.S – the "**elevated mixed layer**".

If dry-adiabatic, lapse-rate will be ~27 K. Won't see mid-level lapse rates larger than this value.

Large-scale impacts on environmental thermodynamics



Large-scale impacts on environmental thermodynamics

First law of thermodynamics…

$$q = c_p \frac{\mathrm{d}T}{\mathrm{d}t} - \alpha \frac{\mathrm{d}p}{\mathrm{d}t}$$

Expand dT/dt and use hydrostatic relationship…

$$q = c_p \left(\frac{\partial T}{\partial t} + \mathbf{v}_\mathrm{h} \cdot \boldsymbol{\nabla}_\mathrm{h} T + w \frac{\partial T}{\partial z} \right) + g w$$

$$q = c_p \left(\frac{\partial T}{\partial t} + \mathbf{v}_\mathrm{h} \cdot \boldsymbol{\nabla}_\mathrm{h} T + w \frac{\partial T}{\partial z} \right) + gw$$

Differentiate with respect to z…

$$-\frac{\partial q}{\partial z} = c_p \left[\frac{\partial}{\partial t} \left(-\frac{\partial T}{\partial z} \right) + \mathbf{v}_\mathrm{h} \cdot \boldsymbol{\nabla}_\mathrm{h} \left(-\frac{\partial T}{\partial z} \right) \right.$$
$$\left. + w \frac{\partial}{\partial z} \left(-\frac{\partial T}{\partial z} \right) - \frac{\partial \mathbf{v}_\mathrm{h}}{\partial z} \cdot \boldsymbol{\nabla}_\mathrm{h} T - \frac{\partial w}{\partial z} \frac{\partial T}{\partial z} \right]$$
$$- g \frac{\partial w}{\partial z}, \tag{7.3}$$

Rewrite where –dT/dz = gamma, and Td = g/cp

$$\frac{\partial \gamma}{\partial t} = -\,\mathbf{v}_{\mathrm{h}} \cdot \nabla_{\mathrm{h}} \gamma - w \frac{\partial \gamma}{\partial z} + \frac{\partial \mathbf{v}_{\mathrm{h}}}{\partial z} \cdot \nabla_{\mathrm{h}} T$$

I II III

$$+ \frac{\partial w}{\partial z}(\Gamma_d - \gamma) - \frac{1}{c_p}\frac{\partial q}{\partial z}.$$

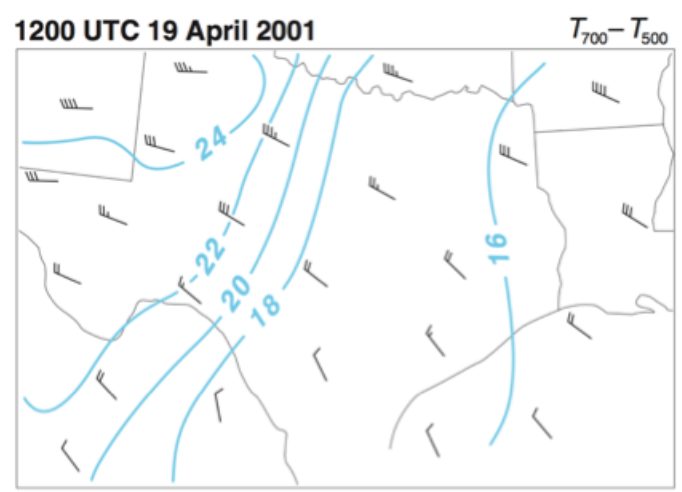
IV V

Lapse rate tendency equation

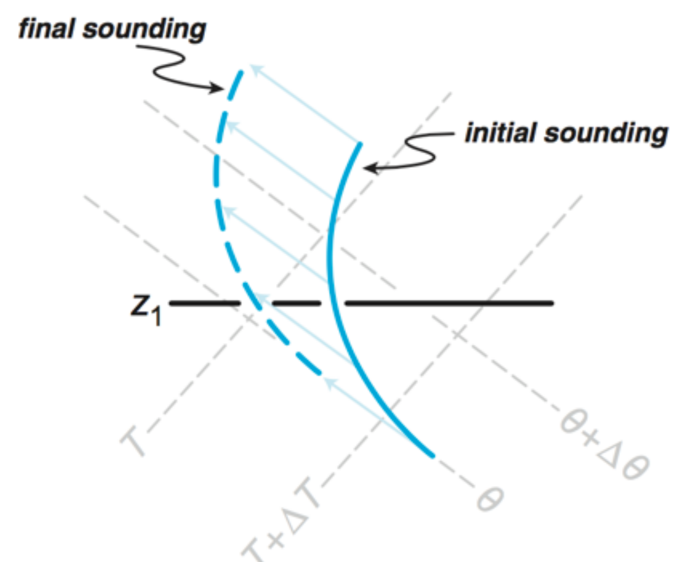
$$\frac{\partial \gamma}{\partial t} = -\mathbf{v}_\mathrm{h} \cdot \nabla_\mathrm{h} \gamma - w \frac{\partial \gamma}{\partial z} + \frac{\partial \mathbf{v}_\mathrm{h}}{\partial z} \cdot \nabla_\mathrm{h} T$$

I II III

I: Horizontal lapse rate advection



II: Vertical lapse rate advection

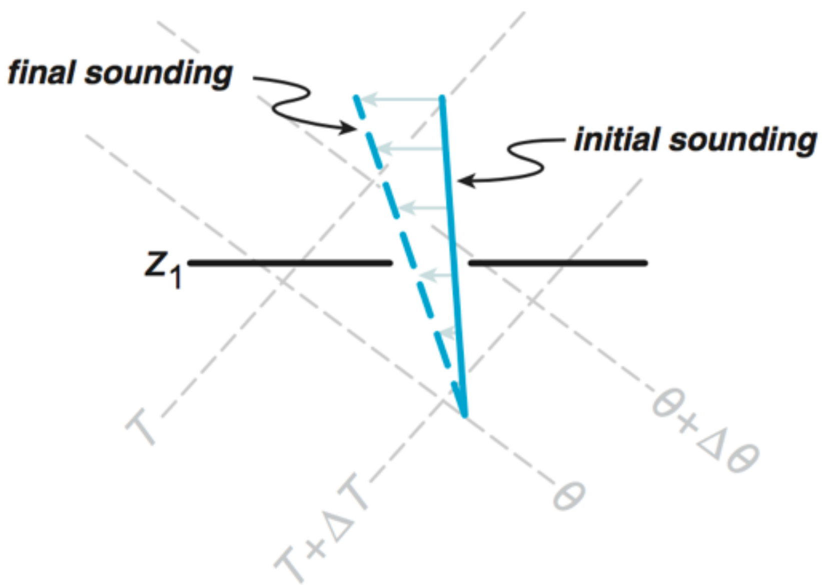


Cooling and increased lapse rate at z_1

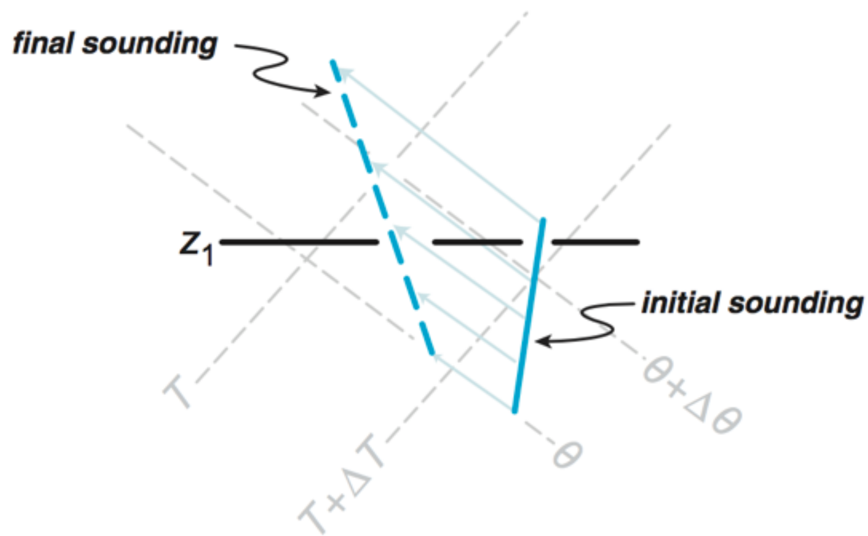
$$\frac{\partial \gamma}{\partial t} = \underbrace{-\,\mathbf{v}_\mathrm{h} \cdot \nabla_\mathrm{h} \gamma}_{\mathrm{I}} \underbrace{-\, w \frac{\partial \gamma}{\partial z}}_{\mathrm{II}} + \underbrace{\frac{\partial \mathbf{v}_\mathrm{h}}{\partial z} \cdot \nabla_\mathrm{h} T}_{\mathrm{III}}$$

III: Differential temperature advection

(same effect as term I)



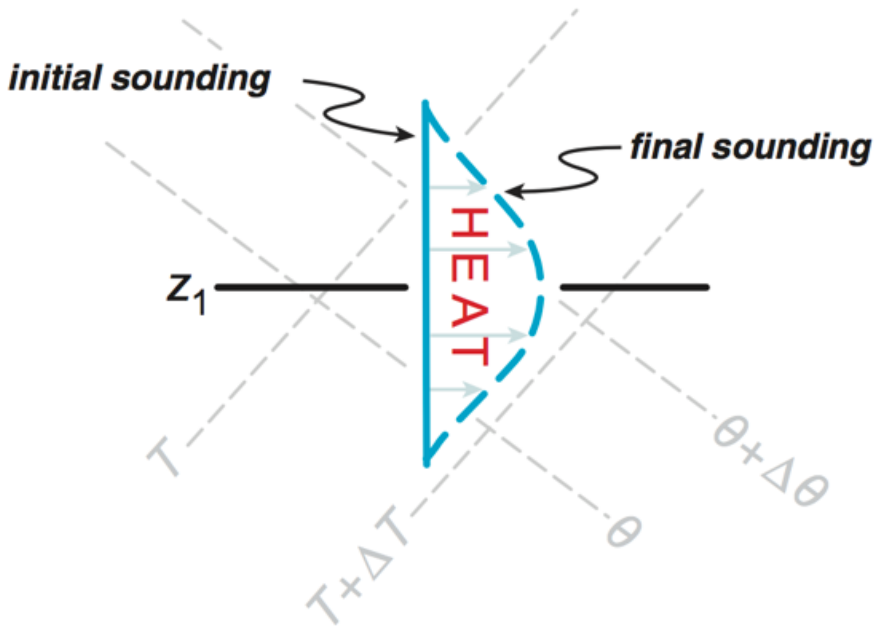
IV: Stretching term



$$\frac{\partial \gamma}{\partial t} = - \mathbf{v}_{\mathrm{h}} \cdot \nabla_{\mathrm{h}} \gamma - w \frac{\partial \gamma}{\partial z} + \frac{\partial \mathbf{v}_{\mathrm{h}}}{\partial z} \cdot \nabla_{\mathrm{h}} T$$

I II III

V: Differential diabatic heating



Lapse rate tendency equation – typical magnitudes on synoptic-scale:

$$\frac{\partial \gamma}{\partial t} = -\,\mathbf{v}_{\mathrm{h}} \cdot \nabla_{\mathrm{h}} \gamma - w \frac{\partial \gamma}{\partial z} + \frac{\partial \mathbf{v}_{\mathrm{h}}}{\partial z} \cdot \nabla_{\mathrm{h}} T$$

I II III

10^{-7} K m^{-1} s^{-1} 10^{-8} K m^{-1} s^{-1} 10^{-8} K m^{-1} s^{-1} 10^{-8} K m^{-1} s^{-1} 10^{-9} K m^{-1} s^{-1}

Could be order of magnitude larger on mesoscale

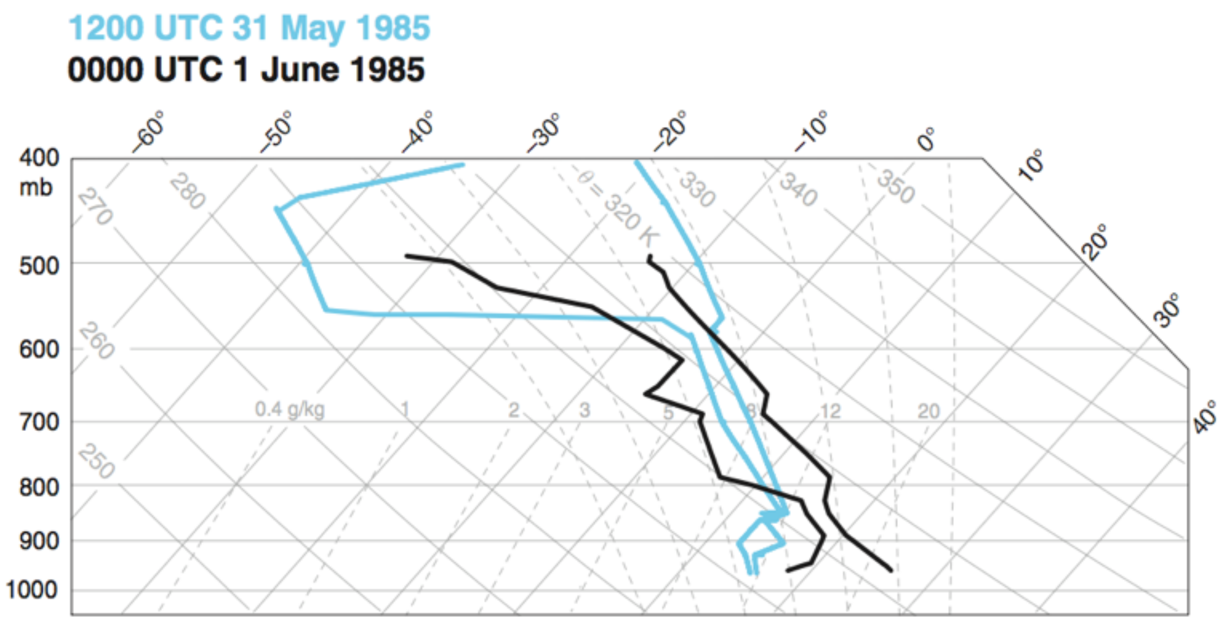
Terms I and III together represent effects of differential temperature advection

$$\underbrace{\frac{\partial \mathbf{v}_\mathrm{h}}{\partial z} \cdot \boldsymbol{\nabla}_\mathrm{h} T}_{\mathbf{III}} - \underbrace{\mathbf{v}_\mathrm{h} \cdot \boldsymbol{\nabla}_\mathrm{h} \gamma}_{\mathbf{I}} = \underbrace{-\frac{\partial}{\partial z}(-\mathbf{v}_\mathrm{h} \cdot \boldsymbol{\nabla}_\mathrm{h} T)}_{\textit{Differential temperature advection}}$$

Note: only the vertical shear of the *ageostrophic* wind contributes to III since

$$\frac{\partial \mathbf{v}_\mathrm{g}}{\partial z} \cdot \boldsymbol{\nabla}_\mathrm{h} T = 0$$

Large-scale impacts on environmental thermodynamics

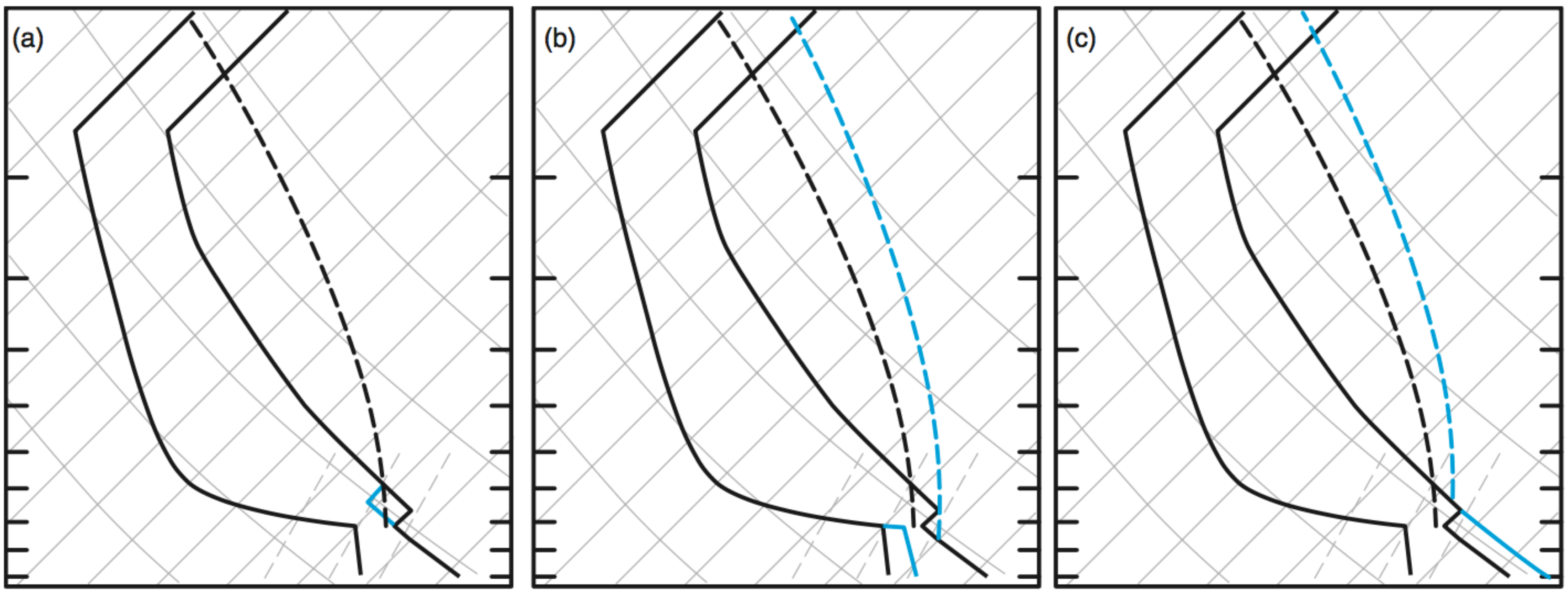


Processes often act in unison to modify environmental thermodynamic profile.

Moisture advection and boundary layer modification can have an even more significant impact on instability compared to lapse-rate changes.

Large-scale impacts on environmental thermodynamics

Other ways to reduce convective inhibition

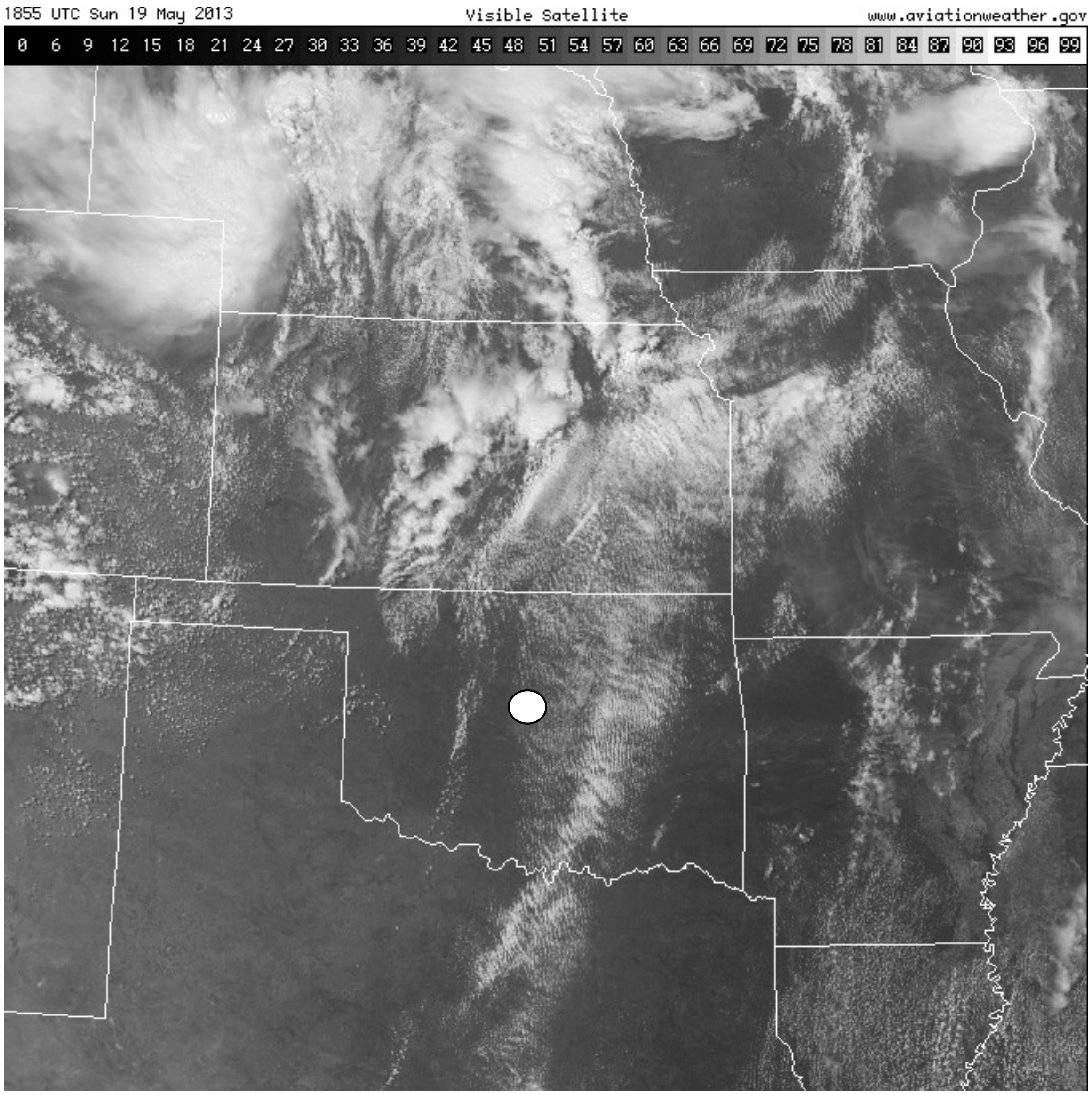


Vertical motion (not necessarily increasing with height).

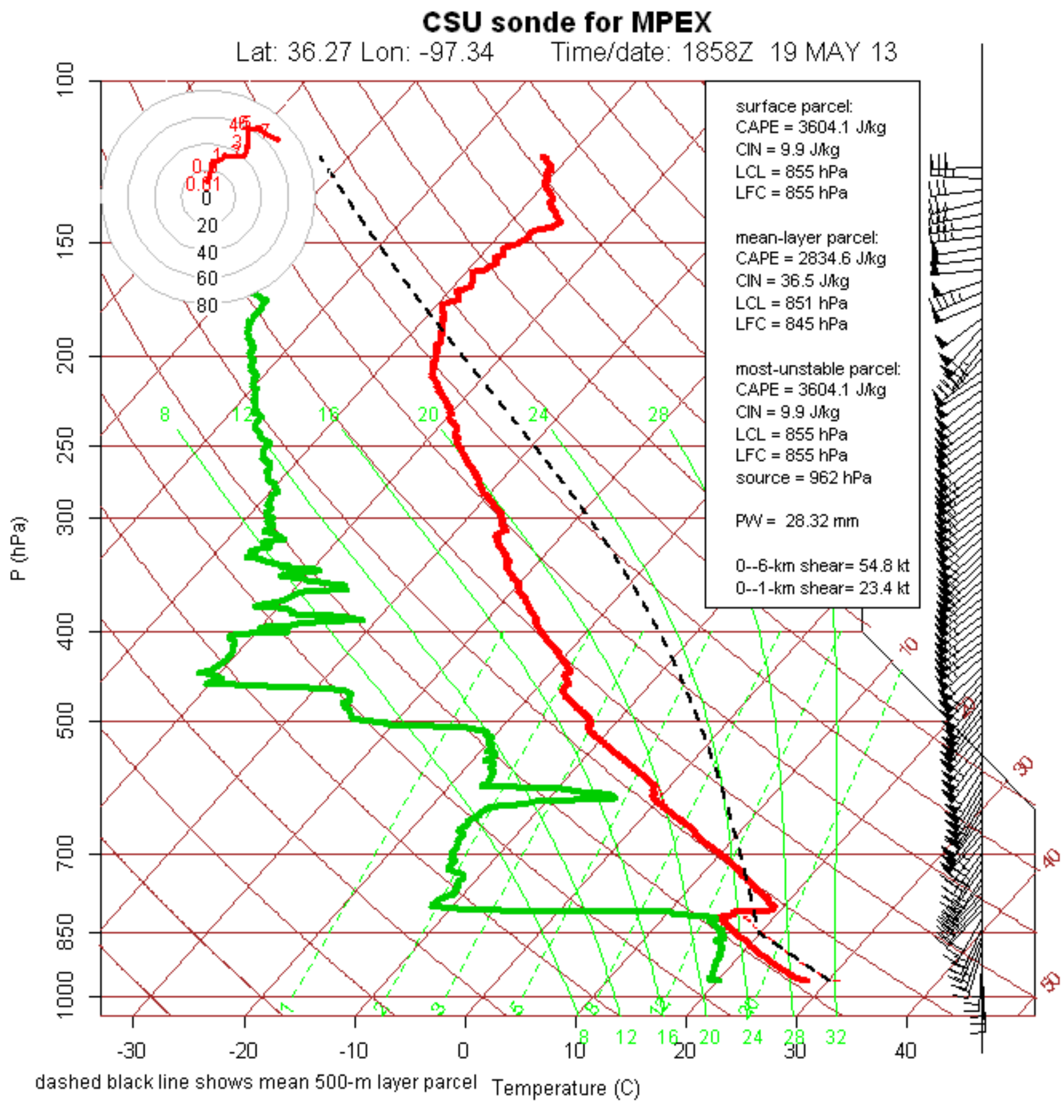
Moisture advection in boundary layer

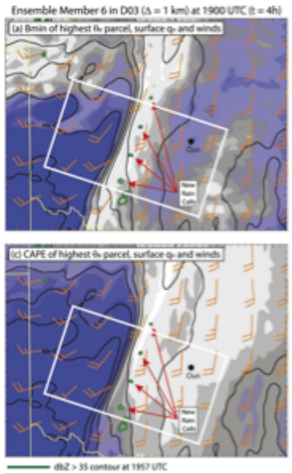
Boundary layer warming

Low-level warming/moistening decrease CIN & increase CAPE


1855 UTC Sun 19 May 2013
Visible Satellite
www.aviationweather.gov
0 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93 96 99

MPEX (Mesoscale Predictability Experiment) radiosondes taken in pre-convective environment





CIN reduced in confined area near mesoscale surface boundary, leading to initiation of deep convection.

In this case, width of zone of negligible negative buoyancy (lower CIN; small B_{min}) for surface-based parcels was important.

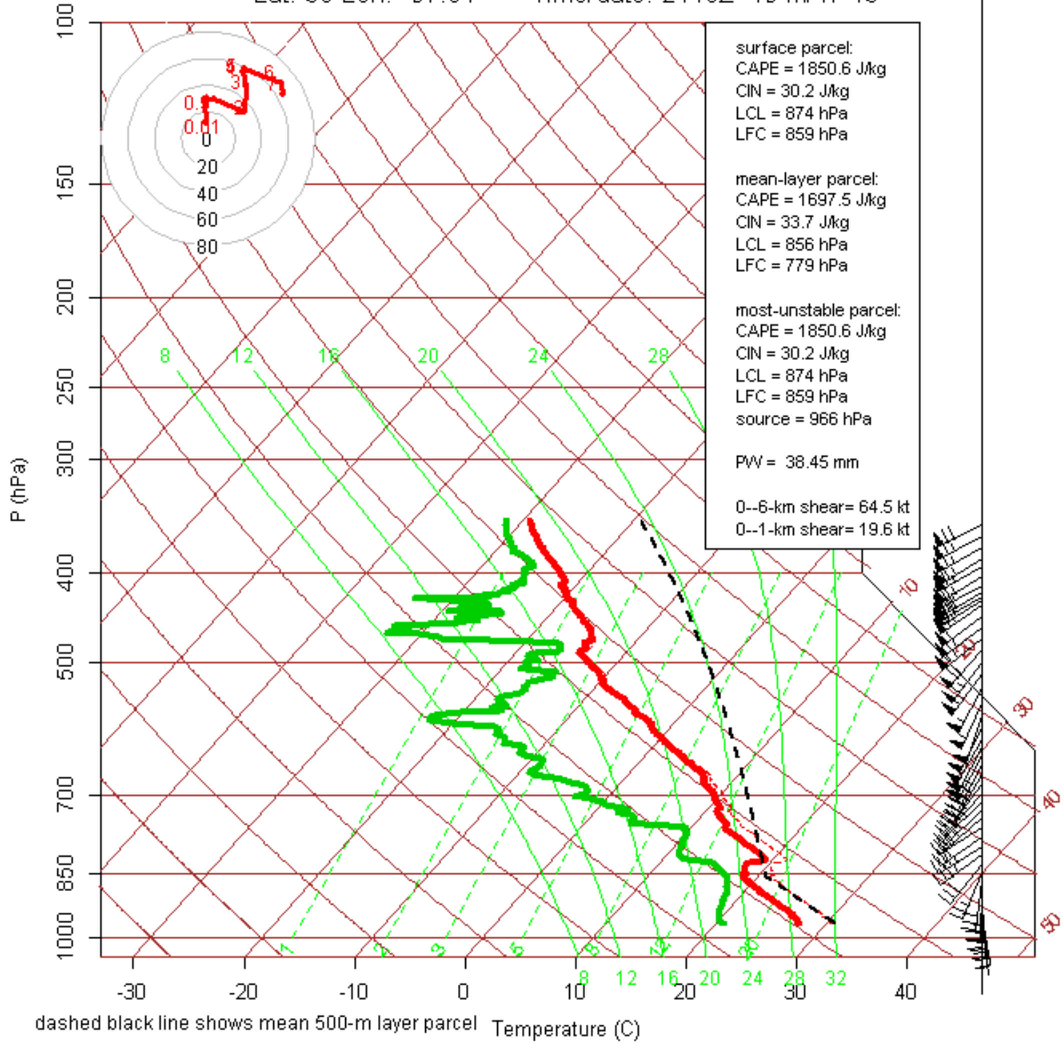
In situations where width was smaller, convection did not mature before encountering unfavorable environment.

Once mature, convection survived *in spite of* negative buoyancy.

CIN reduction in part due to mesoscale circulation associated with surface boundary. More details in Trier et al. (2015).

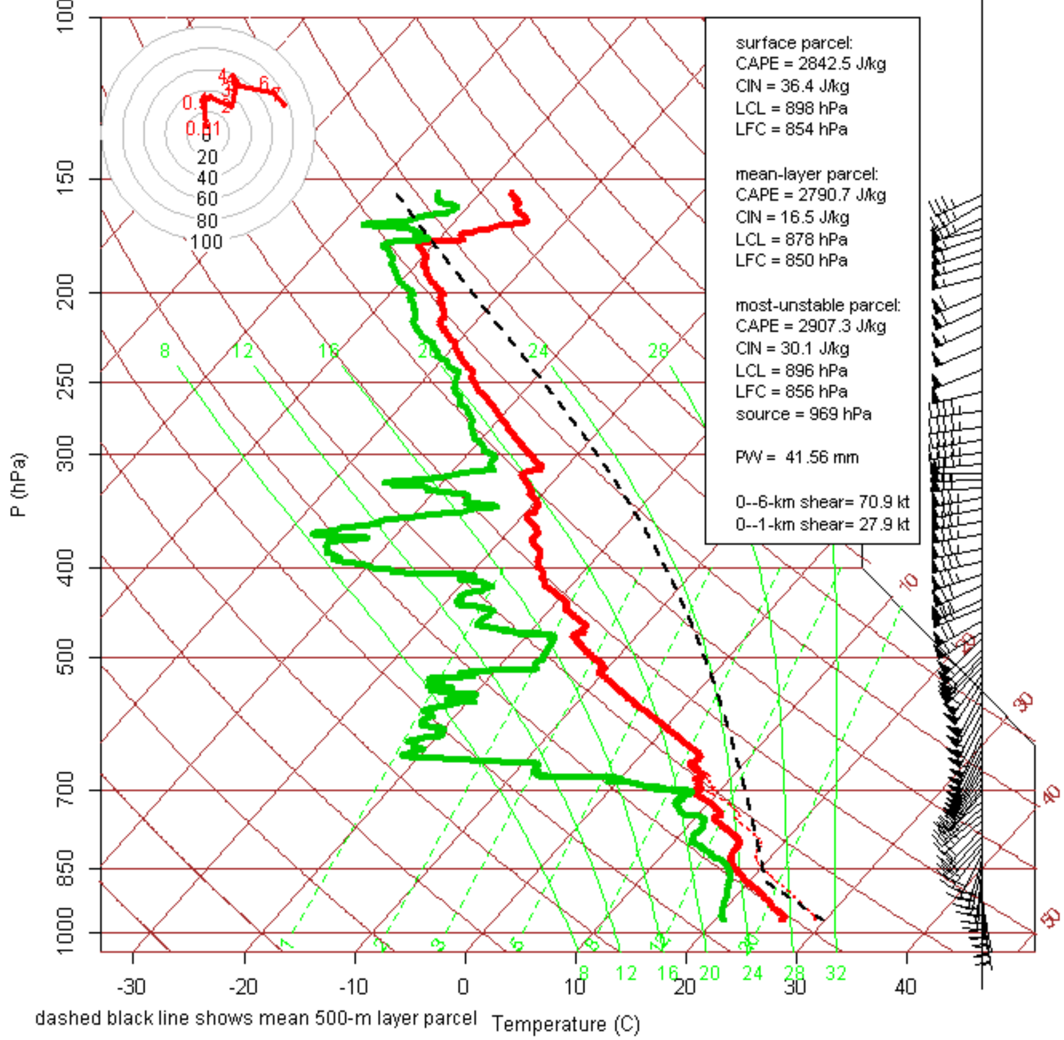
CSU sonde for MPEX

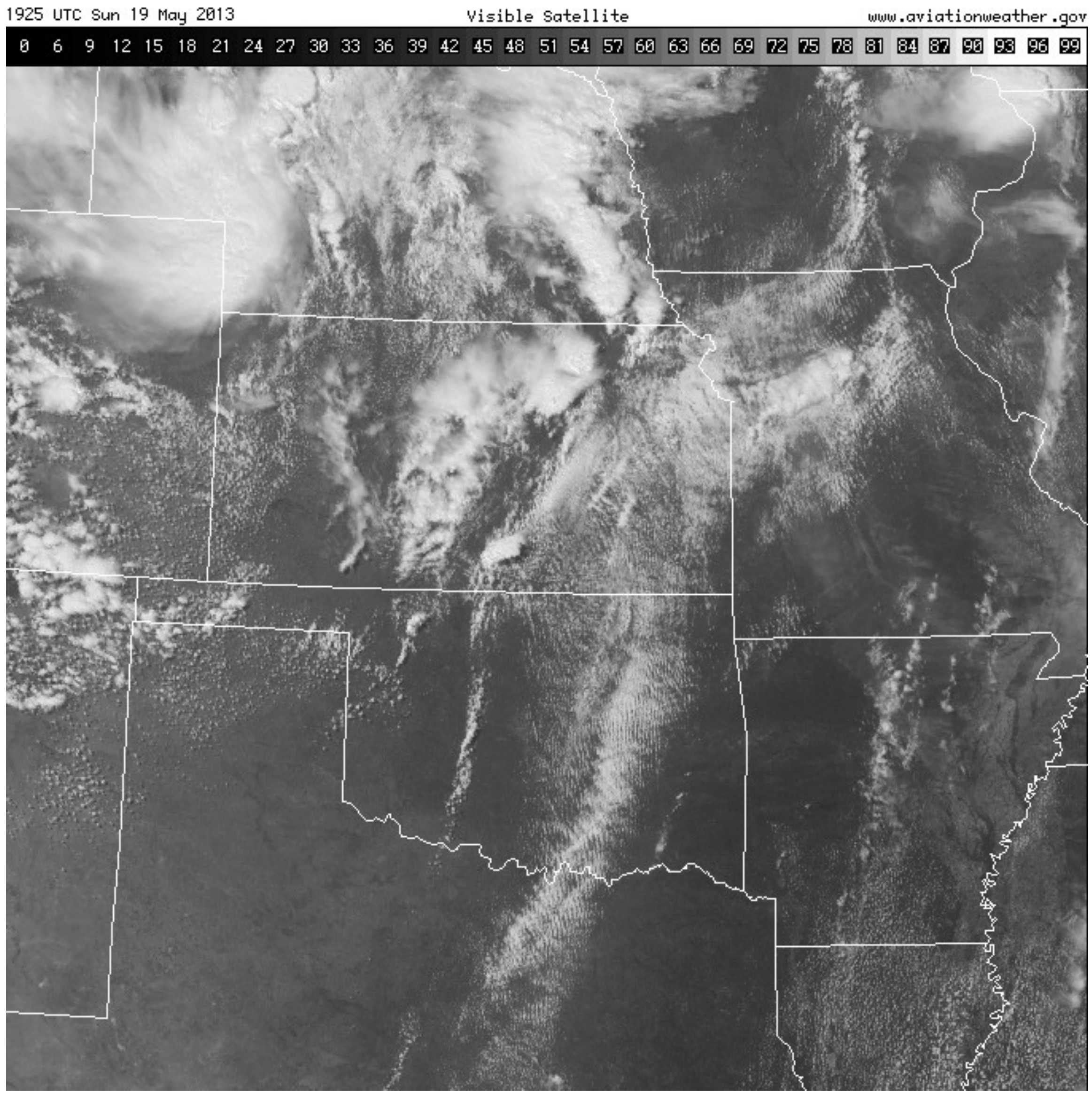
Lat: 36 Lon: -97.04 Time/date: 2110Z 19 MAY 13



CSU sonde for MPEX

Lat: 35.73 Lon: -96.68 Time/date: 2247Z 19 MAY 13

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Visible Satellite
www.aviationweather.gov
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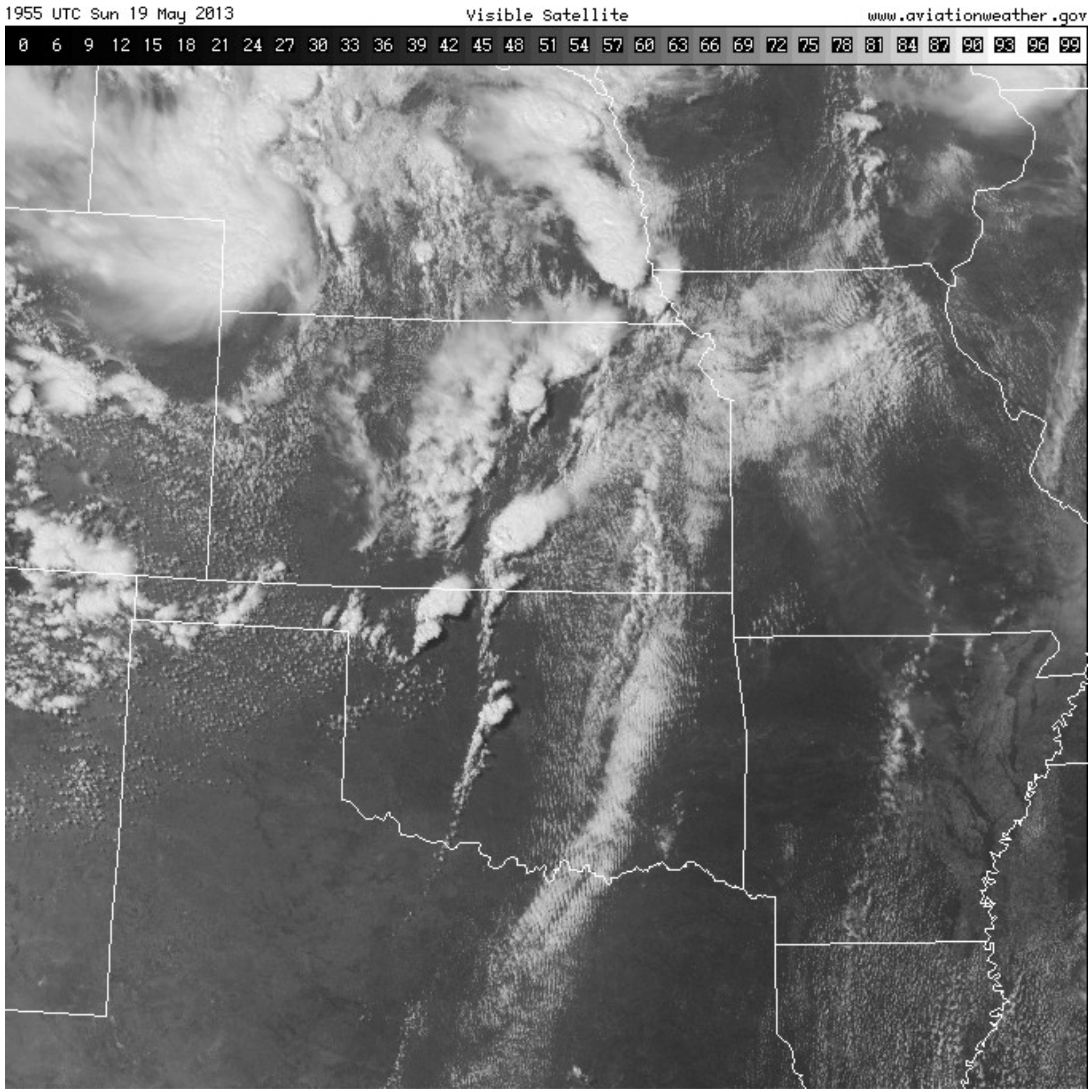
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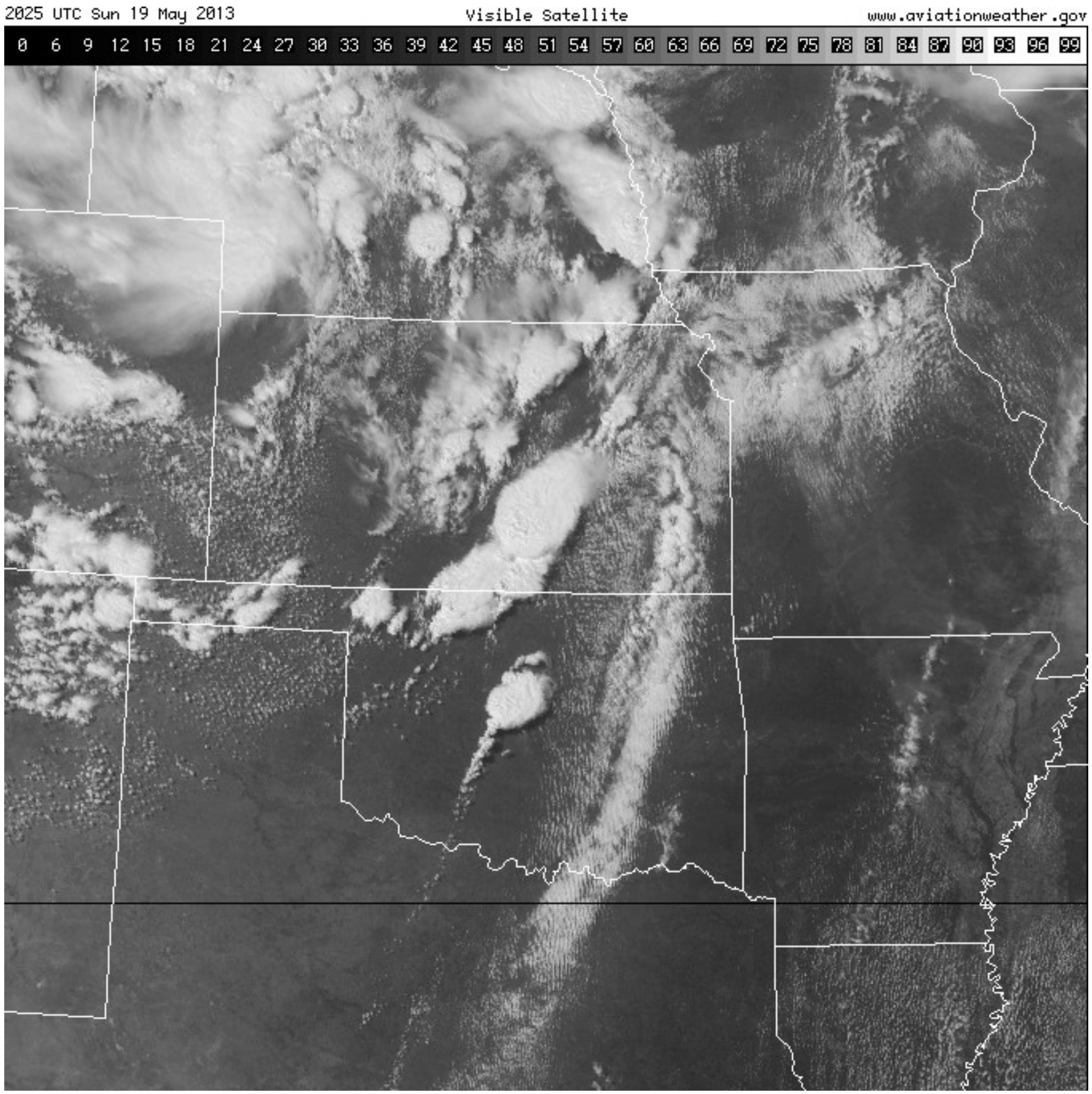

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www.aviationweather.gov
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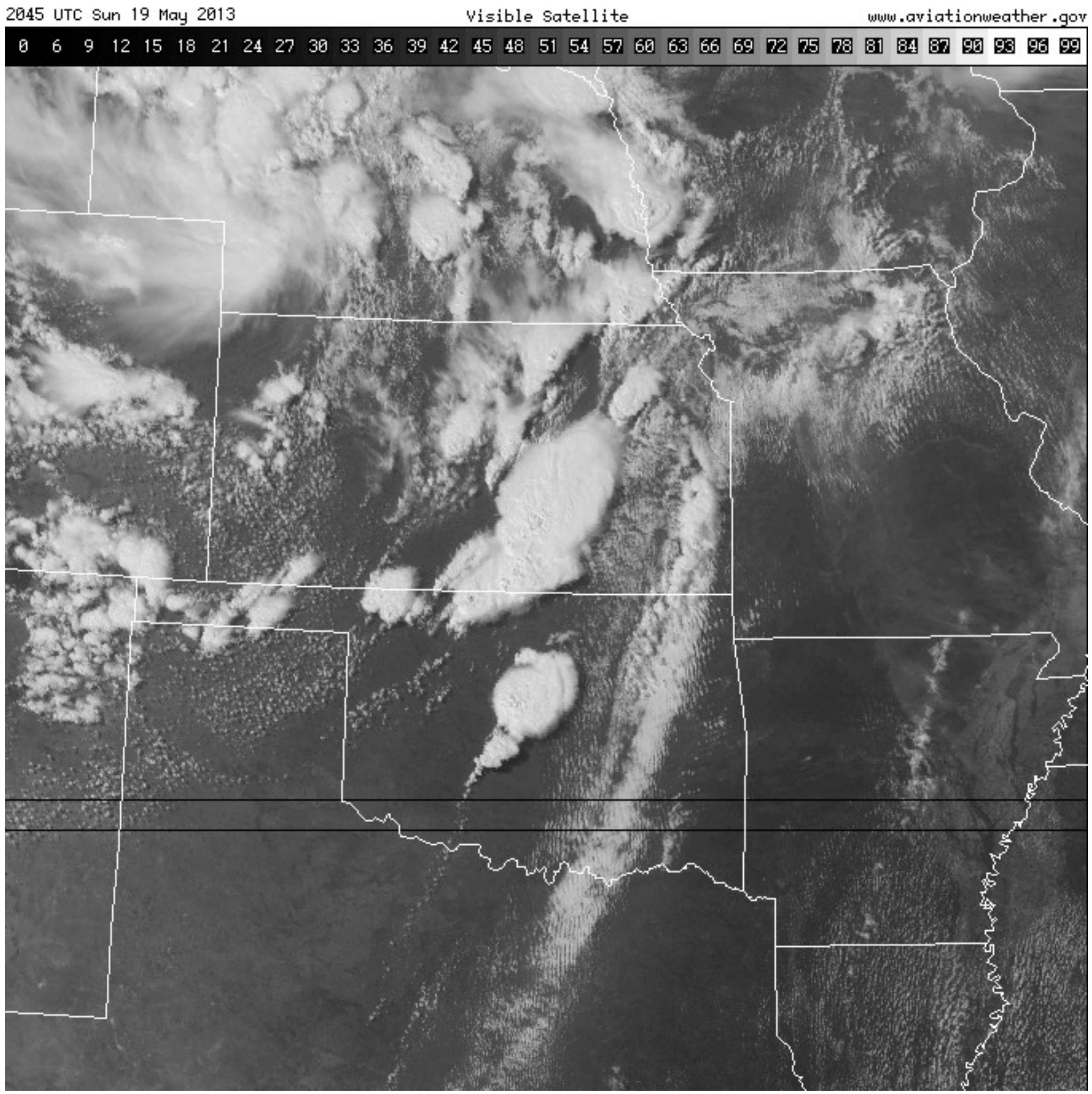

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www.aviationweather.gov
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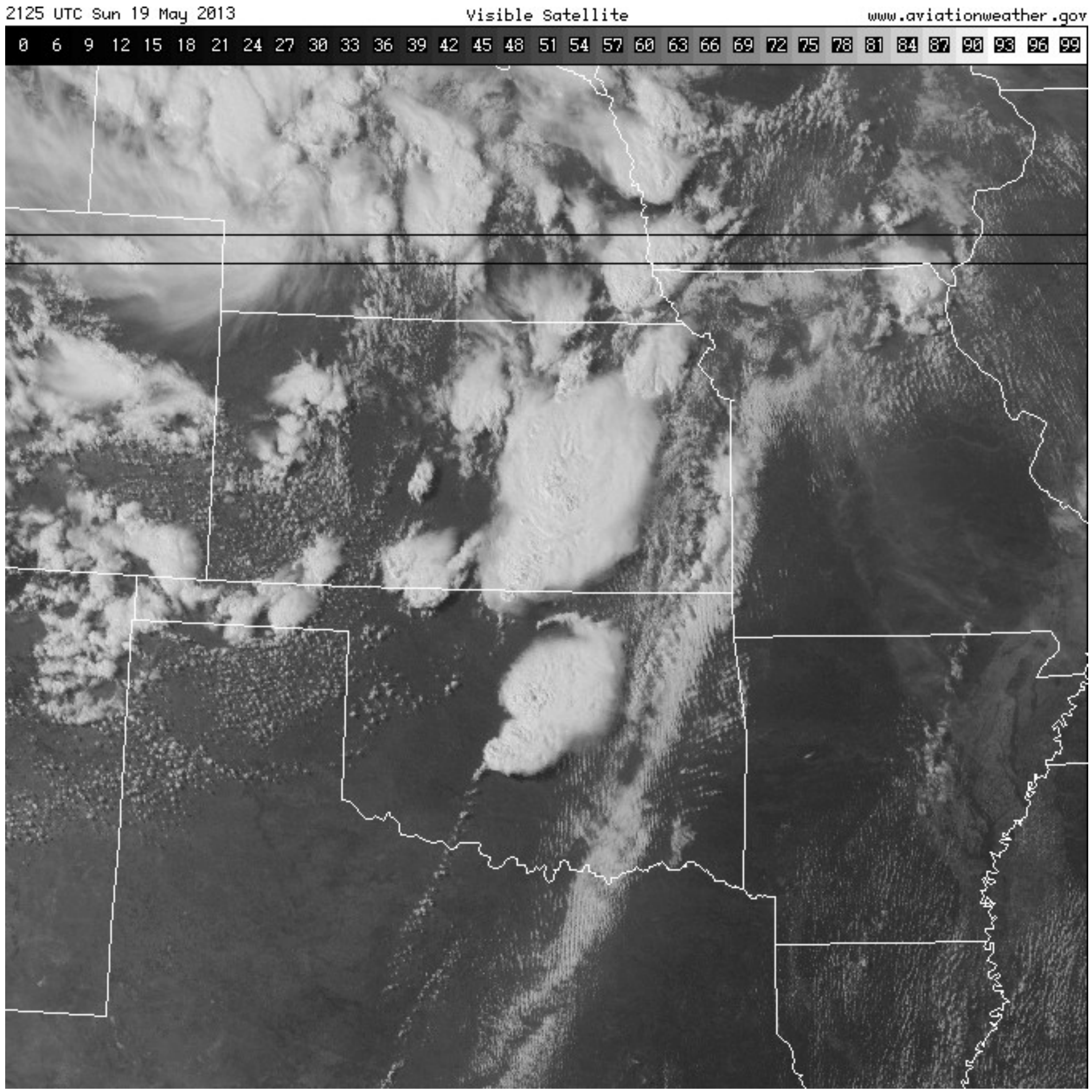

2125 UTC Sun 19 May 2013
Visible Satellite
www.aviationweather.gov
0 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93 96 99

The role of vertical wind shear on convective organization

Vertical wind shear tends to promote **storm organization and longevity**.

Much of what we know about relationships between wind shear and convective behavior comes from **numerical modeling studies** where the environmental characteristics can be carefully controlled.

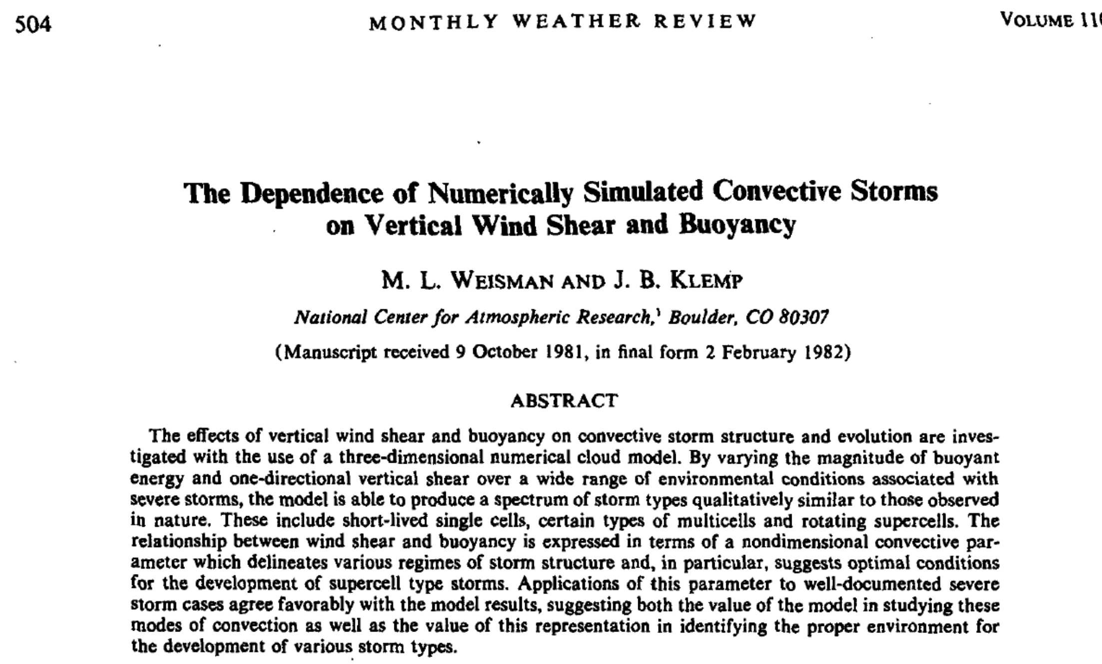
In most of these studies, convection is initiated via artificial mechanisms (such as the method used in CM1 – a **warm "bubble"** inserted into the initial conditions).

In nature, convection initiated by localized areas of convergence or forced ascent.

Schlesinger (1975)
Klemp and Wilhemson (1978)
Schlesinger (1978)
Wilhelmson and Klemp (1978)
Schlesinger (1980)
Wilhelmson and Klemp (1981)
Rotunno and Klemp (1982)
Weisman and Klemp (1982)

The first papers to use *three-dimensional* cloud model to investigate convective storm behavior as a function of environmental shear and buoyancy

read for next week…


504 MONTHLY WEATHER REVIEW VOLUME 110

The Dependence of Numerically Simulated Convective Storms on Vertical Wind Shear and Buoyancy

M. L. WEISMAN AND J. B. KLEMP
National Center for Atmospheric Research,[1] Boulder, CO 80307

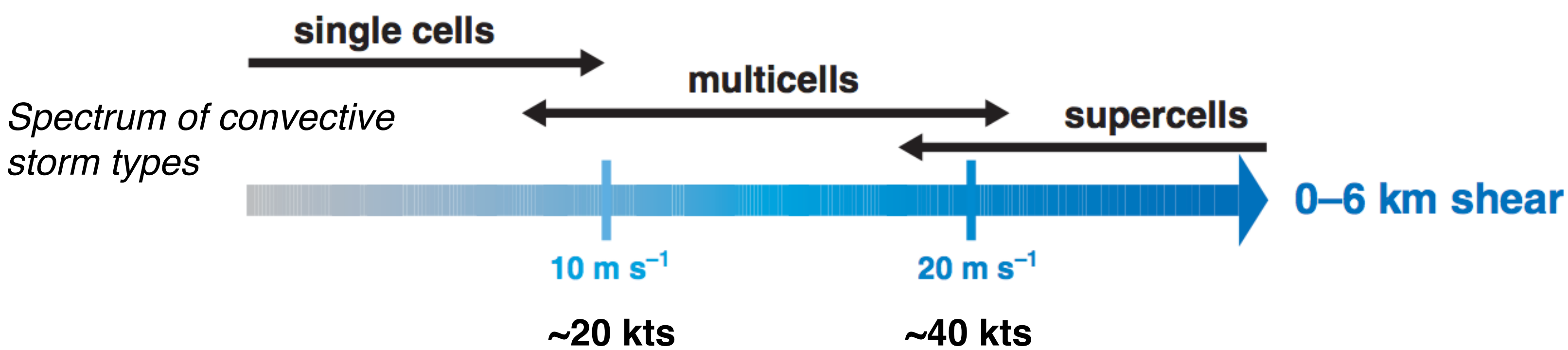
(Manuscript received 9 October 1981, in final form 2 February 1982)

ABSTRACT

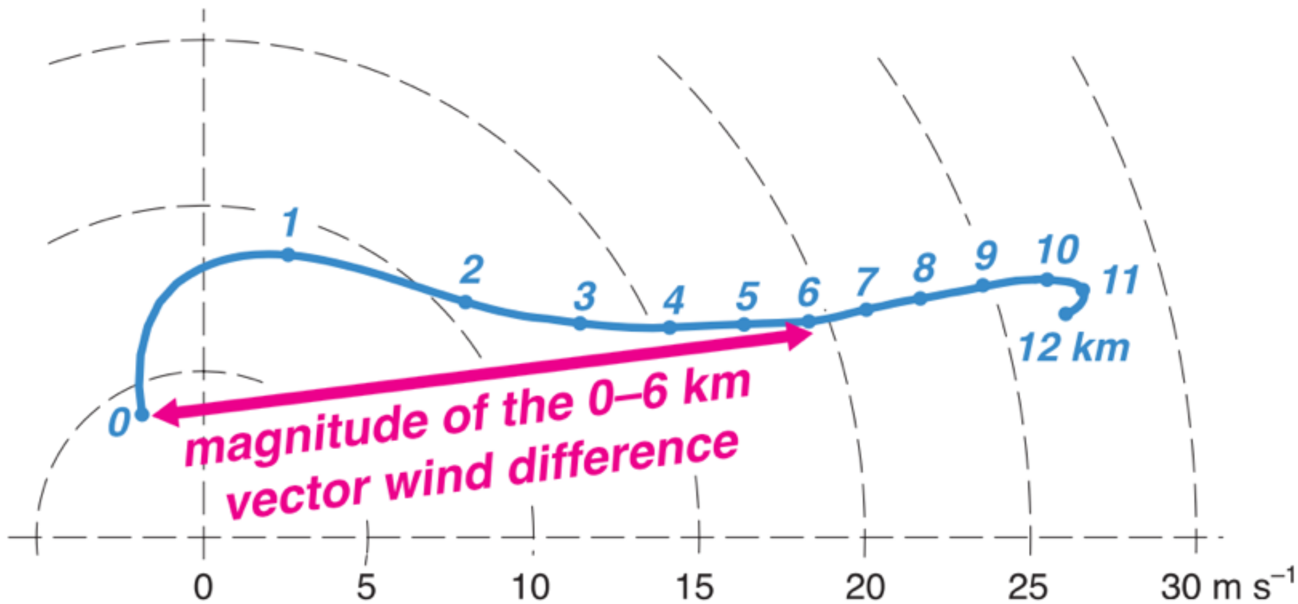
The effects of vertical wind shear and buoyancy on convective storm structure and evolution are investigated with the use of a three-dimensional numerical cloud model. By varying the magnitude of buoyant energy and one-directional vertical shear over a wide range of environmental conditions associated with severe storms, the model is able to produce a spectrum of storm types qualitatively similar to those observed in nature. These include short-lived single cells, certain types of multicells and rotating supercells. The relationship between wind shear and buoyancy is expressed in terms of a nondimensional convective parameter which delineates various regimes of storm structure and, in particular, suggests optimal conditions for the development of supercell type storms. Applications of this parameter to well-documented severe storm cases agree favorably with the model results, suggesting both the value of the model in studying these modes of convection as well as the value of this representation in identifying the proper environment for the development of various storm types.

The role of vertical wind shear on convective organization

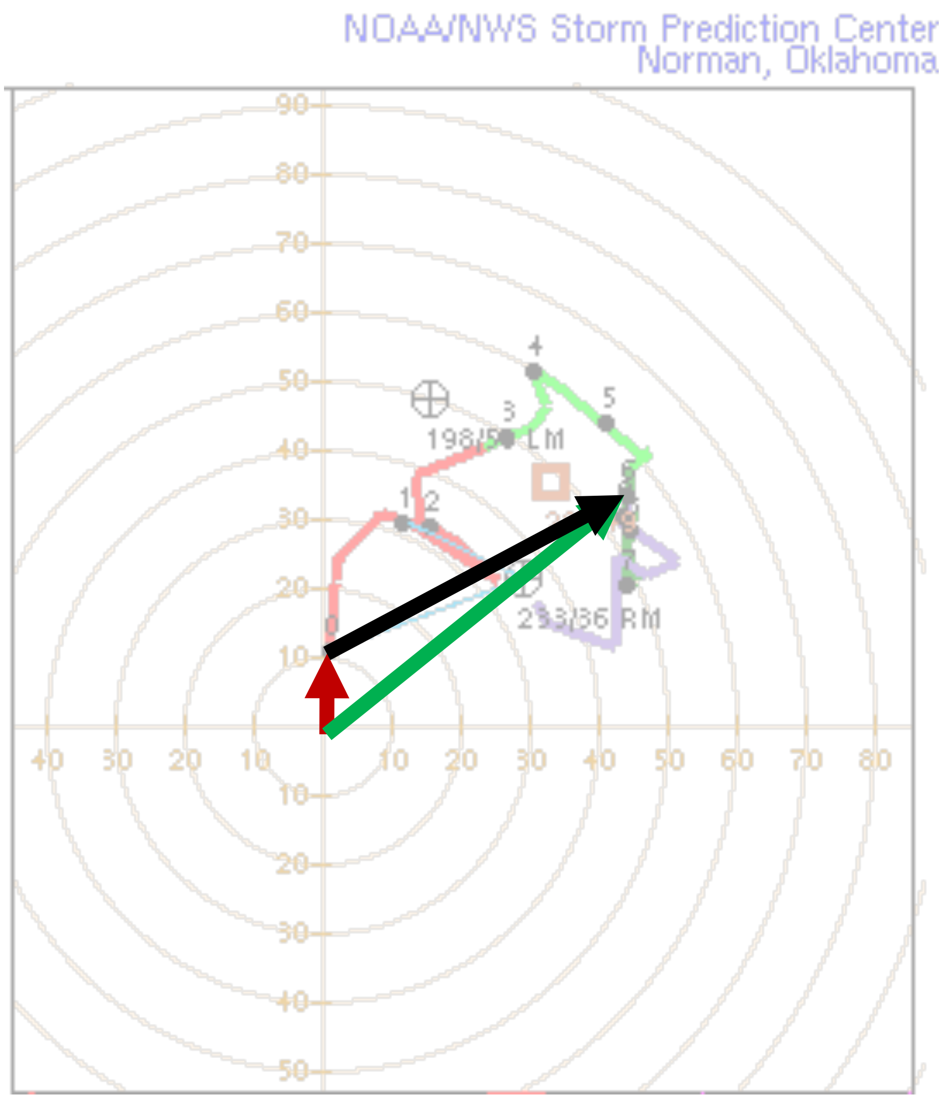
Observational studies prior to the advent of cloud models identified three primary storm types:



The role of vertical wind shear on convective organization



Magnitude of the **0 – 6 km vector wind difference** referred to as “deep-layer” shear (other layers may be used with similar discriminatory ability).



"Bulk" shear between 0 km and 6 km AGL:

Vector difference between 6 km ground-relative wind vector and 0 km (really, 10 m) ground-relative wind vector.

Does the magnitude of the 0-6km shear vector change if using storm-relative winds?

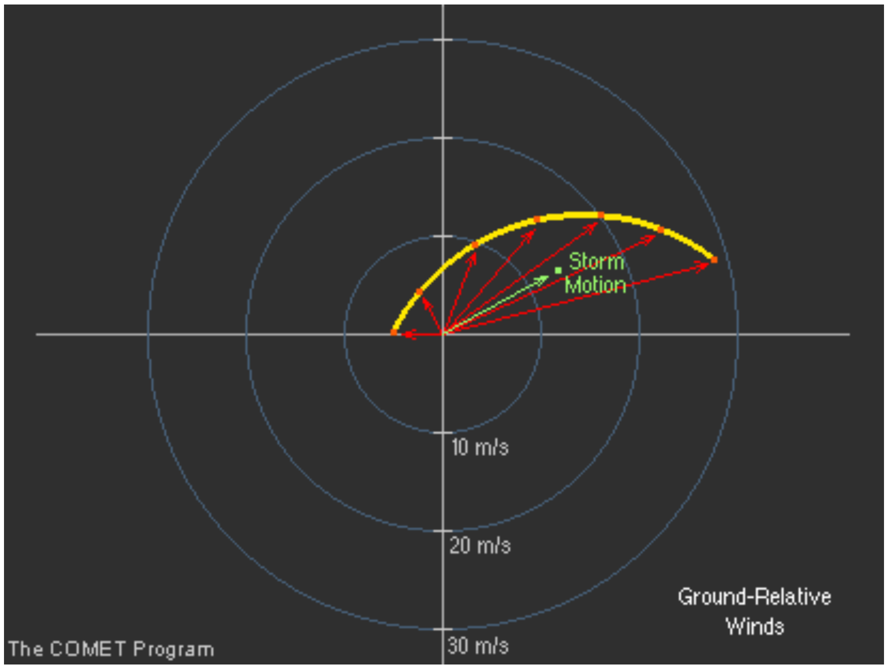
	SRH(m2/s2)	Shear(kt)	MnWind	SRW
SFC - 1 km	147	22	189/22	91/25
SFC - 3 km	246	40	205/30	109/17
Eff Inflow Layer	147	22	189/23	92/25
SFC - 6 km		49	211/38	139/14
SFC - 8 km		47	215/39	148/12
Lower Half Storm Depth		45	212/39	142/14
Cloud Bearing Layer		51	220/44	177/11

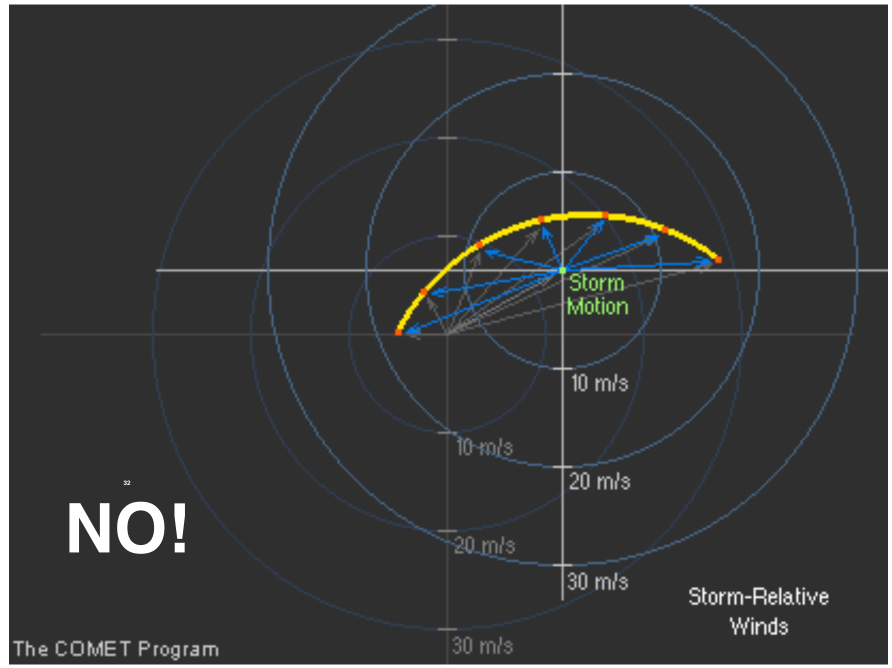
BRN Shear = 71 m²/s²
4-6km SR Wind = 204/25 kt

.....Storm Motion Vectors.....
Bunkers Right = 233/36 kt
Bunkers Left = 198/50 kt

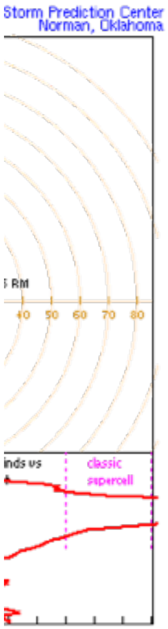
Corfidi Downshear = 231/74 kt
Corfidi Upshear = 244/27 kt

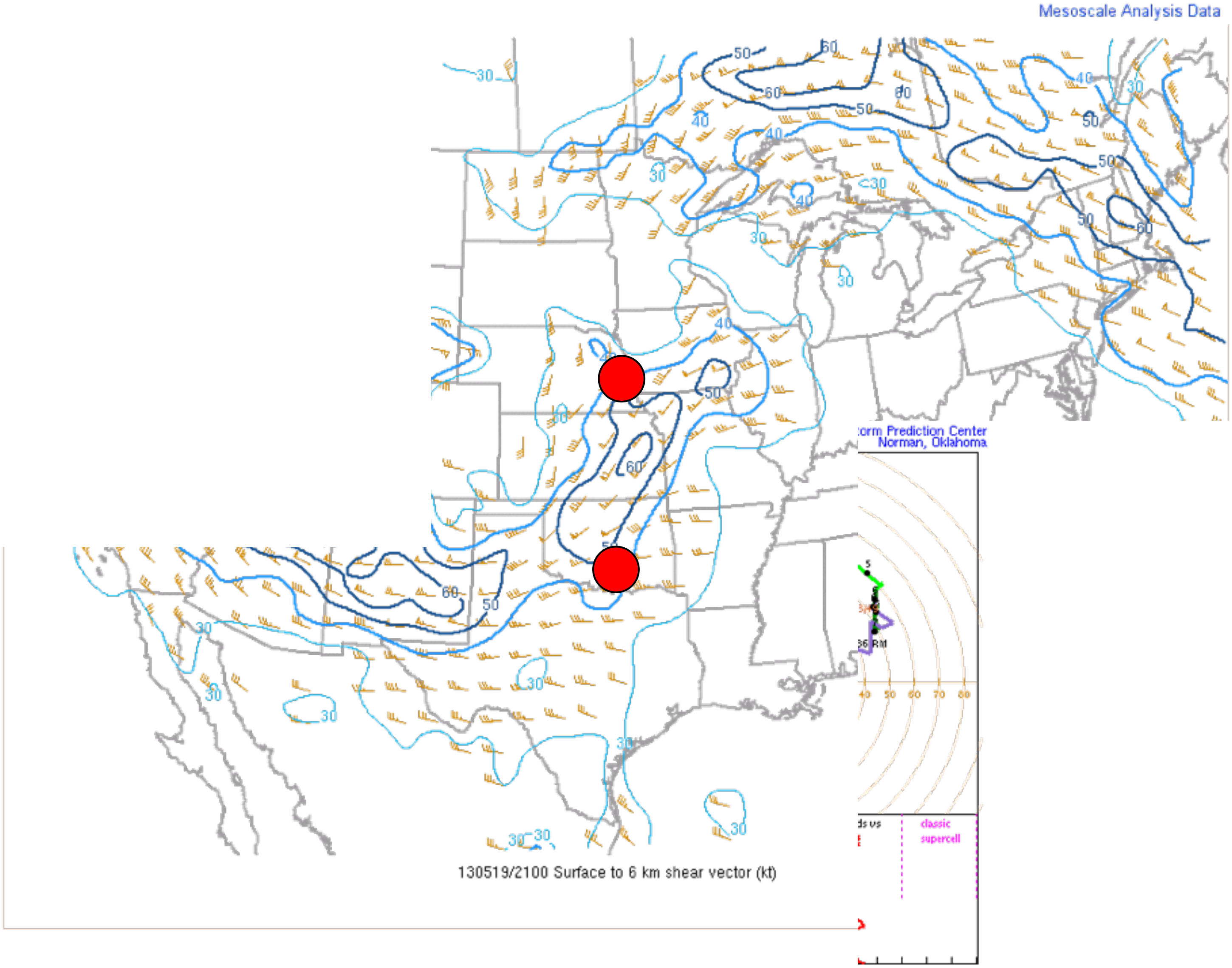
Does the magnitude of the 0-6 km shear vector change if using storm-relative winds?

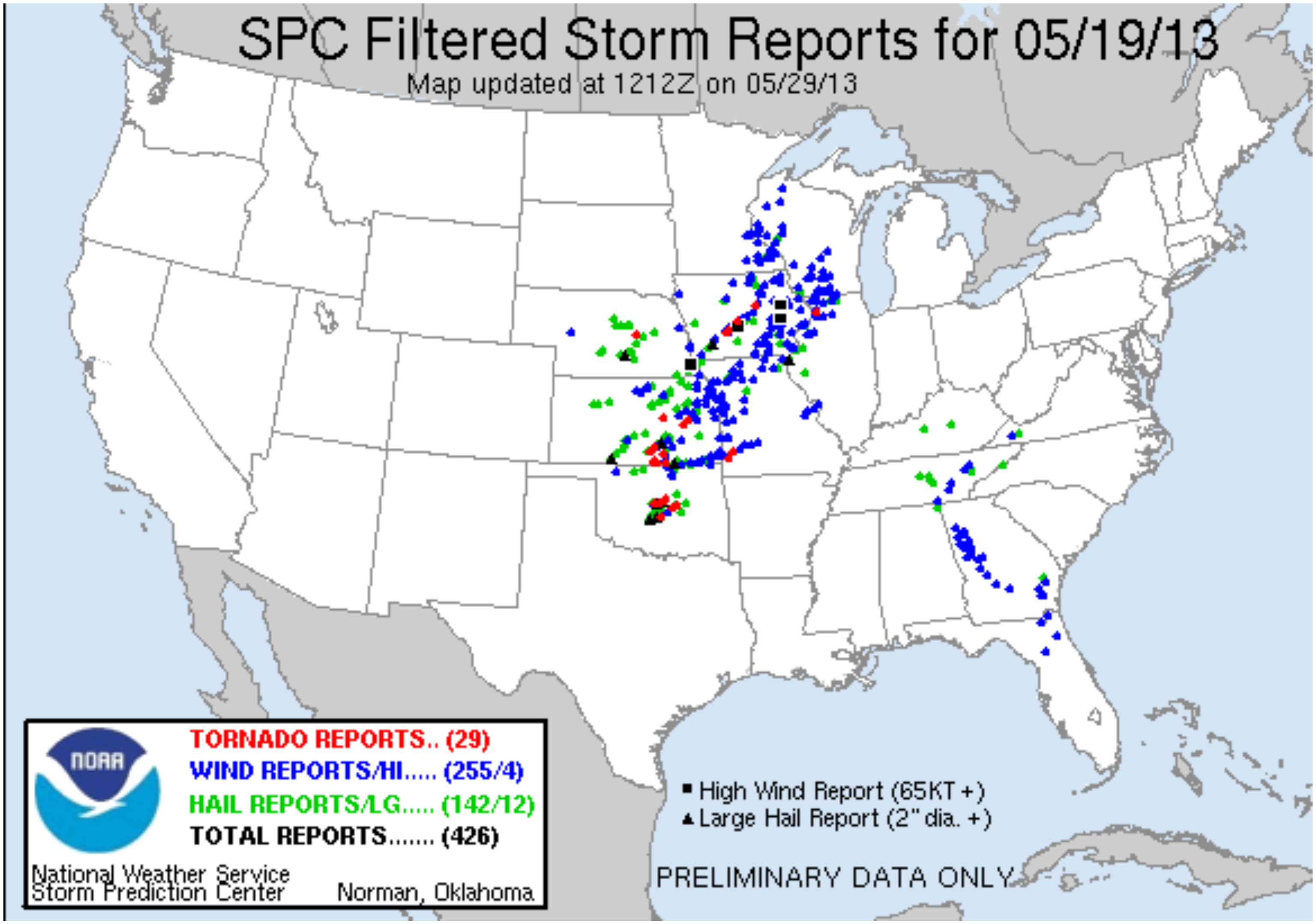




6 km SR wind vector = 6 km GR wind vector – storm motion vector
0 km SR wind vector = 0 km GR wind vector – storm motion vector
Storm motion cancels out when computing vector difference


Storm Prediction Center
Norman, Oklahoma
classic
supercell


Mesoscale Analysis Data
130519/2100 Surface to 6 km shear vector (kt)
Norman, Oklahoma
classic
supercell


SPC Filtered Storm Reports for 05/19/13
Map updated at 1212Z on 05/29/13
TORNADO REPORTS.. (29)
WIND REPORTS/HI..... (255/4)
HAIL REPORTS/LG..... (142/12)
TOTAL REPORTS....... (426)
National Weather Service
Storm Prediction Center
Norman, Oklahoma
High Wind Report (65KT +)
Large Hail Report (2" dia. +)
PRELIMINARY DATA ONLY