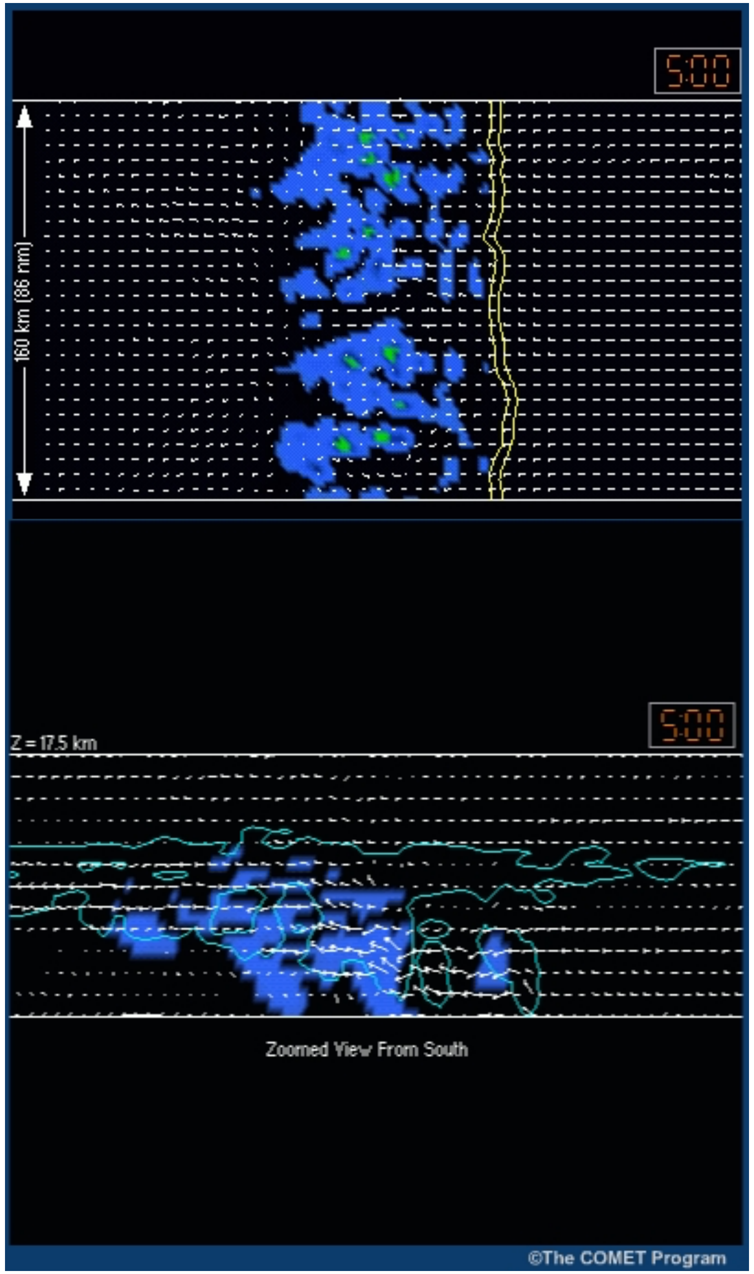
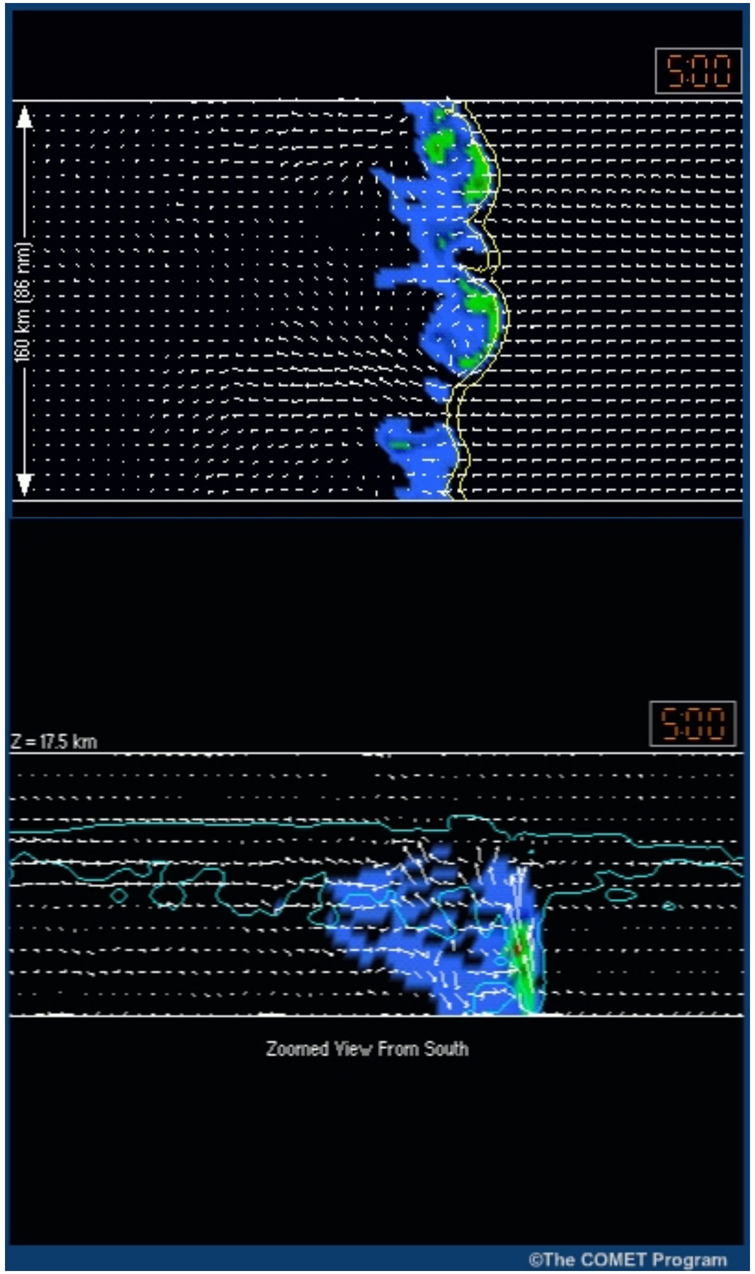
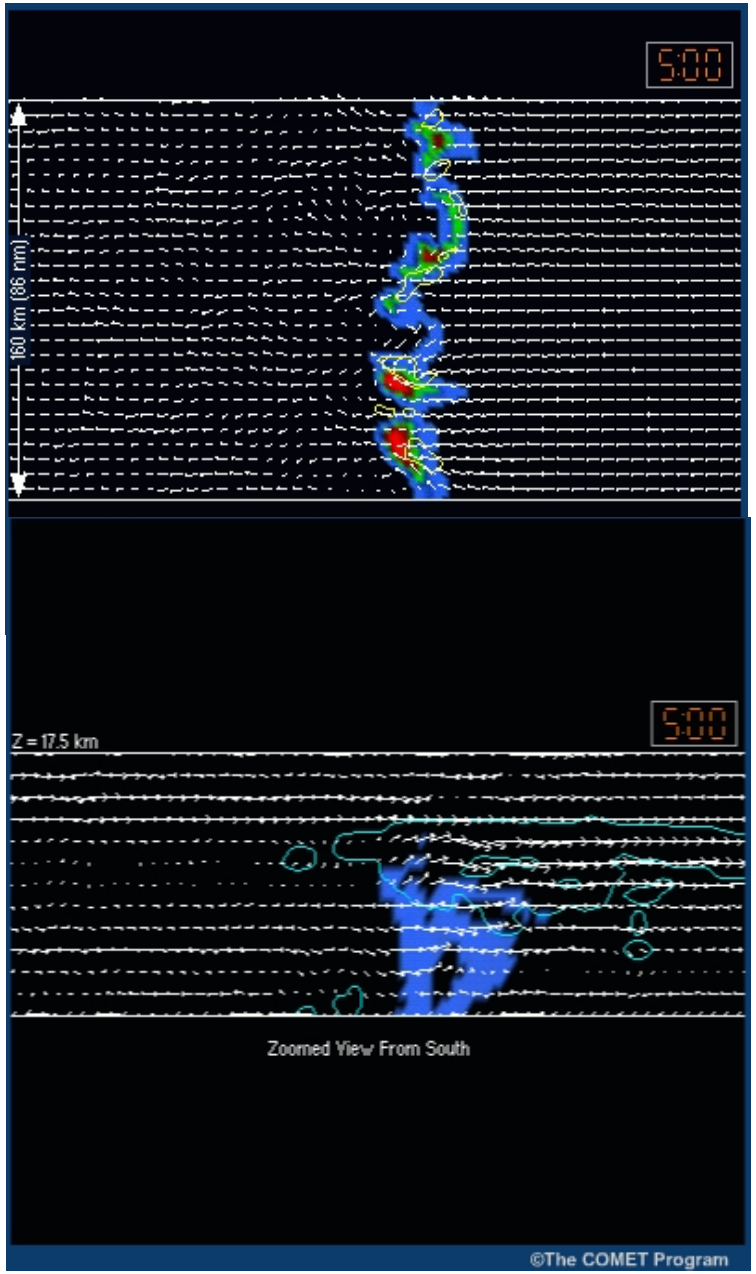
Weak, shallow shear (A1)




Strong, shallow shear (C1)

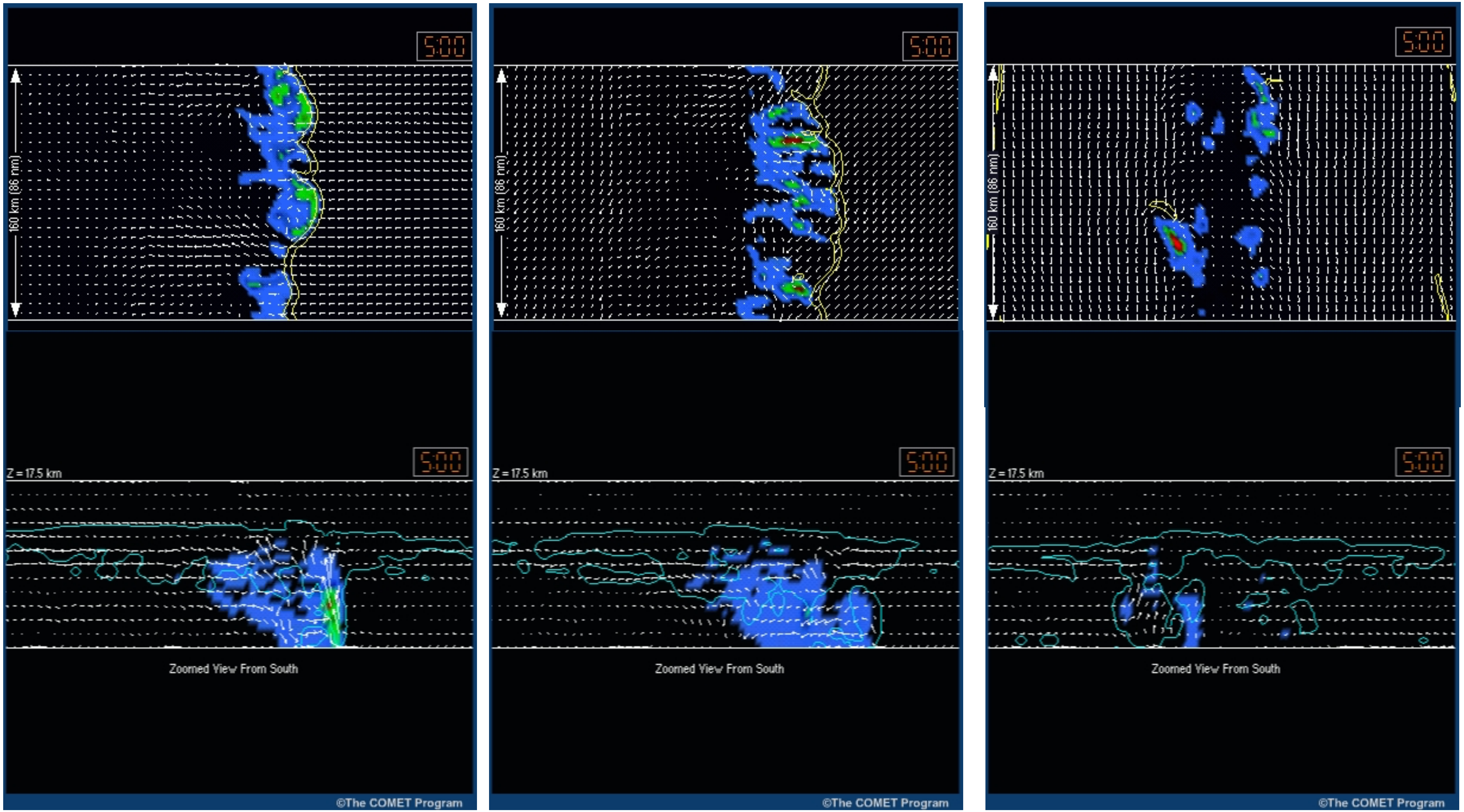



Moderate/strong, deep shear (G1)

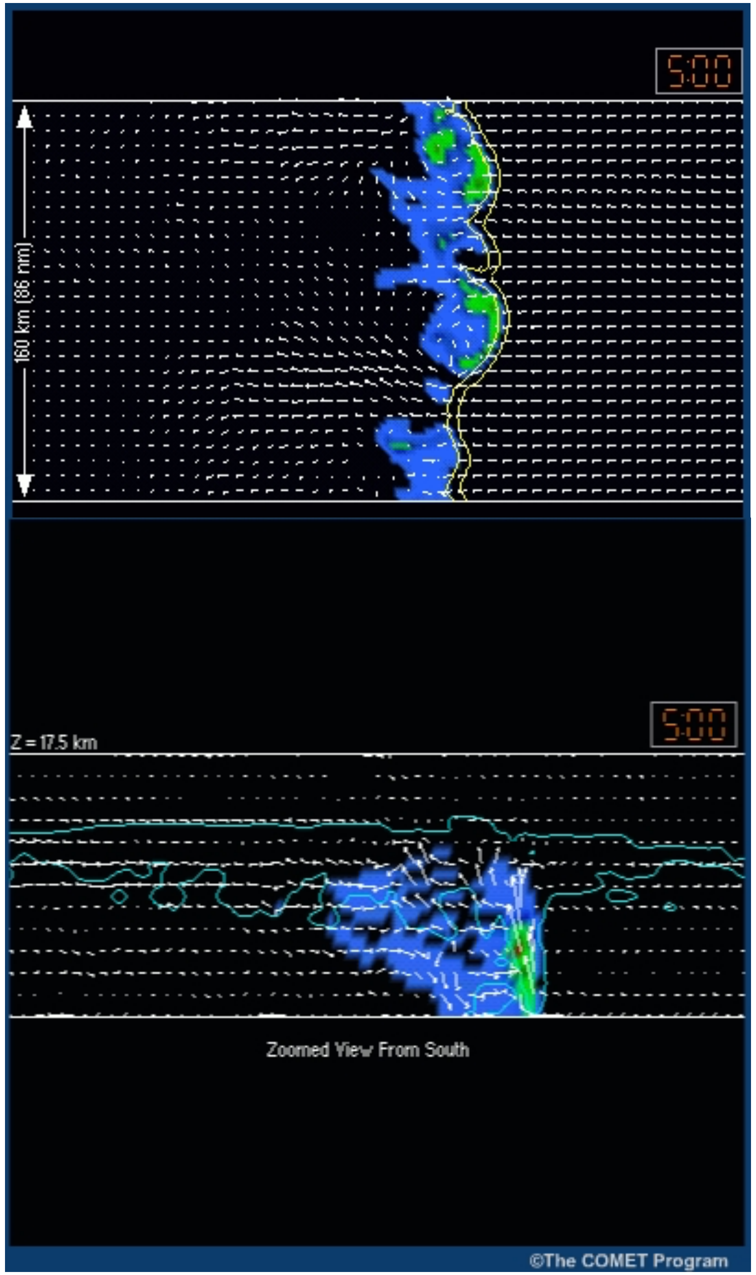


Line-perpendicular shear (C1)

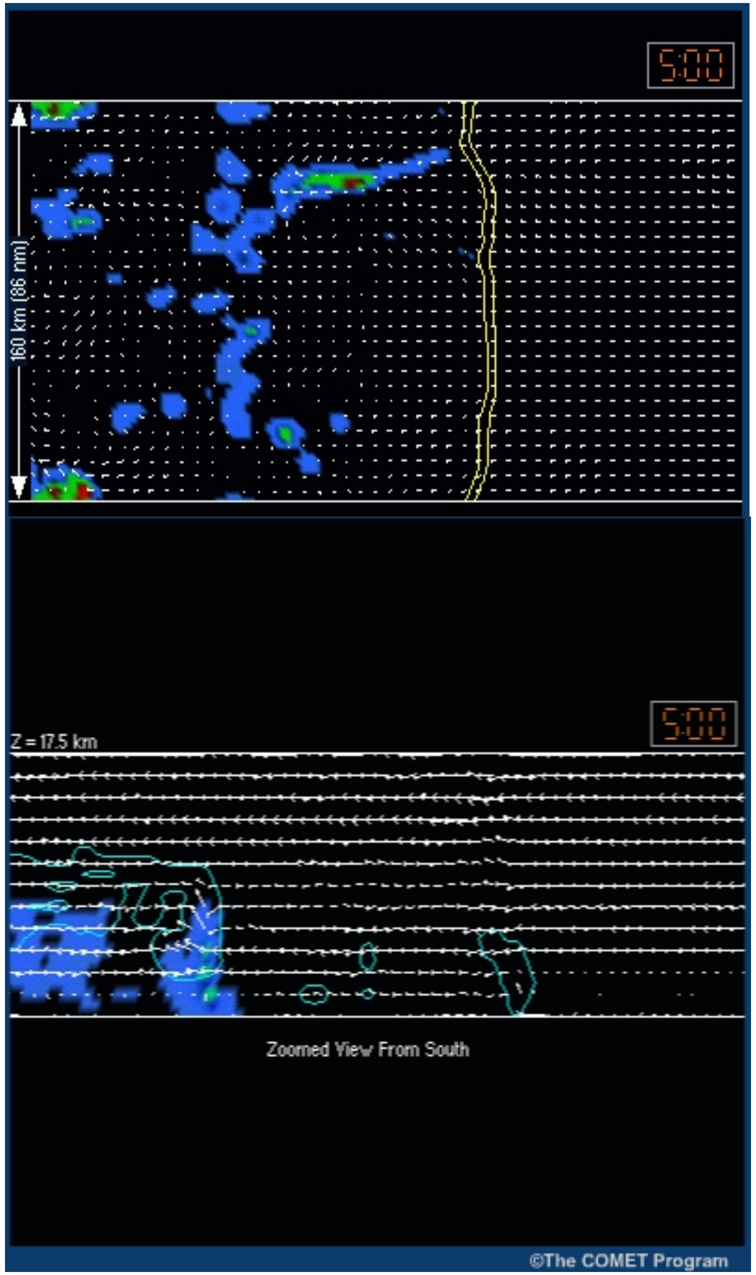
Line-parallel shear (E1)



Strong, shallow shear

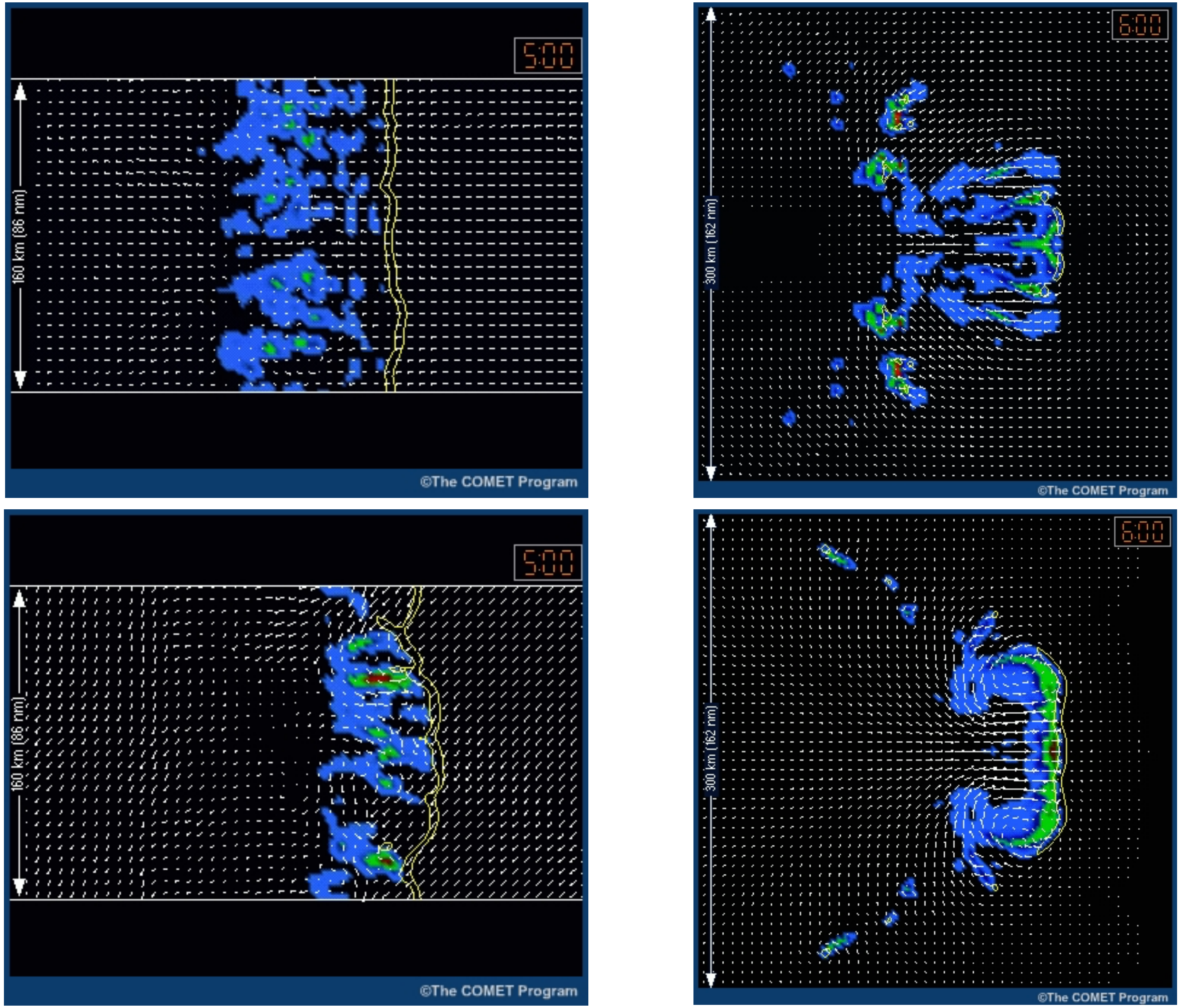



“Jet-like” shear profile



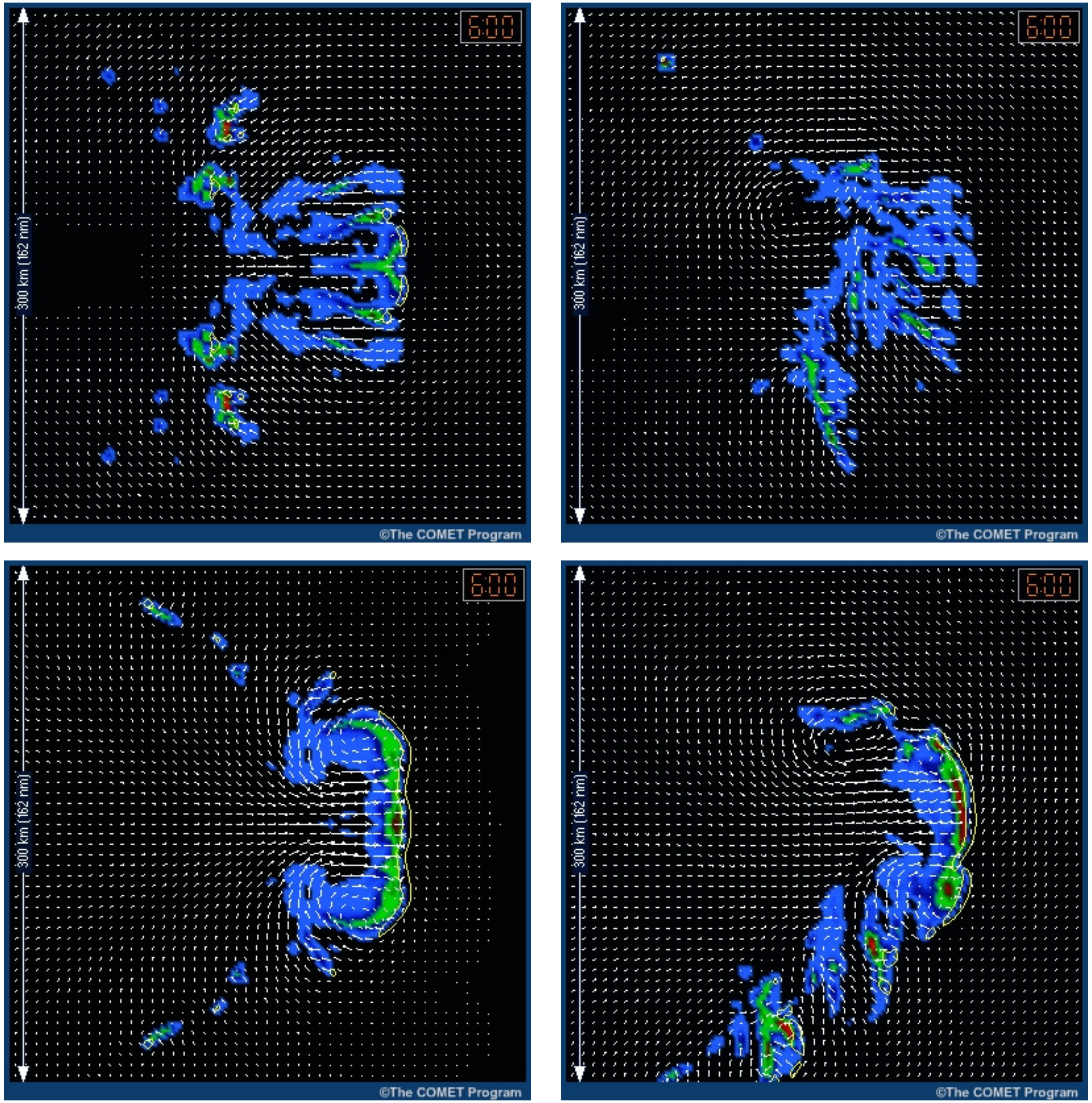
Quasi-2D

3D

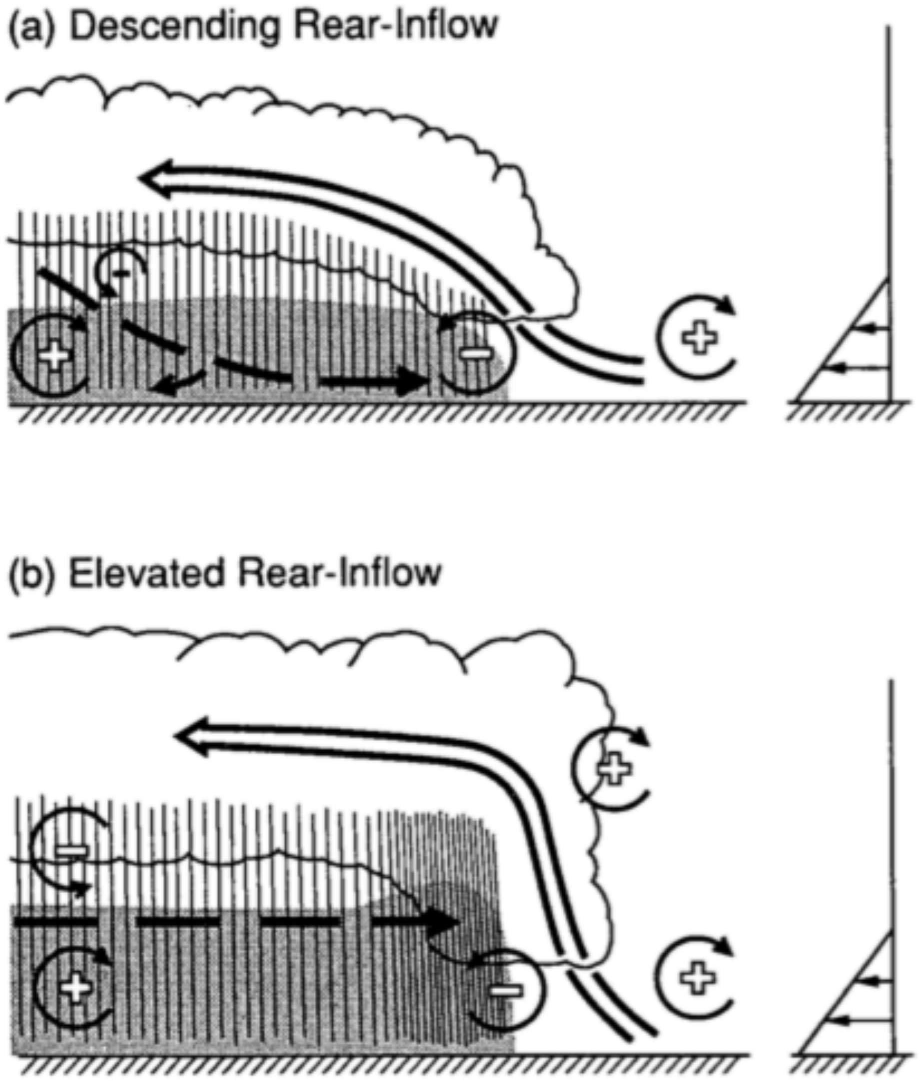


5:00
160 km (86 nm)
©The COMET Program
6:00
300 km (162 nm)
©The COMET Program
5:00
160 km (86 nm)
©The COMET Program
6:00
300 km (162 nm)
©The COMET Program

3D (A2) | 3D w/ Coriolis (A3)

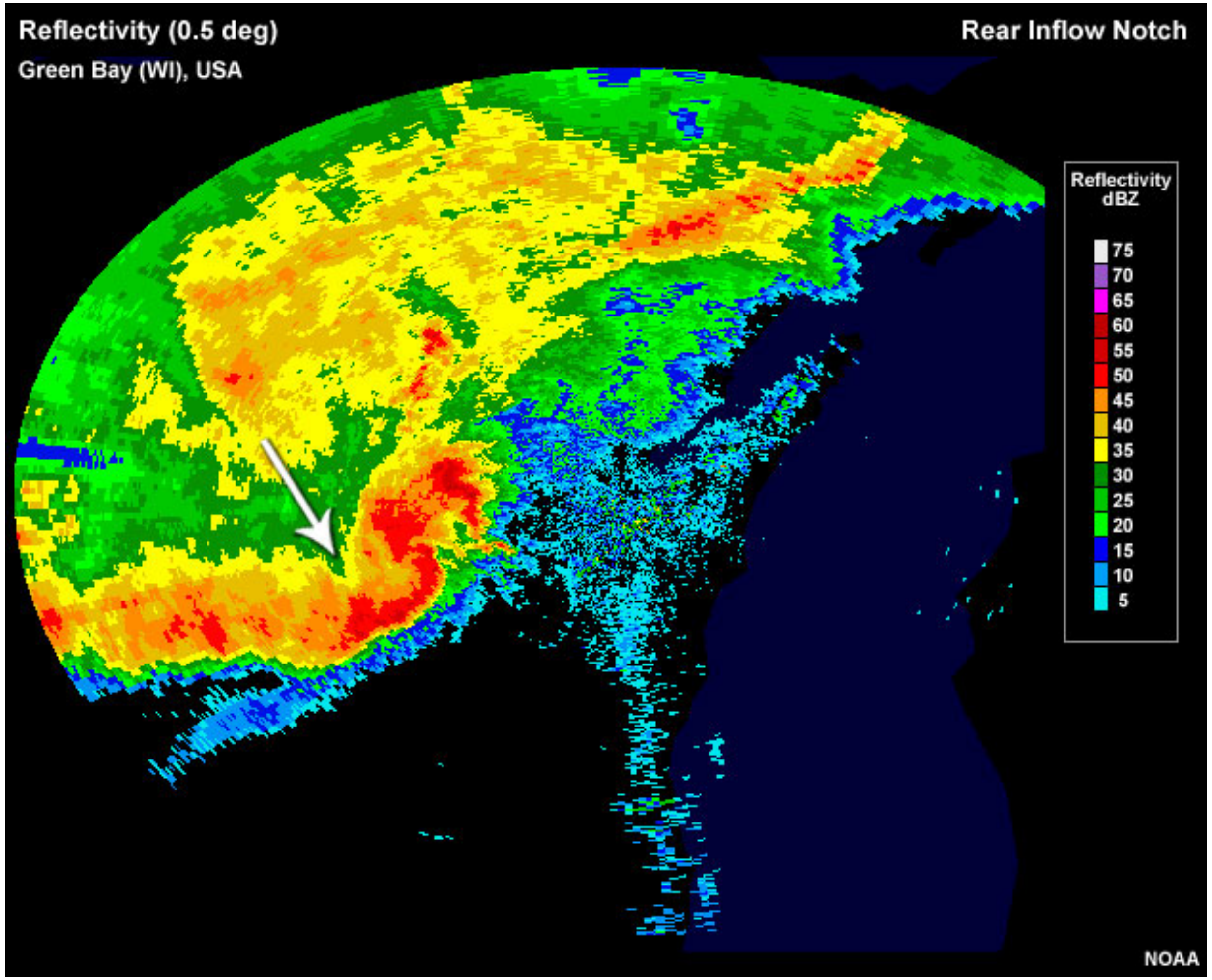


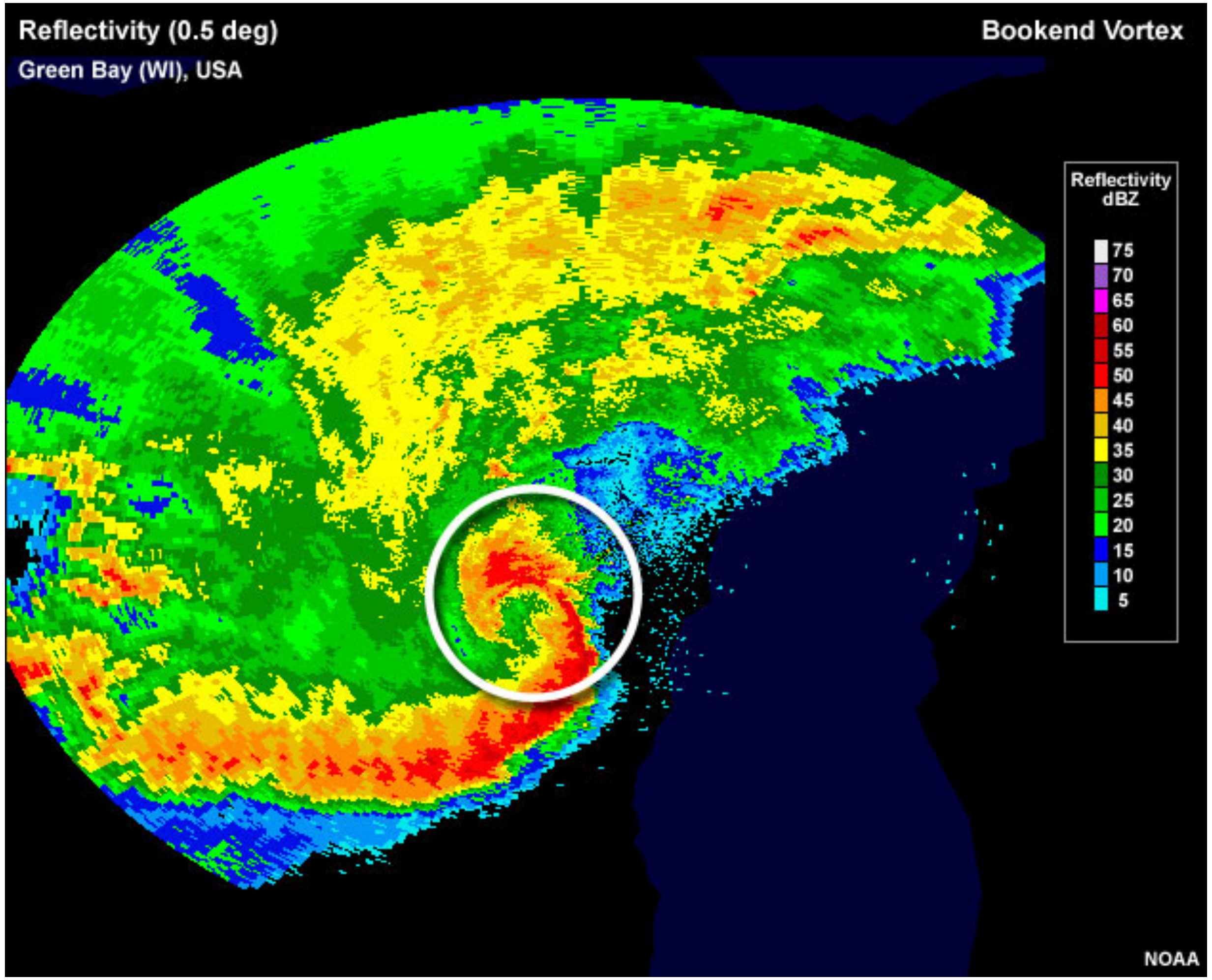
# Development of rear-inflow jet and bookend vortices



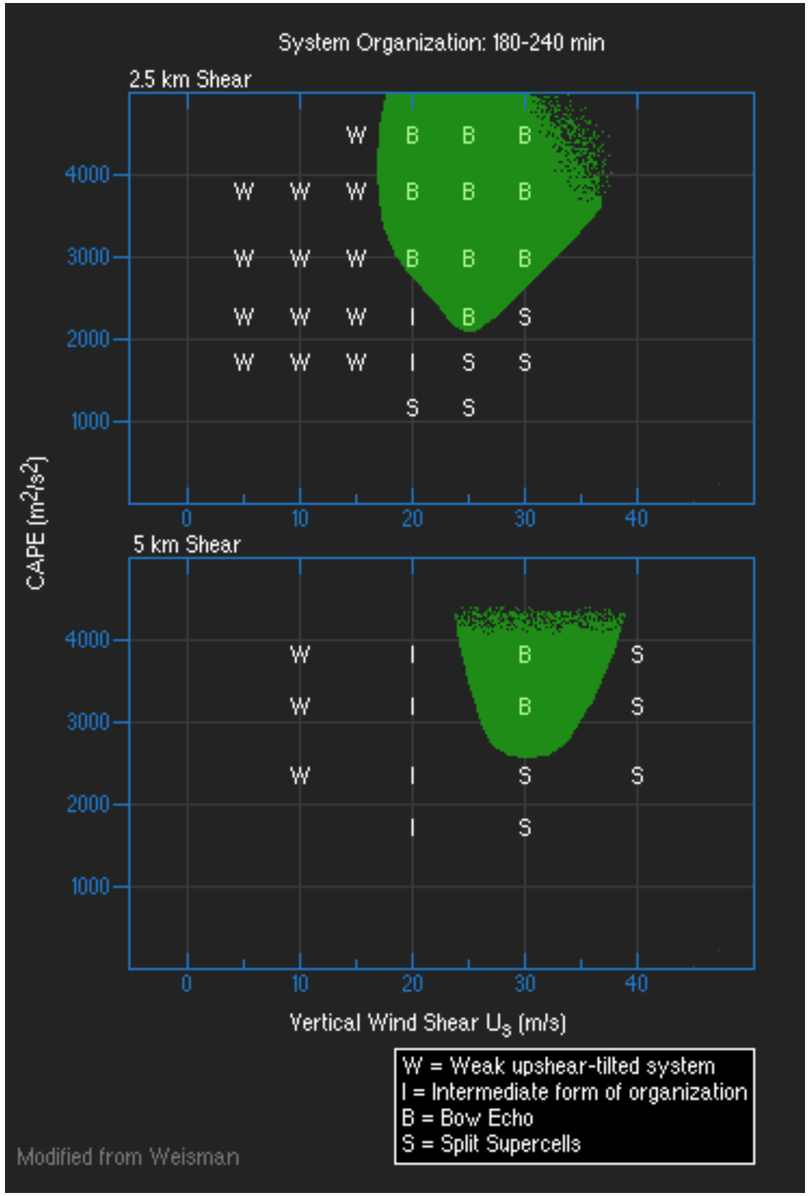

Weisman (1992) argued that a descending vs. elevated rear-inflow jet impacts the cold pool circulation, enhancing the ability to produce new convection in the case of an elevated rear-inflow jet, and weakening the system in the case of a descending rear-inflow jet.

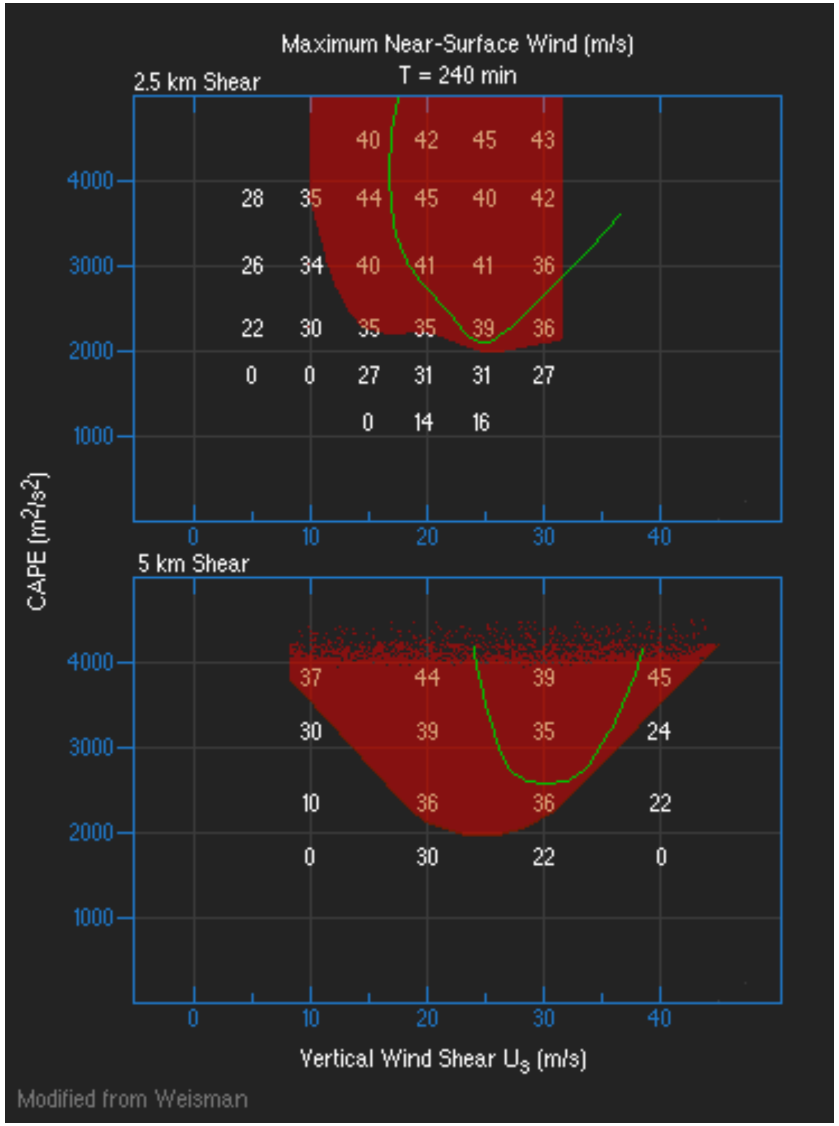
# Development of rear-inflow jet and bookend vortices



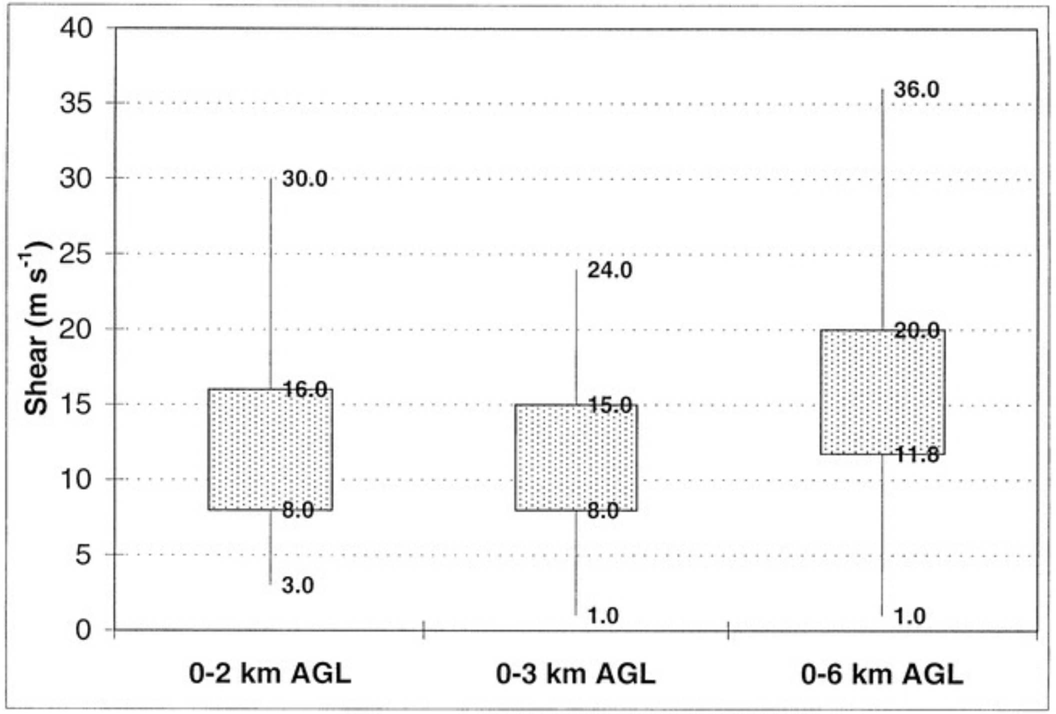



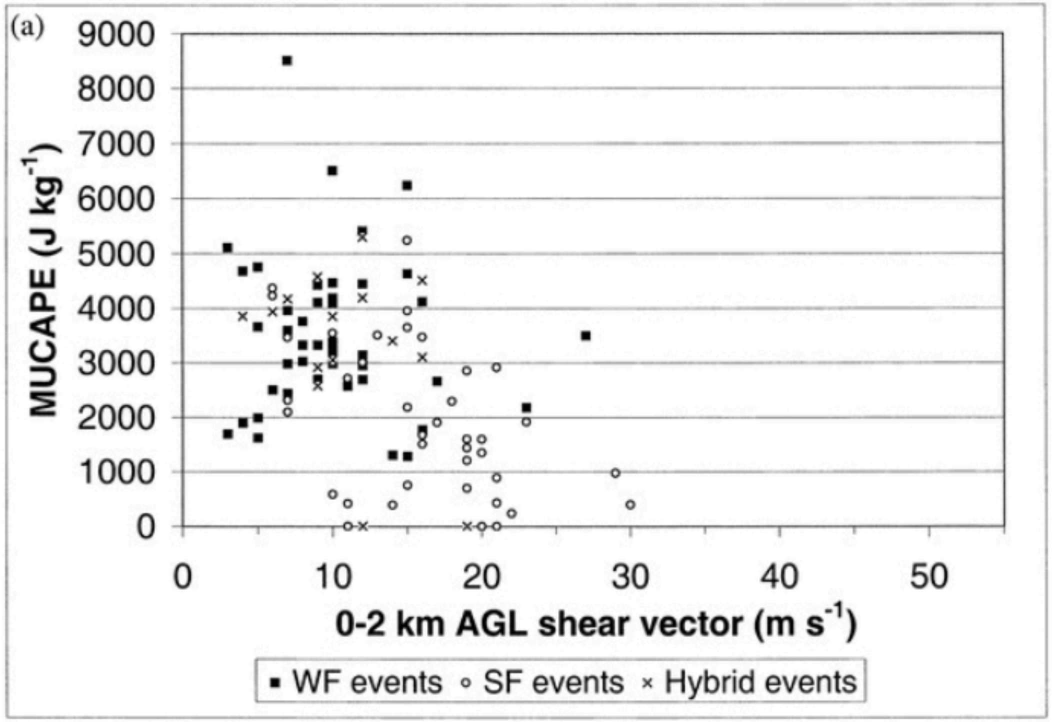
# Simulated Bow Echo Environments



# Observed Severe Bow Echo (Derecho) Environments

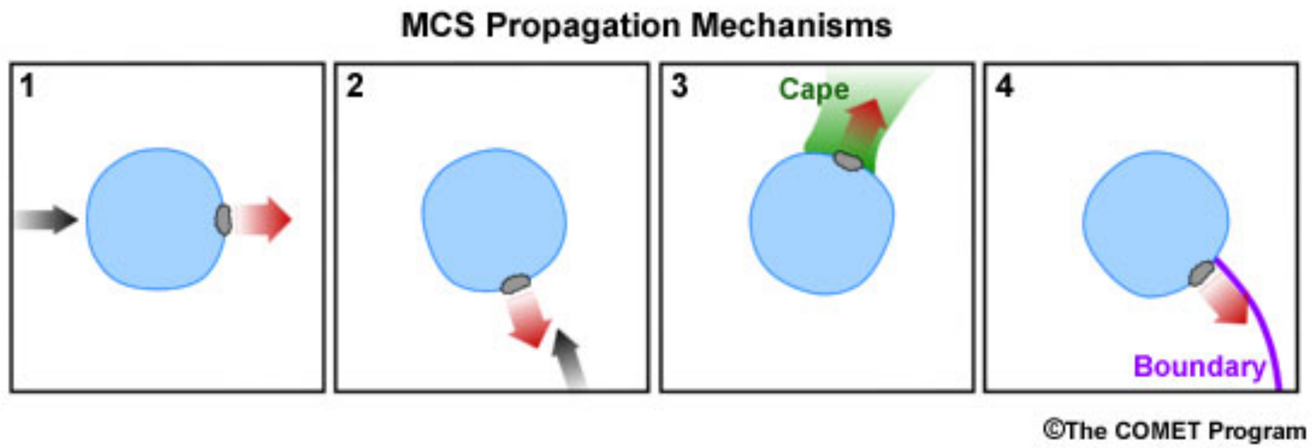



“However, a comparison between WF derecho and nonderecho MCSs implies that it is the **strength of the mean flow**, and its possible effects on speed of movement, that enhances the development of sustained severe wind gusts at the surface, given similar thermodynamic environments.”

*Evans and Doswell (2001)*

# MCS Propagation Mechanisms

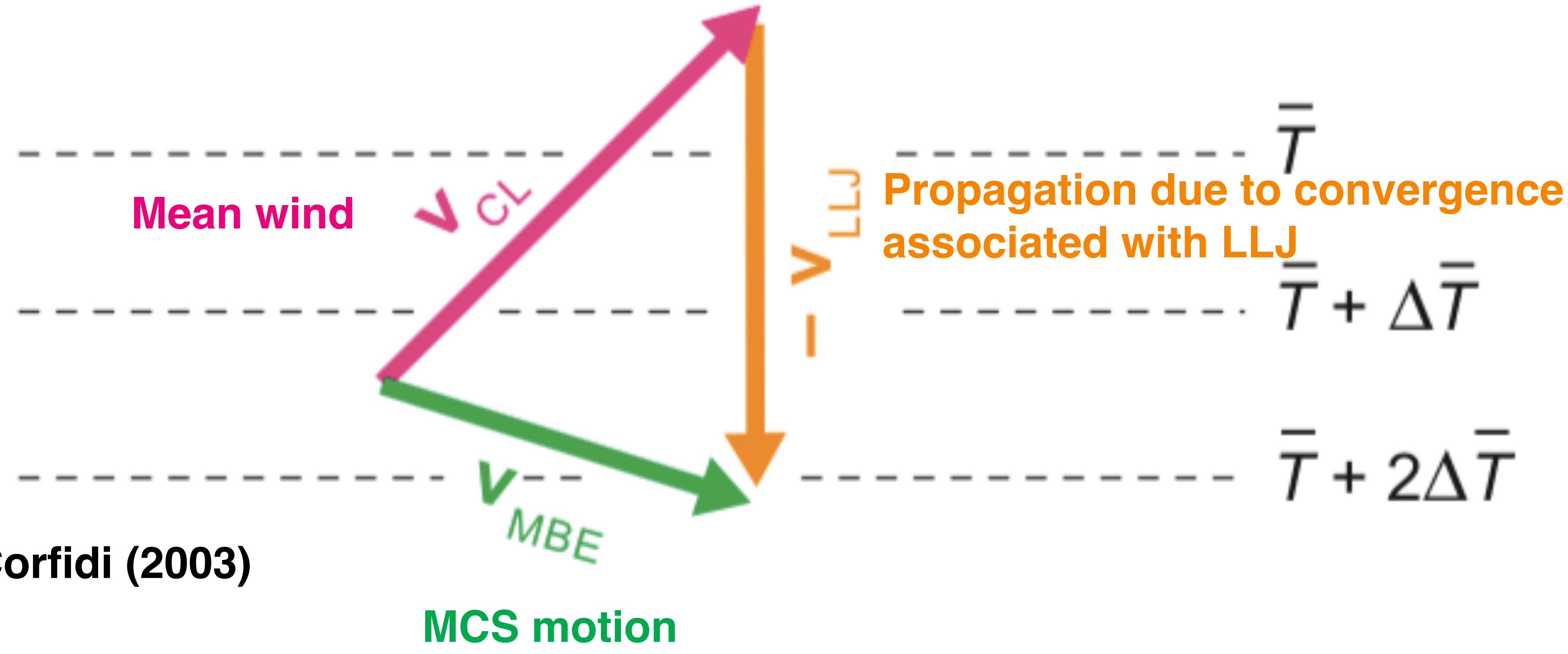



MCS motion often proceeds in direction where convection is favored to develop (**propagation**). Depending on the environment, this can occur in several ways:

1) Downshear propagation – (cold pool/shear balance)
2) Propagation due to low-level convergence (strongest headwind; e.g., low-level jet)
3) Propagation into an axis of surface-based instability
4) Propagation due to boundary interactions

# MCS Propagation Mechanisms

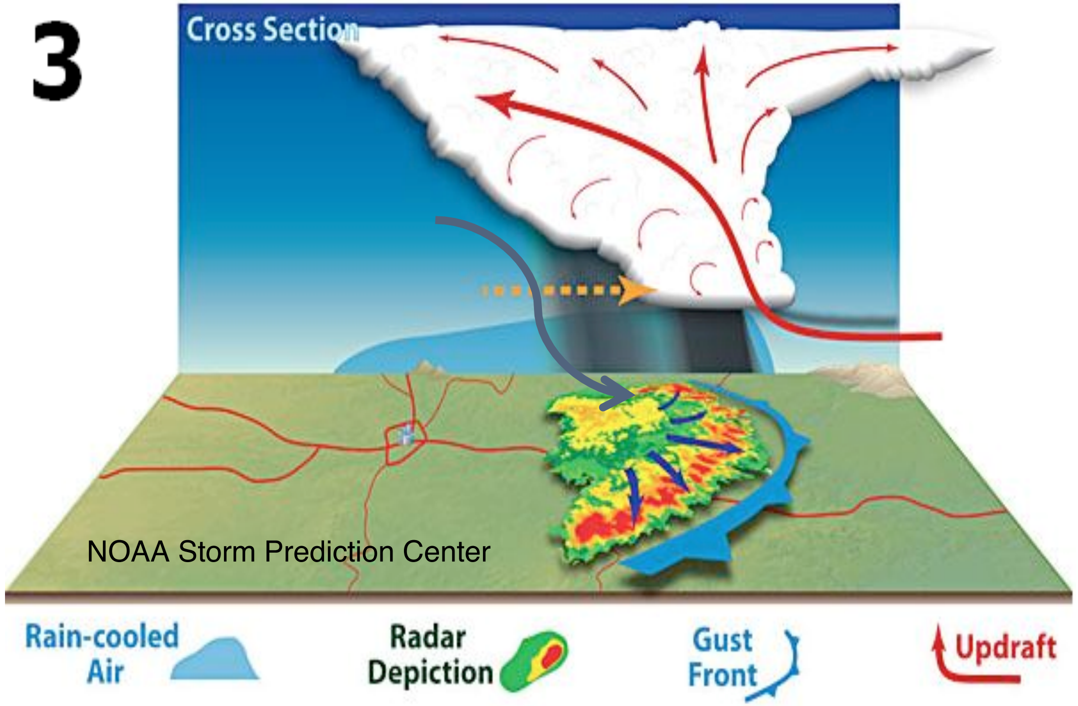
Many MCS are initiated by lifting over a synoptic-scale boundary by a low-level jet. In these cases, a good estimate of the MCS motion is:




Corfidi (2003)

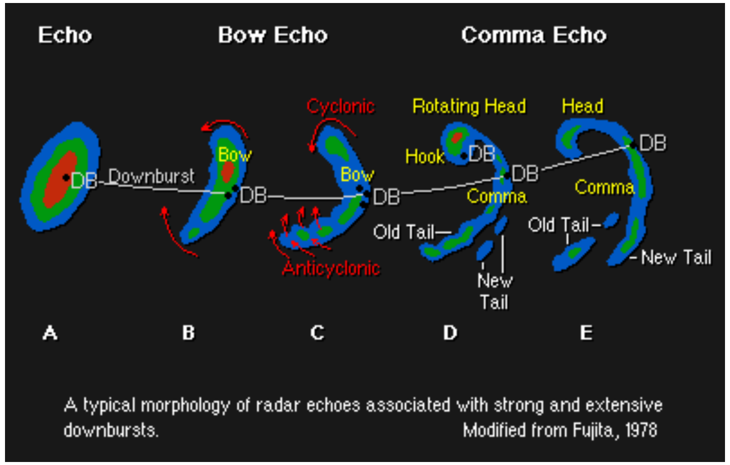
# Derechos: Severe Lines of Thunderstorms
# Hinrichs (1888); Johns and Hirt (1987)

- Straight-line winds
- Long swaths (> 400 km), long duration (> 6 h)
- Rapid movement: 20-30 m/s




**See Corfidi et al. BAMS, 2016**

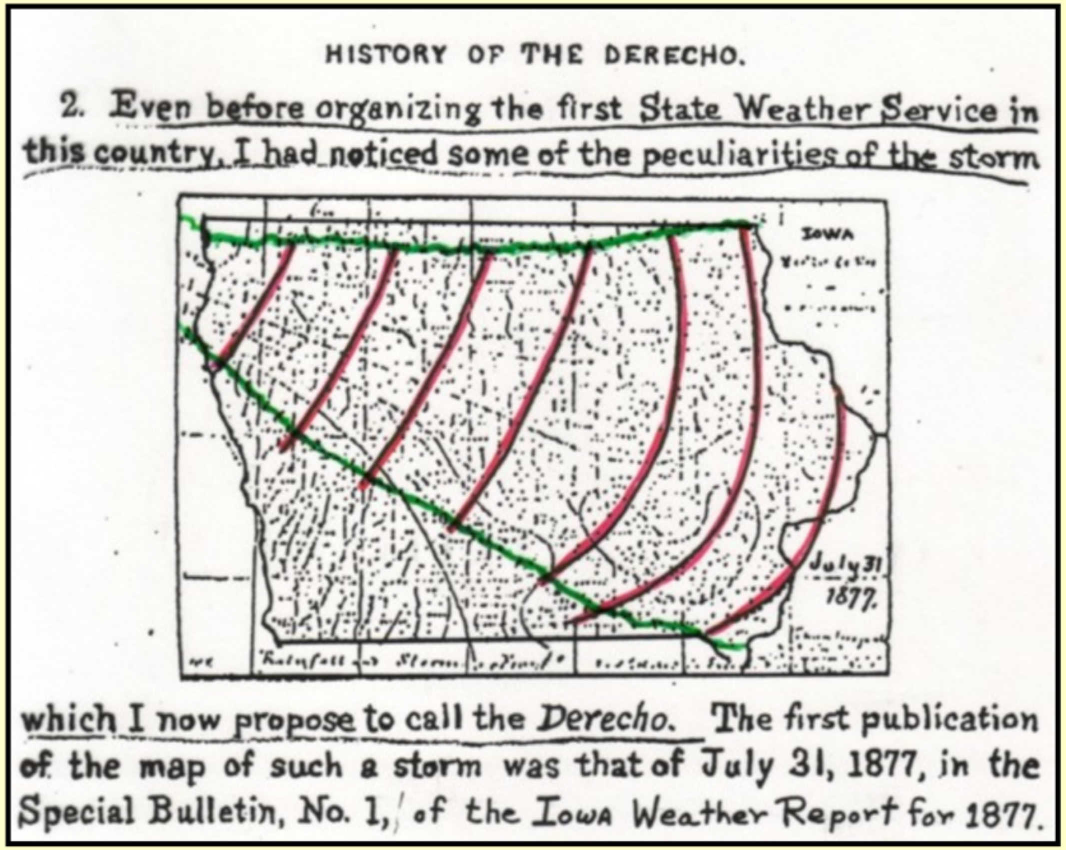
A key structural component is often a bow echoes (e.g., Fujita)




A typical morphology of radar echoes associated with strong and extensive downbursts. Modified from Fujita, 1978

# THE ORIGIN OF THE TERM "DERECHO"

**The term "derecho" was defined by Dr. Gustavus Hinrichs in a paper published in the *American Meteorological Journal* in 1888. The figure below shows part of a page from that paper, illustrating the path taken by a derecho over Iowa on July 31, 1877.**



HISTORY OF THE DERECHO.

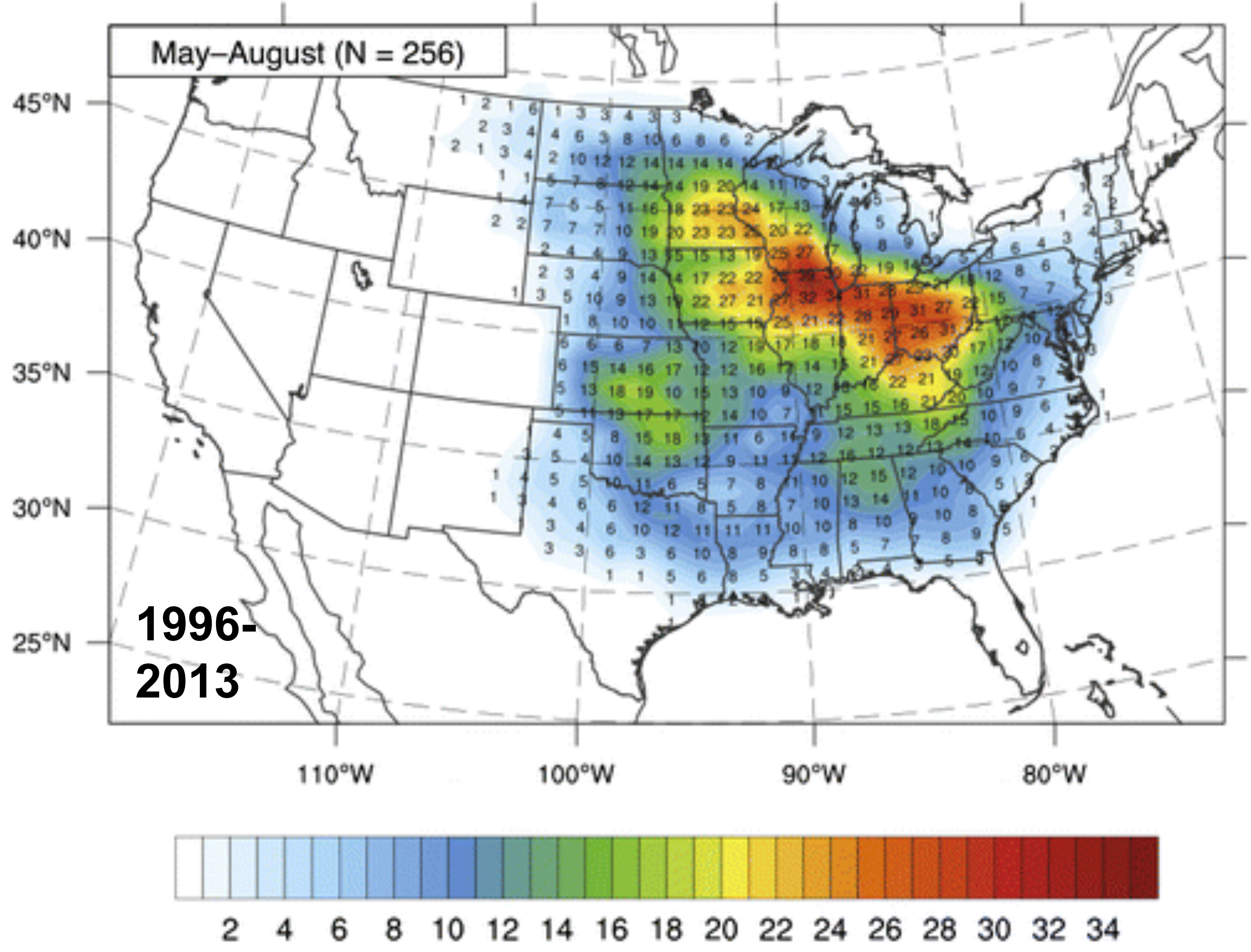
2. Even before organizing the first State Weather Service in this country, I had noticed some of the peculiarities of the storm

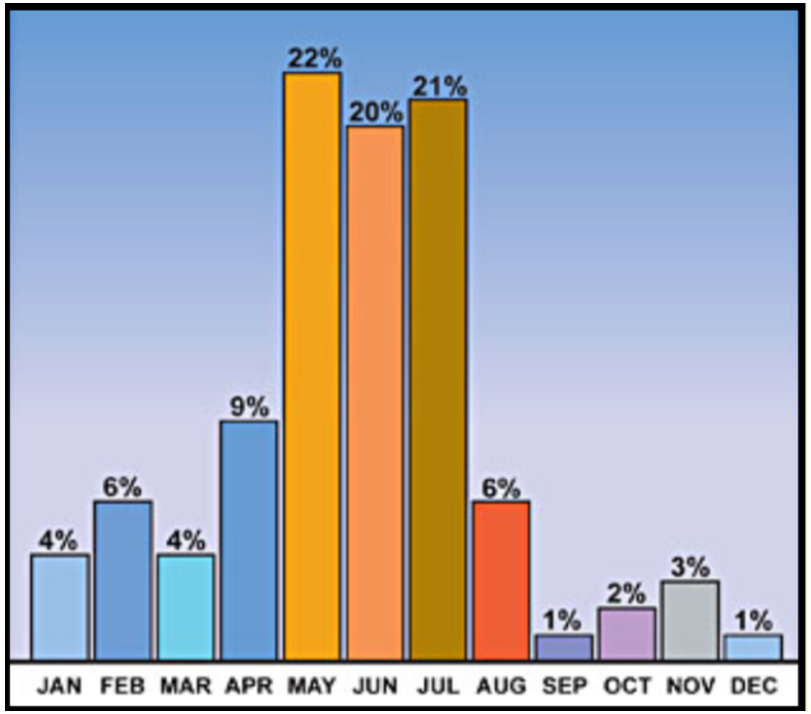


which I now propose to call the *Derecho*. The first publication of the map of such a storm was that of July 31, 1877, in the Special Bulletin, No. 1, of the Iowa Weather Report for 1877.

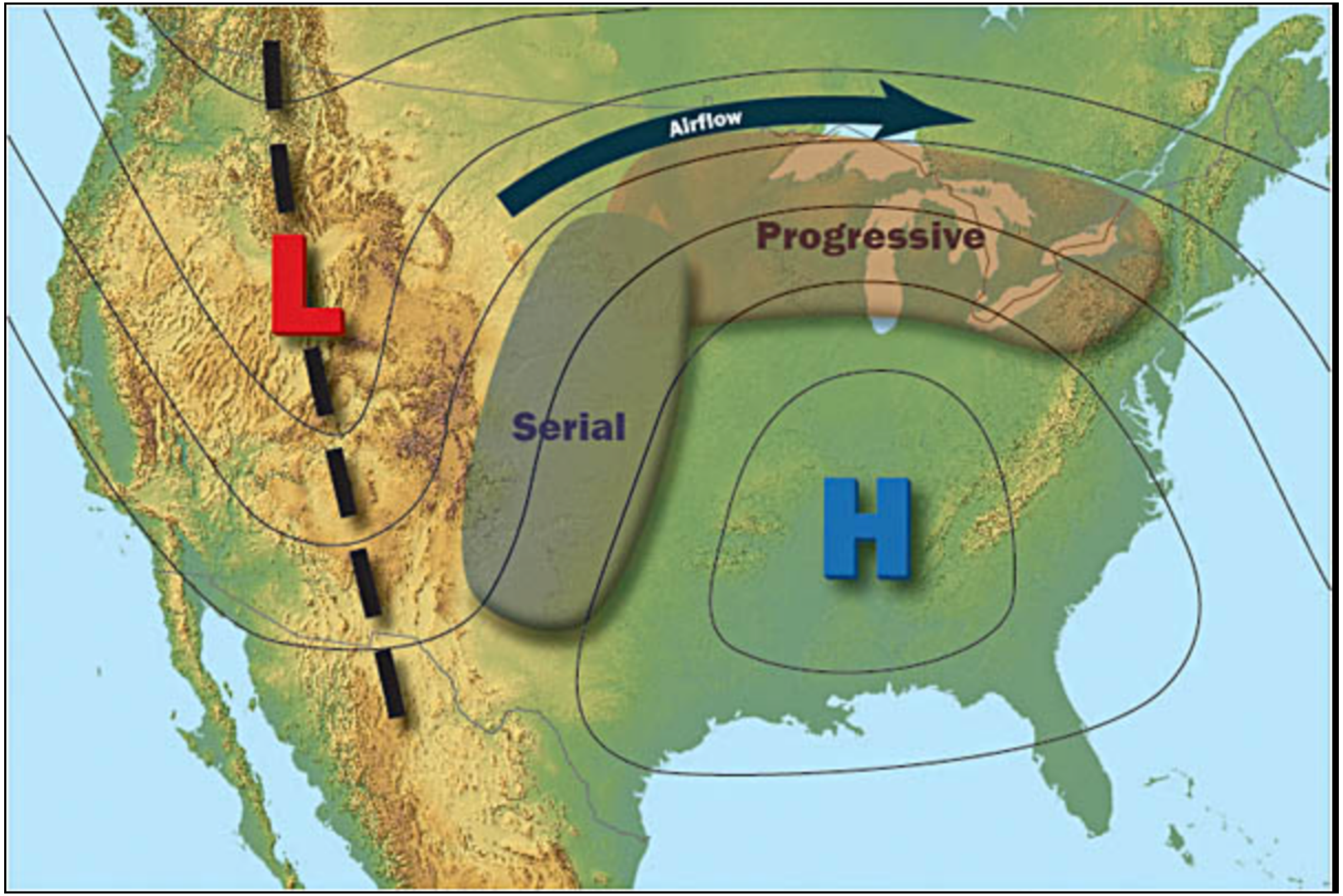
***Gust front "shelf cloud" (or "arcus") on the leading edge of a derecho-producing convective system. The photo was taken on the evening of July 10, 2008 in Hampshire, Illinois as the storm neared the Chicago metropolitan area. The derecho had formed around noon in southern Minnesota. (Courtesy of Brittney Misialek)***

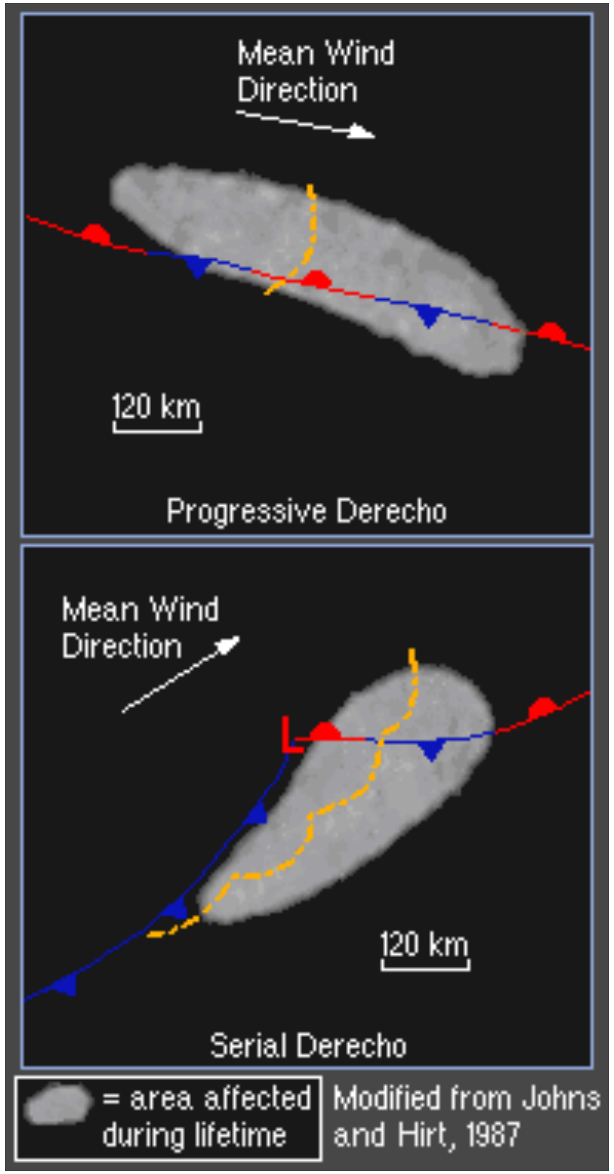
# Derecho Climatology (Guastini and Bosart 2016)



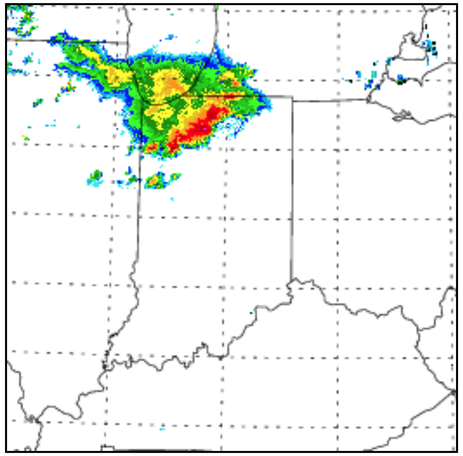
# Types of Derechos



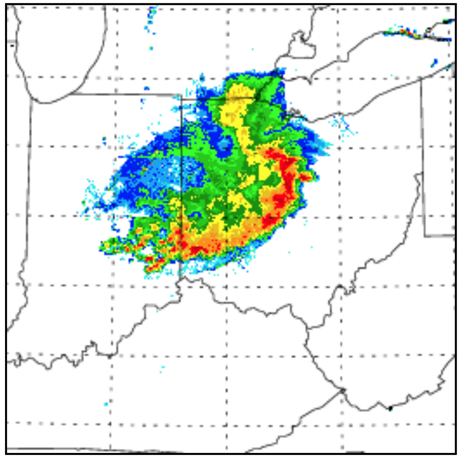



# 29 June 2012 Derecho

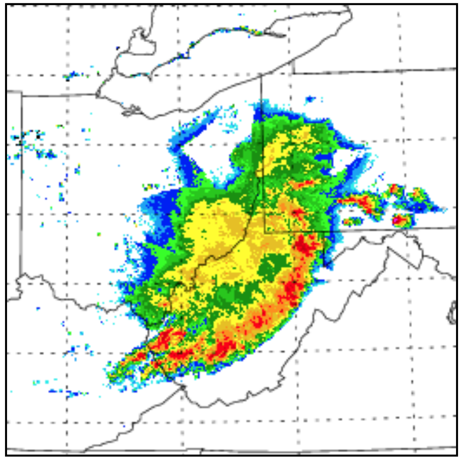
18 UTC



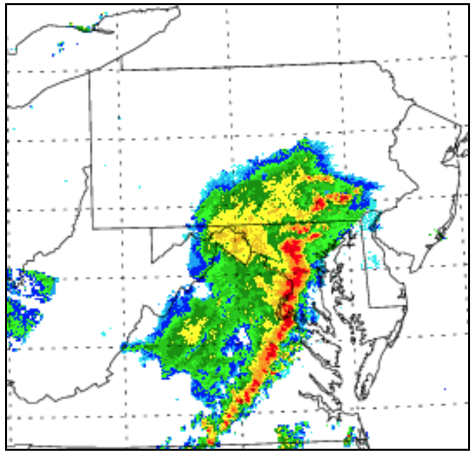
21 UTC



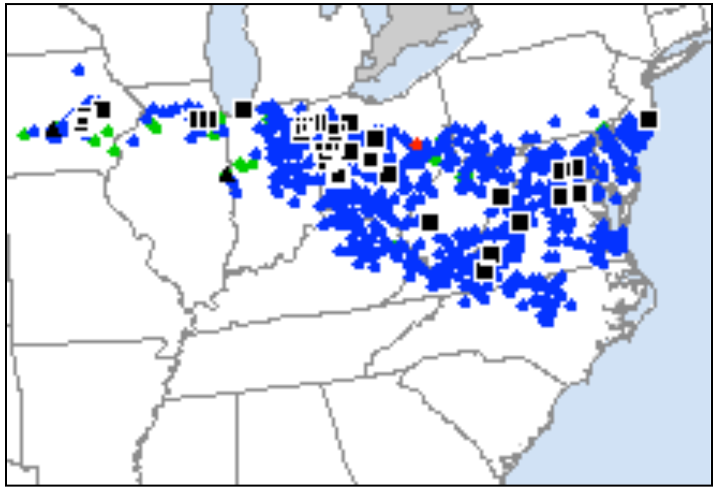
00 UTC



03 UTC



SPC Storm Reports



■ High Wind Report (65KT +)
▲ Large Hail Report (2" dia. +)

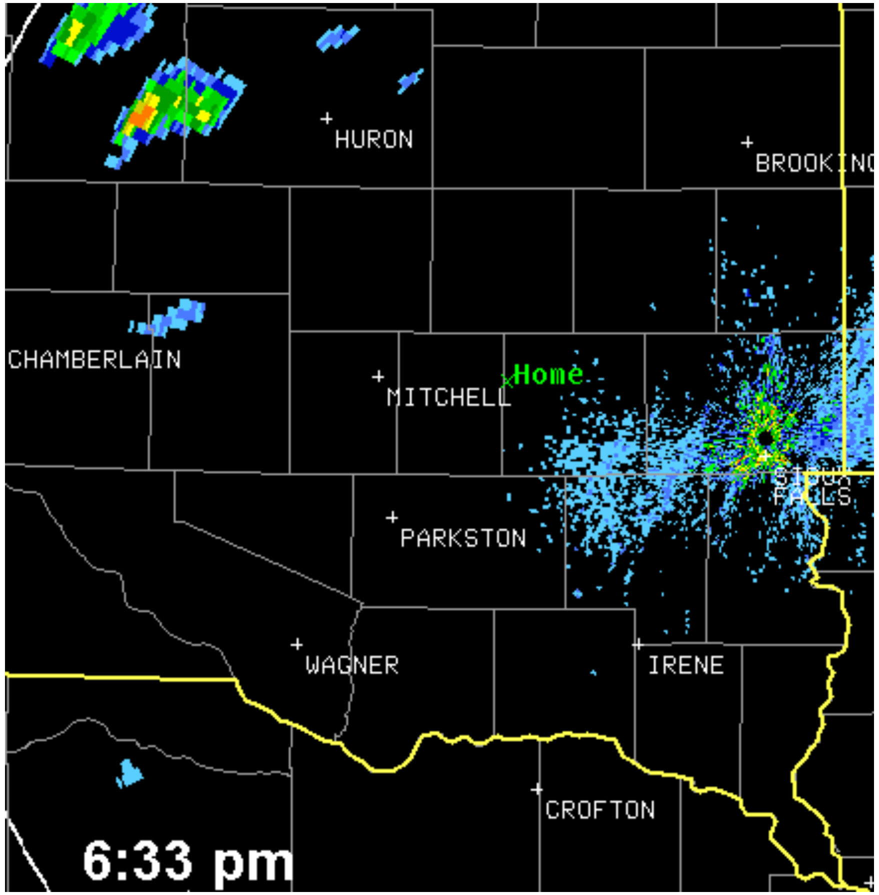
TORNADO REPORTS.. (2)
WIND REPORTS/HI..... (984/36)
HAIL REPORTS/LG..... (57/5)
TOTAL REPORTS....... (1043)

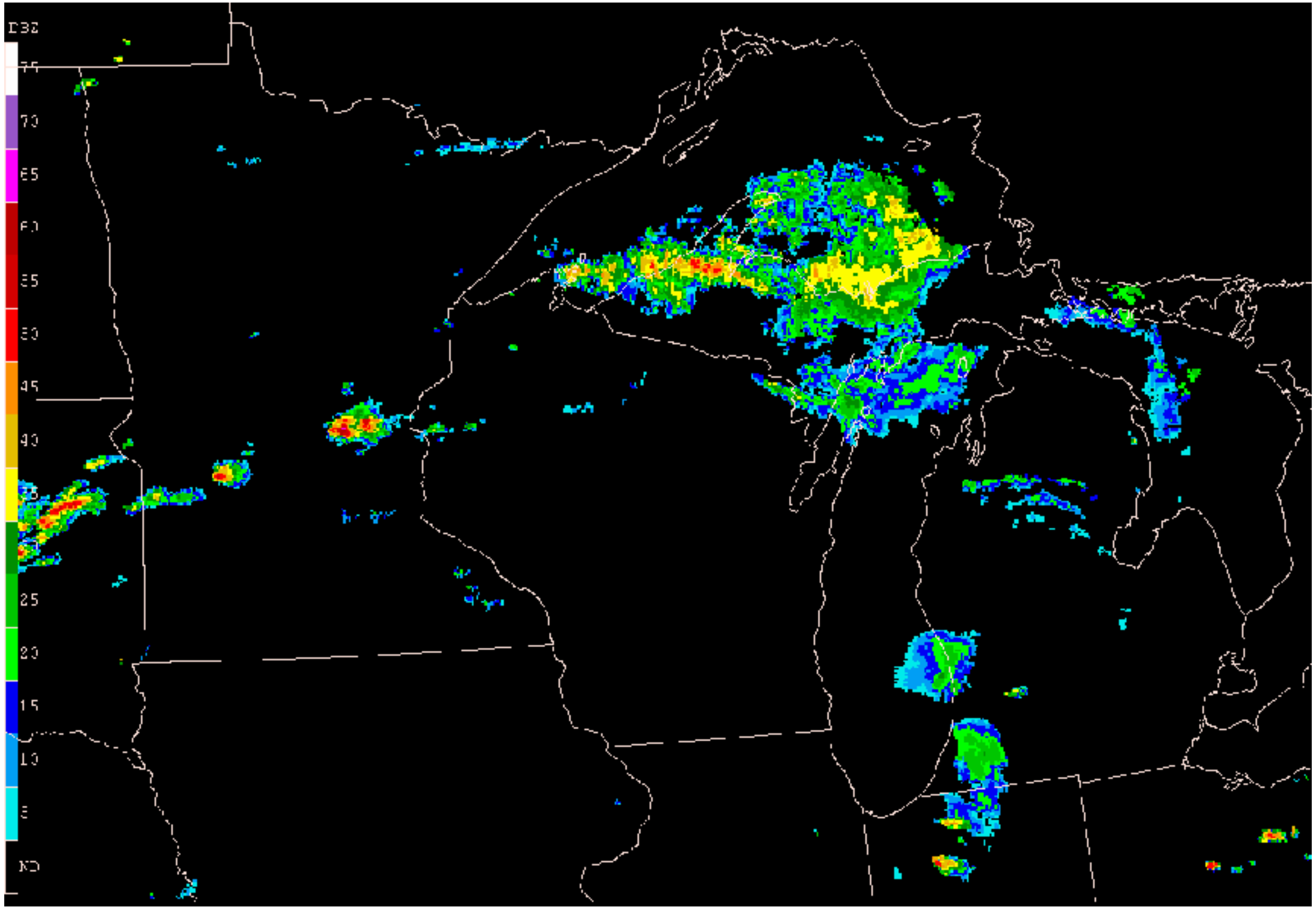
National Weather Service
Storm Prediction Center
Norman, Oklahoma

# "The Southern Great Lakes Derecho of 1998"

30-31 May 1998

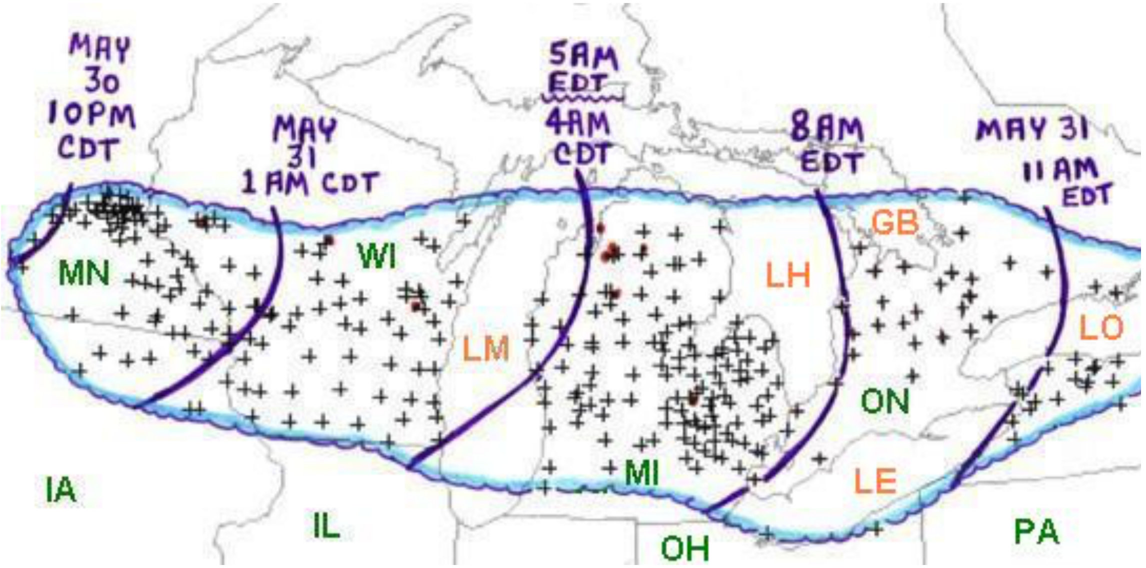
**Initial supercells > squall line**

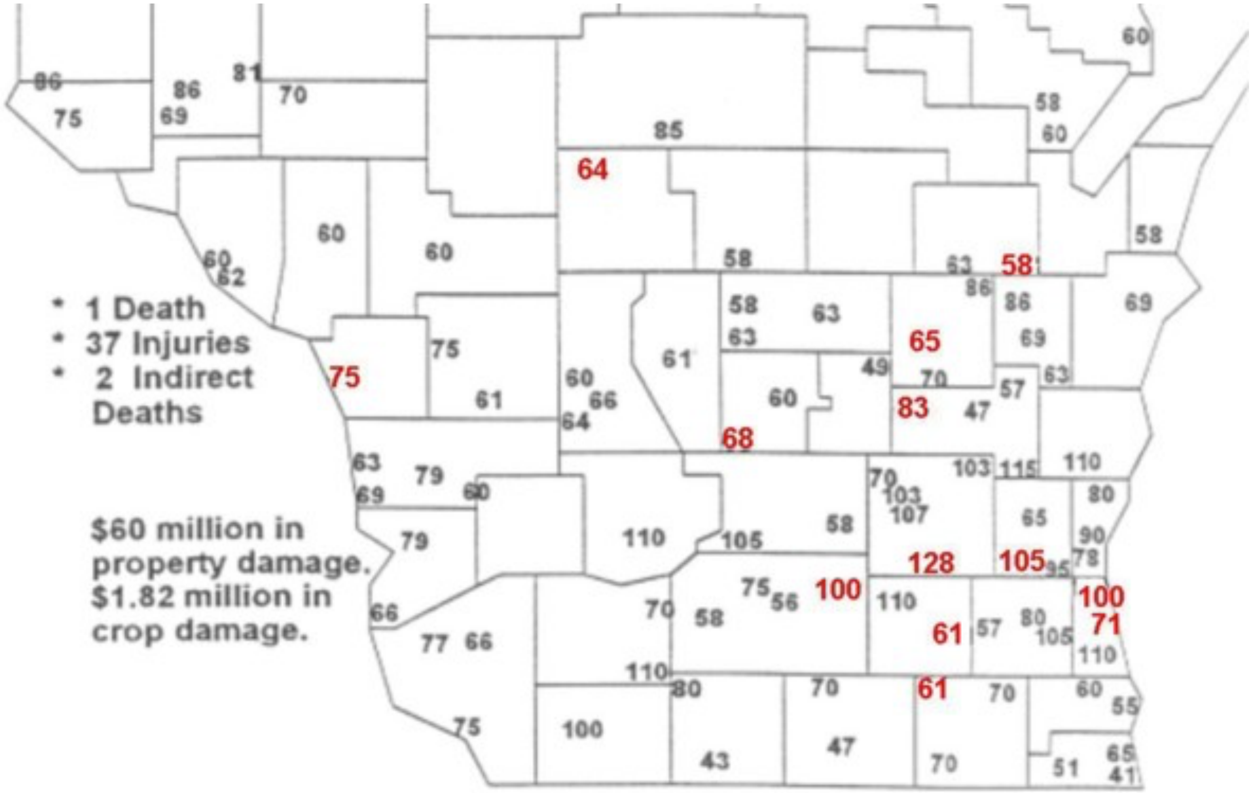


# "The Southern Great Lakes Derecho of 1998”

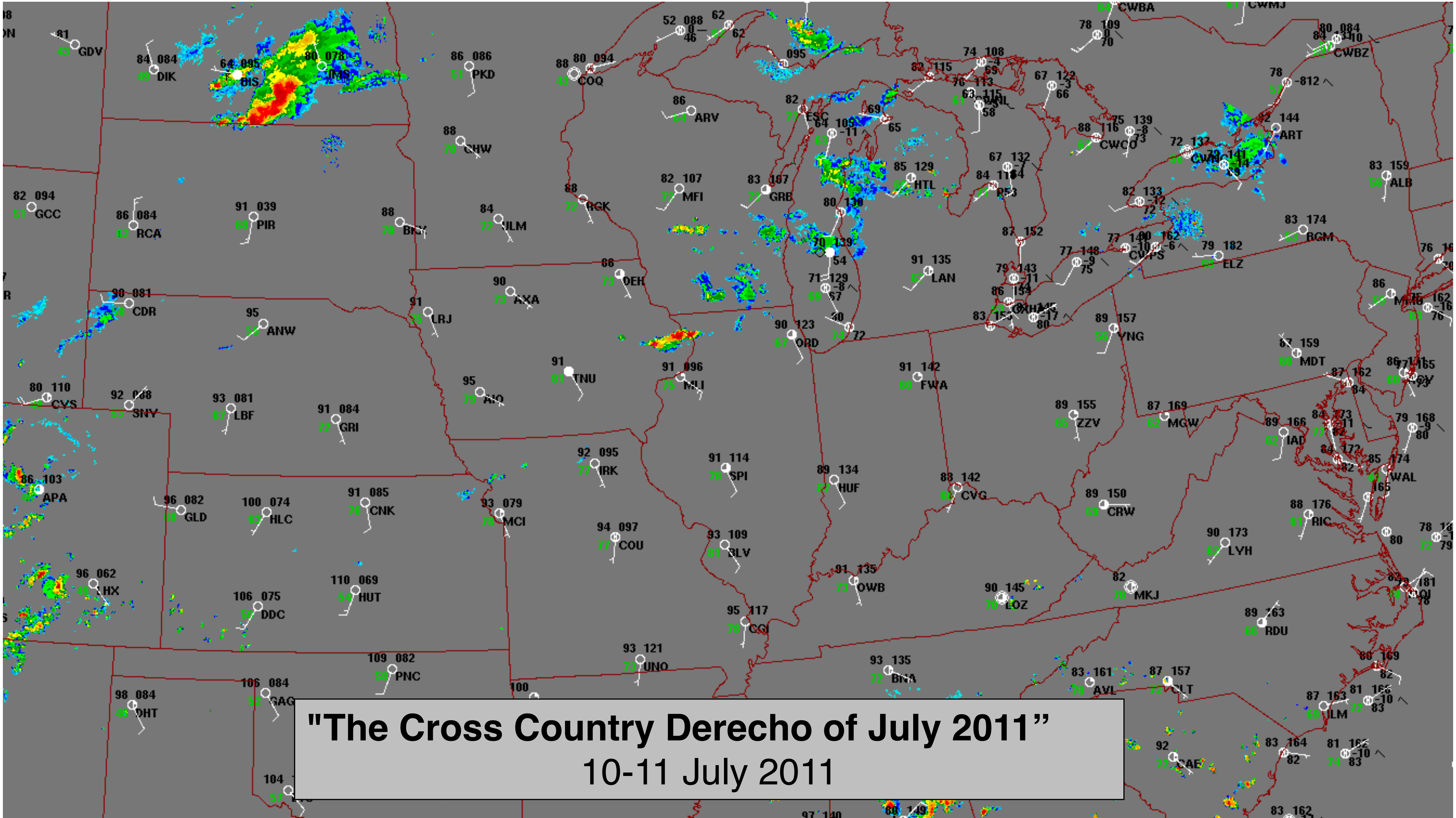
30-31 May 1998




**+ -- wind damage/severe gusts**
**red dot - tornadoes**

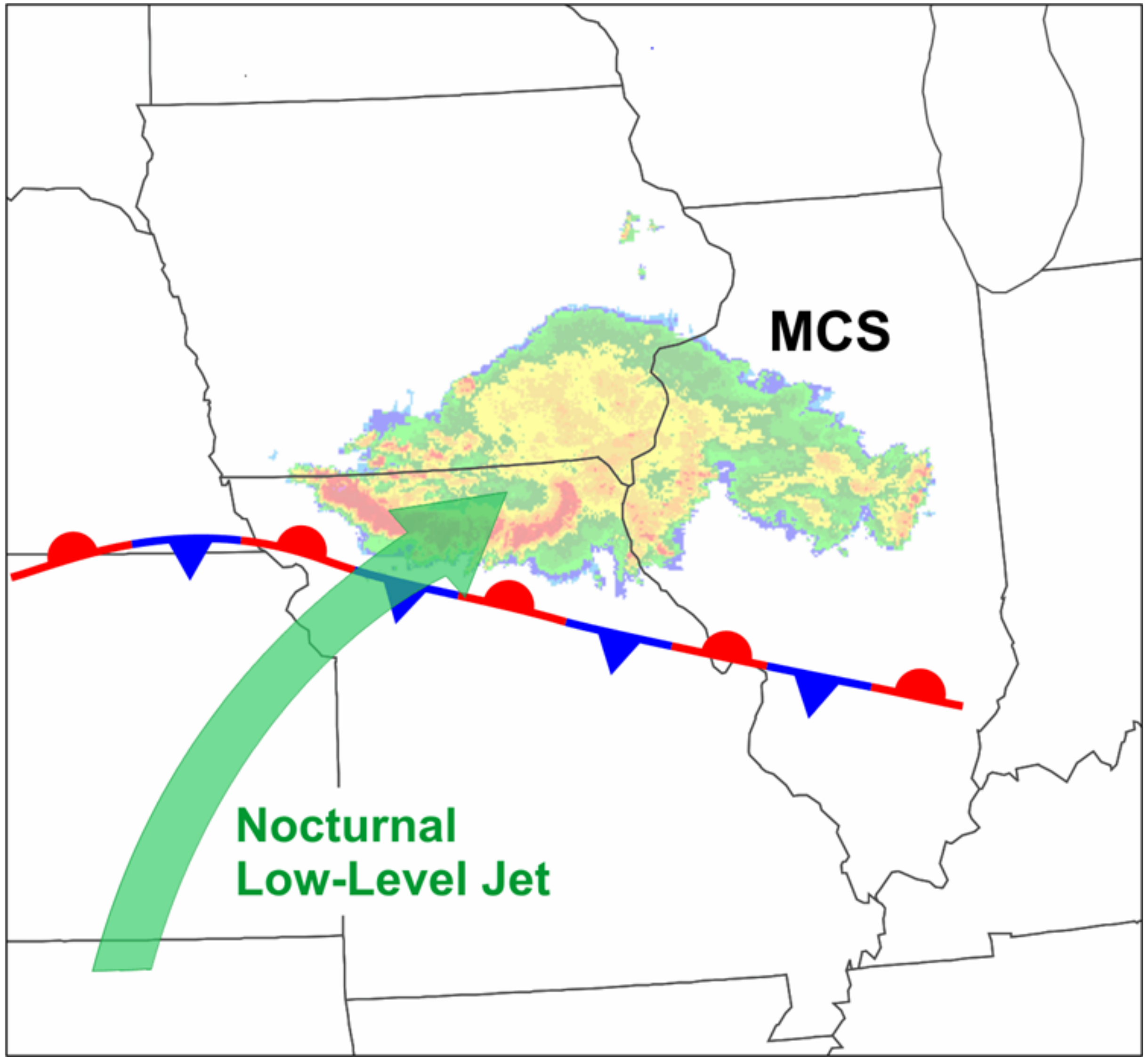
http://www.spc.noaa.gov/misc/AbtDerechos/



# "The Cross Country Derecho of July 2011"

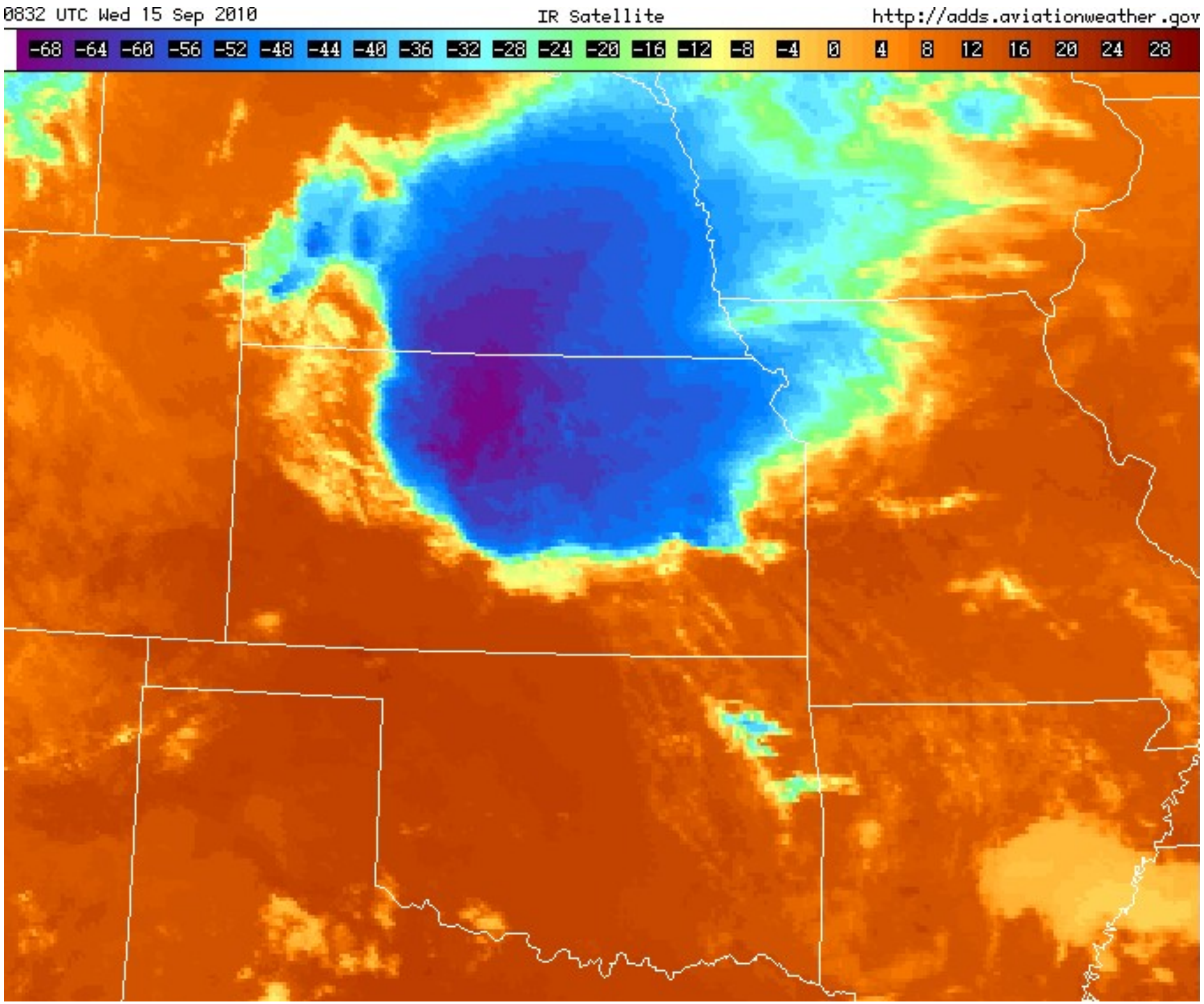
10-11 July 2011

# Conceptual Model of Elevated MCS

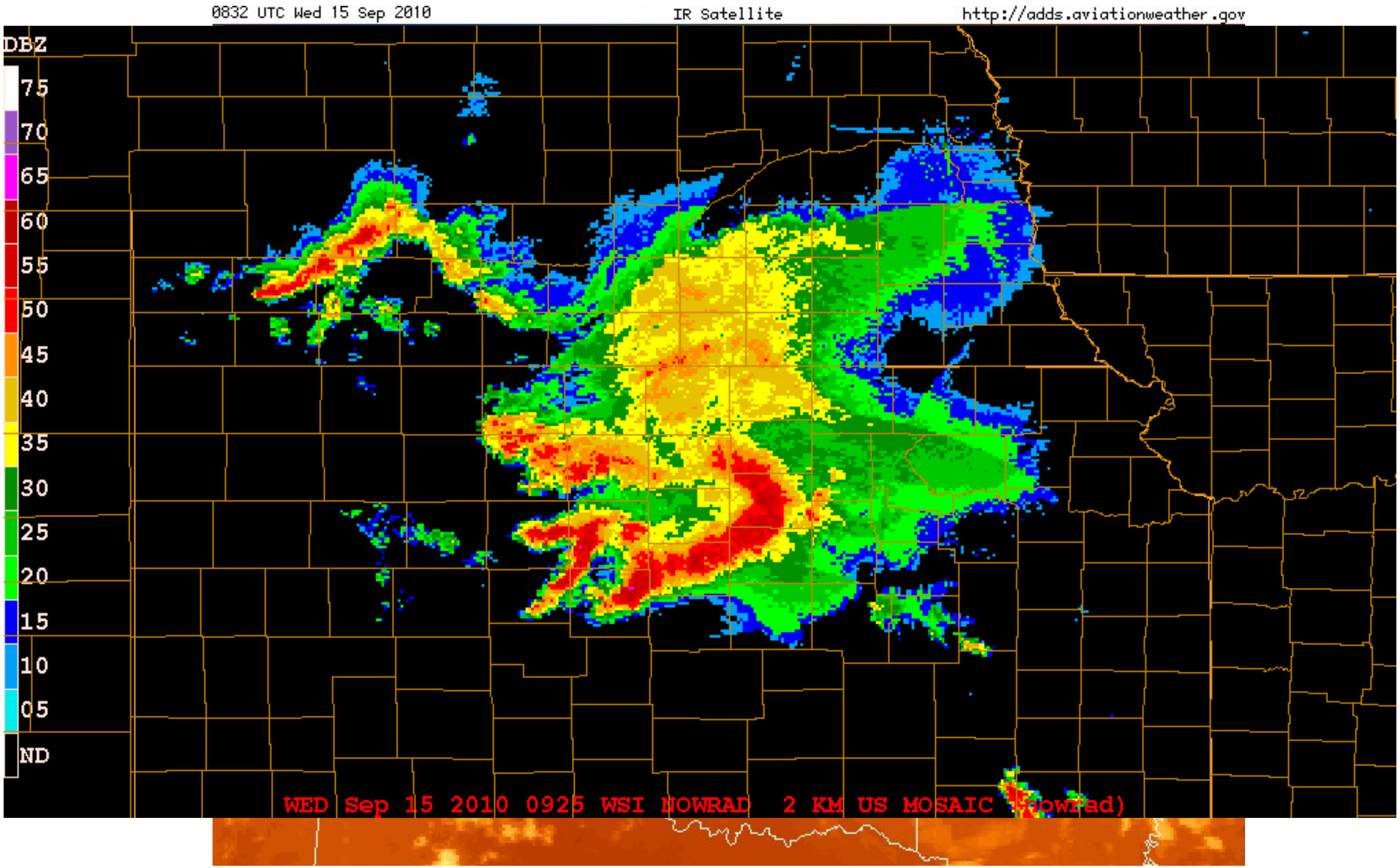



These often occur overnight within the central U.S.

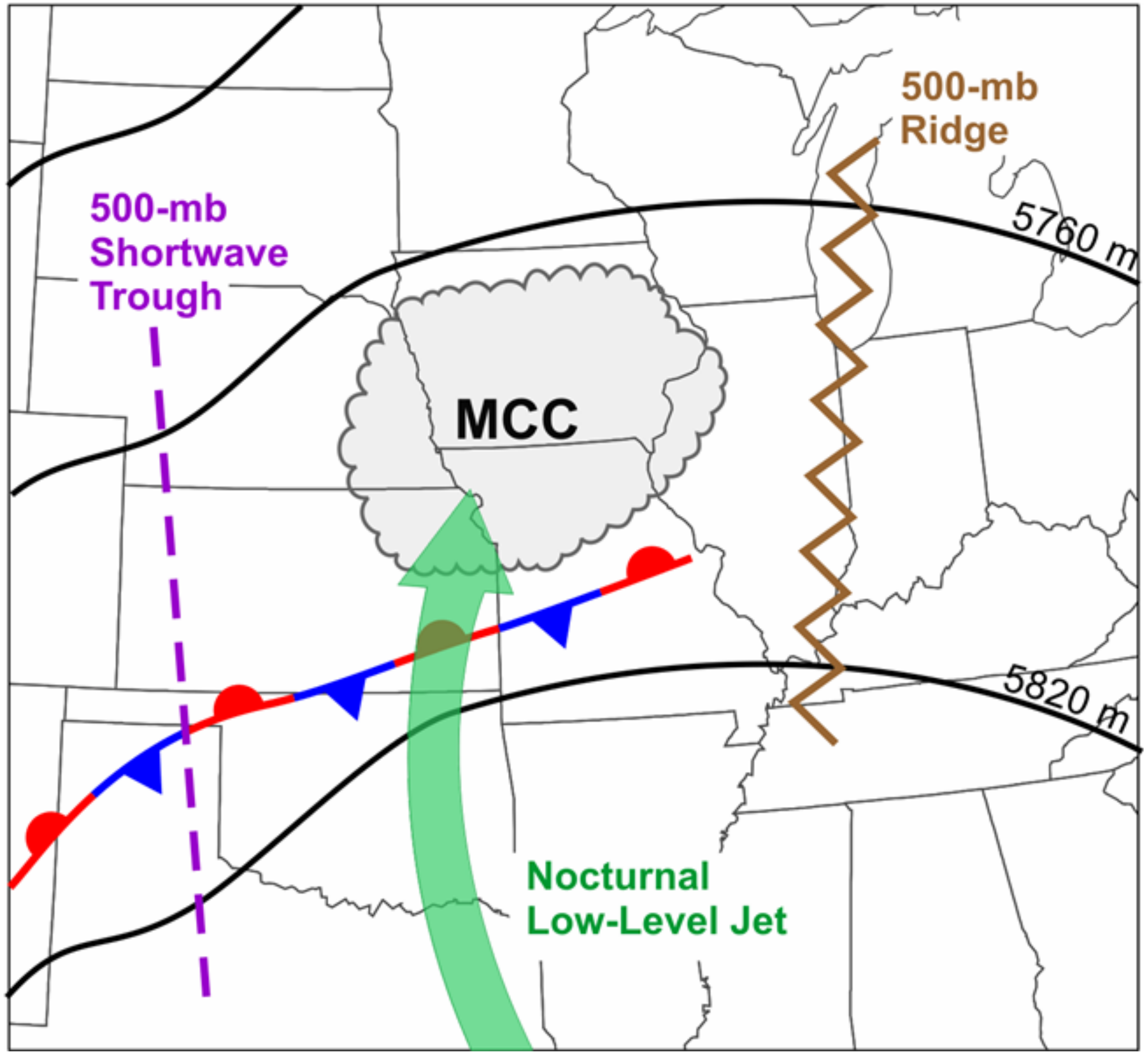
# In some situations, these can become MCCs…



# In some situations, these can become MCCs…



# MCC Favored Locations



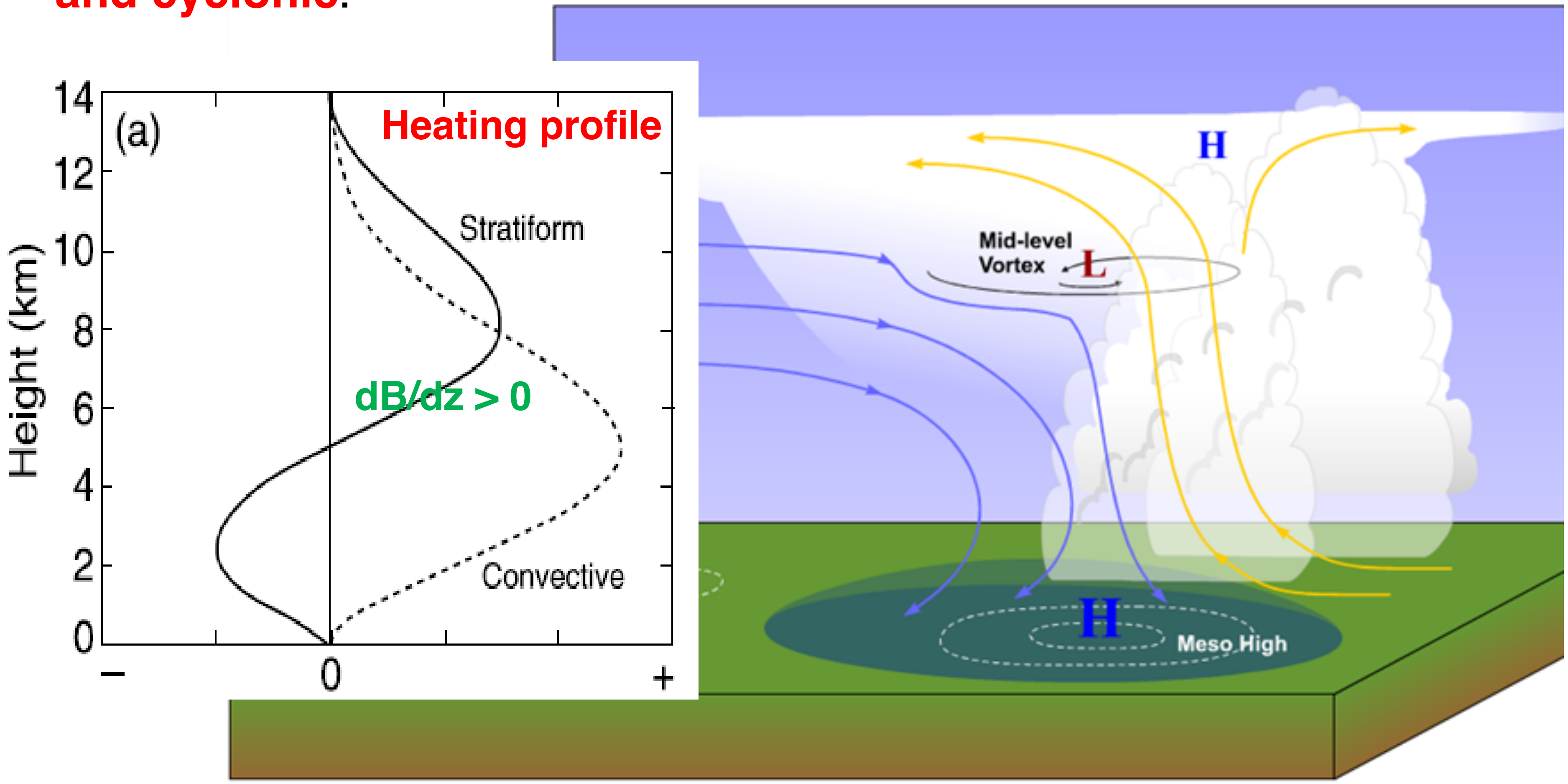
# Physical definition of a MCC

TABLE 1. Mesoscale convective complex (MCC) definition, physical characteristics.

| | |
|---|---|
| Size: | A. Cloud shield with IR temperature $\leqslant -32°C$, must have an area $\geqslant 100\,000\ km^2$<br>B. Interior cold cloud region with temperature $\leqslant -52°C$, must have an area $\geqslant 50\,000\ km^2$ |
| Initiate: | Size definitions A and B are first satisfied |
| Duration: | Size definitions A and B must be met for a period $\geqslant 6$ h |
| Maximum extent | Contiguous cold cloud shield (IR temperature $\leqslant -32°C$) reaches maximum size |
| Shape: | Eccentricity (minor axis/major axis) $\geqslant 0.7$ at time of maximum extent |
| Terminate: | Size definitions A and B no longer satisfied |

Recall that **p’** is proportional to **dB/dz** (low pressure found where dB/dz > 0 and high pressure found where dB/dz < 0).

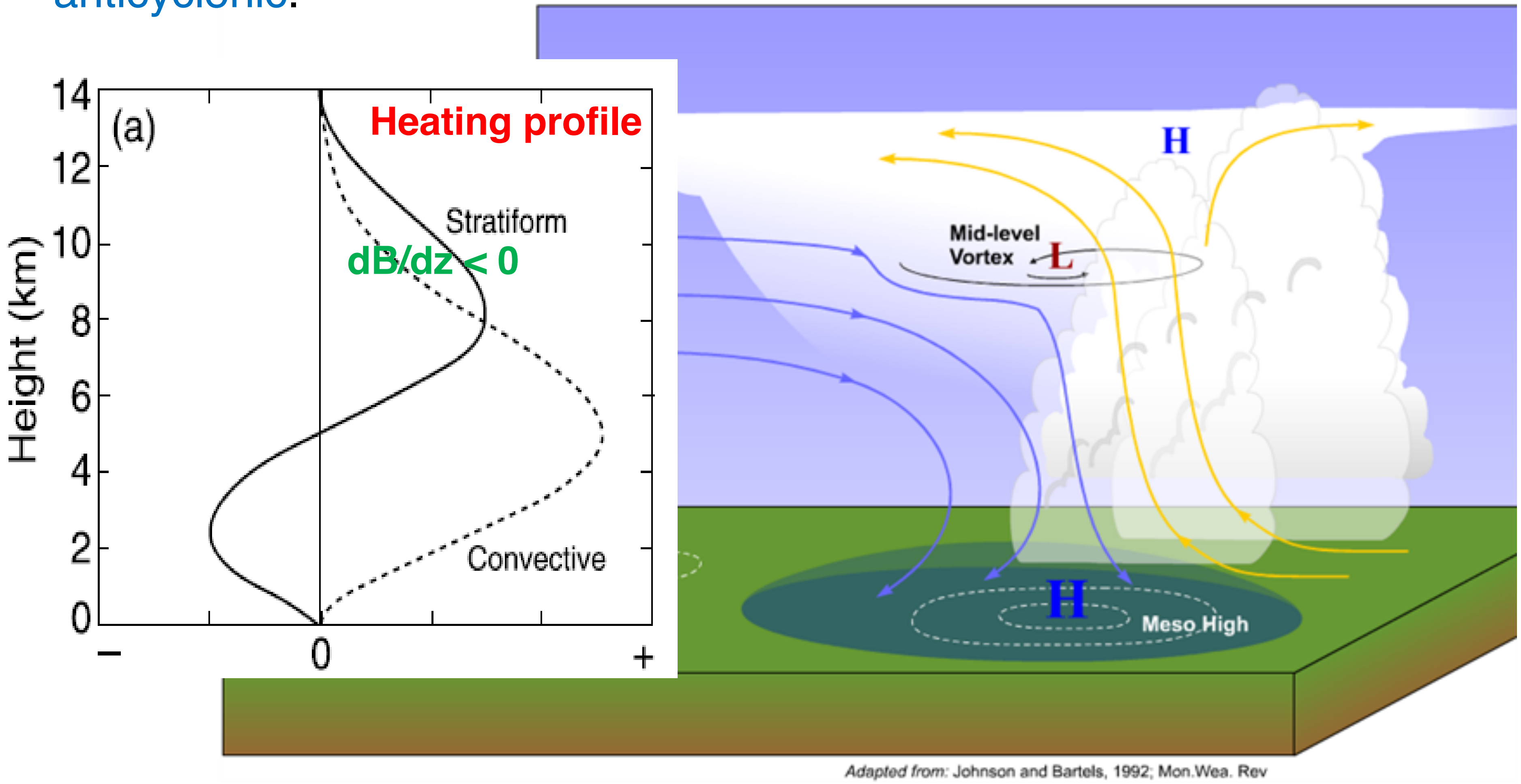
On time-scales of many hours, flow into **mid-level low** (which is placed below maximum convective heating) becomes **convergent and cyclonic**.

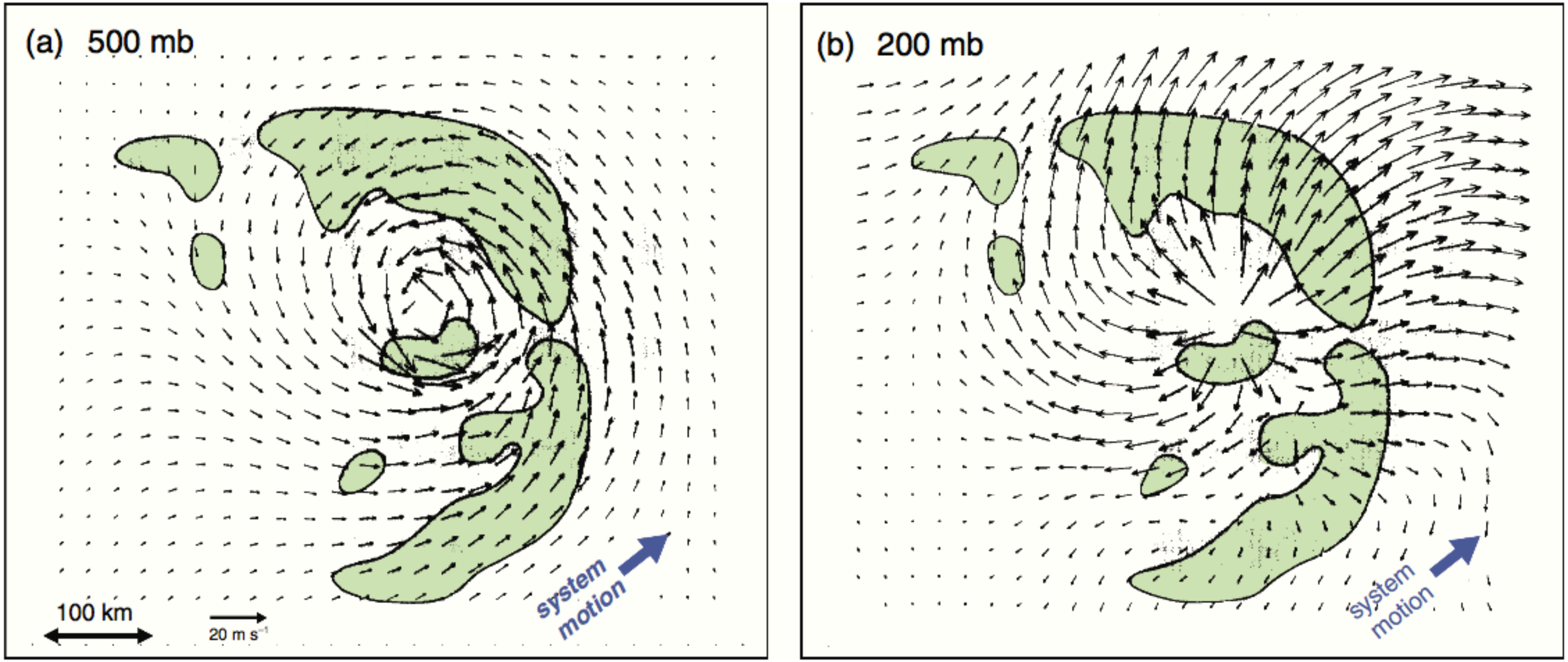



*Adapted from:* Johnson and Bartels, 1992; Mon.Wea. Rev

Recall that **p’** is proportional to **dB/dz** (low pressure found where dB/dz > 0 and high pressure found where dB/dz < 0).

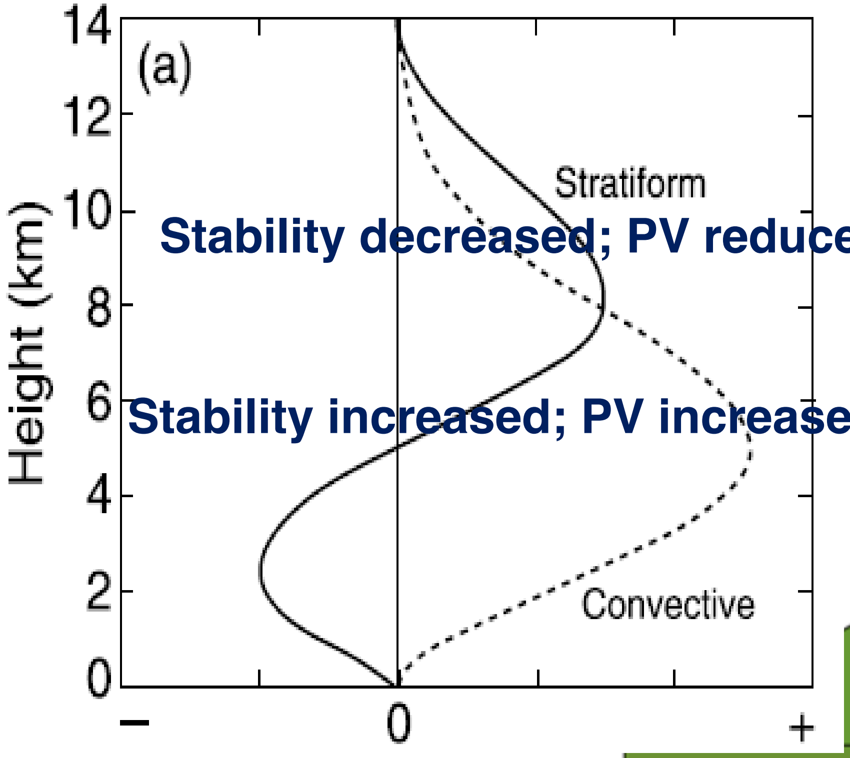
On time-scales of many hours, flow into **upper-level high** (which is placed above maximum convective heating) becomes divergent and anticyclonic.

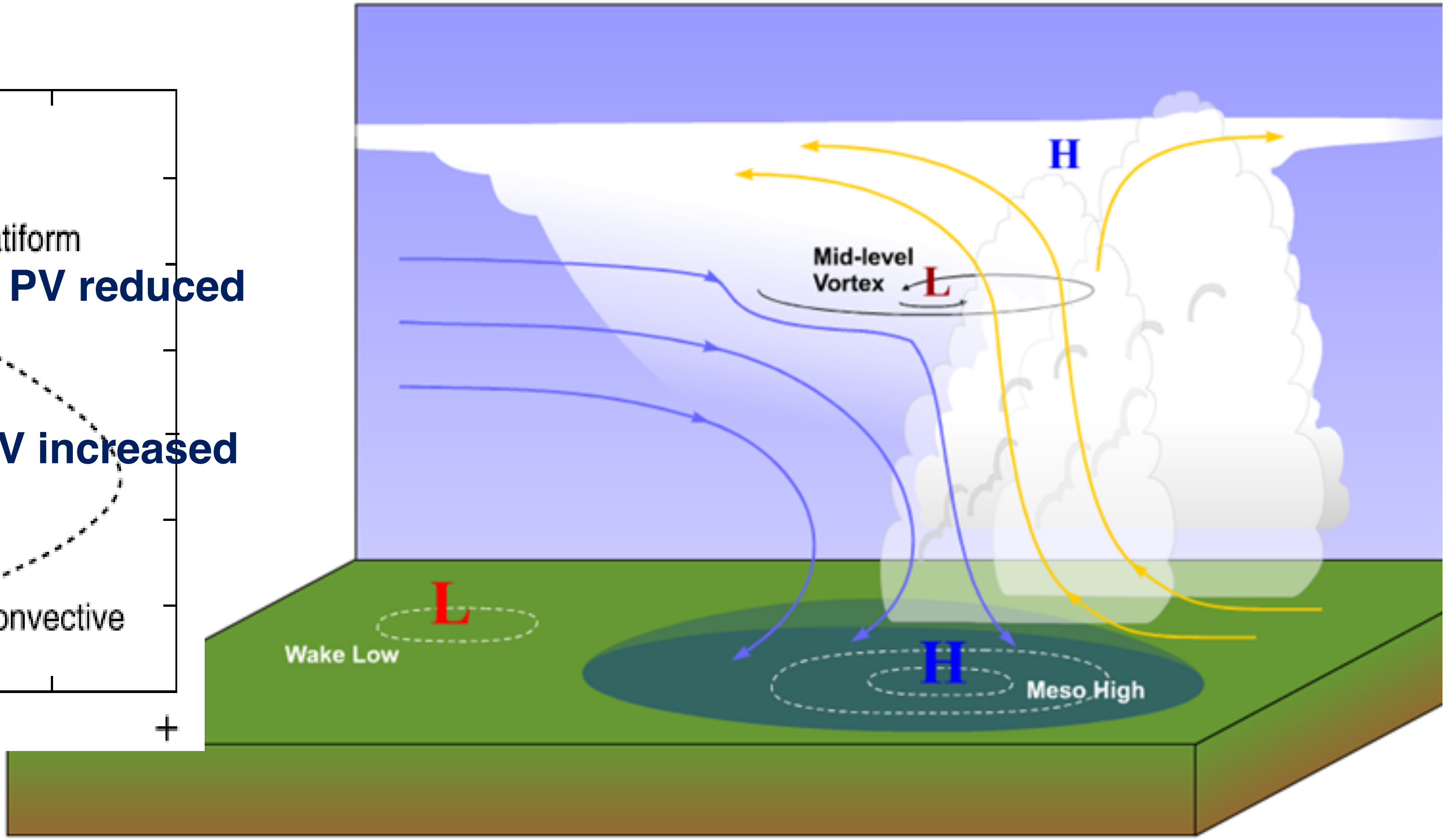



(a) 500 mb
100 km
20 m s⁻¹
system motion
(b) 200 mb
system motion

**Can interpret via PV thinking…**

$$\mathrm{PV} = \frac{(\boldsymbol{\omega} + f\mathbf{k}) \cdot \nabla\theta}{\rho} \approx \frac{\zeta + f}{\rho}\frac{\partial\theta}{\partial z}$$

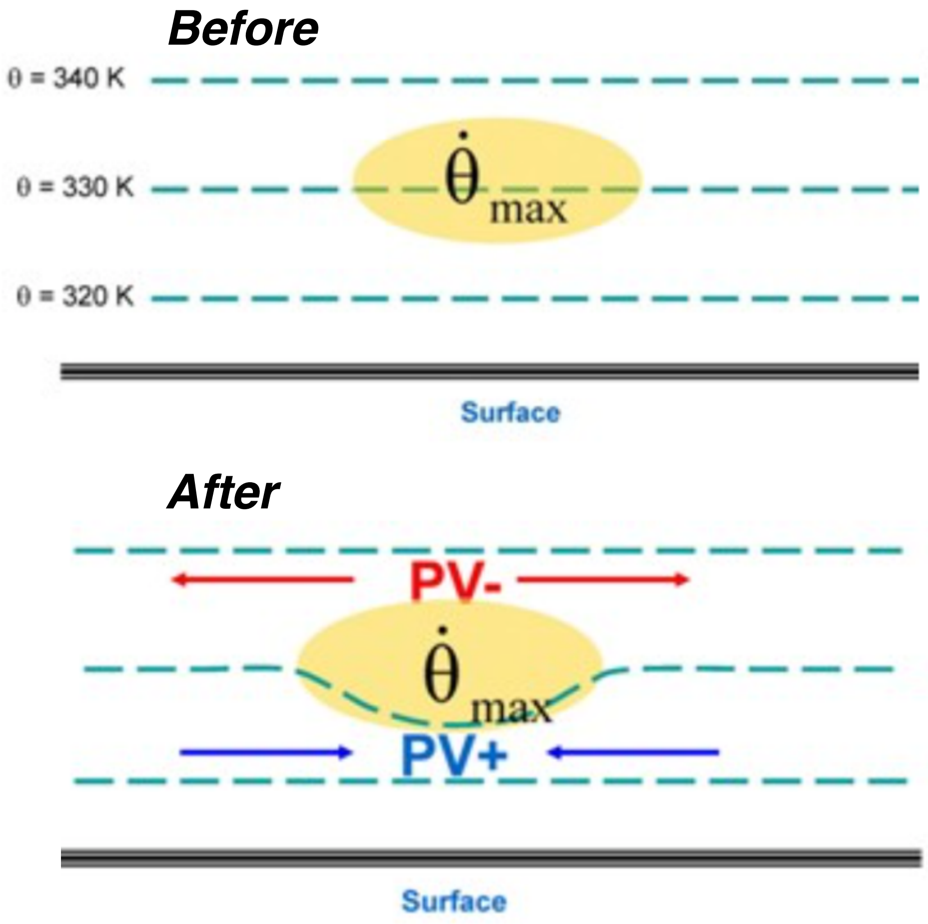



*Adapted from:* Johnson and Bartels, 1992; Mon.Wea. Rev

Potential vorticity defined as,

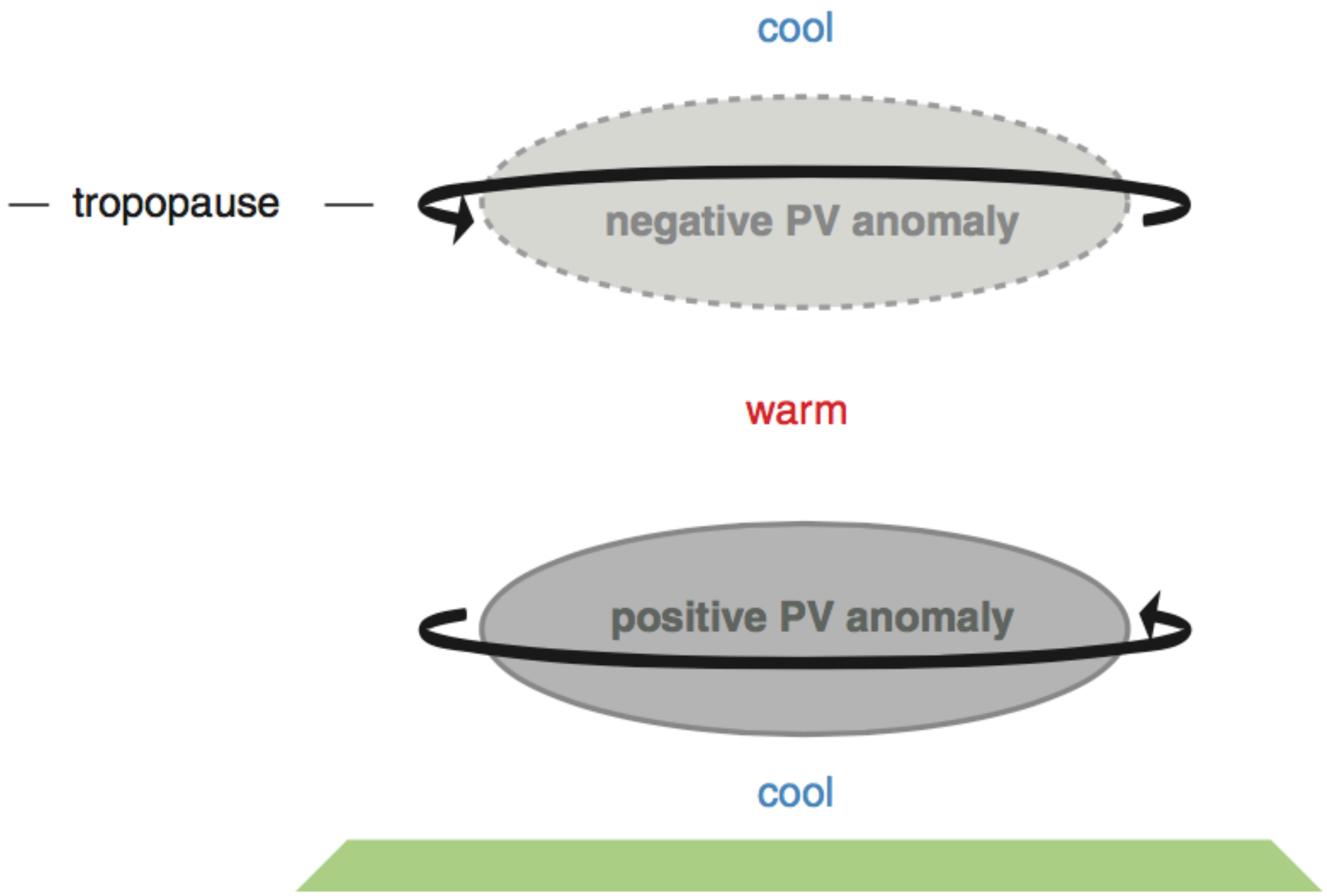
$$\mathrm{PV} = \frac{(\boldsymbol{\omega} + f\mathbf{k}) \cdot \nabla\theta}{\rho} \approx \frac{\zeta + f}{\rho}\frac{\partial\theta}{\partial z}$$




The PV anomalies induce height gradients that accelerate air horizontally, eventually producing circulation as Coriolis acts.

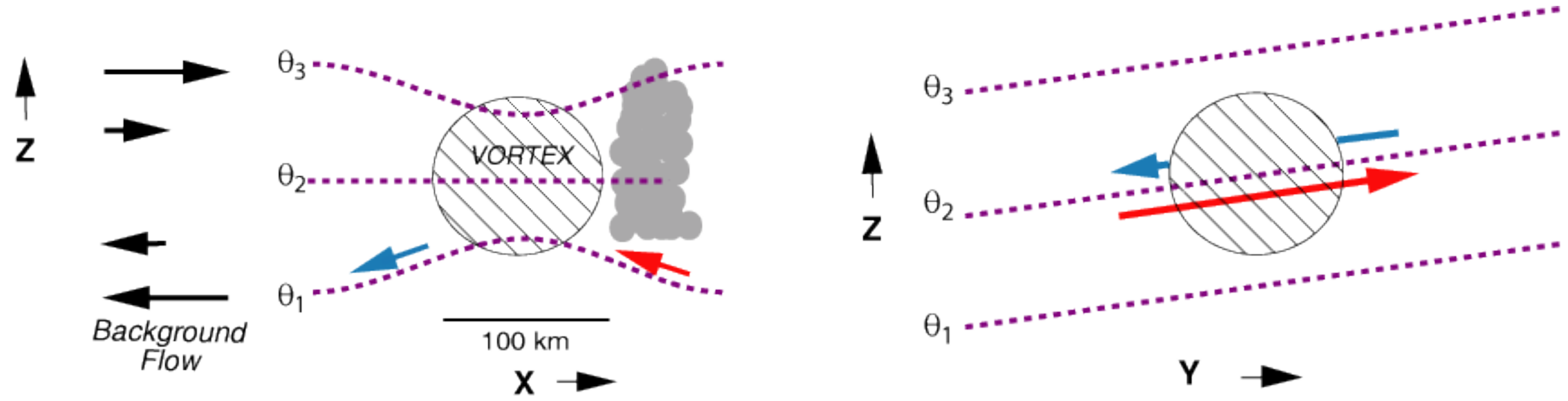
Potential vorticity defined as,

$$\mathrm{PV} = \frac{(\boldsymbol{\omega} + f\mathbf{k}) \cdot \nabla\theta}{\rho} \approx \frac{\zeta + f}{\rho} \frac{\partial \theta}{\partial z}$$




Raymond and Jiang (1990)

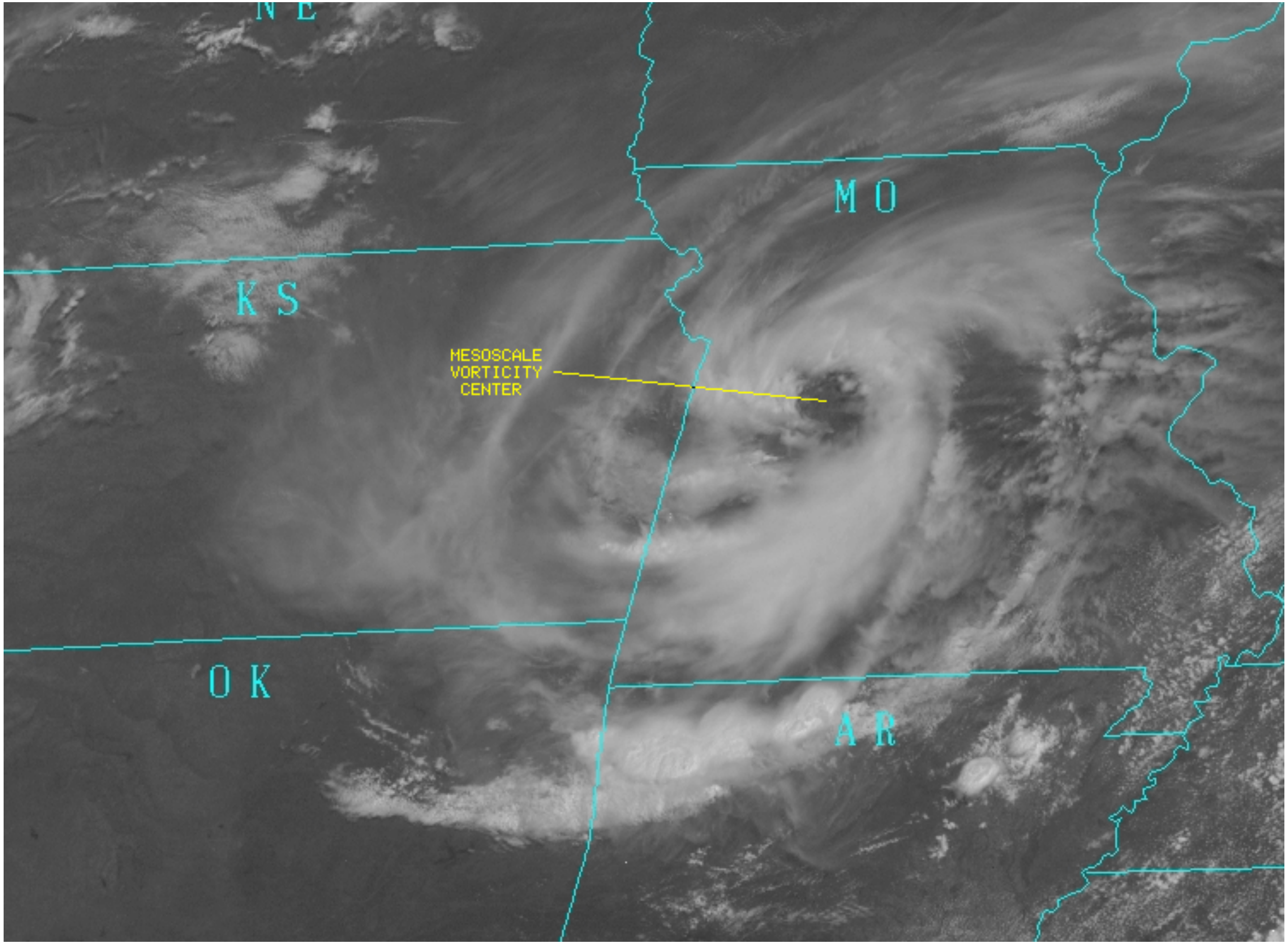
# Raymond and Jiang (JAS 1990) Conceptual Model of Isentropic Lifting within a Steady Balanced Vortex (e.g., MCV)

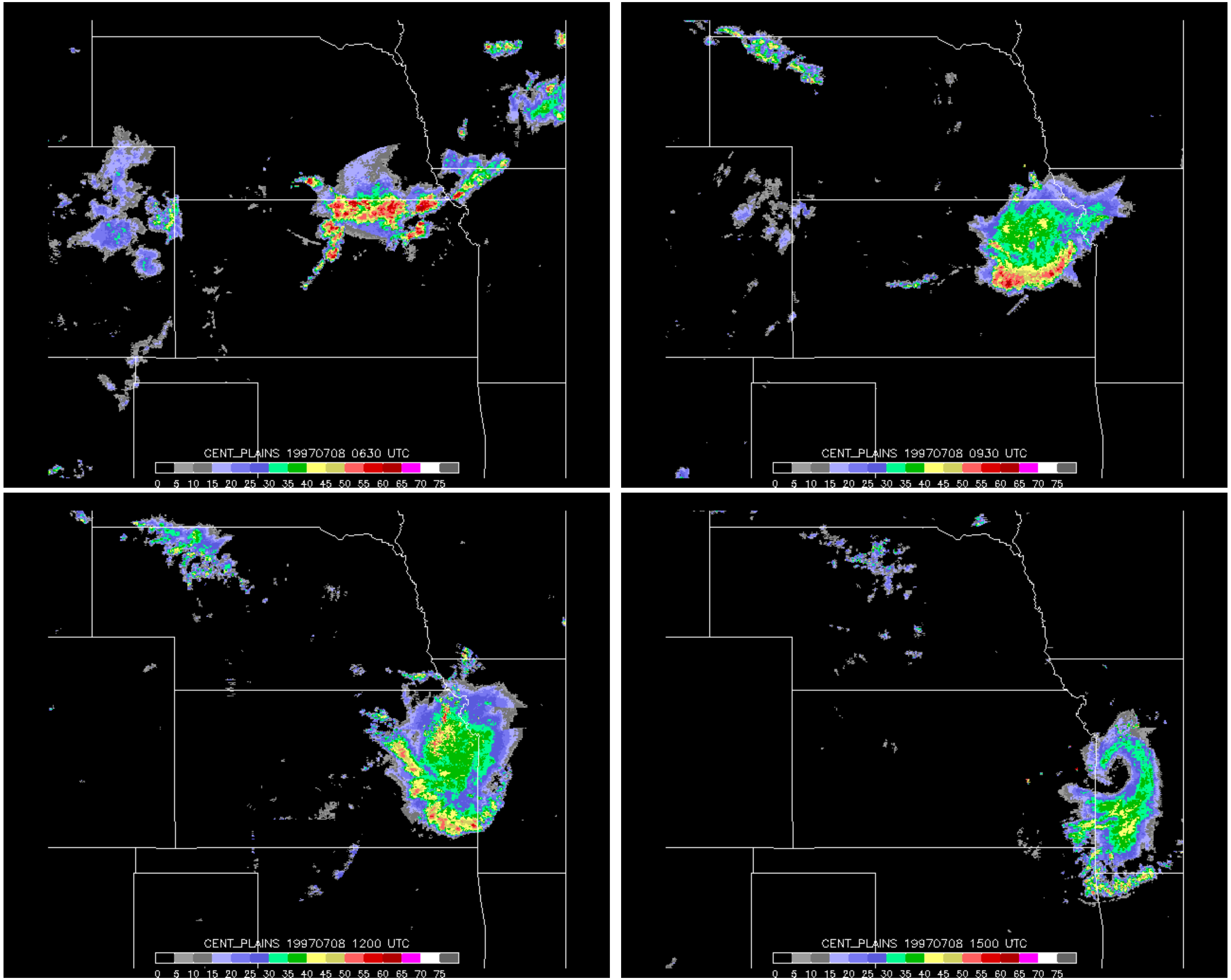


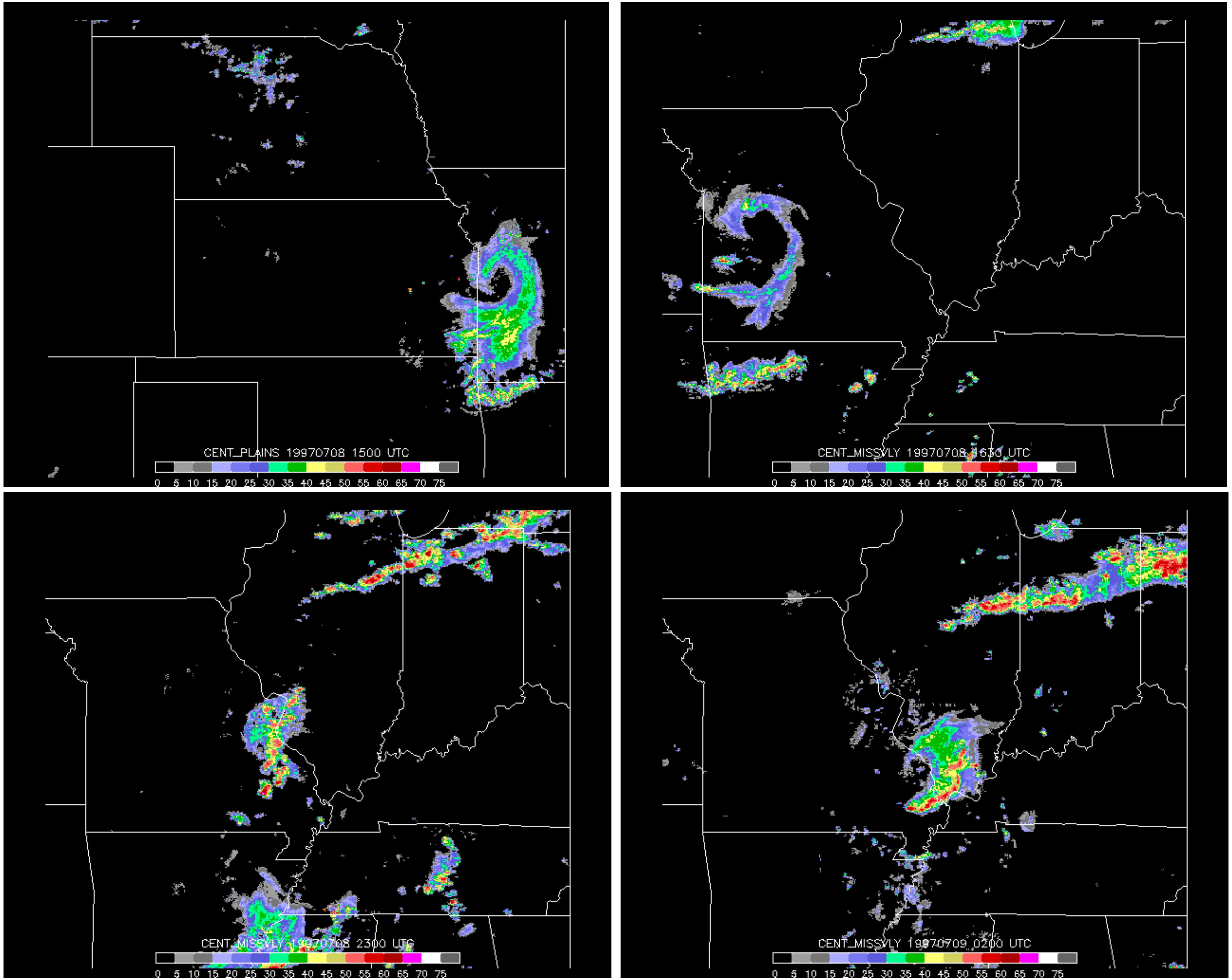

(a) Background shear-induced isentropic motion within baroclinic zone associated with balanced vortex

(b) Vortex-induced isentropic motion within background baroclinic zone

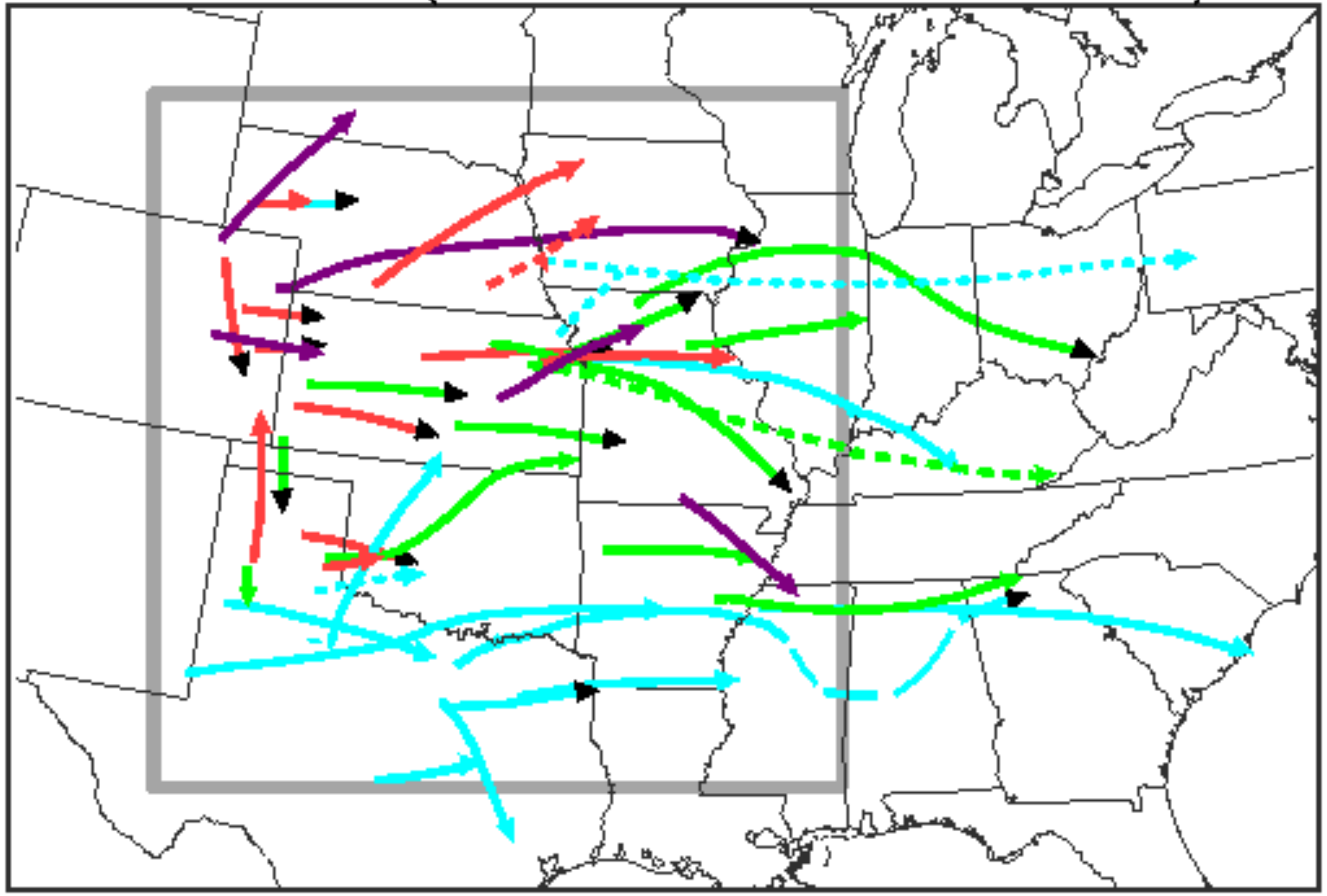
Isentropic lifting associated with a PV anomaly in sheared flow occurs on the **east** side of a PV anomaly moving west to east.


NE
MO
KS
MESOSCALE
VORTICITY
CENTER
OK
AR


CENT_PLAINS 19970708 0630 UTC
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
CENT_PLAINS 19970708 0930 UTC
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
CENT_PLAINS 19970708 1200 UTC
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
CENT_PLAINS 19970708 1500 UTC
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75


CENT_PLAINS 19970708 1500 UTC
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
CENT_MISSVLY 19970708 1630 UTC
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
CENT_MISSVLY 19970708 2300 UTC
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
CENT_MISSVLY 19970709 0200 UTC
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75

# MCV Tracks (1998 and 1999 Warm-Seasons)



15 May - 15 June
15 June - 15 July
15 July - 15 August
15 August - 15 September

Black arrow head => 1998
Colored arrow head => 1999

## Vertical Heating Profiles associated with MCSs

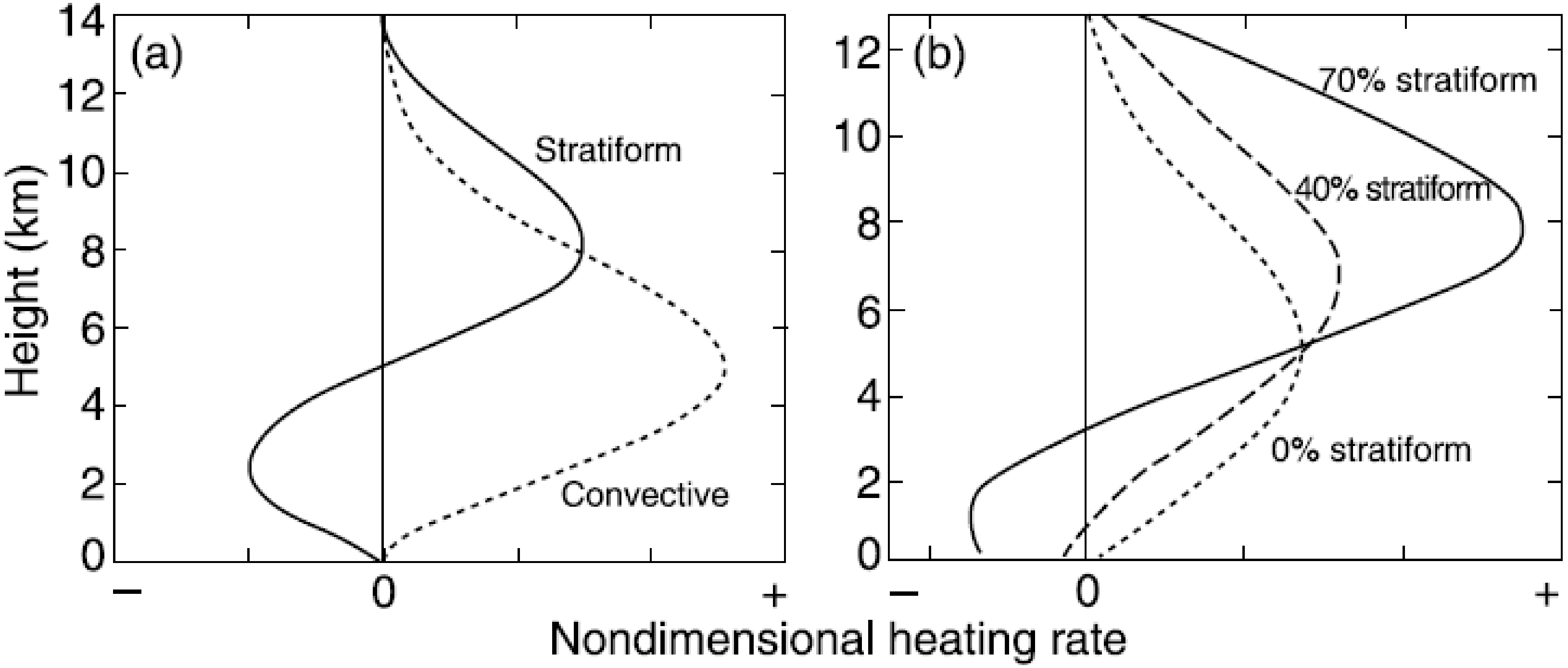



**Figure 4.** (a) Idealized profiles of net heating associated with convective and stratiform precipitation in a mesoscale convective system. The $x$ axis is nondimensional until precipitation amounts are specified for the convective and stratiform regions. (b) Profiles of net heating by a mesoscale convective system with different fractions of stratiform precipitation. Adapted from *Schumacher et al.* [2004].

# Stratiform region important for MCV generation

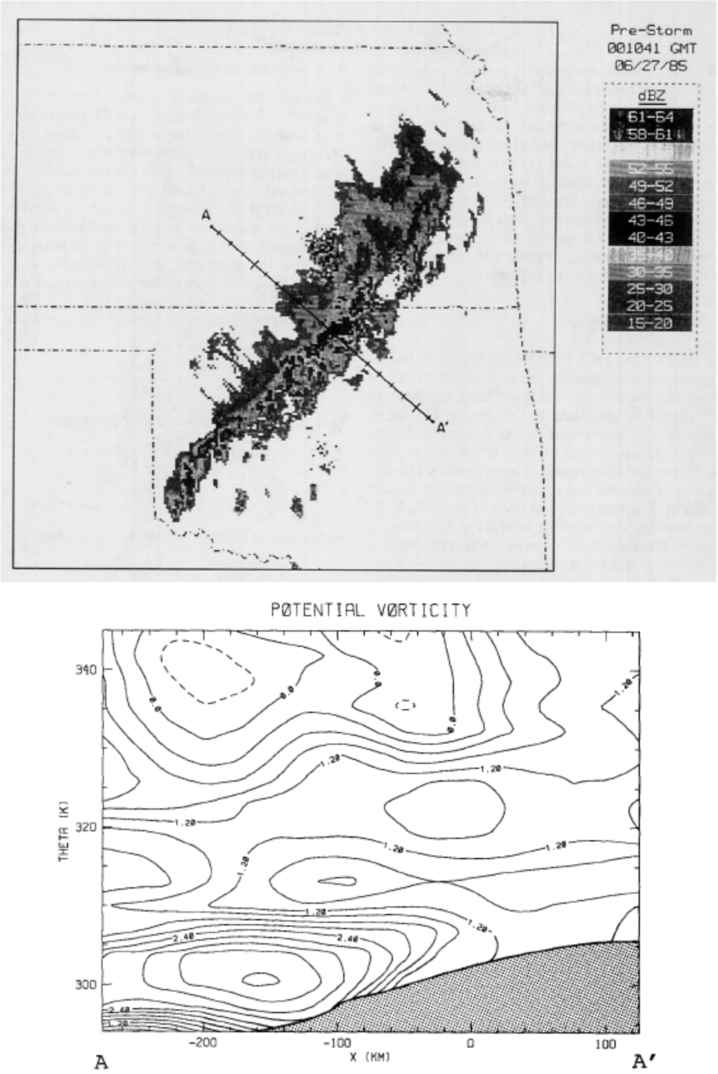



FIG. 1. (a) Composite of the 0000 UTC 27 June 1985 base-level scans of the WSR-57 10-cm radars at Wichita and Oklahoma City, with different levels of shading representing 15, 25, 35, and 45 dBZ. Also shown is the Oklahoma–Kansas PRE-STORM mesonet domain used for analyses in this study. The line AA′ indicates the location of the potential vorticity cross section shown in (b). The contours in (b) are isolines of $P/f$ with a contour interval of 0.3. Dashed contours represent negative values. The leading edge of the squall line is located at $x = 0$.

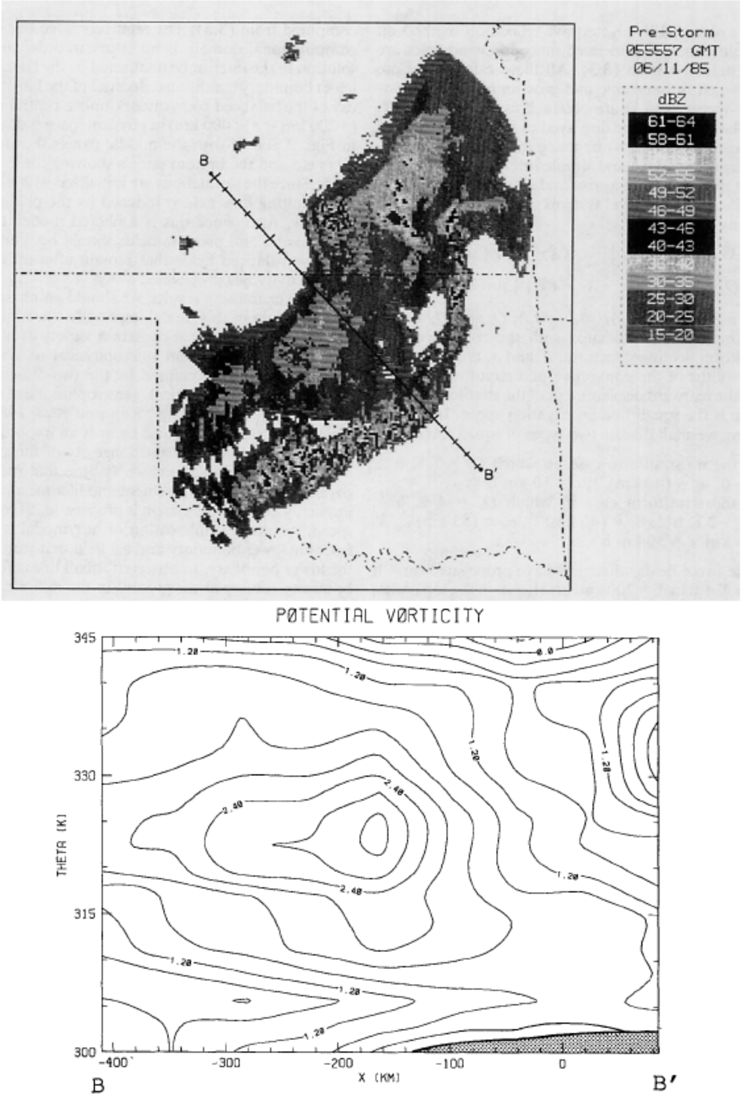



FIG. 2. Same as in Fig. 1 except for 0600 UTC 11 June 1985. The line BB′ indicates the location of the potential vorticity cross section shown in (b).

Hertenstein and Schubert (1991)

# Stratiform region important for MCV generation

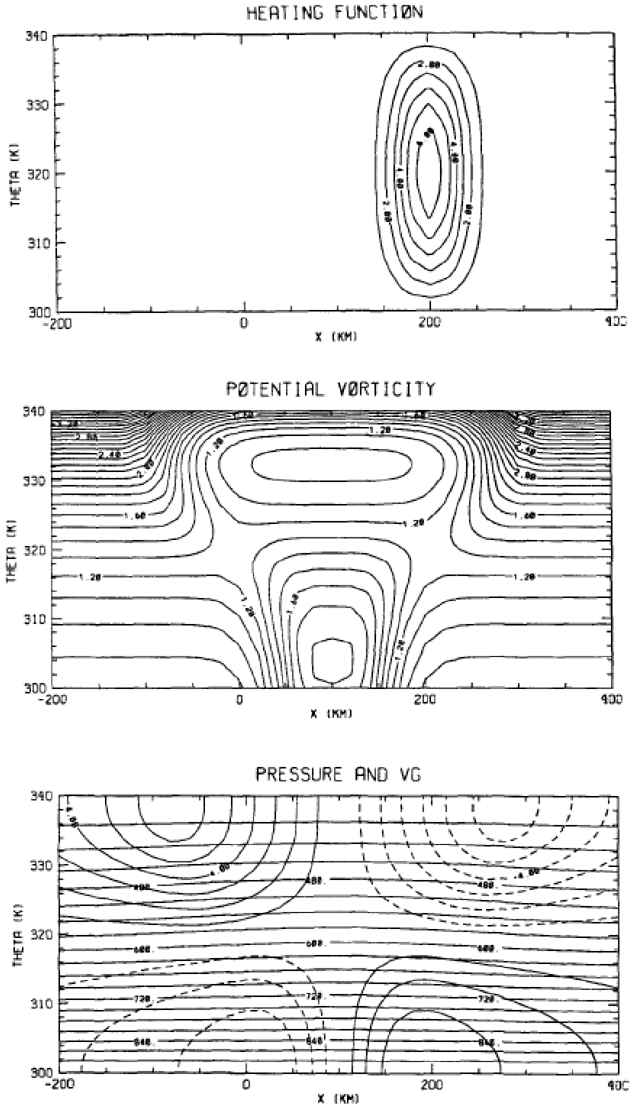



FIG. 3. (a) Heating function for the no stratiform case. For both model simulations, the squall line started at $X = 0$ and propagated to $X = 200$ km. Values are kelvins per hour with a contour interval of 1 K $h^{-1}$. (b) Dimensionless potential vorticity $P/f$ in the wake of the squall line. Contour interval is 0.1. (c) Geostrophic flow along the squall line in meters per second with a contour interval of 1 m $s^{-1}$. Negative values represent northerly flow for a north–south aligned squall line. Also shown are isolines of pressure with a contour interval of 30 mb.

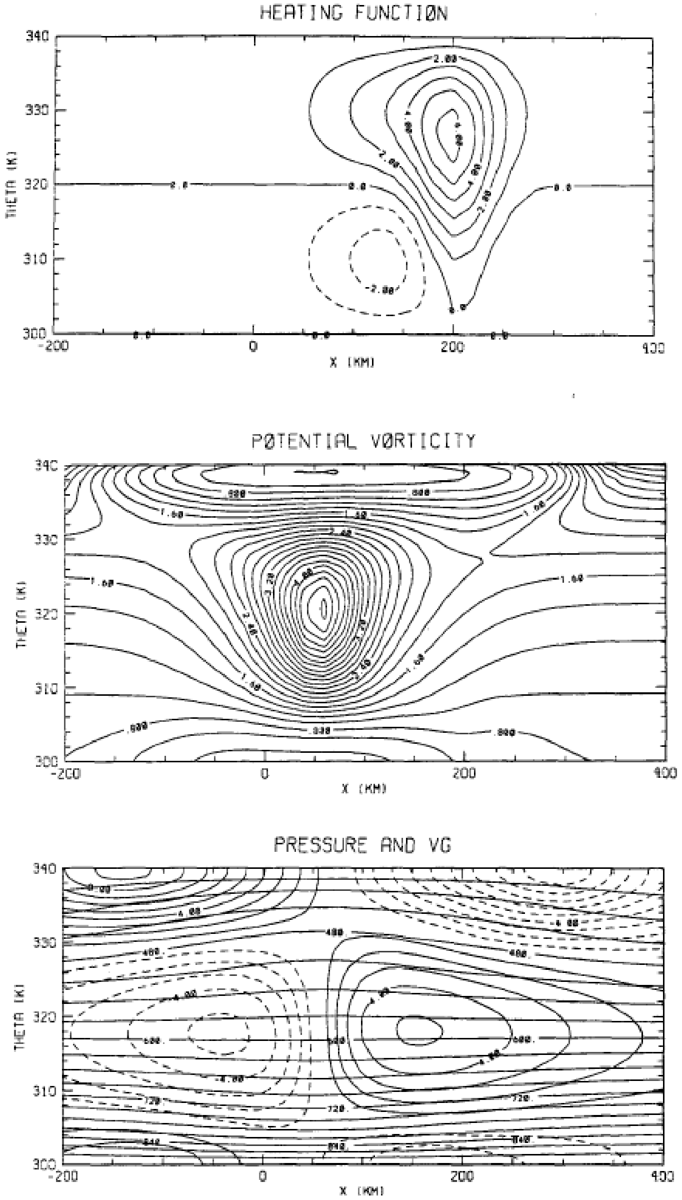
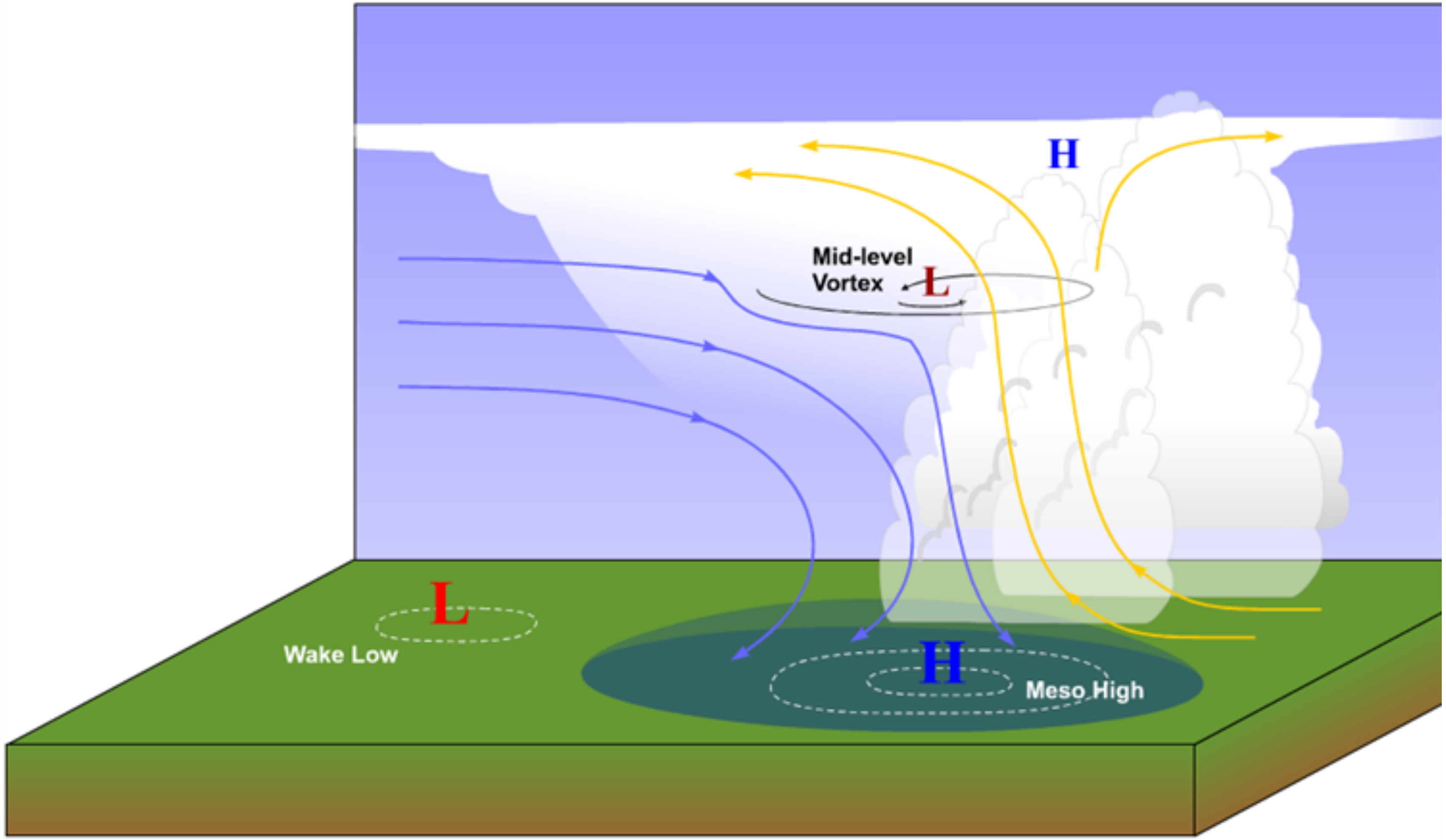



FIG. 4. Same as in Fig. 3 except for the stratiform case. Heating is indicated by solid contours while dashed lines represent cooling. Note that the contour interval for the potential vorticity field is 0.2.

“A mature MCC represents an inertially stable MCS that is in a nearly balanced dynamical state and whose horizontal scale is comparable to or greater than a locally-defined **Rossby radius of deformation**” - Cotton et al. (1989)




Adapted from: Johnson and Bartels, 1992; Mon.Wea. Rev

# Rossby radius of deformation and convection

Identifies the scale at which rotational influences become important.

$$\lambda_R = \frac{c}{\sqrt{\eta\left(f_0 + 2v/r\right)}}$$

For features with scales greater than $\lambda_R$, the system is balanced (e.g. geostrophic) such that the circulations evolve slowly, and vertical motions are largely controlled by primary horizontal circulations.

When **r << $\lambda_R$**, **mass** field adjusts to **wind** field, e.g., **most convection**
When **r >> $\lambda_R$**, **wind** field adjusts to **mass** field, e.g., **MCCs**