Toward the Long-range Prediction of Severe Convective Windstorms

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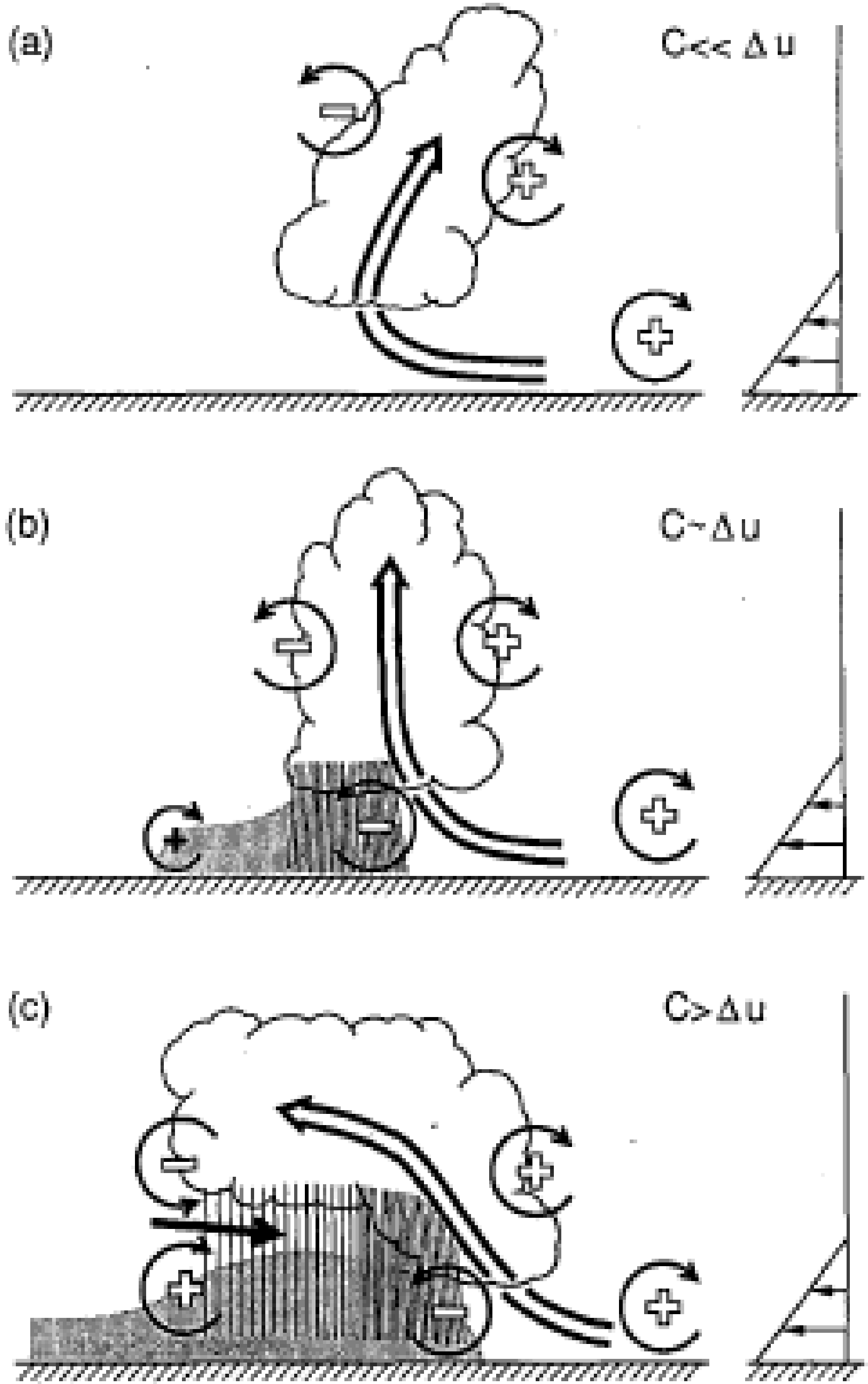
Objectives

- Present background and results of literature review pertaining to severe convective windstorm (SCW) structure and evolution.
- Identify potential signatures for (SCW) forecasting using satellite, radar, and NWP resources.
- Apply signatures to a case study of a recent significant SCW event.
- The results of this study will serve as a basis for the development of a long-range SCW prediction technique.

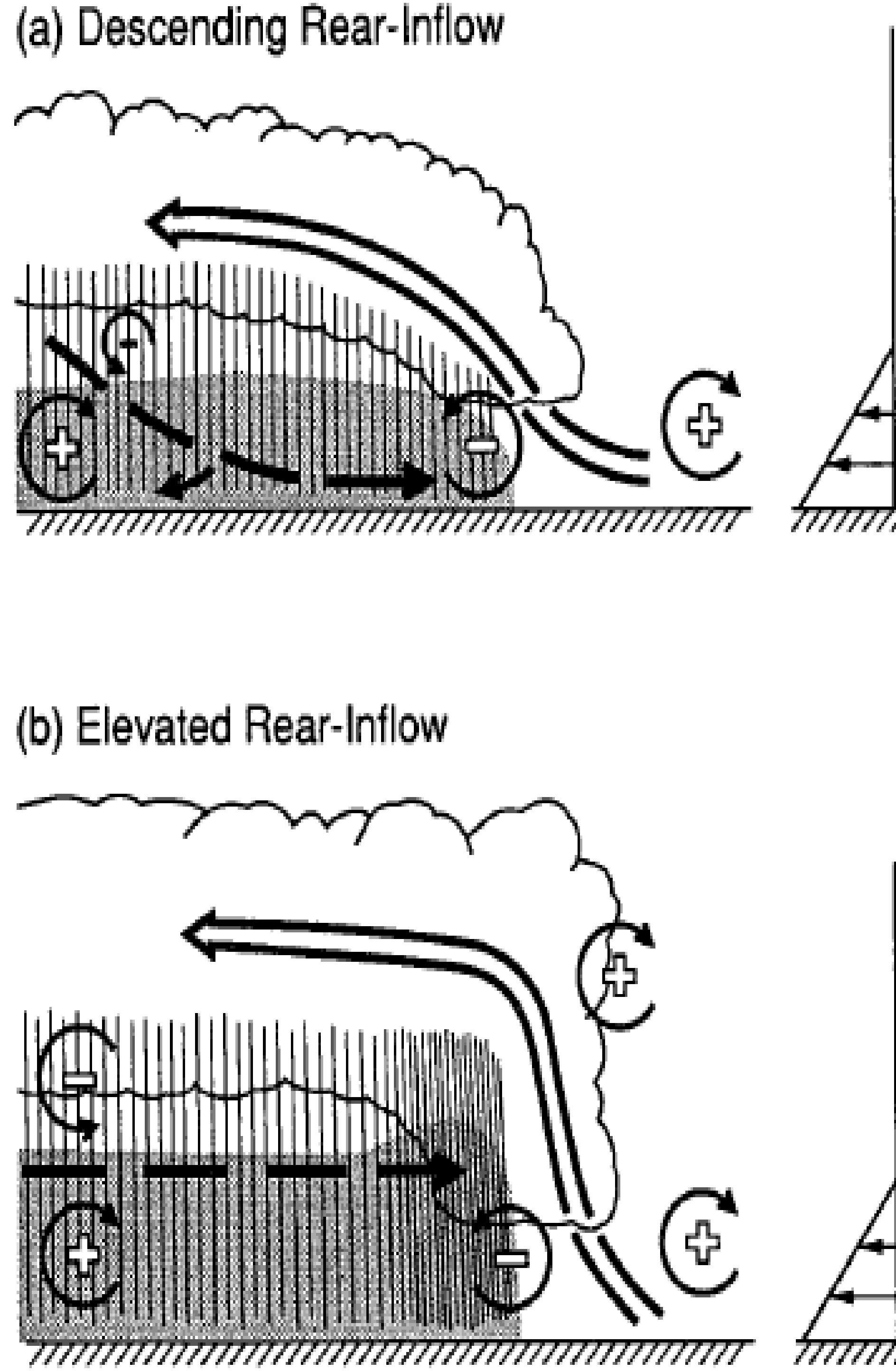
Background

- Severe windstorms resulting from large thunderstorm systems (or mesoscale convective system (MCS)), cause major disruption to society, including widespread power outages, tree and structural damage, and transportation accidents that affect multi-state regions and metropolitan areas along their track.

- A derecho is defined as a long-lived, widespread severe convective windstorm (SCW) composed of numerous downbursts (intense thunderstorm downdrafts) that are organized into clusters and/or families of clusters (Fujita and Wakimoto 1981; Johns and Hirt 1987).



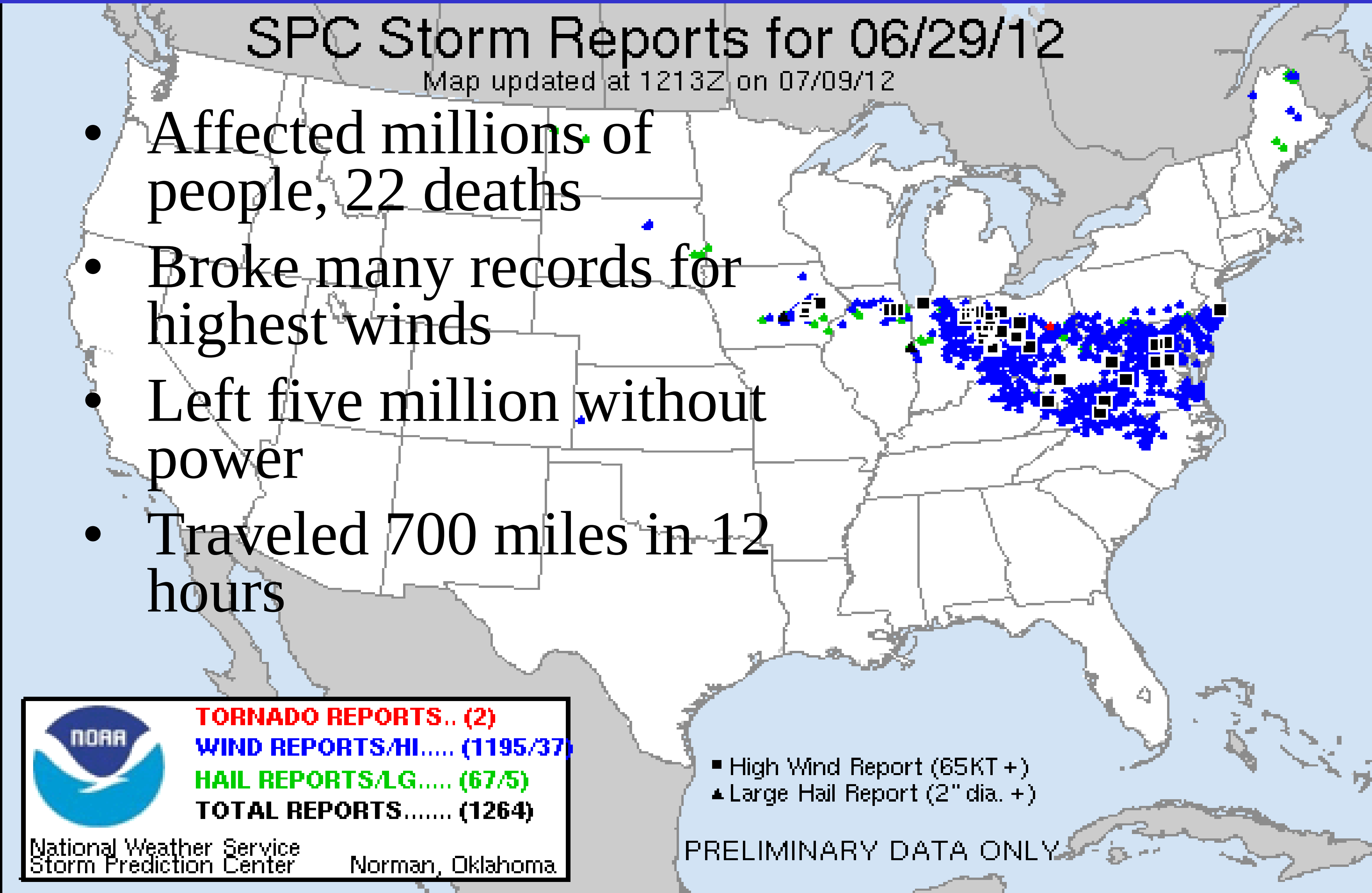
(a)
C<< Δu
(b)
C~Δu
(c)
C>Δu



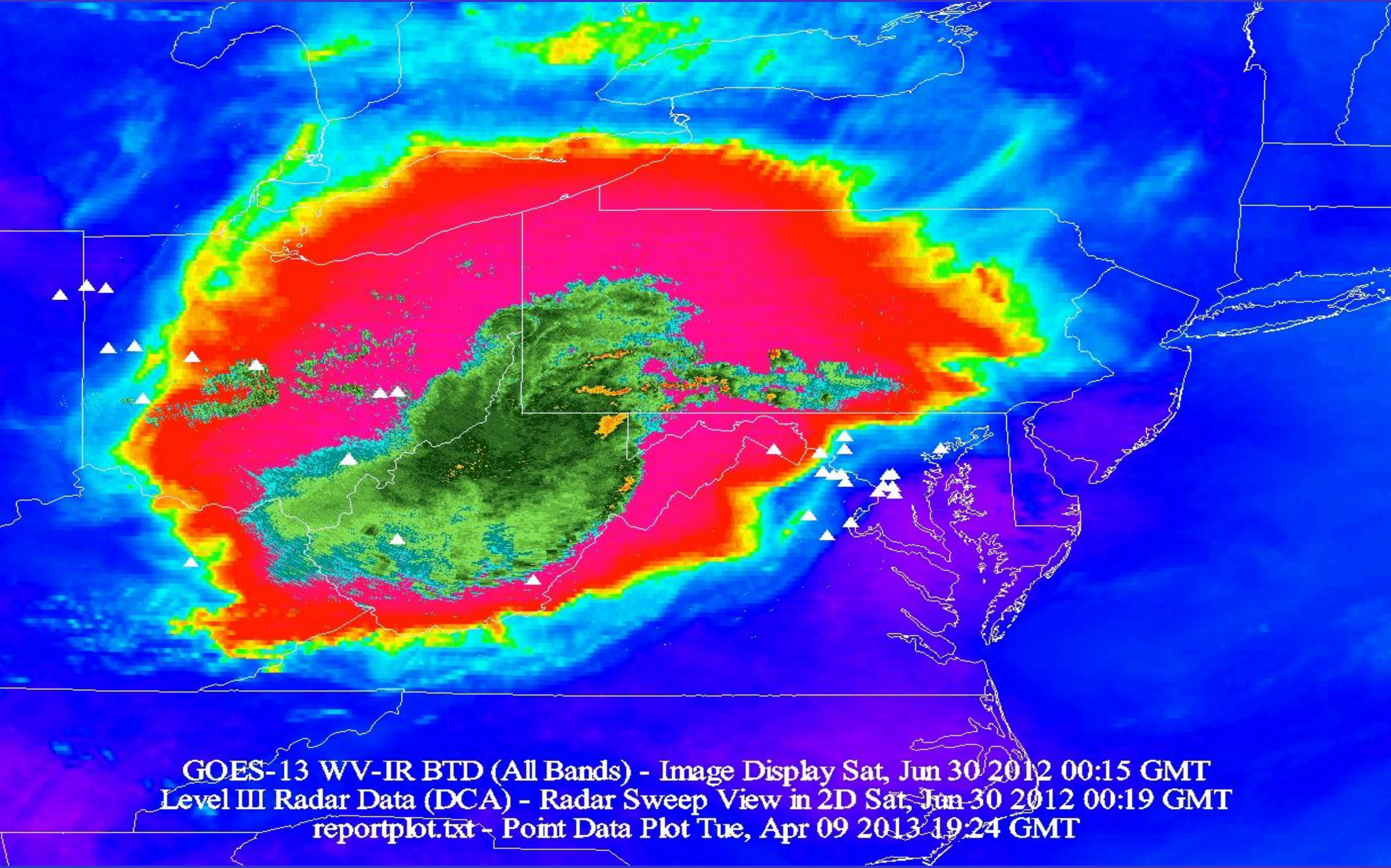
(a) Descending Rear-Inflow
(b) Elevated Rear-Inflow

The June 2012 Derecho

- Affected millions of people, 22 deaths
- Broke many records for highest winds
- Left five million without power
- Traveled 700 miles in 12 hours



June 2012 Derecho Overview



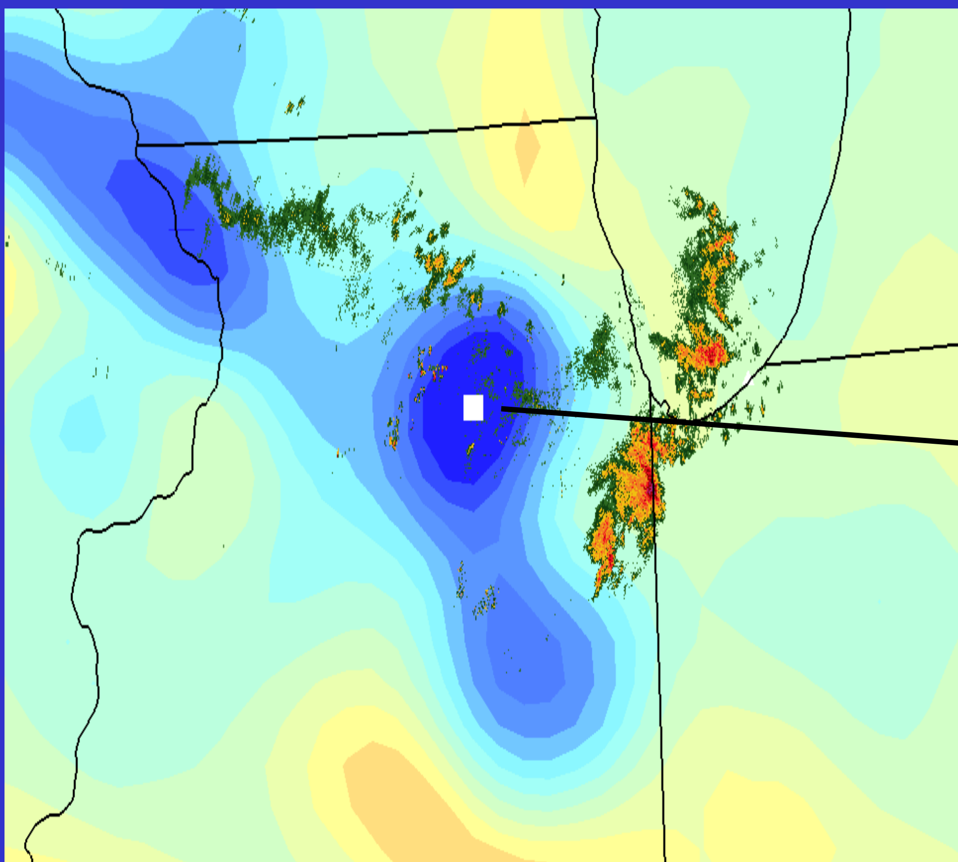
http://www.spc.noaa.gov/misc/AbtDerechos/casepages/jun292012page.htm#

Methodology: Candidate SCW Predictor Selection

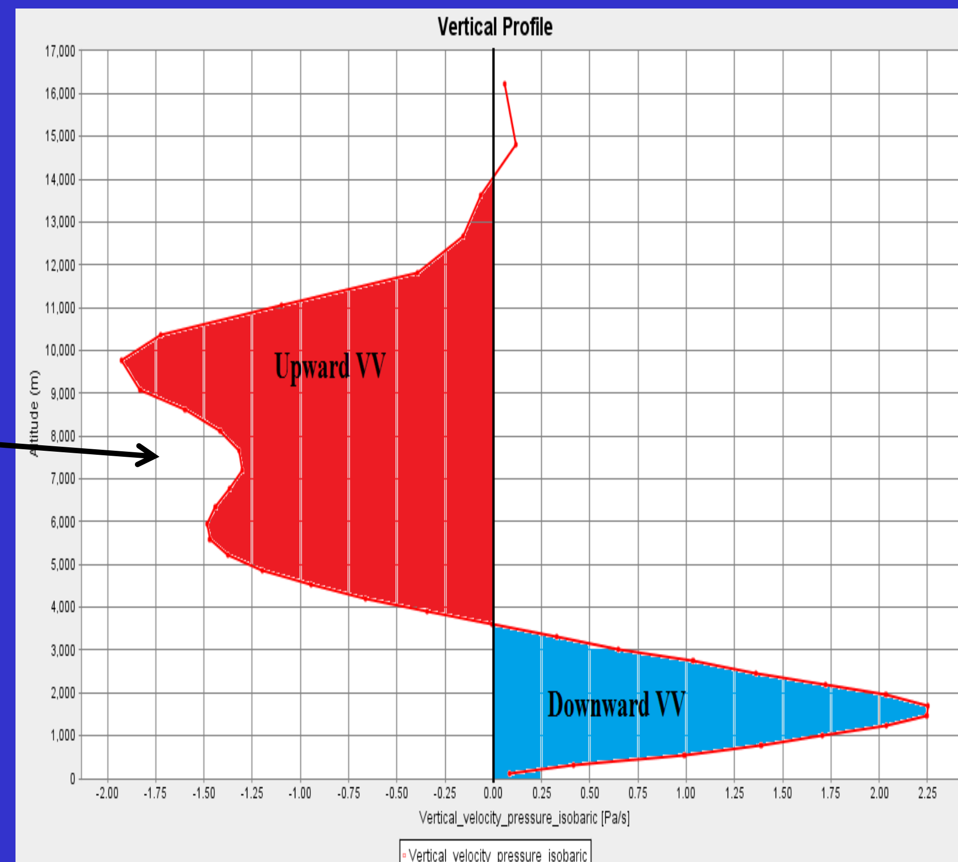
- Upper and lower-tropospheric vertical velocity (VV) and the vertical velocity difference (ΔVV) between these fields:
  - Found to correspond to the presence of elevated rearward ascending flow and the presence of a cold pool, respectively.
- Equivalent Potential Temperature advection ($\mathbf{V} \cdot \nabla\theta_e$):
  - A conserved quantity, and considered to be a measure of moist static energy in the atmosphere.
  - Effective as a parameter for SCW generation based on the premise that mid-tropospheric negative theta-e advection, where cooler and drier air aloft is being transported into an MCS environment and is interacting with the trailing stratiform precipitation and leading convective storms, serves as a major forcing mechanism for intense downdrafts.
- Incorporated into a numerical weather prediction (NWP) model or a satellite hyperspectral sounder profile, the combined use of these parameters could serve to indicate the presence of a mature convective system with a rear inflow jet that has the potential to generate widespread severe winds.

Methodology: Vertical Velocity Analysis

RAP model-derived 850-mb vertical velocity with overlying radar reflectivity at 1700 UTC 29 June 2012

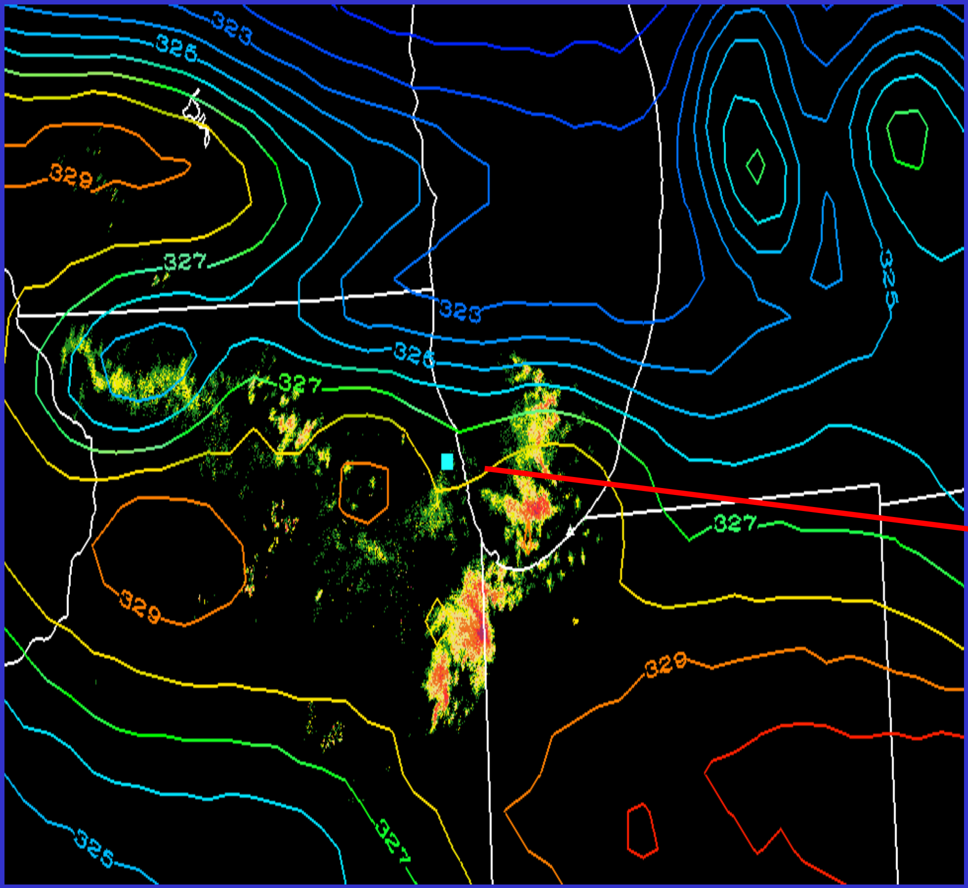


Vertical velocity profile in maximum difference region over northern Illinois

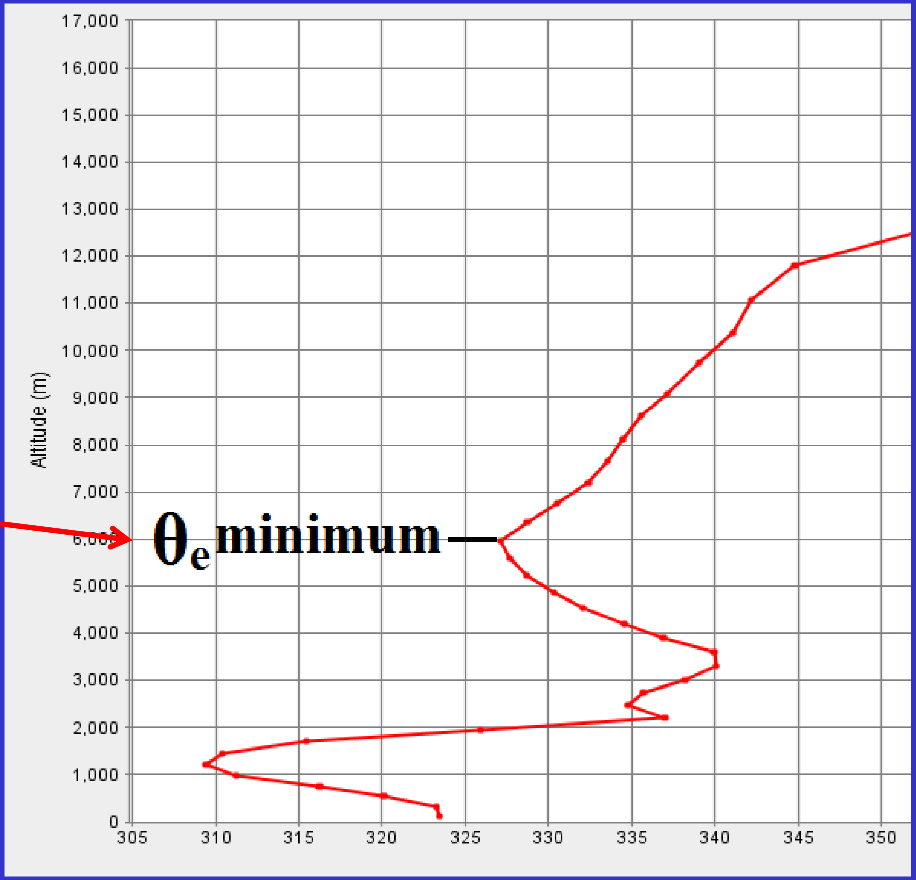


Methodology: Theta-e (θ_e) Analysis

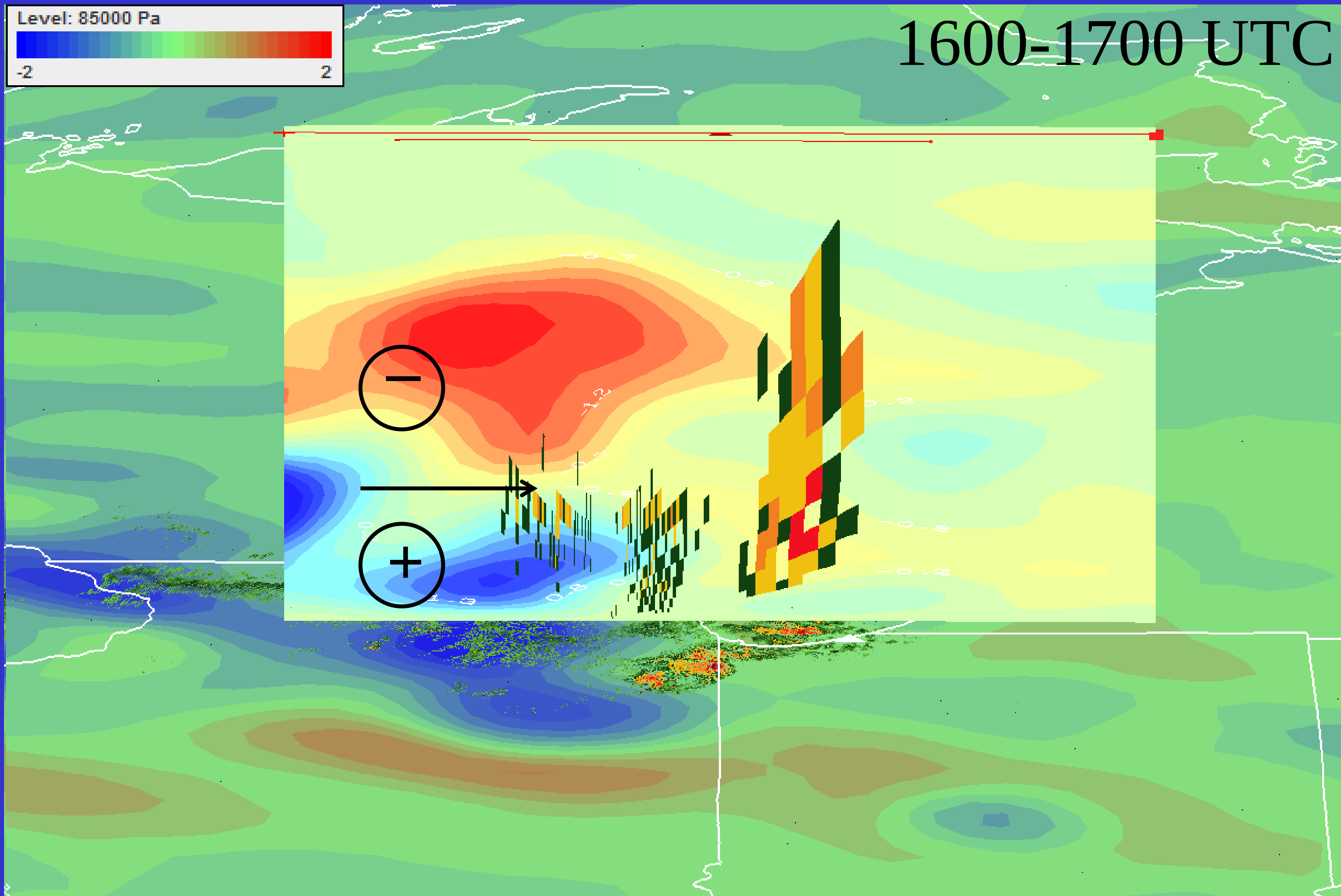
RAP model-derived 500 mb theta-e analysis at 1700 UTC 29 June 2012



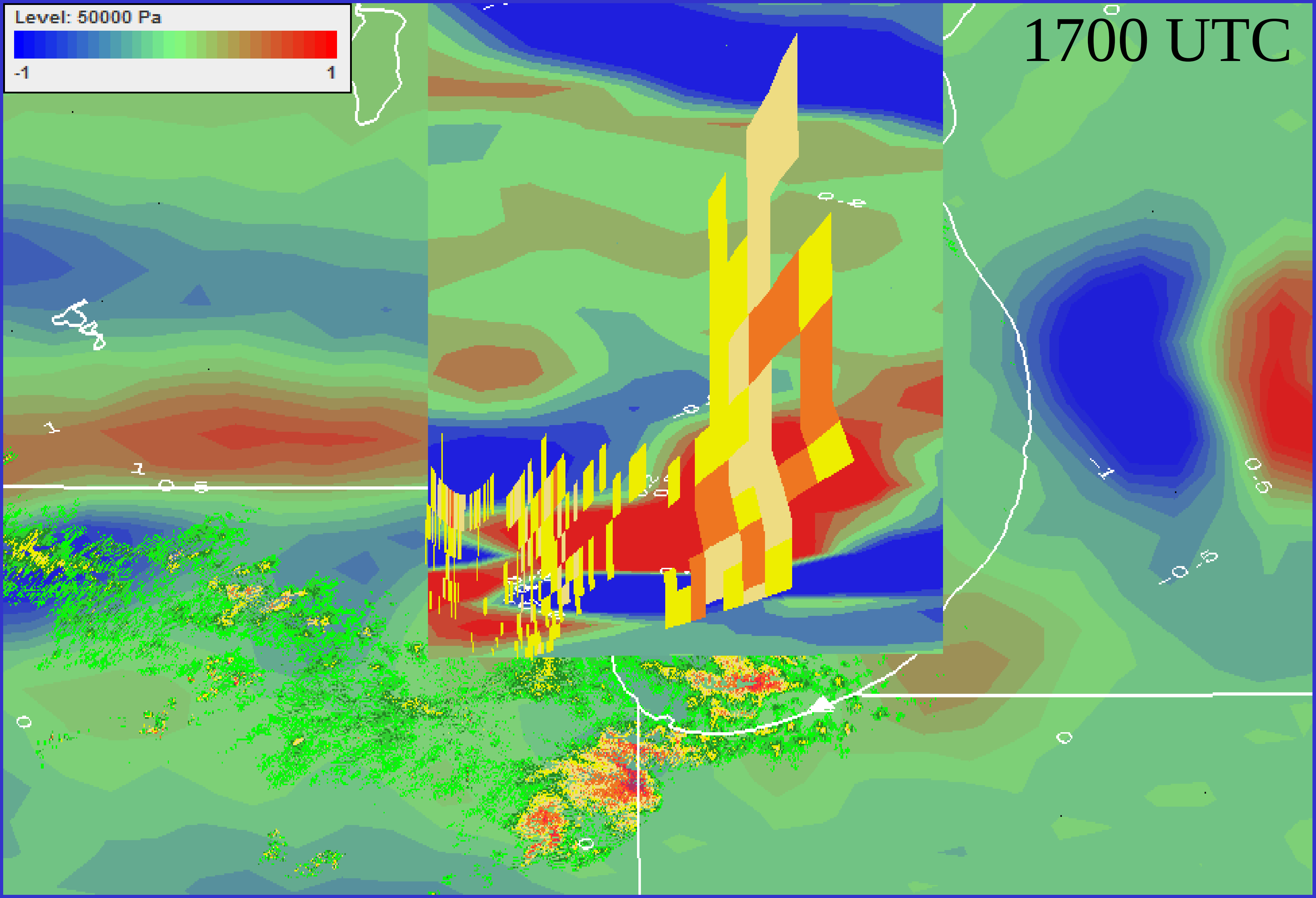
Vertical theta-e profile near Chicago, Illinois at 1700 UTC 29 June 2012



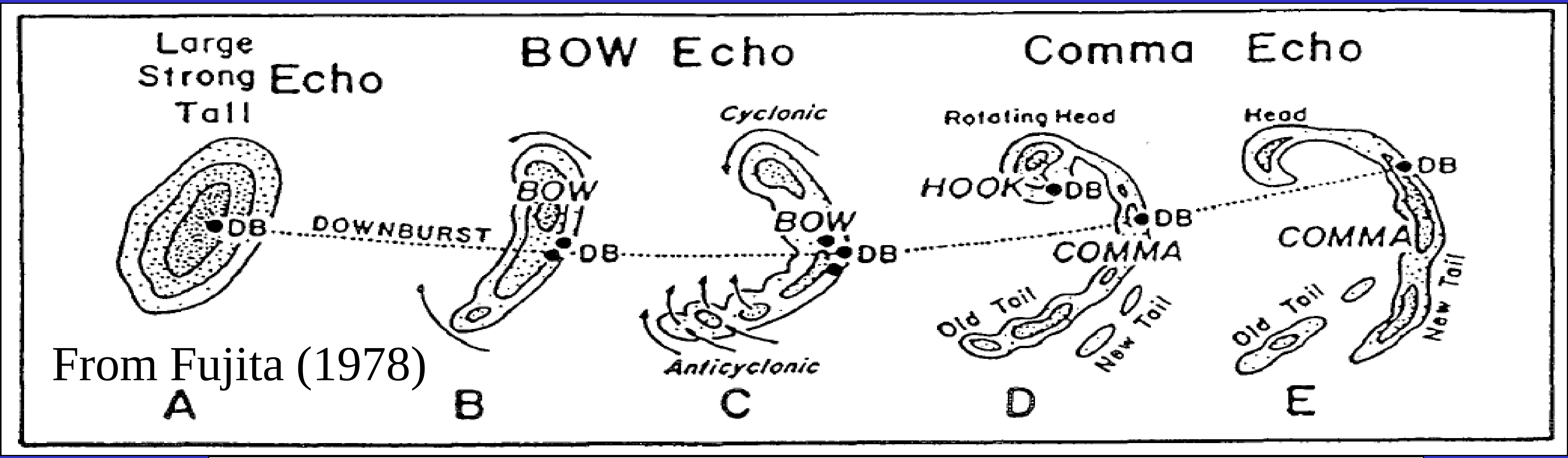
Derecho Initiation: VV Analysis

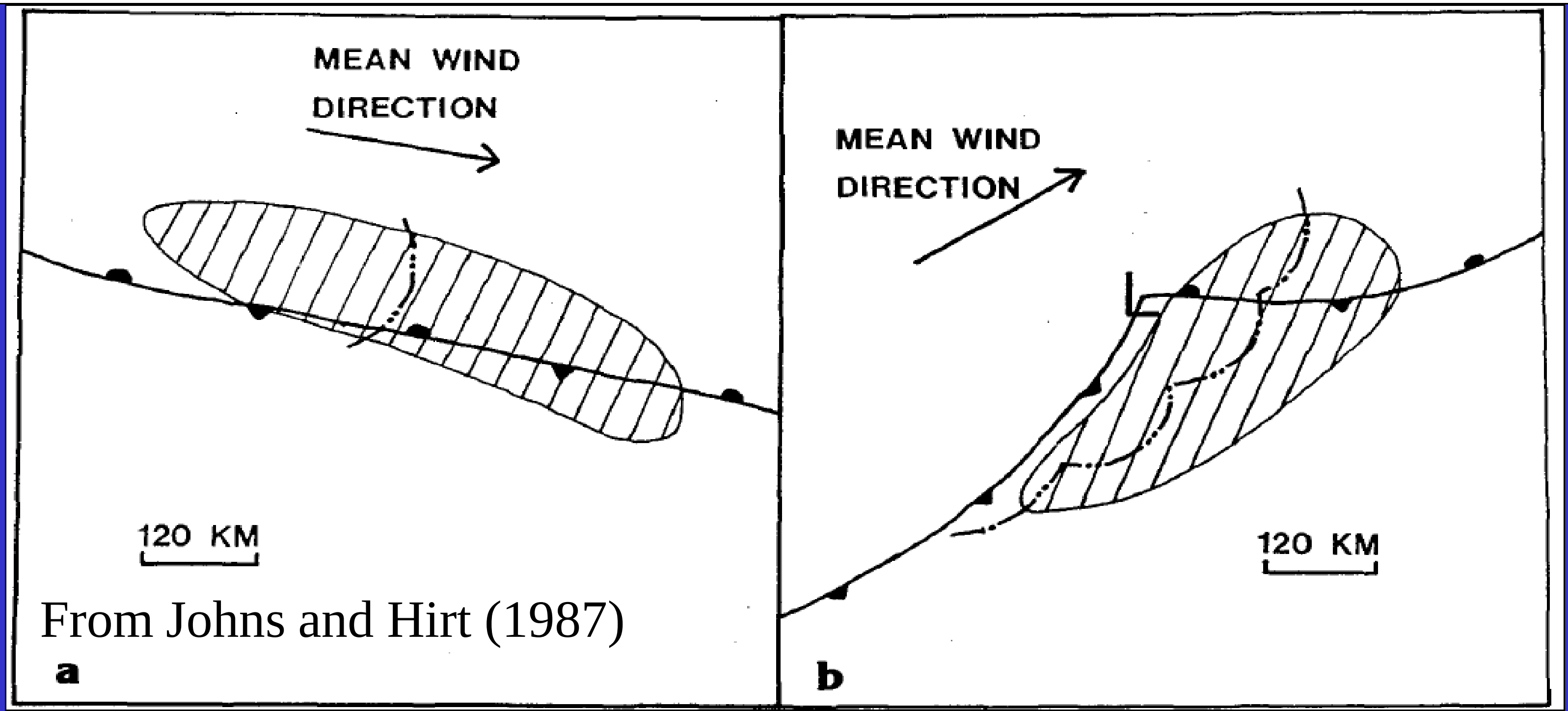


Derecho Initiation: Theta-e Advection

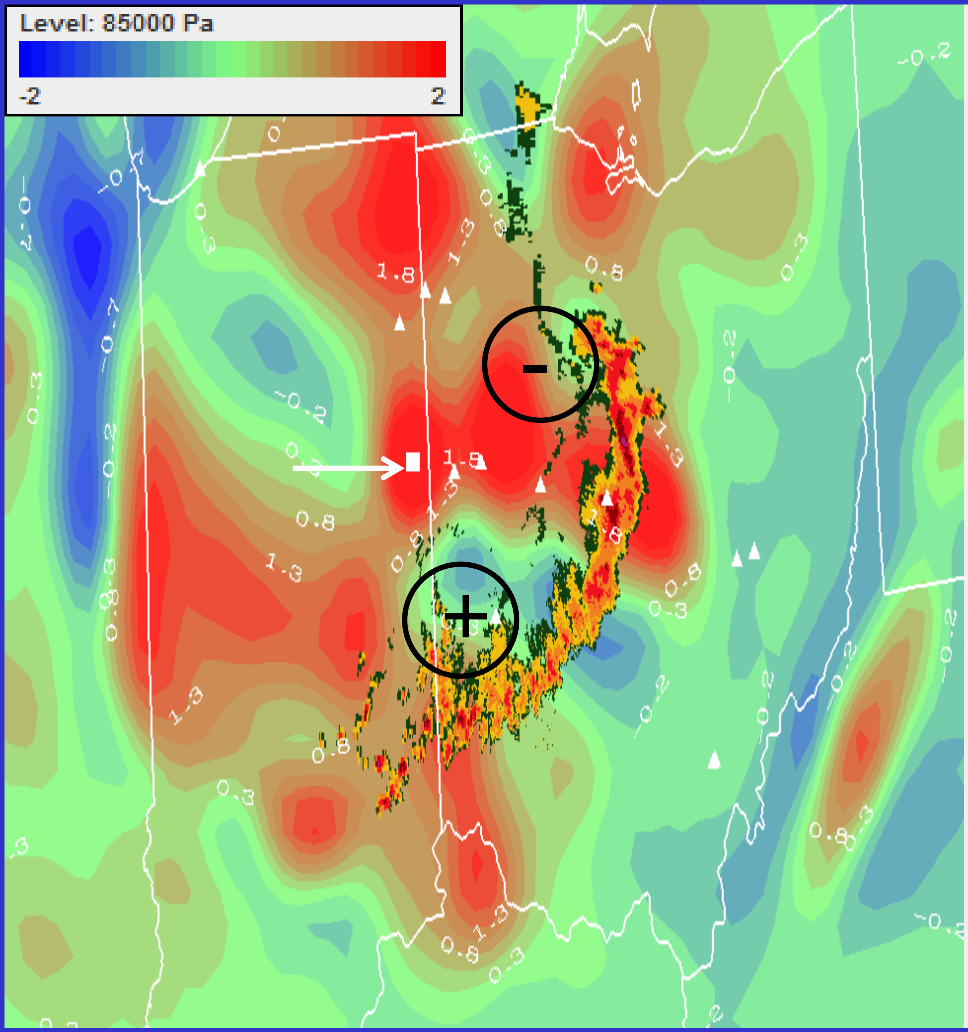


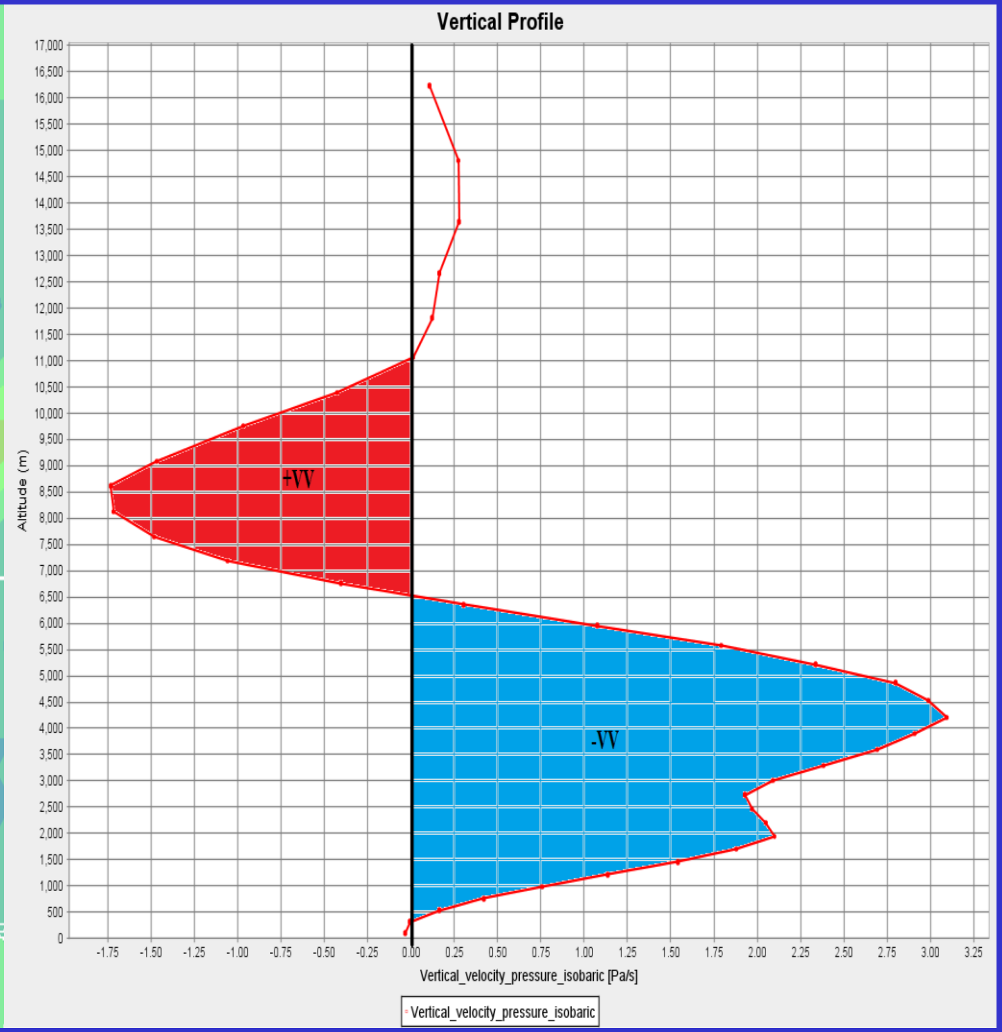
Bow Echo/Derecho Conceptual Models





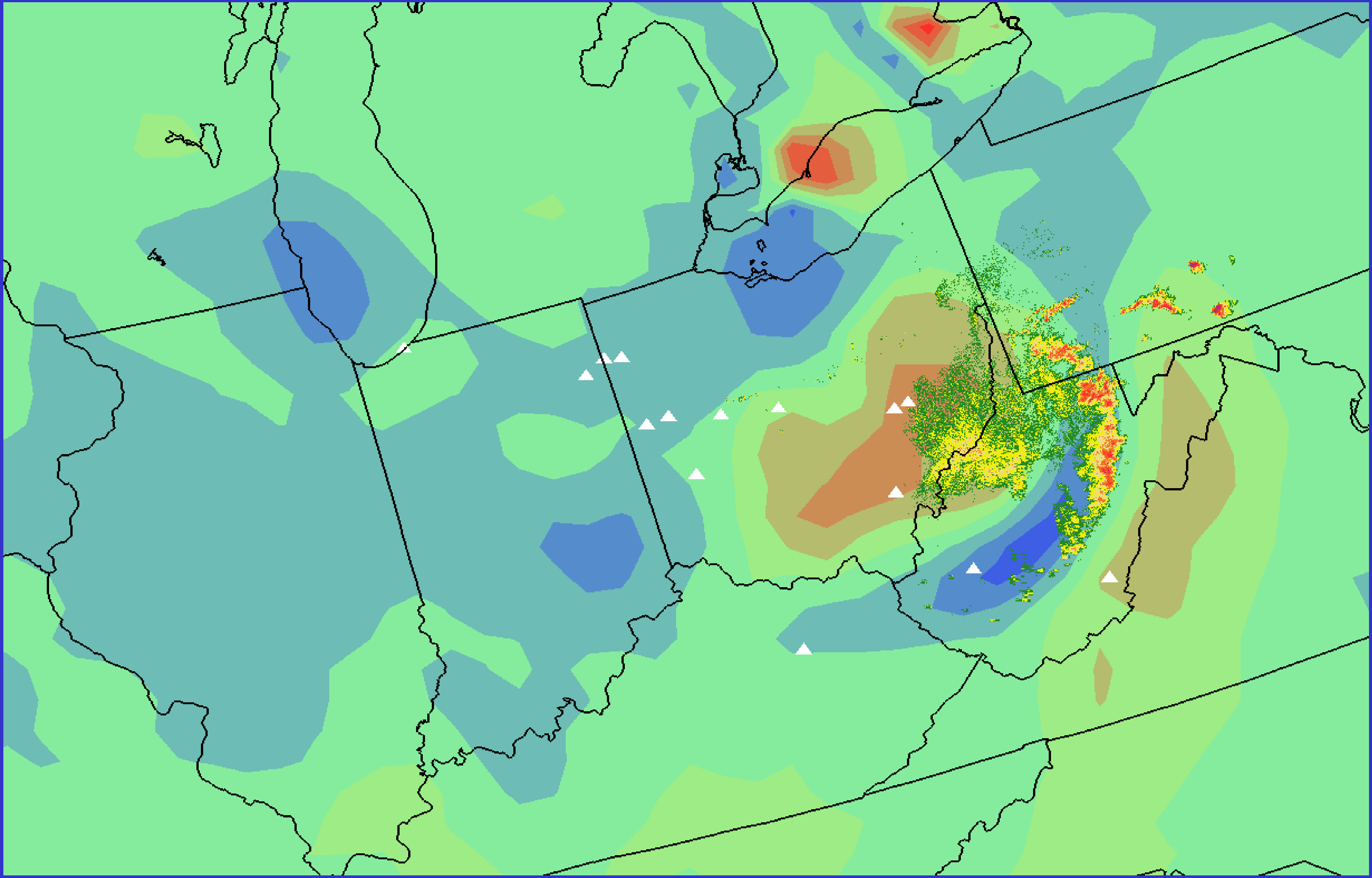
Mature Phase: VV Difference





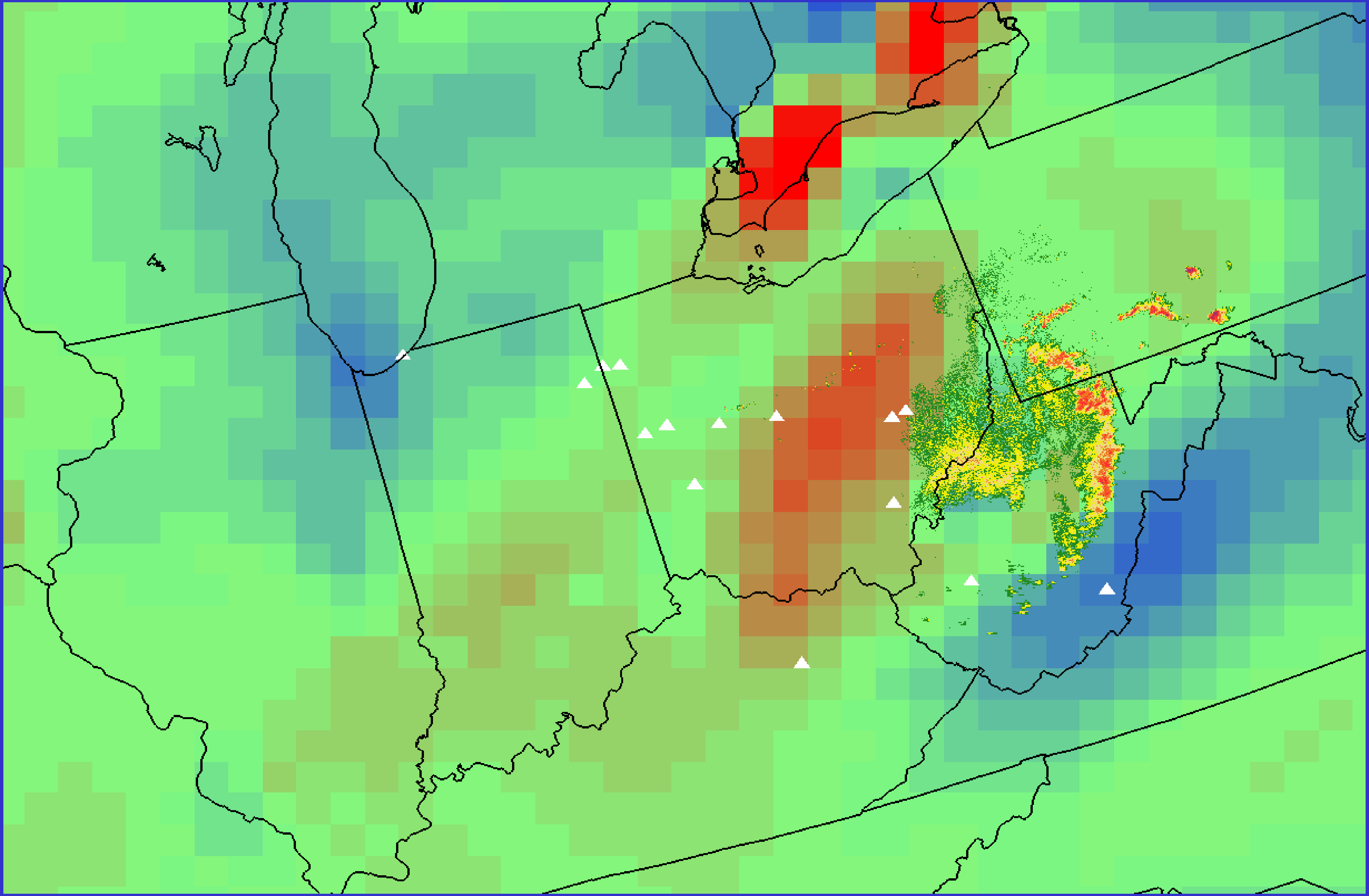
2100 UTC 29 June 2012

Mature Phase: VV Difference



1800-2100 UTC 29 June-0000 UTC 30 June

Mature Phase: Theta-e Advection



1800-2100 UTC 29 June-0000 UTC 30 June

Discussion

- Ascending front-rear flow overlying strong, deep cold pools rearward of the leading convective storm lines:
  - induces the development of horizontal vorticity cells on the storm's rear flank that channel drier mid-tropopheric air forward toward leading edge of the MCS.
  - results in the development of an elevated rear-inflow jet that interacts with the leading line storms of the MCS to produce widespread downburst activity.
- Highest wind gusts were observed near the apex of the bow echo where rear inflow was strongest.

Conclusions

- The lower-upper tropospheric vertical velocity difference and mid-tropospheric theta-e advection have been found to effectively indicate the favorability of an MCS to evolve into a SCW.
  - detects upper tropospheric upward/lower tropospheric downward vertical velocity couplets to the rear of leading convective storm lines of the mature MCSs
- The combined use of ΔVV and $\mathbf{V} \cdot \nabla\theta_e$ parameters shows potential as a short term SCW prediction technique.

Future Work

- Further observational data analysis in which temporal and spatial patterns, both horizontal and vertical, of NWP model-simulated VV and theta-e advection fields will be compared to patterns of satellite and radar observed severe wind-producing convective storm systems.
- Historical simulation of 30-km resolution Climate Weather Research and Forecasting (CWRF) model (Liang et al. 2012) data in comparison with 32-km North American Regional Reanalysis (NARR) and 13-km Rapid Refresh (RAP) model data will be conducted to infer any new signals of SCW occurrence.

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