Variability of the Influence of Convection on Conveyor Belts: Development of Conceptual Models and Forecast Methodologies

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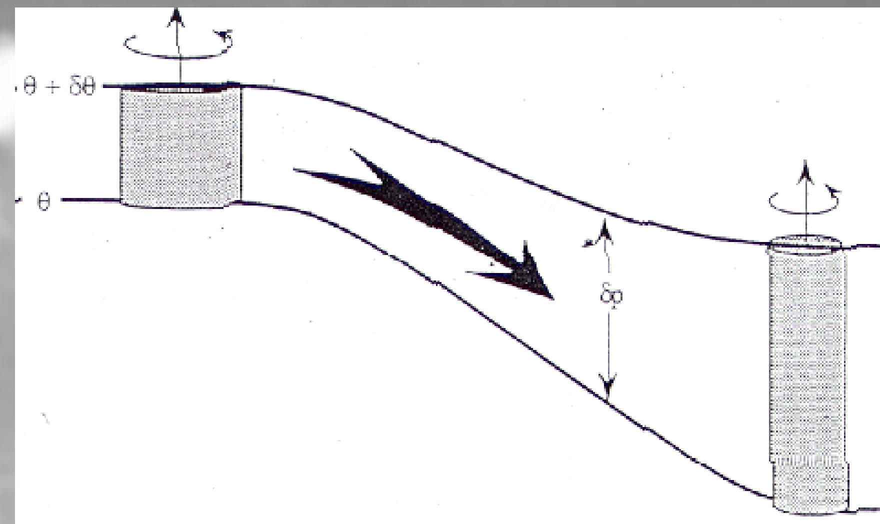
Question

- **What role can convection play in the physical processes that create snowfall further to the north?**
  - Motivated by AFDs that refer to "robbing" or "stealing" moisture
  - Does warm-sector convection aid or inhibit the development of snowfall further north?
  - How can convection influence the balance of processes that create snowfall?
  - Is convection always the dominant source of model forecast errors in these situations?
  - Previous work by Brennan and Lackmann (2006), Mahoney and Lackmann (2007), and Baxter (2006) examine the role of N-S oriented convection, this case features E-W oriented convection

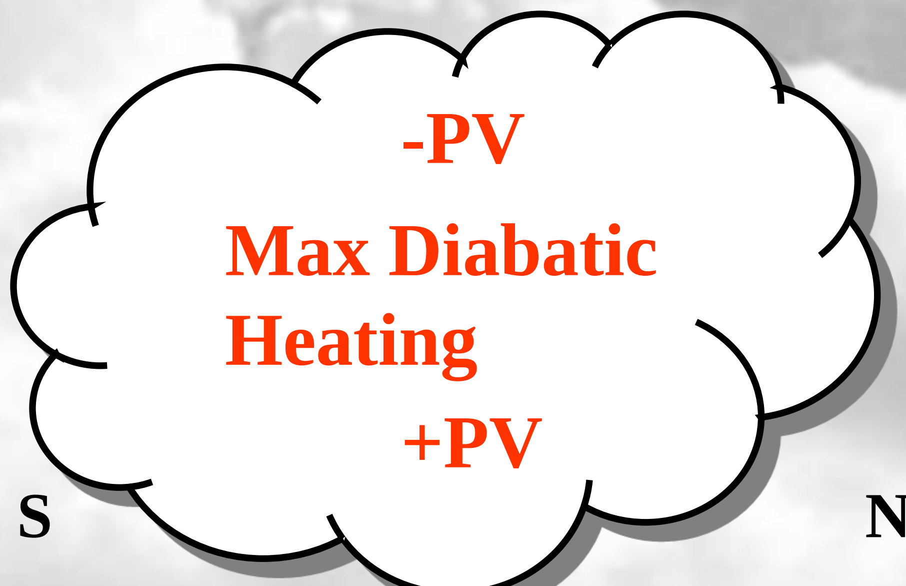
Definition of Isentropic Potential Vorticity (IPV):

$$IPV = -g \frac{\left(\zeta_\theta + f\right)}{\frac{\partial P}{\partial \theta}}$$



- IPV is conserved for flow that is frictionless and adiabatic

- IPV will be created beneath areas of diabatic heating and destroyed above regions of diabatic heating



The Invertability Principle

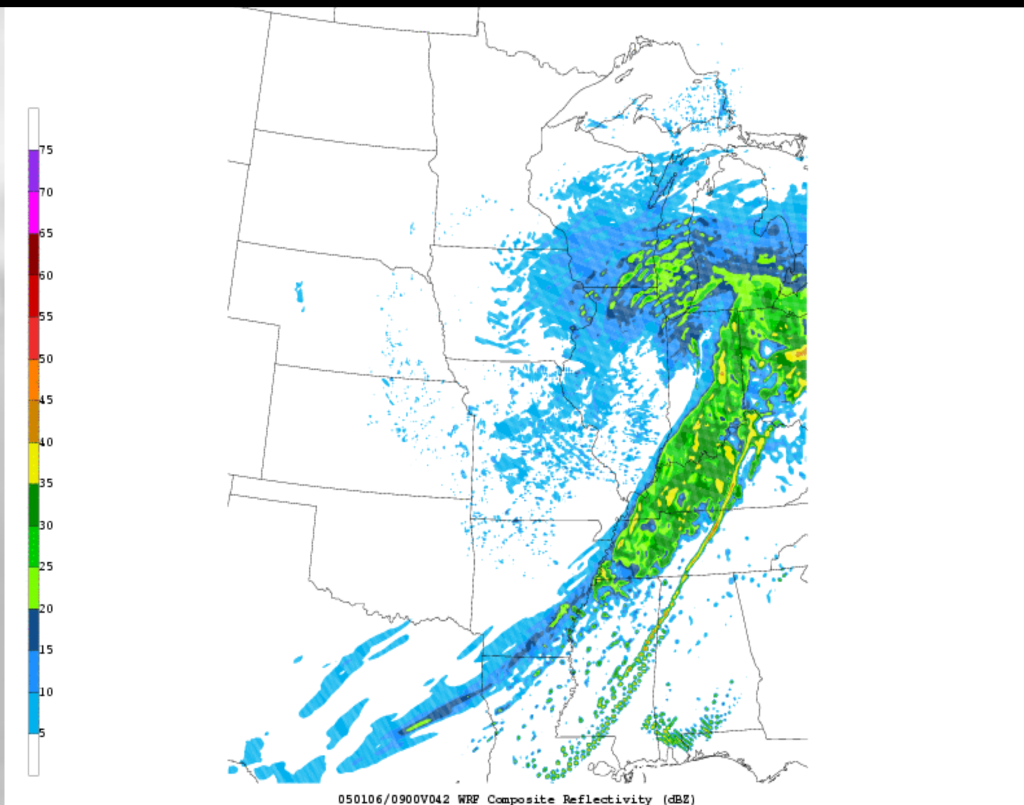
- It is possible to recover the wind and height fields from the full IPV field (PV inversion), or from a particular IPV anomaly (piecewise PV inversion)
- The wind and height fields recovered will not contain unbalanced motions
- The wind and height fields are said to be “induced” by the IPV anomaly.
  - The influence of a PV anomaly spreads both vertically and horizontally, and can be for long distances
- This principle allows us to implicitly analyze the impact a diabatically-generated PV anomaly will have on wind, and this can lead to influences on such things as areas of moisture, lift, and instability
- This makes it a very useful technique for analyzing the relationship between precipitation and snowfall further north

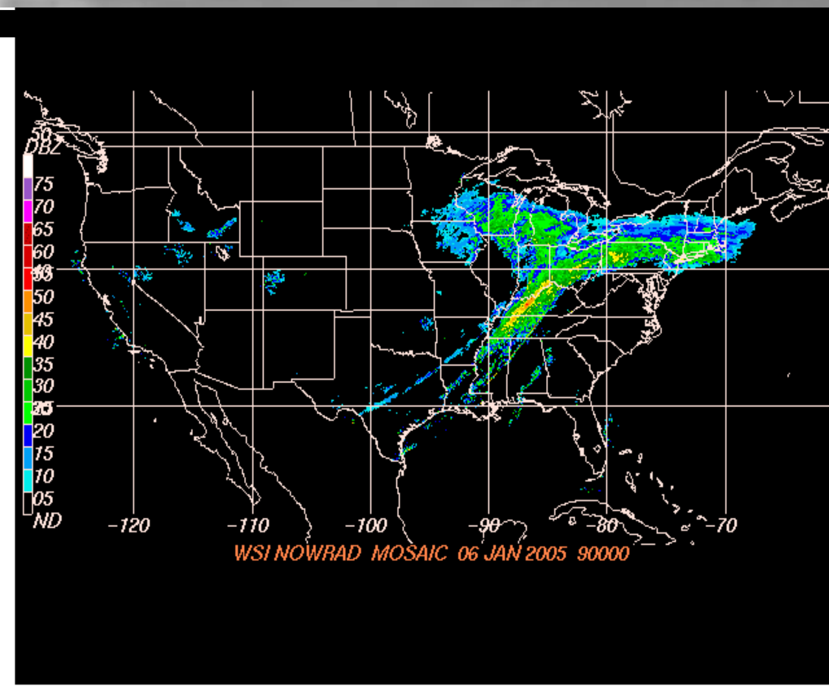
Methodology

- **Jan 4-6 2005**
- 48 hour simulations were performed using the WRF-ARW
    - Horizontal Domains: 36-12-4 km, two-way nesting
    - Vertical Resolution: 50 levels, model top of 100 mb
    - Initial and Lateral Boundary Conditions: NARR - 32 km, 45 layers, updated every 3 hrs
    - Lin et al., RRTM, Dudhia, Monin-Obukov, Thermal Diffusion, YSU PBL, Kain-Fritsch (on two outermost domains only)
- WRF-ARW simulations were compared with NARR data and Eta forecasts
- Piecewise inversions performed on the NARR and WRF done in four layers, 900 to 500 hPa (cyclonic PV), 975 to 500 hPa (cyclonic PV), 450 to 175 hPa (cyclonic PV), and 450 to 175 hPa (all PV)

WRF Simulated Reflectivity and Observed Radar

Case Example, Jan 4-6, 2005





18Z Jan 04 through 09Z Jan 06

Synoptic Overview

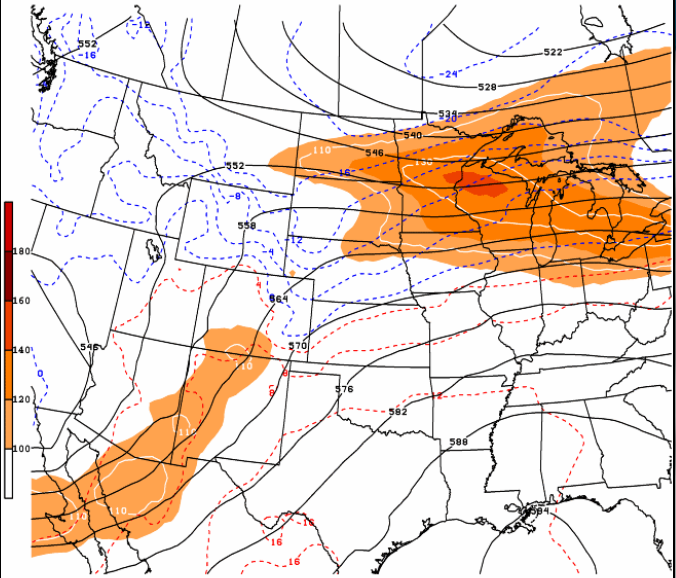


Fig 2a. 1200 UTC 4 Jan. 300 hPa jet shaded and controued in white. 500 hPa heights in black, and h850 hPa temperatures dashed.

12Z
01/04

00Z
01/05

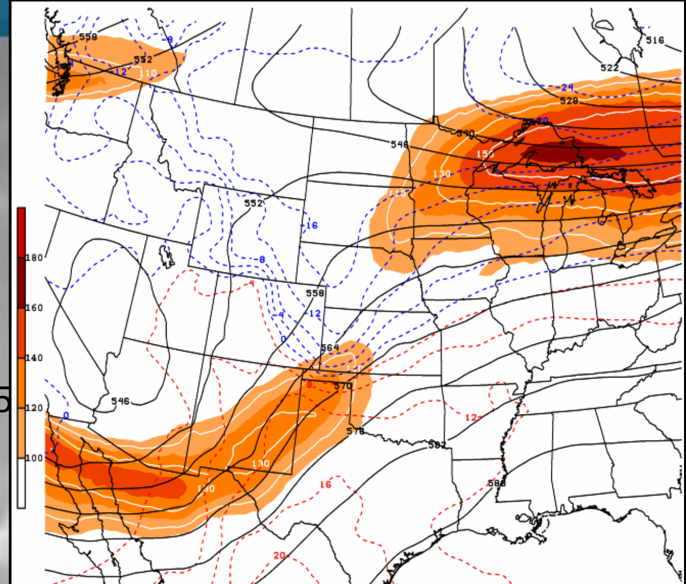


Fig 2b. Same as figure 2a for 0000 UTC 5 Jan.

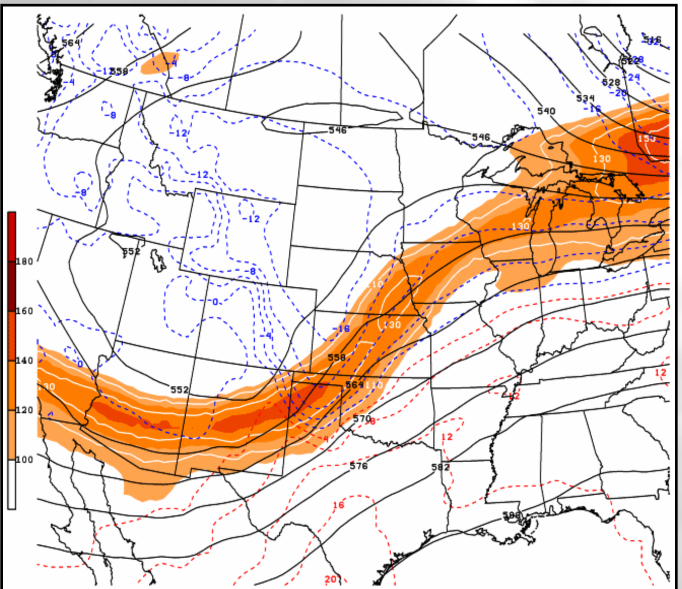


Fig 2c. Same as figure 2a, but for 1200 UTC 5 Jan.

12Z
01/05

00Z
01/06

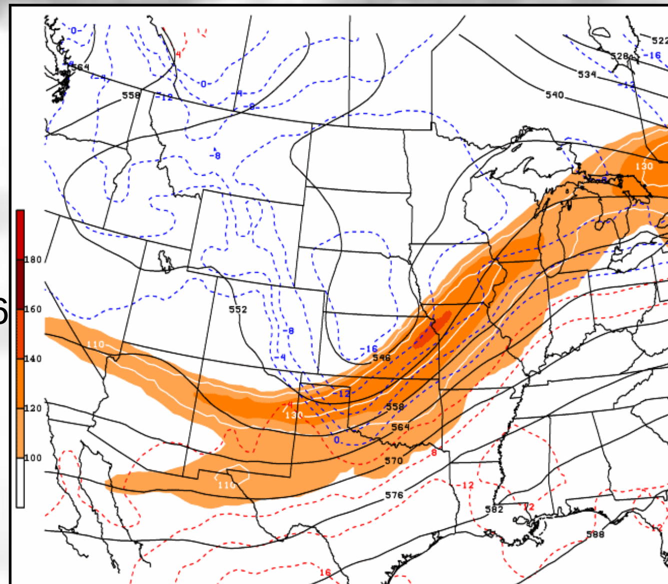


Fig 2d. Same as figure 2a, but for 0000 UTC 6 Jan.

WRF and NARR 3- hr Precipitation

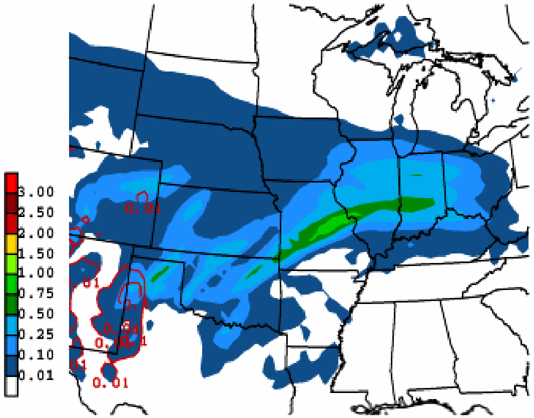


Fig 3a. WRF 3-hr accumulated precipitation. Convective precipitation contoured in red. Valid 0600 UTC Jan 05.

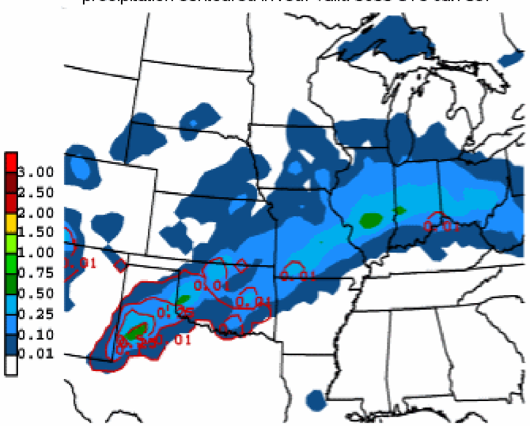


Fig 3b. NARR 3-hr accumulated precipitation. Convective precipitation contoured in red. Valid 0600 UTC 5 Jan.

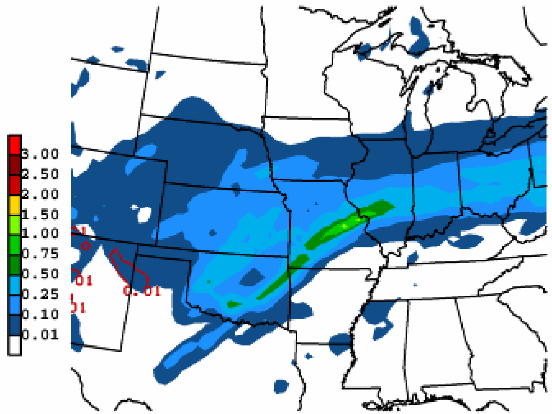


Fig 3c. Same as figure 3a, but valid 0900 UTC 5 Jan.

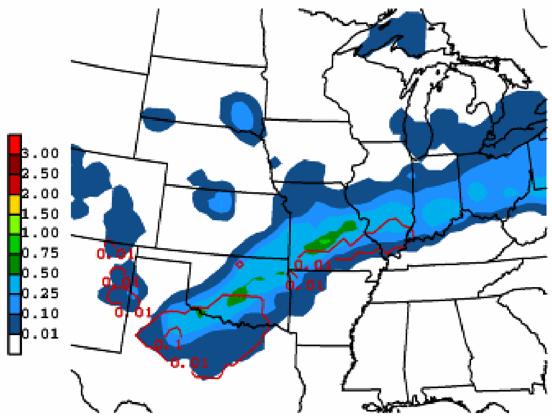


Fig 3d. Same as figure 3b, but valid 0900 UTC 5 Jan.

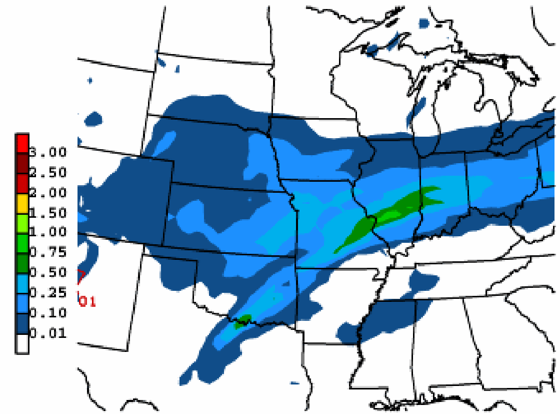


Fig 3e. Same as figure 3a, but valid 1800 UTC 5 Jan.

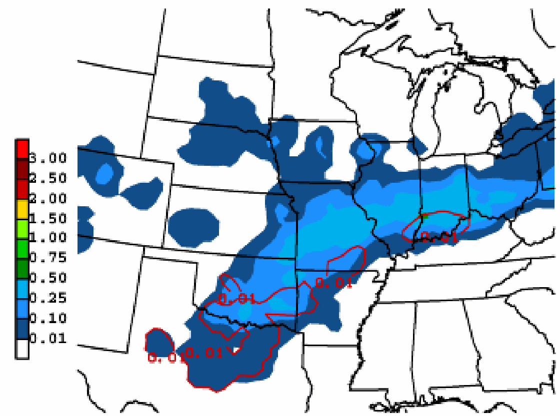


Fig 3f. Same as figure 3b, but valid 1800 UTC 5 Jan.

WRF

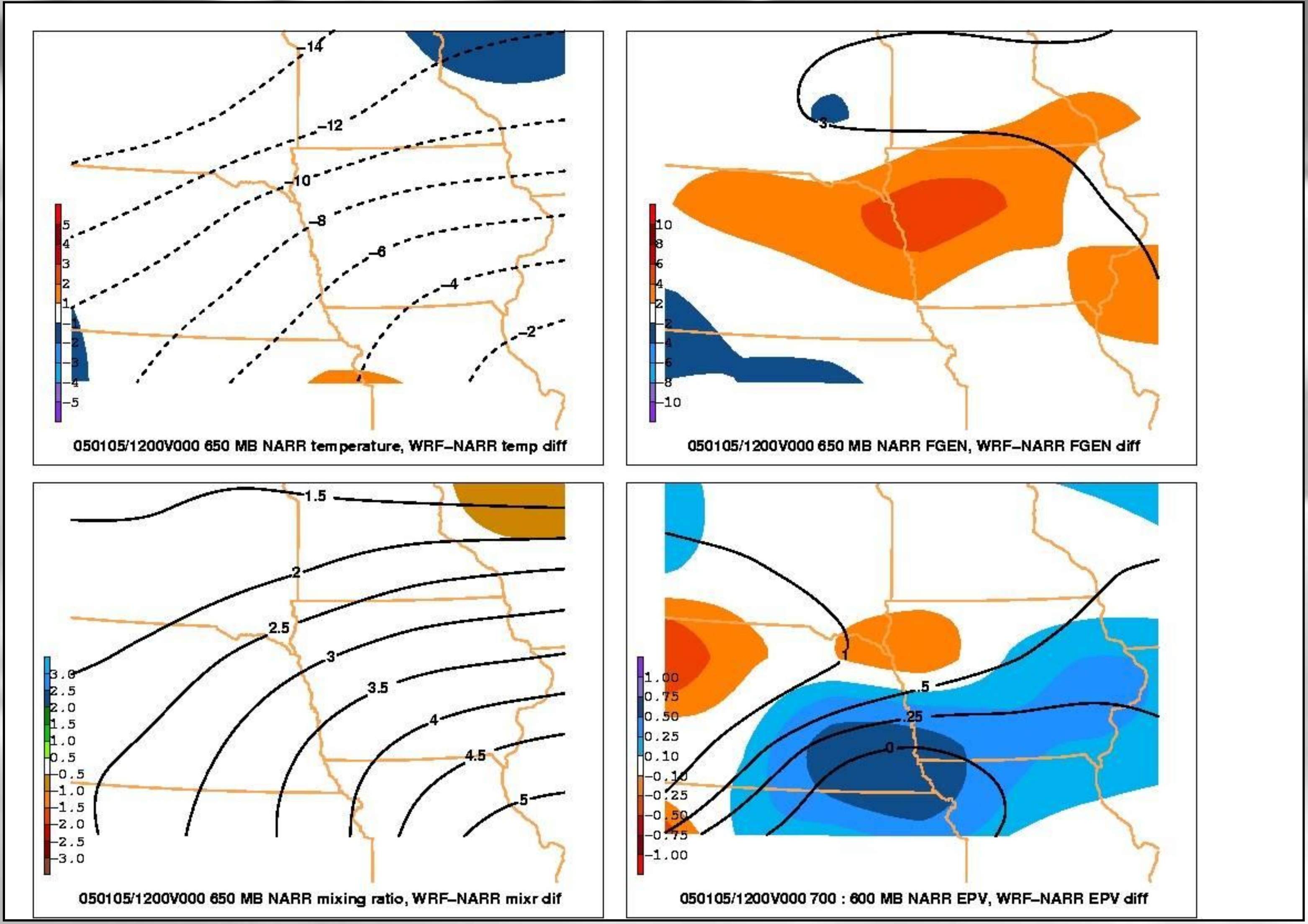
NARR

0600 UTC

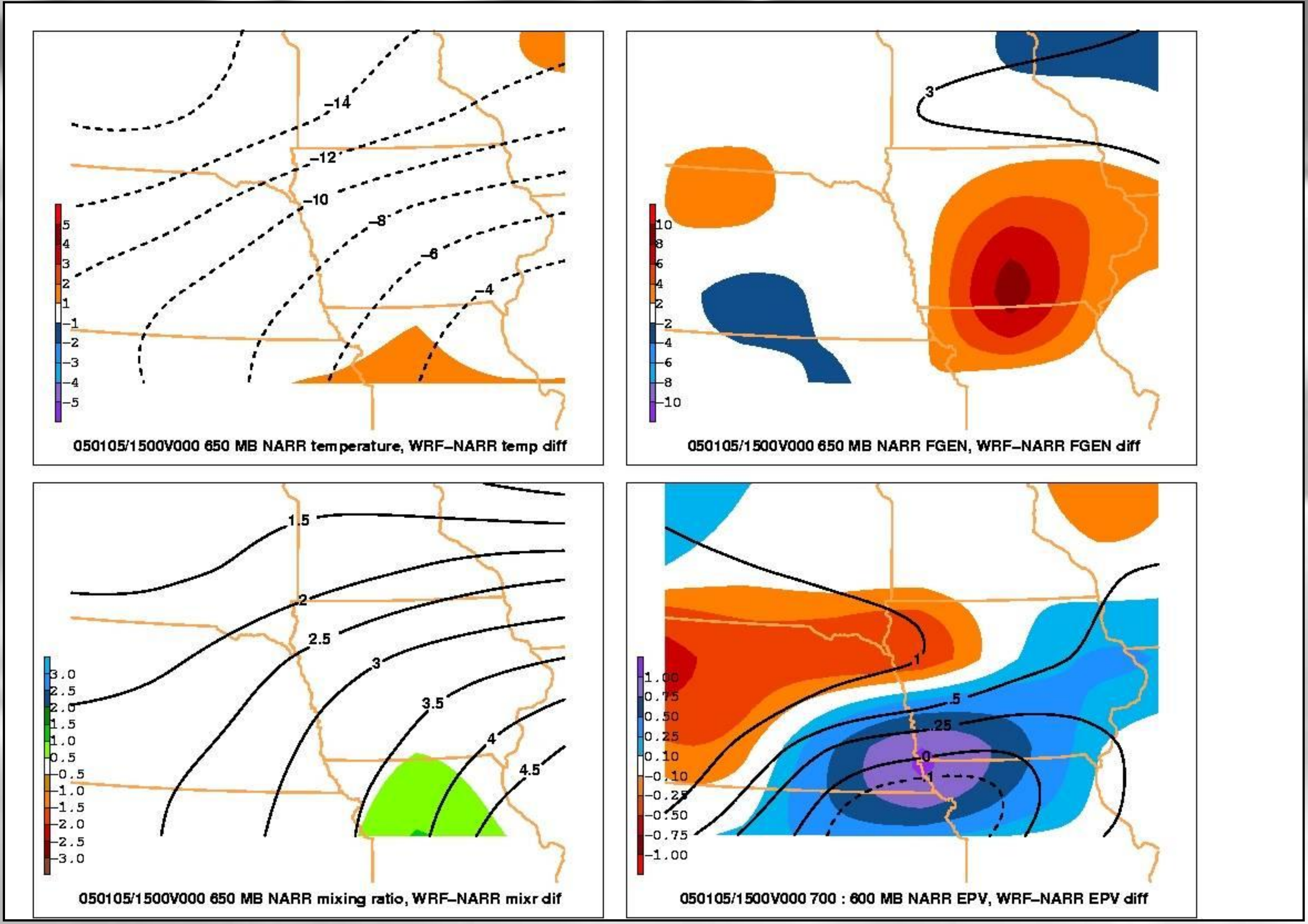
0900 UTC

1800 UTC

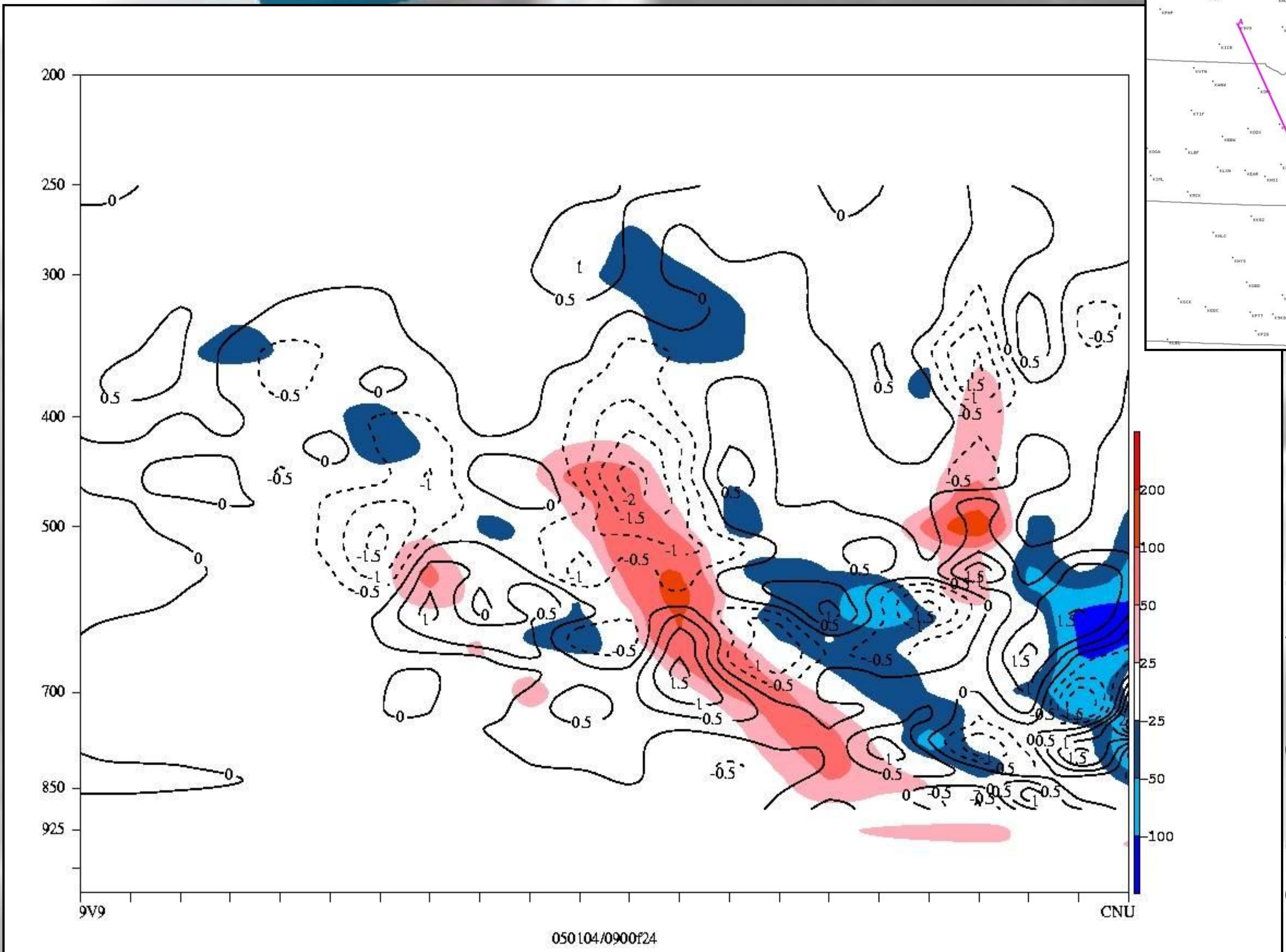
1200 UTC Frontogenesis and EPV compare

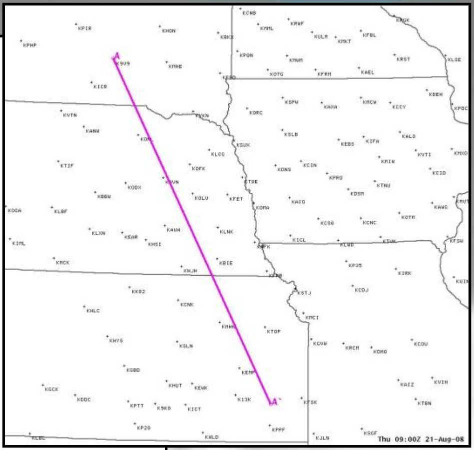


1500 UTC Frontogenesis and EPV compare



WRF 0900 UTC Cross Section





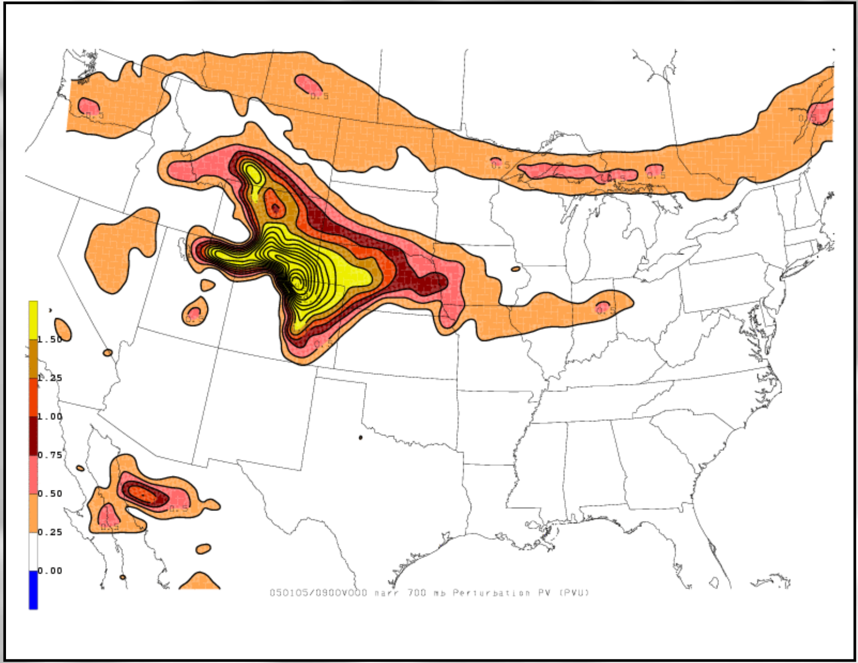
Diabatic Heating (Cooling) shaded

PV tendency due to Diabatic Heating (Cooling) contours

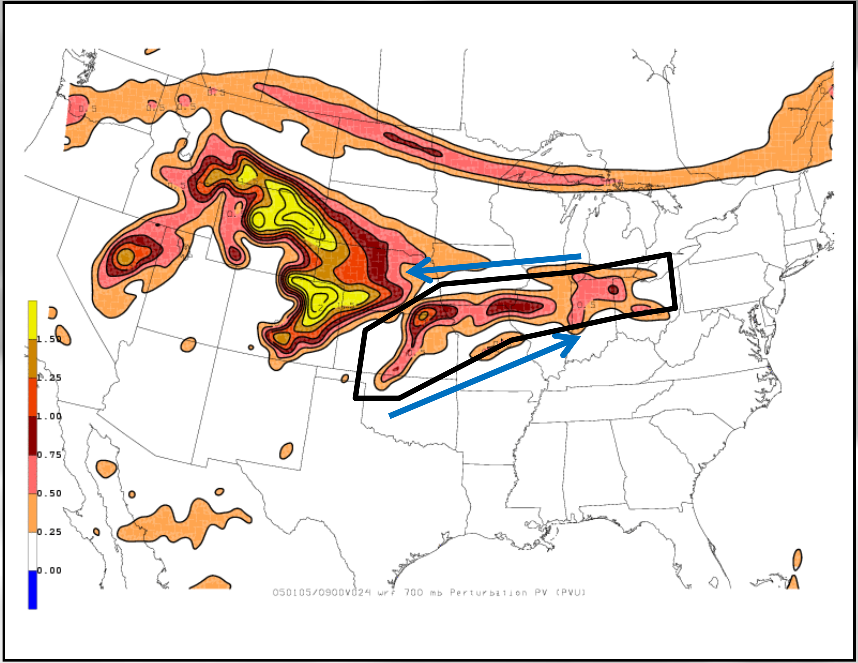
Evolution of lower level PV

700 hPa 0900 UTC

NARR



WRF



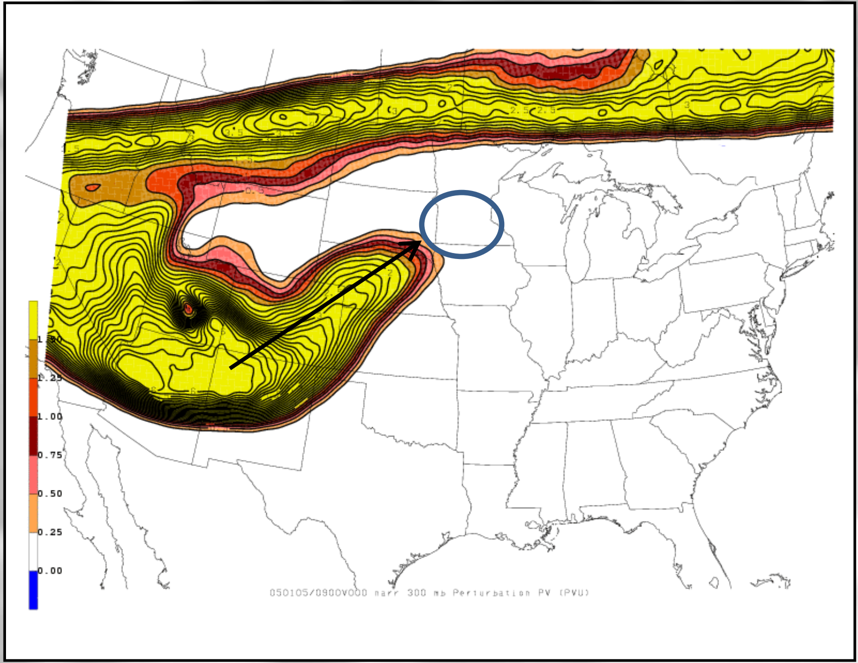
- Little convective PV anomaly indicated
- Would suggest little in the way of induced flow

- Deep convective PV anomaly from KS into MO
- Assumed induced flow allows stronger low/mid level flow

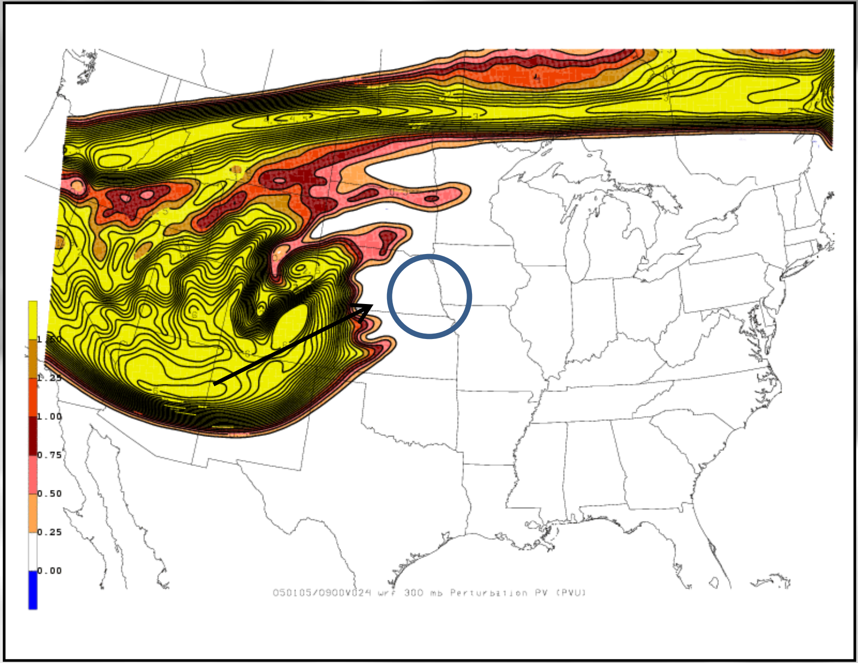
Evolution of upper level PV

300 hPa 0900 UTC

NARR



WRF



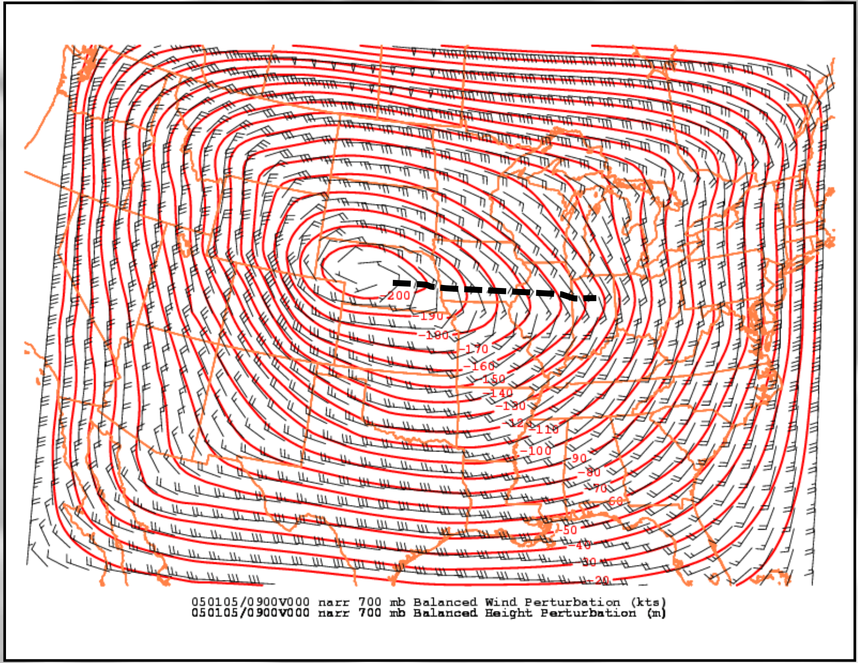
- Initial short-wave trough moving into the northern plains
- Moving into region of higher static stability

- Continued convection destroying upper level PV
- Allows for an extended period of PV advection over NE/KS

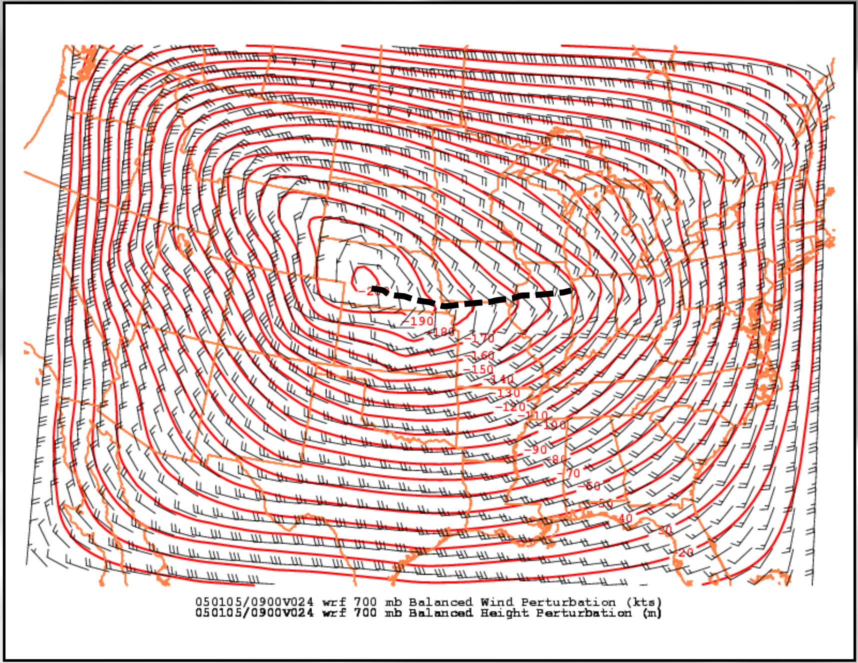
700 hPa heights and winds perturbation from cyclonic PV from 975 to 500 hPa

0900 UTC

NARR



WRF

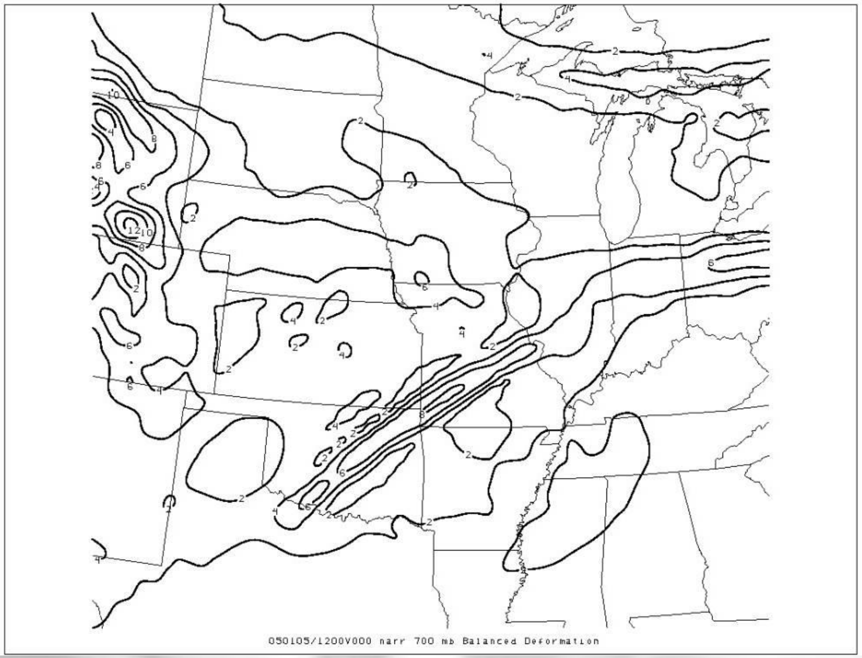


- Axis is farther north
- More cyclonic flow at 700 hPa

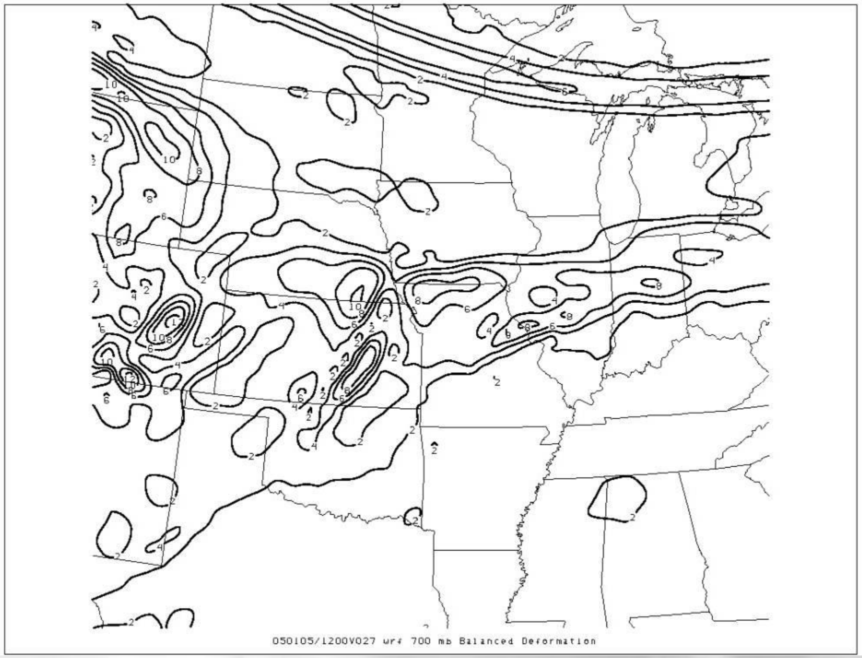
- Farther south axis
- More convergence than NARR

Deformation at 700 hPa at 1200 UTC

NARR



WRF

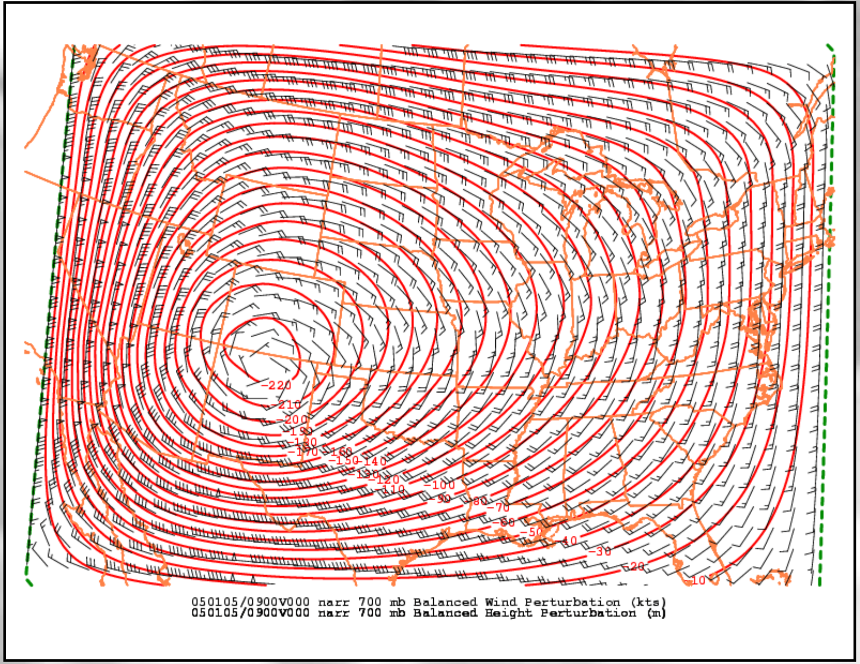


- Persistent convection/precipitation over KS/NE in the WRF led to PV development in the model
- Induced flow from PV anomaly allowed for stronger confluence in the wind field and associated significantly stronger deformation

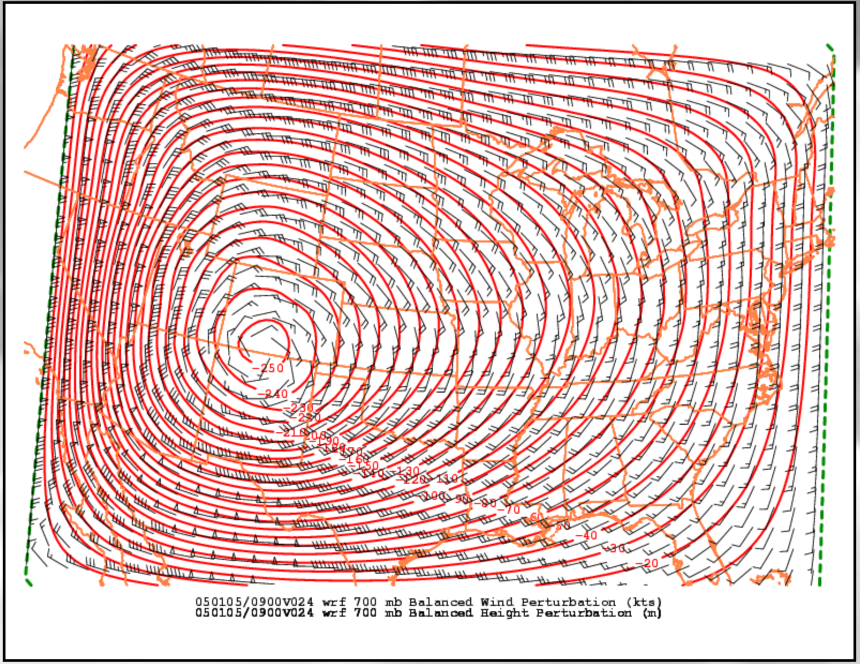
700 hPa heights and winds perturbation from cyclonic PV from 450 to 175 hPa

0900 UTC

NARR

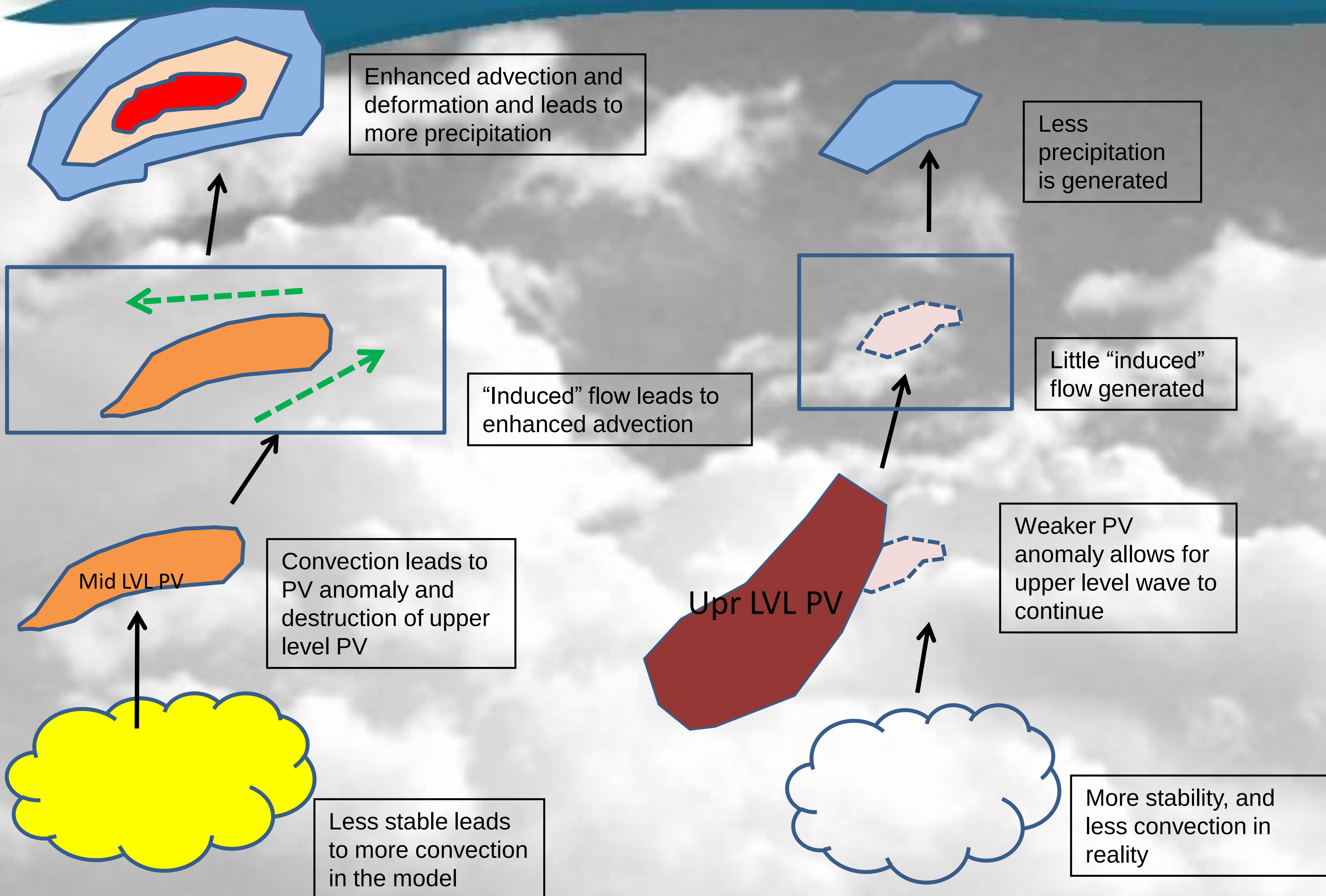


WRF



- Only small differences in heights and winds from NARR to WRF
- Suggests main difference is in lower level cyclonic PV

Draft Conceptual Model



Conclusions

- Convection does play a role in the evolution of winter weather systems!
  - Appears role of convection is variable from system to system
  - Convection appears to effect the distribution of moisture instead of "robbing"
- Evaluating the accuracy of a 48 h forecast that features multiple episodes of stratiform and convective precipitation remains a significant forecast challenge
- The use of PV Thinking and PV Inversion on the operational forecast desk could lead to a greater understanding of how individual PV features are impacting one another
  - This would allow for a greater understanding of the differences between two different models
  - Increased understanding could lead to better adjustment of model solutions based upon expected or incipient precipitation development
- Future work will involve setting up a system for inversion using a locally run WRF-ARW at local Weather Service office

The End

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For more information on the use of PV in operational forecast see AWOC Winter 5.1 A Review of QG Theory and Potential Vorticity
http://www.wdtb.noaa.gov/courses/winterawoc/IC5/lesson1/player.html

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