A Comparison of Mid-Level Frontogenesis to Radar-Indicated Heavy Snowbands

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Overview

- Background
- Motivation
- Data (10 cases)
- Methodology
- Results
- Conclusions

Background

- Banded Snow Parameters
  - Frontogenesis
    - 600mb-850mb
  - Deformation
    - Col Point – region where winds ~ 0
  - Saturation equivalent potential vorticity < .25 PVU
    - Moist symmetric & convective instability
  - Trowal
  - Isentropic Lift

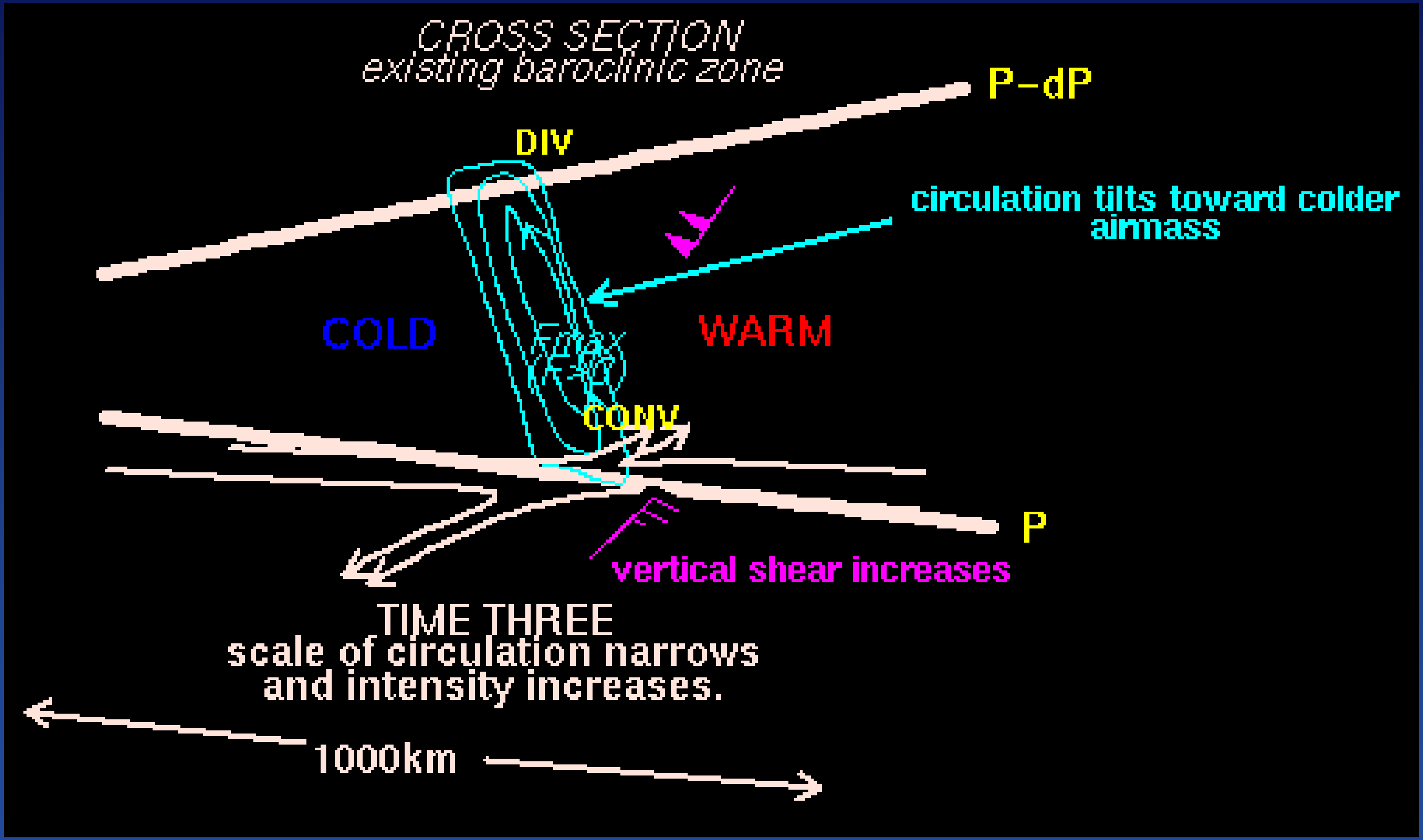
Frontogenesis

$$F = \frac{1}{|\nabla_p \theta|}\left[-\left(\frac{\partial \theta}{\partial x}\right)^2 \frac{\partial u}{\partial x} - \frac{\partial \theta}{\partial y}\frac{\partial \theta}{\partial x}\frac{\partial v}{\partial x} - \frac{\partial \theta}{\partial x}\frac{\partial \theta}{\partial y}\frac{\partial u}{\partial y} - \left(\frac{\partial \theta}{\partial y}\right)^2 \frac{\partial v}{\partial y}\right]$$

- 2D scalar frontogenetic function (Petterssen 1956).

- (Definition) The initial formation of a front or frontal zone, caused by an increase in the horizontal gradient of an airmass property, and the development of the accompanying features of the wind field that typify a front. (American Meteorological Society 2006)

Frontogenesis



(Banacos 2003)

Saturation Equivalent Potential Vorticity (EPV*)

$$EPV^* = g \left[\frac{\partial \theta_{es}}{\partial x}\frac{\partial v_g}{\partial p} - \frac{\partial \theta_{es}}{\partial y}\frac{\partial u_g}{\partial p} - \left(\frac{\partial v_g}{\partial x} - \frac{\partial u_g}{\partial y} + f \right) \frac{\partial \theta_{es}}{\partial p} \right]$$

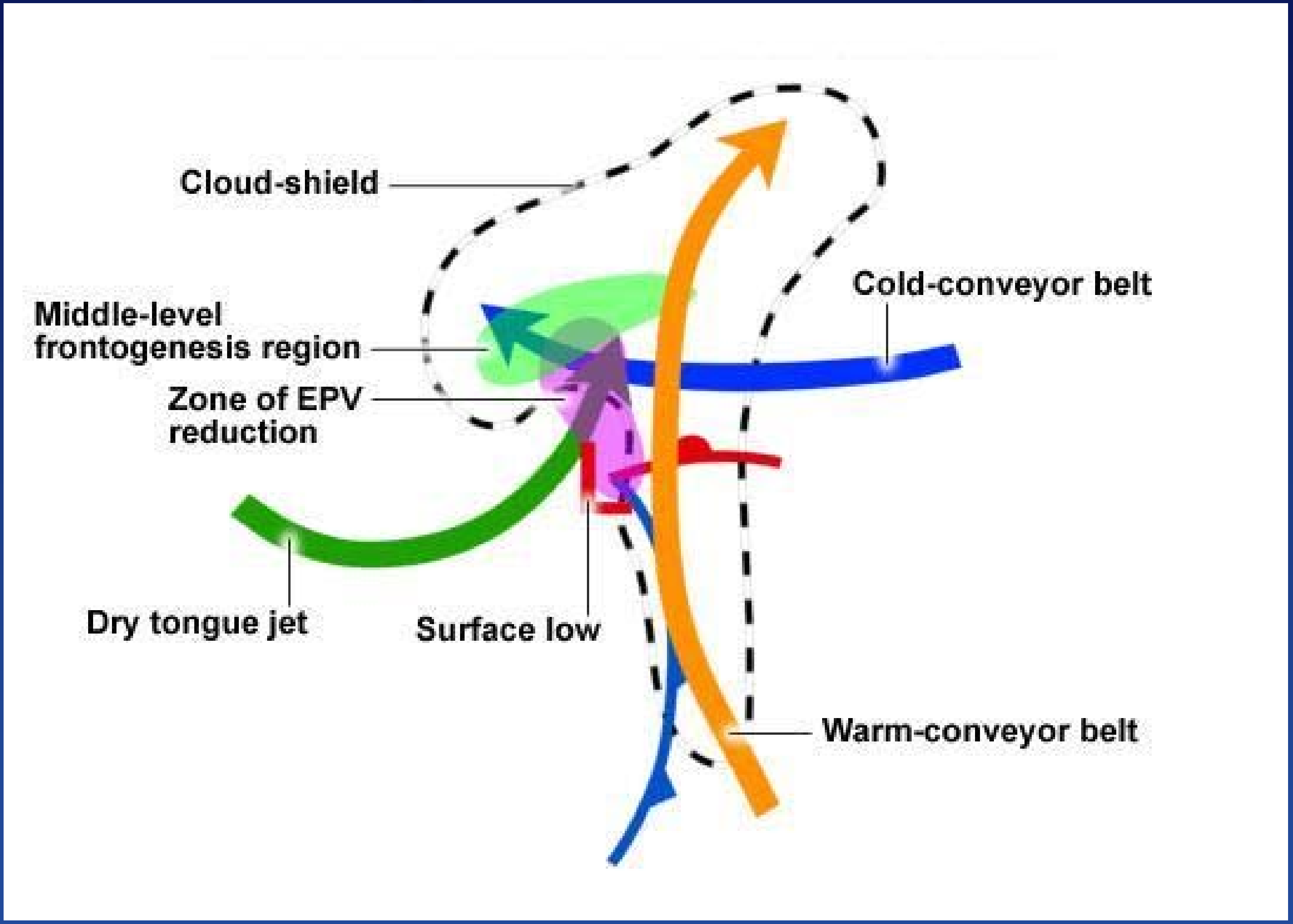
- 3D form to compute grid data (McCann 1995).

- Used to indicate the presence of moist symmetric instability (MSI) and convective instability (CI).
  - Symmetric instability can be thought of as isentropic inertial instability (Holton 2004).
- Release of MSI results in moist slantwise convection (Schultz and Schumacher 1999).

EPV*

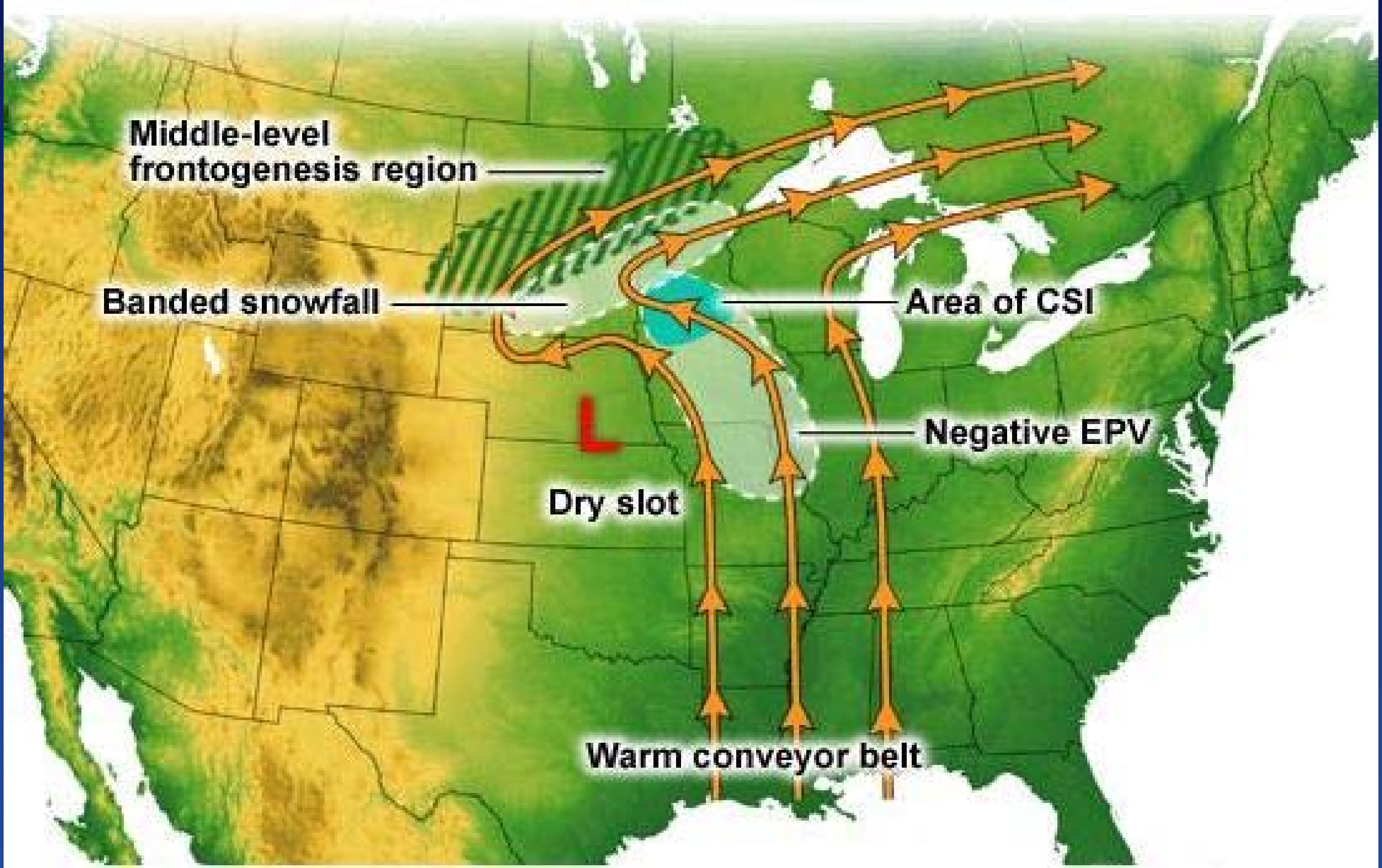
- EPV* < 0, Potential symmetric instability and Convective instability are present (Moore and Lambert 1993).
- EPV* < 0.25 PVU acceptable (Schumacher 2003).
- EPV calculated with θ_{es} rather than θ to diagnose regions of conditional symmetric instability (Schultz and Schumacher 1999).

Conceptual Model #1



(Nicosia & Grumm 1999)

Conceptual Model #2



(The Comet Program)

Motivation

- Is there a specific level or layer of frontogenesis that aligns best with banded heavy snow?
- Which conceptual model is most frequently verified?
  - Is one model better than the other?

Data

- Radar
- Frontogenesis
- EPV*
- Surface Observations

Archived Radar Data

- WSR-88D
  - Obtained from the Iowa Environmental Mesonet, UCAR, and NCDC.
  - Composite imagery available for 7 of the 10 cases.
  - Analyzed using image viewers, GEMPAK, and GRLevel2.

Frontogenesis/EPV*

- Analyzed using 80km Eta/Nam model
  - Model initializations and six hour forecasts displayed using GEMPAK.
  - Obtained from the Iowa Environmental Mesonet (IEM).
  - Frontogenesis units: K/100km/3hrs.
  - EPV* < 0.25 PVU used (Schumacher 2003).

Observational Surface Data

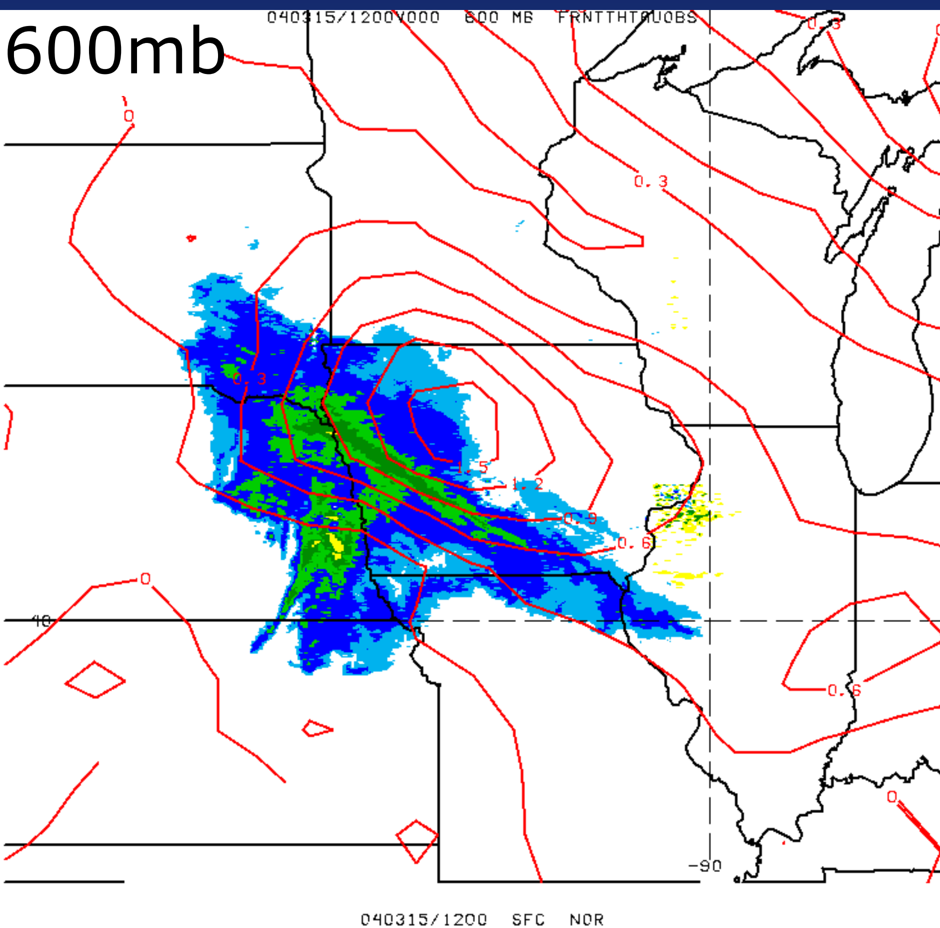
- Verify radar-indicated snowbands.
  - Surface obs., cooperative snow obs., and National Weather Service (NWS) obs.
  - Obtained from IEM, NWS, and the Pennsylvania State University meteorological system.

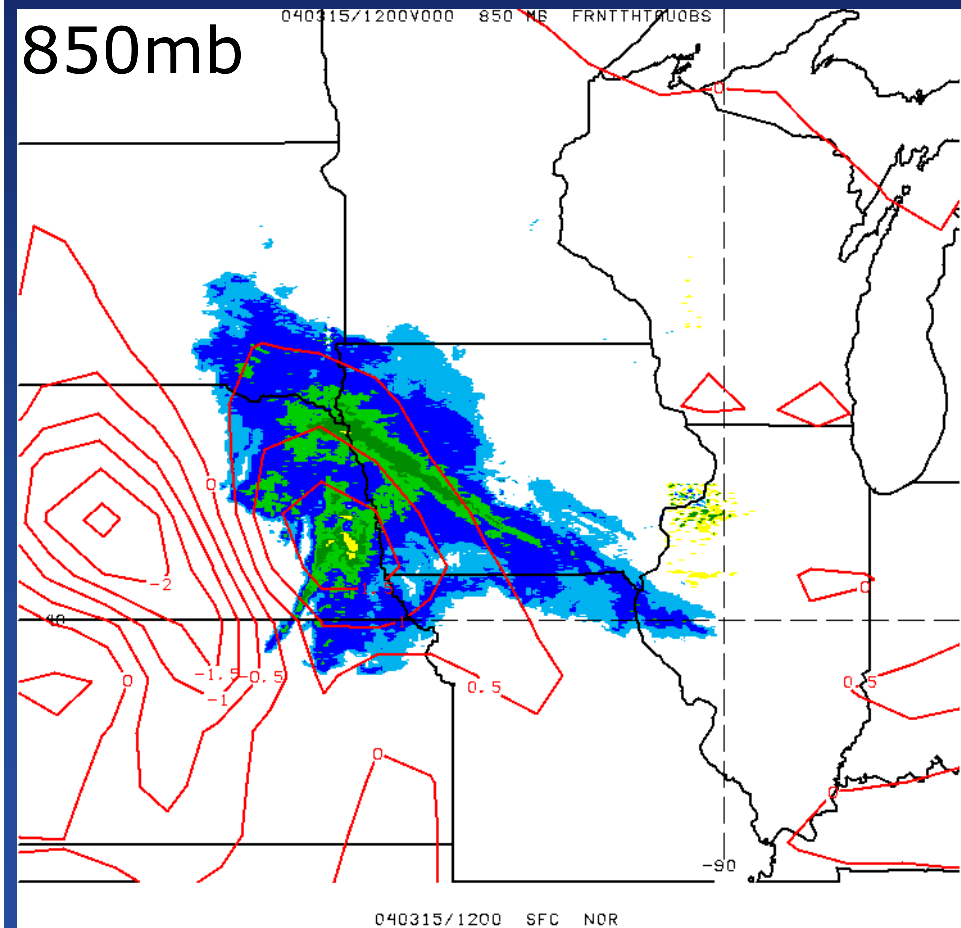
Methodology

- Six pressure levels were used to compare frontogenesis and EPV* (Banacos 2003).
  - 600mb
  - 650mb
  - 700mb
  - 750mb
  - 800mb
  - 850mb

Methodology

- Positive Distance = snowband on warm side of frontogenesis
- Negative Distance = snowband on cold side of frontogenesis



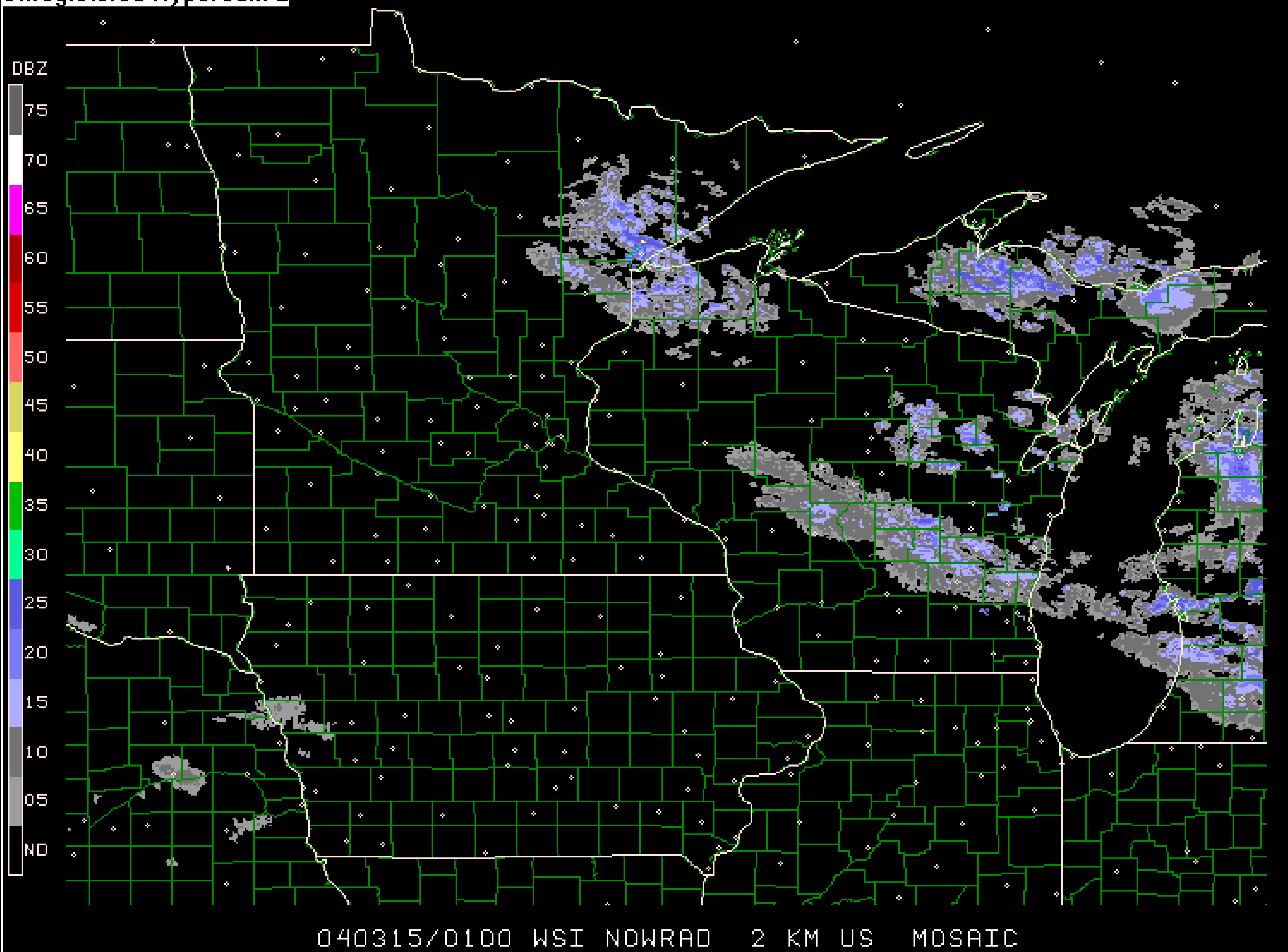


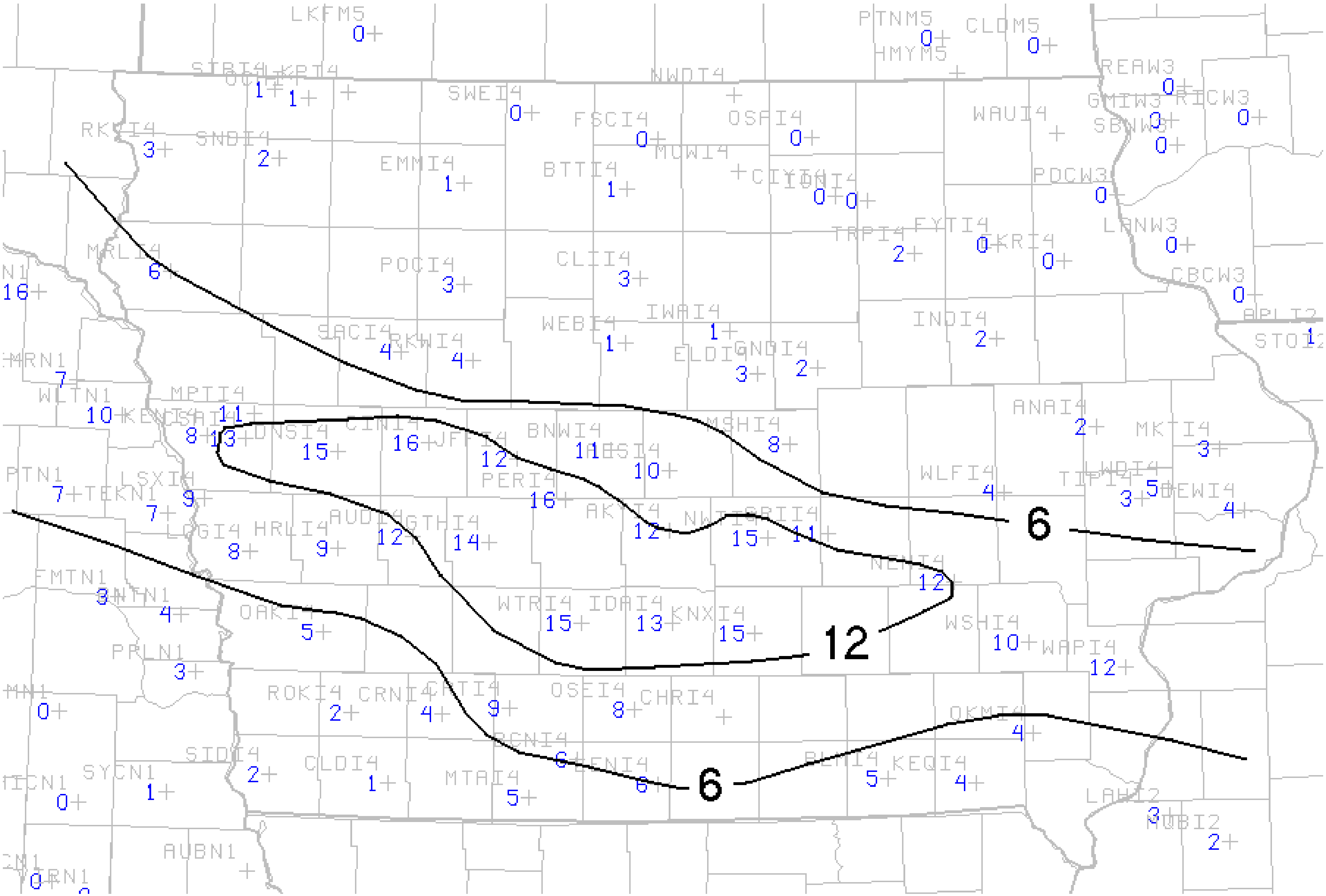
Data

- 10 Cases Analyzed (38 time periods)
  - Jan. 26-27, 1996
  - Dec. 3-5, 1999
  - Jan. 29-30, 2001
  - Nov. 26-27, 2001
  - Dec. 23-24, 2002
  - Feb. 23, 2003
  - Mar. 15-16, 2004
  - Mar. 18-19, 2005
  - Nov. 28, 2005
  - Mar. 15-16, 2006

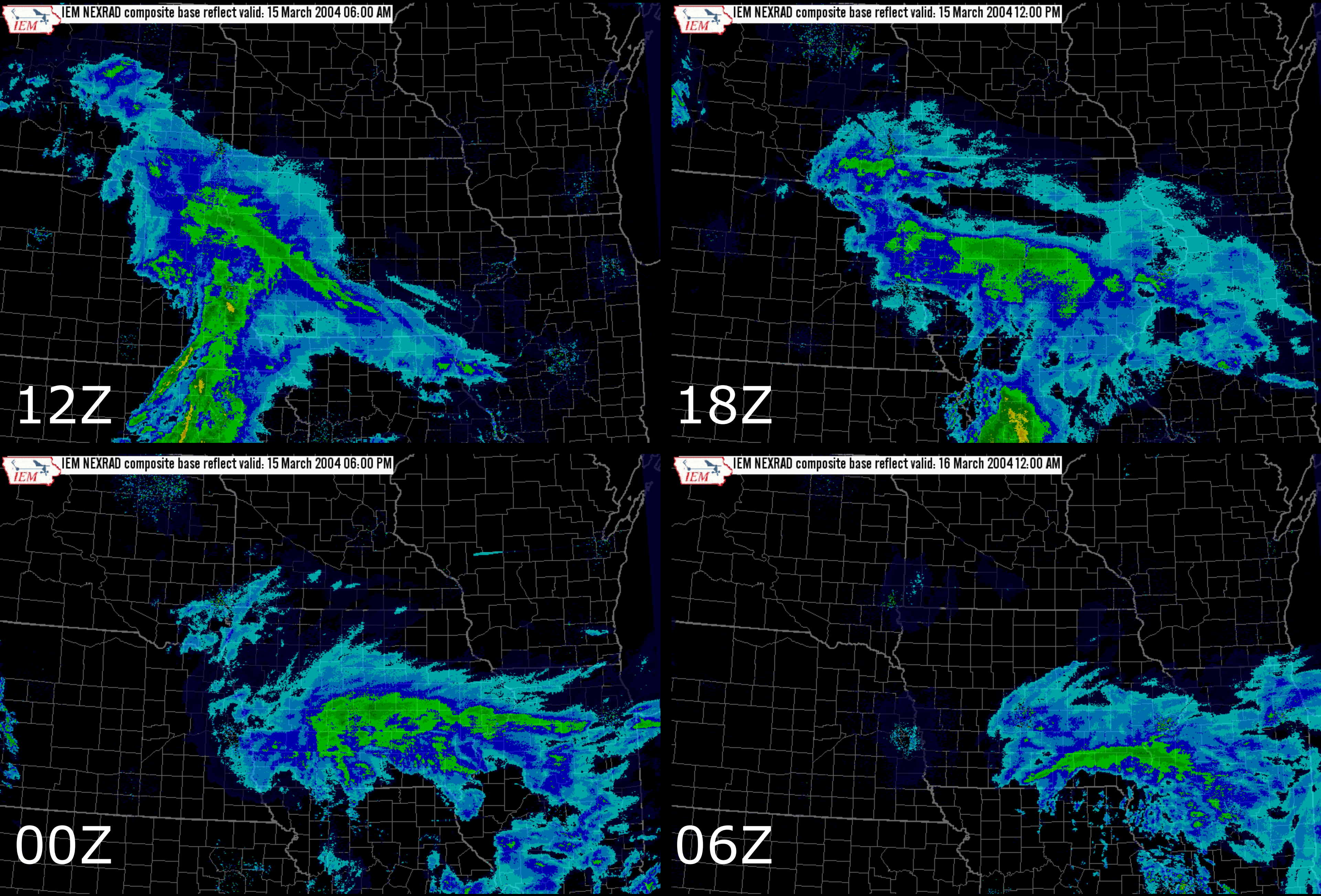
March 15-16, 2004

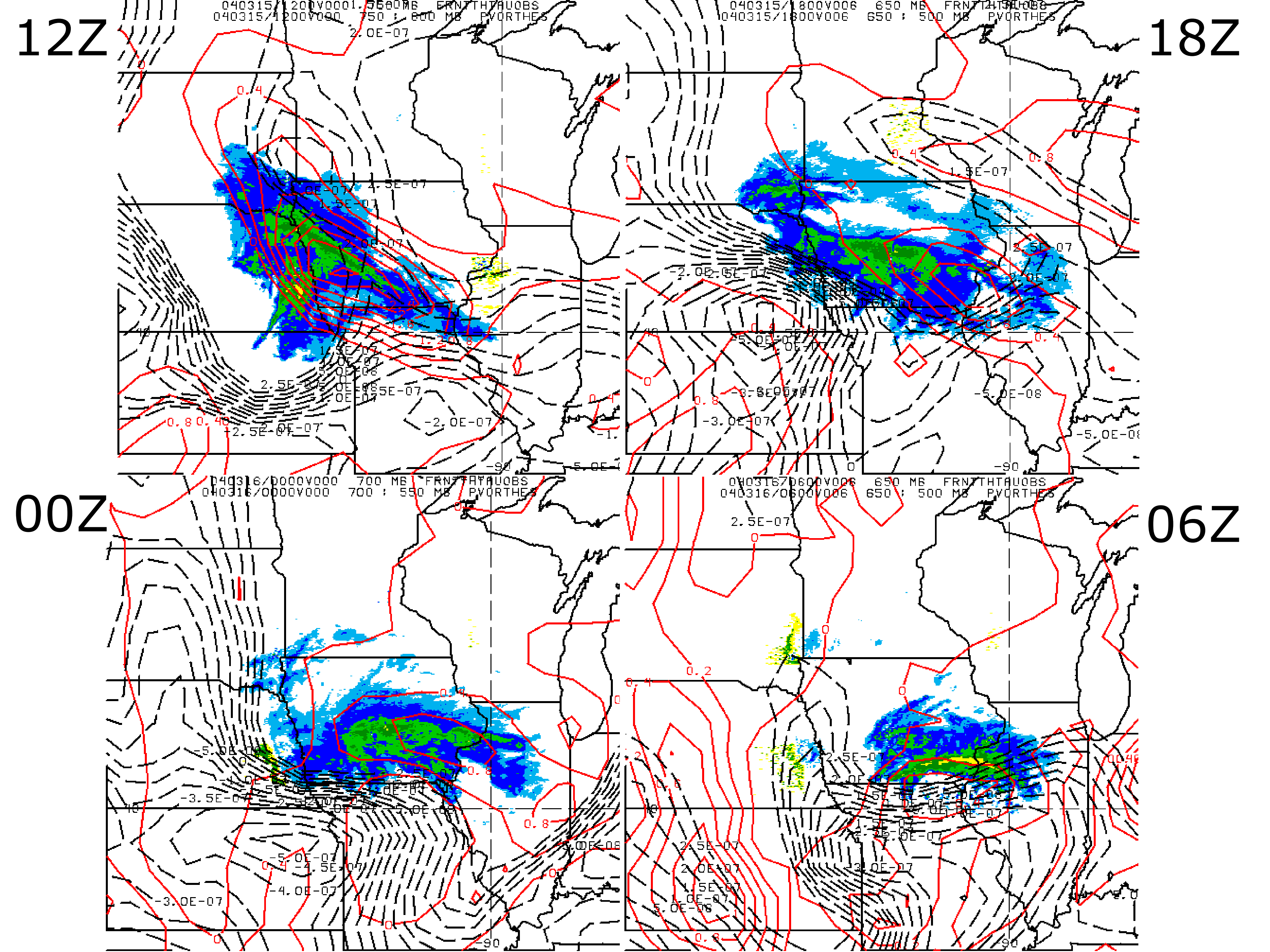
- 4 time periods analyzed.
  - 12Z & 18Z on the 15th.
  - 00Z & 06Z on the 16th.
- Record setting snow day for Des Moines.


DBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
05
ND
040315/0100 WSI NOWRAD 2 KM US MOSAIC

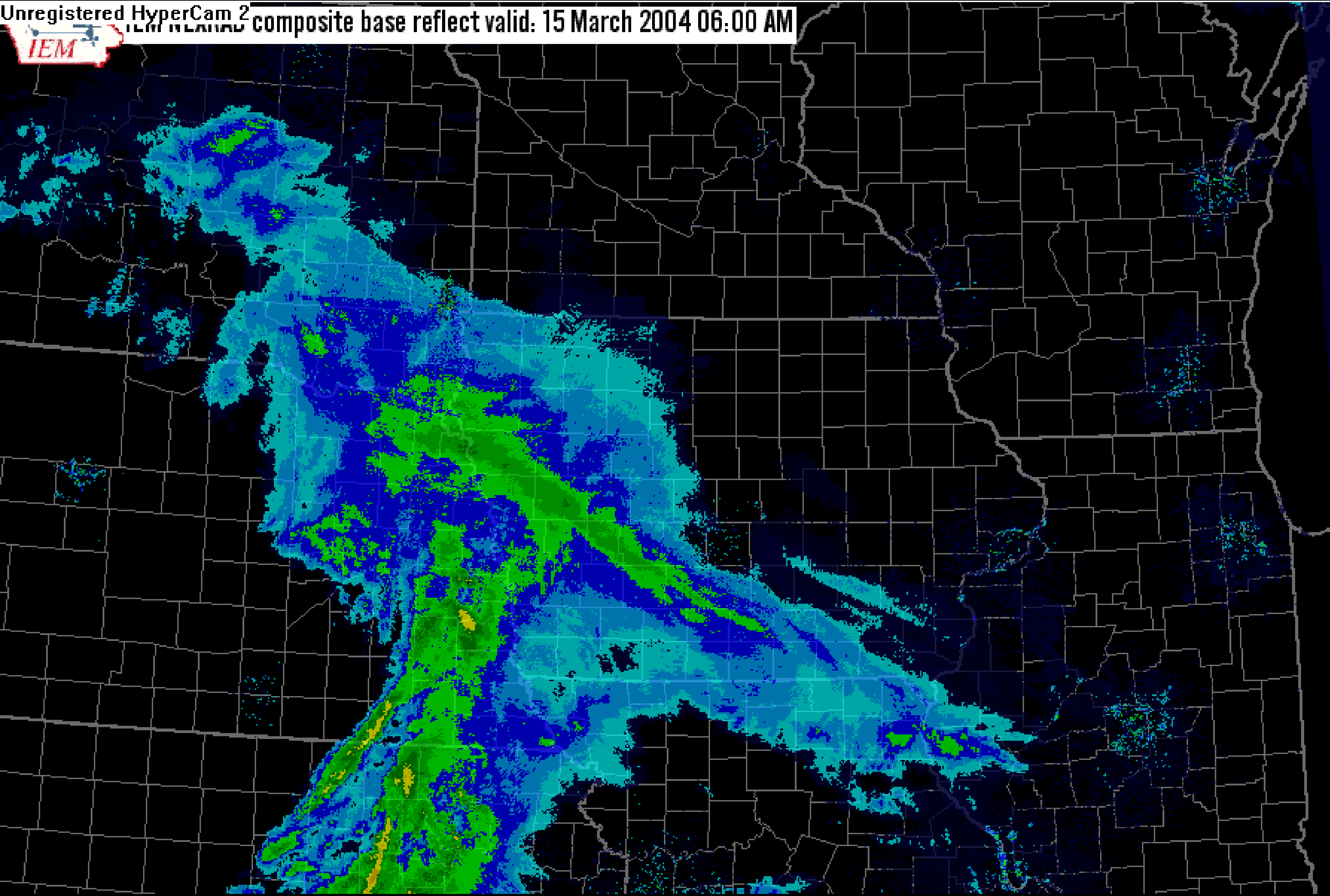


040316/1300 NWS COOP SNOW DEPTH REPORTS [inches]


IEM NEXRAD composite base reflect valid: 15 March 2004 06:00 AM
12Z
IEM NEXRAD composite base reflect valid: 15 March 2004 12:00 PM
18Z
IEM NEXRAD composite base reflect valid: 15 March 2004 06:00 PM
00Z
IEM NEXRAD composite base reflect valid: 16 March 2004 12:00 AM
06Z

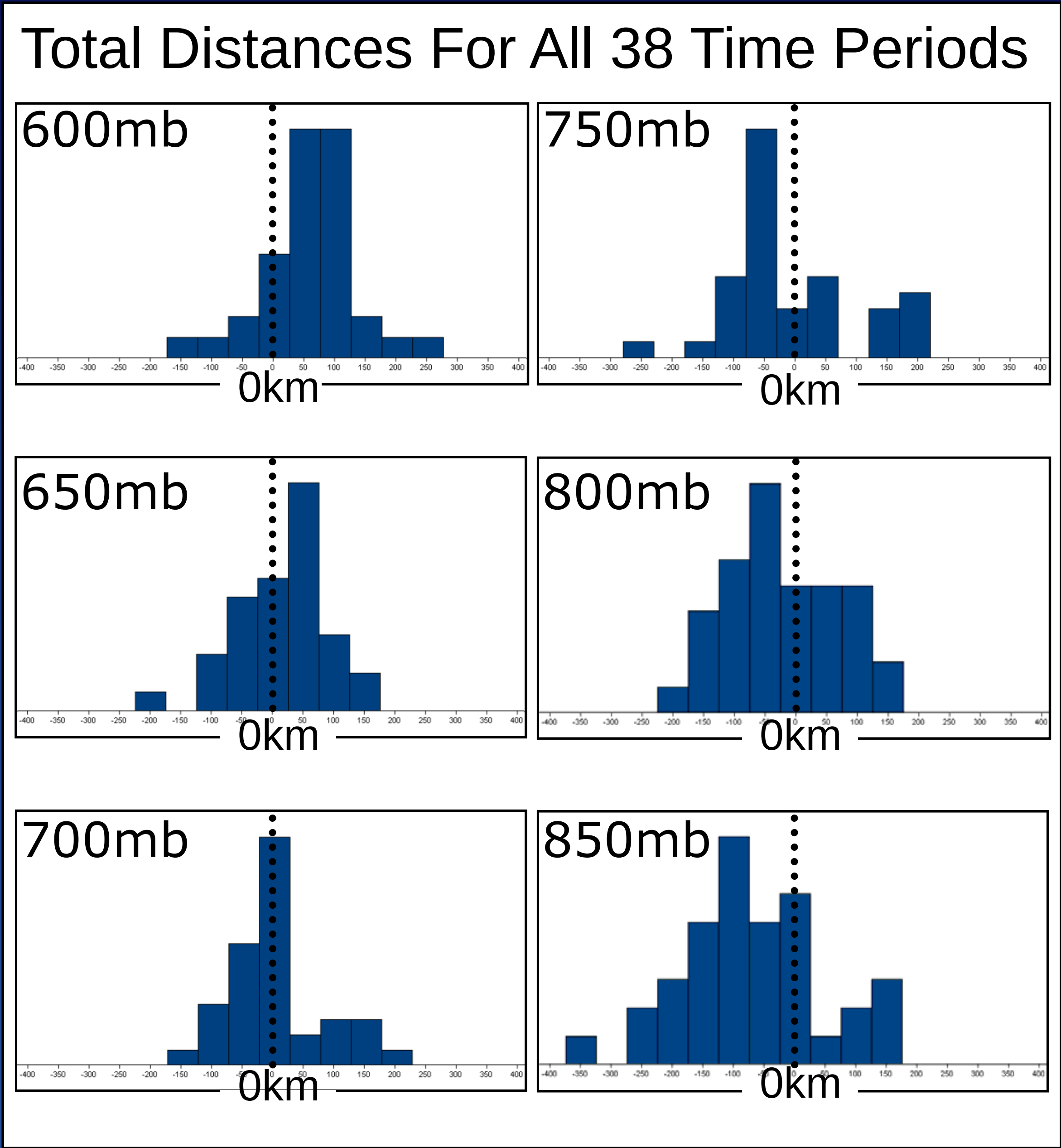


12Z
040315/1200V000 750 : 600 MB PVORTHES
18Z
040315/1800V006 650 : 500 MB PVORTHES
00Z
040316/0000V000 700 MB FRNTTHTAUOBS
040316/0000V000 700 : 550 MB PVORTHES
06Z
040316/0600V006 650 MB FRNTTHTAUOBS
040316/0600V006 650 : 500 MB PVORTHES

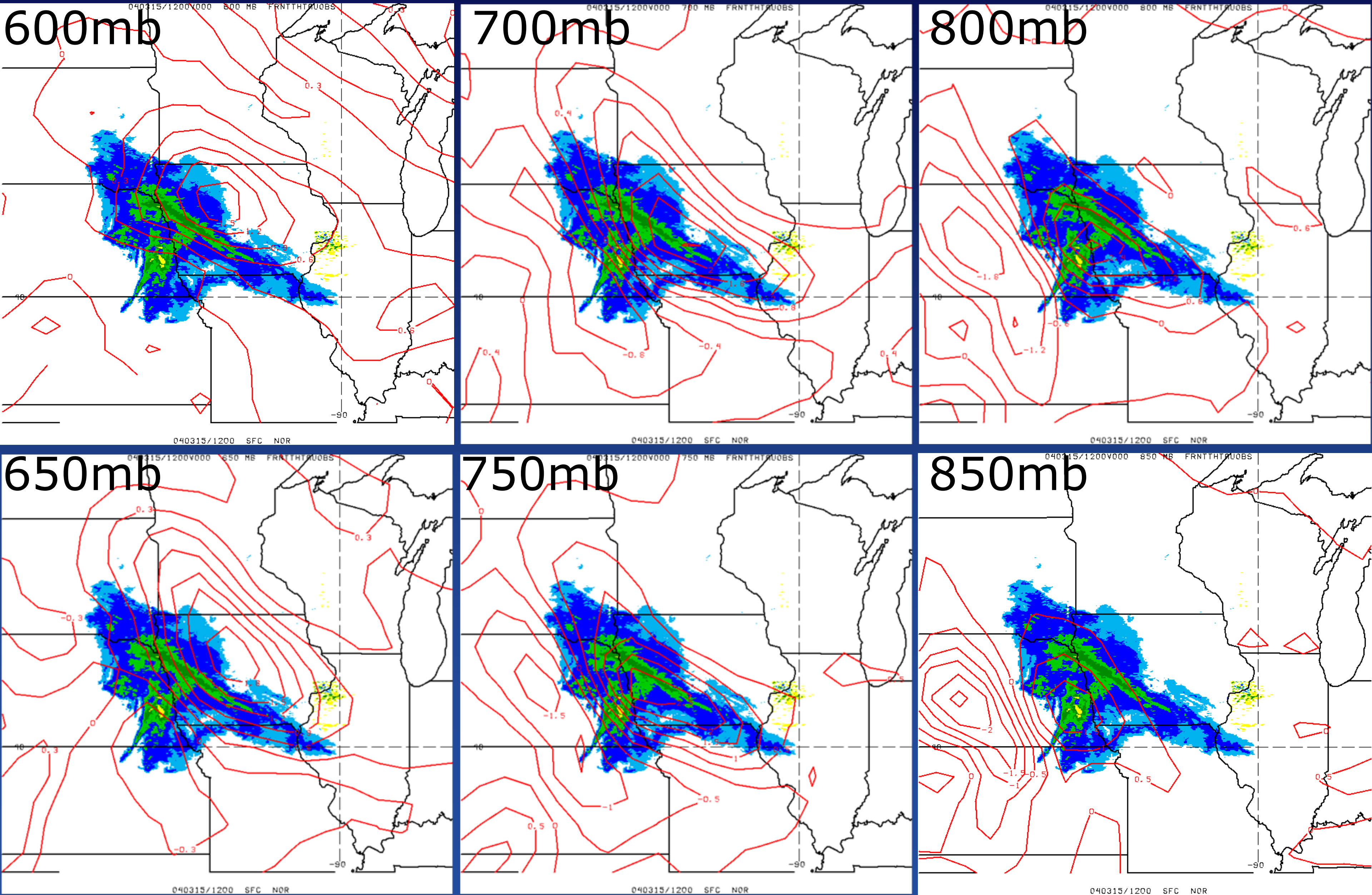

Unregistered HyperCam 2
composite base reflect valid: 15 March 2004 06:00 AM
IEM

Results

- A shift in the distributions is evident.
  - Mainly positive distances aloft at 600mb
  - Mainly negative distances below at 850mb
- Emphasizes a tilt in the frontal structure with height.



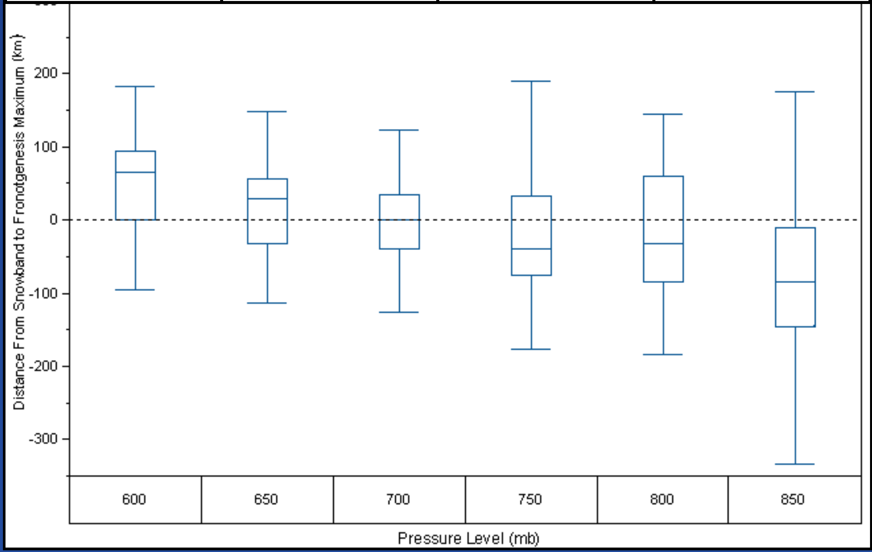
6 Levels of Frontogenesis



Results

- 650mb, 700mb, 750mb, & 800mb means and medians of distances close to snowband.
  - >40km ~ size of county
- Less variability as height increases.

Statistics For Distances (km)			
	Mean	Median	St. Dev.
600mb	56	65	75
650mb	14	33	69
700mb	10	0	81
750mb	-8	-39	109
800mb	-19	-33	89
850mb	-71	-83	116

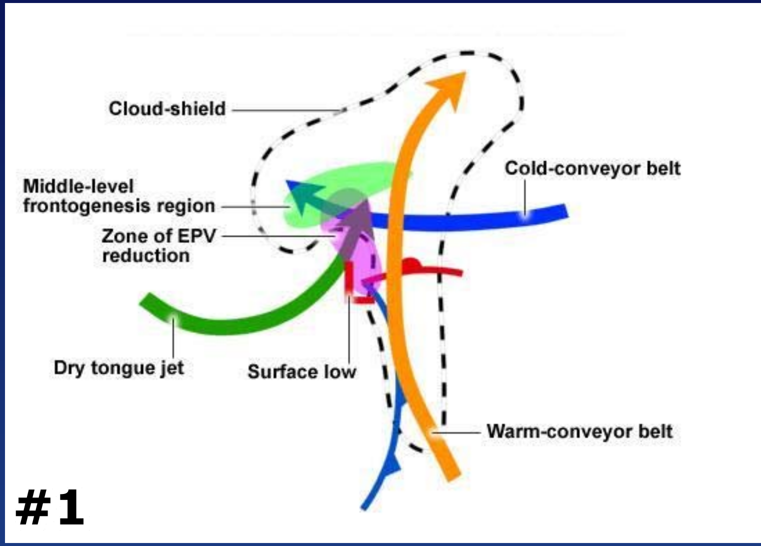


Results

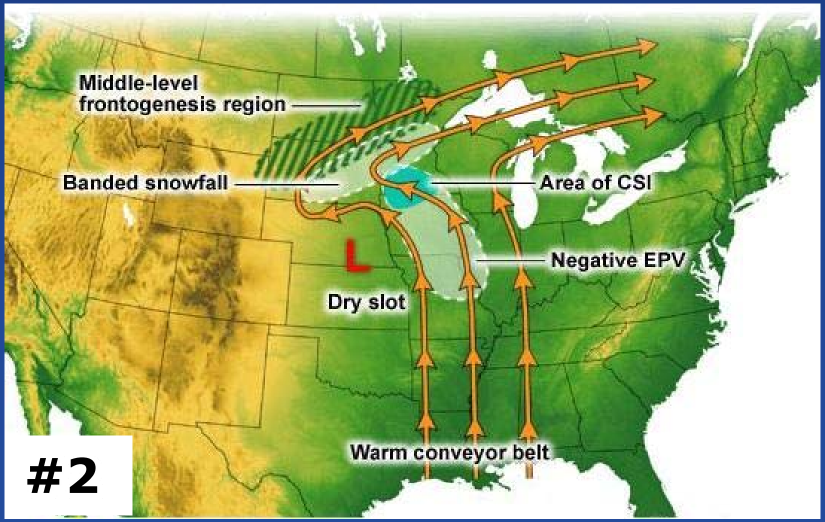
- Of the 38 time periods analyzed…
  - 700mb
    - Closest to snowband 13 times.
    - Within 40km of snowband 21 times.
    - Median of 0km.
  - 750mb
    - Closest to snowband 3 times.
    - Within 40km of snowband 14 times.
    - Never directly aligned.

Results

- For EPV*, 3 Cases (13 times periods) were analyzed in greater detail.
  - Both conceptual models were validated in 2 of the 3 cases
  - All 13 of these time periods support #2.



(Nicosia and Grumm 1999)



(The Comet Program)

Conclusions

- The 800mb, 750mb, 700mb, and 650mb levels are shown to be in proximity to the radar indicated snowband
  - Emphasizes the utility of frontogenesis in operationally forecasting heavy snow.

- 650mb had the least variability. This level should more definitively show the location of the snowband (30-60km → warm side).

Conclusions

- 700mb & 750mb levels shown guidelines.
  - More emphasis toward 700mb.
- Both conceptual models validated.
  - More emphases toward #2.

Future Work

- Can the variability of frontogenesis with time be further justified?
  - More analysis of EPV*
  - Col point?
  - Variable level at which symmetric instability is released?
  - Comparison of temperatures in the -12° to -18°C (dendritic growth zone)

Acknowledgements

- Dr. William Gallus, Jr.
- Daryl Herzmann
- Jon Hobbs
- Adam Clark

Questions

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Presentation and Thesis available at:

http://www.meteor.iastate.edu/~ckarsten/portfolio/research.html