An Investigation into the Evolution of Frontogenesis and Equivalent Potential Vorticity for Fifteen Midwest Mesoscale Snowband Events

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The Problem

We have a basic understanding of the ingredients responsible for mesoscale snowbands, but questions remain about the evolution of the ingredients relative to the snowband life cycle.

Background

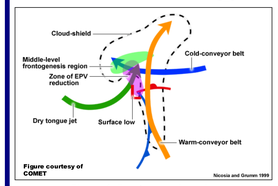

Figure 1: Frontogenesis and Reduced EPV in conjunction with the conveyor belts (Nicosia and Grumm 1999)

The conveyor belts create an environment conducive to heavy banded snow northwest of the surface low pressure center

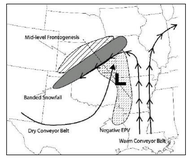

Figure 2: Conceptual Model of mesoscale processes contributing to heavy-banded snow formation (Plan-View) (Moore et al. 2005)

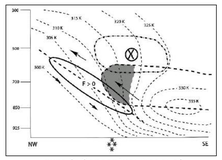

Figure 3: Conceptual Model of mesoscale processes contributing to heavy-banded snow formation (Cross-Section) (Moore et al. 2005)

EPV is used to indicate areas conducive to the release of CSI

CSI or CI → -0.25 < EPV < 0

WSS → 0 < EPV < 0.25

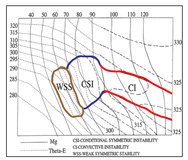

Figure 4: Nolan-Moore Conceptual Model (adapted by Schultz and Schumacher 1999)

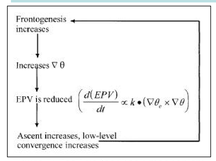

Figure 5: Positive feedback mechanism Between Frontogenesis and the reduction of EPV (Nicosia and Grumm 1999)

If the evolution of frontogenesis and EPV is investigated, can we see evidence of the positive feedback between them?

Questions?

- Can we see the positive feedback between Frontogenesis and EPV in the evolution of numerous cases?
- Is there a pattern to the positive feedback mechanism and can it be conceptualized?
- Can the Nicosia and Grumm (1999) positive feedback mechanism predict the intensification and maturation of a snowband?

Hypothesis

- Two possible patterns related to the positive feedback mechanism before a snowband intensifies:
  1. A sharp increase in Frontogenesis just before EPV is reduced
  2. A sharp increase in Frontogenesis after EPV is reduced
- Alternative hypothesis: the positive feedback is not taking place and the reduction in EPV and increase in Frontogenesis is not correlated

Evolution of Mesoscale Ingredients

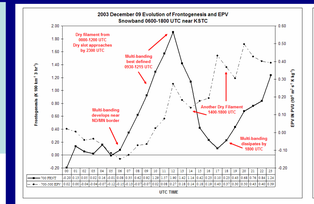

Figure 6: 20-km RUC Evolution for 2003 Dec 09

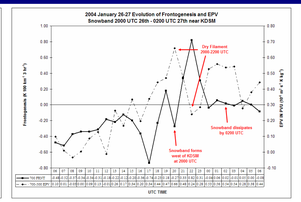

Figure 7: 20-km RUC Evolution for 2004 Jan 27

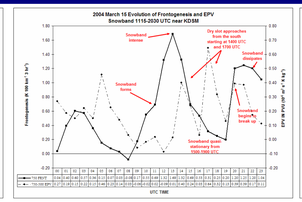

Figure 8: 20-km RUC Evolution for 2004 March 15

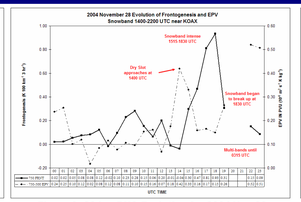

Figure 9: 20-km RUC Evolution for 2004 Nov 28

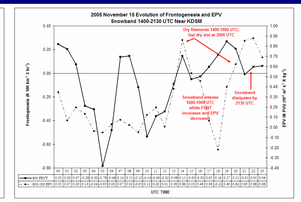

Figure 10: 20-km RUC Evolution for 2005 Nov 15

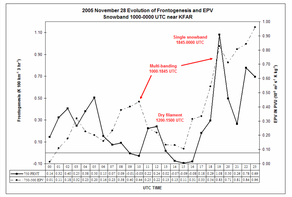

Figure 11: 20-km RUC Evolution for 2005 Nov 28

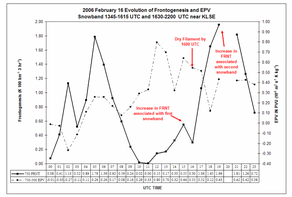

Figure 12: 20-km RUC Evolution for 2006 Feb 16

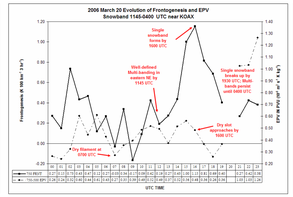

Figure 13: 20-km RUC Evolution for 2006 Mar 20

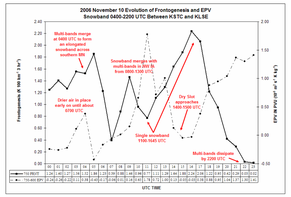

Figure 14: 20-km RUC Evolution for 2006 Nov 10

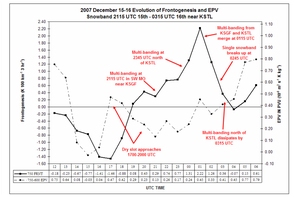

Figure 15: 20-km RUC Evolution for 2007 Dec16

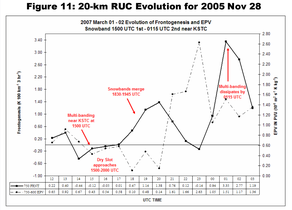

Figure 16: 20-km RUC Evolution for 2007 Mar 01

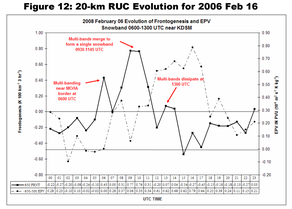

Figure 17: 20-km RUC Evolution for 2008 Feb 06

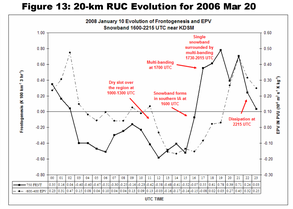

Figure 18: 20-km RUC Evolution for 2008 Jan 10

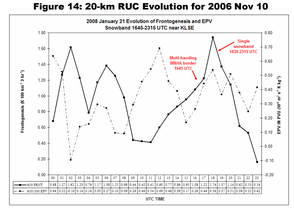

Figure 19: 20-km RUC Evolution for 2008 Jan 21

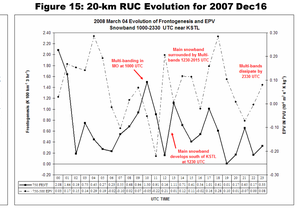

Figure 20: 20-km RUC Evolution for 2008 Mar 04

Patterns in Evolution

- **A consistent pattern where EPV minimized before Frontogenesis maximized**
- **13 cases EPV minimum before Frontogenesis peak**
- **1 case EPV minimum and Frontogenesis peak occur at the same time**
- **1 case EPV minimum after Frontogenesis peak**
- **Break down the pattern further:**
  - **Does EPV minimized before or after frontogenesis starts to increase?**

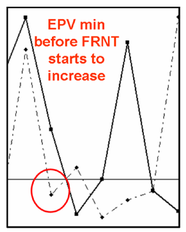

Figure 21: Example of EPV minimum occurring before Frontogenesis starts to increase

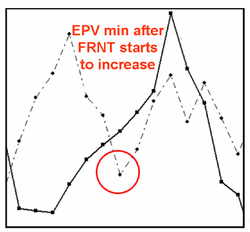

Figure 22: Example of EPV minimum after Frontogenesis starts to increase

Case	EPV minimized before FRNT starts to increase	FRNT starts to increase before EPV minimized	Time (hrs)
2003 Dec 09 (M)		Yes (3R)	-6
2004 Jan 27 (S)	(same time)	(same time)	0
2004 Mar 15 (S)		Yes (3R)	-4
2004 Nov 28 (S)	Yes (3R)		-6
2005 Nov 15 (S)		Yes	-1
2005 Nov 28 (S)	Yes		-4
2006 Feb 16 (S)	Yes (2R)		-7
2006 Mar 20 (M)		Yes	2
2006 Nov 10 (S)		Yes	-1
2007 Mar 01 (M)		Yes (2R)	-2
2007 Dec 16 (M)	Yes (3R)		-4
2008 Jan 10 (M)	Yes (2R)		-5
2008 Jan 21 (M)		Yes	-3
2008 Feb 06 (S)	Yes (2R)		-5
2008 Mar 04 (M)		Yes (5R)	-3

Table 1: Summary of EPV reductions. Case where (S) is single band and (M) is multi-banding. Timing of EPV reduction. (#R) represents the total number of reductions during band life-cycle. Time in hours between the initial EPV reduction and Frontogenesis peak

Correlations

Correlation	T-6	T-5	T-4	T-3	T-2	T-1
(+) 99 CI	20	33	7	40	13	20
(+) 95 CI	0	0	7	7	0	7
(+) 90 CI	0	0	0	0	7	0
(+) 80 CI	13	0	0	7	13	0
(+/-) < 80 CI	27	27	27	20	33	20
(-) 80 CI	7	7	0	0	0	7
(-) 90 CI	0	0	13	0	0	0
(-) 95 CI	0	13	7	0	7	13
(-) 99 CI	33	20	40	27	27	33

Table 2: Percent of correlation within confidence interval bins for T-6 to T-1

(-) 99 CI bin contains a majority of the correlations

T-6, T-4, T-2, T-1, T+4, T+6

Preference for negative correlations and EPV reduction

(+) 99 CI bin contains a majority of the correlations

T-5, T-3,T=0, T+5

Preference for positive correlations

At T=0 both EPV and FRNT may be increasing

Both (-) 99 CI and (+) 99 CI contain the same number of correlations

T+1, T+2, T+3

T+1, T+2 are weighted positively; preference for positive correlations

T+3 is weighted negatively; preference for negative correlations

Correlation	T=0	T+1	T+2	T+3	T+4	T+5	T+6
(+) 99 CI	53	21	29	15	22	50	13
(+) 95 CI	0	14	21	0	0	13	0
(+) 90 CI	0	7	0	15	11	0	0
(+) 80 CI	0	0	0	0	11	0	13
(+/-) < 80 CI	13	29	14	38	22	25	13
(-) 80 CI	0	0	7	0	0	0	0
(-) 90 CI	0	0	0	8	0	0	0
(-) 95 CI	0	7	0	8	0	13	13
(-) 99 CI	27	21	29	15	33	0	50

Table 2: Percent of correlation within confidence interval bins for T=0 to T+6

Methodology

Average Evolution Plots

- Choose 10 latitude and longitude pairs across the band at a time before it begins to dissipate
- Using 20-km RUC data and gdpoint and gdlist to find the value of frontogenesis and EPV at each point for every hour
- Average the values for each hour to arrive at an average evolution of the mesoscale ingredients

Lag Correlations

- Lag correlations were calculated to determine any significance to the lag time of EPV reductions relative to the Frontogenesis peak
  - The Frontogenesis peak is assigned a time of T=0
  - Time periods of EPV values were named according the lag before or after the Frontogenesis peak T-6, T-3, T=0, T+3, T+6
- Histograms of the correlation values were created to determine significance
  - Hypothesis test for linear correlation
    - 20 degrees of freedom
    - 99, 95, 90, 80 confidence intervals were calculated

Conclusions

- The evolution of Frontogenesis and EPV of 15 case studies revealed a consistent pattern in the evolution where EPV reduced before Frontogenesis maximized
- The majority of cases exhibited multiple EPV reductions and this was independent of whether they were multi- or single banded cases
- There is a tendency for a case to exhibit more EPV reductions if EPV minimizes before Frontogenesis starts to increase
- Preference for negative correlations and EPV reductions occurred at lag times T-6, T-4, T-2, T-1, T+4, T+6 relative to the frontogenesis peak

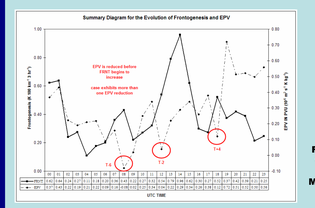

Figure 23: Summary Evolution when EPV is reduced before FRNT starts to increase. Multiple EPV reductions at T-6, T-2, and T+4

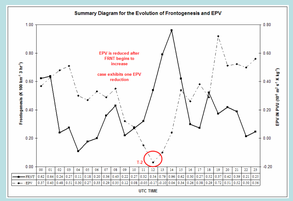

Figure 24: Summary Evolution when EPV is reduced after FRNT starts to increase. One reduction at T-2.