# A Conceptual Model Depicting Processes Important for the Generation of Meso-Beta Scale Snow Bands

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## Mesoscale Snow Band Forecast Problems

Mesoscale banded snowfall is a common occurence over the Midwest during the cold season. Forecasting such small-scale phenomena is extremely difficult for operational meteorologists. This is, in part, due to the inability of today's current operational numerical models to resolve these small-scale structures.

1) These are small-scale bands, often 5-50 km wide and 100-200 km in length.
2) They often form far away from synoptic-scale boundaries.
3) They often form in low-level northeasterly flow, associated with cold air advection.
4) They often form in the vicinity of arctic highs.
5) They are associated with high snow-to-liquid ratios (e.g., 20 : 1)
6) Key parameters (frontogenesis, instability, etc) are weak, nothing to write home about.
7) These bands are associated with light snowfall but still cause socioeconomical problems.

These snowbands have the potential to cause a variety of socioeconomical problems. According to Weather Information for Surface Transportation (2002):

1) 74% of the National Highway System is in the nation's snowbelt.
2) 69% of the U.S. population live in areas that normally receive more than five inches of snowfall each year.
3) 28% of all highway crashes and 19% of all fatalities are directly or indirectly related to adverse weather conditions.
4) Weather-related crashes have an estimated annual economic impact of nearly 42 billion USD.
5) City, state, and county highway maintenance agencies spend 2.1 billion USD per year to treat snow and ice on roadways.

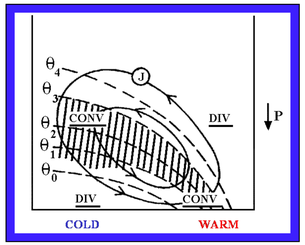
## Research Objective

The objective of the present study is to focus upon the horizontal and vertical location, depth, and variability of the magnitude of key processes as they synergistically interact to modify upward vertical motion, mesoscale instability, and depth of moisture in the formation of mesoscale snow bands.

In this way, the present research has allowed the development of a conceptual model. Conceptual models help operational forecasters by establishing unique environmental patterns while linking the key processes in a three-dimensional construct. Therefore, forecasters will have the opportunity to recognize a potential mesoscale snow band situation before it becomes a surprise snow storm for the community.

Using four cases (6, 15-16, 23, and 26 February 2003) along with collaboration with the National Weather Service Forecast Office, St. Louis, Missouri, a conceptual model was developed using key parameters.

## Frontogenesis and Vector Frontogenesis




Carlson, Mid-latitude Weather Systems (1991)

Frontogenesis is defined as the change of the potential temperature gradient following a parcel along the flow.

The response is a direct thermal circulation (DTC).

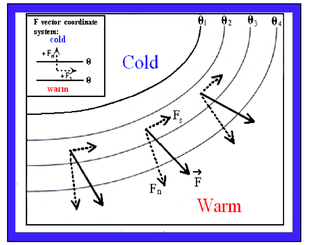
This enhances snowfall by increasing upward vertical motion.

Snowfall is found on the warm side of the frontogenesis axis (upward branch of the DTC).

Fn is the magnitude component, oriented normal to the potential temperature gradient. Fn is associated with frontal scale circulations (Keyser et al. 1988, 1992)

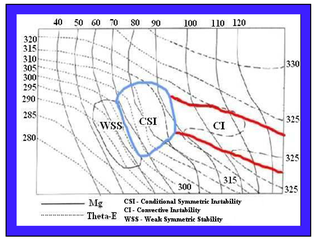
Fs is the directional component, oriented parallel to the potential temperature gradient. Fs is associated with circulations on the scale of synoptic disturbances (Keyser et al. 1988, 1992).

The banded nature of the mesoscale bands is more closely related to the Fn component than the Fs component (Banacos 2003).




Keyser et al. (1988, MWR) and Augustine and Caracena (1994, WAF)

## Symmetric Instability and the Reduction of Equivalent Potential Vorticity




Schultz and Schumacher (1999, MWR)
*(James Moore and Sean Nolan Original Image)*

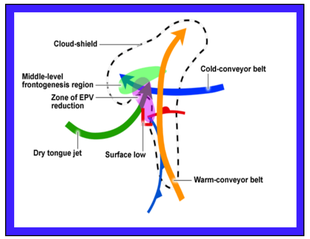
Both weak symmetric stability (WSS) and conditional symmetric instability (CSI) can enhance narrow, banded snowfall.

CSI is diagnosed in regions where absolute geostrophic momentum (Mg) surfaces are flatter than θe surfaces.

WSS is diagnosed in regions where Mg surfaces are parallel to θe surfaces.

Equivalent potential vorticity (EPV) is a way of measuring CSI (EPV<0) and WSS (.25>EPV>0).

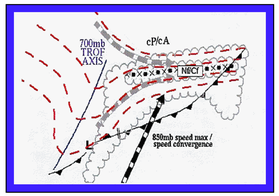
The reduction of EPV occurs when the dry tongue jet overlays the CCB causing θe surfaces to increase in slope.




Nicosia and Grumm (1999, WAF)

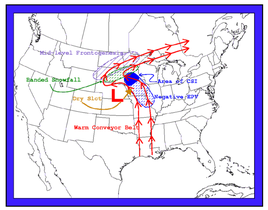
## Other Conceptual Models

Frontal Zones with Modest Surface Cyclone Development



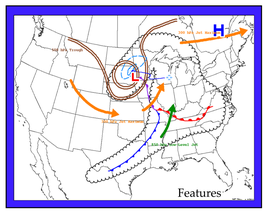

Banacos (2003, 10th Conference on Mesoscale Processes)

Heavy Banded Snowfall Events



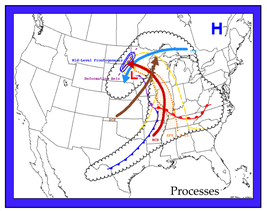
Moore et al. (2002, WAF)

Heavy Banded Snowfall Events



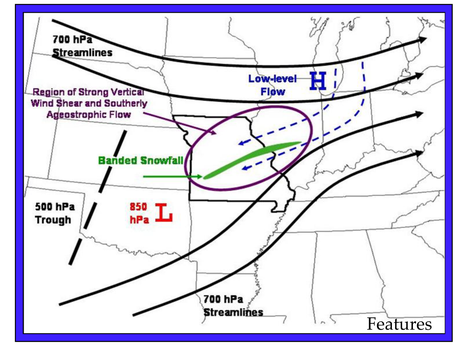

Ng (2005, Doctoral Dissertation)

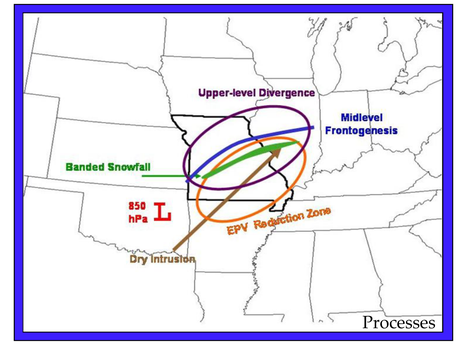
Heavy Banded Snowfall Events




Ng (2005, Doctoral Dissertation)

## Conceptual Model




## What Makes This Conceptual Model Different?

1) These snow bands are associated with weak surface cyclogenesis (1006 hPa or greater).
2) The surface cyclone is not always a prominent feature. So, the position of the 850 hPa circulation is used instead.
3) The intensity of the mid-level frontogenesis is weak (< 0.7 K per 100 km per 3 h).
4) Instability is typically WSS over the region of banded snowfall.
5) The snowfall is associated with low-level northeasterly flow, which maintained a cold and sometimes very shallow, stable lower tropospheric layer.
6) Typically, a southerly low-level jet is not directly associated with the area of snowfall.
7) The trowal does not appear, diagnostically, to be a contributor to the snowfall.