The Big Three for Winter Snowfall

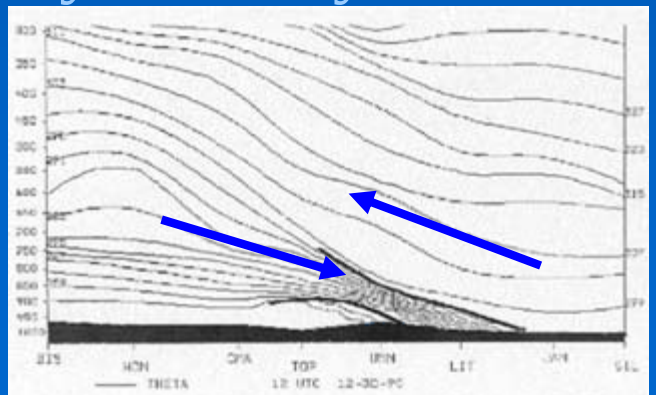
Awareness of Lift, Instability, and Snow Growth

Lift: Frontogenesis

➡ Frontogenesis in the vicinity of the frontal surface will elicit a circulation favoring vertical motion along isentropic or equiv isentropic surfaces.

➡ The atmosphere is responding to frontogenetical forcing. This forcing typically provides front-parallel vertical motion regions on the warm side of the boundary.

➡ This lift can move parcels that may be ready to move in an unstable environment.



Stability: CSI/PSI

➡ The atmosphere is stable to both vertical (upright) and horizontal (inertial) motions, but potentially unstable to slantwise movements: small or -EPV* (~0.20 and below).

➡ In the presence of adequate moisture and lift, this instability (small or -EPV*) can be released in the form of slantwise convection.

➡ There are several conditions required to have CSI:

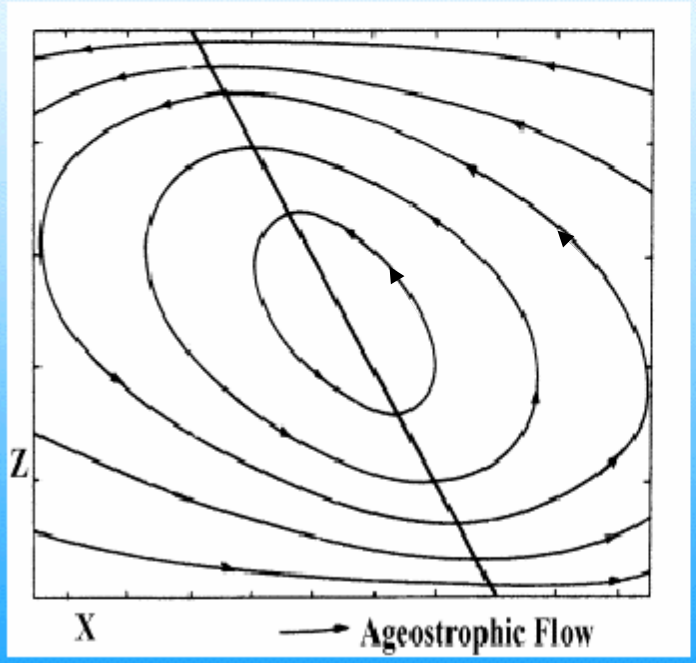
- Airmass nearly saturated
- Near neutral stability (EPV* ~0.20 or below)
- Strong vertical speed shear (strong thermal wind ensure more horizontal momentum surfaces)
- Source of lift : Frontogenesis

Stability: CSI/PSI

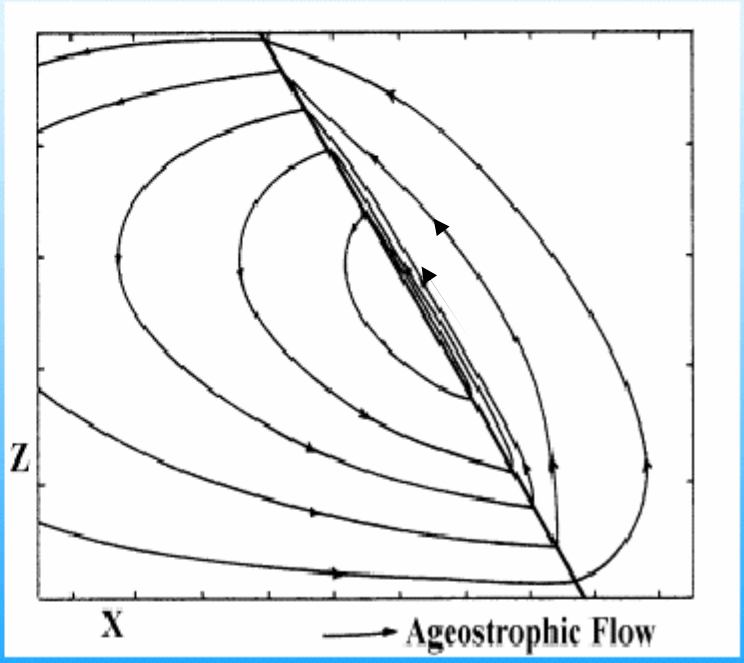
Stability

- Atmospheric stability augments forcing response

Emanuel 1985



Large Stability

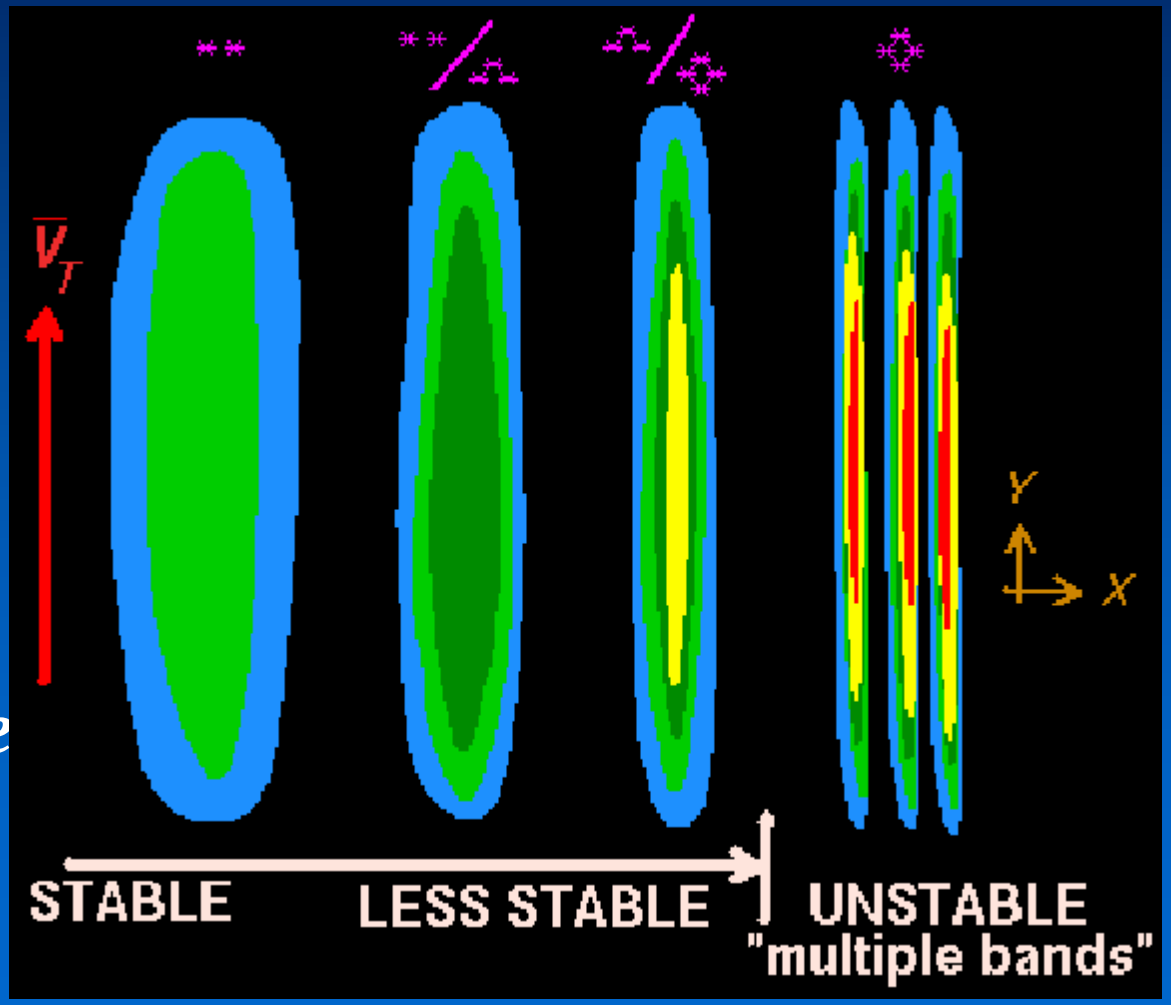


Small Stability

Stability

Modulation of Bands via Stability

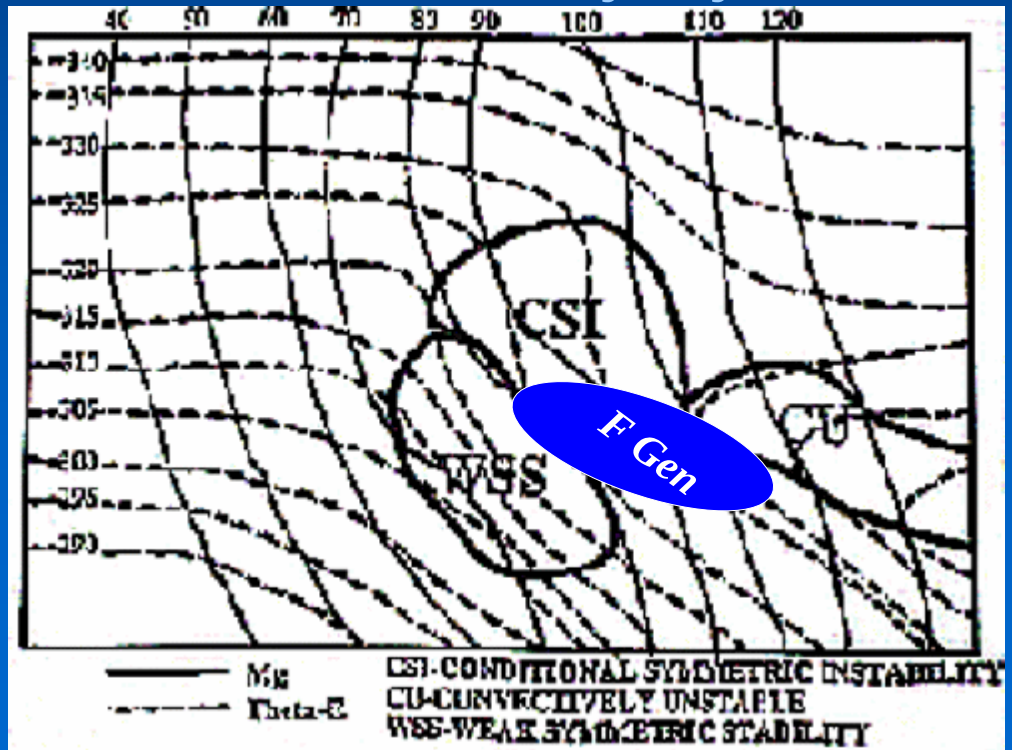
As gravitational or symmetric stability decreases, the horizontal scale of the band decreases while the intensity of the band increases. Multiple bands become established in an unstable regime.



Frontogenesis and CSI/PSI

➡ Regions of CSI/PSI are often elevated. Look at the frontogenetical forcing to see if the response is deep enough to reach the area of instability: CSI/PSI trigger.

➡ Fgen at the base of an instability layer is favorable!



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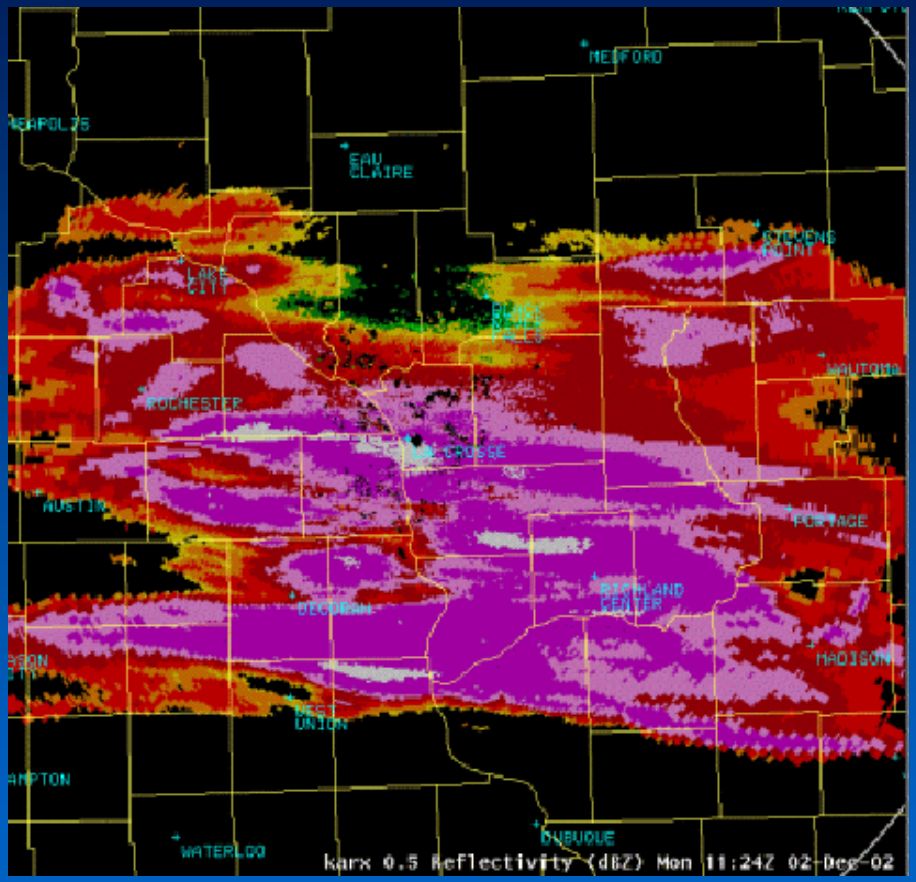
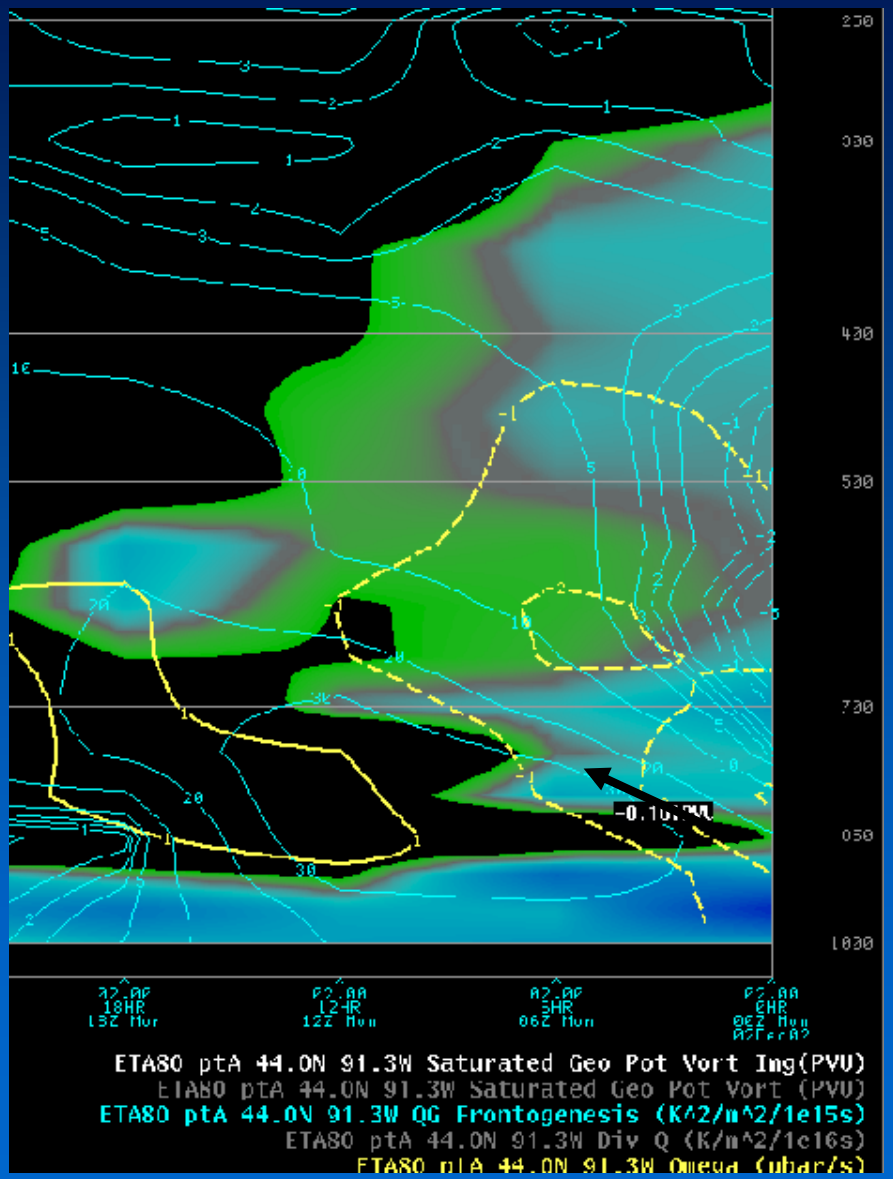
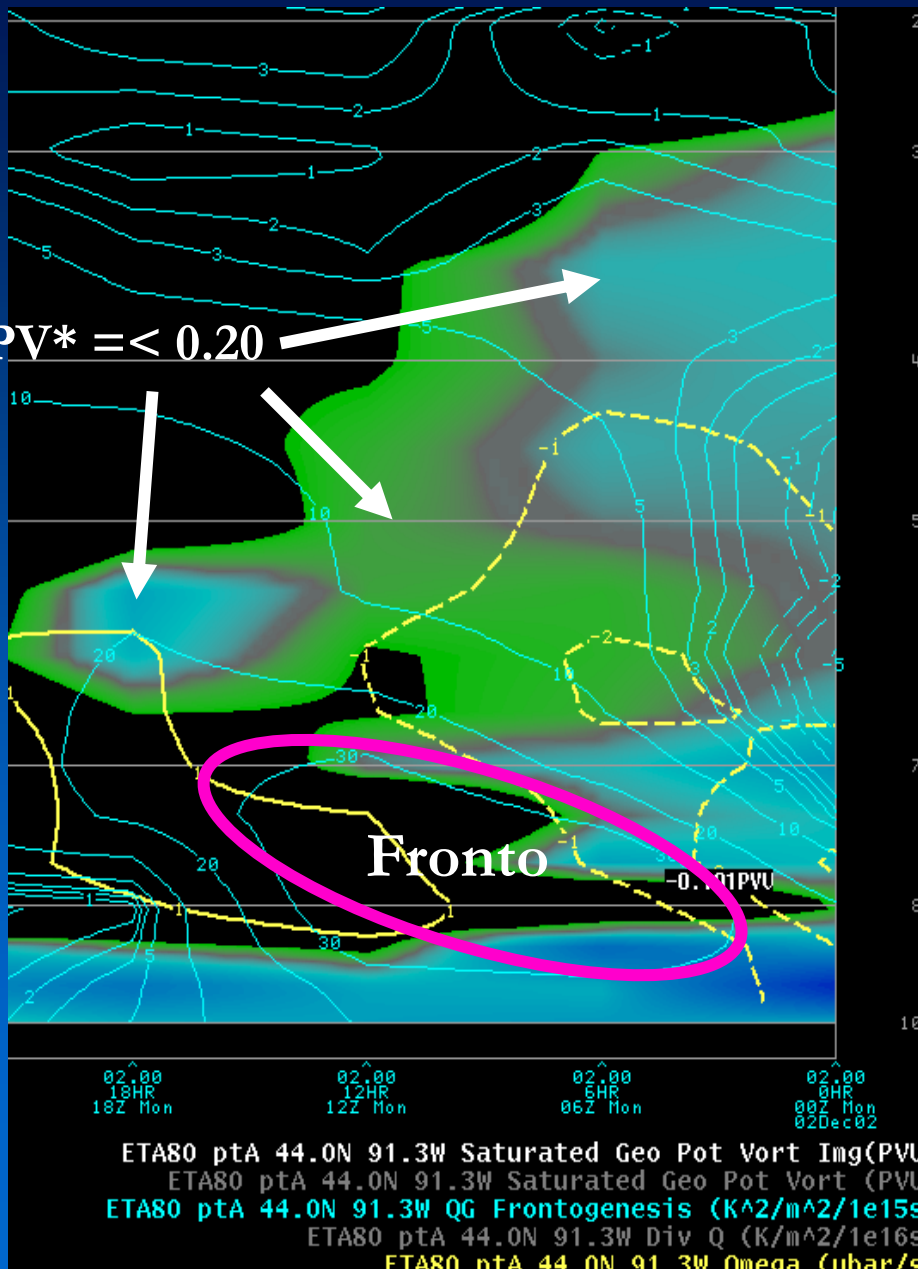




No Model QPF Doesn't Necessarily Result in No Precipitation: December 2, 2002 Steven Thompson

EPV*'s Character

- In this case, a deep low or negative EPV* layer is seen above the layer of forcing.



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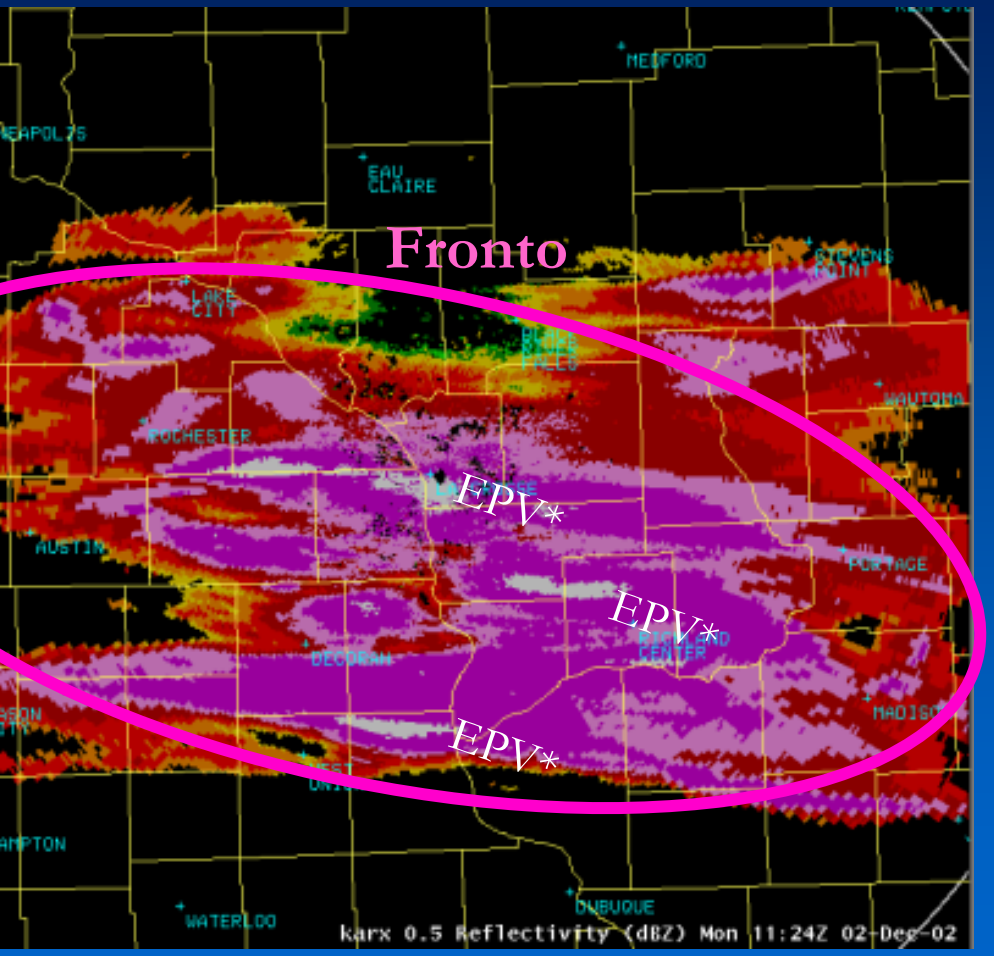
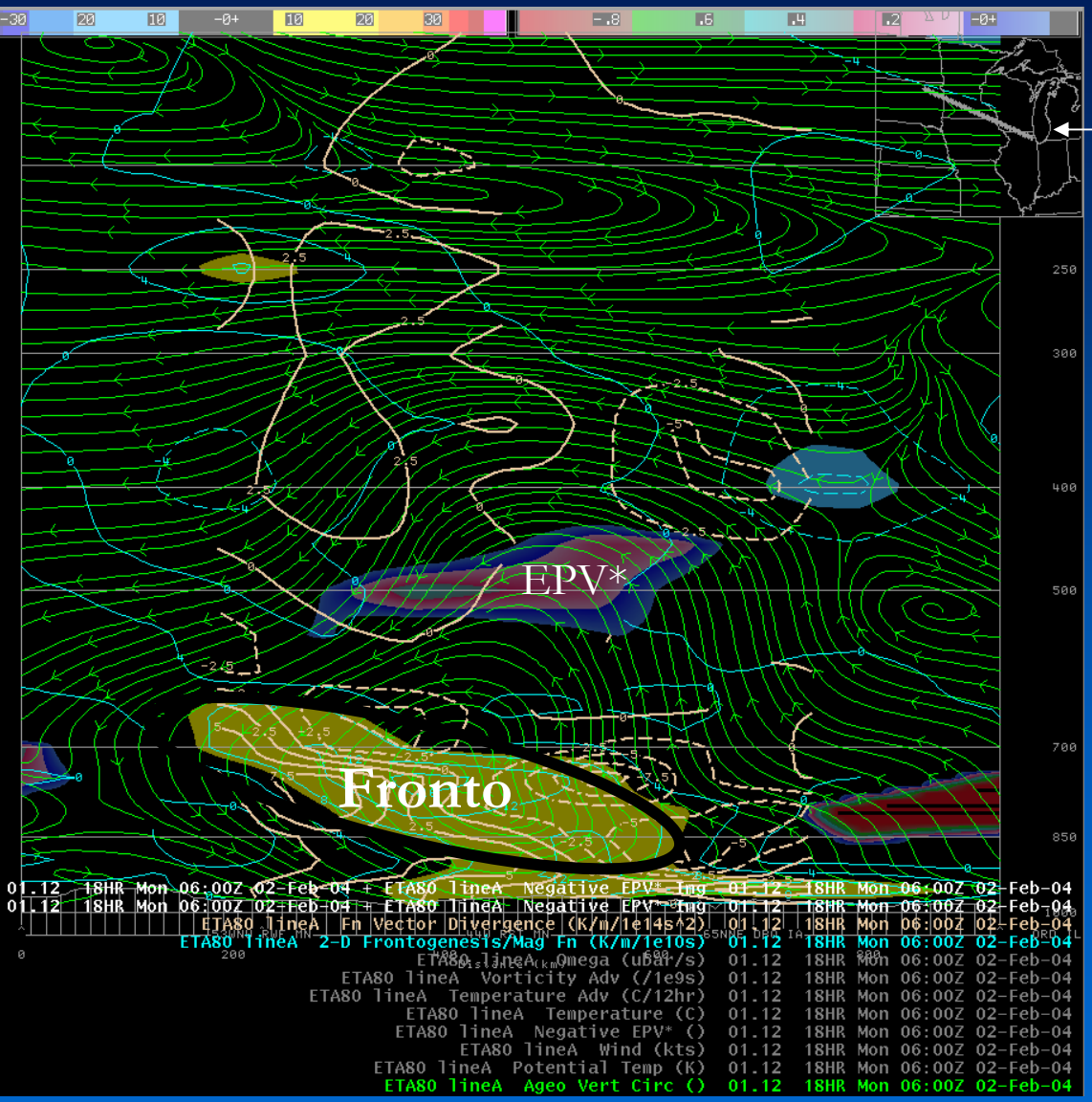


- While the frontogenesis defines the broader band of echo, the deep, unstable EPV* produces the smaller scale bands of heavier snowfall.

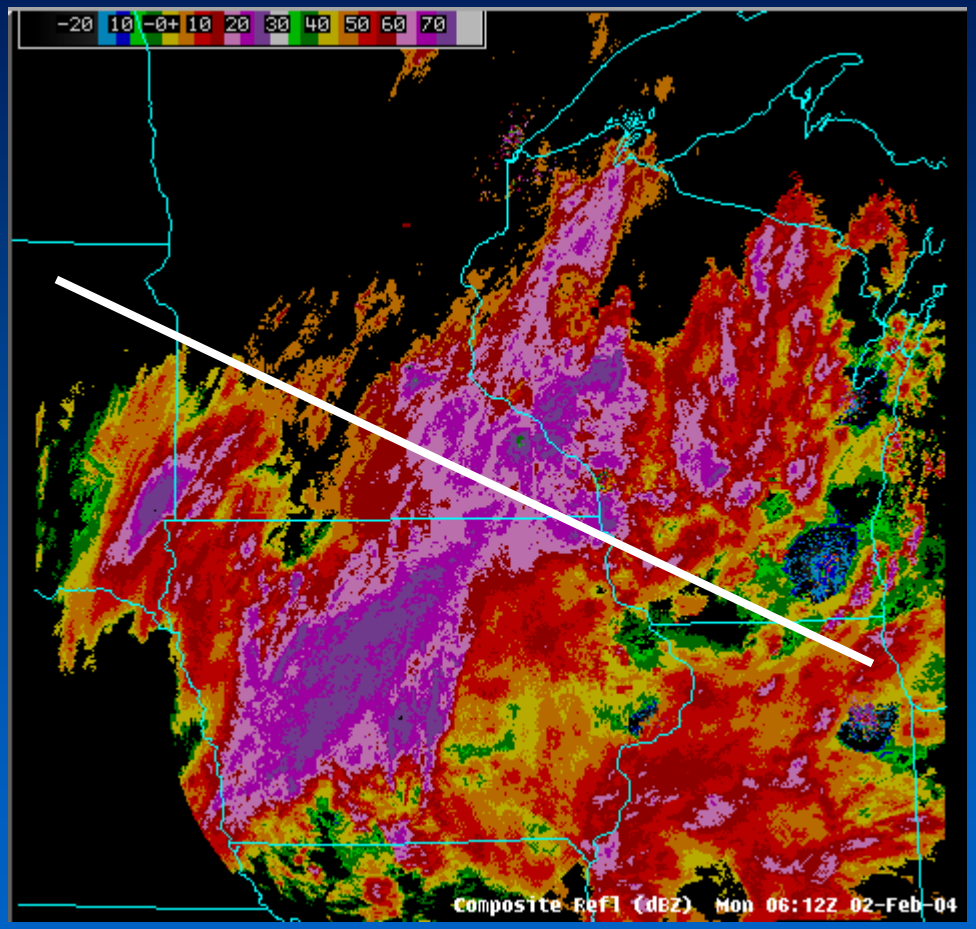
No Model QPF Doesn't Necessarily Result in No Precipitation: December 2, 2002 Steven Thompson

EPV*'s Character



- Feb 2 2004 WES case
  - Cross-section from KABR-KORD.
- PRO: Unstable EPV* area exists.
- CON: EPV* area displaced away from frontogenesis layer.
- CON: EPV* area is quite shallow (~75 mb).
- Result: 1 Broad Band

EPV*'s Character



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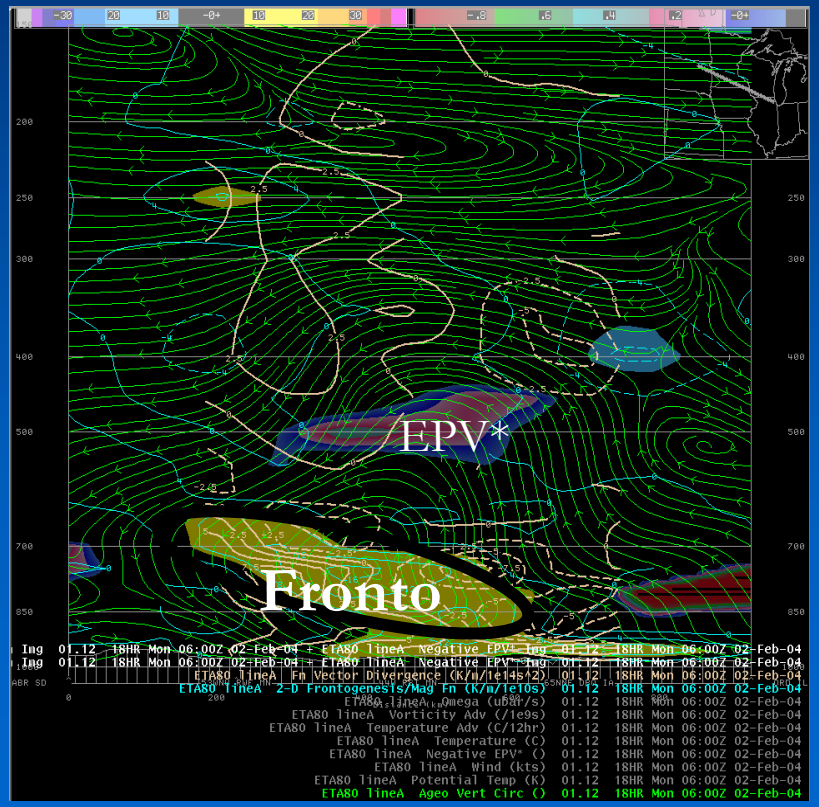


Winter 2004 WES Case: February 1-3 2004

EPV*'s Character: Summary

- While the frontogenesis defines the broader band of echo, the deep, unstable EPV* produces the smaller scale bands of heavier snowfall.

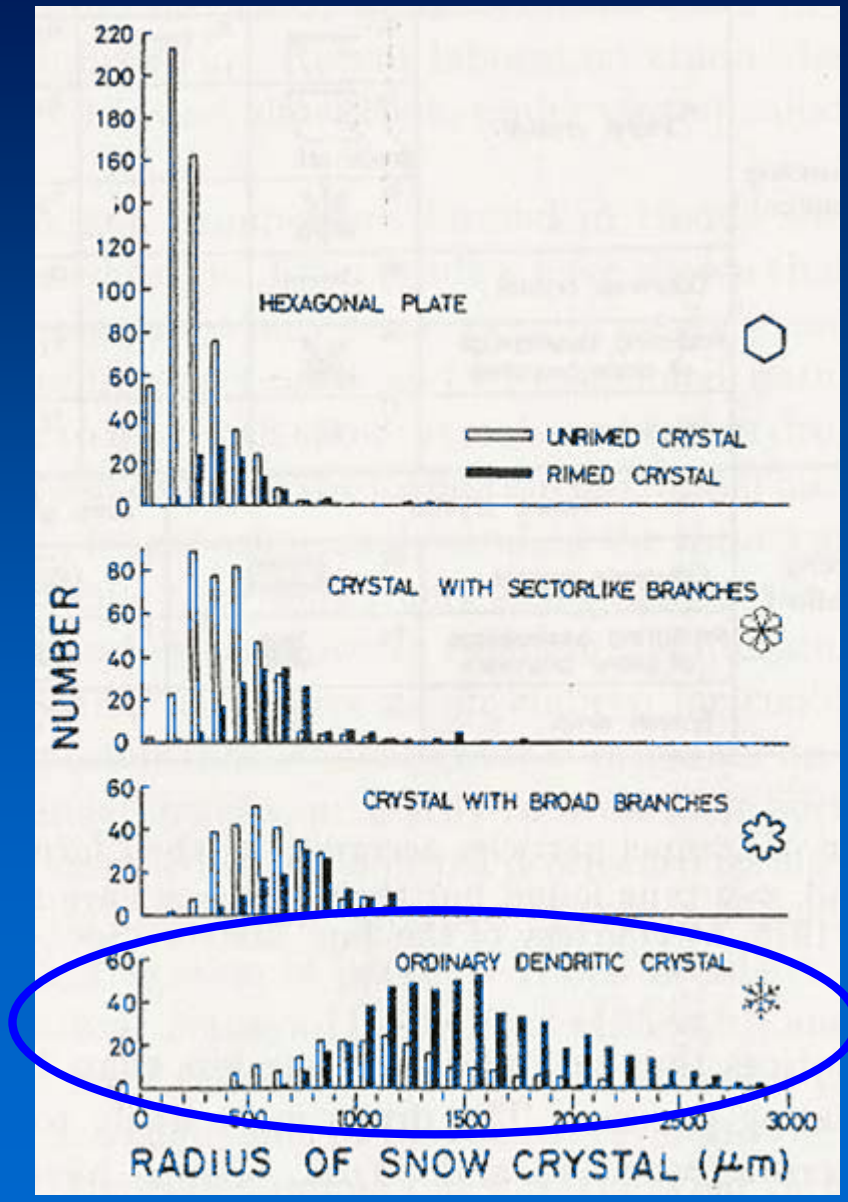
- So, you need some depth to the unstable EPV* to create the heavier bands.

- Operationally, the unstable EPV* should be thought of as an accelerator of snow fall rate.
    - Light QPF to Advisory
    - Advisory to Warning
    - Warning to Higher End Warning

Ice Growth

➡ Dendritic crystals typically are the largest in diameter.

➡ Because of this, they can provide higher snow:liquid water ratios and larger accumulations for a given water vapor supply.



Ice Growth

➡ Dendritic crystal growth is favored around the -15C isotherm.

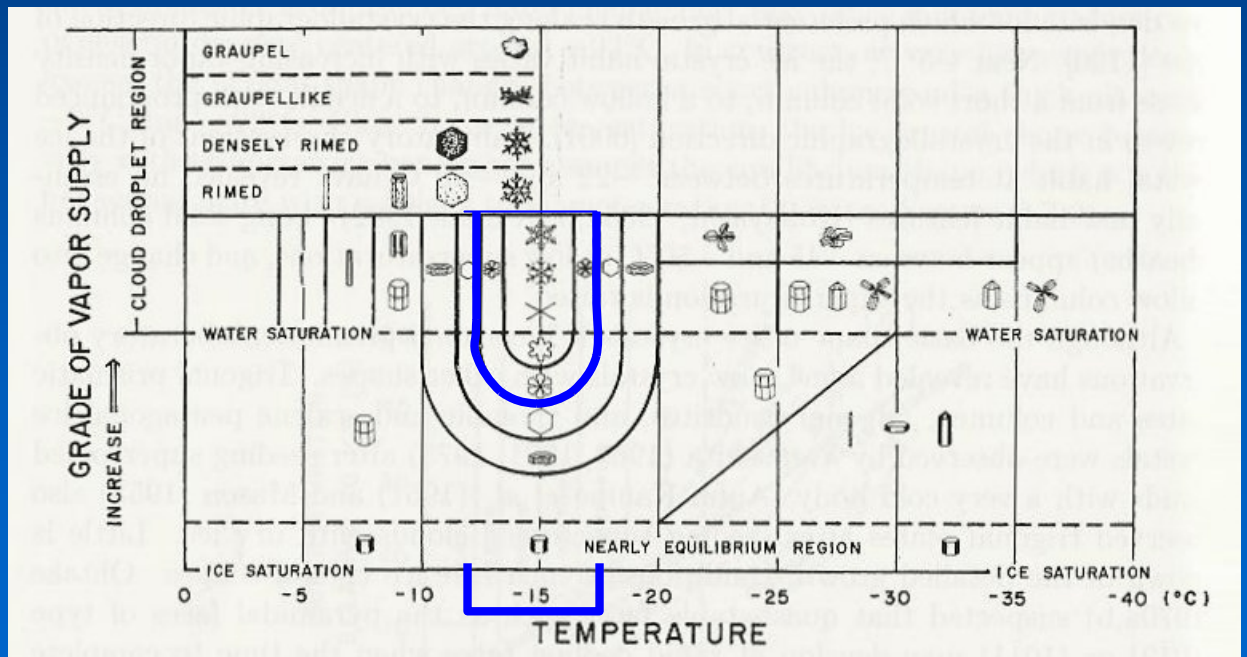
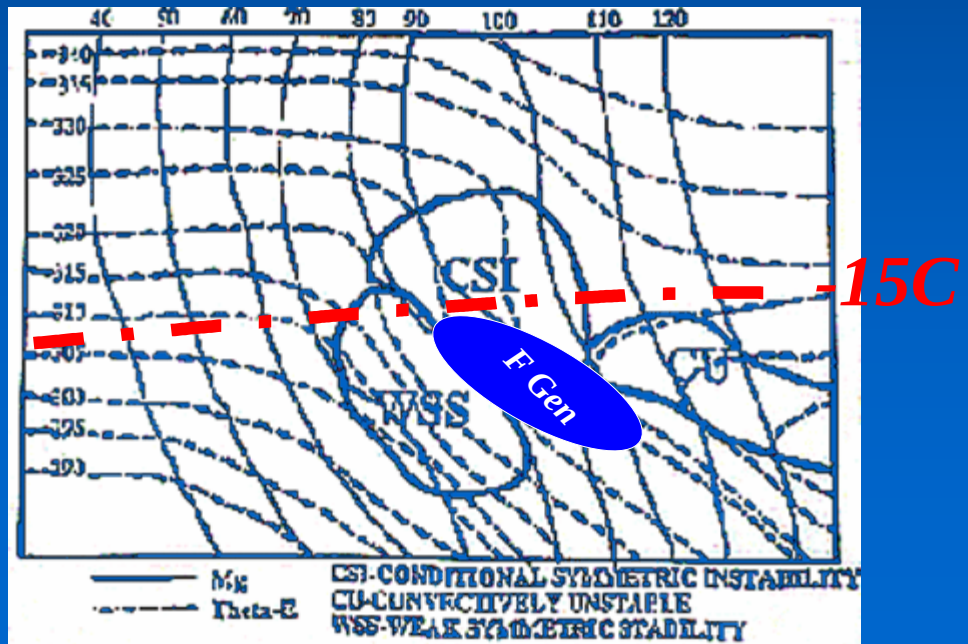


Fig. 2-37: Temperature and humidity conditions for the growth of natural snow crystals of various types. (From Magono and Lee, 1966; by courtesy of *J. Fac. Sci.*, Hokkaido University.)

Ice Growth

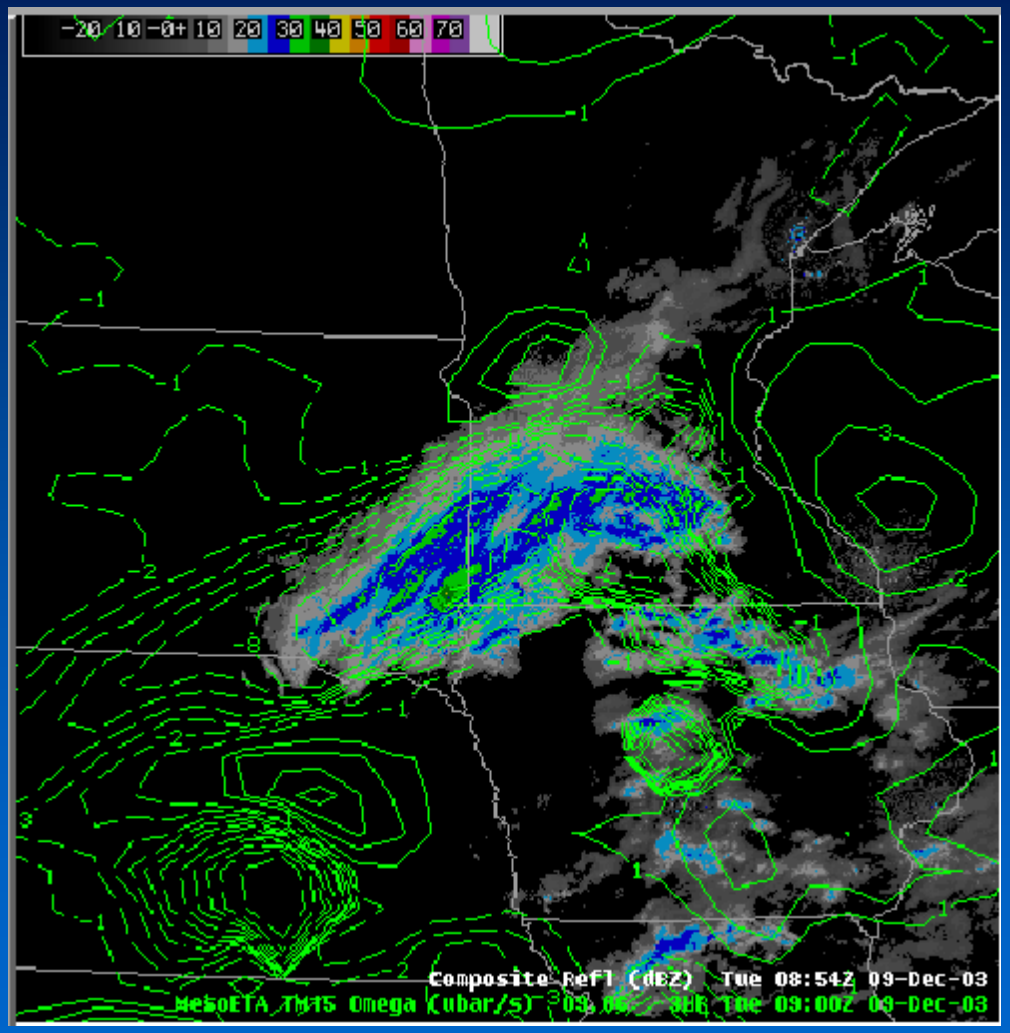
➡ What if forcing for lift exists in a 600-700mb layer, with -EPV* in the 450-650mb layer, AND the -15C region is placed within the -EPV* area?

➡ Intensity of snowfall and snow production should be high. Intensity * Duration = QPF



Ice Growth

➡ Somewhat parallel to the cross-hairs technique (Bufkit omega and -15C co-located), you can view the vetical motion (omega) on the -15C isotherm in AWIPS.



Operational Use

- "Big Three" 4-Panels

- Looks at Frontogenesis (Lift), the stability layer above it (EPV*), and the layer temperature where the snow grows.

900mb Divergence of Qn/Fn Vectors 900-800mb Sat Geo Equiv Pot Vort (EPV*) 900-800mb Upright or Slantwise instability icons 900-800mb Layer Ave Temp (C)	800mb Divergence of Qn/Fn Vectors 800-700mb Sat Geo Equiv Pot Vort (EPV*) 800-700mb Upright or Slantwise instability icons 800-700mb Layer Ave Temp (C)
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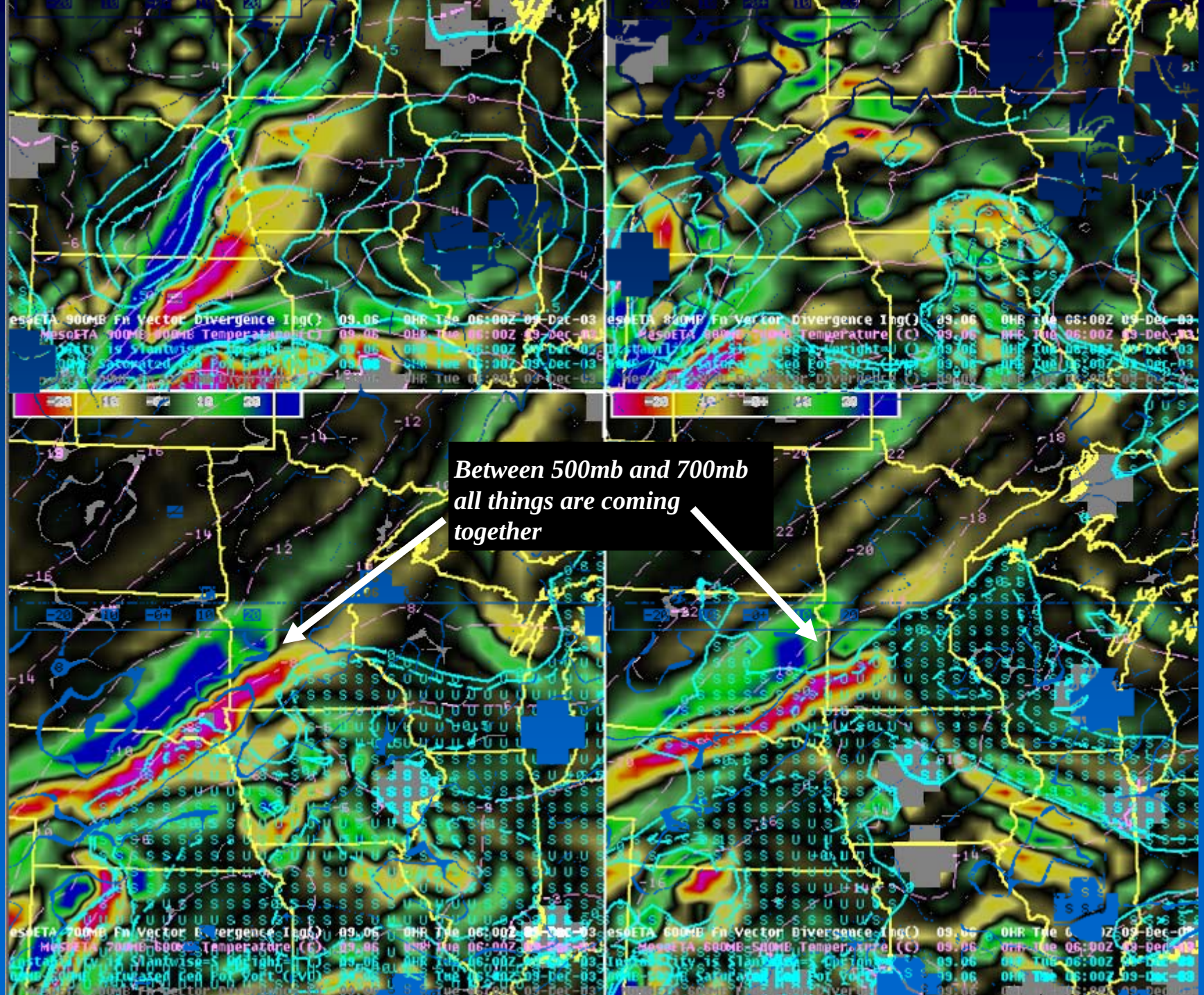
Between 500mb and 700mb all things are coming together

Assessing in Ops

Big Three

TRIGGER/LIFT: Q- or F-Vectors

- Watch 600-700 mb

STABILITY: Stable? Slantwise Unstable? Upright Unstable?

- How much? (EPV* ~0.20 or below)
- Above the TRIGGER/LIFT area?

EFFICIENCY? Ice Growth

- Dendritic crystal growth near -15C? 12-20 to 1 snow ratios.

MOISTURE?

- High moisture: less lift and instability needed.
- A system is not moisture “starved”, it is dynamics starved.

DURATION?

- How long will the forcing last? Intensity * Duration = QPF