

The Importance of a Well Mixed PBL in the Great Plains Severe Storms Environment

Jonathan Garner

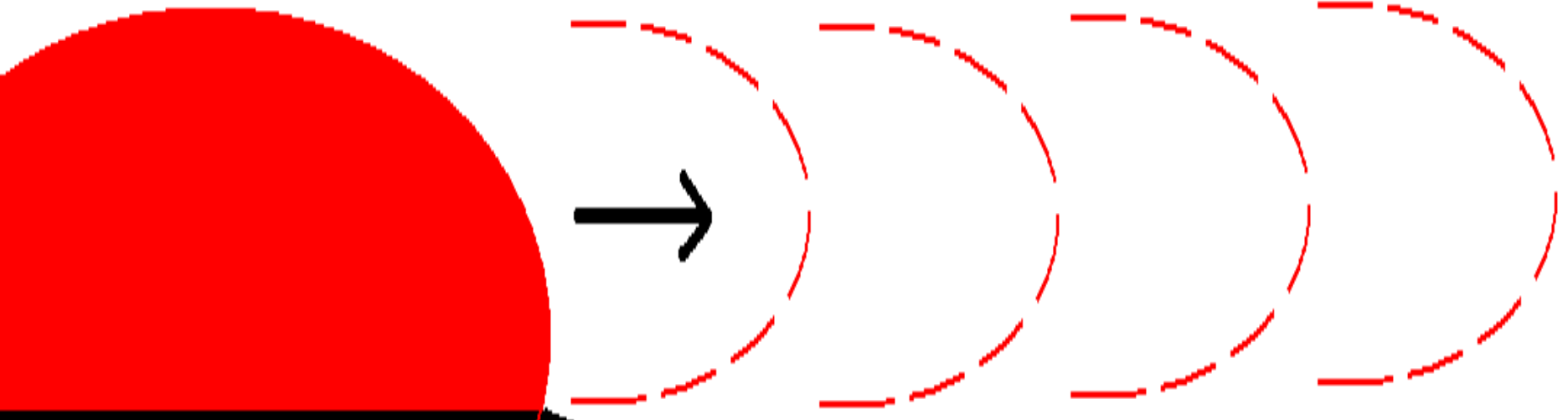
National Weather Service
North Platte, NE

Formation of the well mixed PBL

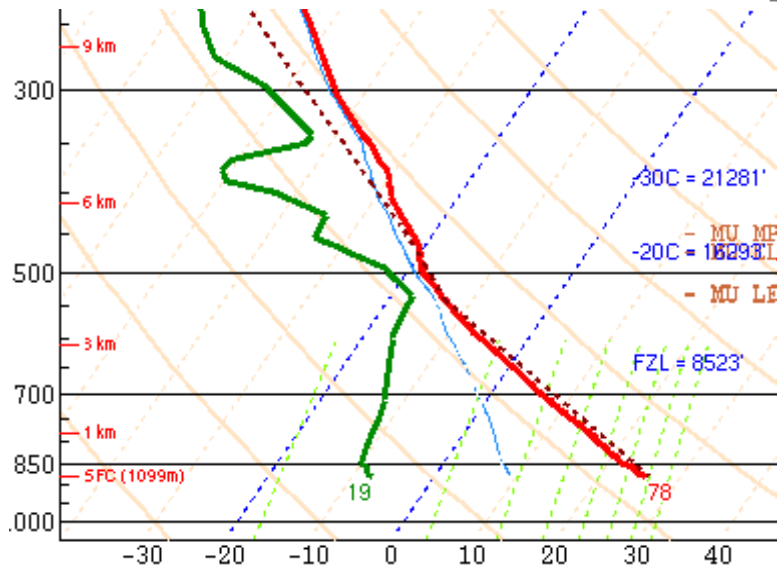
- EML (Lanicci and Warner 1987, 1991, 1997) spreads east across the Plains
- Deep well mixed PBL forms during the afternoon (Carlson et al. 1983, Lanicci et al. 1987, Chang and Wetzel 1991)
 - Where PBL moisture is shallow and surface wetness is low
 - Characterized by steep low-level lapse rates, strong surface heating, and veering surface winds
- Downstream, well mixed PBL does not form and capping inversion persists
- The interface between these two PBL airmasses is most favored for severe convection

EML is swept east across the plains
by strengthening west/southwest
upper-level flow

Elevated Mixed Layer (EML)



EML provides a capping inversion over the moist boundary layer
located over the lower terrain

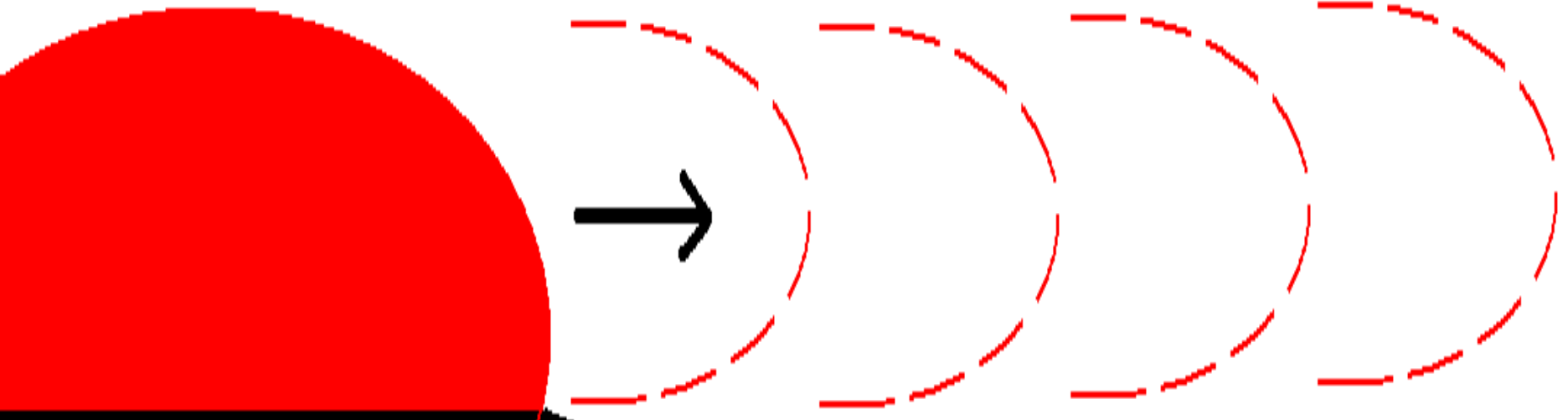


Shallow moisture depth: More prone
to deep vertical mixing

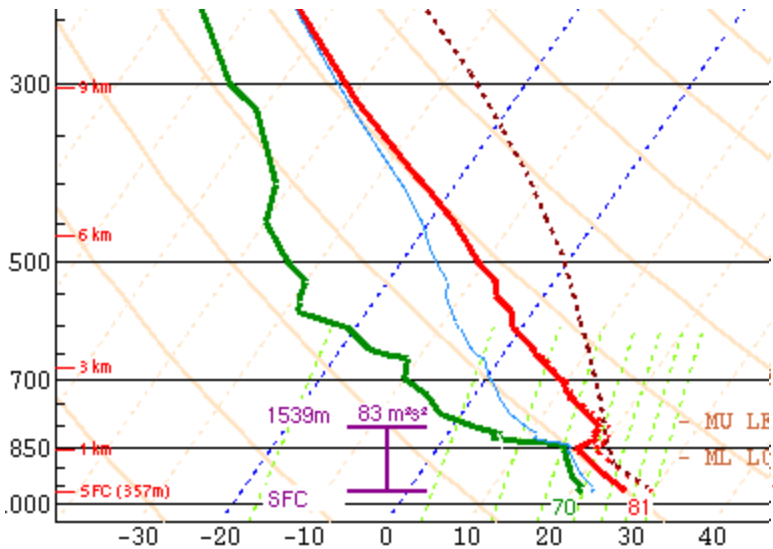
Deep moisture depth: Less prone
to deep vertical mixing

EML is swept east across the plains
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upper-level flow

Elevated Mixed Layer (EML)

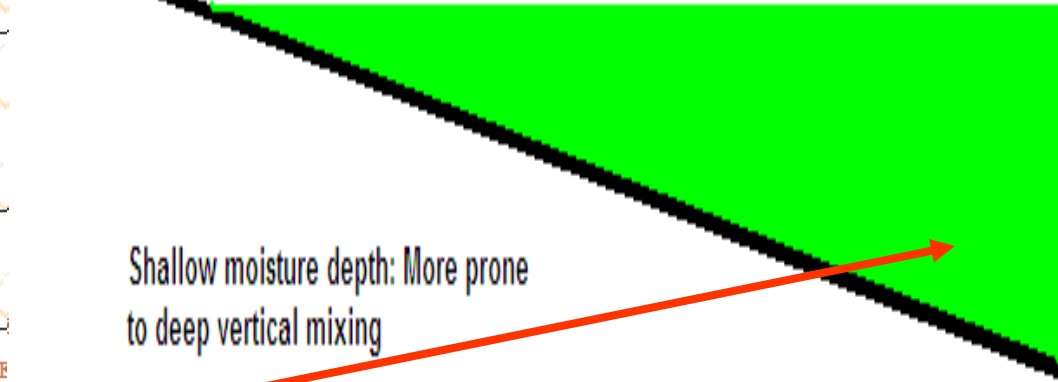


EML provides a capping inversion over the moist boundary layer
located over the lower terrain



Shallow moisture depth: More prone
to deep vertical mixing

Deep moisture depth: Less prone
to deep vertical mixing



Maximum in Low-Level Diabatic Heating

- Diabatic heating which decreases with height from the surface results in:
 - Rising motion and upper-level height rises...ageostrophic response and continuity produce low-level convergence
 - Increasing cyclonic vorticity in the BL enhances height perturbation and rising motion
 - Changing pressure gradient forces an isallobaric component to the wind
 - Mass flux into the pressure fall region
 - Increases moisture advection into the pressure fall region
 - Modifies the low-level and deep layer vertical wind shear
 - Density is lower over the hot, well mixed PBL...induces an ageostrophic response (“inland seabreeze”)
 - Ageostrophic response can increase the magnitude of the low-level jet

Re-Inforcement or Development of Low-Level Thermal Boundary

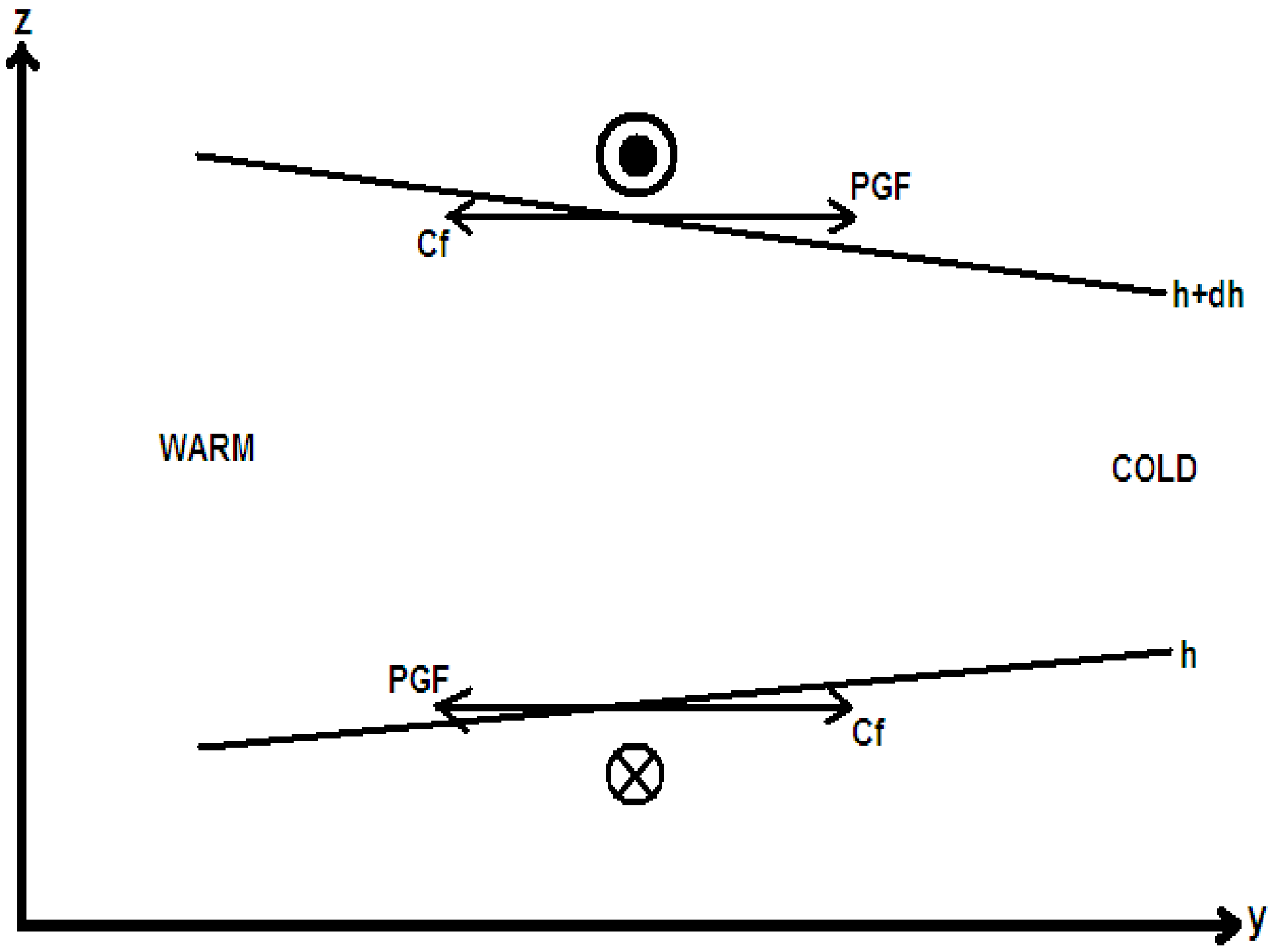
- A well mixed PBL adjacent to a region of greater static stability enhances the thermal gradient between the two regions
- Strong surface heating is maximized over the well mixed PBL region
- Sensible heating is weaker over the more stable PBL region
- Possible Implications:
 - Increasing frontogenesis
 - Additional low-level focus for thunderstorm initiation
 - Creation/enhancement of thermal boundary favorable for tornadic storms

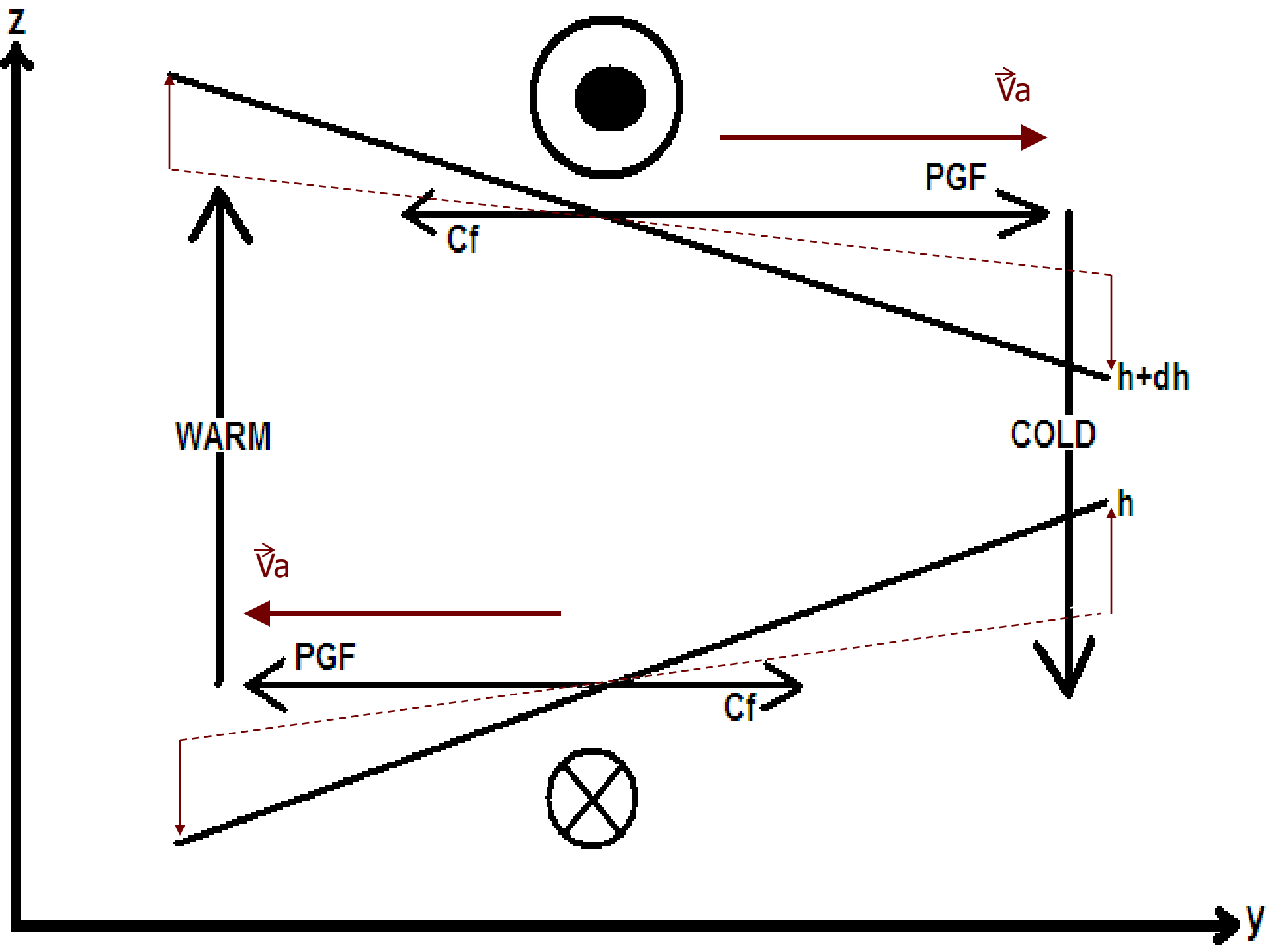
Horizontal Variation in Low-Level Heating

- If wind flows from the hot well mixed PBL to the cooler PBL, then:
 - Warm air advection is maximized downwind of the well mixed PBL (destabilization process)
 - Synoptic-scale ascent and surface pressure falls become more prominent downwind
 - WAA regime is also generally associated with enlarged clockwise curving hodographs
 - Favorable for tornadic supercells

Thickness Perturbation

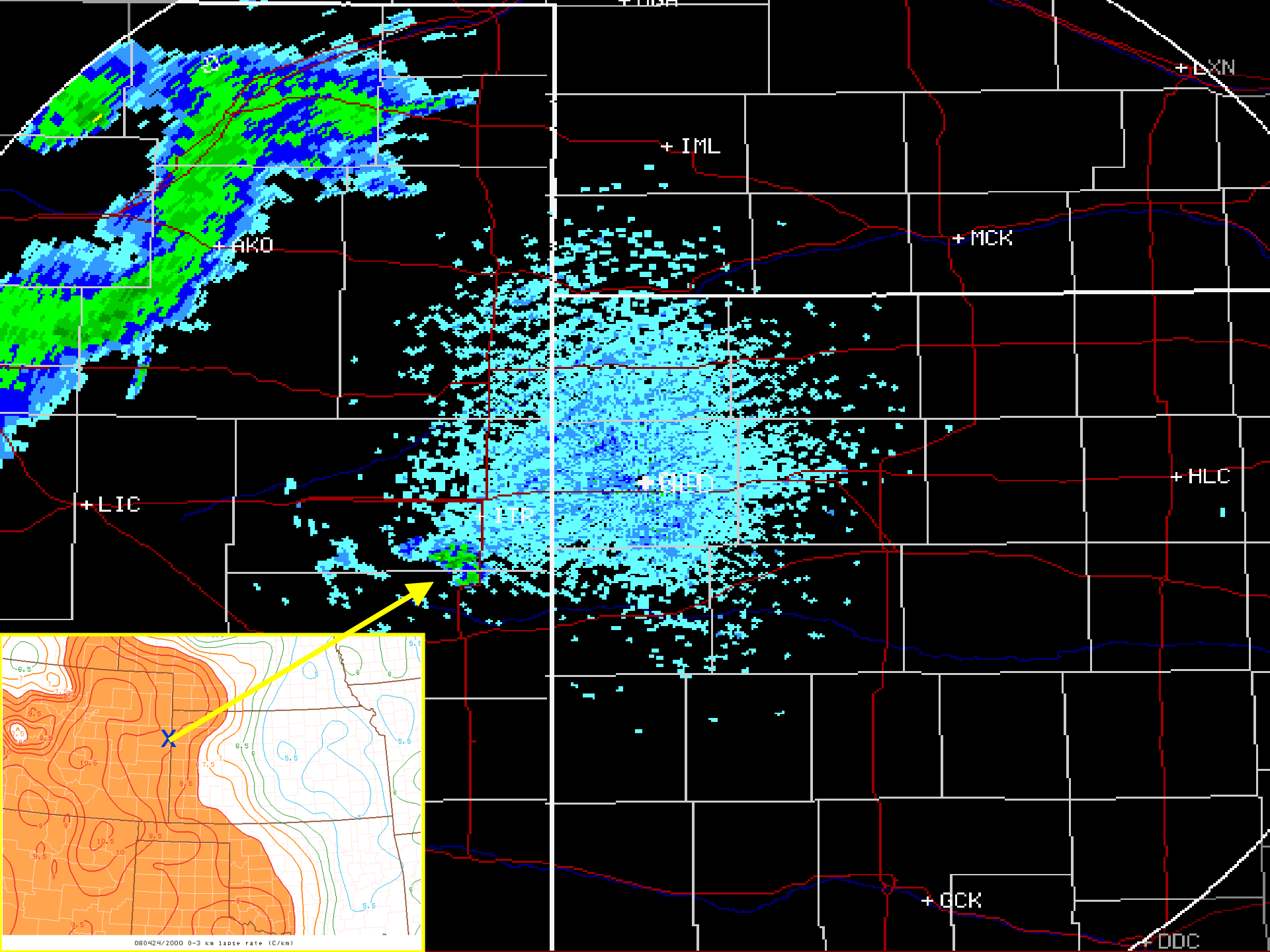
- Strong diabatic heating within the well mixed PBL perturbs the thickness (increase in thickness) (Kaplan et al. 1984)
- Changing thickness requires a QG response
 - Large-scale ascent increases over the region of increasing thickness (enhanced by very low static stability)
 - in order to instantaneously cool the recently warmed column
 - Ageostrophic response is induced in order to achieve thermal wind balance (thermally direct circulation)
 - Upper-level divergence and low-level convergence increase





Rapid Destabilization

- A region of rising motion now becomes established (which aids in removing the capping inversion)
 - Rising motion within the hot well mixed PBL may initiate high based convection that will intensify upon reaching the moist potentially unstable airmass downstream (Umsheid and Johnson 2005, Houston and Niyogi 2007)
- Influx of low-level moisture occurs adjacent to a region of strong diabatic heating
 - The interface between these two airmasses maximizes low-level theta-e and CAPE
- Stage is set for rapid severe storm development
 - Destabilization and increasing convective instability have become collocated, greatly enhancing the potential for severe thunderstorm development over a localized region



+AKO

+IML

+MCK

+LKN

+LIC

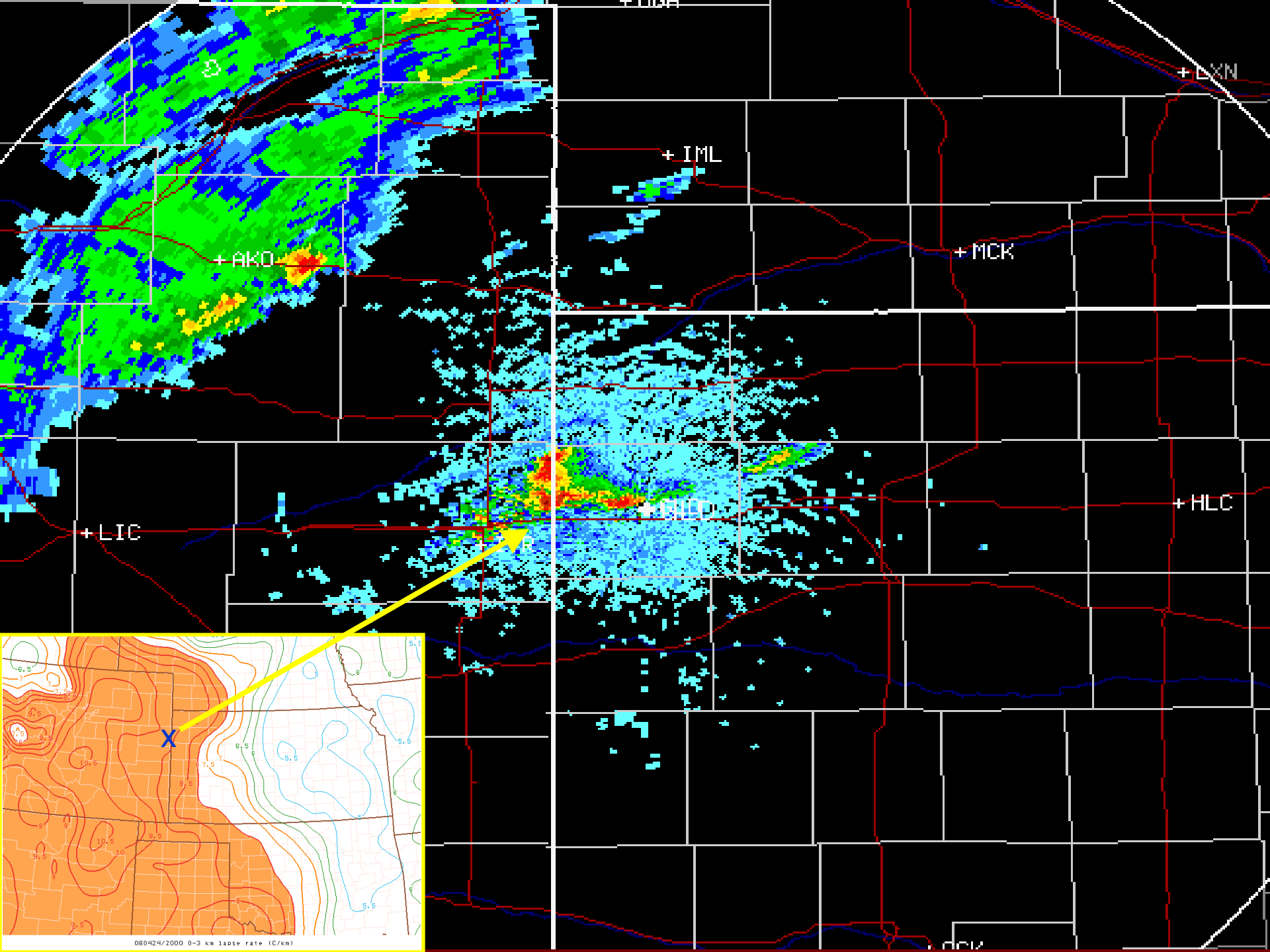
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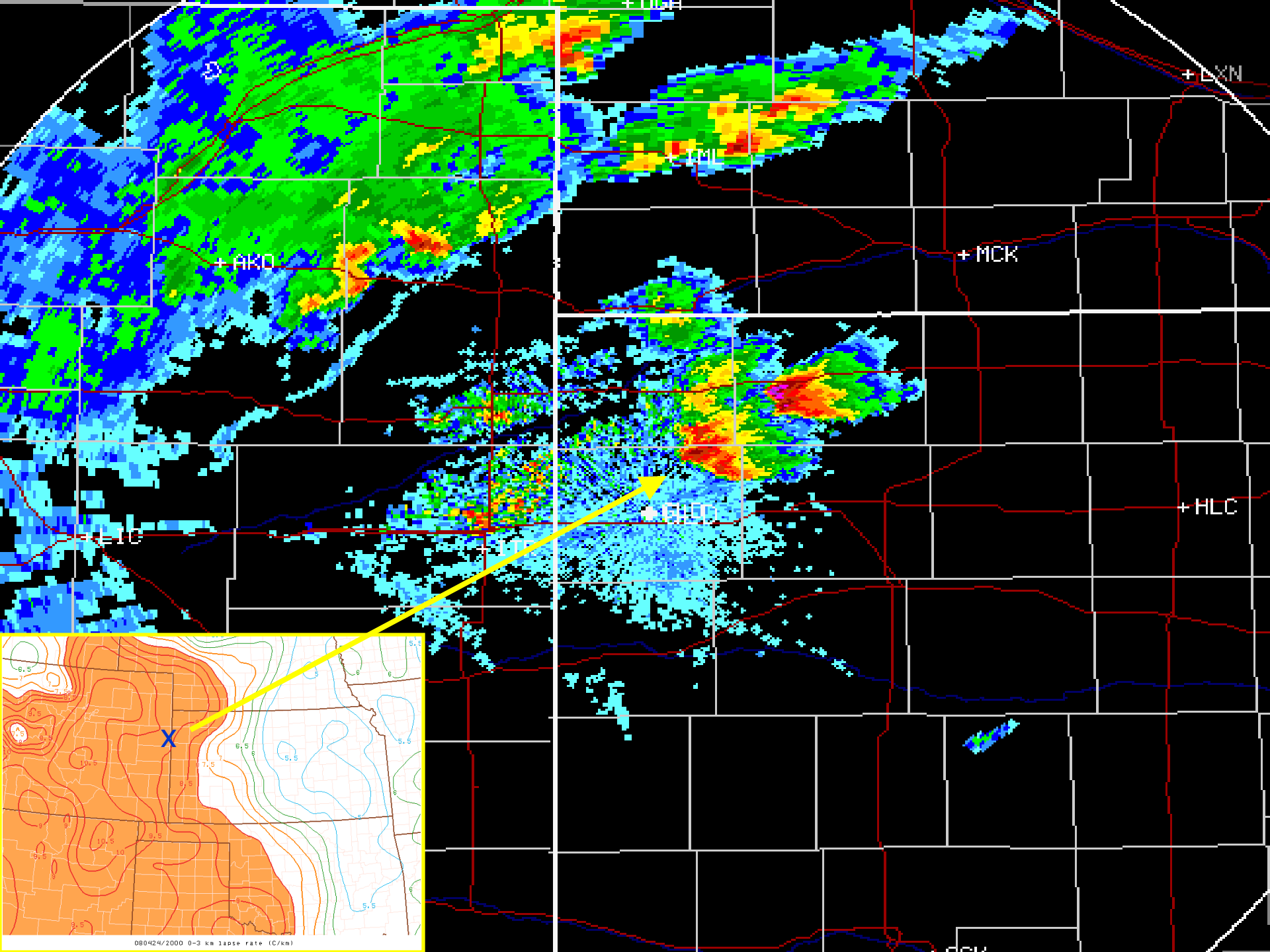
+BCK

+DDC

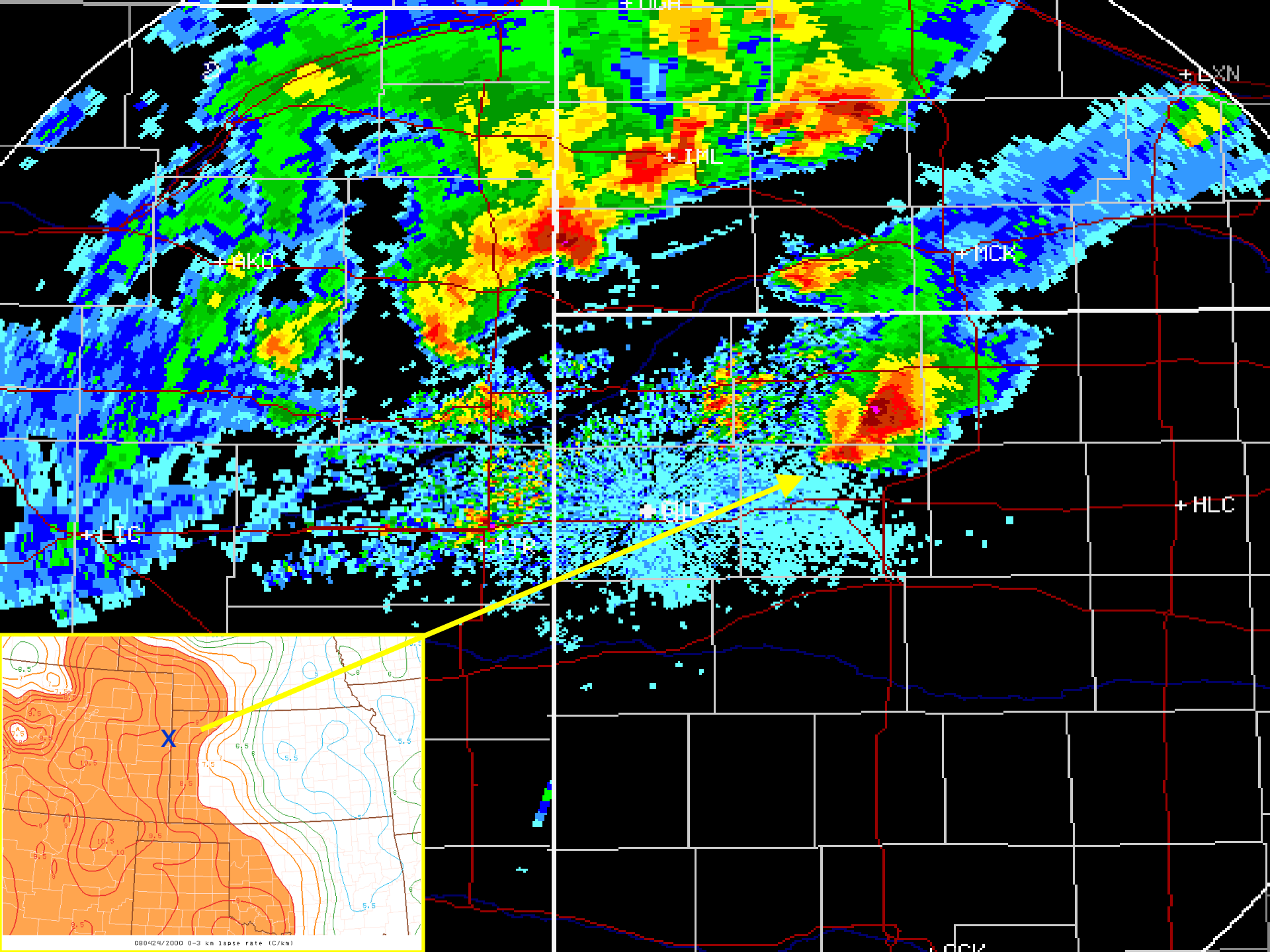
080424/2000 0-3 km lapse rate (C/km)



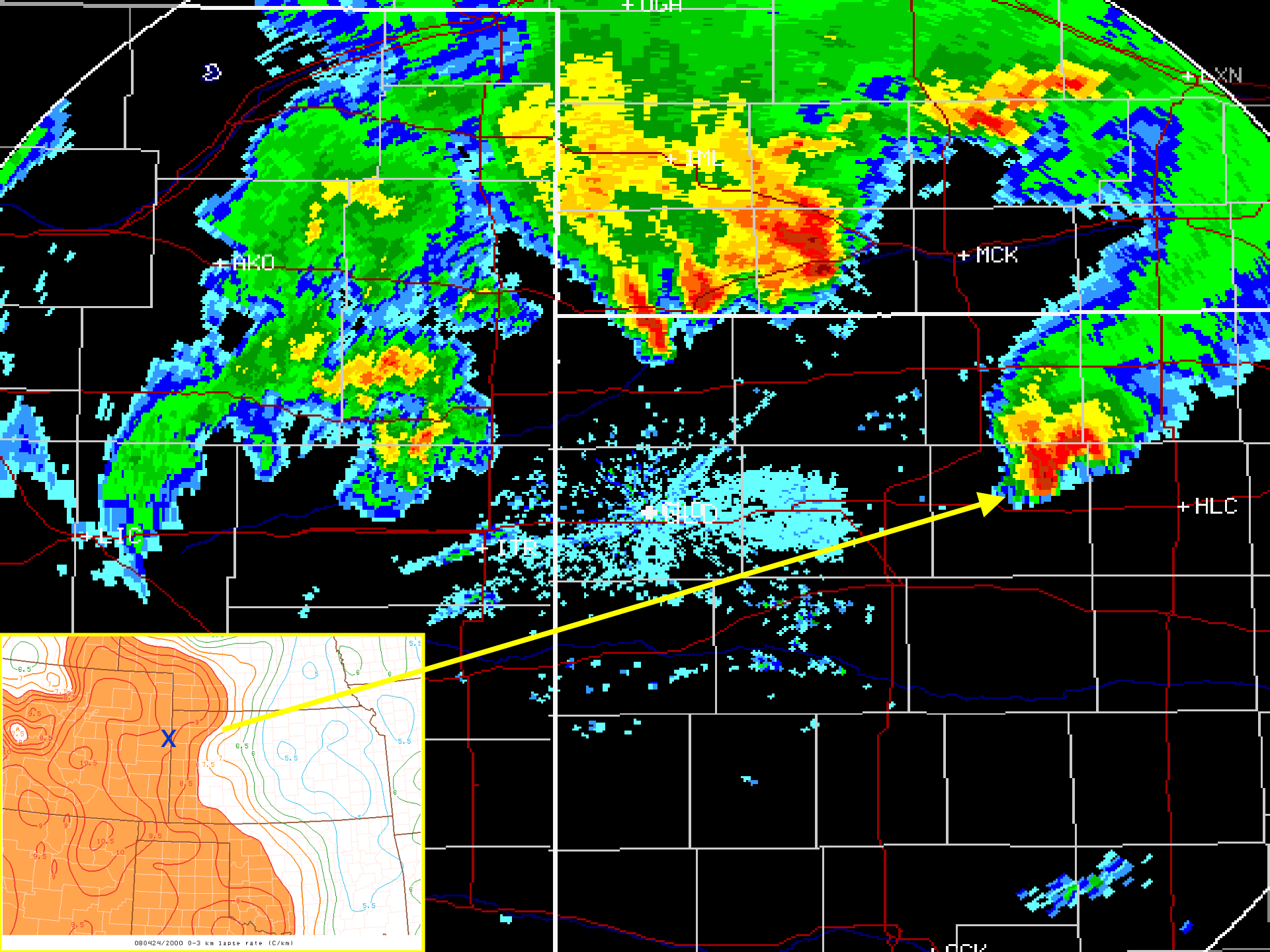
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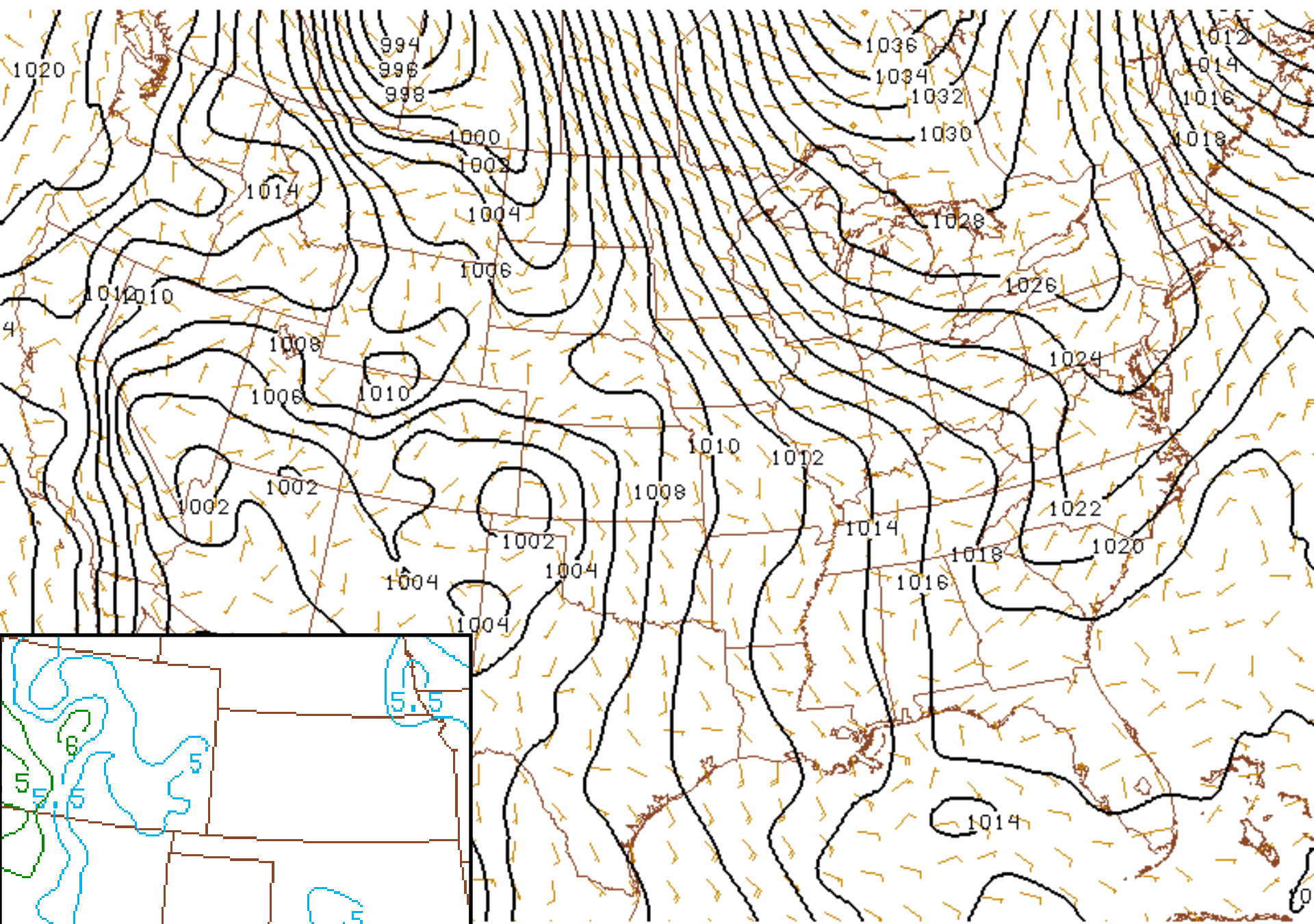
080424/2000 0-3 km lapse rate (C/km)

Ideal Setting

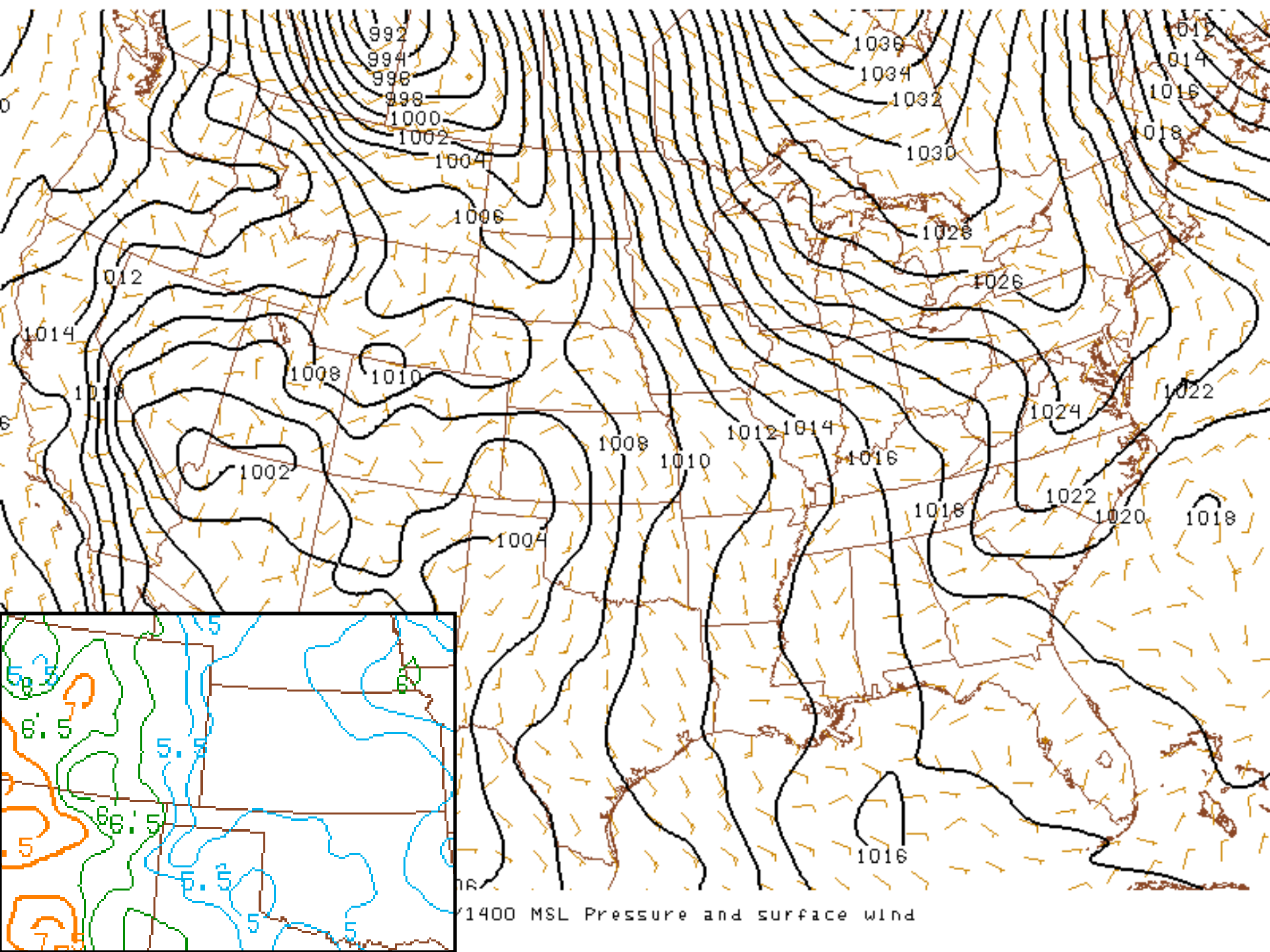
- Upstream mobile mid/upper-level disturbance approaches a well mixed PBL region
 - Well mixed PBL is characterized by steep 0-3 km lapse rates
- The well mixed PBL protrudes into a pool of rich/deep low-level moisture located downstream
- Mass fields respond vigorously due to the interaction between the hot well mixed PBL and approaching disturbance
 - Ageostrophic motion and ascent, moisture advection, convective instability, and vertical wind shear become focused immediately downwind of the well mixed PBL
 - Violent convection is most favored to erupt in this region of enhanced ingredients

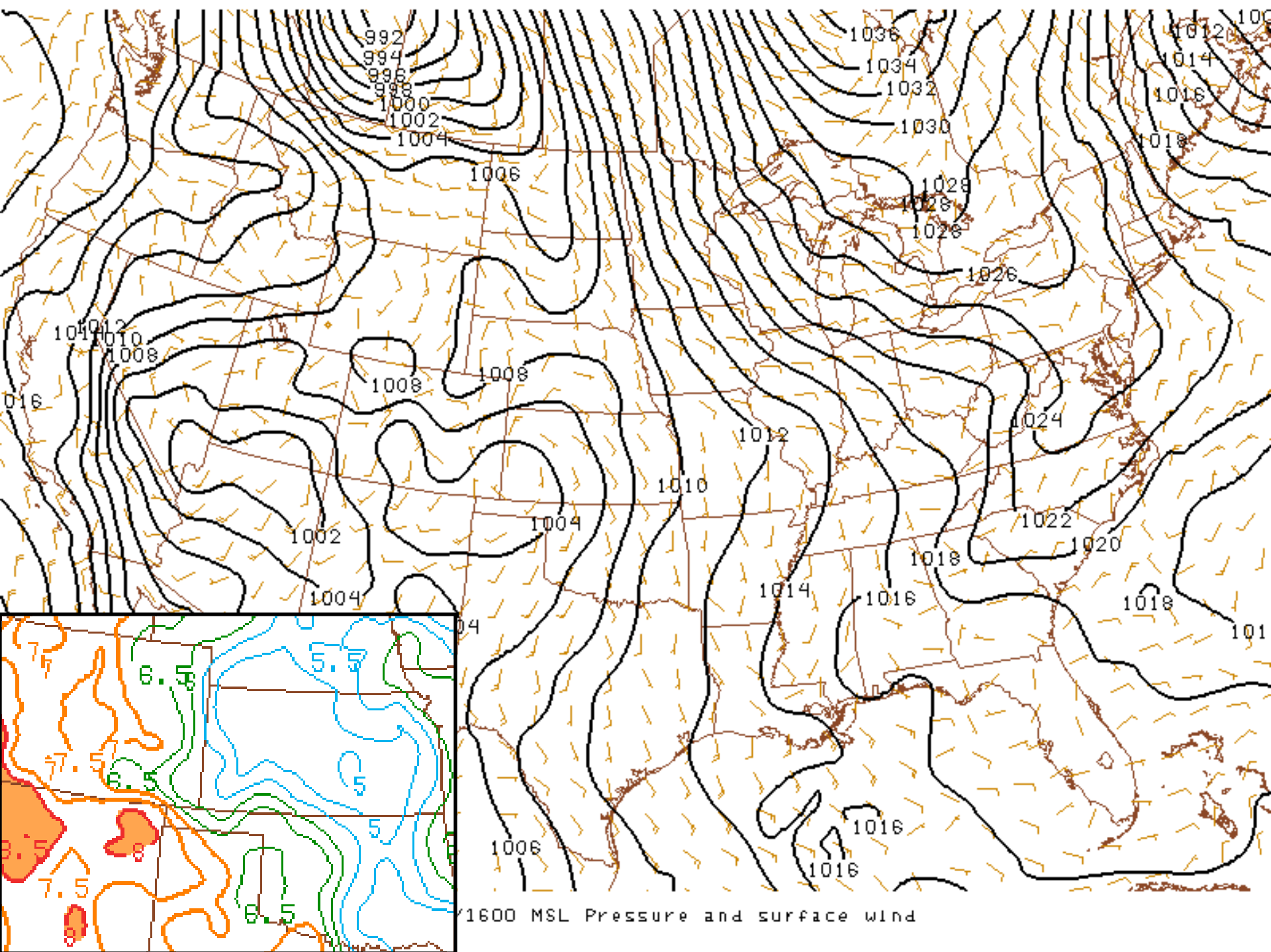
4 May 2007

- Supercell emanated out of the well mixed PBL
 - Storm produced several large, significant tornadoes
- Mobile upper trough was located upstream
- Moist, potentially unstable low-level airmass positioned downstream
- Favorable “processes” were focused immediately downstream of the hot, well mixed PBL

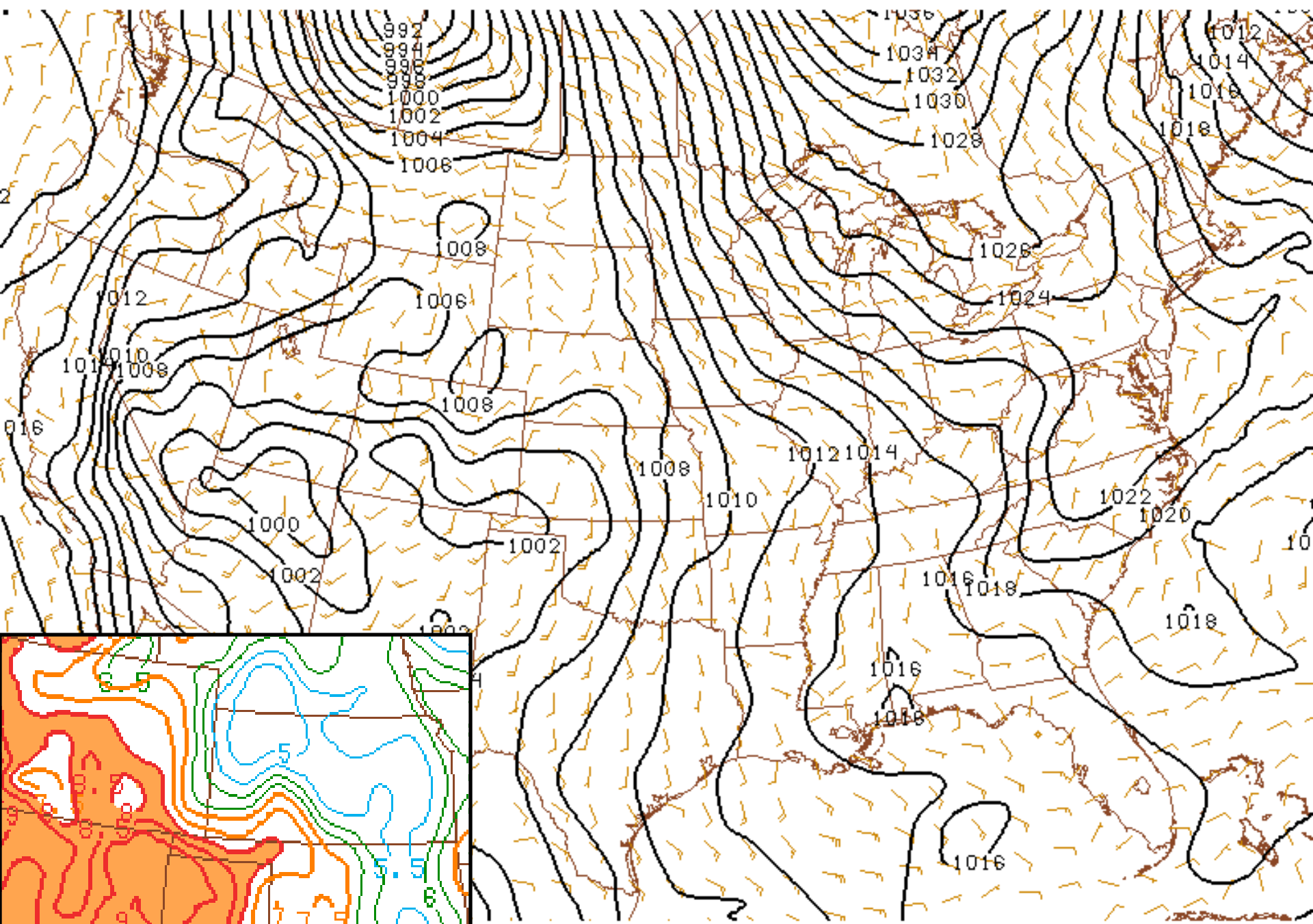


1200 MSL Pressure and surface wind

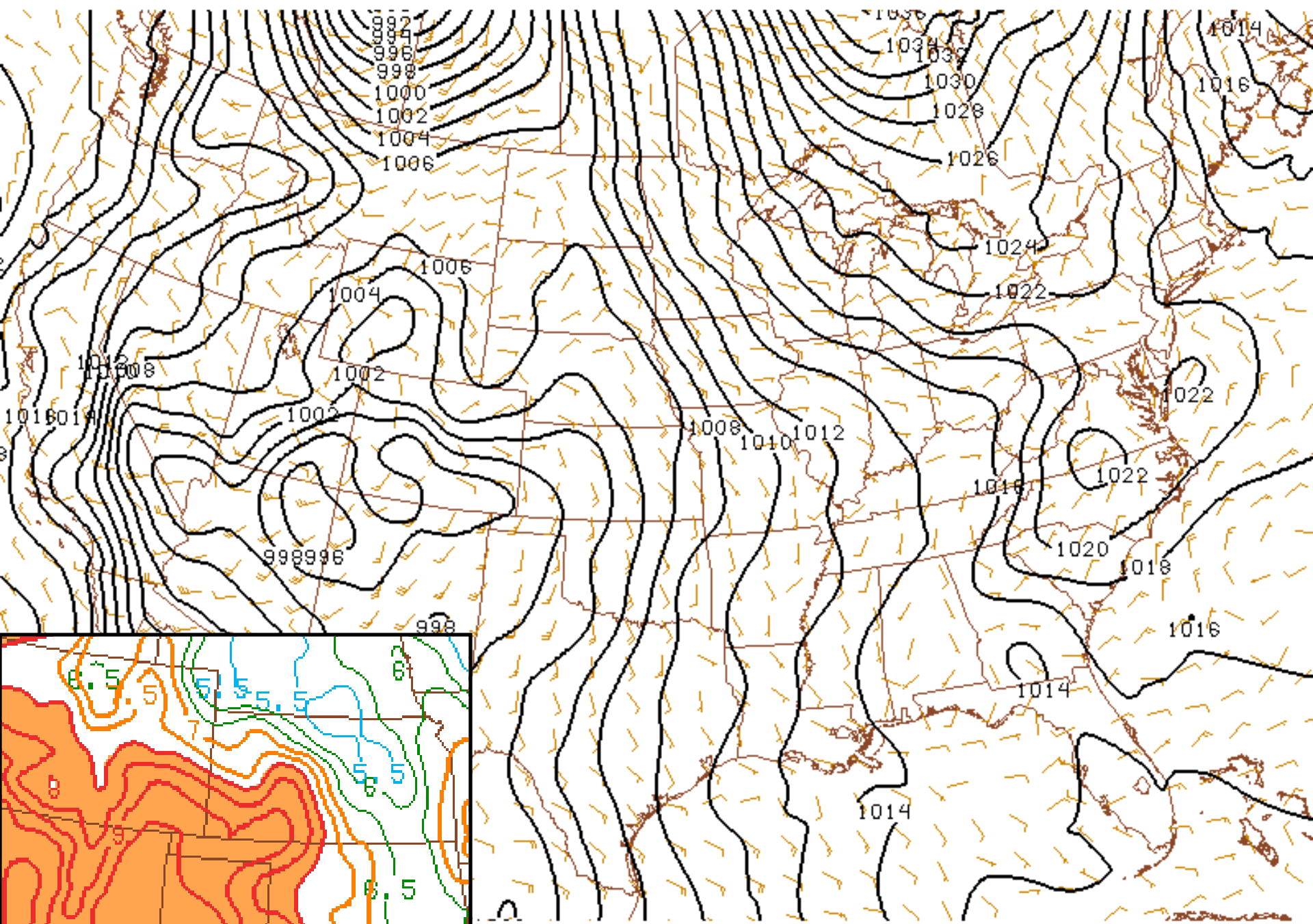




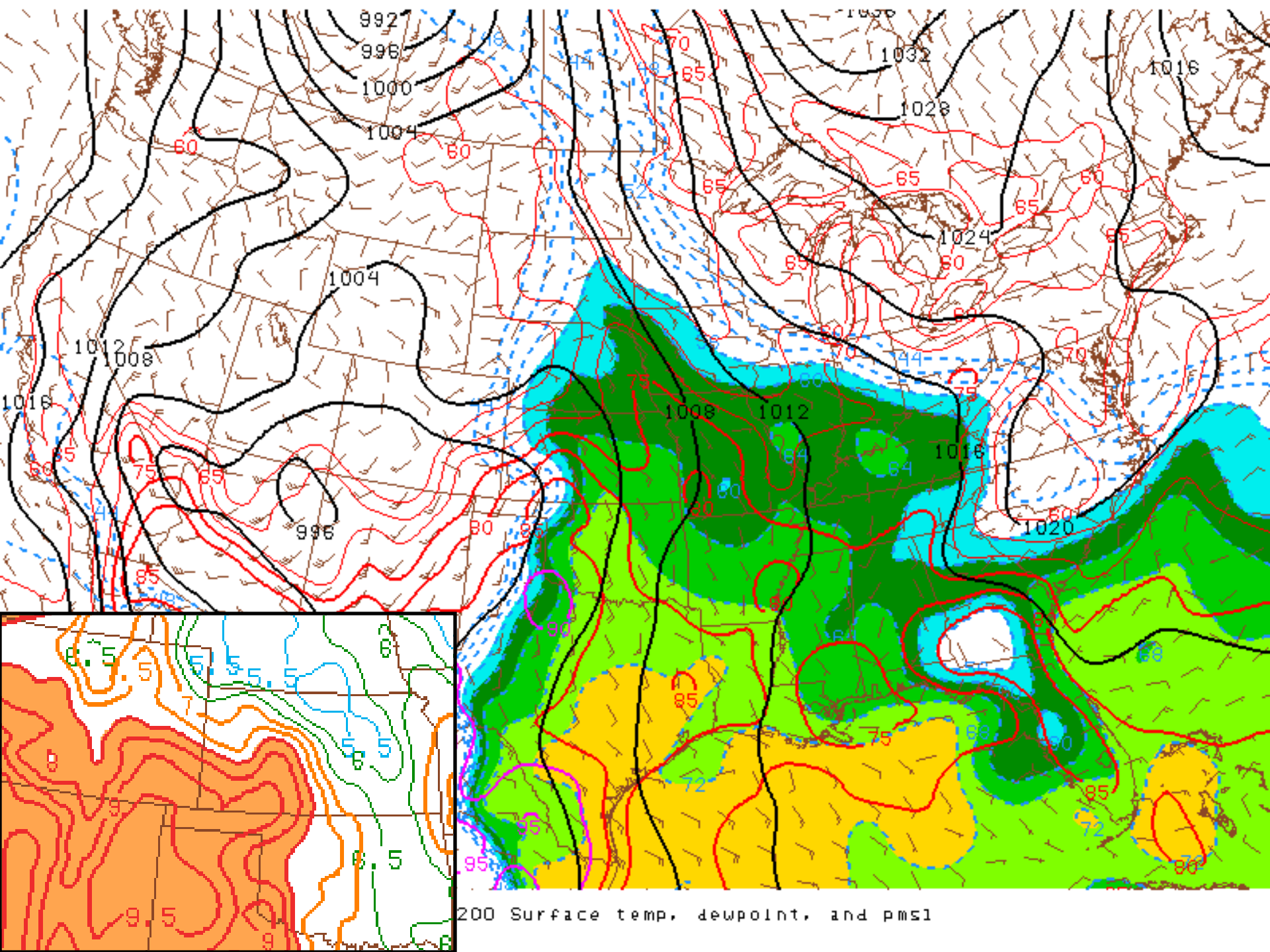
1600 MSL Pressure and surface wind



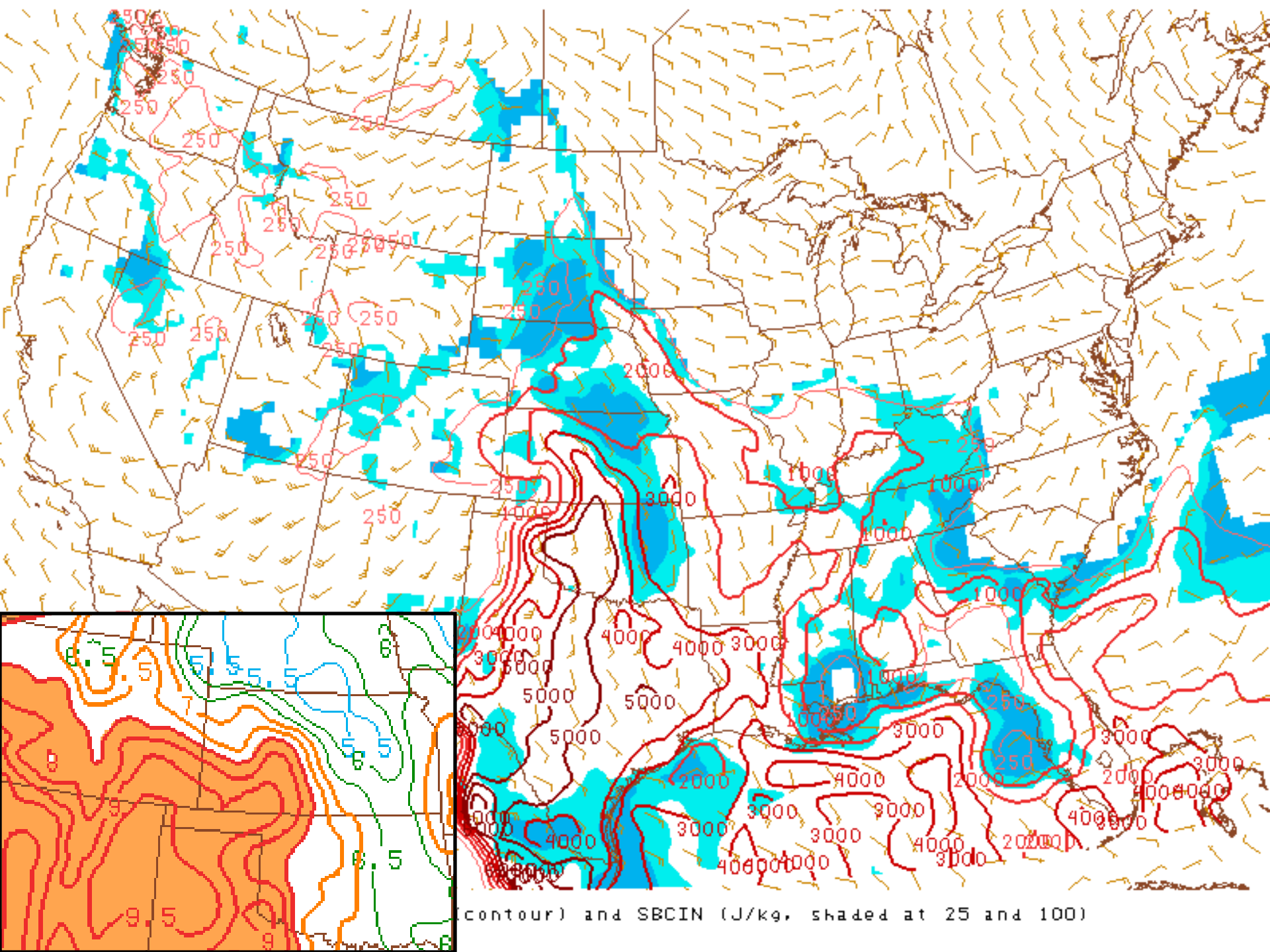
1800 MSL Pressure and surface wind



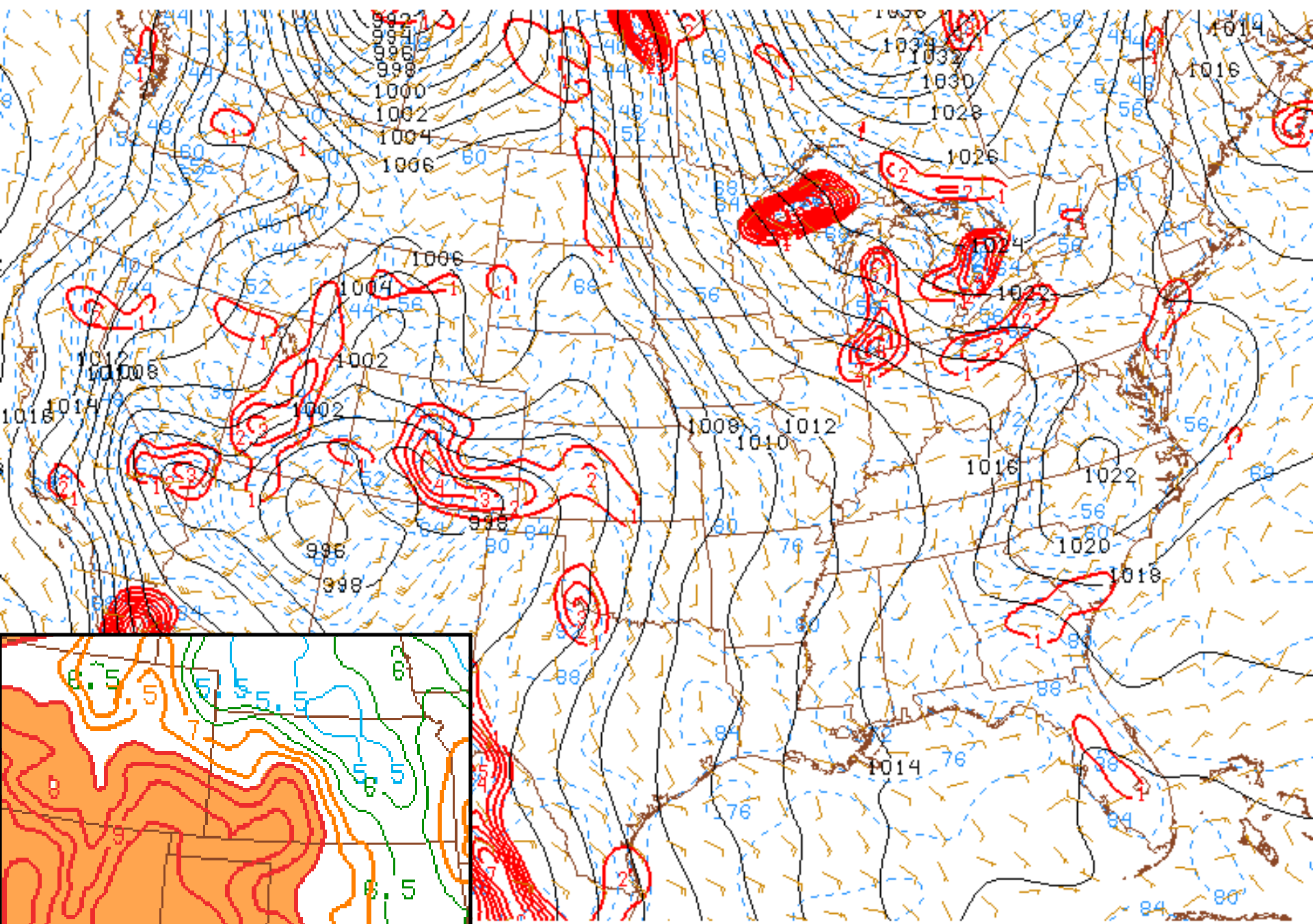
2200 MSL Pressure and surface wind



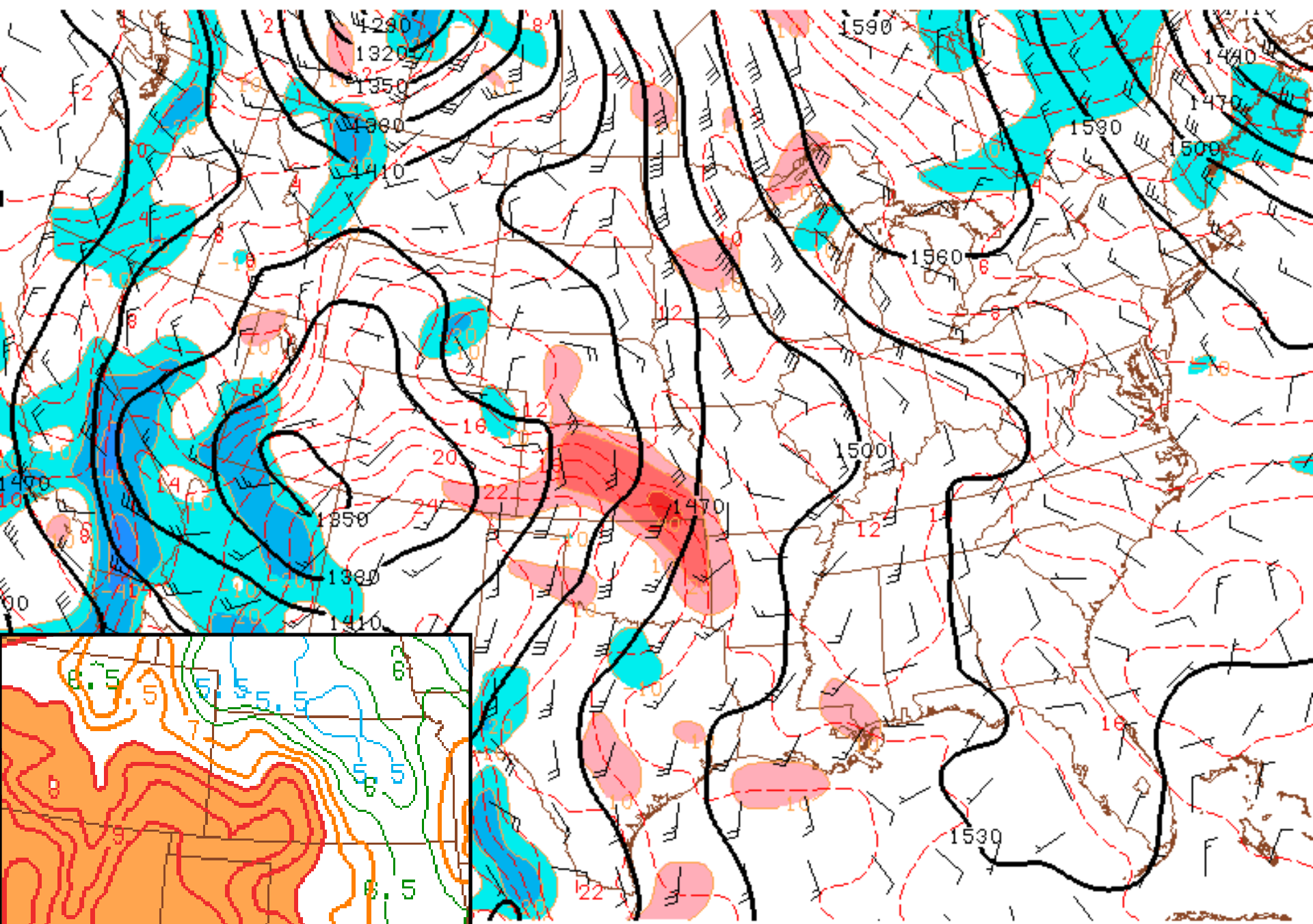
200 Surface temp, dewpoint, and pms1



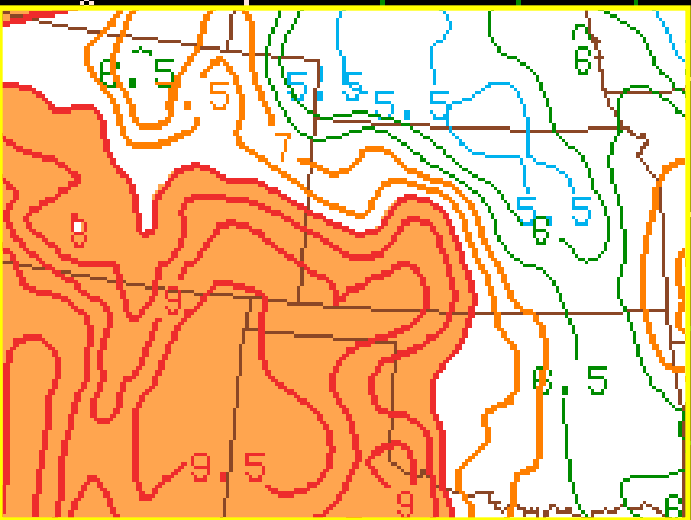
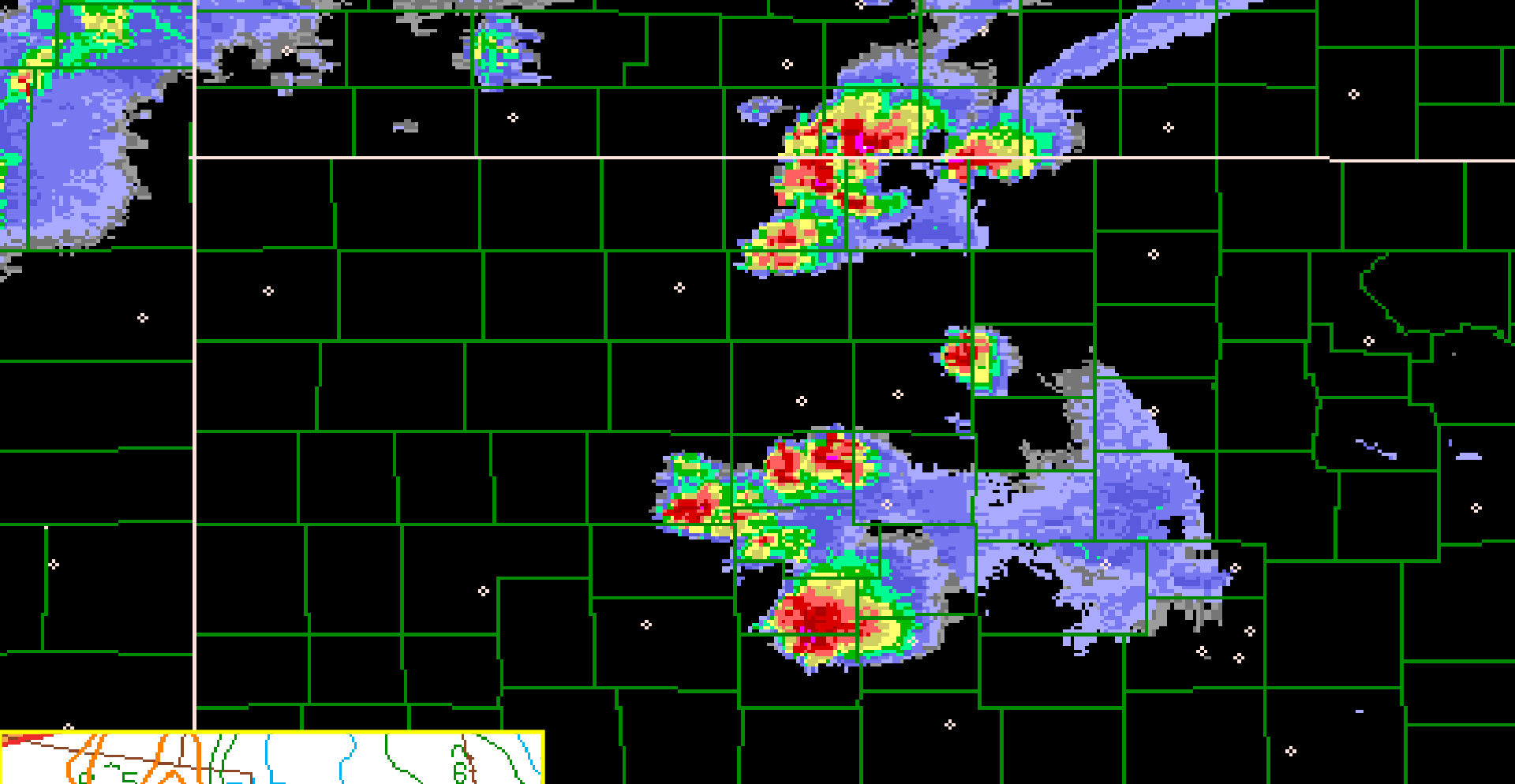
contour) and SBCIN (J/kg, shaded at 25 and 100)



Surface frontogenesis, temp, pres and wind

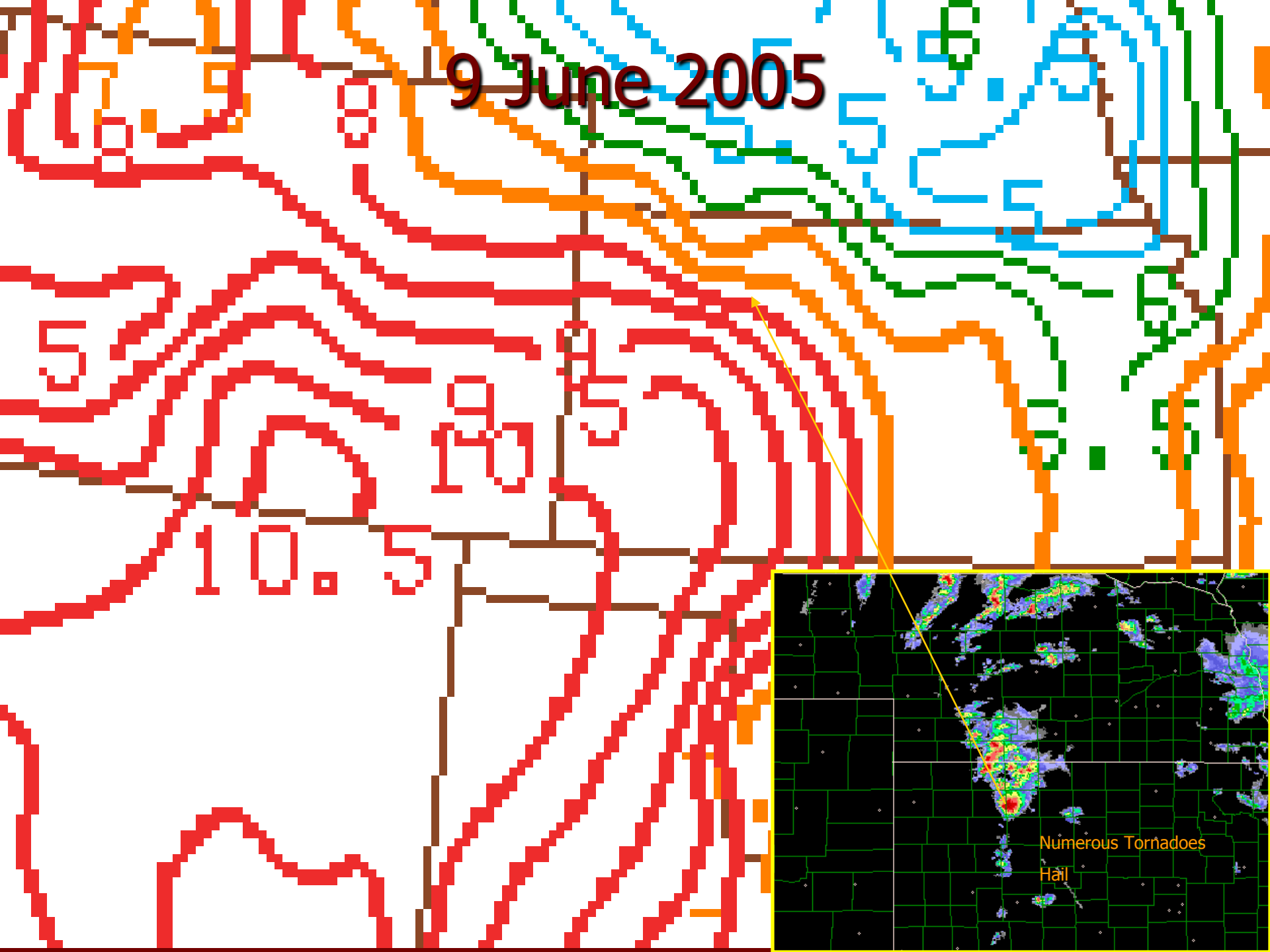


001 850 mb temperature advection (fill)
001 850 mb height, temperature and wind

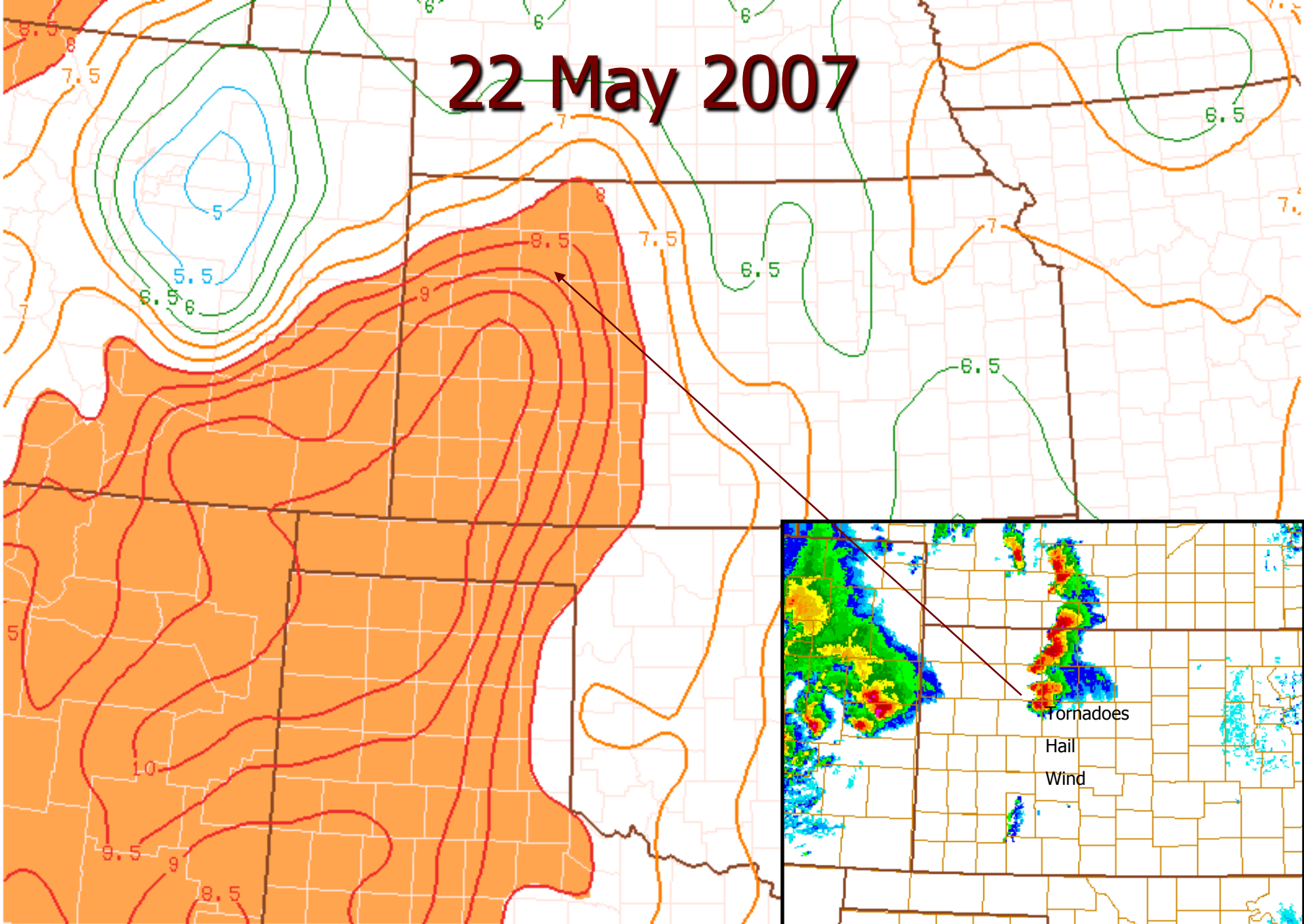


0330Z

9 June 2005

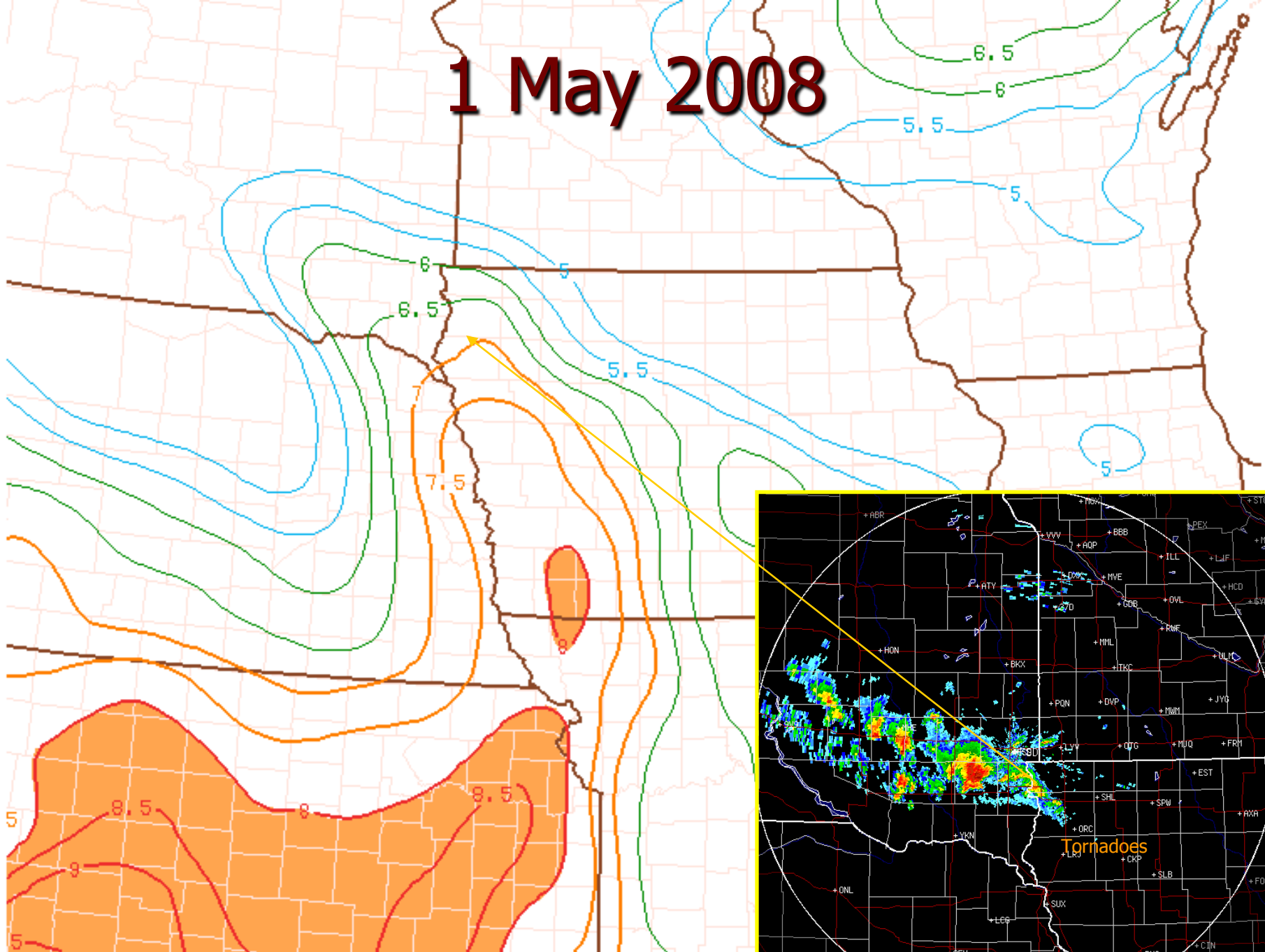


22 May 2007

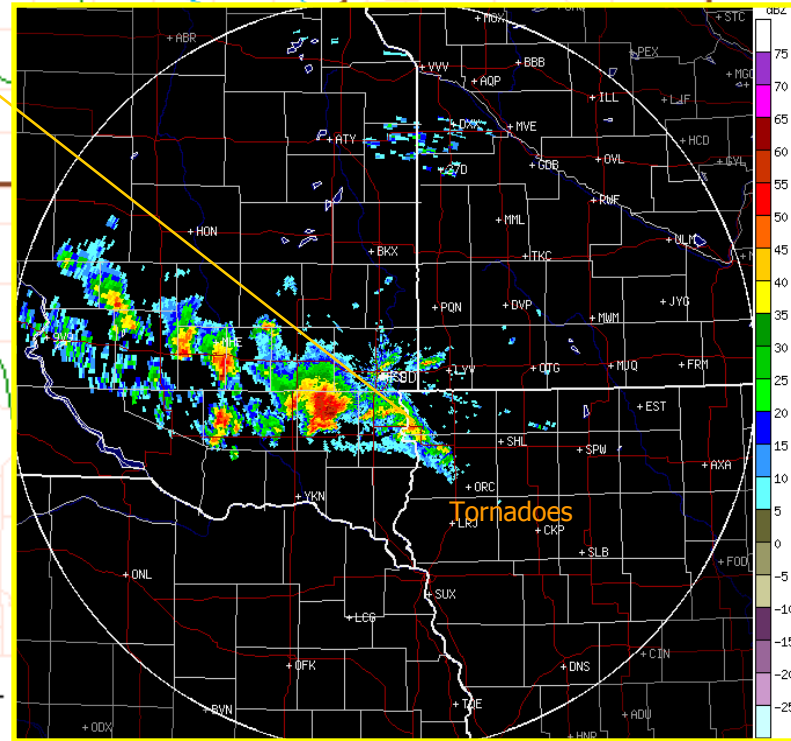


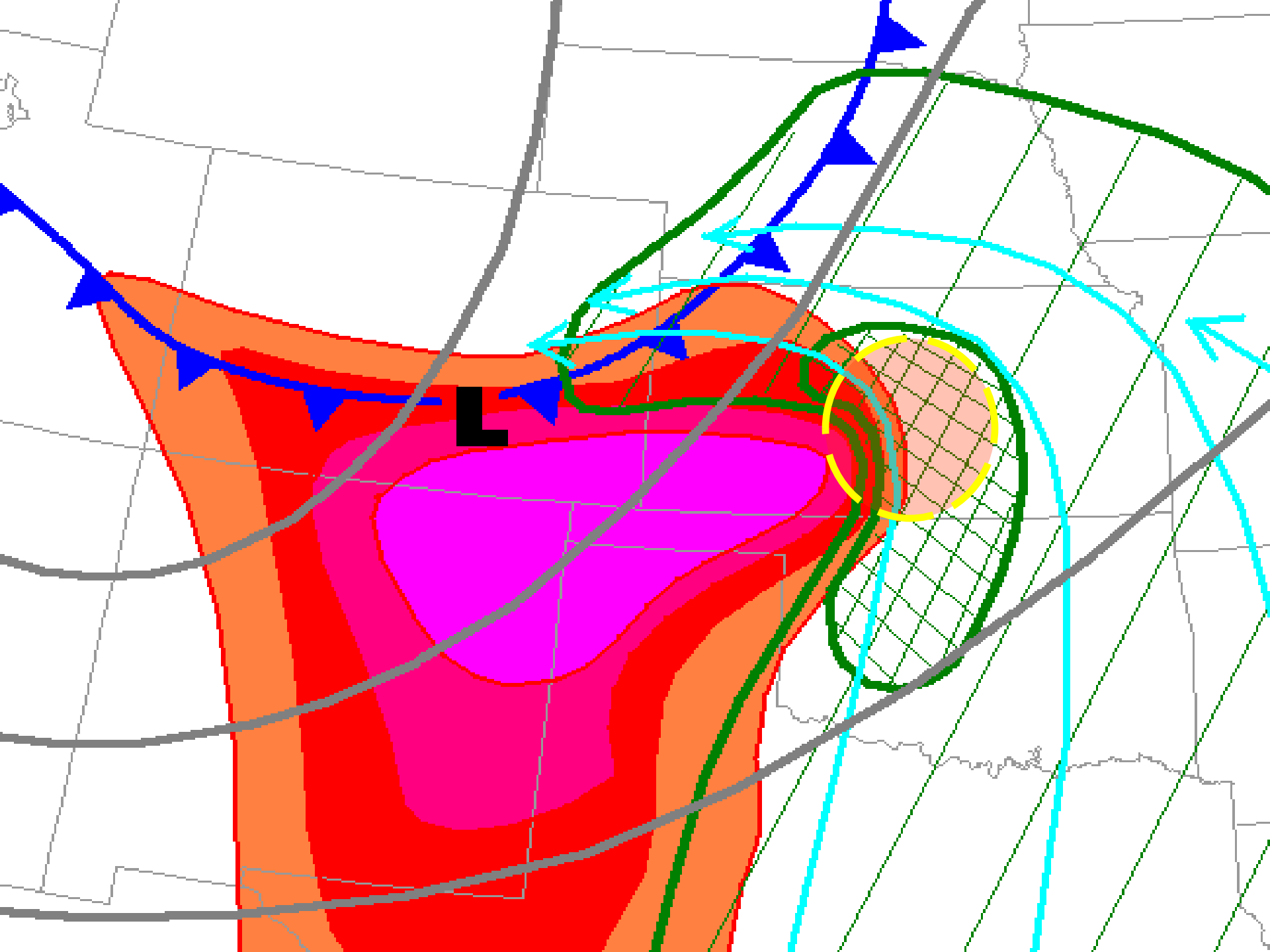
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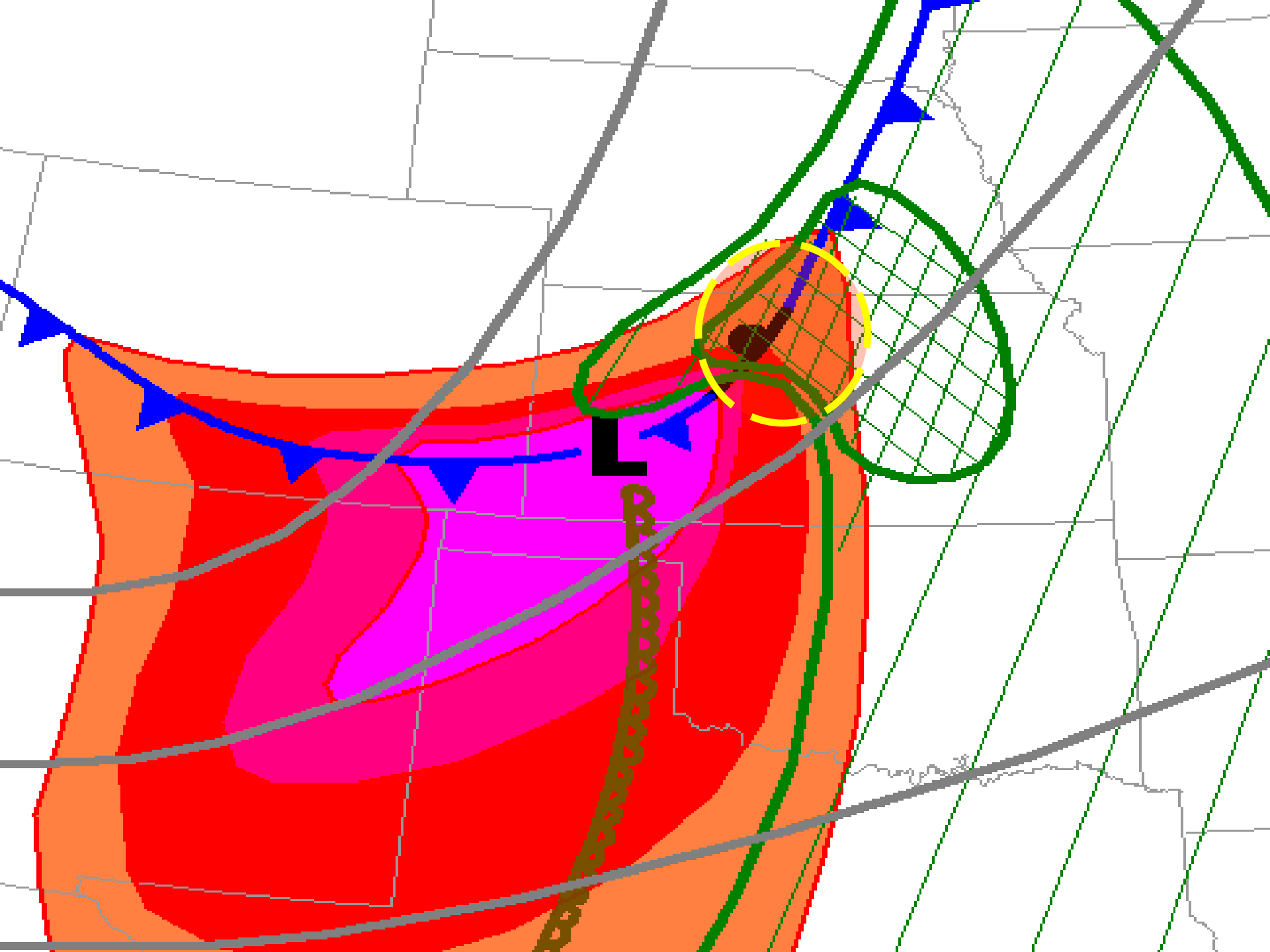
1 May 2008

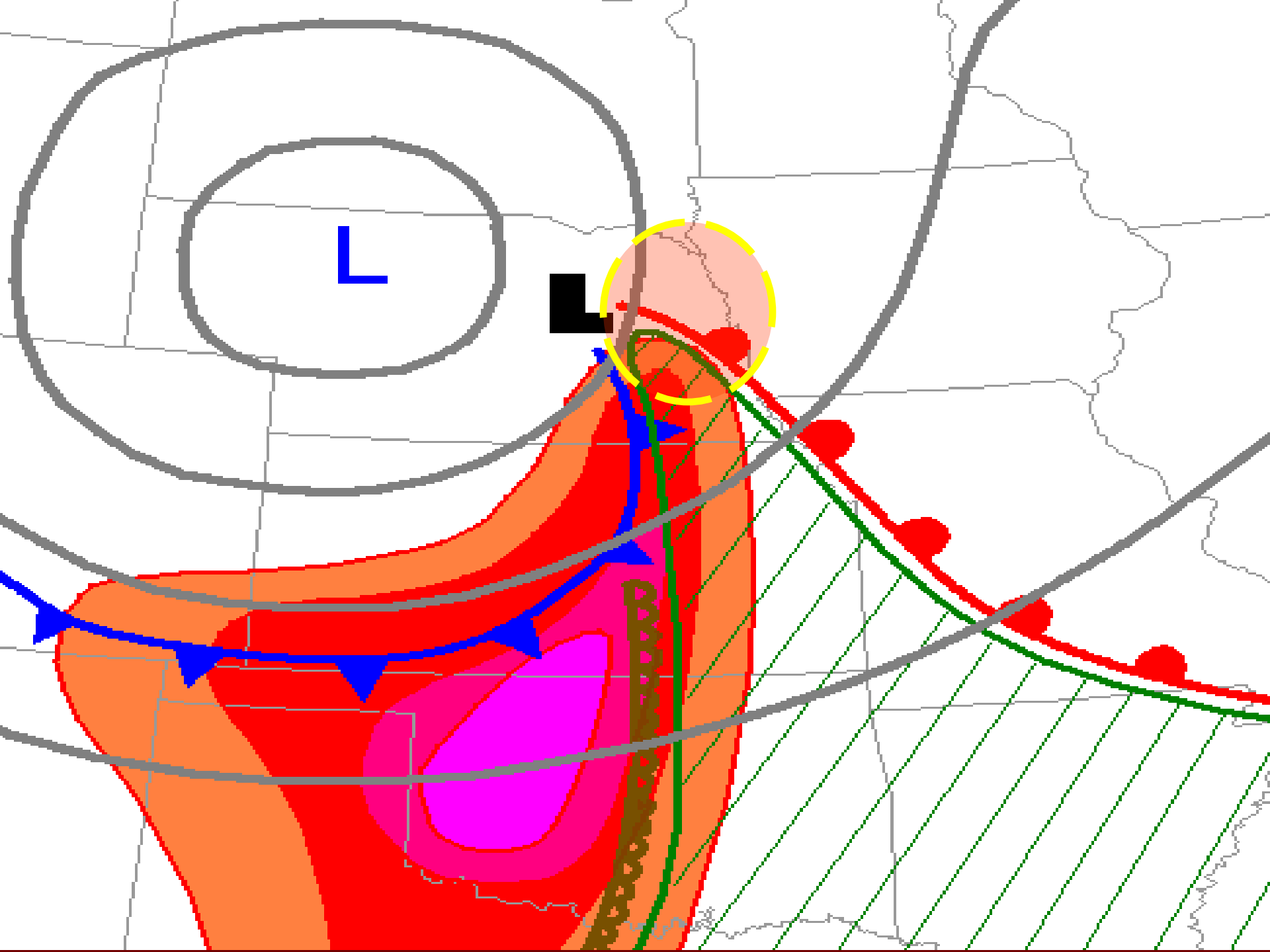


080501/2200 0-3 km lapse r









Summary

- Locate the well mixed PBL upstream from a region of rich low-level moisture and downstream from a mobile shortwave trough
 - Low-level WAA and Fgen are focused immediately downwind
 - Strongest destabilization takes place between the cooler but moist BL airmass and the hot well mixed PBL
 - Enhancements to upper-level divergence/low-level convergence are favored over the strongly heated well-mixed PBL
 - Ageostrophic response and low-level WAA can yield favorable hodograph structure for tornadic supercells
- Low-level lapse rate axis
 - Subjective experience shows that the most intense (often discrete) convective episodes occur on the “nose” of the low-level lapse rate axis
 - Look for LLR axis that protrudes into the moist boundary layer
 - This is an area that should be monitored for signs of rapid thunderstorm development
- All of the features highlighted in this presentation can be monitored in near-real time using the SPC mesoanalysis sectors, or in your AWIPS browser