Rapid Environmental Changes observed by Remote Sensing Systems in the local vicinity of an unusual Colorado Tornado

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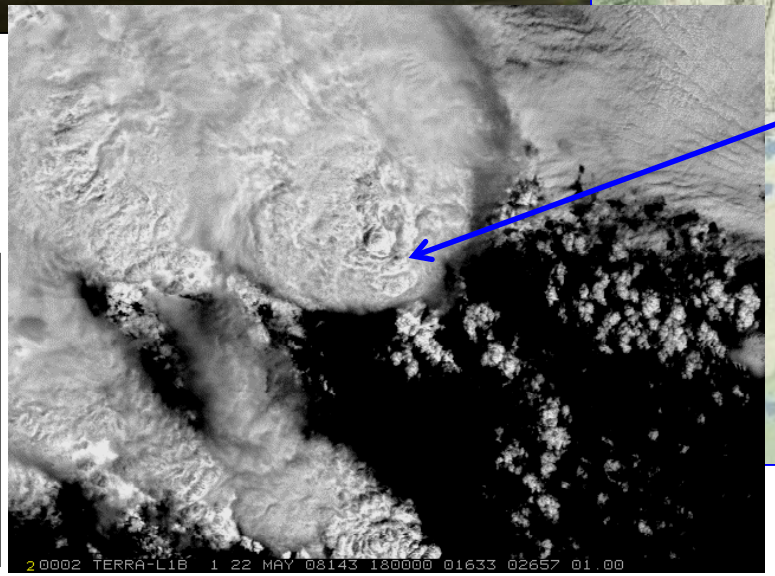
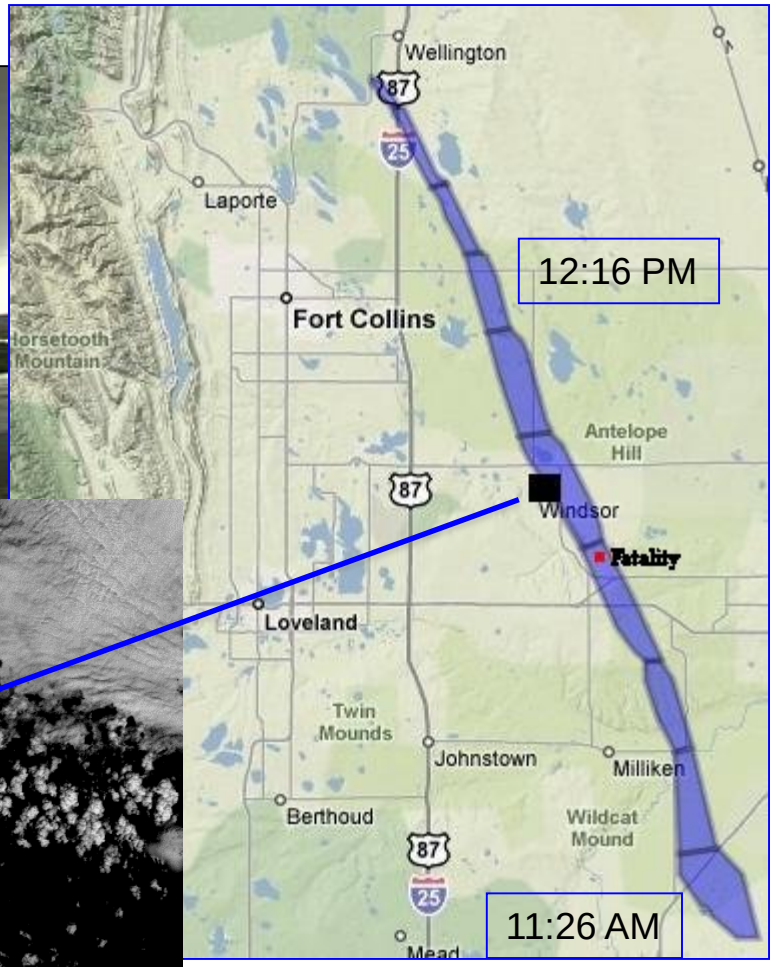
Steven E. Koch
NOAA National Severe Storms Laboratory (NSSL)

Hongli Jiang
NOAA Earth System Research Laboratory (ESRL)
Cooperative Institute for Research in the Atmosphere (CIRA)

Randolph Ware
Radiometrics Corporation
National Center for Atmospheric Research
Cooperative Institute for Research in the Environmental Sciences (CIRES)

The Unusual Windsor Tornado of May 22, 2008

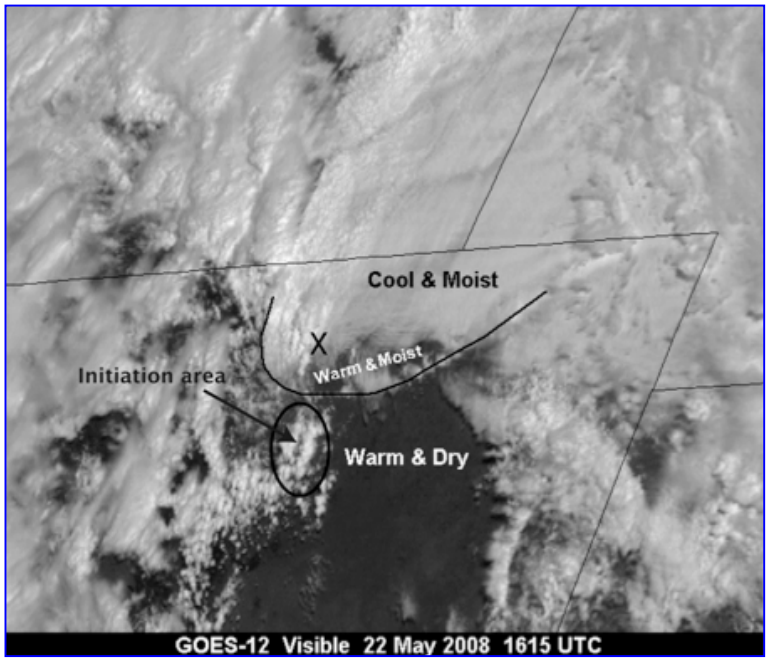




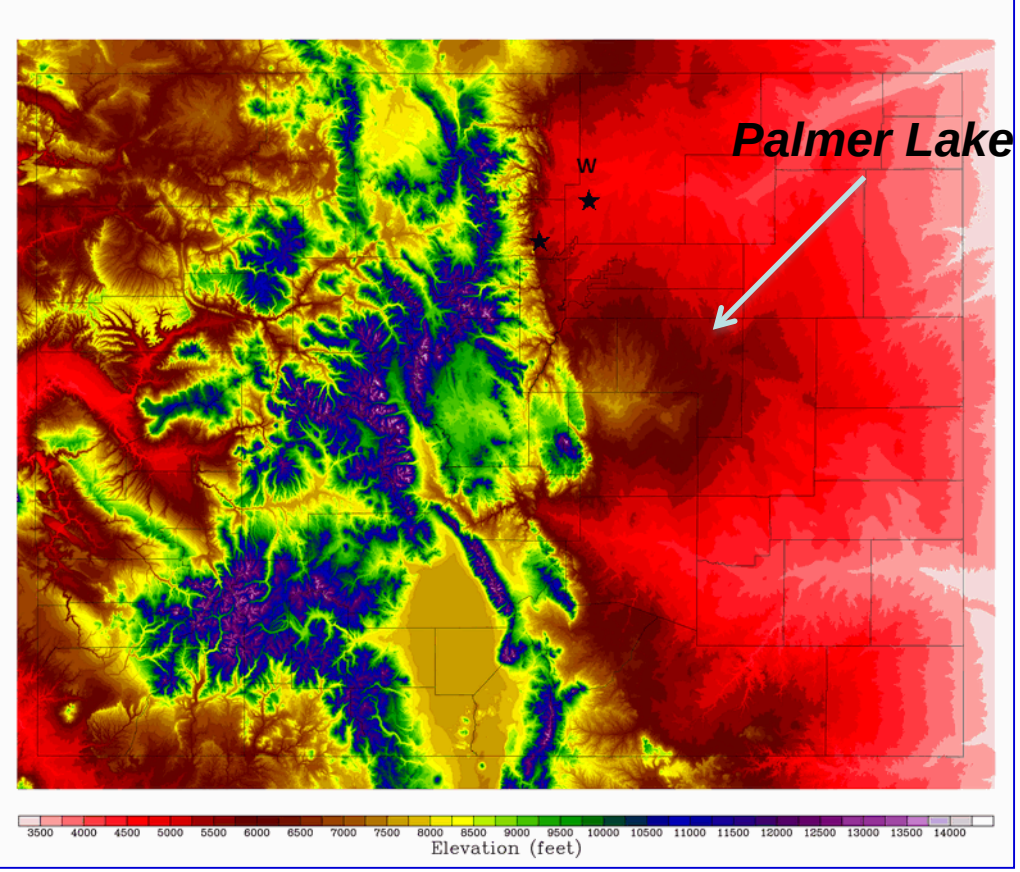
Windsor was hit by a mile-wide EF3 tornado – the costliest tornado in Colorado history - around lunch time (1726 UTC at Platteville). The tornado tracked northwestwardly on the ground for 55 km through northern Colorado.

Severe Weather Ingredients
(Schumacher et al. 2010)

- ✓ Moisture
- ✓ Instability
- ✓ Lift
- ✓ Vertical Wind Shear

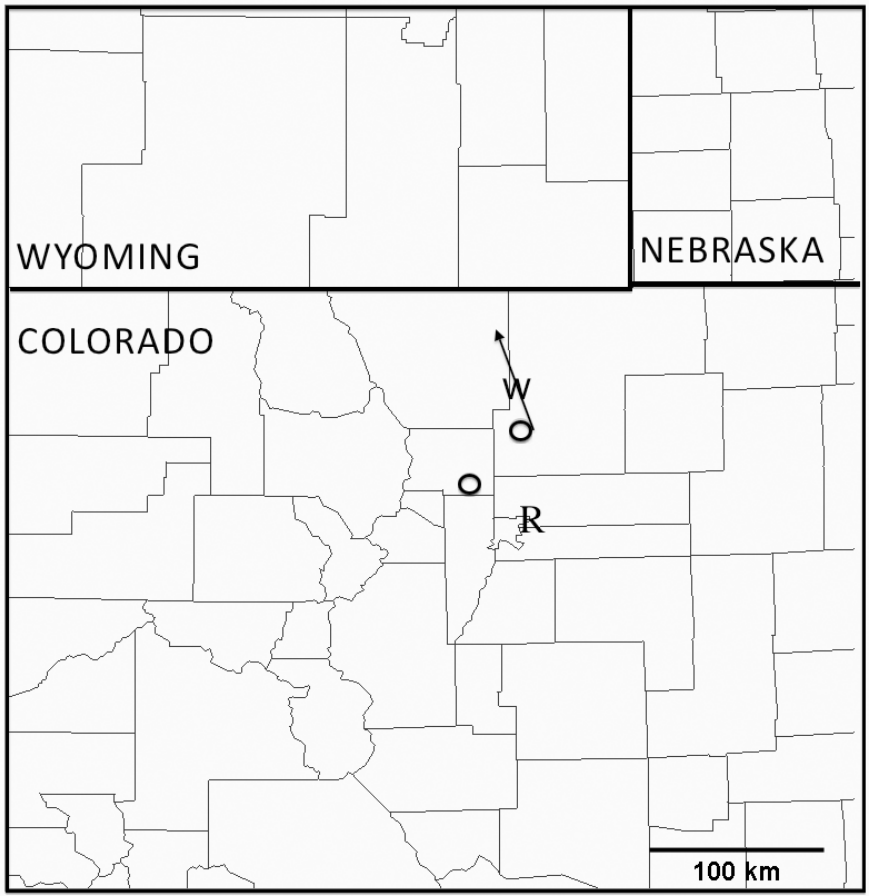


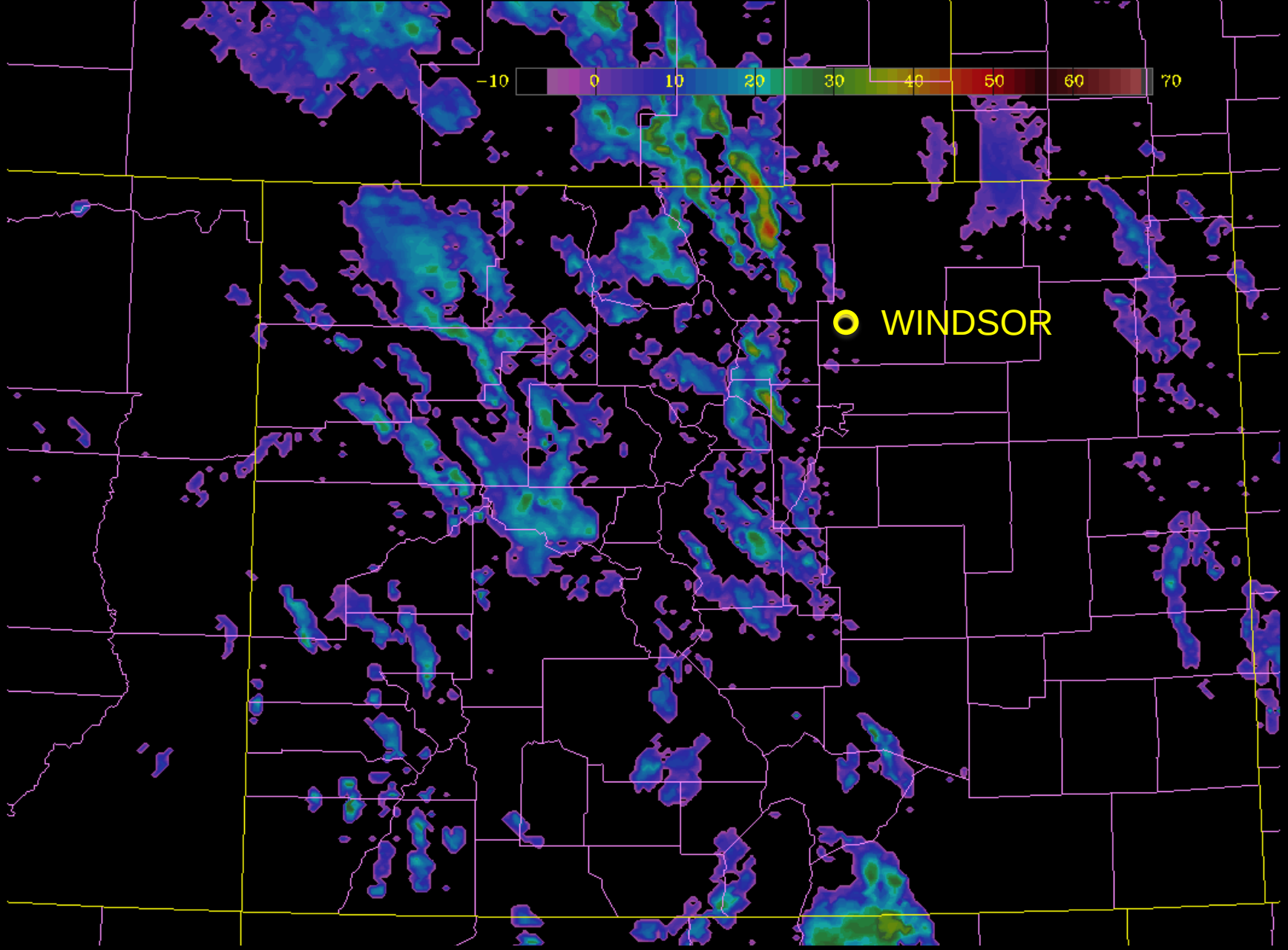
- Td = 55°F, LCL = 1.1 km AGL
- Modified 18Z DEN sounding MLCAPE = 2094 J kg^{-1}
- Lift: storm initiation along dryline-warm front boundary intersection
- 0–1 km vector shear =19.5 m s^{-1}
- Storm-relative helicity = 219 m^2s^{-2}
- Geerts et al. (2009): mesocyclone acquired some of its vertical vorticity from PV banners initiated along the Front Range

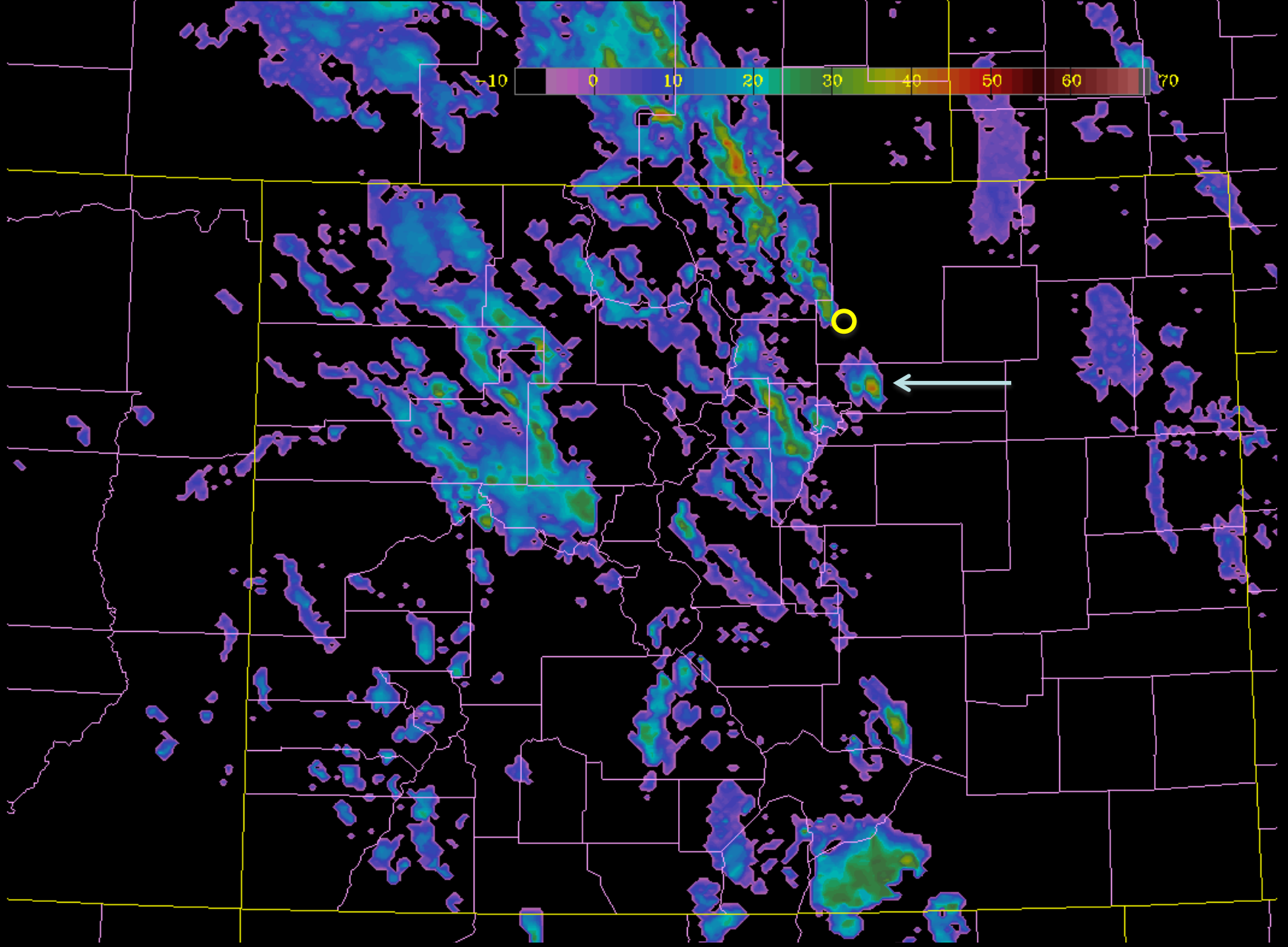


Colorado Topographic Map

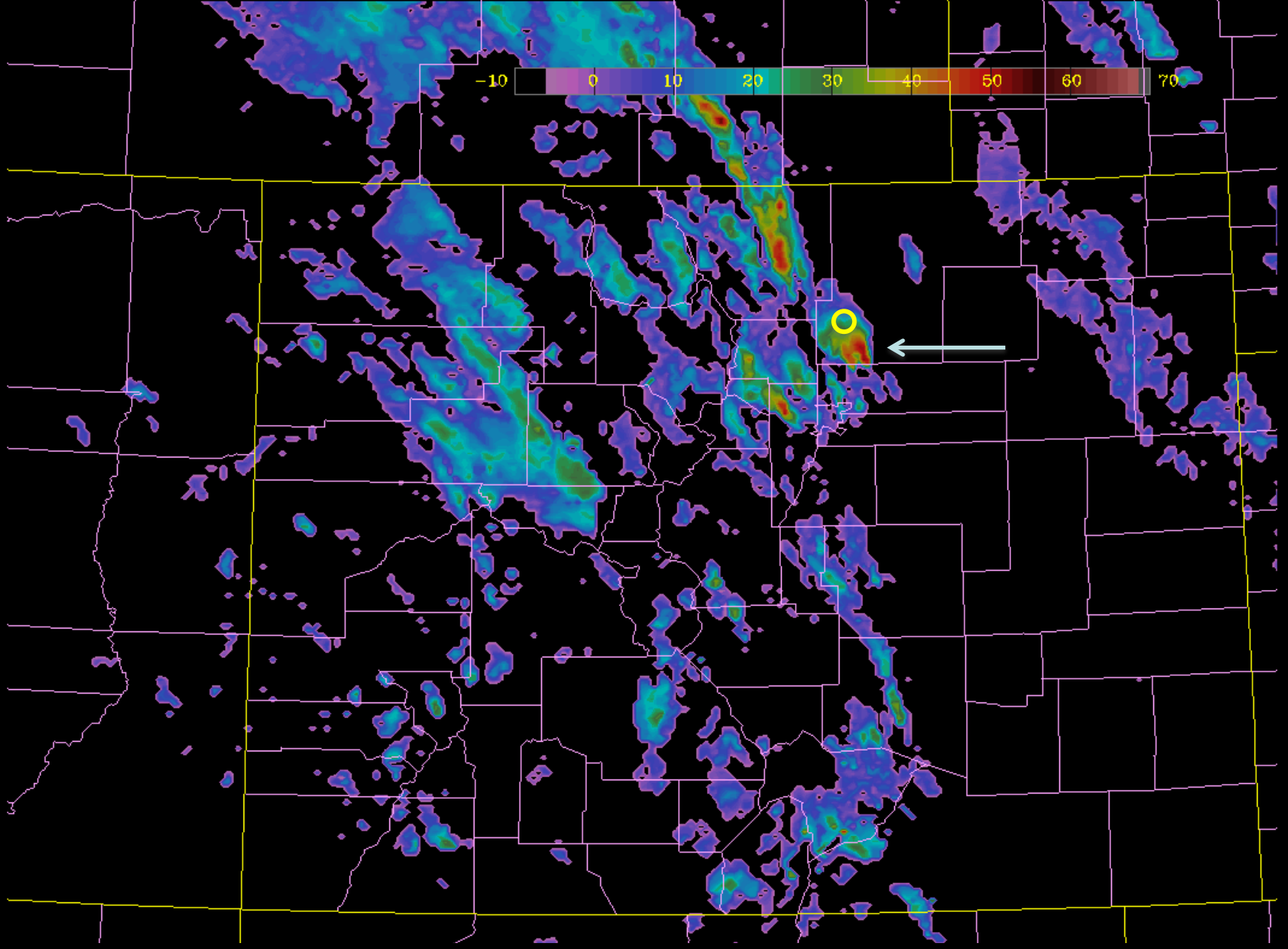
- **Variational LAPS (vLAPS) domain**
- **Location of Windsor (W)**
- **Locations of Denver Raob (R), MW Radiometer and Wind Profiler**
- **Storm motion**




-10
0
10
20
30
40
50
60
70
WINDSOR
1600 UTC



1630 UTC


-10
0
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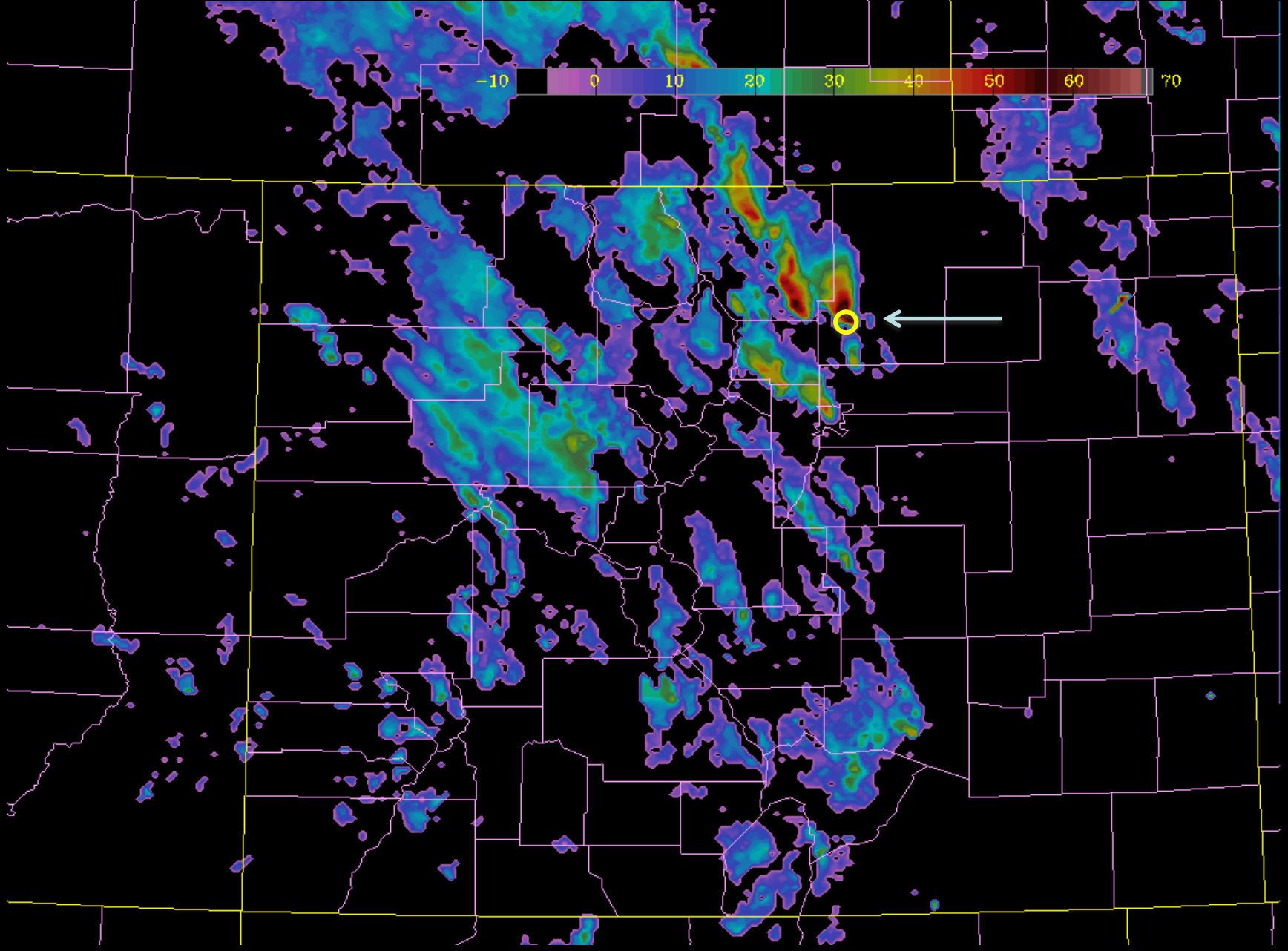
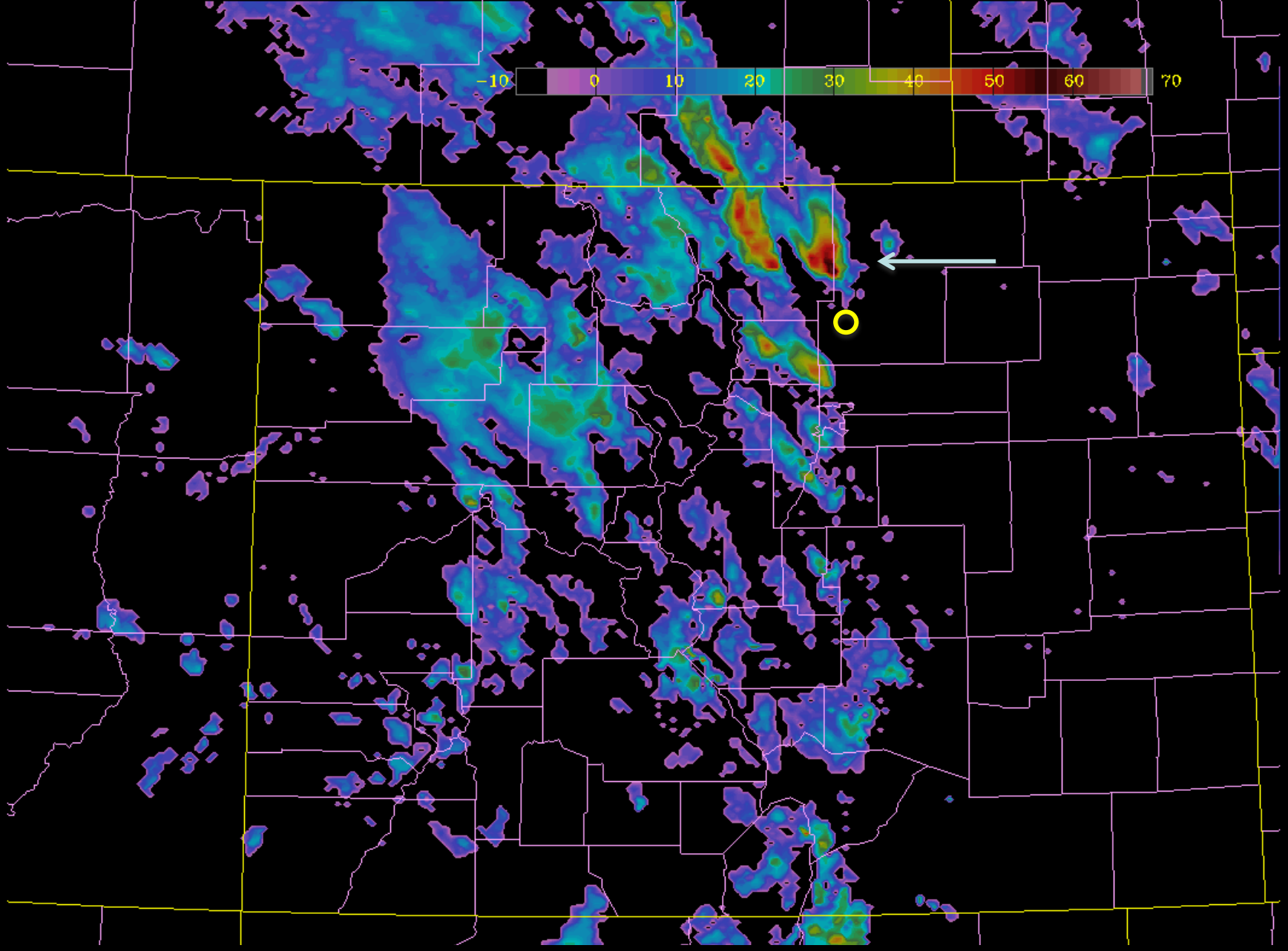
70
1700 UTC



1730 UTC

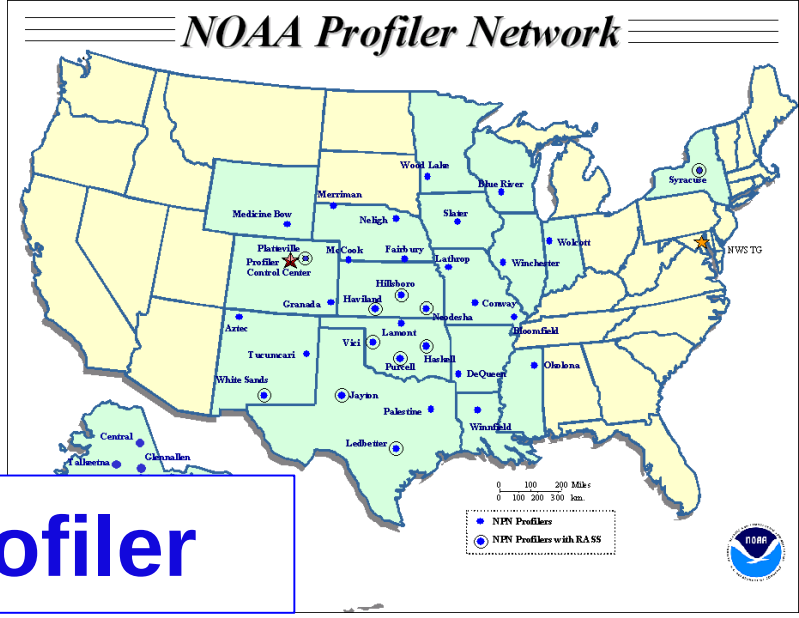


1800 UTC

Recommendations from National Research Council Reports

- The most critical observing needs to accurately nowcast severe local storms are measurements of moisture and wind in the lower troposphere.
- Federal agencies and their partners should deploy lidars and radio frequency profilers nationwide at approximately 400 sites to continually monitor conditions to 3 km AGL.
- Humidity, wind, and diurnal boundary layer structure profiles are the highest priority for a network, the sites for which should have a characteristic spacing of ~50–200 km and vertical resolution of ~100 m.

"Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks", Committee on Developing Mesoscale Meteorological Observational Capabilities to Meet Multiple Needs, National Research Council, 2008.



UHF Wind Profiler

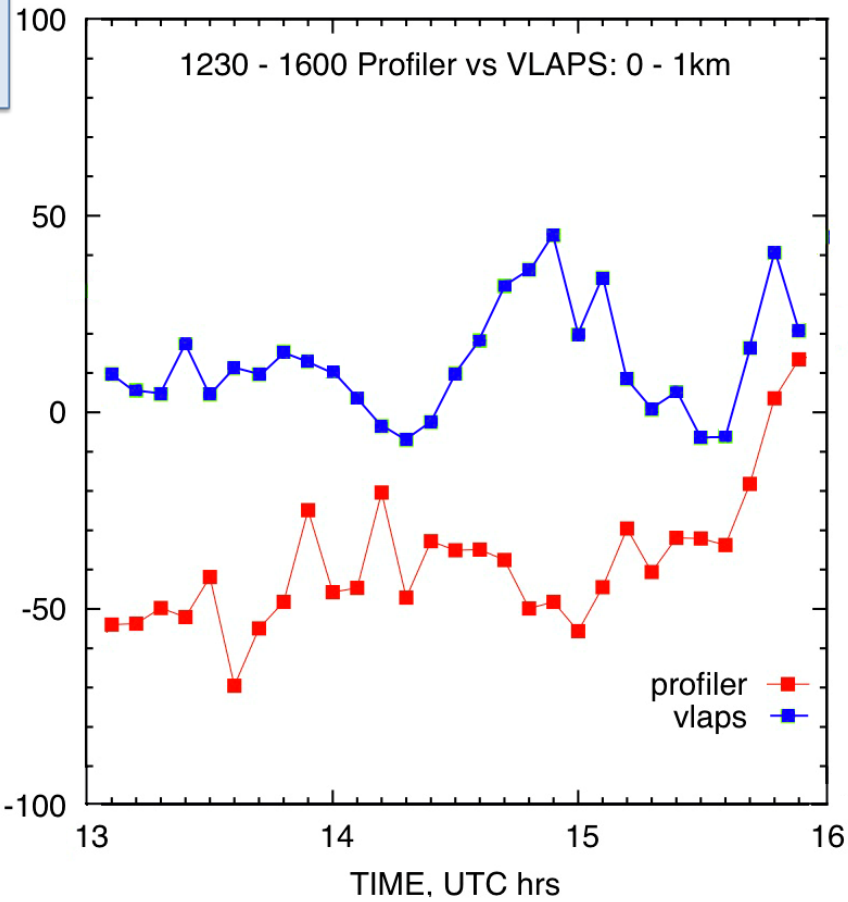
- NOAA operated a network of UHF 404-MHz tropospheric wind profilers from 1992–2013, but there is no plan to make these operational.
- Fluctuations in the radio refractive index are the primary energy scattering mechanism (Bragg scatter). Assumed that these fluctuations are advected by the mean wind as long as horizontal homogeneity exists across all three beams (violated in deep convection).
- NOAA Profiler sampled in two modes, but we only used the low mode (ground to 7.5 km AGL at **250-m vertical resolution**)
- **Temporal sampling = 6 min** irregular base data interpolated to a uniform *(t-z)* grid via 2-pass Barnes scheme (Trexler and Koch 2000).

Data availability over 24 h from 21 – 22 May 2008

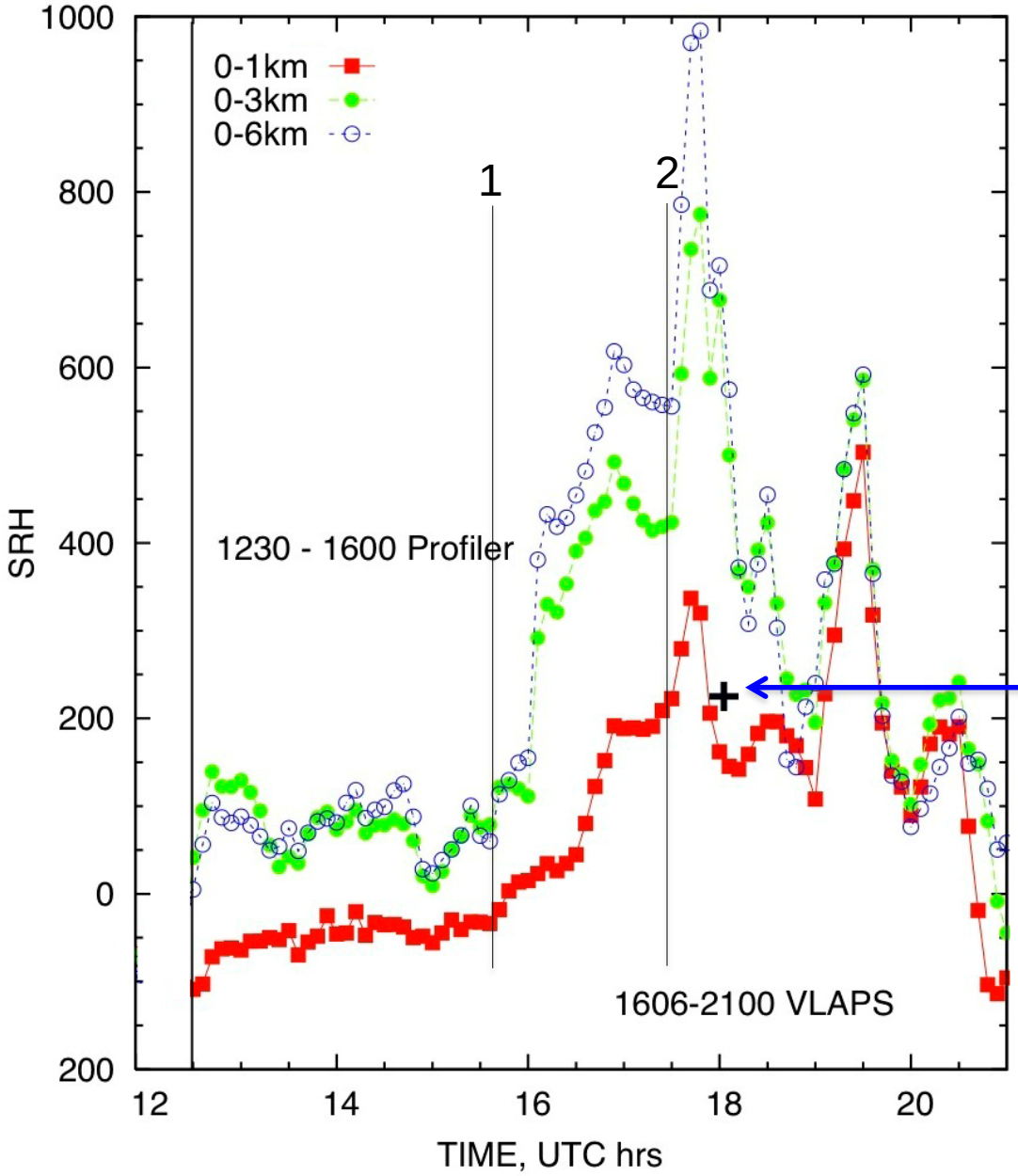
Data Sources	Availability (0 – 24 h)
Microwave Radiometer	0000 UTC – 2359 UTC
Wind Profiler	0000 UTC – 1600 UTC
vLAPS	1300 UTC – 2359 UTC

Platteville Profiler during tornado 1726 UTC

Storm-relative 0 – 1 km helicity: Comparison of Profiler to vLAPS



Time series of Storm-Relative Helicity from merged Profiler-vLAPS dataset

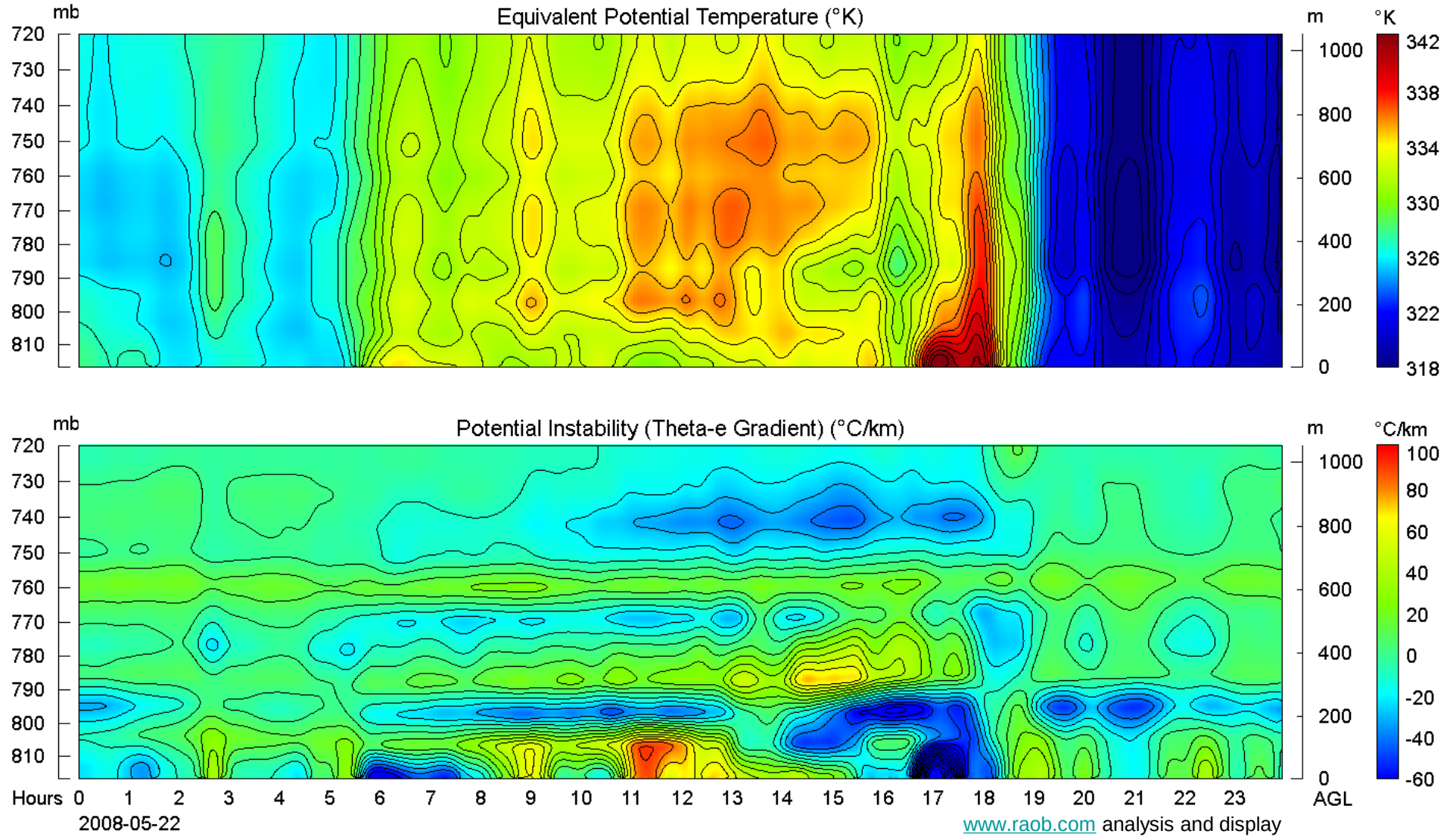


Schumacher 18Z est.

Passive Microwave Radiometer (MWR)

- The MP-3000 observed brightness temperatures related to atmospheric moisture in 5 frequency channels from 22–30 GHz and atmospheric temperature in 7 channels from 51 to 59 GHz. Cloud liquid water profiles also obtainable.
- MWR is able to profile with 10-sec temporal resolution (we used **5-min data**) under all weather conditions.
- Neural network method used to derive temperature and moisture profiles from the measured brightness temperatures by coupling MWR observations with historical representative radiosonde profiles.
- **Vertical resolution degrades from ~50m near the surface to 250m at 2km**.

Radiometer time-height profiles of Equivalent Potential Temperature (top) and Potential Instability (bottom, blue)

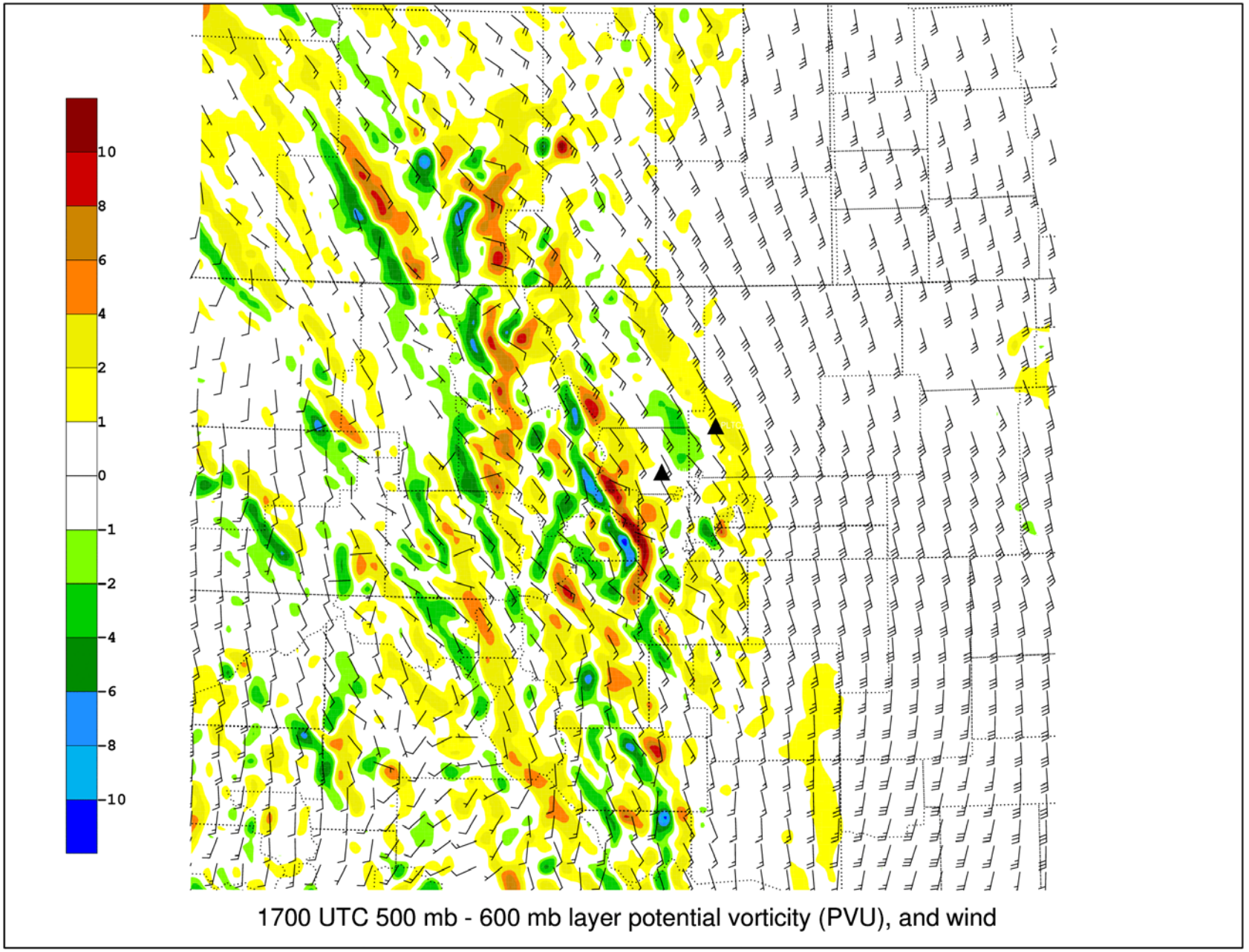


Radiometer-derived time series of SBCAPE

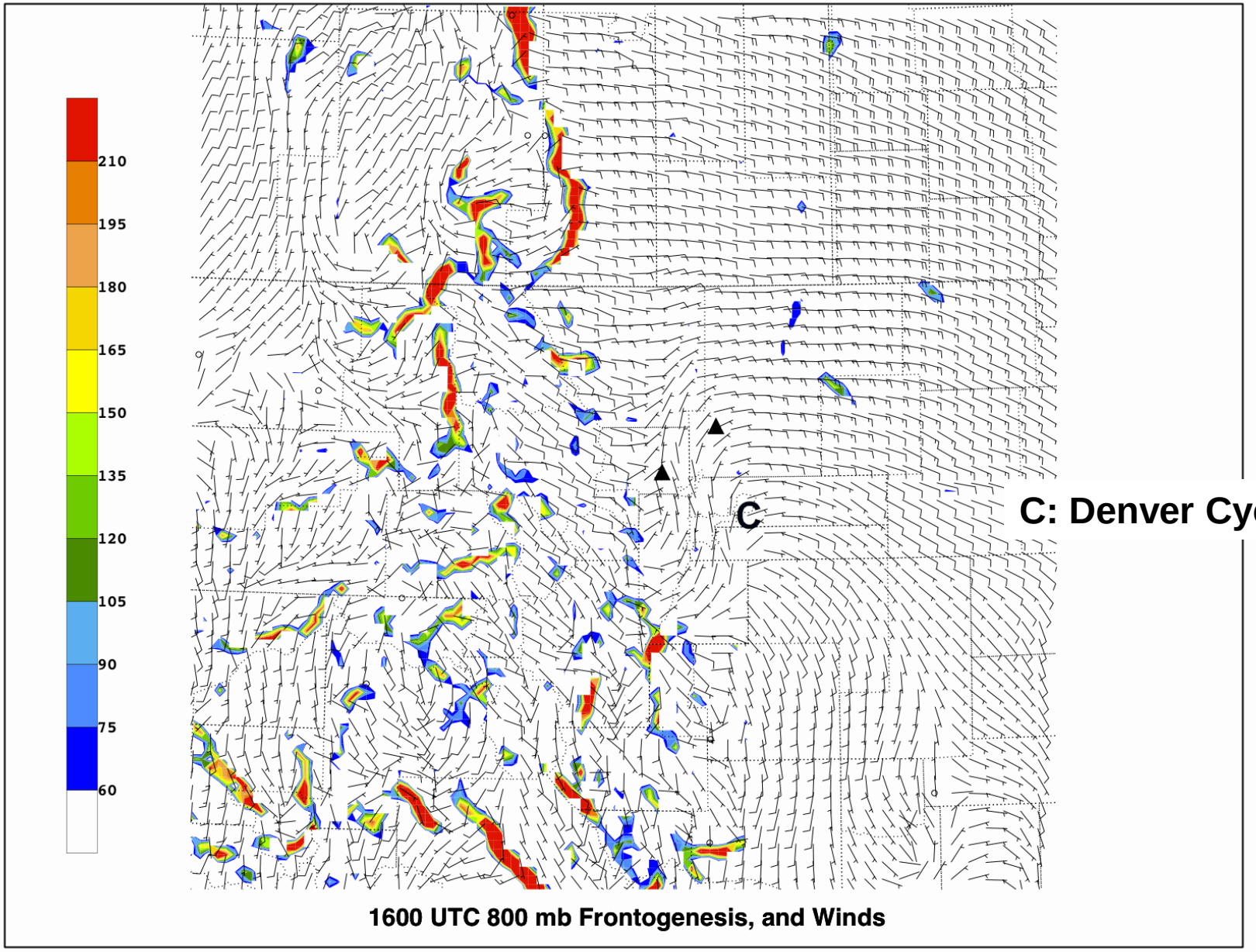
Radiometer-derived time series of CIN

www.raob.com analysis and display

500- 600 hPa PV streamers at 1700 UTC (1.67-km vLAPS)

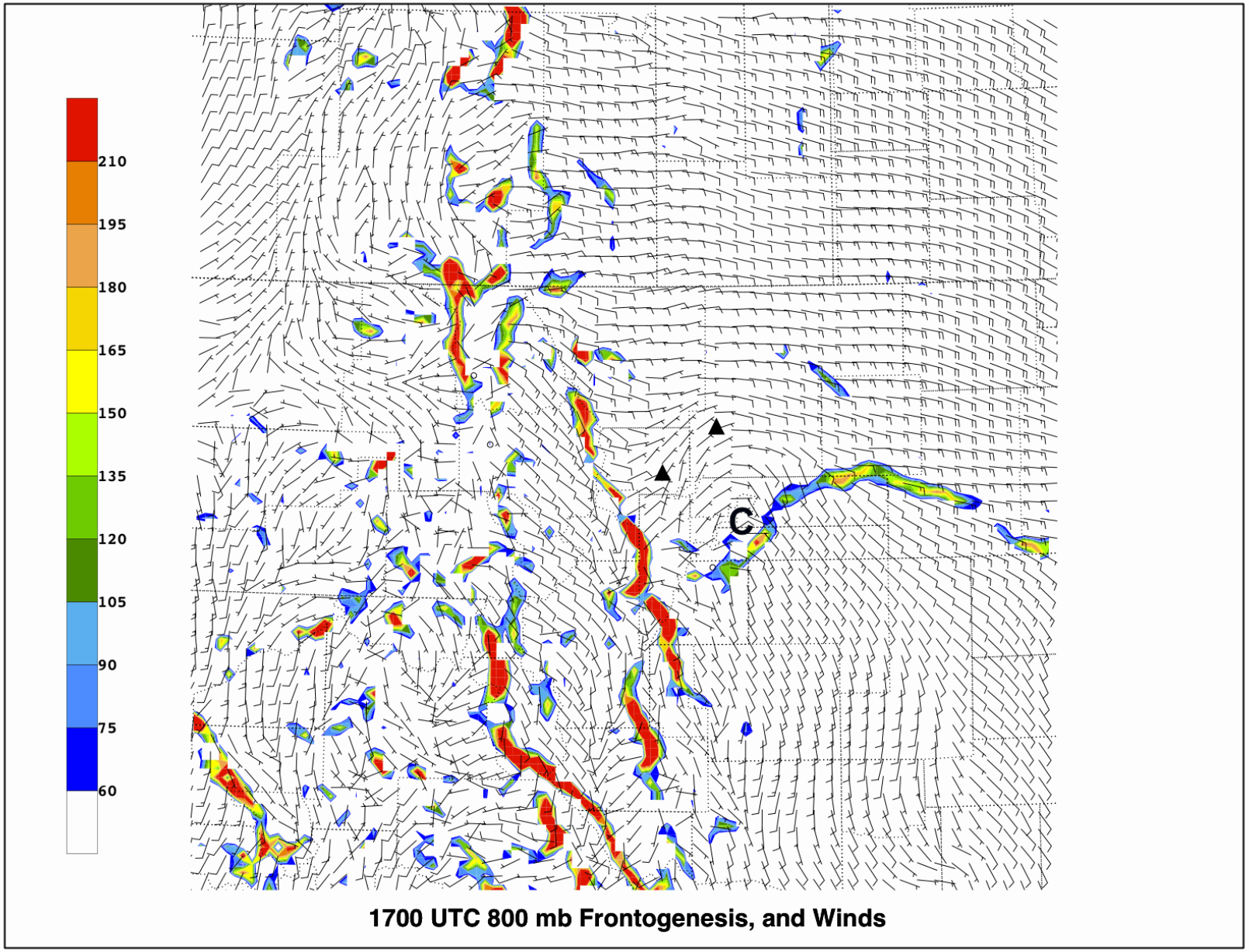


Frontogenesis @ 1600 UTC

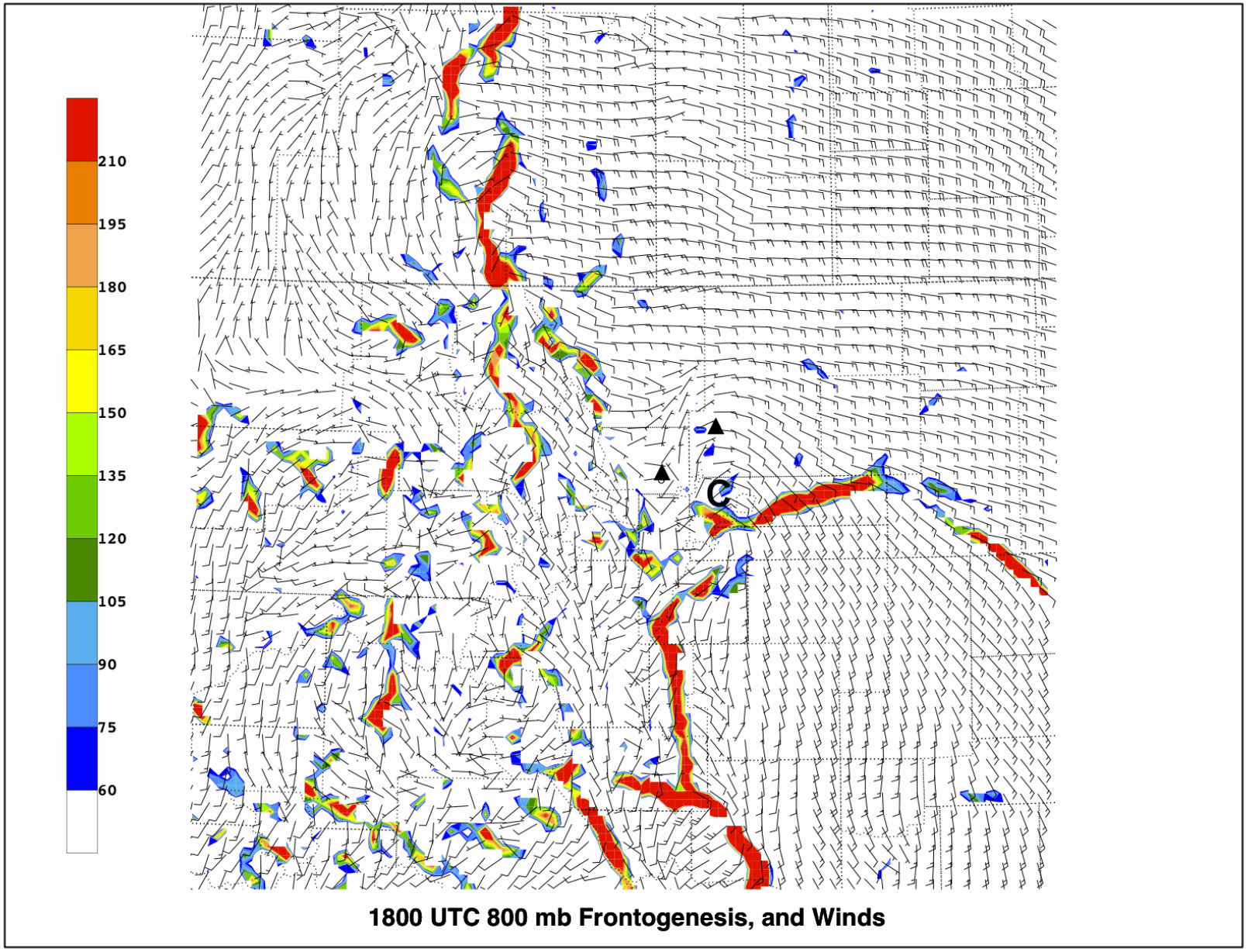


C: Denver Cyclone

Frontogenesis @ 1700 UTC



Frontogenesis @ 1800 UTC



Summary

- Windsor Tornado case demonstrates how rapidly local low-level wind and thermodynamic conditions can change and the need to monitor them
- Combined use of a microwave radiometric profiler and a UHF Wind Profiler captured these rapid changes as a two-stage event: mesoscale and storm-scale
- Radiometer represented time when CIN→0 accurately
- Lifting mechanism for the supercell under investigation, but suggests some combination of orographically-forced isentropic PV streamers and low-level frontogenesis
- How extreme was the Windsor event in terms of the rapidity in changes in the near-storm environment?