Composite Analysis of Cool-Season Severe Weather Outbreaks in the Lower Ohio Valley

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Introduction

- According to Brooks et al. (2000 & 2003), severe weather in the Ohio Valley is most frequent in the spring and summer months.

- However, cool-season severe weather events, while rare, are capable of posing a significant forecast challenge due to limited research on these events and their associated environments.

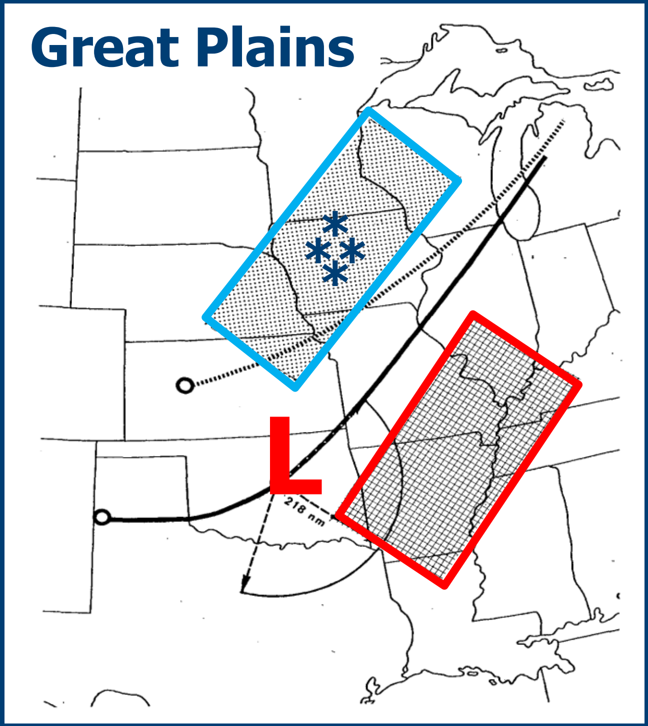
- One avenue of research is to examine the climatology of cool-season severe weather outbreaks and their attending environmental conditions to provide situational awareness and impact potential.

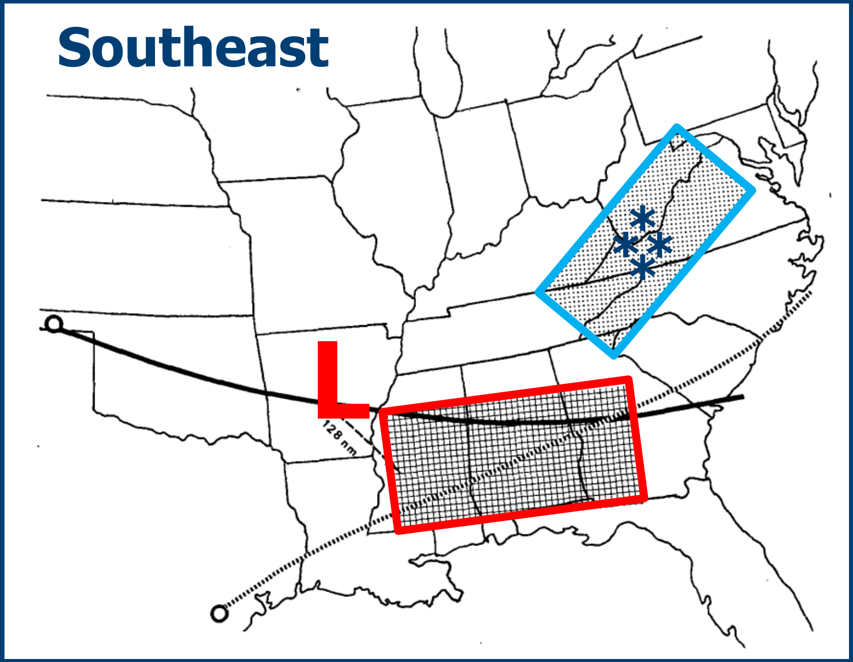
- Previous research such as Beebe (1956), Glass et al. (1995), Bierly and Winkler (2001), Moore et al. (2003), and Thomas and Martin (2007) have shown the effectiveness of a composite analysis approach to diagnose the synoptic and mesoscale phenomena associated with certain weather events.

Previous Cool-Season Severe Research

- Outbreaks involving ten or more tornadoes were investigated in order to determine their climatological aspects (Galway 1977).

- Mean storm tracks were found for winter tornado outbreaks, which comprised almost 10 percent of all tornado outbreaks between 1950 and 1979 (Galway and Pearson 1981).





Previous Cool-Season Severe Research

- Smith et al. (2006) found that cool-season severe weather in the Ohio Valley is relatively uncommon, but when it occurs, it is sometimes in the form of a regional tornado outbreak.

- Smith et al. (2008) examined three severe weather components (severe reports, convective mode of severe storms, and cool-season mesoscale environments associated with severe reports), and found that severe wind reports resulting from QLCS's are the most common severe weather type for the Ohio and Tennessee Valleys in the cool season.

PAH & LMK Climatology Overview

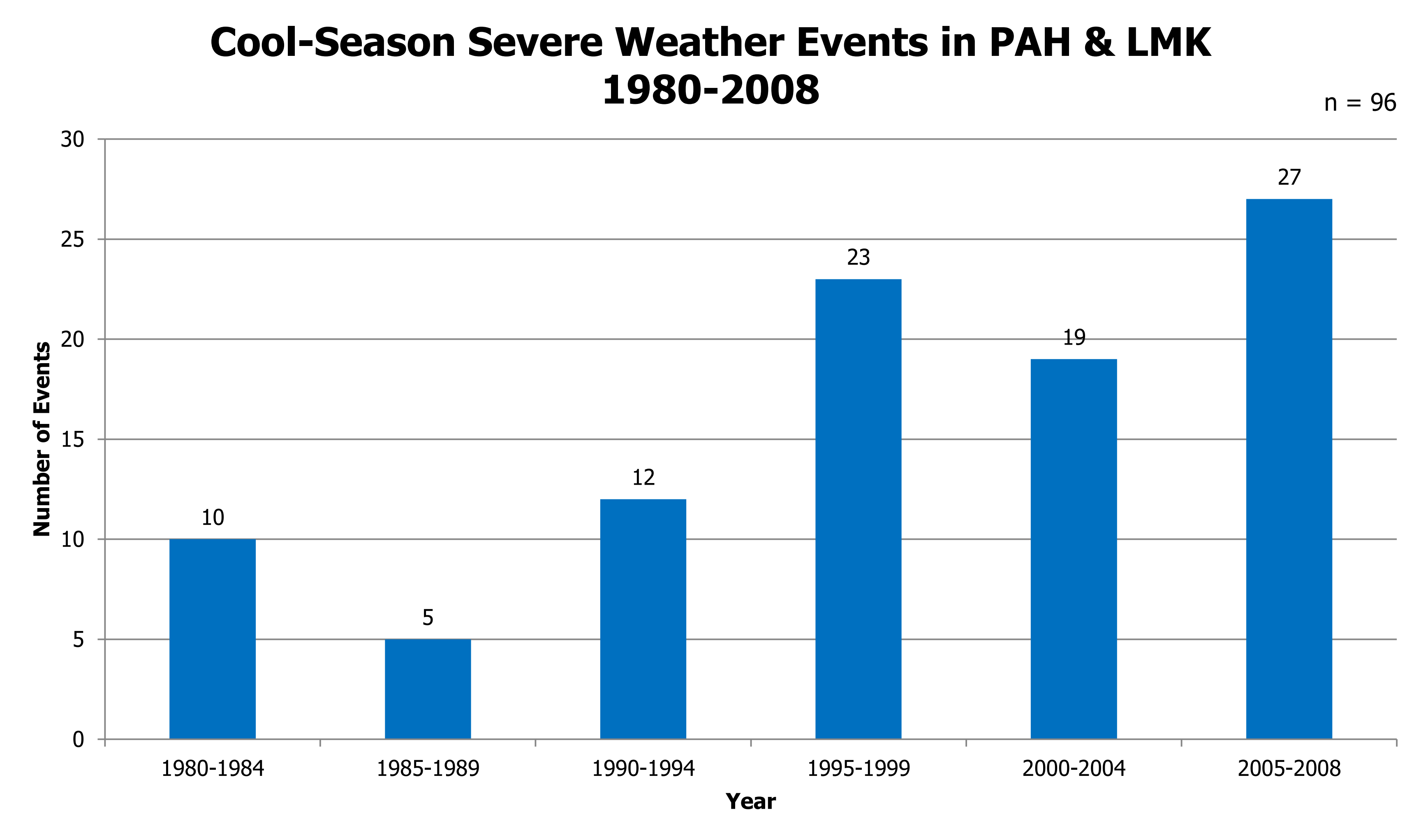
- 29-year (1980-2008) climatology of cool-season (defined as November through February) severe weather events in the NWS Paducah (PAH) and NWS Louisville (LMK) County Warning Areas (CWAs).

- There were 96 events in this period with at least 1 storm report per event (tornado, wind, or hail).

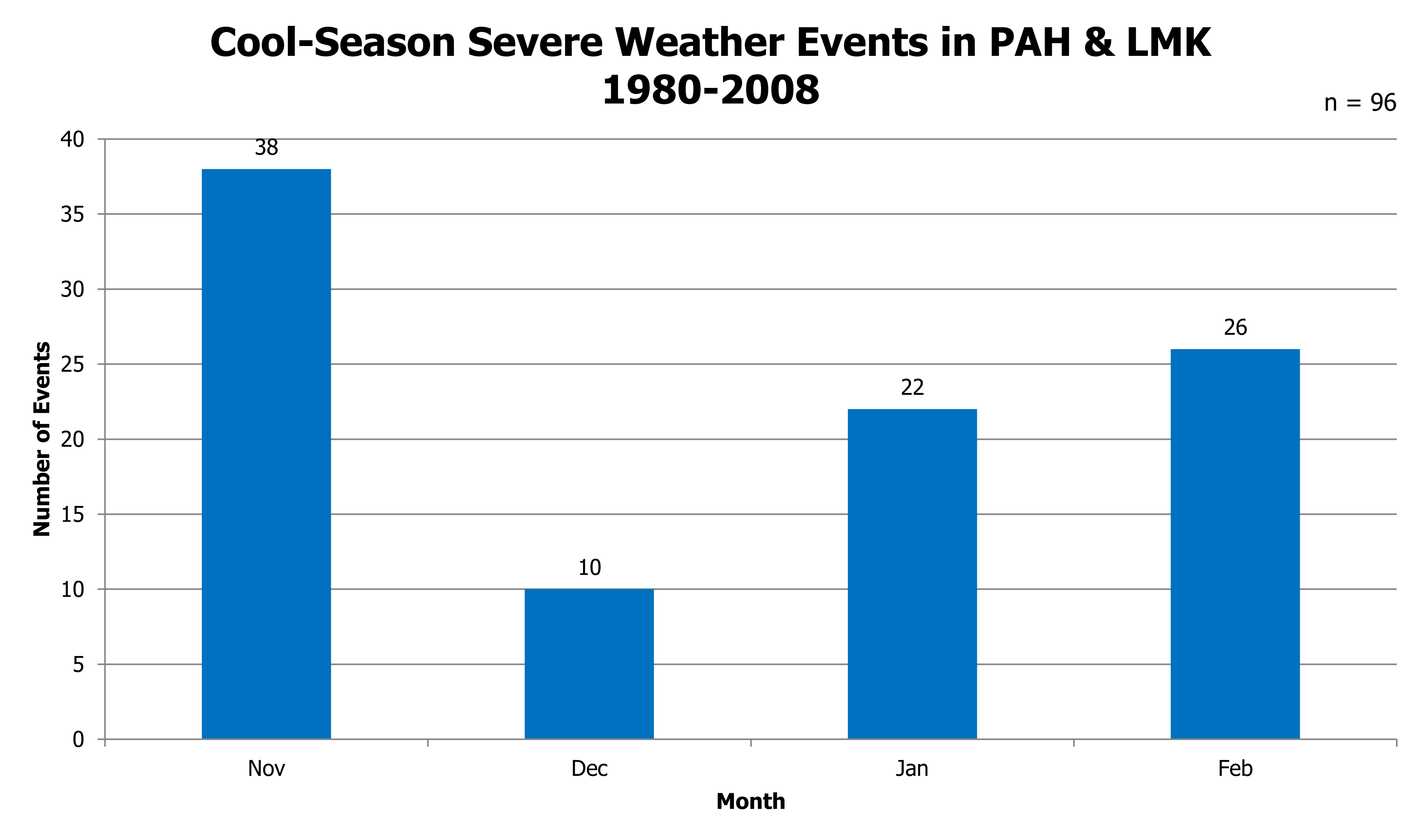
- In 96 cool-season severe weather events, there were 1321 severe storm reports. Of the 1321 reports, there were
  - 296 hail reports
  - 902 wind reports
  - 123 tornado reports

- Note: Composites are an average of events. Therefore, they can dampen (lessen) parameter values of individual cases. Anomaly composites (shown later in presentation) can better stratify smaller vs. larger severe weather events and associated parameter values.

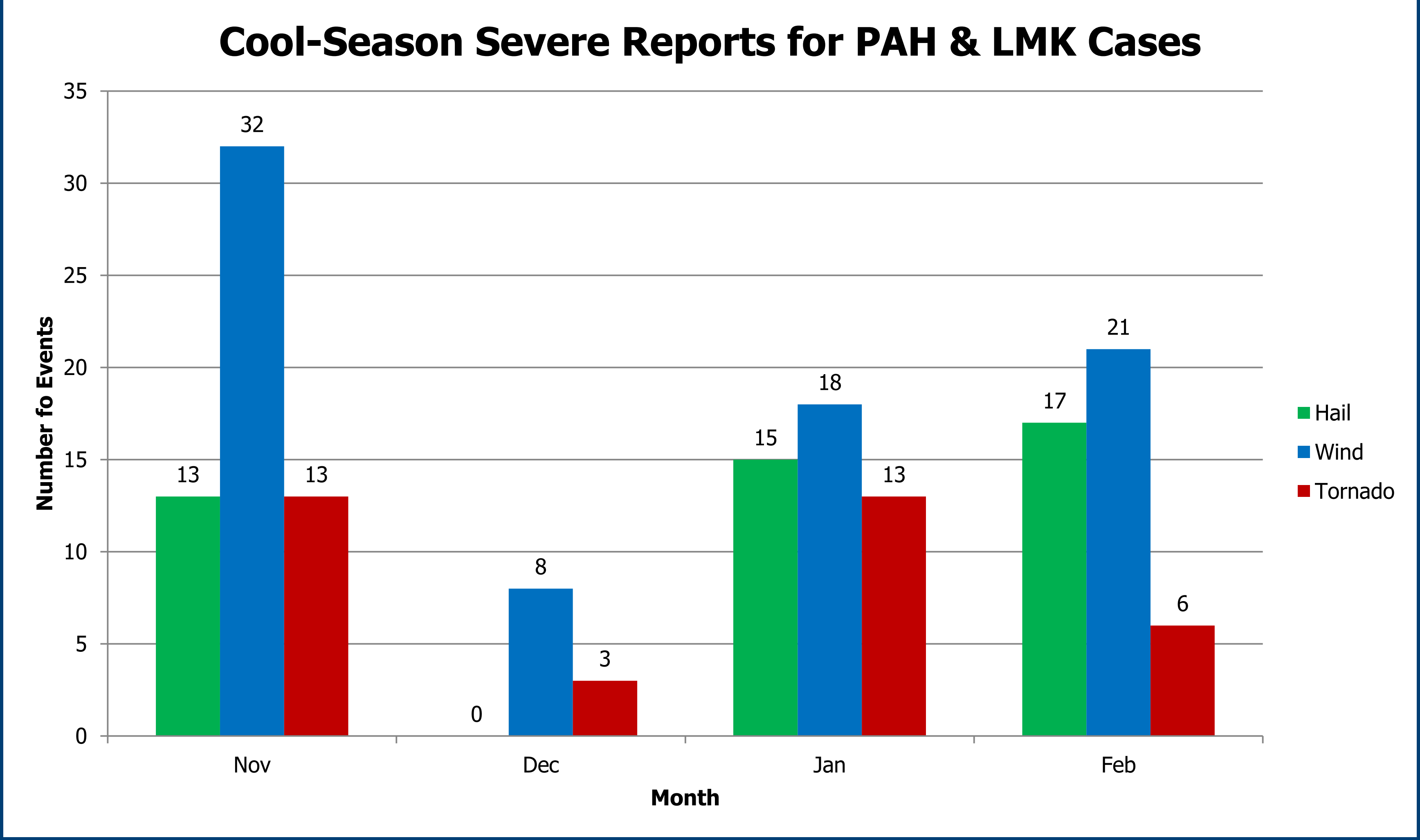
Yearly Comparison – PAH & LMK Cases



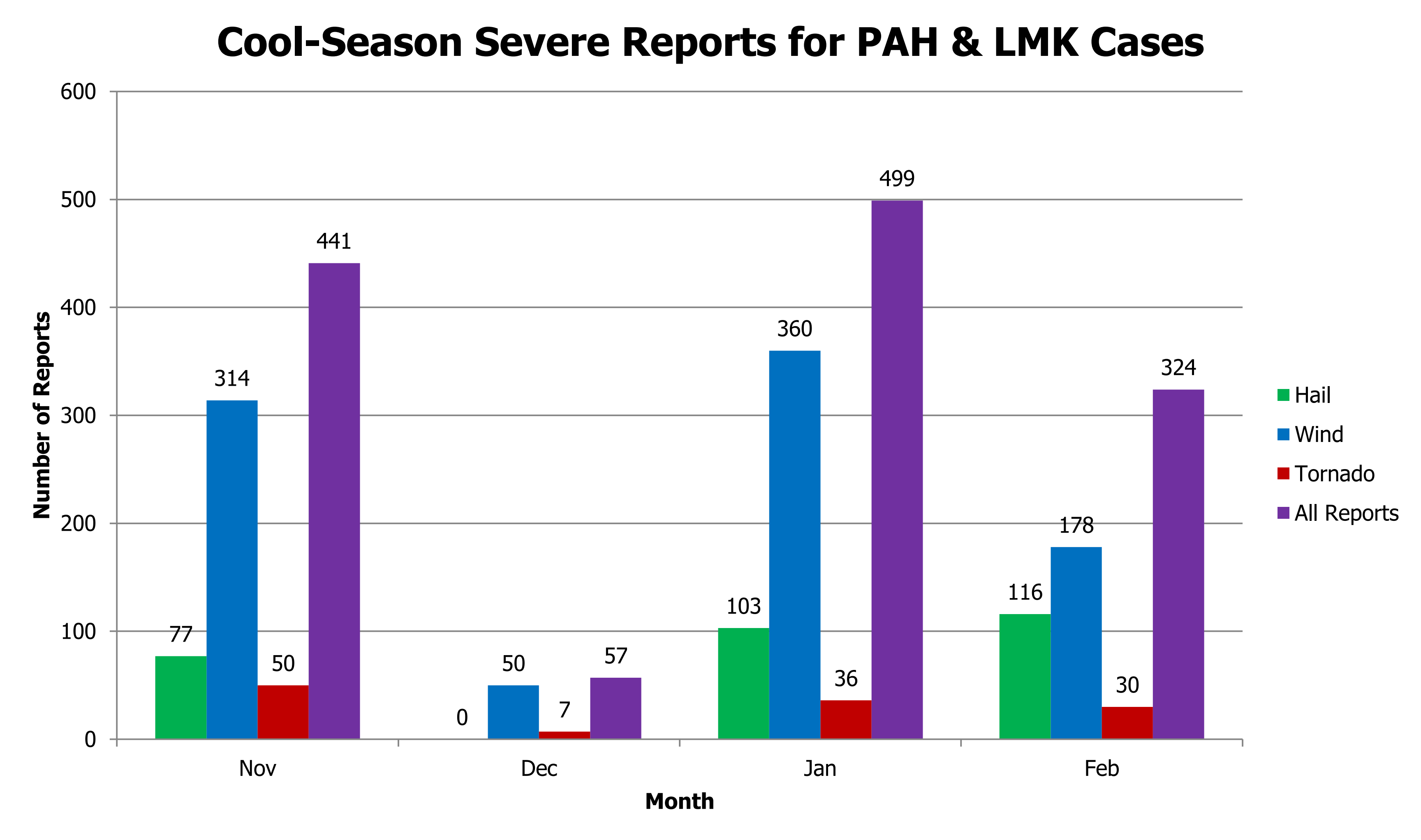
Monthly Comparison – PAH & LMK Cases



Monthly Comparison – Events with Severe Reports

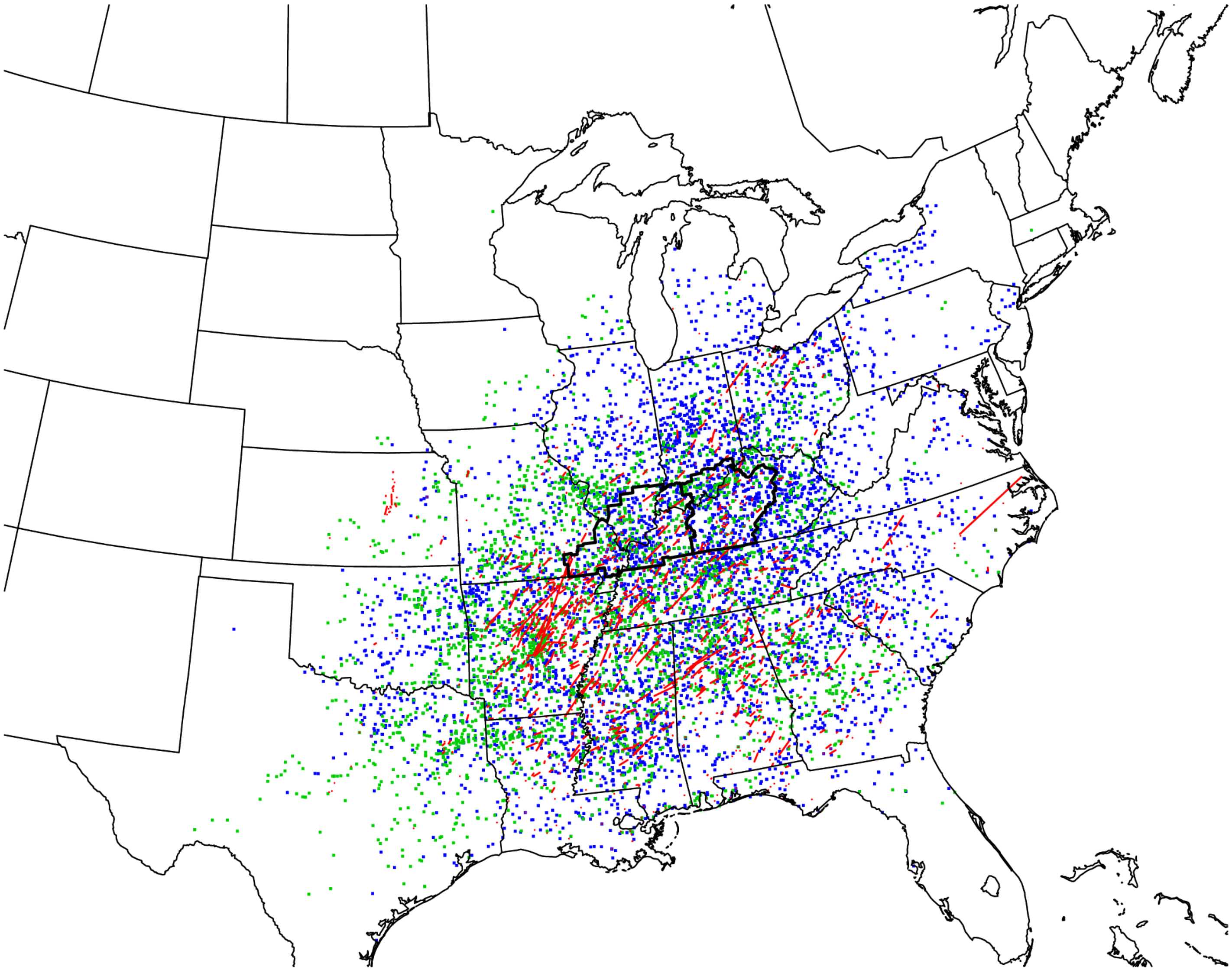


Monthly Comparison – Number of Severe Reports



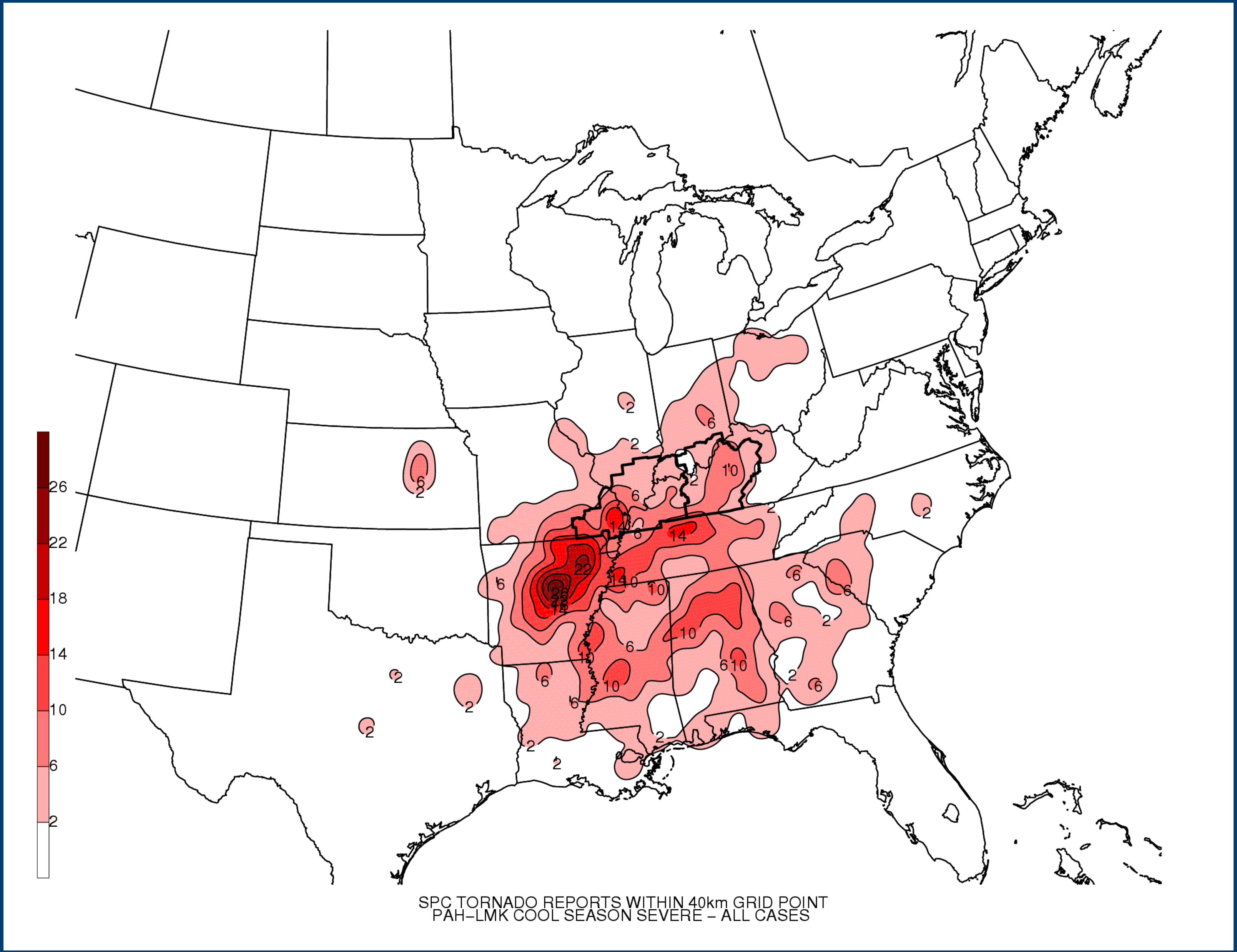
Interestingly, January (in the heart of winter) had the most severe weather reports of any cool season month.

Severe Reports for PAH & LMK Cases

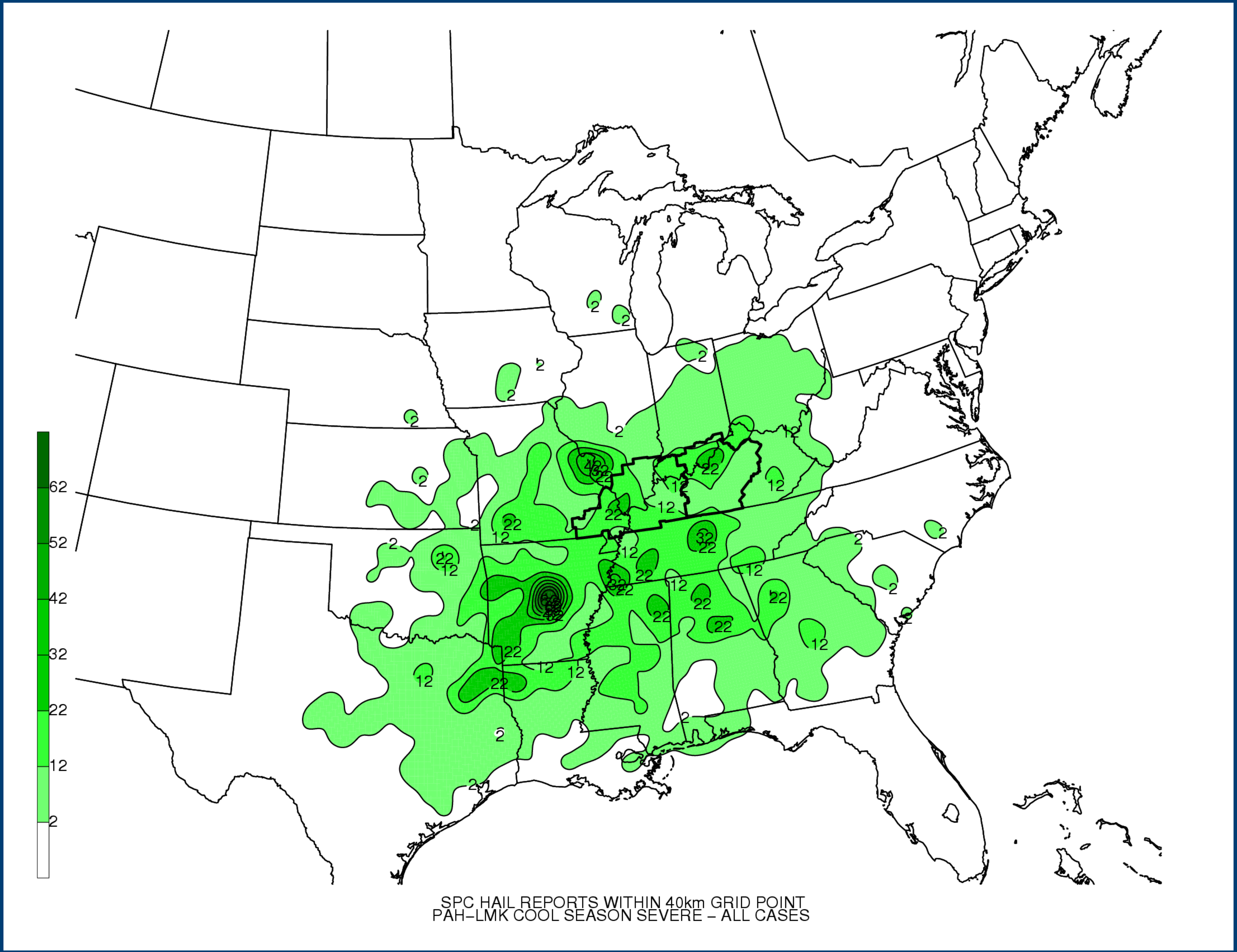


SPC SEVERE REPORTS PAH-LMK COOL SEASON CASES - ALL

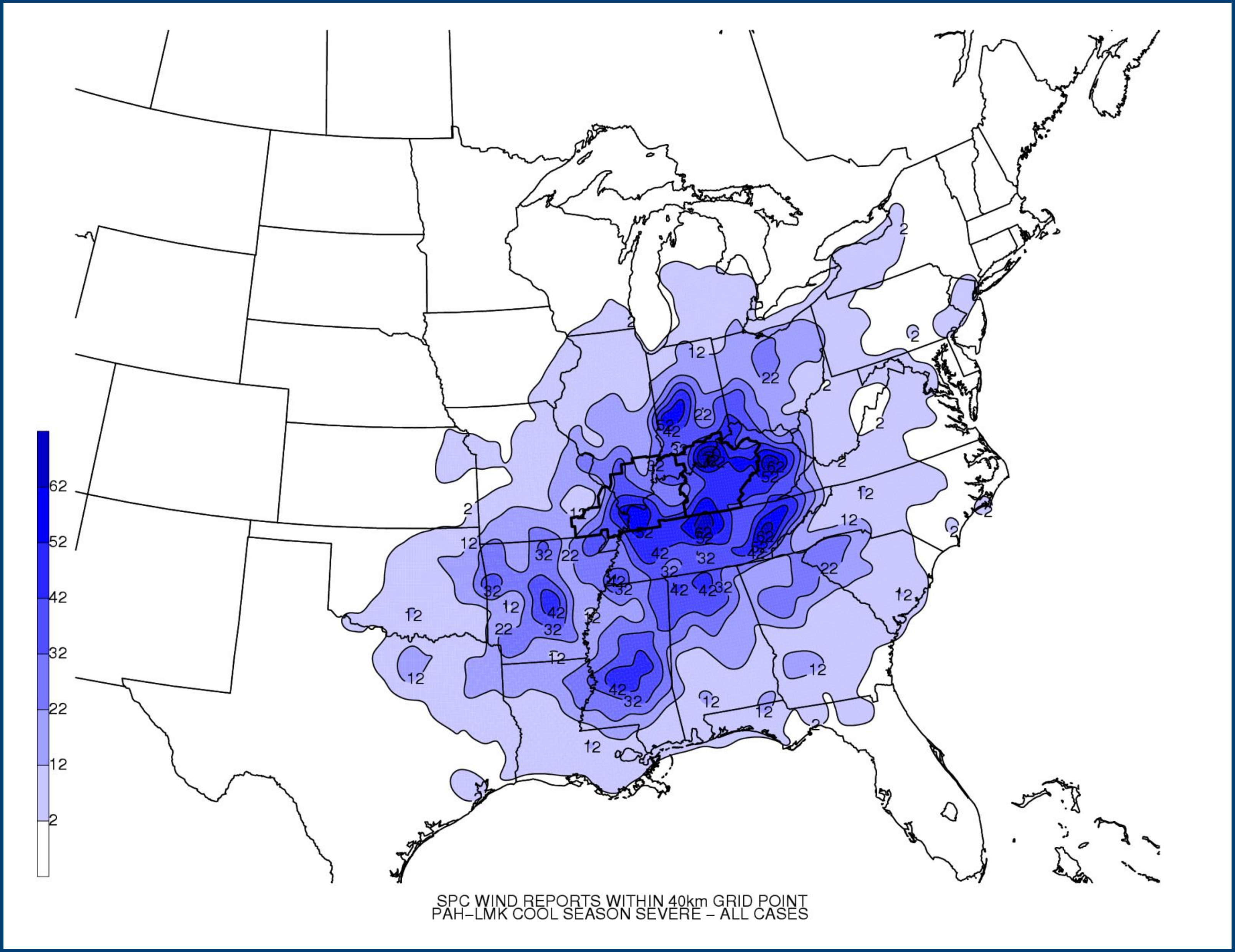
Tornado Reports for PAH & LMK Cases



Hail Reports for PAH & LMK Cases



Wind Reports for PAH & LMK Cases



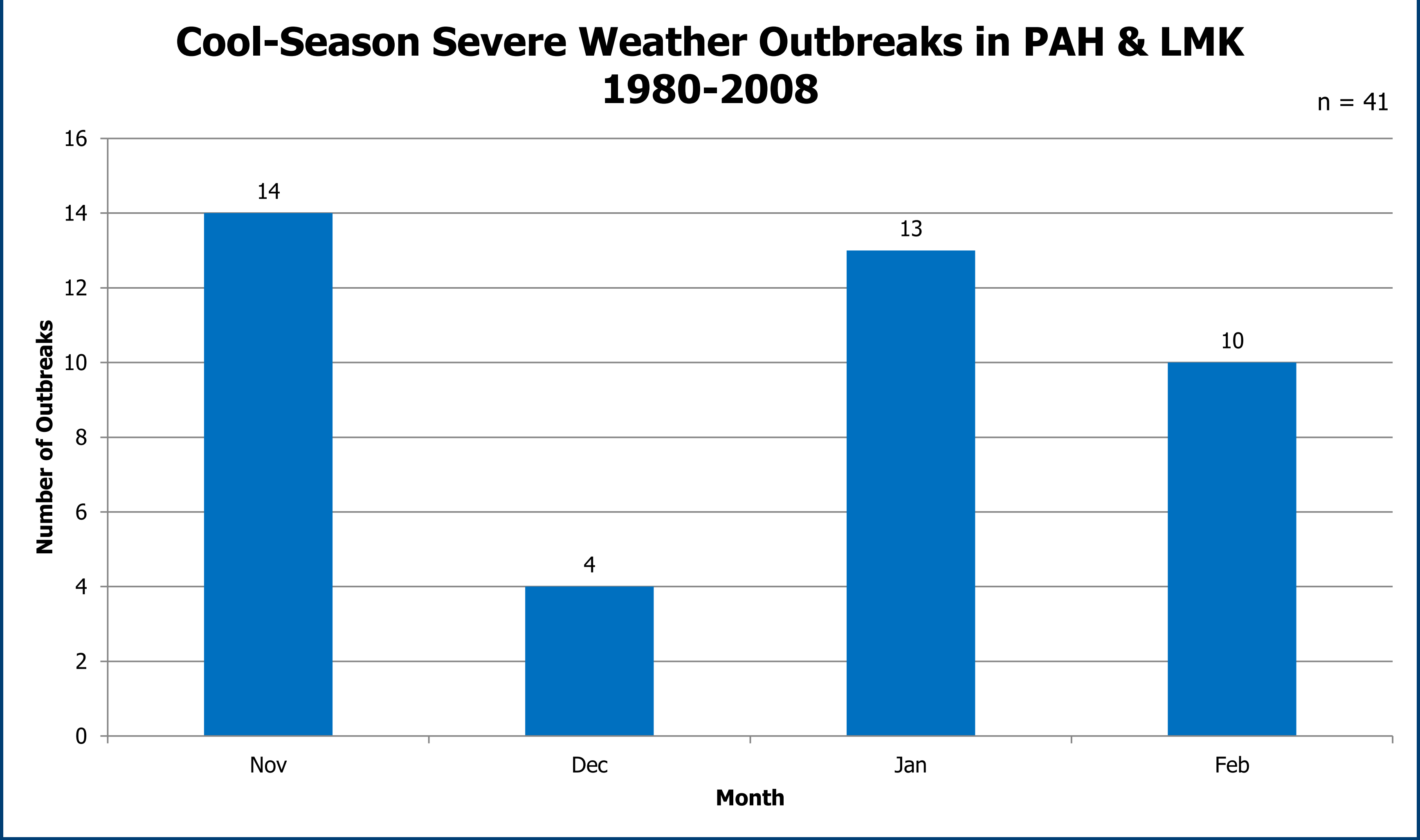
Examining the PAH & LMK Outbreaks

- An **outbreak** was classified as an event containing 6 or more storm reports, which represented the top 43% of all possible events.

- 41 events were classified as outbreaks. Of the 41 outbreaks,
  - 38 contained at least 1 wind report.
  - 29 contained at least 1 hail report.
  - 24 contained at least 1 tornado report.

- In the 41 outbreaks, there were 1205 severe storm reports. Of the 1205 reports, there were
  - 273 hail reports
  - 825 wind reports
  - 107 tornado reports

Monthly Comparison – PAH & LMK Outbreaks



Composite Methodology

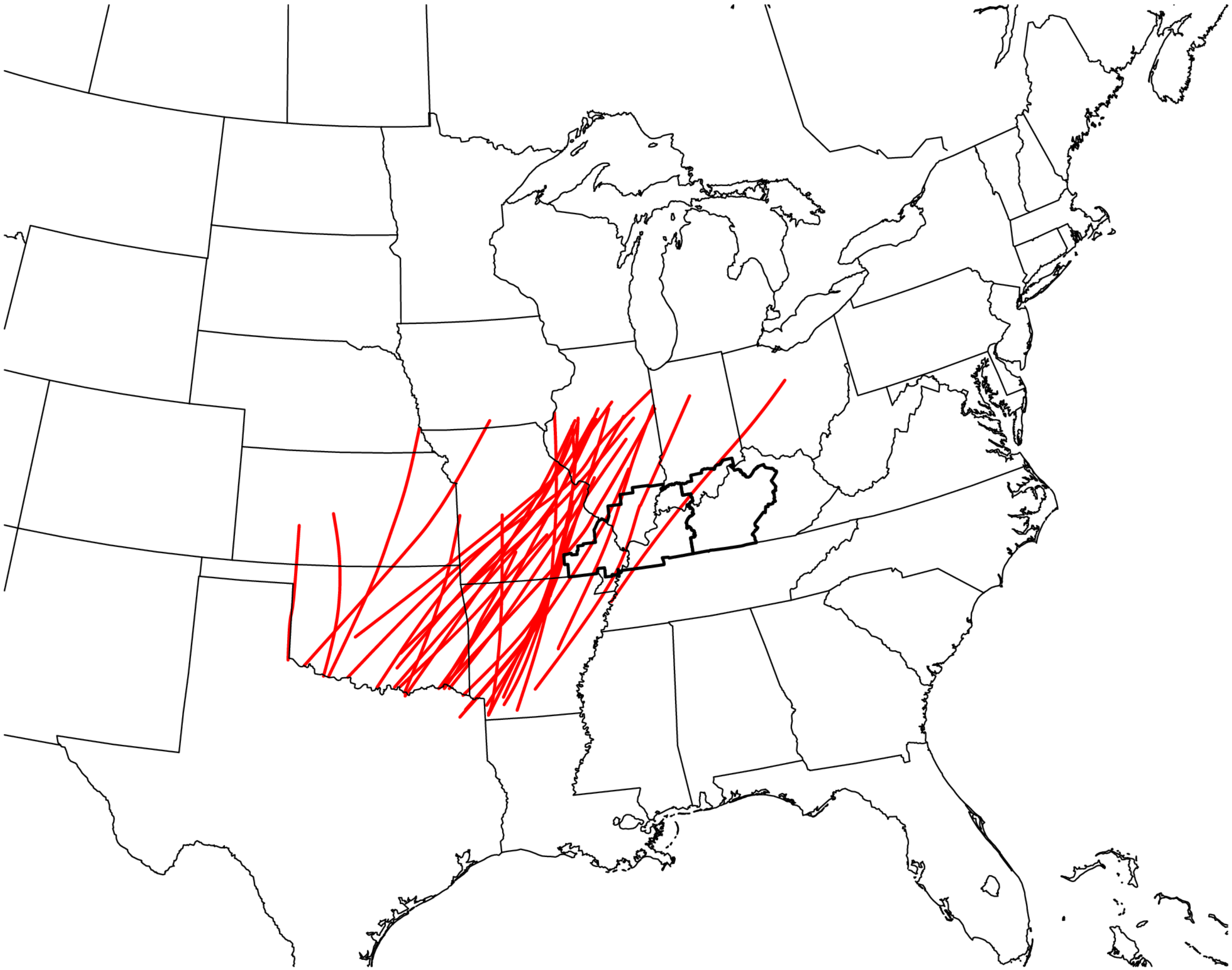
- Using the General Meteorological Package (GEMPAK) with the North American Regional Reanalysis (NARR), system-relative composites were generated.

- An initial analysis time (t=0h) for each outbreak was defined as the time at which the cold front was on the western edge of the storm reports. It was assumed that the cold front was associated with the initiation of convection and resultant severe weather (Smith et al. 2008).

- The locations of the 925-mb lows for the 32 events (9 events were omitted because the 925-mb circulation was undefinable) were used as the center of the compositing grid.

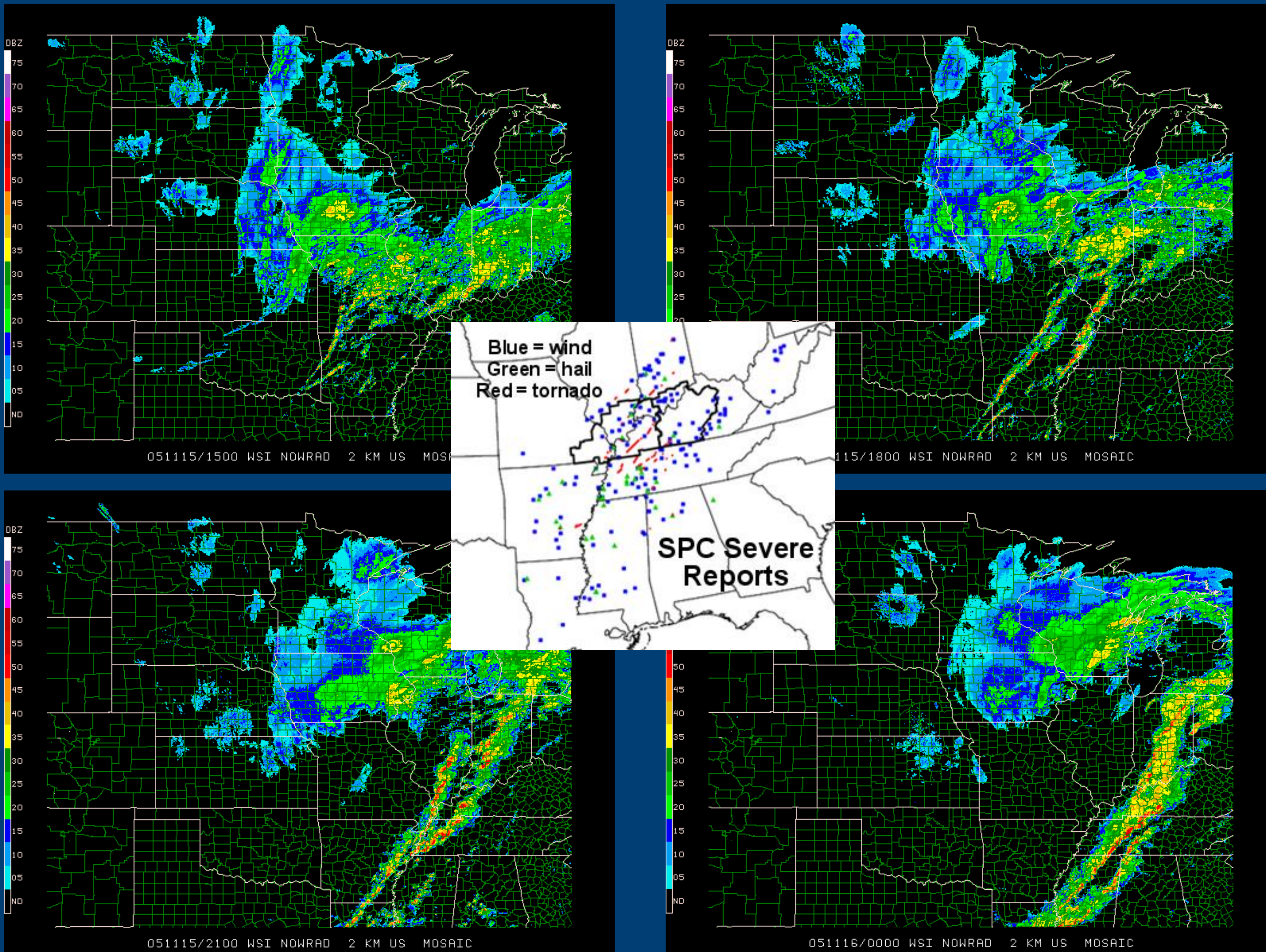
- In order to track the progression of the system, the locations of the 925-mb lows were also used to generate system-relative composites at t=-6h and t=+6h.

Positions of Cold Front at t=0h for PAH & LMK Outbreaks

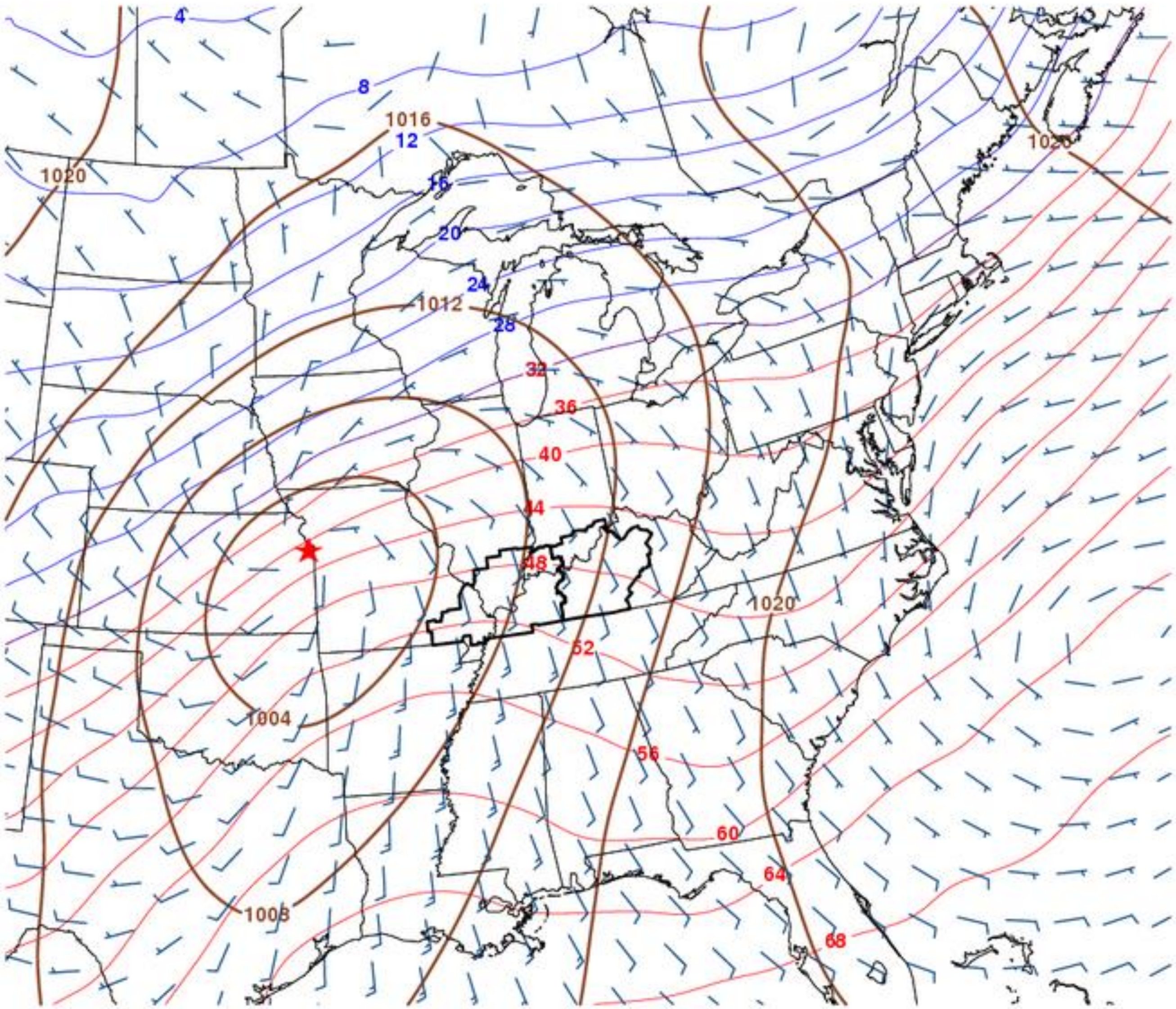


FRONTAL POSITIONS at t=0

Radar Data and Storm Reports for 16 Nov 2005 Outbreak

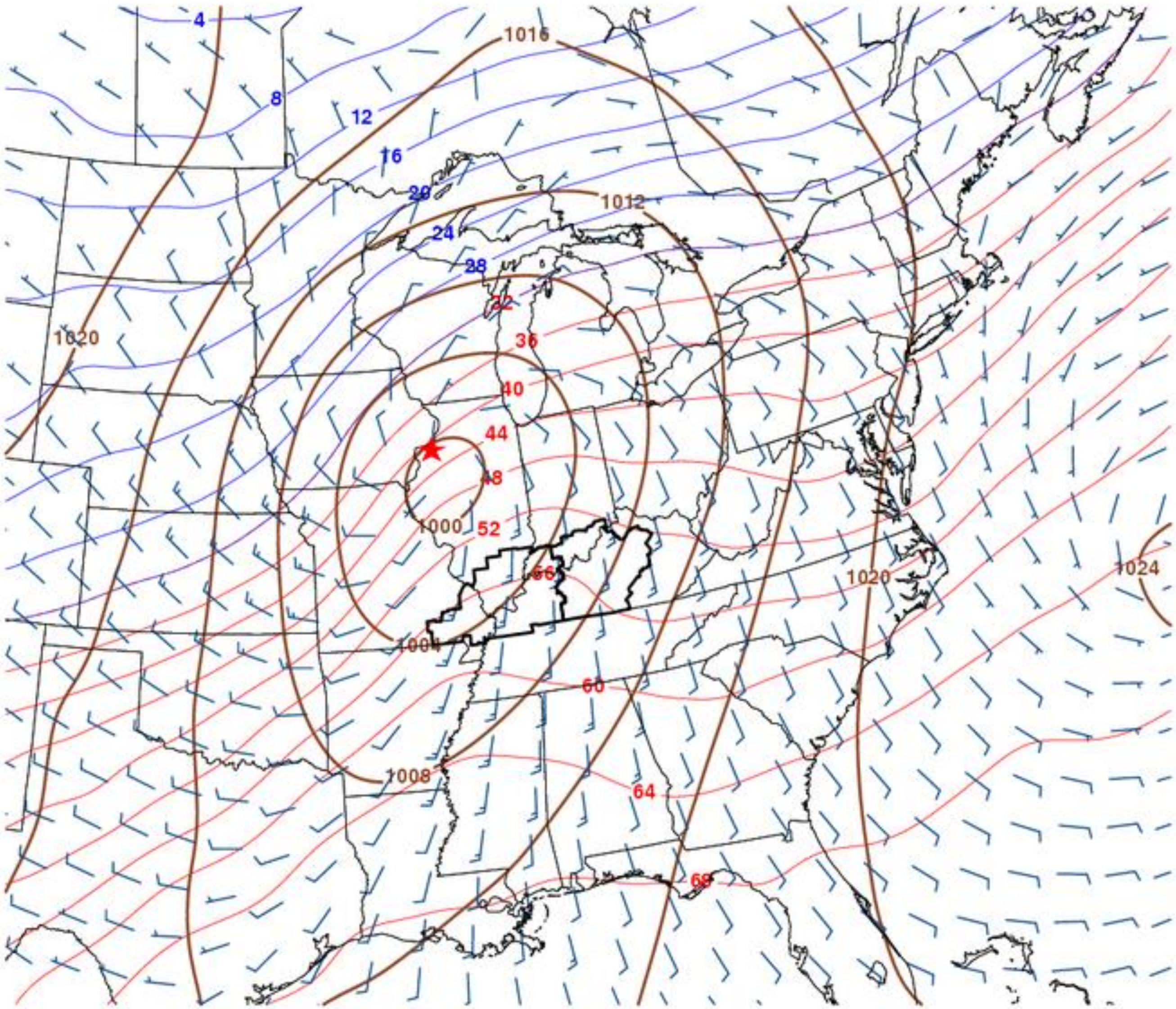


Mean PMSL, 10m Winds, and 2m Temperature at t=-6h



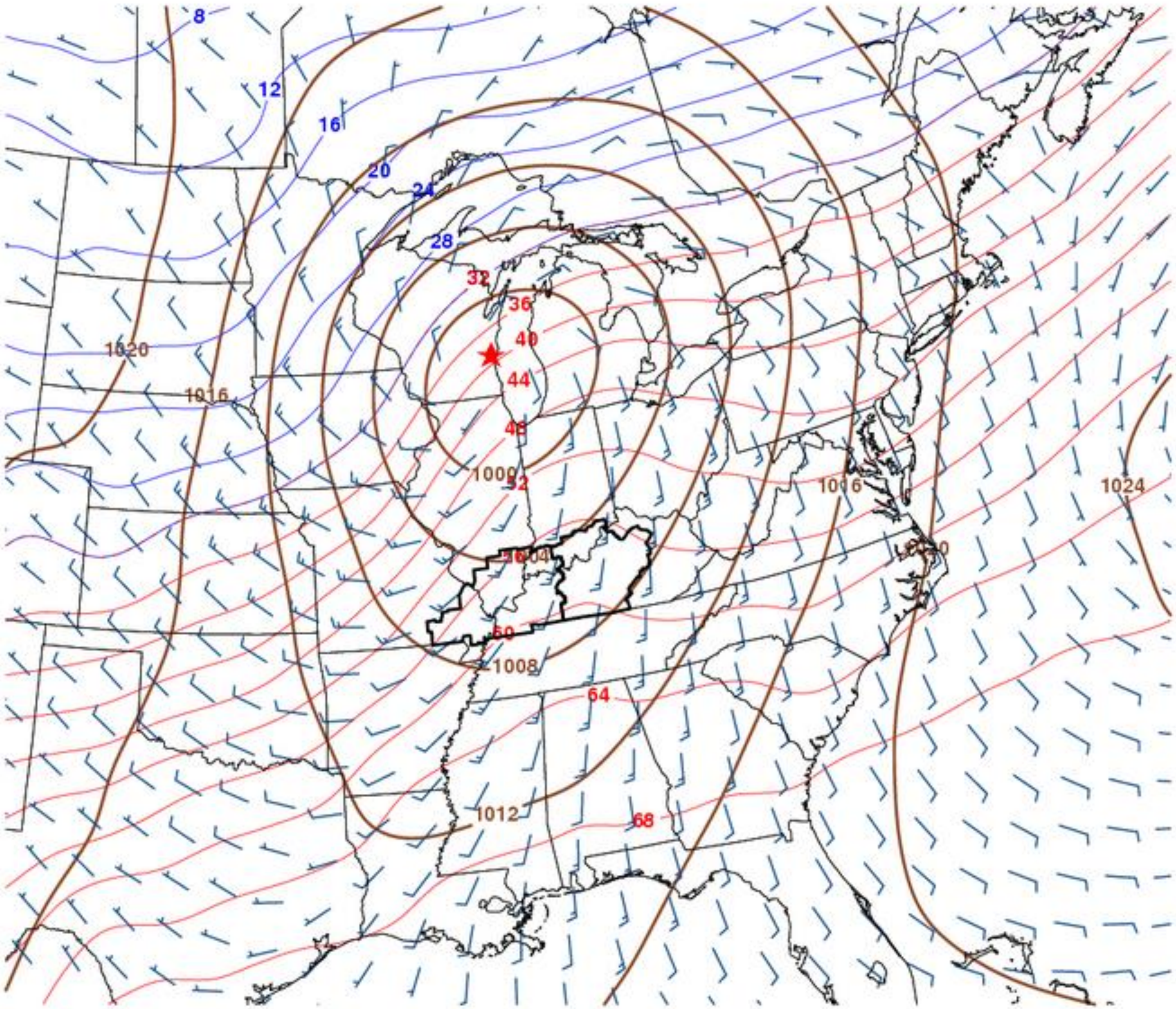
MEAN PMSL [mb], 10m WND [kts], and 2m TEMPERATURE [F] at t=-6h

Mean PMSL, 10m Winds, and 2m Temperature at t=0h



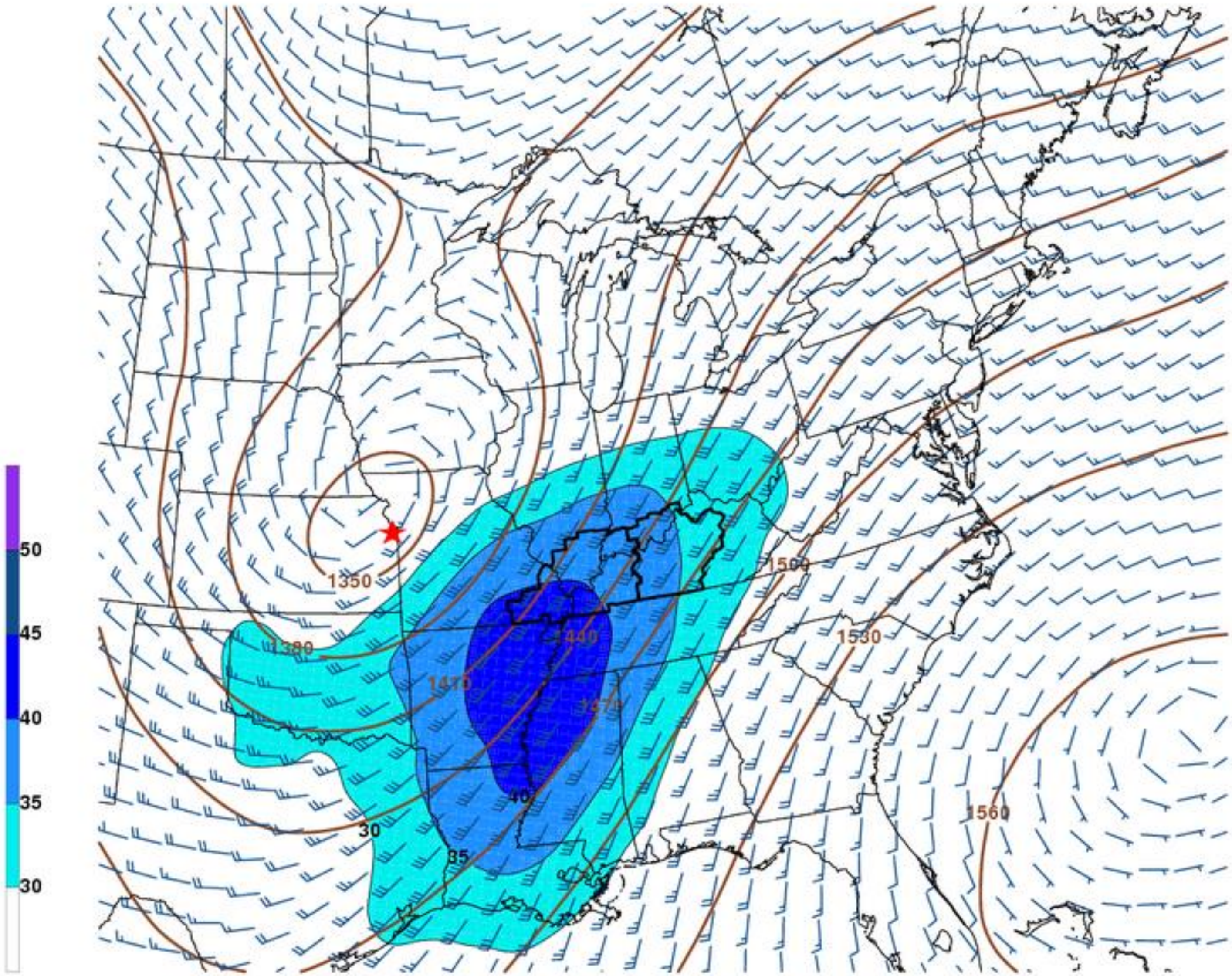
MEAN PMSL [mb], 10m WND [kts], and 2m TEMPERATURE [F] at t=0h

Mean PMSL, 10m Winds, and 2m Temperature at t=+6h



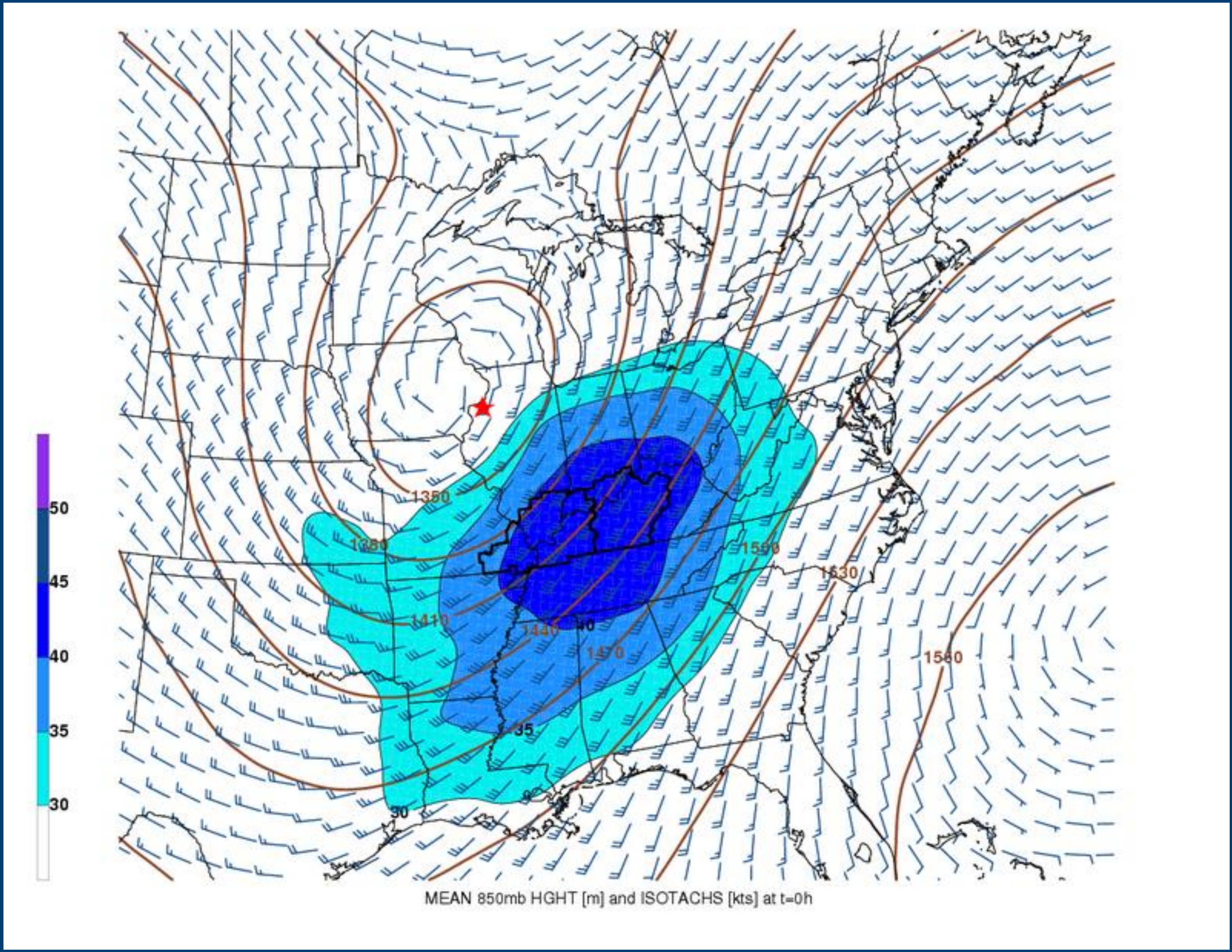
MEAN PMSL [mb], 10m WND [kts], and 2m TEMPERATURE [F] at t=+6h

Mean 850mb Heights and Isotachs at t=-6h

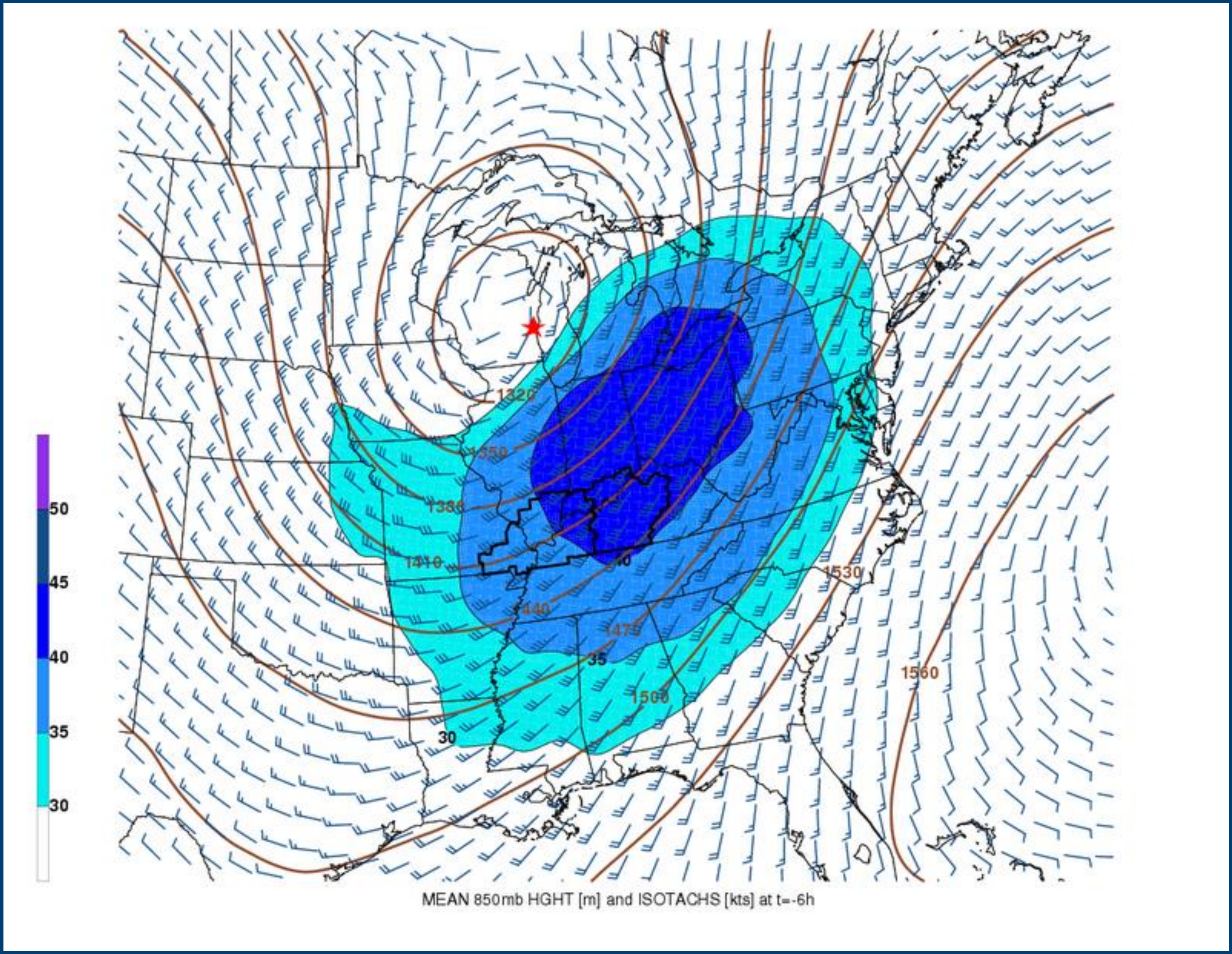


MEAN 850mb HGHT [m] and ISOTACHS [kts] at t=h

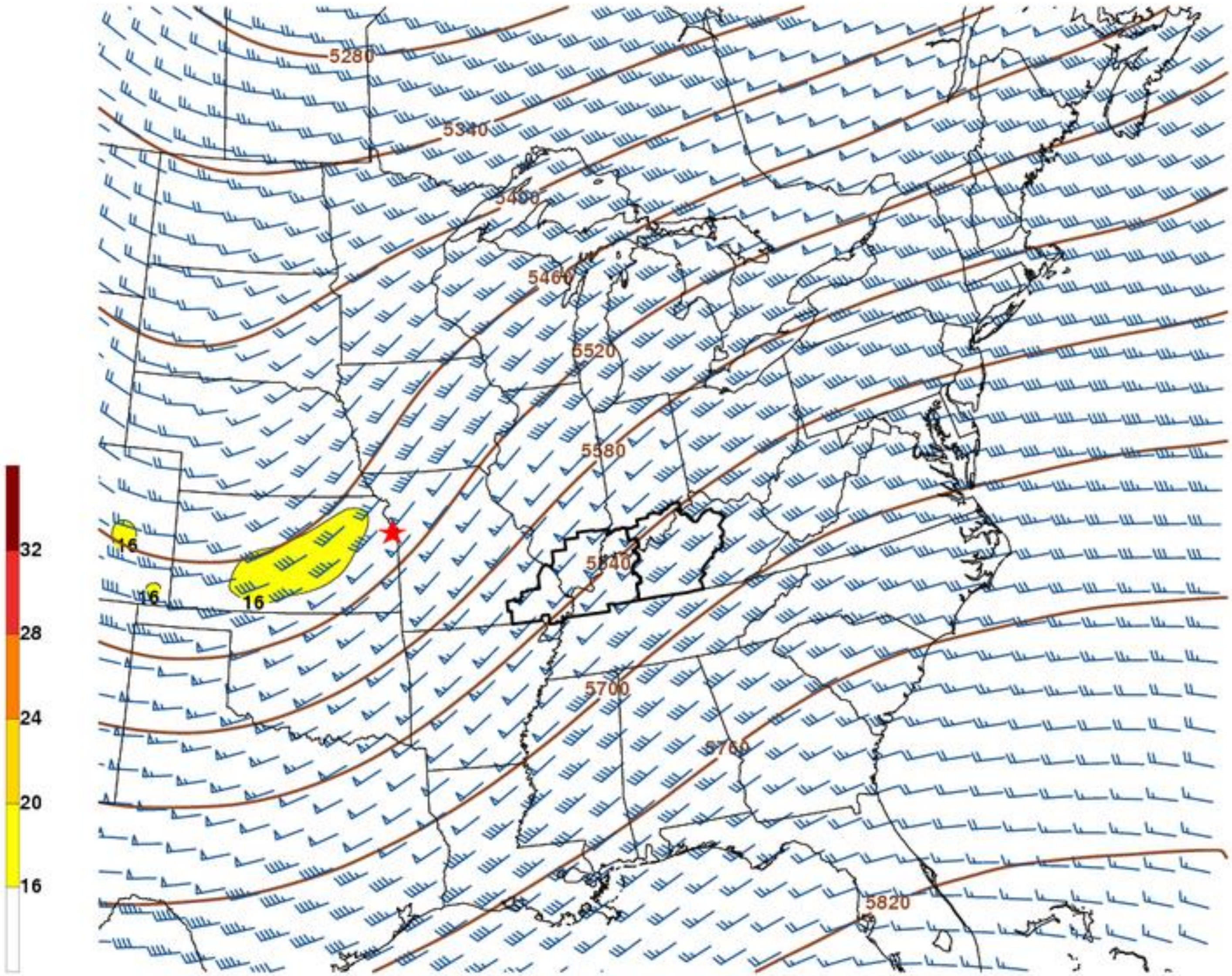
Mean 850mb Heights and Isotachs at t=0h



Mean 850mb Heights and Isotachs at t=+6h

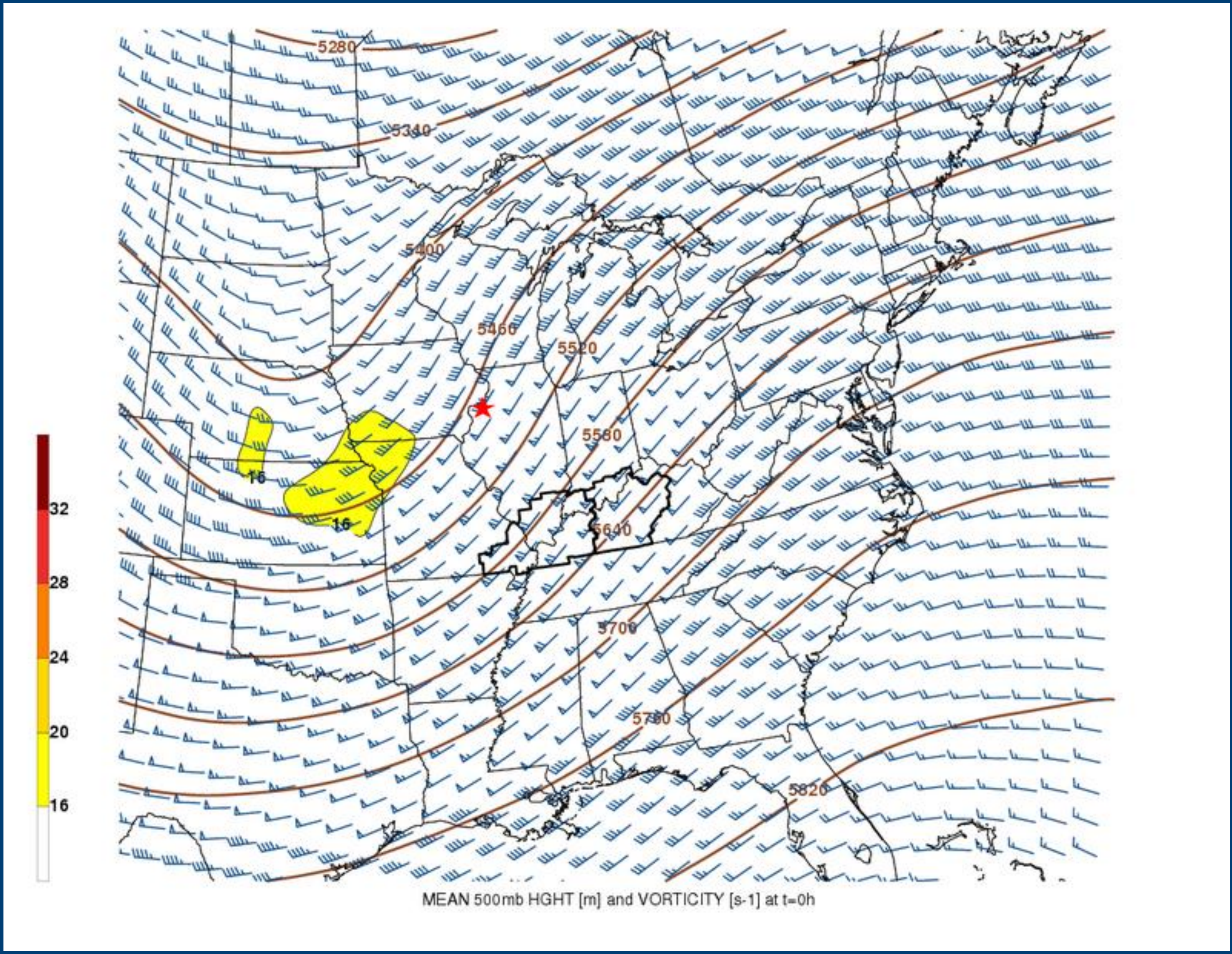


Mean 500mb Heights and Vorticity at t=-6h

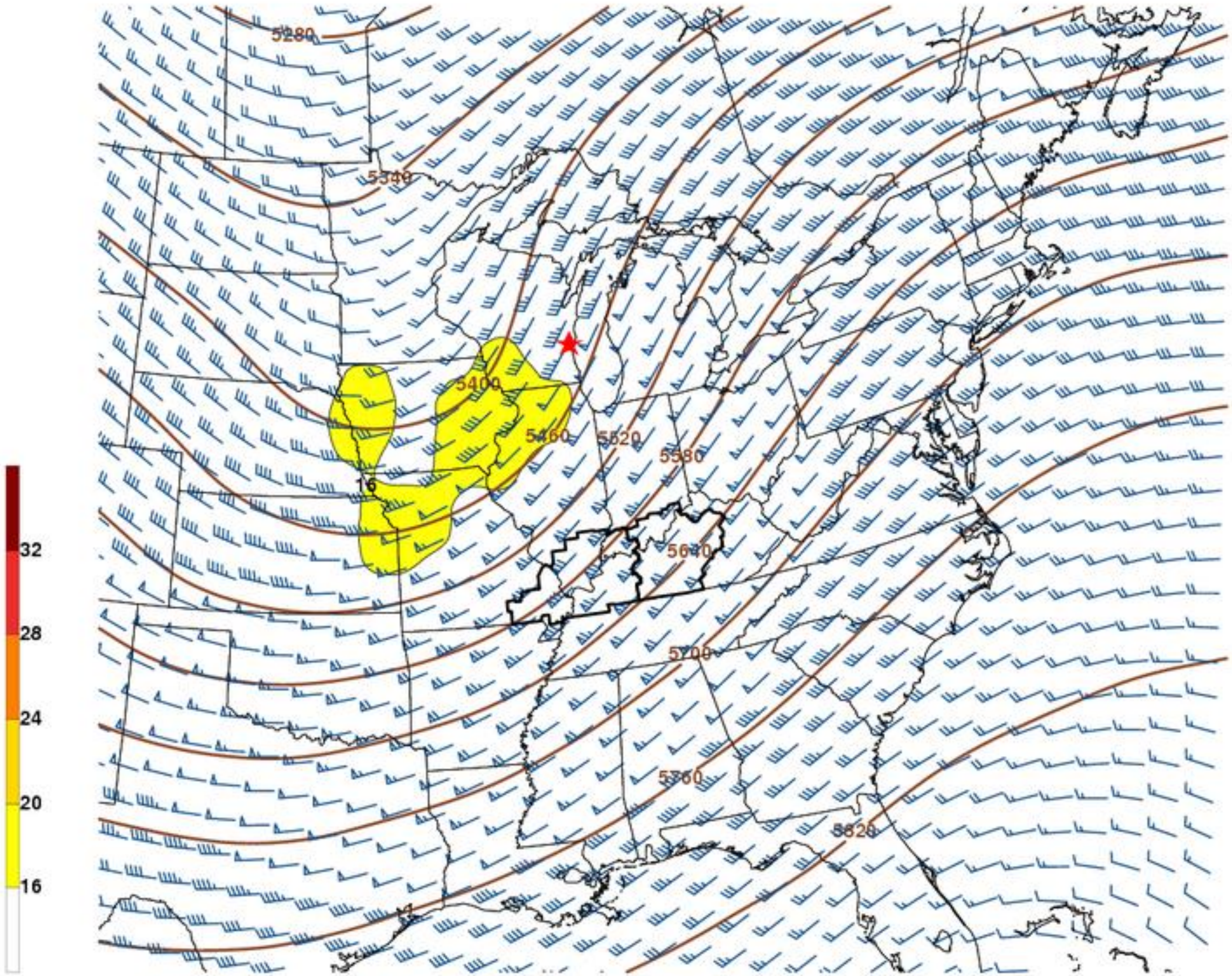


MEAN 500mb HGHT [m] and VORTICITY [s-1] at t=-6h

Mean 500mb Heights and Vorticity at t=0h

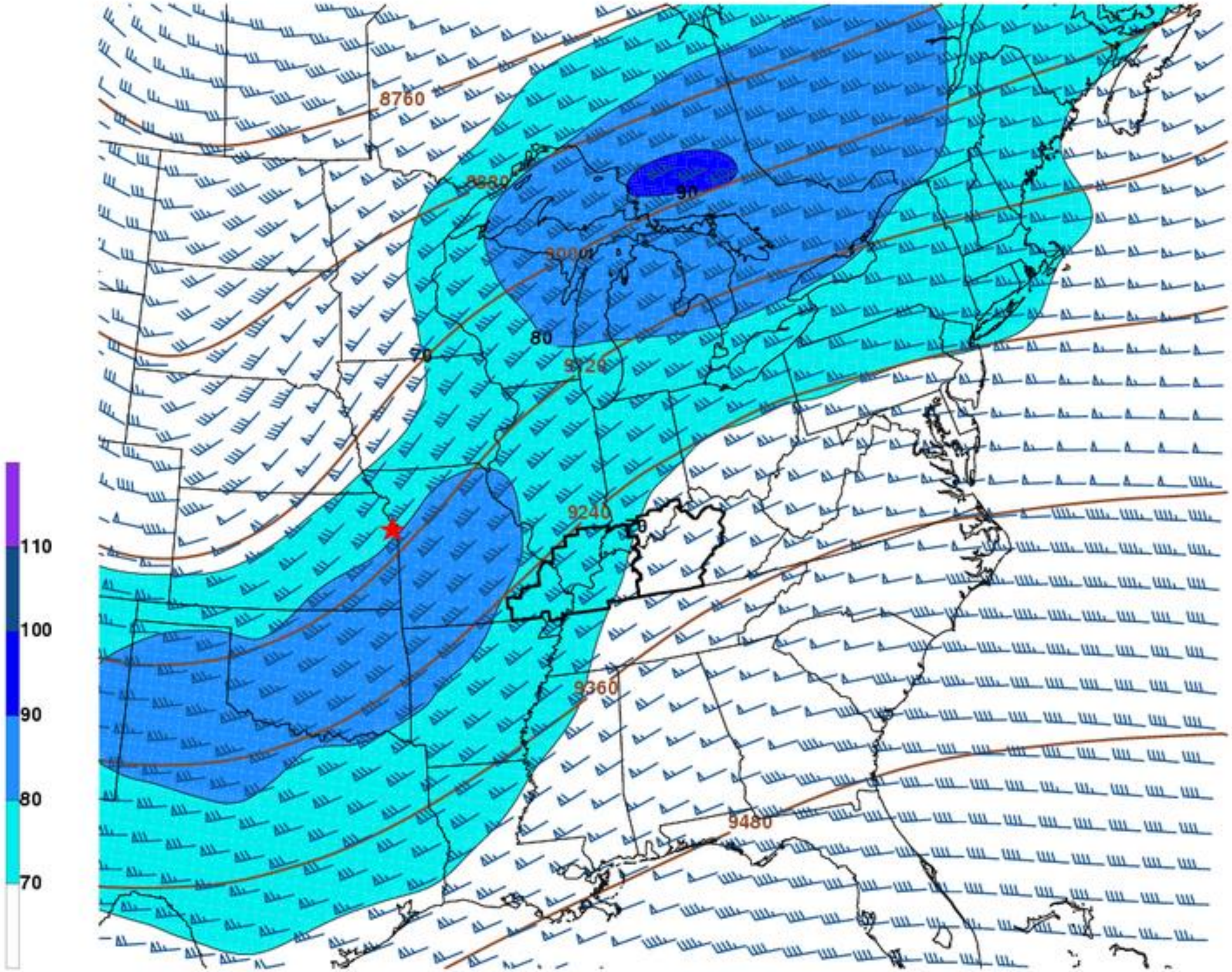


Mean 500mb Heights and Vorticity at t=+6h



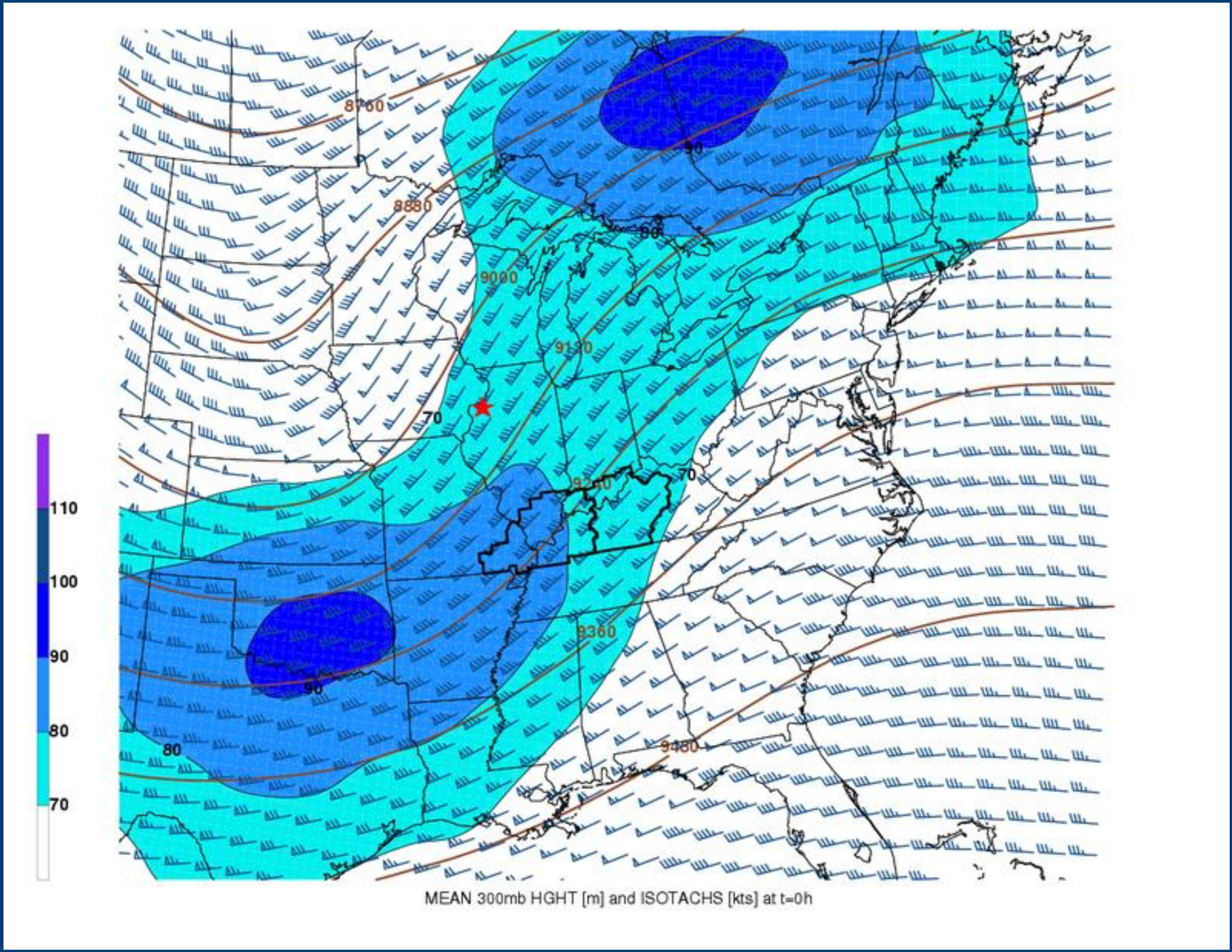
MEAN 500mb HGHT [m] and VORTICITY [s-1] at t=+6h

Mean 300mb Heights and Isotachs at t=-6h

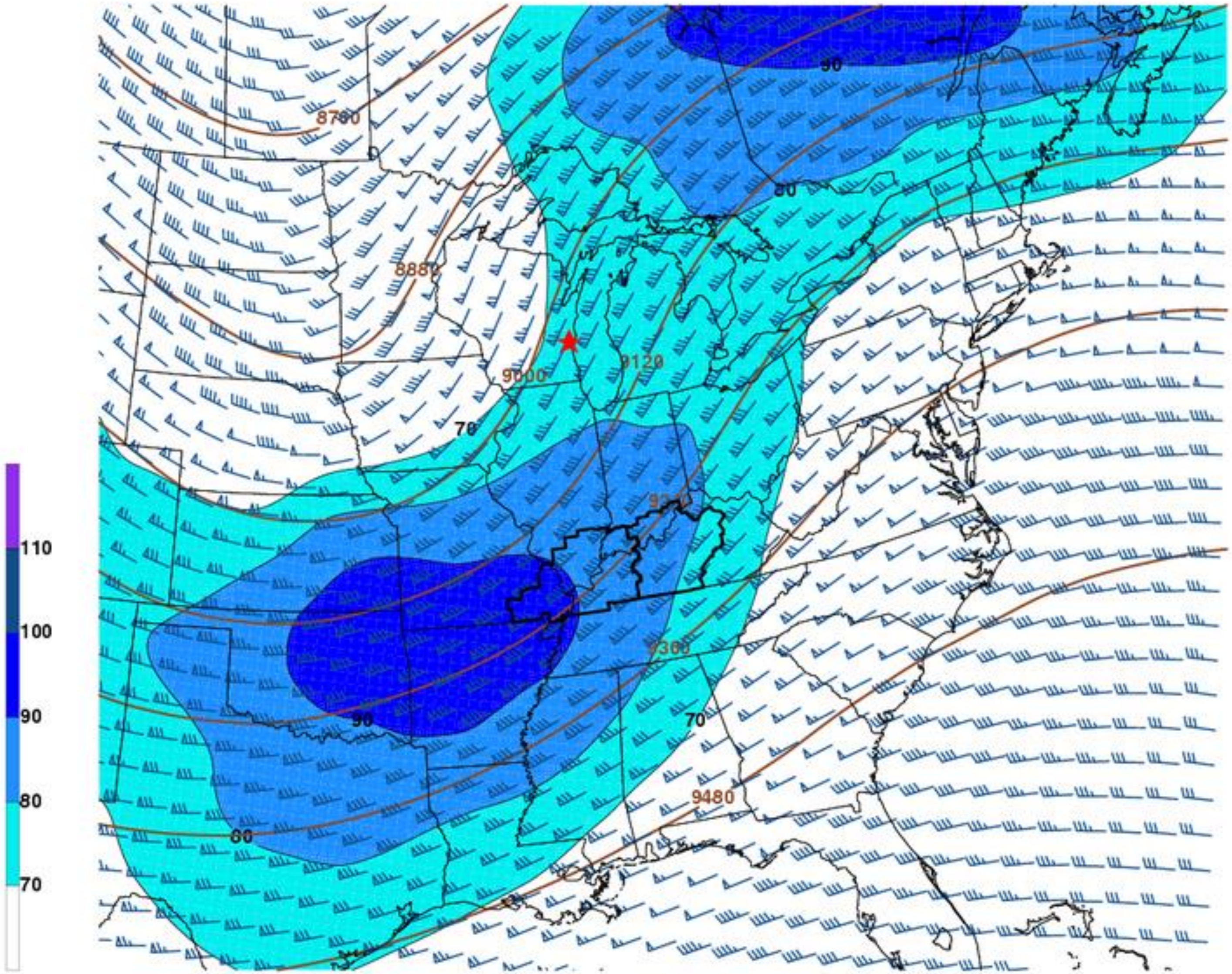


MEAN 300mb HGHT [m] and ISOTACHS [kts] at t=-6h

Mean 300mb Heights and Isotachs at t=0h

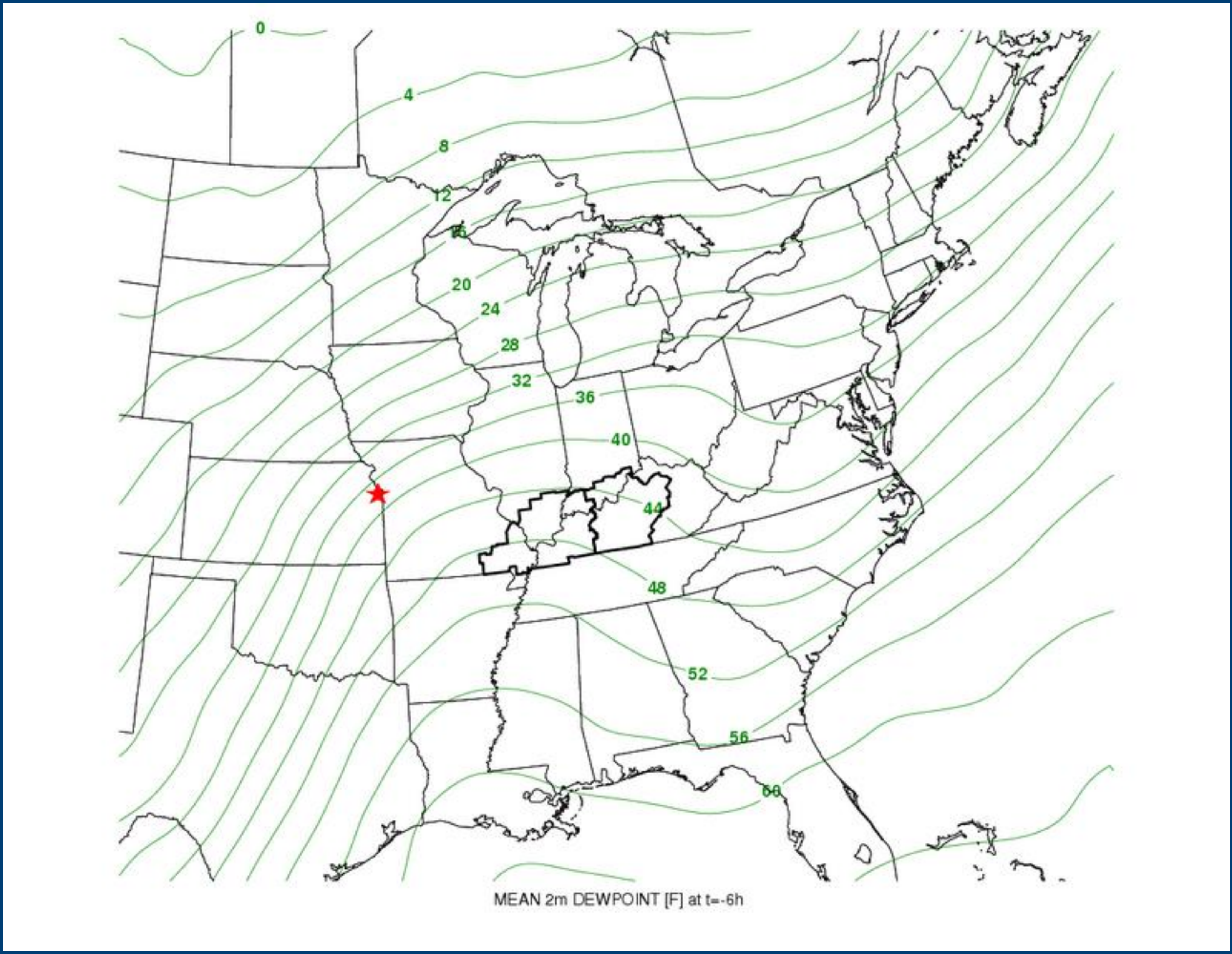


Mean 300mb Heights and Isotachs at t=+6h

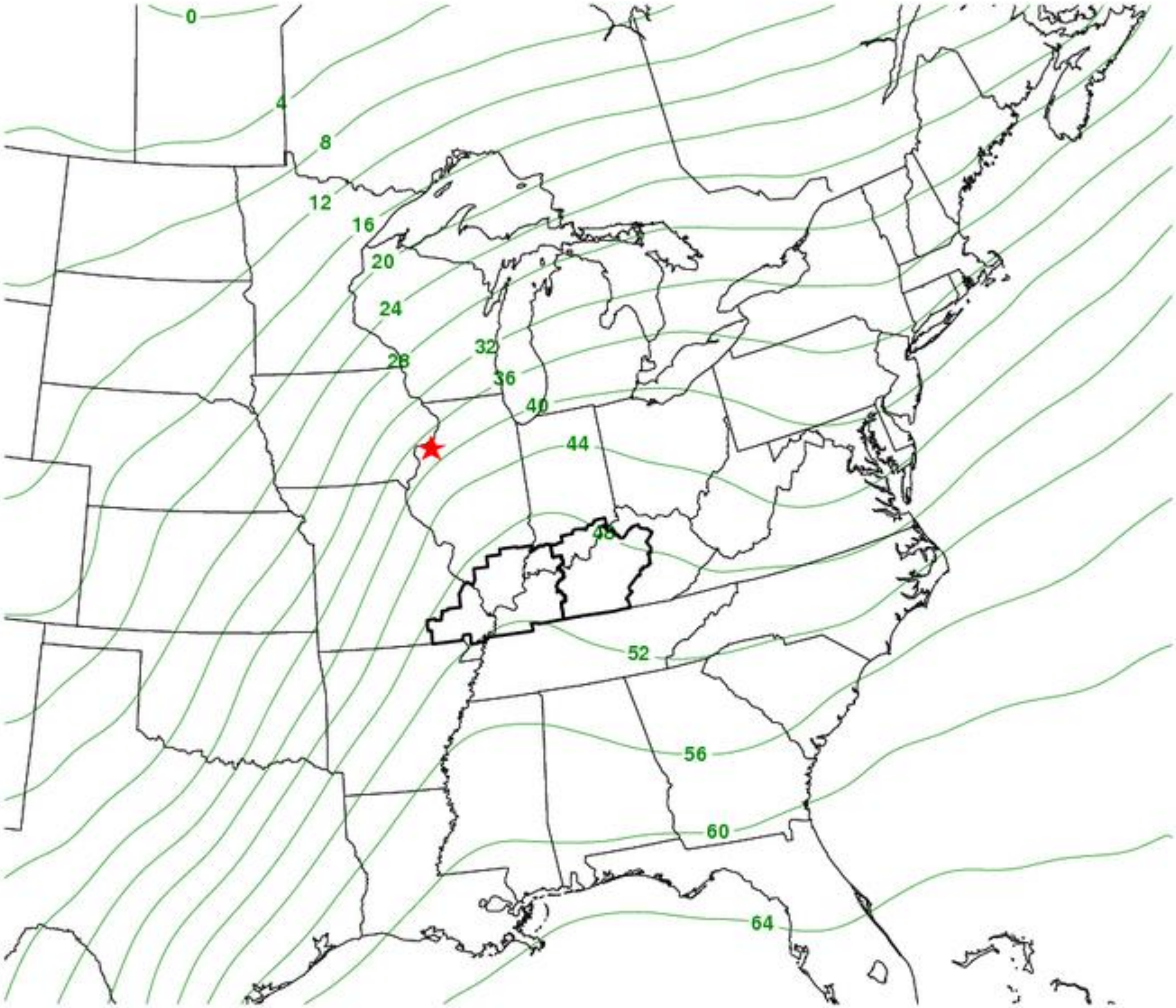


MEAN 300mb HGHT [m] and ISOTACHS [kts] at t=+6h

Mean 2m Dewpoint at t=-6h

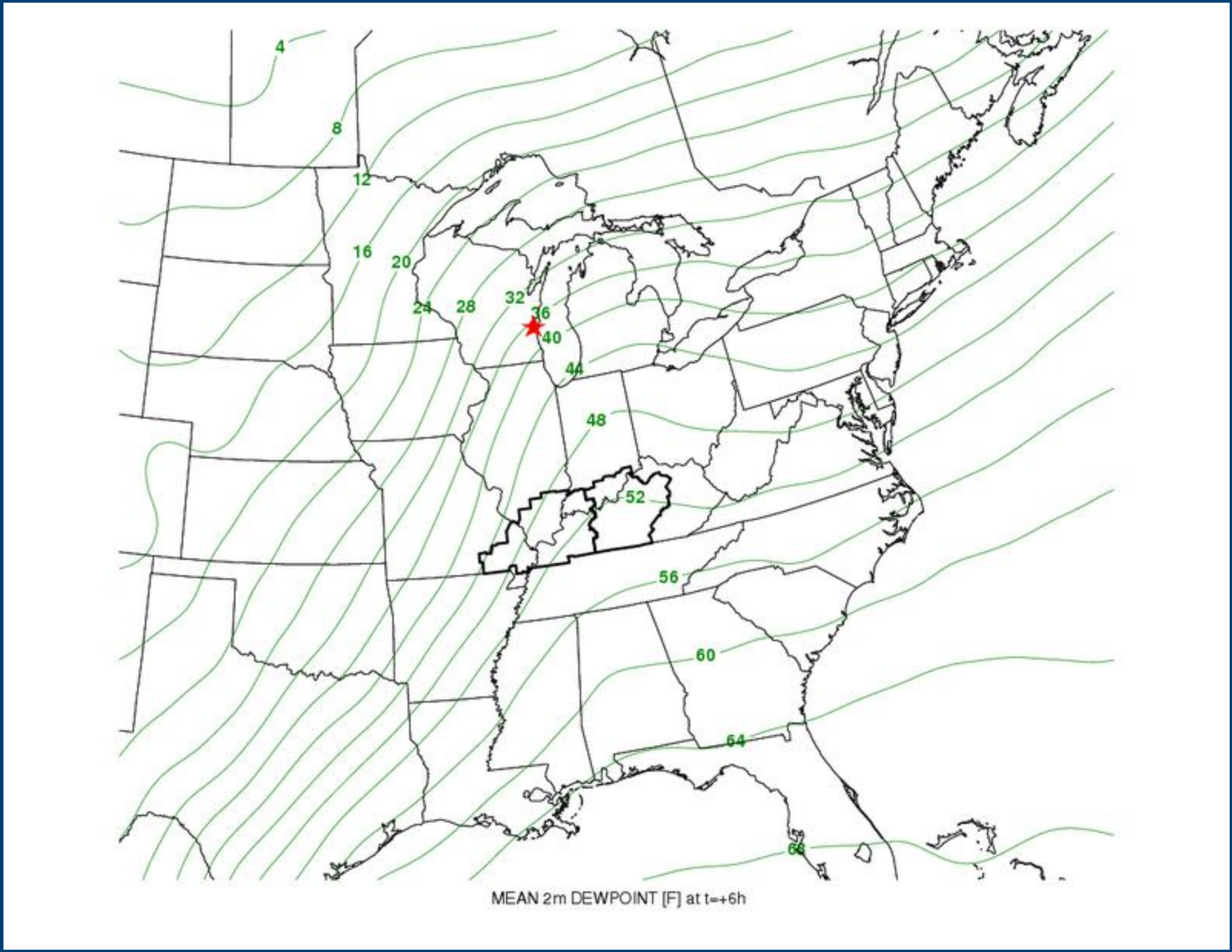


Mean 2m Dewpoint at t=0h

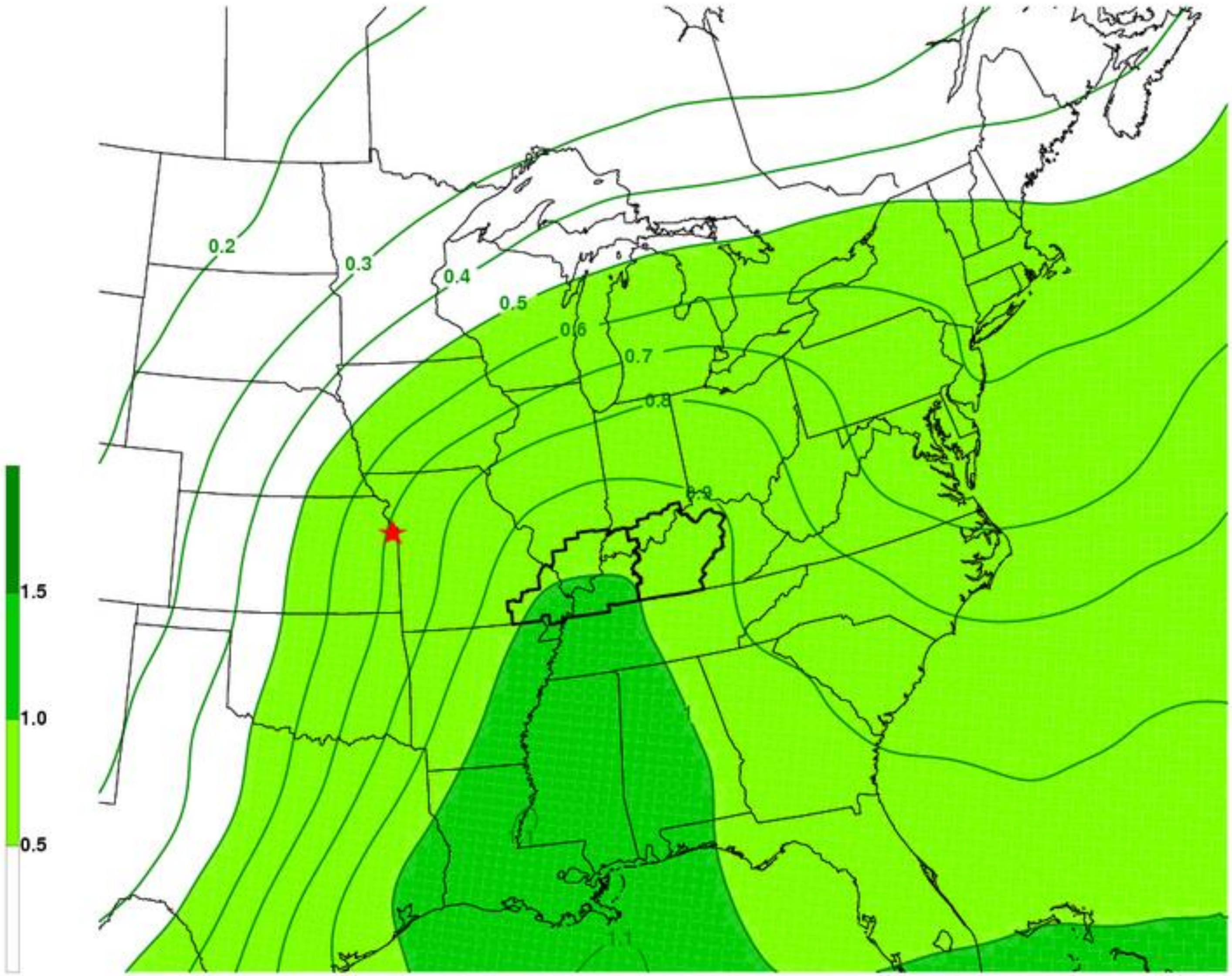


MEAN 2m DEWPOINT [F] at t=0h

Mean 2m Dewpoint at t=+6h

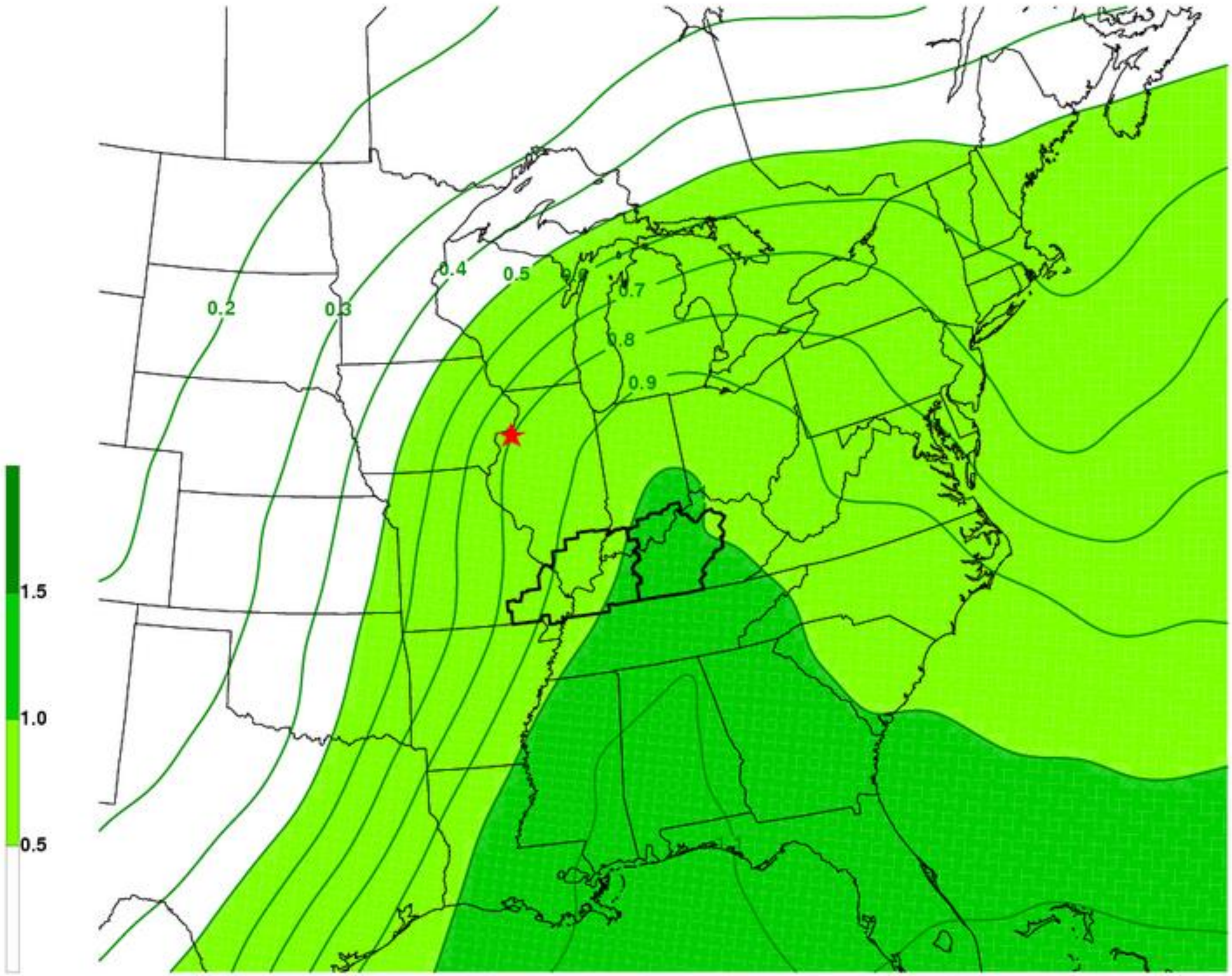


Mean Precipitable Water at t=-6h



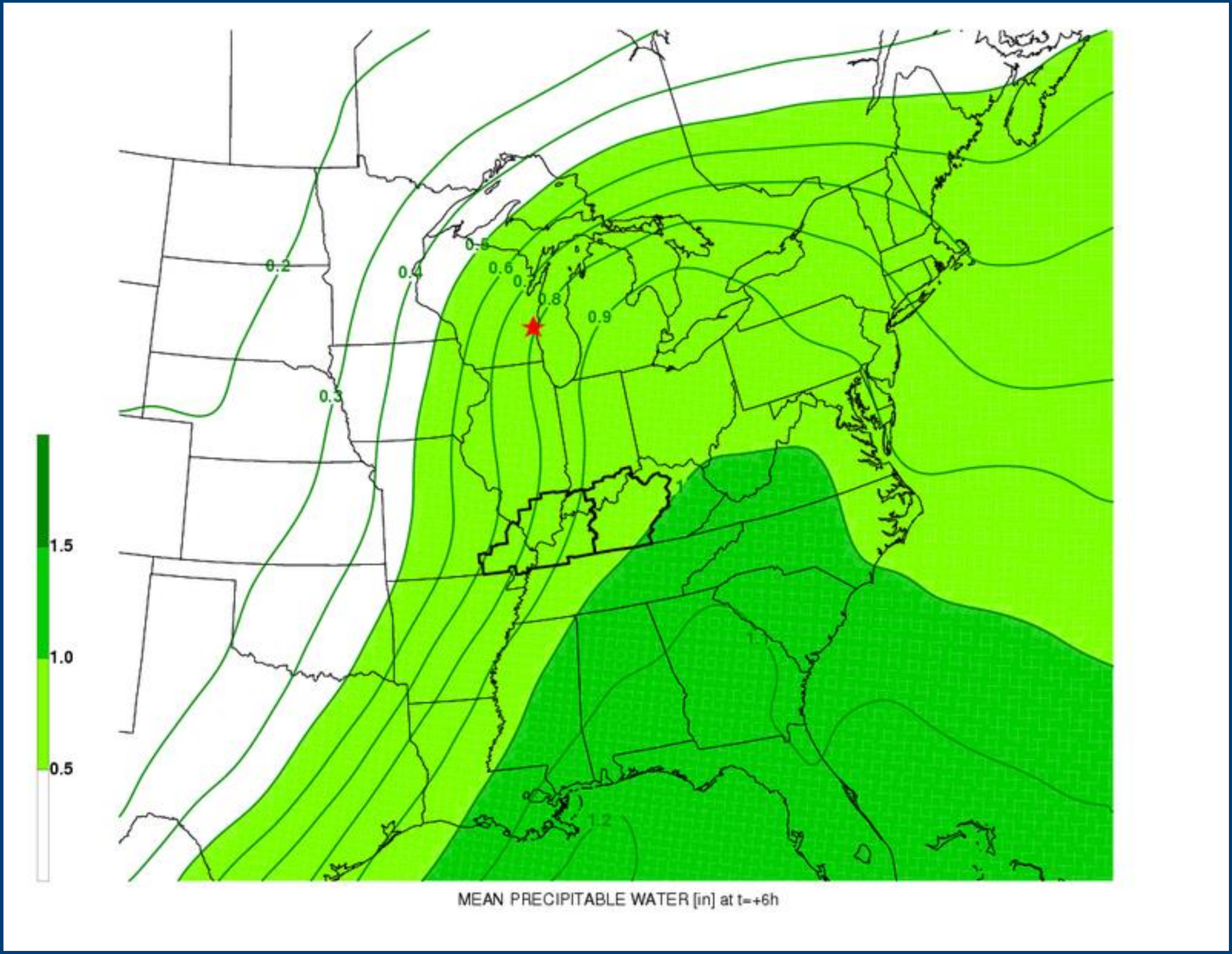
MEAN PRECIPITABLE WATER [in] at t=-6h

Mean Precipitable Water at t=0h

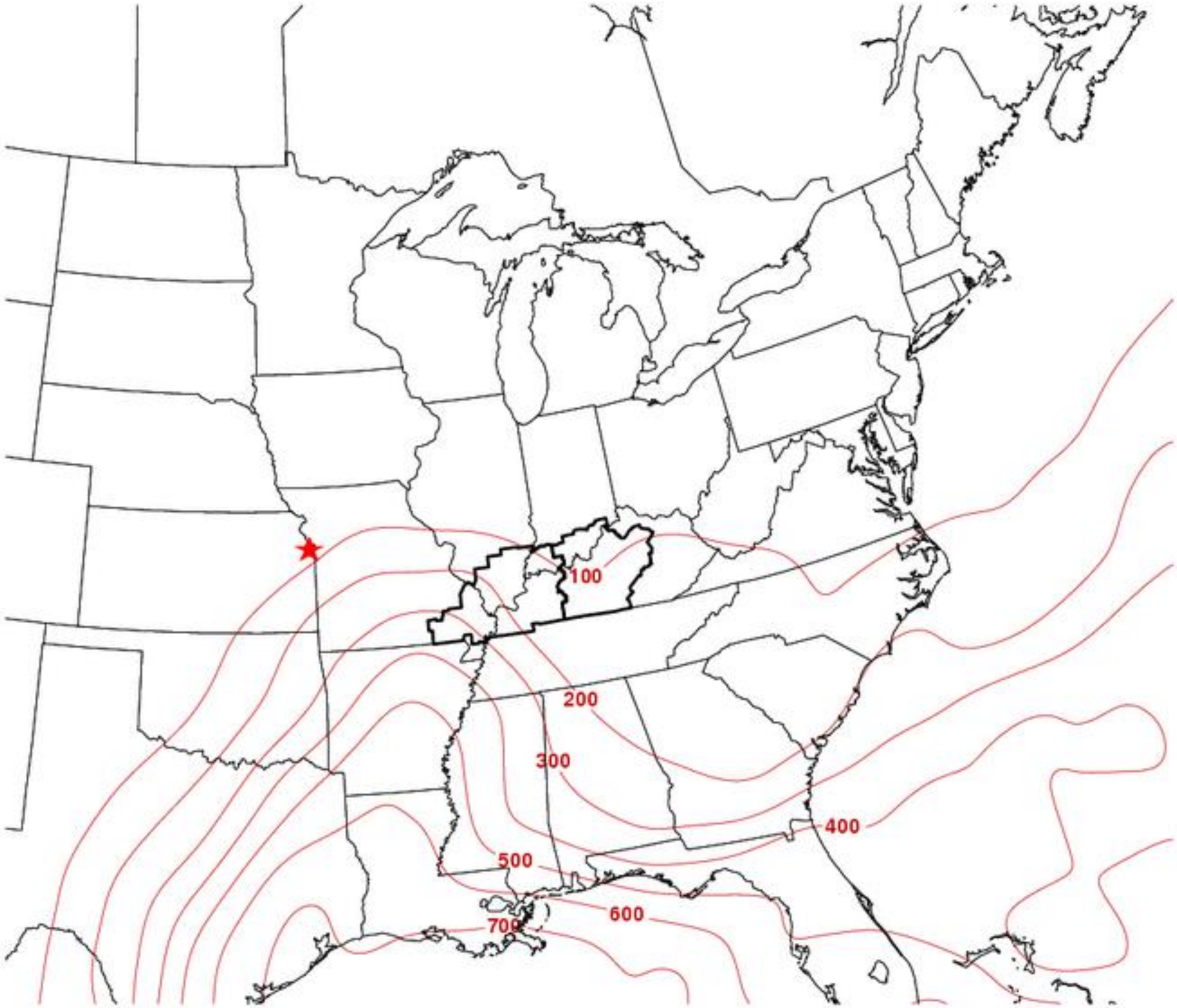


MEAN PRECIPITABLE WATER [in] at t=0h

Mean Precipitable Water at t=+6h

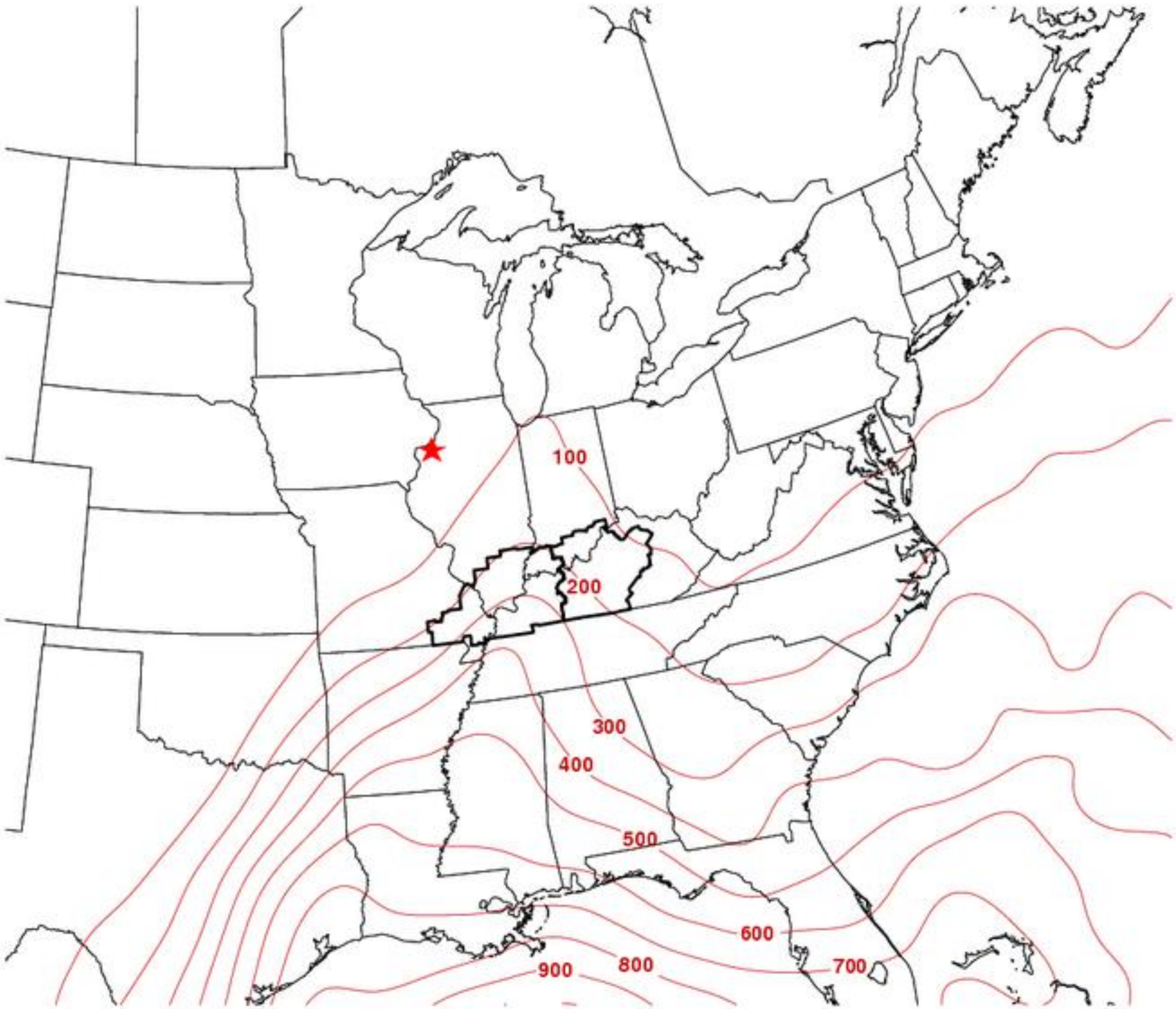


Mean CAPE at t=-6h



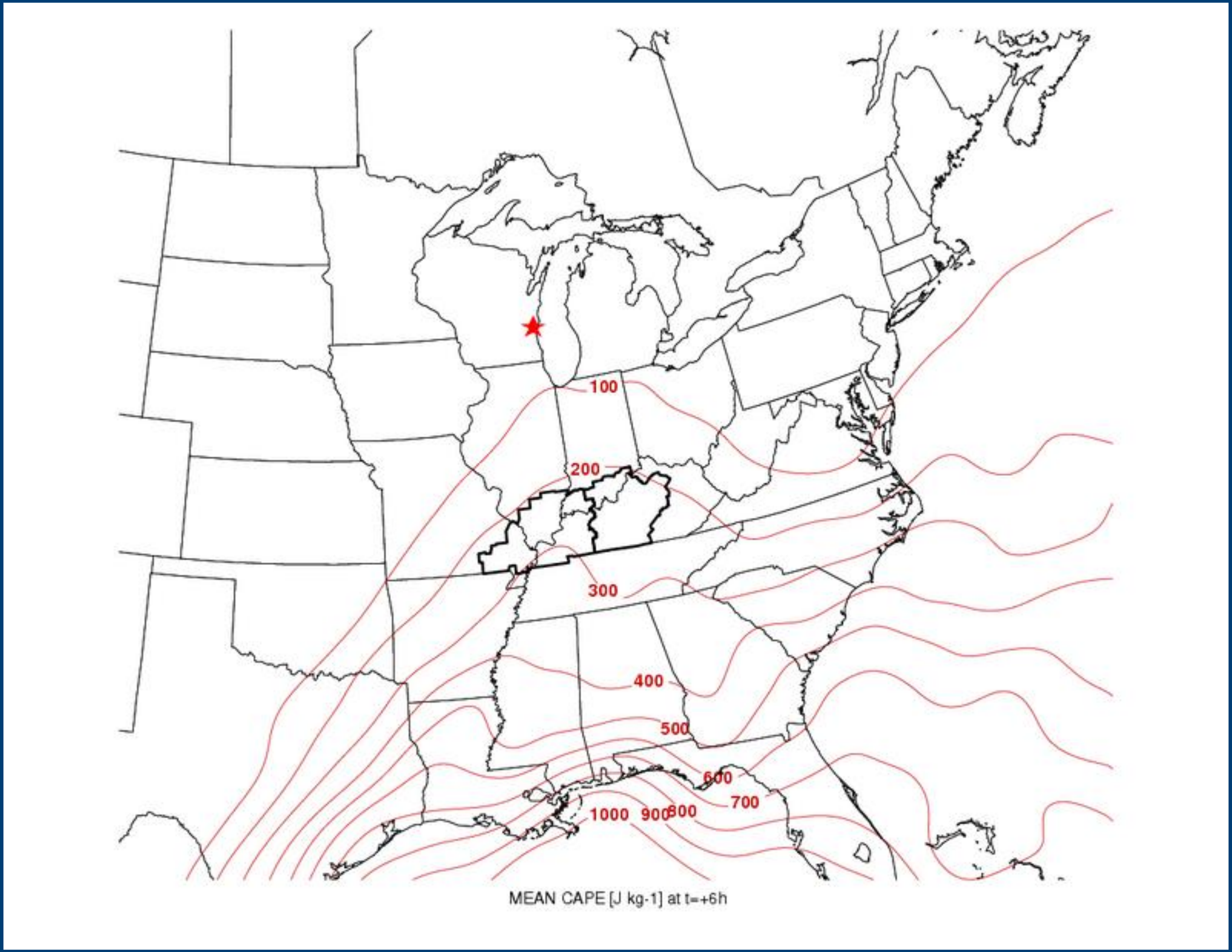
MEAN CAPE [J kg-1] at t=-6h

Mean CAPE at t=0h

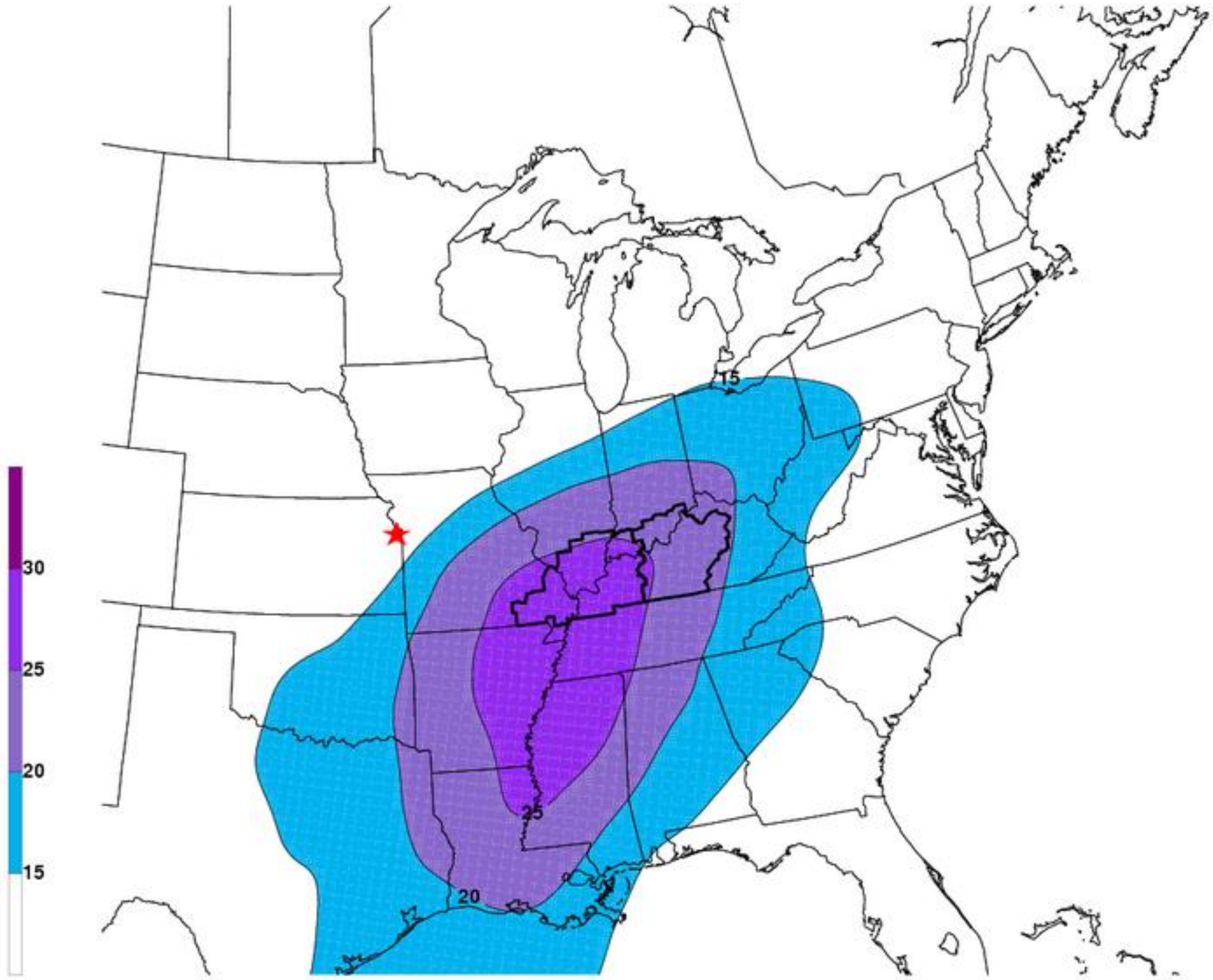


MEAN CAPE [J kg-1] at t=0h

Mean CAPE at t=+6h

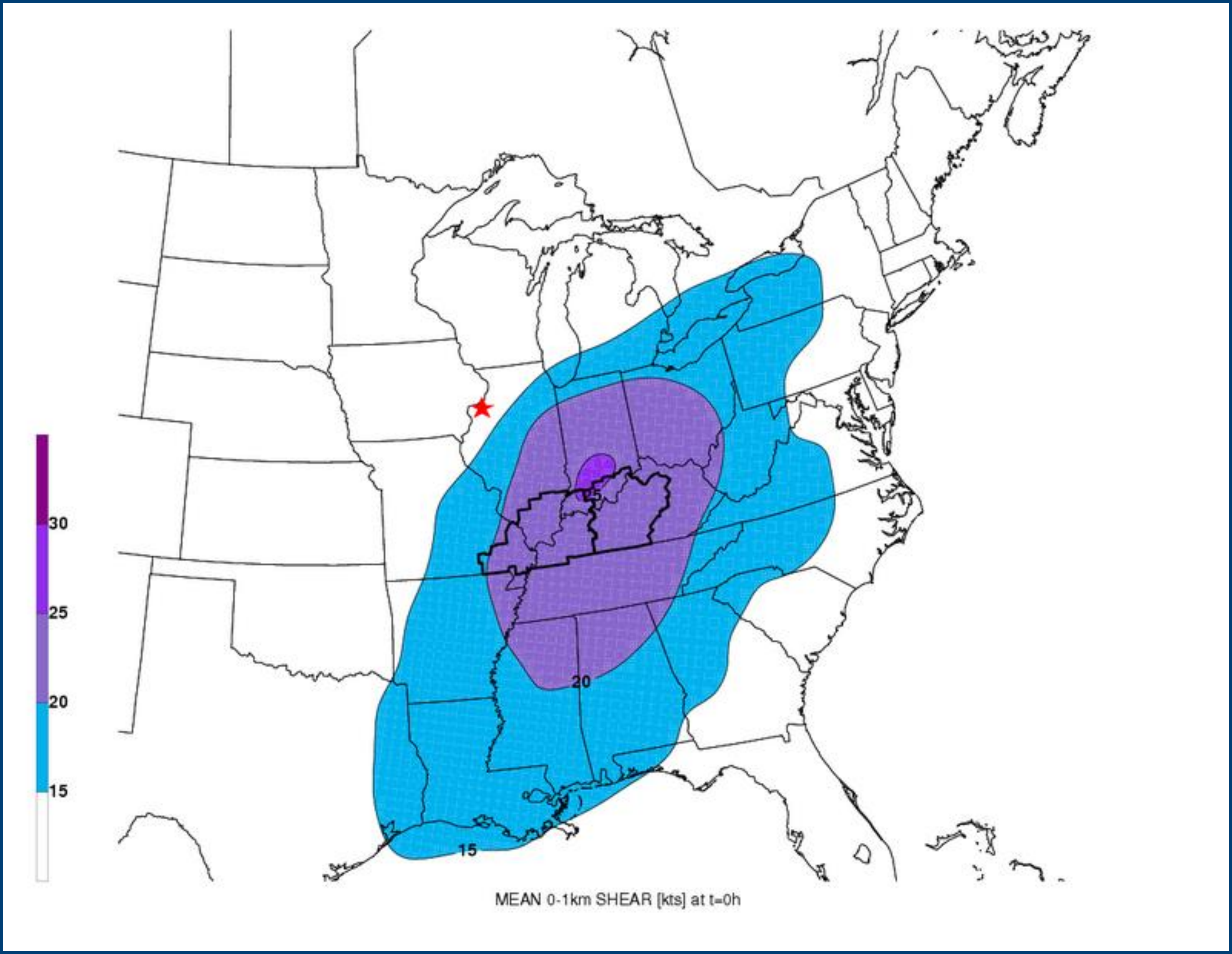


Mean 0-1km Speed Shear at t=-6h

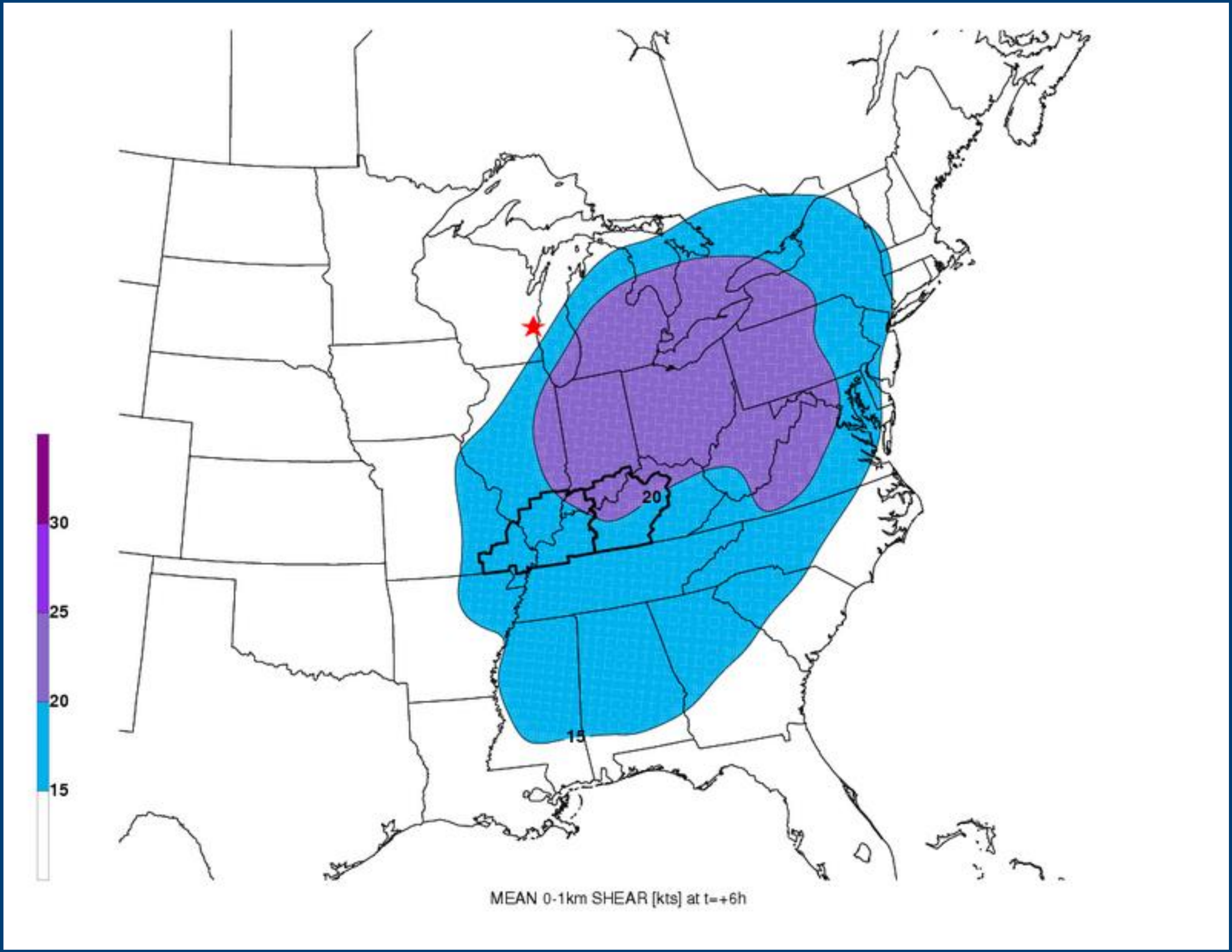


MEAN 0-1km SHEAR [kts] at t=-6h

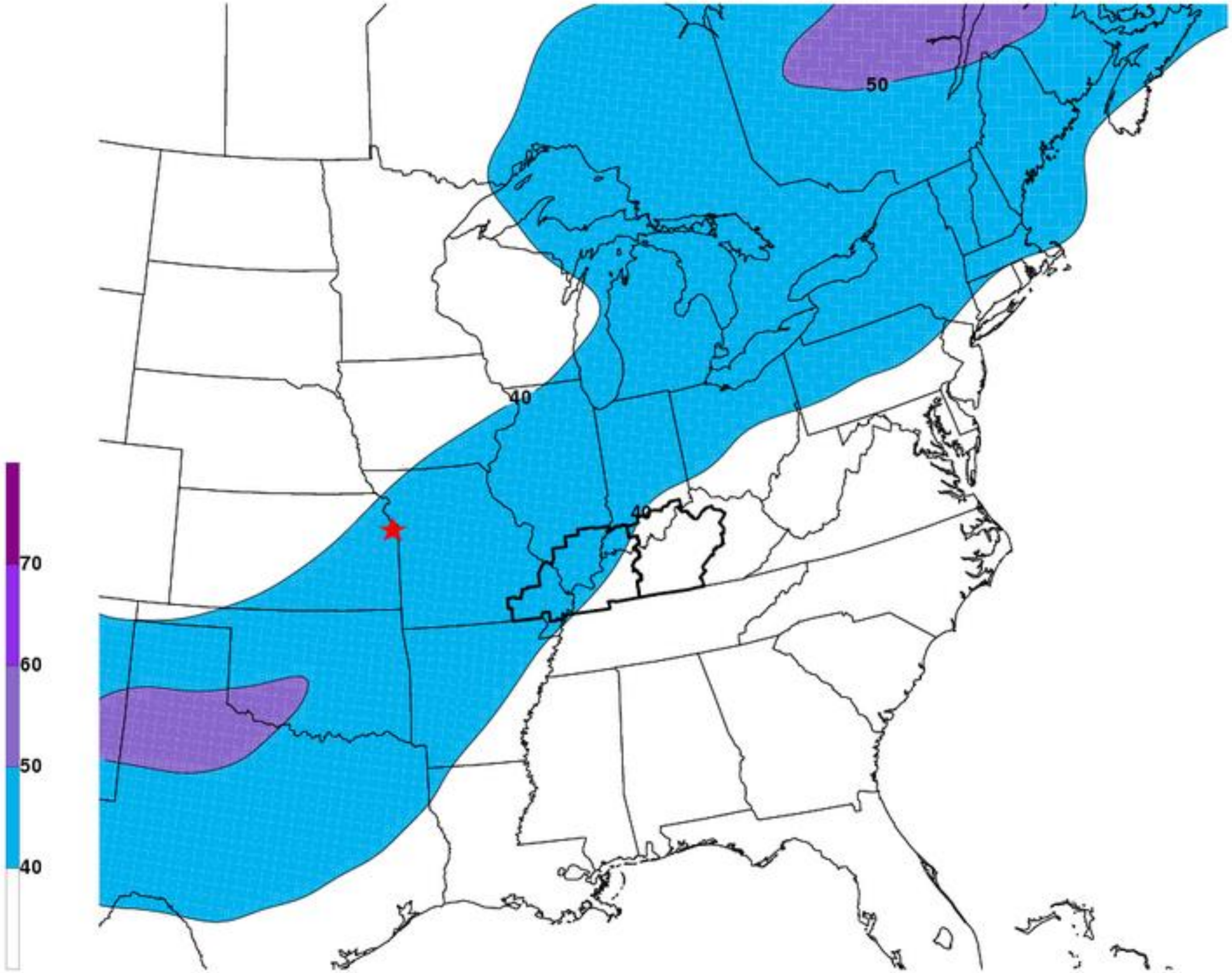
Mean 0-1km Speed Shear at t=0h



Mean 0-1km Speed Shear at t=+6h

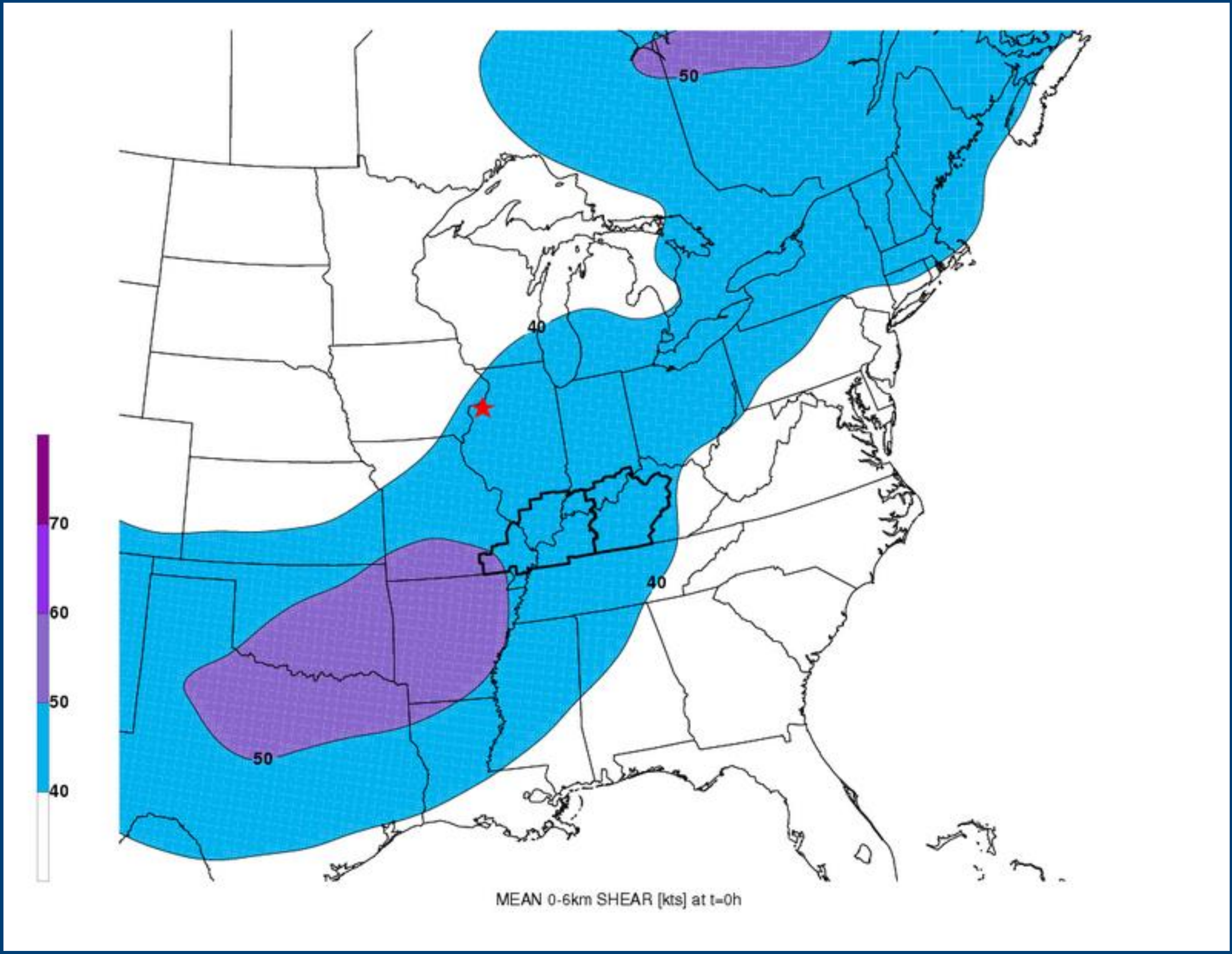


Mean 0-6km Speed Shear at t=-6h

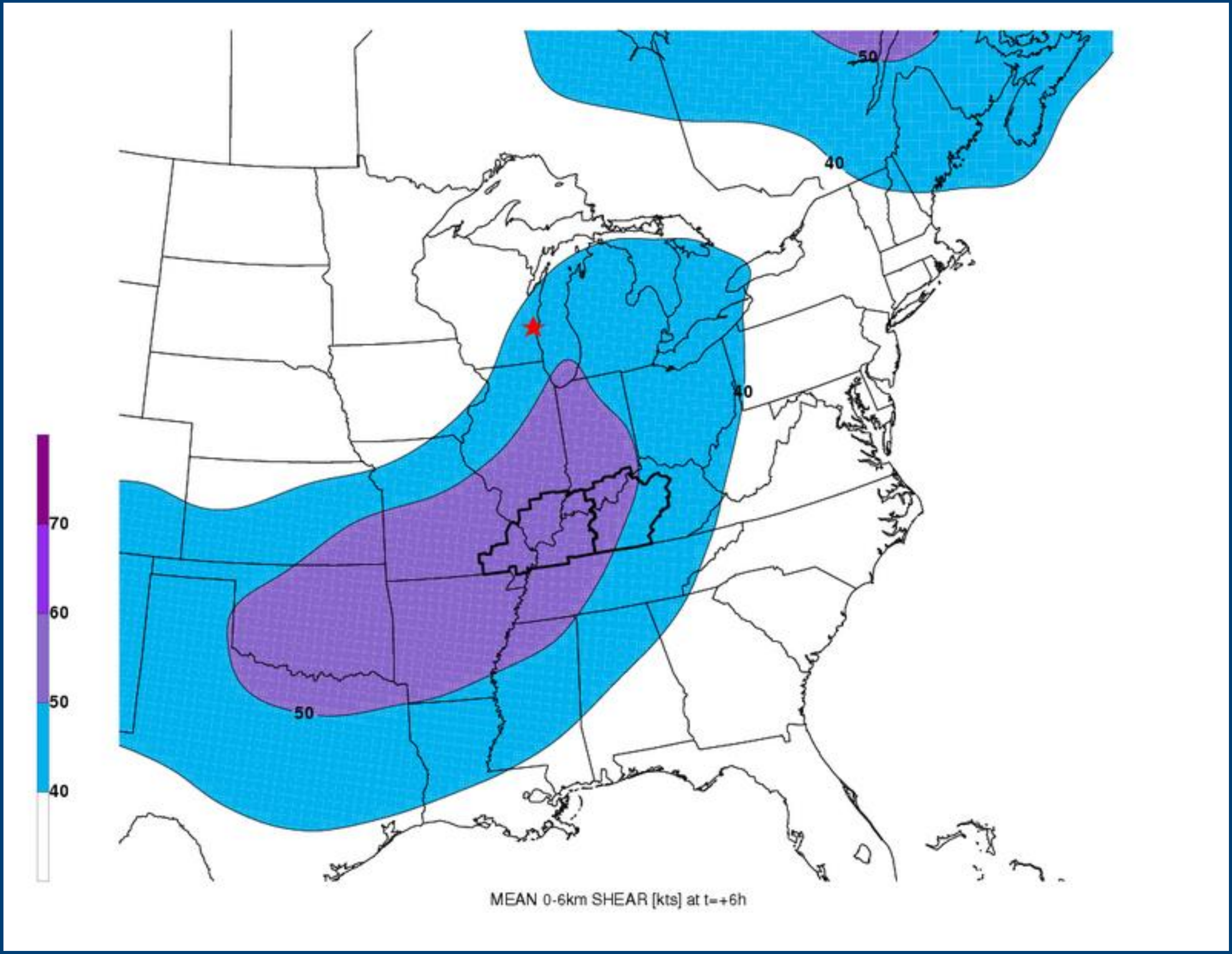


MEAN 0-6km SHEAR [kts] at t=-6h

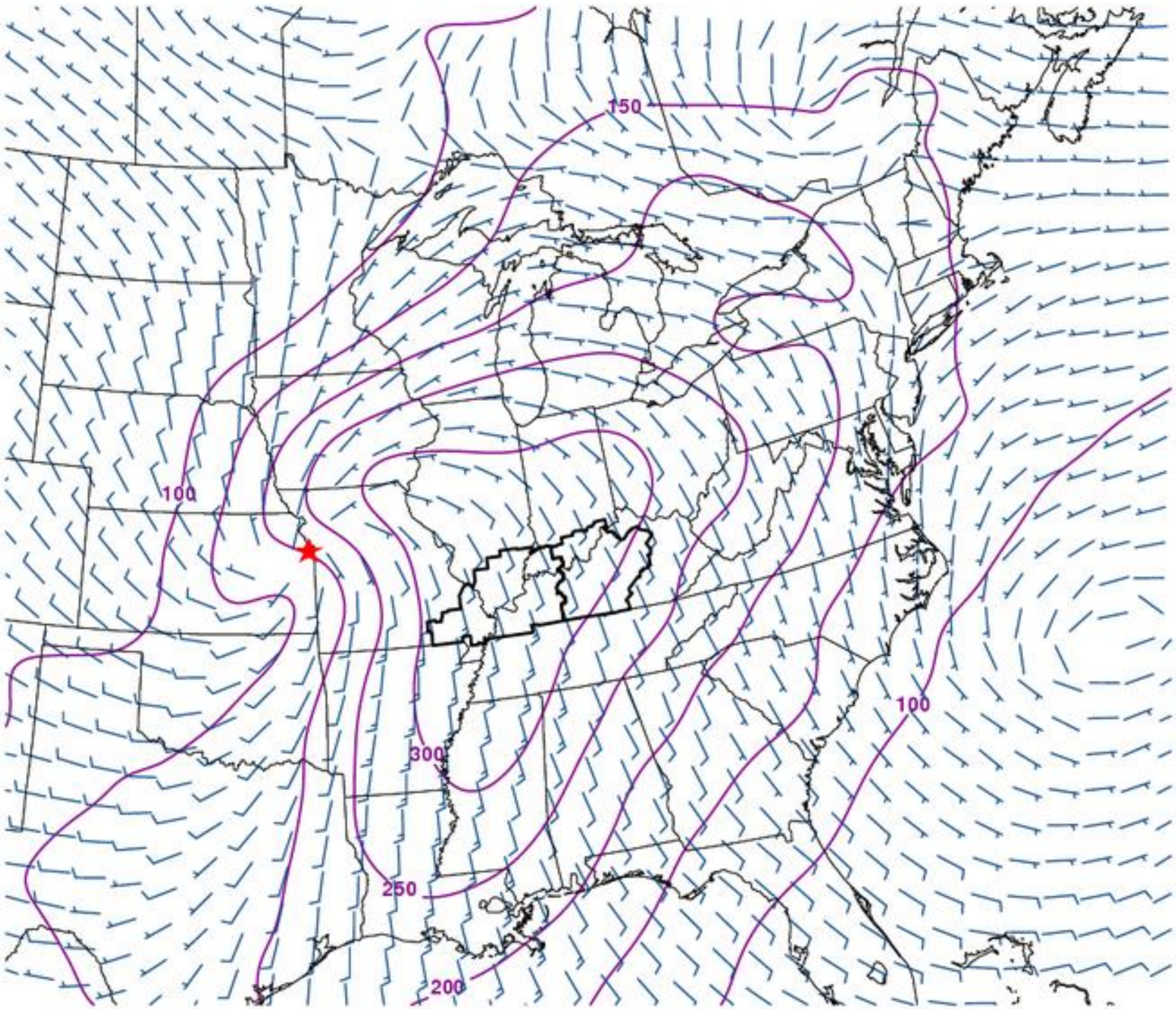
Mean 0-6km Speed Shear at t=0h



Mean 0-6km Speed Shear at t=+6h

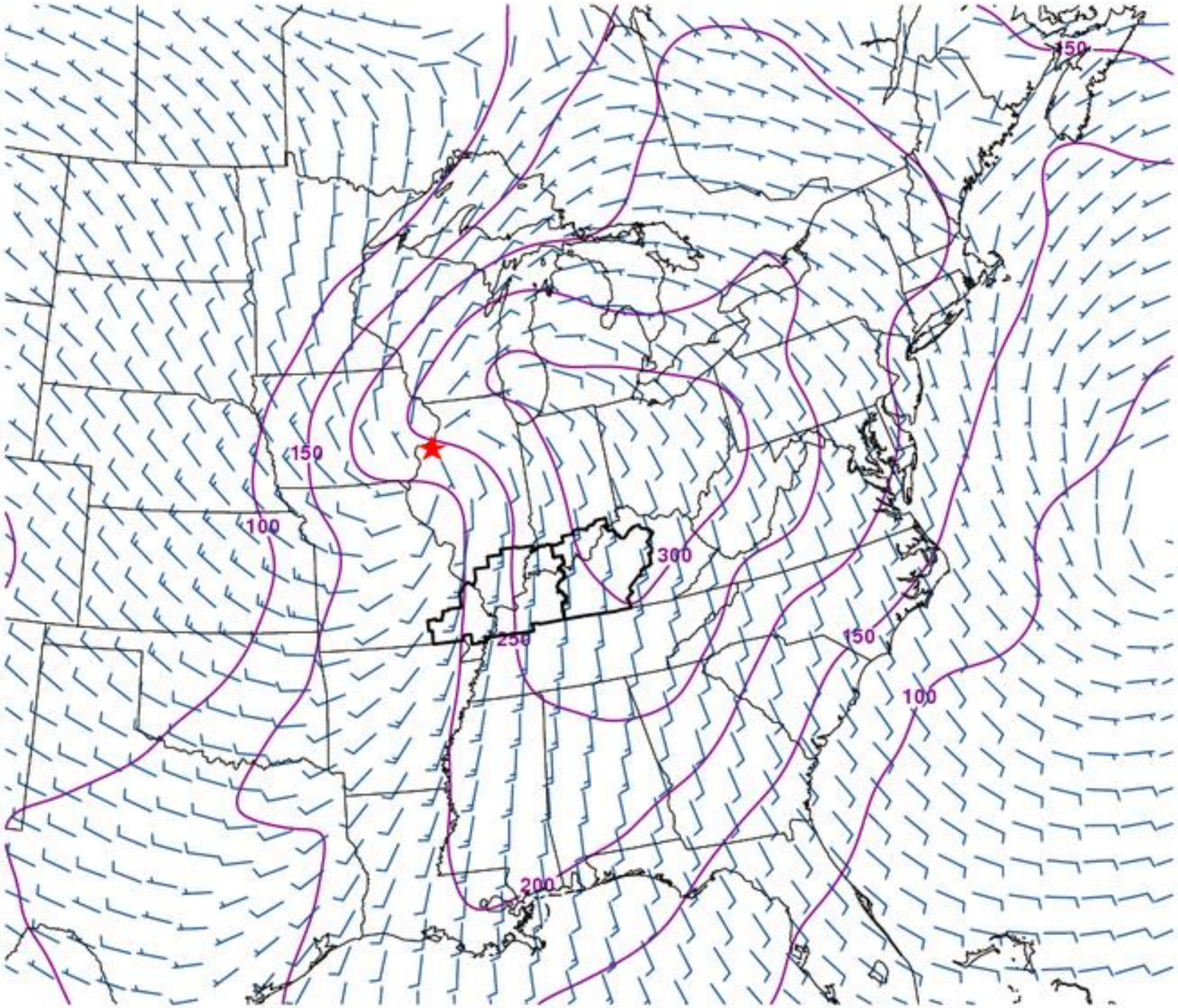


Mean 0-3km SRH and 10m Winds at t=-6h



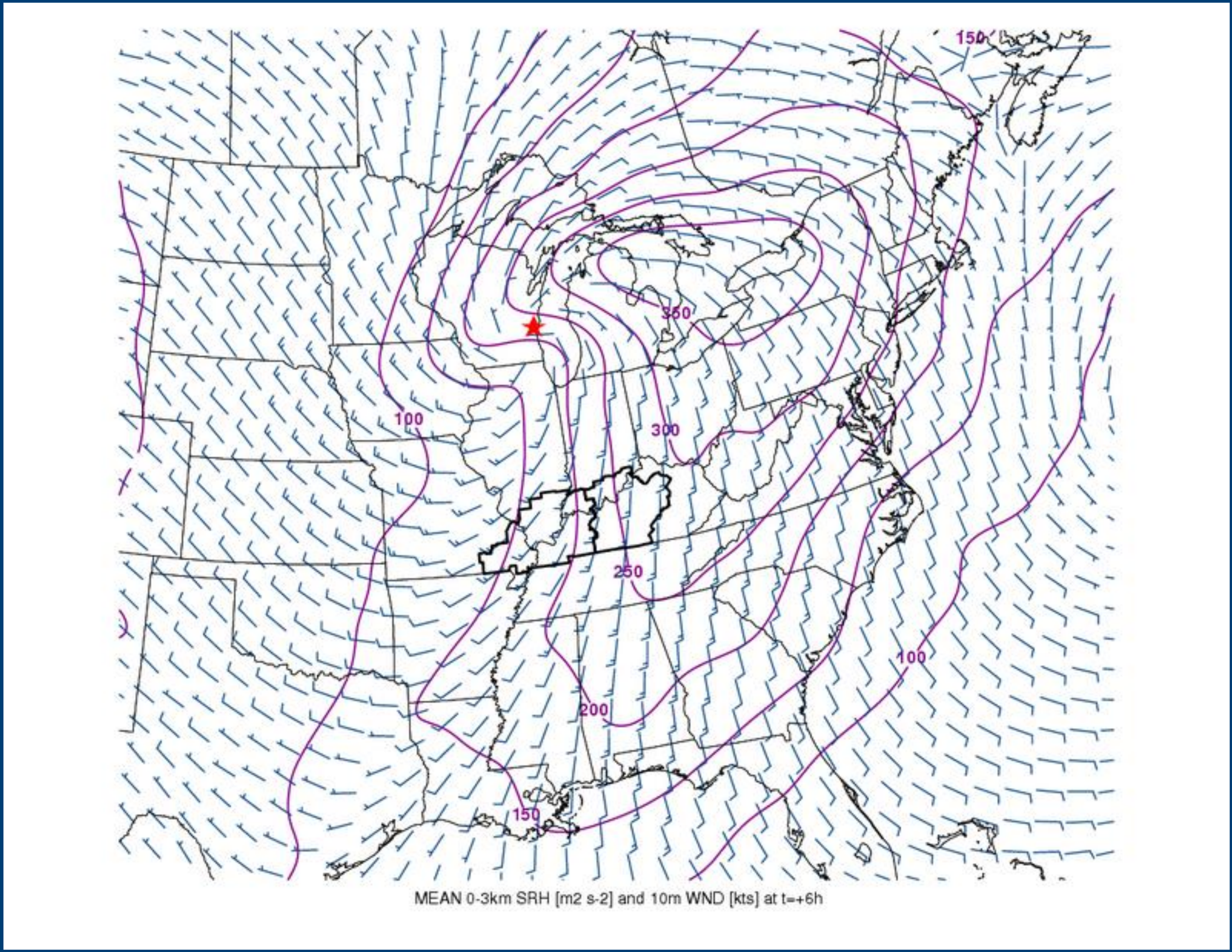
MEAN 0-3km SRH [m2 s-2] and 10m WND [kts] at t=-6h

Mean 0-3km SRH and 10m Winds at t=0h



MEAN 0-3km SRH [m2 s-2] and 10m WND [kts] at t=0h

Mean 0-3km SRH and 10m Winds at t=+6h



Percentile and Probability Composites

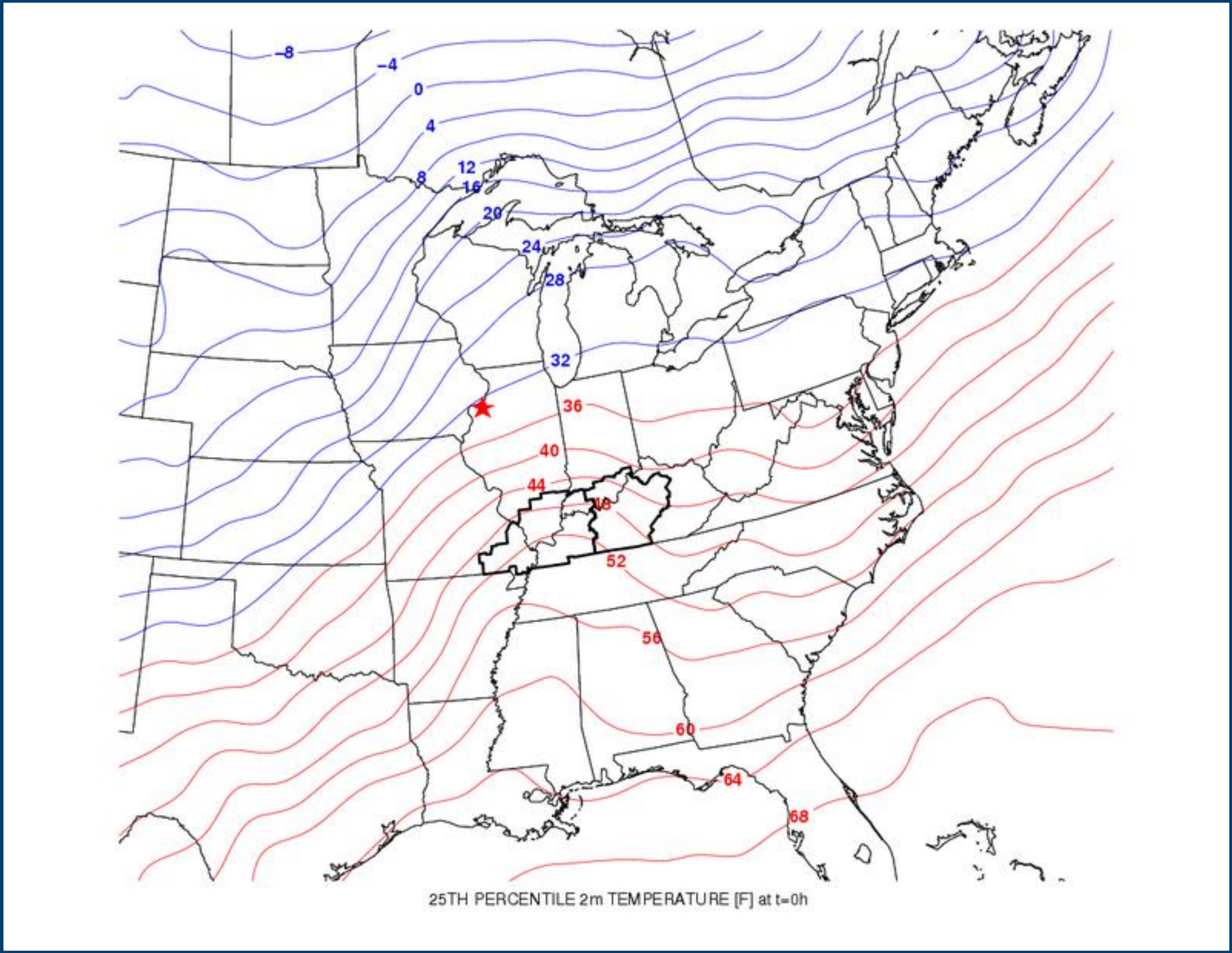
- Percentile composites were generated for both the low-end (25^{th} percentile) and high-end (75^{th} percentile) values.

- 25^{th} percentile composites show that 75% of cases have values exceeding those present, or 25% of cases have values less than those shown.

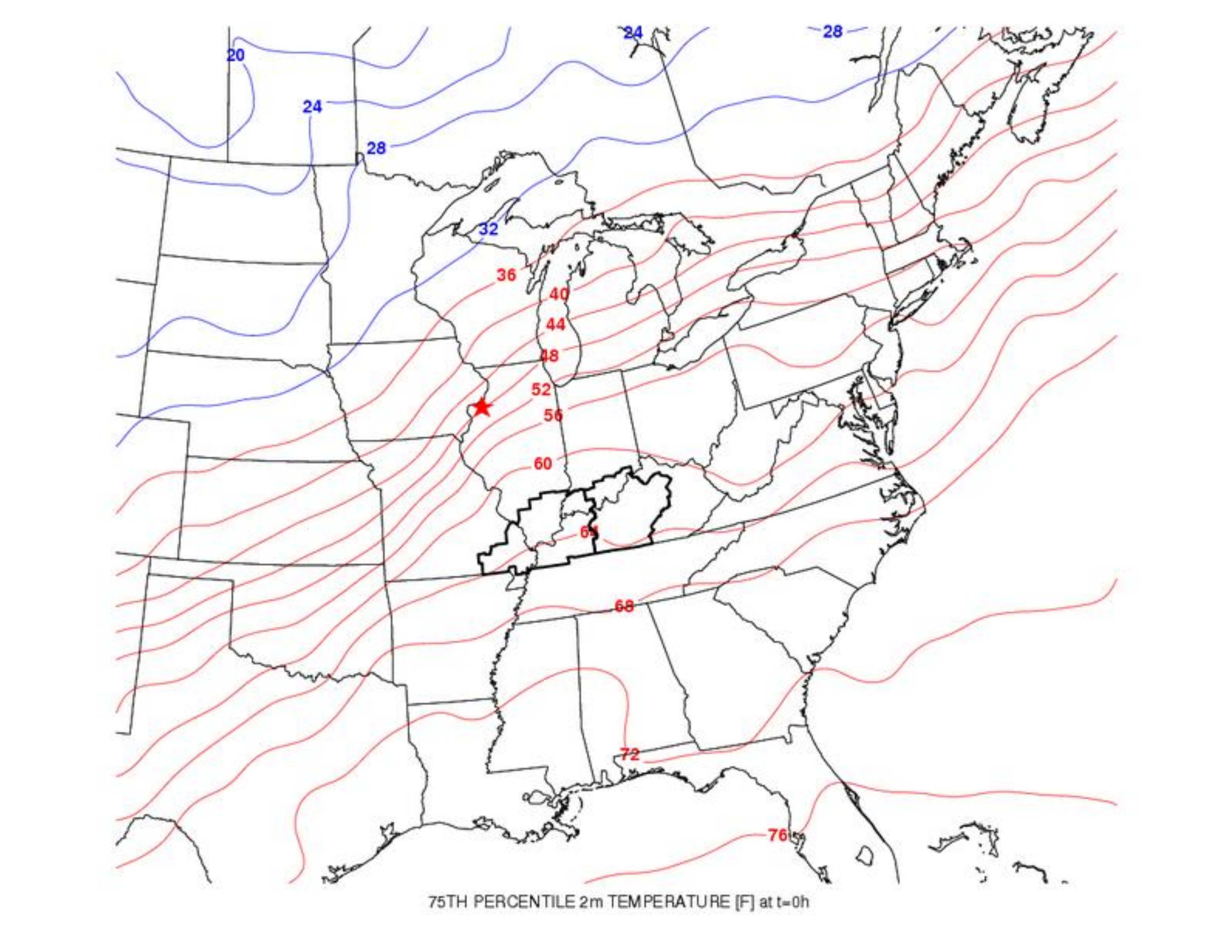
- 75^{th} percentile composites show that 25% of cases have values exceeding those present, or 75% of cases have values less than those shown.

- Probability composites show the percent of cases exceeding a certain threshold (e.g., the percentage of cases that had 0-1km speed shear >15 kts) for each time interval.

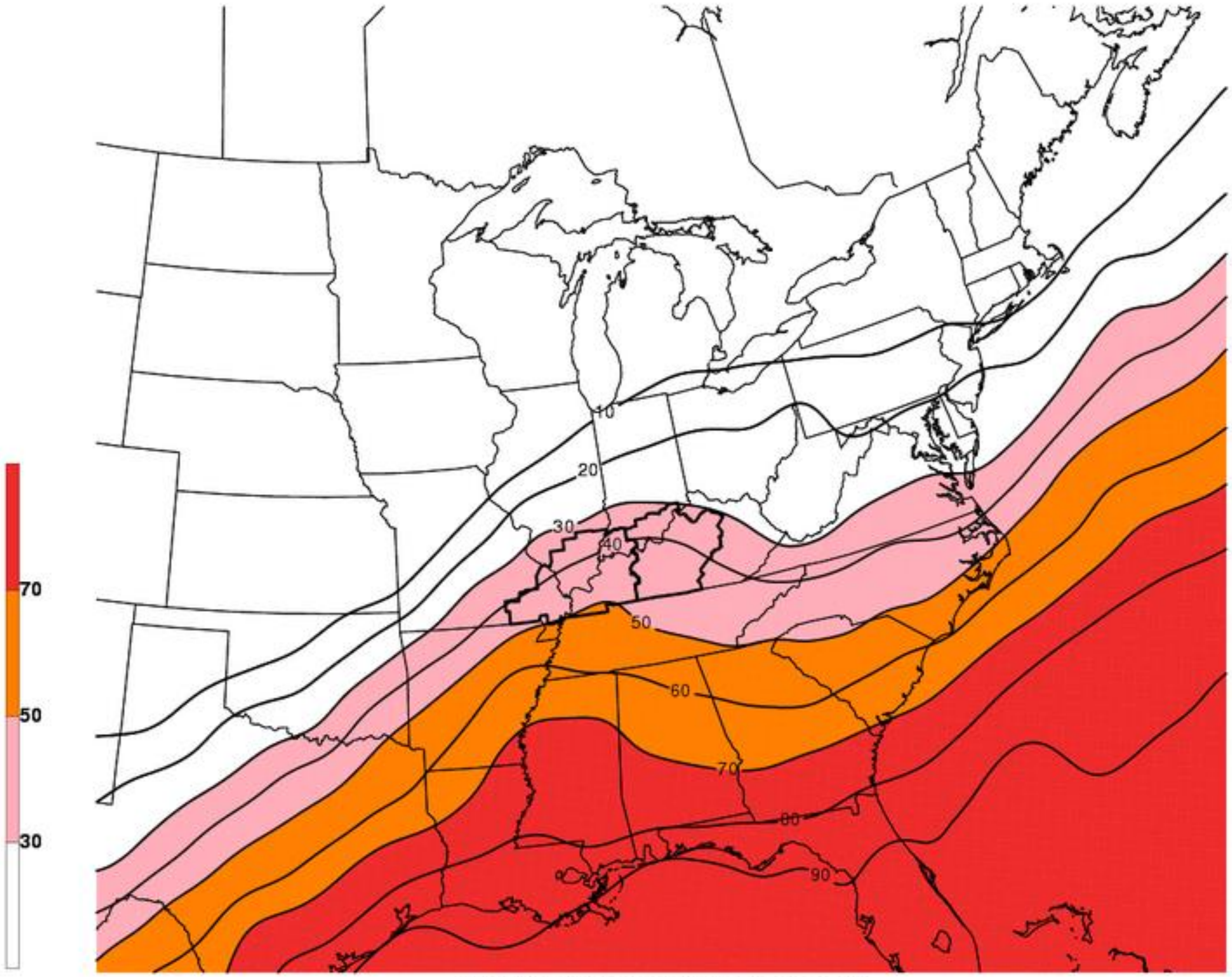
25th Percentile 2m Temperature at t=0h



75th Percentile 2m Temperature at t=0h

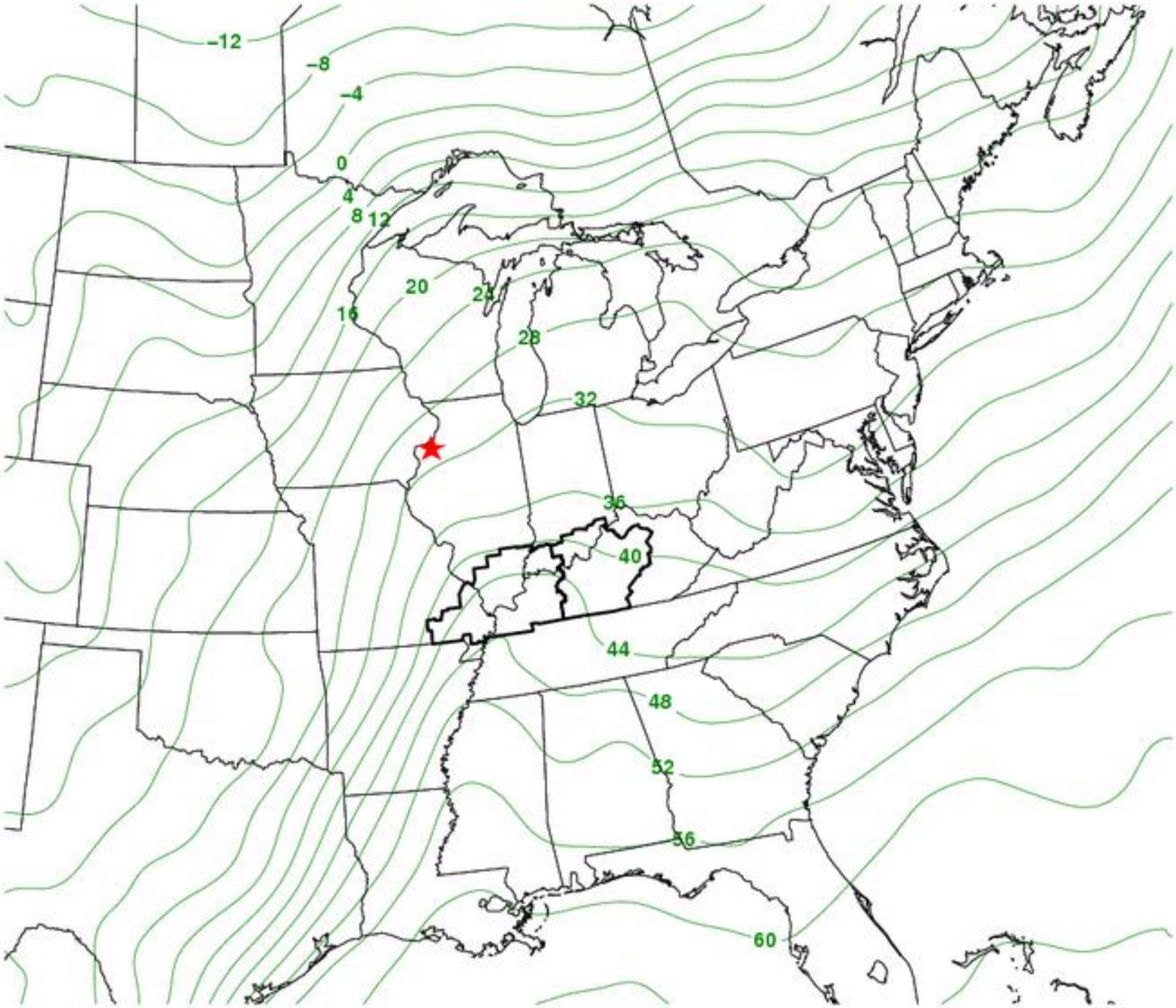


Probability of 2m Temperature > 60 F at t=0h



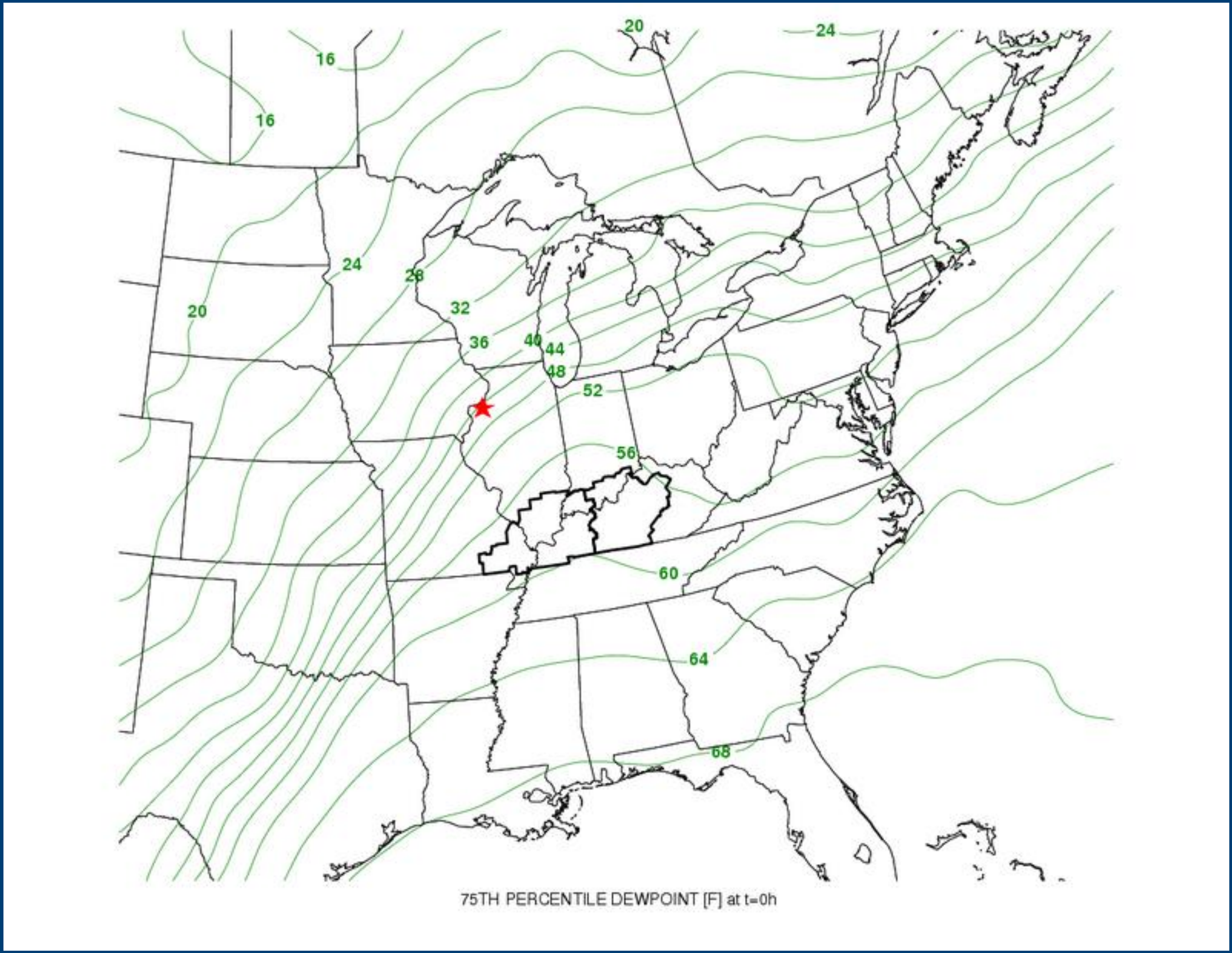
PROBABILITY 2m TEMPERATURE >60 F at t=0h

25th Percentile 2m Dewpoint at t=0h

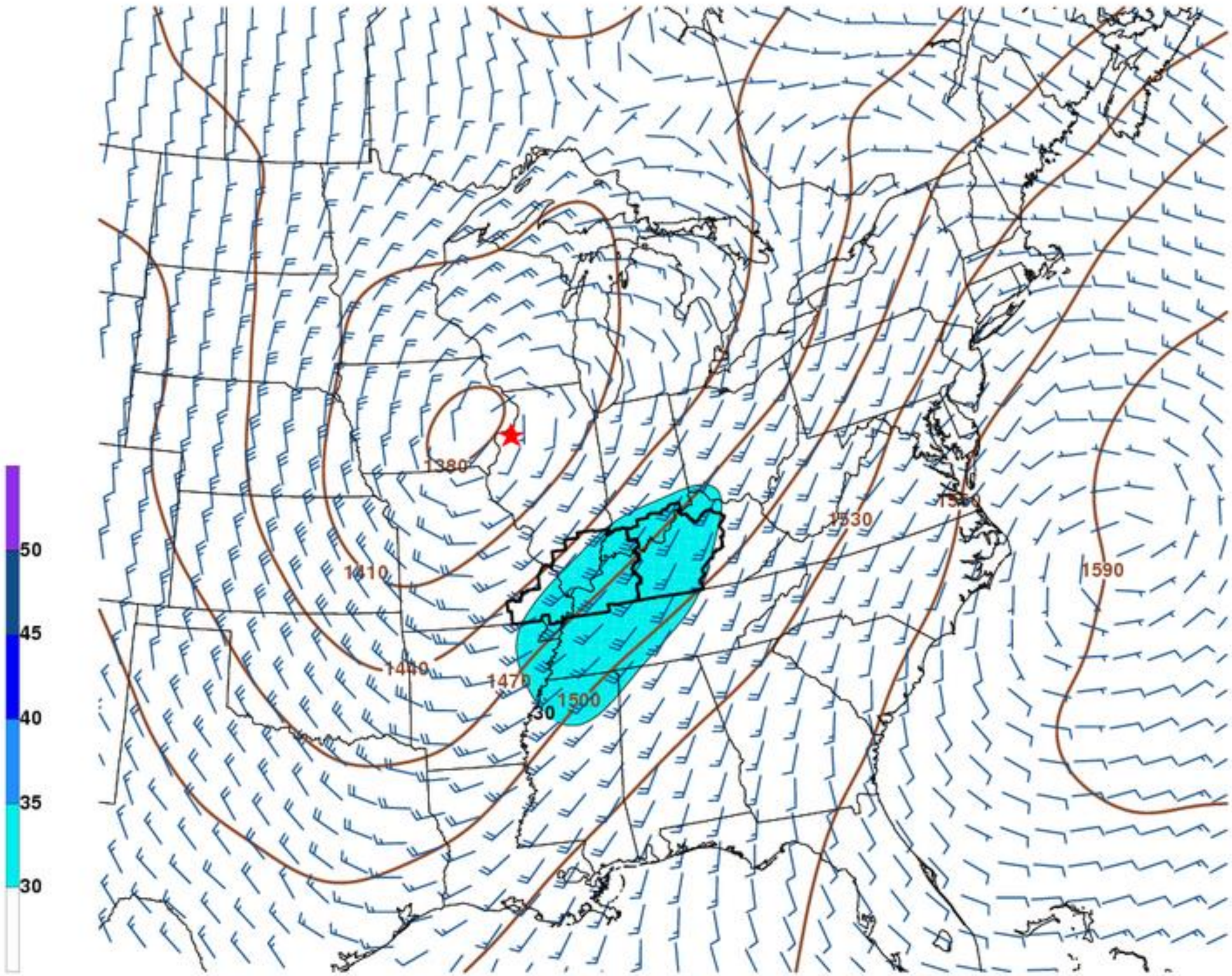


25TH PERCENTILE 2m DEWPOINT [F] at t=0h

75th Percentile 2m Dewpoint at t=0h

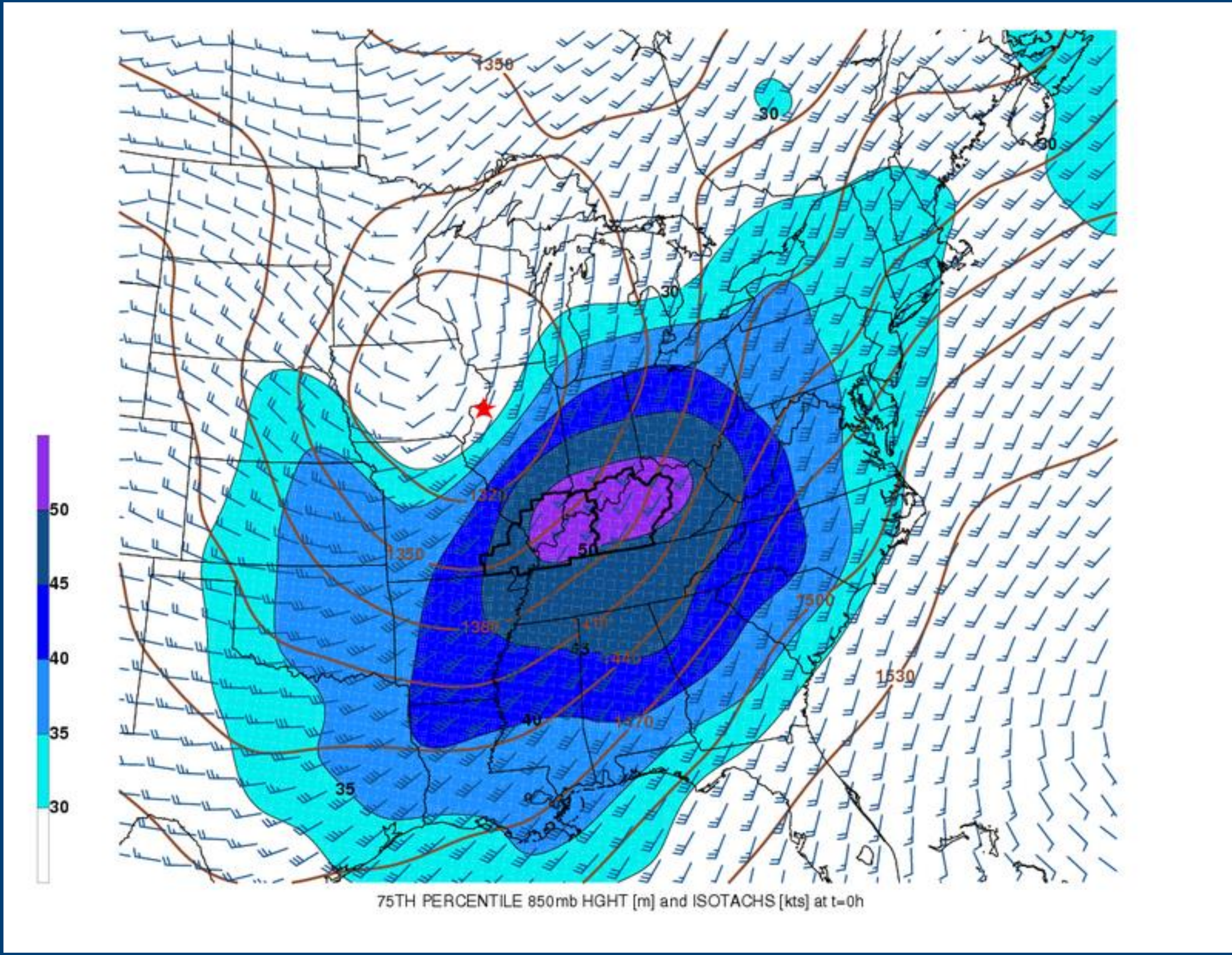


25th Percentile 850mb Heights and Isotachs at t=0h

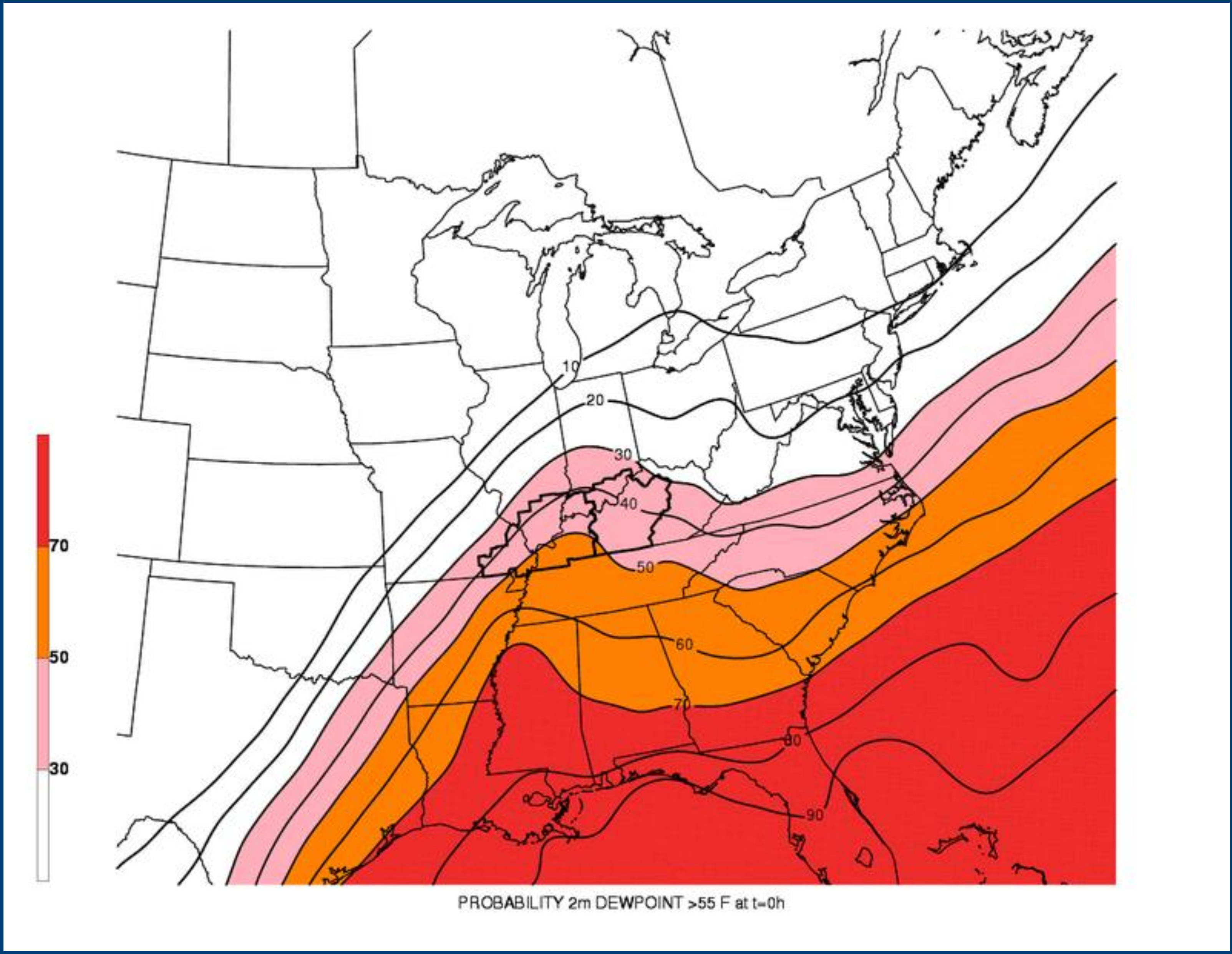


25TH PERCENTILE 850mb HGHT [m] and ISOTACHS [kts] at t=0h

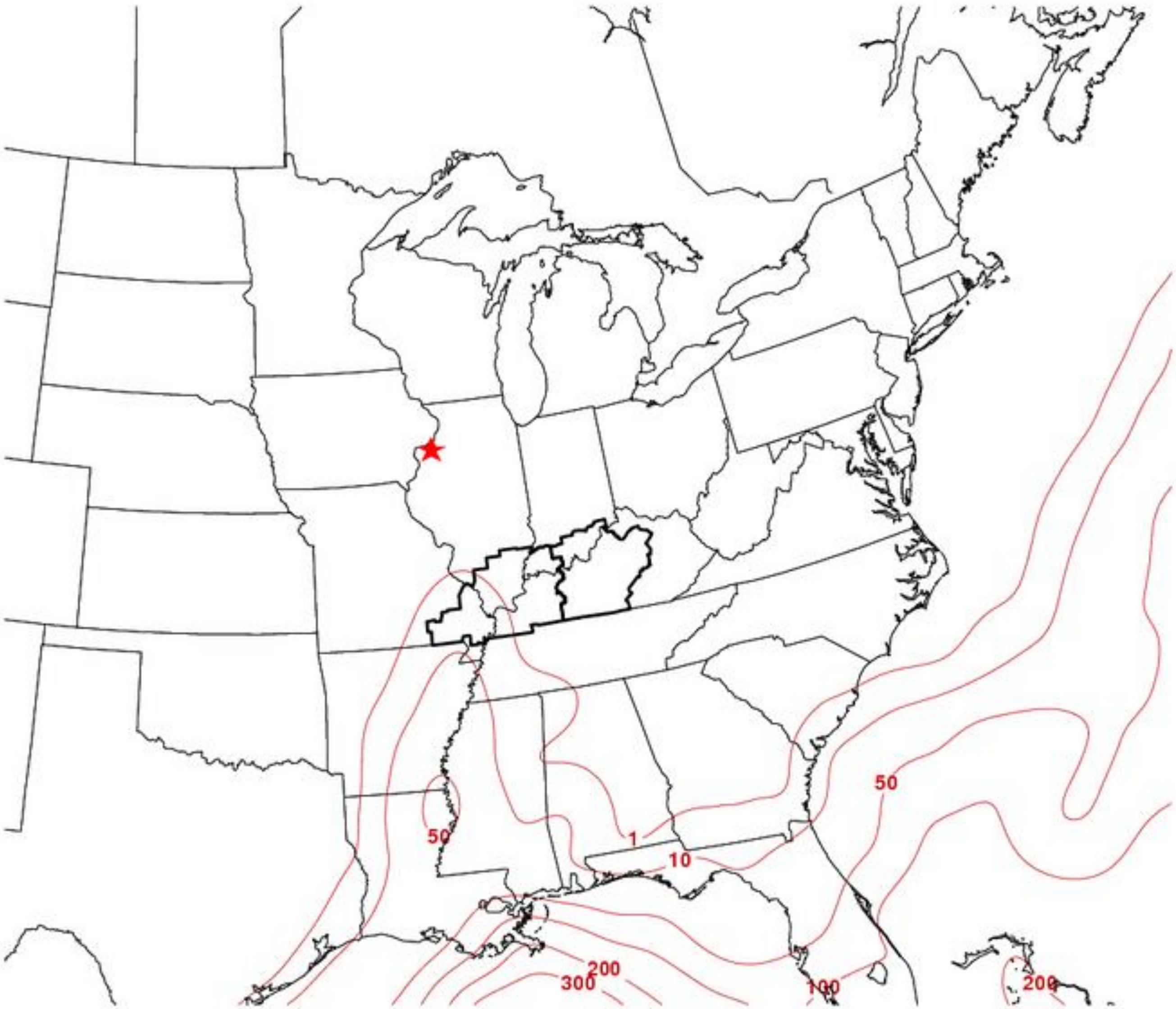
75th Percentile 850mb Heights and Isotachs at t=0h



Probability of 2m Dewpoint > 55 F at t=0h

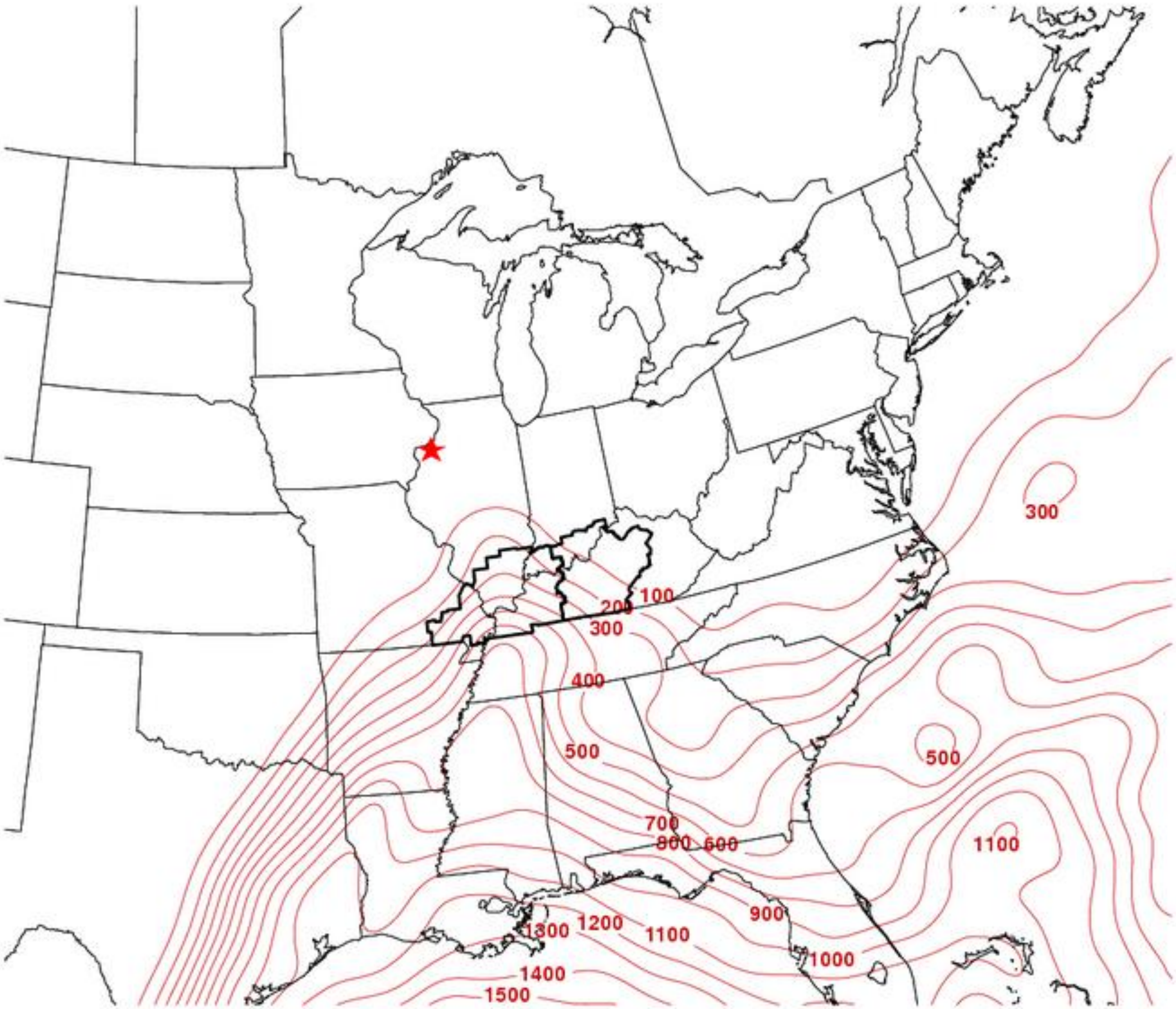


25th Percentile CAPE at t=0h



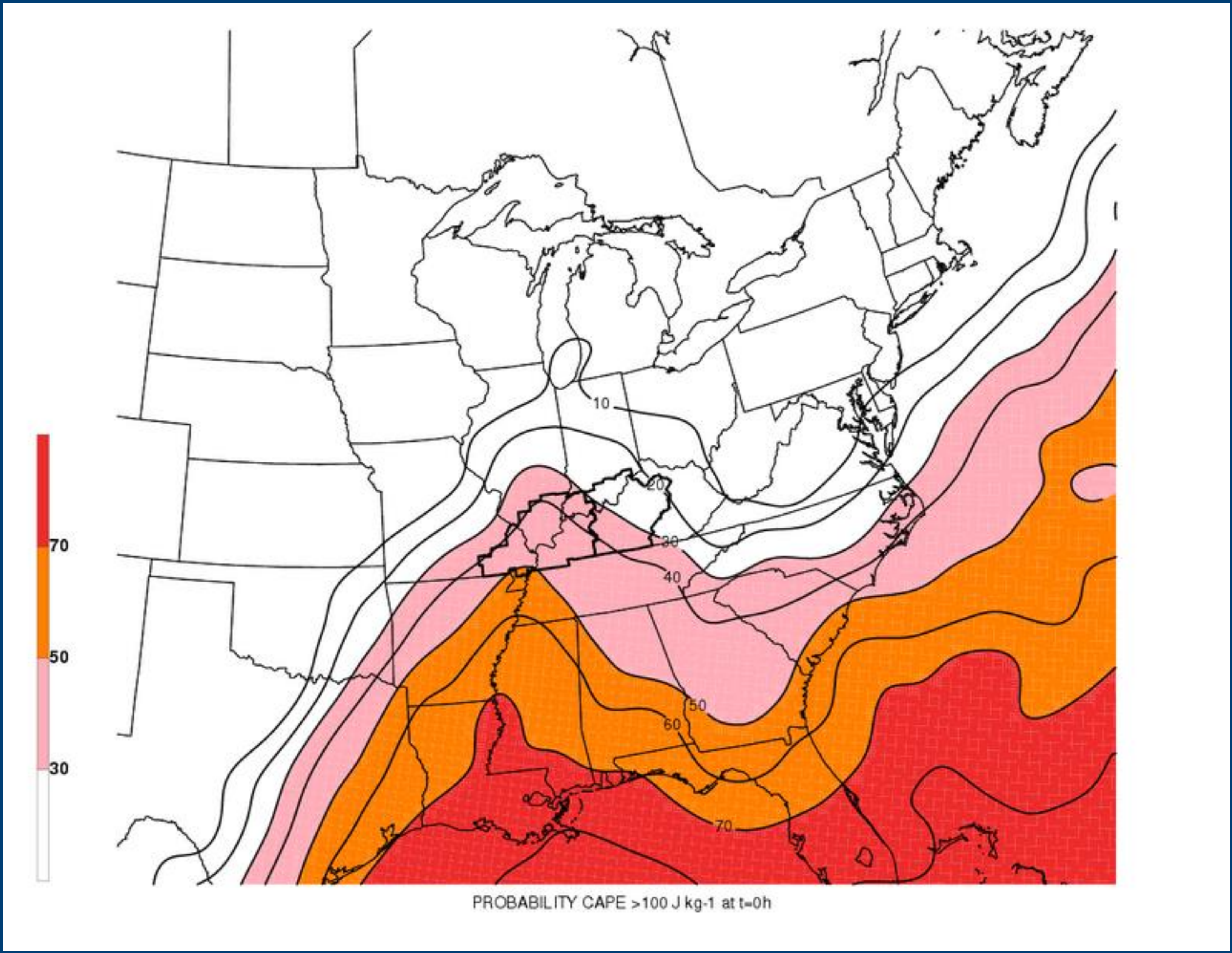
25TH PERCENTILE CAPE [J kg-1] at t=0h

75th Percentile CAPE at t=0h

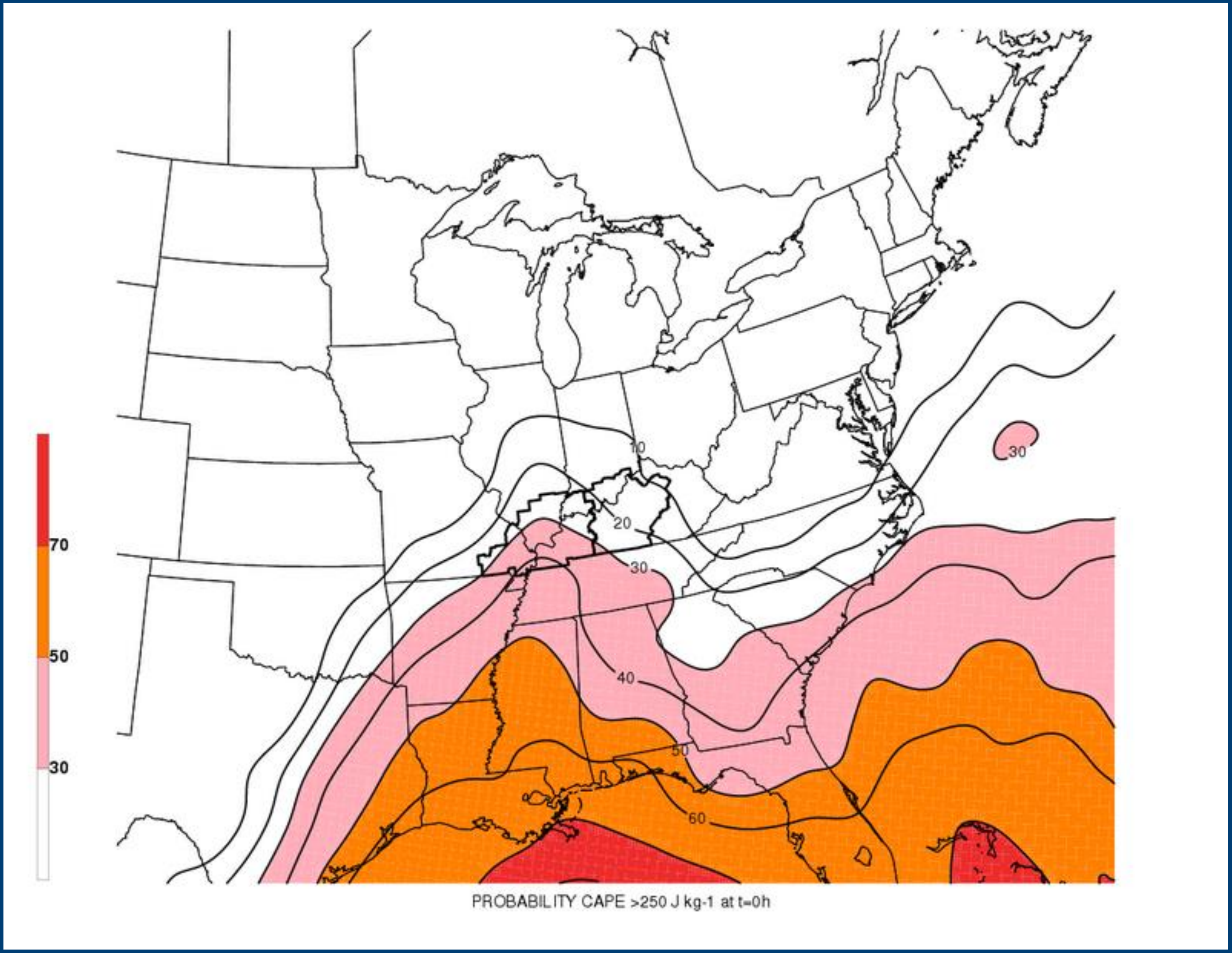


75TH PERCENTILE CAPE [J kg-1] at t=0h

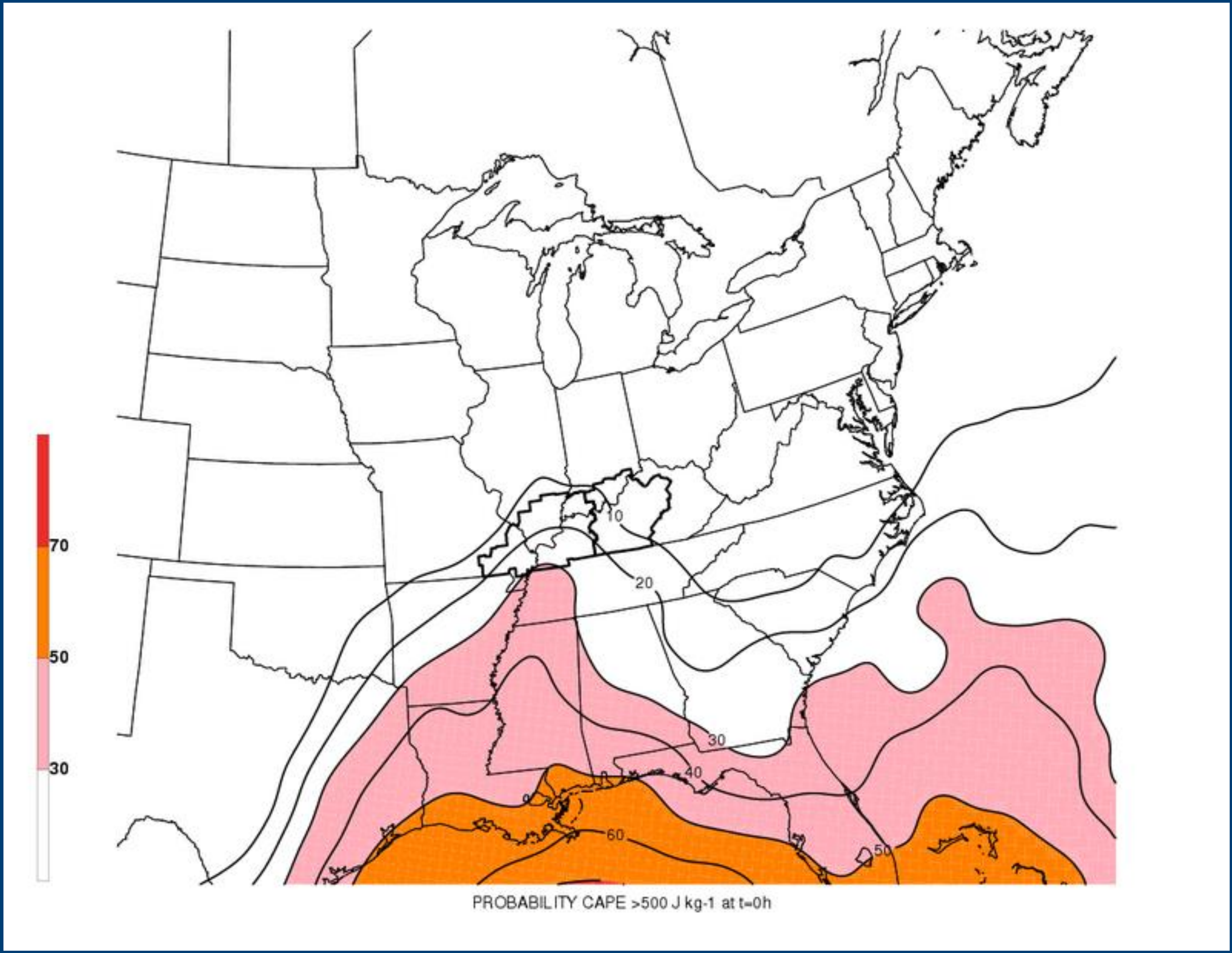
Probability of CAPE > 100 J kg^{-1} at t=0h



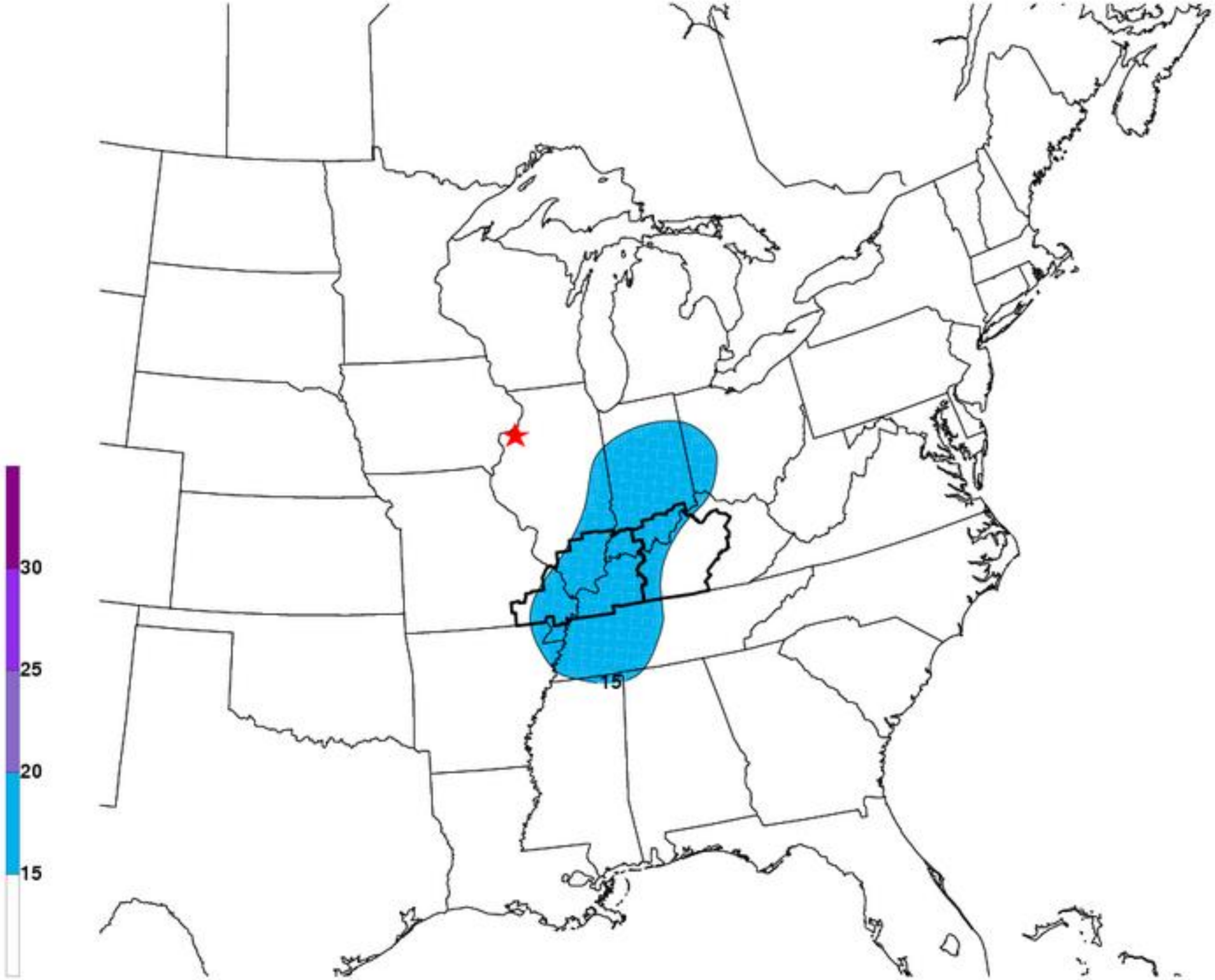
Probability of CAPE > 250 J kg^{-1} at t=0h



Probability of CAPE > 500 J kg^{-1} at t=0h

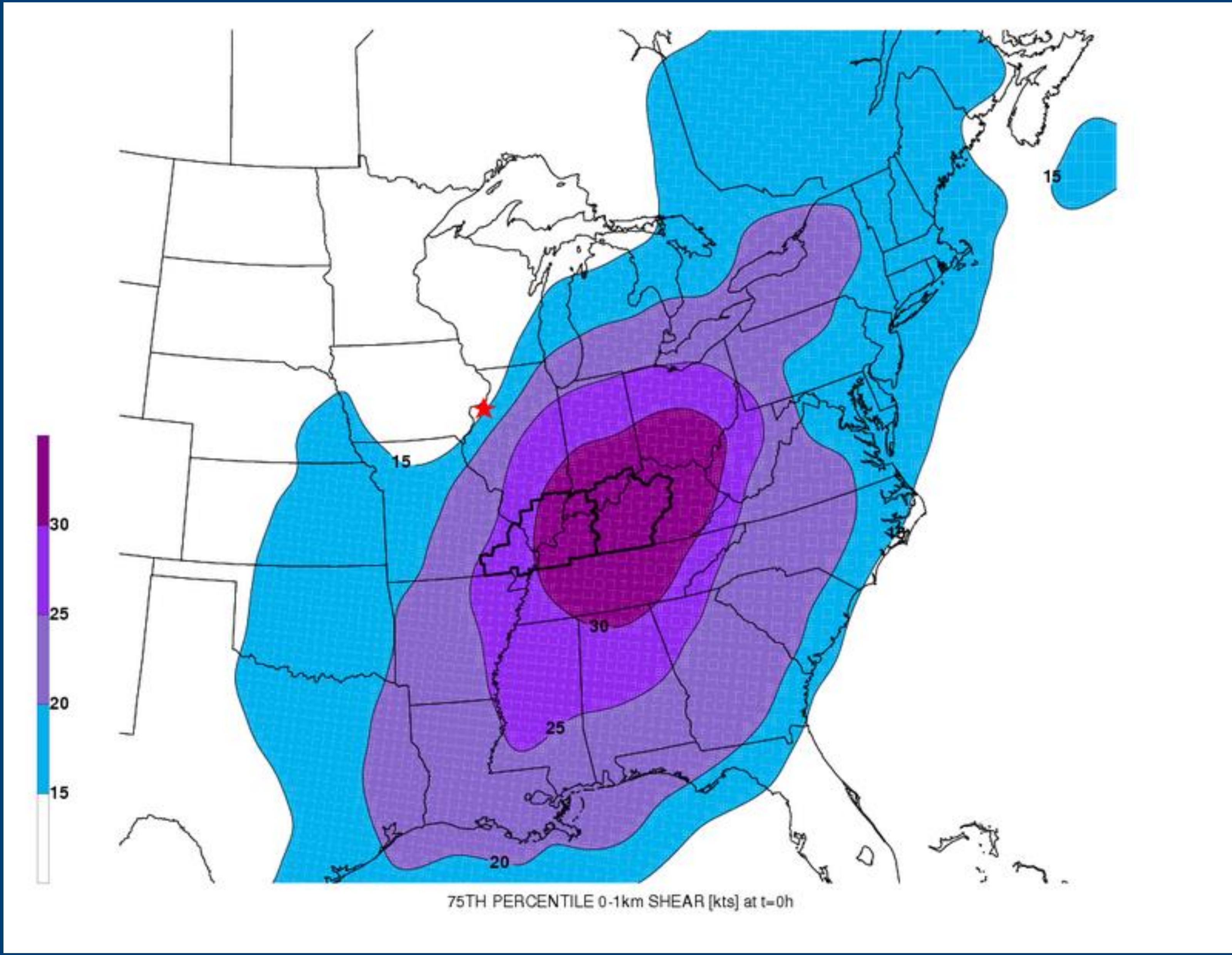


25th Percentile 0-1km Shear Magnitude at t=0h

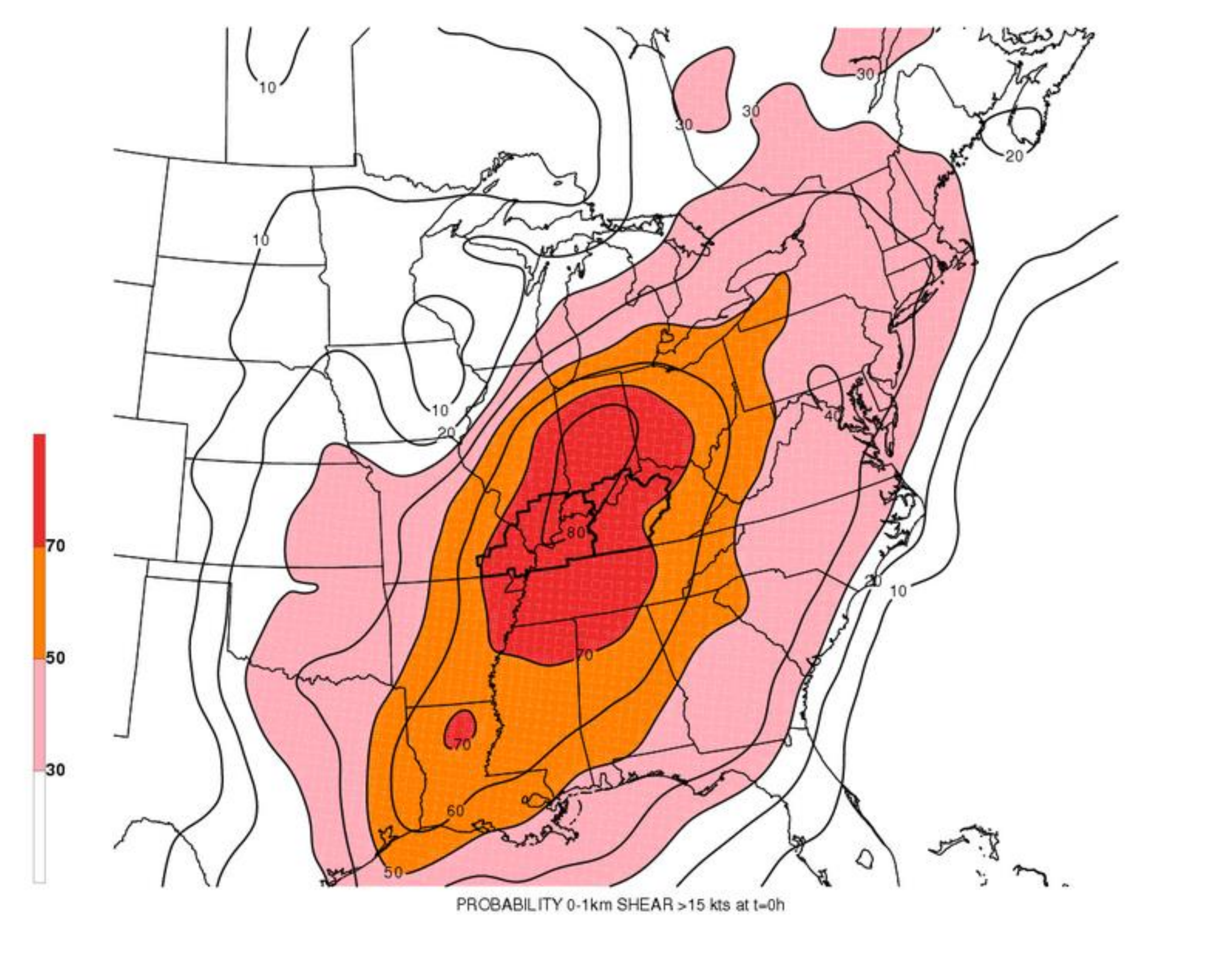


25TH PERCENTILE 0-1km SHEAR [kts] at t=0h

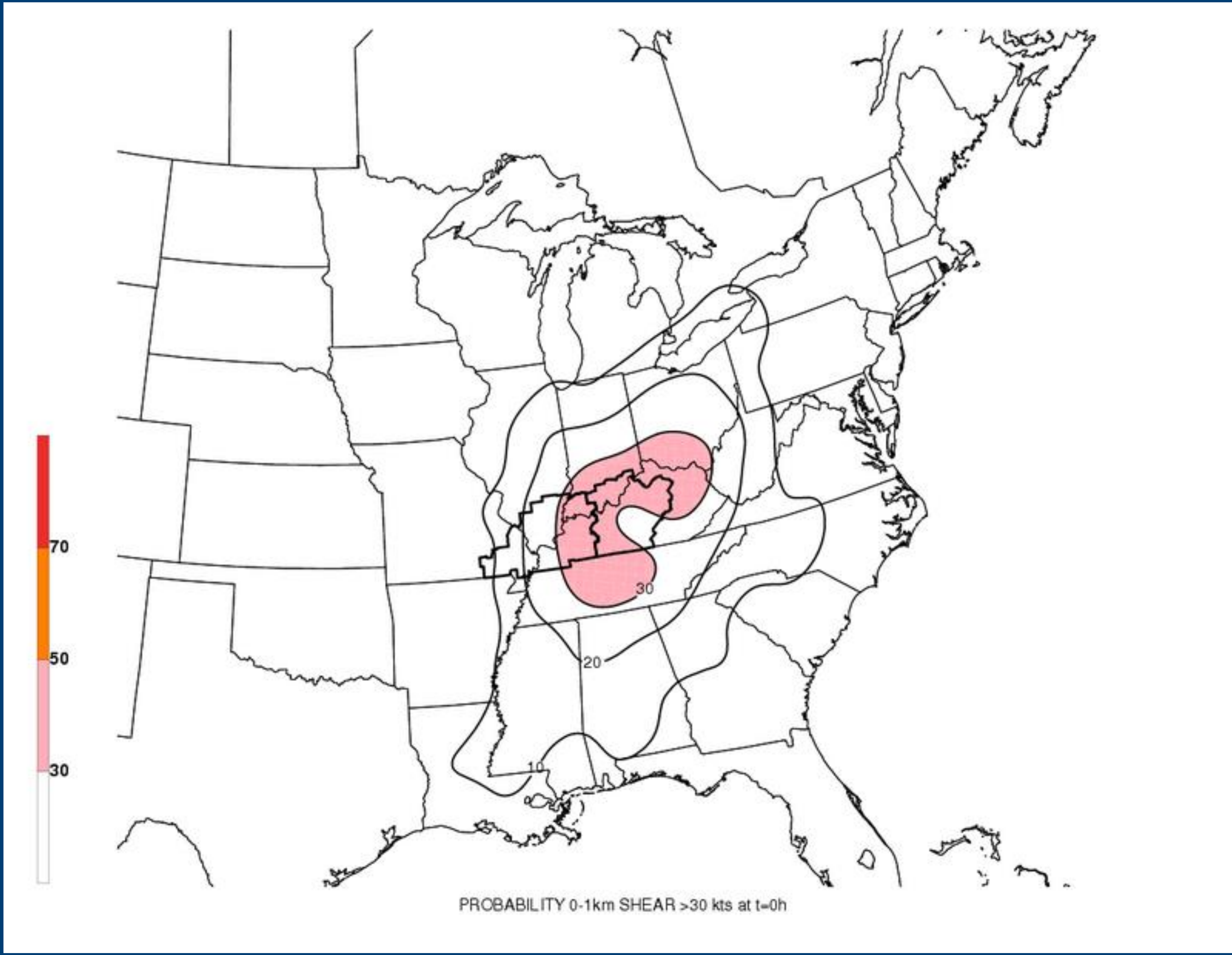
75th Percentile 0-1km Shear Magnitude at t=0h



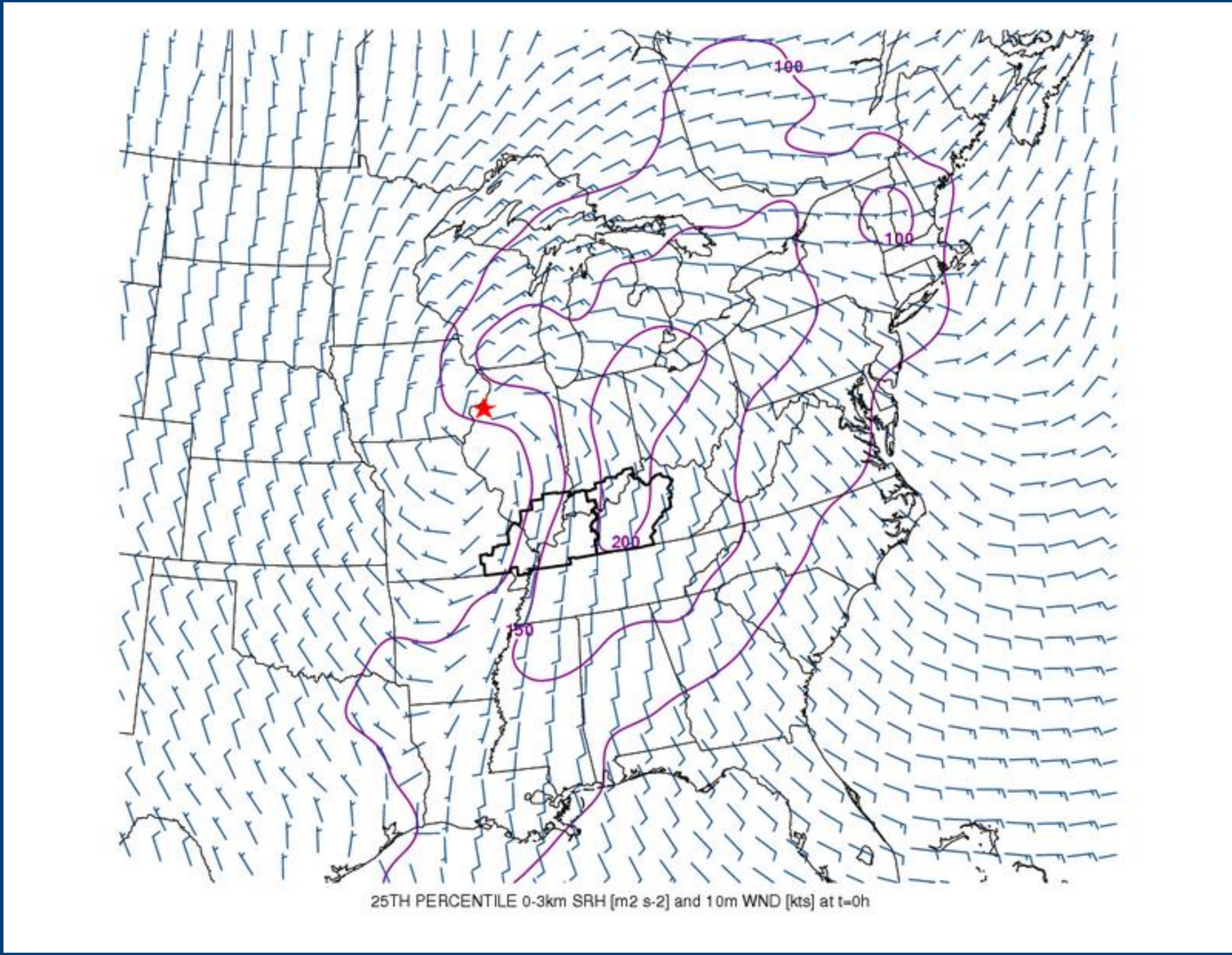
Probability of 0-1km Shear > 15 kts at t=0h



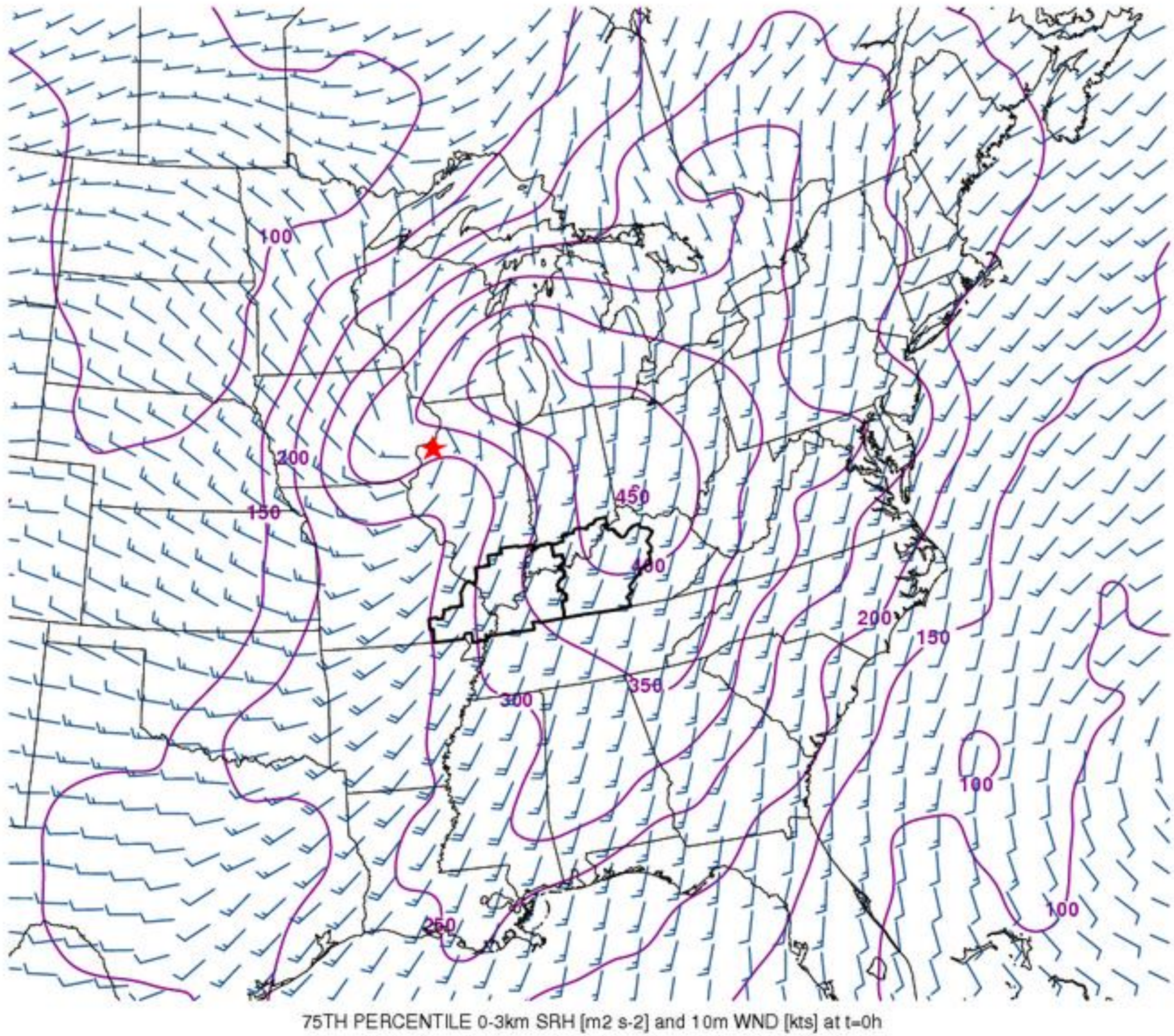
Probability of 0-1km Shear > 30 kts at t=0h



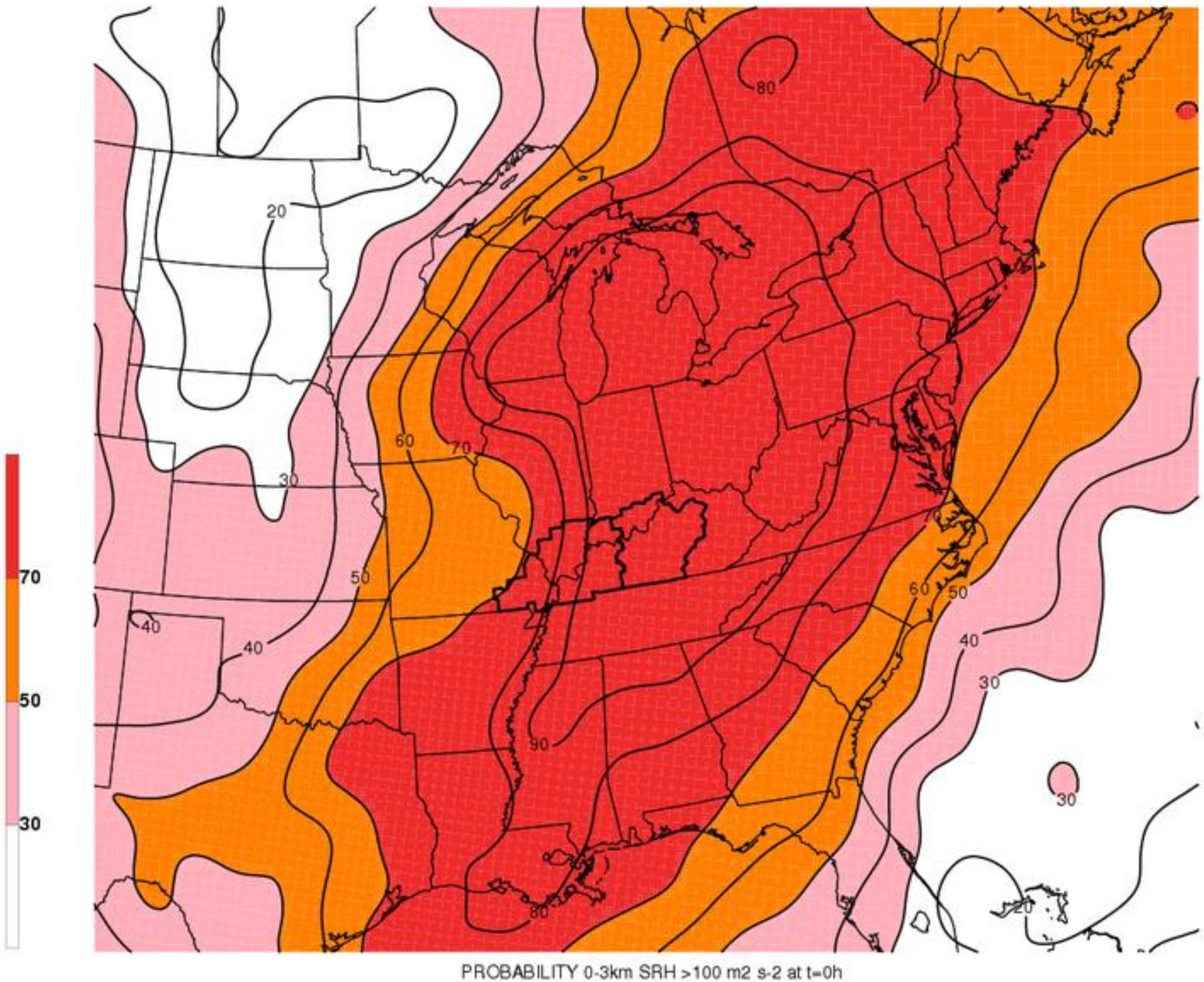
25th Percentile 0-3km SRH and 10m Winds at t=0h



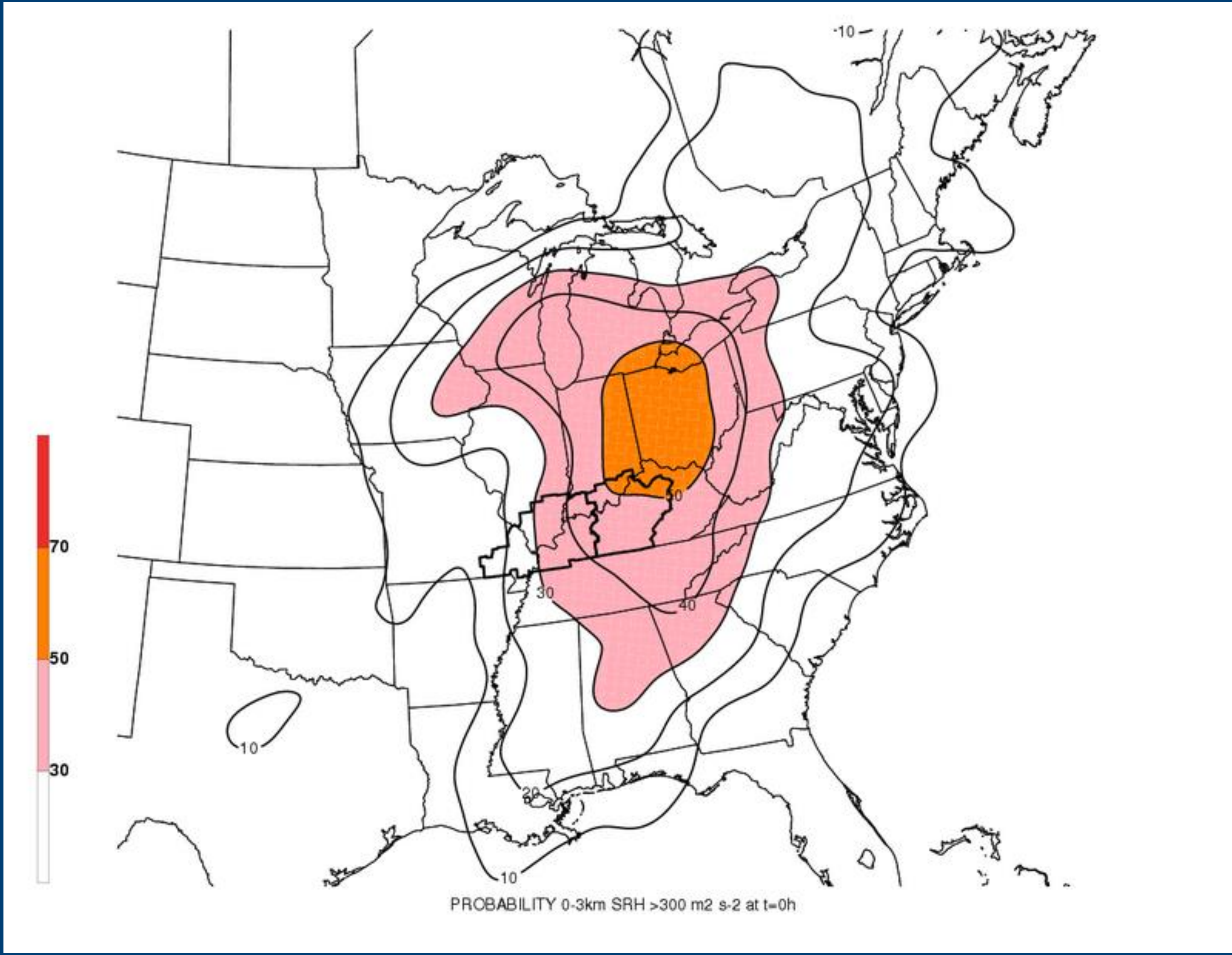
75th Percentile 0-3km SRH and 10m Winds at t=0h



Probability of 0-3km SRH > 100 $m^2 s^{-2}$ at t=0h



Probability of 0-3km SRH > 300 $m^2 s^{-2}$ at t=0h



Observations & Conclusions

- Composite analyses depict features and their evolution that are representative of a typical event.

- A classic developing mid-latitude cyclone moves through the Mid or Upper Mississippi River Valley accompanied by mid-level and upper-level support.

- Abundant mid-level and low-level shear
  - 50 to 60 kts mid-level jet streak (500mb)
  - 0-6 km speed shear ~50 kts
  - 850 mb low-level jet ~40 kts
  - 0-3 km SRH greater than 250 $m^2 s^{-2}$
  - 0-1 km speed shear ~30 kts
  - Surface winds suggest strong 0-1 km SRH (SSE at t=-6h to S at t=0h; currently unavailable)

- Marginal CAPE (instability) nosing into the area of interest (< 300 J kg^{-1}). However, cool season severe events need only marginal instability to occur, given strong wind fields and low-level shear.

- Anomalous moisture present at the surface (dewpoints about 50F) and through the troposphere (precipitable water values in excess of 200% of normal).