Performance of the NSSL Experimental Warn-on-Forecast System in Varying Mesoscale Environments

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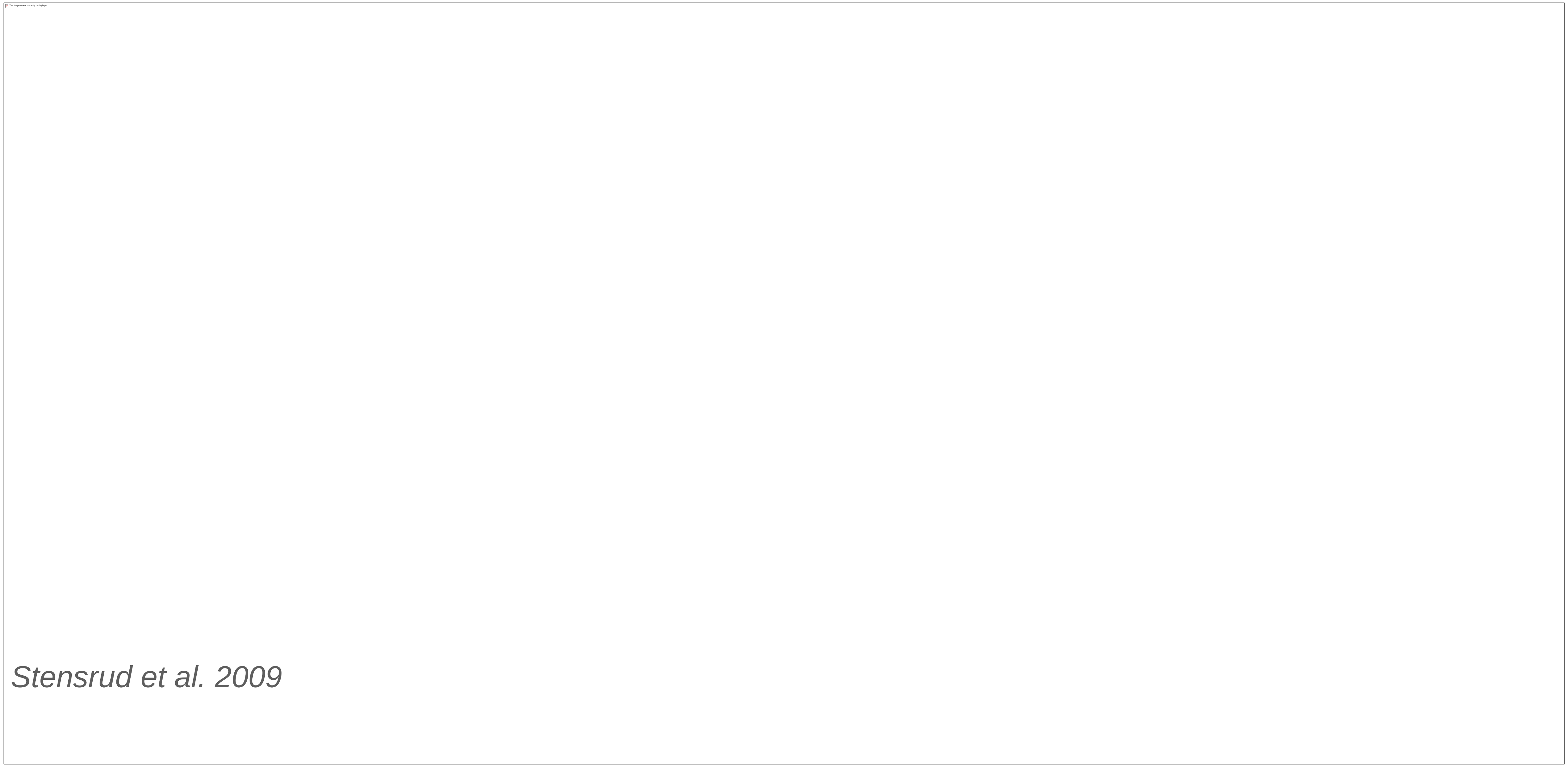
International Symposium on Data Assimilation 2016

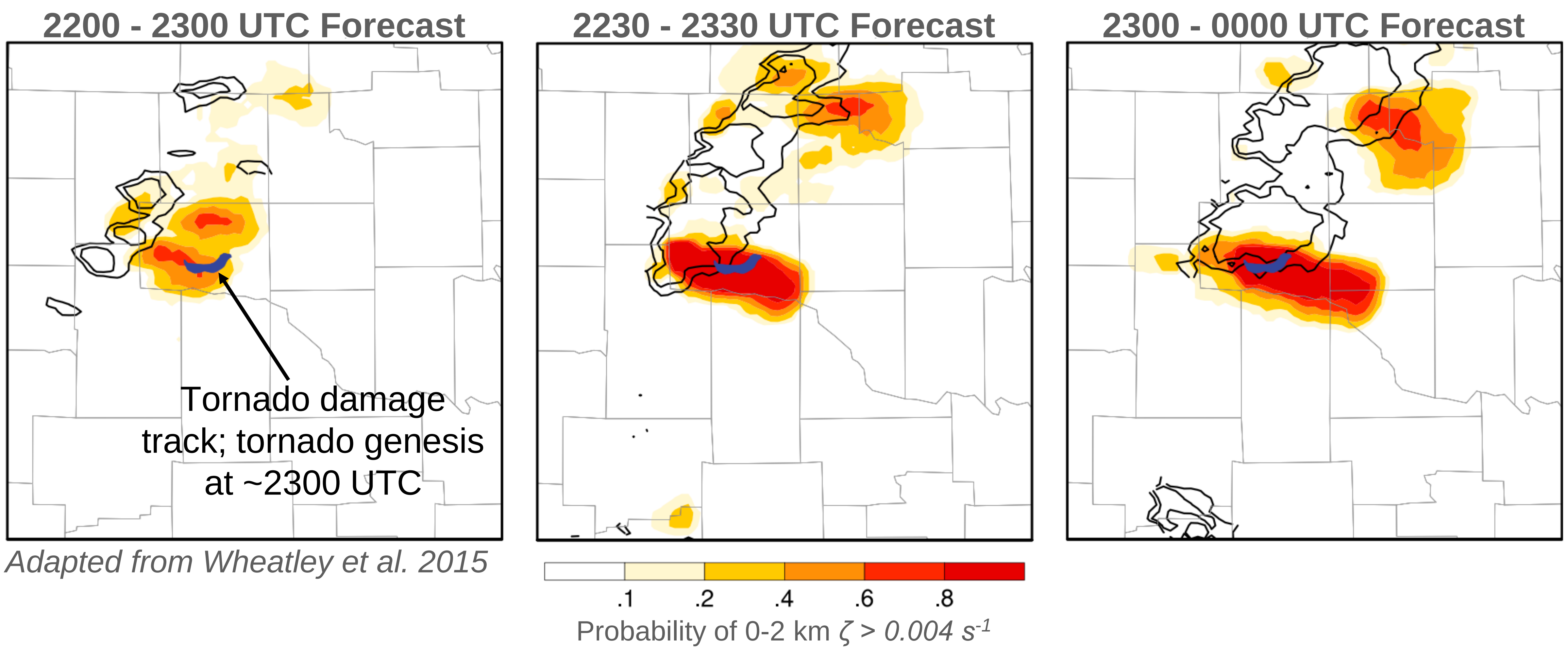
Vision for Warn-on-Forecast:



Stensrud et al. 2009

NOAA's Warn-on-Forecast project aims to use ensembles of convection-allowing models to produce probabilistic forecasts of short-term, O(1hr), thunderstorm hazards

Motivation:

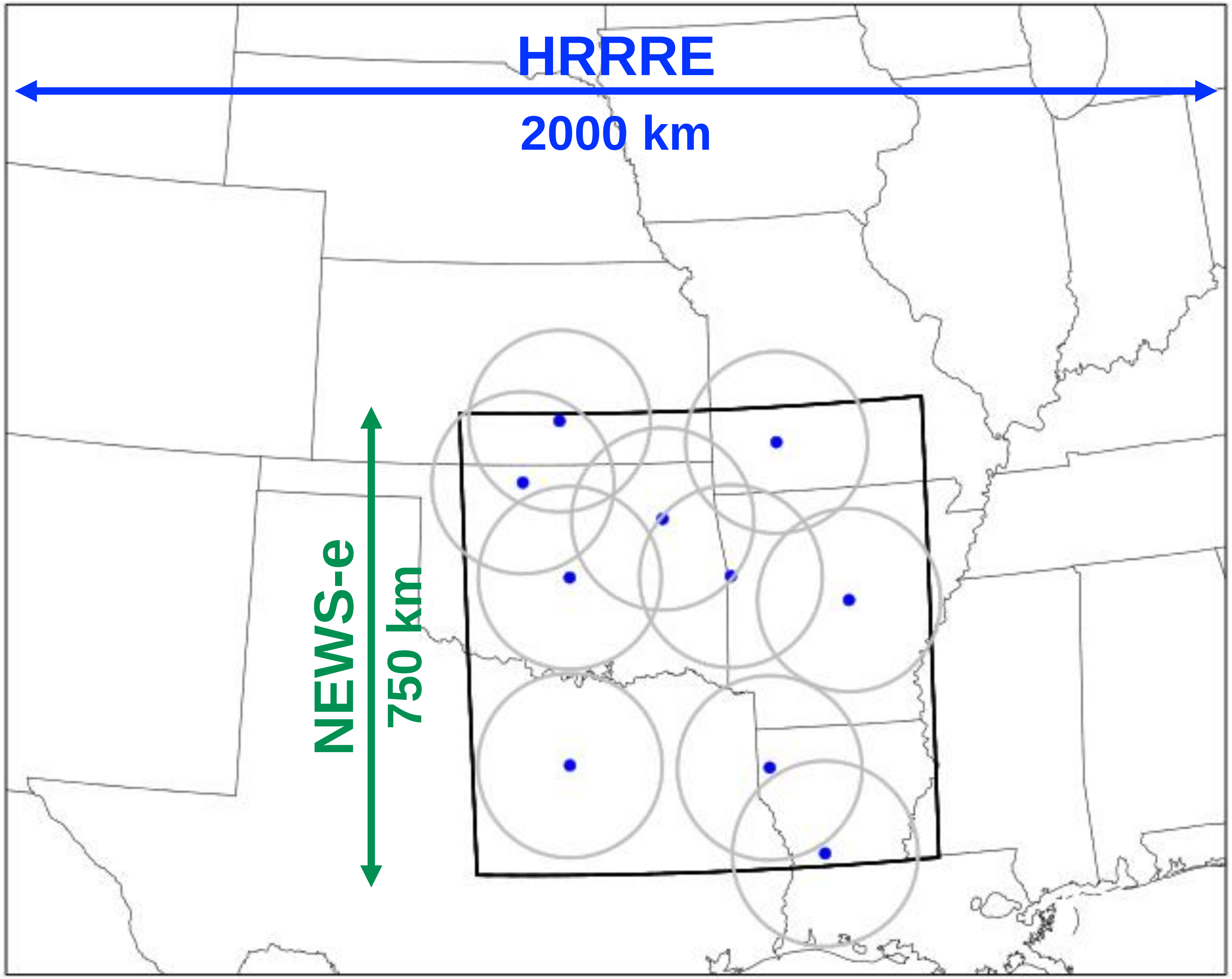


Adapted from Wheatley et al. 2015

- EnKF-based assimilation of Doppler radar, and recently satellite data, have reliably produced accurate analyses and short-term rotation forecasts for high-impact events from the springs of 2013 - 2016 (e.g. Wheatley et al. 2015; Yussouf et al. 2015; Jones et al. 2016)
- These forecasts have typically been performed for discrete supercells in strongly favorable environments for tornado development

- ***Less is known about forecast accuracy for tornadoes with greater storm coverage and marginally favorable environments***

Spring 2016: Demonstration of Prototype Warn-on-Forecast System for VORTEX-Southeast Field Project



Radar locations within NEWS-e grid shown as blue dots with 150-km range rings

- High-Resolution Rapid Refresh Ensemble (HRRRE) run at NOAA/ESRL
- Hourly-updated storm-scale ensemble for a fixed domain

- NSSL Experimental Warn-on-Forecast System for ensembles (NEWS-e)
- 15-min updated storm-scale ensemble with radar and satellite assimilation run for an event-dependent domain

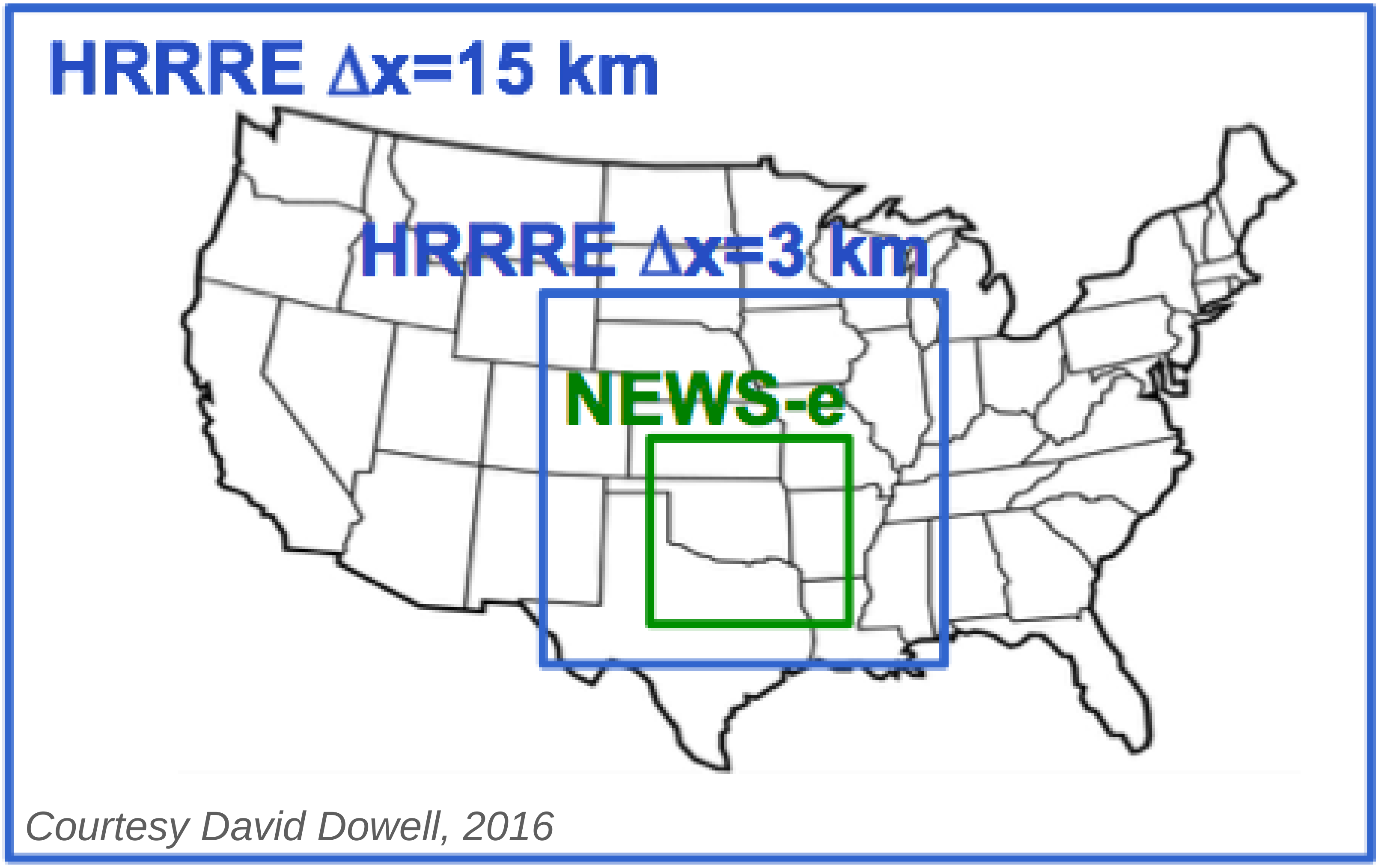
- *Forecasts for VORTEX-SE designed to test system performance for marginal tornado environments*

System Configuration:

	HRRRE	NEWS-e
Model Version	WRF-ARW v3.6+	WRF-ARW v3.6+
Grid Points	415 × 325 × 50 / 650 × 550 × 50	250 × 250 × 50
Grid Spacing	15 km / 3 km	3 km (1 km in research)
EnKF Cycling	20-40 mem w/ **GSI-EnKF every 1 h**	36 mem w/ **DART every 15 min**
Observations	**conventional obs only:** T, q_v, u, v, and p from rawinsonde, aircraft, surface (land and marine), profiler	**Doppler velocity from ~20 WSR-88D sites; MRMS radar reflectivity; cloud-water path**
Radiation LW/SW	RRTMG/RRTMG	**Dudhia/RRTM or RRTMG/ RRTMG**
Microphysics	Thompson (aerosol aware)	Thompson
Cumulus Param.	GF + shallow / none	none
PBL	MYNN	**YSU, MYJ, or MYNN**
LSM	RUC (Smirnova)	RUC (Smirnova)

Courtesy David Dowell, 2016

System Workflow:

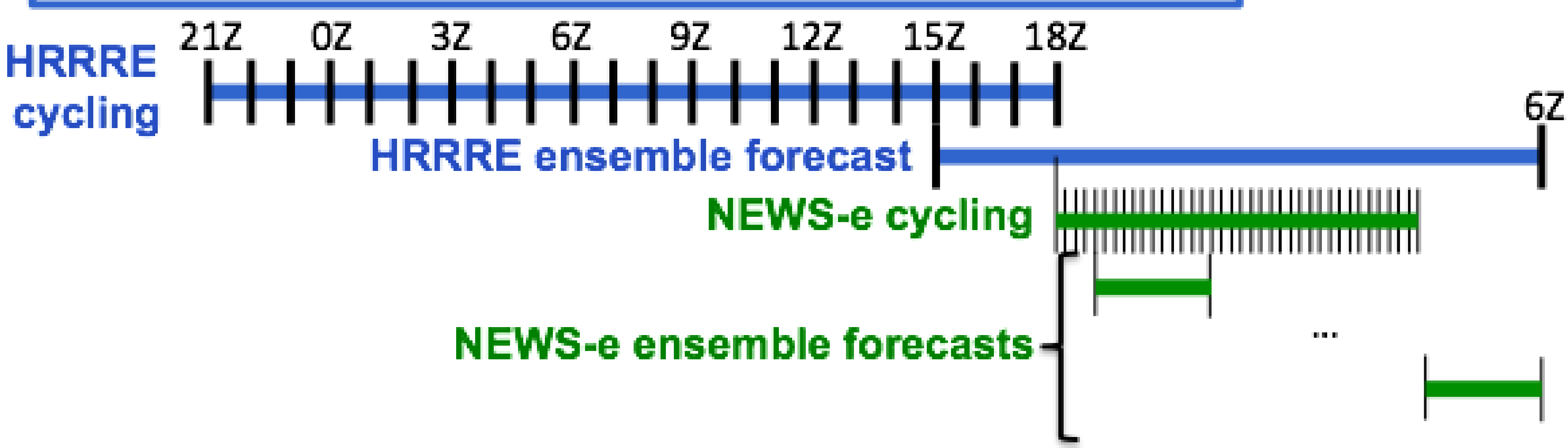


Courtesy David Dowell, 2016

NEWS-e Forecasts:

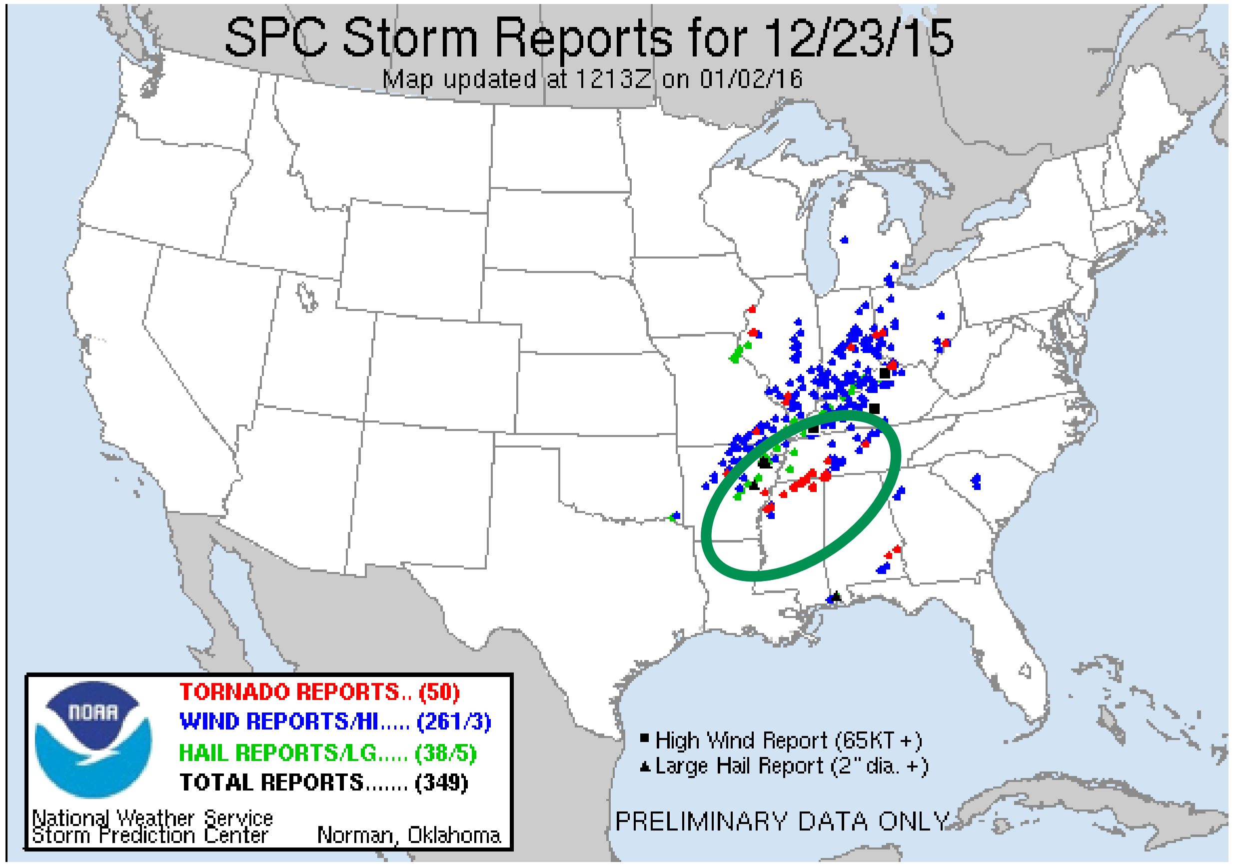
Time (UTC)	Length
1900	180
1930	90
2000	180
2030	90
2100	180
2130	90
2200	180
2230	90
2300	180
…	…

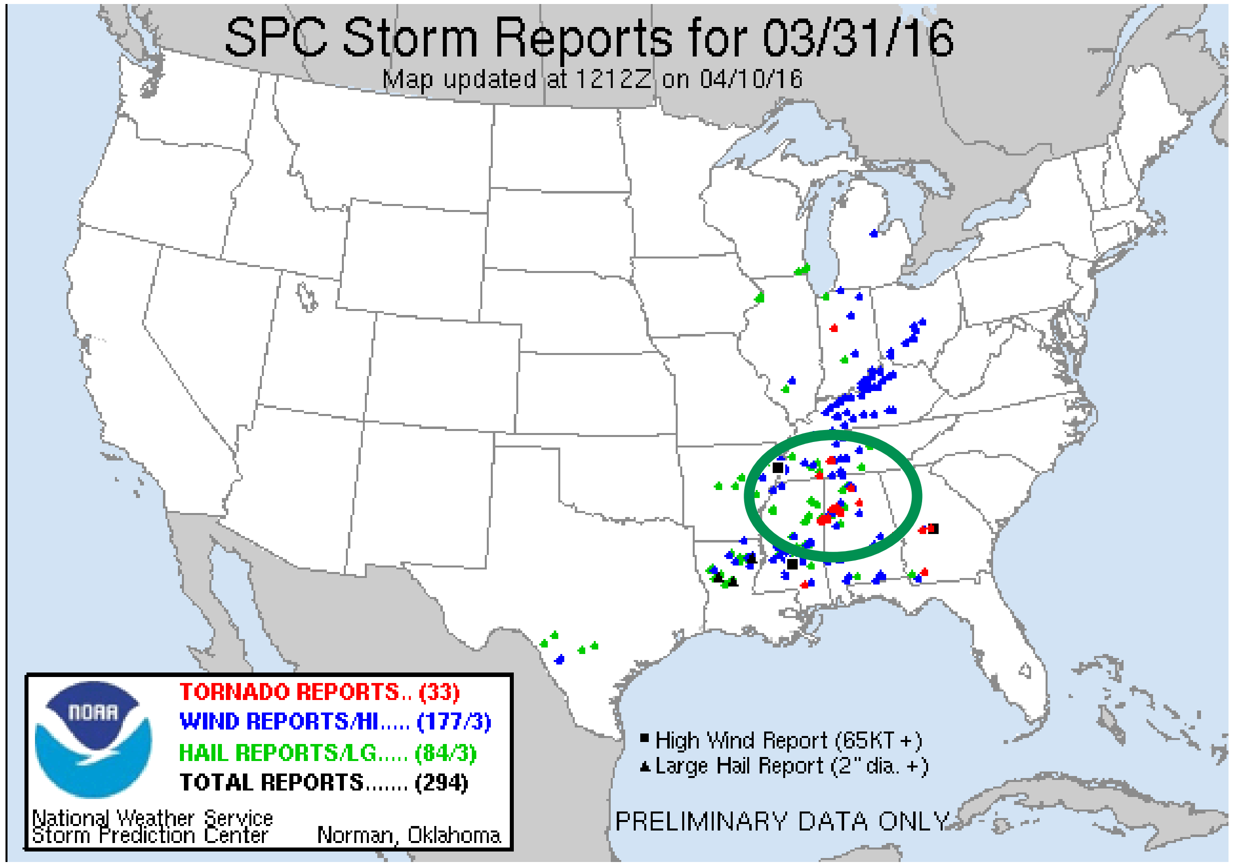
Forecast output available ~30 min following initialization



NEWS-e Experiments for VORTEX-SE:

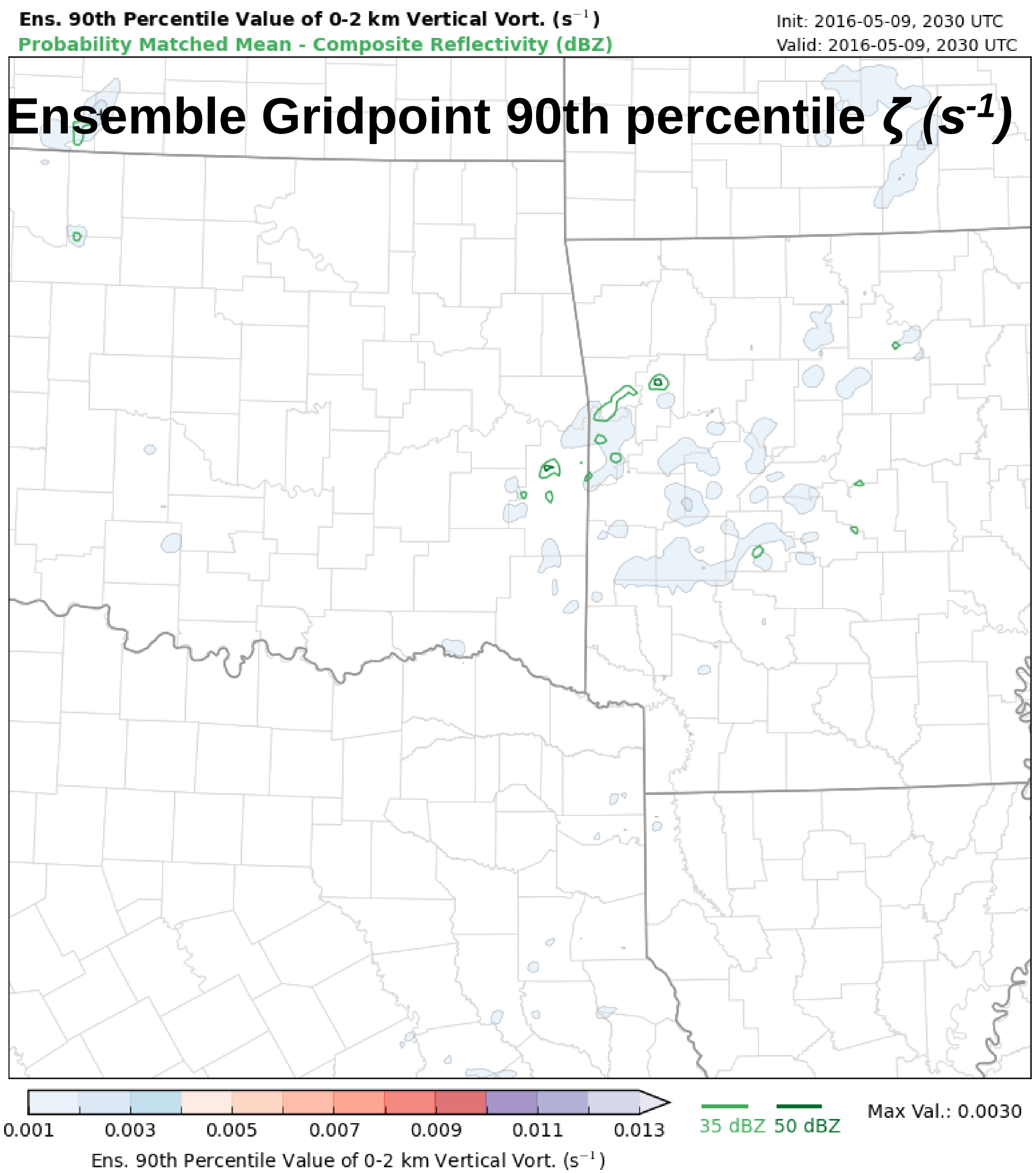
- 23 December 2015:
  - Tornado outbreak across northern Mississippi and southern Tennessee
  - Well-defined risk area ahead of stationary front, with moderate CAPE (>1500 J kg^{-1}) and strong 0 - 1 km shear (>15 m s^{-1})
- 31 March 2016 (V-SE IOP):
  - Tornadoes in northwestern Alabama and southern Tennessee
  - Localized region of moderate CAPE and strong wind shear, but greater storm coverage
- 29 April 2016 (V-SE IOP):
  - QLCS with mesovortices in northern Alabama but no tornado reports
- 10 May 2016:
  - Tornado outbreak in western Kentucky





Example of a ‘Good’ Low-Level Rotation Forecast:

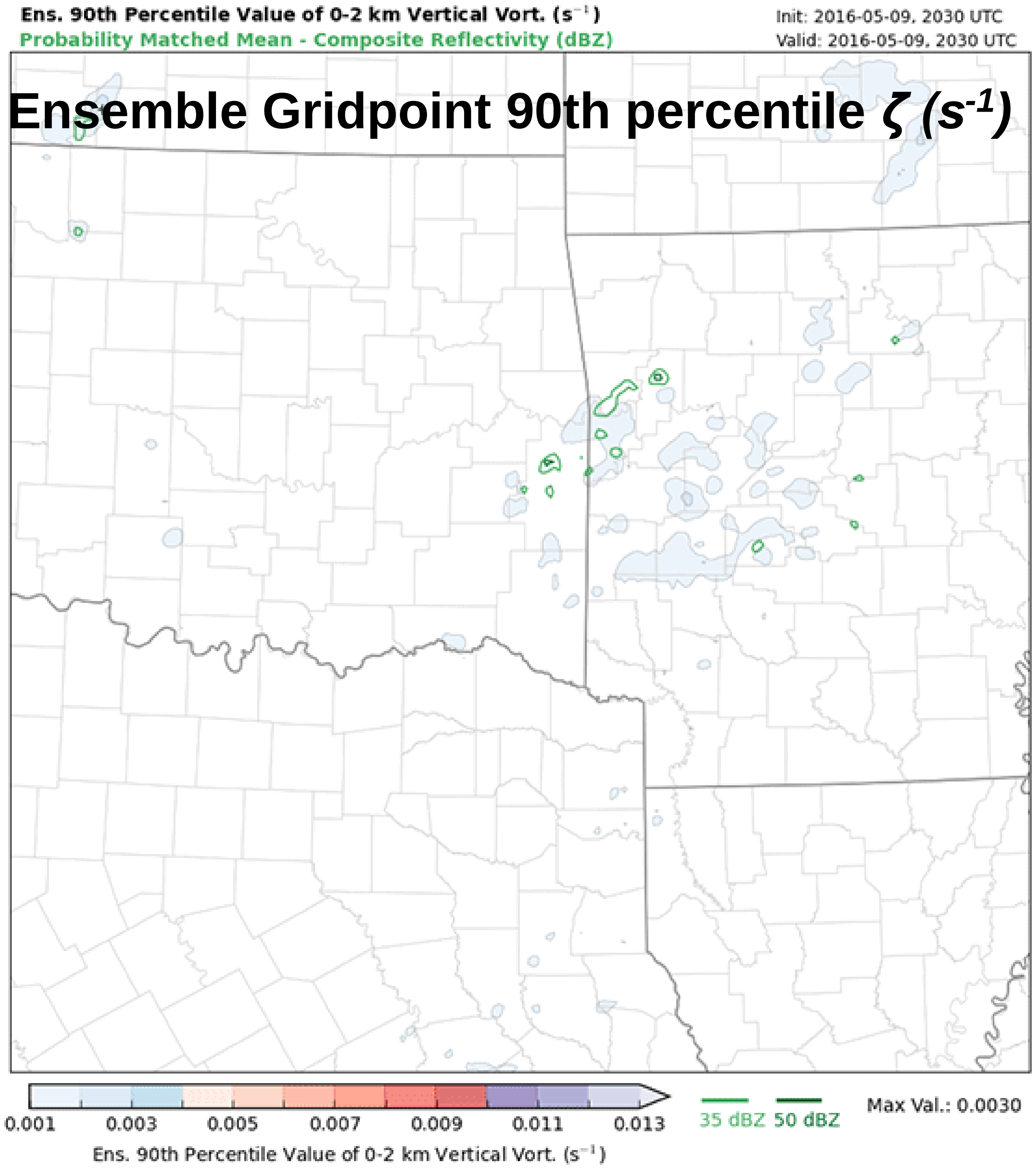
Ensemble Gridpoint 90th percentile *ζ (s^{-1})*

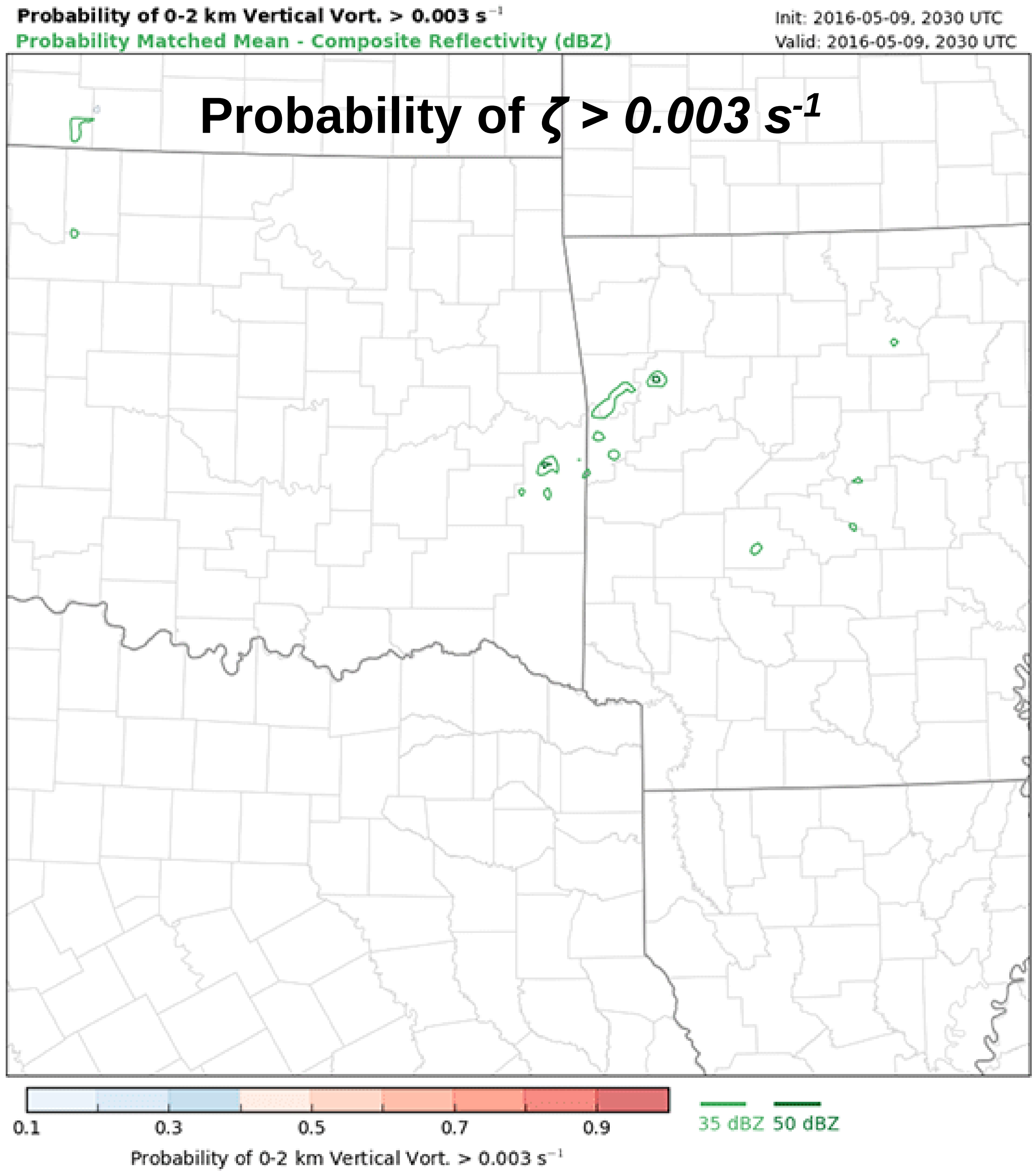


Probability of *ζ* > *0.003 s^{-1}*

Developing
Convection (<40 dBZ)

Example of a 'Good' Low-Level Rotation Forecast:



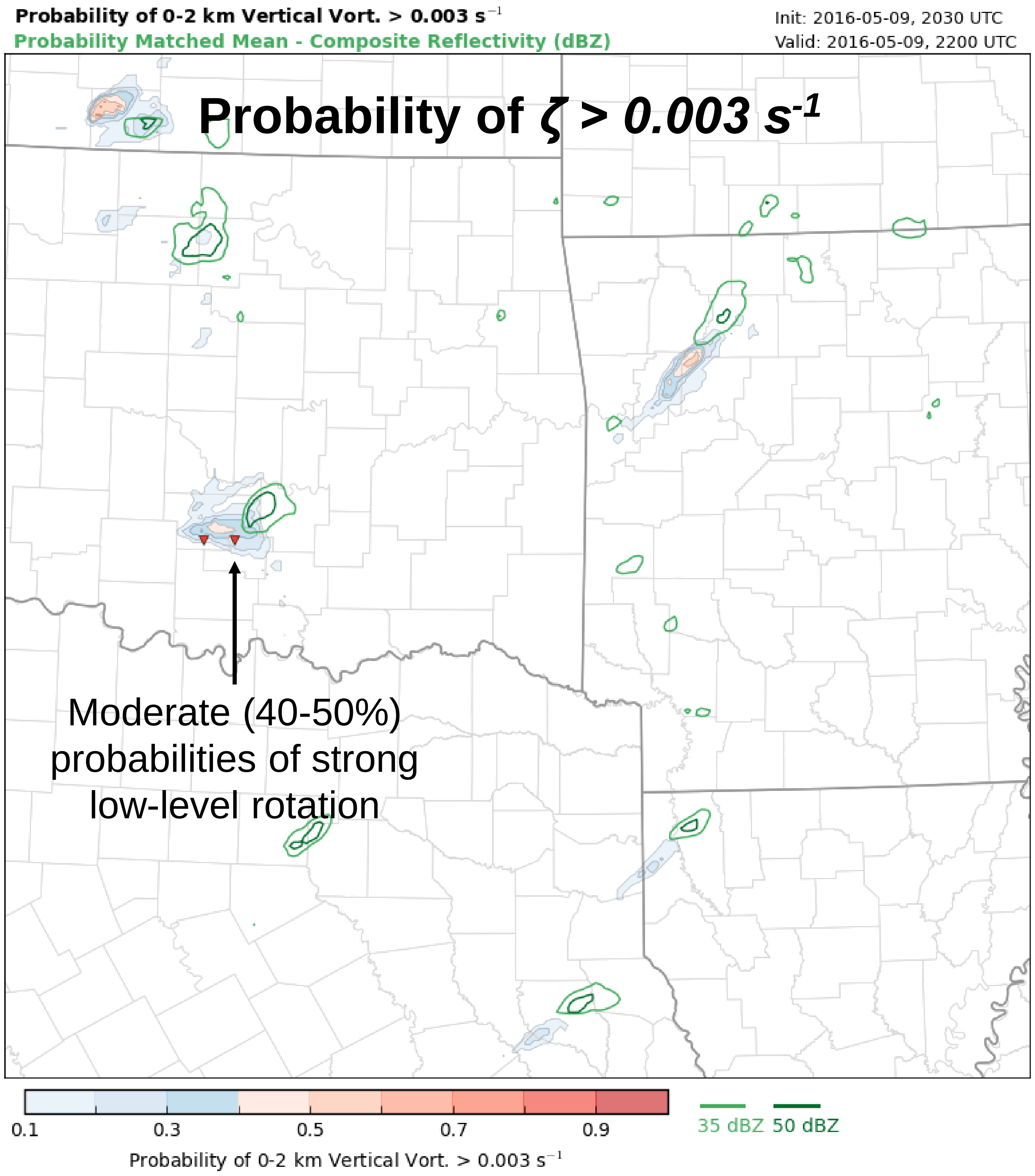


Example of a ‘Good’ Low-Level Rotation Forecast:

Ensemble Gridpoint 90th percentile *ζ (s^{-1})*

High 90th percentile values indicates possibility of intense low-level mesocyclone

Probability of *ζ* > *0.003 s^{-1}*



Moderate (40-50%) probabilities of strong low-level rotation

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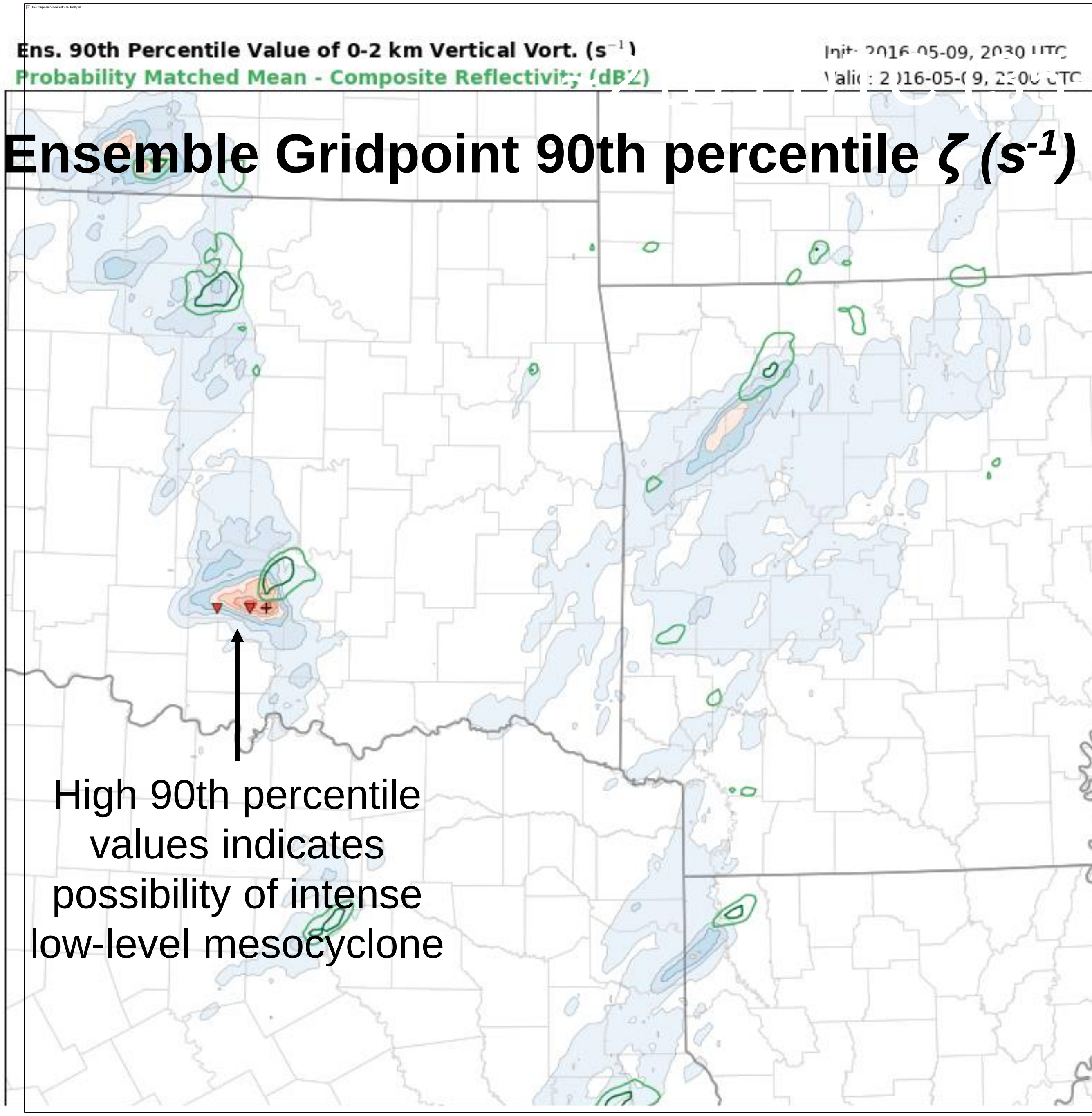
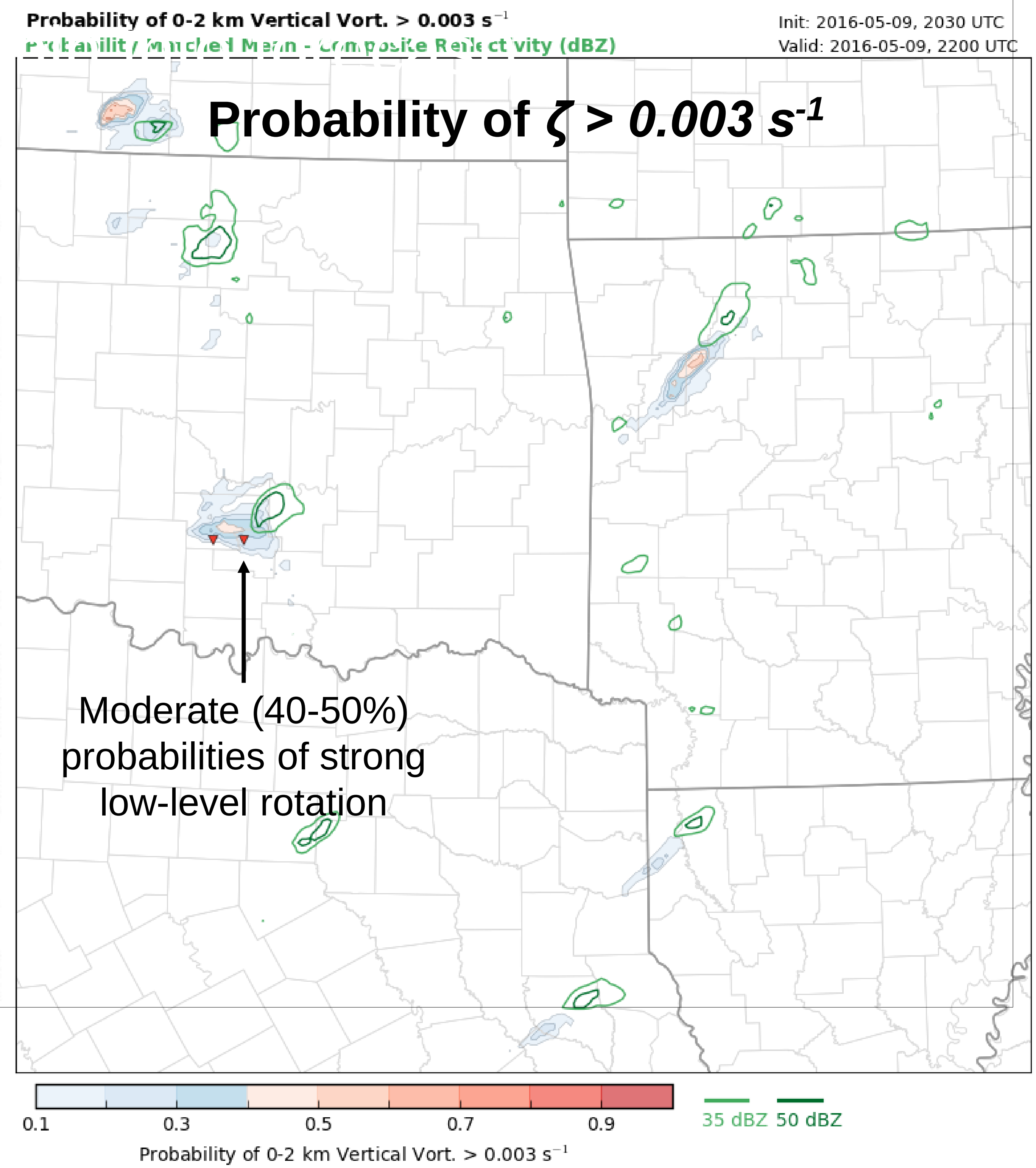
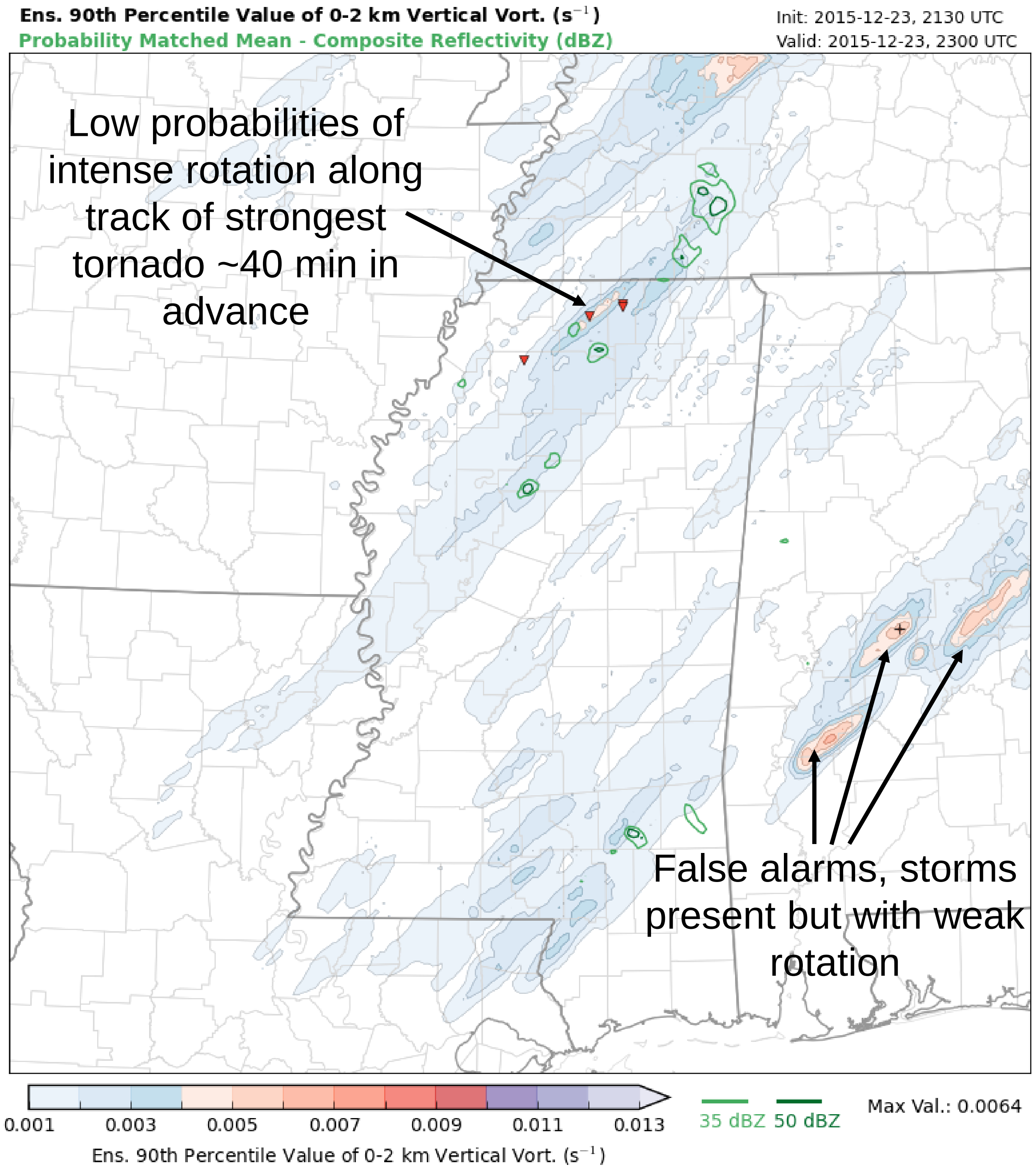


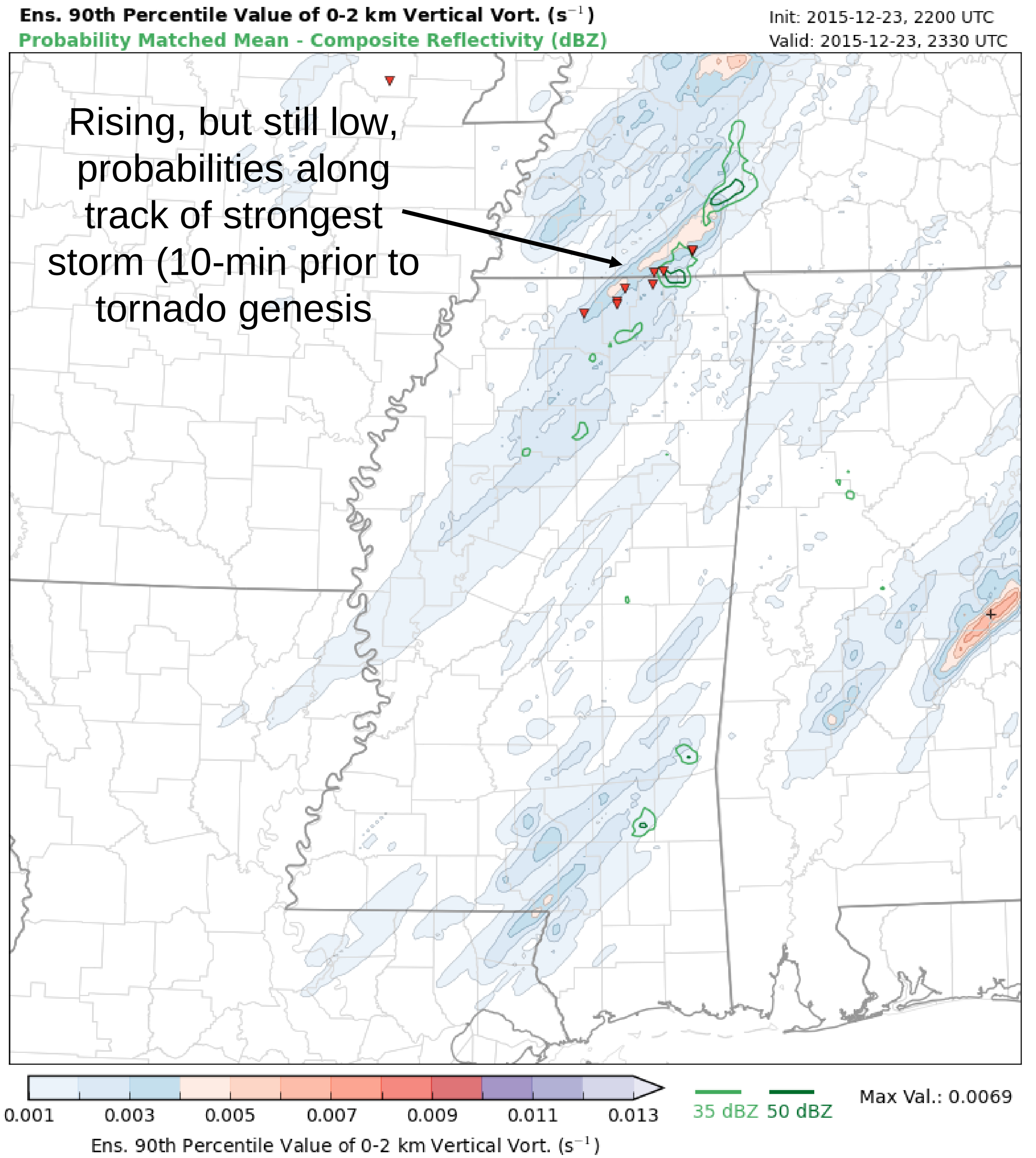


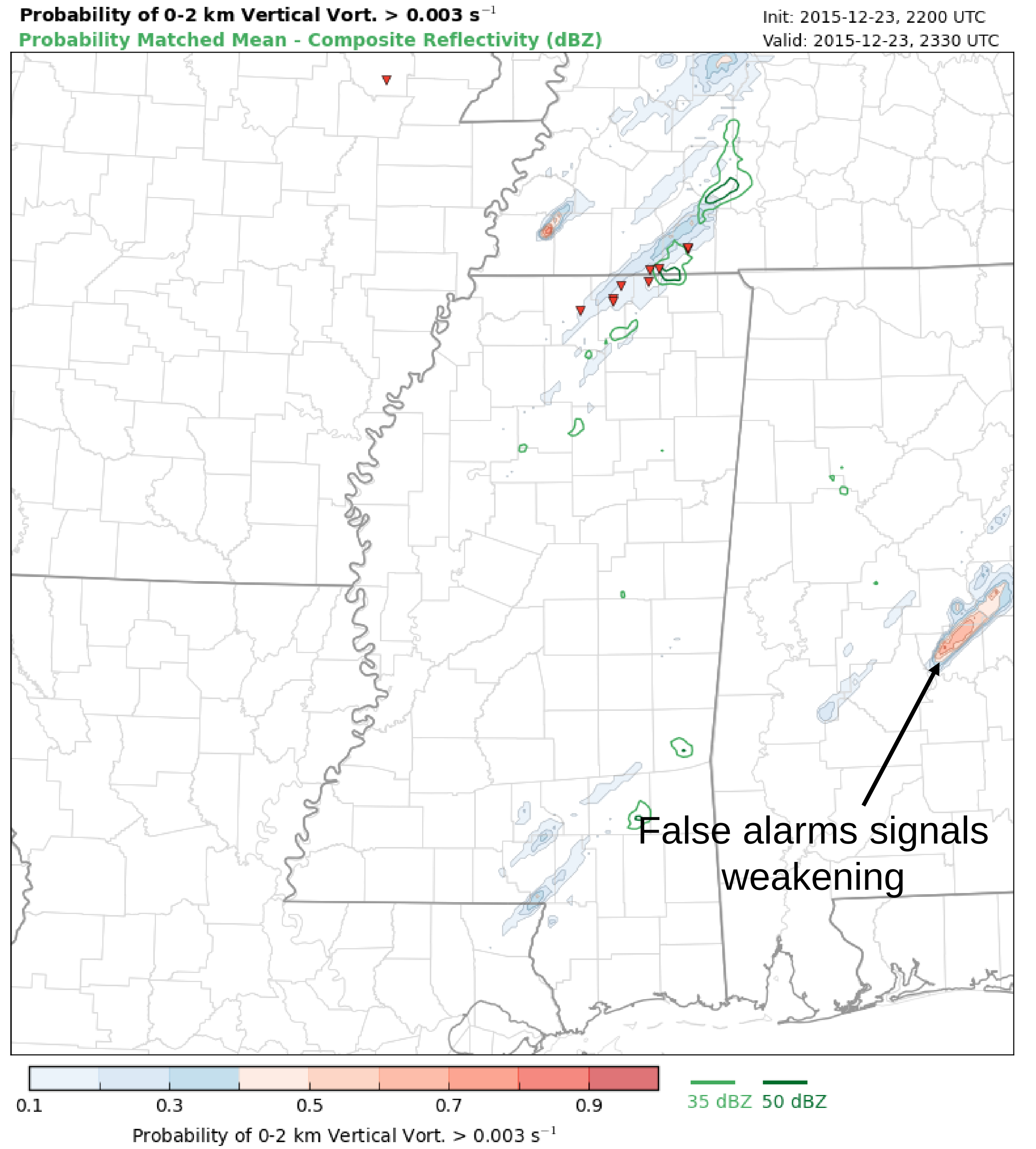
23 December 2015: 2130 Forecast



Early event missed

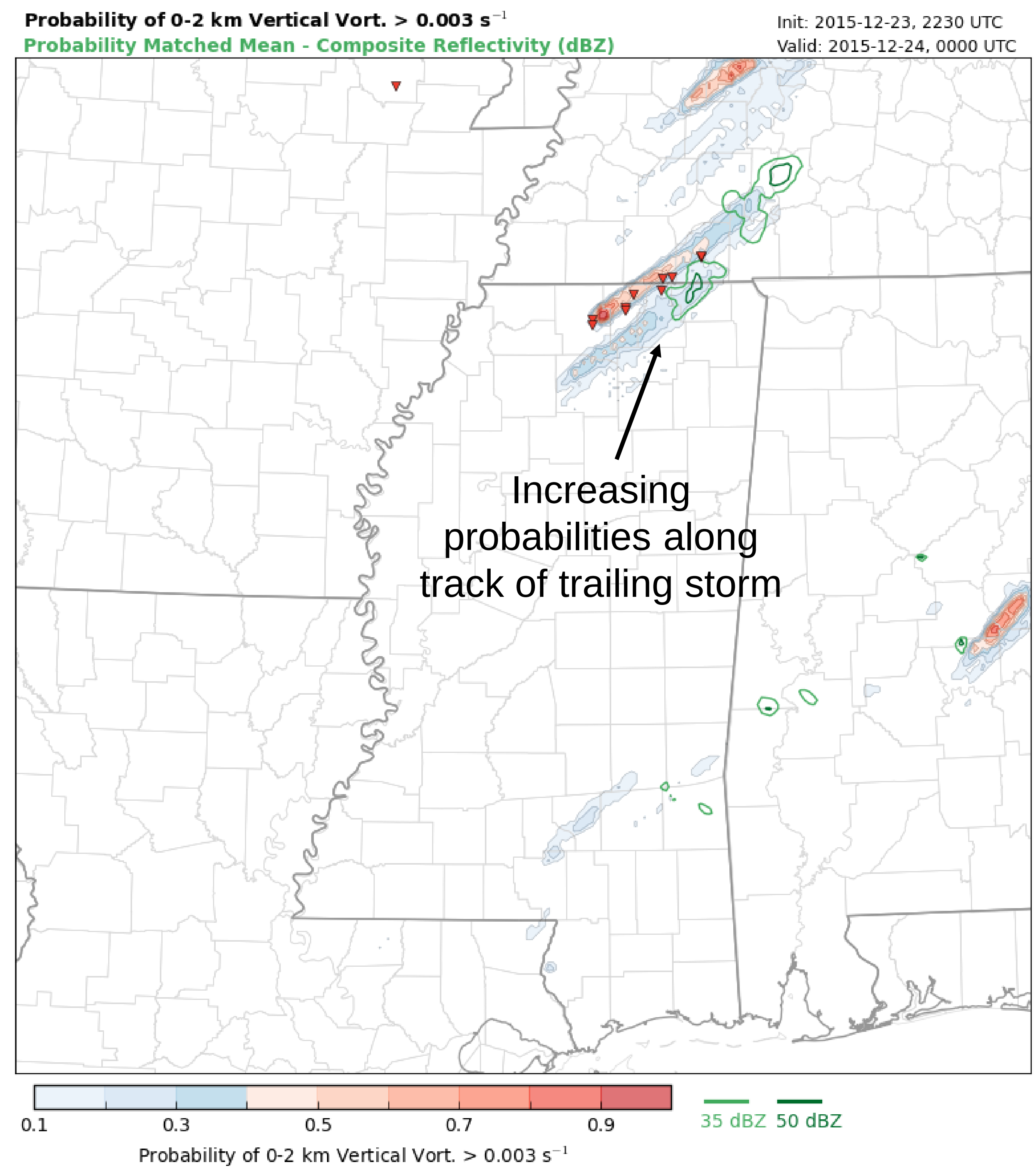
23 December 2015: 2200 Forecast





23 December 2015: 2230 Forecast

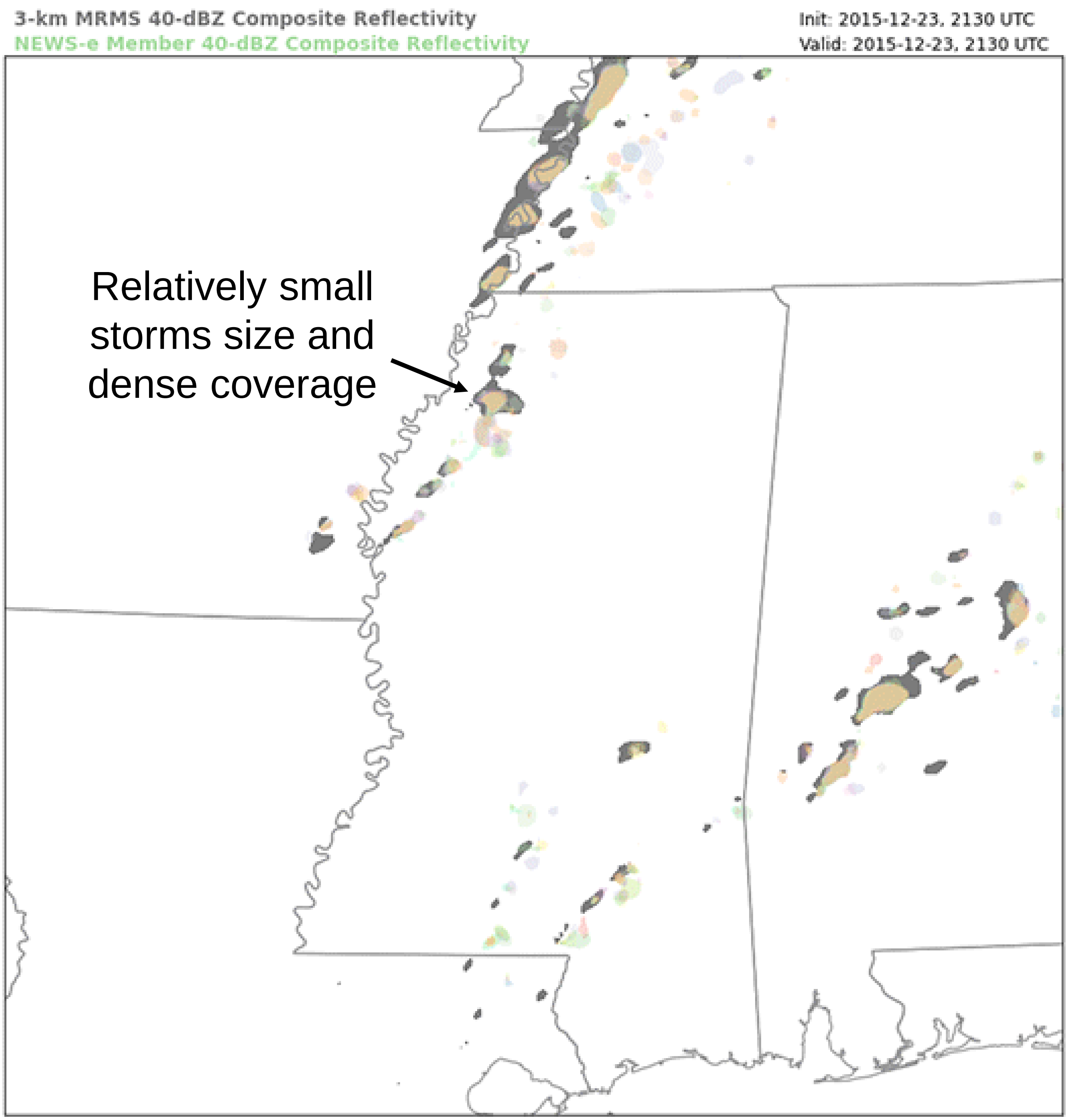
Identifies high probabilities of intense rotation along ongoing long-track tornado



Increasing probabilities along track of trailing storm

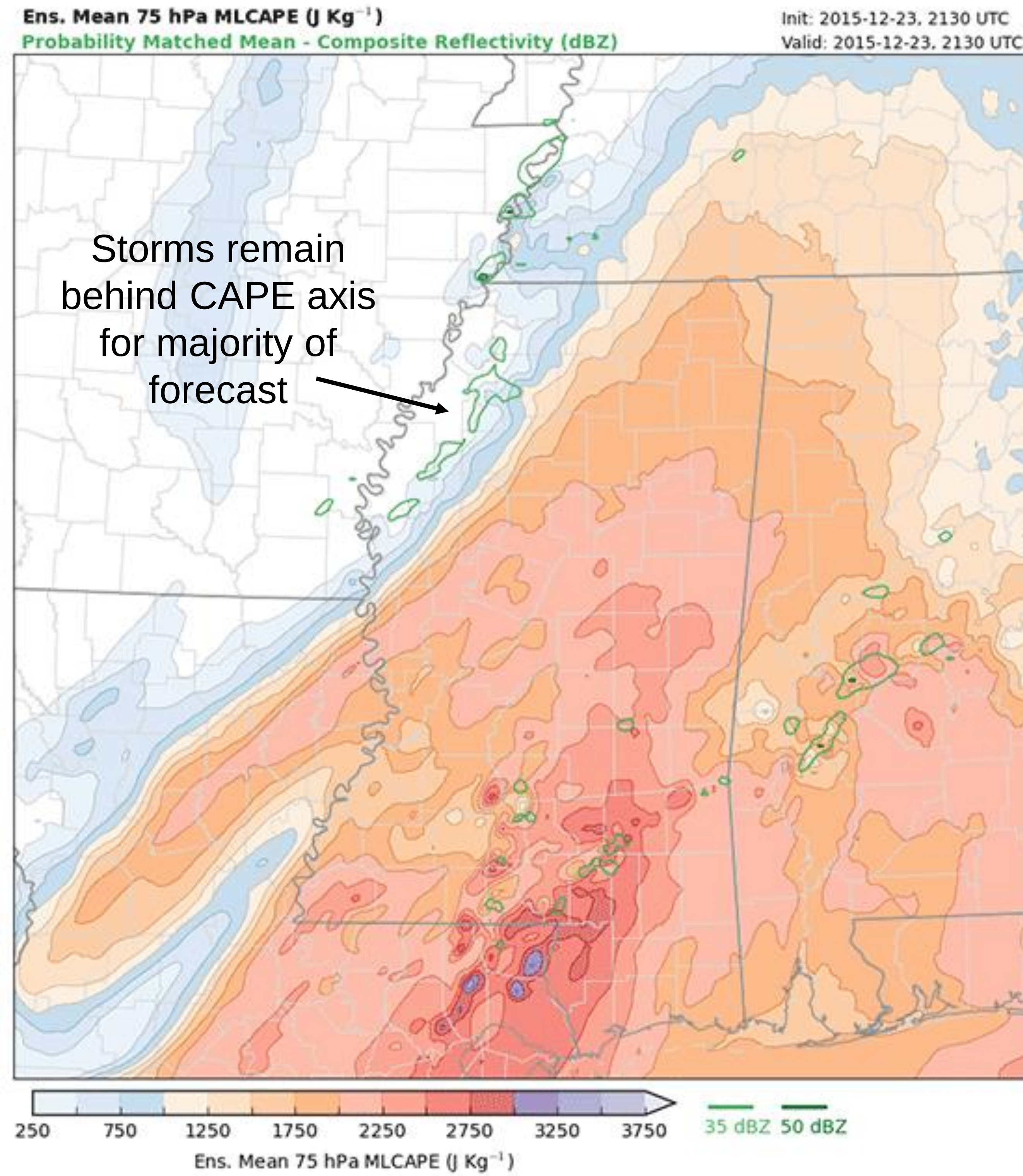
23 December 2015: Poor 2130 Forecast

Storm-Scale Challenge:



Gray Shading: Observed 40 dBZ Contour
Colored Shading: Individual Member 40 dBZ Contours

Mesoscale Challenge:



31 March 2016: 2230 Forecast

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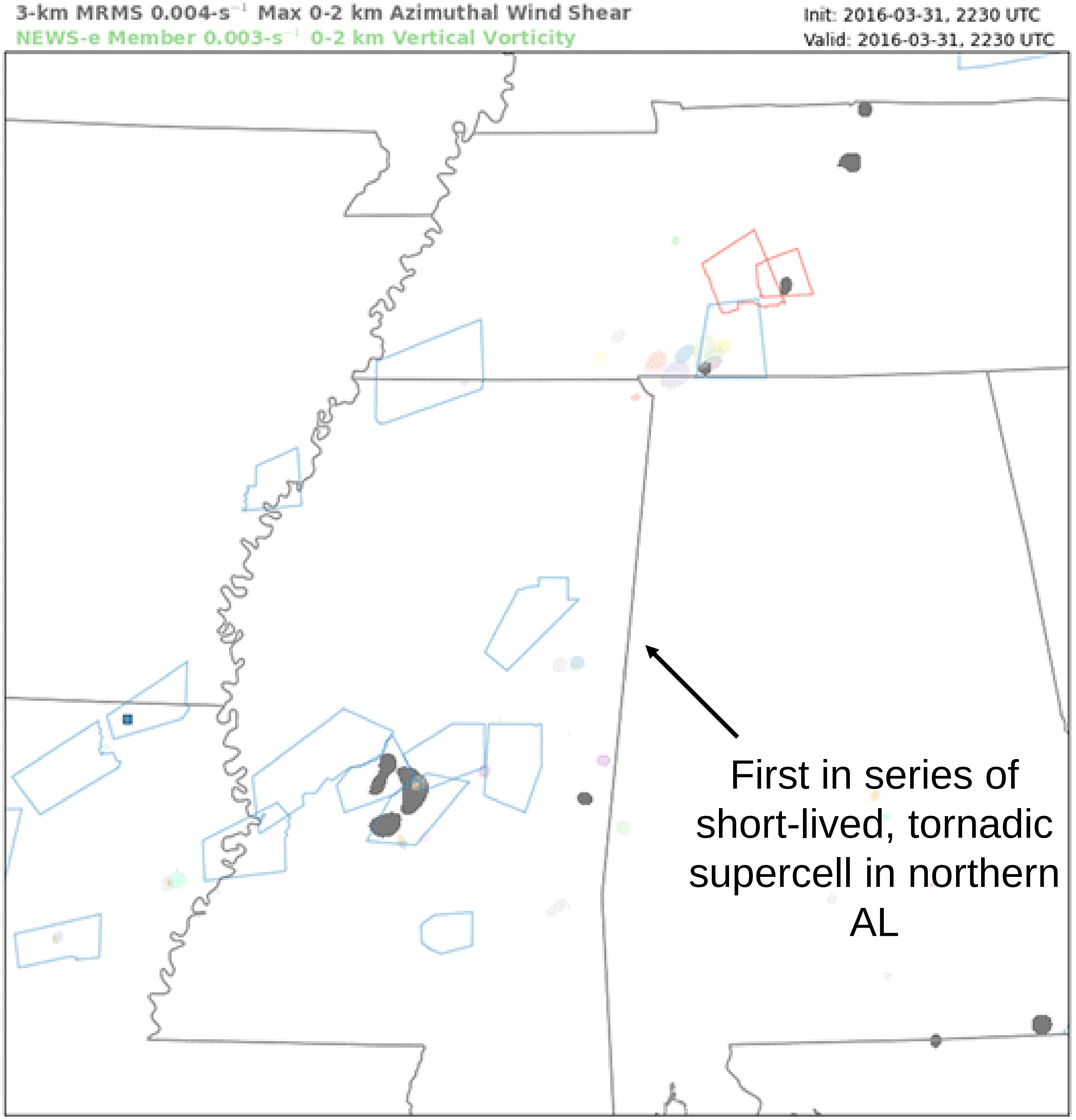
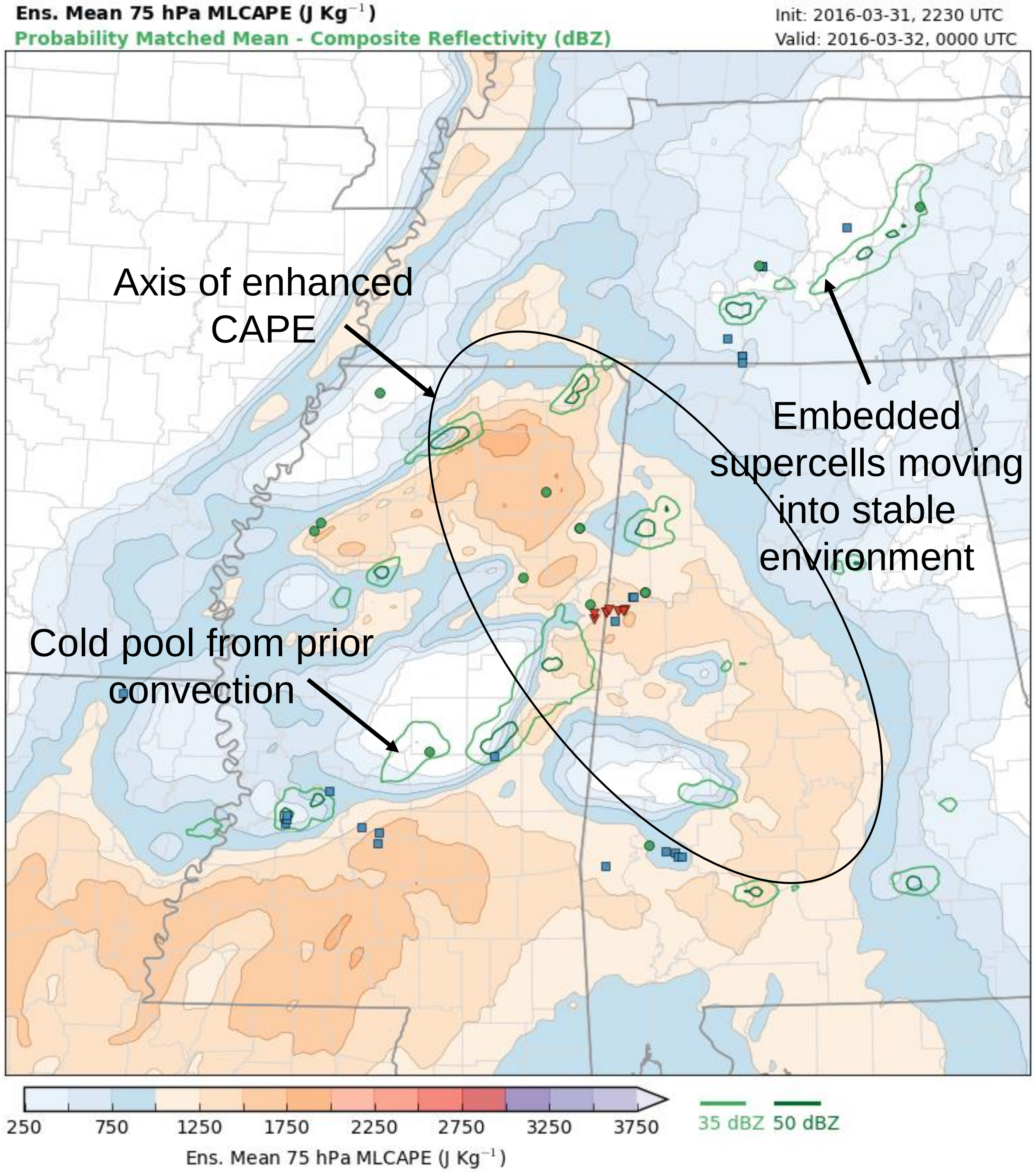


Gray Shading: Observed AZ shear objects
Colored Shading: Individual Member vertical vorticity objects

Mesoscale Challenge:



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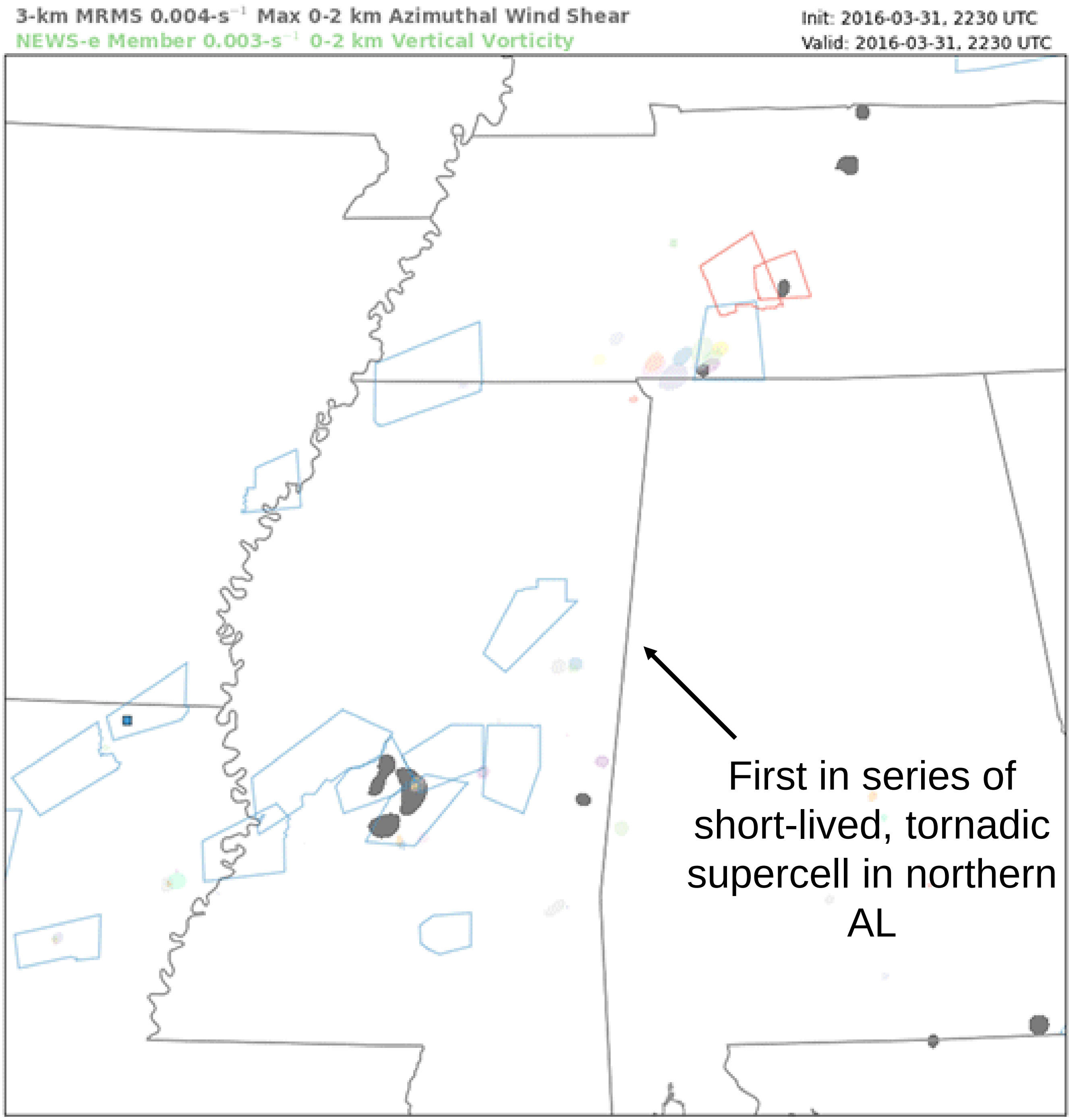

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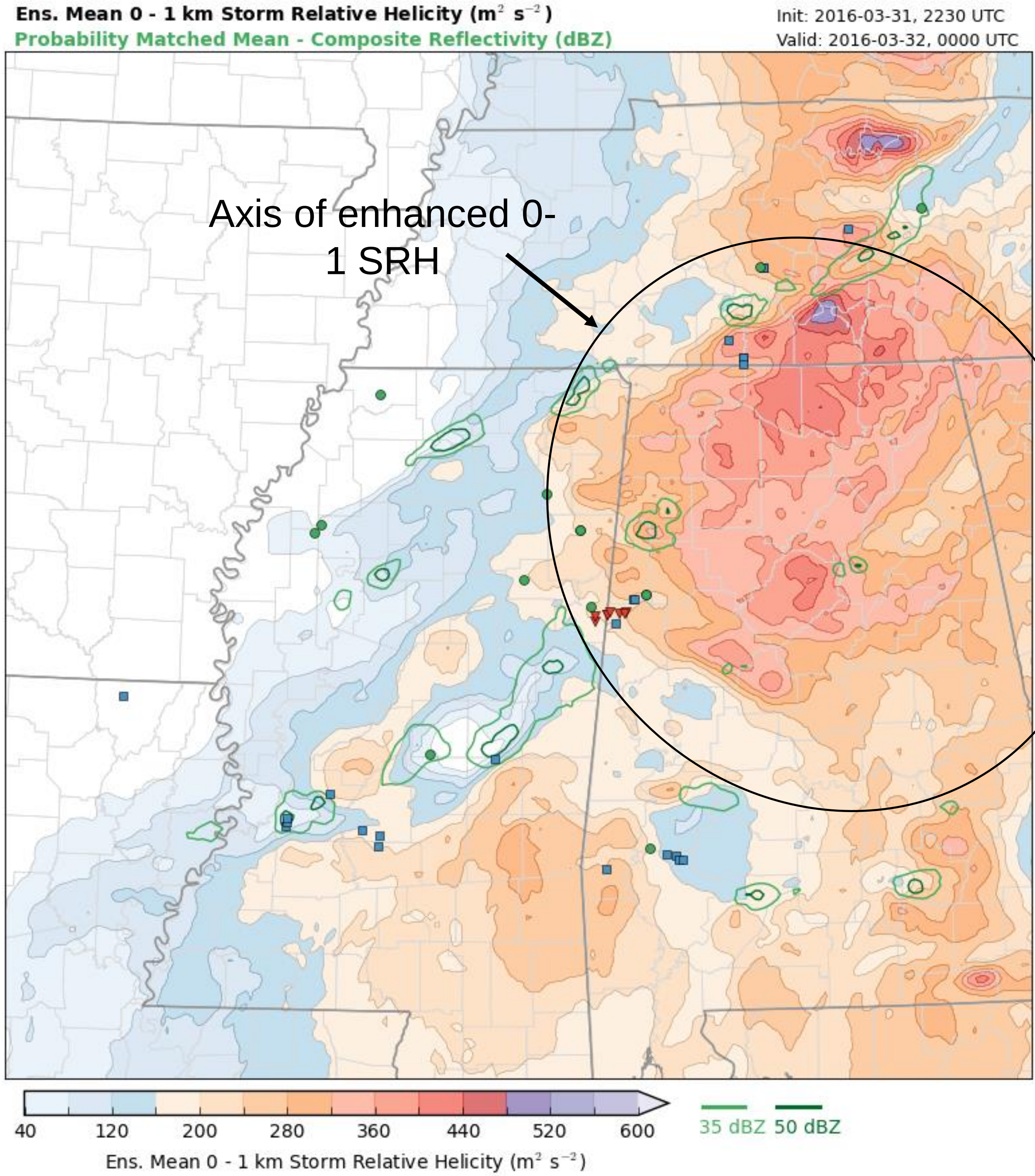

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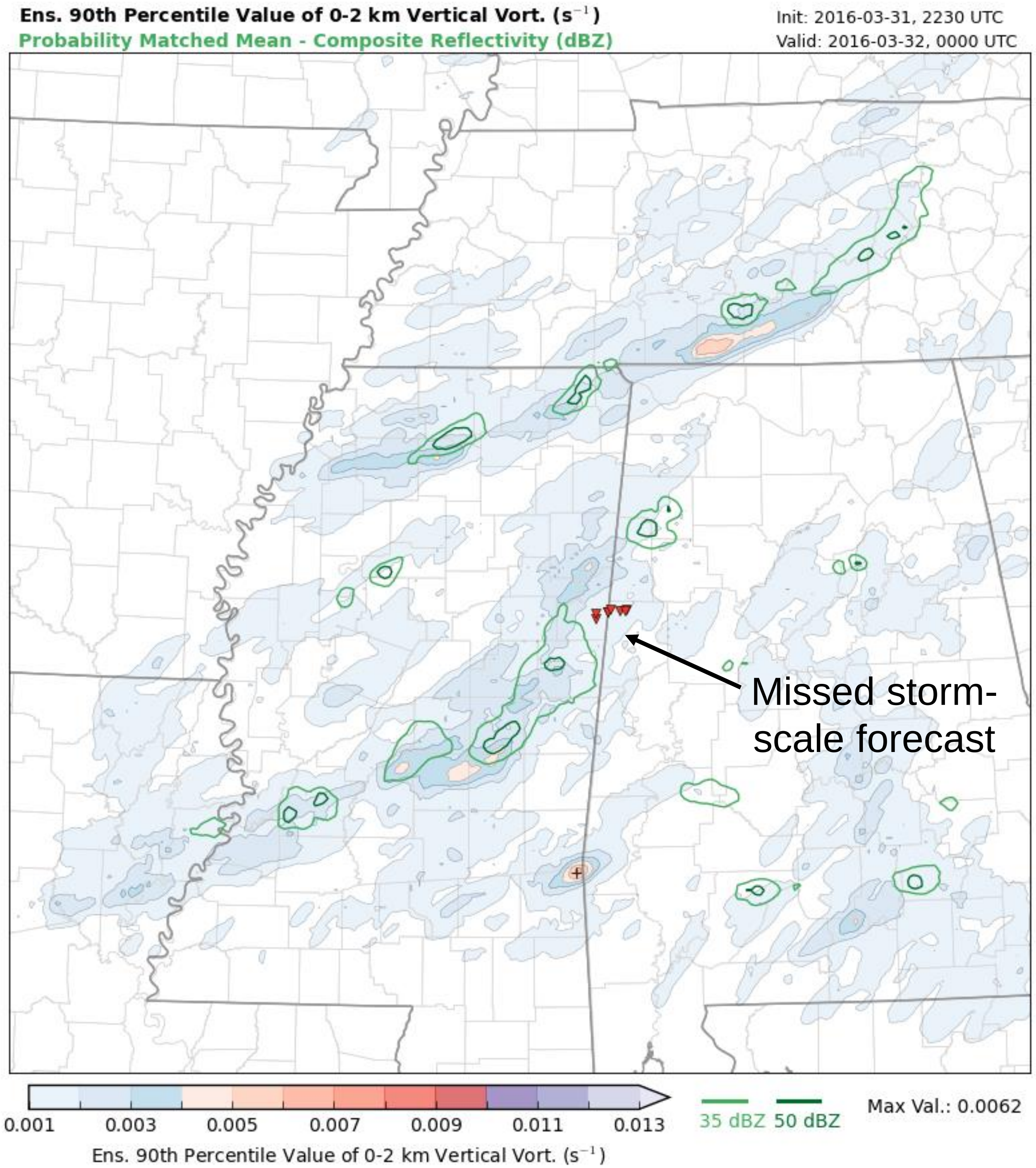
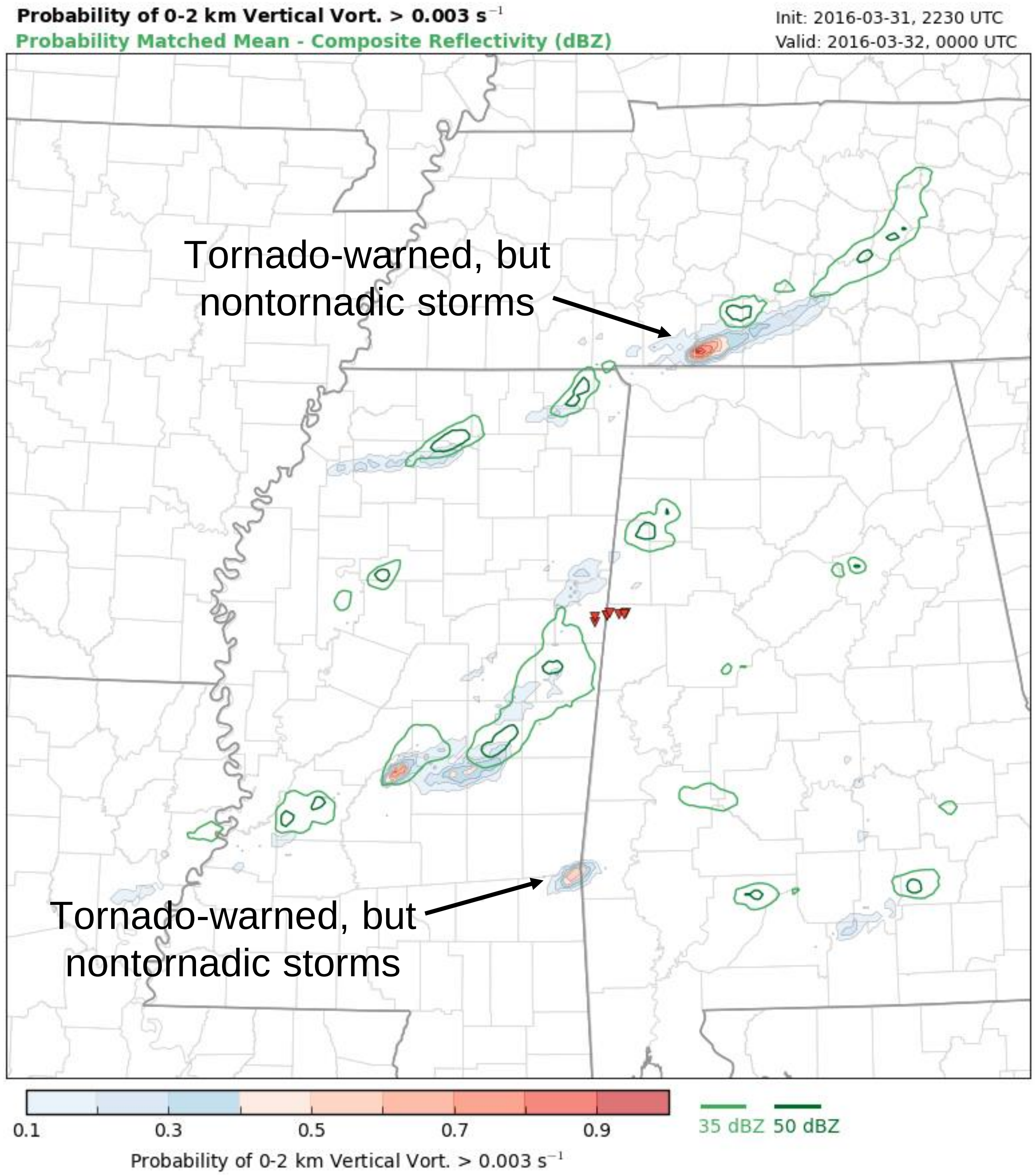
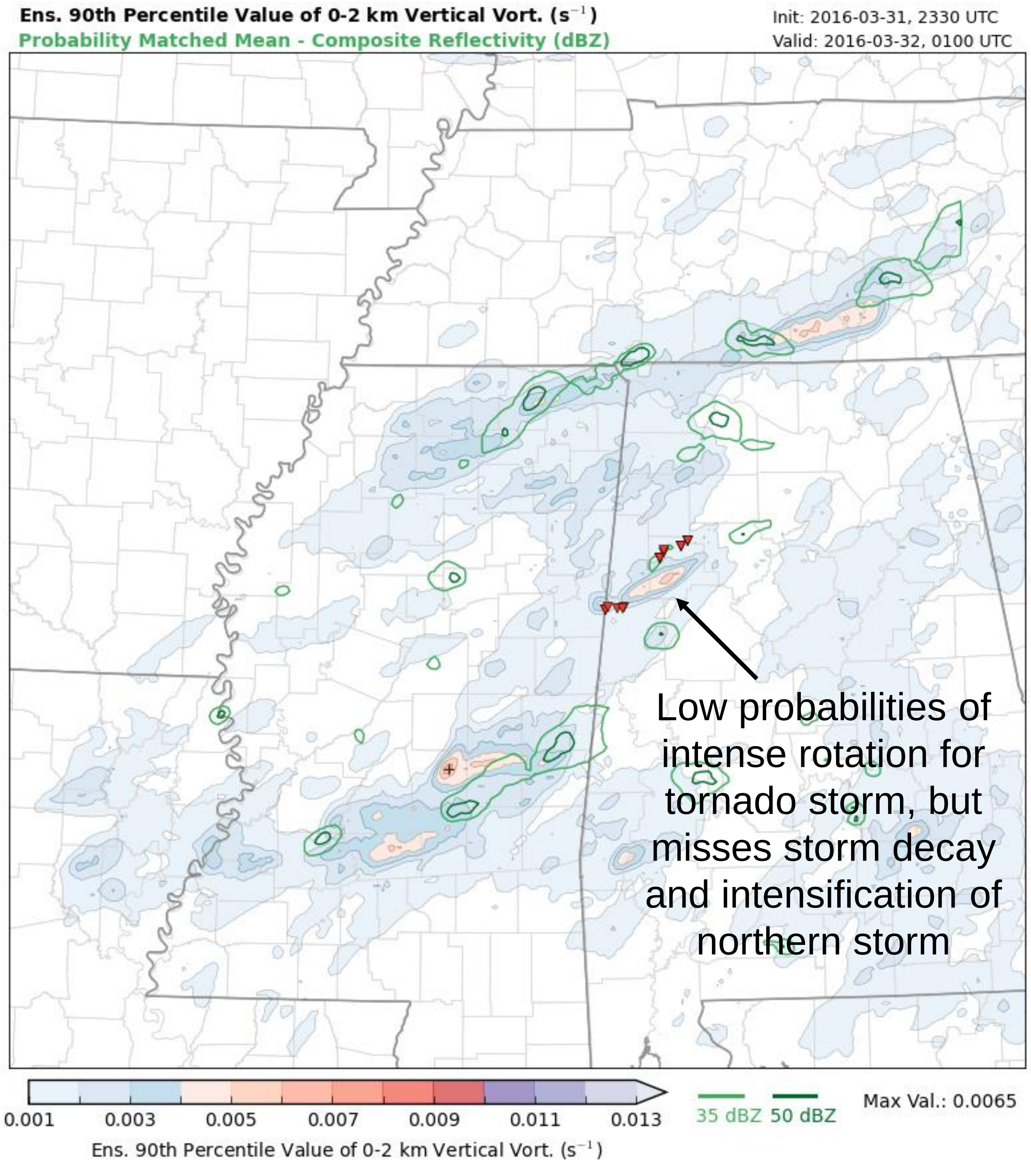
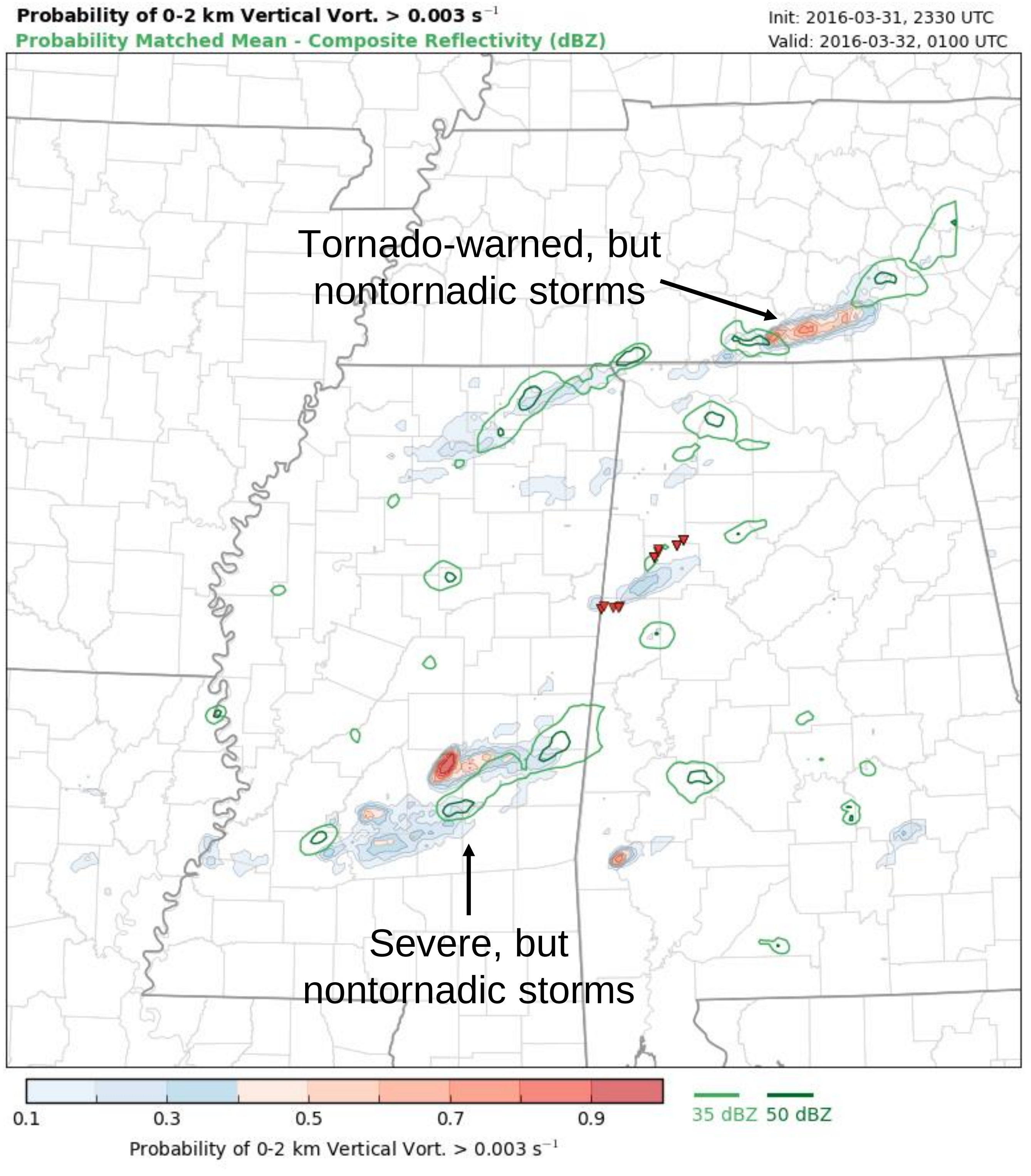




23 December 2015: 2330 Forecast





Summary:

- A prototype Warn-on-Forecast system has been demonstrated for the Spring of 2016

- Accurate low-level rotation forecasts have been produced across a variety of mesoscale environments; however, both storm and mesoscale challenges in accurately analyzing and forecasting individual thunderstorms remain

- Storm-scale Challenges:
  - Dense storm coverage can lead to unrealistic storm and cold-pool interactions
  - Small or shallow storms limit the number of radar observations assimilated, slowing spin-up
  - *May be mitigated by increasing storm and observation resolution (i.e. 1-km horizontal grid spacing) and utilizing multi-moment microphysics*

- Mesoscale Challenges:
  - Lack of observations for characterizing mesoscale environment
  - Model error
  - *Improved accuracy in forecasting the storm environment will result in similar improvements in storm-scale forecasts*

Future Work:

- Need quantitative verification of NEWS-e forecasts:
  - Model climatology of storm properties (i.e. 0-2 km vertical vorticity)
  - Object-based verification of storms
  - Near-storm environment characterization