

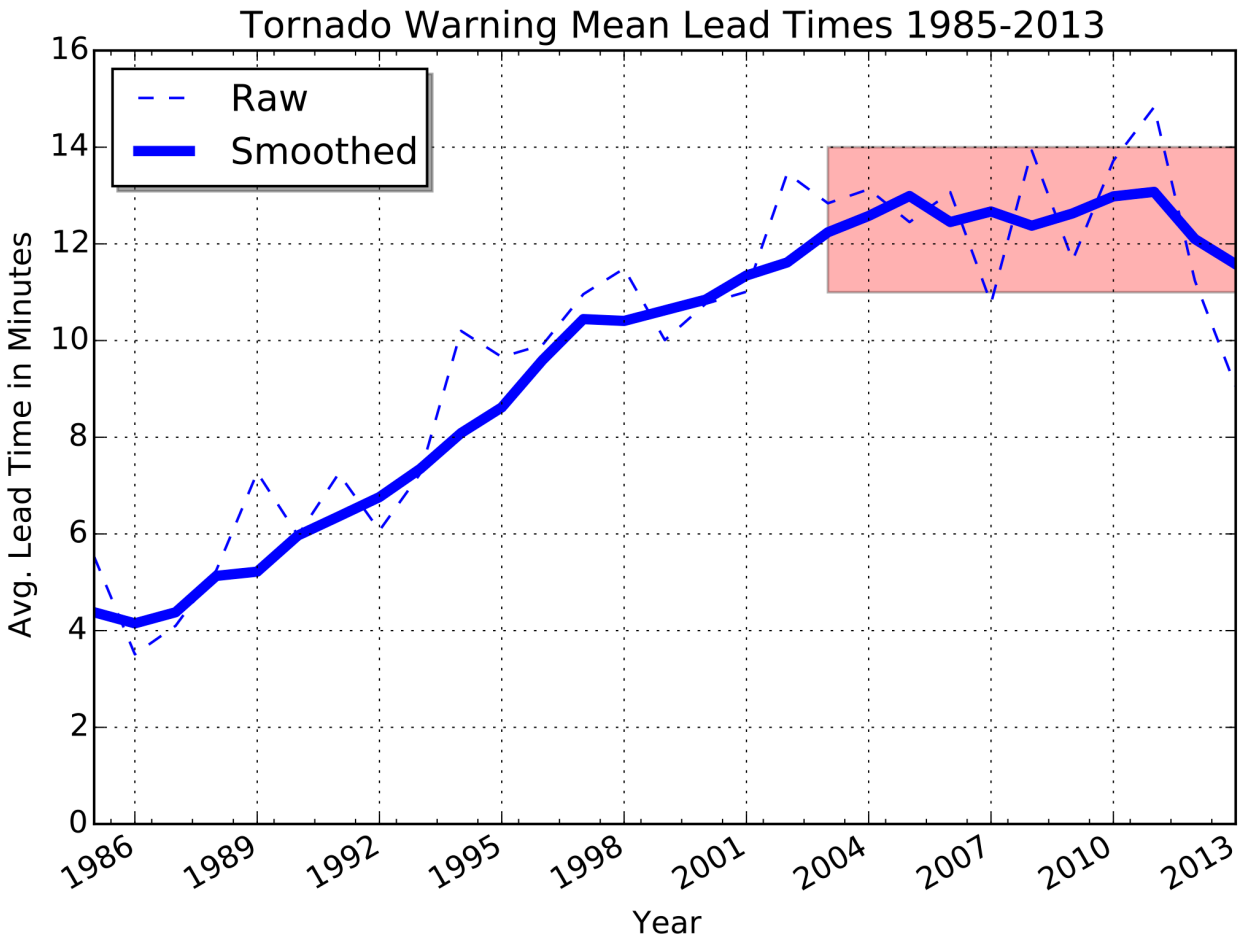

# NSSL's Warn-on-Forecast Project

Dr. Lou Wicker

February 25–27, 2015

National Weather Center
Norman, Oklahoma

# Motivation: Tornado warning lead-times have stopped improving



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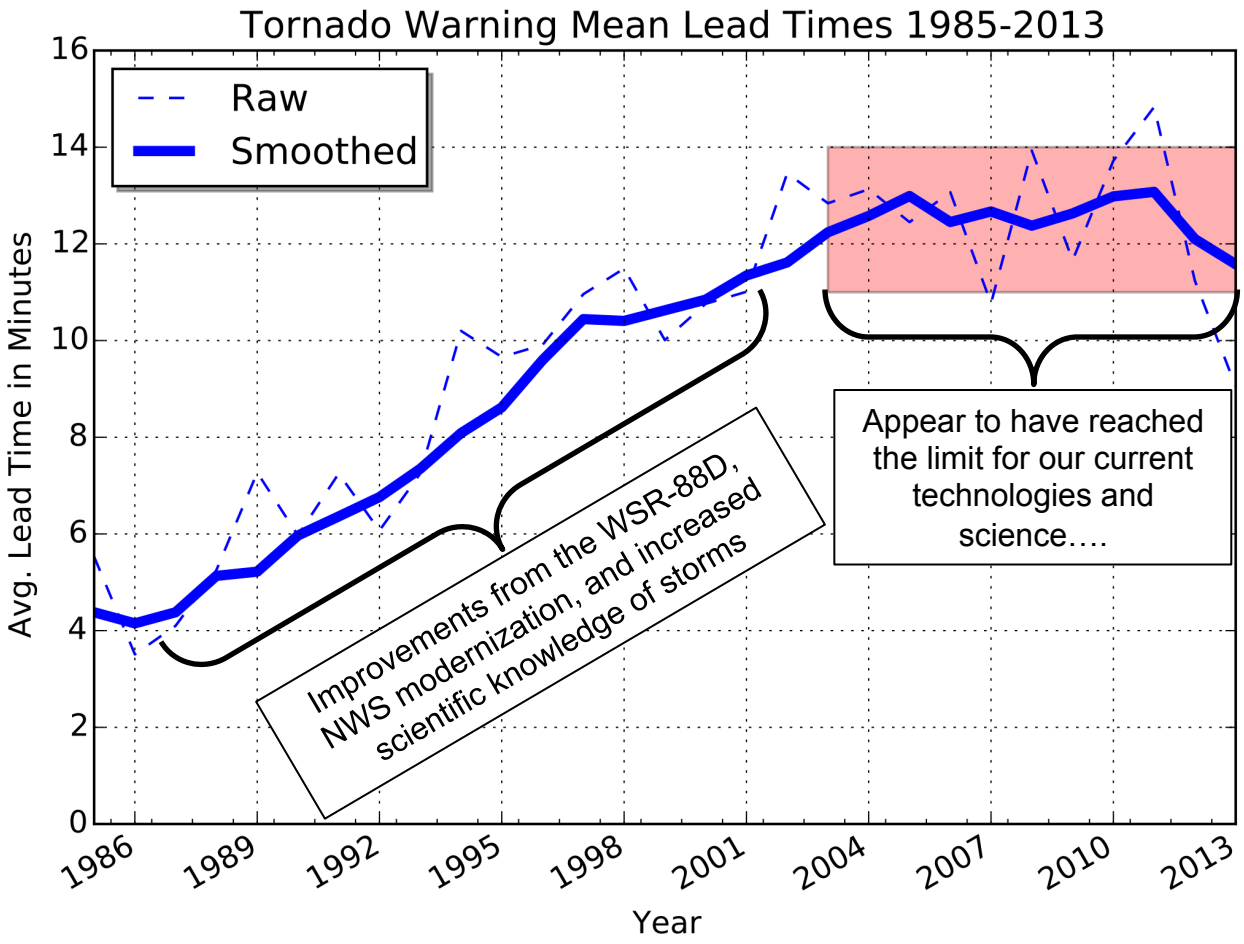

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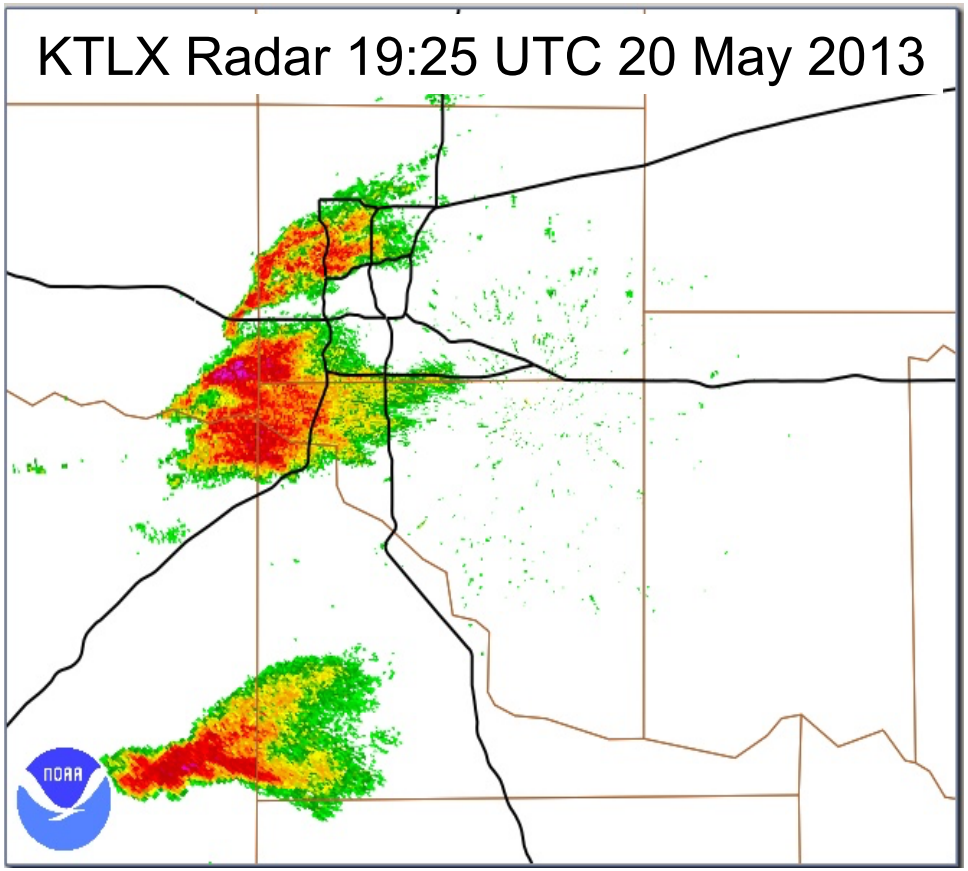

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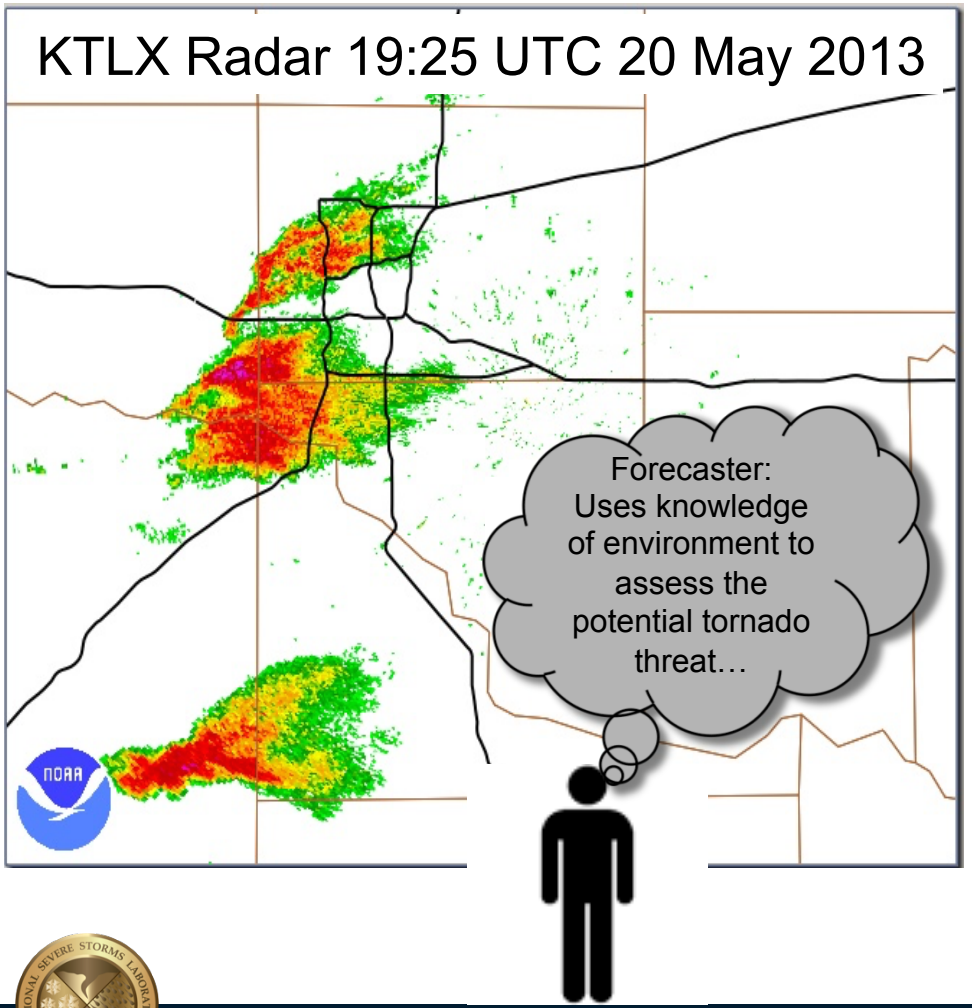

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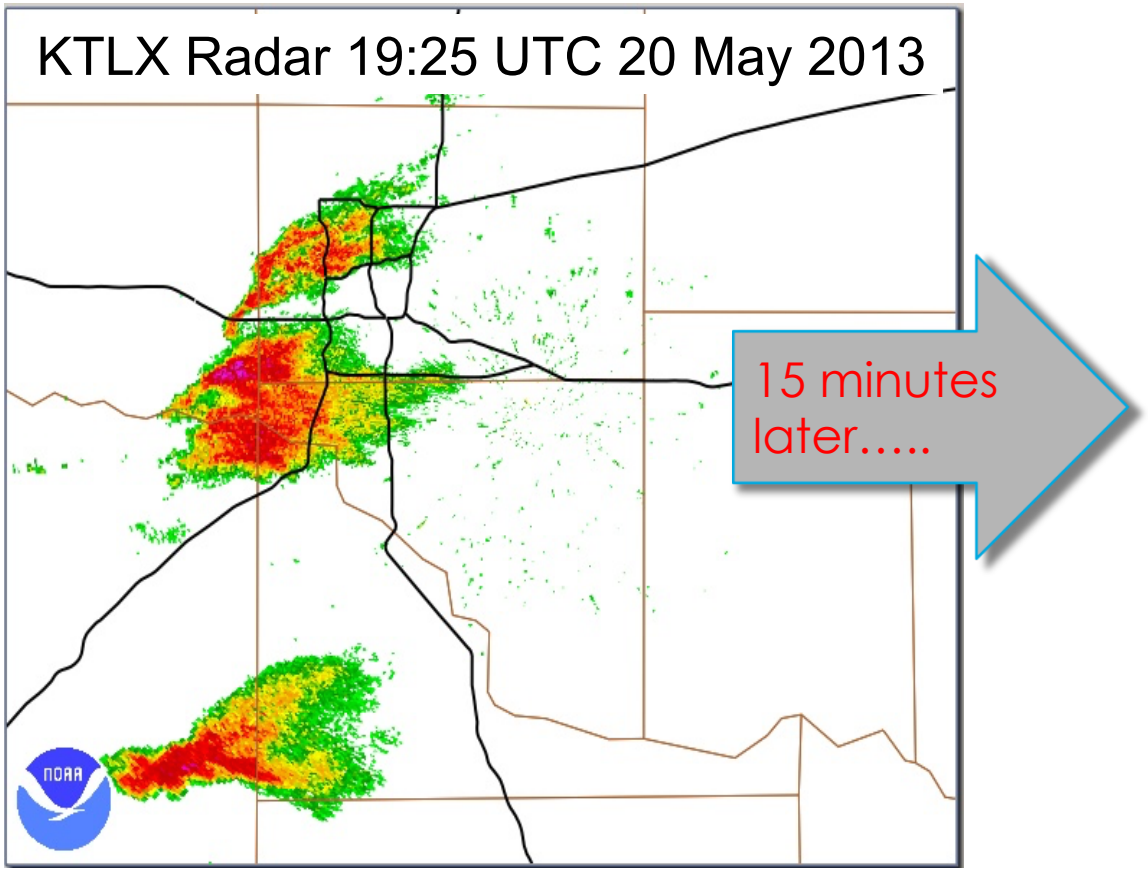

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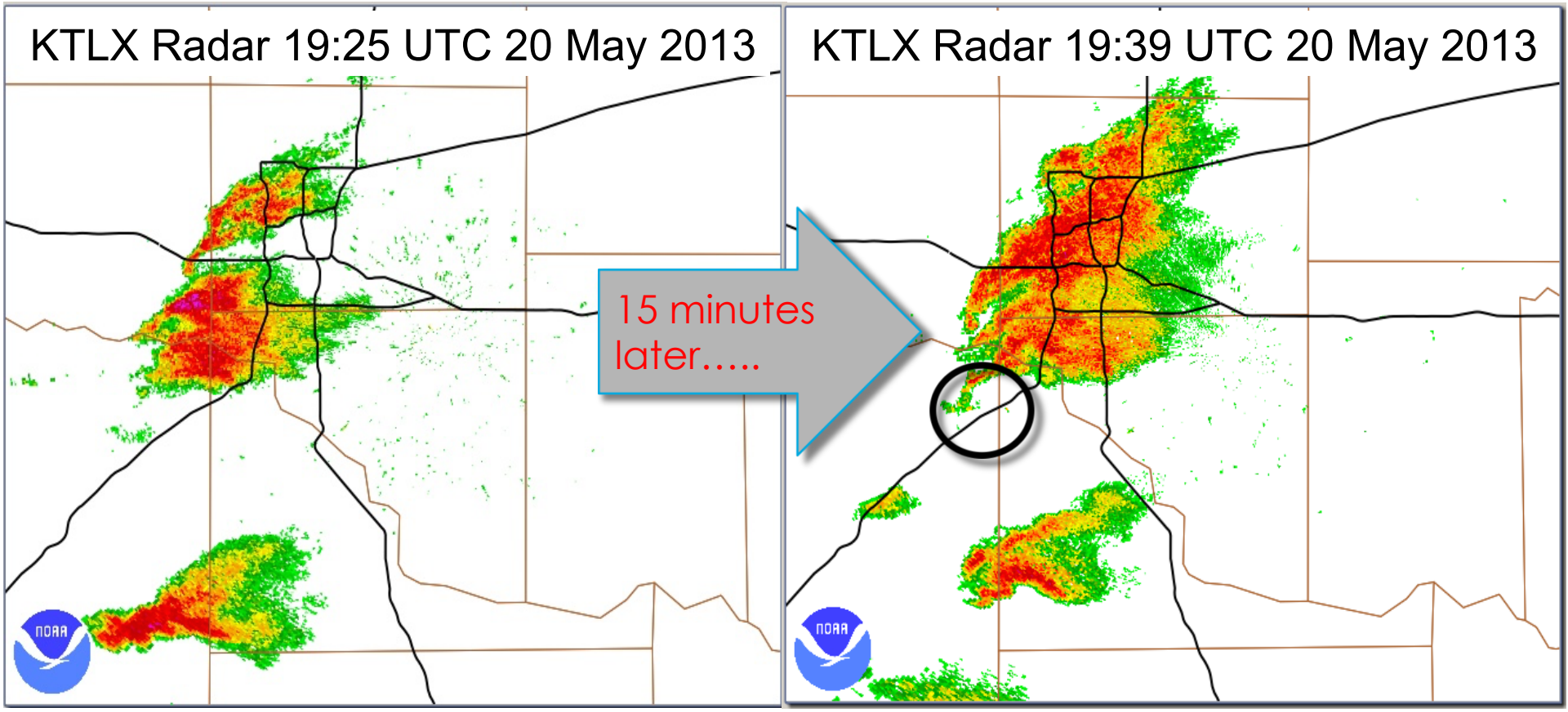

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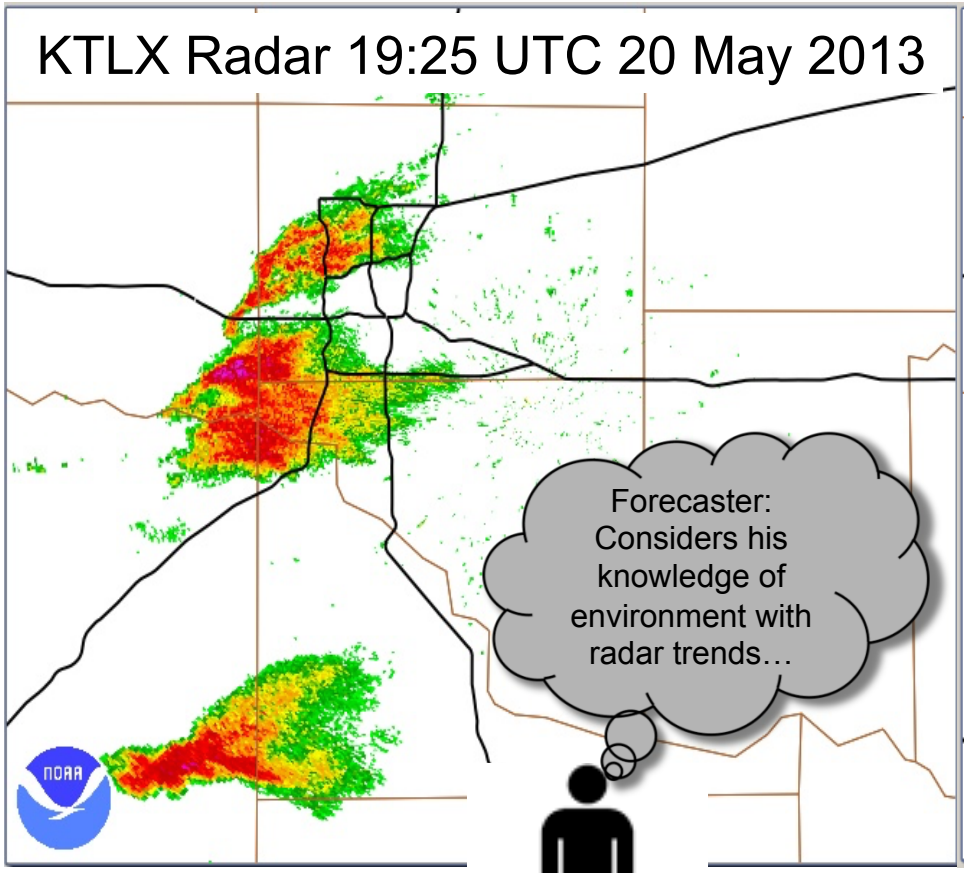


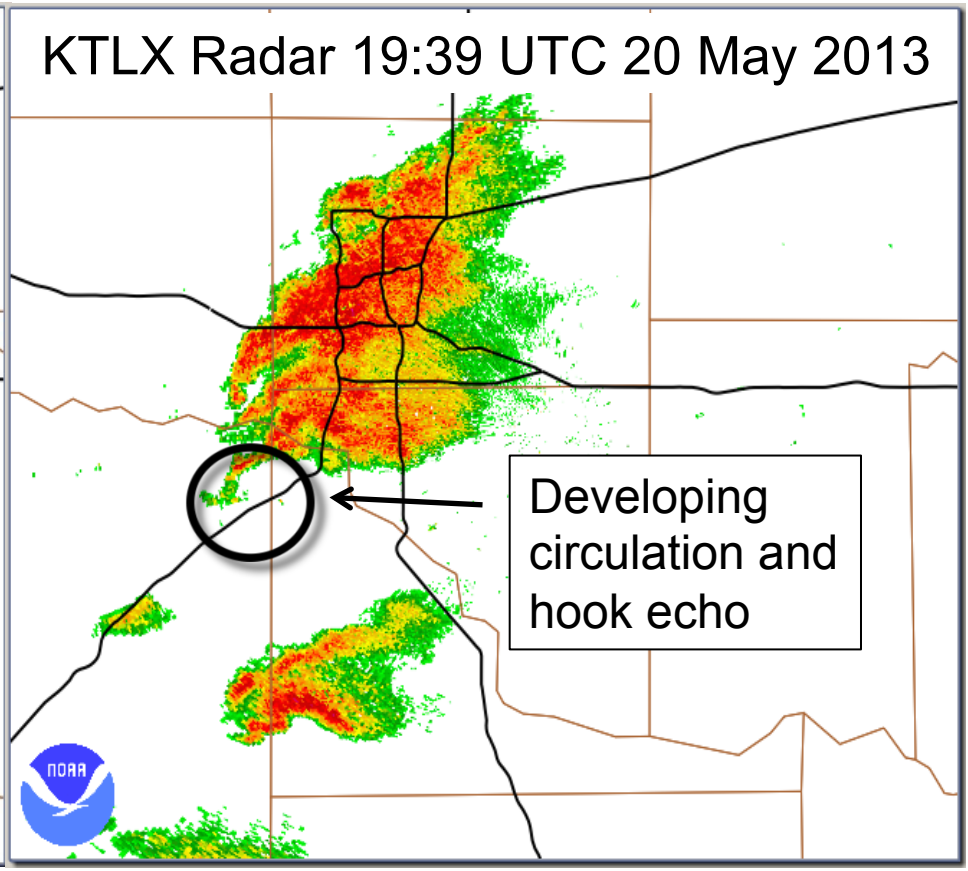

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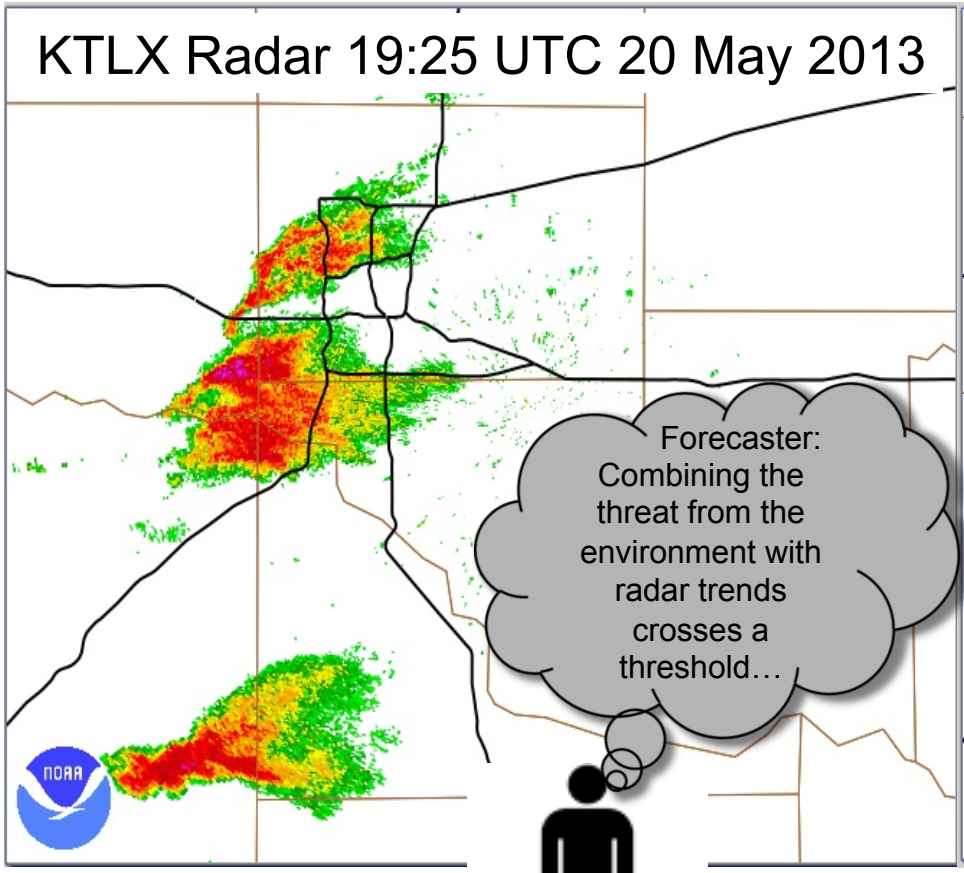
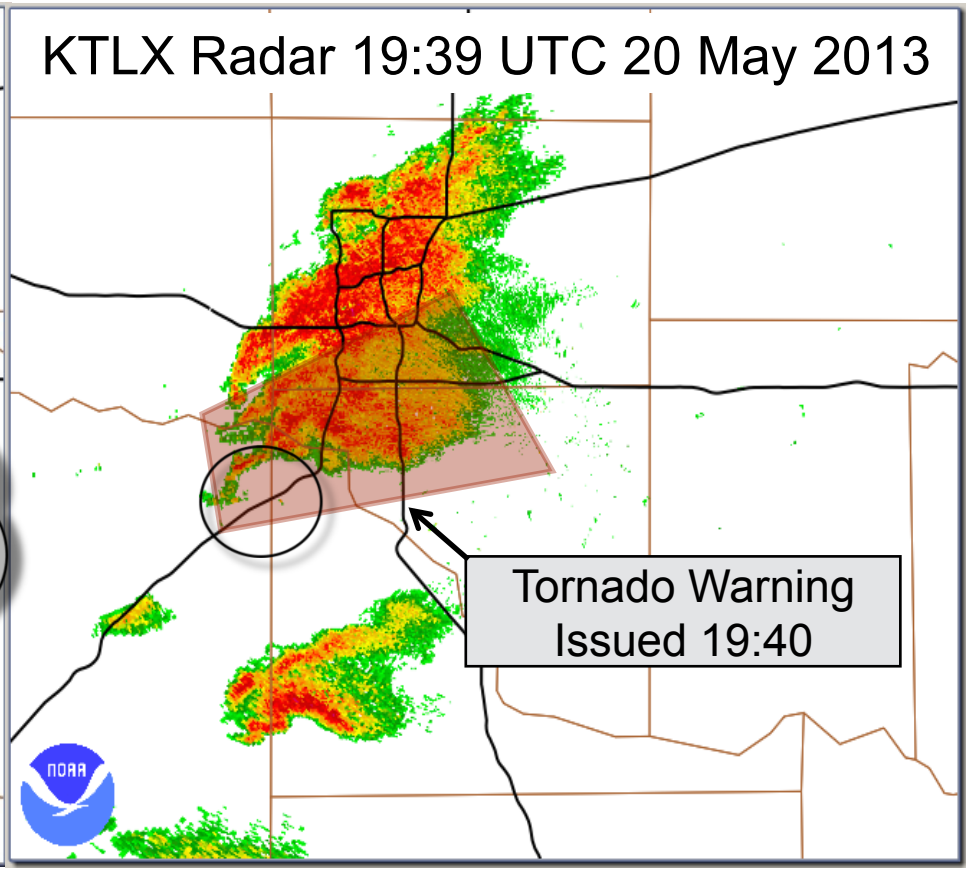
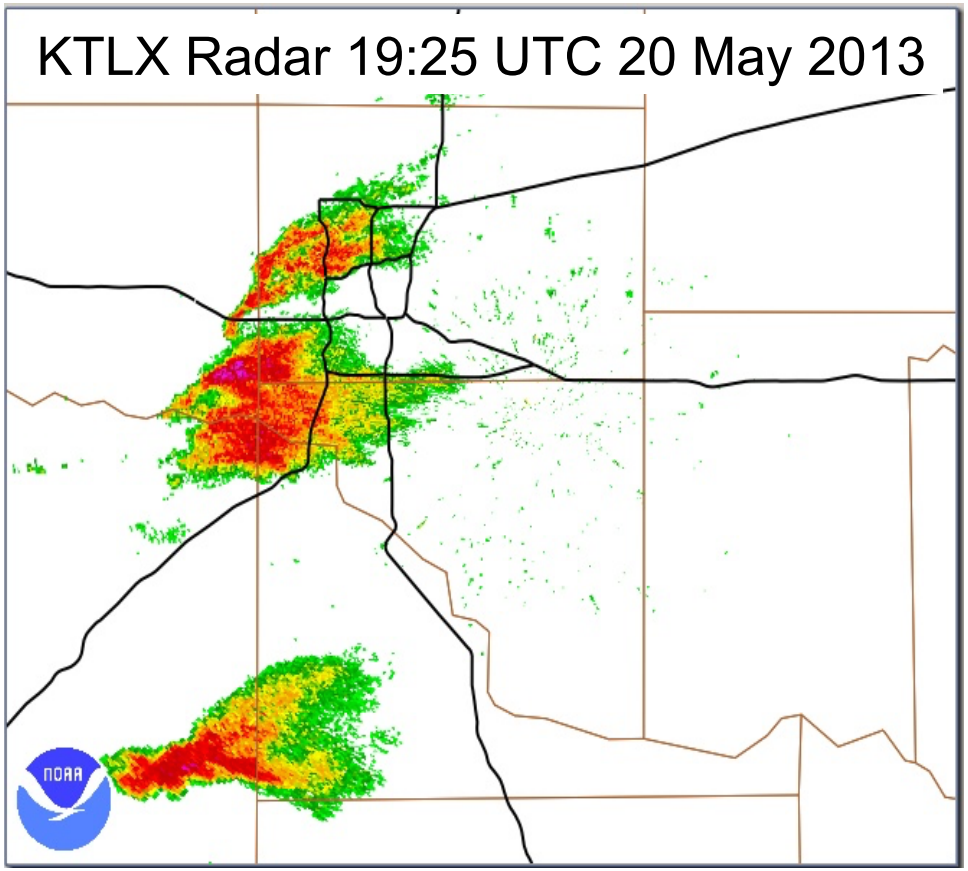



*Lead time for Moore storm: 16 min*

# Future Warning Process: *"Warn on Forecast"*



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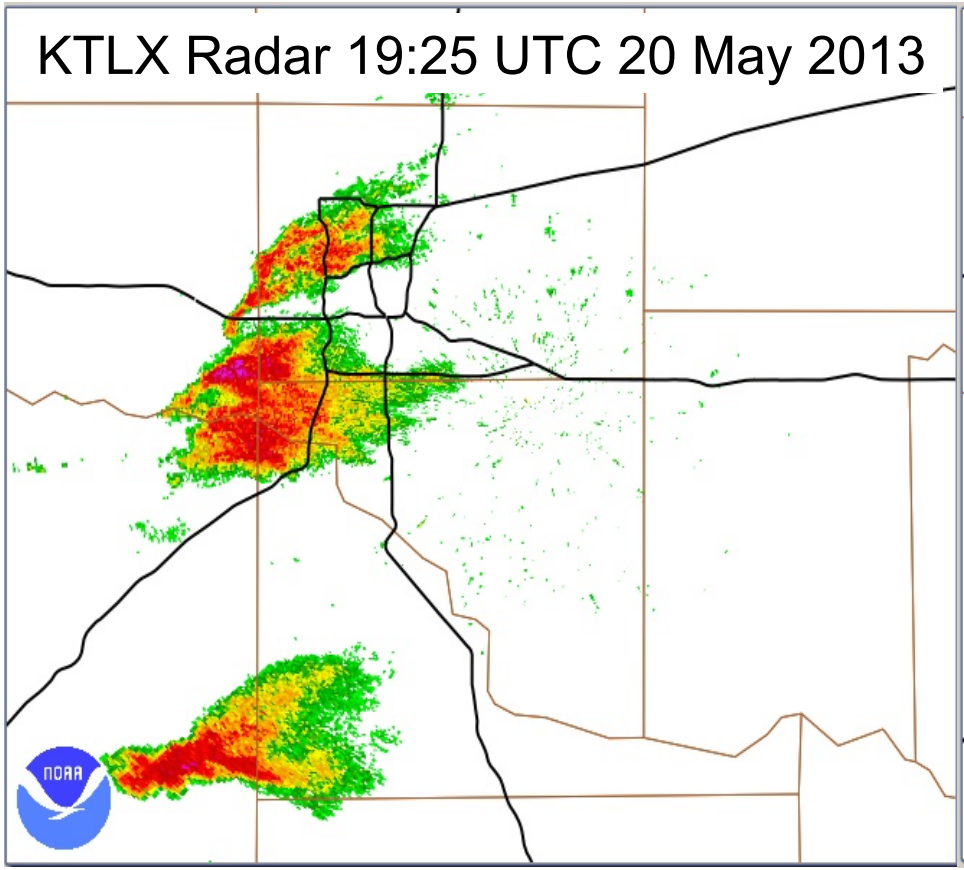
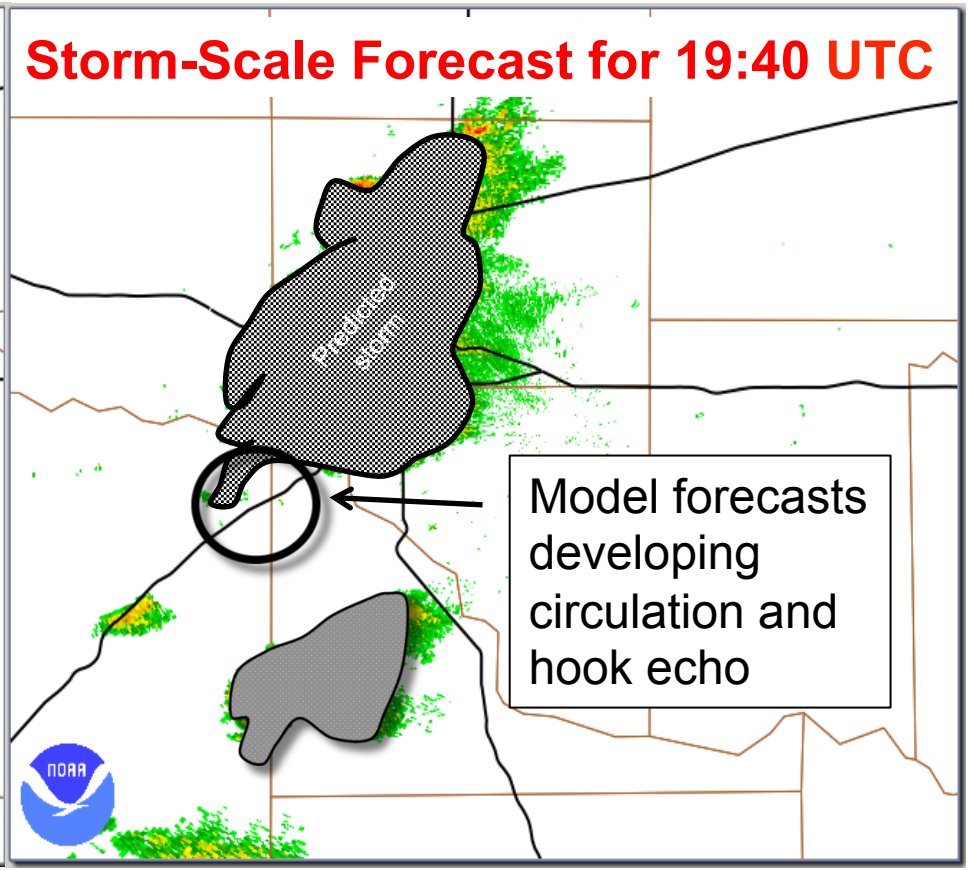
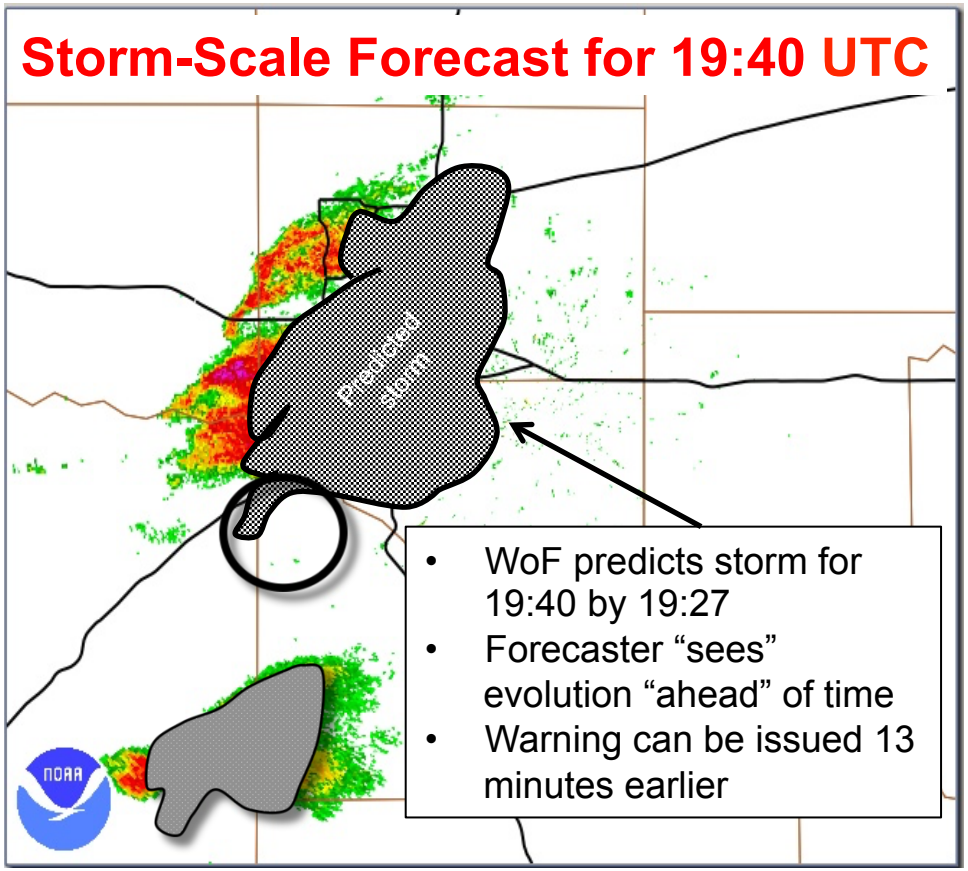


# Future Warning Process: *"Warn on Forecast"*

*"Probabilistic warnings enabled by combining observations with rapidly-updating, high-resolution storm-scale models"*



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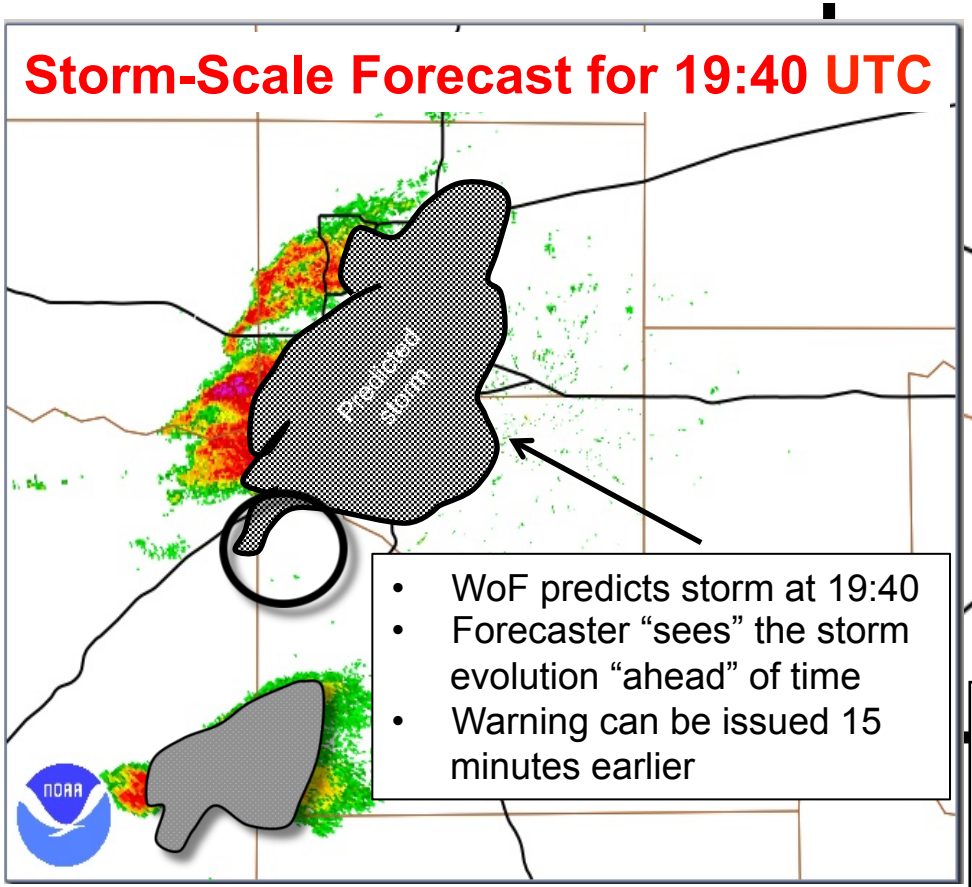
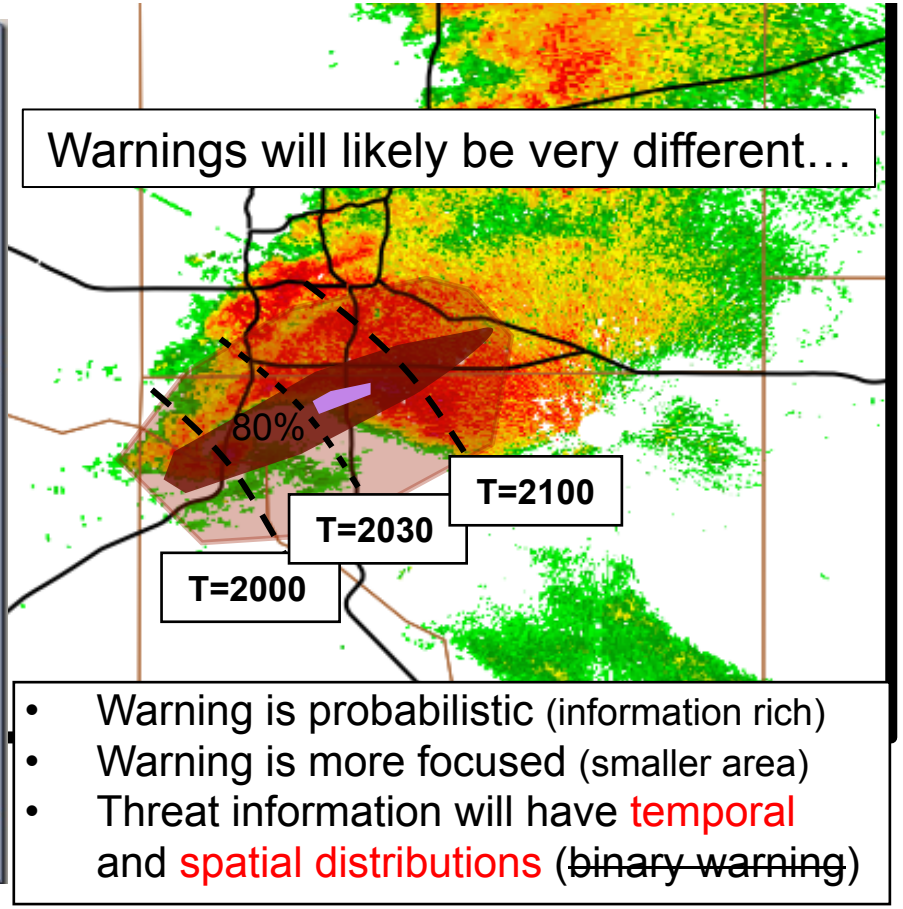



***FACETS will be the delivery system for WoF-probabilistic warnings***

# Why NSSL?

- **Our Core Strengths**
  - Radar (Doppler, dual-Pol, MPAR)
  - Severe storms observations and dynamics
  - Storm-scale NWP and ensembles
    - NSSL has introduced these into SPC and OUN through HWT interactions
  - Warnings research and applications
    - NSSL has long history of R2O for NWS warning operations

# Warn on Forecast Overview

- **~$2.6M annual budget**
- **Supports:**
  - Internally
    - 9 PhD scientists currently
    - 4 post-docs / 2.5 staff support
    - 1-3 M.S./Ph.D. students supported on average
  - Externally supports (~$800K)
    - funding goes to SPC, NWS OUN, GSD, CAPS, OU, PSU
    - Supports 4-5 more staff positions and several senior scientist months
- **Other significant collaborations**
  - CIMSS (Wisc.), NESDIS, NCEP/EMC
  - NCAR Mesoscale Prediction Group &  IMAGe
- **Measures of Quality and Relevance and Progress (last 5 years)**
  - ~100 peer-reviewed papers published in the last 5 years
  - ~200 presentations at national or international conferences and workshops
  - ~dozen regional WoF prediction test cases completed in last two years

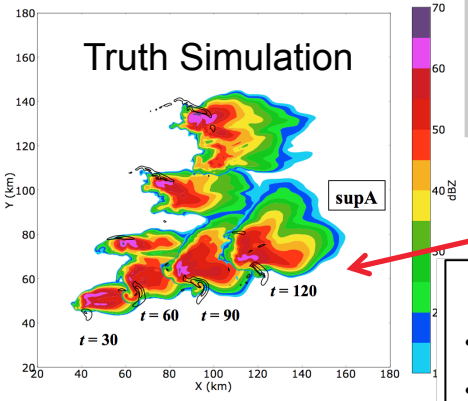
# WoF Science…

- Rest of presentation will focus on our scientific achievements…
  - *Practical predictability of supercells and other severe weather threats?*
  - *Are the current prediction systems ACCURATE enough to predict these events reliably?*
  - *Could rapid-scan radar data (MPAR) improve storm-scale forecasts?*

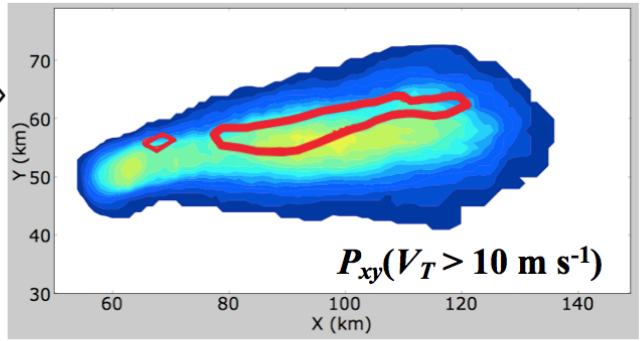
# Practical Predictability of Supercells?

Potvin, C. K., L. J. Wicker, 2013: Assessing ensemble forecasts of low-level supercell rotation within an OSSE framework. ***Wea. Forecasting*, 28**, 940–960

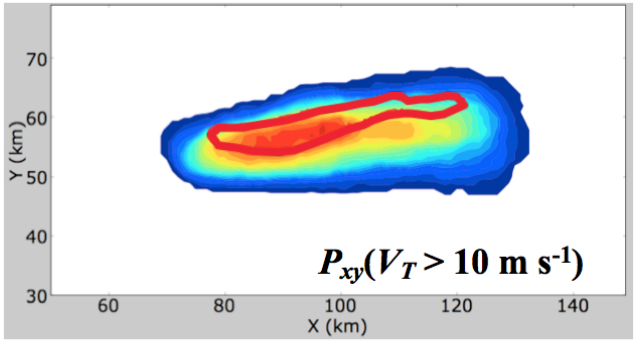
**Both radars located far away from storm (> 100 km)**



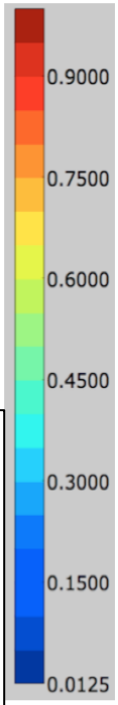

***Probability of Sig. Rotation Forecast after 7 radar Volumes***




***Probability of Sig. Rotation Forecast after 11 radar Volumes***




Probability From Ensemble




**Red contour:**
**Where "truth" storm has rotational velocity > 10 m $s^{-1}$**

## What is an Observing Systems Simulation Experiment (OSSE) study?

- Generate synthetic observations using "nature run" from a high-resolution prediction model
- Assimilate these synthetic observations back into your NWP system
- Because you know the "truth" from the "nature run" – you what the answer should be – can study…
  - Best assimilation methods / impact of new observations / needed obs resolution, etc.
  - Here: OSSE used to study radar location and its impact on forecasts
- Problem: **Hard** to create OSSEs that accurately represent real-world errors: Results are too optimistic!

# Practical Predictability of Supercells?

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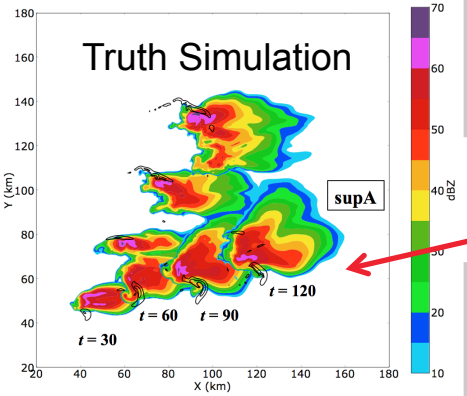
## OSSE Study

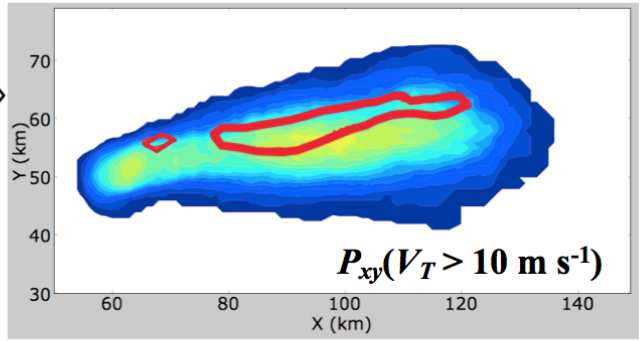
- Generate synthetic observations using model
- Assimilate observations back into model
- Determine potential impact and predictability

**Both radars located far away from storm (> 100 km)**




**2nd radar 50-60 km from storm**

***Probability of Sig. Rotation Forecast after 7 radar Volumes***

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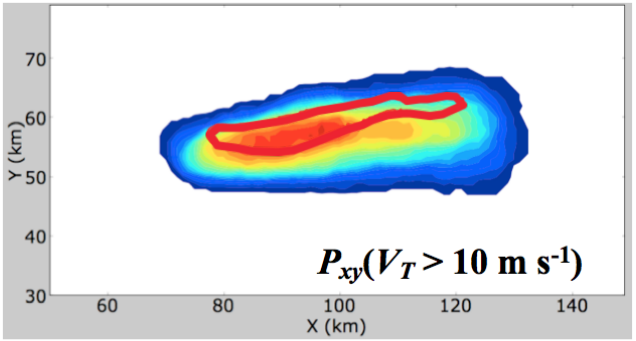
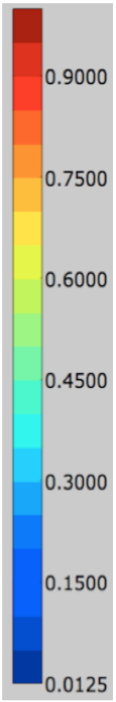



Probability From Ensemble

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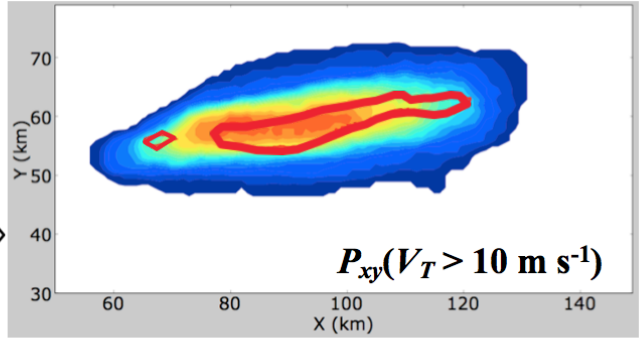
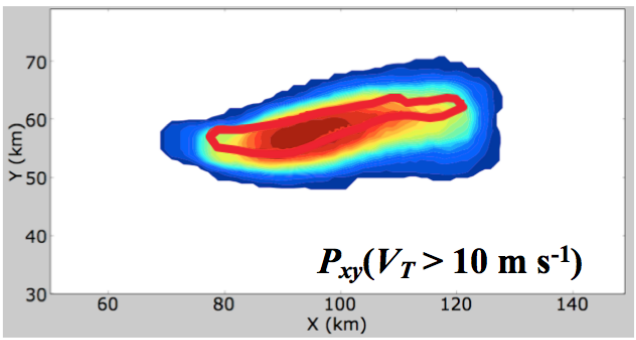


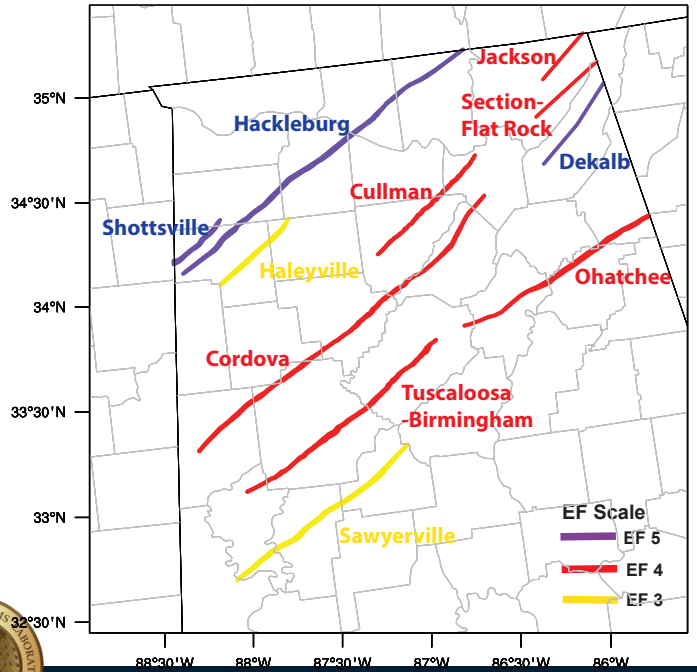



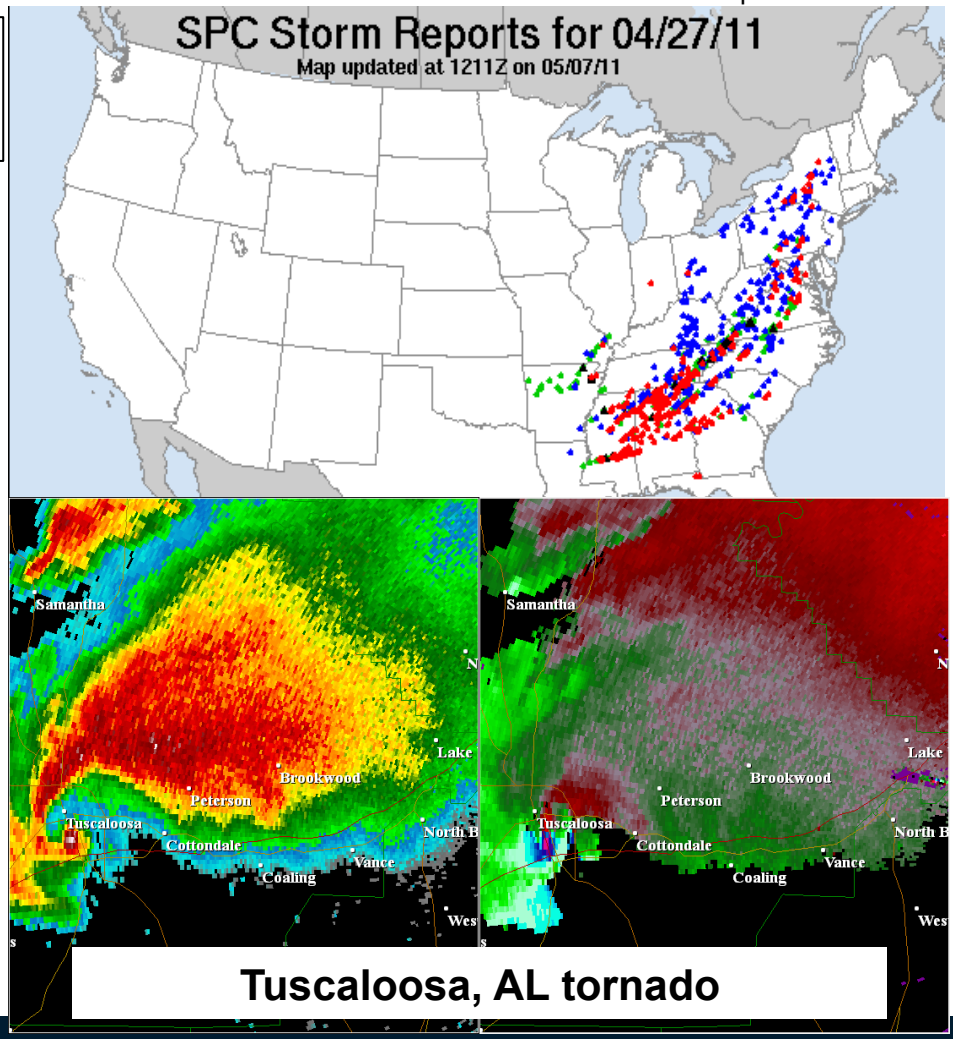
# Are Models Accurate Enough?

Yussouf, N., D. C. Dowell, L. J. Wicker, K. Knopfmeier, and D. M. Wheatley, 2015: Storm-scale data assimilation and ensemble forecasts for the 27 April 2011 severe weather outbreak in Alabama. ***Mon. Wea. Rev***. Accepted with revisions

## Storm-scale Predictions from 27 April 2011 Super Outbreak

**~300 tornadoes**
**348 fatalities from tornadoes and other thunderstorm hazards**

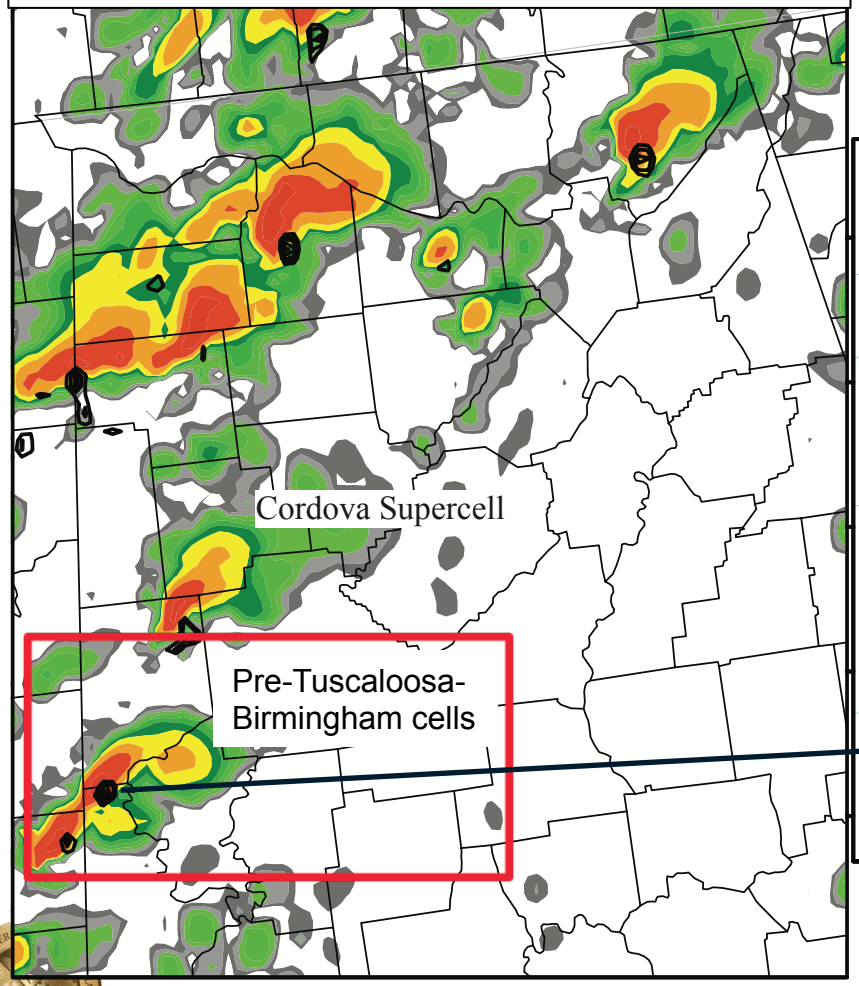



**Tuscaloosa, AL tornado**

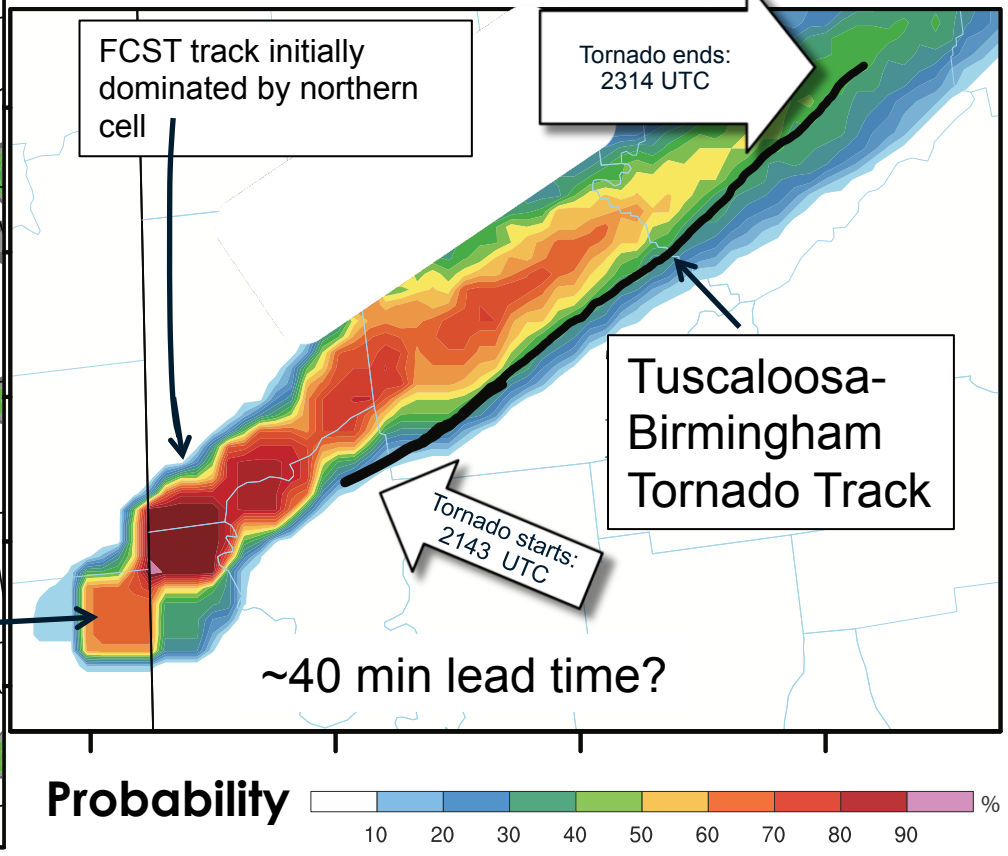
# Are Models Accurate Enough?

Model Reflectivity Analysis
Valid: 2100 UTC



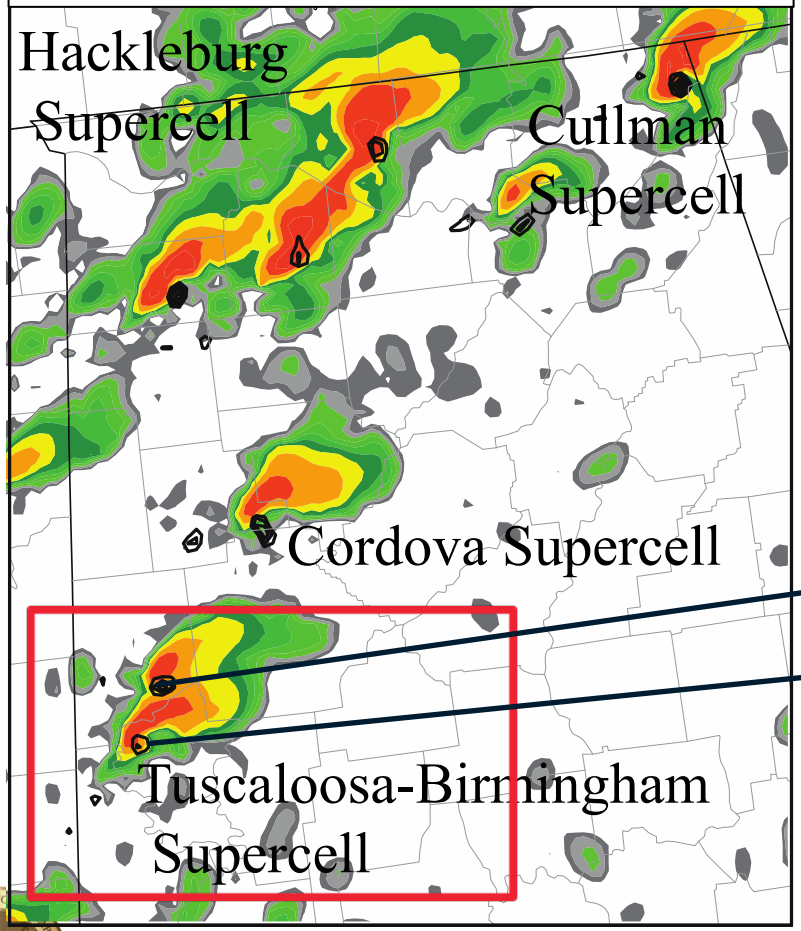

Rotation track prediction for
Tuscaloosa-Birmingham storm
Valid: 2100-2315 UTC (135 min forecast)

*Two storms are near MS border ….*

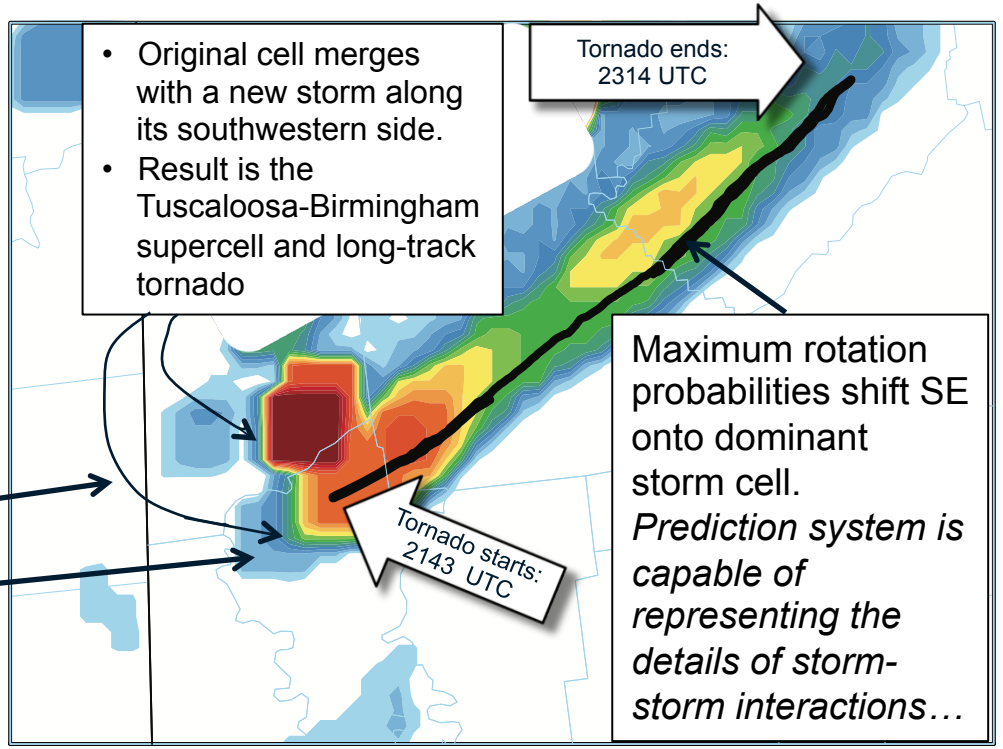


# Are Models Accurate Enough?

Model Reflectivity Analysis
Valid: 2130 UTC

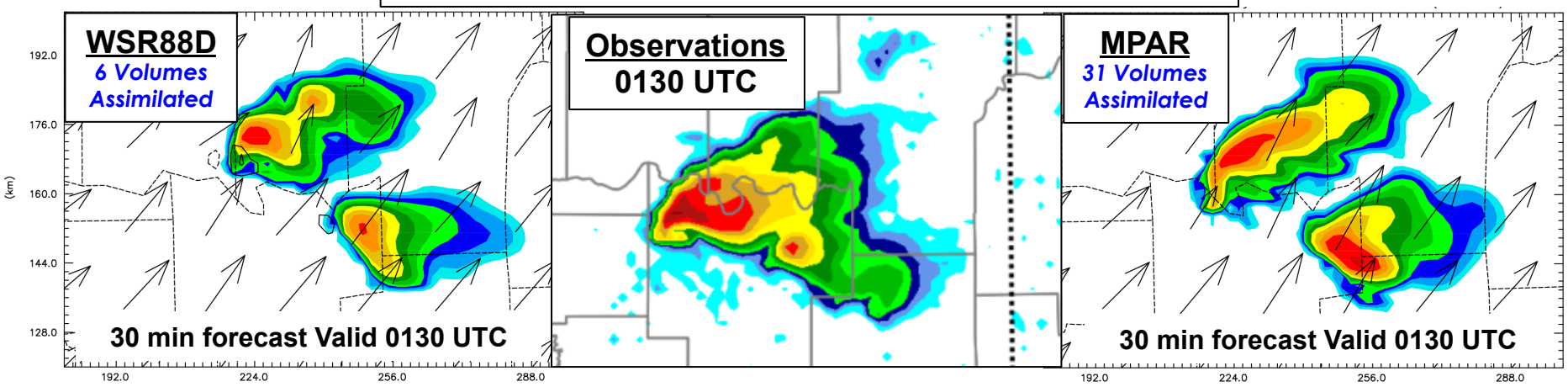



30 Minutes Later: Rotation Track Prediction
Valid: 2130-2315 UTC (105 min forecast)
*Southwestern cell becomes dominant…..*



# Impact from Rapid-Scan Radar (MPAR) on Storm-scale NWP

**Mean forecasts after 30 min of data assimilation**




Cheng, J. and N. Yussouf
**Mon. Wea. Rev.**, 2016?

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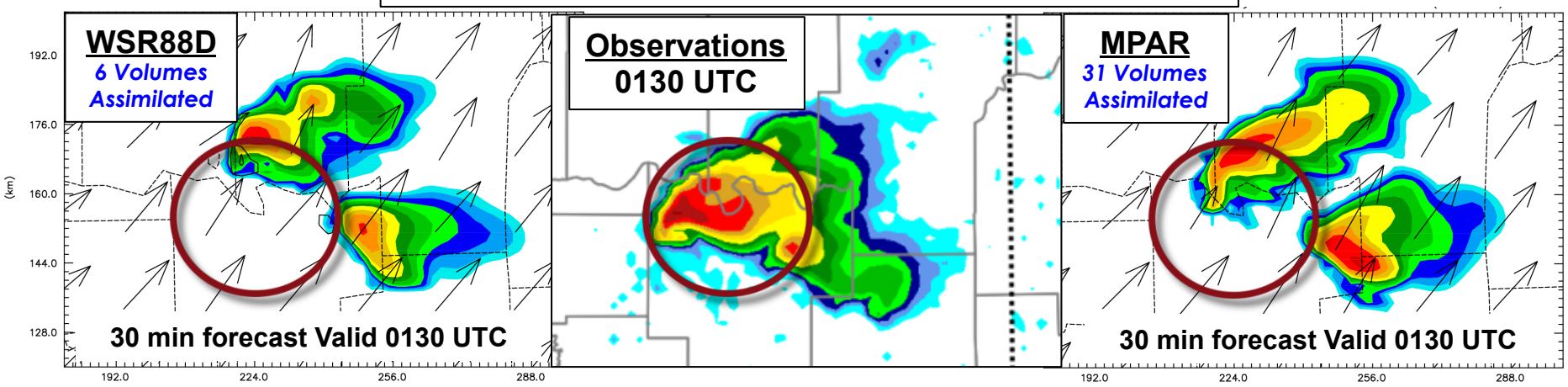


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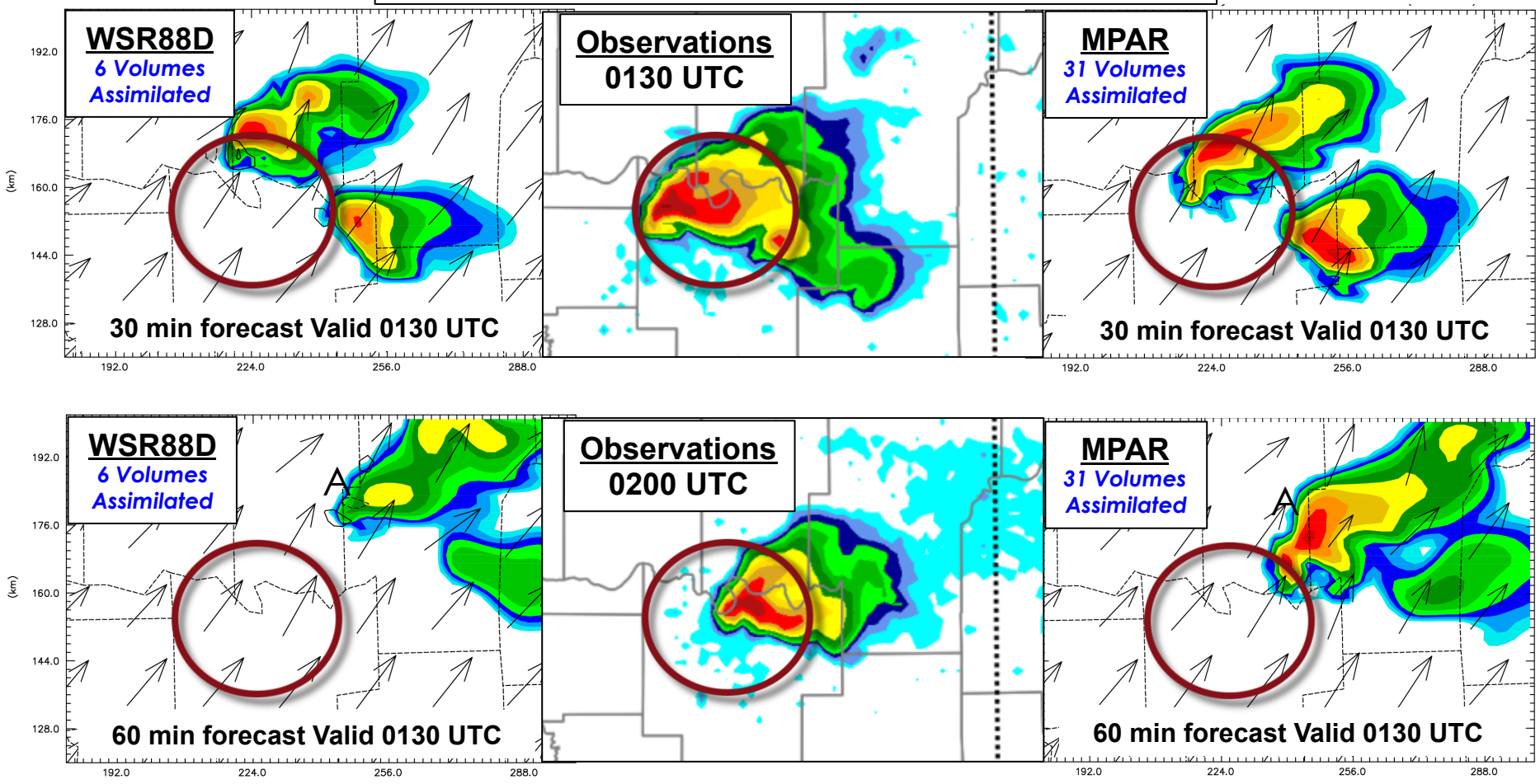


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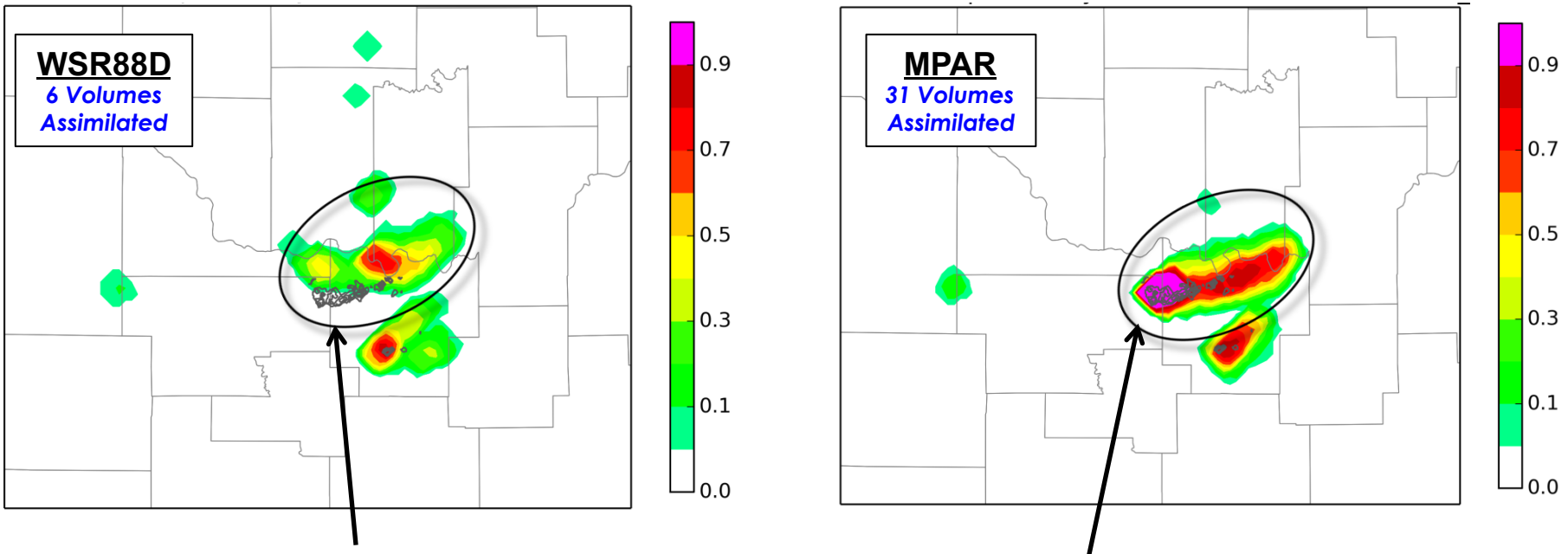
# Impact from Rapid-Scan Radar (MPAR) on Storm-scale NWP

## One hour ensemble forecasts after 30 min of data assimilation

Ensemble Probability of Strong Low-level Rotation ($z > 0.002\ s^{-1}$)

**Forecast Period: 0100-0200 UTC**




Gray contours are the WDSS-II rotation locations
Tornado is from 0119-0141 UTC

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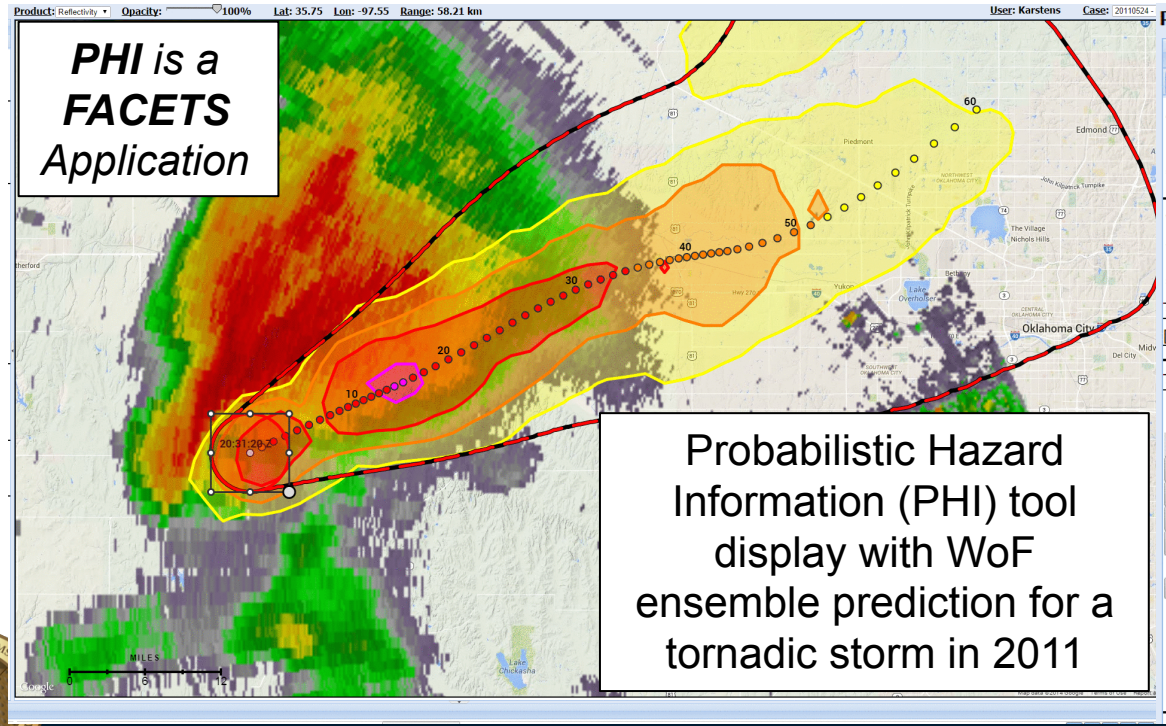
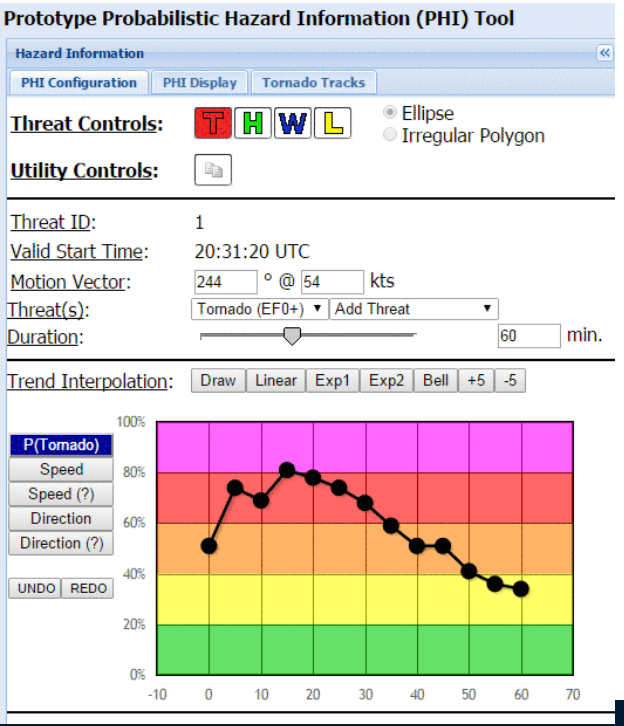
# How will forecasters use a storm-scale prediction system?

- *NSSL experimental WoF System-enKF (NeWS-e) experiment (May 2015)*
  - Prototype WoF system at 3 km resolution over relocatable 700 km$^2$ domain
  - Storm-scale ensemble analysis every 15 min / 90-min forecast every hour
  - Output evaluated using the Probabilistic Hazard Information (PHI) tool



# Summary

- WoF project has demonstrated skill predicting storm tracks and rotational intensities for 0-2 hours for real-data case studies.
- Improved forecasts from assimilation of MPAR data relative to 88D data
- NSSL experimental WoF System tests of EnKF, cycled 3DVAR, hybrid all on the way…
- QRP for last 5 years:
  - ~100 peer-reviewed / ~200 presentations / ~ dozen case studies / real time system development


# Summary (continued..)

## Future Work

- Improve balance in storm-scale analyses from remotely-sensed observations.
  - *Use of dual-polarization radar data in storm-scale analysis systems?*
  - *Incorporation of dynamical constraints in analysis and reduction in model errors*
- Understanding how WoF output could/would be used by operational forecasters
  - *How to post-process ensemble data output into probabilistic forecasts:* ***"FACETS"***
  - *How can forecasters feedback guide our research emphasis?* ***O2R!***
- For WoF to reach its full potential requires a more accurate measurement of the storm-scale environment than the current observational network permits.
  - *Vertical profiles of temperature, humidity and wind in boundary layer needed for CONUS. Ground-based thermodynamic and Doppler lidar profilers?*
  - *More radar observations are needed for CONUS in lowest 2 km!*

# Questions?