INFORMATION EXTRACTION AND VERIFICATION OF CONVECTION-ALLOWING MODELS FOR TORNADO FORECASTING

Israel Jirak, *NOAA/Storm Prediction Center*
Harold Brooks, *NOAA/National Severe Storms Laboratory*
Matt Pyle, *NOAA/Environmental Modeling Center*

Robert Hepper, *CIMMS/SPC Research Associate*
Jeff Milne, *OU Grad Student and CIMMS/SPC Research Assistant*

Project Overview

- Collaborative effort among SPC, NSSL, and EMC to improve severe weather forecasting
- Direct involvement with the Hazardous Weather Testbed (HWT) for testing and evaluation of products/techniques
- Addresses NGGPS program priority of advancing forecasts for high-impact weather in days 0-3 by focusing on the operational utility of CAMs and CAM ensembles
- Two primary components:
  - Verification
    - Evaluate various convection-allowing model (CAM) ensemble configurations and assess current skill of CAMs using appropriate metrics
  - Information Extraction
    - Develop techniques/diagnostics to mine useful information embedded within convection-allowing models for severe weather forecasting

Verification:
CAM Ensemble Design

- **Community-Leveraged Unified Ensemble (CLUE)**
  - *Inspired by the UMAC to provide evidence-based decision making with regard to the design of a future operational convection-allowing ensemble*
  - *Unprecedented effort to leverage several academic and government research institutions to help guide NOAA's 0-36 h operational prediction of convective storms*
  - GOAL: **Design experiments to provide more controlled datasets that can be better utilized to inform configuration of near-future operational systems**
  - Contributors agreed on a set of model specifications (e.g., model version, grid-spacing, domain, vertical levels, physics, input data).
  - Post-processing was also formalized. All groups output the same set of fields in grib2 format using a modified version of UPP.
  - **2018 Contributors:** OU (CAPS & MAP), NCAR, NSSL, and ESRL/GSD – 70 Total CLUE Members

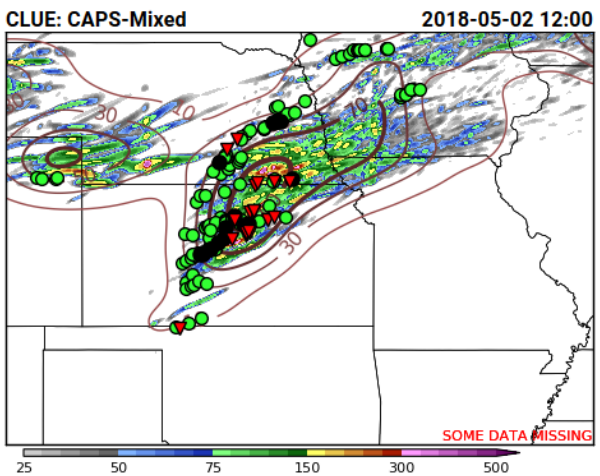
Verification:
2018 HWT CLUE Experiments

- The design of the 2018 CLUE allowed for three primary controlled experiments:
  - Data assimilation experiments (HRRRe, NCAR, OU MAP)
  - FV3 physics experiments at CAM scales (CAPS, GFDL, NSSL)
  - **Stochastic physics experiment** (CAPS) - Three different eight-member CAM ensembles using the same initial conditions and lateral boundary conditions:
    - *Single physics*: all members using HRRR physics (MYNN, Thompson)
    - *Stochastic physics*: members with stochastic perturbations applied to HRRR physics, as recommended by DTC and GSD
    - *Mixed physics*: members with varied PBL (MYNN, MYJ, YSU) and microphysics schemes (Thompson, NSSL, Morrison, P3)

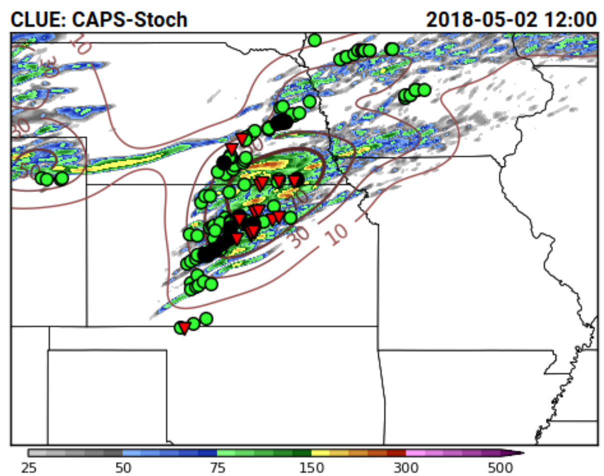
Verification:

2018 HWT CLUE Experiments: ***Stochastic Physics***

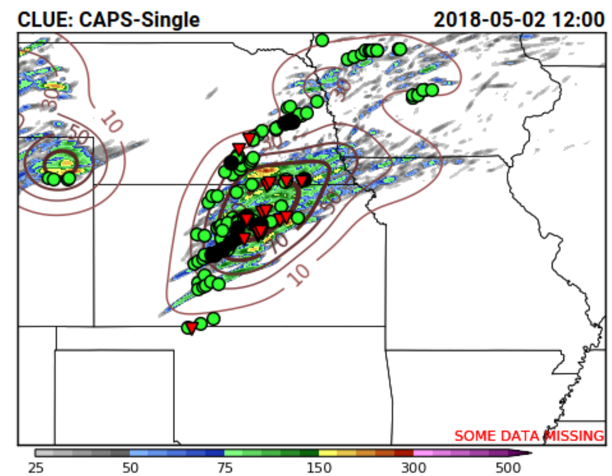
- HWT SFE participants examined the ensemble UH forecasts from the stochastic physics experiment and subjectively rated the quality of the forecasts from a severe weather perspective.



Mixed Physics



Stochastic Physics



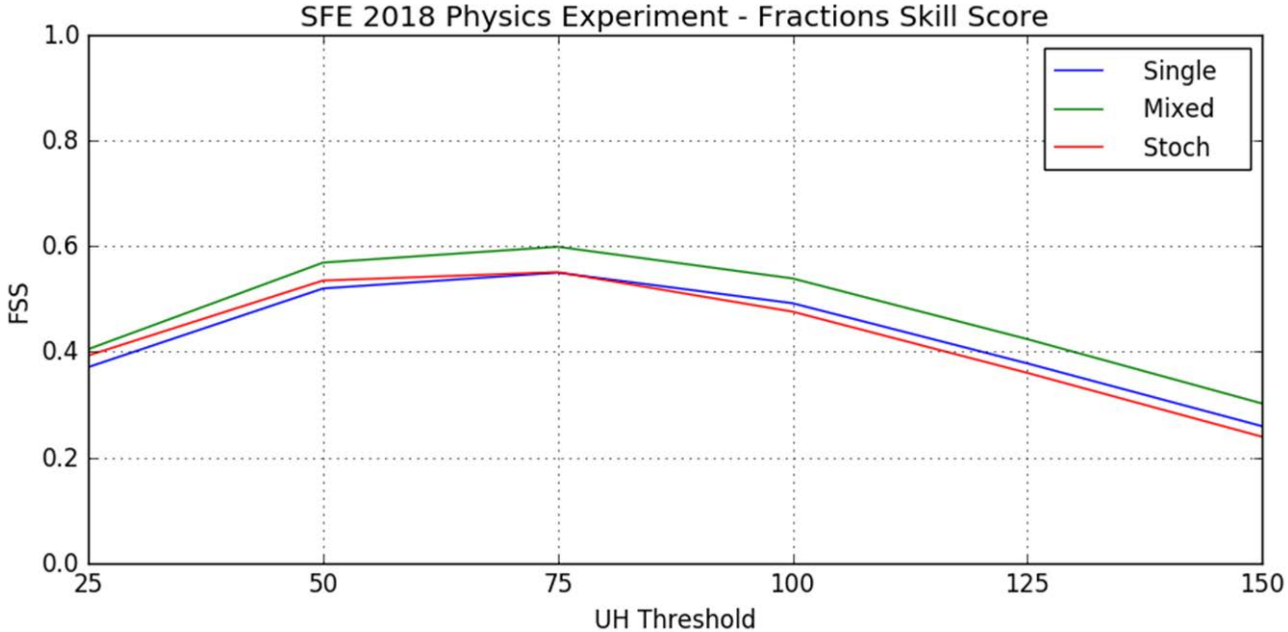
Single Physics

36-h Forecast of 24-h Updraft Helicity
Valid 12Z 01 May 2018 – 12Z 02 May 2018

Verification:

2018 HWT CLUE Experiments: ***Stochastic Physics***

- Surrogate severe verification (Sobash et al. 2016) suggests very similar performance between single- and stochastic-physics ensembles and a slight edge overall in performance to the mixed-physics ensemble

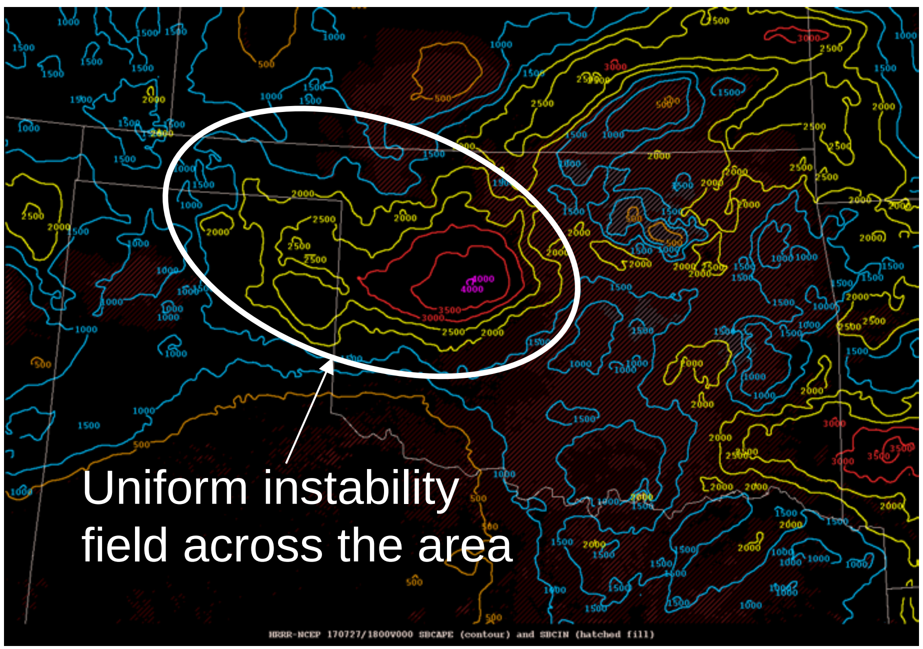


	25	50	75	100	125	150
Single	0.371	0.520	0.550	0.492	0.378	0.259
Mixed	0.405	0.569	0.599	0.539	0.424	0.302
Stoch	0.393	0.535	0.551	0.476	0.360	0.239

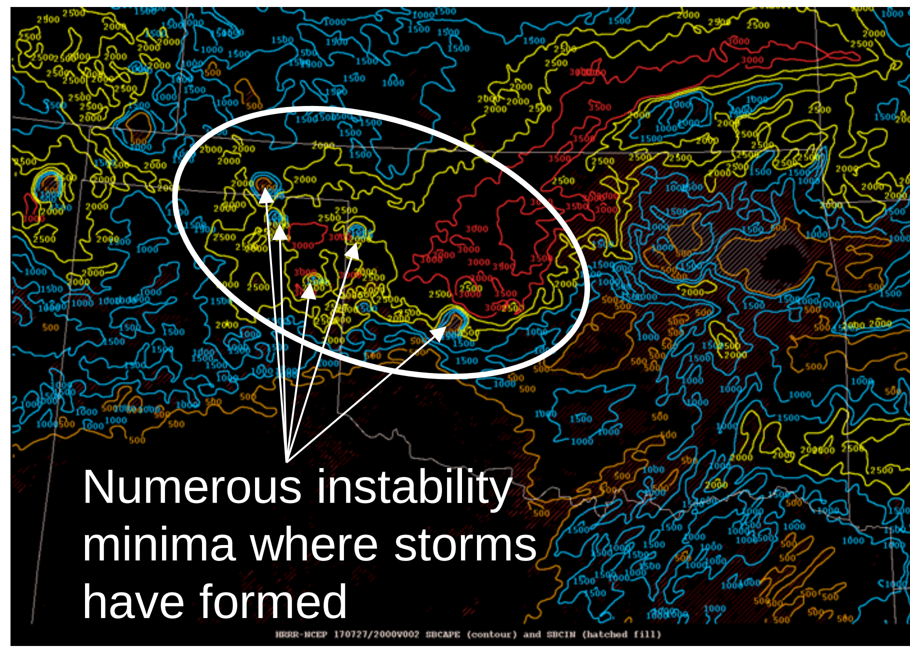
Information Extraction:

Pre-Convective/Near-Storm Environment in CAMs

- Near-storm environment fields from CAMs are very detailed and strongly modulated after models initiate storms, so forecasters often prefer examining these fields from coarser resolution models
- Identify an optimal approach for extracting pre-convective and near-storm environment information from CAMs



18Z HRRR 0-h SBCAPE/SBCIN
Valid 18Z on 27 July 2017

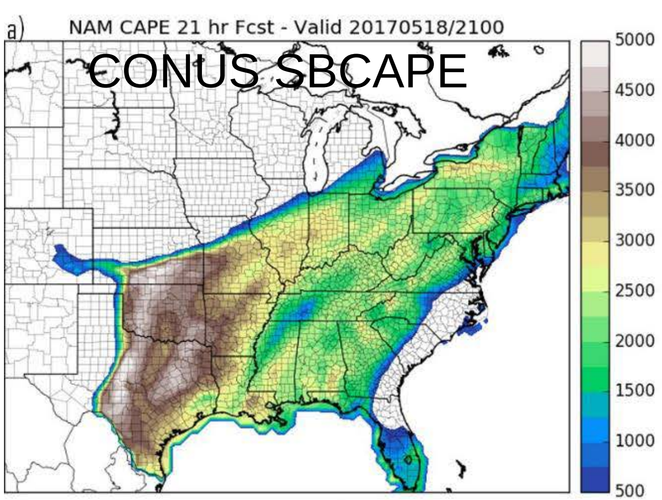


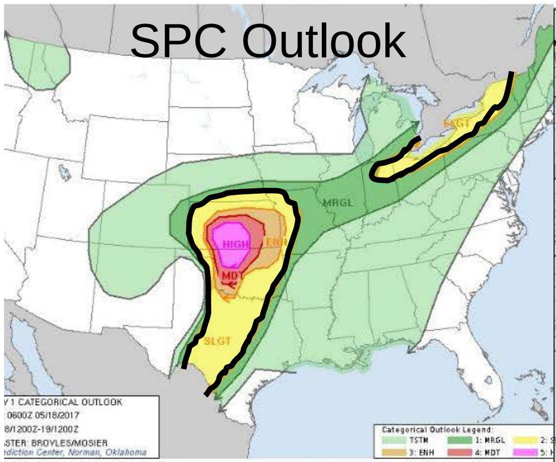
18Z HRRR 2-h fcst SBCAPE/SBCIN
Valid 20Z on 27 July 2017

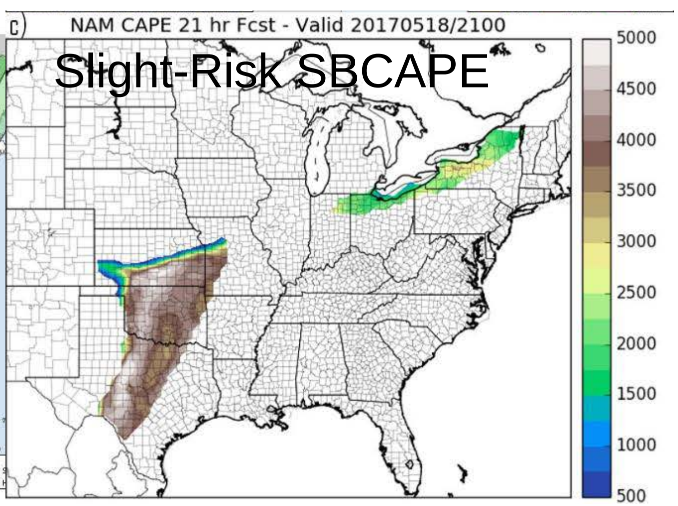
Information Extraction:

Pre-Convective/Near-Storm Environment in CAMs

- Examined 0-36 hour forecasts of convective-related fields, such as surface-based convective available potential energy (SBCAPE), from 0000 UTC runs of the NAM parent (12-km) and NAM Nest (3-km) for April-August 2017
- These NAM forecasts were re-gridded to a 40-km grid to match that of the verification dataset, which is the RAP-based SPC mesoanalysis
- Statistics (RMSE, bias) were calculated for the full CONUS and for SPC Slight-Risk areas



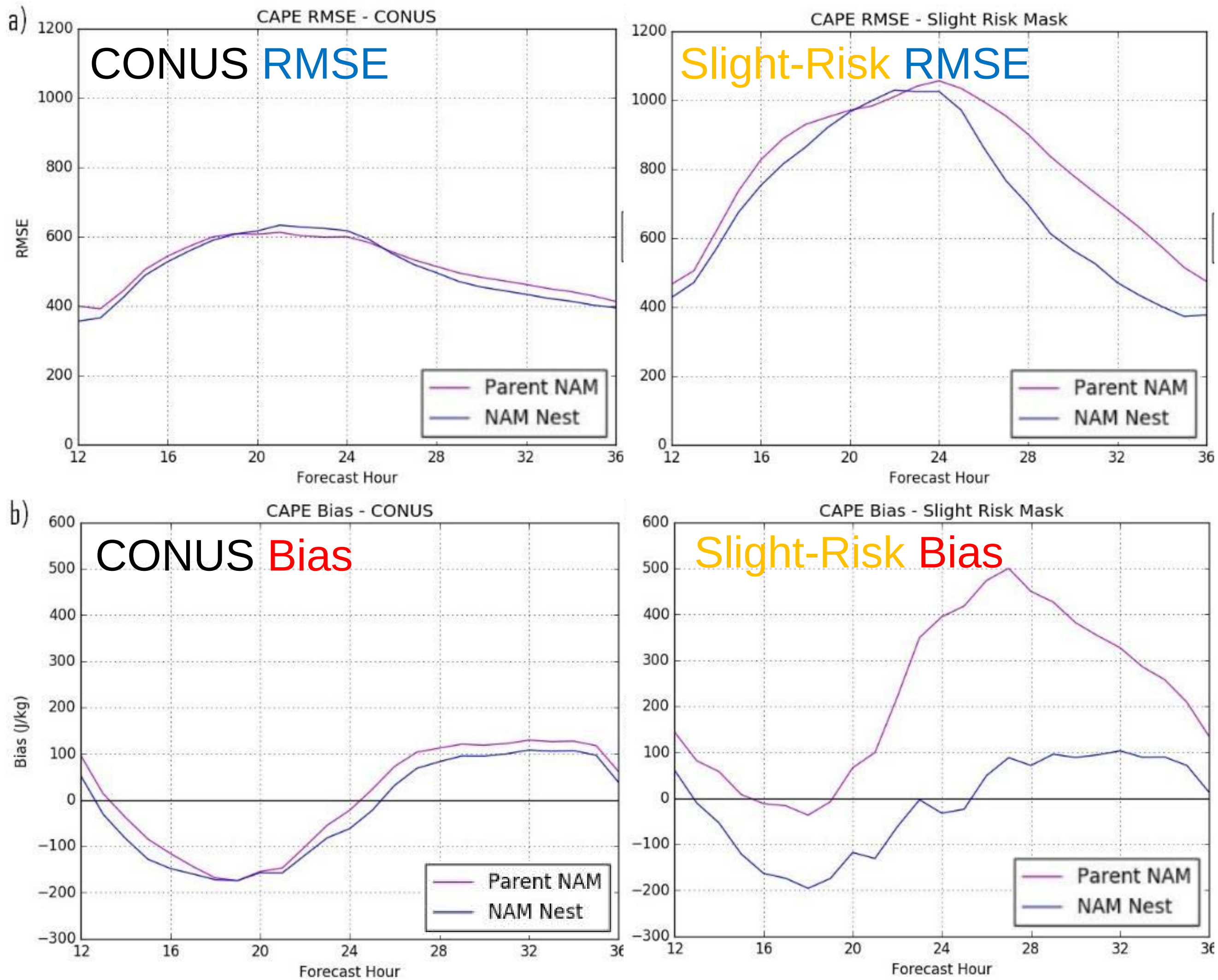




Information Extraction:

Pre-Convective/Near-Storm Environment in CAMs

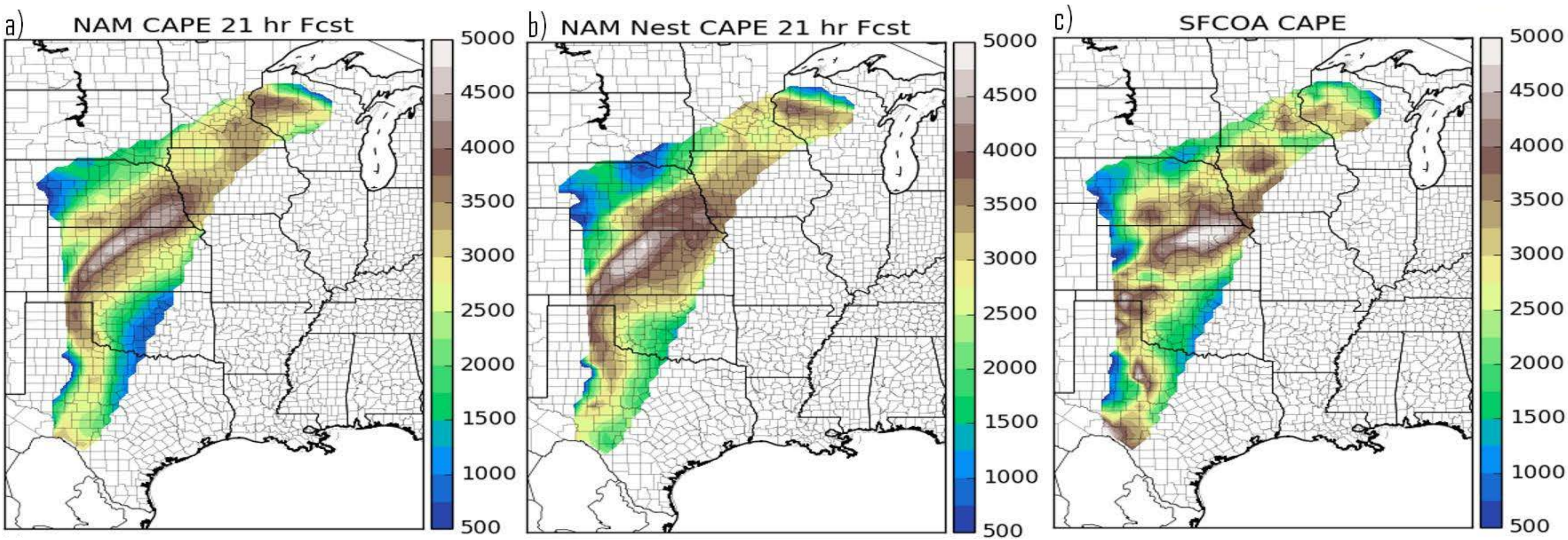
- NAM Parent and Nest perform similarly over CONUS for SBCAPE forecasts, but Nest is much improved over parent for SPC Slight Risk areas after 23 UTC
- Similar results for other fields (e.g., 2-m Td)



Information Extraction:

Pre-Convective/Near-Storm Environment in CAMs

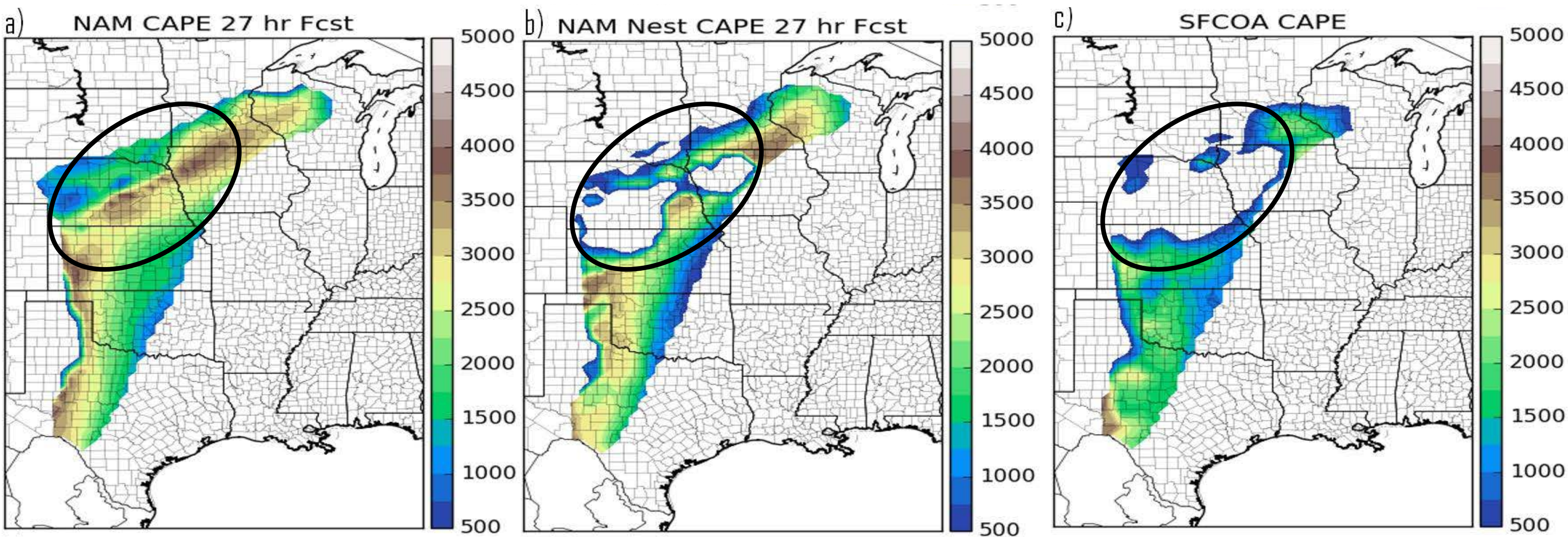
- For this example on 16 May 2017, the NAM parent (left) and NAM Nest (middle) 21-h SBCAPE forecasts look similar (magnitudes, instability axes, etc.)
- The RAP-based SPC mesoanalysis (SFCOA) used for verification is shown on the right



Information Extraction:

Pre-Convective/Near-Storm Environment in CAMs

- Six hours later into the forecast (valid 03 UTC on 17 May), the NAM Nest (middle) does a much better job than the NAM Parent (left) in removing instability where thunderstorms and precipitation have occurred



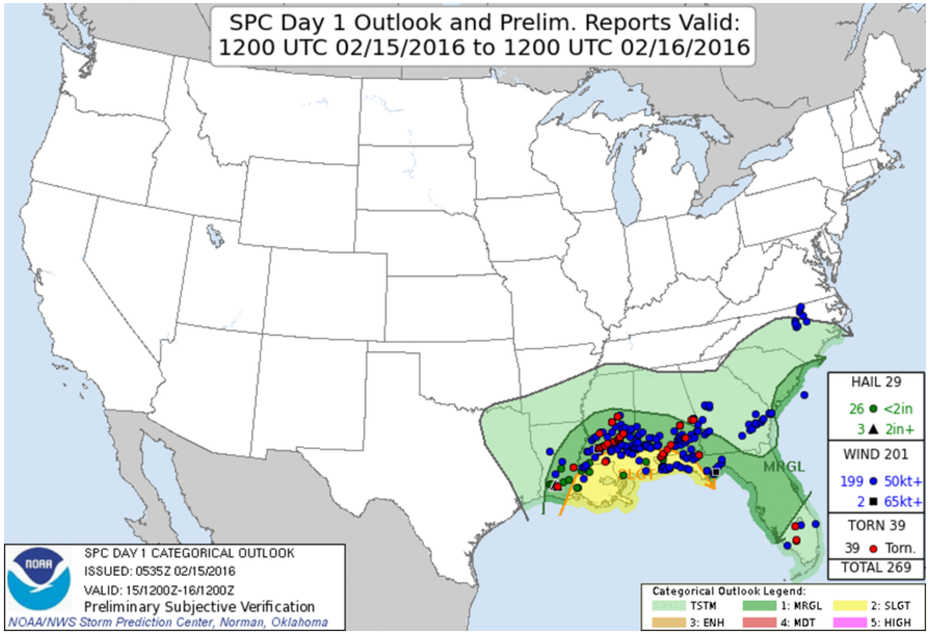
Information Extraction:

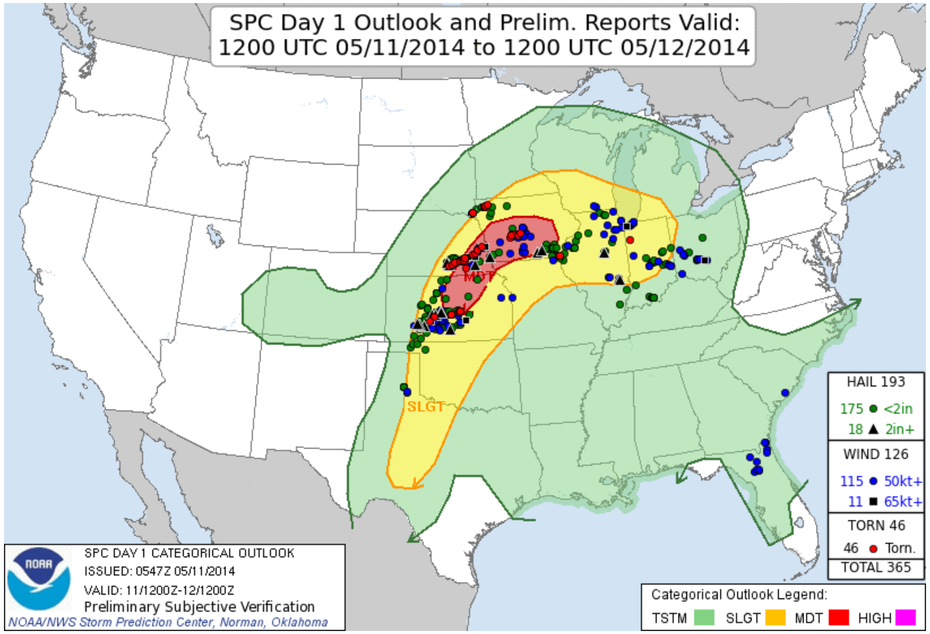
Refine UH Diagnostic for Tornado Prediction

- While updraft helicity (UH) output provides indication of rotation in simulated storms, more information needs to be considered for tornado potential
- UH formula: $UH = \int_{z_0}^{z_1} w * \zeta \, dz$
- UH is usually calculated between **2-5 km** or 0-3 km AGL
- Want to investigate how w and ζ behave and change with time and height within simulated storms
- Goal is to generate a UH diagnostic that best identifies tornado potential in CAMs

Information Extraction:
Refine UH Diagnostic for Tornado Prediction

- Performed two simulations using NSSL-WRF configuration at 3-km grid spacing for a detailed investigation of UH:
  - Cool-Season Southeast Tornado Event: 15 February 2016
  - Spring Plains Tornado Event: 11 May 2014

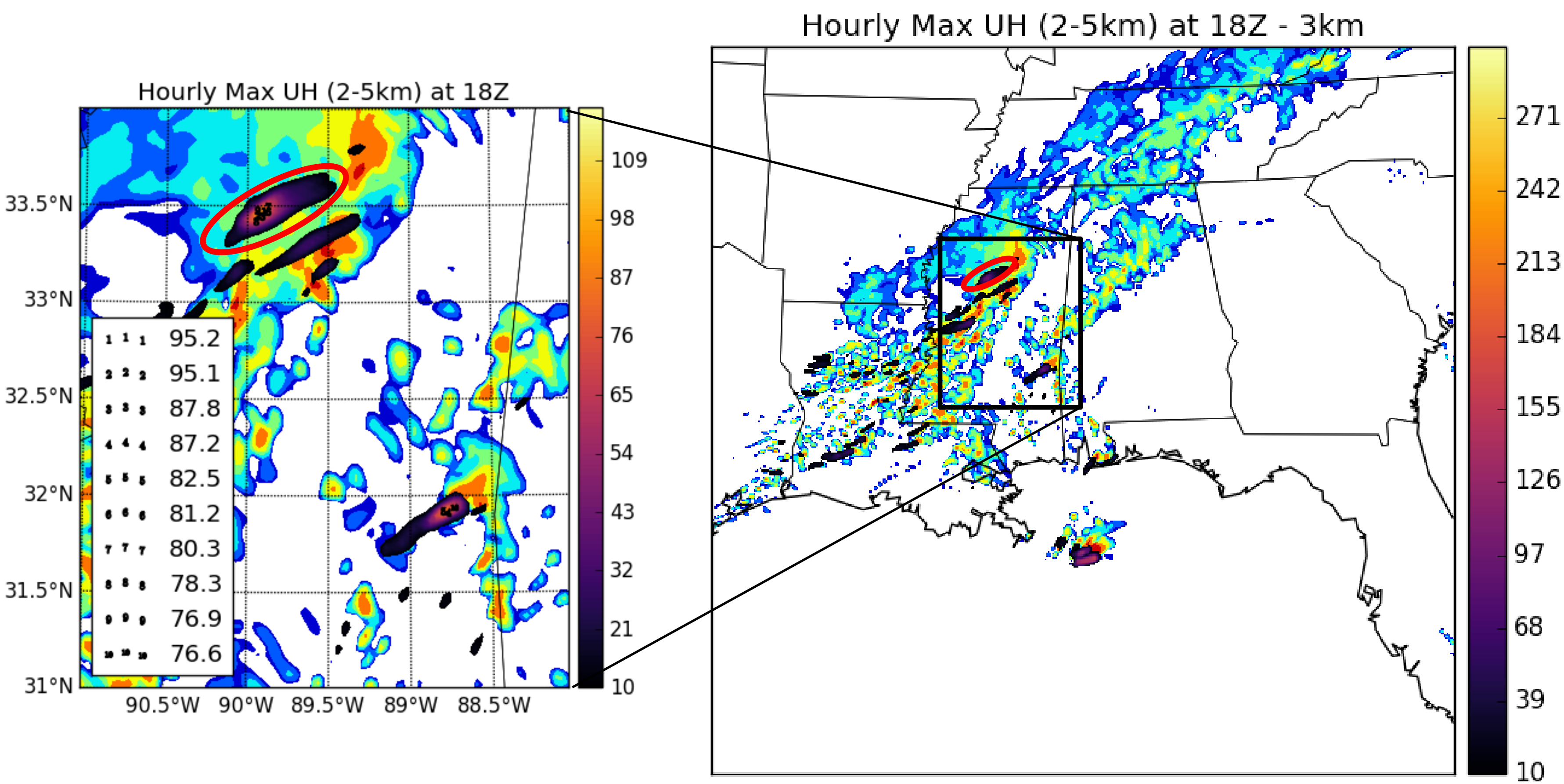




Information Extraction:

Refine UH Diagnostic for Tornado Prediction: 15 Feb

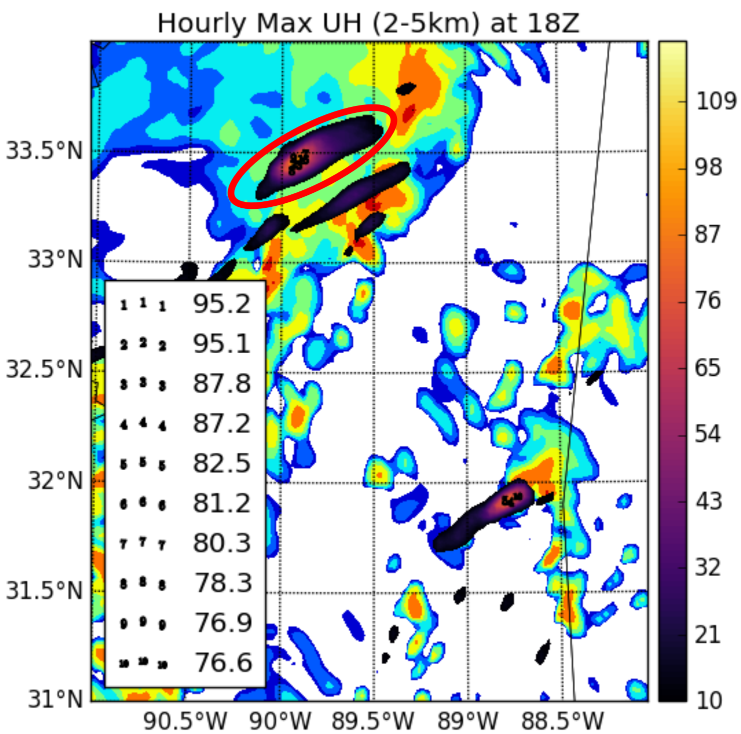
- For the cool season case, the focus will be on 2-5 km AGL UH swaths in northern Mississippi between 17 and 18 UTC

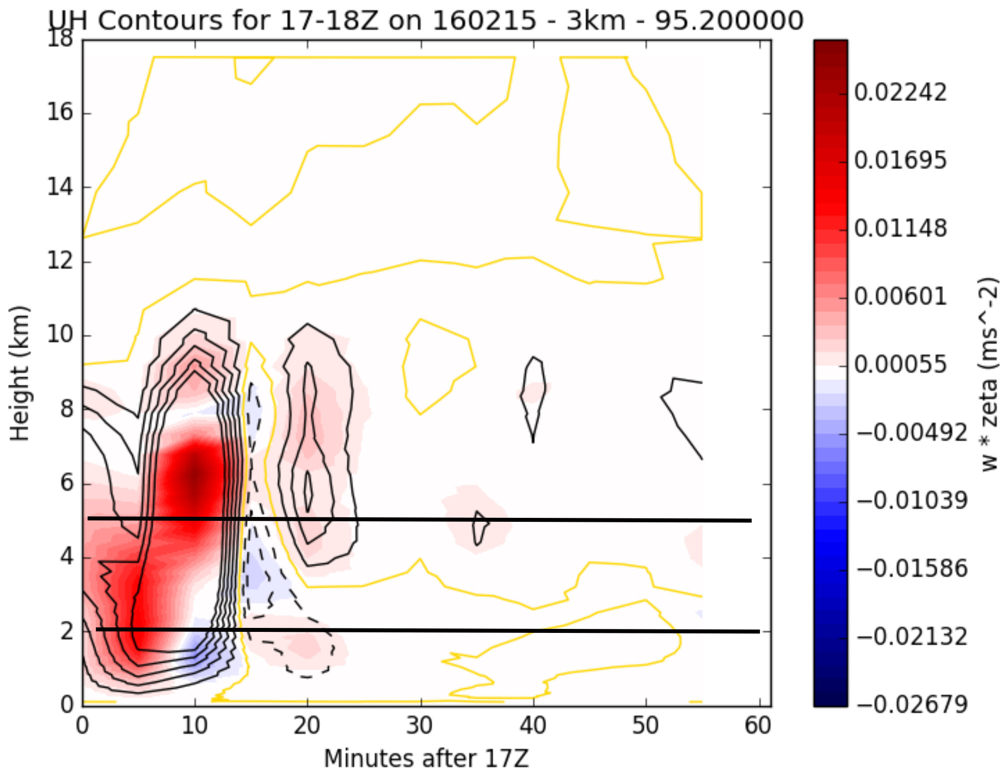


Information Extraction:

Refine UH Diagnostic for Tornado Prediction: 15 Feb

- Looking at the evolution of w*ζ over the hour at a single grid point, the peak magnitude occurs near 6 km AGL

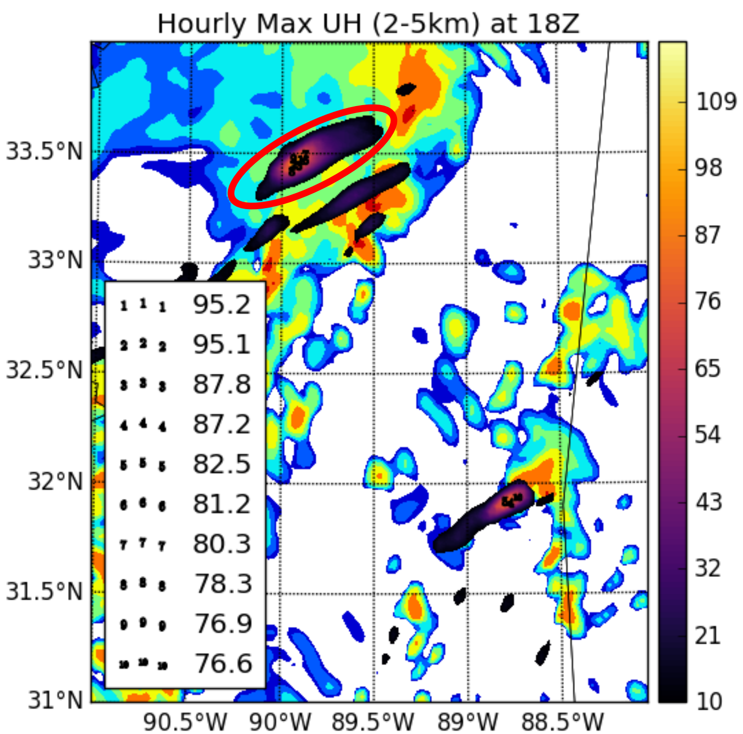


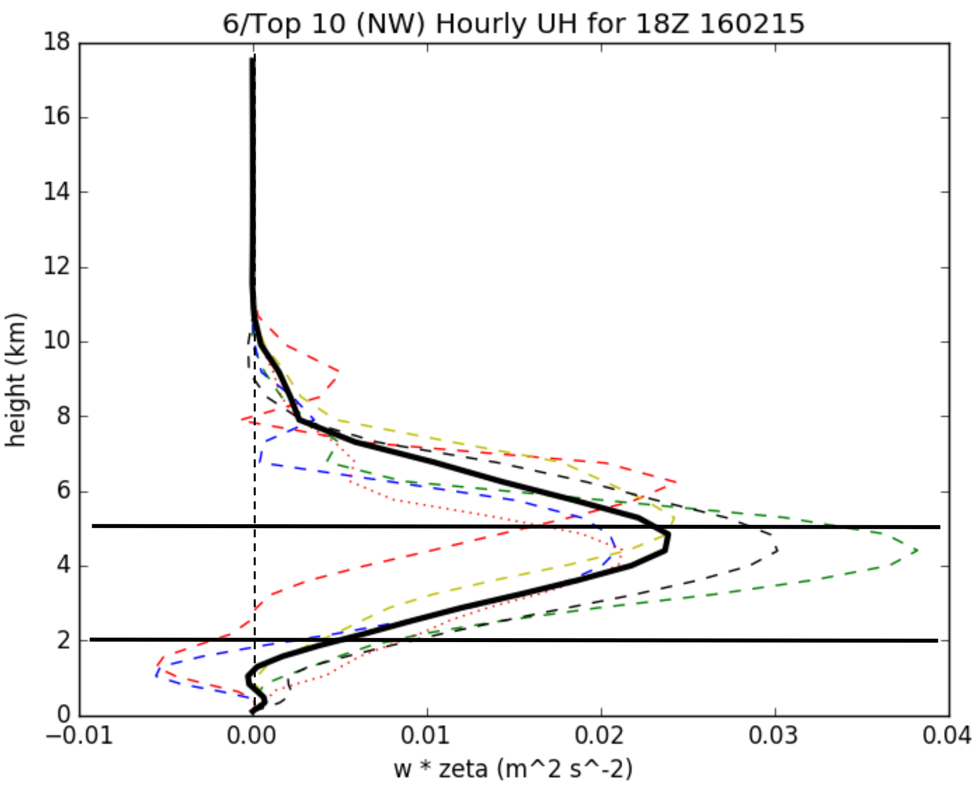


Information Extraction:

Refine UH Diagnostic for Tornado Prediction: 15 Feb

- The vertical w*ζ profiles from the northern UH swath look similar with values peaking near 5 km AGL

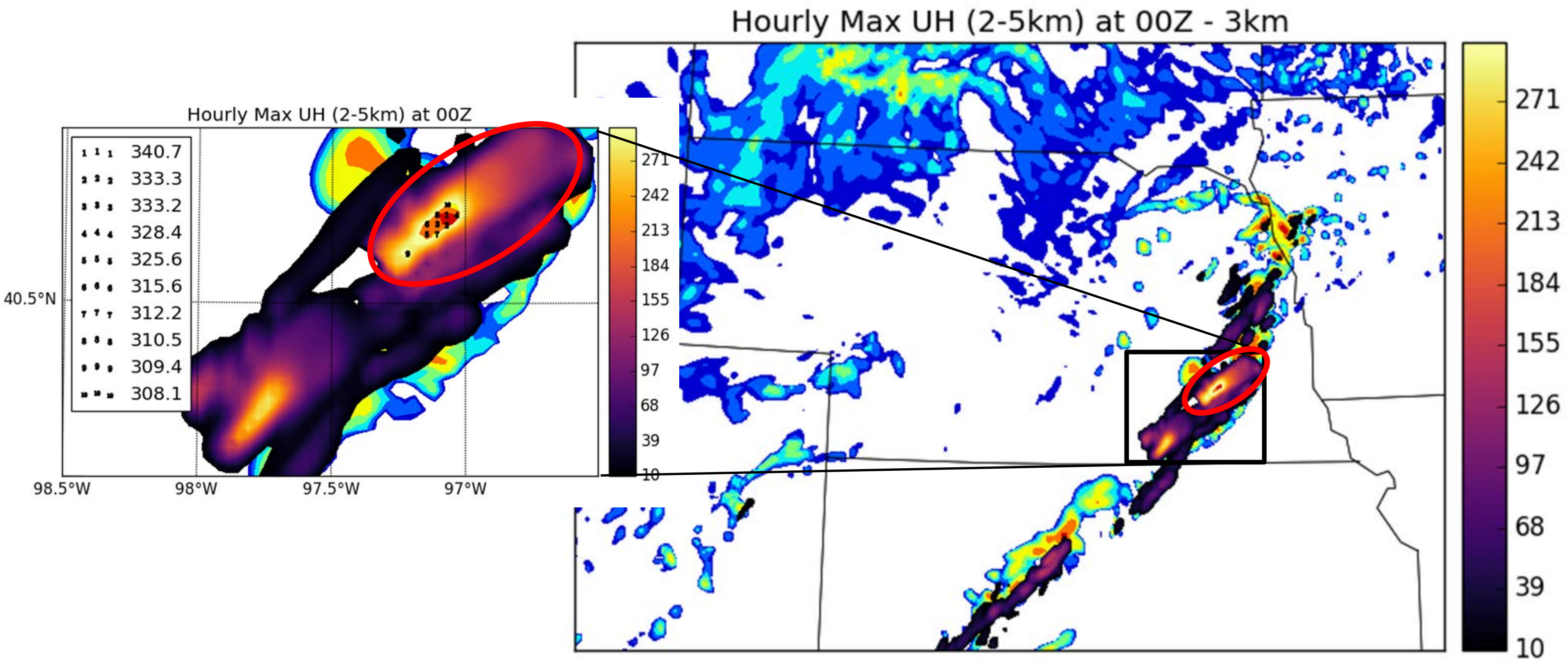




Information Extraction:

Refine UH Diagnostic for Tornado Prediction: 11 May

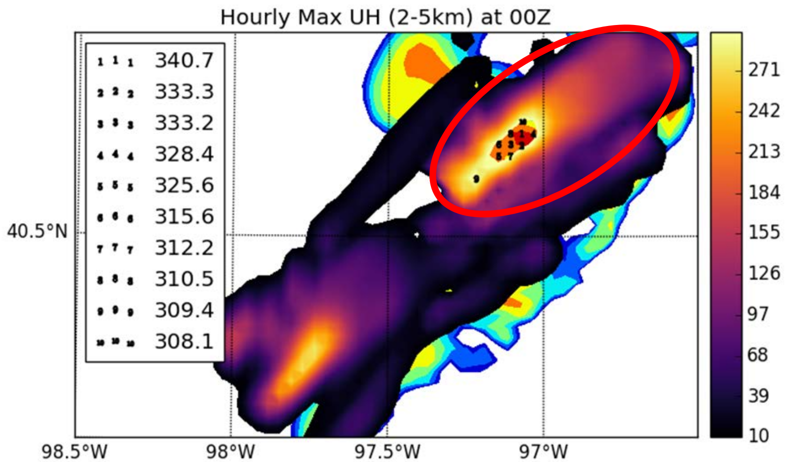
- For the spring case over the plains, the focus will be on 2-5 km AGL UH swaths in southeastern Nebraska between 23 and 00 UTC

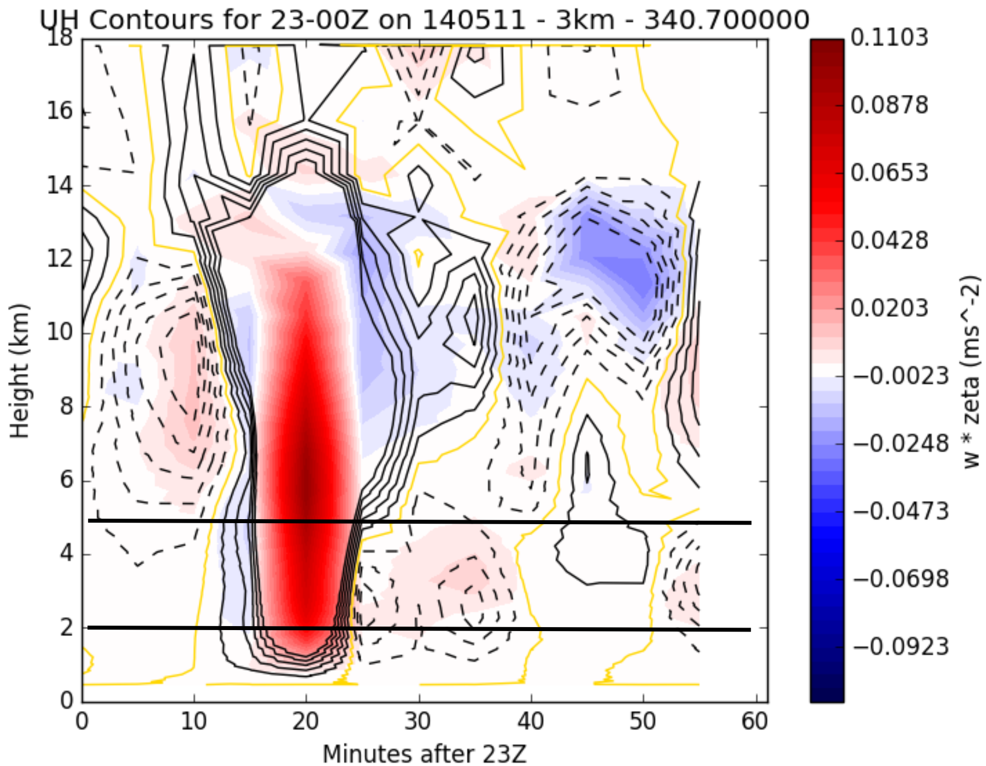


Information Extraction:

Refine UH Diagnostic for Tornado Prediction: 11 May

- This case shows a much stronger and deeper w*ζ profile as the storm moves over the grid box
- Generally, the signal is weak below 2 km AGL

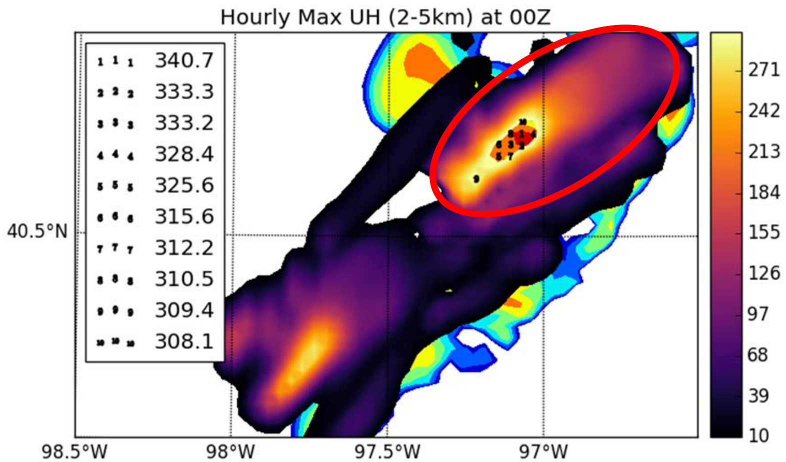


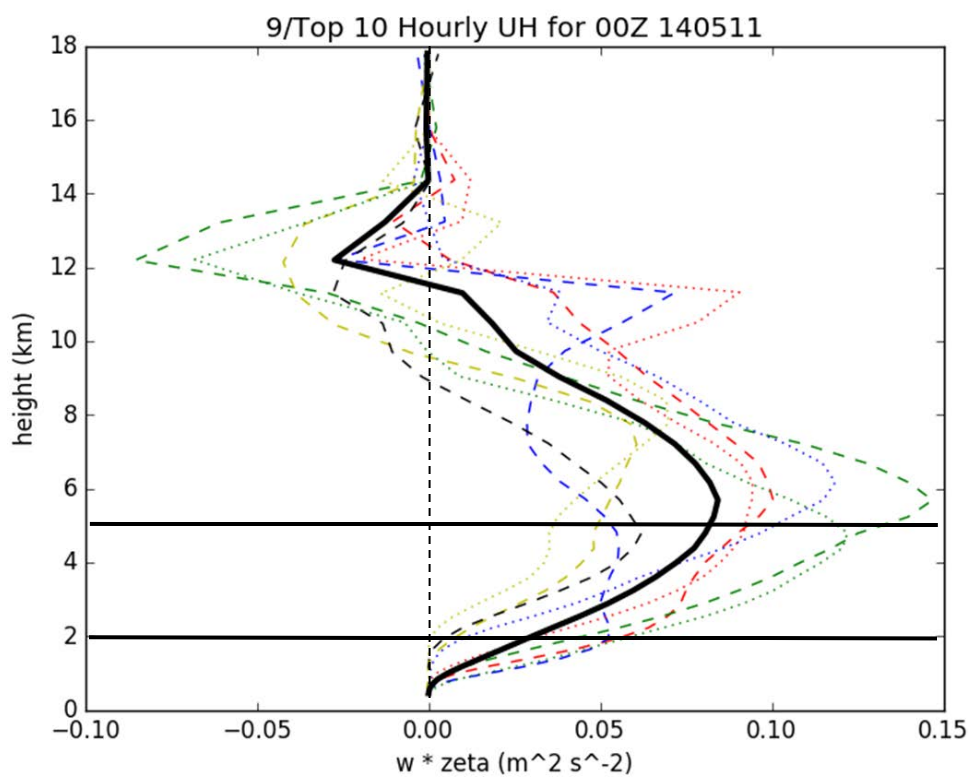


Information Extraction:

Refine UH Diagnostic for Tornado Prediction: 11 May

- The w*ζ profiles vary in magnitude across the UH swath, but generally have magnitudes that peak above 5 km AGL
- Clearly, more information could be extracted, but would it provide unique information? Varying, rather than fixed, layers?





Summary

- The **Community-Leveraged Unified Ensemble (CLUE)** examined during the HWT Spring Forecasting Experiment (SFE) has been an effective way to bring the community together to work on CAM ensemble design:
  - The **stochastic-physics** ensemble did not show forecast improvement over the **single-physics** ensemble and yielded slightly worse forecasts than a **mixed-physics** ensemble for severe weather
- The NAM Nest can generate improved forecasts of the mesoscale environment compared to the parent NAM for regions with severe weather potential by properly removing instability in the wake of convection/precipitation
- Current UH calculations over fixed vertical layers are not capturing the full information content of simulated supercells, so exploring calculation of UH over flexible, varying layers.