NATIONAL WEATHER SERVICE

Methods and Tools Used to Verify Convection-Allowing Model Guidance at the NCEP/Environmental Modeling Center

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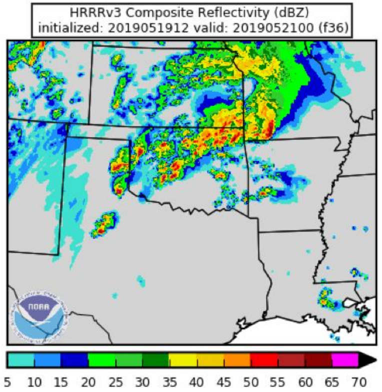
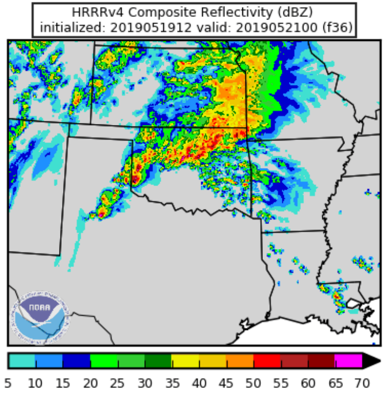
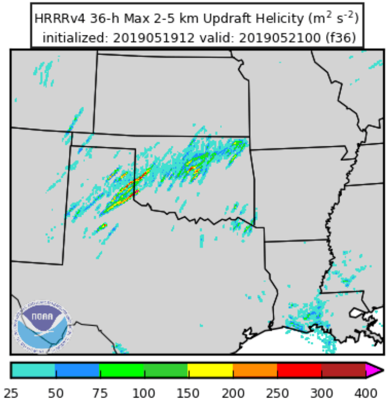
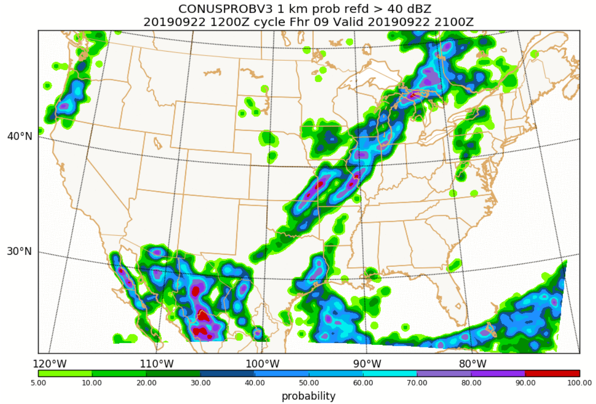








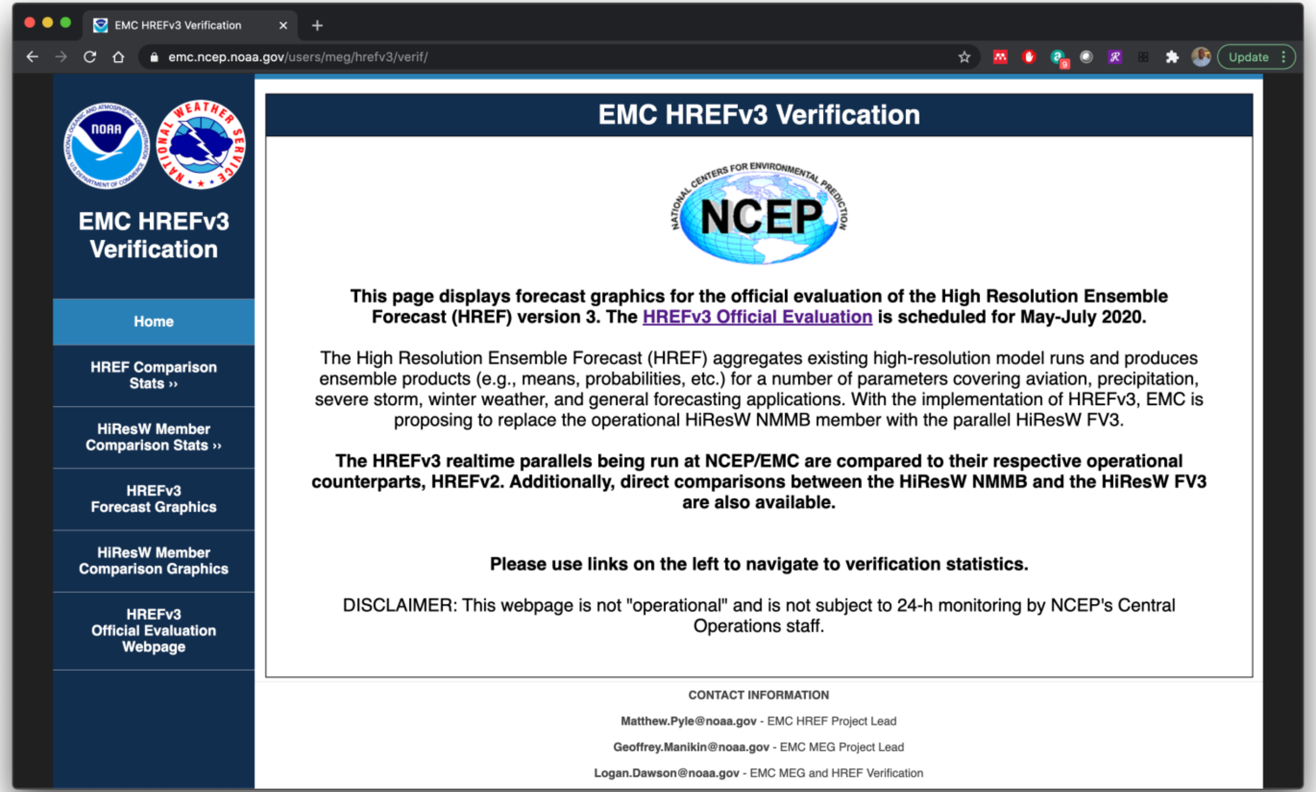
Convection-Allowing Models (CAMs) and Verification at EMC

- CAMs are run at sufficiently high resolution (~3-km) to adequately represent deep, moist convection without the use of a cumulus parameterization scheme
- Allow for extraction of storm attribute information, such as convective mode and potential convective hazards, from NWP guidance
- Until recently, CAM verification at EMC had not evolved much beyond “traditional” metrics and methods that have long been used for mesoscale and global models
  - e.g., verification of standard surface and upper-air synoptic fields, precipitation, reflectivity, and aviation parameters
- Recent efforts have been made to improve prior methods and incorporate additional methods for objectively verifying storm-attribute fields and new probabilistic products to help EMC better make decisions during the model development process

CAM Metrics Outlined at 2018 DTC Community Unified Forecast System Test Plan and Metrics Workshop

Forecast Field	Application	Vertical Attribute	Temporal Attribute	Validation Source	Skill Scores
Temperature	Environmental	Column	Instantaneous	RAOBs	RMSE, BIAS
Specific Humidity					
Wind					
CAPE/CIN		Mixed, Most-Unstable, Surface-Based			
Storm Relative Helicity		0-1, 0-3 km AGL			
Temperature		2-m		METARs	
Dewpoint		2-m			
Wind		10-m			
Downward Shortwave	Air Quality/Energy	Surface	Instantaneous/Avg	ARM, Surfrad, USCRN	
Ceiling	Aviation	Column	Instantaneous	METARs	CSI, BIAS, FSS, POD, FAR, AUR, Performance Diagram
Visibility		Surface			
Echo Top Height		Column		MRMS Echo Top	
Simulated Reflectivity	Severe	Composite		MRMS Mosaic Composite	
Updraft Helicity		2-5, 0-3 km AGL	Hourly Maximum	Storm Reports	
Precipitation	QPF/Winter	Surface	1-hr, 6-hr, 24-hr	Stage IV Precip	

Effort Was Made to Provide Comprehensive Verification for the Official Evaluation of HREFv3



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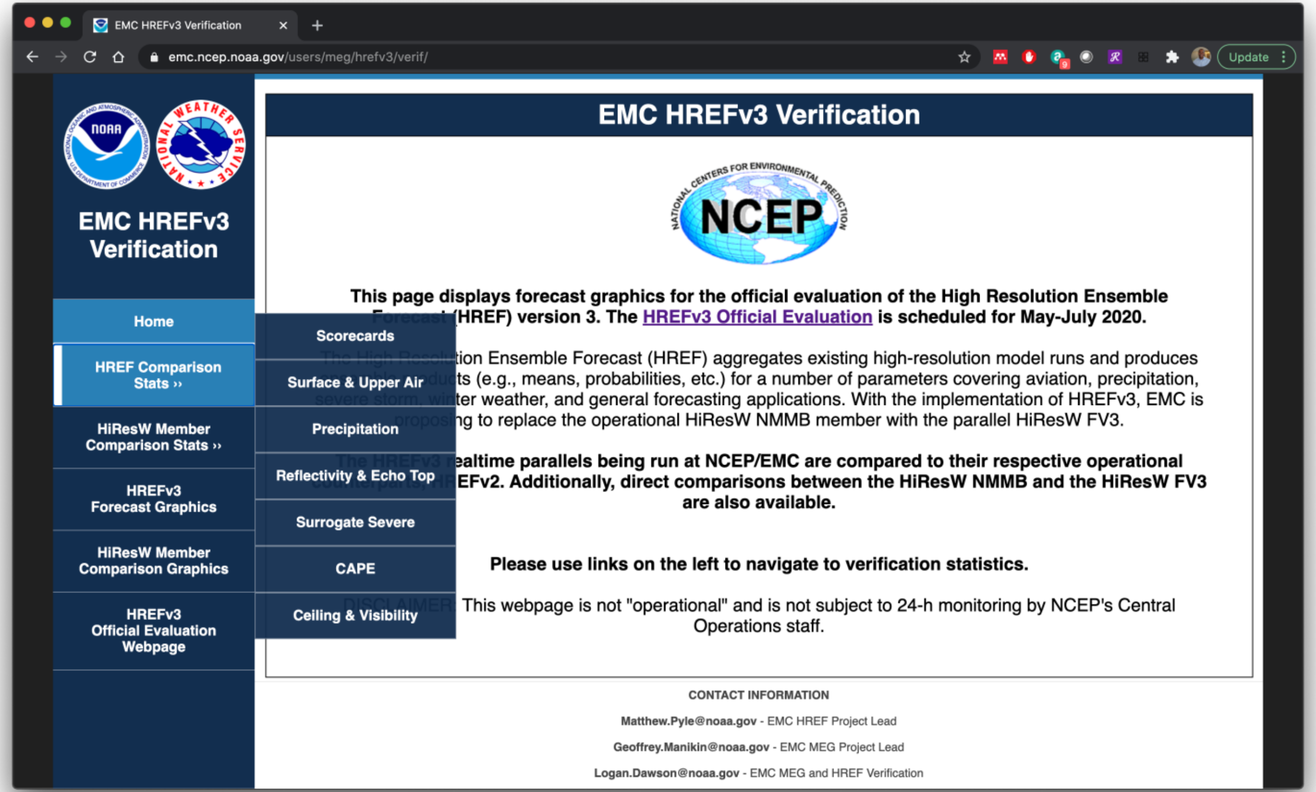

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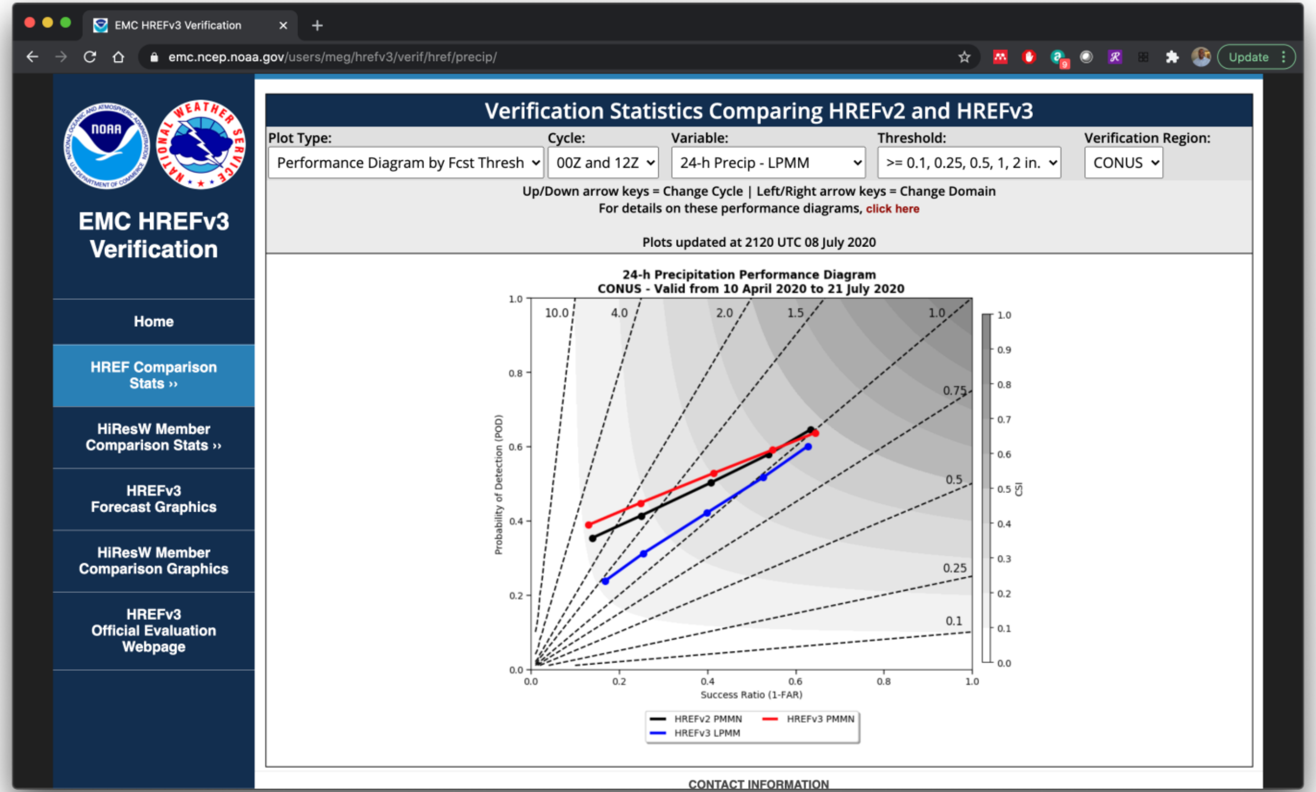


Highlights of Enhancements to CAM Verification

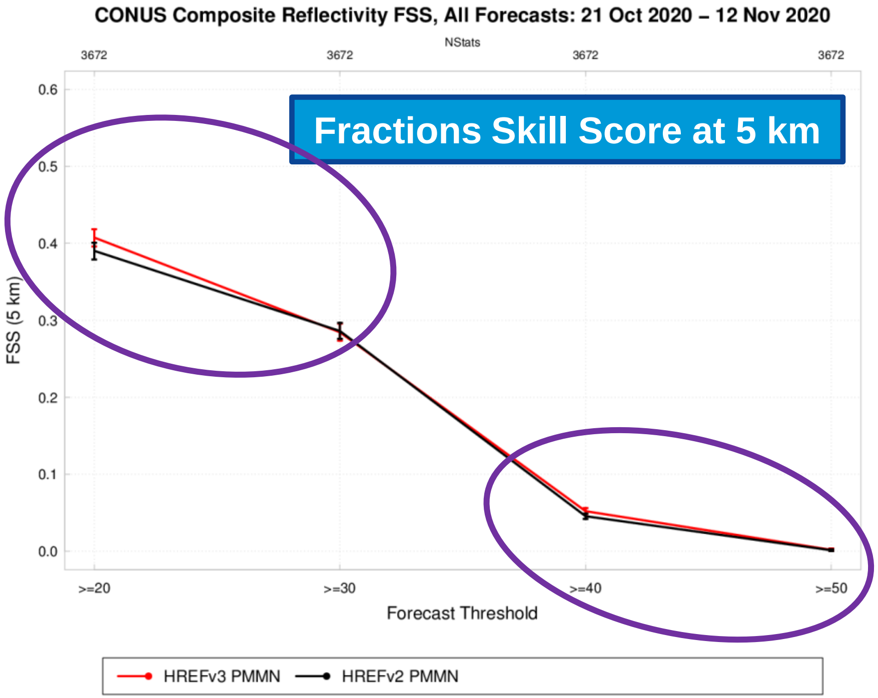
- Radar verification improvements
- Addition of surrogate severe verification
- Using convective outlook areas as verification masking regions

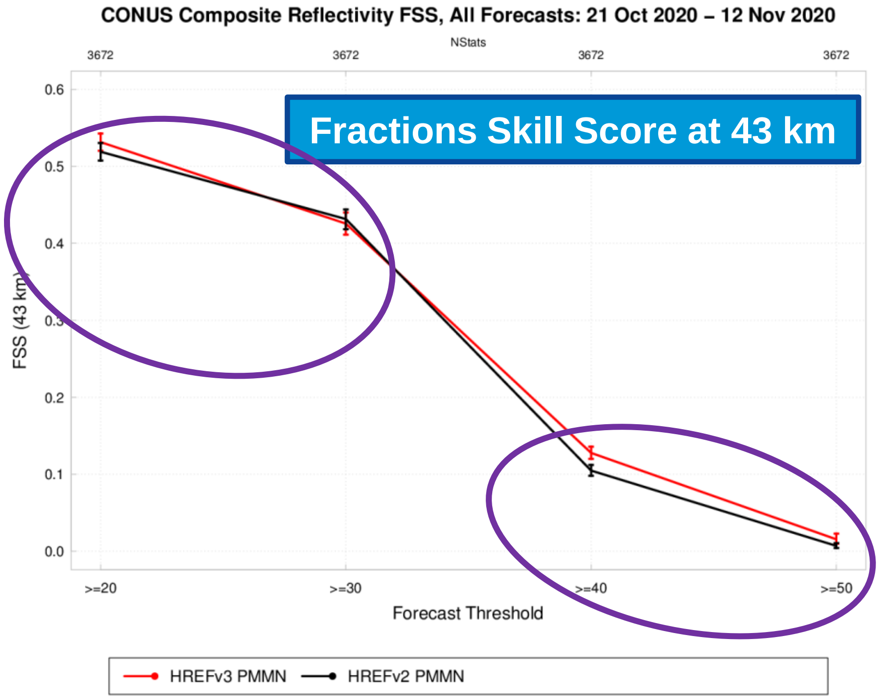
All enhancements discussed herein have been implemented using MET, METplus, and METviewer

Radar Verification Improvements

- Updated from legacy NCEP Mosaic products to the higher quality Multi-Radar Multi-Sensor (MRMS; Smith et al. 2016) products for radar observations
  - Rigorously QC'ed using algorithms that are continually being improved
- Enhancing verification using neighborhood-maximum approach
  - Categorical threshold exceedances are based on maximum value within a specified neighborhood (~40 km)
- Jointly using neighborhood and probabilistic methods for verifying reflectivity and echo top probability products
  - Allows the verification to provide context on model performance at the same scale as convective outlooks issued by NCEP/Storm Prediction Center (SPC)
  - Outlooks are based on the probability of severe convective hazards occurring within 25 miles (~40 km) of a point

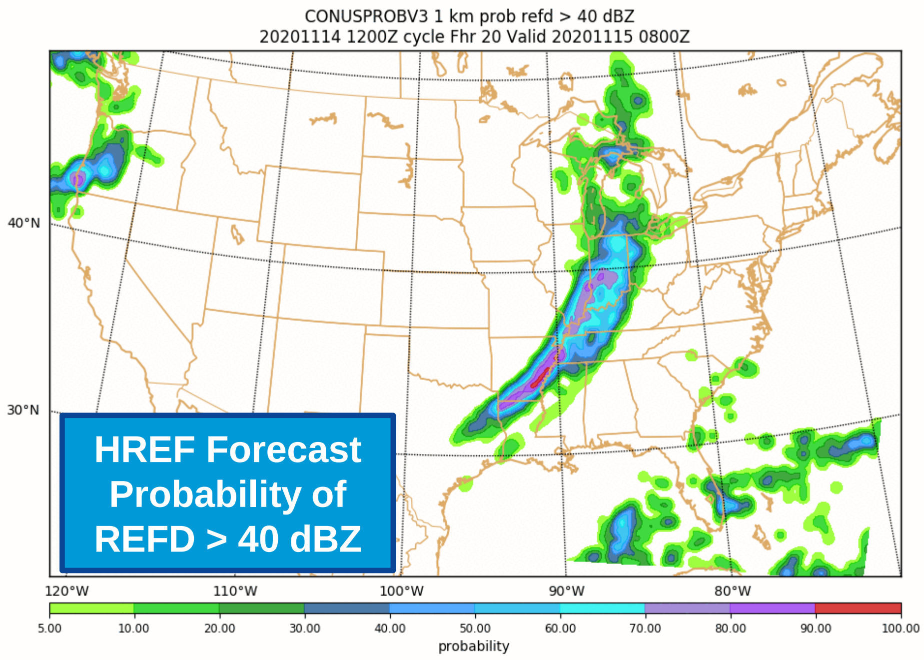
Radar Verification Improvements

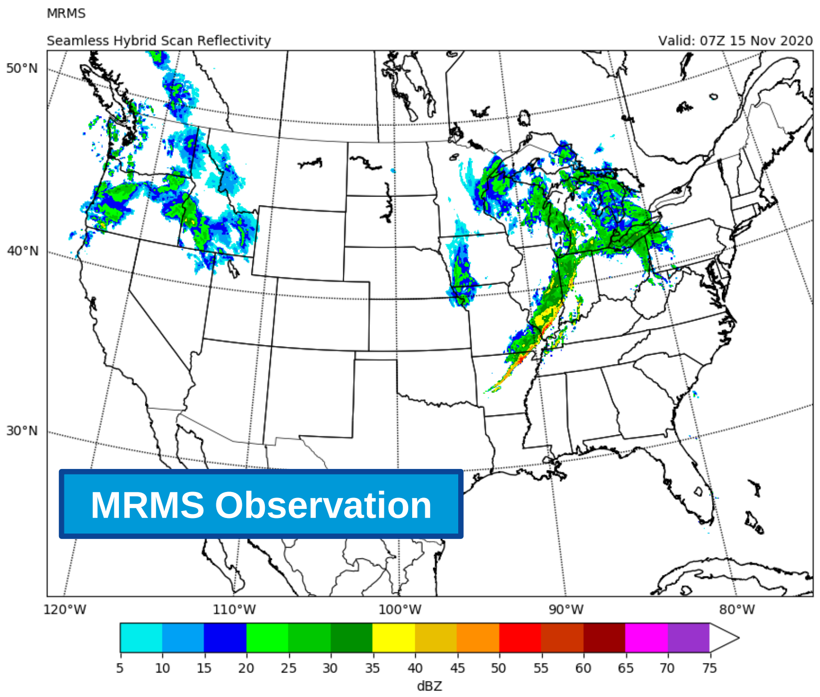




- Reflectivity forecasts are more skillful on the scale at which SPC convective outlooks are issued

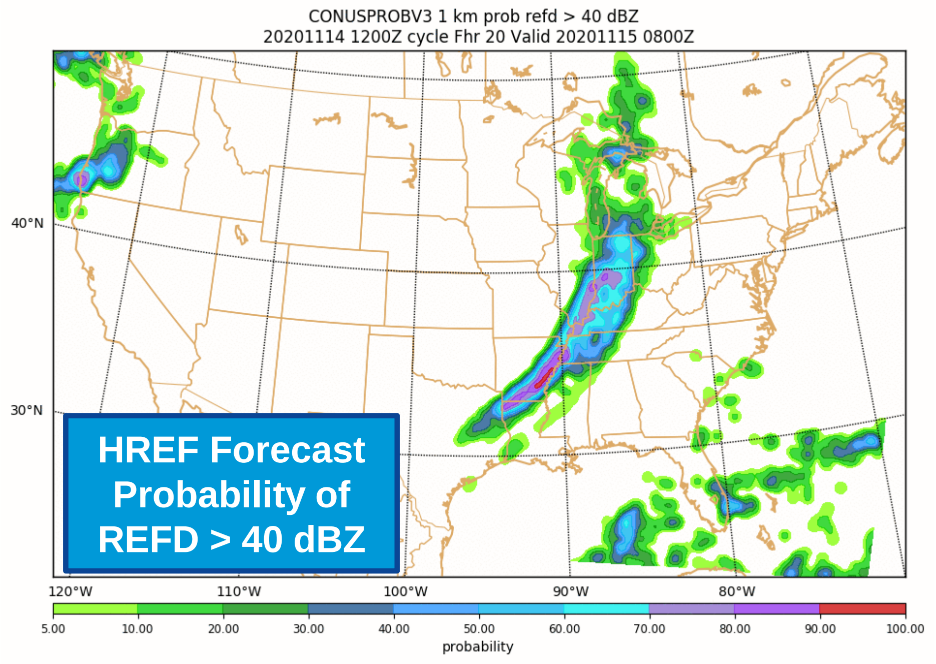
Radar Verification Improvements

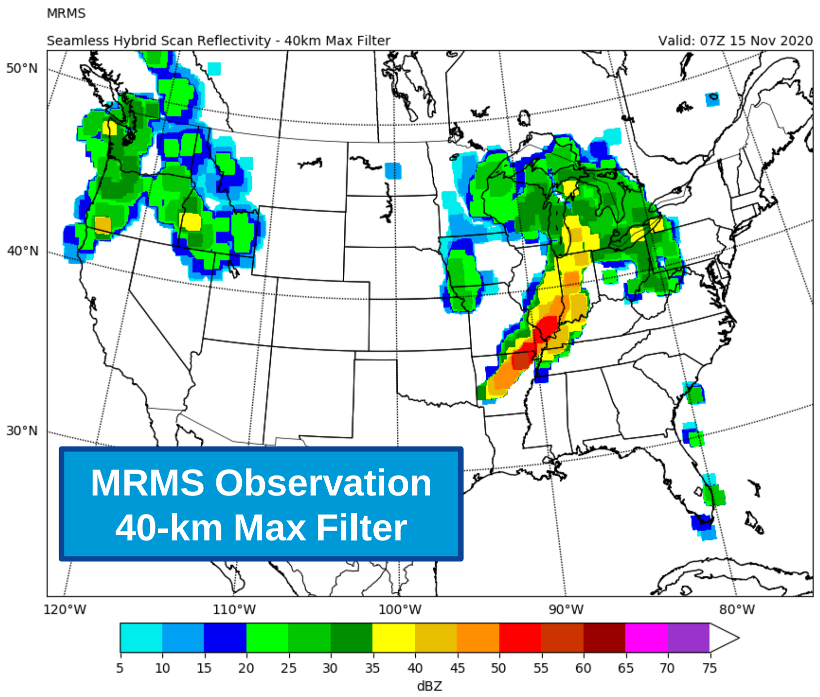




- HREF computes **neighborhood maximum** probabilities for reflectivity – based on maximum value within a ~40 km neighborhood
- Ensuring fair treatment of forecasts by generating obs fields by following the same steps with MET

Radar Verification Improvements





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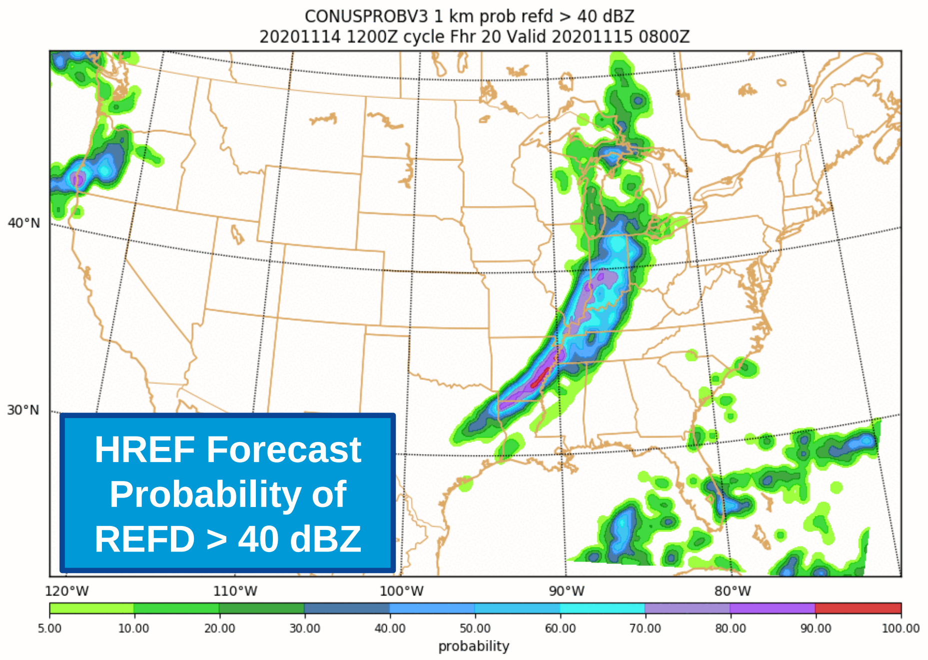

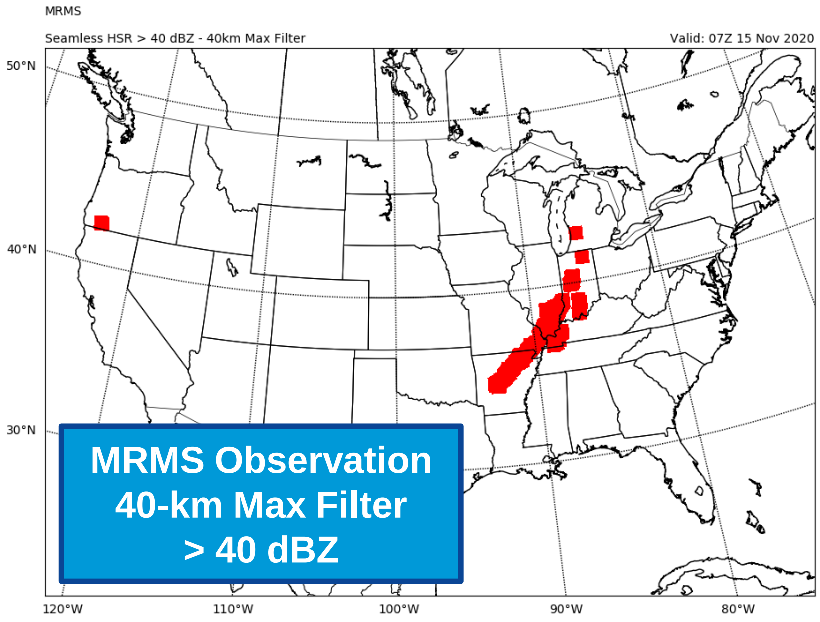

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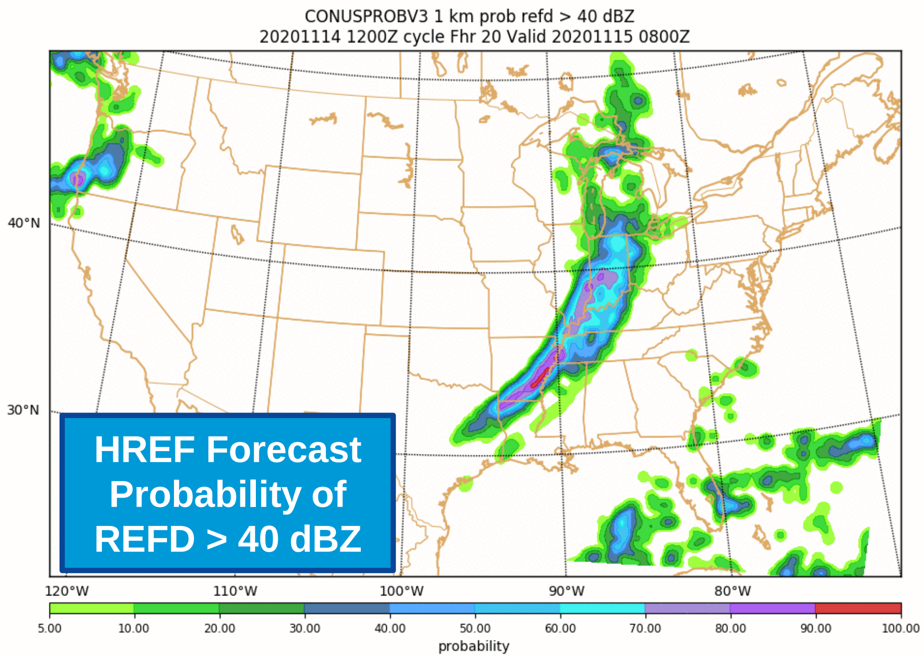

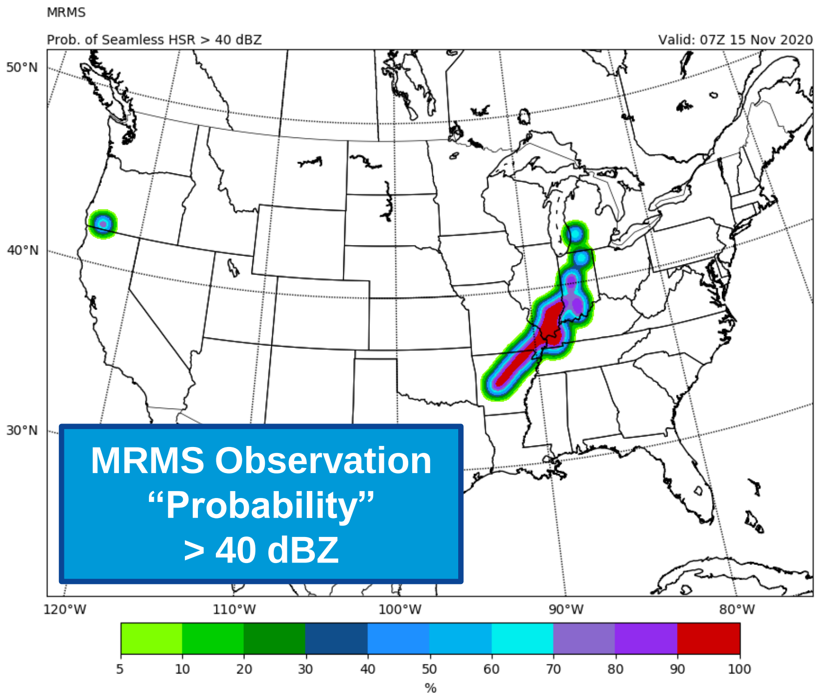

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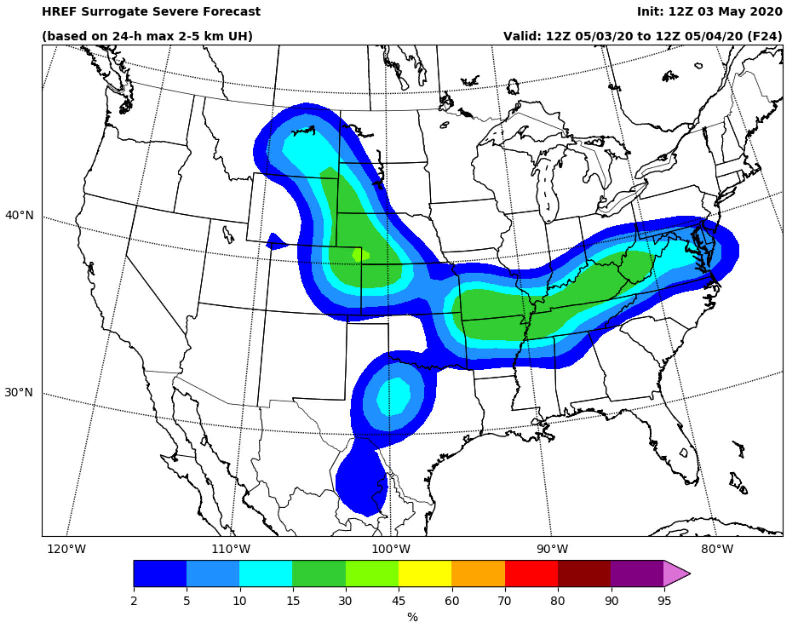
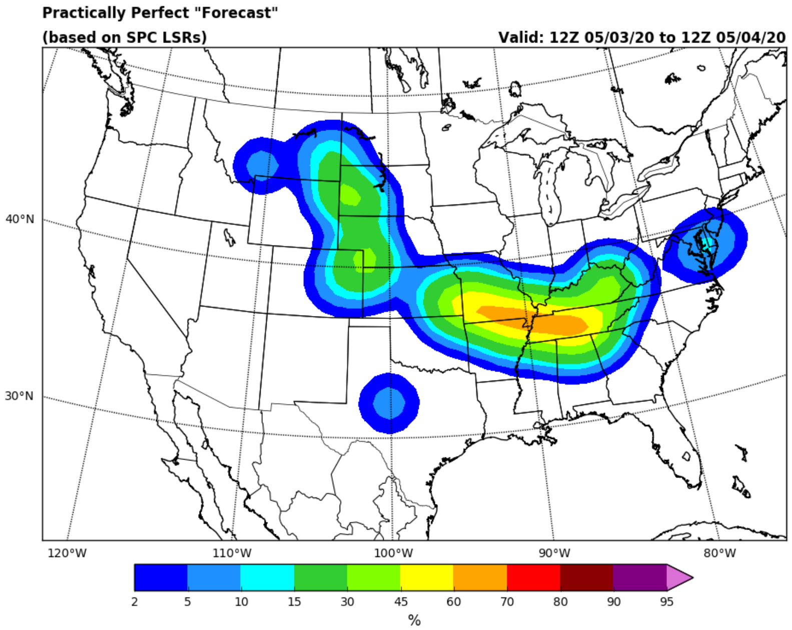
Surrogate Severe Verification

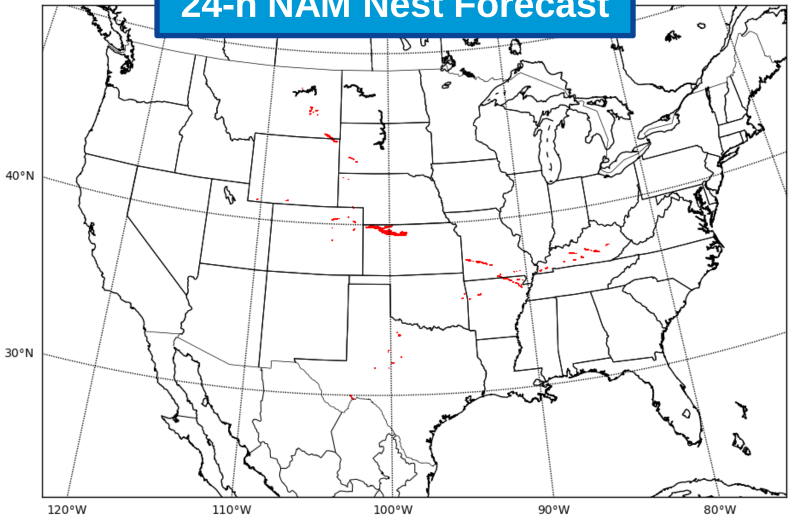




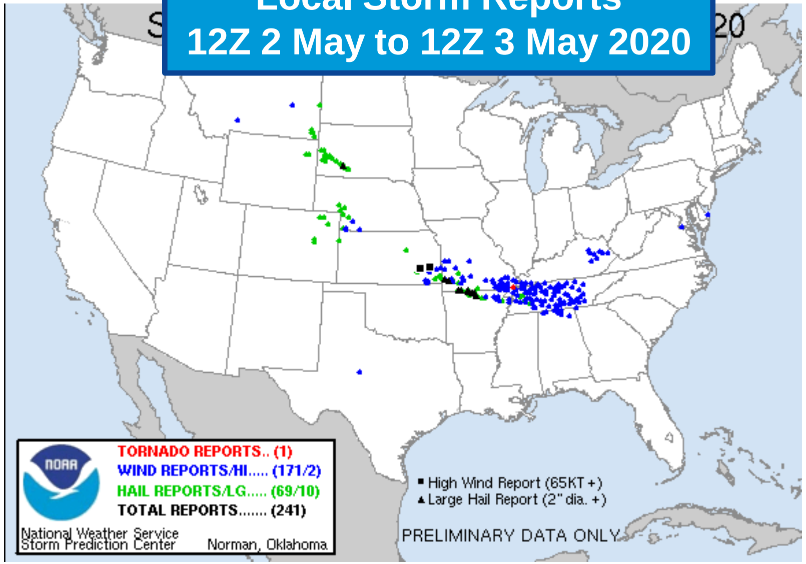
- Uses updraft helicity (UH) exceedances as “surrogates” to generate probabilistic forecasts for severe convection (Sobash et al. 2011, 2016)
- Probabilistic forecasts are verified using practically perfect “forecasts” based on local storm reports (LSRs) (Hitchens et al. 2013)

Surrogate Severe Verification

Severe Surrogates from 24-h NAM Nest Forecast



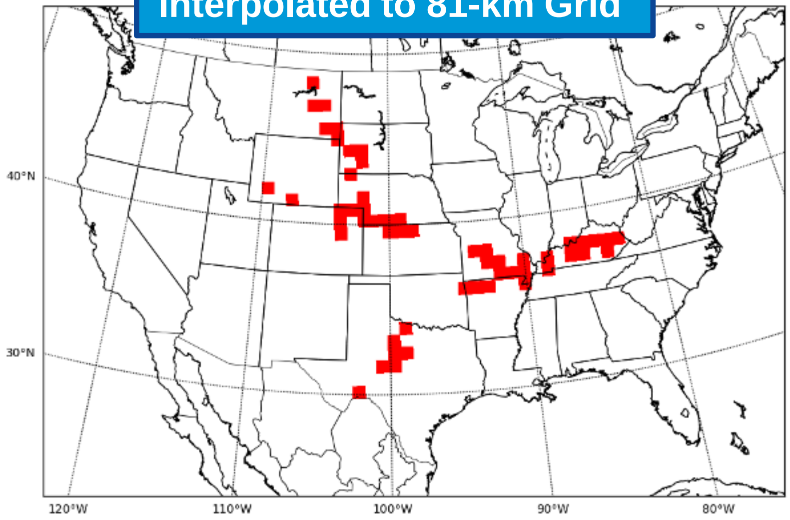
Local Storm Reports 12Z 2 May to 12Z 3 May 2020



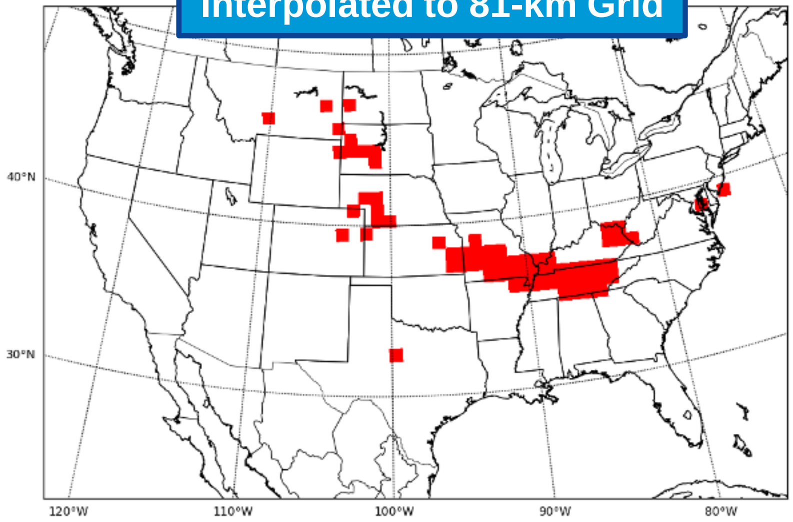
- Surrogates are identified using thresholds based on each model's UH climatology
  - UH is sensitive to model configuration (dynamics, resolution, physics, etc.), so percentile-based thresholds must be used to fairly compare different models

Surrogate Severe Verification

Severe Surrogates Interpolated to 81-km Grid

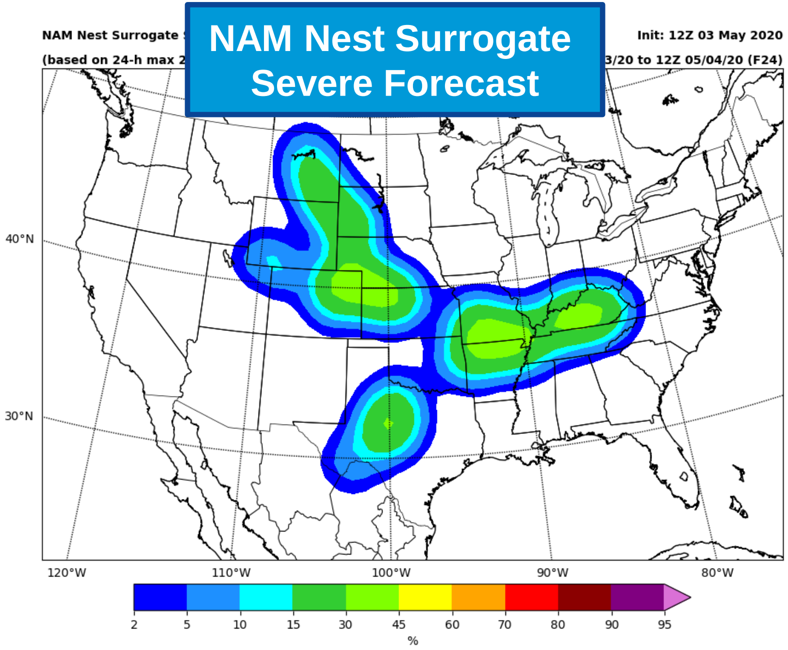


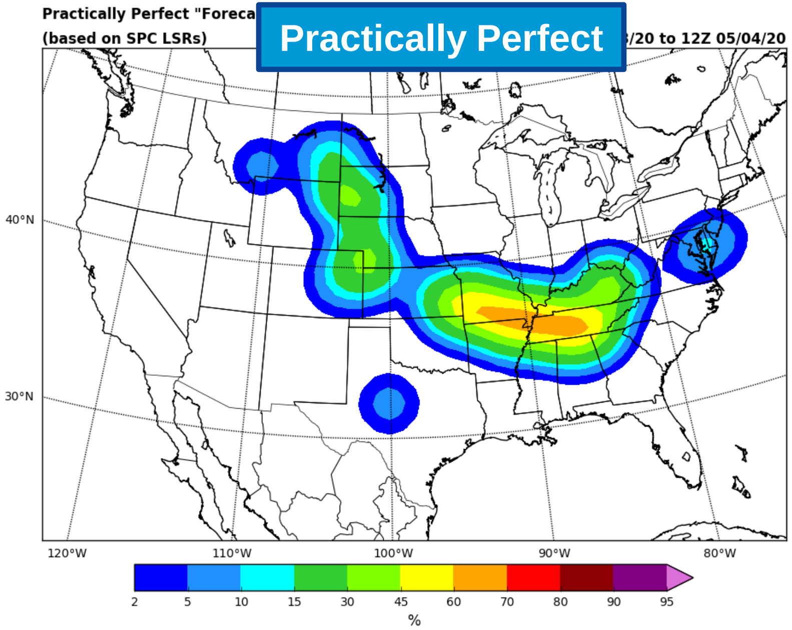
Local Storm Reports Interpolated to 81-km Grid



- Forecast surrogates and observed LSRs are interpolated to an 81-km grid using MET
  - By generating on the 81-km grid, the surrogate severe forecast product is on approximately the same scale as convective outlook probabilities (probability of severe weather within 25 mi of a point) issued by the NCEP/SPC

Surrogate Severe Verification

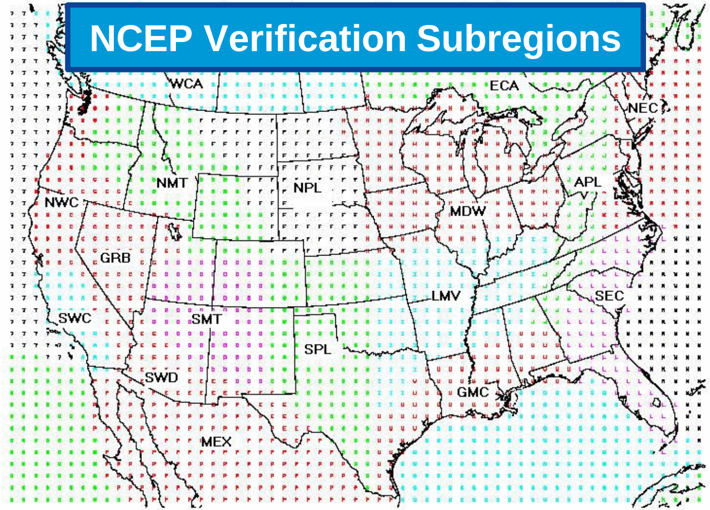




- Probabilistic fields are generated using the Gaussian smoothing capability available in MET's RegridDataPlane tool
- Probabilistic metrics and contingency table statistics are then computed from resulting fields

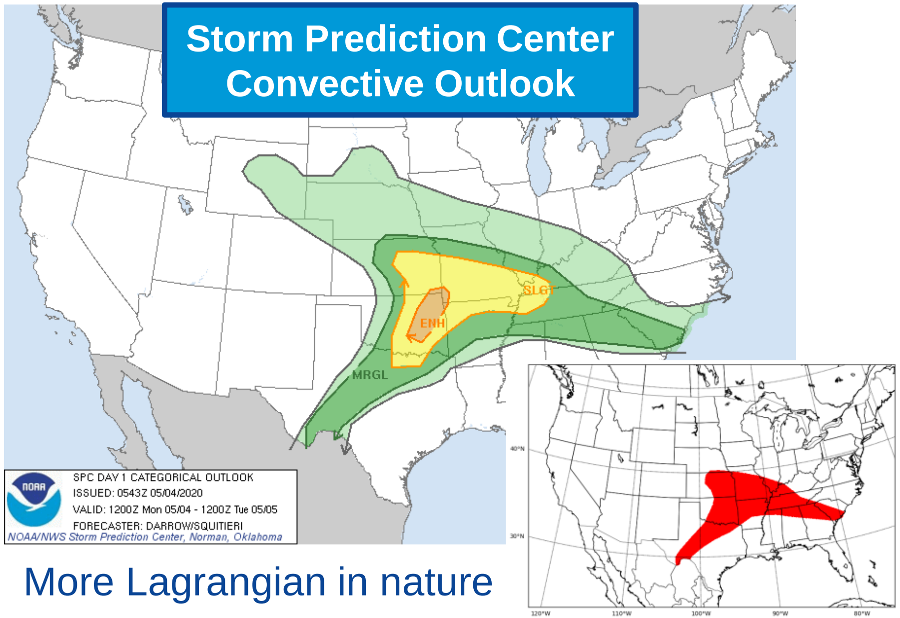
Using Convective Outlook Areas as Verification Masking Regions

NCEP Verification Subregions



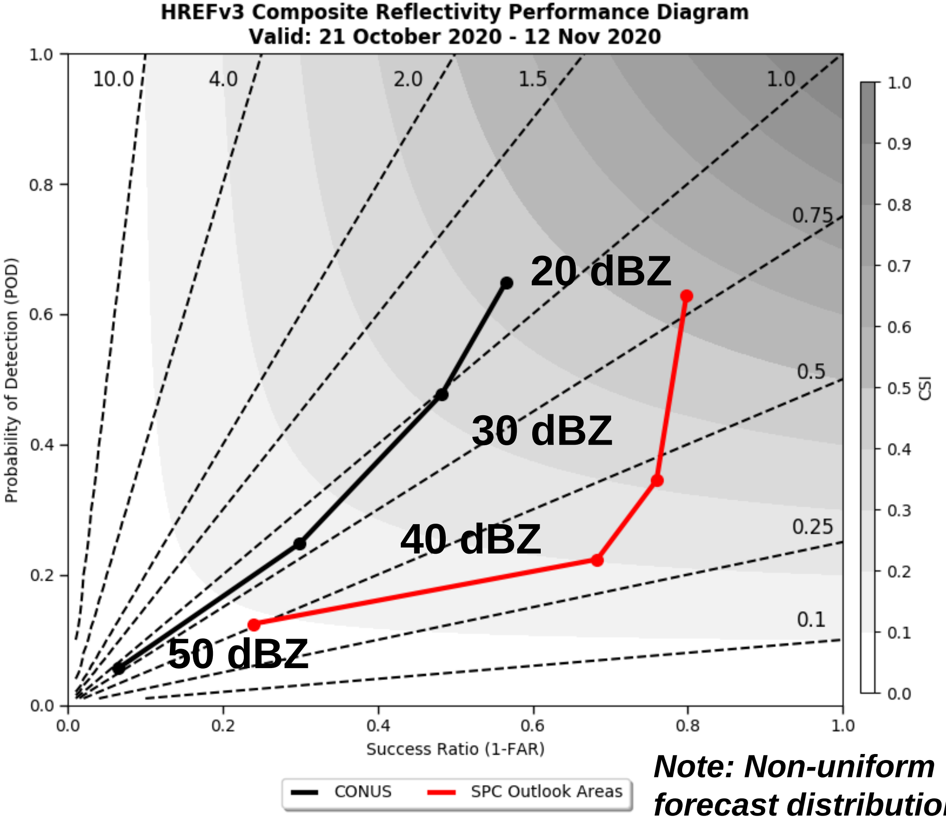
- Eulerian approach to verification
- Can attempt to constrain metrics of interest in time and space, but locations of severe weather threats are not constant in space

Storm Prediction Center Convective Outlook



- More Lagrangian in nature
- How well do our forecasts perform in these environments with heightened threats?
- Facilitated by MET's GenVxMask tool, which can read shapefiles defining these areas

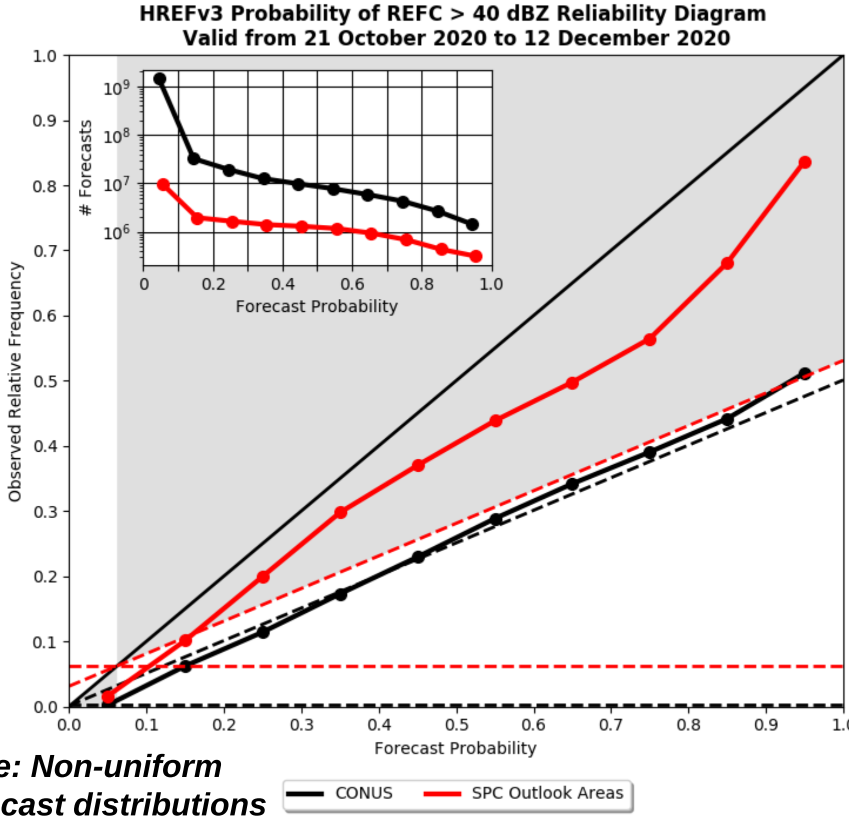
Using Convective Outlook Areas as Verification Masking Regions



Note: Non-uniform forecast distributions

- HREFv3 reflectivity forecasts are generally more skillful in **SPC Outlook Areas** than across the **CONUS** as a whole
  - Consistent reduction in FAR with limited impact on POD
  - Increased CSI at 3 of 4 thresholds, especially at 40 and 50 dBZ thresholds
- Expected, given that convective outlook areas highlight potential for organized convection, which generally should be more predictable

Using Convective Outlook Areas as Verification Masking Regions



Note: Non-uniform forecast distributions

- HREFv3 probabilistic reflectivity forecasts are generally more skillful and reliable in **SPC Outlook Areas** than across the **CONUS** as a whole
  - Despite changes in forecast distributions, reliability is improved
  - Increased positive contributions to Brier Skill Score (using sample climatology as reference)
- Expected, given that convective outlook areas highlight potential for organized convection, which generally should be more predictable

Future Considerations

- Metrics and methods applied to NCEP's CAMs will be refined following the 2021 DTC Unified Forecast System Evaluation Metrics Workshop
- Model climatology for updraft helicity is an important factor in the surrogate severe methodology, and we must develop a strategy to account for it in real-time
- Proper treatment of observation data must be expanded to the verification of other neighborhood-maximum (or neighborhood-minimum) probabilistic forecast products
    - Will be increasingly important with potential product additions for NCEP's next-generation CAM ensemble, the Rapid Refresh Forecast System
- Use of outlook areas for verification masking could be expanded to other phenomena, such as heavy QPF and fire weather, with existing geospatial forecast products