SPC Ensemble Applications:
Current Status and Future Plans

Israel Jirak
Science and Operations Officer
Storm Prediction Center
Norman, OK

Acknowledgments: Steve Weiss, Andy Dean, and Chris Melick

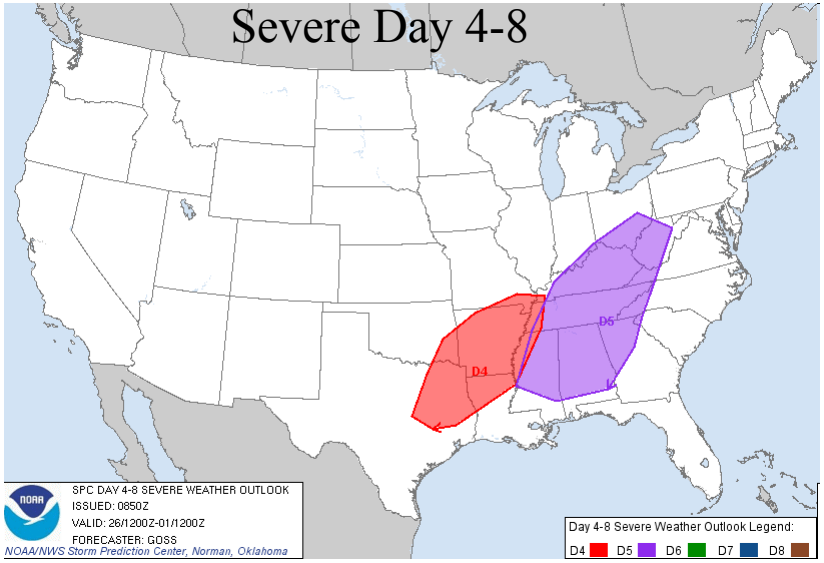
SPC Ensemble Applications
Outline

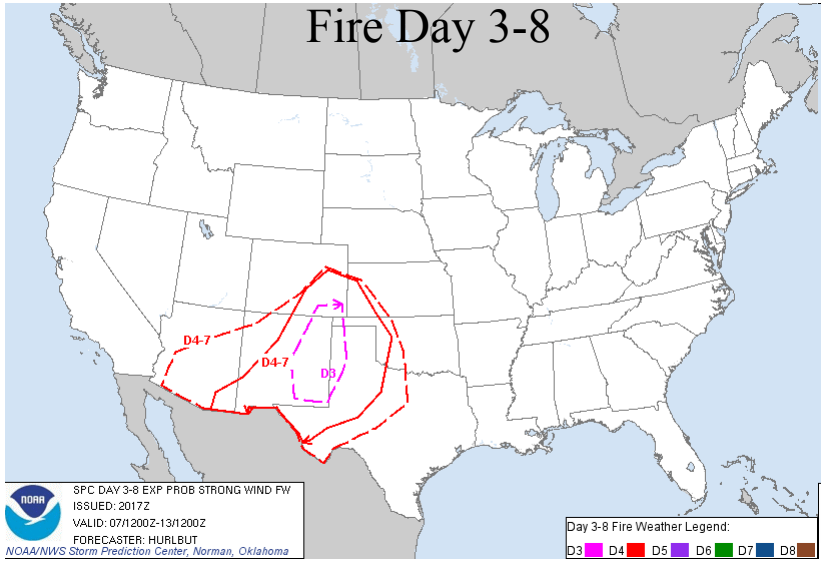
- Large-Scale Guidance: GEFS
  - Extended Outlooks: Severe, Fire
  - GEFS Calibrated Products: Thunder, Severe
- Mesoscale Guidance: SREF
  - Overview, Calibrated Severe
  - Performance
- Convection-Allowing Guidance: SSEO
  - Overview
  - Comparisons, Configuration
  - Calibrated Severe
  - Combined Guidance

SPC Ensemble Applications

Large-Scale Guidance: Extended Outlooks

- SPC forecasters look at deterministic models along with GEFS and ECMWF ensemble to assess the large-scale pattern and its predictability
  - Unfortunately, ensembles are still under-utilized by some SPC forecasters for extended range outlooks
- Extended Range Outlooks
  - Severe Weather Outlook Day 4-8 : ≥30% probability of severe weather w/in 25 mi of point with addition of 15% threshold planned for Q4 FY14
  - Fire Weather Outlook Day 3-8: 40% & 70% probability of fire wx conditions w/in 12 mi of point along with 10% & 40% probability of dry thunderstorms

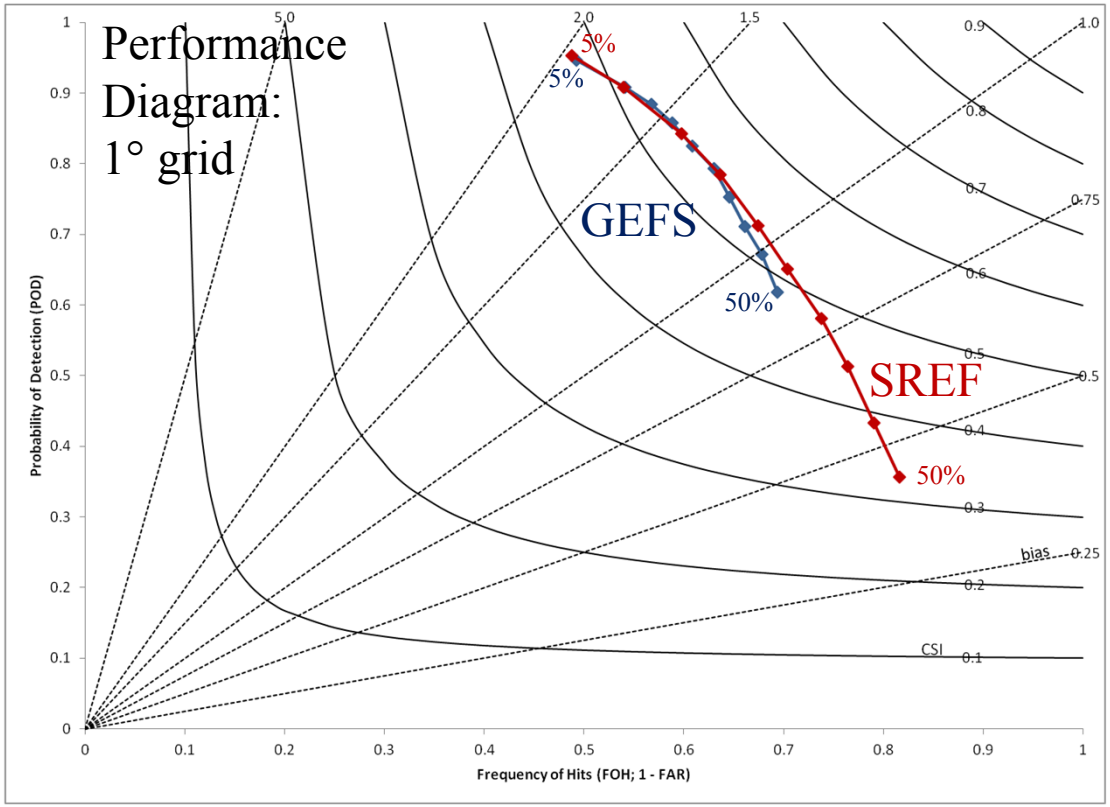




SPC Ensemble Applications

Large-Scale Guidance: GEFS Calibrated Products

- Addition of Day 3 general thunder line on our convective outlooks prompted creation of 24-h calibrated thunder guidance from GEFS
- Calibration uses probability of 24-h precipitation >0.01” and CPTP*>1 and adjusts values based on historical frequency of CG lightning occurrence



*Cloud Physics Thunder Parameter

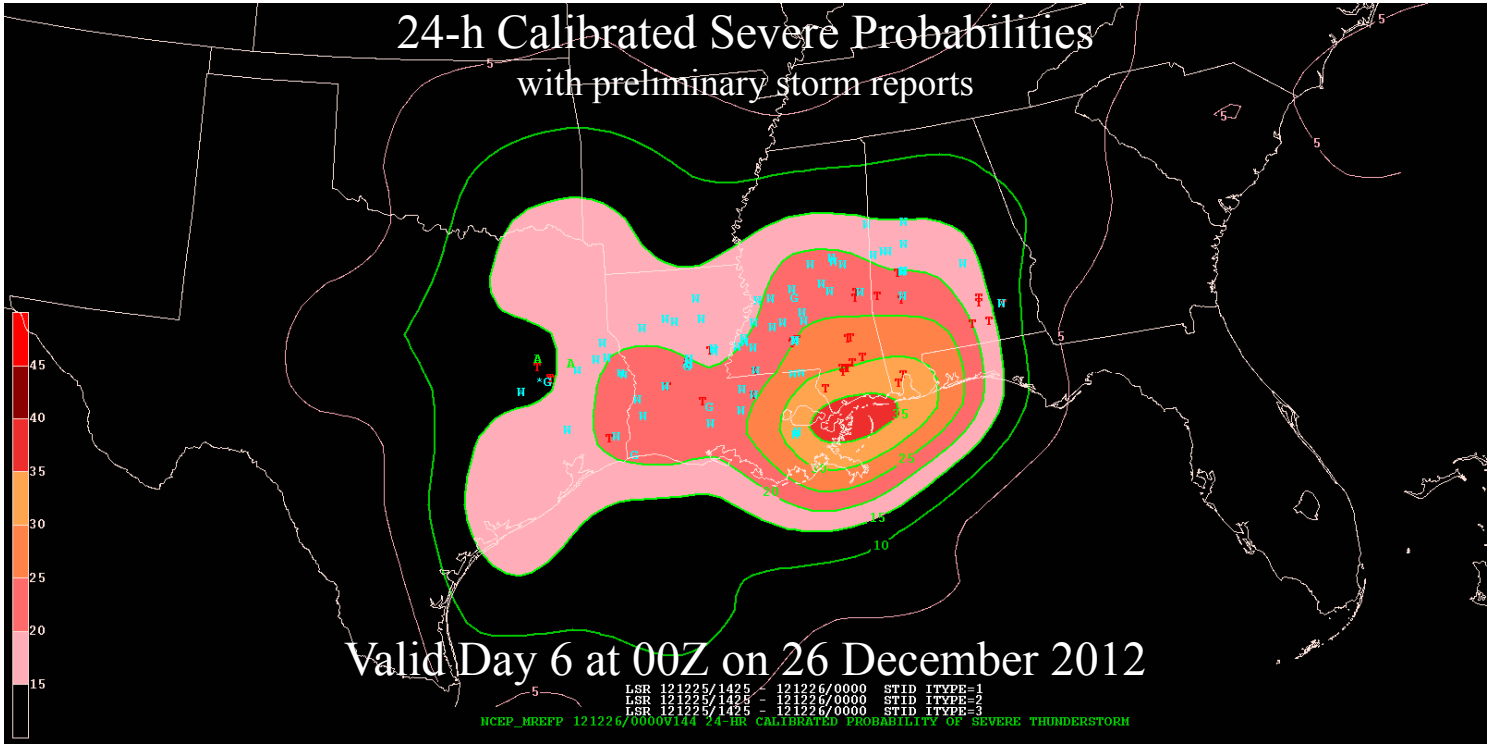
24-Hour Calibrated Thunder Probabilities

Valid **Day 3**
7/15/12 – 9/15/12

SPC Ensemble Applications

Large-Scale Guidance: GEFS Calibrated Products

- Upcoming addition of 15% probability line and increasing visibility of extended outlook highlighted need for GEFS calibrated severe guidance
- Similar calibration method is used here as in thunder guidance, but uses 24-h calibrated thunder probability and probability of SCP*>1 and adjusts values based on historical frequency of severe weather reports



*Supercell Composite Parameter

SPC Ensemble Applications

Mesoscale Guidance

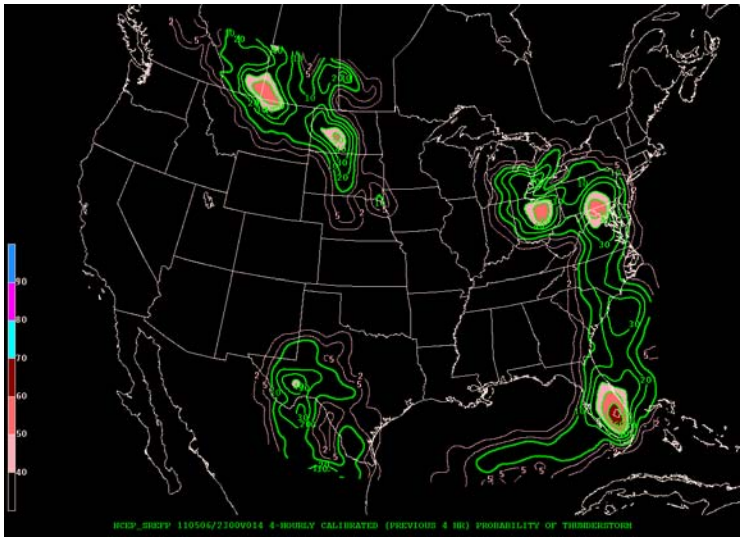
- *The Challenge*: High impact events often occur on temporal and spatial scales below the resolvable resolutions of most observing and forecasting systems
- *Key premise*: We must use knowledge of the environment and non-resolved processes to determine the spectrum of possible hazardous weather, where and when it may occur, and how it may evolve over time



SPC Ensemble Applications

Mesoscale Guidance: SREF

- Specialized guidance for the specific application: thunderstorms, severe weather, fire weather, & winter weather
- Output designed to…
  - Provide guidance for uncertainty/probabilistic forecasts
  - Provide guidance that aids (deterministic) confidence
  - Illustrate a range of plausible scenarios
  - Allow for diagnostic analysis
    - not just a statistical black-box
  - Facilitate extensive use of probabilistic products
- Recent developments/improvements include combining environment information from the SREF with storm information from SSEO

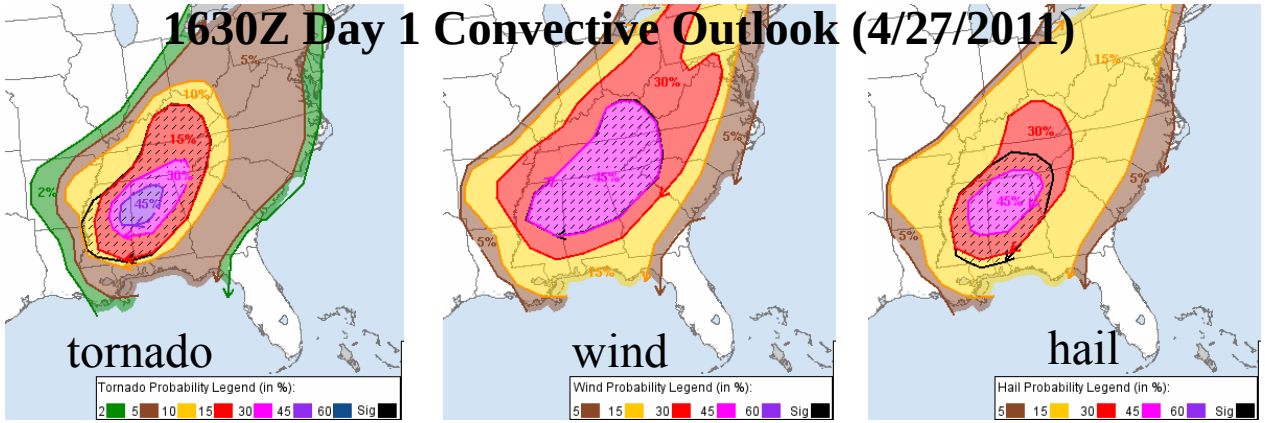


SPC Ensemble Applications

Mesoscale Guidance: SREF Calibrated Products

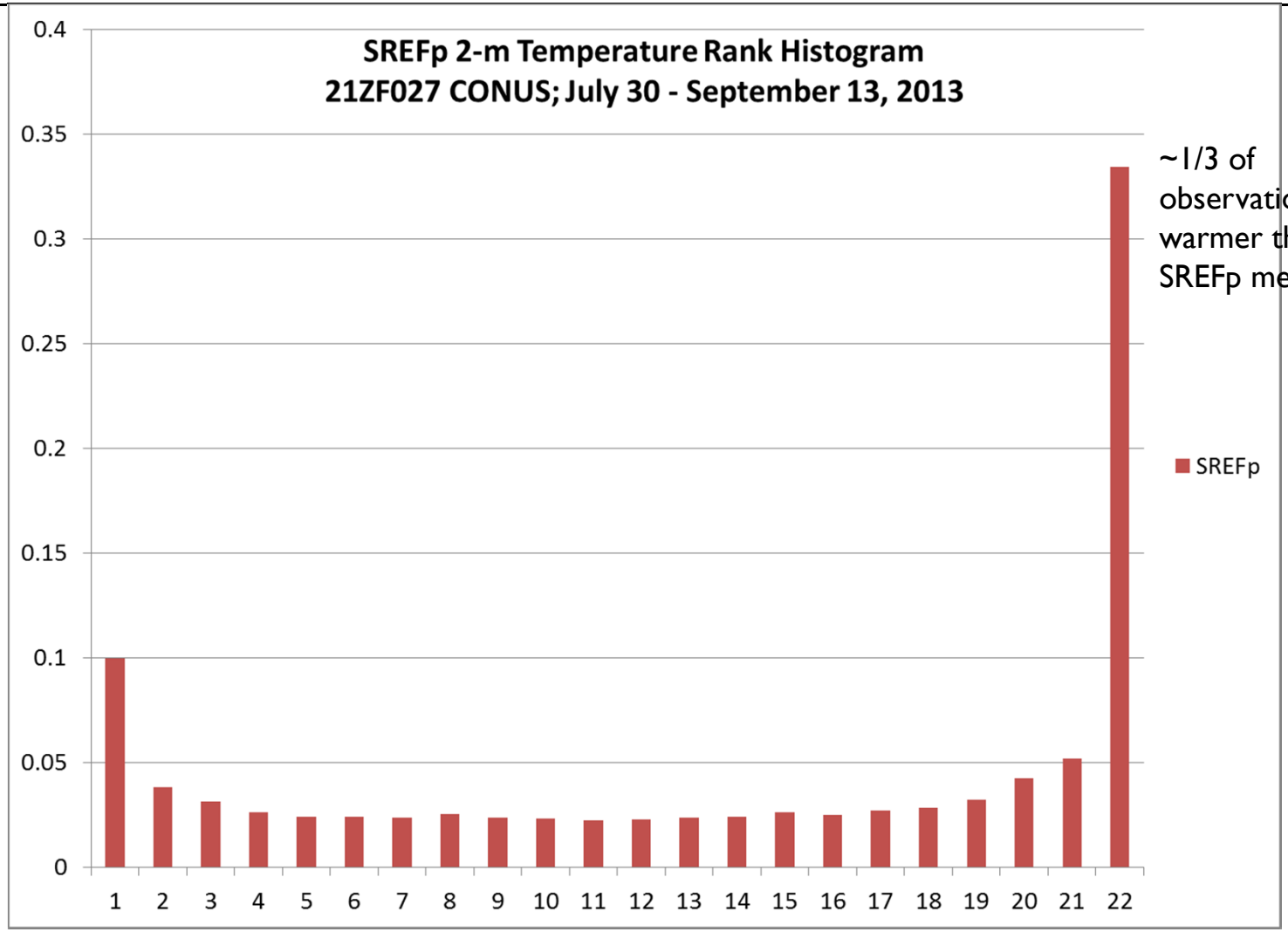
- Provide guidance to forecasters when making probability forecasts of thunderstorms and severe weather
- Currently Day 1 Outlook includes probability forecasts for each type of severe hazard (tornado, wind, and hail)
- Additionally, higher temporal resolution thunderstorm and severe outlooks (e.g. 4-hr periods) are desired
- Difficult to get hazard type and timing from ***environment*** alone, so combining information from convection-allowing ensembles should improve usefulness of guidance (more later)

1630Z Day 1 Convective Outlook (4/27/2011)



SPC Ensemble Applications

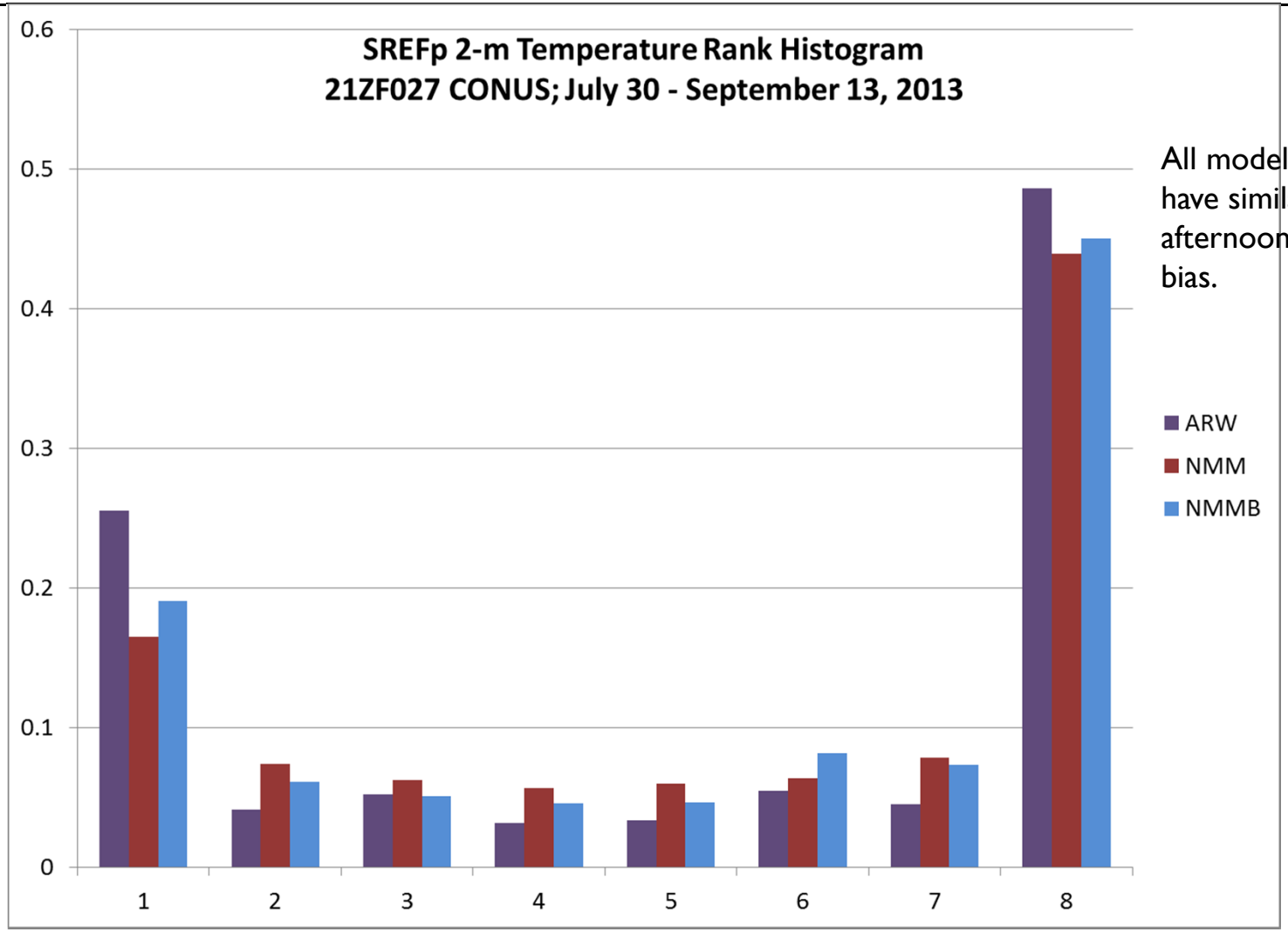
Mesoscale Guidance: SREF Performance



~1/3 of observations are warmer than any SREFp member

SPC Ensemble Applications

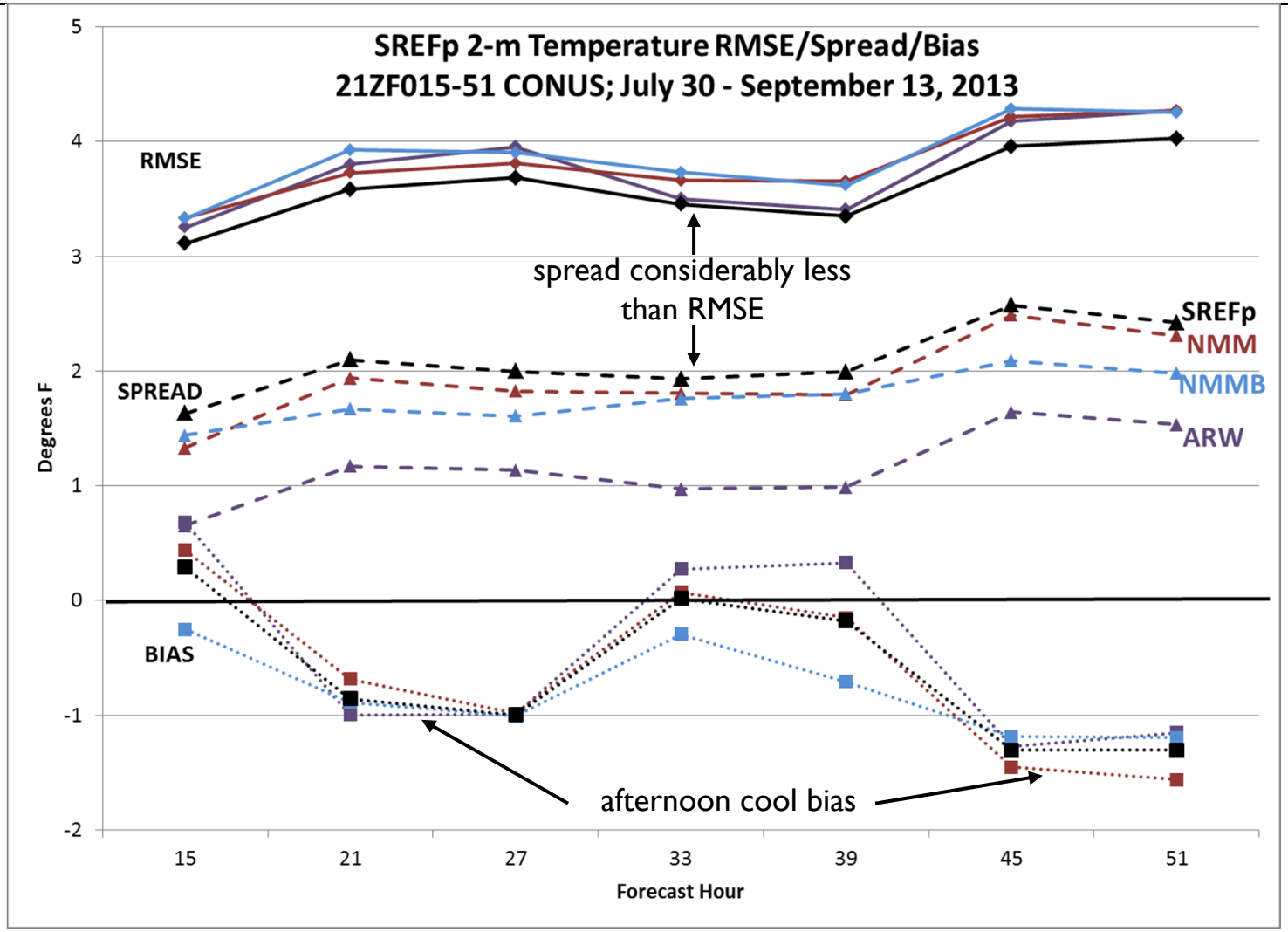
Mesoscale Guidance: SREF Performance



All model cores have similar afternoon cool bias.

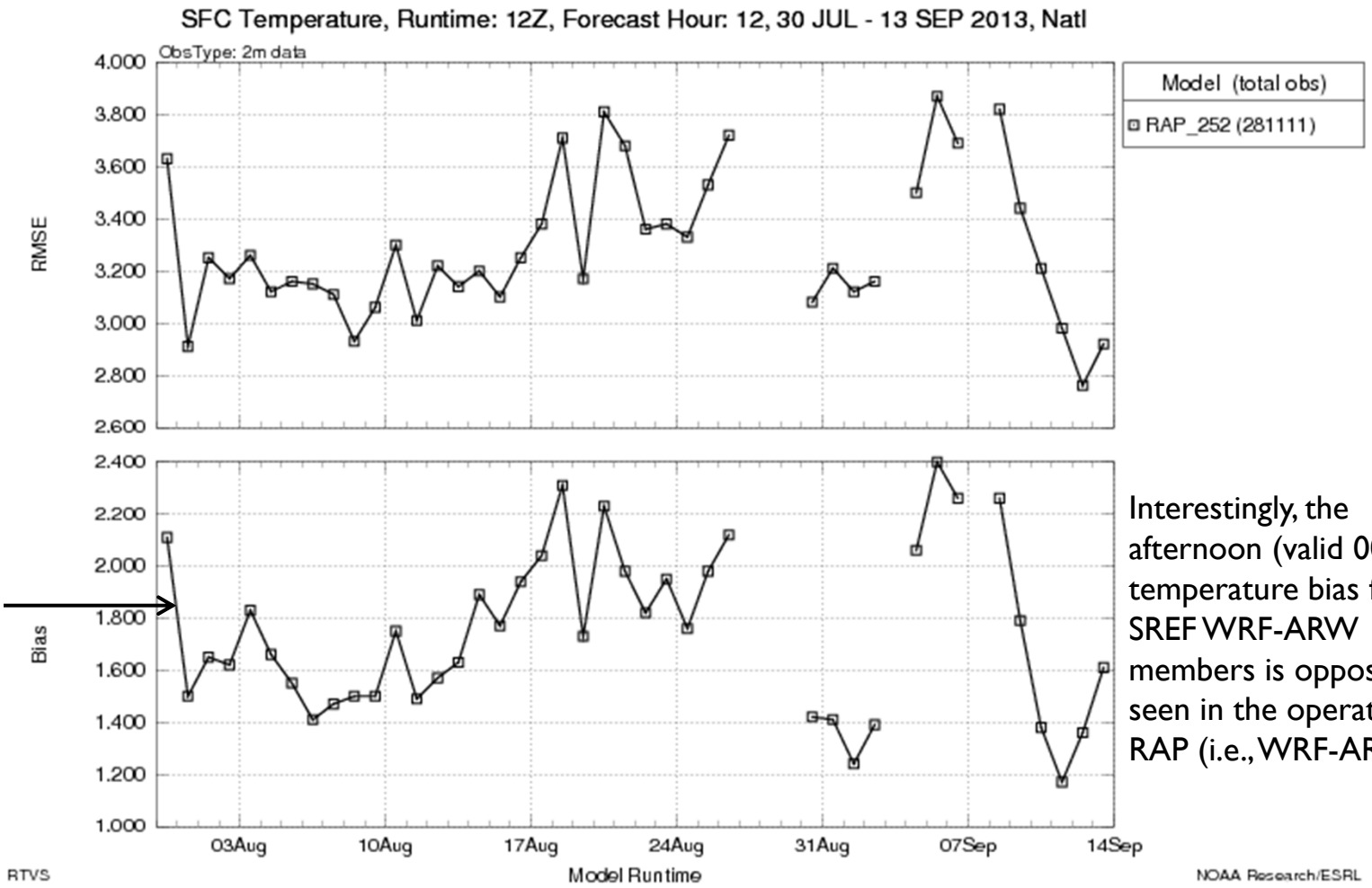
SPC Ensemble Applications

Mesoscale Guidance: SREF Performance



SPC Ensemble Applications

Mesoscale Guidance: SREF Performance

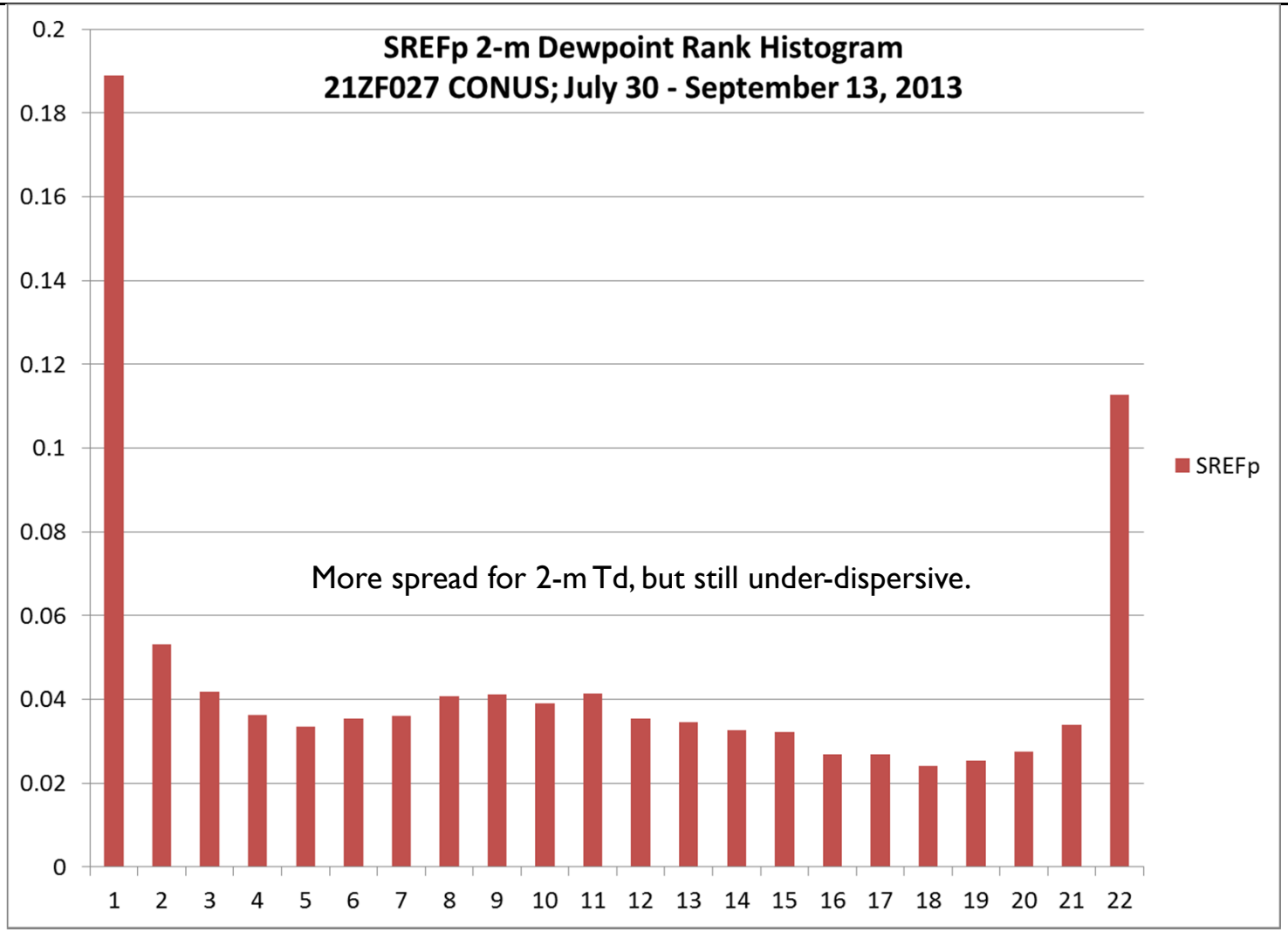


Afternoon warm bias in RAP →

Interestingly, the afternoon (valid 00Z) 2-m temperature bias for the SREF WRF-ARW members is opposite that seen in the operational RAP (i.e., WRF-ARW).

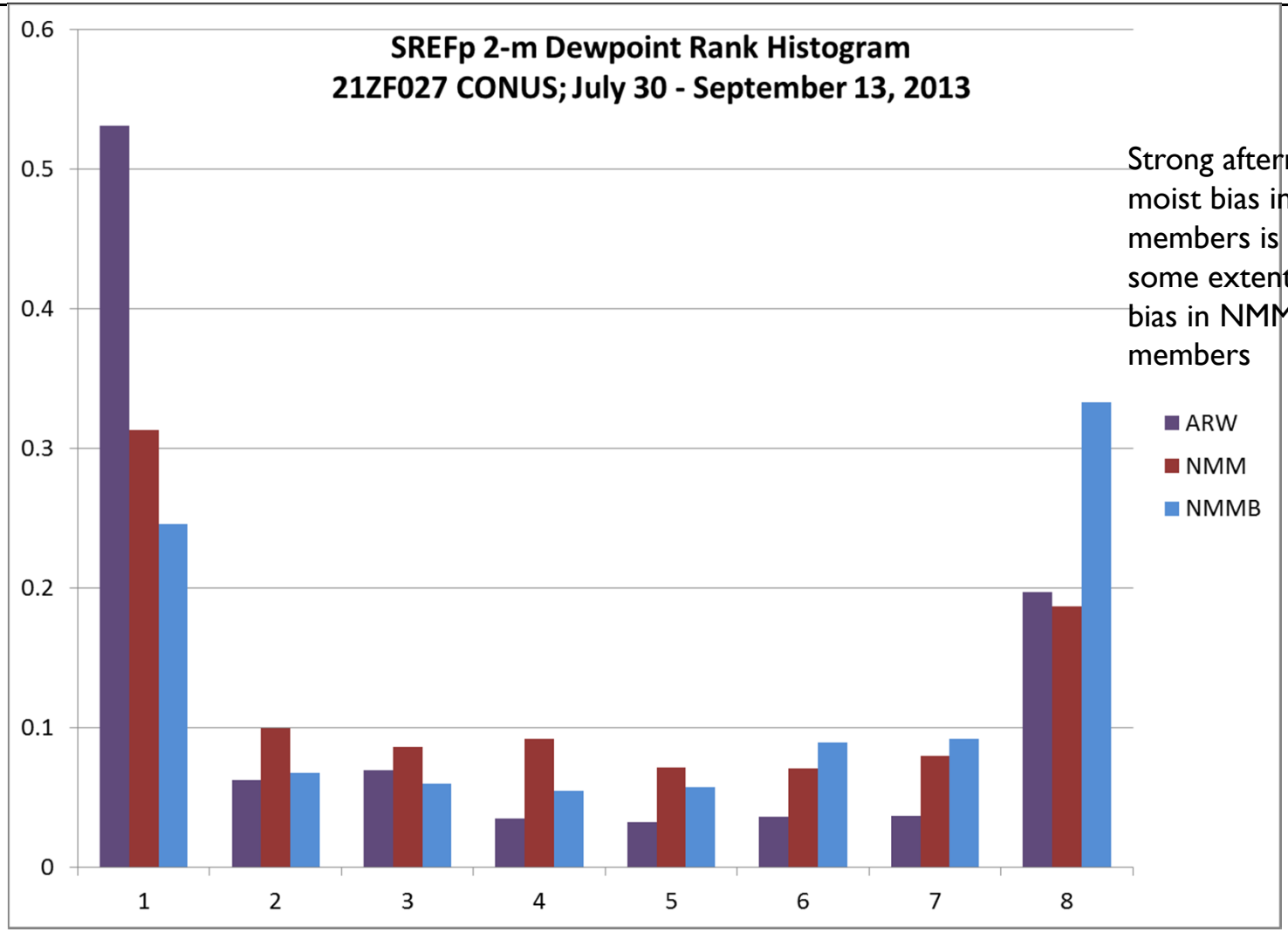
SPC Ensemble Applications

Mesoscale Guidance: SREF Performance



SPC Ensemble Applications

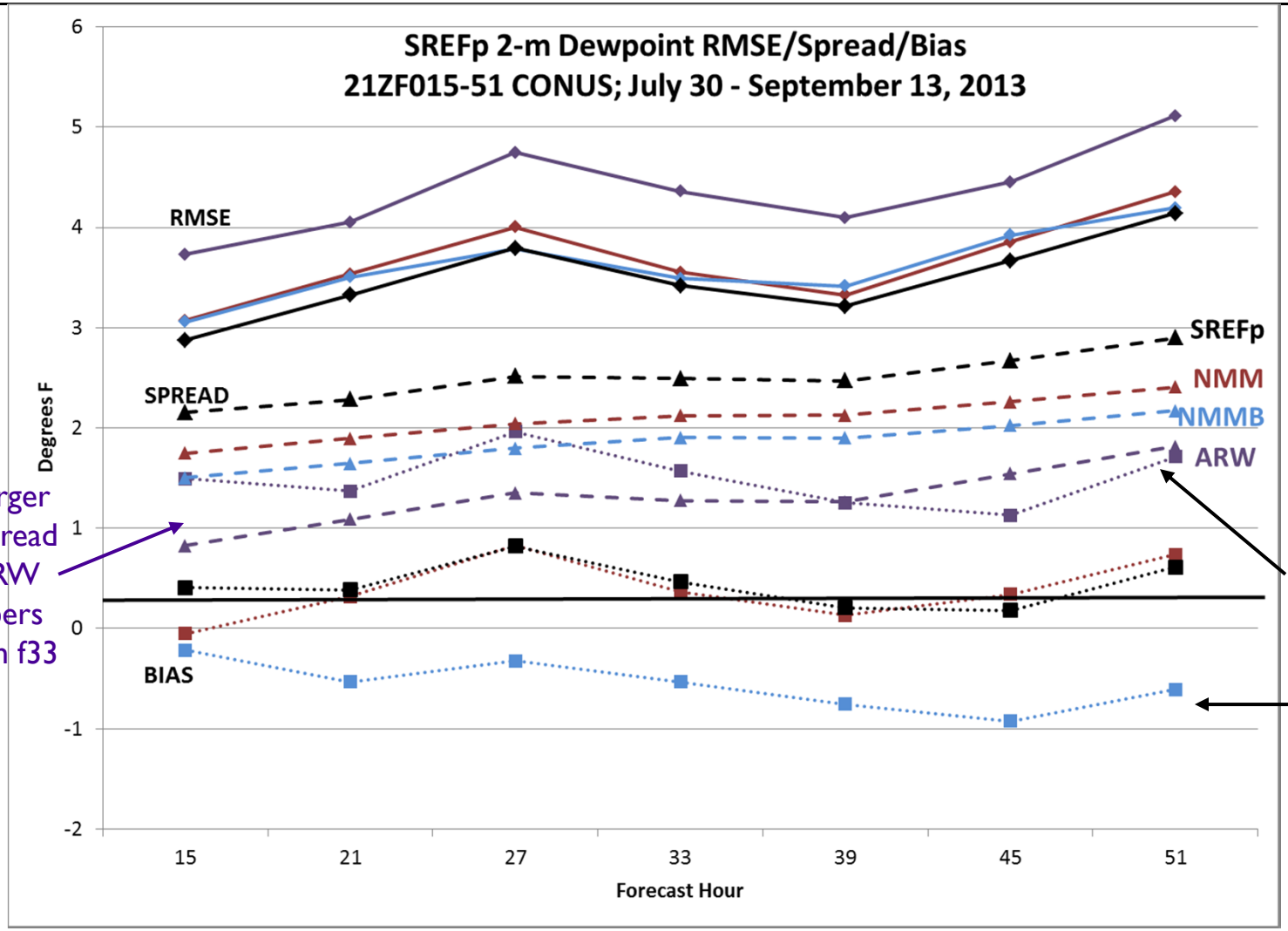
Mesoscale Guidance: SREF Performance



Strong afternoon moist bias in ARW members is offset to some extent by dry bias in NMMB members

SPC Ensemble Applications

Mesoscale Guidance: SREF Performance



Bias larger than spread for ARW members through f33

Fortuitous offsetting effects of moist ARW members and dry NMMB members

SPC Ensemble Applications

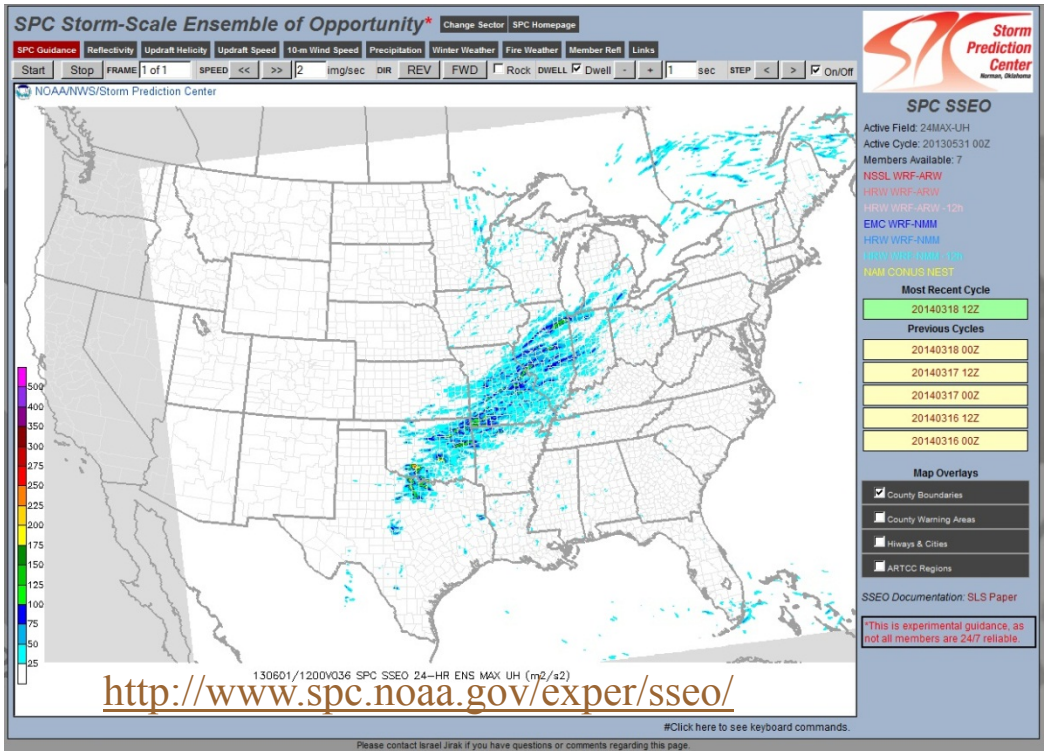
Mesoscale Guidance: SREF Performance

- The SREF is an important modeling system for SPC operations: *convective outlooks (Days 1-3), fire weather outlooks (Days 1-3), thunderstorm outlooks (Day 1), and winter weather mesoscale discussions (Day 1)*
- Given the importance of the SREF in providing guidance to SPC forecasters, we would like to see a focus on improving the overall performance of the ensemble through testing and evaluation to determine the best design and configuration
  - For example, the SREF WRF-ARW control member could be configured similarly (or identically) to the RAP (WRF-ARW)
    - Significant effort has been placed in developing and configuring the RAP to meet users' needs, so that work could be leveraged
    - Confusing to forecasters when a given model (e.g., WRF-ARW) has different biases based on version/configuration; they find comfort in knowing what to expect from a model
- Other components of the overall SREF system, like post-processing, products, and verification, could be performed by other groups to ensure proper resources are dedicated to design and configuration

SPC Ensemble Applications

Convection-Allowing Guidance: SSEO

- The SPC Storm-Scale Ensemble of Opportunity (SSEO) has been available in SPC operations for ~3 years and is used for severe, fire, and winter weather forecasting on Day 1
- The SSEO is created by processing deterministic CAMs from EMC and NSSL as an ensemble in an effort to efficiently summarize the data from high-resolution guidance
- Through an effective collaboration with EMC, upcoming upgrades to CAMs (HiResW, NAM Nest) will include aspects of diversity (physics, initial conditions) from an ensemble perspective to maximize utility from these runs until a formal convection-allowing ensemble becomes operational.

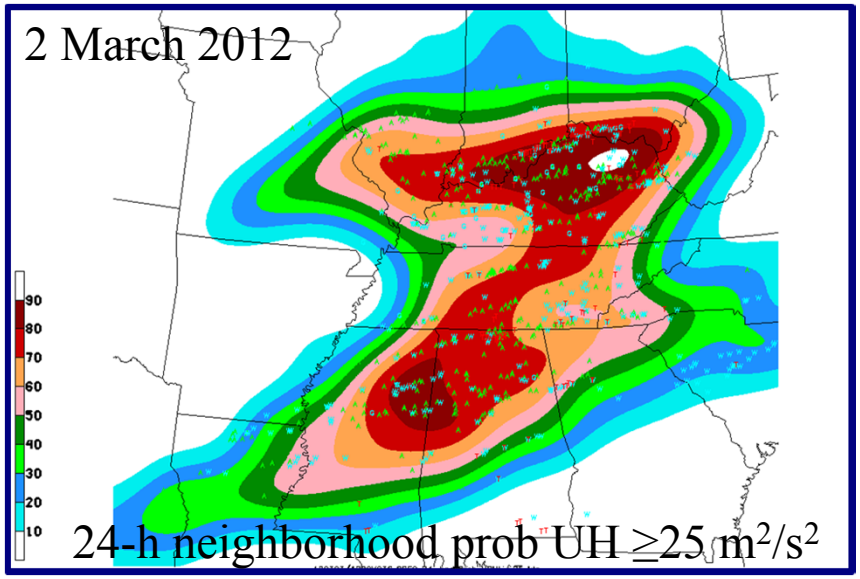


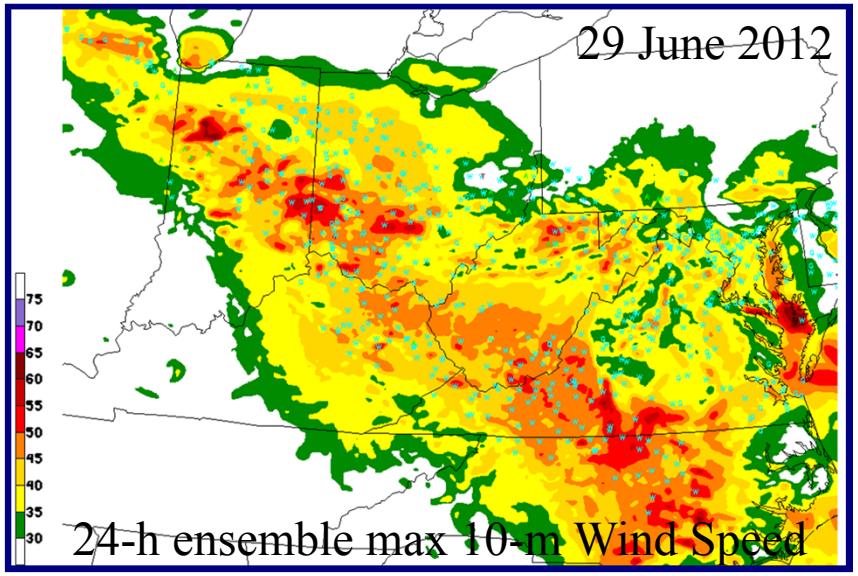
http://www.spc.noaa.gov/exper/sseo/

SPC Ensemble Applications

Convection-Allowing Guidance: SSEO

- As an added benefit, the SSEO serves as more than just a summary tool for CAMs. It also provides useful ensemble guidance for severe weather events, including significant days.
- Additionally, the SSEO has performed as well as or better than more formal convection-allowing ensembles during the previous three HWT Spring Forecasting Experiments.



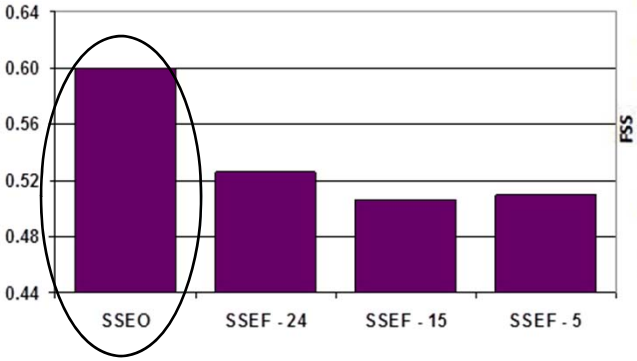


SPC Ensemble Applications

Convection-Allowing Guidance: SFE Comparisons

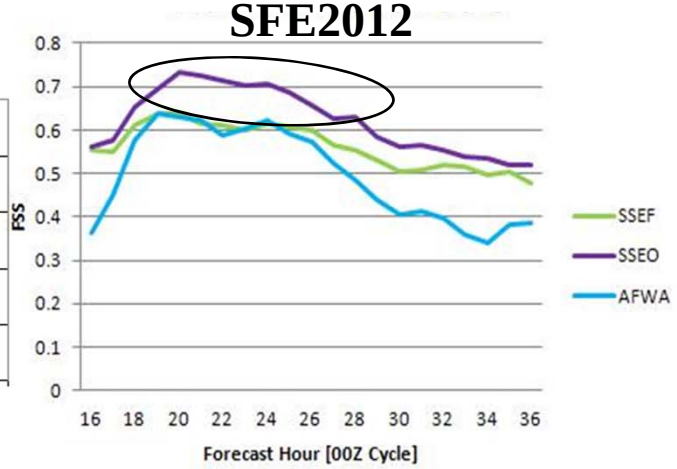
- When compared to the OU CAPS Storm-Scale Ensemble Forecast (SSEF) system in SFE2011, the SSEO had higher fractions skill score (FSS) for neighborhood probabilities of UH ≥25 m^2/s^2
- In SFE2012, SSEO outperformed the SSEF and AFWA convection-allowing ensembles in terms of FSS for neighborhood probabilities of reflectivity ≥40 dBZ (bug later found in SSEF)
- Last year in SFE2013, SSEO again performed as well as the SSEF for reflectivity during the daily peak of convective activity.
- Subjective ratings from participants were consistent with these results

SFE2011



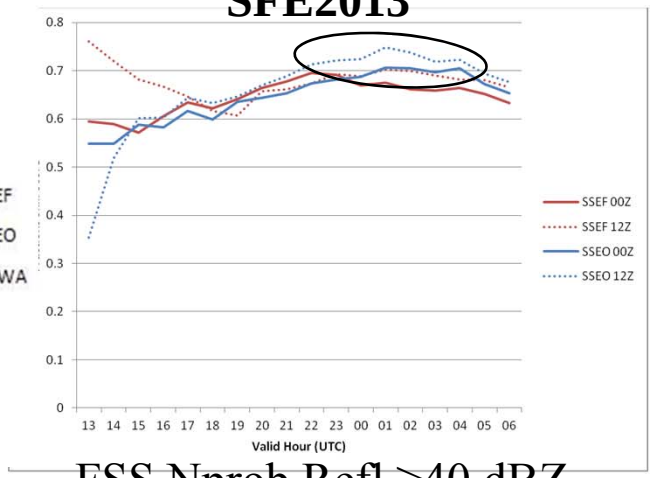
FSS Nprob UH ≥25 m^2/s^2

SFE2012



FSS Nprob Refl ≥40 dBZ

SFE2013



FSS Nprob Refl ≥40 dBZ

SPC Ensemble Applications

Convection-Allowing Guidance: Configuration

- Why is a "poor man's ensemble" performing as well as formally designed ensembles? Let's look at differences among them:

- **SPC Storm-Scale Ensemble of Opportunity (SSEO)**
  - 7 members at 00Z & 12Z; 4 to 5.1-km grid spacing
  - ***Multi-model*** (WRF-ARW, WRF-NMM, and NMM-B), multi-physics: NAM initial conditions, including two 12-h time-lagged members
  - Basic data assimilation through NDAS

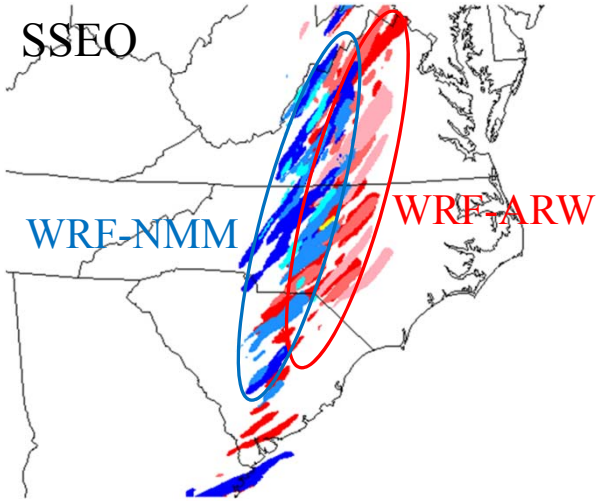
- **OU CAPS Storm-Scale Ensemble Forecast (SSEF) System**
  - 15 core members at 00Z; 8 members at 12Z; 4-km grid spacing
  - ***Single model*** (WRF-ARW), multi-physics, multi-initial conditions: apply SREF perturbations to NAM initial conditions
  - Advanced physics, radar data assimilation

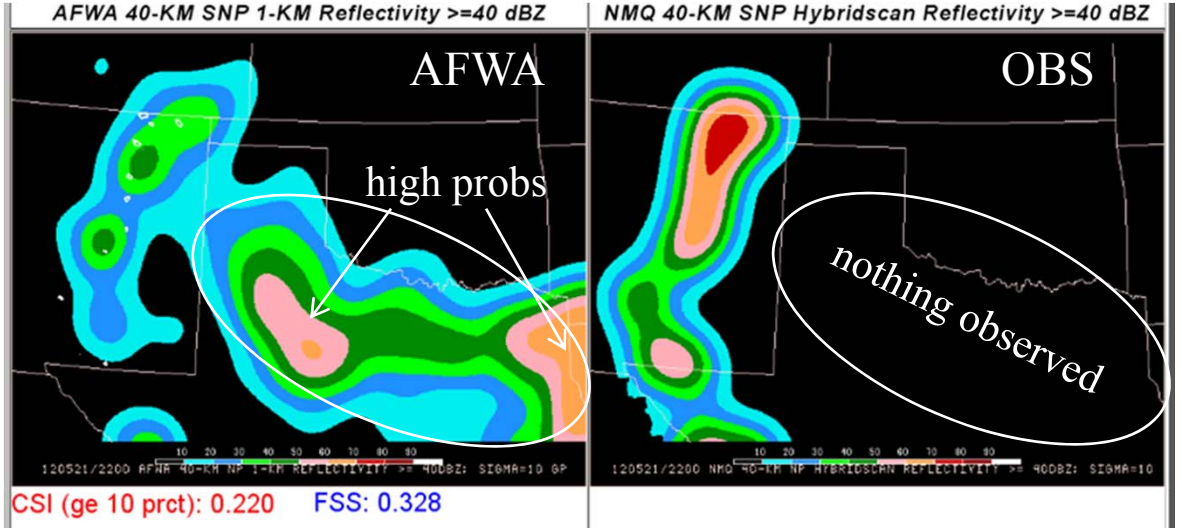
- **Air Force Weather Agency (AFWA) Ensemble**
  - 10 members at 00Z & 12Z with 4-km grid spacing
  - ***Single model*** (WRF-ARW), multi-physics, multi-initial conditions: cold start from downscaled global model forecasts
  - No data assimilation

SPC Ensemble Applications

Convection-Allowing Guidance: Configuration

- **Multi-model vs. single model**:
  - Even with the same initial conditions, clustering often occurs by model core
  - Generally more confident in a solution if different model cores are in agreement
- **Initial conditions**:
  - AFWA approach often leads to higher, overconfident probabilities
  - SSEF approach not an obvious improvement over single, unperturbed IC (i.e. SSEO), suggesting ICs not properly perturbed at this scale
  - What is the best approach? More work is needed in this area

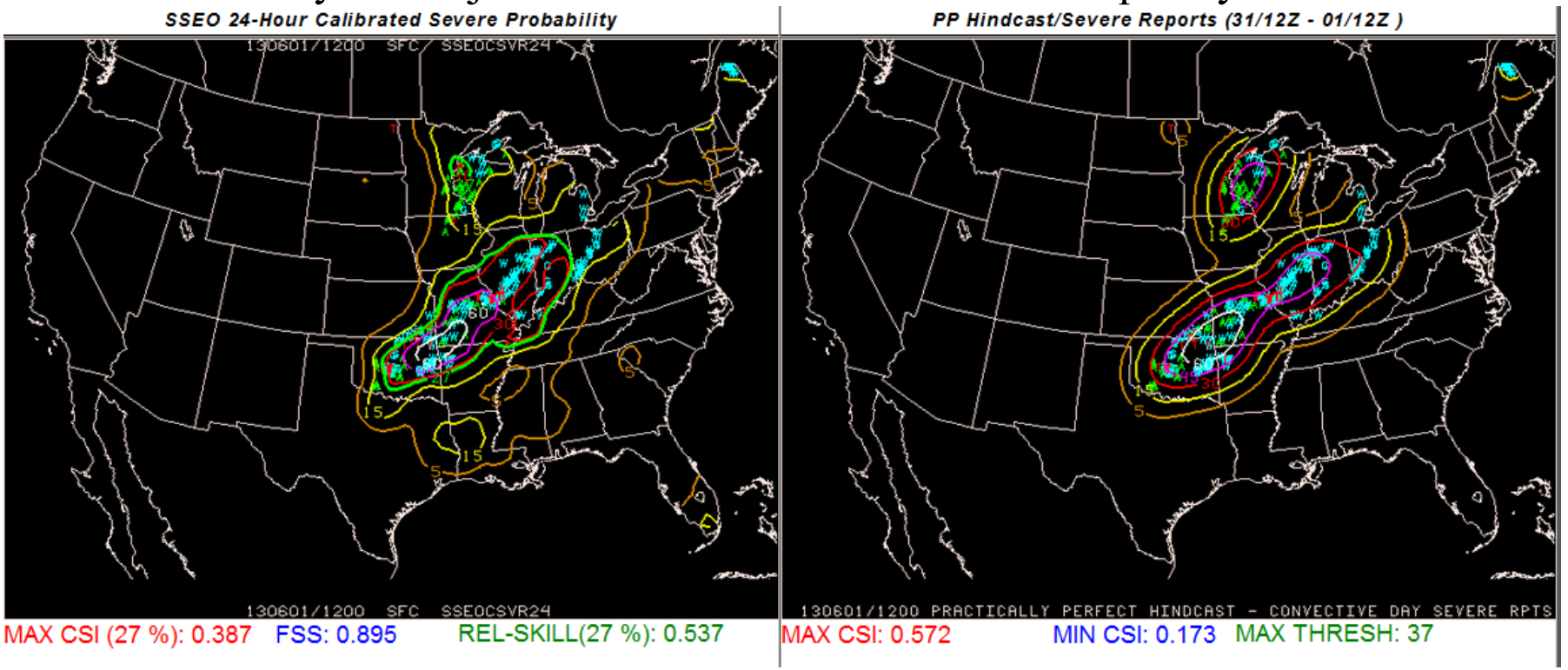




SPC Ensemble Applications

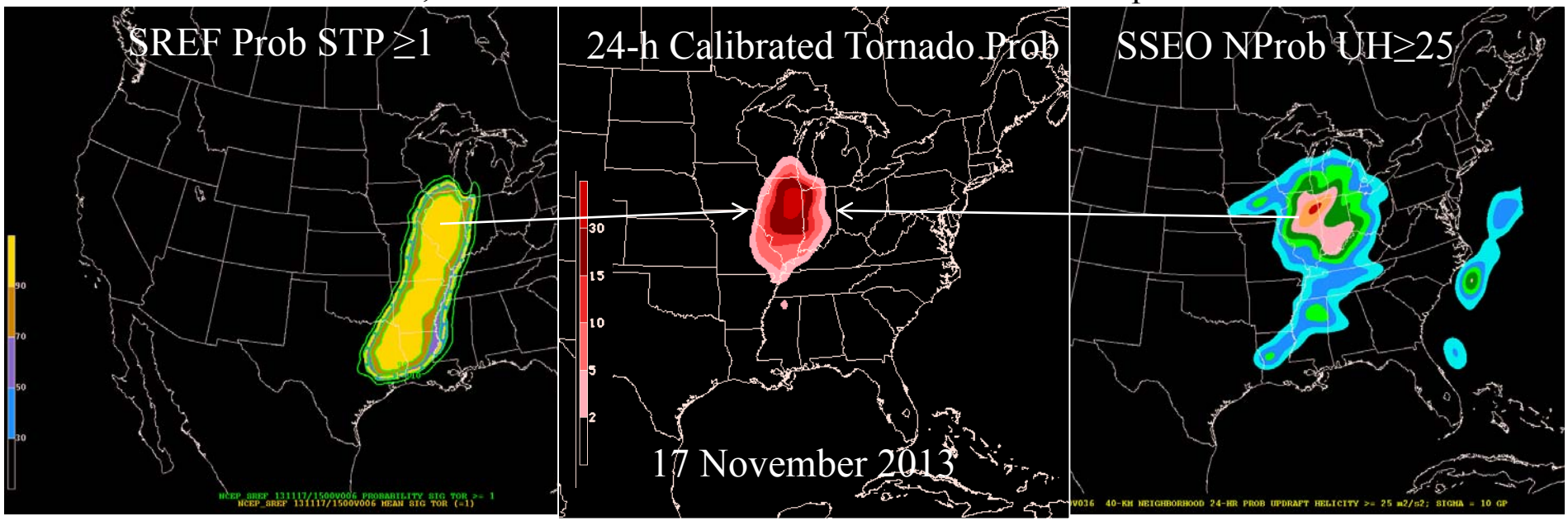
Convection-Allowing Guidance: SSEO Calibrated Severe

- Year-round availability of the SSEO allows for a sufficient data sample to generate calibrated severe probabilities based on ***explicit storm attributes***
- Calibration method uses neighborhood probabilities of updraft helicity, updraft speed, and 10-m wind speed in combination with simulated reflectivity and adjusts values based on historical frequency of severe weather



SPC Ensemble Applications
Combining Guidance: SSEO & SREF

- A storm with a rotating updraft (supercell) in a model (and reality) does not directly correspond to tornado occurrence; likewise, a favorable environment for tornadoes does not necessarily lead to tornado development
- This approach combines ***environment*** information from the SREF and ***explicit storm attribute*** information from the SSEO to arrive at calibrated probabilities for individual hazards: tornado, hail, & wind
  - Analogous to forecaster thinking – Given a storm (of certain mode/intensity) in this environment, what is the likelihood of severe and what are the possible hazards?



SPC Ensemble Applications
Summary

- Large-Scale Guidance: GEFS
  - Additional probabilistic threshold for extended severe outlooks along with calibrated severe guidance should lead to increased usage of GEFS
- Mesoscale Guidance: SREF
  - The last two implementations of SREF with sub-optimal characteristics support the need to focus on testing and development of the design and configuration to improve overall performance
- Convection-Allowing Guidance: SSEO
  - Convection-allowing ensembles will play an important role in the future of severe weather forecasting, and the SSEO provides a glimpse of the utility and capability of these types of systems
  - The HWT Spring Forecasting Experiment provides an opportunity to cultivate ideas and test configurations for this next-generation ensemble
  - Combining environment information from the SREF and storm-attribute information from the SSEO appears to be a promising approach for extracting hazard and timing information from the ensembles