102 Comparison of the SPC Storm-Scale Ensemble of Opportunity to other Convection-Allowing Ensembles for Severe Weather Forecasting

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1. INTRODUCTION

The Storm Prediction Center (SPC) has been generating the Storm-Scale Ensemble of Opportunity (SSEO; http://www.spc.noaa.gov/exper/sseo/) in real-time since 2011. Since that time, the SSEO has proven its utility in SPC operations on a year-round basis and has fared quite well when compared to formally designed convection-allowing ensembles during past Spring Forecasting Experiments (SFEs) in the NOAA Hazardous Weather Testbed (HWT). As such, the SPC SSEO is generally considered the standard against which other convection-allowing ensembles are compared and provides a baseline for the performance of a future operational convection-allowing ensemble.

The 2016 HWT SFE (SFE2016) was conducted from 2 May – 3 June with a focus on testing various aspects of convection-allowing ensemble design. As part of SFE2016, a group of similarly configured convection-allowing models (CAMs) was contributed by community collaborators to comprise the Community-Leveraged Unified Ensemble (CLUE). A few of the CLUE subsets, including ensemble Kalman filter (EnKF)-based systems, were available for comparison with the SSEO during SFE2016 for severe weather forecasting.

The basic configuration of the convection-allowing ensembles can be found in the following section (with detailed information available in the operations plan: http://hwt.nssl.noaa.gov/Spring_2016/HWT_SFE2016_operations_plan_final.pdf). Results from the comparison of CLUE subsets to the SSEO during SFE2016 are presented in the third section, followed by conclusions and discussion.

2. ENSEMBLE CONFIGURATION

As in previous SFEs, a suite of state-of-the-art experimental CAM guidance contributed by our large group of collaborators was central to SFE2016. However, this year a major effort was made to coordinate CAM-based ensemble configurations much more closely than in previous years. Specifically, instead of each group providing a separate, independently designed CAM-based ensemble, all groups agreed on a set of model specifications (e.g., grid-spacing, vertical levels, domain size, physics, etc.), so that the simulations contributed by each group could be used in carefully designed controlled experiments. This design allowed us to conduct several experiments geared toward identifying optimal configuration strategies for CAM-based ensembles. This large number of CAM members has been termed the Community Leveraged Unified Ensemble, or CLUE, and included 65 members with 3-km grid-spacing. Three of the more advanced CLUE subsets were selected for comparison with the SSEO: a 10-member CLUE mixed-core ensemble, the 10-member NCAR EnKF ensemble, and a 9-member EnKF ensemble from the Center for Analysis and Prediction of Storms (CAPS).

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2.1 SSEO

The SPC SSEO (Jirak et al. 2012) is a 7-member, multi-model and multi-physics convection-allowing ensemble consisting of deterministic CAMs with ~4-km grid spacing available to SPC year-round. This "poor man's ensemble" has been utilized in SPC operations since 2011 with forecasts to 36 hrs from 0000 and 1200 UTC, and it provides a practical alternative to a formal operational storm-scale ensemble. All members are initialized as a "cold start" from the operational North American Mesoscale model – i.e., no additional data assimilation is used to produce ICs.

2.2 CLUE Mixed-Core Ensemble

The CLUE mixed-core ensemble includes 5 WRF-ARW and 5 NMMB members for a total of 10 members. The forecasts extend out 60 hours on a 3-km grid. The 0000 UTC NAM analyses on the 12-km grid are used for initialization of two non-perturbed members and as first guess for the initialization of the eight perturbed members with the initial condition perturbations coming directly from the NCEP Short-Range Ensemble Forecast (SREF). The physics parameterizations are chosen to optimize performance from each model core and are constant in the ensemble for a given model core.

2.3 NCAR EnKF Ensemble

The NCAR ensemble (Schwartz et al. 2015) is a 10-member, CONUS domain, 3-km grid-spacing, EnKF-based ensemble with forecasts to 48 h. This ensemble uses NCAR's DART (Data Assimilation Research Testbed) software. The analysis system is comprised of 50 members (with constant physics) that are continuously cycled using the ensemble adjustment Kalman filter (EAKF). New analyses are produced every 6 h with 15-km grid-spacing using the following observational sources: MADIS ACARS, METARs, radiosondes, NCEP MARINE, CIMMS cloud-track winds, and Oklahoma Mesonet. From this mesoscale background, ten downscaled 3-km forecasts are initialized daily at 0000 UTC using the same physics as the data assimilation system, but without cumulus parameterization.

2.4 CAPS EnKF Ensemble

An EnKF-based, 3-km grid-spacing ensemble from CAPS consists of 9 members running out to 60 hours over the CONUS. Starting at 1800 UTC, a six-hour EnKF cycling process with 40 WRF-ARW members is performed on a 3-km grid over the CONUS domain. This ensemble is configured with initial perturbations and mixed physics options to provide input for the EnKF analysis. Each member uses Thompson microphysics with different parameter settings. EnKF analysis (cycling), with radar data and other conventional data, is performed from 2300 to 0000 UTC every 15 minutes over the CONUS domain, using the 40-member ensemble as background. A 9-member ensemble forecast (out to 60-h) ensues using the last EnKF analyses at 0000 UTC. More information about the CAPS EnKF system is found in Kong et al. (2015).

3. RESULTS

Forecasts from the different 0000 UTC-initialized ensembles were available for evaluation in SFE2016, providing an opportunity for comparisons among the different convection-allowing ensembles with varying degrees of complexity and diversity. There were two primary components to this comparison of the convection-allowing ensembles: 1) objective verification of neighborhood probabilities of reflectivity ≥40 dBZ and 2) subjective evaluation of ensemble hourly maximum fields (HMFs; Kain et al. 2010), such as updraft helicity (UH) and 10-m wind speed, relative to preliminary storm reports.

3.1 Objective Verification of Reflectivity Forecasts

The fractions skill score (FSS; Roberts and Lean 2008; Schwartz et al. 2010) was calculated for the ensemble neighborhood probability of 1-km AGL simulated reflectivity ≥40 dBZ using observed radar reflectivity for verification. When looking at the FSS for reflectivity by forecast hour during SFE2016 (Fig. 1), the SSEO had the highest FSS through forecast hour 29 (i.e., valid 0500 UTC), followed by the multi-core CLUE ensemble. The single-core (i.e., WRF-ARW) EnKF ensembles generally had lower FSS during much of the forecast cycle, but especially during the peak convective period of the afternoon (i.e., 1900-2300 UTC)

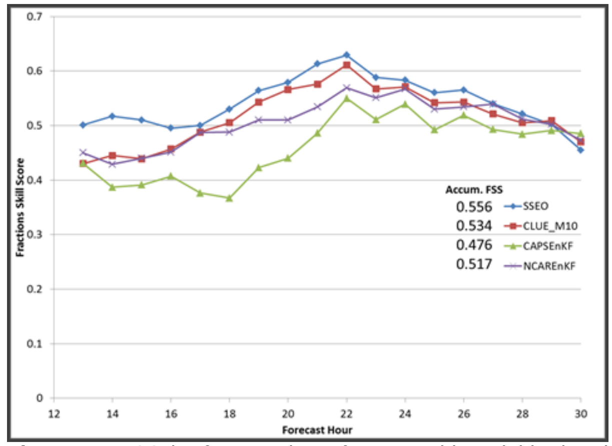

Figure 1. FSS by forecast hour for ensemble neighborhood probabilistic reflectivity forecasts ≥40 dBZ from the SSEO (blue line) and three CLUE subsets during SFE2016.

From another statistical perspective, the area under the relative operating characteristic (ROC) curve for probabilistic forecasts of 1-km AGL simulated reflectivity ≥40 dBZ was also calculated for the ensembles (Fig. 2). The results were similar to those for FSS, as the SSEO had the largest area under the ROC curve while the multi-core CLUE ensemble had the second highest ROC area. Once again, the CAPS EnKF ensemble trailed the other ensembles by a substantial margin.

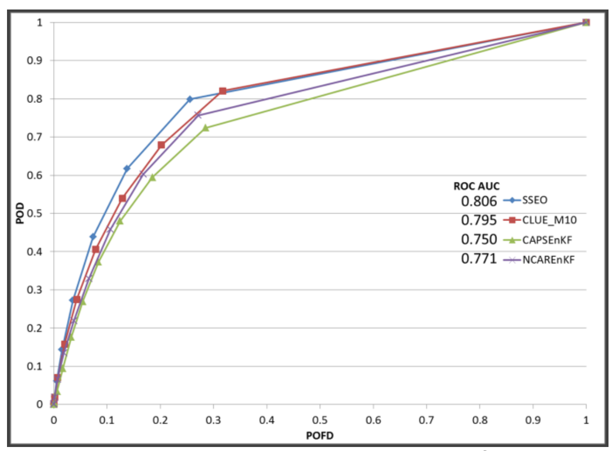

Figure 2. ROC curves for probabilistic reflectivity forecasts ≥40 dBZ from the SSEO (blue line) and three CLUE subsets during SFE2016.

Since ROC diagrams and areas are not sensitive to forecast biases (Wilks 2006), reliability diagrams were also examined for probabilistic forecasts from the ensembles (Fig. 3). While all of the ensembles exhibited an overforecast bias, the SSEO probabilistic forecasts were the closest to perfect reliability (solid diagonal line in Fig. 3). This overforecast bias is an indication of the underdispersive nature of the convection-allowing ensembles in forecasting convective storms.

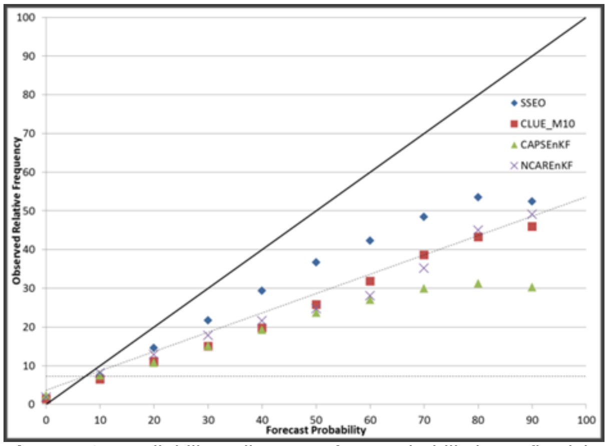

Figure 3. Reliability diagram for probabilistic reflectivity forecasts ≥40 dBZ from the SSEO (blue diamonds) and three CLUE subsets during SFE2016.

3.2 Subjective Evaluation of HMF Forecasts

During SFE2016, HMFs, such as UH, were examined from the ensembles during the 1800-0200 UTC period and compared to severe weather reports. Participants were asked to rate the usefulness of the ensembles in providing guidance for a severe weather outlook. The subjective ratings of the ensemble HMF forecasts were generally similar among the ensembles (Fig. 4), except for the CAPS EnKF. The CAPS EnKF had the lowest-rated forecasts in terms of the median and upper quartile of the rating distribution. Meanwhile, the SSEO had fewer low-rated forecasts than the other ensembles, as evidenced by the upward-shifted lower quartile. Overall, the subjective HMF ratings agree reasonably well with the objective verification results for probabilistic reflectivity forecasts in highlighting a preference for SSEO forecasts.

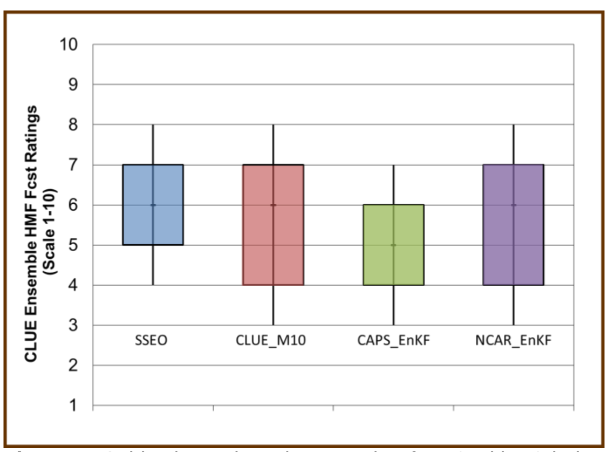

Figure 4. Subjective ratings (on a scale of 1-10 with 10 being the highest rating) of HMF forecasts valid 1800-0200 UTC from the SSEO and three CLUE subsets during SFE2016.

4. CONCLUSIONS

An unprecedented effort was made in the HWT during the SFE2016 to coordinate CAM-based ensemble configurations much more closely than in previous SFEs, which was done in the context of the Community Leveraged Unified Ensemble (CLUE). Three advanced convection-allowing ensembles from the CLUE were compared to the SSEO in real time during the five-week SFE2016. In the subjective evaluation of HMF forecasts from the ensembles, the SSEO forecasts were slightly favored over the other ensembles. Additionally, the SSEO verified better objectively than any CLUE subset, including EnKF systems, for probabilistic reflectivity forecasts ≥40 dBZ during SFE2016. The diversity of the SSEO appears to help in reducing the overforecast bias (i.e., underdispersive nature), leading to improved probabilistic forecasts over other ensembles. As a result, the SSEO can serve as a meaningful baseline for the performance of a future operational convection-allowing ensemble.

Acknowledgements. SFE2016 would not have been possible without dedicated participants and the support and assistance of numerous individuals at SPC and NSSL. In addition, collaborations with OU CAPS and NCAR were vital to the success of SFE2016. In particular, Ming Xue (OU CAPS), Fanyou Kong (OU CAPS), Kevin Thomas (OU CAPS), Keith Brewster (OU CAPS), Glen Romine (NCAR), Craig Schwartz (NCAR), and Ryan Sobash (NCAR) were essential in generating and providing access to ensemble forecasts examined on a daily basis.

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