Jirak, I. J., C. J. Melick, and S. J. Weiss, 2015: Comparison of convection-allowing ensembles during the 2015 NOAA Hazardous Weather Testbed Spring Forecasting Experiment . Extended Abstract, *40th Natl. Wea. Assoc. Annual Meeting*, Oklahoma City, OK.

AP-36 Comparison of Convection-Allowing Ensembles during the 2015 NOAA Hazardous Weather Testbed Spring Forecasting Experiment

ISRAEL L. JIRAK[1], CHRISTOPHER J. MELICK[1,2], AND STEVEN J. WEISS[1]
[1]NOAA/Storm Prediction Center, Norman, Oklahoma
[2]Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma

ABSTRACT

As the Storm Prediction Center (SPC) moves toward severe weather outlooks with higher temporal resolution, convection-allowing ensembles will play an increasingly important role in providing the forecaster with probabilistic guidance regarding storm initiation, coverage, mode, timing, and intensity. During the 2015 NOAA Hazardous Weather Testbed Spring Forecasting Experiment (SFE2015), a total of six convection-allowing ensembles were examined and compared for providing guidance in generating experimental severe weather outlooks. The convection-allowing ensembles were provided by the SPC, National Severe Storms Laboratory (NSSL), United States Air Force (USAF), National Center for Atmospheric Research (NCAR), and the University of Oklahoma (OU) Center for Analysis and Prediction of Storms (CAPS; two ensembles). The difference in configuration and initialization/perturbation strategies of these small-member ensembles provided an opportunity to identify strengths and weaknesses of the various approaches. Overall, each of the convection-allowing ensembles provided similar, useful guidance during SFE2015 both objectively for reflectivity forecasts (>40 dBZ) and subjectively for severe weather forecasting, regardless of the design and complexity of the ensemble.

1. Introduction

The 2015 Spring Forecasting Experiment (SFE2015) was conducted from 4 May – 5 June by the Experimental Forecast Program (EFP) of the NOAA/Hazardous Weather Testbed (HWT). SFE2015 was organized by the Storm Prediction Center (SPC) and National Severe Storms Laboratory (NSSL) with participation from numerous forecasters, researchers, and developers from around the world to test emerging concepts and technologies designed to improve the prediction of hazardous convective weather. SFE2015 aimed to address several primary goals that are consistent with the Forecasting a Continuum of Environmental Threats (FACETs) and Warn-on Forecast (WoF) visions.

One of the primary scientific activities of SFE2015 was to compare convection-allowing ensembles and identify strengths and weaknesses of the different configurations and initialization/perturbation strategies. For SFE2015, six (6) convection-allowing ensembles were available for examination and evaluation: SPC storm-scale ensemble of opportunity (SSEO), NSSL-WRF ensemble, United States Air Force (USAF) ensemble, National Center for Atmospheric Research (NCAR) ensemble, and the University of Oklahoma (OU) Center for Analysis and Prediction of Storms (CAPS) storm-scale ensemble forecasts (SSEF; two ensembles).

Corresponding author address: Israel L. Jirak, Storm Prediction Center, 120 David L. Boren Blvd., Norman, OK 73072. E-mail: Israel.Jirak@noaa.gov

The basic configuration of the convection-allowing ensembles can be found in the following section (with more detailed information available in the operations plan: http://hwt.nssl.noaa.gov/Spring_2015/HWT_SFE_2015_OPS_plan_final.pdf). Results from SFE2015 are presented in the third section, followed by conclusions and discussion.

2. Ensemble configuration

All of the convection-allowing ensembles available during SFE2015 were configured differently with varying levels of complexity. Although the differences in the ensemble configurations did not allow for controlled experiments, the ensemble output from each of the systems could be compared in terms of providing guidance for severe weather forecasts.

a. SPC SSEO

The SPC Storm-Scale Ensemble of Opportunity (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, which will not be available in the near-term because of computational limitations in NOAA. 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.

b. NSSL-WRF Ensemble

The NSSL-WRF ensemble includes eight additional 4-km WRF-ARW runs that – along with the deterministic NSSL-WRF (Kain et al. 2010) – comprised a nine-member NSSL-WRF-based ensemble. The additional eight members are initialized at 0000 UTC and use 3-h forecasts from the NCEP Short Range Ensemble Forecast (SREF) system initialized at 2100 UTC for initial conditions (ICs) and corresponding SREF member forecasts as lateral boundary conditions (LBCs). The physics parameterizations for each member are identical to the deterministic NSSL-WRF. Although the unvaried physics will have lower spread than a multiple-physics ensemble, SPC forecasters and NSSL scientists are very familiar with the behavior of the NSSL-WRF physics, allowing for the isolation of ensemble spread contributed only by ICs/LBCs.

c. USAF 4-km Ensemble

The U.S. Air Force (USAF, formerly AFWA) ensemble includes 10 WRF-ARW members at 4-km grid spacing over the CONUS (Kuchera 2014). Forecasts are initialized at 0000 UTC and 1200 UTC using downscaled 6- or 12-hour forecasts from three global models: a version of the Met Office Unified Model (UM), the NCEP Global Forecast System (GFS), and the Canadian Meteorological Center Global Environmental Multiscale (GEM) Model. Diversity in the USAF ensemble is achieved through IC/LBCs from the different global models and varied microphysics and boundary layer parameterizations. No data assimilation is performed in initializing these runs.

d. 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.

e. CAPS SSEF 3DVar

The legacy 0000 UTC SSEF system for SFE2015 consists of 12 "core" members that are used for ensemble products. The grid-spacing of the SSEF was reduced from 4-km to 3-km for SFE2015 with forecasts extending out to 60 hours. The 0000 UTC NAM analyses available on the 12-km grid are used for initialization of control and non-perturbed members and as first guess for the initialization of perturbed members with the initial condition perturbations coming directly from the NCEP Short-Range Ensemble Forecast (SREF). WSR-88D reflectivity and velocity data, along with available surface and upper air observations, are analyzed using ARPS 3DVAR/Cloud-analysis system.

f. CAPS SSEF EnKF

A separate EnKF-based, 3-km grid-spacing ensemble from CAPS consists of 12 members also 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 WSM6 microphysics with different parameter settings. All members also include random perturbations with recursive filtering of ~20 km horizontal correlations scales, with relatively small perturbations (0.5K for potential temperature and 5% for relative humidity). 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 12-member ensemble forecast (out to 60-h) ensues using the last EnKF analyses at 0000 UTC. More information about both CAPS SSEF systems is found in Kong et al. (2015).

3. Results

Forecasts from the six different 0000 UTC-initialized ensembles were available for evaluation in SFE2015, providing an opportunity for comparisons among multiple convection-allowing ensemble designs with varying degrees of complexity and diversity. There were two primary components to this comparison of the convection-allowing ensembles: 1) objective evaluation of neighborhood probabilities of reflectivity ≥40 dBZ and 2) subjective verification of ensemble hourly maximum fields (HMFs; Kain et al. 2010), such as updraft helicity and 10-m wind speed, relative to preliminary storm reports.

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. The ensembles had a similar distribution of daily FSS over the five-week SFE2015 (Fig. 1) with the SSEF EnKF showing the lowest skill overall. While the USAF and NCAR ensembles tended to produce more forecasts of lower skill than the SSEO, NSSL, and SSEF, the median and upper quartile values were similar among the five best-performing ensembles.

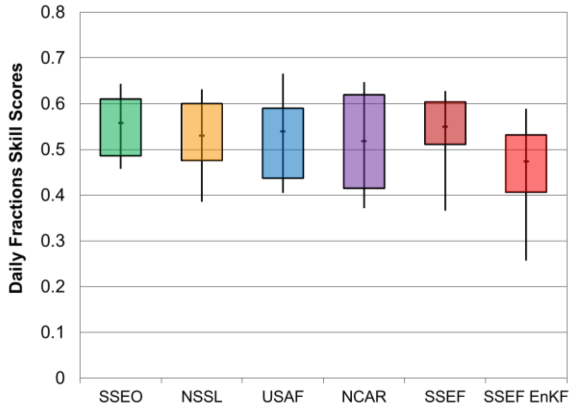

Figure 1. Distribution of daily FSS for ensemble neighborhood reflectivity forecasts from the six different convection-allowing ensembles during the five-week SFE2015. The boxes comprise the interquartile range of the distributions and the tips of the whiskers extend to the 10th and 90th percentiles.

When looking at the FSS for reflectivity by forecast hour (Fig. 2), some additional characteristics are apparent regarding the ensembles. The SSEF EnKF generally had the lowest FSS throughout the forecast cycle. Although the SSEO had the highest cumulative FSS twelve hours into the forecast, it finished the forecast 24 hours later with the lowest FSS. Aside from the SSEF EnKF, the other five ensembles generally had similar performance during the peak convective period of 2000-0200 UTC. Even with very different configurations and methods of initialization, the ensembles appeared to perform similar statistically during the spring.

In terms of the subjective ratings of the ensemble hourly-maximum field (HMF) forecasts in providing guidance for severe weather forecasts, the distribution of ratings among the ensembles was rather similar (Fig. 3), except for the SSEF EnKF, which was the lowest-rated ensemble. For the top-performing ensembles, they more often than not provided useful severe weather guidance (i.e. mean rating above 5). The NSSL ensemble had a slightly higher mean/median rating than the other ensembles while the NCAR and USAF ensembles had slightly lower mean ratings than the SSEO, NSSL, and SSEF. The similar ratings among the ensembles highlight the fact that the complexity of convection-allowing ensemble design does not appear to strongly correspond to the ability of an ensemble to provide useful guidance for severe weather outlooks.

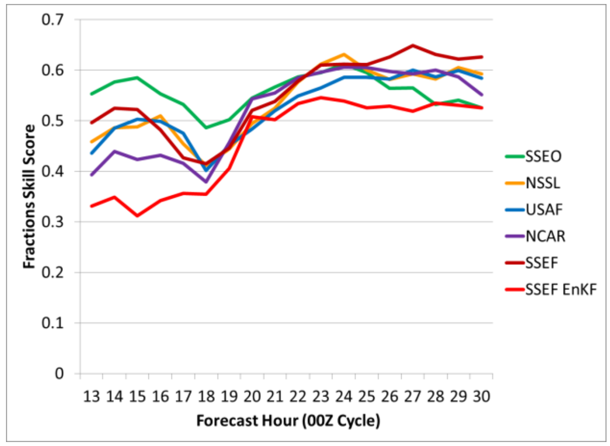

Figure 2. FSS by forecast hour for ensemble neighborhood reflectivity forecasts from the six convection-allowing ensembles during SFE2015.

4. Conclusions

An unprecedented number of convection-allowing ensembles were available for examination and evaluation in real-time during the SFE2015. The six convection-allowing ensembles were designed and generated independently by various groups and organizations with different configurations and levels of complexity. In general, all of the convection-allowing ensembles provided similar, useful guidance both objectively for reflectivity forecasts (>40 dBZ) and subjectively for severe weather forecasting (i.e., forecast hours 12 to 36 from 0000 UTC initialization) during SFE2015 regardless of design and complexity.

These results are spurring more community collaboration to systematically compare impacts of model core, IC/LBC perturbations, data assimilation, and physics diversity on convection-allowing ensemble design. The tentative plans for SFE2016 include controlled convection-allowing ensemble design experiments to provide evidence for informed decision making at NCEP for an operational convection-allowing ensemble.

Acknowledgements. SFE2015 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, USAF, NCAR and the Met Office were vital to the success of SFE2015. In particular, Ming Xue (OU CAPS), Fanyou Kong (OU CAPS), Kevin Thomas (OU CAPS), Keith Brewster (OU CAPS), Yunheng Wang (OU CAPS), Evan Kuchera (USAF), Scott Rentschler (USAF), Glen Romine (NCAR), Craig Schwartz (NCAR), and Ryan Sobash (NCAR) were essential in generating and providing access to model forecasts examined on a daily basis.

REFERENCES

Jirak, I. L., S. J. Weiss, and C. J. Melick, 2012: The SPC storm-scale ensemble of opportunity: Overview and results from the 2012 Hazardous Weather Testbed Spring Forecasting Experiment. *Preprints*, 26th Conf. Severe Local Storms, Nashville, TN. Amer. Meteor. Soc., P9.137.

Kain, J. S., S. R. Dembek, S. J. Weiss, J. L. Case, J. J. Levit, and R. A. Sobash, 2010: Extracting unique information from high-resolution forecast models: Monitoring selected fields and phenomena every time step. Wea. Forecasting, 25, 1536–1542.

Kong, F. , M. Xue, Y. Jung, K. Brewster, K. Thomas, Y. Wang, F. Shen, A. Clark, I. L. Jirak, S. J. Weiss, J. Correia Jr., and C. J. Melick, 2015: An overview of CAPS storm-scale ensemble forecast for the 2015 NOAA HWT Spring Forecasting Experiment. 27th Conf. on Weather Analysis and Forecasting/23rd Conf. on Numerical Weather Prediction. Amer. Meteor. Soc., Chicago, IL. (P32)

Kuchera, E., S. Rentschler, G. Creighton, and J. Hamilton, 2014: The Air Force weather ensemble prediction suite. 15th Annual WRF Users' Workshop, Boulder CO. Website: http://www2.mmm.ucar.edu/wrf/users/workshops/WS2014/ppts/2.3.pdf

Roberts, N. M. and H. W. Lean, 2008: Scale-selective verification of rainfall accumulations from high-resolution forecasts of convective events. *Mon. Wea. Rev*., **136**, 78–97

Schwartz, C. S., J. S. Kain, S. J. Weiss, M. Xue, D. R. Bright, F. Kong, K. W. Thomas, J. J. Levit, M. C. Coniglio, and M. S. Wandishin, 2010: Toward improved convection-allowing ensembles: Model physics sensitivities and optimizing probabilistic guidance with small ensemble membership. *Wea. Forecasting*, **25**, 263–280.

Schwartz, C. S., G. S. Romine, R. A. Sobash, K. R. Fossell, and M. L. Weisman, 2015: NCAR's experimental real-time convection-allowing ensemble prediction system. *Wea. Forecasting*, **30**, 1645–1654.

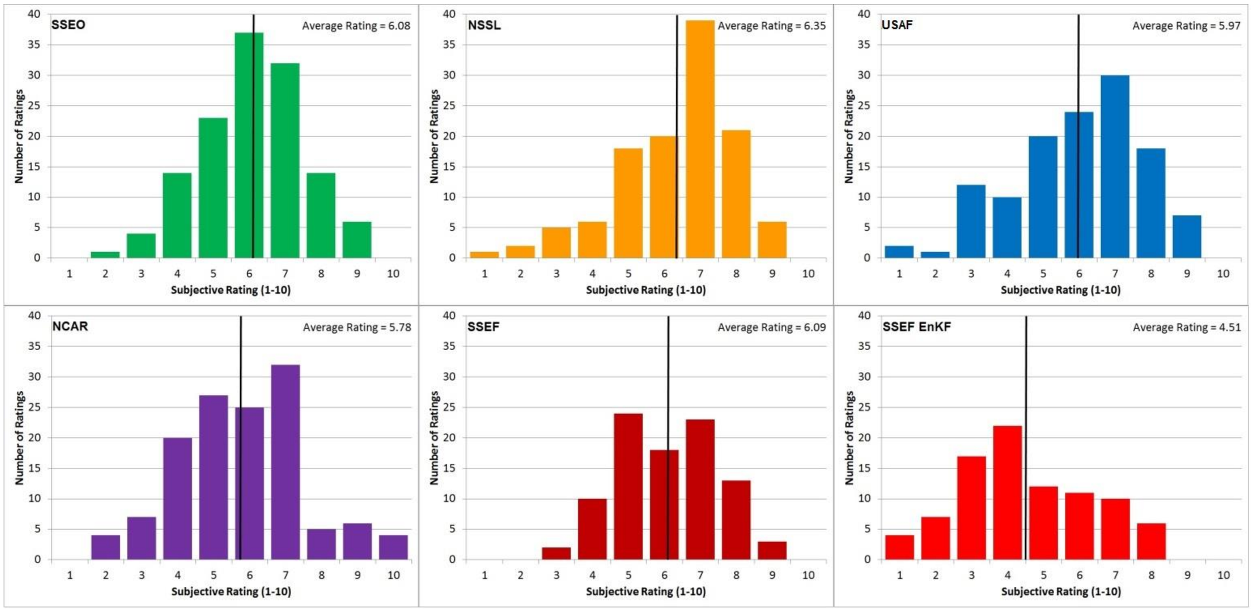

Figure 3. Distribution of subjective ratings for the ensemble HMF forecasts compared to local storm reports for the six different convection-allowing ensembles during SFE2015.