P9.137 The SPC Storm-Scale Ensemble of Opportunity: Overview and Results from the 2012 Hazardous Weather Testbed Spring Forecasting Experiment

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1. INTRODUCTION

The number of operational and experimental deterministic convection-allowing models (CAMs) available to forecasters at the Storm Prediction Center (SPC) has been increasing over the past few years. While the volume of high-resolution numerical model data has increased, the amount of time available to examine and scrutinize the data in creating a forecast has not changed. Thus, the concept of the SPC Storm-Scale Ensemble of Opportunity (SSEO) was developed to process the deterministic CAMs as an ensemble in an effort to efficiently summarize the data from high-resolution guidance. Given the limited computing resources available at NOAA in the foreseeable future, this approach provides a practical alternative to a formal storm-scale ensemble.

The objective of this paper is to document the configuration and the processing and display techniques utilized in the generation of the SPC SSEO. Additionally, results from the 2012 NOAA Hazardous Weather Testbed Spring Forecasting Experiment (SFE2012) are presented, especially in comparing the utility of the SSEO to other storm-scale ensembles for convective and severe weather forecasting.

2. SPC SSEO OVERVIEW

2.1 Configuration

The 00 UTC SPC SSEO is a multi-model, multi-physics ensemble comprised of seven (7) deterministic CAM runs already available in real-time to SPC forecasters (Table 1). The following five models are included in the SSEO: NSSL WRF-ARW, High-Resolution Window (HRW) WRF-ARW, HRW WRF-NMM, CONUS WRF-NMM (sometimes referred to as the "SPC Run" by EMC and NWS forecast offices), and the NAM (i.e., NEMS NMM-B) CONUS Nest. Two 12-h time-lagged HRW runs (one ARW and one NMM) are added for initial condition diversity to bring the 00 UTC SSEO to a total of seven members.

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Unfortunately, the only member of the SSEO that is always available for every cycle is the NAM CONUS Nest. The HRW runs are operational, but they are currently subject to pre-emption when there are three or more hurricane model runs (HWRF and GFDL), which is fairly common from June through November. The NSSL WRF-ARW and EMC WRF-NMM are non-operational runs that are not supported 24/7 and are subject to outages for various reasons. Nevertheless, all seven members of the SSEO were available for about 75% of the days in the past year.

2.2 Fields Processed

Only a few fields are specifically selected to be processed as part of the SSEO. In particular, storm-attribute hourly maximum fields (HMFs; Kain et al. 2010) are a focus for severe convective weather forecasting.

Table 1: Membership configuration of the 00 UTC SSEO. Members highlighted with an asterisk (*) are 12-h time-lagged members.

	Grid Spacing	Vert Levels	Time Step	Fcst Length	PBL	Micro
NSSL WRF-ARW	4 km	35	24 s	36 h	MYJ	WSM6
EMC HRW WRF-ARW	5.15 km	35	30 s	48 h	YSU	WSM3
EMC HRW WRF-ARW*	5.15 km	35	30 s	48 h	YSU	WSM3
EMC HRW WRF-NMM	4 km	35	7.5 s	48 h	MYJ	Ferrier
EMC HRW WRF-NMM*	4 km	35	7.5 s	48 h	MYJ	Ferrier
EMC CONUS WRF-NMM	4 km	35	7.5 s	36 h	MYJ	Ferrier
EMC CONUS NAM NEST	4 km	60	8.9 s	60 h	MYJ	Ferrier

The four HMFs included in the SSEO are ***1-km AGL simulated reflectivity*** for diagnosing convective mode and intensity, ***updraft helicity*** (UH; Kain et al. 2008) for representing a rotating updraft in a simulated storm (i.e., supercell), ***updraft speed*** for providing a measure of convective overturning, and ***10-m AGL wind speed*** for identifying convective wind gusts.

In addition to the storm-attribute HMFs, a small number of other fields are processed as part of the SSEO for fire- and winter-weather forecasting. These fields include 2-m temperature and relative humidity, accumulated precipitation, and precipitation type. By combining these variables together, several useful guidance products can be created to aid in the forecasting responsibilities of the SPC.

2.3 Processing Techniques

Some processing techniques are utilized to help summarize and extract the most useful information from the ensemble. These techniques are primarily applied to the storm-attribute HMFs. One technique involves taking the temporal maximum of an HMF over some specified time period. Given the unique aspect of the storm-attribute HMFs, the maximum value each hour over the lifetime of a storm provides a simulated "storm track" and corresponding "swaths" of severe weather potential. Furthermore, extracting the temporal maxima over the period during which a convective outlook is valid (e.g., 12-12 UTC) nicely summarizes expected storm activity and severity over that time period in a single plot.

Another processing technique is used to account for spatial uncertainty and the lack of grid point agreement in the placement of storms among the CAMs. This technique involves taking the maximum value within a specified horizontal radius (i.e. neighborhood). Following the results of Harless et al. (2010) and the SPC probabilistic definition utilized in convective outlooks, the maximum value of storm-attribute HMFs is found within a 40-km neighborhood. This approach provides meaningful probabilistic information when ensemble members have similar, but not identical, placement of storms.

2.4 Display Techniques

Many of the typical ensemble display techniques (e.g., mean, maximum, exceedance probabilities) are utilized with the SSEO. Some of the most useful ensemble displays of the storm-attribute HMFs include spaghetti plots, ensemble maximum displays, and smoothed neighborhood probability plots. Spaghetti plots simply display each member in a different color for a given field and threshold (e.g., Fig. 1a). With a multi-model ensemble like the SSEO, spaghetti plots are useful in determining which models, and specifically which model cores, are in agreement for a particular solution. The ensemble maximum (e.g., Fig. 1b) provides an estimate of the upper-end of storm intensity for a particular forecast. Smoothed neighborhood probabilities (e.g., Fig. 1c) show the degree to which the models are in agreement with one another in the placement of storms. For the SSEO, neighborhood probabilities are calculated for a 40-km radius and smoothed using 2-D Gaussian kernel density estimation (Brooks et al. 1998) with a smoothing parameter of 40 km. All three types of ensemble displays should be used in a complementary manner to better understand the distribution and characteristics of an ensemble HMF.

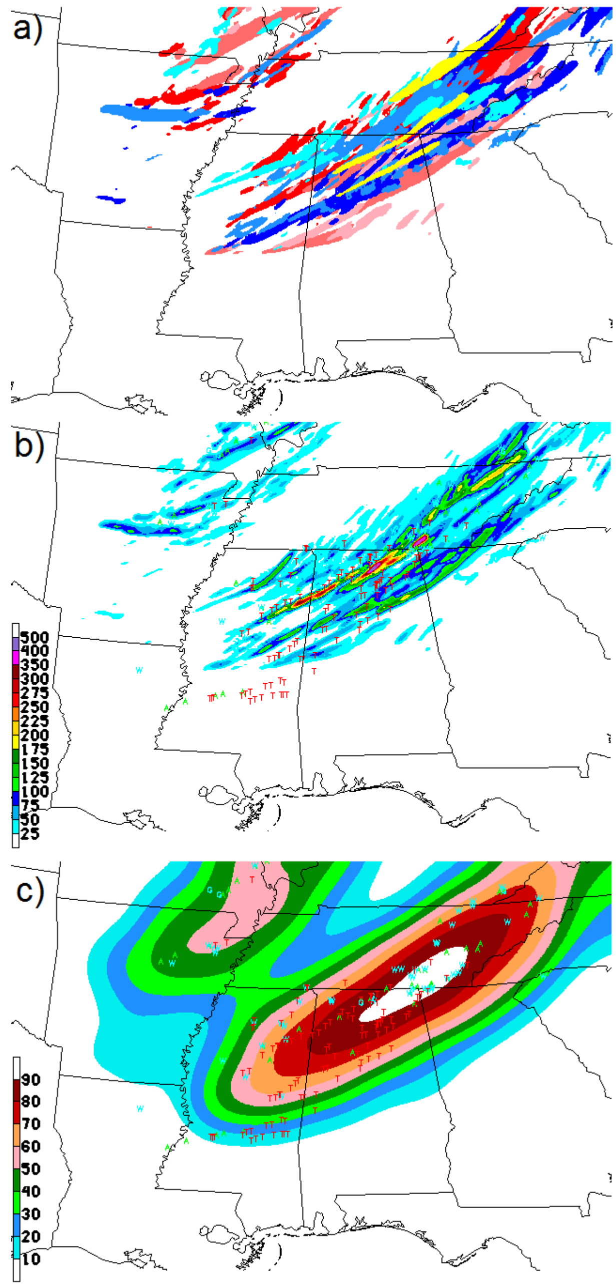

Figure 1. SSEO forecasts valid for the 6-h period ending at 00 UTC on 28 April 2011: a) 6-h spaghetti plot of UH ≥25 m^{2}s^{-2}, b) 6-h ensemble maximum of UH (m^{2}s^{-2}), and c) 6-h smoothed neighborhood probability of UH ≥25 m^{2}s^{-2} (%). In b) and c), the preliminary storm reports from this 6-h period are shown (tornado – red, hail – green, and wind – blue).

3. SFE2012 ENSEMBLE VERIFICATION OVERVIEW

The SFE2012 was conducted over a five-week period running from 7 May – 8 June. During the SFE2012, there were three storm-scale ensembles available for evaluation (see the Operations Plan at http://hwt.nssl.noaa.gov/Spring_2012/ for more information): the SPC SSEO, which was described previously, the University of Oklahoma Center for Analysis and Prediction of Storms storm-scale ensemble forecast (SSEF) system, and the Air Force Weather Agency storm-scale ensemble (AFWA). The SSEF was a 12-core member multi-model (10 WRF-ARW), multi-physics ensemble with initial condition diversity derived by using SREF perturbations for initial conditions (IC) and lateral boundary conditions (LBCs). The AFWA was a 10-member single-model (WRF-ARW), multi-physics ensemble with initial condition diversity derived by using downscaled global model forecasts for IC/LBCs.

To compare the forecast skill among the storm-scale ensembles, objective verification was performed on the smoothed neighborhood probabilities of 1-km AGL simulated reflectivity ≥40 dBZ. The ensembles were verified against the NMQ hybrid-scan reflectivity (Zhang et al. 2011) with a 40-km neighborhood maximum and 40-km Gaussian smoother applied to the observations to emulate the ensemble probabilities. A 2x2 contingency table was tallied to calculate the critical success index (CSI) at a forecast value of 10% ("yes" forecast if >=10%, otherwise a "no" forecast) hourly from 16-12 UTC for each day throughout the SFE2012. Similarly, the fractions skill score (FSS; Roberts and Lean 2008; Schwartz et al. 2010) was calculated hourly and accumulated during the SFE2012.

4. SFE2012 ENSEMBLE VERIFICATION RESULTS

4.1 Objective Verification: Reflectivity Probabilities

Daily CSI and FSS values were calculated for smoothed neighborhood probabilities of reflectivity ≥40 dBZ from 16-12 UTC during the SFE2012. The distribution of daily scores reveals considerable overlap amongst the ensembles (Fig. 2). The SSEO has higher median and 25th percentile values than the SSEF and AFWA for both CSI and FSS. The metrics objectively indicate that the SSEO was at least as good as, if not better than, the more formal storm-scale ensembles in probabilistic forecasts of convection (i.e., reflectivity ≥40 dBZ) during this five-week period in the late spring/early summer.

Accumulated scores of CSI and FSS over the entire SFE2012 show similar results between the two metrics (Fig. 3). The SSEO scored the highest of the three ensembles during the SFE2012 followed by the SSEF and AFWA. Again, this result supports the utility of the SSEO for probabilistic convective forecasting when compared to other storm-scale ensembles. Examination of objective metrics by forecast hour (Fig. 4) reveals some interesting diurnal trends. The maxima in CSI and FSS occur during the period of peak convective activity (i.e. 20-00 UTC) for all of the ensembles. During this late afternoon/early evening period, the SSEO shows the largest improvement in objective metrics over the SSEF and AFWA while the difference at other times of the diurnal cycle appears to be much less.

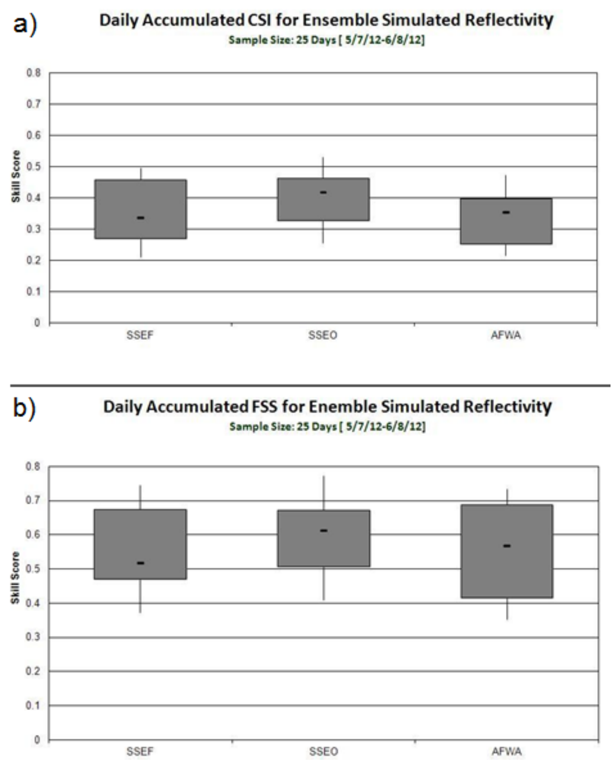

Figure 2. The distribution of daily (16-12 UTC) a) CSI at 10% and b) FSS for smoothed neighborhood probabilities of simulated reflectivity ≥40 dBZ of each ensemble, as available (3 days missing for AFWA and 1 day missing for SSEF). The boxes show the 25th to 75th percentile values (with the median as indicated by a dash) while the whiskers show the 10th and 90th percentile values.

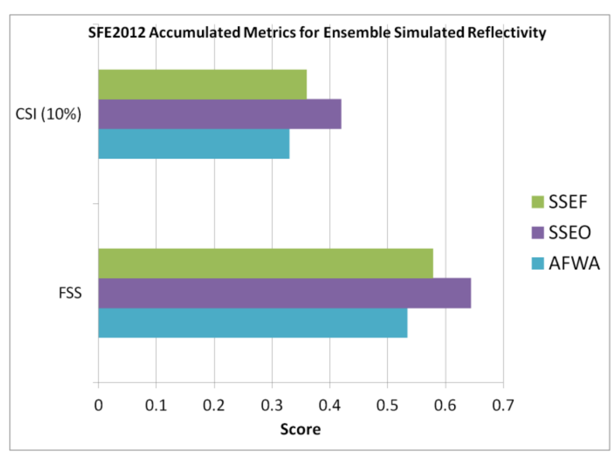

Figure 3. The accumulated CSI (10%) and FSS for each ensemble during the SFE2012 for smoothed neighborhood probabilities of simulated reflectivity ≥40 dBZ.

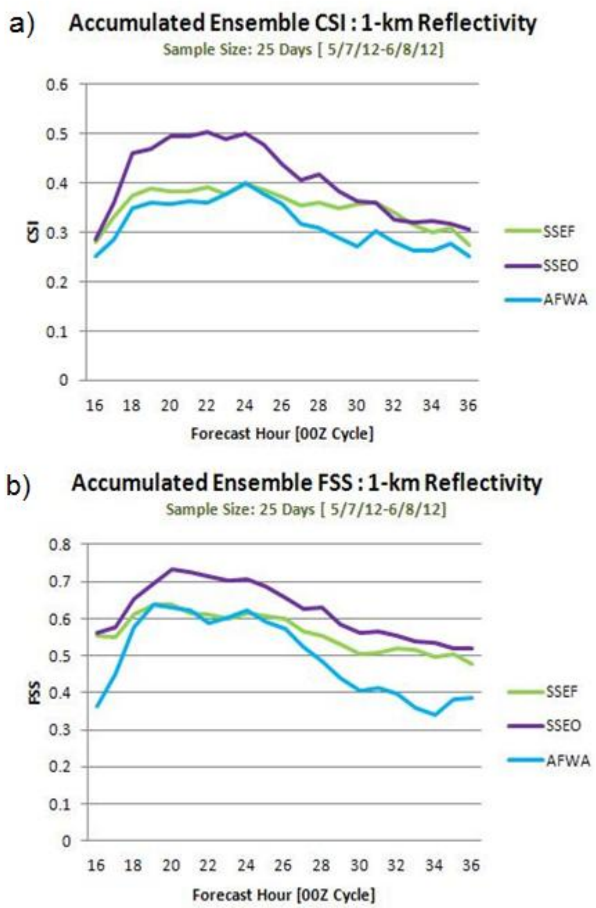

Figure 4. The accumulated a) CSI (10%) and b) FSS by forecast hour during the SFE2012 for neighborhood probabilities of simulated reflectivity ≥40 dBZ for each ensemble.

4.2 Subjective Verification: Reflectivity Probabilities

During the afternoon sessions of the SFE2012, participants would examine the forecasts from the previous day and rate the perceived usefulness of the forecasts in providing guidance to severe weather forecasters. The subjective ratings consisted of 5 categories ranging from very poor to very good. Although each ensemble was rated independently, ensemble intercomparison did occur as part of the rating process. The subjective ratings of the smoothed neighborhood probabilities of reflectivity ≥40 dBZ (Fig. 5) generally agreed with the objective results just discussed. The SSEO received more “good” ratings than the SSEF and AFWA combined. The subjective ratings slightly favored the AFWA over the SSEF with more “good” and “fair” ratings and fewer “poor” and “very poor” rated forecasts while the objective metrics gave a slight edge to the SSEF (c.f., Fig. 3). Overall, the subjective ratings of reflectivity forecasts confirm the higher objective verification scores of the SSEO as compared to the other ensembles.

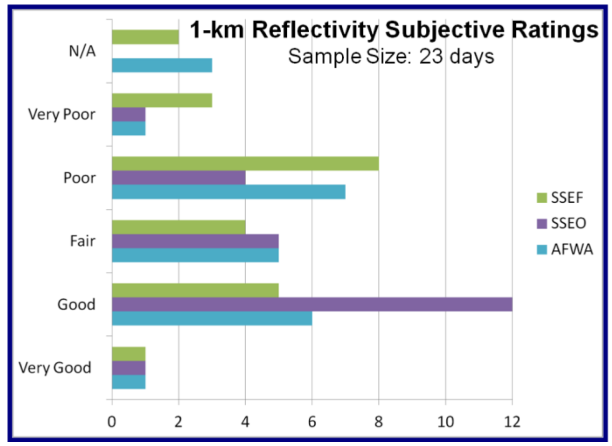

Figure 5. Subjective ratings by SFE2012 participants of the perceived usefulness of the reflectivity probability forecasts for each ensemble from very poor to very good.

4.3 Subjective Verification: UH Forecasts

In a similar manner, UH forecasts (ensemble maximum and smoothed neighborhood probabilities of UH ≥25 m^2s^{-2} and UH ≥100 m^2s^{-2}) were subjectively compared to preliminary storm reports and subsequently assigned ratings from very poor to very good. The subjective ratings for UH forecasts (Fig. 6) show similar trends to those for the reflectivity forecasts with the SSEO receiving the highest number of “good” and “very good” ratings. The AFWA received a rating of “fair” or better for 75% of its forecasts while over three-fourths of the SSEF UH forecasts were rated as “fair” or worse.

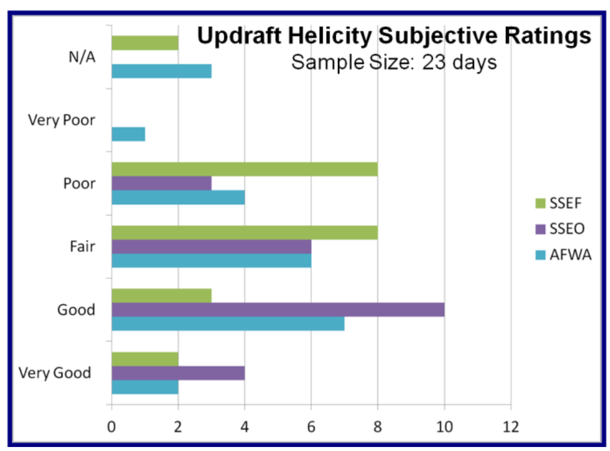

Figure 6. Subjective ratings by SFE2012 participants of the usefulness of UH probability forecasts for each ensemble from very poor to very good.

5. SUMMARY AND CONCLUSIONS

The SPC SSEO is comprised of deterministic CAMs already available to SPC forecasters. Processing these deterministic models as an ensemble allows for a more efficient and effective way of summarizing the output than looking at each model individually. Additionally, the availability of necessary computing resources to generate a formal operational storm-scale ensemble within NOAA does not appear likely in the near future; thus, the SSEO is a practical approach to generating storm-scale ensemble data.

In utilizing CAMs for forecasting severe weather, a focus is placed on storm-attribute HMFs, especially simulated reflectivity, updraft helicity, updraft speed, and 10-m wind speed. Processing the temporal and spatial maxima of these fields aids in extracting the most important information from the dataset. Furthermore, examination of multiple ensemble displays, such as spaghetti plots, ensemble maximum, and smoothed neighborhood probabilities, helps in understanding the characteristics and behavior of the ensemble.

The objective and subjective results presented from the SFE2012 reveal that the SSEO can provide useful guidance for convective and severe weather forecasting, including indications that the SSEO performs as well as or better than more formal storm-scale ensembles. Results from the SFE2011 (not shown) and positive comments from SPC forecasters using the data operationally for the past 18 months support these findings.

Although the initial impetus of the SSEO was for severe weather forecasting, it also provides unique and useful guidance for fire- and winter-weather forecasting. A few select graphics of these fields have been made available on an SPC web site (Fig. 7; http://www.spc.noaa.gov/exper/sseo). In the future, more fields, features, and enhancements will be added to this site as time allows.

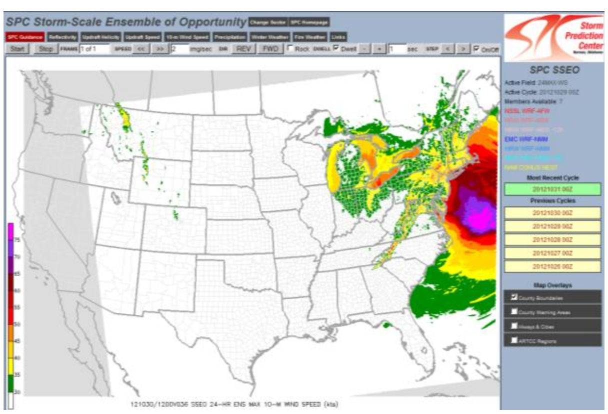

Figure 7: Screen capture of the SPC SSEO web site. Regional sectors can be selected at the top to zoom into an area of interest.

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