STORM-SCALE ENSEMBLE FORECASTING FOR THE NOAA HAZARDOUS WEATHER TESTBED

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I. INTRODUCTION

Accurate prediction of convective-scale hazardous weather events continues to be a major challenge because of the small spatial and temporal scales of the associated weather systems, and the inherent nonlinearity of their dynamics and physics. Uncertainties in numerical weather prediction (NWP) and the high-nonlinearity of the weather systems at the convective-scales render probabilistic forecasts from high-resolution ensemble forecasting systems especially valuable to operational forecasters. Though ensemble forecasting has long become the cornerstone of medium-range global NWP in weather centers around the world and the regional short-range ensemble forecasting (SREF) has been in operation over a decade (Toth and Kalnay 1997; Kalnay 2003; Du and Tracton 2001), the storm-scale ensemble forecasting (SSEF) study is in its very early stage.

A multi-year realtime SSEF effort has been conducted since 2007 at the Center for Analysis and Prediction of Storms in University of Oklahoma as part of the NOAA Hazardous Weather Testbed (HWT) Spring Experiment (Xue et al. 2007, 2008, 2009; Kong et al. 2007, 2008, 2009; Clark et al. 2011). The CAPS SSEF consists of 20-50 members from three NWP model systems (WRF-ARW, WRF-NMM, and ARPS), covering the full continental United States at a 4-km horizontal grid pacing (the domain is shown in FIG.1). SSEF members are configured with a combination of initial perturbations extracted from the coarser grid NCEP SREF ensemble members and various physics options in microphysics, PBL and land-surface model, and radiation. Radar data from over 140 WSR-88D Doppler weather radars, both radial wind and reflectivity, are analyzed into the SSEF in realtime using the ARPS 3DVAR/Cloud Analysis system. A wide range of ensemble products are made available, including QPF and PQPF (both grid-wise and neighborhood), and the probability matched ensemble mean QPF. Experimental probability products of lightning threat and CI parameters are also produced from the SSEF starting 2011 Spring.

II. CAPS SSEF OVERVIEW

Each spring in the past five years from 2007 to 2011, the Center for Analysis and Prediction of Storms (CAPS), in collaboration with the Storm Prediction Center (SPC) and the National Severe Storm Laboratory (NSSL) and funded by the NOAA Collaborative Science, Technology, and Applied Research (CSTAR) program, had conducted highly successful real-time storm-scale ensemble forecast (SSEF) experiment to support the NOAA Hazardous Weather Testbed (HWT) Spring Experiment Program (Xue et al. 2007, 2008, 2009; Kong et al. 2007, 2008, 2009). TABLE I outlines the CAPS SSEF system and its evolution history.

Year	2007	2008	2009	2010	2011
Member	10	10	20	26	51
Domain - CONUS	2/3 (4 km)	3/4 (4 km)	3/4 (4 km)	Full (4 km)	Full (4 km)
Forecast	33 h	30 h	30 h	30 h	36 h
Model	WRF-ARW	WRF-ARW	ARW NMM ARPS	ARW NMM ARPS	ARW NMM ARPS
Radar	No radar	Radial wind, reflectivi	Radial wind, reflectivi	Radial wind, reflectivi	Radial wind, reflectivi

TABLE 1: Highlight of CAPS SSEF annual evolution since 2007.

For the 2011 Spring Experiment, the CAPS SSEF features 51-member multi-model, multi-physics, convection-allowing (at 4-km horizontal grid spacing) forecasts that are produced daily for 36-h. The storm-scale ensemble is consist of 41 ARW members, 5 NMM members, 4 ARPS members, and 1 COAMPS members. WRFV3.2.1 is used for both dynamic cores. Forecasts were initiated every weekday at 00

UTC throughout the Spring Experiment period that ran from 25 April to 10 June 2011, all performed remotely on the supercomputing facilities in the National Institute of Computational Science (NICS) in the University of Tennessee, a NSF funded Teragrid supercomputer facility.

In addition to a core 24-member sub-ensemble that has a combination of IC/LBC perturbation, model physics variation, and radar data analysis, and that contributes to post-processed ensemble product available to the HWT, HPC, and DTC, several sub-ensemble groups are configured to include variations in microphysics, microphysics parameters, and in PBL option and PBL parameters in order to evaluate sensitivities of the WRF forecasts. Through a case of April 27 Alabama super-tornado event, the microphysics option and microphysics parameter variations are seen affecting the storm pattern and intensity vary widely. FIG. 1 shows sample images from the April 27 case.

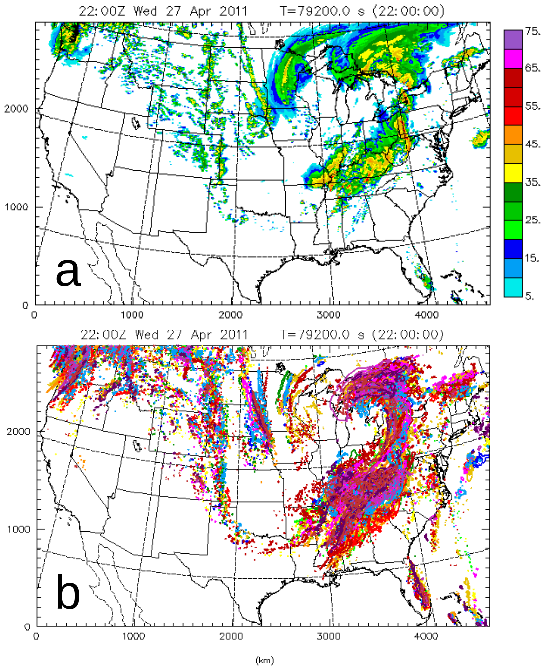

FIG. 1: 22-h forecast composite reflectivity for the ARW control member (a) and the ensemble spaghetti map of composite reflectivity equal to 35 dBZ (b), valid at 22 UTC 27 April 2011.

The more detail description on the SSEF system, including membership configuration, and on the 2011 Spring Experiment can be found in the CAPS 2011 Plan Document (Kong, 2011)[1].

III. RESULTS AND EVALUATIONS

FIG.2 shows a sample case, the heavy precipitation case of 19-20 May 2010. In late 19 May through early 20 May, moderately heavy precipitation fell in the southern and eastern portion of Kansas and in the northern part of Oklahoma. The SSEF probability matched (PM) means provide the best depiction of the precipitation distribution, structure and magnitude. Between 1200 and 1800 UTC, SSEF produced heavy precipitation in southeast Kansas and near the northern Oklahoma border, organized in a southwest-northeast orientation, similar to the observed. The NCEP operational SREF, however, predicts a general precipitation pattern that is northwest-southeast oriented, with the heavy precipitation core located too far northwest in northern Kansas. The same problem occurs with the NAM forecast, whose maximum precipitation is better than SREF.

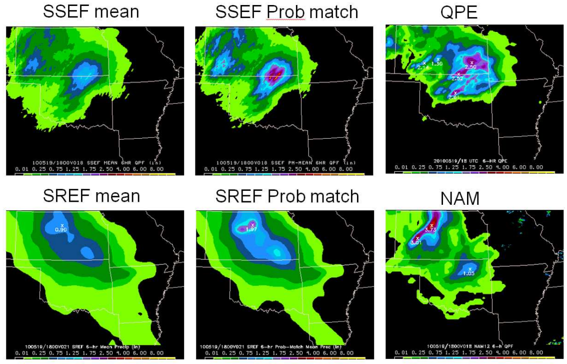

FIG. 2: Various forms of six-hour accumulated precipitation. In the left column are the ensemble mean of the CAPS SSEF forecasts and the NCEP SREF forecasts, while in the central column are the corresponding probability-matched ensemble means. In the right column are the QPE (observed precipitation), and the NCEP NAM forecast. They are valid at 1800 UTC, 19 May 2010, corresponding to 18 h forecast lead time.

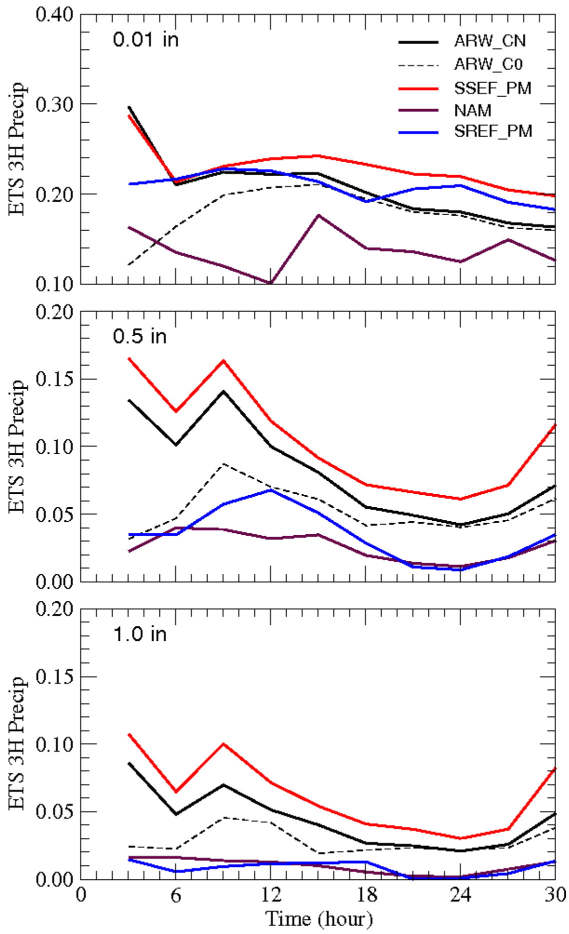

FIG. 3: ETS scores of various thresholds for the 3-h accumulated precipitation predicted from two SSEF members (CN and C0), the probability mathed mean (PM), and from the NCEP operational NAM and SREF, using 2010 forecast data of 36 complete dates.

Objective evaluation of the CAPS SSEF dataset shows promising potentials in improving QPF and probabilistic

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[1] http://forecast.caps.ou.edu/SpringProgram2011_Plan-CAPS.pdf

QPF skills. For QPF at storm-scale, probability matched means (PM) (Ebert, 2001) are good replacement to the simple ensemble means, as the former outscore the later and all individual SSEF members (not shown), and also outscore the operational 12km NAM by a wide margin (see FIG. 3). FIG.3 also shows the radar data analyses contribute to higher ETS scores (ARE_CN vs. ARW_C0) throughout the entire forecast duration, mostly evident between 0 – 18 h.

ROC areas from the SSEF are far greater than the operational coarser-resolution PQPF from the NCEP operational SREF (see FIG. 4).

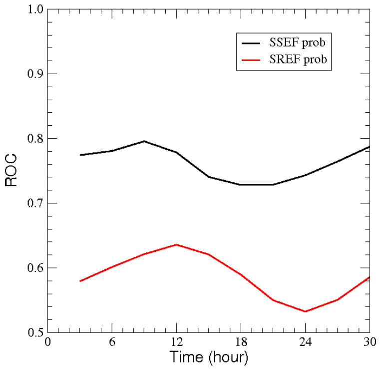

FIG. 4: Comparison of ROC areas of frequency based probabilities of 3-h accumulated precipitation exceeding 0.5 inch, throughout the forecast duration.

Finally, we present examples of two post-processed ensemble products in the form of neighbourhood probability, including the newly implemented experimental lightning threat algorithm, for the Alabama tornado case (FIG. 5).

Bias removal and calibration remain a big challenge for the SSEF.

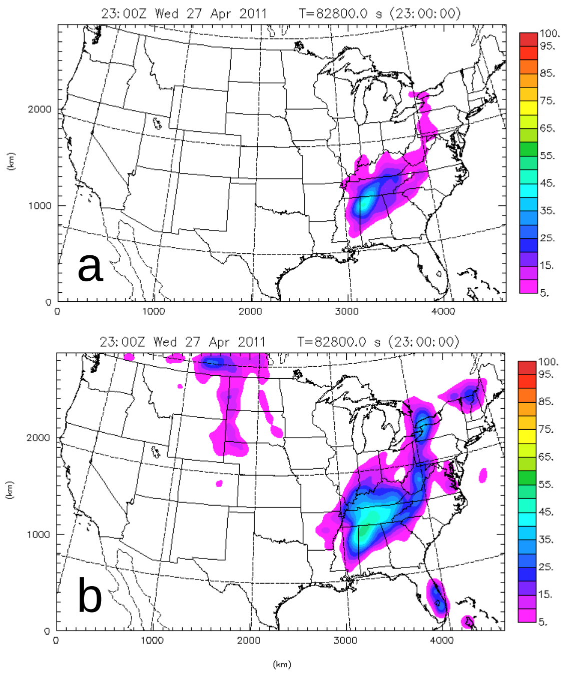

FIG. 5: 23 h forecast neighborhood probability of the hourly max updraft helicity exceeding 50 m^2/s^2 (a) and the lightning threat exceeding 0.5 flashes/km^2/5min, valid 27 April 2011.

IV. ACKNOWLEDGMENTS

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