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5A.6 REAL-TIME STORM-SCALE ENSEMBLE FORECAST SYSTEM AS PART OF NOAA HWT 2010 SPRING EXPERIMENT

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1. INTRODUCTION

In the past three years from 2007 to 2009, 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 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). In 2010 spring, under the new three-year CSTAR grant and with newly added collaborations with DTC, AWS, and HPC, the CAPS storm-scale ensemble forecasting system (SSEF) has been brought to a new level. Major changes in SSEF for the 2010 HWT Spring Experiment include: 1) The forecast domain has been expanded to cover the entire continental United States (Figure 1), increasing total computing grid points by ~40% compared to 2009 domain; 2) The total number of ensemble members is increased to 26, consisting of two WRF dynamical cores (ARW and NMM) and the Advanced Regional Prediction System (ARPS); 3) New microphysics schemes coming with WRFV3.1 are included in some ARW members; 4) A comprehensive set of ensemble post-processed products are generated and made available near real-time to the HWT participants; 5) A single 30 h WRF-ARW forecast at 1-km grid spacing is performed over the same full CONUS domain daily utilizing over 140 WSR-88D radar data on native grid.

As the real-time ensemble forecast Experiment is currently still underway, this extended abstract presents some highlights of the ensemble system and examples of the real-time ensemble forecast products. The preliminary assessment of the multi-model storm-scale ensemble system will be presented in the Workshop.

2. EXPERIMENT HIGHLIGHT

The CAPS 2010 Spring Program started on 26 April 2010 and will end on 18 June, encompassing the NOAA HWT 2010 Spring Experiment that is officially between 17 May and 18 June. This experiment period is shifted into mid-June to accommodate Aviation Weather Testbed activity. Three numerical weather models are used to produce a 26 member 30 h ensemble forecast during weekdays, initialized at 0000 UTC, covering a full-CONUS domain (Figure 1) at 4 km horizontal grid spacing. Nineteen members are produced using the Weather Research and Forecast (WRF) Advanced Research WRF core (ARW), five members are produced using the WRF Nonhydrostatic Mesoscale Model core (NMM), and two members are produced using the Advanced Regional Prediction System (ARPS). Both WRF cores are V3.1.1 release.

All forecasts are initiated at 0000 UTC, using NAM 12 km (218 grid) 00Z analyses as background for initialization with the initial condition perturbations for the ensemble members coming from the NCEP Short-Range Ensemble Forecast (SREF). Doppler radar radial wind and reflectivity data from over 140 available WSR-88D stations within the domain are assimilated through ARPS 3DVAR and Cloud Analysis package into all but three members (one from each model group).

The daily 30 h ensemble forecasts, on the weekdays from Monday through Friday, start at 0000 UTC and end at 0600 UTC of the next day. Special weekend runs are arranged if it is requested by HWT based on the severe weather outlook. Unlike previous years, all 4 km ensemble forecast and the single deterministic 1 km forecast in 2010 are performed on *Athena*, a Cray XT4 supercomputer system with 18000+ computing cores, at the NSF sponsored National Institute of Computational Sciences (NICS) in the University of Tennessee. This allows the entire forecasts – 26 ensemble runs at 4 km grid and 1 deterministic run at 1 km grid – to use the entire machine in dedicated mode overnight, brings the total forecast walltime down to within 6 h. Hourly model outputs are archived on the mass storage HPSS at NICS.

Figure 1 shows the coverage area of the model domains.

Since NMM uses rotated E-grid while both ARW and ARPS use C-grid, special software codes were developed at CAPS to convert between the two grids in order to utilize a single 3DVAR/Cloud Analysis over a larger outer domain that encompasses both forecast domains (Figure 1) by converting the analysis to the forecast domains, and to convert NMM forecast to a common verification domain that is the same as the ARW and ARPS forecast domain. These special codes were upgraded to be compatible with the new WRF version (V3.1.1) used in 2010 season.

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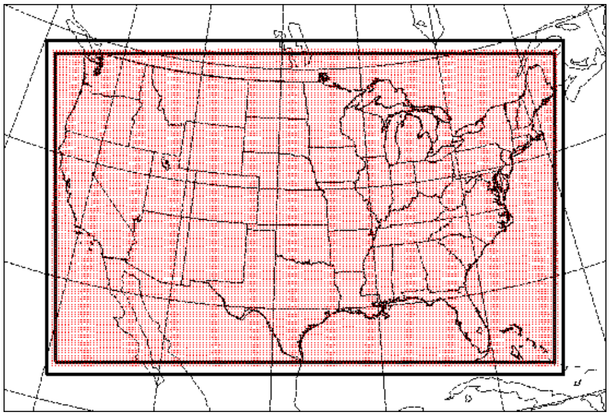

Figure 1. Computational domains for the 2010 Spring Experiment. The outer thick rectangular box represents the domain for performing 3DVAR/Cloud Analysis (1200×780). The red dot area represents the WRF-NMM forecast domain (790×999). The inner thick box is the domain for WRF-ARW and ARPS forecast and also for common verification (1160×720).

Table 1-3 outline the configurations for each individual members of each model group (arw, nmm, and arps). *cn* refers to the control member, with radar data analysis, *c0* is the same as *cn* except for no radar data is analyzed in. *m3 – m19* are members with either initial perturbation or physics perturbation or both added on top of *cn* initial condition. NAMa and NAMf refer to 12 km NAM analysis and forecast, respectively. ARPSa refers to ARPS 3DVAR and Cloud Analysis using NAMa as the background. For the perturbed members arw_m5~m14 and nmm_m3~m5, the ensemble initial conditions consist of a mixture of bred and ET perturbations coming from the 21Z SREF perturbed members (4 WRF-em (ARW), 4 WRF-nmm (NMM), 2 ETA-KF, 2 ETA-BMJ, and 1 RSM-SAS) and physics variations (grid-scale microphysics, land-surface model (LSM), and PBL physics). New in 2010 Spring Experiment is the addition of three random perturbation members (arw_m3~m5) and five extra physics-perturbation-only members (arw_m15~m19). Two types of random perturbations are added, one is Gaussian type perturbation and another is Gaussian perturbation plus a recursive filter with convective storm scale length. The physics-perturbation-only members are added to help assessing impacts from different microphysics and PBL schemes. The lateral boundary conditions come from the corresponding 21Z SREF forecasts directly for those perturbed members and from the 00Z 12 km NAM forecast for the non-SREF-perturbed members.

For the ARPS model group, the only members are cn and c0, as in 2009 season.

Table 1. Configurations for each individual member with WRF-ARW core. NAMa and NAMf refer to the 12 km NAM analysis and forecast, respectively. ARPSa refers to ARPS 3DVAR and cloud analysis

member	IC	BC	Radar data	microphysics	LSM	PBL
arw_cn	00Z ARPSa	00Z NAMf	yes	Thompson	Noah	MYJ
arw_c0	00Z NAMa	00Z NAMf	no	Thompson	Noah	MYJ
arw_m3	arw_cn + random pert	00Z NAMf	yes	Thompson	Noah	MYJ
arw_m4	arw_cn + RF-smoothed pert	00Z NAMf	yes	Thompson	Noah	MYJ
arw_m5	arw_cn + em-p1 + recur pert	21Z SREF em-p1	yes	Morrison	RUC	YSU
arw_m6	arw_cn + em-p1_pert	21Z SREF em-p1	yes	Morrison	RUC	YSU
arw_m7	arw_cn + em-p2_pert	21Z SREF em-p2	yes	Thompson	Noah	QNSE
arw_m8	arw_cn – nmm-p1_pert	21Z SREF nmm-p1	yes	WSM6	RUC	QNSE
arw_m9	arw_cn + nmm-p2_pert	21Z SREF nmm-p2	yes	WDM6	Noah	MYNN
arw_m10	arw_cn + rsmSAS-n1_pert	21Z SREF rsmSAS-n1	yes	Ferrier	RUC	YSU
arw_m11	arw_cn – etaKF-n1_pert	21Z SREF etaKF-n1	yes	Ferrier	Noah	YSU
arw_m12	arw_cn + etaKF-p1_pert	21Z SREF etaKF-p1	yes	WDM6	RUC	QNSE
arw_m13	arw_cn – etaBMJ-n1_pert	21Z SREF etaBMJ-n1	yes	WSM6	Noah	MYNN

arw_m14	arw_cn + etaBMJ-p1_pert	21Z SREF etaBMJ-p1	yes	Thompson	RUC	MYNN
arw_m15	00Z ARPSa	00Z NAMf	yes	WDM6	Noah	MYJ
arw_m16	00Z ARPSa	00Z NAMf	yes	WSM6	Noah	MYJ
arw_m17	00Z ARPSa	00Z NAMf	yes	Morrison	Noah	MYJ
arw_m18	00Z ARPSa	00Z NAMf	yes	Thompson	Noah	QNSE
arw_m19	00Z ARPSa	00Z NAMf	yes	Thompson	Noah	MYNN

* For all members: ra_lw_physics= RRTM; ra_sw_physics=Goddard; cu_physics= NONE

Table 2. Configurations for each individual member with WRF-NMM core

member	IC	BC	Radar data	mp_phy	lw_phy	sw-phy	sf_phy
nmm_cn	00Z ARPSa	00Z NAMf	yes	Ferrier	GFDL	GFDL	Noah
nmm_c0	00Z NAMa	00Z NAMf	no	Ferrier	GFDL	GFDL	Noah
nmm_m3	nmm_cn + nmm-n1_pert	21Z SREF nmm-n1	yes	Thompson	RRTM	Dudhia	Noah
nmm_m4	nmm_cn + nmm-n2_pert	21Z SREF nmm-n2	yes	WSM 6-class	RRTM	Dudhia	RUC
nmm_m5	nmm_cn + em-n1_pert	21Z SREF em-n1	yes	Ferrier	GFDL	GFDL	RUC

* For all members: cu_physics= NONE; pbl_physics= MYJ.

Table 3. Configurations for each individual member with ARPS

member	IC	BC	Radar data	Microphysics	radiation	PBL	Turb	sf_phy
arps_cn	00Z ARPSa	00Z NAMf	yes	Lin	Chou/Suarez	TKE	3D TKE	Force-restore
arps_c0	00Z NAMa	00Z NAMf	no	Lin	Chou/Suarez	TKE	3D TKE	Force-restore

* For all members: no cumulus parameterization

3. ENSEMBLE PRODUCTS

Selected 2D weather fields from each ensemble member are written in GEMPAK format and are directly transferred into SPC's N-AWIPS system to be evaluated by 2010 HWT Spring Experiment participants at HWT's daily weather briefing in SPC during the weekdays. In addition, CAPS also makes available a realtime forecast webpage showing the 2010 Spring Experiment products (**http://forecast.caps.ou.edu/**), with highlights to a demonstrative ensemble post-processed product page[1] and an animation movie page[2] playing high frequency (5 min interval) composite reflectivity movies from the real-time forecasts (arw_cn, arw_c0, and the 1 km forecast).

[1] http://www.caps.ou.edu/~fkong/sub_atm/spring10.html
[2] http://forecast.caps.ou.edu/ywang/animation

New in 2010 Spring Experiment regarding forecast product is the generation, in near realtime, of a large set of post-processed ensemble products from a subset of 15 out of 26 ensemble members (orange colored in Table 1-3) that represent multi-model, IC perturbation, and physics variation ensemble with influence of radar data assimilation. The products include ensemble maximum and mean, probability matching mean (Ebert 2001; Clark et al. 2009; Kong et al 2008), ensemble exceedance probability, and neighborhood probability. Variables processed include forecast reflectivity, 1-, 3-, and 6-h accumulated precipitation, 2-m temperature and dew point, 10-m wind, 3-6 km updraft/downdraft velocities, echo top exceeding 18 dBZ, updraft helicity, 0-1 km and 0-6 km wind share, vertically integrated grapeul/hail content, and some convective storm related indices (CAPE, CIN, LCL). Other variables diagnosed include Bunkers right-moving storm motion vector and speed, Supercell Composite Parameter (SCP), Significant tornado Parameter (STP) (Bunkers et al. 2000; Thompson et al. 2002, 2004).

Both individual member and ensemble products are made available to HWT, AWS and DTC. The latter is also available to HPC. In order to minimize the data flow, the GEMPAK dataset, including individual member and ensemble product, is only a sub-domain that covers the eastern 2/3 of CONUS (Figure 2). CAPS still keeps a complete set of 2D variables in full domain in HDF4 format, extracted from the realtime forecasts for post-season analysis and for external collaborations.

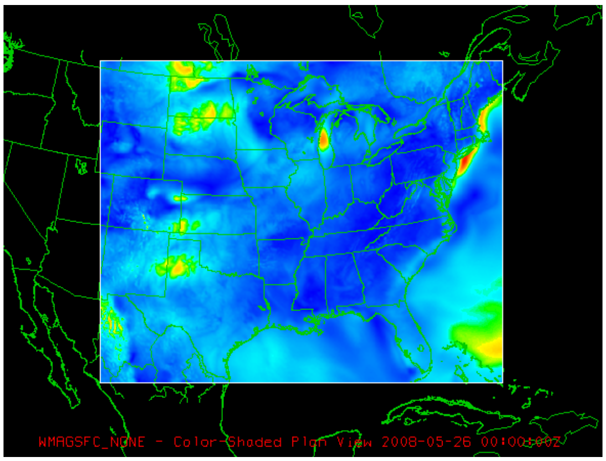

Figure 2. SPC/NSSL sub-domain for the HWT GEMPAK dataset (860x690).

Preliminary assessment of the ensemble system performance and the new post-processed ensemble products will be presented in the Workshop.

4. ACKNOWLEDGMENTS

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