AN OVERVIEW OF THE 2010 HAZARDOUS WEATHER TESTBED EXPERIMENTAL FORECAST PROGRAM SPRING EXPERIMENT

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MODEL SPECIFICATIONS. *CAPS models.* The cornerstone of the experimental model guidance used for the 2010 NOAA Hazardous Weather Testbed Spring Forecasting Experiment (SE2010) was a multimodel Storm-Scale Ensemble Forecast (SSEF) system with 26 members and 4-km grid spacing produced by the Center for Analysis and Prediction of Storms (CAPS). Ensemble specifications are provided in Table S1, and further details on the configurations can be found in Xue et al. (2010). The SSEF system was initialized on weekdays at 0000 UTC, providing 30-h forecasts for a conterminous United States (CONUS) domain (Fig. S1). The Advanced Research Weather Research and Forecasting model (ARW-WRF; Skamarock et al. 2008) dynamic core was used for 19 SSEF members, the nonhydrostatic mesoscale model (NMM; Rogers et al. 2009) dynamic core was used for 5 members, and the Advanced Regional Prediction System (ARPS; Xue et al. 2003) was used for 2 members. Radial velocity and reflectivity data from 140 Weather Surveillance Radar-1988 Doppler (WSR-88D) radars and other observational data were assimilated into initial conditions (ICs) of 23 members using the ARPS three-dimensional variational data assimilation (3DVAR) (Xue et al. 2003; Gao et al. 2004) data and cloud analysis (Xue et al. 2003; Hu et al. 2006; Xue et al. 2008) system. Analyses from the 0000 UTC North American Mesoscale Model (NAM) (Rogers et al. 2009) were used as the analysis background. As in previous years, one control member from each model (ARW, NMM, and ARPS; members 2, 21, and 26 in Table S1, respectively) did not assimilate additional radar and other high-resolution observational data to isolate its impacts on forecast performance (Kain et al. 2010; Xue et al. 2010).

IC perturbations were derived from evolved (through three hours) perturbations of 2100 UTC Short-Range Ensemble Forecast (SREF; Du et al. 2006) system members and added to the ARPS 3DVAR analyses (members 5–14 and 22–24 in

Table S1). Corresponding SREF member forecasts (1-hourly updates) were used for lateral boundary conditions (LBCs). Three ARW members (members 3–5 in Table S1) contained smaller-scale perturbations to facilitate postanalysis of multiscale error growth and predictability implications. To account

Table S1. SSEF member specifications. All WRF members used version 3.1.1. NAMa and NAMf refer to the 12-km NAM analysis and forecast, respectively. ARPSa refers to ARPS 3DVAR and cloud analysis. Elements in the ICs column followed by a "+" or "–" indicate SREF member perturbations added to the control member ICs. Boundary layer schemes included Mellor–Yamada–Janjić (MYJ; Mellor and Yamada 1982; Janjić 2002), Yonsei University (YSU; Noh et al. 2003), Mellor–Yamada–Nakanishi–Niino (MYNN; Nakanishi 2000, 2001; Nakanishi and Niino 2004, 2006), quasi-normal scale elimination (QNSE; Sukoriansky et al. 2006), and a 1.5-order closure scheme developed for ARPS (Xue et al. 2001). Microphysics schemes included Thompson et al. (2004), WRF single-moment 6-class (WSM6; Hong and Lim 2006), WRF double-moment 6-class (WDM6; Lim and Hong 2010), Ferrier et al. (2002), Purdue Lin (Chen and Sun 2002), and Morrison et al. (2005). Radiation schemes included the Rapid Radiative Transfer Model (RRTM) shortwave (SW) (Mlawer et al. 1997), Goddard longwave (LW) (Chou and Suarez 1994), and Geophysical Fluid Dynamics Laboratory (GFDL) SW (Lacis and Hansen 1974) and LW (Fels and Schwarzkopf 1975; Schwarzkopf and Fels 1991). Land surface models included the Noah (Chen and Dudhia 2001), RUC (Smirnova et al. 1997, 2000), and force–restore (Xue et al. 2001). TKE refers to turbulent kinetic energy.

Ensemble member	Initial conditions (ICs)	Lateral boundary conditions (LBCs)	Radar data	Microphysics	Shortwave radiation	Longwave radiation	Land surface model	Boundary layer
arw_cn	0000 UTC ARPSa	0000 UTC NAMf	Yes	Thompson	Goddard	RRTM	Noah	MYJ
arw_c0	0000 UTC NAMa	0000 UTC NAMf	No	Thompson	Goddard	RRTM	Noah	MYJ
arw_m3	+ random pert	0000 UTC NAMf	Yes	Thompson	Goddard	RRTM	Noah	MYJ
arw_m4	+ recursive pert	0000 UTC NAMf	Yes	Thompson	Goddard	RRTM	Noah	MYJ
arw_m5	+ em-p1 + recur pert	em-p1	Yes	Morrison	Goddard	RRTM	RUC	YSU
arw_m6	+ em-p1_pert	em-p1	Yes	Morrison	Goddard	RRTM	RUC	YSU
arw_m7	+ em-p2_pert	em-p2	Yes	Thompson	Goddard	RRTM	Noah	QNSE
arw_m8	– nmm-p1_pert	nmm-p1	Yes	WSM6	Goddard	RRTM	RUC	QNSE
arw_m9	+ nmm-p2_pert	nmm-p2	Yes	WDM6	Goddard	RRTM	Noah	MYNN
arw_m10	+ rsmSAS-n1_pert	rsmSAS-n1	Yes	Ferrier	Goddard	RRTM	RUC	YSU
arw_m11	– etaKF-n1_pert	etaKF-n1	Yes	Ferrier	Goddard	RRTM	Noah	YSU
arw_m12	+ etaKF-p1_pert	etaKF-p1	Yes	WDM6	Goddard	RRTM	RUC	QNSE
arw_m13	– etaBMJ-n1_pert	etaBMJ-n1	Yes	WSM6	Goddard	RRTM	Noah	MYNN
arw_m14	+ etaBMJ-p1_pert	etaBMJ-p1	Yes	Thompson	Goddard	RRTM	RUC	MYNN
arw_m15	arw_cn	0000 UTC NAMf	Yes	WDM6	Goddard	RRTM	Noah	MYJ
arw_m16	arw_cn	0000 UTC NAMf	Yes	WSM6	Goddard	RRTM	Noah	MYJ
arw_m17	arw_cn	0000 UTC NAMf	Yes	Morrison	Goddard	RRTM	Noah	MYJ
arw_m18	arw_cn	0000 UTC NAMf	Yes	Thompson	Goddard	RRTM	Noah	QNSE
arw_m19	arw_cn	0000 UTC NAMf	Yes	Thompson	Goddard	RRTM	Noah	MYNN
nmm_cn	0000 UTC ARPSa	0000 UTC NAMf	Yes	Ferrier	GFDL	GFDL	Noah	MYJ
nmm_c0	0000 UTC NAMa	0000 UTC NAMf	No	Ferrier	GFDL	GFDL	Noah	MYJ
nmm_m3	+ nmm-n1_pert	nmm-n1	Yes	Thompson	RRTM	Dudhia	Noah	MYJ
nmm_m4	+ nmm-n2_pert	nmm-n2	Yes	WSM6	RRTM	Dudhia	RUC	MYJ
nmm_m5	+ em-n1_pert	em-n1	Yes	Ferrier	GFDL	GFDL	RUC	MYJ
arps_cn	0000 UTC ARPSa	0000 UTC NAMf	Yes	Lin	Goddard	Goddard	Force–restore	TKE
arps_c0	0000 UTC NAMa	0000 UTC NAMf	No	Lin	Goddard	Goddard	Force–restore	TKE

for model physics uncertainty, different boundary layer, microphysics, radiation, and land surface schemes were used. Six of the ARW members had differences only in their boundary layer or microphysics parameterizations (members 1 and 15–19 in Table S1) to facilitate the evaluation of new physics schemes available in ARW-WRF version 3.1.1.

CAPS also produced a deterministic forecast with 1-km grid spacing configured identically to the ARW control member (member arw_cn in Table S1) except for horizontal grid spacing, and 4-km ARW-WRF runs were initialized at 0900, 1200, 1500, and 1800 UTC in a smaller central Great Plains domain (Fig. S1) supporting the Verification of the Origins of Rotation in Tornadoes Experiment 2 (VORTEX2; Bluestein et al. 2009; Wurman et al. 2010)

Other models. Since fall of 2006, Storm Prediction Center (SPC) forecasters have used 0000 UTC initialized 4-km grid-spacing ARW-WRF runs produced by the National Severe Storms Laboratory (NSSL ARW in Table S2). These runs were examined during SE2010, and products are also available year-round in SPC workstations and online (at www.nssl.noaa.gov/wrf/). Several innovative diagnostic fields have been developed at NSSL using this modeling framework.

The Earth System Research Laboratory Global Systems Division (ESRL/GSD) contributed the 3-km High-Resolution Rapid Refresh (HRRR) model [GSD HRRR (ARW) in Table S2]. The HRRR is nested within the hourly 13-km Rapid Update Cycle (RUC; Benjamin et al. 2004) model, which provides ICs/LBCs for the HRRR. The RUC model uses an hourly 3DVAR system that incorporates many observational datasets, including radar reflectivity via the radar diabatic digital filter initialization (DDFI; Smith et al. 2008). The HRRR is initialized hourly over a CONUS domain (Fig. S1), providing 15-h forecasts throughout the year. At initialization, the cloud fields come from a 1-h RUC forecast. The initialization procedure of the HRRR allows convective features to spin up rapidly within the first hour of the forecast. Real-time HRRR forecasts used by SPC forecasters are available in SPC workstations and online (at http://ruc.noaa.gov/hrrr/). For SE2010, the HRRR was primarily used

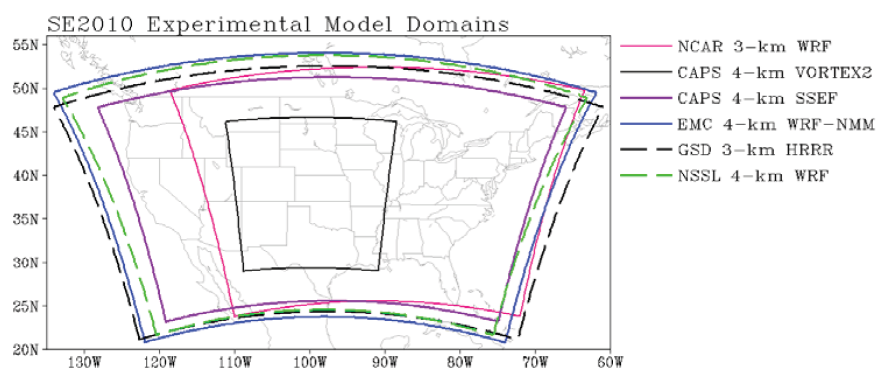

Fig. S1. Computational domains for modeling systems used during SE2010.

Table S2. Model specifications for deterministic runs used in SE2010.

	GSD HRRR (ARW)	EMC NMM	NCAR ARW	NSSL ARW	CAPS ARW1	CAPS V2
Grid spacing (km)	3.0	4.0	3.0	4.0	1.0	4.0
Vertical levels	50	35	34	35	51	51
PBL scheme	MYJ	MYJ	MYJ	MYJ	MYJ	MYJ
Microphysics scheme	Thompson	Ferrier	Thompson	WSM6	Thompson	Thompson
Radiation (SW/LW)	Dudhia/ RRTM	GFDL/GFDL	Goddard/ RRTM	Dudhia/ RRTM	Goddard/ RRTM	Goddard/ RRTM
Land surface model	RUC–Smirnova	Noah	Noah	Noah	Noah	Noah
ICs	13-km RUC	32-km NAM	13-km RUC	40-km NAM	CAPS 3DVAR	CAPS 3DVAR
LBCs	RUC forecasts	NAM forecasts	GFS forecasts	NAM forecasts	NAM forecasts	NAM forecasts
Forecast length (h)	15	36	48	36	30	21, 18, 15, or 12
Initialization times	Hourly	0000 UTC	0000 and 1200 UTC	0000 UTC	0000 UTC	0900, 1200, 1500, and 1800 UTC

for afternoon updates of the day 1 severe and aviation weather outlooks. See Alexander et al. (2010) for further details on the HRRR.

The National Center for Atmospheric Research (NCAR) produced a 3-km grid-spacing ARW-WRF run using ICs from the 13-km RUC (NCAR ARW in Table S2). The LBCs were provided by the National Centers for Environmental Prediction's (NCEP) Global Forecast System (GFS) model. The NCAR 3-km WRF was run twice daily at 0000 and 1200 UTC for 48-h forecasts over a three-fourths CONUS domain (Fig. S1).

SPC forecasters have used output from versions of the Environmental Modeling Center's (EMC) WRF NMM model since the spring of 2004. The current version (EMC NMM in Table S2) uses NAM ICs/LBCs and is run throughout the year over a CONUS domain (Fig. S1) twice daily at 0000 and 1200 UTC using 4-km grid spacing. Forecast products to 36 h are available in SPC workstations and online (at www.emc.ncep.noaa.gov/mmb/mpyle/cent4km/conus/00/).

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