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NCEP Regional Ensembles: evolving toward hourly-updated convection-allowing scale and storm-scale predictions within a unified regional modeling system

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1. List of regional ensembles acronyms

SREF=Short Range Ensemble Forecast (~10km)

NARRE=North America Rapid Refresh (~10km)

NARRE-TL=Time-Lagged North America Rapid Refresh (~10km)

NCASE=NCEP Convection-Allowing Ensemble (~3km, same as HRRRE)

NCASE-TL=Time-Lagged NCEP Convection-Allowing Ensemble (~4km)

NSSE=NCEP Storm Scale Ensemble (~1km)

2. Current system: SREF

The NCEP Short Range Ensemble Forecast (SREF) system was operationally implemented in 2001 (Du and Tracton, 2001). It is currently a 16km, 21-member, multi-analysis, multi-model and multi-physics regional ensemble prediction system running 4 cycles (03, 09, 15, 21z) per day up to 87hr over North America domain. Besides 21 individual forecasts, it also produces many ensemble products including mean, spread, probability, range (min to max), percentiles and clusters related to precipitation, convection, aviation, winter weather, hurricane and fire weather predictions. Some forecast variables are also bias-corrected and/or downscaled to 5km. The SREF has become an integral part of U.S. NWP modeling system by providing useful and critical info to forecasters and other users (private and academic) in their daily weather forecasting and research. The technical details of the current SREF are listed in Table 1. This system is planned to be upgraded to ~12km system in about a year, where the main change will be the transition from a 3-model to a 2-model system by eliminating WRF_NMM model.

SREF provides useful and sometimes critical information to forecasters in high-impact weather prediction. Figure 1 show the SREF probabilistic forecasts of the historical Boulder, CO

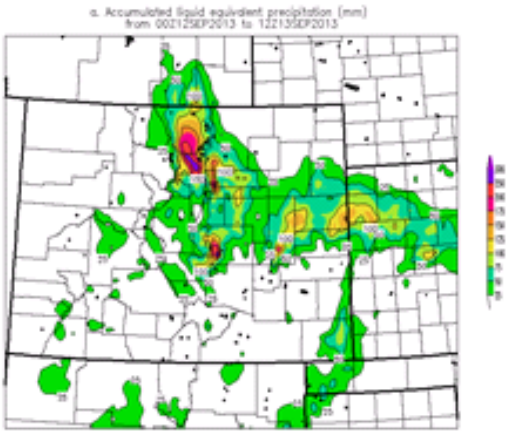
Table 1: The current SREF configurations

Member (Model)	IC	IC perturb.	physics							Land surface		
			conv	mp	lw	sw	pbl	Sfc layer	stochastic	model	initial	perturb.
nmmb_p1	NDAS	BV	BMJ	FER	GFDL	GFDL	MYJ	MYJ	no	NOAH	NAM	no
nmmb_n1												
nmmb_p1												
nmmb_n2			SAS	GFS	GFDL	GFDL	GFS	MYJ	no	NOAH		
nmmb_p2												
nmmb_n3			BMJ	WSM6	GFDL	GFDL	MYJ	MYJ		NOAH		
nmmb_p3												
nmm_p1	GFS	BV+ETR	BMJ	FER (new Eta)	GFDL	GFDL	MYJ	M_Obuhou (Janic Eta)	no	NOAH	NAM	no
nmm_n1												
nmm_p1												
nmm_n2			SAS	FER (new Eta)	GFDL	GFDL	MYJ	M_Ouhou (Janic Eta)	no	NOAH		
nmm_p2												
nmm_n3			KF (new Eta)	FER (new Eta)	GFDL	GFDL	MYJ	M_obuhou (Janic Eta)	no	NOAH		
nmm_p3												
arw_p1	RAP	BV	KF (new Eta)	FER (new Eta)	GFDL	GFDL	MYJ	M_obuhou (Janic Eta)	no	NOAH	NAM	no
arw_n1												
arw_p1												
arw_n2			BMJ	FER (new Eta)	GFDL	GFDL	MYJ	M_obuhou (Janic Eta)	no	NOAH		
arw_p2												
arw_n3			BMJ	FER (new eta)	GFDL	GFDL	MYJ	M_Obuhou (Janic Eta)	no	NOAH		
arw_p3												

extreme precipitation event of September 12, 2013, which is the only operational model consistently and correctly predicting this record-breaking event (Hamill, 2014). The flash flood brought by the extreme heavy rainfall caused enormous property damages and life losses during this event. Figure 2 shows another successful story of SREF probabilistic forecasts indicating the January 21, 2014 major snow-storm impacting Northeast U.S. two days ahead of time in the 09z 1/19/14 SREF run, half a day earlier than other operational model guidance. The increasing trend of the SREF-based probability is obvious when it is closer to the event, which provides extra confidence to forecasters to issue a warning. This snow-storm is a sudden event with short-predictability and caused major distraction to people life in Northeast U.S. by cancelling flights, closing schools and governments etc.

Fig. 1: Success story 1 on high-impact weather

SREF is the only operational model consistently indicating a historical heavy rain event over Boulder, CO region days ahead (Hamill 2014; plots from Rich Grumm)



Observed 36hr (00z, Sept. 12 – 12z, Sept. 13, 2013) accumulated precipitation.

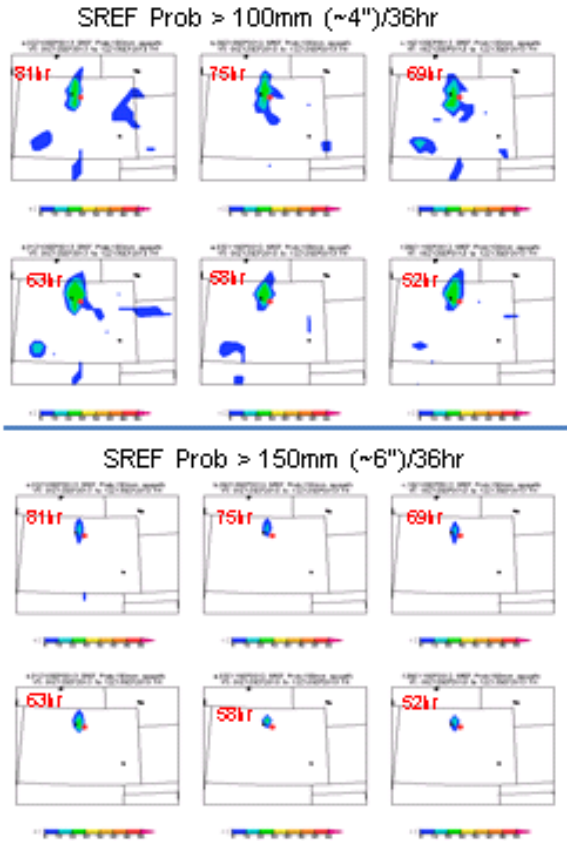
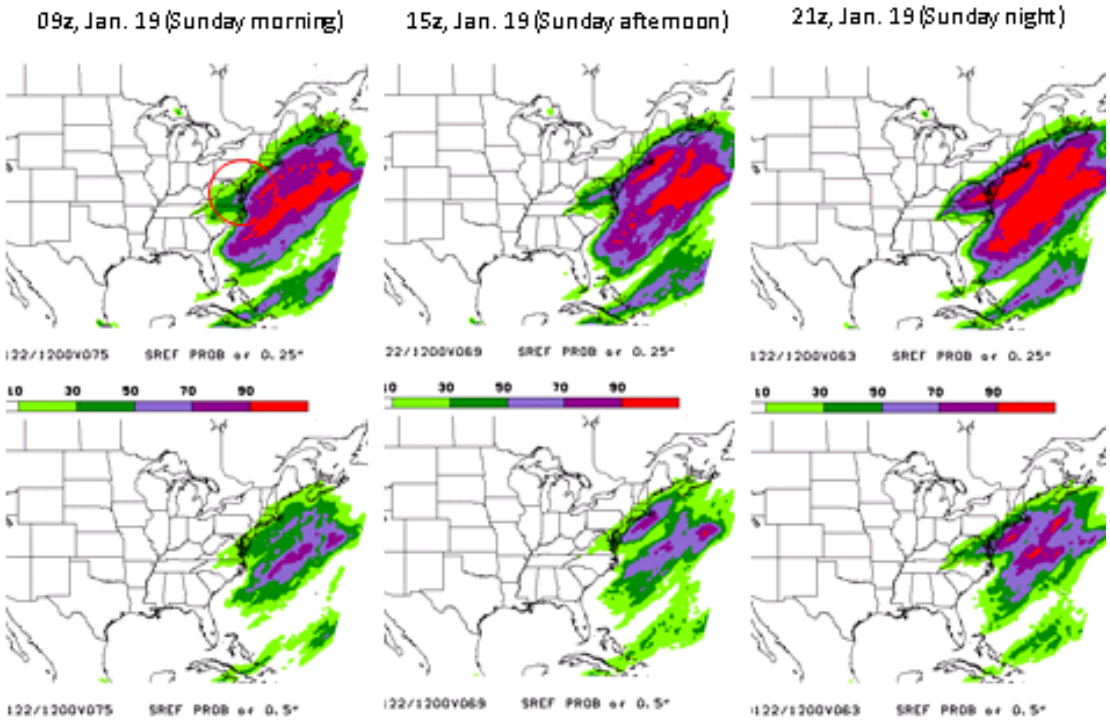


Fig. 2: Success story 2 on high-impact weather

SREF is the earliest operational model indicating the Jan. 21, 2014 major but sudden (short-predictability) Northeast snow storm (about half a day earlier than other models)



3. Interim systems: NARRE-TL, NCASE-TL

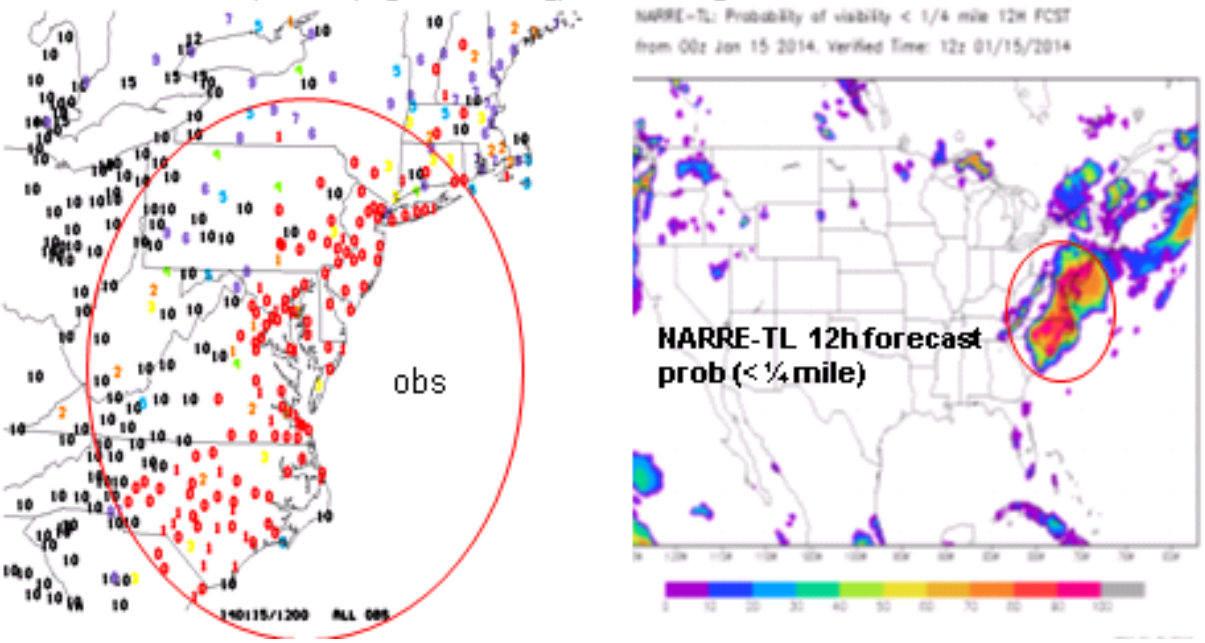
Prior to the implementation of actual state-of-the-art NARRE and NCASE, two prelude systems have been developed based on time-lagged approach to meet users' needs by mimicking the future NARRE and NCASE ensemble products. NARRE-TL is a 12km, 10-member, multi-model and hourly updated system in operational status, while NCASE-TL is a 4-5km, 20-member and multi-model system in experimental status. Their details are listed in Table 2.

Table 2: Prelude of NARRE and NCASE

NARRE-TL (12km, 10 mem, multi-model)	NCASE-TL (4-5km, 20 mem, multi-model)
North America Rapid Refresh Ensemble – Time Lagged (implemented in May 1, 2012)	NCEP Convection-Allowing Scale Ensemble - Time Lagged (experimental)
10 weighted time-lagged (multi-model) members from: 6 NCEP's operational RAP members (12km) 4 operational NAM members (12km)	20 weighted time-lagged (multi-model) members from: NCEP 4km NAM nest (NMMB), NCEP 4km Hi-Res Window (ARW and NMM), EMC 5km SPC WRF-NMM run GSD 4km HRRR (ARW) runs
Forecast hours: 12 hours (hourly update)	Forecast hours: 12 hours (3 hourly update)
Output grids: CONUS and Alaska	Output grids: CONUS
Products: Aviation, convection	Products: Convection, aviation, fire weather and energy (wind).
http://www.emc.ncep.noaa.gov/mmb/SREF_avia/FCST/NARRE/web_site/html/icing.html	http://www.emc.ncep.noaa.gov/mmb/SREF_avia/FCST/NSSE/web_site/html/storm.html

The products from the both systems are available online and used by field forecasters in real time. Positive feedbacks have been received from operational forecasters. Figure 3 is an example of its probabilistic forecast in successfully predicting January 15, 2014 major east coast dense fog event 12-hour ahead of time when some of other operational models failed to predict. Two positive comments from the eastern region forecasters are also recorded in Fig. 3.

Fig. 3: Positive feedbacks from WFOs about NARRE-TL:
(1) Dense fog is difficult to forecast as we all know. The Rapid Refresh Ensemble did very well with tonight's event - much better than traditional MOS. ... Jeff
(2) This product performed really well again tonight. As early as the 02z run, it showed the dense FG over PHL/NJ expanding N/NE into NYC/LI between 10-11z which matched satellite trends and the synoptic setup. Allowed for more confidence in the TAFs as there was big model discrepancy...NAM was also on the money, while GFS was out to lunch and completely dry in the low-levels. Adrienne referenced it in her AFD.



4. Future NCEP 3-tier regional ensemble prediction systems: SREF/NARRE, NCASE and NSSE

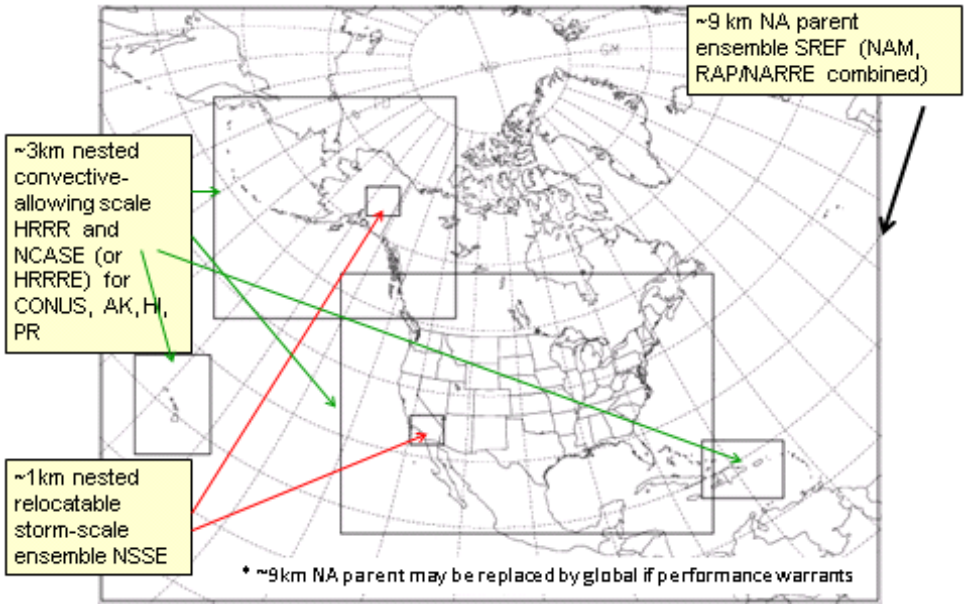
Table 3 and Figure 4 below describe a strategic plan of future NCEP regional ensembles and other regional modeling systems as a unified regional modeling system. It follows two main themes: (1) the implementations of hourly updated 3km-convective-allowing scale ensemble (NCASE) over various regions (CONUS, AK, HI, PR) and 1km-storm-scale ensemble (NSSE) in removable domains; and (2) mesoscale ensembles replace all regional deterministic modeling guidance. For example, the current NAM will be either the control member or ensemble mean of the 9km parent SREF; NARRE will be the first 24hr forecasts of SREF updated hourly (SREF will be updated 6hrly afterward extended to 84 or 96hr); the current HiResWindows and NAM nests will be part of NCASE; and the current Fire Weather runs will be part of NSSE.

Table 3: Strategic Plan: Mesoscale Ensembles Replace Regional Deterministic Guidance

Start of WCOSS Phase1 Current	End of WCOSS Phase 1 ~2015	End of WCOSS-era 2 petaflop Machine
SREF continental scale	**SREF continental scale**	**SREF continental scale**
WRF-ARW, -NMM, NMMB	WRF-ARW & NMMB	WRF-ARW & NMMB
7 each = 21 members 16 km	10 each = 20 members ~12 km	10 each = 20 members ~9 km (parent)
35 levels 6 hourly to 87 hr	40-60 levels 6 hourly to 87 hr NARRE run hourly to 18 hr	50-60 levels 6 hourly to 96 hr NARRE run hourly to 24 hr
Convection-Allowing-Scale	**Convection-Allowing-Scale**	**Convection-Allowing-Scale (NCASE*)**
Irregular suite of guidance 3-6km [Hi ResWindows & NAM nests] ~6 hourly to 48/60 hr for CONUS, Alaska, HI, PR	Single hourly 3 km HRRR & NAM nest run to 15 hr for CONUS Upgrade irregular suite to ~3 km 6 hourly to 48/60 hr for CONUS, Alaska, HI, PR	Ensemble HRRR (HRRRE) Multiple hourly 3 km Run to 24 hr for 6 hourly extended to 60 hr for CONUS, Alaska, Hi, PR
Storm Scale	**Storm Scale**	**Storm Scale (NSSE*)**
Single placeable sub-nest [fire weather run] 1.33-1.5 km Run 6 hourly to 36 hr	Single placeable/movable sub-nest 1-1.5 km Run 6 hourly to 36 hr	Storm-scale ensemble (NSSE) Multiple placeable/movable sub-nests: ~1 km run hourly to 18 hr and run 6 hourly to 36 hr

Fig. 4: Stategic Plan: unified 2-model (NMMB, ARW) regional modeling system

Ensembles replace all regional deterministic guidance (SREF/NARRE/HRRRE/SSE)



5. Summary

The current NCEP operational SREF is a 16km, 21-member, 3-analysis, 3-model and multi-physics regional ensemble prediction system running 4 times (03, 09, 15 and 21z) per day up to 87hr over North America domain, which is an integral part of U.S. NWP modeling system by providing useful and critical info to forecasters and other users in their daily weather forecasting and research. It is planned to be upgraded to ~12km 2-model system in about a year.

Convection-allowing scale (~3km NCASE or HRRRE) and storm-scale (~1km NSSE) ensembles are planned to be implemented in about 5 years at NCEP. Prior to real NARRE and NCASE, NARRE-TL (12km) and NCASE-TL (4-5km) have been developed as their prelude to meet users' needs. Note, NSSE might take longer due to technical challenges.

Mesoscale ensembles will replace all regional deterministic guidance by strategically developing a unified regional modeling system at NCEP.

6. References

Du, J., and M. S. Tracton, 2001: Implementation of a real-time short-range ensemble forecasting system at NCEP: an update. Preprints, 9th Conference on Mesoscale Processes, Ft. Lauderdale, Florida, Amer. Meteor. Soc., 355-356, available online at http://www.emc.ncep.noaa.gov/mmb/SREF/reference.html.

Hamill, T. , 2014: Performance of operational model precipitation forecast guidance during the 2013 Colorado Front Range Floods, *MWR*, submitted, available online at http://www.esrl.noaa.gov/psd/people/tom.hamill/