11.2 Recent Upgrades to the NCEP Short Range Ensemble Forecasting System (SREF) and Future Plans

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1. INTRODUCTION

The NCEP multi-Initial Condition (multi-IC) and multi-model Short Range Ensemble Forecasting (SREF) system has been operationally running since May 2001 (Du et al. 2003). The SREF system was developed to provide a regional, short-range (0-3 days) ensemble prediction system that produces operationally relevant and useful guidance on the probability distribution of weather elements or events. The probabilistic information provided by SREF will help meet the NWS strategic goal of "providing probabilistic gridded products to the NWS/WFOs, service centers and other users".

In September 2003, NCEP added 5 Eta-KF (Kain-Fritsch convective parameterization) members to the original ten member system. (Du, et al., 2003). The system consisted of 5 ETA-KF, 5 Eta-BMJ (Betts-Miller-Janjic convective parameterization, Black, 1994) and 5 Regional Spectral Model (RSM, Juang, et al., 1997) members, for 15 total members. SREF is run twice per day (09z and 21z) out to 63hrs; with output available every 3hrs using regional bred initial state perturbations.

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2. OPEATIONAL SREF CONFIGURATION

Previous studies have shown the importance of multi-physics ensemble forecasts in improving ensemble diversity. Also, clustering of ensemble members by parent model in the operational SREF is a main concern of NWS field forecasters. Therefore, a new physics based ensemble system at 32 km horizontal resolution (SREF-32) was developed and evaluated. This implementation incorporates additional physics diversity by running various convective and cloud microphysics parameterizations along with single paired breeding (one positive and one negative perturbation to the initial state), to improve system diversity and forecast spread information. Table 1 lists SREF model member configuration implemented into NCEP operations on August 17, 2004 (Du, et al., 2004)

In addition to improved physics diversity, a change was implemented in the SREF initial condition breeding technique to control the unrealistically high initial condition perturbations noted in the previous technique. The initial condition perturbations are now scaled by a factor inversely proportional to the difference between the previous run's 12-hour perturbed 850 mb temperature forecasts. Finally, the Eta and RSM model members were upgraded to the versions used in NCEP operations.

3. SREF OUTPUT PRODUCTS

Mean and spread output products from the NCEP operational and experimental SREF systems are summarized in Table 2. Spread is defined as the standard deviation of ensemble members from the ensemble mean. All outputs are produced on AWIPS Grid 212 (Lambert Conformal 40 km, 185x129, CONUS grid). Probabilistic output products are summarized in Table 3. Probability estimates are defined as the percentage of predictions out of the total (15) that meet or exceed the specified criterion.

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Table 2. SREF Ensemble Products

Mean/Spread Parameter (3 hrly)	**Units**	**Levels**
2 m Temperature	K	Sfc
10 m U, V wind	m/s	Sfc
Total Precipitation (3, 6, 12, 24 hrly)	kg/m^2	Sfc
CAPE	J/kg	
Convective Inhibition (CIN)	J/kg	
Storm Relative Helicity (SREH)	m^2/s^2	0-3000 m
Lifted Index		0-30mb AGL
MSLP	Pa	Sfc
Categorical rain *	Y/N	Sfc
Dominant Precip Type (3hrly) *	1-7	Sfc
Large-scale snowfall (12 hrly)*	kg/m^2	Sfc
Snow depth (12hry)*	kg/m^2	Sfc
Accumulated snowfall (12 hrly)*	kg/m^2	Sfc
Pressure	Pa	1000-50 mb
Absolute Vorticity*	/s	1000-50 mb
Geopotential Height	gpm	1000-50 mb
U, V wind	m/s	1000-50 mb
Temperature	K	1000-50 mb
Thickness	gpm	1000-50 mb
Relative Humidity	%	1000-50 mb

*=means computed only

Table 3. SREF Ensemble Event Probability Products.

Field	***Units***	***Levels***	***Probability of occurance***
Temperature	F	2m	>75,80,85,90,95 F
Winds	m/s	10m, 850, 700 mb	> 5, 10, 15, 20, 25 m/s
Precipitation	kg/m^2	3, 6, 12, 24 hrly	>0.1, 0.25, 0.5, 1.0, 2.0 inches
Dominant Precip	1-7	3 hrly	Probability of precip type
Snowfall	kg/m^2	3, 6, 12, 24 hrly + min, max	>1, 2.5, 5, 10, 20 inches
CAPE	J/kg		>500, 1k, 2k, 3k, 4k
Lifted Index	K		< 0, -4, -8

Additionally, the current NCEP SREF system products are displayed on the NCEP web page at: http://wwwt.emc.ncep.noaa.gov/mmb/SREF/SREF.html. Aviation probabilistic guidance products (e.g.: turbulence, icing) are also available from this web site.

Several papers have been written on applying SREF for severe convection forecasting (Manikin, et al., 2004), aviation weather (Zhou, et al., 2004) and Energy applications (Stensrud, et al., 2005). Figure 1 shows an example of two SREF products that could be used by forecasters to predict short-term forecasts. The ensemble mean forecasted 2 m temperature (solid lines) and the spread or standard deviation of the forecasted temperatures (color filled values) show areas with possible forecast spread of up to 6-8° F (yellow color fill). The magnitude of ensemble spread is sometimes used to estimate forecast uncertainty. The probability of the temperature-humidity index exceeding 75° F for this same case (Fig. 1b) shows a moderate probability of 50-70% (green color fill) in Southern Pennsylvania and New Jersey. An energy forecaster could therefore account for the possibility of more energy demand in these areas.

4. SREF EVALUATIONS

Standard error time-series of the grid domain mean, average and standard deviations for the SREF-I and II systems of various products (listed below) are computed at the standard evaluation times for each run as part of SREF system processing. These evaluations are produced for the following fields:

- MSLP
- 500 mb Heights
- 850 mb Temperature, RH, U and V-wind components and wind speed
- 250 mb Temperature, U and V-wind components and wind speed.

The following standard error plots are computed:

- Root Mean Square Error (RMSE)
- Correlation Coefficient (%)

- Bias
- Equitable Threat Scores (ETS)

Complete SREF verification statistics are updated monthly on the NCEP-SREF verification page. (http://wwwt.emc.ncep.noaa.gov/mmb/SREF/VERIFICATION/2003.htm).

Results have shown that the addition of the 32 km improved physics diversity and breeding system provides more accurate mean forecasts as well as ensemble diversity and more forecast spread in the SREF. An improvement in 2 m temperature forecasts for all forecast hours with the SREF-32 system (Fig. 2a,b) averaged for all forecasts during the NEHRT 2004 Summer experiment is shown. Daytime temperature RSME was reduced by about 0.8° C for the day two forecast from the SREF-48 and Eta-12 system errors. Temperature biases (Fig. 2b) were reduced to near zero with the SREF-32 (green, dashed line) as compared to the SREF-48 (black, dotted line) and operational Eta-12 deterministic run (red, solid line).

Probabilistic plots are produced by the NCEP SREF system to summarize the system performance.

- Talagrand Analysis Ranked Histogram plots are produced by binning each of the 15 members into equal ranges for the forecast fields. Fields for each member are compared to the operational analysis at corresponding grid points. The numbers of ensemble members at each grid point that agree with the analysis value range bin are then summed and plotted. The results yield the percentage of the ensemble system that encompasses the verifying analysis.

- Talagrand Equal Likelihood Frequency Plots yield the percent chance that an individual member is closest to the analysis. 15 members are currently analyzed. (See SREF web page, for examples)

5. SUMMARY AND FUTURE PLANS

This paper overviewed improvements to the operational NCEP SREF system that include a scaled breeding initialization, improved physics diversity member configuration, postprocessed products and ensemble based verification tools. Results show that adding physics diversity and scaled breeding improves the SREF system's ability to capture more forecast uncertainty. This SREF system products directly supports NCEP's strategic goal of delivering improved probabilistic products and services. These improvements to the operational SREF system capability are part of a larger plan to gradually increase the forecast accuracy and provide improved confidence information over the next several years. This project, which will increase ensemble diversity information and add forecast products, is planned to expand in the following years to include more and higher resolution ensemble members, improved member physics, model core and initialization diversity, and additional ensemble post-processed products.

Specific improvements include the addition of 5-6 Weather Research and Forecast (WRF) members to SREF with Bred vector initial perturbations, post-processed bias correction and calibration techniques, extension of the SREF runs to 4 times per day out to 87 forecast hours, improved initial and lateral boundary condition generation from upgraded NCEP Medium Resolution Ensemble Forecast system (MREF) using ensemble transform initial condition perturbations. In addition, ensemble products will be generated for Alaska and Hawaii regions. Additional severe weather, energy, hydrological and aviation related products and ensemble mean meteograms will also be added to the SREF system.

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Table 1. Description of NCEP operational SREF system implemented on August 17, 2004.

Model	Convection	Microphysics	GFS ensemble Lateral Boundary Conditions Used	Initial condition Breeding cycles
Eta-32 Rogers , et al, 1996	Betts-Miller-Janic (BMJ)	Operational Ferrier	Control, N1, P1	Control1 + 1 pair (N1, P1)
Eta-32	Kain-Fritsch (KF)	Operational Ferrier	Control, N2, P2	Control2+ N2, P2
RSM-40 (Juang, et al. 1997)	Simple Arakawa Shubert (SAS)	Zhou GFS	Control, N1,P1	Control1 + N1, P1
RSM-40	Relaxed Arakawa-Shubert (RAS)	Zhou GFS	N2, P2	N2, P2
Eta-32	BMJ-SAT (50% Saturated moisture profiles)	Operational Ferrier	N1, P1	N3, P3
Eta-32	KF-DET (20% cloud detrainment)	Experimental Ferrier*	N2, P2	N4, P4

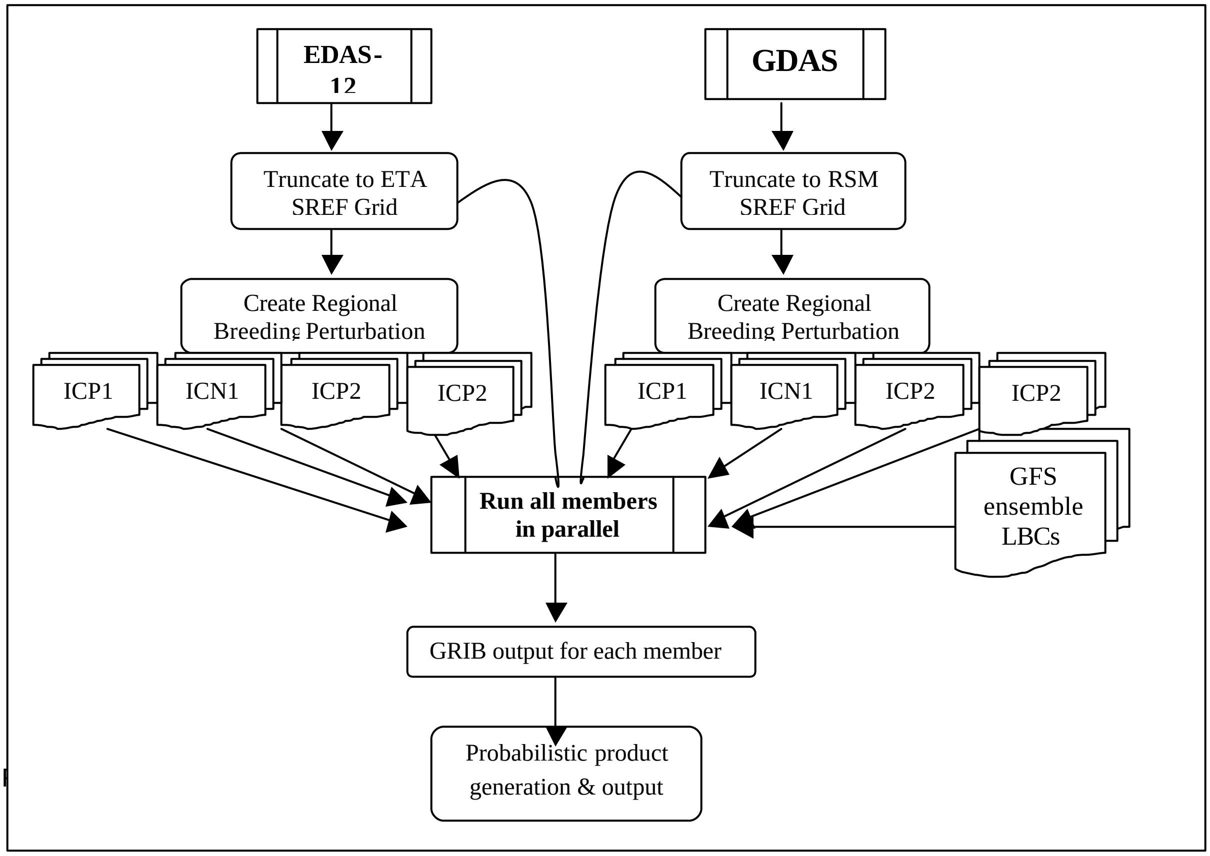
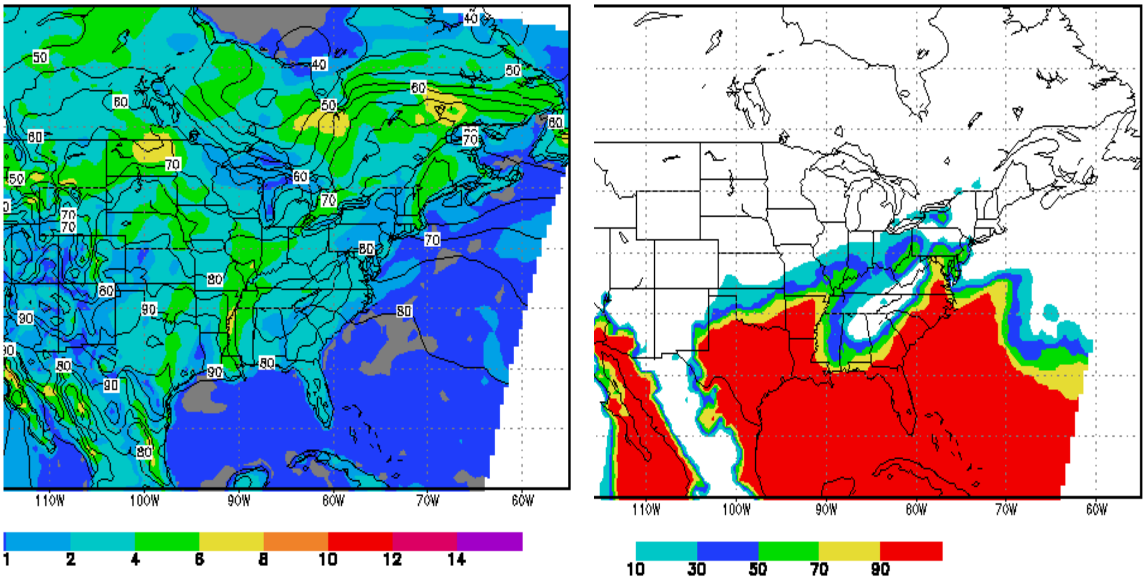


Figure 1. Outline of NCEP SREF Operational system run (Multi-IC) in 2003. ICP, ICN, I represent Initial Condition files for the Positive and Negatively perturbed runs, respectively. In addition, a control run was initialized with the truncated Initial condition grid (curved arrows). 2 perturbation pairs were run similar to the SREF-I configuration outlined in Table 1. In September, 2003, 5 additional members from the Eta run with Kain-Fritsch convection parameterization were added to the SREF Operational system.



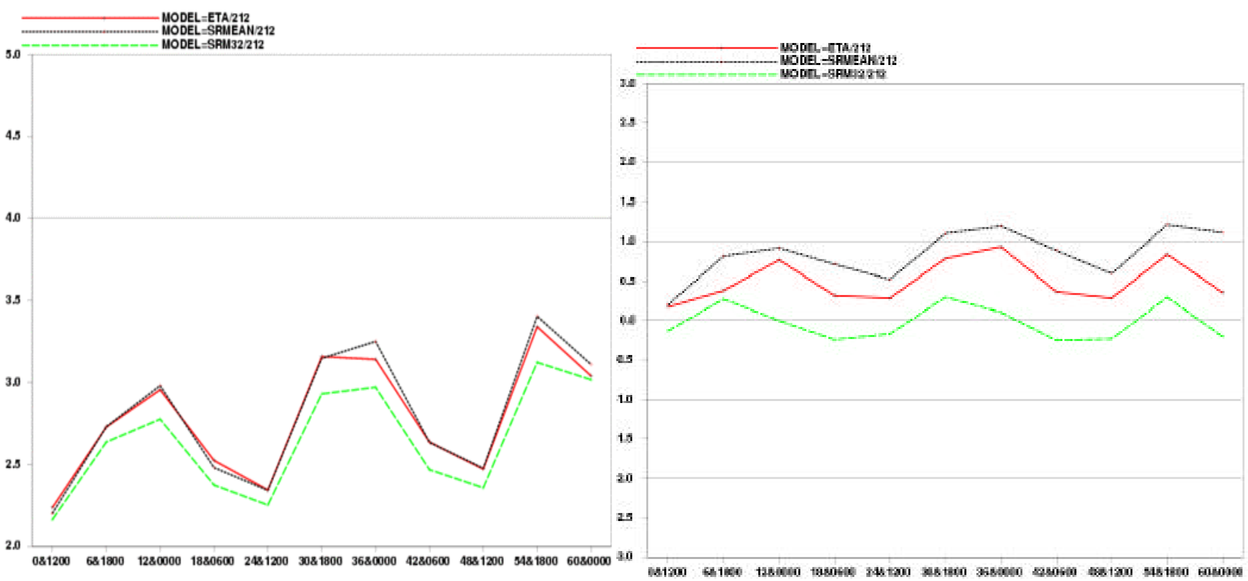


Figure 3. a) RMSE and b) Bias errors for 2 m temperature forecasts (°C) for the Summer 2004 tests. 12 UTC Eta-12 (red solid line) and 09 UTC SREF-48 (black dotted) and SREF-32 (green dashed) forecasts. Errors averaged over all observed stations over the continental U.S.