21.3 The NOAA/NWS/NCEP Short Range Ensemble Forecast (SREF) system: Evaluation of an Initial Condition vs Multiple Model Physics Ensemble Approach

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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). Recent studies have shown the benefits of adding physics perturbation members to an ensemble system (Stensrud et al. 2000). Also, ensemble members clustering by model is a main concern of field forecasters. Therefore, a new physics ensemble system has been developed and is now under testing and evaluation. This paper summarizes the NCEP SREF system and reports on some of our findings from a comparison study between a multi-IC and multi-physics ensemble approach for short range forecasts (1-3 days).

The 32 km experimental SREF breeding (I) and physics perturbation (II) experiments were run to support the New England High Resolution Temperature Program (NEHRT) during the Summer, 2003. (Wilczak et al. 2004). Thinned GRIB files and BUFR files from all SREF members were provided to NOAA/OAR to perform bias-corrected forecasts at several locations in New England. A subset of probabilistic products is sent to the NCEP SREF web page for forecaster use. For more information, see http://highrestemp.noaa.gov.

2. EXPERIMENTAL SREF CONFIGURATION.

During the Summer, 2003, the 32 km (60 levels) SREF was run twice per day at 06 and 18 UTC, producing 3 hourly forecasts out to 63 hours. Six-hour-old NCEP Global Forecast System (GFS) outputs were used for boundary conditions. The domain covers most of North America. Table 1 summarizes the SREF Multi-IC (SREF-I) membership. All runs used lateral boundary conditions from the GFS ensembles. For the SREF-I configuration, each model is run with 1 control run plus 2 initial condition breeding pairs (n1, p1, n2, p2). Each pair is perturbed positively and negatively using the NCEP breeding technique described by Toth and Kalney (1997). Figure 1 outlines the SREF forecast system run process. Table 2 summarizes the members used for SREF Multi-physics perturbation (SREF-II) model configuration.

Both SREF systems were made up of members from the NCEP Eta model (Rogers et al. 1996; Ferrier, et al. 2003) and Regional Spectral Model (RSM, Juang et al. 1997). The various convective parameterizations and cloud microphysics chosen for the SREF-II multi-physics system are described in more detail in Ferrier (2004).

3. SREF OUTPUT PRODUCTS

Mean and spread output products from the NCEP operational and experimental SREF systems are summarized in Table 3. 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 4. 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 3. SREF Grib File Statistical 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 4. SREF Grib File Probabilistic Threshold 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. An example of a SREF mean and spread diagram for total precipitation is shown in Fig. 2. An example of probability of occurance for specific values for precipitation is shown in Fig 3.

4. SREF MEAN AND SPREAD EVALUATION

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).

Three error time-series are usually plotted:
Mean: mean of all ensemble members
Best: The best ensemble member as computed from the evaluation statistic
OPR: Eta-12 operational forecast error.

An example of the mean and spread plots are shown on the SREF evaluation web page (http://wwwt.emc.ncep.noaa.gov/mmb/SREF/VERIFICATION/2003.htm).

Preliminary results have shown that the spread is increased with the SREF-II system, however, the mean accuracy results are similar for key fields (not shown). Wilczak et al. (2004) also showed that the mean 2 m temperature accuracies were similar between both SREF approaches during the Summer 2003 NEHRT experiment.

5. SREF PROBABILISTIC EVALUATION

The following probabilistic plots were produced by the NCEP SREF system to summarize the SREF system statistical characteristics. More information on probabilistic verification is summarized by Toth et al. (2002).

- 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. Currently 16 bins (membership plus 1) are used. For example, for MSLP 16 bins are created ranging from min pressure to max pressure in the analysis. The results yield the percentage of the ensemble system that encompasses the analysis. (Figs. 4 and 5).
- 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)

The Analysis Rank Histogram plots for several fields from the SREF-I and II systems are shown in Fig. 4 and 5, respectively. The U-shaped distribution indicates that both SREF-I and II are under-dispersive; however, error for the SREF-II system is more equally spread among all value ranges. The amplitude of the outlier ranges (bins 1 and 16) are also reduced for the SREF-II system, implying a better chance that the verifying analysis falls within the ensemble forecast ranges than in SREF-I. The MSLP histograms (Fig. 4 and 5 a), for example, show that 24% of the SREF-I member forecasts lie outside of the verifying analysis as compared to 19% for SREF-II. Both systems, however, still underestimate the the true uncertainty in the forecast.

A spaghetti diagram of the MSLP 1004 mb contour for SREF-I and SREF-II systems is shown in Fig. 6 for 06 UTC July 9, 2003 SREF runs. A wider diversity of contours is shown in the SREF-II system, indicating more spread predicted than for the SREF-I system for this forecast.

6. SUMMARY AND FUTURE PLANS

This paper overviewed the current NCEP SREF system that includes breeding initialization, member configuration, postprocessed products and ensemble based verification tools. The preliminary results show that adding physics diversity improves the SREF system's ability to capture more forecast uncertainty. This SREF system product directly supports NCEP's strategic goal of delivering improved probabilistic products and services. This upgrade to the operational SREF system capability will be 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.

In the near term, a SREF system similar to SREF-II will be implemented this coming winter. Specific improvements include the development of post-processed bias correction and calibration techniques, extension of the SREF runs to 4 times per day, improved initial and lateral boundary condition generation, and the addition of energy, hydrological and aviation related products and ensemble mean meteograms.

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Members	Model	ΔX	# levels	Members	Cloud physics	PBL, Sfc physics
5	Eta-BMJ	32 km	60	Ctl,n1,n2,p1p2 *	Bett-Miller-Janic (BMJ) convection Ferrier microphysics	Mellor-Yamada TKE NOAH-LSM
5	RSM-SAS	32 km	28	Ctl,n1,n2,p1,p2	Simple Arakawa-Shubert (SAS) convection	MRF K theory NOAH-LSM
5	Eta-KF	32 km	60	Ctl,n1,n2,p1,p2	Kain-Fritsch(KF) convection Operational Ferrier microphysics	Mellor-Yamada TKE NOAH-LSM

Table 1. Description of NCEP experimental SREF Multi-IC (SREF-I) system run for the Summer, 2003 NEHRT Program.

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# Members	Model	Δx	# levels	Members	Cloud physics	Convective parameterization
3	RSM-SAS	32 km	28	Ctl, n1,p1	GFS physics	Simple Arakawa-Shubert
2	*RSM-RAS*	*32 km*	*28*	*n1,p1*	*GFS Physics*	*Relaxed-Arakawa - Shubert*
3	Eta-BMJ	32 km	60	Ctl,n1,p1	Op. Ferrier microphysics	Betts-Miller-Janic
1	*Eta-RAS-Mic*	*32 km*	*60*	*p2*	*Exp. Ferrier microphysics (more mixed-phased processes)*	*Relaxed-Arakawa - Shubert*
1	*Eta-RAS*	*32 km*	*60*	*n2*	*Op. Ferrier microphysics*	*Relaxed Arakawa-Shubert*
2	Eta-KF	32 km	60	n1,p1	Op. Ferrier microphysics	Kain-Fritsch
1	*Eta-FER*	*32 km*	*60*	*Ctl*	*Op. Ferrier Microphysics*	*Ferrier Shallow Convection*
1	*Eta-KF-DET*	*32 km*	*60*	*n2*	*Op. Ferrier microphysics*	*Kain-Fritsch w/full detrainment*
1	*Eta-KF-CON*	*32 km*	*60*	*p2*	*Exp. Ferrier microphysics w/ more freq. calls to cloud water condensation & ice deposition*	*Kain-Fritsch*

Table 2. Description of the multi-physics experimental SREF configuration (SREF_II). * and italisized members are unique runs from the multi-IC breeding SREF-I experiment, and are used to make up the SREF-II configuration.

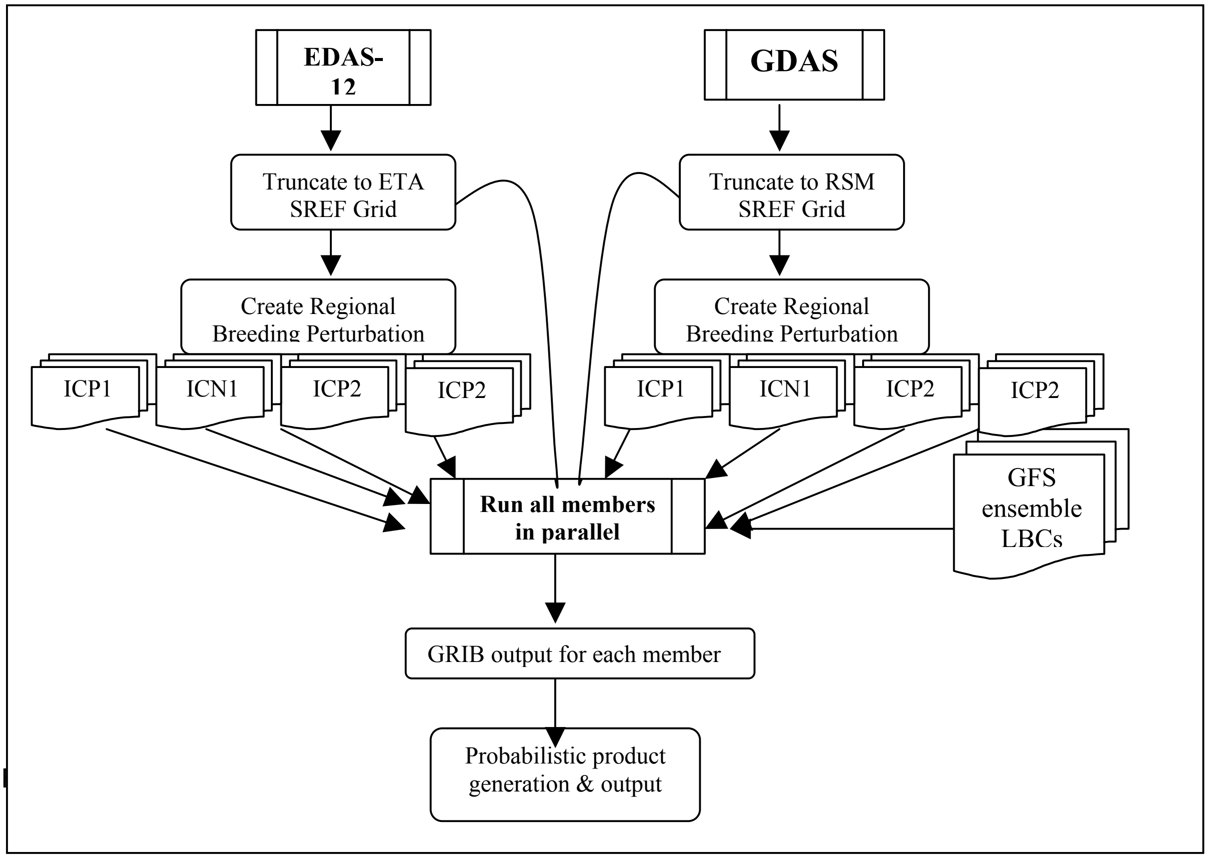


Figure 1. Outline of NCEP SREF Operational system run (Multi-IC) in 2003. ICP, ICN, I represent Initial Condition files for the Positive and Negatively perturbed runs, respectively. In addition, a control run was initialized with the truncated Initial condition grid (curved arrows). 2 perturbation pairs 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.

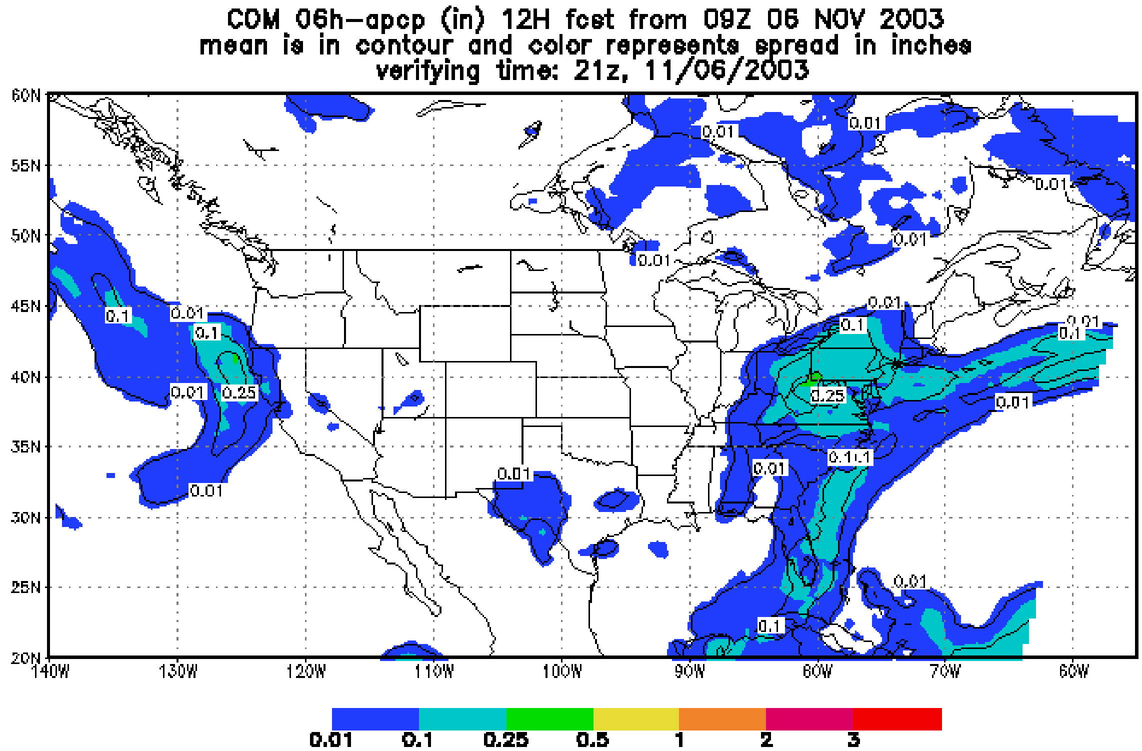


Figure 2. Example of a mean (solid lines. inches) and spread (standard deviations from all 15 members, color fill, inches) 6 hourly accumulated precipitation forecasts from NCEP SREF system.

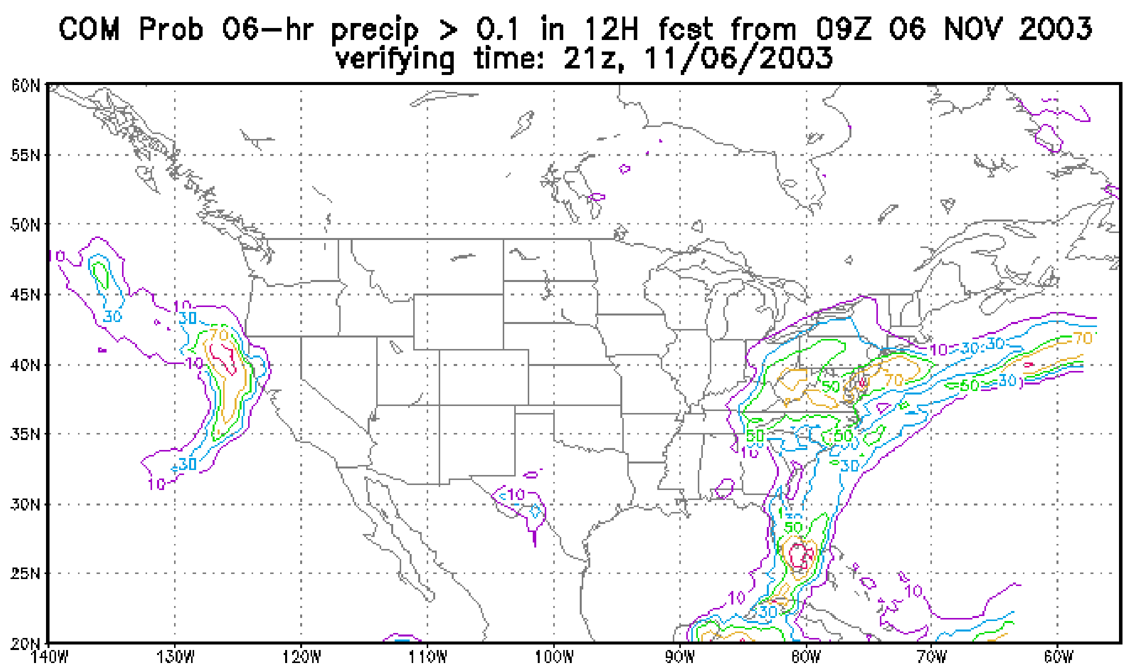


Figure 3. Example of 6 hourly accumulated precipitation probability of exceedence (%) of amounts greater than 0.1" in a 12 hour period. Highest probabilities are in orange and red.

Chances Ens Encompasses Anl at 60h (ini, July 03)

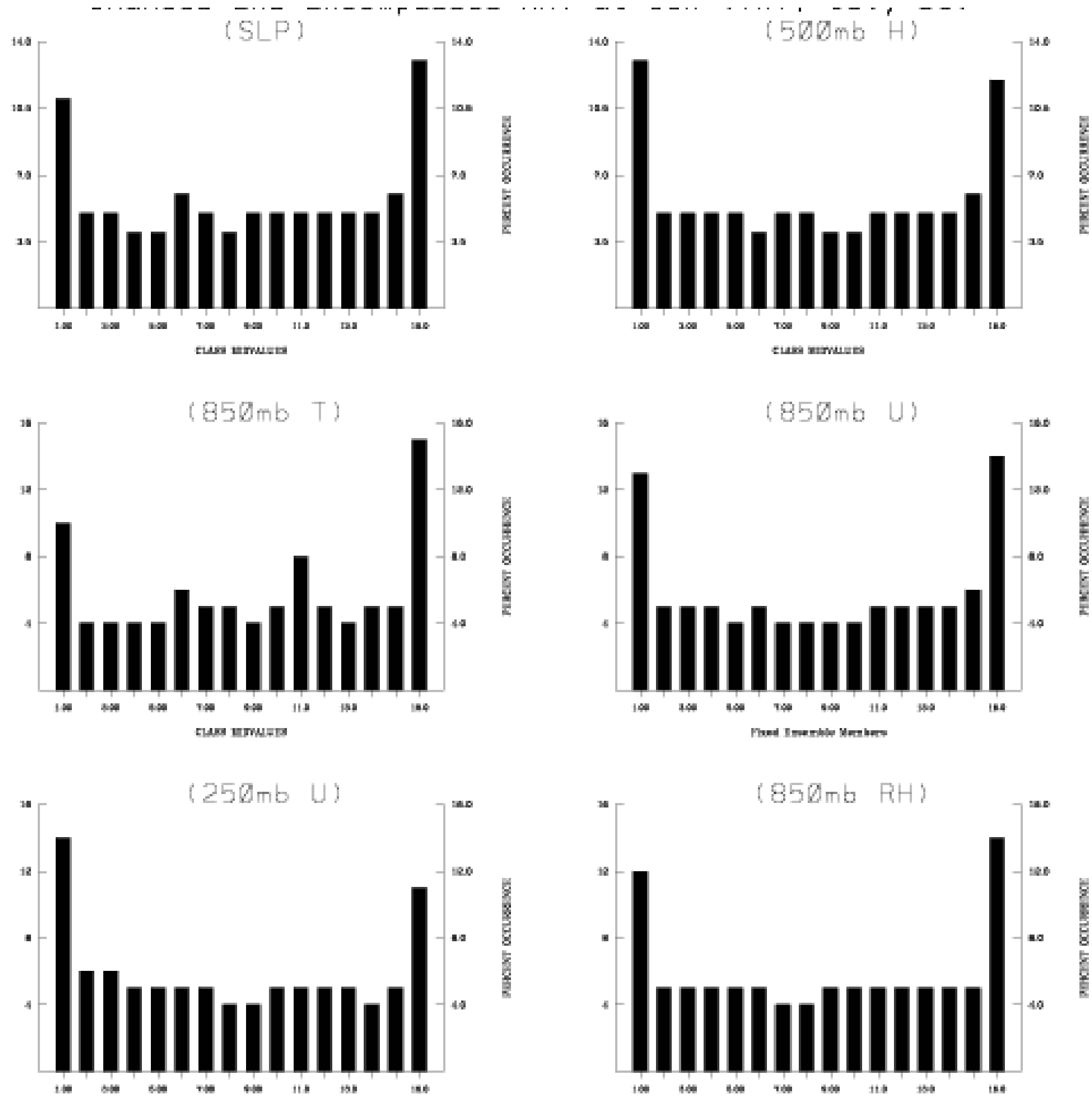


Figure 4. Talagrand Analysis Ranked Histogram diagrams for SREF-I multi-IC system for July 2003 from the SREF 06 and 18 UTC cycle 60 hour forecast. 16 ordered bins are shown representing equal value ranges for each variable from the variable minimum to maximum value. The leftmost and rightmost bins represent outliers. The y-axis represents the percent of the ensembles that lied within the analysis bin (0-16%) Talagrand diagrams are shown for a) MSLP, b) 500 mb height, c) 850 mb temperature, d) 850 mb Wind, e) 250 mb wind, f) 850 mb RH. See section 5 for a more detailed description of Talagrand diagrams

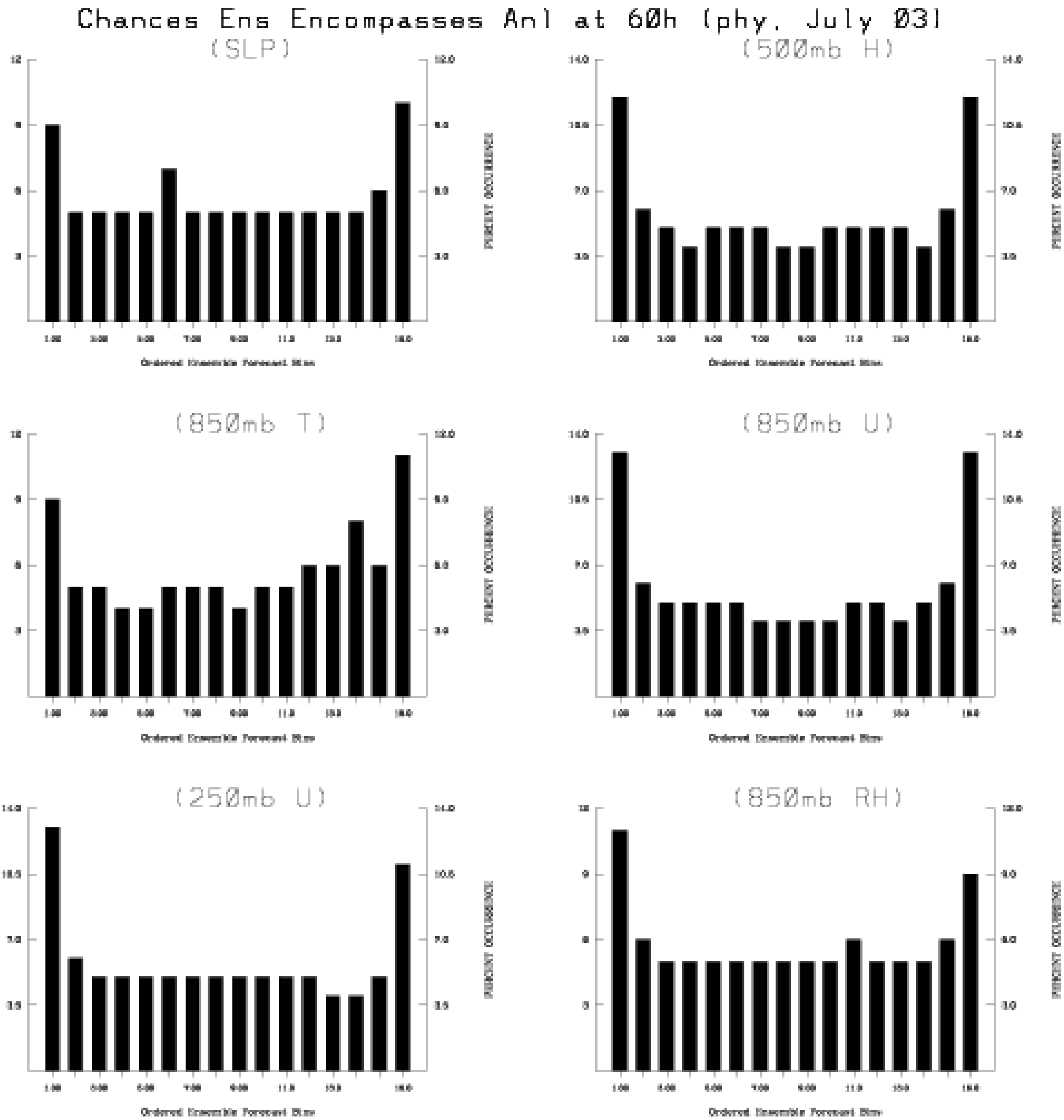
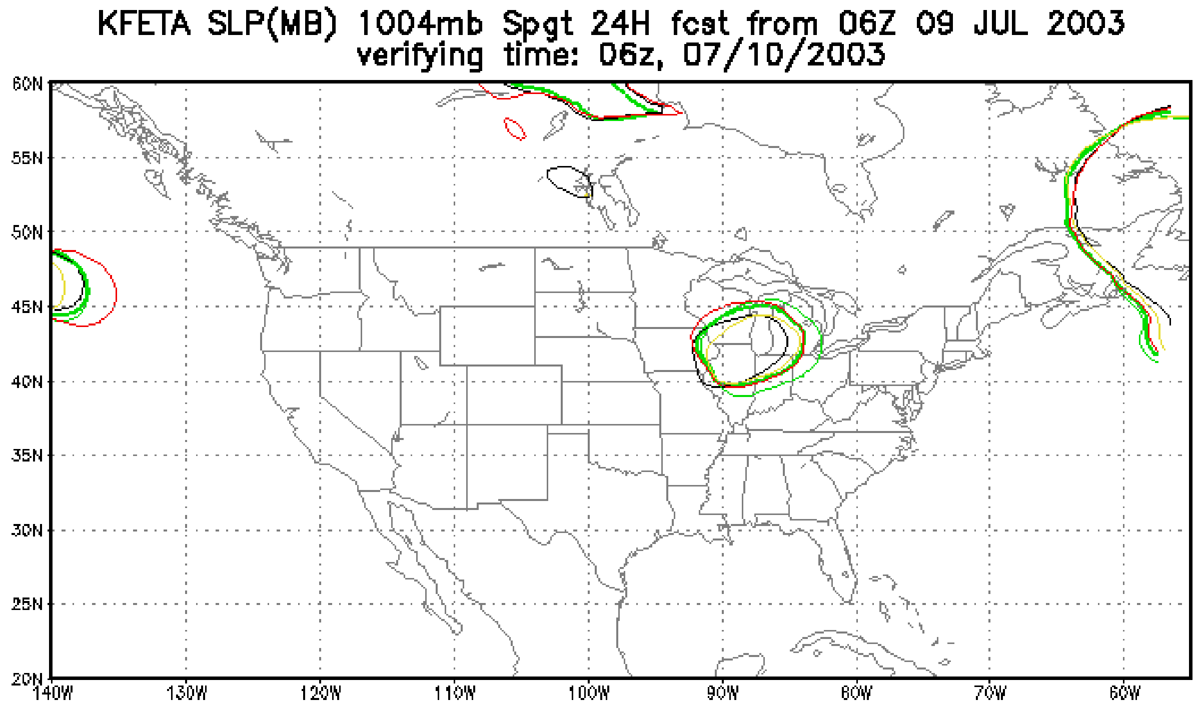


Fig. 5 Same as Figure 4 except for the SREF-II enhanced physics diversity system. Y-axis range is now 0-12%.



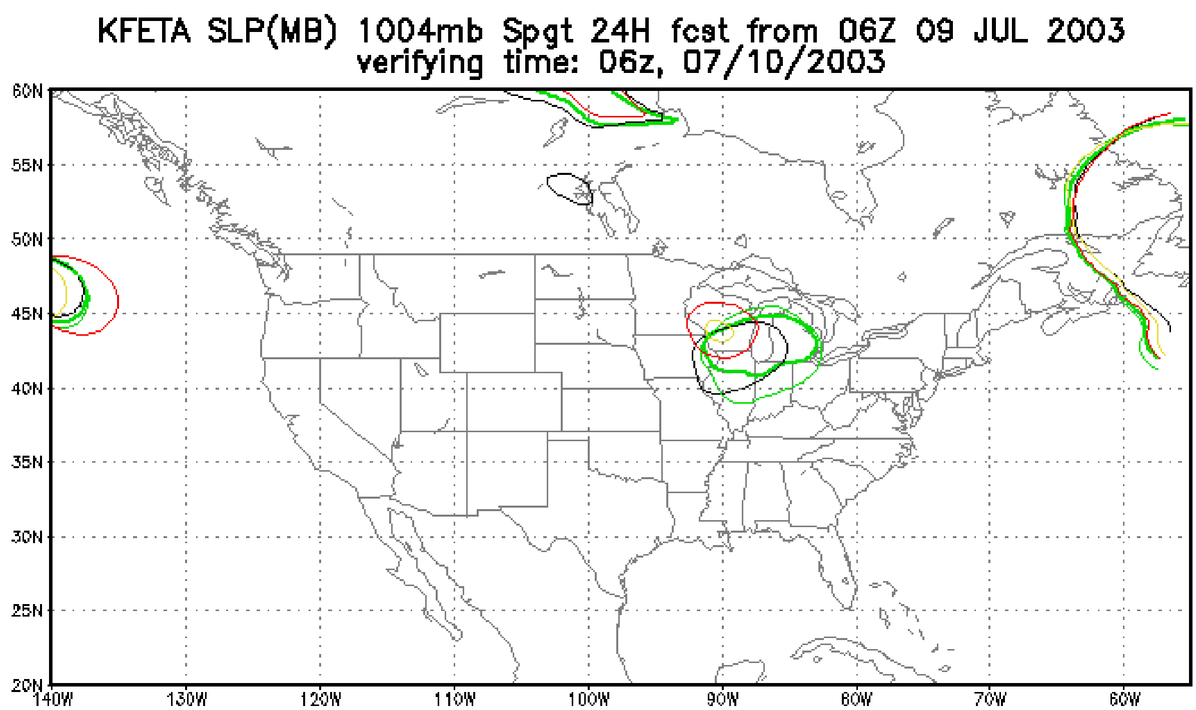


Figure 6. MSLP (mb) spaghetti diagram 24 h forecast of mslp contour 1004 mb valid July 10, 2003 at 0600 UTC for all a) SREF-I multi-IC members and b) SREF-II enhanced physics diversity members. (showing Eta-KF component only)