NCEP SHORT-RANGE ENSEMBLE FORECASTING (SREF) SYSTEM: MULTI-IC, MULTI-MODEL AND MULTI-PHYSICS APPROACH

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1 Current System

A prototype SREF system has been developed, implemented and run since April, 2001 at NCEP (Tracton et al., 1998; Du and Tracton, 2001). It consists of 10 members with two regional models (Eta and RSM) at 48km resolution over North America domain. Each model contributes five (5) members initiated with different perturbed initial conditions (ICs) created by the breeding method (Toth and Kalnay, 1993). It runs twice a day (09z and 21z) with a forecast length of 63 hours. Three types of SREF products, including ensemble mean/spread, spaghetti charts and probabilistic forecasts of many selected fields, are produced and displayed in real time at the following web site: http://wwwt.emc.ncep.noaa.gov/mmb/SREF/SREF.html

Preliminary results from this prototype SREF system are promising (Tracton and Du, 2001). An important lesson was also learned from our participation in the SAMEX experiment (Hou et al., 2001) during the early stage of the SREF system developement; *i.e.* perturbations in LBCs have a big impact on ensemble spread when the model computation domain is too small in size (Du and Tracton, 1999). Most of our previous reports focused mainly on multi-IC aspects. This report will, however, mainly address multi-model aspects.

2 Results from Multi-Ensemble Systems

Since both our preliminary results and the SAMEX report suggested that an ensemble system with multi models was always better than one with a single model, in terms of ensemble mean and probabilistic forecasts, a multi-model approach is one of the directions we are exploring. To continue to explore in this direction, another set of five (5) members from Eta model, but with Kain-Fritch convective scheme to replace the Betts-Miller-Janic scheme normally used by the Eta model, have been added to the 10-member SREF system to make a total of 15 members (note: strictly speaking, this step is a multi-physics rather than a multi-model approach).

Figures 1 and 2 show the September 2002 average scores of 48km ensemble median forecasts, with varying numbers of models involved, as well as the operational 12km Eta forecasts. For all six selected variables, increase in forecast accuracy of the ensemble median or mean forecasts are astonishingly significant, as the number of models increase from one model (5 members) to two models (10 members) and to three models (15 members). It's also interesting to see that the ensemble median from the 48km 5-member 1-model system performs no better than the single 12km Eta, while that from 10-member of 2-model system performs generally better than or at least comparable to the 12km Eta and that from 15-member of 3-model system outperforms the 12km Eta significantly! Similar results, but with lesser significance, can be seen for precipitation forecasts too (Fig. 3a). Figure 3b shows the improvement of probabilistic forecasts measured by Ranked Probabilistic Skill Score (RPSS) as the number of models increases.

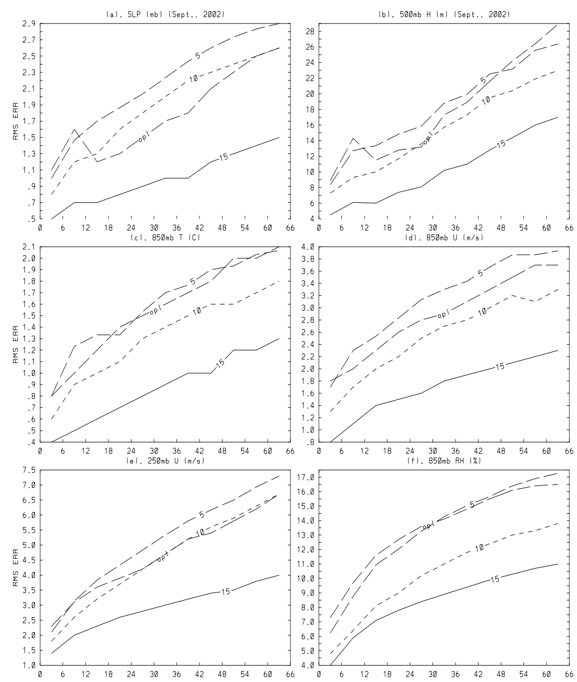

Figure 1: Sept 2002 rmse of 48km ensemble median forecasts with 1-model (averaged over “5-Eta”, “5-RSM” and “5-KFeta”: “5”), 2-model (“5-Eta + 5-RSM”: “10”) and 3-model (“5-Eta + 5-RSM + 5-KFeta”: “15”) SREF systems and operational 12km Eta (“opl”). Both Eta and GFS analysis are used.

One might argue that such significant improvements through a multi-model approach could stem from model bias cancellation when you combine forecasts from more than one model. Therefore, a simple technique was applied to first remove biases individually from each model and then to repeat the above calculation. It is found that the results are virtually unchanged (not shown). Of course, more study is needed to verify this. Since the ensemble size

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	SREF System	out of range	expected	diff	spread
six basic fields (same as in Fig. 1)	one model (5 members)	47%	33.3%	13.7%	under dispersive
	two models (10 members)	25%	18.2%	6.8%	near perfect
	three models (15 members)	0%	12.5%	-12.5%	over dispersive
precipitation	one model (5 members)	37%	33.3%	3.7%	near perfect
	two models (10 members)	22%	18.2%	3.8%	near perfect
	three models (15 members)	15%	12.5%	2.5%	near perfect

Table 1: Average percentages of analysis not encompassed by forecasted ensemble range as measured by Talagrand distribution during September 2002.

also increases (from 5 to 15) when the number of models increases (from 1 to 3) in this study, one could argue that this big improvement resulted from the increase in ensemble size rather than in model number. However, a previous study (Du et al., 1997) shows that improvements in forecast accuracy through ensemble averaging decrease when

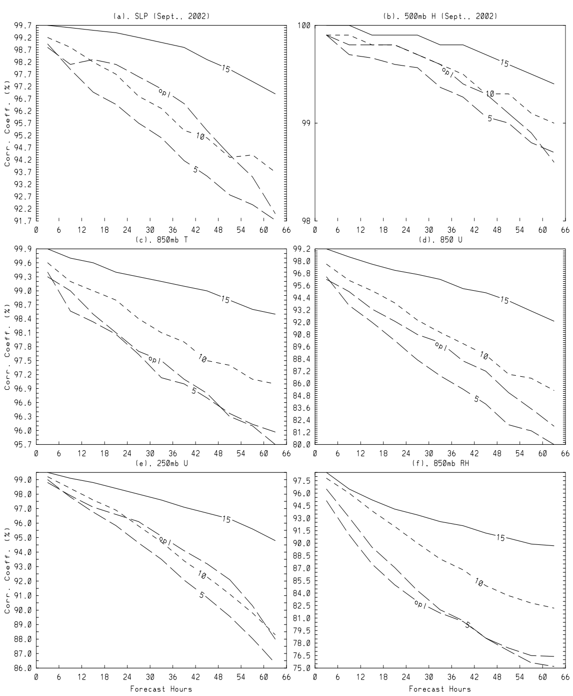

Figure 2: Same as Fig. 1 except for correlation coefficient.

ensemble size increases in a one-model ensemble system (multi-IC only). We therefore believe that these significant improvements (note: the improvement from 10 to 15 members was even more significant than that from 5 to 10 members!) are a result of combining multi-IC with multi-model, *i.e. multi-ensemble systems approach*!

Table 1 is a summary of the percentages where true atmosphere was beyond the range predicted by ensemble during September 2002. It can be seen that the ensemble spread is *under-dispersive* in a one-model system (5 members), but *over-dispersive* in a three-model (15 members) system. *Near-perfect spread* is seen in the precipitation forecasts.

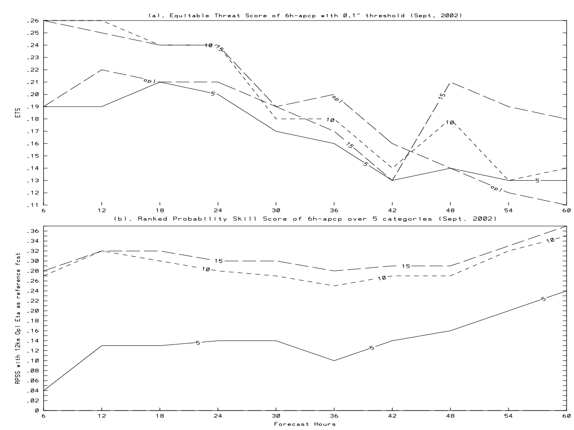

Figure 3: Same as Fig. 1 but for (a) ETS of 6h-apcp with 0.1" threshold; and (b) RPSS over five MECE categories, using 12km Eta as reference forecast. NCEP precip analysis is used in the verification.

3 Problems and Plans

Based on the positive results, NCEP SREF system will continue to be developed along the line of multi-ensemble systems. Currently, two new subsets of 5 members each with RUC and ARPS regional models respectively are being tested and will be implemented if proven to add value. Over-dispersion in spread is a possible problem in this approach that may need to be corrected.

Another problem related to this approach is that the ensemble members cluster by model in some situations. To increase the degree of freedom, given the importance of uncertainty in model physics (Stensrud et al., 2000), a new SREF system is under construction. It will address physics diversity in each model by using different alternative physics packages for a given model. Finally, the current 48km system, running twice per day, will be upgraded to 32km, running four cycles per day, in the near future.

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