RUC Short-Range Ensemble Forecast System

Chungu Lu[1], Stan Benjamin[2], Jun Du[3], and Steve Tracton[4]
[1] NOAA Forecast Systems Laboratory and CIRA, Colorado State University
[2] NOAA Forecast Systems Laboratory
[3] NOAA NWS/NCEP and SAIC
[4] Office of Naval Research

1. Introduction

Because of uncertainties in atmospheric model dynamics, physical parameterizations, initial and boundary conditions, a single deterministic forecast has some degree of error. In this sense, a deterministic forecast is used merely as a reference to the forecast of the true atmospheric states. Therefore, statistical analysis of a sample of forecasts becomes a plausible approach for the improvement of numerical weather prediction (NWP). To best generate such a sample of forecasts poses an important area of scientific challenge and development.

In collaboration with NCEP's multi-model Short-Range Ensemble Forecast (SREF) initiative, we have developed a SREF system based on the RUC model targeting for both operations and research needs.

The Rapid Update Cycle (RUC) forecast system is a NOAA operational weather prediction system (Benjamin et al. 2003a, b). One of the unique features of the RUC is that its dynamical core is based on a hybrid potential-temperature/sigma vertical coordinate. This feature will certainly add to the model diversity as far as a multi-model ensemble is concerned, and thus possibly increase the ensemble spread.

Currently, the RUC SREF runs twice daily with a total of 10 members. The SREF domain encompasses the entire North America including Alaska, Central America including the Caribbean Sea, the western Pacific including the Hawaiian Islands, and the western Atlantic. The forecast is run out to 60 hours with output every 3 hours. The horizontal spacing is 48 km. Fig. 1 shows the RUC SREF domain (the solid boundary) in comparison with the Eta 48-km domain (the dashed boundary).

Corresponding author address: Dr. Chungu Lu, NOAA/FSL, R/FS1, Boulder, CO, 80305. Email: Chungu.Lu@noaa.gov.

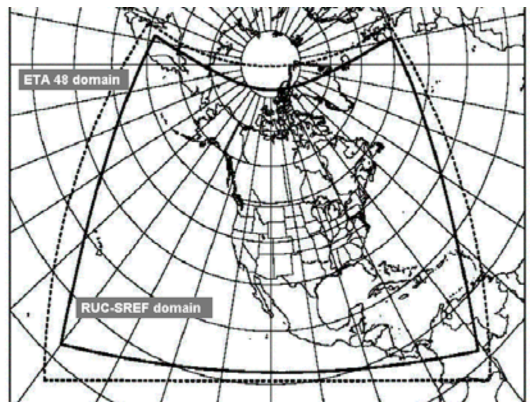

Fig. 1: RUC SREF domain (solid boundary) vs. Eta 48-km domain (dashed boundary).

2. The setup of RUC-SREF system

The RUC SREF system includes an interpolation package which interpolates NCEP's regional breeding modes gridded data onto RUC hybrid-coordinate grids; a preprocessor which prepares initial and lateral boundary conditions, land/ocean surface data and other fixed data files ready for model integrations; an operational forecast model (RUC); and a post-processor which packs the forecast data into GRIB format and derives all the other diagnosed fields. Fig. 2 is a schematic diagram of RUC SREF system.

NCEP's regional breeding cycle (Tracton and Du 2003) provides five members of initial perturbations twice daily for the RUC-SREF forecasts. The perturbations for lateral boundary conditions were obtained from the NCEP's global model ensemble system. Since the RUC-SREF domain is much larger than the operational RUC forecast CONUS domain, fixed files such as topography, soil types were first generated using the WRF standard initialization package (McGinley et al. 2000).

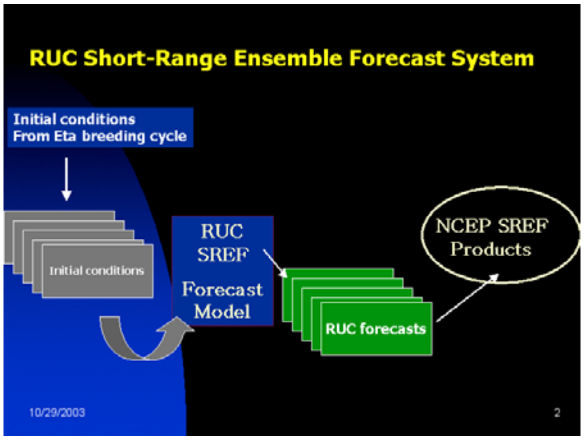

Fig. 2: Flow chart of RUC SREF system.

3. Forecast variability among RUC-SREF members

Figs. 3a and 3b show the 36-h forecasts of sea-level pressure and 3-h accumulated precipitation from the RUC-SREF control run for the case of 25 September 2002. Various tropical and extratropical weather systems were presented in this forecast. In particular, the transient (synoptic) component of Aleutian and Icelandic lows, a typical Canadian comma synoptic weather system were captured in the extratropical regions. In the tropics, the ITCZ depression and Hurricane Isidore were in the forecast.

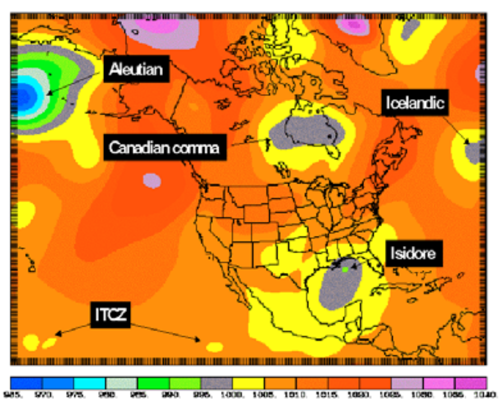

Fig. 3a: 36-h forecast of sea-level pressure from RUC SREF control run, initialized at 00Z of September 25, 2002.

In order to examine the ensemble members' forecasts in detail, we focused on the forecasts of Hurricane Isidore in the Gulf of Mexico. Fig. 4a and 4b are the zoom-in plots of 3a and 3b for the five ensemble forecasts. One can see that there

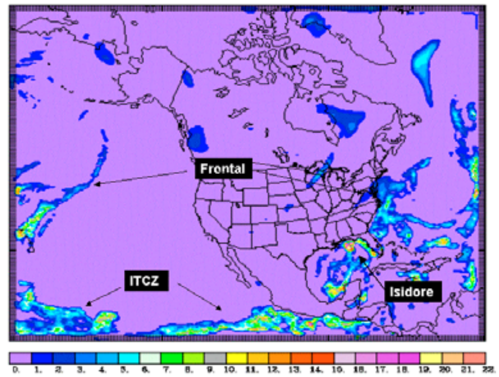

Fig. 3b: Same as Fig. 3a, except for the 3-h accumulated precipitation.

is large variability of position and intensity forecasts for Hurricane Isidore among the five members.

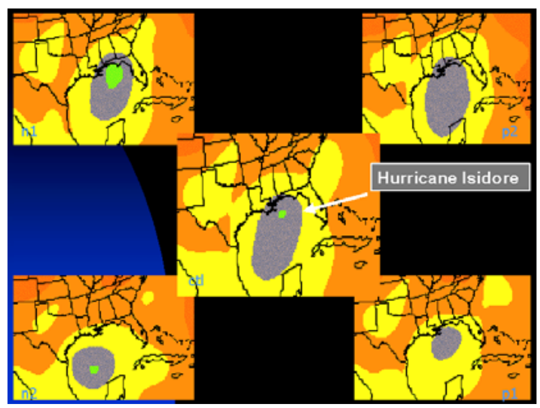

Fig. 4a: 36-h Forecasts of sea-level pressure from five RUC-SREF members for Hurricane Isidore.

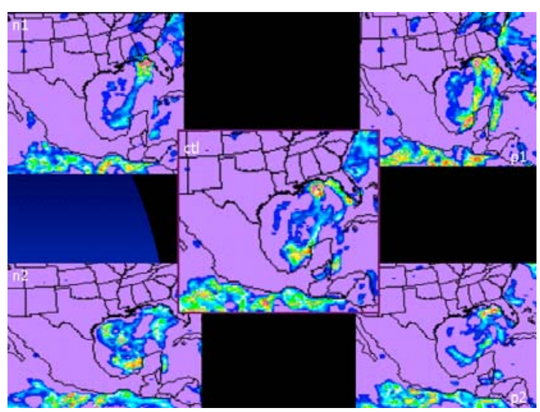

Fig. 4b: Same as Fig 4a, except for the 3-h accumulated precipitation.

4. RUC-SREF ensemble spread

Figure 5a and 5b showed the domain-averaged ensemble spread for geopotential height and temperature at various pressure levels for the case of April 26, 2003. By comparing with SAMEX 98 (Hou et al. 2001) for ensemble spread in a different application, it appears that the RUC SREF provides larger or comparable spreads in these forecast fields.

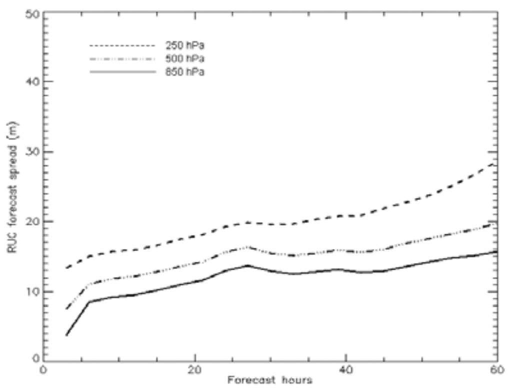

Fig. 5a: Domain-averaged ensemble spread for geopotential height at various pressure levels.

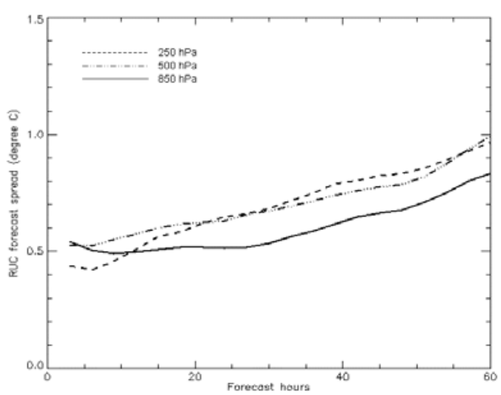

Fig. 5b: Same as Fig. 5a, except for temperature.

5. Statistical verifications

Statistical verification of RUC SREF forecasts was conducted over the one-week period beginning 26 April 2003, against Eta analyses. For comparison, the verification of the Eta 12-km operational forecast is also included. Figures 6a-6c show RMS forecast errors for the five RUC-SREF ensemble members, the ensemble mean, and Eta 12-km operational run for sea-level pressure (panel a), 500-hPa height (panel b), and 850-hPa temperature (panel c). One can see that the ensemble mean (solid-black line) generally possesses the smaller forecast error than any one of the ensemble members (color lines), and is closer to the error of the high-resolution Eta model forecasts (dash-black line).

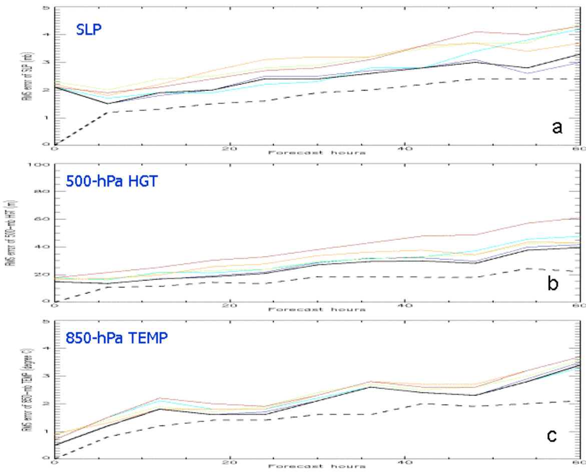

Fig. 6: RUC SREF RMS forecast errors verified against Eta analyses. Color lines are for each individual members, solid-black line is for ensemble mean, and dashed-black line is for Eta 12-km operational run.

For a perfect ensemble system, the ensemble spread should possess approximately the same values as the standard deviation error in the ensemble mean (Hou et al. 2001) for all forecasts. Figures 7a and 7b are the scatter diagrams of ensemble spread vs. standard deviation error of the ensemble mean for various forecast hours for 500-hPa height and 850-hPa temperature for the case of April 26, 2003.

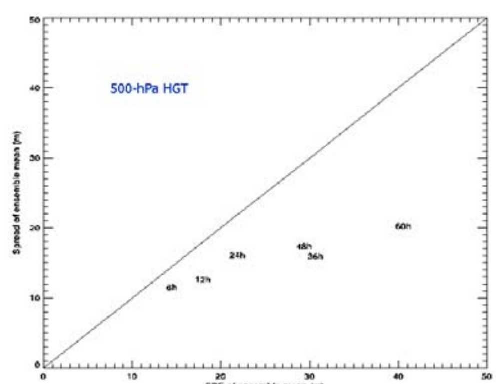

Fig. 7a: Scatter diagram of ensemble spread vs. standard deviation error of ensemble mean for 500-hPa height forecasts.

One can see from Fig. 7a that the RUC SREF has a comparable size of spread and forecast error up to 24 hours. After 24 hours, the RUC SREF begins to produce large forecast errors relative to its ensemble spreads.

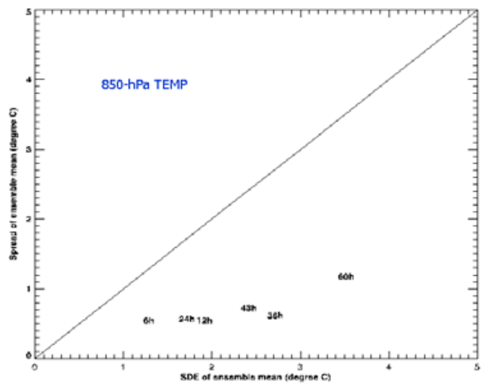

Fig. 7b: Same as Fig. 7a, except for 850-hPa temperature forecasts.

For 850-hPa temperature forecasts (Fig. 7b), the correlation between ensemble spread and standard deviation error in the ensemble mean seems to be not as good as the 500-hPa height forecasts.

6. Summary

In collaboration with NCEP's multi-model Short-Range Ensemble Forecast (SREF) initiative, we have developed a RUC SREF system targeting for both operations and research needs.

The statistical verification scores show the RUC SREF forecasts compare well against Eta analysis and Eta 12-km operational runs, and yet the forecast spread calculations show that there is significant variability among the forecast members.

Continued future development of RUC SREF is still in order. In particular, we are planning to experiment various initial perturbation methods while still using the Eta regional breeding method, and continue to develop posterior analysis, verification schemes, and probability forecast products. The development of an upgrade version for higher horizontal resolution and some research applications are also being planned. FSL will work with NCEP/EMC in running the RUC SREF as part of a retrospective test of current and prospective members of the NCEP SREF.

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