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GRIDPOINT STATISTICAL INTERPOLATION FOR RAPID REFRESH

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1. INTRODUCTION

The Rapid Update Cycle (RUC) is an operational mesoscale data assimilation and numerical forecasting system developed by NOAA Research Forecast Systems Laboratory (FSL) in Boulder, CO. The first version of the RUC (RUC1) became operational at the National Centers for Environmental Prediction (NCEP) in 1994. Several major upgrades have been introduced since then, the most recent, RUC13, in June 2005. RUC13 has a 13-km horizontal resolution, 50 vertical levels, and utilizes a 1-h intermittent data assimilation cycle (for general information about RUC see Benjamin et al. 2004a,b). With this latest upgrade the RUC series will be terminated and a new design for rapid updating, called Rapid Refresh (RR), will be introduced. Both the RUC data assimilation system and dynamical model will be replaced by components more suited for the Weather Research and Forecasting model (WRF) framework and/or the Earth System Modeling Framework (ESMF).

This paper describes new developments related to the data assimilation aspects of RR. In the present RUC system a three-dimensional variational (3DVAR) scheme (Devenyi and Benjamin 2003, Benjamin et al. 2004a) is used in RUC's hourly update cycle for analysis of data from diverse sources, including RAOB, METAR, buoy observations, commercial aircraft (ACARS), wind profilers, geostationary (GOES) and polar-orbiting (SSM/I) satellites, ground-based GPS, and radars (VAD winds). In the new RR, following a design decision in June 2005, the Gridpoint Statistical Interpolation (GSI) scheme will be used for data assimilation instead of the current RUC 3DVAR scheme.

GSI is under development at NCEP as a new generation of 3DVAR to replace the successful Spectral Statistical Interpolation (SSI) analysis scheme, developed during the early 1990s by Parrish and Derber (1992).

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2. INITIAL ACCESS TO GSI SOFTWARE AND ITS INSTALLATION BY FSL

FSL first became acquainted with the GSI software through the March 2004 tarball and since then has worked with every monthly update. FSL's testing described below is based on the December 2004 tarball. Our initial goal was to get a version running on FSL's supercomputer; an Intel 32-bit Linux cluster containing 768 Intel Pentium 4 Xeon nodes (for more details see http://hpcs.fsl.noaa.gov). This required modifying the December 2004 version from NCEP for testing at FSL.

By late April 2005, GSI had been installed on the FSL's supercomputer. The installation required several other steps including

- installation of the MPI-2 I/O system on our supercomputer in order to perform parallel I/O required for input of the WRF mass core binary test file provided by NCEP,
- installation of Message Passing Environment Utilities (MPEU) library,
- modification of the BUFR library,
- modification of the GSI code for I/O,
- fixing arraybound problems in GSI code.

All modifications needed for working with our versions of GSI code and libraries were communicated to and discussed with NCEP through Dr. Russ Treadon. These code-related issues are not discussed in this paper. It is fair to say that the adaptation of the GSI libraries to our supercomputer's little-endian environment at FSL was time-consuming, but is now complete.

In June 2005, GSI was compiled and successfully run on a newer and more faster 64-bit supercomputer component at FSL. According to expectations, the speed of computation was about double that on the older supercomputer. Both computer platform versions of the GSI code are available for further comparative testing.

As of June 2005, additional software was received from NCEP to support visualization of GSI results in the Grid Analysis and Display System (GrAD) graphical package. Software is successfully installed, but the set-up requires some more fine-tuning.

3. RESULTS OF TESTS PERFORMED AT FSL TO DATE

The date of the test run was 2004090706 (06 UTC 7 Sept 2004) using the WRF West High Resolution Window regional domain. The grid size is 269x298x50. (The present RUC13 grid dimensions are 451x337x50.)

The input files used and their size include the observational prepbufr file: gblav.t06z.prepbufr.nr (13.9 Mbytes) and the background GRIB file: wrfinput_west_mass_d01_bi (191Mbytes). Other files (such as background error-related data, emissivity, etc.) were used, as required by GSI.

Timing results of the two tests performed, with and without satellite radiance data on FSL's older supercomputer

Wall times *without* satellite data

Processors	Wall time
24	24:52
48	14:16
96	10:10

Wall times *with* satellite data

Processors	Wall time
24	28:26
48	16:13
96	9:08
192	7:27

Satellite data are from AMSU-A, -B, and HIRS.

In both test cases, 200 iterations were performed (two outer cycles) without stopping for any converge condition.

Inspection of GSI test results and other diagnostics, generated by the code itself, demonstrated that the code is executing properly in FSL's computer environment. All the numbers are close to those generated in NCEP's own experiments. The 32-bit arithmetic has not resulted in a perceptible loss of accuracy in the computations.

GSI has been tested both with a full set of observations and in single observation mode. Individual observations were generated and perturbed to test the impact of single observations on analyses. The tests were satisfactory. Sample test results will be shown at the conference.

4. FEATURES OF PRESENT RUC 3DVAR IMPORTANT FOR RAPID REFRESH APPLICATION

The RUC system performed well in a 1-h data assimilation cycle as a result of the specific features listed below. It is mandatory that the RR retain or even improve on these features.

- Assimilation of surface data within full 3DVAR: analysis of METAR data (and other surface mesonet observations) is an integral part of RUC 3DVAR. The contribution of these observations to the analyses is especially important at nonsynoptic times.

- Cloud/hydrometeor analysis using background three-dimensional hydrometeor fields, derived from GOES cloud-top pressure/temperature, METAR cloud/visibility and radar data.

- Revised balance and background error covariances (standard errors and scales) appropriate for 1-h rapid updating.

- Calculation (and application) of innovations for METAR/buoy data, including application of similarity theory in the observation operator for 2m temperature and mixing ratio, and 10m wind. Use of pseudo-innovations for surface observations through estimated PBL depth.

- QC buddy check, including RAOB/GPS-IPW checks, platform flagging, and limiting the size of innovations.

- Adjustment of background soil temperature/moisture based on surface temperature/moisture analysis increment, depending on the conditions (daytime, no cloud/precipitation, etc.)

- Land-use dependency near the surface.

All these requirements have already been discussed between FSL and NCEP EMC, including how best to meet them.

5. FUTURE WORK

All GSI tests reported above were performed using the December 2004 version of GSI. As of this writing, updating to the June 2005 version of GSI is under way and will be finished in the very near future. After that, a higher frequency code update is planned, probably every two- or three months.

Another important task is to introduce important RUC features into GSI. Some of them (such as assimilation of surface data) are already under way. Other RUC enhancements, such as the cloud/hydrometeor analysis (Benjamin et al. 2004a) may be done outside the core GSI framework. The biggest challenge is related to the computation time. In the present RUC, data assimilation takes about 4 minutes; no more time will be available for GSI in RR. However, RR will use a much larger domain than the present RUC CONUS domain (Fig. 1).

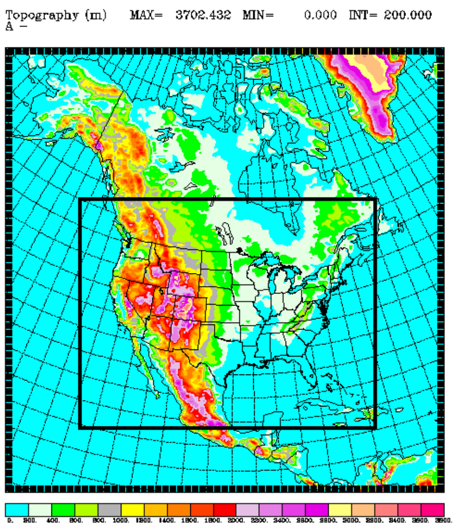

Fig. 1. Planned analysis and forecast domain and topography for Rapid Refresh. Inner frame represents present RUC CONUS domain.

The RR domain will have about 2.5 times more grid points than the present RUC domain. More tests should be performed on present RUC domain to determine the best achievable runtimes as a function of the number of processors and software (MPI, OpenMP, etc.). Preliminary tests show that with more code optimization and use of FSL's advanced supercomputer, the present runtime with 76 processors is just above 3 minutes.

RR is expected to be operational at NCEP late in 2007. At least one year of real-time testing is anticipated at FSL prior to porting the code to operations.

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