9.1 FROM THE 13-KM RUC TO THE RAPID REFRESH

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1. INTRODUCTION

The Rapid Update Cycle in the U.S. is the only 1-h assimilation and mesoscale forecast cycle in the world running operationally as part of an operational numerical prediction center (U.S. National Centers for Environmental Prediction - NCEP). Predictions from the Rapid Update Cycle (RUC) are used heavily as mesoscale guidance for short-range forecasts. Many phenomena important for this application are better predicted with higher spatial resolution, including convection, icing and clouds, turbulence, and surface events influenced by topography, coastlines, and other land-surface variations..

Rapid updating of NWP guidance on a 1-3h frequency has been provided operationally in the U.S. by the RUC since its initial implementation in 1994. Since then, a number of upgrades occurred to improve forecasts through higher resolution, improved data assimilation, model components, and higher update frequency, all targeted to improve needs from the user community, especially for aviation and severe-storm forecasting. In June 2005, another upgrade to the RUC, probably the most significant in the last 7 years, was implemented at NCEP, including a change of the horizontal resolution from 20 km to 13 km (Benjamin et al. 2004a). In this paper, we summarize two milestone changes to the RUC covering the present and the future:

- 2005 – The 13-km RUC – higher resolution, assimilation of new observations, improved physics. At least 9h forecasts now produced hourly.
- 2008 – Planned implementation of the successor to the RUC, the Rapid Refresh, a new rapid updating system using a version of the WRF model covering all of North American on a 1-h update cycle.

2. MOTIVATION

Automated decision-support systems are proliferating in many areas, spearheaded by those being developed for aviation. For this reason, the Rapid Update Cycle was originally motivated by requirements in the aviation community. However, similar requirements for *frequently updated* guidance using latest observations and sophisticated mesoscale numerical weather prediction systems have emerged in other transportation areas, other commercial activities, and various aspects of public safety. The planned transition from the RUC to the Rapid Refresh reflects the need for hourly NWP updating over a larger area including Alaska, Canada, and Puerto Rico. It is also motivated by the increasing availability of high-frequency observations over wider areas (e.g., aircraft, satellite, profiler, GPS precipitable water, automated surface observations, and radar). Finally, the transition to use of the Weather Research and Forecasting (WRF) model embraces development from a larger community in the US for modeling and assimilation development.

3. 13-KM RUC

After a 2-year testing period, the 13-km Rapid Update Cycle was implemented in June 2005.

The increase in resolution from 20 km down to 13 km produces significant improvements in RUC forecasts of weather phenomena that are important for aviation, severe weather, and general forecasters. In particular, the RUC13 provides improved guidance for forecasts of convection, icing, ceiling, visibility, and turbulence. Benefits of the higher resolution RUC13 also include improved depiction of terrain-induced airflow perturbations, sea/lake and land breezes, resolved clouds, and convective and resolved-scale precipitation. Improvements evident in cloud and precipitation forecasts during initial testing result from both revised microphysics and convection parameterizations as well as higher spatial resolution. These changes in the RUC13 are considered to be quite significant for aviation and severe weather forecast users.

The RUC13 analysis implementation included the following significant assimilation changes:

- Cycling of all fields at 13km resolution, including hydrometeor and land-surface variables. Higher horizontal resolution is thus represented in initial conditions for each RUC forecast.
- Assimilation of new observational types: GPS precipitable water (PW) retrievals, METAR cloud/visibility/current weather observations, and mesonet surface temperature and dewpoint. GPS PW observations improve accuracy of short-range forecasts of lower-tropospheric moisture.
- A much improved version of the RUC 3-d hydrometeor/cloud analysis, now adding the METAR ceiling/visibility data to the GOES cloud-

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top data, both used together to correct the previous 1-h forecast 3-d hydrometeor fields.

- Modification of moisture analysis variable from ln q (natural logarithm of water vapor mixing ratio) to pseudo relative humidity, defined as q / q-saturation-background (Dee and DeSilva 2003). Most importantly, this allows an integrated variational assimilation of in situ and integrated observations (PW) simultaneously. This change also reduces occasional noise in moisture fields sometimes previously evident in operational RUC20 analyses.

For cloud microphysics treatment, the RUC13 continues to use a recent version (Thompson et al. 2004) of the NCAR scheme originally described by Reisner et al (1998). This scheme is under continual development, with the goal of improving prediction of aircraft icing potential. The major changes implemented in the RUC13 at NCEP include the following:

- Replacement of the mixing-ratio dependence of the zero-intercept parameter in the exponential size distribution of snow particles by an empirical temperature-dependent distribution from Houze et al (1979). This has the effect of reducing vapor deposition on snow when snow mixing ratios are small.

- Introduction of a mixing-ratio dependence for the zero-intercept parameter in the exponential size distribution for raindrops (distinguished from cloud drops in that they have a non-zero terminal velocity). This dependence is intended to allow two different treatments of raindrops: 1) as drizzle-sized drops (zero intercept 2 x 10^9 m^{-4}) at mixing ratios below 10^{-4} g/g, and 2) as rain-sized drops (zero intercept 2 x 10^7 m^{-4}) at mixing ratios above 10^{-4} g/g. As discussed in Thompson et al (2004), this is a simple procedure to allow the model to predict drizzle (including freezing drizzle) rather than rain, under conditions of weak vertical motion.
- Replacement of Kessler formulation for autoconversion of cloud water to rain water with the formulation of Berry as modified and corrected by Walko and Thompson et al (2004). This allows for a crude accounting of the role of the dispersion of cloud drop sizes in initiating the collision-coalescence process. A number concentration for cloud drops of 100 cm^{-3} is assumed, following the recommendation of Thompson et al. (2004).

As described in Benjamin et al (2004b), the Grell-Devenyi convective parameterization scheme used in the RUC is unique in that it addresses uncertainties in our understanding of how convection is related to the larger scale flow by allowing an ensemble of various closure and feedback assumptions to operate on the explicitly predicted flow. (Closures and feedbacks are both expressed as tendencies for the explicitly

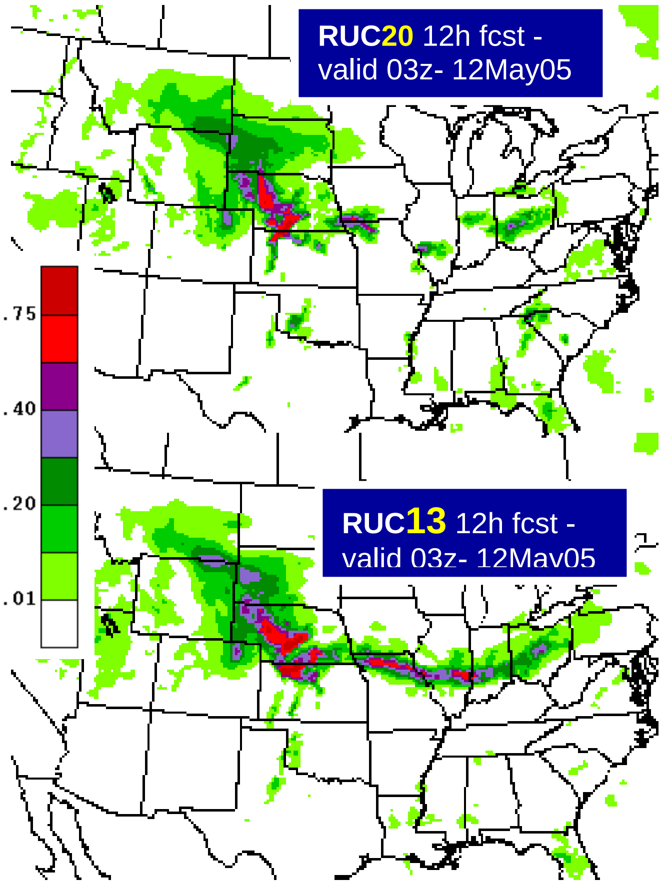

Figure 1. RUC 9-12h precipitation forecasts valid 00-03z 12 May 2005 (In/3h). a) from RUC20, b) from RUC13.

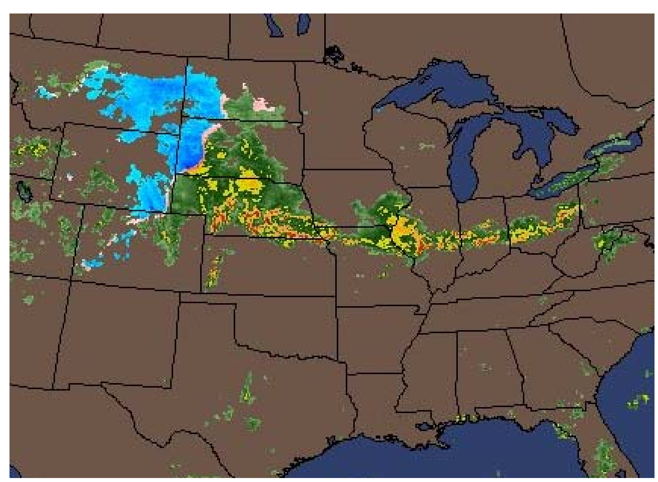

Figure 2. Observed radar reflectivity valid 0115 UTC 12 May 2005.

predicted variables in the model.) In the previous 20-km RUC, these ensemble values were calculated by using equal weighting of values from each assumption, certainly not the optimal approach. Based on testing in summer 2004, a redistribution of weighting of the ensemble members was implemented in the RUC13 to improve precipitation forecasts (both for detection of convective events, areal coverage of those events, and quantitative precipitation forecasts (QPF)) .

An example of improved precipitation with the RUC13 is presented in Fig. 1, with the RUC20 9-12h forecast presented in Fig. 1a and the same for the RUC13 in Fig. 1b. The precipitation along the west-east frontal zone is much improved in the RUC13, according to the verifying radar reflectivity presented in Fig. 2. The better precipitation forecast in the RUC13 is attributed to improved physics (both in the sub-grid (convective) and resolved precipitation), improved assimilation (GPS, new moisture analysis), and higher horizontal resolution.

A summary of the characteristics of the 13-km RUC is available at http://ruc.noaa.gov/ruc13_docs/RUC13-summary.html. More details on the RUC assimilation cycle and the RUC model are available in Benjamin et al. (2004a,b).

4. PLANS FOR THE *RAPID REFRESH*

NOAA committed a few years ago to a long-range plan to take advantage of expertise and resources in the larger US modeling community toward development of the Weather Research and Forecast (WRF) model. One part of this long-range plan was to use the WRF model as a pathway to a sub-10km horizontal scale requiring accounting for non-hydrostatic effects.

Current goals for the Rapid Refresh are as follows:

- Replace the current RUC modeling system with a WRF-based Rapid Refresh by 2008 (date under current discussion). A version of the WRF model will also be used for the North American Mesoscale (NAM), replacing the current Eta/NAM in 2006.
- Expand the Rapid Refresh (RR) domain from the current RUC domain to a larger North American domain to provide hourly updated guidance over Alaska, Canada, Puerto Rico, and the Caribbean (Fig. 3).
- Use the Gridpoint Statistical Interpolation (GSI) assimilation program, developed initially at NCEP/EMC, for the Rapid Refresh, adding RUC-specific enhancements developed in the RUC 3DVAR analysis (e.g., cloud/hydrometeor analysis). The GSI will also be used for the NAM.

Since 2002, NOAA/ESRL/GSD (formerly NOAA/FSL) has been running the WRF-ARW (advanced research WRF) using RUC initial conditions at 20-km and 13-km resolution (Smirnova et al. 2005). The purpose has been to compare the WRF performance to that of the RUC model using the same initial conditions. Results up to this point (Smirnova et al. 2005) have shown the following:

- Similar performance in surface forecasts (2m temperature, dewpoint, 10m wind)
- Superior precipitation forecasts by the WRF-ARW model.
- Similar performance in upper-level winds, with a slight edge to the WRF model in warm-season and to the RUC model in cold season.

As of November 2005, GSD has begun running the WRF-NMM (Non-hydrostatic Mesoscale Model, developed at NCEP/EMC) model, and some initial results will be presented at the conference.

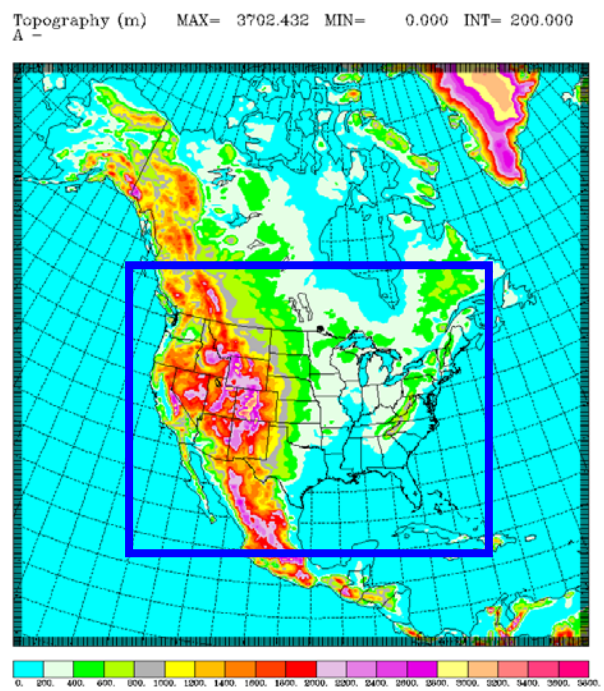

Figure 3. Domain for Rapid Refresh. Blue insert shows current RUC domain.

A proposed plan for the following testing of the Rapid Refresh leading up to its implementation is as follows:

- Nov 2005 – May 2006 – Compare performance of ARW and NMM core performance both using RUC initial conditions, current RUC CONUS domain at ~13km resolution, and same physical parameterizations
- June 2006 – Decision on dynamic core for Rapid Refresh

- Summer 2006-spring 2006 – Testing of Rapid Refresh over enlarged North American domain (Fig. 2) with cycling using GSI.
- Summer 2007 – Transfer of WRF configuration to NCEP/EMC for testing at EMC and NCEP/NCO.
- Spring 2008 – Operational implementation of Rapid Refresh replacing 13km RUC.

6. ACKNOWLEDGMENTS

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