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A 13-KM RUC AND BEYOND: RECENT DEVELOPMENTS AND FUTURE PLANS

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1. INTRODUCTION AND MOTIVATION

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 weather events influenced by topography and coastlines. In April 2002, the horizontal resolution of the operational RUC changed from 40 km to 20 km (Benjamin et al. 2004a). In anticipation of further planned computer power increases at the National Centers for Environmental Prediction (NCEP), NOAA/FSL has tested in real time a 10-km regional domain RUC model since early 2001. In fall 2003, FSL began producing 13-km full CONUS domain RUC model forecasts initialized from the 20-km RUC (no 13-km assimilation yet at that point).

In April 2004, real-time tests began at FSL of a fully configured RUC13, including implementation of the RUC 3DVAR assimilation at 13km and cycling of all initial fields at 13 km resolution. The experimental 13-km RUC at FSL also incorporates important modifications to the analysis and model components. As of this writing (August 2004), NCEP and FSL plan to begin case study testing at NCEP of the 13-km RUC late this fall, leading toward an implementation in the first half of 2005.

This increase in resolution down to 13 km is expected to produce significant improvements in RUC forecasts of weather phenomena that are important for aviation, severe weather, and general forecasters. In particular, the RUC13 is expected to produce improved 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.

Here, we describe the configuration and recent results from the 13-km CONUS RUC. At the conference we will compare FSL's RUC13 performance to that of a RUC20 cycle using the same observational input. In addition, we will discuss the proposed roadmap to the next operational version of the RUC, called Rapid Refresh, which will run in the Weather Research and Forecast (WRF) framework at a horizontal resolution of about 10 km. The Rapid Refresh will likely use one of the two non-hydrostatic WRF dynamical cores, and will likely incorporate a RUC-adapted version of the Gridded Statistical Interpolation (GSI) 3DVAR analysis under development at NCEP. Operational implementation of this version is planned for 2007.

2. 13-KM RUC CONFIGURATION

The 13-km RUC domain was configured with a 50% increase of resolution for each horizontal dimension over the current 20-km resolution. (The precise resolution in the RUC13 is 13.33.. km at the true point of the Lambert conformal map projection used for the RUC.) Higher spatial resolution allows more accurate depiction

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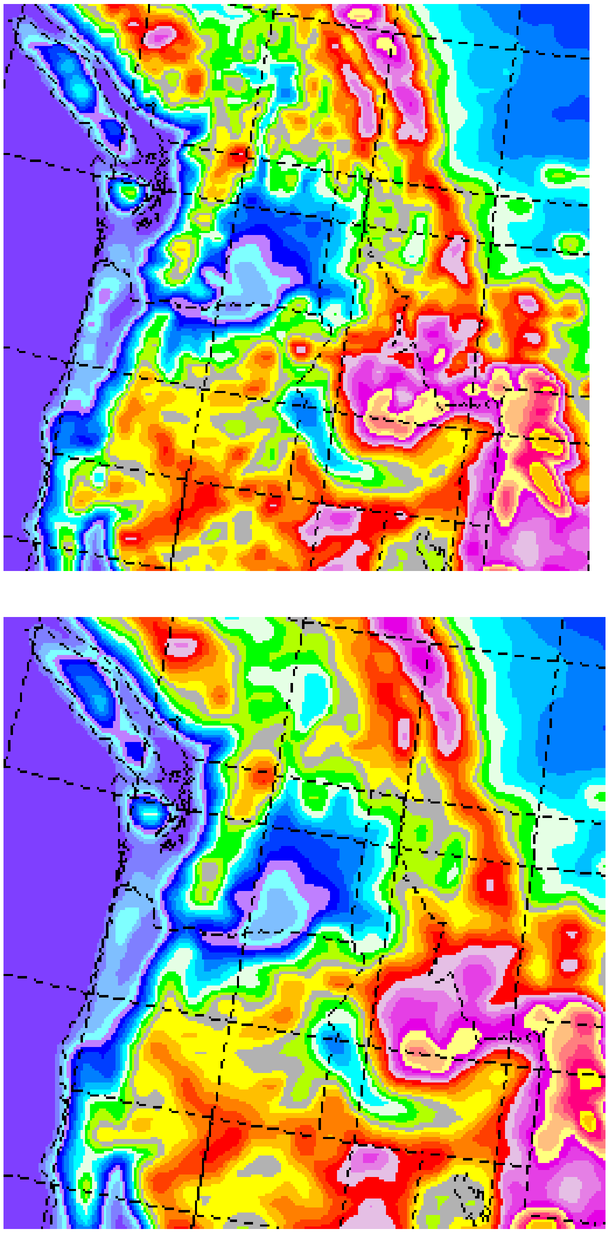

Figure 1. Terrain elevation from 13-km (top) and 20-km (bottom) RUC, extracted for northwest U.S. Contour interval – 100 m.

of the actual terrain. Figure 1 depicts the terrain over the northwestern U.S. from the 13-km and 20-km versions of the RUC. Higher elevation is evident in many of the mountainous areas, and the representation of the valleys of the Columbia River (Washington and Oregon) and Snake River (Idaho) is also improved with the 13-km RUC.

The 13-km configuration more faithfully represents coastlines and lake boundaries, and smaller bodies of water can now be resolved. Figure 2 shows that the 13-km RUC reflects the coastline around the Great Lakes and eastern US coastline more accurately than the 20-km RUC and also is able to capture lakes (e.g., Lake St. Clair near Detroit, MI; Lake Champlain near Burlington, VT) and islands not shown in the 20-km RUC.

The RUC13 continues to use 50 vertical levels and retains the same isentropic-sigma hybrid coordinate found advantageous in previous RUC versions (Benjamin et al. 2004a,b).

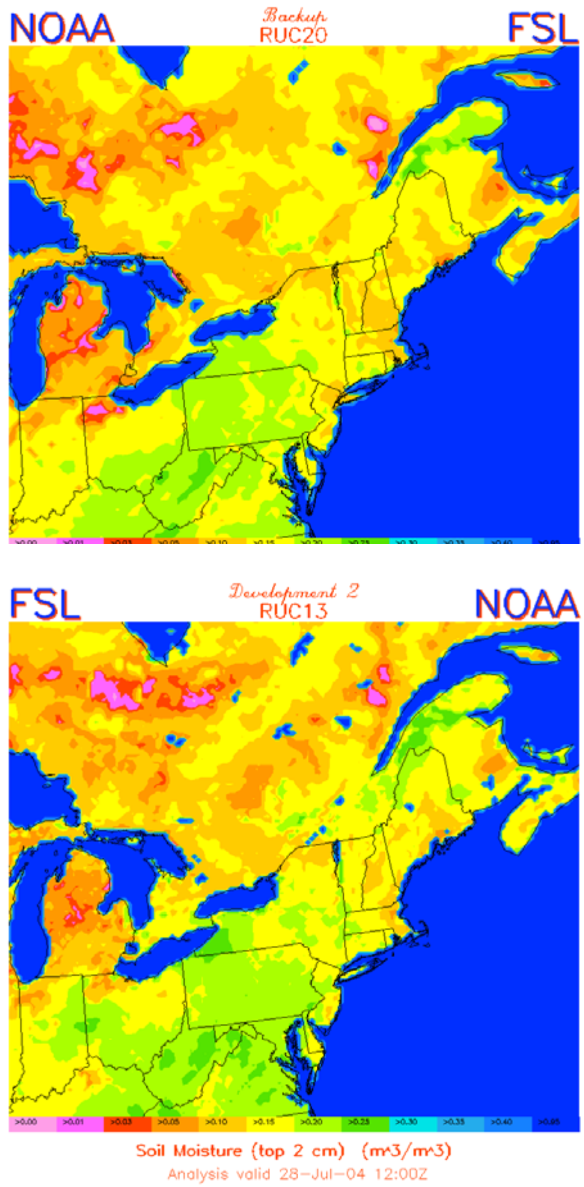

Figure 2. Soil moisture with water areas shown in blue from 13-km RUC (top) and 20-km RUC (bottom).

3. ASSIMILATION CHANGES IN THE RUC13

The RUC13 analysis implementation at NCEP is planned to include 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, mesonet surface observations, and boundary-layer (915 MHz) wind profilers. GPS PW observations improve accuracy of short-range forecasts of lower-tropospheric moisture (Smith et al. 2004)
- 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. This change, now in development at FSL, reduces occasional noise in moisture fields sometimes evident in operational RUC20 analyses.
- Nudging of soil temperature and moisture values at upper soil levels. This modification, now in real-time testing at FSL, has been found to substantially improve 2-m temperature and dewpoint forecasts in the warm season.

4. MODEL CHANGES IN THE RUC13

The RUC forecast model as of 2003 is described in Benjamin et al (2004). Some further major revisions to the physics schemes described in that paper and used in the current RUC have been in development and testing in the RUC model over the last two years.

a. Mixed-phase bulk cloud and precipitation microphysics

The RUC13 continues to use 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 described in Thompson et al (2004) that are currently under test in the RUC13 at FSL 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 10^{10} m^{-4}) at mixing ratios below 10^{-4} g/g, and 2) as rain-sized drops (zero intercept 8 x 10^{6} 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).

b. Grell-Devenyi convective parameterization

As described in Benjamin et al (2004b), this scheme 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 predicted variables in the model.) In the current RUC, these ensemble values are calculated by using equal weighting of values from each assumption. However, this is not necessarily the optimal approach, depending on how one assesses accuracy of convection forecasts from different assumptions. Summertime precipitation, primarily produced by convection, provides a readily available quantity (albeit with substantial uncertainty) for determining optimal weights, depending on horizontal grid point and time of day. Currently, summer 2004 forecasts are being analyzed in an initial attempt to examine the weighting of the ensemble members that will provide the most consistently superior precipitation forecasts. Once these weights are determined, they will be used in the parameterization, and it is expected that these optimized weights will be used in the version of the Grell-Devenyi scheme that becomes operational with the RUC13.

Also to be incorporated are minor changes, including one to prevent occasional unrealistic large negative tendencies of water vapor mixing ratio near the surface.

c. Other model changes

Some modifications have been made to the digital filter initialization (DFI, see Benjamin et al. 2004a) used in the RUC model to be incorporated into the RUC13 operational system. These changes to the DFI result in improved moisture fields, w saturation present before DFI application at any 3-d grid point is set to also be present after the DFI.

Changes to the land-surface model will also be included to account for difference in saturation vapor pressure over ice versus water for frost and dew deposition. This modification eliminates a previous problem with excessive fog at night over snow cover.

5. 13-KM CONUS RUC FORECASTS

The 13-km full CONUS domain version of the RUC model has been running in real time since fall 2003. Since April 2004, the RUC13 has been running with full 1-h cycling in a test at FSL, now allowing evolution of smaller-scale features at 13-km resolution.

Statistical verification of RUC13 forecasts has been performed against surface and precipitation observations, for which RUC13 forecasts are showing improved skill over those from 20-km RUC runs. These improvements appear to result from higher horizontal resolution giving more accurate detail for surface forecasts and more intensity for convective precipitation.

An example of a precipitation forecast from 28-29 July 2004 is presented below (Fig. 3). Twelve-hour forecasts valid at 0000 UTC 29 July are shown for both the RUC13 and RUC20 (backup RUC run at FSL, very similar to the operational RUC20). The sharper definition of convective storm systems is evident with the 13-km RUC, typical of its behavior for warm-season precipitation. A radar summary valid at 2315 UTC is also provided in Fig. 3 (top) to allow subjective verification. The precipitation in the RUC13 is sharper than RUC20 overall, particularly for convective systems in northern Kansas and from southwestern Minnesota to the southeastern tip of South Dakota.

In addition to 13-km experiments, forecasts with a 10-km version of the RUC model over three different regional domains from 2000-2004 have been reliable, demonstrating the viability of the RUC isentropic/terrain-following coordinate down to 10-km resolution. A case study comparing 20-km and 10-km RUC forecasts (for a 36-h cyclogenesis event from February 2001) is provided in a recent journal paper describing the RUC model by Benjamin et al. (2004b). In this case study, the 10-km RUC model provided a superior forecast of mean sea-level pressure (MSLP) and precipitation, with a 36-h position error of about 50 km for the low-pressure center of an intense East Coast winter storm.

6. FUTURE WORK

Testing of the 13-km version of the RUC will begin at NCEP this fall, in anticipation of an implementation in the first half of 2005. NCEP will coordinate with NOAA/FSL toward this testing and implementation.

The RUC13 is also being used in summer 2004 to provide experimental 48-h forecasts as part of a NOAA New England High-Resolution Temperature Project, in collaboration with NOAA/ETL, NOAA/NCEP, and NOAA/NSSL. A version of the WRF model (Smirnova et al. 2004) is also being run at FSL out to 48 h projection, initialized from the RUC13 cycle (named the WRF-RUC). Similarly, 20km versions of the RUC and WRF-RUC are also run out to 48-h forecasts as part of this same project. These WRF-RUC tests are part of FSL’s testing and development toward the planned future use of the WRF model in a replacement of the current operational RUC.

Currently, implementation of the WRF model into the Rapid Update Cycle, replacing the current RUC hydrostatic model, is planned for early 2007. This version of the RUC with a WRF model component will be known as the Rapid Refresh cycle.

7. ACKNOWLEDGMENTS

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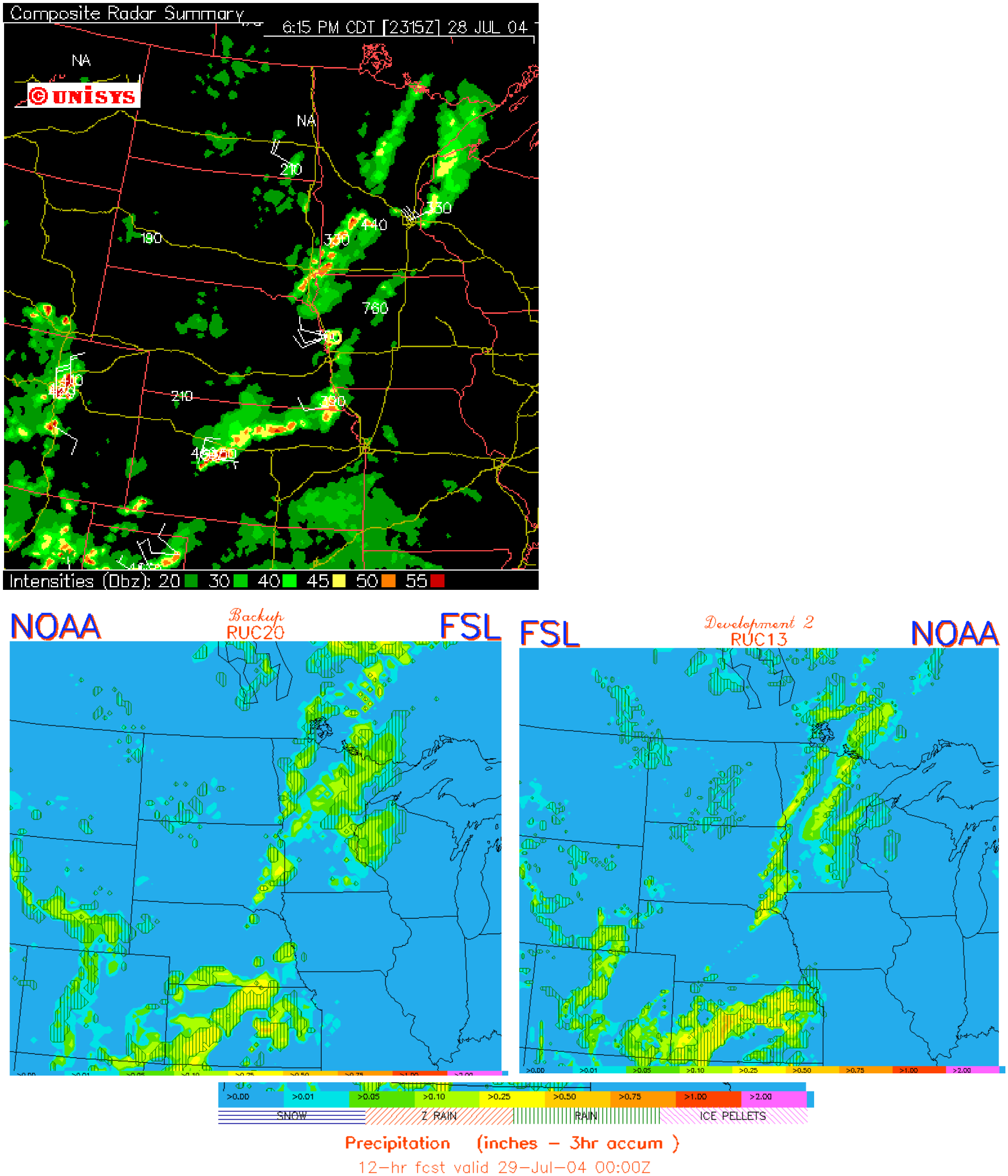

Figure 3. RUC20 vs. RUC13 precipitation comparison. Comparison of radar summary (courtesy – Unisys, upper, valid 2315 UTC) with (lower left) operational 20-km RUC and (lower right) 13-km RUC, valid for 3-h period from 2100 UTC to 0000 UTC 29 July 2004.