1. INTRODUCTION AND MOTIVATION

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 (US National Centers for Environmental Prediction). 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 and coastlines. In June 2005, the horizontal resolution of the operational RUC was changed from 20 km to 13 km (Benjamin et al. 2004a).

In the planned presentation at the symposium, we will briefly describe the key design aspects to the RUC for assimilation and initialization, and model physics and dynamics, and how we define success for 1-6h forecasts. We will give special attention to the RUC design for assimilation of cloud/hydrometeor data from satellite and METAR (surface) data, and use of boundary-layer depth in assimilation of surface data. Treatment for assimilation of radar data will be emphasized in a related talk (Weygandt).

This increase in resolution 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 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.

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 of the actual terrain.

The 13-km configuration more faithfully represents coastlines and lake boundaries, and smaller bodies of water can now be resolved. 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).

3. ASSIMILATION CHANGES IN THE RUC13

The RUC13 analysis implementation at NCEP on 28 June 2005 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

Corresponding author address: Stan Benjamin, NOAA/FSL, 325 Broadway, Boulder, CO 80305, USA, stan.benjamin@noaa.gov
temperature and dewpoint. GPS PW observations improve accuracy of short-range forecasts of lower-tropospheric moisture (Smith et al. 2004)

- A much improved of the RUC 3-d hydrometeor/cloud analysis, now adding the METAR ceiling/visibility data to the GOES cloud-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. 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.
- 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 (2004b). 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 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 $8 \times 10^{6}$ 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.

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, with 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 were also 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. This testing was carried up through the operational implementation in June 2005.

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.

Results from case studies and statistical verification will be presented at the meeting.

6. FUTURE WORK

We will present details at the symposium on the RUC analysis and forecast design toward its very-short-range numerical forecasts.

We will also discuss the planned transition to a version of the Rapid Update Cycle to a WRF-based version to be called the Rapid Refresh. The Rapid Refresh will become operational at NCEP in 2007. 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 effort. 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.
7. REFERENCES


