14.1 The 20-km RUC in Operations

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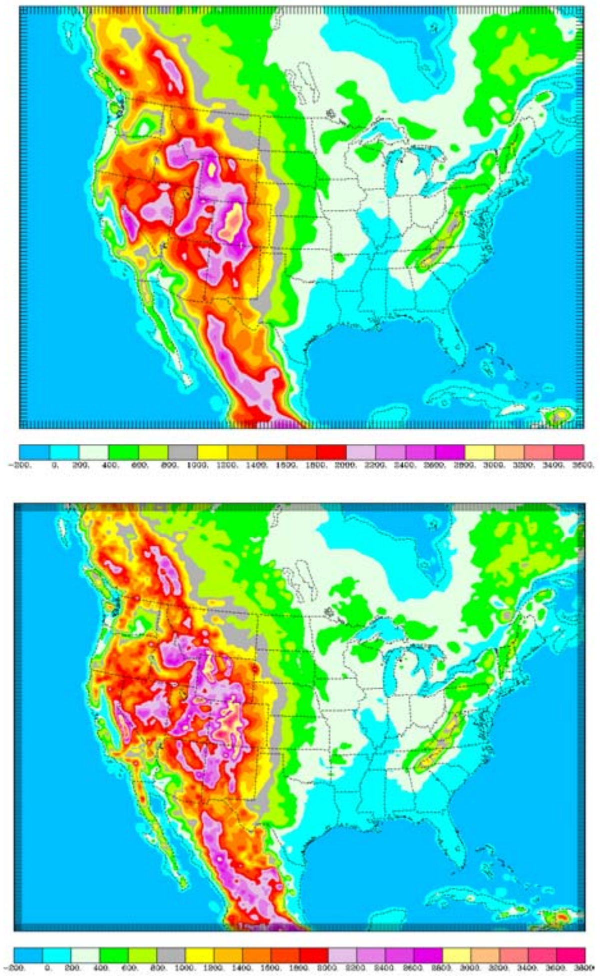

Figure 1. Terrain elevation for 40-km RUC-2 (RUC40), above, and the RUC20 (20-km), below.

1. INTRODUCTION

A new version of the Rapid Update Cycle (RUC) was implemented into operations at the National Centers for Environmental Prediction (NCEP) on 17 April 2002. This new version includes a doubling of horizontal resolution (40-km to 20-km), an increased number of computational levels (40 to 50), and improvements in the analysis and model physical parameterizations. A primary goal for development of the 20-km RUC (or RUC20) was improvement in warm-season and cold-season precipitation forecasts. Improvements in near-surface forecasts and cloud forecasts were also targeted. The RUC20 provides improved forecasts for these variables, as well as for wind, temperature, and moisture above the surface. The RUC20 implementation benefits general public forecasting as well as aviation and severe-weather forecasting. The RUC20 continues to produce new analyses and short-range forecasts hourly, with forecasts out to 12 h run every 3 h. The implementation of the RUC20 in 2002 follows previous major implementations of a 60-km 3-h cycle version in 1994 and a 40-km 1-h cycle version (known as RUC-2 or RUC40) in 1998. In this paper, we present an overview of these changes in the RUC20 and an assessment of their impact on forecast applications.

2. HORIZONTAL AND VERTICAL RESOLUTION CHANGES

The RUC20 occupies the same spatial domain as the previous 40-km RUC-2, as shown in Fig. 1. The RUC20 grid points are still a subset of the AWIPS Lambert conformal grid (AWIPS/GRIB grid 215 for 20-km) used as a distribution grid by the National Weather Service. Direct use of the AWIPS grid reduces the number of distribution grids for the RUC. The AWIPS grid ID for the RUC20 is 252, compared to 236 for the RUC40. The RUC20 domain size is 301 x 225 grid points (compared with 151 x 113 for RUC40). The 20-km grid spacing used by the RUC20 provides better resolution of variations of terrain elevation, leading to improved forecasts of topographically induced low-level circulations, mountain waves, and orographic precipitation. It also allows better resolution of land-water boundaries and other land-surface discontinuities. While the most significant differences in the terrain resolution of the

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RUC20 vs. RUC40 (Fig. 1) are in the western United States, a number of important differences are also evident in the eastern part of the domain. The true grid spacing is 20.317 km at 35º N, about 19 km at 43º N, and about 16 km at the northern boundary.

The RUC20 continues to use the hybrid isentropic/sigma coordinate of previous versions. The RUC20 has 50 vertical levels, compared to 40 levels for the RUC40. Additional levels have been added near the tropopause and lower stratosphere and also in the lower troposphere.

Implications for forecasts: More detailed near-surface forecasts, especially for winds and precipitation from higher horizontal resolution, sharper (and more realistic) frontal structures. Improved forecasts of wind and temperature at the tropopause and lower stratosphere.

3. ANALYSIS CHANGES

The key enhancements to the RUC20 assimilation of observations are 1) an improved optimal interpolation (OI) analysis and 2) the assimilation of GOES cloud-top pressure, as discussed below. The most important changes in the RUC20 OI analysis are the observation preprocessing and matching to background values. For assimilation of surface data, the RUC20 uses a background for 2-m temperature/moisture and 10-m winds at the station elevation, instead of 5-m values for both. The effect of this is reduced biases in the analysis. Surface observations near coasts now match a background value with the correct land use to avoid inappropriate surface analysis results near coasts. Individual aircraft ascent/descent profiles are used much more completely in the RUC20 by a more intelligent observation search strategy that still avoids ill-conditioning in the OI matrix solution.

The RUC20 analysis also includes modifications to the three-dimensional (3-D) hydrometeor fields using GOES cloud-top data (single field-of-view data provided by NESDIS). The purpose of the GOES cloud-top assimilation is to improve short-range RUC forecasts of cloud/hydrometeors and precipitation. With the RUC40, the initial conditions for these fields were simply those carried over from the previous 1-h RUC forecast. In the RUC20, cloud clearing and building is performed, providing more realism in those 3-D fields. The analysis/prognostic hydrometeor fields that are modified in the RUC20 cloud assimilation are mixing ratios of cloud water, ice, rain, snow, graupel, and mixing ratio, and the number concentration for ice particles. More detail on the RUC20 cloud analysis procedure is provided by Benjamin et al. (2002) and Kim and Benjamin (2001).

Implementation of a 3-D variational scheme for the RUC20 was deferred until later in 2002 after testing of recent modifications revealed a need to produce a slight improvement in 3-h wind forecast accuracy.

Implications for forecasts: Better matching of surface observations in RUC20 analyses, improved fit to aircraft observations, improved wind and temperature 3-12 h forecasts. Improved cloud, icing potential and precipitation forecasts out to 12 h.

4. FORECAST MODEL CHANGES

The RUC20 forecast model is also significantly modified from the RUC40 version, including the following:

- Grell/Devenyi (2001) convective parameterization, with ensemble approach to closures (driving parameterized convection) and feedback. There are 108 ensemble members in the RUC20 version of the Grell/Devenyi scheme, and an ensemble mean mass flux is used to calculate feedback. The scheme also now includes detrainment of cloud water and ice to the grid scale, where it is treated by the mixed-phase microphysics.
- Improved linkage between convective parameterization and other components of the RUC model.
- Modified version of Smirnova-RUC land-surface parameterization (Smirnova et al. 2000a) including frozen soil processes and two-layer snow model.
- Upgraded RUC/MM5 mixed-phase cloud microphysics (Brown et al. 2000), with improved representation of supercooled liquid water and reduction of excessive amounts of graupel (e.g., Fig. 3, Benjamin et al. 2001). The microphysics is now called with a 2-min time step in RUC20 instead of the previous 10-min time step.

Implications for forecasts: Improved forecasts of warm-season and cold-season precipitation, precipitation type, clouds, surface variables.

5. POSTPROCESSING CHANGES

Several of the RUC diagnostic algorithms have been changed for the RUC20, including those for

- *visibility* (see Smith et al. 2002, Smirnova et al. 2000b) – use of multiple levels near surface and modification in hydrometeor and relative humidity effects
- *helicity* – corrections to helicity and storm-relative motion calculations, including change to Bunkers et al. (2000) formulation
- *convective available potential energy*
- *2-m temperature and dewpoint, and 10-m winds*. Similarity theory used to derive values at these levels rather than previous approximation with 5-m values.

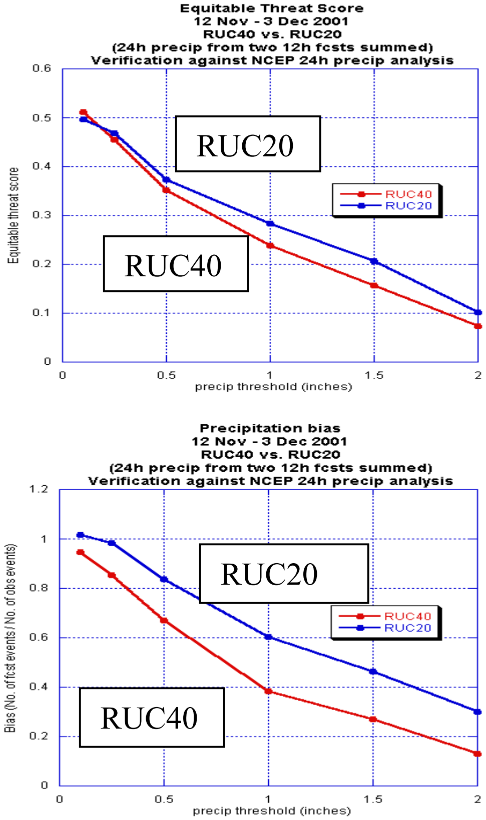
Improved BUFR data are available from RUC20. Hourly BUFR soundings with the same format as used for the Eta model are available with the RUC20, including individual station files. The station list is the same as that used for the Eta model for stations within the RUC domain. (One small difference in the BUFR data is that the RUC uses 6 soil levels compared with 4 levels with Eta BUFR output.)

Implications for applications: Decreased bias in RUC20 visibility fields, improved 2-m temperature and dewpoint, 10-m winds, easier access to model forecast soundings with hourly output to 12 h.

6. OTHER IMPROVEMENTS

The RUC20 uses more frequently updated boundary conditions from the Eta model, with new runs applied every 6 h instead of every 12 h as with the RUC40.

Land-use and soil-type fields are specified with much more horizontal detail in the RUC20. These fields are taken from 1-km raw land-use and soil-type information, with the prevailing type within each RUC20 grid box.



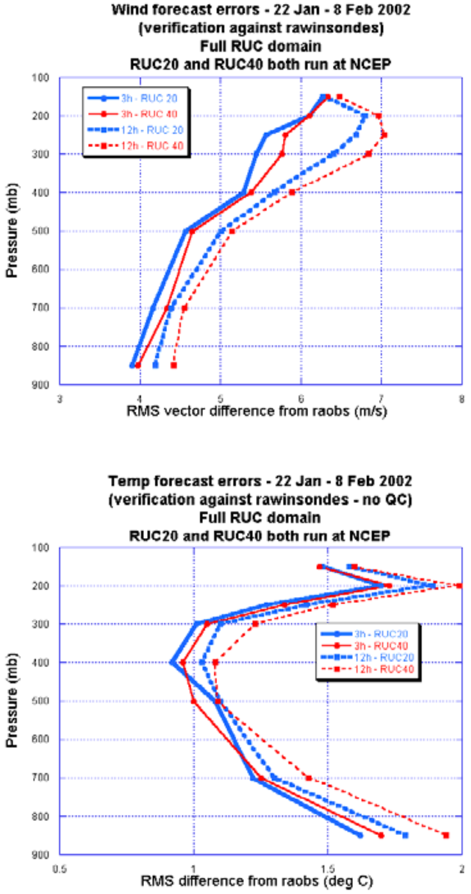
Equitable Threat Score
12 Nov - 3 Dec 2001
RUC40 vs. RUC20
(24h precip from two 12h fcsts summed)
Verification against NCEP 24h precip analysis

Precipitation bias
12 Nov - 3 Dec 2001
RUC40 vs. RUC20
(24h precip from two 12h fcsts summed)
Verification against NCEP 24h precip analysis

Figure 2. Precipitation verification against 24-h NCEP precipation analyses for RUC20 and RUC40 forecasts for a) above, equitable threat score, and b) below, bias. Upper line on both graphs is for RUC20.

7. STATISTICAL VERIFICATION

Precipitation verification is performed for RUC20 and RUC40 12-h forecasts by summing two 12-h forecasts to produce a 24-h total and comparing that with the NCEP 24-h gauge-based precipitation analysis. Figures 2a and 2b show that the RUC20 gives a substantial improvement in both equitable threat score and bias over RUC40 results. However, although the RUC20 has reduced the dry precipitation bias from RUC40, these figures show that this bias still exists in the RUC20 and that further work is needed in this area.



Wind forecast errors - 22 Jan - 8 Feb 2002
(verification against rawinsondes)
Full RUC domain
RUC20 and RUC40 both run at NCEP

Temp forecast errors - 22 Jan - 8 Feb 2002
(verification against rawinsondes - no QC)
Full RUC domain
RUC20 and RUC40 both run at NCEP

Figure 3. Verification of RUC20 (thick) and RUC40 (thin) 3-h (solid) and 12-h (dashed) forecasts against rawinsonde observations. a) above, wind RMS vector difference, b) below, temperature standard deviation difference.

Above-surface forecasts of wind and temperature are generally improved from RUC20 vs. RUC40 at both 3-h and 12-h projections. For winds (Fig. 3a), 3-h RUC20 forecasts are more accurate than RUC40 counterparts by 0.1-0.3 m s^{-1} from 850-250 hPa. For 12-h wind forecasts, RUC20 forecasts are improved by 0.2-0.5 m s^{-1} at all levels. The value of rapid updating is also shown in Fig. 2a in that 3-h wind forecasts are substantially more accurate than 12-h forecasts valid at the same time. The same is true for temperature forecasts, as shown in Fig. 2b. RUC20 temperature forecasts also are more accurate than RUC40 forecasts, and the largest improvement is in the lower troposphere (850-700 hPa).

Verification of RUC20 and RUC40 2-m temperature and 10-m wind forecasts against METAR surface observations has been performed, as reported by Schwartz and Benjamin (2002). These results show that the RUC20 provides superior surface forecasts to RUC40 in the daytime with comparable skill at night.

8. CONCLUSIONS

A significant upgrade to the Rapid Update Cycle with 20-km resolution and major improvements to analysis and forecast model (RUC20) was implemented operationally at NCEP on 17 April 2002. Results of statistical and case study (not shown here but to be shown at the conference) intercomparisons between the RUC20 and previous 40-km RUC-2 (RUC40) indicate that these improvements result in improved forecasts of wind, temperature, and moisture at upper levels and at the surface for wind, temperature and precipitation. The RUC20 thus provides improved weather guidance both at the surface and above the surface.

Plans for near-term future improvements include a change to a 3-D variational analysis, assimilation of radar reflectivity data (Kim et al. 2002), and refinements to the Grell/Devenyi convective scheme and RUC/MM5 cloud microphysics scheme.

9. ACKNOWLEDGMENTS

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