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Evaluation of the RUC-initialized WRF for its application in the Rapid Refresh at NCEP

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1. INTRODUCTION

The Rapid Update Cycle (RUC) at NCEP is going to be replaced in 2007 with the WRF-based "Rapid Refresh" (RR) system implemented on an expanded domain covering most of North America (Fig. 1). Two real time experimental versions of the WRF model were set up to run at the Forecast Systems Laboratory (FSL) in 2003. Currently, they run for the horizontal resolutions 20 km and 13km twice daily at 00 UTC and 12 UTC with forecasts out to 48-h over the current RUC CONUS domain. The WRF models use the advanced Research WRF (ARW) dynamical core and are initialized by analyses from the RUC three-dimensional variational (3DVAR, Devenyi et al. 2004) scheme. Of the physics parameterizations provided in WRF as officially supported options, only the land-surface parameterization – RUC Land-Surface Model (LSM, Smirnova et al. 1997, 2000), and shortwave radiation – Dudhia shortwave radiation scheme (Dudhia 1989) -- are identical to the RUC. Other physics options used in WRF at FSL include the Grell-Devenyi convective scheme (Grell and Devenyi 2002), which is an advanced version of the ensemble scheme implemented in RUC at FSL and NCEP. Surface and boundary layer physics follow from the Eta model parameterizations, and the WRF Single-Moment 5-class scheme is used for microphysics.

2. WRF MODEL VERIFICATION

The performance of the WRF model is routinely compared against the RUC model for such variables as cloud cover and precipitation, temperature and wind in the upper atmosphere, as well as surface wind, temperature, and dew point. Overall, the WRF model shows improvements over the RUC model in the precipitation verification at both resolutions. The WRF runs have better forecasts of mesoscale features in the precipitation field, and areas of intensive precipitation often agree better with the observations. At the same time, the amounts of accumulated precipitation are often overestimated in these areas of intensive precipitation. This is illustrated in Fig. 2, which shows a comparison of 24-h accumulated total precipitation consisting of two consecutive 0–12 h forecasts from WRF 13-km runs and from RUC 13-km runs. In addition, comparative precipitation statistics demonstrate the better skill of the WRF model for 0.10–1.0 inch thresholds. Similar results are obtained for the 20-km WRF model (Table 2). Both equitable threat scores and biases show superior performance of the WRF model for the thresholds higher than 0.10 inch compared to the 20-km RUC and the ETA models, although at the 3-inch threshold, the WRF bias is too high due to a wider coverage of heavy precipitation than observed.

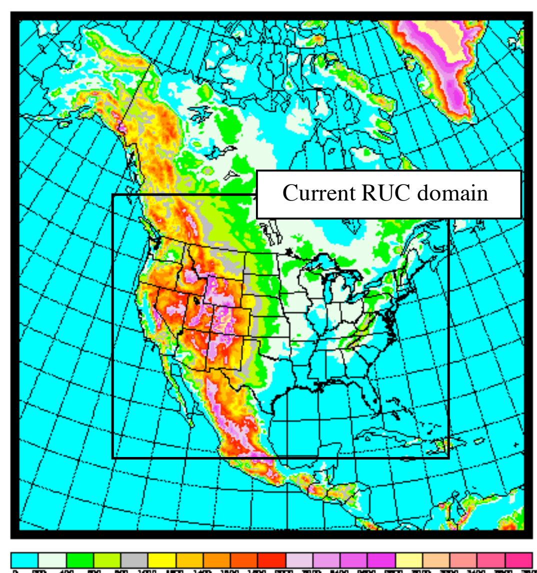

Figure. 1. Topography of WRF-based Rapid Refresh (RR) system on expanded North America domain with 13-km horizontal resolution.

The statistics of surface temperature, dew point, and wind verification averaged over the CONUS domain for the WRF and RUC with both 20- and 13-km resolution demonstrate competitive performance of the two models. Table 1 shows comparisons of averaged RMS errors and biases between RUC and WRF with 20-km horizontal resolution for the period 11 June 2004 – 20 January 2005. The RMS errors from RUC and WRF are comparable for all variables, while the nighttime warm and moist biases in RUC are significantly reduced in the WRF model. This result is encouraging on the way toward replacing RUC with WRF, although the daytime cold bias in the WRF model still should be reduced. Case studies with different physics options in the WRF model are being performed in the attempt to understand the existing deficiencies of the WRF model configurations run at FSL, and some results from these tests will be demonstrated at the Workshop.

Temperature and wind forecasts verifications in the upper atmosphere demonstrate that the RUC model is still superior compared to the WRF model, especially during the cold season (Fig. 3,4). This deficiency may be related to the vertical configuration of the WRF model, and to the choice of physics options in the WRF model, as well. Further investigating of this issue is needed before the operational implementation of the WRF model in the Rapid Refresh at NCEP.

Variables	20-km RUC	20-km WRF
Wind spd – s.d.	2.00	2.02
Temp – s.d.	2.64	2.64
Temp – bias 12z	0.86	0.41
Temp – bias 00z	-0.31	-0.82
Dewpoint – s.d.	2.89	2.84
Dewpoint – bias	0.79	0.26

Table 1. Standard deviations and biases of 12-h surface forecasts of wind speed, temperature, and dew point from RUC and WRF with 20-km horizontal resolution over the CONUS domain averaged for the period 11 June 2004 – 20 January 2005.

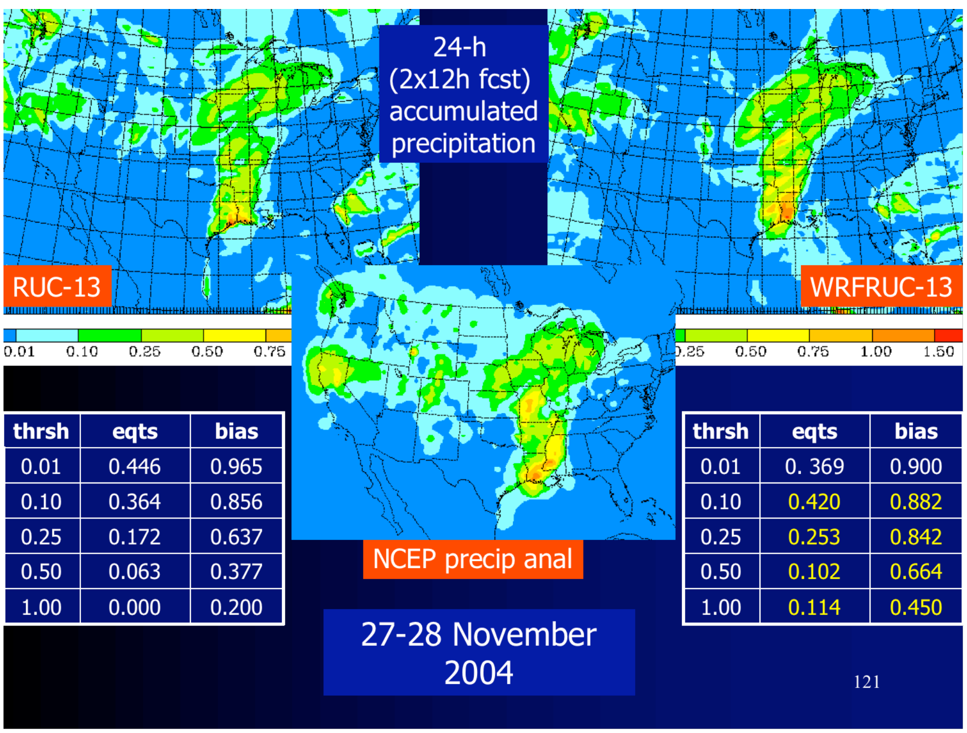

Figure 2. Top 3 panels: Comparisons of 24-h precipitation from two consecutive 12-h forecasts of 13-km WRF, and RUC to NCEP precipitation analysis valid at 0000 UTC 28 November 2004. Table at bottom: Precipitation verification statistics from 13-km RUC (left) and 13-km WRF (right) depending on the precipitation amounts for the same 24-h period.

	20-km RUC		20-km WRF	
Trsh	Eqts	bias	Eqts	bias
0.01	0.497	1.000	0.437	1.249
0.10	0.523	0.925	0.530	1.086
0.25	0.482	0.883	0.512	1.097
0.50	0.401	0.734	0.462	1.059
1.00	0.214	0.450	0.350	1.014
1.50	0.133	0.367	0.218	1.058
2.00	0.114	0.309	0.158	1.095
3.00	0.107	0.265	0.019	1.316

Table 2. Verification statistics (equitable scores and biases for different thresholds) for 24-h accumulated precipitation averaged over the period from 2 November 2004 to 20 January 2005 for 20-km RUC, 20-km WRF and ETA models.

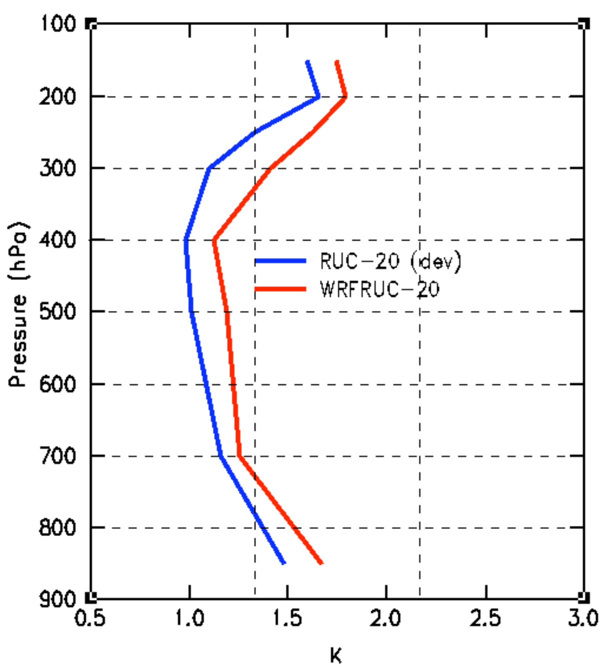

Figure.3. 12-h temperature forecast errors verified against the rawinsonde data (92 stations) for 20-km RUC and WRF models averaged for the period 1 October 2004 – 20 January 2005.

Both WRF and RUC with 20-km and 13-km horizontal resolution were providing 48-h forecast grids for NOAA's New England High Resolution Temperature Program (NEHRTP) during summer 2004. This gave us a good opportunity to evaluate and compare the models' performance using the data from a special network of boundary-layer wind profilers and from surface meteorological stations in the New England area. An example of a 48-h forecast verification from 20-km RUC and 20-km WRF for Concord, NH is presented in Figure 5. This station is located in the deciduous broadleaf forest according to both WRF and RUC land-use type classifications, but the observation instruments are actually installed in a grassland area. This might account for some discrepancies between the model results interpolated to the station coordinates and the observations. Nevertheless, the models are, overall, capturing the diurnal variations of surface temperature, dew point, wind, surface pressure, precipitation, and net radiation reasonably well.

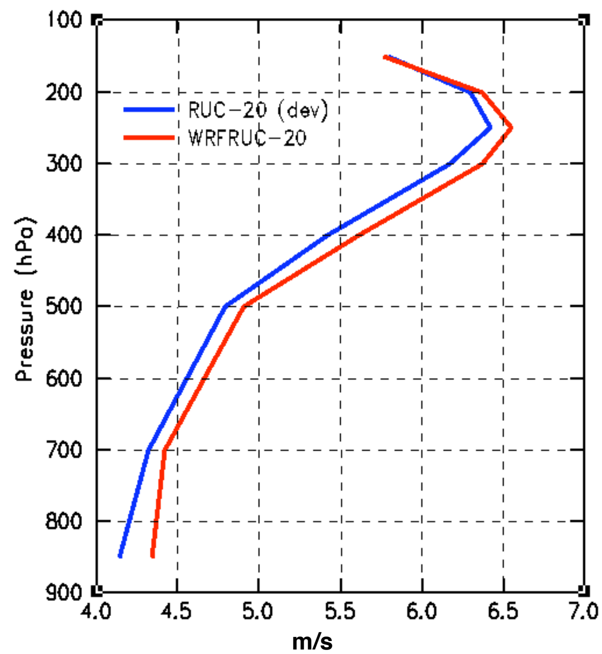

Figure 4. 12-h wind forecasts errors verified against the rawinsonde data (92 stations) for 20-km RUC and WRF models averaged for the period 1 October 2004 – 20 January 2005.

Thus, the FSL configuration of the WRF model demonstrates overall improved performance compared to RUC in the precipitation verification, competitive performance in the surface verification except for higher daytime cold bias in WRF, but the upper-air verification of wind and temperature indicates that further improvements in WRF performance are needed.

3. FUTURE WORK

Future work in preparation for implementing WRF in RR will include setting up a fully cycling WRF run at FSL on the expanded North America domain (Fig. 1), using the NCEP Gridded Statistical Interpolation (GSI) procedure modified for the RR frequent-updating application. In addition, evaluation of the time evolution of the noise level in WRF relative to RUC during the first several hours of the forecast indicates higher levels of noise (as measured by the domain average of the time step by time step change in surface pressure) in WRF than in RUC. This points to the necessity of introducing a digital filter initialization into WRF, as used for the RUC forecast model (Benjamin et al. 2004). Monitoring of WRF model performance and verification of WRF versus RUC for surface and upper-air variables will be continued for the expanded domain.

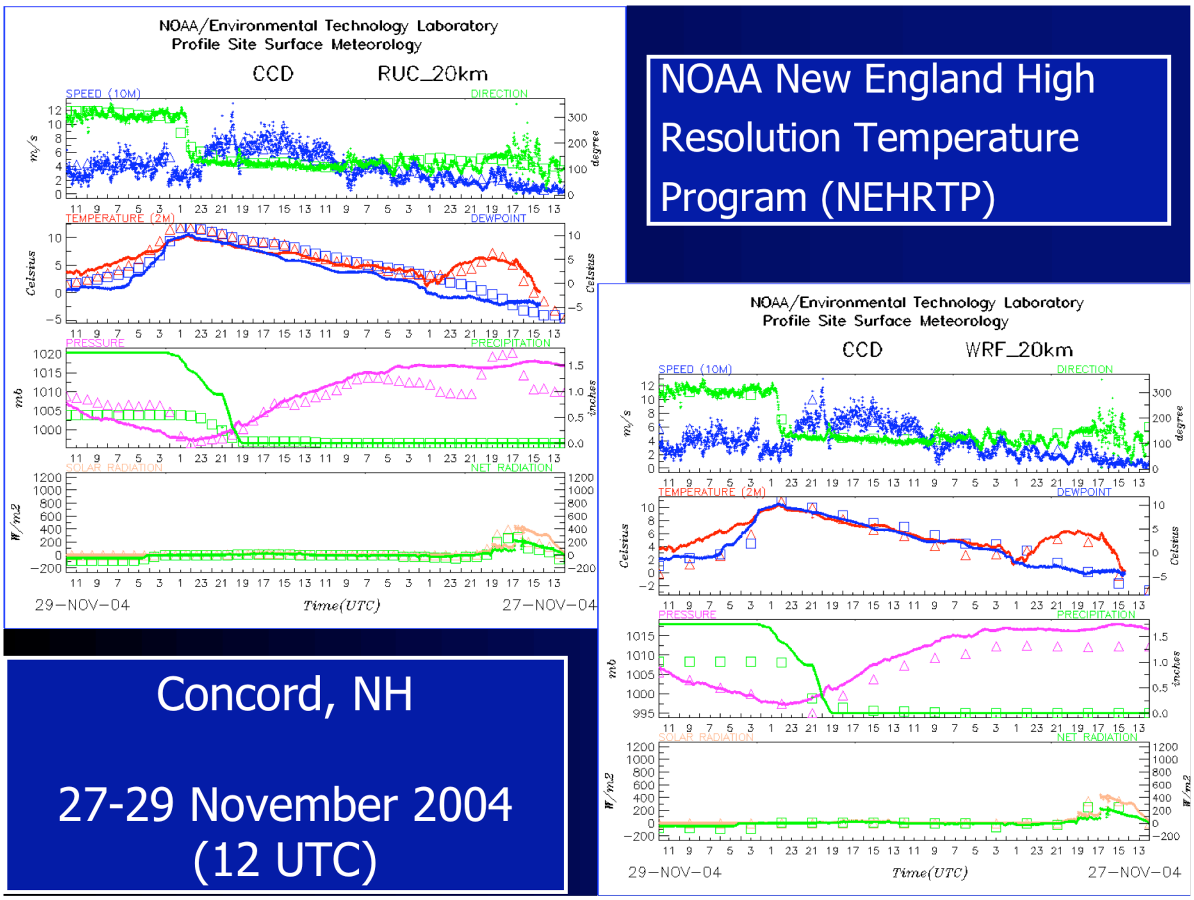

Figure 5. Verification of the diurnal cycles of wind, temperature, dew point, surface pressure, precipitation, and net radiation from 20-km RUC and 20-km WRF for Concord, NH, 27-29 November 2004. (Courtesy, J. Wilczak, NOAA/ETL)

4. REFERENCES

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