9.1 PRELIMINARY RESULTS OF WRF MODEL PERFORMANCE AS A STEP TOWARDS THE NCEP RAPID REFRESH

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1. INTRODUCTION

In preparation for the replacement of the Rapid Update Cycle (RUC) model by the Weather Research and Forecasting (WRF) model in the "Rapid Refresh" (RR) slot at National Centers for Environment Prediction (NCEP) planned in 2007, the Eulerian Mass version of the WRF model has been set up at FSL to run in two configurations in real time on the continental U.S. (CONUS) domain of the operational RUC. Each of these configurations is spawned from the 20-km RUC cycle running at FSL, initialized from the RUC three-dimensional variational (3DVAR, Devenyi et al. 2004) analysis at 0000 and 1200 UTC, and runs to 48-h. Version 2 of WRF is now used for both runs. The first of these runs, at 20-km horizontal resolution on the identical grid to the current operational 20-km RUC, has been running regularly since spring of 2003 with an earlier version of the WRF code, and with version 2 since May 2004. The second run, at 13-km horizontal resolution on the same domain, was initiated June 2004 and has used Version 2 since its inception. Improved efficiency of the version 2 WRF Standard Initialization (SI) will allow WRF to run with even higher horizontal resolution over the CONUS in compliance with the current plans to implement the initial operational RR version of WRF at NCEP at a horizontal grid spacing of 8–10 km beginning in 2007.

Of the physics parameterizations provided in WRF as officially supported options, only land-surface parameterization – the RUC Land-Surface Model (LSM, Smirnova et al. 1997, 2000), and shortwave radiation – Dudhia shortwave radiation scheme, are identical to their counterparts in the RUC (Dudhia 1989). 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. Surface and boundary layer physics follow from the Eta model parameterizations, and the NCEP 5-class scheme is used for microphysics. This difference in configuration affects the performance of RUC LSM in RUC and WRF environments. Also, in version 1 of WRF several inconsistencies between the variables in boundary layer and surface physics packages degraded the WRF performance in the simulation of the diurnal cycle of temperature and dew point at the surface. For example, erroneous treatment of moisture feedback from the surface caused excessively dry conditions in WRF. These inconsistencies are eliminated in version 2 of the WRF code released in May 2004.

2. WRF MODEL VERIFICATION

The performance of the WRF model is routinely compared against the RUC model for such variables as precipitation, cloud, surface wind, temperature, and dew point. A clear result of the precipitation comparisons is that, overall, the WRF runs have better forecast 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 on Fig. 1, which shows a comparison of 24-h accumulated total precipitation consisting of two consecutive 0–12 h forecasts from WRF 20-km runs and from RUC 20-km runs. In addition, comparative precipitation statistics demonstrate the better skill of the WRF model for 0.25–1.5 inch thresholds, but for higher thresholds the biases are too high due to a wider coverage of heavy precipitation than observed.

Both WRF and RUC with 20-km and 13-km horizontal resolution are providing 48-h forecast grids for NOAA's New England High Resolution Temperature Program (NEHRTP) during summer 2004. This will give 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 all participating models for Concord, NH is presented in Figure 2. 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, and wind reasonably well.

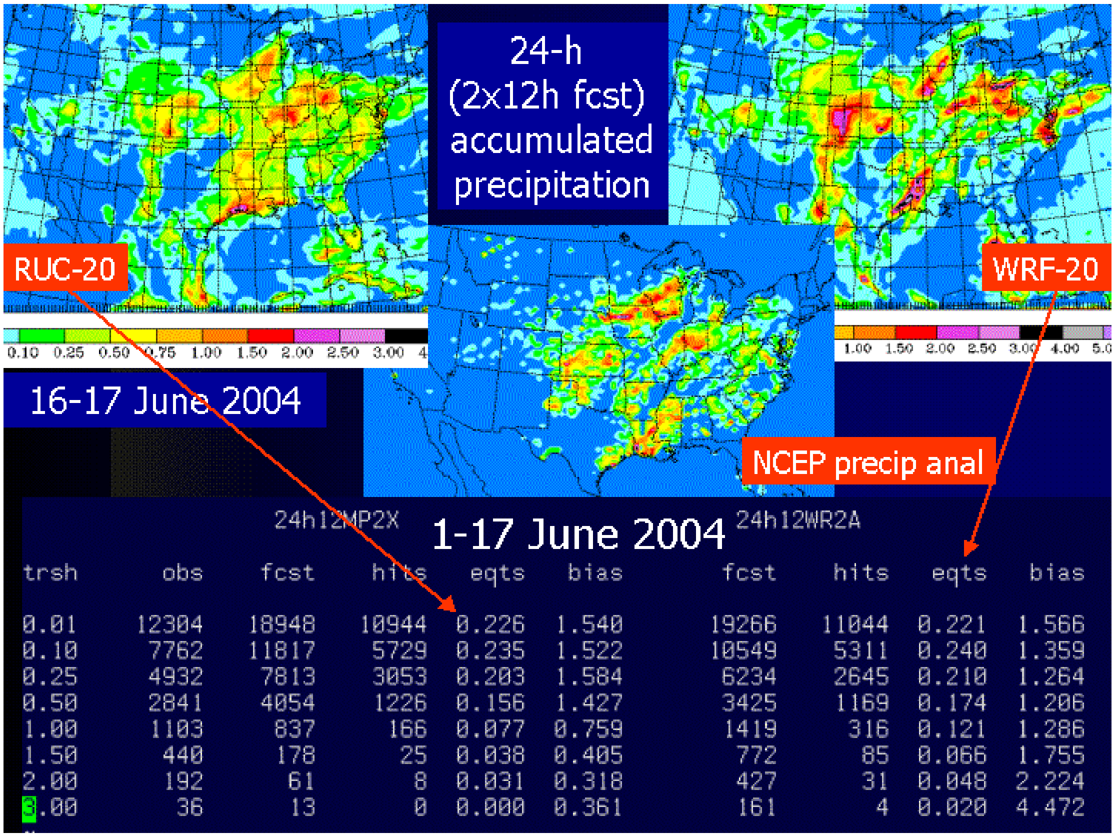

Figure 1. Top 3 panels: Comparisons of 24-h precipitation from two consecutive 12-h forecasts of 20-km WRF and RUC to NCEP precipitation analysis valid at 0000 UTC 17 June 2004. Table at bottom: Precipitation verification statistics from 20-km RUC (left) and 20-km WRF (right) depending on the precipitation amounts for the period 1–17 June 2004.

Variables	20-km RUC	20-km WRF
Wind spd – s.d.	3.30	3.19
Wind spd - bias	0.14	0.12
Temp – s.d.	2.31	2.22
Temp– bias 12z	1.86	0.49
Temp– bias 00z	0.41	-0.21
Dewpoint – s.d.	2.28	2.20
Dewpoint - bias	0.98	0.23

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 Eastern part of the domain averaged for the period 17 July – 3 August 2004.

The models' performance is dependent on many factors, including the horizontal resolution, but station verification of one particular forecast for a particular day is not enough to conclude which model is superior. For example, the 13-km RUC initial conditions are too moist and warm reaching more realistic values after 24 h. But on the second day into the forecast, the 13-km RUC is superior to the 20-km RUC and both the 13- and 20-km WRF, which daytime temperature forecasts are too cool. It is typical for station verifications to have one model perform better than another for one day and worse for a different day. Therefore, statistical analysis over longer periods of time and over larger areas will be more representative of the overall model performance. Table 1 demonstrates comparisons of averaged RMS errors and biases between RUC and WRF with 20-km horizontal resolution for the eastern part of the domain for the period 17 July – 3 August 2004. The RMS errors from RUC and WRF are comparable, the WRF model being only slightly superior. But 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 upper-air verification is also needed to demonstrate competitive performance of WRF against RUC. Also, the improved performance of WRF versus RUC should be demonstrated at higher horizontal resolutions.

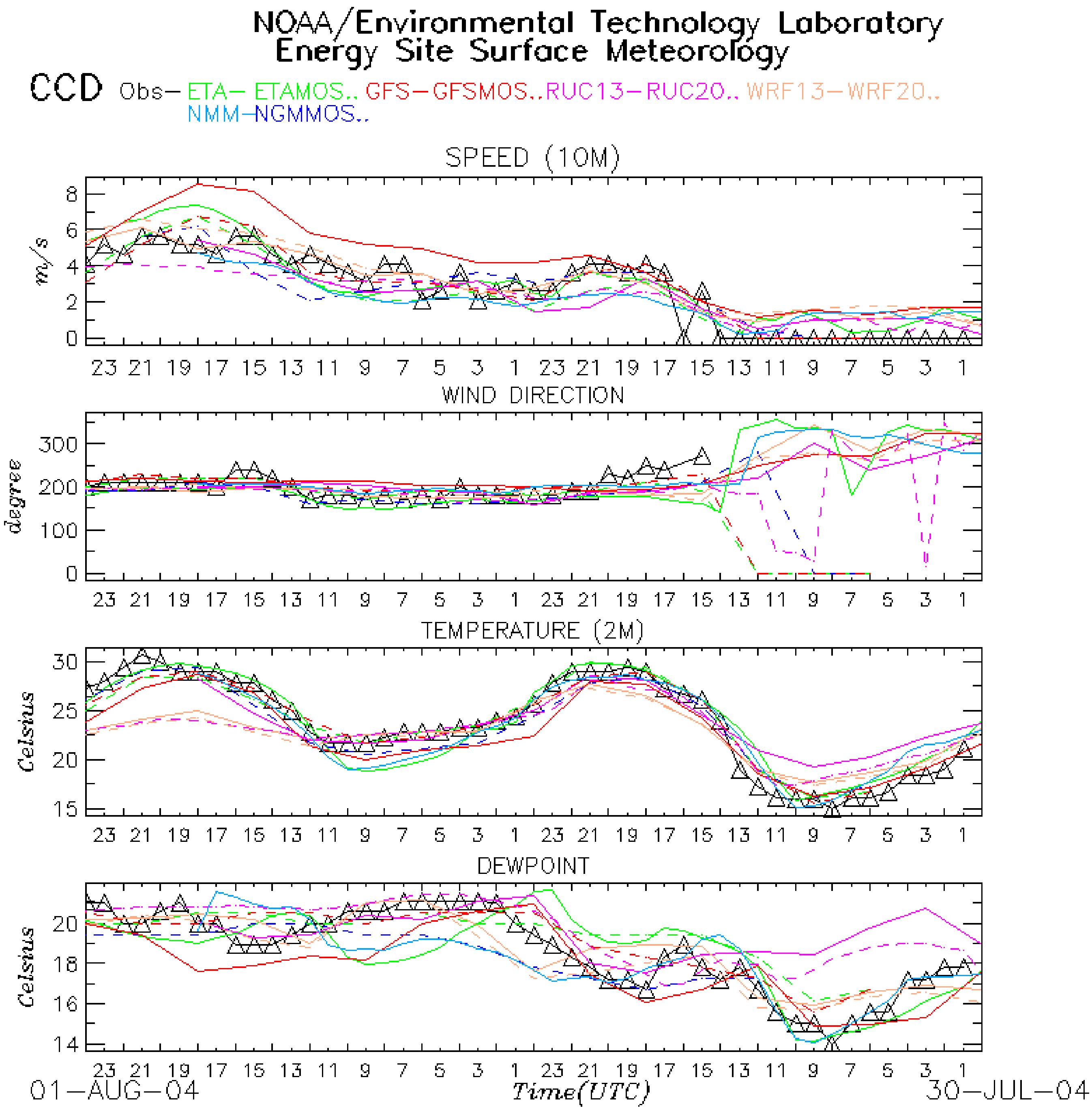

Figure 2. Verification of the diurnal cycles of wind, temperature and dew point for Concord, NH, 30 July – 1 August 2004. (Courtesy, J. Wilczak, NOAA/ETL)

3. FUTURE WORK

Future work in preparation for implementing WRF in RR will include setting up a fully cycling WRF run at FSL, using either the RUC 3DVAR adapted to the WRF vertical grid configuration, or 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 (Fig. 3). 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 and extended to include 13-km runs.

4. REFERENCES

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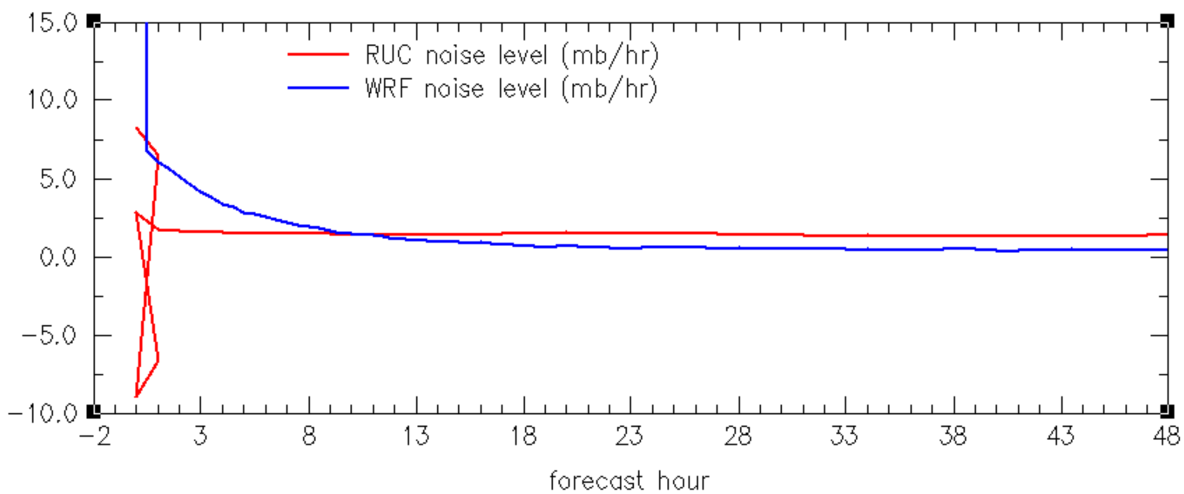

Figure 3. Time evolution of the domain average change in surface pressure (in millibars per hour) obtained from RUC and WRF 48-h forecasts initialized at 1200 UTC 30 March 2004. Note that the RUC reaches an equilibrium value of about 2-3 mb/h by the end of the first hour of the forecast. It takes the WRF without initialization 9 h to settle down to this value.