Improving 2-m Temperature Forecasts in the NCEP Global Forecast System

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Like precipitation, the accurate prediction of 2-m temperature is one of the essential components for numerical weather prediction, and is also considered a challenging task because of the multiplicity of physical processes and their complex interactions (Holtslag et al., 2013, Steeneveld, 2014). It has long been known that the NCEP Global Forecast System (GFS) has large errors in the forecast of near-surface temperature for some seasons. In particular, large biases in late afternoon and nighttime 2-m temperatures usually happen in the spring, autumn and winter seasons. This study focuses on improving near-surface air temperature forecasts under stable conditions in the GFS model. We identify the systematic deficiencies and cause of errors in near-surface temperature forecasts by investigating the physics of the Noah land surface model and land-atmosphere interactions, and find a practical solution to reduce these kinds of forecasting errors. The modifications were proposed to include updated roughness length and preventing the coupled system from decoupling. Sensitivity tests for case studies and two one-month experiments for the summer and winter seasons were performed. The results demonstrate a substantial reduction of errors in near-surface 2-m air temperature forecasts using the proposed modifications, and include a notable reduction in bias and root-mean-square error of temperature in the lower atmosphere. Furthermore, surface dew point temperature, surface wind speed and scores for light and medium precipitation are also improved.

Figure 1 shows a winter case over snowpack with the proposed modifications in the GFS. The sensitivity test (EXP) demonstrates that the large cold bias of 2-m temperature occurring over New York State was reduced in the experiment. At Utica, New York, the 2-m temperature for the control run (CTL) dropped quickly between 21Z, Feb. 16 and 00Z, Feb. 17, 2015 and the rapid cooling was up to 15 °C during these 3 hours, indicating an unrealistic decoupling of the atmosphere from the surface. Compared to the observations, the sensitivity test substantially avoided rapidly dropping the temperatures. This decoupling phenomenon happened again on the following day, and the sensitivity test again prevented it.

The one-month GFS free forecasts for the winter season show good improvement in 2-m temperature over the CONUS regions. Figure 2 gives 2-m temperature and its root-mean-square error (RMSE) averaged over the northwest CONUS. The sensitivity test reduced the cold bias in late afternoon and early evening up to 1.2 °C, with RMSE reduced up to 1 °C which was about 25% of the total error.

References

Holtslag, A. A. M., Svensson, G., Baas, P., Basu, S., Beare, B., Beljaars, A. C. M., et al. (2013). Stable atmospheric boundary layers and diurnal cycles: challenges for weather and climate models. Bull. Am. Meteorol. Soc. 94, 1691–1706. doi: 10.1175/BAMS-D-11-00187.1

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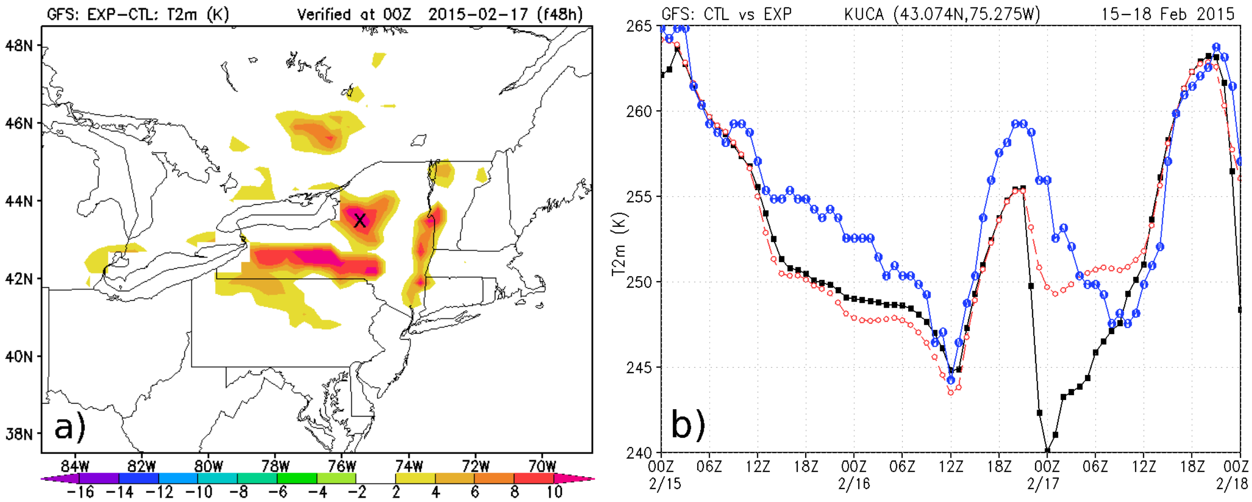

Fig.1 Difference of 2-m temperature between EXP and CTL at 00Z, Feb.17, 2015 (a); and (b) 2-m temperature time series at Utica labeled with “X” in (a) for observation (blue line), CTL (black line) and EXP (red line).

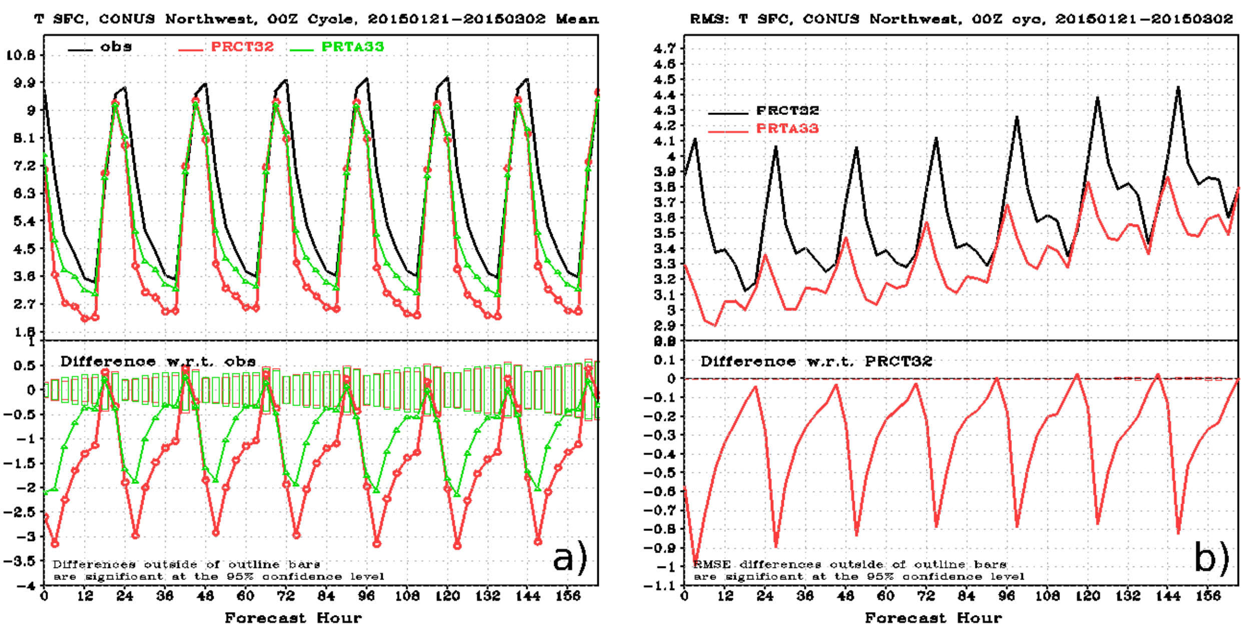

Fig. 2 Comparison of 2-m temperatures for GFS tests averaged over a period from Jan. 21 to March 2, 2015 over the northwest CONUS. (a) 2-m temperatures for the observations (black line), CTL (red lines) and EXP (green lines); (b) RMSE for CTL (black line) and EXP (red line), and their difference.