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Improving the Stable Surface Layer in the NCEP Global Forecast System

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ABSTRACT

The NCEP Global Forecast System (GFS) has a longstanding problem of severe cold bias in the 2-m air temperature forecasts over land in the late afternoon and nighttime during most seasons. This study examines the performance of the NCEP GFS surface layer parameterization scheme for strongly stable conditions over land in which turbulence is weak or even disappears because of high near-surface atmospheric stability. Cases of both deep snowpack and snow-free conditions are investigated with a series of five GFS experiments. The control run (CTL) uses the current GFS operational version. EXP1 tests the impact of using both the updated momentum roughness length z_{0M} and constant C_{zil} = 0.8 treatments. EXP2 applies only the updated z_{0M} treatment, EXP3 applies only the change to a constant C_{zil} = 0.8 and EXP4 applies only the Monin–Obukhov stability parameter constraint. Finally, EXP5 is performed with all three changes. The results show that decoupling and excessive near-surface cooling may appear in the late afternoon and nighttime, manifesting as a severe cold bias of the 2-m surface air temperature that persists for several hours or more (Fig.1). Concurrently, due to negligible downward heat transport from the atmosphere to the land, a warm temperature bias develops at the first model level. We test changes to the stable surface layer scheme that include introduction of a stability parameter constraint that prevents the land-atmosphere system from fully decoupling and modification to the roughness-length formulation. GFS sensitivity runs with these two changes demonstrate the ability of the proposed surface-layer changes to reduce the excessive near-surface cooling in forecasts of 2-m surface air temperature. The proposed changes prevent both the collapse of turbulence in the stable surface layer over land and the possibility of numerical instability resulting from thermal decoupling between the atmosphere and the surface. We also execute and evaluate daily GFS 7-day test forecasts with the proposed changes spanning a one-month period in winter. Our assessment reveals that the systematic deficiencies and substantial errors in GFS near-surface 2-m air

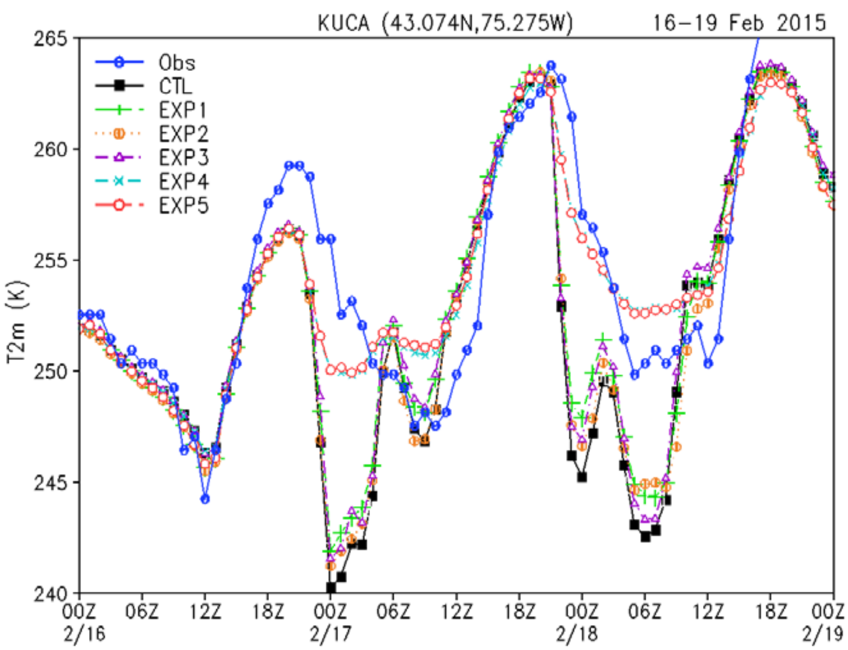

Fig. 1 Hourly time series of 2-m air temperature (K) at Utica, NY for observations (blue), CTL (black), EXP1 (green), EXP2 (orange), EXP3 (purple), EXP4 (light blue) and EXP5 (red), during the 72-hour period of 00 UTC on 16 February to 00 UTC on 19 February, 2015.

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temperature forecasts are considerably reduced, along with a notable reduction of temperature errors throughout the lower atmosphere and improvement of forecast skill scores for light and medium precipitation amounts.

The second version of the NCEP Climate Forecast System (CFSv2) made operational at NCEP in March 2011 employs the same land surface model and surface layer scheme, and similarly, has severe cold biases of 2-m air temperature, typically occurring in the late afternoon and nighttime over land or sea ice. The proposed approach of proper treatment of surface layer parameterization under very stable conditions in this study is under testing in the CFSv2. Reduction of model forecast errors thus improvement of the subseasonal to seasonal climate service are anticipated.

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References

Zheng W., M. Ek, K. Mitchell, H. Wei, and J. Meng, 2017: Improving the stable surface layer in the NCEP Global Forecast System. *Mon. Wea. Rev*., **45**, 3969-3987. https://doi.org/10.1175/MWR-D-16-0438.1