Improving Near-Surface Field Forecasts in NCEP Forecast Models

Yihua Wu[1,2], Weizhong Zheng[1,2], Helin Wei[1,2],
Jesse Meng[1,2], Jiarui Dong[1,2] and Mike Ek[2]
[1]IMSG at NOAA/NCEP/EMC, [2]NOAA/NCEP/EMC

INTRODUCTION

The accurate representation of land surface processes and their interactions with atmosphere in numerical models is regarded as the key for improving numerical weather and climate prediction and a challenging task owing to the multiplicity of the related physical processes and their complex interactions. It has been noticed that the Global Forecast System (GFS) and the North American Mesoscale Forecast System (NAM) at NCEP have large errors in surface temperature and surface humidity forecasts in some seasons. In particular, excessive cooling of 2-m temperature happens during sunset in GFS while a systematic wet bias in 2-meter dew point temperatures and cold bias in 2-meter temperature occur in NAM.

GFS systematic errors in near-surface temperature forecast were identified by investigating the Noah LSM and the land-atmosphere interactions, and practical solutions were found.

1. An improvement in surface layer scheme considerably reduced the systematic deficiencies and substantial errors in GFS near-surface 2-m air temperature forecasts, along with a notable reduction of bias and root-mean-square of air temperature throughout the lower atmosphere.
2. Further updates include use of the high resolution land surface characteristic data (IGBP vegetation type and STATSGO soil type data) to replace the coarse data in the current operational GFS and use of the new MODIS-based maximum snow albedo data.

Three error sources in NAM have been identified through investigation:

1. The frozen soil water content effect on transpiration is ignored.
2. An unrealistic constant LAI is used for all plant types and all seasons.
3. The LAI effect on canopy resistance is too weak.

The total soil moisture includes three parts: solid (ice), liquid (water) and gas (water vapor). The liquid soil moisture is the same as the total soil moisture in unfrozen soil (summer), but is the difference between the total soil moisture and soil ice in frozen soil (winter). Soil Ice is not available for plant transpiration. In most LSMs, the calculation of evapotranspiration is based on the total soil moisture, not liquid soil moisture, which is also the case in the NAM. This not only causes an inconsistency between the evapotranspiration calculations in summer and winter, but also overestimates evapotranspiration in winter seasons.

GVF characterizes land surface and is used for the partitioning of land surface into the parts of bare ground, vegetated surface and the combination of bare ground and vegetated surface. LAI characterizes plant canopies, and is used to compute canopy resistance. An unrealistic constant LAI is used for all plant types in NAM. In addition, LAI in the scheme for the light effect on canopy resistance has conflict effects. All together, the modifications to solve these three issues clearly improve NAM performance.

METHODS AND MATERIALS

The excessive cooling of 2-m temperature happens during sunset in GFS was caused by numerical instability of the surface layer scheme under very stable conditions. A practical method was used. The cold bias was significantly reduced.

To reduce the wet bias of dew point temperature in NAM, three modifications were made:

(1) the calculation of evapotranspiration is based on liquid soil moisture, instead of the total soil moisture;
(2) the unrealistic constant LAI is scaled by GVF;
(3) The improved scheme for the light effect on canopy resistance is more sensitive to LAI.

Total 48 runs (Control run with the operational NAM and Test Run with the modified NAM) were conducted for 2014, two days from each month (the beginning day and middle day of each month). 84 hour simulation was conducted for each run. Analysis was done for all land points over 218 grid domain.

RESULTS

The comparison between operational GFS, parallel GFS and experimental GFS runs are shown in Figure 1. The cold bias at afternoon and night time was reduced by about 1.2 °C while RMSE at afternoon and night time was reduced up to 1.0 °C. Scores for light and medium precipitation was improved and their bias was also reduced.

The comparison between operational NAM and experimental NAM runs are shown in Figure 2. Latent heat fluxes were reduced while sensible heat fluxes were increased during winter season in the experimental NAM run when frozen soil effects was considered. Replacing the constant LAI with the GVF-scaled LAI reduced latent heat flux, but increased sensible heat flux. Consequently, the wet bias of 2 meter dew point temperature was clearly reduced.

Figure. 1 GFS Improvements

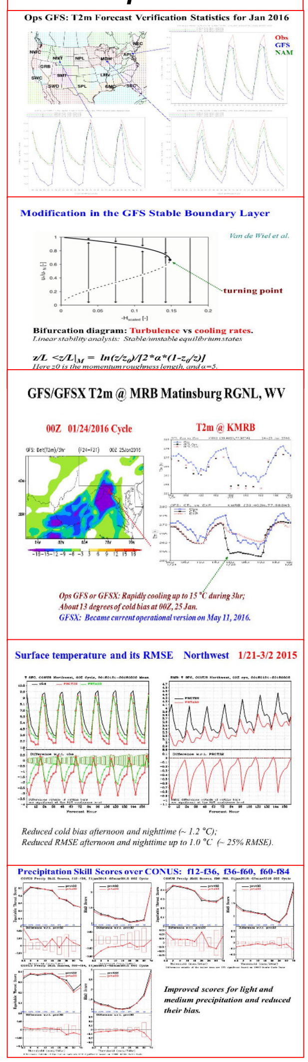
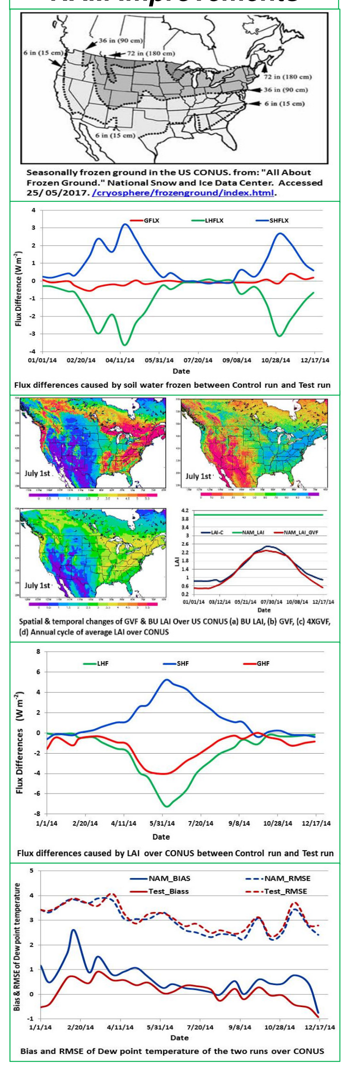


Figure. 2 NAM Improvements



SUMMARY

Some systematic near-surface field forecast errors in GFS and NAM have been identified by investigating the Noah LSM and the land-atmosphere interactions, and were clearly reduced by applying practical solutions. These improvements have been implemented in the latest version GFS and NAMv4.0

CONTACT

Yihua Wu
NOAA/NCEP/EMC
5830 University Research Court
College Park, MD 20740
Email: yihua.wu@noaa.gov
Phone: 301-683-3691