J3.3 IMPACT OF LAND-SURFACE INITIAL CONDITIONS SPIN-UP ON WARM SEASON PREDICTABILITY SIMULATED BY THE NCEP GFS COUPLED WITH THE NOAH LSM

Cheng-Hsuan Lu [1, 2] and Kenneth Mitchell [2]
[1] RS Information Systems Inc, McLean, VA
[2] Environmental Modeling Center, NOAA/NWS/NCEP, Camp Springs, MD

1. INTRODUCTION

As part of the NCEP effort to unify the use of the advanced Noah Land Surface Model (LSM) in all NCEP regional and global models and their associated data assimilation systems, the Noah LSM has been implemented into the testbed for the NCEP Global Forecast System (GFS) in late 2002. This experimental version of GFS (referred to as GFS_Noah) has been used in various studies, such as seasonal forecasts, to evaluate the Noah LSM in the GFS and to assess its impact on GFS forecasts. Initial conditions for GFS_Noah runs are taken from the NCEP Global Data Assimilation System (GDAS) using the operational GFS (coupled with old LSM), and thus, these modeling studies could not reflect a fair evaluation of Noah LSM due to the inconsistency in initial land states and model land physics.

The GFS_Noah has been incorporated into the framework of the NCEP GDAS in early 2003. A retroactive data assimilation run starting from Aug 1, 2002 are in progress. Noah cycled GDAS run employs reduced resolution (T62 L28) with respect to the operational system (T254 L64). A low-resolution GDAS run using the operational version of GFS (with the old LSM) is run in parallel. These data assimilation efforts aim to evaluate the impact of LSM upgrade on GFS forecasts as well as to provide continuously cycled Noah LSM land states in GDAS.

* *Corresponding author address*: Cheng-Hsuan Lu, RSIS and NOAA/NCEP/EMC, 5200 Auth Rd, Camp Springs, MD 20746; e-mail: Sarah.Lu@noaa.gov

In this study, the NCEP GFS is used for warm-season seasonal hindcasts for 2003. Initial conditions are taken from: (1) low resolution GDAS using the operational GFS, and (2) low resolution GDAS using an experimental version coupled with the Noah LSM. Results from GFS summer time integrations are analyzed and compared with the CPC gauge date. The impact of using Noah cycled GDAS (which provides initial land states that are strictly self consistent with land physics in the experimental GFS) on warm season predictions is assessed.

2. MODEL USED

The model used for this study is a global spectral model with T62 resolution (about 200km) in the horizontal and 28 levels in the vertical. It is a slightly modified version of the GFS used for medium range weather forecasting at the NCEP. Key model physical parameterizations include the Relaxed Arakawa Schubert convection, long wave and short wave radiation, cloud-radiation interaction, explicit cloud microphysics, non-local vertical diffusion, gravity wave drag, and mean orography.

Two versions of GFS are used: the operational version of GFS, which utilizes the Oregon State University land surface model (OSU LSM, Pan and Mahrt, 1987), and an experimental version coupled with the latest version of the NCEP Noah LSM (an advanced descendant of the OSU LSM, Ek et al., 2003). The vertical configuration is 2 (at depths of 10 and 200 cm) and 4 (at depths of 10, 40, 100, 200 cm) for the OSU LSM and Noah LSM, respectively. Major advances in the Noah LSM include frozen soil physics, patchy snowpack treatment, and improved snow albedo, ground heat flux, and soil evaporation.

3. EXPERIMENT DESIGN

Three sets of summer-time seasonal hindcasts initialized around mid-May, 2003 are conducted in this study. These include: (1) *Ctr_OSU*: GFS runs initialized from OSU cycled GDAS, (2) *Ctr_Noah*:

GFS_Noah runs initialized from Noah cycled GDAS, and (3) *Exp_Noah*: GFS_Noah runs initialized from OSU cycled GDAS. Five realizations for atmospheric and land initial conditions are taken from the corresponding GDAS (see above), with 24 hours apart. The length of integration is four and half months, ending on Oct 1, 2003. The ocean surface boundary fields are taken from observed 1-deg NCEP Reyolds/Stokes SST. Not only the impact of land states initialization on the seasonal predictions can be assessed, the differences due to the application of different LSM can also be evaluated.

Figure 1 shows the initial volumetric soil moisture (in fraction) from OSU cycled GDAS and Noah cycled GDAS, averaged over the 5 members. In general, soil moisture for the top 10cm from Noah cycled GDAS is similar to that from OSU cycled GDAS. For deep layers, land states from Noah cycled GDAS are wetter and show more small-scale features than that from OSU cycled GDAS. Since both GDAS runs start from August 1, 2002, the initial conditions (e.g., May 11-15, 2003) used in this experiment reflect a nine month land state spin-up.

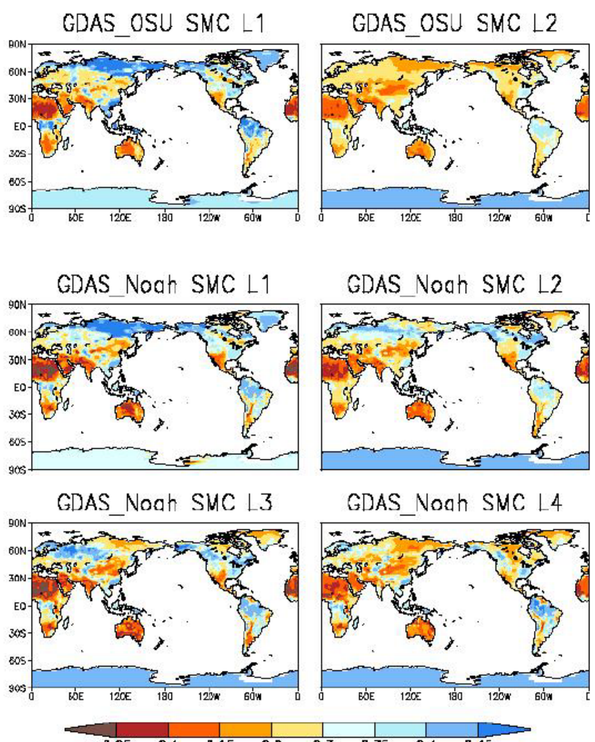

Figure 1. Initial volumetric soil moisture (in fraction) from OSU cycled GDAS (top panels) and from Noah cycled GDAS (middle and bottom panels.)

4. RESULTS

Figures 2a and 2b show the time series of volumetric soil moisture (in fraction) and soil temperature (in K) for one member initialized from May 11, 2003. While the time evolution of soil wetness and temperature at the top 0-10cm is very noisy, the fluctuations cascade at deep layers. A warmer trend is seen at all soil layers at all sites throughout the entire period except the last 2-3 weeks. For soil moisture, a slowly drying trend is seen for the top three layers (down to 1 m depth) at all sites. The drying trend also extends to the 4th layer at these regions where root zone is down to 2 m (such as PA). Similar features are seen in the remaining 4 members (not shown here).

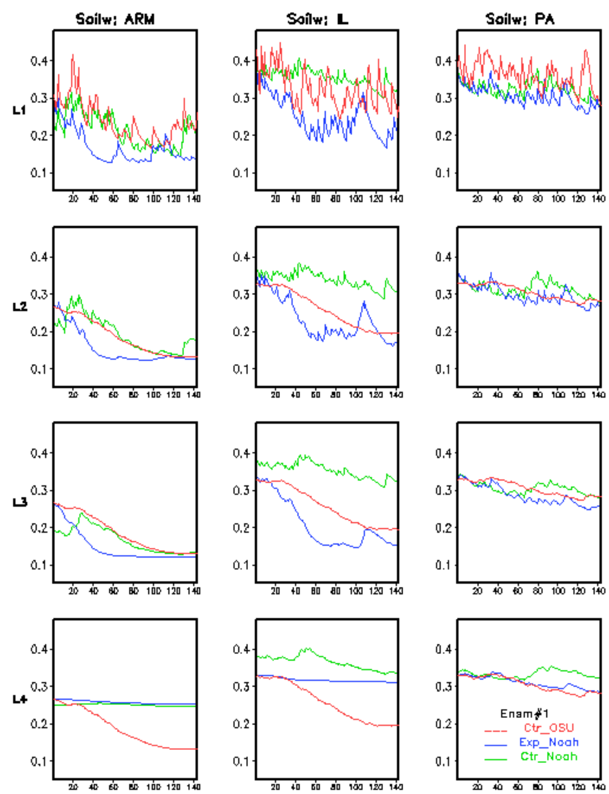

Figure 2a. Time series of volumetric soil moisture (in fraction) for 0-10cm (top panels), 10-40 cm (second panels), 40-100 cm (third panels), and 100-200 cm (bottom panels) from Ctr_Noah runs (green) and Exp_Noah runs (blue). For Ctr_OSU runs (red), soil wetness at top 0-10cm [10-200 cm] is displayed at top panels [bottom three panels]. The left, middle, and right panels are results for OK, IL, and PA sites, respectively.

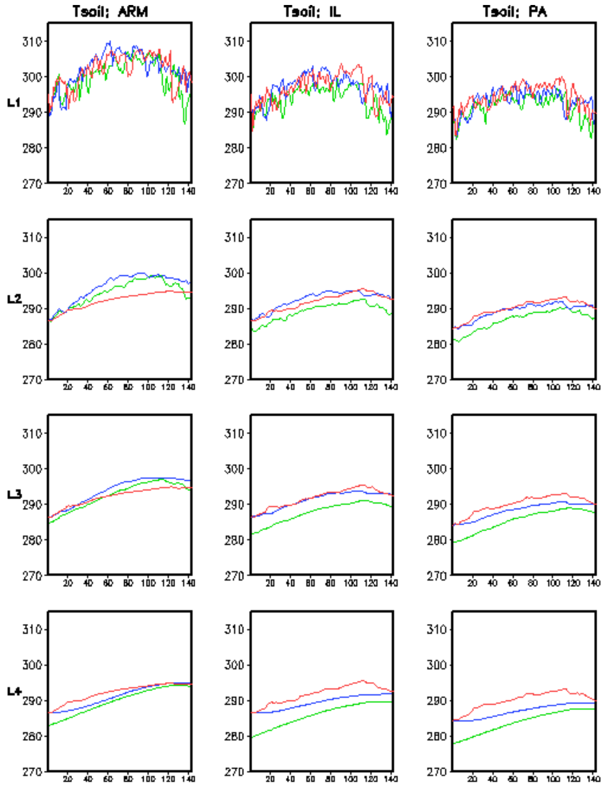

Figure 2b. Same as 2a, except for soil temperature (in K).

Figures 3 and 4 show soil wetness (in mm) and soil temperature (in K), averaged over July, at the 10-200 cm layer (e.g., layer 2 for Ctr_OSU run; layers 2-4 for Ctr_Noah and Exp_Noah runs). For reference, the corresponding land states from NCEP/DOE Reanalysis 2 (R-2) are also shown. Considering Exp_Noah as the reference (bottom right panel), the differences between Ctr_OSU and Exp_Noah indicate the impact of land physics and the difference between Ctr_Noah and Exp_Noah indicate the impact of land states initialization. For soil temperature, it is shown that the impact of land states initialization is comparable to that of land physics except at the high altitude regions where Ctr_OSU is warmer than the other two runs. For soil moisture, the impact of land state initialization on seasonal hindcasts is significant. Ctr_Noah run shows a wetter monthly average than that from Ctr_OSU and Exp_Noah runs. In addition, soil wetness from Ctr_Noah shows a better agreement with that from R-2. A simple land data assimilation scheme using Xie-Arkin pentad precipitation has been used in R-2 soil wetness analysis (Kanamitsu et al., 2002). The agreement mentioned above implies an enhancement in the forecast skills resulted from the use of Noah cycled GDAS.

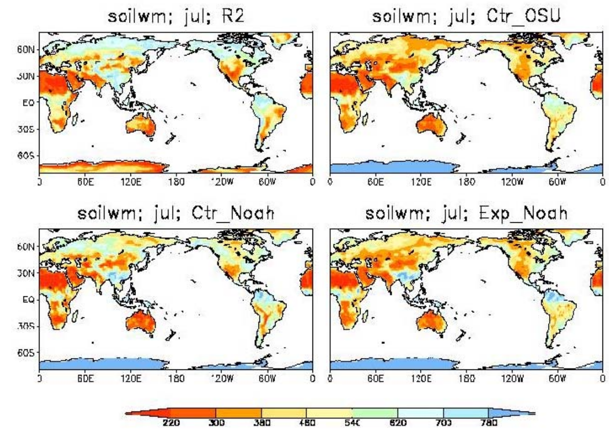

Figure 3. July soil wetness (in mm) for the 10-200 cm layer from Reanalysis 2 (top-left), Ctr_OSU (top-right), Ctr_Noah (bottom-left) and Exp_Noah (bottom-right).

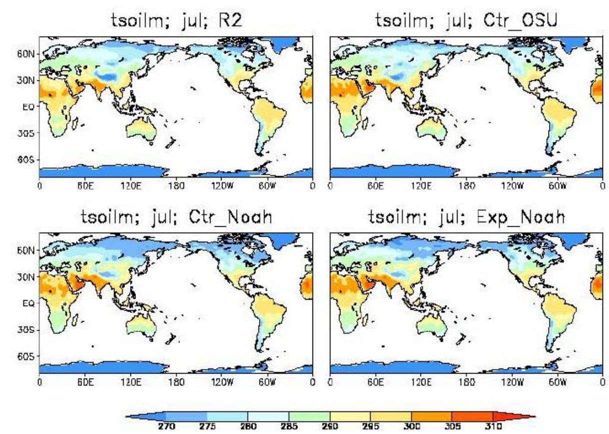

Figure 4, same as Figure 4 except for soil temperature (in K).

The impact of land states initialization on atmospheric fields is less evident, as shown in Figure 5 (near surface temperature in K). Height fields at 500 and 850 mb among the three runs are also very similar (not shown here). Since soil moisture is a key component of memory for the climate system, it is anticipated that the impact of land states initialization on hindcasts is most significant for the soil wetness field. The impact on the fields other than soil wetness, however, is likely to be underestimated in this study due to the following two factors. First, land states used in this study reflect a 9-month data assimilation. This is considerably shorter than that suggested by Mitchell et al. (2003) based on Northern American Land Data Assimilation System (NLDAS). Second, a soil wetness nudging procedure (with relaxation time equals to 60 days) has been used in the NCEP GDAS. The application of nudging is likely to reduce the differences between OSU cycled GDAS versus Noah cycled GDAS.

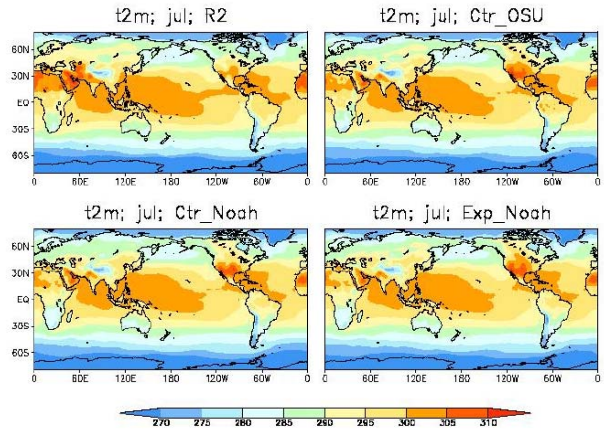

Figure 5, same as Figure 3 except for near surface temperature (in K).

Finally, the GFS simulated precipitation is compared with the CPC Unified Precipitation Data. Figures 6-9 show the monthly-averaged daily precipitation (in inch) from gauge observations and from the three runs over the US for June, July, August, and September. Precipitation from Ctr_Noah is comparable to those from other two runs at early months, but a better agreement between Ctr_Noah and observation emerges at latter months. This once again indicates that the use of Noah cycled GDAS could improve seasonal forecast.

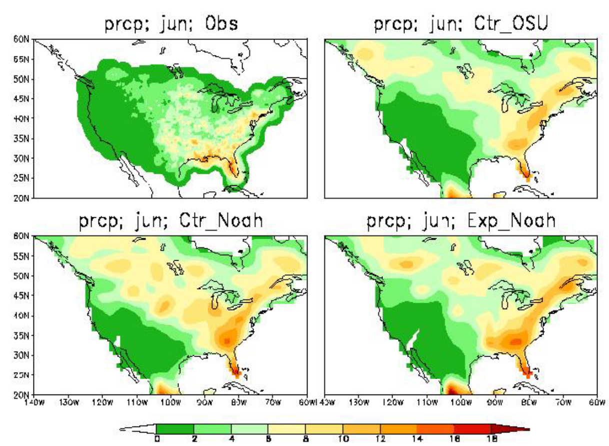

Figure 6. June-averaged daily precipitation (in inch) from observation (top-left), Ctr_OSU (top-right), Ctr_Noah (bottom-left), and Exp_Noah (bottom-right) over the US.

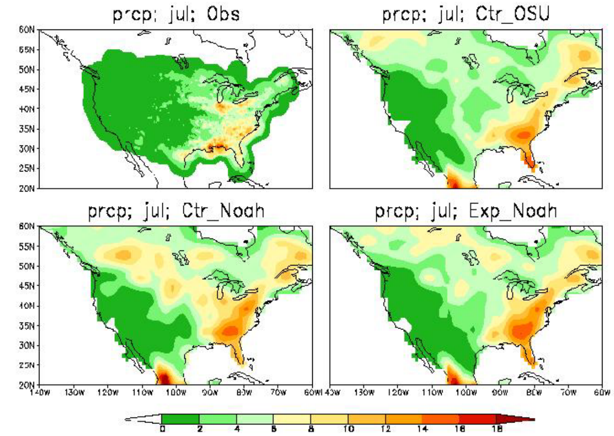

Figure 7. Same as Figure 6, except for July period.

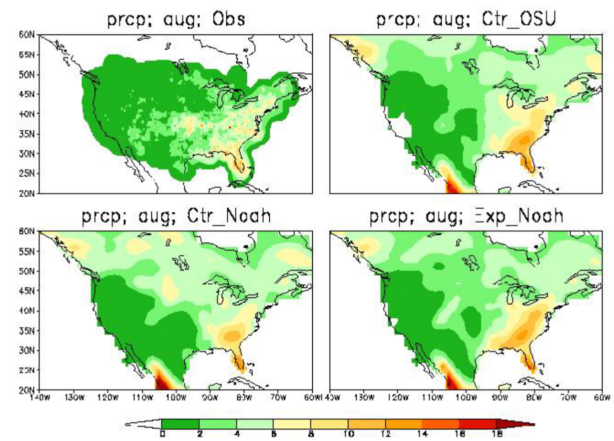

Figure 8. Same as Figure 6, except for August period.

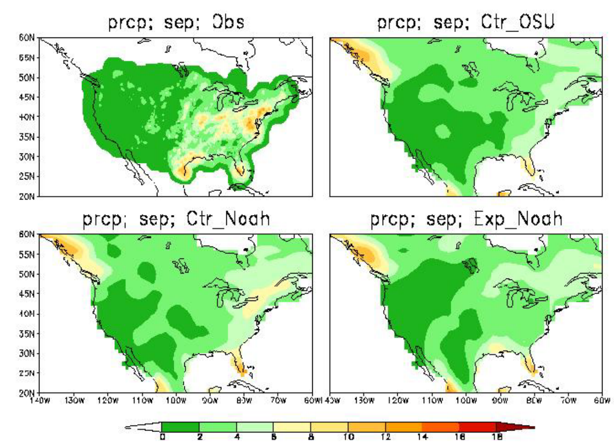

Figure 9. Same as Figure 6, except for September period.

5. CONCLUSIONS

This study presents the summer-time seasonal hindcasts for 2003. Two versions of GFS are used, on is based on the operational version that coupled with the OSU LSM and the other is an experimental versions coupled with the Noah LSM.

The impact of using Noah cycled GDAS (which provides initial states that are strictly self consistent with the experimental version of GFS) on warm season prediction is examined. The impact of land state spin-up is evident for soil wetness at deep layers, while the impact on other fields is less evident.

The use of Noah cycled GDAS to enhance seasonal forecast skills appears promising. In specific, a better agreement with R-2 soil wetness analysis is found and a positive impact on precipitation emerges at later months. However, some issues remains, such as insufficient spin-up of land states from a nice-month GDAS; and (2) the need for a GDAS run without soil moisture nudging.

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