A Systematic Assessment of Noah-MP in Simulating Land-Atmosphere Energy, Water and Carbon Exchanges over the Continental United States

Ning Ma[1,2] and Guo-Yue Niu[2]

1 Key Laboratory of Tibetan Environment Changes and Land Surface Processes, Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing, China; 2 Department of Hydrology and Atmospheric Sciences and Biosphere 2, University of Arizona, Tucson, AZ, USA (Email: niug@email.arizona.edu)

1.Introduction

- Land Surface Models (LSMs) provide the lower boundary condition for Earth System Models (ESMs). The LSM evaluation is key to not only understanding its accuracy in simulating land-atmosphere energy and mass exchange but also future model improvement.
- As an augmented land surface scheme for the WRF, Noah-MP has been widely evaluated at local scales and regional scales, but there is still much need of understanding the performance skills over a wide range of climate divisions.

2. Model set-up and Evaluation

- Noah-MP was driven with the NLDAS atmospheric forcing over CONUS domain from 1980 to 2015 at 0.125° and 1 h resolution. The model was spun-up with a repeated 6-cycle (i.e. 216 years) run.
- We focused on the major energy (Rn, H, LE), water (TWS, Runoff, SCF) and carbon (GPP) variables by comparing the model output with the ground- and satellite-measured data.
- We evaluated the model performance over the 18 USGS Hydrological-Unite-2 regions (Fig. 1) within the CONUS which span a wide range of climate zones .

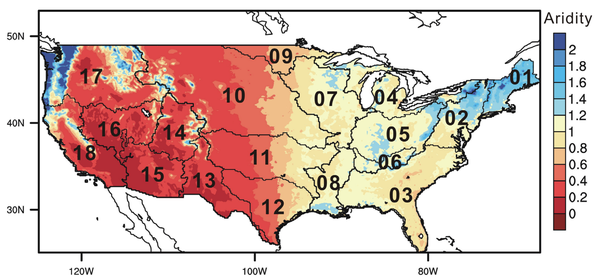

Figure 1. The geographic area of USGS hydrological unit code-2 (HUC-2) regions over continental United States (01 New England, 02 Mid-Atlantic, 03 South Atlantic-Gulf, 04 Great Lakes, 05 Ohio, 06 Tennessee, 07 Upper Mississippi, 08 Lower Mississippi, 09 Souris-Red-Rainy, 10 Missouri, 11 Arkansas-White-Red, 12 Texas-Gulf, 13 Rio Grande, 14 Upper Colorado, 15 Lower Colorado, 16 Great Basin, 17 Pacific Northwest, 18 California) and their climatological mean (1980-2015) annual aridity.

3. Results

3.1 GPP, Rn, H and LE

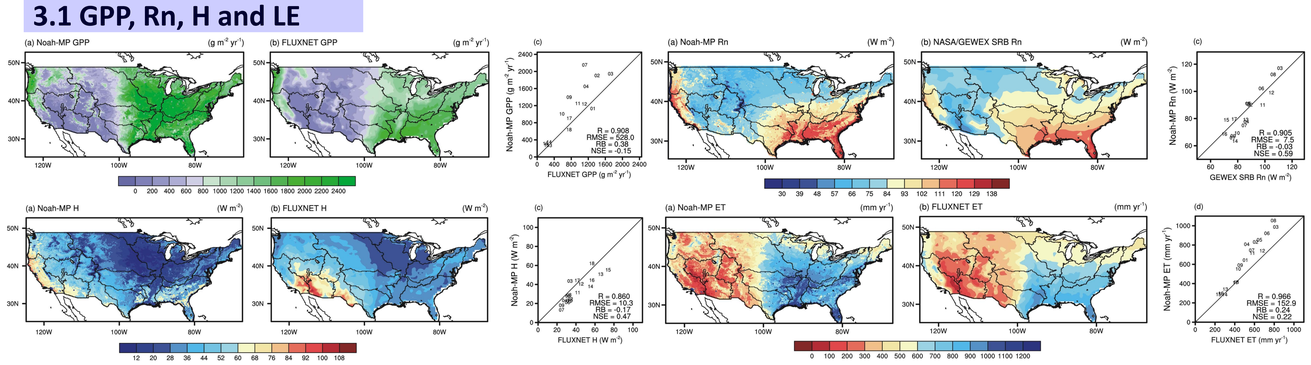

Fig 2 The Noah-MP simulated and the observed spatial pattern of the climatological mean (1982-2008) annual GPP, Rn, H and LE over the CONUS

Noah-MP is capable of capturing the observed general spatial pattern of GPP, Rn, H and LE (Fig.2). Specifically, the simulated annual Rn shows greatest agreement with the observed values. However, it appears that the model overestimated the GPP to some extent in the wet regions of CONUS which is reflected in its lowest NSE compared with other variables. The overestimation of GPP in these regions occurred mainly in Spring season (Fig. 3), leading to the overestimation of LE (RB of 0.15) and the underestimation of H (RB of -0.17)over most wet regions.

- CONUS: Continental United States; NLDAS: North American Land Data Assimilation System; GPP: gross primary production; Rn: net radiation; H: sensible heat flux; LE: latent heat flux; TWSA: Terrestrial Water Storage Anomaly; SCF: snow cover fraction; r: correlation coefficient; RMSE: root mean square error; NSE: Nash-Sutcliffe efficiency
- For the validation data, the GPP, H and LE are from FLUXNET-MTE, Rn is from NASA/GEWEX SRB, Runoff is from USGS, TWSA is from GRACE, SCF is from MODIS.

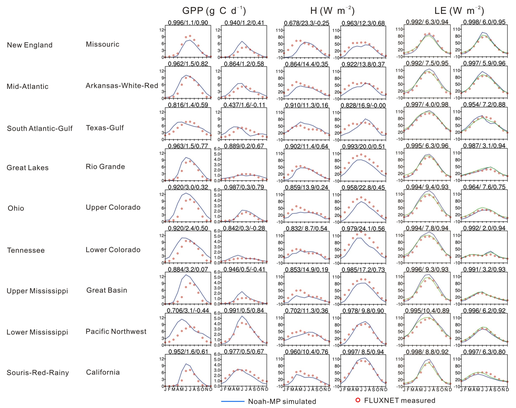

Fig 3 Noah-MP simulated and FLUXNET measured regional-average climatological mean (1982-2008) seasonal cycle of the GPP, H and LE [r/RMSE/NSE]

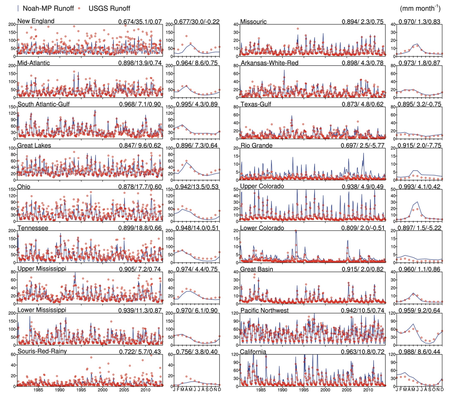

Fig 4 Noah-MP simulated and USGS measured regional-average monthly and climatological mean (1982-2008) monthly runoff [r/RMSE/NSE]

3.2 Runoff

Noah-MP overall simulated the runoff well over most regions (the NSE over half of them are larger than 0.7 at a monthly scale, Fig. 4). It however produced too much runoff over the Rio Grande and the Lower Colorado but less runoff in the New England. Such mismatch can be apparently attributed to the NLDAS precipitation product since the simulated ET and TWSA did not show much error over these regions.

3.3 Terrestrial Water Storage

Noah-MP is able to capture the monthly TWSA over most regions (the NSE over 14 regions are larger than 0.5, Fig. 5). Compared to Noah, Noah-MP showed obvious improvement in simulating TWSA since it explicitly incorporates the groundwater dynamics. However, Noah-MP showed a little bit larger error over Great Lakes and Texas-Gulf. The reason is that the model excludes (i) the representation of rivers, lakes, or reservoirs and (ii) the irrigation due to anthropogenic activities.

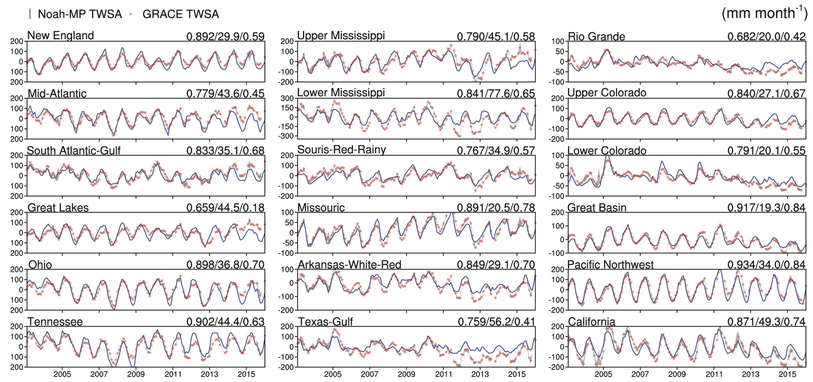

Fig. 5 The regional-averaged Noah-MP simulated and GRACE-measured monthly TWSA, 2003-2015[r/RMSE/NSE]

3.4 Snow Cover Fraction

Spatially, the simulated climatological mean SCF (Fig. 6) in three periods are overall consistent with the MODIS-based results. The NSE over most regions with much snow falls in winter are larger than 0.8 at a monthly scale. Among them, the New England shows largest discrepancy. This may be due to the uncertainties in the precipitation forcing which may has too much snow in winter, leading to a delay in runoff generation in Spring.

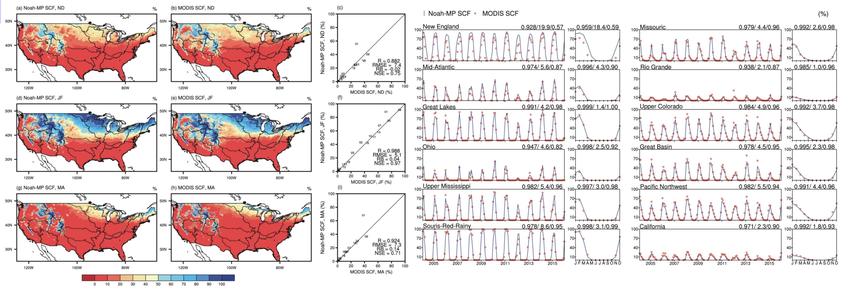

Fig. 6 The Noah-MP simulated and MODIS-measured spatial pattern of climatological mean SCF in three periods and regional-averaged monthly and climatological mean seasonal cycle of SCF [r/RMSE/NSE]

4. Conclusions

- Noah-MP is capable of reproducing the observed annual and inter-basin variability of the energy (H and LE), water (E and Q), and carbon (GPP) fluxes with a higher capability of simulating Rn and SCF. Seasonally, Noah-MP produces too much GPP in spring and early summer in relatively wet basins, thereby resulting in excessive LE and thus less H.
- Future improvement of Noah-MP may need to focus more on improving representations of carbon assimilation and partitioning into leaves and root, the water storage over lakes/reservoirs and human activities including building dams and irrigation.