The Sensitivity of North American Monsoon System Precipitation to Vegetation and Groundwater Dynamics*

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Background

Accurately predicting precipitation during the North American monsoon season is the goal of the NOAA PACS/GAPP North American Warm Season Precipitation Initiative. Numerous studies have shown that the change in vegetation can have a strong influence on local climate, e.g. temperature, precipitation. A dynamic vegetation model coupled in LSMs is necessary for intraseasonal to interannual climate modeling. Another crucial component, which is often ignored, is groundwater. Most LSMs use free gravitational drainage as the lower boundary condition, which fails to account for upward water flow from groundwater. Incorporating a groundwater component into LSMs can improve the prediction of precipitation. The purpose of this work is to understand the effects of vegetation and groundwater dynamics on regional precipitation in the summer monsoon season by using a regional coupled land-atmosphere model through sensitivity studies.

Model Description

The version 2.1.2 of the Weather Research and Forecasting model (WRF) with time-varying sea surface temperatures is used, and the dynamic relaxation technique is applied in the model buffer zone.

Physics options and input data:
Lin et al. microphysics scheme;
Kain-Fristsch cumulus parameterization scheme;
Yonser University Planetary boundary layer;
A simple cloud interactive radiation scheme;
Rapid Radiative Transfer Model longwave radiation scheme; Noah LSM; NCEP-NARR reanalysis data.

The model domain covers the whole continental US and the resolution is 30km (Fig.1). Model integrated from 1 June to 1 September 2002.

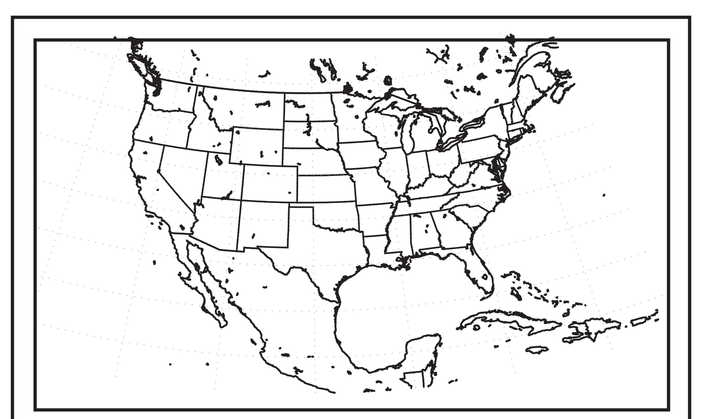

Figure 1. Model domain

Experiment Design

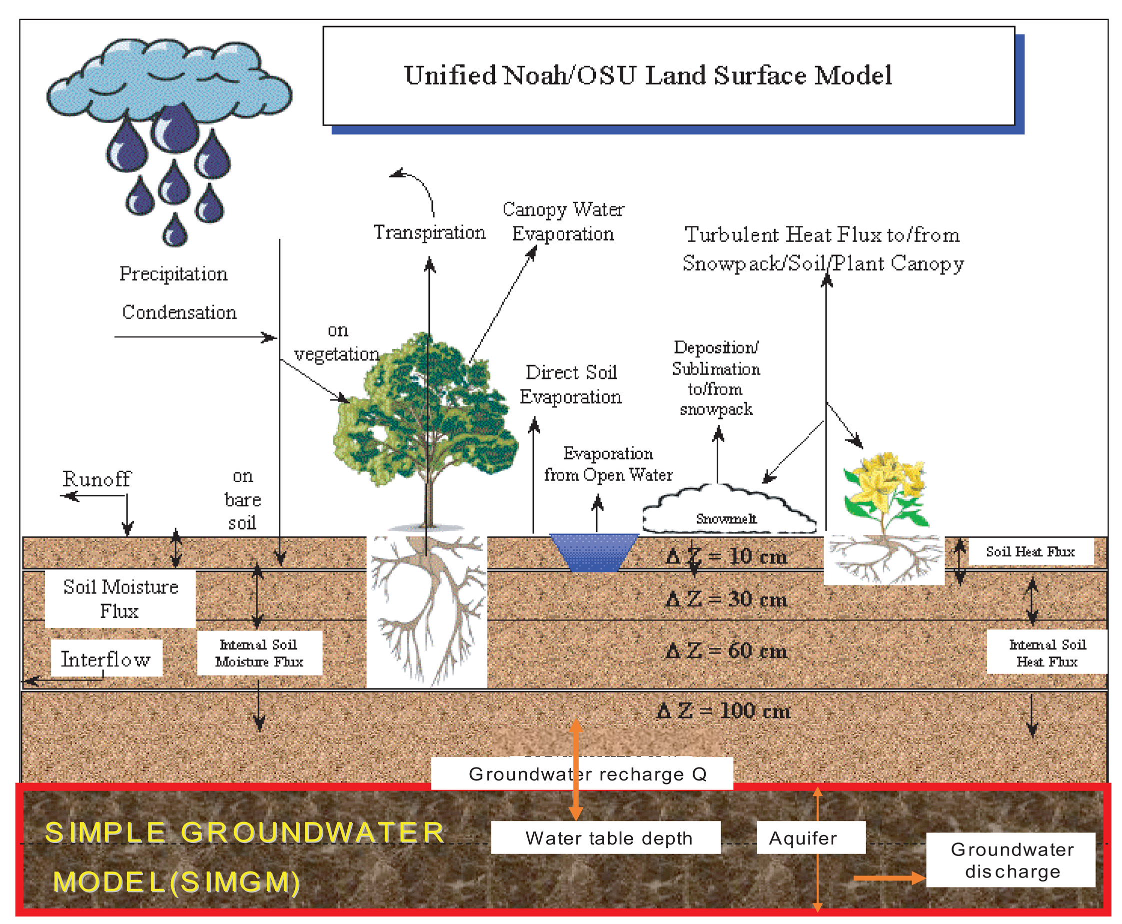

Figure 2. Noah LSM coupled with a groundwater component

The LSM with the WRF model is the unified Noah LSM. A dynamic vegetation model of Dickinson et al. (1998), is coupled to the Noah LSM. We also implement a simple groundwater model (SIMGM) (Niu et al. 2006) into the Noah LSM. The SIMGM has been developed by representing recharge and discharge processes of the water storage in an unconfined aquifer, a single integration element below the bottom soil layer of Noah LSM (Fig. 2). The water table depth is initialized with the initial soil moisture from NARR reanalysis data.

Three sensitivity experiments are defined as follows:
The vegetation fraction is prescribed according to the value on the initial time of the model integration (FIX); the second employing the dynamic vegetation (DV), and the third adding the SIMGM to the second experiment (GWDV).

Premilinary Results(1)

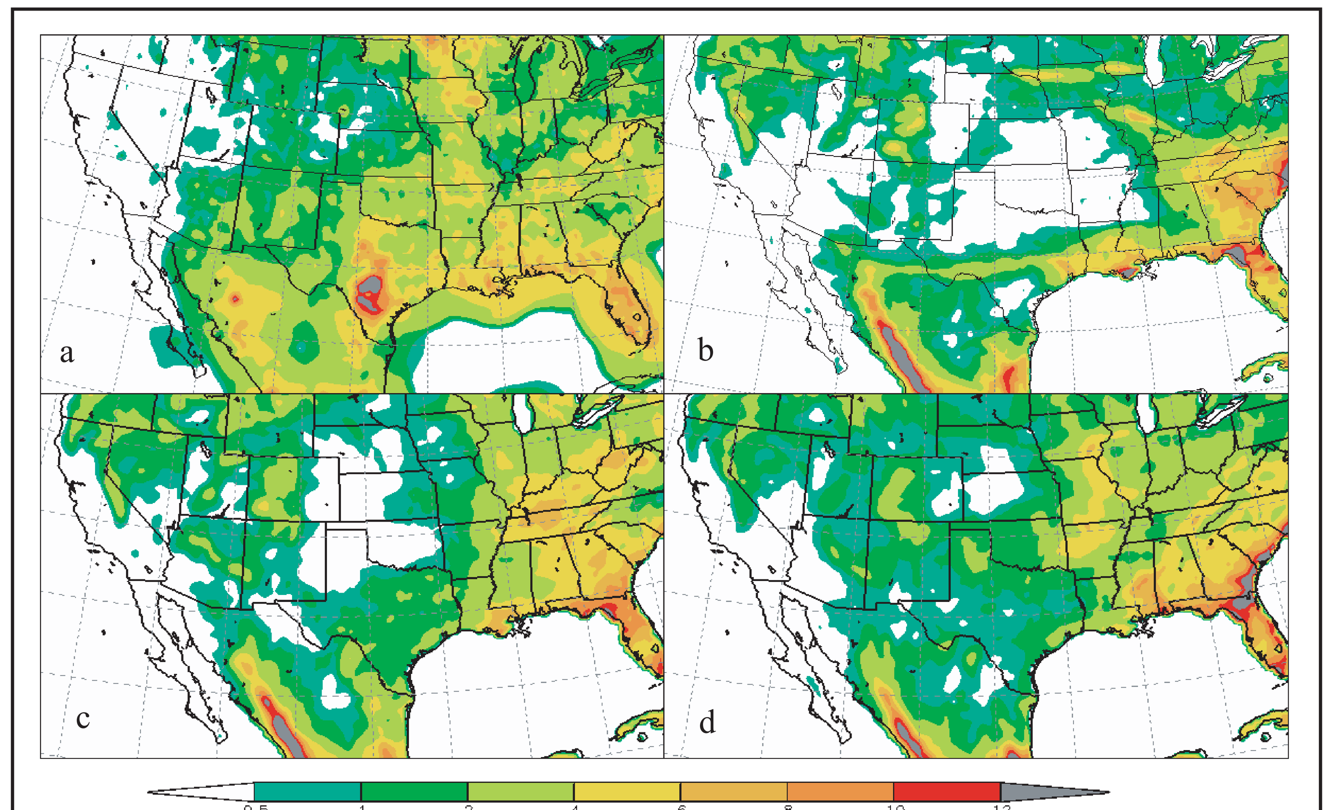

Figure 3. Precipitation mm/day in July 2002 (a. Observation, b. in the FIX experiment, c. in the DV experiment, d. in the GWDV experiment)

The inclusion of the dynamic vegetation improves the July precipitation in the Northern North American Monsoon System (NNAMS) region. The simulation is further improved with the SIMGM in the Noah LSM in the Southern Great Plains (SGP). The areas in which differences in simulated precipitation are the largest are the NNAMS and SGP regions.

Preliminary Results(2)

The most obvious effects of vegetation on precipitation take place in the NNAMS and the Central US. When the groundwater component is added to the Noah LSM, a possible role the groundwater plays in vegetation growth exists. Coupling groundwater component in the Noah LSM increased vegetation cover in the NNAMS and the Central US, especially in the SGP. The increase of vegetation cover agrees well with the increase of precipitation in these regions.

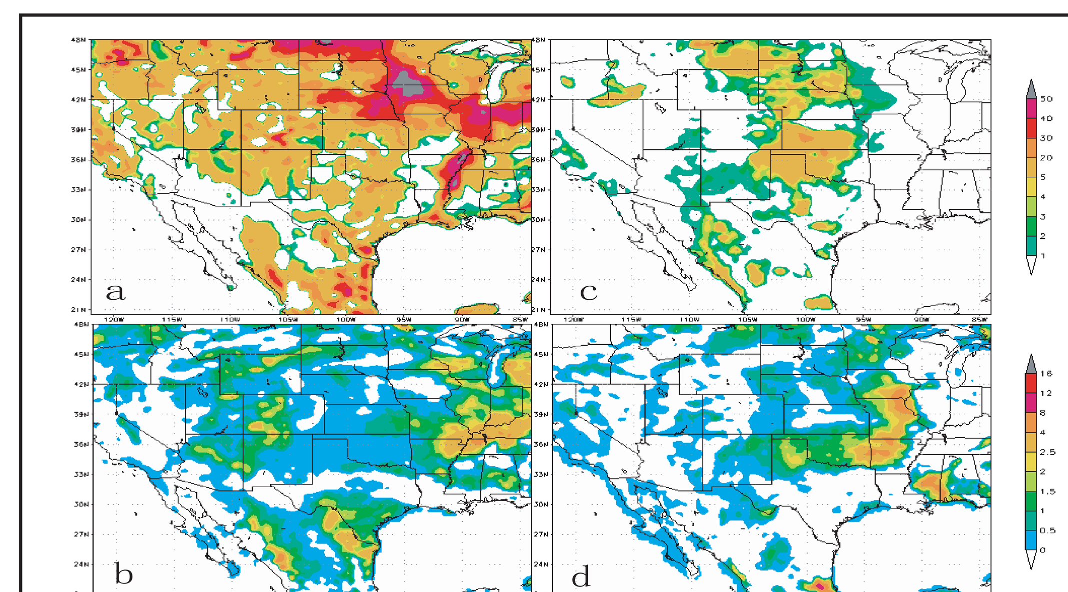

Figure 4. Differences of daily mean vegetation fraction (VF) % and precipitation (P) mm/day in July 2002 (a. VF in DV-FIX comparison, b. P in DV-FIX comparison, c. VF in GWDV-DV comparison, d. P in GWDV-DV comparison)

Preliminary Results(3)

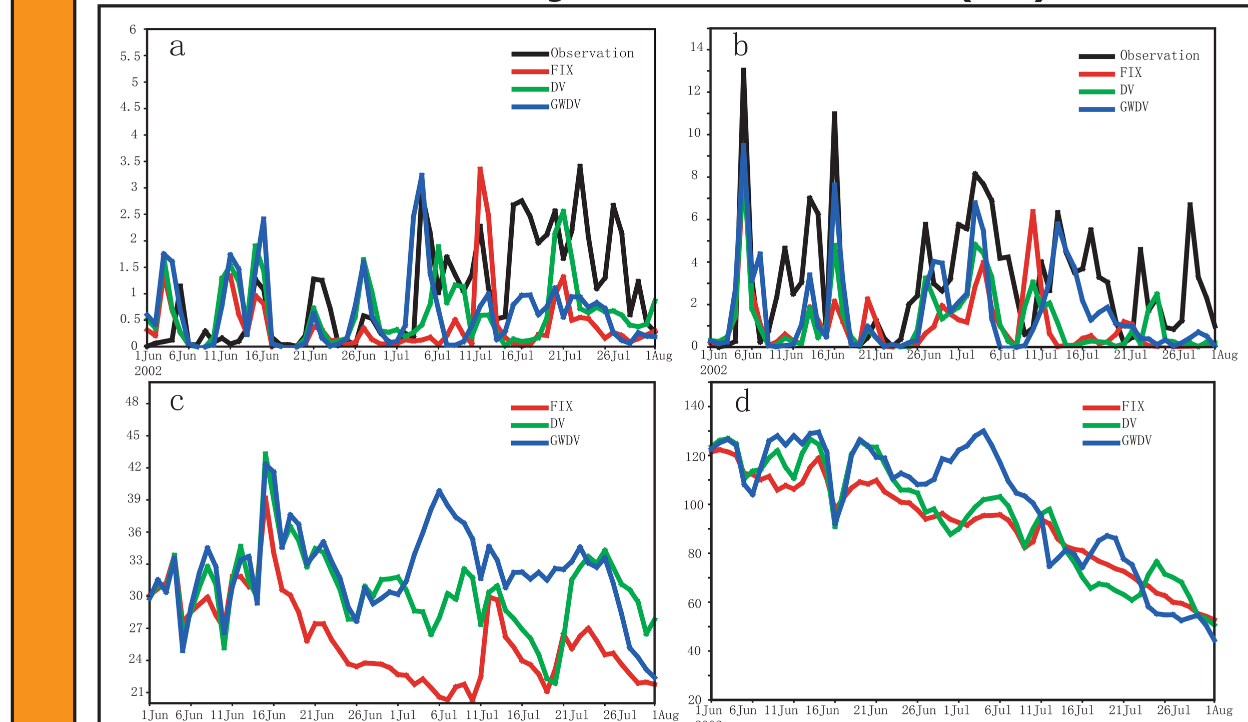

Figure 5. Time series of daily precipitation (P) mm and latent heat flux (LH) W/m^2 (a. P for NNAMS, b. P for SGP, c. LH for NNAMS, d. LH for SGP)

Using groundwater allows the model to capture more peak precipitation in the NNAMS and SGP areas, particularly in the SGP. The frequency pattern of simulated precipitation is consistent with observations. The latent heat flux immediately following the peak precipitation events is much higher than when groundwater is not used.

Conclusion and Ongoing Work

The inclusion of the dynamic vegetation improves the July precipitation in the Northern North American Monsoon System (NNAMS) region. The simulation is further improved with the SIMGM in Noah LSM and more peak precipitation in the NNAMS and Southern Great Plains are captured. But a more realistic water table depth is needed to initialize the groundwater model. Offline runs using Noah LSM coupled with groundwater will be carried out to obtain the initial water table depth for the WRF model.

References:

Dickinson, R. E., M. Shaikh, R. Bryant, et al., 1998: Interactive canopies for a climate model Journal of Climate, 11 (11), 2823-2836.
Niu, G.-Y., Z.-L. Yang, R.E. Dickinson, L.E. Gulden, and H. Su, 2006: A simple groundwater model for use in climate models - The impacts of groundwater dynamics on soil moisture and evapotranspiration, J. Geophys. Res. (Submitted).