Impact of a Dynamic Vegetation Parameterization in the Numerical Simulation of Recent Warm-Season Weather. Preliminary results.

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BACKGROUND AND MOTIVATION

•Several studies have demonstrated that significant feedbacks occur on seasonal time scales when vegetation is allowed to evolve as part of the dynamic modeling system (Lu et al, 2001, Eastman et al, 2001).

•Prescription of the vegetation phenology based on climatology can result in strong atmospheric biases in atmospheric variables and surface fluxes (i.e Xue et al 1996).

•The purpose of this NASA/NOAA GAPP project is to investigate the utility of applying a dynamic vegetation parameterization in an explicitly predictive framework.

•The coupled atmospheric biospheric modeling system GEMRAMS (Eastman et al, 2001) is used to assess that objective.

GEMTM is an eco-physiological process-based model that includes explicit C3 and C4 photosynthesis pathways to determine the assimilation of carbon (Fig 1). Assimilated is allocated among dynamically evolving plant biomass (roots, leaves, stems), which serves in conjunction with the RAMS land-surface scheme (LEAF-2) to determine the canopy resistances, and ultimately the fluxes of heat and water from the model land-surface. Meteorological inputs to LEAF-2/GEMTM are provided by the atmospheric inputs from RAMS (e.g., solar radiation, temperature, rainfall). The fully coupled GEMTM/LEAF2 and RAMS (hereafter GEMRAMS) (Fig 2) contains several options for the typical physical parameterizations of atmospheric modeling systems (e.g., radiation, convection, turbulence).

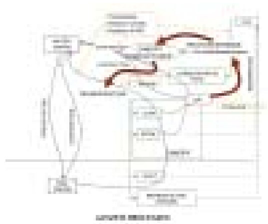

Figure 2. Illustration of the structure of the coupled model through the water (in blue lines) and carbon (in green lines) cycles. LAI and canopy conductance are the links between the two models. Canopy and soil temperature, canopy relative humidity, solar radiation, soil and plant water are some of the controls of the fluxes.

Fig. 1. Schematic of interactive GEMRAMS model

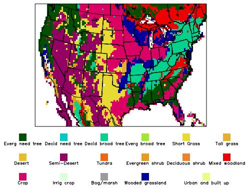

Fig. 3. GEMRAMS vegetation type description for LDAS domain.

EXPERIMENTAL DESIGN

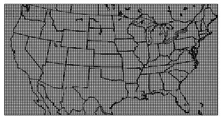

Fig. 3. GEMRAMS grid configuration to be used for regional model integrations for June-August of 2000 and 2001

•40x40 km grid spacing

•120x72 grid size

•Initial and lateral boundary conditions provided by NCEP/NCAR Reanalysis. In a next step, boundary conditions will be provided by a 10 member ensemble of the NCEP Seasonal Forecast Model (SFM).

•Simulation period: 15 May to 1 September 2000 and 2001. Results for June 2000 are presented here.

Initial conditions

Soil moisture initial conditions provided by Land Data Assimilation System (LDAS) models (Figure 4). Also, a sensitivity experiment was performed assuming a spatially homogenous percentage (50%) with respect to saturation level for each soil type

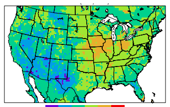

Fig. 4. LDAS volumetric soil moisture initial conditions (m^3m^3).

Leaf area index (LAI) initial conditions:
In GEMRAMS simulations, LAI conditions are derived from satellite observations. The new GIMMS NDVI 8kmx8km for the first 15 days of May of 2000 from NASA-Goddard is used, together with Sellers et al (1996) algorithm to compute initial LAI conditions (Figure 5).

In RAMS simulations, LAI is initialized based on a prescribed annual cycle for each vegetation type, based on time and latitude (Figure 6)

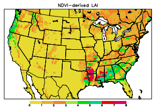

Fig. 5. Initial LAI (m^2m^{-2}) conditions for GEMRAMS runs, according to GIMMS NDVI data set and Sellers et al (1996) algorithm.

Initial conditions in LAI are very different between RAMS and GEMRAMS, with higher values for the RAMS default LAI (Fig 6). Also notice the relatively homogenous spatial distribution. Together with vegetation growth according to temperature and moisture conditions, this could have an impact in the simulated weather (Lu and Shuttleworth, 2002)

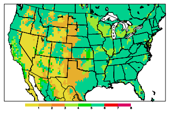

Fig. 6. Initial LAI (m^2m^{-2}) conditions for RAMS runs, default initial LAI*Greenfrac.

For each summer period, two simulations were completed, using RAMS and the coupled GEMRAMS. One of the differences between the two models is the way LAI is generated. In RAMS, LAI is computed based on a prescribed annual cycle for each vegetation type. In GEMRAMS, LAI is updated daily based on leaf biomass growth, according to temperature and moisture conditions, using a specific leaf area parameter for each vegetation type.

An updated version of GEMRAMS was implemented here. The purpose of these GEMRAMS runs is to have a preliminary evaluation of the behaviour of this updated version of the model (i. LAI, precipitation, surface fluxes) with respect to a "control" RAMS runs.

PRELIMINARY RESULTS

LAI

Figure 7 shows that vegetation growth occurred in most of the domain (in particular in the northern crop region), except for 2 small areas in the southern part corresponding to evergreen needleaf trees and crop vegetation types (Fig 3). Temperature and/or low soil moisture values could have been involved in these regions in causing conditions that eventually led to vegetation stress. More evaluation is needed to assess the vegetation behaviour in these cases.

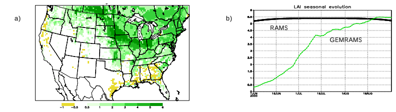

Fig. 7. LAI changes generated by GEMRAMS. a) Differences in LAI between September and June. b) Seasonal evolution of LAI, from RAMS and GEMRAMS for a grid point located in the northern crop region.

PRECIPITATION

Both GEMRAMS and RAMS capture the general precipitation pattern, as given by the observed precipitation (Fig 8d). However, in both cases simulated domain average precipitation was higher than the observations (Fig 8). A relatively low precipitation area compared to simulations is found in the Midwest. Parameter values for the Kain-Fritsch convection scheme and the weak interior nudging applied could be responsible for those anomalies (Castro and Pielke, 2004).
In terms of domain-average, RAMS simulated precipitation is higher than GEMRAMS. Positive differences appear in the center of the domain oriented approximately SW-NE. GEMRAMS appears to do a better job in the simulated precipitation in the center of Texas.

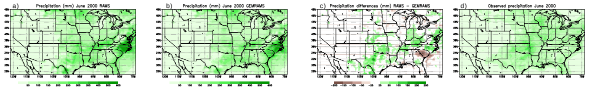

Fig. 8. RAMS (a), GEMRAMS (b), differences RAMS-GEMRAMS and observed (d) accumulated precipitation from the Observed US daily unified precipitation (mm) for June 2000.

SURFACE LATENT AND SENSIBLE HEAT FLUXES

Latent and sensible heat flux values (Fig 9 and 10) agree in general with results from NCEP reanalysis 2 (not shown). As expected from the precipitation results, domain-average sensible latent fluxes were higher for RAMS than for GEMRAMS, and the opposite is true for the sensible heat fluxes. Areas with high latent heat flux values correspond to the maximum precipitation areas. High sensible heat values are located in the western part of the domain, area dominated by semiarid conditions. The different seasonal evolution of vegetation and different LAI initial conditions between the two runs have had an impact on these surface fluxes.

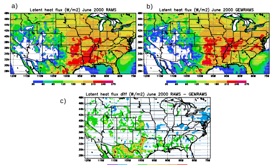

Fig. 9. RAMS (a), GEMRAMS (b) and difference RAMS-GEMRAMS (c) mean latent heat flux (Wm^{-2}) for June 2000.

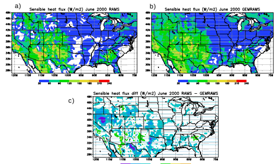

Fig. 10. Same as in Fig. 9 except for sensible heat flux (Wm^{-2}).

Simulations for another year with different precipitation and temperature conditions should provide insights into the atmosphere-biosphere feedbacks between different seasonal vegetation evolution and atmospheric conditions. The goal is to assess if skilful predictions of vegetation phenology results from applying GEMRAMS using diagnosed (NCEP Reanalysis) and using predicted lateral boundary conditions. Also, does this added freedom for vegetation to respond to weather result in more skillful seasonal weather predictions than when vegetation phenology is prescribed (i.e. the RAMS runs)?

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