Numerical Simulations Of Recent Warm-season Weather: Impacts Of A Dynamic Vegetation Parameterization

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1. Background and objectives

- 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; Lu and Shuttleworth 2002).

- The impact of dynamic vegetation on ensemble dynamical forecasts of recent warm-season weather over the continental United States was assessed using the Regional Atmospheric Modeling System (RAMS) and a fully coupled dynamic vegetation version of RAMS, the General Energy and Mass Transfer–RAMS (GEMRAMS).

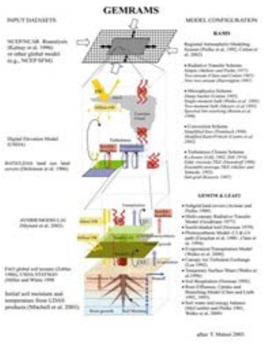

Fig. 1. Schematic of GEMRAMS model

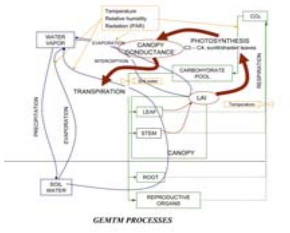

Fig. 2. Illustration of the structure of the coupled model through the water (in blue lines) and carbon (in green lines) cycles. Leaf area index (LAI) and canopy conductance are the links between the two cycles. Canopy and soil temperature, canopy relative humidity, solar radiation, soil and plant water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

The fully coupled GEMRAMS (Fig 1) contains several options for the typical physical parameterizations of atmospheric modeling systems (e.g., radiation, convection, turbulence). The soil-vegetation-atmosphere scheme includes parameterization of canopy conductance based on explicit C_3 and C_4 photosynthesis and dynamically evolving plant biomass (root, leaf), provided by the General Energy and Mass Transfer, GEMTM (Fig. 2). The original RAMS land-surface scheme (LEAF2) provides the heat and water fluxes.

2. Experimental design

- Two 10-member ensembles were produced for the June-August periods of both 2000 and 2001. For each period, one of the members used the standard RAMS, and the other the GEMRAMS version.

- Initial and lateral boundary conditions for the regional model domain for each June-August period were provided by a 10-member global ensemble reforecast produced with the NCEP Seasonal Forecast Model (SFM), which was the operational global dynamical forecast system in use by the Climate Prediction Center during 2000-2001.

- For each period, a pair of "baseline" simulations (not forecasts), one with GEMRAMS and one with RAMS, were created using the NCEP Reanalysis as initial and lateral boundary conditions.

- In this experimental design, the impact of dynamic vegetation in ensemble *forecasts* on a regional domain can be assessed against the use of dynamic vegetation in a *simulation*, produced with a "perfect" global forecast (i.e., Reanalysis).

Soil moisture initial conditions were provided by the Land Data Assimilation System (LDAS) model. In GEMRAMS simulations, LAI initial conditions are derived from satellite observations. The new GIMMS-NASA NDVI 8 km x 8 km (Tucker et al. 2005) for June 2000 and 2001 is used to compute initial LAI conditions. In RAMS simulations, LAI is initialized based on a prescribed annual cycle for each vegetation type, based on date and latitude.

3. Results

3.1 Precipitation: Observed vs. simulated

Both GEMRAMS and RAMS capture the general precipitation pattern, as given by the observed precipitation (Fig 5). However, in both cases simulated domain averaged precipitation was higher than the observations, in particular over the southeast. Precipitation in the regional ensembles was largely controlled by the driving large-scale forcing. A large precipitation bias exists over the regional domain in the NCEP reanalysis and SFM themselves that it is amplified in the RAMS and GEMRAMS simulations. Similar results are found for July 2000 and 2001 (not shown).

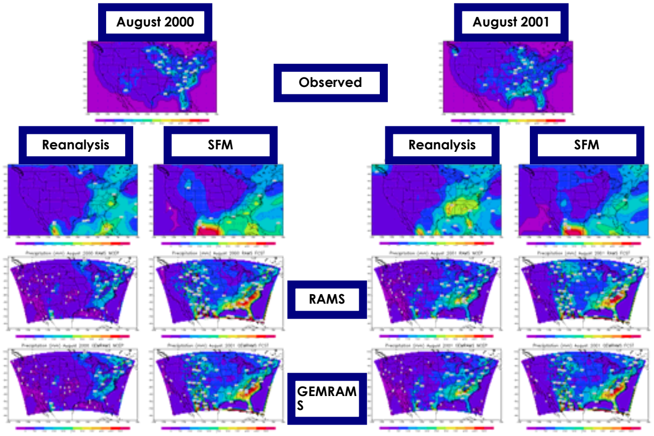

Fig. 5. Observed (top) US daily unified precipitation (mm) for August 2000 (left) and 2001(right); for each month, simulated precipitation by RAMS and GEMRAMS, with NCEP reanalysis (left) and SFM (right) as boundary conditions. Precipitation from NCEP reanalysis and from SFM is shown on the second row.

3.2 Precipitation: SFM ensemble spread

The areas with the largest spread of the ensemble members tended to coincide with the areas with the largest biases, over the SE, but also over the semiarid areas on the W.

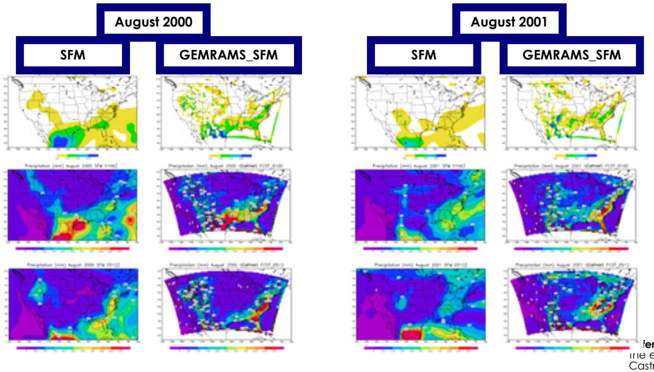

Fig. 6. Spread of monthly precipitation of the 10 ensemble members for August 2000 (left) and 2001(right); for each month, spread from SFM itself (left) and from GEMRAMS-SFM simulations are shown. Also shown as an example are the simulated precipitation from SFM and GEMRAMS-SFM for two ensemble members.

3. Results *(continuation)*

3.3 Surface latent and sensible heat fluxes

As expected from the precipitation results, simulated daytime averaged latent heat flux (LH) was higher for RAMS/GEMRAMS-SFM than for RAMS/GEMRAMS-Reanalysis. Areas with high LH values coincide with the maximum precipitation areas. LH differences between RAMS and GEMRAMS simulations tended to be more noticeable over the SE, particularly when SFM boundary conditions were used. Lowest LH values are located in the western part of the domain, an area dominated by semiarid conditions. Similar results are found for sensible heat fluxes (SH); see Fig. 8.

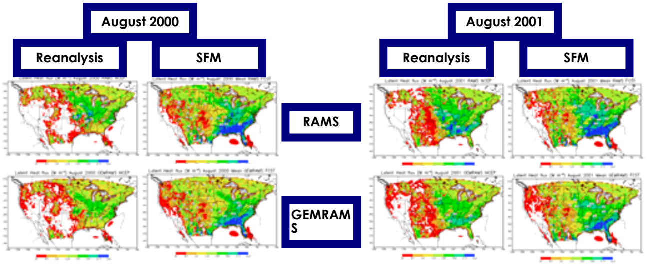

Fig. 7. RAMS (top) and GEMRAMS (bottom) daytime averaged simulated latent heat flux (W m^{-2}) for August 2000 and 2001; for each month, simulated LH when NCEP reanalysis (left) and SFM (right) were the lateral boundary conditions.

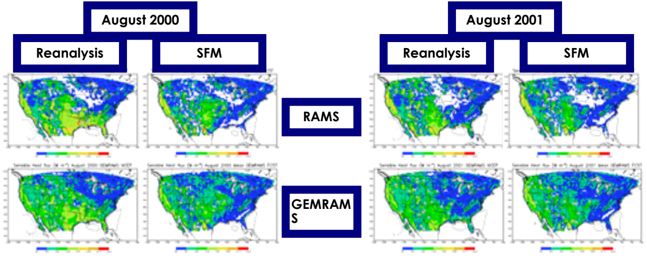

Fig. 8. RAMS (top) and GEMRAMS (bottom) daytime-averaged simulated sensible heat flux (W m^{-2}) for August 2000 and 2001; for each month, simulated SH when NCEP reanalysis (left) and SFM (right) were the lateral boundary conditions.

3.4 Surface latent and sensible heat fluxes: SFM-GEMRAMS spread

The areas with the largest LH spread of the ensemble members tended to coincide with wet-dry transition areas in the Midwest and also over the driest areas of the west. Spread values tended to be higher for LH than for SH.

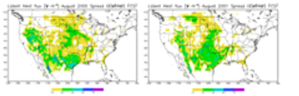

Fig. 9. Spread of LH for GEMRAMS-SFM simulations (W m^{-2}).

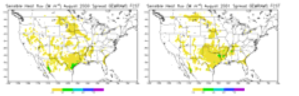

Fig. 10. Spread of SH for GEMRAMS-SFM simulations (W m^{-2}).

4. Conclusions

Precipitation was largely dominated by the large-scale forcing. Large precipitation biases exist in the Reanalysis and in SFM themselves. Thus the use of a regional climate model to dynamically downscale from a global reanalysis only adds value when the global model accurately represents the observed atmospheric conditions. For the time periods and model set-up considered in this work, under an explicitly predictive model configuration, the use of a more complex parameterization of land-surface processes with dynamic vegetation added little value to the skill of the seasonal forecast over the regional domain since it was dominated by the larger-scale model results. This conclusion is consistent with that of Castro et al. (2005) in which lateral boundary conditions have a major role in the accuracy of regional model simulations.

ferences: Beltrán, A., 2005, Ph.D. Dissertation: Using a coupled atmospheric-biospheric modeling system (GEMRAMS) to model the effects of land-use/land-cover changes on the near-surface atmosphere. Dept. of Atmos. Sci., CO State University, 186 pp.
Castro et al., 2005: Dynamical downscaling: Assessment of value retained and added using the Regional Atmospheric Modeling System (RAMS). J. Geophys. Res. - Atmospheres, 110, No. D5, D05108, doi:10.1029/2004JD004721.
Eastman et al. 2001: The effects of CO2 and landscape change using a coupled plant and meteorological model. Global Change Bio., 7, 797-815.
Lu, L., and W. J. Shuttleworth, 2002. Incorporating NDVI-Derived LAI into the Climate Version of RAMS and Its Impact on Regional Climate. *J. Hydrometeor.*, **3**, 347-362.
Lu et al. 2001: Implementation of a two-way interactive atmospheric and ecological model and its application to the central United States. J. Climate, 14, 900-919.
Sellers et al. 1996. A Revised Land Surface Parameterization (SiB2) for Atmospheric GCMs. Part II: The generation of global fields of terrestrial biophysical parameters from satellite data. *J. Climate*, **9**, 706-737.
Tucker et al. 2005: An extended AVHRR 8-km NDVI data set compatible with MODIS and SPOT vegetation NDVI Data. *I.J. Rem. Sen.*, **26**, 4485-4498.

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