Land-atmosphere interactions in semi-arid areas: Examples from Shortgrass Steppe and Jornada LTER sites

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Observations and modeling results have shown that land-use practices have affected regional climate in the Shortgrass Steppe (SGS) region through their influence on energy partitioning and balance.

A coupled atmospheric-vegetation model constitutes an appropriate tool to study the interactions and feedbacks between the vegetation, soil, and the atmosphere. The Regional Atmospheric Modeling System coupled with a plant-scale model GEMRAMS is used to quantify the potential impact of these land-use practices on mesoscale climatic patterns at the SGS LTER site.

At the Jornada LTER, the conversion from the natural landscape of grasses to the current landscape of shrubs has been shown with the high resolution model version of GEMRAMS to result in significant changes in surface heat and moisture fluxes. The same modeling approach carried out in Jornada will be used in the SGS LTER site, which includes a detailed vegetation and soil maps and parameters associated to each vegetation type, like albedo, and soil characteristics.

Some of that data will be measured in the fields while other will be put together from different sources and earlier measurements of CO2 and water and energy fluxes carried out at the SGS.

Measurements of CO2 and water fluxes will also be used to validate the performance of the coupled modeling system GEMRAMS.

The Regional Atmospheric Modeling System (RAMS) RAMS is a general-purpose, atmosphere-simulation model that includes the equations of motion, heat, moisture, and continuity in a terrain-following coordinate system. The land-surface processes are represented by LEAF-2, the Land Ecosystem-Airflow Feedback model (Wakimoto et al. 2000). LEAF-2 components (canopy air, vegetation, snow, soil, and permanent water bodies) exchange heat and moisture between them and the atmosphere. Temperature and water content are predicted for the vegetation, soil, and air above the canopy. Turbulent and radiative fluxes, precipitation, and transpiration are also predicted.

The general energy and mass transport model (GEMTM) is an ecophysiological process-based model, that can be used to simulate the dynamic interactions between the atmosphere and the growing canopy (Chen and Coughenour; 1994). It comprises a plant and root submodel, and a detailed canopy radiation transfer.

The gross daily photosynthesis is calculated considering C3 and C4 photosynthetic pathways. Canopy photosynthesis is computed using the sulk and shaded leaf fractions of the canopy. Some portion is respirated. The available carbon pool is then allocated to leaves, stems, roots, and reproductive organs, depending on temperature and water conditions.

The total leaf carbon is related to the Leaf Area Index (LAI) by the vegetation-prescribed specific leaf area. Water and CO2 exchange between the plant and the atmosphere are regulated by the stomatal conductance, computed using the Ball-Berry model.

Schematic of how atmospheric (i.e., water vapor, temperature) and vegetation (i.e., leaf, root) variables interact in the coupled GEMRAMS modeling system. The atmospheric variables (in yellow) affect water losses to the atmosphere and assimilation of CO2. The variables in blue are included in a soil-water submodel. The plant variables (in green) are simulated by the plant submodel. Soil water and temperature controls biomass production and CO2 losses to the atmosphere, leaf area index (LAI) and stomatal conductance (in brown) are fed back to the atmospheric submodel, controlling transpiration.

Comparison of observed (open symbols) and simulated responses (closed symbols and line) of net assimilation rate (An) to a) internal CO2 concentration (Ci), b) photosynthetic active radiation (PAR), and c) temperature for Picea pungens smithii. Observed data from LeCain et al. (2003).

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