**Center for Multiscale Modeling of Atmospheric Processes: Land-Atmosphere Interaction**

NSF Office of Integrated Activities

2006 – 2016

Exchanges of heat, water, momentum, and trace gases are important determinants of atmospheric circulation and climate. These exchanges modulate surface climates and have direct impacts on human welfare, and are in turn strongly affected by human intervention such as land-use change, irrigation, and other management. It has long been recognized that mesoscale circulations driven by spatially-organized landscapepaters (e.g., agriculture, urban/suburban development, topography) can organize clouds and precipitation at regional scales (e.g., Avissar and Pielke, 1989;Schar et al, 1999; Weaver et al, 2002; Silva Dias et al, 2002). Regional field experiments investigating these interactions and the numerical experiments that hav been used to interpret them have been confined to limited areas and require specification of lateral boundary conditions from larger-scale models or analyses. We propose to extend these analyses to the global scale using the multiscale moddleing environment provided by CMMAP.

Current state-of-the-science land-atmosphere coupling in climate models considers heterogeneity at the land surface using non-spatially-explicit “tiles” to represent fractional areas with different states or parameters that all share the same overlying atmosphere: that is, they all share the same weather (e.g., Dickinson et al, 2006). A separate instance of the parameterized land surface is integrated once for each “tile” using forcing (e.g., radiation, temperature, precipitation) from the overlying atmosphere, and the resulting fluxes of heat, water, momentum, and carbon are weighted by the subgrid-scale areas of each tile before being passed back to the atmospheric model as a grid-scale mean. Subgrid-scale tiles may be organized by plant functional type (Bonan et al, 2002), or by hydrologic units such as catchments Koster et al, 2000; Chen and Kumar, 2001; ) or the depth of the water table (e.g., Wood et al, 1992, Gedney et al, 2003; Decharme and Douville, 2006). Approaches to subgrid-scale heterogeneity in global models have focused either on variations in vegetation or in topographically-distributed soil moisture, but none have considered covariance of these effects. Furthermore, although it is clear from field experiments and from numerical experiments with limited-area models that these variations affect precipitation (e.g., Schar et al, 1999, Silva Dias et al, 2002), it has hetetofore been impossible to consider the feedback between heterogeneous landscapes and the overlying organization of clouds and precipitation.

Early experiments with the prototype MMF turned the logic of current climate models upside down: we simulated many interacting atmospheric columns in the SAM that interacted with only a single underlying land surface. In the second phase of CMMAP, we will explore the interactions between heterogeneous land surface vegetation, topography, soil moisture, and snowpack with the circulation, radiation, and phydrologic cycle of the overlying heterogeneous atmospheer, at ultiple scales. These new experiments will be focused on two goals: (1) to better understand the role of land-atmosphere coupling in the current climate; and (2) to improve quantitative treatment of the roles of biogeochemistry and land-use in anthropogenic cliate change.

##### Land-atmosphere coupling in current climate, hydrology, and te carbon cycle

We have coupled the Simple Biosphere model (SiB, Sellers et al, 1996; Baker et al, 2008; Denning et al, 2008; ) to the cloud-resolvingmodel (SAM) used in the prototype MMF. This allows treatment of heterogeneous clouds, radiation,precipitation, infiltration, runoff, soil moisture, and evapotranspiration within a single CAM grid column. Preliminary numerical experiments with the coupled model at the ARM Southern Great Plains site show improved timing of precipitation and simulation of surface fluxes than in the more traditional couopling mode. We will further explore this coupling using the coupled model to study boundary-layer turbulence and clouds in a Giga-LES experiment over land.

Extending the heterogeneous land surface to global simulations in the prototype MMF will require two innovations: (1) topographic variations within a single atmospheric model will have to be simulated in such a way that energy, water, mass, and other key quantitiareaes can be conserved; and (2) the heterogeneous land surface will have to be “sampled” and parameterized under each column of the global model.These problems are not independent, because vegetation type, soil moisture, and topography are highly correlated. Furthermore, representation of mesoscale circulations and fluxes will require that not only the fractional areas but also the covariance length scales (i.e., the “clumpiness”) of the different sub-areas in each column be represented as well. We will experiment with a combined representation of vegetation and hydrological variations. Sellers et al (2007) have shown that complex distributions of soil moisture can be represented with a fairly limited sample.

The global coupled model will be applied to studies of the impact of land-atmosphere coupling in current climate in the western US (with special emphasis on topographic control of snow cover and drought stress), in monsoon climates (emphasizing coupled onset and proagation), and in the Amazon (emphasizing fine-scale deforestation). Previous experiments have demonstrated the sensitivity of precipitation and circualtion in the Amazon to the treatment of soil moisture dynamics (Baker et al, 2008, Harper et al, 2009). Field experiments and numerical experiments with limited area models have shown that fine-scale deforestation and land-use change affects organization of precipitation in that region (Silva Dias et al, 2002).Short expermments with the GCRM will be used to evaluate the multiscale coupled model of land-atmosphere interactions.

Image

Full Proposal

Annual Report 2012

Publications

Students