MODELING THE EFFECTS OF FINE-SCALE SOIL MOISTURE AND CANOPY HETEROGENEITIES ON ENERGY AND SOIL WATER FLUXES IN A TEMPERATE MIXED FOREST

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Land surface is heterogeneous at different scales and the coupling mechanisms between fine-scale soil moisture, vegetation and energy fluxes are strongly non-linear. Current land surface models usually parameterize surface vegetation heterogeneities as aggregated patches with uniform properties. Lumped representation of fine-scale surface variations may produce biased domain-scale energy fluxes, affecting predictive capability of a land surface model. This study aims to better represent the scale impact in the atmosphere-biosphere-hydrosphere interactions. A high-resolution and physically-based ecohydrological model is used as a data integration tool to upscale the dynamics resulting from spatially variable tree-scale canopy and soil moisture to the domain-scale. The modeling work is conducted for a spatially heterogeneous temperate mixed forest located near the Ameriflux tower at the University of Michigan Biological Station (UMBS). Within a small domain (~2 km2), energy fluxes and soil moisture dynamics are simulated at the tree-scale resolution. The modeling results are validated with flux data observed at the AmeriFlux tower and monitored soil moisture data of a 3-m deep profile.

To examine the interactions between heterogeneous canopy and soil moisture and their contributions to the domain-scale energy fluxes, several scenarios of tree-scale heterogeneous canopy and initial soil moisture with the same mean states were designed and used in various permutations. The heterogeneous canopy scenarios account for the spatially distributed photosynthesis (and thus the stomatal conductance), the aerodynamic and leaf boundary layer resistances, as well as the differential radiation forcing due to exposed tall trees and shaded short trees. A 'big-leaf' simulation case with the uniform canopy and initial soil moisture is also used to infer the effects of coarse-scale averaging.

For simulation cases initialized with different spatial soil moisture patterns, canopy exerted control on the ultimate, no w ater-stress distribution of soil moisture that approached a pattern inversely related to the canopy biomass. This pattern can be temporarily wiped out if water stress conditions occur. The differential radiation forcing reduces the domain-scale water stress but also reduces the domain-scale transpiration amount, by altering tree-scale water constraints and by inducing tree-scale radiation saturation effects. The simulated spatial soil moisture in all cases tends to be less variable than observed in the field. Since heterogeneous canopy structures create tree-scale microclimate environment that affect transfer of w ater and heat admixtures, the current model is coupled off-line with a high resolution large-eddy simulation (LES) model and use the resolved three-dimensional profiles of microclimate as inputs to better simulate the energy fluxes over the domain.