Influences of Boundary Layer Flow on Vegetation-Air Exchanges of Energy, Water and Carbon Dioxide

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ABSTRACT

Accurate quantification of vegetation-air exchange is essential to climate modeling and ecological sciences. Despite decades of research, contemporary methods of flux measurement, which are designed in a 1D framework, still suffer from an outstanding problem: measured fluxes of latent and sensible heat do not add up to the available energy. The problem presents a dilemma for climate modelers, because in the models energy must be conserved, and for the ecological community because contrary to similarity reasoning, few researchers adjust their measured net ecosystem production to account for the imbalance. Further compounding the problem is the fact that large scale weather and climate models also use 1D representation of land surface processes. It is important to quantify the extent to which the 1D approaches misrepresent true ecosystem-atmosphere interactions.

The objective of this project is to establish a mechanistic understanding of the interplay among flow heterogeneity in the atmospheric boundary layer (ABL), land surface heterogeneity, and the vegetation-air fluxes of energy, water and CO_2. The project will investigate mechanisms by which mesoscale motions in the ABL influence vegetation-air exchange. It will also quantify the influence of heterogeneity on predictions by 1D column models used in regional and global scale climate models. It is hypothesized that two important ABL processes – entrainment and flow heterogeneity – cause biases in the observational and model estimates of vegetation-air exchange and that the degree of bias is different for active (heat and water) and passive (CO_2) scalars.

The project will deploy the NCAR's large eddy simulation (LES) model coupled to the NOAH land surface model as the key methodology. Three specific tasks are planned: 1) The LES will be fully coupled with NOAH; 2) The coupled LES-NOAH model will be used to investigate energy and carbon balances in the 1D framework of conventional surface flux measurements; 3) Predictions from current parameterizations within regional and global climate models will be evaluated against the LES-NOAH output. The project will be administrated by Yale University. The PI will take a one-year sabbatical leave at NCAR, to be hosted by his collaborator Patton, to undertake part of the modeling work. Through the completion of these tasks, the project will establish the role of entrainment on tower-measured CO_2 fluxes and determine whether they are contaminated by an imbalance problem. It will also determine biases in the ABL transport from 1D column models when assimilating measurements taken in the presence of heterogeneity.