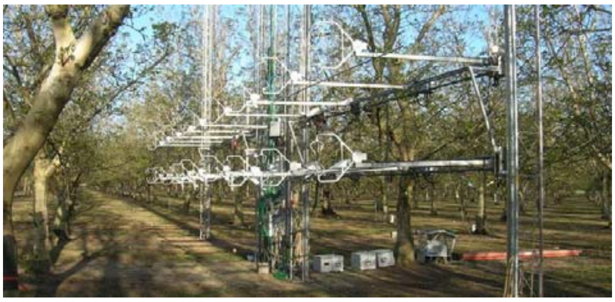
The coupled carbon-water cycle in the terrestrial biosphere

Gabriel Katul, Nicholas School of the Environment, Duke University, Durham, NC 27708, USA.

Topic 3: Up-scaling from the leaf to the canopy using radiative transfer schemes and canopy turbulence theories.



Up to this point, quantifying the leaf exchange of carbon dioxide and water vapor between leaves and their local environment (hereafter referred to as microenvironment) assumed that the micro-climate is imposed upon the canopy. However, a two-way interaction approximates much better the natural reality given that the microenvironment exerts controls over scalar exchange at the leaf surface and leaves have some capacity to regulate their own microenvironment through stomatal opening and closure. This two-way interaction is further complicated by the vertical distribution of foliage within the canopy, leading to significant vertical gradients in the radiation environment and airflow regimes. The intrinsic non-linearity in leaf physiological responses (e.g. leaf-level photosynthesis and transpiration) covered in topic 2 to radiation further exasperates this difficulty. To upscale these results along a heterogeneous micro-climate kernel, basic concepts about the structure of turbulence inside canopies are reviewed. We build a canopy structure and leaf-equations into canopy turbulence formulations as 'closure' schemes with some comments of how to formally do that via volume averaging of multiply-connected spaces. The resulting system allows a formal scaling from leaf to canopy.

Reference: Raupach, M.R., and A. S. Thom, 1981, 1981, Turbulence in and above Plant Canopies, *Annual Review of Fluid Mechanics*, 13: 97-129

Group Project: We will expand the analytical model for CO2 described in Siqueira and Katul (2010) to include water vapor and ozone uptake, and compare these model calculations with a number of numerical model calculations, including simplified higher-order closure ones such as the ones described in Katul and Albertson (1999) as well as a wide range of data sets.

Extra Material: Matlab code of variants of these models will be supplied as a starting point.

Added Refs:

Siqueira, M.B., and G.G. Katul, 2010, An analytical model for the distribution of CO2 sources and sinks, fluxes, and mean concentration within the roughness sub-layer, *Boundary-Layer Meteorology*, doi 10.1007/s10546-009-9453-8

Katul, G.G., and J.D. Albertson, 1999, Modeling CO2 sources, sinks, and fluxes within a forest canopy, *Journal of Geophysical Research*, 104, 6081-6091.