Incorporation of plant physiology and subsoil geophysics for linking water, energy and carbon fluxes in the Soil-Plant-Atmosphere Continuum

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Modelling the exchange of water, energy, and carbon between the land surface and the atmosphere remains a fundamental challenge in the Earth Critical Zone science, particularly in water-limited as well as heterogeneous ecosystems, mostly due to the difficulty of characterizing processes that span multiple spatial and temporal scales within the Soil–Plant–Atmosphere Continuum (SPAC). In this talk we will present on one side the recent advances in the Two-Source Energy Balance modeling framework that accounts for both the horizontal and vertical canopy heterogeneity in radiation partitioning as well as in the turbulent exchange of heat and momentum. On the other hand we present ongoing experiments that combine plant physiological measurements with non-invasive subsoil geophysical surveys to improve the representation of ecohydrological processes across the SPAC. Electrical resistivity tomography (ERT) and electromagnetic induction (EMI) methods are employed to characterize subsoil moisture dynamics and soil physical properties, while measurements of stomatal conductance and leaf water potential provided physiologically-grounded constraints on plant water uptake. These observations have thus the potential of being assimilated into a coupled land-surface model to partition evapotranspiration into its soil evaporation and plant transpiration components, and to resolve the feedback between carbon assimilation and hydraulic stress under contrasting moisture regimes. Preliminary results demonstrate that integrating subsoil structural information significantly reduces uncertainty in modeled root water uptake and improves the simulation of latent heat flux. The proposed framework could advance our mechanistic understanding of SPAC functioning and offers a transferable methodology for improving land-surface parametrization in weather and hydrological models.