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Integrated Imaging of Above and Below Ground Properties and their Interactions

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Watershed systems are characterized by extreme hydrological and pedological heterogeneity that directly impacts the local biotic activity, making plant communities extremely heterogeneous. The ability to characterize such heterogeneity and quantify its coupling with topographic and soil properties is extremely important to predict watershed functioning and responses to hydrological perturbations, such as droughts, floods, and early snowmelt.

In this study, we exploit advanced geophysical and remote sensing (RS) techniques to improve the identification and the understanding of interactions between plant community distribution and dynamic and subsurface properties at various spatial and temporal scales. Data fusion and analysis is complemented by data-constrained, process-based simulation of the influence of soil, vegetation and geomorphic characteristic on hydrological fluxes. This framework is applied in the East River watershed in Colorado, which is a representative Upper Colorado Basin headwaters catchment. We evaluate linkages between physical properties, metrics extracted from digital elevation models and vegetation spectral signature using airborne datasets and multiple ground- and drone-based surveys. We perform our investigation during the growing season in a 500 by 500 m hillslope-floodplain subsystem of the watershed.

First, the data integration shows that geomorphological and soil property spatial variations exert a strong influence on plant community distribution. Second, the temporal variability in the relationship between plant vigor and soil electrical conductivity indicates the significant control of early spring soil condition on plant growth. Further, the ingestion of such diverse data into a process-based data-model assimilation framework enables improvements in the estimation of the hydraulic parameters as well as hydrological and thermal fluxes (incl., evapotranspiration, infiltration). The estimated flux responses indicate how short duration snowmelt events exert a significant influence on water recharge in vadose zone and aquifer. Moreover, the comparison between data and process-based simulation reveals significant potential for improving the estimation of fluxes and their feedback within and between vegetation distribution and soil properties.

Overall, results show that integration of RS data with geophysical measurements provides an unprecedented window into critical zone interactions, revealing significant below- and above-ground co-dynamics. Ongoing research is focusing on the estimation of plant biogeochemical and soil physical and geochemical properties from plant spectral signatures, and an approach to transfer information about the landscape organization and connectivity obtained from RS to larger scales. The developed approaches as well as those currently under investigation are expected to greatly improve our ability to constrain multi-scale, multi-physics hydro-biogeochemical simulations of mountainous watershed responses to hydrological perturbations.