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Spatiotemporal Variability of Ecohydrological Responses to Climate Perturbations in Headwater Watersheds

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Snow-dominated headwater catchments are critical for water resources throughout the world; particularly in the Western US. Under climate change, the temperature increase is known to be amplified in mountainous regions where a large amount of snow is stored. Over the last three decades, there have been many studies reporting changing snowpack conditions and subsequent shifts in plant communities in headwater catchments. However, observational studies are quite limited to quantify how these changes – in temperature, snowpack, and plant communities – affect watershed eco-hydrological responses as well as riverine exports that fuel downstream ecosystems.

This study presents a data-driven multi-scale approach to quantify the effect of exogenous climate drivers on snowmelt, plant phenology, and streamflow dynamics in a headwater watershed, by examining their inter-annual variability and trends over the last 30 years. Motivating our work is the long-term observation of decreasing nitrogen concentrations and fluxes over the past 30 years despite large variability in temperature as well as precipitation and discharge, suggesting a systematic change in watershed scale ecosystem functioning. At the East River, Colorado, where long-term historical changes have been reported, we use a variety of long-term spatially extensive datasets (incl., snow, climate, streamflow, water quality, plant productivity (NDVI), elevation, vegetation) to guide hypothesis development. Results indicate that temperature – particularly spring temperature – has a significant control not only on the *timing* of snowmelt, plant NDVI, and peak flow, but also on the *magnitude* of peak NDVI, peak flow, annual discharge, and river nutrient concentrations. High correlation among June temperature, peak NDVI and annual discharge suggests that spring evapotranspiration limits streamflow volume. Nitrogen and Carbon fluxes, when assessed along the upstream to downstream flow-path, show scaling behavior with watershed characteristics such as drainage area and peak flow. Our results indicate that this observed scaling behavior is affected by the antecedent winter dry or wet conditions of the watershed as a whole. In headwater watersheds above 8,000ft elevation, our yearly flux data show a significant correlation with the average yearly watershed scale NDVI, indicating a biogeochemical link between climate, vegetative response, and watershed exports. Our data-driven approach provides powerful tools that enable the linkage between watershed behaviors of importance such as total flow and nutrient exports to predict future watershed responses to climate change.