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Untangling the role of elevation, aspect, and vegetation type on ecohydrological dynamics along a climate gradient in the Alps

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Vegetation dynamics and performance are strongly influenced by environmental conditions. Specifically, light, precipitation, and air temperature exert a predominant role. These climatic variables covariate with elevation and aspect in areas of complex terrain. Quantification of specific elevation and aspect effects on vegetation productivity and mass and energy fluxes can lead to a better understating of environment-driven distribution of vegetation and parsimonious up-scaling parameterizations useful in hydrological applications. A detailed characterization of climatic differences with elevation is however a daunting task. In this study, two synthetic climate gradients, constructed using hourly meteorological data and a stochastic weather generator, AWE-GEN, are used to force a mechanistic ecohydrological model, Tethys-Chloris, and quantify energy, carbon, and water fluxes for three generic Plant Functional Types (PFTs). One gradient is representative of a dry, sheltered alpine valley (Valais), whereas the other one characterizes a wet, exposed mountain side (Bernese Oberland). Thirty year long time series of cross-correlated precipitation, air temperature, relative humidity, wind speed, solar radiation, and atmospheric pressure for elevation bands from 500 up to 3500 m a.s.l. are generated to represent the climatic differences. The incoming radiation is successively recalculated for different combinations of aspect and slope. Under these specific climatic forcing conditions, the response of deciduous and evergreen trees, and grass typical of the Alpine system is investigated. The parameterization of the ecohydrological model was tested to reproduce vegetation productivity and energy fluxes for several locations in an Alpine climate or similar conditions (Fluxnet dataset) and to correctly simulate snowpack dynamics for forested and open sites worldwide (Snowmip-2 dataset). The three PFTs evolve at different elevations and aspects for dry and wet conditions. Results indicate that differences in hydrological fluxes across PFTs are more evident for the dry, water-limited scenario, rather than for the wet scenario. The optimum for vegetation productivity shifts from low elevations of 500-1000 m in wet conditions to higher elevations (of about 1800-2200 m) for the dry altitudinal gradient. By intercepting snow and shading ground surface, PFTs affect differently snow cover distribution and seasonal duration. The overall role of elevation was found to be predominant when compared to the role of aspect, regardless of the climate type. Nonetheless, we speculate that this is not always the case and the role of aspect, or contributing area might become the dominant control for different ecosystems.