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A high-resolution ecohydrological analysis of the European Alps

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Mountain ecosystems are highly heterogeneous because the complex terrain creates steep gradients in climate and vegetation cover. This heterogeneity complicates our understanding of mountain ecohydrological processes and renders the projection of climate change impacts on mountainous ecosystems highly uncertain. Here, we used the fully distributed, physically-based ecohydrological model Tethys-Chloris to perform a high spatiotemporal resolution simulation of water and carbon fluxes over the entire European Alps (257,000 km^2). By analysing hourly simulation results over three years (2000-2003) with a spatial resolution of 250x250 m^2, we investigated: (1) the major drivers of Alpine runoff and how the latter may respond to climatic changes; (2) the role of forest encroachment for the Alpine water balance; and (3) the impact of the 2003 drought on the Alpine ecosystems. To investigate the drivers of Alpine runoff, we used a space-for-time substitution and found that total annual runoff over the entire Alpine area is mostly controlled by precipitation and therefore it is very resilient to changes in temperature (by up to +3˚C), despite evapotranspiration being energy-limited and temperature-dependent. However, patterns of runoff production are spatially complex and several dry areas, such as inner-Alpine valleys, may become considerably drier in a warmer climate. By examining simulation results for 4000 Alpine catchments we conclude that forest expansion is unlikely to have major effects on annual evapotranspiration and, consequently, on runoff. Finally, analysing model outputs for the 2003 drought, we found a wide spectrum of ecohydrological responses to high temperatures and precipitation deficit, which reflects a contrasting behaviour between low and high elevations. Model simulation results with high spatiotemporal resolution provide novel insights into the underlying ecohydrological processes and their interactions and help us to better understand the responses of Alpine ecosystems to climatic changes.