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Ensemble simulation and uncertainty estimation - Mountain soil moisture variability under climate change

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Climate change impact assessment studies (CCIAS) are a common approach and many publications on hydrological responses to climate change have been published. Nonetheless, CCIAS focusing on soil moisture are widely missing especially at the catchment scale where adaptation strategies are readily viable. The wide neglect of soil moisture in CCIAS contrasts its key role in the ecosystems. We conducted the CCIA in a high mountain catchment (160 km^2) in the Swiss Alps at a high spatial resolution (50m). The impact of climate change on mountain soil moisture were simulated by applying three different downscaling approaches (statistical downscaling, delta change, and direct forcing) and two RCMs (CHRM, and REMO-UBA) to drive a distributed, physically-based hydrological model (WaSiM-ETH) for a reference (1960-1990) and a scenario period (2070-2100). We estimated the uncertainties originating from either the hydrological model or a downscaling approach by comparing the model outputs with observations from discharge and soil moisture measurements and a reference run based on meteorological observations, respectively. While WaSiM-ETH was able to reproduce discharge with a high accuracy (R^2 = 0.95, ME = 0.8, IoA = 0.95), the simulation of soil moisture for different altitudes and land use types was partly limited, since the model was unable to model the total variability of the soil moisture dynamic, but tends to mean values. Uncertainties were found to be unsteadily distributed, both in terms of variables and time. We showed that the choice of downscaling approaches is of circumstantial relevance for discharge and water balance, while for all spatial variables, we found statistical downscaling approaches to perform better than a direct use of RCM data. Finally, we simulated the impact of climate change on soil moisture using all six downscaled climate data at a daily temporal resolution. The consensus of six models driven by two threefold downscaled RCMs revealed the forested areas below 2000 m a.s.l. to be affected at most by climate change in 2070-2100 (-10 vol-%). Thereby, the variability of the results from the six ensembles were remarkably high, offering a bandwidth of possibilities from nearly unchanged soil moisture conditions to strong expansion of drought stress in the future. In addition we found uncertainties from the applied hydrological model and downscaling approaches in the magnitude of the predicted changes (+/- 10 vol-%).