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Distributed climate change impacts and uncertainty throughout mountainous catchments

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A combination of high-resolution models in space and time was used to evaluate the impacts of climate change on streamflow statistics and their uncertainties throughout three mountainous catchments in Switzerland (Thur, K. Emme and Maggia). The two-dimensional AWE-GEN-2d model was used to simulate ensembles of gridded climate variables at an hourly and 2-km resolution based on ground and remote-sensing observations. The model was re-parametrized using the "factors of change" approach, calculated from regional climate models, and it was used to simulate ensembles of climate data until the end of the 21st century. These ensembles were subsequently used as inputs into the fully distributed hydrological model Topkapi-ETH, which is suitable for simulating streamflow over complex terrain, and considers all the relevant hydrological processes. Based on large ensembles of simulated hydrological variables, the changes of the hydrological components in space and time were evaluated along with their uncertainty due to the internal variability of the climate and the climate model selection. Results indicate a rather uniform increase in temperature for all catchments, characterized by high uncertainty toward the end of the century (with strongest increases of over 5°C). On the other hand, the magnitude and spatial patterns (namely, mountain vs valley) of change in precipitation differ between catchments, and the uncertainty of changes in extreme events is of larger magnitude than the climate change signal. The changes in climate are foreseen to affect the hydrological components in the catchments: evapotranspiration is projected to increase, while snowmelt contribution to the streamflow is expected to decrease by 50% at the end of the century. Model results indicate a decrease in streamflow at the outlet during the summer months and an increase in winter as early as the 2020-2049 period. Conversely, changes in extreme discharge show an uncertainty greater than the change signal for most climate models. Spatially heterogeneous changes in temperature and precipitation lead to elevation-dependent hydrological responses: e.g., streamflow annual means would decrease 20% in the upper reaches of the Thur catchment, while decreasing a similar amount in the downstream reaches. Correspondingly, hourly extremes are expected to decrease 20% in the upper reaches and increase up to 50% in the lowest part of the catchment. However, the signals of the change for extreme streamflow, compared to their uncertainty, are stronger for the upper parts of the river network. These results illustrate the benefit of using stochastic downscaling of climate variables to capture climate variability and assess uncertainty, and emphasize the importance of investigating the distributed impacts of climate change in mountainous areas, which may differ between high and low elevation reaches.