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An optimized, very high-resolution atmospheric-hydrological model chain for assessing climate change impacts on the regional hydrology of an Alpine catchment (Berchtesgadener Ache, Germany)

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Mountain regions are climate sensitive zones and a particular challenge for regional climate and hydrology simulations. The complex orography with extreme elevation gradients, as well as varied land cover and ecosystems at small spatial scales lead to a high variability of climatic conditions and hydrological processes. We present a case study for the Berchtesgaden Alps (Germany) using an optimized atmospheric-hydrological model chain to assess potential impacts of a changing climate on the regional hydrology.

The study is based on new high-resolution (5 km) regional climate model (RCM) simulations with WRF for the time periods 1980-2009 (ERA-Interim reanalysis and MPI-ESM control run) and 2020-2049 (MPI-ESM, scenario RCP4.5). The reanalysis simulation is validated on different spatial and temporal scales, ranging from monthly climatology for Central Europe and the Alps using different gridded observation datasets to hourly values at the point scale using station measurements. The focus of the validation is on the meteorological variables that subsequently force the hydrological model (HM) WaSiM, which are temperature, relative humidity, precipitation, wind speed, and short-wave incoming radiation. To account for RCM model biases and differences in elevations between the RCM and HM grids, a specific coupling procedure is implemented using two different bias correction methods. Additionally, the hydrological model is extended to account for important mountain-specific processes (lateral snow transport and snow-canopy interaction).

Validation results show that the RCM simulation is able to reproduce observed temperature from the large scale (mean bias for the Alps: -0.3 °C) to the hourly station scale (R2 between 0.71 and 0.99 with an RMSE of 1.5 °C). Precipitation is overestimated mainly in summer, whereas winter precipitation is captured very well (annual mean bias for the Alps: + 19 %). The coupled RCM-HM simulations reveal that the climate change signal until 2050 has only limited impacts on the runoff characteristics of the investigated catchment. Most remarkably, mean snow cover duration is projected to decrease with a clear seasonal shift of maximum snow melt to earlier months. These changes in snow cover dynamics are less pronounced in forested areas compared to open land.