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Ensemble modelling of runoff conditions in the upper Danube basin under climate scenarios

Harald Kling, Martin Fuchs, and Maria Paulin
Pöyry Energy GmbH, Vienna, Austria (harald.kling@poyry.com)

Runoff conditions are strongly affected by changes in climatic conditions. Therefore, any uncertainties in future climate directly translate to uncertainties in future runoff. There may be considerable differences in climate projections as a result of (1) alternative emission scenarios, (2) differences between climate models and (3) natural climate variability. An ensemble modelling approach - which considers a set of possible climate scenarios - enables to show a plausible range of future runoff conditions. In this study we use such an ensemble modelling approach to assess future runoff conditions in the upper Danube basin upstream of Vienna (101810 km^2). Runoff is simulated with a conceptual, semi-distributed, monthly water balance model by use of precipitation and temperature inputs. The impact of glaciers and large, artificial reservoirs is considered. An evaluation of simulation results for the Danube River and its main tributaries during the period 1887 to 2007 shows the ability of the model to reproduce runoff conditions also in unusually warm, cold, wet or dry years. A transient assessment of runoff conditions up to the year 2100 is obtained for a medium emission scenario (IPCC A1B) by driving the hydrological model with climate data of the ENSEMBLES project. Overall, 23 climate projections with Regional Climate Models – which themselves are driven by different General Circulation Models – are considered. Especially in mountainous areas the systematic biases in the precipitation and temperature data have to be corrected. The ensemble modelling of runoff shows (1) a decrease in seasonality due to changes in snow processes, (2) a decrease in annual runoff due to increase in evapotranspiration and (3) low-flow conditions at the end of summer due to decrease in summer precipitation. The changes become more pronounced in the later period of the 21st century. This has important long-term implications on hydropower and reliability of the Danube River as a year-round waterway.