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The changing role of snowmelt- and rainfall dominated floods in Norway under climate change – observations, projections, and uncertainties

Klaus Vormoor (1), Deborah Lawrence (2), Axel Bronstert (1), Maik Heistermann (1), Lena Schlichting (2), Donna Wilson (2), and Wai Kwok Wong (2)

(1) Institute of Earth- and Environmental Science, University of Potsdam, Germany (kvormoor@uni-potsdam.de), (2) Norwegian Water Resources and Energy Directorate (NVE), Oslo, Norway

Climate change is expected to modify the hydrometeorological conditions in Norway. There is increasing evidence for gradually increasing temperatures and recent changes in the intensity and frequency of (heavy) precipitation as well as in the number of days with snow cover in many parts of Norway. Climate projections for the end of the 21st century indicate continuous warming by 2.3-4.6°C, especially during winter and in northern Norway and increasing precipitation by 5-30 % particularly during autumn and winter along the west coast. Many catchments in Norway are characterized by a mixed snowmelt/rainfall regime with prominent peak flows during spring and autumn under current conditions. Changes in the temperature and precipitation regimes will have direct implications for the snow regime in Norway, and thus, most likely also on runoff and flooding via their direct effect on the relative importance of rainfall vs. snowmelt in runoff and flood generation.

In this study, we have analyzed: (i) trends in the magnitude and frequency of observed snowmelt- and rainfall driven peak flows in up to 211 catchments in Norway; (ii) projected future changes in the seasonality and generation processes of floods in six Norwegian catchments based on a multi-model/multi-parameter ensemble; (iii) the contribution of the individual ensemble components to overall uncertainty; and (iv) the transferability of calibrated hydrological model parameters under contrasting flood seasonality conditions in five catchments with mixed regimes. The major findings of our analyses are as follows:

i. Trends towards increasing flood frequency are more pronounced and spatially more consistent with hydrometeorological drivers than trends in flood magnitude. Regional patterns of positive trends in flood frequency agree with the increasing importance of rainfall driven peak flows, whereas negative trends are found in areas primarily dominated by snowmelt flood generation process.

ii. Autumn and early winter flooding is projected to become more intense and/or frequent in all the six catchments and a possible shift in the current flood regimes from spring to autumn is found in two of the six catchments investigated. Changes in flood seasonality correspond to an increasing relevance of rainfall as the most dominant flood generating process under a future climate.

iii. Climate projections and the methods for downscaling or bias correction tend to be the largest contributors to overall uncertainty. However, the relative role of hydrological model parameter uncertainty is highest for those catchments showing the largest changes in flood seasonality, which may indicate a lack of parameter robustness for simulations under transient hydrometeorological conditions.

iv. The losses in hydrological model performance due to the transfer of calibrated parameters to independent validation series range on average between -5% - -17 %. However, there is no indication that contrasting flood seasonality amplifies performance losses which contradicts our assumption that optimized parameter sets trained on a series dominated by snowmelt generated floods (spring) perform poorly for validation periods comprised primarily of rainfall dominated floods (autumn) and vice versa.

The combined results highlight the added value of considering flood generation processes in climate change impact studies of peak flows.