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Simulating Hydrological Extremes for different Warming Levels – combining Large Scale Climate Ensembles with local observation based Machine Learning models

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Climate change has a large influence on the occurrence of extreme hydrological events. In this study we take advantage of two recent developments that allow for more detailed and local estimates of future hydrological extremes. New large climate ensembles (LE) now provide more insight into the occurrence of hydrological extremes as they offer order of magnitude more realizations of the future weather and thus floods and droughts. At the same time recent developments in Machine Learning (ML) based forecasting have enabled scientists to provide this LE information to a local scale relevant to water managers.

In this study we combine LE, consisting of 2000 years of global data for scenarios representing present-day, 2 and 3 degrees warmer climate [(1)], together with a local, observation-based ML model framework for simulating hydrological extremes for the Netherlands [(2, 3)].

We developed a new post-processing approach that allows us to use LE simulation data for local applications based on historical information. We test the application of the post-processing step based on historical simulations, before implementing in the different scenario runs.

The discharge simulation results for the different scenarios show a clear seasonal cycle with increased low flow periods (both average duration and number of events) from summer till end of autumn (~45% August-October) and increased high flow periods for early spring (~43% February-April) looking at national scale, with the 3-degree warmer climate scenario showing the highest percentages for both (52.5% and 48.3% respectively). Regional differences can be seen in terms of shifts (low flows occurring earlier in the year) and range (higher/lower percentages). These trends can further be detangled into location specific results, due to the added value provided by the ML setup.

We show that by combining the wealth of information from LE and the speed and accuracy of ML models we can advance the state-of-the-art when it comes to modelling and projecting hydrological extremes. The local modelling framework allows to simulate discharge under

different climate change scenarios for national, regional and local scale assessments. The historically and locally trained models provide essential information for water management to be used in long-term planning.

[1)] *Van der Wiel, K., Wanders, N., Selten, F. M., & Bierkens, M. F. P. (2019). Added value of large ensemble simulations for assessing extreme river discharge in a 2 °C warmer world. Geophysical Research Letters, 46, 2093– 2102.*
[2)] *Hauswirth, S. M., Bierkens, M. F., Beijk, V., & Wanders, N. (2021). The potential of data driven approaches for quantifying hydrological extremes. Advances in Water Resources, 155, 104017.*
[3)] *Hauswirth, S. M., Bierkens, M. F., Beijk, V., & Wanders, N. (2022). The suitability of a hybrid framework including data driven approaches for hydrological forecasting. Hydrology and Earth System Sciences Discussions, 1-20.*