Improving realism of high-resolution hydrological modeling with anthropogenic water use: a study on the Rhine basin

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Summary: This study demonstrates the importance of integrating water demand and abstractions into high-resolution hydrological modeling to better capture the impact of anthropogenic activities on water fluxes and states in the Rhine basin. By simulating surface and groundwater abstraction and return flows at ~1 km resolution, we show that anthropogenic water use significantly affects discharge, particularly under summer low-flow conditions.

Background: water availability continue to decrease and water demand continues to increase due to climate change. It is essential develop tools to improve hydrological understanding and river discharge forecasting.

Knowledge gap: Global hydrological models are insufficient for regional water assessment. Spatial and temporal hydrological response due to water abstractions are more pronounced at regional scale.

Aim: to develop and evaluate evaluate effective methods for integrating water demand into regional hydrological models and investigate the impact on the hydrological response.

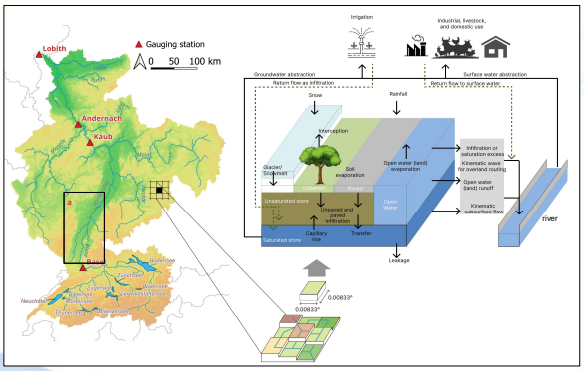

Fig 1

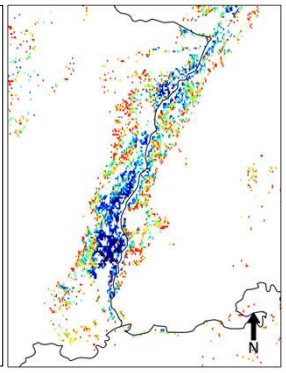

Fig 1a

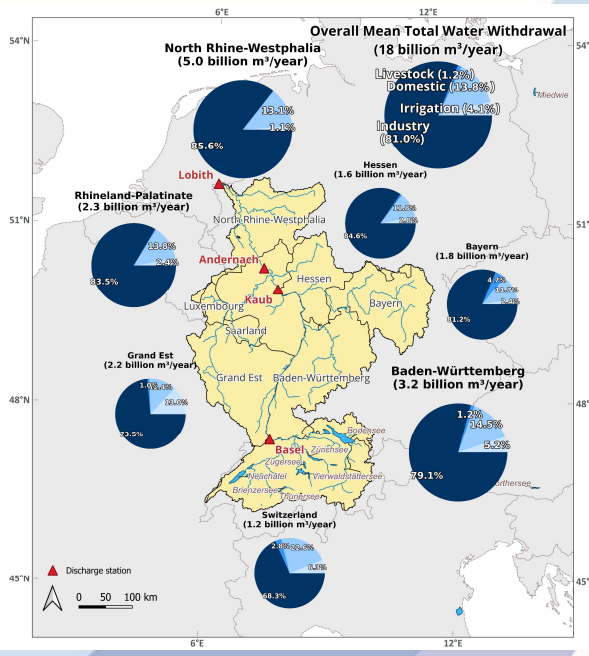

Fig 2

Material and methods

The latest version of the hydrological model wflow_sbm v0.8.1 (van Verseveld et al., 2024) allows for the estimation of water demand and abstractions for urban, industrial, livestock, and irrigation at a spatially gridded scale and daily temporal resolution (see **Fig 1** and **1a**) (Wada et al., 2014). These demands are met through surface water and groundwater abstraction. Return flows from the domestic and industrial sectors are routed back to surface water via overland flow.

Results

We did an analysis spanning from 1990 to 2019 to investigate the impact of incorporating human water use on the hydrological response (only discharge shown here **Fig 3a** and **Fig 3b**). Our methodology involved using high-resolution of irrigated map of the Rhine basin that has been generated based on MODIS observations. The irrigated map was compared against Eurostat statistics for the years 2013 and 2016 with a good agreement (R^2 = 0.76 – 0.77). We compared probability plots of extreme low flow for observed and simulated discharge from models with and without abstraction to satisfy water demand explicitly, based on the annual minimum of a 7-day moving average during the period 1990–2019 for: a) Lobith, b) Andernach, c) Kaub, and d) Basel (**Fig 3c**).

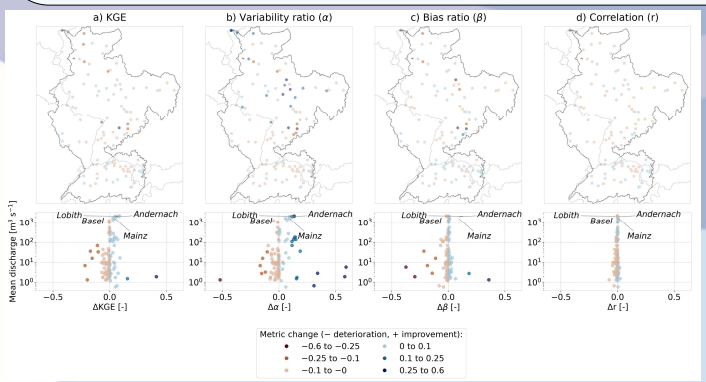

Fig 3a

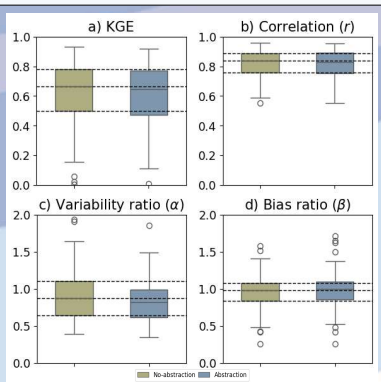

Fig 3b

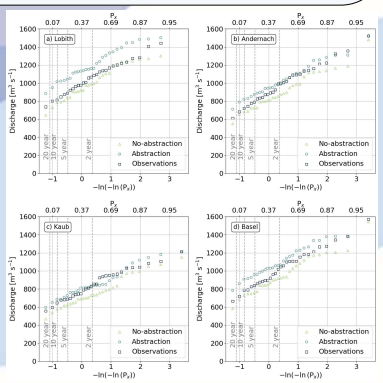

Fig 3c

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