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How does climate change affect the inundation characteristics of a floodplain? A case study to assess the cascade of uncertainty in modeling the impact of climate change on inundation characteristics.

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The different inundation characteristics of floodplains (e.g. height of water level, flood duration, recurrence interval) and the resulting exchange between surface water and groundwater are of importance for the ecosystem. Wide habitat heterogeneity and highly specialized species are dependent on high groundwater levels and regular inundations. Climate change will have an effect on floodplains, their hydrological processes and consequently their functionality. This arises due to general changes in the hydrological cycle, more precisely due to changes in the seasonality and the extremes of low and high flows.

To assess the climate change impact on inundation frequency and duration on a floodplain of the Rhine River in Hesse, Germany (14.8 km2), we set-up a framework including different projections and models: projections of two General circulation models (GCMs) and three emission scenarios (RCPs), a rainfall-runoff model (HBV) to simulate the discharge of the Rhine river and a coupled surface water-groundwater model (CMF) to project spatially distributed flood characteristics in the floodplain. The climate projections (GCMs and RCPs) are used as driving forces for the hydrological model and the coupled surface water-groundwater model. The generated discharge time series are used to drive the coupled surface water-groundwater model. On top of this, we also investigate various components of the underlying uncertainty of our projections.
Parameter and predictive uncertainty of the HBV model are derived through an innovative combination of Bayesian calibration and a heteroscedastic error modeling approach through a Box-Cox transformation. The monthly mean range of the water level between the 5^{th} and 95^{th} percentile is rather small (parameter uncertainty: 0.35 m – 0.56 m, predictive uncertainty: 1.18 – 1.35 m) and the difference between the climate projections even smaller (< 0.17 m). In contrast, the inundation characteristics (inundation days per year and inundation mean duration) show large differences between the climate projections. However, the results are largely depending on the GCMs and the input driving data for the groundwater-surface water modeling. The inundation characteristics change in different directions and intensities: While one GCM indicates an increase in annual inundation days over large areas, the other one even projects a decrease at some sites. In total, the degree of the uncertainty is higher, when clustering the results based on the considered GCMs or input driving data for groundwater-surface water model from the HBV model, as compared to the uncertainty introduced by the RCPs. The spatial extension of quantitative uncertainty is almost the same for all three uncertainty sources in the far future but smaller for the uncertainty introduced by input driving data for the near future.

Overall a shift in the inundation pattern and extent is observed and consequently a shift in habitat availability and species distribution is expected to occur in the course of climate change. Such information is particularly valuable for the long-term success of renaturation projects in biodiversity-rich floodplains. We underline the relevance of consideration of different uncertainty sources and their spatial occurrence within a hydrological modeling process for future risk assessment.