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Bridging scales: comparing the human influence on streamflow drought in global-scale models and catchment-scale observations

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Drought impacts are experienced worldwide at all spatial scales, which makes drought a global problem. There is a need to better understand the drivers of streamflow drought, including human influences, at those larger spatial scales, especially with new drought policies being designed on global and continental scales. Global hydrological models (GHMs) have recently seen rapid development on including human impacts on hydrology. Process definitions in the current generation of models could still be improved, but data and understanding to parameterise the anthropogenic effects on drought are often lacking. On the catchment scale, there is increasing understanding of the human drivers of streamflow drought from case studies. However, upscaling results from specific catchment-based studies to continental and global scales remains challenging.

In this study, we aim to use GHMs to bridge the gap between the catchment and global scale. We compare the effect of human influences on drought in catchment-scale data and GHM output for 20 case studies spread around the world. GHM simulated streamflow data was derived from the ISI-MIP project. For both modelled and observed data, streamflow droughts were defined with the threshold method. We calculated the drought threshold from the natural situation and applied that to the natural and human-influenced situation to obtain streamflow drought characteristics for both. For each case study, we mimicked the methodology used to derive the catchment-scale results with the GHM data, for example by comparing droughts between natural and human-influenced scenarios for a single catchment or by comparing droughts between a natural and a human-influenced grid cell.

We find that in some cases both catchment-scale and global-scale (GHM-based) results show an aggravation or alleviation of streamflow drought due to human influence, whereas other cases have a contrasting response between GHM results and catchment-scale results. The main reason is the mismatch in spatial scale between the catchment data and model data. We also hypothesize that differences in human influence on drought between the approaches are related to the process description of human influences in GHMs, which makes it challenging to get the balance right between positive and negative human influences on drought; so whether water abstraction (mainly aggravating drought) or water storage in reservoirs (mainly alleviating drought) is dominant in regions where both processes occur. Finally, how human responses to drought and feedbacks between drought and water use are parameterized has a large influence on the model results.

This study has defined ways forward in using knowledge from both catchment-scale case studies and global-scale hydrological models. This knowledge helps to improve the large-scale models, extrapolate understanding gained from detailed catchment studies and, finally, understand the anthropogenic drivers of streamflow drought on a global scale.