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Human water consumption intensifies hydrological drought worldwide

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Drought is a natural phenomenon caused by below-normal precipitation over a prolonged period. Recent studies suggest an intensification of drought events over substantial regions due to anthropogenic global warming. Over the past decades, human water consumption has more than doubled, primarily due to a large increase in irrigation, and substantially reduced streamflow over various regions. It can thus be expected that upstream human water consumption intensifies hydrological drought in many regions of the world. Yet, few studies have investigated this impact up to now.

We use the global hydrological model PCR-GLOBWB to simulate surface freshwater availability, i.e. water in rivers, lakes, reservoirs and wetlands, at a 0.5^o spatial resolution for the period 1960-2001. We also estimate human water consumption, i.e. water withdrawal minus return flow, from agricultural, industrial and domestic sectors for the same period. Since country statistics on consumptive water use rarely exist, we use available socio-economic data to reconstruct past sectoral water consumption at a 0.5° grid. We then perform two simulation runs in which the impact of upstream human water consumption on downstream surface freshwater availability and resulting hydrological drought is assessed. The first run evaluates streamflow under variable climate inputs and with human water consumption set to the level of 1960. From this run, the Q_{80} is derived as the onset of hydrological drought following the widely used variable threshold level method. The second run is subject to the reconstructed water consumption over 1960-2001 and the ensuing deficit volume calculated relative to the 1960 reference, which are indicative of the intensification of hydrological drought and its implication for water supply. We standardize deficit volumes to compare the severity of hydrological drought among different catchments.

Results show that upstream human water consumption substantially alters downstream water availability and intensifies the severity of hydrological drought worldwide. The severity of hydrological drought increases by more than 50% due to reduced water availability downstream, particularly in regions where surface water is heavily exploited (e.g., Indus, Ganges, Krishna-Godavari, Huang He, Hai He, Colorado). In these regions, hydrological drought has also become more frequent and persistent. Overall, the severity of hydrological drought has been aggravated in many parts of the world as human water consumption is rising rapidly in recent years.