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Detection of Human influence in global accounts of observed indicators of low, mean and high streamflow

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Anthropogenic climate change as well as human water and land management are expected to impact the world's freshwater resources and hydrological extremes. However, model estimates are imperfect, leaving many open questions regarding the sign and the magnitude of the associated impacts. Likewise, relevant in-situ observations have incomplete spatio-temporal coverage and are often not sufficient to disentangle the effects of anthropogenic climate change and land management from natural variability and observational errors. The recently established Global Streamflow Indices and Metadata archive (GSIM) includes observations from more than 30000 stations and hence provides an unprecedented opportunity to investigate observed trends in indicators of low, mean and high streamflow at the global scale. Analysing the GSIM reveals complex spatial patterns of global hydrological change, where some regions (e.g. the Mediterranean) are getting significantly dryer, while others (e.g. North Europe) have been subject to wetting. Notably, these changes are often consistent throughout the entire flow distribution, implying that increasing drought risk might be compensated by decreasing flood magnitudes. To investigate whether human water management or anthropogenic climate change are driving this change pattern, detection and attribution methods are used. These methods exploit ensembles of factorial global model experiments in which the hypothesised agents of change (e.g. greenhouse gas emissions, human water management) are systematically switched on and off. Simulations from the ISIMIP2b ensembles are considered which combines the versatility of global hydrology models (GHM) with state of the art global climate model (GCM) runs. The results highlight that the observed global-scale trend pattern cannot be explained by natural variability alone, as estimated by driving GHMs with GCM runs forced with pre-industrial greenhouse gas levels. Adding water management (e.g. irrigation, flood regulation) to the GHMs is also not sufficient for capturing the observed trend patterns. However, trend patterns derived from simulations that account for both water management (through GHMs) and historical greenhouse gas emissions (through GCMs) do qualitatively capture the observed streamflow trend patterns at the global scale. Repeated analysis of the data using correlation based methods and optimal fingerprinting suggests that this outcome is most stable for low-flow indicators ($p<0.1$) while the results are less stable for mean and high flows. The results highlight that the combined effect of human water management and ongoing anthropogenic climate change is already detectable in freshwater resources at continental to global scale, thereby increasing confidence in future projections of the world's freshwater resources.