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Statistical analysis of global river streamflow regime changes and their alignment with trends in human drivers

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Climate change, land cover change, water use, and flow regulation are driving river streamflow changes globally, and it is crucial to understand the varying contributions of these drivers to prevent and mitigate harmful impacts caused by streamflow alteration. However, previous, scenario-based approaches on this are notably uncertain and may miss interdependencies between different drivers. Here, to overcome these shortcomings, we use a large sample of observed streamflow data globally to quantify flow regime changes and align those against trends in precipitation, evapotranspiration, water use, and damming. With this study, we achieve unprecedented coverage and detail in analysing how varying streamflow regime changes may be linked to different drivers.

We queried the Global Streamflow Indices and Metadata (GSIM) database to yield 5,220 catchments across all continents (surface area greater than than 1,000 km^2 and more than ten years of record available). Each catchment was assigned a flow regime change (FRC) class based on linear trends in four streamflow metrics: mean, standard deviation, high flows (95th percentile) and low flows (5th percentile). Within FRC classes, we further separated between catchments in which precipitation shows a decreasing or an increasing trend. Finally, within groups formed by FRCs and precipitation trends, we analysed linear trends in total evapotranspiration and water use, and increases in damming (by degree of regulation; DOR).

We find that *shift down* (mean, low, and high flows decreasing) and *shrink* (standard deviation and high flows decreasing, low flows increasing) are more common FRCs than *shift up* (mean, low, and high flows increasing) and *expand* (standard deviation and high flows increasing, low flows decreasing). Most commonly, precipitation trends are parallel to the FRC – decreasing in the shift down and shrink FRCs and increasing in the shift up and expand FRCs. This is more likely in FRCs describing a shift than in FRCs indicating a change in variability, which suggests that drivers beyond precipitation are more likely to exist in catchments that belong to the shrink and expand FRC classes. Water use trends are comparatively strong between shift down, shrink and expand FRCs but nearly nonexistent in the shift up FRC. The general direction of evapotranspiration trends

agrees with precipitation trend direction in all four FRCs. When the FRC class and precipitation trend contradict (e.g. shift down FRC & increasing precipitation trend), we find that changes in water use and damming are often strong. Damming mostly affects streamflow by decreasing and homogenising flow because strongly increasing DOR is also associated with the shrink FRC but changes in DOR are minor within the shift up and expand FRCs

Our global large-sample statistical insights agree with process-based understanding on how different human drivers affect streamflow, which provides a promising outlook on identifying the dominant drivers of streamflow change at large scales.