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Catchment-scale contaminant transport under changing hydro-climatic conditions in the Aral Sea Drainage Basin, Central Asia

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Dependable projections of future water availability and quality are essential in the management of water resources. Changes in land use, water use and climate can have large impacts on water and contaminant flows across extensive catchments that may contain different administrative regions where shared water resources must be managed. We consider the extensive Aral Sea Drainage Basin (ASDB) and the Amu Darya River Delta in Central Asia, which are currently under severe water stress due to large-scale irrigation expansion. We interpret data on hydro-climatic conditions, main contaminants of surface water and shallow groundwater systems, location of rivers and canal networks, and groundwater flow directions. The data are used together with climate change projections from general circulation models (GCMs) as input to hydrological and (advective) transport modelling. The main goal is to assess how regional transport pathways and travel times have changed, and are likely to change further, in response to past and projected future hydro-climatic changes. More specifically, the hydrological modelling was based on temperature and precipitation change (ΔT and ΔP) results from 65 GCM projections of 21^{st} century conditions (specifically considering time periods around 2025, 2050, and 2100), relative to reference conditions around 1975 (taken from the reference period 1961-1990).

Whereas ΔT is robustly projected to increase with time, the projected magnitude of ΔP differs more among projections for the distant future (2100) than for the near future (2025), with uncertainty remaining even about the direction of change (i.e., positive or negative ΔP). However, mainly due to the projected temperature-driven increases in evapotranspiration, ensemble average results show that the Amu Darya river discharge Q in the downstream ASDB is likely to show a decreasing trend throughout the 21^{st} century. Notably, projected changes in the upstream, mountainous regions have a relatively large impact on these Q-projections. For example, the locally created runoff of the downstream region is projected to be maintained or even increase slightly, in contrast to the decreasing Q-trend that reflects an integrated, average response of the entire catchment. A continued drying of surface waters within the Amu Darya river delta implies that advective travel times are increasingly governed by the groundwater system. Such diminished exchanges with surface waters imply increased mean travel times from shallow groundwaters to the (drying) river and drainage canal network by an order of magnitude (from months to years). This can considerably influence mass flow and retention of contaminants in the river delta region, which suffers from e.g. copper, chromium and lead contamination.