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Large-scale long-term hydrological dynamics in the changing landscapes and climate of the anthropocene

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The effects of different types of anthropogenic and natural change drivers on large-scale long-term hydrological dynamics are difficult to detect and distinguish. Most studies so far have addressed local rather than regional-to-global hydrological changes, and over relatively short rather than multi-decadal or longer time periods. For example, a survey of 21,433 scientific articles found in the scientific literature on wetlands shows that research attention has mostly focused on the scale of an individual wetland (80% of surveyed published papers) rather than on the large-scale functioning of whole wetlandscapes with multiple more or less connected wetlands over entire hydrological basins. This paper synthesizes a set of recent studies of large-scale hydrological dynamics and changes over the last century across various parts of the world up to the global scale. The investigations consider large-scale water fluxes (precipitation, evapotranspiration, runoff) as well as water-storage changes in soil moisture and groundwater. The results indicate human land-use and water-use developments in the landscape as important drivers of large-scale hydrological change. For example, local flow regulation and irrigation developments correlate well and consistently with significant large-scale hydrological changes across different parts of the world and over all continents. The large-scale effects of such local landscape-internal change drivers may in some cases be opposite to, and thus dampen concurrent climate-driven change effects. However, some disturbing large-scale geographic patterns of freshwater changes still emerge over vulnerable land areas. In particular, some of the world's driest land areas in the northern-hemisphere subtropics have become drier in terms of their already small average runoff level, even though precipitation has partly increased and only partly decreased in these areas. The reason is that evapotranspiration has overall increased, even though the average surface temperature has mostly decreased or remained unchanged here. Such evapotranspiration increase, which is not readily explainable from observed atmospheric climate change, may be a telltale effect of dominant landscape-internal anthropogenic change drivers. As one comparative example, some of the wettest land areas in the world, in the northern-hemisphere tropics, have also become drier over the last century, but only in terms of decreased precipitation. With a nearly as large decrease in the overall evapotranspiration flux back to the atmosphere, the corresponding change in runoff (and thus in the availability of annually renewable water for human societies and ecosystems on land) has been small in these areas. In general, the found historic hydrological changes challenge and problematize some over-simplistically stated aspects of climate change with regard to water-related changes, drivers and effects on land. Such aspects include for example: (1) a common change statement that dry (wet) areas will generally get drier (wetter) under climate change; (2) the meaning of just simply stating changes as wetter or drier conditions for land areas; (3) the division of climatic changes and their drivers-effects into just natural and primarily atmosphere-affecting anthropogenic ones (greenhouse gas- or aerosol-related).