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The effects of groundwater abstraction on low flows

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In regions with frequent water stress and large aquifer systems, groundwater often constitutes an essential source of water. If groundwater abstraction exceeds groundwater recharge over a long time and over large areas persistent groundwater depletion can occur. The resulting lowering of groundwater levels can have negative effects on agricultural productivity but also on natural streamflow and associated wetlands and ecosystems, in particular during low-flow events when the groundwater contribution through baseflow is relatively large.
In this study we focus on the effects of global groundwater abstraction on low-flow magnitude, frequency and duration for the major rivers of the world for the period 1960-2000. As a basis, we use the large-scale hydrological model PCR-GLOBWB that calculates all major water balance terms on a daily time step at a 0.5ox0.5o resolution. Currently, PCR-GLOBWB represents groundwater and the associated baseflow by means of a linear reservoir that is parameterized using global lithological data and drainage density. It simulates renewable groundwater storage within each 0.5o cell. Lateral flow between cells is not considered. The specific runoff from the model is subsequently transformed into discharge by means of a kinematic wave routing scheme.
In this study we perform a sensitivity analysis in which we evaluate the effects of total water demand for the period 1960-2000 (Wada et al., 2011: doi:10.5194/hess-15-3785-2011). This demand is preferentially met by renewable groundwater storage, secondly by surface water. Any remainder is assumed to stem from non-renewable (i.e. fossil) groundwater resources. Thus, groundwater abstractions act as a direct sink of (renewable) groundwater storage, whereas surface water abstractions act as a direct sink of streamflow. The resulting response is non-trivial as abstractions are variably taken from both groundwater and surface water, where return-flows contribute to a single source: return flow from irrigation demand contributes to groundwater, that from industrial and domenstic demands to surface water. Moreover, groundwater abstractions may lead tot increased capture which we parameterized by including additional recharge through the riverbed when groundwater abstraction is large than the instantaneous baseflow.
Model results are compared with observed river discharges of GRDC. The effect of groundwater abstraction on low flows is evaluated by analyzing the difference in simulated discharge between a transient run with increasing abstraction rates over 1960-2000 and a reference run with fixed abstractions rates forced to 1960. Results show that the effects on discharges of both groundwater and surface water abstractions are evident at the global scale, particularly on the magnitude and duration of low flows. Results also show that including return flows is important, particularly in intensively irrigated areas where the magnitude of low-flows generally increased due to water abstractions.