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Reconstruction of groundwater depletion using a global scale groundwater model

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Groundwater forms an integral part of the global hydrological cycle and is the world's largest accessible source of fresh water to satisfy human water needs. It buffers variable recharge rates over time, thereby effectively sustaining river flows in times of drought as well as evaporation in areas with shallow water tables. Moreover, although lateral groundwater flows are often slow, they cross topographic and administrative boundaries at appreciable rates. Despite the importance of groundwater, most global scale hydrological models do not consider surface water-groundwater interactions or include a lateral groundwater flow component. The main reason of this omission is the lack of consistent global-scale hydrogeological information needed to arrive at a more realistic representation of the groundwater system, i.e. including information on aquifer depths and the presence of confining layers. The latter holds vital information on the accessibility and quality of the global groundwater resource.

In this study we developed a high resolution (5 arc-minutes) global scale transient groundwater model comprising confined and unconfined aquifers. This model is based on MODFLOW (McDonald and Harbaugh, 1988) and coupled with the land-surface model PCR GLOBWB (van Beek et al., 2011) via recharge and surface water levels. Aquifers properties were based on newly derived estimates of aquifer depths (de Graaf et al., 2014b) and thickness of confining layers from an integration of lithological and topographical information. They were further parameterized using available global datasets on lithology (Hartmann and Moosdorf, 2011) and permeability (Gleeson et al., 2014). In a sensitivity analysis the model was run with various hydrogeological parameter settings, under natural recharge only. Scenarios of past groundwater abstractions and corresponding recharge (Wada et al., 2012, de Graaf et al. 2014a) were evaluated. The resulting estimates of groundwater depletion are lower than earlier flux-based estimates and more similar to estimates based on well data, mainly due to enhanced recharge from surface waters. Our results present a global overview of water table depth and reveal hotspots of groundwater depletion, generally occurring in groundwater irrigated systems.