Fate of water pumped from underground and contributions to sea level rise

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The contributions from terrestrial water sources to sea-level rise (SLR), other than ice caps and glaciers, are highly uncertain and heavily debated. Recent assessments indicate that groundwater depletion (GWD), i.e. the extraction of groundwater reserves at rates greater than its replenishment, may become the most important positive terrestrial contribution. Future projections of increasing reliance on groundwater suggests that GWD will become the most important singular terrestrial contribution to SLR over the next 50 years, likely equal in magnitude to the current contributions from glaciers and ice caps. However, a critical common assumption of these existing estimates is that nearly 100% of groundwater extracted from aquifers eventually ends up in the oceans. Due to limited knowledge on the pathways and mechanisms governing the ultimate fate of pumped groundwater, the relative fraction of global GWD that contributes to SLR remains unknown. Here we present a coupled climate-hydrological model simulation to track the fate of water pumped from underground, and to estimate the portion of GWD contributing to sea level changes. Our results show that the fraction of GWD that ends up in the ocean is 80%. Roughly two thirds of the GWD contribution to SLR results from an increase in runoff to the ocean, while the remainder results from the enhanced net flux of precipitation minus evaporation over the ocean, due to increased atmospheric vapor transport from the land to the ocean. The contribution of GWD to global SLR amounts to 0.02 (±0.004) mm yr^{-1} in 1900 and increased to 0.27 (±0.04) mm yr^{-1} in 2000. This indicates that existing studies have substantially overestimated the contribution of GWD to global SLR by a cumulative amount of at least 10 mm during the 20th century and early 21st century. With other terrestrial water contributions such as the filling of dams included, we estimate the net terrestrial water contribution during the period 1993-2010 to be +0.12 (±0.04) mm yr^{-1}, suggesting that the net terrestrial water contribution reported in the IPCC AR5 report is likely overestimated by a factor of three.

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