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# The spatio-temporal evolution of groundwater dependent precipitation

**Cristina Passet**, Lan Wang-Erlandsson, Yoshihide Wada, Agnes Pranindita, and Agatha De Boer
Stockholm University, Sweden (cripasset@outlook.com)

A substantial portion of groundwater abstracted from aquifers is used for irrigation and evaporated to the atmosphere, potentially contributing towards downwind precipitation. While the fate of evaporation fluxes from land have been analysed, the atmospheric pathways of evaporation originating from groundwater have not yet been globally quantified. This study analysed the geographical distribution, the seasonality and the magnitude of groundwater-dependent precipitation (Pgw) at a global scale and for a selection of countries and river basins. The Eulerian moisture tracking WAM-2layers model was used to process meteorological and groundwater abstraction input data from 1980 to 2010. Results show considerable contributions of groundwater to precipitation downwind of the most heavily irrigated areas, leading to net groundwater losses over these areas. Globally, 40% of the Pgw precipitates directly in the oceans, and do not contribute to biomass production in terrestrial ecosystems. Some of the countries with the highest rates of groundwater abstraction (India, the USA, Pakistan and Iran), receive low volumes of Pgw and are net losers of groundwater resources. The countries with the highest net gain of groundwater are China, Canada and Russia. At river basin scale, the Indus, Ganges and Mississippi basins are net losers of groundwater to downwind Pgw, while the Yangtze, Tarim and Brahmaputra basins receive more Pgw than their groundwater withdrawals. The share of precipitation that originates from groundwater varies considerably with seasons, and can be especially high when low local precipitation levels occur in combination with high upwind groundwater abstraction. Furthermore, precipitation dependence on groundwater (ρgw), has steadily increased between 1980 to 2010 in all studied areas and globally. Our study suggests that the countries and basins with a high and increasing dependency on ρgw to support their precipitation can be vulnerable to groundwater availability upwind.