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Simulating the effects of irrigation pumping on global groundwater depletion

Yadu Pokhrel[†]; Sujan Koirala; Tomohito Yamada; Naota Hanasaki; Pat Yeh; Kei Yoshimura; Shinjiro Kanae; Taikan Oki
[†] University of Tokyo, Japan
Leading author: pokhrel@rainbow.iis.u-tokyo.ac.jp

Groundwater is an important source of human water use in many regions around the world. At present, at least one-fourth of the world's population uses groundwater for domestic, industrial, and agricultural purposes. During the last several decades, rapid growth in groundwater irrigation has led to significant increase in agricultural water withdrawal. In semi-arid regions, where most croplands with intensive irrigation are located, extraction of groundwater at a rate that exceeds annual recharge has caused groundwater depletion at an alarming rate. In this study, we assess the impact of irrigation pumping on groundwater depletion by using an integrated model which has been developed by incorporating anthropogenic water regulation modules (reservoir operation, irrigation, water withdrawal) and a fully dynamic shallow groundwater representation into an advanced land surface model called the MATSIRO. Irrigation demand is estimated by the irrigation module and the withdrawal module withdraws water from surface and/or sub-surface sources based on water availability. When the surface water sources such as river channels and reservoirs deplete below a prescribed threshold, water is pumped from groundwater reservoir. The groundwater scheme is an unconfined aquifer model in which soil column is separated into continuously interacting saturated and unsaturated zones by the water table. Therefore, the integrated model simulates the flow of water taking into account anthropogenic water regulation and also groundwater pumpage and return flow of irrigation water. Simulations are conducted at 1^{o} x 1^{o} (longitude and latitude) spatial resolution at the global scale. Simulated groundwater withdrawals for the major aquifers in the United States compare well with the observations by the United States Geological Survey (USGS). For the high plains aquifer, simulated groundwater withdrawal is ~25 km/yr which is in close agreement with the observational record of ~24 km/yr. We also evaluate the simulated groundwater depletion against the observations by GRACE satellite mission for the period of 2002-2007. Results show decreasing groundwater storage and agree fairly well with GRACE observations. In many aquifers, the model tends to exaggerate groundwater depletion, which is possibly due to the underestimation of groundwater recharge and irrigation return flow from irrigated croplands.