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Evaluation of groundwater depletion in North China using the Gravity Recovery and Climate Experiment (GRACE) and ground-based measurements

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Regional groundwater storage changes in North China are estimated from the Gravity Recovery and Climate Experiment (GRACE) satellites and ground-based measurements over 2003-2010. The study area includes Beijing, Tianjin municipality, Hebei province and Shanxi province ($\sim$370,000 km^2), which is one of the largest irrigation areas in the world and subjected to intensive groundwater-based irrigation. The groundwater depletion in North China is estimated by removing the simulated soil moisture changes from the GRACE-derived terrestrial water storage changes. The rate of groundwater depletion in North China based on GRACE is 2.2 $\pm$ 0.3 cm/yr over 2003-2010, which is equivalent to 8.3 $\pm$ 1.1 km^3/yr in volume. The groundwater depletion rate estimated from monitoring well stations in the same time period is in the range of 2.0-2.8 cm/yr, which is consistent with the GRACE result. However, the estimate of groundwater depletion rate in shallow plain aquifers from Groundwater Bulletin of China Northern Plains (GBCNP) in the same time period is only about 2.5 km^3/yr. The difference in groundwater depletion rates between GRACE and GBCNP indicates the important contribution of deep aquifers' groundwater depletion in plain and piedmont regions of North China.