



## Identifying water mass depletion in Northern Iraq observed by GRACE

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Observations acquired by Gravity Recovery And Climate Experiment (GRACE) mission indicates a mass loss of  $31 \pm 3$  km<sup>3</sup> or  $130 \pm 14$  mm in Northern Iraq between 2006 and 2009. This data is used as an independent validation of a hydrologic model of the region including lake mass variations. We developed a rainfall-runoff model for five tributaries of the Tigris River, based on local geology and climate conditions. Model inputs are precipitation data from Tropical Rainfall Measurement Mission (TRMM) observations, and potential evaporation from GLDAS parameters. Our model includes an extensive network of karstified aquifers that causes large natural groundwater variations in this region. Observed river discharges have been used to calibrate our model. In order to get the total mass variations, we correct for lake mass variations derived from Moderate Resolution Imaging Spectroradiometer (MODIS) data in combination with satellite altimetry and some in-situ data. Our rainfall-runoff model confirms that Northern Iraq suffered a drought between 2006 and 2009 and is consistent with the mass loss observed by GRACE in that period. Also, GRACE picks up the annual cycle predicted by the rainfall-runoff model. The total mass depletion seen by GRACE between 2006 and 2009 is  $130 \pm 14$  mm, which is mainly explained by a lake mass depletion of  $74 \pm 4$  mm and a natural groundwater depletion of approximately 50 mm. Our findings indicate that man-made groundwater extraction has a minor influence in this region while depletion of lake mass and geology play a key role.