Global groundwater storage estimates through assimilation of GRACE data into a land surface model

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Groundwater is one of the most important natural resources for the global community, with more than 2 billion people relying exclusively on groundwater for drinking water and 43% of irrigation water being supplied by aquifers. However, the scarcity of groundwater variation data at the global scale hinders our ability to monitor and manage groundwater resources effectively. The terrestrial water storage (TWS) changes derived from the Gravity Recovery and Climate Experiment (GRACE) satellite mission have shown great promise in detecting groundwater storage changes around the world. The application of GRACE data for groundwater hydrology can be facilitated by GRACE data assimilation, which constrains model estimates while providing vertical disaggregation and spatial downscaling. Building upon previous studies at regional to continental scales, this study assimilates a state-of-the-art GRACE TWS product into NASA's Catchment land surface model (CLSM) at the global scale with an improved ensemble smoother. The GRACE data were derived using a regional mass concentration approach with time variable constraints applied during the inversion of satellite ranging observations (as opposed to after inversion) to better preserve the information in those measurements. Time series of in situ data from nearly 4,000 wells located in different continents and climate zones were obtained to evaluate the impact of GRACE data assimilation on CLSM estimated groundwater. The comparison shows that GRACE data assimilation has a strong positive impact on simulated groundwater storage, with estimation errors reduced by 36% and 10% and correlation improved by 16% and 22% at the regional and point scales, respectively. The improvements are climate dependent, with the largest observed in regions with substantial interannual variability in precipitation, where simulated groundwater responds too strongly to changes in atmospheric forcing. We discuss the impacts of GRACE data assimilation on the temporal and spatial variability of TWS and groundwater storage and model deficiencies, including the lack of groundwater pumping, that limit its ability to distribute assimilated TWS properly. Application of this dataset for groundwater drought monitoring is also described.

Publication:
American Geophysical Union, Fall Meeting 2018, abstract #H44G-06

Pub Date:
December 2018

Bibcode:
2018AGUFM.H44G..06L

Keywords:
1655 Water cycles; GLOBAL CHANGEDE: 1816 Estimation and forecasting; HYDROLOGYDE: 1847 Modeling; HYDROLOGYDE: 1855 Remote sensing; HYDROLOGY