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Data assimilation of GRACE terrestrial water storage estimates into a regional hydrological model of the Rhine River basin

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Terrestrial water storage (TWS) can be defined as an integrated measure of surface water, soil moisture, snow water, and groundwater. TWS data is valuable for water resources management and hydrology. The ability to simulate realistic TWS is essential for understanding past hydrological events and predicting future changes of the hydrological cycle. Inadequacies in physics, deficiencies in land characteristics and uncertainties in meteorological data commonly limit the performance of hydrological models in estimating TWS. In this study, we investigated the benefits of assimilating TWS derived from the Gravity Recovery And Climate Experiment (GRACE) into the Wflow HBV-96 model using the Ensemble Kalman Filter (EnKF). Since hydrological model parameters are often uncertain over a large part of the Earth, we investigated the impact of GRACE assimilation in different model scenarios representing different degrees of data availability. Four case studies were considered comparing calibrated and non-calibrated model parameters and local and global forcing data. The chosen study area is the Rhine River basin. Our results were validated using in-situ stream gauge data. In all scenarios, the temporal signatures of the averaged TWS are similar after assimilating GRACE while the spatial distribution is heavily influenced by the model parameters and input data as well as their uncertainties. Assimilation using the EnKF reduced the standard deviation at every updating stage, resulting in lower standard deviations than the model or the observations alone. Discrepancies between the local and global precipitation products had a significant impact on discharge estimates. For instance, when the global forcing data were used, discharge was drastically overestimated when spurious heavy rainfall occurred during the winter. Based on the correlation coefficient, Nash-Sutcliffe coefficient (NS), and root-mean-square error (RMSE) computed between the estimated and measured discharges at 13 gauge stations, we concluded that GRACE assimilation slightly improves the model performance when the model is well calibrated (calibrated parameters with local forcing data). More importantly, the improvement observed for the non-calibrated model (non-calibrated parameters with global forcing data), suggests that the impact of GRACE assimilation may be more significant in data-sparse regions.