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Implications of river storage for integrating GRACE TWS observations into a global hydrological model

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Over the last decade Terrestrial Water Storage (TWS) variations from GRACE and GRACE-FO satellite gravimetry have provided valuable observations for validation and calibration of hydrological models, and for data assimilation. While GRACE estimates represent the vertically integrated variations of all water storages, previous studies have shown the regional relevance of surface water and flood plain storage for TWS variations, and the inability to reproduce observed TWS by global hydrological models is often attributed to neglecting processes of river routing and floodplain dynamics. However, it is unclear if these processes need to be considered by computationally expensive river routing schemes in hydrologic model calibration and validation at large to global scales.

In this exploratory analysis, we assess the effect of river water storage that is included in the vertically integrated GRACE TWS variations on the calibration of a global hydrological model, and its relevance for model validation. For this purpose, we first determine an observation-based estimate of river storage by applying a routing scheme on GRUN runoff data, considering different effective flow velocities. Obtained river storage is then removed from GRACE TWS, and the TWS variations either with or without river storage are used along with other observational based data of evapotranspiration, soil moisture and runoff to constrain parameters of a simple global hydrological model that does not encompass a river routing module in a multi-criteria calibration approach.

While the removal of river storage changes the TWS constraint itself, especially its amplitude, at regional and global scale, we do not find a significant influence on calibrated parameters and thus model simulations. Instead, issues related to data uncertainty and inconsistency, as well as hydrological processes neglected by the model impose greater limitations than the rather local to regional relevance of river water storage. Furthermore, additional constraints from other data streams seem to not allow for adjustment to the changed TWS constraint in the calibration approach. However, simulating and adding river storage to modelled TWS after model calibration improves model validation relative to GRACE TWS globally and regional. Largest improvement is obtained in tropics and Northern low- and wetlands, where a substantial volume of water

accumulates in major rivers, highlighting the importance of considering river water in these regions. Difficulties to reproduce TWS variations are mainly apparent in semi-arid regions where a generally lower volume of water is stored on land surface and neglected processes (e.g. evaporation and percolation from the flow channel) play a role.

While it’s arguable that the presented results are quite specific to the used data and model structure, the key issues are shared among global hydrological modelling studies. Therefore, our findings suggest that omitting routing for large-scale model calibration against GRACE TWS is a valid option, considering limited computational and temporal resources. Nonetheless, the findings encourage the inclusion of river storage dynamics for validation of large-scale hydrological studies.