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Modeling local water storage changes using in-situ gravity observations as calibration constraints

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In hydrology, the appropriate estimation of the water storage term in the water balance equation is challenging. Temporal gravity data are influenced by local water storage changes (WSC) and hence, can be a direct measure of the status change of the hydrological system.
In this context, we will focus on the use of temporal gravimeter measurements as an integral signal for hydrological application, by exemplarily evaluating the use of temporal gravity measurements for hydrological model calibration. A simple conceptual model based on the HBV model is used to estimate local WSC in the snow, soil, unsaturated saprolite and saturated aquifer storage. The model was calibrated based on the GLUE method against superconducting gravimeter (SG) data on the one hand and several groundwater and/or soil moisture data on the other. These different calibrated models are compared by performing a split sample test and validated by comparing the results to totally independent estimated WSC from a state-of-the-art lysimeter.
The model better reproduce the temporal behavior of the gravity response than the temporal variation of the groundwater and/or soil moisture. In general, the uncertainty band of the different behavioral model sets is larger for models calibrated with groundwater and/or soil moisture data than for the model calibrated with SG data. Comparing the modeled hydrological gravity response to the SG residuals for the whole study period both signals show not only similarities in terms of amplitude, long, seasonal and short-term variations, but are also strongly related to general weather conditions of the Bavarian Forest.
This study identifies advantages and limitations of the use of temporal gravity observations in the context of hydrological model calibration. Comparing the SG to groundwater and soil moisture data shows the problem of the 'representativeness' of single point measurements. Terrestrial gravity measurements have a much larger sphere of influence but it is difficult to unambiguously identify the source of the gravimeter signal. Nonetheless, temporal gravity data can improve water balance studies and might be especially useful in elevated areas, like upslope areas, because until now no adequate measurement technique is available to estimate local WSC for these areas, far away from the river.