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The efficacy of combining satellite water storage and soil moisture observations as constraints on water balance estimation

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The ability to accurately estimate terrestrial water storage (TWS) and its components (e.g. soil moisture, groundwater, surface water and snow) is of considerable value to water resources assessment. Due to the imperfection of both model predictions and observations, data assimilation methods have been widely applied to hydrological problems for optimal combination of model and observations. Recent studies on the assimilation of TWS data have shown its capability to improve simulated groundwater storages, but the assimilation of TWS only does not guarantee accurate estimation of surface soil moisture (SSM). We investigated the efficiency of data assimilation combining TWS change estimates, derived from temporal changes in Earth's gravity field measured by the Gravity Recovery and Climate Experiment (GRACE), with SSM, retrieved from emitted microwave radiation at L-band observed by the Soil Moisture and Ocean Salinity (SMOS) satellite.

The global World Wide Water (W3) water balance model was used. The specific satellite data products used were the SMOS CATDS level 3 daily SSM product and the JPL mascon monthly GRACE product. Both the ensemble Kalman filter (EnKF) and smoother (EnKS) were implemented to determine the best option for the assimilation of SSM observations only and the joint assimilation of SSM and TWS. The observation models, which map model states into observation space, are the top-layer soil relative wetness and monthly average TWS (i.e. aggregated daily top-, shallow-, deep-layer soil water storage, ground- and surface water storages). Three assimilation experiments were conducted with each method: a) assimilation of SSM data only; b) assimilation of TWS data only; c) joint assimilation of SSM and TWS data. Results were compared against in-situ soil moisture and groundwater observations, and the performance assessed with respect to open-loop results.

Results for the Murray-Darling Basin in Australia demonstrate that the assimilation of SSM data only improves estimation of the soil moisture profile (0 -1 m) but has little impact on TWS. The assimilation of TWS data significantly improves the deep soil moisture and groundwater dynamics, but causes a slight degradation of SSM estimation. Analysis showed that both observations can be jointly assimilated without imparting conflicting constraints and there is clear advantage in integrating them to ensure accurate estimates of both SSM and TWS.