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Improving drought simulations within the Murray-Darling Basin by combining GRACE data and hydrological models

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Simulating hydrological processes within the (semi-)arid region of the Murray-Darling Basin (MDB), Australia, is very challenging especially during droughts. In this study, a novel calibration and data assimilation (C/DA) framework is applied to integrate terrestrial water storage changes (TWSC) observed by the Gravity Recovery And Climate Experiment (GRACE) satellites into the WaterGAP Global Hydrology Model (WGHM) within the MDB during the so-called 'Millennium Drought' (2003-2009). In particular, we test the ability of the approach to reproduce long-term decline of water storage components, which is generally poorly represented in hydrological models due to simplifications of the model structure, as well as uncertainties in forcing data and parameter calibration. For the first time, the impact of the parameter equifinality problem on the C/DA results is evaluated. We also investigate the influence of selecting a specific GRACE data product and filtering method on the final C/DA results.

The assessment of our results clearly showed the strengths and limitations of the current C/DA implementation. It is possible to restore linear trends into WGHM, and also improve the seasonality. The association of the water decline with the correct water storage component, i.e. groundwater in our study, is achieved and validated against ground-based well measurements. Our results indicate that by implementing C/DA the response of soil water and groundwater storage to climate variability within the MDB was improved. It was also shown that although river discharge simulations were not improved by assimilating limited resolved GRACE data, river storage simulations can be considerably improved. Reducing the number of calibration parameters helps to avoid equifinality, i.e. reducing the uncertainties of calibration parameters, enabling their values to converge, and better capturing the influence of climate conditions on the groundwater component.