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Improving modelled long-term storage variations with standard hydrological models in data-scarce regions

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In the Luangwa river basin in Zambia, the total water storage observed by GRACE (Gravity Recovery and Climate Experiment) shows an oscillating pattern, such that the annual minimum/maximum storage decreased in 2002 – 2006 after which it increased until 2010, which was again followed by a storage decrease. However, this pattern was not reproduced by a standard conceptual hydrological model. Similarly, previous studies illustrated the inability of standard conceptual hydrological models to reproduce long-term storage variations in many river basins world-wide. This study identified processes that potentially caused the observed long-term storage variations in the Luangwa basin through data analysis and model hypothesis testing. During data analysis, long-term storage variations were compared to satellite-based products for precipitation, actual evaporation, potential evaporation and NDVI observations. During model hypotheses testing, we analysed 1) four different model forcing combinations and 2) five alternative model hypotheses for groundwater export to neighbouring basins. The results indicated that the benchmark model did not reproduce the observed long-term storage variations partly due to the forcing data and partly due to the missing process of regional groundwater export. Alternative model forcing data affected the modelled annual maximum storage, whereas the annual minima improved when adapting the model structure allowing for regional groundwater export from a deeper groundwater layer. In other words, standard conceptual hydrological models can reproduce long-term storage variations when using a suitable model structure.