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Comprehensive, Process-based Identification of Hydrologic Models using Satellite and In-situ Water Storage Data: A Multi-objective calibration Approach

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The credible identification of vertical and horizontal hydrological components and their associated parameters is very challenging (if not impossible) by only constraining the model to streamflow data, especially in regions where the vertical processes significantly dominate the horizontal processes. The prairie areas of the Saskatchewan River basin, a major water system in Canada, demonstrate such behavior, where the hydrologic connectivity and vertical fluxes are mainly controlled by the amount of surface and sub-surface water storages. In this study, we develop a framework for distributed hydrologic model identification and calibration that jointly constrains the model response (i.e. streamflows) as well as a set of model state variables (i.e. water storages) to observations. This framework is set up in the form of multi-objective optimization, where multiple performance criteria are defined and used to simultaneously evaluate the fidelity of the model to streamflow observations and observed (estimated) changes of water storage in the gridded landscape over daily and monthly time scales. The time series of estimated changes in total water storage (including soil, canopy, snow and pond storages) used in this study were derived from an experimental study enhanced by the information obtained from the GRACE satellite. We test this framework on the calibration of a Land Surface Scheme-Hydrology model, called MESH (Modélisation Environmentale Communautaire – Surface and Hydrology), for the Saskatchewan River basin. Pareto Archived Dynamically Dimensioned Search (PA-DDS) is used as the multi-objective optimization engine.

The significance of using the developed framework is demonstrated in comparison with the results obtained through a conventional calibration approach to streamflow observations. The approach of incorporating water storage data into the model identification process can more potentially constrain the posterior parameter space, more comprehensively evaluate the model fidelity, and yield more credible predictions.