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Added Value of Earth Observation Constraints for Multi-Model Drought Detection in the Rhine Basin

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Reliable characterisation of soil-moisture drought is critical for water management, yet hydrological models can diverge substantially because of parametric uncertainty [1] even when forced with identical meteorology. This work is conducted within the ESA 4DHydro initiative (https://4dhydro.eu/) and builds on our EO-constrained parameter estimation framework [2]. We assess whether Earth Observation (EO) data reduce this divergence using a four-model ensemble (CLM, JULES, mHM, PCR-GLOBWB) over the Rhine Basin. We compare three parameter estimation strategies: (i) a non-EO baseline using default model configurations, (ii) EO-only calibration using satellite soil moisture (SM) and evapotranspiration (ET), and (iii) a hybrid EO+Q calibration combining EO constraints with streamflow (Q).

The latter ensures both spatial pattern matching of EO-derived SM, ET, and water balance closure. For the major droughts of 2015, 2018, and 2019, EO-only calibration notably reduces inter-model spread and strengthens the detection of extreme dry conditions, improving ensemble agreement by up to ~0.09 in extreme-event cases. Joint SM+ET calibration provides the best trade-off between sensitivity to extremes and ensemble stability across models.

The EO+Q strategy yields the highest temporal skill, including station-scale improvements (e.g.,

RMSE reductions of ~0.02 and correlation gains of ~0.06 in independent validation), but also exposes larger between-model differences, especially in Alpine headwaters where snow and glacier processes remain challenging. Overall, EO constraints can meaningfully tighten multi-model drought estimates, while also highlighting persistent structural uncertainties that should be communicated in operational drought early-warning systems.

References:

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