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Prognostic ParFlow Integrated Hydrologic Model Applications at Stakeholder Scale Over Central Europe

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Integrated physics-based hydrologic models (IHMs) have evolved into versatile tools constituting a cornerstone of many water resources and hydrologic hazard impacts applications from catchments to global model domains. IHMs allow for a physically consistent terrestrial water cycle representation, where groundwater and surface processes interact. To simulate groundwater-to-atmosphere feedbacks more realistically and account for the lateral redistribution of water, IHMs are hence increasingly incorporated into coupled Earth system models. Here we show applications of high-resolution prognostic simulations with the IHM ParFlow (https://github.com/parflow). Since 2020, ParFlow, with its integrated Common Land Model, is applied on GPUs in an experimental quasi-operational setup over central Europe, at a spatial resolution of approximately 600m for daily 10-day forecasts in a 52 member probabilistic forecast ensemble driven by ECMWF forecasts. Additionally, a 7-month seasonal prediction ensemble is run each meteorological season. Informed primarily by agricultural stakeholder needs in a co-design process, we provide diagnostics, such as water table depth, seepage water, plant available water, total water storage, etc., of the current state and the near-term evolution of the terrestrial water cycle through specific, targeted interfaces to data and information products (e.g., https://wasser-monitor.de, in German). The seasonal predictions are disseminated with a focus on water availability through an experimental Water Resources Bulletin (https://www.adapter-projekt.de/bulletin/index_en.html) that shows subsurface monthly water storage anomalies, including shallow groundwater down to 60m depth, with reference to a long-term ParFlow climatology, that captures the recent hydrometeorological extremes very well. ParFlow prognostic capabilities have also been demonstrated through a process-based analysis of forecasts and hindcast runs of the 2021 extreme flood event in western Germany and eastern Belgium. While this is an uncalibrated model, ParFlow well simulates many aspects including magnitude and timing of this extreme event. The physical representation of groundwater-surface water interactions affords hypothesis testing and is used to improve our process understanding of the 2021 flood event.

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