



Conference Abstract

Assessment of the skill of seasonal probabilistic water table depth forecasts with the hydrological model ParFlow/CLM over central Europe

Alexandre Belleflamme[‡], Suad Hammoudeh[‡], Klaus Goergen[‡], Stefan Kollet[‡]

[‡] Forschungszentrum Jülich, IBG-3 (Agrosphere), Jülich, Germany

Corresponding author: Alexandre Belleflamme (a.belleflamme@fz-juelich.de)

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Abstract

In recent years, alternating drought and extreme precipitation events have highlighted the need for subseasonal to seasonal forecasts of the terrestrial water cycle. In particular, predictions of the impacts of dry and wet extremes on groundwater resources are crucial to assess the impacts of groundwater scarcity and excess on ecosystem dynamics as well as to provide stakeholders in agriculture, forestry, the water sector, and other fields with information supporting the sustainable use of these resources.

In this context, we calculate four times per year seasonal probabilistic hydrological forecasts at 0.6 km resolution, from the surface down to 60 m depth, for the upcoming seven months over Germany and surrounding regions (hydrological Germany). These forecasts

are generated using the integrated, physics-based hydrological model ParFlow/CLM (Kuffour et al. 2020) with the setup described in Belleflamme et al. (2023), forced by 50 ensemble members of the SEAS5 seasonal forecast from the European Centre for Medium-Range Weather Forecasts (ECMWF). The predicted evolution of the terrestrial water cycle is released at the beginning of each meteorological season for the total subsurface water storage anomaly in our experimental Water Resources Bulletin (<https://adapter-projekt.de/bulletin/index.html>).

To evaluate our forecasts, we evaluated six 7-months probabilistic forecasts covering the vegetation period (March to September) for the years 2018 to 2023 with a reference long-term historical time series based on the same ParFlow/CLM setup. The forecast skill was assessed by comparing these seasonal forecasts to a climatology-based 10-member pseudo-forecast over the 2013–2023 period (using the leave-one-out method), extracted from the reference time series.

The monthly Continuous Ranked Probability Skill Score (CRPSS), which evaluates the ensemble distribution based on daily water table depth data, indicates that the probabilistic forecast outperforms the climatology-based pseudo-forecast in most regions, except in 2018 and, to a lesser extent, in 2020 and 2022 (see Fig. 1). This can be attributed to an under-representation of extremely dry members in the ensemble, combined with the memory effect of the initial conditions at increasing soil depths. For example, while March 2018 started with a slightly below-average water table depth and experienced a strong meteorological drought leading to an agricultural drought and eventually an increase in water table depth (i.e., groundwater depletion), the initial water table depth anomaly in March 2019 was already positive, with a less pronounced precipitation deficit during the vegetation period. This resulted in a much higher forecast skill, because of the memory effect accurately simulated with the physics-based model. Notably, the forecast skill only slightly decreases with increasing lead time, both for precipitation and water table depth.

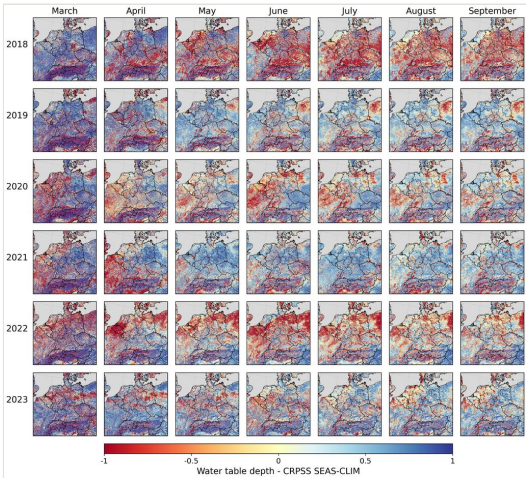


Figure 1. [doi](#)

Monthly Continuous Ranked Probability Skill Scores for seven-months probabilistic forecasts with the hydrological model ParFlow/CLM over the period 2018-2023. The seasonal forecasts are driven by 50-member ensemble SEAS5 forecasts from ECMWF. The 10-member climatology-based pseudo-forecasts are extracted from the reference time series driven by HRES from ECMWF over the period 2013-2023, leaving out the considered year. Regions where the seasonal probabilistic forecast shows a higher (resp. lower) skill than the climatology-based pseudo-forecast present positive (resp. negative) values.

The analysis of the Relative Operating Characteristic Skill Score (ROCSS) for the upper quintile of the water table depth distribution assesses whether positive water table depth anomalies (i.e., droughts) are adequately represented within the probabilistic forecast ensemble. The results are consistent with those of the CRPSS, showing lower skill in 2018. Nevertheless, the ROCSS analysis overall indicates high skill for the probabilistic forecast, while the climatology-based pseudo-forecast demonstrates no skill. This means that the forecast ensemble covers a sufficiently wide range of possible scenarios to include extreme events of the order of magnitude as the droughts experienced in central Europe over recent years.

To conclude, this evaluation confirms that the dry conditions experienced in central Europe in recent years were captured within the probabilistic forecast, underlining the added value of these forecasts and their potential usefulness for predicting and assessing the impact of groundwater fluctuations on ecosystem functioning and dynamics.

Keywords

Water table depth, Groundwater resources, Seasonal probabilistic forecast, Hydrological modelling, ParFlow/CLM

Presenting author

Alexandre Belleflamme

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Conflicts of interest

The authors have declared that no competing interests exist.

References

- Belleflamme A, Goergen K, Wagner N, Kollet S, Bathiany S, El Zohbi J, Rechid D, Vanderborcht J, Vereecken H (2023) Hydrological forecasting at impact scale: the integrated ParFlow hydrological model at 0.6 km for climate resilient water resource management over Germany. *Frontiers in Water* 5 (1183642). <https://doi.org/10.3389/frwa.2023.1183642>
- Kuffour BN, Engdahl NB, Woodward CS, Condon LE, Kollet S, Maxwell RM (2020) Simulating coupled surface-subsurface flows with ParFlow v3.5.0: capabilities, applications, and ongoing development of an open-source, massively parallel, integrated hydrologic model. *Geoscientific Model Development* 13: 1373-1397. <https://doi.org/10.5194/gmd-13-1373-2020>