

Assessment of the skill of seasonal probabilistic hydrological forecasts with ParFlow/CLM over central Europe

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Context

Forecasting the terrestrial water budget becomes increasingly important, esp. for the **agricultural, forestry, and water management sectors**, in the context of

- Resilience to **extreme weather events** like the droughts of 2018, 2019, 2020, and 2022 → **Fig. 1** for anomalies of total subsurface water storage
- Adaptation to **climate change**
- Sustainable management of soil and **water resources**



→ **Experimental Water Resources Bulletin**

with 7-months probabilistic forecast released four times per year

Methodology

Seasonal forecasts

- Probabilistic seasonal forecast with **hydrological model ParFlow/CLM** [1,2]
- Driven by **SEAS5** 50-member ensemble forecast from **ECMWF**

Evaluation

- Focus on total subsurface water storage – TSS (from surface to 60m depth)
- Over vegetation period: forecast initialized on March 1st
- **Reference time series**: same ParFlow/CLM setup driven by ECMWF HRES h0-h24 → considered as “perfect” forecast [3]
- **Climatology-based pseudo-forecast**: 10 “members” from reference time series over 2013-2023, with leave-one-out method
- General skill of ensemble distribution: Continuous Ranked Probability Skill Score – **CRPSS**
- Skill for dry extreme events: Area Under Curve of the Relative Operating Characteristic – **AUC-ROC** for lower quintile of the distribution

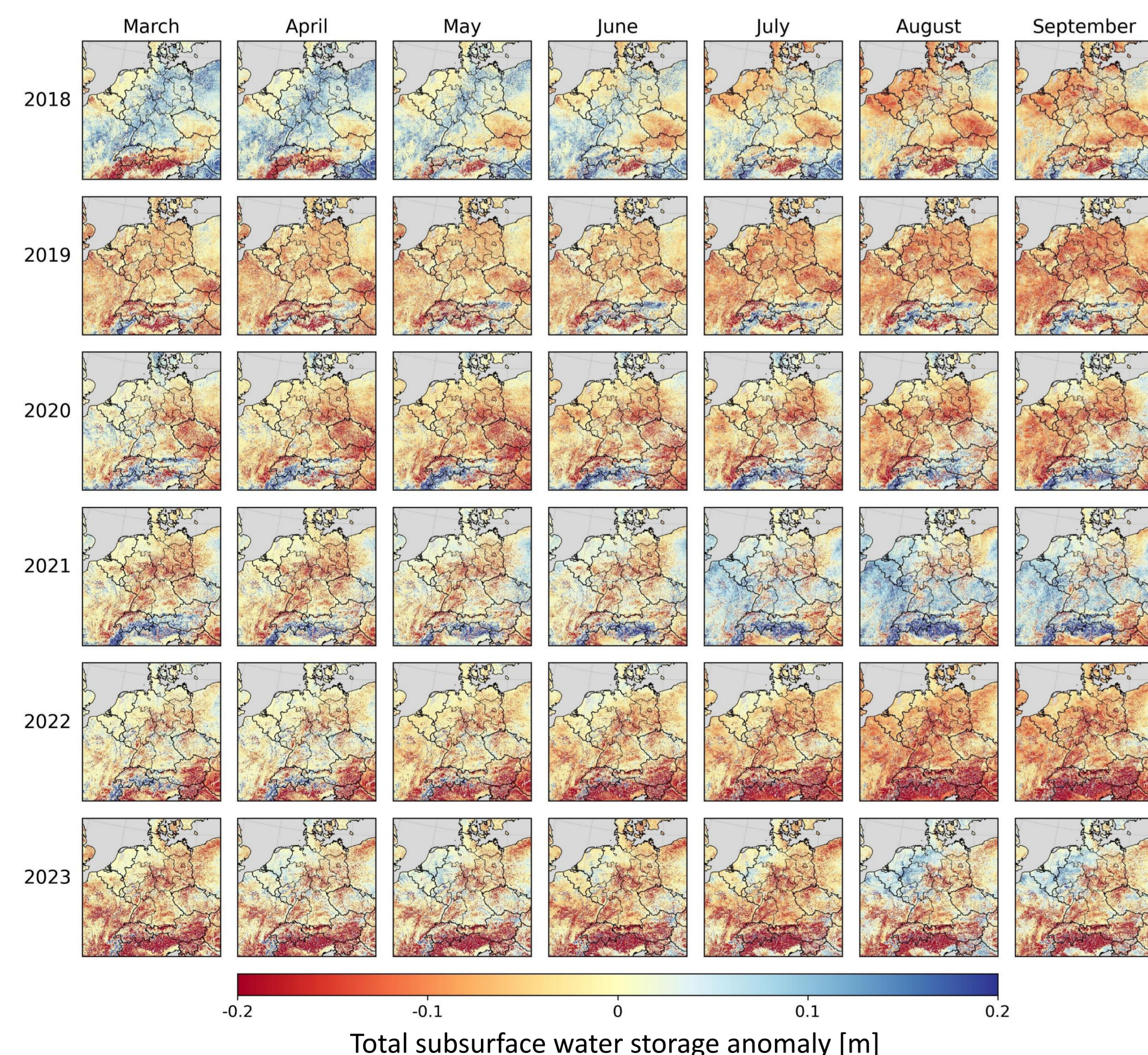


Figure 1: Anomaly of monthly mean TSS [m] for 2018-2023 compared to 2013-2023.

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Assessment of ensemble skill

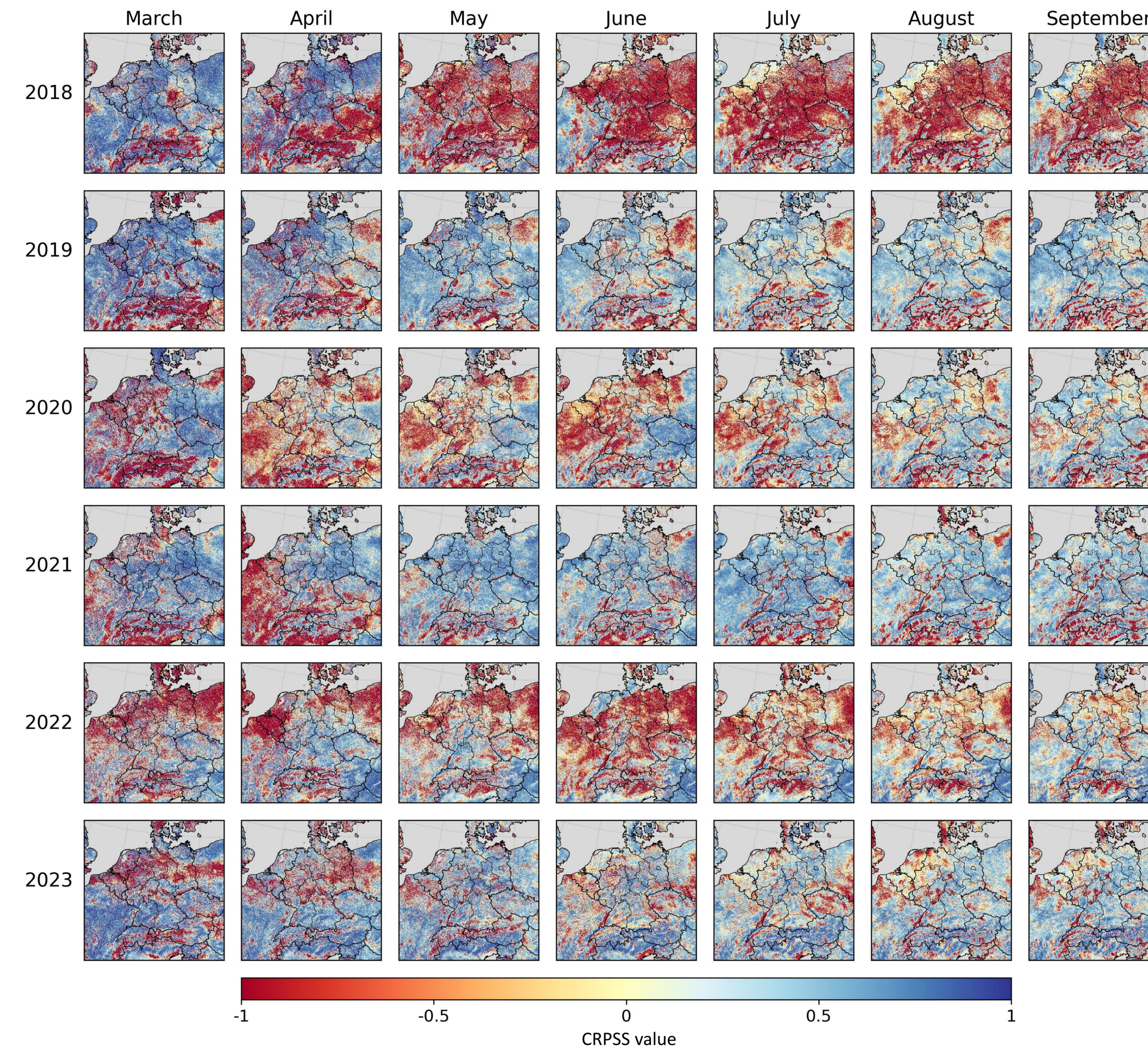


Figure 2: Monthly CRPSS for total subsurface water storage seven-months probabilistic forecasts with ParFlow/CLM over 2018-2023 compared to climatology-based pseudo-forecasts. In regions with positive values, the seasonal probabilistic forecast shows higher skill than the climatology-based pseudo-forecast.

Probabilistic forecast outperforms climatology-based pseudo-forecast for CRPSS → Fig. 2

Except when there is a stronger **change / reversal in the anomaly** (→ Fig. 1) during the forecast period, e.g.:

- 2018: above-average TSS in spring + strong meteorological drought → agricultural drought onset → low skill
- 2019: negative TSS anomaly + less pronounced precipitation deficit → agricultural drought continuing → higher skill

→ Underrepresentation of extremely dry members in the ensemble

→ Role of **memory effect**

→ Only **slight decrease in forecast skill** over time after the first month, also for precipitation → Fig. 4

AUC-ROC skill is very high for the first month, but remains **generally positive** over the whole forecast period → Fig. 3

→ More extreme, dryer conditions are represented in the probabilistic ensemble

→ Climatology-based pseudo-forecast shows no skill → Fig. 5

References

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- ² Kuffour B., Engdahl N., Woodward C., Condon L., Kollet S., Maxwell R., 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, doi: 10.5194/gmd-13-1373-2020
- ³ Belleflamme A., Goergen K., Wagner N., Kollet S., Bathiany S., El Zohbi J., Reich D., Vanderborcht J., and 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, doi: 10.3389/frwa.2023.1183642

Assessment of extremes' skill

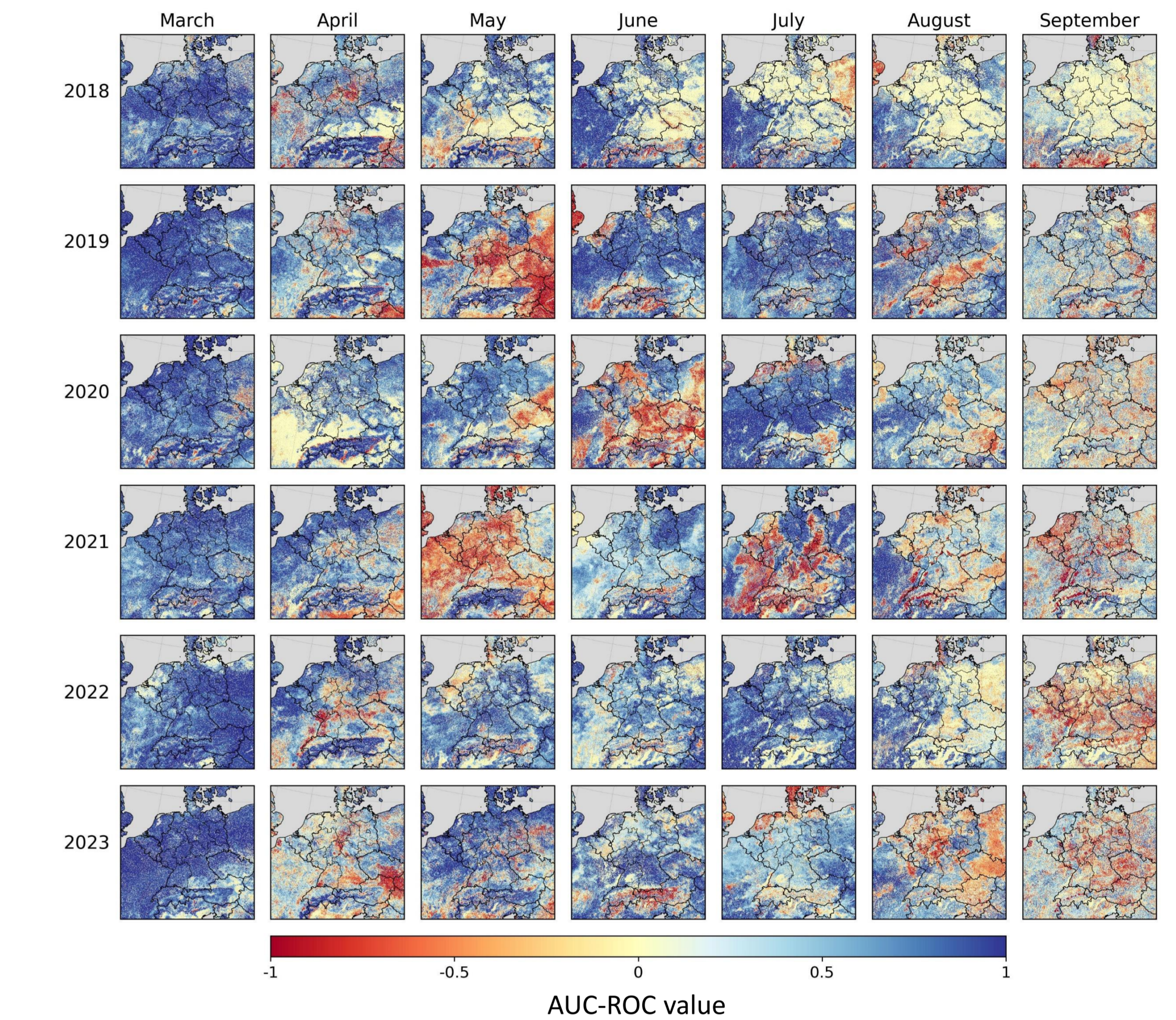


Figure 3: Monthly AUC-ROC for the lower quintile of the total subsurface water storage seven-months probabilistic forecasts with ParFlow/CLM over 2018-2023. In regions with a high value, low tss (i.e., drought) conditions are well represented in the seasonal probabilistic forecast.

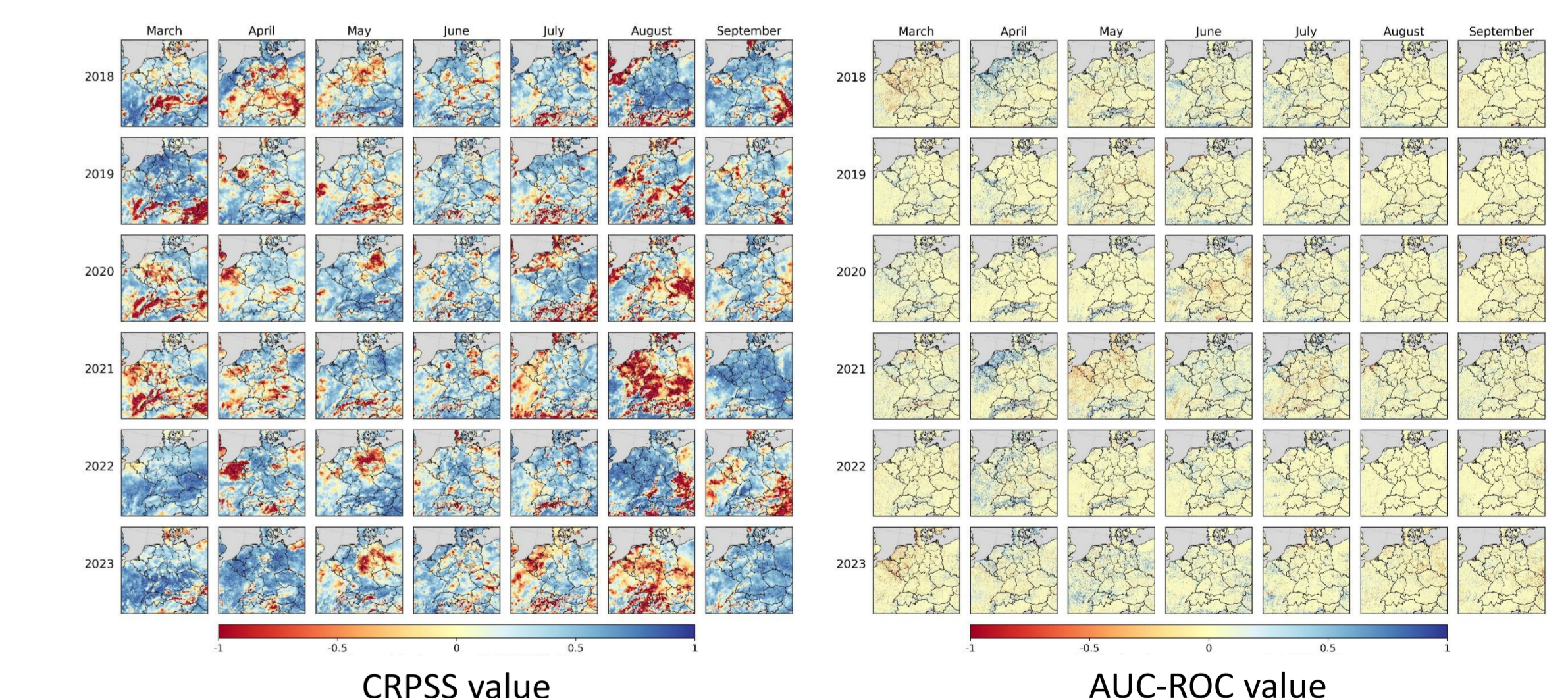


Figure 4: Same as Fig. 2 but for precipitation.

Figure 5: Same as Figure 3 but for the climatology-based pseudo-forecasts over 2013-2023.

Take home messages

- Probabilistic seasonal forecast generally outperforms climatology-based pseudo-forecast
- ECMWF SEAS5 forecast has strongest impact on skill
- Memory effect also plays an important role
- General ensemble analysis is not sufficient when looking at extremes → zoom on distribution tail or even specific members