Skill of seasonal forecasts with the hydrological model ParFlow/CLM to predict subsurface water resources under drought conditions in central Europe

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Why do we need seasonal forecasts?

Repeated droughts (2018, 2019, 2020, 2022) in central Europe

→ Need for **seasonal forecasts of subsurface water resources**
- Upcoming drought (risk)
- Water management strategies dealing with reduced water resources
- Regeneration of water resources after a drought
- Agriculture, forestry, water resources

→ **How reliable, meaningful are these seasonal forecasts?**

→ Analysis for summer drought 2022 with forecast initialized on 2022-06-01.

Seasonal forecasts with ParFlow/CLM

ParFlow/CLM (www.parflow.org)

Hydrological model that simulates 2D/3D **hydrological processes in the saturated and unsaturated zone**, including groundwater and overland flow [1,2].

Its integrated land surface module CLM (Common Land Model) allows for a representation of the **interactions at the surface** (water and energy fluxes) [2].

Experiment setup [3]

2000 x 2000 grid points over **central Europe** (Fig. 1) over **15 depth layers** from surface to 60m, with increasing thickness, **611m resolution**, hourly time step.

Seasonal forecasts

50-member ensemble seasonal forecast over **seven months** driven by ECMWF SEAS weather forecast ensemble, every three months.

Part of short-term and seasonal forecasting system → **www.adapter-projekt.de**

Initialization from reference time series calculated with first 24h from each daily deterministic forecast.

Experimental Water Resources Bulletin

www.adapter-projekt.de/bulletin/index_en.html

→ poster by S. Hammoudeh et al.

(A) Elevation over land

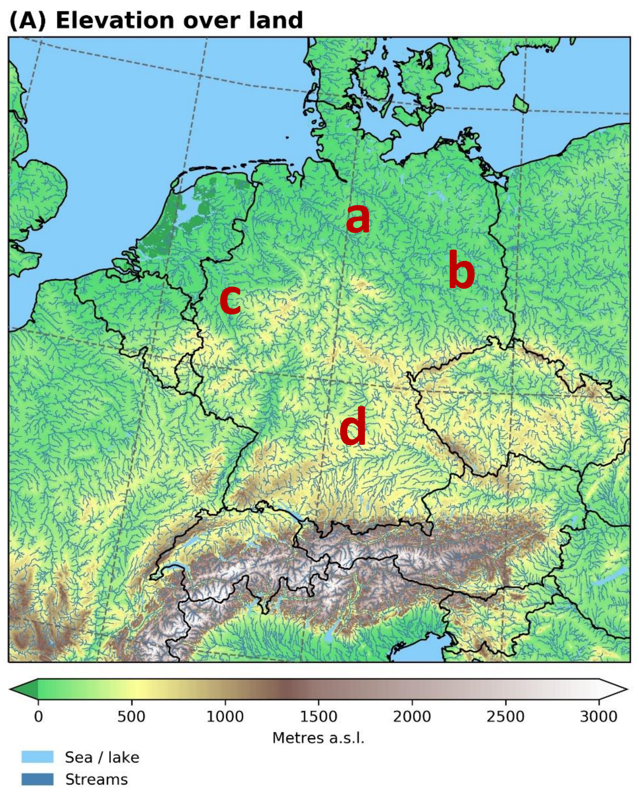

Fig. 1: Domain extension, elevation, and localisation of analysed regions.

Forecasted cumulated precipitation

➢ Precipitation was predicted to be **(above) normal** (Fig. 2).

➢ "Perfect" forecast **often drier** than 25th or even 10th percentile.

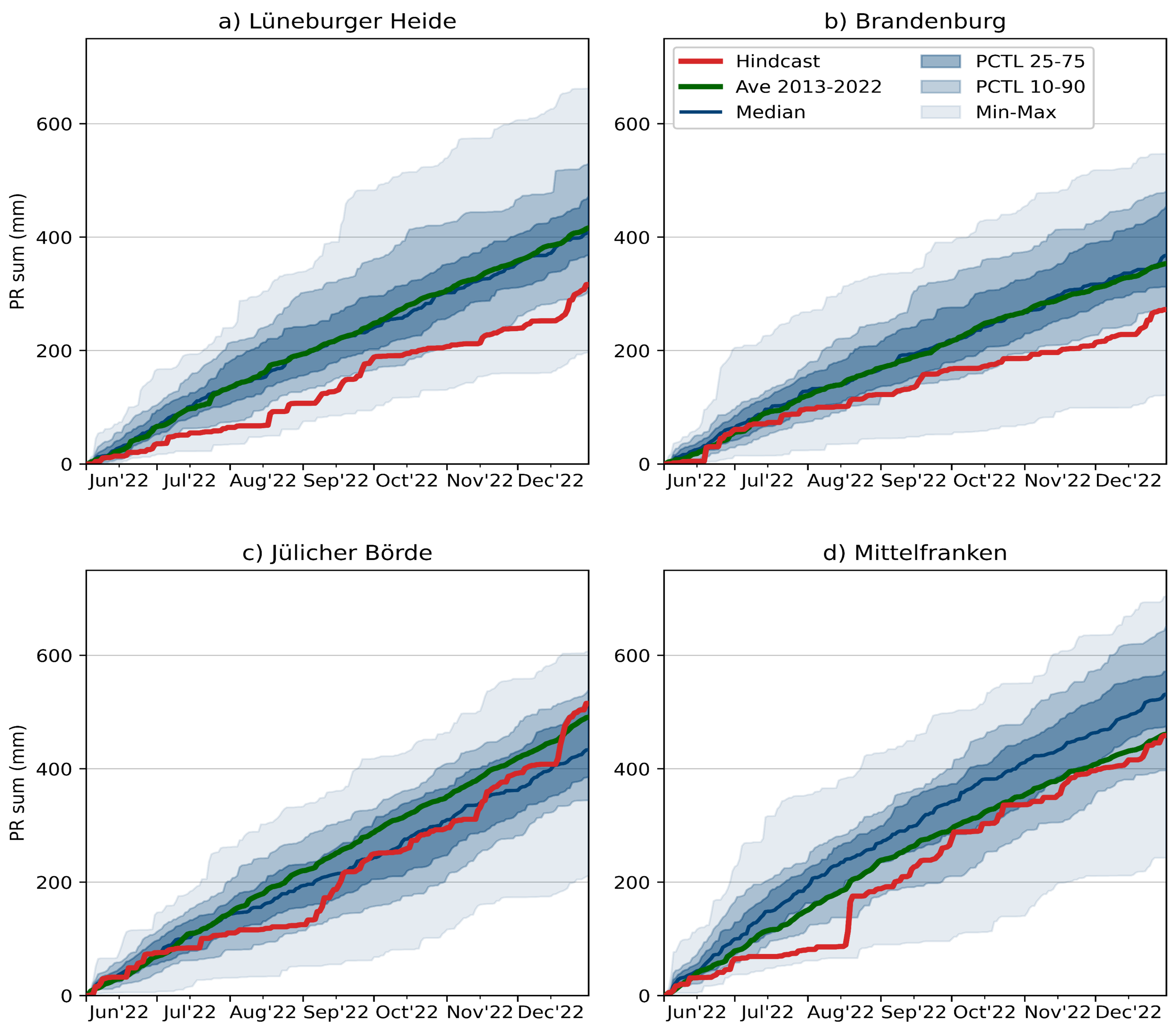

Fig. 2: Cumulated precipitation from initialisation of seasonal forecast.

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References

[1] Kollet S., Maxwell R., 2006, Integrated surface-groundwater flow modeling: A free-surface overland flow boundary condition in a parallel groundwater flow model, *Advances in Water Resources*, 29, 945-958, doi: 10.1016/j.advwatres.2005.08.006

[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., Rechid D., Vanderborght J., Vereecken H., 2023, Hydrological forecasting at impact scale: the integrated ParFlow hydrological model at 0.6 km for climate resilient water resources management over Germany, *Frontiers in Water*, 5:1183642, doi: 10.3389/frwa.2023.1183642

[4] Jülich Supercomputing Centre, 2019, JUWELS: Modular Tier-0/1 Supercomputer at the Jülich Supercomputing Centre. *Journal of large-scale research facilities*, 5, A135, doi: 10.17815/jlsrf-5-171

Forecasted change in subsurface water storage

➢ Dry conditions were much **better forecasted** for the subsurface water storage (Fig. 3).

➢ **Memory effect / latency** of subsurface water dynamics increases forecast skill.

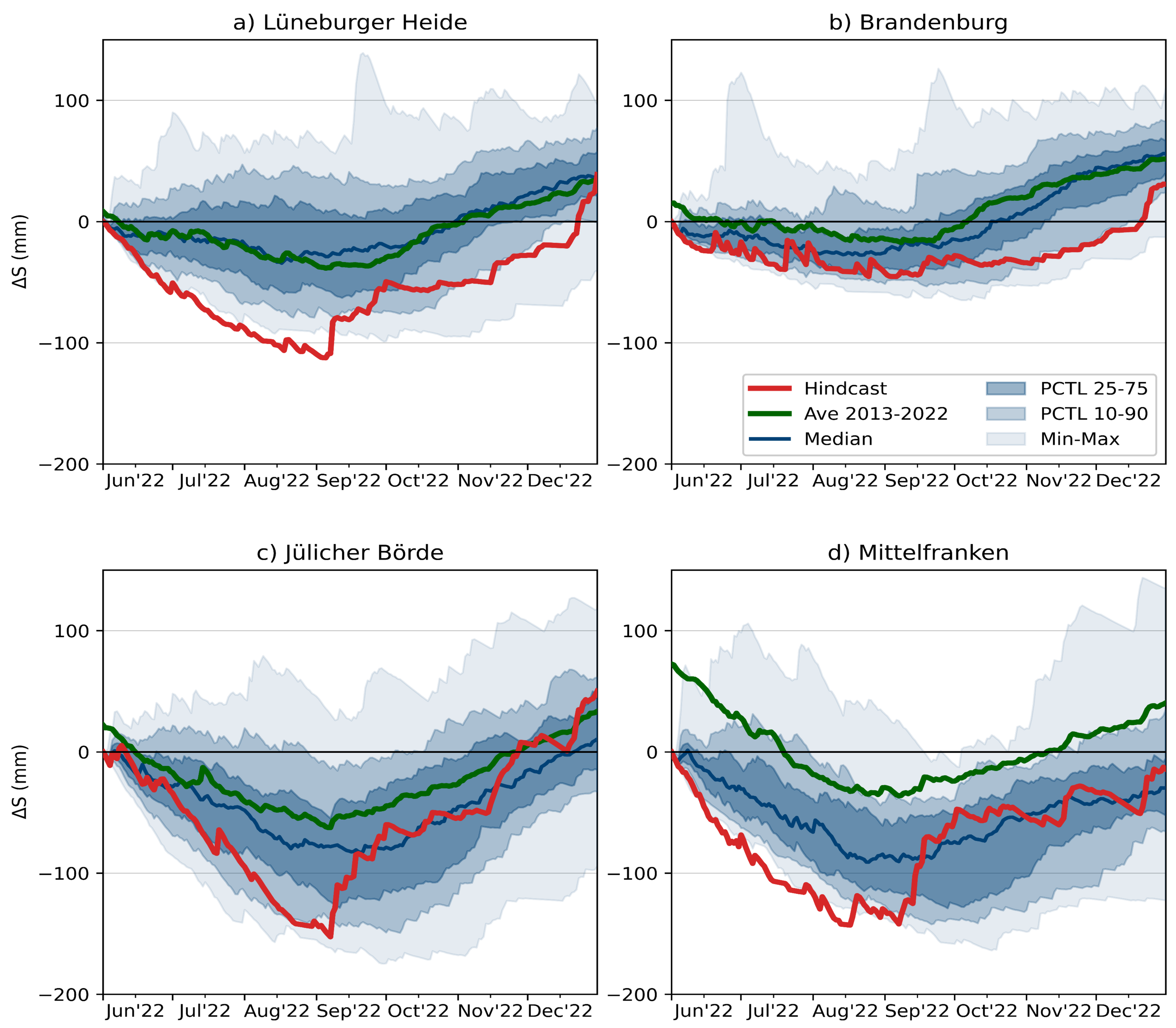

Fig. 3: Change in subsurface water storage (0-2m depth) from initialisation of seasonal forecast.

Distribution of ensemble members for subsurface storage

➢ For the **0-2m** subsurface water storage, most members show a **high correlation** (Fig. 4).

➢ Role of **memory effect**, influence of surface processes is smoothed out.

➢ But they generally **underestimate the variability** → Why? Coarser resolution of forcing?

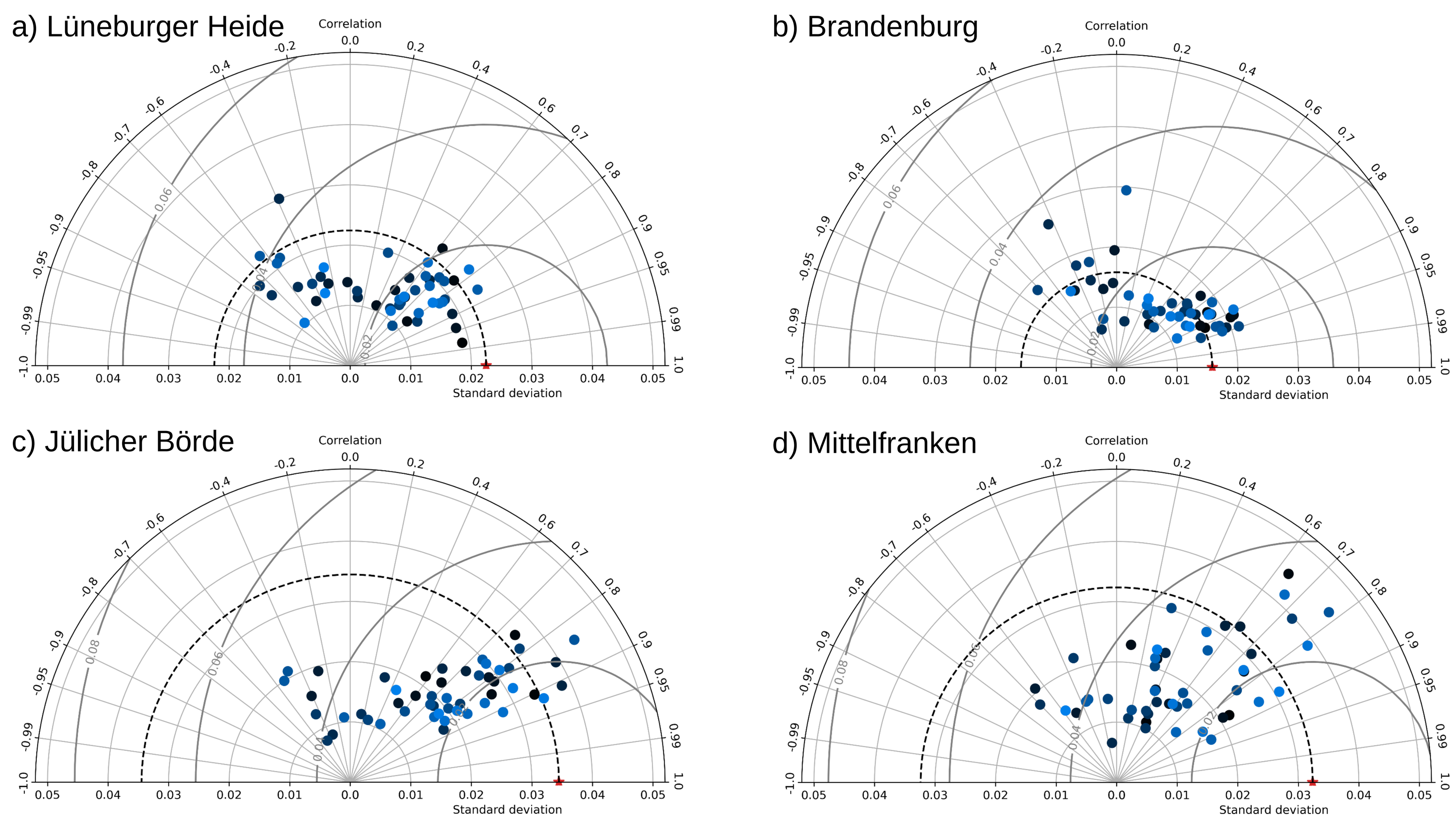

Fig. 4: Taylor diagrams of 0-2m subsurface water storage for the forecast from 2022-06-01. Each dot represents JJAS for one member.

➢ For the **0-30cm** subsurface water storage, **correlation is much lower** (Fig. 5).

➢ Stronger influence / **connection with surface processes** (high variability of P and ET).

➢ Still **underestimation of the variability** except for Brandenburg (sandy soils).

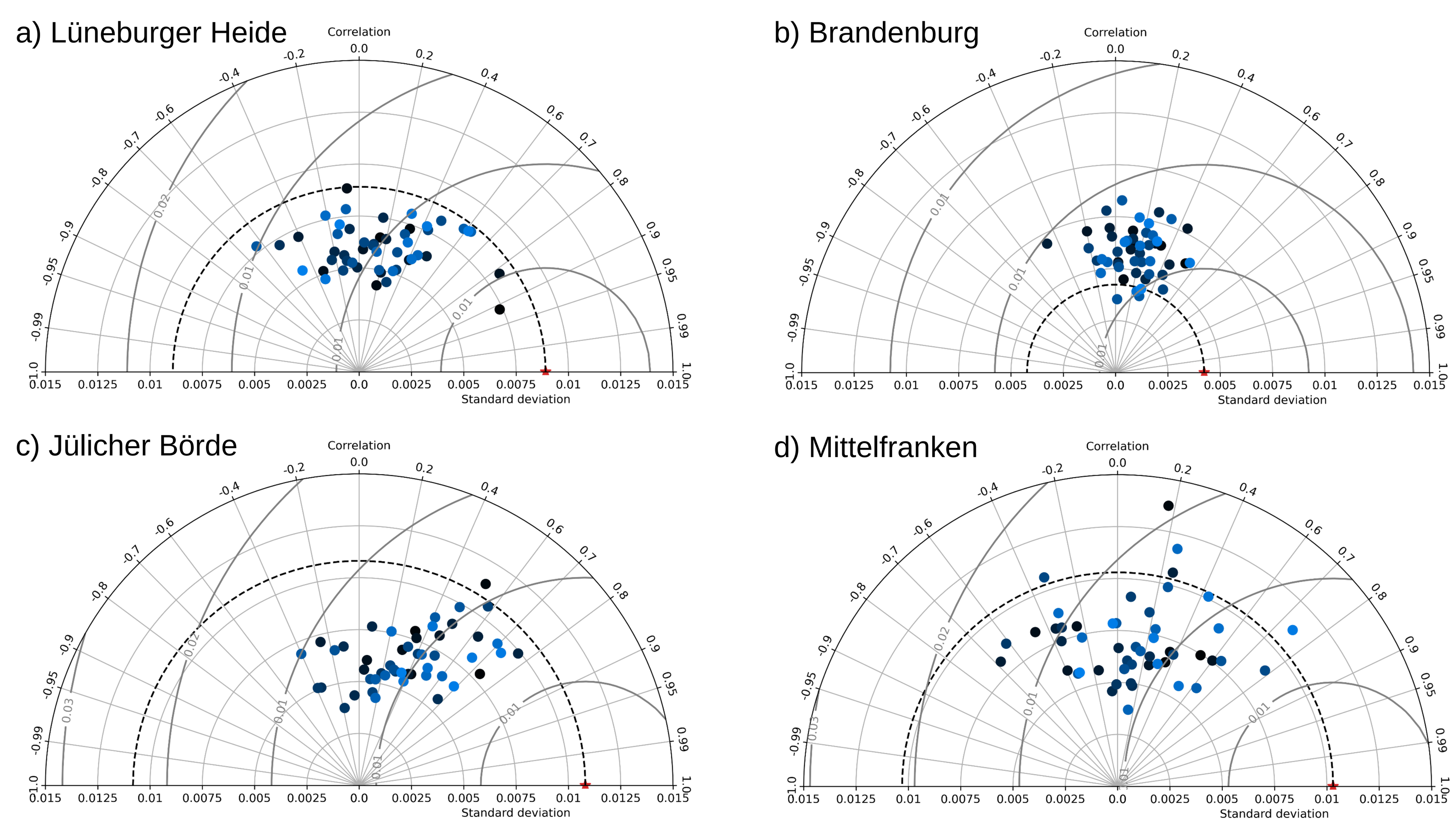

Fig. 5: Taylor diagrams of 0-30cm subsurface water storage for the forecast from 2022-06-01. Each dot represents JJAS for one member.