Evaluation of the skill of probabilistic seasonal forecasts in predicting droughts with the hydrologic model ParFlow/CLM over central Europe

2026-08-07 – EFI Conference I **A. Belleflamme[1,2], S. Hammoudeh[1,2], K. Goergen[1,2], S. Kollet[1,2]**

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HPSC TerrSys
A Geoverbund ABC/J Competence Centre

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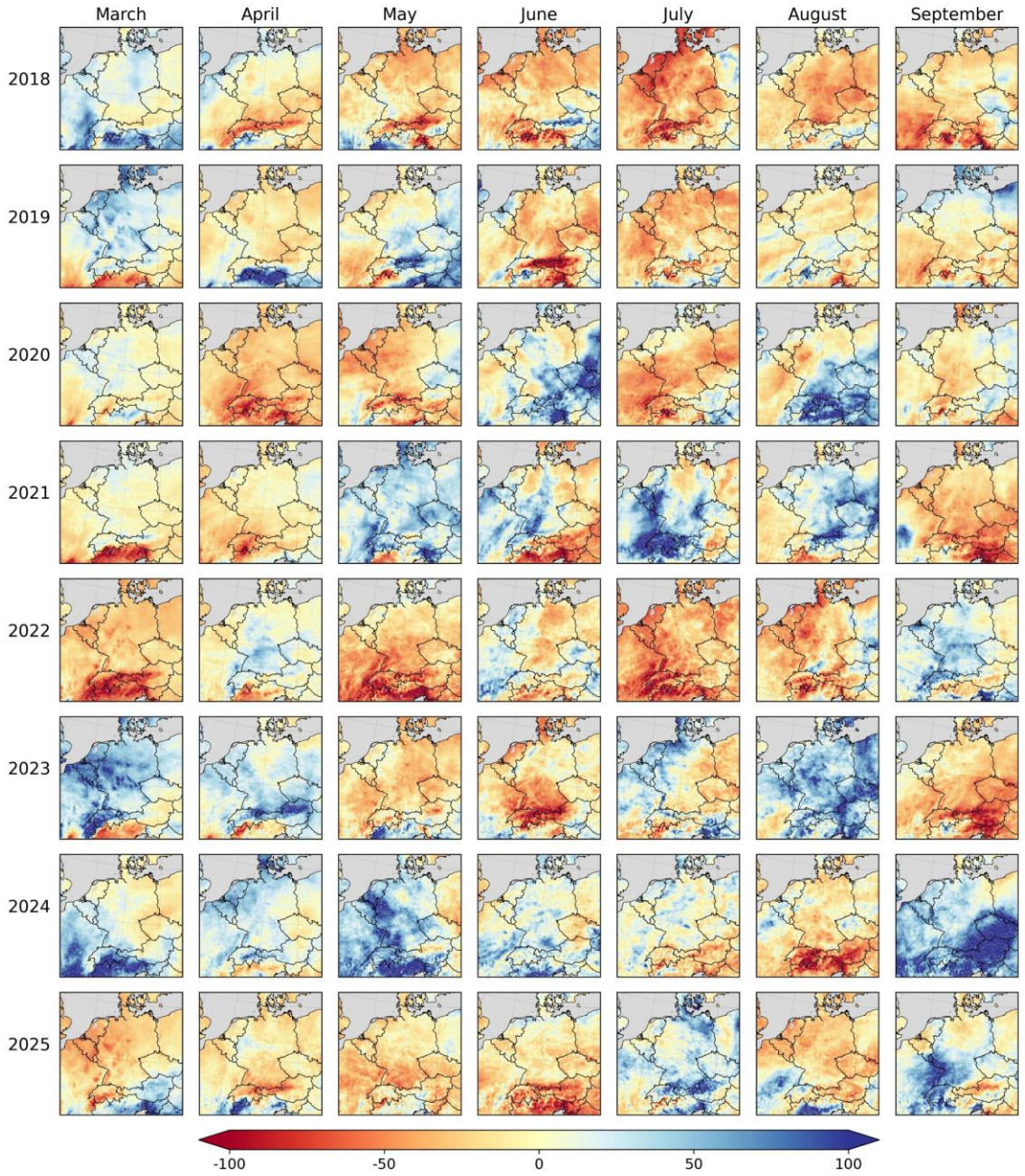


Monthly anomalies (mm) of precipitation sum compared to 2011-2025

There is a need for (sub-) seasonal forecasting of water resources

Repeated droughts in central Europe

→ 2018, 2019, 2020, 2022, 2026

Multi-year droughts

→ insufficient **regeneration of (ground) water resources**

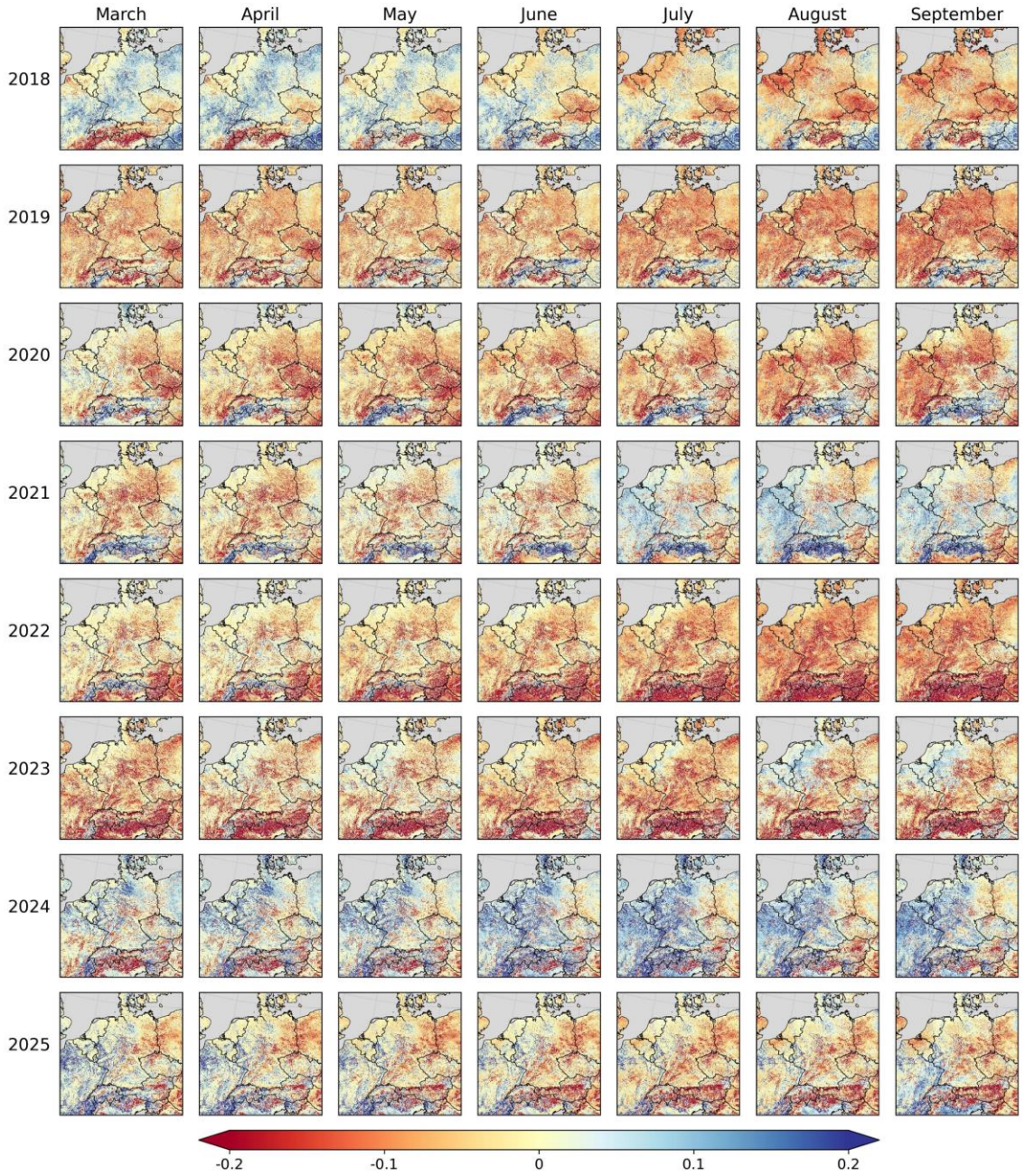
→ **Seasonal forecasts**

Upcoming drought (risk)

Regeneration of water resources

Water management strategies dealing with reduced water resources

Agriculture, forestry, water management



Monthly anomalies (m) of total subsurface water storage compared to 2011-2025

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Experimental Water Resources Bulletin: information for water resources management

www.adapter-projekt.de/bulletin/index_en.html - seasonal probabilistic predictions of subsurface water storage

FZJ Experimental Water Resources Bulletin for Germany, Summer 2026

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www.wasser-monitor.de/bulletin Release date: 2026-06-23, the eWRB Team

The **Forschungszentrum Jülich (FZJ) experimental water resources bulletin (eWRB)** gives a **regular seasonal update** on the **current state and the upcoming potential evolution of terrestrial near-surface water resources**. The eWRB is an open access research data product for an expert environmental sciences and stakeholder audience as well as the interested public.

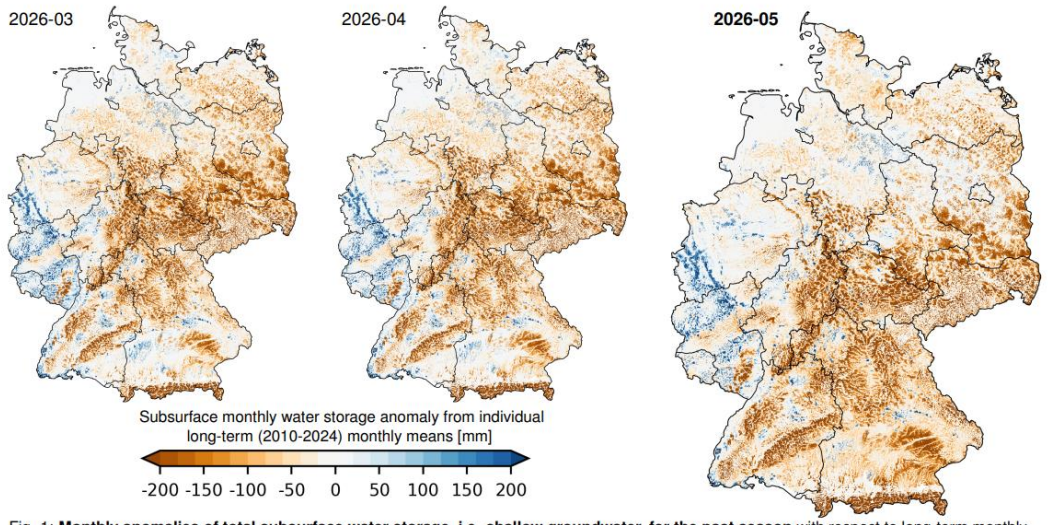

Fig. 1: **Monthly anomalies of total subsurface water storage, i.e. shallow groundwater, for the past season** with respect to long-term monthly means from 2010-2024 in **mm water column**. With the **eWRB, the total subsurface water storage includes the shallow soil zone and groundwater to a depth of 60m.** Data: Hindcasts from ParFlow/CLM simulations with ECMWF HRES atmospheric forcing.

monthly anomalies of previous season

7-months forecast based on 50-member ensemble

State and possible developments: During spring, subsurface water storage continued to decline in the south. This trend is expected to continue nationwide throughout the summer. Particularly in summer increasing deficits are expected in southern, central, and eastern Germany, exceeding 2018, 2019, 2020, and 2022 drought years. Basis: 50-member ensemble forecast from 2026-06-01.

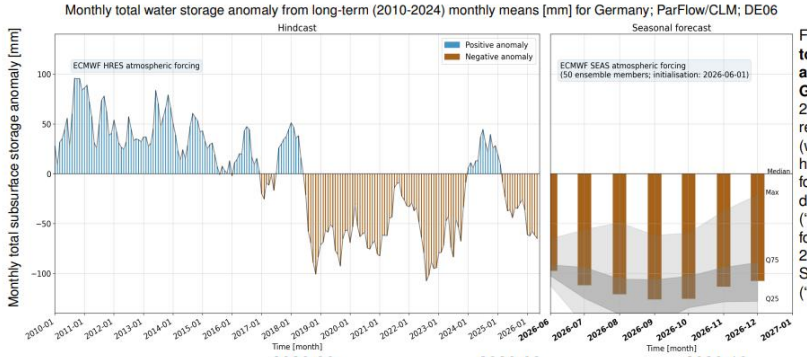

Fig. 2: **Past evolution of monthly total subsurface water storage anomalies as spatial means for Germany** from 2010-Jan to 2026-May as simulated at 611m resolution with the ParFlow/CLM (www.parflow.org) integrated hydrological model based on daily forecasts driven by ECMWF HRES deterministic atmospheric forcing ("hindcast"), and 7-months forecast from 2026-Jun to 2026-Dec based on ECMWF SEAS 50-member ensemble ("seasonal forecast").

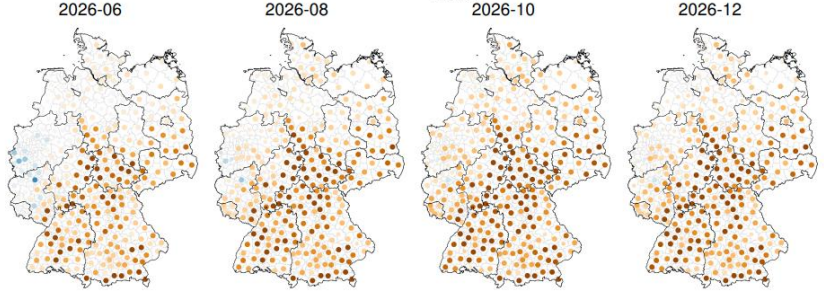

Fig. 3: **Seasonal forecasts (2026-Jun to 2026-Dec)**; mean of total subsurface water storage anomalies from 50-member ParFlow/CLM ensemble (initialized on 2026-06-01), ECMWF SEAS seasonal ensemble prediction driven. Dots: NUTS-3 level administrative regions; dot size: proportional to how many members agree in their sign.

Please observe the disclaimer on the back side

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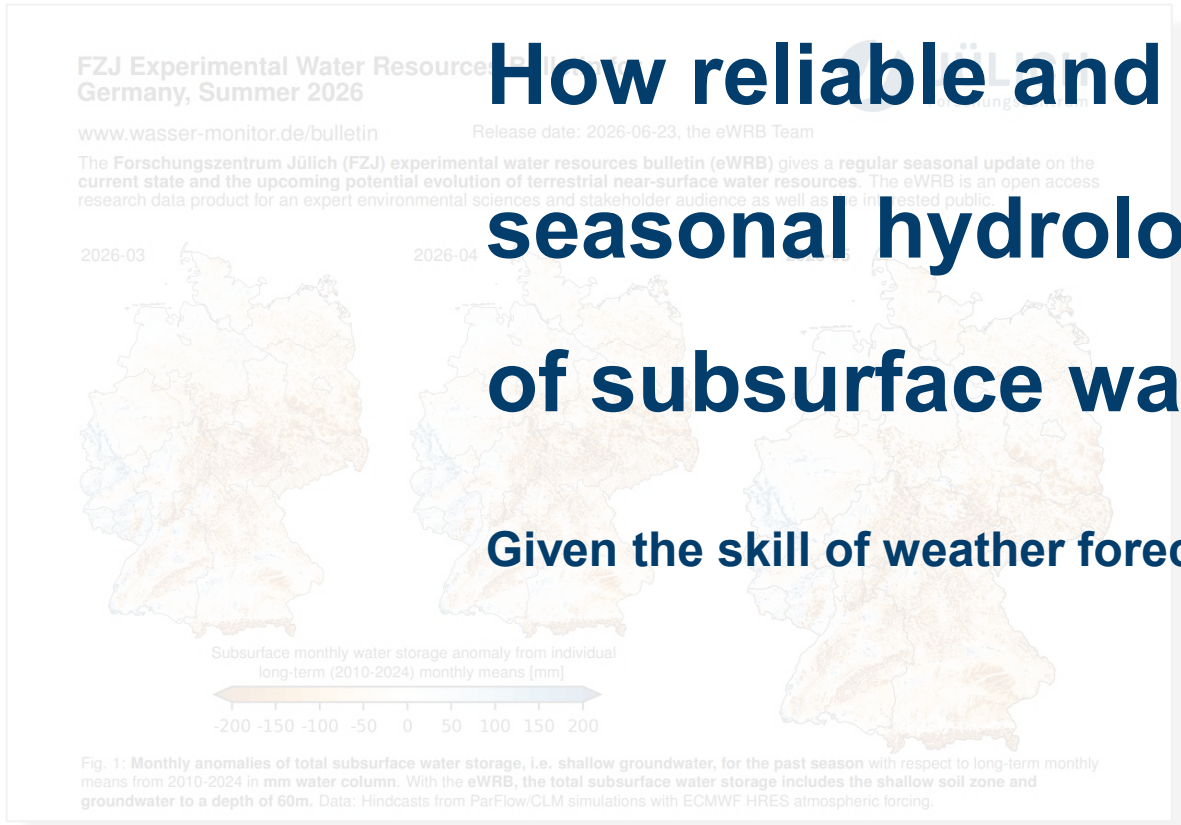
Experimental Water Resources Bulletin: information for water resources management

www.adapter-projekt.de/bulletin/index_en.html - seasonal probabilistic predictions of subsurface water storage



monthly anomalies of previous season

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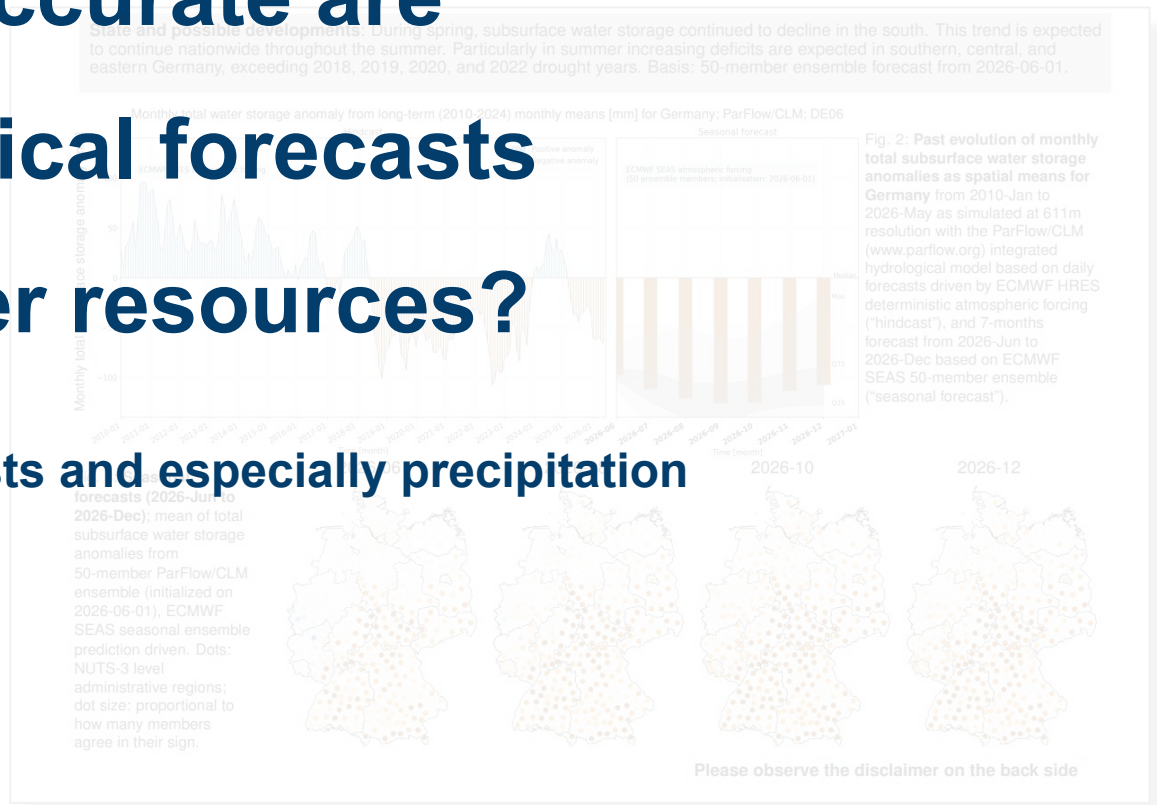

How reliable and accurate are seasonal hydrological forecasts of subsurface water resources?

Given the skill of weather forecasts and especially precipitation

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ParFlow allows for a complete representation of the soil water budget

With interactions at the land surface

ParFlow

Integrated hydrologic model

Fully coupled, 2D/3D dynamical representation of the hydrologic processes in the variably saturated zone, including groundwater and overland flow

CLM (Common Land Model)

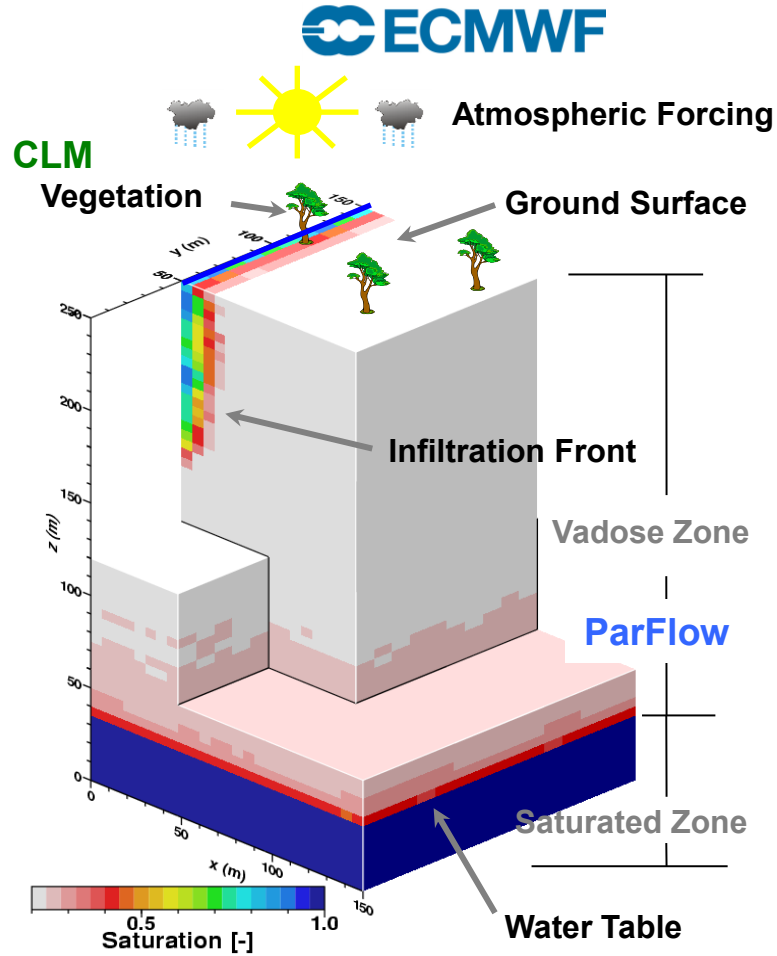
Subroutine land surface module

Representation of the interactions at the surface (water and energy fluxes)

HPC: JUWELS Booster (GPUs) (Jülich Supercomputing Centre)

Total subsurface water storage

Water column from surface to 60 m depth



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A 50-member probabilistic forecast is calculated four times per year

Starting from the climatology

Atmospheric forcing

ECMWF seasonal probabilistic forecast SEAS5

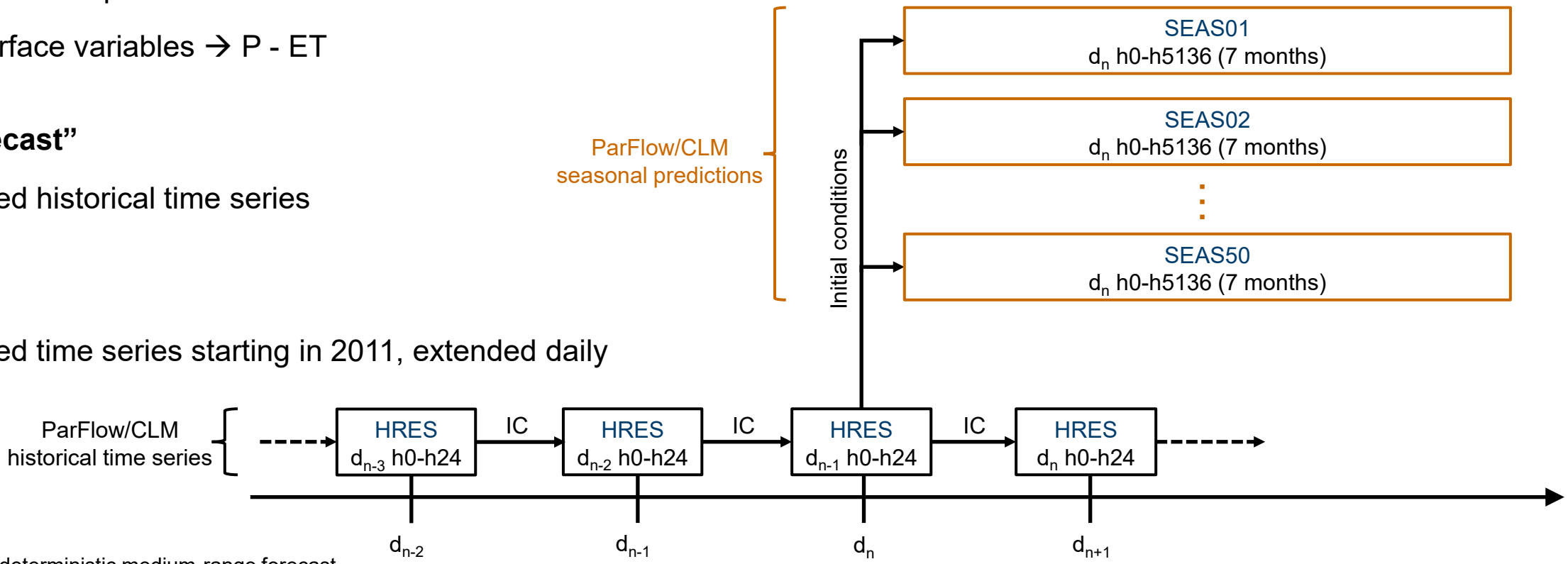
8 (near) surface variables → P - ET

"Perfect forecast"

HRES-based historical time series

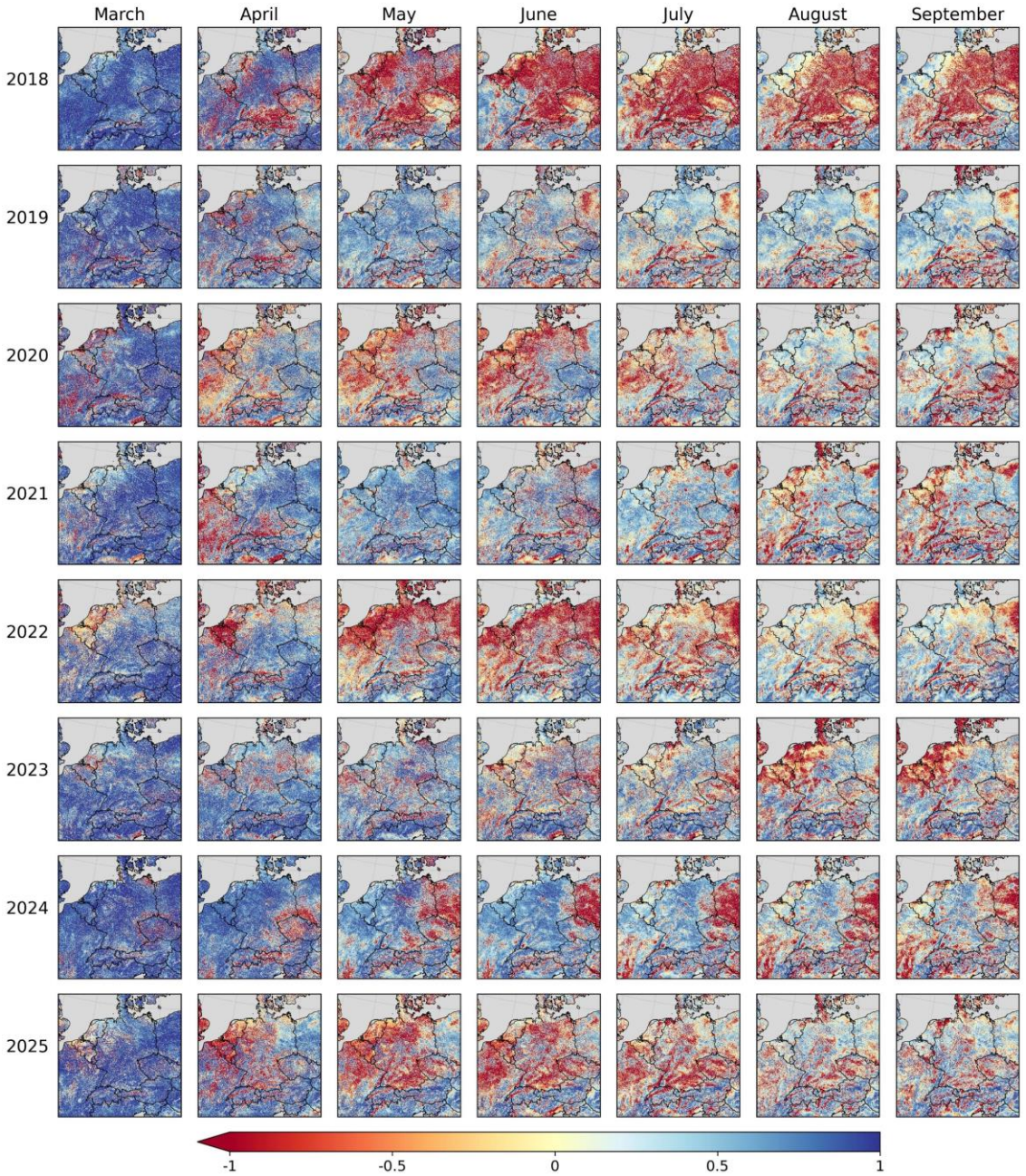
Climatology

HRES-based time series starting in 2011, extended daily



HRES = ECMWF deterministic medium-range forecast

SEAS = ECMWF seasonal probabilistic 50-member ensemble forecast



Monthly fCRPSS for total subsurface water storage from seasonal forecast compared to 2011-2025 climatology-based "pseudo-forecast"

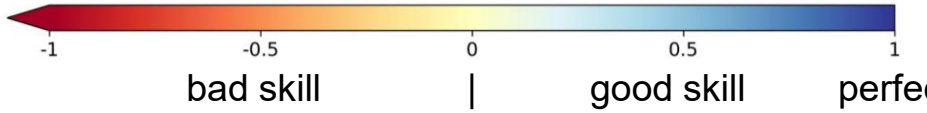
Seasonal forecast shows higher skill than climatology-based forecast

Fair Continuous Ranked Probability Skill Score

→ General skill of ensemble distribution

→ Compares the distribution with the expected value

→ Seasonal forecast ensemble vs climatology-based "pseudo-forecast"



High skill for first month, then gradual decrease

Extreme events appearing **during a forecast** seem to be **missed**

Role of **inherited conditions** and **memory effect**

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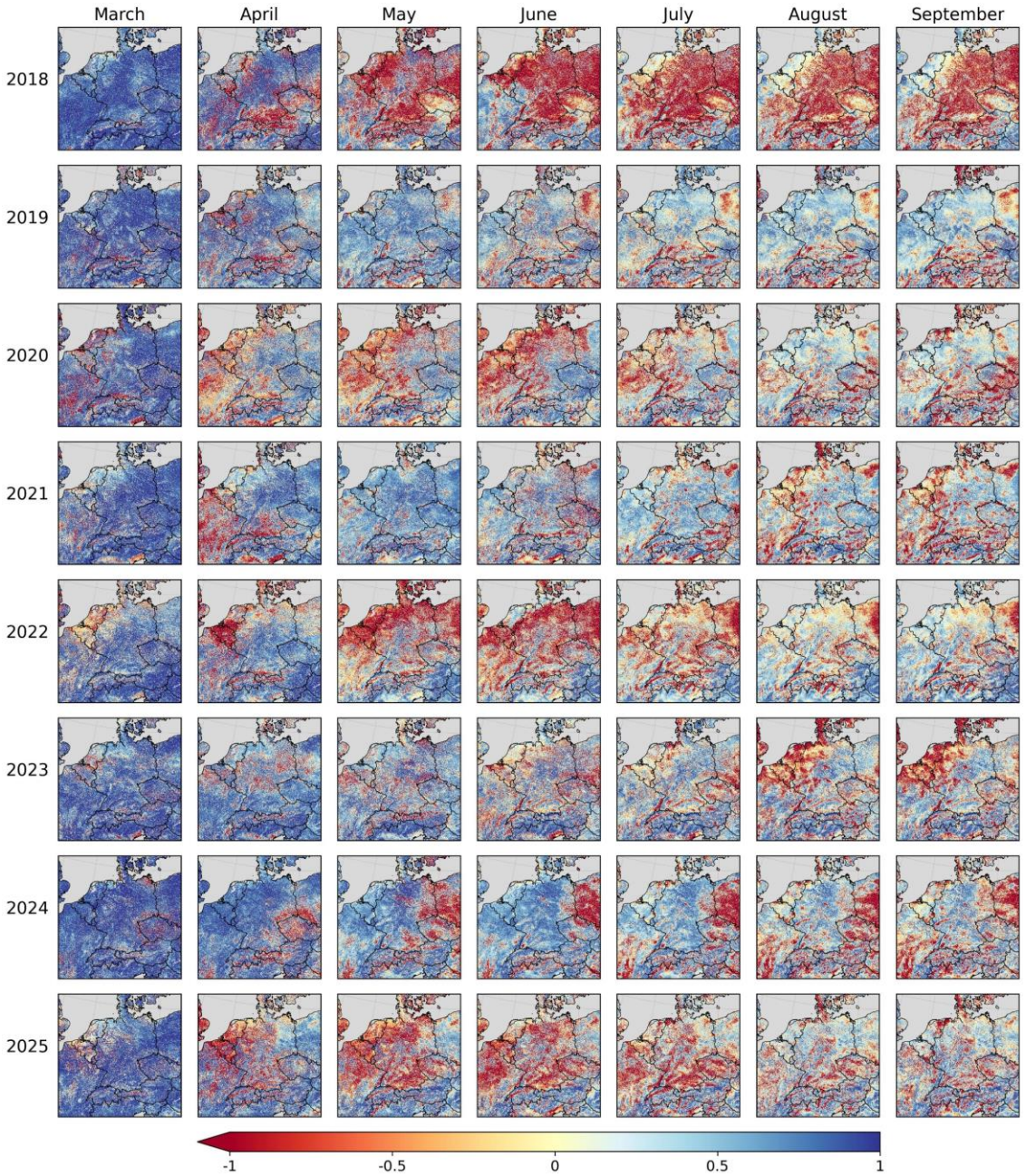

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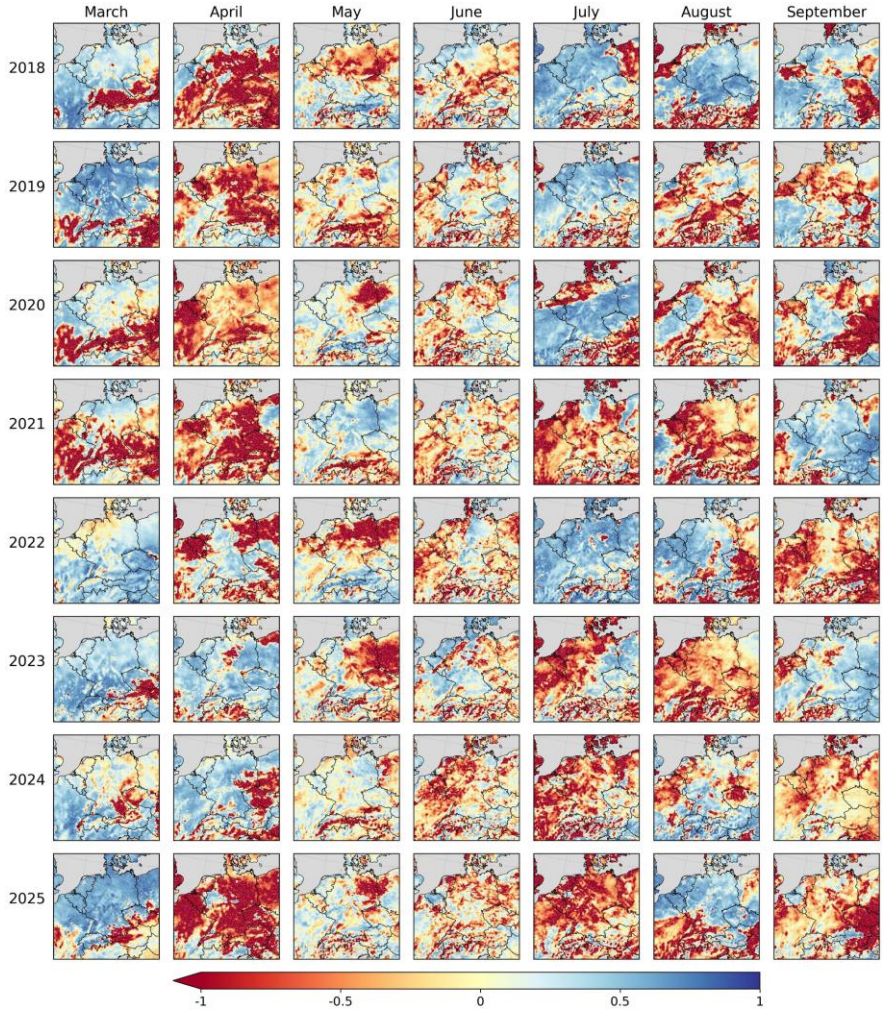

Skill more variable and generally lower for **precipitation**

Monthly fCRPSS for precipitation from seasonal forecast compared to 2011-2025 climatology-based "pseudo-forecast"

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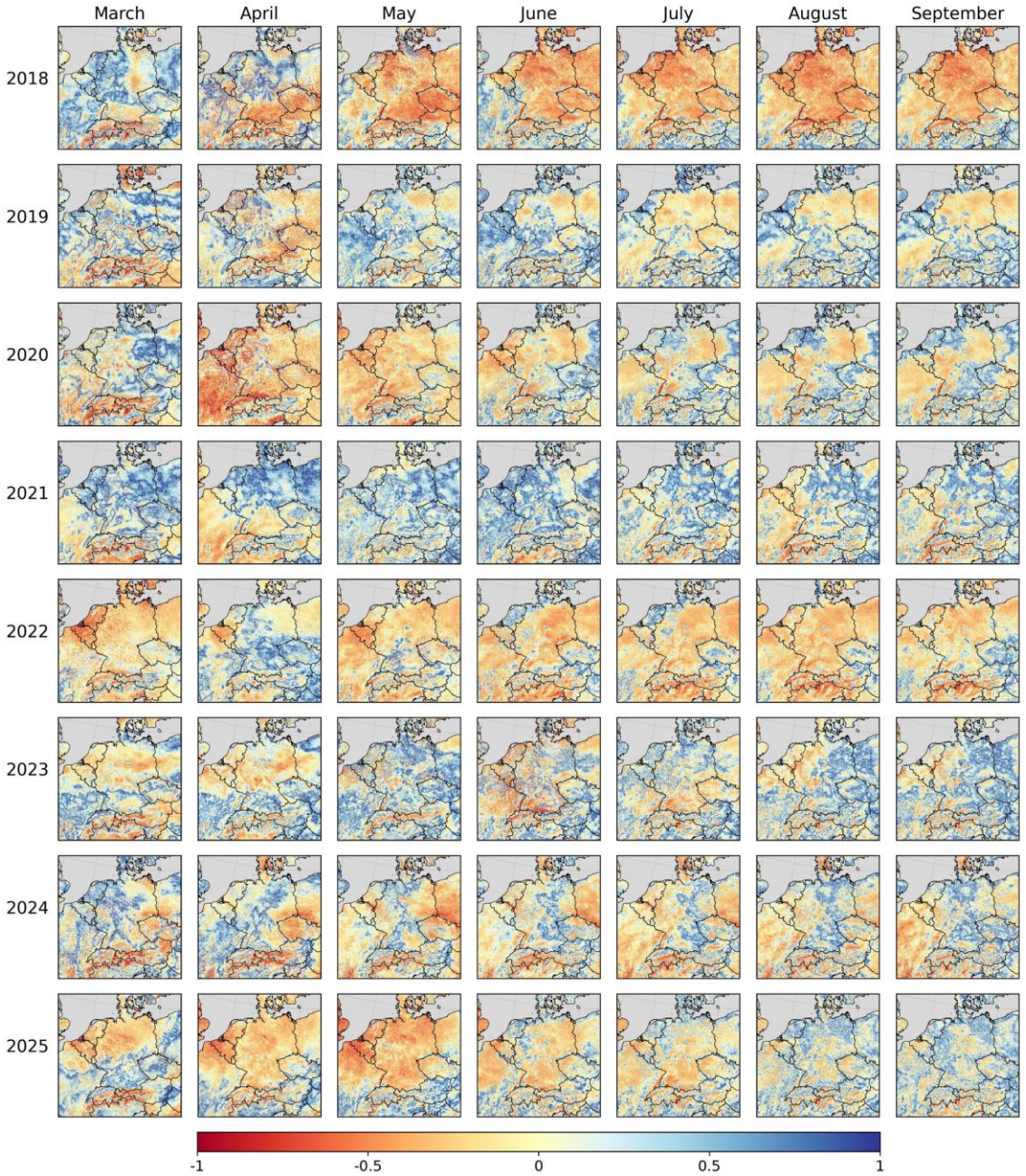


Monthly normalized Spread Skill Score for total subsurface water storage

Ensemble tends to be underdispersed in case of extremes

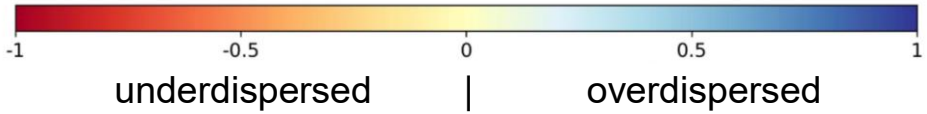
Normalized Spread Skill Score

→ Meaningfulness of forecast with regard to its error

→ Ratio between ensemble spread and mean error

→ Overdispersion: forecast likely accurate but imprecise

→ Underdispersion: forecast precise but likely inaccurate



Underdispersion consistent with **low fCRPSS skill**

Extremes are underrepresented in the ensemble

Role of **inherited conditions** and **memory effect**

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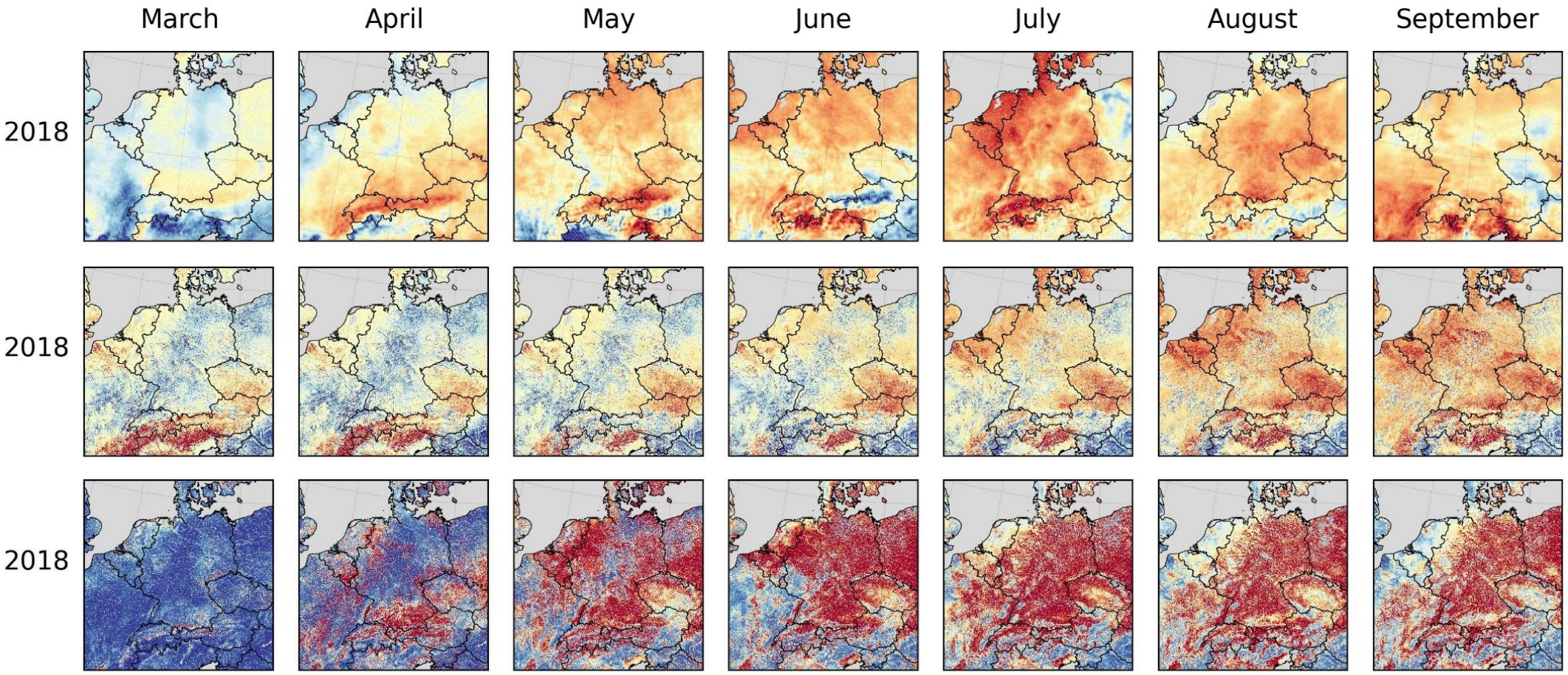
Forecast skill is dominated by inherited conditions and memory effect



Wet conditions in spring + strong meteorological drought
→ agricultural & hydrological drought onset → low skill

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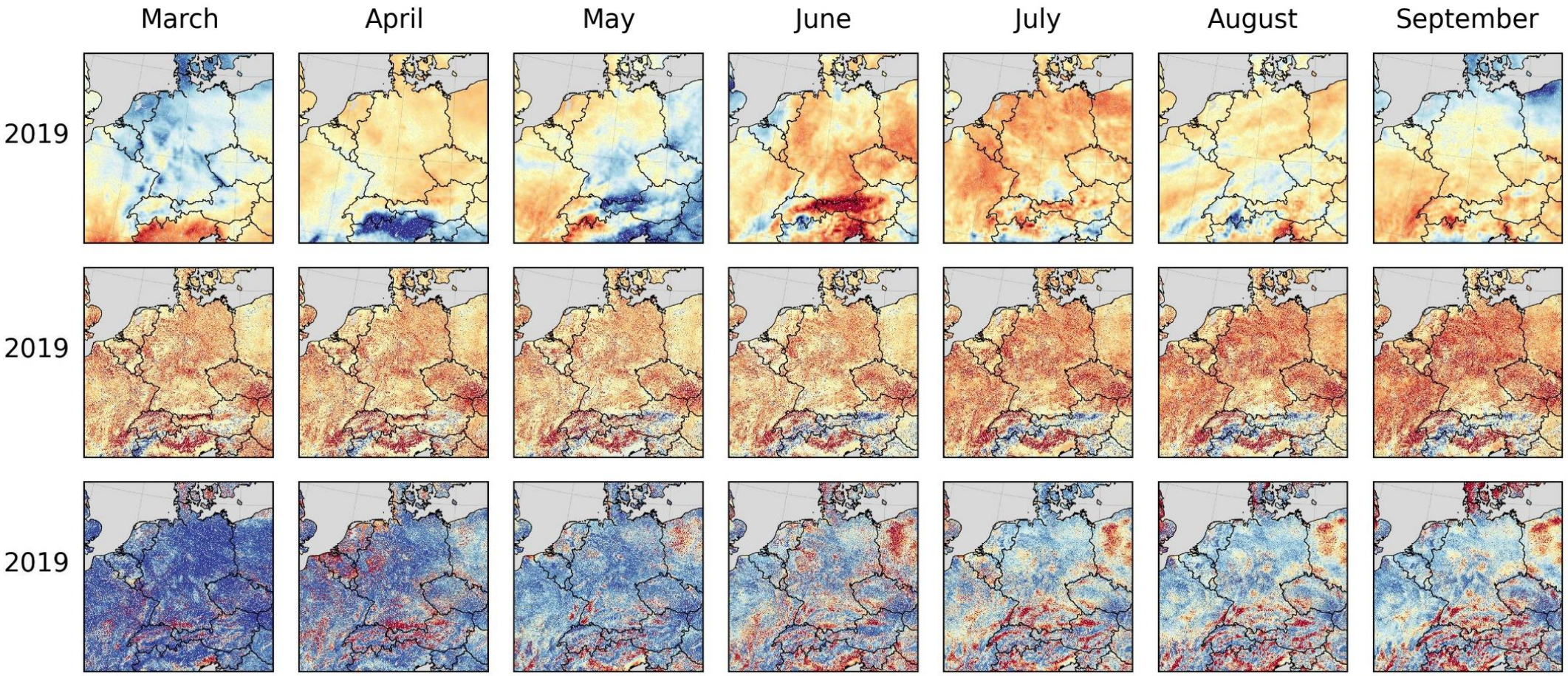

Dry conditions in spring + less pronounced precipitation deficit
→ agricultural & hydrological drought continuing → higher skill

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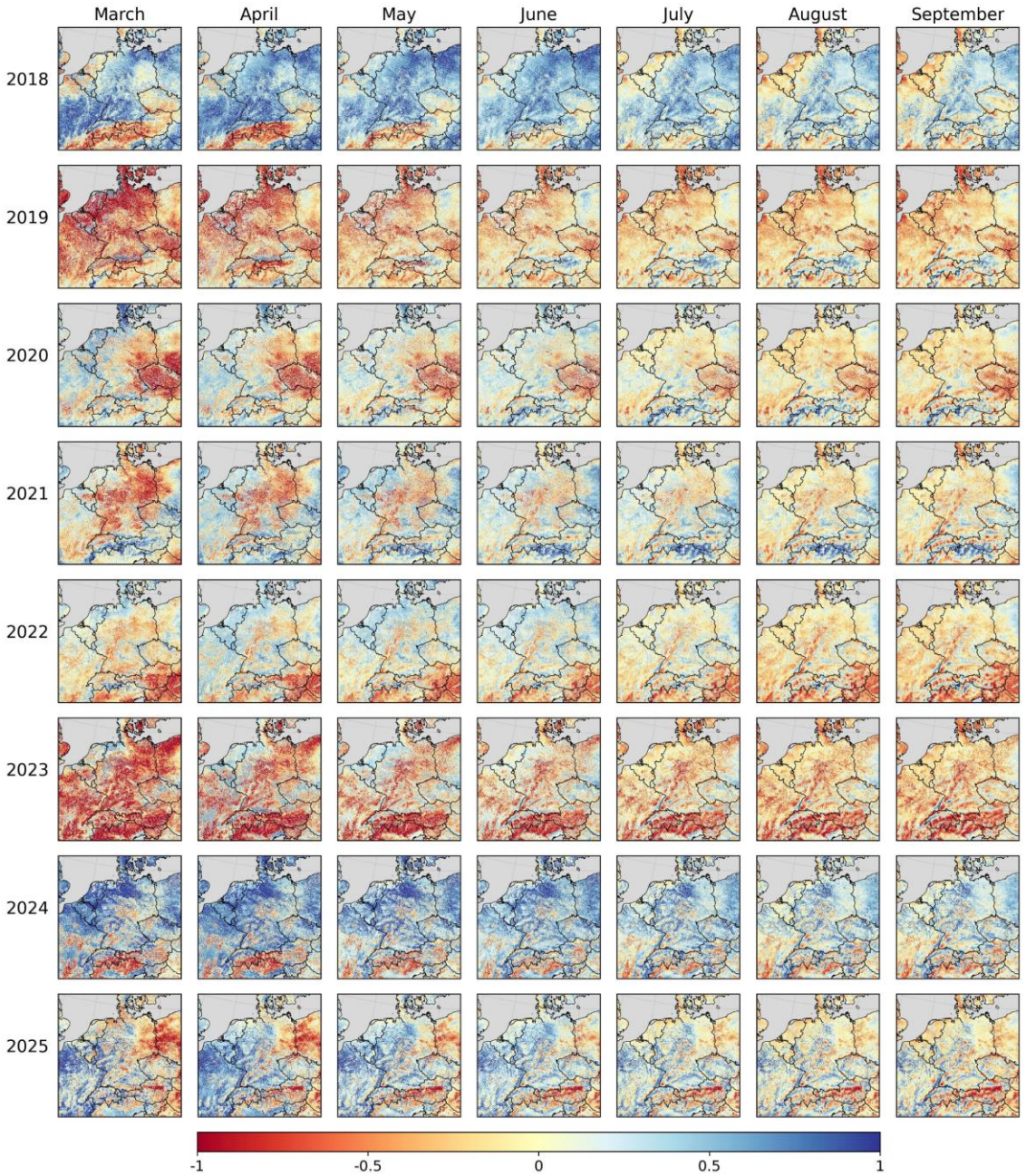


Monthly EFI for total subsurface water storage from seasonal forecast compared to 2011-2025 climatology-based "pseudo-forecast"

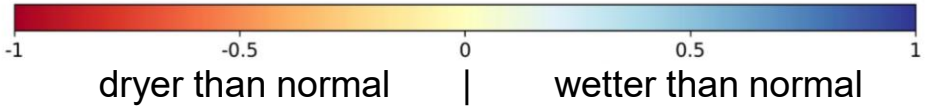
Forecast anomaly largely depends on inherited conditions

Extreme Forecast Index

→ Anomaly ("extremeness") of forecast ensemble distribution

→ Compared with climatological distribution

→ Whole distribution, no focus on extremes



Positive and strong negative **anomalies** **tend to attenuate** over the forecast period

2018 drought missed except in north-west, **2022** drought unclear

Droughts in **2019** and **2020** (east) and inherited dry conditions in **2023** forecasted

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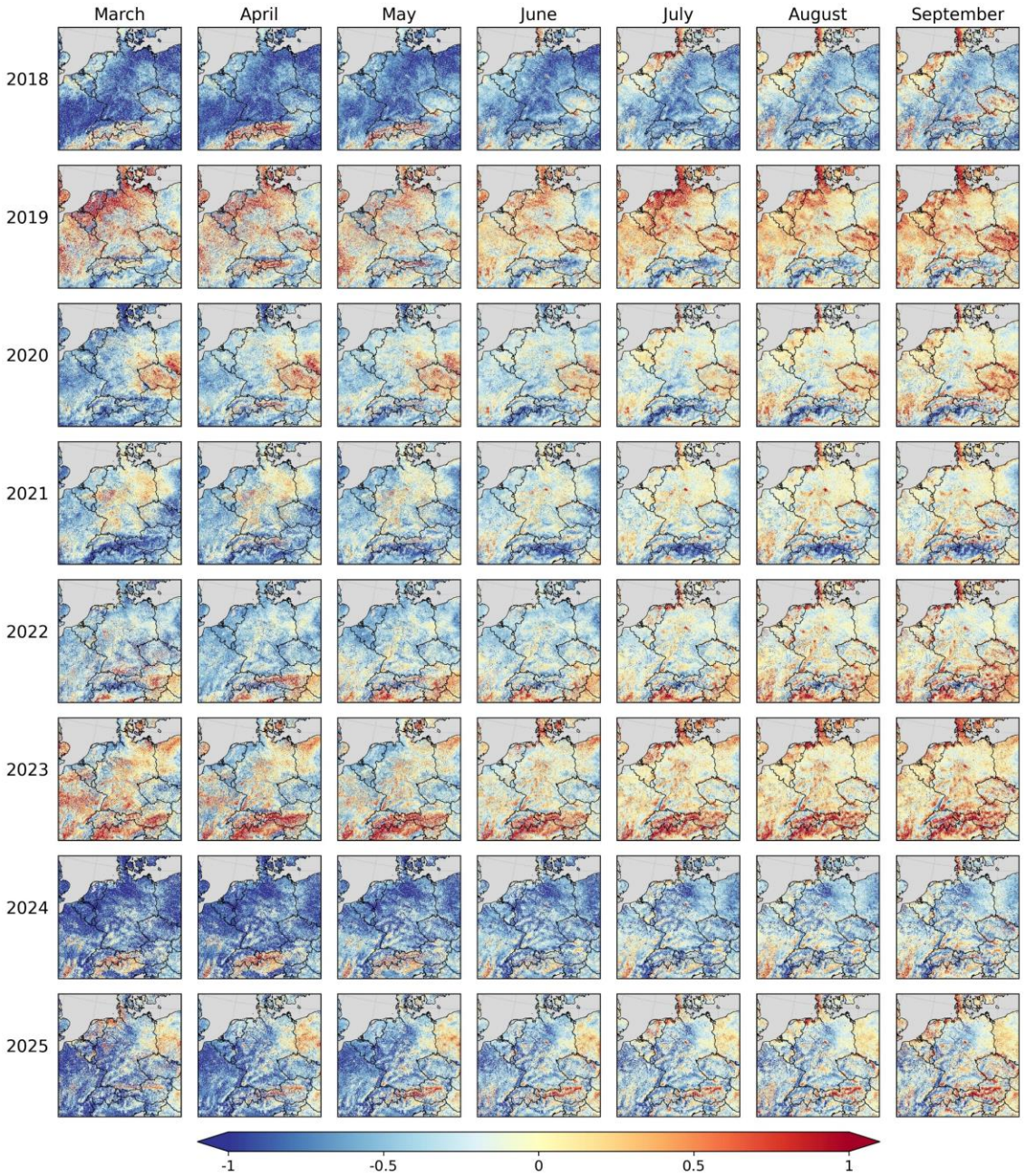


Monthly SOT for the lower decile for total subsurface water storage from seasonal forecast compared to 2011-2025 climatology-based "pseudo-forecast"

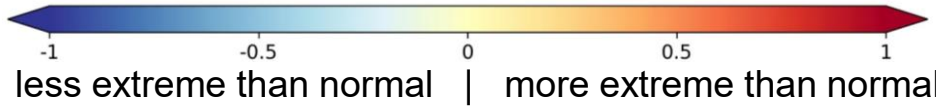
Extreme drought events can be predicted by the seasonal forecasts

Shift Of Tails

→ Extremeness of the tail of the forecast ensemble distribution

→ Compared with the tail of climatological distribution

→ Focus on dry extremes: lower decile (D10)



Strong **link with EFI**, consistent with underdispersion of nSSS

Dry events mostly of **same order of magnitude as climatological extremes**, sometimes regionally more extreme

Tendency to **more extreme events over the summer**, due to precipitation patterns

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Seasonal forecast skill of drought forecasts with ParFlow/CLM

How do we perform the forecasts?

→ Hydrologic model ParFlow driven by ECMWF forecast

→ 50-member probabilistic forecast with different atmospheric forcings

What is the overall skill of the forecasts?

→ Seasonal forecast generally outperforms climatology-based “pseudo-forecast”

→ Mainly due to inherited conditions and memory effect

→ TSS skill constrained by atmospheric forcing skill

Are we able to forecast droughts?

→ Yes, but not all events

→ Ensemble analysis not sufficient, need to focus on tail of distribution

More information, seasonal and daily forecasts (in German):

→ **www.wasser-monitor.de**

→ **www.adapter-projekt.de**

Experimental Water Resources Bulletin

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

Data

→ **doi: 10.26165/JUELICH-DATA/GROHKP**

Acknowledgement

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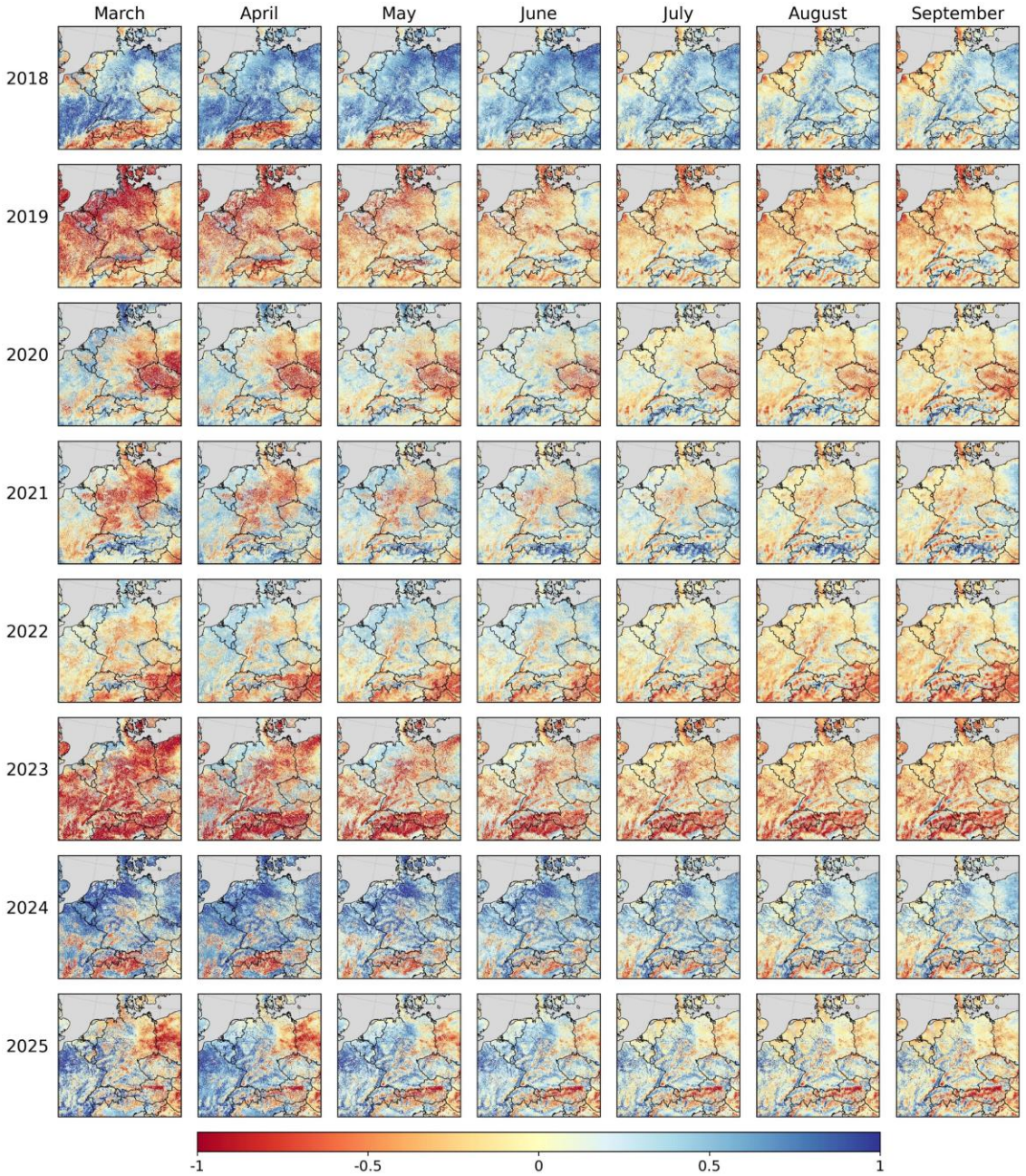
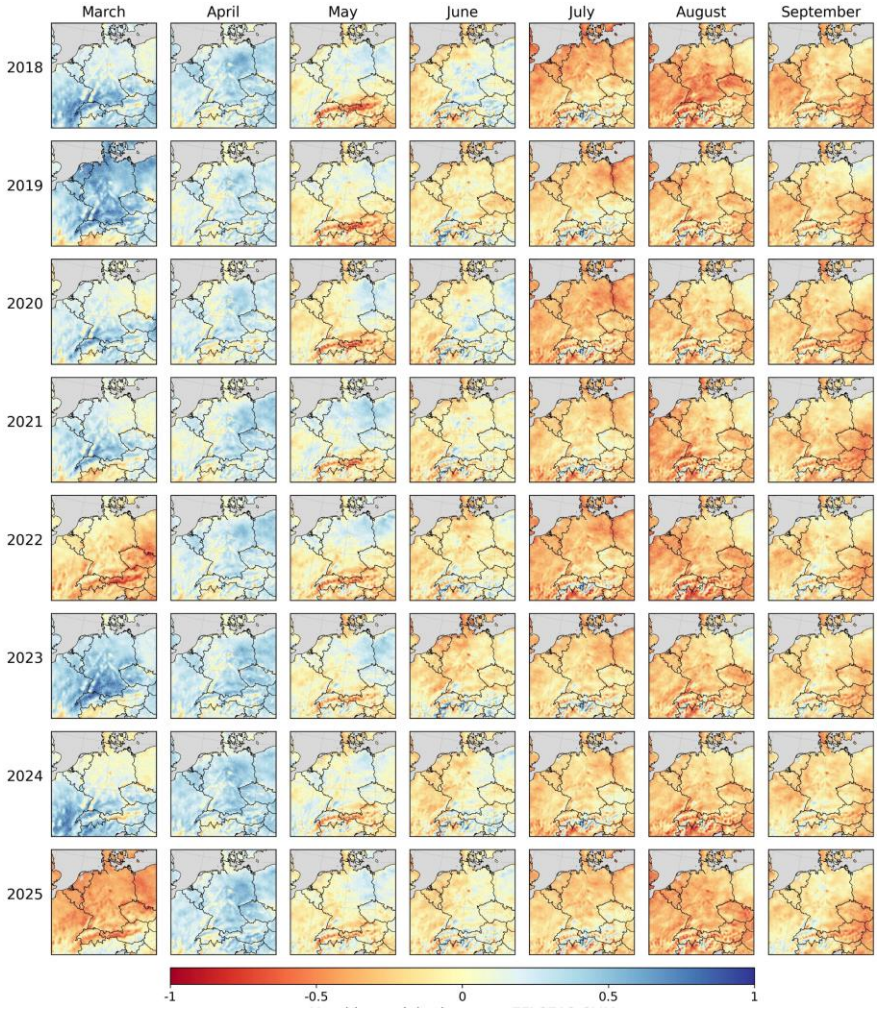
Forecast anomaly largely depends on inherited conditions



Monthly EFI for total subsurface water storage from seasonal forecast compared to 2011-2025 climatology-based "pseudo-forecast"



Monthly EFI for precipitation from seasonal forecast compared to 2011-2025 climatology-based "pseudo-forecast"

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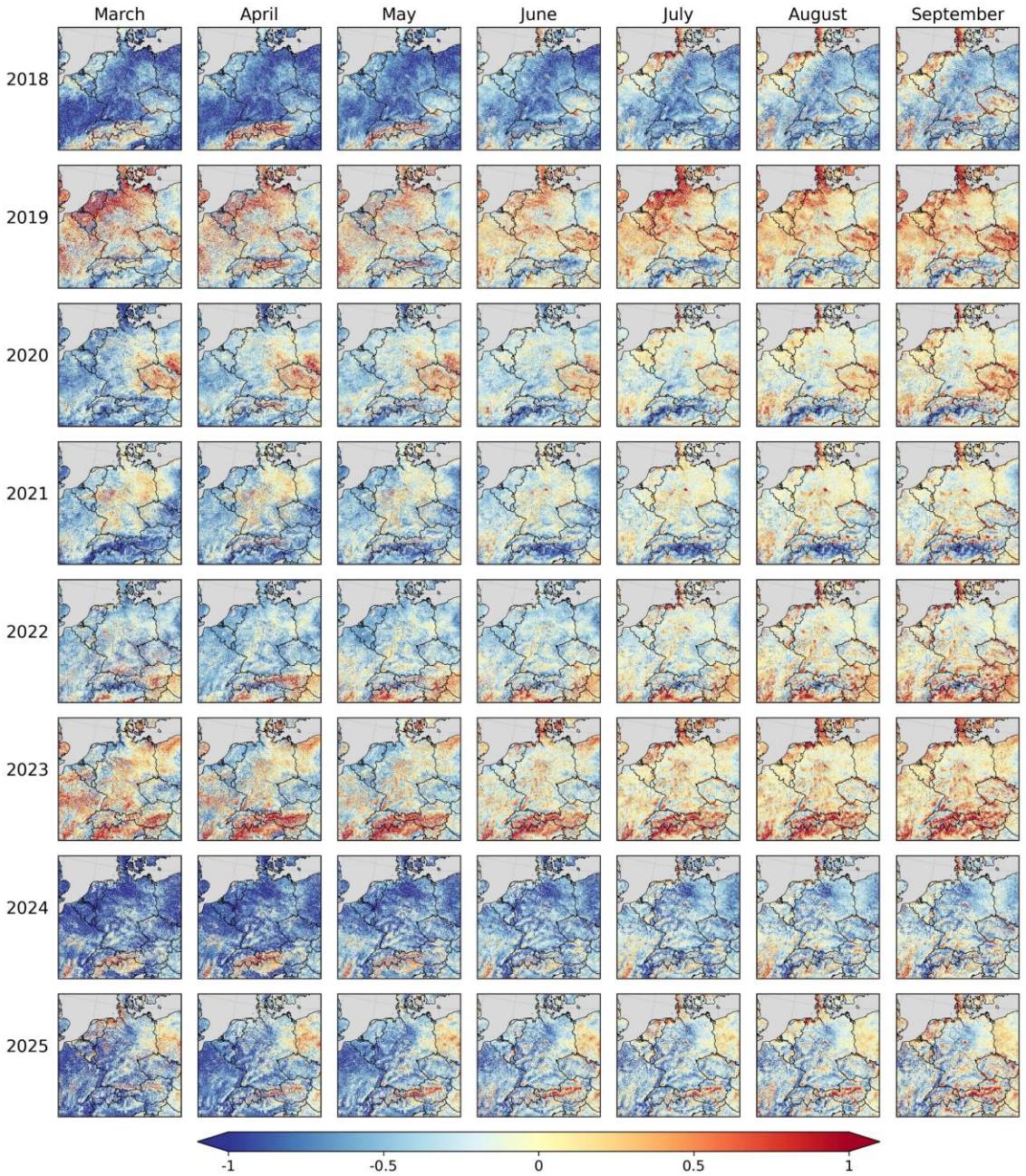
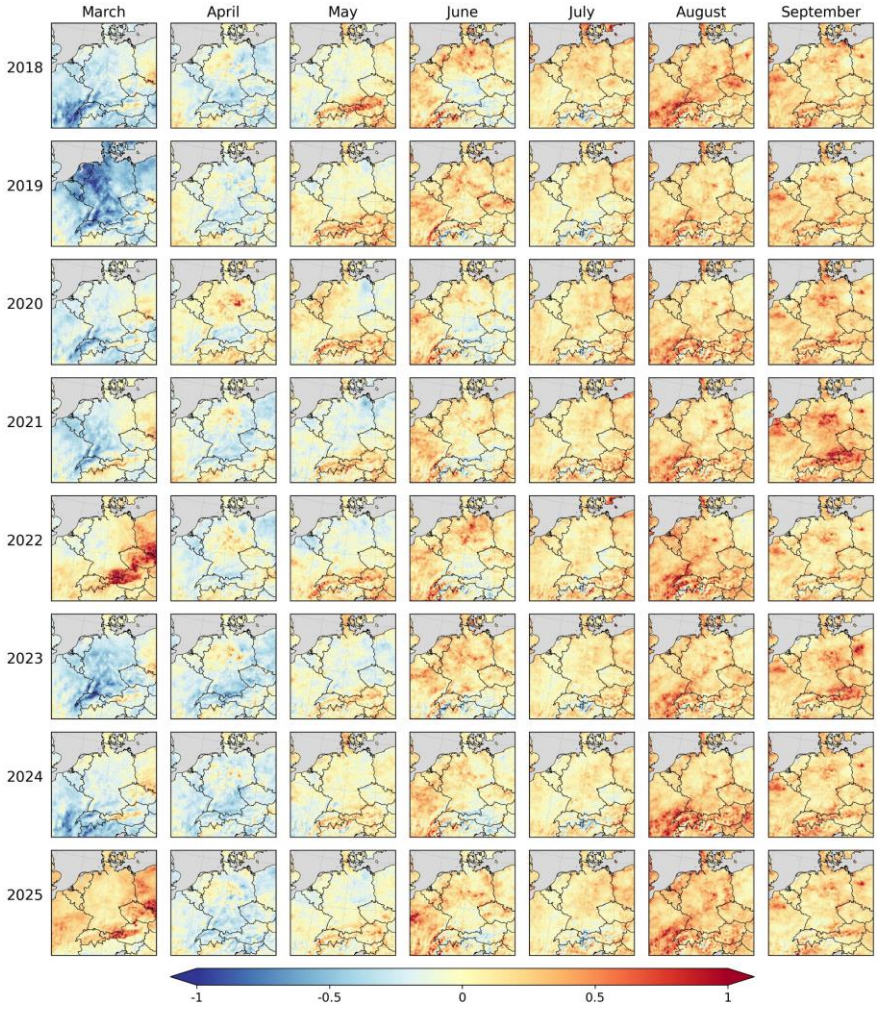
Extreme drought events can be predicted by the seasonal forecasts



Monthly SOT for the lower decile for total subsurface water storage from seasonal forecast compared to 2011-2025 climatology-based "pseudo-forecast"



Monthly SOT for the lower decile for precipitation from seasonal forecast compared to 2011-2025 climatology-based "pseudo-forecast"

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