eLTER SCIENCE CONFERENCE 2025

PHOTOS ALLOWED

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

2025-06-26 | **A. Belleflamme[1,2], S. Hammoudeh[1,2], K. Goergen[1,2], S. Kollet[1,2]**

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Geoverbund ABC/J shaping geosciences

HPSC TerrSys

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

Especially in relation to droughts

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

Multi-year droughts

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

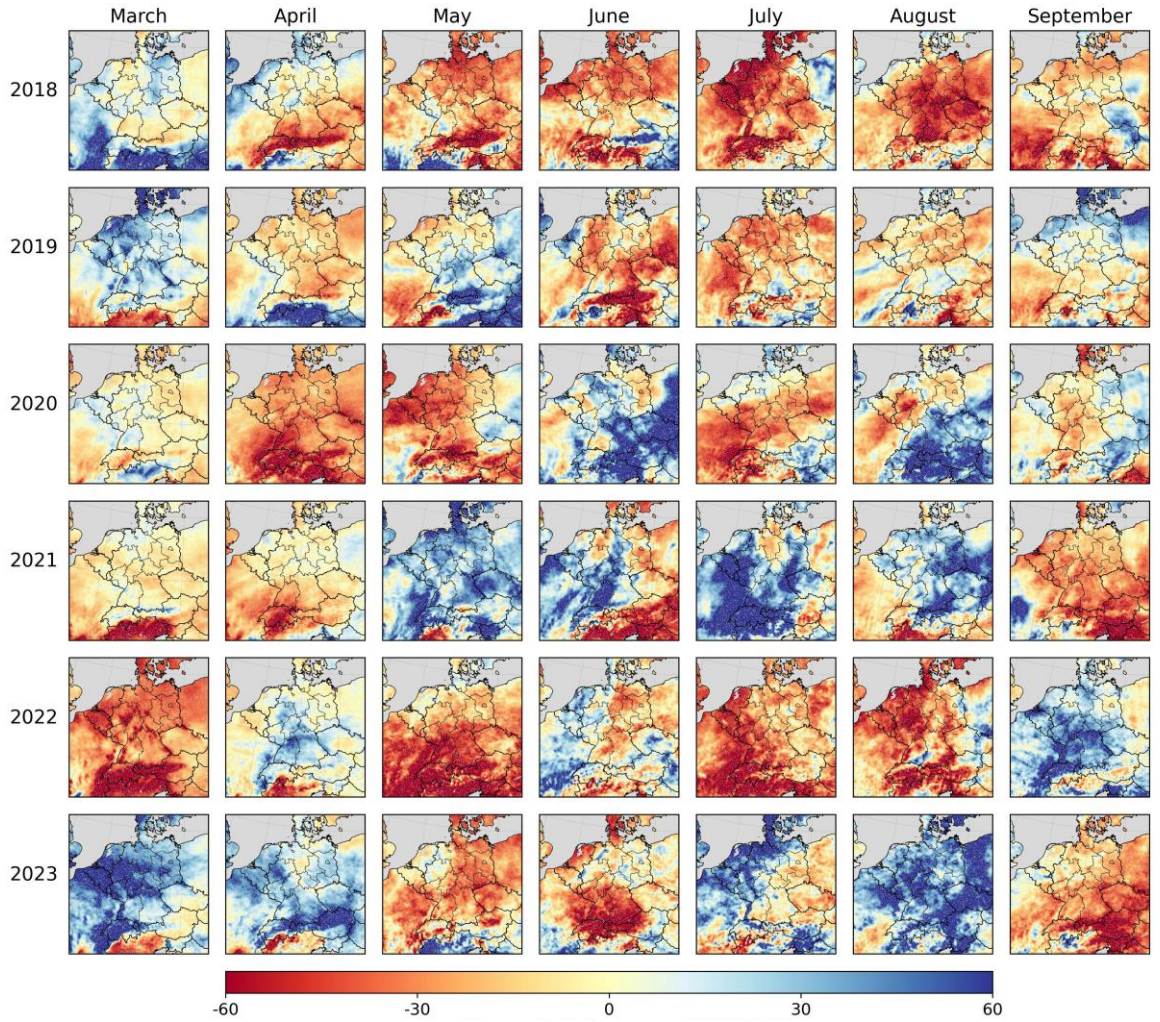
→ **Seasonal forecasts**

Upcoming drought (risk)

Regeneration of water resources

Water management strategies dealing with reduced water resources

Agriculture, forestry, water management



Monthly anomalies (mm) of precipitation sum compared to 2013-2023

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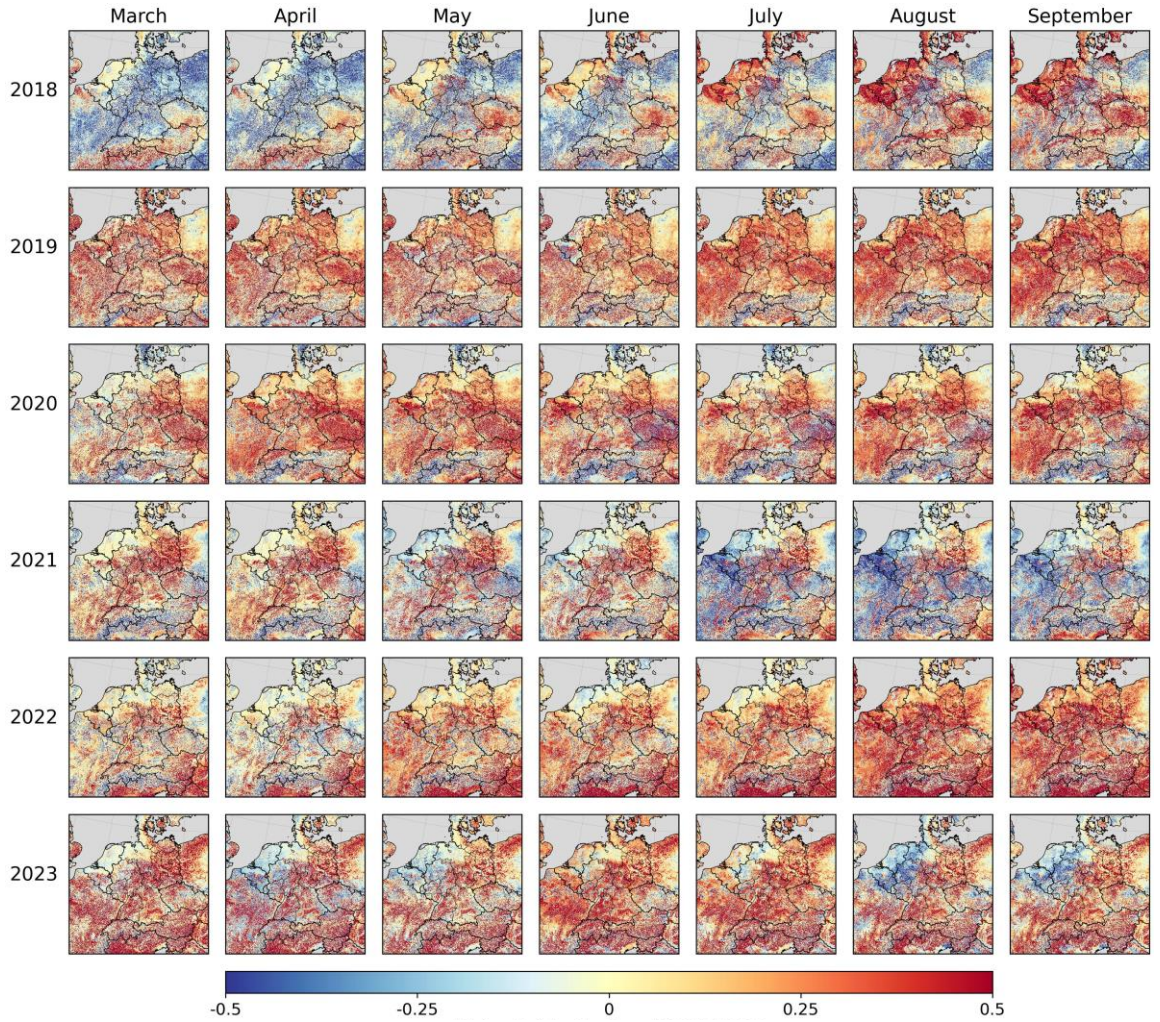
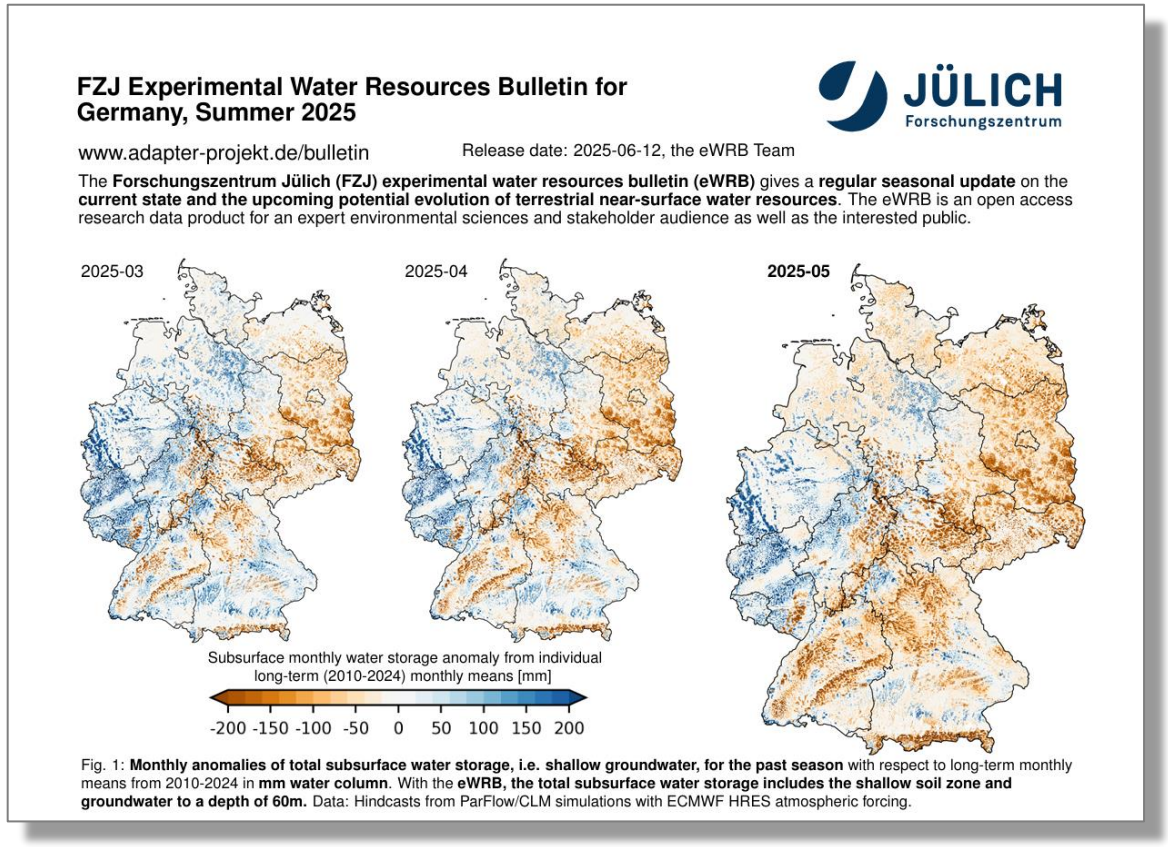


Monthly anomalies (m) of water table depth compared to 2013-2023

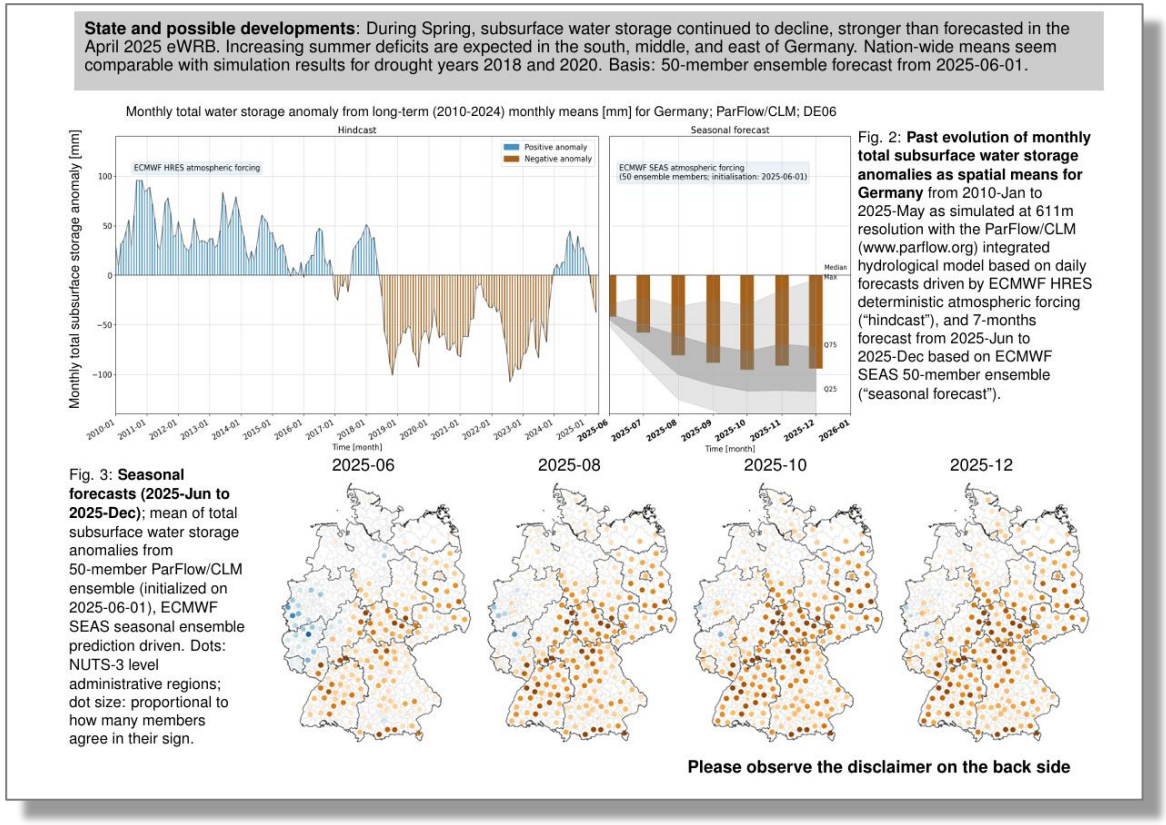
Experimental Water Resources Bulletin: information for water resources management

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



monthly anomalies of previous season

7-months forecast based on 50-member ensemble



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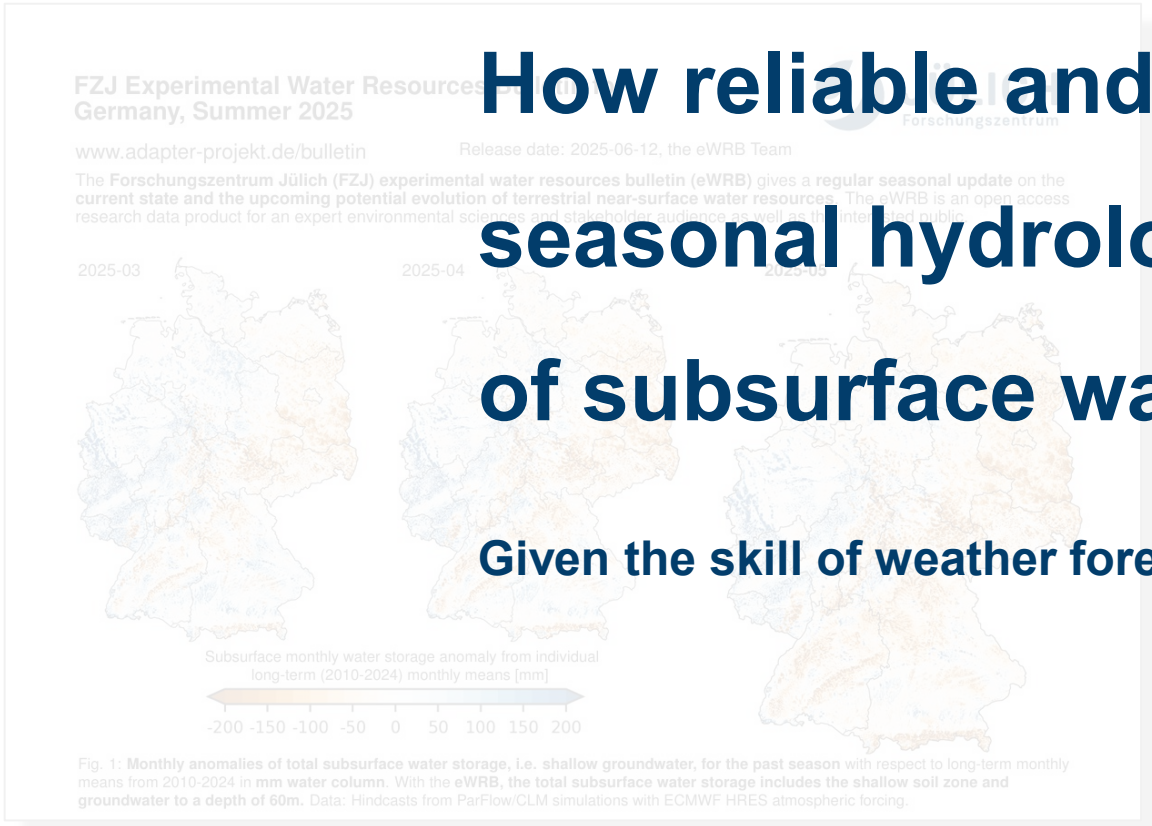

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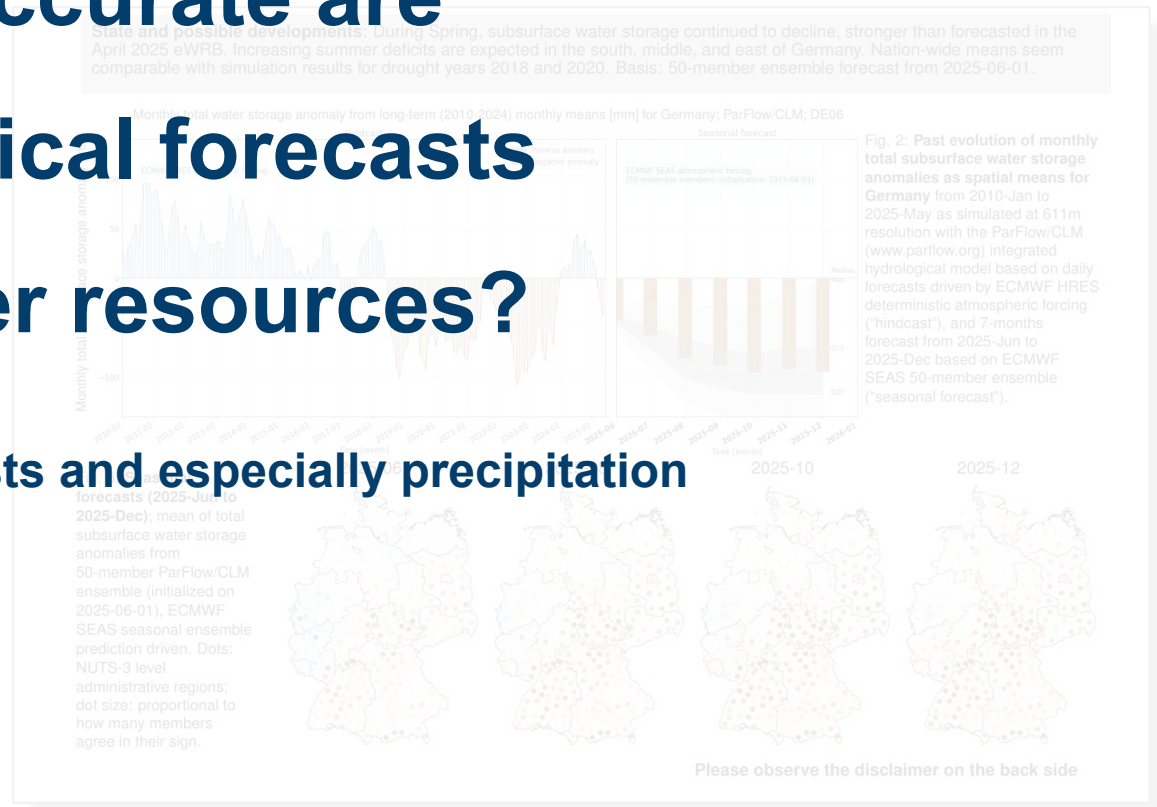

How reliable and accurate are seasonal hydrological forecasts of subsurface water resources?

Given the skill of weather forecasts and especially precipitation

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Seasonal forecast skill of water table depth with ParFlow/CLM

How do we perform the forecasts?

What is the overall skill of the forecasts?

Are we able to forecast droughts?

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ParFlow allows for a complete representation of the soil water budget

With interactions at the land surface

ParFlow

Integrated hydrological model

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

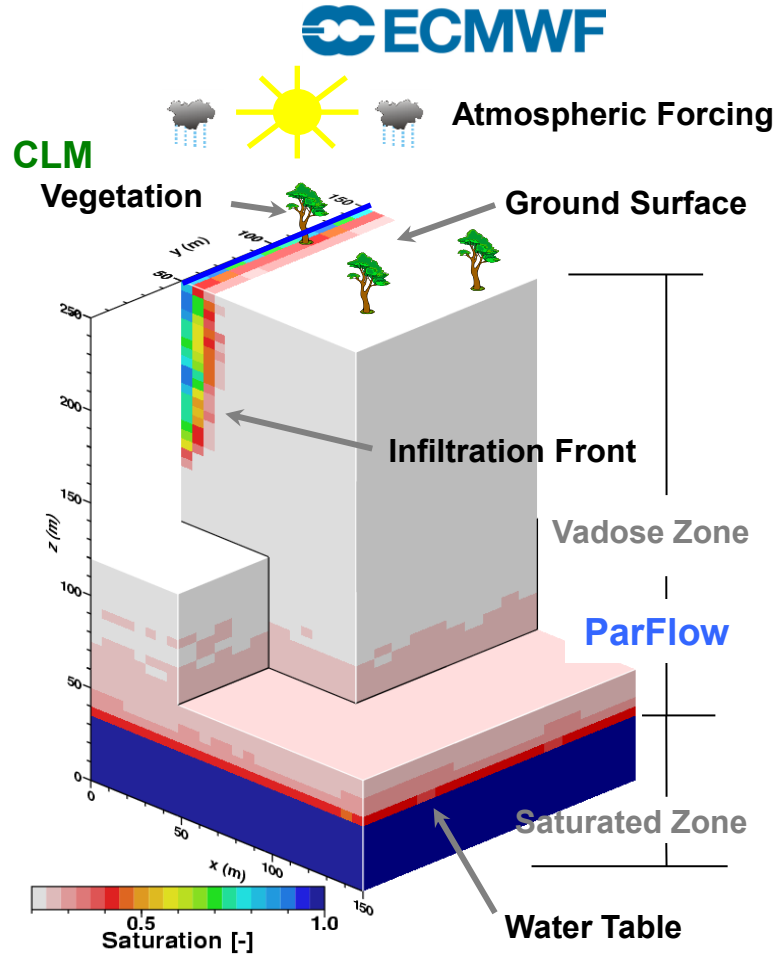
CLM (Common Land Model)

Subroutine land surface module

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

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

Overland flow routing turned off to decrease computing time



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

Starting from the climatology

Atmospheric forcing

ECMWF seasonal probabilistic forecast SEAS5

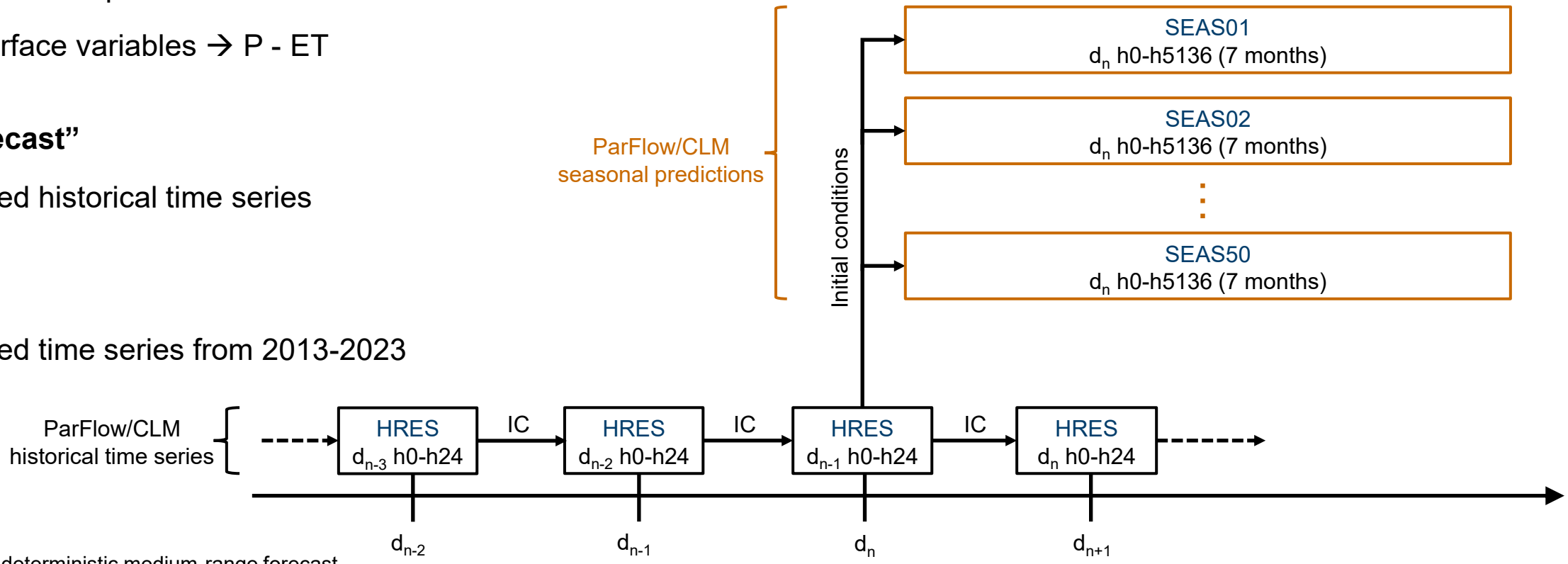
8 (near) surface variables → P - ET

"Perfect forecast"

HRES-based historical time series

Climatology

HRES-based time series from 2013-2023



HRES = ECMWF deterministic medium-range forecast

SEAS = ECMWF seasonal probabilistic 50-member ensemble forecast

Seasonal forecast skill of water table depth with ParFlow/CLM

How do we perform the forecasts?

What is the overall skill of the forecasts?

Are we able to forecast droughts?

Seasonal forecast shows higher skill than climatology-based forecast for WTD

Except when stronger change in anomaly

Continuous Ranked Probability Skill Score

→ General skill of ensemble distribution

→ Compares the distribution with the expected value

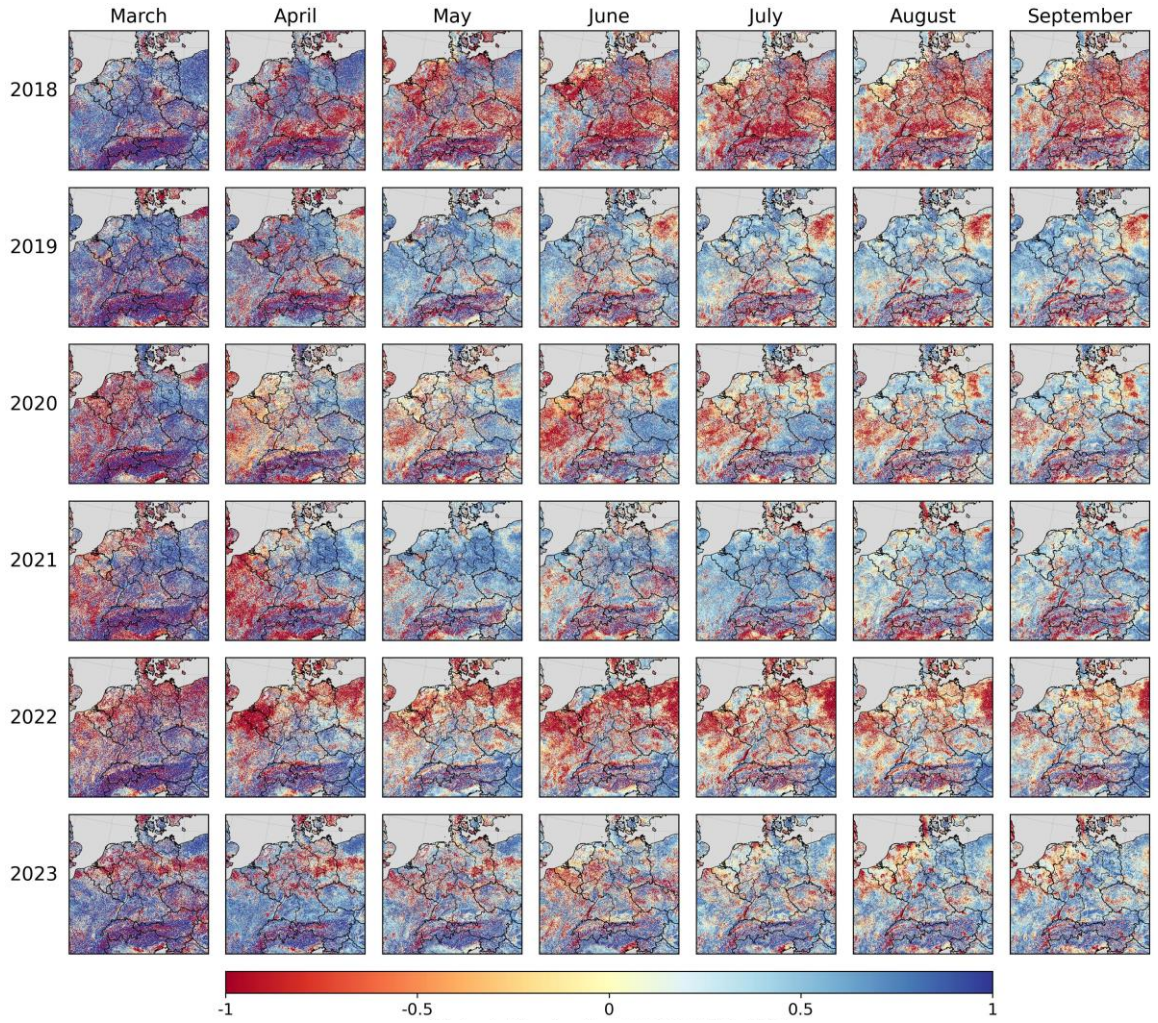
→ Seasonal forecast ensemble vs climatology-based “pseudo-forecast”

→ > 0 = good skill, < 0 = bad skill

Underrepresentation of extremely dry members

Role of **memory effect**

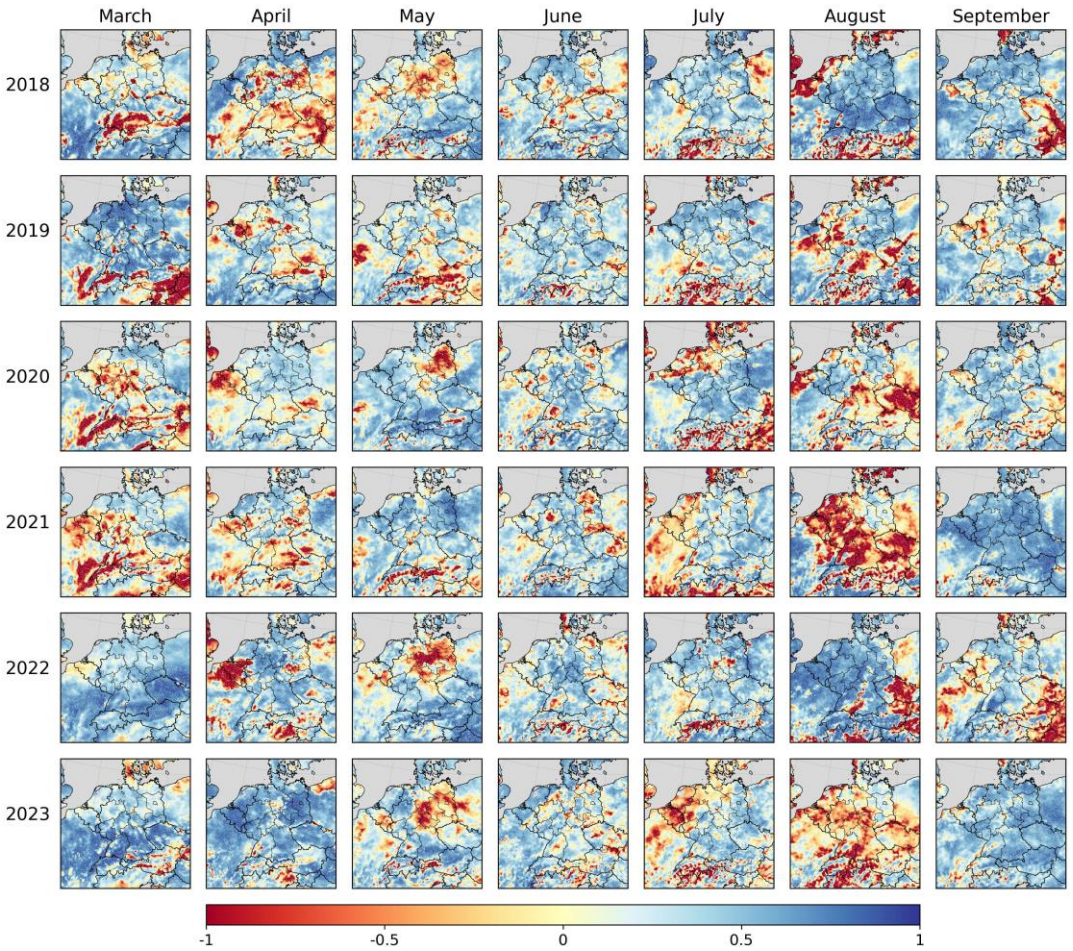
Only **slight decrease in skill** after first month



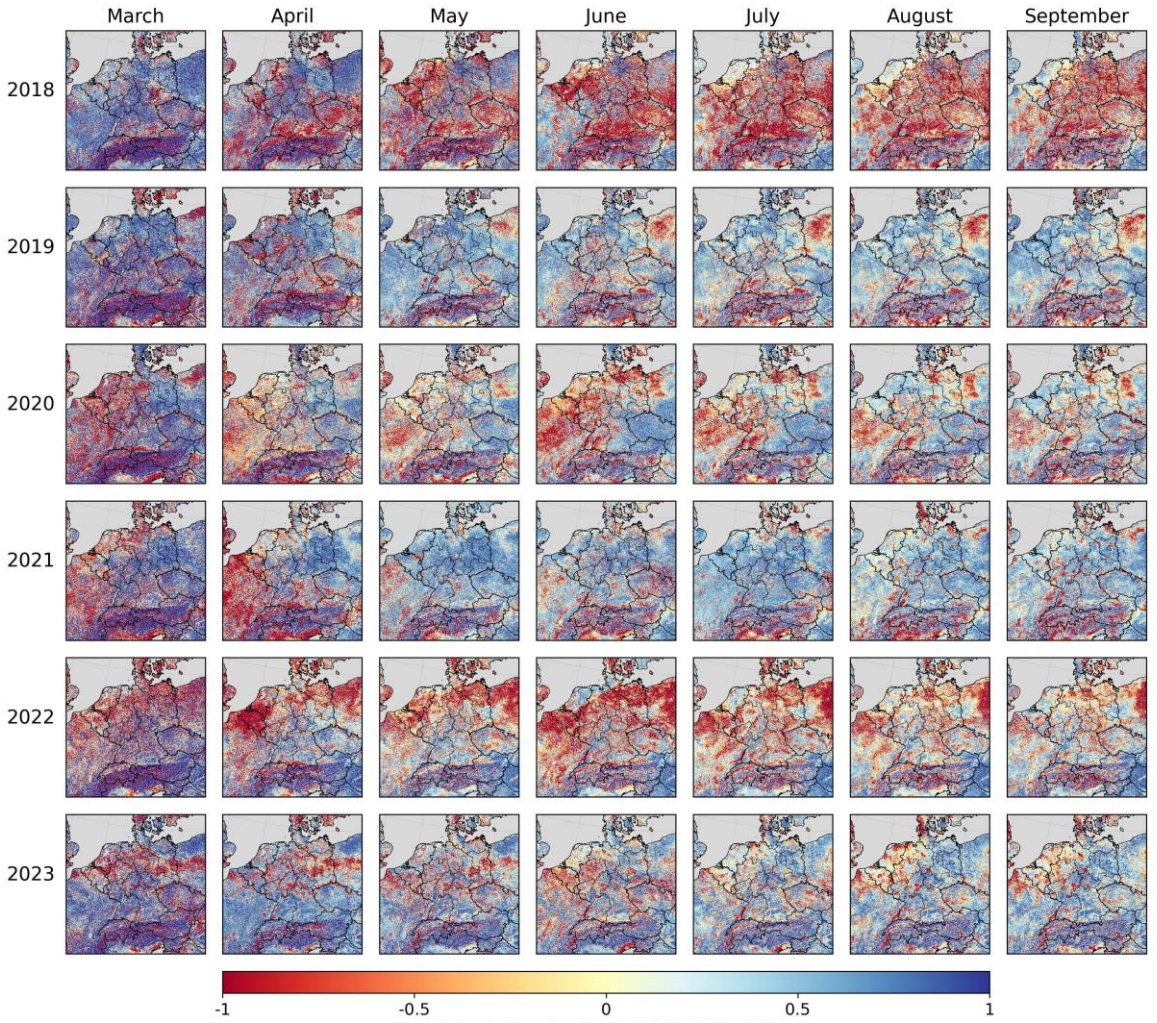
Monthly CRPSS for water table depth from seasonal forecast compared to 2013-2023 climatology-based “pseudo-forecast”

Seasonal forecast shows higher skill than climatology-based forecast for WTD

Skill much more variable for precipitation



Monthly CRPSS for precipitation sum from seasonal forecast compared to 2013-2023 climatology-based "pseudo-forecast"



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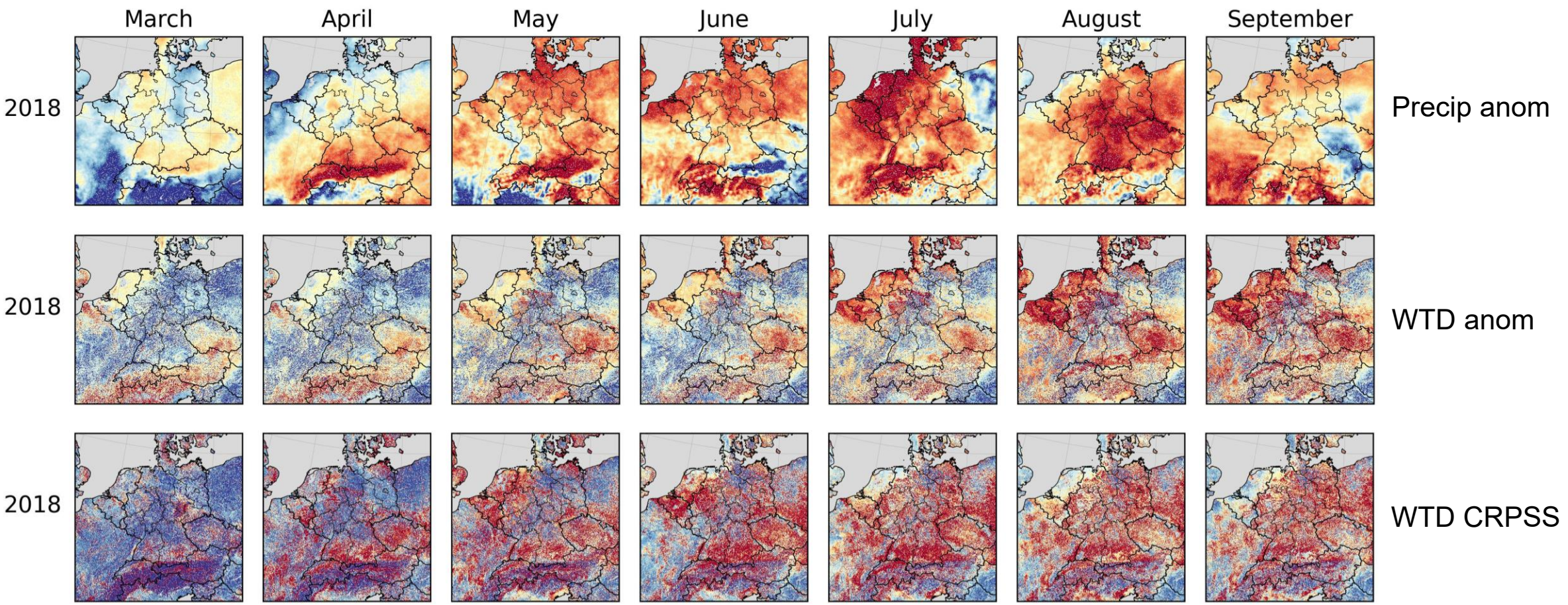
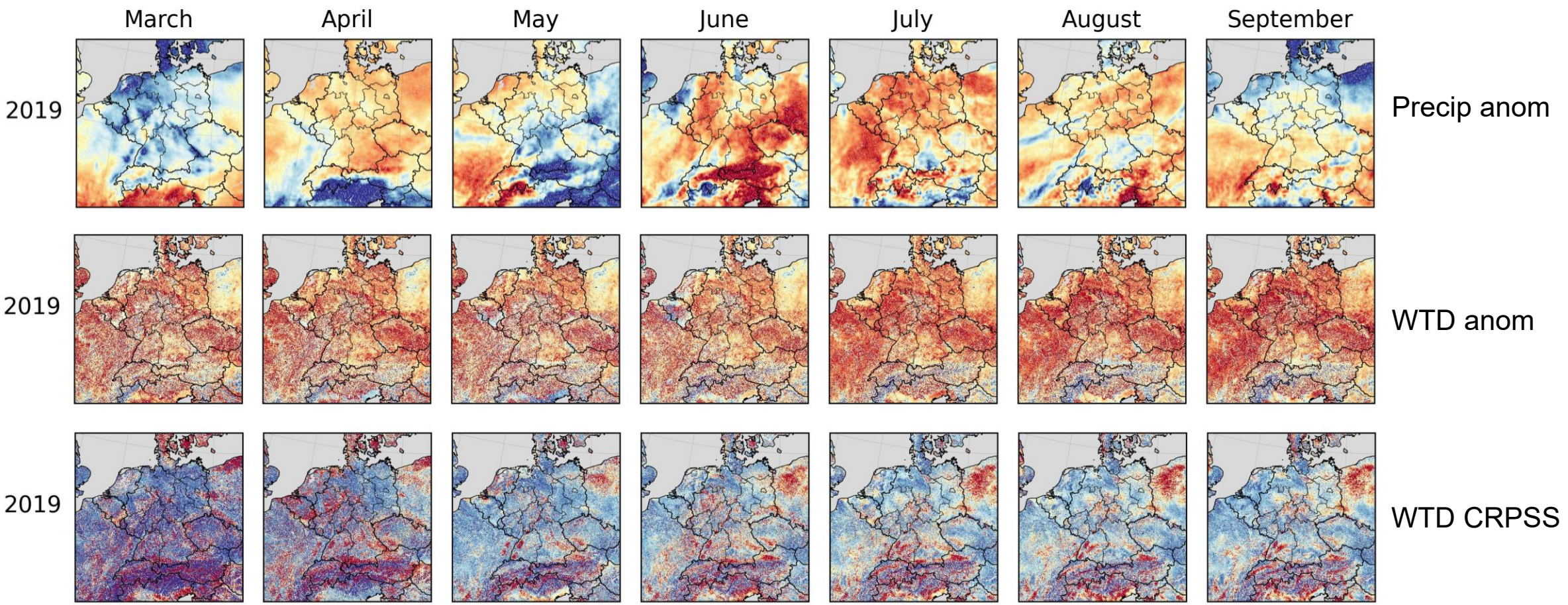


wet conditions in spring + strong meteorological drought
→ agricultural drought onset → low skill

Seasonal forecast shows higher skill than climatology-based forecast for WTD



dry conditions in spring + less pronounced precipitation deficit
→ agricultural drought continuing → higher skill

Seasonal forecast skill of water table depth with ParFlow/CLM

How do we perform the forecasts?

What is the overall skill of the forecasts?

Are we able to forecast droughts?

Dry conditions are generally well forecasted

Even if the skill decreases after the first month

Area Under Curve of the Relative Operating Characteristic

→ Skill for dry extreme events

→ Probabilistic contingency table for lower quintile of distribution

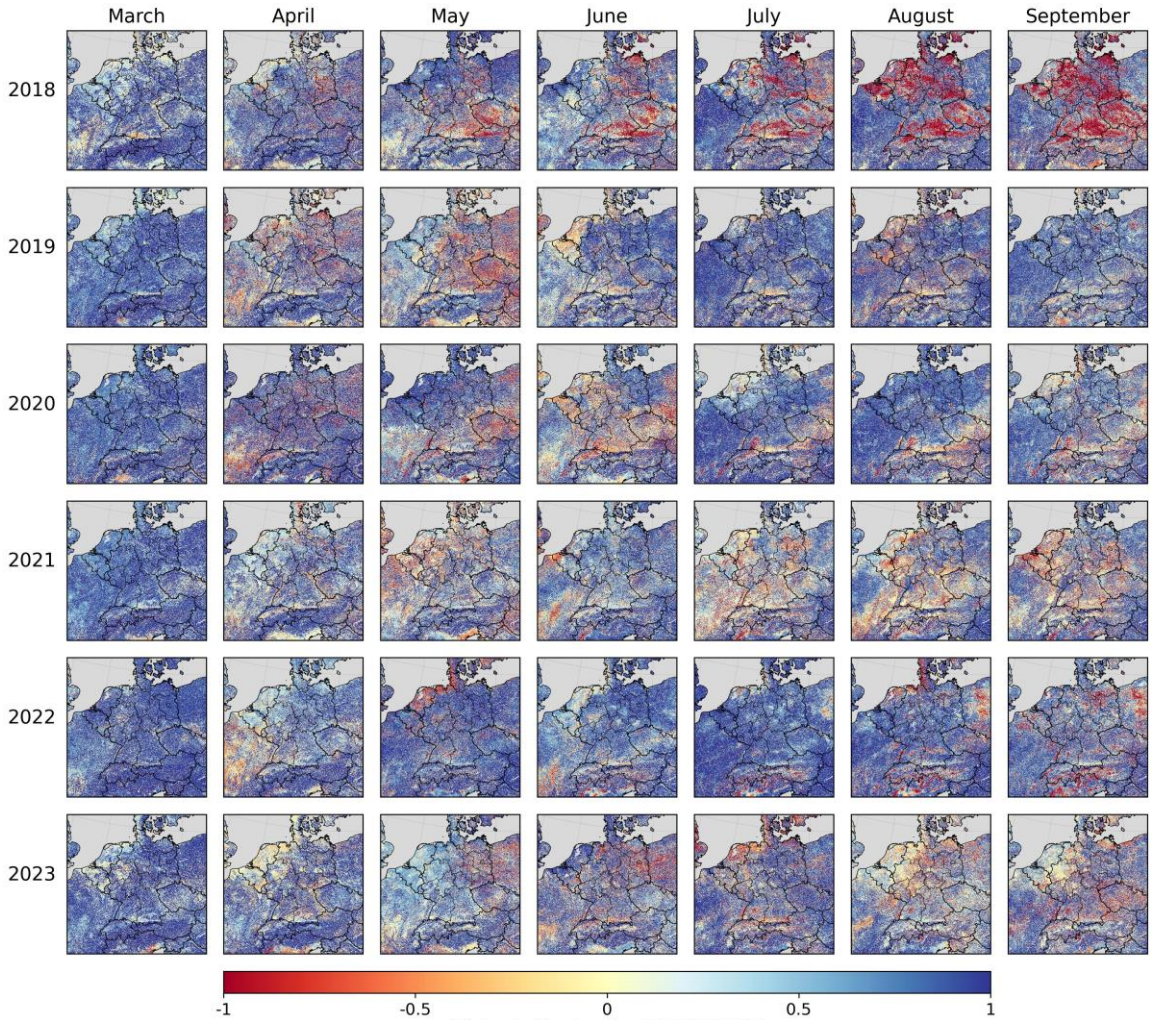
→ 1 = high skill, ~ 0 = no skill

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

Skill decreases in 2018, spring 2019 and 2020, etc.

Climatology-based “pseudo-forecast” shows **no skill**

Precipitation from seasonal forecast and climatology also shows **no skill**



Monthly AUC-ROC for lower quintile for water table depth from seasonal forecast

Dry conditions are generally well forecasted

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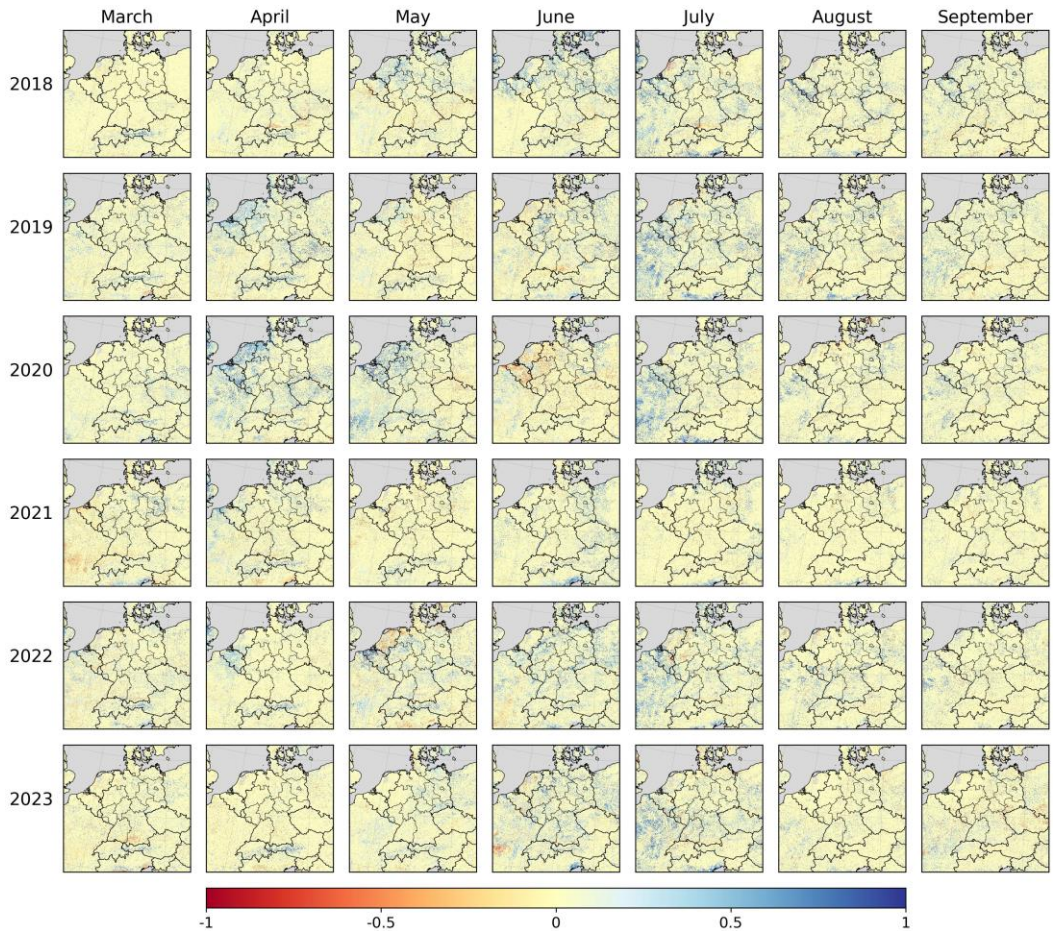
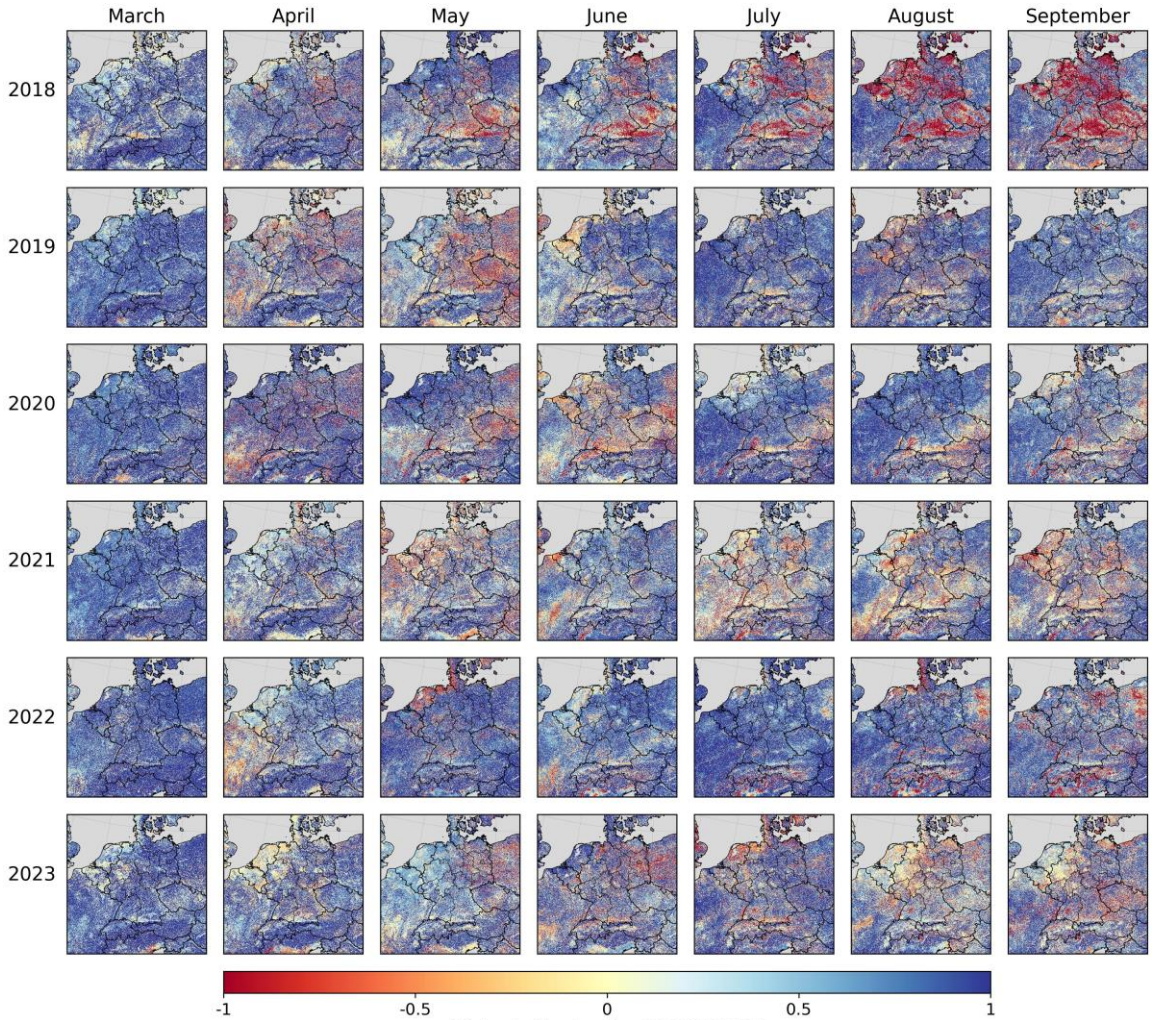


Monthly AUC-ROC for lower quintile for water table depth from climatology-based "pseudo-forecast"



Monthly AUC-ROC for lower quintile for water table depth from seasonal forecast

Seasonal forecast skill of water table depth with ParFlow/CLM

How do we perform the forecasts?

→ Hydrological 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 the memory effect

→ WTD skill highly dependent from atmospheric forcing skill

Are we able to forecast droughts?

→ Yes, but needs further investigation

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

More information, seasonal and daily forecasts:

→ www.wasser-monitor.de

→ www.adapter-projekt.de

Acknowledgement

The authors gratefully acknowledge the Earth System Modelling Project (ESM) for funding this work by providing computing time on the ESM partition of the supercomputer JUWELS at Jülich Supercomputing Centre (JSC).