A Real-time Ensemble Hydrological Forecasting System over Germany at Sub-seasonal to Seasonal Time Range

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Modular Observation Solutions for Earth Systems

MOSES
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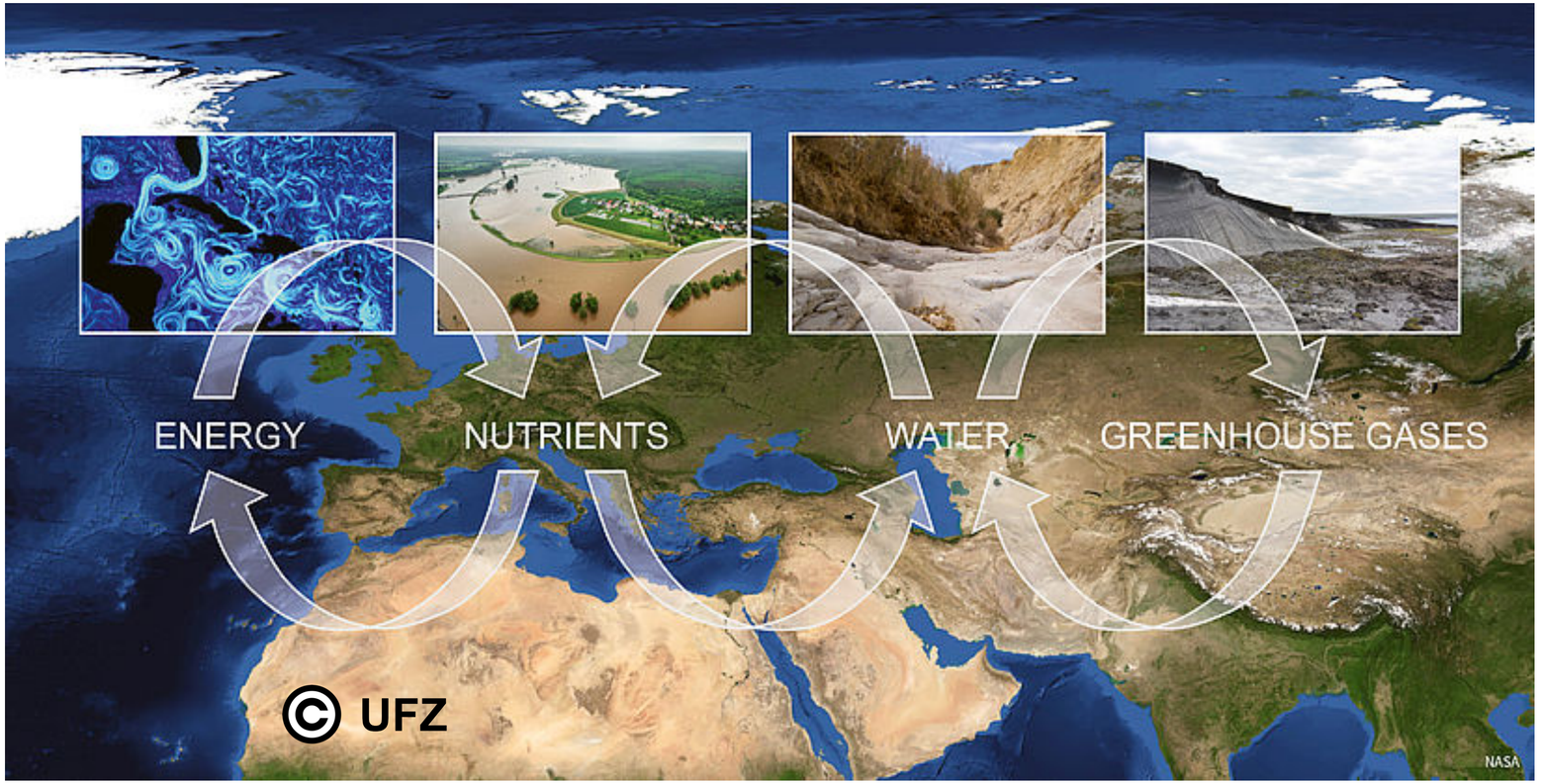


RESEARCH FOR GRAND CHALLENGES

- A joint facility of HELMHOLTZ based on the "system of systems" approach
- Observing systems combined into Hydrological extremes and heatwaves modules
- Designed for event-driven observation campaigns
- Delivere high-resolution data in space and time
- Comprehensive investigation of the processes along the event chain
- Automation of observing systems

UFZ HELMHOLTZ Centre for Environmental Research

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

GFZ Helmholtz Centre POTSDAM

HelmholtzZentrum münchen
German Research Center for Environmental Health

KIT Karlsruher Institut für Technologie

GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel

Source: https://www.ufz.de/moses/

Operational Hydroclimate Forecast Model Chain

Main Approaches

German Drought Monitor (GDM)

1 Benchmark
ESP

2 ECMWF
Dynamic
(ENS Extended)

Data and Hydrologic Model

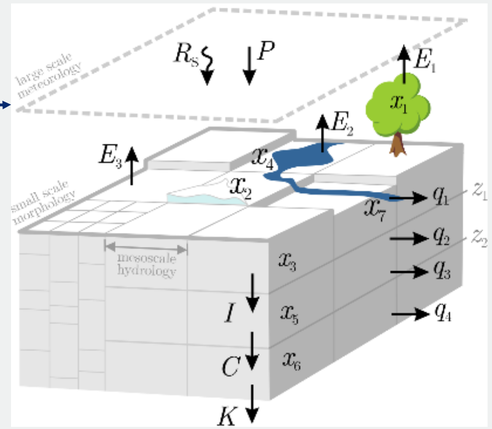
DWD
Prcp
Tmin
Tmax
Tavg

Real-time in-situ observations

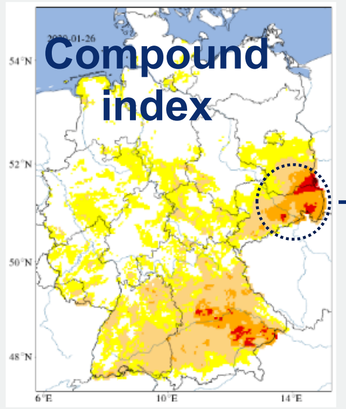
EDK

External Drift Kriging

mHM



Outputs



1 Pre & Temp forecast
2 Heatwave index
3 Soil moisture index
4 Streamflow index
5 River temperature

Issue an Alert

EcFlow

Figure 1. Data and Model chain

MOSES Operational Forecasting System

Domain

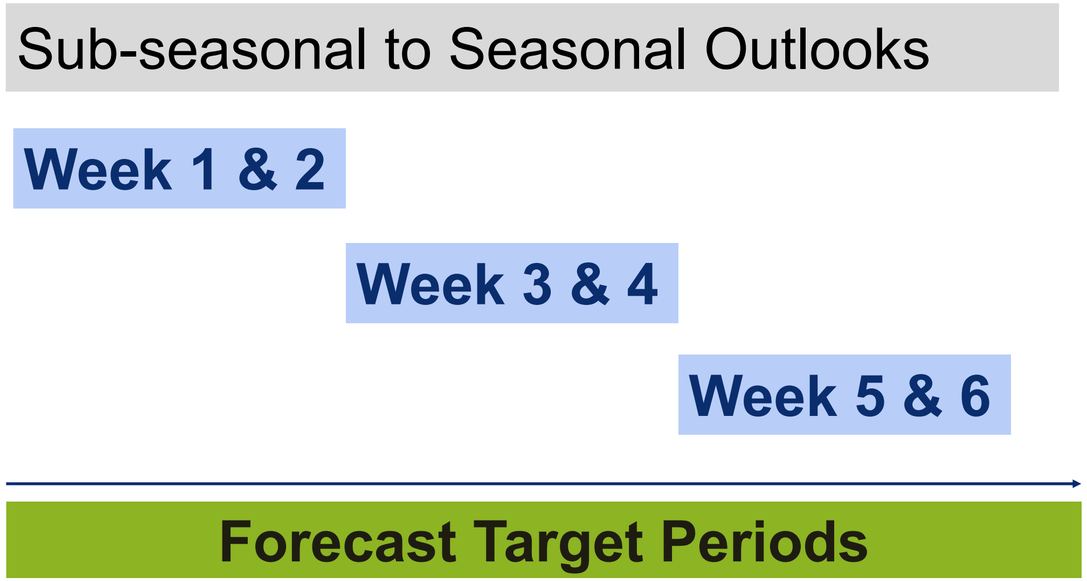
56°N 4°E 45°N 20°E

Verification

- Historical period (hindcast – previous 20 year)
- Real-time (2020)

Final Product

Individual hydroclimate forecast maps
Combined maps (online portal)



Key characteristics of hydrological forecasting Systems

Approach	Ens. Size	Frequency	Atmospheric Res.
ESP	51	Everyday	0.2 degree
Dynamic (ECMWF ENS Extended)	51	Mondays / Thursday	0.2 degree (Day 15-46: Interpolated)

UFZ German Drought Monitor (GDM)

- ✓ More than 1000 station daily records of precipitation and temperature are collected operated by German weather service (DWD).
- ✓ Daily near real-time observations are used as input to meso-scale hydrological model (mHM) to simulate soil moisture
- ✓ Monitoring agricultural drought conditions country-wide based on soil moisture states at 4-km resolution
- ✓ Monitoring drought development based on total soil column, top soil (25 cm), and plant available water

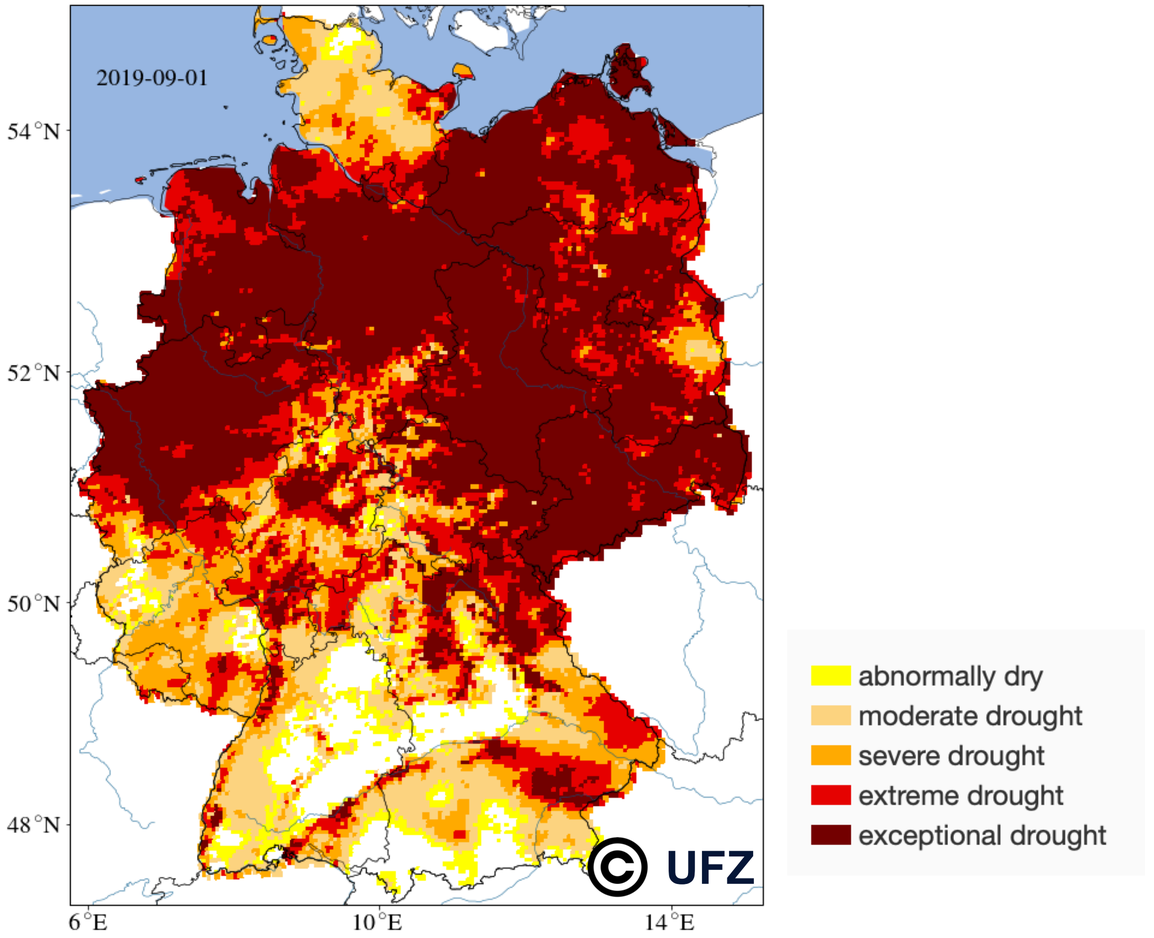
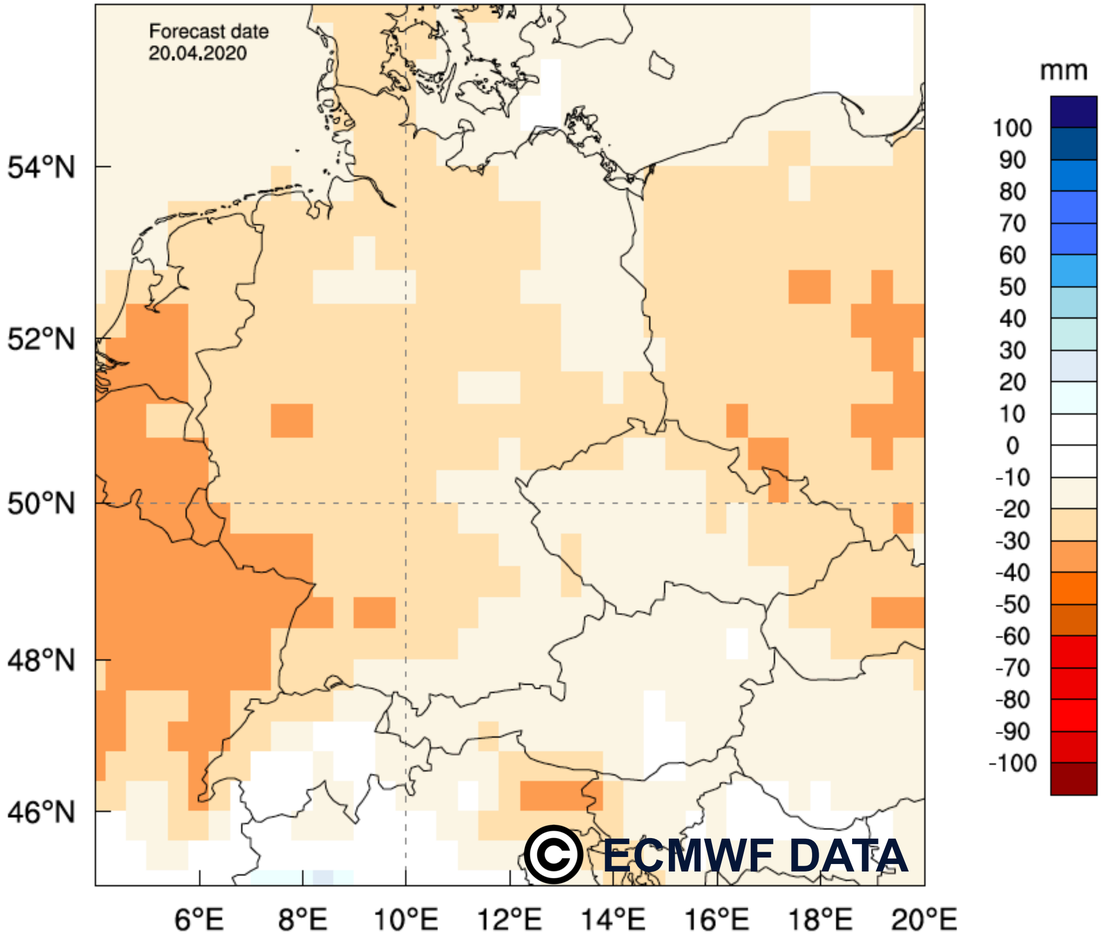


Figure 2. GDM output example for 2019 drought

Source: https://www.ufz.de/index.php?en=37937

Research Highlight: 2020 drought development over Germany?

Cumulated precipitation forecast anomaly for April 20- June 6 (based on ECMWF Ensemble Prediction System)



Soil moisture from total soil column (mHM simulation)

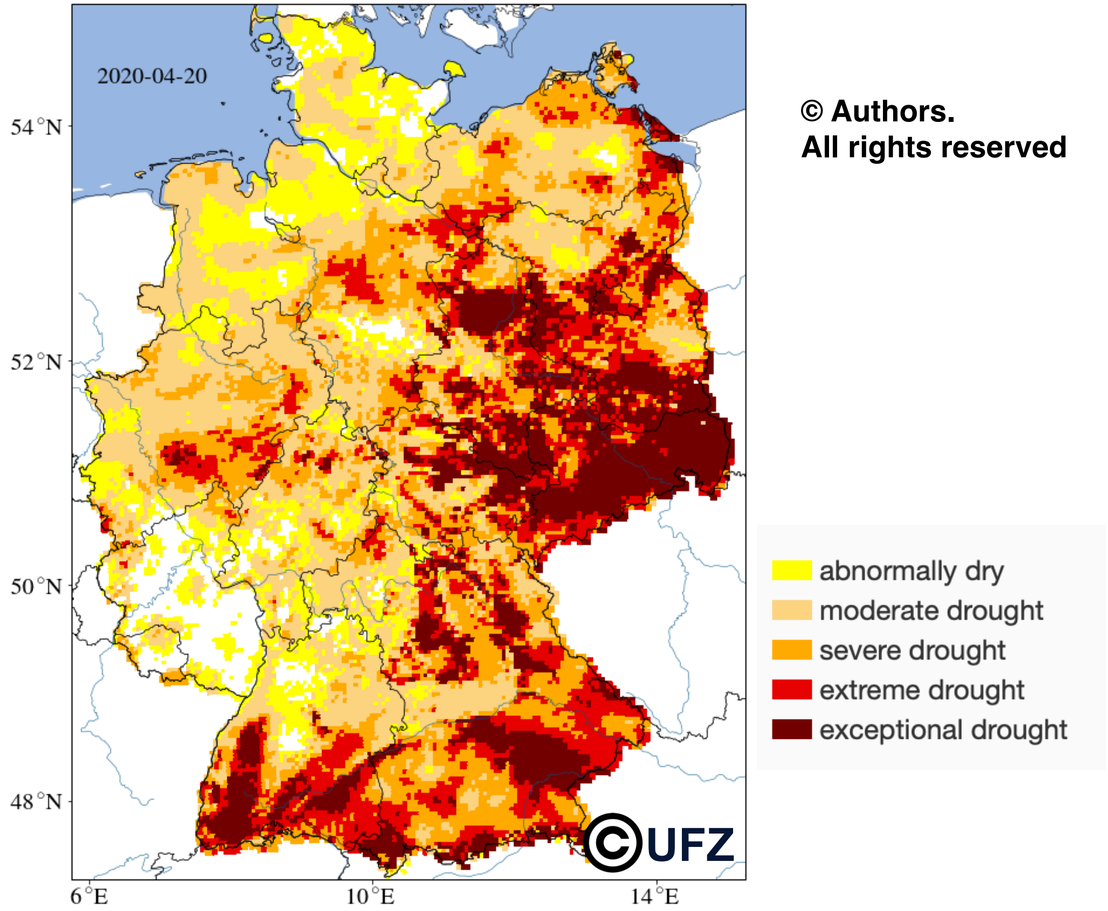


Figure 3. ECMWF forecast issued on April 20 (left), soil moisture (GDM) from total soil column (right)

Full picture of drought development analysis

- ✓ The GDM has already shown a great deficit in the deep soils which will take a long time to be recovered
- ✓ We keep the track of monitoring and looking at S2S real-time forecasts issued every Monday and Thursday
- ✓ Precipitation and temperature forecasts are not enough to understand complex hydroclimate states of the system
- ✓ Soil moisture and discharge forecasts will provide added value to understand drought development

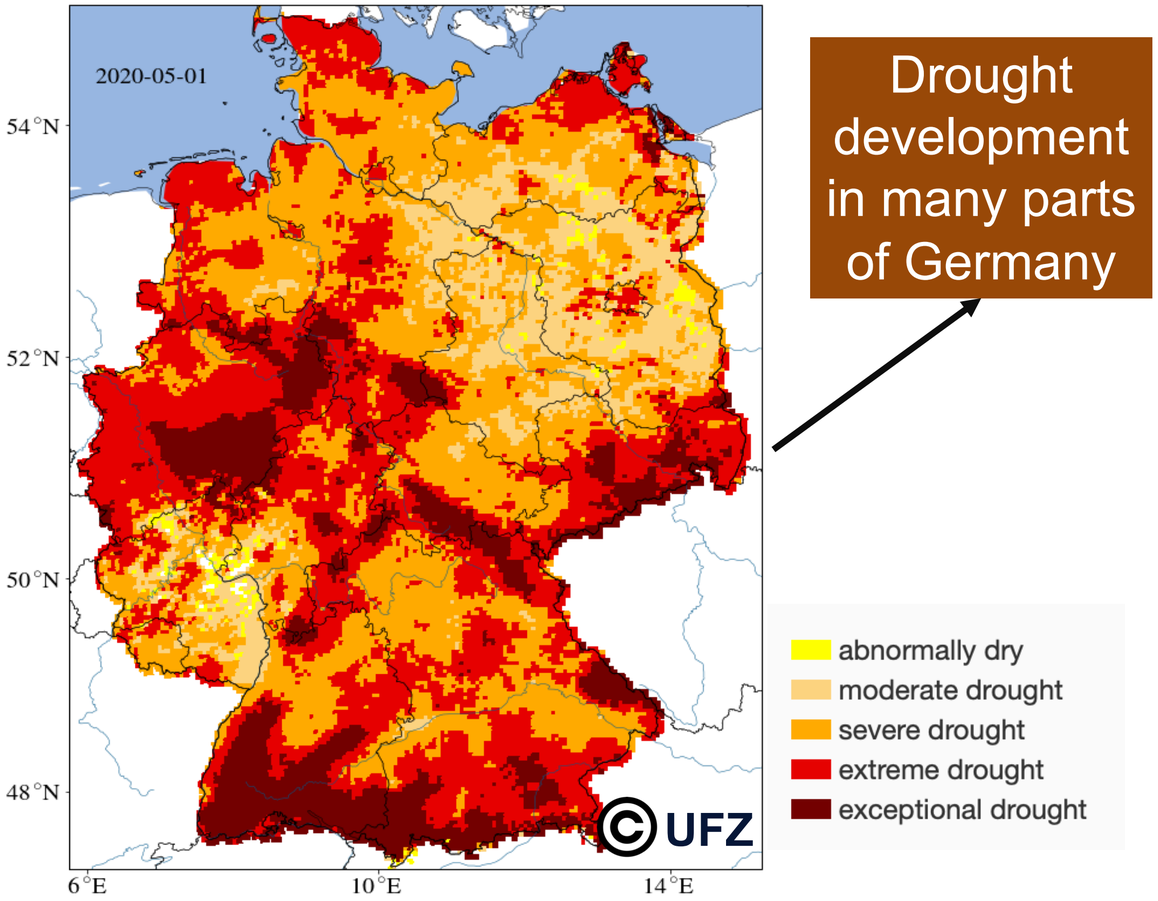


Figure 4. Monthly total soil column soil moisture
Source: *https://www.ufz.de/index.php?en=37937*

Dry signal is changed to wet in 2020-04-27 forecast

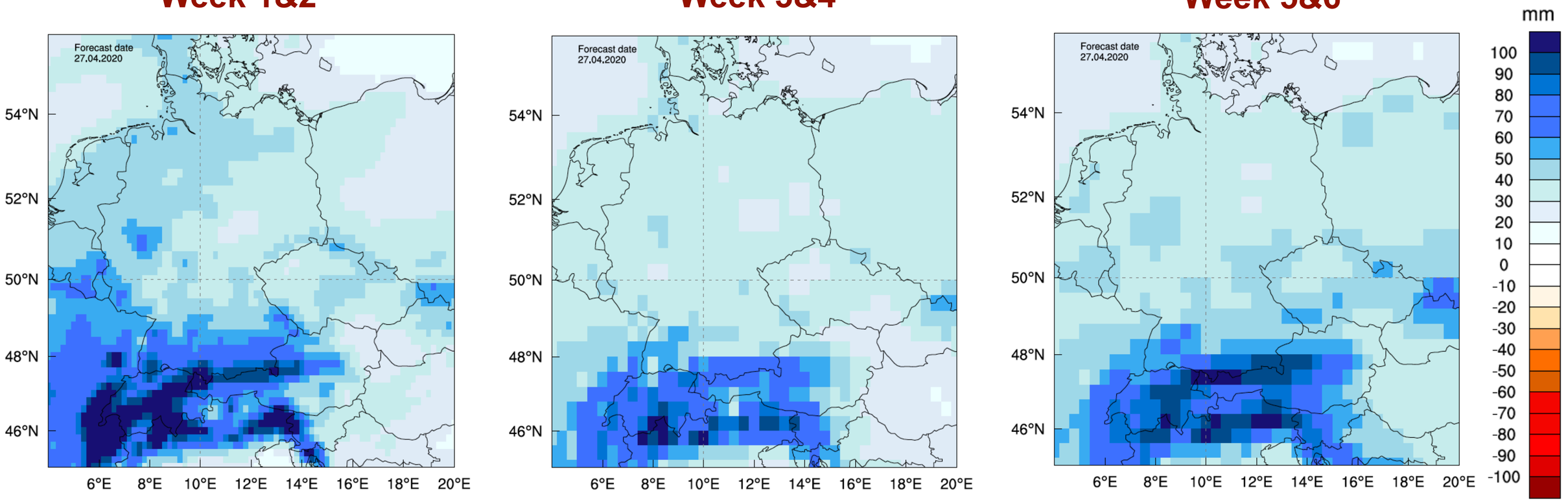


Figure 5. Cumulated precipitation forecast anomalies issued on 2020-04-27 based on ECMWF Ensemble Prediction System

Wet or dry? What spatial pattern of bias suggests?

- ✓ ECMWF real-time forecast shows a wet anomaly for week 1&2
- ✓ A dry bias appears for 15-day target period (averaged over 20-year hindcast period)
- ✓ Final judgement is possible by verifying against ground truth not anytime before May 11
- ✓ Bias correction?

ECMWF real-time precipitation forecast anomaly (ens mean)

Bias (ens mean)

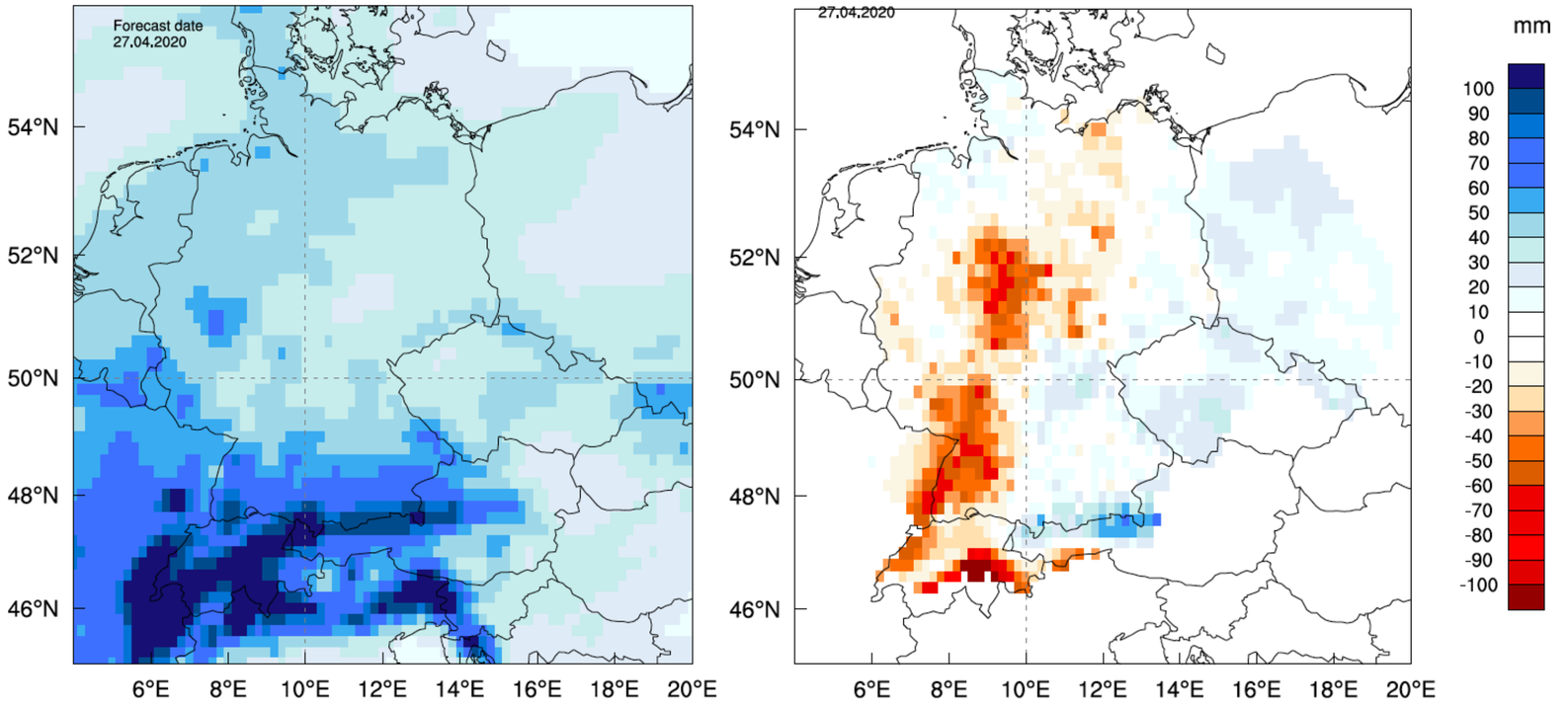


Figure 6. ECMWF real-time S2S forecast anomaly (left), bias for the same 15-day calculated from hindcast (right). *Reference data for bias calculation: DWD (inside Germany) and EOBS (outside Germany, covering headwaters). Real-time forecast was issued on 27.04.2020*

ECMWF Real-time Precipitation Forecast Error

Skill and reliablity of the forecast must be communicated well

- ✓ DWD station data (precipitation) was collected and cumulated for the period between March 16 – May 1, 2020
- ✓ Precipitation records was interpolated to 0.4 degree grids to calculate ECMWF real-time forecast deviation from the ground truth
- ✓ ECMWF real-time precipitation forecast was overestimated (0 to 2 mm/day)

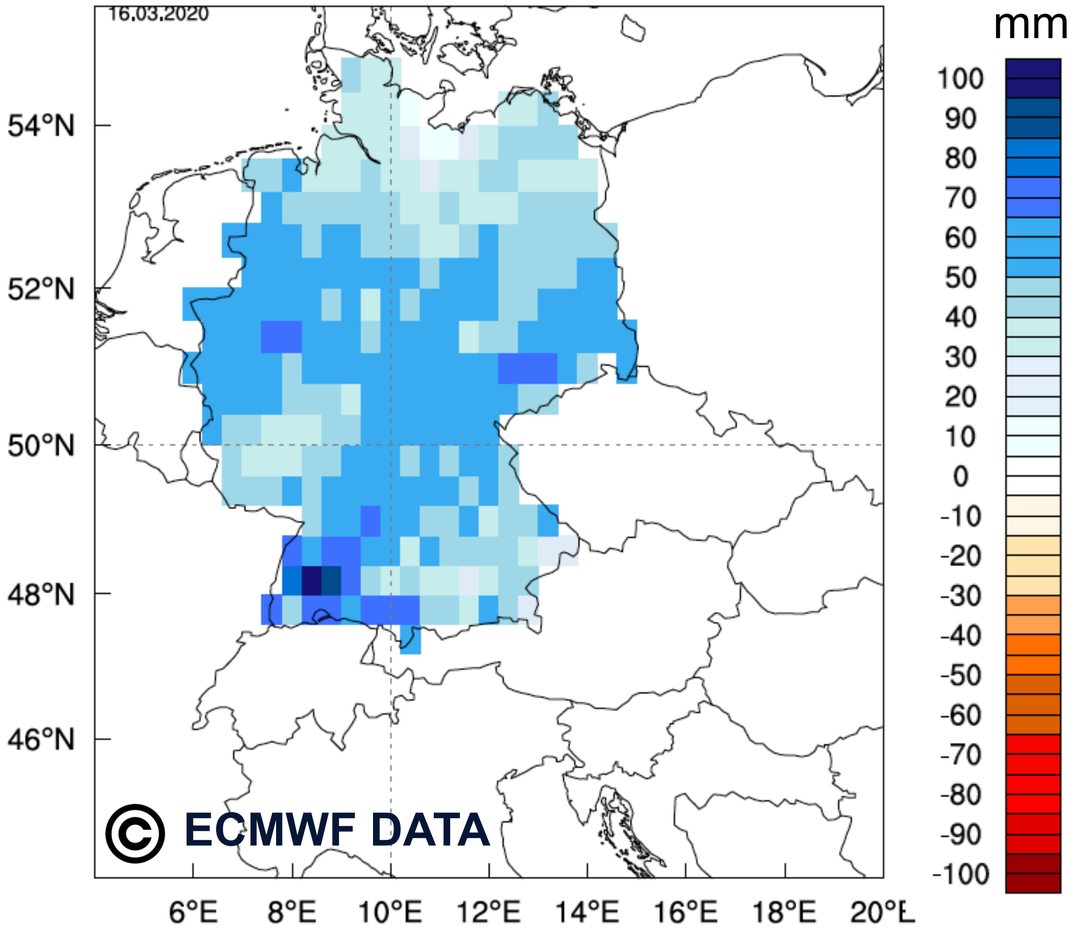


Figure 7. Difference between ECMWF and DWD (interpolated) for 47-day cumulated precipitation *Forecast issued on March 16, 2020.*

Steps Ahead

- ✓ ECMWF precipitation and temperature reforecast skill assessment
- ✓ Apply bias correction to ECMWF (ENS Extended) forecasts
- ✓ Developing dynamic-based soil moisture and discharge forecast
- ✓ Compare dynamic-based and ESP forecast skill
- ✓ Developing high-resolution heatwave forecasting system
- ✓ Developing high-resolution early warning system for compound hydroclimate events
- ✓ Skill assessment based on MOSES high-resolution field campaign measurements

Summary

- ✓ Hydroclimate forecast skill and its uncertainty must be communicated well for decision making.
- ✓ Verification of reforecast and real-time forecasts will provide uncertainty and current skill of hydroclimate forecasts.
- ✓ Soil moisture forecast based on ECMWF forecasts and its comparison to ESP will be developed for drought forecasting.
- ✓ High resolution and reliable soil moisture forecasts will support event-driven campaigns of MOSES.