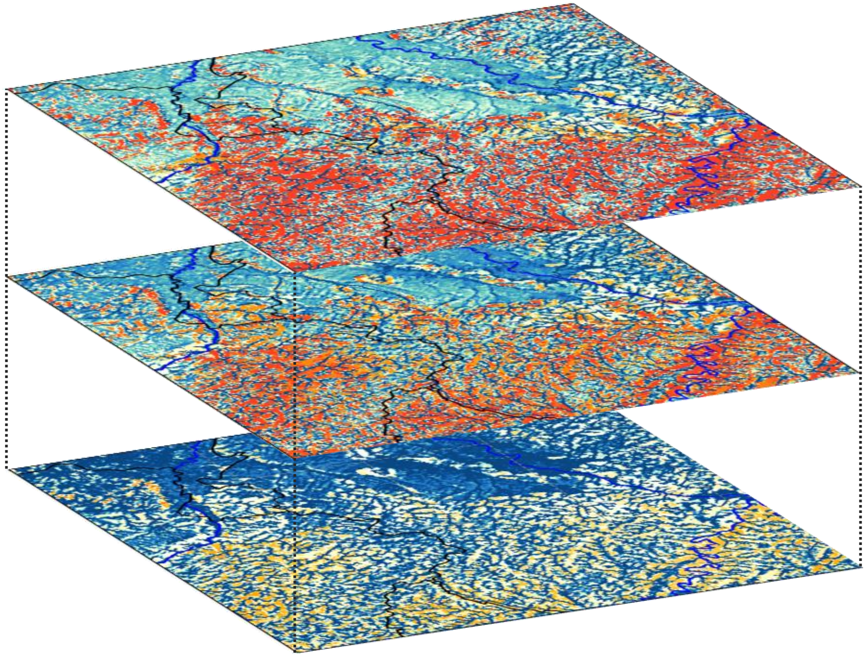
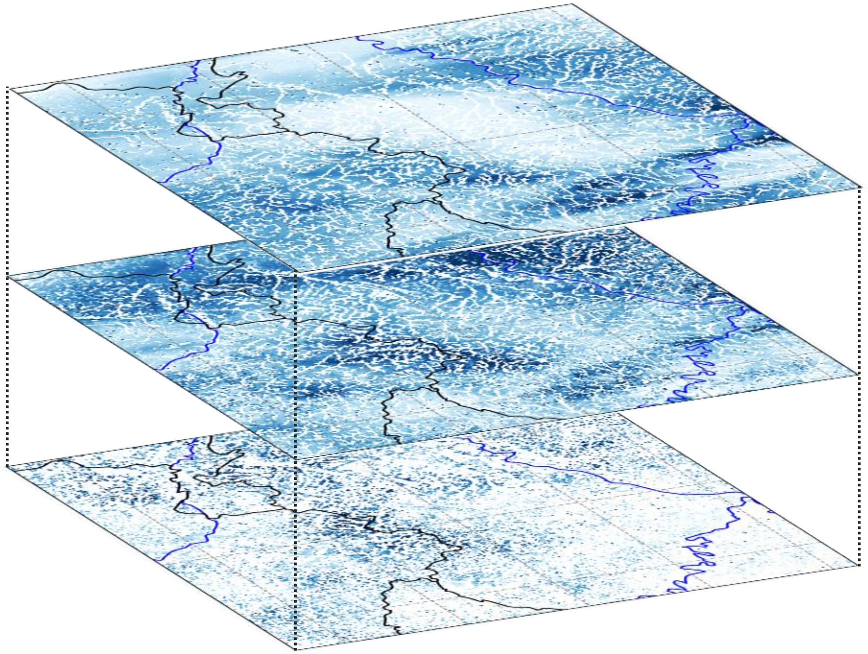
CC BY





Forecasts of plant available and seepage water for agricultural usage during recent extreme hydrometeorological conditions in western Germany using a convection-permitting regional Earth-system model

ADAPTER

EGU – 08/05/2020 I **A. Belleflamme[1,2], K. Goergen[1,2], N. Wagner[1,2], S. Bathiany[3], D. Rechid[3], S.Kollet[1,2]**

[1] Institute of Bio- and Geosciences (Agrosphere, IBG-3), Research Centre Jülich, Jülich, Germany

[2] Centre for High-Performance Scientific Computing in Terrestrial Systems (HPSC TerrSys), Geoverbund ABC/J, Jülich, Germany

[3] Climate Service Center (GERICS), Helmholtz-Zentrum Geesthacht, Hamburg, Germany

GERICS Climate Service Center Germany

geoverbund aachen bonn köln jülich

HPSC TerrSys

JÜLICH Forschungszentrum

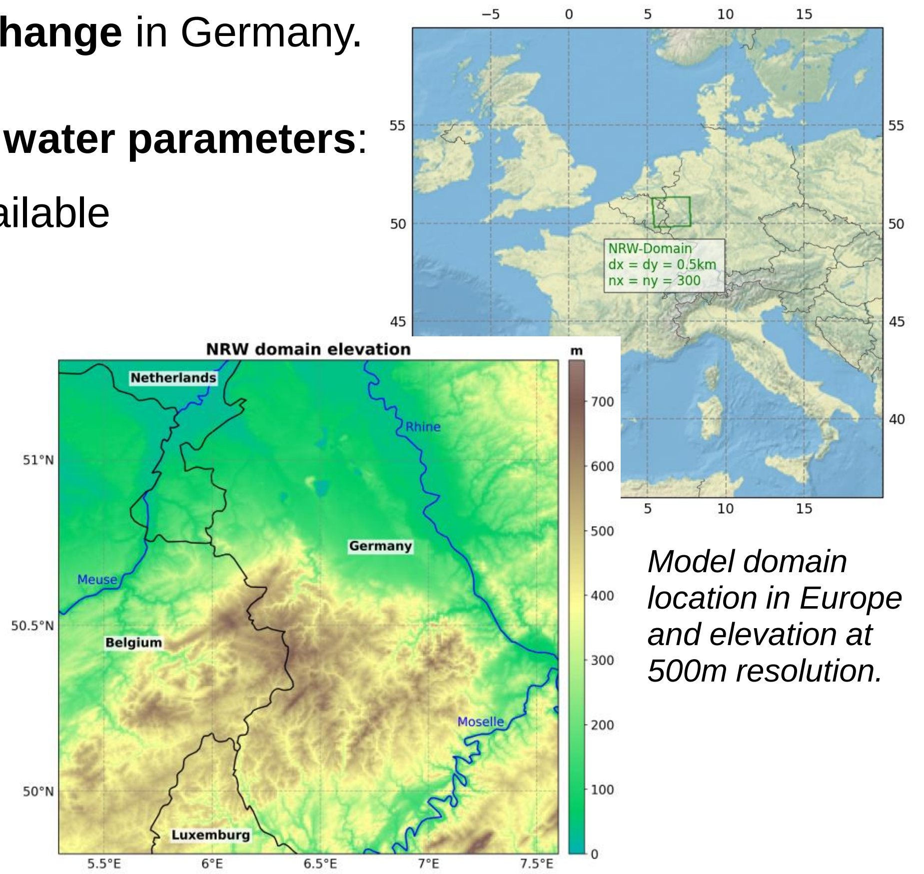
Extreme weather conditions relevant for agriculture are simulated with TSMP

Plant available water and soil water flux are key parameters in agriculture

- The ADAPTER **project** (www.adapter-projekt.de) aims to develop specific products and usable information that help improve agriculture's resilience to **extreme weather conditions and climate change** in Germany.

- In the context of the droughts of the last years in Europe, we focus on **two soil water parameters**:
  - **plant available water** (PAW), the fraction of the soil water amount that is available for plants, scaled with the permanent wilting point and the field capacity,
  - **soil water flux above the water table** (SW), calculated as the vertical component of the Darcy flux in an unsaturated porous medium.

- We use daily forecasts of the **Terrestrial Systems Modelling Platform** TSMP:
  - composed of **COSMO** (1km), **CLM** – Community Land Model (500m), and **ParFlow** hydrologic model (500m)
  - driven by the deterministic ECMWF forecast run **HRES**
  - over **North-Rhine Westfalia** (Germany)
  - see also www.terrsysmp.org and www.parflow.org

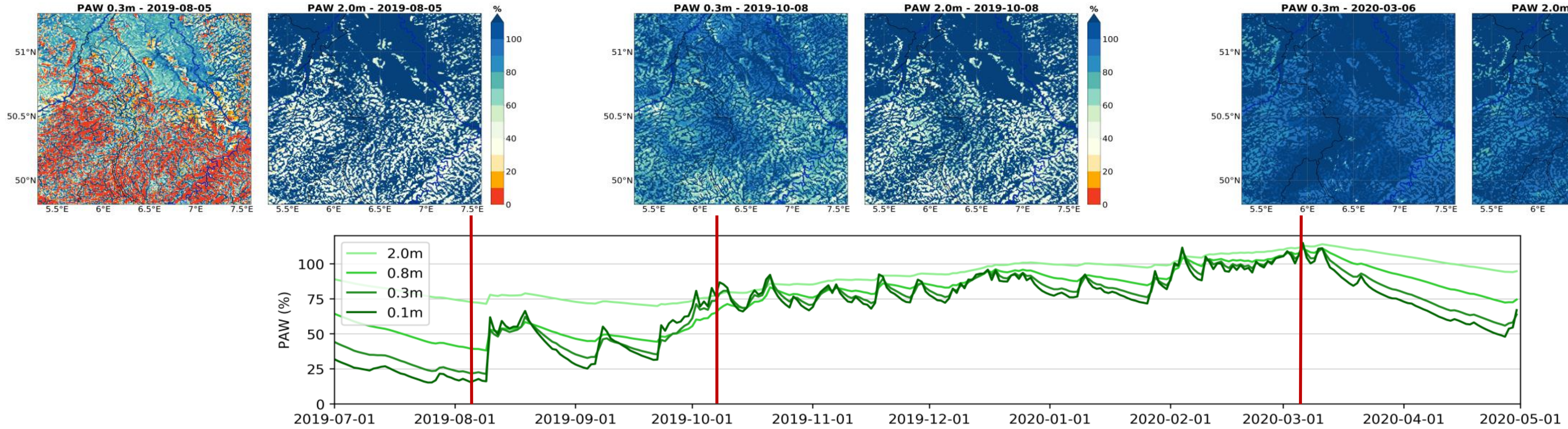


Model domain location in Europe and elevation at 500m resolution.

Plant available water shows a strong 3D spatial variability

High resolution simulations and 3D water flow representation play an important role

- The 2019 summer drought had **different impacts for agriculture and forestry**, depending on the rooting depth of plants:
  - PAW < 30% = water stress for plants in upper layers in summer,
  - nearly no change at 2m rooting depth between July and October 2019.
- PAW is strongly **influenced by topography**, leading to a high spatial heterogeneity (e.g. higher values in valleys and low lands).



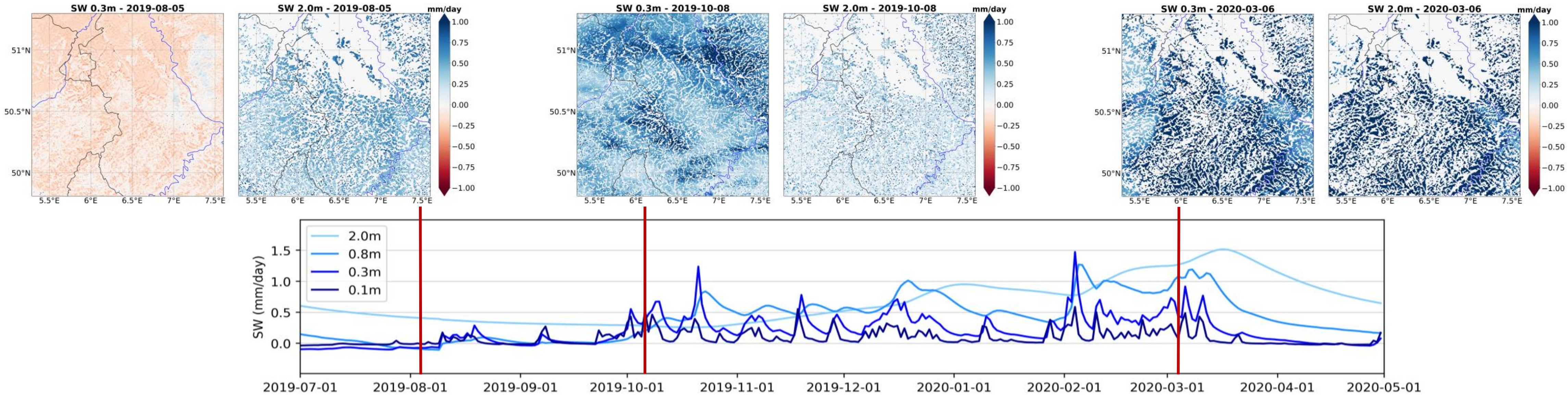
PAW daily means at 0.3m (left) and 2m (right) depth for three representative situations and time series at four depths. The time series are averaged over the domain areas where the water table is below 2m depth on 2020-08-05.

JÜLICH Forschungszentrum

Soil water flux depends on depth and spatial distribution of precipitation

A realistic spatial distribution of precipitation and initial conditions are crucial

- A correct representation of the soil water state is important, as shown by the **strong response delay** of deeper layers:
  - upper layers had to “refill” first, before seepage water reached deeper layers, which took ~3-4 months after the 2019 drought,
  - for a single rain event, the signal is delayed by 3-5 days at 0.8m depth, and by 3 weeks at 2m depth.
- The potential **leakage of nutrients and pollutants** through seepage into groundwater shows a high spatial variability.



SW daily sums at 0.3m (left) and 2m (right) depth for three representative situations and time series at four depths. The time series are averaged over the domain areas where the water table is below 2m depth on 2020-08-05. Downward (upward) flux is shown by positive (negative) values. White areas are below water table, i.e. in groundwater.

JÜLICH Forschungszentrum

Supplementary information

More about… the ADAPTER project

Innovative and simulation-based products for a weather and climate resilient agriculture

The aim of the project is to generate weather and climate products to help agriculture to become more resilient against extreme weather conditions and climate change.

We develop:

- weather forecast products based on TSMP (IBG-3, Research Centre Jülich),
- prototypical climate products based on climate model simulations (GERICS, HZG).

Our products are designed through a permanent dialogue with our practice network composed of key partners and stakeholders, like farmers, chambers of agriculture, plant breeders, and rural district administrations.

These products are made available for free on our product platform (www.adapter-projekt.de).

Within our citizen science framework, we build an observation network with participating farmers, focused on soil moisture, from which the data will be assimilated in our forecast model.

ADAPTER is funded by the Helmholtz Association Initiative and Networking Fund.

More about… plant available water

Estimating the water stress of plants

Plant available water (PAW) is represented here as the fraction of the soil water amount (θ) that is available for plants, thus between the permanent wilting point (PWP) and the field capacity (FC):

$$PAW = \frac{\theta - \theta_{PWP}}{\theta_{FC} - \theta_{PWP}}$$

PAW is a representation of the saturation level of the soil, and it depends on the soil properties.

PAW is higher than 100% when the soil water content lies above the field capacity,
and dryness becomes critical for plants when PAW is below 30%.

Here, daily PAW is calculated for the soil volume from the surface down to a given depth (0.1m, 0.3m, 0.8m, and 2m), on the basis of the soil water pressure head computed by ParFlow hydrologic model.

More about… soil water flux above the water table

Calculating the water percolation

Vertical soil water flux (SW) above the water table is considered here, allowing to go further than a strict seepage water analysis. It is calculated with the Darcy flux formula for unsaturated porous media on the basis of the vertical hydraulic gradient between two layers.

SW is shown here as the daily cumulated downward (> 0 ; ~ seepage water) and upward (< 0 ; capillary rise) flux at each given soil depth (0.1m, 0.3m, 0.8m, and 2m).

As for PAW, it is calculated on the basis of the soil water pressure head forecasted by ParFlow.

SW can be used to quantify the groundwater recharge, but also to estimate the leakage of nutrients and pollutants, which makes this parameter very important in agriculture.

More about... the Terrestrial Systems Modelling Platform - TSMP

A high-resolution convection-permitting regional Earth-system model

TSMP (www.terrsysmp.org) is a fully coupled model system composed of:

- COSMO for the atmospheric component,
- CLM (Community Land Model) for the land surface interface,
- ParFlow hydrologic model (www.parflow.org) for the surface and subsurface simulation of the water flow.

The model domain covers the south-western part of North-Rhine Westfalia (150 x 150km), in Germany at a spatial resolution of 1km (atmosphere) and 500m (surface and subsurface).

This setup allows a representation of the closed water budget, including 3D subsurface and groundwater flow

More about… TSMP in forecast mode

Each forecast is initialized by a corrected simulation based on radar data

5.5 days forecasts at a hourly time step are computed daily on the high-performance cluster JURECA from the JSC (Jülich Supercomputing Centre). Currently, we are expanding the forecast time span to 10 days.

The boundary conditions are provided 3-hourly by the deterministic forecast simulation HRES of the European Centre for Medium-Range Weather Forecasts (ECMWF).

A “radar correction” is applied by repeating the forecast for the first 24 hours and replacing the HRES precipitation by radar data (RADOLAN data set) from the German Weather Service (DWD), as:

- precipitation forecasts have a high spatial and temporal uncertainty,
- that would lead to biases in the subsurface water budget.

This corrected run is than used to initialize the forecast of the following day.

Here, we use the first 24 hours of each daily forecast run to build a complete time series from 2020-07-01 to 2020-04-30.