Project: 983
Title: Decadal variability of extreme events over Europe
Report for period 01.01.2023-31.12.2023

In recent years, our project has focused on quantifying flood risk across multiple Central European River networks. Our primary data source is the LAERTES-EU dataset (Ehmele et al., 2020, 2022), containing an unprecedented 12,000 years of regional climate model data. When combined with high-resolution modelling studies, our findings yield fresh insights into recent catastrophic river flood events, such as the Ahr flood of July 2021 (Mohr et al., 2023, Ludwig et al., 2023). Furthermore, we have redirected our research to examine the decadal fluctuations of intense winter storms and prolonged drought incidents alongside significant low water levels in river systems. Through this, we aim to investigate both ends of the extreme event spectrum in the LAERTES-EU data set (see the 2024 proposal for more information). In 2023, we conducted preliminary calibration studies for hydrological modelling using WRF-Hydro and performed high-resolution calibration/ tuning simulations of extreme windstorm events across Europe with the ICON model.

Severe Drought / Low Water Events

In a PhD project[1] that is funded by CEDIM, the interdisciplinary research center for disaster management and risk reduction technology at KIT, we are simulating drought and low-water events in the Rhine River that affect transport of goods during such extreme events. We are using the WRF-Hydro model in combination with the WRF model to achieve this goal. The initial step is to calibrate the WRF-Hydro hydrological model by utilizing ERA5 dataset as input meteorological forcing data and focusing on recent drought incidents, such as the 2018 drought. Through this calibration procedure and adjusting different parameters manually, a more accurate approximation to observed data can be achieved, as outlined by Gochis et al. (2020)
A digital elevation model (DEM) was employed to define the area of interest for WRF-Hydro, with a resolution of 90 m providing the channel grid. The necessary 6-hourly forcing data comprises of air temperature, specific humidity, u and v wind components, surface pressure, rain rate as well as incoming short and longwave radiation at the surface, sourced from the ERA5 data pool at DKRZ. Initially, and still ongoing as noted in the 2024 computing time application, it is necessary to calibrate the parameters that impact water volume and other factors such as the infiltration retention factor, surface retention depth, Manning's roughness coefficient, or overland flow roughness coefficient that affect the shape of hydrographs for the catchment under consideration.

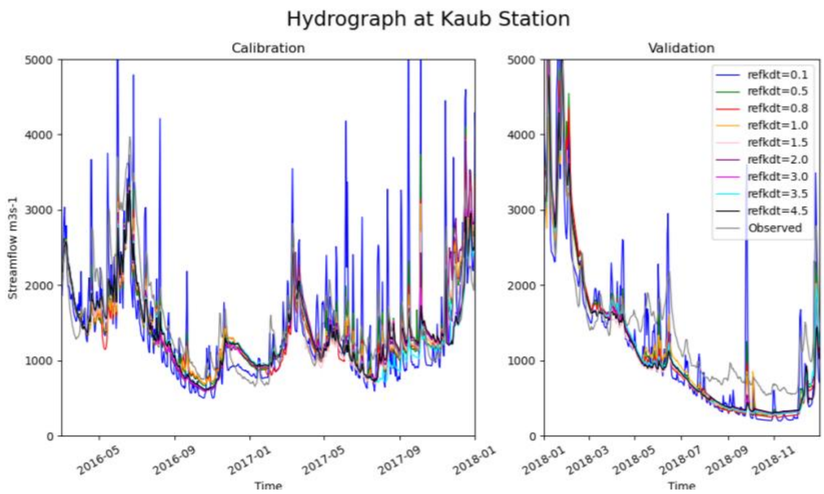

Figure 1. Daily streamflow [m3/s] at Kaub station (Rhine River) modeled with WRF-Hydro (color) for the period 2016-2018 in contrast with the observed data (GRDC, grey) for different values of the infiltration retention factor

A range of parameter values will undergo testing during the 2016-2018 period, utilizing resources in project bb0983. Figure 1 illustrates the various results produced by runs of the model, indicating high peaks of streamflow resulting from low REFKDT (infiltration retention factor) values. Following this, simulations will be subjected to statistical analysis, such as Nash-Sutcliff Efficiency (NSE), Kling-Gupta Efficiency (KGE), and Correlation Coefficient (Corr). The outcome of this assessment for REFKDT can be seen in Figure 2.

[1] https://www.cedim.kit.edu/english/3457.php

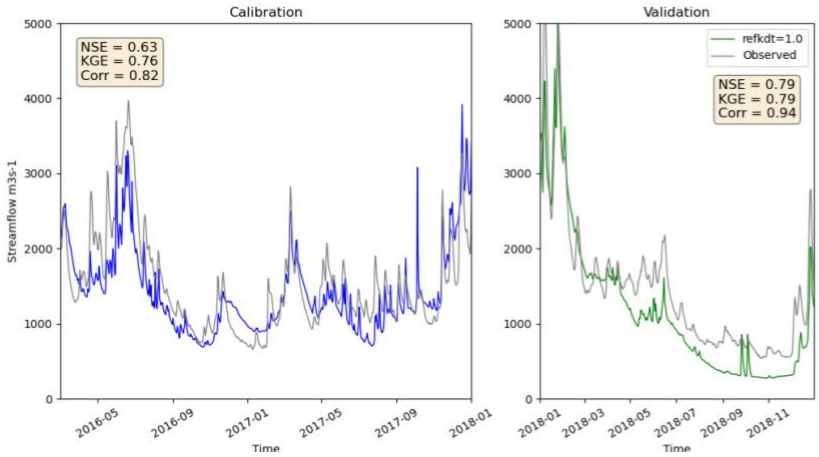

Figure 2. Observed and simulated (WRF-Hydro) daily hydrographs at Kaub: calibration period 2016-2017 (left), validation period 2018 (right).

Severe European Windstorm Events

The project's second focus in 2023 was on setting up high-resolution regional ICON windstorm simulations across Europe, with a 3 km horizontal resolution. The goal is to create a storm catalog in high resolution that dates to the early 60s and covers recent years. These simulations, in combination with the LAERTES-EU data, will enable an unprecedented study of possible changes in storm characteristics over the past few decades and provide a comprehensive understanding of decadal variability in storm activity over Europe. In 2023, the objective is to calibrate and fine-tune the ICON model over the European domain, in collaboration e.g., with the UDAG project 1364. Figure 3 provides exemplary footprints of the extreme winter storms Anatol (1990) and Lothar (1999).

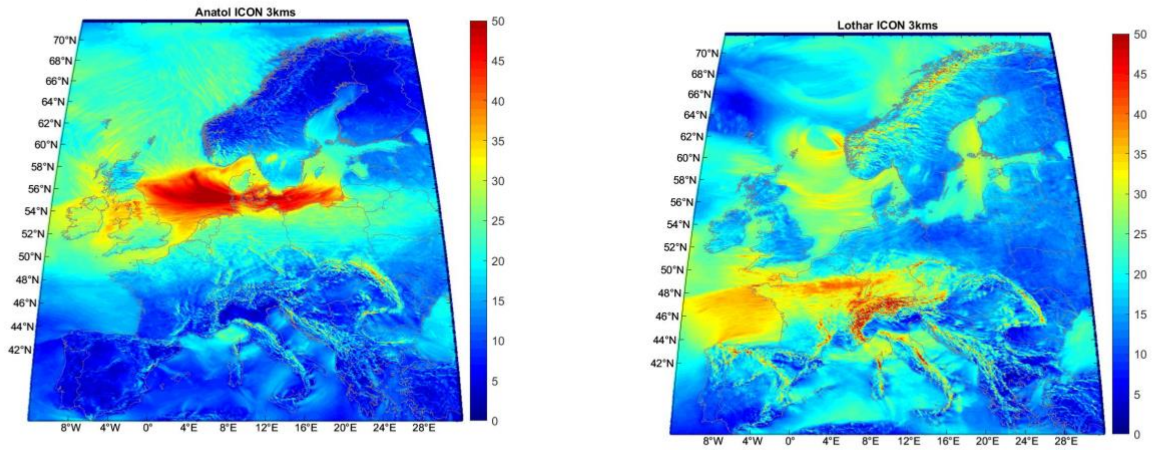

Fig. 3: Footprints of maximum wind gusts simulated by ICON at 3km grid spacing for Anatol (left) and Lothar (right)

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