Project: 983
Title: Decadal variability of extreme events over Europe
Report for period 01.01.2024-31.12.2024

In recent years, our project has focused on several extreme events (single cases) and their (decadal) variability across Europe. Besides new high-resolution model simulations (with WRF/WRF-Hydro and ICON-CLM), 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. In 2024, we conducted 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 that is funded by CEDIM[1], 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 was 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. This entire procedure was completed in 2024 and a paper of the results is currently under review in GMD[2]. In a next step (in 2025), we will focus on scanning the LAERTES-EU data, which contains more than 12.000 years of meteorological data to extract extreme drought events. The task involves using drought indices and statistical analysis of variables such as precipitation and temperature (see proposal for 2025).

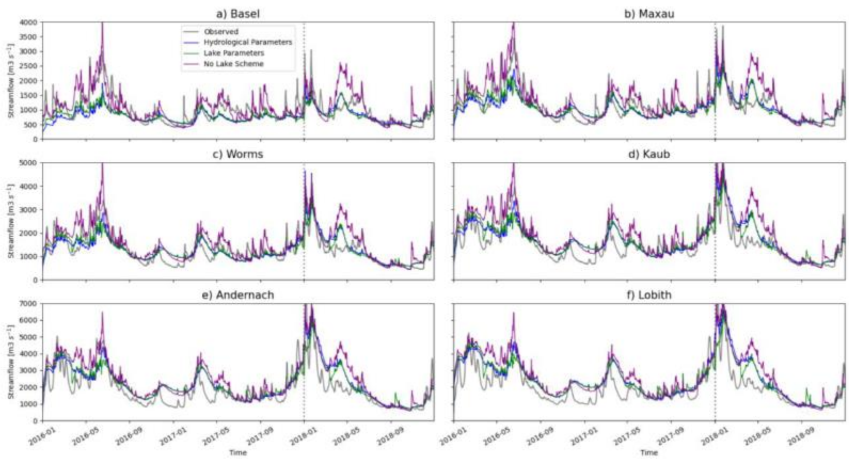

Fig 1. Daily streamflow hydrographs after calibration of the model's hydrological parameters (blue), lake parameters (green), without the lake scheme (purple), and the observed data (gray line) from the stations (see Fig. 1 for their location). The calibration period is on the left side of the horizontal dotted line, and the validation period is on the right side

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[1] https://www.cedim.kit.edu/english/3457.php
[2] Campoverde, A. L., Ehret, U., Ludwig, P., and Pinto, J. G.: Model calibration and streamflow simulations for the extreme drought event of 2018 on the Rhine River Basin using WRF-Hydro 5.2.0, Geosci. Model Dev. Discuss. [preprint], https://doi.org/10.5194/gmd-2024-134, in review, 2024

Severe European Windstorm Events

After setting up and calibrating the ICON model for high-resolution windstorm simulations over the European domain mainly in 2023, this year's objective of the project was to produce a storm catalog including the strongest events of the past decades. So far, 150 extreme windstorm events between 1961 and 2023 have been simulated, each with a duration of ~5 days. More simulations are planned for Q4 of 2024. The simulations are driven by hourly ERA5 data that is available at DKRZ and cover Europe at a resolution of 0.028°.

Decadal variability of European Windstorms

We are investigating the variability and trends of near-surface wind speeds in (LAERTES-EU) data set for the period covered from 1900 to 2028. We address the challenges and advantages of using this large ensemble dataset, comprising approximately 12500-years of regional climate model data. In comparison with reanalysis data and station observations, LAERTES-EU exhibits comparable statistical characteristics, which indicate consistency and robustness of the simulations. Further, the climatology, trends and the seasonal variations present in LAERTES-EU indicate that the simulations can reproduce large scale features and variability very well. Likewise, the dataset did not show any significant long-term trends of wind speed over Europe, apart from a slight negative trend, which is consistent with observed global terrestrial stilling. We can show that the decadal variability is the most prominent mode of variation in LAERTES-EU, although seasonal to multi-decadal variations are also present within the dataset. These analyses are ongoing and will continue in 2025 (see request for 2025), with eventually submitting a paper on that work.

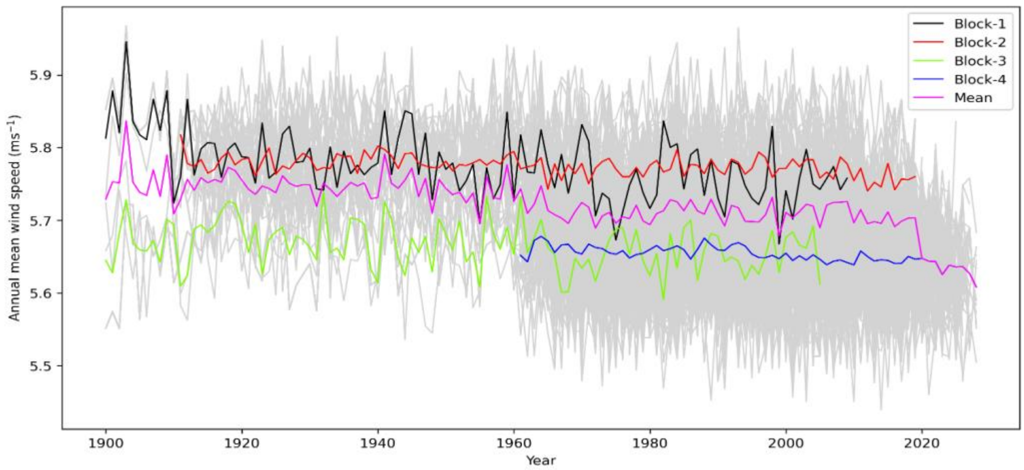

Fig. 2: Time series of area-averaged annual mean wind speed (10m) over Europe. The mean of the individual blocks are shown in black (Block-1), red (Block-2), green (Block-3) and blue (Block-4) and the full ensemble mean of four blocks are shown in magenta.

References:

Ehmele, F., Kautz, L.-A., Feldmann, H., and Pinto, J. G. (2020): Long-term variance of heavy precipitation across central Europe using a large ensemble of regional climate model simulations, Earth Syst. Dynam., 11, 469–490, https://doi.org/10.5194/esd-11-469-2020.

Ehmele, F., Kautz, L.-A., Feldmann, H., He, Y., Kadlec, M., Kelemen, F. D., Lentink, H. S., Ludwig, P., Manful, D., and Pinto, J. G. (2022): Adaptation and application of the large LAERTES-EU regional climate model ensemble for modeling hydrological extremes: a pilot study for the Rhine basin, Nat. Hazards Earth Syst. Sci., 22, 677–692, https://doi.org/10.5194/nhess-22-677-2022.