Project: 983
Title: Decadal variability of extreme events over Europe
Report for period 01.01.2026-31.12.2026

In recent years, our working group 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 2026, we conducted hydrological modelling using WRF-Hydro and LISFLOOD to estimate low flow events on the Rhine River 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 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 to study their impact on the transport of goods during such extreme events. The initial step was to calibrate the WRF-Hydro hydrological model using the ERA5 dataset as input meteorological forcing data, focusing on recent drought incidents like the 2018 drought. This entire procedure was completed in 2024/2025. Next, we focused on scanning the LAERTES-EU data, which contains more than 12.500 years of meteorological data to extract extreme drought events. The task involves using drought indices and statistical analysis of precipitation and temperature variables, such as the Standard Precipitation and Evapotranspiration Index (SPEI). We were able to determine the 10 most extreme cases based on a combined cumulative SPEI value of three, six, and twelve months. The selected events were run with the calibrated WRF-Hydro model and compared to the navigation threshold (GlQ20), which indicates the severity of the drought event concerning navigation. A paper showing this results in currently available in NHESS in open discussion.

Severe European Windstorm Events

During 2026, the setup for high-resolution simulation of severe convective storms (SCS) has been optimized by simulating selected high-impact events (e.g. 2014 Pentecost SCS) with the ICON model. To accurately represent the timing, location and severity of SCS, we tested different domain sizes, grid resolutions and model configurations (see Fig.1), including testing the HAILCAST model that is implemented in ICON.

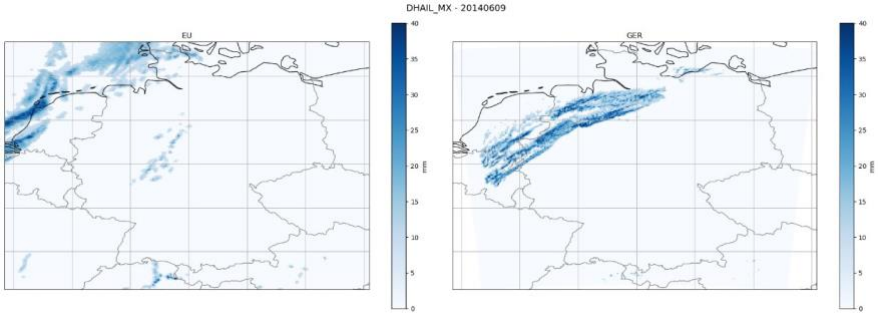


Fig. 1: Comparison of simulated hail parameters of the 2014 Pentecost SCS for different domains and resolutions. Left: Simulation over Central European domain at 3 km resolution. Right: Simulation over Germany at 1 km resolution.

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

Furthermore, high-impact events are used to define proxies for SCS based on ERA5. With this aim, multiple methods for identifying SCS in ERA5 are currently tested and validates against lightning data and severe weather reports from ESWD[2]. The method combining deep-layer shear, CAPE, and precipitation occurrence seems to performed best and will be used to identify large-scale severe convective outbreaks in ERA5 (see Fig. 2). The identified events will be simulated with ICON in the next year. Furthermore, the method will be applied to LAERTES-EU to extent the data basis of such outbreaks under recent climate conditions.

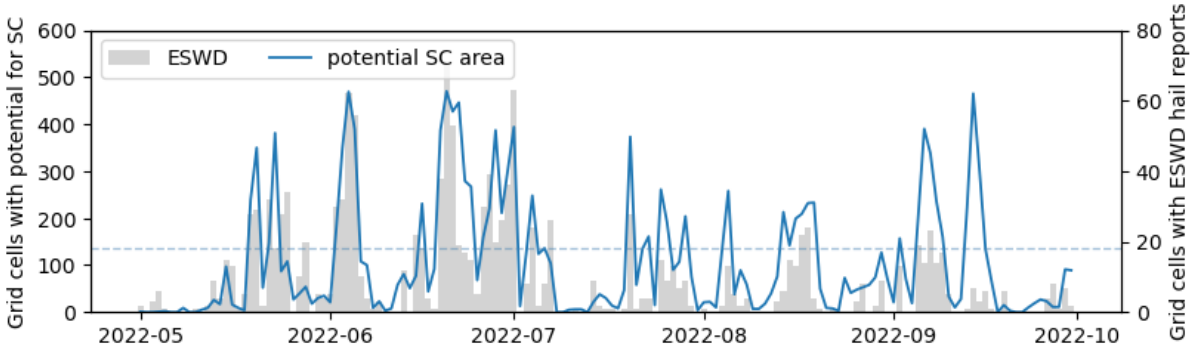


Fig. 2: Time series of the daily number of ERA5 grid cells with potential for SC (based on thresholds for deep-layer shear, CAPE, and precipitation) in blue. The number of ERA5 grid cells with hail reports from the ESWD (European Severe Weather Database) is shown in grey. The dashed horizontal line marks the threshold for a large-scale SC outbreak.

Decadal variability of European Windstorms

The final paper about the decadal variability of euroepean windstorms has been submitted and is currently under consideration to be published as discussion paper in NHESS:

Florian Ehmele, Lea Eisenstein , Hendrik Feldmann , Patrick Ludwig , Alexandre M. Ramos , Athul Rasheeda Satheesh , Jisesh Sethunadh , and Joaquim G. Pinto (2026): On the representation of near-surface winds and wind gusts in the LAERTES-EU regional climate model ensemble with respect to severe windstorms, NHESS (submitted)

References:

Campoverde, A. L., Ehret, U., Ludwig, P., and Pinto, J. G.: Drought propagation in the Rhine River basin and its impact on navigation using LAERTES-EU regional climate model dataset, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2025-3988, 2025.

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.

[2]https://eswd.eu/de