Meteorological to hydrological drought propagation using the large ensemble of regional climate model simulations for Europe (LAERTES-EU). A case study for the Rhine River Catchment

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1. Motivation

- Recent drought events and extreme low water levels on the Rhine River.
- Low water levels in 2018 were a 100-year event in some gauges (Fig. 1).
- Significant economical impact on the river transport of goods along the middle Rhine because transportation was not possible (Fig. 2).
- Integration of hydrological processes into a meteorological model for climate change research.

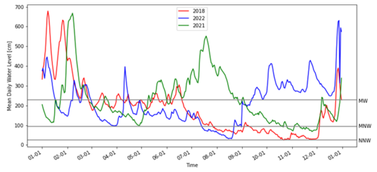

Fig. 1. Source: Global Runoff Data Center (GRDC)

Fig. 2. Source: Deutschlandfunk (dpa/Rolf Vennenbernd)[1]

2. Data set LAERTES-EU

- Regional climate model COSMO-CLM was used to dynamical downscale global model simulations from MPI-ESM for present day.
- Simulations varied according to the resolutions of boundary conditions and initializations, resulting in 12.000 years of meteorological information (Ehmele et al., 2020)[2].
- The data was divided in four blocks: two with long-term simulations and two with decadal hind-and forecast simulations, with a resolution of 25Km (Ehmele et al.. 2022)[3].

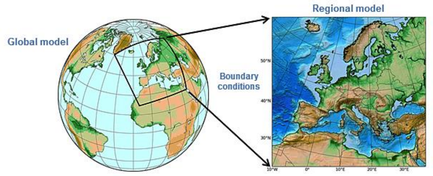

Fig. 3. Downscale Simulation. Source:Deutcher Wetterdienst (DWD)[4]

3. WRF-Hydro model and Study Area

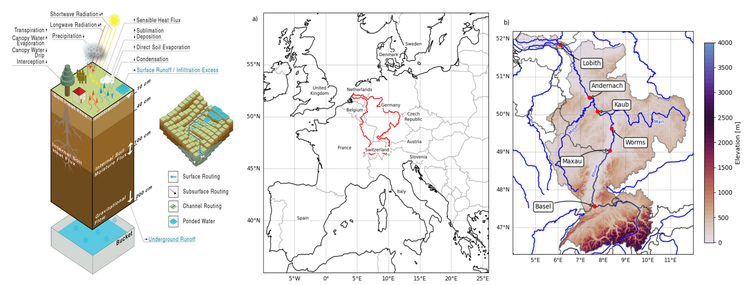

Fig 4. Schematic description of WRF-Hydro[5] (left), location of the Rhine River's catchment in Europe (middle), and Rhine River's Basin (right) with the selected hydrological gauge stations (red dots)

4. Methodology

- Standard Precipitation Evapotranspiration Index (SPEI) has a good correlation with hydrological drought index. (Erfurt et al., 2020)[6].
- Logistic distribution was trained with a 30-year-spatial mean of temperature and precipitation, using an entire LAERTES-EU block.
- Ranking from the results of SPEI 3(Aug), 6(Sep), and 12(Dec) to determine the top ten meteorological drought events (Fig. 5).

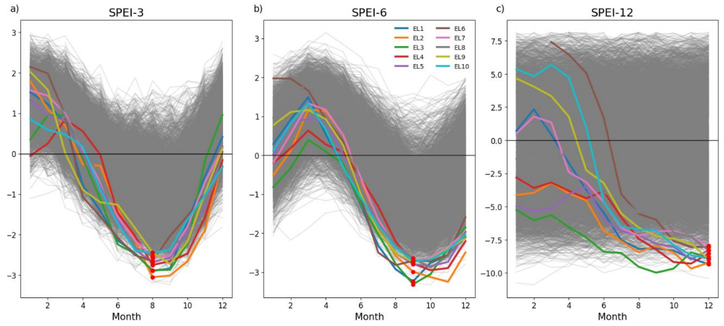

Fig. 5. SPEI values for accumulated periods of 3, 6, and 12 months in the Rhine River Catchment

5. Results

- Simulated streamflow values are lower than the observed discharges during the exceptional 2018 drought year and below a threshold for navigation (Fig. 6).
- In contrast with the historical observed data, the ranking of the events allocates the LAERTES-EU EV2, EV3, EV4, and EV5 events on the top five positions. (Fig 7)

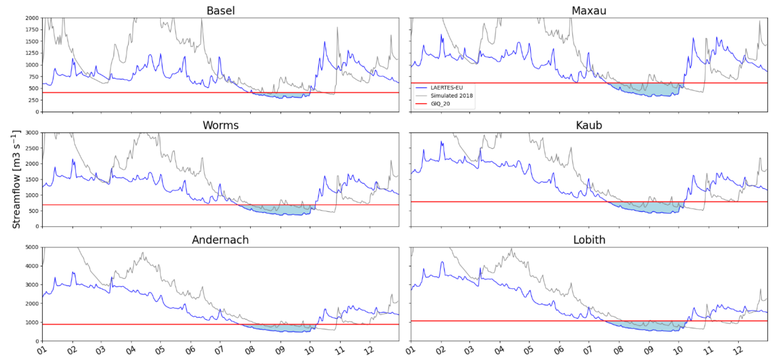

Fig. 6. Daily hydrographs of Event 1 (blue) in comparison with simulated year 2018 (gray) and navigation threshold GIQ20 (red)

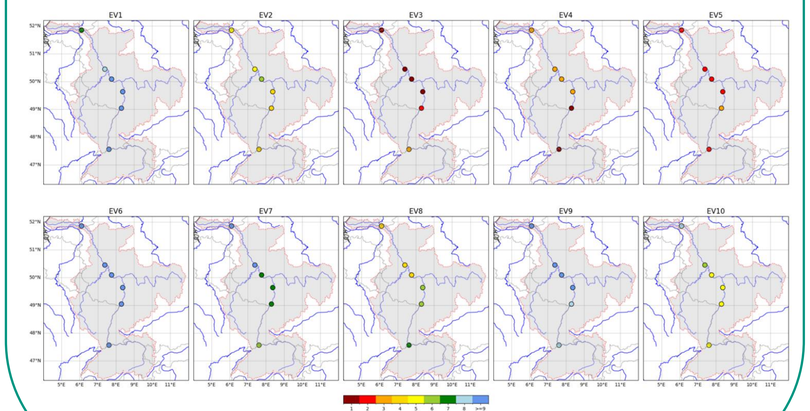

Fig. 7. The selected 10 extreme years were ranked among the historical observed hydrological information from all the gauges.

6. Conclusion and outlook

Conclusions:

- LAERTES-EU includes more severe events than the historical droughts.
- Extreme values of SPEI in short and long accumulation periods, SPEI12(dec) in particular, were very informative and can be used to assess propagation to hydrological droughts in the Rhine River basin.
- An extreme meteorological drought does not imply a same severity hydrological drought.
- Drought characteristics and propagation are unique to each river basin.
- Extreme non-observed scenarios are a good tool for navigation logistics.

Outlook:

- Further assessment of the hydrological impacts from the selected extreme cases.
- Use a pseudo global warming (PGW) approach to assess the possible range of extreme discharges under global warming (+2K, +4K)

References:

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