Project: 983
Title: Decadal variability of flood triggering extreme precipitation events
Report for period 01.01.2022-31.12.2022

The main focus of the project is on the quantification of flood risk for several Central European river networks. The main data source is still the LAERTES-EU data set (Ehmele et al., 2020, 2022). This unprecedented data set of 12.000 years of regional climate model data in combination with additional high resolution modelling studies provides new insights into recent river flood events like the July 2021 Ahr flood (Mohr et al., 2022, Ludwig et al., 2022). Additional plans are currently made to include flash floods originating from compound events (Perreira et al., 2018). Including investigations of long-lasting droughts and corresponding low river stands, we will also explore the 'other side' of the extreme event distribution in the LAERTES-EU data set (see also application for 2023).

Ahr Flood 2021

A heavy precipitation event over western Germany and neighboring countries in July 2021 led to widespread floods in the Ahr and Erft river catchments. The event was among the five heaviest precipitation events of the past 70 years in Germany. However, considering the large LAERTES-EU regional climate model (RCM) ensemble clearly highlights the uncertainty of a return period estimation solely based on such (short-termed) data sets or for specific areas.

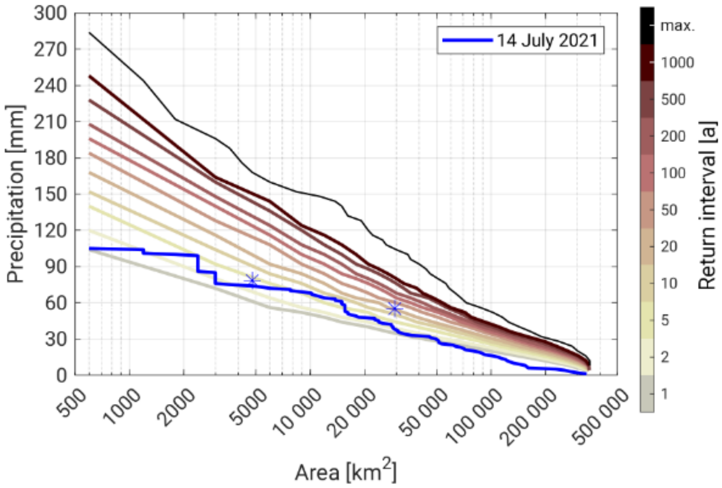

Figure: Empirical return intervals (colored curves) estimated from the bias-corrected LAERTES-EU data set for precipitation clusters in Germany (affected area of contiguous grid points, x-axis) above certain precipitation thresholds (y-axis) for 24-hour totals. The uppermost solid black line represents the maximum values within LAERTES-EU equivalent to a return interval of one in 12 500 years. The blue curve represents the July 2021 event (based on RADOLAN interpolated to the 0.22 (see Figure 5 in Ludwig et al., 2022).

Additionally, the role of climate change and how the 2021 event would unfold under warmer or colder conditions (within a –2 K to +3 K range, 0.5K interval) was analyzed based on ***pseudo-global-warming (PGW) model experiments*** performed in project bb0983 at DKRZ. These simulations showed that the spatial mean precipitation scales to first order with the theoretical Clausius-Clapeyron (CC) relation predicting a 7 to 9 % increase per degree warming. Using the PGW rainfall simulations as input to a hydrological model of the Ahr river basin revealed a strong and non-linear effect on flood peaks: For the +2 K scenario, the 18 % increase in areal rainfall led to a 39 % increase of the flood peak at gauge Altenahr. The following Figure shows the simulated precipitation patterns of the event under different background climates and the precipitation scaling for all PGW simulations.

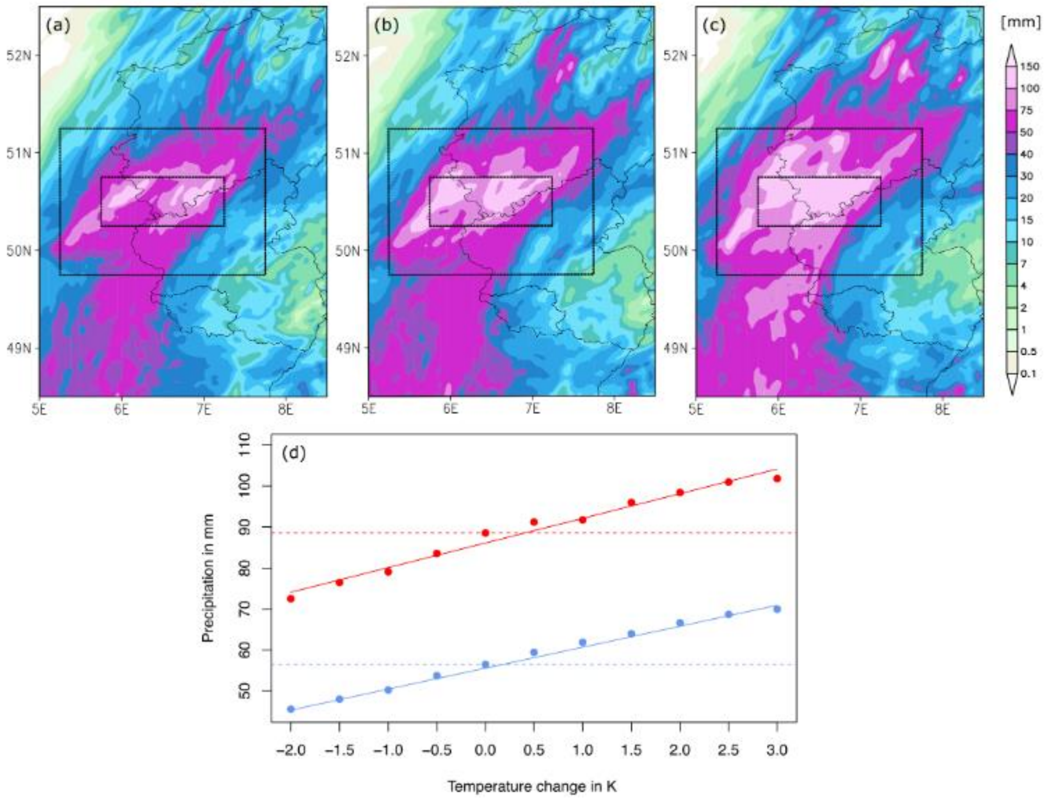

Figure: 24-hour precipitation sums (14 July 2021, 06:00 UTC to 15 July 2021, 06:00 UTC) from PGW experiments using the WRF model. Horizontal distributions for (a) PGW –1 K, (b) control run ±0 K, and (c) PGW +2 K. (d) Area averaged 24-hour precipitation sums (large box in blue, small box in red) plotted against temperature change for all conducted PGW experiments. Taken from Ludwig et al., 2022 (Figure 9).

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.

Ludwig, P., Ehmele, F., Franca, M. J., Mohr, S., Caldas-Alvarez, A., Daniell, J. E., Ehret, U., Feldmann, H., Hundhausen, M., Knippertz, P., Küpfer, K., Kunz, M., Mühr, B., Pinto, J. G., Quinting, J., Schäfer, A. M., Seidel, F., and Wisotzky, C.: A multi-disciplinary analysis of the exceptional flood event of July 2021 in central Europe. Part (2022): Historical context and relation to climate change, Nat. Hazards Earth Syst. Sci. Discuss. [preprint], https://doi.org/10.5194/nhess-2022-225, in review.

Mohr, S., Ehret, U., Kunz, M., Ludwig, P., Caldas-Alvarez, A., Daniell, J. E., Ehmele, F., Feldmann, H., Franca, M. J., Gattke, C., Hundhausen, M., Knippertz, P., Küpfer, K., Mühr, B., Pinto, J. G., Quinting, J., Schäfer, A. M., Scheibel, M., Seidel, F., and Wisotzky, C. (2022): A multi-disciplinary analysis of the exceptional flood event of July 2021 in central Europe. Part 1: Event description and analysis, Nat. Hazards Earth Syst. Sci. Discuss. [preprint], https://doi.org/10.5194/nhess-2022-137, in review.

Pereira, S., Ramos, A. M., Rebelo, L., Trigo, R. M., and Zêzere, J. L (2018:: A centennial catalogue of hydro-geomorphological events and their atmospheric forcing, Adv. Water Resour., 122, 98–112, https://doi.org/10.1016/j.advwatres.2018.10.00.