FONA Research for sustainability | CLIMXTREME Climate Change and Extreme Events

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

# *Attribution of extreme weather events in Germany*

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*The extreme weather event attribution aims to quantify the role of anthropogenic climate change on different types of extreme events like heat waves and extreme precipitation. As part of the project ClimXtreme funded by the German Federal Ministry of Education and Research the attribution workflow will be operationalized and automated as much as possible. For this, the synthesis of the different used climate models has a very important role, especially for the final statement.*

### State-of-the-art synthesis by the World Weather Attribution group (WWA)

The WWA differentiates two types of synthesis: The weighted and unweighted synthesis. The unweighted synthesis takes the average of every used model and observation while the weighted synthesis increases the influence of the observations by weighing them equally to the climate models as follows:

$$\mu_{mod} = \sum_j \frac{\mu_j}{\sigma_j^2 + (2\tau_{mod})^2} \Big/ \sum_j \frac{1}{\sigma_j^2 + (2\tau_{mod})^2}$$

$$\chi^2(\mu_j, \sigma_j; \tau_{mod}) = \sum_j \frac{(\mu_j - \mu_{mod})^2}{\sigma_j^2 + \tau_{mod}^2} = N_{mod} - 1$$

with $\mu_j, \sigma_j$ location and scale of single models, $\tau_{mod}$ model spread, $\mu_{mod}, N_{mod}$ location of model synthesis and number of models. Both methods are available in the KNMI Climate Explorer.

### Synthesis: Bayesian Approach

The Bayesian approach (Ribes et al., 2020) includes the whole distribution of probability into the analysis. The models are seen as realizations of the same truth. A Gaussian distribution is calculated as a model synthesis:

$$\widehat{\theta_i} \sim N(\mu_m, \Sigma_m + \Sigma_{\theta,i})$$

with $\theta_i$ value $\theta$ of for model $i$, $\widehat{\theta_i}$ its estimate, $\mu_m, \Sigma_m$ mean and variance of multimodel population and $\Sigma_{\theta,j}$ as uncertainty related to internal variability.

**Unweighted synthesis**

Pro:
- ➔ (All models have the same weight)
- ➔ Method easy to understand

Con:
- ➔ Observations are treated as a single model
- ➔ No variability between models included

**Weighted synthesis**

Pro:
- ➔ Models are weighted
- ➔ Observations are weighted higher
- ➔ Includes model spread

Con:
- ➔ Weight for models with very low confidence intervals (high ensembles) are weighted very high

**Bayesian Approach**

Pro:
- ➔ Use of the complete distribution of the synthesis
- ➔ No weighting of results necessary
- ➔ Includes natural trends

Con:
- ➔ No model verification based on observations beforehand

Tivig, M., Schröter, J., Lorenz, P., Sauerbrei, R., Knauf, J. und Kreienkamp, F.: Attributionsstudie zu den Niederschlagsereignissen in Niedersachsen Dezember 2023 - Januar 2024, Bericht des DWD, 2024.

KNMI: Gitlab of Climate Explorer. https://gitlab.com/KNMI-OSS/climexp, 2024.

Ribes, A., S. Thao, and J. Cattiaux, 2020: Describing the Relationship between a Weather Event and Climate Change: A New Statistical Approach. J. Climate, 33, 6297–6314, https://doi.org/10.1175/JCLI-D-19-0217.1.



**Use case of the weighted WWA-synthesis: Extreme precipitation in Lower Saxony in December 2023 and January 2024**

- ➔ “Christmas Flood” in river basins of Ems, Elbe and Weser
- ➔ Several days of severe precipitation
- ➔ Already oversaturated soils
- ➔ Precipitation sum for Lower Saxony highest since start of recordings
- ➔ Return period inside the red marked box: 120 years

**Event definition**

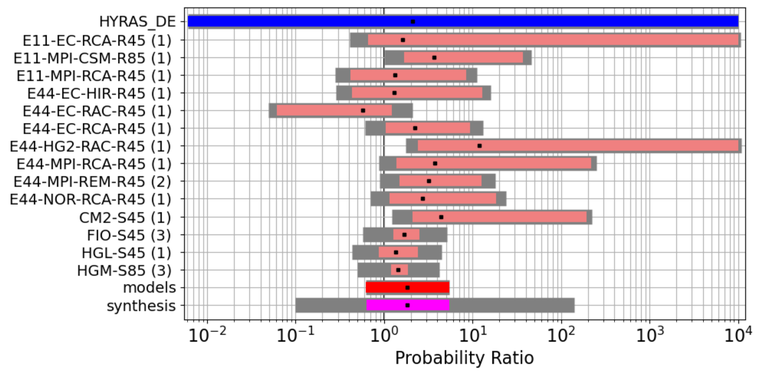
- ➔ 51.5 °N to 53.5 °N, 8 °E to 11 °E
- ➔ Variable: RX1mon (mm/day): Highest monthly mean precipitation from November to January

**Results**

Return period: 120 years (16-∞)

Probability ratio
- ➔ 1.2 K colder climate: 1.8 (0.1-140)
- ➔ 0.8 K warmer climate: 1.5 (0.95-2.5)

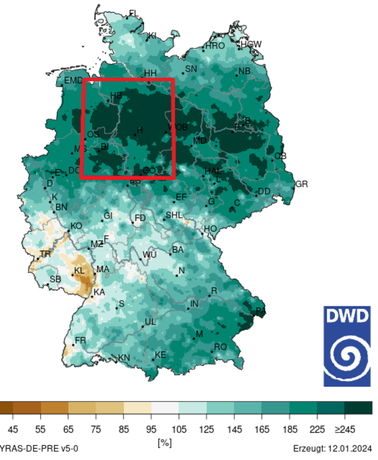
Intensity change
- ➔ 1.2 K colder climate: +5 % (-7 % - +21 %)
- ➔ 0.8 K warmer climate: +3 % (-0.5 % - +7 %)




**Take home messages**

- ➔ *Multiple synthesis approaches for attribution exist with different advantages and disadvantages*
- ➔ *Finding the fitting synthesis approach is difficult and can change the outcome of the study*
- ➔ *Not all attribution studies show clear results, especially for precipitation*
- ➔ *Probability for large scale precipitation in Lower Saxony in early winter has a small positive trend*

**Relative anomaly of monthly precipitation sum in December 2023**
**Reference: 1991-2020**




*Figures:*

*Top: Photo of flood in winter 2023/2024 in Lower Saxony. © Uwe Kirsche/DWD*

*Bottom right: Relative anomaly of the precipitation sum for December 2023 in Germany based on the HYRAS-DE-PRE v5.0 dataset. The red box indicates the analysed region of the attribution study.*

*Bottom left: Probability ratio PR between the current and a 1.2 K colder climate for the variable RX1mon of the observations (blue) and climate models (light red). In dark red and violet, the model synthesis and overall synthesis is shown, grey describes the uncertainty due to the model spread. This synthesis is based on the synthesis approach of the World Weather Attribution.*

**Regional Climate Office Potsdam** http://www.dwd.de/attribution/
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