Did the number of heat-related deaths increase in Germany in the 21st century?

Extended Abstract with Preliminary Results

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Abstract

The impact of climate change on human health and, ultimately, on mortality have become focal aspects in the academic as well as in the public sphere. Based on data from the German Federal Statistical Office and weather data from the German Weather Service, we analyzed whether the number of heat-related deaths has increased in Germany and its 16 states during the 21st century. We used a Generalized Additive Model to estimate the number of deaths using smooth terms for the impact of calendar time, seasonality as well as for temperature. The number of heat-related deaths was exceptionally high in Germany and most of its states in 2022. With the exception of that year we could not find a clear trend towards an increase in the number of heat-related deaths. They typically constitute less than one percent of all deaths in a year. It has been argued in the literature that people are better able to adapt to changing climate conditions since the mortality response to a given temperature has declined over time. This might explain the lack of a trend in heat-related deaths. We aim to address this question, among other questions, in the coming months.

1 Research Question

The impact of climate change on human health and, ultimately, on mortality have become focal aspects in the academic as well as in the public sphere. Our goal is to address the question whether the number of heat-related deaths has actually increased in Germany and in its 16 states in the 21st century.

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2 Data & Methods

2.1 Data

Daily deaths in Germany and its 16 states were obtained from the Federal Statistical Office of Germany as part of its special collection ("Sonderauswertung") for the period from 01 January until 24 September 2023. We removed data for 29 February to ensure comparability across years when converting data to calendar weeks. Following Winklmayr et al. (2022) we analyzed only calendar weeks 15 through 40 for the summer period. Corresponding data on a) daily mean and b) daily maximum temperature were obtained from the German Meteorological Service (Deutscher Wetterdienst, DWD): Based on those daily measurements for 1353 weather stations, we estimated the daily average for each of the two measurements for Germany as a whole and by state ("Bundesland").

2.2 Methods

Excess deaths such as cold-related and heat-related deaths are (virtually) always estimated as the (positive) difference between observed and expected deaths. While the number of observed deaths is obvious, the number of expected deaths can vary considerably depending on the implicit model assumptions as shown, for instance, by Schöley et al. (2023) for the case of COVID-19 excess mortality estimates.

By using a Generalized Additive Model (Hastie and Tibshirani, 1990; Wood, 2006), we pursued a similar strategy as Winklmayr et al. (2022) to estimate the expected number of deaths: Deaths are assumed to follow a negative binomial distribution to allow for potential overdispersion in the count data. Besides the population size being employed as a log-offset, the model takes a general trend component into account via a smooth term for calendar year, a seasonal component via a smooth term for calendar week, a changing seasonal pattern via a smooth interaction term between year and calendar week, a smooth term for the effect of daily mean temperature and a smooth term for the effect of daily maximum temperature. Since so-called mortality displacement is discussed in the literature, our first goal was to find the best model. We allowed for lag periods of up to 21 days for the mean as well as for the maximum daily temperature. The best model was obtained by splitting the data for Germany into two halves: a training set and a test set. The best model was chosen by the minimum root mean squared error ("RMSE") in the test data after training the model with the training data set. After running the 484 models, we found (to our surprise), the smallest RMSE between estimated and observed deaths when no lag period was applied, neither for

the mean temperature nor for the maximum temperature. We differentiated between daily and weekly heat-related mortality: Daily heat related mortality is the sum of all positive deviations between the daily observed and the daily expected number of deaths. For weekly heat related mortality we first aggregated the daily number of deaths (observed as well as expected) into weeks before estimated the annual number. The initial aggregation leads necessarily to lower estimates for excess deaths since it takes also negative deviations from the expected value into account.

3 (Preliminary) Results

Figure 1 (page 3) illustrates our estimates for Germany as a whole. The left panel refers to daily heat-related deaths, the right panel to weekly heat-related deaths in the summer. Please note that the data for 2023 are not yet complete which leads estimates which will still increase when data are fully available.

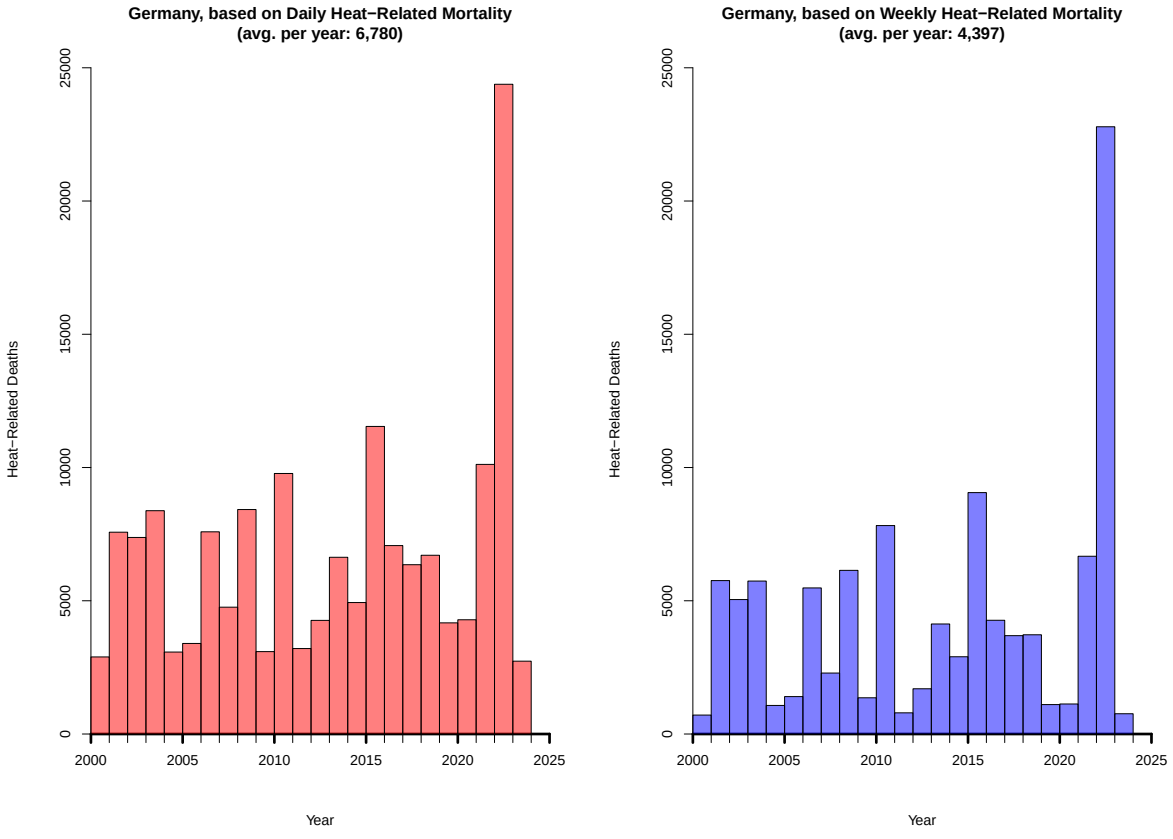

Figure 1: Heat-related daily (left) and weekly (right panel) deaths in Germany in 2000–2023

As expected based on the explanation at the end of the methods section, the bars in the right panel are smaller than in the left panel. Depending on the perspective, we estimate an annual number of heat related deaths of 6,780 for the daily estimate and

4,397 for the weekly estimate. Considerung that at least 900,000 deaths are observed each year in Germany, both estimates are well below one percent of all deaths.

Apart from the year 2022—with an obvious spike in weekly heat-related deaths—we would argue that there is no clear trend over time for an increase in heat-related mortality. Fig. 2 (daily) and Fig. 3 (weekly) on pages 5 & 6 show the corresponding estimates for the 16 states of Germany. Despite some variation across the states, the general impression is similar: 2022 was a year of exceptionally high heat-related deaths. But there is no clear indication of a trend towards more heat-related deaths.

4 Outlook

We plan to differentiate our analysis further: The results we have estimated so far refer to the total population. It has been shown, however, that older people are more vulnerable to detrimental environmental influences. Therefore we plan to look at different age-groups. The large amount of weather stations allows to investigate whether rural areas differ from urban areas. Winklmayr et al. (2022) also postulated, based on their results, that the mortality response to a given temperature has become smaller. This suggests adaptation to heat periods in Germany. We want to analyze whether can also find support for this hypothesis.

References

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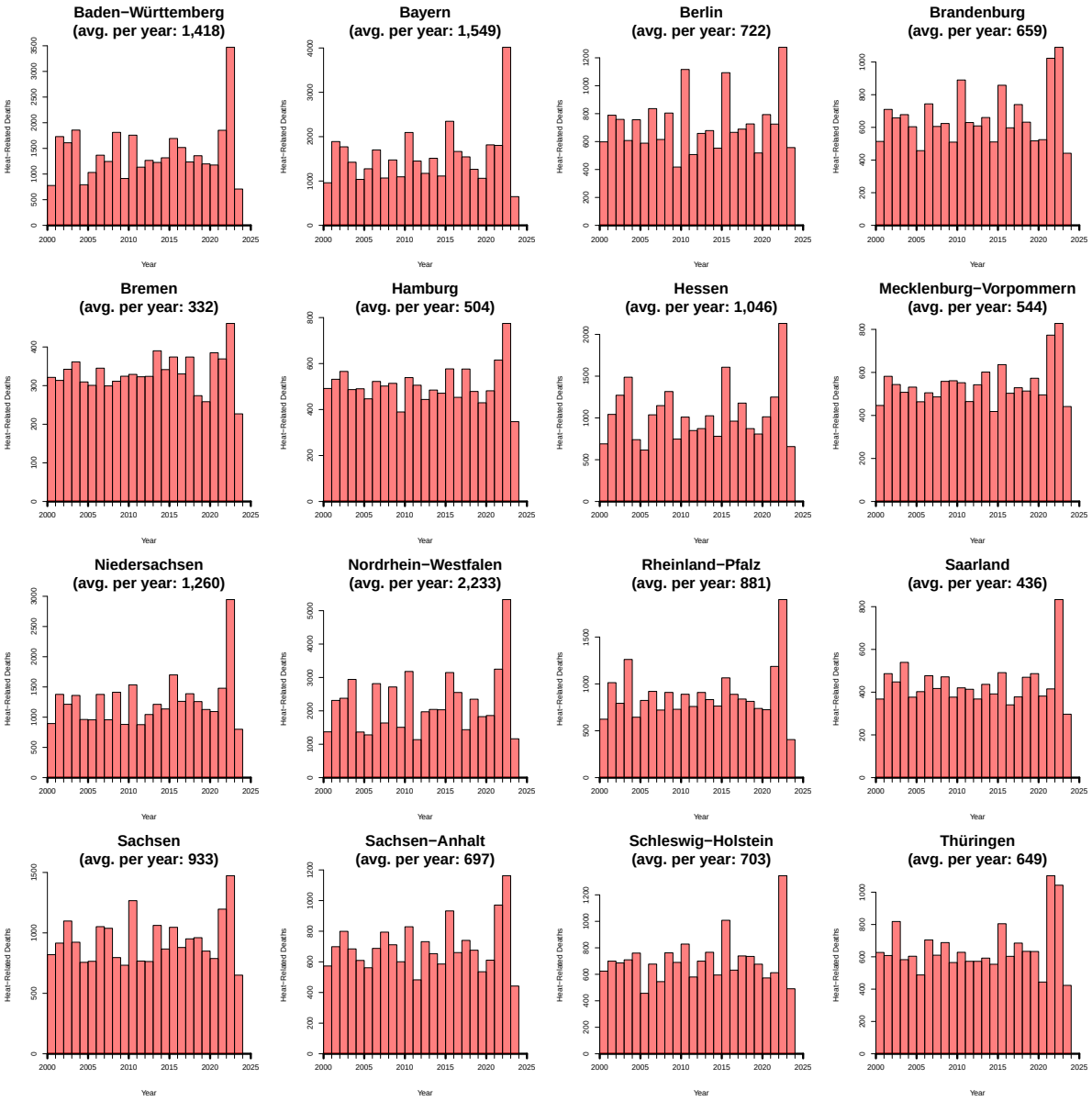

Figure 2: Heat-related daily mortality in Germany's 16 states per year in 2000–2023

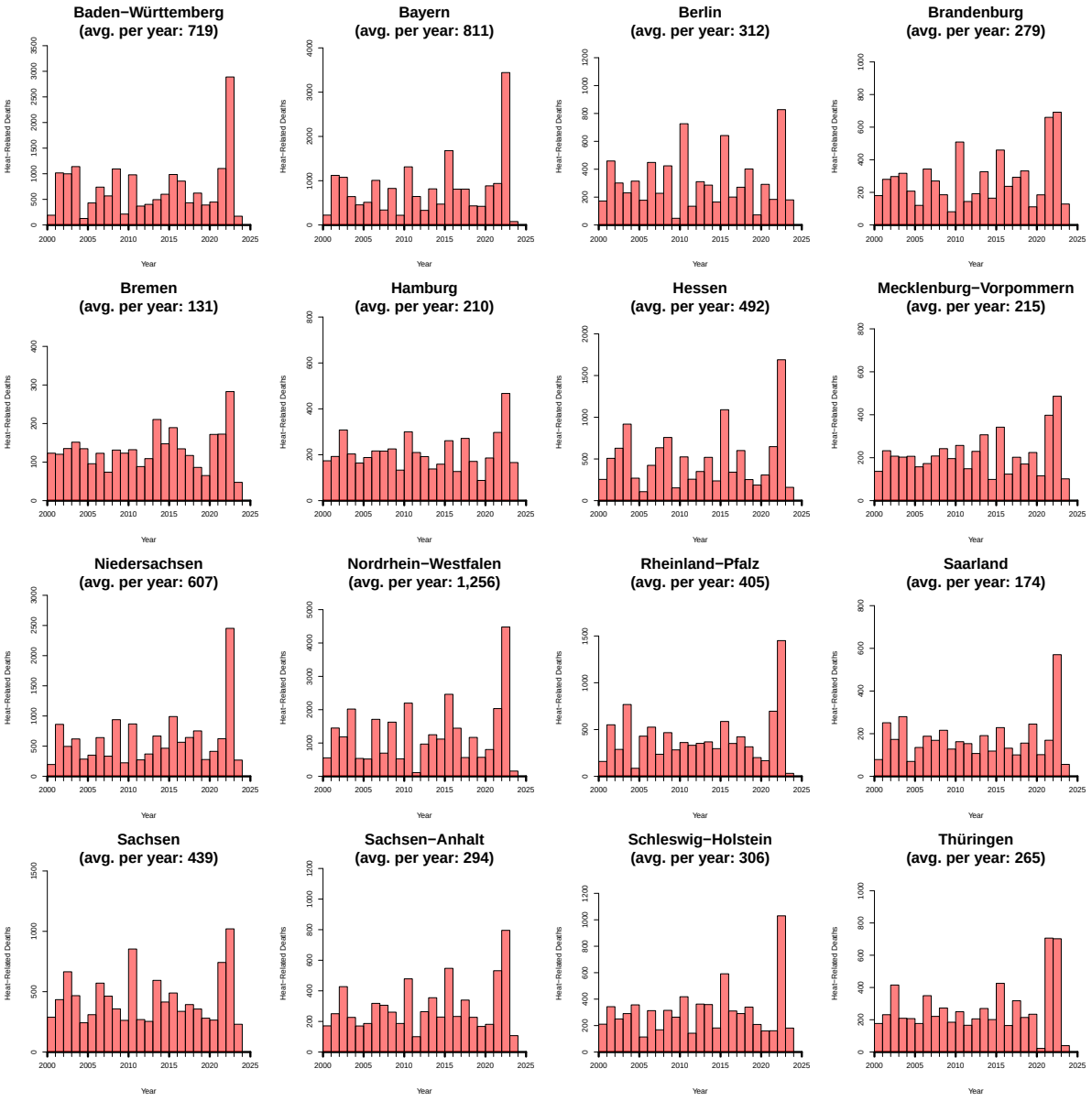

Figure 3: Heat-related weekly mortality in Germany's 16 states per year in 2000–2023