Attributing observed trends in heat-related excess mortality to climate change

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1 Background

Past studies quantifying the burden of heat-related mortality attributable to climate change have mostly focused on specific extreme events (1) or considered multi-decadal averages (2,3). Here, we contribute to the scarce literature on the attribution of observed temporal trends in heat-related mortality to climate change (4,5).

2 Key research questions

- **What is the role of climatic versus non-climatic factors in driving temporal trends in heat-related excess mortality in Germany over recent decades?**
- **How much has climate change contributed to the observed trend?**

3 Methods

Our study is based on daily all-cause mortality time-series from 14 major German cities over 1993-2020. Counterfactual climate data was derived from century-long measurement series of daily mean temperatures by removing trends related to the observed rise in global mean temperature (6). To estimate time-varying warm-season temperature-mortality associations we subdivided our data into seven 4-y subperiods and restricted the analysis to Jun-Sep. We applied a two-stage design, using quasi-Poisson regression models including distributed lag non-linear models and longitudinal multivariate meta-regression models, according to (2,7). Heat related excess mortality by city was computed based on best linear unbiased predictors (BLUPs) from the final meta regression model, and the observed mortality averaged by day of the year. The difference between estimates based on factual and counterfactual data was considered to be attributable to climate change.

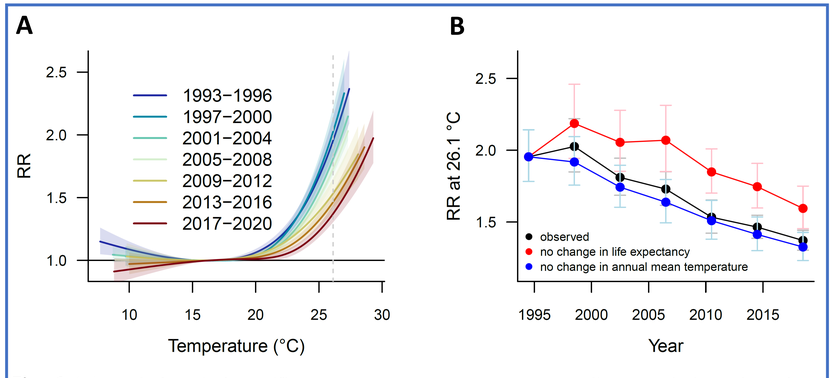

Fig. 1 (A) Pooled period-specific warm-season temperature-mortality associations, based on prediction of the best longitudinal meta-regression model with country average of meta-predictors (life expectancy, annual mean temperature). (B) Relative risk at the 99th percentile of the first-period distribution of daily mean temperatures, based on observed values of meta-predictors (black), with fixed (1993-1996) life expectancy (red), and with fixed (1993-1996) annual mean temperatures (blue).

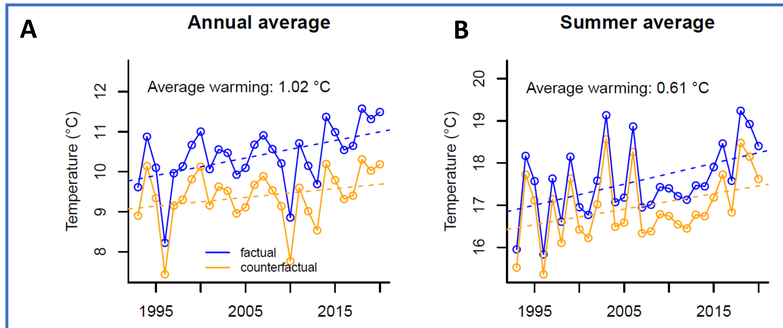

Fig. 2 Annual (A) and summer (B) mean temperature averaged across the 14 German cities considered based on observed data (blue) and counterfactual data (orange).

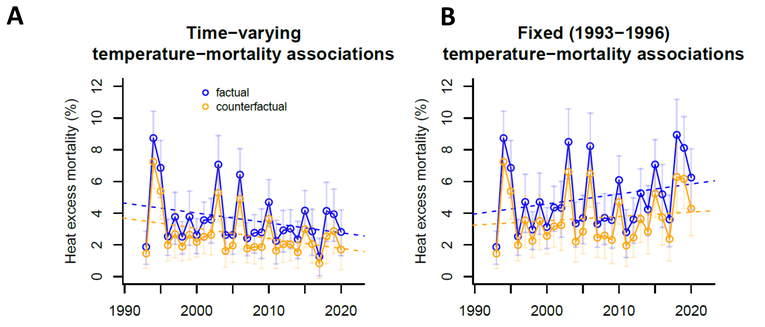

Fig. 3 Heat-related excess mortality in the 14 German largest cities based on time-varying (A) and fixed (B) temperature mortality associations, computed based on factual (blue) and counterfactual (orange) temperature data.

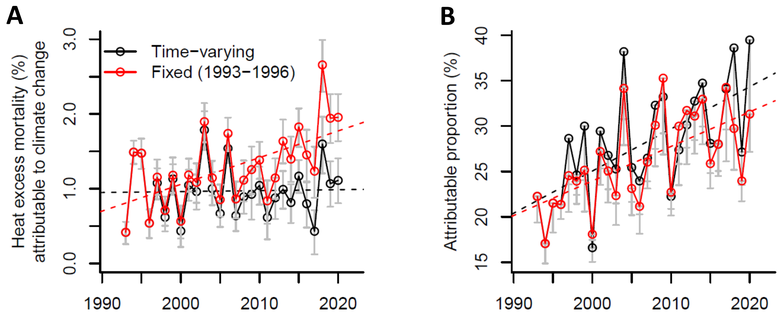

Fig. 4 Heat-related excess mortality attributable to climate change, based on time-varying heat risks (black) and fixed heat risks at 1993-1996 levels (red). (A) shows attributable mortality as a percentage of total warm-season mortality. (B) shows the relative proportion of attributable mortality compared to factual heat-related mortality.

4 Key (preliminary) findings

- Over the 28-year study period, the susceptibility to heat has decreased over time in the 14 German cities studied, in great part due to general improvements of population health as represented by increasing life expectancies.
- As a result, heat-related excess mortality decreased over time, despite increasing temperatures observed over the same period.
- If heat susceptibility had stayed the same as in the mid 1990s, the German cities would have seen a rise in heat-related excess mortality in recent years, partly due to climate change.
- Heat-related excess mortality attributable to climate change were estimated to be 0.97% of total warm-season mortality, corresponding to approximately 450 deaths per year across all cities, with no observed temporal trend when changes in heat susceptibility were accounted for.
- The relative percentage of heat-related excess deaths attributable to climate change was 28% averaged across the study period, with a significant trend of +0.5% per year (p<0.001).

5 Outlook

Further analysis should account for the influence of climate in determing heat susceptibility via annual mean temperature as meta-predictor in the meta-regression and minimum mortality temperatures, which have increased over the 28-year study period.

References

1. Mitchell D et al. (2016) Attributing human mortality during extreme heat waves to anthropogenic climate change. *Env Res Lett*, doi: 10.1088/1748-9326/11/7/074006
2. Vicedo-Cabrera A et al. (2021) The burden of heat-related mortality attributable to recent human-induced climate change. *Nat Clim Change*, doi: 10.1038/s41558-021-01058-x
3. Aström DO et al. (2013) Attributing mortality from extreme temperatures to climate change in Stockholm, Sweden. *Nat Clim Change*, doi: 10.1038/nclimate2022
4. Christidis N et al. (2010) Causes for the recent changes in cold- and heat-related mortality in England and Wales. *Clim Change*, doi: 10.1007/s10584-009-9774-0
5. Vicedo-Cabrera A et al. (2018) A multi-country analysis on potential adaptive mechanisms to cold and heat in a changing climate. *Env Int*, doi: 10.1016/j.envint.2017.11.006
6. Mengel M et al. (2021) ATTRICI v1.1 – counterfactual climate for impact attribution. *Geosci Model Dev,* doi: 10.5194/gmd-14-5269-2021
7. Sera F and Gasparrini A (2022) Extended two-stage designs for environmental research. *Env Health*, doi: 10.1186/s12940-022-00853-z

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