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Concerns over calculating injury-related deaths associated with temperature

Dann Mitchell[1]✉, Myles Allen[2], Kristie L. Ebi[3], Antonio Gasparrini[4], Clare Heaviside[4,5], Y. T. Eunice Lo[1] and Ana M. Vicedo-Cabrera[6,7]

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Parks et al.[1] reported projections of an additional 1,601 temperature-related deaths associated with injuries in the United States under the Paris Agreement climate goals. However, we believe that these analyses misinterpret the Paris Agreement and that there are potential flaws in the epidemiological modeling that limit the validity of the findings.

The Paris Agreement goals refer explicitly to "the increase in global average temperature … relative to pre-industrial levels", further clarified by the Intergovernmental Panel on Climate Change Special Report on 1.5 °C (SR1.5) as "an increase in multi-decade global mean surface temperature above pre-industrial levels"[2], with the pre-industrial era defined as 1850–1900. However, the 1.5 °C and 2 °C temperature variations used in the main analyses of Parks et al. were local temperature changes, relative to those of 1980–2017. Two issues are noted here. The first is that local temperatures can differ substantively from global averaged temperatures, especially over land that warms faster than the global mean. The second is that the increase in global mean surface temperature between the baseline period used (1980–2017) and pre-industrial times is ~0.7 °C[3], meaning that Parks et al. use a substantially warmer baseline period than that defined in the Paris Agreement.

In the United States, local temperature changes in a 1.5 °C future climate relative to 1980–2017 could vary between 0 °C and 2.5 °C depending on the location and month (Fig. 1). Extreme high temperatures are rising faster than mean temperatures in many land regions as temperature distributions change with global warming[4], and we believe that simply considering a uniform 1.5 °C change at all locations and in all months is inappropriate.

Further, the hypothesis of a causal relationship with temperature for some categories of injuries is unsupported. A range of environmental variables are likely to play a role (for example, rainfall for transport accidents[5]). The temperature associations in the study did not control for these variables or for changes in associations with additional climate change and adaptation. Temperature and health relationships are often nonlinear[6,7], and assuming linearity would substantially bias the results. For instance, nonlinearities can explain the different age patterns in the category 'falls', given that the elderly can be more at risk during icy weather conditions of falls outside their residence (which were not differentiated from 'all falls')[8].

The use of monthly averaged temperature and health data is of concern because exposure occurs on shorter timescales. The use of daily data would provide more power (there is very limited

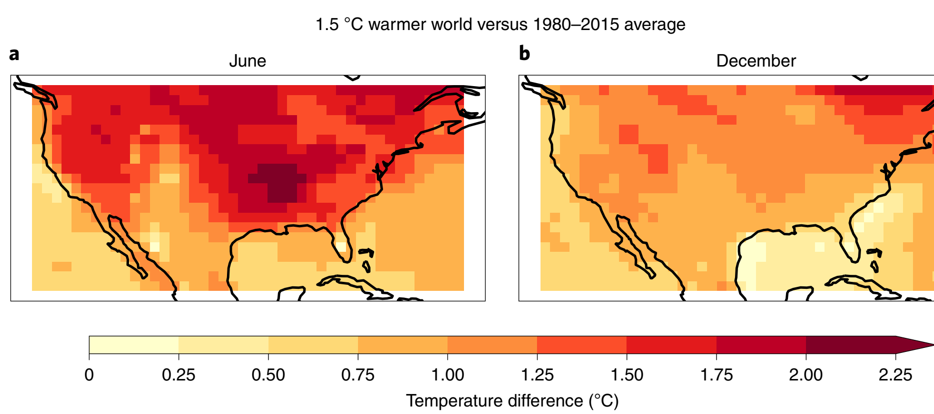

Fig. 1 | An example of monthly averaged temperature anomalies over the contiguous United States between 1980–2015 and a 1.5 °C warmer world. **a**,**b**, Monthly averaged temperature anomalies for June (**a**) and December (**b**). The data are taken from the first ten ensemble members of the MIROC5 model as part of the HAPPI project[9].

[1]Cabot Institute for the Environment, University of Bristol, Bristol, UK. [2]Environmental Change Institute, University of Oxford, Oxford, UK. [3]Centre for Health and the Global Environment, University of Washington, Seattle, WA, USA. [4]Faculty of Public Health and Policy, London School of Hygiene and Tropical Medicine, London, UK. [5]Institute for Environmental Design and Engineering, UCL, London, UK. [6]Institute of Social and Preventive Medicine, University of Bern, Bern, Switzerland. [7]Oeschger Center for Climate Change Research, University of Bern, Bern, Switzerland. ✉e-mail: d.m.mitchell@bristol.ac.uk

variability in exposure defined by monthly anomalies) and, more importantly, make the analysis less prone to ecological biases. The choice by Parks et al. was justified by computational limitation of the Bayesian model used, although two-stage designs and modeling tools are available that would increase confidence[9].

In summary, the authors motivate their analysis as relevant for the Paris Agreement climate goals, but we believe that their interpretation and experimental design are inaccurate, which could lead to the use of erroneous climate data as input into the heat–injury assessment. We also raise concerns about several assumptions and approaches in the epidemiological analyses, which could have implications for the validity of the overall conclusions.

Online content

Any methods, additional references, Nature Research reporting summaries, source data, extended data, supplementary information, acknowledgements, peer review information; details of author contributions and competing interests; and statements of data and code availability are available at https://doi.org/10.1038/s41591-020-1113-z.

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Data availability
The data in this study are freely available through the HAPPI consortium (www.happimip.org), or through contacting the corresponding author directly.

Author contributions
All authors designed the paper by discussing the key concerns to be included. D.M. wrote the initial draft. M.A., K.L.E., A.G., C.H. and A.M.V.-C. adapted the draft. Y.T.E.L. prepared the figure. All authors approved the final draft.

Competing interests
The authors declare no competing interests.

Additional information
Correspondence and requests for materials should be addressed to D.M.

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