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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Influence of heat index on regional mortality in Europe" *by* D. Lee and T. Brenner

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The authors would like to thank both referees for their constructive and helpful comments on the article. We have attempted to address all points in the following text.

1 Physiological acclimatization in the hypotheses

As the referees note, the potential role of physiological acclimatization to hot weather and climate should certainly be incorporated into the assumed mechanisms underlying hypothesis 4. In this case the hypothesis can be accurately reworded as follows:

> "Regions in Europe with high average HI will be affected less strongly by high HI events than regions with low average HI, because their populations are better adapted for dealing with heat load (e.g. physiological acclimatization, use of architectural styles which collect cool air in buildings, air conditioning, clothing styles, etc.)."

This is supported by the literature, handled exhaustively in e.g. Cheung & McLellan (1998), and acknowledged in subsequent literature which we will gladly reference in the revised article.

Cheung, Stephen S., and Tom M. McLellan. "Heat acclimation, aerobic fitness, and hydration effects on tolerance during uncompensable heat stress." Journal of Applied Physiology 84, no. 5 (1998): 1731-1739.

2 Category definitions

To answer the questions about the definitions of the categories:

The persistent heat situation described in the example would be counted as one heat wave of the category "danger". Although the two days of "extreme danger" would be represented in other metrics, they would not be counted as a heat wave in and of themselves, as their total consecutive duration did not reach five days. In the reworked manuscript we are more than willing to provide example exercises to make this more clear. We agree that the variables could be described better - also with variables of the class "cross" a clearer explanation is possible and will be included in a reworked final manuscript. Here, for the sake of explanation, we can use the same persistent heat situation described in the question. 10 days would be counted to "cross_danger", while 2 days would be counted to "cross_ext_danger" for the reason that if the "ext_danger" level is reached, the heat event is counted toward that and not to the intermediate danger categories.

3 Specific, local metrics accounting for physiological acclimatization

Differences across Europe in acclimatization were not considered in setting HI thresholds, because these thresholds were transferred from the definitions used by the US National Weather Service. While the referee is certainly correct in recognizing the significance of local conditions in describing resilience to weather conditions, the task of describing a large geographical area with a single metric confronts one with inevitable difficulties. There are approaches that use relative climate indicators in order to warn of extreme weather events, such as the Extreme Forecast Index used by ECMWF (Laurette & Grijn, 2002). This can be considered a good strategy for dealing with climate extremes from an environmental standpoint. However, no amount of acclimatization will make climate the only relevant factor in the effects of hot weather on the human body. Lacking literature which proposes appropriate thresholds for different areas in Europe, our option was to produce such thresholds in the context of the study - which, however, would have at least the scope of a complete study in and of itself, if not more - or of leveraging a metric which could be considered robust against variable local acclimatization.

The thresholds provided by NWS are designed for use in a wide geographical area (the United States) which is comparable in area to that of Europe and are used in a wide variety of local climates. Moist, hot climates in the southeast are considered, as are hot desert areas in the southwest. More temperate areas, e.g. in the northeast, are served by the same metric with success. This naturally does not mean that the metric or the thresholds used with it are perfect, but it is tried and true in several other articles. Due to the wealth of studies cited in the paper which use it as a basis, we decided to use it without modification. The robustness and generality of the thresholds, as well as the transferability of results, overweighed the advantages of creating bespoke thresholds for the various geographical areas within the scope of the study.

Lalaurette, François, and Gerald van der Grijn. "Ensemble forecasts: can they provide

useful early warnings." ECMWF Newsletter 96 (2002): 10-18. Harvard

4 Clarity in data usage

The referees are absolutely correct in questioning the years of data used to analyze mortality vs. the years of meteorological data. The longer time series of meteorological data was used to classify the local climates of the areas in the study, whereas only the years in which a complete coverage of both mortality and meteorological data were available were used in computing the regressions. This will be explained more clearly in the revised article.

5 Causes of mortality

Although in some cases limited cause of death data was available, this was neither universally available, nor did it have the necessary thematic granularity in order to identify specific, heat-related deaths. Additionally, listed causes of death did not explicitly include heat. Therefore, many causes of death which could be linked to the weather situation - for example cardiovascular failure - would thus disappear from our study. Additionally, other causes of death which could be causally but not physiologically linked to heat would not appear in our metrics if we were to explicitly include certain causes of death. Lowered productivity, precision and concentration are symptopms of heat exhaustion, for example, but fatal industrial accidents resulting from a worker's lack of concentration would also be eliminated if deaths were filtered by attribution.

Thus we are faced with a common problem familiar from the field of econometrics - essentially, the study attempts to isolate a signal (mortality rate) propogating from a given source (weather) in a pool of noisy data. This is compounded by the heteroge-

neous quality of the data available. A clear attribution of the data points to a known, given cause is not possible and a relativation of the ratios on grounds of various events which took place within the study areas would introduce a degree of arbitrarity to the investigation. In light of this fact, we decided to examine the total mortality as a means of investigating heat's holistic effects on the populations of the study.

This approach of not creating any special cases within the data was also applied to the signal generated by the deadly heat wave in 2003. It is true that this was an extroadinary heat event which has been handled prominently in the literature. Removing it, however, would have resulted in the loss of an important data point and would have unnecessarily shortened the time series. Because a panel regression approach was used, removing this year would have shortened the longest time series by almost a full tenth and affected the sample size for regions with patchy data availability even more strongly. Additionally, we believe that this significant event provides insightful data for the regressions we used.

In the revised manuscript it would be possible to include a robustness check in which data from this year are eliminated in order to judge their effects.

6 Possible effects of GDP on mortality

The referees duly note that GDP is a known determinand of mortality, as well as weather. It is true that partitioning regions across GDP-defined boundaries separates regions with higher GDP, where lower mortality would be expected, from those with lower GDP and thus a higher expected mortality. This partitioning was in fact adopted in part in order to prevent this signal from leading to a false conclusion that HI leads to higher mortality, when in fact GDP would be the dominant determinand. By analyzing regions with similar GDP we capture the variability amongst regions with similar GDP that is caused by variations in HI.

7 Goodness of fit of regression models

We would be happy to update all tables to provide goodness of fit metrics on the regression models in the updated manuscript.

8 Expansion of discussion section

We would be glad to update the discussion section as requested by Referee #1 in order to include a section critically reflecting on the approach and synthesizing the results of all hypotheses holistically, as well as discussing possible underlying mechanisms in greater detail. We will also be glad to update the article in the next manuscript to reference literature showing the possibilities of adapting to hot weather by mitigating its effects physiologically (e.g. turning on air conditioning, drinking enough water, wearing proper clothing, etc.). These had not been included previously because of their wide acceptance as common knowledge.

Of course we are also willing to include further discussion of the approach used and in particular further questions raised by the research that can and should be pursued in future studies, as recommended.

9 Extended literature review

We thank the referees for their valuable references applied and would be happy to include these in the next manuscript in the context of the research we present.

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