Climate change projected to reduce European life expectancy

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General impression

The paper proposes to assess the impact of climate change on life expectancy with the argument that the latter is a better indicator of population health that is more easily understood by policy makers. More specifically, the authors addressed two research questions: what is the cost of inaction on climate change on human longevity? and how does climate change related mortality compare to other mortality vectors?

I agree with the general conclusion on the first research question, that climate change has the potential to reduce life expectancy in some European countries, but disagree with results on the second question. In particular, I cast doubt on how the authors assess the contributions of non-climate change causes-of-death to changes in life expectancy and the consequent rankings of major causes of death (Table 1). I elaborate on this in the section on main comments.

I praise the authors for the effort to translate the impact of climate change from overall number of deaths to a more meaningful metric of population health such as life expectancy. Their approach and results, however, made me wonder if the focus of the paper is appropriate and their conclusions are scientifically justified based on the evidence included in the manuscript. For example, the authors place so much emphasis on comparing major causes of deaths vs. climate change (Table 1) but I believe the data available and the described methodology are not clear enough to sustain such comparison (see below).

I believe the authors could make a stronger case for their results if they only focus on climate change related mortality, for which they have a reliable way of projecting excess deaths into the future, and exploit the possibility of differentiating the impact of these deaths by age on changes in life expectancy (which the authors did not do). For example, as the authors note on page 9 (second paragraph), climate change is more likely to affect the older adult population and population forecasts predict an increasing older population in most European countries, so the natural question is how much would life expectancy by reduced by changes in mortality among older adults if climate change is likely to increase mortality in these age group? Such analysis will have a direct impact on costs associated with health care and the like.

I outline below some comments that may help enhance the paper's contribution and that may help justify the issues I raised above. Particularly my skepticism about the authors' conclusions when comparing major causes of deaths vs. climate change (Table 1).

In all of my comments I refer to the page numbers provided in the submitted version of the manuscript.

Main comments

1. **Methods.**

   - **Time periods to assess changes in life expectancy.** The paper focuses on changes in life expectancy at birth and then links these changes to changes in cause-specific mortality, particularly deaths associated with climate change. The authors create two time periods, period 1: most recent mortality data from HMD (in the authors words: "the most recent complete life table from HMD"), period 2: year 2080. Thus, when the authors describe changes in life expectancy at birth they imply changes between period 1 and period 2. The authors need to assemble a set of mortality rates in each period and these mortality rates need to be disaggregated by cause-of-death. The process thus involves the following:

Deaths due to	Period 1	Period 2
climate change	GBD-HMD	projections using predicted excess mortality to the year 2080 from Forzeri et al. & GBD-HMD
Non-climate change		
respiratory	GBD-HMD	???
heart disease	GBD-HMD	???
Dis nervous syst	GBD-HMD	???
Lunc cancer	GBD-HMD	???
Colorectal	GBD-HMD	???
Suicide	GBD-HMD	???
Transport accidents	GBD-HMD	???

   There are two main issues with this approach.

   (a) The authors project climate change deaths to 2080 using Forzeri et al. but the question remains of how these deaths could be compared to non-climate change deaths. This is important because causes of death are reported using a standard international classification of diseases (the so called ICD), and as the authors note on page 9, the ICD does not contain a cause of death called "climate change". Yet, the data on causes of death from GBD is based on the ICD coding so the authors are assuming that climate change deaths are completely unrelated to respiratory, heart disease, lung cancer, etc. This process is analogous to saying that we are going to project smoking attributable deaths into the future but will keep these deaths separate from cardiovascular disease, lung cancer, etc.; there is a clear overlap between smoking attributable deaths and these other deaths. For instance, a "climate change" death is not a medically recognizable cause-of-death (so no ICD code exist), but given that the authors are using climate change deaths as those due to environmental heat and cold exposure (page 3), it is likely that these deaths could be due to heart-related diseases (environmental heat may increase heart failure in older adults) or respiratory diseases (cold exposure) so it is unclear how the authors can treat climate change deaths as separate from the other causes of death. Finally, how can the authors rank the contribution of climate change mortality vs. all other non-climate change mortality?

   (b) It is unclear how mortality rates for non-climate change deaths were created in

period 2. I assumed the non-climate change mortality data was also projected for 2080, otherwise it would not be a fair comparison if only one set of deaths is projected into the future. How is it possible to claim that "climate change could become the third largest life expectancy reducer behind heart disease and cancer"? what assumptions were made to project these deaths to 2080? I could not find a description of this process in the manuscript.

- **Creation of scenarios.** The authors combine data from all-causes (Human Mortality database, HMD) with cause-specific mortality from the Global Burden of Disease (GBD) to create scenarios using data from Forzieri. Their base scenario (equation 1) is based entirely on data from HMD while the other three scenarios add information on climate change mortality (low, mid, high).

  Using the authors' notation, equation 2—which is the base equation for creating the climate change scenarios— can be rewritten as:

$$\begin{aligned} {}_n\hat{m}_{x,i,s} &= ({}_nD^{HMD}_{x,i} + (\hat{D}_i \cdot_n t_{x,i}))/{}_nP^{HMD}_{x,i} \\ &= ({}_nD^{HMD}_{x,i}/{}_nP^{HMD}_{x,i}) + (D^{GBD}_{x,i}/{}_nP^{HMD}_{x,i}) \cdot (\hat{D}_i/\sum_{x=0}^{80} D^{GBD}_{x,i,}) \\ &= {}_nm_{x,i,BASE} +_n m_{x,i,GBD} * R_i \end{aligned} \quad (1)$$

  where R_i is the relative fraction of deaths from Forzieri relative to GBD. Note that R_i does not depend on age.

  Equation (1) above shows that the authors are creating scenarios for climate change as the mortality rates from HMD plus a fraction of mortality rates from GBD. There is nothing inherently problematic with this approach, but I urge the authors to spend more time on the implications of this process.

  Put simply, the authors are taking mortality rates from HMD, then take mortality rates shown in Figure 3 (GBD) and move the entire figure up or down according to the value of R in each country i (hence the importance of R not depending on age), and sum HMD and GBD values to get the corresponding climate change mortality rate scenario. The main assumption here is that the intensity of mortality by age due to climate change would remain with exactly the same 'shape' as that shown in Figure 3; thus, countries that in Figure 3 show lower mortality rates at ages 60-80 relative to ages 50-60 (in color blue and pink) are assumed to continue this age-pattern into 2080. These runs at odds with what we know about the potential impact of climate change among older adults: they are the most vulnerable age group for environmental heat and cold exposure, and yet, the authors' projection method assumes that this is not the case in some countries.

  I would expect a more thoughtful description of the assumptions behind the authors' projection method.

Minor comments

1. **Figure 1.** It needs to specify a time period for the change in life expectancy; is this from the most recent available year in each country to 2080?

2. **Text page 4, second paragraph.** "We find that climate change could alter life expectancy by -0.23 years ... This reduction is comparable to mortality due to influenza and pneumonia in the United States." For which years in the US does this result refer to?

3. **Methods page 13, text after equation 2.** in the denominator in the formula for ${}_nt_{x,i}$, the summation index is missing in the term, it should be $\sum_{\alpha=0}^{80} {}_nD_{\alpha,i}^{GBD}$

4. **Methods page 13, text after equation 2.** $\hat{D}_x$ should not have a subindex x since data from Forzieri is not by age

5. **Methods page 13, equation 2.** the right-hand side of the equation is missing a subscript s