Potsdam Institute for Climate Impact Research

A model of human adaptation to heat-stress for use in climate-impact studies.

"The impact of climate change on human health is a serious concern. In particular, changes in the frequency and intensity of heat waves and cold spells are of high relevance in terms of mortality and morbidity." Rachel Lowe 2015.

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PIK RD II Climate Impacts and Vulnerability

MOTIVATION

The Minimum Mortality Temperature (MMT) is a direct outcome of epidemiological studies investigating human mortality due to heat stress. MMT's inform on ***the lower point of the temperature-mortality relationship*** for a given location (e.g., city) and time interval (see Fig.1). As a rule, warmer locations display higher MMT's than cold ones, thus reflecting the higher capacity of the population to withstand heat stress.

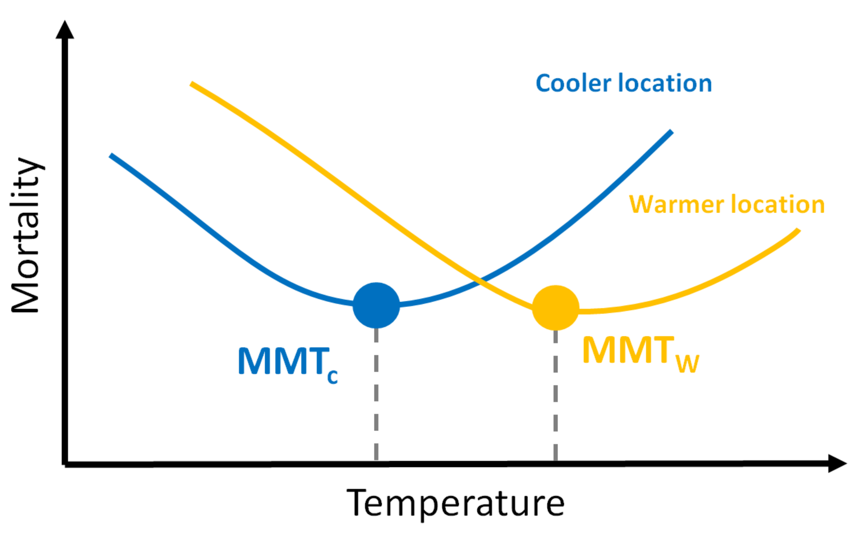

Figure 1. *Stylized temperature-mortality relationship for cooler and warmer locations.*

Although estimates of MMT's from epidemiological are available for many locations (see Fig.2), a unifying model explaining the observed regional variations is currently missing. Establishing such model is crucial to ***1) approximate MMT's across the globe***, based on a consistent set of drivers, and ***2) simulate future MMT's in the context of a warming climate***.

FROM CASE STUDIES TO THE GLOBAL LEVEL

We make use of consistently-derived MMT's for location shown in Fig.2 to establish a predictive model. We assume the MMT of a given location *i* to be a function of the climatic conditions (C_{ps}) preceding the epidemiological study, and the biophysical factors and socio-economic conditions (B_{ds}, S_{ds}) during the epidemiological study (see formalization below).

$$MMT_i = f\,(C_{ps}\ B_{ds}\ S_{ds})$$

For each location we average the *S* and *B* drivers in Tab.1 for the time-frame of the epidemiological study. Drivers representing *C* are calculated, on an yearly basis, until 50 years preceding the study.

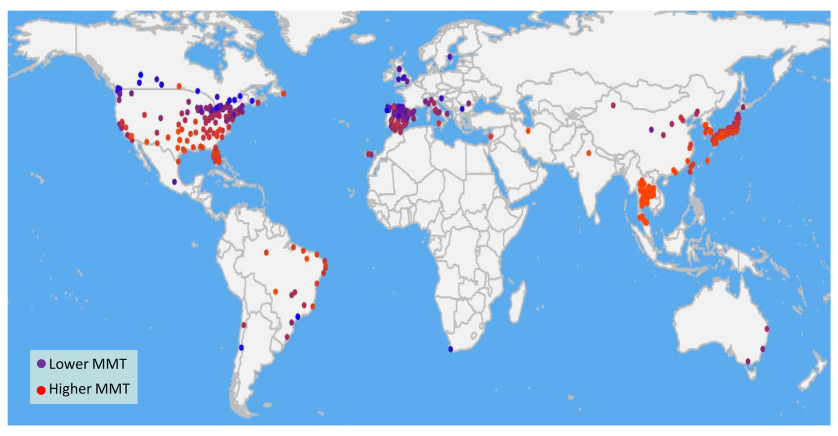

Figure 2A. *Locations and their respective MMT's used in the regression analysis.*

A ***stepwise multivariate backward linear regression*** is used to select the best predictors of MMT based on R^2 and Akaike criteria. Details and sources of the data used for the regression analysis is shown in Tab.1.

Table 1. *Drivers of MMT considered and respective data sources.*

Climate	Socio-economic	Bio-physical
Annual mean temperature[a]	Population density[c]	Elevation[e]
Summer mean temperature[a]	Life expectancy (female/male)[d]	Distance to coast[f]
Annual amplitude[a]	Fraction of population > 65[d]	
Summer relative humidity[b]	Fraction of population < 25[d]	

a - Center for Climatic Research Department of Geography University of Delaware Newark, Willmott, C. J. and K. Matsuura (2001) Terrestrial Air Temperature and Precipitation: Monthly and Annual Time Series (1950 - 1999)
b- Kalnay et al.,The NCEP/NCAR 40-year reanalysis project, Bull. Amer. Meteor. Soc., 77, 437-470, 1996.
c - Jones, B., O'Neill, B.C., 2016. Spatially explicit global population scenarios consistent with the Shared Socioeconomic Pathways. Environmental Research Letters 11, 84003. DOI:10.1088/1748-9326/11/8/084003.
d - United Nations, Department of Economic and Social Affairs, Population Division . World *Population Prospects*: The 2017 Revision.
e - Jarvis, A., H.I. Reuter, A. Nelson, E. Guevara, 2008, Hole-filled SRTM for the globe Version 4, available from the CGIAR-CSI SRTM 90m Database (http://srtm.csi.cgiar.org).
f - Own calculations

THE GLOBAL DISTRIBUTION OF MMT'S

We found that an excess of ***75% in the variability of MMT's*** in a given location can be explained by 26-year average of summer temperature preceding the epidemiologic study; and population density and % of population > 65 during the study (all variables with p-values < 0.01), see Fig.3A and Fig.3B. Summer temperature and population density returned a positive relation with MMT, while % of population above 65 a negative relation.

Backed by the optimistic correlations, we estimate present-day MMT's globally (Fig.3C) and superimpose these with the distribution of population. We concluded that >90% of present-day population to live in locations where MMT ranges between 20 and 40 degrees Celsius.

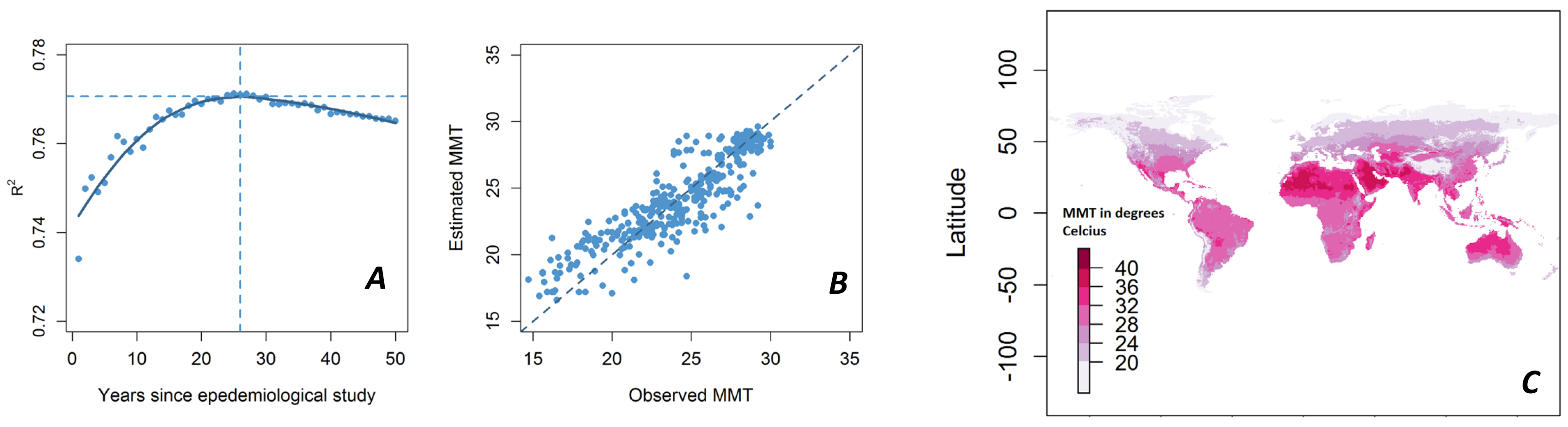

Figure 3 A - *R^2 of the empirical model with increasing C_{ps}.* ***B -*** *Cross plot of observed vs estimated MMT's.* ***C -*** *Application of the empirical model to the global scale.*

APPLICATION TO PORTUGAL AND OUTLOOK

We drive the statistical model using CORDEX data and provide a spatially detailed estimation of MMT change in continental Portugal (Fig.4) between current (circa 2005) and future (2050) time-frames (using SMHI-RCA4 driven by HadGEM2 under RCP4.5). Population density is taken from (Jones et al, 2016) and % of population > 65 from UN population prospects 2017.

Pushed by increasing summer temperatures the ***MMT in Portugal is projected to increase from an average of 26.0 in 2005 to 26.2 degrees Celsius in 2050, according to RC4P4.5.*** The gains in MMT by 2050 could be 0.1 degrees higher if % of population above 65 would be kept at present-day (2005) levels. The spatial distribution of the increase in MMT is presented on the map.

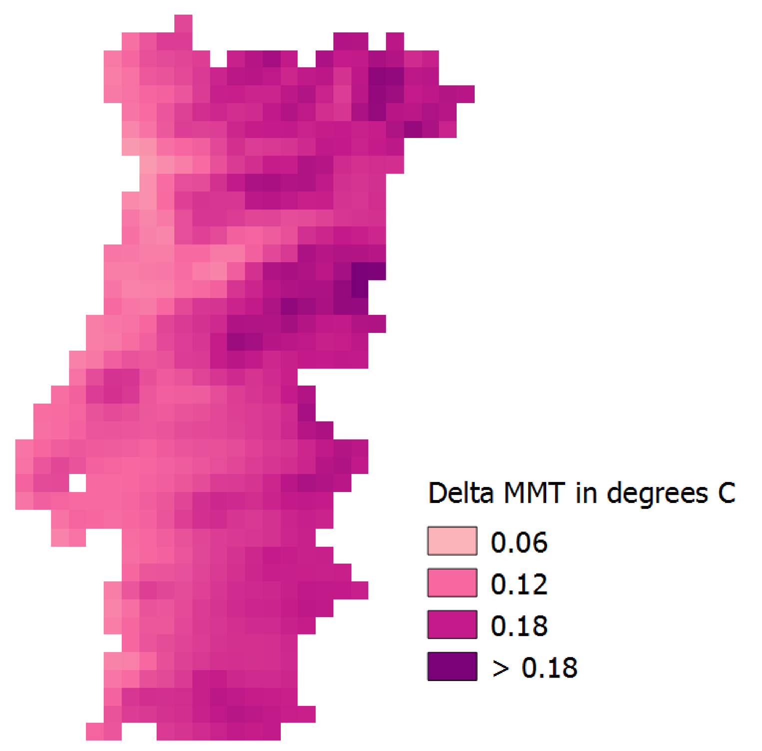

Figure 4. *Projected delta of MMT's for continental Portugal (2005-2050).*

Despite its infancy, the established model opens new line of research to evaluate the ***combined effect of climate, population density and age structure in modifying the future capacity of the population to face heat-stress***; a fundamental information required in forthcoming global impact studies of heat-related mortality.

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