Changes in heat related mortality in Vienna based on regional climate models

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Abstract

The development of mortality due to heat stress in Vienna was assesses by using two regional climate models in the emissions scenarios A1B and B1. Heat stress was described using the human-biometeorological index PET. Two approaches were applied, to estimate the increases with and without long-term adaptation. Until 2011-2040 no significant changes compared to 1971-2000 were found. In the following decades heat-related mortality could increase up to 129 % until the end of the century, if no adaptation takes place. The strongest increase occurred due to extreme heat stress (PET ≥ 41° C). With long-term adaptation the increase is less pronounced, but still notably. This encourages the need for additional adaptation measurements.

1. Introduction

The huge number of heat-related death in summer 2003 (Robine et al. 2007) in combination with the probability of an increase of heat waves in frequency and duration due to climate change (Schär et al., 2004) creates the need to assess the future development of heat-related mortality.

2. Data and Methods

The study uses the prior found relation between heat stress and mortality (Muthers et al. 2010), and applies this relation to regional climate model data.

To analyze the relation, daily mortality data for the period 1970-2007 and climate data from the ZAMG climate station (Central Institute for Meteorology and Geodynamics) "Hohe Warte" in Vienna was used. The human-biometeorological index PET (Physiologically Equivalent Temperature) at 14 CET was applied, to assess the thermo-physiological impact of heat stress on the human body (Höppe und Mayer 1987, Höppe, 1984). Based on the station data PET was calculated by the RayMan model (Matzarakis et al., 2007). To estimate the baseline mortality and to include short-term adaptation processes, two approaches by Koppe and Jendritzky (2005) were applied. Percentage deviations from the baseline were used as relative mortality.

The impact of climate change on the heat related mortality was assessed using the two regional climate model REMO (Jacob and Podzun, 1997) and CLM (Böhm et al. 2006; Rockel et al. 2008) in the emissions scenarios A1B and B1. For REMO the climate data for 13-14 CET was selected. For CLM, where only three hour periods were available, the 12-15 CET period was selected. For each day, the PET was estimated using RayMan (Matzarakis et al., 2007). The study is limited to the month April to October, since it focuses on the impact of heat stress.

In a first step, the projected change in the number of days per year for four different grades of thermo-physiological stress was considered. Compared to Matzarakis and

Mayer (1996) the number of grades is limited to four grades, since it was found that PET < 29° C are characterized by a mean mortality significantly below the baseline, while the other three heat stress grades show significantly higher mortality values (Muthers et al., 2010). The comparison was made relative to the period 1971-2000 and for the three future periods 2011-2040, 2041-2070 and 2071-2100.

The assessment of the development of heat related mortality is a difficult and complex topic, since it depends on the levels of adaptations (Kalkstein and Greene, 1997). Two different approaches were applied, to assess the possible range of future sensitivity, i. e. the relation between thermal stress and mortality. The first approach is a rather pessimistic approach, which applied the mean relation of the period of examination (1970-2007) to the three future periods. In this approach no adaptation is assumed. For the three periods, the mean mortality for each heat stress grade is combined with the number of days per year. The product of both is called cumulated heat-related mortality and describes the cumulated deviations of the mortality from the baseline for a year.

The first approach is probably too pessimistic, since significant decreases in the heat related mortality in some grade were found in the period of examination. Hence, the mean value of 1970-2007 is already too high at the beginning of the 21[th] century. To assess the future level of adaptation, significant trends of the period of examination were extrapolated using the statistically most conservative trend line (Fig. 1 – "significant trend"). If no significant trends were found between 1970 and 2007, the sensitivity at the end of the period of examination was used (Fig. 1 – "no significant trend"). Since this approach assumes continuous long-term adaptation, it could be too optimistic.

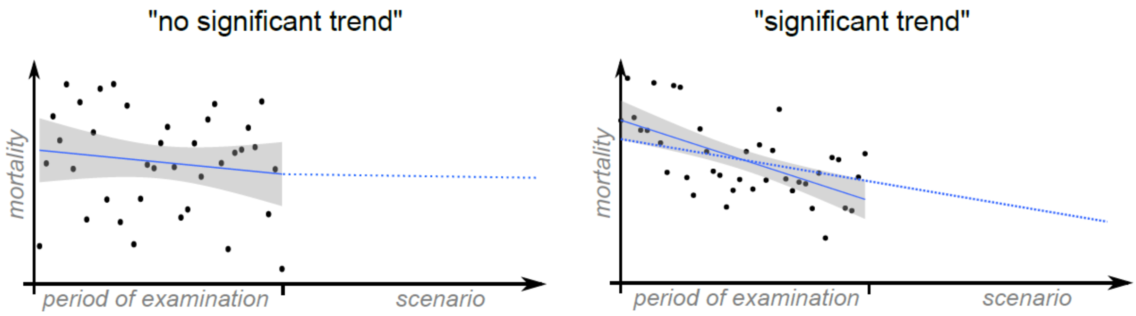

Fig. 1: Diagram of the two approaches to assess the future development of sensitivity to thermal stress. Size of period of examination and scenario is not to scale

For both approaches, the mean mortality per grade (with or without adaptation) was combined with the number of days per year for each grade and the relative changes in cumulated heat related mortality were compared to the period of investigation.

3. Results

The first approach assumes the relation between thermal stress and mortality to be constant until 2100. In this case, significant higher relative mortality exists on days with moderate heat stress (PET 29-35° C, relative mortality: 0.9 %, CI: 0.4, 1.4), on days with strong heat stress (PET 35-41° C, rel. mortality: 5.8 %, CI: 5.0, 6.5) and extreme heat stress (PET ≥ 41° C, rel. mortality 13.0 %, CI: 11.1, 14.7). These values including CI were combined with the projected relative change in the number of days per grade.

In the first period (2011-2041), no significant change in the number of days per grade compared to 1971-2007 occurs (except moderate heat stress in REMO-A1B). Until 2041-2070 heat stress increases significantly in A1B in most of the grades and in B1 in the extreme heat stress grade (~ 50 %). In the last period (2071-2100) significant increase were found for all heat stress classes, with the highest relative values on days with extreme heat stress. In Vienna, the number of days could increase between 57 % (REMO-B1) and 129 % (CLM-A1B), compared to 7 days between 1971 and 2000. Days with strong heat stress could increase by 29 % to 43 % (Fig. 2).

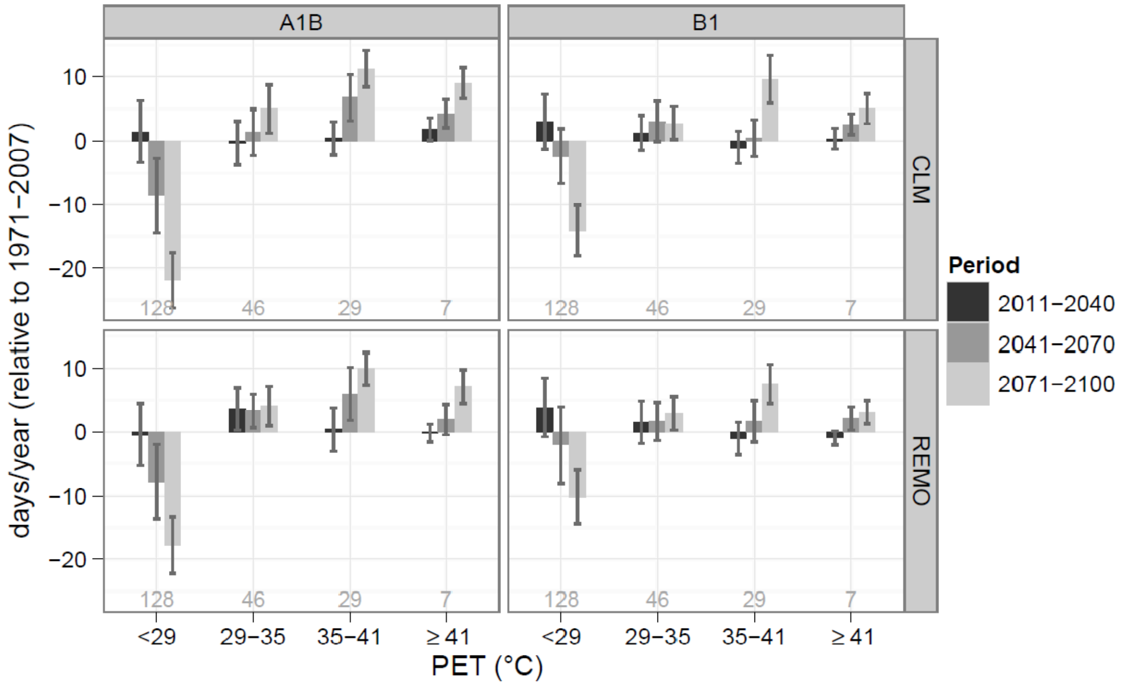

Fig. 2: Number of days per grade of thermo-physiological stress in two regional climate models and two SRES-scenarios

In the first approach (no adaptation, Fig. 3), no significant increases in heat related mortality were found for the first period (2011-2040). For 2041-2070 increases were detected in most cases. Until 2071-2100 heat related mortality could increase by 41 % to 121 % on days with extreme heat stress and 26 % to 39 % on days with strong heat stress. The changes on days with moderate heat stress are marginal.

The increases were higher for the female population as well as for cardiovascular or respiratory diseases, since these groups show a higher sensitivity to thermal stress.

A different development was found, when long-term adaptation is included (Fig. 4). Due to significant trends in the grades of moderate and strong heat stress (Muthers et al., 2010), mortality on these days decreases continuously. For moderate heat stress, the mean mortality already fell below the baseline at the end of the period of examination.

Hence, this grade is omitted in the following. On days with strong heat stress, a trend of -0.06 % per year is used. This results in proceeding reduction of cumulated heat-related mortality on these days, although the number of days per year increases. At the end of the 21th century, mortality on days with extreme heat stress is only slightly raised, by

6 % in REMO-B1 and 7 % in CLM-A1B and it is considerable lower compared to the period of examination.

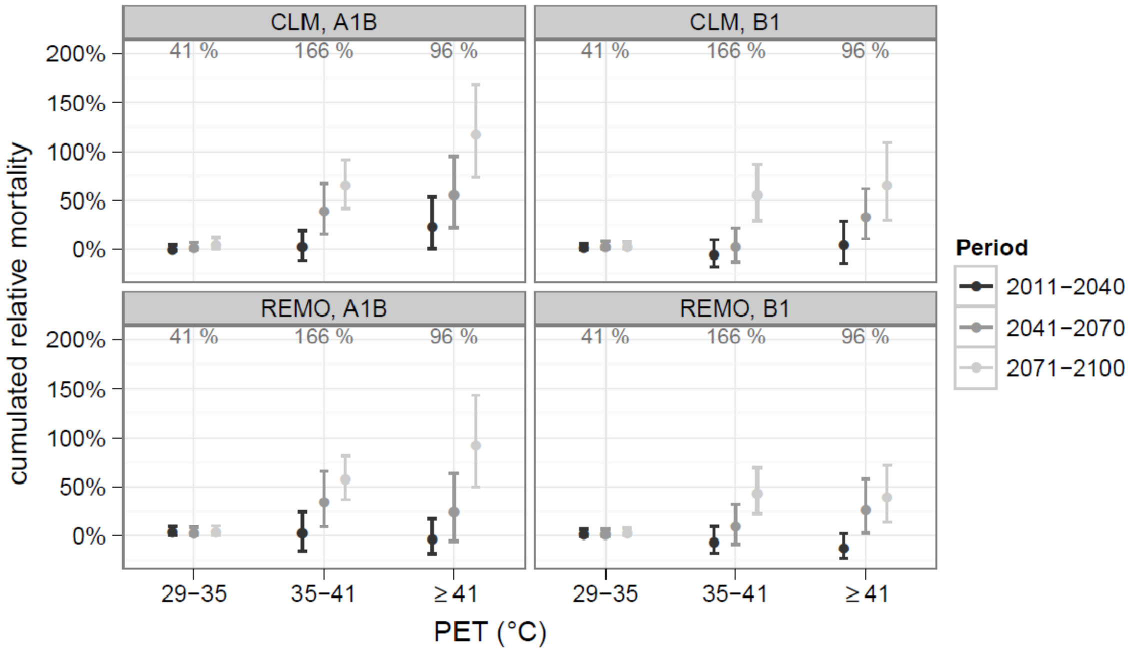

Fig. 3: Changing cumulated heat related mortality without adaptation. The value of the period of examination is shown in grey in the upper margin of each panel

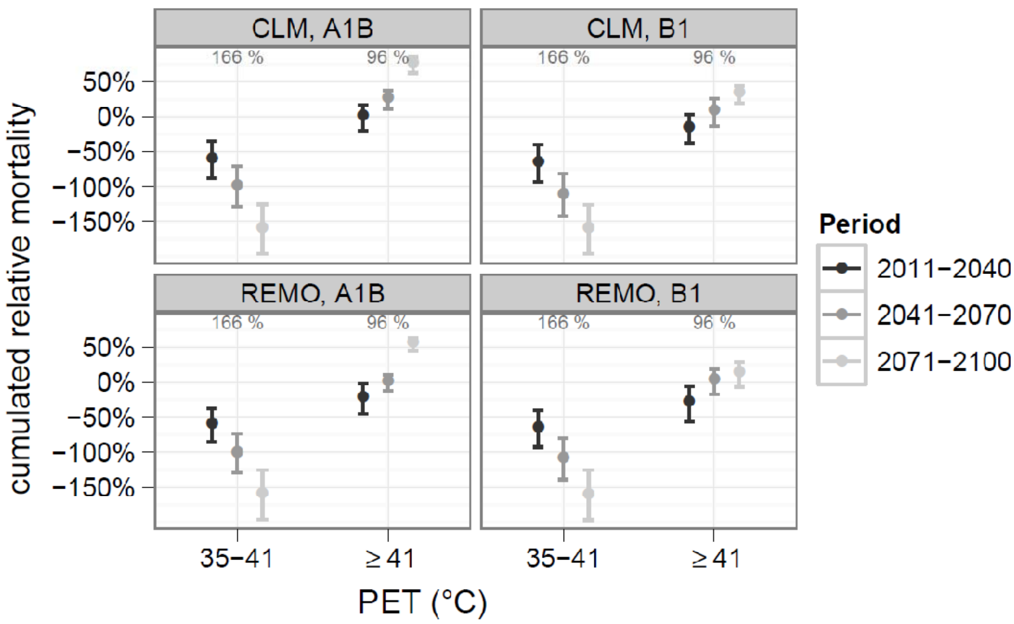

Fig. 4: Changing cumulated heat related mortality including long-term adaptation. The value of the period of examination is shown in grey in the upper margin of each panel. Days with moderate heat-stress were omitted

For mortality due to extreme heat stress, no significant trend was found. Hence, the sensitivity at the end of the period of examination (10.5 %) is used. This results in an increase of cumulated heat-related mortality on days with extreme stress. From 2041-2070 on the increase could be significant (CLM-A1B). Until 2071-2100 increases between 15 % (REMO-B1) and 77 % (CLM-A1B) relative to the 96 % of the period of examination were found.

For women, the increase on days with extreme heat stress was higher, with values between 25 % (REMO-B1) and 106 % (CLM-A1B) for 2071-2100. For cardiovascular or respiratory an increase between 14 % and 85 % was found.

4. Conclusions

Two different approaches were applied, so assess the range of development of heat related mortality in the future. The upper limit is formed by an approach without any long-term adaptation; the lower limit assumes continuous adaptation. In both approaches the heat related mortality could increase significantly till the end of the 21th century.

No significant changes compared to the period of investigation were found for 2011-2040. Hence, time for planning and implementation of additional adaptation measures is available. Measures could g. e. consider the topic of heat stress in urban planning by reducing the radiation component of the thermal environment (Mayer et al. 2008; Lin et al. 2010). On a larger scale heat health warning systems could form a promising step, to reduce the health impact of extreme heat waves (WHO 2004).

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