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The impact of extreme temperature on human mortality in the most populated cities of Romania

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The impact of extreme temperature on human mortality in the most populated cities of Romania --Manuscript Draft--

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Abstract:	<p>The impact of extreme weather conditions on humans is one of the most important topic in biometeorology studies. The main objective of this study is to analyze the relationship between temperature-related weather conditions and natural mortality. In the five most populated cities in Romania: Bucharest, Cluj-Napoca, Constana, Iai and Timioara. The results of the study aim to cover a gap in the national research. For the present research we used daily natural mortality data, and daily meteorological data (minimum, mean, and maximum air temperature, wind speed at 10 m above ground, relative humidity, cloudiness). The use of four climate indices (amount of cool days, amount of hot days, amount of cold nights, amount of warm nights) developed by the Expert Team on Sector-Specific Climate Indices, the bioclimatic index Universal Thermal Climate Index, and distributed lag non-linear model has allowed to identify the weather conditions associated with natural mortality. The most important results are: i. higher daily mortality is associated with high frequency of heat stress conditions; ii. higher maximum temperature increases the relative risk of natural mortality; iii. the maximum number of fatalities was recorded on the first day of the hot thermal events. The main conclusion of the study is that inhabitants of the most populated cities of Romania are more sensitive to thermal hot stress compared to the thermal cold stress.</p>				
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TITLE PAGE

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The impact of extreme temperature on human mortality in the most populated cities of Romania

Andreea-Sabina Scripcă, Fiorella Acquaotta, Adina-Eliza Croitoru, Simona Fratianni

Abstract

The impact of extreme weather conditions on humans is one of the most important topic in biometeorology studies. The main objective of this study is to analyze the relationship between temperature-related weather conditions and natural mortality. In the five most populated cities in Romania: Bucharest, Cluj-Napoca, Constanța, Iași and Timișoara. The results of the study aim to cover a gap in the national research. For the present research we used daily natural mortality data, and daily meteorological data (minimum, mean, and maximum air temperature, wind speed at 10 m above ground, relative humidity, cloudiness). The use of four climate indices (amount of cool days, amount of hot days, amount of cold nights, amount of warm nights) developed by the Expert Team on Sector-Specific Climate Indices, the bioclimatic index Universal Thermal Climate Index, and distributed lag non-linear model has allowed to identify the weather conditions associated with natural mortality. The most important results are: i. higher daily mortality is associated with high frequency of heat stress conditions; ii. higher maximum temperature increases the relative risk of natural mortality; iii. the maximum number of fatalities was recorded on the first day of the hot thermal events. The main conclusion of the study is that inhabitants of the most populated cities of Romania are more sensitive to thermal hot stress compared to the thermal cold stress.

Keywords: Bioclimatic stress; Extreme temperature; Bioclimatic indices; Natural mortality; Romania

1. Introduction

In the last century, climate change has been considered one of the biggest threats to human health (IPCC 2015; Vicedo-Cabrera et al. 2019). Due to intensification of climate change by increasing the frequency and intensity of extreme weather-related events, researchers worldwide have focused their attention on studying the impact of meteorological variables and/or different weather-conditions on humans (e.g. Morabito et al. 2014; Acquaotta et al. 2017; Di Napoli et al. 2018; Moirano et al. 2018; Chai et al. 2019; Croitoru et al. 2019; Sangkharat et al. 2020).

Many of the latest research analyzed the relationship between air temperature, including extreme temperature conditions, and mortality (De' Donato et al. 2015; Gasparrini et al. 2015; Guo et al. 2017; Åström et al. 2018; Scovronick et al. 2018; Smith and Sheridan 2019; Royé et al. 2020). Some studies investigated the impact of air temperature considering general mortality (natural causes of death), some other focused on different groups of diseases (respiratory or cardio-vascular diseases) (e.g. Gasparrini et al. 2015; Chen et al. 2018; Scortichini et al. 2018).

The impact of weather and climate on humans' health can be assessed by using the climatic and bioclimatic indices (Nastos and Matzarakis 2011; Vaneckova et al. 2011; Di Napoli et al. 2018). Among them, the Universal Thermal Climate Index (UTCI) synthesizes very well the heat stress induced by meteorological conditions to the human body (Błażejczyk et al. 2018; Di Napoli et al. 2018).

Other researchers identified the high impact of heat on humans in several major cities in Europe. In detail, excessive heat in Europe (identified by heat waves) has led to a greater impact in the Mediterranean region than in the northern continental cities (Baccini et al. 2008; D'Ippoliti et al. 2010). The low and the high temperatures increase the

80 risk of producing deaths under different climatic conditions: population living in colder climate areas, is more sensitive
81 to the high temperatures, and the inhabitants of the warmer climate areas are more vulnerable to low temperatures (Kovats
82 and Hajat, 2008; Zhang et al., 2014). Population seems to be less able to cope with the extreme heat, compared to the
83 extreme cold (Barnett et al., 2012). As a possible explanation for adapting to environmental conditions is the behavior of
84 the inhabitants of certain parts of Europe. People in the cold regions of Europe take more cold-protective measures
85 compared to the inhabitants of the warm regions (Keatinge et al., 2000).

86 There are only a few studies focused on Eastern European countries (e.g. Pattenden et al. 2003; McMichael et.
87 al. 2008; Papathoma-Koehle et al. 2016). Concerning Romanian state, the researchers on climate and health is still scarce.
88 Only a small number of studies focused on Romania's territory so far, and most of them are part of researches investigating
89 larger regions. In general, they considered single cities like Bucharest (McMichael et. al. 2008), Cluj-Napoca (Croitoru
90 et al. 2018), or other areas (Leitte et al. 2009; Papathoma-Koehle et al. 2016), but none of the previous papers have been
91 conducted to cover more cities in this country.

92 The main objective of this study is to analyze the relationship between severe thermal conditions, assessed by
93 using simple or complex bioclimatic indices, and natural mortality recorded in the five most populated cities in Romania.
94 We intend to carry out the risk assessment for human health under certain climatic conditions.

95

96 **2. Materials and methods**

97 *2.1. Reference population and environment*

98 Romania is located in Eastern Europe, in a temperate climate in transition from western maritime climate to
99 semi-arid continental climate. There are some regional differences, induced by the presence of the Carpathian Mountains,
100 which form a natural barrier in front of different types of air masses. As general features, the Extra-Carpathian regions
101 (eastern and southern Romania) are hotter in summer, colder in winter and drier all over the year compared to the Intra-
102 Carpathian regions, which are wetter and cooler during summer and milder in winter (Sandu et al. 2008; Piticar et al.
103 2017). The Black Sea serves as an important climate moderator for the south-eastern region of the country.

104 For this study, we considered 5 cities: Bucharest (1), Cluj-Napoca (2), Constanța (3), Iași (4) and Timișoara (5).
105 They are located in various local conditions in terms of topography and climatic conditions covering very good almost
106 all regions of Romania. Their spatial distribution is presented in *Fig 1*.

107

108 Fig. 1. Study area and considered weather stations.

109

110 The most relevant climatic features of the cities studied are detailed in *Supplementary material 1*.

111 Their climatic specificity derives from their position and from air mass tracks over the region: Atlantic oceanic
112 influence is dominant in Cluj-Napoca; Timișoara is more influenced by the Mediterranean and the Atlantic Ocean; the
113 semi-arid East-European climatic influence is dominant in Bucharest and Iași, whereas Constanța, located on the Black
114 Sea shore has a more humid and temperate moderate climate (Badea et al. 1983; Sandu et al. 2008).

115 All these urban entities are among the most economically developed cities in the country, with prestigious
116 universities and an important medical infrastructure, including a network of renowned university hospitals.

117 The cities included in this study are the top five most populated cities in the country, considering the number of
118 inhabitants residing in Romania, on July 1, 2016 (<http://www.insse.ro>). In 2016, the population of the capital city,
119 Bucharest, exceed two million inhabitants (2,102,675 inhabitants) and the other four cities had a population between

120 316,000 and 366,000 inhabitants each (321,965 in Cluj-Napoca; 316,777 in Constanța; 365,660 in Iași; and 332,192 in
121 Timișoara) (<http://www.insse.ro>).

122

123 **2.2. Data collection**

124 To develop the present study we used historical daily weather data as well as daily mortality data over a 18-yr
125 period (1999-2016) registered in the five cities mentioned above. The period was selected according to the mortality data
126 availability (death with the clear diagnosis mentioned) and it is long enough not to be influenced by inter-annual
127 variations and anomalies (Storch and Zwiers 2003; Acquaotta et al. 2017, 2019).

128

129 *2.2.1. Mortality data*

130 The mortality data were freely provided by the National Institute for Statistics (NIS) as anonymized
131 (unidentifiable) mortality microdata (individual data).

132 For the period 1999-2016, the datasets include the dead people with the stable (permanent) residence or normal
133 residence (defined as the place/city where a person lived mostly in the last 12 month of his/her life) in the five cities
134 considered. Also, the database includes leading cause of death classified by the International Statistical Classification of
135 Diseases and Related Health Problems, 10th Revision (ICD-10) (WHO 2016).

136 In this study we used only the data on natural mortality (deaths with disease codes between A00-R99).

137

138 *2.2.2. Meteorological data*

139 For this analysis, historical daily maximum (TX) and minimum (TN) temperature data over the period 1999-
140 2016 were used. They were collected from different sources: for the period 1999-2009, the data were freely downloaded
141 from ECA&D project database (Klein Tank et al. 2002; www.ecad.eu) (non-blend data series) and for the period 2010-
142 2016, they were reconstructed from row synoptic messages available on www.meteomanz.com. The datasets
143 corresponding to the Timișoara weather station were collected from the ROCADA database (for the period 1999-2013)
144 (Dumitrescu and Bîrsan 2015) and supplemented with data extracted from www.meteomanz.com for the period 2013-
145 2016. Partially, these data sets were developed under the framework of the project *Extreme Weather Events related to Air*
146 *Temperature and Precipitation in Romania* (www.granturi.ubbcluj.ro/fmetpro).

147 Mean daily values of temperature (T), relative humidity (RH), cloudiness (N), wind speed at 10 m height (v10),
148 were provided by the Romanian National Meteorological Administration (RNMA). In case of missing data, they were
149 derived as follows:

150 • for the Bucharest-Băneasa weather station, the N missing data from 2001 were filled in with the data from the
151 archive available on www.meteomanz.com;

152 • for Cluj-Napoca weather station, the T data were extracted from the ECA&D project archive (Klein Tank et al.
153 2002; <https://www.ecad.eu/>) (for the interval 1999-2015) and from www.meteomanz.com (for the year 2016);

154 • also, for Cluj-Napoca weather station data for the year 2016, the v10, RH and N were downloaded from
155 www.meteomanz.com and www.rp5.ru.

156

157 **2.3. Methods**

158 *2.3.1. Data quality control*

159 Data quality control (QC) represent a pre-requisit step; both meteorological and mortality data were checked for
160 quality and homegeneity before using them in analysis.

161 The QC of the temperature datasets was performed by employing ClimPACT2 software, which allowed us to
162 identify outliers and other unrealistic values (Baronetti et al. 2018). Temperature series were tested for homogeneity by
163 employing RhtestV4 (Wang and Feng 2013; Fortin et al. 2016).

164 The RH, N, and v10 data series were provided by the Romanian National Meteorological Administration
165 (RNMA) as homogenized datasets.

166 For the analyzed period, the missing data were only for the Constanța station, for the meteorological parameters
167 v10m and RH (with values of 0.5%, respectively 0.2%).

168 Mortality data were checked for each city. Some data have been invalidated because the disease code was not
169 clearly specified, and thus they have been excluded from further analysis. They covered an insignificant number of deaths:
170 0.001% in Bucharest; 0.002% in Constanța and Iași.

171

172 2.3.2. *Indices calculation*

173 The analysis was carried out on four climate extreme indices: amount of cool days (TX10p), amount of hot days
174 (TX90p), amount of cold nights (TN10p), amount of warm nights (TN90p) (*Table 1, section a*). They are part of the
175 core indices list created by the Expert Team on Sector-specific Climate Indices (ET-SCI) (Alexander and Herold 2016).
176 The fifth index is a complex bioclimatic index: Universal Thermal Comfort Index (UTCI). It is one of the most recent
177 thermal climate indices developed by a multidisciplinary research team, in the frame of COST Action 730 (Bröde et al.
178 2012; Jendritzky et al., 2012).

179 We have also calculated the daily values of UTCI. To derive the data sets, the BioKlima ver. 2.6 freely available
180 software package was used (<https://www.igipz.pan.pl/Bioklima-zgik.html>).

181 In this study, the UTCI values are calculated as a polynomial regression function and the input data include
182 meteorological (T, mean radiant temperature, RH, and v10, and non-meteorological (a metabolic rate of 135 W m^{-2} and
183 a walking speed of 1.1 m s^{-1} , albedo of clothing) data (Błażejczyk et al. 2012, 2015). Radiant temperature is necessary
184 for UTCI calculations. Therefore, the statistical SolAlt model (Błażejczyk and Matzarakis 2007; Błażejczyk et al. 2015,
185 2018) was adopted in order to use as input data for total cloud cover, sun altitude and albedo of clothing (Błażejczyk et
186 al. 2015). The stress categories for UTCI index are presented in *Table 1, section b*.

187

188 Table 1. a) Definitions of the ET-SCI climate indices analysed (after Alexander and Herold 2016); b)
189 Assessment scale for the UTCI index (after Glossary of Terms for Thermal Physiology (2003); www.utci.org; Błażejczyk
190 et al. 2012 (modified)).

191

192 2.3.3. *Relationships between indices and natural mortality*

193 a. *Relationship between ET-SCI temperature-based indices and natural mortality*

194 The first relationship between climate index and mortality was carried out using the anomaly index. The anomaly
195 indice was calculated taking into account the annual average (per year for the period analyzed) (AnnMM), and multi-
196 annual average (during 1999-2016) for number of deaths (MannMM). We identified the years when the mortality was
197 above the mean multi-annual average (naming those years as having in excess mortality), and years with the mean annual
198 number of deaths was below the multiannual value (years with deficit mortality). Then we analyzed the indicators values
199 during the years with excess and deficit of mortality.

200

201 b. *Relationship between UTCI and natural mortality*

202 To correlate the mortality values with daily UTCI, we employed daily mortality data and the analysis was
203 performed at a seasonal scale and for the extreme seasons: summer (June-July-August) and winter season (December-
204 January-February). The reason for this selection was that climatic characteristics are very different in these two seasons,
205 and we wanted to find out when exactly the human body is the most vulnerable. On the other hand, we chose to conduct
206 this analysis at the season scale, because the number of deaths is different (the highest in the winter and the lowest in the
207 summer). The same seasonal distribution of deaths was reported in other studies, too (Rodrigues et al., 2019).

208 Also, for this analysis we used the anomaly index. Initially, we calculated the daily mean multi-annual value of
209 mortality for each season chosen for this analysis. Then, we selected those days when deaths number was at least equal
210 to or higher than the mean daily mortality. In the next step we calculated the frequency of days with mortality greater
211 than or equal to the average value (*excess mortality days*) (*Ex.M*) and the frequency of days when the number of deaths
212 was below average (*deficit mortality days*) (*De.M*) for each class of bioclimatic comfort.

213 214 2.3.4. Calculation of relative risk for mortality in case of extreme temperature

215 The distributed lag non-linear model (DLNM) was used to examine the relationship between daily TX and TN
216 and daily natural mortality during the mentioned interval, with a maximum lag of 20 days. Since, numerous previous
217 studies revealed that the cold effect is spread over a week or more after a cold day and the heat effect is more immediate
218 (Armstrong 2006), we decided to extend the lag period to 20 days to include the long delay of the effects of cold and hot
219 temperature and for potential short-term mortality displacement.

220 DLNM allows describing the exposure-lag-response association, considering the non-linear temperature-
221 mortality relationship and its delayed effects over time (Gasparrini 2011). The cross-basis for temperature is composed
222 by double-threshold functions with cut off points at 25th / 20th percentile and 75th / 80th percentile for the dimension of the
223 predictor and a natural cubic spline with knots at equally spaced values in the log scale for lag. The cross-basis matrix is
224 included in the the package *dlnm* (Gasparrini 2011).

225 All tests listed above were performed for individual cities, for the period 1999-2016.

226 227 2.3.5. Visualization

228 The map was drawn using ArcMap10.2 software and the graphs were designed by employing Excel and RStudio
229 packages.

230 231 3. Results

232 3.1. Relationship between ET-SCI temperature-based indices and natural mortality

233 The analysis between climatic indices and natural mortality (Fig. 2) revealed a more pronounced anomaly with
234 hot extremes indices calculated (TX90p and TN90p), emphasizing that urban population is more vulnerable to hot
235 extremes compared to the cold ones. The years when the annual mortality exceeded the mean multi-annual mortality
236 (excess mortality years) were mainly characterized by high values (above the average) of TX90p for Bucharest, Cluj-
237 Napoca, Constanța, and Iași, as well as for TN90p for all cities. We also considered for analysis the consecutive in excess
238 mortality years (2012-2016 for Cluj-Napoca and Iași, 2013-2016 for Timișoara, and 2014-2016 for Bucharest and
239 Constanța), but this analysis did not identify a specific pattern between mortality and indices. Like most European cities,
240 the urban population in Romania faces the phenomenon of demographic aging. This is a possible explanation for the
241 increase in mortality over the average, in the last years analyzed.

242

243 Fig. 2 Results of correlations between climate indices and natural mortality, where: AnnMM = annual mean of
244 mortality; MannMM = multiannual mean of mortality

246 3.2. Relationship between UTCI and natural mortality

247 Daily mortality higher than the mean summer mortality is associated with high frequency of heat stress
248 conditions. 100 % exceedence of mean daily mortality (for Bucharest) and 50 % (for Constanța) were recorded during
249 periods of strong heat stress (label 3). Days with excess mortality, with a rate of more than 60 % were found when the
250 UTCI indicates strong heat stress (label 2) (61,5 % - Constanța, 68,6 % - Timișoara, 70,9 % - Iași, 73,8 % - Cluj-Napoca,
251 and 79,6 % - Bucharest). When UTCI identifies thermal comfort conditions (label 0), the mortality has similar rates as
252 during the days in which less deaths than seasonal average is recorded, for four of the five cities examined (except
253 Bucharest) (Table 2). This means that an increasing sensitivity of the population in the focus areas was recorded during
254 hot heat stress conditions.

255 During winter, most of the days with maximum cold stress conditions registered an excess mortality, too. The
256 days belonging to the extremely cold stress class (label -5) coincide with the days with above average mortality 50 % in
257 Constanța, and 100 % for the cities of Bucharest, Iași and Timișoara. For all cities, during the bioclimatic conditions
258 related to the severe cold stress class (label -3), excess mortality was recorded in more than 50 % of the days, with values
259 ranging from 51,5 % in Cluj-Napoca and 71,4 % in Timișoara. Mortality above average covers less than 50 % of the days
260 included in other classes for cold stress such as moderate cold stress (label -2) and mild cold stress (label -1) for Bucharest
261 and Timisoara and slightly above 50 % for the other three cities analyzed.

262
263 Table 2. Correlation between UTCI and natural mortality (%).

264
265 The increased risk of death is recorded when bioclimatic stress synthesizes positive thermal conditions; as
266 expected, for cold stress classes, mortality increased during very severe conditions. However, population in the focus
267 cities seems to be more adapted to the bioclimatic conditions given by the cold thermal stress.

269 3.3. Relative risk for mortality calculated for extreme temperature

270 The effect of TX and TN on mortality was expressed as the Relative Risks (RR).

271 The following analysis presents the RR of natural mortality for TX and TN, insisting on the effect in time given
272 by extreme temperatures on human body (Fig. 3).

273 In all cities analyzed (Bucharest, Cluj-Napoca, Constanța, Iași, and Timișoara), the RR of natural mortality was
274 greater in the case of high TX and, in general, for lags of 0 - 5 days (Fig. 3 a., b., c., d., e.). The effect of hot thermal
275 extremes is felt in the very first days of the extreme temperature event. Detailing this issue, it turned out that for the
276 mortality in Bucharest, the RR has high values in the first 5 days (0-5 lag), for the deaths recorded in the cities of Cluj-
277 Napoca and Timișoara, the TX effect is present for 7 days from the beginning of the event (RR with high values in the
278 range 0-6 lag). The results for Constanța and Iași revealed the TX effect on mortality increases in the first five consecutive
279 days of the extreme temperature event.

280 In Bucharest, Cluj-Napoca, Constanța, and Timișoara the TX effect on mortality is maximum on the same day
281 with the temperature increase (lag 0) when the RR recorded its highest values. Thus, the maximum number of casualties
282 occurs immediately after the maximum temperature, and their number decreases gradually afterwards, with the decrease

283 of the RR value. An exception is the city of Iași, where the TX effect on mortality is maximum the day after the highest
284 temperature is recorded (lag 1).

285 For all the urban areas considered, the TN effect (*Fig. 3-f, g, h, i, j.*) lasts for a much longer period and varies
286 largely from one city to another: from a few days, in Cluj-Napoca and Iași, to about two weeks for the other three cities.
287 These different patterns from one city to another may be also caused by different climatic characteristics of these urban
288 areas. Population living in cities with a more frequent occurrence of positive thermal extremes (Bucharest, Constanța,
289 and Timișoara) is more exposed to longer time effects of cold extremes.

290

291 Fig. 3. The RR of natural mortality by maximum temperatures (a., b., c., d., e.) - the *column on the right* indicates the RR
292 value. The RR of natural mortality by minimum temperatures (f., g., h., i., j.) - the *column on the left* indicates the risk of
293 natural mortality.

294

295

4. Discussions

296 Many studies in the literature have focused on the impact of extreme phenomena (such as heat and cold waves)
297 on mortality (e.g. Baccini et al. 2008; D'Ippoliti et al. 2010; Barnett et al. 2012), but there are a few studies that have
298 quantified the results between indices that synthesize thermal extremes and deaths (Yang et al. 2019). We consider that
299 our study fills in such a gap for the five most populated cities in Romania.

300 In relation to the most complex bioclimatic index, the results from several European countries, have led to the
301 conclusion that the mortality relation - UTCI is strictly related to the thermal bioclimate to which a population is exposed
302 and adapted (Błażejczyk et al. 2018; Di Napoli et al. 2018). The results we obtained are similar to those calculated for
303 Poland (Błażejczyk et al. 2013). In another recent study (Błażejczyk et al. 2018) in comparison to no thermal stress
304 conditions, the significant increase of mortality is observed in days with strong and very strong heat stress conditions.

305 Our results obtained based on UTCI show that although mortality increases both in hot and cold thermal stress
306 conditions, the stronger effect was recorded during hot thermal stress. They are in line with findings obtained in different
307 regions of the world and makes from this index (UTCI) an important tool to forecast health problems when recording
308 extreme high temperatures (Pappenberger et al. 2015; Di Napoli et al. 2018).

309 In Romania, a recent study indicated a statistically significant increase in number, duration and intensity of the
310 extreme hot thermal events (heat waves) over the last decades, especially during summer (Croitoru et al. 2018). Another
311 study revealed that climatic changes of extreme thermal events identified based on excess heat factor are more consistent
312 compared to those identified based on excess cold factor (Piticar et al. 2017). Under these circumstances when more
313 frequent, longer duration and higher intensity extreme hot events characterize almost the entire country, including the five
314 cities considered for this research, it is supposed that they severely impact on human health leading to an increase in
315 vulnerability of the population, caused primarily by the nonadaptation to the hot thermal stress. As previously presented,
316 the vulnerability can be attributed to poor living conditions, such as small houses or lacking of air conditioned devices,
317 too (García-Herrera et al. 2010). In Romania, most of the houses in the focus areas (especially the apartments built
318 between 1950 and 1985) are quite small, with two or three rooms in their great majority. The extreme thermal events and
319 heat waves that occur frequently in Bucharest trigger significant thermal stress and thermal risks, especially in buildings
320 with inadequate ventilation (Constantinescu et al. 2016).

321 It is possible underline that when low temperatures are recorded, individuals are much easier to adapt to these
322 conditions (by wearing warmer clothing, or stay in house as much as possible). By contrast, in order to diminish the
323 impact of extreme heat, people need modern techniques, such as air conditioned, which are relatively new and expensive.

324 For their operation and maintenance significant amounts of money are needed, which cannot be supported by a great part
325 of Romania's population. Exposure to environmental stressors generates effects delayed in time (Anderson and Bell 2009;
326 Gasparrini et al. 2011). Our results are in agreement with the international researches stating that the positive thermal
327 extremes are felt by the human body on the day the temperature was recorded, respectively the day after. The effects of
328 cold thermal extremes are registered by the human body with a delay of several days and the impact on mortality is exerted
329 over a longer period of time (Anderson and Bell 2009; Gasparrini 2011). We identified for all cities analyzed that the RR
330 values increased with the increase of the TX. Other studies reported that mortality risk increased with temperature or heat
331 waves intensity or duration or (Anderson and Bell 2009; De' Donato et al. 2015; Scovronick et al. 2018).

332

333 **5. Conclusions**

334 According to analyzes performed, the population of the analyzed cities is sensitive to the thermal conditions
335 that synthesize the most severe cold stress and the vulnerability increases during the bioclimatic conditions of hot thermal
336 stress. The highest risk is specific during hot thermal discomfort periods, or when the maximum temperature exceeds
337 certain thresholds.

338 Due to the intensification of the extreme temperature events in Romania and high vulnerabilty, measures to
339 prevent and raise awareness of the population, especially when the discomfort of hot thermal stress is predicted are
340 needed. As an immediate consequence, our results can be used to improve the preparation of the public health system for
341 the primary and secondary prevention of the population during periods with adverse weather conditions. These results
342 can become the start point to develop biometeorological forecast system for the Romanian cities and also an early warning
343 system during extreme temperature events.

344 Furthermore, these findings fill in a gap in the national research and it could be of interest for the valuable increase
345 in the knowledge of the temperature-mortality relationships in a country that is under-studied in the literature.

346

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357

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362 results and research. The authors declare that they have no known competing financial interests or personal relationships
363 that could have appeared to influence the work reported in this paper.

364 **Availability of data and material (data transparency):** The authors do not have the permission to publish the mortality
365 microdata or the raw climatic data.

366 **Code availability (software application or custom code):** Not applicable.

367 **Authors' contributions:** conceptualization: A.S.S; data processing: A.S.S and F.A.; analysis and writing the paper:
368 A.S.S., A.E.C., F.A., S.F.; visualization: A.S.S.; supervision: S.F.; correspondence: A.E.C.

369 **Ethical standards**

370 The research presented complies with the current laws in Romania and with the ethical standards in Babeş-Bolyai
371 University.

372

373 **References**

374 Acquaotta F, Ardissino G, Fratianni S, Perrone M. (2017) Role of climate in the spread of shiga toxin-producing
375 *Escherichia coli* infection among children. *Int. J. Biometeorol.* 61:1647–1655. doi:10.1007/s00484-017-1344-y

376 Acquaotta F, Fratianni S, Aguilar E, Fortin G (2019) Influence of instrumentation on long temperature time
377 series. *Climatic Change.* 156 (3):385-404

378 Alexander L, Herold N (2016) *ClimPACT2 Indices and Software*. University of South Wales: Sidney, Australia.
379 <https://github.com/ARCCSSextremes/climpact2>

380 Anderson BG, Bell ML (2009) Weather-Related Mortality. *Epidemiology* 20(2):205–213.
381 doi:10.1097/ede.0b013e318190ee08

382 Armstrong B. (2006) Models for the relationship between ambient temperature and daily mortality.
383 *Epidemiology.* 17, 624–631. DOI: 10.1097/01.ede.0000239732.50999.8f

384 Åström DO, Ebi KL, Vicedo-Cabrera AM, Gasparri A (2018) Investigating changes in mortality attributable
385 to heat and cold in Stockholm, Sweden. *Int. J. Biometeorol.* 62(9):1777–1780. doi:10.1007/s00484-018-1556-9

386 Baccini M, Biggeri A, Accetta G et al. (2008) Heat Effects on Mortality in 15 European Cities. *Epidemiology*
387 19(5), 711–719. doi:10.1097/ede.0b013e318176bfcd

388 Badea L, Gastescu P, Velcea, VA et al. (1983) *Geografia Romaniei. Geografia Fizica*. Editura Academiei
389 Republicii Socialiste Romania, Bucharest

390 Barnett AG, Hajat S, Gasparri A, Rocklöv J (2012) Cold and heat waves in the United States. *Environ. Res.*
391 112:218–224. doi:10.1016/j.envres.2011.12.010

392 Baronetti A, Acquaotta F, Fratianni S (2018) Rainfall variability from a dense rain gauge network in North -
393 West Italy. *Climate Research* 75(3):201-213. DOI: <https://doi.org/10.3354/cr01517>

394 BioKlima ver. 2.6 software. Available online at <https://www.igipz.pan.pl/Bioklima-zgik.html>. Accessed 30 April
395 2016

396 Błażejczyk K, Matzarakis A (2007) Assessment of bioclimatic differentiation of Poland based on the human
397 heat balance. *Geographia Polonica* 80(1):63-82

398 Błażejczyk K, Epstein Y, Jendritzky G, Staiger H, Tinz B (2012) Comparison of UTCI to selected thermal
399 indices. *Int. J. Biometeorol.* 56(3):515–535. DOI: 10.1007/s00484-011-0453-2

400 Błażejczyk K, Idzikowska D, Błażejczyk A (2013) Forecast changes for heat and cold stress in Warsaw in the
401 21st century, and their possible influence on mortality risk. *Papers on Global Change.* 20:47–62. DOI 10.2478/igbp-2013-
402 0002

403 Błażejczyk K, Baranowski J, Jendritzky G, Błażejczyk A, Bröde P, Fiala D (2015) Regional features of the
404 bioclimate of Central and Southern Europe against the background of the Köppen-Geiger Climate Classification,
405 *Geographia Polonica* 88(3):439-453. <http://dx.doi.org/10.7163/GPol.00274>

406 Błażejczyk A, Błażejczyk K, Baranowski J, Kuchcik M (2018) Heat stress mortality and desired adaptation
407 responses of healthcare system in Poland. *Int. J. Biometeorol.* 62(3):307–318. doi:10.1007/s00484-017-1423-0

408 Bröde P, Fiala D, Błażejczyk K et al. (2012) Deriving the operational procedure for the universal thermal climate
409 index (UTCI). *Int. J. Biometeorol.* 56:481–494. doi: 10.1007/s00484-011-0454-1

410 Chai G, He H, Su Y, Sha Y, Zong S (2019) Lag effect of air temperature on the incidence of respiratory diseases
411 in Lanzhou, China, *Int. J. Biometeorol.* <https://doi.org/10.1007/s00484-019-01795-x>

412 Chen K, Wolf K, Breitner S et al. (2018) Two-way effect modifications of air pollution and air temperature on
413 total natural and cardiovascular mortality in eight European urban areas. *Environ. Int.* 116:186–196.
414 doi:10.1016/j.envint.2018.04.021

415 Constantinescu D, Cheval S, Caracaş G, Dumitrescu A (2016) Effective monitoring and warning of Urban Heat
416 Island effect on the indoor thermal risk in Bucharest (Romania). *Energy and Buildings*, 127:452–468.
417 doi:10.1016/j.enbuild.2016.05.068

418 Croitoru AE, Piticar A, Sfică L et al. (2018) Extreme Temperature and Precipitation Events in Romania. Ed.
419 Academiei Române, Bucharest

420 Croitoru AE, Dogaru G, Man TC, Mălăescu S, Motricală M., Scripcă AS (2019) Perceived Influence of Weather
421 Conditions on Rheumatic Pain in Romania. *Advances in Meteorology* 1–9. doi:10.1155/2019/9187105

422 D'Ippoliti D, Michelozzi P, Marino C et al. (2010) The impact of heat waves on mortality in 9 European cities:
423 results from the EuroHEAT project. *Environ. Health.* 9(1). doi:10.1186/1476-069x-9-37

424 De' Donato, F, Leone M, Scortichini M et al. (2015) Changes in the Effect of Heat on Mortality in the Last 20
425 Years in Nine European Cities. Results from the PHASE Project. *Int. J. Environ. Res. Public Health.* 12(12):15567–
426 15583. doi:10.3390/ijerph121215006

427 Di Napoli C, Pappenberger F, Cloke HL (2018) Assessing heat-related health risk in Europe via the Universal
428 Thermal Climate Index (UTCI). *Int. J. Biometeorol.* 62(7):1155–1165. doi:10.1007/s00484-018-1518-2

429 Dumitrescu A. Bîrsan MV (2015) ROCADA: a gridded daily climatic dataset over Romania (1961–2013) for
430 nine meteorological variables. *Nat. Hazards.* 78(2):1045–1063. doi:10.1007/s11069-015-1757-z

431 Fortin G, Acquavota F, Fratianni S (2016) The evolution of temperature extremes in the Gaspé Peninsula, Quebec,
432 Canada (1974–2013). *Theor. Appl. Climatol.* 1–10. doi: 10.1007/s00704-016-1859-x

433 García-Herrera R, Díaz J, Trigo RM, Luterbacher J, Fischer EM (2010) A Review of the European Summer Heat
434 Wave of 2003. *Critical Reviews. Environ. Sci. Technol.* 40(4):267–306. doi:10.1080/10643380802238137

435 Gasparrini A (2011) Distributed Lag Linear and Non-Linear Models in R: The Package *dlnm*. *Journal of*
436 *statistical software* 43(8):1-20. doi: 10.18637/jss.v043.i08

437 Gasparrini A, Armstrong B, Kovats S, Wilkinson P (2011) The effect of high temperatures on cause-specific
438 mortality in England and Wales. *Occupational and Environmental Medicine*, 69(1): 56–61.
439 doi:10.1136/oem.2010.059782

440 Gasparrini A, Guo Y, Hashizume M et al. (2015) Temporal Variation in Heat–Mortality Associations: A
441 Multicountry Study. *Environ. Health Perspect.* 123(11):1200–1207. doi:10.1289/ehp.1409070

442 Glossary of Terms for Thermal Physiology (2003) *Journal of Thermal Biology* 28:75-106

443 Guo Y, Gasparrini A, Armstrong BG et al (2017) Heat Wave and Mortality: A Multicountry, Multicommunity
444 Study. *Environ. Health Perspect.* 125(8), <https://doi.org/10.1289/EHP1026>
445 Intergovernmental Panel on Climate Change (IPCC) (2015) *Climate change 2014: mitigation of climate change.*
446 Cambridge University, England
447 Jendritzky G, De Dear R, Havenith G (2012) UTCI - why another thermal index? *Int. J. Biometeorol.* 56 (3)421
448 – 428. doi: 10.1007/s00484-011-0513-7
449 Keatinge WR, Donaldson GC, Cordioli E, Martinelli M, Kunst AE, Mackenbach JP, Nayha S, Vuori I (2000)
450 Heat related mortality in warm and cold regions of Europe: observational study. *BMJ.* 321(7262), 670–673.
451 Klein Tank AMG, Wijngaard JB, Konnen GP et al. (2002) Daily dataset of 20th-century surface air temperature
452 and precipitation series for the European climate assessment. *Int. J. Climatology.* 22, 1441–1453.
453 Kovats RS, Hajat S (2008) Heat stress and public health: a critical review. *Annu Rev Public Health.* 29, 41–55.
454 Leitte AM, Petrescu C, Franck U. et al. (2009). Respiratory health, effects of ambient air pollution and its
455 modification by air humidity in Drobeta-Turnu Severin, Romania. *Sci. Total Environ.* 407(13):4004–4011.
456 doi:10.1016/j.scitotenv.2009.02.042
457 McMichael A, Wilkinson P, Kovats RS et al. (2008). International study of temperature, heat and urban
458 mortality: the “ISOTHURM” project. *International Journal of Epidemiology*, 37(5):1121–1131. doi:10.1093/ije/dyn086
459 Moirano G, Gasparrini A, Acquavota F, Fratianni S, Merletti F, Maule M, Richiardi L (2018) West Nile Virus
460 infection in Northern Italy: Case-crossover study on the short-term effect of climatic parameters. *Environ. Res.* 167:544–
461 549. doi:10.1016/j.envres.2018.08.016
462 Morabito M, Crisci A, Messeri A, Capecci V, Modesti PA, Gensini GF, Orlandini S (2014) Environmental
463 temperature and thermal indices: what is the most effective predictor of heat-related mortality in different geographical
464 contexts? *Sci. World. J.* 1–15. doi:10.1155/2014/961750
465 Nastos, P.T., Matzarakis, A., 2011. The effect of air temperature and human thermal indices on mortality in
466 Athens, Greece. *Theor. Appl. Climatol.* 108:591–599. <https://doi.org/10.1007/s00704-011-0555-0>
467 Papathoma-Koehle M, Promper C, Bojariu R et al. (2016) A common methodology for risk assessment and
468 mapping for south-east Europe: an application for heat wave risk in Romania. *Nat. Hazards.* 82: 89–109.
469 <https://doi.org/10.1007/s11069-016-2291-3>
470 Pappenberger F, Jendritzky G, Staiger H, Dutra E, di Giuseppe F, Richardson DS, Cloke HL (2015) Global
471 forecasting of thermal health hazards: the skill of probabilistic predictions of the Universal Thermal Climate Index
472 (UTCI). *Int. J. Biometeorol.* 59(3):311–323. doi: 10.1007/s00484-014-0843-3
473 Pattenden S, Nikiforov B, Armstrong BG (2003) Mortality and temperature in Sofia and London. *J Epidemiol*
474 *Community Health.* 57(8):628-33. DOI: 10.1136/jech.57.8.628
475 Piticar A, Croitoru AE, Ciupertea FA, Harpa GV (2017) Recent changes in heat waves and cold waves detected
476 based on excess heat factor and excess cold factor in Romania. *International Journal of Climatology*, 38(4):1777–1793.
477 doi:10.1002/joc.5295
478 Rodrigues M, Santana P, Rocha A (2019) Effects of extreme temperatures on cerebrovascular mortality in
479 Lisbon: a distributed lag non-linear model, *Int. J. Biometeorol.* 63: 549. <https://doi.org/10.1007/s00484-019-01685-2>
480 Royé D, Codesido R, Tobías A, Taracido M (2020) Heat wave intensity and daily mortality in four of the largest
481 cities of Spain. *Environ. Res.* 182, 109027. doi:10.1016/j.envres.2019.109027
482 Sandu I, Pescaru VI, Poiana I, Geicu A, Cădea I, Tâștea D (2008) *Clima României.* Ed. Academiei Romane,
483 Bucharest

484 Sangkharat K, Mahmood MA, Thornes JE, Fisher PA, Pope FD (2020) Impact of extreme temperatures on
485 ambulance dispatches in London, UK. *Environ. Res.* 182:109100. <https://doi.org/10.1016/j.envres.2019.109100>

486 Scortichini M, de' Donato F, De Sario M et al. (2018) The inter-annual variability of heat-related mortality in
487 nine European cities (1990–2010). *Environ. Health.* 17(1). doi:10.1186/s12940-018-0411-0

488 Scovronick N, Sera F, Acquaotta F, Garzena D, Fratianni S, Wrightd C, Gasparrini A (2018) The association
489 between ambient temperature and mortality in South Africa: A time-series analysis. *Environ. Res.* 161:229–235.
490 <https://doi.org/10.1016/j.envres.2017.11.001>;

491 Smith ET, Sheridan SC (2019) The influence of extreme cold events on mortality in the United States. *Sci. Total*
492 *Environ.* 647:342–351. doi:10.1016/j.scitotenv.2018.07.466

493 Storch HV, Zwiers F (2003) *Statistical analysis in climate research.* Cambridge University Press, 349

494 Vaneckova P, Neville G, Tippet V, Aitken P, FitzGerald G, Tong S (2011) Do biometeorological indices
495 improve modeling outcomes of heat-related mortality? *J. Appl. Meteorol. Climatol.* 50(6):1165–1176.
496 <https://doi.org/10.1175/2011JAMC2632.1>

497 Vicedo-Cabrera AM, Sera F, Gasparrini A (2019). Hands-on Tutorial on a Modeling Framework for Projections
498 of Climate Change Impacts on Health. *Epidemiology.* 30:321–329. doi: 10.1097/EDE.0000000000000982.

499 Wang XL, Feng Y (2013) *RHtestsV4: User Manual.* Climate Research Division, Atmospheric Science and
500 Technology Directorate, Science and Technology Branch, Environment Canada. Downsview, Ontario, Canada

501 World Health Organization (WHO) (2016) International statistical classification of diseases and related health
502 problems, 10th Revision. Available at:
503 <https://apps.who.int/iris/bitstream/handle/10665/246208/9789241549165V2eng.pdf?sequence=2&isAllowed=y>.
504 Accessed 22 July 2017

505 Yang Z, Wang Q, Liu P (2019) Extreme temperature and mortality: evidence from China. *Int. J. Biometeorol.*
506 doi:10.1007/s00484-018-1635-y.

507 Zhang Y, Li S, Pan X, Tong S, Jaakkola J, Gasparrini A, Guo Y, Wang S (2014) The effects of ambient
508 temperature on cerebrovascular mortality: an epidemiologic study in four climatic zones in China, *Environ. Health.* 13:24
509 [dataset] <http://www.insse.ro>
510 [dataset] www.ecad.eu
511 [dataset] www.meteomanz.com
512 [dataset] www.rp5.ru
513 www.utci.org. Accessed 13 February 2018
514 www.granturi.ubbcluj.ro/fmetpro

Table 1. a) Definitions of the ET-SCI climate indices analysed (after Alexander and Herold 2016); b) Assessment scale for the UTCI index (after Glossary of Terms for Thermal Physiology (2003); www.utci.org; Błażejczyk et al. 2012 (modified)).

a) Simple indexes					b) Complex index		
					Stress Category	UTCI (°C) range	Labels
					Extreme cold stress	< -40.1	-5
					Very strong cold stress	-4.0 - -27.1	-4
					Strong cold stress	-27.0 - -13.1	-3
Amount of cool days (TX10p)	Percentage of days when TX < 10th percentile	Fraction of days with cool day time temperatures	%	Year	Moderate cold stress	-13.0 - 0.0	-2
Amount of hot days (TX90p)	Percentage of days when TX > 90th percentile	Fraction of days with hot day time temperatures			Slight cold stress	0.1 - +9.0	-1
Amount of cold nights (TN10p)	Percentage of days when TN < 10th percentile	Fraction of days with cold night time temperatures			No thermal stress	+9.1 - +26.0	0
Amount of warm nights (TN90p)	Percentage of days when TN > 90th percentile	Fraction of days with warm night time temperatures			Moderate heat stress	+26.1 - +32.0	1
					Strong heat stress	+32.1 - +38.0	2
			Very strong heat stress	+38.1 - +46.0	3		
			Extreme heat stress *	> +46.1	4		

Table 2. Correlation between UTCI and natural mortality (%).

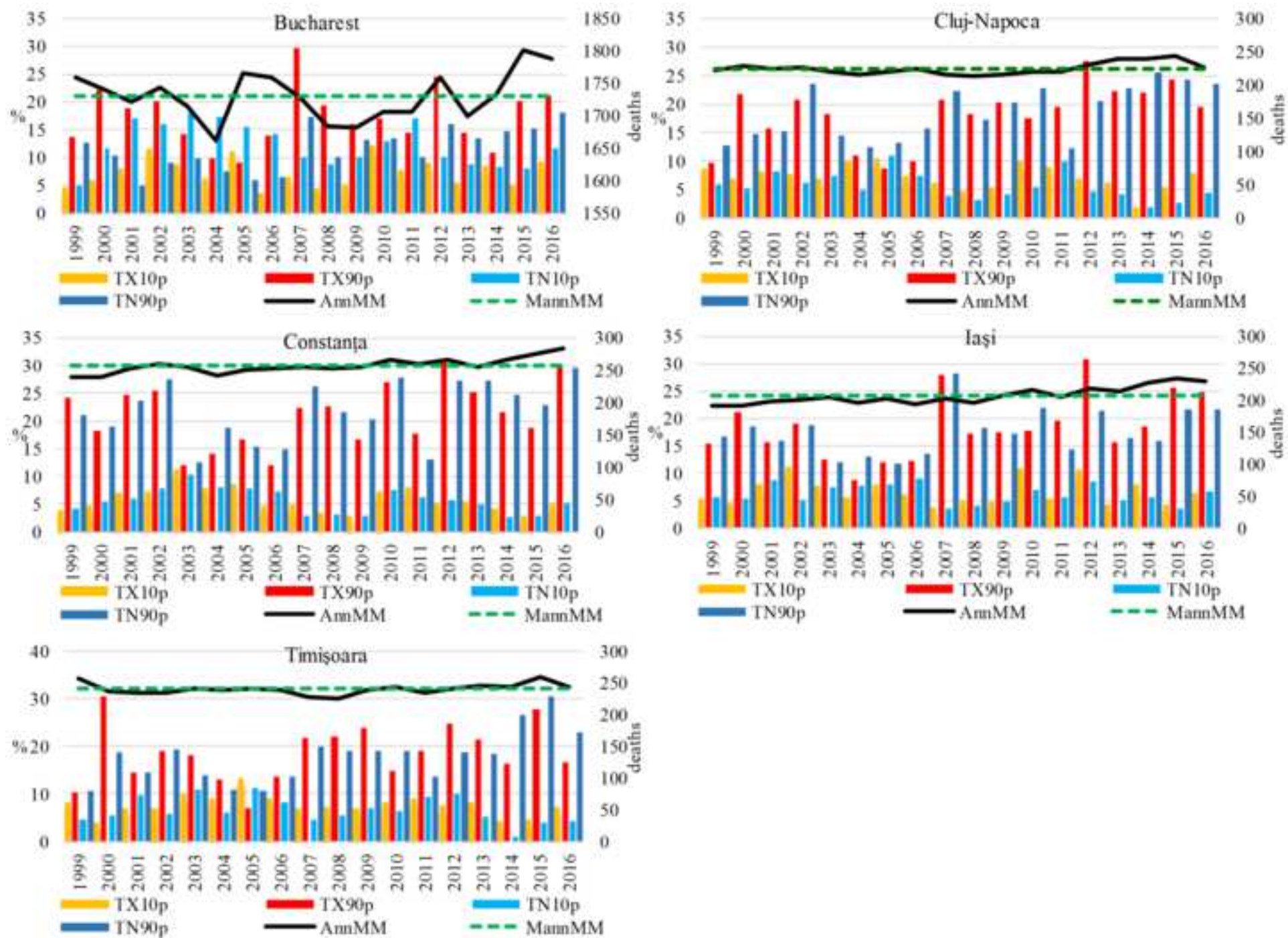
Season	UTCI confort classes	Bucharest		Cluj-Napoca		Constanța		Iași		Timișoara	
		Ex.M	De.M	Ex.M	De.M	Ex.M	De.M	Ex.M	De.M	Ex.M	De.M
Summer	-5	/	/	/	/	/	/	/	/	/	/
	-4	/	/	/	/	/	/	/	/	/	/
	-3	/	/	/	/	/	/	/	/	/	/
	-2	/	/	0.0	100.0	0.0	100.0	100.0	0.0	/	/
	-1	100.0	0.0	75.0	25.0	25.0	75.0	27.3	72.7	66.7	33.3
	0	30.9	69.1	50.5	49.5	46.8	53.2	55.2	44.8	50.0	50.0
	1	46.5	53.5	54.7	45.3	47.9	52.1	59.8	40.2	60.8	39.2
	2	79.6	20.4	73.8	26.2	61.5	38.5	70.9	29.1	68.6	31.4
	3	100.0	0.0	/	/	50.0	50.0	/	/	/	/
Winter	-5	/	/	/	/	50.0	50.0	100.0	0.0	100.0	0.0
	-4	44.4	55.6	/	/	55.8	44.2	53.1	46.9	100.0	0.0
	-3	55.6	44.4	51.5	48.5	63.9	36.1	61.6	38.4	71.4	28.6
	-2	49.1	50.9	51.5	49.1	57.4	42.6	57.9	42.1	45.7	54.3
	-1	47.1	52.9	54.0	46.0	53.7	46.3	59.4	40.6	46.3	53.7
	0	39.4	60.6	61.5	38.5	51.3	48.7	57.1	42.9	50.0	50.0
	1	/	/	/	/	/	/	/	/	/	/
	2	/	/	/	/	/	/	/	/	/	/
	3	/	/	/	/	/	/	/	/	/	/

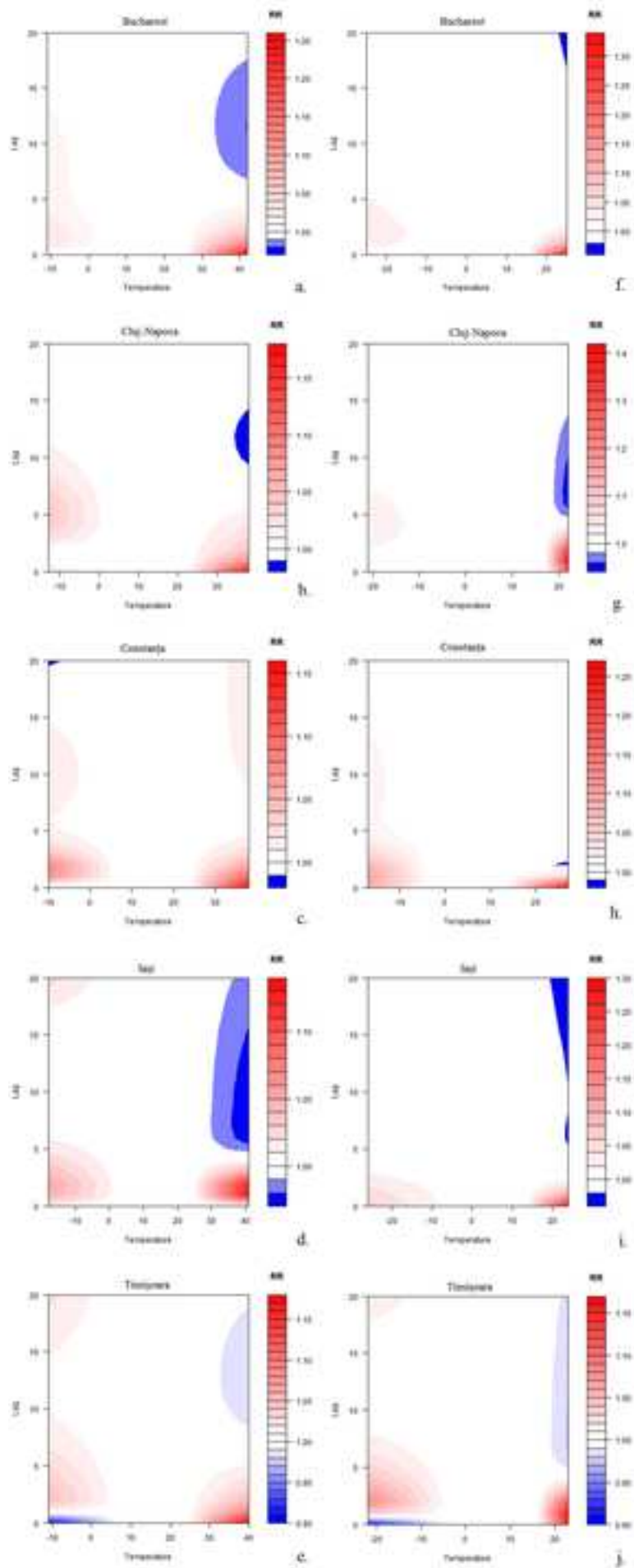
Note: Ex.M = excess mortality; De.M = deficit of mortality; / = no days with these bioclimatic conditions recorded.

Figure 1



Figure 2







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Electronic Supplementary Material
Supplementary_material_1.docx

