Physics AUC, vol. 27, 85-94 (2017) PHYSICS AUC

Changes in the mortality related to cerebrovascular diseases in a warmer climate – case study for Dolj county, Romania

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Abstract

The changes in the mortality related to cerebrovascular diseases in the context of climate change scenarios are investigated for the area of Dolj County, Romania. The study employs several data sources: (a) medical data, aggregated monthly, during 2003-2013 and provided by the Authority for Public Health Dolj; (b) meteorological data for daily maximum and minimum air temperature, daily mean relative humidity and daily mean atmospheric pressure, provided by the freely available ROCADA dataset; (c) results of numerical experiments performed with three regional climate models within EUROCORDEX, for the RCP45 and RCP85 climate change scenarios for near-term (2021-2050) and long term (2071-2100) time horizon. The use of regression models (multilinear, polynomial and Poisson generalized linear model) confirms the strong influence of monthly mean temperature on the seasonal variability of the monthly mortality due to cerebrovascular diseases. The results also highlight that the effect of some sub-monthly climatic characteristics, such as the pronounced thermal discomfort, may be visible in the monthly mortality data. By applying the multilinear regression model accounting for minimum and maximum air temperature and mean relative humidity, the analysis of projected climatic changes reveals an overall decrease of mortality due to cerebrovascular diseases in the area investigated, more pronounced during winter.

Keywords: cerebrovascular diseases, mortality, thermal discomfort, climate change

1. Introduction

The fifth report of Intergovernmental Panel on Climate Change marks as 'virtually certain' the increase of weather episodes with high temperatures along with a reduction in the occurrence of cold temperature extremes over most land areas on daily and seasonal timescale, as the mean air temperature increases (IPCC, 2014). High-resolution climate change projections for Europe (Jacob et al, 2014) indicate more frequent heatwaves, especially in the Southern Europe. In Romania, the climate change projections highlight also the increase of mean air temperature (e.g. Busuioc et al, 2010, Bojariu et al, 2015), the increase in the number of heatwaves and in the number of tropical nights (Bojariu et al, 2015). As a result, the heat-related mortality may increase, particularly in areas where the mortality risk is associated with significant vulnerability of population (e.g. large proportion of elderly population, low socio-economic living conditions,

limited access to medical care etc) or with additional local climatic effects as the enhancement of temperatures due to the urban heat island effect in urban areas. Conversely, the heat-related mortality may be attenuated by adaptation/mitigation measures targeting, among others, the vulnerability factors.

In the recent years, a growing number of studies have projected future heat-related mortality due to climate change (e.g. Baccini et al, 2009; Dessai, 2003; Peng et al, 2011; Sheridan et al, 2012; Ostro et al, 2012), most of them predicting substantial increases (Petkova et al, 2014). The main cause of heat-related mortality is linked with cardiovascular diseases (e.g. de Blois et al, 2015), but other medical conditions (e.g. cerebrovascular diseases) may be involved too under extreme temperature episodes. The studies targeted various geographical locations and/or spatial scales, but there is no study- to the authors' best knowledge – to address this issue for the Romanian territory or any region within it.

We aim to investigate the potential changes in the mortality related to cerebrovascular diseases as a sub-category of heat-related mortality in Dolj county, under the most recent climate change scenarios. Dolj county is one of the official administrative divisions within South-West Oltenia region, situated in the South-Western corner of Romania. Regarding the climate conditions, Dolj county is characterized by a temperate climate with Mediterranean influences, with significant sub-monthly variations of air temperature (especially during winter), air pressure (during cold season) and humidity (during whole year). The area of Dolj county also experiences pronounced thermal discomfort (up to 17 days during July, as a long-term average). For this study, we employ several data sources -observational data regarding the mortality stratified at monthly scale on cause of death, long-term climatological data derived from observations as well as climate projection information for near-term and long-term time horizont. This study makes use and extends a previous analysis (Velea et al, 2017) performed for the same region but accounting for four causes of death.

2. Data and methods

The monthly number of deaths in Dolj county for the period 2003-2015, classified by the main cause of death is provided by the Authority for Public Health of Dolj county. Data regarding four categories of cardiovascular diseases (myocardial infarction, hypertension, cerebrovascular diseases and other ischemic diseases) is available; however, as a previous analysis (Velea et al, 2017) showed that mortality related to cerebrovascular diseases (CD) presents the strongest link with the seasonal climate fluctuations, we use only this type of data in this study. The mortality data includes all deaths in a category registered in Dolj county, regardless of the age, gender or area of residence (urban/rural) of the individuals. The local climate conditions are described using the freely available meteorological data from ROCADA dataset (Dumitrescu and Birsan, 2015). ROCADA provides daily mean values for 9 meteorological parameters during the period 1961-2013, in a 0.1x0.1 deg. grid over the entire Romanian territory; from these, daily minimum (Tmin) and maximum temperature (Tmax) and daily mean relative humidity (RH) are employed in the present study; a daily temperature range (DTR), defined as the difference between Tmax and Tmin for each day, was also computed. As the ROCADA dataset contains information only until 2013, the medical data was selected such that it has a common period for the analysis, namely January 2003- December 2013.

In order to account for the spatial variations of the meteorological parameters over the area of Dolj county, we selected 84 gridpoints in ROCADA dataset covering the area of interest (Fig. 1). The daily mean values for the selected gridpoints are used to compute the area-average long-term monthly means (1970-2000), as well as the monthly mean values for each year of the period under study (2003-2013) for the three atmospheric parameters considered.

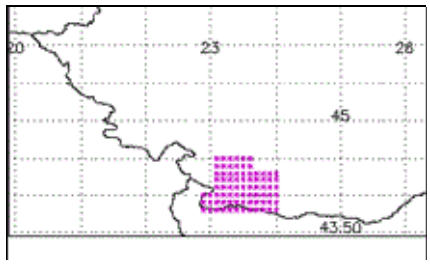

Fig.1. Selected gridpoints from ROCADA dataset covering the area of Dolj county.

Furthermore, several climatic indices relating to severe weather conditions – pronounced thermal discomfort, below/above normal low and high temperatures, large daily temperature amplitude - are derived for each of the selected gridpoints and their arithmetical means over the area of interest are used in the study. As these indices refers to sub-monthly time scales of atmospheric situations (e.g. cold spells, heat waves, specific synoptic configurations), they were aggregated at monthly scale in the form of categorical variables (yes/no values). The extreme weather indices derived are defined as follows:

- months with at least 3 days with pronounced thermal discomfort, expressed through values of the Temperature-Humidity Index (THI) equal or above the threshold of 80 units. The THI index (Dobrinescu et al, 2015) is one of the thermal stress indices recommended by WMO and defined by the formula:

$$THI = (T * 1.8 + 32) - (0.55 - 0.55 * RH/100) * (T * 1.8 - 26) \qquad (1)$$

where T is the air temperature (°C) and RH is the relative humidity (%). In Romania, THI is used to characterize thermal discomfort during warm season and it is routinely forecasted and disseminated to population from May to September. It is also used in the Romanian legislation to define extremely high temperature episodes: these conditions are met when either air temperature exceeds 37°C or the equivalent felt temperature, expressed through THI values, exceeds 80 units.

-months with at least 3 days of below-normal low temperatures. The latter conditions were defined in relation with long-term monthly mean of Tmin, such that the daily minimum temperature to be less than the long-term monthly mean of Tmin with at least 1 standard deviation (of the long-term monthly mean):

$$(\mathrm{Tmin})_{\mathrm{daily}} \leq (\mathrm{Tmin})_{\mathrm{long\text{-}term\_mean}} - 1*\mathrm{STDEV} \qquad (2)$$

-months with at least 3 days of above-normal high temperatures, the latter being defined as daily minimum temperature larger than the long-term monthly mean of Tmax with at least 1 standard deviation:

$$(\mathrm{Tmax})_{\mathrm{daily}} \geq (\mathrm{Tmax})_{\mathrm{long\text{-}term\_mean}} + 1*\mathrm{STDEV} \qquad (3)$$

-months with at least 3 days of large daily variations of temperature (DTR $\geq$14 ^{o}C).

The threshold values in the definitions above, regarding the minimum number of days in a month, the deviation from the long-term monthly mean of Tmin and Tmax, as well as DTR values were chosen through a trial-and-error procedure; the range of these values varied from 1 to 5 for days with extreme temperatures of thermal discomfort, 1 or 2 standard deviations for the definition of below/above normal or extremely low/high temperatures, 10 to 17°C for DTR. The values finally selected lead to the most relevant results in the analysis.

The potential changes in the CD mortality in Dolj County in the context of climate changes are investigated by employing results of high resolution numerical simulations performed within EURO-CORDEX (http://www.euro-cordex.net/). As part of the WCRP Coordinated Regional Downscaling Experiment (CORDEX, http://wcrp-cordex.ipsl.jussieu.fr; Giorgi et al. 2006), EURO-CORDEX provides regional climate projections for the European area at 50km (EUR-44) and 12.5 km (EUR-11) spatial resolutions, which downscales the global climate simulations from the CMIP5 (Taylor et al, 2012) long-term experiments up to the year 2100.

The climate projections used in this study are based on two greenhouse gas emission scenarios (Representative Concentration Pathways, RCPs): (a) corresponding to stabilization of radiative forcing after the 21st century at 4,5 W/m² (RCP45) and (b) rising radiative forcing crossing 8,5 W/m² at the end of 21st century (RCP85) (Moss et al., 2010 and 2008; Nakicenovic et al., 2000; Van Vuuren et al., 2008). We employ the results regarding monthly values of Tmin, Tmax and RH from three models (Table 1) run within EUR-11 experiment. The results of the historical runs (1971-2000) are used to establish the model climatology and further, as a reference for changes in the near-future (2021-2050) and on longer term (2071-2100).

RCM model	**Running Center**	**Spatial resolution**	**References**	**Acronym used in this study**
RACMO2.2	Royal Netherlands Meteorological Institute (KNMI)	0.11x0.11deg.	Meijgaard van et al. (2012)	KNMI_RACMOE22
RCA4	Swedish Meteorological and Hydrological Institute (SMHI)	0.11x0.11deg.	Samuelsson et al. (2011), Kupiainen et al. (2011)	SMHI_RCA4
HIRHAM5	Danish Meteorological Center (DMI)	0.11x0.11deg.	Christensen et al. (1998)	DMI_HIRHAM5

Table 1. Characteristics of the regional climate models providing output data for this study, based on simulations performed within EUROCORDEX.

The relationship between CD mortality and climate conditions is investigated through the analysis of the available time-series. The analysis is performed using the Interactive Data Language (IDL) software, which comprises dedicated routines and functions for statistical analysis. Three regression models accounting for the variations in the monthly mean values and/or the categorical indices, are employed aiming to investigate the relative influence of the atmospheric parameters on the monthly mean mortality related to cerebrovascular diseases. The regression models are derived based on mortality and ROCADA data for the period 2003-2013; the multilinear regression model is further applied on the climate projection data.

3. Results

3.1 Relative influence of meteorological parameters on the CVD-related mortality in the current climate conditions. Regression models

In the attempt of estimating the relative influence of the climatic parameters on the monthly CD mortality, we employ three regression models (multilinear, polynomial, Poisson regression) to reproduce the characteristics of mortality time-series. The Pearson correlation coefficients between the observed and modelled data, together with the predictors used for each model, are shown in Table 2.

Regression model type	**Predictors**	**Pearson correlation coefficient between the observed and modelled time-series**
Multilinear	Monthly mean values of **Tmin, Tmax, RH**	0.700
3rd order Polynomial	**Tmin**	0.692
Poisson Generalized Linear Model	3 categorical variables: (1) months with thermal discomfort, (2) extremely low temperatures (3) large daily temperature amplitude 3 continuous variable: monthly mean **Tmin, Tmax, RH**	0.699

Table 2. Characteristics of regression models applied for modelling the monthly mortality due to cerebrovascular diseases.

It may be easily observed that the best results are produced by the multilinear regression model which takes into account the monthly mean values of Tmax, Tmin and RH; these are the predictors with the highest correlations with the mortality data and, consequently, the regression model fits well the observed time-series with regards to temporal variability (Fig.2). The peaks of the mortality data are strongly underestimated, especially in the first part of the time-series. A very similar result is obtained when employing a 3rd order polynomial regression model which uses monthly mean Tmin (or Tmax; not shown) as predictor; using a higher order for the fit function does not improve the model performance.

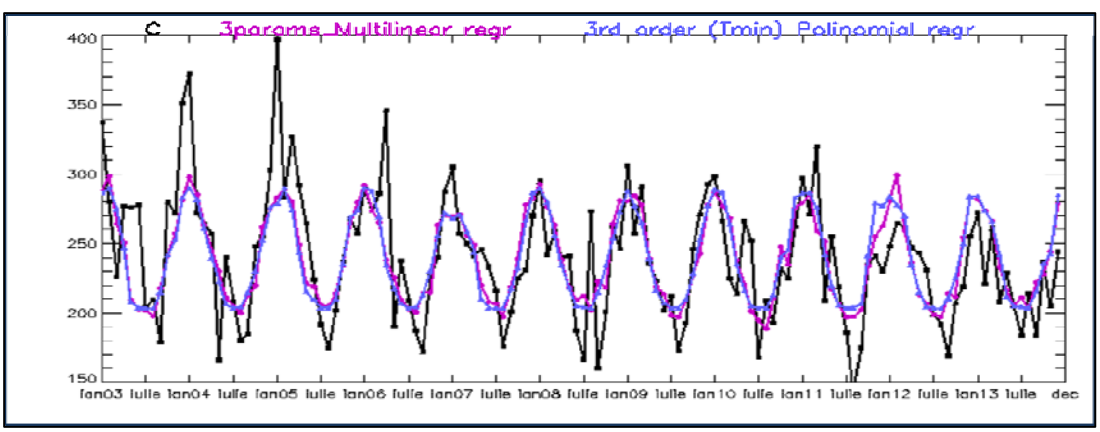

Fig. 2. Observed (black) and modelled time-series of mortality due to cerebrovascular disease using a multilinear (pink line) and a 3rd order polynomial (blue line) regression model.

Assuming that sub-monthly climatic characteristics may have a contribution to the peaks in the observed time-series, we apply a Poisson generalized linear model, which accounts for three continuous variable (monthly mean Tmin, Tmax and RH) and three categorical variables described in Section 2. The model performance is very similar with those of the linear and polynomial models, the amplitude of variations in the observed time series being underestimated as before (not shown). By using as thermal discomfort categorical data the warm months (JJA) instead of months with at least 3 days with THI≥80, the correlation coefficient between the observed and the modelled time-series is slightly reduced – to 0.618 instead of 0.69, suggesting that exposure to pronounced thermal discomfort does have a contribution to the mortality rate visible even at monthly scale. However, the impact of sub-monthly climatic variations is not as evident at this time-scale as for example when using daily data. The studies employing a high temporal frequency in data aggregation allow for a much finer analysis including the determination of an 'optimal' temperature corresponding to the lowest daily mortality rate (e.g. Honda et al, 2007; Iniguez et al, 2010) and may provide a sounder foundation for designing prevention measures in the public health sector.

3.2 Changes in the CD-related mortality under climate change scenarios

Using the outputs of climate scenarios simulations based on the three regional climate models described in Table 1, we try to estimate the relative changes in the number of deaths due to cerebrovascular diseases in the near future (2021-2050) and on longer term (2071-2100) in the context of RCP45 and RCP85 climate change scenarios. We apply the multilinear regression model based on the monthly minimum and maximum air temperature, as well as on the monthly mean relative humidity. The expected changes in atmospheric parameteres for Dolj county are obtained from the EUROCORDEX regional climate models simulations. The model data is extracted from a domain of 72 grid points neighboring the ROCADA points, thus assuring a good coverage of the area of interest. We first compute, for each model, the area-averaged of monthly mean value of Tmin, Tmax and RH for each scenario (i.e. RCP45 or RCP85) and each period (2021-2050 and 2071-2100), as well as the reference climatology provided by HIST simulations (1971-2000). The arithmetic mean of the three RCM timeseries, for each parameter, is employed in the regression model, to simulate the evolution of number of deaths due to cerebrovascular diseases under the simulated future conditions.

Since the regression model explains about 70% of the variance in the original mortality data, we do not expect to simulate accurately the quantitative changes in the mortality. We may still get an estimation of the impact of changes of atmospheric parameters, by looking at the relative change in the mortality under the conditions described by the climate change scenarios compared to the historical simulations. Therefore, we apply the multilinear regression model for the 3 RCMs-averaged timeseries for each parameter, then we compute the relative change (in %) between the RCP experiment and HIST simulation, for each period considered. We obtain 4 timeseries of relative changes (in %) in the CD monthly mortality under the conditions of RCP45_2021-2050, RCP45_20271-2100, RCP85_2021-2050 and RCP85_2071-2100, compared to HIST_1971-2000. Under the projected climate changes, both Tmin and Tmax increase compared to HIST conditions with an average value (over 30 year period) between 1.4-1.5 ^{o}C

(under RCP45_2021-2050 conditions) to 4.3-4.2 °C (the latter, under RCP85_2071-2100 conditions), while RH slightly decreases (maximum -2.6% under RCP85_2071-2100 conditions).

The results show an overall decline of CD mortality for each period compared to the reference period– from a mean decrease of -0.96% during 2021-2050 under RCP45 scenario, to -3.57% during 2071-2100 under RCP85 scenario. The decrease is manifesting during all seasons, slightly more often (as number of months) being found during winter. The average amplitude of the relative decrease in CD mortality is largest during winter (up to -7.4% under the RCP85 scenario for the period 2071-2100), followed by spring and fall for all periods and for both scenarios analyzed. At monthly scales, December and January present the largest frequency within the months with decreasing CD mortality, as well as the largest amplitude of decrease, for all scenarios and periods analyzed (Fig. 3 and Fig. 4). Secondary peaks are found for March, May and August in terms of frequency and for February and November in terms of the amplitude of decreasing CD mortality.

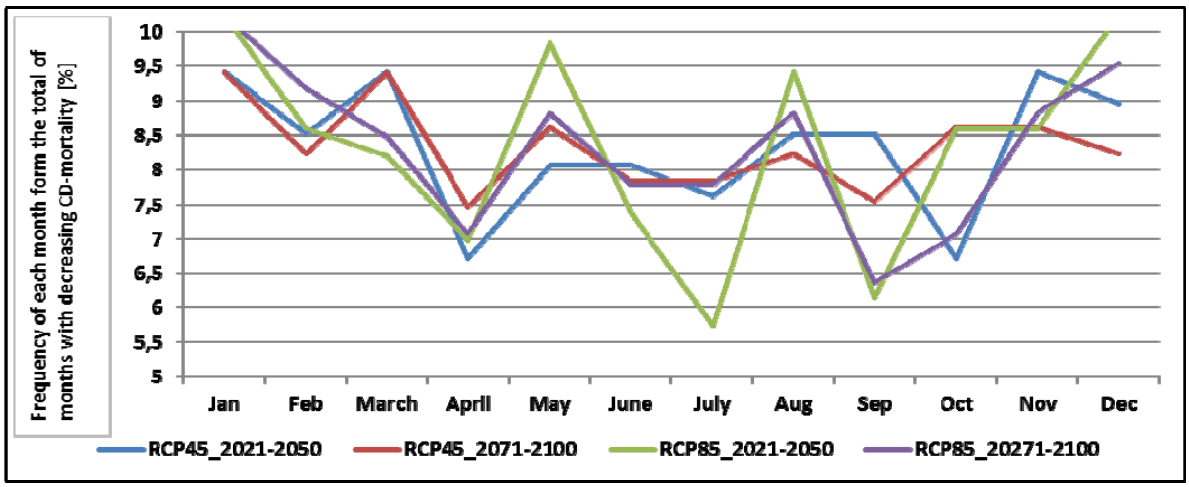

Fig. 3 Frequency [%] of each month with decreasing CD mortality compared to the reference simulation, within the total number of decreasing months under climate change scenarios.

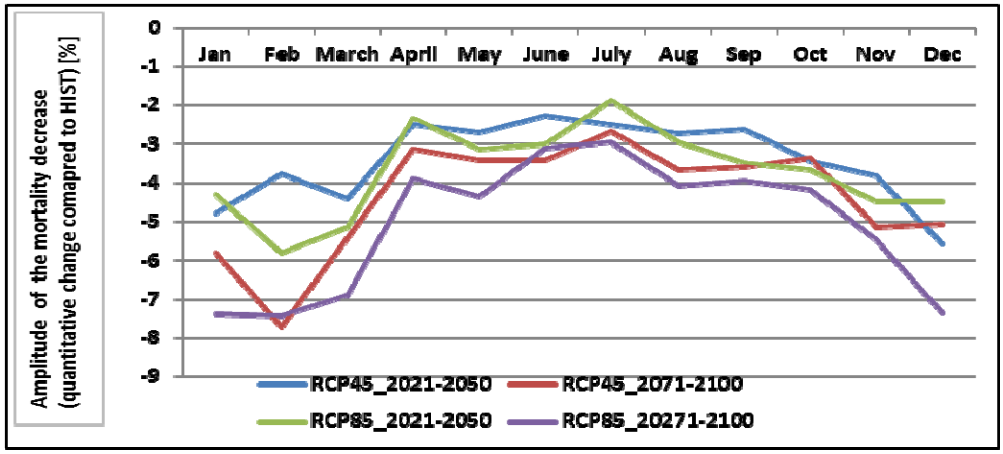

Fig. 4 Mean monthly amplitude [%] of decreasing in CD mortality under climate change scenarios relative to the same period in the reference simulations.

There are also cases (months) when the CD mortality increases compared to the reference period, mainly during summer and fall (up to 30-35% from all months when increasing CD mortality is found). The amplitude of the relative increase in CD mortality is larger during winter months (around 3.5%) for the period 2021-2050 under both scenarios, followed by either fall (RCP45 scenario) or spring (for RCP85 scenario), while for the period 2071-2100 it has quite similar values during all seasons.

The overall decrease of CD mortality under climate change scenarios is, apparently, in opposition with the results of other studies (e.g. Gasparini et al, 2017; Petkova et al, 2014) which indicates an increase of heat-related mortality under warmer climate conditions. However, the comparison is limited by several factors, of which the most apparent one is the time-scale of mortality data: we used monthly mortality data, while all other studies employ daily data, which is not available for the region under consideration in this study. The focus on the heat-related cause of death is another important methodological difference in explaining the apparently contradictory results: while other studies employ all heat-related mortality (e.g. Gasparini et al, 2017; Weinberger et al, 2017; Petkova et al, 2014) or cardiovascular diseases related deaths (e.g. Li et al, 2015; de Blois et al, 2015) we consider only the mortality related to cerebrovascular diseases. Our previous study (Velea et al, 2017) showed that CD mortality in Dolj county presented the strongest seasonal pattern from the four causes of deaths analyzed, with a maximum in winter, in agreement with other studies (e.g. Zhang et al 2015). Warmer winters thus may lead to a lower CD mortality, as found in the present study. Also, the CD-related mortality data employed presents a decreasing linear tendency for the period of analysis (2003-2013), obviously due to other factors than climate conditions. This linear decreasing tendency is included in the multilinear regression model developed and further applied to the climatic projections, thus it has an additional contribution (e.g. as an adaptation/mitigation factor) to the overall decreasing CD-mortality under climate change conditions as found in this analysis; in all other similar studies, the impact of adaptation/mitigation measures of climate change effects was not considered or considered solely through the characteristics of the climate change scenarios (e.g. RCP26 and RCP45 include mitigation policies, contrary to RCP6 and RCP85, Gasparini et al, 2017).

4. Conclusions

The relationship between the monthly climatic characteristics and the mortality due to cerebrovascular diseases for Dolj county is investigated with the use of regression models, which are further applied to climate change conditions based on two RCP scenarios. The results show that the combination of three climate parameters – Tmin, Tmax and RH – explains 70% of the variability in the mortality data. The impact of sub-monthly climatic variations – although detectable to some degree - is not as evident at this time-scale as for example when using daily data. The analysis of CD mortality under climate change conditions, based on the multilinear regression model developed in the first step, indicates an overall decrease in both scenarios analyzed, more pronounced toward the end of the century and especially under the warmest scenario. This is probably due to the observed linear decrease tendency of CD mortality which is further applied to climate projections through the multilinear regression model, as an

adaptation/mitigation factor (e.g. due to improvement in medical prevention, better access to health facilities, improved socio-economic conditions and life-style etc).

The findings of the study have some limitations that should be addressed in future research, such as, for instance, the lack of stratification of the medical data related to CD mortality based on age, gender, socio-economic conditions or area of residence (urban/rural), the monthly scale of mortality data or the limited geographical region considered. Furthermore, additional information is needed to document the secondary influences of other illness for the people who deceased from cerebrovascular diseases as well as the impact of other factors (e.g. socio-economic, age etc.) on the decreasing trend in the observed CD-related mortality.

References

Baccini, M.; Biggeri, A.; Accetta, G.; Kosatsky, T.; Katsouyanni, K.; Analitis, A.; Anderson, H.R.; Bisanti, L.; D'Ippoliti, D.; Danova, J.; et al. (2008): Heat effects on mortality in 15 European cities. *Epidemiology*, *19*, 711–719.

Bojariu R, Bîrsan MV, Cică R, Velea L, Burcea S, Dumitrescu A, Dascălu SI, Gothard M, Dobrinescu A, Cărbunaru F, Marin L (2015): Climate changes-from physical basis to risks and adaptation (in Romanian), *Editura Printech*, București. 200 p., ISBN: 978-606-23-0363-1, available also from http://www.meteoromania.ro/anm/?page_id=2893 , DOI: 10.13140/RG.2.1.1341.0729

Busuioc A, Caian M. Cheval S, Bojariu R, Boroneant C, Baciu M, Dumitrescu A (2010): Variability and climate change in Romania (in Romanian), *Editura Pro Universitaria*, București, 228 p

Christensen OB, Christensen JH, Machenhauer B, Botzet M (1998): Very high-resolution regional climate simulations over Scandinavia— Present climate. *J Climate*, 11:3204–3229

de Blois, J., Kjellstrom , T., Agewall , S., Ezekowitz . J.A., Armstrong, P.W., Atar, D. (2015): The Effects of Climate Change on Cardiac Health. *Cardiology* 2015;131:209–217 DOI: 10.1159/000398787

Dessai, S. (2003): Heat stress and mortality in Lisbon Part II. An assessment of the potential impacts of climate change. *Int. J. Biometeorol*, *48*, 37–44.

Dobrinescu, A., Busuioc, A., Birsan, M.V., Dumitrescu, A. and Orzan, A. (2015): Changes in thermal discomfort indices in Romania and their connections with large-scale mechanisms, *Clim. Res.,* 01/2015; DOI:10.3354/cr01312

Dumitrescu A. and Birsan, M.V. (2015): ROCADA: a gridded daily climatic dataset over Romania (1961–2013) for nine meteorological variables, *Nat. Hazards*, Volume 78, Issue 2, pp 1045-1063, doi: 10.1007/s11069-015-1757-z

Gasparini, A. et al (2017): Projections of temperature-related excess mortality under climate change scenario, *Lancet Planet Health*, http://dx.doi.org/10.1016/S2542-5196(17)30156-0

Honda, Y., Kabuto, M., Ono, M., & Uchiyama, I. (2007). Determination of optimum daily maximum temperature using climate data. *Environmental Health and Preventive Medicine*, 12(5), 209–216. http://doi.org/10.1265/ehpm.12.209

Iñiguez, C., Ballester, F., Ferrandiz, J., Pérez-Hoyos, S., Sáez, M., & López, A. (2010). Relation between Temperature and Mortality in Thirteen Spanish Cities. *International Journal of Environmental Research and Public Health,* 7(8), 3196–3210. doi:10.3390/ijerph7083196

IPCC (2014): Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Jacob, D., Petersen, J., Eggert, B. et al. (2014): EURO-CORDEX: new high-resolution climate change projections for European impact research, *Reg Environ Change* 14: 563. https://doi.org/10.1007/s10113-013-0499-2

Kupiainen M, Samuelsson P, Jones C, Jansson C, WillénU, Hansson U, Ullerstig A, Wang S, Döscher R (2011) : Rossby Centre regional atmospheric model, RCA4. *Rossby Centre Newsletter*, June

Li, T., Ban, J., Horton, R.M., Bader, D.A., Huang, G., Sun, Q., Kinney, P.L. (2015): Heat-related mortality projections for cardiovascular and respiratory disease under the changing climate in Beijing, China. *Scientific Reports* | 5:11441 | DOI: 10.1038/srep11441

Meijgaard E van, Van Ulft LH, Lenderink G, de Roode SR, Wipfler L, Boers R, Timmermans RMA (2012): Refinement and application of a regional atmospheric model for climate scenario calculations of Western Europe. *Climate changes Spatial Planning* publication: KvR 054/12, ISBN/EAN 978-90-8815-046-3, pp 44

Moss RH, Edmonds JA, Hibbard KA, Manning MR, Rose SK, van Vuuren DP, Carter TR, Emori S, Kainuma M, Kram T, Meehl GA, Mitchell JFB, Nakicenovic N, Riahi K, Smith SJ, Stouffer RJ, Thomson AM, Weyant JP, Wilbanks TJ (2010): The next generation of scenarios for climate change research and assessment. *Nature* 463:747–756. doi: 10.1038/nature08823

Nakicenovic, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K., Grubler, A., Jung, T.Y., Kram, T., La Rovere, E.L., Michaelis, L., Mori, S., Morita, T., Pepper, W., Pitcher, H., Price, L., Riahi, K., Roehrl, A., Rogner, H.-H., Sankovski, A., Schlesinger, M., Shukla, P., Smith, S., Swart, R., van Rooijen, S., Victor, N. and Z. Dadi (2000): IPCC Special Report on Emissions Scenarios**.** *Cambridge University Press*, Cambridge, United Kingdom and New York, NY, USA. 599 pp.

Ostro, B.; Barrera-Gomez, J.; Ballester, J.; Basagana, X.; Sunyer, J. (2012): The impact of future summer temperature on public health in Barcelona and Catalonia, Spain. *Int. J. Biometeorol.*, 56, 1135–1144.

Peng, R.D.; Bobb, J.F.; Tebaldi, C.; McDaniel, L.; Bell, M.L.; Dominici, F. (2011): Toward a quantitative estimate of future heat wave mortality under global climate change. *Environ. Health Perspect.***,** 119, 701–706.

Petkova, E.P., Bade, D.A., Anderson, G.B., Horton, R.M., Knowlton,K., Kinney P.L., (2014): Heat-Related Mortality in a Warming Climate: Projections for 12 U.S. Cities. *Int. J. Environ. Res. Public Health* **2014**, *11*, 11371-11383; doi:10.3390/ijerph111111371

Samuelsson, P., Jones, C. G., willén, U., Ullerstig, A., Gollvik, S., Hansson, U., Jansson, C., Kjellström, E., Nikulin, G. and Wyser, K. (2011), The Rossby Centre Regional Climate model RCA3: model description and performance. *Tellus A*, 63: 4–23. doi:10.1111/j.1600-0870.2010.00478.x

Sheridan, S.; Allen, M.; Lee, C.; Kalkstein, L. (2012): Future heat vulnerability in California, Part II: Projecting future heat-related mortality. *Clim. Change*, *115*, 311–326.

Taylor K. E., Stouffer R. J., Meehl G. A. (2012): An overview of CMIP5 and the experiment design. *Bulletin of the American Meteorological Society*, **93**, 485-498, doi:10.1175/bams-d-11-00094.1.

van Vuuren DP, Edmonds J, Kainuma M, Riahi K, Thomson A, Hibbard K, Hurtt GC, Kram T, Krey V, Lamarque J-F, Matsui T, Meinshausen M, Nakicenovic N, Smith SJ, Rose SK (2011) Representative concentration pathways: an overview. *Climatic Change* 109:5–31. doi: 10.1007/s10584-011-0148-z

Velea, L., Udristioiu, M., Bojariu, R., Sararu, L. and Prunariu, L. (2017): The Influence of Climate Conditions on the Mortality Related to Cardiovascular Diseases in Dolj County (Southern Romania). TIM 15-16 Conference Proceedings, doi: 10.1063/1.4972381.

Weinberger KR, Haykin L, Eliot MN, Schwartz JD, Gasparrini A, Wellenius GA (2017): Projected temperature-related deaths in ten large U.S. metropolitan areas under different climate change scenarios, *Environ Int.*, doi: 10.1016/j.envint.2017.07.006

Zhang, X.J., Ma, W.P., , Zhao, N., Wang, X.(2015): Time series analysis of the association between ambient temperature and cerebrovascular morbidity in the elderly in Shanghai, China, *Scientific Reports* | 6:19052 | DOI: 10.1038/srep19052