DETECTION OF URBAN SUMMER WARMING IN TEMPORAL CHANGE OF HEAT STRESS-RELATED INDICES IN THE ROMANIAN PLAIN REGION

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Key-words: urban and suburban areas, summer temperature change, heat stress, Romanian Plain.

The study presents evidence of an increased frequency of hot temperatures and the corresponding urban heat stress in southern Romania, in response to the observed changes in the upper tails of the probability density function distribution of summer daily maximum temperatures, since the mid 1980s. This paper discusses the seasonal variability trends of some relevant heat stress-related indices, yet not directly comparable by their definitions, derived from daily minimum and maximum temperature *in situ* measurements. The analyses aimed also at assessing the change in the frequency, persistence and magnitude of heat stress at six weather stations located in the Romanian Plain Region, found representative for urban and suburban thermal conditions. The study suggests that, during the last decades, the cities in the Romanian Plain Region experienced a significant increase of heat stress under a higher occurrence probability of hot summer days and nights and prolonged heat waves, corrensponding to a growing need for cooling in summer, as well as in early autumn and late spring months, in response to the recent seasonal trends in minimum and maximum temperatures.

1. INTRODUCTION

Europe's climate is changing and air temperatures are projected to increase at levels higher than the global average, at a rate of about 2–6°C by the end of the 21st century (EEA, 2008, 2012b). In addition, Europe exhibits regions of relative large changes in the frequency of some extreme events (e.g. floods, heat waves, storms, droughts) and this pattern is projected to amplify by the end of the 21st century (Beniston *et al*., 2007; IPCC, 2013), posing serious threats to human health, physical assets and economic activities in most European cities, as well as great challenges for their adaptation to climate change. Recent outstanding examples stand for the European summer heat wave of 2003, which resulted in 80,000 excess deaths across twelve European Countries (Brücker, 2005; Sardon, 2007; Robine *et al*., 2008) and the intense heatwave in Eastern Europe of 2010 (Russia), which determined 55,000 deaths (Barriopedro *et al*., 2011, NatCatService, 2012). Rosenzweig *et al*. (2011) emphasized that worldwide, many cities had already faced significant climatic and environmental challenges, related to the urban heat island effect, air pollution and existing disruptive climatic extremes (e.g. typhoons, hurricanes).

Climate change is increasingly being discussed as an emerging global security issue (UNEP, 2012) and cities are greatly aware of the need to prepare for coping with greater variability in temperature, precipitation, as well as an intensification of weather extremes (*Guide to climate adaption in cities*, 2011). In 2013, the Carbon Disclosure Project (http://www.cdpproject.net) published the summary (the third consecutive year) of the most comprehensive survey carried out on global cities and climate change. The selected cities account currently for just over 1 billion tonnes of greenhouse gas emissions and report over 1,000 individual actions designed to reduce emissions and adapt to a changing climate. The results of this survey showed that most participatory cities (110) have

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Rev. Roum. Géogr./Rom. Journ. Geogr., **57**, (2), p. 105–117, 2013, Bucureşti.

experienced significant climate change-related risks, the "temperature increase/heat waves" (88) and "more intense/frequent rainfall" (81) being the most commonly risk categories identified. A similar pattern was also observed among the participatory European cities (30) (Fig. 1).

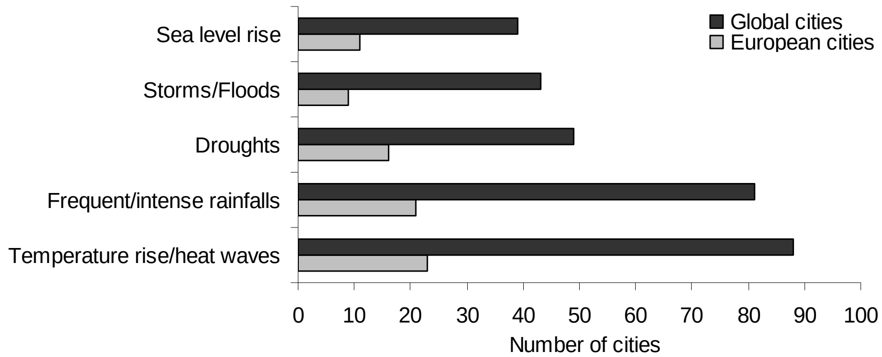

Fig. 1 – Climate change-related risks reported by global and European cities (After: GDP Report, 2013).

The European Commission has recently adopted (April 2013) its first EU strategy on Adaptation to Climate Change, which explicitly states the aim to promote climate adaptation actions in European cities. Furthermore, the proposal of the EU Multi-annual Financial Framework for the period 2014–2020 foresees a much higher share (20%) of the budget for climate change actions, including the support for both adaptation and mitigation of climate change impacts in urban areas. In support, the recently established European Climate Adaptation Platform CLIMATE-ADAPT (http://climate-adapt) brings together adaptation case studies, the outputs of European complementary research projects (e.g. EU Cities Adapt project) and guidance on adaptation planning. Currently, a rather small number of European cities and urban regional governments have developed or are in the early stages of implementing local plans for climate change adaptation (e.g. Copenhagen, London).

In response to the EU Green Paper "Adapting to climate change in Europe – options for EU action", in 2008 the Ministry of Environment and Forests of Romania developed the "*Guide to the adaptation to the climate change effects*" (GASC), approved by Ministerial Order (no. 1170/2008), providing a set of recommendations aiming at reducing the negative effects of climate change in 13 key sectors (agriculture, biodiversity, water resources, forests, infrastructure, construction and urban planning, transport, tourism, energy, industry, health, recreational activities and insurance). The National Climate Change Strategy 2012–2020 (launched in December 2011 for public debate), has no special referees on climate change adaptation for cities. As regards local climate adaptation actions, worth mentioning is the initiative of the Romanian Municipalities Association to assess climate change risk and its implications for public services and local communities, as well as their capacity to adapt to climate change. Climate change has been increasingly recognized as a major challenge for European cities to adapt to and cope with its related effects. The EU Cities Adapt aims at providing capacity building and assistance in developing and implementing local adaptation strategies for 21 cities. The Sfântu Gheorghe town is the only Romanian one participating in this action.

The present study is focussed on understanding the challenge of coping with signficant summer warming in some urban areas of medium (Roşiori de Vede, Călăraşi), large (Craiova, Buzău, Galați) and very large-size (Bucureşti), located in southern Romania (the Romanian Plain Region). Relative to other countryside regions, the thermal discomfort in the cities located in the Romanian Plain is rather strong during summer months (Table 1), in response to the intense and prolongued warm and dry spells, whose occurrence was rather frequent in the last decade (Georgescu *et al*., 2013). This research has sought to investigate the frequency and magnitude of summer warming in southern Romania, as a measure of the general physical exposure of urban communities to the heat stress. In Europe, the summer heat stress is closely related to the increase of mortality rate of urban population in recent years, from 7.6% in 1990 to 33.6% in 2004 (D'Ippoliti *et al.*, 2010).

Table 1

Types of bioclimatic thermal discomfort at some weather stations located in the Romanian Plain (1961–1990) (After Ionac and Ciulache, 2008).

Weather stations	DI-Thom (°C)			HUMIDEX (°C)			Scharlau (units)		
	Jun	Jul	Aug	Jun	Jul	Aug	Jun	Jul	Aug
Bucureşti–Băneasa	Moderate discomfort (24–27)			Discomfort (30–40)			Significant discomfort (<-3)		
Buzău	Slight discomfort (21–24)	Moderate discomfort (24–27)		Discomfort (30–40)			Significant discomfort (<-3)		
Călăraşi	Significant discomfort (27–29)			Discomfort (30–40)			Significant discomfort (<-3)		
Craiova	Moderate discomfort (24–27)			Discomfort (30–40)	Significant discomfort (40–55)		Significant discomfort (<-3)		
Galați	Slight discomfort (21–24)	Moderate discomfort (24–27)		Discomfort (30–40)			Significant discomfort (<-3)		
Roşiori de Vede	Moderate discomfort (24–27)			Discomfort (30–40)	Significant discomfort (40–55)		Significant discomfort (<-3)		

2. DATASETS AND INDICES

The analysis is based on the daily mean, minimum and maximum temperature records from six weather stations (Table 2), available from the European Climate Assessment and Datasets project (http://www.eca.knmi.nl), which cover a 49-year period of observations (1961–2009). The non-blended temperature time-series were checked for inconsistencies and outliers, using the RClimdex package. The daily temperature time-series used in this study have no missing data. The weather stations used in this work reflects both urban and suburban climatic conditions (Table 2). According to Raliță (2005), most of the selected stations have open meteorological platforms and no/or no major nearby natural or anthropic obstacles were identified to add inhomogeneities to the *in situ* temperature measurements (except for Bucureşti–Băneasa, located in a nearby forest and orchard area). No site relocations have been reported during the 49-year period surveyed in this study.

Table 2

Weather stations location parameters and settings.

Weather station	**Latitude**	**Longitude**	**Altitude**	**Station type**	**Relief units**
Bucureşti–Băneasa	44°30'	26°08'	90 m	Urban	Vlăsia Plain
Buzău	45°09'	26°49'	97 m	Suburban	Buzău Plain
Călăraşi	44°12'	27°21'	19 m	Urban	Danube Floodplain
Craiova	44°19'	23°52'	192 m	Periurban	Contact between the Olteț Piedmont and the Romanați Plain
Galați	45°29'	28°02'	69 m	Urban	Galați Plain
Roşiori de Vede	44°06'	24°59'	102 m	Periurban	Boianu Plain

The paper is focused on high-impact hot weather phenomena that have affected the southern Romania region frequently and severely during the last decades (e.g. hot days, hot nights, heat waves). The analysis is based on several relevant indices aiming at quantifying the response of climatological heat stress to temperature change under current climate conditions:

1. Tropical heat stress (THS), a composite index which combines the day-time (THS_{day}) and night-time (THS_{night}) heating effect of warm and dry tropical advections. The index was computed for summer by cumulating the absolute frequency of tropical days (Tmax >30°C) and nights (Tmin >20°C). Because of the urban heat island effect (UHI), minimum temperature is generally higher in urban areas compared to rural and suburban areas, tending to underestimate the heat stress exposure. No paired sites analysis was undertaken in the present study to quantify the UHI effect.

2. Combined heat stress (CHT), also a composite index between the number of tropical nights (Tmin >20°C) and hot days (Tmax >35°C), introduced by EEA (EEA, 2012a).

3. Heat waves (HW) were defined as number of consecutive days when the maximum temperature exceeded 35°C, the corresponding threshold of canicular day occurrences. This fixed threshold, roughly corresponds to the long-term daily 95th percentile of maximum temperatures within the June–August season, at all the selected weather stations, calculated for the 49-year period of observations.

4. Cooling degree-days (EEA, 2012b) is derived from daily mean temperature measurements and is defined relative to the 22°C base temperature (the outside temperature below which a building is assumed to need cooling according to STAS 6648/2, which regulates the size of cooling systems for buildings, based on external temperatures in July).

The Mann-Kendall (MK) non-parametric test was used to assess the local statistical significance of the trends and change rates in the variability of the selected heat stress indices. The MK test is a rank-based procedure and is particularly suitable for analysis of data series containing outliers. The significance threshold was set to the 5% level. The trends and change-points in the variability of summer temperature and heat stress indices were identified using the non-parametric Pettitt test, which is based on the Mann-Whitney test.

The generalized extreme value (GEV) distribution has been fitted to the 49-year time series of the highest maximum temperature summer records to assess the magnitude of some rare and severe heat wave episodes and the corresponding return periods of these records.

3. CURRENT AND FUTURE TEMPERATURE CHANGE SIGNALS IN SOUTHERN ROMANIA

The analysis of the long trends of countrywide temperature time-series (1901–2005) has indicated a significant rise of the annual average temperature by about 0.5°C (0.05°C/decade), for most regions of Romania, but yet, at higher rates in the southern and eastern ones (including the littoral area), up to 0.07–0.08°C/decade (GASC, 2008). This behaviour has been confirmed by the results of the analysis on the evolution of temperature extremes in the Romanian Plain Region over the 1961–2009 period. Regionally wide, the 49-year trends of both temperature extremes are persistently positive since the mid-to-late 1980s for most seasons, except autumn. The six selected weather stations show common variability patterns and similar seasonal change rates. Peak warming rates are specific to summer for most sites (0.5–0.6°C/decade), excepting Craiova and Bucureşti–Băneasa stations where winter warming is the largest over the period, yet at comparable rates of about 0.5°C/decade. At all the stations the entire distribution of the summer extreme temperatures shifts significantly towards higher values, most visible changes occurring in the upper tail of the maximum temperature extremes, after 1985. This shift is accompanied by a decadal change in the extreme tails of the probability density function (PDF): an increase of the 95% quantile of summer maxima (of 0.6° to 1.6°C) and a similar shift even at the 99th percentile level (of 0.6° to 2.6°C).

In one of the most comprehensive synthesis on climate variability and change in Romania, Busuioc *et al*. (2010) showed that the Extra-Carpathian regions of Romania (particularly the southern ones) are under a higher frequency and duration of warm extremes since mid-to-late 1980s or early 1990s. Furthermore, these trends pinpoint areas that appear to widely overlap those which have also experienced more frequent episodes of severe droughts in the recent decades (e.g. 2000, 2007) (Sandu *et al*., 2010). In a study conducted on the mechanisms of controlling hot summer occurrence in Romania (Busuioc *et al*., 2007), the strong summer temperature anomalies in recent years (2000, 2003, 2007) have been associated to the increased frequency of high-pressure systems in altitude (500 mb level), which were optimum correlated to positive temperature anomalies at 850 mb level centered above the South-East European territory (in terms of both spatial extension and anomalies).

The climate projections by the end of the 21st century, under A1B scenario (CECILIA FP7 Project – www.cecilia.org), indicate a further intensification of summer warming in the southern Extra-Carpathian regions:

– by maximum temperatures: at a rate ranging from 0.7–0.8°C (2021–2050) to 4.0–4.3°C (2071–2100);

– by minimum temperatures: at a rate ranging from 0.7–0.8°C (2021–2050) to 3.7–4.1°C (2071–2100);

It is also projected that some warm extremes (e.g. summer days when Tmax>25°C, tropical days when Tmax>30°C) will significantly increase in summer until 2100, at a rate of 7 to 40%.

4. RESULTS

4.1. Tropical heat stress (THS)

The tropical heat stress is considered a reliable variable in the assessment of the thermal extreme regime of urban regions, as combining the day-time and night-time heat exposure of city communities. Considering the value range of the two THS components, the Romanian Plain Region displays one of the highest tropical heat exposure in Romania. Among the cities surveyed in this study, Roşiori de Vede and Călăraşi show the highest THS_{day} (37–39 days/summer), while Galați and Buzău distinguish themselves by the highest frequency of THS_{night} (about 8 nights/summer). The large-scale circulation patterns resulting in a great tropical heat stress across the region explain the narrow value range of this index, from 36 to 44 units. Yet, peak THS values are recorded at Roşiori de Vede (41 units) and Călăraşi (44 units), while its minima are specific to Galați (36 units) and Craiova (37 units). Generally, THS_{day} has the highest share to the overall THS across the region (above 77%), while the contribution of THS_{night} does not exceed 20% (excepting Galați 22.8%) (Fig. 2a).

In response to the summer maximum and minimum temperature rise, THS is on a significant increase across the Romanian Plain Region, since the early 1980's, which marks a recent warming phase across the whole country (Fig. 2b). Table 3 indicates the decadal changes in THS components over the study period, with considerable increase in the day-time heat stress (above 100 cases at Buzău, Craiova and Roşiori de Vede), particularly between the second and third decades (Table 3). The THS trends over the period are robust (>5% level) at all the selected sites, but they are highly significant at Roşiori de Vede, Buzău, Galați and Călăraşi (0.1% level)

Table 3

Decenial variation of the day- and night-time tropical heat stress (number of cases) in urban areas of the Romanian Plain Region.

Weather stations	1961–1970		1971–1980		1981–1990		1991–2000		2001–2009	
	THS_{day}	THS_{night}	THS_{day}	THS_{night}	THS_{day}	THS_{night}	THS_{day}	THS_{night}	THS_{day}	THS_{night}
Bucureşti–Băneasa	333	30	229	10	317	30	408	12	426	20
Buzău	272	51	187	40	307	43	383	102	355	135
Călăraşi	345	35	288	32	357	27	462	53	469	76
Craiova	297	35	188	11	296	39	402	81	378	66
Galaţi	217	86	187	26	249	46	327	100	366	139
Roşiori de Vede	325	22	240	13	375	37	457	47	438	76

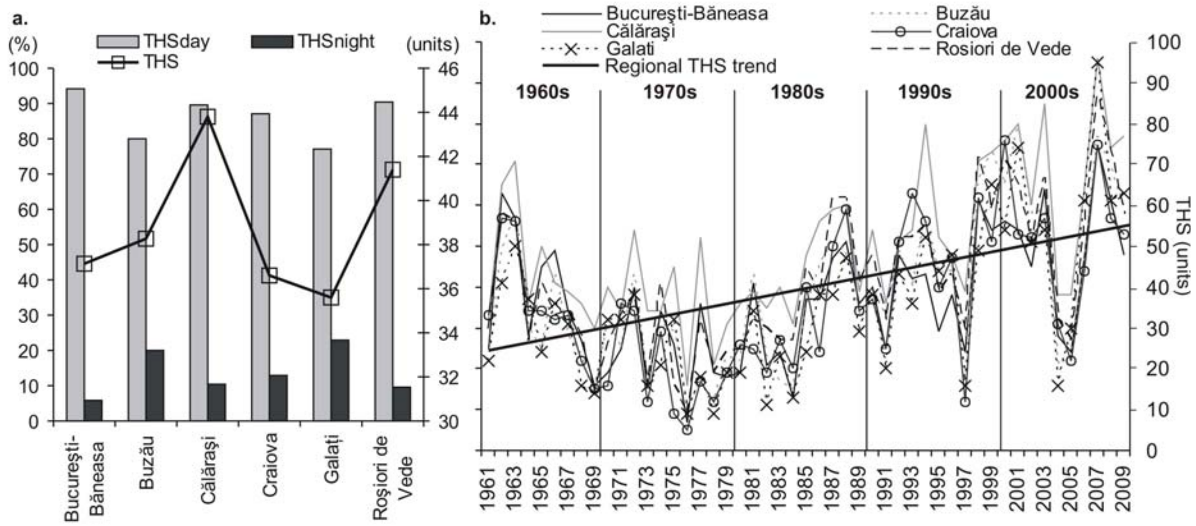

Fig. 2 – Average share of THSday and THSnight to the total THS (a) and the 49-year variability of the total THS (b).

4.2. The combined heat stress (CHT)

The combined heat stress index (CHT) is an exposure indicator of urban comunities to the heat summer thermal stress, which has been found to explain the spatial and temporal variance in excess mortality during the recent heat waves in Europe (EEA, 2012a).

The cities located in the Southern Romanian Plain display a considerable combined heat stress, similarly to those located in the plain and tableland regions of Central and Southern Europe, frequently exposed to persistent hot and dry summer airflows of North-African origins (e.g. the central and southern areas of the Iberic Peninsula, the Padan Plain, the Pannonian Plain). Southern Romania is particularly affected by hot days and tropical nights in summer. Consequently, the value range of the CHT across the region is rather small, showing a fairly similar heat stress exposure among the selected sites, under common large-scale circulation patterns: from 6.3 units at Bucureşti–Băneasa to 10.3 units at Galaţi and Buzău (Fig. 3a). The changes in the CHT evolution under current climate conditions are robust at all the sites and are particularly explained by a growing share of tropical nights at four out of the six sites. Along with, a slight expansion heat stress interval towards early autumn was observed in several years under the influence of some warm September months e.g. 1986–1987, 1994, 2008 (Fig. 3b).

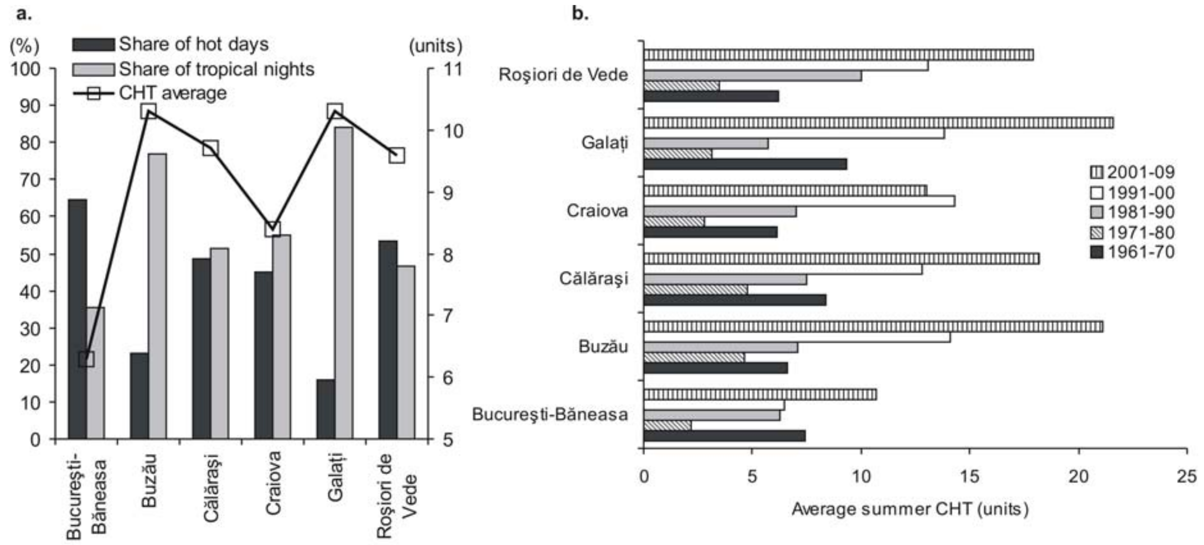

Fig. 3 – The share of hot days and tropical nights to the summer CHT (a) and its decennial variation (b).

The 21st century projections (IPCC A1B emission scenario), averaged from five Regional Climate Model simulations within the EU-ENSEMBLES project, indicate an ongoing increase of the CHT index (relative to the 1961–1990), implying a clear northward expansion of the affected regions (Fischer and Schär, 2010) (Fig. 4).

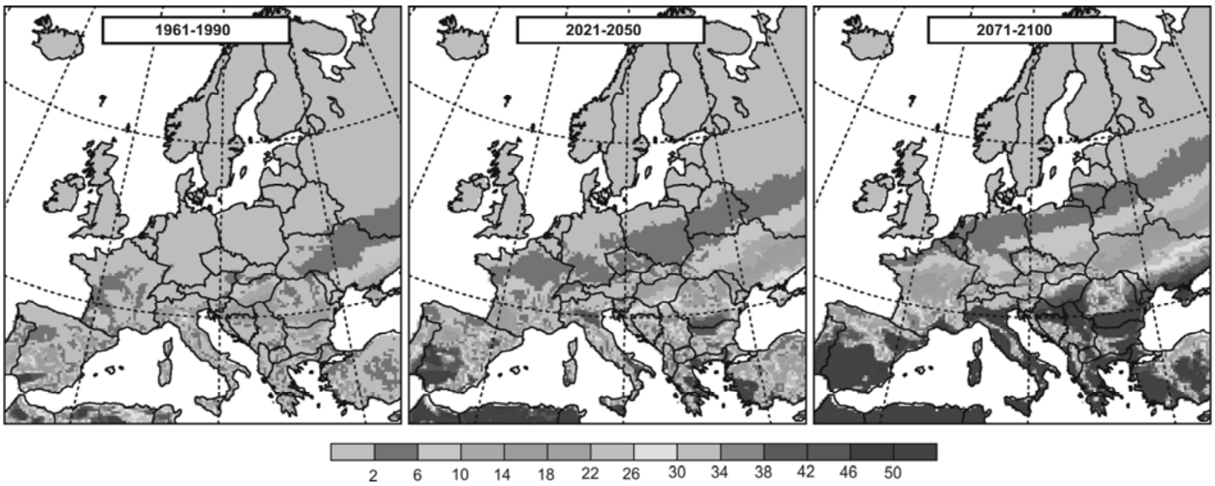

Fig. 4 – Projected CHT change over the 21st century in Europe (EEA, 2012).

4.3. Heat waves (HW)

There is a great concern for cities in warmer climates (e.g. hot summers in most European cities) due to an increased duration and severity of heat waves (EEA, 2012). In the study-region, heat waves are sporadic but highly recurrent and their frequency, duration and intensity are closely related to hot tail maximum temperatures of over 35°C. The cities particularly prone to frequent heat waves (>50 cases/period) are: Călărași (57), Roșiori de Vede (55) and București–Băneasa (52), as for the rest of the cities, their frequency did not exceed 40 cases/period: Craiova (39), Buzău (33), Galați (26). There is a clear evidence of increasing frequency of these extremes in the region over the 1961–2009 period, from less than 10 cases/decade during the 1961–1990 interval to more than 10 cases in the 1991–2009 period (Fig. 5a).

The duration of an individual heat wave episode did not exceed 11 days across the region (July 1987 at Roşiori de Vede) and did not fall below 9 consecutive days in the rest of urban and suburban sites. On an annual average basis, the heat wave duration is rather low in the region (below 5 days), with a 70 to 90% probabilty in all the locations. The occurrence probability of heat wave durations of 6 to 10 days is up to 30%, while those of more than 10 days did not exceed 10%, providing evidence of hot and dry summer incidence (e.g. 1988, 2000, 2007). The evolution of decadal cummulated heat wave durations suggests a significant summer warming in all the surveyed cities, mostly visible in the last two decades of the 49-year period (Fig. 5b).

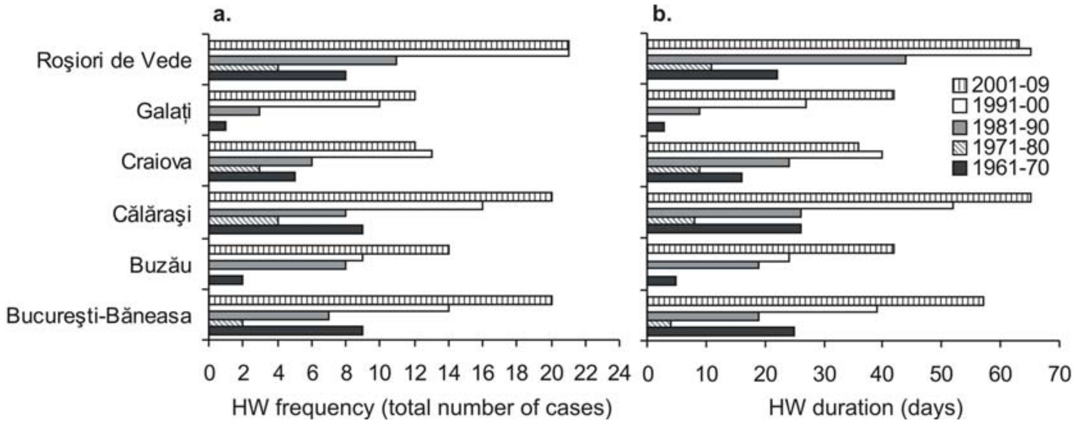

Fig. 5 – Decadal change in the cumulated frequency (a) and duration of heat waves (b).

The exposure to heat stress of the urban and suburban areas of the Romanian Plain Region is on an overall increase: at a rate of 5–7 days/decade of the annual duration of HW and of about 0.2–0.5 days/decade of the maximum length of individual HW (Fig. 6). These trends are highly statistically significant (for 5% to 0.1% levels). However, two out of the six selected urban areas appear to be the ones most exposed to more persistent HW under current climate conditions (Roşiori de Vede, Călăraşi).

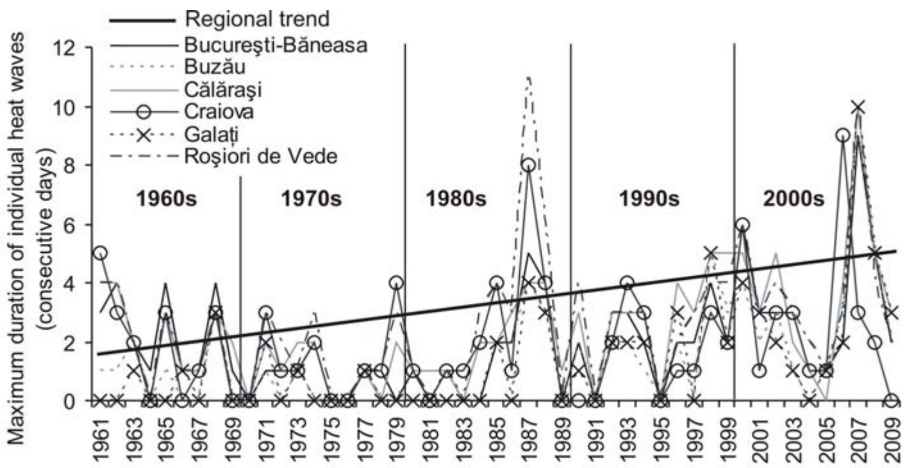

Fig. 6 – Variability of the maximum duration of individual heat waves.

These results are confident to those obtained by Busuioc *et al.* (2010), who emphasized similar variability patterns of these extremes across the country and a concentration of the most persistent heat wave episodes after 2000. However, the southern and eastern plain regions appear to be particularly exposed to such extremes, as they are showing the highest increasing rates in their duration, also to share common large-scale circulation causality. Georgescu *et al*. (2013) investigated the connections between the large-scale circulation patterns using the COST733 catalogue and heat waves and droughts recorded during the May–September interval after 2000, in Romania. Accordingly, the occurrence and persistence of hot temperatures and prolonged drought episodes in southern Romania is closely correlated to quasi-stationary high pressure circulation anomalies over South-Eastern Europe, with a strong southern circulation component. Ioniță *et al*. (2013) linked the the multi-decadal variability of summer temperature over Romania to the sea surface temperature anomalies associated to the Atlantic Multidecadal Oscillation (AMO).

The maximum intensities of heat waves were fitted in the Generalized Extreme Value (GEV) distribution in order to derive the return periods of their values. The highest magnitudes of the heat wave episodes were recorded in 2000 (Craiova 42.3°C and Bucureşti–Băneasa 42.2°C) and more widely in 2007 (Roşiori de Vede 42.7°C, Craiova 42.6°C, Galați 40.5°C, Buzău 40.3°C). The return periods of these events were of at least 30 years (Craiova 30.6 years, Buzău 36.3 years) and exceptionally over 120 years in a single location (Bucureşti–Băneasa 125.9 years) (Fig. 7a). Heat wave episodes of more than 40°C intensity had an occurrence probability of only 4 to 10% over the study period. The intensification of heat waves in southern Romania became highly visible after 1985–1988 (Fig. 7b), when over the study period of observations the magnitude of heat waves reached for the first time the 40°C threshold, which represents the now-casting maximum temperature threshold corresponding to the orange alert of the National Meteorological Administration (NMA). However, in 2007 (a maximum temperature record year for most weather stations in southern Romania), the magnitude of heat waves measured at Roşiori de Vede and Craiova stations was only 0.3–0.4°C lower than the NMA red alert threshold (43°C).

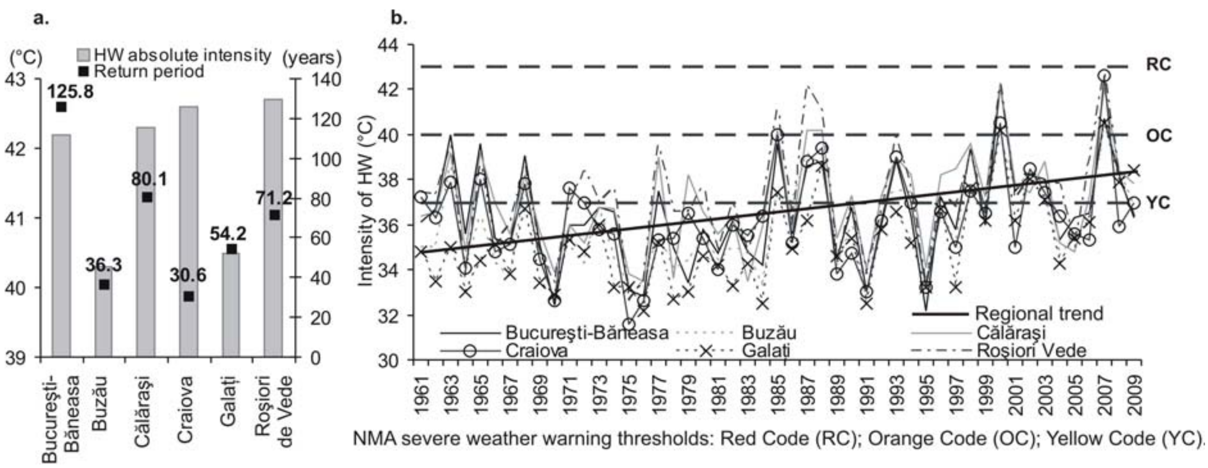

Fig. 7 – The absolute intensity of heat waves and the corresponding return periods (a) and the observed variability of heat wave intensity (b).

4.4. Cooling degree days (CDDs)

Rising peak energy demand in summer is an issue of particular concern for policy-makers, particularly in countries with significant summer peaking, where the awareness of cooling demand is already strong (e.g. the Mediterranean countries) (Aebischcher *et al*., 2007). The cooling-degree days index is a proxy for the energy demand for indoor cooling and for the magnitude of heat stress, as it is based on the external temperature directly affected by climate change. The observed increase in the number of hot days and heat waves resulted in an increase in the cooling demand in most southern European cities (EEA, 2012b) and a higher energy consumption, as cooling is delivered currently, almost exclusively through electricity. For such reasons, climate adaptation action in Europe uses weather-related derivatives, based on specific weather triggers (e.g. rainfall, temperature, number of heating or cooling degree days, soil humidity), as components of the overall risk management strategy (European Climate-Adapt Platform).

The regional average CDDs in summer is about 217, showing a variation range of 191 (Bucureşti–Băneasa) and 239 (Călăraşi). The share of summer to the overall cooling degree days in the selected urban areas is about 90.8%, while the contribution of extra-summer months (May and September) count up to 4.3% and 4.6%, respectively (Fig. 8a). Explicitly, the share of April and October is rather insignificant (below 0.5%), as their contribution to the overall annual CDDs is visible only in some warm spring (e.g. 1983, 1998, 2000) and autumn months (e.g. 1993, 1999, 2001).

In response to the recent temperature rise over the last two decades of the 49-year period analyzed, the summer CDDs is on a statistically significant increase (for 5% to 0.1% levels) at all the selected sites (Fig. 8b). Summer months are mostly responsible for the overall positive trend in the urban cooling demand, at rates of 26 to 34 CDDs/decade in most locations. The nearby local vegetation of the Bucureşti–Băneasa measurement site (consisting in forest vegetation and orchards) explains the lower values of the indicator, as well as the change rates in summer (16 CDDs/decade), still significant but only for the 10% level.

The projected temperature change, resulting from higher temperatures and heatwaves, are expected to affect human health and to entail a number of socio-economic and environmental impacts in cities across Europe, e.g. disturbancies in energy and water supply and transport services along with additional socio-economic challenges in summer such as failure of power transport networks, higher energy demand for cooling, failure of power supplies (Schauser *et al*., 2010, EEA, 2008). However, indoor cooling (using air conditioning units) in highly-dense built-up urban areas, is not an option for outdoor activities during hot days or for low-income groups and is considered only a mid-term adaptation option to reduce heat exposure (WHO, 2009).

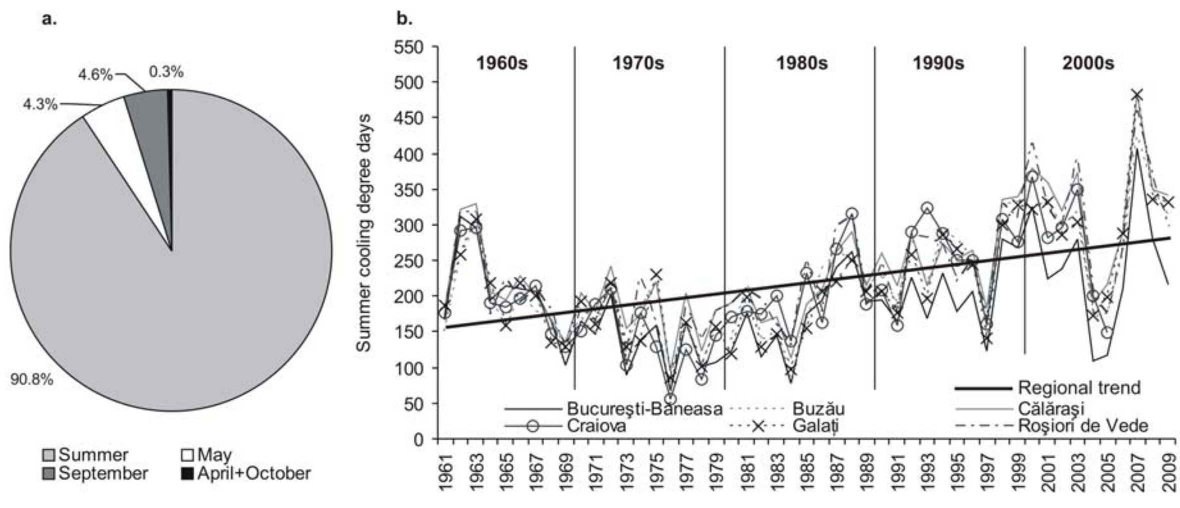

Fig. 8 – Share in the annual CDDs (a)
and the summer CDDs variability and trend (b).

5. CONCLUSIONS

The foregone analyses serve to emphasize the intensification of summer thermal heat stress in all the selected urban/suburban sites of southern Romania, in response to the behaviour of minimum and maximum temperature evolution in recent decades. However, some local city features proved to be more important than regional climate characteristics in sizing the heat stress exposure variation (e.g. the Bucureşti–Băneasa case).

Comparing the observed trends of the heat stress indices, the cities located in the Romanian Plain Region are tending to experience a strong increase in the frequency and persistence of hot summer weather, a fact also confirmed by changes in the upper extreme tails of PDFs of maximum temperatures. The mid-1980s marks a robust shift in the variability of the selected heat stress indices all over the study region, suggesting the beginning of a recent warming phase in most regions of Romania (as confirmed by Busuioc *et al*., 2010).

The results suggest that the cities selected for this analysis are clustered in a wider region sensitive to heat impact including the southern and south-eastern parts of the Romanian teritorry, which also shares similar variability patterns of summer temperature with many urban areas located in some South European countries (e.g. Spain, Italy, Bulgaria, Greece). The recent extreme temperature change patterns in summer explain the visible rise in the frequency of hot tropical days by the end of the period (above 30° and even 35°C) after 1981–1985. The differences between the average and maximum frequency of hot nights before 1980 and after 1981 is of 12–17 days and up to 34 days, respectively, regardless of the urban and periurban local settings. Combining the day- and night-time tropical heat stress (THS index), Roşiori de Vede, Buzău, Galaţi şi Călăraşi appear to be the most affected, as the THS increase is highly significant over the period (0.1% level). The consecutive occurrence of canicular days and hot nights has been found to explain the spatial and temporal variability of heat stress during the persistent warm airflows of tropical origin (North-African). The change signals of the combined heat stress effect of tropical nights and hot days (CHT index) are significant for all the selected urban and suburban areas of the Romanian Plain Region and they are perceptible after 1985. There is a strong evidence from the EU-ENSEMBLE projections (A1B SRES scenario) that in the study region, as well as in the limitrophe northern regions (e.g. the Subcarpathian sector) the heat stress impact will be further amplified by the end of the 21st century, considering the changes in the CHT index value range and expected heat wave occurrences.

The heatwave episodes recorded in recent decades (particularly in 2000 and 2007 years) in the study region were among the most severe ones, determining prolongued intervals of hot temperatures and extremely high intensity peaks (30 to 125 year return periods). The Călăraşi, Roşiori de Vede and Bucureşti–Băneasa sites appear to be the ones most frequently affected by this phenomena (above 50 case/period). After 1985–1988, the severity of heat waves has visibly increased, reaching and exceeding the 40°C threshold (the NMA orange alert level) and even spreading, in some locations (Roşiori de Vede and Craiova), towards the NMA red alert code threshold of 43°C by the end of the study period (in 2007).

In response to the recent temperature rise observed in the second half of the 49-year period, the summer cooling need is on a significant increase (for 5 to 0.1% levels) in all the selected cities. An expansion of the cooling interval towards the late spring (May) and early autumn months (September) was also observed in the region, in response to the higher occurrence probability of hot summer temperatures and heat waves after 1985–1990.

Considering the model results concerning the mid-term and long-term temperature projections for Europe and Romania, the human population living in the Romanian Plain Region (in urban, suburban and rural environments) is expected to become more sensitive to the summer temperatures increase of over 4°C (on average). Most cities located in southern Romania are likely to grow more vulnerable to heat stress impact as heat waves and hot summer days are projected to occur with greater frequency by the end of the 21st century.

Acknowledgements: This study was carried out under the Romanian Academy fundamental research theme focusing on the *Climate hazards in the Romanian Plain Region. Drought and desertification* (the 2013 phase).

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Received September 10, 2013