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Urban areas in Oltenia in the context of climate changes: estimating summer extreme temperatures for the near-future (2021-2040)

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Abstract

The estimation of direction and amplitude of change for four indices characterizing the high temperatures conditions during extended summer season (May-September) based on selected simulations of near-future period (2021-2040) is presented for the five major urban areas (Craiova, Slatina, Ramnicu Valcea, Targu Jiu, Drobeta Turnu Severin) in Oltenia region. The indices are derived from daily maximum temperature and they make use of threshold values relevant either at country level (e.g. 25 degC, 35 degC, 37 degC) or at local scale (i.e. 99% percentile derived from 20years local climatology for each month and each city). The estimation of changes is accompanied by estimations of the uncertainty associated with the selected data and methods.

Keywords: urban areas, thermal comfort, climate change

1. Introduction

The pace of climate change imposes increasing pressure on the society to devise solutions for adaptation to these changes and to mitigate their impact on human systems. Urban areas are prone to be affected in a significant degree due to a higher population, concentration of economic actors and their own effects on local climate as manifested for example through the Urban Heat Island effect. In the 5th IPCC report [1], 3 out of 8 key-risks associated with climate changes refer to urban areas. Although the risks are expected to be higher for large urban agglomeration, even smaller size cities have to deal with the local impact of climate changes. Valuable information toward this goal may be provided by investigating the characteristics of expected changes in the local climate.

Oltenia region is located in the southwestern part of Romania (Fig.1) and comprises five counties (Dolj, Gorj, Mehedinti, Olt, and Valcea), with 50% of population living in urban areas at 1 July 2020, according to the National Institute of Statistics [2]. About 65% of the urban population is concentrated in the five the major cities - Craiova, Targu-Jiu, Drobeta Turnu Severin, Slatina, Ramnicu Valcea which are the target urban areas of the present study.

Adaptation to climate changes is among the goals of the local authorities in Romania in general and in Oltenia in particular, as four out the five major cities adhered to the Global Covenant of Mayors for Climate & Energy (https://www.globalcovenantofmayors.org/).

Furthermore, a Green City Action Plan is in development for Craiova, financed through European Bank for Reconstruction and Development [3], which will look at ways to invest in greener transport, rehabilitation of some public buildings, water and waste management, prioritizing and connecting cities' environmental challenges with sustainable infrastructure investments and policy measures to build a better and more sustainable future for cities and their residents.

In this line, our study aims to explore the physical impacts of climate changes related to high temperatures cases during extended summer season (May-September) in the near future (2021-2040) in the five major urban areas of Oltenia region, by highlighting the particularities of the impacts for each city and each months of the season considered, with possible impacts in several socio-economic sectors.

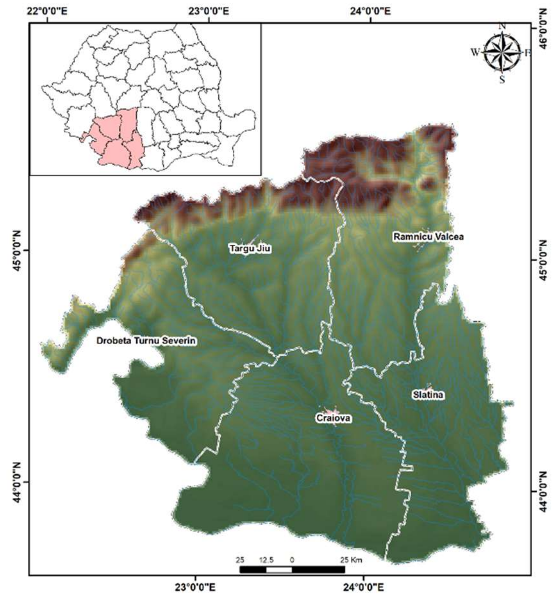

Fig.1. Localization of main urban areas in Oltenia.

2. Data and methods

We employ daily maximum temperature (Tmax) data provided by bias-corrected results of 11 climate projections performed with 5 regional and 5 global climate models, in the context of RCP45 and RCP85 scenarios at European scale, based on EURO-CORDEX experiment. The data is available from Joint Research Centre (https://data.jrc.ec.europa.eu/dataset/jrc-liscoast-10011). Regional climate models (RCMs) outputs have been bias-adjusted using the methodology described in e.g. [4] using the observational data set EOBSv10, and applied to the EURO-CORDEX data by Dosio [5] and Dosio and Fischer [6]. We focus on the near future period (2021-2040), considering 1991-2010 as base period for interpreting the climate projection data.

The range of changes for four indices derived from daily maximum temperature time series is estimated based on a selection of model simulations which highlights the lower and respectively the upper limit of projected mean temperature change in the two climate change scenarios. Thus, we firstly identify the models simulations which lead to the lowest increase in the mean air temperature averaged over the entire Romanian territory in the context of RCP45 scenario and respectively to the highest increase, in the RCP85 scenario (Fig. 2). The selection of the simulations accounts for the uncertainties associated with numerical climate models (both large-scale and regional models) by choosing different regional climate models driven by different large-scale models. It also accounts for the uncertainties associated with the climate change scenarios by using simulations for two different scenarios (RCP45 and RCP85). Furthermore, since we are interested in the range of the changes, the selection method assures that the selected simulations are representative for the study area and for the objectives of the study.

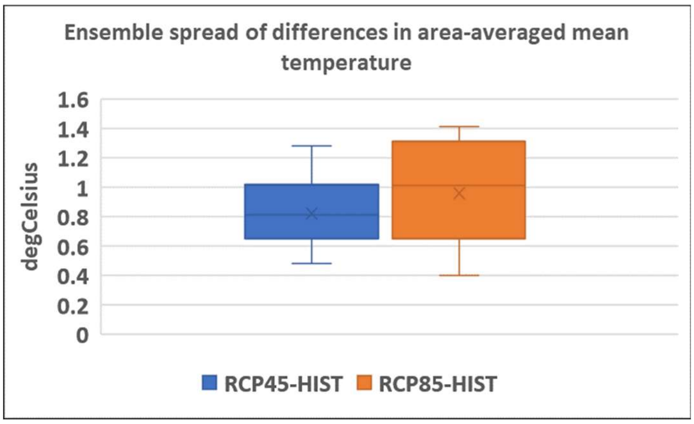

Figure 2. Ensemble spread of differences in the mean temperature area-averaged over the Romanian territory, for 11 climate projection simulations for the periods 1991-2010 (BASE) and 2011-2040 (RCP45, RCP85).

The characteristics of summer thermal regime are described by four indices based on widely used indicators and computed for the extended summer season (May-September), namely:

- number of days with acceptable heat load (ND_AH) - are defined by maximum temperatures between 25 and 35 degC. This indicator is based on Summer Days index [7];
- number of days with pronounced heat load (ND_PH), as used in the operational practice by National Meteorological Administration, defined by the maximum temperature of at least 35 degC. Aiming to detail the changes in the extreme high temperature, we present this index as the number of days with maximum temperature between 35 and 37 degC;
- number of days with very strong heat load (ND_VH), as defined by Romanian legislation [8], [9] and characterized by maximum temperature of at least 37 degC.
- Excessively warm days (ND_EW), defined by the maximum temperature above the value of 99% percentile (p99) for a specific month and a specific location. This index is similar to the Very Warm Days index [7], the latter being defined at annual scale. For this study, the 99% percentile is computed for each city and each month from the probability distribution function based on 20years time series of daily Tmax as provided by model simulations for the BASE period (1991-2010); it is further used to estimate how often this temperature threshold is surpassed during 2021-2040 based on projections of Tmax. As in the current climate conditions defined by the BASE period Tmax values above p99 have a probability of occurrence of 1%, this index may be interpreted as describing rare cases of high temperature in the current climate.

The analysis focuses on changes of the indices during period 2021-2040 compared with 1991-2010 interval. The indices are computed for each model, in each scenario, for the BASE and future periods. The results are presented in terms of absolute difference between values for 2021-2040 period and values for 1991-2010 period (i.e. RCP-BASE), highlighting the range of change of the indices as defined by the selected simulations. This allows to account for the uncertainty associated with the climate projection data and the method employed with regard to the amplitude of the change.

3. Results

Although an overall increase in temperature in Oltenia region is expected, it is modulated by local factors (e.g. geographical positioning, orography) such that the response will vary between the analyzed cities. A first example is provided in Figure 3, which presents the threshold values defining the Excessively Warm Days for each month and each city considered. It may be seen that Targu Jiu and Drobeta Turnu Severin present the highest threshold (about 38 degC) among all cities, while the lowest value is found at Ramnicu Valcea (36.3 degC). Also, Targu Jiu and Drobeta Turnu Severin reaches the maximum p99 over the extended summer season in August, but for the other cities considered this peak is found in July. The range of p99 is largest for May and September for all cities, indicating a lower agreement between the selected simulations, possibly due to synoptic characteristics of these months and to the models performance in simulating them.

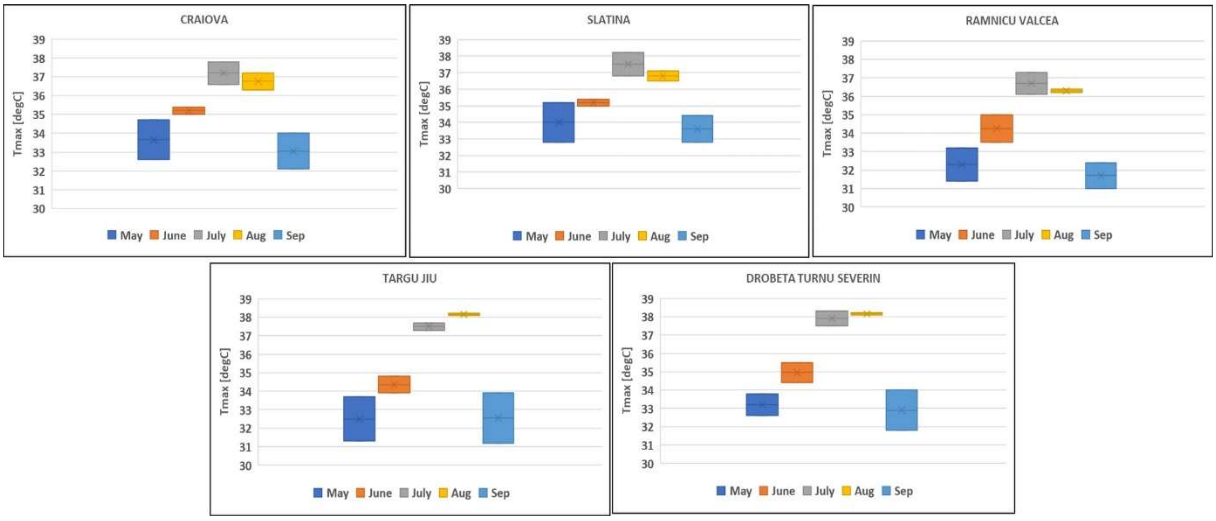

Fig. 3 Daily Maximum Temperature defining Excessively Warm Days for the five cities considered, derived from model simulations for the BASE period (1991-2010).

For Craiova (Fig. 4), in May and September is expected to increase the number of days with acceptable heat load, while cases with maximum temperatures above 35 degC are expected to remain quite constant compared to 1991-2010 period. Furthermore, in September the number of excessively warm days is estimated to be the largest of all months for this city, indicating a considerable shift of thermal characteristics toward higher temperatures during this month compared to the BASE period. However, the uncertainty on the amplitude of the ND_EW index during September is quite significant, as expressed by the range of change. The month of June is characterized by a slight increase of all indices employed, associated with a tight range of change and thus with a good level of confidence. During July, the shift toward more frequent cases with pronounced and strong heat load is well marked and it is associated with a good level of confidence too. A higher uncertainty is associated with changes of indices during August and in particular for ND_VH index, for which both positive and negative changes are suggested by the simulations considered.

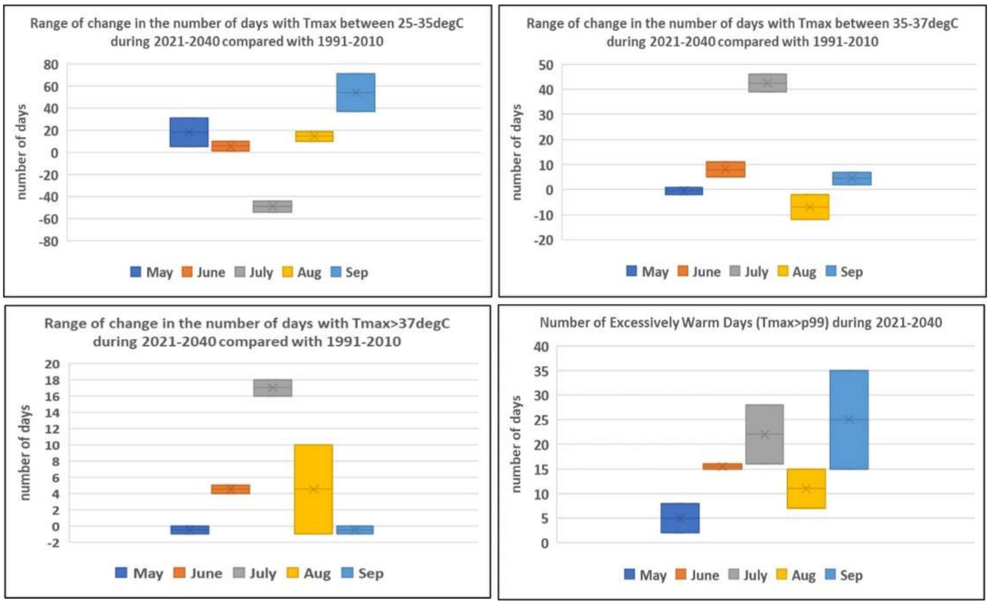

Fig. 4 Projected range of changes of the four indices for CRAIOVA.

A similar behaviour for ND_AH and ND_PH indices is found for Slatina (Fig. 5), where the shift in July toward cases with temperatures between 35 and 37 degC, compared with cases with Tmax<35degC, is evident and associated with a good level of confidence. Also, in July is expected the largest additional number of days with Tmax>37 degC among all cities (an average of 28 days within 2021-2040 period compared to 1991-2010), as well as the largest number of days with maximum temperatures considered rare in the local current climate (ND_EW index).

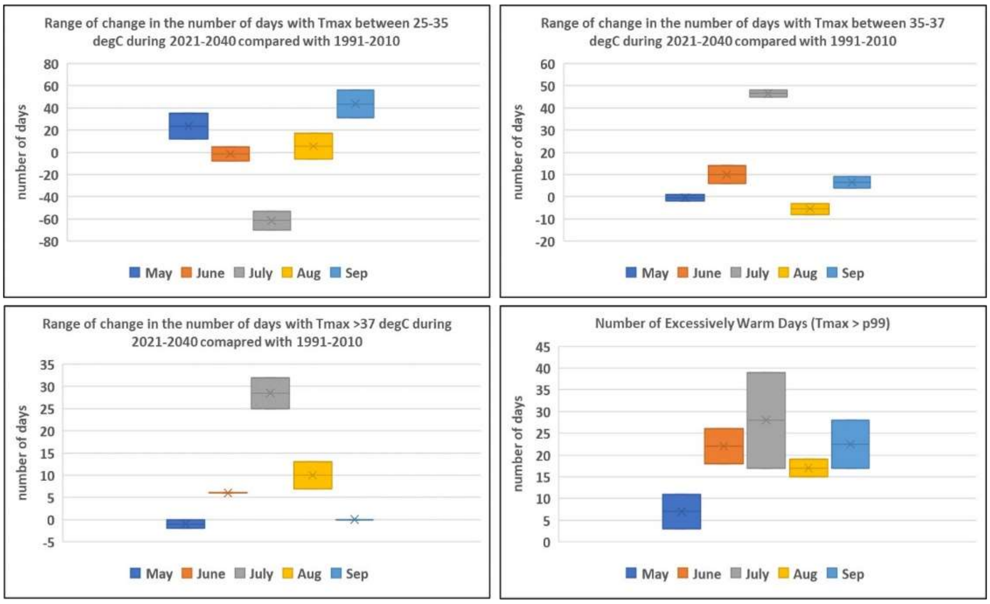

Fig. 5 Projected range of changes of the four indices for SLATINA.

The changes in the distribution of maximum temperatures during 2021-2040 compared to 1991-2010 period for Ramnicu Valcea (Fig. 6) are similar to those of other cities during May for all indices, while in June the city is expected to have a large increase of days with acceptable heat load. The shift during July toward temperatures above 35 degC is visible for Ramnicu Valcea too, although less pronounced than for Craiova and Slatina. During August small changes in all indices are found. September is characterized by a larger number of days with acceptable heat load, but the amplitude of the change is associated with a low degree of confidence. Similarly, the exceedance of excessively warm days threshold, although of relatively low amplitude, is associated with large uncertainty for almost all months.

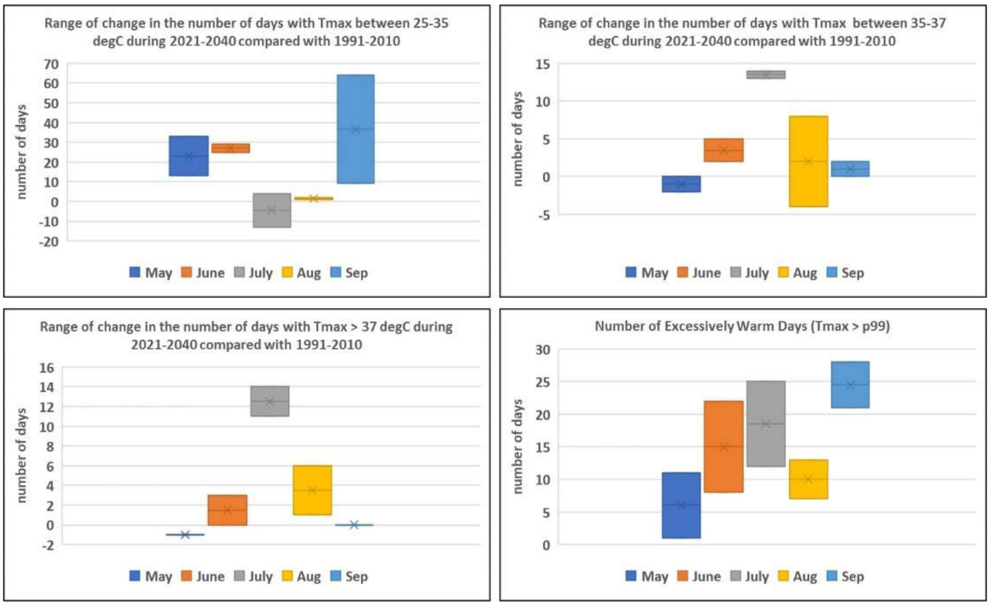

Fig. 6 Projected range of changes of the four indices for RAMNICU VALCEA.

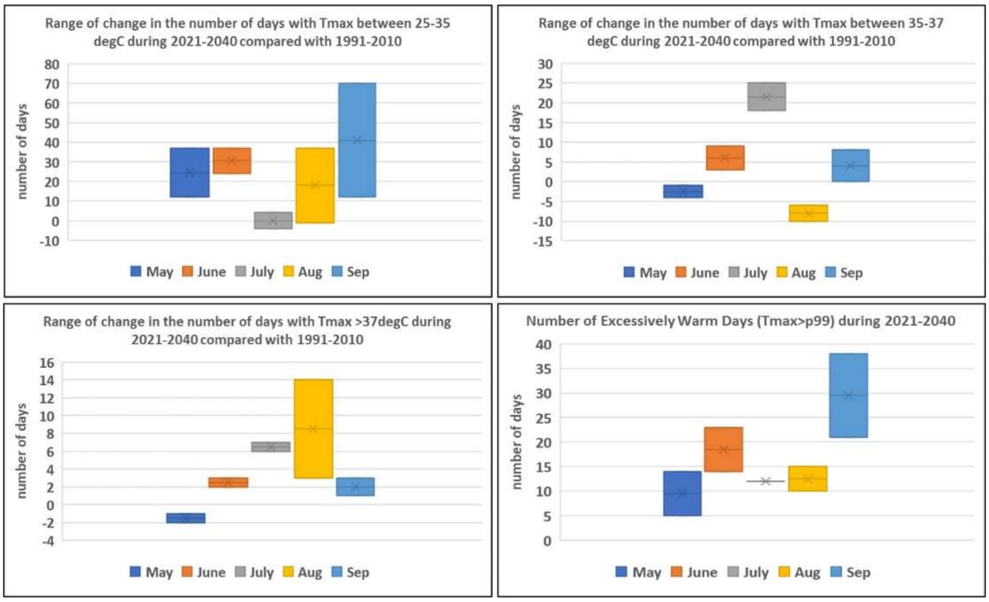

Fig. 7 Projected range of changes of the four indices for TARGU JIU.

For Targu Jiu (Fig. 7) during May there are found the most numerous cases, among all cities, of days with maximum temperatures exceeding the 99%percentile for the local current climate. June is characterized, for Targu Jiu, by the largest increase in ND_AH (an average of additional 30 days during 2021-2040 compared to 1991-2010), as well as by the lowest additional number of days with Tmax between 35-37 degC. Compared to Craiova and Slatina, at Targu Jiu the increase in the number of cases with pronounced and strong heat load during July is much smaller, such that the change in ND_VH is the lowest among all cities, during this month. Nevertheless, the impact of temperature increase is visible during August, when the increase in ND_AH and ND_VH is most evident at Targu Jiu among all cities. The amplitude of the changes in both these indices are however associated with a low degree of agreement between the selected simulations.

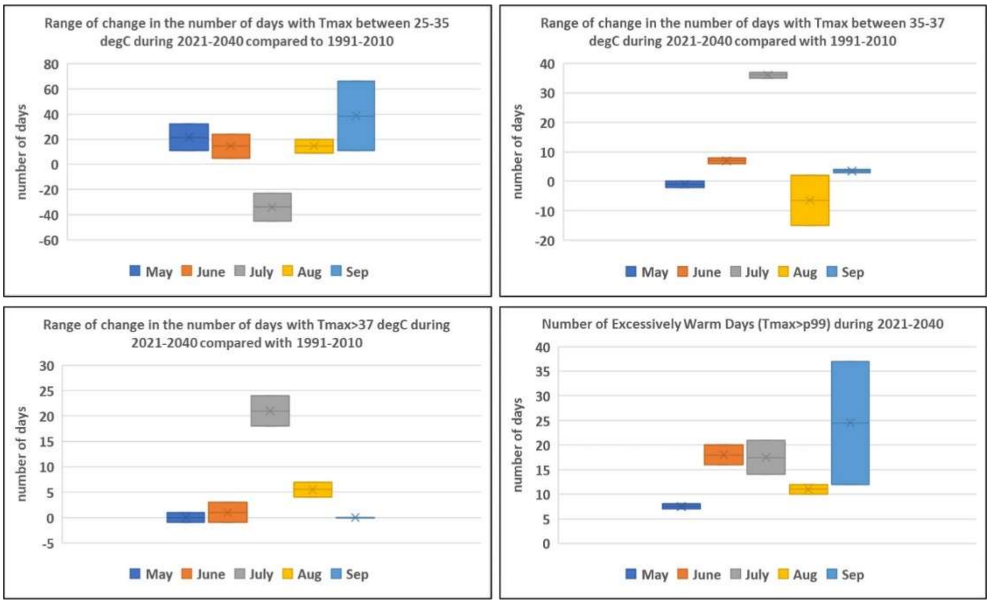

Fig. 8 Projected range of changes of the four indices for DROBETA TURNU SEVERIN.

The results for Drobeta Turnu Severin show an increase of ND_AH index for almost all months. The shift during July toward more days with temperatures above 35 degC is visible too, with an amplitude slightly lower than for Craiova and Slatina. The largest uncertainties are associated with the amplitude of changes during August (for ND_AH and ND_VH) and September (for ND_EW).

4. Conclusions

The results highlight the expected increase of days with higher temperatures but differentiated on temperature intervals, months and cities.

The number of days with acceptable heat load (Tmax between 25-35 degC) is expected to increase in all cities in all months except for July, the largest amplitude of the change being found for Craiova during September. Larger uncertainties are associated with the amplitude of the change in this index during September at Targu Jiu and Ramnicu Valcea.

The cases with pronounced heat load (Tmax between 35-37 degC) are expected to increase during July, especially at Slatina and Craiova and to be less frequent during 2021-2040 compared to 1991-2010 in August at Craiova, Slatina and Targu Jiu; the direction of change in this index for Ramnicu Valcea and Drobeta Turnu Severin is associated with a low degree of confidence as it is not well defined, both positive and negative changes being derived from the selected simulations.

The number of cases with Tmax>37 degC is expected to increase in July in all cities, however the amplitude of the change is quite low (an average of additional number of days during 2021-2040 compared to 1991-2040 varying between 30 days at Slatina to about 7 at Targu Jiu).

The number of excessively warm days is expected to increase in all months and for all cities, more pronounced during September (e.g. at Targu Jiu), while the lowest amplitudes of the change are found during May (e.g. for Craiova and Slatina). The largest uncertainty associated with changes in this index are found in September for Drobeta Turnu Severin and in July for Slatina.

The increase of daily maximum temperatures in the near future presents different features for the cities analyzed, which may provide valuable information for devising efficient city-specific adaptation measures to climate change, as the physical impacts analyzed have effects in various socio-economic sectors.

For example, an increase of the number of days with warmer conditions (e.g. Tmax >25 degC) during May and September may allow the extension of tourism season for this months too, opening new opportunities for local development in this sector. Tourism is one of the fields with a high potential for specialization in Oltenia, due to the region touristic resources such as protected areas, natural parks, mountains, caves, non-polluted rural areas, mineral waters and spas, cultural tourism [10]. Four of the cities analyzed – Craiova, Ramnicu Valcea, Targu Jiu and Drobeta Turnu Severin – are important touristic destinations in Oltenia, with more than 90000 tourists overnights in 2019. Extension of favorable weather conditions during bounding months of the warm season may positively contribute to increase the tourism in these cities and surrounding areas as well as the associated economic sectors.

The southern part of the country is already affected by increasing trend of air temperature in the last half century as shown by several studies involving long-term measurement data over the Romanian territory [11], [12], [13]. Associated with the local effect of urbanization expressed for example through the UHI effect as documented for Craiova [14], the shift of July temperatures toward more values above 35 degC, may have a negative impact on a range of socio-economic sectors. Increasing of maximum temperatures may lead to increased outdoor thermal discomfort [15], [16] with impact on human health like the aggravation of pre-existing medical conditions [17],[18] or potential increase in mortality due to cerebro-vascular diseases (e.g. [19], [20]). Also, outdoor activities as for example in constructions may be affected, being necessary the reduction of working time during day or application of special measures to improve the working conditions as required by the Romanian legislation [8],[9]. The indoor thermal discomfort may also increase, with consequences like reduced work efficiency [21], [22] or even health-related problems. The energy consumption for assuring optimal indoor thermal comfort may rise [23] [24] both for office spaces and for residential sector, while water management at the city scale may also need adaptation and mitigation measures to cope with the associated effects of increased temperatures.

The results presented here should be interpreted in the limits set by the data and method used, as suggested by the associated level of confidence. Generally speaking, two major sources of uncertainty are related to the uncertainty associated with the climate change scenarios and to the limitations of numerical models in simulating the climate system. The natural variability of the climate system resulting from unpredictable or non-linear natural processes within the climate system is another major source of uncertainty, adding to the scenario and model uncertainty. These are treated usually be employing more than one climate change scenario and a large number of models, at both global and regional scale. The method employed in the present study follows this line but with only two model simulations, which describe 'extreme' instances of possible evolution of climate in the near future, in terms of change of mean temperature at country level, based on a set of 11 simulations. Although this method fits the aim of the study, it is possible that a higher level of confidence may be obtain by using more model simulations.

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