EXTREME HEAT IN SERBIA

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FINAL HEAT RESEARCH REPORT

EXECUTIVE SUMMARY

In the past six months (May-October 2022), intensive work was done in order to achieve the defined milestones and provide deliverables on the topic of extreme heat in Serbia. This work is financed by the Research Grant on Extreme Heat. In the proposed project, we have defined six milestones and deliverables and all of them are achieved. Below is the executive summary:

1. *First Milestone and Deliverable*: Analysis of climate conditions on national level using data from official meteorological stations in Serbia for the period 2000-2020. Collected data included air temperature, relative humidity, wind speed and cloudiness. Data were presented through text, graphs and maps in a short Climate report on five pages. *Climate Report for Serbia* can be freely seen and downloaded from the official website of our project: https://sites.google.com/view/extremeheatinserbia/home;
2. *Second Milestone and Deliverable*: We have calculated the values of outdoor thermal comfort indices HUMIDEX, Physiologically Equivalent Temperature (PET) and Universal Thermal Climate Index using data from a number of official meteorological stations in Serbia for the period 2000-2020. Data were presented through text, graphs and maps in a short Bioclimate report on five pages. *Bioclimate Report for Serbia* can be freely seen and downloaded from the official website of our project https://sites.google.com/view/extremeheatinserbia/home. Based on milestones and deliverables 1 and 2, an original *scientific paper* entitled *"Analysis of long- and short-term biometeorological conditions in the Republic of Serbia"* was written and submitted to a scientific journal named International Journal of Biometeorology (Impact Factor 3.7 for 2021);
3. *Third Milestone and Deliverable*: assessment of temperature, humidity, and biometeorological indices on mortality across Serbia in the period 2001-2015. Special focus was on mortality during summer season when intensive heatwave periods occur. An original *scientific paper* entitled "*The effects of summer temperature on human mortality in Serbia*" was written and submitted to a scientific journal named International Journal of Biometeorology (Impact Factor 3.7 for 2021);
4. *Fourth Milestone and Deliverable*: Impacts of extreme heat on hospitalization in diverse urban areas of Novi Sad during heatwaves in the period 2016-2017 were assessed. An original *scientific paper* entitled "*Hospital admission tendencies caused by day-to-day temperature changes during summer: a case study for the city of Novi Sad (Serbia)*" was written and submitted to a scientific journal named Natural Hazards (Impact Factor 3.2 for 2021);
5. *Fifth Milestone and Deliverable*: During the project, we have organized one hybrid (in person and online) workshop for stakeholders and citizens with 4 presentations. The title of the workshop is ""BEAT THE HEAT SERBIA" and it was given in English and Serbian language. It was realized on 21st October 2022. In total, 21

persons joined the workshop in person, and 10 persons joined the workshop via Zoom platform. More details are provided in Section Methodology and in *Appendix 1*.

6. *Sixth Milestone and Deliverable*: Youtube channel, project webpage and social media profiles were created and updated with project-related content during the past 6 months. Project's Youtube channel can be assessed at https://www.youtube.com/channel/UCoyVnqzBLTNSR5YVNUqJfkA, Project webpage at https://sites.google.com/view/extremeheatinserbia/home, Linkedin profile at https://www.linkedin.com/company/research-on-extreme-heat-in-serbia/ and Twitter profile at https://twitter.com/extreme_heat_rs; In total, about 6000 people were reached using social media channels of the project. More details can be seen in *Appendix 1*.
7. *Seventh Milestone and Deliverable*: Leaflet with project summary and outcomes in hard copy and online versions were created in English and Serbian language. The leaflet consists of important project-related information and data presented on four pages. It can be freely downloaded from project website: https://sites.google.com/view/extremeheatinserbia/home#h.irinkp3g35wy . More information about leaflet can be seen in *Appendix 1*.

In total, two reports, three scientific papers, one workshop and four online profiles for the project were realized during the project realization period (May-October 2022).

PURPOSE

Hot summers with intensive heatwaves lead to strong heat-related mortality across Europe. Up to now, there are only a limited number of studies investigating heat-related mortality in the Republic of Serbia. This project tried to fill this research gap by identifying the local heat thresholds and triggers in Serbia, located in Southeast Europe. More specifically, we dealt with two research questions: 1) Mortality and hospitalization in Serbia in the investigated period; and 2) Impact of climate and bioclimate elements on mortality and hospitalization in Serbia with special focus on summer and heat wave periods. Research outputs are promoted among citizens and community leaders to increase knowledge on heatwaves and their impact on people and to develop policies and actions to deal with extreme heat.

LITERATURE REVIEW

In order to achieve the defined milestones and deliverables, numerous scientific literature and available climate and mortality/hospitalization data sources were used. In the study *"Analysis of long- and short-term biometeorological conditions in the Republic of Serbia"*, 68 references were used; in the study "*The effects of summer temperature on human mortality in Serbia*", 43 references were used; and in the study "*Hospital admission tendencies caused by day-to-day temperature changes during summer: a case study for the city of Novi Sad (Serbia)*", 56 references were used. In addition, 18 references are used in this report. In general, through literature review, it was noticed a general lack od studies dealing with heat and mortality/hospitalization in Serbia. We hope the provided deliverables will fill this research gap by providing three new studies about these issues in the Republic of Serbia.

METHODOLOGY

In order to achieve proposed milestones and deliverables, numerous methods have been applied. They included data collection, statistical analyses, climate modeling, report and scientific papers writing, etc. The following methods below were used for the milestones and deliverables no. 1-6.

Methodology and data for the First Milestone and Deliverable – Climate Report: Collection and statistical analysis of air temperature (Ta) and wind speed (v) from 47 official meteorological stations and relative humidity (RH) and cloudiness data from 34 official meteorological stations in Serbia for the period 2000-2020 were performed. These climate elements are selected for the analysis as they are the most important parameters for the analysis of human biometeorology, outdoor thermal comfort and heat stress conditions. Changes compared to the initial proposal are as follows: we planned to use RH data from 47 stations, however, 13 stations had more than 5% of missing data and were excluded from the analysis. In addition, we planned to use global radiation data, but this data was not available for the weather stations, so we included the data on cloudiness which is freely available on the official website of the Serbian Hydrometeorological Service. Cloudiness data were used for 34 stations, while 13 stations had to be omitted as they had more than 5% of missing data. Cloudiness is an adequate substitute for global radiation data in microclimate models (e.g., RayMan model) as it can indicate cloudy and sunny (hot) days. Furthermore, RayMan model provides average global radiation data for Serbian stations based on their latitude and longitude. This data were used to write the *Climate Report* for Serbia.

Methodology and data for the Second Milestone and Deliverable – Bioclimate Report and Scientific Paper: Based on the above climate data compilation and analysis, we have calculated the most widely used biometeorological indices HUMIDEX, Physiological equivalent temperature (PET) and Universal Thermal Climate Index (UTCI) for 47 meteorological stations in Serbia for the period 2000-2020. The HUMIDEX was calculated in Excel based on the Masterton and Richardson (1979) formula, while PET and UTCI were calculated in Rayman microclimate model (Matzarakis et al., 2007; Matzarakis et al., 2010). 13 stations had >5% of missing data for HUMIDEX and 20 stations had more than 5% missing data for PET and UTCI and had to be excluded from detailed analysis in order not to affect the quality of the obtained values and trends. Accordingly, data from 34 stations for HUMIDEX and from 27 stations for PET and UTCI were analyzed on annual and summer level in the period 2000-2020. In addition, a detailed hourly analysis of biometeorological conditions at five stations during the summer heat wave periods was performed. These are the most important weather stations in Serbia (Belgrade, Novi Sad, Nis, Loznica and Vranje) and the only stations that have freely available hourly data (7h, 14h, and 21h) at the official website of the RHMSS. These data were applied to create *Bioclimate* *report* for Serbia and to write the scientific paper *"Analysis of long- and short-term biometeorological conditions in the Republic of Serbia*". More details about the applied methodology are provided below.

In the abovementioned study, meteorological data from official weather stations of the Republic of Serbia have been used. We have obtained data from 47 stations located across the country for the period 2000-2020. Data assimilation consisted of two steps: 1) Acquisition of air temperature (Ta), relative humidity (RH), wind speed (v) and cloudiness (N) data from the official website of the RHMSS; and 2) Calculation of biometeorological indices HUMIDEX, PET and UTCI in RayMan microclimate model. After quality control of the data, meteorological data from 34 stations were used for the calculation of HUMIDEX and data from 27 stations were used for the calculation of PET and UTCI. Stations having more than 5% of missing data were excluded from further detailed analysis. Temporal analysis is focused on the annual level, summer season, and heat wave periods in order to obtain insights into long- and short-term biometeorological conditions in Serbia with a focus on the hottest season and extreme heat events. Two heat wave periods that were present across the country are selected. They lasted from 16 to 25 July 2015 and from 23 Aug to 2 Sep 2019. For the heat wave analysis, only data from stations Belgrade, Novi Sad, Nis, Loznica, and Vranje were used as only these stations had hourly data (7h, 14h, 21h) available on the official RHMSS website.

This study applied different methods and tools in order to assess the biometeorological conditions in Serbia. HUMIDEX, an outdoor thermal comfort index developed by Masterton and Richardson (1979), was calculated based on Ta and RH data obtained from the RHMSS. The main advantage of using this index is that only requires two main meteorological elements for its calculation. On the other hand, its main disadvantage is that the impacts of wind speed and mean radiant temperature are not included (Geletič et al., 2018). HUMIDEX calculation is done in Excel using formula developed by Vysoudil et al. (2016). PET was calculated based on the Ta, RH, v, and N data, geographical coordinates and altitude of stations, personal characteristics, clothing and activity. PET is defined as "the air temperature at which, in a typical indoor setting (without wind and solar radiation), the energy budget of the human body is balanced with the same core and skin temperature as under the complex outdoor conditions to be assessed" (Höppe 1999). The calculations were performed using the RayMan model (Matzarakis et al. 2007; Matzarakis et al. 2010). PET classes for humans specifically developed for Europe were used to assess thermal sensation and physiological stress level of humans (Matzarakis and Mayer, 1996). UTCI is defined as Ta of the reference condition causing the same model response as the actual conditions (Błazejczyk et al. 2010; Fiala et al. 2012). This thermal comfort index is a one-dimensional quantity that can summarize the interactions between Ta, RH, v, and mean radiant temperature (Bröde et al. 2012). UTCI was also calculated using the RayMan model and its assessment scale in terms of thermal stress (Glossary of Terms for Thermal Physiology, 2003).

Methodology and data for the Third Milestone and Deliverable – Scientific Paper: Temperature, humidity and biometeorological indices impacts on mortality in Serbia in the period 2001-2015 was assessed. The impacts of air temperature on mortality in Serbia was analyzed in more details and written as a scientific study entitled "*The effects of summer temperature on human mortality in Serbia*". This study is submitted to a scientific journal named International Journal of Biometeorology (Impact Factor 3.7 for 2021). During the observed period 2001-2015, summer 2007, 2012, 2015 were characterized with intensive heatwaves. In July 2007, average daily number of death (in five cities: Belgrade, Novi Sad, Niš, Loznica and Vranje) was for 9.5% higher compared with average number of daily deaths during the summer period 2001-2015. In July 2012, average daily number of death (in five cities: Belgrade, Novi Sad, Niš, Loznica and Vranje) was for 6.8% higher compared with average number of daily deaths during the summer period 2001-2015. In August 2012, average daily number of death (in five cities: Belgrade, Novi Sad, Niš, Loznica and Vranje) was for 1.4% higher compared with average number of daily deaths during the summer period 2001-2015. In July 2015, average daily number of death (in five cities: Belgrade, Novi Sad, Niš, Loznica and Vranje) was for 12.2% higher compared with average number of daily deaths during the summer period 2001-2015. In August 2015, average daily number of death (in five cities: Belgrade, Novi Sad, Niš, Loznica and Vranje) was for 2.7% higher compared with average number of daily deaths during the summer period 2001-2015. Furthermore, in order to ensure comparable measurements and avoid any slope due to geographical divergency and population growth over time, mortality was standardized per 100,000 inhabitants, as crude death rate (CDR). Our results suggest that the average dialy CDR over the summer period in the 2001-2015 was 2.7 in Vranje, 2.8 in Novi Sad, 3.0 in Loznica, 3.1 in Niš, and 3.2 in Begrade. Results also showed that the average daily number of deaths during the summer for the period 2001-2015 was 74 (in five cities: Belgrade, Novi Sad, Niš, Loznica and Vranje). The analysis was focused on the large cities across the country with available data. The methodology applied in this study is as follows.

Air temperature data for Belgrade, Novi Sad, Niš, Loznica and Vranje were obtained from the official website of the RHMSS (https://www.hidmet.gov.rs/). Data consists of air temperature values registered at 7h (morning), 14h (midday) and 21h (evening). Based on this data, average daily air temperatures were calculated for each station for the summer period in 2001-2015. Afterwards, average daily air temperature data were used in association with population and mortality data. For each location (area), data about population and mortality were represented by daily counts of all-cause deaths (ICD-10, code A00-U85) by gender, for the period 2001-2015. Data were obtained from Statistical Office of the Republic of Serbia (SORS). SORS provided anonymized mortality data for single area on daily level, and in order to ensure comparable measurements and avoid any slope due to geographical divergency and population growth over time, mortality was standardized per 100,000 inhabitants, as crude death rate (CDR). In 2015, the areas included in analysis had a share in the total population of country with 34.5%, while capital city Belgrade, Novi Sad and Niš are the most settled cities in Serbia. Belgrade exceeded 1.5 million inhabitants, while other two (Novi Sad and Niš) have population from 250 to 350 thousand, while Vranje and Loznica have between 75 and 82 thousand of inhabitants. To assess the climate impact on population, statistical analysis was performed using Ta and CDR relationship. Generalized linear model (GLM) assuming the Poisson distribution with log as the link function, was used to quantify Ta-related CDR. Month and year were included in model as confounder variables. Similar approach was already applied in several studies dealing with population vulnerability to climate change, treating health indicators such as mortality and hospitalization (El-Zein et al. 2004; Romaszko-Wojtowicz et al. 2020). In addition, the preliminary analysis of thermal comfort index PET and relative humidity (RH) was done, and these results will be analyzed in more detail in the upcoming period and published as separate study. Preliminary results on RH impacts on mortality indicate negative correlation between these two variables, respectively lower RH during the summer was followed with increase in mortality. This relation was noticed in all observed regions. Highest correlation was observed in Belgrade and Novi Sad. Results for the correlation between PET and mortality has confirmed positive correlation in PET-mortality association. During the summer period, higher value of PET was followed with higher mortality. This was confirmed in four areas (Belgrade, Novi Sad, Nis, Loznica). Vranje did not show statistically significant association in PET-related mortality.

Methodology and data for the Fourth Milestone and Deliverable – Scientific Paper: Data on daily hospital admission for Novi Sad was obtained from the database of the Institute of Public Health of Vojvodina (org. Institut za javno zdravlje Vojvodine), and in this study were used datasets from the January 1st, 2016, to December 31st, 2017. The Institute of Public Health of Vojvodina is a public institution in charge of collecting and processing information related to emergency medical cases and hospital admission in the entire area of the city of Novi Sad, as well as in the entire area of the Autonomous Province of Vojvodina (northern region of the Serbia). These 2-years datasets provide information about date of admission and discharge, then general patient data such as date of birth and gender, and finally primary causes of admission according to the International Classification of Diseases (ICD-10). In this study, the thermal condition-related with all-cause hospital admissions (ICD from A00 to U85) was performed. Finally, the total number of all-cause hospital admissions during the summer seasons in Novi Sad that are registered during the 2-years period, and later analyzed in this paper is 13,068. Since 2016, the Institute of Public Health of Vojvodina has been regularly collected and analyzed hospital admissions in way that are available for further re-usability, and for the thermal conditions monitoring the Novi Sad Urban Network (NSUNET) system (Šećerov et al. 2015) was used with available meteorological measurements from mid-2014 to the end of 2017. Therefore, in this study is analyzed 2-years period (2016-2017) based on accessible and usable admission/climate datasets on hourly/daily levels.

Temperature datasets are obtained from developed urban meteorological network called NSUNET which contains multiple sensor-stations (12 pieces), precipitation stations (15 pieces) and automatic weather stations (six pieces) located in urban area of Novi Sad and its hinterland and has role to provide high-resolution monitoring/measurements of urban climate processes (Šećerov et al. 2015). NSUNET stations are deployed in different urbanization types in order to monitor climate differences (e.g., thermal patterns) and effects of urbanization on overall climate conditions. For temperature analysis in this study, we considered the 12 sensor-stations that are equipped with air temperature (Ta), and relative humidity (RH) measuring instruments. Also, all sensor-stations are equipped with radiation protection shields where are sensors placed and the accuracy of the Ta sensor is ± 0.3 °C and the RH sensor has accuracy of ± 2 % (20-80 % RH). The measurement frequency of NSUNET sensor-stations is 10-minutes, but for research in this study were used Ta datasets on 1-hour measurement frequency. Before the analysis, the quality control was performed on the raw Ta datasets on 10-minutes measurements, using pre-processing algorithm, and this procedure is explained in detail in the papers of Savić et al. (2018) and Milošević et al. (2022). Finally, we used hourly Ta datasets from sensor-station 2.2, which is located in the most urbanized area of Novi Sad, and based on long-term monitoring, represents the hottest spot in the urban area. Also, we tested the other eleven sensor-stations with data on hospital admissions, but we did not get significant differences compared to the temperature-admission relations shown from station 2.2. Therefore, in our research case, the urban area of Novi Sad can be viewed as a temperature-uniform space. Finally, from the 1-hour Ta datasets, we extracted daily maximum (Tmax) and minimum (Tmin) temperature values.

In this research, we focused on the Tmax and Tmin values. The Tmax values were obtained based on the hourly measured temperatures in a range of 24 hours, i.e., maximum value between 00:00 and 23:00 CEST during the day. The Tmin values were obtained from the hourly measured temperatures in the range of 24 hours, i.e., minimum value between 00:00 and 23:00 CEST from the single day. To reveal the relationship between temperature characteristics and tendencies of hospital admission we used two temperature indices, such as: (a) the diurnal temperature range (DTR); and (b) day-to-day changes in Tmax. The daily DTR represents the difference between the maximum and minimum temperature within one day and is obtained using the following formula:

$$Tr = Tmax - Tmin \quad (1)$$

where Tr is the mark of the DTR in this study, Tmax is the maximal temperature value in a 24-hour period, and Tmin is the minimal temperature in a 24-hour period.

The magnitude of the change in Tmax between adjacent days (Tmax,c) represents the difference in maximum temperature values between two neighboring days. Therefore, the Tmax,c was obtained using the following calculation:

$$Tmax{,}c = Tmax{,}t - Tmax{,}t{-}1 \quad (2)$$

where Tmax,t is the maximum value from the reference day, and Tmax,t-1 is the maximum value from the day before the reference day. According to the defined formula, if Tmax,c is positive, it means that Tmax is higher on the reference day compared to the previous day. If Tmax,c is negative, then Tmax was higher the previous day.

To examine effects of thermal conditions on different population groups, near using all-cause hospital admissions (Ha), we created two subgroups that are classified as: (a) "non-old population" age that are younger than 65 (Ha<65 - "bellow 65"), and (b) "old population" age that are 65 and over (Ha≥65 - "65 and over"). Hence, the daily number of all-cause hospital admissions were stratified according to defined subgroups.

In order to explain in more detail, the possible temporal differences in temperature and hospital admission cases, the whole week is defined in two subgroups, such as: (a) working day – WD representing the period Monday-Thursday, and (b) weekend – WE representing the period Friday-Sunday. Although Friday is officially working day, but this day is related to the weekend, based on hospital admission data, that is, the Ha tendencies on Friday are closer to the characteristics of the weekend than working days. Data on temperature and hospital admissions were used from the summer periods of 2016 and 2017. The summer period is defined as a three-month period, i.e., from June 1st to August 31st. In total, we analyzed 184 days in those two years.

Statistical analysis was performed to reveal the relationship between temperature conditions and number of hospital admissions, by using the Pearson correlation coefficient and One-way ANOVA. Also, we used generalized linear model (GLM) assuming the Poisson distribution with log as the link function (El-Zein et al. 2004; Panagiotakos et al. 2004; Anderson et al. 2013; Romaszko-Wojtowicz et al. 2020). All statistical test and modeling were performed using STATA16.0.

Methodology and data for the Fifth, Sixth and Seventh Milestone and Deliverable – Awareness rising: Increasing knowledge on heatwaves and their impact on people in Serbia through organized dissemination activities. These activities included the organization of the Workshop for stakeholders and citizens named "Beat the heat - Serbia". It lasted for one day with participants from relevant local, regional and national institutions as well as interested citizens and organization groups. At least 30 different stakeholders and experts participated in the workshop. It was a hybrid event in Serbian and English language in order to also attract international experts and stakeholders. Project webpage was also developed, and it contains information about project goal and activities, project team, documentation and promotional material, sponsors, as well as project outputs. Youtube channel with videos showing project activities was also created. Twitter and Linkedin profiles with the info about project activities were created and updated during the project. Finally, leaflet with the information about heat and health implications in Serbia (500 pieces in English and 500 pieces in Serbian language) were created and disseminated during the workshop and at other occasions where project members participated. This leaflet is also available on project website. More information about milestones and deliverables 5-7 are provided in *Appendix 1*.

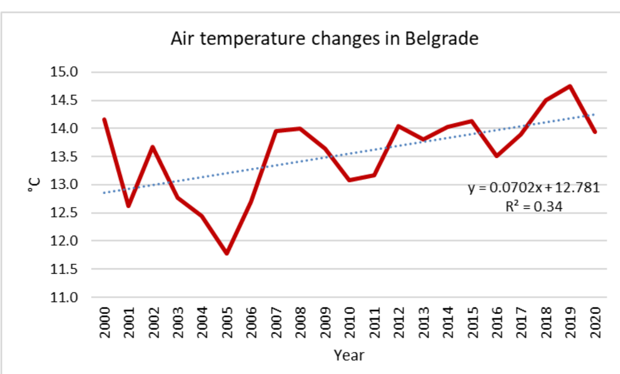
FINDINGS AND CONCLUSIONS

The main findings and conclusions obtained from the seven milestones and deliverables are as follows.

First milestone and deliverable - Climate report: This report provides and overview of the temperature, humidity, wind and cloudiness changes in Serbia in the period 2000-2020. The selected climate elements are among the most important for the health and well-being of population. The focus of the report is on the country's largest cities (Belgrade, Novi Sad and Niš) where majority of population lives, and on the annual and summer periods.

Temperature changes in Serbia

Analysis of air temperature changes from 47 stations in Serbia shows substantial temperature increase in the past two decades (2000-2020). It goes from 0.5 °C per decade in the south of country to 0.7 °C per decade in the north of country (*Figure 1*). Temperature increases are even higher during the summer period, especially in August.



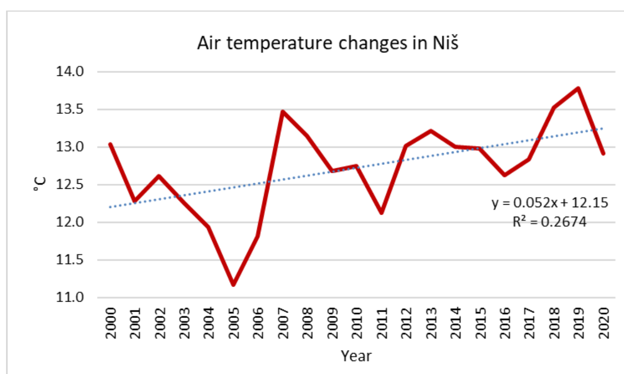


Figure 1. Air temperature changes in Belgrade and Niš in the period 2000-2020

Humidity changes in Serbia

Analysis of air humidity changes from 34 stations in Serbia shows mixed signal with both increases and decreases in relative humidity (RH) in the past two decades (2000-2020). For example, station Novi Sad in north Serbia showed RH increase, while station Niš in south Serbia showed RH decrease (*Figure 2*). In summer, decrease in RH is even more substantial and can be seen throughout the country.

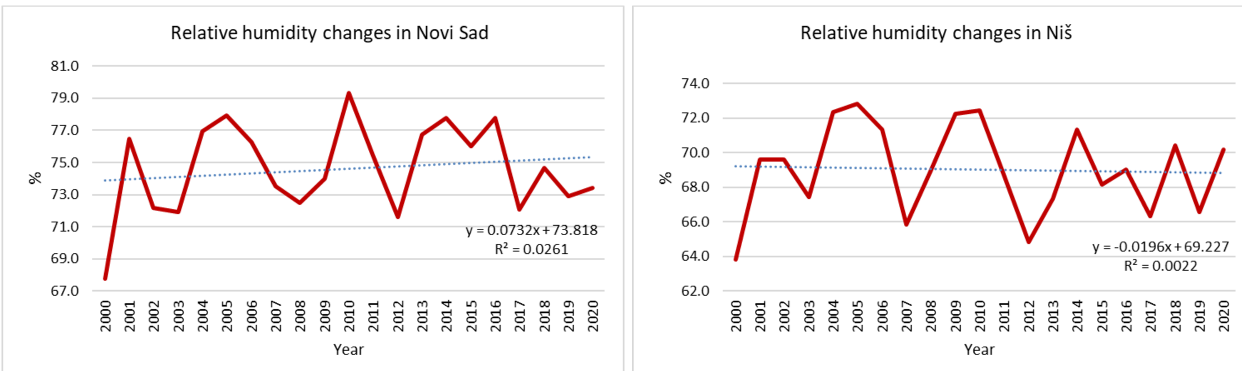


Figure 2. Relative humidity changes in Novi Sad and Niš in the period 2000-2020

Cloudiness changes in Serbia

Analysis of cloudiness changes from 34 stations in Serbia shows mixed signal with both increases and decreases in the past two decades (2000-2020). For example, station Novi Sad in north Serbia showed cloudiness increase, while stations Belgrade and Niš in central and south Serbia showed cloudiness decrease on annual level (*Figure 3*). However, cloudiness in summer is decreasing throughout the country.

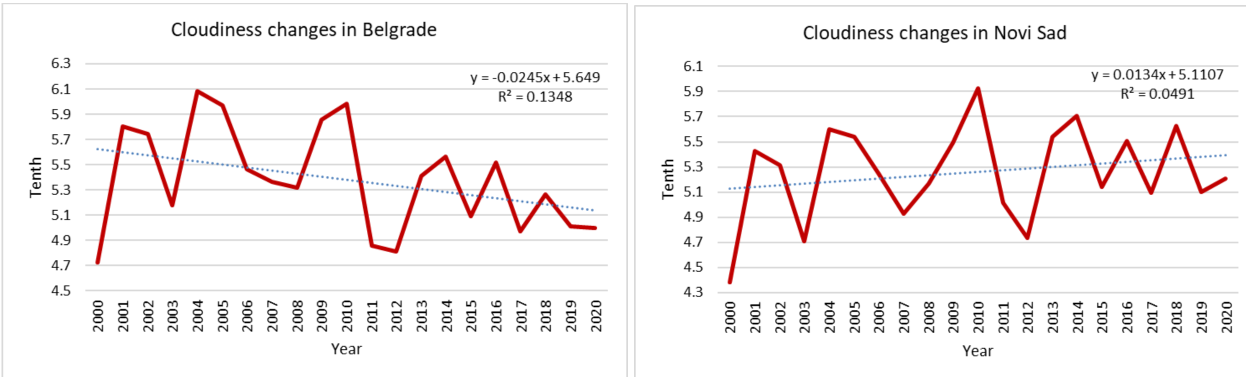


Figure 3. Cloudiness changes in Belgrade and Novi Sad in the period 2000-2020

Wind speed changes in Serbia

Analysis of wind speed (*v*) changes from 47 stations in Serbia shows mixed signal with both increases and decreases in of *v* in the past two decades (2000-2020). For example, station Novi Sad in north Serbia showed *v* increase, while station Niš in south Serbia showed *v* decrease (*Figure 4*). The situation is similar during the summer season.

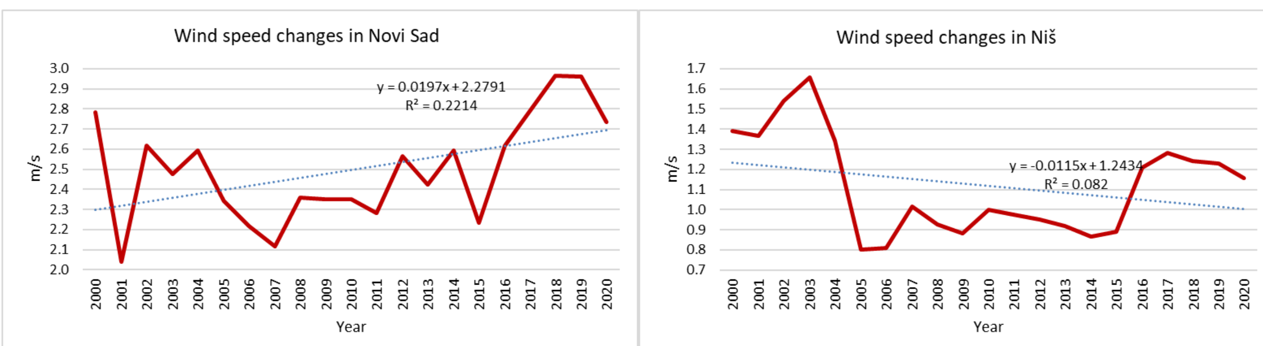


Figure 4. Wind speed changes in Novi Sad and Niš in the period 2000-2020

In conclusion, changes in climate of Serbia are noticed based on the analysis of the most important climate parameters in the period from 2000 to 2020. Especially evident are changes in air temperatures with substantial increases in the past two decades. This certainly impacts the health and well-being of local population. However, air temperature is not the only climate elements that impacts the population. In addition, we need to consider humidity, wind, and cloudiness (or global radiation) in order to obtain a more comprehensive picture of climate impacts on humans. Thus, we also calculated biometeorological indices that show the impact of climate and other parameters on human thermal comfort and occurrence of heat or cold stress. These results are provided in the next report named “Bioclimate report for Serbia 2000-2020”. The climate report can be seen and downloaded from the project website: https://sites.google.com/view/extremeheatinserbia/home

Second milestone and deliverable - Bioclimate report and Scientific Paper entitled "Analysis of long- and short-term biometeorological conditions in the Republic of Serbia": In Bioclimate report the data from official weather stations in Serbia for the period 2000-2020 are used to calculate three types of thermal indices which are most frequently used in assessment of human outdoor thermal comfort: Physiologically equivalent temperature PET, Universal thermal comfort index (UTCI) and HUMIDEX, all expressed in ºC. PET and UTCI indices are calculated in RayMan software, and HUMIDEX (H) calculation was based on the Masterton and Richardson (1979) formula, but the calculation procedure itself was performed in Excel using formula transcribed by Vysoudil et al. (2016). The selected indices are most often used for outdoor thermal comfort assessment of humans.The focus of the report is on the country's largest cities (Belgrade, Novi Sad and Niš) where majority of population lives, and on the annual and summer periods.

PET changes in Serbia

Analysis of PET dynamics from 26 stations in Serbia shows substantial PET values increase in the past two decades (2000-2020). Yearly average data for Belgrade show that, there is slight cold thermal stress (PET values 13-18 ºC) (*Figure 5*). On the other hand, data from summer month (July) show that Niš was under moderate heat stress (PET values 29-35ºC) in the summer, and in some years (2007, 2012, 2013, 2016) it goes into the strong heat stress (PET values 35-41 ºC).

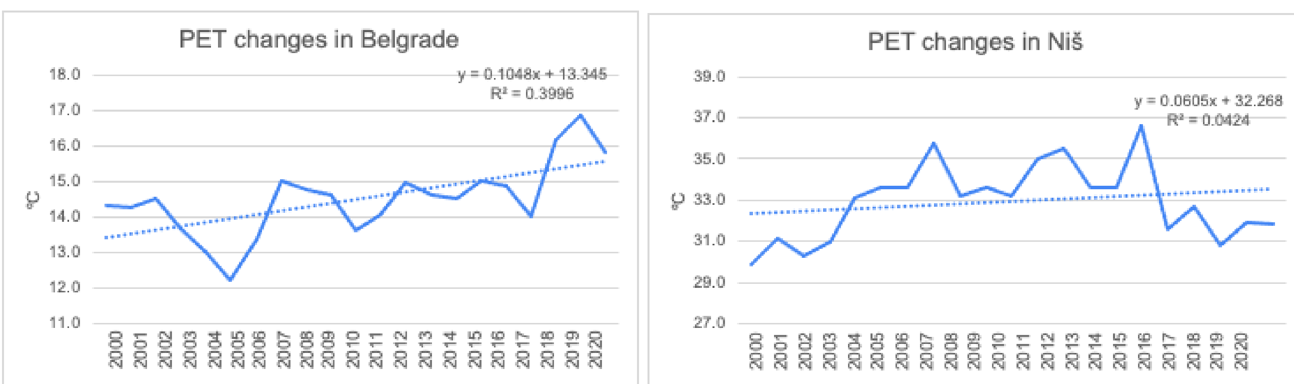


Figure 5. PET changes in Belgrade and Niš (July) in the period 2000-2020

UTCI changes in Serbia

Analysis of UTCI changes from 26 stations in Serbia shows mixed signal with both increases and decreases in UTCI in the past two decades (2000-2020), but on average according to the UTCI scale there is no thermal stress (*Figure 6*; Novi Sad; UTCI values 9-26ºC). This is not very precise because averaged yearly data are considered. On the other hand, in summer in Belgrade (August), it can be noticed that there is moderate heat stress (UTCI values 26-32 ºC). Trendline shows that in the recent years, in August the intensity of the heat stress is increasing in Belgrade, and similar situation is in other cities as well.

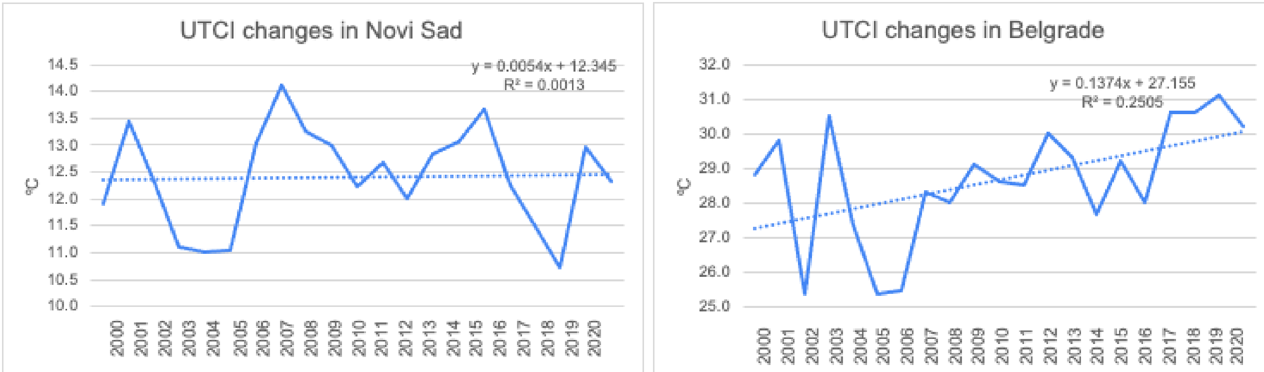


Figure 6. UTCI changes in Novi Sad and Belgrade (August) in the period 2000-2020

HUMIDEX changes in Serbia

Analysis of HUMIDEX changes from 26 stations in Serbia shows mixed signal with both increasesand decreases in the past two decades (2000-2020). However, when looking into average yearly records, similar to the PET and UTCI index, there is no discomfort observed with HUMIDEX index either (HUMIDEX values <29ºC) in Niš (*Figure 7*), but in other Serbian cities as well. In summer month - July, for example, HUMIDEX values in Novi Sad showed some discomfort, butonly in 2012. However, trendline in both cases, yearly averages and summer averages, shows that the values of the HUMIDEX index are rising, just like in the cases of PET and UTCI indexes.

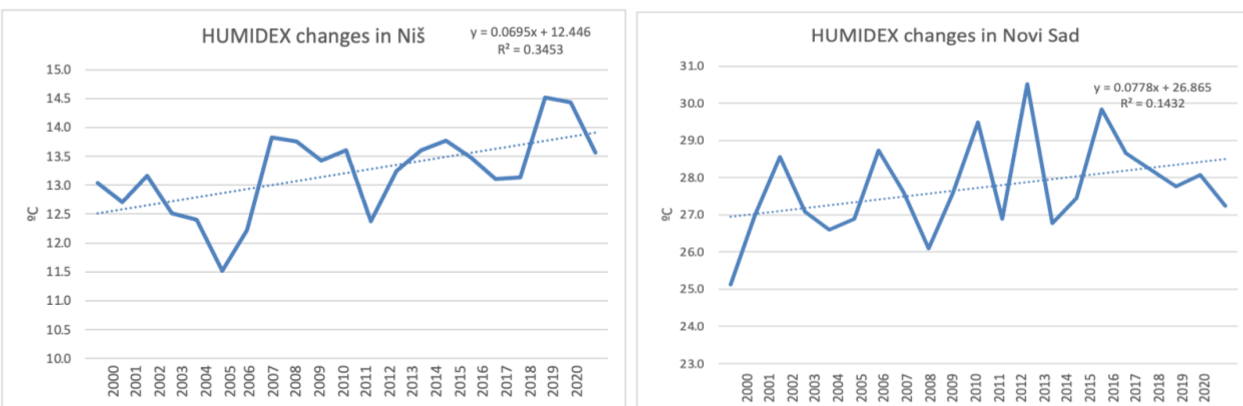


Figure 7. HUMIDEX changes in Belgrade and Novi Sad in the period 2000-2020

In conclusion, changes in climate of Serbia are noticed based on the analysis of the most used bioclimate indices in the period from 2000 to 2020. Especially evident are changes in summer months, in major cities of Serbia according to PET, UTCI, and HUMIDEX indices, with increases in the past two decades. This certainly impacts the health and well-being of local population. However, the results presented in this report are quite general, and only used to show general trend in increasing the values of thermal comfort indices leading to the thermal discomfort, especially in the summer months. In addition, we need to consider much more detailed analysis of thermal comfort assessment to obtain a more comprehensive picture of climate impacts on humans. Thus, we will calculate biometeorological indices with much more detailed spatial and temporal resolutions that show the impact of climate and other parameters on human thermal comfort and occurrence of heat or cold stress according to the season of the year. These results will be provided in scientific articles in the appropriate journals. The bioclimate report can be seen and downloaded from the project website: https://sites.google.com/view/extremeheatinserbia/home

Scientific paper entitled "Analysis of long- and short-term biometeorological conditions in the Republic of Serbia": In this study, HUMIDEX, PET and UTCI values have been analyzed on the annual and summer level for the period 2000-2020. In addition, analysis of the intensive heat wave periods for the main meteorological stations was performed.

Annual and summer biometeorological conditions based on HUMIDEX, PET, and UTCI

Average annual values of HUMIDEX range from 6.6 ℃ in Sjenica (1038 m a.s.l.) to 14.2 ℃ in Belgrade (132 m a.s.l.). Lower HUMIDEX values are also registered at Zlatibor Mountain, while higher values are registered at stations located in northern Serbia with plain relief. During summer, the lowest average HUMIDEX values are again registered in the mountainous areas (between 18 and 20 ℃), while the highest are registered in B. Petrovac, Negotin and Belgrade (about 27-28 ℃) (*Table 1*). The HUMIDEX values below 29 ℃ indicate no discomfort, thus, average annual and seasonal HUMIDEX values in Serbia belong to this category.

Table 1. Average annual and seasonal HUMIDEX values at official meteorological stations in Serbia

Station	Summer	Annual
B. Crkva	27.5	13.6
B. Petrovac	28.1	13.8
Babusnica	24.5	11.6
Beograd	27.6	14.2
Cuprija	26.3	12.7
Dimitrovgrad	23.6	10.8
Kikinda	26.5	12.8
Knjazevac	27.0	12.8
Kragujevac	26.3	13.0
Kraljevo	26.2	12.8
Krusevac	26.4	12.9
Kursumlija	24.2	11.5
Leskovac	25.7	12.3
Loznica	26.7	13.4
Negotin	27.9	13.4
Nis	26.6	13.2
Novi Pazar	23.9	11.1
Novi Sad	26.8	13.1
Palic	26.3	12.5
Pirot	26.2	12.7

Pozega	24.4	10.9
Rekovac	26.0	12.5
S. Mitrovica	26.5	12.9
S. Palanka	26.6	13.0
Sjenica	18.6	6.6
Sombor	25.9	12.4
Uzice	22.4	10.1
V. Gradiste	26.9	13.0
Valjevo	26.8	13.2
Vranje	25.0	12.1
Vrsac	26.7	13.4
Zajecar	26.2	12.0
Zenjanin	27.0	13.2
Zlatibor	20.2	8.0

In addition to average values, trends of annual and seasonal HUMIDEX were assessed (*Figure 8*). All trends are positive indicating that increase in HUMIDEX is evident across the country on annual and summer level. Some areas showed negligible increase, while other showed substantial increases in HUMIDEX. On annual level, the most substantial increases in HUMIDEX (0.9-1.1 °C per decade) are generally registered in urban areas, such as in smaller cities Valjevo and Knjazevac, and in large cities Belgrade and Novi Sad. On summer level, the increases are even more pronounced (1.1-1.6 °C) with the highest trends in cities of Valjevo, Cuprija and Sombor (*Figure 8*).

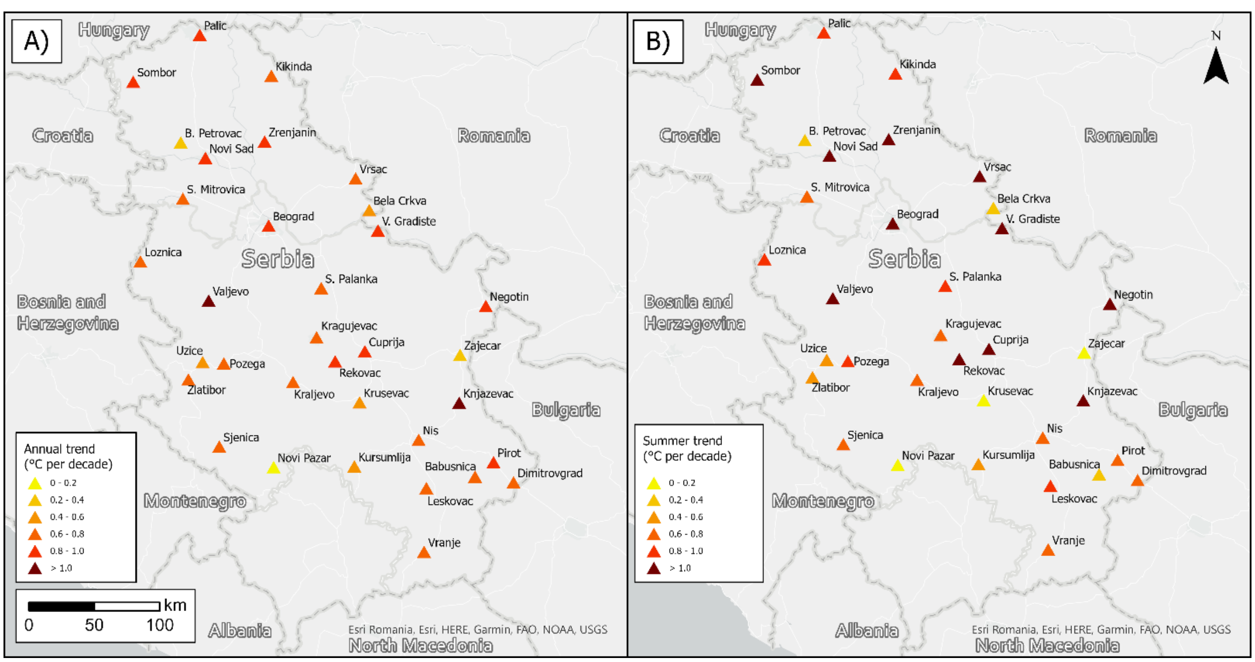


Figure 8. Annual (A) and summer trends (B) of average HUMIDEX values in the Republic of Serbia in the period 2000-2020. NOTE: The trends are expressed in °C per decade

Based on average summer PET values, majority of the country experienced slight heat stress (17 of 27 stations), followed by moderate heat stress registered at 9 of 27 stations. The most uncomfortable are cities Nis and Negotin in southern and eastern Serbia. Only high-latitude station Sjenica experiences no thermal stress with average PET value of 22.6 °C. If UTCI is considered, 6 stations show no thermal stress, and they are mostly located in southeastern Serbia. 21 stations have UTCI value higher than 26 °C, which indicates moderate heat stress, and the worst conditions are again noticed in Nis, Negotin and Loznica (*Table 2*). On annual level, PET values indicate the occurrence of cold stress throughout the country. Moderate cold stress is registered at 10 stations, while slight cold stress is registered at 17 stations. The lowest average annual PET values are registered on high altitude stations Sjenica and Zlatibor, while the highest are registered at stations Loznica and Nis. Average annual UTCI values indicate no thermal stress in the whole country ranging from 10.2 °C in Vrsac (northeastern Serbia) to 19.4 °C in Loznica (western Serbia) (*Table 2*).

Table 2. Average annual and summer PET and UTCI values at official meteorological stations in Serbia for the period 2000-2020. Values are given in °C. NOTE: Colors indicate different thermal stress categories (legend is provided below the table)

Station	Summer		Annual	
	PET	UTCI	PET	UTCI
B. Petrovac	28.6	28.4	13.2	13.5
Beograd	29.0	28.0	14.5	14.3
Cuprija	30.4	29.3	15.7	17.2
Dimitrovgrad	24.7	25.2	11.3	11.3
Kikinda	26.2	25.7	12.0	10.7
Kragujevac	30.6	29.3	16.1	17.3
Kraljevo	28.6	28.1	14.7	16.1
Krusevac	29.6	28.7	15.4	16.9
Leskovac	30.8	29.4	17.2	18.9
Loznica	30.9	29.6	17.7	19.4
Negotin	31.1	29.6	15.9	17.1
Nis	32.0	30.0	17.2	18.4
Novi Sad	27.4	27.1	12.8	12.4
Palic	26.7	26.2	12.3	11.7
Pozega	30.1	28.8	16.5	19.2
S. Mitrovica	27.0	26.9	12.9	13.2
S. Palanka	29.2	28.4	14.7	15.6
Sjenica	22.6	24.0	9.7	11.8
Sombor	27.6	27.2	13.0	13.3
Uzice	24.6	25.1	11.3	11.7
V. Gradiste	28.6	28.2	13.4	13.3

Valjevo	28.9	28.4	15.3	17.1
Vranje	26.8	26.4	13.7	14.5
Vrsac	26.2	25.7	12.4	10.2
Zajecar	28.7	28.2	14.2	15.6
Zenjanin	28.7	28.1	13.8	14.0
Zlatibor	23.1	24.3	10.1	11.5

NOTE: Categories for PET and UTCI

PET
dark blue - cool (moderate cold stress)
light blue - slightly cool (slight cold stress)
green - comfortable (no thermal stress)
yellow - sligthly warm (slight heat stress)
red - warm (moderate heat stress)

UTCI
green - no thermal stress
red - moderate heat stress

Analysis of PET and UTCI trends during summer show a general increase in the period 2000-2020. 25 stations show positive PET trends, while only 2 stations show negative PET trends. The most substantial PET increase (> 2 ℃ per decade) during summer is registered in Sremska Mitrovica (northern Serbia) and in Vranje (southern Serbia). On the contrary, the most substantial decrease in summer PET (> 1 ℃) is registered at stations Krusevac and Pozega in central Serbia (*Figure 9*). UTCI summer trends show a general increase on 24 out of 27 stations, which is similar to the PET results. The only contrast is that UTCI shows a small decrease on station Kragujevac (central Serbia), while PET shows a small increase on this station (*Figure 10*). Annual trends also indicate increase in PET and UTCI on almost all stations (24 of 27), with only a few exceptions in central Serbia.

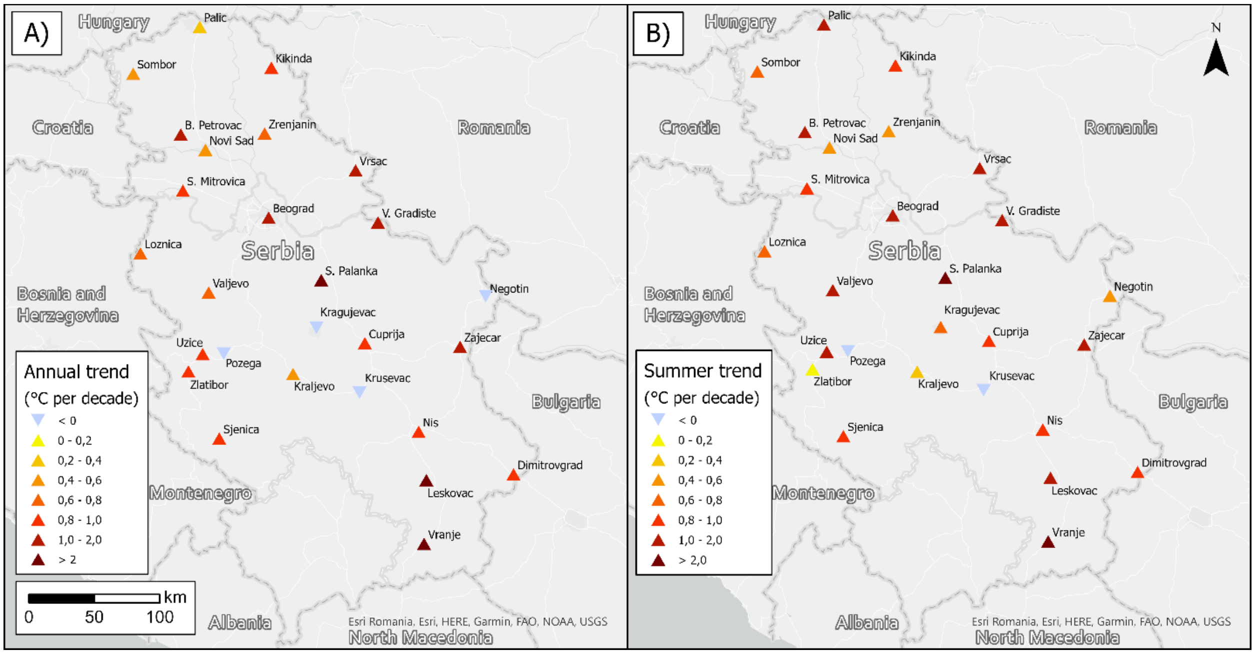


Figure 9. Annual (A) and summer (B) trends of average PET in the Republic of Serbia in the period 2000-2020. NOTE: The trends are expressed in ℃ per decade.

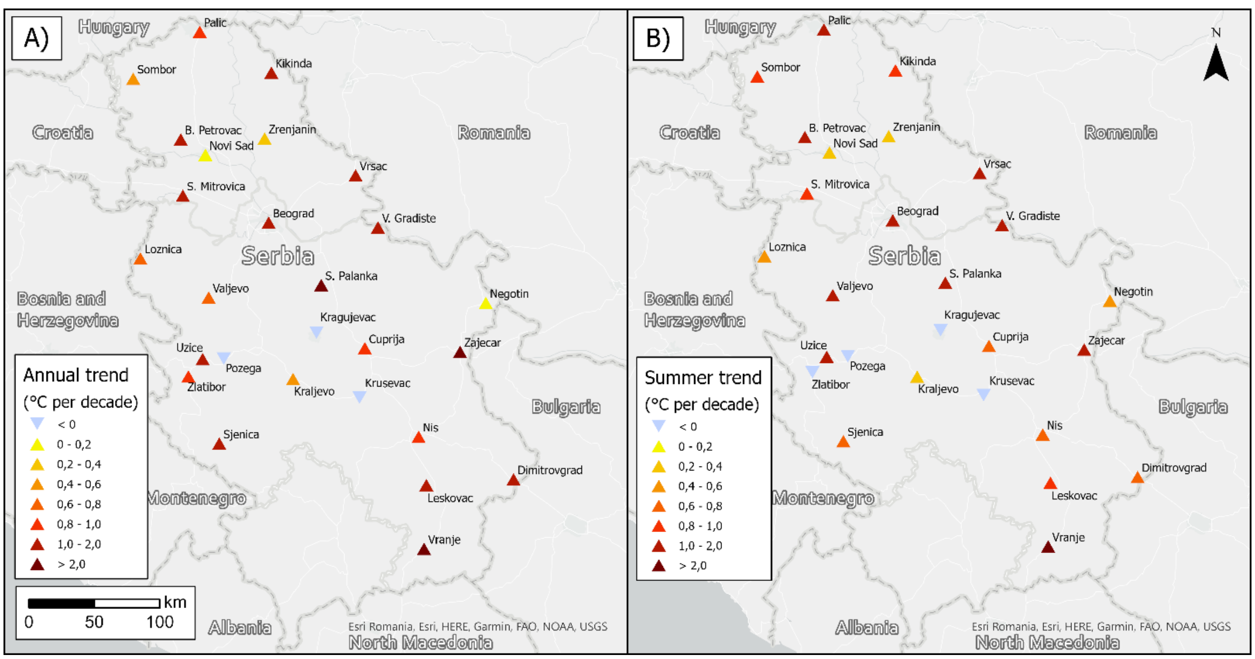


Figure 10. Annual (A) and summer (B) trends of average UTCI in the Republic of Serbia in the period 2000-2020. NOTE: The trends are expressed in ℃ per decade.

Biometeorological conditions during heat wave based on HUMIDEX, PET, and UTCI

The assessment of extreme heat conditions was performed during two intensive summer heat waves in 2015 and 2019. Average HUMIDEX values indicate no discomfort (HUMIDEX < 29 °C) in the morning at all stations, except for Belgrade that experiences some discomfort (*Table 3*). During midday, average HUMIDEX values indicate that some discomfort (HUMIDEX between 30 and 39 °C) at all stations with highest average value registered in Novi Sad. The discomfort continues in the early evening hours (21h) at all stations, except for Vranje where no discomfort is registered. The maximum HUMIDEX values are above 40 °C at all stations, which indicates great discomfort and exertion should be avoided (when HUMIDEX is between 40 and 45 °C). At station Novi Sad, HUMIDEX is above 45 °C indicating that outdoor biometeorological conditions are dangerous for human health. Minimum HUMIDEX values (*Table 3*) indicate no discomfort during morning and evening hours at all stations, while they show some discomfort during midday at all stations during the hours when minimum HUMIDEX occurred.

Table 3. Average, maximum and minimum HUMIDEX values at 7h (morning), 14h (midday) and 21h (evening) in Serbia during the heat wave periods. NOTE: bold – highest values; italic – lowest values; and NA – not available

Station	*HUMIDEX_average*		
	7h	14h	21h
Belgrade	**29.5**	38.3	**32.5**
Loznica	27.1	38.3	31.1
Nis	23.7	37.4	29.6
Novi Sad	28.8	**38.9**	31.0
Vranje	*21.8*	*36.0*	*27.9*
Station	*HUMIDEX_max*		
	7h	14h	21h
Belgrade	33.9	43.8	37.3
Loznica	34.8	42.7	37.7
Nis	*29.7*	42.8	*35.3*
Novi Sad	**35.2**	**45.2**	**38.8**
Vranje	30.9	*40.3*	36.6
Station	*HUMIDEX_min*		
	7h	14h	21h
Belgrade	**22.9**	34.0	**26.7**
Loznica	20.9	34.0	25.3
Nis	16.6	*30.9*	24.1
Novi Sad	19.5	**34.1**	24.2
Vranje	*14.3*	31.3	*21.5*

Average, maximum and minimum PET and UTCI values are analyzed for three specific hours: 7h (morning period), 14h (midday period) and 21h (evening period) during the HW period (*Figure 11*).

Average morning PET values are the highest (29.5 °C) in Nis (southern Serbia) where moderate heat stress occurs. Slight heat stress occurs on all other stations with the lowest PET values (25.1 °C) in Novi Sad (northern Serbia) and Vranje (southern Serbia). Due to low wind speeds, UTCI is not obtained for the morning period at Loznica and Nis. Belgrade has the highest average UTCI value in the morning with 27.2 °C, which indicates moderate heat stress. Other stations did not show heat stress occurrence based on the average morning UTCI value. During the midday period, extreme heat stress (average PET > 41 °C) occurs at almost all stations with the highest average PET of 44 °C obtained for station Nis (southern Serbia). Only station Vranje, also located in southern Serbia, is characterized by strong heat stress. Average UTCI values indicate somewhat different heat stress occurrence during the midday period. Majority of stations are characterized by strong heat stress (38 °C < UTCI > 32 °C), with only station Nis (southern Serbia) characterized by very strong heat stress (38.5 °C UTCI). During the evening period, only station Belgrade is characterized with a slight heat stress (23.9 °C PET), while other stations indicate comfortable outdoor conditions with no thermal stress. Average UTCI values during the evening also indicate no thermal stress at all analyzed stations (*Figure 11*). Maximum PET values in the morning period range from 34.9 °C in Belgrade (moderate heat stress occurs) to 39.6 °C in Novi Sad (strong heat stress occurs). During midday period, maximum PET values increase up to 55.2 °C PET at station Nis (extreme heat stress occurs), while the maximum UTCI values during midday go to 42.6 °C at the same station (very strong heat stress occurs). In the evening period, maximum PET values indicate occurrence of slight heat stress at all stations with the maximum PET of 28.7 °C in Belgrade. Similar results are provided with the UTCI maximum values (*Figure 11*). Minimum PET values range from 14 °C in Novi Sad (slight cold stress) to 21 °C in Belgrade (comfortable, no thermal stress) during the morning period. Slight cold stress is also registered at stations Vranje, Nis and Loznica. On the contrary, minimum UTCI values in the morning indicate no thermal stress at all stations. During midday of the heat wave period, even the minimum PET values do not decrease below 32 °C. This shows that extreme heat conditions are present during the midday of the heat waves when even the minimum PET values belong to the category of moderate and strong heat stress at analyzed stations. Minimum UTCI values during midday also indicate occurrence of moderate or strong heat stress at all stations. In the evening period, slight cold stress occurs at stations Vranje, Loznica and Novi Sad, while comfortable conditions are in Belgrade and Nis, based on the minimum PET values. Minimum UTCI values in the evening period indicate no thermal stress at all stations (Figure 11).

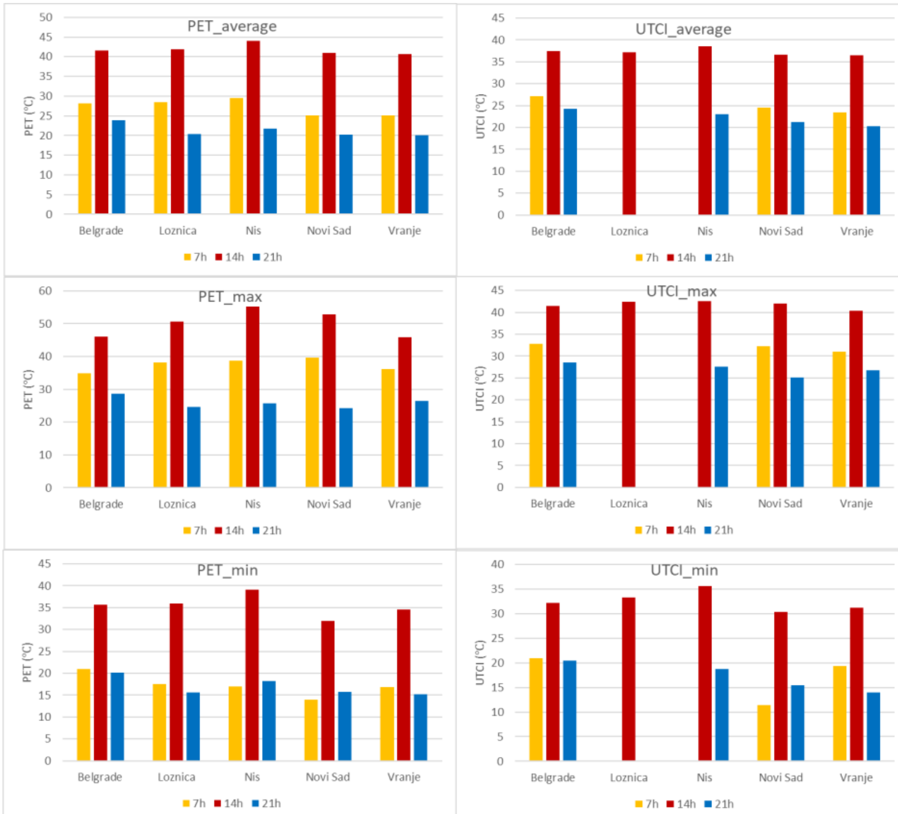
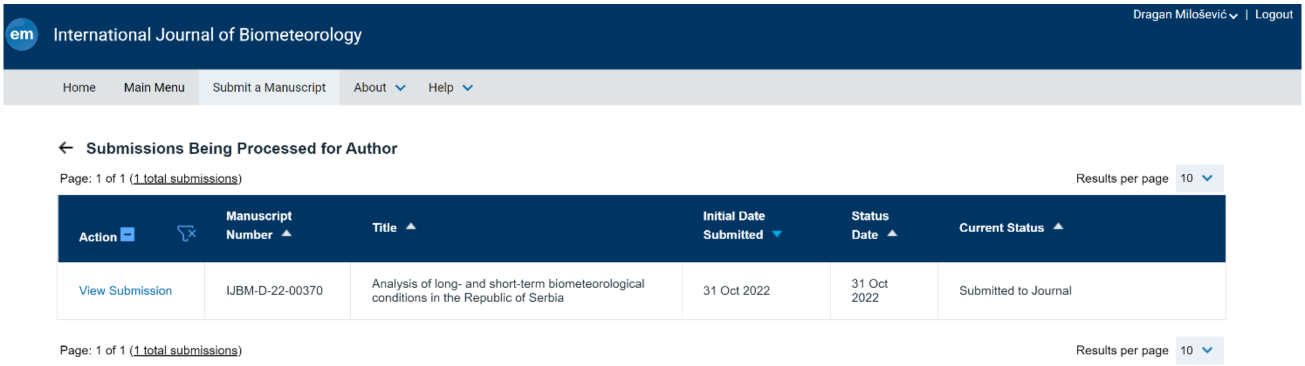


Figure 11. Average, maximum and minimum PET and UTCI values at 7h (morning), 14h (midday) and 21h (evening) in Serbia during the heat wave periods

Main conclusions from the study - Acquisition of the short- and long-term biometeorological conditions can provide important information for data-driven adaptation to climate change on country or city level. In this study, three different biometeorological indices have been used in order to reveal biometeorological conditions in Serbia in the period 2000-2020. The focus was on annual, summer and heat wave periods. Depending on the applied index, different biometeorological conditions were revealed. This indicates that it is important to be careful when choosing a biometeorological index and that the focus should be on applying more comprehensive indices, such as PET and UTCI, that consider a broader spectrum of meteorological and other parameters. For example, HUMIDEX indicates no discomfort during summer, while PET and UTCI indicate the occurrence of heat stress throughout the country. This is because HUMIDEX does not consider important biometeorological elements, such as mean radiant temperature, while PET and UTCI consider the impact of radiant temperature on human body. What is common for all indices is that all show increasing trends on annual and summer level in the period 2000-2020 in Serbia. The analysis of extreme heat wave periods indicated occurrence of extreme heat stress during the midday period of the day with the most severe situation in southern and eastern Serbia. These extreme biometeorological conditions lead to substantial pressures on human health and well-being and they should be mitigated by applying adequate measures, such as development of climate-sensitive urban design, early warning systems for extreme heat and guidelines for the local population.

This study is submitted to a scientific journal named International Journal of Biometeorology (Impact Factor 3.7 for 2021). Evidence of submission is provided in *Figure 12*.



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Submissions Being Processed for Author

Page: 1 of 1 (1 total submissions)

Results per page 10

Action	Manuscript Number	Title	Initial Date Submitted	Status Date	Current Status
View Submission	IJBM-D-22-00370	Analysis of long- and short-term biometeorological conditions in the Republic of Serbia	31 Oct 2022	31 Oct 2022	Submitted to Journal

Page: 1 of 1 (1 total submissions)

Results per page 10

International Journal of Biometeorology

Analysis of long- and short-term biometeorological conditions in the Republic of Serbia

--Manuscript Draft--

Manuscript Number:	
Full Title:	Analysis of long- and short-term biometeorological conditions in the Republic of Serbia
Article Type:	Original Research Paper
Keywords:	biometeorology; outdoor thermal comfort; HUMIDEX; PET; UTCI; Serbia
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Funding Information:	Global Disaster Preparedness Center — Dr Dragan D. Milošević Red Cross Red Crescent Climate Center — Dr Dragan D. Milošević Global Heat Health Information Network — Dr Dragan D. Milošević
Abstract:	Long- and short-term biometeorological conditions in the Republic of Serbia were analyzed using official meteorological data from numerous weather stations located across the country. Selected biometeorological indices HUMIDEX, Physiologically Equivalent Temperature (PET) and Universal Thermal Climate Index (UTCI) are calculated based on air temperature, relative humidity, wind speed and cloudiness data from the meteorological stations on annual and summer level as well as during selected heat wave periods during 2000-2020. Application of different biometeorological indices provide similar but somewhat different results. For example, average annual HUMIDEX and UTCI values indicate no thermal stress and no discomfort at all stations, while PET indicates the occurrence of slight to moderate cold stress at all stations. Average summer PET and UTCI indicate the occurrence of slight to moderate heat stress throughout the country, while HUMIDEX indicates no discomfort. Trends of biometeorological indices on annual and summer level show a general increase throughout the country. Furthermore, heat wave analysis indicated that the most populated cities of Serbia are under dangerous and extreme heat stress during these extreme temperature events, which can influence human health and well-being. The obtained biometeorological information can be used for the preparation of climate adaptation strategies that consider the human biometeorological conditions, with a special focus on developing climate-sensitive and comfortable cities.

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Figure 12. Study entitled "Analysis of long- and short-term biometeorological conditions in the Republic of Serbia" submitted to International Journal of Biometeorology

Third milestone and deliverable – Scientific paper entitled "The effects of summer temperature on human mortality in Serbia":

Findings - In all analyzed cities (Belgrade, Novi Sad, Niš, Vranje, and Loznica) summer Ta varied from 21.7 °C (in Vranje) to 23.3 °C (in Belgrade). Belgrade has the highest mean summer Ta possibly to the urban heat island effect as it is the most urbanized city in the country. In addition, the lowest and highest Ta with values of 7.6 °C and 34.6 °C were also observed in Belgrade (*Table 4*).

Table 4 Descriptive statistics of weather stations, daily average temperature (Ta) and crude death rate (CDR) for the summer period 2001-2015

	Belgrade	Novi Sad	Niš	Vranje	Loznica
	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)
Latitude	44□48□	45□19□	43□20□	42□33□	44□32□
Longitude	20□28□	19□50□	21□54□	21□55□	19□14□
Elevation (m)	132	86	202	433	121
Average daily CDR	3.2 (0.5)	2.8 (0.99)	3.1 (1.1)	2.7 (1.8)	3.0 (1.95)
Average daily CDR-male	3.5 (0.7)	3.1 (1.4)	3.3 (1.7)	2.8 (2.7)	3.4 (2.8)
Average daily CDR-female	3.0 (0.7)	2.6 (1.3)	3.0 (1.5)	2.6 (2.5)	2.9 (2.7)

*Number of observed days in the series is 1380, *S.D. stands for standard deviation

The analysis of summer temperatures on mortality was performed by using daily Ta and CDR for the summer period 2001-2015. Five Poisson regression models, for each area, were constructed, and each considered summer Ta and CDR. Four models (Belgrade, Novi Sad, Niš and Loznica) showed statistically significant (at 1% level) relationship between Ta and CDR, i.e., increase in Ta was followed with increase in CDR. The effect of Ta on CDR was presented as relative risk (RR), which was obtained as the exponential regression coefficient of the models. RR for four area indicates that under higher Ta, CDR is more likely to increase, *with 1 °C increase in Ta associated with a 1.93% increase in the CDR for Belgrade, 1.87% for Novi Sad, 1.61% Niš and 2.05% for Loznica* (see *Table 5*). Model for Vranje did not quantify statistically significant increase for CDR in relation to Ta (RR=1.0115, 95% CI 0.9998-1.0232).

Figure 13 shows scatter plot of daily CDR versus Ta in summer period. As it can be noticed, *the graphical determination indicates Ta range from which CDR varies. For Belgrade and Novi Sad this threshold is around 20 °C and 25 °C, while Niš and Loznica move forward close to the 30 °C.* With respect to the gender, similar results were found as stated above. Four models suggest statistically significant increase in CDR-related to Ta, for both male and female population, with slightly higher risk for women (see *Table 5*). *For 1 °C increase in Ta, increase in CDR for males varied from 1.70% (in Belgrade), 1.36% (in Novi Sad), 1.42% (in Niš) and 1.52% (in Loznica). For females, increase in CDR for 1 °C has value of 2.17% (in Belgrade), 2.41% (in Novi Sad), 1.82% (in Niš) and 2.64% (in Loznica).* For Vranje, daily Ta effect on CDR was not confirmed as statistically significant, neither for male (RR=1.0065, 95% CI 0.9905-1.0228) or female (RR=1.0171, 95% CI 1.0006-1.0337).

Table 5 Relative risk (RR) estimated from Poisson regression models of daily CDR value associated with °C increase in Ta

	All	Male	Female

Area	RR	95% CI	RR	95% CI	RR	95% CI
Belgrade	1.0193	1.0171-1.0215	1.0170	1.0143-1.0198	1.0217	1.0187-1.0247
Novi Sad	1.0187	1.0135-1.0239	1.0136	1.0065-1.0208	1.0241	1.0165-1.0317
Niš	1.0161	1.0106-1.0217	1.0142	1.0063-1.0222	1.0182	1.0102-1.0262
Vranje	1.0115	0.9998-1.0232	1.0065	0.9905-1.0228	1.0171	1.0006-1.0337
Loznica	1.0205	1.0106-1.0306	1.0152	1.0020-1.0286	1.0264	1.0117-1.0414

CI: confidence interval

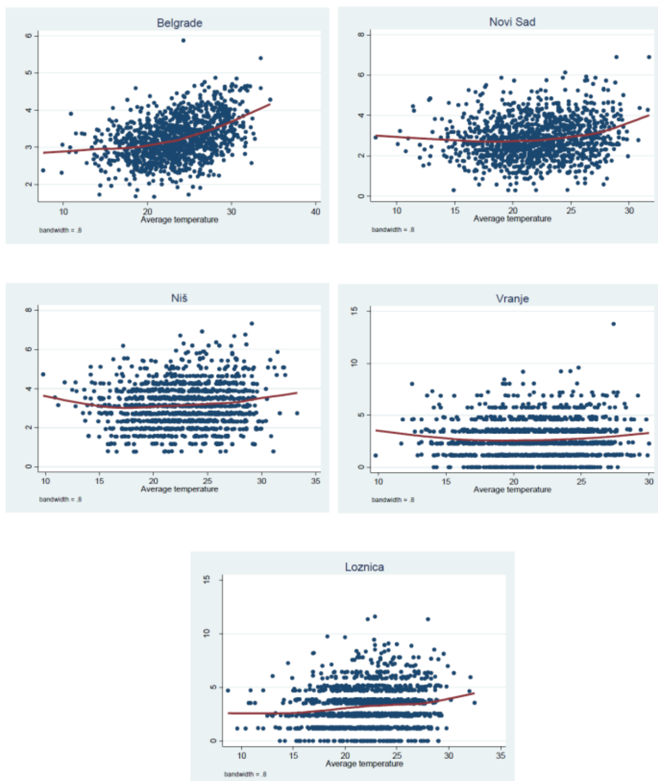
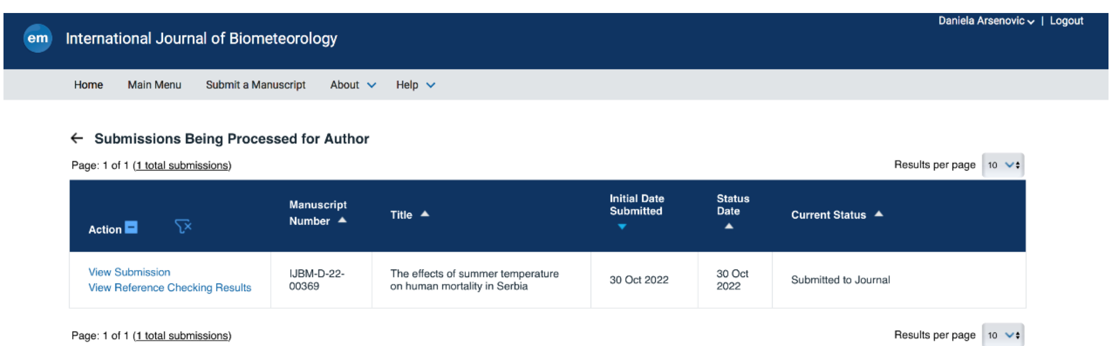


Figure 13. The effects of average temperature (Ta in °C) on crude death rate (CDR)

Daily CDR as a function of Ta confirmed positive association in four areas. These results were expected for Belgrade, since that is the largest and most populated city, with high population density, where more than 80% of inhabitants lives in urban area. Novi Sad and Niš are the other two large cities where majority of population is settled within urban area (S.Tab.1). Certain divergency was demonstrated in models for Loznica and Vranje. Both counts significantly lower number in total population (less than 100,000) and despite the higher proportion of urban population in Vranje compared to Loznica where only about 30% inhabitants live in urban area, RR value of CDR for Loznica was higher with increase in Ta. During the investigated summer periods from 2001 to 2015, Vranje has lower Ta compared to other four locations, which could be revealed as factor of lower RR value for Vranje. Moreover, for Loznica was found the highest increase in CDR associated with 1 °C increase in Ta. Our results suggest that urban areas, regardless of population size, are exposed to temperature-related health impacts with adverse mortality risks. This study also followed association between Ta and CDR by gender, reporting positive correlation between Ta and CDR for both male and female population, with slightly higher risk for female. For the time being, there is no clear evidence about gender related differences in exposure to high temperature. Few authors addressed socio-demographic and biological factors as main drivers of slope in association between temperature and mortality by gender. As the females have higher life expectancy, negative health effects due to high temperatures and heat exposure partly could be attributable to the fact that mean age of females in certain age groups is higher than average age of males. Since those women live longer, they are more vulnerable to heat, whereas ageing is associated with increased mortality during heatwaves. Further, physiological changes in thermoregulation might explain some of differences. The temperature threshold above which sweating mechanisms are activated is founded to be higher for women, which results in less perspiration heat loss, and consequently higher sensitivity to heat. The time lag effects were not observed in this study.

The main findings form the study - The performed analysis shows adverse effects of average temperature on human mortality, indicating temperature-related vulnerability of inhabitants in the region during the summer. The study provides evidence that not only highly, but also moderately urbanized areas could be exposed to increase in mortality due to non-optimal average temperatures and reveals future research in which more data about predictor indicators should be included, with aim to consider cause-specific population groups and location-specific characteristics. According to our findings, this is the first study about temperature-attributable mortality assessing different geographical locations in Serbia and these results could be adopted in forthcoming research in terms of different geographical areas. Lack of the data on the daily level for other cities and municipalities in Serbia, regarding to the climate indices, could be exceeded using mobile measurements during summer and heatwave periods or developing urban meteorological networks. In future studies, it is planned to investigate the association between thermal comfort indices, such as HUMIDEX, PET and UTCI, with mortality during summer.

This study is submitted to a scientific journal named International Journal of Biometeorology (Impact Factor 3.7 for 2021). Evidence of submission is provided in *Figure 14*.



International Journal of Biometeorology

The effects of summer temperature on human mortality in Serbia

--Manuscript Draft--

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Abstract:	In the context of recent climate change, temperature-attributable mortality has become important public health threat all around world. A large number of studies in Europe identified relationship between temperature and mortality, while only limited number of scholars provided evidence for Serbia. This study aims to assess impact of summer temperature on population in Serbia, using daily average temperature (Ta) and mortality (CDR). Analysis was conducted for five areas (Belgrade, Novi Sad, Niš, Loznica and Vranje), covering summer period 2001-2015. With aim to quatify Ta-related CDR, generalized linear model (GLM) assuming the Poisson distribution with log as the link function, was used. Five regression models, for each area, were constructed revealing statistically significant relationship between Ta and CDR in four areas, respectively, with the increase of Ta folowed with increase in CDR. The effect of Ta on CDR was defined as relative risk (RR), which was obtained as the exponential regression coefficient of the models. RR indicates that respectively 1 °C increase in Ta was associated with a 1.93% increase in the CDR for Belgrade, 1.87% for Novi Sad, 1.61% Niš and 2.05% for Loznica. Model for Vranje did not quantify statistical significant increase for CDR in relation to Ta (RR=1.0115, 95% CI 0.9998-1.0232). Similar results were confirmed for gender, with slightly higher risk for women.
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Figure 14. Study entitled "The effects of summer temperature on human mortality in Serbia" submitted to International Journal of Biometeorology

Fourth milestone and deliverable – Scientific paper entitled "Hospital admission tendencies caused by day-to-day temperature changes during summer: a case study for the city of Novi Sad (Serbia)":

The main findings from the study - Statistical analysis of datasets: Correlation analysis of daily temperature variables for the entire research period (summer period of 2016 and 2017), that is, a total of 184 analyzed days, shows very strong and statistically significant correlations at the $p \leq 0.001$ level in all cases (*Table 6*). *Tables 8 and 9* show the relationships of temperature variables with subgroups of all-cause hospital admissions. *Based on the entire research period, only statistically significant correlations (at the level of $0.05 < p \leq 0.1$) were observed for Tmin and all-cause hospital admission subgroups (Ha) with a negative value ($r = -0.122$), and Tmax,c and Ha / hospital admissions in the population below 65 (Ha<65) with positive values ($r = 0.125$ and 0.129)* (*Table 7*). Based on weekends only (78 days), correlation coefficient analysis shows good relationships between Tmax,c with all subgroups of all-cause hospital admissions at the $p \leq 0.001$ level. All other cases are not statistically significant (*Table 8*). Finally, in the *Table 9* are presented descriptive statistics of all temperature variables and all-cause hospital admission subgroups, showing mean, median, standard deviation, minimum and maximum values for the whole research period.

One-way ANOVA (*Table 10*) for all five temperature variables shows that the summer of 2016 is characterized by a lower mean value than in the summer of 2017. However, for monthly periods and weekends, no differences were observed between 2016 and 2017. When we look at subgroups of hospital admissions, we do not see any differences between 2016 and 2017 for summer periods. On the other hand, monthly differences are observed for the hospital admissions in the population aged 65 and over (Ha≥65 subgroup). Namely, there were statistically significantly more Ha≥65 hospital admission during June, compared to July and August. In all other cases there is no significant difference. Finally, a statistically significant difference was observed during the weekend, where the number of hospital admissions were significantly lower compared to working days. *Figure 15* visually confirms this claim, where it is noticeable that in all summer/month cases, Ha is significantly lower on weekends (WE) compared to working days (WD).

Table 6 Matrix of Pearson correlation coefficient between daily temperature variables (summers of 2016 and 2017, all days, n=184 days); Tavg – average daily air temperature, Tmax – daily maximum air temperature, Tmin – daily minimum temperature, Tmax,c – day-to-day change of Tmax, Tr – daily temperature range (Tr = DTR)

	T_{avg}	T_{max}	T_{min}	$T_{max,c}$
T_{max}	0.972^{***}			
T_{min}	0.926^{***}	0.841^{***}		
$T_{max,c}$	0.345^{***}	0.447^{***}	0.121^{***}	
T_r	0.611^{***}	0.762^{***}	0.290^{***}	0.645^{***}

Statistical significance: * 0.05<p≤0.1; ** 0.01<p≤0.05; *** p≤0.001

Table 7 Pearson correlation coefficient between daily temperature variables and all-cause hospital admissions (summers of 2016 and 2017, all days, n=184 days); Tavg – average daily air temperature, Tmax – daily maximum air temperature, Tmin – daily minimum temperature, Tmax,c – day-to-day change of Tmax, Tr – daily temperature range (Tr = DTR), Ha – all-cause hospital admissions, Ha<65 – all-cause hospital admissions in population bellow 65, Ha≥65 – all-cause hospital admissions in population 65 and over

	Tavg	*Tmax*	*Tmin*	*Tmax,c*	T_r
Ha	-0.081	-0.070	-0.122^{*}	0.125^{*}	0.022
Ha<65	-0.075	-0.068	-0.108	0.129^{*}	0.009
Ha≥65	-0.082	-0.066	-0.135	0.098	0.046

Statistical significance: * 0.05<p≤0.1; ** 0.01<p≤0.05; *** p≤0.001

Table 8 Pearson correlation coefficient between daily temperature variables and all-cause hospital admissions (summers of 2016 and 2017, weekends, n=78 days); Tavg – average daily air temperature, Tmax – daily maximum air temperature, Tmin – daily minimum temperature, Tmax,c – day-to-day change of Tmax, Tr – daily temperature range (Tr = DTR), Ha – all-cause hospital admissions, *Ha<65 – all-cause hospital admissions in population bellow 65, Ha≥65 – all-cause hospital admissions in population 65 and over*

	T_{avg}	T_{max}	T_{min}	$T_{max,c}$	T_r
H_a	-0.025	0.020	-0.079	0.372***	0.133
H_a<65	-0.010	0.034	-0.052	0.374***	0.126
H_a≥65	-0.053	-0.016	-0.118	0.274**	0.113

Statistical significance: * 0.05<p≤0.1; ** 0.01<p≤0.05; *** p≤0.001

Table 9 Descriptive statistics of daily temperature variables and all-cause hospital admissions (summers of 2016 and 2017, all days, n=184 days); Tavg – average daily air temperature, Tmax – daily maximum air temperature, Tmin – daily minimum temperature, Tmax,c – day-to-day change of Tmax, Tr – daily temperature range (Tr = DTR), Ha – all-cause hospital admissions, Ha<65 – all-cause hospital admissions in population bellow 65, Ha≥65 – all-cause hospital admissions in population 65 and over, SD – standard deviation

	Mean	Median	SD	Min	Max
Temperature var.					
$Tavg$	24.7	24.4	3.75	15.4	33
$Tmax$	30	30	4.59	16.6	40.2
$Tmin$	19.7	19.4	3.11	12.3	27.2
$Tmax,c$	0.044	0.8	4.1	-14.2	10.1
T_r	10.3	10.4	2.59	2	17.2
All-cause hosp. admin.					
Ha	101	111	37.1	28	162
Ha<65	71.5	79	26.8	17	116
Ha≥65	29.4	31	12.1	5	61

Table 10 Results of the One-Way ANOVA for daily temperature variables and all-cause hospital admissions per summer (2016 and 2017), month and weekend; Tavg – average daily air temperature, Tmax – daily maximum air temperature, Tmin – daily minimum temperature, Tmax,c – day-to-day change of Tmax, Tr – daily temperature range (Tr = DTR), Ha – all-cause hospital admissions, Ha<65 – all-cause hospital admissions in population bellow 65, Ha≥65 – all-cause hospital admissions in population 65 and over

	summer	month	weekend
Temperature var.			
T_{avg}	F=17.02, p<0.001	F=2.11, p=0.124	F=1.16, p=0.284
T_{max}	F=17.93· p<0.001	F=1.20, p=0.304	F=1.45, p=0.229
T_{min}	F=7.45, p<0.01	F=3.00, p=0.052	F=1.90, p=0.169
$T_{max,c}$	F=0.00, p=0.972	F=0.07, p=0.932	F=0.04, p=0.8442
T_r	F=17.00, p<0.001	F=1.96, p=0.144	F=0.23, p=0.634
All-cause hosp. admin.			
H_a	F=0.00, p=0.951	F=2.23, p=0.110	F=362.16, p<0.001
H_a<65	F=0.50, p=0.481	F=1.18, p=0.311	F=329.12, p<0.001
H_a≥65	F=1.92, p=0.167	F=5.64, p<0.01	F=185.60, p<0.001

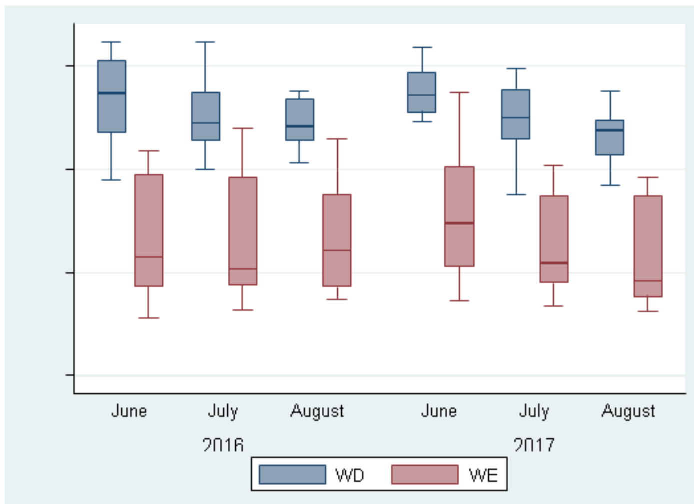


Figure 15. All-cause hospital admissions defined in WD (working day) and WE (weekend) subgroups, and presented by summer months (June, July and August) and summer periods (2016 and 2017) (n=184 days)

Modeling the relationship between temperature and hospital admissions - Day-to-day changes in Tmax

Based on the results from the previous analysis, *Tmax,c gives the best correlation with all-cause hospital admissions*. Therefore, *Figure 16* shows the scatter diagrams of all three subgroups of hospital admissions (Ha, Ha<65, Ha≥65) with Tmax,c data. The obtained data show that when the value of Tmax,c is positive (which means that Tmax is higher compared to previous day), there is an increase in the number of hospital admissions in all three subgroups. Therefore, *the results show that when Tmax,c has values between 6 °C and 10 °C, then a significant increase in the number of hospital admissions is noticeable in all three subcategories. In situations where the Tmax,c value is negative, i.e. Tmax is lower compared to the previous day, the impact on the increased number of hospital admissions is not significant.*

Table 11 shows the effects of addition control variables in regression models. Only month and weekend had a significant effect. The coefficient of Tmax,c and the corresponding RR remained unchanged from 1.010 to 1.012. The final models including the two control variables (weekend and month) are given in *Tables 13, 14 and 15* for Ha, Ha<65 and Ha≥65, respectively. *Hospital admissions of Ha and Ha<65 subgroups increased by 1.0% due to a 1 °C increase in Tmax,c (95% confidence interval: 0.6–1.4%) and increased by 0.8% in the subgroup Ha≥65.*

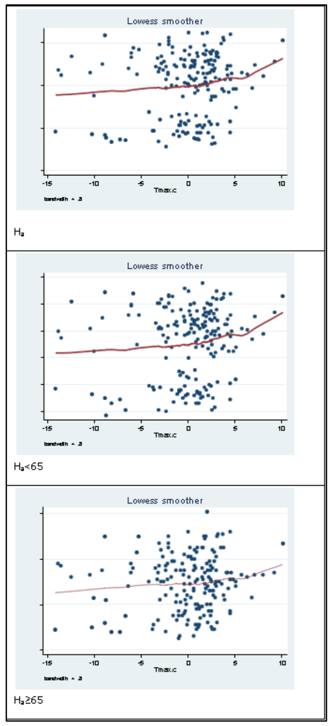


Figure 16. Scatter diagram of all-cause hospital admissions (Ha, Ha<65, Ha≥65) vs. Tmax,c (lowess smoother, bandwidths=0.8)

Table 11 Effects of control variables in model if Tmax,c is included; RR – risk ratio, SE – standard error, CI - confidence interval for RR; # statistical significance

variable	Coef.	RR	SE	z	95% CI
No control	0.0115	1.012	0.0018	6.24***	1.008-1.015
with lag1($T_{max,c}$)	0.0112	1.011	0.0019	6.01***	1.008-1.015
with control of weekend#	0.0099	1.010	0.0018	5.53***	1.006-1.014
with control of weekend#	0.0099	1.010	0.0018	5.53***	1.006-1.014
with control of month#	0.0113	1.011	0.0019	6.09***	1.008-1.015
weith control of summer	0.0115	1.012	0.0018	6.24***	1.008-1.015

Table 12 Model coefficients of all-cause hospital admissions for Ha, RR – risk ratio, SE – standard error, CI - confidence interval for RR

variable	Coef.	RR	SE	z	P>|z|	95% CI
$T_{max,c}$	0.010	1.010	0.002	5.31	0.000	1.006-1.013
weekend (WE)	-0.652	0.521	0.016	-39.66	0.000	0.505-0.538
month (July)	-0.082	0.921	0.018	-4.59	0.000	0.889-0.954
month (August)	-0.131	0.877	0.018	-7.3	0.000	0.847-0.908
const	4.912		0.013	369.07	0.000	

Table 13 Model coefficients of all-cause hospital admissions for Ha<65, RR – risk ratio, SE – standard error, confidence interval for RR

variable	Coef.	RR	SE	z	P>|z|	95% CI
$T_{max,c}$	0.010	1.010	0.002	4.78	0.000	1.006-1.014
weekend (WE)	-0.656	0.519	0.020	-33.54	0.000	0.500-0.540
month (July)	-0.060	0.942	0.021	-2.79	0.005	0.903-0.982
month (August)	-0.082	0.921	0.021	-3.84	0.000	0.883-0.961
const	4.545		0.016	284.6	0.000	

Table 14 Model coefficients of all-cause hospital admissions for Ha≥65; RR – risk ratio, SE – standard error, confidence interval for RR

variable	Coef.	RR	SE	z	P>|z|	95% CI
$T_{max,c}$	0.008	1.008	0.003	2.39	0.017	1.001-1.015
weekend (WE)	-0.643	0.526	0.030	-21.17	0.000	0.495-0.558
month (July)	-0.135	0.874	0.033	-4.11	0.000	0.820-0.931
month (August)	-0.251	0.778	0.033	-7.53	0.000	0.728-0.830
const	3.732		0.024	154.92	0.000	

Daily temperature range – *Figure 17* shows the scatter diagrams of all three subgroups of hospital admissions (Ha, Ha<65, Ha≥65) with Tr data. *The obtained results show that when Tr has values between 10 °C and 14 °C, then an increase in the number of hospital admissions is noticeable in all three subcategories.*

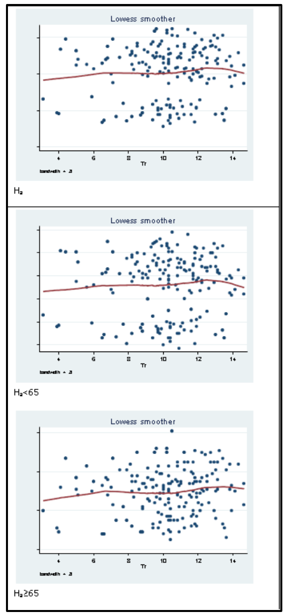


Figure 17. Scatter diagram of all-cause hospital admissions (Ha, Ha<65, Ha≥65) vs. Tr (lowess smoother, bandwidths=0.8)

Table 15 shows the effects of addition control variables in regression models, and 1 day time lag, month and weekend had a significant effect. The final models including the two control variables (weekend and month) are given in *Tables 16, 17 and 18* for Ha, Ha<65 and Ha≥65, respectively. *Due to a 1 °C increase in Tr the hospital admissions are increased by 1% in Ha, 0.7% in Ha<65 and 1.6% in Ha≥65 subgroup.*

Table 15 Effects of control variables in model if Tr is included; SE – standard error; #statistical significance

variable	Coef.	SE	z	95% interval	
T_r	0.003	0.003	1.110	-0.002	0.009
lag1(T_r) #	0.007	0.003	2.340	0.001	0.013
weekend#	0.007	0.003	2.580	0.002	0.013
month#	0.005	0.003	1.640	-0.001	0.010
year	0.004	0.003	1.230	-0.002	0.009

Statistical analysis shows that more all-cause hospital admissions in Novi Sad occur in working day (WD) compared to weekend (WE). *Lower number of hospital admissions during the WE could be explained by reasons that are more related to people's habits and administrative restrictions, i.e., people usually wait for the first working day to visit a doctor (e.g. Monday), and during the weekend most health institutions work with reduced capacity. Also, correlation outcomes presented good relations between hospital admissions and Tmax,c and Tr, particularly in weekend periods.*

Table 16 Model coefficients of all-cause hospital admissions for Ha; RR – risk ratio, SE – standard error, CI - confidence interval for RR

variable	Coef.	RR	SE	z	P>|z|	95% CI
T_r	0.010	1.010	0.003	3.29	0.001	1.004-1.015
weekend (WE)	-0.657	0.519	0.016	-39.99	0.000	0.502-0.536
month (July)	-0.088	0.916	0.018	-4.91	0.000	0.884-0.949
month (August)	-0.142	0.867	0.018	-7.92	0.000	0.838-0.899
const	4.821		0.033	148.21	0.000	

Table 17 Model coefficients of all-cause hospital admissions for Ha<65; RR – risk ratio, SE – standard error, CI - confidence interval for RR

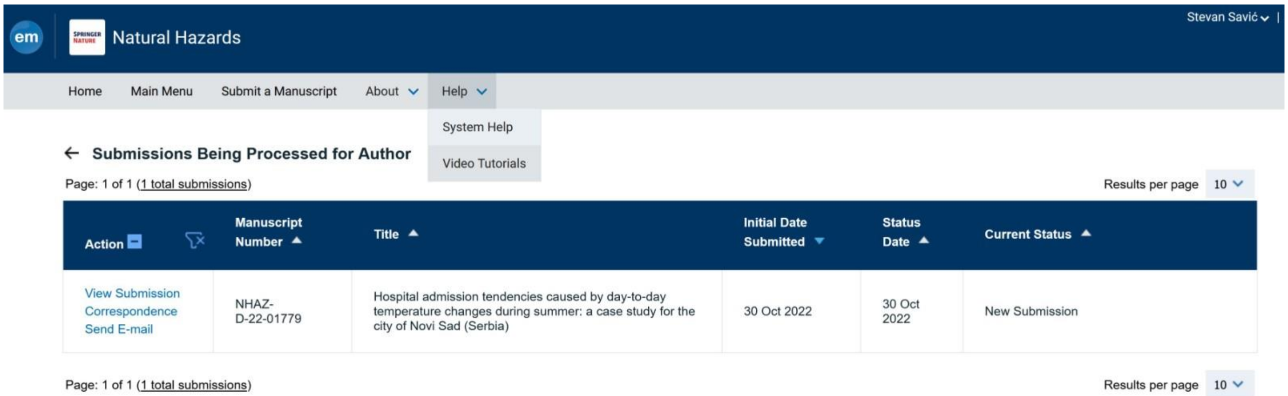
variable	Coef.	RR	SE	z	P>|z|	95% CI
T_r	0.007	1.007	0.003	2.02	0.043	1.000-1.014
weekend (WE)	-0.661	0.516	0.020	-33.86	0.000	0.497-0.536
month (July)	-0.068	0.934	0.021	-3.2	0.001	0.896-0.974
month (August)	-0.094	0.910	0.021	-4.42	0.000	0.873-0.949
const	4.484		0.039	116.45	0.000	

Table 18 Model coefficients of all-cause hospital admissions for Ha≥65; RR – risk ratio, SE – standard error, CI - confidence interval for RR

variable	Coef.	RR	SE	z	P>|z|	95% CI
T_r	0.016	1.016	0.006	2.95	0.003	1.005-1.027
weekend (WE)	-0.646	0.524	0.030	-21.28	0.000	0.494-0.557
month (July)	-0.134	0.875	0.033	-4.09	0.000	0.820-0.932
month (August)	-0.261	0.771	0.033	-7.79	0.000	0.722-0.823
const	3.566		0.061	58.65	0.000	

Conclusions - In this study was presented the analysis of temperature conditions in urban area of Novi Sad (Serbia) and its potential connections with all-cause hospital admission cases during summer periods of 2016 and 2017. According to the provided results, we can conclude that the population health risks are not connected only during the long and intensive heat wave periods, when constantly dominate high temperature during the daytime and night-time, but risk situations are also during the sudden change of weather conditions when temperatures significantly oscillate between neighboring days. Therefore, further steps in the research concept, in the case of evaluation of short- or medium-term climate and public health datasets and calculations based on hourly or daily data, should take into account daily weather changes (synoptic conditions), such as the occurrence of heat waves with the arrival of warm air masses or the cessation of heat waves with the arrival of cold fronts. This type of more detailed "climate - population health" assessments could help emergency services organizations and local or regional disaster management authorities create more adaptive conditions and contribute to the prevention of public health problems in cities.

This study is submitted to a scientific journal named Natural Hazards (Impact Factor 3.2 for 2021). Evidence of submission is provided in *Figure 18*.



Natural Hazards

Hospital admission tendencies caused by day-to-day temperature changes during summer: a case study for the city of Novi Sad (Serbia)

--Manuscript Draft--

Manuscript Number:	NHAZ-D-22-01779
Full Title:	Hospital admission tendencies caused by day-to-day temperature changes during summer: a case study for the city of Novi Sad (Serbia)
Article Type:	Manuscript
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Funding Information:	Global Disaster Preparedness Center, Red Cross Red Crescent Climate Centre, and the Global Heat Health Information Network — Dr. Dragan Milošević
Abstract:	Increased temperature risk in cities threatens the health and well-being of the urban population and is fueled by climate change and intensive urbanization. Consequently, further steps must be taken in the assessment of temperature conditions in cities and their association with public health, in order to improve public health prevention measures at the local or regional level. This study aims to contribute to solving the problems by analyzing the connection between extreme temperatures and the tendencies of all-cause hospital admissions. The analyzes used (a) one-hour air temperature data, and (b) daily data of all-cause hospital admissions. The datasets include the summer periods (June, July, August) for the years 2016 and 2017. We tested the effects of two temperature indices, day-to-day change in maximum temperature – Tmax,c and daily temperature range – Tr, with all-cause hospital admission subgroups, such as: all-cause cases – Ha, hospital admissions in the

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Figure 18. Study entitled "Hospital admission tendencies caused by day-to-day temperature changes during summer: a case study for the city of Novi Sad (Serbia)" submitted to Natural Hazards journal

LIMITATIONS

During the realization of the project and developing of project deliverables, certain limitations occurred. The main limitations were related to the unavailability of certain data, or the collected data had certain flaws. For example, from initial 47 meteorological stations, we were able to use data from 27 to 34 stations (depending on the analysis parameter). The problem was that a number of stations had missing (or abnormal) values >5% and they were excluded in order to avoid their impact on the obtained results. Regarding mortality and hospitalization data, certain adjustments had to be made in terms of analyzed parameters, period or number of stations. For the analysis of impacts of extreme heat, humidity and biometeorological indices on mortality in Serbia, we have done a detailed analysis of temperature impacts on mortality in Serbia and provided in a scientific paper, while the impacts of humidity and biometeorological indices are only preliminary assessed and they will be published in the next scientific paper. This paper will also include the acknowledgement that the research was supported by the Global Disaster Preparedness Center (GDPC) of the American Red Cross, Red Cross Red Crescent Climate Center and the Global Heat Health Information Network (GHHIN). We did not include this preliminary analysis in the paper "*The effects of summer temperature on human mortality in Serbia*" as the International Journal of Biometeorology requires that original research papers are limited to a maximum of 7,500 words (see here - https://www.springer.com/journal/484/submission-guidelines; submitted paper already has 7481 words with only temperature impacts included). For the analysis of extreme heat impacts on mortality and hospitalization in Novi Sad (the second largest city in Serbia), we included years 2016 and 2017 and omitted year 2015 due to lack of more than 5% of temperature data in 2015. Climate-hospitalization analysis for Novi Sad is provided in paper "*Hospital admission tendencies caused by day-to-day temperature changes during summer: a case study for the city of Novi Sad (Serbia)*", while climate-mortality analysis for Novi Sad is provided in paper "*The effects of summer temperature on human mortality in Serbia*". Finally, regarding workshop organization, a certain number of invited attendees could not join the workshop in person or online due to health issues related to COVID-19.

Even though certain limitations occurred, the project team managed to achieve the proposed milestones and deliverables proposed in the initial project. With two climate and bioclimate reports developed, three scientific papers written and submitted to scientific journals with impact factor, one hybrid workshop organized, and developed project website and social media channels, the project team worked passionately during the past 6 months in order to provide the information and raise awareness about climate/bioclimate impacts on mortality and hospitalization in the Republic of Serbia. In this regard, a knowledge gap regarding these issues was partially filled for our country. Future work by the project team will further fill this research gap in order to increase heat resilience in Serbia.

If any additional clarifications regarding the rationale for changes in methodology and statistical analyses are required, please contact project leader Dragan Milosevic, PhD, via e-mail: dragan.milosevic@dgt.unc.ac.rs.

PRACTICAL APPLICATION FOR HUMANITARIAN WORK AND RECOMMENDATIONS

Two report, three scientific papers, and collected databases can be used for the practical application of the results for humanitarian work and recommendations on how to tackle the adverse impact of climate and bioclimate parameters on health and well-being of population in Serbia. All deliverables are freely available via project website (https://sites.google.com/view/extremeheatinserbia/home) and project members can be contacted for additional help and expertise.

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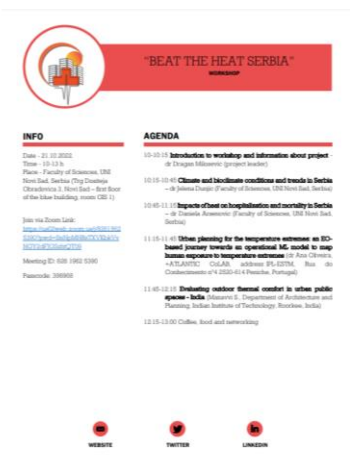
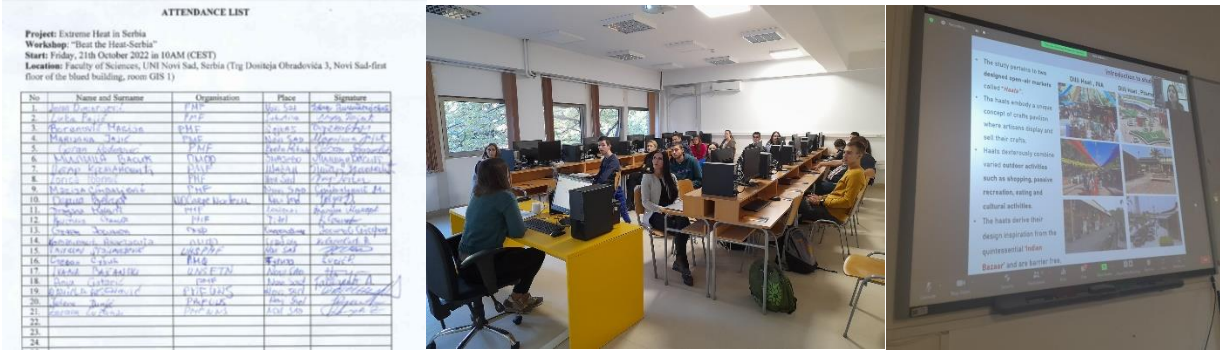
APPENDIX 1

Fifth Milestone and Deliverable - Organization of *workshop* for stakeholders and citizens. On 21st October 2022, the workshop named “Beat the heat – Serbia” was organized for stakeholders and citizens. The workshop was organized in premises of the Faculty of Sciences, Department of Geography, tourism and hotel management in Novi Sad, but it was hybrid event, so interested parties could join both in person and online via Zoom platform. Invitations with the Agenda and Zoom link were sent on 19th October 2022.



Invitation for workshop “Beat the heat – Serbia”

Many stakeholders and different target groups were invited to participate at the workshop, including general public (citizens and students), and employees from different public and private institutions such as: local and regional public authorities, national public authority, higher education and research institutions, small and medium enterprises, and business support organizations. The invitation e-mails were sent to the major stakeholders, but invitations were also shared on the project website, via Twitter and LinkedIn accounts of the project leader and members. The invited stakeholders were chosen due to their interest to include the findings from this project in their activities, and their capacity to contribute to mitigating the extreme heat in Serbia on individual, local, regional and national level. In total, 21 participants attended the workshop in person, while 10 participants attended online via Zoom platform.



ATTENDANCE LIST

Project: Extreme Heat in Serbia
Workshop: "Beat the Heat-Serbia"
Start: Friday, 21th October 2022 in 10AM (CEST)
Location: Faculty of Sciences, UNI Novi Sad, Serbia (Trg Dositeja Obradovića 3, Novi Sad-first floor of the blued building, room GIS 1)

No	Name and Surname	Organisation	Place	Signature
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Photos from the workshop and the attendance list

Five presentations were held on the workshop. Project leader, Dragan Milošević introduced the project "Research on Extreme heat in Serbia" to the audience, mentioning the main idea, objectives and members involved in realization of the project. In the Introduction presentation, project manager introduced four presentations that will be presented at the workshop.

The four other presentations were presented afterwards, two were held by project members Jelena Dunjić and Daniela Arsenović, and two were held by our colleagues from Portugal and India:

1. Climate and bioclimate conditions and trends in Serbia – dr Jelena Dunjic (Faculty of Sciences, UNI Novi Sad, Serbia)
2. Impacts of heat on hospitalization and mortality in Serbia – dr Daniela Arsenovic (Faculty of Sciences, UNI Novi Sad, Serbia)
3. Urban planning for the temperature extremes: an EO- based journey towards an operational ML model to map human exposure to temperature extremes (dr Ana Oliveira, +ATLANTIC CoLAB, address: IPL-ESTM, Rua do Conhecimento no4 2520-614 Peniche, Portugal)
4. Evaluating outdoor thermal comfort in urban public spaces - India (Manavvi S., Department of Architecture and Planning, Indian Institute of Technology, Roorkee, India)

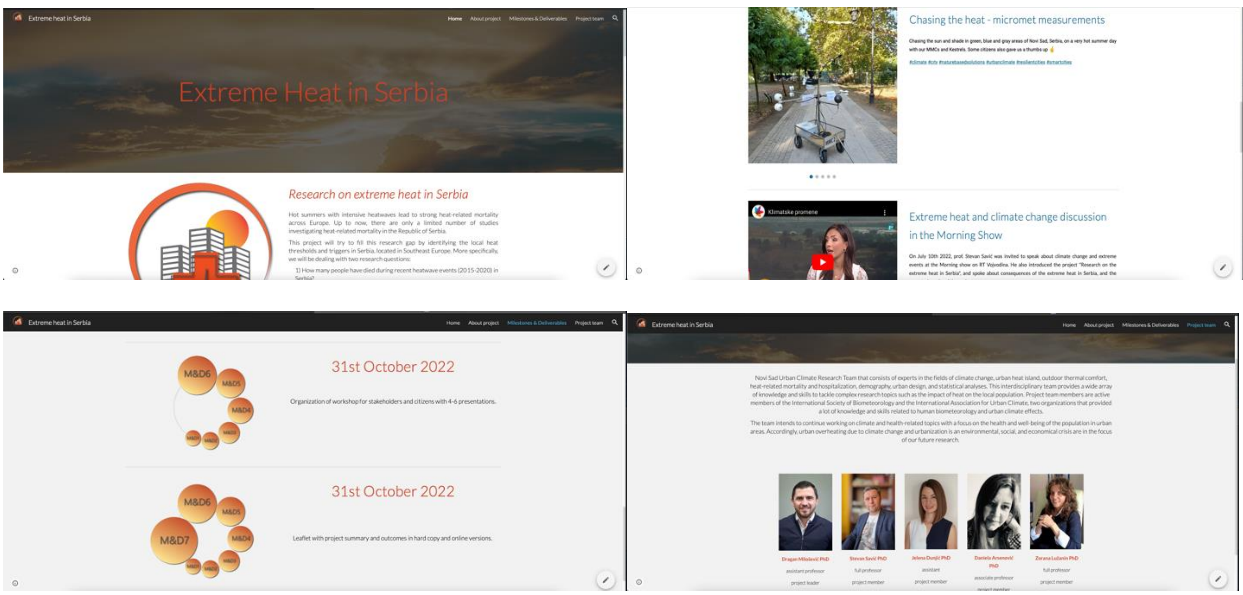
Link to presentations: https://www.youtube.com/channel/UCoyVnqzBLTNSR5YVNUqJfkA

Sixth Milestone and Deliverable: Youtube channel, project webpage and social media profiles

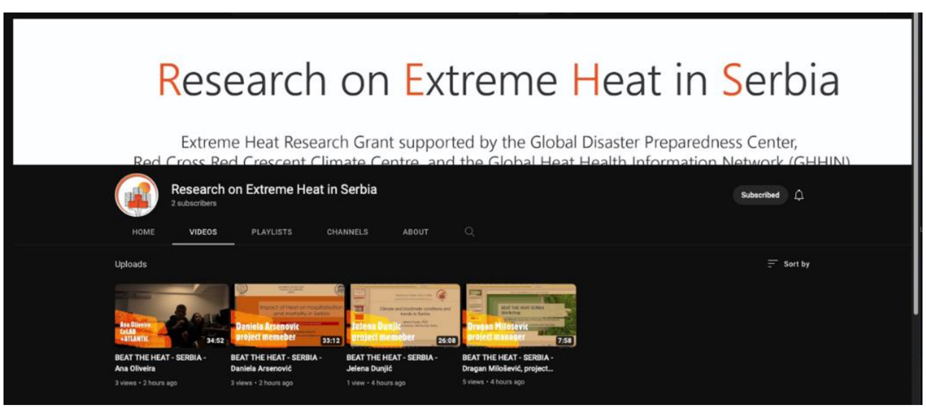
For the project dissemination and communication with scientific community and general public, web-page and social media profiles (YouTube, Twitter and Linked In) were created. For the purpose of the effective communication of the project deliverables, visual identity was created through project logo and banner.

Project logo and banner

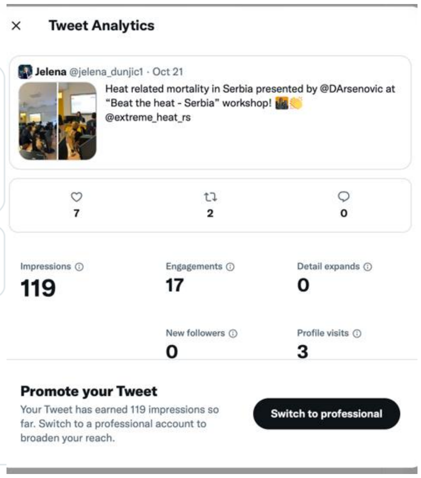
Project webpage was created using free platform Google Sites. All the information about project idea, objectives, milestones, project team and news can be found at the project website (https://sites.google.com/view/extremeheatinserbia/home).

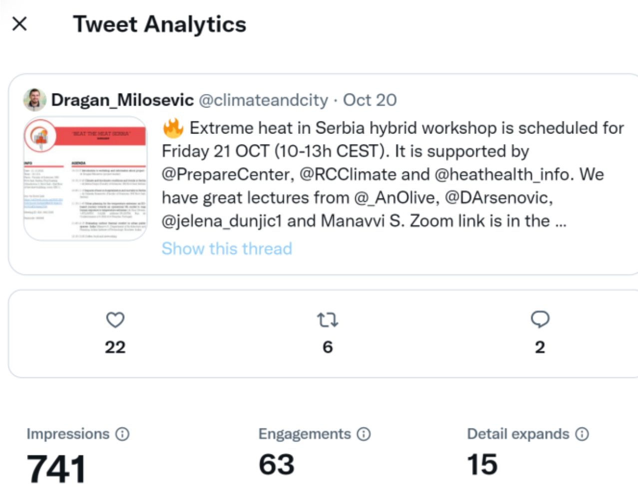


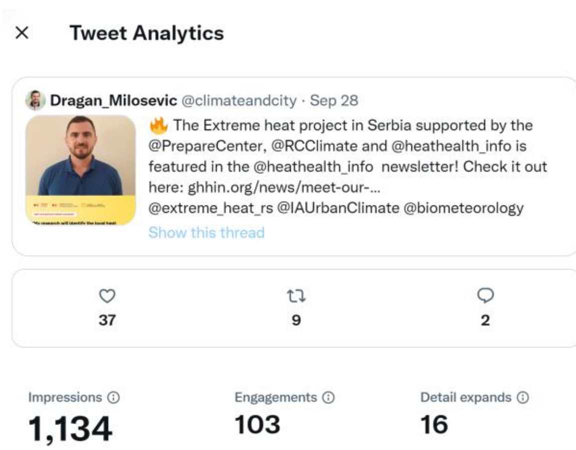
YouTube channel of the project was created in order to share video content relevant to the project. Link to the YouTube channel: https://www.youtube.com/channel/UCoyVnqzBLTNSR5YVNUqJfkA



Social media pages on Twitter and Linked In served for communication with public and scientific community and to share the information on project activities. Project members used their personal SM profiles to share the information about project mentioning the project profile.

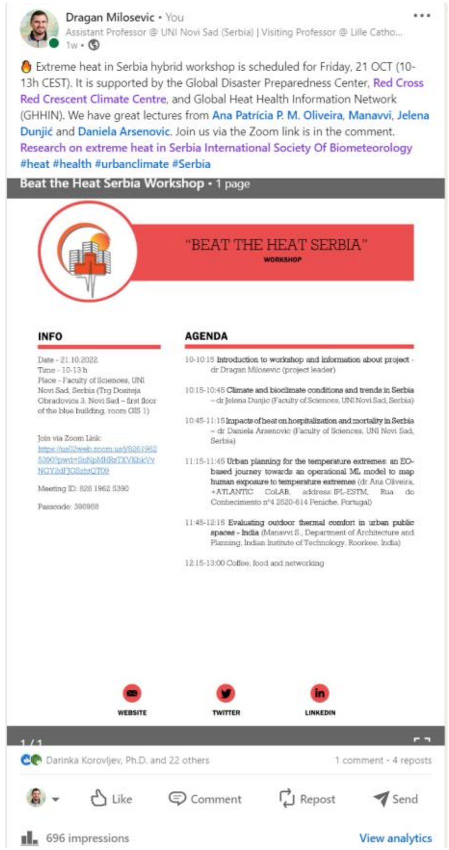


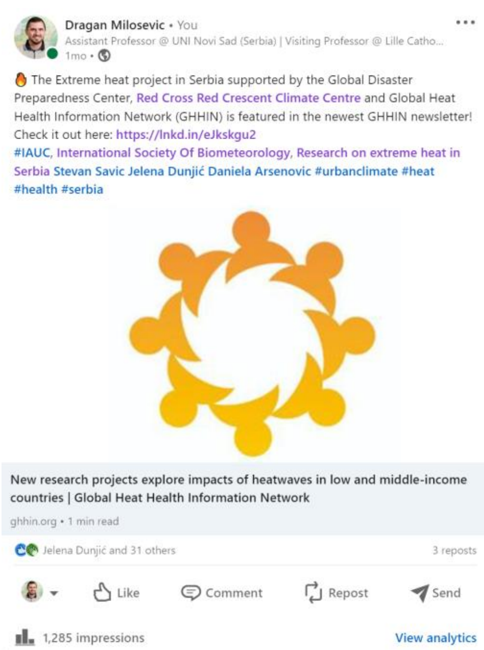




There was significant reach achieved through *Twitter* posts of the project members, with every tweet related to the project activities more than *2465 impressions* were achieved.

Linked In page for the project was also created in order to enhance the project communication with general and scientific community as well as stakeholders. Again, project members shared information from their personal profiles mentioning the project profile.





Screenshots from Linkedin

There was significant reach achieved through *LinkedIn* posts of the project members as well, with every post related to the project activities gained more than *3402* reactions.

Seventh Milestone and Deliverable – project leaflet - As one of the project deliverables Leaflet with project summary on extreme heat in Serbia online and hard copy was created, in English and Serbian laguage.

Leaflets consist of all the information about project, the main idea, milestones and deliverables, as well as expected results, project team, funding institutions and contact. Leaflets are shared online on LinkedIn profile, website, and hard copies are distributed at relevant institutions in Serbia, as well as in other countries, such as Bosnia and Herzegovina and Austria.