# Analysis of the Temperature Characteristics and Trends in Novi Sad Area (Vojvodina, Serbia)

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***Abstract***

This work analyses temperature characteristics in order to identify temperature trends in Novi Sad area for the period between the years 1951-1990. The data used were obtained in meteorological stations in Rimski Šančevi and in Petrovaradin. This study presents annual mean temperatures, average values at 7, 14 and 21h, average mean maximum and minimum values and average values per different seasons, respectively. Different statistical methods (arithmetic mean, standard deviation and correlation coefficient) and formulae of vertical gradient of air temperature and thermal coefficient were applied when analyzing temperature values.

On the basis of analyzed and given results, it can be concluded that Novi Sad area experiences the trend of air temperature rise. A significant temperature rise is recorded during winter and spring period, while similar trend of rise is noticed when minimum average temperatures are observed. On the other hand, average maximum values show a rather slower trend of rise or even the fall in temperature, while a significant trend of air temperature fall is recorded during summer and spring periods.

**Key words:** Novi Sad area, air temperatures, temperature trends, temperature inversion, climatic changes

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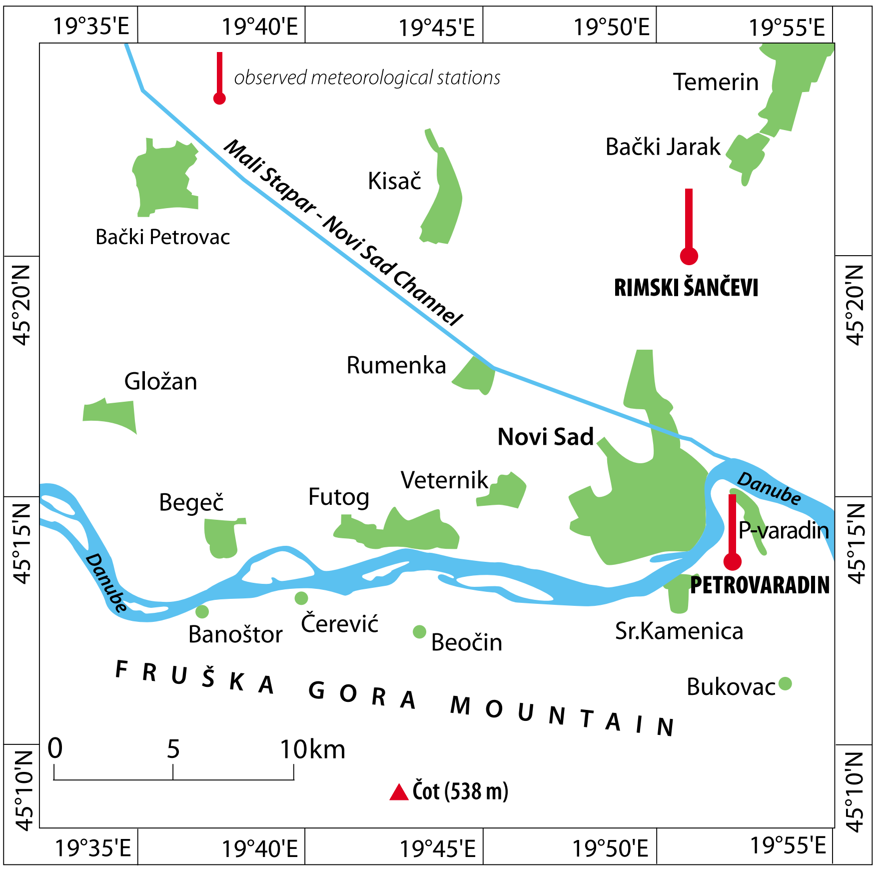
## Introduction

Development and oscillations in air temperatures during 20th century, especially in the last couple of decades, is the subject of a great interest of researchers who study the problems of climatic changes and consequences they have upon nature and man. Many climatic models predict rise in global and regional air temperature due to the increase of the concentration of gases that cause the "greenhouse" effect (Hansen et al., 1988; Karl et al., 1991). According to the data of IPCC (2001) global air temperature has risen for 0.6 ± 0.2°C since the mid-19th century. Similar results were obtained by Nicholls et al. (1996) who are of the opinion that average global temperature has risen for 0.6°C since the beginning of 20th century. Wiin-Nielsen (1997) noticed a sharp rise of temperature on the north hemisphere in the second half of 1980s, with the greatest heat peak during 1994 and 1995. This rise in air temperature reflected upon the rise of average global air temperature. While studying temperature characteristics in Europe, Parry (2000) concluded that the rise of average annual temperature for 0.8°C happened during 20th century and that, when observing average annual and average winter temperatures, the last decade of 20th century




| meteo. station | latitude | longitude | height a.s.l. (m) |
|---|---|---|---|
| Rimski Šančevi | 45°20′ | 19°51′ | 86 |
| Petrovaradin | 45°15′ | 19°52′ | 132 |

**Figure 1** Novi Sad area and locations of the Rimski Šančevi and Petrovaradin meteorological stations and their geographical coordinates

represents the warmest period. The same scientist claims that average annual air temperature over Europe rises on average between 0.1°C and 0.4°C/decade. The greatest warming is recorded in Southern Europe (Spain, Italy, Greece) and North-eastern Europe (Finland, western Russia), while the smallest rate of warming is recorded along the Atlantic coast.

The area of Novi Sad is located on the south of the Bačka region, i.e. on the border of Bačka and Srem, in the middle part of Vojvodina. The geographical coordinates of the researched area are φN 45°15' and 45°20' and λE 19°51' and 19°52' (Figure 1). The northern part of Novi Sad area stretches along Bačka loess, i.e. pleistocene terrace, while towards the south the relief follows alluvial terrace and inundant plane of the Danube (Bukurov, 1975). The southern part is represented by the slopes of Fruška gora mountain which steeply descend towards the Danube. Higher parts of Fruška gora mountain are covered in Pleistocene sediments, thus forming Srem loess plateau (Bugarski et al., 1998b). The Danube river represents the most important hydrographic object in this area, and its width varies from 350 to 750 meters (Bukurov, 1975). The biggest urban settlement on the Bačka side is Novi Sad (about 200.000 inhabitants), whereas on the Srem side that is Petrovaradin (about 14.000 inhabitants).

There is a small number of works that deal with the problems of temperature movements in Novi Sad and surrounding area. Bukurov (1975) and Dukić (1973), as part of their climatic researches of the Bačka region and of Novi Sad area, give only general characteristics of air temperature movements, while Milosavljević (1957) gives a general picture of air temperatures for Fruška gora region. Somewhat more detailed analysis of temperature oscillations on the area of Bačka and Srem was given by Katić et al. (1979), Bugarski and Tomić (1987), Bugarski et al. (1998a) and Radovanović and Ducić (2004).

The aim of this paper is to present a new database of research area (annual mean temperature, average maximum and minimum and mean seasonal temperatures) and to analyse it in order to identify temperature trends.

## Data and methods

In order to present the researched area and determine the localities of meteorological stations, we used topographic map of Serbia and Montenegro with 1:300.000 scale and topographic maps with 1:50.000 scale – sections Mitrovica (72) and Belgrade (73).

The data obtained in meteorological stations in Rimski Šančevi (R.Š.) and in Petrovaradin were used for the analysis of average air temperatures at 07h, 14h and 21h, annual mean temperatures, average maximum and minimum values and average values per different seasons, respectively. Used temperature values for meteorological station Rimski Šančevi refer to the time period 1951-1990 while temperature data for meteorological station Petrovaradin refer to the period 1956-1990. Shown values of temperatures for both metrological stations were taken from meteorological yearbooks of Republic Hydrometeorological Service of Serbia and Hydrometeorological Service of the Province of Vojvodina. Figure 1 shows geographical coordinates and height above sea level which these two meteorological stations are located at. During the observed time period, meteorological stations did not change their locations. In this paper the data was not obtained after 1990 because the meteorological station in Petrovaradin had been stopped to function after 1992. Therefore, data only for meteorological station Rimski Šančevi can not give appropriate picture of temperature characteristics in the whole research area during the last decade of 20th century.

Different statistical methods were used in the process of data processing: arithmetic mean, standard deviation (SD) and Pearson product-moment correlation coefficient (r). In order to determine vertical temperature gradient, we used annual mean air temperatures (AMT) for both meteorological stations, as well as their relative altitude difference (46 m). The equation of F. Kremer was used when determining the continentality or maritime characteristics of the climate of Novi Sad area.

## Results

Figure 2 shows the graphs of mean air temperature values at 7, 14 and 21h, as well as the average annual values for meteorological stations R.Š. and Petrovaradin during forty-year, i.e. thirty-five–year long observing period. Annual mean tempera-

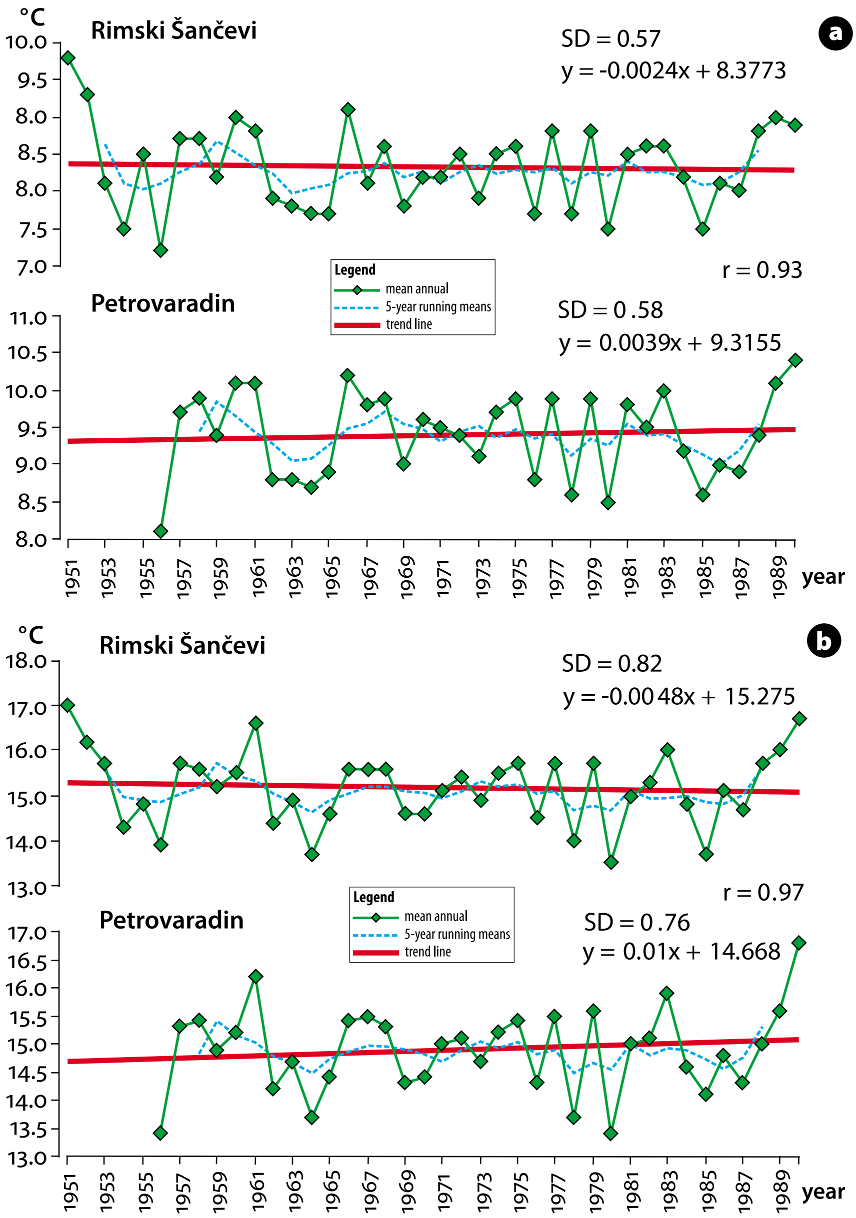



**Figure 2** Trend of changing the mean temperature in a) 07 AM, b) 02 PM during the period 1951-1990

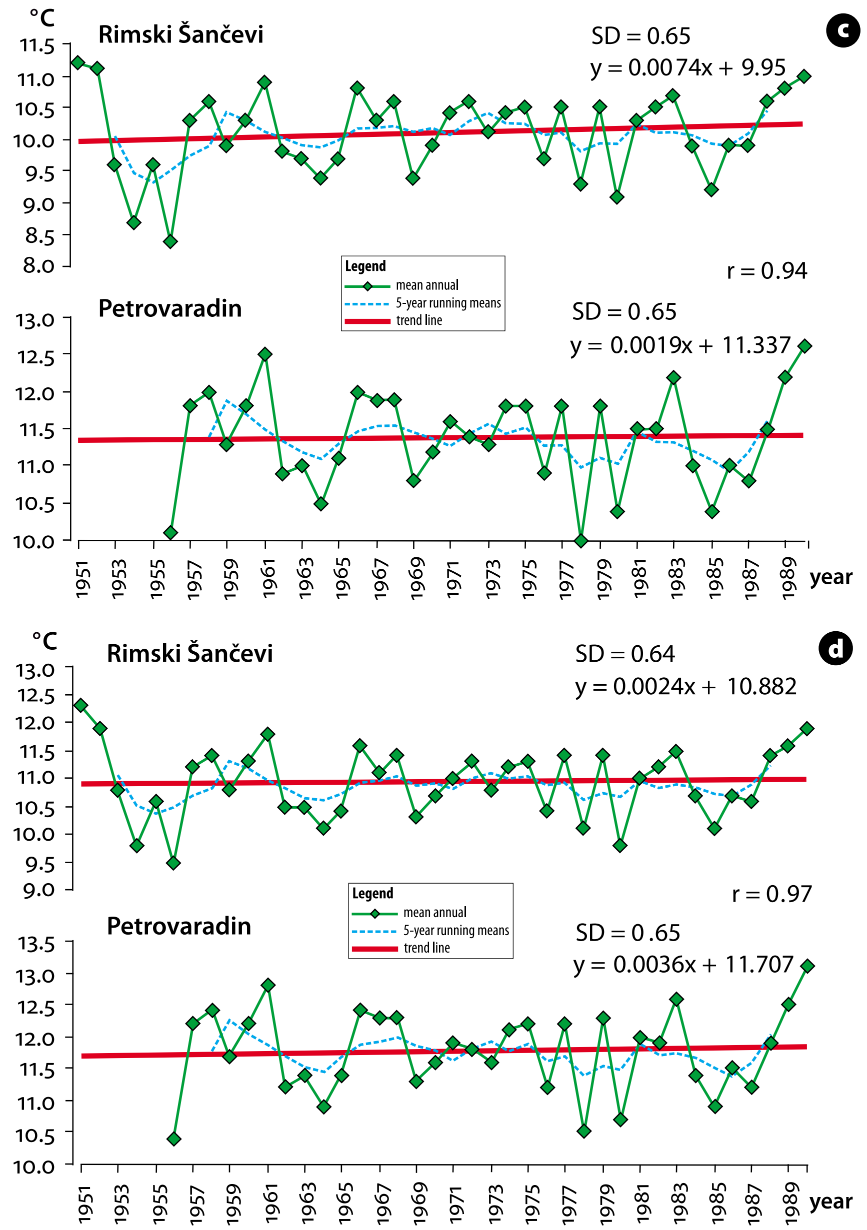



**Figure 2** Trend of changing the mean temperature in c) 09 PM and d) mean annual during the period 1951-1990

ture (Figure 2d) in station R.Š. in the period observed is 10.9°C and shows the rising trend of 0.024°C/decade, while mean annual temperature in Petrovaradin is 11.8°C, with a rising trend of 0.036°C/decade. From the data stated, it can be concluded that the annual mean temperature in Petrovaradin is higher for 0.8°C than in R.Š. The values of standard deviation are rather similar and are 0.64 for R.Š. and 0.65 for Petrovaradin.

In order to examine the movements of daily air temperatures over Novi Sad area in more details, we represented mean temperature values at 7, 14 and 21h. Figure 2a shows that mean temperature in R.Š. at 7h is 8.3°C with a falling trend of 0.024°C/decade, while mean temperature in Petrovaradin is higher for 1.1°C with a rising trend of 0.039°C/decade. This kind of temperature relation indicates upon the correlation coefficient of r=0.93. Deviations from the arithmetic mean are much lower and are as follows: station R.Š. 0.57, and Petrovaradin 0.58.

Comparison of data measured in both stations for 21h (Figure 2c) shows similar relations (r=0.94). Average temperature in Petrovaradin (11.4°C) is higher for 1.3°C, while the trend of temperature rise in the period observed is slightly higher, in R.Š. 0.074°C/decade, and in Petrovaradin 0.019°C/decade.

According to the data of mean temperatures at 14h (Figure 2b), somewhat higher values were measured in R.Š. (15.2°C) than in Petrovaradin (14.9°C). However, R.Š. experiences the trend of temperature fall for 0.048°C/decade, while in Petrovaradin that trend rises for 0.1°C/decade. The highest value of SD was recorded here (R.Š. – 0.82; Pet. – 0.76), while small differences in values between these two stations are proved by correlation coefficient (r=0.97).

Generally speaking, when observing the values of annual mean air temperatures, as well as the values of average temperatures at 7, 14 and 21h, certain shorter warmer and colder periods are noticed. Warmer periods were identified between 1951 and 1953, and at the end of 1980s, i.e. in 1988, 1989 and 1990. Colder periods were identified in 1956 and from 1962 to 1965. Significant oscillations of AMT were recorded between 1975 and 1981.

Figure 3a shows mean annual maximum temperatures for the period observed. No significant differences between values measured in R.Š. and Petrovaradin (r=0.96) are noticed. Average maximum temperature measured in R.Š. is 16.3°C and is higher for 0.1°C than in Petrovaradin. What else is notices is the trend of temperature fall for 0.057°C/decade in R.Š. meteorological station, while in Petrovaradin the temperature rises for 0.061°C/decade.

Annual mean minimum temperatures (Figure 3b) in both stations show significantly higher trend of rise (R.Š. 0.108°C/decade, Petrovaradin 0.082°C/decade). The difference of average minimum temperature for both stations is 1.8°C; i.e. the temperature measured in Petrovaradin is 7.7°C, while in R.Š. it is 5.9°C. Correlation coefficient proves these differences – r=0.85. SD values are much lower than it was measured for average maximum temperatures.

Tendencies of the appearance of warmer and colder periods in Figure 3 completely coincide with values presented in Figure 2.

The tendencies of temperature movements according to seasons for meteorological stations R.Š. and Petrovaradin in the period 1951-1990 are shown in details in Figure 4. What can be seen on these graphs is a noticeable trend of air temperature rise during winter and spring period, while temperatures fall with a similar intensity during summer and autumn.

Mean winter temperature (Figure 4a) in R.Š. (0.6°C) is for 1.1°C lower than in Petrovaradin (1.7°C), which can not be noticed on the base of correlation coefficient values (r=0.98). During the coldest period the trend of temperature rise is even 0.252°C/decade for R.Š., i.e. 0.373°C/decade for Petrovaradin. Similar relations are noticed during spring period (Figure 4b) when the trend of temperature rise is 0.244°C/decade in R.Š., and 0.238°C/decade in Petrovaradin. The difference between mean spring values is lower and it represents 0.7°C (R.Š. 11.1°C; Petrovaradin 11.8°C). SD in both seasons exceeds value 1. However, the oscillations during winter period are much higher (winter: R.Š. 1.84, Petrovaradin 1.78; spring: R.Š. 1.13, Petrovaradin 1.29). The appearance of colder period during winter was recorded in the period 1962-1964 and 1985-1987. Warmer periods in both seasons were recorded in the period 1951-1953 and 1988-1990. The conclusions of the appearances of warmer and colder periods coincide with the values shown in Figure 2 and Figure 3.

Figure 4c shows movements of average temperatures during the warmest period which is characterized by falling trend for 0.22°C/decade in R.Š., i.e 0.168°C/decade in Petrovaradin. Mean summer air temperature in Petrovaradin is for 0.5°C higher than in R.Š. SD shows much lower values compared to winter and spring.

During autumn (Figure 4d) the trend of temperature fall continues in R.Š., but with a slightly weaker intensity – 0.178°C/decade, while that intensity in Petrovaradin is much higher – 0.298°C/decade. However, average temperature in Petrovaradin is higher for 1.1°C than in R.Š., which can be seen from correlation coefficient – 0.97. SD values are 1.07 (R.Š.) and 1.21 (Petrovaradin). One warmer period was noticed during summer at the end of 1980s, while colder period was recorded during autumn between 1971 and 1975.

## Discussion

The results of annual mean air temperatures for the period observed show the rising tendency of 0.24°C/century in R.Š. and 0.36°C/century in Petrovaradin (Figure 2d), which follows the general trend of global warming (Wiin-Nielsen,1997). However, the presented values are lower compared to the results of Parry (2000) and IPCC (2001). The reason probably lies in temperature values during 1990s that, according to many researchers (Wiin-Nielsen, 1997; Quereda Sala et, al., 1999; Jones et al., 1999a; Parry, 2000; IPCC, 2001) represent the hottest decade in the 20th century. According to the results of these researchers, temperature peaks appeared in 1998, 1997, 1995, and 1990, which was probably also the case in Novi Sad area, especially because the rise of mean annual temperatures was recorded during 1988, 1989 and 1990. This kind of the rise of average temperatures would probably reflect upon the rise of the rising trend of temperatures in the researched area. On the other hand, the results by Domonkos and Zoboki (2000), who examined temperature conditions in Hungary, those by Alexandrov (2000) who examined conditions in Bulgaria, by Ogrina (1994, 2003) who examined the area of Ljubljana and Trieste and those by Radovanović and Ducić (2004) who examined the territory of Serbia, show that there is no significant trend of temperature rise during the 20th century.

Easterling and Horton (1997) think that the rise of mean global temperature is mainly conditioned by the rise of mean minimum temperatures and then by the changes of mean maximum values. The

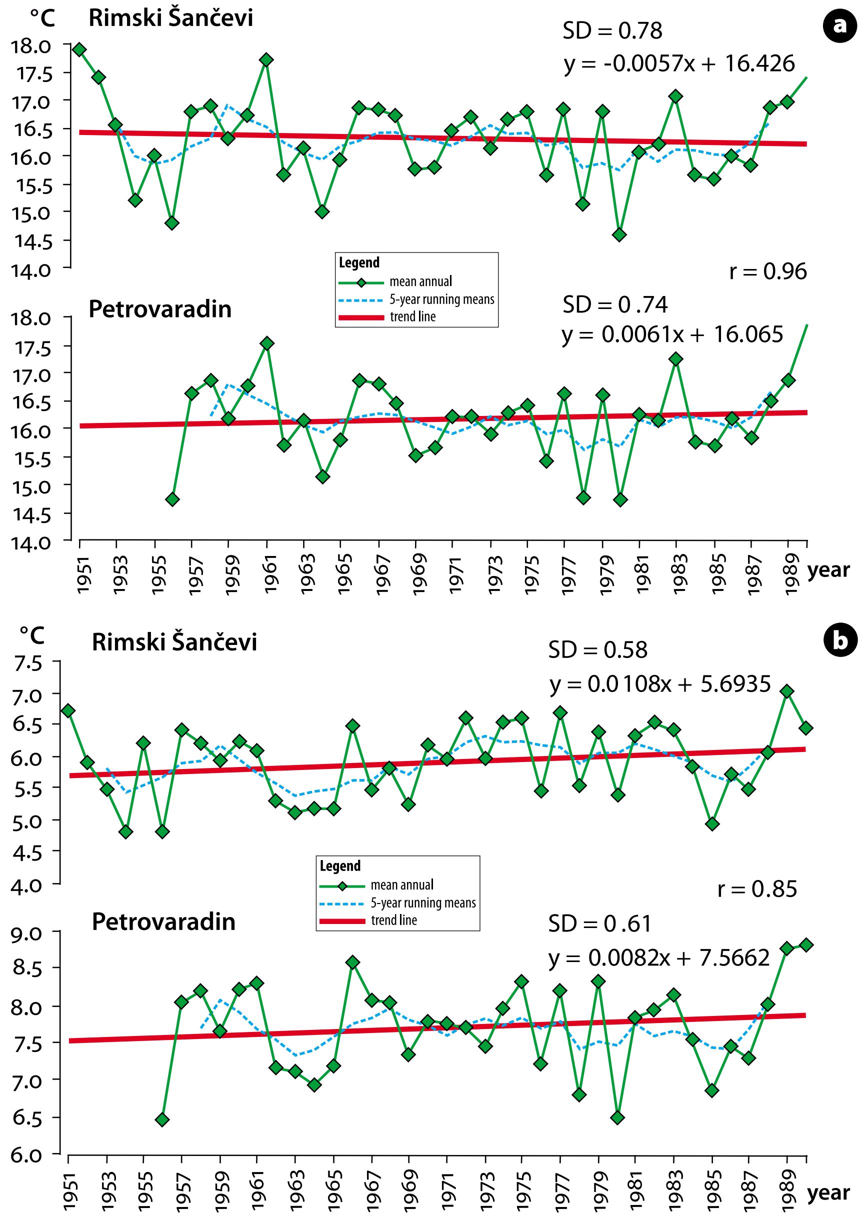



**Figure 3** Trend of changing mean a) maximum and b) minimum temperatures

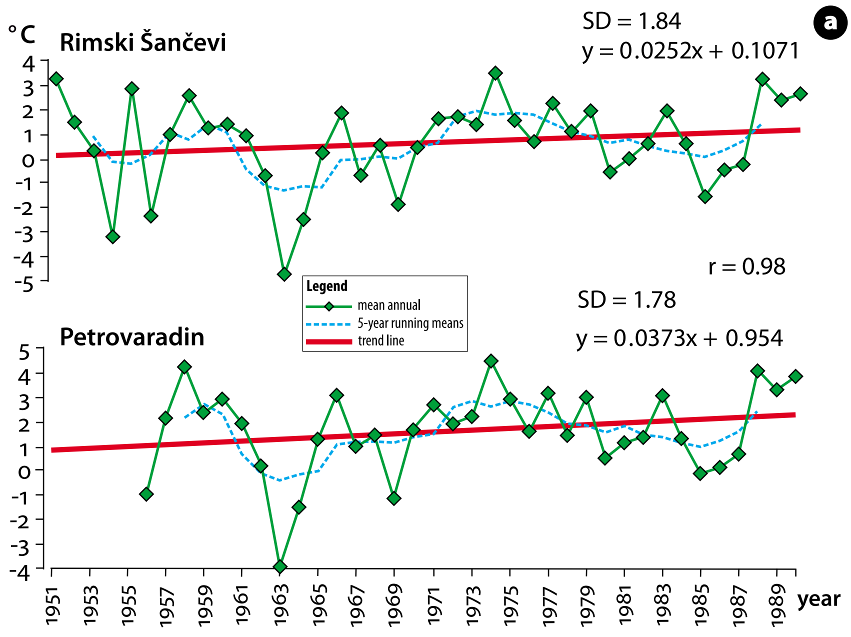



**Figure 4** The changing of mean a) winter temperatures during the period 1951-1990

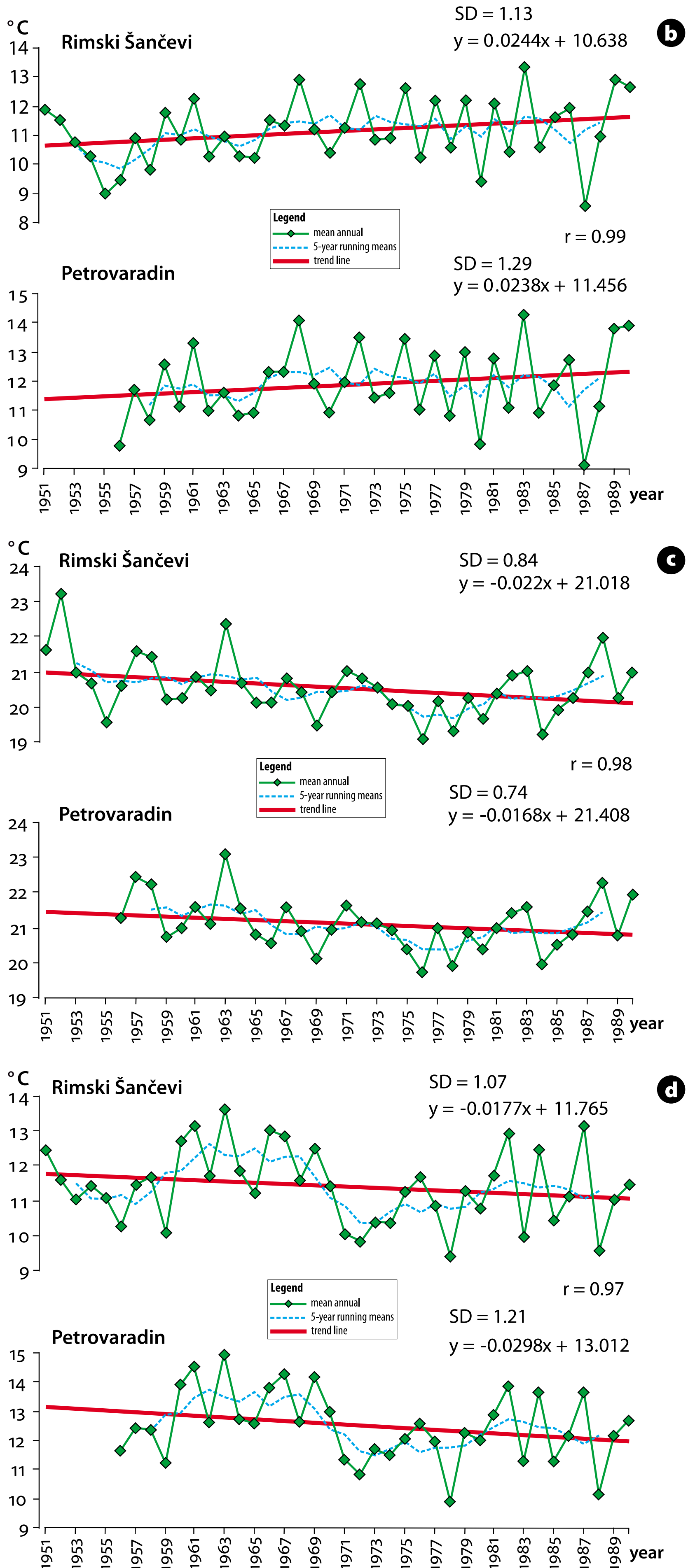



**Figure 4** The changing of mean b) spring, c) summer and d) autumn temperatures during the period 1951-1990

trend of the fall of maximum values is recorded on lower heights above sea level (Weber et al., 1994; Rebetez and Beniston, 1998) probably due to the increase of cloudiness and concentration of aerosols of anthropogenic origin (Karl et al., 1993; Hansen et al., 1995; 1997; Rebetez and Beniston, 1998). When analysing temperature conditions in central England, Jones et al. (1999b) noticed significant fall of the frequency of very cold days in the last twenty years, while on the other hand, no significant rise of very hot days was recorded. Rebetez (2001) came to similar conclusions when studying temperature conditions in Neuchatel and Davos. The tendencies of the movements of mean maximum and minimum values in station in R.Š. i Petrovaradin (Figure 3) completely coincide with the statements of above mentioned researchers. The trend of the rise of mean minimum temperatures varies from 0.8°C/century (Petrovaradin) to even 1.1°C/century (R.Š.). On the other hand, mean maximum temperature in R.Š. falls for 0.6°C/century, while the situation in Petrovaradin, which is situated on a higher sea level, is completely opposite.

Mean values of all four seasons have higher values in meteorological station in Petrovaradin (Figure 4). A significant trend of temperature rise is recorded during winter and spring periods (R.Š.: winter 2.5°C/century, spring 2.4°C/century; Petrovaradin: winter 3.7°C/century, spring 2.4°C/century), and it is followed by high values of SD. The parallel rise of mean temperatures and SD values probably indicates the rise of the frequency of warm periods, i.e. the rise of extreme temperatures (WMO, 2001). Temperature conditions during winter and summer periods in Novi Sad area coincide with the conclusions of Del Rio et al. (2005) who examined climatic conditions in Kastile and Leon, stating that the trend of temperature rise is conditioned by the rise of mean monthly values, mostly in December and then in January, February and March. Ogrin (2003) gives the trend of the rise of winter and spring periods for stations in Ljubljana (winter 1.6°C/century, spring 1°C/century) and Trieste (winter 0.7°C/century, spring 0.3°C/century). However, they are smaller than same values measured in Novi Sad area. In his researches, Parry (2000) noticed that winter temperatures are the main factor of the rise of mean annual temperatures in Europe.

The trend of temperature fall during summer period is recorded is 2.2°C/century in R.Š. and 1.7°C/century in Petrovaradin, while in autumn period the falling trend is 1.8°C/century (R.Š.) and 3°C/century (Petrovaradin). Our values do not coincide with the results by Ogrin (2003) and Del Rio et al. (2005) probably due to much higher continentality of Novi Sad area. The research-

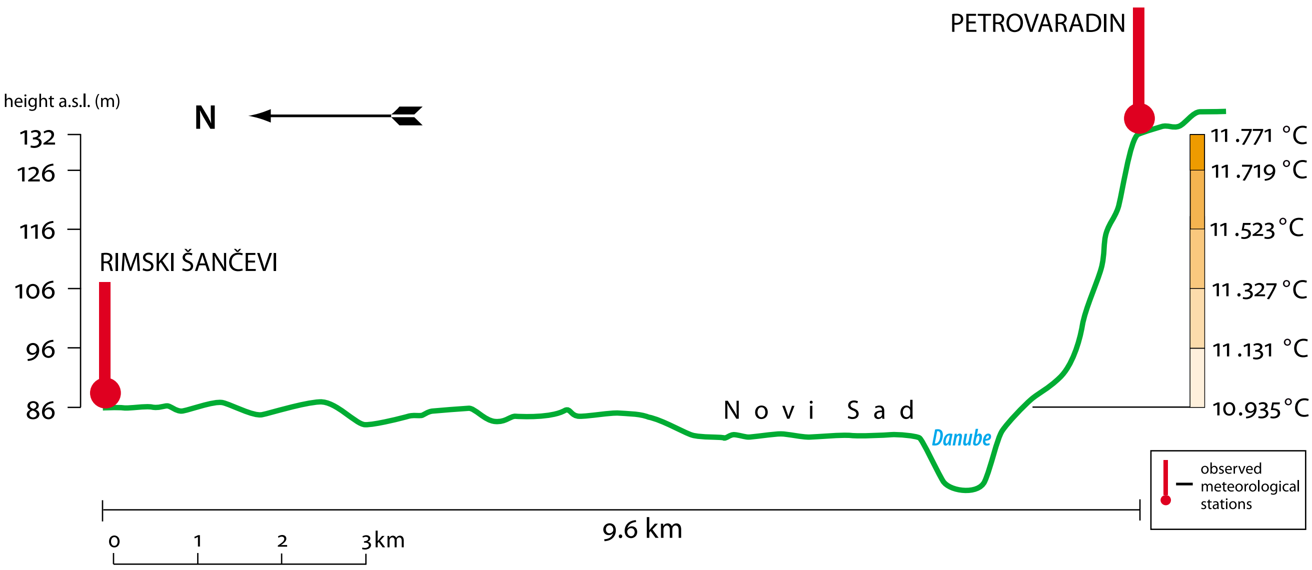



**Figure 5** Temperature inversion in Novi Sad area

es performed by Unkašević et al. (2005) also show significant rise of mean summer temperature for meteorological station in Belgrade, which is probably the result of great influence of Urban Heat Island (UHI) upon this metropolis city. It should also be mentioned that our analysis does not include the last decade of the 20th century which experienced significant rise of summer temperatures. That could be one of the reasons of great differences of data when compared to other researchers.

The analysis of mean daily observations at 7 and 21h and average annual values, during the whole observed period, shows higher air temperatures in station in Petrovaradin than in station in R.Š. Meteorological station Petrovaradin is situated on 132 m absolute height above sea level, while meteorological station R.Š. is on 86 m absolute height a.s.l. From the facts stated above, it can be concluded that the area of Novi Sad experiences the phenomenon of temperature inversion. After calculating temperature gradient on the base of mean annual data, it is seen that the average temperature rise with the height is 0.196°C/10m (Figure 5). However, the intensity of temperature inversion decreases with the height, which can be seen on the heights above sea level from 126 to 132 m. That probably means that on lower height above sea level the influence of major modifiers (the Danube and city of Novi Sad), which cause temperature inversion, is significantly higher and that on every 10 m of height the temperature rises for more than 0.196°C, while as it goes towards Petrovaradin it constantly decreases and in the very vicinity of the station the rise should be less than 0.196°C/10m.

By comparing temperature values of both meteorological stations, what is noticed is a significant influence of temperature modifiers upon values in Petrovaradin. The Danube flows only 400 m from the station. The river has a width between 350 and 750 m and represents an important aquatorium that reduces the temperature extremes, especially during winter and summer periods. Towards the west, at 1 km distance, and towards the east, at 0.5 km from the station there is a big urban settlement Novi Sad (about 200.000 inhabitants) and settlement Petrovaradin (about 14.000 inhabitants)(Figure 6). The influence of UHI (Urban Heat Island) significantly contributes to the rise of mean air temperatures, which was proved by the researches of Klysik and Fortuniak (1999), Unger et al. (2001a, 2001b), Alonso et al. (2003) and Unkašević et al. (2005).

There is probably no influence of urban environment and the Danube aquatorium upon the meteorological station R.Š., and if there any kind of influence it is probably rather irrelevant (Figure 6). That is why the meteorological station in R.Š. recorded higher values of mean temperatures at 14h

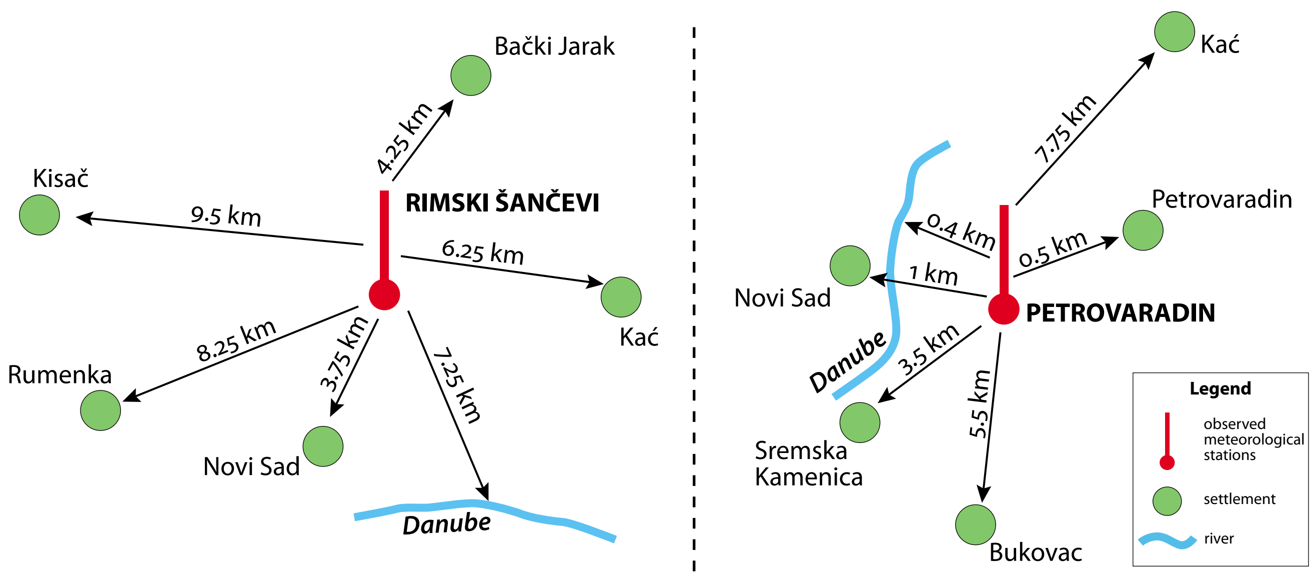



**Figure 6** Spatial distance of the meteorological stations from urban areas and the river Danube

and mean maximum temperatures. This kind of temperature relation is probably influenced by a higher level of continentality which is 0.9% on the area of R.Š. and 3.69% in Petrovaradin.

## Conclusion

The analysis of annual mean temperature values for meteorological stations in Rimski Šančevi and Petrovaradin for the period 1951-1990, i.e. 1956-1990, show the trend of air temperature rise for 0.2 – 0.4°C/century in Novi Sad area.

Annual mean minimum temperature in both stations is represented by a significant rising trend (R.Š. 1.1°C/century; Petrovaradin 0.8°C/century). This rising trend is even more expressed during winter (R.Š. 2.5°C/century; Petrovaradin 3.7°C/century) and spring (R.Š. 2.4°C/century; Petrovaradin 2.4°C/century) period. According to many authors, the rise of extreme and mean winter and spring temperatures mostly contribute to the process of global temperature rise and this process has been noticed in the research area.

According to many previous science papers, the last decade of 20th century is the warmest period in the whole history of instrumental observing. Analyzing data from meteorological station R.Š. in the period 1951 to 2000, we got rapid increasing trends of the temperature parameters. Annual mean temperature in the fifty-year period has a rising trend of 0.98°C/century, rising trend for annual mean minimum temperature is 1.6°C/century and mean winter temperature shows little lower rising trend, than in forty-year long observing period, and it is 2.3°C/century.

Annual mean temparature in the period 1991-2000 shows value of 11.3°C, presented the warmest decade in the fifty-year long observing period. The same situation we have got analyzing annual mean minimum temperature (6.5°C), which means that is the last decade warmer for 0.4°C than the same temperature parameter during the eighties (6.1°C) and seventies (6.1°C). Similar analysed data we have got for mean winter temperature, comparing values of the last decade of 20th century and values of previous decades.

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