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TEMPERATURE AND PRECIPITATION CHANGES IN SERBIA BETWEEN 1961 AND 2010

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ABSTRACT

The study aimed to evaluate spatiotemporal changes of temperature and precipitation in Serbia using observations from 26 meteorological stations over the period 1961–2010. Temporal trends were determined by a least-squares linear regression method for each station and for the entire Serbian territory using the average series for the periods 1961–2010 and 1986–2010. It was found that both minimum and maximum temperatures had significantly increased in Serbia, with the greater magnitude in the recent-past. Annual precipitation has not displayed significant change over the entire period. In the more recent period, a lager increase in precipitation was recorded, significant at a greater number of stations.

INTRODUCTION

Climate change has been a topic of interest of many studies in last decades, due to its biological, environmental, and socio-economic implications. According to the IPCC's Fifth Assessment Report, the globally averaged surface air temperature increased by 0.85°C over the 1880–2012 period (IPCC, 2013). The rate of warming was especially high from 1951 to 2012 (0.12°C decade^{-1}).Precipitation trends are more spatially variable. Generally, precipitation has increased over land north of 30°N in the period 1900–2005, while mostly downward trends were recorded at lower latitudes since the 1970s (IPCC 2013).

Agricultural production can be strongly affected by long-term changes in temperature and precipitation. Predicting how crop production and related physiological processes will respond to increasing temperatures and carbon dioxide concentration, and precipitation irregularity is very complex. Firstly, many physiological processes are non-linear functions of temperature and other meteorological conditions. Secondly, the crop production and physiological processes may depend upon preceding conditions, resulting in acclimation and down-regulation. Therefore, climate change will become a great challenge that agriculture will face in the future.

The objective of this study was to spatially analyze historical trends in maximum and minimum temperatures and precipitation over Serbia in order to provide baseline information for scientists, policy-makers, and end-users regarding climate change at a national level.

MATERIAL AND METHOD

The temperature data, consisting of daily observations of maximum (TX) and minimum (TN) air temperature, as well as precipitation (RR) data were provided by the Republic Hydrometeorological Service of Serbia (RHMSS). A total of 26 meteorological stations selected for analysis are quite uniformly distributed over the entire Serbian territory. Recent data were not available for the Autonomous Province of Kosovo and Metohija located in southwest of Serbia, because this area has not been covered by the

RHMSS since late 1990s. The acronym, name, geographical location, altitude are presented for each station in Table 1.

Temporal trends of each variable for each station were determined using the least-squares linear regression method. Linear trends for the entire Serbian territory were estimated using the average series for each variable. The statistical significance of trends was calculated using a *t*-test.

Table 1

Geographical position and elevation (H) of meteorological stations used in the study, average minimum temperature (TN), maximum temperature (TX) and precipitation (RR) for the period 1961–2010.

Code	**Name**	**Lat** (°N)	**Lon** (°E)	**H** (m)	**TN** (°C)	**TX**(°C)	**RR** (mm)
BG	Beograd	44.80	20.47	132	8.2	17.1	679
CU	Cuprija	43.93	21.37	123	5.5	17.2	643
DM	Dimitrovgrad	43.02	22.75	450	4.7	16.3	625
KI	Kikinda	45.85	20.47	81	6.3	16.4	539
KG	Kragujevac	44.03	20.93	185	6.2	17.2	618
KV	Kraljevo	43.72	20.70	215	6.1	17.0	732
KS	Krusevac	43.57	21.35	166	5.8	17.2	627
KU	Kursumlija	43.13	21.27	383	4.7	16.7	631
LE	Leksovac	42.98	21.95	230	5.4	17.3	587
LO	Loznica	44.55	19.23	121	6.6	17.2	831
NE	Negotin	44.23	22.55	42	6.5	16.8	618
NI	Nis	43.33	21.90	204	6.5	17.8	575
PA	Palic	46.10	19.77	102	6.3	16.0	543
PZ	Pozega	43.83	20.03	310	4.4	16.1	720
RS	Rimski Sancevi	45.33	19.85	86	6.3	16.6	608
SJ	Sjenica	43.27	20.00	1038	0.9	12.5	721
SP	S. Palanka	44.37	20.95	121	6.0	17.0	624
SO	Sombor	45.77	19.15	87	5.8	16.5	586
SM	S. Mitrovica	45.02	19.55	82	6.0	16.9	602
VA	Valjevo	45.77	19.15	87	6.0	17.1	783
VG	V. Gradiste	44.75	21.52	80	6.4	16.7	653
VR	Vranje	42.55	21.92	432	5.6	16.8	587
VS	Vrsac	45.15	21.32	84	6.5	16.9	640
ZA	Zajecar	43.88	22.28	144	4.9	16.9	587
ZL	Zlatibor	43.73	19.72	1028	3.6	12.1	975
ZR	Zrenjanin	45.40	20.38	80	6.4	16.6	560

RESULTS AND DISCUSSIONS

Decadal trends of minimum temperature (TN), maximum temperature (TX) and precipitation (RR) for each station over the periods 1961–2010 and 1986–2010 are shown in Figure 1, while nationally averaged time-series are displayed in Figure 2.

During the entire studied period from 1961 to 2010, TN significantly increased at most stations, except at a few stations in south-eastern part of the country (Figure1a). During the same period, TX significantly increased at all stations (Figure 1b). Trends in TN ranged from -0.01°C per decade at Vranje to 0.38°C per decade at Negotin, while trends in TX were between 0.22°C per decade at Kursumlija and 0.51°C per decade at Zlatibor. Nationally averaged rates of change in TN and TX were 0.25 and 0.33°C per decade (Figure 2a and 2b), respectively.

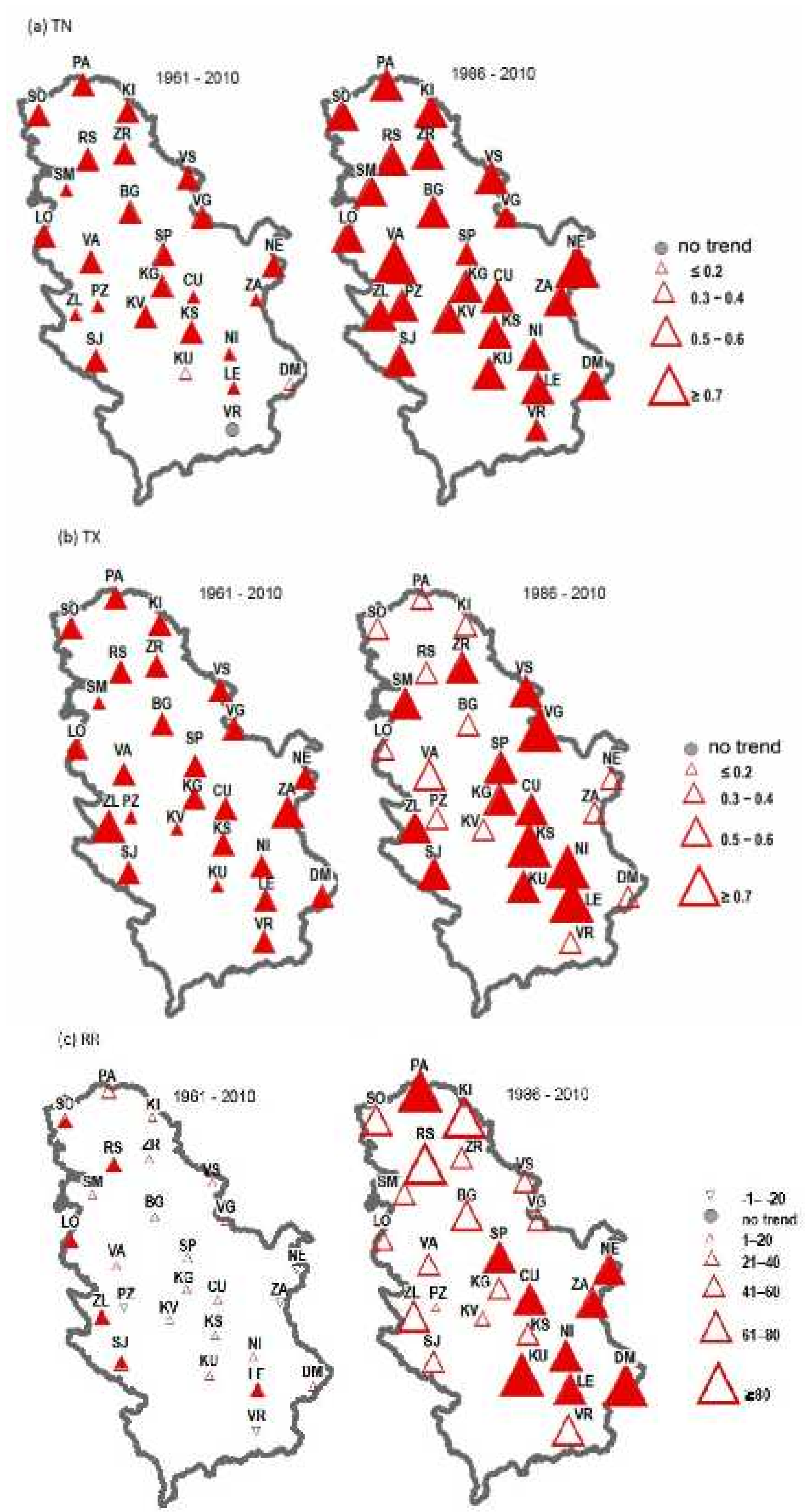

Figure 1. Spatial distribution of decadal trends and inter-annual variation of (a) mean annual minimum temperature (TN), (b) mean annual maximum temperature (TX) and (c) precipitation (RR) in Serbia. Left and right panels: station linear trends over the periods 1961–1980 and 1981–2010, respectively. Upward/downward pointing triangles show increasing/decreasing trends. The filled triangles correspond to statistically significant trends (significant at the 0.05 level), while dots indicate the stations with no trend.

In the more recent period from 1985 to 2010, TN significantly increased at all stations (Figure1a), while TX significantly increased at half stations (Figure 1b). Trends in TN ranged from 0.35°C per decade at Smederevska Palanka to 0.73°C per decade at, while trends in TX were between 0.29°C per decade at Zajecar and 0.87°C per decade at Smederevska Palanka. On average for all stations, TN and TX rose 0.52°C and 0.45°C per decade, respectively (Figure 2a i 2b).

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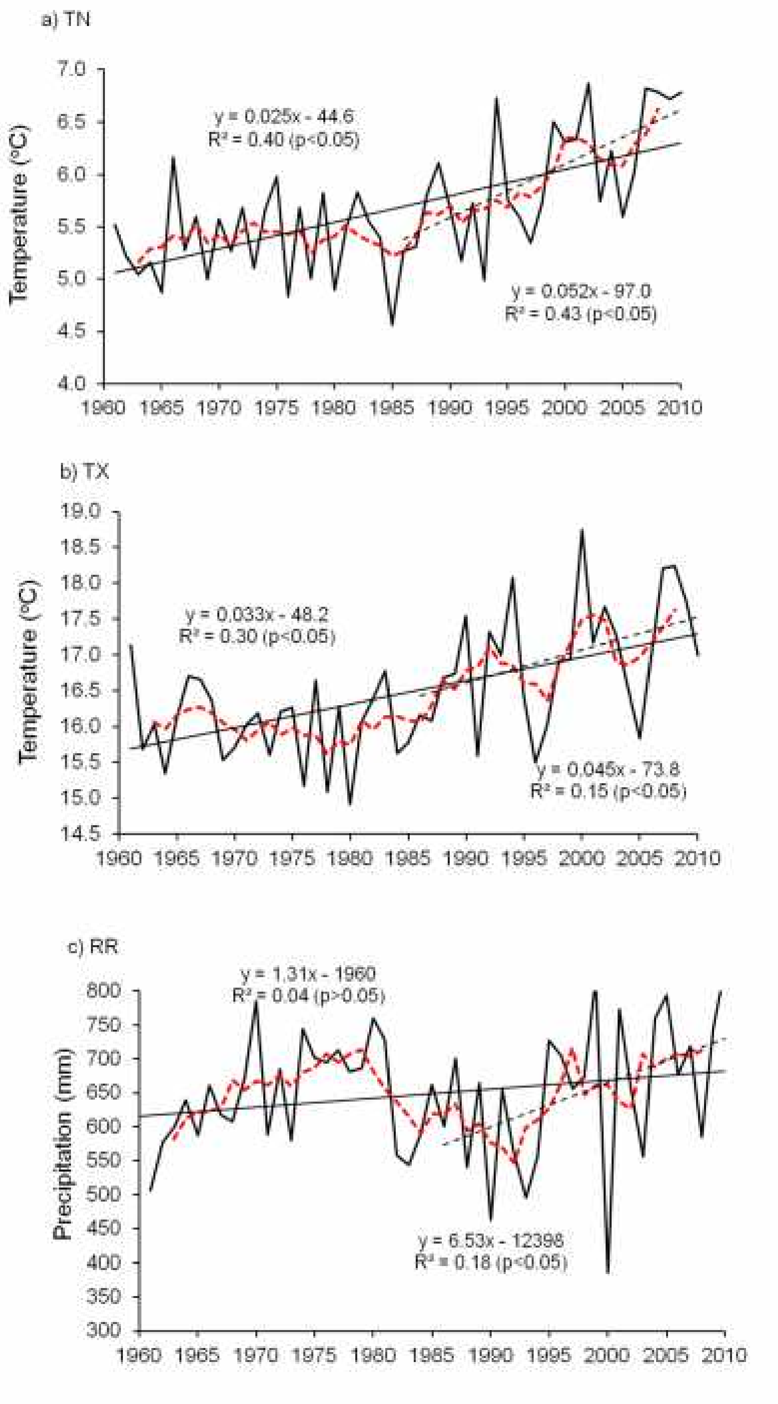

Figure 2. Inter-annual variation of (a) mean annual minimum temperature (TN), (b) mean annual maximum temperature (TX) and (c) precipitation (RR) averaged over 26 stations during 1961–2010. The dashed curves show five-year moving averages. The solid and dashed lines represent best-fit linear regressions for the periods 1961–2010 and 1986–2010, respectively..

It is important to point out that temperature did not uniformly rise over entire examined period (Figure 2a and 2b). Till early 1980s, temperature did not exhibit a rising trend. TX even showed a decreasing trend (Figure 2b).

Since early 1980s, both TN and TX showed a marked, coherent and significant increase throughout the country, especially TN. There was no apparent association between decadal trends in TN and TX. For example, Smederevska Palanka was the station with the greatest trend in TX and the smallest trend in TN over the period 1986–2010.

Obtained results for Serbia are in general agreement with many previous studies that found a warming trend in both the maximum and minimum temperature across the world, with stronger trends in more recent decades. In most of these studies TN was increasing faster than TX on the global scale (Alexander et al., 2006; Donat et al., 2013) or on a regional or national scale (e.g. Hundecha and Brádossy, 2005 – western Germany; Moberg and Jones, 2005 – central and western Europe; El Kenawy et al., 2011 – northeast Spain).

However, Klein Tank and Können (2003) found that the marked warming between 1976 and 1999 in Europe was rather associated with an increasing trend in warm extremes than with a decreasing trend in cold extremes. Moreover, in several studies for the Mediterranean region (Kostopoulou and Jones, 2005; Efthymiadis et al., 2011; Burić et al., 2014; Fioravanti et al., 2016), stronger warming trends for hot extremes rather than for cold extremes was recorded.

Precipitation did not follow trend pattern of temperature (Figure 2). The five-year moving average line (Figure 2c) indicates that RR in Serbia displayed increasing tendency till 1980, then RR was decreasing till early 1990s, and from then on RR has been increasing.

Over entire period, RR did not display significant increasing trend, but over the last 25 years of the observational period, the average series for entire territory of Serbia did display significant increase (Figure 2c). On average for all stations, the increase of RR was 65 mm per decade for the period 1986–2010.

The results from this study (Figure 1c) confirm that precipitation exhibits a strong spatial variability from the regional to the local scale. A decreasing trend in RR during entire examined period was recorded at Negotin, Zajecar, Pozega and Vranje (less than 10 mm per decade), while among stations with an increasing trend Zlatibor displayed the greatest increase in RR (37 mm per decade). In more recent period, marked with increase in RR at all stations, the greatest change in RR was observed at Rimski Sancevi (91 mm per decade), and the smallest at Pozega (17 mm per decade).

CONCLUSIONS

The minimum and maximum temperatures in Serbia exhibited increasing trend between 1961 and 2010, with greater increase in the period from 1986 to 2010. Over the entire exaimined period, nationally averaged rates of change in TN and TX were 0.25 and 0.33°C per decade, respectively, while in the recent decades these trends were 0.52°C and 0.45°C per decade. The precipitation displayed a mixed pattern of positive and negative change across Serbian teritory in the period 1961–2010, while in the period 1986–2010, an increase of precipitation was recorded at all stations, with nationally averaged rate of 65 mm per decade.

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