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Statistical analysis of annual and seasonal temperature regime change in Rasina River basin, Serbia

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Abstract— In this research, changes in annual and seasonal trends of mean temperatures were analyzed on the territory of the Rasina River basin (central Serbia). We used data from four meteorological stations during three periods: 1961–1989, 1990–2018, and 1979–2013. The change detection analysis has been conducted using the Pettitt's test, von Neumann ratio test, Buishand's range test, and standard normal homogeneity (SNH) test, while the linear regression, Mann-Kendall, and Sen's slope tests have been applied for trend analysis. The results show that the change in summer temperatures occurred shortly after 1980. The analysis results showed that inhomogeneous structures are generally observed between 1976 and 1984, between 1997 and 1998, and in 2006. The trend of all the data on annual basis showed positive increasing trend. The analysis indicated that the average annual, winter, and summer temperatures show significant increasing trend both in the longer period (1961–2018) and in the second part of the period (1990–2018). In the first part of the period (1961–1989), autumn temperatures in Kruševac, summer and autumn temperatures in Blace, as well as winter and autumn temperatures in Goč showed significant decreasing trend. The significant rising trend in the summer and winter months in the last 30 years may affect water availability and water demands in the region.

Key-words: annual and seasonal temperature, statistical homogeneity tests, Mann-Kendall test, Rasina River, Serbia

1. Introduction

Climate change, particularly temperature trend and variation, is an important topic in climate research. Climate change is a well-known threat to the social, economic, and environmental spheres (Croitoru et al., 2011; Tan et al., 2019). Recent climate changing is the result of both natural and anthropogenic influence. The number and intensity of recorded natural hazards such as flood, drought, heatwave, and wildfire have increased as climate change exacerbates in several regions of the world (Emmanuel et al., 2019, Tan et al., 2019; Mahmood et al., 2019). In recent years, potential impacts of climatic change and variability have received a lot of attention from researchers. The studies include different regions in the world, and the result shows that there is an air temperature growth trend at all temperature variables (maximum, minimum, and mean temperatures) (Jain et al., 2013; Zarenistanak et al., 2014; Chattopadhyay and Edwards, 2016; Hadi and Tombul, 2018; Tan et al., 2019; Emmanuel et al., 2019; Mahmood et al., 2019; Cherinet et al., 2019; Panda and Sahu, 2019).

According to the IPCC (2013) report, the average global surface temperature of the world has increased by $0.74\text{ }^{\circ}\text{C} \pm 0.18\text{ }^{\circ}\text{C}$ in the past 100 years. Available records show that the 1990s have been the warmest decade of the millennium in the Northern Hemisphere. The analysis of historical series of mean monthly and annual temperatures in different parts of the globe suggested, that 2005 was the warmest year in the historical series. Other warm years in the series that have occurred after 1990 were 1998, 2003, 2002, 2004, 2001, 1999, 1995, 1990, 1997, 1991, and 2000 (Jaiswal et al., 2015).

This increase in global temperature is not homogeneously distributed over the Earth's surface. It varies among regions and locations. The seasonal and annual European series of the mean temperature exhibited an increasing trend during the twentieth century. Maximum and minimum temperatures in Europe have increased more in winter ($1.0\text{ }^{\circ}\text{C}/100\text{ years}$) than in summer ($0.8\text{ }^{\circ}\text{C}/100\text{ years}$) (Moberg et al., 2006). Temperatures have risen faster than the global average in the Mediterranean region in the last decades with strong enhancement in the occurrence of extremely warm events (Lionello et al., 2014). Brunetti et al. (2004) noted that the temperature trend in Italy was positive for each season in the south, and for autumn and winter in the north. They found that Greece, in general, exhibits a cooling trend in winter, whereas in summer it exhibits an overall warming trend. Hadi and Tombul (2018) examined trends of annual and seasonal surface air temperature time series for 81 stations in Turkey for the period 1901–2014. They found that annual temperature has a significant, increasing trend, and 1993 was observed as the year of the most probable change. Seasonal temperature showed an increasing trend in all the seasons, and the highest increasing trend was observed in the summer. Analysis of the surface air temperature observed in Bulgaria indicated a decreasing trend in average air temperature in the northeast, east, and south regions, while the west, northwest,

and central regions have a positive trend (*Alexandrov et al.*, 2004). Seasonal air temperature for the period 1984–2010 in Bulgaria have also positive trend (*Chenkova and Nikolova*, 2015). Analysis of temperature changes in Slovenia showed statistically significant positive trend of mean temperatures in the period 1961–2011 (of around 0.3–0.4 °C/decade). Temperature rise has been particularly pronounced in summer, spring, and winter (*Milošević et al.*, 2017). Mean annual air temperature in Croatia in the period 1981–2018 has a clear upward trend. Higher mean annual air temperature (0.7–1.5 °C higher) occurs between 1998 and 2006 (*Tadić et al.*, 2019).

Along with the rest of the world, Serbia has experienced temperature changes during recent decades. The annual mean surface air temperature has increased significantly in almost all parts of Serbia, except the southeast part of the country. The rises in temperatures were higher in the northern than in the southern parts of Serbia, and the increase was the highest in spring (*Malinović-Milićević et al.*, 2016). The regions with the greatest increase in temperature are Eastern Serbia and the region Vojvodina (*Radivojević et al.* 2015; *Gavrilov et al.*, 2015, 2016). According to *Unkašević and Tošić* (2013), extreme temperature in Serbia increased in the period 1949–2009. The warmest summers with regards to heat wave duration and severity occurred within the periods 1951–1952, 1987–1998 (especially in 1996), and 2000–2007 (*Popović et al.*, 2009). Because Serbian regions are not always covered in European studies, the analysis of temperature tendencies can contribute to better understanding of the temperature changes. In addition to these results, the climate in Serbia was studied in other recent papers (*Radovanović and Ducić*, 2004; *Ducić et al.*, 2009; *Tošić et al.*, 2014; *Gavrilov et al.*, 2015, 2016, 2018; *Ruml et al.*, 2017; *Vukoičić et al.*, 2018).

In the present study, statistical methods of trend detection and change point analysis have been used for annual and seasonal temperature in the Rasina River basin from 1961 to 2018. Mean annual and monthly data were used to identify general trends in the temperature regime. These data were provided by the Republic Hydrometeorological Service of Serbia. The objective of the research was to examine homogeneity of the data during the period of observation, and to pinpoint the components of a trend in the data on annual and seasonal average air temperatures. This would allow us to determine of the moment t_c for marking a shift of the annual average air temperatures, implicating a statistically significant difference between the average temperatures in the period before and after this break-point moment (*Radivojević et al.*, 2015).

2. Study area

The basin of is situated in the south part of the middle Serbia connecting Dinaric and Serbian – Macedonian masses (*Fig. 1*). It covers an area of 979.6 km² (*Dimitrijević*, 2010). The largest part of the Rasina River basin is situated in the

zone of temperate continental climate with continental pluviometric regime, while mountainous climate is represented on the mountain edge of the basin. In the north, the basin is wide open towards Župa and the valley of the Zapadna Morava, from where continental air masses penetrate unhindered. The basin is surrounded by the mountain massifs of Goč, Željin, Kopaonik, and Jastrebac from the west, southwest, and east (*Stričević, 2015*).

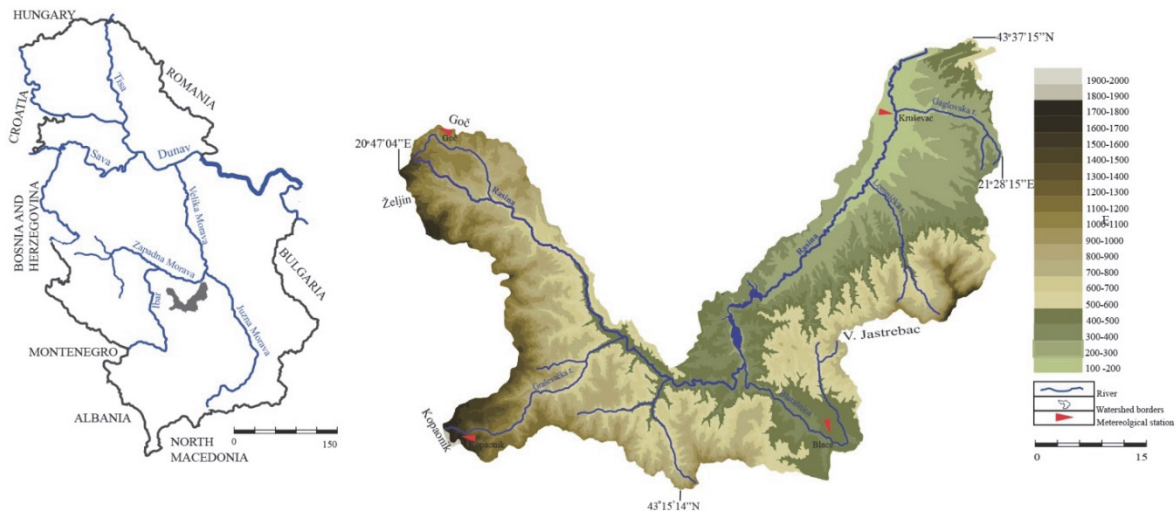


Fig. 1. Geographical location of the research area and position of meteorological stations in the Rasina River basin.

According to the Kppen’s classification, most of the basin belongs to the so-called C climate, i.e., it is moderately warm, because the average temperatures in the coldest month are higher than $-3\text{ }^{\circ}\text{C}$, while the average temperatures of the warmest month are higher than $18\text{ }^{\circ}\text{C}$. The exception is the mountainous area of Kopaonik, which belongs to the D climate, that is, has a moderately cold climate with temperature lower than $-3\text{ }^{\circ}\text{C}$ in the coldest month, while the temperature is higher than $10\text{ }^{\circ}\text{C}$ in the warmest month. According to the climatic regionalization of *T. Rakićević (1980)*, the Rasina basin belongs to the West Moravian climate region in its middle and lower course, while the upper part of the basin, which includes the mountain massifs of Kopaonik, Goč, and Željin belongs to the Kopaonik climate region.

3. Data

Annual and seasonal average temperature data recorded at 4 stations in the Rasina River basin in the period 1961–2018 were analyzed. Selected stations are located on the territory of different climatic regions of Serbia: temperate continental climatic region (Kruševac and Blace) and mountainous climatic region (Goč and

Kopaonik). The locations of the stations are presented in *Fig. 1*, and their main parameters are given in *Table 1*. Monthly temperature was provided by the Republic Hydrometeorological Service of Serbia. Seasons were defined as follows: winter – W (December–February), spring – S_p (March–May), summer – S_m (June–August), and autumn – A (September–November). The average seasonal temperature for each station was calculated using the standard season definition. All the seasons correspond to the calendar year except for the winter season, which corresponds to January-February of the calendar year and to December of the previous year.

Table 1. List of stations with the basic geographical information

Meteorological station	Latitude (°N)	Longitude (°E)	Elevation (m)	Climate type
Kruševac	43°34'	21°20'	166	Temperate continental
Blace	43°18'	21°18'	395	Temperate continental
Goč	43°33'	20°51'	990	Mountainous
Kopaonik	43°17'	20°48'	1711	Mountainous

4. Methodology

A number of methods were applied to determine change points of a time series by many researchers such as *Buishand* (1982), *Radivojević et al.*, (2015), *Ming Kang and Yusof*, (2012), *Zarenistanak et al.* (2014), *Jaiswal et al.* (2015), *Palaniswami and Muthiah* (2018), *Hadi and Tombul* (2018), *Emmanuel et al.* (2019), *Javari* (2016), *Kocsis et al.* (2020), and many more. The change point detection is an important aspect to assess the period from which significant change occurred in a time series. The Pettitt's test, Buishand range test, standard normal homogeneity test, and von Neumann ratio test have been applied for change point detection in climatic series. The details of various change point tests applied in the study are presented here.

The Pettitt's test for change detection, developed by *Pettitt* (1979), is a non-parametric test, which is useful for evaluating the occurrence of abrupt changes in climatic records. The Pettitt's test is the most commonly used test for change point detection because of its sensitivity to breaks in the middle of any time series (*Wijngaard, et al.*, 2003; *Jaiswal et al.*, 2015). According to Pettitt's test, if there is a change point in a series of n observed data, the distribution function of first t samples (F_1) will be different from the distribution function of the second part of

the series (F_2). Null hypothesis H_0 implies that the data are homogeneous throughout the period of observation, and alternative hypothesis H_1 implies the presence of a non – accidental component among data causes a shift of the location parameter at a particular moment. The non-parametric test statistics Ut for this test may be described as follows:

$$Ut = \sum_{i=1}^t \sum_{j=i+1}^n \text{sgn}(x_i - x_j) \quad (1)$$

$$\text{sgn}(x_i - x_j) = \begin{bmatrix} 1, \text{if } (x_i - x_j) > 0 \\ 0, \text{if } (x_i - x_j) = 0 \\ -1, \text{if } (x_i - x_j) < 0 \end{bmatrix} \quad (2)$$

The test statistic K and the associated confidence level (ρ) for the sample length (n) may be described as:

$$K_T = \max |U_t|, \quad (3)$$

$$p = \exp\left(\frac{-K}{n^2 + n^3}\right). \quad (4)$$

When ρ is smaller than the specific confidence level, the null hypothesis is rejected. The approximate significance probability (p) for a change-point is defined as:

$$P = 1 - p. \quad (5)$$

When there is a significant change point, the series is segmented at the location of the change point into two subseries. The test statistic K can also be compared with standard values at different confidence levels for the detection of a change point in a series. The critical values of K at 5% confidence level has been presented in *Tables 2* and *3*.

Table 2. Homogeneity test's statistic – Kruševac and Blace

Test	Period	Variable	Kruševac				A	Blace				
			T _{av}	W	S _p	S _m		T _{av}	W	S _p	S _m	A
Pettitt's test	1961-2018	<i>Kt</i>	696	379	488	743	324	620	269	320	558	303
		<i>tc</i>	1997	1993	1998	1991	1999	1997	1993	1998	1991	1969
		<i>p</i>	0.0001	0.015	0.0002	0.0001	0.505	0.0001	0.168	0.058	0.0001	0.083
		<i>TI</i>	10.876	0.682	11.224	20.055	11.560	9.876	0.412	10.405	18.994	10.628
		<i>T2</i>	12.076	1.744	12.500	21.822	11.560	10.847	0.412	10.405	20.185	10.628
	1961-1989	<i>Kt</i>	80	111	35	107	156	92	88	80	161	153
		<i>tc</i>	1968	1969	1972	1972	1969	1968	1965	1972	1972	1970
		<i>p</i>	0.286	0.059	0.980	0.065	0.001	0.155	0.196	0.291	0.0006	0.002
		<i>TI</i>	10.807	0.738	11.259	20.038	12.511	9.845	0.161	10.269	19.708	11.440
		<i>T2</i>	10.807	0.738	11.259	20.038	10.610	9.845	0.161	10.269	18.518	9.953
	1990-2018	<i>Kt</i>	141	112	131	127	111	174	99	123	162	74
		<i>tc</i>	2006	2006	1998	2006	2007	2006	2006	1998	2006	2007
		<i>p</i>	0.004	0.052	0.011	0.016	0.054	0.0001	0.108	0.025	0.001	0.374
		<i>TI</i>	11.438	1.541	11.111	21.30	11.921	10.20	0.662	9.478	19.612	10.790
		<i>T2</i>	12.333	1.541	12.500	22.308	11.921	11.190	0.662	11.020	20.758	10.790
SNH test	1961-2018	<i>Tt</i>	32.963	10.689	15.500	29.178	7.689	28.5118	7.4161	8.0815	18.9030	9.0431
		<i>t</i>	1998	1969	1998	1991	1999	2006	1965	1998	2006	1969
		<i>p</i>	0.0001	0.016	0.0004	0.0001	0.075	0.0001	0.084	0.054	0.0001	0.037
		<i>TI</i>	10.889	-0.022	11.224	20.055	11.560	9.976	0.412	10.405	19.233	11.567
		<i>T2</i>	12.110	1.390	12.500	21.822	11.560	11.190	0.412	10.405	20.758	10.455
	1961-1989	<i>Tt</i>	5.470	7.175	1.823	4.315	13.235	6.278	6.673	3.993	11.321	12.051
		<i>t</i>	1968	1969	1988	1964	1969	1968	1965	1972	1972	1969
		<i>p</i>	0.160	0.063	0.872	0.371	0.0005	0.101	0.077	0.373	0.0019	0.002
		<i>TI</i>	10.807	0.738	11.259	20.038	12.511	9.845	0.161	10.269	19.708	11.567
		<i>T2</i>	10.807	0.738	11.259	20.038	10.610	9.845	0.161	10.269	18.518	9.979
	1990-2018	<i>Tt</i>	11.223	4.329	10.751	6.278	5.243	13.61	3.605	10.060	10.213	2.284
		<i>t</i>	1999	2006	1998	2006	2007	2006	2006	1998	2006	2007
		<i>p</i>	0.003	0.323	0.006	0.161	0.233	0.0003	0.486	0.009	0.013	0.781
		<i>TI</i>	11.156	1.541	11.111	21.717	11.921	10.20	0.662	9.478	19.612	10.790
		<i>T2</i>	12.137	1.541	12.500	21.717	11.921	11.190	0.662	11.020	20.758	10.790
Buishand test	1961-2018	<i>Q</i>	21.082	11.210	14.376	20.699	10.117	18.7091	8.4432	10.3804	16.0233	8.3645
		<i>t</i>	1997	1993	1998	1991	1998	1997	1993	1998	1991	1969
		<i>p</i>	0.0001	0.016	0.0002	0.0001	0.037	0.0001	0.130	0.030	0.0001	0.125
		<i>R</i>	21.082	11.209	14.376	20.699	17.395	18.709	9.534	14.304	18.411	14.125
		<i>TI</i>	10.876	0.682	11.224	20.055	11.247	9.876	0.412	10.082	18.994	10.628
		<i>T2</i>	12.076	1.744	12.500	21.822	12.155	10.847	0.412	11.020	20.185	10.628
	1961-1989	<i>Q</i>	5.729	6.792	1.867	5.161	9.224	6.137	5.348	5.394	9.082	8.802
		<i>t</i>	1968	1969	1968	1972	1969	1968	1965	1972	1972	1969
		<i>p</i>	0.131	0.045	0.994	0.204	0.001	0.085	0.191	0.181	0.0008	0.002
		<i>R</i>	6.167	7.727	3.700	7.209	9.224	6.394	7.135	6.452	9.807	8.802
		<i>TI</i>	10.807	-0.022	11.259	20.038	12.511	9.845	0.161	10.269	19.708	11.567
		<i>T2</i>	10.807	1.170	11.259	20.038	10.610	9.845	0.161	10.269	18.518	9.979

Table 2. Continued

Test	Period	Variable	Kruševac				A	Blace				
			T _{av}	W	S _p	S _m		T _{av}	W	S _p	S _m	A
Buishand test	1990-2018	<i>Q</i>	8.642	5.616	8.314	6.723	6.089	9.958	5.125	8.042	8.626	4.019
		<i>t</i>	2006	2006	1998	2006	2007	2006	2006	1998	2006	2007
		<i>p</i>	0.003	0.150	0.006	0.044	0.090	0.0004	0.229	0.009	0.002	0.492
		<i>R</i>	8.642	8.322	8.314	6.875	6.452	9.958	6.543	8.042	8.626	5.610
		<i>T1</i>	11.438	1.541	11.111	21.300	11.921	10.20	0.662	9.478	19.612	10.790
		<i>T2</i>	12.333	1.541	12.500	22.308	11.921	11.190	0.662	11.020	20.758	10.790
von Neumann test	1961-2018	<i>N</i>	0.789	1.415	1.504	0.973	1.475	0.966	1.511	1.709	1.058	1.715
		<i>p</i>	0.0001	0.012	0.028	0.0001	0.021	0.0001	0.030	0.137	0.001	0.133
	1961-1989	<i>N</i>	2.05	1.333	2.303	1.459	1.289	2.133	1.172	2.322	1.241	1.428
		<i>p</i>	0.556	0.033	0.796	0.063	0.022	0.647	0.009	0.804	0.014	0.053
	1990-2018	<i>N</i>	0.997	1.758	0.983	1.934	2.125	1.093	1.874	1.159	1.514	2.223
		<i>p</i>	0.002	0.254	0.001	0.421	0.637	0.005	0.374	0.009	0.087	0.721

Table 3. Homogeneity test's statistic – Goč and Kopaonik

Test	Period	Variable	Goč					Kopaonik				
			T _{av}	W	S _p	S _m	A	T _{av}	W	S _p	S _m	A
Pettitt's test	1961-2018	<i>Kt</i>	663	528	485	706	310	766	589	644	790	237
		<i>tc</i>	1997	1987	1998	1986	2007	1984	1986	1980	1986	2007
		<i>p</i>	0.0001	0.0001	0.0003	0.0001	0.072	0.0001	0.0001	0.0001	0.0001	0.274
		<i>T1</i>	7.211	-1.785	6.608	15.265	8.672	2.621	-5.615	0.510	10.308	4.664
		<i>T2</i>	8.440	-0.306	7.950	16.803	8.672	4.665	-4.031	2.571	12.563	4.664
	1961-1989	<i>Kt</i>	57	106	29	88	145	199	113	120	149	62
		<i>tc</i>	1968	1969	1972	1973	1970	1976	1976	1980	1974	1974
		<i>p</i>	0.684	0.077	0.997	0.196	0.004	0.0001	0.047	0.030	0.003	0.587
		<i>T1</i>	7.179	-1.634	6.655	15.383	9.32	2.213	-5.856	0.510	9.879	4.345
		<i>T2</i>	7.179	-1.634	6.655	15.383	7.789	3.662	-4.885	2.178	11.020	4.345
	1990-2018	<i>Kt</i>	199	56	158	182	126	171	69	134	142	112
		<i>tc</i>	2006	2012	2005	2006	2008	2006	2012	1998	2006	2008
		<i>p</i>	0.0001	0.707	0.0006	0.0002	0.023	0.0001	0.459	0.011	0.004	0.051
		<i>T1</i>	7.571	-0.355	6.863	16.247	8.653	4.347	-4.062	1.622	12.141	4.983
		<i>T2</i>	8.928	-0.355	8.254	17.692	9.740	5.383	-4.062	3.175	13.333	4.983
SNH test	1961-2018	<i>Tt</i>	37.589	14.649	15.731	26.763	9.912	39.689	19.310	25.306	33.703	7.139
		<i>t</i>	2006	1987	2000	2006	2008	1980	1986	1980	1986	2008
		<i>p</i>	0.0001	0.001	0.0005	0.0001	0.019	0.0001	0.0001	0.0001	0.0001	0.158
		<i>T1</i>	7.324	-1.785	6.638	15.702	8.450	2.375	-5.615	0.510	10.308	4.664
		<i>T2</i>	8.928	-0.306	8.033	17.692	9.740	4.579	-4.031	2.571	12.563	4.664
	1961-1989	<i>Tt</i>	2.837	6.282	2.273	5.446	10.270	19.949	8.038	10.294	10.105	3.026
		<i>t</i>	1987	1969	1988	1986	1969	1978	1986	1980	1974	1973
		<i>p</i>	0.620	0.095	0.795	0.266	0.006	0.0001	0.032	0.014	0.012	0.589
		<i>T1</i>	7.179	-1.634	6.655	15.383	9.433	2.283	-5.615	0.510	9.879	4.345
		<i>T2</i>	7.179	-1.634	6.655	15.383	7.815	3.809	-3.733	2.178	11.020	4.345

Table 3. Continued

Test	Period	Variable	Goč					Kopaonik				
			T _{av}	W	S _p	S _m	A	T _{av}	W	S _p	S _m	A
SNH test	1990-2018	<i>Tt</i>	19.925	3.588	11.632	13.077	8.101	13.225	4.234	10.970	9.585	7.132
		<i>t</i>	2006	2012	2000	2006	2011	2006	2012	1998	2006	2008
		<i>p</i>	0.0001	0.503	0.003	0.007	0.034	0.0005	0.347	0.003	0.022	0.067
		<i>TI</i>	7.571	-0.355	6.591	16.247	8.732	4.347	-4.062	1.622	12.141	4.983
		<i>T2</i>	8.928	-0.355	8.033	17.692	9.957	5.383	-4.062	3.175	13.333	4.983
Buishand test	1961-2018	<i>Q</i>	20.773	14.666	14.307	19.286	9.331	23.004	16.789	18.369	22.179	8.671
		<i>t</i>	1998	1987	1998	1995	2007	1980	1986	1980	1986	1998
		<i>p</i>	0.0001	0.0003	0.0006	0.0001	0.0680	0.0001	0.0001	0.0001	0.0001	0.109
		<i>R</i>	20.773	14.666	14.307	19.286	15.192	23.004	16.789	18.369	22.180	9.960
		<i>TI</i>	7.218	-1.785	6.608	15.466	8.672	2.375	-5.615	0.510	10.308	4.664
	<i>T2</i>	8.487	-0.306	7.950	17.100	8.672	4.579	-4.031	2.571	12.563	4.664	
	1961-1989	<i>Q</i>	3.741	6.355	1.508	3.895	8.125	11.877	6.515	8.135	8.706	4.741
		<i>t</i>	1968	1969	1988	1986	1969	1978	1976	1980	1974	1973
		<i>p</i>	0.585	0.072	0.999	0.521	0.008	0.0001	0.061	0.007	0.002	0.306
		<i>R</i>	6.398	6.355	2.705	7.368	8.125	11.877	6.611	8.135	9.218	6.788
		<i>TI</i>	7.179	-1.634	6.655	15.383	9.433	2.283	-5.421	0.510	9.879	4.345
	<i>T2</i>	7.179	-1.634	6.655	15.383	7.815	3.809	-5.421	2.178	11.020	4.345	
	1989-2018	<i>Q</i>	12.049	4.205	9.190	9.761	7.308	9.816	4.568	8.398	8.357	6.973
		<i>t</i>	2006	2012	2005	2006	2008	2006	2012	1998	2006	2007
		<i>p</i>	0.0001	0.436	0.001	0.0001	0.016	0.0001	0.354	0.003	0.003	0.033
<i>R</i>		12.049	5.281	9.190	9.761	9.424	9.816	5.248	8.398	8.357	7.891	
<i>TI</i>		7.571	-0.355	6.863	16.247	8.653	4.347	-4.062	1.622	12.141	4.567	
<i>T2</i>	8.928	-0.355	8.254	17.692	9.740	5.383	-4.062	3.175	13.333	5.664		
von Neumann test	1961-2018	<i>N</i>	0.587	1.264	1.806	0.837	1.364	0.202	1.133	0.928	0.578	1.336
		<i>P</i>	0.0001	0.0009	0.237	0.0001	0.008	0.001	0.0001	0.0001	0.0001	0.004
	1961-1989	<i>N</i>	2.123	1.128	2.732	1.460	1.492	0.237	1.057	1.747	0.881	1.335
		<i>P</i>	0.637	0.006	0.981	0.064	0.081	0.0001	0.003	0.246	0.0001	0.038
	1990-2018	<i>N</i>	0.507	1.882	1.157	1.247	1.438	0.906	1.839	0.888	1.602	1.466
		<i>p</i>	0.0001	0.367	0.011	0.023	0.055	0.0005	0.335	0.0001	0.137	0.071

The Buishand range (BR) test is also a non-parametric test which checks the presence of a change point in the given data marking a change of the location parameter (average values) distribution. The null hypothesis H_0 implies data homogeneity in terms of the location parameter, i.e., absence of a change regarding the said parameter over time. The alternative hypothesis H_1 implies presence of a change-point involving an increase or decrease of the average value of the observed feature. The adjusted partial sum (S_k), that is, the cumulative deviation from mean for k th observation of a series $x_1, x_2, x_3, \dots, x_k, \dots, x_n$ with mean \bar{x} can be calculated using the following equation:

$$S_k = \sum_{i=1}^k (x_i - \bar{x}). \quad (6)$$

A series may be homogeneous without any change point if $S_k \cong 0$, because in random series, the deviation from mean will be distributed on both sides of the mean of the series. The significance of shift can be evaluated by computing rescaled adjusted range (R) using the following equation:

$$R = \frac{\max(S_k) - \min(S_k)}{\bar{x}}. \quad (7)$$

The computed value of $R = R/\sqrt{n}$ is compared with critical values given by *Buishand* (1982) and *Wijngaard et al.* (2003) and has been used for detection of possible change.

The standard normal homogeneity (SNH) test, is a statistical test which also checks if the data originate from the same population with the same distribution or indicate presence of a significant difference in the location parameter between the data before and after a specific change-point t_c bringing an increase or decrease of the value of the observed feature. The test statistic (T_t) is used to compare the mean of first t observations with the mean of the remaining $(n-t)$ observations with n data points (*Alexandersson*, 1986; *Toreti et al.*, 2011; *Ming Kang and Yusof*, 2012; *Jaiswal et al.*, 2015):

$$T_t = tZ_1^2 + (n - t)Z_2^2, \quad (8)$$

$$Z_1 = \frac{1}{t} \sum_{i=1}^t \frac{x_i - \bar{x}}{\sigma}, \quad (9)$$

$$Z_2 = \frac{1}{n-t} \sum_{i=t+1}^n \frac{x_i - \bar{x}}{\sigma}, \quad (10)$$

where \bar{x} and σ are the mean and standard deviations of the series. The year t can be considered as a change point and comprises a break where the value of T_t attains the maximum value. To reject the null hypothesis, the test statistics should be greater than the critical value, which depends on the sample size (n).

The von Neumann test (*Neumann*, 1941) also tests the null hypothesis H_0 implying data homogeneity in terms of the location parameter and absence of its change over the period of observation, as opposed to the alternative hypothesis H_1 , which implies the presence of the moment t_c when the change of the location parameter occurs. If the alternative hypothesis is accepted, the von Neumann test

cannot pinpoint the moment t_c marking the change of the location parameter. The test statistics used in this test are as follows:

$$N = \frac{\sum_{i=1}^{n-1} (x_i - x_{i-1})^2}{\sum_{i=1}^n (x_i - \bar{x})^2}. \quad (11)$$

There are some differences between the SNH, BR, and Pettitt tests. SNH test is sensitive in detecting the breaks near the beginning and the end of the series. BR test and Pettitt test are easier to identify the break in the middle of the series. Besides, the SNH and BR tests assume X_i is normally distributed, whereas the Pettitt test does not need this assumption, because it is a non-parametric rank test (Kang and Yusof, 2012).

The trends in historical series of meteorological data have been assessed using the linear regression test and the Mann-Kendall test.

In the linear regression test, a straight line is adjusted to the data, and the slope of the line may or may not be significantly different from zero. For a series of observations x_i , $i=1, 2, 3, \dots, n$, a straight line in the form of $y = a + bx$ can be calculated as:

$$a = \frac{\sum X_i Y_i - \frac{1}{n} \sum X_i \sum Y_i}{\sum X_i^2 - \frac{1}{n} (\sum X_i)^2}, \quad (12)$$

$$b = \frac{(\sum Y_i)(\sum X_i^2) - (\sum X_i)(\sum X_i Y_i)}{n \sum X_i^2 - (\sum X_i)^2}, \quad (13)$$

where y is the temperature in °C, a and b are the intercept and slope of the fitted line, x is the time in years (Jaiswal et al., 2015; Gavrilov et al., 2016). This approach gives results which are simple to interpret; both graphically and analytically on the basis of the shape and parameters of the trend equation. The sign of the temperature trend depends on the value of the slope: when the slope is higher than zero, less than zero, or equal to zero, the sign of the trend is positive (increase), negative (decrease), or there is no trend (no change), respectively (Gavrilov et al., 2015, 2016, 2018).

The statistical significance of the trend in annual and seasonal series was analyzed using the non-parametric Mann-Kendall (MK) test (Mann, 1945; Kendall, 1975). The MK test has been used in the analysis of a number of researchers to ascertain the presence of a statistically significant trend in hydrological climatic variables, such as temperature, precipitation, and

streamflow, for example: temperature: *Mohorji et al.*, 2017, temperature and precipitation *Jain et al.*, 2013; *Chattopadhyay and Edwards*, 2016; *Bhuyan et al.*, 2018; *Emmanuel et al.*, 2019; *Tan et al.*, 2019; *Mosase et al.*, 2019; *Panda and Sahu*, 2019; precipitation: *Kumar et al.* 2010; *Burić et al.*, 2015; *Hussain*, 2015; *Merabtene et al.*, 2016; *Kocsis et al.*, 2020; *Meena*, 2020; *Ramezani et al.*, 2020; *Borse and Agnihotri*, 2020; precipitation and streamflow: *Da Silva et al.*, 2015; streamflow: *Radevski et al.*, 2018; temperature, precipitation, and flow: *Cherinet et al.*, 2019; evapotranspiration – *Sharma et al.*, 2020.

The MK test checks the null hypothesis of no trend versus the alternative hypothesis of the existence of increasing or decreasing trend (*Kumar et al.*, 2010). A positive MK value indicates an increasing trend, while a negative MK value shows a decreasing trend. The Mann-Kendall statistics can be presented as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^n \text{sign}(X_j - X_i), \quad (14)$$

where n is the total length of data, x_i and x_j are the time series of the annual and/or seasonal values of the temperatures in years $j = i + 1, i + 2, i + 3, \dots, n$ and $i = 1, 2, 3, \dots, n-1$, where $j > i$, and n is the last year in the time series. Function $\text{sign}(x_i - x_j)$ assumes the following values:

$$\text{sign}(X_j - X_i) = \begin{bmatrix} 1, \text{if}(X_j - X_i) > 0 \\ 0, \text{if}(X_j - X_i) = 0 \\ -1, \text{if}(X_j - X_i) < 0 \end{bmatrix}. \quad (15)$$

According to this test, the statistic S is approximately normally distributed with the mean $E(S)$ and the variance $Var(S)$ can be computed as follow (*Jaiswal et al.*, 2015):

$$E[S = 0],$$

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{k=1}^n t_k(t_k-1)(2t_k+5)}{18}, \quad (16)$$

where n is the number of data in the time series, and t_k is the number of data in the k th tied group. (*Kocsis et al.*, 2020). The standardized statistics Z for this test can be calculated by the following equation:

$$Z = \begin{bmatrix} \frac{S-1}{\sqrt{Var(S)}}, \text{if } S > 0 \\ 0, \text{if } S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, \text{if } S < 0 \end{bmatrix}. \quad (17)$$

The positive values of Z indicate upward (increasing) trends in time series, and the negative values show downward (decreasing) trends. Trends are then tested against some critical values ($Z_{1-\alpha}$) to show whether they are statistically significant or not. For example, if $|Z| > Z_{1-\alpha}$, (e.g., $Z_{1-\alpha}$ at $\alpha = 0.05$); the null hypothesis of no-trend is rejected, and alternative hypothesis of a significant trend is accepted. In this study to represent the confidence level ***, **, *, and + signs have been used to represent 100%, 99%, 95%, and 90% levels of confidence, respectively.

The magnitude of the trend in the time series was determined using the Sen's slope test (Sen, 1968). The Sen's method assumes a linear trend in the time series and has been widely used for determining the magnitude of a trend in hydro-meteorological time series (Hirsch et al., 1991; Hussain et al., 2015; Mahmood et al., 2019; Cherinet et al., 2019; Kocsis et al., 2020). In this method, the slopes (T_i) of all data pairs are first calculated by:

$$T_i = \frac{X_j - X_k}{j - k}, \text{ for } i = 1, 2, \dots, N, \quad (18)$$

where x_j and x_k are data values at time j and k ($j > k$), respectively. The median of these N values of T_i is the Sen's estimator of slope, which is calculated as follows:

$$\beta = \left[\frac{T_{N+1}}{2} \right] \left[\frac{1}{2} \left(\frac{T_N}{2} + \frac{T_{N+2}}{2} \right) \right]. \quad (19)$$

A positive value of β indicates an upward (increasing) trend, while a negative value indicates a downward (decreasing) trend in the time series.

5. Results and discussion

In the present study, the first various change point tests, including the Pettitt's test, von Neumann's ratio test, Buishand's range test and SNH test, have been applied to detect a change point in annual and seasonal series of temperature in the Rasina River basin. For each of the tests, we failed to reject the null hypothesis when the estimated p -value was greater than the significance level of 0.05. After detecting the change point, the trend analysis was applied by using the linear regression and Mann-Kendall tests.

The test statistics of various tests and acceptance or rejection of null hypothesis for annual and seasonal temperatures are presented in *Tables 2* and *3*. *Figs. 2–5* show the change points of average annual and seasonal temperatures during the period 1961–2018.

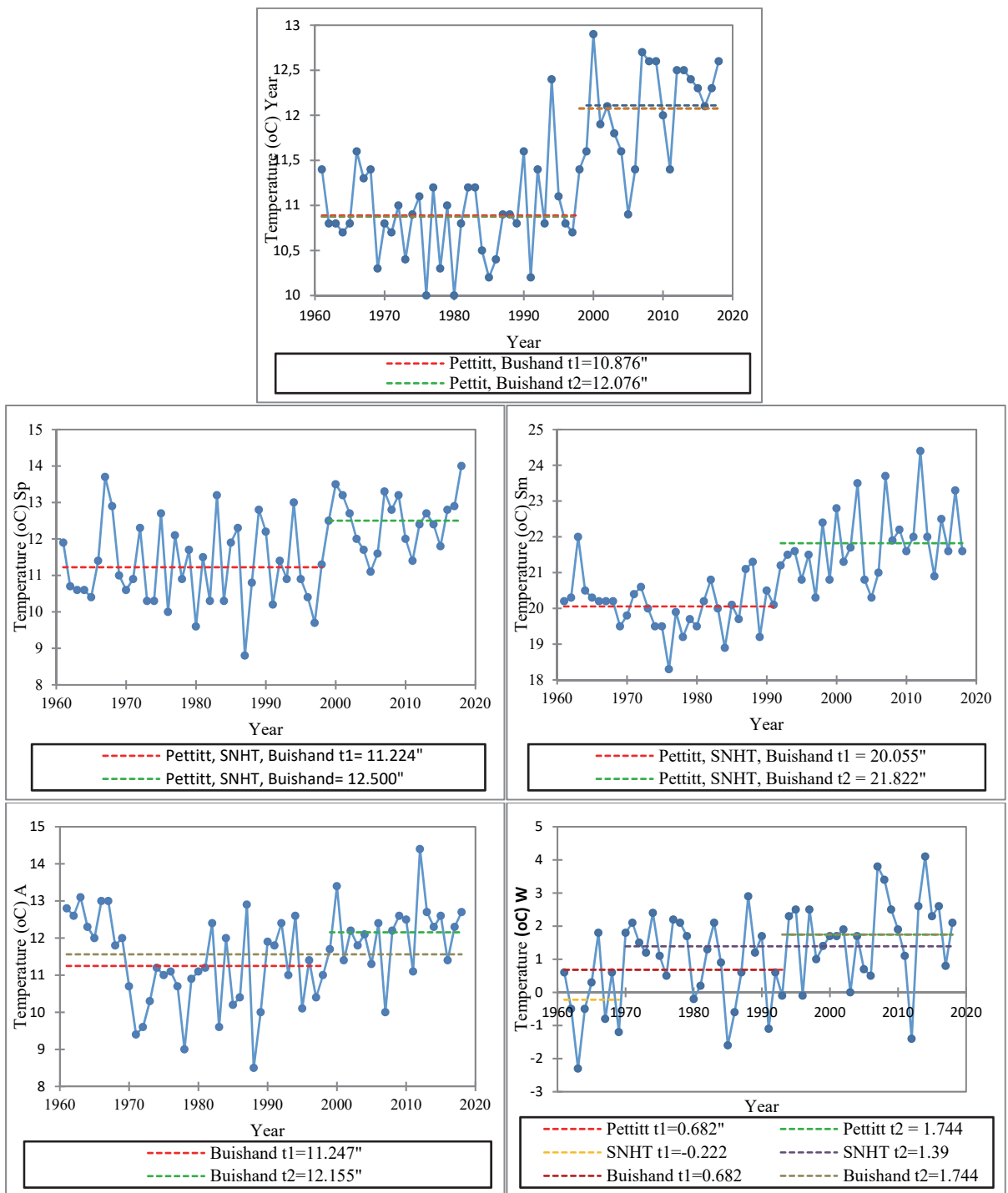


Fig. 2. Change points of average annual and seasonal temperatures in Kruševac.

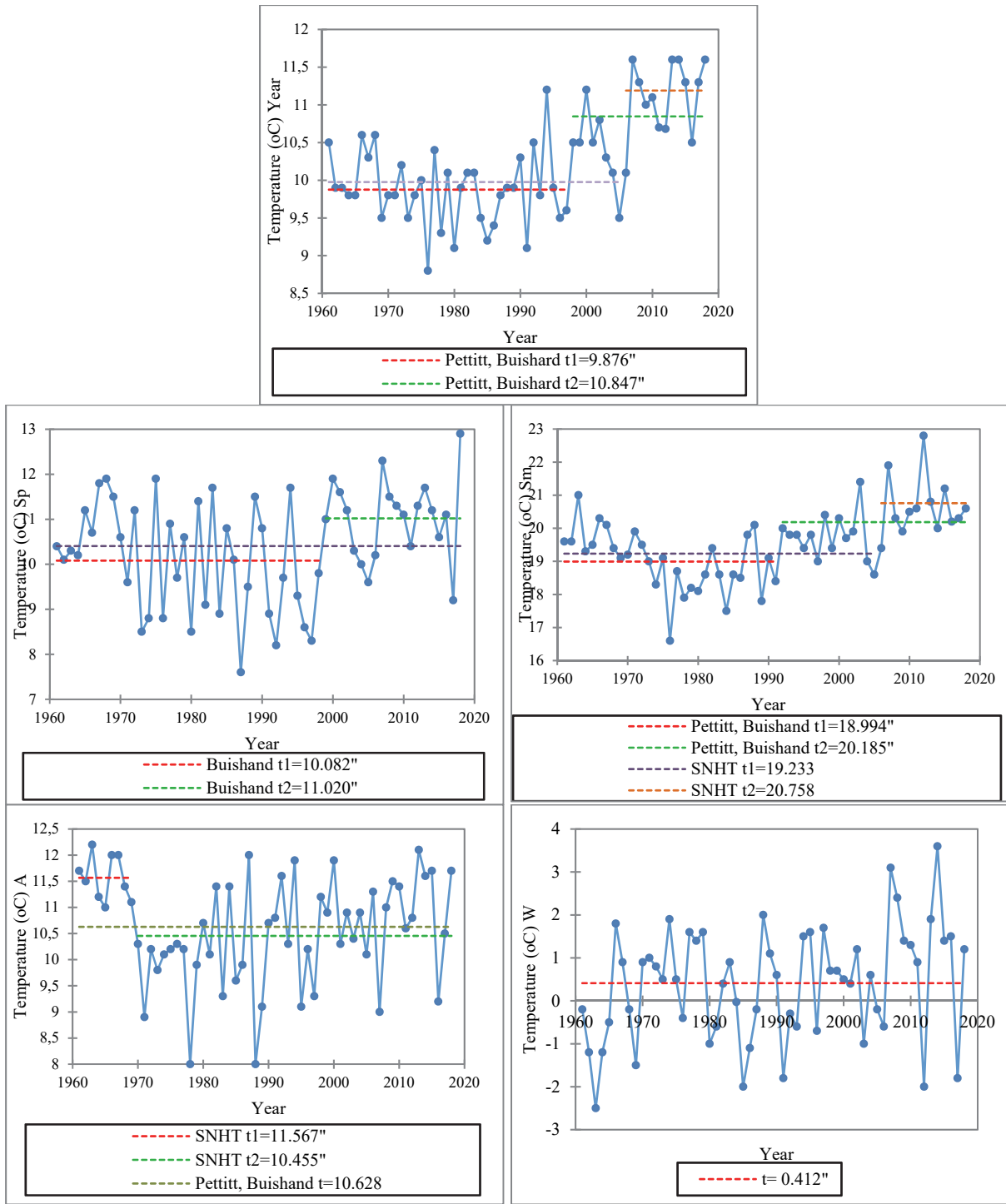


Fig. 3. Change points of average annual and seasonal temperatures in Blace.

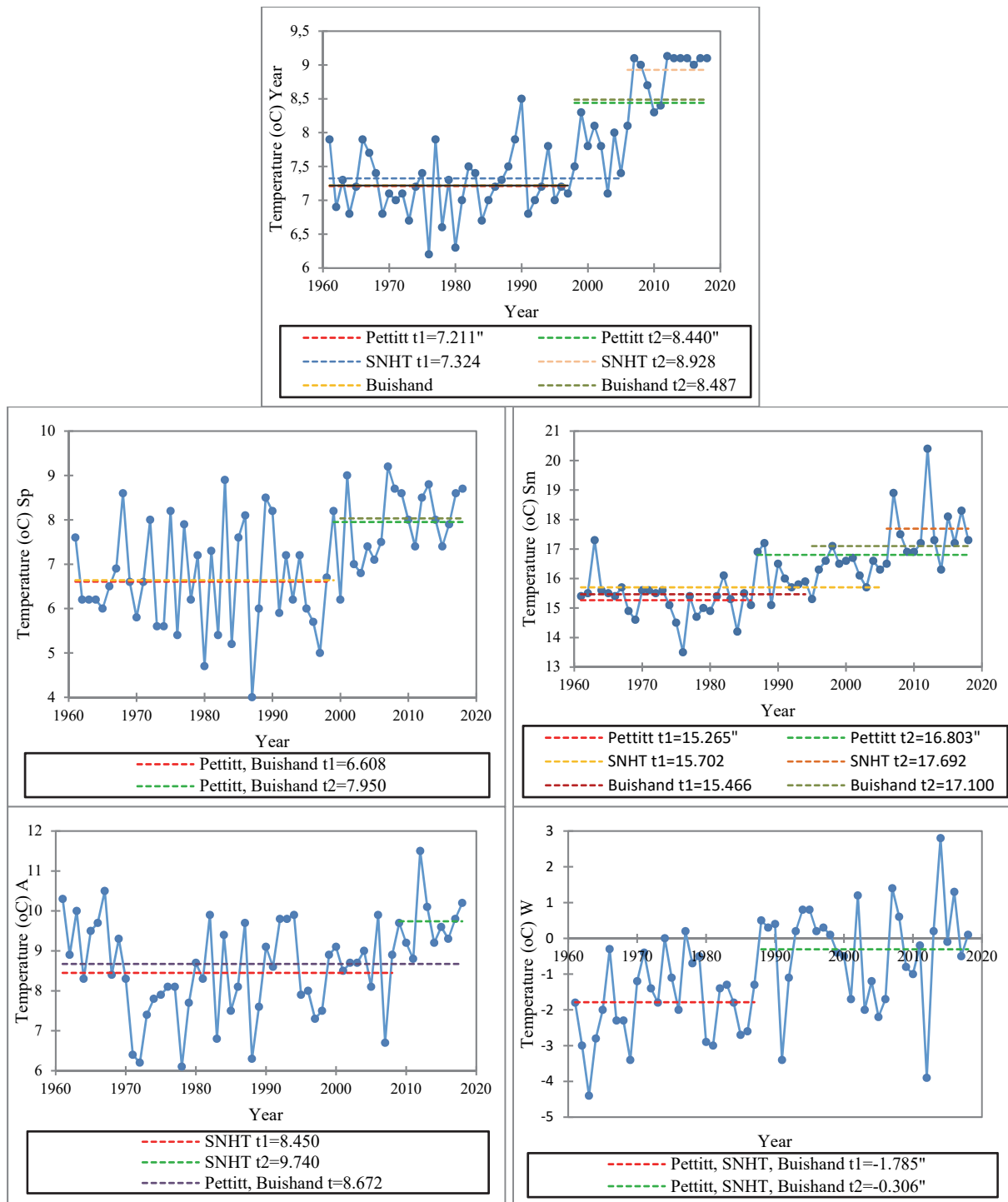


Fig. 4. Change points of of average annual and seasonal temperatures in Goč.

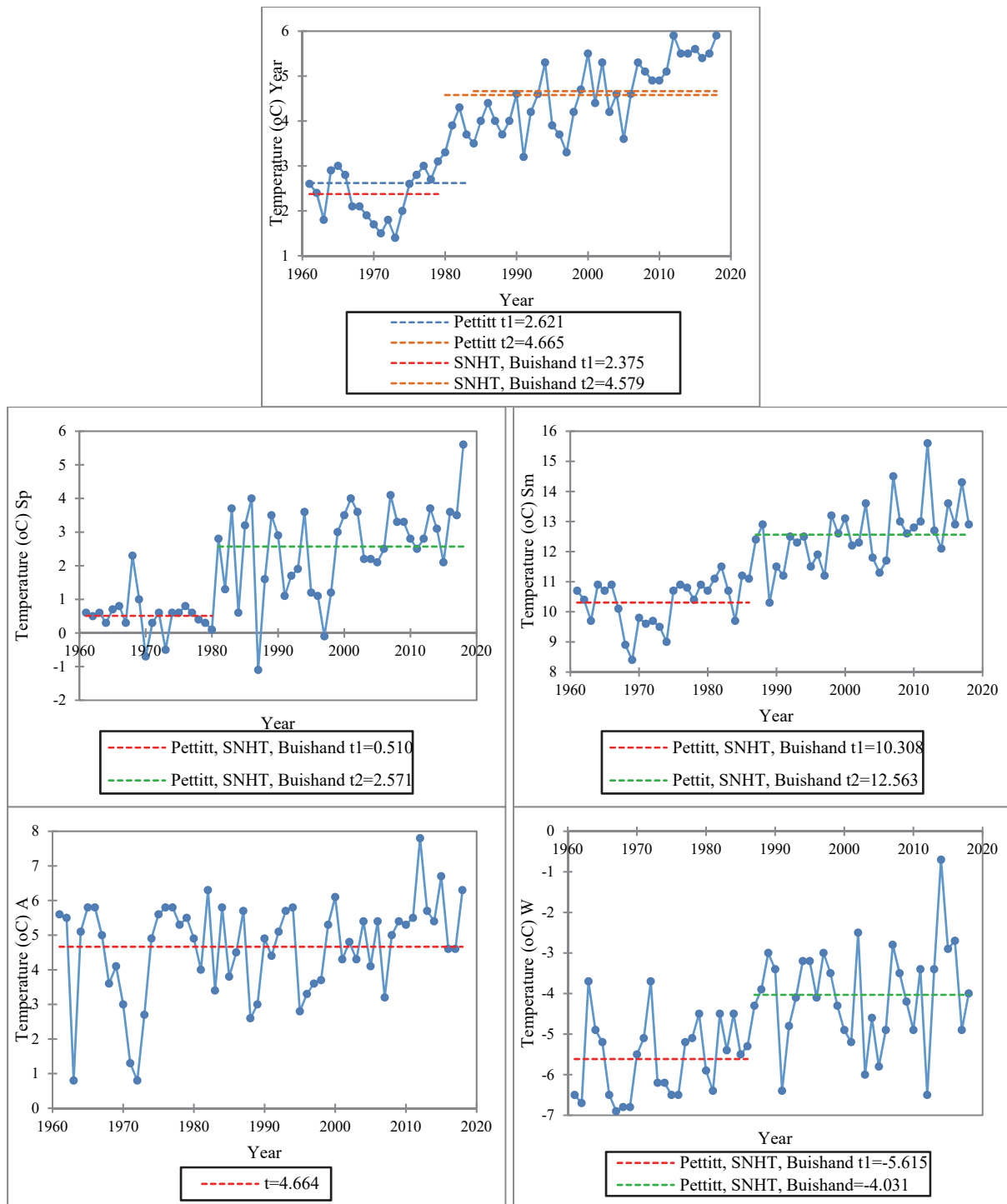


Fig. 5. Change points of of average annual and seasonal temperatures in Kopaonik.

The average annual, winter, summer, and spring temperature series in the period 1961–2018 on all the stations indicated a significant change point, except in Blace, where spring and winter data can be considered as homogeneous in nature. All the analyzed stations have passed the critical test value at a 95% significance level as a result of the application of Pettitt,SNH and Buishard tests.

The analysis results shown in *Tables 2 and 3* indicate that the inhomogeneous structure is generally observed between 1976 and 1984, between 1997 and 1998, and in 2006. All the tests on Kruševac and Blace stations indicate that the change in annual temperature occurred in 1997, except for SNH test, which identifies the year of 1998 as a changing point in Kruševac and 2006 as a changing point in Blace. In the mountainous parts of the basin, on Goč station, the change in annual temperature occurred in 1997 and 1998, according to the Pettitt's and Buishand tests, while in Kopaonik, the change in average temperature occurred in 1980 and in 1984. The average annual temperature in the period 1961–2018 increased in Kruševac from 10.88 °C to 12.08 °C, in Blace from 9.88 °C to 10.85 °C, in Goč from 7.21 °C to 8.44 °C, whereas in Kopaonik it increased from 2.62 °C to 4.67 °C.

The Pettitt's and Buishand tests indicate an increase in average winter temperatures in Kruševac and Blace from 1993, while in Goč and Kopaonik, the increase started in 1987 and 1986.

The analysis of spring temperature confirmed that the change point may have occurred in 1998 in Kruševac, Blace, and Goč, while it may have occurred in 1980 in Kopaonik.

All the tests on Kruševac and Blace stations indicate that the change in the average summer temperature occurred in 1991, except for the SNH test, which identifies the year of 2006 as a changing point in Blace. On the Kopaonik station, the change in the average summer temperature occurred in 1986. The average summer temperature in Kruševac increased from 20.06 °C to 21.82 °C, in Blace from 18.99 °C to 20.19 °C, in Goč from 15.27 °C to 16.80 °C, while in Kopaonik, it increased from 10.31 °C to 12.56 °C.

The results of the von Neumann test of homogeneity call for acceptance of the alternative hypothesis too, i.e., they lead to a conclusion that in the series of average annual temperatures there is a change point regarding the location parameter.

As the time series was 58-year-long, it was long enough to be divided it into two equal 29-year-long periods, in order to gain a better insight. The first half of the period occurred between 1961 and 1989, while the second occurred between 1990 and 2018.

In the first half of the period (1961–1989), all the tests indicated a significant change point in the average autumn temperatures in Kruševac, average autumn and summer temperatures in Blace and Goč, and average annual, winter, summer, and spring temperatures in Kopaonik.

All the tests on the Blace station indicate that a decrease of the average summer temperature occurred in 1972, while in Kopaonik, an increase of the summer temperature was observed from 1974. The average summer temperature in Blace decreased from 19.71 °C to 18.52 °C, and in Kopaonik increase from 11.02 °C to 11.55 °C.

In the second half of the period 1990–2018, all test in all stations detected year 2006 as changing point of the average annual and summer temperatures and

1998 as changing point of the annual spring temperature (except in Goč, where the change in annual spring temperature occurred in 2005).

The main conclusions derived from the presented results are that the temperature is increasing with accelerated rate, with more pronounced increase in maximum temperatures, especially during the summer. According to the used data, the hottest year on the territory of the Rasina basin was 2000, while out of 10 hottest years, 9 have occurred since the year of 2000. The hottest summer was during 2012, same as on the territory of the whole Serbia (*Vuković et al.*, 2018). The mean annual temperature for the period of 1990–2018 increased by 1.3 °C with respect to the period of 1961–1989. The highest increase of 1.5 °C is recorded for the summer season. The season with the second highest increase in temperatures is spring.

These results may be the basis for the future analysis of the reasons for inhomogeneity in these stations and of the question whether the inhomogeneity of these stations are caused by variations of natural meteorological conditions or by other environmental conditions.

To determine a trend, the linear regression test and the Mann-Kendall test have been applied in the different series of meteorological variables. *Figs. 6–9* show annual and seasonal mean temperatures during the period 1961–2018 with three trend equations: above (1961–2018) and below (1961–1989 and 1990–2018); and three trend lines: for longer and two shorter periods, respectively.

In strictly formal terms, some trends can be observed in all cases. However, all the trends do not have the same sign, magnitude, and probability. To obtain a final evaluation of the temperature trends in the Rasina River basin, all the numerical parameters, visual representation of trends, and results of the MK test were used (*Gavrilov et al.*, 2015, 2016, 2018). The MK test statistics for annual and seasonal temperature are presented in *Tables 4–7*.

In the first period (1961–1989), the trend is negative for average annual, spring, summer, and autumn temperatures at all the stations, except Kopaonik. MK testing proves whether these statements are true. As the computed probability values p are greater than the significance level α in cases: $Y-T_{av}$, W , S_p , S_m (Kruševac), $Y-T_{av}$, S_m , W (Blace), $Y-T_{av}$, S_p , S_m, A (Goč), $Y-T_{av}$, W , S_p , S_m (Kopaonik), the H_0 cannot be rejected. Probability values p for A (Kruševac), S_p and A (Blace), W (Goč), and A (Kopaonik) are lower than α , so the H_0 should be rejected, and the H_a should be accepted for all of these cases. The MK test indicated a non-significant decrease in the trend of the annual temperature in Kruševac, Blace, and Goč and significant increase in the trend of the annual temperature in Kopaonik.

The average annual and seasonal temperatures in the second period (1990–2018) show a positive trend at all the stations. The MK test indicated a significant increase in temperature during all the seasons in Kruševac, in spring and summer in Blace and Goč, and during spring, summer, and autumn in Kopaonik, with very high certainty ($\alpha=0.005-0.0001$). The annual temperature exhibits an increasing

trend from 0.5 °C/decade in Kruševac and Blace, 0.8 °C/decade in Goč and 0.7 °C/decade in Kopaonik. Spring mean temperature increased from 0.7 °C/decade in Kruševac and Blace, 0.9 °C/decade in Goč, and 0.8 °C/decade in Kopaonik, while summer temperature increased from 0.5 °C/decade in Kruševac and Blace, 0.6 °C/decade in Goč and Kopaonik.

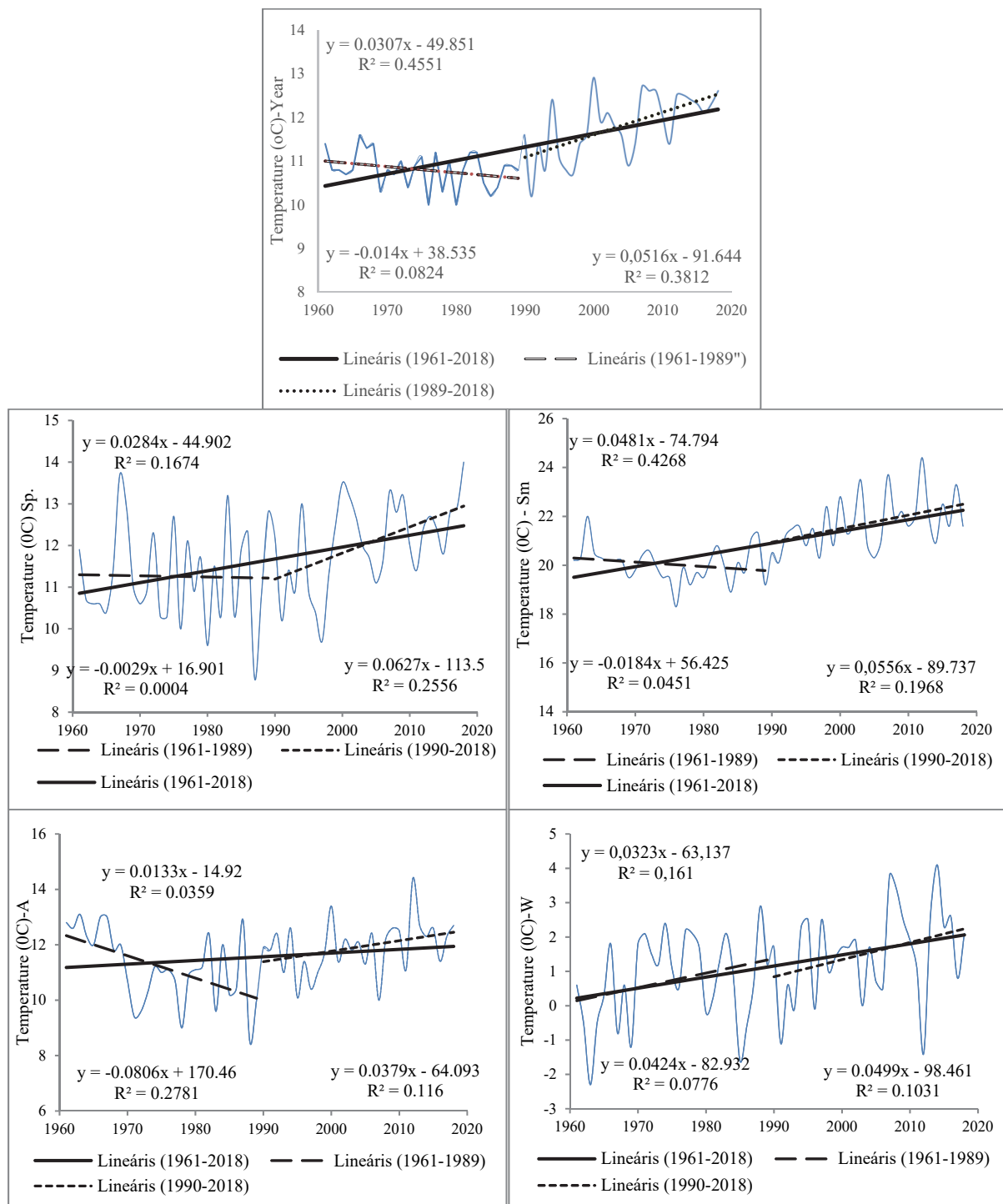


Fig. 6. Average annual and seasonal temperatures, trend equations, and trend lines for Kruševac.

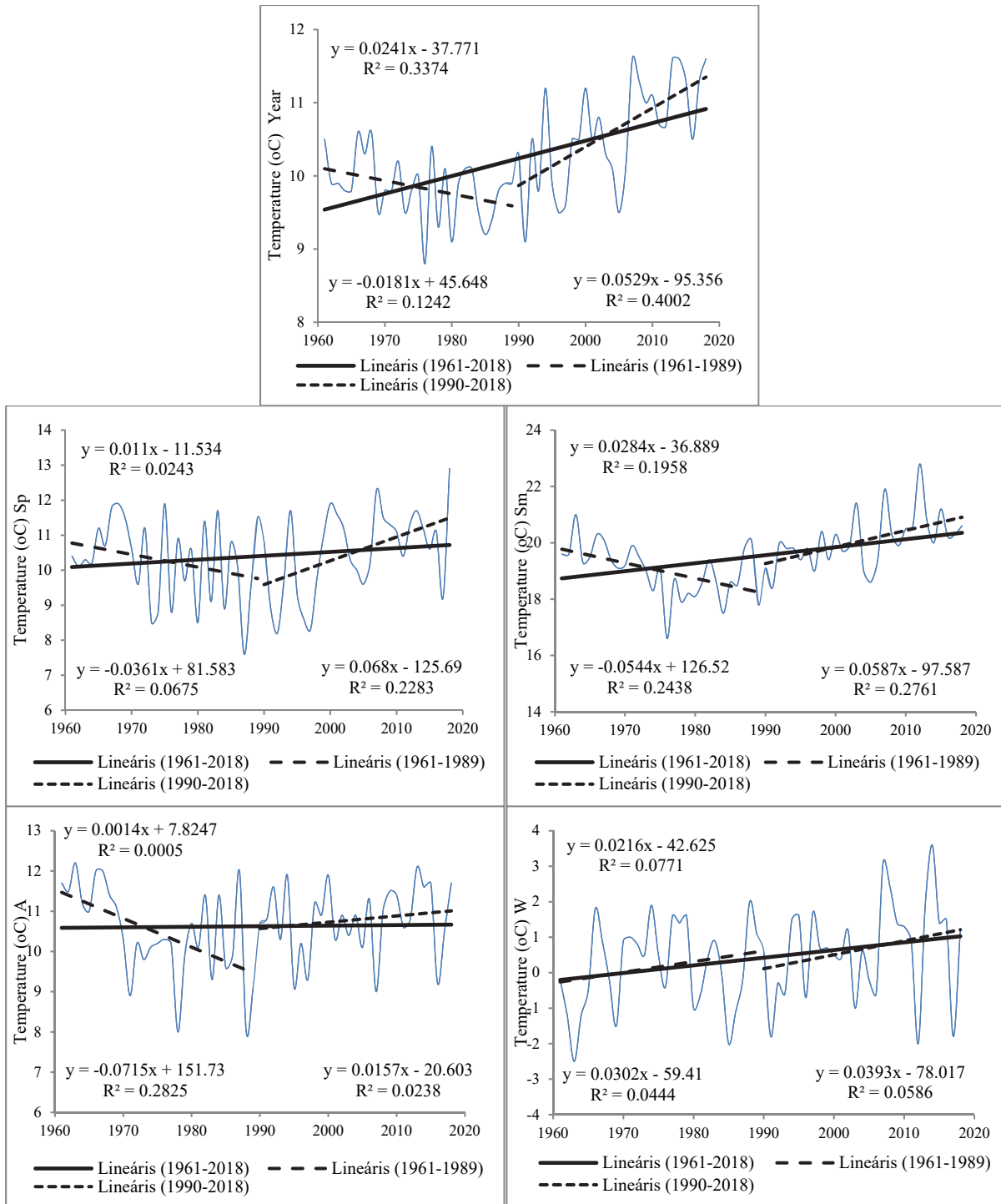


Fig. 7. Average annual and seasonal temperatures, trend equations, and trend lines for Blace.

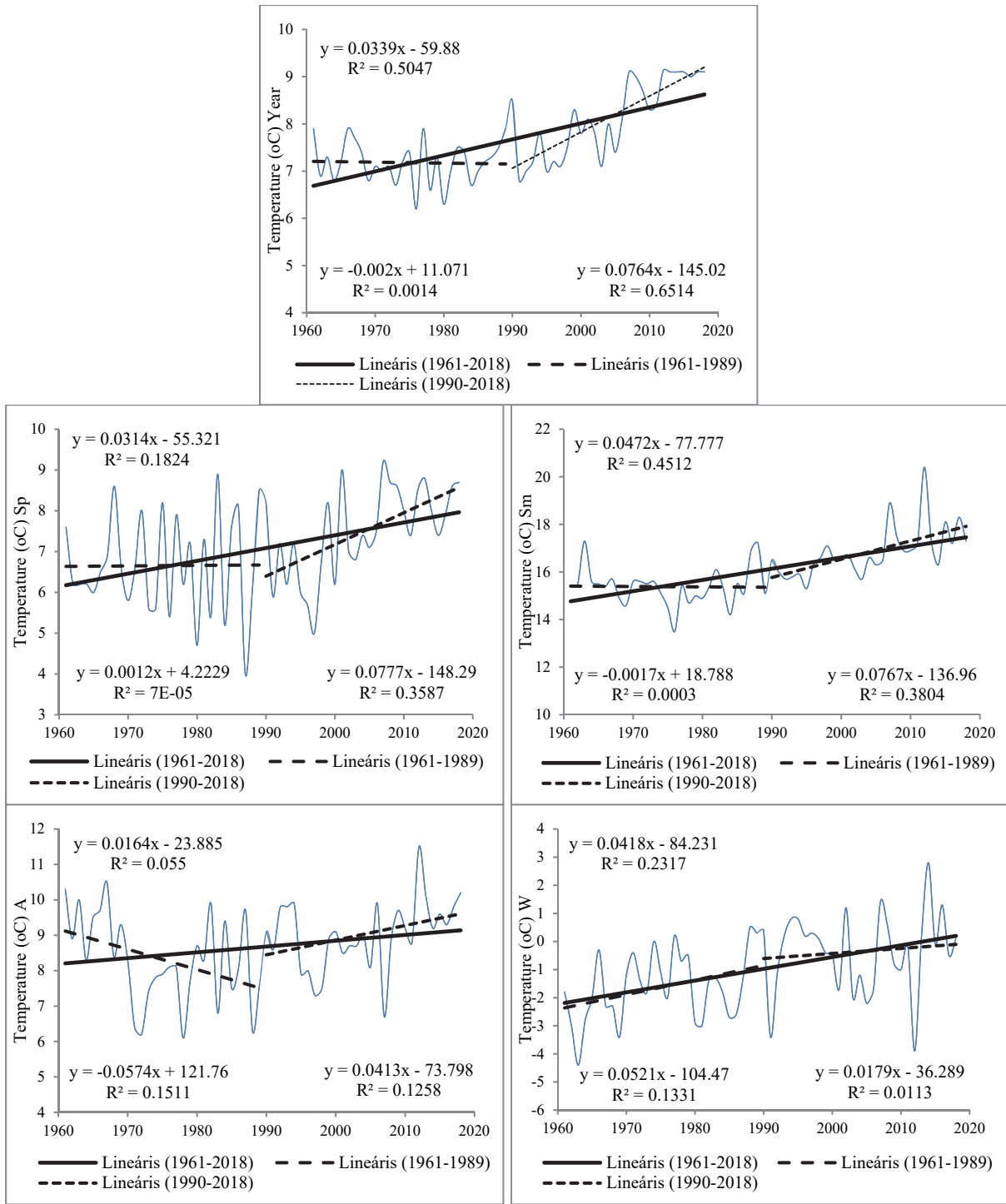


Fig. 8. Average annual and seasonal temperatures, trend equations, and trend lines for Goč.

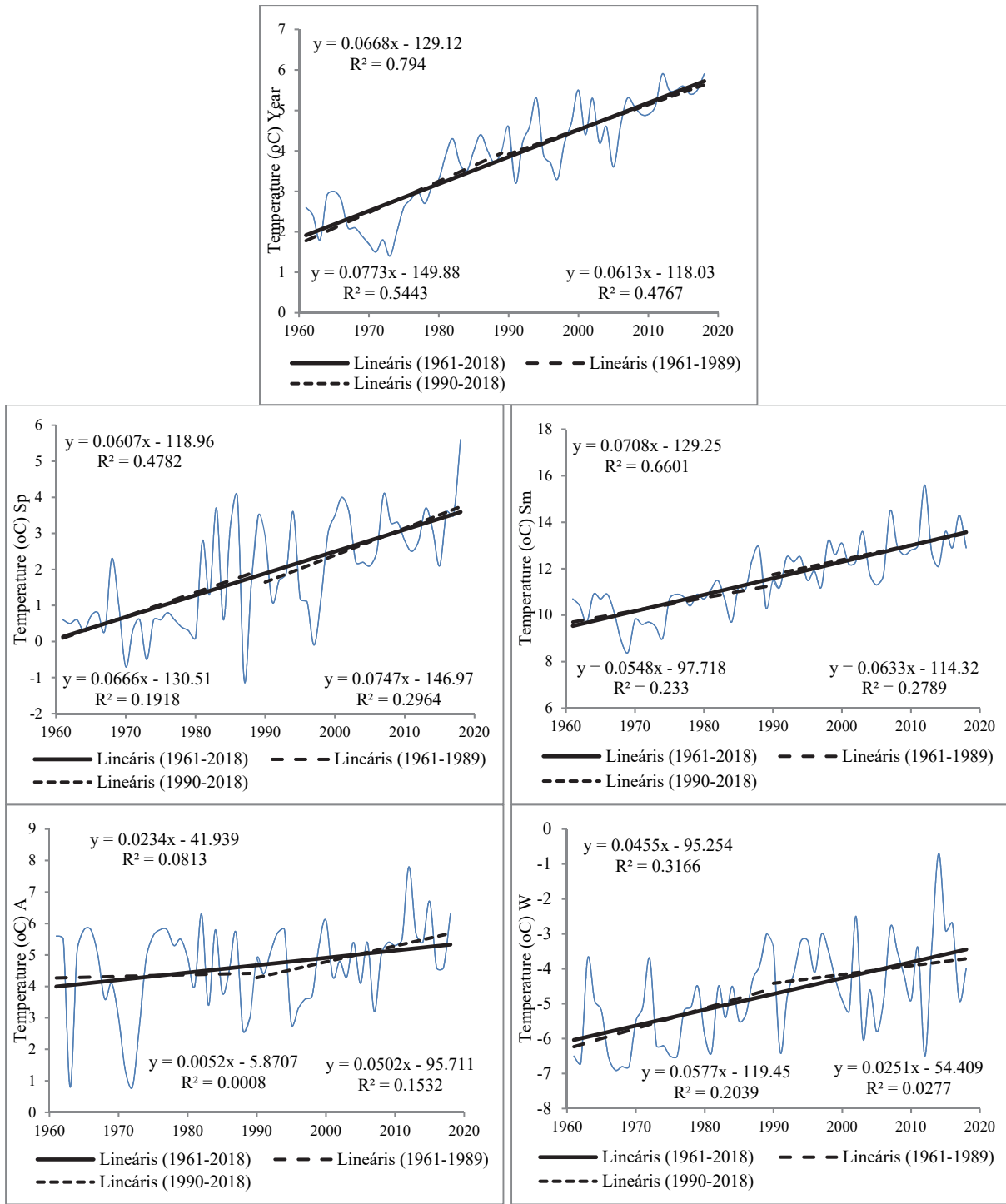


Fig. 9. Average annual and seasonal temperatures, trend equations and trend lines for Kopaonik.

Table 4. Man – Kendall test's statistics for Kruševac

Period		Min.	Max.	Mean	St.dev.	Z – value of trend	B	Sen's slope	α – level of significance
1961–2018	T _{av}	10.0	12.9	11.31	0.769	4.86	10.53	0.030	***
	W	-2.3	4.1	1.140	1.359	3.01	0.37	0.032	**
	S _p	8.8	14.0	11.66	1.174	3.08	10.76	0.029	**
	S _m	18.3	24.4	20.88	1.243	5.16	19.68	0.043	***
	A	8.5	14.4	11.56	11.560	1.44	11.31	0.014	-
1961–1989	T _{av}	10.0	11.6	10.8	0.417	-1.13	11.07	-0.14	-
	W	-2.30	2.90	0.74	1.295	1.17	0.34	0.038	-
	S _p	8.80	13.70	11.26	1.161	-0.21	10.94	-0.002	-
	S _m	18.30	22.0	20.04	0.738	-1.53	20.32	-0.024	-
	A	8.50	13.10	11.20	1.302	-2.80	12.53	-0.091	**
1990–2018	T _{av}	10.20	12.90	11.814	0.712	2.94	11.12	0.053	**
	W	-1.40	4.10	1.54	1.323	1.88	0.91	0.056	+
	S _p	9.70	14.0	12.07	1.055	2.44	11.12	0.065	*
	S _m	20.10	24.40	21.72	1.067	2.61	20.89	0.053	**
	A	10.0	14.40	11.92	0.948	2.09	11.54	0.037	*

*** - $\alpha=0.001$; ** - $\alpha=0.01$; * - $\alpha=0.05$; + - $\alpha=0.1$

Table 5. Man – Kendall test's statistics for Blace

Period		Min.	Max.	Mean	St.dev.	Z – value of trend	B	Sen's slope	α – level of significance
1961–2018	T _{av}	8.8	11.6	10.23	0.701	4.13	9.62	0.023	***
	W	-2.5	3.6	0.41	1.316	1.93	-0.08	0.023	+
	S _p	7.6	12.9	10.41	1.195	1.09	10.39	0.012	-
	S _m	16.6	22.8	19.55	1.083	3.30	18.90	0.025	***
	A	8.0	12.2	10.63	1.019	0.28	10.68	0.002	-
1961–1989	T _{av}	8.8	10.6	9.84	0.438	-1.57	10.03	-0.178	-
	W	-2.5	2.0	0.16	1.219	0.98	-0.20	0.030	-
	S _p	7.6	11.9	10.27	1.184	-0.94	10.85	-0.030	-
	S _m	16.6	21.0	19.01	0.939	-3.10	19.69	-0.055	**
	A	8.0	12.2	10.47	1.146	-3.16	11.49	-0.080	**
1990–2018	T _{av}	9.1	11.6	10.61	0.712	3.36	10.05	0.05	***
	W	-2.	3.6	0.66	1.381	1.31	0.31	0.043	-
	S _p	8.2	12.9	10.54	1.211	2.16	9.50	0.066	*
	S _m	18.4	22.8	20.07	0.952	3.08	19.27	0.052	**
	A	9.0	12.1	10.79	0.865	1.18	10.62	0.237	-

*** - $\alpha=0.001$; ** - $\alpha=0.01$; * - $\alpha=0.05$; + - $\alpha=0.1$

Table 6. Man – Kendall test's statistics for Goč

Period		Min.	Max.	Mean	St.dev.	Z – value of trend	B	Sen's slope	α – level of significance
1961–2018	T _{av}	6.2	9.13	7.66	0.807	5.33	6.7	0.033	***
	W	-4.4	2.8	-0.99	1.468	3.65	-2.27	0.043	***
	S _p	4.0	9.2	7.07	1.240	3.24	6.15	0.032	**
	S _m	13.50	20.40	16.11	1.186	5.68	14.83	0.043	***
	A	6.10	11.50	8.67	1.179	1.86	8.16	0.020	+
1961–1989	T _{av}	6.20	7.90	7.18	0.453	0.09	7.20	0	-
	W	-4.40	0.50	-1.63	1.216	1.78	-2.43	0.051	+
	S _p	4.0	8.90	6.66	1.245	-0.11	6.50	0	-
	S _m	13.50	17.30	15.38	0.797	-0.77	15.51	-0.008	-
	A	6.10	10.50	8.32	1.258	-2.14	8.98	-0.059	*
1990–2018	T _{av}	6.80	9.13	8.13	0.806	4.70	6.83	0.083	***
	W	-3.90	2.80	-0.36	1.435	0	0.10	0	-
	S _p	5.0	9.20	7.49	1.105	3.16	6.14	0.085	**
	S _m	15.30	20.40	16.84	1.059	3.99	15.82	0.064	***
	A	6.70	11.50	9.03	0.992	2.24	8.33	0.048	*

*** - $\alpha=0.001$; ** - $\alpha=0.01$; * - $\alpha=0.05$; + - $\alpha=0.1$

Table 7. Man – Kendall test's statistics for Kopaonik

Period		Min.	Max.	Mean	St.dev.	Z – value of trend	B	Sen's slope	α – level of significance
1961–2018	T _{av}	1.4	5.9	3.82	1.266	7.89	1.90	0.067	***
	W	-6.9	-0.7	-4.74	1.365	4.53	-6.05	0.048	***
	S _p	-1.1	5.6	1.86	1.483	5.30	0.05	0.058	***
	S _m	8.4	15.6	11.50	1.471	7.04	9.57	0.067	***
	A	8.5	14.4	11.56	11.560	1.44	11.31	0.014	-
1961–1989	T _{av}	1.4	4.4	2.86	0.893	3.95	1.63	0.083	***
	W	-6.9	-3.0	-5.42	1.089	2.60	-6.50	0.063	**
	S _p	-1.1	4.0	1.03	1.295	1.76	0.21	0.039	+
	S _m	8.4	12.9	10.47	0.966	2.45	9.85	0.05	*
	A	0.8	6.3	4.34	1.585	-0.38	5.02	-0.006	-
1990–2018	T _{av}	3.2	5.9	4.78	0.756	4.07	3.70	0.067	***
	W	-6.5	-0.7	-4.06	1.286	0.58	-4.19	0.016	-
	S _p	-0.1	5.6	2.69	1.168	2.67	1.48	0.075	**
	S _m	11.2	15.6	12.63	1.021	2.80	11.64	0.055	**
	A	2.8	7.8	4.98	1.093	2.09	4.35	0.05	*

*** - $\alpha=0.001$; ** - $\alpha=0.01$; * - $\alpha=0.05$; + - $\alpha=0.1$

The trend pattern indicated a significant increase in the average annual, winter, and summer temperatures in the whole series from 1961 to 2018 at all the stations. Statistical significant increase is also detected in spring in Kruševac, Goč and Kopaonik. The annual temperature for the Rasina River basin exhibits an increasing trend of annual temperature from 0.2°C / decade in Kruševac, 0.3 °C/decade in Blace and Goč and 0.7 °C/decade in Kopaonik. The spring mean temperature increased from 0.3 °C/decade in Kruševac and Goč, to 0.6 °C/decade in Kopaonik. The summer temperature increased from 0.4 °C/decade in Kruševac and Goč, 0.3 °C/decade in Blace, and 0.7 °C/decade in Kopaonik. In the analyzed period, a significant increase in winter temperature from 0.3 °C/decade in Kruševac, 0.2 °C/decade in Blace, 0.4 °C/decade in Goč, and 0.5 °C/decade in Kopaonik was observed. The autumn temperature showed statistically significant increase of 0.2 °C/decade only in Goč.

Higher temperatures occurred at the beginning and the end of the period, while lower temperatures occurred in the middle of the period from the 1970s until the mid-1980s. Our results are in accordance with the results of *Unkašević* and *Tošić* (2009) and *Gavrilov et al.*, (2015, 2016). Analyzing the temperature data from 1949 to 2007 and from 1949–2013, they found that the slow decrease in the summer temperatures until 1975 was followed by temperature increase that lasted until the end of the analyzed periods (Serbia).

Similar results in temperature changes were observed in the neighboring areas. According to a report of the *Slovenian Environment Agency* (2011), in the period 1961–2011, the most significant change of climate in Slovenia is the increase of the mean air temperature by about 0.36 °C per decade. The most evident warming is observed in spring and summer, which is about 0.4 or 0.5 °C per decade in most of Slovenia. Conversely, the autumn temperature change is not statistically significant.

Chenkova and *Nikolova* (2015) found that the trend of the seasonal air temperature for the period 1984-2010 in Bulgaria is positive. A statistically significant positive trend was observed during the summer season with the values of 0.7 °C to 0.8 °C/decade. *Croitoru et al.* (2011) found that increasing average trend slopes for four summit stations in the Romanian Carpathians amount to 0.683 °C / decade.

6. Conclusion

The variability of temperature, due to the change in the climate or due to human involvement can influence different human activities: agriculture, planning and managing water resources, tourism, and ecosystems. In the present study, change point detections followed by trend analyses have been carried out using different non-parametric statistical tests.

On the basis of the statistical tests used, it can be concluded that there is a change point marking occurrence of an increase in the average annual and seasonal air temperatures in the Rasina River basin. Depending on the test used, different values regarding the year of temperature break have been obtained. The results of the Pettitt and Buishard range tests show, that the change points in the annual temperature data in the period 1961–2018 were identified in 1997 and 1998 at all the stations, except Kopaonik, where the change in the annual temperature occurred in 1980 and 1984. The SNH test identifies 2006 as the year of changing point in Blace. *Piticar and Ristoiu (2012)* obtained similar results for the temperatures in Romania, where 1988, 1995, and 1998 were detected as break-point years. The obtained results are also compliant with numerous other researches carried out in Europe.

Except for the average annual temperatures, an increasing trend was observed in the average winter, spring, and summer temperatures. The Pettitt's and Buishard tests indicate increase of average winter temperatures in Kruševac and Blace from 1993, while in Goč and Kopaonik, the increase started in 1987 and 1986. For spring temperatures, the change point may have occurred in 1998 in Kruševac and Blace, while it occurred in 1980 in Goč and Kopaonik. At the Kopaonik station, the change in the average summer temperature occurred in 1986, while at all other stations, the years of change were 1991 and 2006.

In the first half of the period 1961–1989 all the tests indicate a significant change point in the average autumn temperature in Kruševac, in the average autumn and summer temperatures in Blace and Goč, and in the average annual, winter, summer and spring temperatures in Kopaonik. All tests in Blace indicate that the decrease in the average summer temperature occurred in 1972, while in Kopaonik, an increase of the summer temperature was observed from 1974.

In the second half of the period (1990–2018) all the tests in all the stations detect 2006 as a changing point in average annual and summer temperatures and 1998 and 2005 as changing points in annual spring temperature.

The whole data trend on annual basis showed a positive increasing trend. The analysis indicated that the average annual, winter and summer temperature, have significant increasing trends due to positive values of both Z and Sen's statistics in the longer period (1961–2018) and in the second part of the period 1990–2018. In the first part of the period 1961–1989, the autumn temperatures in Kruševac, summer and autumn in Blace, as well as winter and autumn temperatures in Goč showed a significant decreasing trend due to the negative value of Z and Sen's statistics. All the other seasons have a non-significant decreasing trend. The exception is the Kopaonik station, where the average annual spring and summer temperatures show a positive increasing trend, while winter temperatures shows a significant decreasing trend.

The effects of climate change may exacerbate the existing social and economic states across the country, mainly where people are reliant on resources

sensitive to climate variability. Improved capacity to cope with future climate variability extremes can lessen the extent of economic and social losses.

The results of this research can be helpful for further analysis of temperature changes and other climatic elements, primarily from the aspect of their impact on natural resources and human activities.

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