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The analysis of annual and seasonal surface air temperature trends of southern and southeastern Bosnia and Herzegovina from 1961 to 2017

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Abstract— In some areas of the world, regional climate change is in good agreement with global climate change. This study brings new information about what defines climate change in the contact area of Adriatic Sea and Southeastern Europe, and conclusions are based on trend analysis of annual and seasonal temperatures in the southern and southeastern parts of Bosnia and Herzegovina. Trend analysis was applied on mean annual surface air temperatures, mean maximum temperatures, and mean minimum temperatures of all four seasons. This study used 4 meteorological stations: Livno, Bileća, Mostar, and Ivan Sedlo for 56 years. The main statistical method is the Mann-Kendall test. The total number of analysis is 48. A statistically significant positive trend was determined in 36 analysis, while in the rest of the tests this was not the case. The highest amount of temperature increase is present in the mean maximum summer air temperatures in Livno and Ivan Sedlo. Mean minimum autumn air temperatures had the smallest increase. Negative trend is present in the mean autumn surface air temperatures and mean maximum autumn temperatures. Using a geographical information system resulted in visualizing regional differences in the spatial distribution of isotherms. The study area has combined the influence of orography and maritime effects of the Adriatic Sea. Having in mind these results, the growing temperature has been recognized as a problem which needs more attention in Bosnia and Herzegovina. Unfortunately, official documents which propose economic adaptation on climate change in this country are not at a satisfactory level.

Key-words: climate change, temperature trends, Mann-Kendall test, GIS, Bosnia and Herzegovina

1. Introduction

Numerous papers have been published about climate variations, and their impact on the environment. It has been proven that the increase of global air temperature from 1906 to 2005 is 0.74 °C now. The study from *Trenberth et al.* (2007) shows how the growing air temperature on the Earth has been doubled up in the last fifty years, rising 0.13 °C per decade. Regional changes in temperature can be even greater than those on global level, from 0.65 °C to 1.06 °C (*Blunden* and *Arndt*, 2015). The Intergovernmental Panel for Climate Change proved existence of the warmest ever thirty year cycle on the Northern Hemisphere during the last 800 years (1983–2012). In Europe, a mean annual air temperature of this decade has been warmer than the last one (2008–2017) by 1.6–1.7 °C . This makes it the warmest decade ever recorded (*EEA*, 2018). In the Norhern Hemisphere, summer and autumn months were warmer during the last decades of 20th century than in the first half of the same century. The decade with the warmest spring and autumn months was 80s in the last century (*Jones* and *Briffa*, 1991). *Trenberth et al*. (2007) confirm this statement and add that the average global surface air temperature is now higher by 0.27 °C in comparison with the year 1979. The most intensified warming has been recorder during the winter and spring months in the Northern Hemisphere. *Luterbacher et al.* (2004) reconstructed monthly and seasonal temepratures in Europe during the last 1500 years. The reconstruction shows that the climate over the last decades of the 20th century and the beginning of the 21st century is most probably warmer than the climate in the last 500 years ($p<0.05$). The Medditerranean region is very vurnerable to climate change. Some studies show how temperature increases more in summer than in winter (*Alcamo et al.*, 2007). By doing analysis of data from 49 meteorological stations in Italy from 1961 to 2006, there are great differences between the seasons: a) during the winter months there is no trend, except for North Italy, where the temperature increase was present in the 60s.; b) during the summer months there was a negative trend until 1981, when the trend changed into positive; c) autumn months have temperature increasmnent which started in the 70s (*Toreti et al.,* 2010). *Espírito Santo et al.* (2014) analyzed 23 meteorological stations in Portugal. The study focused on extreme values of air temperature. The results show increasing mean air temeperature during the spring and summer months, from 1941 to 2006. *Bilbao et al.* (2019) confirm this, and conclude that the autumn months have the lowest increase in temperature in Spain from 1950 to 2011. Over the past few decades, trends of aridity and the posibility for extreme climate events are present (*Mishra* and *Singh*, 2010; *Trenberth et al.*, 2015). Future predictions of climate in Medditerranean region are characterized by higher annual and seasonal surface air temepratures, where the summer months will be particulary affected (*Giorgi* and *Lionello*, 2008; *Spinoni et al.*, 2017).

In Southeastern Europe, there are a lot of papers which deal with analysis of mean temperatures on annual and seasonal levels, as well as aridity change as one the best indicators for climate change (*Jovanović et al.*, 2002; *Ducić* and *Radovanović*, 2005; *Milošević et al.*, 2013; *Unkašević* and *Tošić*, 2013; *Bajat et al.*, 2015; *Gavrilov et al*., 2015, 2016, 2018; *Tošić et al.*, 2016; *Trbić et al.*, 2017; *Bačević et al.*, 2017, 2018, 2020; *Milošević et al*., 2017; *Radaković et al.*, 2017; *Vukoičić et al.,* 2018, *Milentijević et al.*, 2018, 2022).

In this paper, southern and southeastern Bosnia and Herzegovina (B&H) are being investigated in terms of annual and seasonal trends of surface air temperatures. Similar studies have been published (*Trbić et al.*, 2017; *Popov et al.*, 2017, 2018a, 2018b, 2019a, 2019b; *Papić et al*., 2020), but the aim of this study is to show the seasonal trends in temperature, because there is lack of such information in this country. This study can help in creating a more comprehensive picture of climate change in the Medditerranean.

2. Study area

Southern and southeastern Bosnia and Herzegovina are placed in the historical region called Herzegovina, which is bordered with Croatia and Montenegro on southwest and south, while at the north it is surrounded by municipalities of Livno, Tomislavgrad, Prozor, Konjic, Kalinovik, Foča, and Čajniče (*Fig. 1*). The study area is located between the 44°23’ and 42°55’N, and 16°52’ and 19°25’E. Meteorological stations, their geographic coordinates, and elevation are marked in *Fig. 1* and *Table 1*.

Table 1. Meteorological stations and their geographical coordinates and elevations in southern and southeastern Bosnia and Herzegovina.

Station No.	Station location	Altitude	Latitude	Longitude
1	Livno	739 m	43° 49′ 22″ N	17° 00′ 04″ E
2	Bileca	480 m	42° 52′ 04″ N	18° 25′ 29″ E
3	Mostar	48 m	43° 20′ 53″ N	17° 47′ 38″ E
4	Ivan Sedlo	955 m	43° 45′ 04″ N	18° 02′ 10″ E

Fig. 1. The location of southern and southeastern Bosnia and Herzegovina with used meteorological stations.

3. Material and methods

3.1. Material

The analyzed period in this study is from 1961 to 2017. The raw data is measured by the Federal Hydrometeorological Institute of Bosnia and Herzegovina (https://www.fhmzbih.gov.ba/) and Republic Hydrometeorological Service of Republika Srpska (https://rhmzrs.com/?script=lat). Because of the civil war during 1991–1995, the Service was not working, and thus, data for these years do not excist. The only exception is the meteorological station in the city of Mostar, which has continuous data. The method of interpolation was used to fill the missing data (*Kasam et al.*, 2014; *Kilibarda et al*., 2015). Different elevations of meteorological stations cause different climate types. For example, the relative elevation between the highest (Ivan Sedlo 955 m.a.s.l.) and the lowest meteorological stations (Mostar 48 m.a.s.l.) is 907 m. Obvious differences in elevation cause the presence of vertical thermic gradient. That means that the temperature decreases on every 100 m by 0.65 °C (*Oliver*, 2005). The specific relief conditions combined with the influence of Adriatic Sea make need for analysis of climatological data for each station separately.

The average annual surface air temperatures (YT), mean maximal surface air temperatures (YT_x), and mean minimal surface air temperatures (YT_n) were analysed in this study. These three parameters were used for calculation of seasonal values: winter, spring, summer and autumn (*W*, *Sp*, *Su* and *A*). A total of 48 time series were analyzed. Each of these series is marked with different acronyms, which indicate meteorological station, season, and temperature type. They can be found in *Table 2*.

Table 2. The list of 48 time series with unique acronyms obtained in this study, separated by used meteorological stations.

Station	Time series	Station	Time series
Livno (L)	*L-W-YT*	**Mostar (M)**	*M-W-YT*
	L-W-Ytx		*M-W-Ytx*
	L-W-Ytn		*M-W-Ytn*
	L-Sp-YT		*M-Sp-YT*
	L-Sp-Ytx		*M-Sp-Ytx*
	L-Sp-Ytn		*M-Sp-Ytn*
	L-Su-YT		*M-Su-YT*
	L-Su-Ytx		*M-Su-Ytx*
	L-Su-Ytn		*M-Su-Ytn*
	L-A-YT		*M-A-YT*
	L-A-Ytx		*M-A-Ytx*
	L-A-Ytn		*M-A-Ytn*
Bileća (B)	*B-W-YT*	**Ivan Sedlo (IS)**	*IS-W-YT*
	B-W-Ytx		*IS-W-Ytx*
	B-W-Ytn		*IS-W-Ytn*
	B-Sp-YT		*IS-Sp-YT*
	B-Sp-Ytx		*IS-Sp-Ytx*
	B-Sp-Ytn		*IS-Sp-Ytn*
	B-Su-YT		*IS-Su-YT*
	B-Su-Ytx		*IS-Su-Ytx*
	B-Su-Ytn		*IS-Su-Ytn*
	B-A-YT		*IS-A-YT*
	B-A-Ytx		*IS-A-Ytx*
	B-A-YT		*IS-A-Ytn*

3.2. Methods

Three statistical approaches were used. The first one is a linear trend for each time series (*Draper* and *Smith,* 1966), the second one includes the Mann-Kendall test (*Mann,* 1945*; Kendall*, 1938; *Gilbert,* 1987), and the last is called the magnitude of trend (*Gavrilov et al.,* 2016). For data analysis, the software Microsoft Office Excel 2007 (12.0.6611.1000 SP3 MSO 12.0.6607.1000) and its extension XLSTAT (https://www.xlstat.com/en) were used.

3.2.1. Linear trend equation

The method of linear trend is commonly used for analysis, evaluation, and distribution of temperature changes in time (*Heim*, 2015; *Ghebrezgabher et al*., 2016). The trend line is the unique line that minimizes the sum of squared deviations from the data, measured in the vertical direction. It is expressed by the equation:

$$y = ax + b, \tag{1}$$

where*y* presents the temperature in °C, *a* is the slope, or in other words the increase per period, *x* represents year, while *b* is the value where the trend line intersects the ordinate in the beginning of the period. The trend will follow the value of the slope, where there are three possible options: a) the slope is higher than zero- the trend is positive; b) the slope is equal to zero- there is no trend; c) the slope is lower than zero- the trend is negative.

3.2.2. The magnitude of a trend

The linear trend equasion can be used for calculation of the magnitude of a trend (*Gavrilov et al.*, 2015, 2016). In this case it can be expressed as:

$$\Delta y = y(1961) - y(2017), \tag{2}$$

where Δy presents the magnitude of a trend in °C, *y*(1961) is the temperature from the beginning of the period, and *y*(2017) is the temperature of the last year in the used period. There are three cases for the trend: a) when Δy is greater then zero - the trend is negative; b) when Δy is lower than zero - the trend is positive; c) when Δy is zero - there is no trend magnitude.

3.2.3. Mann-Kendall trend tests

This is a famous nonparametric method for the validation of trend in geosciences (*Mohorji et al*. 2017), because of its robustness, as well as fast and simple use (*Mann,* 1945; *Kendall*, 1938; *Gilbert*, 1987). The purpose of this test is to show which of the two possible hypotheses are true: the null hypothesis (H_o) – there is no trend in the time series; and the alternative hypothesis (H_a) – there is a statistically significant trend for the chosen α value. The main role in this test has a p value, or probability value (*Karmeshu,* 2012; *Razavi et al.*, 2016), which confirms the confidence of the hypothesis. If the p value is below than or equal to the alpha ($p< 0.05$), then the null hypothesis must be rejected, and the result is statistically significant. Contrary to this, if the p value is greater than alpha, the H_o is accepted (*Mudelsee*, 2014).

3.2.4. GIS numerical analysis

GIS (Geographical Information System) of data presents a very powerful tool for calculating and estimating the climate data. This meteorological data may be used in calculating the climate properties in the area. With the help of two open-source GIS softwares, QGIS 3.4.12 and SAGA, we calculated and elaborated climate data in the study area. Climate characteristics of a two-dimensional profile were analyzed in this paper (*Valjarević et al.*, 2018a). There are plenty of scientists which had used some advanced GIS algorithms and methods (*Valjarević et al.*, 2018b; *Zabel et al.*, 2014). The special algorithms used in this research are semi-kriging, spatial interpolation, interpolation, and grid analysis. Analyzed meteorological data were transformed with the usage of GIS tools and presented via maps. These maps present annual and seasonal climate properties and interpolated data.

4. Results

4.1. Trend parameters

Four meteorological stations (Livno, Bileća, Mostar, and Ivan Sedlo) have the four season time series for average annual surface air temperatures (*YT*), mean maximal surface air temperatures (YTx), and mean minimal surface air temperatures (YTn) which makes a total of 48 different time series. *Fig. 2* presents these parameters with their trend equations in the analysed area from 1961 to 2017. The trend magnitude (Δyt) and the probability (p), for each time series and each meteorological station, are presented in *Tables 3* and *4*.

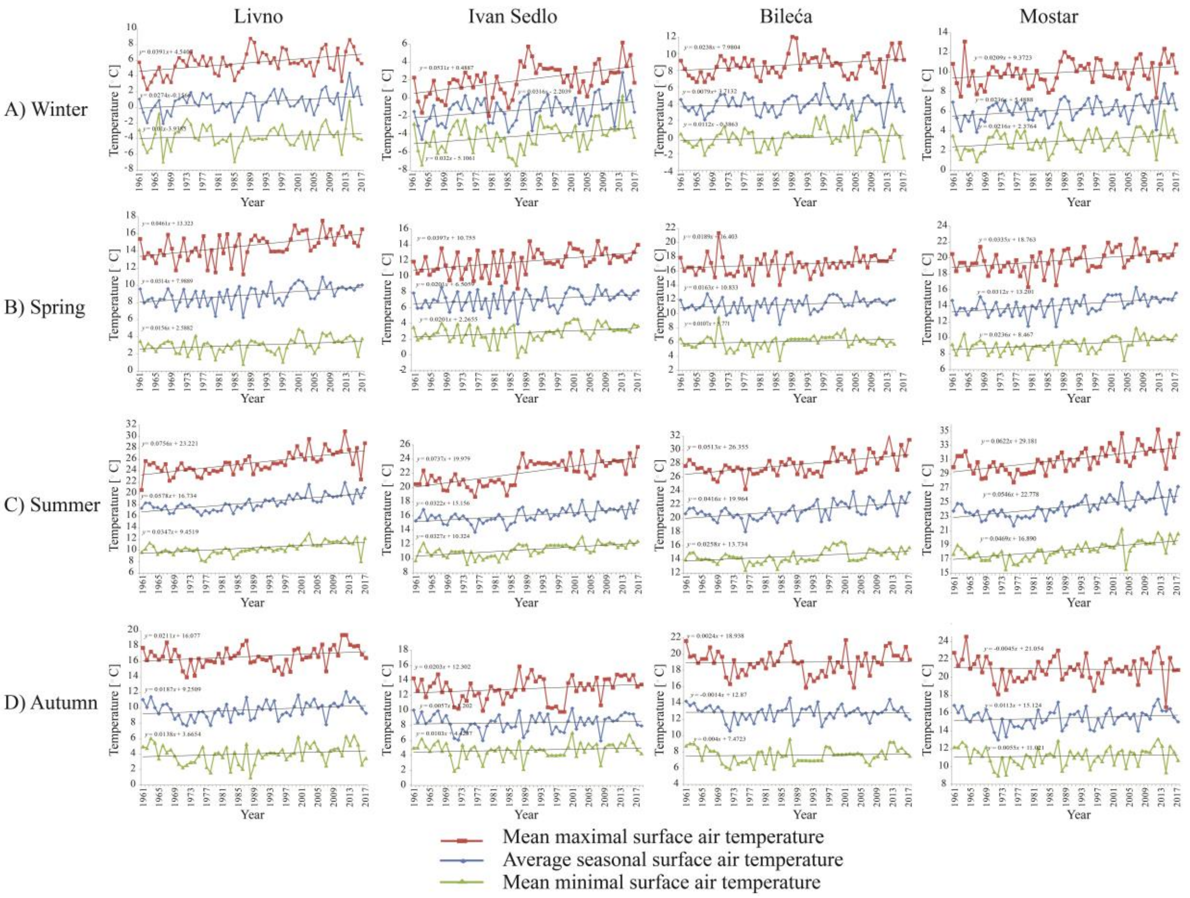

Fig. 2. A) Winter, B) spring, C) summer, and D) autumn; mean maximal surface air temperatures, average seasonal surface air temperatures, and mean minimal surface air temperatures, with linear trend equations from 1961 to 2017, for the four used meteorological stations.

Table 3. Trend equation y, trend magnitude *Δy*, and probability *p* of the confidences for 48 time series.

Time series	**Trend equation**	***Δy*(°C)**	***p*(%)**
L-W-YT	$y = 0.02x - 0.15$	1.5	0.009
L-W-YTx	$y = 0.03x + 4.54$	2.2	< 0.001
L-W-YTn	$y = 0.01x - 3.93$	0.6	0.380
B-W-YT	$y = 0.01x + 3.71$	0.4	0.815
B-W-YTx	$y = 0.02x + 7.98$	1.3	0.581
B-W-YTn	$y = 0.01x - 0.38$	0.6	0.336
M-W-YT	$y = 0.02x + 5.48$	1.3	0.002
M-W-YTx	$y = 0.02x + 9.37$	1.2	0.015
M-W-YTn	$y = 0.02x + 2.37$	1.2	0.013
IS-W-YT	$y = 0.03x - 2.20$	1.8	0.011

Table 3. Continued

Time series	Trend equation	Δy(°C)	p(%)
IS-W-YTx	$y = 0.05x + 0.48$	3.0	0.001
IS-W-YTn	$y = 0.03x - 5.10$	1.8	0.008
L-Sp-YT	$y = 0.03x + 7.98$	1.8	< 0.001
L-Sp-YTx	$y = 0.04x + 13.32$	2.6	< 0.001
L-Sp-YTn	$y = 0.01x + 2.58$	0.9	0.009
B-Sp-YT	$y = 0.01x + 10.83$	0.9	0.017
B-Sp-YTx	$y = 0.01x + 16.40$	1.1	0.007
B-Sp-YTn	$y = 0.01x + 5.77$	0.6	0.027
M-Sp-YT	$y = 0.03x + 13.20$	1.7	< 0.001
M-Sp-YTx	$y = 0.03x + 18.76$	1.9	0.001
M-Sp-YTn	$y = 0.02x + 8.46$	1.3	0.001
IS-Sp-YT	$y = 0.02x + 6.50$	1.1	0.0156
IS-Sp-YTx	$y = 0.03x + 10.75$	2.2	0.001
IS-Sp-YTn	$y = 0.02x + 2.26$	1.1	0.004
L-Su-YT	$y = 0.05x + 16.73$	3.2	< 0.001
L-Su-YTx	$y = 0.07x + 23.22$	4.2	< 0.001
L-Su-YTn	$y = 0.03x + 9.45$	1.9	< 0.001
B-Su-YT	$y = 0.04x + 19.96$	2.3	< 0.001
B-Su-YTx	$y = 0.05x + 26.35$	2.9	0.001
B-Su-YTn	$y = 0.02x + 13.73$	1.4	0.001
M-Su-YT	$y = 0.05x + 22.77$	3.0	< 0.001
M-Su-YTx	$y = 0.06x + 29.18$	3.5	< 0.001
M-Su-YTn	$y = 0.04x + 16.89$	2.6	< 0.001
IS-Su-YT	$y = 0.03x + 15.15$	1.8	< 0.001
IS-Su-YTx	$y = 0.07x + 19.97$	4.1	< 0.001
IS-Su-YTn	$y = 0.03x + 10.32$	1.8	< 0.001
L-A-YT	$y = 0.01x + 9.25$	1.0	0.008
L-A-YTx	$y = 0.02x + 16.07$	1.2	0.014
L-A-YTn	$y = 0.01x + 3.66$	0.8	0.135
B-A-YT	$y = -0.01x + 12.87$	-0.1	0.815
B-A-YTx	$y = 0.01x + 18.93$	0.1	0.581
B-A-YTn	$y = 0.01x + 7.47$	0.2	0.336
M-A-YT	$y = 0.02x + 15.12$	0.6	0.092
M-A-YTx	$y = -0.01x + 21.05$	-0.3	0.591
M-A-YTn	$y = 0.01x + 11.02$	0.3	0.292
IS-A-YT	$y = 0.01x + 8.20$	0.3	0.243
IS-A-YTx	$y = 0.02x + 12.30$	1.1	0.030
IS-A-YTn	$y = 0.01x + 4.42$	0.6	0.292

Table 4. The main results of the analysis of temperature trends for 48 time series.

Time series	Trend equation	The classical MK test
L-W-YT	positive trend	significant positive trend
L-W-YTx	positive trend	significant positive trend
L-W-YTn	positive trend	no trend
B-W-YT	positive trend	no trend
B-W-YTx	positive trend	significant positive trend
B-W-YTn	positive trend	no trend
M-W-YT	positive trend	significant positive trend
M-W-YTx	positive trend	significant positive trend
M-W-YTn	positive trend	significant positive trend
IS-W-YT	positive trend	significant positive trend
IS-W-YTx	positive trend	significant positive trend
IS-W-YTn	positive trend	significant positive trend
L-Sp-YT	positive trend	significant positive trend
L-Sp-YTx	positive trend	significant positive trend
L-Sp-YTn	positive trend	significant positive trend
B-Sp-YT	positive trend	significant positive trend
B-Sp-YTx	positive trend	significant positive trend
B-Sp-YTn	positive trend	significant positive trend
M-Sp-YT	positive trend	significant positive trend
M-Sp-YTx	positive trend	significant positive trend
M-Sp-YTn	positive trend	significant positive trend
IS-Sp-YT	positive trend	significant positive trend
IS-Sp-YTx	positive trend	significant positive trend
IS-Sp-YTn	positive trend	significant positive trend
L-Su-YT	positive trend	significant positive trend
L-Su-YTx	positive trend	significant positive trend
L-Su-YTn	positive trend	significant positive trend
B-Su-YT	positive trend	significant positive trend
B-Su-YTx	positive trend	significant positive trend
B-Su-YTn	positive trend	significant positive trend
M-Su-YT	positive trend	significant positive trend
M-Su-YTx	positive trend	significant positive trend
M-Su-YTn	positive trend	significant positive trend
IS-Su-YT	positive trend	significant positive trend
IS-Su-YTx	positive trend	significant positive trend
IS-Su-YTn	positive trend	significant positive trend
L-A-YT	positive trend	significant positive trend
L-A-YTx	positive trend	significant positive trend
L-A-YTn	positive trend	no trend
B-A-YT	negative trend	no trend
B-A-YTx	no trend	no trend
B-A-YTn	no trend	no trend
M-A-YT	Positive trend	no trend
M-A-YTx	negative trend	no trend
M-A-YTn	no trend	no trend
IS-A-YT	positive trend	no trend
IS-A-YTx	positive trend	significant positive trend
IS-A-YTn	positive trend	no trend

4.2. The Mann-Kendall test

The results of the Mann-Kendall trend test for seasonal temperatures from 1961 to 2017 in the territory of southern and southeastern Bosnia and Herzegovina are presented in *Table 4*. In most of the analyzed cases, the trend is statistically significant and positive. For the final evaluation of the surface air temperature trend, all the numerical parameters and graphical interpretations included in Mann-Kendall tests were considered. The hypothesis H_a was accepted for 36 time series. The Mann-Kendall test proved wrong - eight time series which had a positive linear trend. The similar situation occurred when the linear trend in two cases was negative, but the Mann-Kendall test accepted the H_0 hypothesis.

If the probability p in the time series YT, YTx, and YTn was lower than α, the hypothesis H_0 (there is no trend) was rejected and the hypothesis H_a (there is trend) was accepted.

In the next paragraph, the results will be presented by seasonal criterium. During the spring and summer months, all of the 24 cases had significant positive trend in mean maximal surface air temperatures, mean minimal surface air temperatures, and average summer and average spring surface air temperatures. This brings to conclusion that the rising temperature trend is present for at least half of the year in the entire analyzed territory. In all of the mentioned situations during the spring and summer, the H_a hypothesis is accepted. During the autumn, from the 12 analyzed cases (three for each station), only 25% had a positive significant trend. These are the mean maximal surface air temperatures of Livno and Ivan Sedlo. Livno is the only station, where the average autumn surface air temperature has a significant positive trend proven by the Mann-Kendall test. The other 9 cases had no trend: *L-A-YTn, B-A-YT, B-A-YTx, B-A-YTn, M-A-YT, M-A-YTx, M-A-YTn, IS-A-YT,* and *IS-A-YTn*; where their *p* values were 0.1357, 0.0273, 0.5813, 0.3362, 0.0923, 0.5911, 0.2921, 0.2434, and 0.2921; while the risk to reject the H_0 while it is true was 13.58%, 2.74%, 58.13%, 33.63%, 9.24%, 59.11%, 29.21%, 24.35%, and 29.22%, respectively. The winter period has a different situation from the other seasons. It is shown that only 25% of the cases had no trend detected by the Mann-Kendall test. These include mean minimal winter surface air temperature of Livno and Bileća. Even though they are not on the highest elevation on the study area, their winter conditions are being conserved, especially in Bileća, where even the average winter temperatures were found to have no trend. For the time series *L-W-YTn*, *p* value is 0.3860. The risk to reject the H_0 while it is true, is lower than 38.07%. The p value for meteorological station Bileća in the time series *B-W-YTn* is 0.0740. The risk to reject the H*0* while it is true, is lower than 7.37%. For the time series *B-W-YT*, *p* values is 0.8155. The risk to reject the H_0 while it is true, is lower than 81.55%.

4.3. GIS numerical analysis

Average annual surface air temperatures (YT), mean maximal (YTx) and mean minimal (YTn) surface air temperatures per seasons for the period from 1961 to 2017 are shown in *Figs. 3, 4, 5,* and *6*. Isotherms follow the temperatures and indicate the effect of the Adriatic Sea and higher terrain. Meteorological station Ivan Sedlo is a mountainous station, while meteorological station Livno is situated in the karst polje. This is the reason they have lower temperatures, while meteorological stations Mostar and Bileća are in the lower terrain, and thus have the Adriatic influence.

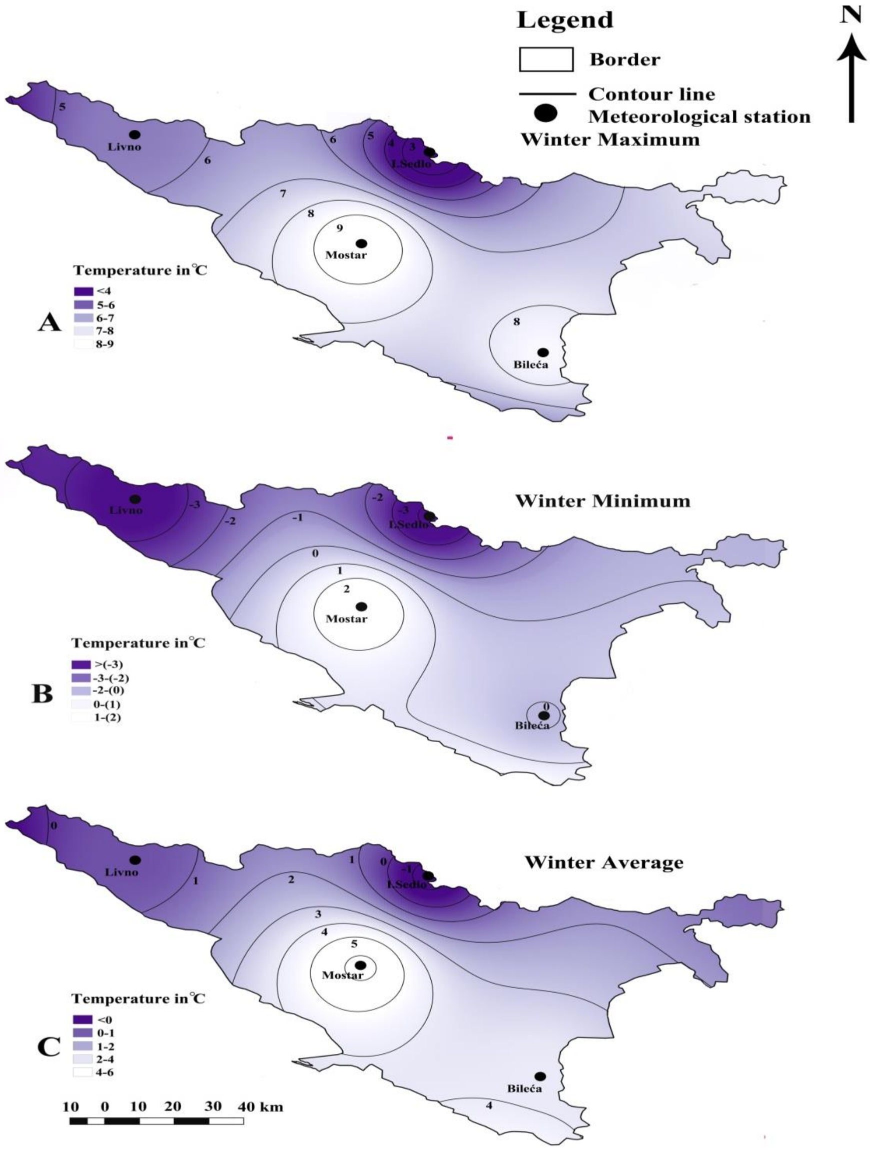

Fig. 3. Average winter, mean maximal, and mean minimal surface air temperatures during the winter from 1961 to 2017 in southern and southeastern Bosnia and Herzegovina.

Fig. 3 shows the analyzed temperatures during the winter. The average annual surface air temperatures go from -1 °C to 5 °C. The mean minimal temperatures go from 0 °C to -3 °C, while the mean maximal temperatures go from 3 °C to 9 °C.

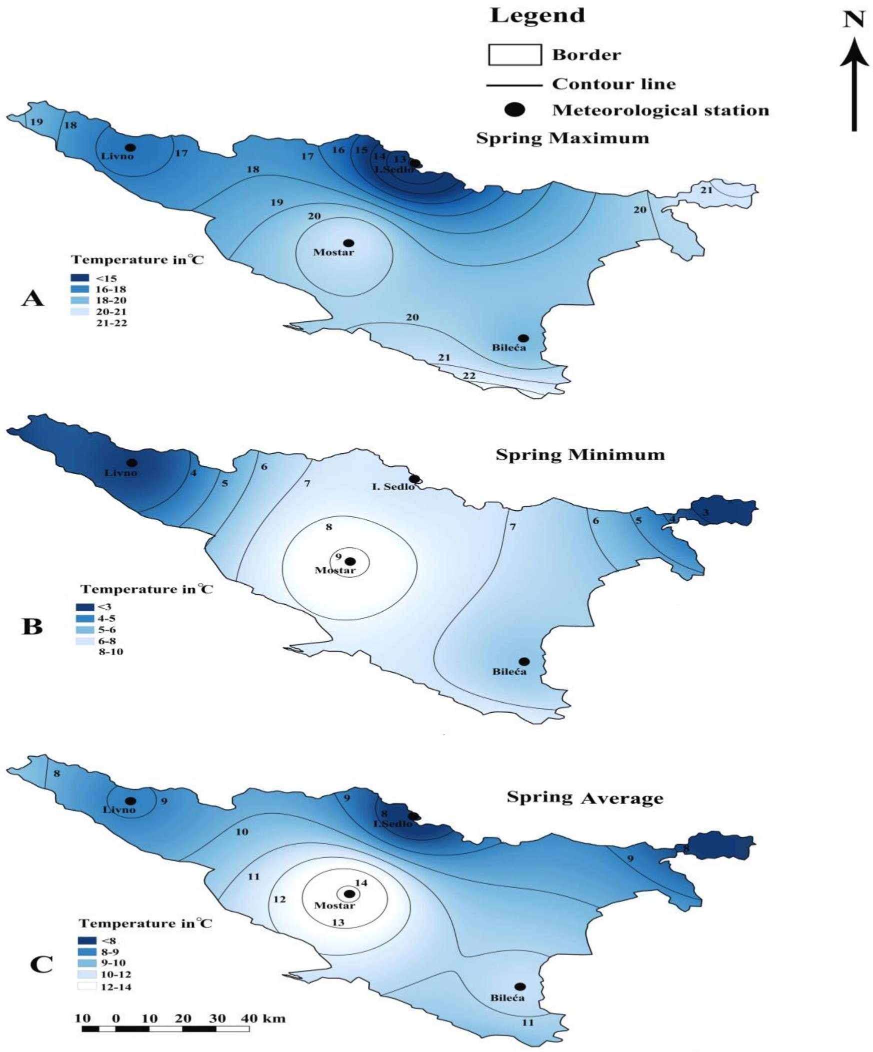

Fig. 4. Average spring, mean maximal, and mean minimal surface air temperatures during the spring from 1961 to 2017 in southern and southeastern Bosnia and Herzegovina.

Fig. 4 shows the analyzed temperatures during the spring. The average annual surface air temperatures go from 8 °C to 14 °C. The mean minimal temperatures go from 3 °C to 9 °C, while the mean maximal temperatures go from 13 °C to 22 °C.

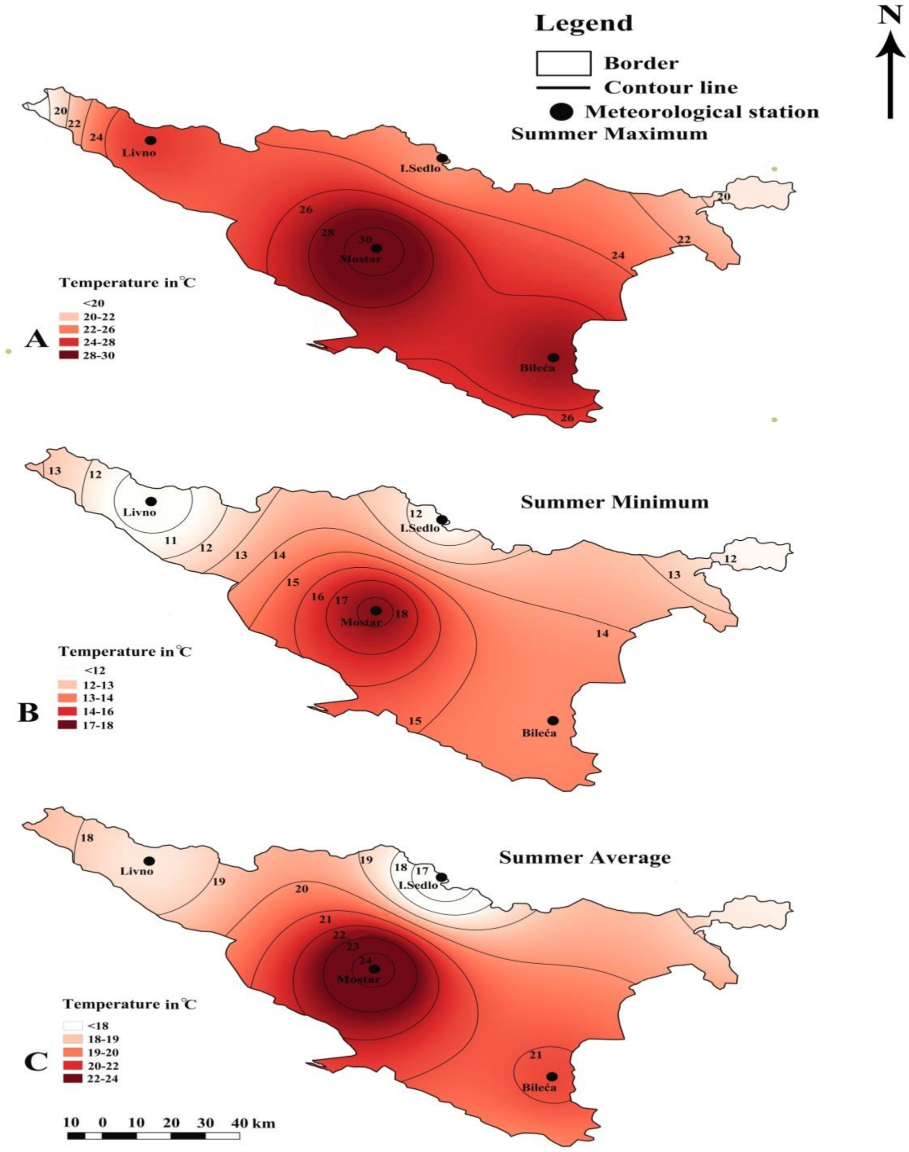

Fig. 5. Average summer, mean maximal, and mean minimal surface air temperatures during the summer from 1961 to 2017 in southern and southeastern Bosnia and Herzegovina.

Fig. 5 shows that the average summer surface air temperatures go from 17 °C to 24 °C. The mean minimal temperatures go from 11 °C to 18 °C, while the mean maximal temperatures go from 20 °C to 30 °C.

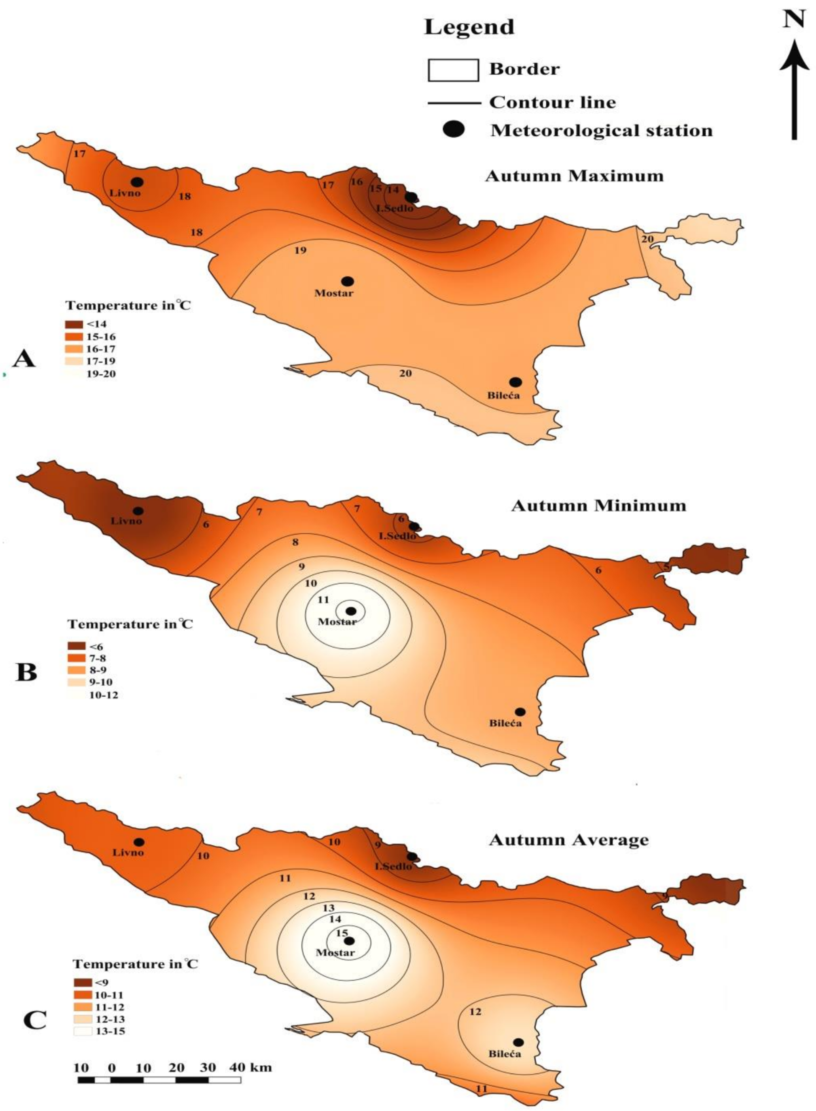

Fig. 6. Average autumn, mean maximal, and mean minimal surface air temperatures during the autumn from 1961 to 2017 in southern and southeastern Bosnia and Herzegovina.

Fig. 6 shows that the average autumn surface air temperatures go from 9 °C to 15 °C. The mean minimal temperatures go form 5 °C to 11 °C, while the mean maximal temperatures go from 14 °C to 20 °C.

5. Discussion

The presented results show that the temperature is increasing in 36 cases, from the 48 cases in total. The summer temperature has the highest growing trend when considering the summer maximal surface air temperatures. This includes the following time series: *L-Su-YTx* (4.2 °C) and *IS-Su-Ytx* (4.1 °C).

The smallest changes are present in the minimal autumn surface air temperatures, for example, *B-A-Ytn* (0.2 °C) and maximal autumn surface air temperature *B-A-Ytx* (0.1 °C) in Bileća. The mean autumn surface air temperatures in Bileća, *B-A-YT* (-0.1 °C), and maximal autumn surface air temperatures in Mostar, *M-A-Ytx* (-0.3 °C) have the decrease of temperature values.

Spring temperatures have the greatest changes when analyzing the maximum surface air temperatures *L-Sp-Ytx* (2.6 °C) and *IS-Sp-Ytx* (1.9 °C). The smallest increase of temperature values during the spring is present in average spring temperatures *B-Sp-YT* (0.9 °C), and in mean minimal surface air temperatures *B-Sp-Ytn* (0.6 °C).

The average increase in temperature is more expressed over the winter in comparison to autumn and spring. The greatest rise in temperature belongs to the winter maximum surface air temperature *IS-W-Ytx* (3.0 ℃) and average winter surface air temperature in Ivan Sedlo *IS-W-YT* (1.8 ℃). The smallest temperature change has occurred in winter minimal surface air temperature *B-W-Ytn* (0.6 ℃), and average winter surface air temperature *B-W-YT* (0.4 ℃) in Bileća.

The results from this study are in good agreement to those in previous studies. Even though this region is experiencing such temperature changes, not all the regions on Earth are equally affected (*IPCC*, 2007, 2014, 2018). *Toreti et al*. (2010) found that seasonal temperatures have a positive trend in Italy, even though there are regional differences. Winter temperature trends do not exist, except for the stations at the north. On the other side, there is a positive spring temperature trend (for 1.1 °C). During the summer, there are even negative trends from 1961 to 1981, but positive trends from 1981 to 2006. This resulted in the increase of the mean summer temperatures over Italy for 1.5 °C. The trend in the mean autumn temperatures starts to show up from 1970, until when the temperature raised by 1. 6 °C in Italy. *Espírito Santo et al.* (2014) analyzed seasonal temperatures change in two periods: from 1945 to 1975, and from 1976 to 2006. In the first period, maximal and minimal surface air temperatures decrease in all of the seasons, except in winter. On the other side, only the temperature trend in spring is statistically significant. In the second period, all of the seasons have the increasing of selected parameters, which is statistically significant during the spring and summer, and also in minimal autumn and maximal winter surface air temperatures. *Bilbao et al.* (2019) found positive temperature trend in mean seasonal, mean maximal, and mean minimal temperatures. Mean maximal temperatures intensify during the summer and spring. Mean minimal temperatures are rising more in winter and spring than in autumn. Similar results in rising the mean surface air temperatures are recorded in Vojvodina, Northern Serbia (*Gavrilov et al.*, 2015, 2016), in Central and Western Serbia (*Vukoičić et al.*, 2018), and Slovenia (*Milošević et al.*, 2013, 2017). Spotted temperature changes in the southern and southeastern parts of Bosnia and Herzegovina show similarity to the global temperature change from the 1980's (*Hardy*, 2006). This study shows that there is a comparable process in temperature during the same seasons in the wider region. There are technical, technological, financial, and educational constraints that must be considered (*Trbić et al.*, 2018). Opportunities for the adaptation of the economic sector to climate change in this country aim to reduce the sensitivity of this sector to the emerging climate trends by a) reducing the negative effects of climate change; b) increasing the resilience of society, and c) seizing the opportunity for development caused by climate change (*Radusin et al*., 2013; *Trbić et al*., 2018; *Popov et al.*, 2019a).

6. Conclusion

In this study, annual and seasonal trends of mean, mean maximal, and mean minimal surface air temperatures over the southern and southeastern parts of Bosnia and Herzegovina were analyzed from 1961 to 2017. Methods can be separated into three parts: a) linear trend equation, b) the magnitude of trend, and c) Mann-Kendall test. There is a statistically significant trend in 36 time series. This increase goes in the interval from 0.1 °C to 4.2 °C. The highest growing trend is discovered in the summer mean maximal surface air temperatures in Livno and Ivan Sedlo stations. There is also a negative trend, which is between -0.1 °C and -0.3 °C, in maximal autumn surface air temperatures in Mostar. Generally, in this study it is found, that the average increase in temperature is more expressed over the winter in comparison to autumn and spring. Our trends fit the wider region and our results confirm the IPCC scenario. These changes have an impact not only on ecosystems but also on the economy. Bosnia and Herzegovina lack the studies about adaptation to the temperature change. The analysis of temperature behavior of the past few decades, like in this study, needs to be the basis of policy, planning, and regional development. The guidelines defined in this way must be fulfilled, having in mind that climate events have the tendency to be more extreme and more frequent in the future.

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