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SUMMER AIR TEMPERATURE VARIABILITY AND TRENDS WITHIN OLTENIA PLAIN

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Abstract: The interannual and decadal variability and trends of summer (June to August) air temperature over the Oltenia Plain area is analysed for the period 1961 to 2010. The datasets cover monthly temperatures from six meteorological stations. Linear regression and the non-parametric Mann-Kendall test are used to discover any trends present in the datasets. As expected, the most significant trends found for temperature mark increases of up to 0.5°C. From the temporal variations, a dramatic increase in temperature is observed particularly in the last two decades. This enhancement of average temperature is strongly consistent with the results of present studies made in Europe, warming being mainly attributed to an increase in anthropogenic greenhouse gases. From the spatial distribution viewpoint, most stations behave quite similarly, indicating that the increasing trends are more likely linked to large-scale rather than local processes. The analysis of temperature during distinct seasons is quite important as different seasonal warming rates may have important consequences for natural vegetation, agriculture, human health, and energy consumption, amongst others.

Key words: air temperature trends, Mann-Kendall test, Oltenia Plain

Introduction

Air temperature is one of the most frequently used parameters in the assessment of climate change. According to IPCC (2007), the second half of the 20th century is clearly the warmest in the past 1,300 years over the northern hemisphere. Thus, all recent studies, pointed out temperature increase at least in the last five decades as compared to the first half of the last century. Over the past century, temperature increase was estimated at about 0.6ºC (Nicholls et al., 1996; Jones et al. 1999). However, warming intensity shows considerable variability, namely, it does not occur linearly in time and space. Data analysis indicated that the Northern Hemisphere generally and, especially the middle and higher latitudes, received greater amounts of heat (Jones et al., 1999; Karl et al., 2000, Klein Tank et al., 2002), thus warming at a higher rate than the rest of the globe. For Europe, one of the main issues experts focused on lately is that of

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seasonal temperature variability and trends. Thus, according to certain studies (Della-Marta et al., 2007; Parey et al., 2010; Yiou et al., 2009), central and southern Europe registers a significantly increasing variability in summer temperature, trend that is projected to intensify in future decades (Fischer & Schär, 2010; Kjellström et al., 2007; Vidale et al., 2007).

In Romania, the results of certain studies indicated changes observed in the surface air temperature (mean and extremes), pointing out their direct correlation with the changes of large-scale circulation patterns. Thus, Bojariu and Paliu (2001) revealed the connection between NAO phases and temperature variability over Romania in winter. There were also studied the multidecadal variability of summer temperature in relation with AMO (Ionita et al., 2012), the connection between seasonal mean maximum temperature and various large-scale circulation patterns (Tomozeiu et al., 2002), or the influence of European climate variability on air temperature (Matei, 2013). Certain studies focussed on annual and monthly temperature trends at different time scales for the entire territory of the country (Ciulache & Cismaru, 2000), on summer temperature patterns and variability in some particular years, such as 2007 (Busuioc et al., 2007; Burada & Sandu, 2009), while others analysed regional temperature trends – northwestern Romania (Hauer et al., 2003), Suceava Plateau (Mihăilă, 2005), northeastern Romania (Piticar & Ristoiu, 2012), Oltenia Plain (Vlăduț et. al, 2011), etc.

Under these circumstances, the analysis of temperature trends and variability during distinct seasons, in this particular case, that of summer, is quite important as different seasonal warming rates may have important consequences for natural vegetation, agriculture, human health, and energy consumption, amongst others.

Data and methods

Oltenia Plain is located in the south of Romania, representing the western extremity of the Romanian Plain, the largest plain unit in the country; this sector is limited by the Danube River in the west and south and by the Olt River in the east, while the northern limit, towards the Getic Piedmont, is sinuous (Fig. 1).

For the present study, we used mean monthly temperature data recorded over the last fifty years (1961-2010) at the main meteorological stations from the Oltenia Plain (Table 1).

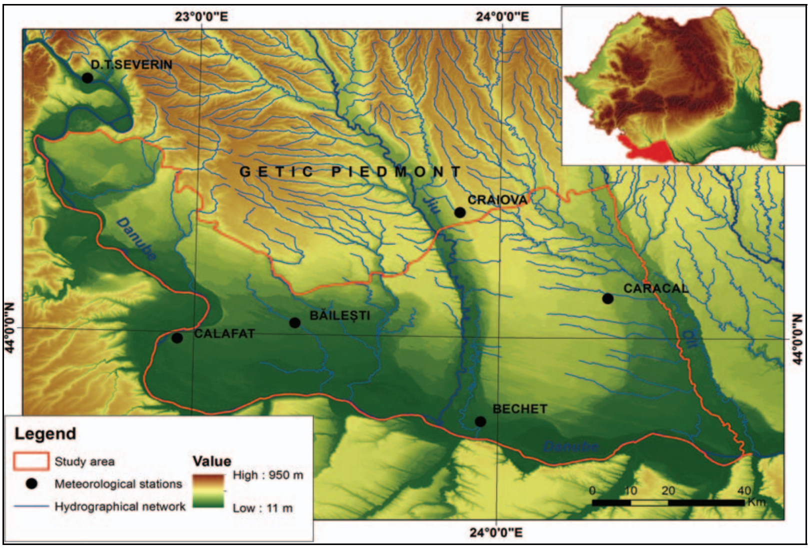

Figure 1 Location of Oltenia Plain within Romania and the Romanian Plain and the main meteorological stations

Table 1. Location of the meteorological stations within Oltenia Plain

No.	Station	Altitude (m)	Latitude	Longitude
1.	Calafat	61	43°59`	22°57`
2.	Bechet	36	43°47`	23°57`
3.	Băilești	57	44°01`	23°20`
4.	Caracal	106	44°06`	24°22`
5.	Craiova	192	44°19`	23°52`
6.	Dr. T. Severin	77	44°38`	22°38`

In order to estimate if there occurred any changes in the mean summer temperature we examined and calculated the deviation of each summer values by comparison to the mean of the period 1961-1990, which is the classical period defined by the World Meteorological Organization. For a more detailed analysis, we also examined the linear trend of these deviations and the mean of 10-year sub-intervals of the total data, respectively 1961-1970, 1971-1980, 1981-1990, 1991-2000 and 2001-2010.

In order to detect trends in the time series of summer temperature values, it was used the Excel template MAKESENS (Mann-Kendall test for trend and Sen's slope estimates), developed by the researchers of the Finnish Meteorological Institute (Salmi et al., 2002). Mann-Kendall test is a non-parametric test used for rendering the significance of a linear trend against the null hypothesis of "no trend". The test statistic Z enables us to compare the absolute value of Z to the standard normal cumulative distribution to detect a certain trend at a certain level of significance α. Thus, positive values of Z clearly indicate upward trends, while negative values of Z indicate downward trends. Sen's method enables the estimation of the magnitude of a trend.

Results and discussion

Mean summer temperature evolution

The analysed region displays a high homogeneity in terms of mean summer temperatures, the normal values (mean of the period 1961-1990) ranging between 21.04ºC in the north, at Craiova and 21.86ºC, in the south-west, at Calafat (Table 2). Based on the comparison between the mean values of each summer and the normal, it was emphasized the clear predominance of positive deviations starting with 1987, as well as the upward trend of the deviations (Fig. 2). Thus, between 1987 and 2010, the minimum number of negative deviations was one, while the maximum number was three (only two meteorological stations), registered in the same years, namely 1989, 1997 and 2005. However, the negative deviations did not exceed -0.6ºC for this interval, while positive deviations exceeded 3ºC, with one except, Bechet (2.8ºC), all maximum values being registered in 2007.

The analysis of mean summer temperatures for each decade revealed the same evolution pattern within the entire plain unit. Thus, it seems that the first 10 years were warmer than the next decade, mainly within the Danube alluvial plain, where summer temperature reached about 22.1°C. However, starting with the second decade, values indicate a continuous temperature increase from one 10-year interval to another, which generally oscillated between 0.40 and 0.55°C. The greatest temperature increase from one decade to another was registered between the 4th and the 5th decades and it ranged between +0.8°C and +1.1°C, but it does not correspond to the highest deviation compared to the normal mean temperature.

The highest positive deviations compared to the mean correspond to the last decade, 2001-2010 and they vary between +1.39°C (in the northern extremity, at Craiova) and +1.64°C (in the southwest, at Calafat). It is the first decade, when mean temperatures exceeded 23°C within the entire plain, except for the northern extremity, where it was registered a value of 22.5°C (Fig. 3). We can speak about a significant increase taking into account that, in the previous decade, temperatures were above this threshold only in the southwestern part of the plain, at Calafat (Table 2). It is worth mentioning that 48.93% of the total number of cases when monthly mean temperatures were above 25°C in the last fifty years registered in the last decade (Vladut, 2013).

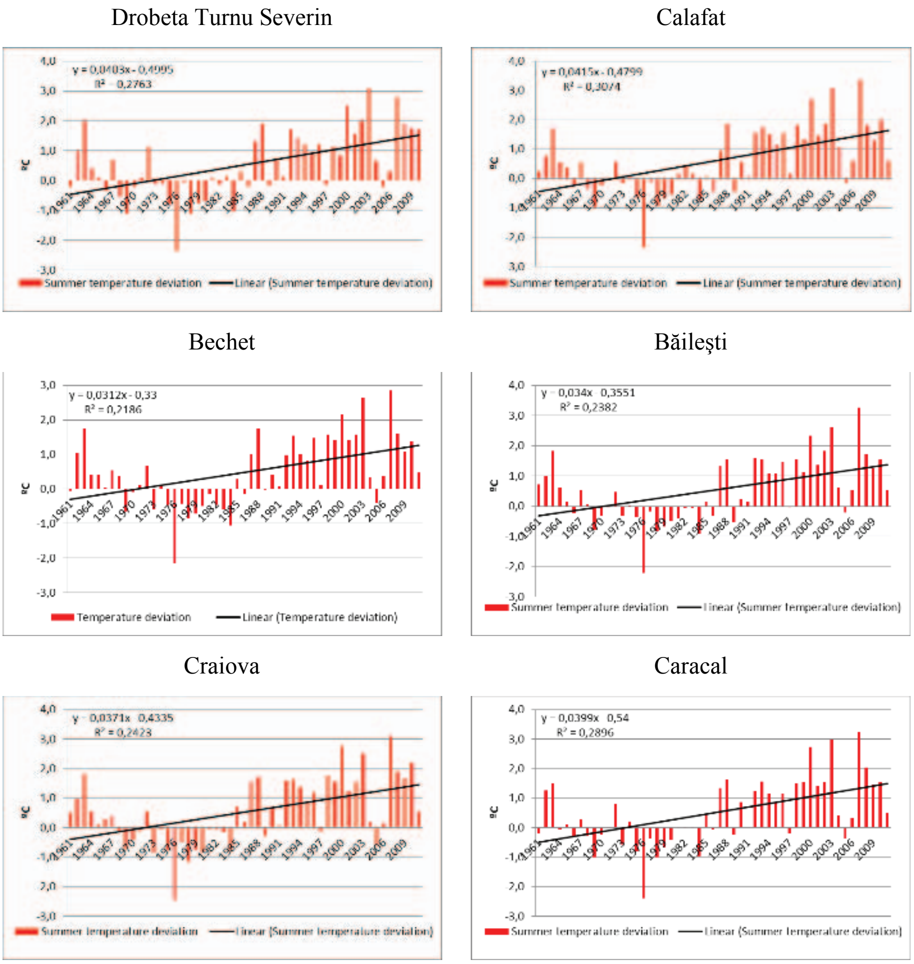

Fig. 2 Summer temperature deviation and linear trend within Oltenia Plain (1961-2010)

Table 2. Summer mean temperatures for the last five decades within Oltenia Plain (1961-2010)

Summer temperatures						
Decade / Station	D.T. Severin	Calafat	Bechet	Băileşti	Craiova	Caracal
1961-1970	21.98	22.09	22.13	21.99	21.38	21.74
1971-1980	21.32	21.38	21.27	21.17	20.35	21.11
1981-1990	22.09	22.12	21.86	21.73	21.40	21.92
1991-2000	22.88	23.22	22.87	22.82	22.31	22.79
2001-2010	23.35	23.50	23.04	23.09	22.43	23.09
1961-1990	21.79	21.86	21.75	21.63	21.04	21.59

Source: Vlăduţ, 2013

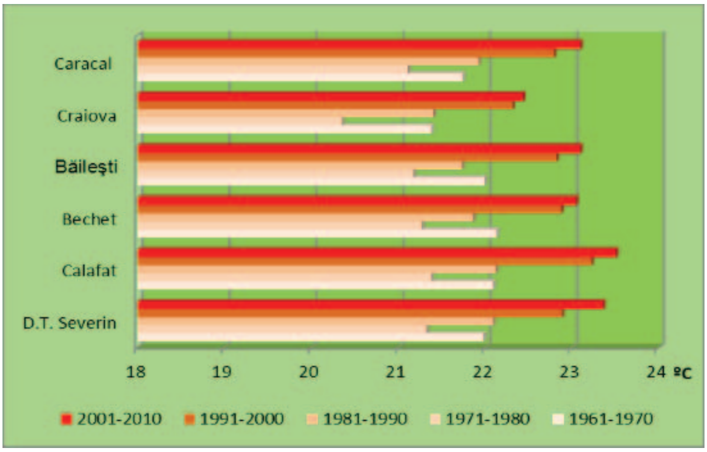

Figure 3 Mean summer temperatures for 10-year intervals within Oltenia Plain

Temperature trend analysis

The Mann-Kendall test was applied to the 18 data sets (summer mean values and mean values of each summer month) for the interval 1961-2010, for all of the analysed stations.

In all summer months, at all the meteorological stations, there were registered positive slopes with statistically significant levels of α. There were not found data sets with negative trends at any of the station. The significance level for the positive slopes varies from 0.001 to 0.05. The significance level 0.001 indicates that the existence of a monotonic trend is very probable, namely 0.1% probability, while the significance level 0.1 means that there is a 10% probability that we make a mistake when rejecting H0.

June displays upward trends within the entire analysed region. However, the significance level of the positive slopes oscillates between 0.05 (the southeastern and western part of the plain) and 0.01 (the rest of the plain) (Table 3, Fig. 4), which is consistent with the decade mean temperature deviations. Thus, in the southeast of the plain (Bechet), the first three decades present significant negative deviations, almost -1°C, and the last two decades a slight positive deviation, up to +0.25°C; in the north (Craiova), there is only one decade with negative deviation (1971-1980, -0.33°C), while in the last two decades, the positive deviations reached 1.42°C, respectively 1.19°C.

July represents the month with the most obvious upward trends, the positive slopes displaying statistically significant levels of α of 0.001 at three of the analysed stations – D.T. Severin, Calafat and Caracal and of 0.01 at the other three stations Bechet, Băileşti and Craiova. In the first case, at D.T. Severin, positive deviations constantly increased starting with the third decade, from +0.45°C to +1.69°C, while at Craiova, there is the same tendency, but with lower deviation values, namely from +0.46°C to +1.44°C.

August is quite similar to June in terms of significance level, but, in this case, the level of significance of 0.05 is registered in the southwest, at Calafat, and in the central part of the plain, at Băileşti, while at the other stations, it is 0.01. In terms of deviations of decade mean temperatures compared to the normal, there is registered the same pattern as in the case of the other two summer months, namely the increase is obvious starting with the third decade, from 0.15°C to 1.6°C at Băileşti, in the central part of the plain, and from 0.45°C to 1.76°C at Caracal, in the east.

Referring to the summer season, all the trends are statistically significant (more than 99% confidence level) within the entire plain. From the spatial distribution viewpoint, most stations behave quite similarly and this indicates that the increasing trends may be linked more probably to large-scale rather than local processes.

Table 3. Test Z, statistical significances (SS) and Sen's slope estimate (Q) for air temperature trends within Oltenia Plain for the period 1961-2010

Station / Month	D.T. Severin			Calafat			Bechet			Băileşti			Craiova			Caracal		
	Z	SS	Q	Z	SS	Q	Z	SS	Q	Z	SS	Q	Z	SS	Q	Z	SS	Q
June	2.47	*	0.033	3.11	**	0.042	2.30	*	0.032	2.60	**	0.036	2.80	**	0.040	2.88	**	0.040
July	3.34	***	0.044	3.69	***	0.045	2.93	**	0.031	3.12	**	0.035	3.14	**	0.038	3.47	***	0.040
August	2.67	**	0.044	2.48	*	0.045	2.59	**	0.038	2.54	*	0.038	2.70	**	0.044	3.01	**	0.050
Summer	3.69	***	0.041	3.91	***	0.042	3.16	**	0.032	3.14	**	0.033	3.30	***	0.038	3.92	***	0.042

*** if trend at $\alpha = 0.001$ level of significance; ** if trend at $\alpha = 0.01$ level of significance; * if trend at $\alpha = 0.05$ level of significance

Conclusion

The analysis of summer temperature recorded over a 50-year period at six meteorological stations situated within Oltenia Plain is strongly consistent with the results of other studies made in Europe and worldwide, warming being mainly attributed to an increase in anthropogenic greenhouse gases.

The analysis of mean temperatures registered each summer and the mean 10-year values confirms the general tendency corresponding to the Romanian territory, namely up to 0.6ºC in the last 100 years (1901-2007) (Busuioc et. al., 2007). The decade 1971-1980 was the coldest over the Oltenia Plain region in the last fifty years. Thereafter a heating trend is obvious, statistically significant at more than 95% confidence level for all the analysed stations, the warmest decade being the last one. It is worth mentioning that the first three hottest summers in the analysed period correspond to this decade (2000, 2003, and 2007), in 2007, at Calafat, mean temperature exceeding for the first time 25ºC (25.23ºC).

The Mann-Kendall test applied to monthly data sets for the interval 1961-2010, for all of the analysed weather stations, indicated that the most important increase in air temperature was specific to July, when all the stations have shown statistically significant positive slopes (more than 99% confidence level). Referring to the entire summer season, it resulted that the positive slopes are statistically significant, the level of confidence reaching 99% in the southeastern extremity and in the central part, while in the rest of the region, it was above this threshold.

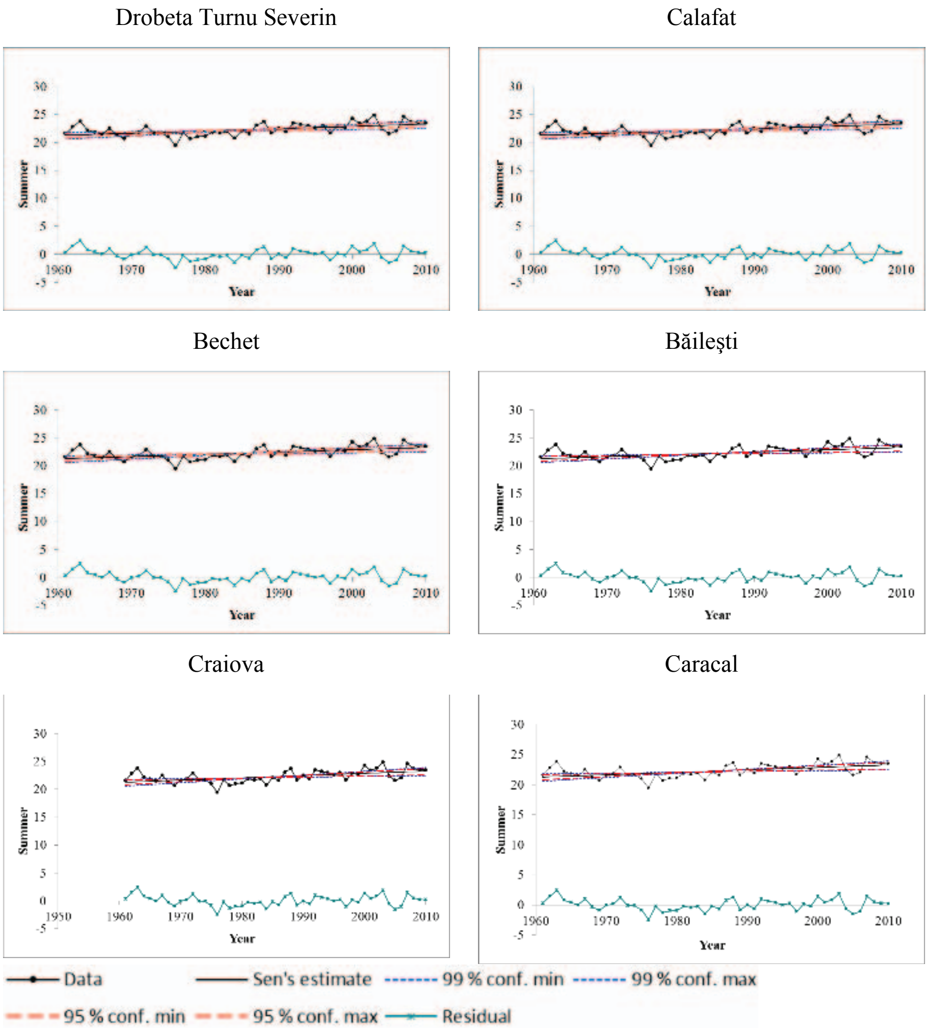

Figure 4 Trends for summer air temperatures within Oltenia Plain (1961-2010)

The analysis also emphasized that there is high connection among stations, as there were not detected any significant spatial differences. Thus, based on our own results, as well as on the results obtained for other regions of the country, it appears that warming may be related to large-scale factors, local features also enhancing positive deviations and upward trends (soil type, vegetation cover, distance from settlements, etc.). We may also assume that the significant increase in summer temperatures has greatly contributed to the annual temperature increase so far, or, otherwise, summer is the season that has been getting warmer than the other seasons. However, further research in this field is needed in order to clarify this issue and to assess the vulnerability of the region to climate change.

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