

RESEARCH ON THE LONG TERM FLUCTUATIONS OF THE AIR TEMPERATURES IN THE AREA OF BOTEV PEAK

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Abstract

The present work considered the fluctuations of the air temperatures in the high meteorological station Botev Peak (1961-2016). By statistical methods are examined the peculiarities of the temperature fluctuations. Mostly positive deviations are established, reaching 1.4°C above normal.

Keywords: *climate change, air temperatures, statistical methods, regional climate*

1. INTRODUCTION

The problem of climate change is considered to be one of the great challenges for humanity. Climate fluctuations and possible negative consequences would affect the ability of all countries to achieve sustainable development. Particularly relevant is the issue of the magnitude and direction of climate change, the impact of human activity and the danger of natural disasters. Often, information on climate change on a regional or local scale is too scarce. The issue is also addressed in the reports of the Intergovernmental Panel on Climate Change, where one of the recommendations relates to the need to promote regional and local researches [1]. The multi-year fluctuations of the main climatic elements for the territory of Bulgaria have been studied in a number of studies - Vekilska, B., D. Topliiski, 1980 [2], Koleva, Ek., 1981, 1987 [3,4], Vankova, N., 1995 [5], Velez, 1998 [6], Topliiski, D., 2005 [7], Koleva-Lizama, I., B. Lizama Rivas, 2004 [8], Koleva and Alexandrov, 2008 [9] and other authors. In summary, the conclusions of the various authors can be summarized as follows:

1. The above mentioned papers deal with the changes of basic climatic elements, complex climatic indicators and the manifestation of extreme meteorological phenomena.
2. The period from 1961 to 1990 was adopted for the climatic norm (modern climate).
3. Most studies cover the period up to the late 1980s or the late 1990s.
4. During the last decades of the 20th century, positive trends in average annual air temperatures were recorded.
5. As of the end of the last and the beginning of this century, there was a decrease in the annual rainfall for the low parts of the country.
6. The incidence of some dangerous meteorological phenomena has increased.
7. The basic method for studying the changes of the climatic elements studied is that of the moving averages.
8. Trends in climatic elements are revealed using statistical methods.

2. MATERIALS AND METHODS

2.1. Materials

Botev peak (2376,0 m) is located in the central parts of the Stara Planina Mountain and is its highest point. At the same location is the meteorological station, built in 1940. In addition to the geographic location, the formation of the climate has significant influence on the altitude, exposure, slope, etc. These climatic conditions also determine the specific condition of the individual climatic elements - low thermal values, significant cloudiness, high precipitation, strong wind activity and others. Changes in air temperature (1961-2016) were analyzed on the basis of data on the average monthly values

obtained from the archive of National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences. As a baseline, the average monthly temperatures used for the period 1961 - 1990, as defined by the World Meteorological Organization as a modern climate, were used. The latter will be compared to the average air temperatures for the period 1961-2016 (called the basic) and those of the last three decades - 1987-2016.

2.2. Methods

To clarify the homogeneity of the data, appropriate statistical methods have been used to reveal the scattering and data distribution indicators - perennial averages ($\bar{x}$), errors at the average multiannual values (E_r), median (Me), modality (Mo), standard deviation (σ), coefficient of variation (V), asymmetry coefficients (As), excess (Ex) and their respective errors, etc. The Shapiro and Wilk test was also used to determine the normal distribution of data [10]. Linear regression methods reveal a trend in air temperature changes as well as its statistical significance. Perennial peculiarities, in the course of average annual air temperatures, have been studied and presented using the moving average method, using a 10-year configuration (filter) for this purpose.

3. RESULTS

The main statistical characteristics of air temperatures are reviewed by months and years, and the analysis of the temperature characteristics used includes the determination of the following parameters: average monthly and annual value ($\bar{x}$) median (Me), mode (Mo), standard deviation (σ), average minimum (Min) and maximum (Max) values (Table 1).

Botev Peak (2386 m)	$\bar{x}$	Me	Mo	(σ)	Min	Max
I	-8	-8,1	-9	2,03	-12	3,1
II	-8,2	-8,2	-6,3	2,56	-14,2	-2
III	-6,1	-5,9	-7,3	2	-11,6	-1,3
MIV	-2,3	-2,6	-2,9	1,83	-7,8	1,9
V	2,4	2,5	2,9	1,6	-1	6,9
VI	5,7	5,6	5,1	1,21	3,5	9,1
VII	7,7	7,6	6,8	1,34	5	11,8
VIII	7,9	7,8	9,2	1,6	3,6	11,3
IX	4,8	4,6	3,3	1,62	1,1	9,2
X	1,4	1,1	-0,8	1,63	-1,8	5,4
XI	-2,4	-2,3	-3,8	2,03	-7,2	1,3
XII	-6,2	-6,1	-6,8	1,65	-10,9	-2,8
Annuals	-0,3	-0,3	-0,2	-0,66	-1,5	1,4

Table 1. Basic statistical indicators of the average monthly and annual air temperatures (°C) for the period 1961-2016.

Source: National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences.

The results of the study of the average monthly and annual air temperatures during the analyzed periods as well as the deviations from the norm are shown in Table 2.

Botev Peak (2386 m)	Modern climate (1961–1990)	Average temperatures (1961–2016)	Difference from the modern climate (Δt)	Average temperatures (1987–2017)	Difference from the modern climate (Δt)
I	-8,4	-8	+0,4	-7,4	+1
II	-8,5	-8,2	+0,3	-7,7	+0,8
III	-6,1	-6,1	0	-6,1	0
IV	-2,4	-2,3	+0,1	-2,2	+0,2
V	2	2,4	+0,4	2,6	+0,6
VI	5,1	5,7	+0,6	6,2	+1,1
VII	7,1	7,7	+0,6	8,5	+1,4
VIII	7,2	7,9	+0,7	8,6	+1,4
IX	4,6	4,8	+0,2	4,9	+0,3
X	1	1,4	+0,4	1,7	+0,7
XI	-2,7	-2,4	+0,3	-2,3	+0,4
XII	-6,3	-6,2	+0,1	-6,2	+0,1
Annals	-0,6	-0,3	+0,3	0	+0,6

Table 2. Average monthly and annual air temperatures (°C) for the periods 1961-2016, 1987-2016 and differences over the modern climate (1961-1990).

Source: National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences.

The results obtained for the trends in the average monthly and annual air temperatures (1961-2016) are presented in a Table 3. The relationship between the fluctuations of air temperatures and the years of the main period (1961-2016) is determined by correlation analysis.

Botev Peak (2386 m)	Equation of trend	(r)	(r ²)
I	<u>$y = 0,0328x - 8,9333$</u>	<u>0,26</u>	<u>0,07</u>
II	$y = 0,032x - 9,1189$	0,20	0,04
III	$y = 0,0134x - 6,4477$	0,11	0,01
IV	$y = 0,017x - 2,7973$	0,15	0,02
V	<u>$y = 0,0292x + 1,5582$</u>	<u>0,30</u>	<u>0,09</u>
VI	<u>$y = 0,0371x + 4,675$</u>	<u>0,50</u>	<u>0,25</u>
VII	<u>$y = 0,0464x + 6,406$</u>	<u>0,56</u>	<u>0,32</u>
VIII	<u>$y = 0,0488x + 6,5013$</u>	<u>0,50</u>	<u>0,25</u>
IX	$y = 0,0152x + 4,3424$	0,15	0,02
X	$y = 0,0226x + 0,7451$	0,23	0,05
XI	$y = 0,0191x - 2,9415$	0,15	0,02
XII	$y = 0,0158x - 6,6599$	0,16	0,02
Annals	<u>$y = 0,027x - 1,0417$</u>	<u>0,66</u>	<u>0,44</u>

Table 3. Trends in average monthly and annual air temperatures over the main survey period (1961-2016).

* The statistically significant values are highlighted and are in red.

The results obtained for the trends in the average monthly and annual air temperatures (1987-2016) are presented in a Table 4. The relationship between fluctuations in air temperatures and the years of the last three decades is determined by correlation analysis.

Botev Peak (2386 m)	Equation of trend	(r)	(r ²)
I	$y = -0,0265x - 7,0295$	0,12	0,01
II	$y = 0,048x - 8,4905$	0,16	0,03
III	$y = 0,0583x - 7,0111$	0,22	0,05
IV	$y = 0,0622x - 3,1423$	0,28	0,08
V	$y = 0,0712x + 1,5247$	0,39	0,15
VI	$y = 0,0657x + 5,1739$	0,48	0,23
VII	$y = 0,0388x + 7,8885$	0,28	0,08
VIII	$y = 0,0666x + 7,5881$	0,41	0,17
IX	$y = 0,038x + 4,3275$	0,19	0,04
X	$y = 0,0294x + 1,2032$	0,16	0,02
XI	$y = 0,1321x - 4,361$	0,50	0,25
XII	$y = 0,0575x - 7,091$	0,25	0,06
Annuals	$y = 0,0523x - 0,7674$	0,66	0,44

Table 4. Trends in average monthly and annual air temperatures over the last thirty years (1987-2016).

* The statistically significant values are highlighted and are in red.

The deviations from the average annual values (1961-2016) against the accepted norm (1961-1990) and the trend equation are shown in Fig. 1.

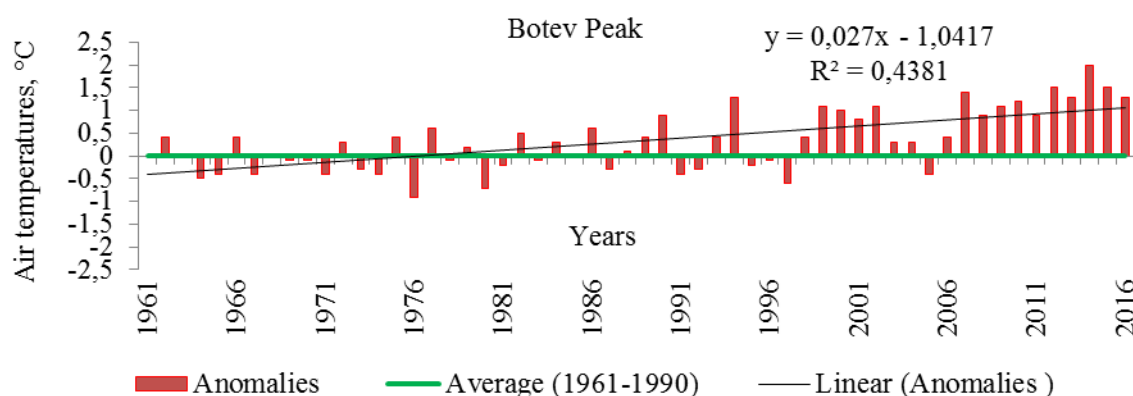


Fig. 1. Modern climate (1961-1990), anomalies and trends in the average annual air temperatures for Botev Peak (1961-2016).

The peculiarities in the chronological structure of the average annual air temperatures are revealed by the moving average method, which eliminates short period fluctuations in the course of temperatures. Through the graphs, the positive and negative cycles, as well as their duration, can be visually identified (Fig. 2).

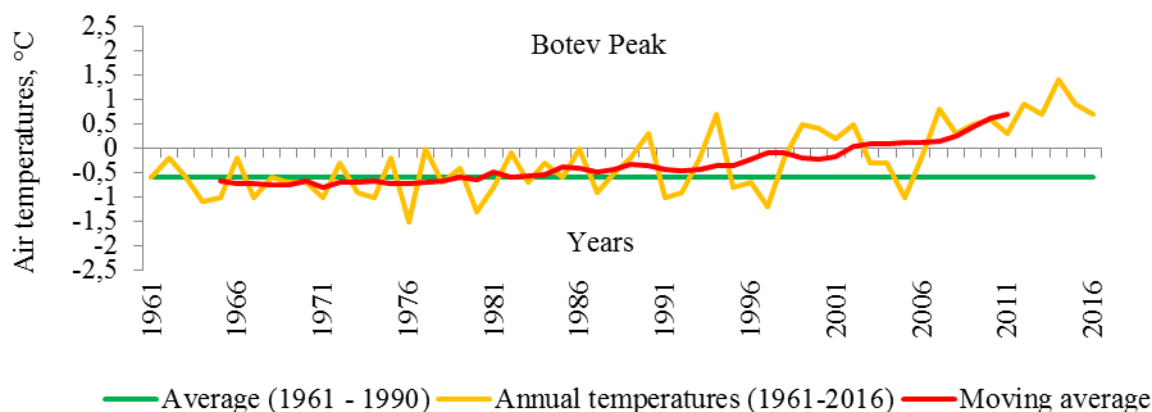


Fig. 2. Average monthly temperatures, modern climate and 10-year moving average for Botev Peak (1961-2016).

4. DISCUSSION

The established close values, at key central points (Table 1), prove that the data is subject to the law of normal distribution [11]. The results of the “Shapiro and Wilk” test varied in the relatively narrow range of 0.962 to 0.990. As the values are close to 1.00, they are an indication of normality distributions [10].

For the main period (1961-2016), the average monthly air temperatures were found to be mostly exceeded (Table 2). An exception is the average for March, in which no changes are detected. The most significant are the increases in the average for the months - August (0.7°C), June and July (0.6°C) and lower for January, May and October (at 0.4°C). For the other months, increases are from 0.1 to 0.3°C. At average annual temperatures an increase of 0.3°C was found. Similar are the results for the average annual air temperature for the period 1982 - 1994, in the area of coniferous forests of Bulgaria [12]. Warming in the last two decades of the 20th century has been established in other parts of the country [13].

For the period of the last three decades (1987-2016) the increase over the norm in the average monthly air temperatures is more significant. The exception is again the average for March in which no change is detected. The most significant are the increases in the average for the months - July and August (1.4°C), June (1.1°C) and January (1°C). Fewer are February (0.8°C), October (0.7°C) and May (0.6°C). For the remaining months, the positive deviations are from 0.1 to 0.4°C. At average annual temperatures, the increase reached 0.6°C (Table 2). Similar conclusions are made by St. Velev [14] and P. Nojarov and I. Kalapov [15], which record an increase in the average annual temperature at the end of the last century and the beginning of this century, for Musala Peak.

Positive trends (1961-2016) were found in air temperatures for the twelve yearly months and at the annual average, most pronounced in January, February, May, June, July and August. (Table 3). The statistical analysis confirms the significance of the positive trend for the average temperatures of the months - January, May, June, July, August and the average annual values, at a level of significance $p < 0.05$. Correlation coefficients show significant positive relationships between the changes in temperatures and years of the surveyed period for June, July and August, as well as the average annual values (Table 3).

Over the last three decades (1987 - 2016), positive trends in air temperatures have been observed for eleven months as well as at annual average temperatures. Exceptions are the average for the month of January, for which negative trends have been established. The positive trend for November, May, August, June and April is most pronounced. (Table 4). The statistical analysis confirms the significance of the positive trend for the average temperatures of the months - May, June, August, November and at the average annual values, at a level of significance $p < 0.05$. Correlation coefficients

show a moderate positive correlation between the changes in temperatures and years of the surveyed period for the May, June and August data. Significant positive correlation have been established for the averages of November as well as for the average annual values (Table 4).

The graph in Figure 1 shows that over the last two decades the number of positive anomalies and their amplitude have increased.

The moving average form two main periods (Fig. 2). The first covers the years from the beginning of the survey until 1980, when the values are slightly below the norm. The second began after 1984 and covered the years until the end of the study, with the moving average forming a well-expressed warm period.

5. CONCLUSIONS

In conclusion, we can say that during the studied periods, the average monthly and annual average air temperature increases in the area of the Botev Peak high-mountain meteorological station. The exception is the average for March, which coincides with the average of the norm/ modern climate. Over the last three decades warming is more sensitive. The most significant change was observed for the average of the months of January, June, July and August, where the positive deviations reach from 1.0°C to 1.4°C. During the analyzed periods the trends in the average monthly and average annual temperatures are positive. Exceptions are the average for January, for the period 1987-2016, where negative trends were found. It was found that after 1984, a warmer period began covering the years until the end of the study. The results gained enrich the knowledge of modern climate change on a local scale, which will contribute to the sustainable management of natural resources and to adequate measures against possible negative effects on ecosystems.

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