ГЛАСНИК Српског географског друштва 98(1) 49-59
BULLETIN OF THE SERBIAN GEOGRAPHICAL SOCIETY 2018

Original scientific paper
UDC 551.524.36 (23) (497.2)
https://doi.org/10.2298/GSGD180415007N

Received: April 15, 2018
Corrected: May 13, 2018
Accepted: May 25, 2018

Nina Nikolova[1*], Jocelin Laporte[**], Galina Tomova[*]

[*] *Sofia University, Faculty of Geology and Geography, Sofia, Bulgaria*
[**] *University of Lille, France (Erasmus student in Sofia University)*

EXTREME TEMPERATURE MONTHS IN RILA MOUNTAIN, BULGARIA (1960-2012)

Abstract: The air temperature is the main climatic parameter which gives important information about climate change and variability. The increasing of the temperature and frequency of occurrence of extreme high temperatures during the recent years is one of the features of climate which is associated with the global climate change. The present study aims to analyze the variability of air temperatures in the mountainous area of Bulgaria and in Rila Mountain in particular by the investigation of chronological distribution of extreme cold and extreme warm months. Extreme temperature months are determined according to 10-th and 90-th percentiles of the distribution of monthly data. On the basis of the investigation of extreme temperature months during the period 1960-2012 the increase of warm and decrease of cold months are determined at annual level and also for summer-time and winter-time. The results show that the warming during the summer-time (May – October) is more clearly established that in winter-time (November – April).

Key words: extreme temperature months, threshold of 10-th and 90-th percentile, Rila Mountain

[1] nina@gea.uni-sofia.bg (corresponding author)

Introduction

The reports of Intergovernmental Panels of Climate Change point out the increasing of air temperature in global and regional scale. The results of the investigation show unprecedented warming during the last decades (IPCC, 2013). The decreases of cold extremes and increases of warm extremes since the middle of the 20th century is pointed out in the scientific publication as Nikolova & Penev, 2007; Pokladnıkova et al., 2008; Seneviratne et al. 2012; Chitu et al., 2015. Most of existing publications estimate temperature extreme on the basis of daily data (European Climate Assessment & Dataset project, Brown et al, 2008; Caesar, 2006, Klein Tank & Können, 2003). On the other hand, knowledge of the extreme values of the monthly temperatures contributes to the clarification of the trends in the multi-years variability in the air temperatures.

The study of temporal and spatial variability of air temperature in the mountainous areas is important for understanding the specifics of regional climate in the context of global climate change. The spatial distribution and regime of air temperature in the Bulgarian mountains were the subject of the research by a number of authors as Stanev (1955), Bozhkov (1958), Glovnya (1963), Tishkov (1976), Stoychev (1978, 1981), Koleva (1989) Velev (2010) etc. Stanev (1955) have established the differences in the temperature regime on the slopes with northern and southern aspect in the Rila Mountains. The temperature conditions on different aspects in Rila were also investigated by Stoychev (1981), who points out that the stations on the southern slopes have higher temperatures of 0.5°C to 1.6°C compared to those on the northern slopes. In observing the annual cycle of air temperature, Velev (2010) reveals that with increasing of the altitude the average January temperatures for the period 1931-1980 decreases and reaches -10.9°C at the station Musala peak (2,925 m), while the summer temperatures are about 5°C.

Despite the increasing interest to the mountainous climate the existing publications on air temperature in Bulgarian mountains are based mainly on average monthly, seasonal and annual values for the period up to the 1980s which determine the necessity for extending the research work with the new indicators and data for the recent years.

The aim of the paper is to analyse temporal variability of the extreme monthly temperature in Rila Mountain, Bulgaria during the period 1960-2012. To study this evolution we used the data of 6 meteorological stations: Blagoevgrad, Samokov, Rila, Rila Monastery, Borovec, and Musala.

Studied area, data and methods

Rila Mountain is located in the southwestern part of Bulgaria. With Musala peak (2,925 m) Rila is the highest mountain on the Balkan Peninsula and is it is main hydrographic unit. The climate of Rila Mountain is mainly determined by the geographic location, peculiarities of relief and atmospheric circulation. Rila is situated on the border between temperate continental and continental Mediterranean climates. As a result of the changes of the climatic elements in relation to the peculiarities of the relief - aspect, altitude, dislocation and inclination of the slopes, a specific microclimate is formed.

In order to achieve the aim of study the data for monthly air temperature from six meteorological stations are used. The stations are situated on various elevation and exposure in Rila Mountain (Fig. 1, Tab. 1).

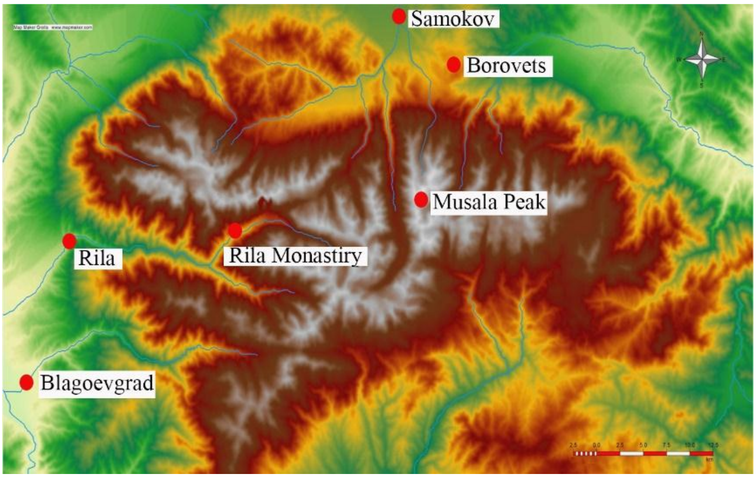

Fig.1. Geographical location of the meteorological stations used in the research

Tab. 1. List of meteorological stations used in the research – geographical coordinates and average annual temperatures for period 1960-2012

Meteorological stations	Latitude	Longitude	Altitude (m)
Blagoevgrad	42° 00'	23° 05'	424
Rila	42° 06'	23° 07'	505
Rila Monastery	42° 08'	23° 21'	1,150
Samokov	42° 19'	23° 34'	904
Borovets	42° 15'	23° 36'	1,244
Mussala peak	42° 10'	23° 35'	2,925

Fig. 2 shows the average annual values of the air temperature at the analysed stations. For the period 1960 - 2012 the temperatures at the foot, low and middle parts of the mountain (stations Blagoevgrad, Rila, Samokov, Rila Monastery and Borovets) were between 12.8°C and 5.7°C. In the high parts of the mountain, over 2,300 m, the average annual temperature is negative - Musala peak (-2.6°C).

In order to analyse extreme months we have applied 10th and 90th percentile threshold method. According to IPCC, 2001, extreme weather event are those which are rarer than the 10th or 90th percentile. 10th and 90th percentile was used also by European Climate Assessment and Dataset Project for determination of cold and warm days.

To select the extreme cold and warm months, we have identified the 10-th and 90-th percentiles of empirical distribution of the monthly data for each station for the period 1960-2012. As extreme cold months we consider the months with monthly temperature less than the 10-th percentile and the extreme warm months are the months with the temperature higher than the 90-th percentile. The same method was applied by Nikolova and Penev (2007) for the temperature in non-mountainous part of Bulgaria.

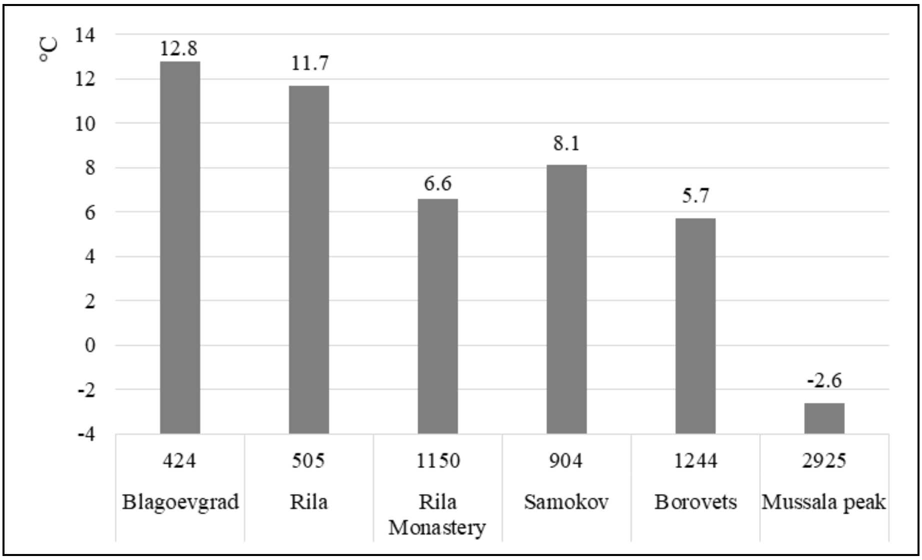

Fig. 2. Annual air temperature for the period 1983-2012

Results and discussion

The chronological distribution of extreme hot months is shown on Fig. 3. The occurrence of at least one extreme warm month during each year is observed in most of the investigated stations. Exception is the 1970s of the last century when extreme warm months has been observed only in one or two of stations situated on northern slop of Rila mountain. The results of the analysis show that the warmest years for the investigated period are 2000 and 2012 when in all of analysed stations three and more extreme hot months are occurred (Fig. 3).

The results of investigation show that the years with three and more extreme hot months in different station occurred mostly since 1990. In fact except the first year of the investigated period 1960, there is not any year before 1990 with at least two stations that register more than 3 warm months. From 1990 to 2012 there are 13 years when 3 and more extreme hot months are registered in at least two stations. Similar results have been obtained by Nikolova & Penev (2007) who investigated the fluctuation of extremely cold and warm months mainly in non-mountainous stations from Bulgaria during the period 1961-2004.

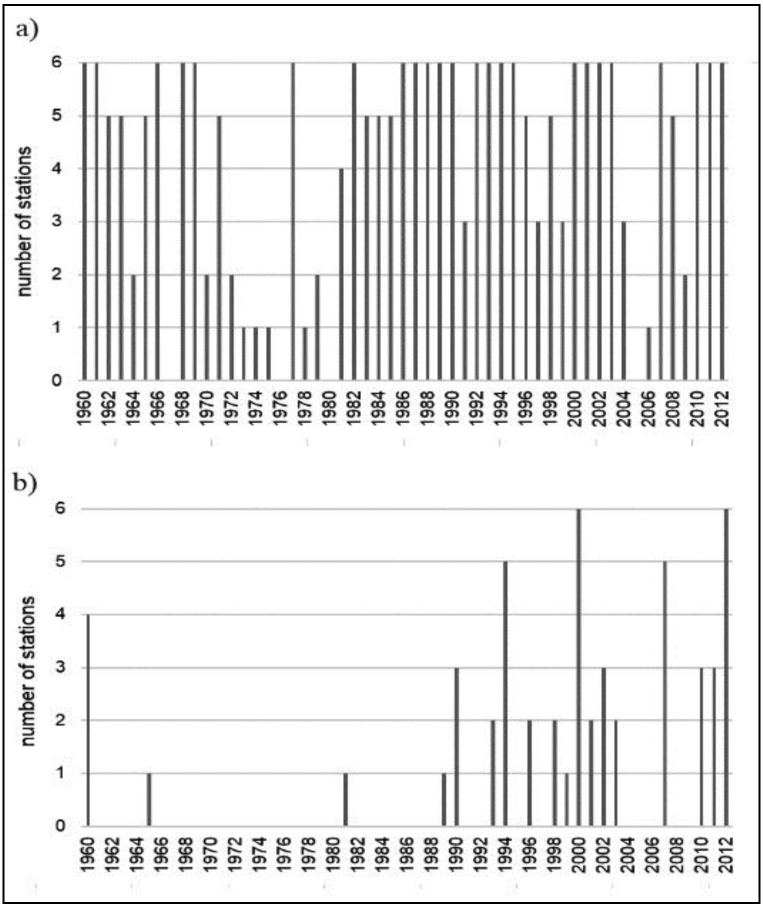

Fig. 3. Number of stations with a) at least one extreme warm month and b) 3 and more extreme warm months in the year

At least one extreme cold month was observed during each year in most of the analysed stations. Nevertheless the extreme cold months are more characteristic for the first half of the investigated period (Fig. 4). The concentration of extreme cold months during the first part of the period 1960-2012 is more visible in relation to the distribution of stations with three and more extreme cold months (Fig. 4, b).

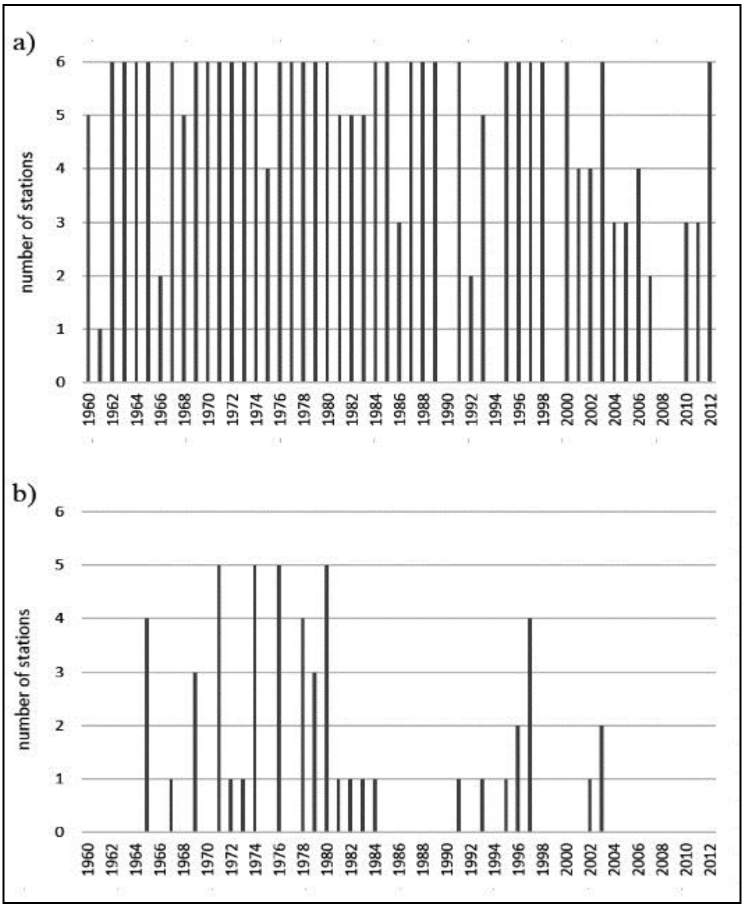

Fig. 4. Number of stations with a) at least one extreme cold month and b) 3 and more extreme cold months in the year

The results from the investigation of extreme temperature months show that the occurrence of extreme cold months is quite the opposite of the occurrence of the extreme warm months (Fig. 4, b and 3, b). During the 1970s there is not any station that recorded more than three warm month in the same year and from other side, the 1970s appear like the coldest decade with four years (1971, 1974, 1976, 1980) that count five station that recorded more than three cold month.

The 1980s (1985, 1986, 1987, and 1988) appear like "normal" or average years without extreme warm or cold month. The analysis of figures 3 and 4 and in particular the occurrence of three and more extreme warm or cold months shows the unequal repartition of the warm and cold months during the period 1960 – 2012 and allow us to point out that the temperature in Rilla mountain increased during the period (1960-2012). In order to confirm this further detailed analysis of the distribution of all extreme months in the investigated stations for the period 1960 – 2012 is done. For this purpose we consider two equal periods 1961-1986 and 1987-2012.

Fig. 5 shows the ratio of extreme warm and cold months in the two periods (1961-1986 and 1987-2012). It is obvious that during the recent years (1987-2012) the number of extreme cold months is lower than during the period 1961-1986 and represent about 40% of extreme cold months for all investigated period (Fig. 5, a). The difference between two 26-periods is higher in regard to the distribution of extreme warm months. During the first period (1961-1986) the extreme warm months are 30% of all extreme warm months for the investigated period while in the second period (1987-2012) the extreme warm months represent 70% of all extreme warm months for the period 1961-2012 (Fig. 5, b). The similar tendency has been established by Pokladnıkova et al., 2008 for south Moravia during the period 1961-2007.

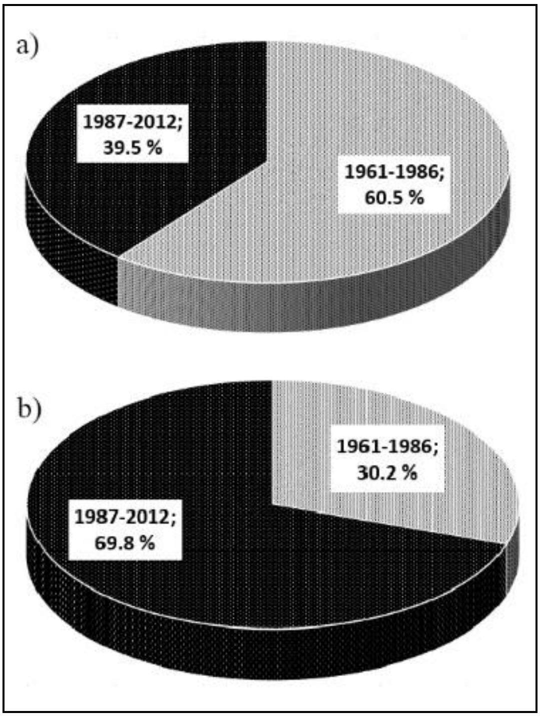

Fig. 5. Distribution of extreme temperature months: a) Extreme cold months during two periods (in % of extreme cold months for the period 1961-2012; b) Extreme warm months during two periods (in % of extreme warm months for the period 1961-2012

Analysis of seasonal distribution of extreme warm and cold months is done on the basis of the data for winter time (November–April) and summer time (May-October) for all of the investigated stations. In order to answer the question if the warming occurred similarly in the different period of the years we investigate two 26-years periods: 1961-1986 and 1987-2012 for winter-time and for summer-time (Fig. 6).

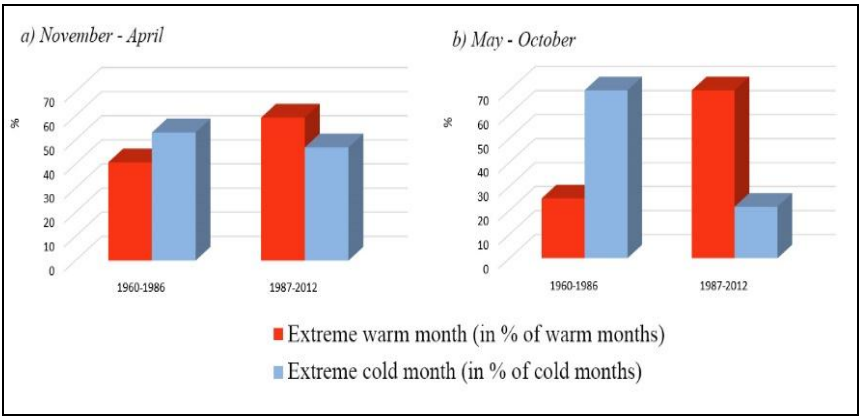

Fig. 6. Seasonal distribution of extreme warm and cold months during the periods 1961-1986 and 1987-2012

Generally the increasing number of extreme warm months and decreasing number of extreme cold months are observed both in cold and warm parts of year but the differences are bigger during the summer time (period May – October).

The results of the research show that the increase of number of warm month and the decrease the number of cold month have note exactly in the same proportion. This is well determined for winter time. In comparison to the period 1961-1986 the number of warm months increases during the period 1987-2012 with 18.6% of all number of warm months during the period November – April. The number of cold months in winter decreases with 6.2% only.

In summer time (May – October) the difference between extreme temperature months is higher than in winter-time. During the period 1961-1986 the number of warm month was 25% from all warm months observed in summer-time but the considerable increase was determined for the period 1987-2012 when the number of warm months was 75% of all warm months in summer-time (Fig. 6, b). The similar difference is observed for extremely cold months during the period May – October but with a negative sign.

The seasonal distribution of extremely warm and cold months for two periods (1961-1986 and 1987-2012) shows that on the background of the general increasing of temperature the warming during summer time in Rila mountain is better determined than the warming during the winter-time. This result is confirmed by trend analysis of monthly maxima and minima of air temperature for each year (Tab. 2).

The positive trend is characteristic for both maximal and minimal monthly air temperatures for the period 1960-2012. Statistically significant trend with values between 0.46 and 0.68°C/10 years is established for monthly maximal temperature while monthly minimal temperatures increase with 0.11 to 0.27°C/10 years and the trend is not statistically significant. This results correspond to the outcomes from Rebetez & Reinhard, 2008 who point out that the warming is related mainly to the increase of maximum temperature than to the to increases in the minimum temperature.

Tab. 2. Trend of monthly maximal and monthly minimal temperatures for the period 1960-2012 (°C /10 years)

Meteorological stations	Trend of monthly maximal temperatures	Trend of monthly minimal temperatures
Blagoevgrad	**0.68**	0.27
Rila	**0.46**	0.26
Rila monastery	**0.49**	0.20
Samokov	**0.61**	0.21
Borovets	0.17	0.11
Mussala	**0.48**	0.12

Conclusion

The paper examines the peculiarities of the distribution of air temperature in the highest mountain in Balkan Peninsula – Rila Mountain. The accent of the study is on the chronological variability of extreme temperature months during the period 1960-2012.

The results of the analysis show that extremely warm months were observed more frequent since 1990s while the previous years are characteristic with the occurrence of extremely cold months. During the recent years (1987-2012) the extreme warm months were about 70% of extreme temperature months for the period 1961-2012).

The increase of frequency of occurrence of extremely warm months during 1987-2012 is more clearly determined for summer-time period (May – October) while during the winter-time (November – April) the difference between number of extremely temperature months for the periods 1961-1986 and 1987-2012 is smaller.

The results from the analysis allow us to conclude that the warming during summer-time is better manifested than in the winter-time. On the background of general tendency to increase the air temperature the trend of monthly maximal temperature is well determined and statistically significant.

The future work on the variability of air temperature in Rila Mountain as well as in other Bulgarian mountains will be directed to the clarification of the relation between occurrence of extreme temperature months and large scale circulation processes, e.g. North Atlantic Oscillation (NAO) and the Mediterranean Oscillation (MO) which will bring to enhancing the knowledge about the mechanism for air temperature variability and change.

References

Bozhkov, R. (1958). Unusually high maximum temperatures in December are Bulgaria. *Hydrology and Meteorology*, 1.

Brown, S.J., Caesar, J. & Ferro, C.A.T. (2008). Global changes in extreme daily temperatures since 1950. *Journal of Geophysical Research – Atmospheres,* 113, 11.

Caesar, J., Alexander, L. & Vose, R. (2006). Large-scale changes in observed daily maximum and minimum temperatures: creation and analysis of a new gridded data set. *Journal of Geophysical Research – Atmospheres*, 111, 10. DOI: 10.1029/2005JD006280

Chitu, E., Daniela Giosanu, D. & Mateescu, D. (2015). The Variability of Seasonal and Annual Extreme Temperature Trends of the Latest Three Decades in Romania. *Agriculture and Agricultural Science Procedia* 6, 429 – 437.

European Climate Assessment & Dataset project. Retrieved from: https://www.ecad.eu/

Glovnya, M. (1963). *Rila*. Sofia: Science and Art

IPCC (2001). Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T.,Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881

IPCC (2007). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996

IPCC (2013). Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Klein Tank, A. M. G. & Können, G. P. (2003). Trends in Indices of Daily Temperature and Precipitation Extremes in Europe, 1946–99. *Journal of Climate* 16, 3665-3680.

Koleva, E. (1989). *The natural and economic potential of the mountains in Bulgaria: Nature and resources*. Vol. 1. Sofia: BAS

Nikolova, N. & Penev, D. (2007). Fluctuation of Extremely Cold and Warm Months in Bulgaria. *Geographica Pannonica*, 11, 19-21.

Pokladnıkova, H., Roznovsky, J. & Streda, T. (2008). Evaluation of the monthly air temperature extremity for the 1961-2007 period. *Contributions to Geophysics and Geodesy*, 38/4, 391-403.

Rebetez, M. & Reinhard, M. (2008). Monthly air temperature trends in Switzerland 1901-2000 and 1975-2004. *Theoretical and Applied Climatology*, 91, 1-4, 27-34.

Seneviratne, S. I., et al. (2012). Changes in climate extremes and their impacts on the natural physical environment. In: *IPCC Special Report on Extremes*, 109-230.

Stanev, S. (1955). On the temperature regime in Bulgaria. *Studies of Hydro meteorological service*, 4

Stoychev, K. (1978). The altitudinal zonality of certain climatic and hydrological elements in the Rila Mountain with regard to its landscape regionalization. *Sofia University Year book*, 72(2).

Stoychev, K. (1981). *Rila – Nature and Resources*. Sofia: Science and art

Tishkov, H. (1976). *Climate of the mountainous regions in Bulgaria*. Sofia: BAS

Velev, S. (2010). *Climate of Bulgaria*. Sofia: Heron Press

Nina Nikolova[*], **Jocelin Laporte**[**], **Galina Tomova**[*]

[*] *Универзитет у Софији, Факултет за геологију и географију, Софија, Бугарска*
[**] *Универзитет у Лилу, Француска (Студент Erastmus програма на Универзитету у Софији)*

МЕСЕЧНЕ ЕКСТРЕМНЕ ТЕМПЕРАТУРЕ ВАЗДУХА НА ПЛАНИНИ РИЛИ, БУГАРСКА (1960-2012)

Резиме: Овим истраживањем се приказује годишња и сезонска дистрибуција месеци са екстремном температуром на планини Рили (Бугарска) и суседним територијама. Значај студије одређује чињеница да карактеристике климе у планинским областима Бугарске и даље нису добро истражене. С друге стране, сазнања о променама температуре ваздуха у планинама може пружити важне информације о климатским променама уопште. Студија је израђена на основу месечних података о температури ваздуха са шест метеоролошких станица за период 1961-2012. Станице се налазе на различитим надморским висинама и експозицијама на планини Рила и околном простору.

Прагови од 10 и 90 процената дистрибуције месечних података за сваку станицу за период 1961-2012. година користе се за одређивање екстремних температурних месеци. Екстремно хладним месецима сматрамо оне са месечном температуром мањом од 10-тог перцентила, а екстремно топлим са температуром вишом од 90-тог перцентила. Сезонска дистрибуција екстремно хладних и екстремно топлих месеци анализира се за зимско време (новембар-април), а за лето од маја до октобра. Испитивани период је подељен на два једнака периода: 1961 – 1986. и 1987 - 2012.

Резултати анализе показују да су се екстремно топли месеци појављивали чешће од 90-их година, док су године пре тога карактеристичне по изузетно хладним месецима. Током последњих година (1987-2012) екстремно топли месеци чине око 70% екстремно температурних месеци периода 1961-2012.

Повећање учесталости појава екстремно топлих месеци у периоду од 1987. до 2012. године је јасније одређено за летњи период (мај-октобар), док је у зимском периоду (новембар-април) разлика између броја месеци са екстремним температурама периода 1961-1986. и 1987-2012. мања.

Сезонска дистрибуција екстремно топлих и хладних месеци за два периода (1961-1986. и 1987-2012.) показује да је у позадини општег повећања температуре, загревање током летњег периода на планини Рили јасније исказано од загревања током зимског периода.