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EXTREME AIR TEMPERATURES AT THE
SOUTHWESTERN SLOPE OF PIRIN MOUNTAIN
(BULGARIA) AND RELATED SYNOPTIC CONDITIONS

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Abstract

The article examines the occurrence of extremely cold and extremely warm days as an indicator of environmental changes in the Pirin Mountain (Bulgaria). The study is based on hourly air temperature data recorded by an automatic weather station. By averaging the hourly data, daily values are calculated. The occurrence of extremely cold and extremely warm days during the period 2015–2018 for January, April, July and October are analyzed. Extreme temperature days are determined by threshold values for the 10th and 90th percentiles. Characteristic synoptic situations related to the manifestation of extreme temperatures are presented. As a result of the research it was established that the advections of air masses are the leading factor for the occurrence of extreme temperatures. In addition very important for the extremely low temperatures is the high air pressure over the Balkan Peninsula.

Key words: extreme cold days, extreme warm days, synoptic situations, mountain, Bulgaria

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Introduction. The increasing of air temperature and frequency of the occurrence of extreme temperatures in recent years has been one of the features of climate associated with the global climate change. Many research works indicate the increase in number of warm days and nights, especially in summer which was observed across high and low elevations [1–3]. According to CHEN et al. [4] most climate models show increase of warming at the mountains due to snow melting and decrease of albedo. The characteristics of air temperature in mountainous areas give important information about climate change and variability and are essential for the occurrence of various geomorphological processes as well as for tourist activities development. For climate analysis at regional and local scale in the mountain areas it is necessary to take into account the limits and representativeness of available climate data [2]. In the mountainous areas the temperature extremes depend on the altitude rather than the latitude [5]. Additionally to the altitude the air temperature is related to the peculiarities of the topography and local weather conditions (i.e. wind, cloudiness and precipitation) but it is also influenced by the large scale atmospheric processes. The knowledge of local temperature characteristics can bring successfully to the understanding climate change and the impact of climate change in the mountain regions [6,7].

The scientific investigation about climate in mountainous regions of Bulgaria are still insufficient due to the lack of meteorological measurements, especially in the recent decade. Current climate studies of the mountainous areas in Bulgaria are based mainly on the data from meteorological stations located in Stara Planina [8,9], Vitosha [10], Rila [11] or the Rhodopes [12]. There are no published climatic data that would characterize the changes in the elements on various altitude in Pirin Mountain, as well as analyses of the microclimatic peculiarities and the extreme meteorological phenomena that influence the exogenous processes in the mountains. The environment in the mountainous areas is extremely sensitive to climate change and anthropogenic activity as well and can be a good indicator of existing and expected climate change.

The present study aims to analyse the observed changes of air temperatures at the southwestern slope of Pirin Mountain and in particular the region of River Begovitsa by the investigation of extreme warm and extreme cold events and related synoptic conditions. The influence of the atmospheric circulation on the occurrence of extreme high and extreme low temperature is revealed.

1. Study area, data and methods. The research is based on the hourly data for air temperature for the period January 2015 – December 2018. The data are taken from the environmental monitoring organized by the Department of Climatology, Hydrology and Geomorphology, Sofia University, Bulgaria, in relation to various scientific projects and operates now in the frame of the project titled

Fig. 1. Study area and location of measurement points

“Environment under climate change in the Pirin Mountain”¹, contract No DN 14/6, 13.12.2017, financed by the National Science Fund, Ministry of Education and Science – Bulgaria. The study area is situated above 1700 m a.s.l. (Fig. 1), where an automatic weather station (AWS) Wireless Vantage pro2 was installed.

The study area is a part of the catchment of Begovitsa River, which is developed on the south-western slope of Pirin Mountain. The river starts its flowing from the cirque Begovitsa Lakes, located at an altitude between 2294 and 2247 m a.s.l.

By averaging the hourly air temperature values, daily average values were obtained. Based on daily data² the monthly data are obtained and the annual cycle of the temperature was investigated. On the other hand, the accent of the study is the occurrence of extremely warm and cold temperatures during the months which are representative for the seasons: January for winter, April for spring, July for summer and October for autumn. The extreme temperature days were determined according to the following thresholds: extremely cold days are the days with daily air temperature less than or equal to 10th percentile of the daily values distribution for the respective month, and extremely warm days are

¹Project information and summarized data from meteorological observation can be found here <https://bit.ly/3zJUiyu> (accessed by 29 July 2021; in Bulgarian only)

²<https://bit.ly/3ycBtN0> (accessed by 29 July 2021)

the days with daily air temperature more than or equal to 90th percentile for the respective month for the investigated period. In order to clarify the reasons for the occurrence of extreme temperature days the synoptic situations for these days were analysed in regard to sea level pressure and temperature at 850 hPa.

2. Results and discussion. The annual cycle of monthly air temperature at the investigated station has a minimum in January (-3.8°C) and maximum in July (14.9°C). The obtained data show a typical mountainous climate in terms of annual temperature range. The monthly temperatures for the months representative for the seasons, show that between the investigated years the coldest winter is in 2017 and the warmest is in 2018. The maximum monthly average temperature in July is in 2015 (15.4°C) and the lowest average air temperature for July is in 2018 (13.8°C), Table 1. The average monthly extreme temperatures in January vary between 1.3°C and -9.1°C . During the warmest month, July, the monthly minimum is around 10.5°C and monthly maximum reaches 20.9°C , (Table 1).

T a b l e 1

Monthly mean and average monthly extreme air temperature

	Monthly mean				Monthly minimum				Monthly maximum			
	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct
2015	no data	4.1	15.4	6.1	no data	0.3	10.5	3.4	no data	8.9	20.9	9.5
2016	-4.1	6.8	14.9	6.6	-6.8	3.0	10.3	3.2	-1.2	12.1	20.1	10.0
2017	-5.9	2.1	15.3	5.1	-9.1	-1.5	10.6	1.8	-3.0	6.6	20.5	9.4
2018	-1.7	7.6	13.8	6.8	-4.5	3.3	9.6	6.3	1.3	12.8	18.7	7.2

2.1. Extremely cold days. The highest number of extremely cold days was established in April 2017 (8 days). In July and October the maximum number of extremely cold days was observed also in 2017 while in January the extremely cold days were more frequent in 2016. According to CONY et al. [13] extremely cold days in Europe are related to the increase of average minimum temperature. In the present study the investigated data show that the minimum monthly air temperatures in January and April 2018 are considerably higher than in the previous three years (Table 1).

A typical synoptic situation that determines the recording of very low air temperatures in January is presented in Fig. 2a. There is a powerful meridional invasion from the north over Bulgaria, combined with the formation of a centre of high atmospheric pressure and the associated additional cooling of the surface air. Temperatures decrease to -12 – -13°C at an altitude of 1500 m (T 850 hPa), to below -22°C on the map of AT 700 hPa (not presented in the paper). Subsequently, the centre of the anticyclone (at pressures above 1030 hPa) settled over Bulgaria.

The weather situation on 21 April 2017 confirms the rule that a large in mag-

Fig. 2. Synoptic situations related to the occurrence of extremely cold weather: left – sea level pressure (hPa); right – temperature ($^{\circ}\text{C}$) at 850 hPa

nitude and territorial extent meridional air intrusion of Arctic origin is necessary in order to record extreme low air temperatures (Fig. 2b). The analysis of temperature map from 21 April 2017 at 850 hPa very clearly outlines the cold area with a temperature of -15°C , a residue of a thermal valley with an axis from north to south. On the earth's surface, the synoptic conditions are characterized by the invasion of cold air in the eastern periphery of the anticyclone and the origination of a local centre of high atmospheric pressure.

A clear situation which leads to the occurrence of low temperatures has been observed in July 2017. During the period 16–18 July 2017 the weather over most of Europe is determined by the Azores anticyclone and its ridge growing from the Atlantic Ocean to the inland part of Europe (Fig. 2c). Cold air descends from its northern latitudes to eastern periphery of the anticyclone, which also covers the Balkan Peninsula. In the western and southwestern parts of Bulgaria the air temperatures decreased and dropped below 9°C at 850 hPa.

The analysis of the land surface synoptic map for 31 October 2017 identified cold air flow from north-northwest over the Balkan Peninsula and in particular over Bulgaria, in the east part of a well-formed anticyclone centred over Central Europe (Fig. 2d). The presence of a very well-formed cyclone over the European territory of Russia (ETR) further helps to attract fresh cold air from the high latitudes and directly transports it to the Balkans and Southeast Europe. The result is three consecutive days with extremely low temperatures, as on 31.10.2017. At an altitude of 1500 m (850 hPa) the isotherm -6°C covers the Northwestern half of Bulgaria.

2.2. Extremely warm days. The analysis of extremely warm days indicates the year 2018 with the warmest winter for the period 2015–2018. Four consecutive warm days are observed from 7 to 10 January 2018. In spring and autumn (April and October) the warmest year was 2016 with periods of three consecutive warm days. In July extremely warm days were more frequent in 2017.

As a result of a well-defined meridional advection, during the period 7–10 January 2018 good conditions were created to bring warm air over the Balkan Peninsula. Significant temperature anomalies were observed in Europe – Western Europe is quite colder than the southeast part of the continent (Fig. 3a).

The territory of Bulgaria is in the area with temperatures between 0 and 4°C . Cold air covers Spain and large parts of Morocco, where at altitudes of 1500 m the temperatures are around -10°C . This further intensifies the flow of warm air over the Eastern Balkans.

In the last week of April 2018, the typical of the summer season atmospheric circulation is established over Southern Europe. A well-formed baric ridge with an axis from North Africa to the Central Mediterranean existed at an altitude of about 5000 m. Under its influence the advection of warm air masses is observed. At the surface layer, in the conditions of high air pressure the pressure gradient over the Balkans is weak (Fig. 3b) and the daily overheating is high.

Fig. 3. Synoptic situations related to the occurrence of extremely warm weather: left – sea level pressure (hPa); right – temperature ($^{\circ}\text{C}$) at 850 hPa

The maximum air temperatures in July were related to a powerful air advection from southwest due to well-developed Azores anticyclone and low air pressure over the north of Europe (Fig. 3c). The high temperatures in October 2016 were a consequence of an invasion of warm air from south-southwest (Fig. 3d), which sharply raises the air temperatures at the upper air layers.

3. Conclusion. The present study helps to improve the capacity for studying environmental processes, completing the insufficient meteorological data for Pirin Mountain and clarifying the peculiarities of climate in the mountainous areas. Apart from purely scientific interests, environmental monitoring in mountain regions is fundamental for defining the state of the environment, conducting reliable risk assessments, and dealing effectively with environmental change-related challenges. The data analysis and the classification of the weather conditions causing extreme high and extreme low temperatures in the studied area during the representative for the seasons months, allow us draw the following conclusions:

Extremely warm months have been observed mainly in 2018. Exception is July 2017 where days with maximum air temperature above 25 °C have been observed at the altitude around 1800 m. The year 2017 makes impression with the occurrence of the highest number of extremely cold days as well.

The occurrence of extreme temperature days is connected to the meridional air advection. In all seasons, extremely high temperatures are the consequence of a powerful meridional flow of warm air from the southwest, while extremely low temperatures are the result of cold air invasion from the north-northwest.

For maximum temperatures, the formation of high atmospheric pressure over the Balkan Peninsula has no significant effect on the duration of the warm period. On the other hand, for low temperatures, the formation of an anticyclone state of the atmosphere and the establishment of cold and dry air contribute to a further decrease of air temperatures in the next 48 hours as a result of intensive effective radiation.

The results of the present study coincide with those of PRZYBYŁAK and MASZEWSKI [14] which reveal that for the region of Bydgoszcz–Toruń (Poland) the leading factor for the weather conditions is the advection of air mass while the isobaric system has lower influence.

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