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Climate profile of Bulgaria in the period 1988-2016 and brief climatic assessment of 2017

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Abstract: With regard to national and international obligations of the National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences (NIMH-BAS), climate profile of Bulgaria in the period 1988-2016 as well as brief climatic assessment of 2017 are prepared on the basis of monthly and annual data, provided by the Meteorological database of the NIMH-BAS, for 115 meteorological stations on the territory of Bulgaria and the obtained results are presented.

Keywords: Bulgaria, climate profile, climatic assessment of 2017

1. INTRODUCTION

In accordance with the United Nations Framework Convention on Climate Change, Member States of the Convention are required to provide national communications on a regular basis with information on the process of implementation of the Convention. As a part of the Seventh National Communication on Climate Change of Bulgaria and in view of the requirements of the Ministry of Environment and Water, climate profile of Bulgaria in the period 1988-2016 is prepared at the National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences (NIMH-BAS). Also a brief climatic assessment of 2017 is made as a contribution of the NIMH-BAS to the publication „Annual Bulletin on the Climate in WMO Region VI – Europe and Middle East". The results of the corresponding investigations and more detailed climatic background (as compared with the previous National Communications) are presented in the paper.

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2. DATA

Monthly and annual data concerning air temperature, precipitation, snow cover and number of days with thunderstorms and hail precipitation, provided by the Meteorological database of the NIMH-BAS, for 115 meteorological stations on the territory of Bulgaria in the period 1961-2017 are used in the study. Data processing is performed by program procedures.

3. CLIMATE PROFILE OF BULGARIA IN THE PERIOD 1988-2016

3.1. Climatic background

Bulgaria has unusually various climate conditions due to the influence of the strongly different continental and Mediterranean climates and diverse landscape. The climate has four distinct seasons and varies with altitude and location. According to the accepted in the NIMH-BAS climate classification, the territory of Bulgaria is divided into two climatic areas (European-Continental and Continental-Mediterranean), four climatic subareas (Moderate-Continental, Transition-Continental, South-Bulgarian and Black-Sea), and twenty-five climatic regions, which include the corresponding coastal and mountainous zones.

Clear expressed seasonality in the intra-annual course of insolation (relevant to the intra-annual alteration of sunshine duration) determines the levels of heat balance and thence the affiliation of the country to the regions of the continent with warmer climate. Because of the distance from the ocean, the Atlantic air masses appear chilled during the cold half year and overheated in the warm half year. Comparatively large and compact area of the Balkan Peninsula advantages the formation of local continental air masses, which during the summer become almost like tropical air, and during the winter – like cold continental air. The short distance to Mediterranean Sea enhances the climate differences between Northern and Southern Bulgaria. The immediate proximity to the Black Sea reinforces some characteristics of atmospheric circulation, mainly in the cold half year, and results in formation of specific sea climate in coastal area (20-40 km). High mountains serve as barriers for the air masses transfer, which predetermines the distribution of precipitation. The Mediterranean cyclones are most frequently observed from November to May/June; they have significant influence over the weather and climate in Southern Bulgaria. The Atlantic cyclones rarely reach the central areas of the Balkan Peninsula but they have influence over the weather and climate in Northern Bulgaria; their frequency is highest from February until June (with a maximum in May). The north-western anticyclones appear most frequently from the middle of spring until the middle of summer and usually cause cold spells in late spring and early summer. The western anticyclones cause warm spells in the winter and cold spells in the summer. The south-western anticyclones usually bring tropical air masses and the highest temperatures and droughty spells in the period July-September. The arctic anticyclones (moving from north/north-east towards southern continental areas) bring prolonged snowfalls and snowstorms in February and March. The process of formation of local anticyclones in the ridges of north-eastern ones causes the lowest temperatures in Bulgaria.

The sunshine duration reaches the highest average annual value in the southern border part of Struma Valley – 2800 hours. Along the Black Sea coast, in the Thracian Lowland, and Mesta Valley, the annual value of sunshine duration is 2200-2300 hours; in the Danube Plain – 2100 hours. Due to the higher cloudiness and naturally narrowed horizon in the mountains, the sunshine duration decreases to 1900 hours per year. For the non-mountainous parts of Bulgaria, the average annual values of the total solar radiation vary from 4000 MJ/m^2 to 4700 MJ/m^2 (up to 5000 MJ/m^2 in the southern parts of the country). In December as well as in January, the total solar radiation is 3-4% of its annual values. In the summer months (June, July and August) the total solar radiation is about 40-45% of the annual values.

During the winter, the average temperature in January is negative in the Danube Plain (from –2.3°C to about –1°C) and in the higher valleys of the West Central Bulgaria (below minus 2°C), and positive in the Thracian Lowland (0-1.5°C) as well as in the southern parts of Black Sea region (above 3°C). In the mountains, the temperature in January drops with altitude with 0.3-0.4°C per 100 m. The spatial distribution of average seasonal air temperature in the winter is shown on Fig. 1 (left panel).

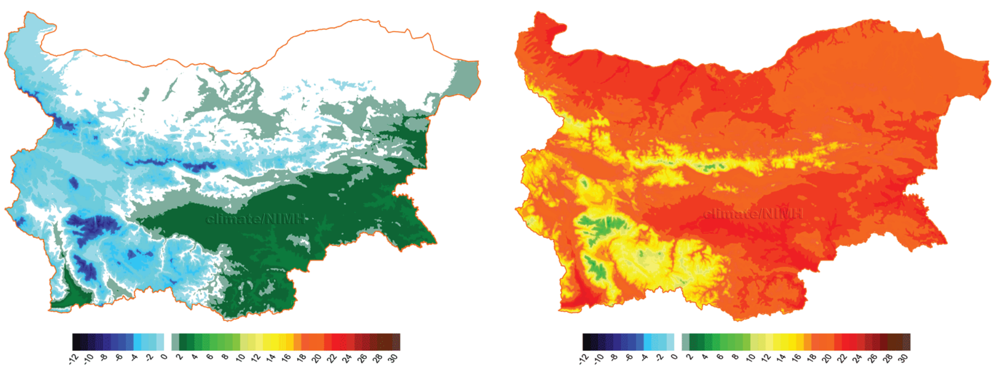

Fig. 1. Air temperature (°C) in the winter (left) and summer (right) during the current climate 1961-1990

In the spring, spells of warm and cold weather succeed each other because of the exchange of air masses from different origin. Foehn winds are often observed in Northern Bulgaria. Thermal differences between northern and southern parts of the country almost disappear except the southernmost parts. The average temperature in April is 10-13°C (greater than 13°C in the southern regions and lower than 10°C in the valleys). In the mountains, the temperature decreases with the elevation with 0.6-0.7°C per 100 m. Conditions for the onset of spring frost appear during the cold snaps, when the minimum temperatures even in the lowlands fall below 0°C.

During the summer, thermal conditions are dominated by the transformed Atlantic air masses with Azorean origin in the circumstances of intense solar radiation. The temperatures to the north and south of the Balkan Mountains are almost equal. The average temperature for July is 21-24°C in the Danube Plain, and 22-24°C in the Thracian Lowland. The average monthly temperature is around or less than 20°C in the high valleys of the West Central Bulgaria, 22°C in the Black Sea region and above 23°C in the southern regions (24-25°C along the Struma Valley). A marked decrease in the temperature with altitude is observed in the mountains (0.7°C/100 m). The spatial distribution of average seasonal air temperature in the summer is shown on Fig. 1 (right panel).

In the autumn, the transfer of cold air masses from north-west and north-east is registered more frequently. The barrier effect of the Balkan Mountains and southern mountains (Rila-Rhodope region) causes some differences in the climate between northern and southern parts of the country. The values of average monthly temperature in October are lowest in the Danube Plain (11-12°C) as well as in the high valleys of West Central Bulgaria (lower than 11°C). The autumn is warmer in the Thracian Lowland (above 12°C), on the Black Sea coast and in the southernmost regions (13-14°C). In the higher parts of the country the differences are not so obvious in comparison with the spring and summer and the temperature decreases with 0.5°C per 100 m.

Absolute maximum temperatures in the non-mountainous parts of Bulgaria are higher than 40°C (35°C for the Black Sea coast); the set up temperature record is 45.2°C in Sadovo, registered in 1916.

Absolute minimum temperatures range from –20°C to –30°C in the lowlands and from –15°C to –20°C in the coastal zone. The lowest air temperatures aren't measured in the mountains but in the plains. The set up record for absolute minimum air temperature is –38.3°C (Tran, 1947).

The annual course of precipitation is closely related with the peculiarities of atmospheric circulation over the country and strongly differs in the mentioned above climatic areas. Average annual values of precipitation alter from 450-500 mm in the Black Sea region and some parts of the Danube Plain and the Thracian Lowland to 900-1100 mm in the mountainous regions (Fig. 2). In the mountains, the annual amount of precipitation increases linearly with altitude up to 2000 m.

During the winter, in the Moderate-Continental climatic subarea, the precipitation amount is smallest – 18-20% of the annual sum (100-110 mm in the lowland parts and 190-200 mm in the highest parts of the mountains). In the Continental-Mediterranean climatic area, the winter precipitation amount is highest: 150-300 mm. In the spring, the rainfall in the Moderate-Continental subarea increases to 25-27% of the annual amount. More frequently are observed rains of convective type. In the regions with Continental-

Mediterranean climate, the precipitation decreases to 23-25% of the annual amount. In the Moderate-Continental climatic subarea, the precipitation maximum is during the summer – from 28-33% to 35% of the annual totals. The highest are the values in June (60-120 mm). In the regions with Continental-Mediterranean climate the summer rainfall is smallest: 100-160 mm or 20% of the annual amount but this value increases with the elevation. The end of the summer is a droughty period in the country, which persists sometimes until the mid-September. In October and November prolonged heavy rainfalls are observed, more frequently in Southern Bulgaria. In the regions with Continental-Mediterranean climate seasonal precipitation represents 26% of the annual amount; in the regions with temperate continental climate this value is smaller than the precipitation amounts in the spring and summer. The maximum 24-hour rainfall can reach more than 200-250 mm.

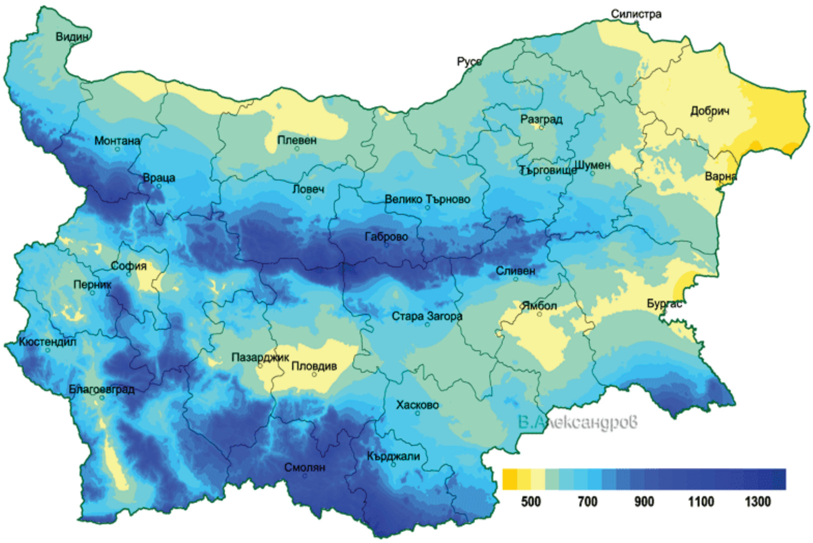

Fig. 2. Annual precipitation amount (mm) during the current climate 1961-1990

The snow cover in Bulgaria is characterized by marked variability in time and space. In the lower parts of the country, it forms and disappears several times per season (the average depth is about 10-15 cm per season). Rarely, the snow cover depth could reach 30-40 cm in the coastal region, above 60-70 cm in Dobrudzha and above 100-110 cm in the Danube Plain. In the mountainous areas the maximum of snow accumulation shifts with altitude from the end of January until the beginning of March. In the hilly parts (500-800 m) the accumulation of snow begins in December; for the high parts (1000-1500 m) – even in November. The average snow cover depth in the lower parts of the mountains is 25-30 cm in January and February. The maximum values can reach to 200 cm and more in the highest parts in March and April, when the maximum accumulation is observed.

The prevailing winds are north-west/west and north-east (in some southern parts of the country). Several regions could be outlined with relation to the average annual wind speed. The first one includes lowland parts, where the average wind speed does not exceed 2 m/s (with maximum in February/March and minimum in September/October). The second region comprises the north-eastern parts of the country and the unsheltered low mountainous regions (up to 1000 m), where the average annual wind speed is 2-4 m/s (with maximum in February-March and minimum in August-September). The third region consists of unsheltered and deforested mountainous regions over 1000 m, where the wind speed exceeds vastly 4 m/s, with an annual maximum in February and minimum in August. Among the local winds, the most characteristic are the breeze (3-5 m/s), mountain-valley winds (3-6 m/s), katabatic winds (Sliven's wind with velocity more than 15 m/s) and foehn winds (10-20 m/s).

3.2. Main climatic characteristics in the period 1988-2016

Since the middle of 1980s, the tendency of the average annual air temperature in Bulgaria is towards warmer climate (Fig. 3). In the period 1988-2016, the average annual air temperature for the lower part of the country (for areas up to 800 m altitude) is increased on average with 0.8°C relative to the climatic normal for the reference period 1961-1990 and ranges between 10.6°C and 13.0°C. The tendency in the long-term variations of the average annual air temperature remains positive. In fact, the annual temperature anomalies are positive from 1997 to now. Moreover, they are equal or exceed 1°C for the all years after 2007 (except 2011). Since the beginning of 21st century, 2015 appears as the warmest year (1.6°C above the climactic normal in the areas up to 800 m altitude); in Northern Bulgaria – 1.8°C above the normal (Fig. 4). Warmest months are November, July and January, with deviations from the monthly normal +3.2°C, +2.7°C and +2.6°C, correspondingly.

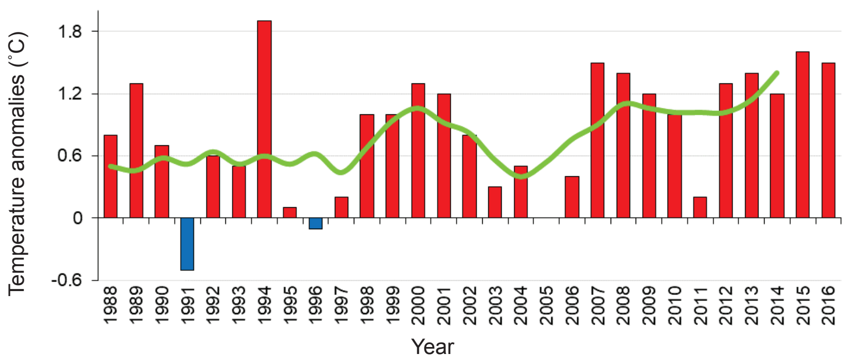

Fig. 3. Anomalies of annual temperature in areas up to 800 m altitude for the period 1988-2016 relative to the period 1961-1990

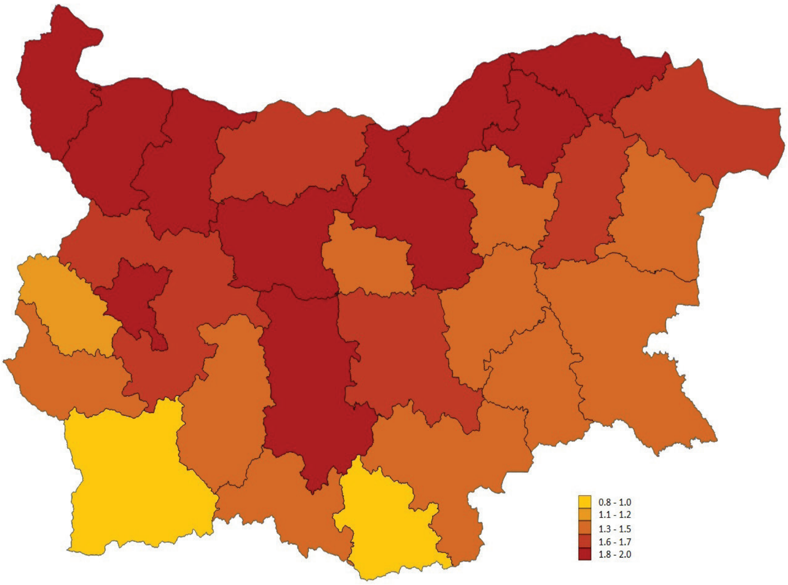

Fig. 4. Deviations of annual average air temperature (°C) in areas up to 800 m altitude for 2015 relative to the climatic normal for the period 1961-1990 (averaging by districts)

Climate in Bulgaria became not only warmer but also drier at the end of the 20th century. During the last decade however, precipitation totals have increased (Fig. 5) but heavy rainfall events caused severe floods damaging various socioeconomic sectors. 2014 is the rainiest year in the whole period 1988-2016 (Fig. 6). The average annual precipitation amount is 1013 mm for the areas up to 800 m altitude that is more than the previous reached maximum of 924 mm in 2005. Most rainy months are September (902% of the monthly normal in Asenovgrad), October (487% in Avren, Varna district) and December (370% in Silistra). In 2014, in the period April-October, have been measured extreme 24-hour rainfall amounts. The largest value of 245 mm (Burgas district) ranks 2014 among the seven years in the period 1988-2014 with extreme 24-hour precipitation above 220 mm.

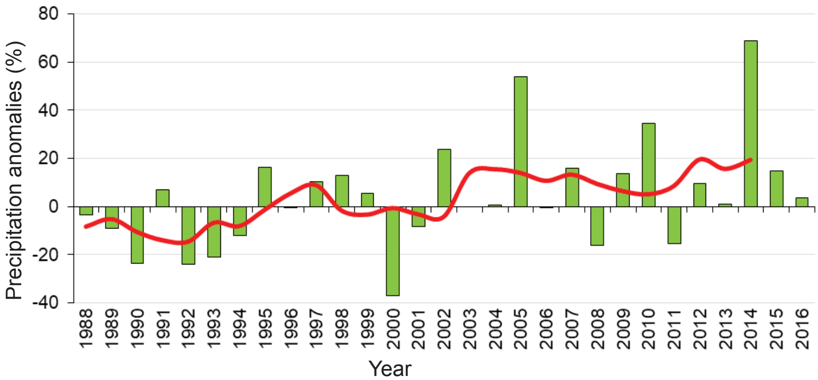

Fig. 5. Anomalies of annual precipitation in areas up to 800 m altitude for the period 1988-2016 relative to the period 1961-1990

During the period 1988-2016 the decreasing trend of the average maximum snow cover depth in the upland areas (800-1800 m altitude) is retained, as in 2014 was reached the lowest value of this indicator – 24 cm. Excluding 2012, the snow cover persistence decreased considerably in the last years (Fig. 7).

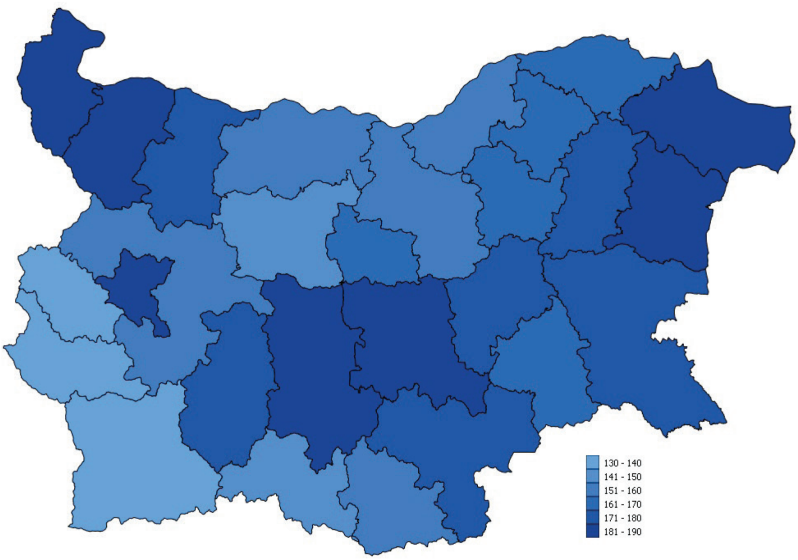

Fig. 6. Deviations of annual precipitation (%) in areas up to 800 m altitude for 2014 relative to the climatic normal for the period 1961-1990 (averaging by districts)

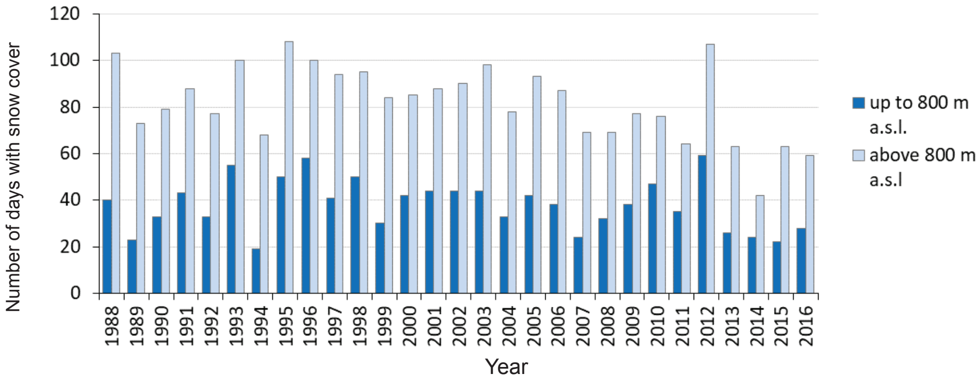

Fig. 7. Snow cover persistence in the period 1988-2016

3.3. Climate change and extreme events

Weather and climate extremes have increased during the last decades, as shown on Fig. 8. In line with the tendency of global warming, one of the basic indicators of winter severity – number of ice days – has diminished with over 25% in all climatic subareas in the period 1971-2010, compared to the period 1931-1970 (Fig. 8a). Since the middle of 1990s, recurrent disastrous situations, mainly related to the development of powerful convective storms, brought to economic losses and human casualties. Especially, in 2014 dangerous weather phenomena of convective origin such as intense heavy rains, thunderstorms, and heavy hails (often accompanied by strong wind gusts) caused human victims and serious damage to agricultural production, infrastructure, and buildings in many areas of the country.

During the period 1991-2014 the intra-annual distribution of number of days with convective precipitation ≥ 60 mm/24h, registered at least in 4 districts shows the increasing trend (Fig.8b). Shift of the maximum in the distribution of heavy rain days connected with thunderstorms during the periods 1991-2002 and 2003-2014 is observed. While during the first period the greatest number of heavy rain days is observed in July, in the second period such type of precipitation more frequently occurred in September and October, where their increase is about 30-100%. Furthermore, increasing in frequency of the heavy rain episodes in all months from June to October (except July), as well as in the cold season months December and March, is observed in the period 2003-2014.

During the period 1991-2014, the annual number of days with convective precipitation ≥ 60 mm/24h has shown a positive tendency in almost all regions of the country. The increasing in the number of convective heavy rain days is statistically significant for North East (NE), South Central (SC) and South West (SW) Bulgaria (Fig. 8c).

In the period 1988-2016, about 75% of all hail events occur during the period April-July (with maximum in May and June), more frequent in western and central south parts of the country, nearby to the mountains because of the favourable orographic conditions for development of convective processes. The largest number of days with hail precipitation is registered in 2014, followed by 2005. In comparison with the period 1961-1990, the number of days with wide-spread hail precipitation (observed in at least 4 districts) also has increased, reaching maximum value in 2014 (Fig. 8d).

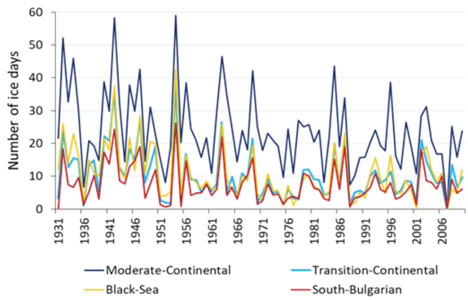

Fig. 8a. Number of ice days (daily $T_{max} < 0°C$) during the cold season (November-March)

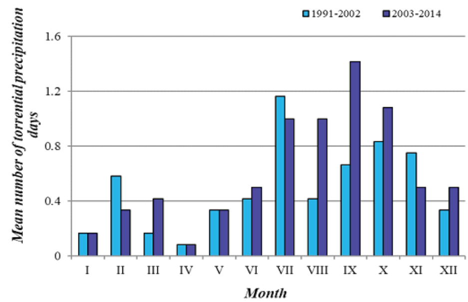

Fig. 8b. Intra-annual distribution of torrential precipitation days

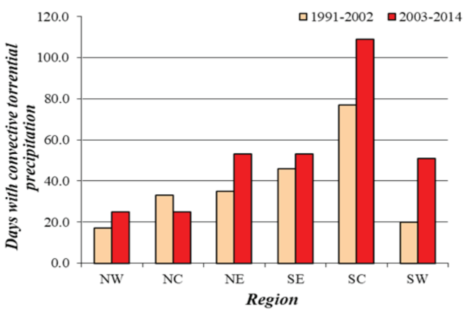

Fig. 8c. Distribution of days with convective heavy rainfall by regions

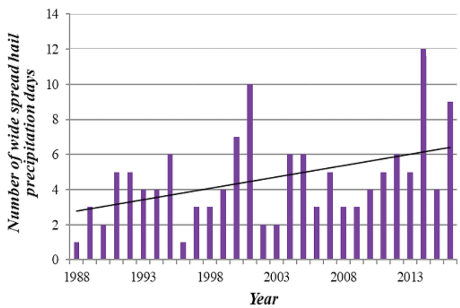

Fig. 8d. Number of wide-spread hail precipitation days

Fig. 8. Changes in the rate of extreme weather events

4. BRIEF CLIMATIC ASSESSMENT OF 2017

In 2017 the mean annual air temperature for the lower parts of Bulgaria (up to 800 m altitude) increased on average with 1.2°C relative to the climatic normal that arranges the year among the hottest since 1980. According to the deviation from the monthly normal, the warmest month was March (+1.7°C to +5.6°C), followed by December (+1.3°C to +4.6°C) and August (+0.5°C to +3.9°C). The coldest month was January with deviations from –6.1°C to –2.1°C.

Winter season was –1.2°C colder than normal, after cold December 2016 (with deviations down to –2.7°C in North Bulgaria and –3.9°C in South Bulgaria) and 7-day cold spell in January (06-13.01.2017). Minimum temperatures in January 2017 in some parts of West Bulgaria were close to the absolute minimum possible at least once in 50 years (–26°C in Kyustendil and –27°C in Pernik). The extremely cold weather in January 2017 in Bulgaria was caused by the advection of a pool of cold air from northern Russia to the southwest at the first decade.

Low temperatures come after the heavy snowfall developed over the relatively warm Mediterranean Sea when a compact low pressure system forms in the region. Snow cover held over whole month in many regions. This development was linked to the amplification of a ridge over the north-eastern Atlantic and of a trough downstream. Later the trough formed a cut-off low over south-eastern Europe and prolonged cold spell in Bulgaria till 12-13 January (Fig. 9).

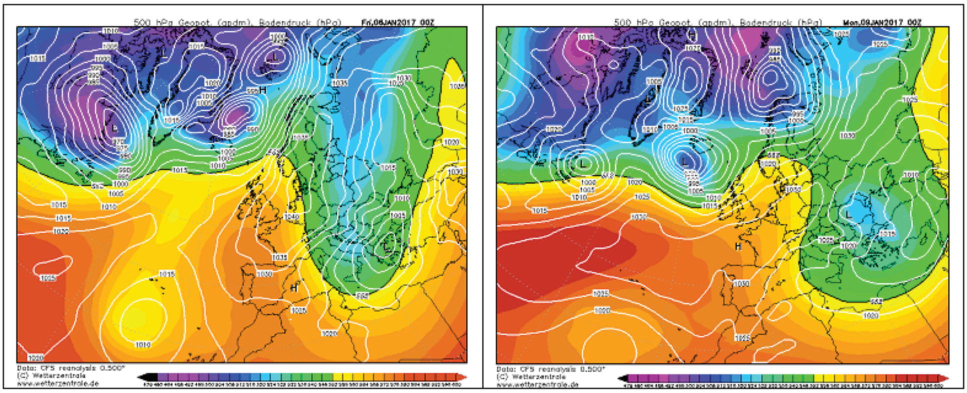

Fig. 9. Sea-level pressure (white contours), height of the 500 hPa surface (colors) on 6 and 9 January 2017. Source: NOAA/NCEP via http://www.wetterzentrale.de

Spring was +1.1°C warmer than normal. After warm March, the season continued with slightly negative anomaly in April (–2.5°C to +1.3°C) and positive in May (–1°C to +1.5°C).

Summer anomalies reached +4.6°C in North Bulgaria in June and +3.9°C in South Bulgaria in August during two severe heat waves: 1) from 20.06 to 2.07.2017 with maximum temperature up to 42.5°C in Sandanski and 43.6°C in Ruse; 2) in the period 30.07-13.08.2017 in South Bulgaria (40.8°C in Sandanski), and from 30.07 to 07.08.2017 in North Bulgaria (40°C in Vidin).

Prolonged heat waves (up to 13 days) are caused by combinations of different synoptic situations. Mainly the heat waves persist from 3-4 day during SW (South-West) advection up to 5-6 days during radiative overheating. During the first part of the period 20.06-02.07.2017 the active frontal zone in the upper air is moved to the north. Positive radiation balance during sunny days in a low-gradient anticyclone field causes radiative overheating and heat wave for 5-6 days. The temperature on 850 hPa over whole Southern Europe during this period increased up to 20-22°C (Fig. 10). Gradually the atmospheric circulation was transformed and during the second part of the period a deep trough over Western Europe in the upper air and low pressure over Northern Europe caused prolonged advection of warm air from SW. The air temperature on 850 hPa additionally is increased up to 24-26°C.

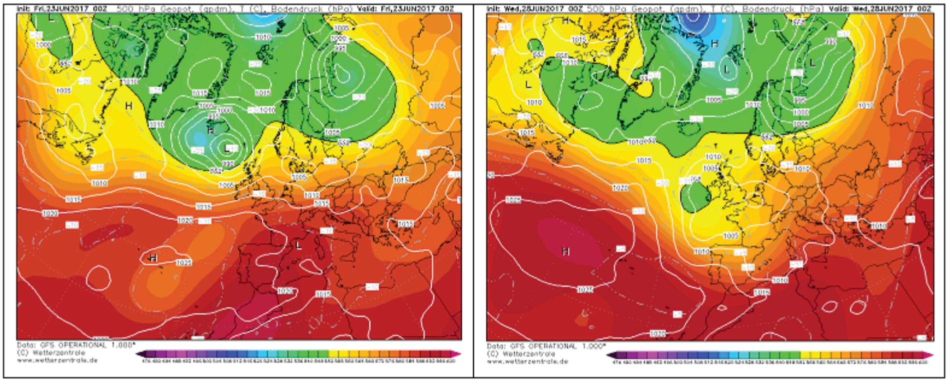

Fig. 10. Sea-level pressure (white contours), height of the 500 hPa surface (colors) on 23 and 28 June 2017. Source: NOAA/NCEP via http://www.wetterzentrale.de

Autumn was +1.2°C warmer than normal in North Bulgaria and +0.9°C – in South Bulgaria. December 2017 was warm with deviations of +3.1°C on average in North Bulgaria (+4.6°C in Knezha), and +2.3°C on average in South Bulgaria (+3.6°C in Kotel).

Average annual precipitation in areas up to 800 m altitude was mostly near-normal despite the small parts of South-Central and South-East Bulgaria (with annual totals up to 160% of the 1961-1990 normal). Seasonal precipitation amounts were: 80% of climatic normal in the winter, 108% in the spring, 100% in the summer, and 154% in the autumn. Considerable spatial variability of deviations from monthly normal was registered on the territory of the country. January was not only very cold but also very snowy month with positive precipitation anomalies, especially in East Bulgaria (257% in Omurtag, North-East Bulgaria; 287% in Sredets, South-East Bulgaria). The snow cover reached 1m in Isperih, North-East Bulgaria. The rainiest month was October with average precipitation about 2.5-3 times more than monthly normal (692% in Karnobat, Burgas district).

The year was marked by a number of extreme weather events (Fig. 11). Severe convective storms, associated with hail and strong winds hit northwestern and northcentral parts of the country on 3 July. In some meteorological stations more than 4 hail-fall events were registered in the time interval 00:00-05:45 local time. In Mezdra and Levski the giant hail stones with size up to 8 cm were observed.

Very warm weather in August led to occurrence of fires in different regions of Bulgaria. The most destructive of them was those nearby Kresna in South-West Bulgaria in which more than 1300 ha of pine plantations and deciduous stands was destroyed. According to expert analysis more than 50 years will be necessary to restore the forest.

Torrential precipitation with duration more than 30 hours caused local floods in the southeastern parts of Burgas district in September. More than 10 villages were flooded. In Gramatikovo, the 24-hour precipitation amount of 198 mm was measured on 27 September, which was 4 times over the monthly normal.

3 July: Radar image from BAHS radars | **28 August:** Fire near Kresna (Source: Darik.news) | **25 October:** After heavy rain in Burgas district (Source: BNT 1)

Fig. 11. Notable extreme weather events in 2017

In the end of October, again in Burgas district, a prolonged 20-hour heavy precipitation led to overflowing dams and rivers, local floods, great damages on infrastructure and 4 victims. In Karnobat, 24-hour precipitation amount of 178 mm was measured on 25 October (460% of monthly normal).

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