



Brief climate analysis and extreme weather events in Bulgaria during 2022

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Abstract: This review paper presents a brief analysis of climate conditions and extreme weather events in Bulgaria in 2022 based on observations from the meteorological, hydrological, and agrometeorological networks of the National Institute of Meteorology and Hydrology (NIMH). Other sources of information are also used in the complex assessment of extreme events in the country. Our analysis shows that 2022 was the 4th warmest since 1930. The average annual precipitation was around 20% below the climate norm without considerable difference between North and South Bulgaria. From the hydrological point of view, 2022 was characterized as a dry year with a total annual volume of river runoff in the country about 35% less than the previous year. The agrometeorological conditions of 2022 were determined by frequent and sharp fluctuations in temperatures and the amount of precipitation in individual months and seasons. The vegetation season was marked by heat stress on crops, a prolonged drought during the summer that extended into the autumn, and periods of frost in the spring, which caused damage to orchards. The high-impact weather events were associated with severe convective storms and intense precipitation, as well as prolonged agrometeorological drought during the summer and autumn months.

Keywords: climate analysis, heavy precipitation, floods, drought

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1. INTRODUCTION

This review paper summarizes the analyses prepared by NIMH as a country-level contribution to two annual publications supported by the World Meteorological Organization (WMO). The first one, State of the Climate in 2022 (https://ametsoc.net/sotc2022/SOTC2022_FullReport_final.pdf), is a comprehensive annual summary of the global climate published as a supplement to the Bulletin of the American Meteorological Society (BAMS). The second publication summarizes the state of the climate and high-impact weather events during the year for the WMO RA VI (Europe and Middle East) domain (WMO, 2023). Since 2021, the WMO RA VI State for the Climate has been a practically joint publication with the European Centre of Medium-Range Weather Forecasts (ECMWF) and the European Union's Copernicus Climate Change Service.

The analyses presented in the Annual Hydrometeorological Bulletin of NIMH for 2022 are also taken into consideration (<https://bulletins.cfd.meteo.bg/>).

Globally, the year 2022 was either the 5th or the 6th warmest year on record despite the cooling effect of La Niña. The years from 2015 to 2022 were the eight warmest years on record in all data sets (WMO, 2023). In Europe, the annual average temperature was between the 2nd and 4th highest on record, depending on the data set used, and summer was the warmest. In many countries in western and southwestern Europe, 2022 was the warmest year on record. Meanwhile, precipitation levels were below average across much of the region. High-impact weather and climate events during the year were connected mostly with exceptional heat waves and wild-fires during the summer (to which about 16000 fatalities across Europe were attributed). Additionally, severe convective storms led to local floods caused by intense rainfall and strong winds. In the context of this wide variety of climate events on the continental scale, the paper aims to contribute to a clearer understanding of the climate's state and extreme climate events in Bulgaria during 2022.

2. DATA AND METHODS

The brief annual and seasonal climate analysis was prepared using data from 43 synoptic and 74 climatological stations from the meteorological network of NIMH (Figure 1).

In the long-term historical analyses, we consider the period since 1930 because, from this year, the stations in the meteorological network of Bulgaria have a sufficiently good spatial distribution and are representative of all climatic regions of the country. Temperature and precipitation normals are defined as the 1991-2020 averages. The ranking in the warm/cold or wet/dry categories (at a yearly, seasonal and monthly scale) since 1930 is based on the country-averaged mean air temperature and precipitation totals, while detailed analysis is focused on averages for the low part of the country (up to 800 m altitude) where the populated areas are mainly located.

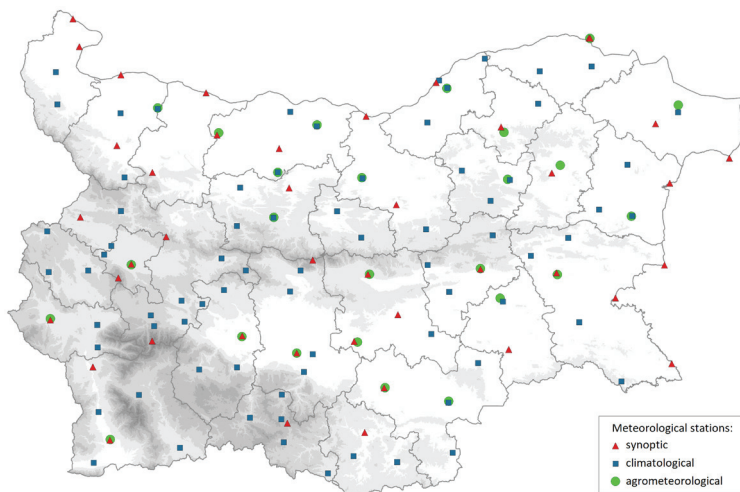


Fig. 1. Spatial distribution of the meteorological stations used in the survey: synoptic (red triangles), climatological (blue squares) and agrometeorological (green circles)

3. TEMPERATURE AND PRECIPITATION

The average annual air temperature in 2022 was 12.1 °C (+ 0.82 °C above the norm), making it the 4th hottest year since 1930 (Figure 2). According to the monthly temperature anomalies, the warmest month was December (the 4th warmest since 1930), with a deviations range (+1.9 °C to +5.5 °C), followed by November (+1.0 °C to +4.1 °C) and February (+0.4 °C to +4.0 °C). The coldest months were March (−4.2 °C to −1.1 °C), September (−2.0 °C to +1.4 °C) and April (−1.9 °C to +1.7 °C).

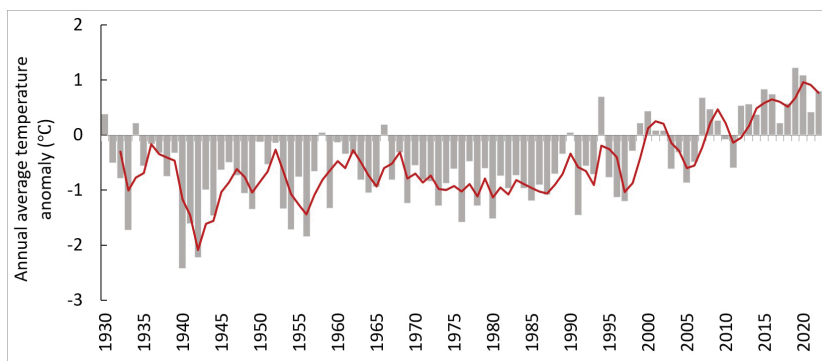


Fig. 2. Deviation of the country averaged mean annual air temperature in the period 1930-2022 from the climate norm

The winter was the 9th warmest since 1930, with a temperature anomaly of +1.8 °C. December 2021 was +1.9 °C warmer in North Bulgaria (+3.3 °C in Krushari, Dobrich District) and +1.8 °C in South Bulgaria (+3.0 °C in Elhovo, Yambol District). January and February 2022 were also warmer than normal, especially in North Bulgaria. The average anomaly for North and South Bulgaria was +1.9 °C and +0.8 °C in January, respectively, and +2.6 °C and +1.5 °C in February. The lowest minimum temperatures were measured during the cold spell on 20-26 January (−25 °C in Tran, Pernik District; −23 °C in Sevlievo, Gabrovo District).

Spring was cold (−0.8 °C below the norm). After the cold March, with an average anomaly of −2.6 °C, the season continued with about normal temperatures in April and May. The number of Ice days in March was comparable to that in January for the lower parts of the country (8 vs. 11 days on average). Negative deviations in daily minimum temperature retained almost until the end of the month. The lowest temperatures for the season were measured during the second decade of March in South Bulgaria (reaching below −15 °C in Pernik District).

Summer was the 6th warmest since 1930, with anomalies of +1.0 °C in North Bulgaria and +0.7 °C in South Bulgaria. June and July were the 7th and 10th warmest since 1930, respectively. However, negative deviations were registered in particular low-mountainous regions (−1.2 °C in Elena, Veliko Tarnovo District), as well as in the eastern part of the country. August was +1.0 °C warmer than normal (+1.3 °C in North Bulgaria and +0.8 °C in South Bulgaria on average). The largest positive anomalies occurred in East Bulgaria (+3.4 in Sungurlare, Burgas District), while the negative deviations predominated in South-West Bulgaria.

Autumn was the 8th warmest since 1930, with an average deviation of +1.1 °C. September was slightly cooler than normal. The largest negative anomalies occurred mainly in the low-mountainous regions and southwestern parts of the country (−2.0 °C in Teteven, Lovech District). October was warmer than normal, with +0.9 °C, but the negative anomalies were retained in some areas. November was the 7th warmest since 1930, with an average deviation of +2.5 °C. Although the first 4-5 days were like summer ones, the maximum temperatures remained far from last year's records. The highest temperature was measured in Sadovo, Plovdiv District (31.4 °C).

The average annual precipitation for the areas up to 800 m was around 80% of the climate norm without considerable difference between North and South Bulgaria (Figure 3). Seasonal precipitation amounts were 87% of the norm in the winter, 77% in the spring, 104% in the summer, and 79% in the autumn.

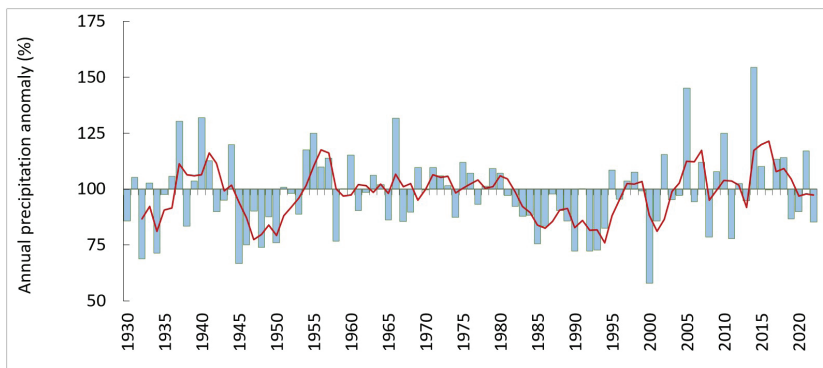


Fig. 3. Deviation from the climate normal of the country-averaged annual precipitation for the period 1930-2022.

The rainiest month of 2022 was June, with precipitation averaging 141% of the monthly norm (up to 474% in Koprivlen, Blagoevgrad District). Wetter months were also April and August, with an average anomaly of 133% and 129%, respectively. The driest months were October (14% of the monthly normal on average), March (40%) and July (42%).

Regarding the winter of 2021-2022, December 2021 was the wettest month (9th wettest since 1930), with precipitation ranging from 70-80% to over 300% of the monthly norm. Precipitation in January 2022 was around half the normal in nearly the entire non-mountainous part of the country (in some places, below 20% of the monthly norm). Although the precipitation in February was close to normal, it remained below normal in parts of the Danube plain, the valleys south of the Balkan and individual places in South-West Bulgaria. The highest 24-hour precipitation amount of 160 mm was measured in the region of Kardzhali on December 12, 2021.

Spring was the 11th driest since 1930, and March had been one of the driest for the last ten years (40% of the monthly norm on average). April was rainy (about 130% of the monthly norm). In May, precipitation varied significantly, ranging from as low as 4-5% to over 200% of the monthly norm. The precipitation deficit in May was more pronounced in the Black Sea coastal zone and central parts of the country. The highest 24-hour precipitation amount was measured in Smolyan District on May 29, 2022 (113 mm, rain and hail).

Precipitation in summer was around normal despite significantly lower amounts in July (in most of the country, monthly totals did not exceed 50% of the norm). In general, the precipitation deficit in July was more pronounced in East Bulgaria. In June and August, monthly precipitation ranges from 40-50% to over 300% of normal. Heavy rains led to flooding in some areas. The largest 24-hour rainfall was recorded in the region of Sliven on June 11 (100 mm).

During autumn, precipitation is around and below the climatic norm, with a distinct precipitation deficit in South-East Bulgaria. In some areas, mainly in the western part of the country, rainfall in September was 2-4 times above the norm, while in the southeast, it was below normal. Heavy rains led to severe flooding and the declaration of a state of emergency in some municipalities. October was a very dry month (6th driest since 1930). Precipitation in South-East Bulgaria and along the Black Sea coast was below 10% of the monthly norm, and in West Bulgaria – below 50%. In November, precipitation was around and above the norm for almost the entire territory of the country, but in some places (mainly in the southern part of the country and along the Black Sea coast), the precipitation remained below normal. The 24-hour precipitation amount of 164 mm, measured in Rozino, Plovdiv District, on September 2, was the largest for the autumn.

The precipitation deficit accumulated in October and November in some eastern and southern regions of the country was worsened by below-normal rainfall in December.

4. EXTREME WEATHER EVENTS

4.1. Hot and cold spells, drought and agrometeorological impact

The winter of 2022 is the ninth warmest winter since 1930 – for the low part of the country, the average deviation from the norm is +1.8 °C. There were no prolonged cold spells, except from January 20-26, when the lowest temperatures of the season were recorded (–25 °C in Trun and –23 °C in Sevlievo). March was very cold, with an average anomaly of about –2.6 °C. Minimum temperatures remain below normal almost until the end of the month. The lowest temperatures were measured in southern Bulgaria in the second ten days of March (below –15 °C in Pernik region).

The summer of 2022 is the sixth warmest summer since 1930. Hot spells, with maximum daily temperatures of 32 °C and more, were registered from mid-July to the second decade of August (12-14 days in North Bulgaria and 26-32 days in South Bulgaria). The highest temperature was measured in Ruse (42.0 °C on July 24).

November was the seventh warmest November since 1930 (for the low part of the country, the average deviation from the norm is +2.5 °C). Although the first 4-5 days felt almost like summer, the maximum temperatures did not reach the records set the previous year. The highest measured temperature was 31.4 °C (in Sadovo).

Hot spells are defined as periods with maximum air temperature $\geq 32, 34, 36, 38$ and 40 °C with a corresponding duration of at least 6, 5, 4, 3 and 2 consecutive days. This climate indicator describes the extreme heat in the country well by estimating its intensity and duration. In recent decades, there has been a clear tendency towards increasing the frequency of hot spells (Malcheva et al., 2021; 2022).

According to the analysis of the Copernicus Climate Change Service, the summer of 2022 was the hottest in the entire history of meteorological measurements across much

of Europe (<https://climate.copernicus.eu/esotc/2022/extreme-heat>), with prolonged periods of unusually high temperatures. In Bulgaria, the summer of 2022 in terms of heat intensity is comparable to the summer of 2019, but is far from the extremes of 2000, 2007 and 2012.

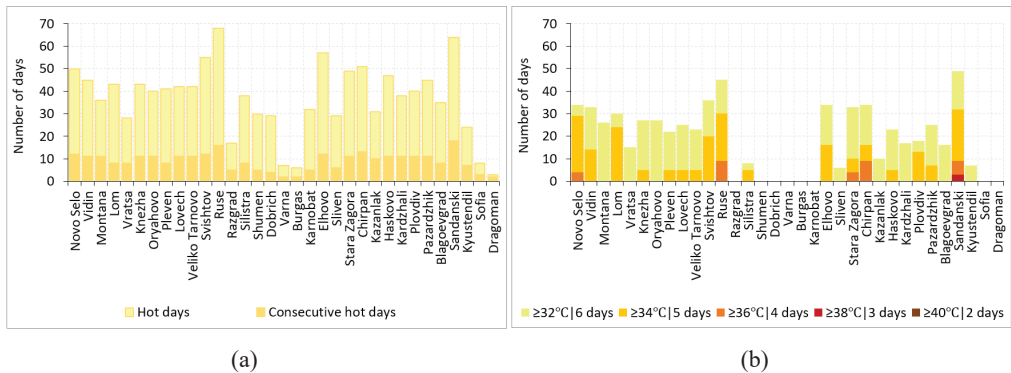


Fig. 4. Hot weather indicators calculated by data of 33 synoptic stations: (a) number of hot days and maximum number of consecutive hot days; (b) hot spells duration at different thresholds

The average number of hot days for the low part of the country is 31, and the average maximum number of consecutive days with hot days is 8 (Figure 4a). The respective maxima of 76 and 30 days were reached in the Petrich region. The total duration of hot periods with temperatures ≥ 32 and 34°C on average for the country is 15 and 6 days (Figure 4b). Hot periods with temperatures $\geq 36^{\circ}\text{C}$ were recorded in the Danube Plain and the Upper Thracian Plain (4-5 days) and along the Struma Valley (7-10 days). Summer temperatures reached their highest values on July 23-24, when two-day periods with temperatures $\geq 40^{\circ}\text{C}$ were recorded in separate places (in Plevna and Plovdiv regions).

During all three spring months, severe drought was observed in particular regions, but in general, the southwestern and central parts of the country were most seriously affected. The Standardized Precipitation Index (SPI) calculated for a 3-month accumulation period outlines the same parts of the country as the mainly affected by drought from March to May (Figure 5a). The unusual spring drought also affected agriculture, with soil water deficits limiting winter and early spring crops.

In April, frosts were registered in the northern part of the country, and during the first ten days of May in the northeastern part, which caused damage to the orchards. In the period June 14 – August 20, an agrometeorological drought lasting between 40 and 71 days affected around 780 000 ha in various regions of the country (99 500 ha in North-East Bulgaria, 407 600 ha in South-East Bulgaria, 213 000 ha in central areas, and 65 000 ha in western and northwestern parts of the country). The unfavorable phenomenon had a negative effect on the development of spring crops and their yield (Figure 5b).

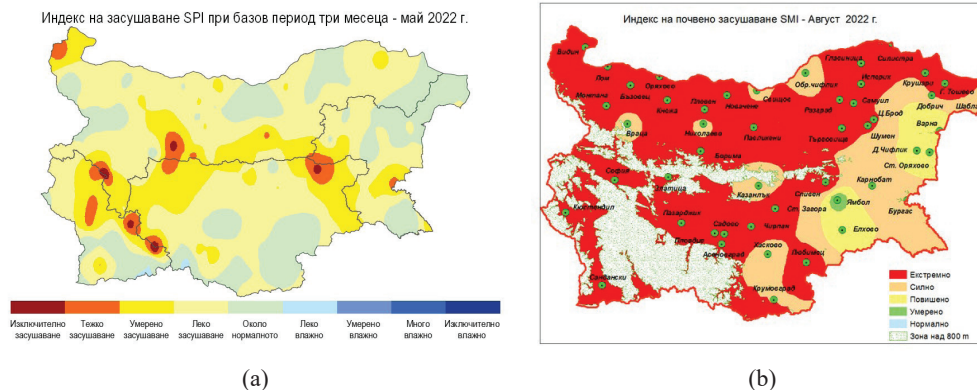


Fig. 5. Spatial distribution of drought indices on the territory of the country: (a) 3-month SPI for May 2022; (b) SMI for August 2022 (more information and archive of drought indices maps for recent 12 months is available at: www.hydro.bg)

4.2. Heavy precipitation and floods

The weather was extremely dynamic for almost the entire month of June 2022, with frequent thunderstorms accompanied by local torrential rain, strong wind and hail. In different areas of the country, they caused floods, destruction of agricultural production and damage to infrastructure, buildings and vehicles.

On June 10, severe thunderstorms, accompanied by intense rainfall, caused a flood in Gorna Oryahovitsa, North Central Bulgaria, where more than 30 reports were obtained for flooded homes and public buildings. After the intense rainfall on the night of June 11, the Botunya River overflowed and flooded part of the town of Varshets, North West Bulgaria. On June 12, a partial state of emergency due to the heavy rains was also declared in Tryavna city, North Central Bulgaria.

Due to intense rainfall in the afternoon hours of August 22, many streets and buildings were flooded in Karlovo, Plovdiv District. A partial state of emergency has been declared in the city. The next day, intense rain again flooded streets and buildings. The total two-day precipitation amount was over 350% of the monthly norm. More than 40 houses, shops and administrative buildings were flooded (the High School for Railway Transport was the most damaged). Stara River overflowed its bed and caused damage to the streets and houses.

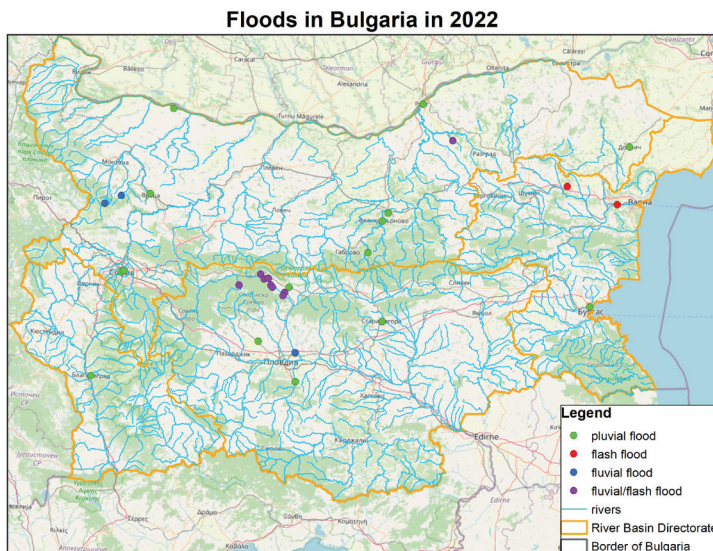


Fig. 6. Recorded floods in Bulgaria in 2022.

On September 2 and 3, heavy and intensive rainfall in the upper part of the watershed of the Stryama River (around the village of Klisura, Plovdiv District) formed high waves in the mountainous part of the tributaries. They swept away trees, timber and stones from the slopes and were carried by the streams until they reached the most affected villages: Bogdan, Karavelovo, Stoletovo, Rozino and Slatina. In these villages, most of the infrastructure and many houses were destroyed or inundated with a mixture of water and mud. At least 150 people were displaced. An emergency situation was declared in the municipality of Karlovo. Along the lower part of the Stryama River, the high wave overflowed the dikes and flooded arable land and part of Trilistnik village. The return period of the high wave formed along the Stryama River is estimated to be around 600 years. The 24-hour rainfall amounts, measured on 02.09.2022 in Rozino (164 mm) and Klisura (156.5 mm), were the biggest ever measured in this area (the return periods are estimated to be 441 years and 609 years, respectively). The damages are for more than 30 million Euro. There are 342 destroyed buildings, and 60 cars vanished; 150 000 m² street pavement was destroyed, and 7 bridges were damaged.

It can be summarized that 31 floods were recorded on the territory of Bulgaria in 2022 following the methodology described by Balabanova et al. (2019). They were registered in May (2), June (12), August (4) and September (13). The floods can be divided by type into four groups: fluvial floods – 3 (blue dots on Figure 6), flash floods – 2 (red dots on Figure 6), pluvial floods – 17 (green dots on Figure 6), and fluvial floods combined with flash floods – 9 (violet dots on Figure 6). As a result of significant amounts of rainfall, a larger number of floods were recorded in the periods June 10–12 and September 2–3.

4.3. Strong wind events and severe convective storms

In the meteorological stations of NIMH, days with strong winds in a large part of the territory of the country were registered mostly during the spring and autumn months of 2022, and significant damages were reported in several of them.

On March 31 and April 1, strong winds with gusts of over 40 m/s caused damages in some districts in North-West Bulgaria. A partial state of emergency was declared in Vratsa. Fallen trees, damaged cars, partially destroyed roofs, etc., were reported. Also, there were damages from wind gusts in Sofia, Haskovo and several other cities.

On April 11, a strong wind with gusts reaching up to 28 m/s knocked down trees and damaged building facades in Sliven area.

On October 1-2, a cold atmospheric front passed over the country. The wind from the west-northwest increased to stormy with gusts of 24-28 m/s and caused damages in many areas, such as demolished fences, uprooted trees, blown metal roofs and power outages.

From the second half of May to the end of June 2022, the weather was extremely dynamic, with frequent thunderstorms, hail and intense rainfall leading to local floods and damages in many parts of the country. During June, flashes of lightning burned three roofs and caused damage to buildings and property in different regions of the country.

On May 28-29, series of strong convective storms with a duration of 15-25 minutes caused significant damage in some areas in South Central Bulgaria. Large hail, the size of a tennis ball, hit the towns of Zlatograd and Madan (and five more villages in the Smolyan District) on May 28 and the villages of Orizari and Sborishte in Sliven District on May 29. In the affected areas, the hail completely destroyed crops, more than 100 cars were damaged, and more than 10 people were injured. Photovoltaic panels, windows and roofs were also damaged. Intense hail formed more than 20 cm of ice in the region of Zlatograd.

On June 6, a strong storm with extremely intense precipitation, hail and squall was recorded in Ruse in the early morning hours. According to information from the synoptic station in the city, an amount of precipitation of about 35 mm was recorded in 20 minutes, the size of the hailstones was about 3 cm, and the wind gusts exceeded 20 m/s.

5. CONCLUDING REMARKS

This review paper is aimed at a wide range of readers interested in the special climatological features of 2022 in Bulgaria. The analyses show that 2022 is one of the warmest years since 1930 in our country, with an average annual temperature of 0.82 °C above the norm. Annual precipitation was about 20% below the norm. The year was warmer but with less precipitation than in 2021 (Bocheva et al., 2022). The number of extreme weather events in 2022 is moderately high, as in all previous years since the

beginning of 21st century. The most significant severe events were connected with heavy precipitation and local floods. They caused the greatest damage in the warm half of the year, especially in June, August and September, while damages from strong wind events were more significant during the spring and autumn months. There were cold spells again in April. During the late spring and summer, severe convective storms often led to local floods and other damages in different regions of the country.

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