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Comparative analysis of temperature and precipitation changes in the city of Shumen for the periods 1971-1980 and 2013-2023

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Abstract: *The main climatic elements and meteorological phenomena in the area of the meteorological observatory in the city of Shumen were studied for the periods 1971-1980 and 2013-2023. A detailed analysis of changes in temperatures and precipitation has been carried out, revealing the trends in their changes. Significant differences in temperature were found between the warm and cold part of the year. For the period 1971-1980, the average January temperatures are from -3.0°C to $+2.5^{\circ}\text{C}$, and the average June temperatures from $+18.4^{\circ}\text{C}$ to $+21.3^{\circ}\text{C}$, while for the period 2013-2023 they are, respectively, the average January temperatures from -2.8°C to $+5.7^{\circ}\text{C}$, and the average June temperatures from $+19.1^{\circ}\text{C}$ to $+22.3^{\circ}\text{C}$. Temperature analysis reveals warmer months of January and June for the period 2013-2023. The average annual temperature for the period 1971-1980 is $+10.73^{\circ}\text{C}$, while for the period 2013-2023 it is $+12.48^{\circ}\text{C}$, i.e. for the second period an increase of 1.75°C is reported. The average maximum monthly temperatures for the city of Shumen for the period 1971-1980 in the summer range from $+17.6$ to $+21.8^{\circ}\text{C}$, while for the period 2013-2023 they are from $+19.1$ to $+24.6^{\circ}\text{C}$, i.e. for the second period, an increase of about 2°C is reported. The same trend is observed for the average annual temperature amplitudes, which in the period 1971-1980 were from 20°C to 24.4°C , while for the period 2013-2023. are from 19.9°C to 25.8°C . The average annual precipitation for both periods is approximately the same (1971-1980 - 608.64 mm; 2013-2023 - 648.89 mm), but by year in the period 2013-2023 there are very large differences - from 418.4 mm (2019) to 1185.4 mm (2014). Four years of the 2013-2023 period: 2019, 2020, 2022, and 2023 can clearly be identified as years of significant drought. The complex analysis of the climate of the city of Shumen allowed in the final part of the study to draw conclusions about the prevailing types and classes of weather.*

Keywords: Shumen, climate, temperature, precipitation, regional change

Introduction

The interest of scientists of different fields towards the quick climate changes in the last few decades has been consistently growing.

The scientific studies of climate change can be divided into three categories - global, regional and local. While global studies are dominant, regional and local studies are fewer and are mostly on separate climate elements. Moreover, the regional and local studies on climate change for periods of a few decades and by seasons are relatively scarce.

The transitional geographic placement of Bulgaria in terms of the main distribution of air masses over Europe creates a good opportunity to instrumentally note the quick climate changes on the Balkan Peninsula in a relatively shorter period.

The study presented is on the climate changes in the area of Shumen city in the periods of 1971-1980 and 2013-2023 and includes an analysis of the main elements of climate – air temperature and precipitation. The results obtained are also compared to earlier periods in time so the tendencies in the changes of these elements can be highlighted more clearly. The suggested study can be defined as a local climate study on the quick changes of the local climate in Shumen city.

The object of the study is the climate of Shumen city and the subject of study are the peculiarities in the changes of precipitations and the temperatures in the hydrometeorological observatory in Shumen in the periods of 1971-1980 and 2013-2023. The Hydro-meteorological Observatory in the town of Shumen (Fig. 1) is a part of the national network for hydro-meteorological measuring of the National Institute of Meteorology and Hydrology (NIMH). Administratively, Hydro-meteorological Observatory in the town of Shumen (HMO-Shumen) is under the direct control of the Hydro-meteorological Observatory in the city of Varna.



Figure 1. The Hydro-meteorological Observatory in the town of Shumen (coordinates: 43°16'46"N ; 26°56'38"E) <https://wikimapia.org/14769689/>

Shumen city is placed in the Northeast, the East and the Southeast foot of the Shumen plateau at an average altitude of 200-220 meters. The hydrometeorological observatory is placed in the Northeast foot of the plateau on an even terrain with an absolute altitude of 219 meters.

The main aim of the current study is to clarify the development of the main climate indicators – precipitations and temperatures, which form the climate of Shumen city.

The study was conducted by using different methods and approaches: mainly the genetic, the systematic approach, and the leading method is the comparative geographic method with which we compare certain geographic characteristics of climate with the goal of determining the degree of difference or similarity.

Different statistical meteorological data of the HMO-Shumen have been used while studying the components of the climate in the region of Shumen. The processing of the meteorological data was done by using complex analysis and the mathematically statistical method.

In order to achieve the goals of the study, the following tasks have been defined:

- To analyze the role of the local natural and geographic environment as a predisposition for the formation of a specific topoclimate in the region of Shumen city.
- To track and analyze the temperature of air and the quantity of precipitations recorded in the station in Shumen by defining the tendencies of the changes.
- To track and analyze the extreme air temperatures and the extreme quantities of precipitations that were measured in the meteorological observatory in Shumen.
- To study the availability or the unavailability of snow coverage, the appearance of winds and other typical climate components.
- To formulate scientifically backed conclusions of the typical peculiarities of the change of the local climate in Shumen city in the periods of 1971-1980 and 2013-2023 through a complex analysis of the collected information.

Geographic placement of the studied region and atmospheric circulation

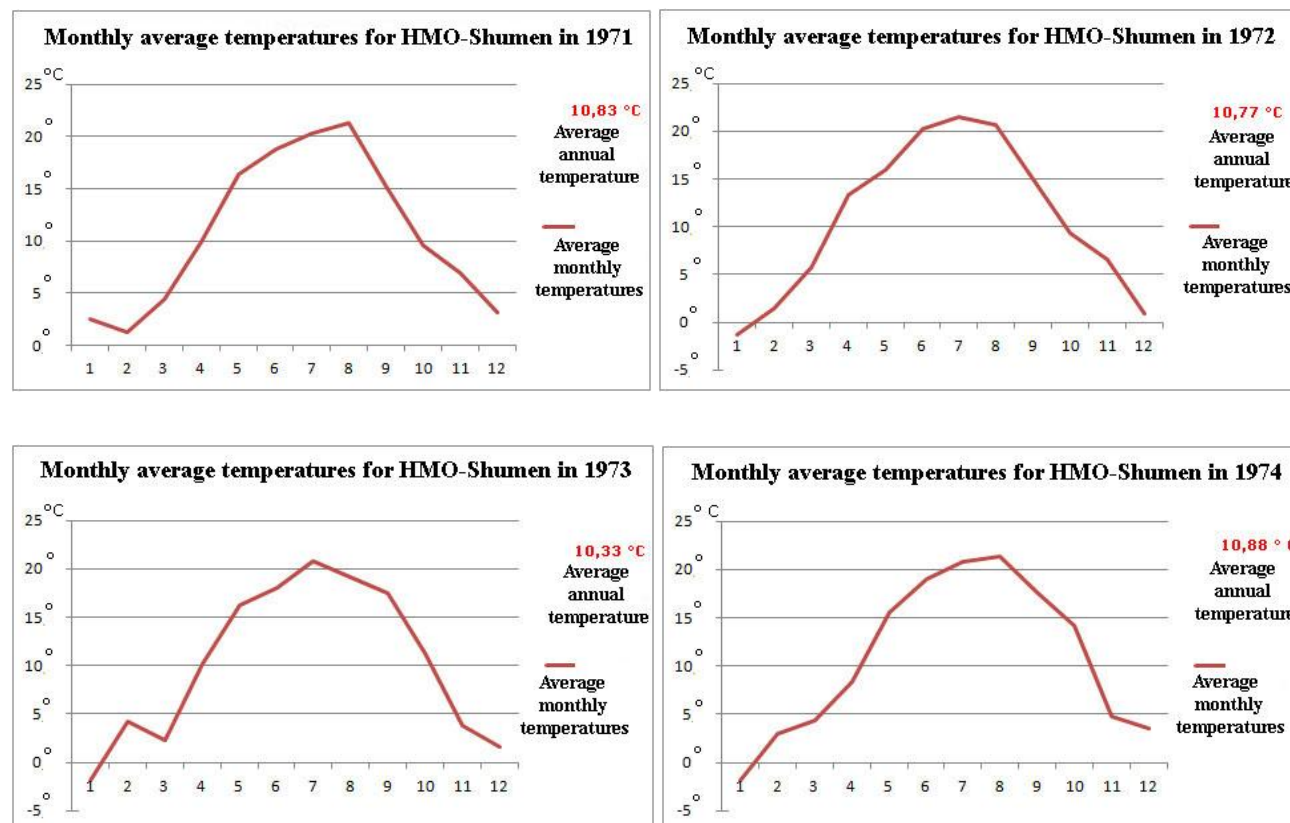
The studied region is located in Northeast Bulgaria. The following big positive forms of relief play a role of defining the specific topoclimate: The Shumen plateau (peak Tarnov tabiya, 501.9 m a.s.l.), The Razgrad Heights (peak The Big Linden, 481.8 m a.s.l.), The Samuilovo Heights (peak Captain Petkov Sart, 441 m a.s.l.), The Provadiya plateau (peak Two Mounds, 429.8 m a.s.l.), the Voyvodsko plateau (peak Kodzhayuk, 475.8 m a.s.l.), The Royaksko plateau and the Preslav-Dragevo mountain (peak Golyama Vashkadalnitsa, 429.8 m a.s.l.). The listed forms of relief surround the studied region and affect the atmospheric circulation in this part of the Middle-European temperate continental climatic region.

The climate in the area of Shumen is formed mainly by transformed ocean air masses, which come in mainly from northwest and west (more rarely from north and northeast), and by continental air masses that are formed over the Balkan Peninsula. The entrance of arctic air masses in the winter half year and tropical air masses from the South is also common and their frequency and intensity decreases in North Bulgaria. In the area of the studied region, the continentality is relatively well pronounced and it gradually decreases when heading south.

Air temperature

In the region of Shumen, there are significant temperature differences between the warm and the cold part of the year, which is also common for other places from the temperate geographic widths. The average yearly temperatures of the coldest winter month – January, are between -0.8°C and -1.6°C in the flat and the hilly lands of North-East Bulgaria [1].

For HMO-Shumen the average January temperatures for the period of 1971-1980 vary between -3.0°C and $+2.5^{\circ}\text{C}$ and the average June temperatures – between $+18.4^{\circ}\text{C}$ and $+21.3^{\circ}\text{C}$ (Fig. 2). In 1971-1980, the average yearly temperature amplitudes for North-East Bulgaria are in the range of $23-25^{\circ}\text{C}$, while in Shumen the average temperature amplitudes for the same period have a higher value – from 20°C to 24.4°C [4].



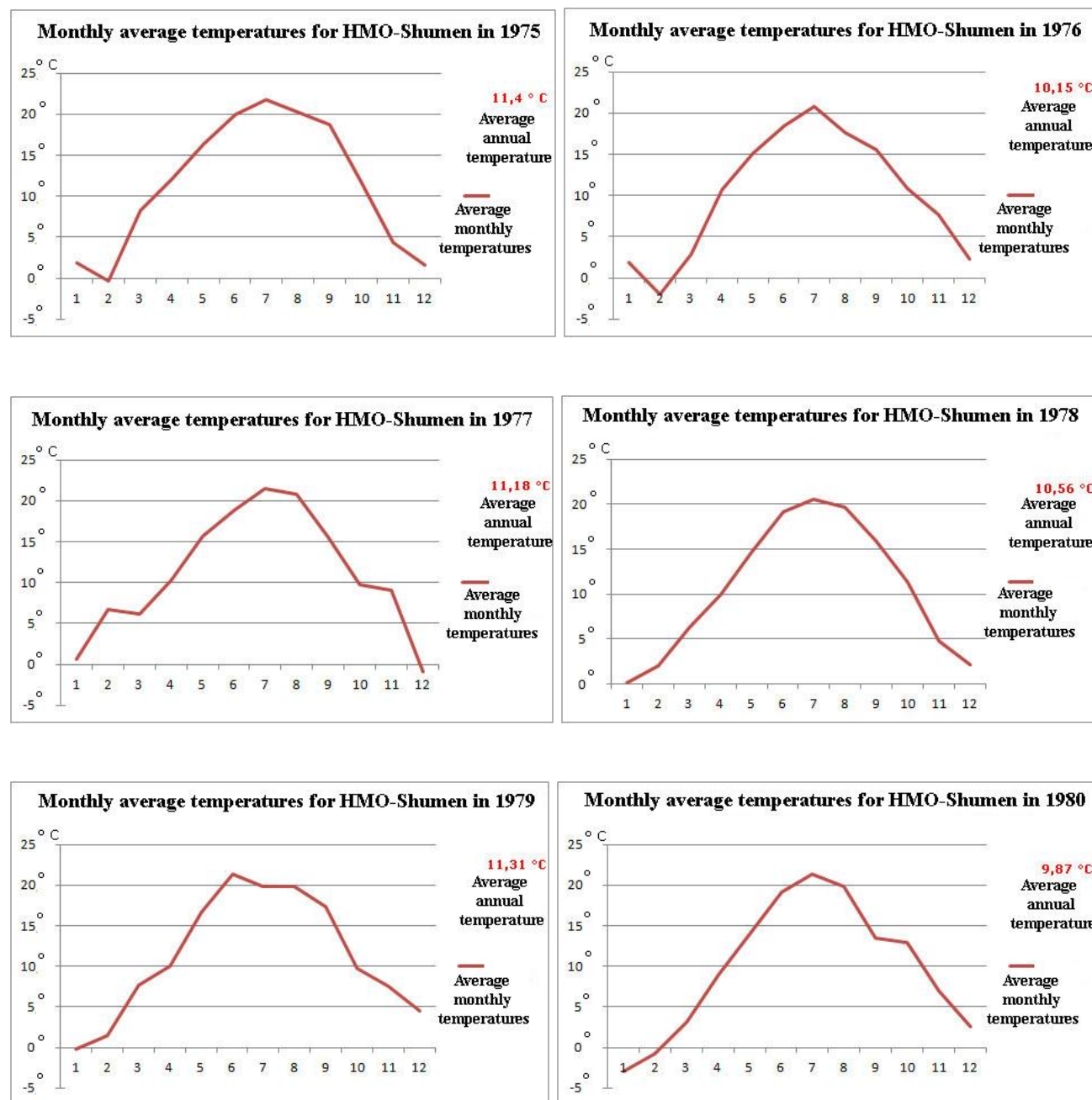
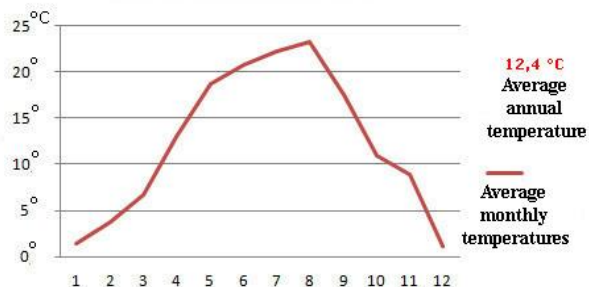


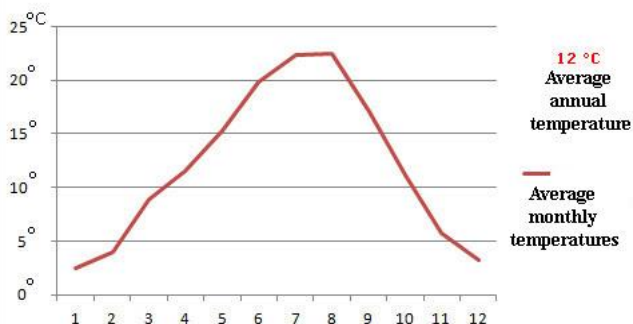
Figure 2. Average monthly and average yearly temperatures of HMO-Shumen in the period 1971-1980

In the period of 2013-2023 the average January temperatures were from +2.8°C up to +5.7°C and the average June temperatures - from +19.1°C to +22.3°C (Fig. 3).

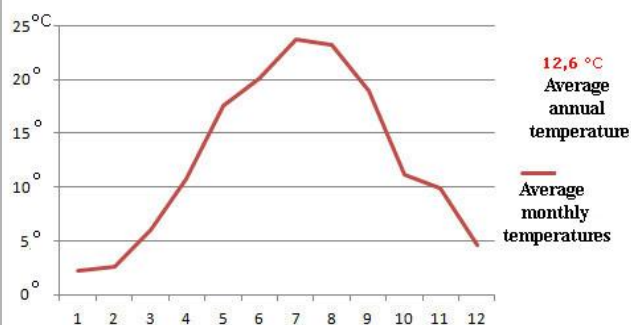
Monthly average temperatures for HMO-Shumen in 2013



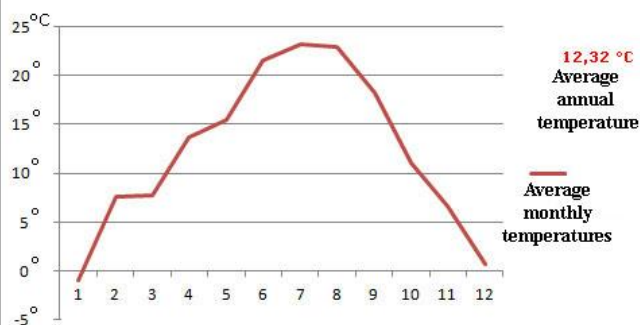
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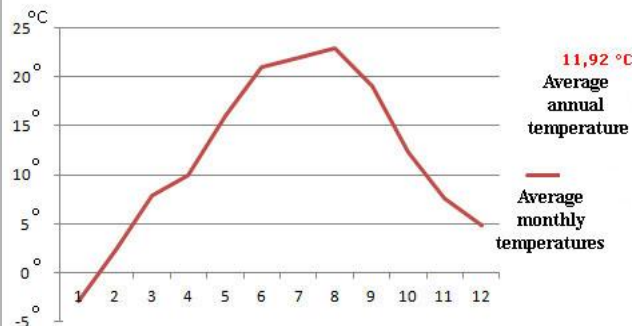
Monthly average temperatures for HMO-Shumen in 2015



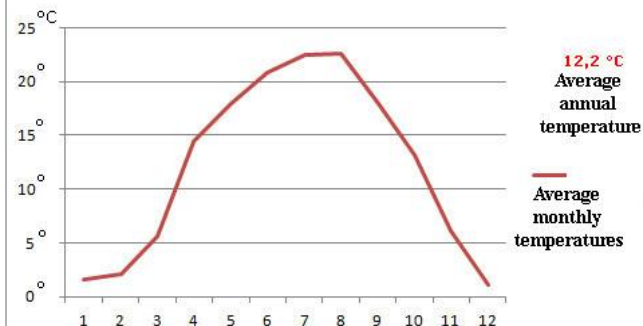
Monthly average temperatures for HMO-Shumen in 2016



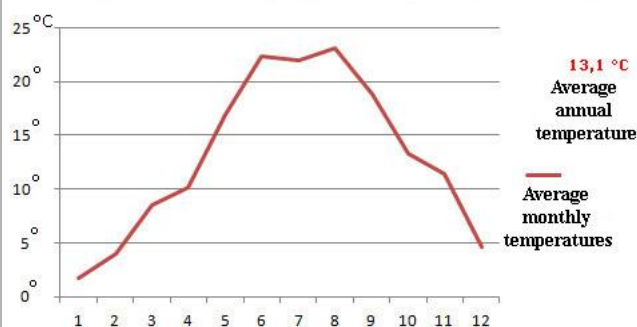
Monthly average temperatures for HMO-Shumen in 2017



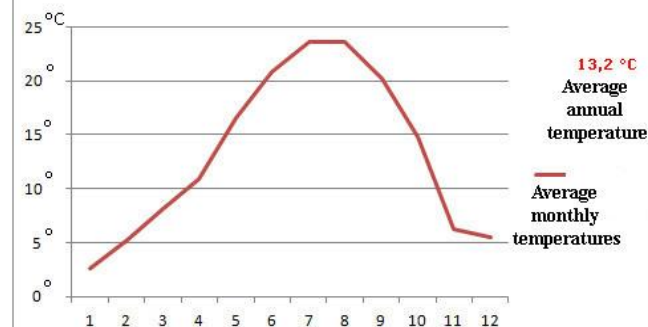
Monthly average temperatures for HMO-Shumen in 2018



Monthly average temperatures for HMO-Shumen in 2019



Monthly average temperatures for HMO-Shumen in 2020



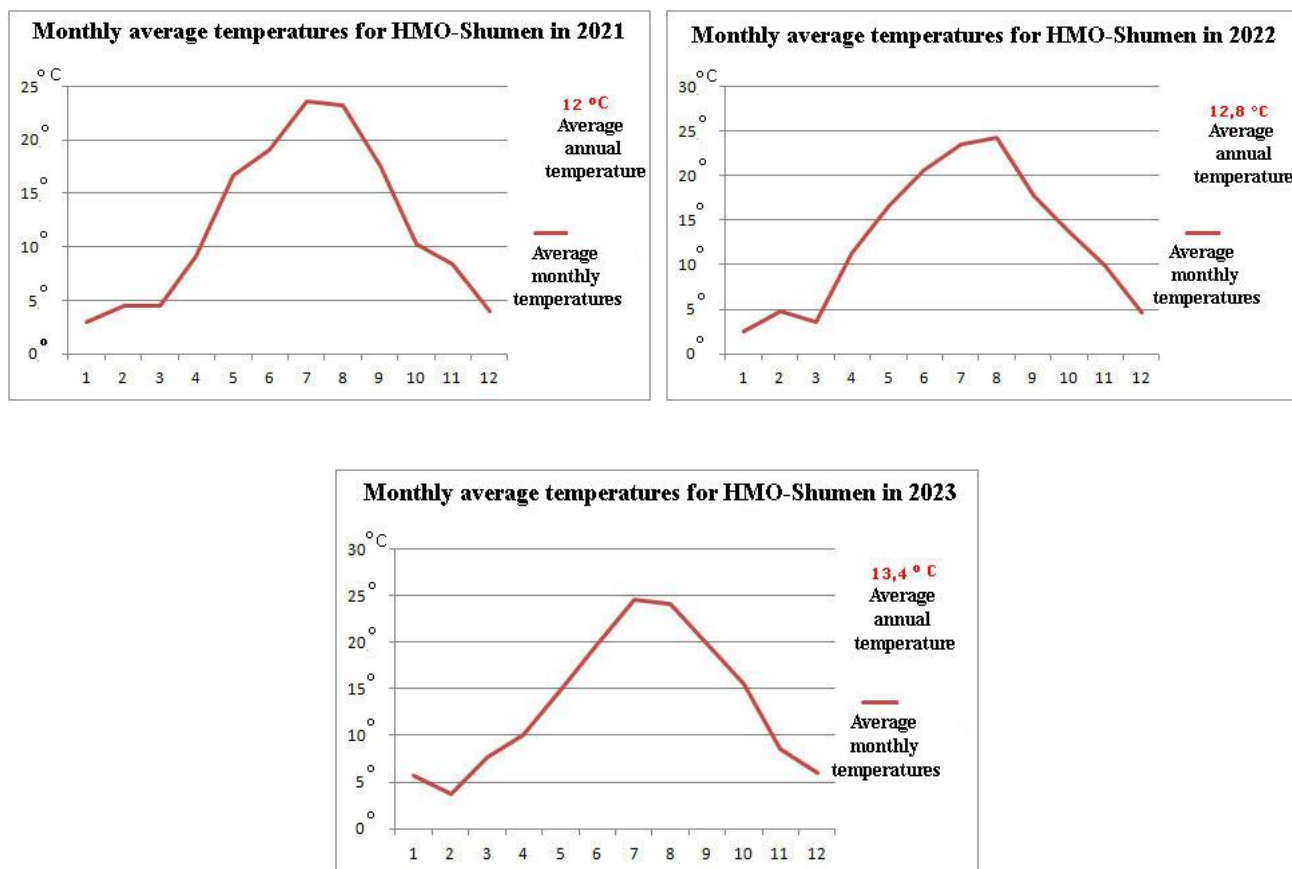


Figure 3. Average monthly and average yearly temperatures of HMO-Shumen in the period 2013-2023

The yearly temperature amplitudes for the area of HMO – Shumen in the period of 2013-2023 are in the range of 19.9°C to 25.8°C [3]. The analysis of the temperatures shows that the months of January and June have been significantly warmer in the period of 2013-2023 in comparison to the temperatures in the period of 1971-1980.

A similar correlation is noted for the average yearly air temperature as well – for the period of 1971-1980 it was +10.73°C while in the period of 2013-2023 it was +12.48°C, which means that a significant increase of the average yearly temperature of 1.75°C has been noted for the second period for such a short timespan [3, 4].

This is an important proof of the warming up of the climate in Shumen during the last decade. In comparison, the average yearly air temperature in the period of 1916-1965 was between +10°C and +11°C. [1].

The average date of transition of temperature with a sustainable retention of the average daily temperatures above +10°C for Northeast Bulgaria varies in the range of 5-10 days. The average starting date

of the period for the western parts of Northeast Bulgaria is 10th-15th of April and for the Eastern – 15th-25th of April. For the region of HMO-Shumen, the sustainable retention of the average daily temperatures above +10°C happens around 15th-20th April. In the month of May, in the area of Shumen city, the average daily temperatures are already steadily over +15°C [1].

The average maximal monthly temperatures for the station of Shumen in summer for the period of 1971-1980 vary between +17.6°C (August 1976) to up to +21.8°C (July 1975), while for the period of 2013-2023 they are from +19.1°C (June 2021) to up to +24.6°C (July 2023). [3,4] The same tendency can be noticed in the average yearly temperature amplitude in both periods as well. The average maximal summer temperatures in the period of 1916-1965 were from +35 °C up to +36°C [1].

Precipitations

In order to uncover the tendencies in the changes of precipitation, a detailed analysis of the monthly average sums of precipitations and the yearly average sum of both periods has been conducted as the values have been compared to the period of 1931-1985 (Table 1).

Table 1. Average monthly sum of precipitations /in mm/ in HMO–Shumen /1931-1985, 1971-1980, 2013-2023/

Period/ Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1931-1985	39	38	36	53	65	78	57	45	32	44	53	57
1971-1980	28,54	35,76	36,86	53,67	83,96	86,91	67,64	54,09	42,08	40,59	46,56	31,98
2013-2023	55,26	45,62	58,8	80,79	64,16	81,92	52,65	42,9	43,32	46,25	62,65	44,94

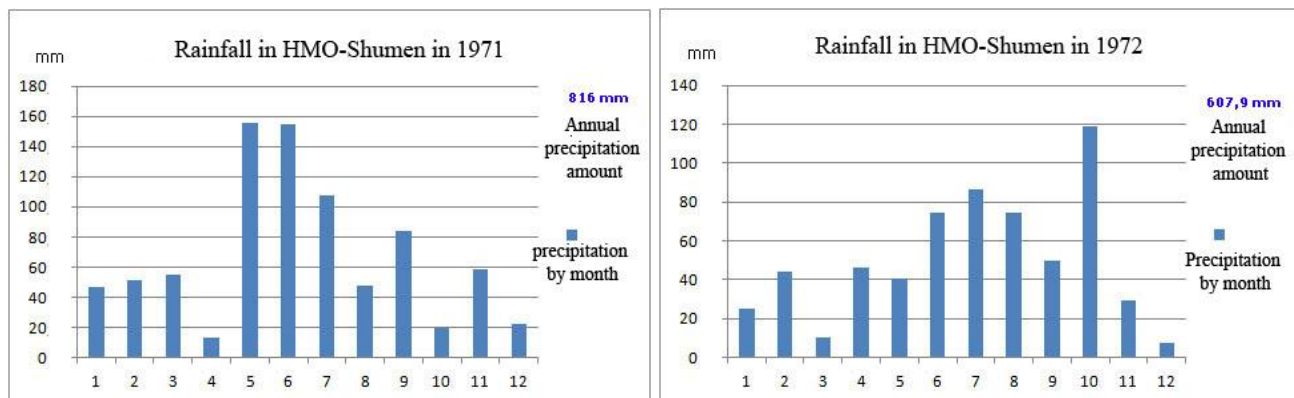
The average monthly sum of precipitation by seasons for the region of Shumen in the period of 1931-1985 is as it follows: winter – 134 mm; spring – 154 mm; summer – 180 mm and autumn – 129 mm [2].

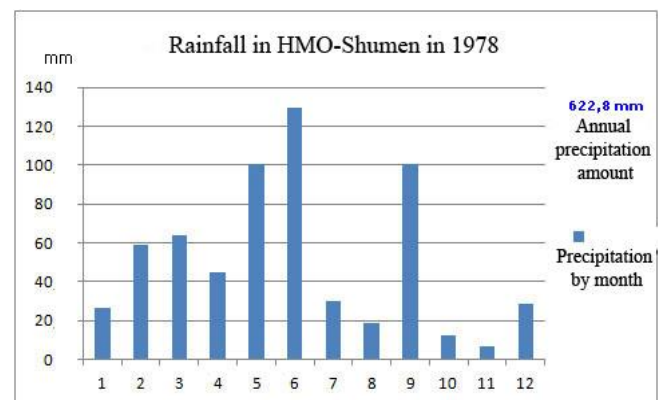
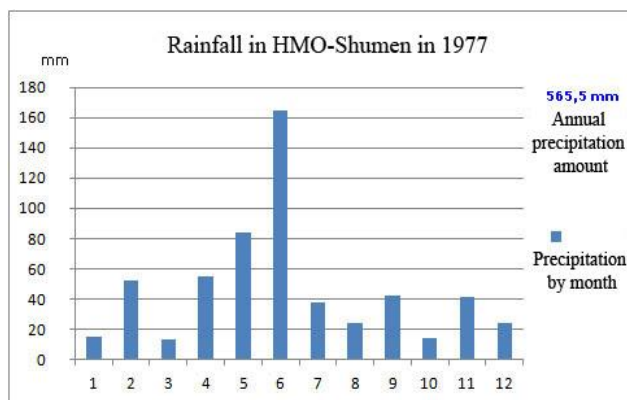
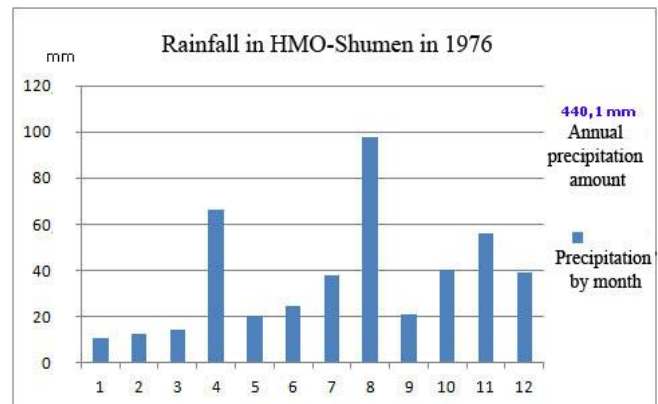
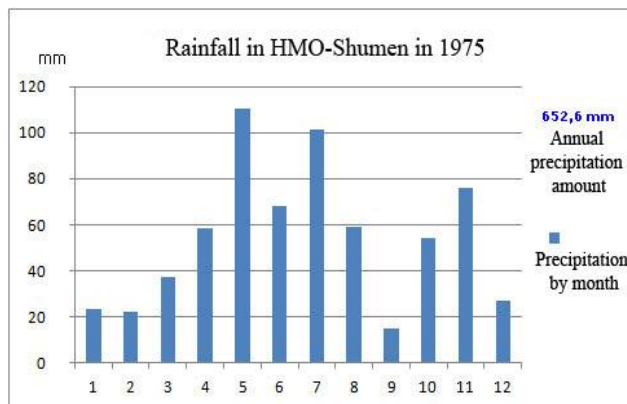
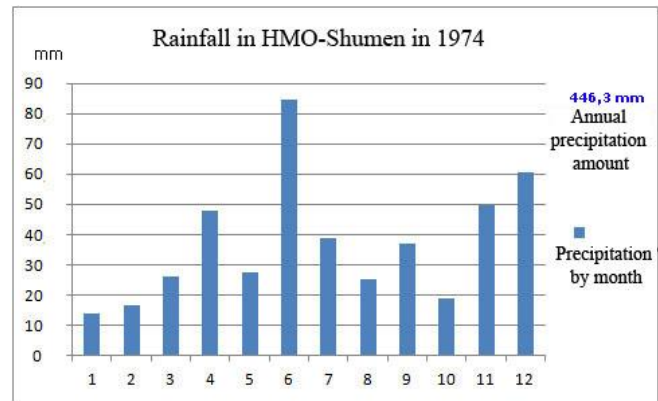
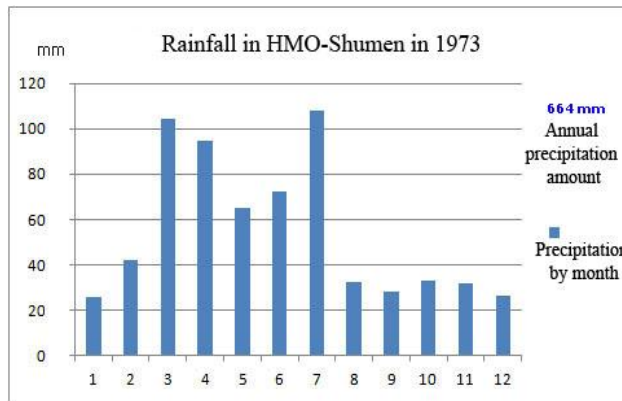
The average yearly precipitations for both periods are almost identical (1971-1980 – 608.64 mm; 2013-2023 – 648.89 mm) (Table 2) but in the latter period, for the time from 2013 to 2023, big differences in the sum of the yearly precipitation's quantities can be noted – from 418.4 mm in 2019 to up to 1185.4 mm in 2014. This peculiarity confirms the global tendency for the more frequent appearance of different precipitation situations in different years on the same territory and logically, more significant quantity differences of the fallen precipitations [3, 4].

Table 2. Sum of precipitations in years and average sum of precipitations by periods /in mm/
in HMO–Shumen /1931-1985, 1971-1980, 2013-2023/

Year/ Period	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1971- 1980	1931- 1985
Precipitation amount /mm/	816	607,9	664	446,3	652,6	440,1	565,5	622,8	691,8	579,4	608,64	597
Year / period	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2013- 2023
Precipitation amount /mm/	705,7	1185,4	632,9	609,4	686,7	759,5	418,4	442,9	698,3	427,6	571	648,89

For precipitations of the two periods studied, the yearly precipitation sums are almost identical. In the period of 1971-1980 (Fig. 4) the average yearly sum of precipitations was 608,64 mm and for the period of 2013-2023 – 648.89 mm [3, 4]. Those precipitation quantities aren't significantly different in value from the period of 1896-1965 when the average sum of precipitations was 627 mm [1].





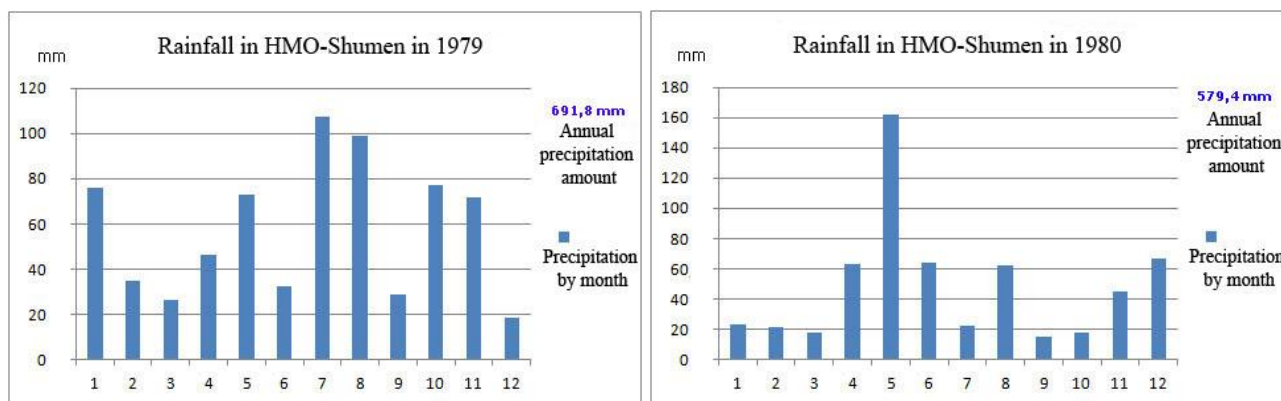
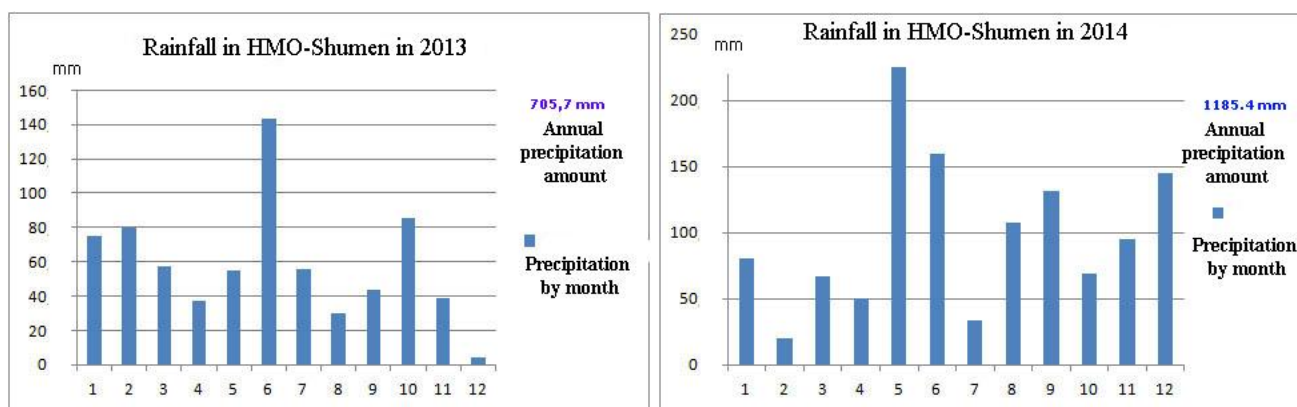
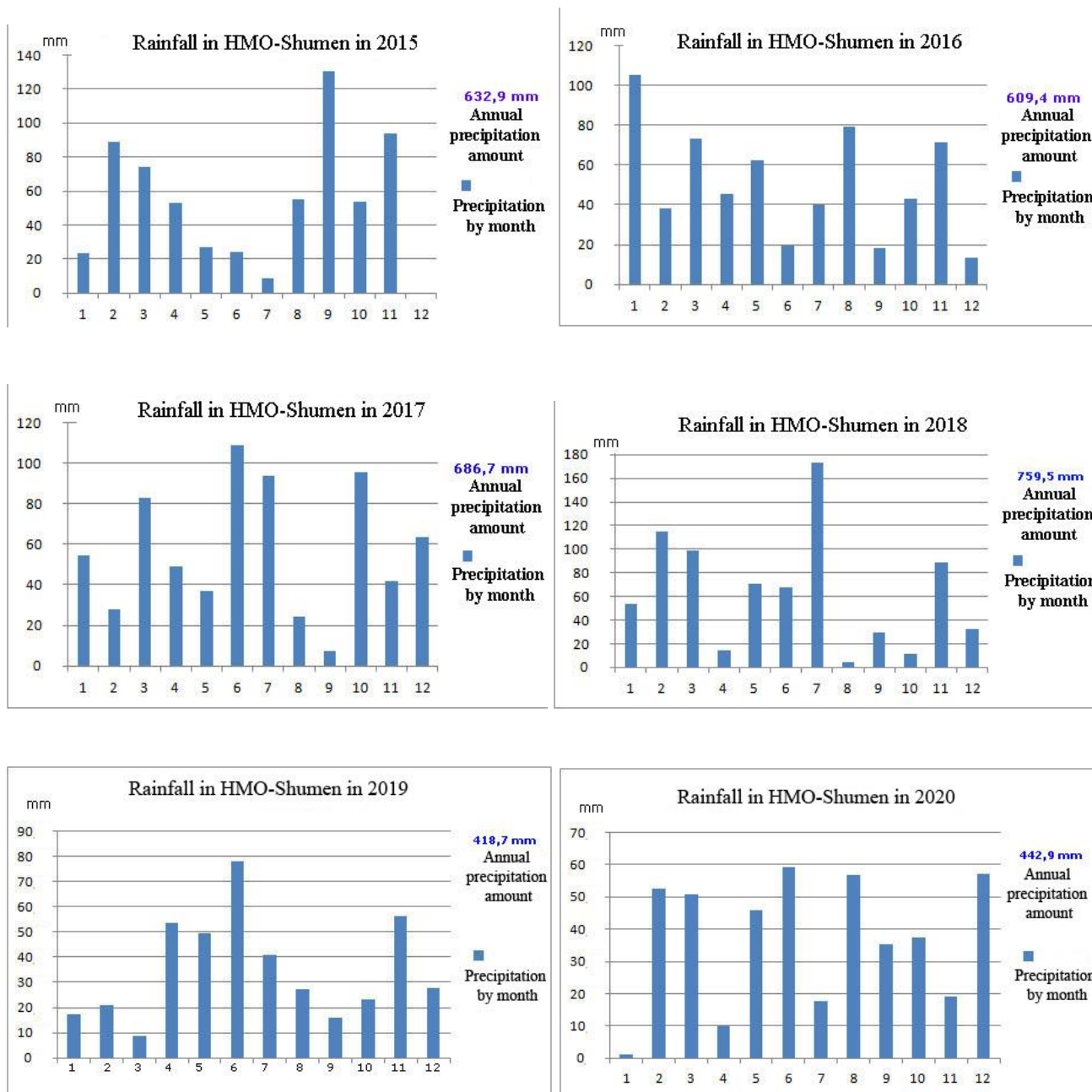


Figure 4. Monthly precipitations and yearly sums of precipitations in HMO–Shumen in the period of 1971–1980

In both of those periods, we can notice significant differences in precipitations by seasons and by years. In comparison, the average precipitation by seasons for the period of 1896–1965 for the station of Shumen is as it follows: winter – under 100 mm, increasing to the east to up to 125 mm; spring – varies between 150–200 mm, summer with a maximal precipitation of over 200 mm; autumn – 125–150 mm [1].

In the period of 2013–2023, the yearly sums of precipitations vary from 418.4 mm (2019) to 1185.4 mm (2014), which does not appear in the earlier period. Four years of the second period /2013–2023/ - 2019, 2020, 2022 and 2023, undoubtedly can be defined as years of significant draught as in those years the precipitations were very scarce (Fig. 5) [3].





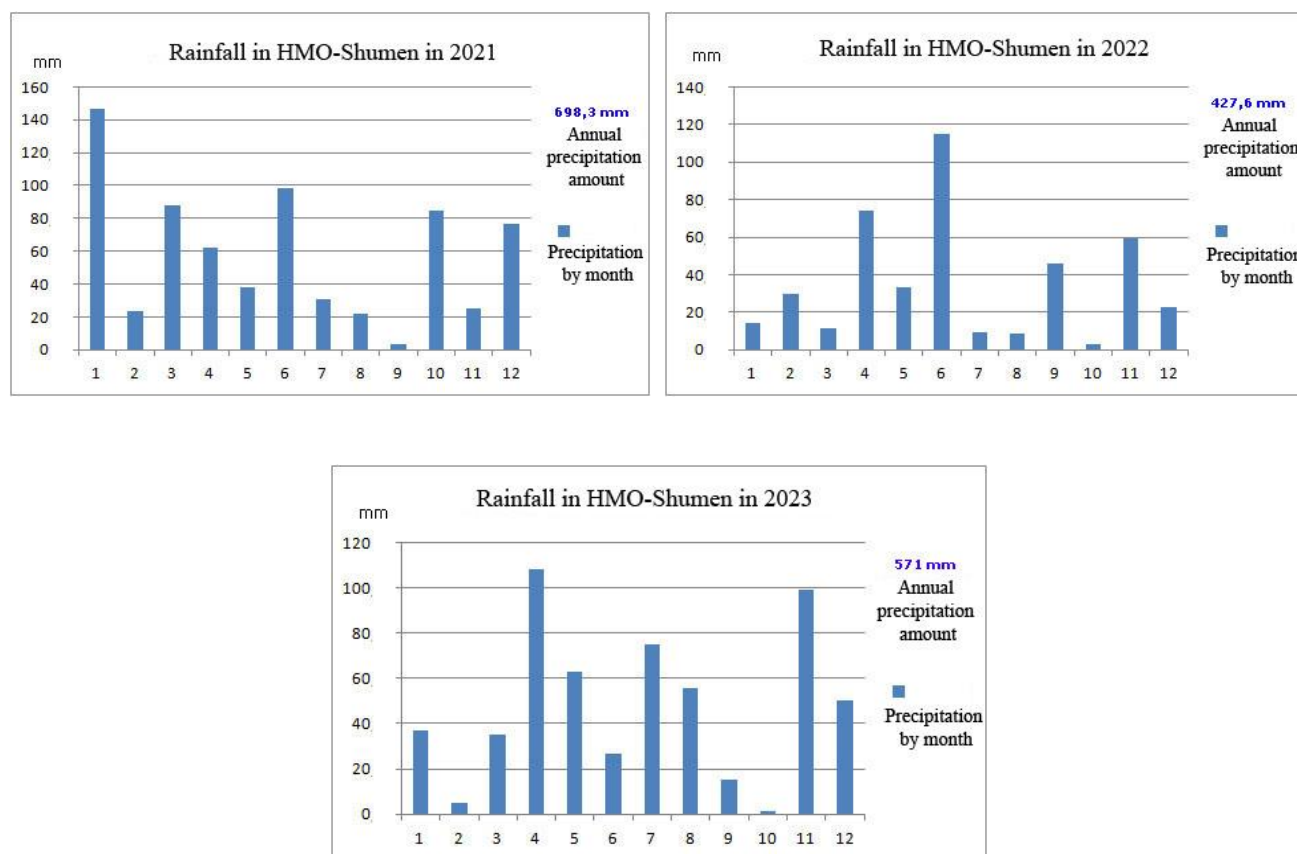


Figure 5. Monthly precipitations and yearly sums of precipitations in HMO–Shumen in the period of 2013–2023

The winters of 2013 (January and February), 2016 (January and March) and 2018 (February and March) can be noted as the most precipitous in the period of 2013–2023 according to the data of HMO–Shumen. The least precipitous were 2014 (January and February), 2017 (February), 2019 (February and March) and 2020 (January and February). The winter of 2012 has the most days of precipitation of just snow (20 days) and the winters of 2019 and 2020 have the least such days – 5 and 3 accordingly [3].

The comparison analysis reveals that the average number of days with precipitation (rain + snow) in winter in the period of 2010–2020 is relatively identical to the one from the period of 1931–1985 but while in the past the precipitations of snow were prevalent, in the last decade the tendency is exactly the opposite – rain precipitations are twice as common as the snow ones (Table 3) [1, 6].

Table 3. Number of days with precipitation/precipitation of just snow/with snow coverage in HMO–Shumen /2010-2020 [6]

Year/Month	January	February	March	December
2010	16 / 7 / 17	16 / 2 / 16	13 / 5 / 5	15 / 4 / 11
2011	10 / 5 / 16	10 / 4 / 7	10 / 5 / 9	11 / 3 / 10
2012	15 / 6 / 14	12 / 10 / 26	6 / 4 / 1	12 / 2 / 19
2013	12 / 6 / 24	15 / 2 / 3	10 / 1 / 2	5 / 2 / 1
2014	10 / 4 / 6	6 / 3 / 14	13 / 1 / 0	17 / 3 / 4
2015	10 / 3 / 5	14 / 5 / 5	10 / 0 / 0	2 / 1 / 0
2016	12 / 6 / 20	11 / 0 / 1	13 / 1 / 1	7 / 5 / 7
2017	12 / 10 / 31	5 / 2 / 15	12 / 0 / 0	14 / 2 / 1
2018	11 / 3 / 10	18 / 5 / 10	22 / 6 / 14	12 / 2 / 12
2019	15 / 4 / 3	5 / 1 / 3	5 / 0 / 0	9 / 3 / 1
2020	3 / 0 / 0	8 / 2 / 5	9 / 1 / 3	13 / 1 / 3

The snow coverage in Shumen lasted the longest in the winter of 2010 (38 days), 2012 (41 days) and 2017 (46 days) and the shortest in 2019 (6 days) and 2020 (8 days). The highest snow coverage in Shumen was measured on the 31st of January and the 5th of February (48 and 47 cm accordingly), on the 26th of January and the 5th of February (36 cm) and the 29th of January (32 cm) and the 2nd of February (37 cm) 2012. The winter of 2019 there was almost no snow coverage [3, 6].

Conclusions

1. Based on the usual peculiarities of the temperate continental climate, defined by the distribution of the sun radiation and the atmospheric circulation, the topoclimate in the area of HMO-Shumen is at a big degree defined by the geographic placement, the covering surface and the spatial position of the positive relief shapes – the Preslvsko-Dragoevo Mountain, the Razgrad heights, the Samuilovo heights and the table lands Shumensko, Voyvodsko, Stana, Provadiysko and Royaksko, which close the region of Shumen from all sides. The studied territory is located between two climatic sub-districts of the temperate climate – the Southeast and the Pre-Balkan. The influence of the Northeast climatic district prevails.

2. In the HMO-Shumen, in the period of 1971-1980, the variations of the average January temperatures were to up to 5.5°C and of the average June temperatures - +2.9°C. In the period of 2013-2023, the variations of the average January temperatures were up to 2.8°C and of the average June temperatures – up

to 3.2°C. Bigger variations can be clearly seen in the average January temperatures in the period of 1971-1980 and winter was better pronounced while there aren't significant differences in the June temperatures.

3. The comparison analysis reveals that the months of January and June were warmer in the period of 2013-2023 compared to those in the period of 1971-1980. In the month of May in HMO-Shumen, the average daily temperatures were steadily over 15°C and the average absolute temperature for 2013-2023 was +16.63°C – up to 1.5°C higher compared to the one of the 1971-1980 period.

4. The average monthly maximum temperatures for HMO-Shumen for the period 1971-1980 in summer fluctuate within 4.2°C, while for the period 2013-2023 these differences are up to 5.5°C. During the second period, the average maximum temperatures in the summer months increased by about 2°C.

5. The average yearly temperature in HMO-Shumen for 1971-1980 was +10.73°C and for 2013-2023, it was +12.48°C, which means that for the latter period, the average yearly temperature has increased by 1.75°C. The variations of the average yearly temperature amplitudes for HMO-Shumen for 1971-1980 are up to 4.4°C while for 2013-2023 they are bigger – up to 5.9°C.

6. The average precipitations in HMO-Shumen for both of the periods studied are relatively identical but in the period of 2013-2023 bigger differences have been noted by years.

7. The most precipitous winters in the studied period were those of 2013 and 2018, while the least precipitous were in the years 2014, 2017, 2019 and 2020. The winter of 2012 had the most days with precipitations of just snow and the winters of 2019 and 2020 had the least.

8. The snow coverage in Shumen lasted the longest in the winter of 2010, 2012 and 2017, while we had the fewest days with snow coverage in 2019 and 2020.

In conclusion, we can say that the climate in Shumen in the period of 2013-2023 has become warmer in the summer months by around 2°C and the average yearly temperature has increased by 1.75°C. At the same time, snow precipitations have decreased significantly and the precipitations are distributed more and more unevenly in the seasons and through the years. The last four years of the 2013-2023 period can be defined as years of significant draught.

Acknowledgements

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