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ANALYSIS OF TRENDS OF CLIMATE FLUCTUATIONS IN BOSNIA AND HERZEGOVINA

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Fluctuation is a legitimate geographical category and includes long-term systemic fluctuations in natural phenomena and processes. The fluctuations are conditioned by the rhythms, and the rhythms with cycles. Rhythms define mild changes in natural processes that arise in causation and relationships between teluric and cosmic forces. Rhythms can be one-day (shift of day and night), annual (shift of seasons), cantennial (hydrological and climatic fluctuations) and secular (paleogeographic changes of the appearance of the planet Earth through the geological past). Fluctuation is the general trend of legitimate changes in natural processes expressed through rhythms and cycles, which take place around equilibrium natural states. These oscillations fall into the domain of natural fluctuations, such as, inter alia, oscillations of climatic elements and phenomena.

The analysis of the climate indicators of the instrumental period in Bosnia and Herzegovina presents the fluctuation of the centuries-old isothermal and isohietal regime. The fluctuation of climatic parameters takes place around the equilibrium level at certain rhythms and is sufficiently correlated with the world's indicators. For the display of fluctuation strings as an etalon, centennial monitoring of the climate regime of the meteorological observatory in Sarajevo was used. In addition to analyzing the compression sections of the centennial series of climate parameters for the mentioned climate observatory, it is necessary to compare them with the climatic parameters of different climatic periods, from at least two, in order to obtain the results of total climate fluctuations in Bosnia and Herzegovina.

Key words: fluctuation, climate fluctuations, analysis, climatological monitoring.

INTRODUCTION

Natural processes are a consequence of the variable states of natural elements and phenomena in a certain part of the Earth and, apart from the local, also have a global character. Variability is visually noticed, and is checked and confirmed by instrumental monitoring. Monitoring is widely used in climate research, because on the basis of averages, the prevailing normal climatic condition is defined as the climate. The determined average value is often treated as normal for any climatic indicator. When defining the prevailing or normal state of an element, the considered period must not be representative and represent the normal state of a climatic element or climatic event. Consequently, neither the climate defined by the data of the average conditions of climatic elements and phenomena determi-ned by the instrumental procedure obtained, according to the established international criteria, has no privilege to be considered a normal climate, and because such a fixed period has no guarantee that it represents the average of normal values from a series of decades and centuries of measurement. In addition, neither the length of the periods in which normal states are observed, have clearly defined boundaries according to some, for example, teluric-cosmic laws, on the basis of which the periodicity of certain elements would be defined. The climate represents only one, but not average, entire state of the complete system; that is just one link or one link of an infinite series.

In order to accurately determine the tendency of some value such as the climate tendency, it is necessary to have a fixed benchmark, ie, standard size with which the previous and subsequent climatic periods are compared. Thus, for the climate, according to the international convention, the *"Standard Size"* of a time series of 30 years is agreed, with the first period calculated from 1931 to 1960 and defined as the first climatic sequence; the second from 1961 to 1990, and the third will end next year, in 2020.

It should be emphasized that even the length of the standard period is not universal for all climatic elements, nor is it general for all geosystems (natural zones) on Earth. Thus, for example, in a tropical geosystem for a time series of only a few years, a representative isotermic image can be obtained, while a long period of time is needed for the determination of the same parameter in the continental temperate zone. For this reason, the International Meteorological Association has adopted a universal term on variations and fluctuations of climate parameters called *climate change*. In this case, the estimated average value is treated as *"normal"* for any climatic indicator (J.M. Mitchell et al., 1966). Based on numerous statistical indicators and analysis of climatic elements and phenomena, data on variations in climate in cycles ranging from 5 to 11 years have been reported. Trends in climate oscillations at specified time intervals show slight increases or declines in average values and have a legitimate fluctuation around the equilibrium level.

Based on the climate monitoring collected from the Observatory in Sarajevo, the fluctuation of the thermal and isohietal regime has been demonstrated for 112 years, which, as has been emphasized, is the normal state of the basic climate indicators.

The methodology of this research was based on the graphic representation of average annual temperatures and precipitation in the shape of points interconnected in the graph of the long-term thermal and pluviometric series. The graph shows a great diversity of average annual temperatures and precipitation, which are not repeatable and identical for any year presented over the centuries.

On the basis of cyclical annual distribution of average temperatures, the thermal rhythms of falling temperatures or cooling and increase in temperature or warming cannot be clearly seen, as well as the rhythm of increasing and decreasing precipitation. Therefore, the compression of the distribution of a long-term cyclical series of five years, which is called moving averages, is made. The compression of annual temperatures was done by the equilibrium method, for as many periods as the number of years for which moving averages are calculated. By applying sliding averages over a period of 5 years, new points were obtained, which, when combined, formed a graph of a wave appearance that oscillates around the equilibrium level and represents a thermal or pluviometric fluctuation (Fig 1). On the basis of the graph of thermal fluctuation, the periods of warming and cooling periods are defined, based on the pluviometric series of fluctuations of precipitation in relation to the centennial average (Spahić, M. 2013).

Apart from this method, which involves analysis of wave graphs and linear monitoring of the thermal and isohietal centennial regime, it is possible to analyze the fluctuation graphs for several places in Bosnia and Herzegovina, selected according to physiognomic geographical regionalism. On the basis of comparison of thermal diagrams from certain climatic periods for geographical regions defined by the normal climate, mutual differences are shown on the basis of which it is possible to define the greatest deviations from the entire monitoring line.

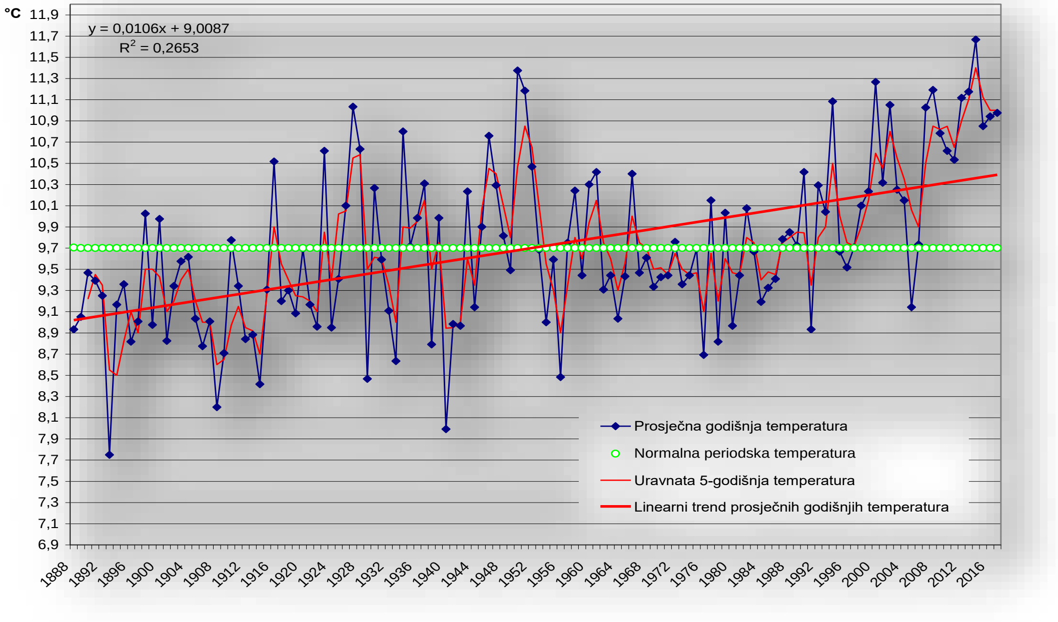

Fig. 1. The fluctuation of the thermal regime in Sarajevo for more than a century

MATERIAL AND METHODS

Climate monitoring

A comparative analysis of climate monitoring is based on climatic indicators obtained by standard constant monitoring of basic climate parameters, primarily air temperatures and precipitation for at least two climatic periods. Climate analysis is presented by indicators of individual and collective monitoring for individual geographic regions of Bosnia and Herzegovina.

After conducting the analysis of the climate flows, primarily the thermal regime, their fluctuation was defined using the method of calculating the inter-climatic variability of monthly air temperatures in the geographic regions of Bosnia and Herzegovina between the two climatic periods: first 1950-1982. and another 1983-2015. In addition, the fluctuations of the thermal and isohietal regime in geographical regions by seasons for the same climatic periods were analyzed.

Climatic indicators are correlated with centuries of temperature and precipitation fluctuations. Special analyzes included Sarajevo and Bjelašnica, since these climate observatories have four, or three, climatic periods for instrumental monitoring of climate parameters.

All table and graphic climate indicators developed are based on instrumental climate monitoring obtained from hydrometeorological institutes of the entities of Bosnia and Herzegovina.

Climate factors and physiognomic regions of Bosnia and Herzegovina

Climate monitoring in Bosnia and Herzegovina has been selected based on the physiognomy of its territory that respects the zonal, sectoral and azonal factors.

The zonal factor expressed in terms of latitude can almost be ignored given the rather narrow range of geographical coordinates in Bosnia and Herzegovina between the northernmost (Gradina Donja φ = 45º16'30 ") and the southernmost point (Podštirovnik φ = 42º33'00 ") of only 2º43'30 ", which in the longitudinal units is rounded up to 303 km.

The geographical sectoring of Bosnia and Herzegovina is expressed by the geographical longitude and distance from the oceanic and marine sectors related to the predominant cyclonic and anti-cyclone activities that are transmitted over the territory of our country. Geographically, by the longitude, Bosnia and Herzegovina is located between the meridian of the westernmost (Bugar λ = 15º44'00 ") and the easternmost point (Žlijebac λ = 19º37'41 ") in the diapason of latitude λ = 03º53'41 " or 309 km.

Fig. 2. Physionomic geographical regions of Bosnia and Herzegovina

In such geographical coordinates, with the elimination of the relief, Bosnia and Herzegovina would not show significant climate deviations in relation to statistical ones, especially expressed in latitude, which for each geographical degree lowers the air temperature by about 1 ° C, which in our case would amount to slightly more than 2 ° C and would have no specific implications for the climatic elements of the northernmost and southernmost regions of Bosnia and Herzegovina. The azonal or height-belts factor in Bosnia and Herzegovina is dominant on the forming of weather and hence the climate. In addition to modifying the zonal and sectoral factors, the azonal factor dominantly influences the horizontal and height wise dissipation and thus the geographical regionalization of Bosnia and Herzegovina. Geographical regions are quite separate and unique due to the pronounced morphographic diversity. The elevation explained by the Dinarides morphostructure divides Bosnia and Herzegovina into three macro units: northern, central and southern, which at the same time constitute the backbone of the regional geographical division of Bosnia and Herzegovina. In addition, orographic morphostructures are at the same time the boundaries of the regions and sub-regions of Bosnia and Herzegovina.

Thus, the geographic region of Northern Bosnia includes the northern part of Bosnia and Herzegovina to the Sava River border in the north, and the southern borders are represented by the mountain range of ore and flysch mountains: Grmeč, Srnetica, Manjača, Čemernica, Vlašić, Konjuh and Javor.

This geographic region covers approximately 1/2 of the total area of Bosnia and Herzegovina. The geographic region of Northern Bosnia dominantly forms hipsometric levels of 100-200 m above sea level, without taking into account the low horst mountains and foreground steps. It has very small energy of relief with a somewhat more significant horizontal diversity conditioned by the dissection of the river flows: Sava, Drina, Bosna, Vrbas and Una.

According to the principle of complex geographic homogeneity, the geographical region of Northern Bosnia is defined by three subregional units: Una-Sana, Donji Vrbaski and Donji Bošnjanski Kraj and the Sprečko-Majevički region with Semberija.

Considering the belt and zonal characteristics of the thermal regime, the geographic region of Northern Bosnia is dominated by the moderate continental climate, which, by the geographical sector from the west to the east, reduces the pluviometric regime by 1/3 on average. The climate representatives of this region are Tuzla, Banja Luka and Bihać (Figure 1).

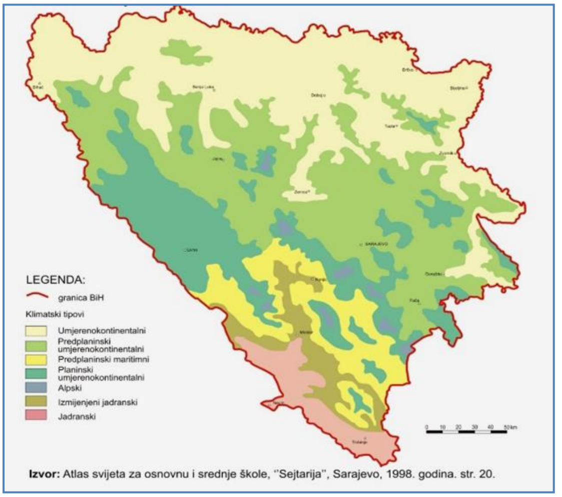

Fig. 3. Regions of climate types in Bosnia and Herzegovina

The geographical region of Central Bosnia covers the area of central Dinaric valleys and valleys with ore and flysch mountains and makes 1/4 of the total area of Bosnia and Herzegovina. The northern borders of Central Bosnia are at the same time the southern borders of the geographical region of North Bosnia, and to the southwest and south of the border are: Lisina, Vitorog, Raduša, Bitovnja, Bjelašnica, Treskavica and Zelengora. The mountain relief of Central Bosnia is distinctly divided by the composite hydrographic system: The Drina, Bosnia and Vrbas. The central place in this geographical region has spacious basins, the most important of which are: Sarajevo-Zenica and Skopaljska. The geographical region of Central Bosnia forms subregional units: The Sarajevo Zenica basin, the Upper Podrinje and the Upper Povrbasje.

Central Bosnia is characterized by an altered continental climate and belongs to a pre-mountainous moderate-warm and humid climate with a predominantly continental influence which is modified to mountainous and alpine climate towards higher altitudes. Given that the valley units occupy the central mountainous position dominated by continental influences, climate representatives are: Sarajevo, Zenica, Goražde and Jajce.

The high karst geographic region extends from Grmeč, in the northwest to the border with R. Montenegro, in the southeast. borders with the geographical regions of Central and Northern Bosnia, in the north, and is separated from Low Herzegovina by: Viduša, Velež, Prenj and Čvrsnica. The area is slightly smaller than the geographical region of Central Bosnia. This region is predominantly contiguous with the complete development of karst forms, processes and phenomena.

The climatic conditions of this region are conditioned by zonal, azoonal and, in particular, sectoral factors. Due to its openness, especially the southern mountainous exposures to the Mediterranean, continental influences of maritime character predominate, which in particular reflects on the increased isohietal regime, especially during the colder period of the year. The geographic region of the High Karst is characterized by two subregional units, namely: Bila and Polja, in the southwest and Rudine in the southeast of Bosnia and Herzegovina. That is why it is dominated by continental influences of a maritime character. The climate representative of this geographical region with the longest period of instrumental monitoring is Livno, Gacko and Bileća.

Lower Herzegovina region includes the lower flow of river systems of Neretva and Trebišnjica. It is an Adriatic and sub Adriatic belt, extended to low, Mediterranean and sub-Mediterranean Herzegovina and covers part of the territory to Posušje, Široki Brijeg, Mostar, Stolac and Trebinje. Its northern border is made up of the southern foothills of Čabulja, Prenj, Velež and Viduša. This region is the smallest and accounts for just over 10% of the total state territory. In the south, Low Herzegovina ends with a mildly razed coastline in the bay of Neum and the Klek peninsula. The region of Low Herzegovina is distinguished by the Mediterranean climate, at higher altitudes and in those moving away from the Adriatic coast, the changed Mediterranean climate. Climate representatives with long-term climate monitoring are: Mostar and Neum.

ANALYSIS OF CLIMATE MONITORING IN BOSNIA AND HERZEGOVINA

Climate monitoring includes temperatures and precipitation from at least two climatic periods, and some climatic stations own three, while Sarajevo has climate-controlled monitoring in meeting the conditions of four consecutive climatic series.

Climate diagrams from two or more climatic series allow the analysis of climatic fluctuations separated by climatic rhythms, based on the annual cycles of climatic elements. The analysis of climate monitoring is composed of representatives of climatic centers by climatic types, which largely correspond to the physiognomic regions of Bosnia and Herzegovina. Izotherms and isohietes, among other elements, are basic oolates of typological geographical regionalization of Bosnia and Herzegovina.

Sarajevo has the longest monitoring of the thermal and isohietal regime for over a century (130 years), and these indicators are very indicative for the assessment of climate fluctuations. The data of the thermal and pluvometric climatological regime were divided into 4 climate periods of 30 years, as required by the International Climate Association, except for the first period, which is longer and is 41 years. Such a long first climate period has been processed to regulate climate indicators in years when the activities of observing and measuring climate elements and phenomena in Sarajevo were interrupted for justified reasons.

Instrumental climate monitoring for at least two climatic periods meets another 9 climatic stations relevant for the assessment of climate fluctuations, which are arranged according to geographic physiognomic regions, according to which the climate regionalization of Bosnia and Herzegovina has been carried out.

In order to understand the essence of climatic fluctuations contained in the tables and graphs, it was necessary to correlate them with the graph of the fluctuation of the sliding averages that found their explanations in several articles of the first author of this paper, given in the literature. From the tabular overview of the climate regime, the inter-climatic variability by months and annual averages is calculated in order to determine the climate amplitude of the climate parameters fluctuations.

From the earlier processed graphic data on the distribution of deviations from average annual temperatures and five-year sliding averages in Sarajevo (Spahić, M. 2013), it cannot be determined in what period of year they are occurring and for which season they are the most intense, which is allowed by the monthly distribution in climatic periods.

Fluctuation of temperate continental climate in the geographical region of Northern Bosnia

The temperate continental climate in Bosnia and Herzegovina dominates northern Bosnia and corresponds with the region of the same name. This region is predominantly influenced by the southern branches of the northern temperate belt and somewhat more mildly northern parts of the subtropical belt, and these are the first ones from the Eurasian land to be more pronounced. Typical representatives of this climate, with at least two climatic periods, are: Bihać, Banja Luka and Tuzla. All three representatives have continuous monitoring from 1950 to 2015, with the period from 1892 to 1913 being processed for Bihać and Banja Luka and it served as a correlative for the next ones with full climatic series. These climatic classes have other representative climatic types. Regardless of the fact that all of them are somewhat deviating from the climate monitoring of Sarajevo, they can still be comparing when it comes to climate fluctuations.

Climate data processing was done cumulatively for the whole region of northern Bosnia on the basis of the above-mentioned aggregate data for subregional sites: Una-Sana, Donji Vrbaski and Bosanski Kraj, and the Sprečko-Majevica region with Semberija. which are influenced by the continental regime and define the typical temperate continental climate of Bosnia and Herzegovina.

The distribution of temperatures in the geographical subregions of the temperate continental climate type in the indicated climatic periods is fairly uniform. The annual average increase in temperature due to the increase in continentality occurs in the comparative direction west - east ie. from Bihać (11.0ºC), through Banja Luka (10.9ºC) to Tuzla (10.5ºC), which is in average 10.8ºC. A similar ratio is the average minimum and maximum temperatures. Thus in Bihać, the coldest month of January is warmer (0.4ºC) in relation to Banja Luka (-0.1ºC) and Tuzla (-0.2ºC) and fluctuates around 0.0ºC, which is the average temperature of the coldest month in this climate. Maximum temperatures occur in July and average for the entire region are 21.0°C.

An analysis of the inter-monthly climate variability of temperatures shows an increase from west to east of the north Bosnia region. When comparing the inter-climatic variability of monthly air temperatures, its rise from the north-west towards the northeast of Bosnia and Herzegovina is noticed. The average annual temperature increase for the mentioned climatic periods is 0.5ºC. The maximum increase in temperatures occurs in January and is on average 0.9°C, while in December there were no changes in temperature for both climatic periods.

The balanced trend of a slight increase in air temperature for observed climatic periods is only recorded in the autumn period.

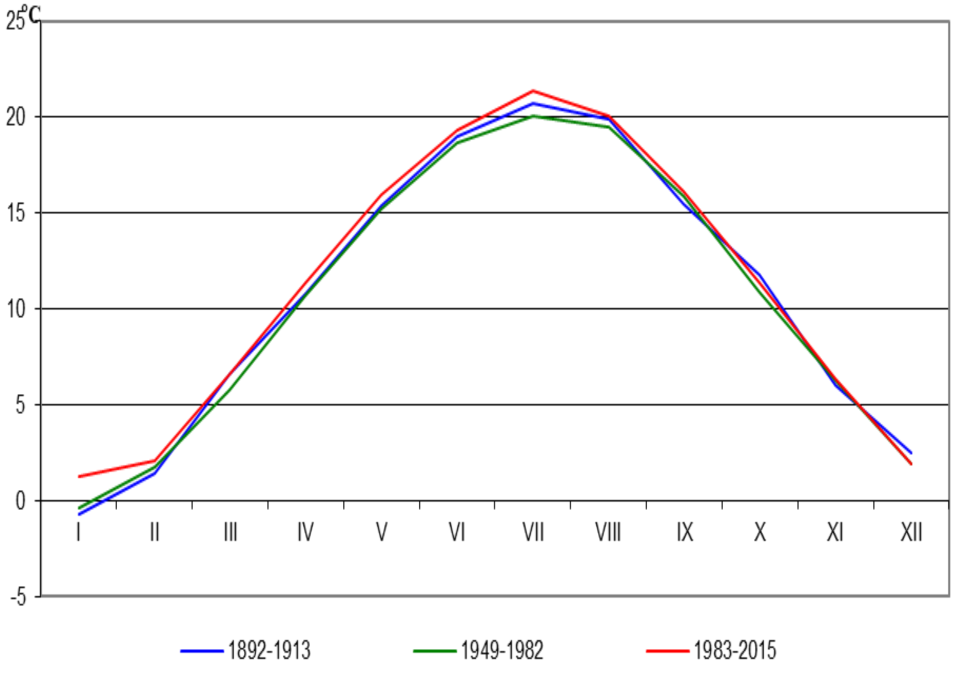

Fig. 4. Chart of air temperature distribution by months in the altered continental climate of Bosnia and Herzegovina in the indicated climatic periods

Changes in seasonal temperate in altered continental climate type, has the highest warming in recent climate period. The chart (Fig. 4) shows a significant temperature shift of all three periods shown, the warmest is the last one (1983-2015). The most significant increase of temperatures in the analyzed periods are during the winter season, from January to the end of February and during the summer period from June to the beginning of September. These changes can also be seen in the table of average seasonal temperatures in all three indicated areas (Tab. 1).

Tab. 1. Climate variability in air temperature (ºC) by season in the geographical region of North Bosnia between two climatic periods: First 1950-1982. and Second 1983-2015.

Period / season	Winter	Spring	Summer	Autumn
1949-1982	1,1	10,5	19,4	11,0
1983-2015	1,8	11,3	20,3	11,3
Average 1949-2015	1,5	10,9	19,9	11,2

Changes in temperatures by seasons for a moderate continental climate type, distinguished by the geographical region of Northern Bosnia, have registered the largest warming in the last climatic period in the spring and summer periods. Thus, during the summer of the last climatic period, the air temperature in the geographical region of North Bosnia grew by 1.1°C, and during the spring it was 0.7°C. The temperature rise during the winter was 0.7°C, while the autumn warming was at least 0.3°C.

The pluviometric regime of a moderate continental type is directly related to the condition of the thermal regime. The amount of precipitation in all climatic periods decreases from the west to the east, which is brought into the context of the impact of the maritime sectorality of the western regions of the Northern Bosnia geographic region, where the amount of rainfall and the continent's higher eastern areas have increased, which reduces precipitation.

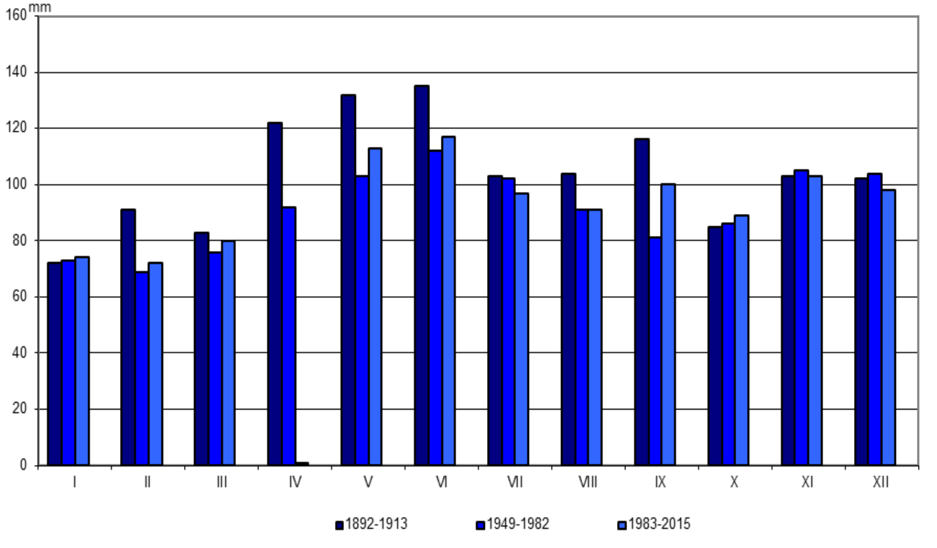

Fig. 5. Precipitation distribution by months in the altered continental climate of northern Bosnia during the indicated climatic periods

From the previous data it is evident that the extreme regime in both climatic periods is quite uniform shows great similarity (Fig. 5). During 7 months of the year, the increase in precipitation in the warmer climatic period is recorded, with this continuity being recorded at the transition from winter to spring, while the second lasts for two months from September to October. An analysis of the emerging regime has noted that in the seasons of the greatest increase in air temperature, there is a decrease in precipitation, which is a consequence of a greater aridity.

Fluctuation of the pre-mountainous climatic type of the moderate continental variant of the geographical region of Central Bosnia

The pre-mountainous climate type of the moderate continental variant refers to the geographical region of Central Bosnia. The fluctuation of its climatic elements was analyzed based on the climate regime of Sarajevo, whose instrumental monitoring is 130 years long and includes 4 representative climatic periods, which represent a basic benchmark for all others in Bosnia and Herzegovina. According to it, the climatic periods of other places, representative of physiognomic geographic regions and the prevailing climate types in them can be compared.

Thermal and pluviometric regime was analyzed separately for Sarajevo in all four climatic periods, while for other places of this climate type of geographical region of Central Bosnia: Zenica, Goražde and Jajce, fluctuations of amplitudes were analyzed from aggregate indicators for the last two climatic periods.

On the basis of these, tables are made for the distribution of average temperatures by climatic periods and charts for the same data. In addition, the table shows the indicators of inter-climatic temperature variability, as well as the distribution of temperatures and precipitation in seasons in given climatic periods. On the basis of these indicators, it is possible to compare the presented climatic elements and determine their regularity.

According to the analysis of climate monitoring, the general trend of fluctuations in the thermal regime is determined based on the average annual values. The first climatic period (1888-1927) was coldest with an average temperature of 9.3ºC, with the average temperature in January being -1.9ºC, and the maximum July 18.8ºC.

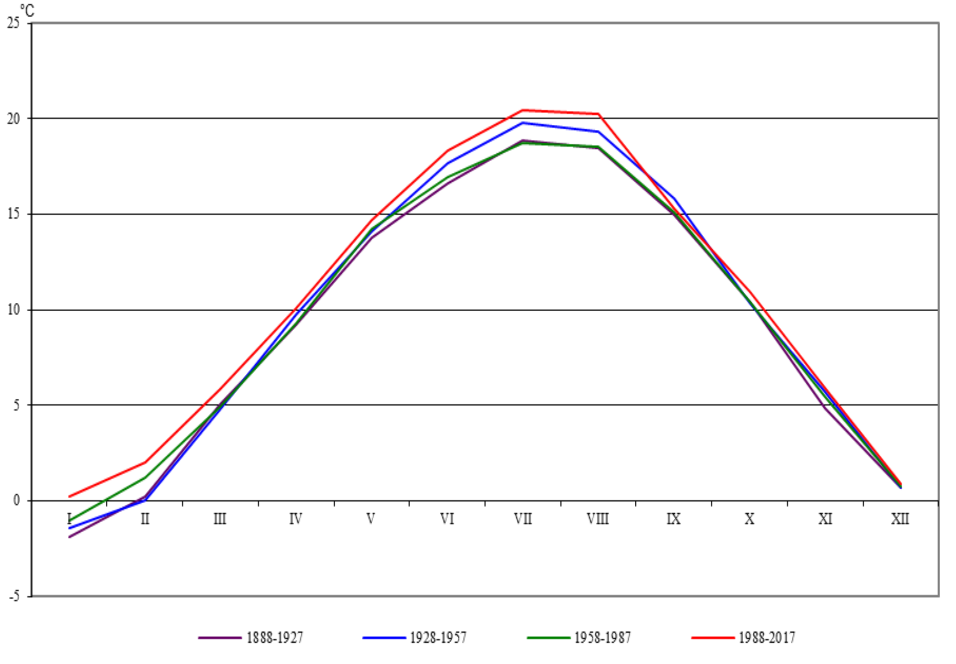

Fig. 6. Chart of monthly air temperature distribution in the altered continental climate of the Central Bosnia region, in case of Sarajevo

The next climatic period (1928-1957) recorded a rise in air temperature by 0.4°C compared to the previous period, with the average January temperatures of 0.5°C more, and the average maximum July temperatures for the entire 1°C. The third climatic period (1958-1987) recorded a decline in the average long-term air temperature in relation to the previous climatic period of 0.2ºC, but it is also warmer in relation to the first climatic period.
The average minimum January temperature for 130 years rose by exactly 1.7ºC (from -1.9ºC

to 0.2ºC) and still recorded positive temperatures. The maximum July temperatures in Sarajevo for the third climatic period are lower compared to the second by 1.1ºC and lower by 0.1ºC compared to the first climatic period.

The fourth climatic period (1988-2017) is the hottest and for 0,8ºC is warmer compared to the previous third, for 0,7ºC compared to the second and for 1,1ºC in relation to the first climatic period. The average minimum January air temperatures increased by 1.2ºC compared to the previous, 1.6ºC compared to the second and even 1.7ºC compared to the first climatic period. Average maximum July temperatures have risen to 20.4ºC and for 1.7ºC are higher compared to the third climatic period, and for 0.6ºC compared to the second and for 1.6ºC compared to the first climatic period.

From the available data, the above-mentioned climatic periods calculate the average, for 130 years, the air temperature in Sarajevo closest to the second climatic period (1928-1957) and is on average 9.7ºC. If more than one century of air temperature is compared to the warmest climatic period (1988-2017) then the increase in the average air temperature for the last 30 years was 0.7°C, with the average January minimal temperature increasing by 1.2°C, and the maximum July for flat 1ºC

According to the indicators in the previous table, the almost constant increase of average monthly temperatures from one to the next climatic period, especially in relation to III to IV climatic period, is observed, as well as in the relation between the average long-term temperature of Sarajevo in relation to the IV climatic period.

Comparison analysis of diagrams for air temperatures in the four climatic periods, clearly shoes their graphical compaction from the first half of April to the middle of May, which represents the first period of the year of uniform temperatures and the second period, which is slightly longer than the uniform temperatures without significant oscillations, from middle September to the end of December. The dispersion of annual isotherms is observed in two annual periods: the first from beginning of January to middle of March with average of 0.5ºC and the second from middle of May to middle of September, with the maximum difference between the coldest and warmest period being observed 0.8ºC in June to 1.1ºC in August. Average temperature increase in Sarajevo for the period of more than 100 years is 0.5ºC.

The average air temperature fluctuations in Sarajevo occur during the summer and range from 0.8°C in June to 1.1°C in August. The second average secondary temperature rise occurs at the transition of the winters in the early spring and amounts to 0.5ºC, while the lowest average temperature rise occurs during autumn and is on average up to 0.3ºC. The annual average temperature increase in Sarajevo in total climate monitoring is 0.5ºC.

Tab. 2. Inter-climatic variability in air temperatures (ºC) by seasons in the analyzed periods for Central Bosnia region, in case of Sarajevo

Period / season	Winter	Spring	Summer	Autumn
1888-1927	1,1	13,2	17,4	5,3
1928-1957	1,3	13,8	18,3	5,5
1958-1987	1,7	13,5	17,4	5,5
1988-2017	2,7	14,4	18,6	5,9
Average 1888-2017	1,7	13,7	17,9	5,6

According to the indicators, the last two climatic periods relating to Zenica, Goražde and Jajce sufficiently correspond to the same periods in Sarajevo. Thus in Zenica the average temperature, the last climatic period in relation to the third increased by 0.8ºC, in

Jajce by 0.6ºC, and in Goražde for only 0.4ºC. The average minimum temperatures in the last climatic period in Zenica and Goražde increased by 0.6°C, and in Jajce for 0.8°C. The average maximum temperatures in Zenica and Goražde increased by 1.0ºC, and in Jajce by 1.5ºC.

The analysis of fluctuations in air temperature by seasons in Sarajevo in all four climatic periods shows a continuous increase, especially during spring and summer (see Table 2). The same applies to other parts of the geographic region of Central Bosnia. Maximum winter temperatures of 1°C and 19.7°C were recorded in the last climatic period (1988-2017), as in other sub-regions of Central Bosnia, while winter temperatures increased by 0.4°C and averaged to 1.6°C. Spring and autumn temperatures fluctuated around the average in the first three climatic periods, while the last one had significant spring warming for 0.6°C and a moderate autumn of 0.3°C in relation to the total climate. The fluctuation of air temperature by season is very similar in other parts of the geographical region of Central Bosnia.

The isohietal regime in Sarajevo was analyzed, as well as thermic one, in four climatic periods, the last two lengths of the period corresponding to the others, which were taken into consideration. According to the table indicators of the long-term distribution of precipitation, their smaller fluctuation in relation to the thermal regime is evident.

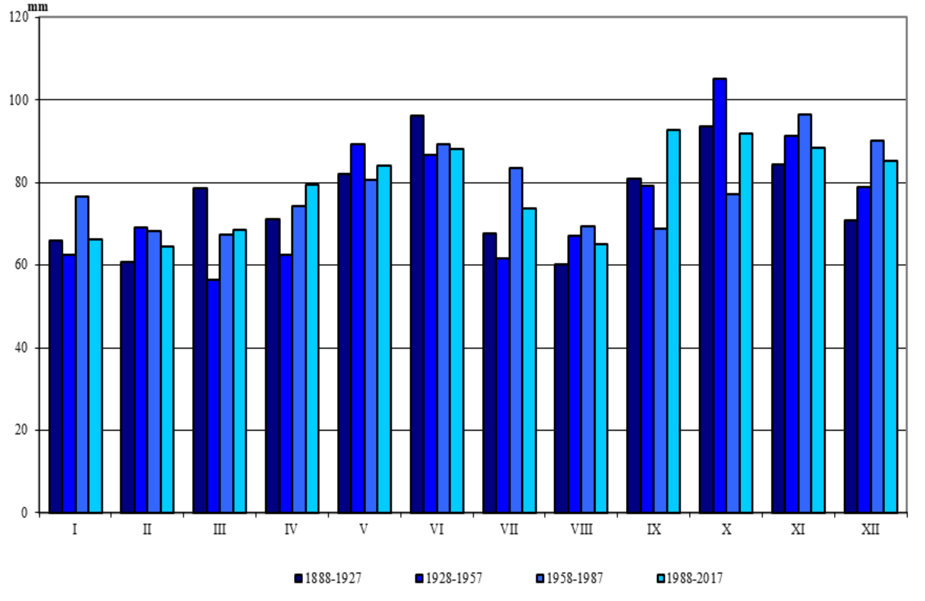

Fig. 7. Distribution of isohietal regime by climatic periods in sub-mountainous altered continental climate, in case of Sarajevo in the analyzed climatic periods

The inter-climatic differences in average monthly precipitation, expressed in mm, do not show significant deviations from the overall average. The greatest deviations of any decrease or increase in precipitation were recorded in the II and III climatic periods. According to the data of the average rainfall fluctuation in the mentioned period, on average annually, they increased by 3.8 mm, which is insignificant compared to the thermal regime.

The isohietal regime of Sarajevo is very similar to those in Zenica, Goražde and Jajce.

The seasonal distribution of the isohietal regime is fairly uniform and, almost, not subject to treatment of high fluctuations in climate change, at least in the way that thermal values show. From the distribution of rainfall regimes, shown by seasons, their even distribution is visible with the maximum in the autumn and the minimum in the winter period. The lawfulness of the eminent with the thermal regime was noticed. In climatic periods in which there is an evident increase in temperature, the amount of precipitation decreases and vice versa. In other words, increased climatic humidity reduces the thermal regime and vice versa, arid periods increase the thermal regime.

Fluctuation of the sub-mountainous and mountain climatic type of the maritime variant of the geographical region of High Karst

The geographical region of the High Karst is separated, as it has been said, southwest of the Central Bosnia region, with the mountain morphostructures: Viduša, Velež, Prenj and Čvrsnica, is separated from Low Herzegovina and extends from the Una river basin and

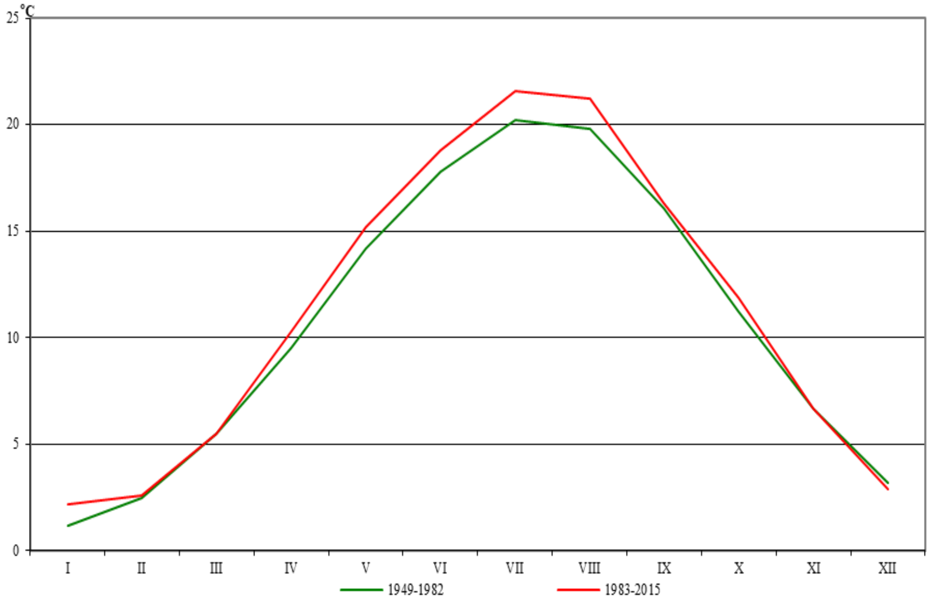

Fig. 8. Chart of monthly air temperature distribution in altered continental climate with maritime influences in the High Karst geographic region

upstream of Sana river, a tributary of the Una river in the northwest, to the border with Montenegro, in the southeast. It is a morphological gradient geographical regional unit oriented towards the Adriatic basin in which the Mediterranean climate impacts are modified by an altitude factor, which is especially reflected in the thermal and isohietal regime. This region is predominantly contiguous with the complete development of karst forms, processes and phenomena.

In order to understand the essence of climate fluctuation, thermal and empirical indicators for two climatic periods were analyzed and linked to other climate types and their variants. In this regard, thermal and pluviometric climatic elements for Livno, a representative of the sub-region of Bila and Polje, were analyzed in the southwest and Bileće as representative of Rudine, in the southeast of Bosnia and Herzegovina.

According to the analysis of the thermal climatic regime shown in the chart (Fig. 8), it is clearly observed that the subsurface climate of the maritime variants indicates the increase in the temperatures of the last climatic period compared to the previous one, especially during July in Livno by 1.4ºC, and in Bileća by 1.5ºC. According to the analysis of the thermal climate regime for the subsurface climate, maritime variants indicate the increase in the temperature of the last climatic period compared to the previous one, especially during July in Livno, even for 1.4ºC, and in Bileća for 1.5ºC. At the annual level, the temperature rise in Livno is 0.6°C, and in Bileća 0.7°C. The difference between the maximum temperatures in July and August in Livno is 0.5ºC, and in Bileća 0.3ºC, which shows that both places have predominant maritime (Mediterranean) influences.

The highest increase of temperature was recorded in July up to 1.0ºC, and the lowest in November by 0.3ºC. In contrast to the graphs analyzed above, the air temperature in this region is significantly different in the last two climatic periods. The most recent climatic period has seen a significant increase in air temperatures throughout the year and the graphs are far more spaced than previously analyzed. Their convergence is recorded from middle of February to middle of March, as well as in the first half of September and middle of November.

Their convergence is recorded from middle of February to middle of March, and during the first half of September to the middle of November.

Other periods of the year show significantly higher temperatures in the last climatic period, especially during summer when the differences are observed to 1.4ºC and during winter when they are 1ºC. Also with the other climate regions and subregions, the least changes were observed during the autumn and then spring periods of the year (Table 3).

Tab. 3. Average air temperatures (ºC) in climate periods indicated in the seasonal table in altered continental climates with maritime influences in the High Karst geographic region

Period / season	Winter	Spring	Summer	Autumn
1949-1982	2,3	9,7	19,3	11,3
1983-2015	2,6	10,3	20,5	11,6
Average 1949-1982	2,5	10	19,9	11,5

The basic difference between the sub-montanous climate with the continental and maritime variant is in the annual distribution of precipitation. The maximum amount of precipitation in the maritime variant is recorded during the colder period of the year, and the minimum during the summer season. The sub-region of Bila and Polja receives a smaller amount of precipitation and in Livno it is 1149 mm, in relation to the Rudin subregion, represented by Bileća with 1600 mm. When we observe a summary table on the distribution of the isohietal regime of the geographical region of the High Karst, it should be noted that the minimum amount of precipitation is observed at the time of maximum air temperatures, in July. The maximum rainfall occurs regularly in November and is average 189 mm.

Comparing the two climatic periods, there is a fluctuation of precipitation, which has a rather trend with the previous geographical regions. The maximum decrease in precipitation in the last climatic period for the month of December amounts to an average of 33.5 mm and a minimum of 0 mm in March. The average fluctuation of precipitation in two climatic periods is 60 mm.

The average maximum amount of precipitation is observed during the autumn and is 149 mm. Increased precipitation continues throughout the winter, and from the beginning of

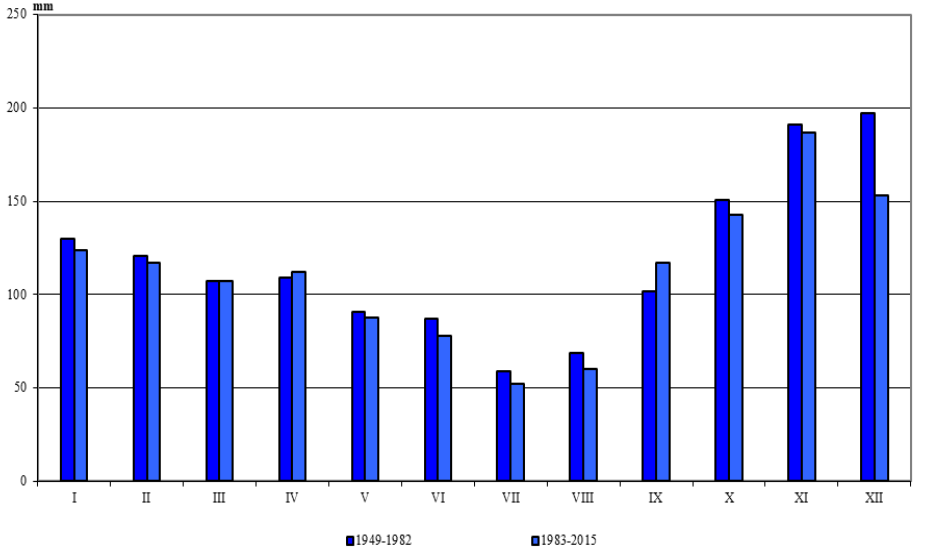

Fig. 9. Monthly precipitation in altered continental climates with maritime influences in the geographical region of the High Karst

the spring to the end of the summer it is continuously decreasing. The precipitation regime during the seasons does not show significant deviations, as is the case with the thermal regime.

Fluctuation of Mediterranean and Submediterranean climate types in the geographical region of Low Herzegovina

The region of Low Herzegovina covers the part of the Lower Neretva River System, which includes the tributary river systems: Trebišnjica and Tihaljina. It is an Adriatic and sub Adriatic belt, extended to low, Mediterranean and sub-Mediterranean Herzegovina and covers part of the territory to Posušje, Široki Brijeg, Mostar, Stolac and Trebinje. Its northern border is made up of the southern foothills of Čabulja, Prenj, Velež and Viduša. Climate representatives of this region with long-term climate monitoring, and these two climatic periods are: Mostar and Neum.

The annual distribution of the thermal regime in Low Herzegovina represent a typical Mediterranean climate, but it is modified by physical and geographical factors especially towards of the Neretva valley and its tributaries, especially Trebisnjica and Tihaljina. In this climate type we have hot summer and mild winter. As a result, the maximum temperatures in Mostar are slightly higher than those in Neum and because of evidence differences in heat capacity; smaller on the carbonate substrate in the interior that heats up faster and higher. The coastal area of the Adriatic Sea has a higher thermal capacity, so the sea water is heated and cooled slowly, which results in a more balanced annual air temperature. Taking into account these facts, the thermal and isohietic regime of the Mediterranean and sub-Mediterranean climate, which characterizes the geographical region of the Low Herzegovina.

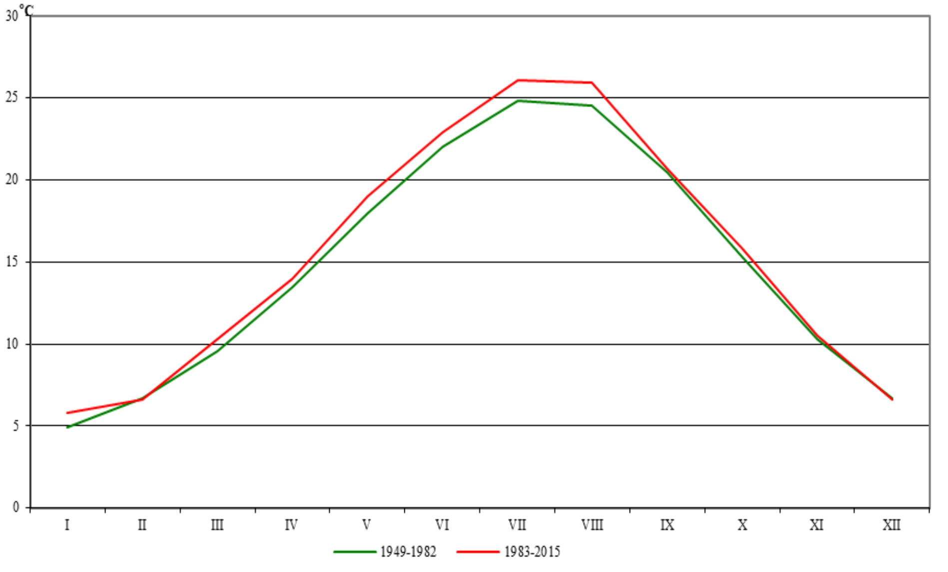

Fig. 10. Chart of the monthly temperature distribution in the geographic region of Low Herzegovina

From the Fig 10. we can see the distribution of monthly air temperature in the last two climatic periods in the Mediterranean and altered Mediterranean climate, maximum temperature is in July, but it is very close to the average of the air temperature in August.

The increase in air temperature in the last climatic period is best demonstrated by the inter-climatic thermal variability, which can be traced on the Fig. 10. The increase in maximum temperatures in the second period compared to the first is 1.3ºC in July and 1.4ºC in August. The inter-climate variability is quite uniform for the minimum temperatures of the colder period. On an annual basis, the average temperature increase for 0,6 ºC in the last climatic period compared to the previous one. In addition, from the Fig.9 we can see the annual thermal regime converging during February and early December, which last only a few days. Other average thermal flows show a clear difference, with the last climatic period being significantly warmer than the previous one.

In the Mediterranean and sub-Mediterranean climate, the difference in temperature increase by seasons is also evident, but not significant as in the continental climate. In the indicated geographic region, the increase in summer temperatures in these two climatic periods is 0.9ºC, spring 0.8ºC, autumn 0.2ºC, and winter 0.5ºC (Table 4). Smaller seasonal variations in the Mediterranean and sub-Mediterranean climate in Bosnia and Herzegovina can be explained by the climatic factors which is the most important for thermal capacity of the substrate.

Tab. 4. Average air temperatures (ºC) in the climatic periods, indicated in the table, by seasons, in the Mediterranean and altered Mediterranean climates in the low Herzegovina region.

Period / season	Winter	Spring	Summer	Autumn
1949-1982	7,0	13,7	23,3	10,8
1983-2015	7,5	14,4	24,2	11,0
Average (1049-2015)	7,3	14,1	23,8	10,9

The isohietal regime in the geographic region of Low Herzegovina is in correlation with the pluviometric regime of the Mediterranean and Submediterranean climate. Unlike temperate continental climate types (continental and Mediterranean variants), the Mediterranean and Submediterranean climate types are more abundant in precipitation that are unevenly distributed throughout the year. The maximum amount of precipitation occurs in the colder half of the year, and the minimum during the summer. The abundant precipitation in Lower Herzegovina is associated with southern marine influences.

It shows a decreasing amount of precipitation in the last climatic period compared to the previous one and corresponds to the lawful reduction of precipitation when the thermal value is growing.

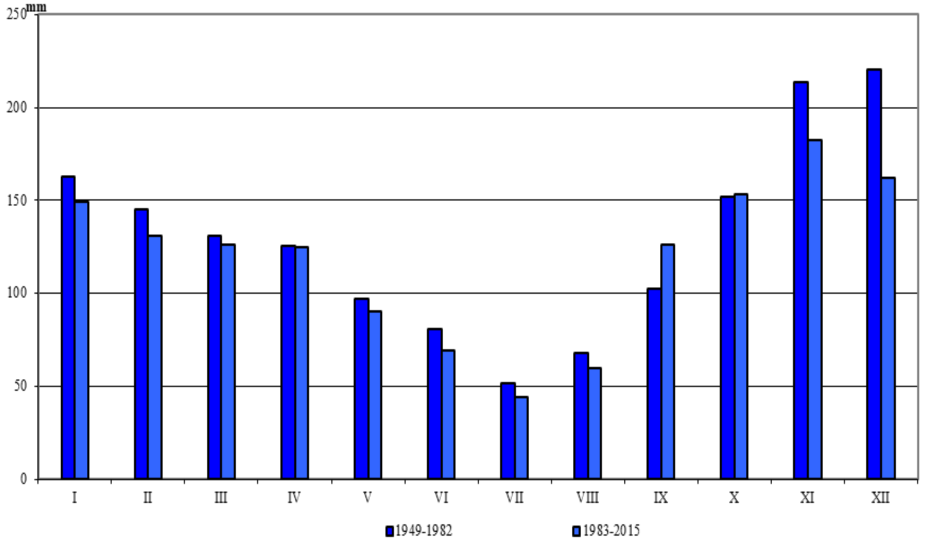

Fig. 11. Monthly precipitation distribution in the Mediterranean and sub-Mediterranean climate in the Low Herzegovina region

The highest average decrease in precipitation in the last climatic period occurs in December, amounting to 43.9 mm, and the lowest in April (0.4 mm) and in October (0.6 mm). The average annual rainfall decrease in the last climatic period compared to the previous one is 132 mm, which is far higher compared to the analyzed previous climate in Bosnia and Herzegovina (Fig. 11).

Seen by seasons, the last climatic period has received a lower amount of rainfall distributed over seasons. In winter, the maximum amount of rainfall occurs, and the summers are quite dry. During the three summer months, a smaller amount of precipitation is obtained by 3.3 times compared to the December maximum of precipitation.

Fluctuation of mountain climate type in the physiognomic region Dinaric mountains

A representative of the mountain climate in Bosnia and Herzegovina, which has all the attributes of the Alpine climate type in Bosnia and Herzegovina, is Bjelašnica. This mountain morphostructure is the start of the physiological Dinaric range, to the southeast to the state border with R. Montenegro. Considering that at the highest peak of Bjelašnica (2067 m) there is a climate observatory, it can rightly be stated that she is a representative of the high Dinaric mountains in Bosnia and Herzegovina. This Climate Observatory is one of the oldest in Bosnia and Herzegovina and the beginning of instrumental measurements dates back to 1895. Given the harsh conditions and war events, there are interruptions in its work, and data for three climatic periods have been collected for this work, the last of which corresponds to the others presented within the geographic regions of Bosnia and Herzegovina.

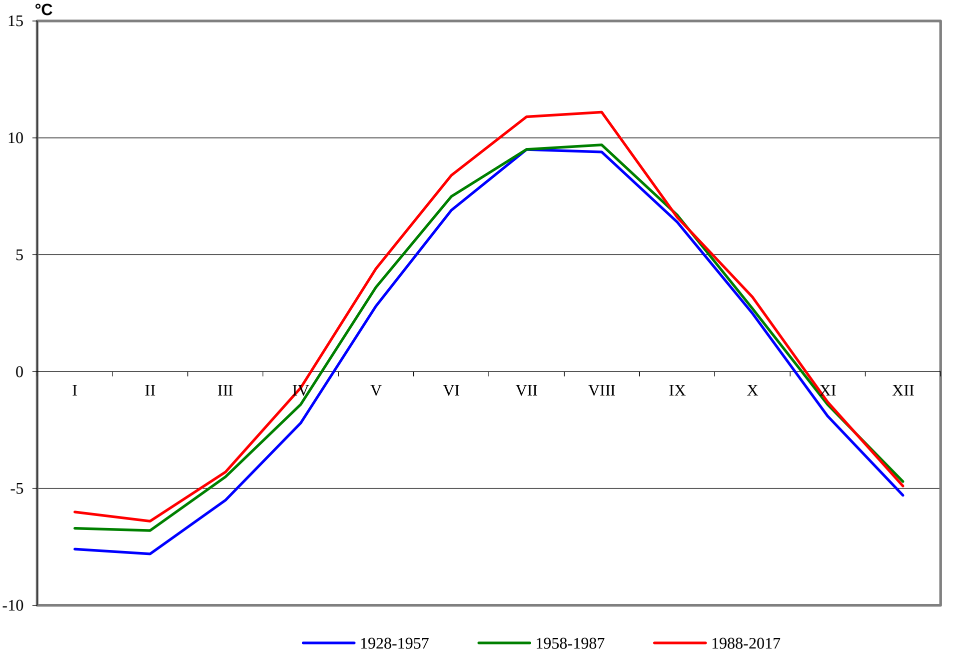

Fig. 12. Chart of the monthly temperature distribution of the Dinarides in case of Bjelasnica

The chart (Fig. 12) show a constant increase in air temperature on the Bjelasnica from first climate period to second one. There is significant increase in temperatures during the winter, especially in the February, when minimum temperatures are recorded, and the differences between the average lower temperatures from first climate period to second one are 1.4ºC. The second period, with heights temperatures, occurs during the summer months from July to the August, when they are increased up to 1.7ºC in the second climatic period. The chart continuously divergence of lines for normal climatic periods, which indicate a permanent increase in average temperatures of climatic periods in the first 9 months. After September, the lines on the chart are denser and show smaller climatic deviations from the four-month averages period. At the annual level, there was a continuous increase in air temperatures up to 0.6ºC.

Tab. 5. Average air temperatures (ºC) in the in the mountain range of the Dinarides in case of Bjelasnica

Period / season	Winter	Spring	Summer	Autumn
1895-1940	-6,9	-1,6	8,6	2,3
1952-1984	-6,1	-0,8	8,9	2,7
1985-2017	-5,7	-0,2	10,1	2,8
Average (1049-2015)	-6,2	-0,9	9,2	2,6

In the distribution of average temperatures, we analyzed three climatic periods, and the highest fluctuations is during the summer up to 1.5ºC, then in spring 1.4ºC, in winter 1.2ºC, and the lowest during autumn period and are 0.5ºC (Table 5).

The distribution of the isohietic regime by the climatic periods, present in the chart above, shows evident inter-climatic variations, especially of the first climatic period. The reason for the increased amount of precipitation does not find its justification in climate fluctuations as much as in the wrong measurement of quantity, especially snowfall.

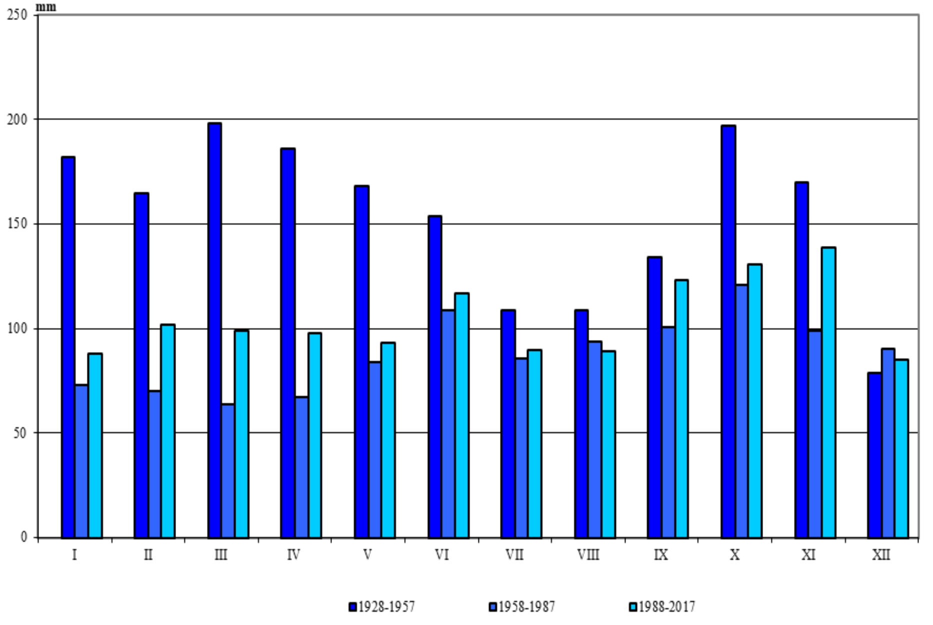

Fig. 13. Monthly precipitation distribution in the mountain range of the Dinarides in case of Bjelasnica

Errors in the measurement of rainfall on Bjelašnica as a result of an incorrectly selected position of raingage. Bjelasnica is dominated by snowfall and strong winds that create blizzards and inflate interference on precipitation instruments. This increased the amount of rainfall, which was recorded by observers and entered into meteorological yearbooks. Therefore, the first column, which represents the oldest period of the rainfall regime, is not considered as the second and third climatic period on the chart. Taking these facts into account, it can be concluded that the precipitation climate in Bjelašnica is very similar to other geographical regions in Bosnia and Herzegovina, where there is a reciprocal link between the thermal and isohietic climate regime similar to other verified indicators in Bosnia and Herzegovina.

CONCLUSION

Based on the collected, arranged and analyzed climatic elements, especially thermal ones, according to the climatic periods, most of them are attached in this paper, it can be concluded that:

Tab. 6. Inter-climatic variability of the monthly air temperatures (ºC) in the geographical regions of Bosnia and Herzegovina between the climatic period: First (1950-1982) and Second (1983-2015)

Month / Period	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Geographical region North Bosnia													
First - Second	0,9	0,3	0,8	0,7	0,8	0,6	0,3	0,6	0,2	0,5	0,1	0,0	0,7
Geographical region Central Bosnia													
First - Second	0,8	0,8	1,0	0,8	0,5	1,4	1,4	1,7	0,2	0,5	0,5	0,2	0,9
Geographical region High Karst													
First - Second	0,5	0,0	0,0	0,4	0,5	0,5	0,7	0,7	0,1	0,3	0,0	-0,2	0,3
Geographical region Low Herzegovina													
First - Second	0,0	-0,1	0,7	0,5	1,0	0,9	1,3	1,4	0,2	0,3	0,2	-0,1	0,6
Dinaric mountain range - Bjelasnica													
First - Second	0,8	0,7	0,6	0,8	0,8	0,8	0,7	0,9	0,2	0,4	0,3	0,4	0,6
Average between climate variability of air temperature in Bosnia and Herzegovina													
First - Second	0,6	0,6	0,6	0,6	0,7	0,8	0,9	1,1	0,2	0,4	0,2	0,0	0,6

- Warming occurs during other seasons, equally during winter and spring when it is 0.6ºC and for the autumn it is just 0.3ºC (Table 6);
- There is a trend which show that vegetation period starts before the usual time, which can be explained by an increase in winter and especially spring temperatures, in average for 0.6ºC;
- There is a general trend of increasing temperatures from the first to the following climatic periods, which can be observed in the attached charts. Temperature from the first to the second climatic period is noticed, while the same decreases from the second to the third, and is most pronounced from the third to the fourth climatic period. These can best be seen on the charts of Sarajevo and Bjelasnica, which have the longest instrumental monitoring of air temperature.
- There is a general pattern in the precipitation regime, which is inversely related to the increase in air temperatures - warming causes aridity, and cooling causes humidity.

Based on the analyzes of the thermal regime in Bosnia and Herzegovina, which show a trend of rising air temperature and undoubtedly confirm the general tendency of global warming, which is especially manifested during the last two climatic periods. Causes should be sought in addition to anthropogenic but also in geogenic and cosmogenic processes and phenomena.

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