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INDICATORS OF SPECIFICITY OF CLIMATE: THE EXAMPLE OF PODGORICA (MONTENEGRO)

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Abstract: Climatic indices complexly display the climate of a place, and certainly influence its more qualitative characterization. In this paper, the specificity of the climate is analyzed, such as the degree of continentality and aridity, in the example of the city of Podgorica. The climate was considered on the basis of the data for almost the entire instrument period (1951–2017). The results obtained for thermal continentality show that maritime influences are primary and predominant, but the influence of the continent is also significant. In a hygric sense, the climate of Podgorica is characterized as poorly arid to poorly humid with significant oscillations during the year. The warmer period of the year, especially the summer, has the characteristics of arid climate. The colder period of the year, especially from November to February, has the characteristics of humid and even perhumidic climate, while the transitional seasons show signs of semi-aridity and semi-humidity.

Keywords: climate; continentality; aridity; Podgorica

Introduction

Podgorica and a great part of Montenegro have the characteristics of the Mediterranean climate. This is also confirmed by the criteria set by V. Köppen (Burić, Ducić, & Mihajlović, 2013; 2014). However, the basic climate elements give a realistic image of the climate of a site or territory, but very often it is also necessary to determine some climate specifies. In such a case, the analysis of the supplementary climate indicators, as well as combined climatic elements, is used. They are calculated from two or more basic climatic elements. These are climate indices. Climatic indices complexly display the climate of a site, and certainly influence its more qualitative characterization. In this paper, the specific characteristics of the climate of Podgorica are analyzed, such as the degree of continentality and aridity.

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Database and research methodology

The specificities of the Podgorica climate were considered on the basis of the data for almost the entire instrument period (1951–2017). The data are for meteorological station, the arrays are mostly complete, and the testing and verification of data have shown that the measurements are reliable (CLIDATA database of the Institute for Hydrometeorology and Seismology of Montenegro was used).

In methodological terms, the climate specificities of Podgorica were determined on the basis of appropriate forms. Thus, the continentality of the Podgorica climate is calculated on the basis of the Gorczynski, Conrad and Kerner formulas, and the aridity by Gracanin rain factor and de Marton and Lobova indexes. All these indicators are given below.

Results and discussion

Continentality of the climate of Podgorica

The continentality of a climate was calculated using the methods of Gorczynski, Conrad and Kerner.

The thermal degree of continentality of the Gorczynski (K) takes into account the latitude and the amplitude of the annual air temperature. It is expressed in percentages and calculated according to the formula (Vujević, 1956):

$$K = 1,7(A - 12\sin\varphi)/\sin\varphi$$

φ–latitude; A – average annual temperature amplitude.

By applying the formula, for Podgorica (φ = 42°26; A = 21.3° C), the thermal degree of climate continentality K = 33.5% is obtained.

A similar value was obtained using Conrad formula (Vujević, 1956):

$$K = (1,7A/(\sin(\varphi+10))-14$$

The signs are the same as in the previous formula, and applied to Podgorica K = 32%.

Kerner introduced the so-called the thermodrom quotient (K), obtained by the formula (Ducić, & Anđelković, 2004).

$$K = (T_X - T_{IV})/A \cdot 100\%$$

TX–average October temperature (for Podgorica 16.1°C);

TIV–average April temperature (for Podgorica 14.3°C);

A – average annual temperature amplitude.

October and April are chosen because their average temperatures are closest to the annual value. According to Kerner, continentality of climate in Podgorica is K = 8.3%, and the limit of maritimity is 15%. If K <15 climate has continental gradations, and if K> 15 is maritime, then the negative values indicate a distinct continentality. Therefore, this indicator clearly shows that the effects of maritimity and continentality in the thermal sense are intertwined in this area, and on the basis of the thermodrom coefficient, it could be said that the climate of Podgorica has weak continental characteristics.

Aridity of the Podgorica climate

In 1950, M. Gracanin introduces a rain factor for each month of the year, as a ratio of monthly rainfall (R_{srm}) and a mean monthly temperature (t_{srm}) for a given month (Ducić, & Anđelković, 2004):

$$KF_m = R_{srm}/ t_{srm}$$

The monthly rain factor (Table 1) was calculated on the basis of the values of monthly rainfall and mean monthly temperatures in Podgorica.

Table 1: Monthly rain factor in Podgorica

Rain factor	*months*											
	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
average	32.4	24.5	14.9	9.5	4.8	2.7	1.4	2.3	6.1	11.1	22.4	32.5

Three summer months are classified as arid. May is semi-arid and September is semi-humid. April and October are humid. From November to March there is a period of high humidity, that is, these months are perhumid. Therefore, the summer in Podgorica is characterized as very dry, and the winter as very humid, while the transitional seasons would be really transient.

The de Marton drought index (I) is another of the frequently used indicators of climate aridity. It is calculated from the ratio of annual precipitation (R_{srg}) and average annual temperature (t_{srg}) increased by 10 (Ducić, & Anđelković, 2004):

$$I_g = R_{srg}/(t_{srg} + 10^{\circ})$$

The drought index can be calculated for each month separately, but the formula is slightly changed:

$$I_m = 12R_{srm}/(t_{srm} + 10^{\circ})$$

On the basis of monthly and annual temperatures and precipitation in Podgorica, the de Marton drought index has the following values (Table 2):

Table 2: The de Marton drought index in Podgorica

Drought		*Months*											
index	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*annual*
average	137.8	120.3	90.3	66.9	38.3	22.7	12.0	19.9	49.7	81.9	139.3	159.0	64.7

According to the Table 2 data, the following can be concluded:

- Only July is classified as semi-arid month (steppe vegetation);
- August and June have similar, i.e. border values of drought index, while other months, despite high temperatures, have high drought index values;
- Autumn and winter months (November-February period) have the highest values;
- The annual value of the drought index shows high humidity, which allows continuous and abundant drainage.

More recently, the Lobova index (Va) is used to assess the aridity of the climate. It is obtained by the formula:

$$V_a = R_{srg} /(6.12\ \Sigma t_{srA\text{-}O} + 30.6)$$

R_{srg} – average annual amount of precipitation; $\Sigma t_{srA\text{-}O}$ – the amount of average monthly temperatures in the period from April to October.

According to the value of precipitation and temperature in Podgorica, the aridity index is: $V_a = 1.8$, which means that climate in Podgorica in the period April-October can be characterized as low-arid.

Conclusion

The considered thermal indicators indicate that the climate of Podgorica cannot be characterized as either maritime or real continental. Consequently, the impacts of the Adriatic Sea (the Mediterranean) and the continent are intertwined in this area. However, the values of thermal continentality are such that maritime influences are primary and predominant, but the influence of the continent is significant.

In a hygric sense, Podgorica's climate is characterized as low-arid to low-humid with significant oscillations during the year. The warmer period of the year, especially the summer months, has the characteristics of arid climate. Cold period of the year, especially November–February, has the characteristics of humid and even perhumid climate. The transient seasons are transient in terms of humidity, so they show the marks of the semi-arid (May) and semi-humid (September) climates.

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