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Physical Geography

Prediction of Temperature Regime of Aridity on the Example of Tbilisi

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(Presented by Academy Member Tamaz Chelidze)

ABSTRACT. The temperature regime of draught was studied and effort of its prediction were conducted based on the example of 1881-2006 daily average air temperature of warm period of Tbilisi. The distribution probability density is ascertained according to the value of those data and the mathematical expressions of temperature temporal change are obtained describing change regulation in linear and non-linear approximations. The cases from the mentioned database are selected, whereas the daily average temperature reaches higher extreme level i.e., when drought and desertification forming favorable conditions are established. Depending on the distribution probability density, 29°C is considered as such temperature. 75 such cases were found in the database discussed. For the purpose of developing prediction method, the previous 6 and the following 5 days of each case are taken and the correlation D between them are studied. It was turned out that optimal was the connection of the 4 day temperature sum prior from draught beginning with 3 day temperature sum. By using ordinary orthogonal disintegration method of random function the prediction method has been received. *© 2019 Bull. Georg. Natl. Acad. Sci.*

Key words: aridity, drought, extreme temperature, random function

Violation of sustainable equilibrium condition of the Earth due to the gradual increase in its energy level that led the global warming created many unwanted problems to humanity. One of these problems is the increase in frequency of aridity and the promotion of desertification. The increase in aridity, as the starting and supportive process of desertification, is characterized by a sharp deviation from the regime condition of temperature and precipitation – the two main parameters identifying atmospheric condition, namely, by the increase in temperature and decrease in precipitation. The atmospheric condition when its regime structure is characterized by excessive temperature and precipitation deficits, was studied significantly in Georgia [1-9]. Information about drought was obtained from existing short-term predictions.

The aim of this work is to study and determine the information on the drought intensity in the pre-drought period temperature values and to use it in preliminary assessment of aridity. We tried to solve this problem by using the values of every day, diurnal average temperature from the Tbilisi Meteostation, having a long period of observation for the warm period according to 1881-2006 years. Distribution of the temperature values, used to conduct research, is given in Fig. 1.

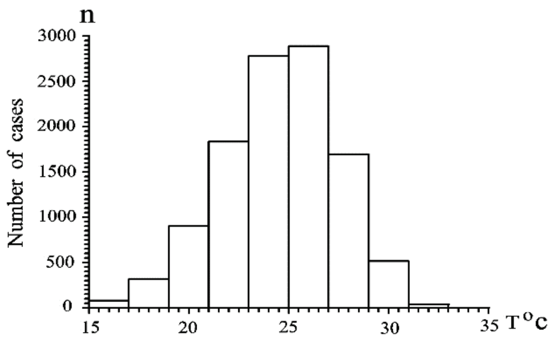

Fig. 1. Distribution of the daily average temperature in Tbilisi from June 15 to September 12 in 1881-2006.

The number of cases (n) and daily average temperatures (°C) are given in the coordinate axes. We considered the warm period of the year the date, when the daily average temperature exceeds 15°C. Such dates turned to be June 15 and September 12. As Fig. 1 shows, the distribution is close to normal with the left asymmetry. To identify the changes in surface temperature field of Tbilisi on the background of modern global warming according to the warm period of the year, shown in Fig. 2. Daily average temperature of warm period of each year during 1881-2006 is given in Fig. 2.

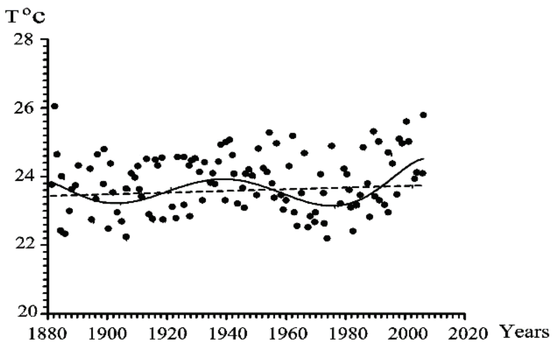

Fig. 2. Changing in daily average temperature of warm period of the year in Tbilisi in 1881-2006 and its linear (intermittent line) and nonlinear (continuous curve) approximation.

A linear approximation gives the approximate picture of the temperature change. In particular, it determines only the increase, decrease or unchangeableness of temperature for the entire period. Equation of the temperature linear change can be obtained by means of the least squares method [10]. Using it the following equation was obtained:

$$T(n) = 18.83 + 0.0025n \qquad (1)$$

where $T(n)$ – is the daily average temperature of the warmest period of any year (from June 15 to September 12) from 1881 to 2006, and n – is a time step of years in the given period starting from 1. Thus, the mentioned period is characterized by a little warming when the average increase in annual temperature is 0.0025 °C. A relatively accurate picture of temperature change gives a non-linear approximation. It was conducted using the least squares method and the sixth line polynom turned to be optimal that implemented the approximation with the least standard error. Finally, the formula depicting temperature change with the sixth polynom was the following:

$$\begin{aligned} T(n) &= -3.97.109 + 1.23.107n - 1.58.104n^2 + \\ &+1.09.101n^3 - 4.21.10 - 3n^4 + 8.68.10 - \\ &-7n^5 - 7.46.10 - 11n^6. \end{aligned} \qquad (2)$$

As shown in the figure, a periodic character of change has been sharply stood out in temperature variables. Thus, the change in temperature field, based on the used actual data, is characterized by periodicity and throughout the period there is a little warming with the intensity of 0.25°C for hundred years. To distinguish a drought period from the used actual data, especially if we use only temperate data, is quite difficult. It is influenced by the lack of precipitations, the lack of humidity in the atmosphere, the moisture storage in the soil, and in addition to all above-mentioned the different requirements of agricultural crops for the above parameters. For distinguishing drought periods using only the temperatures data, a curve of daily average temperatures probability density distribution has been derived (Fig. 3).

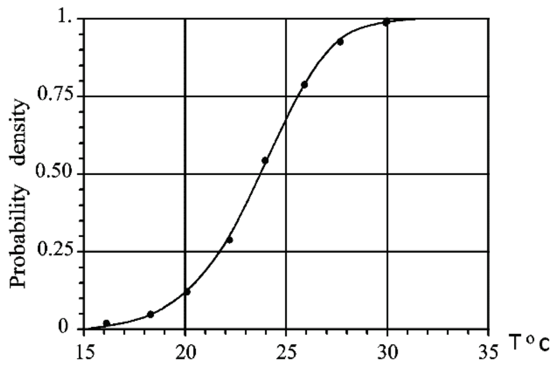

Fig. 3. Distribution of the daily average temperature probability density of the warm period of the year in Tbilisi.

The starting period of the drought was considered the temperature meaning, which gives 5% of the highest temperature cases from the row ranged according to temperature growth. The meaning of such temperature was close to 29°C and we considered it the beginning of drought (hereinafter referred to as "drought criterion"). There were 75 cases (i.e. when the daily average temperature reached 29°C) in the obtained temperature data (Tbilisi, warm period of 1881-2006). The database, which should have been used in the prediction, was built only by these 75 cases. In particular, we took the previous six and five days from the drought criterion. I.e. each case made the 12 daily average temperatures. The average changes in temperature in separate cases and the corresponding average square deviations are given in Fig. 4.

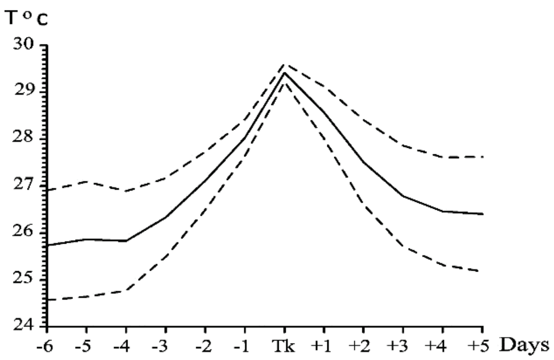

Fig. 4. The previous 6 and following 5 daily average temperature from drought criterion (T≥29°C) and corresponding average square deviation (intermittent line).

Temperature (°C) and previous 6 and following 5 days from drought criteria are depicted in the coordinate axes. As it is seen from Fig. 4, the post-drought period criterion is characterized by the gradual decrease in temperature and it depends on the criterion selection. Prediction can only determine the duration of drought intensity. To check the correlation relation among the days in the conditions of positive extreme temperatures, we calculated the correlation coefficients among the temperature sums of different number of previous and following days of drought criterion. The calculation results are given in Table 1.

Table 1. Correlation relation of temperature sums of previous days of the drought criterion with the temperature sums of arid days

Number of pre-drought days	Number of drought days				
	5	4	3	2	1
6	0.194	0.244	0.253	0.174	0.188
5	0.213	0.247	0.253	0.171	0.170
4	0.221	0.232	0.262	0.167	0.149
3	0.177	0.173	0.183	0.109	0.075
2	0.145	0.140	0.143	0.060	0.030
1	0.090	0.105	0.083	0.029	0.061

First of all, the data of Table 1 show that despite the minimal meanings of the coefficients, their stable variation according to the number of days bears some information. And how it is possible and practical to use this information should be shown by the post researching process. If we use the Table data, we should get the optimal result of forecasting, when we determine the sum of temperatures of 3 drought days with the sum of temperatures of 4 days before drought criterion. According to the Table, the correlation coefficient is the greatest in this case. Based on this fact, the forecasting scheme can be formulated as follows – prediction of following 3 days temperatures sum from drought criterion with the previous 4 days temperatures sum of criterion. Using the method of disintegration of random function into natural orthogonal constituents [11], we identify two rows out of 75 drought cases. These rows are:

$$Tp_1, Tp_2, Tp_3, ..., Tp_{75}, \quad (3)$$

where Tp_i is a sum of temperatures of previous 4 days from drought criterion and

$$Tn_1, Tn_2, Tn_3, ..., Tp_{75}, \quad (4)$$

where the Tn_i – is a sum of temperatures of the following 3 days of drought criterion.

The auto-correlation matrix between the mentioned rows has a following form:

$$\begin{vmatrix} R(Tp\ ,Tp\ ) & R(Tp,Tn) \\ & R(Tn,Tn) \end{vmatrix} \quad (5)$$

It enables us to determine the sum of the temperatures of following three days of drought criterion, by the known meaning of sum of the previous 4 days of drought criterion. As it was already mentioned, for this we use the method of disintegration of random function into natural orthogonal constituents. Based on this method, the formula to be calculated as the following form:

$$T = \overline{T}_n + \frac{R(T_p, T_n)}{R(T_p, T_p)}(T_p - \overline{T}_p) \quad (6)$$

where T_p and T_n are the average arithmetic of (3) and (4) rows respectively.

Using the factual meanings of the obtained rows, the formula (6) obtains the following specific form:

$$T = 82.9 + 0.22(T_p - 107.3) \quad (7)$$

In order to find out the intensity even approximately, we divided the used drought cases into intensive and less intensive cases. Whether it is possible to predict drought intensity, this should be shown by the fact how this division will be reflected on the pre-drought period. For this, we divided the members of the (3) and (4) rows according to drought intensity into two parts – intensive, or when the T_n> 107°C and such cases turned to be 39, and the remaining 36 cases, or when $T_n \leq$ 107°C. Meanings of temperatures of drought days and its previous days obtained as a result of division are presented in Fig. 5, in the coordinate axes.

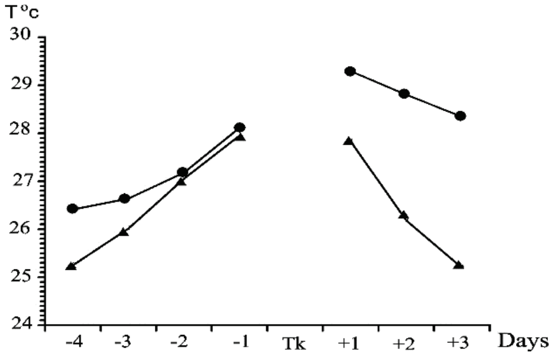

Fig. 5. From the criterion of drought for the previous four and following three days temperatures during intensive (●) and less intensive (▲) droughts.

The average daily temperature, previous and following days from drought criterion are represented (Tk). It is clear from Fig. 5 that there is certain a priori information on drought intensity in the pre-drought days, especially on the 4th and 3rd day before drought. Despite fact that the number of cases is decreasing, and this leads to the worsening the forecast accuracy, we tried to identify, how the drought forecasting is reasonable considering the value of the sum of temperatures of previous period. For this purpose we divided 75 cases used for drought forecasting according to the values of pre-drought 4 days temperatures sums by two and then by three groups. We used the above described method for each group independently and identified the forecasting formula for each group. A forecasting formula, when we divide the pre-drought 4 days temperatures sums into two groups and the boundary is 107°C, takes the following form:

$$T = 81.1 - 0.89(T_p - 103.4), \quad (8)$$

when the pre-drought 4 days temperatures sums is ≤ 107°C:

$$T = 84.5 - 0.18(T_p - 111.0), \quad (9)$$

when the pre-drought 4 days temperatures sums is > 107°C.

Table 2. The accuracy of the drought intensity forecast considering the values of the previous four days temperatures sum

Pre-drought four days temperatures sum grouping and corresponding borders		Average square deviation		Extreme deviations (%)		Error distribution (%)			Random value
Groups	Borders, °C	°C	%	Negative	Positive	≥10	<10; >5	≤5	
Without division	-	5.43	5.4	-12.5	10.7	2	14	59	75
In 2 groups	107≤	3.98	4.9	-16.4	8.5	1	9	26	36
	>107	4.19	5.0	-14.4	7.9	2	8	29	39
In 3 groups	103≤	2.72	3.4	-9.0	5.8	0	2	11	13
	>103; 110≤	4.72	5.3	-18.3	8.2	2	10	28	40
	>110	4.29	5.1	-11.1	7.4	2	5	15	22

In case dividing the pre-drought 4 days temperatures sums into three groups, the drought intensity formulas take the following form:

$$T = 81.3 - 0.30(T_p - 100.2), \qquad (10)$$

when the pre-drought 4 days temperatures sums is ≤ 103°C:

$$T = 81.3 - 0.79(T_p - 106.5), \qquad (11)$$

when the pre-drought 4 days temperatures sums is > 103°C and ≤ 110°C and

$$T = 84.4 - 0.48(T_p - 113.0), \qquad (12)$$

when the pre-drought 4 days temperatures sums is > 110°C.

For the purpose of determining the accuracy of the obtained formula, using all the formulas we calculated the sum of the three days temperatures of drought of 75 cases and compared with the actual values. Meanings of several parameters for determining the accuracy of the above obtained methods are shown in Table 2.

Table data analysis shows that consideration of drought tensity, even when dividing intensity into is unimportant; it varies within 1%; i.e. that when the knowledge of the course of changing in temperature of further three days of drought criterion is a necessary information, its approximate definition is available using the previous four days temperatures sums and the formula (7).

ფიზიკური გეოგრაფია

გვალვიანობის ტემპერატურული რეჟიმის პროგნოზირება ქ. თბილისის მაგალითზე

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**თბილისის სახელმწიფო უნივერსიტეტი, ვახუშტი ბაგრატიონის სახ. გეოგრაფიის ინსტიტუტი, ჰიდროლოგია-კლიმატოლოგიის განყოფილება, თბილისი, საქართველო*

(წარმოდგენილია აკადემიის წევრის თ. ჭელიძის მიერ)

შესწავლილია გვალვიანობის ტემპერატურული რეჟიმი და მისი პროგნოზირების მცდელობა ჩატარებულია თბილისის 1881-2006 წლების თბილი პერიოდის დღე-ღამის საშუალო მიწისპირული ტემპერატურის მონაცემების მაგალითზე. დადგენილია აღნიშნული მონაცემების სიდიდის მიხედვით განაწილების ალბათობის სიმკვრივე და მიღებულია ტემპერატურის დროში ცვლილების მათემატიკური გამოსახულებები, რომლებიც აღწერენ ცვლილების კანონზომიერებას წრფივი და არაწრფივი მიახლოებებით. აღნიშნულ მონაცემთა ბაზიდან შერჩეულია შეთხვევები, როცა დღე-ღამის საშუალო ტემპერატურა ნორმაზე მაღალ ექსტრემალურ მნიშვნელობას აღწევს, ე. ი. როცა ყალიბდება გვალვა და გაუდაბნოების ხელისშემწყობი პირობები. ალბათობის განაწილების სიმკვრივიდან გამომდინარე, ასეთ ტემპერატურად მივიჩნიეთ 29°C. განხილულ მონაცემთა ბაზაში 75 ასეთი შემთხვევა აღმოჩნდა. პროგნოზირების მეთოდის შემუშავების მიზნით ავიღეთ ყოველი შემთხვევის წინა 6 და შემდეგი 5 დღის მონაცემები და შევისწავლეთ მათ შორის კორელაციური დამოკიდებულება. ოპტიმალური აღმოჩნდა გვალვის წინა 4 დღის ტემპერატურის ჯამის კავშირი, გვალვის საწყისიდან 3 დღის ტემპერატურის ჯამთან. შემთხვევითი ფუნქციის ბუნებრივ ორთოგონალურ მდგენელებად დაშლის მეთოდის გამოყენებით მივიღეთ პროგნოზირების მეთოდი.

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