საქართველოს მეცნიერებათა ეროვნული აკადემიის მოამბე, ტ. 7, №3, 2013
BULLETIN OF THE GEORGIAN NATIONAL ACADEMY OF SCIENCES, vol. 7, no. 3, 2013

Physical Geography

The Peculiarities of Temperature Regime in Georgia Contributing to Droughts and Desertification

Maia Ananidze

Shota Rustaveli State University, Batumi

(Presented by Academy Member Tamaz Chelidze)

ABSTRACT. The changes of the positive temperature anomalies in the warm period of year (May-October), including the temperature regime causing drought and desertification in the territory of Georgia, were studied. The territory was divided into the following regions: South-Caucasian highlands; Eastern Georgian area; Meskheti-Djavakheti highlands; Mountain ranges of the Western Georgia. Three different periods of time1906-1940; 1941-1975; 1976-2009 were identified. The statistical charactheristics of positive temperature anomalies of the surface in the warm season were defined. According to the territorial groups the dynamic norms were estimated to the period of 1906-2009, i.e., changes in the norm are determined by the method of the linear approach. Also non-linear approach to the same changes was used with sixth polynomial series. The probability of density distribution of the positive anomalies of the surface temperatures was determined on the territory of Georgia and the set of those anomalies was divided into the following groups: weak, medium and strong ones. Peculiarities of the changes of the weak, medium and strong anomalies were studied with account of global warming. The maps of the weak, average and strong positive temperature anomalies on the territory of Georgia were created. *© 2013 Bull. Georg. Natl. Acad. Sci.*

Key words: *dynamics of temperature field, data series, statistical analysis, observation stations, air temperature.*

Georgia with its versatile climate resources is the richest country. There is a great variety of climate dominating on this relatively small territory beginning with soft, humid subtropical climate of the Black Sea coastline to the rigorous climate zone of the Caucasus high mountains capped with perpetual snow and ice [1]. Nowadays, against the background of global warming the climate change in Georgia is likely to be drastic. Indeed, the current warming process is going on with great peculiarities. Along with warming, it is cold in some regions of this relatively small but fragmented territory [2]. Undoubtedly, the long process of climate warming will activate the processes causing to droughts and desertification [3].

Generally, we can describe the process of climate change in Georgia as follows: in the region of Eastern Georgia, the annual temperature is observed to increase mainly by $0.5^0C/100yr$ with the maximum of $0.8^0C/100yr$. The warming process is relatively greater in Southern Georgia, in Meskheti-Javakheti highland, where the temperature increases by 0.7^{0}C/100yr with the maximum of 1.6^{0}C/100yr. In the mountainous zone of the southern slope of the Caucasus, warming and cooling have been going on almost equally. Warming occurrs in the eastern part of the zone and cooling in the western part. Temperature rise is about 0.3^{0}C/100 yr and cooling -0.2^{0}C/100yr. Comparison of the data of the warm and cold periods of year gives ground to conclude that cooling is greater in the cold season, where the average temperature rise is 0.2^{0}C/100 yr and the average temperature fall is -0.4^{0}C/100yr. As to the western part of the mountainous zone, warming (0.2^{0}C/100yr) is mainly observed in the cold period of year, while in the warm period, actually, there is no cooling at all [4]. Naturally, such a peculiarity of air temperature variation in the last century caused melting of the glaciers in the Caucasian nival zone, which continues even today [5,6]. The cooling process is most of all observed in Western Georgia with the average of -0.4^{0}C/100yr and with the minimum of -0.85^{0}C/100yr.

The climate warming process causes recurring droughts, while recurrence is the main factor contributing to desertification. It should be noted that the desertification process is mainly conditioned by active recurrence of droughts and decrease of precipitation. However, there are other factors having an impact on desertification beginning with atmospheric processes to structural composition of soil [11].

In Georgia the study of the processes causing droughts and desertification has a long history. As far back as in the middle of the last century T. Davitaia contributed much to the study of the recurrence of droughts on the territory of the former Soviet Union and assessed its negative impact on agriculture, developing ways of its reduction [7]. Along with historical analysis of droughts and preventive measures against them D. Mumladze and G. Gagua identified present climatic peculiarities of droughts in Georgia and described possible ways of their prevention [8]. A group of authors studied the case of the year 2000, which was distinguished for intensive and prolonged droughts in Georgia [9]. In particular, the peculiarity of the extreme synoptic and climatic processes caused by droughts was assessed. T. Turmanidze considers droughts as a complex phenomenon depending on atmospheric processes as well as on soil and plant structure [10].

Indeed, out of climate determining factors primarily the temperature rise and reduction of precipitation must be contributing to the activation of the processes of droughts and desertification [3].

The regime of the mentioned two parameters in the warm period of the year is especially important. Using the average monthly data obtained from 28 points of Georgia in 1906-2009, we made an attempt to study the regime of positive anomalies of the Earth's surface temperature in Georgia for the warm period of the year (May-October) and to estimate current changes of that regime against the background of global warming. For general characterization of temperature, we divided the whole period into three parts according to time (1906-1940; 1941-1975; 1976-2009), and according to territory into four regions: high-mountainous zone of the southern slope of the Caucasus; the Eastern Georgia plain; the Meskheti-Javakheti highland; the foothills of Western Georgia. We defined the anomalies from the arithmetic mean of 104 years. The temperature anomalies (Ta), identified in this way, directly show its variation in the three periods. The results obtained and relevant square deviations (σ^2) are given in Table 1.

As the Table shows, the temperature anomalies of the first period are negative in all four regions; afterwards they gradually increase and in the second period their values approach zero. In the third period, temperature anomalies greatly increase, especially in the first three regions, i.e., during the whole period under consideration the temperature field gradually increases.

Values given in the Table are characteristic of annual temperature changes. However, it is the temperature regime of the warm period of year that has the decisive significance for the desertification process. Fig. 1 presents the variation of temperature

Table 1. Temperature anomalies in Georgia and the average change in their square deviations according to the three periods of 1906-2009

Years	High-mountainous zone of southern slope of the Caucasus		Eastern Georgia plain		Meskheti-Javakheti highlands		Western Georgia foothills	
	Ta ^0C	σ^2 ^0C	Ta ^0C	σ^2 ^0C	Ta ^0C	σ^2 ^0C	Ta ^0C	σ^2 ^0C
1906-1940	-0.074	1.495	-0.193	1.576	- 0.181	1.571	-0.051	1.554
1941-1975	-0.084	1.805	0.032	1.736	0.033	1.771	0	1.947
1976-2009	0.163	1.592	0.166	1.552	0.152	1.752	0.053	1.637

anomalies in four regions according to years.

The six-month variation of average values of positive anomalies is approximated by linear and sextic polynomials. It should be noted that linear approximation determines the dynamic norm of the average values of the mentioned temperature anomalies in six months [12], while the sextic polynomial precludes random variations and shows a general biased picture of changes in anomalies.

The lines drawn in the Figures determining the dynamic norm of positive anomalies in each region show that in the period under consideration the greatest global warming occurred in Western Georgia. If we define dynamic norms by the least square method, we

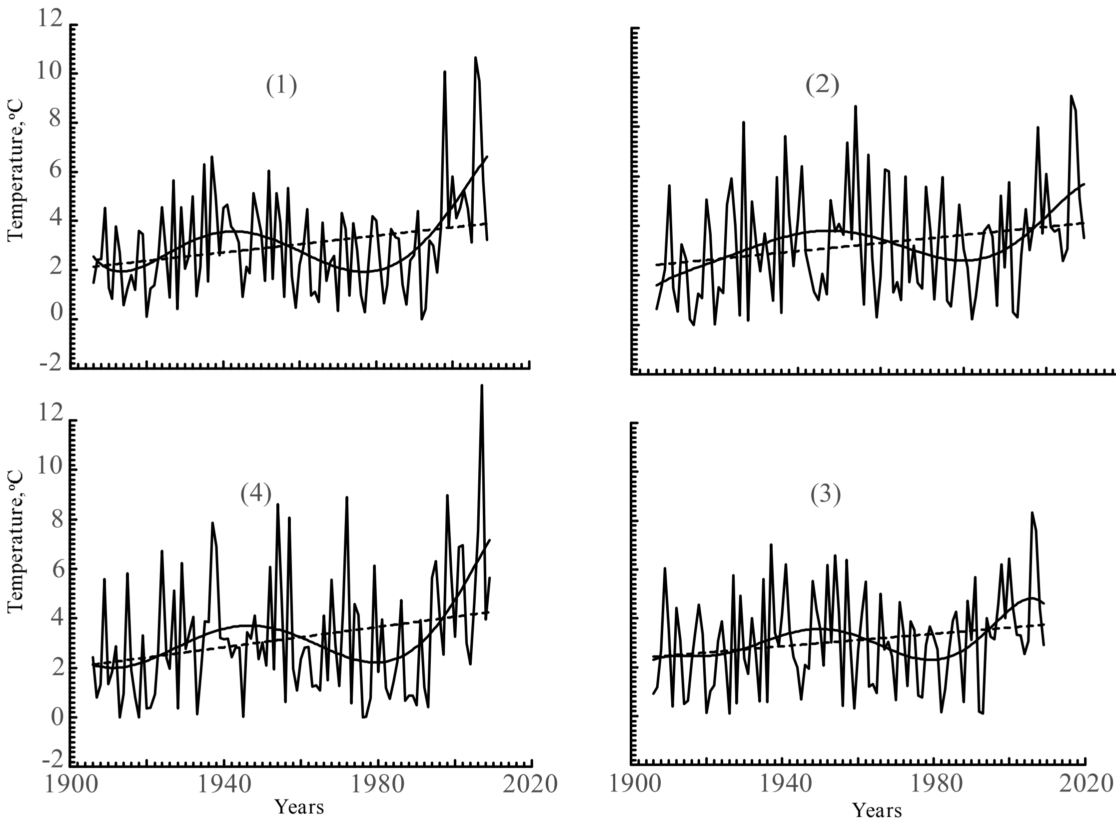

Fig. 1. Actual variation of positive temperature anomalies in 1906 - 2009 (zigzag line), linear (broken) and sextic polynomial (curve) approximation in the high-mountainous zone of the southern slope of the Caucasus (1); the Eastern Georgia plain (2); the Meskheti-Javakheti highland (3); the foothills of Western Georgia (4).

will find that in Western Georgia, annual rise of positive anomalies was 0.021°C/yr. In the eastern and southern regions, the process of growth was almost similar (0.013-0.016 °c/yr). In the high-mountainous zone of southern slope of the Caucasus there was a slightly stronger process of global warming (0.017°c/yr). It should be noted that as the work [2] shows the most intensive temperature growth was observed in the Meskheti-Javakheti highland (Southern Georgia). As to Western Georgia, on the contrary, cooling was dominant. In order to estimate the greater rise of temperature anomalies of the warm seasons in Western Georgia, we tried to represent their changes in time without short-period temperature variations. As known, this is possible by means of the sextic polynomial. The positive anomalies change in time is represented in the Figure by means of the sextic polynomial. As the Figures show, the temperature anomalies variation in time is of one and the same character in all four regions. In particular, from 1906 to 1940-1945 the anomalies were characterized by minor rise. Since then up to 1980, they significantly decreased everywhere, and afterwards a sharp rise of intensive anomalies began throughout the whole territory, which is likely to be going on up to the present. Here, Western Georgia is distinguished because until about the 1990s, either no change in temperature or its decrease was observable. This caused greater temperature anomalies in Western Georgia compared to the other regions.

Both the Table and the Figure show that in the period under consideration there was temperature rise and the positive temperature anomalies increased in the warm period of year throughout the whole territory of Georgia. Indeed, this process could cause droughts and desertification. However, it does not give the answer to the question of how intensive impact the above-described picture of growing anomalies could have on the possible activation of droughts and desertification.

Main factor contributing to the process of droughts and desertification must be strong positive anomalies. Therefore, we tried to divide the obtained values of positive anomalies into three stages of weak, medium and strong anomalies. In order to estimate the division range we built a probability distribution curve from the whole spectrum of the given positive anomalies (Fig.2). It permits to divide all the positive anomalies into equal parts with three similar ranges of probability. The range boundaries are denoted by *A* and *B* points dividing the whole range into three ranges of identical probabilities. As a result of such a division we found that there are boundaries of week anomalies from 0 to 1.72°C; the range of temperature anomalies of medium intensity is from 1.72 to 3.85, and strong anomalies are deviations with values of more than 3.85°C.

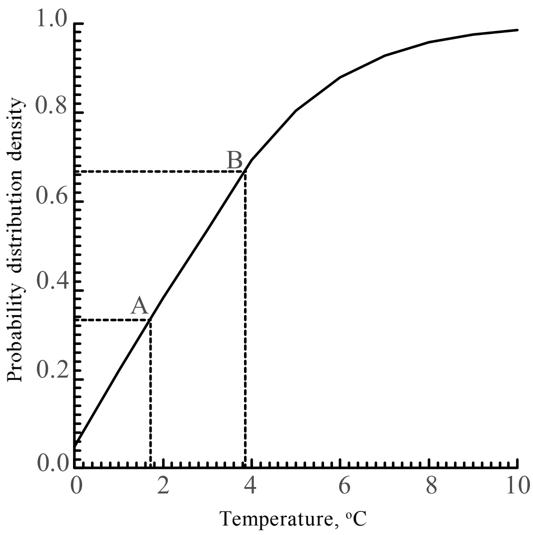

Fig. 2. Probability distribution density of positive temperature anomalies in the territory of Georgia

The favorable conditions for droughts and desertification are determined by the second and especially by the third (strong deviations) ranges. Therefore, for reliability of the results (to increase the number of cases) we considered it reasonable to integrate them. Fig. 3a,b show variation of weak and integrated medium and strong anomalies according to years and the approximations received by their linear and sextic polynomials.

The results obtained describe the variation of positive temperature anomalies in the warm season (May-October) of 1906-2009 as follows: weak positive anomalies almost repeat the same picture characteristic of general positive anomalies (Fig. 2). In

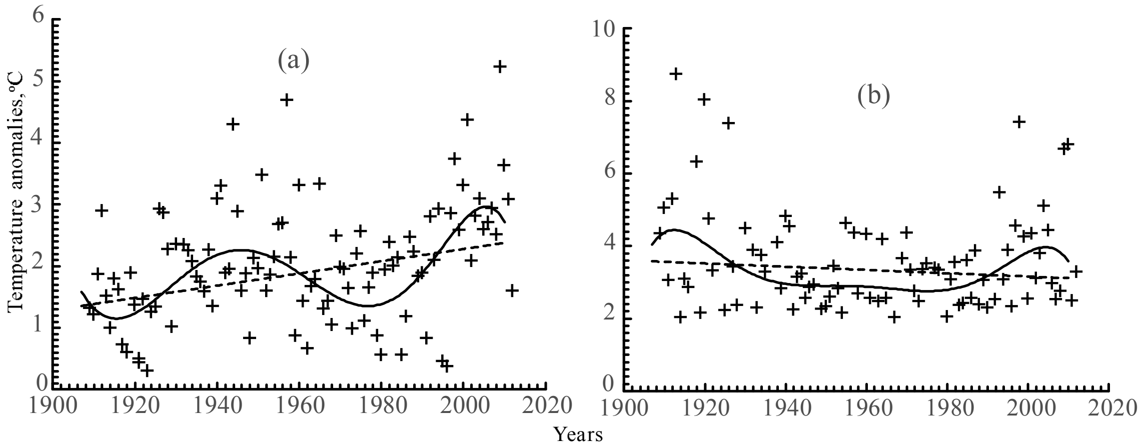

Fig. 3. a.b. Variation of weak (3a) and strong (3b) positive temperature anomalies in the warm season (May-October) of 1906-2009 years and its approximation by linear (broken) and sextic polynomials (curve).

particular, the dynamic norm of the whole period shows the growth tendency with average annual intensity of 0.0099°C, while approximation by polynomial repeats the same process shown in Fig. 2.

There is quite a different picture in the case of strong anomalies. First, it decreased in the period of 1906-2009 with the average annual intensity of – 0.0045°C. As to the approximation by sextic polynomial, it did not suffer decrease from about 1906 to 1980. Then in 2005-2006, it increased sharply. The years 2005-2006 seem to be the period of changes tending to decrease.

Territorial distribution of positive temperature anomalies causing droughts and desertification is very important. To this end we defined the long-term average values of weak and integrated medium and strong anomalies of the 28 observation points under consideration and drew schematic maps, accordingly (Fig. 4 a, b). On the territory of Georgia, the variation range of the long-term average values is from about 1.7°C to – 2.0°C. It is especially small in the lowlands. Growth tendency is observed in the North and South, while it is relatively less intensive in the North-East.

Medium and strong positive temperature anomalies are represented in the central part of the high-mountainous zone of the northern slope of the Caucasus. Here its value reaches 4.4°C. It gradually decreases in the West as well as in the South-East.

In particular, in the central part of the Meskheti-Javakheti highland its annual average value is the least, falling to 3°C. We believe that Fig.4,b describes a favorable regime for droughts and desertification.

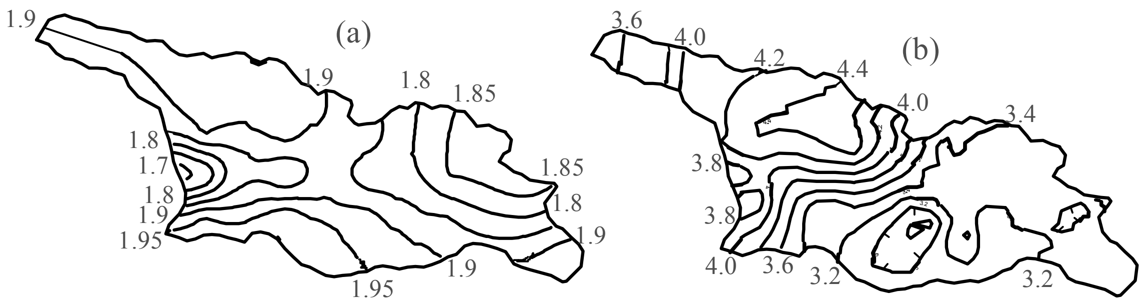

Fig. 4. Distribution of weak (a) and medium and strong (b) positive temperature anomalies on the territory of Georgia.

ფიზიკური გეოგრაფია

გვალვებისა და გაუდაბნოების ხელშემწყობი ტემპერატურული რეჟიმის თავისებურებანი საქართველოში

მ. ანანიძე

შოთა რუსთაველის სახელმწიფო უნივერსიტეტი, ბათუმი

(წარმოდგენილია აკადემიის წევრის თ. ჭელიძის მიერ)

გვალვებისა და გაუდაბნოების ხელშემწყობი ტემპერატურული რეჟიმის თავისებურებანი შეფასებულია მიწისპირა ტემპერატურული ველის დადებითი ანომალიების ვარიაციათა ცვლილებებით წლის თბილი პერიოდისთვის (მაისი–ოქტომბერი), მონაცემთა საერთო სიმრავლე (17 472 შემთხვევა), ტერიტორიის და დროის მიხედვით დაყოფილია შემდეგ ქვესიმრავლეებად: კავკასიონის სამხრეთ ფერდობის მაღალმთიანი ზონა; აღმოსავლეთ საქართველოს ვაკე; მესხეთ–ჯავახეთის ზეგანი; დასავლეთ საქართველოს მთისწინეთი (ოთხი რეგიონი ტერიტორიის მიხედვით); 1906–1940 წწ; 1941–1975 წწ; 1976–2009 წწ (სამი პერიოდი წლების მიხედვით). თითოეული ქვეჯგუფისთვის განსაზღვრულია თბილი პერიოდის მიწისპირა ტემპერატურის დადებითი ანომალიების სტატისტიკური მახასიათებლები. ტერიტორიული ქვეჯგუფების მიხედვით დადგენილია დინამიკური ნორმები 1906–2009 წწ პერიოდის მიხედვით, ანუ დადგენილია აღნიშნულ პერიოდში ნორმის ცვლილება წრფივი მიახლოებით. გამოთვლილია იგივე ცვლილებათა არაწრფივი მიახლოვება მე-6 რიგის პოლინომის გამოყენებით. განსაზღვრულია საქართველოს ტერიტორიისათვის მიწისპირული ტემპერატურის დადებითი ანომალიების ალბათობათა განაწილების სიმკრივე, რის საფუძველზეც ანომალიათა სიმრავლე დაყოფილია სუსტ, საშუალო და ძლიერ ჯგუფებად. გლობალური დათბობის ფონზე შესწავლილია საქართველოში სუსტი, საშუალო და ძლიერი ანომალიების ცვალებადობათა თავისებურებანი. აგებულია სუსტი და გაერთიანებული საშუალო და ძლიერი დადებითი ტემპერატურული ანომალიების განაწილების რუკები საქართველოს ტერიტორიისთვის.

REFERENCES:

1. *K. Tavartkiladze* (2006), in: Proceedings of the Institute of Geography, **1**, 80: 310-320 (in Georgian).
2. *K. Tavartkiladze, E. Elizbarashvili, D. Mumladze, J. Vachnadze* (1999), Empirical model of the change of overground air temperature field. Tbilisi, 128 p. (in Georgian).
3. *K. Tavartkiladze, A. Kikava, R. Solomonidze, N. Gogatishvili* (2010), in: Bulletin of the Academy of Agricultural Sciences of Georgia, 28: 309-317 (in Georgian).
4. *K. Tavartkiladze, N. Begalishvili, T. sintsadze, A. Kikava* (2012), Bulletin of the Georgian National Academy of Sciences, **6**, 3: 55-60.
5. *L. Shengelia, G. Kordzaia, G. Tvauri,* et al. (2011), Science and Technologies, 4-6: 67-78 (in Georgian).
6. Georgia's Second National Communication to the VNFCCC (2009), Ministry of Environmental Protection and Natural Researches – UNPP, Tbilisi, 237 p.
7. *F.F. Davitaia* (1959), Zemledelie, 2: 9-17 (in Russian)
8. *D. Mumladze, G. Gagua* (2002), in: Proceedings of the Institute of Hydrometeorology, 107: 34-38 (in Georgian).
9. *L. Kartlelishvili, E. Elizbarashvili, J. Dolidze,* et al. (2002), in: Proceedings of the Institute of Hydrometeorology, 107: 65-69 (in Georgian).
10. *T. Turmanidze* (2002), in: Proceedings of the Institute of Hydrometeorology, 107: 81-88 (in Georgian).
11. *K. Tavartkiladze, G. Mestiashvili, E. Sajaia, L.Beroshvili* (2002), In: Proceedings of the Institute of Hydrometeorology, 107: 186 (in Georgian).
12. *K. Tavartkiladze, A. Kikava, R. Solomonidze* (2011), Periodical Scientific Journal Khandzta, **4**, 9: 67-78 (in Georgian).

Received January, 2013