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Geophysics

Influence of Global Warming on the Near-Surface Air Temperature Field in Georgia

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ABSTRACT. Statistical analysis was conducted (data of 1906-2009) on the change of near-surface air temperature field for various geographical regions of Georgia. The analysis was fulfilled by the dynamical norm method. Data of 89 points existing in 1906-1995 and 28 points in 1996-2009 were used. Restoration of missing observation data with given accuracy and reduction of the data series to the same period of time were carried out by the method of expansion of the random function in natural orthogonal components in multidimensional space. Natural variability of temperature anomalies, linear and nonlinear trends of the variability, density of space-time change probability are shown. Regional parameters corresponding to two periods of time are compared with each other. Schematic map of change of near-surface air temperature field on the territory of Georgia in 1906-2009 is given. Facts of fall of temperature on the territory of Western Georgia and significant warming in Eastern Georgia in 1906-1995 have been proved. The data of 1906-2009 on warming in all regions under study have also been proved; tendency of the increase of the global warming intensity over the last 10-15 years within the temperature range 0.2-0.5 o C/100yr is shown. Maximal rate of temperature growth observed on the territory of Kvemo Kartli is defined. Results indicate increase of intensity of global warming on the whole territory of Georgia for last 10-15 years. © 2012 Bull. Georg. Natl. Acad. Sci.

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

Study of regional near-surface air temperature field with high accuracy is one of the main problems of modern times since destruction of stable balance of the sun-atmosphere-earth energetic system and a gradual increase of the earth's energy level is doubtless. The first work in this direction for the territory of Georgia was fulfilled for the Initial National Communication and then published as a monograph [1]. In the work the total picture of the change of nearsurface air temperature field made at 89 stations on the territory of Georgia in 1905-1995 was described. Unfortunately, it was modified in the Initial National Communication [2]. As for the change in the nearsurface air temperature field since 1996 numerous studies were carried out using various methods and different ways of solution of the problem.

An independent analysis of time series data, restoration of missing observation data, for different reasons, and verification of homogeneity were carried out by the method of expansion of the random function in natural orthogonal components in multidimensional space

[1,3-8]. It should be noted here that this method is practically the only one which allows us to determine the accuracy of the restoration (error). Furthermore, using this method it is possible to determine time interpolation of series with the error order established a priori. The higher accuracy is required the more data are needed to construct a correlation function. Analysis, restoration and control of homogeneity were made with the use of the eigenvalues and eigenvectors of this function. After the building of a perfect database, which is a decisive factor in the climate change study, the change of near-surface air temperature described in [1] was determined by a linear approximation of multiyear oscillations using the method of the least squares. On the basis of the results of the mentioned study maps were compiled determining changes of the near-surface air temperature in Georgia in the 1906-1995.

It is interesting that global warming in the 20th c. in Georgia was revealed in different ways. It grew a bit colder (0.1-0.2°C/100 yr) in Western Georgia and got perceptibly warmer (0.5-0.6°C/100 yr) in Eastern Georgia [1,2].

Based on the above-said two tasks were marked:

- Determination of the air temperature with new approach (in particular introducing the "dynamical norm" [5]) and comparison of it with the results of earlier researches on the basis of the database existing in the last century (1906-1995) on the territory of Georgia;
- Compilation of a new database which includes the period of 1906-2009. The database consists of observation series of 28 meteorological stations, 14 of which are active at present and characterized by a complete observation period. Therefore restoration in the incomplete series of the remaining 14 points is carried out with minimum interference using the nonmodified natural data and under control of restoration accuracy.

In order to study the first task, the location of 89 observation points on the territory of Georgia in the 20th c. was considered. For further analysis 4 regions (zones) were assigned: (1) – high mountainous zone of the southern slope of the Caucasus; (2) – Eastern Georgia's plain; (3) – Kolkheti lowland and foothills in Eastern Georgia; (4) – Kvemo Kartli and MeskhetiJavakheti highland. The number of observation stations in each zone is respectively (1) – 22; (2) – 22; (3) – 33; (4) – 12.

Statistical analysis is fulfilled according to the data of 89 stations in 1906-1995. The results show that in most parts of Georgia's territory century-long warming has taken place. In particular, mainly annual temperature increase ~0.5°C/100yr with a maximum 0.8°C/100yr was recorded in Eastern Georgia's region. In South Georgia the increase was 0.8°C/100yr with the maximum 0.8°C/100yr. In high mountainous zone warming and fall of temperature were represented equally, but warming concerned the eastern part of the zone and temperature fall – the western part. Increase of temperature there was ~0.3°C/100yr and cooling -0.2°C/100yr. It must be noted that if the data of the warm and cold seasons are considered separately, it is evidence that in this zone temperature fall is more significant in the cold season: an average increase of temperature is 0.2°C/100yr, and an average decrease is 0.4°C/100yr. As for the western part of the high mountainous zone of the Caucasus, mainly warming is recorded in the cold season (0.2°C/100yr) and temperature practically does not fall in the warm season. It is natural that such a peculiarity of a temperature change promoted melting of nival glaciers of the Caucasus, which is continuing to the present [9, 10]. Fall of temperature in Western Georgia was confirmed again in the last century [1,2] – tempera- Influence of Global Warming on the Near-Surface Air Temperature Field in Georgia ture fall was 0.4°C/100yr in average with the minimum 0.85° C/100yr.

Interestingly enough, temperature rise is observed in the warm season in all regions. It totals 0.15-0.62°C/100yr in average with the maximum 1°C/100yr.

Temperature variability within the year should be also noted. In Eastern Georgia the warming takes place almost during the whole year. In this respect only August is an exception: fall of temperature is recorded 0.1°C/100yr in average with the minimum 1°C/100yr, but in October-November the warming-temperature fall spreads equally for areas.

In Western Georgia almost all months were colder except January, February and April. In these three months warming took place on almost the whole territory of the region that finally determined the warming in the cold season of the year in the region.

Peculiarities of the temperature change in Eastern Georgia are repeated in Southern Georgia. August is a different case, temperature fall is registered: 0.5°C/100yr in average with the minimum 1.2°C/100yr.

As for the high mountainous zone of the Caucasus, warming takes place in February-July (6 months, average increase 0.3-1°C/100yr.), and in the other 6 months temperature fall is observed with the average decrease of temperature 0.4-1°C/100yr., which also points to warming in the cold season of year.

In order to study the second problem – dynamics of the air temperature field in 1906-2009, – 28 stations out of 89 were retained for the period of 1996-2009 - 7 stations in each zone. If we take into account that at present 14 stations out of the mentioned 28 are functioning, we can once more point to the minimal interference in the restoration of the observation data of the stations. In this case the restoration and also the reduction of the data of the eration stations to the same period of time were made by the methods of expansion of a random function in orthogonal components (vectors). According to the data of restoration stations in 1906-2009 the accuracy of the month average temperatures (in %) of 1996-2009 in most cases was 85-95%

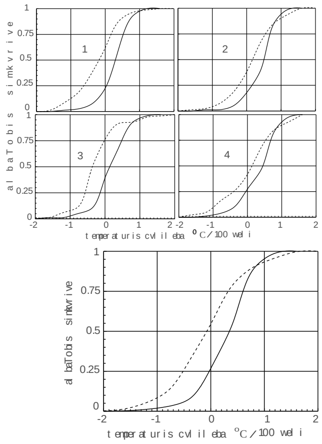

Fig. 1. Temperature change probability density according to 1906-1995 (dashed line) and 1906-2009. (1) – Highmountainous zone of the Caucasus range; (2) – Eastern Georgia's plain; (3) – Kolkheti lowland and foothills in Western Georgia; (4) – Kvemo Kartli and MeskhetiJavakheti highland; (5) – the whole territory of Georgia.

Fig.1 shows probability density of the air temperature change according to the 1906-1995 and 1906- 2009 in each selected region. As seen from the figure, at the 0.05 probability level the value of temperature change in Eastern Georgian plain increased from 0.2°C/100yr to 0.5°C/100yr; on the Kolkheti lowland in Western Georgia and foothills - from -0.4°C/100yr to 0.2°C/100yr (temperature fall was replaced with weak warming); at the high mountainous zone of the southern slope of the Caucasus the temperature was increased from -0.2°C/100yr to 0.4°C/100yr (here temperature fall was also changed to warming); in Kvemo Kartli and Meskheti-Javakheti highland – it was increased from 0.2°C/100yr to 0.5°C/100yr.

Thus, the data of 1906-2009 confirm warming in all four regions with the value within the temperature range 0.2-0.5°C/100yr, which indicates the increase of the global warming intensity over the last 10-15 years.

In Fig.1 the same data are presented for the whole territory of Georgia. In this case at the 0.05 probability level the rate of temperature change increased from ~-0.1°C/100yr to distribution of the temperature anomalies through the territory, which confirms intensification of the global warming on the territory of the country.

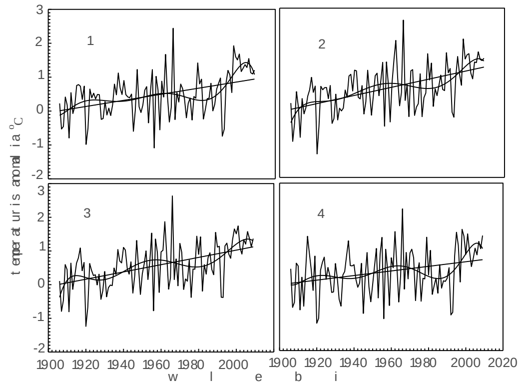

Fig. 2. Changes of temperature anomalies for 4 regions of Georgia (see Fig.1), their linear approximation (linear trend) and 7th order polynomial approximation (nonlinear trend).

Fig. 2 shows natural changes in the temperature anomalies for 4 regions of Georgia, their linear approximation (linear trend) and 7th order polynomial approximation (nonlinear trend). It is of interest that in all regions increase of anomalies is recorded, which is confirmed with both linear and nonlinear trends. The fact should be considered that the nonlinear trend revealed significant decrease for the four regions approximately in 1965-1985, which began in 2004. When the nonlinear trend is considered some questions arise on trends of climatic system development change in Georgia, on continuing a decrease of temperature anomalies a decrease of global warming for the nearest decade, etc.

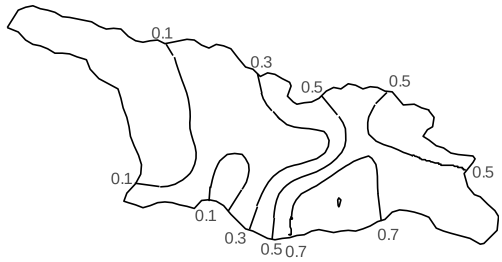

Fig. 3. Temperature field change in Georgia in 1906-2009.

Finally, Fig. 3 presents a schematic map of the changes in near-surface air temperature field in 1906-2009 in Georgia. Isolines depict distribution of the temperature anomalies through the territory.

The picture of temperature field change is homogenous: over the whole territory of Georgia warming is registered, the intensity of which increases from West to East. Maximal rate of temperature growth is observed on the whole territory of Kvemo Kartli where it exceeds 0.8 oC/100yr (Fig. 3)

გეოფიზიკა

გლობალური დათბობის გავლენა საქართველოში მიწისპირა ჰაერის ტემპერატურის ველზე

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# შოთა რუსთაველის სახელმწიფო უნივერსიტეტის გეოგრაფიის დეპარტამენტი, ბათუმი
(წარმოდგენილია აკადემიის წევრის თ. ჭელიძის მიერ)

ქვეყნის 4 გეოგრაფიული რეგიონისთვის – აღმოსავლეთი და დასავლეთი საქართველო, კავკასიონის მაღალმთიანი ზონა, ქვემო ქართლი და მესხეთ-ჯავახეთის ზეგანი, შესრულებულია ჰაერის ტემპერატურის მიწისპირა ველის ცვლილების სტატისტიკური ანალიზი “დინამიკური ნორმის” შემოტანის საფუძველზე. გამოყენებულია 1906-1995 და 1906-2009 წლებში არსებული შესაბამისად 89 და 28 დაკვირვების პუნქტის მონაცემი. დაკვირვების რიგებში გამოტოვებული ელემენტების დათქმული სიზუსტით აღდგენა და რიგების დაყვანა ერთი და იგივე პერიოდამდე შესრულებულია მრავალგანზომილებიან სივრცეში შემთხვევითი ფუნქციის ბუნებრივ ორთოგონალურ ვექტორებათ დაშლის მეთოდით. წარმოდგენილია ტემპერატურის ანომალიების ბუნებრივი ცვალებადობა, მისი წრფივი და არაწრფივი ტრენდები, ტემპერატურის სივრცით-დროითი ცვლილების ალბათობის სიმკვრივეები. ორი პერიოდის შესაბამისი რეგიონალური პარამეტრები შედარებულია ერთმანეთთან. მოცემულია 1906-2009 წლებში საქართველოს ტერიტორიაზე ჰაერის ტემპერატურის მიწისპირა ველის ცვლილების სქემატური რუკა. დადასტურდა გასულ საუკუნეში (1906-1995) დასავლეთ საქართველოს ტერიტორიაზე მცირე აცივების, ხოლო აღმოსავლეთ საქართველოში შესამჩნევი დათბობის არსებობა. 1906-2009 წლების მონაცემებით დაფიქსირებულია დათბობა საქართველოს მთელ ტერიტორიაზე, რომლის ინტენსივობა იზრდება დასავლეთიდან აღმოსავლეთისკენ ინტერვალში 0.2-0.5ოჩ/100წელი. ტემპერატურის მატების მაქსიმალური სიჩქარე დაიკვირვება ქვემო ქართლში, სადაც ის აჭარბებს 0.8ოჩ/100წ. ეს შედეგი მიუთითებს ბოლო 10-15 წლის განმავლობაში საქართველოს ტერიტორიაზე გლობალური დათბობის ინტენსივობის გაძლიერებაზე

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