Regional Climate Change in Georgia Under Global Warming Conditions

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Abstract

Based on the observation data of 87 meteorological stations of Georgia over the period between 1936 and 2009, a trend in changes of air temperature and atmospheric precipitation have been investigated under the conditions of global warming. The geoinformational maps of spatial structure of rate of change in these climate elements have been constructed.

It has been established that changes in temperature and precipitation in Georgia under the conditions of global warming are of heterogeneous nature due to complex physical-geographical and basically orographic and landscape-climatic conditions.

The largest centers and areas of strong warming, with the mean annual air temperature rising at the speed of more than 0.1ºC in a decade have been observed in eastern Georgia. Namely, those are the southern part of Kakheti Ridge, areas in Gudamakari and Kharuli Ridges, Javakheti Plateau. Centers of weak and moderate warming with the temperature rising at a speed of 0.02-0.1ºC in ten years have been basically detected in western Georgia. Decrease in temperature was observed in western Georgia. A sharp drop in temperature has taken place in the most parts of Adjara and northern part of the Black Sea coast where a mean annual air temperature decreased at a speed of more than 0.1ºC in ten years.

On the most part of eastern Georgia total annual precipitation has decreased at a speed of 1-3% in ten years. Total annual Precipitation was increased in some parts of western Georgia - Lechkhumi and Egrisi Ridges, central part of Kolkheti Lowland, western part of Adjara as well as central part of Iori Plateau in east Georgia.

Keywords: climate change, temperature, precipitation

Introduction

Climate change is one of most topical issues of modern times. Given difficult physical and geographic conditions of Georgia, this problem was considered since mid 20th century [I. G. Kurdiani (1956), Y. A. Tsutskiridze (1960), G. I. Chirakadze (1959)], although more reliable patterns of multiyear changes in climate were revealed at the end of 20th and beginning of 21st centuries [K. A. Tavartkiladze, E. Sh. Elizbarashvili, D. G. Mumladze, D. I. Vachnadze (1999), E. Sh. Elizbarashvili, R. Sh. Meskhia, M. E. Elizbarashvili (2005), E. Sh. Elizbarashvili, R. Sh. Meskhia, M. E. Elizbarashvili, L. D. Megrelidze (2009), E. Sh. Elizbarashvili, L. K. Papinashvili (2001)]. Nevertheless, existing sparse meteorological network and complicated mountainous landscape did not allow to obtain a detailed picture of changes in air temperature and atmospheric precipitations in the territory of Georgia under conditions of global warming. At present, 13 meteorological stations operate in Georgia, over the territory of approximately 70,000 square meters, whereas 40 such stations operated as early as in the beginning of the 20th century whilst in the 1940s, up to 200 meteorological stations and posts were up and running.

The aim of this paper was to identify regional peculiarities of the change in basic elements of climate – air temperature and atmospheric precipitations - on the territory of Georgia under global warming conditions.

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Study Area

Georgia is situated in south-western part of the Caucasus between latitudes 41°07’ and 43°05 N, and longitudes 40°05 и 46°44 E. It borders with Russia from the North, Azerbaijan from the East, Turkey and Armenia from the South and Black Sea from the West.

The area of Georgia comprises 67,900 km^2. Location on the border of Mediterranean, arid Aral-Caspian Depression and mountainous Southwest Asia with the continental climate conditioned the diversity of landscape, nature and vegetation of Georgia. The length of Black Sea coastline in Georgia totals 208 km and is free from any significant bays, gulfs, islands or peninsulas. Greater Caucasus Mountain Range runs in the northern part of Georgia.

Southern Georgia highland (often called Lesser Caucasus Mountains) in South Georgia runs parallel to the Main Caucasus Range. Southern Georgia highland is connected to the Main Caucasus Mountain Range by the Likhi Range which represents the watershed of Black and Caspian sea basins.

The territory of Georgia is an extremely rugged topography combining high-mountain, mid-mountain, hilly, lowland-plain, upland and plateau relief. Part of lowlands is located at the sea level whilst separate mountain peaks rise more than 5,000 meters above sea level. In the northern part of Georgia, the Main Caucasus Range extends from north-west to south-east. The highest peak of the country, Shkhara (5068 meters), is located in this stretch of the Main Caucasus. The Main Caucasus Range is the watershed of the rivers in the North Caucasus (Ciscaucasia) and South Caucasus (Transcaucasia). In the high-mountain strip of the country, mountain-erosion, mountain-glacial and nival forms of relief are conspicuous, with glaciers largely contributing to their formation.

A tectonic depression runs between the Southern Georgia highland and the Greater Caucasus Range, which include plains, river valleys, plateaus and lowlands. Distinguished among them by their size and economic importance are the Colchis plain, low-lying plains of Shida Kartli and Kvemo Kartli, the Alazani River plain with its adjacent Shiraki Steppe and Iori Plateau.

Complexity of orographical construction of Georgia’s territory paired with other physical and geographic factors determines a wide variety of landscapes.

Georgia contains various types of soil – from grey-brown and saline semidesertic soils of dry steppes and moderate rainforests to red and ashen-grey soils of humid subtropical zone and alpine mountain meadows.

A significant part of Georgia’s territory is covered by forests, with the total forest resources comprising 3 million hectares. Broadleaved species with evergreen luster can be seen in the lowlands and submontane zone, whilst coniferous species prevail in a high-mountain zone. Timber resources are estimated at 434 million cubic meters.

Recreational resources of the country - both mountainous and seaside resorts – are unique by their characteristics.

In terms of climate, Georgia is extremely diverse. Almost all types of climate can be seen there - from eternal snows and glaciers of alpine zone of the Greater Caucasus Range to humid subtropical climate of the Black Sea shore and continental climate of steppes in the eastern part of Georgia. The Greater Caucasus Range acts as barrier to cold air masses from the North whilst the Black Sea has a large impact on the land adjacent to it. Therefore, a subtropical climate with high humidity and abundant precipitation (between 1000 and 2000 mm annually, and even up to

4000 mm near Batumi) dominate along the Black sea costs and the Colchis plain. The influence of the Black Sea gradually subsides towards the East and almost entirely evaporates at the boundaries of eastern steppes and Southern Georgia highland. The Likhi Range, being an orographic bridge between the Greater Caucasus and the Southern Georgia highland, is also a climate-divider of the western and eastern Georgia with marine humid subtropical climate formed in western Georgia whilst in eastern Georgia, a moderate subtropical climate and a climate transitional to dry continental climate of Southwest Asia.

The river net of Georgia is developed unevenly, with the highest density seen in the western Georgia. Rivers of Georgia belong in two basins - Black Sea (75 percent of river flow) and Caspian Sea. Almost entire flow of the Caspian Sea basin is carried by the Mtkvari River with Mingachevir reservoir located on it. Rivers of the Black Sea Basin (West Georgia) do not form a unified system and flow into the Sea separately. The largest of these rivers is Rioni which runs across the Colchis plain.

The country is rich with plants. Ancient elements of flora, relict and endemic plants are preserved (rhododendrons, boxtrees, cherry laurels, persimmons and others). Fauna is rather diverse. Above 11,000 invertebrate species inhabit the territory of Georgia, including up to 9,150 anthropods (of which above 8,230 species of insects). There are eighty-four river fish species as well as six introduced species; 12 species of amphibians; 52 species of reptilians including three tortoise species, 27 lizard species and 23 snake species (of which three snake species and 12 lizard species are endemic species of the Caucasus). The territory of Georgia is home to 109 species of mammals.

Small mountainous countries, like Georgia, are very responsive to climate change. Rise of average temperature, changes in desertification and redistribution of precipitation, reduction in glaciers, sea level rise, variations in river sedimentation rates and intensification of droughts, strong winds, torrential rains, floods as well as extreme temperatures [E. Sh. Elizbarashvili, R. Sh. Meskhia, M. E. Elizbarashvili (2007), E. Sh. Elizbarashvili, M. R. Tatishvili, R. Sh. Meskhia, M. E. Elizbarashvili (2012)] significantly affect agriculture, economy, health of the population and even the security of the country.

Therefore, it is important to examine changes of air temperature and atmospheric precipitation and construction of the geoinformational maps of spatial structure of rate of change in these climate elements over Georgia.

Material

Along with data of observations of 13 meteorological stations over the period between 1936 and 2011, the following materials were applied to evaluate changes in air temperature and atmospheric precipitations in the territory of Georgia under global warming conditions:

1. Archive of data of the Institute of Hydrometeorology for 90 meteorological stations, created during the preparation of the First National Communication on UN Climate Change Convention (1936-1995);
2. Materials of observation of currently operating 13 meteorological stations (1996-2011);
3. Cadastre data of selected meteorological stations of Georgia's meteorological service;
4. Data of observations of snow-avalanche posts (1995-2011).

These enabled us to use the data of 87 meteorological stations instead of operating 13 meteorological stations in order to evaluate changes in air temperature and atmospheric precipitations in the territory of Georgia.

Methods

Missing data was estimated by applying methods of correlation analysis and corresponding variances or relations. Fig. 1 shows an example of comparison of actual and estimated average monthly temperatures in January at the Kazbegi alpine station over the period between 1936 and 1990, when this station was operational.

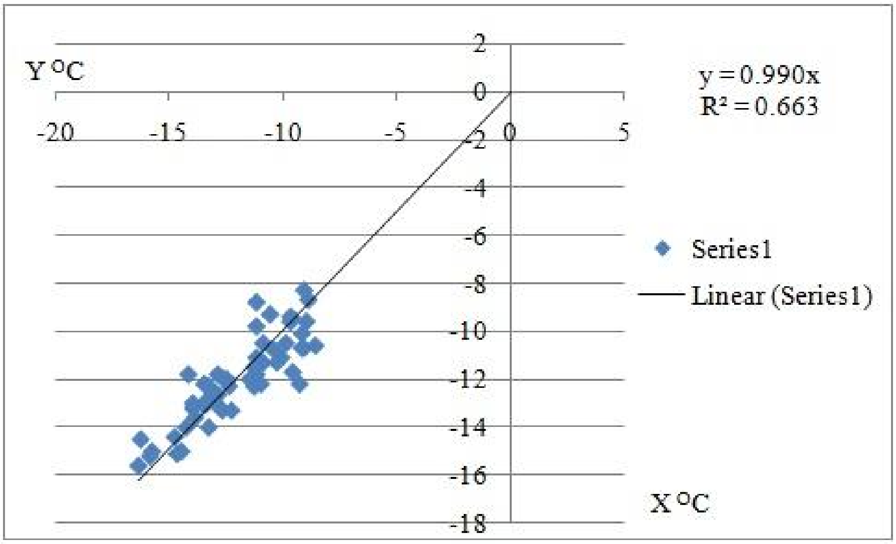

Fig. 1. Dependence between actual (x) and estimated (y) average January temperature at the Kazbegi alpine station over the period between 1936 and 1990, R^2 determination coefficient

The Fig. 1 shows that the dependence between actual and estimated data is almost functional whilst the determination coefficient is rather high. A similar picture is observed at other stations. In this as well as all other cases, the correlation coefficient is substantial with the reliability of over 0.999 which proves that estimated data are quite trustworthy.

After creating a database, linear trends were constructed and rate of change in temperature and precipitation over the period of global warming were identified for every station [E. Sh. Elizbarashvili, M. R. Tatishvili, R. Sh. Meskhia, M. E. Elizbarashvili (2013)].

Depending on the intensity of warming (cooling), the following gradations of rate of changes were nominally determined:

a) For air temperature

- Strong cooling (less than -0.10°C during 10 years);
- Moderate cooling (-0.06- -0.10 °C during 10 years);
- Weak cooling (-0.02 - -0.06 °C during 10 years);
- Unchanged (-0.02- 0.02 °C during 10 years);
- Slight warming (0.02-0.06°C during 10 years);
- Moderate warming (0.06-0.10 °C during 10 years);
- Strong warming (over 0.10°C during 10 years).

b) For atmospheric precipitations

- Significant decrease (less than -5% during 10 years);
- Moderate decrease (-3.1- -5.0% during 10 years);
- Insignificant decrease (-1.1- -3.0 % during 10 years);
- Unchanged (-1- 1% during 10 years);
- Insignificant increase (1.1- 3.0% during 10 years);
- Moderate increase (3.1- 5.0% during 10 years);
- Significant increase (более 5% за 10 years).

Results

Figures 2 and 3 show examples of trends, built by us, in various physical and geographic conditions for temperature and precipitations, respectively.

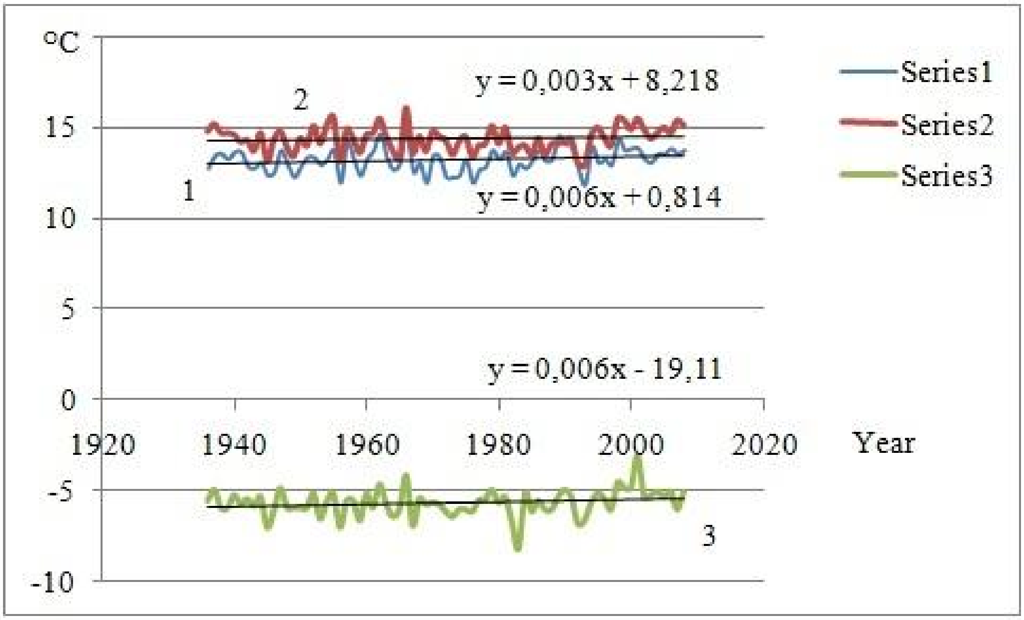

Fig. 2. Multiyear flow of average annual air temperature and corresponding equation of regression: 1 - Tbilisi; 2 - Poti; 3 - Kazbegi alpine

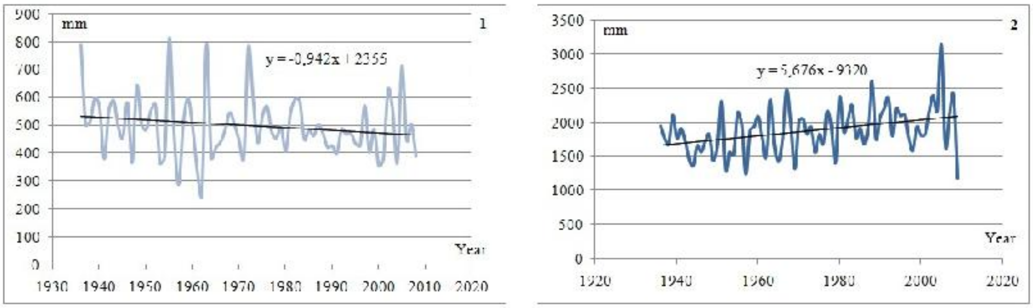

Fig. 3. Multiyear flow of annual sum of atmospheric precipitations and corresponding equation of regression: 1 - Tbilisi; 2 - Poti

Fig. 2 shows that under the conditions of global warming, the observed meteorological stations reveal a tendency of increase in annual air temperature with the rate close to the rate of global warming - 0.06 °C during 10 years. Fig. 3 shows a decreasing trend in annual sum of atmospheric precipitations in Tbilisi and an increasing trend in Poti.

Estimated data of rate of change in temperature and precipitations were used for the construction of the geoinformational maps of changes in these climate features in the territory of Georgia under global warming conditions (Figures 4 and 5).

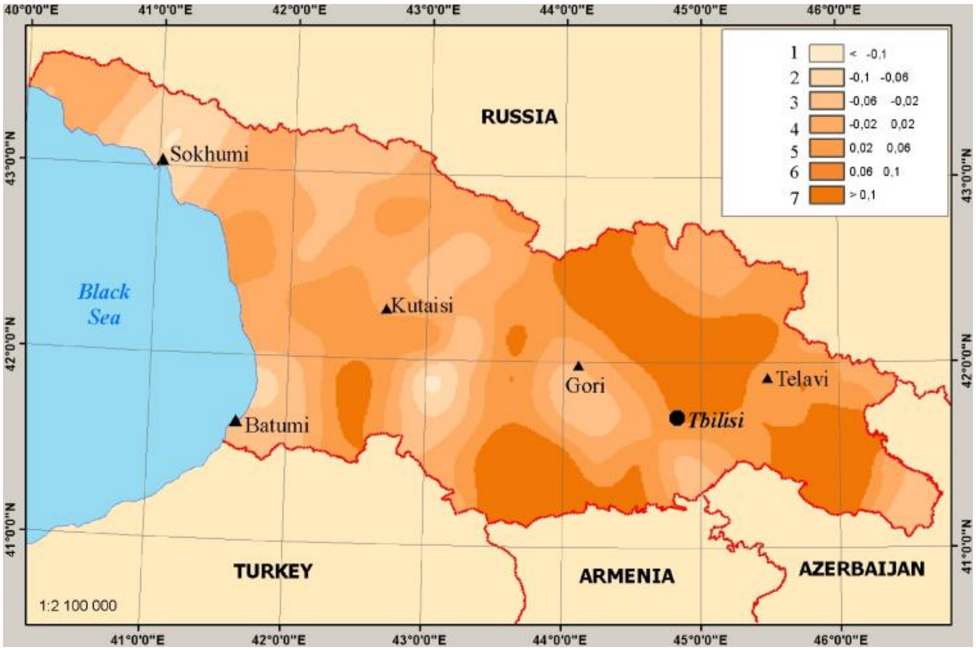

Fig. 4. Rate of change in average annual air temperature, ^{O}C during 10 years

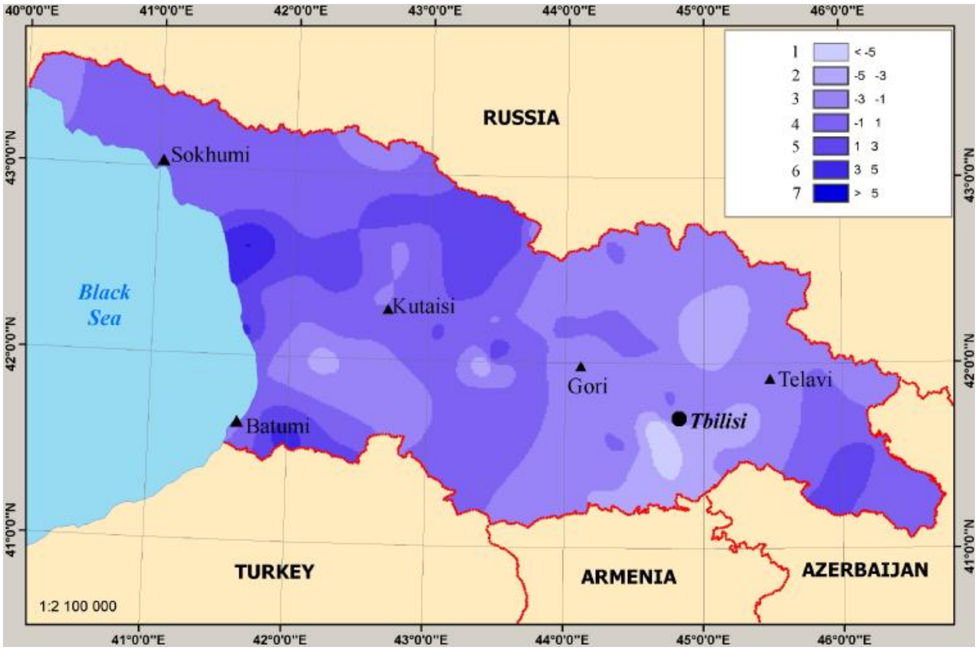

Fig. 5. Rate of change in average annual sum of precipitations, % during 10 years

Conclusions

The presented maps show that changes in temperature and precipitations in the territory of Georgia under global warming conditions are not of uniform nature due to complicated physical and geographic, and basically, orographic and landscape-climate conditions. Largest spots and territories of strong warming, when an average annual temperature increased by more than 0.1°C during 10 years, are observed in eastern Georgia. Spots of weak and moderate warming with the temperature increasing at the rate of 0.02-0.1°C during 10 years, are observed in western Georgia.

Over an insignificant part of Georgia, temperature remained almost unchanged or changed insignificantly. Decrease in temperature is observed mainly in western Georgia. Strong cooling occurs in a significant part of Adjara and northern part of Black Sea coast where an average annual air temperature decreased at the rate of over 0.1°C in 10 years.

Over a significant territory of East Georgia, annual sums of precipitation decreased at the rate of 1-3% during 10 years. The highest rate of decrease in precipitation is observed in Kvemo Kartli (south of Tbilisi), comprising more than 5% in 10 years. Increase in annual sums of precipitation is observed in several districts of West Georgia as well as in the central part of Iori Plateu in East Georgia where the annual sum of precipitation increased at the rate of 1-3% during 10 years. In mountainous Adjara and some other districts of Black Sea coast, the rate of increase in precipitations reached 5%.

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