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Impact of Global Warming on Zero Degree Isotherm of Near Surface Temperature

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Abstract

The evaluation of the modern global warming impact on the zero degree isotherm crossing dates of near-surface temperature is unequivocally determined by the length of the warm (cold) season in a given region. The study was conducted using perennial, near-surface temperature field data from ten observation points in a complex, highland region. The correlation changes of the dates of the crossing of the zero degree isotherm of temperature concerning the vertical and horizontal displacement is studied. The statistical structure of the multi-year change in the dates is established. It is accepted that the increase in the warm season caused by global warming mainly occurs in the first half of the year when the zero-degree isotherm crosses from negative to positive. There are also rare cases when the warm season, for a long time, experiences a decrease in the opposite.

Keywords: Surface temperature, global warming, warm (cold) season

Introduction

For more than a century, the Earth's energy balance has been disturbed - it receives more energy than it emits. The result of the gradual increase of energy potential is global warming. The main factors of global warming - solar energy, gaseous composition of the atmosphere, physical (optical) properties of the underlying surface - cause the increase of the Earth energy potential as the isolated body, can reveal completely different effects by regions [1-3]. There are regions where centres of cooling have emerged in the face of global warming. Such a region can be found in the small area of Georgia. In parallel with global warming, the coastal temperature in western Georgia has been gradually decreasing for decades [4, 5]. The process that creates the near-surface temperature field regime depends on the number of instantaneous and long-acting factors.

The study of regime structure change, especially in such complex relief conditions as in Georgia, is the constant object of research. It is essential to assess the impact of modern warming on extreme deviations in near-surface temperature variations. Interestingly, for the given region, the extreme deviation change by time may be opposing, depending on what we account for the extreme deviation [6].

Methods and Materials

This paper aims to study the effects of modern global warming on the crossing dates of zero degree isotherm by the near-surface temperature. Such crossings occur at least twice at about one kilometre above sea level in the first and second half of the year. These dates are significant for the region as they determine the length of a given year's warm and cold periods. Particular attention should also be paid to the seasonal temperature change [7, 8, 9]. The critical indicator of seasonal change is crossing the zero degree isotherm by near-surface temperature.

Systematic observational data of 10 meteorological stations in the 1070 -3659 km range in Georgia for 1906-2009 are used to solve the given task.

As it is known, the average temperature can cross the zero degree isotherm not twice but several times per year. The reason for this is that the random factors result from short-term weather changes. Therefore, to determine the regime structure of the zero degree isotherm crossing date, it is not the average daily temperature directly used, but the inter annual temperature change constructed by the average monthly temperature. At the beginning of each year and the end of each observation point, the temperature transitions from negative to positive and from positive to negative are determined for the corresponding months. The zero degree isotherm crossing date is calculated by linear approximation and analytically. The range of calculated dates covers almost the entire year. This is only one point of observation (highland Kazbegi), which is located three and a half kilometres above sea level, and there were years when the crossing of the zero degree isotherm took place even in the summer months.

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Results and Discussion

The main effect on the transition date from a negative value to a positive one is the temperature regime of the first half of the year. In the second half, on the contrary, the date of the transition from positive to negative is determined by the regime structure of the second half. The characteristics of the temperature field change in the first and second half of the year can be assessed by Fig. 1. The figure shows the temperature field change, based on 1906-2009 data for ten observation points.

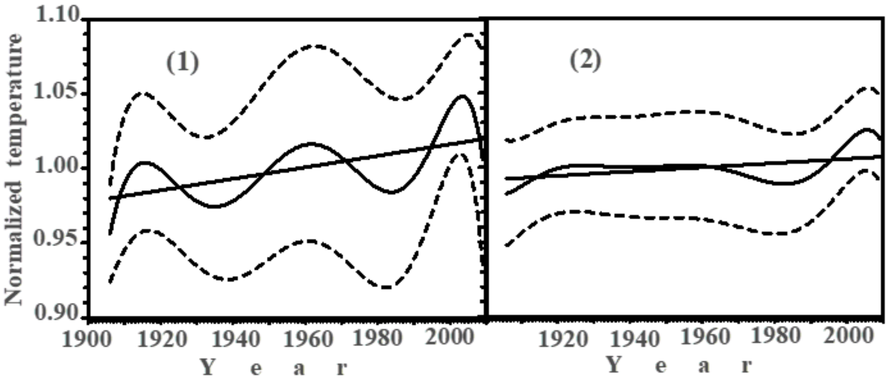

Figure 1. The normalized near surface temperature change of first (1) and second (2) half of the year by the linear and non-linear approximations and corresponding standard deviations (dashed lines) for Georgian highland

In Fig.1, for the first and second half of the year, the normalized temperature changes based on all observation points data are presented, with linear and nonlinear approximations (as the month normalized parameter the monthly arithmetic mean has been taken of this observation point for each observation point, each year). The change direction (cooling or warming) and the magnitude is determined by the so-called "dynamic norm" [10], which can be used to assess the accuracy of the approximation. For example, the representation of temperature change in time by dynamic norm compared to the static norm reduces the standard error by about 5% in the case study (Fig. 1). Moreover, when the temperature goes from negative to positive, the error is reduced by 8%.

The line equation determines the dynamic norm. When switching from negative to positive, it became the following expression:

$$T(n) = 0.245 + 0.00038\, n, \quad (1)$$

And the transition from positive to negative, e.g., in the second half of the year

$$T(n) = 0.722 + 0.00014\, n, \quad (2)$$

where T(n) is the mean temperature of 6 months, n- year

From the equations, it is evident that the near-surface temperature change was of low intensity in the first and especially in the second half of the year of the highland system. In particular, according to (1) and (2), their values are + 0.038°C / 100 year and + 0.014°C/ 100 year.

The nonlinear approximate curves given in Fig.1 are of seventh order polynomials. These polynomials give the least standard errors when describing temperature changes compared to other polynomials. However, it should be noted that in this case, they are only 1.5 - 2.0% more accurate than the linear approximation in determining the temperature change result.

The mean, minimum and maximum intersection dates of the zero degree isotherm for the ten observation points of the highland zone of Georgia are given in Table 1.

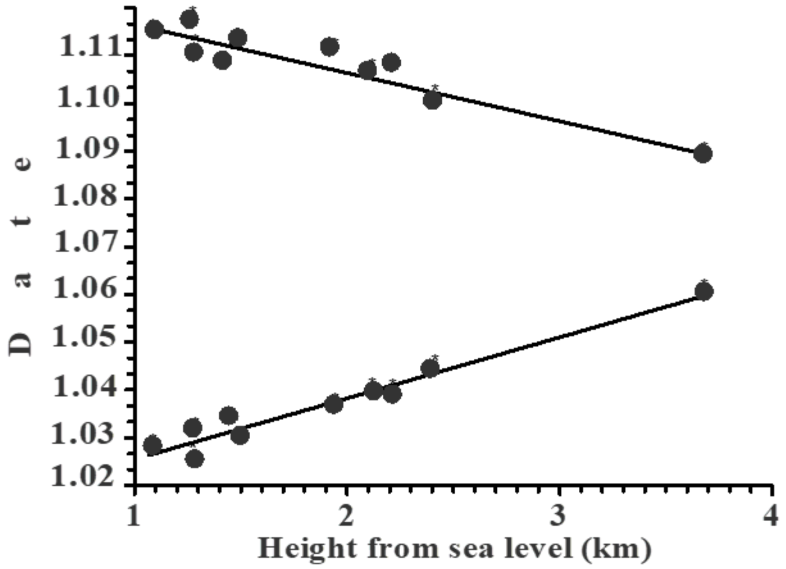

Figure 2. The dependence of warm season duration on place elevation

As seen from the table, in the case of four observation points, the maximum date of crossing the zero degree isotherm is not fixed until the end of the year, which means that it moves on to the following year.

To determine the relationship of the warm season duration of the year to the place elevation above sea level, the average multi-year crossing dates of the zero degree isotherm by temperature were determined. Obtained results are used in Fig. 2, which shows the mean date changes according to the place elevation.

As can be seen from the drawing, in the highlands of Georgia, the so-called warm season, at about one mile above sea level, exceeds nine months. As the height increases, it decreases linearly and becomes less than three months at the three and a half kilometre elevation. Thus, above 1000 meters, as the place elevation increases with every 100 meters, the warm season decreases by 7-8 days.

The obtained result is typical for a highland area covering several hundred square kilometres. It is obtained by combining multiannual data from 10 observation points. In such conditions, it is of interest to determine the relationship between observation points in the variations of the zero degree isotherm crossing dates. For this, we constructed the autocorrelation matrix with the annual dates of all observation points that determined the crossing of the zero degree isotherm for both the first and second half of the year. It is given in Figure 3.

Table 1. The zero degree isotherm crossing dates by temperature for Georgian highland (1906-2009)

N	Observation post	Elevation	Zero degree isotherm crossing data (date, month)					
			Transition from negative to positive temperature			Transition from positive to negative temperature		
			Avg.	min	max	Avg.	min	max
1	Pasanauri	1.07	27.02	30.01	21.03	10.12	9.11	-
2	Dmanisi	1.256	24.02	18.01	24.03	21.12	12.11	-
3	Abastumani	1.265	10.03	9.02	28.03	30.11	5.11	31.12
4	Mestia	1.441	14.03	14.02	6.04	24.11	1.11	14.12
5	Tsalka	1.457	12.03	12.02	1.04	3.12	4.11	-
6	Bakhmaro	1.926	23.03	2.03	20.04	28.11	29.10	-
7	Paravani	2.1	7.04	13.03	20.04	13.11	23.10	3.12
8	Gudauri	2.194	6.04	3.03	23.04	13.11	11.10	22.12
9	Jvari Pass.	2.395	2.06	3.04	18.05	26.10	1.10	22.11
10	Kazbegi	3.659	14.06	10.05	6.07	17.09	28.08	14.10

The observation points on the horizontal axes are placed according to the place height increase from sea level. In general, especially in the first half of the year, there is a gradual decrease in correlation with increasing height distance. Nevertheless, there are certain heights where this natural process is disrupted. As it can be seen from the drawing, such processes are not random. It is permanent for the period under consideration and may be caused by the constant exposure of a different landscape or near-surface to its energy potential redistribution.

Fig. 3 shows the vertical variations of the zero degree isotherm crossing date. To identify what these variations are in the case of horizontal displacement, the correlation coefficients were determined by considering the distance between the observation points. The obtained results are given in Fig.4.

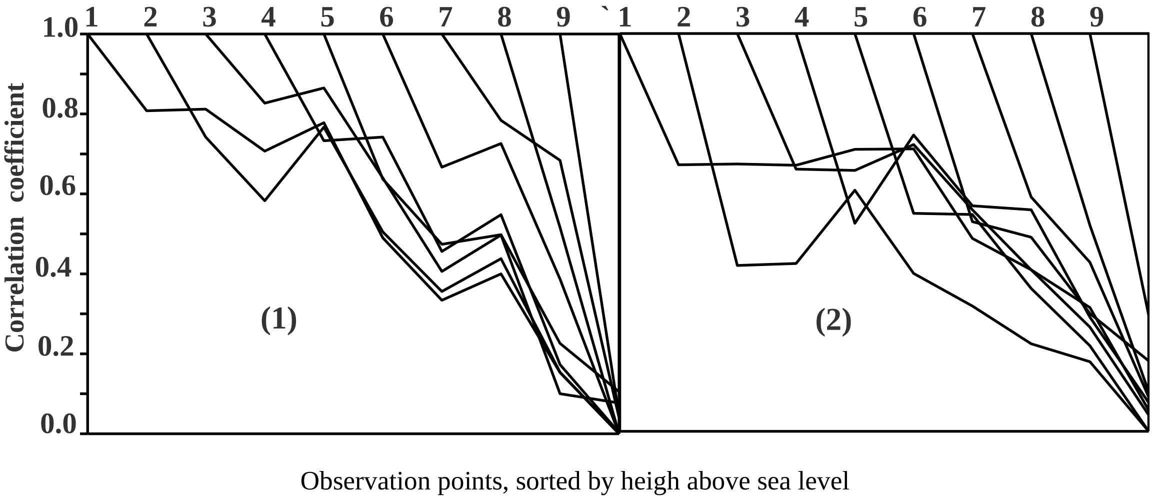

Figure 3. Correlation of zero degree isotherm crossing dates by height between observation points (1,2,3, ..., 10) in the first (1) and second (2) half of the year.

This connection, as expected, will not be significantly changed. It varies approximately in the range of 0.4 to 0.6 correlation coefficients by amount. This is entirely natural, as the maximum distance between observation points does not exceed 250 km.

As mentioned above (Fig. 1), the near-surface temperature change is occurring at very low intensity in the highland zone of Georgia.

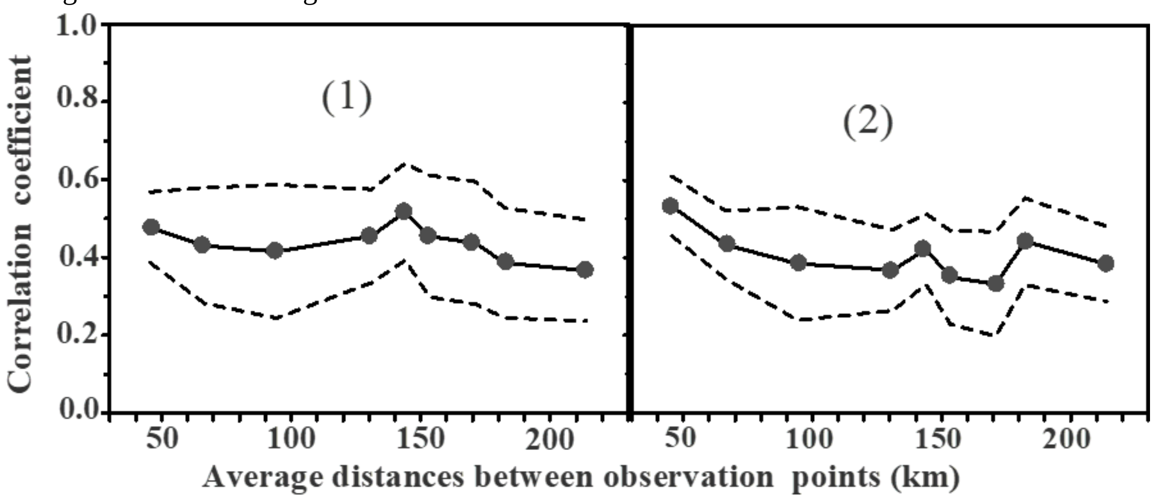

Figure 4. Correlation of zero degree isotherm crossing dates by direct distances between observation points in the first (1) and second (2) half of the year (dashed lines define standard errors).

To determine what impact has the near-surface temperature changed over the date of the zero degree isotherm. In addition, warm-season duration and the impact of global warming on it were also determined for each observation point. The obtained results are given in Table 2.

Table 2. The impact of global warming on the change of zero degree isotherm crossing date

N	Observation post	Zero degree isotherm date change (day /100y)		Warm season duration	
		Transition from negative to positive temperature	Transition from positive to negative temperature	Avg. (day)	Change (day/100y)
1	Pasanauri	-9.7	5.9	280	16
2	Dmanisi	-14.2	15.4	307	29
3	Abastumani	-6.0	-1.3	269	5
4	Mestia	-3.5	-3.3	255	0
5	Tsalka	-6.6	6.4	269	13
6	Bakhmaro	-1.0	-2.8	246	-2
7	Paravani	-3.8	0.6	220	5
8	Gudauri	-1.0	-2.6	224	-2
9	Jvari Pass.	-7.1	1.7	161	9
10	Kazbegi	-8.3	4.0	94	12

As evident from the table, the changes of the emergence dates of the zero degree isotherm in the first and second half of the year are heterogeneous. Whereas the dates of the transition from negative to positive temperature, due to the global warming, recede in the case of all observation points, i.e. shifts in the direction of increase of the warm season duration, changing from positive to negative, in four to ten cases the opposite happens. Nevertheless, the duration of the warm-up season was not reduced for the two observation points (Abastumani, Mestia), as the duration was longer in the first half of the year than in the second half. However, in two observation points (Bakhmaro, Gudauri), the process of global warming was marked by a decreased tendency during the warm season.

As mentioned, the change of the warm season duration by height is subject to a definite regulation. As for the change by time or the change that may be caused by global warming, it is not subject to any regularity. Indeed, warming generally prolongs the warm season, but it is challenging to substantiate the reasons for the two not-so-distant regions (Dmanisi, Abastumani) in one, the duration of the warm season has been increased in 100 years by the month, and in the other - by a few days.

The crossing dates changes of the zero degree isotherm over the years do not differ significantly for the whole study area. Fig. 5 shows the change of one of them (Pasanauri) for the study period for both the first and second half of the year. It is selected from the point of view that the variations in the dates of the crossing of the zero degree isotherm of temperature, both in the first and second half of the year, are more diverse from the general picture than the others.

Dates are marked on the vertical axes of the drawings. In both cases, their change range rarely exceeds 30 days. Linear and nonlinear approximations are used to determine the changing trend. The accuracy of the approximations is estimated using standard errors.

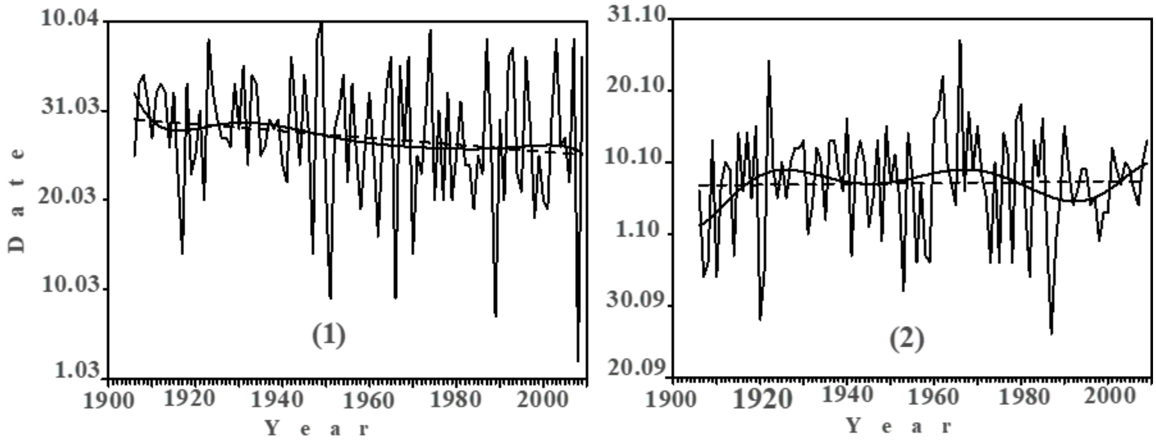

Figure 5. The transition from negative to positive (1) and from positive to negative (2) date change by years of near surface temperature of Paravani using 1906-2009 year data and representation of those changes by linear (dashed) and nonlinear (curved) approximations

The linear approximation of the first half of the year improves the accuracy by 7.51% compared to the arithmetic mean (i.e. when no change is foreseen at all). The nonlinear approximation was performed using a polynomial, the optimal expression of which was determined by the gradual increase of the polynomial order. Typically, the maximum accuracy of a polynomial was reached when the polynomial was of 7 or 8 order (all nonlinear approximations in the present paper are of the seventh order). In the example given, the nonlinear approximation improved the accuracy by 0.06% compared to the linear approximation. As for the case of the second half of the year, i.e. when the temperature crosses the zero degree isotherm from positive to negative, the accuracy of the determined values are the following: The linear approximation reduces the standard error by 2.35% compared to the arithmetic mean. Moreover, by nonlinear approximation, the standard linear approximation error is improved by only 0.14%.

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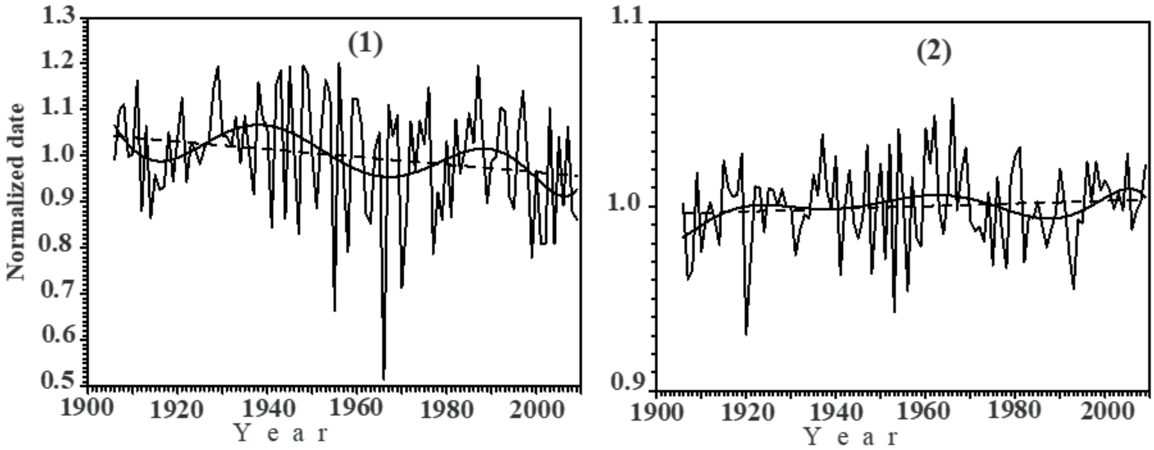

Figure 6. The crossing date change by years of near surface temperature and it representation by linear (dashed) and nonlinear (curved) approximations while temperature transition from negative to positive (1) and from positive to negative (2)

The annual dates change of crossing the zero degrees isotherm by the near-surface temperature field over the years is represented by the normalized values of all observation points. The changes based on the combined data by years are given in Figure 6. First of all, the images show that the dispersion in the second half of the year is almost twice less than in the first half, i.e. the transition from a positive to a negative value is stable in a much shorter time. However, the impact of global warming on this process is not revealed at all. That means that the transition date from positive to negative temperature value does not change. The prolongation of the warm season occurs only during the transition from a negative value to a positive one.

Conclusion

To assess the climate change impact on the duration of the warm season, the nonlinear approximation compared to the linear one gives almost no improved results.

Competing interests

The authors declare that they have no competing interests.

Authors' contribution

All authors discussed the results and contributed to the final manuscript. K. T. conceived the idea; took the lead in writing the manuscript. N. B. provided critical feedback and helped shape the analysis and manuscript, worked out almost all of the technical details.

References

[1] Budiko M. *Klimat v proshlom I budushem* [Climate in the past and the future]. L., Gidrometeoizdat, 1980, 352 p. (in Russian)

[2] Kondratyev K. *Globalnii klimat* [Global climate], Nauka, 1992, 352 p. (in Russian)

[3] Lovejoy T.E. and L. Hannah, eds., Climate Change and Biodiversity. Yale University Press, London. 2005, pp. 440

[4] Amiranashvili A.G., Amiranashvili V.A., Gzirishvili T.G., Kharchilava J.F., Tavartkiladze K.A. Modern Climate Change in Georgia. Radioactively Active Small Atmospheric Admixtures. Tbilisi, 2005 (128).

[5] Tavartkiladze K., Begalishvili N., Tsintsadze T., Kikava A. Influence of Global Warming on the Near Surface Air Temperature Field in Georgia. Bulletin of the Georgian National Academy of Sciences, v.6, N 3, 2012 (55-60).

[6] Sherstyukov B.G. Regionalnie I sezonnie zakonomernosti izmenenii sovremennogo klimata [Regional and seasonal change regulations of the modern climate]. "VNIIGMI-MCD", 2008, 246 p. (in Russian)

[7] Loginov V.F. *Sezonnie osobennosti mnogoletnix izmenenii globalnogo klimata I ikh prichini* [Seasonal features of long-term changes of the global climate and their causes]. Ukrainian Geographical Journal, No. 2, 2013 (26-239). (in Russian)

[8] Tavartkiladze K., Begalishvili N., Tsintsadze T., Kikava A. Influence of Global Warming on the Near-Surface Air Temperature Field in Georgia. Bulletin of the Georgian National Academy of Sciences, v.6, N 3, 2012 (55-60).

[9] Tavartkiladze K., Kikava A. (2021). Annual Amplitude Regime of Ground Surface Temperature Field in Georgia. Georgian Geographical Journal, 1(1). https: //journals.4science.ge/index.php/GGJ/article/view/260

[10] Tavartkiladze K. *Ukiduresi gadakhrebi mitsispira temperaturuli velis variatsiebshi da misi kavshiri havis tsvlilebastan (tbilisis magalitze)* [The extreme deviations of near surface temperature variations and its connection with climate change]. Transactions of the Institute of Geography v.3, 2011, pp.39-45. (in Georgian).