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On the Relationship of Annual Variations of the Intensity of Galactic Cosmic Rays with the Variability of Total Cloudiness, Atmospheric Precipitation and Air Temperature in Tbilisi in 1966-2015

Avtandil G. Amiranashvili, Teimuraz S. Bakradze, Tereza G. Erkomaishvili, Nugzar Ya. Ghlonti, Irakli I. Tuskia

M. Nodia Institute of Geophysics of I. Javakhishvili Tbilisi State University, e-mail: avtandilamiranashvili@gmail.com

ABSTRACT

The paper considers the results of the study of the connection between annual variations of intensity of galactic cosmic rays and the changeability of the total cloudiness, atmospheric precipitation and air temperature in 1966-2015 in Tbilisi. The statistical characteristics of the indicated parameters (trends, random component, linear correlations between real and random components, etc.) are studied. In particular, it was found that, within the variation range, the contribution of the studied parameters to atmospheric precipitation variability is as follows: total cloudiness - 17.1%, real values and random components of cosmic ray intensity - 37.8% and 28.0%, respectively.

***Key Words*:** *Climate change, galactic cosmic rays, cloudiness, atmospheric precipitation, air temperature, statistical analysis.*

Introduction

In Georgia, as elsewhere in the world, in recent decades, special attention has been paid to research on modern climate change. Spatial-temporary variations of the fields of air temperature and precipitations [1-5], cloudiness [6-8], solar radiation [9], air pollution [9,10] and other climate-forming parameters were studied. With the use of different statistical models the estimations of the expected changes of air temperature and atmospheric precipitations for the next decades for some regions of Georgia, including Tbilisi city, were carried out [11-16].

Cosmic radiation is one of the factors, which influence on climate change [17-21]. The possible mechanisms of this influence can be found in the works [9,17,18].

In Georgia studies of the climatic effects on cosmic rays also began recently. In particular, in the works [10,20,21] the effects of cosmic radiation on the formation in the atmosphere of the secondary aerosols, which have an effect on cloudiness, are studied. In the works [22,23] the inter-annual distributions of cloudless days and cloudless nights in Abastumani Astrophysical Observatory, at various helio-geophysical conditions, and their coupling with cosmic factors were studied. In the work [24], a study of the relationship between the annual variations in the intensity of galactic cosmic rays and the variability of cloudiness and air temperature in Tbilisi was carried out according to the data of 1963-1990.

This work is the continuation of the investigation [24]. Results of a study of the relationship between the annual variation in the intensity of galactic cosmic rays with the variability of total cloudiness, atmospheric precipitation and air temperature in Tbilisi in 1966-2015 are presented below.

Material and methods

The data of the National Environmental Agency of Georgia about the mean annual values of total cloudiness (G), annual sum of atmospheric precipitation and (P) and air temperature (T) in Tbilisi are used. Information about annual values of intensity of neutron component of galactic cosmic rays (CR) is obtained at the Cosmic Rays Observatory of M. Nodia institute of geophysics. The period of observation is 1966 - 2015.

In the proposed work, as in [24], the analysis of data is carried out with the use of the standard statistical analysis methods of random events and methods of mathematical statistics for the non accidental time-series of observations [25, 26].

The following designations will be used below: Min – minimal values, Max - maximal values, Range - variational scope, St Dev - standard deviation, Cv, % – coefficient of variation (Cv = 100·St Dev/Average), R - coefficient of linear correlation, R^2 – coefficient of determination, K_{DW} – Durbin-Watson Statistic, Rand – random component, α - the level of significance, Real - measured data. The curve of trend is equation of the regression of the connection of the investigated parameter with the time at the significant value of the coefficient of determination and such values of K_{DW}, with which the residual values are accidental.

A background component usually enters into the curve of trend. The value of background component is most frequently unknown. From the physical aspect, random component can be represented in the form: Rand = Res + absolute value of the min value of Res. In this case random components have positive values with the minimum value = 0 (if the value of background component is known, the min Rand will be = Back). Accordingly, Trend+Back (sum of the trend and background components of time series) will be a curve of equation of the regression of the connection of the investigated parameter and the time minus absolute value of the min value of Res. So, Real = (Trend+Back) + Rand.

Results and discussion

The results are given in tables 1-6 and fig. 1-4.

Table 1. Characteristics of trend of G, P, T and CR in Tbilisi in 1966-2015.

Variable	Form of the equation of regression	R^2 (with year)	K_{DW}
G	Third power polynomial	0.34 (α =0.001)	1.92 (α =0.05)
P	Third power polynomial	0.10 (α =0.02)	2.00 (α =0.05)
T	Linear	0.21 (α =0.003)	1.81 (α =0.05)
CR	Tenth power polynomial	0.73 (α =0.0001)	0.96 (α <0.01)

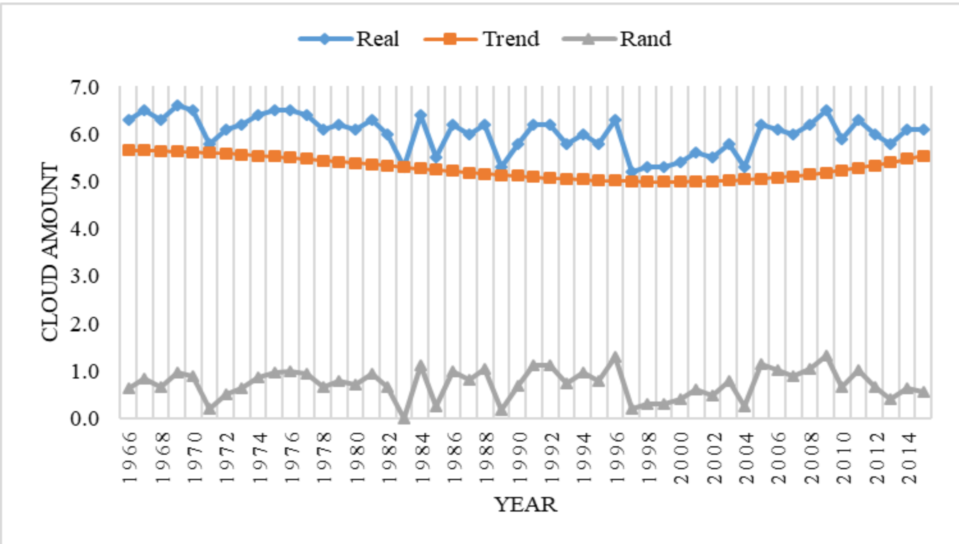

Fig. 1. Trend of the total average annual cloudiness in Tbilisi in 1966-2015.

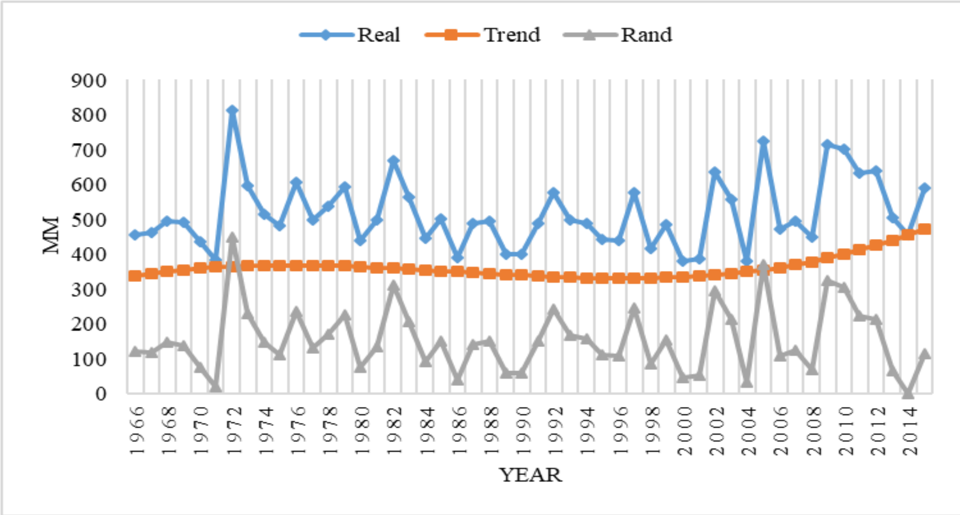

Fig. 2. Trend of the annual sum of atmospheric precipitation in Tbilisi in 1966-2015.

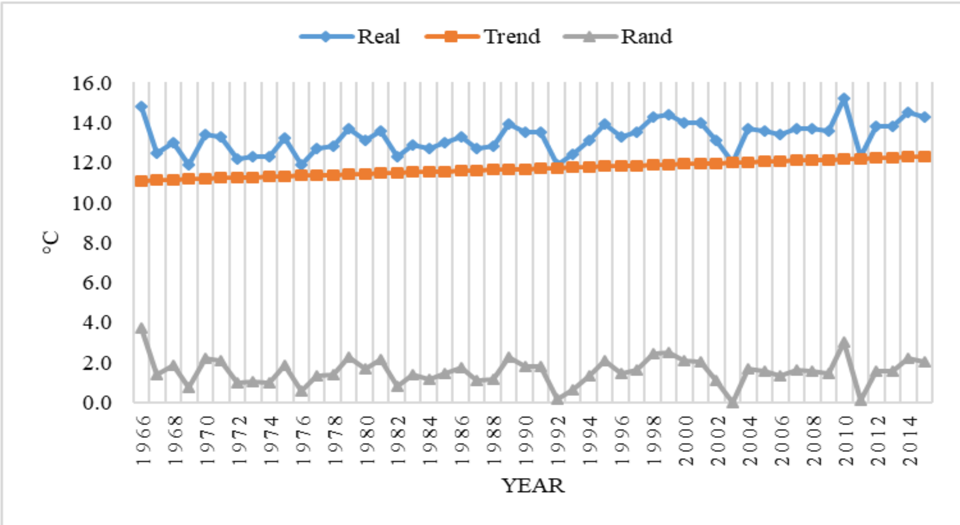

Fig. 3. Trend of the average annual air temperature in Tbilisi in 1966-2015.

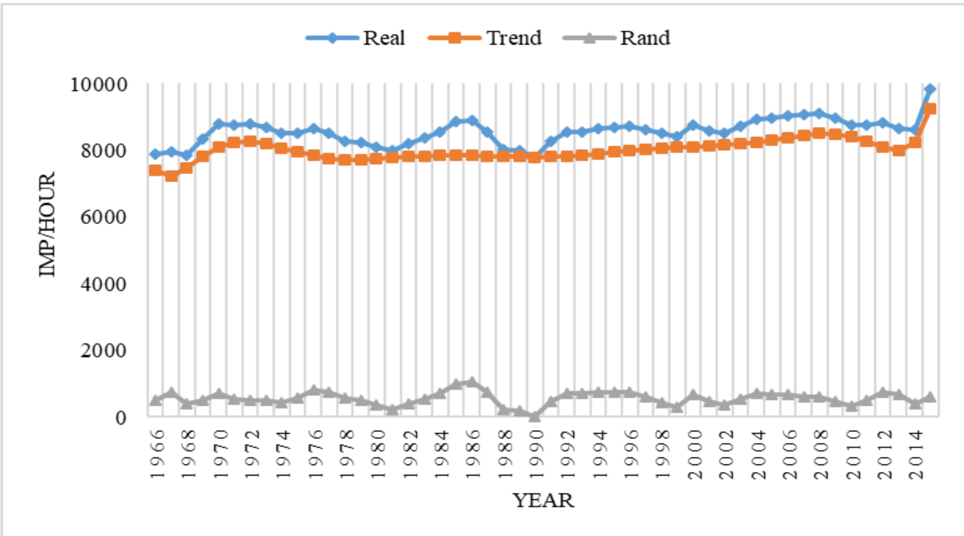

Fig. 4. Trend of the average annual intensity of galactic cosmic rays in Tbilisi in 1966-2015.

According to Table 1 and Fig. 1-4, trends of G and P takes the form of third power polynomial, trend of T is linear and trend of CR take the form of tenth power polynomial.

Table 2 shows the statistical characteristics of real data of G, P, T and CR in Tbilisi.

Table 2. The statistical characteristics of real data of G, P, T and CR in Tbilisi in 1966-2015.

Variable	G, cloud amount	P, mm	T, °C	CR, imp/hour
Max	6.6	813	15.2	9853
Min	5.2	379	11.9	7803
Range	1.4	434	3.3	2050
Average	6.0	516	13.3	8568
St Dev	0.39	100	0.78	382
Cv,%	6.4	19.3	5.9	4.5
Correlation Matrix				
	G	P	T	CR
G	1	0.19 (α=0.20)	-0.36 (α=0.01)	-0.04 (not sign)
P	0.19 (α=0.20)	1	-0.23 (α=0.10)	0.21 (α=0.15)
T	-0.36 (α=0.01)	-0.23 (α=0.10)	1	0.14 (α=0.25)
CR	-0.04 (not sign)	0.21 (α=0.15)	0.14 (α=0.25)	1

According to Table 2, the values of G vary from 6.6 to 5.2 (average = 6.0), values of P – from 813 to 379 (average = 516), values of T – from 15.2 to 11.9 (average = 13.3) and CR - from 9853 to 7803 (average = 8568).

The significant linear correlation between the following investigated parameters is observed: G with P (positive), T (negative); P with T (negative), CR (positive); T with CR (weak positive).

In Table 3 the statistical characteristics of the random components of G, P, T and CR in Tbilisi are presented.

Table 3. The statistical characteristics of random components of G, P, T and CR in Tbilisi in 1966-2015.

Variable	G, cloud amount	P, mm	T, °C	CR, imp/hour
Max	1.3	448	3.7	1063
Average	0.7	154	1.6	558
St Dev	0.3	94	0.7	200
Cv,%	56.6	34.4	42.2	52.5
Correlation Matrix				
	G	P	T	CR
G	1	0.14 (α=0.25)	-0.31 (α=0.03)	0.18 (α=0.20)
P	0.14 (α=0.25)	1	-0.35 (α=0.01)	-0.05 (not sign)
T	-0.31 (α=0.03)	-0.35 (α=0.01)	1	-0.23 (α=0.10)
CR	0.18 (α=0.20)	-0.05 (not sign)	-0.23 (α=0.10)	1

According to Table 3, max and average values of random components of investigation parameters are respectively equal: G - 1.3 and 0.7, P - 448 and 154, T – 3.7 and 1.6, CR – 1063 and 558.

The significant linear correlation between the following investigated parameters is observed (table 3): G with P (weak positive), T (negative) and CR (positive); P with T (negative); T with CR (negative).

Shares of the average values of random components in the average values of the real values of the studied parameters (fig. 1-4, table 2 and 3) constitute: for G – 12.3%, for P – 29.9 %, for T – 11.8 % and for CR – 6.5 %.

The equation of the multiple linear regression of the connection of air temperature and G_{rand}, P_{rand}, and CR_{rand} is represented below:

$$\mathbf{T = -0.52637 \cdot G_{rand} - 0.00244 \cdot P_{rand} - 0.00073 \cdot CR_{rand} + 14.43} \qquad (R^2 = 0.19,\ \alpha = 0.005)$$

Table 4 shows the data about contribution of variations in the values of G_{rand}, P_{rand}, and CR_{rand} to the changeability of T.

Table 4. Contribution of variations in the values of G_{rand}, P_{rand}, and CR_{rand} to the changeability of T.

Variable	In the limits of Range (%)	In the limits of St Dev (%)
G_{rand}	5.2	2.4
P_{rand}	8.2	3.5
CR_{rand}	5.9	2.2

According to Table 4, within the variation range, the contribution of the studied parameters to air temperature variability is as follows: random components of total cloudiness - 5.2%, random components of atmospheric precipitation – 8.2%, random components of cosmic ray intensity - 5.9%.

The equation of the multiple linear regression of the connection of total cloudiness and CR and CR_{rand} has the following form:

$$\mathbf{G = -0.00016 \cdot CR + 0.00042 \cdot CR_{rand} + 7.11} \qquad (R^2 = 0.036,\ \alpha = 0.2)$$

Table 5 shows the data about contribution of variations in the values of CR, and CR_{rand} to the changeability of G.

Table 5. Contribution of variations in the values of CR, and CR_{rand} to the changeability of G.

Variable	In the limits of Range (%)	In the limits of St Dev (%)
CR	5.3	2.0
CR_{rand}	7.4	2.8

According to Table 5, within the variation range, the contribution of the studied parameters to total cloudiness variability is as follows: cosmic ray intensity – 5.3%, random components of cosmic ray intensity - 7.4%.

The equation of the multiple linear regression of the connection of precipitation and G, CR and CR_{rand} is represented below:

$$\mathbf{P = 62.95 \cdot G + 0.095057 \cdot CR - 0.13584 \cdot CR_{rand} - 601.32} \qquad (R^2 = 0.137,\ \alpha = 0.01)$$

Table 6 shows the data about contribution of variations in the values of G, CR, and CR_{rand} to the changeability of P.

Table 6. Contribution of variations in the values of G, CR, and CR_{rand} to the changeability of P.

Variable	In the limits of Range (%)	In the limits of St Dev (%)
G	17.1	9.4
CR	37.8	14.1
CR_{rand}	28.0	10.5

According to Table 6, within the variation range, the contribution of the studied parameters to precipitation variability is as follows: total cloudiness - 17.1%, cosmic ray intensity – 37.8%, random components of cosmic ray intensity - 28.0%.

Conclusion

In the future, to compare the results obtained, similar works will be carried out for other locations of Georgia.

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გალაქტიკური კოსმოსური სხივების ინტენსივობის წლიური ვარიაციების კავშირის შესახებ საერთო ღრუბლიანობის, ატმოსფერული ნალექების და ჰაერის ტემპერატურის ცვალებადობასთან თბილისში 1966-2015 წლებში

ა.ამირანაშვილი, თ. ბაქრაძე, ტ. ერქომაიშვილი, ნ. ღლონტი, ი. ტუსკია

რეზიუმე

წარმოდგენილია გალაქტიკური კოსმოსური სხივების ინტენსივობის წლიური ვარიაციების საერთო ღრუღლიანობის, ატმოსფერული ნალექების და ჰაერის ტემპერატურის ცვალებადობასთან კავშირების კვლევის შედეგები თბილისში 1966-2015 წლებში. შესწავლილია აღნიშნული პარამეტრების სტატისტიკური მახასიათებლები (ტრენდები, შემთხვევითი მდგენელები, კორელაციური კავშირები რეალურ მონაცემებსა და შემთხვევით მდგენელებს შორის და სხვა). კერძოდ მიღებულია, რომ ვარიაციული განშლადობის ფარგლებში გამოსაკვლევი პარამეტრების წვლილი ატმოსფერული ნალექების ცვალებადობაში შემდეგია: საერთო ღრუბლიანობის რეალური მონაცემებისა – 17.1%, კოსმოსური სხივების ინტენსივობის რეალური მნიშვნელობებისა და შემთხვევითი კომპონენტებისა –37.8% და 28.0% შესაბამისად.

О связи годовых вариации интенсивности галактических космических лучей с изменчивостью общей облачности, атмосферных осадков и температуры воздуха в Тбилиси в 1966-2015 гг.

А.Г. Амиранашвили, Т.С. Бакрадзе, Т.Г. Эркомаишвили,
Н.Я. Глонти, И.И. Туския

Резюме

Представлены результаты исследования связи годовых вариаций интенсивности галактических космических лучей с изменчивостью облачности, атмосферных осадков и температуры воздуха в Тбилиси в 1966-2015 гг. Изучены статистические характеристики указанных параметров (тренды, случайные составляющие, корреляционные связи между реальными данными и случайными компонентами и др.). В частности, получено, что в пределах вариационного размаха вклад исследуемых параметров в изменчивость атмосферных осадков следующий: реальных значений общей облачности – 17.1 %, реальных значений и случайных компонент интенсивности космических лучей – 37.8 % и 28.0 % соответственно.