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On the Connection between Annual Variations of the Intensity of Galactic Cosmic Rays and the Changeability of Cloudiness and Air Temperature in Tbilisi

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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 cloudiness and air temperature in 1963-1990 in Tbilisi. The statistical characteristics of the indicated parameters (trends, random component, linear correlations between real and random components, etc.) are studied. In particular, we established that the correlation of the real values of cosmic ray intensity with the real values of total cloudiness is positive, with lower cloudiness – is not significance, with air temperature – is negative. The correlation of the random components of the intensity of cosmic ray intensity with the random components of lower and total cloudiness – are positive, with the air temperature - is negative. Within the variation range the contribution of the studied parameters to air temperature variability is as follows: real values of total cloudiness- 5.0%, random components of lower cloudiness – 1.0%, real values and random components of cosmic ray intensity - 3.0% and 4.1%, respectively.

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

Introduction

Large-scale studies of contemporary climate change in Georgia began in 1996 and they are continued nowadays. First of all, the inventory of greenhouse gases in Georgia [1,2] was carried out, spatial-temporary variations of the fields of air temperature and precipitations [1,3-6], cloudiness [7], solar radiation [8,9], aerosol air pollution [2,3,10], atmospheric ozone [2,3,11] and other climate-forming parameters were studied.

One of the factors, which influence on climate change, is cosmic radiation [2,12,13]. The effect of cosmic rays on climate could be expressed in three ways: (a) through changes in the concentration of cloud condensation nuclei, (b) thunderstorm electrizacation and (c) ice formation in cyclones. The concentration of cloud condensation nuclei depends on the light ions produced during cosmic ray ionization.

Galactic and solar cosmic rays influence physical-chemical process (reactions) in the lower atmosphere including cloudiness, density changes and atmosphere cloud coverage and thus, control the variability of atmosphere transparency and thereby affect solar radiation flax reaching the lower atmosphere. Clouds reflect both the incoming solar radiation flux upward and the Earth's thermal radiation back to it, thereby control thermal energy input in the lower atmosphere, thus establishing a link between cosmic rays and temperature.

There are two mechanisms, which link cosmic rays with cloud. In the first mechanism cosmic ray-produced ions influence the production of new aerosol particles in the troposphere, which may grow and eventually increase the number of cloud condensation nuclei. These nuclei act as seeds for the cloud droplet formation. In the second mechanism cosmic ray-produced ionization modulates the global electric current, which influences cloud properties through charge effects at cloud surface on droplet freezing and other microphysical processes [2,12,13].

In Georgia studies of the climatic effects on cosmic rays also began recently. In particular, in the works [14-16] the effects of cosmic radiation on the formation in the atmosphere of the secondary aerosols, which have an effect on cloudiness [2,12,13], are studied. In the works [17,18] the inter-annual distributions of cloudless days and cloudless nights in Abastumani Astrophysical Observatory (41.75 N, 42.82 E), at various helio-geophysical conditions, and their coupling with cosmic factors were studied.

This work is the continuation of our foregoing studies

Material and methods

The data of the Hydrometeorological Department of Georgia about the annual values of total (G) and lower (g) cloudiness 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 1963 - 1990.

In the proposed work 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 [19, 20].

The following designations will be used below: Min – minimal values, Max - maximal values, Range - variational scope, St Dev - standard deviation, R - coefficient of linear correlation, R^2 – coefficient of determination, K_{DW} – Durbin-Watson Statistic, Res – residual 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) + Res.

Results and discussion

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

Table 1

Characteristics of trend of G, g, T and CR in Tbilisi in 1963-1990.

Variable	Form of the equation of regression	R^2 (with year)	K_{DW}
G	Fifth power polynomial	0.44 (α =0.001)	2.0 (α =0.05)
g	Fifth power polynomial	0.62 (α =0.0001)	1.96 (α =0.05)
T	Linear	0.047 (α =0.25)	2.23 (α =0.05)
CR	Tenth power polynomial	0.93 (α =0.0001)	1.98 (α =0.05)

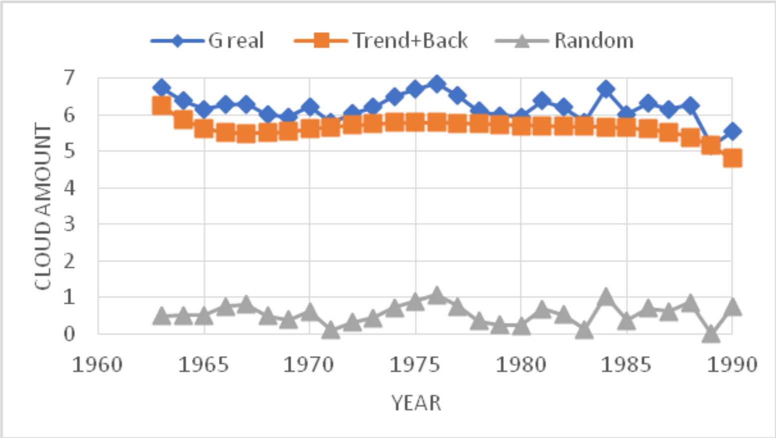

Fig. 1. Trend of the total average annual cloudiness in Tbilisi in 1963-1990.

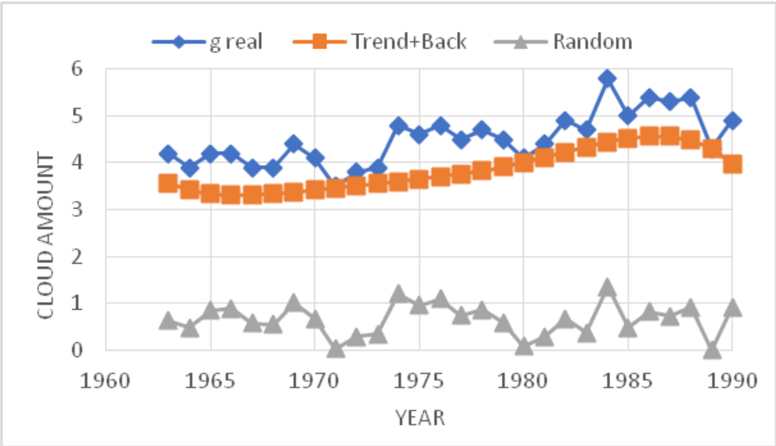

Fig. 2. Trend of the average lower annual cloudiness in Tbilisi in 1963-1990.

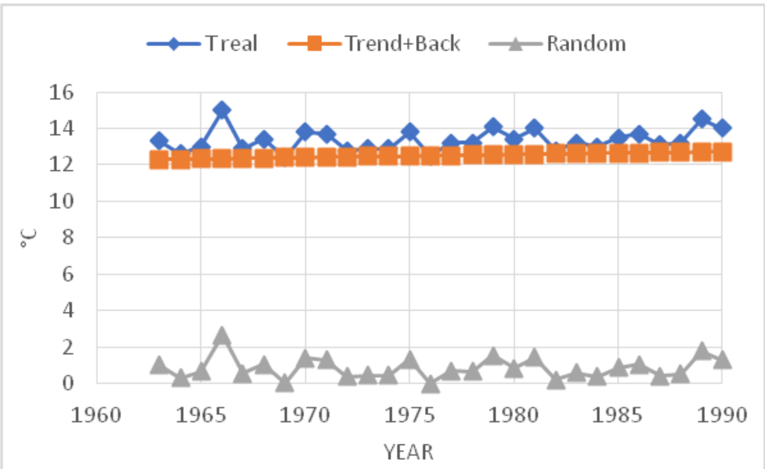

Fig. 3. Trend of the average annual air temperature in Tbilisi in 1963-1990.

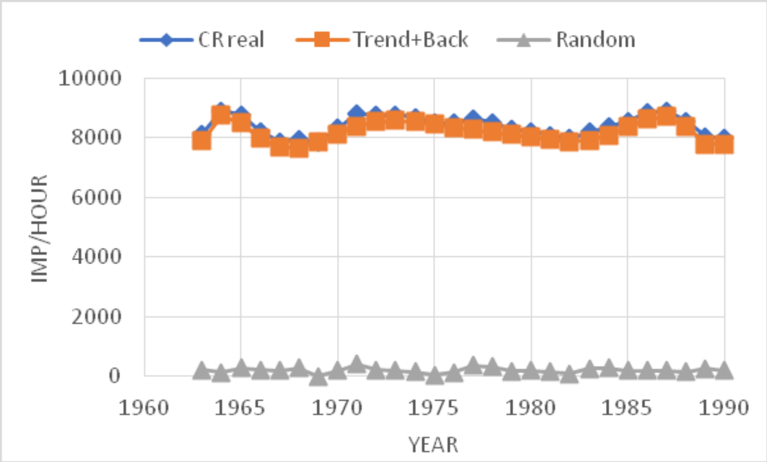

Fig. 4. Trend of the average annual intensity of galactic cosmic rays in Tbilisi in 1963-1990.

According to Table 1 and Fig. 1-4, trends of G and g takes the form of fifth 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, g, T and CR in Tbilisi.

Table 2

The statistical characteristics of real data of G, g, T and CR in Tbilisi in 1963-1990.

Variable	G, cloud amount	g, cloud amount	T, °C	CR, imp/hour
Max	6.9	5.8	15.0	8910
Min	5.2	3.5	12.4	7867
Range	1.7	2.3	2.6	1043
Average	6.2	4.5	13.4	8409
St Dev	0.4	0.6	0.6	336
Correlation Matrix				
	G	g	T	CR
G	1	0.23 (α=0.22)	-0.36 (α=0.06)	0.26 (α=0.17)
g	0.23 (α=0.22)	1	-0.06 (not sign)	0.09 (not sign)
T	-0.36 (α=0.06)	-0.06 (not sign)	1	-0.23 (α=0.22)
CR	0.26 (α=0.17)	0.09 (not sign)	-0.23 (α=0.22)	1

According to Table 2, the values of G vary from 6.9 to 5.2 (average = 6.2), values of g – from 5.8 to 3.5 (average = 4.5), values of T – from 15.0 to 12.4 (average = 13.4) and CR - from 8910 to 7867 (average = 8409).

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

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

According to Table 3, max and average values of random components of investigation parameters are respectively equal: G - 1.1 and 0.6, g - 1.4 and 0.7, T – 2.7 and 0.8, CR – 425 and 210.

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

Table 3

The statistical characteristics of random components of G, g, T and CR in Tbilisi in 1963-1990.

Variable	G, cloud amount	G, cloud amount	T, °C	CR, imp/hour
Max	1.1	1.4	2.7	425
Range	1.1	1.4	2.7	425
Average	0.6	0.7	0.8	210
St Dev	0.3	0.3	0.6	88
Correlation Matrix				
	G	g	T	CR
G	1	0.76	-0.16	-0.26 (α=0.17)
g	0.76 (α=0.001)	1	-0.26 (α=0.17)	-0.29 (α=0.12)
T	-0.16 (not sign)	-0.26 (α=0.17)	1	0.20 (α=0.29)
CR	-0.26 (α=0.17)	-0.29 (α=0.12)	0.20 (α=0.29)	1

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 – 9.0%, for g – 14.6 %, for T – 6.3 % and for CR – 2.5 %.

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

$$\mathbf{T = -0.3956 \cdot G_{real} - 0.09313 \cdot g_{rand} - 0.0003825 \cdot CR_{real} + 0.0012956 \cdot CR_{rand} + 18.807}$$

$R^2 = 0.185$ ($\alpha = 0.03$), R between T_{real} and $CR_{rand} = 0.19$ ($\alpha = 0.30$)

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

Table 4

Contribution of variations in the values of G_{real}, g_{rand}, CR_{real} and CR_{rand} to the changeability of T.

Variable	In the limits of Range (%)	In the limits of St Dev (%)
G_{real}	5.0	2.2
g_{rand}	1.0	0.5
CR_{real}	3.0	1.9
CR_{rand}	4.1	1.7

According to Table 3, within the variation range, the contribution of the studied parameters to air temperature variability is as follows: real values of total cloudiness- 5.0%, random components of lower cloudiness – 1.0%, real values and random components of cosmic ray intensity - 3.0% and 4.1%, respectively.

Conclusion

In the future, for the comparison of the obtained results, similar works will be carried out for other stations of the observation (Telavi, Tsalka, Anaseuli, etc.), and also other, more contemporary periods of measurement.

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გალაქტიკური კოსმოსური სხივების ინტენსივობის წლიური ვარიაციების ღრუბლიანობის და ჰაერის ტემპერატურის ცვალებადობასთან კავშირების კვლევის შედეგები თბილისში

ა.ამირანაშვილი, თ. ბაქრაძე, ნ. ღლონტი, თ. ხუროძე, ი. ტუსკია

რეზიუმე

წარმოდგენილია გალაქტიკური კოსმოსური სხივების ინტენსივობის წლიური ვარიაციების ღრუბლიანობის და ჰაერის ტემპერატურის ცვალებადობასთან კავშირების კვლევის შედეგები თბილისში 1963-1990 წლებში. შესწავლილია აღნიშნული პარამეტრების სტატისტიკური მახასიათებლები (ტრენდები, შემთხვევითი მდგენელები, კორელაციური კავშირები რეალურ მონაცემებსა და შემთხვევით მდგენელებს შორის და სხვა). კერძოდ მიღებულია, რომ კოსმოსური სხივების ინტენსივობის რეალურ მონაცემებსა და საერთო ღრუბლიანობის რეალურ მონაცემებს შორის წრფივი კორელაცია დადებითია, ქვედა ღრუბლიანობისათვის – არ არსებობს, ჰაერის ტემპერატურისათვის – უარყოფითია. კოსმოსური სხივების ინტენსივობის შემთხვევითი კომპონენტების კორელაცია ქვედა და საერთო ღრუბლიანობის შემთხვევით კომპონენტებთან –დადებითია, ჰაერის ტემპერატურასთან – უარყოფითია. ვარიაციული განშლადობის ფარგლებში გამოსაკვლევი პარამეტრების წვლილი ჰაერის ტემპერატურის ცვალებადობაში შემდეგია: საერთო ღრუბლიანობის რეალური მონაცემებისა – 5.0%, ქვედა ღრუბლიანობისათვის შემთხვევითი კომპონენტებისა - 1.0 %, კოსმოსური სხივების ინტენსივობის რეალური მნიშვნელობებისა და შემთხვევითი კომპონენტებისა –3.0% და 4.1% შესაბამისად.

О связи годовых вариаций интенсивности галактических космических лучей с изменчивостью облачности и температуры воздуха в Тбилиси

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Резюме

Представлены результаты исследования связи годовых вариаций интенсивности галактических космических лучей с изменчивостью облачности и температуры воздуха в Тбилиси в 1963-1990 гг. Изучены статистические характеристики указанных параметров (тренды, случайные составляющие, корреляционные связи между реальными данными и случайными компонентами и др.). В частности, получено, что линейная корреляция реальных значений интенсивности космических лучей с реальными значениями общей облачности положительная, нижней облачности – отсутствует, температуры воздуха – отрицательная. Корреляция случайных компонент интенсивности космических лучей со случайными компонентами нижней и общей облачности – положительная, температуры воздуха – отрицательная. В пределах вариационного размаха вклад исследуемых параметров в изменчивость температуры воздуха: реальных значений общей облачности – 5.0 %, случайных компонент нижней облачности - 1.0 %, реальных значений и случайных компонент интенсивности космических лучей – 3.0 % и 4.1 % соответственно.