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The statistical analysis of average seasonal, semi-annual and annual values of surface ozone concentration in Tbilisi in 1984-2003

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Abstract

Results of statistical analysis of the average seasonal, semi-annual and annual values of surface ozone concentration (SOC) in Tbilisi for the period 1984-2003 are presented. It is obtained, that time series of SOC are autocorrelate and non accidental. The estimation of confidence interval of mean values of SOC taking into account the data about the values of autocorrelation coefficient is carried out.

1. Introduction

The increased attention recently is paid to studies of the surface ozone concentration in different countries. This first of all is connected that ozone is the toxic pollutant of the atmosphere, whose concentration frequently exceeds the maximum permissible standard, in consequence of which the World Organization of Public Health included it in the list of five basic pollutants, whose content must be monitored during the determination of the air quality [1].

The regular researches of surface ozone concentration in Tbilisi are conducted by Mikheil Nodia Institute of Geophysics from 1980 to present time. Thus since 1984 there are data of the continuous series of ozone observations [2,3].

In this work some results of the statistical analysis of observational data of the average seasonal, semi-annual and annual values of the surface ozone concentration in the period from 1984 through 2003 are represented (for 15 hours on the local time).

2. Method

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 [4,5].

The following designations will be used below: SOC - surface ozone concentration, Min – minimal values, Max - maximal values, Interv - variational scope, St Dev - standard deviation, σ_m - standard error (68% - confidence interval of mean values), C_v - coefficient of variation (%), A_s - coefficient of skewness, K - coefficient of kurtosis, R - coefficient of linear correlation, R^2 – coefficient of determination, R_s – Spearman's rank correlation coefficient, R_k – Kendall's rank correlation coefficient, R_a - autocorrelation coefficient with a Lag = 1 year, CONF - confidential interval, $CONF_L$ - low level of a confidential interval, $CONF_U$ - upper level of a confidential interval, α - the level of significance, Δ(%) - relative error of mean value.

3. Results

The statistical characteristics of average seasonal, semi-annual and annual values of SOC in Tbilisi for the specified twenty years' period of time are represented in table 1. As follows from this table, the average values of SOC varies from 33 mcg/m^3 in the winter up to 6 mcg/m^3 in the spring, the minimal value of SOC varies from 11 mcg/m^3 in the winter up to 42 mcg/m^3 per warm half-year, maximal - from 53 mcg/m^3 in the winter up to 83 mcg/m^3 in the spring, variational scope from 28 mcg/m^3 per warm half-year up to 49 mcg/m^3 in the spring, standard deviation from 7,2 mcg/m^3 per warm half-year up to 14,5 mcg/m^3 in the spring, standard error from 1,6 mcg/m^3 in the summer and per warm half-year up to 3,2 mcg/m^3 in the spring, coefficient of variation from 12,9 % per warm half-year up to 36,8 % in the winter.

Table 1. Statistical characteristics of average seasonal, semi-annual and annual values of surface ozone concentration in Tbilisi in 1984-2003 (mcg/m^3)

Parameter	Winter	Spring	Summer	Autumn	Cold period	Warm period	Year
Mean	33	61	54	41	56	39	47
Min	11	36	37	24	42	15	29
Max	53	85	66	59	69	55	62
Interval	42	49	29	35	28	40	33
St Dev	12,3	14,5	7,3	9,7	7,2	12,6	9,1
σ_m	2,8	3,2	1,6	2,2	1,6	2,8	2,0
C_v (%)	36,8	23,7	13,5	23,9	12,9	32,2	19,2
A_s	-0,12	-0,02	-0,44	0,15	-0,13	-0,16	-0,12
K	-1,26	-1,26	-0,04	-0,70	0,00	-1,26	-0,92
CONF 95% (+/-)	5,4	6,3	3,2	4,3	3,2	5,5	4,0
$CONF_L$	28	55	51	36	53	34	43
$CONF_U$	39	67	57	45	59	45	51
Δ (%)	16,1	10,4	5,9	10,5	5,7	14,1	8,4

Coefficient of skewness varies from -0,44 in the summer till 0,15 44 in the autumn, coefficient of kurtosis - from -1,26 in the winter, spring and per cold half-year up to 0 per warm half-year. The absolute values of the calculated coefficients of skewness and kurtosis are less than the trebled theoretical value of their standard deviations. Accordingly in general set of function of distribution of monthly average values of SOC for all seasons of year, half-year and year should be close to normal.

95 % confidential interval of average seasonal, semi-annual and annual values of SOC varies from ±3,2 mcg/m^3 in the summer and per warm half-year up to ±6,3 mcg/m^3 in the spring. The relative error of average seasonal, semi-annual and annual values SOC for 95% confidential interval varies from ±5,7 % per warm half-year up to ±16,1% in the winter.

The values of stability parameters of average seasonal, semi-annual and annual SOC observations time series in Tbilisi for 1984-2003 are submitted in the table 2. Coefficient of linear correlation between the specified values of SOC and years varies from 0,25 in the summer up to 0,52 per cold half-year period and year, the values of Kendall's rank correlation coefficient varies from 0,14 in the summer up to 0,4 per cold half-year, the values of Spearmen's rank correlation coefficient varies from 0,21 in the summer till 0,52 in the winter, the values of autocorrelation coefficient with a Lag = 1 year varies from 0,15in the summer up to 0,65 for year. The values of level of significance α for the above mentioned parameters of stability also are given in this table. As shows the analysis of table 2 the time series of average seasonal, semi-annual and annual values of SOC are autocorrelate and non accidental. Relatively weak autocorrelation and weak criteria of non randomness are observed in the time series of average summer values SOC only.

95 % confidential interval average for a seasonal, half-year and year of values SOC taking into account the data about the values of autocorrelation coefficient in observational times series at 1 year lag [4] varies from ±3,7 mcg/m^3 in the summer up to ±12,9 mcg/m^3 per cold half-year. The relative error of monthly average values of SOC for 95% confidential interval SOC taking into account data about of R_a varies from ±6,9 % in the summer up to ±33 % per cold half-year.

Table 2. Stability in time of observational series of average seasonal, semi-annual and annual values of SOC in Tbilisi in 1984-2003

Parameter	Winter	Spring	Summer	Autumn	Could period	Warm period	Year
R^2	0,23	0,23	0,06	0,18	0,17	0,27	0,27
R	0,48	0,48	0,25	0,42	0,41	0,52	0,52
α	0,03	0,03	0,3	0,06	0,07	0,01	0,001
R_k	0,34	0,33	0,14	0,35	0,26	0,4	0,34
α	0,035	0,04	0,38	0,03	0,11	0,015	0,04
R_s	0,52	0,48	0,21	0,43	0,39	0,5	0,49
α	0,02	0,035	0,36	0,06	0,09	0,03	0,03
R_a (L=1)	0,57	0,43	0,15	0,53	0,44	0,69	0,65
α	0,001	0,05	0,5	0,001	0,05	0,0005	0,0005
CONF 95%(+/-)	10,3	10,0	3,7	7,7	5,1	12,9	8,7
$CONF_L$	23	51	51	33	51	26	39
$CONF_U$	44	71	58	48	61	52	56
Δ (%)	30,8	16,4	6,9	18,9	9,1	33,0	18,3

Thus account of autocorrelation in observational time series for average values SOC essentially expands a range of a confidential interval of means (Tale 1 and 2). So, for example, these confidential intervals without the taking into account R_a and taking into account R_a follows: in the winter 5,4 and 10,3 mcg/m^3, spring 6,3 and 10 mcg/m^3, autumn 4,3 and 7,7 mcg/m^3, warm half-year 3,2 and 5,1 mcg/m^3, cold half-year 5,5 and 12,9 mcg/m^3, year 4,0 and 8,7 mcg/m^3. Accordingly relative errors of average values SOC without and with the taking into account R_a are: in the winter 16,1 and 30,8 %, spring 10,4 and 16,4 %, autumn 10,5 and 18,9 %, warm half-year 5,7 and 9,1 %, cold half-year 14,1 and 33 %, year 8,4 and 18,3 %. (For all values, specified in this paragraph, for simplicity of representation the sign ± is omitted).

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Статистический анализ средних сезонных, полугодовых и годовых значений концентрации приземного озона в Тбилиси в 1984 – 2003 гг.

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Резюме

В работе представлены некоторые результаты статистического анализа данных наблюдений за средними сезонными, полугодовыми и годовыми значениями концентрации приземного озона (КПО) в Тбилиси в период с 1984 по 2003 гг. В частности получено, что временные ряды наблюдений за КПО являются неслучайными и автокоррелированными. Проведена оценка величин доверительного интервала средних значений КПО за указанный период времени с учетом автокорреляции.

1984 – 2003 წლებში ქ. თბილისში მიწისპირა ოზონის კონცენტრაციის საშუალო სეზონური, ნახევარწლიური და წლიური მონაცემების სტატისტიკური ანალიზი

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რეზიუმე

ნაშრომში წარმოდგენილია ქ. თბილისში 1984 – 2003 წლებში მიწისპირა ოზონის კონცენტრაციის (მკ) საშუალო სეზონური, ნახევარწლიური და წლიური მნიშვნელობების სტატისტიკური ანალიზის ზოგიერთი შედეგები. კერძოდ, მიღებულია, რომ მკ - ის დაკვირვებების დროითი მწკრივები არაშემთხვევითი და ავტოკორელირებულია. შეფასებულია მკ – ის საშუალო მნიშვნელობების სანდოობის ინტერვალის სიდიდე ავტოკორელაციის გათვალისწინებით დროის მოცემულ პერიოდისათვის.