Changeability of Surface Ozone Concentration in Tbilisi in 1984-2010

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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 [EPA, 1996; Amiranashvili, Gogua et al., 2007; Amiranashvili, Chikhladze, Bliadze, 2010]. 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 [Kharchilava, Amiranashvili, 1989; Amiranashvili et al., 2004,2005, 2008; Amiranashvili, Bliadze et al., 2010]. In this work some results of the statistical analysis of observational data of the average semi-annual and annual values of the surface ozone concentration in the period from 1984 through 2010 are represented (for 15 hours on the local time).

2. METHOD AND DATA DESCRIPTION

The measurements of ozone were conducted by the electro chemical ozone instrument OMG-200. Observational data for 15 hours are presented. The unit of the ozone measurement is omitted below (mcg/m^3). 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 [Kendall, 1981; Kobisheva, Narovlianski, 1978].

The following designations will be used below: SOC - surface ozone concentration, Ywarm, Ycold and Y – the mean six month (April-September, October-March) and yearly values of surface ozone concentration, Min – minimal values, Max - maximal values, Range - variational scope, Range/ Mean (%) - relative variational scope, σ - standard deviation, σ_m - standard error (68% - confidence interval of mean values), C_v - coefficient of variation (%), A - 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, K_{DW} – Durbin-Watson statistic, α - the level of significance.

3. RESULTS

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

Real data. The standard statistical characteristics of mean semi-annual and annual values of SOC in Tbilisi in the upper part of table 1 are represented.

Table1. The statistical characteristics of mean six month and yearly values of SOC in Tbilisi in 1984-2010

Parameter		Warm season	Cold season
	Real data		
Mean	44.1	52.2	36.0
Min	26.3	31.5	15.2
Max	61.8	69.0	55.3
Range	35.5	37.5	40.2

Median	42.3	52.0	30.8
Mode	37.8	51.8	-
σ	10.1	9.8	12.1
σ_m	1.9	1.9	2.3
C_v (%)	22.9	18.8	33.6
A	0.09	-0.60	0.37
K	-0.86	0.19	-1.16
σ_m /Mean (%)	4.4	3.6	6.5
Range/ Mean (%)	80.5	71.9	111.7
	Correlation Matrix (between Y, Ywarm and Ycold)		
Year	1	0.90	0.94
Warm season	0.90	1	0.70
Cold season	0.94	0.70	1
	The non-randomness characteristic of time series		
R with year	-0.18	-0.31	-0.04
(α) R	0.35	0.15	0.95
R_k	-0.11	-0.17	-0.01
(α) R_k	0.40	0.22	0.62
R_s	-0.19	-0.26	-0.02
(α) R_s	0.34	0.19	0.94
R_a . Lag = 1	0.78	0.69	0.76
(α) R_a	0.05	0.05	0.02
	Trend + background ($Y = a \cdot X^4 + b \cdot X^3 + c \cdot X^2 + d \cdot X + e$)		
a	0.00183	0.001761	0.001906
b	-0.09717	-0.09623	-0.09808
c	1.505	1.599	1.411
d	-5.962	-8.161	-3.755
e	34.69	51.40	11.45
K_{DW}	2.03	1.43	2.36
(α) K_{DW}	0.05	0.05	0.05
Mean	36.7	43.2	23.8
Min	23.7	30.5	8.8
Max	50.5	54.4	40
Range	26.8	23.9	31.2
σ	9.2	7.7	11.1
C_v (%)	25.0	17.9	46.7
Range/ Mean (%)	73.0	55.3	131.3
Share of real data	83.3	82.8	66.0
	Random components		
Mean	7.3	8.9	12.2
Max	14.7	21.7	20.1
σ	4.2	6.0	4.8
C_v (%)	57.6	67.3	39.3
Range/ Mean (%)	200.6	242.6	164.8
Share of real data	16.6	17.1	33.9
	Correlation Matrix (between Y, Ywarm and Ycold)		
Year	1	0.83	0.71
Warm season	0.83	1	0.20
Cold season	0.71	0.20	1

As follows from this table, the average values of SOC varies from 36 in the cold period up to 52.2 in the warm season, the minimal value of SOC varies from 15.2 in the cold period up to 31.5 per warm half-year, maximal - from 55.3 in the cold period to 69.0 in the warm period, variational scope from 37.5 per warm half-year up to 40.2 in the cold season, standard deviation varies from 9.8 per warm half-year up to 12.1 in the cold season, standard error - from 1.9 in the warm half-year up to 2.3 in the cold half-year, coefficient of variation from 18.8% per warm half-year up to 33.6 % in the cold period.

Coefficient of skewness varies from -0.60 in the warm season till 0.37 in the cold period, coefficient of kurtosis - from -1.16 in the cold period up to 0.19 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 indicated seasons of year should be close to normal. The relative variational scope change from 71.9% for warm period up to 111.7% per cold season. Coefficient of linear correlation between Y and Ywarm equal 0.90, between Y and Ycold equal 0.94 and between Ywarm and Ycold equal 0.70.

Fig. 1 Autocorrelation functions of mean values of surface ozone concentration in Tbilisi in 1984-2010

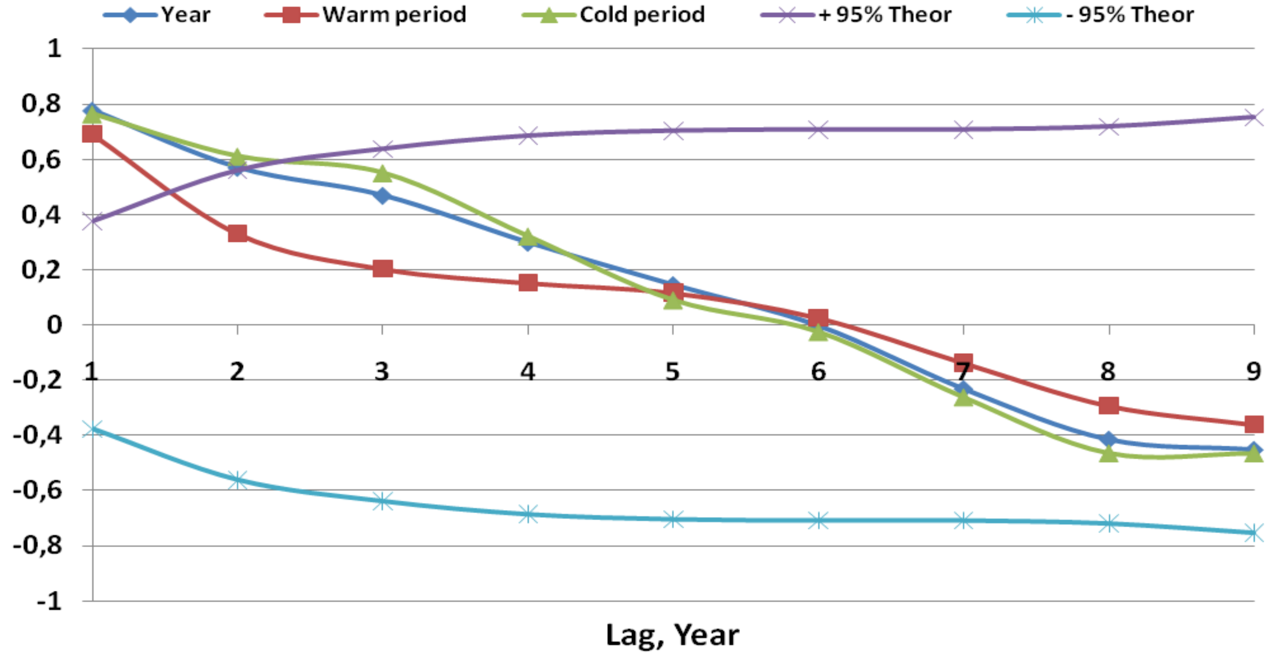


Fig. 2 Trend of mean annual values of surface ozone concentration in Tbilisi in 1984-2010

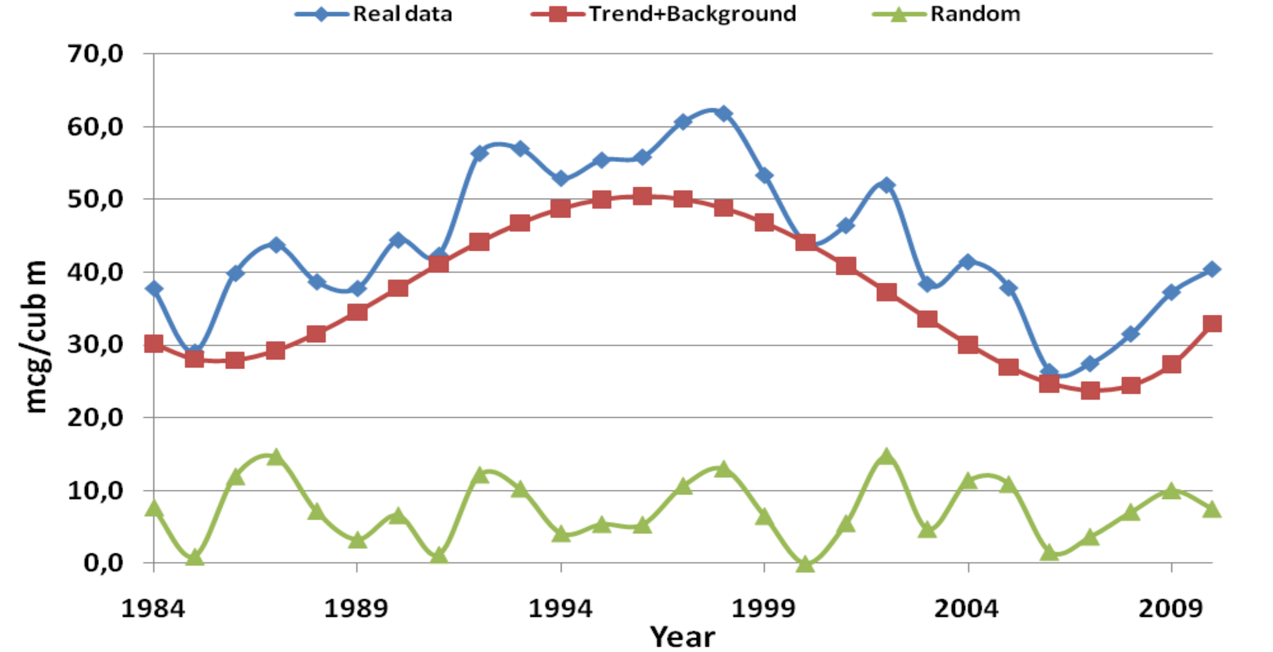


Fig. 3 Trend of mean values of surface ozone concentration in warm period in Tbilisi in 1984-2010

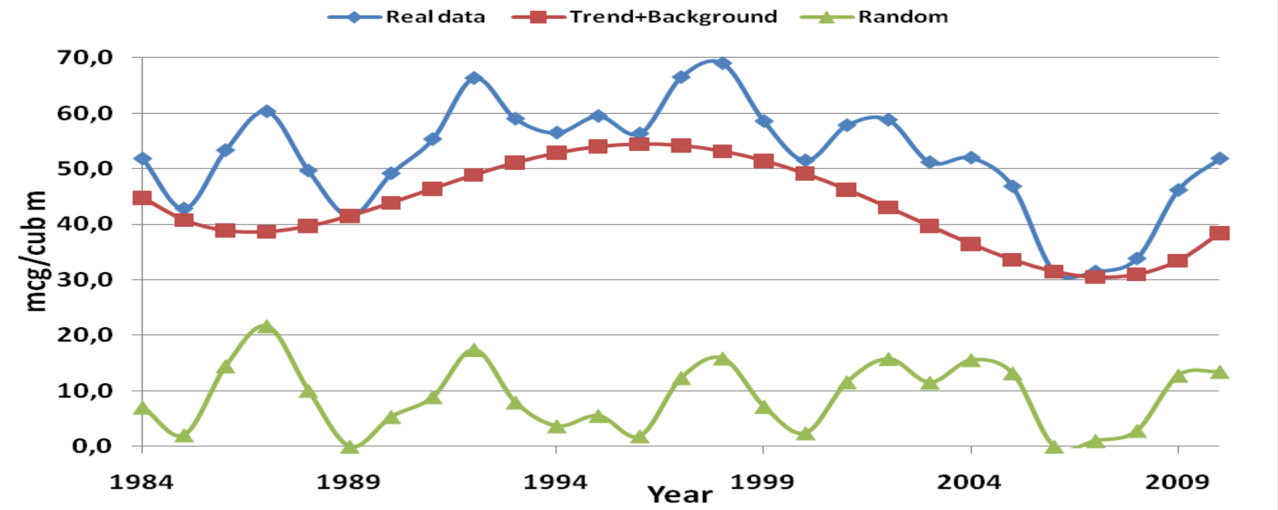
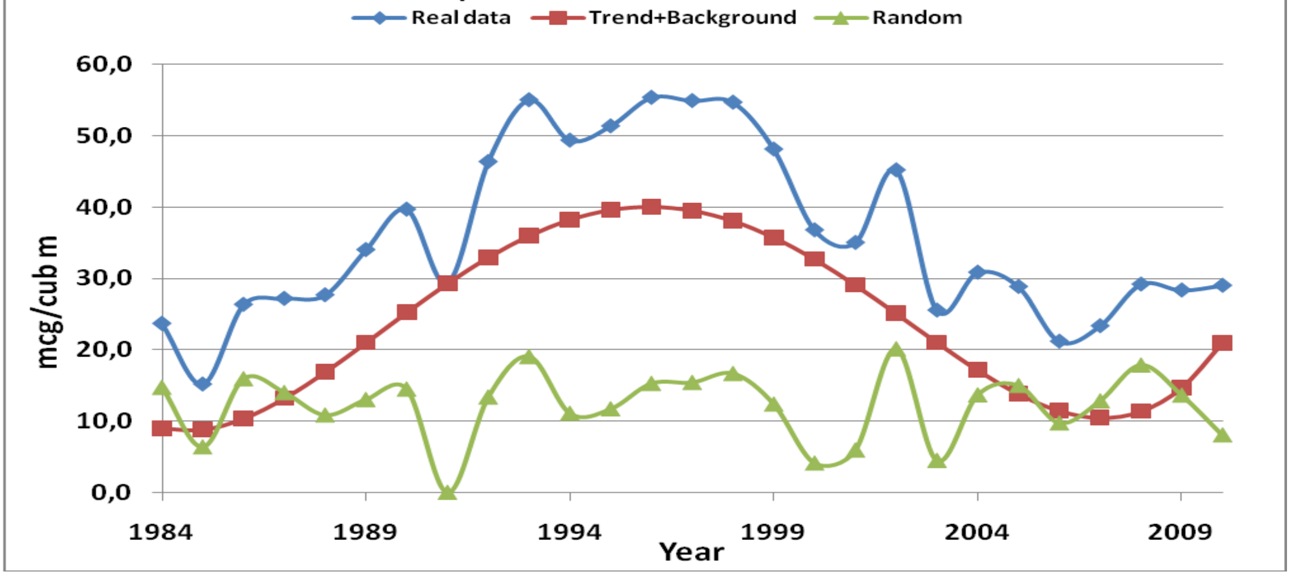


Fig. 4 Trend of mean values of surface ozone concentration in cold period in Tbilisi in 1984-2010



The values of stability parameters of average semi-annual and annual SOC observations time series in Tbilisi for 1984-2010 are submitted in the low part of table 1. Coefficient of linear correlation between the specified values of SOC and years varies from -0.31 in the warm period up to -0.04 per cold half-year, the values of Kendall's rank correlation coefficient varies from -0.17 in the warm period up to -0.01 per cold half-year, the values of Spearmen's rank correlation coefficient varies from -0.26 in the warm period till -0.02 in the cold season, the values of autocorrelation coefficient with a Lag = 1 year varies from 0.78 per the year up to 0.69 for warm season. 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 1 and fig. 1 the time series of average semi-annual and annual values of SOC are autocorrelate and trend has a nonlinear nature. Relatively weak autocorrelation and weak criteria of non randomness are observed in the time series of average warm period values of SOC only.

Trend of the mean half year and annual values of SOC by the fourth power polynomial are described (table 1, fig. 2-4). In table 1 the data of characteristics of trend + background and random components are presented.

Trend + background components. The average values of SOC varies from 23.8 in the cold period up to 43.2 in the warm season, the minimal value of SOC varies from 8.8 in the cold period up to 30.5 per warm half-year, maximal - from 40 in the cold period to 54.4 in the warm period, variational scope from 23.9 per warm half-year up to 31.2 in the cold season, standard deviation - from 17.9 per warm half-year up to 46.7 in the cold season, coefficient of variation from 18.8% per warm half-year up to 33.6 % in the cold period, the relative variational scope change from 55.3 % for warm period up to 131.3% per cold season.

A share of the mean values of the components of trend+background from the mean values of real data constitutes: year - 83.3 %, warm season - 82.8%, cold season - 66.0%. Thus, the long-term variations of SOC in Tbilisi are mainly caused by the component of trend+background.

Random components. The average values of SOC varies from 7.3 in the year up to 12.2 in the cold season, the maximal - from 14.7 in the year to 21.7 in the warm period, standard deviation - from 4.2 per year up to 6.0 in the warm season, coefficient of variation from 39.3 per cold half-year up to 67.3 in the warm period, the relative variational scope change from 164.8 % for cold period up to 242.6 % per warm season. Coefficient of linear correlation between Y and Ywarm equal0.83, between Y and Ycold equal 0.71 and between Ywarm and Ycold equal 0.20.

As follows from fig. 2-4 an increase in the surface ozone concentration in the period from 1984 through 1995-1997 was observed, then – decrease up to 2007 and in period 2008-2010 - newly small increase. Thus, in average: in 1984 Y = 37, into 1996 - 58, into 2010 - 40; in 1984 Ywarm = 54, into 1996 - 63, into 2010 - 47; in 1984 Ycold = 21, into 1996 - 52, into 2010 - 33.

4. CONCLUSIONS

Trend of the mean half year and annual values of Surface Ozone Concentration in Tbilisi in 1948-2010 has a nonlinear nature and by the fourth power polynomial are described. An increase in the surface ozone concentration in the period from 1984 through 1995-1997 was observed, then – decrease up to 2007 and in period 2008-2010 - newly small increase.

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მიწისპირა ოზონის კონცენტრაციის ცვალებადობა თბილისში 1984–2010 წლებში

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რეზიუმე

მოყვანილია ქალაქ თბილისში 1984-დან 2010 წლებში მიწისპირა ოზონის კონცენტრაციის საშუალო ნახევარწლიური და წლიური მონაცემების (შესაბამისად Ywarm, Ycold და Y) დეტალური სტატისტიკური ანალიზის შედეგები. Oოზონის კონცენტრაციის გაზომვები ტარდებოდა OMG-200 ტიპის

ელექტროქიმიური ოზონომეტრით. მოყვანილია 15 საათიანი დაკვირვების მონაცემები. Oოზონის კონცენტრაციის საზომი ერთეული (მკგ/მ^3) ქვემოდ აღარ იხმარება.

შესწავლილია ხსენებული დროის რიგების ვარიაციები (ავტოკორელაცია, ტრენდები, შემთხვევითი მდგენელები და სხვა). კერძოდ, სამივე დროითი მწკრივის ცვალებადობა აღიწერება მეოთხე ხარისხის პოლინომით. 1984-დან 1995-1997 წლებში დაიკვირვებოდა მიწისპირა ოზონის კონცენტრაციის ზრდა, მხოლოდ შემდგომში – კლება. ასე მაგალითად, 1984-ში Y =37, 1996-ში – 58, 2010-ში – 40; 1984-ში Ywarm =54, 1996-ში – 63, 2010-ში – 47; 1984-ში Ycold =21, 1996-ში – 52, 2010-ში – 33. მოყვანილია აგრეთვე დროითი მწკრივების სხვა მახასიათებლებიც.

საკვანძო სიტყვები: მიწისპირა ოზონის კონცენტრაცია, ტრენდი, ჰაერის დაჭუჭყიანება

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