Correlation between ozonosphere variations modulating the UV-B solar radiation level and cycles of acute cardiac infarction

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The correlation between cycles of acute cardiac infarction (ACI) and the total ozone content (TOC) variations is considered. The results of correlation analysis of the series of ACI and TOC indices for the period from 1986 to 2001 in Tomsk are presented. It is shown that the ACI level significantly depends on the variations of the ozonosphere, modulating the level of UV-B solar radiation reaching the earth's surface. Significant coefficients of positive correlation between the ACI and TOC indices are obtained, both for complete series of monthly values over the entire period considered, especially, for warm half-year (April–September), and for annually mean values as well.

At present, many statistical and medical data on the correlation between the incidence, fatality, and other damages of human vitality, including acute cardiac infarction (ACI), with a number of periodic and aperiodic changes of solar activity, weather, and climate are presented in the literature.[1–4] We can trace such correlation not only with an individual climate forcing, but with their totality.[5–7]

In the paper, we investigate the correlation between cycles of the ACI and total ozone content (TOC) variations in the atmosphere, modulating the UV solar flux in the wavelength range from 290 to 320 nm (UV-B radiation). The UV-B radiation stresses bioenvironment (including adverse health effect) and provides the basis of the correlation.[8] The major part of the UV-B radiation is absorbed within the Hartley and Huggins absorption bands already in the stratosphere by the ozone where the ozone content is maximum. TOC controls the UV-B radiation absorption throughout the atmospheric column, hence, TOC variations should influence the human health, particularly, incidence of ACI as a stress-related disease.

Description of original data

Clinical and epidemiological fragments of ACI were taken from the database of the World Health Organization Myocardial Community Registers (Refs. 9, 10), which has been working in Tomsk since 1984. ACI epidemiology is studied among the city residents older than twenty.

From 1986 to 2002, 12 787 the ACI cases were noted (on the basis of WHO criteria) in Tomsk. Maximum number of the cases fell on January and May (1187 and 1174, respectively), minimum – on July and August (979 and 995).

Table 1 and Fig. 1*a* show the monthly distribution of ACI cases in Tomsk in the period under study. In Fig. 1*a*, the linear regression (LR) line indicates systematic increase of ACI during the period. Relative to the line, significant within-year ACI level variations without pronounced seasonality are evident.

Monthly mean TOC values from 1986 to 2002 were taken from the database of Siberian Lidar Station of IAO SB RAS, where TOC daily mean monitoring is performed routinely.[11] The series of the values are presented in Table 2 and Fig. 1*b*.

Within a year, it is characterized by significant variations against the weak negative trend (the LR line). In contrast to ACI level variations within a year, seasonal TOC variations behave regularly with climate maximum in March and minimum in October (Table 2).

For convenience of making the correlation analysis, the data from Fig. 1 were standardized by trends subtraction and recalculation to dimensionless indices $I_i(t)$ by the formula

$$I_i(t) = \frac{\left[X_i(t) - \bar{X}\right]}{SD}, \qquad (1)$$

where $X_i(t)$ is the running value of the series; $\bar{X}$ is the mean value of the series; SD is the standard (root-mean-square) deviation. The series of the input data, standardized in this way, are depicted in Fig. 2.

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Table 1. ACI distribution in Tomsk in 1986–2002

Year	Month												Sum total
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1986	53	56	55	54	56	55	52	46	54	54	53	48	636
1987	70	69	63	44	79	76	54	59	63	60	73	64	774
1988	76	58	60	65	79	61	47	56	47	63	63	61	736
1989	60	59	64	64	85	71	62	58	42	56	60	62	743
1990	73	63	74	50	55	54	44	60	64	67	68	51	723
1991	55	56	60	60	57	65	46	56	57	55	70	47	684
1992	63	50	52	54	45	55	61	59	51	53	55	77	675
1993	53	57	58	52	59	54	47	61	58	70	69	54	692
1994	72	46	63	64	55	55	59	35	56	64	59	58	686
1995	72	50	58	50	69	57	71	55	49	62	61	66	720
1996	79	79	65	63	81	71	58	50	74	62	67	56	805
1997	68	68	68	59	76	78	71	68	61	60	55	63	795
1998	80	59	79	64	70	58	59	57	78	83	78	66	831
1999	72	61	80	66	72	60	52	56	80	82	77	57	815
2000	87	60	72	60	83	74	65	69	61	79	62	69	814
2001	70	63	63	68	77	64	64	69	61	61	65	61	786
2002	84	78	62	72	76	66	67	81	69	72	65	89	881
Sum total	1187	1032	1096	1009	1174	1074	979	995	1025	1103	1100	1013	12787

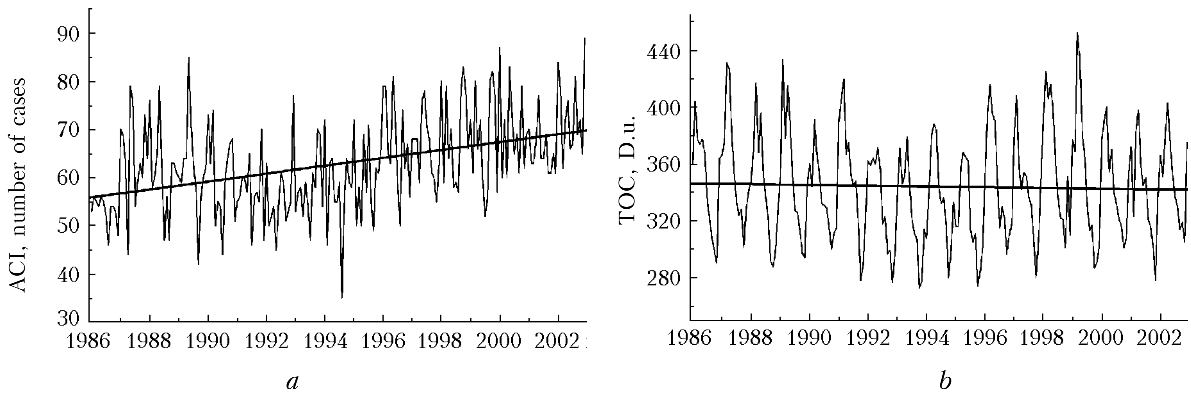

Fig. 1. The monthly ACI distribution (*a*) and monthly mean TOC distribution (*b*) in Tomsk in 1986–2002 (straight lines correspond to linear trends).

Table 2. TOC values (D.u.) in 1986–2000 over Tomsk

Year	Month												Average
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1986	360	404	377	374	377	367	334	321	307	298	290	364	348
1987	366	375	431	427	384	354	333	324	328	301	328	341	358
1988	348	370	417	368	396	353	336	322	292	288	298	326	343
1989	352	433	378	415	389	352	327	326	313	297	224	345	352
1990	360	344	391	367	353	332	331	329	315	300	311	315	337
1991	389	405	420	367	375	352	345	348	317	278	289	324	351
1992	362	359	364	360	371	356	318	323	297	299	277	296	332
1993	336	371	346	352	579	345	321	311	307	273	277	314	328
1994	308	341	380	388	384	343	332	336	316	280	297	333	336
1995	316	316	357	368	365	362	314	305	311	274	284	302	323
1996	351	396	416	396	390	347	315	330	322	297	310	318	349
1997	377	408	357	342	354	351	337	331	307	280	306	352	342
1998	390	425	406	416	398	360	337	322	321	301	351	310	361
1999	377	369	452	435	380	367	331	313	317	287	291	302	352
2000	377	391	400	354	370	340	332	321	317	301	308	352	347
2001	372	383	382	398	358	345	350	321	316	302	278	335	340
2002	366	351	379	403	375	355	337	330	314	319	305	375	351
Average	359	375	391	384	376	352	331	324	313	293	300	330	344

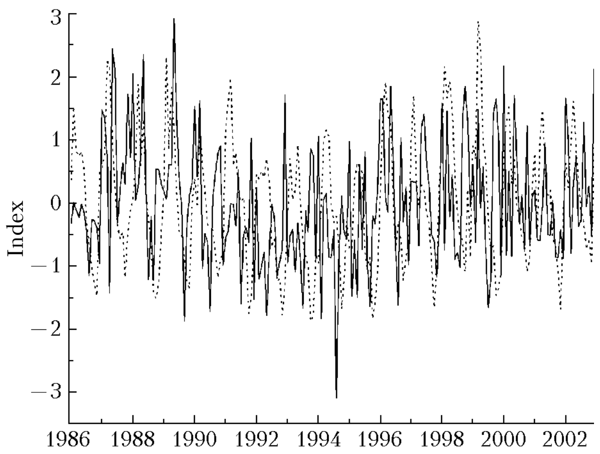

Fig. 2. Time variation of the standardized indices of ACI (solid line) and TOC (dotted line) in Tomsk in 1986–2002.

Results of correlation analysis

The results of correlation analysis of ACI and TOC indices from 1986 to 2002 are presented in Table 3.

Table 3. Correlation coefficients ($r \pm \Delta r$) of ACI and TOC indices from 1986 to 2002 in Tomsk

Sample	Correlation coefficient
All months, 204 points	**0.180 ± 0.113**
Cold months, 96 points	0.141 ± 0.197
Warm months, 102 points	**0.270 ± 0.181**
May–August, 68 points	**0.427 ± 0.196**
Annual mean values, 17 points	**0.705 ± 0.062**

Significance of the r coefficient was estimated from the condition $|r| \geq \Delta r$, where the confidence interval (Δr) was determined within the 95% probability confidence interval by the known formula (Ref. 12)

$$\Delta r = 1.96\frac{1-r^2}{\sqrt{N-1}}, \quad (2)$$

where N is the sample size. In Table 3, the values of the correlation coefficients obeying the significance condition are boldface typed. As is clear from Table 3, the correlation between ACI and TOC indices is significant (0.180 ± 0.133) for the complete series of monthly distributions composed of 204 running values.

It is reasonable that the correlation between ACI and TOC, filtering UV-B radiation in nature, should be less significant in cold months than in warm ones due to higher solar flux level. The values of the correlation coefficients of monthly ACI and TOC indices are presented in Table 3 for cold (October–March) and warm (April–September) months. Such a division differs from the calendar but it permits the regional climatic parameters to be considered and the TOC seasonal trend to be symmetrized about the climate maximum.

As is seen from Table 3, the correlation coefficient between ACI and TOC does not reach the significance point (0.141 ± 0.197) in cold months (a sample of 96 points), and, as expected, confidently exceeds the significance point (0.270 ± 0.181) in warm months (a sample of 102 points). In Tomsk, the warm season is rather from May to August, when the Sun affects human beings directly and UV-B radiation level is maximum. The analysis of monthly distribution of ACI and TOC indices shows higher correlation (0.427 ± 0.196) in these 4 months (the sample of 68 points).

The correlation between ACI and TOC is observed for annual mean indices as well (see Table 3). The trend is shown in Fig. 3.

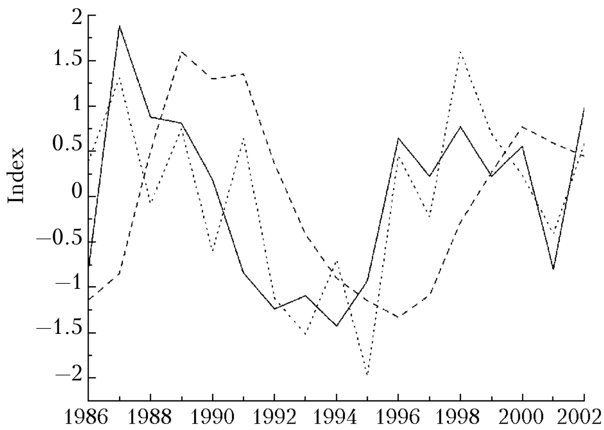

Fig. 3. Time variation of the annual mean indices of ACI (solid line), TOC (dotted line), and solar activity (dashed line) in Tomsk in 1986–2002.

Long-period variations of ACI and TOC in the period under study have two main characteristic maxima in 1987 and 1998 for both indices. The 11-year interval agrees with the well-known sunspot cycle (SC) represented in Fig. 3 in the reduced sunspot indices[13] in Wolf numbers. As is seen, the 11-year sunspot cycle modulating long-period variations of ACI and TOC is out-of-phase with them. Actually, it determines weak direct relationship between ACI and SC or TOC and SC.

And *vice versa*, the 11-year cycle of long-period variations of ACI and TOC is phasing-in well. Moreover, mainly phasing interannual variations of ACI and TOC are distinguished in Fig. 3. The TOC variations are due to the well-known quasi-biennial cycle (QBC) characteristic of the stratospheric circulation.[11]

Evidence of QBC in ACI cycles confirms indirectly the correlation between ACI and UV-B radiation, whose variations are modulated by TOC. Generally speaking, good agreement of phases and cycles of ACI and TOC variations determines the highly statistically significant positive correlation between ACI and TOC for the annual mean sample of 17 points (0.705 ± 0.062).

Conclusion

Thus, we have shown the ACI incidence to depend essentially on the ozonosphere variations, especially on direct effect of UV-B radiation in the warm season. Significant coefficients of the positive correlation between ACI and TOC indices have been obtained for the complete series of monthly values (0.180 ± 0.133). It is worthy to note that the correlation is significant only in warm season (April–September) when the correlation coefficient reaches (0.270 ± 0.181), and insignificant (0.141 ± 0.197) in cold season (October–March).

In Tomsk, the warm season, when people can be affected directly by the Sun, is not longer than 4 months (from May to September). This period is characterized by the maximum level of UV-B solar radiation and the correlation coefficient between ACI and TOC indices increases significantly (0.427 ± 0.196), for the annual mean values it amounts to (0.705 ± 0.062).

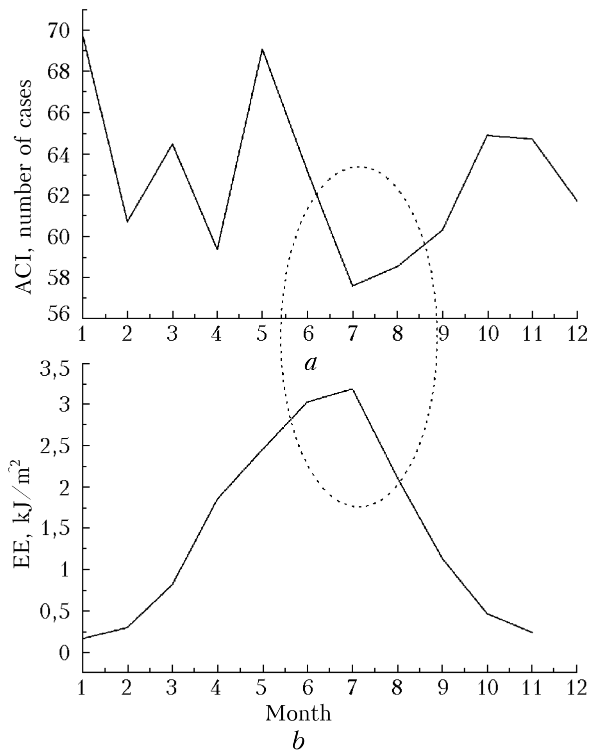

Fig. 4. Annual climate trend of ACI cases averaged over the period from 1986 to 2002 (*a*) and erythemal UV exposure (*b*) in Tomsk.

Since the behavior of the monthly mean values of UV-B radiation is the inversion of the series indices of the monthly mean TOC values (when subtracting the seasonal trend), the results obtained evidence of the fact that the UV-B-radiation level growth decreases the probability of ACI. Hence, the moderate UV preventive irradiation should have the salutary effect on the ACI probability decrease. Such a conclusion is in a good agreement with the fact, that in Tomsk the minimum of annual mean ACI distribution contemporizes with the maximum of climate mean trend of erythemal UV exposure (EE) (TOMS data for the coordinates of Tomsk) in the period under study (Fig. 4).

This conclusion is confirmed indirectly by data of International Cooperative Investigation of ACI Epidemiology of World Health Organization Myocardial Community Registers,[10] according to which the cardiac infarction lowest-incidence areas are the countries with warm climate and lot of sunny days (Bulgaria, Rumania) and the highest-incidence countries are Finland and Sweden.[15]

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