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Phenomenological Features of Mortality and Morbidity Dynamics in Tomsk versus Heliogeophysical Activity

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Abstract—The influence of heliogeophysical activity on the morbidity and mortality of the population in Tomsk is studied epidemiologically on the basis of regional data. The biological effectiveness of heliogeophysical factors selected on the basis of the Karhunen–Loeve method from epidemiological data on the morbidity and mortality in Tomsk in 1990–2008 is estimated. An analysis of the impact of variations in heliogeophysical activity on morbidity and mortality (according to the International Statistical Classification of Diseases and Related Health, ICD-10) showed the existence of common factors within different nosological classes that reliably correlate with the major components of variations in characteristic indices of heliogeophysical activity.

Keywords: solar activity, X-rays, geomagnetic disturbances, morbidity, mortality

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INTRODUCTION

A.L. Chizhevskii was the first to call attention to the influence of heliogeophysical factors on wildlife at the level of population and individuals (Chizhevskii, 1976). Since that time, sufficient facts have been accumulated which confirm a correlation between solar events and human health. The "space weather" term became common. It means the totality of heliogeophysical phenomena that develop under the action of solar activity in the upper layers of the Earth's atmosphere, ionosphere, and circumterrestrial space, are capable of impacting the Earth's biosphere and are explicitly periodic (Vladimirsky et al., 2014). The ecological significance of this environmental factor has been actively studied. It is assumed that solar activity and magnetic storms impact living organisms, including men, via electromagnetic and infrasonic vibrations with frequencies close to the natural frequencies of their internals. Thus, the frequency range of electromagnetic fields generated by a human brain is close to the frequency range of a Schumann cavity (0–40 Hz) (Bliokh et al., 1977). The electromagnetic fields of a cardiovascular system (0.8–2.5 Hz) are in the frequency range of resonance characteristics of an electromagnetic background in the frequency band of ionospheric Alfven cavity (0.1–7 Hz) (Polyakov and Rapoport, 1981). Similar vibrations can resonantly affect the adaptation processes of a living organism and disturb environmental adaptability (Kolesnik et al., 2003; Pobachenko et al., 2006; Bingi, 2011).

The cardiovascular and psychophysical systems are the most sensitive to variations in space weather and, in particular, geomagnetic conditions; this agrees well with the idea about resonance nature of the solar–biosphere links. For example, it has been ascertained that electromagnetic fields of industrial frequencies induced by power-line networks act as a risk factor of different socially significant diseases, in particular, acute myocardial infarction (Gudina et al., 2009). It has been ascertained that if someone is in a region with a decreased total vector of a geomagnetic field, changes in the functioning of their cardiovascular system are observed (Shitov et al., 2013). There are numerous reliable witnesses of an increase in the number of myocardial infarctions and apoplectic attacks during a strong geomagnetic storm (Gurfinkel et al., 1998; Breus et al., 2002; Rapoport et al., 2006).

Inverse correlations have been revealed between the solar activity indices and the number of Down syndrome cases ($r = -0.78$ and $p = 0.008$ for the sunspot number and $r = -0.76$ and $p = 0.01$ for the solar flux). It has been concluded that cosmophysical factors play a significant role in the nosogenesis of chromosome aberrations (Stoupel et al., 2005). An increase in solar activity was noted among possible risk factors of Down's syndrome during a week before conception. In addition, chromosomal disturbances, which are revealed during early pregnancy stages and result, among others, in miscarriages, correlate with cases of extreme solar and geomagnetic activity during the 2nd and 3rd weeks before conception (Grigoriev et al.,

Table 1. Annual values of components of the database on heliogeophysical parameters for 1990–2008

Component index	Heliogeophysical parameter	Component value		
		average	minimum	maximum
XM	Average intensity of X-ray flux, W/m^2	1.02×10^{-6}	7.6×10^{-9}	3.7×10^{-7}
XS	Standard deviations of X-ray flux intensity, W/m^2	1.6×10^{-6}	3.03×10^{-8}	5.4×10^{-6}
XX	X-ray flux intensity maximum, W/m^2	1.9×10^{-5}	5.2×10^{-7}	6.2×10^{-5}
ApM	Average Ap-index of geomagnetic storminess, nT	13.5	6.91	23.4
ApS	Standard deviations of Ap-index of geomagnetic storminess, nT	13.4	5.8	25.6
ApX	Ap-index of geomagnetic storminess maximum, nT	113.5	34.2	203.8
SM	Average Wolf number	68.3	2.8	176.5
SS	Standard deviation of Wolf number	28.15	5.67	56.46
SX	Wolf number maximum	160.63	36	352
FM	Average solar radio flux, SFU*	122.8	68.6	208.03
FS	Standard deviations of solar radio flux, SFU	21.4	5.2	42
FX	Solar radio flux maximum, SFU	201	88.2	359.2

M is the average value of a component for 1990–2008 by daily assessments of the parameters; S is the standard deviation of a component for the same period; X is the component maximum for the period.
*SFU is the solar flux unit at a frequency of 2800 MHz; 1 SFU=10^{-22} W/m^2.

2007). Dependences of the distribution of cerebral strokes over cerebral hemispheres on heliogeophysical factors have been revealed in daily and yearly ranges. It has been noted that variations in dominance of the cerebral hemispheres are synchronous with variations in the planetary heliogeophysical factors. It is assumed that these factors can cause periodic changes in human ideation and behavior (Kornetov et al., 1988; Tsygankov and Grigoriev, 2009). Significant correlations have been revealed between the geomagnetic activity and variations in the number of recorded acts of crime and traffic and aircraft accidents, which witnesses a psychotropic effect of natural electromagnetic disturbances (Chibrikin et al., 1995; Ptitsina et al., 1988; Vishnevskaya et al., 2004; Zenchenko and Merzlyi, 2008).

Questions about the effect of heliogeophysical factors on morbidity remain disputable; they are, first and foremost, connected with the uncertainty in the value and direction of estimates of the contingency of factors related to the heliogeophysical activity and biomedical parameters. This might well be caused by ignorance of the priority of the temporal response of biomedical parameters to solar activity manifestations and noncritical statistical analysis of experimental data due to multicollinearity effects.

In this work, the degree of bioefficiency of cosmophysical parameters is temporally estimated with the use of Wolf numbers as an integral characteristic of solar activity, the Ap-index as one of the most adequate planetary indices of geomagnetic activity in midlatitudes, electromagnetic flux in the transparency window, and solar X-rays in the range from 1 to 8 Å (which do not reach the Earth's surface and are absorbed in the upper atmosphere) on the basis of epidemiological data on mortality and morbidity (according to the International statistical classification of diseases and related health, ICD-10) of population the of Tomsk for 1990–2008.

DATA AND METHODS OF STUDY

Data on the morbidity dynamics for the main classes of diseases and mortality of the population in Tomsk for the period from January 1, 1990, to December 31, 2008, provided by the Tomsk Regional Committee on Statistics were used as source data for the study. Data on solar activity parameters and magnetic disturbances were taken from the open-access Space Physics Interactive Data Resource database (http://spidr.ngdc.noaa.gov) and the database of complex environmental monitoring in Tomsk (http://sosrff.tsu.ru).

Maxima, averages, and standard deviations of X-rays (λ = 1–8 Å), Ap-indices of geomagnetic storminess, Wolf numbers, and electromagnetic flux in the transparency window (XX, XM, XS, AX, ApM, ApS, ApX, SM, SS, FX, FM, and FS, respectively, see Table 1) have been calculated over the above years from their daily assessments. These data have different

Table 2. Annual values of components of epidemiological database (ill per thousand people)

Component index	Component	Persons		
		average	minimum	maximum
SUMZ	Sum of ill per period	1116	789	1233
Z1	Infections and infestations	49	29	68
Z2	Neoplasms	9	4	15
Z3	Diseases of the endocrine, nutritional and metabolic diseases and dysimmunity	9	5	14
Z5	Diseases of the nervous system and sensory organs	88	67	102
Z6	Diseases of the circulatory system	16	9	21
Z7	Diseases of the respiratory system	326	280	356
Z8	Diseases of the digestive system	45	26	87
Z9	Diseases of the genitourinary system	53	24	75
Z10	Pregnancy, childbirth, and the puerperium	35	3	66
Z11	Diseases of the skin and subcutaneous tissue	39	16	72
Z12	Diseases of the musculoskeletal system and connective tissue	33	24	40
Z14	Injury and poisoning	76	64	89
Z15	Oncology (per 100000 people)	283	209	343

initial dimensions; therefore, to eliminate the influence of this factor on the comparison of their dynamics, they have been standardized.

Since the amount of data analyzed is quite large and it is difficult to see a general trend in the processes with pronounced peaks in variations, low-frequency Hamming filtering of the initial data was used (Hamming, 1980).

Again, under the assumption about the existence of common factors for the parameters under study, the totality of the variables was analyzed using the method of principal components. The relationships between the variables in the method of principal components are studied via distinguishing common factors. The main aim of distinguishing primary factors is to determine the minimal number of common factors which satisfactorily reproduce correlations between the variables analyzed. Hence, the minimal number of the common factors can be found from determining the instant when deviations between the calculated and observed correlations can be assigned to sample randomness (distinguishing only the several first components). The problem is not only to find a correlation between the variables from eigenvalues of near-unit matrices, but also to interpret the maximal part of the observation variances. The number of factors distinguished is usually determined by the number of eigenvalues higher or approximately equal to unity (*Faktorny*…, 1989).

The first step in the method of principal components is to determine the minimal number of factors that adequately reproduce the correlations observed and the communality of each variable. The next step is to search for easily interpreted factors with the rotation procedure. The number of factors and the communality of the variables are fixed. There are three approaches to the rotation procedure: (1) graphical, (2) related to analytical methods, and (3) by means of the specification of a priory target matrix.

In this work we use the second approach, where rotation is controlled by a certain selected objective criterion. Two rotation types are distinguished, i.e., orthogonal and oblique. We use orthogonal rotation and the varimax normalized rotation criterion. Normalized factor loadings are usually used to eliminate the undesirable effect of variables with high communality on the rotation results.

STUDY RESULTS AND DISCUSSION

A database was composed of the heliogeophysical parameters under study (XX, XM, XS, ApX, ApM, ApS, SX, SM, SS, FX, FM, and FS) and morbidity (Z1–Z3, Z5–Z12, Z14–Z15 classes) and mortality (S1–S3, S8–S12, S14, and S17–S20 classes) indices, agreed in time, for the detail analysis of cause-effect relations.

To estimate the range of variability of all the variables analyzed for the period selected, their average, maximal, and minimal values have been calculated. Tables 1–3 show the values of the parameters under study for 1990–2008.

Table 3. Annual values of components of epidemiology database (deceased per 100000 people) for 1990–2008

Component index	Component	Persons		
		average	minimum	maximum
SUM S	Sum of dead persons per period	1141	859	1257
S1	Mortality from infections and infestations	22	15	27
S2	Mortality from neoplasms	191	165	214
S3	Endocrine, nutritional, metabolic, and dysimmunity mortality	9	7	13
S8	Circulatory mortality	493	388	537
S9	Hypertension mortality	11	6	21
S10	Mortality from acute myocardial infarction	42	17	72
S11	Respiratory mortality	50	34	62
S12	Digestive mortality	48	26	61
S14	Genitourinary mortality	9	7	10
S17	Mortality from congenital abnormalities	4	2	6
S18	Mortality from conditions originating in the perinatal periodt	9	7	10
S19	Mortality due to ill-defined symptoms and status	119	47	187
S20	Mortality from accidents, poisoning, and injuries	158	117	191

Table 4. Contingency of morbidity indices and heliogeophysical parameters

Heliogeo-physical parameter	Morbidity class												
	Z1	Z2	Z3	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z14	Z15
XM	–0.15	–0.02	–0.32	–0.30	–0.44	**0.50**	0.14	**–0.55**	–0.13	–0.15	0.06	–0.28	–0.38
XS	–0.16	0.10	–0.20	–0.09	–0.24	0.10	–0.01	–0.22	0.10	–0.16	–0.03	–0.23	–0.06
XX	–0.16	0.07	–0.20	–0.13	–0.24	0.10	0.03	–0.22	0.08	–0.19	–0.04	–0.23	–0.09
ApM	–0.17	–0.27	**–0.49**	–0.22	**–0.50**	0.34	0.45	**–0.51**	–0.35	–0.24	0.28	–0.02	–0.43
ApS	–0.19	–0.12	–0.41	–0.13	–0.39	0.17	0.31	–0.38	–0.28	–0.20	0.17	–0.12	–0.30
ApX	–0.04	0.08	–0.24	0.00	–0.24	0.16	0.17	–0.25	–0.11	–0.06	0.14	–0.09	–0.17
SM	0.01	0.08	–0.19	–0.20	–0.36	**0.69**	0.07	**–0.53**	–0.05	0.00	0.12	–0.15	–0.36
SS	0.05	0.05	–0.20	–0.17	–0.35	**0.70**	0.14	**–0.56**	–0.13	0.04	0.21	–0.10	–0.41
SX	0.00	0.03	–0.22	–0.22	–0.38	**0.70**	0.13	**–0.56**	–0.11	–0.02	0.16	–0.14	–0.41
FM	–0.05	0.04	–0.27	–0.26	–0.43	**0.67**	0.13	**–0.60**	–0.14	–0.04	0.09	–0.24	–0.42
FS	–0.06	0.02	–0.29	–0.24	–0.42	**0.60**	0.20	**–0.61**	–0.18	–0.05	0.12	–0.23	–0.44
FX	–0.09	0.01	–0.32	–0.25	–0.45	**0.61**	0.19	**–0.61**	–0.19	–0.07	0.12	–0.24	–0.44

To find possible correlations between the epidemiological data and variations in heliogeophysical indices, a correlation matrix has been constructed which allows the preliminary comparative estimation of the response of parameters under study and shows the dynamics of the population morbidity and mortality rates versus variations in the heliogeophysical factors (Tables 4, 5). Reliable values are bold in the tables (confidence is no worse than 95%).

A positive correlation exists between the indices XM, XS, XX, ApM, ApS, ApX, SM, SS, SX, FM, FS, and FX and the frequency of diseases of respiratory (Z7) and digestive (Z8) systems. The heliophysical indices also positively correlate with the mortality from endocrine, nutritional, and metabolic diseases and dysimmunity (S3), with mortality from congenital abnormalities (S17) and rate of mortality from conditions originating in the perinatal period (S18).

Heliographical indices negatively correlate with the rates of endocrine, nutritional, and metabolic diseases and dysimmunity (Z3); diseases of the circulatory (Z6) and genitourinary (Z9) systems; and the rates of mortality from infections and infestations (S1), neoplasms (S2), circulatory diseases (S8), acute cardiac infarction (S10), and respiratory (S11) and genitourinary (S14) diseases, as well as injury, poison-

Table 5. Contingency of mortality indices and heliogeophysical parameters

Heliogeophysical parameter	Mortality class												
	S1	S2	S3	S8	S9	S10	S11	S12	S14	S17	S18	S19	S20
XM	**–0.74**	–0.40	0.13	**–0.52**	–0.24	–0.25	**–0.67**	–0.32	**–0.59**	**0.60**	0.32	0.02	**–0.72**
XS	**–0.61**	–0.17	–0.01	–0.21	–0.30	0.02	–0.28	–0.08	**–0.53**	**0.56**	0.25	0.19	–0.44
XX	**–0.56**	–0.17	–0.00	–0.21	–0.26	0.01	–0.27	–0.09	**–0.51**	**0.50**	0.20	0.15	–0.42
ApM	**–0.58**	**–0.61**	**0.52**	–0.38	0.20	**–0.47**	–0.41	–0.43	**–0.60**	0.23	0.55	0.32	–0.33
ApS	**–0.58**	**–0.48**	0.36	–0.39	0.05	–0.31	–0.39	–0.38	**–0.65**	0.29	0.35	0.23	–0.41
ApX	**–0.53**	–0.33	0.17	–0.31	–0.09	–0.19	–0.37	–0.22	**–0.52**	0.36	0.30	0.30	–0.42
SM	**–0.66**	–0.35	0.06	–0.41	–0.25	–0.27	**–0.67**	–0.18	–0.43	**0.58**	0.44	0.14	**–0.65**
SS	**–0.64**	–0.42	0.11	**–0.46**	–0.19	–0.34	**–0.70**	–0.24	–0.45	**0.52**	0.43	0.20	**–0.66**
SX	**–0.66**	–0.40	0.11	**–0.45**	–0.21	–0.32	**–0.69**	–0.23	–0.45	**0.55**	0.44	0.15	**–0.67**
FM	**–0.69**	–0.40	0.10	**–0.53**	–0.24	–0.30	**–0.75**	–0.30	**–0.52**	**0.59**	0.39	0.04	**–0.75**
FS	**–0.68**	–0.44	0.14	**–0.53**	–0.20	–0.33	**–0.74**	–0.33	**–0.52**	**0.54**	0.38	0.10	**–0.71**
FX	**–0.71**	–0.45	0.16	**–0.55**	–0.20	–0.34	**–0.75**	–0.35	**–0.54**	**0.57**	0.42	0.09	**–0.74**

ing, and certain other consequences of external causes (S20). We should note that the correlation matrices were constructed of the initial data without low-frequency filtering. Smoothed values are used for further analysis.

The results show some highly conjugated variations in the variables under study, e.g., solar activity and mortality from congenital abnormalities (S17) or geomagnetic disturbances and mortality from conditions originating in the perinatal period (S18) (Figs. 1–3).

A correlation has been also revealed of the standard deviations and maxima of heliophysical parameters with variations in the health indices.

The biological significance of heliogeomagnetic conditions can be concluded from the correlation-analysis results. However, correlations between the epidemiological indices and external heliogeophysical

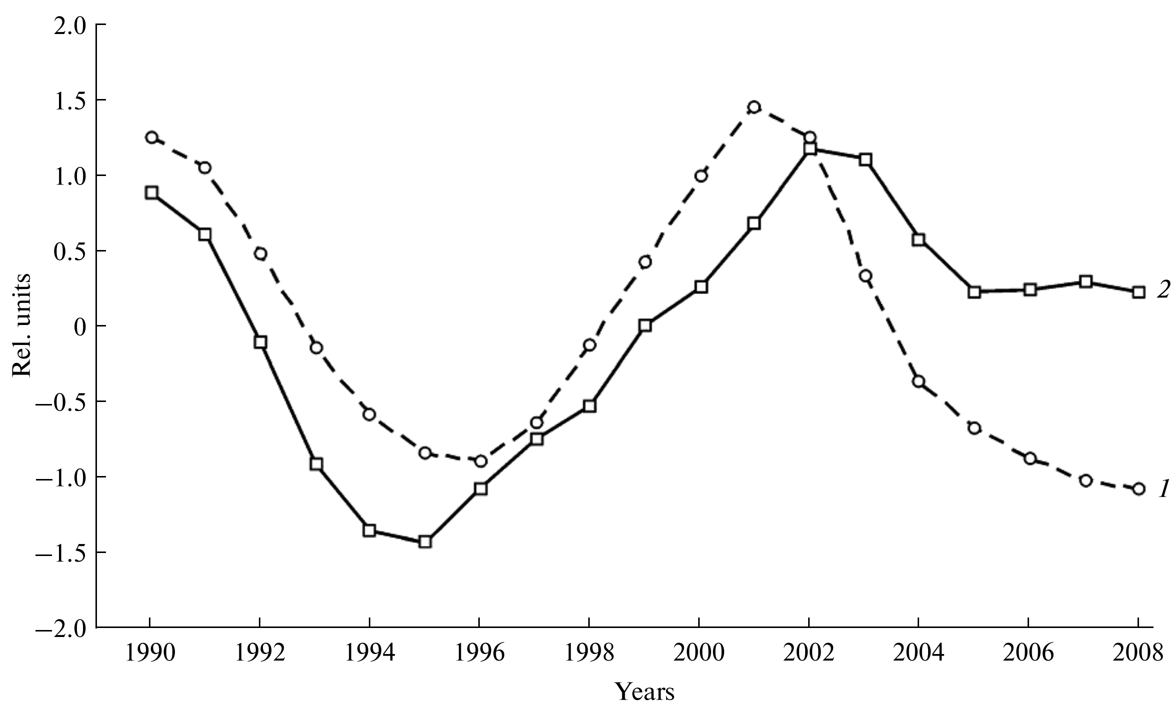

Fig. 1. Dynamics of the average Wolf numbers (*1*) and mortality from congenital abnormalities (*2*) in Tomsk for the period under study.

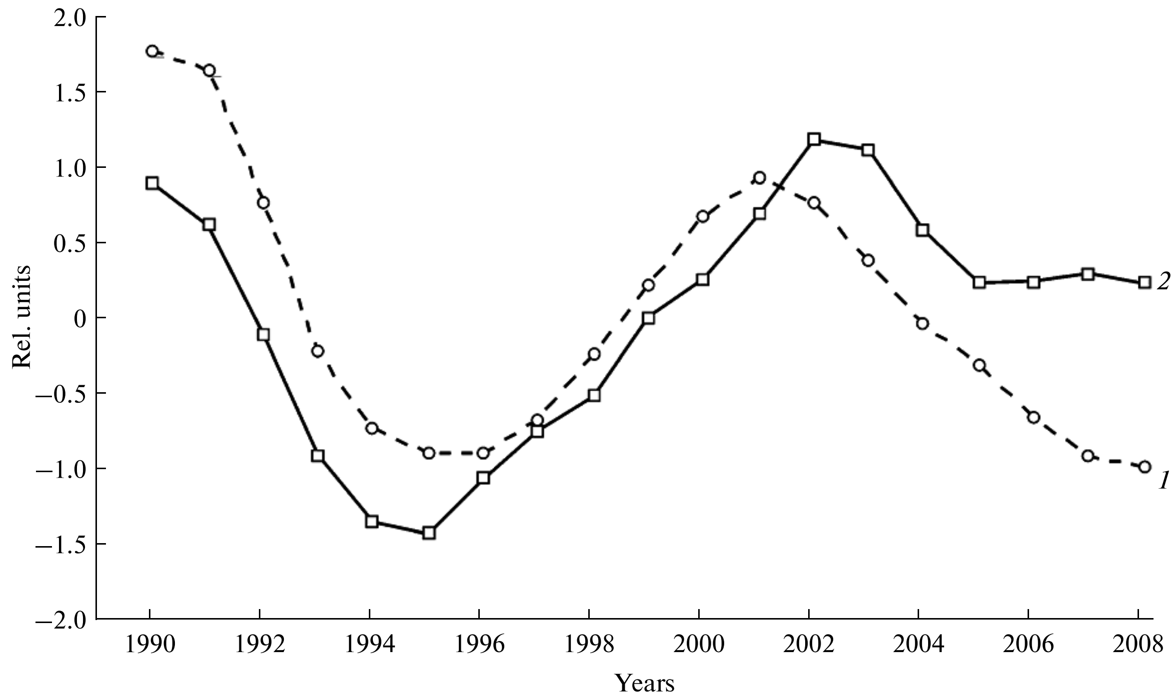

Fig. 2. Dynamics of the average X-ray flux intensity (*1*) and mortality from congenital abnormalities (*2*) in Tomsk for the period under study.

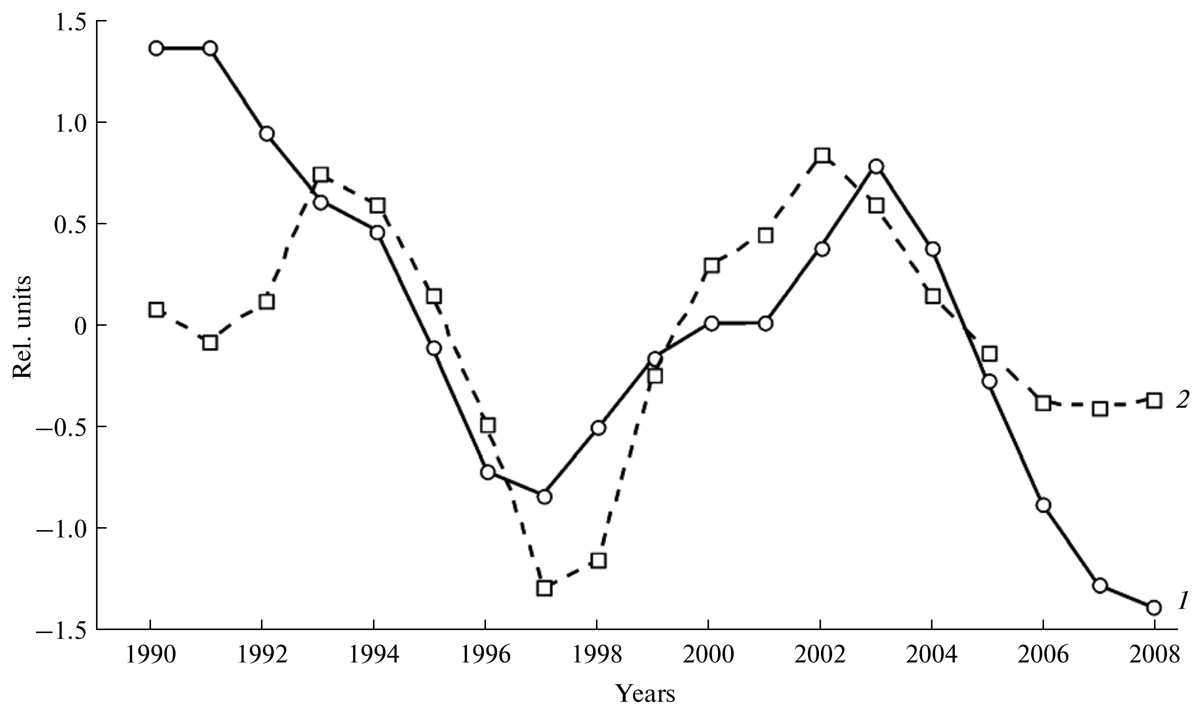

Fig. 3. Dynamics of the average geomagnetic activity index (*1*) and mortality from conditions originating in the perinatal period (*2*) in Tomsk for the period under study.

factors are not always pronounced; i.e., there is an uncertainty of responses of different nosological components (especially for nonsmoothed data), which determines the need for a more detailed analysis of the initial data. The method of principal components is the most appropriate in this case for heliogeophysical

Table 6. Separation of the heliogeophysical parameters by factors

Heliogeophysical parameter	Factor 1	Factor 2	Factor 3
XM	**0.751188**	0.408861	0.489293
XS	0.426124	0.415981	**0.800876**
XX	0.431747	0.384971	**0.811857**
ApM	0.413675	**0.859303**	0.249933
ApS	0.340177	**0.827759**	0.437899
ApX	0.464902	0.688882	0.512274
SM	**0.902610**	0.267525	0.324475
SS	**0.886097**	0.348986	0.284867
SX	**0.889963**	0.320121	0.314265
FM	**0.867003**	0.345070	0.348868
FS	**0.835176**	0.416574	0.339304
FX	**0.813275**	0.450380	0.356550
Eigenvalues	5.937787	3.177844	2.705727
Interpretable percentage of data variance, %	49.4	26.4	22.5

Hereinafter in Tables 7–10, the correlated parameters related to the corresponding factor group are bold.

parameters, morbidity classes, and population mortality. This method allows the number of initial variables to be reduced and a new data set to be produced, which is an additive sum of initial variables.

Three main factors have been revealed from a factorial analysis of heliogeophysical indices (Table 6). Table 6 shows that factor 1 is composed of the variables that characterize the integral solar activity, i.e., the maximal and average values and standard deviations of Wolf numbers (SX, SM, SS), electromagnetic radiation flux in the transparency window (FX, FM, and FS), and the average X-ray flux (XM); factor 2, the average value and standard deviations of Ap-index (index of geomagnetic disturbance) (ApM and ApS); and factor 3, the standard deviations and maximal magnitude of X-rays (XS and XX). According to the results, the percentages of data variances are 49.4, 26.4, and 22.5%, respectively. The accumulated interpretable variance of variations in these components is 98%, which is a quite serious reason to consider the results adequate.

Figure 4 shows the resulted dynamics of the main factors. In the physical point of view, this separation is quite natural, since the integral solar activity characterizes solar nonstationary processes, which are described by parameters such as X-rays, Wolf numbers, and radio flux, while the geomagnetic storminess depends directly on the state of the Earth's magnetosphere. This implies that the dynamic curves of the correlating parameters completely repeat the variations in the corresponding factors. This correspondence is exemplified in Fig. 5.

Morbidity classes have been analyzed in a similar way (Tables 7, 8). Table 7 shows that Z2, Z8, Z10, and Z15 classes compose the group of factor 1; Z1, Z3, Z5, Z6, Z11, Z12, and Z14 classes compose the group of factor 2, and Z7 class compose the group of factor 3. The percentages of the variance are 36.8, 42.5, and 14.9 % for each factor group. The accumulated interpretable variance of variations in the variables under study is 94%.

An analysis of the mortality class dynamics has shown that there are five main factors (see Table 8). The group of factor 1 includes S2, S3, S9, S10, S12, and S17 mortality classes (the data variance percentage is 34.4%); that of factor includes, S8, S11, and S20 (28.3%); factor 3 includes S19 (9.1%); factor 4 includes S1 and S14 (18.4%), and factor 5 includes S18 mortality class (7.8%). The accumulated interpretable variance of variations in the variables under study is 98%.

We assumed that morbidity and mortality are interrelated. Hence, the following procedures were carried out: the epidemiological data were combined, and the method of principal components was applied to the resulting sequence of variables. The results are given in Table 9. It is seen that the group of factor 1 combines such morbidity and mortality classes as Z2, Z8, Z10, Z15, S2, S3, S9, S10, S12, and S17; that of factor 2 combines S19 class; that of factor 3 combines Z7, S8, S11, and S20 classes; factor 4 combines S18 class, and the group of factor 5 combines Z1, Z3, Z5, Z6, Z11, Z12, Z14, S1, and S14 classes.

Fig. 4. Variations in the three main factors of heliogeophysical parameters (see Table 6): factor 1 (*1*), factor 2 (*2*), and factor 3 (*3*).

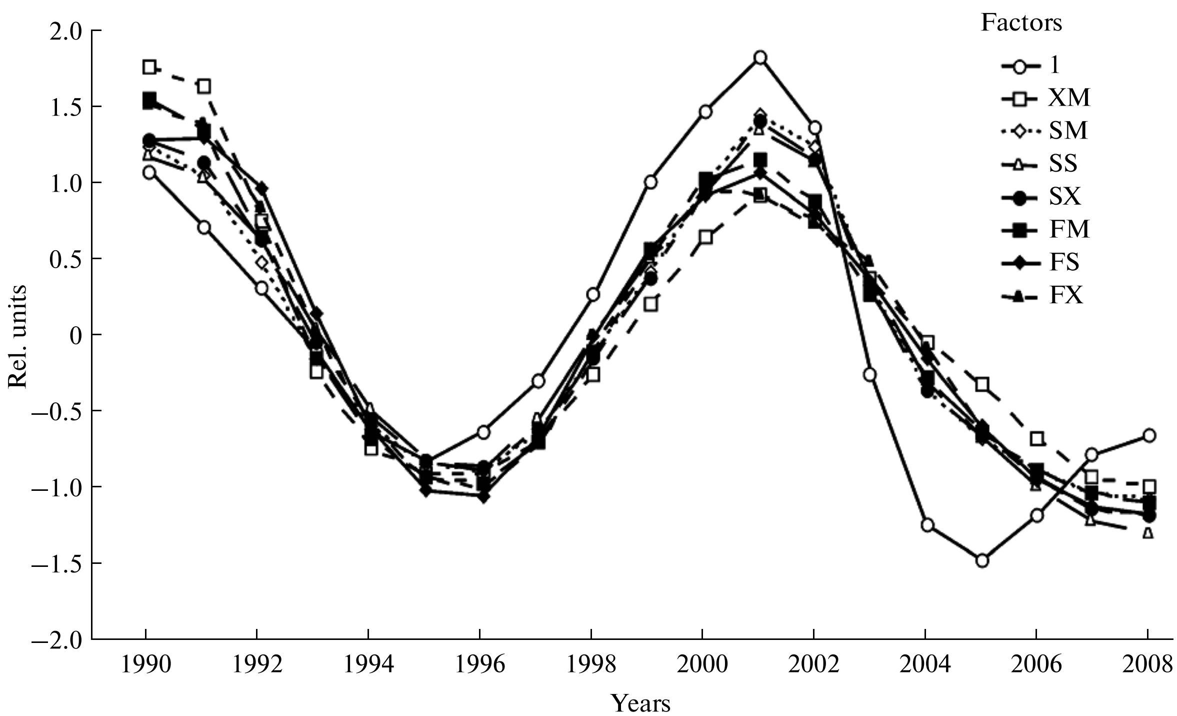

Fig. 5. Dynamics of heliogeophysical parameters related to factor 1.

The variance percentage is 24.4% for the first combined factor, 17.8% for the second factor, 22.3% for the third factor, 14.6% for the fourth factor, and 18.6% for the fifth factor. The accumulated interpretable variance of variations in the variables under study is 97%.

To characterize the contingency of the five factors and heliogeophysical parameters for the variables

Table 7. Separation of the morbidity class dynamics by factors

Morbidity class	Factor 1Z	Factor 2Z	Factor 3Z
Z1	0.147395	**0.950640**	–0.171662
Z2	**0.895387**	0.359937	0.049113
Z3	0.483074	**0.830433**	0.086437
Z5	0.477469	**0.802803**	0.249378
Z6	0.435403	**0.828108**	0.271684
Z7	–0.244085	0.210945	**–0.921257**
Z8	**–0.951662**	–0.149408	–0.166466
Z9	0.562165	0.490332	0.627510
Z10	**0.877522**	0.048840	0.331640
Z11	0.337088	**0.899074**	–0.188156
Z12	–0.628733	**0.709963**	–0.203051
Z14	–0.354750	**0.899685**	0.076810
Z15	**0.791270**	0.212897	0.557330
Eigenvalues	4.786558	5.529917	1.948680
Interpretable percentage of data variance, %	36.8	42.5	14.9

Table 8. Separation of the mortality class dynamics by factors

Mortality class	Factor 1S	Factor 2S	Factor 3S	Factor 4S	Factor 5S
S1	–0.146031	0.450613	–0.064101	**0.824059**	–0.218721
S2	**0.802470**	0.515752	–0.136455	0.253716	–0.035020
S3	**–0.938247**	–0.057622	–0.049817	–0.250011	0.198468
S8	0.397702	**0.844115**	0.182248	0.220368	0.212061
S9	**–0.955519**	0.155320	0.014434	0.221923	0.043484
S10	**0.861264**	0.479270	–0.110324	–0.056029	–0.075357
S11	0.164109	**0.955793**	0.141160	0.129297	–0.051043
S12	**0.701640**	0.571076	0.229042	0.274326	0.160555
S14	0.227290	0.159760	0.135788	**0.915696**	–0.075371
S17	**0.702011**	–0.265806	0.020677	–0.589605	0.281919
S18	–0.169043	0.198374	0.347470	–0.323681	**0.836166**
S19	–0.028836	0.198514	**0.951199**	0.072312	0.218465
S20	–0.147521	**0.912604**	0.074857	0.312551	0.128944
Eigenvalues	4.473430	3.686176	1.193174	2.392695	1.018063
Interpretable percentage of data variance, %	34.4	28.3	9.1	18.4	7.8

under study, a correlation matrix has been constructed which allows us to estimate the response of the variables, i.e., the common factors for morbidity classes, the population mortality rate, and three distinguished factors for heliogeophysical parameters (Table 10). The use of Pearson correlations is reasonable in this case, since all factors are orthogonal.

Table 10 shows that the integral solar activity positive correlates with factors 3 and 4 for the morbidity and mortality classes ($r = 0.84$ and 0.47, respectively). X-ray variations positively correlate with factor 1 for the morbidity and mortality classes ($r = 0.46$); the geomagnetic activity, in contrast, negatively correlates with this factor ($r = -0.64$), as well as with factor 1 for

Table 9. Separation of the dynamics of main morbidity and mortality classes by factors

Factors for morbidity and mortality classes	Factor 1ZS	Factor 2ZS	Factor 3ZS	Factor 4ZS	Factor 5ZS
Factor 1Z	**0.984886**	–0.048738	–0.062311	0.089883	0.057554
Factor 2Z	0.012755	0.648490	0.074137	–0.264508	**0.700656**
Factor 3Z	0.001913	0.093051	**–0.911345**	–0.311304	–0.090659
Factor 1S	**0.991604**	0.024748	0.016158	–0.045632	–0.027897
Factor 2S	0.042372	–0.049503	**–0.968663**	0.116982	0.027370
Factor 3S	–0.023666	**0.995912**	–0.047839	0.030638	0.012310
Factor 4S	0.020320	–0.016485	0.017474	0.034779	**0.993477**
Factor 5S	0.034641	–0.022088	0.100701	**0.988157**	–0.042598
Eigenvalues	1.957413	1.427236	1.791233	1.169322	1.492941
Interpretable percentage of data variance, %	24.4	17.8	22.3	14.6	18.6

Table 10. Contingency between the distinguished factors for morbidity and mortality classes and heliogeophysical parameters

Factors for heliogeophysical parameters	Factor 1ZS	Factor 2ZS	Factor 3ZS	Factor 4ZS	Factor 5ZS
Factor 1	0.15	0.08	**0.84**	**0.47**	0.05
Factor 2	**–0.64**	0.34	0.11	0.10	–0.45
Factor 3	**0.46**	0.15	0.03	–0.18	**–0.78**

the morbidity and mortality classes ($r = -0.78$). The Earth's atmosphere almost completely absorbs the short-wavelength spectral region of the solar electromagnetic radiation; hence, X-rays do not reach the Earth's surface and cannot affect human organisms. The effects revealed can be explained by the presence of intermediaries between solar X-rays and living organisms, e.g., near-Earth cavities, which are capa-

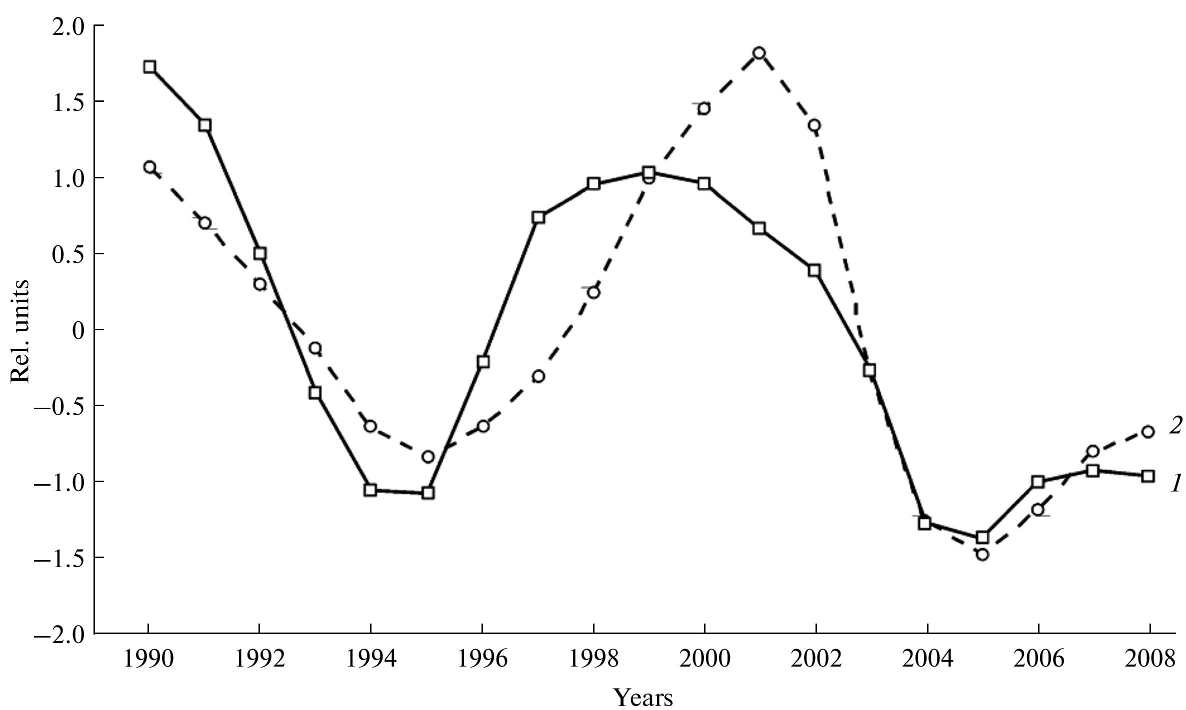

Fig. 6. Dynamics of factor 1 (*1*) and 3ZS (*2*) for the period under study.

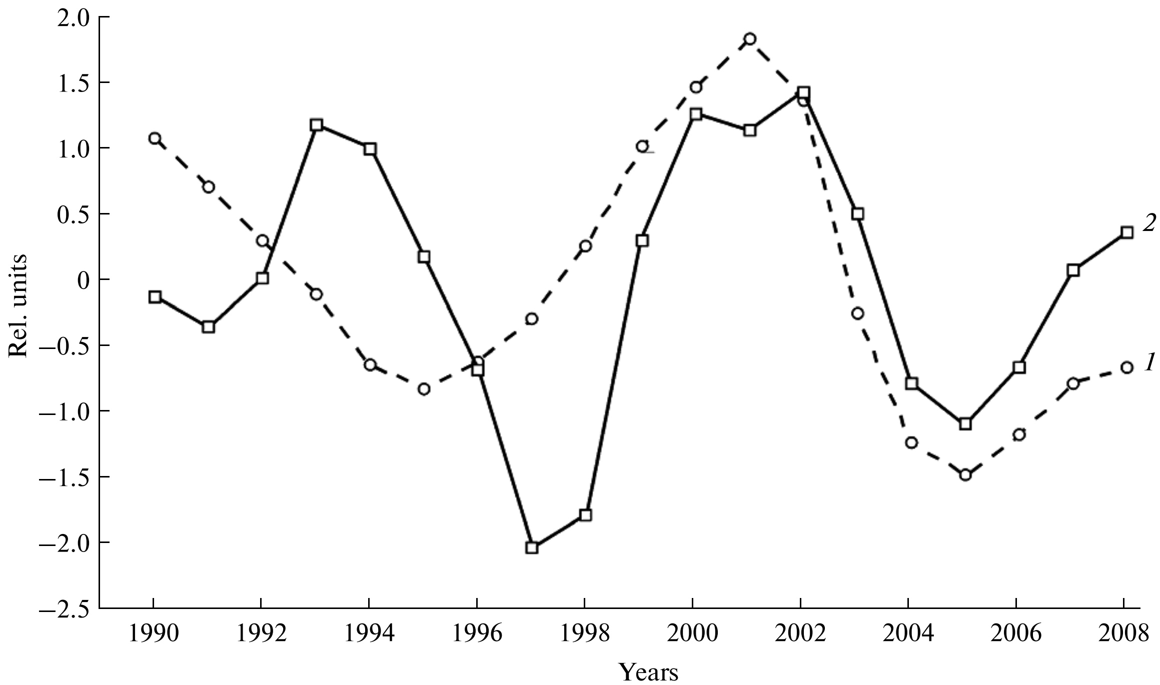

Fig. 7. Dynamics of factor 1 (*1*) and 4ZS (*2*) for the period under study.

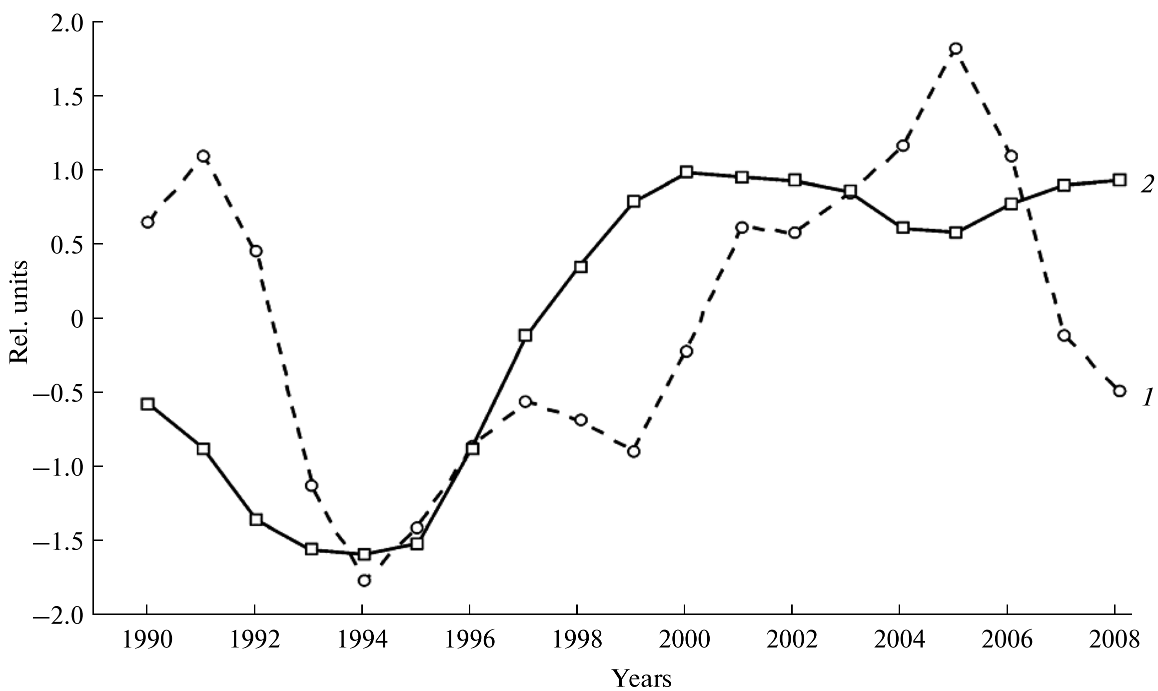

Fig. 8. Dynamics of factor 3 (*1*) and 1ZS (*2*) for the period under study.

ble of responding to sharp variations in solar short-wavelength radiation. The resulting correlations are shown in Figs. 6–10 (negative correlations in Figs. 9 and 10).

The relationships between variations in heliogeophysical parameters and human health factors can be stated. Correlations of the standard deviation and maximum of X-rays (factor 3) with human body reactions (factors 1ZS and 5ZS) are of interest.

As was mentioned above, X-rays do not reach the Earth's surface and cannot affect human organisms. The effects observed can be explained by their indirect

Fig. 9. Dynamics of factor 2 (*1*) and 1ZS (*2*) for the period under study.

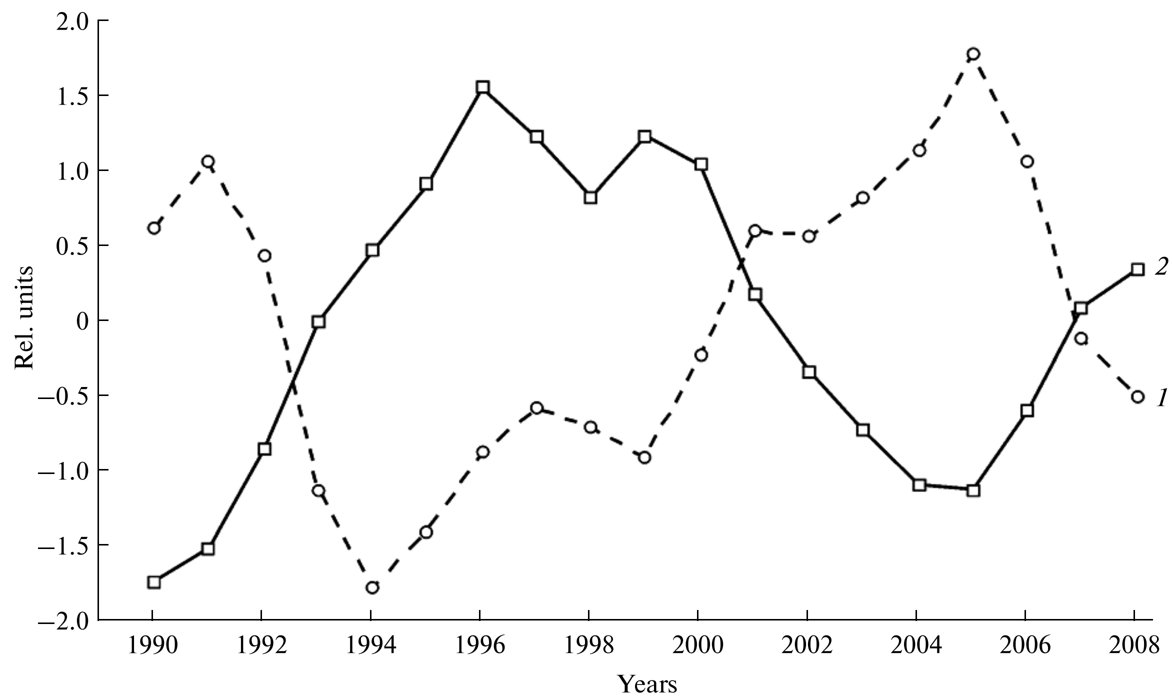

Fig. 10. Dynamics of factor 3 (*1*) and 5ZS (*2*) for the period under study.

action, in particular, via a near-Earth Schumann cavity. Thus, a scientific team revealed changes in the Schumann resonance parameters (i.e., an increase in the frequencies of the first three modes) during a solar X-ray flare (March 24, 2000) (Satori et al., 2005). Another scientific team considered more than 2000 flares of different classes (S, M, and X) that occurred from March 1997 to 2005. The analysis of responses of the frequency and amplitude of the first three modes of a Schumann cavity monitored in this period at Tomsk

Ionospheric Station has shown that the probability of manifestation of solar events, including bursts of X-rays and UV radiation, in Schumann resonance parameters reaches 70% (Bashkuev et al., 2008).

On the other hand, there are compelling evidences that variations in Schumann resonance parameters can significantly affect the health of both healthy and sick humans. These effects are stronger for peoples with cardiovascular diseases (Bardak et al., 2003; 2004). Monitoring brain wave patterns has shown that brain activity is modified by the electromagnetic field of a Schumann cavity (Pobachenko et al., 2006). The regularities revealed agree well with ideas about the resonance nature of solar–biosphere links (Kolesnik et al., 2003). In addition, our results show a periodicity of the relationships during an 11-year solar cycle, which is confirmed by available literature data (Vladimirsky et al., 2004).

CONCLUSIONS

The analysis of the effects of heliogeophysical parameters on morbidity and mortality indices for Tomsk have allowed distinguishing common factors which reliably correlate with variations in solar activity and geomagnetic disturbance indices:

(1) a factor that include respiration diseases and respiration, circulatory, and accident mortality, as well as a factor related to conditions occurring in the perinatal period, correlate with the integral solar activity ($r = 0.84$ and 0.47, respectively);

(2) a factor that includes neoplasms, pregnancy and childbirth implications, diseases of the digestive organs, mortality from neoplasms, congenital anomalies, diseases of the digestive organs, the endocrine system, hypertension, and acute myocardial infarction correlates with geomagnetic disturbances ($r = -0.64$);

(3) a factor that includes infections, diseases of endocrine and nervous systems, skin and musculoskeletal system, circulatory system, injury and poisoning, and infection and genitourinary mortality correlates with variations in X-rays ($r = -0.78$).

We should note that the sign of a correlation for a selected factor does not mean the direction of corresponding variations. In this case, the use of the determination coefficient due to nonlinearity of a relationship and the rotation character when distinguishing principal components is more correct.

The main result of this study is a confirmation of the fact of indirect impact of solar X-rays on human health, probably via the modification of parameters of a near-Earth Schumann cavity.

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