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NATURAL WARMING OF THE EARTH'S CLIMATE IN 18th THROUGH 20th CENTURIES

IDENTIFICATION OF THE ASTRONOMICAL CAUSES OF CLIMATE CHANGES

The purpose of the study reported here is identification of the new evidence justifying the proposition of the natural astronomical causes for the cooling and warming of the earth's climate in the recent centuries. The modern, as well as Holocene coolings and warmings of climate (Boryczka, Wicik, 1994) — the increasingly warmer winters in Europe — are primarily the effect of the variability in the solar activity and of the volcanic eruptions, depending upon the parameters of the solar system. They are most probably conditioned by the gravitational influence of the four greatest planets (giants): Jupiter, Saturn, Uranus and Neptune, on the Sun and the Earth.

It is not sufficient to apply in the identification of the reasons of climate changes the method used until now, that is, the statistical method of "multiple regression and correlation analysis". The coefficients of regression $a_1,...,a_k$ appearing in the equation of the hyperplane of regression

$$y = a_0 + a_1x_1 + ...+ a_kx_k$$

may only play an auxiliary role in the elimination of the statistically insignificant hypothetical causes x_j from among the set $\{x_1,...x_k\}$. The tests used in verification of the coefficients a_j (null hypotheses: in the population a_j) do not resolve the question as to which of the variables x_j condition (influence the shape of) the climate y in the physical sense (and not in the correlational one). It is simply so that the correlation between two chronological sequences: y_i (effect) and x_{ji} (supposed cause) may be incidental. It is not difficult to form two fictitious sequences of numbers (increasing or decreasing) which are strongly correlated with each other.

The proper identification of the causes of climate changes can be done through the analogy to the demonstrations concerning rotation of the Earth around its axis and around the Sun, with the respective cycles of 24 hours and 365.2423 days. These demonstrations are provided by the cycles: for the diurnal rotation — of the azimuth of the Foucault's pendulum (at the pole) and for the annual rotation — of the location of closer stars with respect to the farther ones (annual parallax). Thus, for instance, by measuring the frequency of the waves propagated we can conclude on the emission of a generator. Similarly, on the basis of the spectrum emitted by a body (say, a star) we determine its chemical composition.

We will define the principles of identification of the causes for the natural fluctuation of the earth's climate, which should be approximately fulfilled:

Principle 1. The dense spectra of oscillations (true periods) of the causes (astronomical variables) and of the effects (climatological variables) are the same.

Principle 2. The cycles of variability of the causes and the effects are synchronous (agreement of phases, coincidence of extrema).

Principle 3. The amplitudes of fluctuations of causes and effects in the cycles are positively correlated (the bigger fluctuations of causes entail bigger changes in the effects).

Identification of the causes of natural climate changes can only be properly carried out with the "dense spectra of oscillations", determined with the method of J. Boryczka of the "true cycles". A dense spectrum of oscillations is the sequence of amplitudes $b_1,...,b_N$ of the regression sinusoids

$$y = a_0 + b \ \sin(\frac{2\pi}{\Theta} t + c)$$

having discrete periods $\Theta_1,...,\Theta_N$, varying with the step size $\Delta\Theta = 0.1$ of a year or $\Delta\Theta = 1/12 = 0.083$ of a year.

They are fitted (in terms of the least squares) to the chronological sequence of measurements $y_1,...,y_n$ taken in arbitrary instants of time $t_1,...,t_n$. The true cycles Θ_r having amplitudes b_r and phase delays c_r are the local maxima of the spectrum of oscillations $b_1,...,b_N$ ($N \geq n$, where n is the number of measurements). It is only with the method of "true cycles" that the dense spectrum of oscillations of periodical phenomena, appearing irregularly, can be identified (like that of volcanic eruptions).

The methods applied until now: harmonic analysis (Fourier series) and spectral analysis (together with the autocorrelation method of Fuhrich) are inadequate for identification of the climate change causes. The consecutive harmonic components (elements of the Fourier series), resulting from the breakdown of the chronological sequence of the length n into the parts n, $n/2$, $n/3$,... , constitute too sparse a spectrum of oscillations, and the fictitious periods n, $n/2$, $n/3$,... may be very far from the true ones (the true cycles Θ). With the autocorrelation method we can, on the other hand, identify only a part of the spectrum in the high frequency (short periods) domain. When the period of the length of k years is determined we neglect (do not make use of) the results of measurements from n-k years. When, for instance, $k = 30$ years, the data collected with a great effort during 30 years are neglected. There are no phase delays (of the dates of cycle extrema) which makes it impossible to identify the causes of the climate fluctuations. Besides this, the time interval between the elements of the chronological sequence must be constant, and the data — without any missing values. Such methods fail completely in the studies of periodicity of, for instance, volcanic eruptions and the holocene cycles of climate (on the basis of accumulation of the lake deposits).

The solar system is characterized by the definition of some parameters:
1. acceleration of the sun, $[s''] = \text{km}\cdot\text{day}^{-1}$

$$s'' = \frac{d^2 s}{dt^2}, \qquad \mathbf{s} = M^{-1}\sum m_i \mathbf{r}_i, \qquad s = |\mathbf{s}|$$

2. tidal force on the Sun, $[\Delta G] = 10^{-6} m_3 \cdot AU \cdot year^{-2}$

$$\Delta G = k \sum m_i \left[(r_i - R_0)^{-2} - r_i^{-2}\right] |\cos \Gamma_i|$$

3. momentum of the nine planets, $[J] = m_3 \cdot AU^2 \cdot month^{-1}$

$$\mathbf{J} = \sum m_i \left(\mathbf{r}_i \times \frac{d\mathbf{r}_i}{dt}\right), \qquad |\mathbf{J}| = J$$

4. inertia moments of the planets, $[B] = [B_z] = R_0^2$

$$B = M^{-1} \sum m_i (\mathbf{r}_i - \mathbf{s})^2, \quad B_z = 10^{-3} M^{-1} \sum m_i z_i^2$$

5. tidal force on the Earth, $[F] = 10^{-8} m_3 \cdot AU \cdot year^{-2}$

$$F = k \sum m_i \left[(\rho_i - \rho_0)^{-2} - \rho_i^{-2}\right] |\cos \gamma_i|$$

where: k — gravitation constant; Γ_i, γ_i — angles between the vector radii $\mathbf{r}_i$, $\mathbf{s}$ and ρ_i, $\mathbf{r}_3$; $\mathbf{r}_i$, ρ_i, $\mathbf{r}_3$ — vector radii of the i-th planet (the heliocentric and the geocentric one) and of the Earth ($i = 3$); m_i, $\frac{d\mathbf{r}_i}{dt}$ — the mass and the velocity of the i-th planet; M, m_3 — the masses of the solar system and of the earth; R_0, r_0 — radii of the Sun and the Earth; AU — astronomical unit.

Heliocentric ecliptical coordinates of the nine planets were calculcated from the empirical formulae, describing the secular variability of the parameters of planets (polynomials with respect to time, expressed in hundreds of Julian years, see Reznikov, 1982).

THE INFLUENCE OF THE PARAMETERS OF THE SOLAR SYSTEM ON SOLAR ACTIVITY AND VOLCANIC ERUPTIONS — ON THE EARTH'S CLIMATE

The evidence for the natural causes of the warming of the Earth's climate during the last two centuries is constituted by the similarity of the dense spectra of oscillations (similar cyclicity) of such climatological variables as:

air temperature — in Warsaw (1779-1990), Cracow (1826-1985), Prague (1771-1980), Geneva (1768-1980) and Middle England (1659- 1973),

precipitation — in Warsaw (1813-1980), Cracow (1850-1980) and Colombo (1869-1980),

river runoff — Göta Alv (1807-1979),

the level of the Baltic Sea (1811-1990),

atmospheric circulation (eastern, western and meridional (according to Vangenheim's classification, 1891-1976), cyclonal (1901-1975) and zonal (1899-1979) — according to classification of Osuchowska-Klein),

the following geological variables:

volcanic eruptions (1680-1980) — the DVI (dust veil index) indicator of H. Lamb, 1970, the time interval between two consecutive eruptions Δt, the volcanic activity indicator $I = {}^{DVI}/_{\Delta t}$, and the parameters of the solar system (1700-2000):

distance between the centres of mass of the solar system and the Sun; acceleration of the Sun with respect to the centre of mass of the solar system, s''; tidal force ΔG on the Sun, caused by the gravitational pull of the planets; momentum of the planets, J; inertia moment B, B_z (of mass dispersion) with respect to the centre of the mass of the solar system and the ecliptic plane; tidal force F caused by planets (Tables 1-3, Figs. 1-3).

Extremely high cognitive importance should be attached to the presence of a dozen or so cycles of the climatological variables in the dense spectra of oscillations of the parameters of the solar system. In all the spectra of oscillations the periods of rotation around the Sun of the four greatest planets (giants) dominate, i.e.: of Jupiter (11.862 years), Saturn (29.458 years), Uranus (84.015 years) and Neptune (164.70 years), together with the periods of their mutual identical positions:

Planets	Jupiter	Saturn	Uranus	Neptune
Jupiter	11.862			
Saturn	19.858	29.458		
Uranus	13.812	45.364	84.015	
Neptune	12.782	35.870	171.400	164.70

The fluctuations of air temperature in these cycles in Warsaw are quite significant:

Period Θ	12.1	12.8	14.0	17.7	29.8	34.7	42.2	103.8	220.7 years
Amplitude $2b$	0.18	0.41	0.88	0.38	0.12	0.09	0.24	0.23	1.11 °C

Table 1

The true cycles of: parameters of the solar system (acceleration of the Sun s'', tidal force on the sun ΔG, momentum J, inertia moment B — dispersion of the mass of the solar system with respect to its center) in the years 1700-2000, volcanic eruptions (in terms of DVI, I, Δt) in the years 1680-1980, solar activity (1700-1993), air temperature in: Warsaw (1779-1990), Geneva (1768-1980), as well as the level of the Baltic Sea in Świnoujście (1811-1990, Wiśniewski B. 1978, Kożuchowski K. and Boryczka J. 1996)

Solar system (1700-2000)				Volcanic eruption (1680-1980)			Solar activity	Air temperature Warsaw Geneva		Sea level
s''	ΔG	J	B	lgDVI	lg$I$	Δt	W	T	T	h
3.5	3.5	.	.	2.6	3.3	3.1	.	3.42	3.42	3.1
3.9	4.2	.	.	4.0	4.0	3.7	.	4.17	3.92	3.5
4.8	.	.	.	.	.	.	.	4.75	4.75	4.5
5.0	.	.	.	5.3	5.0	5.1	5.5	5.17	.	5.5
5.6	.	.	.	.	.	.	.	5.50	5.5	5.8
6.4	5.9	.	.	.	6.0	5.9	5.7	5.67	6.00	6.3
6.6	6.6	.	.	.	6.8	.	.	6.42	6.67	6.9
7.5	7.4	.	.	.	7.4	7.3	7.5	7.42	7.42	7.2
7.8	.	.	.	7.9	8.0	.	8.1	7.75	7.83	7.6
8.2	.	.	.	8.6	8.4	8.1	8.4	8.33	8.42	8.6
.	9.4	.	.	.	.	9.7	9.5	9.17	9.25	9.1
9.9	10.0	10.4	10.4	10.5	10.0	.	10.0	.	.	9.7
.	.	10.8	10.8	.	.	10.5	10.5	.	10.33	.
.	11.2	11.2	11.2	11.4	11.2	11.1	11.5	11.17	11.08	11.1
12.0	11.8	11.9	11.9	.	11.7	12.1	12.0	12.8	11.92	12.0
12.8	12.9	12.6	12.6	13.3	12.7	13.0	12.7	12.83	12.83	13.2
13.9	13.9	13.7	.	.	.	14.4	14.4	14.00	14.00	
.	.	.	.	.	15.2	15.5	15.7	15.17	15.25	15.0
.	.	.	.	16.4	.	.	.	.	.	.
18.2	17.6	.	.	.	.	.	17.0	17.67	17.33	18.2
19.9	19.9	.	.	19.8	.	.	.	.	.	20.7
21.8	21.8	.	.	21.6	21.2	.	21.5	21.25	.	.
.	23.2	23.8	23.9	.	.	23.8	24.0	23.67	21.83	23.7
.	25.3	25.9	25.8	25.8	.	.	.	.	25.75	26.8
.	30.3	29.5	29.5	30.4	28.4	27.6	28.9	29.75	31.00	32.8
.	35.6	38.4	38.6	38.6	40.8	42.8	37.1	34.67	40.50	39.4
.	45.1	44.3	44.2	.	.	.	43.2	42.17	.	.
.	58.2	51.8	51.4	52.2	57.0	56.0	52.7	.	.	.
.	.	61.8	61.1	.	.	.	.	.	.	60.1
.	74.9	.	.	65.9	64.3	76.3	.	68.92	76.00	.
.	91.4	84.5	84.1	91.8	90.5	118.6	101.6	103.75	.	101.9
.	170.1	170.1	175.7	223.8	221.5	202.5	192.1	220.75	166.25	184.5

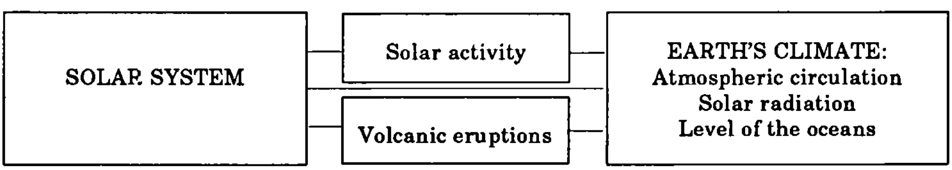
In the dense spectra of oscillations of the parameters of the solar system (the physical magnitudes) we do observe, besides the ten so called planetary cycles (related to configurations of planets) also some other ones as well (Table 1). There are also three other interesting air temperature cycles in Warsaw: 4.2, 7.8, 11.2 years, whose amplitudes are, respectively, 0.44, 0.62 and 0.25°C. Similar cyclicity appears in the oscillations of the parameters of the solar system and volcanic eruptions. The four-year cycle of air temperature is perhaps connected with the strongest, four-year cycle of the tidal force on the Earth, *F*, caused by the gravitational pull of the planets (much weaker than that of the moon and of the Sun).

It is now understandable why some cycles, like those of 12, 13 or 14 years of periodicity, appear in the spectra of oscillations of the air temperature, and have bigger amplitudes than the 11-year cycle. They are probably the effect of the rotation of Jupiter (11.86 years) and its position with respect to Neptune (12.78 years) as well as Uranus (13.91 years) which do also appear in the spectra of oscillations of the solar system.

Likewise, the discrepancy of the lengths of the Brückner cycle of precipitation, resulting from two similar planetary cycles, becomes inderstandable, these cycles being: of 29.458 years (the period of rotation of Saturn around the sun) and 35.87 years (the period of repetitions of mutual position of Saturn and Neptune).

The domination of the planetary cycles and of other cycles of the parameters of the solar system in the dense spectra of solar activity, volcanic eruptions and climatological variables imply the proposition here forwarded of the astronomical causes for the modern coolings and warmings of the Earth's climate (Tables 2 and 3).

According to Principle 1 of identification of the astronomic causes for the changes in the earth's climate: "dense spectra of oscillations of causes and effects are the same", it is possible to conclude of three kinds of gravitational influence of the planets on the earth's climate:



The results of the analysis are quite trustworthy: almost all of the true cycles are statistically significant at the confidence level of 90%. They were determined on the basis of long chronological series, primarily the consecutive 12 month values (the number of elements thus being n years 12 months — 11, in accordance with the Fisher-Snedecor test of $n_1 = 2$, and $n_2 = n$-3 degrees of freedom).

Table 2

The real cycles of: he parameters of the solar system in the years 1700-2000 (s'', ΔG, J, B, s), volcanic eruptions in the years 1680-1980 (lgDVI, lg$I$, Δt) and air temperatures in Warsaw (1779-1990), Cracow (1826-1985), Prague (1771-1980), Geneva (1768-1980) and Middle England (1659-1973) — with respect to planetary periods

Planetary cycles	Parameters of Solar System 1700-2000									
	s''		ΔG		J		B		s	
	Θ	R	Θ	R	Θ	R	Θ	R	Θ	R
11.86	12.0	0.16	11.8	0.40	11.9	0.75	11.9	0.58	12.0	0.16
12.78	12.8	0.36	12.9	0.27	12.6	0.16	12.6	0.12	12.7	0.44
13.81	13.9	0.20	13.9	0.19	13.7	0.07	13.7	0.05	13.9	0.26
19.86	19.9	0.36	19.9	0.42	23.8	0.07	19.4	0.03	19.9	0.82
29.46	.	.	30.3	0.14	29.5	0.61	29.5	0.70	28.3	0.08
35.87	.	.	35.4	0.41	34.2	0.14	34.2	0.17	36.2	0.16
45.36	.	.	45.1	0.31	44.3	0.07	44.2	0.09	48.5	0.09
84.02	.	.	91.4	0.04	84.5	0.24	84.1	0.36	101.3	0.06
164.70	.	.	.	.	.	.	.	.	163.7	0.09
171.40	.	.	170.1	0.19	170.1	0.16	175.7	0.27	.	.
Years	Volcanic eruptions						Solar activity			
	1680-1980						1700-1993		1749-1993	
	lgDVI		lg$I$		Δt		W		W	
11.86	11.4	0.31	11.7	0.29	12.1	0.21	12.0	0.28	11.9	0.26
12.78	13.3	0.28	12.7	0.26	13.0	0.23	12.7	0.14	12.8	0.13
13.81	13.9	0.18	15.2	0.29	14.4	0.28	14.4	0.08	14.4	0.13
19.86	19.8	0.25	21.2	0.32	19.6	0.23	21.5	0.07	21.0	0.10
29.46	30.4	0.19	28.4	0.28	27.6	0.25	28.9	0.12	29.7	0.12
35.87	38.6	0.22	40.8	0.24	36.6	0.23	37.1	0.12	34.9	0.08
45.36	52.2	0.17	57.0	0.33	42.8	0.23	43.2	0.13	41.4	0.15
84.02	91.8	0.34	90.5	0.25	118.6	0.22	101.6	0.30	99.2	0.28
164.70	.	.	.	.	.	.	.	.	.	.
171.40	223.8	0.23	221.5	0.35	202.5	0.17	192.1	0.22	.	.
Years	Air temperature									
	Warsaw		Cracow		Prague		Geneva		England	
	1779-1990		1826-1985		1771-1980		1768-1980		1659-1973	
11.86	12.1	0.07	11.4	0.16	11.3	0.08	11.9	0.09	11.8	0.09
12.78	12.8	0.16	12.5	0.15	12.9	0.16	12.8	0.17	12.5	0.15
13.81	14.0	0.14	14.3	0.08	14.2	0.20	14.0	0.11	14.1	0.12
19.86	17.7	0.14	16.7	0.19	17.8	0.17	21.8	0.11	17.8	0.12
29.46	29.8	0.03	31.7	0.11	29.4	0.14	31.0	0.22	23.6	0.24
35.87	34.7	0.03	40.1	0.13	35.8	0.15	40.5	0.30	35.1	0.11
45.36	42.2	0.09	54.6	0.17	51.2	0.12	.	.	47.7	0.11
84.02	103.8	0.09	82.8	0.18	80.9	0.17	76.0	0.29	102.8	0.29
164.70	.	.	.	.	160.3	0.39	166.0	0.34	.	.
171.40	220.7	0.43	.	.	.	.	.	.	175.9	0.24

Table 3

The real cycles of: precipitation in Warsaw (1813-1980), Cracow (1850-1980) and Colombo (1869-1980), runoff of Göta Alv river (1807-1979), the level of the Baltic Sea in Świnoujście (1811-1990, Wiśniewski B., 1978) atmospheric circulation: eastern, western and meridional (1891-1976), cyclonal (1901-1975) and zonal (1899-1979) — with respect to planetary periods

Planetary cycles	Precipitations						Runoff		Baltic Sea Level	
	Warsaw		Cracow		Colombo		Göta Alv			
	1813-1980		1850-1980		1869-1980		1807-1979		1811-1990	
	Θ	*R*	Θ	*R*	Θ	*R*	Θ	*R*	Θ	*R*
11.86	11.7	0.16	12.2	0.20	10.8	0.15	11.4	0.20	12.0	0.13
12.78	13.8	0.09	.	.	12.2	0.25	13.8	0.19	13.2	0.09
13.81	16.3	0.21	14.0	0.22	14.1	0.10	14.8	0.18	15.0	0.18
19.86	19.3	0.21	23.1	0.20	16.5	0.18	18.8	0.18	18.2	0.15
29.46	28.0	0.10	29.6	0.33	25.0	0.13	28.5	0.21	26.8	0.16
35.87	39.3	0.10	.	.	37.9	0.41	32.3	0.23	0.10	
45.36	56.4	0.19	.	.	42.0	0.36	43.2	0.21	39.4	0.11
84.02	112.5	0.17	62.3	0.26	109.8	0.32	86.9	0.12	101.9	0.10
164.70	.	.	.	.	.	.	.	.	.	.
171.40	.	.	.	.	.	.	.	.	184.6	0.46
Years	Atmospheric Circulation									
	1981-1976						1901-1975		1899-1979	
	Eastern		Western		Meridional		Cyclonal		Zonal	
11.86	10.3	0.14	9.5	0.21	11.1	0.13	10.3	0.21	10.3	0.20
12.78	12.1	0.13	11.8	0.14	.	.	12.9	0.26	12.3	0.34
13.81	14.0	0.09	14.1	0.18	16.3	0.34	.	.	16.2	0.21
19.86	22.2	0.29	17.2	0.23	22.8	0.35	23.5	0.11	23.8	0.26
29.46	29.8	0.34	30.5	0.36	.	.	.	.	.	.
35.87	.	.	.	.	.	.	.	.	.	.
45.36	48.2	0.43	46.2	0.19	.	.	.	.	.	.
84.02	.	.	.	61.2	0.49	69.3	0.22	75.7	0.38	.

WARM WINTERS IN EUROPE AND THEIR NATURAL REASONS

The measured values of air temperature $T_1,\ldots,T_n$ in the time instants $t_1,\ldots,t_n$ are the sum (resultant) of two components: the natural, T', and the anthropogenic one, ΔT:

$$T = T' + \Delta T$$

The natural component can be separated, since it is a superposition of the true (natural) cycles Θ_j:

$$T' = a_0 + \sum_j b_j \sin\left(\frac{2\pi}{\Theta_j} t + c_j\right)$$

The resultant tendency $\frac{dT}{dt} = A$ is defined by the equation of the regression line

$$T = A_0 + At$$

On the other hand the tendency of the natural variability $\frac{dT'}{dt}$ is defined by the equation of the regression line

$$T' = B_0 + Bt$$

The tendency of anthropogenic variability, $\frac{d}{dt}\Delta T = a$, is then expressed by the difference

$$a = A - B$$

Winters in Warsaw in the years 1779-1990 are increasingly warmer — on the average by 1.03°C/100 years:

$T = -3.747 + 0.0102912t,\ r = 0.26.$

This is the effect of variability of the air temperature in the longest cycle — the one of 218.3 years, and the superposition of the natural cycles: two — 113.1 and 218.3 years, four — 38.3, 66.7, 113.1 and 218.3 years, and ten — 3.5, 5.5, 8.3, 12.9, 15.2, 18.0, 36.3, 66.7, 113.1 and 218.3 years (see Fig. 4):

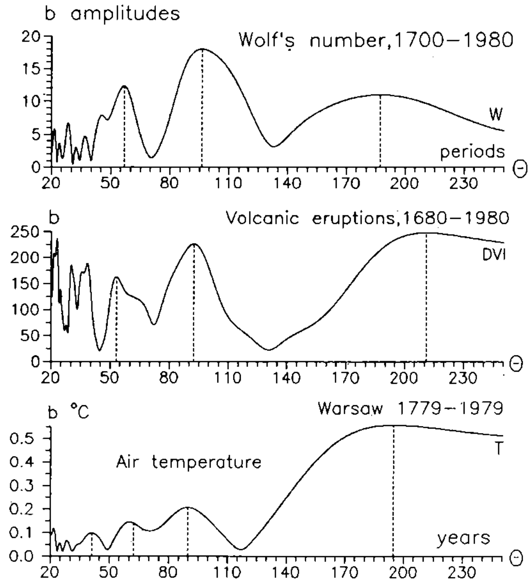


Fig. 1. Analogy between the dense spectra of oscillations of solar activity (1700-1980), volcanic eruptions in terms of DVI (dust veil index, 1680-1980) and air temperature in Warsaw (1779-1979)

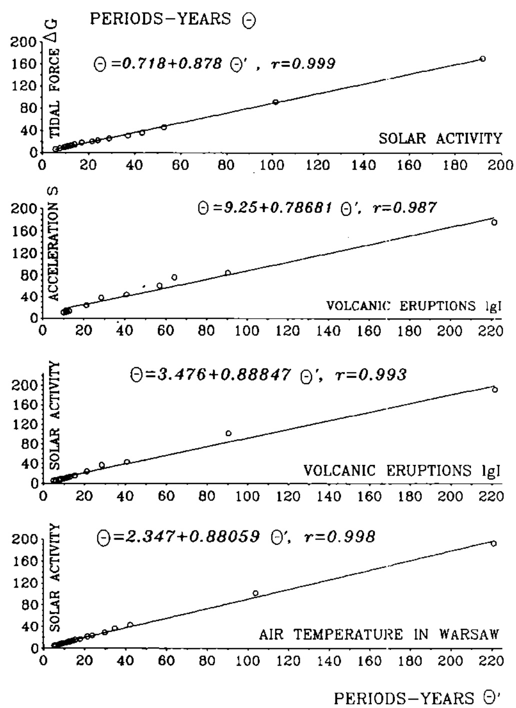


Fig. 2. Similarity of the dense spectra of oscillations (true cycles) of: the tidal force on the Sun, ΔG, acceleration of the Sun, s" in the years 1700-2000), solar activity (1700-1993), the I index (1680-1980), and the air temperature in Warsaw (1779-1990)

The model	*The number of cycles*	
$T' = -3.540 + 0.008375t$,	$r = 0.81$	1
$T' = -3.571 + 0.008377t$,	$r = 0.76$	2
$T' = -3.605 + 0.008908t$,	$r = 0.70$	4
$T' = -3.655 + \underline{0.009315t}$,	$r = 0.46$	10

The anthropogenic component $\Delta T = T - T$ has the increasing tendency: $a = A - B = 1.029 - 0.931 = 0.1$ °C/100 years.

It should be noticed that the considered periodicity does not apply to the anthropogenic factors, such as the contents of CO_2 in the atmosphere (and the greenhouse effect brought about by CO_2). The CO_2 concentrations undergo only daily and seasonal oscillations (the level of CO_2 decreases due to photosynthesis during the growing season).

The annual average of the air temperature in Warsaw in the years 1779-1990 increases by 0.66°C/100 years on the average:
$T = 6.915 + 0.006572t, \quad r = 0.57$

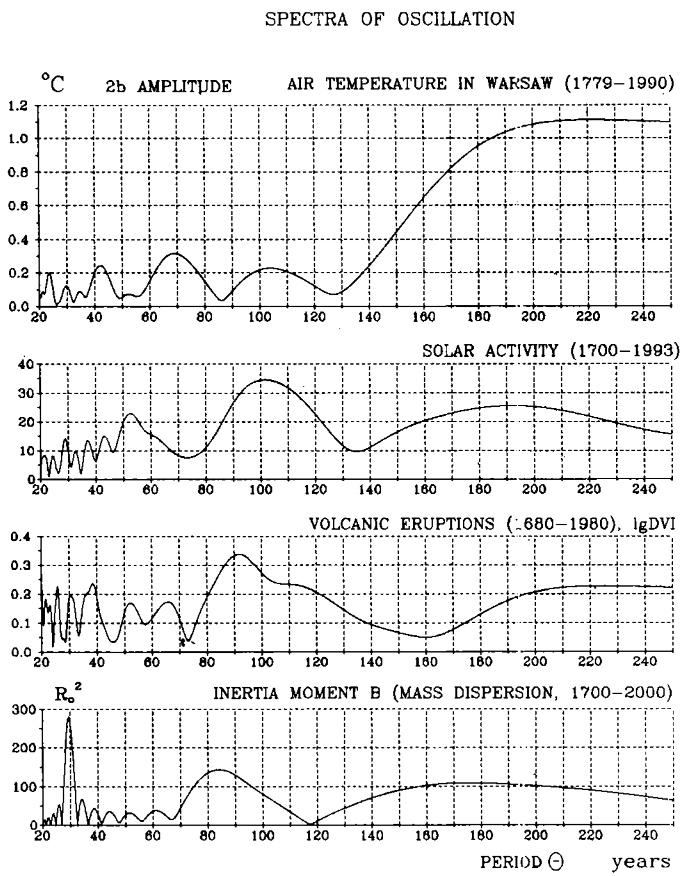


Fig. 3. Similarity of the dense spectra of oscillations of air temperature in Warsaw (1779-1990), solar activity (1700-1993), volcanic activity — in terms of lg*I* (*I* = DVI/Δ*t*, 1680-1980), and the inertia moment B (dispersion of the mass in the solar system with respect to its mass centre, 1700-2000)

This warming is most probably caused by the increase of activity of the Sun in the years 1779-1993 — by 15.3/100 years — and by the decrease of volcanic activity I — by 49 DVI/year·100years. Going further back this warming of climate during the 18th-20th centuries might have been caused by the smaller dispersion of mass in the solar system with respect to the ecliptical plane: (decrease of B_z by 0.011 R_0^2/100 years (Fig. 5):

$W = 24.23 + 0.152965t$, $r = 0.31$,

$I = 258.31 - 0.49066t$, $r = 0.21$,

$B_z = 0.122968 - 0.0001105t$, $r = 0.25$.

The secular coolings of the Earth's climate appeared in conditions of low activity of the Sun, high volcanic activity and low concentration of the mass of the solar system in the ecliptical plane.

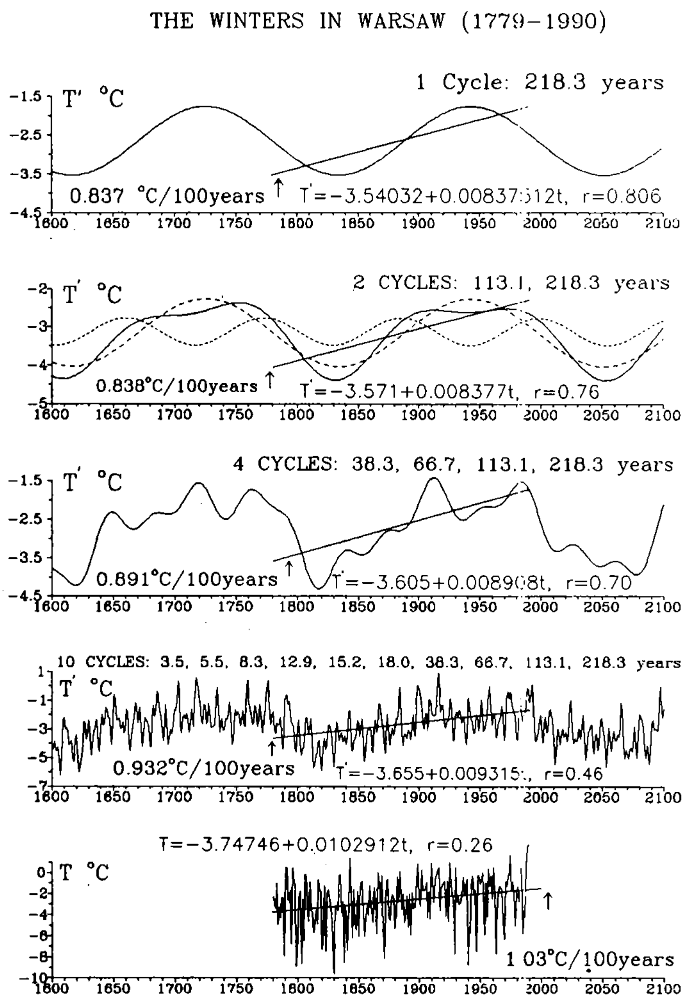


Fig. 4. Winters in Warsaw in the years 1779-1990. The increasing tendency in the air temperature by 1.03°C/100 years is the effect of superposition of the natural cycles whose periods range from 3.5 to 218.3 years

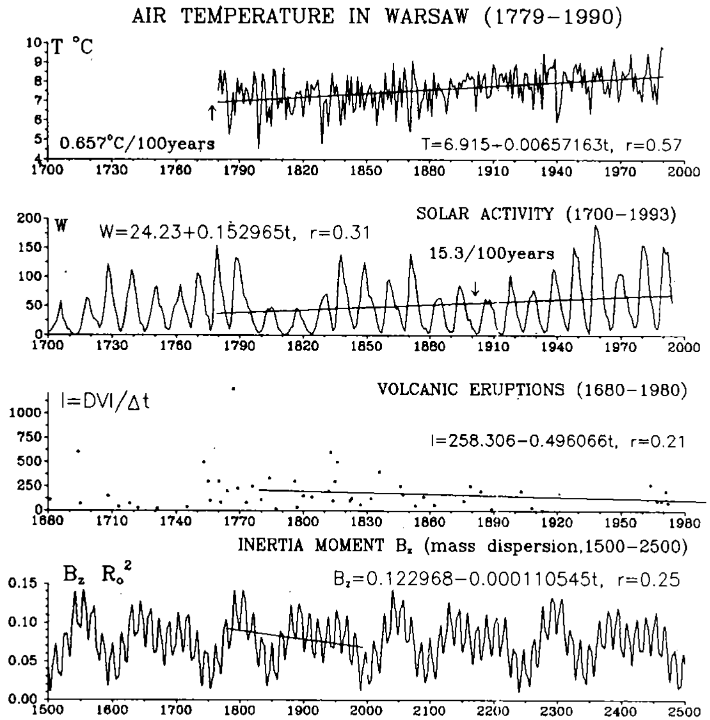


Fig. 5. The tendencies: the increasing one of the average annual air temperature in Warsaw (1779-1990) — by 0.66°C/100 years and of solar activity (1779-1993) — by 15.3/100 years, the decreasing one of the volcanic activity in terms of *I* (1779-1980) — by 49.6 DVI/year100 years and of the inertia moment *B* (i.e. of mass dispersion in the solar system with respect to its mass centre, 1700-2000)

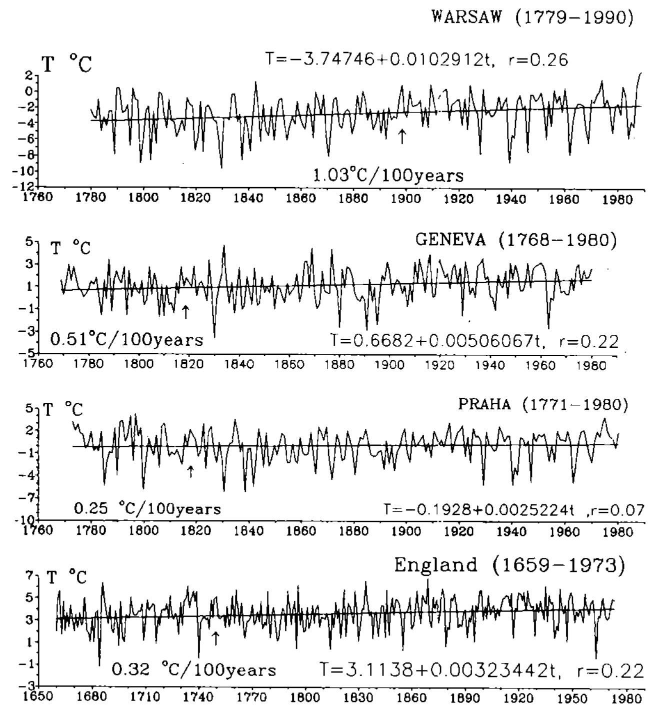


Fig. 6. Winters in Europe in 17th — 20th centuries. The increasing tendencies of air temperatures in: Warsaw (1779-1990) — by 1.03°C/100 years, Geneva (1768-1980) — by 0.51°C/100 years, Prague (1771-1980) — by 0.25°C/100 years and Middle England (1659-973) — by 0.32°C/100 years

Winters in other places in Europe are also increasingly warmer (see Fig. 6). The increasing tendency of the air temperature is there the resultant of the superposed natural cycles as well.

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