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COOLING AND WARMING OF CLIMATE OF THE EARTH'S NORTHERN HEMISPHERE (ON THE BASIS OF FLUCTUATIONS OF THE OXYGEN ISOTOPE $\delta^{18}O$ AND DENDROLOGICAL DATA)

Abstract: Content fluctuations of the oxygen isotope $\delta^{18}O$ in the Devon Island ice core during the last 100 000 years are a measure of climate fluctuations in the Northern Hemisphere. The course of content of the oxygen isotope $\delta^{18}O$ and the sums of solar radiation reaching the upper edge of the atmosphere are characterized by approximate minima and maxima (by positive correlation). This proves that, during the last hundred thousand years, climate fluctuations (cooling and warming) in the Northern Hemisphere were conditioned by long-term changes of the orbit and altitude of the Earth's axis. Climate fluctuation forecasts for the Northern Hemisphere were developed for the next 40 000 years on the basis of the established periods of change of the oxygen isotope $\delta^{18}O$ and the known solar radiation periodicity. Climate changes in Europe during the last 25000 years were presented together with a forecast for 1000 years (according to organic substances in deposits and radiation) as well as climate changes in Europe in the period from -500 years BP to 2100 AD (according to $\delta^{18}O$ and pine tree-rings). It showed that climate changes depended on the concentration of planet mass in relation to the ecliptic plane (from the gravitational impact of planets on the Sun). Concentration courses of planet mass in the Solar System and climate fluctuations in the Northern Hemisphere were compared. Of interest are examples of synchronic fluctuations, i.e. dispersal of planet mass in the Solar System, the widths of pine and spruce tree rings and air temperatures in Europe.

Key words: isotope $\delta^{18}O$, Devon Island, *Pinus sylvestris*, *Picea abies***,** tree the ring widths, solar radiation, periods, moment of inertia of planets, mass momentum of largest planets, forecast.

The objective of the study is to determine that fluctuations of the Earth's climate (cooling and warming in the last hundred thousand years) were generated by natural factors – astronomical and geological. In addition, the study aims to determine the dependence of climate changes on the concentration of planet moment of inertia in relation to the ecliptic plane – from the gravitational impact of planets on the Sun.

FLUCTUATION OF CLIMATE OF THE NORTHERN HEMISPHERE IN THE LAST 100 000 YEARS WITH A FORECAST FOR THE NEXT 40 000 YEARS (ACCORDING TO $\delta^{18}O$ AND RADIATION)

In the past, the greatest climate cooling (glaciation) was set off by periodic changes of the Earth's elliptic orbit and altitude of the Earth's axis. They were the outcome of fluctuation of solar radiation in high parallel latitudes, especially in circumpolar areas. They are the result of overlapping of three long cycles: orbital *eccentricity* – 92 000 years (from e=0 to e=0,068), inclination of the plane of the equator to the ecliptic – 40 000 years (from $\varepsilon=21^{\circ}58'$ to $\varepsilon=24^{\circ}36'$) and the ecliptic length of the perihelion (Ω) in relation to the point of the spring equinox – 21 000 years (Milankowich, 1930; Berger 1988). Every 20 900 years, at the same time of the year, the Earth is the shortest distance away from the Sun. If, for example, during winter the Earth is in perihelion of the orbit (with a an eccentric of 0,066) then the daily total solar radiation on the parallel $\varphi=60^{\circ}$ diminishes by about 44,4%, when the inclination of the ecliptic to the equator increases from $21^{\circ}58'$ to $24^{\circ}36'$.

Approximate periods, i.e. 23 000, 42 000 and 100 000 years were detected later in changes of the oxygen isotope ^{18}O contained in calcium carbonates of deep sea sediments (Hays et al., 1976). Rhythms constitute the geological justification for this periodicity: glacier range, change of ocean levels, seismic and volcanic activity, changes in of the positioning of equators – of a length of 40 700 years (Maksimov, 1972). Periods of the phase differences of maxima (minima) of these cycles are: (Ω, e) – 21211 years) (ε, Ω) – 44210 years, (ε, e) – 70769 years. The configuration of inclination of the ecliptic plane $\varepsilon=24^{\circ}36'$, with a circular orbit, repeats itself every 70 769.

Important information on global climate changes are provided by changes in the oxygen isotope $\delta^{18}O$ in the Antarctica ice cores (Brevier et al., 1999, Boryczka, 2004) and by the Arctic (Fisher, 1979; Gieszcz 2008). The isotope $\delta^{18}O$ contained in the Devon Island ice core comes from evaporation of heavy water ($H_2{}^{18}O$) from the oceans which increases during warming periods. Periods of the mean annual values of the oxygen isotope $\delta^{18}O$ <0 (°/oo) coefficient in the Devon Island ice core (in the Canadian Arctic), identified by the J. Boryczka method (1998) by the sinusoidal regression: $y=a_0+b\sin(2\pi t/\Theta+c)$, is shown in table 1.

In the spectrum of the oxygen isotope $\delta^{18}O$ in the Devon Island ice core, are present periods Θ (essential on level 0.05): 4500, 4700, 6200, 7300,8700, 11300, 16700, 24700, 45900 years and Θ=86100>n/2 are present. The oxygen isotope $\delta^{18}O$ coefficient is characterized by two periods: 24700 and 45900 years – similar to the change periods of the ecliptic length of the perihelion and inclination of the equator plane to the ecliptic.

Table 1. Periods Θ (years), amplitudes b and phases c of the cycles of the oxygen isotope $\delta^{18}O$ coefficient in the Devon Island ice core – from 110977 years ago (R – multiple correlation coefficient)

Periods Θ	***b***	***c***	***R***
1100	0.134	2.1566	0.041
2200	0.105	2.3140	0.056
2800	0.200	1.6527	0.059
3400	0.392	2.1201	0.079
4500	0.383	2.6125	0.115
4700	0.291	2.4280	0.107
6200	0.402	-2.5822	0.153
7300	0.290	2.5228	0.164
8700	0.326	2.8119	0.151
11300	0.064	-0.8220	0.100
16700	0.604	-2.7634	0.378
24700	1.237	3.0170	0.613
45900	1.962	2.2622	0.764
58750	4.700	2.477	0.766
86100	3.028	-2.7487	0.770

The interference of the cycles of the oxygen isotope content in the ice core: $\delta^{18}O=f(t)=a_{o+}at+\Sigma b_j \sin(2\pi t/\Theta_j+c_j)$ was determined with omission of the longest periods tj. $\Theta > 0.5\ n$ and the linear component (a=0). The resultant of the oxygen isotope $\delta^{18}O$ cycles (Table 1) in the years: from t=-110977 years ago with a prognosis to t=40 000 years is shown in Figure 1 by the graph (continuous line, standardized values). The minima t_{min} of the oxygen isotope $\delta^{18}O$ content in the ice core show the greatest climate cooling in the Northern Hemisphere, and the maxima t_{max} – warming.

In order to show the causes of climate fluctuations (fluctuations of the content of oxygen isotope $\delta^{18}O$ in the ice core), the daily total solar radiation on the 65° N parallel of latitude was calculated. In evaluating total solar radiation in the months from March to September (III-IX), the following period lengths were taken into consideration: the eccentric – 100 000 years, the Earth's axis – 40 000 and perihelion – 21 000 years. It was accepted that the eccentric of the e elliptic orbit of the Earth in the 100 000 year cycle changes from 0 to 0,066 (currently e=0,017), and the inclination of the ecliptic to the equator in a 40 000 year cycle changes from 21°58' to 24°36' (currently ε=23°30').

The main extrema (minima and maxima) of total solar radiation at the φ=65° N parallel of latitude in these months correspond to the dates of the next glacial and interglacial phases (the extrema of the oxygen isotope $\delta^{18}O$ content). For example, the last deep minima of the sums of solar radiation I_{min}=5971 MJ/m² take place during t_{min}=-21500, i.e. at the Würm glacial stage. The last local sum maximum of solar radiation I_{max}=6813MJ/m², which took place during t_{max}=-10500 years, takes place at the maximum of the oxygen isotope $\delta^{18}O$ content coefficient, i.e. on the *climatic optimum* of the Holocene.

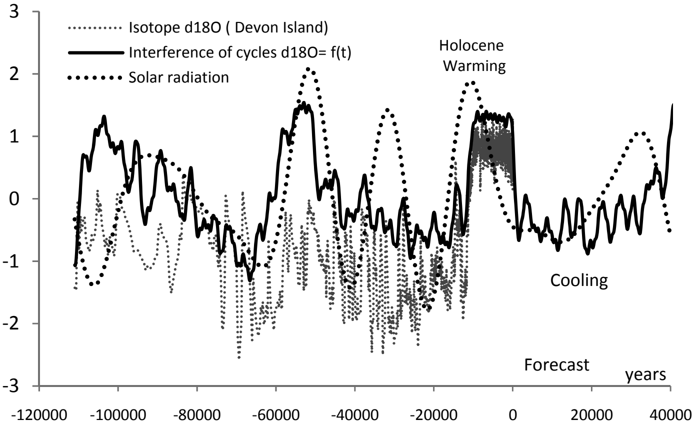

Fig.1. Changes of isotope $\delta^{18}O$ (Devon Island) and interference of cycles $f(t)$ and solar radiation in the timeframe: $-110977 < t < 40000$ years

Comparison between the forecasted values of the oxygen isotope $\delta^{18}O=f(t)$ and the sums of solar radiation 40000 years ahead (t=0, 1900 AD) deserves attention. Intense climate cooling may be expected in subsequent centuries (next glaciation of the Earth).

CLIMATE CHANGES IN EUROPE DURING THE LAT 25 000 YEARS WITH A FORECAST FOR 1000 YEARS (ACCORDING TO ORGANIC SUBSTANCES IN SEDIMENTS AND RADIATION)

In Europe, Holocene cooling and warming of climate is known on the basis of examination of organic substances (and the content of the oxygen isotope ^{18}O) deposited in Gościąż Lake (Boryczka, Wicik, 1994). In the laminated sediments of Gościąż Lake it is possible to determine calendar time (counting the annual increase of sore sediments). The content of organic substances during the period from 15750 to 12 540 BP was reconstructed and a forecast for the next 1000 years was made on the basis of interference $y=f(t)$ of cycles: 50, 230, 360, 390, 540, 590, 1120, 1380, 1770, 2970, 6080, 12380 years, present in the spectrum of organic substance content.

Climate cooling and warming are the local minima and maxima of temporal courses $y=f(t)$ of organic substance concentration (in %) in the sediments of Lake Gościąż (Fig.2). The changes in the sums of the solar radiation were also introduced (III-IX), from -25000 years ago to+1000, calculated keeping in mind periodical changes of the parameters of the Earth orbit. The course of radiation is characterized by two extrema: minimum t_{min}=-21500 (5791 MJ/m^2)

and maximum t_{max}=-10500 (6813 MJ/m^2). The greatest values $y=f(t)$ of organic substances in the sediments of Lake Gościąż (standardised positive, i.e. above average) they coincide with the extensive maxima of the sums of solar radiation.

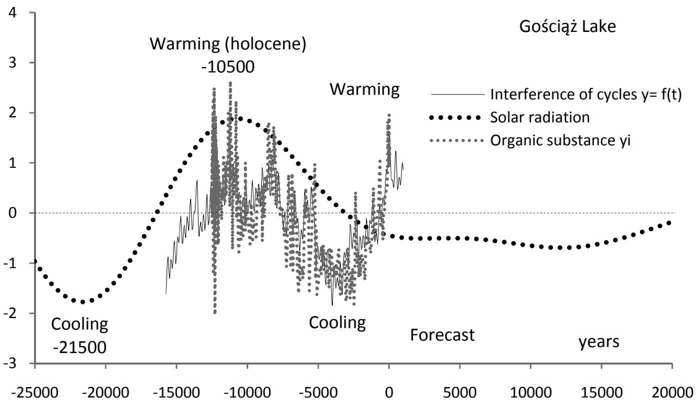

Fig.2. The change of the organic substance content in Lake Gościąż during: -15750 <t< 1000 in reference to the sums of solar radiation

Thus, the main reason for the Holocene climate optimum was the growth of the sums of solar radiation caused by changes in the Earth's orbit.

The least amount of organic substances in Lake Gościąż was during the time: t_{min}=-15750 (y_{min}=9,1 %) and t_{min}=-4000 (y_{min}=8,2 %). The graph of the resultant interference of cycles $y=f(t)$ has two maxima: t_{max}=-11250 (y_{max}=21,2%) and t_{max}=0 tj.1984 AD (y_{max}=21,1%). It may be concluded from the solar radiation forecast and periodicity of organic substances in Lake Gościąż that during the next 1000 years it will probably be cooling – from the minimum t_{min}=600, i.e. around the year 22580 (y_{min}=16,9%).

CLIMATE CHANGES IN EUROPE DURING THE PERIOD FROM -500 YEARS BP TO 2100 AD (ACCORDING TO $\delta^{18}O$ AND PINE TREE RINGS)

Reconstructions of air temperature in the ground layer in various places of the Earth show the principal timeframe of climate warming and cooling: the Warm Epoch (the Roman Period Optimum): – 500 BP-500 AD, the Cool Epoch – 500-800 AD, the Warm Epoch (the Mediaeval Optimum) – 800-1200 AD, the Little Ice Age – 1400-1900 AD and contemporary warming up – from 1900.

Europe's climate changes from the time -500 BP until the year 2100 are characterized by courses of the measured values of the oxygen isotope $\delta^{18}O$ coefficient in the Devon Island ice core from the years -500 BP until the year

1984 and the width of pine tree rings (*Pinus sylvestris*) in Forfjorddalen (Norway) during the years 877-1994 (Fig.3).

There is quite a good concordance of courses: fortuitous $y=f(t)$ interference of the width cycles of rings this pine (listed in table 2) with fluctuations of the oxygen isotope $\delta^{18}O$. The largest standardised width of pine rings (y_{max}=2,56) occurred during Europe's Mediaeval Climate Optimum (t_{max}=1138 AD). The next forecasted climate cooling period, according to the temporal trend of pine tree (Pinus sylvestris) ring width in Forfjorddalen, will occur 2027. Largest value of the coefficient of the oxygen isotope $(\delta^{18}O)_{max}$=-33.58 °/oo occurred during the Roman Period Optimum t_{min}=-110 BP

Table 2. Periods Θ (years) of width of pine tree rings *Pinus sylvestris* in Forfjorddalen (877–1994), *R*- the multiple correlation coefficient, F_{obl} – the Fisher-Snedecor statistics

Periods Θ	9	22	35	59	71	99	112	133	189	257
R	0.094	0.108	0.147	0.113	0.139	0.166	0.177	0.17	0.12	0.041
F_{obl}	44.9	59.2	110.8	64.2	98.0	141.8	162.7	149.6	73.4	8.5

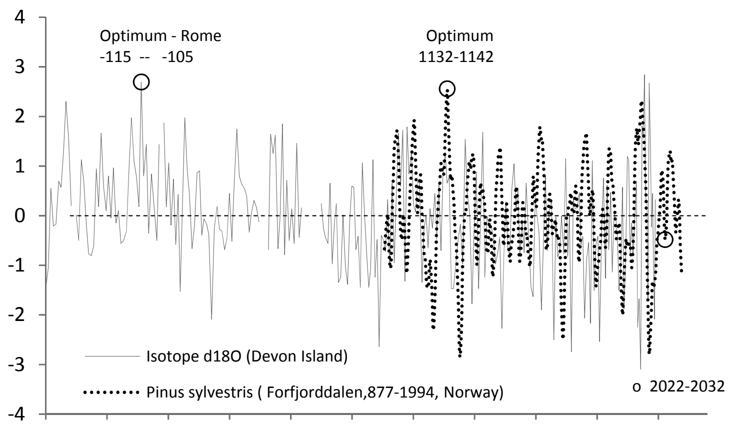

Fig.3. Change of the of oxygen $\delta^{18}O$ isotope in the Devon Island ice core from -500 BP to 2100 AD and the width of pine tree rings (*Pinus sylvestris*) in Forfjorddalen (Norway) during the years 877-2100 AD (consecutive averages for 11 years, standardized)

IMPACT OF THE PLANET MASS CONCENTRATION IN THE SOLAR SYSTEM ON THE FLUCTUATIONS OF CLIMATE IN THE NORTHERN HEMISPHERE

The dependence of fluctuation of the Earth's climate on dispersal of planet mass in the Solar System was examined. On the basis of parameters of the Earth's orbit (Reznikov, 1982) the moment of planet inertia was calculated (B_z, accepting R^2_o as the unit, R_o – as a sun ray in relation to the plane:

$$B_z = M^{-1} \Sigma\, m_i\, z^2_i$$

where: m_i – mass of i planet, z_i- the distance of the centre of the Solar System mass from the ecliptic plane. On the basis of current research (Boryczka, 2003), it may be concluded that Solar activity (Wolf numbers) depends on the location of the moment of inertia of the four largest planets: Jupiter, Saturn, Uranium and Neptune, on the mass momentum $\Sigma\, m_i\, r_i$, where r_i – distance of the i. planet from the Sun. The moment of inertia B_z of planets is the measure of dispersal of the planet mass in relation to the ecliptic plane.

Of interest is the comparison of changes in the growth of tree rings widths of Scots pine (*Pinus sylvestris*) in Karhunpesakivi (1398-1993, Finland) and Norway spruce tree (*Picea abies*) – in Falkenstein (1540-1995, Germany) with the course of the planet mass concentration coefficient ($-B_z$) in the years 1500-2500 (Fig.4-5). A comparison was made of the resultant $y=f(t)$ of the interference of cycles Θ of the Scots pine and Norway spruce tree rings widths determined on the basis of cycles (Table 3-4) with the coefficient $-B_z$.

Table 3. Periods Θ (years) of the Scots pine tree ring widths *Pinus sylvestris* in Karhunpesakivi – Finland (1396–1993)

Periods Θ	23	28	32	49	72	85	107	137	176	265
R	0.137	0.155	0.190	0.166	0.201	0.306	0.178	0.178	0.118	0.487
F_{obl}	5.63	7.30	11.15	8.45	12.43	30.62	9.71	9.71	4.21	92.30

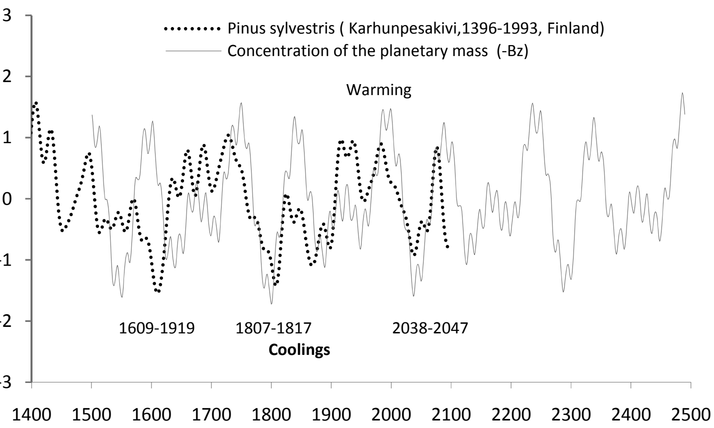

Fig. 4. Changes in the widths of the Scots pine tree rings (*Pinus sylvestris*) in Karhunpesakivi (1400-2100) and the coefficient ($-B_z$) of concentration of the planet moment of inertia in relation to the ecliptic (1500-2500)

Table 4. Periods Θ (years) of the Norway spruce tree ring widths *Picea abies* in Falkenstein – Germany (1540–1995)

Periods Θ	8	12	15	25	46	53	73	110	189	429
R	0.057	0.059	0.143	0.123	0.217	0.160	0.328	0.303	0.416	0.399
*F*obl	0.74	0.79	4.72	3.46	11.23	5.92	27.34	22.96	47.39	42.85

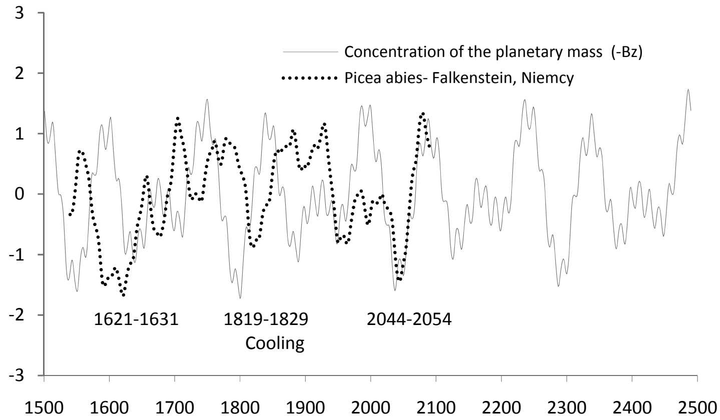

Fig.5. Changes in the widths of the Norway spruce tree rings (Picea abies) in Falkenstein (1540-2100) and the coefficient ($-B_z$) of concentration of the planet momentum of inertia in relation to the ecliptic (1500-2500)

The course of the widths of the Scots pine tree rings in Karhunpesakivi (Fig. 4) is characterised by three main minima: 1609–1919, 1807–1817, 2038–2047 (extrapolation). The synchronicity of fluctuation takes place, above all, in the years 1700–2100. The key minima of the widths of tree rings of this pine: 1807–1817, 2038–2047 (forecasted) take place on the minima of the planet moment of inertia concentration in relation to the ecliptic $(-B_z)_{\min}$. The course of the widths of the Norway spruce tree rings in Falkenstein is also similar to the course of concentration of the planet mass ($-B_z$) – with three similar minima in the years: 1621–1631, 1819–1829 and the forecasted 2044–2054 (Fig. 5). The minima of the tree ring widths indicate the greatest cooling of climate in Europe. Attention should be paid to the forecasted minima of the widths of the Scots pine tree rings in 2038–2047 (Karhunpesakivi) and Norway spruce in 2044–2054 (Falkenstein), i.e. a forecast of significant climate cooling – as was in the beginning of the XIXth century.

The widths of the Scots pine tree rings (*Pinus sylvestris*) in Forfjorddalen (Norway) have a similar course to the dispersal of planet mass in relation to the ecliptic plane (moment of inertia B_z) (Fig.6). In this case, the main minima of the widths of Scots pine tree rings take place during small dispersal of the mass B_z. They probably depend on atmospheric precipitation which is greater during the minima of Solar activity.

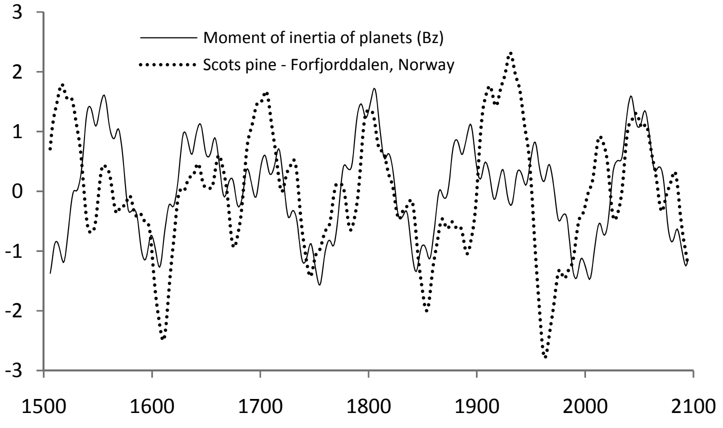

Fig. 6. Changes in the widths of Scots pine tree rings (*Pinus sylvestris*) in Forfjorddalen (Norway) and the moment of inertia (B_z) of the planet mass in the Solar System in relation to the ecliptic (1500-2100)

The most recent maximum cooling took place following the weakest 13-year cycle of sun-spots (1811–1823), at the time when the distance between the Sun and the centre of the Solar System mass (0.14 sun ray, 1811) was the shortest. It took place (also in Poland) during intensive volcanic activity (Lamb, 1974), following the greatest explosive eruptions: 1803 – Cotopaxi (*DV*I=1100), 1815 – Tambora (*DVI*=3000), 1835 – Cosiguina (*DVI*=4000) – with a large *DVI* coefficient (Lamb 1974).

Therefore, activity of the Sun (the number of sun-spots) depends on the planets' gravitational forces which bring about the Earth's revolution (with varying acceleration) around the centre of the Solar System mass. However, the tidal forces of the Moon and the Sun on the Earth cause tension inside the revolving Earth which has impact on the time of volcanic eruptions.

The Sun's activity (Wolf numbers) depends on changes in position of the mass centre of the four largest planets – Jupiter, Saturn, Uranium, Neptune with the periods of circulation: 11,862, 29,458, 84,015, 164,79 years. This is confirmed by comparison of the courses of mass momentum $\mu = \Sigma\, m_i\, r_i$ with Wolf's numbers in the years 1700-2100 (Boryczka, 2003). The course of the standardised Wolf numbers in the years 1700–2002 describes well the mass momentum formula $\mu = f(M_{ij})$, taking into account the modulation of the impact on the Sun of closer planets by more distant planets:

$$\mu=\sin(2\pi t/11.862+c_J)(1+M_{12}\sin(2\pi t/29.458+c_S)+M_{13}\sin(2\pi t/84.015+c_U)$$
$$+M_{14}\sin(2\pi t/164.79+c_N))+M_{12}\sin(2\pi t/29.458+c_S)(1+M_{23}\sin(2\pi t/84.015+c_U)$$
$$+M_{24}\sin(2\pi t/164.79+c_N))+M_{13}\sin(2\pi t/84.015+c_U)(1+M_{34}\sin(2\pi t/164.79+c_N)$$
$$+M_{14}\sin(2\pi t/164.79+c_N)$$

where: relative moments of inertia of individual planets M_{ij} (divided by M_{11}=1653,617 of Jupiter) are: M_{12}=0,549629, M_{13}=0,168967, M_{14}=0,314122,

M_{23}=0,30742, M_{24}=0,571516, M_{34}=1,859073, and phase shifts calculated by the sinusoidal regression method: $c_{J=}$1,238896, $c_{S=}$-1.646381, c_U=2,115445, c_N=2,061512.

Application of Jupiter's mass momentum M_{11} as a unit is approximately equivalent to statistical standardisation of the Wolf numbers. The Wolf numbers (*W*) in the years 1700-2001 may be obtained, with good approximation, from the transformation: $W=W_o+\mu\ s$ (W_o – arithmetic mean, s – standard deviation). This is proved by the „parallelism " of changes of the standardised Wolf numbers and values of the mass momentum (μ) of the largest planets (Fig.7).

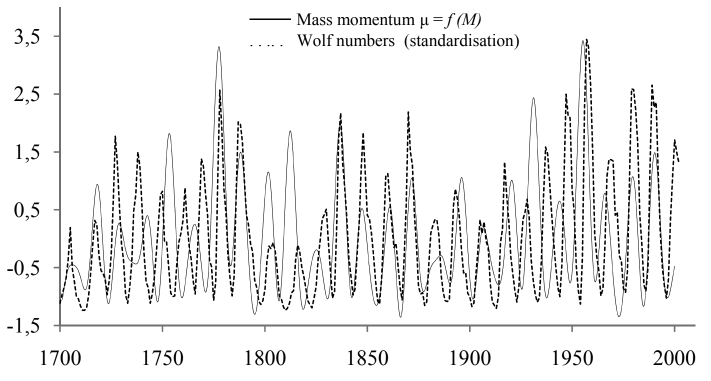

Fig. 7 Changes in the standardised Wolf numbers and the values of the planet mass momentum μ=*f(M)* in the years 1700-2000 (consecutive averages for 11 years, standardized)

SYNCHRONICITY OF FLUCTUATION OF THE WIDTHS OF PINE AND SPRUCE TREE RINGS AND AIR TEMPERATURES

Continuation of research on the synchronicity of fluctuation of the widths of pine and spruce tree rings and air temperatures in Europe (Stopa-Boryczka, Boryczka et al., 2007 and Boryczka, Stopa-Boryczka, Bijak, 2008) constitutes a comparison of the changes in the widths of pine tree rings from Falkenstein (1540–2100) with the course of air temperature in Geneva in the years 1650-2100 (Fig. 8). A comparison was made between the resultant of interference of the essential cycles of air temperature $T=f(t)$, listed in table 5, with the widths of spruce tree rings. The correlation coefficient is r=0,352.

Table 5. Periods Θ (years) of the mean annual air temperature in Geneva (1768–1980)

Θ	3.1	7.8	10.3	12.9	31.1	40.6	75.8	163.9
R	0.176	0.187	0.176	0.170	0.219	0.311	0.300	0.340
F_{obl}	3.35	3.82	3.35	3.11	5.27	11.21	10.40	13.72

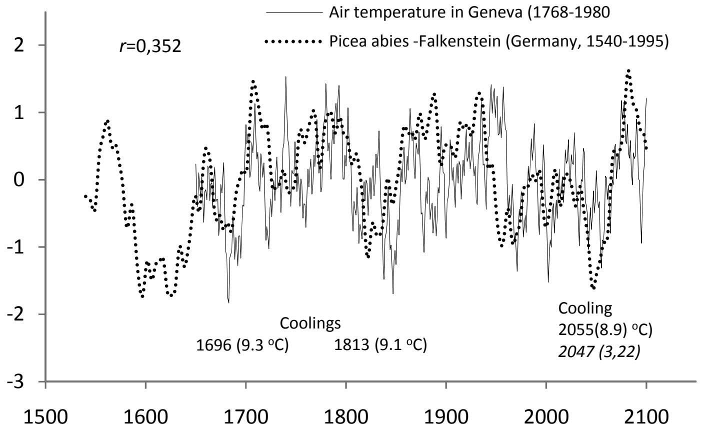

Fig..8. Changes of air temperature in Geneva in the years 1650-2100 and the widths of pine tree rings from Falkenstein (1540-2100)

The main minima of air temperature in Geneva fall on the dates: 1696 (9.3 °C) and 1813 (9.1 °C), and the prognosed cooling (T_{min}=8.9 °C) is expected in the years: 2055, and according to the trend of increase of the widths of pine tree rings – in 2047 (y_{min}=3.22).

Climate fluctuations are generally synchronic throughout Europe. This is confirmed, for example, by the intensely correlated (r=0.362) widths of Norway pine tree rings (*Pinus sylvestris*) growing in Forfjorddalen (Norway) and Karhunpersakivi (Finland) – Fig. 9.

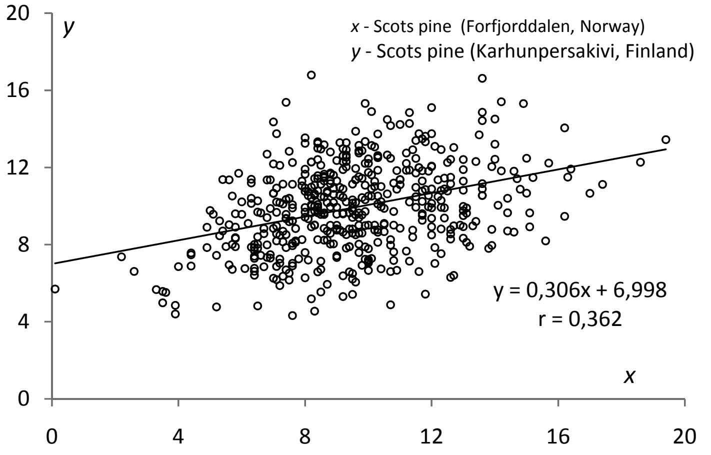

Fig. 9. The correlation between the widths of the Scots pine tree rings (Pinus sylvestris) in Forjorddalen (Norway) and in Karhunpersakivi (Finland)

Natural cooling of climate (and waters of the oceans), expected in the middle of the XXIth century, will reduce the total greenhouse effect of the atmosphere. The currently progressive climate warming of the Earth is leading toward an increase of the natural part of the greenhouse effect which is a result of decreasing absorption of carbon dioxide of CO_2 by ocean waters.

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