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VIEW OF CLIMATE CHANGES BASED ON THE WAVELET ANALYSIS OF SOLAR INTENSITY

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The view of existing tendencies in climate changes proposed by the authors is based on the available facts. Earlier, cyclic behaviour of the world's river flows was discovered, which was found to correlate with the cycles of solar intensity. Similar correlation was revealed by the authors for global temperature anomalies. Based on the wavelet analysis it became possible to notice a phase inversion in these processes, which, in the authors' opinion, could be associated with re-magnetisation of the Sun. This, for example, explains the hitherto inexplicable interruption in the temperature rise during the 1950-70-ies. The authors stress that the processes of global climate changes are of ambiguous character, being consisted of the natural and the anthropogenic components.

1. INTRODUCTION

The problem of climate changes is now at the focus of attention in the world. Public concern about their consequences has led to major achievements in this area. The principles of rational energy use have been recognised, and diversified energy saving technologies mastered by now. Practice shows that the energy consumption can be reduced significantly – in households even by 50%. In the power industry the main challenge is to maximally raise the efficiency of equipment so that less fossil fuel is burnt. A permanent growth is observed in the use of alternative energy sources; cogeneration (combined heat and power) plants are now widely spread.

The question as to whether the global processes associated with climate changes are understood well enough cannot be answered positively. Their origin is highly conjectural, and it would be worthwhile to possess all the available information. The authors' opinion has not formed yet, being based on the available facts, which to a considerable extent might replenish the existing notions. Now, let us take a closer look at these facts.

Not long ago, we faced the problem when investigating the regularities in river flows [1]. We then employed methods of spectral analysis to compare these regularities with the solar intensity cycles. In the course of investigation some interesting peculiarities were revealed.

At analysing, by analogy, the global temperature variations, some unclear points arise that should be decoded, such as:

1) Why in the process of temperature change are there observed harmonic fluctuations?
2) What was the cause of interruption in the temperature rise in the 50-70-ies of the past century?
3) How fast does the Earth atmosphere react to the processes going on the Sun?

4) How could the start of temperature rise in 1910 be explained when there was no anthropogenic effect of huge carbon dioxide emissions? (see Fig. 1).

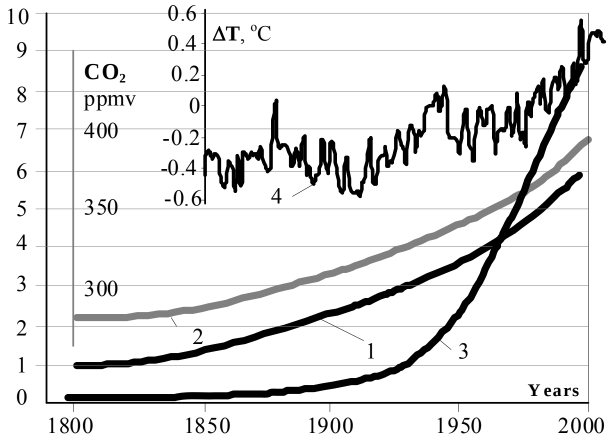

Fig. 1. Variations in the CO_2 content of terrestrial atmosphere and in the global mean temperatures as compared with other factors: *1* – number of people (10^9); *2* – CO_2 emission, ‰ ; *3* – energy production (10^9 toe); *4* – global mean temperature anomalies relative to 1961–1990.

2. ANSWERS TO THE QUESTIONS BY INVOKING THE RESULTS OF WAVELET ANALYSIS

There are good grounds to believe that the global mean temperature anomalies are affected by the processes going on the Sun. The average annual data of solar intensity observations (expressed in Wolf numbers, see Fig. 2) have been available since the year of 1700. In turn, the information on the mentioned anomalies is dated back to 1850 (Fig. 3).

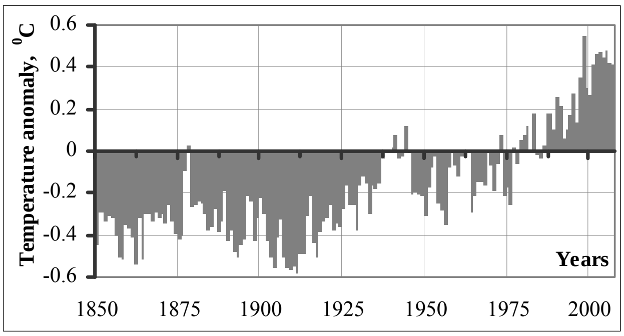

Fig. 2. Global mean surface temperature anomalies in 1850–2007 relative to 1961–1990. [http://www.cru.uea.ac.uk/cru/data/temperature/hadcrut3gl.txt].

To reveal a possible cyclic behaviour of the processes, the wavelet spectral analysis could successfully be invoked, which is suited best for investigations into natural processes. In this analysis, a natural process is split into a family of curves, each describing this process in a definite frequency range. The results of such an analysis for variations in global temperatures and solar intensity for the period of 1850–2007 show cyclic behaviour of the process components, with 11-, 25-, 100-, and 165-year periods (comparison of d_3, d_4, d_6 and d_7 components is displayed in Fig. 4).

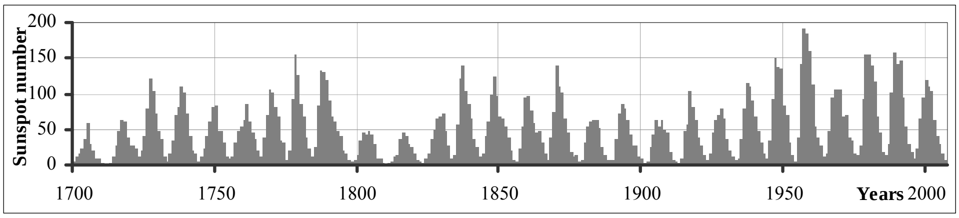

Fig. 3. Solar intensity in the Wolf numbers.
[ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SUNSPOT_NUMBERS/YEARLY.PLT].

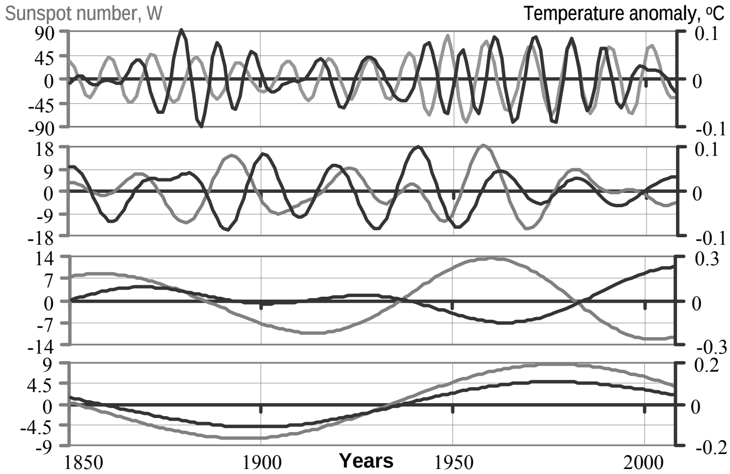

Fig. 4. Comparison of wavelet transform components for solar intensity (grey lines) and global mean temperature anomalies (black lines).

Of the mentioned, the 11-year cycle (d_3) is well known. The 25-year cycle (d_4) is close to the (also known) Bruckner cycle. E. Brukner – a German scientist who studied glaciers of Switzerland and river flows of Russia – in 1890 called attention to a 30-year climate cycle. In our investigation [1] a 100-year cycle was discovered for river flows. The same periodicity was established by glaciologists and scientists studying solar processes. The longest cycle mentioned (d_7) cannot be determined precisely enough due to insufficient information.

The temperature cycles characterised by d_3, d_4, and d_6 components evidence that the temperature response of the Earth atmosphere to the solar processes is practically simultaneous (on the global scale).

One striking peculiarity was noticed in recent investigations into the river flow cycles[1]: the process' phase changed by 180° as the year of 1910 was approached. The meaning of this phenomenon could not then be comprehended; its physical sense has become clear by now, since a similar phenomenon of phase inversion was revealed for global temperature variations during the present in-

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1 not published.

d3

vestigation. Before the inversion the solar intensity gradually decreased, and after that the processes resumed their usual course. This indicates a bifurcation of the influencing factor, which in our case is a well-known phenomenon of re-magnetisation of the Sun.

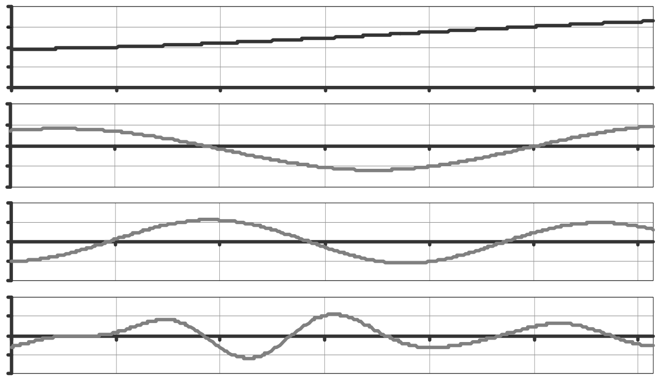

Fig. 5. Wavelet transform components of solar intensity.

To answer the second question the data for a longer time span were needed. For this purpose, a full 300-year spectrum of solar intensity was analysed. The results (shown in Fig. 5) validate the existence of 100-year cycles (d_6) in solar intensity, thus widening the scope of previously obtained results (cf. Fig. 4). Here the phase inversion created an anti-phase component of the longer process, which retarded the temperature rise, with its stabilisation in the 1950-70-ies. Therefore also these nuances stem from the behaviour of solar intensity changes. This fact is evidence that there are yet unknown natural relations between the Earth temperature and the solar magnetic field. The question of how the changes in the latter influence the former should be addressed to geophysicists.

Some features of 200-year (d_7) and 300-year (d_8) cycles are now discernible. Unfortunately, the time of observation was insufficient to define their shape more clearly. On the last curve (a_8) a half of one semi-period could be seen, which is possibly a fragment of the 1000-year cycle. A precise shape of this cycle cannot be obtained by direct observation but it can be inferred from indirect data.

3. THE 1000-YEAR CYCLE OF SOLAR INTENSITY

The 1000-year cycle is of importance in the life of mankind, which is con–firmed by historical and archeological facts. Thus, for example, it is known that in the IX–X centuries a Vikings' expedition reached an ice-free land, which was named by them Grenland (a green land). Another expedition arrived at a land covered with vineyards and called it Vinland (now Newfoundland). Later on, in the XIII century, one more expedition departed for Greenland to visit their ancestors, and this time there was a kilometre-high glacier, with no traces of man revealed.

It is known that 2000 years BC an ancient Egyptian kingdom (famous with its pyramids) completely disappeared. Archeologists found out that Egypt then suffered a humanitarian catastrophe caused by Nil's being dried up due to unusually low temperatures. This fact was confirmed by archeological excavations as well as by investigations of stalactites. It is now established that at those times thawless icebergs of the Atlantic Ocean reached latitudes of Africa.

A more accurate account of 1000-year climate changes was obtained at studying the ice cores from Greenland glaciers in the places where snow remains unthawed in summer. It is known that a glacier is pressed snow, which at its re-crystallization transforms into ice. In the millennial ice cores annual layers could well be discerned. These layers are separated from each other by summer and winter sediments, which have different structure, density, and dust composition (depending on the season). All these differences should present no problems for several last millennia; however, in deeper horizons these layers are fused under the influence of pressure, and the dating becomes more complicated and less precise.

In the stage of ice formation the air becomes stored in bubbles. Therefore to isolate it from the ice core the data on the atmosphere composition and climatic conditions of that time are needed. In the atmosphere, apart from simple hydrogen and oxygen isotopes ^{1}H and ^{16}O, there are contained in minor quantities heavy isotopes ^{2}H and ^{18}O. It turns out that between the specific weights $^{2}H/^{1}H$ and $^{18}O/^{16}O$ (designated by $\delta\ ^{18}O$ and $\delta\ ^{2}H$ and expressed in promiles, ‰, with respect to the SMOW (standard mean ocean water)) and paleo-atmospheric mean temperature a linear relationship exists [5, 6]. Thus, for example, a 1‰ decrease in $\delta\ ^{18}O$ indicates a 1.5 °C temperature fall, while 6‰ decrease in deuterium ($\delta\ ^{2}H$) – a 1 °C temperature reduction. A good correlation between these values is found also in other investigations, which provides grounds to consider the glacial cores of Greenland as a natural monitor of temperature fluctuations. A smoothed (in 50 years) diagram of Fig. 6 presents the GISP2 ice core data (Greenland) for the last 5000 years [7].

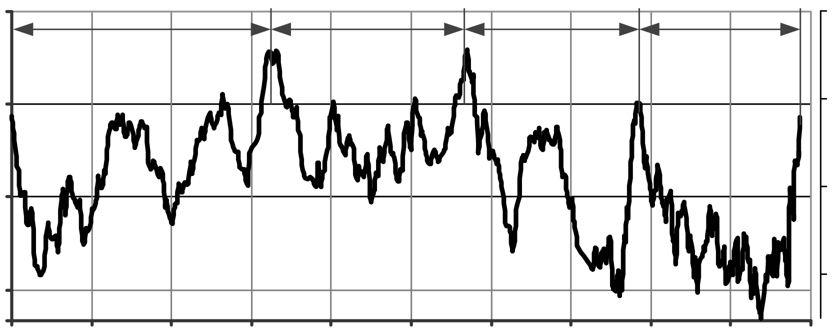

Fig. 6. Distribution of oxygen $\delta\ ^{18}O$ isotope in the upper layers of the GISP2 ice cores (the values are smoothed in 50 years); corresponding scale of temperature anomalies on the right. [Grootes, P.M., and Stuiver, M. 1997. Oxygen 18/16 variability in Greenland snow and ice with 10^3 to 10^5-year time resolution. Journal of Geophysical Research 102:26455-26470].

These data convincingly show that the time of Vikings' expedition exactly correlates with an extreme temperature rise which lasted for about 50 years – i.e. a period long enough for glaciers to thaw. In the second case mentioned above – that of an ancient Egyptian kingdom's downfall 2000 years before our era, when a humanitarian catastrophe took a heavy toll of human lives – an extreme temperature fall (shown in Fig. 6) occurred. In this figure also the XVII century – the coldest time of "a small ice period" [7] (XII–XVIII) – is clearly seen. At those times in Europe owing to severe cold there were bad harvests followed by famine, plague, and other calamities. The temperature changes had a U-like shape, with short-term temperature rises. Population of that time suffered mostly from cold.

4. NATURAL CLIMATE CHANGES

The data on the deepest layers of ice cores made it possible to reconstruct the temperatures for 600 thousand years, which are shown in Fig. 7. Here we also can see the above mentioned U-like behavior of the temperature changes, with rare and short-term extreme temperature rises against the background of low temperatures. During these 600 thousand years there were six glacial epochs, 100 thousand years each, with short (approximately 10–20 thousand years) interruptions. This indicates the temperature changes of approx. 110 thousand years, which corresponds quite well to the cycles of changes in solar intensity (although there is another hypothesis to explain these temperature changes – the precession of the terrestrial globe axis, i.e. its regular deviations from the orbital plane). Let us remember that we are now living in the closing stage of an inter-glacial epoch.

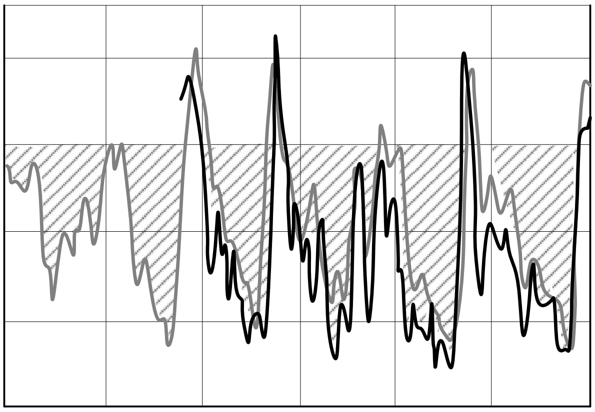

Fig. 7. Relative temperature deviations during glacial epochs in Antarctic over the last 600 thousand years: oceanic calcite oxygen isotope $\delta\ ^{18}O$ (grey line); temperature deviations in Antarctic (black line); glacial epochs are stressed.

We have every reason to believe that between the solar intensity and average changes in the global temperature definite relationships exist, and it is not excluded that they are of linear character. Under such circumstances, by graduating these relationships with respect to the 300 years of observations, it could be possible to approach a solution to the inverse problem: how to judge about the solar long-cycle shape from the global temperature changes.

5. THE AMBIGUOUS CHARACTER OF THE PROCESSES

When analysing the climate changes, we are dealing with two causes of temperature changes:

1) natural, lasting for thousands of years, and
2) anthropogenic (resulting from human activities), which occurred in the last several tens of years overlapping each other.

The factor of natural changes could be derived from the obtained relationships and from the data on 1000-year cycles. Against the background of natural changes of especial importance becomes the anthropogenic factor, owing to which the temperature rise can be found as its total change minus the change caused by natural processes:

anthropogenic change = real change – natural change.

The natural processes are rather intricate, and their nuances have not yet been studied completely. However, from the cause-and-effect viewpoint these are transparent. While in the past the temperature changes were caused solely by the processes going on the Sun, nowadays we have to add the anthropogenic factor in the form of CO_2 gases, whose enhanced emission accidentally coincides with the recurrent 1000-year extreme of natural temperatures. In this connection a question arises: would the current temperature rise, taking into account the anthropogenic factor, mitigate the expected temperature fall or its consequences might be heavier?

What we know about the carbon dioxide gas present in the atmosphere? It is recognised that its total annual amount equals 40 milliard tons, from which 700 million tons are thrown into atmosphere – i.e. less than 2%. The remaining quantity is absorbed mainly by oceans. Annually, 6 million tons of non-absorbable anthropogenic CO_2 arrive at the atmosphere. It is known that the greenhouse effect ensures the thermostatic properties of the Earth, maintaining its mean temperature 33^{o}C higher than without this effect. Naturally enough, to maintain the mean temperature, the greenhouse effect should be kept in definite limits. At CO_2 specific weight in the atmosphere increasing to 500 million particles (now it is 380 million), the temperature can be raised by 2.5 ^{o}C, which will create serious problems. Between the oceans and the particles of atmospheric CO_2 a dynamical equilibrium exists, which is regulated by physical laws. This is well known to the power engineers dealing with water preparation at electricity plants. The water used in boilers must be cleaned from salts (boiler-stones) and the gases dissolved in them (corrosion). These gases (oxygen included) are eliminated by heating the water (see Fig. 8). The same could be observed in nature: when a temperature rise is caused by natural phenomena, part of oceanic CO_2 finds its way out into the atmosphere, and returns to the ocean at a temperature fall. A notion about the CO_2 and temperature variations during the last 420 thousand years can be received from Fig. 9 showing the ice core isotope data obtained at the *Vostok* station in Antarctic.

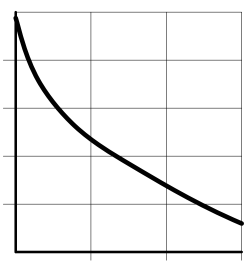

Fig. 8. Absorption capacity of CO_2 gases depending on the temperature at pressure 0.1 MPa (≈ 1 atm).

To avoid contradictory conclusions, the secondary phenomena should be separated from the primary ones. From the above it follows that the primary factor (cause) is the natural temperature change, whereas the secondary one (effect) – the release of CO_2 gases into the atmosphere.

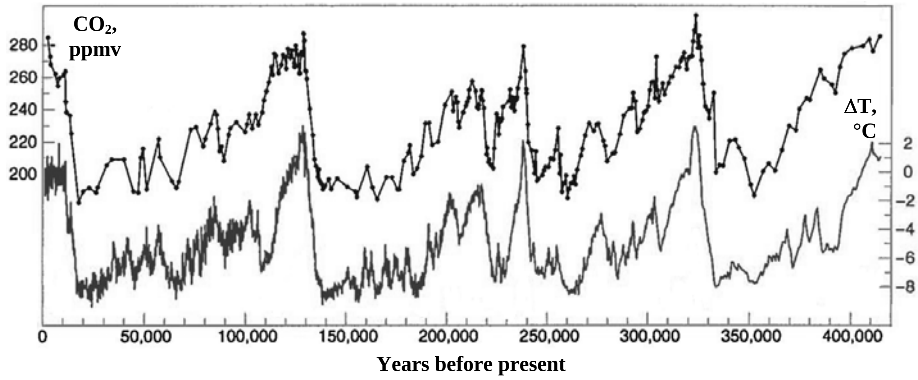

Fig. 9. Correlations between the temperature and CO_2 concentrations (from the 'Vostok' ice core data for the past 420,000 years). [Petit, J.R., *et al.*, 2001, Vostok Ice Core Data for 420,000 years, IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series #2001-076. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA].

Of course, this latter process can, in turn, influence the temperature through a definite limited positive feedback under the condition that at the corresponding CO_2 concentration the greenhouse effect is clearly expressed. One more feedback is the albedo effect – a contraction of white surfaces in the Polar Regions in a warm period, when they reflect part of the solar energy into the space. In any case, the cause should not be confused with the effect.

The process of climate changes should be analysed as bi-layer: the anthropogenic component against the background of natural changes. Those who recognise only natural changes neglect the anthropogenic factor, whereas supporters of the purely anthropogenic position judge about the matter being ignorant as to the natural changes. Taking into account the duality of this process, the views of both the sides could be significantly corrected.

In the end, we would like to express certain astonishment about so poor public knowledge of the geophysical aspects of the matter. Taking into account the utmost importance of the problem and the success already achieved in the energy consumption and production as well as the fact that the tendency towards decrease in the fossil fuel combustion leads to reduction in harmful emissions, it would be worthwhile to work out, based on the scientifically substantiated theoretical considerations, a model of the atmospheric processes which would allow for a deeper insight into the future.

6. CONCLUSION

The authors hope that the presented comparison of the spectral analysis data on the Earth temperature and the solar intensity variations would add, to some extent, to the notion about the process of climate changes by taking into consideration its natural and anthropogenic components.

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SKATIENS UZ KLIMATA IZMAIŅĀM, IZMANTOJOT SAULES INTENSITĀTES VEIVLETANALĪZI

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K o p s a v i l k u m s

Publikācijā autori, balstoties uz pieejamiem faktiem, parāda klimata izmaiņas tendences. Līdz šim, pētot upju caurplūdumus, tika pielietota spektrālā analīze, kura ļāva atklāt šo parādību ciklisku raksturu. Salīdzinot to ar Saules intensitātes analīzes datiem, atklājas interesantas likumsakarības. Analoģiska pieeja izmantota, analizējot temperatūras izmaiņas. Pateicoties veivletanalīzei, izdevās atklāt procesa fāzes apvērsumu, kas, pēc mūsu domām, ir saistīts ar Saules pārmagnetizēšanos. Tas izskaidro līdz tam nesaprotamu temperatūras paaugstinājuma pārtraukumu no 1950. gada līdz 1970. gadam. Analizējot šīs parādības, uzmanība vērsta uz procesu izmaiņu divslāņaino raksturu, kas sastāv no divām komponentēm – dabiskās un antropogēnās.

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