CURRENT LONG-TERM NEGATIVE AVERAGE ANNUAL ENERGY BALANCE OF THE EARTH LEADS TO THE NEW LITTLE ICE AGE

by

Habibullo ABDUSSAMATOV

Pulkovo Observatory of the Russian Academy of Sciences, Saint Petersburg, Russia

Original scientific paper
DOI:10.2298/TSCI140902018A

The average annual decreasing rate of the total solar irradiance is increasing from the 22nd to the 23rd and 24th cycles, because the Sun since the 1990 is in the phase decline of quasi-bicentennial variation. The portion of the solar energy absorbed by the Earth is decreasing. Decrease in the portion of total solar irradiance absorbed by the Earth since 1990 remains uncompensated by the Earth's radiation into space at the previous high level over a time interval determined by the thermal inertia of the Ocean. A long-term negative deviation of the Earth's average annual energy balance from the equilibrium state is dictating corresponding variations in it's the energy state. As a result, the Earth will have a negative average annual energy balance also in the future. This will lead to the beginning of the decreasing in the Earth's temperature and of the epoch of the Little Ice Age after the maximum phase of the 24th solar cycle approximately since the end of 2014. The influence of the consecutive chain of the secondary feedback effects (the increase in the Bond albedo and the decrease in the concentration of greenhouse gases in the atmosphere due to cooling) will lead to an additional reduction of the absorbed solar energy and reduce the greenhouse effect. The start of the total solar irradiance Grand Minimum is anticipated in the solar cycle 27 ± 1 in 2043 ± 11 and the beginning of the phase of deep cooling of the 19th Little Ice Age for the past 7,500 years around 2060 ± 11.

Key words: *energy balance, Grand Minimum, climate, Little Ice Age, feedback effects*

Introduction

The average annual balance of incoming and outgoing energy for the Earth (on the outer layers of the atmosphere) in the equilibrium state determines the stability of the climate. The main reason for long-term deviations from the equilibrium state is the quasi-bicentennial cyclical variation of the total solar irradiance (TSI) and the absorbed of the Earth its portion due to the thermal inertia of the Ocean. Thereby, the climatic system is affected by quasi-bicentennial cyclic external actions connected with corresponding variations of the TSI. The basic features of climate variations are connected, in particular, with fluctuations of the power and velocity of both the atmospheric circulations and oceans currents, including the thermal current of Gulfstream driven by the heat accumulated by oceans water in the tropics. They are determined by common action of bicentennial and eleven-year cyclic variations of TSI. Significant climate variations during the past 7.5 millennia indicate that bicentennial quasi-periodic TSI variations

Author's e-mail: abduss@gao.spb.ru

define the corresponding cyclic mechanism of climatic changes from global warming to Little Ice Age and set the timescales of practically all physical processes that occur in the Sun-Earth system [1-3]. The observed long-term decline of TSI since 1990 and upcoming deep cooling will, first of all, essentially affect climate-dependent natural resources and hence the economic brunches closely connected with the state of the climate. The upcoming global cooling will dictate the direction of variations of different natural processes on the Earth's surface and in the atmosphere as well as the change for the worse of conditions for creating material and financial resources of the society. For practical purposes, the most important task is to determine the tendencies of expected climate changes for the next 50-100 years until the middle and the end of the 21th century.

The average annual energy balance of the Earth

The average annual energy balance of the Earth, *E,* (on the outer layers of the atmosphere) is defined by the difference between E_{in}, the incoming TSI ($S_\odot$), and E_{out}, the reflected portion of TSI ($AS_\odot$, where A is the Bond albedo) and by emitted long-wave radiation of the Earth (from the outer layers of the atmosphere) outgoing into space [4]:

$$E = \frac{(S_\odot + \Delta S_\odot)}{4} - \frac{(A + \Delta A)(S_\odot + \Delta S_\odot)}{4} - \varepsilon\sigma(T_p + \Delta T_p)^4 \tag{1}$$

or by the difference between the portion of energy of the TSI absorbed by the Earth and its emitted long-wave radiation into space:

$$E = \frac{(S_\odot + \Delta S_\odot)(1 - A - \Delta A)}{4} - \varepsilon\sigma(T_p + \Delta T_p)^4 \tag{2}$$

Here ε is the emissivity of the Earth, σ – the Stefan-Boltzmann constant, and T_p – the planetary thermodynamic temperature. The increment of the Earth's effective temperature ΔT_{ef} due to the increments of the TSI $\Delta S_\odot$ and Bond albedo ΔA is determined by:

$$\Delta T_{ef} = \frac{\Delta S_\odot (1 - A - \Delta A) - \Delta A S_\odot}{16\sigma T_{ef}^3} \tag{3}$$

The ratio of relative contribution of the increments $\Delta S_\odot$ and ΔA to the increment ΔT_{ef} is determined by:

$$\frac{\Delta S_\odot}{S_\odot} = \frac{\Delta A}{(1 - A - \Delta A)} \tag{4}$$

A cyclical decrease of the portion TSI absorbed by the Earth remains uncompensated by high level of radiation into space at the previous same level over a time interval 20 ± 8 year that is determined by the thermal inertia of the World Ocean [5]. That is why the debit and credit parts of the average annual energy balance of the Earth as a planet (eq. 2) always deviate from the equilibrium ($E \neq 0$), which is the basic state of the climatic system. Long-term deviation of the average annual energy balance of the Earth from the equilibrium state (excess of incoming TSI accumulated by the Ocean $\Sigma E > 0$ or its deficiency $\Sigma E < 0$) dictates a corresponding change of the Earth's energy state and hence the climate. As a result, the Earth will gradually warm up or cool down, respectively, what imply an upcoming climate variation and its amplitude with account forecasted quasi-bicentennial variations of the TSI and the subsequent feedback effects (Bond albedo and greenhouse gases: H_2O, which is the most important, and CO_2). That is why the Earth's climate will change in a quasi-bicentennial cycle every 200 ± 70 years from the global warming to the Little Ice Age. My definition of the Little Ice Age with quasi-bicentennial cycle differs from an often mentioned in the literature long period of global cooling in the 14 to 19 centuries, which have been interrupted by several quasi-bicentennial warming periods. Deep cooling associated with Wolf (~1280-1340), Sporer (~1450-1550), Maunder (~1645-1715), and Dalton (~1790-1830) Grand Minima cannot be regarded as a single Little Ice Age.

At the same time, insignificant more long-term variations of the average annual TSI entering the Earth's upper atmosphere due to changes in both the shape of the Earth's orbit, inclination of the Earth's axis relative to its orbital plane, and precession, known as the astronomical Milankovitch cycles [6], together with the subsequent non-linear feedback effects, lead to the Big Glacial Periods (with the period of about 100,000 years). These variations of the TSI cause significant temperature fluctuations from the global warming to the Big Glacial Period, as well as of atmospheric concentration of the greenhouse gases. Antarctic ice cores provide clear evidence of a close coupling between variations of the temperature and atmospheric concentration of the CO_2 during at least the past 800,000 years induced by Milankovitch cycles. According to the ice core data drilled near Vostok site, Antarctica: the peaks of the CO_2 concentration have never preceded the warming, but on the contrary always took place 800 ± 400 years after them, being their consequences [7, 8]. Since according to Henry law, warm liquid absorbs less gas and hence more CO_2 remains in the atmosphere. Considerable changes of the content of greenhouse gases in the atmosphere are always governed by the corresponding temperature fluctuations of the World Ocean. The amount of natural flows of water vapor and CO_2 from the Ocean and land to the atmosphere and from the atmosphere to the Ocean and land exceeds many times the anthropogenic discharges of these substances into the atmosphere [9]. The overall content of the CO_2 in the Ocean is 50 times higher than in the atmosphere, and even a weak *breath* of the Ocean can change dramatically the CO_2 level in the atmosphere. There is no evidence that CO_2 is a major factor in the warming although CO_2 has some warming influence but the Sun plays a far greater role in the whole scheme of things. Natural causes play the most important role in climate variations rather than human activity since natural factors are substantially more powerful.

The current trend decreasing TSI suggests starting the new Little Ice Age epoch

Herschel was the first to report correlation between a level of solar activity and a climate after his discovery of inverse interrelation between a wheat price and a level of cyclic variations of solar activity [1]. During high levels of solar activity the wheat production increased resulting in a drop of prices. Nobody could explain the nature of this phenomenon. Later was discovered interconnection between clearly determined periods of significant variations of the solar activity during the last millennium and corresponding deep climatic changes in both phase and amplitude [2]. During each of 18 deep Maunder-type minima of solar activity with a quasi-bicentennial cycle found in the preceding 7.5 millennia, deep cooling was observed, while during the periods of high maximum – warming [3]. Our studies have shown (fig. 1) that a physical nature of these phenomena is directly connected with corresponding variations of TSI since cyclic variations of the solar activity and TSI are synchronized and inter-correlated in both phase and amplitude [10-13]. The Sun provides the largest TSI at the maximum of solar activity. Thus, significant climate variations during at least the past 800,000 years indicate that quasi-bicentennial and 100,000 years cyclic variations of the TSI entering the Earth's upper atmosphere (taking into account their direct and subsequent non-linear secondary feedback influences) are the main fundamental cause of corresponding alternations of climate variations from global

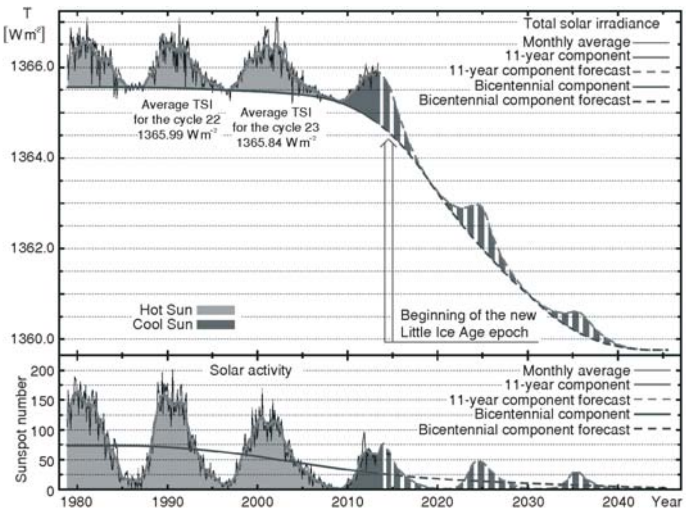

Figure 1. Cyclic variations of the TSI (data are taken from [14]) and sunspot number (data are taken from [15]) are synchronized and inter-correlated in both phase and amplitude, the hot Sun is marked by gray and the cool Sun is marked by black. The arrow indicates the beginning of the new Little Ice Age epoch

warming to the Little Ice Age and Big Glacial Period. The quasi-bicentennial variations of the TSI set the timescales of practically all physical processes taking place in the Sun-Earth system and are the key to understanding cyclic changes in both the nature and the society.

Since 1990 the Sun is in the quasi-bicentennial phase of decline, and we have been observing a decrease in both eleven-year and quasi-bicentennial the components of the TSI and the portion of its energy absorbed by the Earth. The 11-year component of TSI in the current cycle has decreased by more 0.6 W/m^2 with respect to cycle 23 (fig. 1). Decrease of the TSI from the 22nd cycle to the 23rd and 24th cycles is increasing: an average annual decrease rate in the 22nd cycle was ~0.007 W/m^2 per year, while in the 23rd cycle it already became ~0.02 W/m^2 per year. The current increasing rate of an average annual TSI decline is almost 0.1 W/m^2 per year and this will continue in the 25th cycle. The average cyclical values of the TSI were also lower by ~0.15 W/m^2 in the 23rd cycle than in the 22nd cycle. The value of TSI at the minimum between 23/24 cycles (1365.27 ± 0.02 W/m^2) was lower by ~0.23 and by ~0.30 W/m^2 than at the minima between 22/23 and 21/22 cycles, respectively (fig. 1).What we are seeing now in the solar cycle 24 and the quasi-bicentennial cycle and also at stability of temperature (fig. 2) has been predicted by me in 2003-2007, long before the cycle 24 began [10-13]. These forecasts have been confirmed both by the Sun itself and by stabilization of both the temperature and the Ocean level for the past 17 years which are the result of TSI fall since 1990 and a sign of the upcoming beginning Grand Minimum of TSI.

Every time the TSI experienced its quasi-bicentennial peak up to ~0.5% [17] a global warming began with a time delay of 20 ± 8 years defined by the thermal inertia of the Ocean, and each deep quasi-bicentennial descent in the TSI caused a Little Ice Age (together with the subsequent non-linear feedback effects). All eighteen periods of significant climate changes found during the last 7,500 years were entirely caused by corresponding quasi-bicentennial variations of TSI together with the subsequent feedback effects, which always control and totally determine cyclic mechanism of climatic changes from global warming to Little Ice Age.

Observed decrease of the TSI portion absorbed by the Earth since 1990 has not been compensated by decrease of its average annual energy emitted into space which practically remains on the same high level during 20 ± 8 years due to thermal inertia of the Ocean. The Earth as a planet will continue to have a negative average annual energy balance in the future cycles

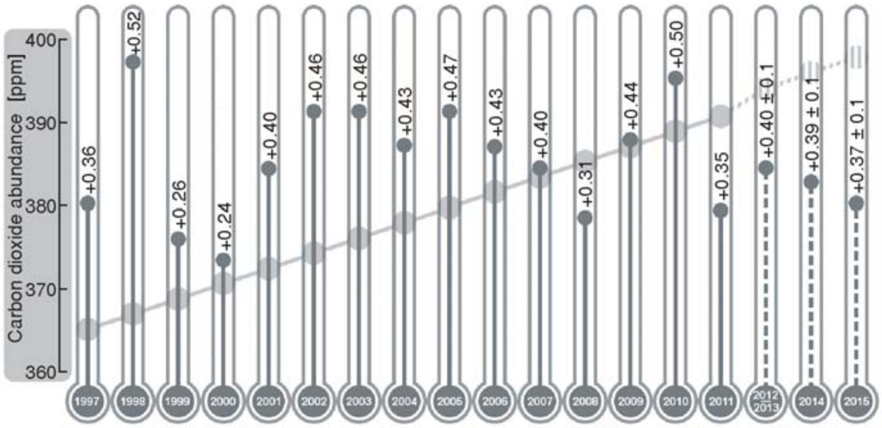

Figure 2. The trend of both the annual average of the global temperature (with respect to the average temperature for the time interval 1961-1990) (data are taken from [16]) and the CO_2 concentration

25-28 because the Sun is moving to the Grand Minimum. Gradual consumption of the solar energy accumulated by the Ocean during the whole XX century will to begin decrease of global temperature after 20 ± 8 years due to the long-term negative average annual balance of the energy incoming and emitted by the Earth into space. As a result should expect the beginning of a stable temperature decrease and of the epoch of the Little Ice Age after the maximum phase of the solar cycle 24 approximately since the end of 2014. The direct impact of the TSI variations on the climate changes is always additionally (with some time-lag) enhanced due to the secondary feedback effects: non-linear changes in Bond albedo (additional changes of TSI fraction being absorbed) and opposite changes in the concentration of greenhouse gases in the atmosphere – additional variations of the greenhouse effect influence. The Bond albedo increases up to the highest level during a deep cooling and decreases to the minimum during a warming, while the concentration of greenhouse gases in the atmosphere varies inversely since their variations are mostly defined by the temperature of the Ocean. Variations in the parameters of the Earth's surface and atmosphere generate successive non-linear changes in the temperature due to multiple repetitions of such causal cycle of the secondary feedback effects, even if the TSI subsequently remains unchanged over a certain period of time, as in the late 20th century. The subsequent increase of the Bond albedo (in particular, because of increasing surface of snow and ice coverage) and decrease in the content of greenhouse gases (mostly water vapor in the surface air, as well as CO_2 and other gases) in the atmosphere due to cooling will lead to an additional reduction of the absorbed portion of solar energy and reduce the influence of the greenhouse effect. These changes will lead to a chain of recurrent drops in the Earth's temperature, which can be comparable to or surpass the influence of the direct effect of the TSI decrease in a bicentennial cycle. The start of the Grand Minimum of TSI is anticipated approximately in cycle 27 ± 1 approximately in 2043 ± 11 and the beginning of the phase of deep cooling of the 19th Little Ice Age (of the Maunder Minimum type) in the past 7,500 years approximately in 2060 ± 11, with possible duration of 45-65 years (fig. 3).

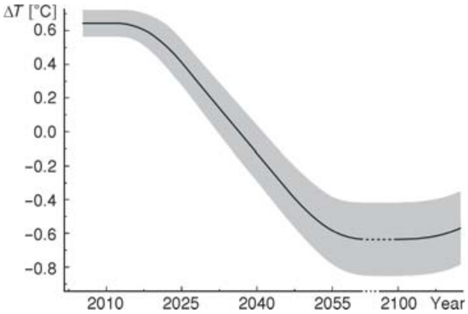

Figure 3. The prognosis of natural climate changes for the next hundred years

Even insignificant long-term TSI variations may have serious consequences for the climate of the Earth and other planets of the Solar System. Warming on the Mars [18] and other planets was observed in the 20th century practically simultaneously, that indicated the season of *solar summer* and alternation of climate conditions throughout the Solar System. By analogy with the seasons on the Earth there is also a similar alternation of climatic conditions in the Solar System, dictated by the quasi-bicentennial cycle variation of the TSI. From this point of view, after the maximum phase of solar cycle 24 (approximately at the end of 2014), after the season of *solar summer* in our Solar System as a whole we expect beginning of a season *solar autumn*, and then, approximately in 2060 ± 11, beginning of a season of *solar winter* of the quasi-bicentennial solar cycle.

Sensitivity of climate to the carbon dioxide abundance drops with the increase of water vapor content

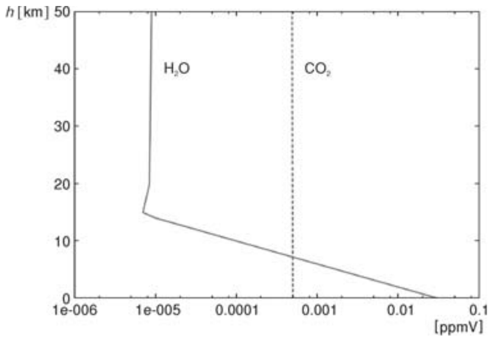

Figure 4. The changes in the content of water vapor and CO_2 with height [19]

Water plays an essential role in the greenhouse effect. The volume concentration of the water vapor in the atmosphere in contrast to that of CO_2 strongly depends on the height (fig. 4). The water vapor has its maximum concentration in the surface layer. Long-term small rise of TSI leads to increase of a temperature which according to the Clausius-Clapeyron relation results leads to increase of water evaporation rate. This leads to substantial changes in the transfer of thermal flow of long wave radiation of the Earth's surface by the water vapor. As a result, the climate sensitivity to increasing content of carbon dioxide decreases with significant growth of water vapor concentration in the surface layer. Negligible effect of the human-induced carbon dioxide emission on the atmosphere has insignificant consequences.

Convection, evaporation and condensation together with the greenhouse effect participates in the transfer of thermal flow the Earth's surface

As early as in 1908 Wood made two identical boxes (mini-greenhouses) of the black cardboard: one of them was covered with a glass plate, while another – with the plate made of rock salt crystals which are almost transparent in the infrared part of the spectrum [20]. The temperature in both green-houses simultaneously reached ~54.4 °C. However, the plate made of rock salt is transparent at long wavelengths and, according to the commonly adopted theory of the greenhouse effect this cover should not produce it at all. Wood is established that in the greenhouse, where the heat is blocked from all sides and there is no air exchange with the atmosphere, the radiative component is negligibly small compared to the convective component. Heat accumulated in the greenhouse only slightly depends on its cover transparency to the infrared radiation. Thus convection, evaporation and condensation together with the greenhouse effect participate in the transfer of thermal flow of long wave radiation of the Earth's surface to the atmosphere.

Powerful volcanic eruptions lead only to short-term cooling periods

The volcanic eruptions increase the number of solid particles and gases in the lower stratosphere. Their scattering, screening and partial absorption of the incident solar radiation decrease the portion of TSI reaching the surface which can result in short-term climate cooling. However, these changes are not long-term because of the limited lifetime of volcanic particles in the atmosphere. The atmosphere is able to self-cleaning and gradual increase of its transparency up to its previous level over a time span from 6 months to a few years. The role of volcanic eruptions in climate variations cannot be long-term and determinant.

Future deep cooling can become one of the major risks in the development of hydrocarbon deposits in the Arctic

Intense interest in the development of the Arctic is stimulated by UN experts predicted further melting of Arctic ice due to warming. This could open up new areas of the shelf, making them available for deep-water drilling. However due to the beginning of the phase of deep cooling of the Little Ice Age in the middle of this century would be almost impossible to exploit offshore fields, pump oil and gas in the tens to hundreds of kilometers from the coast. In the future a fuel and energy complex will not be of *easy* oil and gas in the Arctic. So that long-term forecasts portend to fuel and energy complex even more complex difficult working conditions and not only in the Arctic.

Physical interconnection between the duration and power of the 11-year solar cycle

Previously, it has been found that the duration of the 11-year solar cycle (fig. 5) is a possible indicator of climate change, because there is a correlation between the duration of the cycle and the Earth's surface temperature in the Northern Hemisphere [21]. We try to

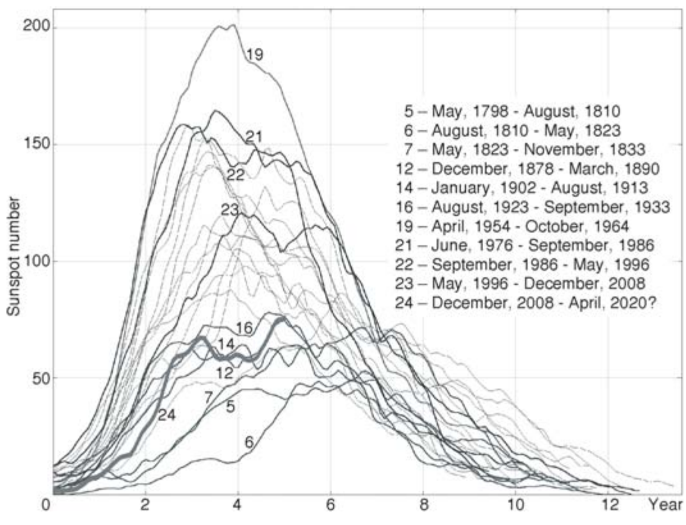

Figure 5. Cycles 1-24 of the solar activity (data are taken from [15])

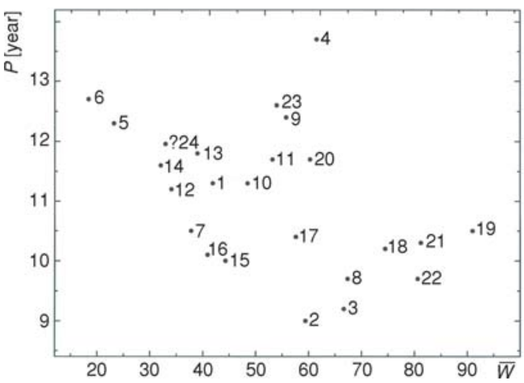

Figure 6. Dependence power of the 11-year cycle solar activity $\overline{W}$ from its duration P. The numbers refer to solar cycles

establish why it could happen. For this purpose, we have constructed a graph showing interconnections between the duration of solar cycle and its power $\overline{W}$ – the average level of the index of solar activity throughout the cycle (fig. 6).

Average level of the index of solar activity throughout the cycle is $\overline{W} = \Sigma W\Delta t/\Sigma\Delta t$. Here W sunspot number, Δt – the time interval between successive observations throughout the cycle. Figure 6 is showing physical dependence power of the 11-year cycle solar activity from its duration. It is obvious that such an interconnection exists also between the cycle TSI variation and its duration. Therefore, the previously observed dependence of [21] can be easily explained of established by us existence interconnections between the duration of the 11-year solar cycle and its power. Only the average weighted level of the cycle both solar activity and TSI may allow objectively and quantitatively determine the average level of the relative power of the 11-year cycle, as well as to predict their impact on the processes occurring in the Sun-Earth system.

Conclusions

Long-term deviation of the average annual energy balance of the Earth from the equilibrium state (excess of incoming TSI accumulated by oceans or its deficiency) practically determines a corresponding change of the energy state of the Earth-atmosphere system and, hence, a forthcoming climate variation and its amplitude. Long-term cyclic variations of the total energy of solar radiation entering the upper layers of the Earth's atmosphere are the main fundamental cause of corresponding climate variations. The Sun is controlling and practically totally determining the mechanism of quasi-bicentennial cyclic alternations of climate changes from warming to Little Ice Age and set corresponding time-scales for practically all physical processes taking place in the Sun-Earth system. The current long practically stable levels of World Ocean and of temperature additionally reflects the current state of global warming during past 17 years, which are under the direct control of the quasi-bicentennial decrease of TSI. Approximately in the end of 2014 we begin the descent into 19$^{\text{th}}$ Little Ice Age in the past 7,500 years [22, 23]. Early understanding of reality of the upcoming global cooling and physical mechanisms responsible for it directly determines a choice of adequate and reliable measures which will allow the mankind, in particular, population of countries situated far from the equator, to adapt to the future global cooling. Pictures of the frozen Thames and a historical study of the effects of recently deep cooling in the period of Maunder minimum are warning about the serious alarm to the future of energy security humanity. Mankind since the middle of current century will meet with the same very difficult times as well as of change for the worse conditions for creating material and financial resources of the society. The most reasonable way to fight against the coming Little Ice Age is to work out a complex of special steps aimed at support of economic growth and energy-saving production in order to adapt mankind to forthcoming period of deep cooling which will last approximately until the beginning the 22$^{\text{nd}}$ century. The mathematical modeling of climate processes without its a fundamental modernization and also without the use of the quasi-bicentennial variations of the TSI will not allow to obtain significantly more reliable results [24]. The most reliable method for accurately predicting the depth and time of the coming Little Ice Age is to study the long-term variations of the effective global parameter: an average annual energy balance in the budget of the Earth-atmosphere system in the income and expenditure of thermal power.

References

[1] Herschel, W., Observations Tending to Investigate the Nature of the Sun, in order to Find the Causes or Symptoms of its Variable of Light and Heat; with Remarks on the Use that May Possibly Be Drawn from Solar Observations, *Phil. Trans. R. Soc., 91* (1801), Apr., pp. 265-318
[2] Eddy, J. A., The Maunder Minimum, *Science, 192* (1976), 4245, pp. 1189-1202
[3] Borisenkov, E. P., *et al*., *Climate Oscillations of the Last Millennium* (Kolebaniya Klimata za Poslednee Tisyaceletie, in Russian), Gidrometeoizdat, Leningrad, SSSR, 1988
[4] Abdussamatov, H. I., Bicentennial Decrease of the Solar Constant Leads to the Earth's Unbalanced Heat Budget and Deep Climate Cooling, *Kinematics and Physics of Celestial Bodies, 28* (2012), 2, pp. 62-68
[5] Abdussamatov, H. I., *et al.*, Modeling of the Earth's Planetary Heat Balance with Electrical Circuit Analogy, *J. Electromagn. Anal. Appl., 2* (2010), 3, pp. 133-138
[6] Milankovitch, M., *Canon of Insolation and the Ice Age Problem. With Introduction and Biographical Essay by Nikola Pantic (*Kanon der Erdbestrahlungen und seine Anwendung auf das Eiszeitenproblem, in German), Alven Global, 1998
[7] Petit, J. R., *et al.*, Climate and Atmospheric History of the Past 420,000 Years from the Vostok Ice Core, Antarctica, *Nature, 399* (1999), 6735, pp. 429-436
[8] Pedro, J. B., *et al.*, Tightened Constraints on the Time-Lag between Antarctic Temperature and CO_2 During the Last Deglaciation, *Clim. Past., 8* (2012), 4, pp. 1213-1221
[9] Nigmatulin, R. I., The Ocean: Climate, Resources, and Natural Disasters, *Herald of the Russian Academy of Sciences, 80* (2010), 4, pp. 338-349
[10] Abdussamatov, H. I., About the Long-Term Coordinated Variations of the Activity, Radius, Total Irradiance of the Sun and the Earth's Climate, *Proceedings*, IAU Symposium, Cambridge, UK, 2004, Vol. 223, pp. 541-542
[11] Abdussamatov, H. I., Long-Term Variations of the Integral Radiation Flux and Possible Temperature Changes in the Solar Core, *Kinematics and Physics of Celestial Bodies, 21* (2005), 6, pp. 328-332
[12] Abdussamatov, H. I., Decrease of the Solar Radiation Flux and Drastic Fall of the Global Temperature on the Earth in the Middle of the XXI Century, *Izv. Krym. Astrofiz. Observ., 103* (2007), 4, pp. 292-298
[13] Abdussamatov, H. I., Optimal Prediction of the Peak of the Next 11-Year Activity Cycle and of the Peaks of Several Succeeding Cycles on the Basis of Long-Term Variations in the Solar Radius or Solar Constant, *Kinematics and Physics of Celestial Bodies, 23* (2007), 3, pp. 97-100
[14] Frohlich, C., Solar Constant, 2013, www.pmodwrc.ch/pmod.php?topic=tsi/composite/SolarConstant
[15] ***, SIDC – Solar Influences Data Analysis Center, 2014, http://sidc.oma.be/sunspot-data/
[16] ***, HadCRUT3, http://www.metoffice.gov.uk/research/monitoring/climate/surface-temperature
[17] Shapiro, A. I., *et al*., A New Approach to the Long-Term Reconstruction of the Solar Irradiance Leads to Large Historical Solar Forcing, *Astron. Astrophys., 529* (2011), A67, pp. 1-8
[18] ***, Odyssey Studies Changing Weather and Climate on Mars. The Changing South Polar Cap of Mars: 1999-2005. MGS MOC Release No. MOC2-1151, 13 July 2005. http://www.msss.com/mars_images/moc/2005/07/13/
[19] Abdussamatov, H. I., The Sun Dictates the Climate, Fourth International Conference on Climate Change (ICCC-4), ppt-presentation, Chicago, USA, 2010, http://climateconferences.heartland.org/habibullo-abdussamatov-iccc4-2/
[20] Wood, R. W., Note on the Theory of the Greenhouse, *Philosophical Magazine, 17* (1909), pp. 319-320
[21] Friis-Christensen, E., Lassen, K., Length of the Solar Cycle: an Indicator of Solar Activity Closely Associated with Climate, *Science, 254* (1991), 5032, pp. 698-700
[22] Abdussamatov, H. I., 2014 – the Beginning of the New Little Ice Age, Ninth International Conference on Climate Change (ICCC-9) (2014), ppt-presentation, Las Vegas, Nev., USA,

http://climateconferences.heartand.org/habibullo-abdussamatov-iccc9-panel-7/?utm_source=rss&utm_medium=rss&utm_campaign=habibullo-abdussamatov-iccc9-panel-7
[23] Abdussamatov, H. I., *The Sun Dictates the Climate of the Earth* (Solnce Diktuet Klimat Zemli – Russian), Logos, Sankt Petersburg, Russia, 2009
[24] Abdussamatov, H. I., *Grand minimum of the total solar irradiance leads to the Little Ice Age* (Glubokiy Minimum Moshnosti Solnechnogo Izluceniya Privedet k Malomu Lednikovomu Periodu, in Russian), Nestor-Istoriya, Sankt Petersburg, Russia, 2013

Paper submitted: September 2, 2014
Paper revised: November 4, 2014
Paper accepted: December 2, 2014