**The 24 PowerPoint slides from the presentation by astrophysicist**

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**at the 9th International Conference on Climate Change on 8 July 2014**

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

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

or by the difference between the portion of energy of the TSI absorbed by the Earth and its longwave radiation into space

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

The increment of the Earth's effective temperature $\Delta T_{ef}$ due to the increments of the TSI $\Delta S_{\odot}$ and Bond albedo $\Delta A$ is determined by

$$\Delta T_{ef} = [\Delta S_{\odot}(1 - A - \Delta A) - \Delta A S_{\odot}]/(16\sigma T_{ef}^3).$$

Here $\varepsilon$ is the emissivity of the Earth, $\sigma$ is the Stefan-Boltzmann constant, $T_p$ is the planetary thermodynamic temperature.

*Abdussamatov H.I.* **Grand Minimum of the Total Solar Irradiance Leads to the Little Ice Age.** St. Petersburg. 2013. –246 p.

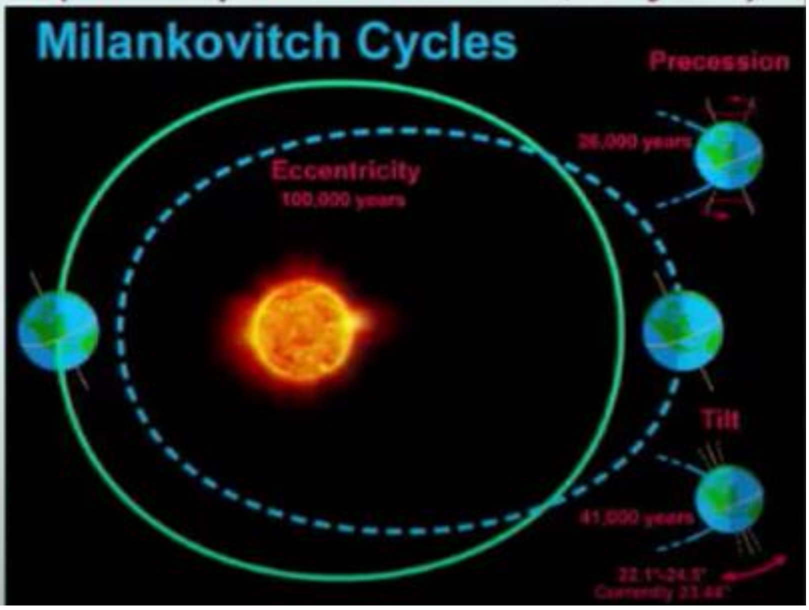
Slide 1

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 XIV-XIX centuries,** which was interrupted by several quasi-bicentennial cycles of warming. Deep cooling associated with **Wolf** (~1280-1350), **Spörer** (~1450-1550), **Maunder** (~1645-1715) and **Dalton** (~1790-1820) Grand Minima **can't be regarded as a single Little Ice Age.**

Slide 2

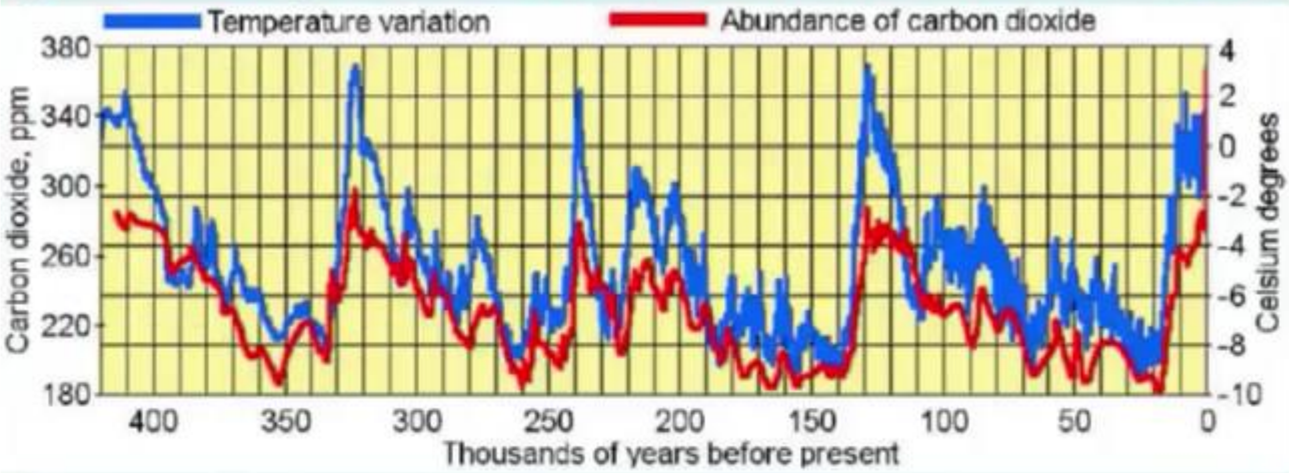
At the same time, **more long-term variations** of the average annual TSI entering the Earth's upper atmosphere due to changes in both the shape of the Earth's orbit, inclination of the Earth's axis relative to its orbital plane, and precession, known as the astronomical Milankovitch cycles, **together** with the subsequent **nonlinear** 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 warmings to the Big Glacial Periods, as well as of atmospheric concentration of the greenhouse gases.




Slide 3

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 the astronomical Milankovitch cycles. According to the ice core data drilled near Vostok site, Antarctica:




The peaks of the carbon dioxide concentration have never preceded the warmings, but on the contrary always took place 800 ± 400 years after them, being their consequences. Since according to **Henry law, warm liquid absorbs less gas** and hence more carbon dioxide remains in the atmosphere. **There is no evidence that carbon dioxide is a major factor in the warming.** Increased concentration of the atmospheric carbon dioxide stimulates the plant growth.

Slide 4

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 vapour and carbon dioxide from the Ocean and land to the atmosphere ($M_{in}$) and from the atmosphere ($M_{out}$) to the Ocean and land exceeds many times the anthropogenic discharges of these substances into the atmosphere ($M_{ant}$):

***Nigmatulin R.I.*** **(Director of Shirshov Institute of Oceanology of RAS)** ***The Ocean: climate, resources, and natural disasters // Herald of the Russian Academy of Sciences.*** 2010. ***80.*** 338-349.

The overall content of the carbon dioxide in the Ocean is 50 times higher than in the atmosphere, and even a weak “breath” of the Ocean can change dramatically the carbon dioxide level in the atmosphere.

Natural causes play the most important role in climate variations rather than human activity since **natural factors are substantially more powerful.**

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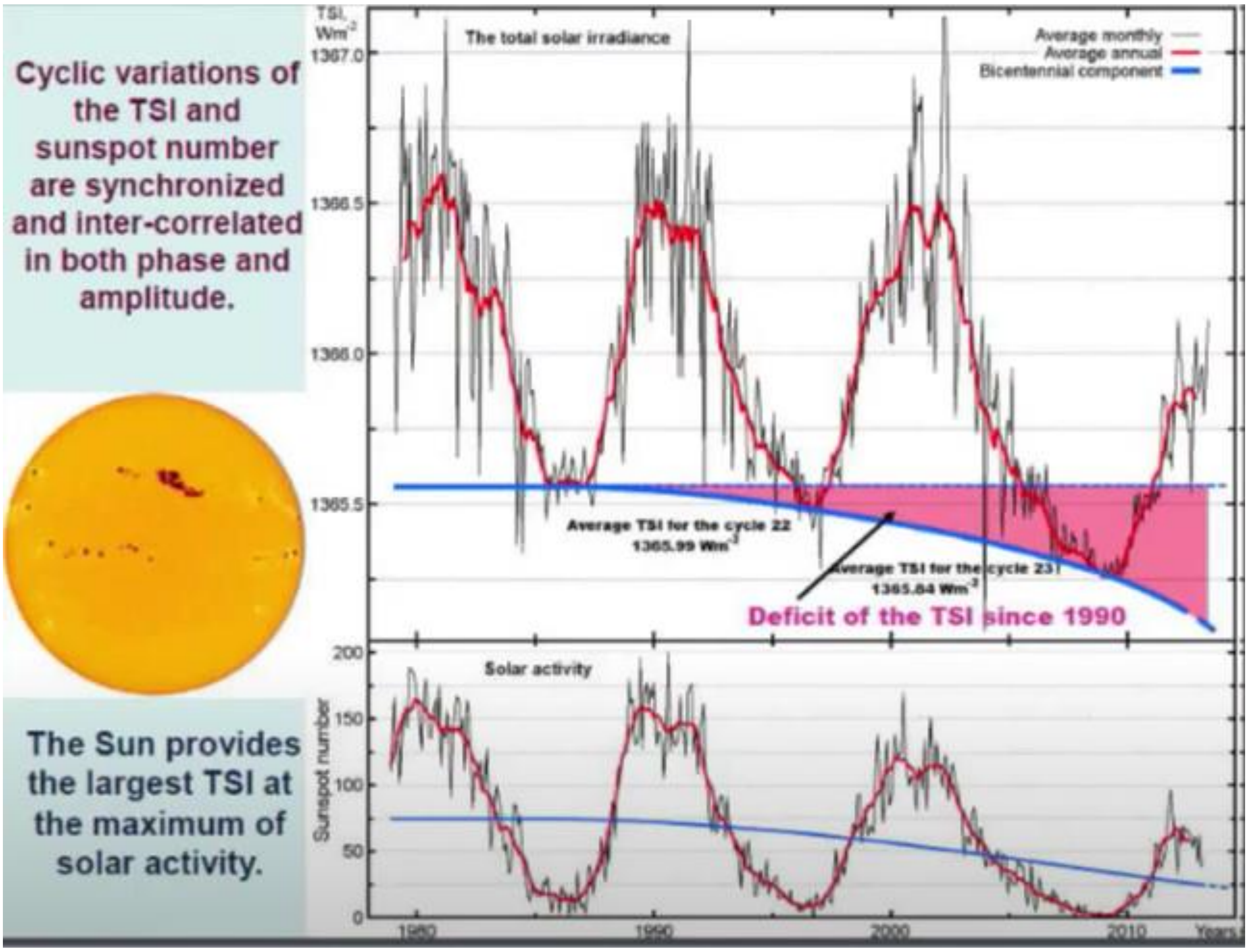


Slide 6

English astronomer **W. Herschel (1801)** 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. 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 *(American astronomer **J. Eddy**,1976)*.

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 *(Russian geophysicist **E. Borisenkov**, 1988)*.

Our studies have shown that a physical nature of these phenomena is directly connected with corresponding variations of TSI since cyclic variations of solar activity and TSI are synchronized and inter-correlated in both phase and amplitude.

Slide 7

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: nonlinear 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 nonlinear 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.

Slide 8

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 nonlinear secondary feedback influences) **are the main fundamental cause** of corresponding alternations of climate variations from global warmings to the Little Ice Ages and Big Glacial Periods.

**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.**

**Cyclical variations of the solar activity** being the accompanying phenomena of the physical processes occurring in the interior of the Sun **don't substantially affect both TSI and terrestrial climate.**

Slide 9

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 almost 0.7 $Wm^{-2}$ with respect to cycle 23.

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 $Wm^{-2}$/yr, while in the 23rd cycle it already became ~0.02 $Wm^{-2}$/yr. The current increasing rate of an average annual TSI decline is almost 0.1 $Wm^{-2}$/yr and this will continue in the 25th cycle. The observed trend of the increasing rate of TSI decline allows us to suggest that this decline as a whole will correspond to the analogous TSI decline of the period Maunder minimum.

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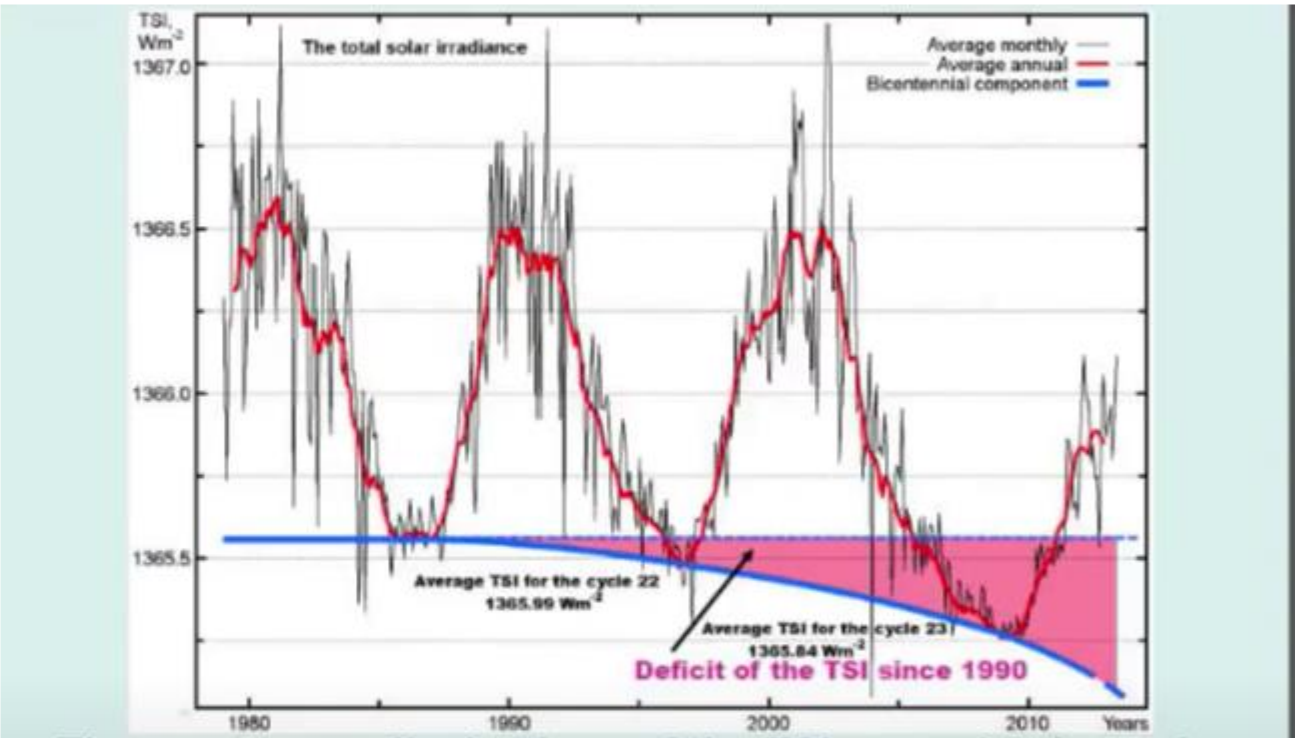



The average cyclical values of the TSI were also lower by ~0.15 $Wm^{-2}$ in the 23rd cycle than in the 22nd cycle.

The value of TSI at the minimum between 23/24 cycles (1365.27 ± 0.02 $Wm^{-2}$) was lower by ~0.23 and by ~0.30 $Wm^{-2}$ than at the minima between 22/23 and 21/22 cycles, respectively.

Slide 11

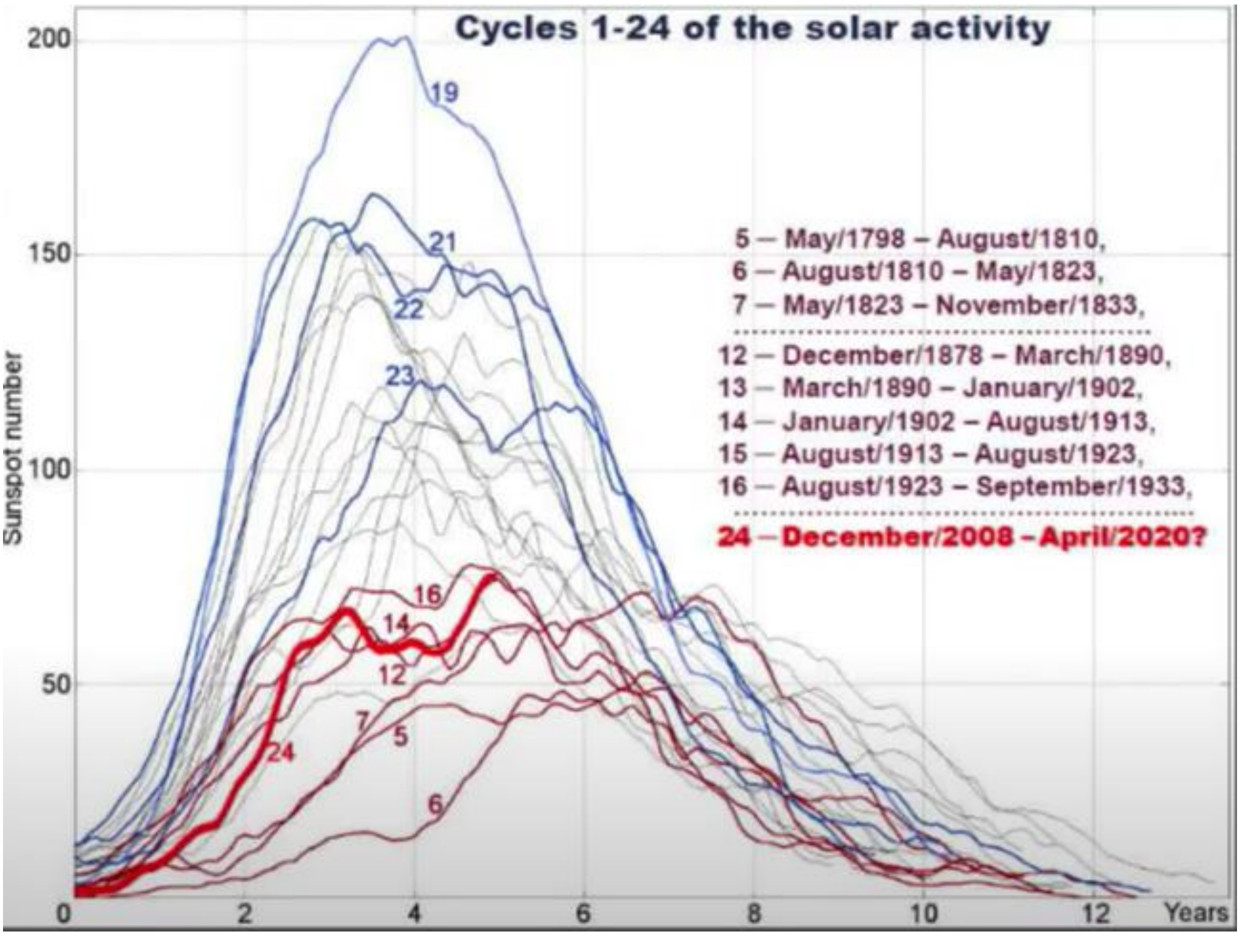
Observed decrease of the TSI portion absorbed by the Earth since 1990 **has not been compensated** by decrease of its average annual energy emitted into space which practically remains on the same high level during 20 ± 8 years due to thermal inertia of the Ocean.

The Earth will continue to have a negative energy balance in the future cycles 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 result in 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.

This will lead to the beginning of the epoch of the new Little Ice Age after the maximum phase of the solar cycle 24 approximately since the second half of 2014.

Slide 12

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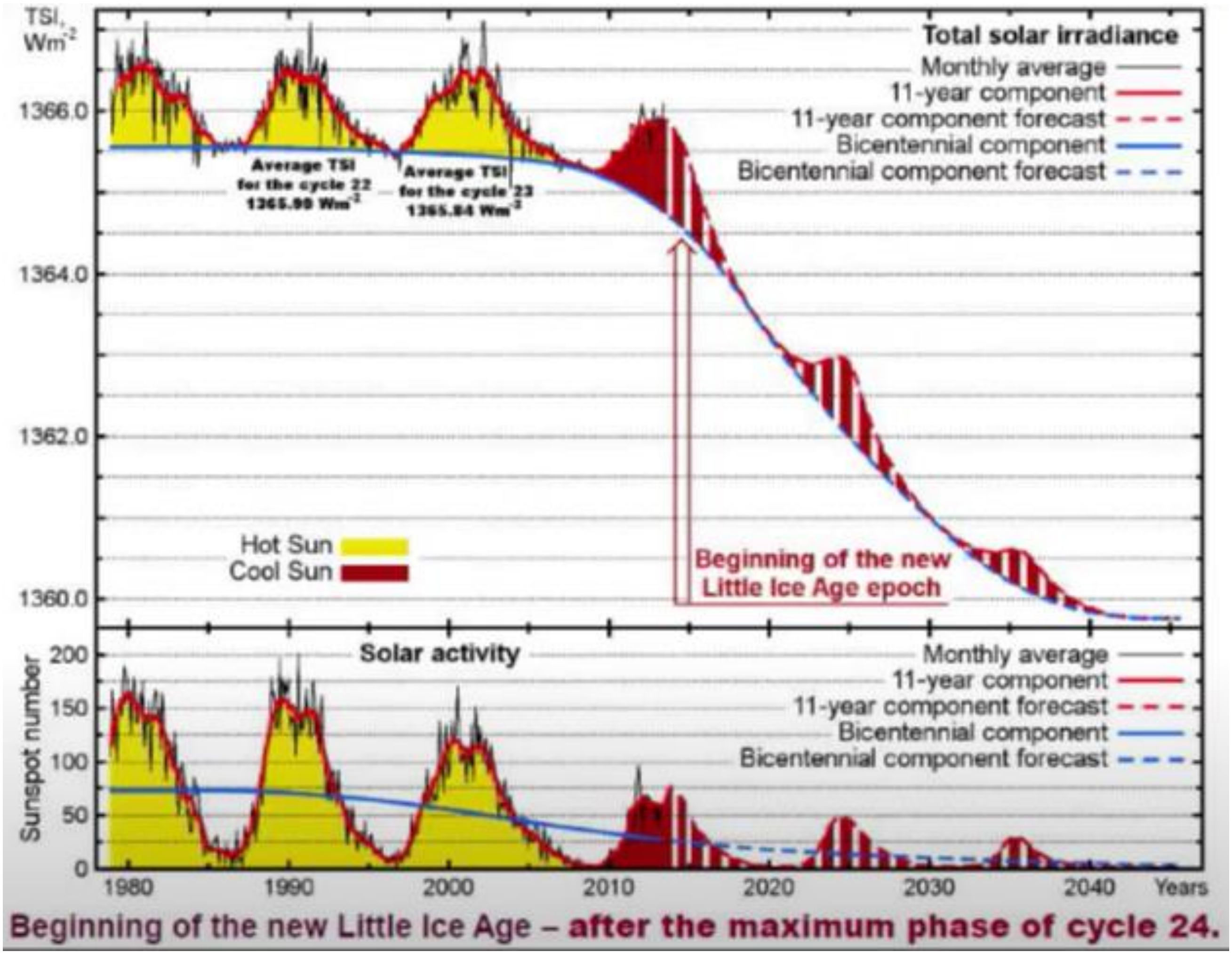


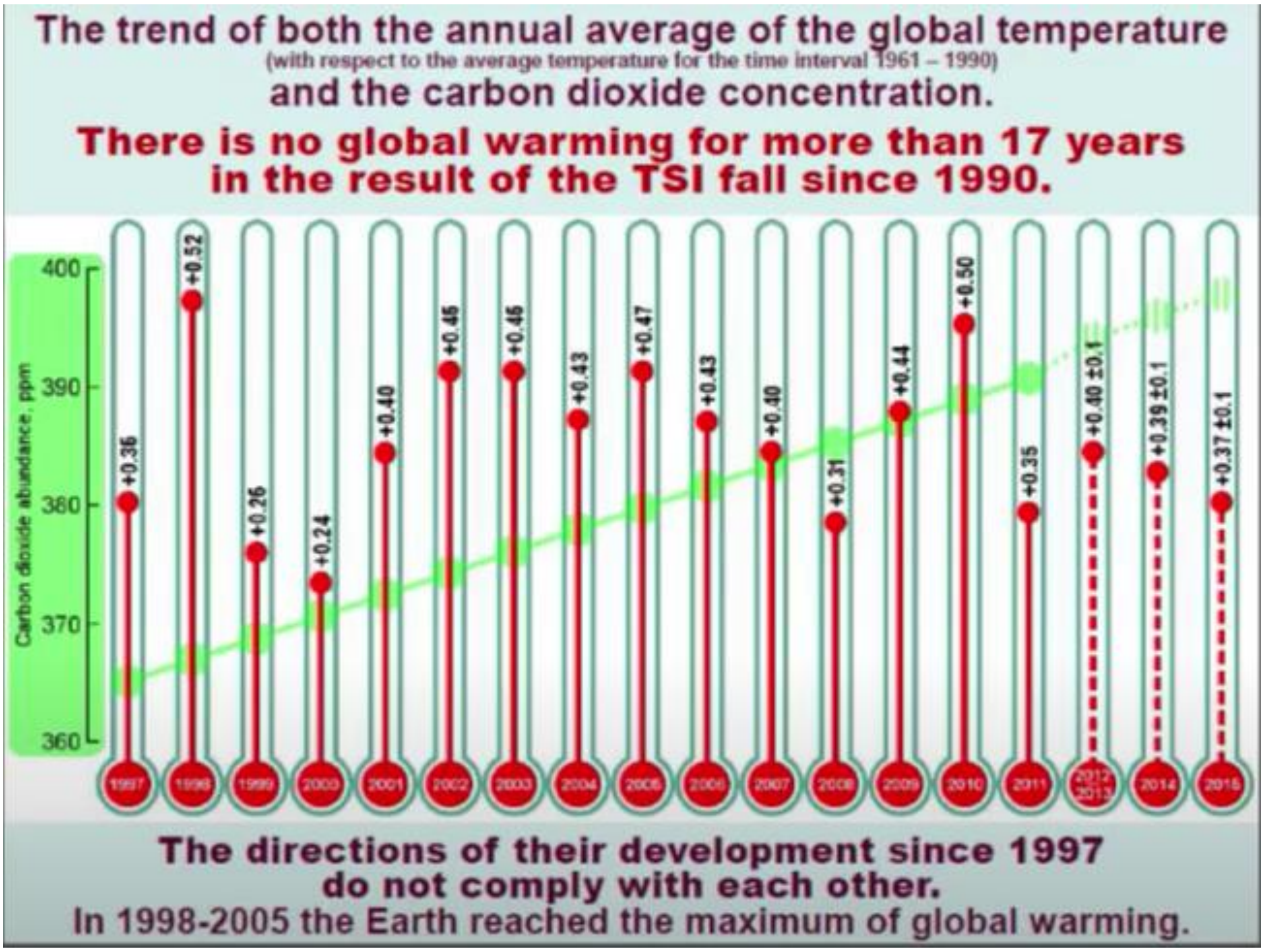

Slide 14

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 carbon dioxide 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 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.

Slide 15

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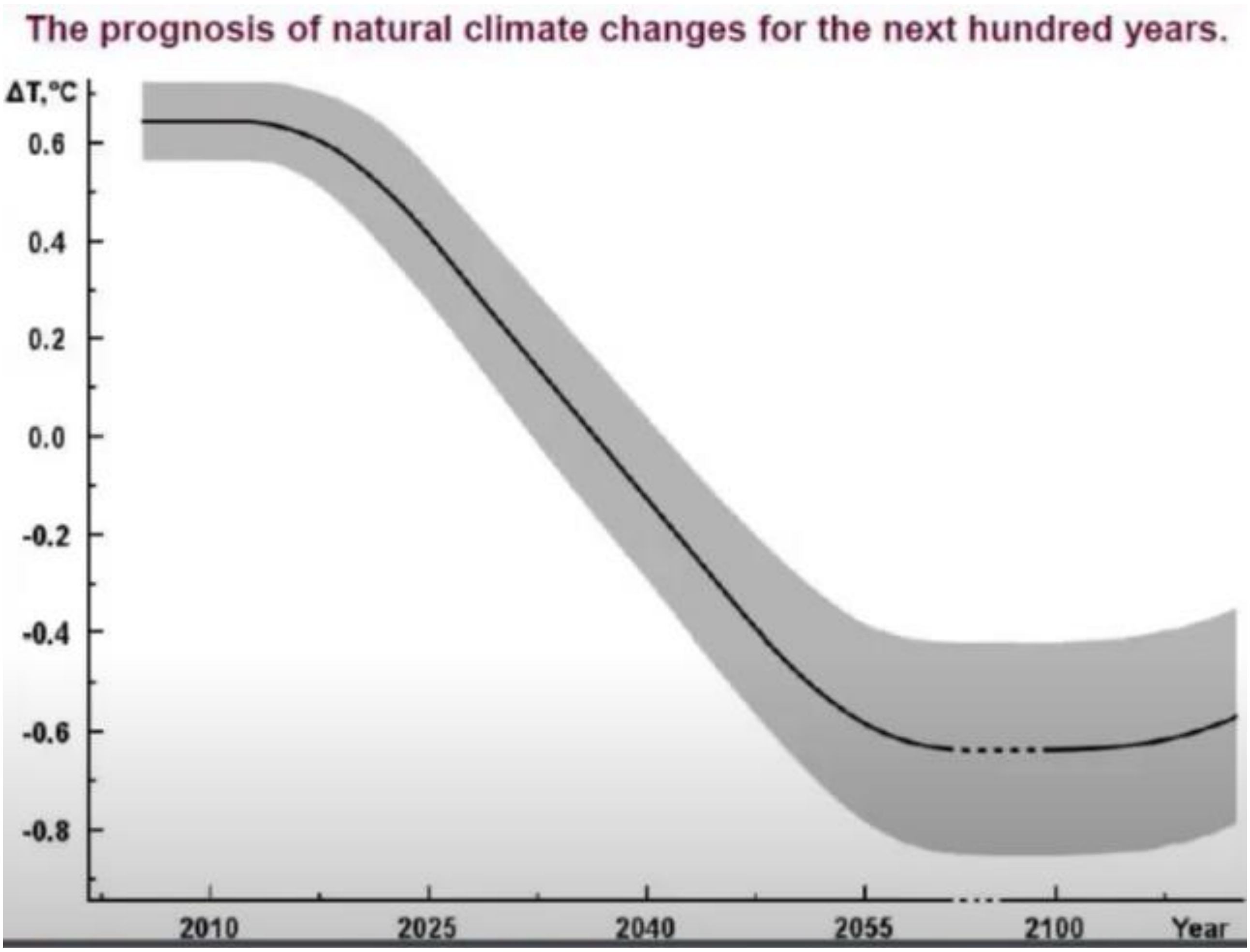



Slide 18

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 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.

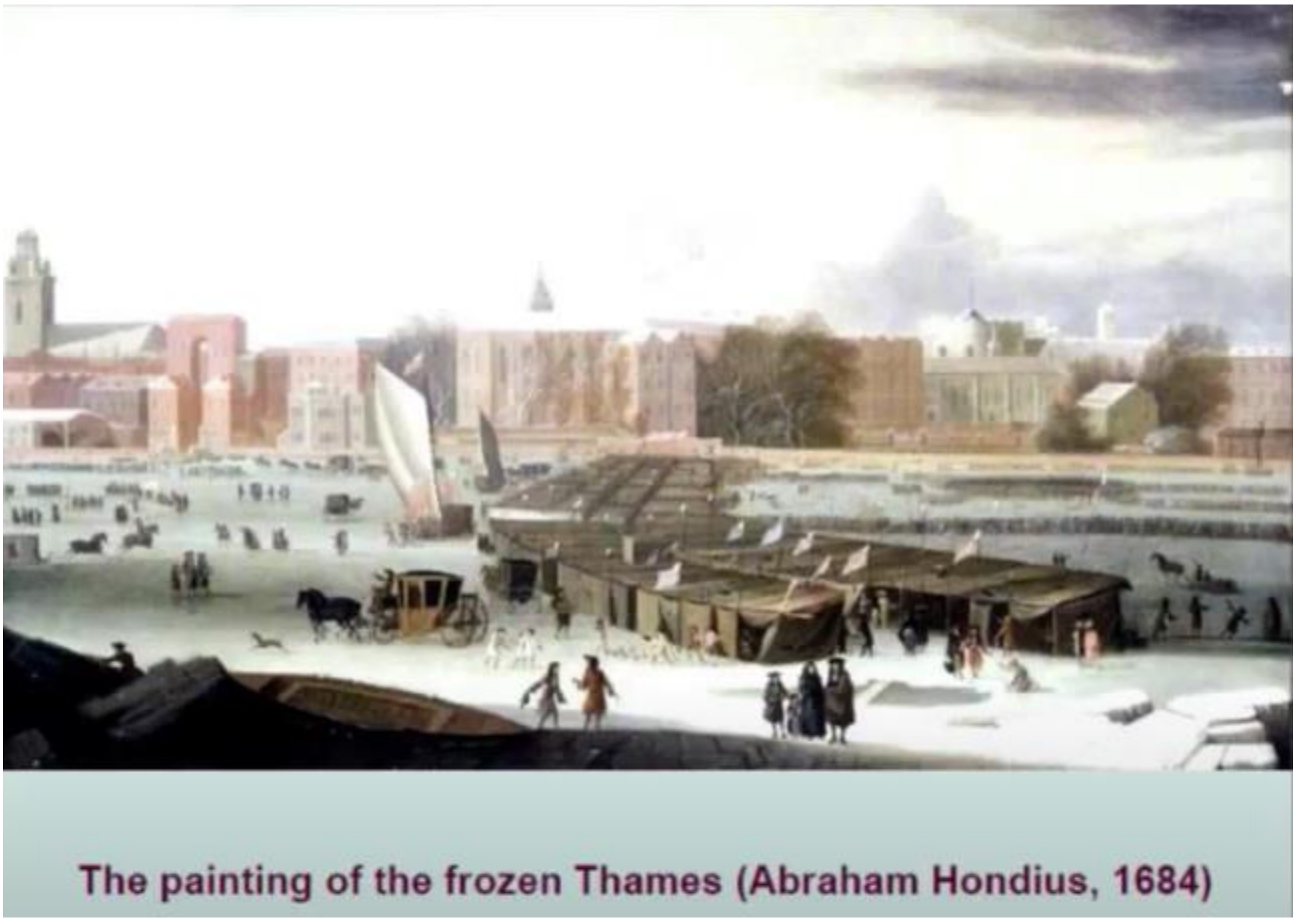
From this point of view, after the maximum phase of solar cycle 24 (approximately at the second half of 2014), after the season of **"solar summer“** in our Solar System as a whole we expect a season of **"solar autumn"**, and then, approximately in 2060 ± 11, the season of **"solar winter“** of the quasi-bicentennial solar cycle.

Geologists call past **warm epochs – optimums times, and cold times – dark ages,**
yet governments across the world are preparing only for warming.

Slide 19

The painting of the frozen Thames (Jan Griffier, 1683)

Slide 20

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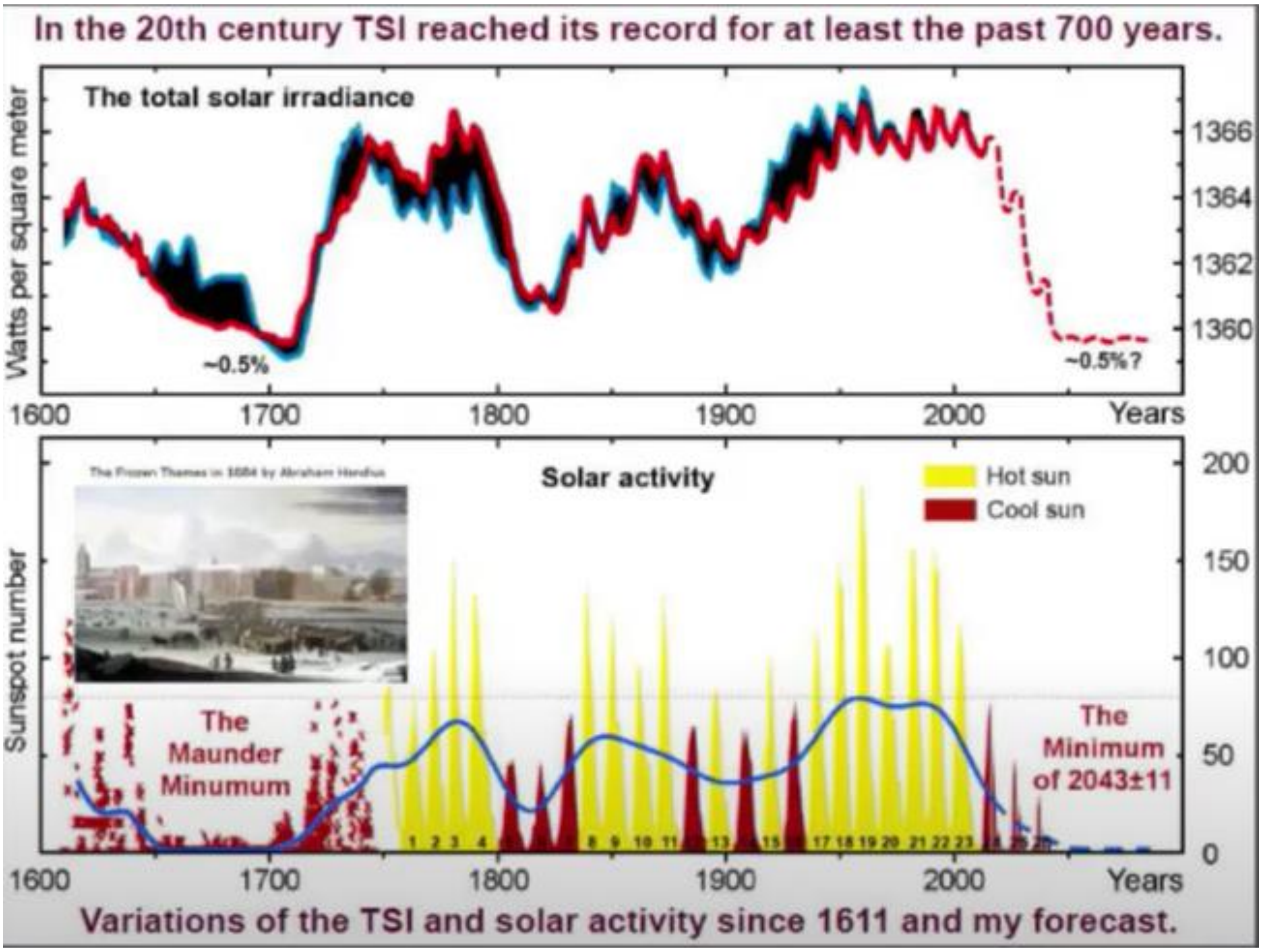



Slide 22

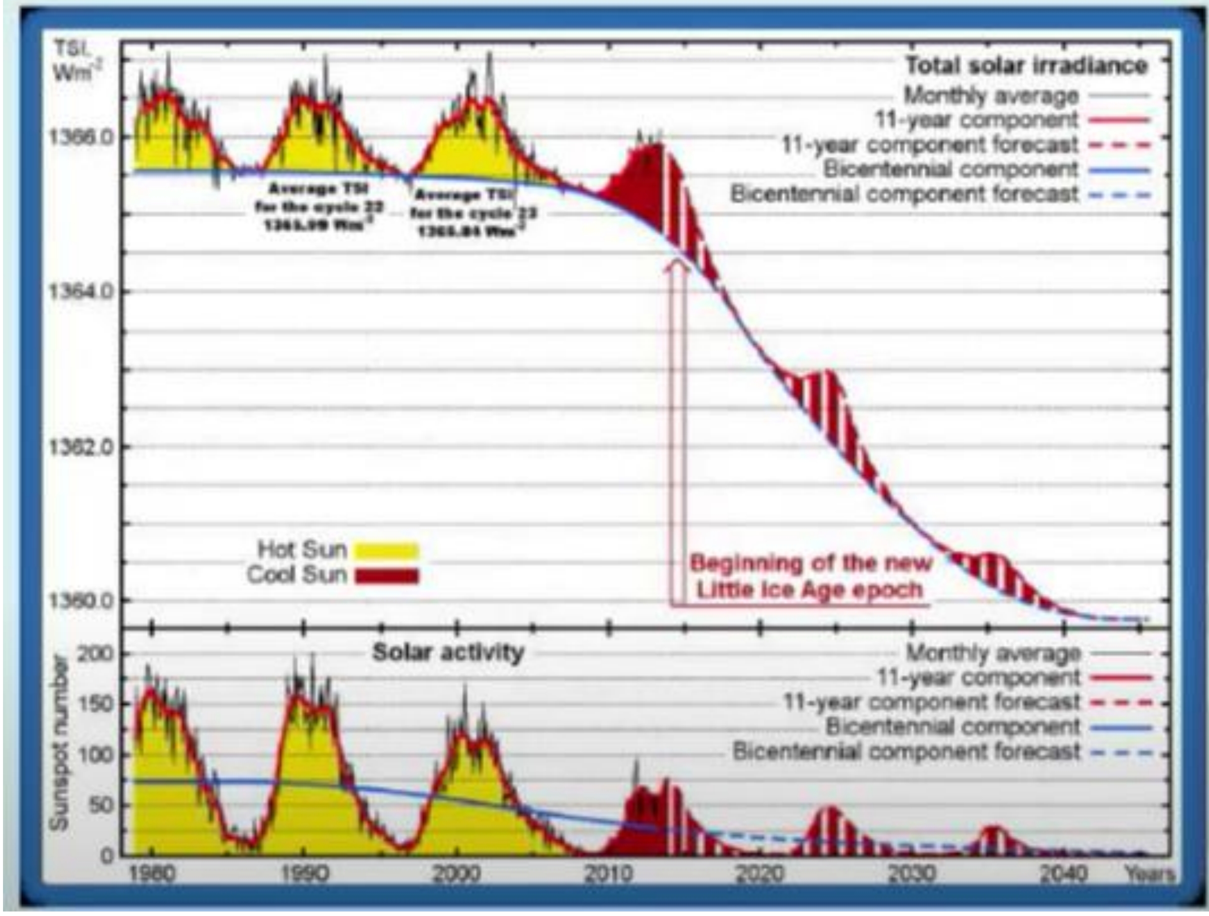
The use of practically **full identification of the climate changes with variations in the incoming solar energy** (taking into account their direct and subsequent secondary feedback influences) within a climate model provides a sufficiently precise reconstruction of climatic processes taking place in the past and in the nearest future.

**The Sun is the main factor controlling the climatic system and it is more powerful than abilities of human beings. The climate changes are beyond human control and are practically not connected with his activities.**

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 of the XXII century.

Slide 23

## Thanks for your attention




Slide 24