# 2014 – the beginning of the new Little Ice Age


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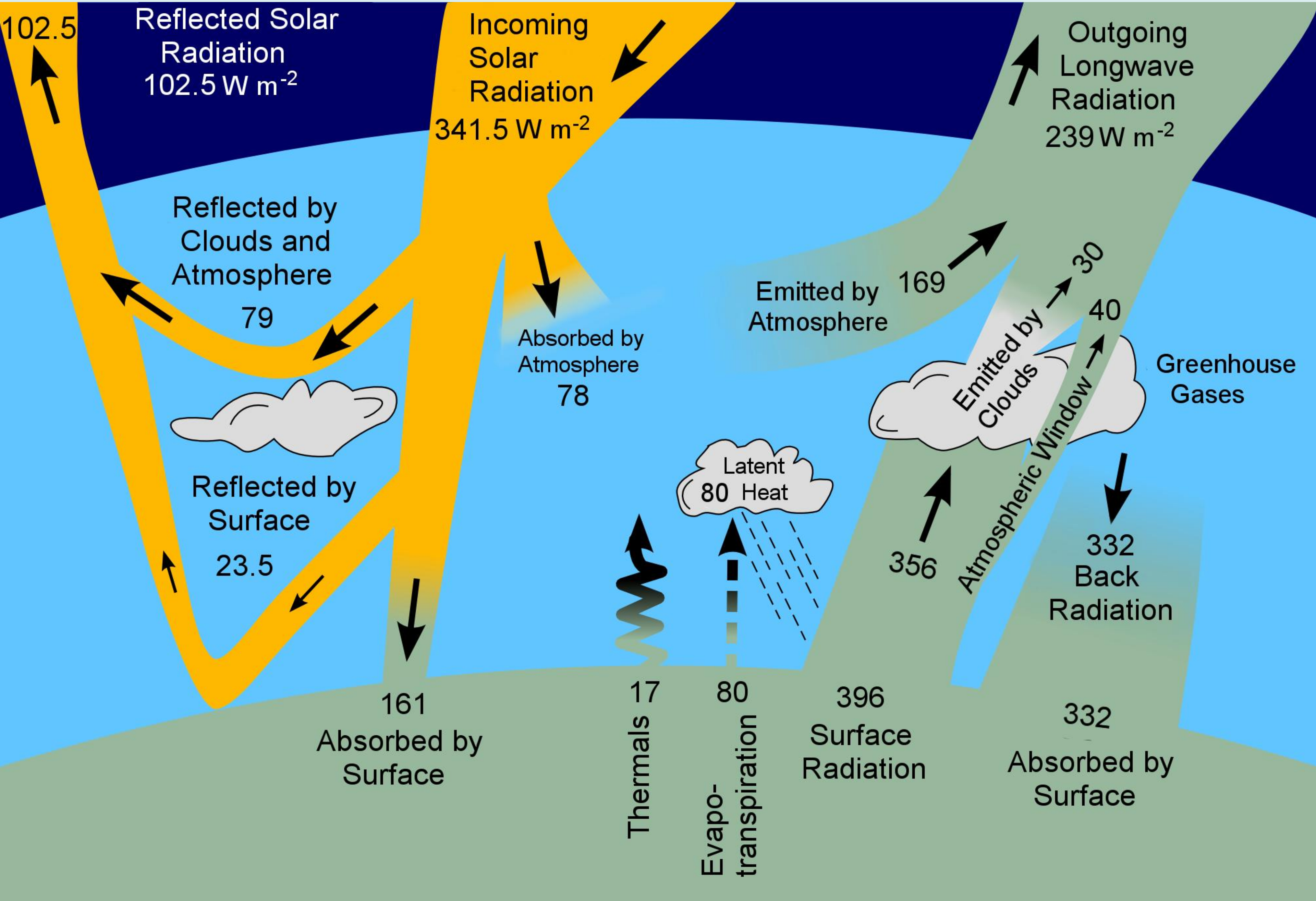
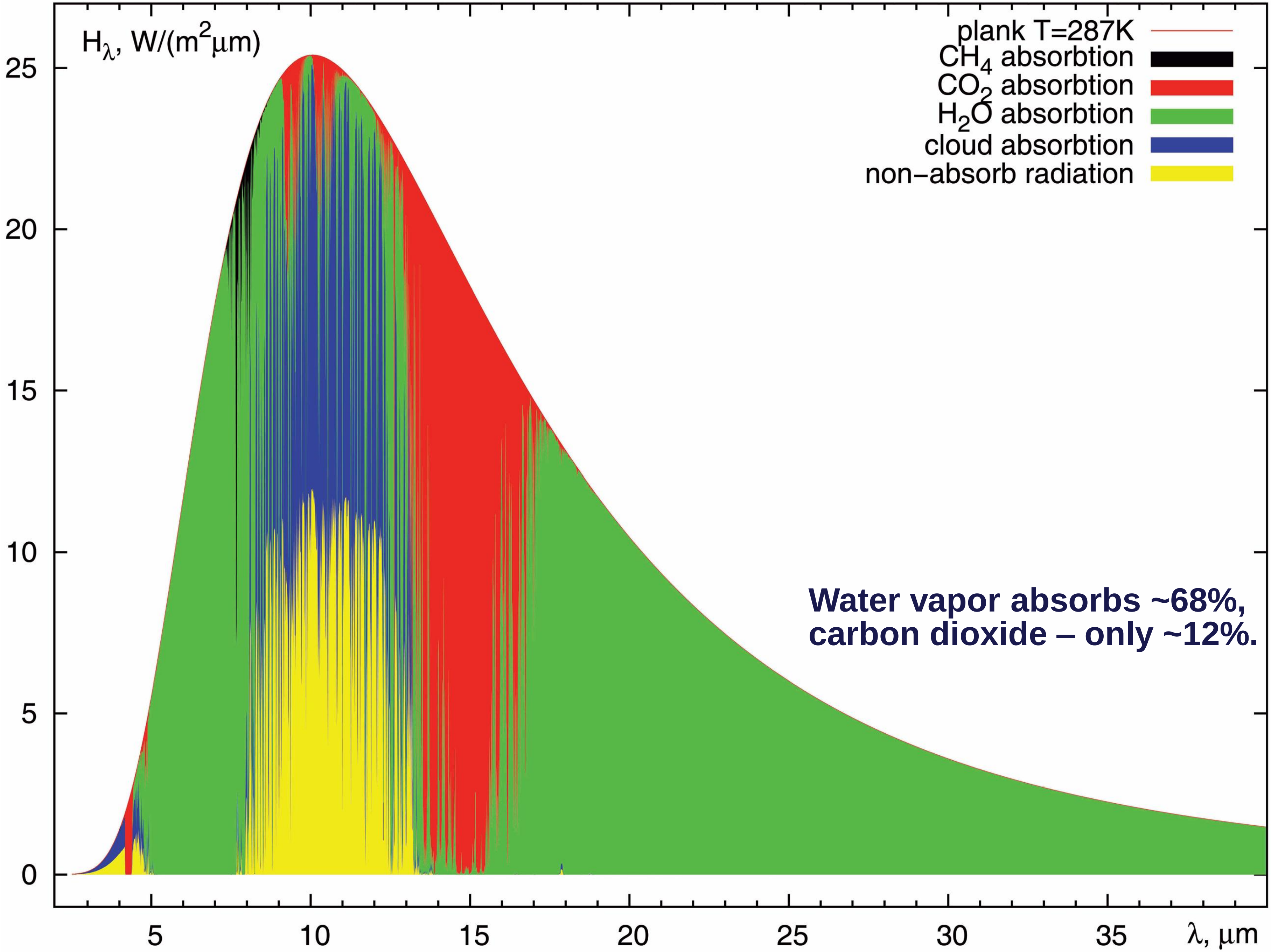
**The average annual energy balance of the Earth in the equilibrium state $E = 0$ (on the outer layers of the atmosphere) establishes the stability of climate.**






**The spectral density of the thermal flow longwave radiation of the Earth's surface.**

**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.

**Quasi-bicentennial cyclical variation of the TSI absorbed by the Earth remains uncompensated by the energy emission into space over the time interval which is controlled by the thermal inertia of the World Ocean (20 ± 8 year). That is why the debit and credit parts of the average annual energy balance of the Earth 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.**

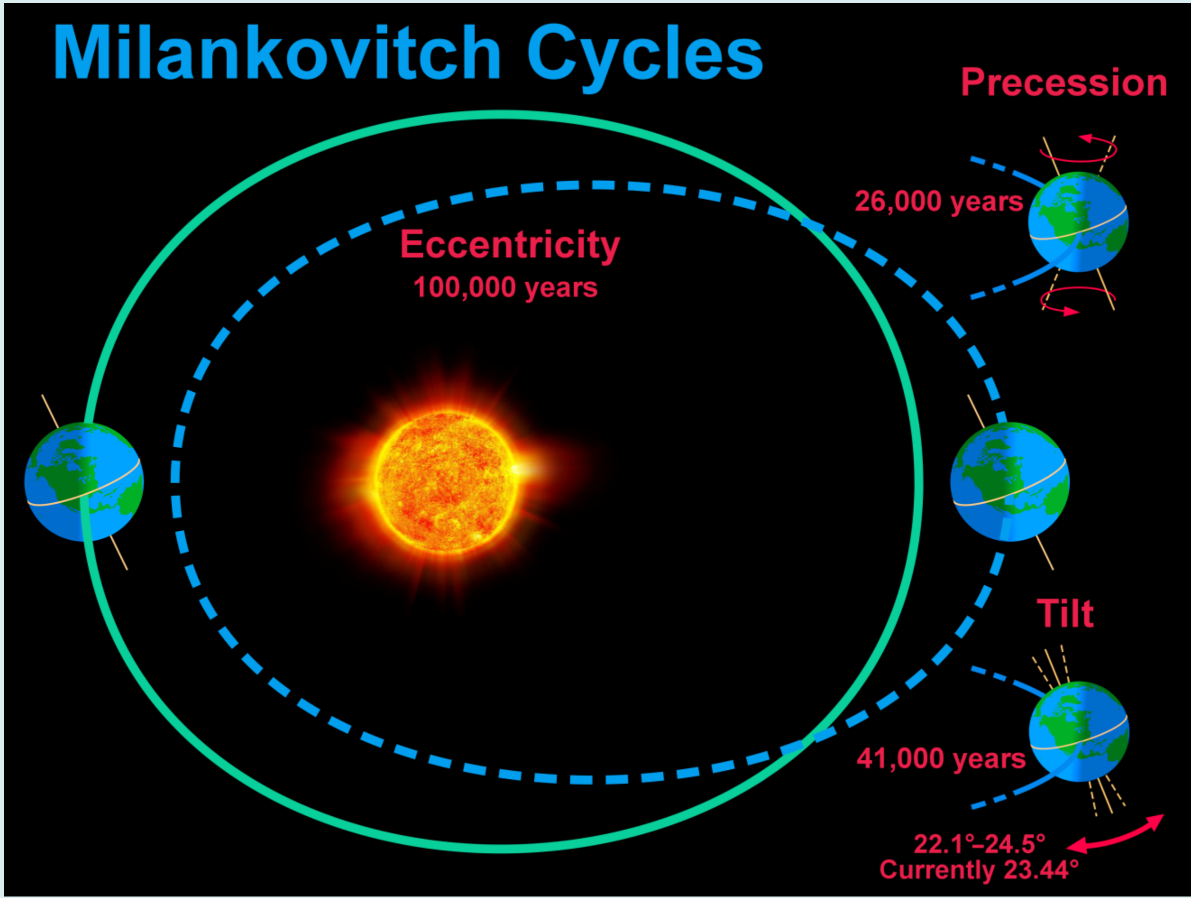
**As a result, the Earth will gradually warm up or cool down, respectively what imply an upcoming climate variation and its amplitude with account forecasted quasi-bicentennial variations of the TSI and the subsequent feedback effects (Bond albedo and greenhouse gases: $H_2O$, which is the most important, and $CO_2$).**

**That is why the Earth's climate will change in a quasi-bicentennial cycle every 200 ± 70 years from the global warmings to the Little Ice Ages.**

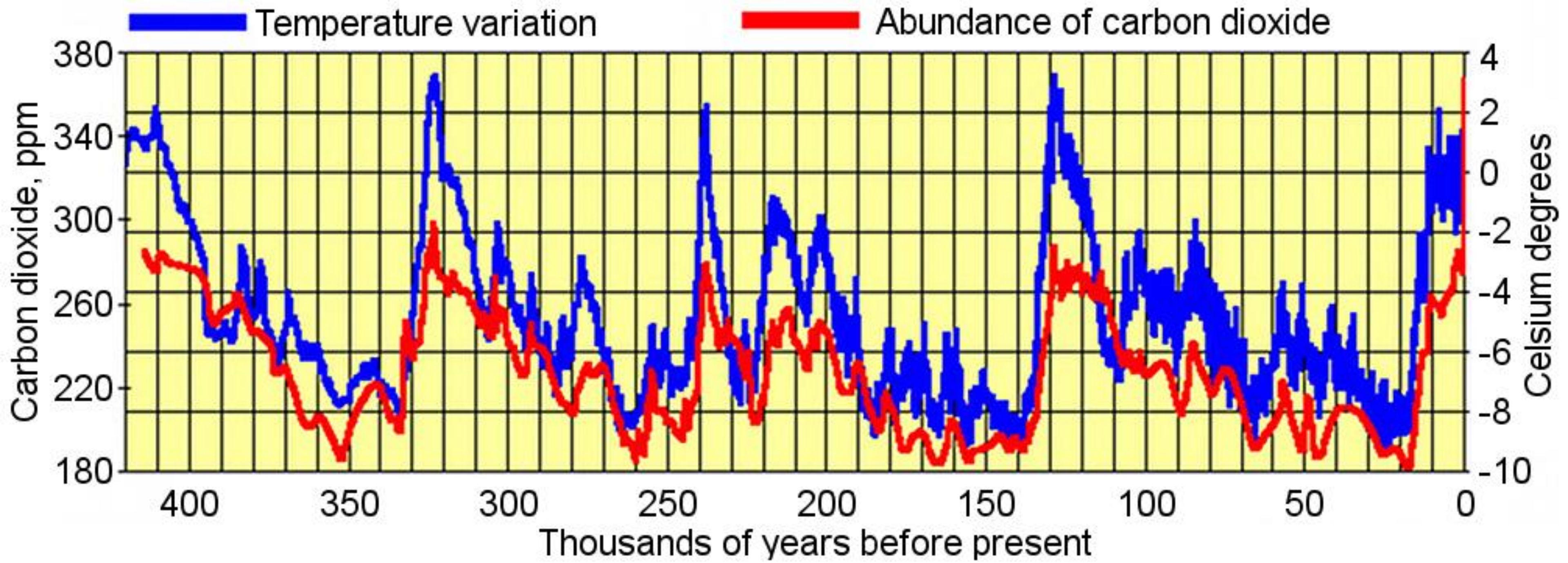
My definition of **the Little Ice Age** with quasi-bicentennial cycle **differs** from an often mentioned in the literature long period of **global cooling in the XIV-XIX centuries,** which was interrupted by several quasi-bicentennial cycles of warming. Deep cooling associated with **Wolf** (~1280-1350), **Spörer** (~1450-1550), **Maunder** (~1645-1715) and **Dalton** (~1790-1820) Grand Minima **can't be regarded as a single Little Ice Age.**

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.**



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.

**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.*

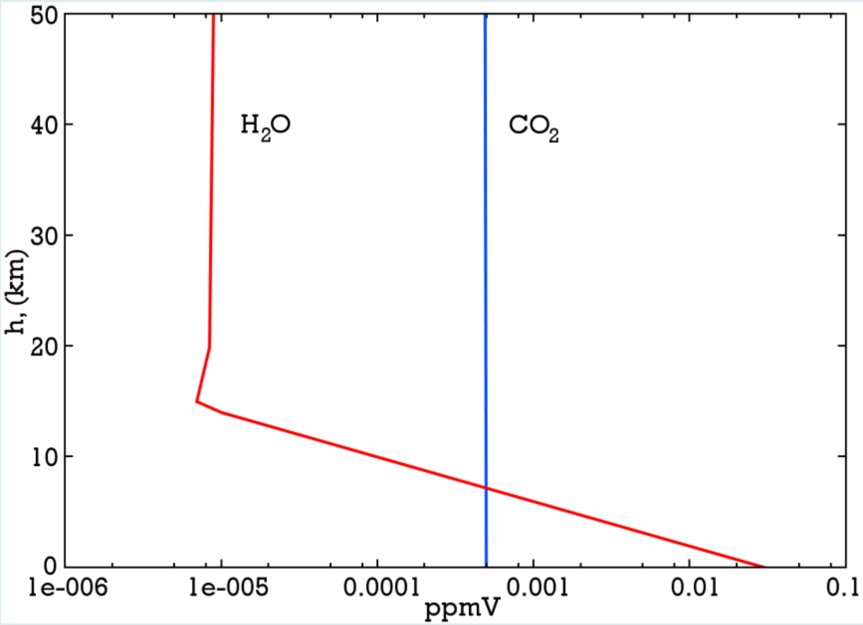
**The overall content of the carbon dioxide in the Ocean is 50 times higher than in the atmosphere, and even a weak "breath" of the Ocean can change dramatically the carbon dioxide level in the atmosphere.**

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

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

Water plays an essential role in the greenhouse effect. The volume concentration of the water vapor in the atmosphere in contrast to that of carbon dioxide strongly depends on the height. The water vapor has its maximum concentration at the surface. Long-term small rise of TSI leads to a temperature increase which, according to the Clausius-Clapeyron relation results in the increase of water evaporation rate. This leads to substantial changes in the transfer of thermal flow of longwave 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.




The changes in the content of water vapour and carbon dioxide with height.

## Convection, evaporation and condensation, together with the greenhouse effect determines the energy balance.

As early as in 1908 American physicist **Robert 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. The temperature in both green-houses simultaneously reached ~54.4$^o$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.

Thus it 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.

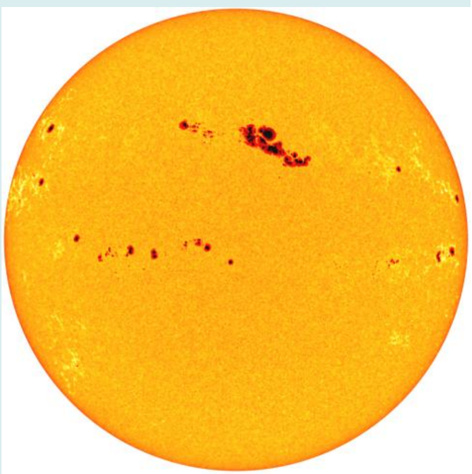
English astronomer **W. Herschel (1801)** was the first to report correlation between a level of solar activity and a climate after his discovery of inverse interrelation between a wheat price and a level of cyclic variations of solar activity. During high levels of solar activity the wheat production 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*).

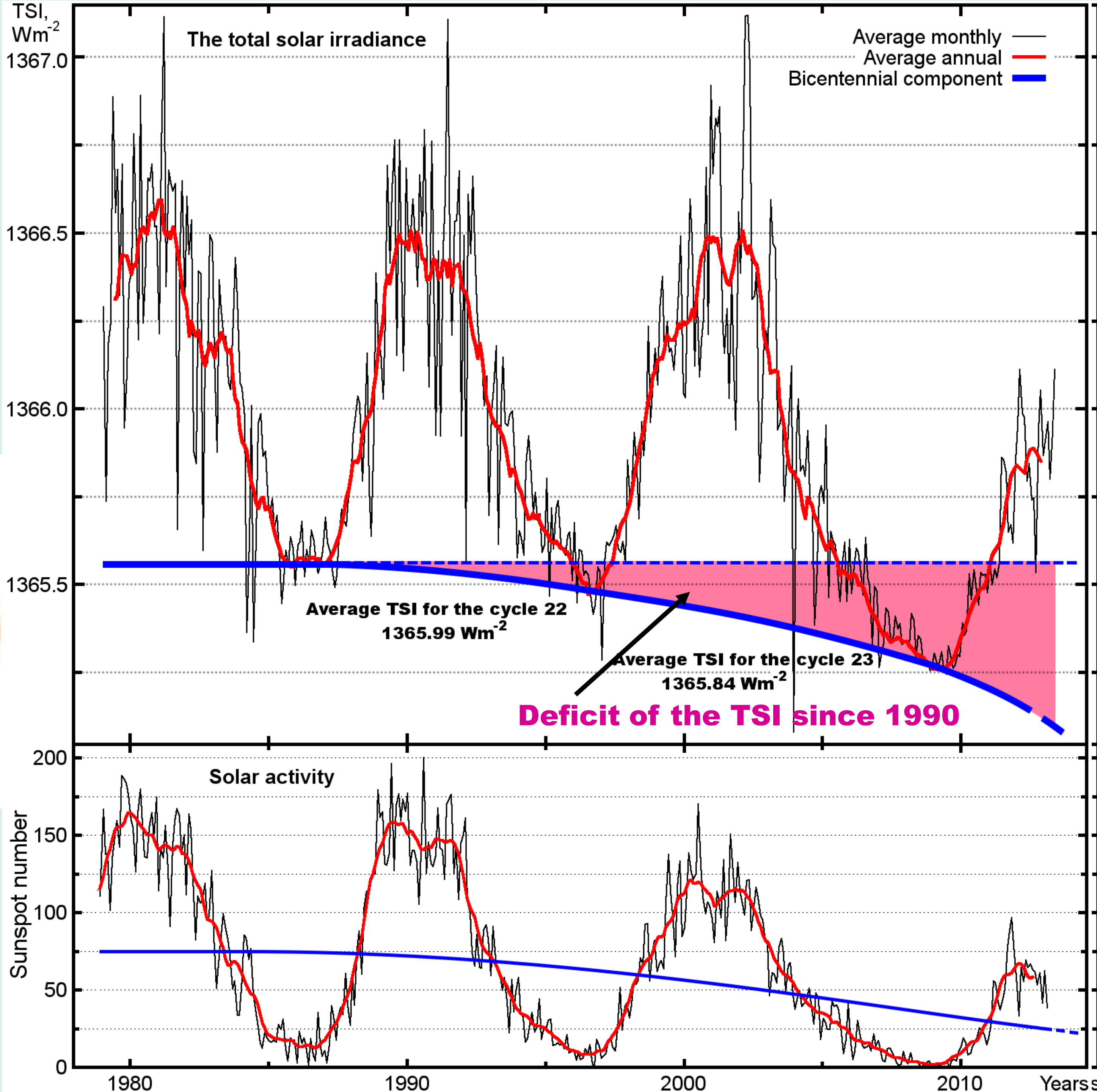
During each of 18 deep Maunder-type minima of solar activity with a quasi-bicentennial cycle found in the preceding 7.5 millennia, deep cooling was observed, while during the periods of high maximum – warming (Russian geophysicist ***E. Borisenkov***, *1988*).

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.

**Cyclic variations of the TSI and sunspot number are synchronized and inter-correlated in both phase and amplitude.**



**The Sun provides the largest TSI at the maximum of solar activity.**



**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 warmings to Little Ice Ages.**

**Every time the TSI experienced its quasi-bicentennial peak up to ~0.5% 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 nonlinear feedback effects).**

**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.**

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.

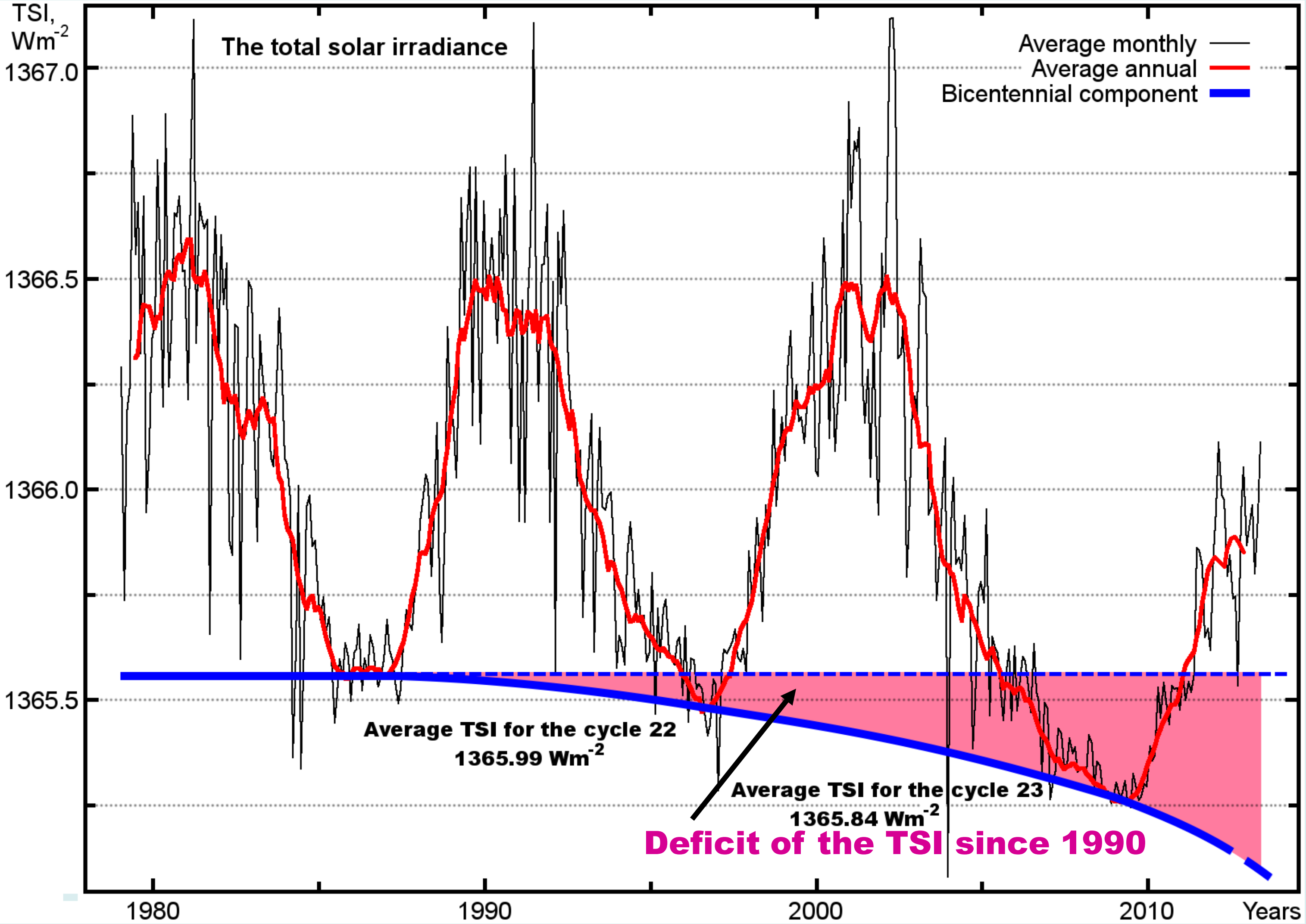
**The quasi-bicentennial variations of the TSI** set the timescales of practically all physical processes taking place in the Sun-Earth system and **are the key to understanding cyclic changes in both the nature and the society.**

**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.**

**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.**




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

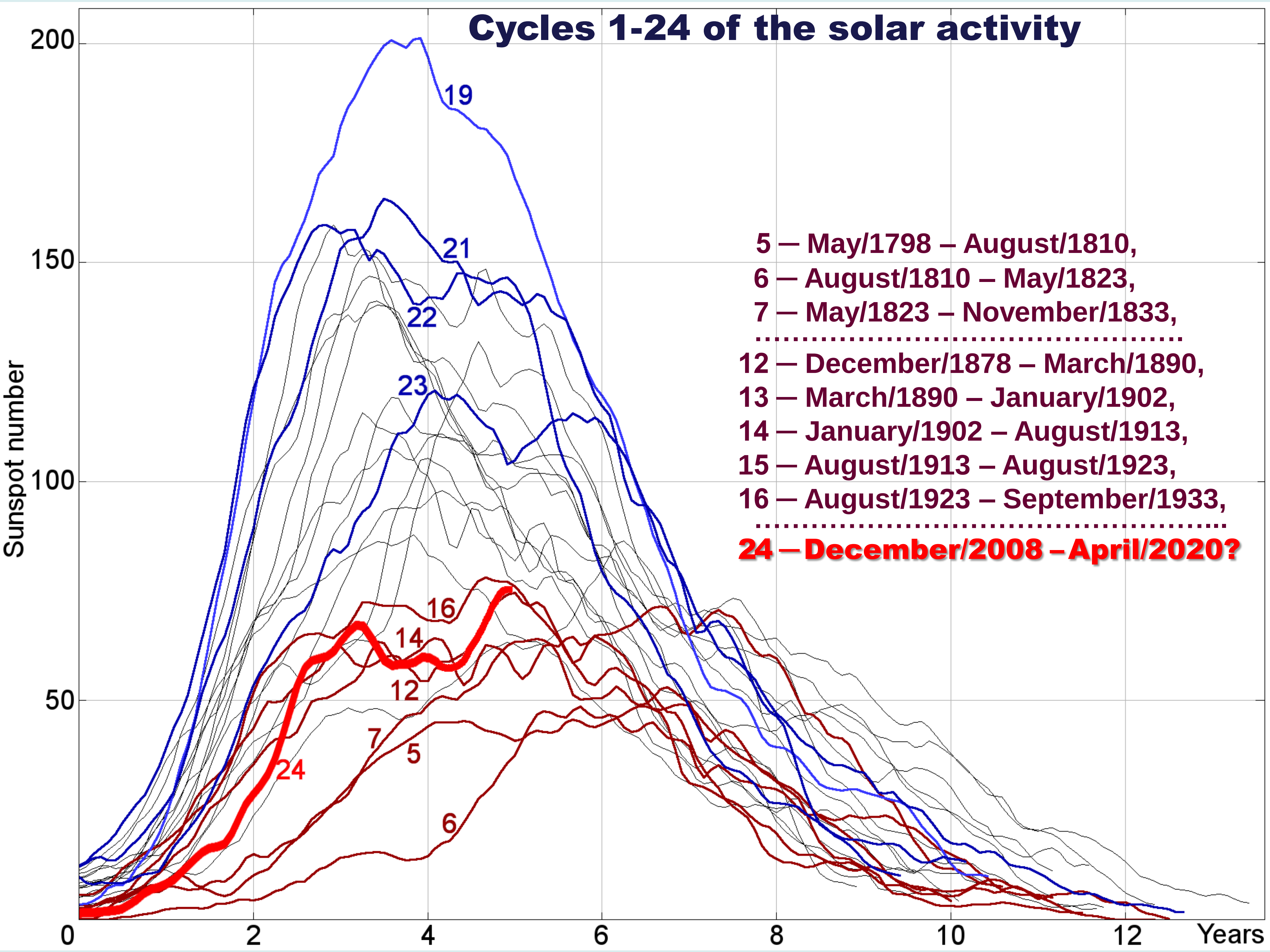
**The value of TSI at the minimum between 23/24 cycles (1365.27 ± 0.02 Wm$^{-2}$) was lower by ~0.23 and by ~0.30 Wm$^{-2}$ than at the minima between 22/23 and 21/22 cycles, respectively.**

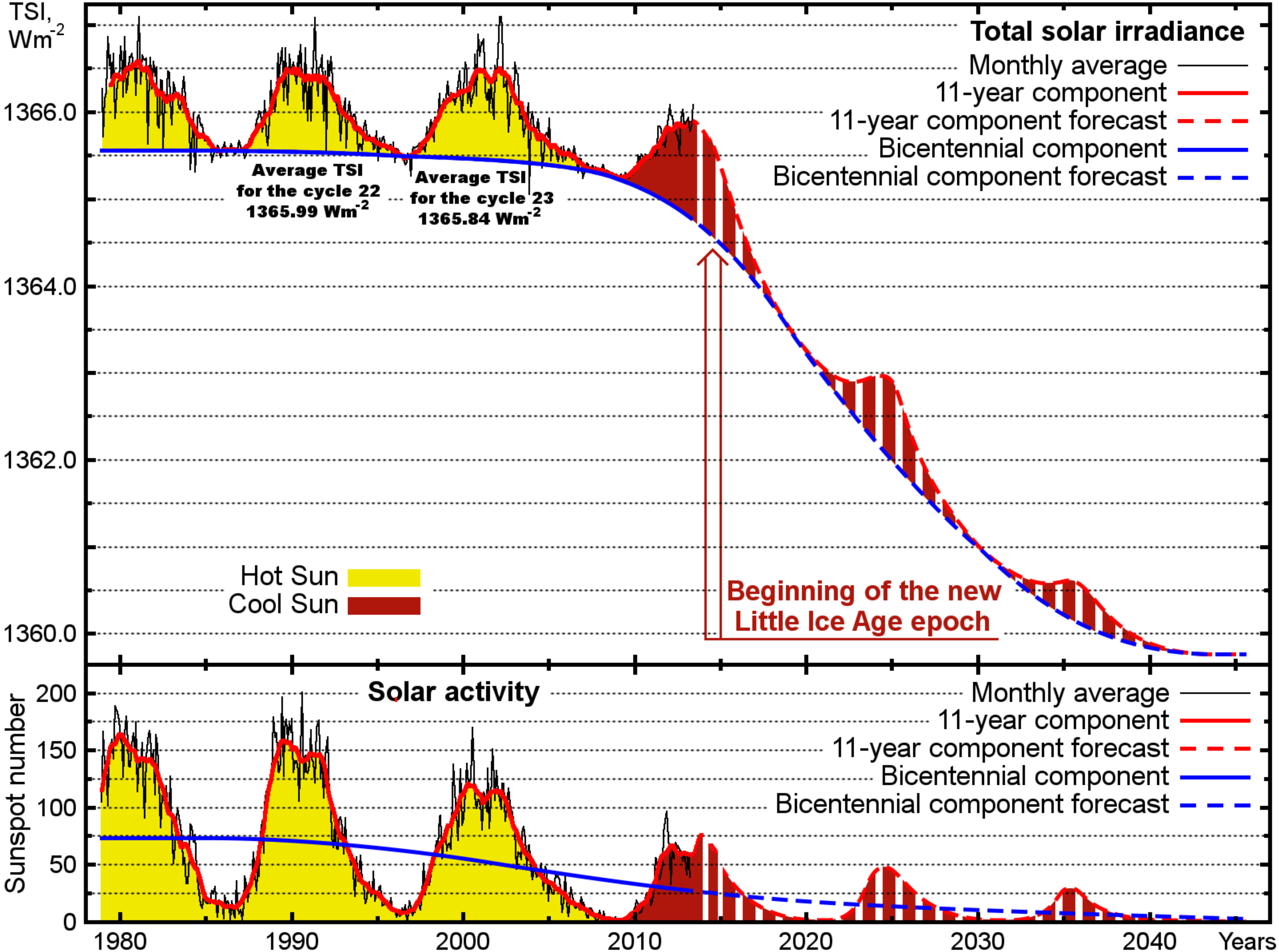
Observed decrease of the TSI portion absorbed by the Earth since 1990 **has not been compensated** by decrease of its average annual energy emitted into space which practically remains on the same high level during 20±8 years due to thermal inertia of the Ocean.

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.


Cycles 1-24 of the solar activity
Sunspot number
200
150
100
50
0
2
4
6
8
10
12
Years
19
21
22
23
16
14
12
7
5
24
6
5 — May/1798 – August/1810,
6 — August/1810 – May/1823,
7 — May/1823 – November/1833,
12 — December/1878 – March/1890,
13 — March/1890 – January/1902,
14 — January/1902 – August/1913,
15 — August/1913 – August/1923,
16 — August/1923 – September/1933,
24 — December/2008 – April/2020?




**Beginning of the new Little Ice Age – after the maximum phase of cycle 24.**

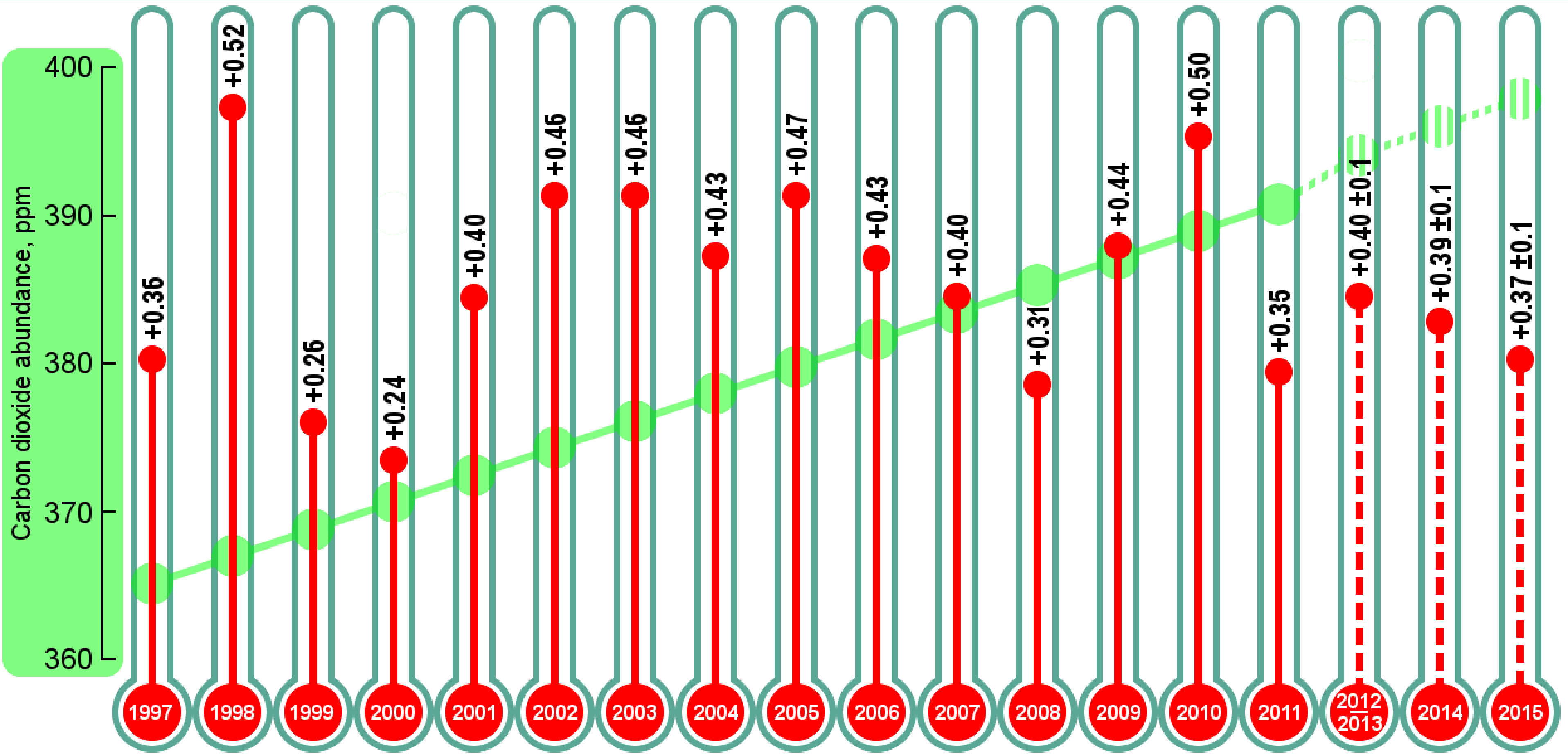
**The subsequent increase of the Bond albedo (in particular, because of increasing surface of snow and ice coverage) and decrease in the content of greenhouse gases (mostly water vapor in the surface air, as well as carbon dioxide and other gases) in the atmosphere due to cooling will lead to an additional 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.**

# The trend of both the annual average of the global temperature
(with respect to the average temperature for the time interval 1961 – 1990)
# and the carbon dioxide concentration.

## There is no global warming for more than 17 years in the result of the TSI fall since 1990.




**The directions of their development since 1997 do not comply with each other.**

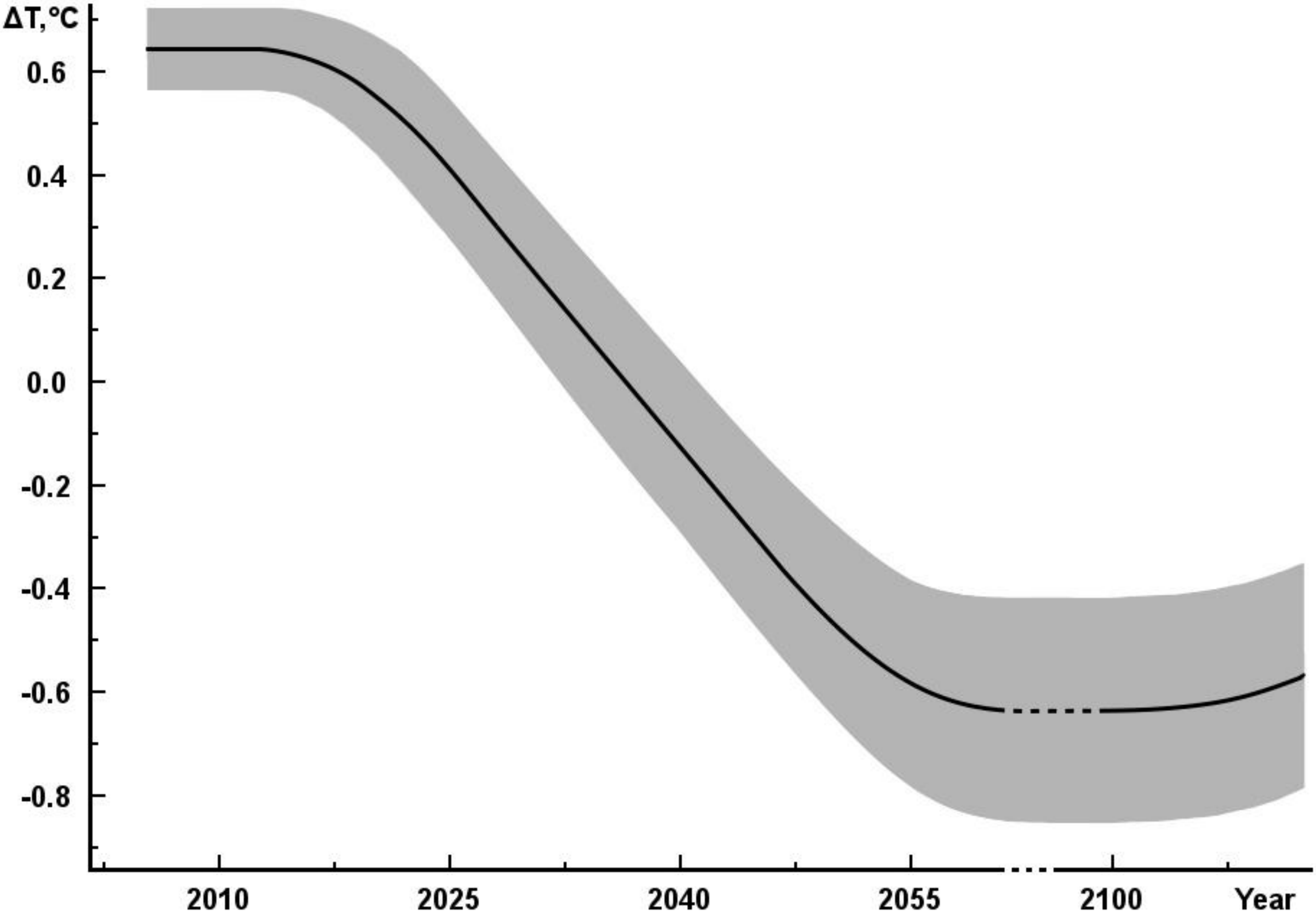
**In 1998-2005 the Earth reached the maximum of global warming.**

**What we are seeing now in the solar cycle 24 and the quasi-bicentennial cycle had been predicted by me in 2003-2007, long before the cycle 24 began .**

**These forecasts have been confirmed 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 approximately in 2043±11.**

# 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 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.**

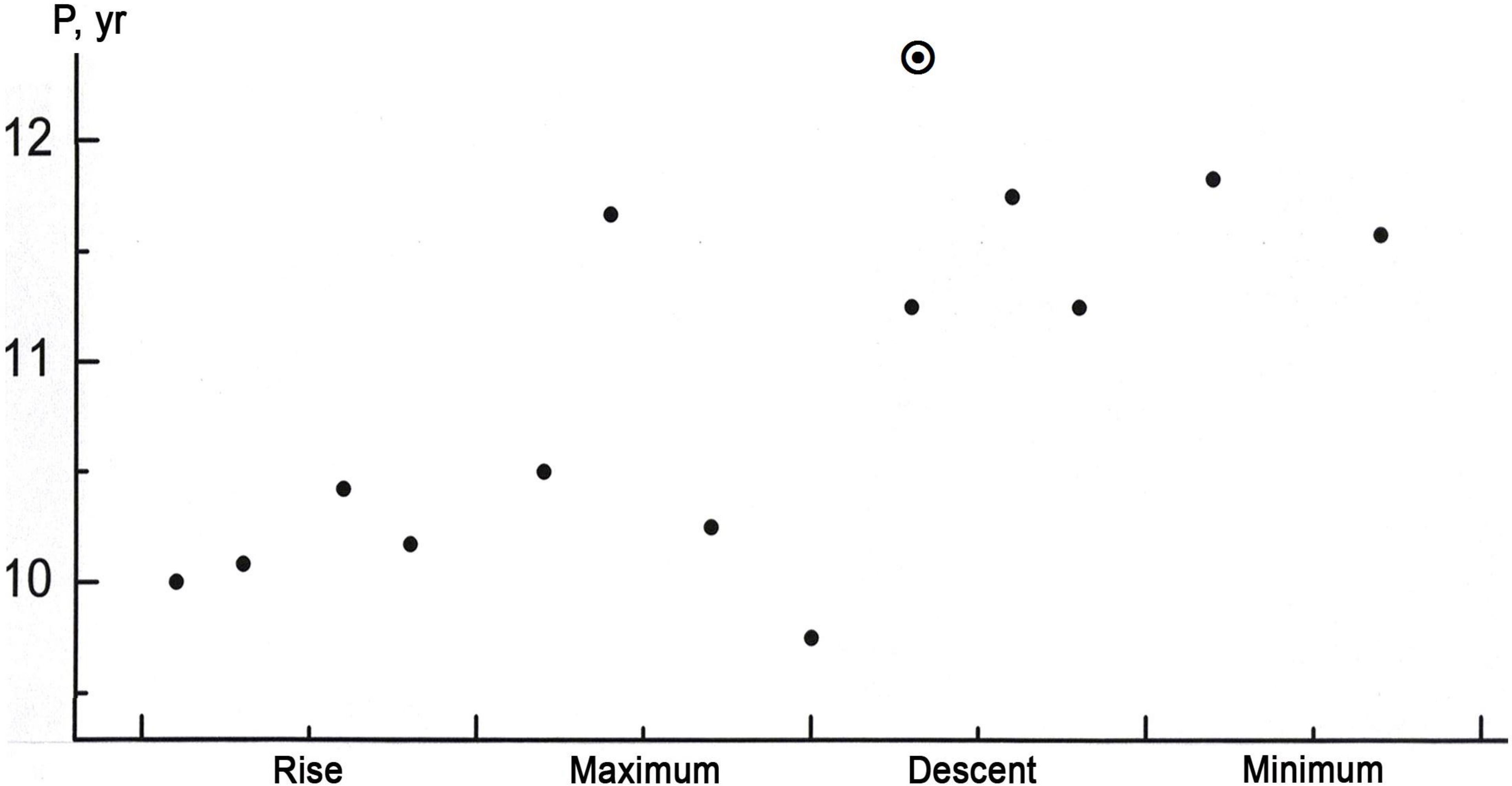
**From this point of view, after the maximum phase of solar cycle 24 (approximately at the second half of 2014), after the season of "solar summer" in our Solar System as a whole we expect a season of "solar autumn", and then, approximately in 2060 ± 11, the season of "solar winter" of the quasi-bicentennial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

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

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

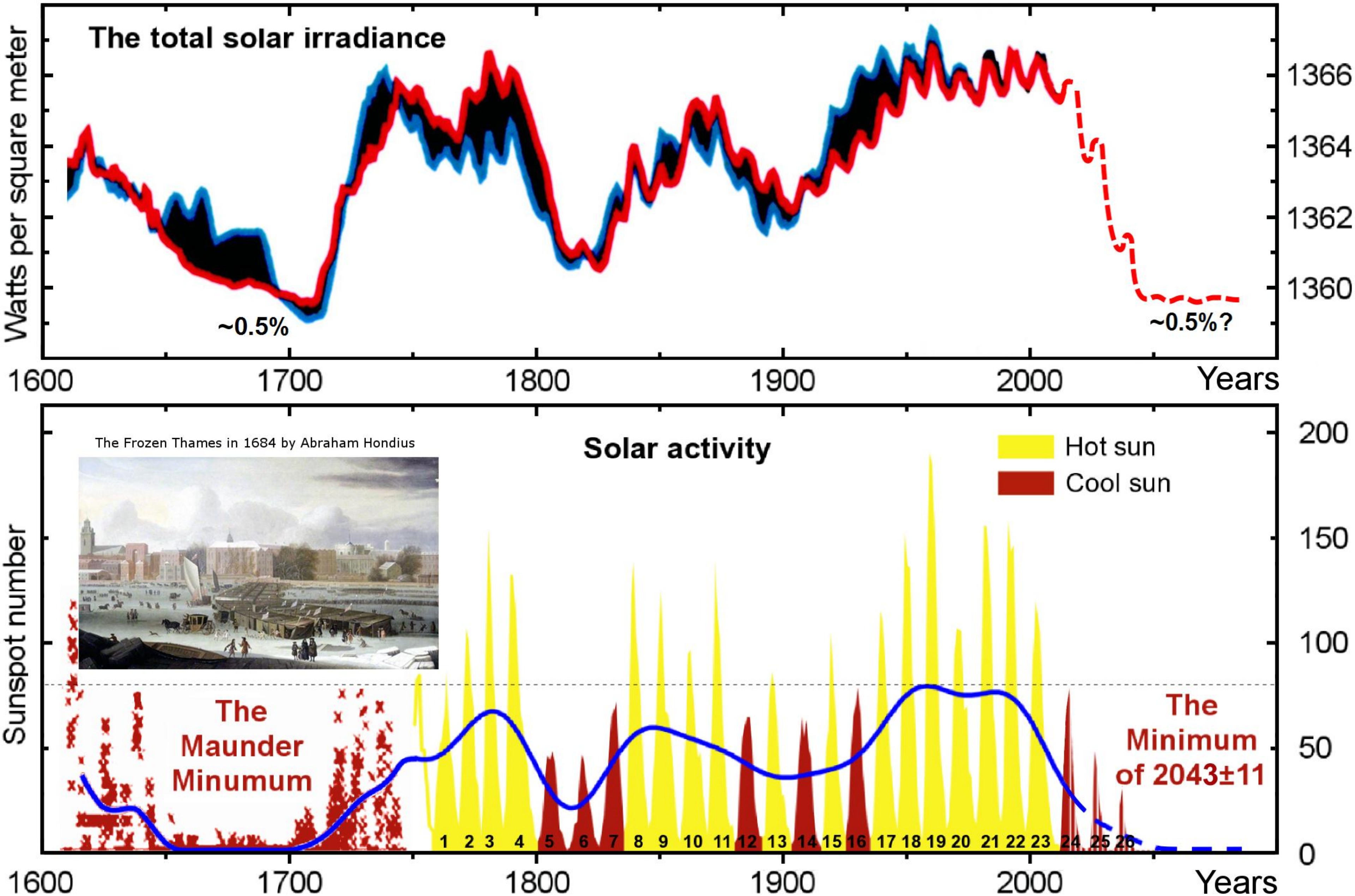
**The painting of the frozen Thames (Abraham Hondius, 1684)**

**The duration of an eleven-year cycle depends on the phase of a quasi-bicentennial cycle and consequently increases from the rise phase to the phase of maximum and decrease of the quasi-bicentennial cycle.**




**Dependence of 11-year solar activity cycles duration (for the cycles 10-23) on the phase of a quasi-bicentennial cycle (⊙ – cycle 23)**

# In the 20th century TSI reached its record for at least the past 700 years.




**Variations of the TSI and solar activity since 1611 and my forecast.**

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.

We have developed the special space project:

**"Monitoring of deviation the Earth's average annual energy balance from the equilibrium state”**

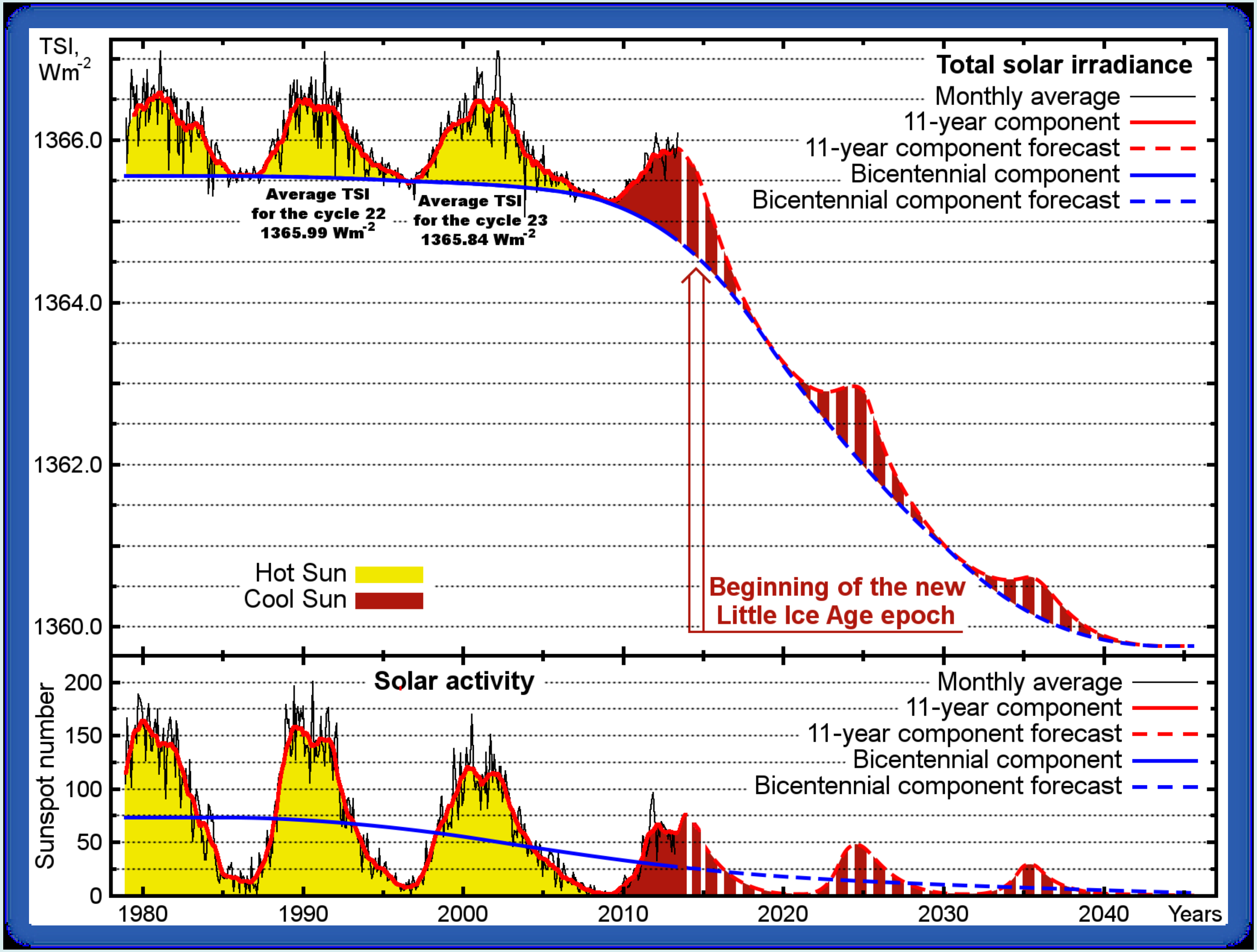
$$E = (S_\odot + \Delta S_\odot)/4 - (A + \Delta A)(S_\odot + \Delta S_\odot)/4 - \varepsilon\sigma\,(T_p + \Delta T_p)^4$$

by monitoring of the reflected portion of TSI, outgoing from the outer layers of the atmosphere into space $(A + \Delta A)(S_\odot + \Delta S_\odot)/4$, and of long-wave radiation of the Earth $\varepsilon\sigma\,(T_p + \Delta T_p)^4$.

Long-term deviation of the Earth’s average annual energy balance from the equilibrium state (excess of incoming TSI accumulated by the Ocean $\Sigma E>0$ or its deficiency $\Sigma E<0$) in the course of a quasi-bicentennial cycle of the TSI dictates a corresponding change of the energy state of the Earth.

As a result, the Earth will gradually warm up or cool down, respectively, and, thus, imply an **upcoming climate variation** and its amplitude with account for the forecasted quasi-bicentennial variations of the TSI.

# Thanks for your attention



## 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 life-time 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.**