The total solar irradiance controls the climate
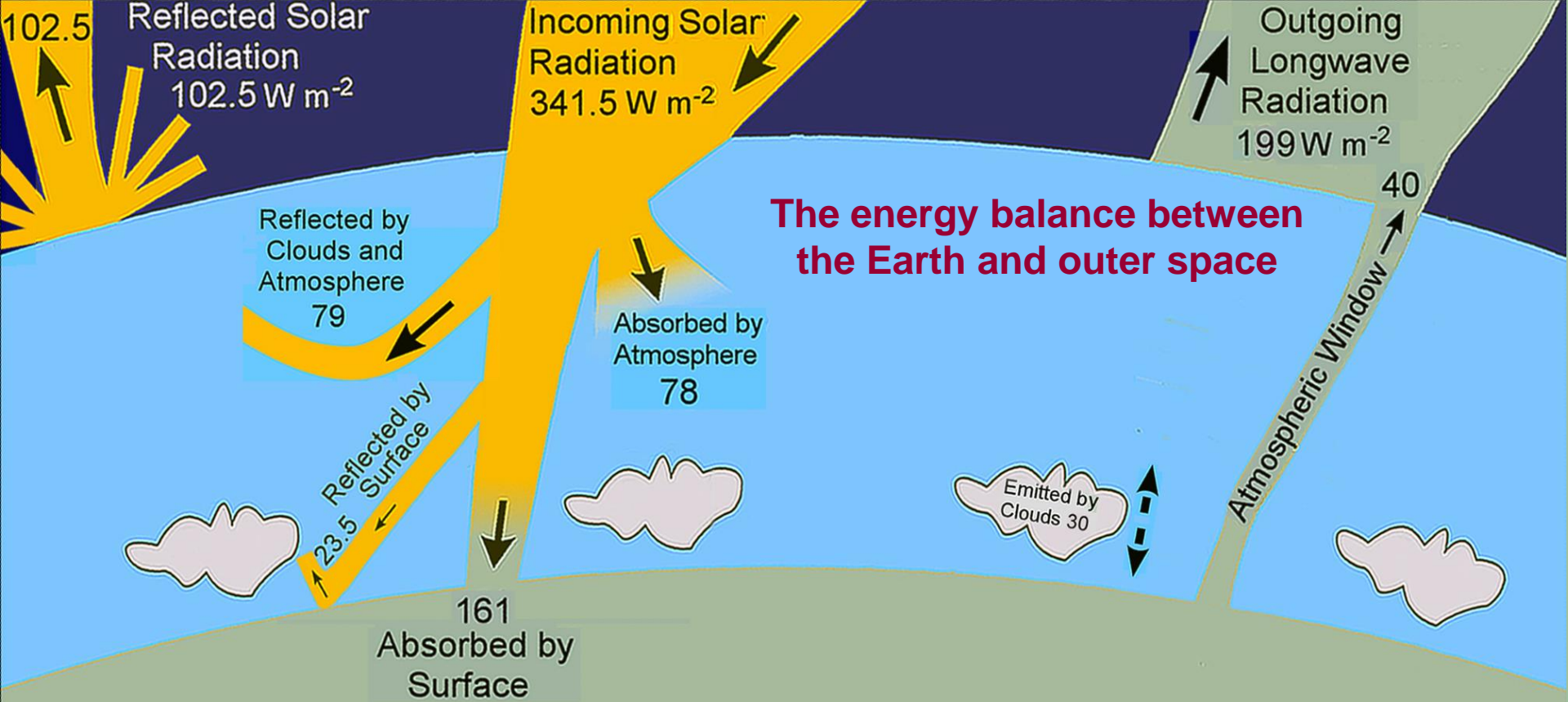
Habibullo I. Abdussamatov

© Pulkovo observatory of the RAS
St. Petersburg, Russia

The climate system depends at an extremely complex set of long-term (≥ 30 years) physical processes in the ocean-land-atmosphere systems, which, in turn, are constantly influenced mainly quasi-bicentennial variations of the **total solar irradiance (TSI).**

The variations of TSI (0.4-0.5%) in quasi-bicentennial cycle, insignificant by the standards of a star, is capable of drastically changing the Earth's climate.

Deep climate change is an absolutely natural and inevitable process, and man has practically nothing to do with it today.

The temperature is always cooler during long-term periods of low TSI and warmer during periods of high TSI is an important established aspect of the climate impact of TSI over the past 8,000 years.

The energy balance between the Earth and outer space

Reflected Solar Radiation 102.5 W m^{-2}

Incoming Solar Radiation 341.5 W m^{-2}

Outgoing Longwave Radiation 199 W m^{-2}

Reflected by Clouds and Atmosphere 79

Absorbed by Atmosphere 78

Reflected by Surface 23.5

Emitted by Clouds 30

Atmospheric Window

161 Absorbed by Surface

40

The only and most reliable way to predict the amplitude and the exact time of future changes in climate is to study long-term variations in the Earth's energy imbalance (EEI) – difference between the amounts of TSI coming to the external atmospheric layers and the total energy outgoing back to space:

$$E = \frac{(S_\odot + \Delta S_\odot)}{4} - \frac{(A_{\mathrm{BE}} + \Delta A_{\mathrm{BE}})(S_\odot + \Delta S_\odot)}{4} - \varepsilon\sigma(T_p + \Delta T_p)^4.$$

The variation of the EEI, regardless of its causes, over a period of about 30 years or more is the main measure of subsequent climate change and global temperature.

The temperature change is the result of long-term increments TSI and subsequent changes in Bond albedo and the physical properties (parameters) of the Earth's surface and atmosphere:

$$\Delta T = \frac{\Delta S_\odot (1 - A_{BE} - \Delta A_{BE}) - \Delta A_{BE} S_\odot}{16 \sigma T^3}.$$

In so doing the average annual energy of the Earth's own thermal radiation into space, due to the thermal inertia of the Ocean, always the time lags 30±10 years from the energy of absorbed solar radiation since the planet's thermal inertia constant

$$t = 0.095\ (1+0.42\ H)\ \text{years,}$$

where H is the depth of the active layer of the Ocean, which is equal to about 500-1000 m it today.

Since ~1990, the Sun has been in the declining phase of the quasi-bicentennial variation in TSI.

As a result, **we have the long-term negative Earth's energy imbalance.**

The signs of solar variations are seen in cyclic 11-year and bicentennial variations of a number of sunspots on the solar surface.
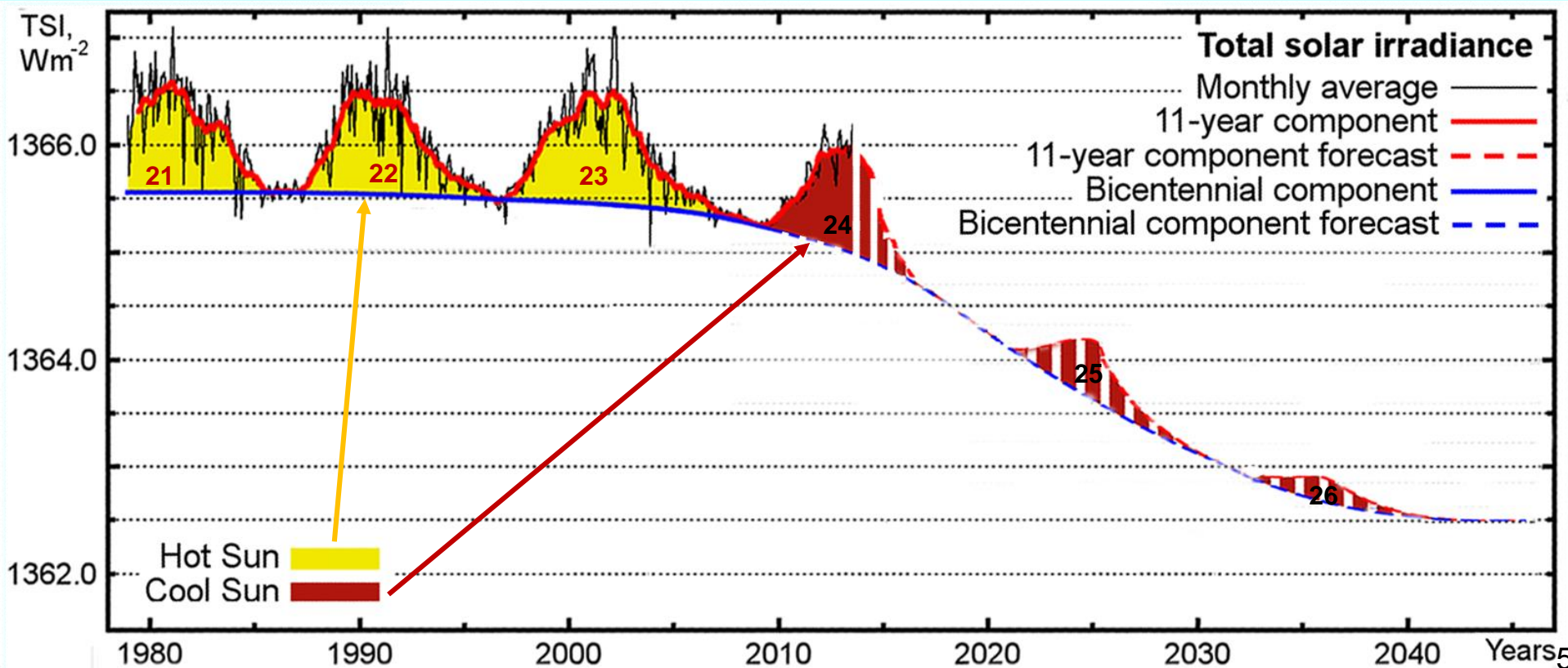
Because the proportional decrease in the average annual TSI portion absorbed by the Earth since ~1990 has not been compensated by a decrease in the average annual energy radiated into space due to the thermal inertia of the oceans.

Therefore since ~1990, the Earth radiates more energy back into space than, it became absorbs.

In fact, the solar warming ended in the 1990.

As a result, a long-term deficit of the Earth's energy balance leads to cool down. Then the subsequent multiple influences of secondary causal chain feedback effects leads to an additional decrease in temperature up to few times in comparison with the direct impact of the TSI.

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.**
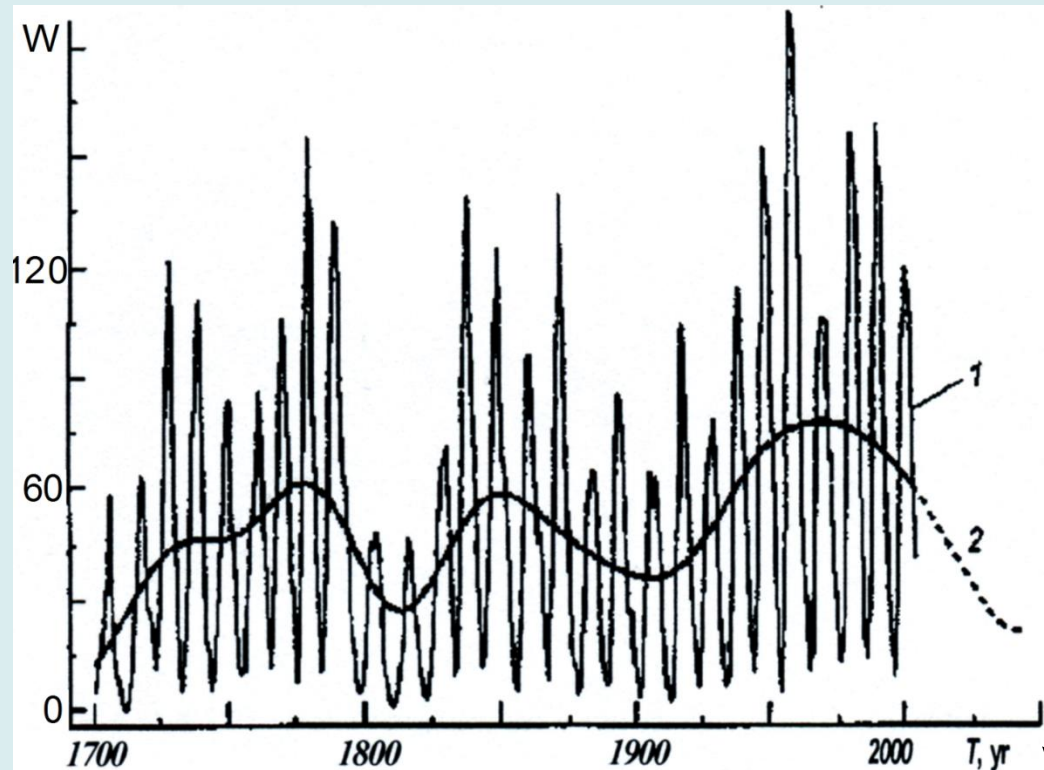
Observed levels of the quasiperiodic 11-year oscillations of the Wolf number *W* over the last 300 years (curve *1*) and cyclic variations of the secular component (curve *2*).

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.* **2005.** V. 21, pp. 328-332.

Solar Activity Variations 1700-2040
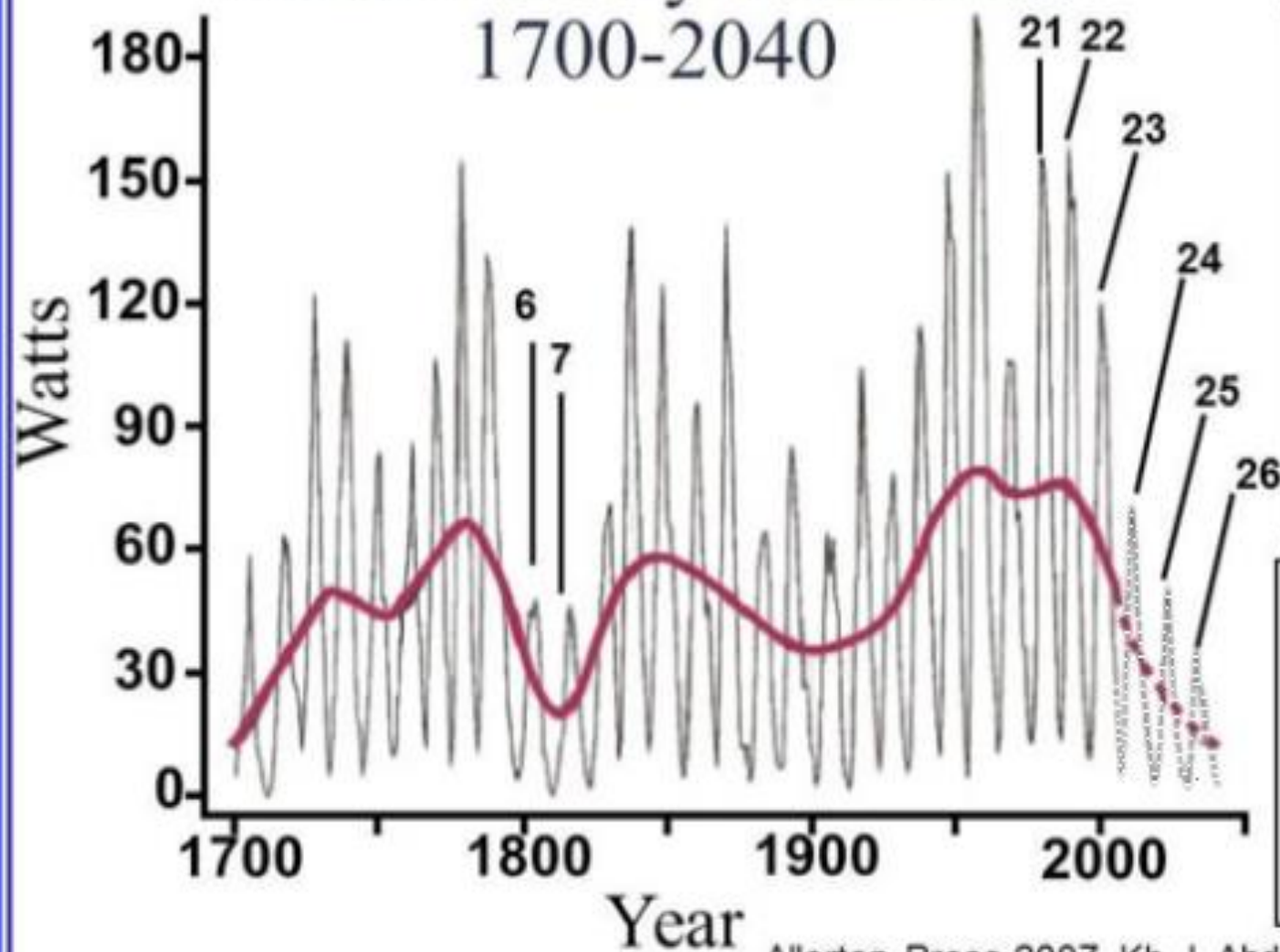
Time variations of the total solar irradiance (TSI) and solar activity over the past 400 years.

The total solar irradiance

Watts per square meter

1366
1364
1362
1360

~0.5%

~0.3%?

The data of TSI long-term reconstruction
by *Shapiro et al., 2011; Egorova et al., 2018*

1600   1700   1800   1900   2000   Years

Sunspot number

The Frozen Thames in 1684 by Abraham Hondius

Solar activity

Hot sun
Cool sun

200
150
100
50
0

The Maunder Minumum

The Minimum of 2043±11

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26

1600   1700   1800   1900   2000   Years

Decrease in only TSI at the phase of decline (at $\triangle S_{\odot}$=-(4-5) Wm^{-2} will lead to a drop in temperature (at $\Delta A_{BE} = 0$) by **ΔT ≥ 0.2 K** (**excluding other contributions**). However, even such a slight decrease in temperature is extremely important as a trigger mechanism for subsequent multiple exposures of a long chain of secondary causal feedback effects. It will cause a few times in decrease temperature thanks to:

- An increase in the area of snow-ice covers and also changes in the physical properties (parameters) of the Earth's surface and atmosphere, and as a result, (**add. decrease in a temperature**);

- Reducing the concentration of the main GHG – water vapor and other GHGs in the atmosphere in accordance with the Clapeyron-Clausius ratio and Henry's law (**add. decrease in a temperature**);

- Enhanced atmospheric transmission of thermal radiation of the Earth's surface ria the transparency window (**add. decr. in temp.**);

- A decrease in **the "dark" surface of the Ocean,** caused by a decrease in water level due to an increase in the mass of glaciers and compression of water upon cooling (**add. decrease. in temp.**).
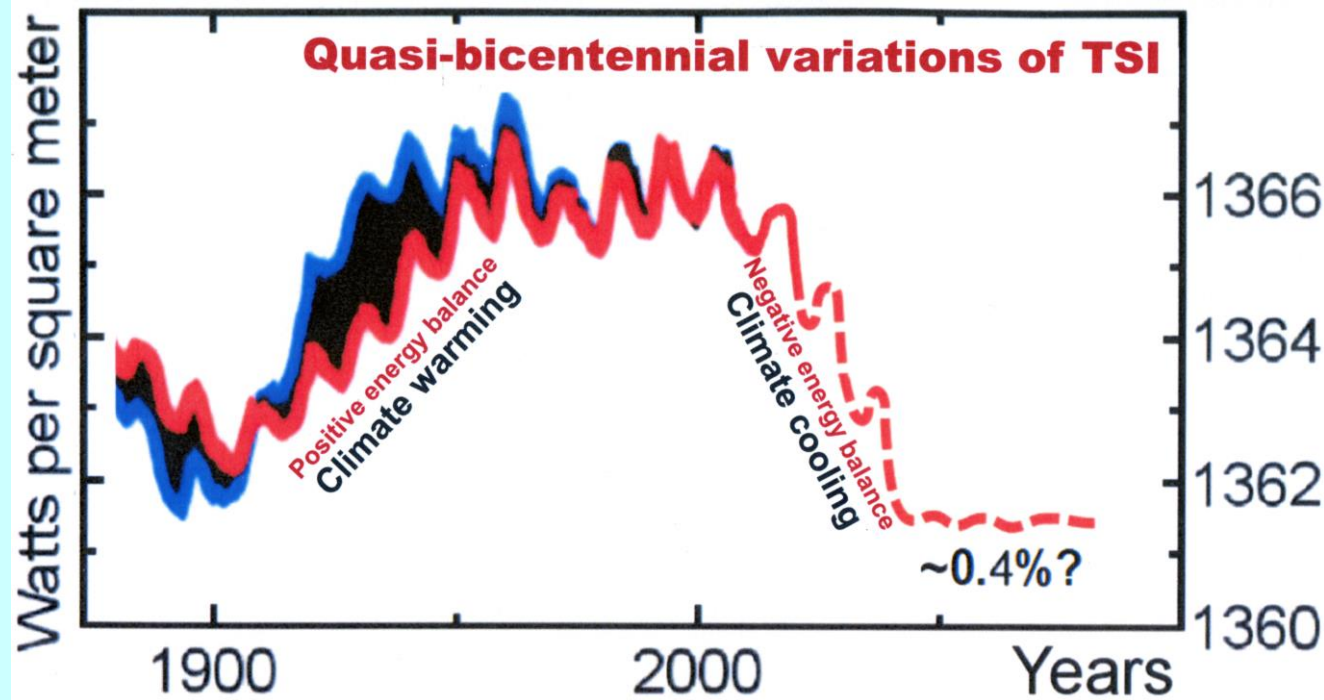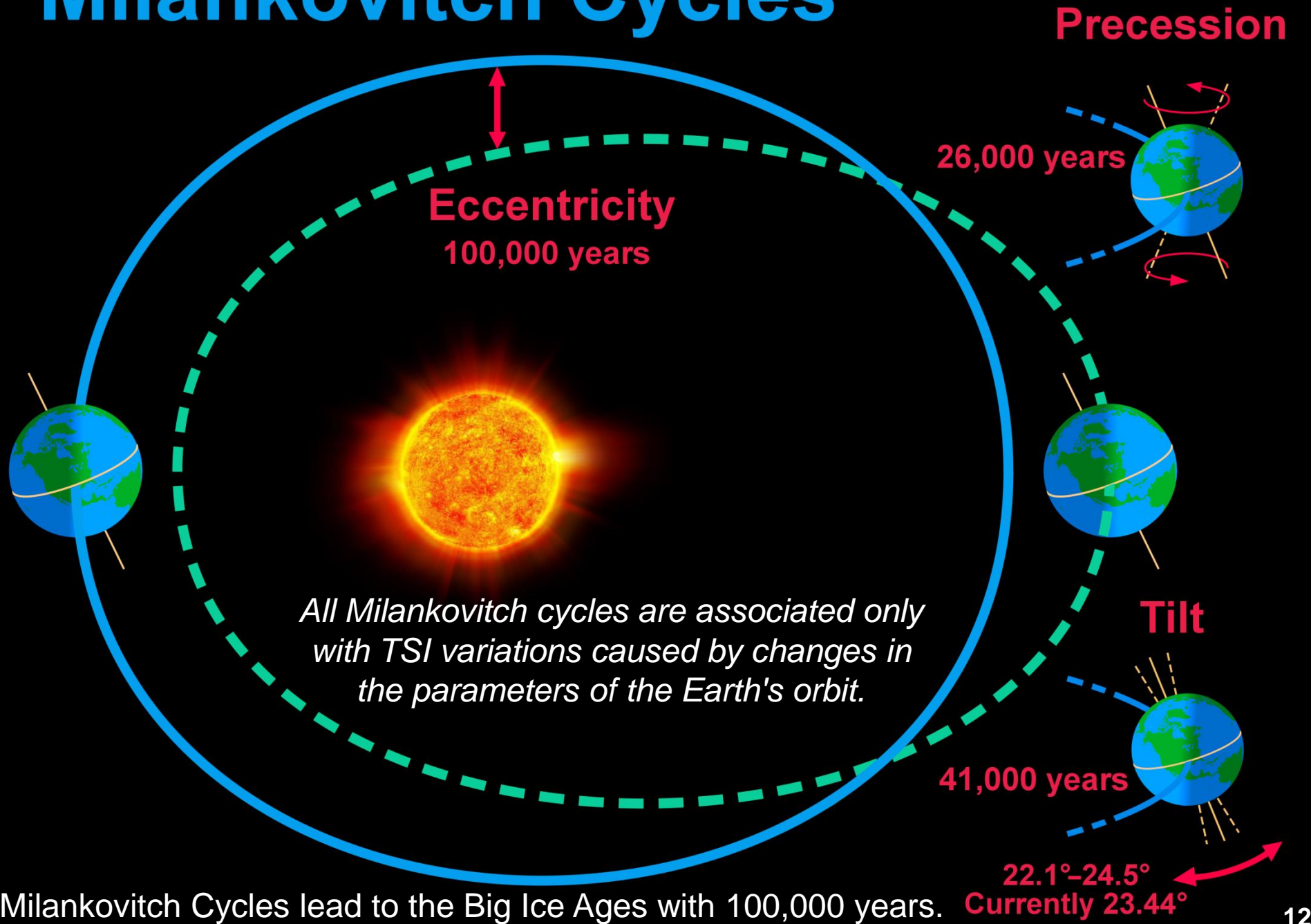
Always in the period ~35-65 years of the decline phase of the quasi-bicentennial cycle TSI the Earth emits more energy into space than receives and its the average annual energy budget is negative **(E<0),** because it had not time accordingly to cool down **due to the thermal inertia.**

As a result of a long-term deficit of energy **the Earth will cool down.**

Then the subsequent multiple influences of secondary causal chain feedback effects leads to a decrease in temperature up to few times in comparison with the direct impact of the TSI.
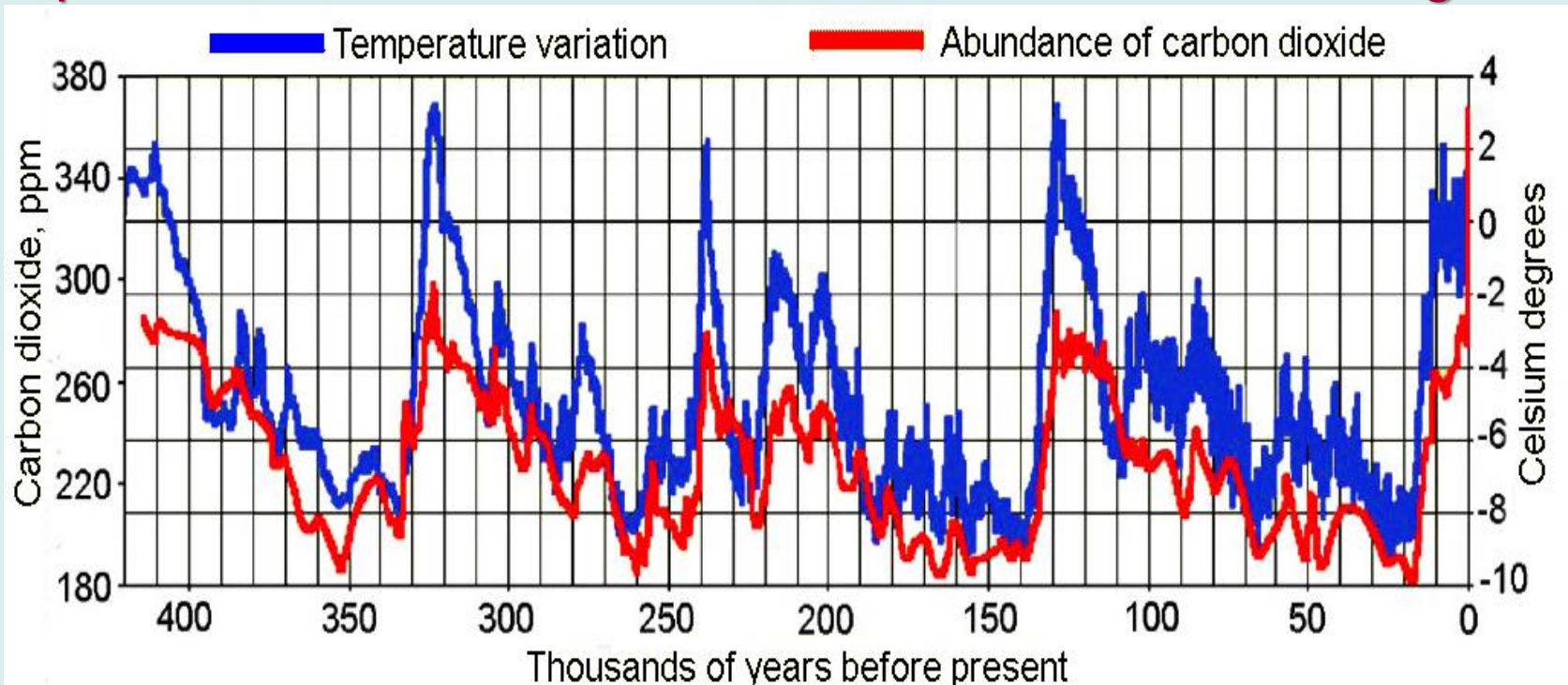
In the grows phase the reverse is true (E > 0).

Milankovitch Cycles

Precession

26,000 years

Eccentricity
100,000 years

All Milankovitch cycles are associated only with TSI variations caused by changes in the parameters of the Earth's orbit.

Tilt

41,000 years

22.1°–24.5°
Currently 23.44°

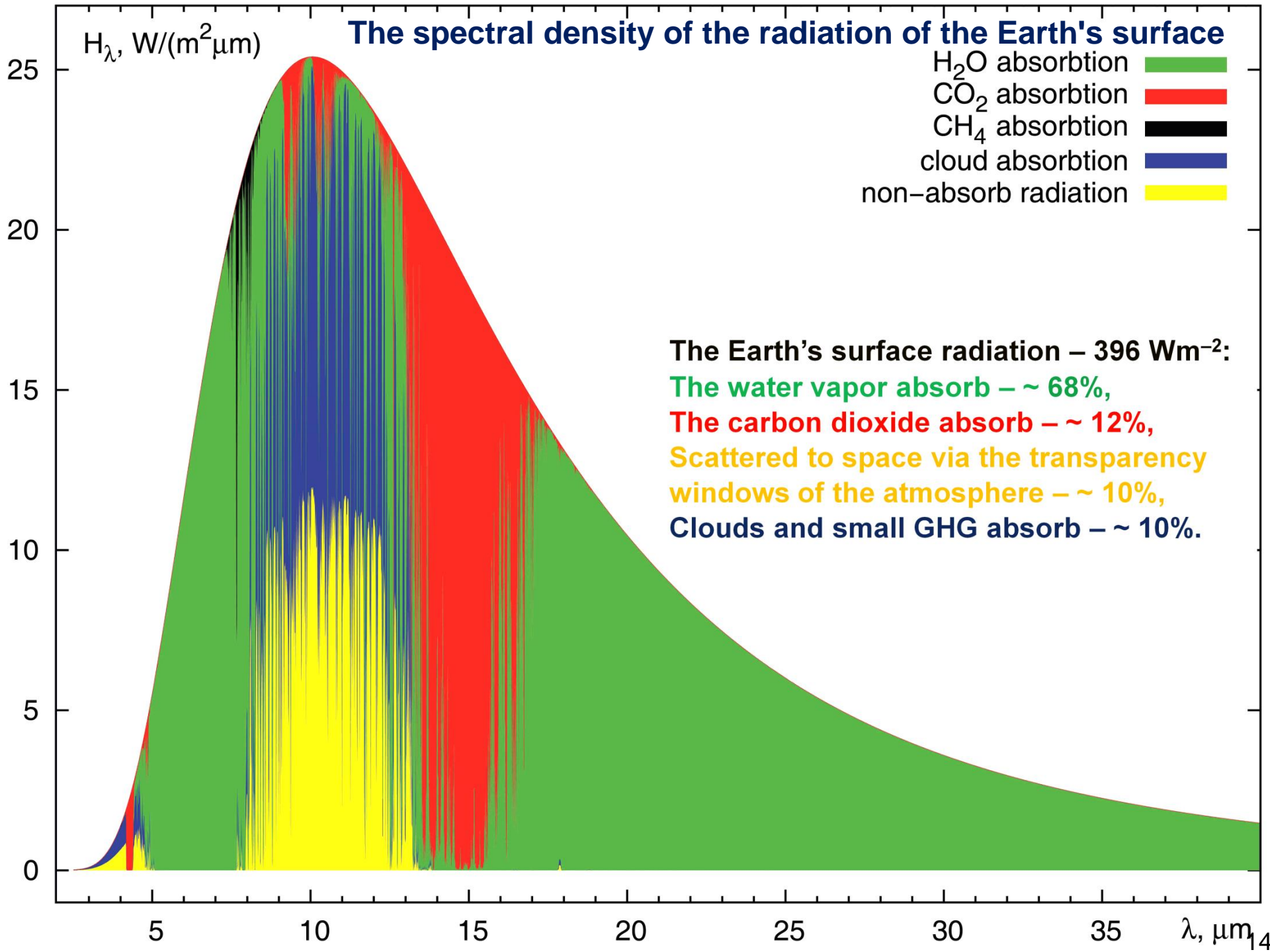Milankovitch Cycles lead to the Big Ice Ages with 100,000 years.

Studies of the ice core of Antarctica showed that:

- Significant periodic increases in atmospheric CO_2 in the past 800,000 years have always been a consequence of **temperature growths with a lag of 800 ± 400 years;**

- The increase in CO_2 abundance in the atmosphere **began later, but also ended later** than warming has changed followed by cooling;

- The temperature reached its peak value and then began to decrease despite the fact that the concentration of GHG was still growing.

The spectral density of the radiation of the Earth's surface

H_λ, W/(m²μm)

Legend:
- H₂O absorbtion (green)
- CO₂ absorbtion (red)
- CH₄ absorbtion (black)
- cloud absorbtion (blue)
- non−absorb radiation (yellow)

The Earth's surface radiation – 396 Wm⁻²:
The water vapor absorb – ~ 68%,
The carbon dioxide absorb – ~ 12%,
Scattered to space via the transparency
windows of the atmosphere – ~ 10%,
Clouds and small GHG absorb – ~ 10%.

λ, μm

A quasi-centennial fall in the global temperature due to the forecasted Grand minimum of TSI has begun.
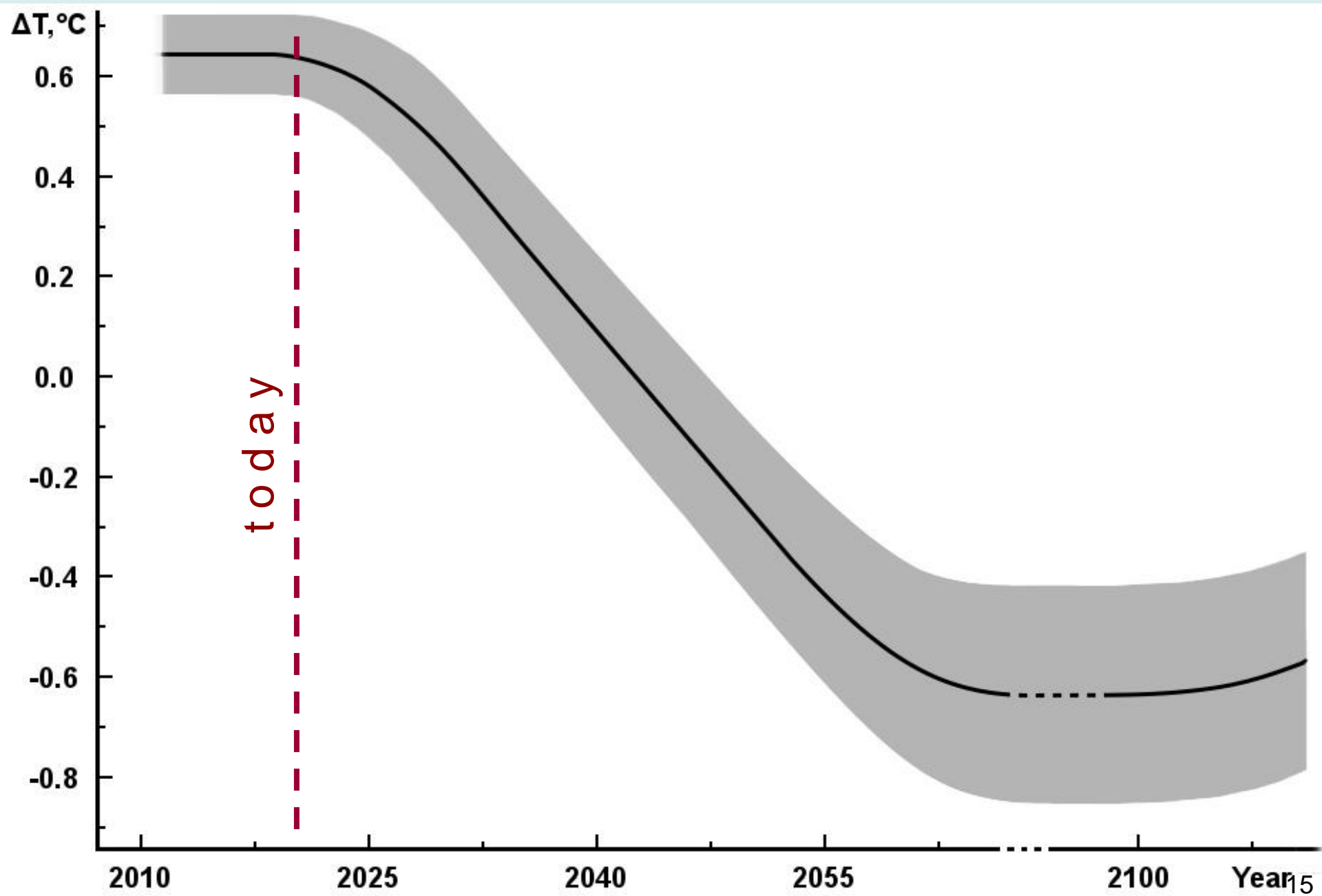
The global warming of the late 20th century was actually due to long-term changes in the Sun's energy output almost throughout the 20th century can account for practically all climate changes on to planets of the Solar system.

Warming was observed on Mars and other planets, attributed to a "**solar summer**" and alternation by the quasi-bicentennial climate conditions throughout the Solar system.

At 2016, after the maximum phase of solar cycle 24, the "**solar summer**" **ended** and the "**solar autumn**" began, and then in 2070±11 the "**solar winter**" is expected. A "**spring**" in the Solar system will come only at the beginning of the 22nd century.

All changes in the Earth's climate from the Little to the Big Ice Ages **will come and go, as always, without our help or permission.**

All these changes **are due to only long-term cyclic variations in the TSI,** **taking into account not only direct but also more important subsequent secondary feedback effects.**

The gradual **weakening of the Gulf Stream power will result in even stronger cooling** in the zone of its action: in Western Europe and the eastern parts of the United States and Canada.
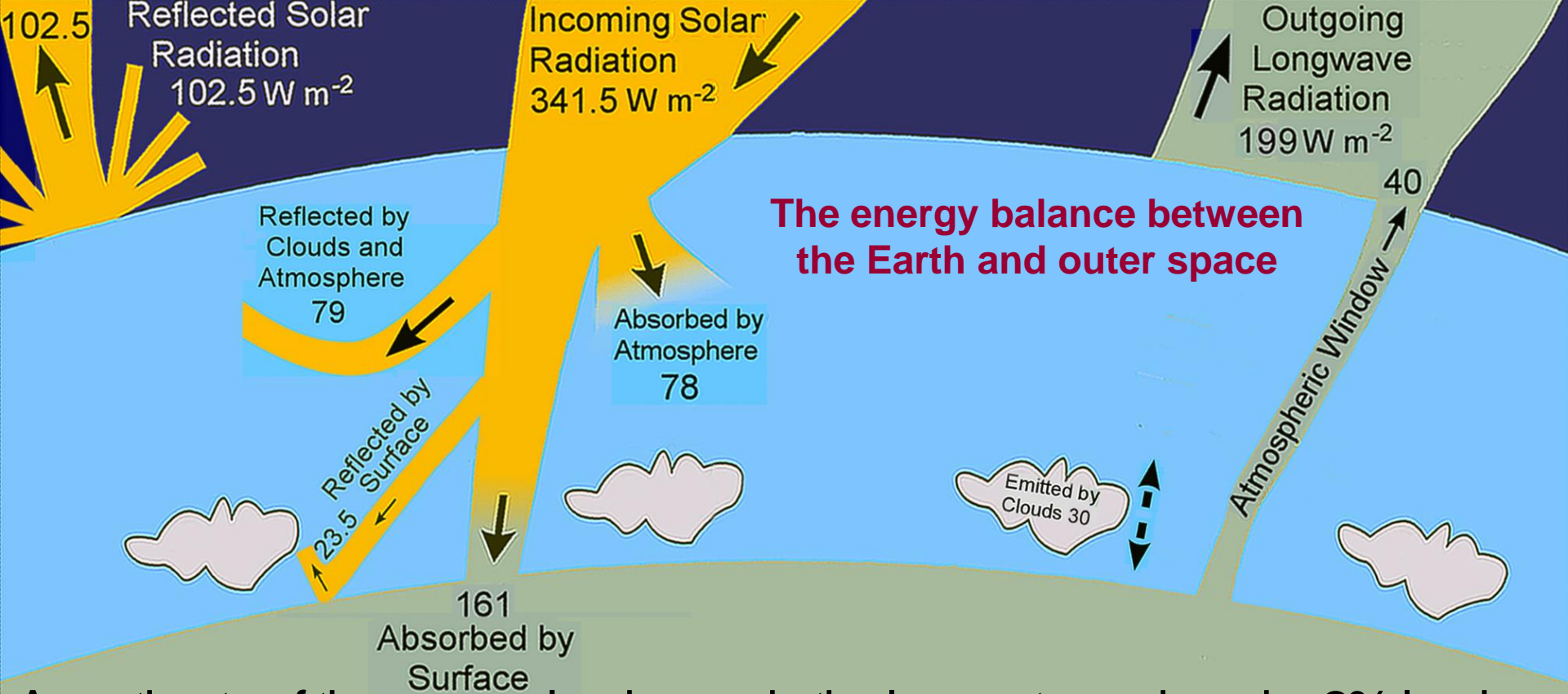
The impact of an increase in the area of the cloud cover, <u>presumably</u> caused by the growth of the cosmic rays flux, <u>on climate is practically absent.</u>

Abdussamatov H.I. The Earth's climate does not depend on variations in cosmic rays and cloud coverage // Geomagnetism and Aeronomy (Published 11 March 2020). 2019, Vol. 59, No. 7, pp. 935–941. DOI: 10.1134/S0016793219070028.

Abdussamatov H.I. Energy imbalance between the Earth and space controls the climate // Earth Sciences. 2020. Vol. 9, No. 4, pp. 117-125. doi: 10.11648/j.earth.20200904.11

Abdussamatov H.I. Absence of the impact of the flux of cosmic rays and the cloud cover on the energy balance of the Earth // Journal of Atmospheric Science Research (JASR). 2020. Vol. 3, No. 3, pp. 1-7. DOI: https://doi.org/10.30564/jasr.v3i3.2129

Abdussamatov H.I. Cosmic rays and clouds variations effect on the climate is insignificantly // Applied Physics Research. 2018, 10(4), 81-86.

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102.5

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An estimate of the grows cloud cover <u>in the lower atmosphere</u> by 2% leads:
- to a decrease of the EEI E_o on -0.02·79 Wm^{-2} = –1.58 Wm^{-2};
- to an increase of EEI E_o on +0.02·40 Wm^{-2} = +0.8 Wm^{-2};
- to an increase of EEI E_o on +0.02·23.5 Wm^{-2} = +0.47 Wm^{-2};
- to an increase of EEI E_o (the greenhouse effect) on +x.xx Wm^{-2};
- to a decrease of E_o (emitted by clouds) on -0.02·30 Wm^{-2} = -0.6 Wm^{-2};
- to an increase of E_o (emitted by clouds) on +0.02·30 Wm^{-2} = +0.6 Wm^{-2}.

New $E_1 \approx E_o$ - 1.58 Wm^{-2} + 0.8 Wm^{-2} + 0.47 Wm^{-2} + X.XX Wm^{-2} -0.6 Wm^{-2} + 0.6 Wm^{-2}.
Thus, $E_1 – E_o \approx 0$ or may be $E_1 – E_o > 0$, what can lead to warming.

So, the warming of the twentieth century is not the result of human activity, but the result of natural a quasi-bicentennial cycles of TSI, which, for at least 8,000 years, caused the corresponding quasi-periods of warming and deep cooling (1.5 – 2°C) and also variations in the concentration of H_2O and CO_2 in the atmosphere.

The growth of CO_2 in the atmosphere
is very useful for life on Earth.

However, too many people consciously prefer to focus on CO_2 in order to advance the restructuring of the energy industry.

The effectiveness of the right choice of a scientifically sound climate policy on a global scale is directly related to the coming in trillion-dollar flow.

We have developing the special space project
Lunar Observatory (LO)
for monitoring the Earth's energy imbalance and climate.

LO is a system of two identical special optical telescopes-robots with diameter of the primary mirror 300 mm with visor (**SOTR-300V**) operating successively in the automatic mode on a single program of Earth observation **as a single telescope.**

Telescopes installs along narrow latitude of the equatorial zone of the Moon's surface on two opposite edges relative to its visible center at points at a distance 9.1°±0.1° respectively from the eastern and western edges.

Comprehensive measurements variations of reflected and scattered by the Earth of the portion TSI in all directions in the wavelength range Δλ = 0.2-4 μm, the thermal radiation of the Earth in ranges Δλ = 4-50 μm and Δλ = 8-13 μm, as well as of the remote sensing of the Earth from surface of the Moon (RSM) in certain narrow predetermined ranges of the spectrum are carried out consecutively by two SOTR-300V in during no less 94% lunar day continuously only at night in places of their installation.

<1500 mm
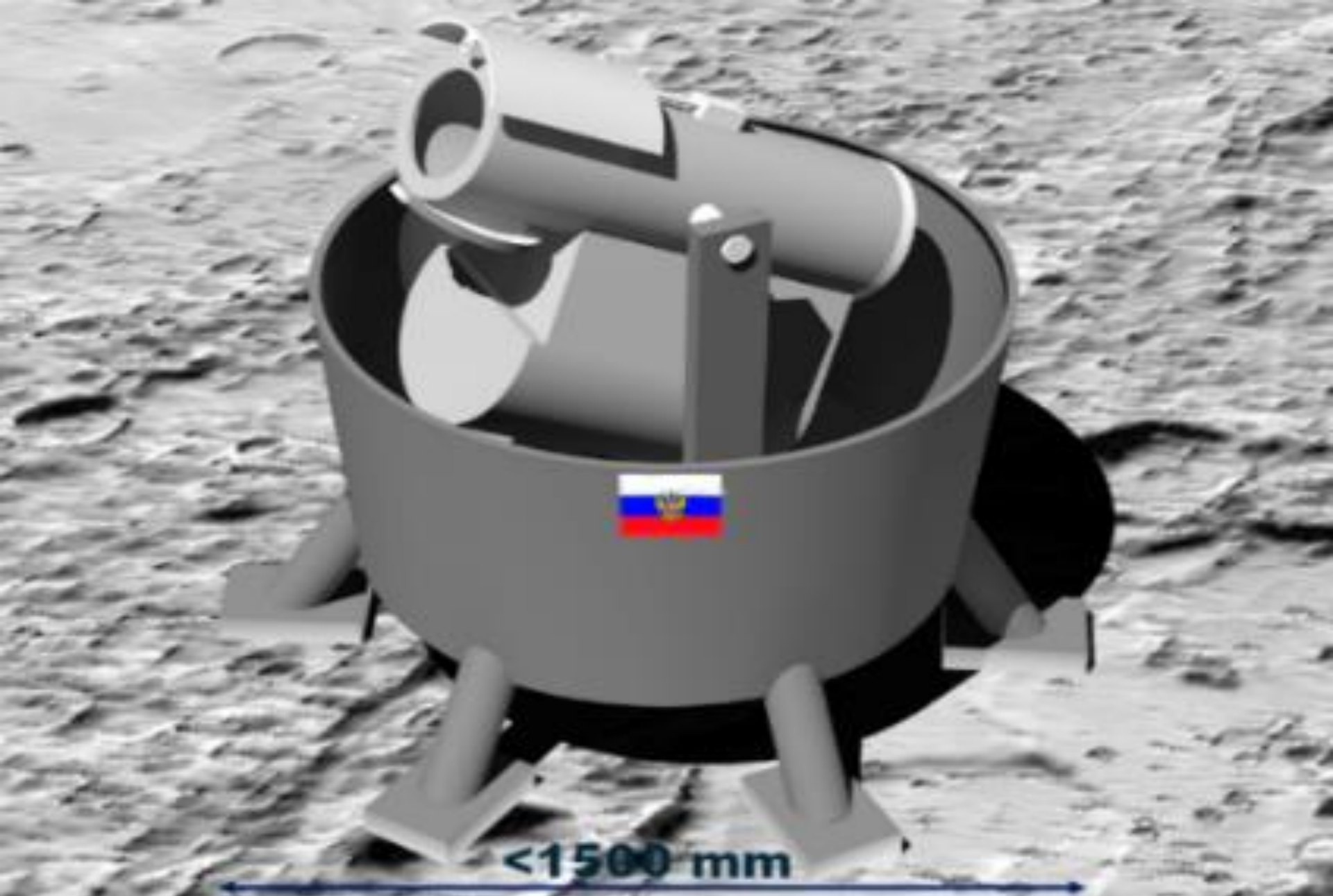
General view of the SOTR-300V complex on the lunar surface without solar panels and soft landing engines.

Quasi-bicentennial variations of TSI along with very important successive multiple influences of the feedback effects **are the main fundamental cause** of corresponding alternations of climate variation from warming to the Little Ice Age **and by the main factor that controls the climate.**

Global warming results not from the emission of GHG into the atmosphere, but from an unusually high level of solar irradiance and a lengthy – almost throughout the last century growth in its intensity.

However, cyclical variations in solar activity are the accompanying phenomena of physical processes occurring in the interior of the Sun and do not substantially affect either the TSI and the climate.

The Sun entered a prolonged cooling period.

We will are experiencing a period of unusually weak solar cycles in 21st century. The last time a prolonged solar minimum was in effect was the Maunder minimum, which saw seven decades of freezing weather, began in 1645 and lasted through to 1715, and happened when solar irradiance was at deep minimum level.

In the second half of the 21st century temperature will dropped globally approximately on 1.3°C which leading to shorter seasons and ultimately shortages food, energy and et al. in this period.

Governments should prepare for this scenario, prepare resources and plans to adapt the economy to new conditions.

The consequences of a deep cooling in the Maunder period warn about the need to ensure the safety of mankind in the coming difficult times.

The painting of the Frost Fairs on the frozen River Thames in 1683, by Jan Griffier

The painting of the Frost Fairs on the frozen River Thames in 1684, by Abraham Hondius.

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