H.I. Abdussamatov 2009 "Russian project Astrometria to measure temporary variations of shape and diameter, TSI etc of the Sun" http://www.gao.spb.ru/english/astrometr/index1_eng.html

The project Astrometria to measure temporary variations of shape and diameter of the Sun – the total solar irradiance, as well as fine structure and dynamics of the granulation on the Service module of the Russian segment of the International Space Station

The main goal of the project:

The study of global processes occurring deeply inside the Sun and of consequent variations of physical processes in the system Sun-Earth as well as the study of fine structure and dynamics of active and quiet regions of the photosphere and of their cyclic variations.

The study of cyclic variation of behaviour of the Sun as of the nearest star and of the physical processes occurring deeply inside it as well as of energy and thermal instability of its condition has a key meaning for all astrophysics, because the theory of stars was actually born in the process of and proven by the study of the Sun. The Sun is available for a detailed research which is impossible for any other star. The physical processes observed on the Sun are obviously characteristic for the majority of other stars but they can be studied in detail only on the Sun. Unfortunately, nowadays it is impossible to find and study variations of radiation intensity and radii of the stars similar to the Sun. This fact additionally confirms the importance of the research dedicated to these phenomena on the Sun particularly by observations from airless space, because this research will supply all needed information about the mechanism of energy transport from the center of a star to its surface and about the nature of processes occurring deeply inside the stars. The study of physical processes on the Sun not only gives us an understanding of a large number of astrophysical questions, but also of the questions of geophysics, meteorology, biology and medicine. All energy sources used by humanity are linked to the Sun. The heat and light of the Sun ensured the development of life on the Earth, formed the deposits of coal, oil, gas etc. Additionally, all life on the Earth and

its future conditions directly and almost in whole depend on the total solar irradiance (TSI) — the so-called "astronomical solar constant". The radiative energy of the Sun is the most important power source for all natural processes occurring on the surface of the Earth and within the atmosphere and for all forms of life on our planet. Any changes in the physical modes of the Sun cause changes in the near-earth space and the Earth. The TS activity of the Sun defines temporal scales for practically all physical processes in the system Sun-Earth. The solar energy flux dynamically defines the climate of the Earth and other planets of the Solar System. The solar energy flux is in turn defined by the area of solar surface or, in the other words, by the diameter of the Sun. An exact value of variations of the solar diameter is an important fundamental parameter and the most important indicator of the TSI variation and of sunspot activity. Consequently, long and exact measurements of the solar radius will provide a possibility for a more reliable determination of the TSI and its temporal variations on different time scales.

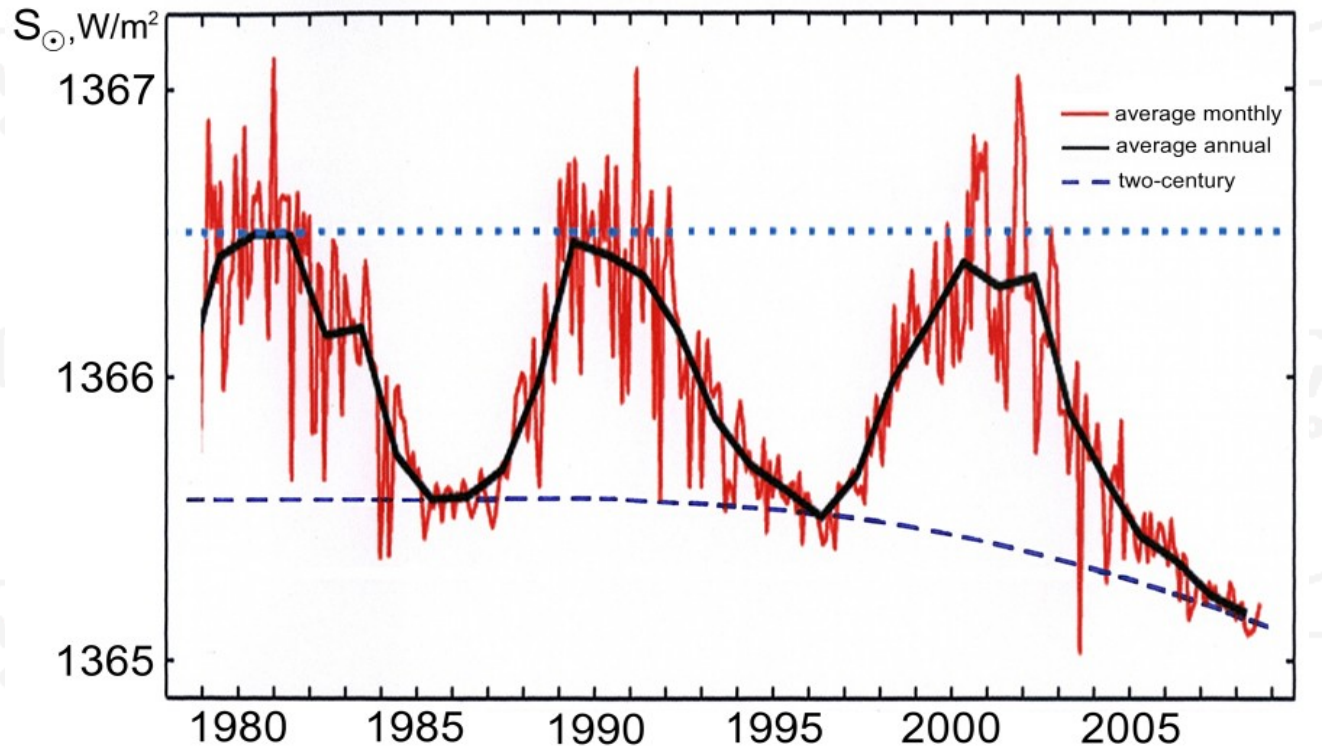
Precise measurements of the temporal variations of the shape and diameter of the Sun, not distorted by instabilities of the Earth atmosphere and oscillation processes within it, can only be conducted from an airless space. The study of reasons of the long-term changes in 11-year and 2-century components of the solar shape and diameter variations —the TSI, and, consequently, of the long-term variations of the Earth climate in the past, present and future is particularly topical due to upcoming climate changes. Thus, only the planned long-term and precise (with an error of 3-4 km) extra-atmospheric measurements of temporal variations of the shape and diameter of the Sun within the Astrometria project would allow us to forecast the climate changes more precisely. If the Astrometria project is implemented in time, we will be able to issue a reliable forecast of the time and scale of the upcoming global fall of temperature on the Earth within approximately 8 years by conducting an active research of temporal variations of the shape and diameter of the Sun and of the solar energy flux on-board the ISS during no less than a half of the on-going 24th "short" 11-year cycle. A solution of this problem would allow us to correct the humans' economical activity beforehand according to the upcoming climate changes and, consequently, to significantly decrease economical, demographic and other crises caused by the upcoming natural global cooling.

On the basis of sunspot activity data analysis, J. Eddy (Eddy J. A. Science. 1976. **192**, 1189), has revealed a correlation between the reliably determined periods of significant variations of sunspot activity during the whole passed millennium and the corresponding considerable climate changes on the Earth. The cyclic variations of climate, especially in Europe during the passed millennium, were not associated with fundamental climate changes, but the changes were frequently sufficient to affect the life of nations and several states leading to economical and demographic crises. By conducting a similar research, Eugene Borisenkov (Climate variations during the last millennium. Leningrad. 1988. p. 275) has found that during each of 18 deep minima of sunspot activity similar to the Maunder minimum with quasi two hundred years period during the last 7500 years, the periods of global climate cooling were observed. The two hundred year maxima of sunspot activity were in turn followed by global warmings. These fundamental changes in the Earth climate could be caused only by the corresponding long term and considerable changes in integral power of the coming solar radiation flux, because any industrial influence was non-existent in those times. This is the evidence of the

fact that during two hundred years maxima of sunspot activity, the TSI was considerably higher and during the periods of two hundred years minima of sunspot activity, it was considerably lower. In the other words, within any significant period of observations, the two hundred year variations of sunspot activity and of the TSI are in whole cross correlated in phase and amplitude. The course of the two hundred year component of the TSI variation was in whole defined by the course of the corresponding variation of sunspot activity.

Thus, not 11-year but two hundred year cycles of solar variations which are mainly defined by the corresponding considerable changes in the TSI are the dominating reason for climate changes — long term geophysical effects, lasting for decades. In whole, **the solar cycles are a key to our understanding of different cyclic variations in the nature and society.**

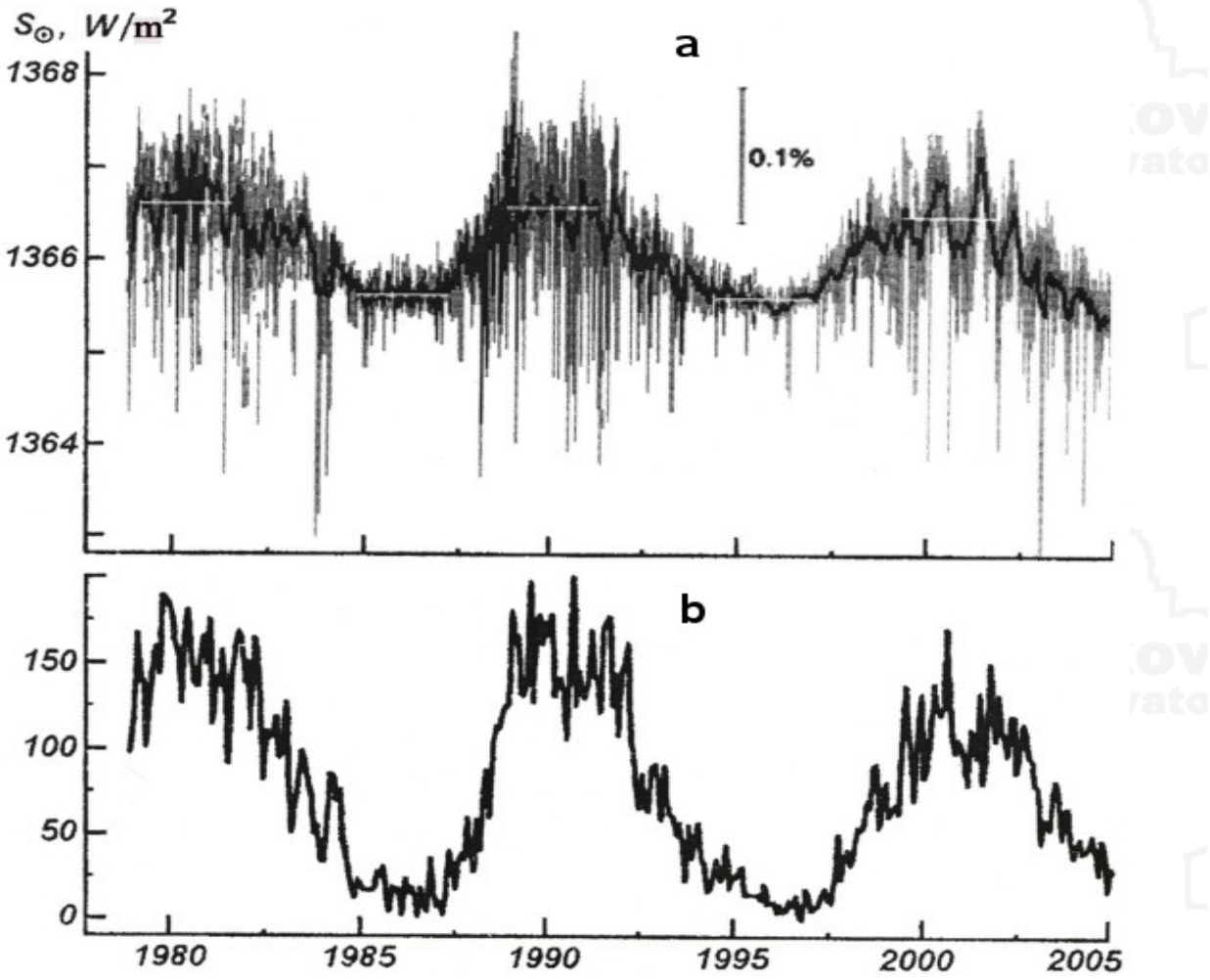
We currently have an uninterrupted long observation series of the TSI $S_{\odot}$ since 1978 (bold line on the figure), directly measured by several special space instruments. The amplitude of 11-year smoothed cyclic variations of the TSI at the maximum of the two century cycle was approximately equal to 1.0 W/m^2 or 0.07% and it has been gradually decreasing since the beginning of 1990s.**The 11-year cyclic variations of the TSI occur in relation to the component of its 2-century variation,** which was for the first time revealed by us in 2005 (dash line on the figure).



11-year and revealed by us 2-century cyclic variations of the TSI for the period of Nov, 16 1978 – Nov, 29 2008 (Frohlich C., Lean J. Astronom. Astrophys. Review. 2004, **12**, 273; www.pmodwrc.ch/pmod.php?topic=tsi/composite/SolarConstant; Abdussamatov H.I.

Kinematics and Physics of Celestial Bodies. 2005, **21**, 328; **(KPhCB). 2007**, **23**, 97).

The curves of 11-year variations of solar activity and the TSI are cross-correlated and quasi-parallel both in phase and amplitude (Abdussamatov H. I. Kinematics and Physics of Celestial Bodies **(KphCB). 2005**, **21**, 471). The 2-century component of the TSI variation shows a subsequent and accelerated (in our times) decrease since cycle 21 to cycles 22 and 23 (dash line on the figure). A similar correlated decrease during the above period is observed (as expected) in the corresponding sunspot activity variations. The observed simultaneous parallel accelerated decrease of 2-century components of both sunspot activity and the TSI suggests the beginning of the active descent phase of the common Grand 2-century cycle of solar activity.



TSI variations since 1978, taken from www.pmodwrc.ch/pmod.php?topic=tsi/composite/SolarConstant (a) and sunspot number W monthly averages (b).

The solar constant is defined by equation

$$S_{\odot}=\frac{\sigma R_{\odot}^{2} T_{eff}^{4}}{A^{2}},$$

where σ is Stephan-Boltzmann constant; A – astronomical unit; $R_{\odot}$ – radius of the Sun; T_{eff} – effective temperature of the photosphere of the Sun. Long-term cyclic variations of the solar constant are caused by the corresponding changes in the solar radius $R_{\odot}$ and effective temperature T_{eff}:

$$\frac{\Delta S_{\odot}}{S_{\odot}}=\frac{2\Delta R_{\odot}}{R_{\odot}}+\frac{4\Delta T_{eff}}{T_{eff}}.$$

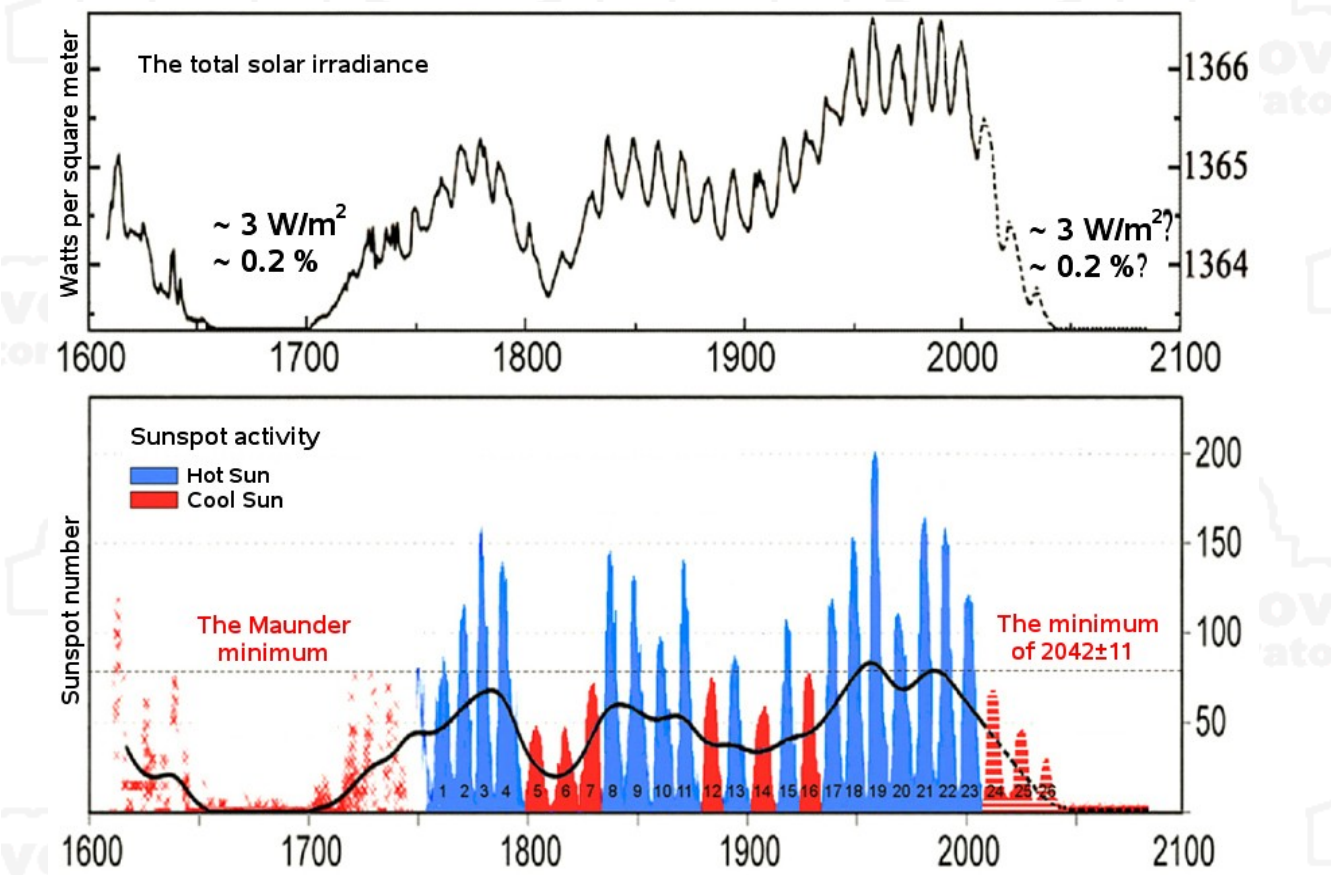
It occurs due to physically complex fundamental processes which take place deeply inside the Sun and are caused by the variations of its base internal properties. Gradual change of the surface layer temperature reaching 0.001°daily maximum leads to the change of pressure within the surface layer and, consequently, breaks the hydrostatic equilibrium defined by the balance of internal pressure and gravitation. The Sun can return to thermodynamical equilibrium only by correspondingly changing its size to the value that ensures the balance of internal pressure and gravitation, which in turn leads to the change of surface temperature to the initial value when $\Delta T_{eff} = 0$ (Abdussamatov H.I. Proceedings of IAU **Symposium. 2004**, No. 223. P. 541; KPhCB. 2005. **21**, 471). The changes in TSI are a result of 11- and 200-year cyclic variations of radius (area of radiating surface) of the Sun, in the other words, the equation

$$\Delta R_{\odot}\approx\frac{R_{\odot}\Delta S_{\odot}}{2S_{\odot}}=k\Delta S_{\odot}$$

takes place, where

$$k=\frac{R_{\odot}}{2S_{\odot}}=255\frac{km}{W/m^{2}}.$$

Consequently, the amount of solar energy supplied to the Earth is directly linked to the value of solar radius, in the other words to the radiating area of our star. Cyclic variations of the TSI occur due to the oscillations of solar radius with amplitude up to 250 km within a "short" 11-year cycle and up to 750 km within a Grand 2-century cycle.

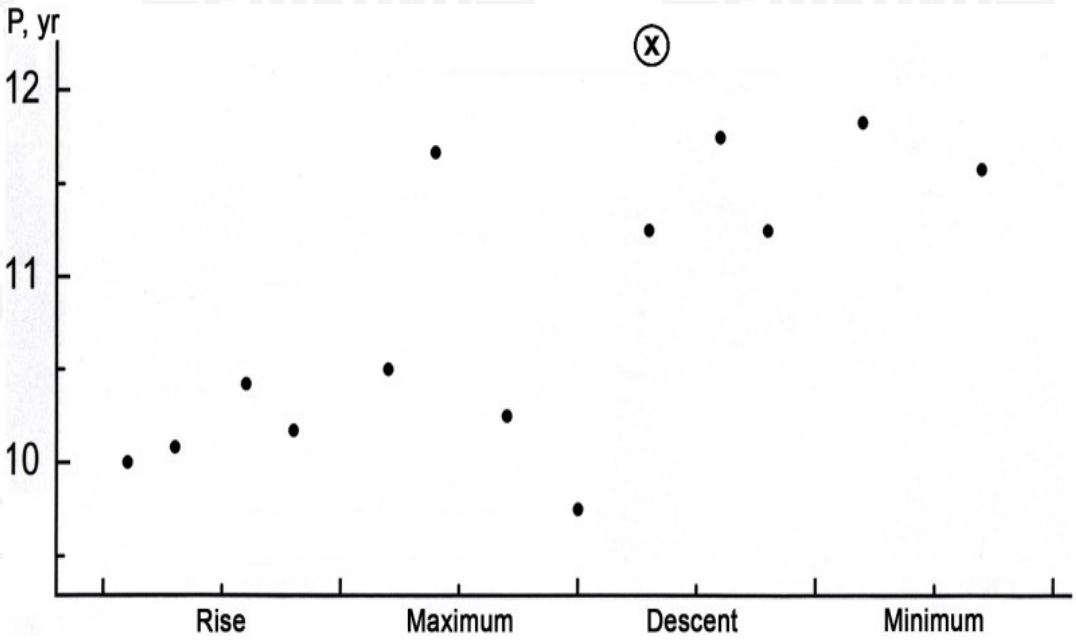


TSI variations (using the reconstructed data) Lean J.L. (2000) and Wang Y.M., Lean J.L., Sheeley N.R. (2005) before 1978 and sunspot activity since 1611 and our forecast of their changes after 2008 (dash lines).

Thus, easily performed conventional Earth-based long-term observations of 11-year and 2-century components of sunspot activity variations, illustrate at the same time the corresponding courses of quasi-proportional changes in the values of the solar radius and the TSI and vice versa. It is established that 11-year and 2-century cyclic variations of the TSI, sunspot activity and solar radius, being the consequences of the same physical processes occurring deeply inside the Sun, are synchronized and cross-correlated both in phase and amplitude. The above regularity enables one, on the basis of the existing long-term data series on sunspot activity, to deduce the course of the TSI during passed centuries and even millenniums to confront these data with the past climate changes and predict the future climate variations.

The 2-century Grand solar cycle plays a dominating role, it manages and defines the regularities of development of the subsidiary "short" 11-year cycles, because the duration of an 11-year cycle, as revealed by us, depends in whole on the phase of the corresponding 2-century solar cycle and subsequently increases from the phase of growth to the phases of

maximum and the descent phase of a 2-century cycle (Abdussamatov H.I. **KPhCB. 2006**. **22**, 141). Duration of the solar cycle 23 which has elapsed in 2008 is not an exception and it confirms this regularity in whole. However, the uniqueness of the elapsed cycle 23 is confirmed by the fact that this cycle became the longest (~12.5 years) among all ascertained and studied 11-year solar cycles for more than 150 years of reliable observations starting from the cycle 10. This fact additionally confirms that the ongoing 2-century cycle is entering its descent phase.



Dependence of 11-year sunspot activity cycles duration for the cycles 10–23 (P) on the phase of a 2-century cycle (x – cycle 23).

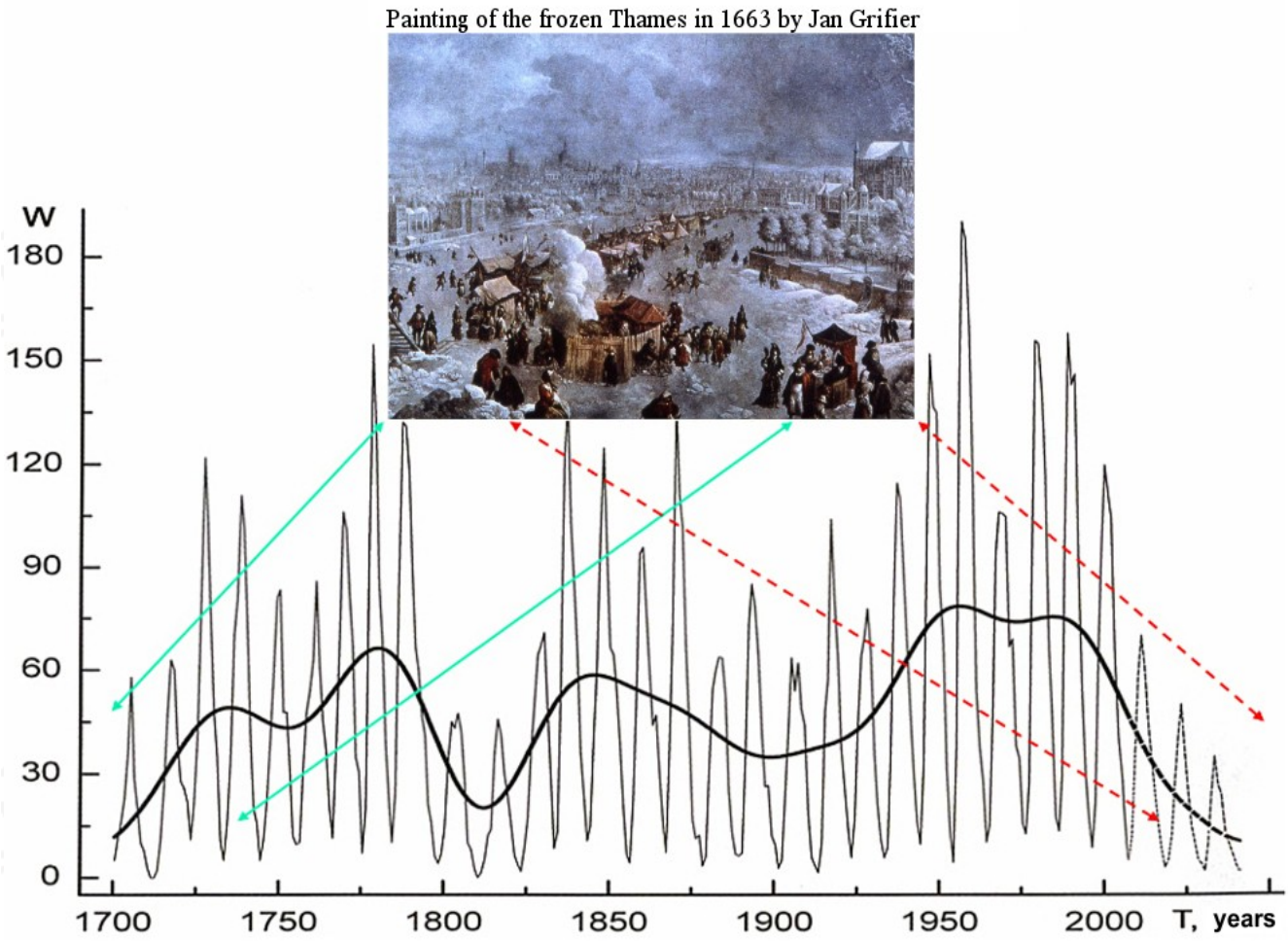
Existence of the 11-year and 2-century solar cycles of identical and synchronized variations of luminosity, sunspot activity and diameter of the Sun is one of the most reliably ascertained facts in solar physics. Strictly speaking, the Sun is not in stationary condition of thermodynamical and mechanical equilibrium, i.e. the global behaviour of the Sun is neither regular nor strictly predictable. The Sun is a variable star and it is changing its global spatial and physical parameters due to the coordinated variations of the TSI, sunspot activity and radius (both in phase and amplitude) in relation to their average level (for a 2-century period) caused by the corresponding changes in the amount of energy released from the depths of the Sun and by superposition of short and Grand cycles (Abdussamatov H. I. The Sun defines a climate. **Nauka i zhizn, 2009**. No. 1, pp. 34-42; The Sun and a climate. **The State Management of the Resources. 2009**. № 3, pp. 22—33).

The cyclic **oscillations of sunspot activity**, occurring simultaneously with the similar oscillations of the solar radius and the TSI, being an accompanying phenomenon of the cyclic solar activity, themselves **neither considerably affect** the variations of the solar radius and

the TSI**, nor influence** climate changes.

The analysis of the physical processes occurring in the depths of the Sun shows that core temperature changes of different amplitudes and periods cause the corresponding changes of pressure inside it, i.e. lead to a disequilibrium of the system. The oscillations of thermonuclear fusion energy emitted by the core can be the first cause of this instability. The Sun can return to thermodynamical equilibrium by suitably changing its size to the value that ensures restoration of the balance between gravitation and internal pressure.

The long-term quasi-periodic increases of temperature and, consequently, of the core pressure, cause inevitable overall heating of the Sun, increase its size and the TSI proportionally to the change of its radius, and they will lead to the corresponding cyclic physical and spatial reorganizations of the whole Sun. As a result, the long-term radial proper motions of plasma, periodically changing their direction depending on the sign of temperature variation, should appear inside the Sun. Such long-term quasi-periodic variations of the internal structure of the whole Sun and the corresponding variations of the radius — internal proper motions — can also become the catalysts of generation and descents of the sunspot activity and of the TSI cycles. An additional energy released by the core can become a source of energy for them. Cyclic disturbances of the tachocline, its shifting along the radius and possible changes in its thickness caused by variations in the internal parameters of the Sun and by internal proper motions, can play a role of catalysts of the generations and descent of the sunspot activity cycles, because according to the new theories, the tachocline – a thin boundary layer between radiative and convective zones of the Sun – plays a very important role in the solar magnetic field formation. Amplitude of the solar core temperature variations and, correspondingly, of the solar radius variations, defines the power of a cycle. Minor variations in core temperature and radius lead to the development of minor cycles (a small amplitude of solar activity and TSI variations), while considerable variations of the temperature and radius cause powerful cycles.



Observed variations in 11-year sunspot activity (solid thin curve) and in 2-century solar activity (solid thick curve) over the period from 1700 to 2008 and our forecast of the variations of these values from 2009 to 2042 (dashed lines) (Abdussamatov H. I. **KPhCB, 2007**. **23**, 97).

The course of 2-century component of the TSI variation during three subsequent "short" cycles defines the further course of the TSI and sunspot activity for not only the coming but also for several succeeding cycles (with smaller accuracy). Thus, the most probable maximum level for the on-going 24th sunspot cycle will be 65 ± 15 (relative sunspot number units). During the subsequent 25–26 cycles which fall on the descent phase of the ongoing 2-century cycle, the tendency of the TSI to fall will prevail, the corresponding maximum levels of sunspot activity will be 45 ± 20 and 30 ± 20, respectively. Thus, a deep minimum of the two secular cyclic activity of the Sun, of the TSI, sunspot activity and radius will most likely come in the beginning of cycle 27, approximately in 2042 ± 11 year. This minimum can last for approximately 45–65 years (Abdussamatov H. I. KPhCB. 2005. **21**, 471; KPhCB. 2007. **23**, 141). Here, the Gnevyshev-Ohl rule (an empirical rule according to which the sum of sunspot numbers over an odd cycle exceeds that of the preceding even cycle), which was broken for

cycles 22-23, should also be broken for cycles 24-25. The breaches of Gnevyshev-Ohl rule are a regular result of the decrease of the 2-century activity component and they indicate the coming of an active descent phase of the ongoing 2-century cycle. Thus, the coming 24-26 cycles will see a tendency of the further decrease in 11-year variations amplitude and the TSI.

The most notable event of XX century's life of the Sun has been an irregularly high level and a century-long growth of the solar radiation flux (the TSI). A similar increase of the solar radiation flux as in XX century has not been observed for more than 700 years. However, its effect — the observed global warming — is not an abnormal, but a regular and natural event for the Earth. The climate of the Earth have always been periodically changing and our planet have already experienced several global warmings, similar to the one we observe. The global warmings have always been followed by deep coolings within regular 2-century cycles. Neither a deep cooling nor a global warming cannot last longer than they are permitted by the corresponding 2-century variations of the size and luminosity of the Sun.

The observed global warming of XI–XIII centuries within the period of a long-term increase in the TSI and sunspot activity, called "a Little Climatic Optimum", which is similar to the observed global warming or even more intensive, caused serious climate changes. In the middle ages vineyards were cultivated in Scotland, Greenland justified its name and was inhabited by Normans in the end of X – beginning of XI century. Europe enjoyed an economic growth which gave rise to Renaissance, middle Asia went through the best period in its history. The last global decrease of temperature (the most cold phase of the Little Ice Age) was observed not only in Europe, North America and Greenland, but also in any other part of the world during the Maunder minimum of sunspot activity and of the total solar irradiance in 1645–1715 years. All channels in the Netherlands were frozen, glaciers were taking over the Greenland and people were forced to leave their settlements, inhabited for several centuries. The Thames river in London and Seine in Paris were frozen over every year. The humanity has always been prospering during the warm periods and suffering during the cold ones. The climate has never been and will never be stable.

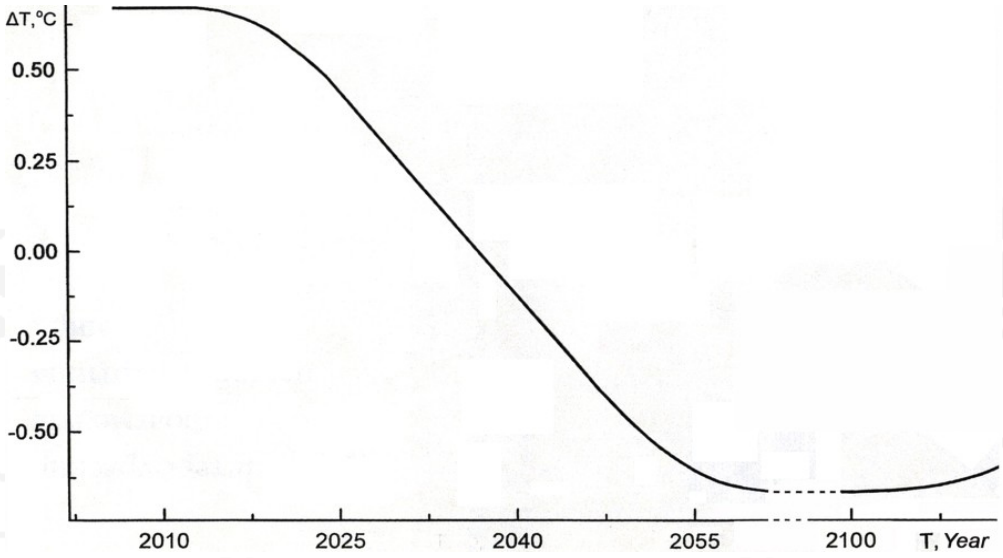
The solar radiation flux reaching the Earth gradually decreases since 1990s both within the 11-year and 200-year cycles, caused by a decrease of the solar radius and solar radiative area. According to our estimates, the solar radiation flux will reach its minimum in 2042 ± 11 year and, in contravention of the presently common opinion, this will lead to the global fall of temperature and cooling of the climate similar to the one observed during the Maunder minimum. By the middle of the century, the deficiency of solar energy received by the Earth, following the analogy of the Maunder minimum, can reach approximately 0.2% or up to 3 W per one square meter of surface of the external atmospheric layers in relation to the maximum average level of 1980s. Here, despite the fact that the amplitude of TSI variation is approximately 0.07% during the "short" 11-year cycle, its influence on climate is softened by the thermal inertia of the ocean. But if an increase or decrease of the TSI variations amplitude will last for two subsequent cycles given a similar course of its 2-century component, the climate will eventually change correspondingly, but with a delay of 17 ± 5 years caused by the thermal inertia of the ocean.

During the elapsed "short" cycle 23 which took approximately 12.5 years, each square meter of the external atmospheric layers received in average 0.19 W less solar energy in relation to the amount of solar energy received in the preceding "short" cycle 22. Annually this deficiency constitutes 6 x 10^6 J for each square meter of the external atmospheric layers of the Earth. The external layers of the Earth hemisphere directed to the Sun (the Earth disc) with the area of 127.5 x 10^6 square kilometers saw a shortage of 24 million of megajoules of heat during the last ~12.5 years. This is an irrefutable evidence of the fact that the Sun has ceased to warm the Earth the way it did in former times and that our planet has been experiencing a deficiency of solar energy during the last 12.5 years, comparable to the full power of 21 million nuclear power plants similar to Leningrad Nuclear Power Plant. Thus, today our planet lives in the conditions of the "cooling" Sun. Consequently, the mankind should not expect a catastrophic ice melting. We should, instead, expect a growth of ice caps on the poles. It has practically begun by now: the area of ice cover in Arctics, in contravention of all forecasts, has increased from September 2007 to September 2008 by 390 thousands of square kilometers (from 4.13 to 4.52 million of km^2).

Some UK researchers blame the so-called "La Nina" ("La Niña" means "a girl" in translation from Spanish) phenomenon for the ongoing cooling. The phenomenon is a long-term decrease in the temperature of surface layers of the central and eastern parts of Pacific ocean, cyclically observed near the coasts of Ecuador, Peru and Columbia. The group of processes accompanying La Nina and the corresponding interactions between the atmosphere and ocean lead to an anomalous decrease of ocean surface temperature by in average 0.5–1 Celsius degrees. Another well-known diametrically opposite phenomenon is called El Nino ("El Niño" means "a boy" in translation from Spanish) which is characterized by an anomalous increase of the surface temperature of the ocean. Both phenomena are equally complicated for forecasting and explanation. In their turn, some American physicists studying El Nino and La Nina suggest that these phenomena can be both just a short-term fluctuations within a longer natural cycle "Super Nino". We consider that all these phenomena, La Nina, El Nino and Super Nino are of a natural origin and are caused by 11-year and 2-century cyclic oscillations of the integral solar radiation flux reaching the surface of the ocean. The change in intensity of solar radiation reaching the surface of the ocean as a result of superposition of "short" and Grand cycles causes the corresponding heating or cooling of its upper layers. There is a temporal correlation between these phenomena and the cyclic variations of solar activity.

The tendency of decrease in the global Earth temperature started in 2006–2008 will temporarily pause in 2010–2012. The increase in TSI within a short 11-year cycle 24 is expected to temporarily compensate the decrease in TSI within the ongoing 2-century variation. Only the decrease in TSI within the ongoing 11-year cycle 24 accompanied by continued decrease of its 2-century component in 2013–2015 will lead to stable subsequent cooling of our planet, which is expected to reach its minimum in the phase of a deep cooling by 2055–2060 ± 11 (Abdussamatov H.I. **Izv KrAO.** 2007. **103**. No. 4. p. 292–298). The cooling can be similar to the one observed in the whole Europe, North America and Greenland in 1645–1715 in the period of Maunder minimum of solar luminosity and sunspot

activity when the temperature will fall by 1–1.5 Celsius degrees down to the mark of the so-called Maunder minimum. The regular period of climatic minimum (the stage of global cooling) will last for approximately 45–65 years and the new warming will eventually come afterwards within the regular 2-century solar cycle. The deep cooling is expected to be regularly replaced by warming only by the beginning of 22nd century. A forecast of the global cooling by the middle of the 21st century and of the new 200-year cycle followed by global warming in the beginning of the 22nd century is shown on the figure.

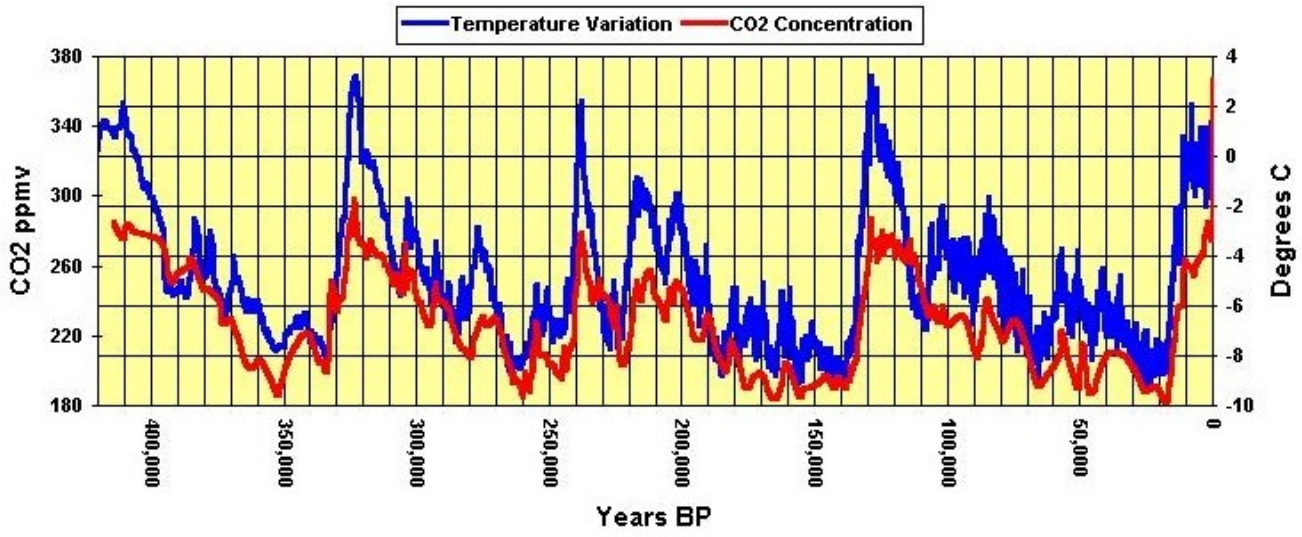


The forecast of global cooling scenario by the middle of XXI century

Scientists took samples of ice from deep (more than 3 km) drilled wells in the Antarctic ("Vostok" station) and in Greenland. It has been found that cyclic terrestrial apocalypses are recorded in the many kilometers thick layer of ice as in the book, because the ice contains bubbles of air from the epoch of ice formation. Modern methods allow to determine the concentration of carbon dioxide, oxygen and other components of relict atmosphere in the ice core with high precision. The temperature of ice formation can be determined as well. By examining the ice samples, the scientists found that natural considerable increases of carbon dioxide concentration and global warmings took place cyclically in the distant pre-industrial epoch when there were no traces of industrial influence. Additionally, it has been found that cyclic considerable increases of atmospheric carbon dioxide concentration during the past 420,000 years have never preceded the global warmings but instead they followed the rises of temperature with the time lag of 200–800 years, thus being the effects of global warmings. Moreover, even considerable increase of atmospheric carbon dioxide concentration during the past 400 millennia has never caused the rise of temperature on the Earth. And the natural concentration of carbon dioxide in the atmosphere during the glacial periods has always been 2 times lower that nowadays.

The increase in greenhouse gases concentration is not the reason of global warming, but on the contrary, the result of the rise of temperature caused by prolonged increase in the TSI.

The rise of atmospheric concentration of carbon dioxide takes place with a delay (from the moment of global warming). The delay is necessary to heat deep layers of the ocean and to melt virtually all floating icebergs (200–800 years). The ocean is the major storage of carbon dioxide and because the solubility of gases in water decreases with the rise of temperature, heating of the ocean causes the emission of a large volume of gases into the atmosphere. Another source of carbon dioxide emission was found several years ago by the scientists of Eastern department of Russian Academy of Sciences: a large amount of old dead algae frozen inside the icebergs floating in Arctic and near the coast of Antarctica. Being thrown out in the warm water after ice melting, they decompose, being another major source of emission of CO_2 into the atmosphere. This proves that the observed increase in atmospheric $C0_2$ concentration is mainly the result of natural increase in temperature of the land and ocean. Consequently, the popular statement that the industrial activity of humans plays a major role in global warming has emerged from mixing up the cause and effect or, in the other words, "a locomotive" and "a wagon".



Variations of Earth temperature and the concentration of CO_2 in its atmosphere over the last 420,000 years

(Antarctic ice core data: www.daviesand.com/Choices/Precautionary_Planning/New_Data/).

Thus, the observed global warming on the Earth is not caused by human-induced greenhouse gases emission, but mostly by unusually high intensity of the solar radiation during the whole passed century. The coming decrease of global temperature will take place even if the anthropogenic CO_2 emission will reach record high levels in the future.

The interesting fact is that in XX century global warming took place on Mars as well as on the Earth. This global warming has been caused by considerable and prolonged increase in TSI in XX century. NASA researches were keeping a track of changes on the surface of our neighbour planet — Mars over the period from 1999 to 2005 and they have discovered a gradual melting of ice on its south pole during three Martian years and a simultaneous global

warming on Mars, without, of course any participation of Martians and greenhouse effect caused by them. The same simultaneous global warming as on Mars and on the Earth have also been observed on the Jupiter, Triton (a satellite of Neptune), Pluto and several other planets of the solar system. These warmings can only be consequence of the same and only factor — a prolonged and unusually high value of the TSI during almost whole XX century. The simultaneous global warmings on the Earth, Mars and in virtually whole solar system are the phenomena of the natural solar origin and are caused by natural — astronomic reasons and not by industrial activity of the humans.

The global warming observed on Mars during 6 years — from 1999 to 2005 is not a result of changes in the shape of its orbit and its the tilt of axis as frequently stated by some researchers. The changes in the shape of orbit and its the tilt of axis of Mars and the Earth have a period of around tens thousands years and they are unable to increase significantly the quantity of solar energy supplied to Mars and to change its climate during the minor period of 6 (six!) years. At the same time, the dust storms currently observed on Mars can be a result of increase in absorbing capacity of the Mars and of uneven heating of different parts of its mountainous surface caused by long influence of the increased TSI during the whole XX century. Not only global warming on the both planets is among the consequences of an increased solar luminosity. The warming in its turn has led to an increased absorption capacity of the surfaces of the planets and has changed the physical properties of their atmospheres. These indirect secondary effects of the Sun influence have led to an additional increase of temperatures on Mars and on the Earth being comparable to the one caused directly by 2-century increase of the TSI.

Our calculations show that the maximum amounts of energy absorbed by CO_2 (within the absorption bands 2.2 – 3 micrometers; 3.6 – 4.7 micrometers; 12.8 – 17.3 micrometers) and by H_2O vapour (4.4 – 8.8 micrometers; 5.5 – 7.5 micrometers; 15–30 micrometers and more than 20 micrometers) account for approximately 63% of integral power of the Earth radiation, given that we have an optically thick layer, i.e. the flux is fully absorbed in each of the absorption spectral bands. Of these 63% approximately 51% are absorbed by H_2O vapour and only 12% by CO_2. This proportion is caused by a partial overlap of the absorption bands of these gases and a constant humidity of the atmosphere for small variations of pressure and temperature. The atmosphere of the Earth releases approximately 10% of the Earth radiation to space, the remaining 27% are absorbed by clouds and by the molecules of other greenhouse gases, among which methane (CH_4) is probably the most active one. Thus, the atmospheric absorption of the radiation of the Earth is defined mainly by the concentration of water vapour which is responsible for over a half of the absorbed radiation, while the concentration of carbon dioxide is less important.

If we imagine a hypothetical possibility to remove carbon dioxide from the atmosphere, then the atmospheric absorption would fall from 63% to 51%. But the increase of CO_2 concentration, given its presently high level, will not lead to any considerable increase in atmospheric absorption of the radiation of the Earth. It can be explained by the following

circumstances. Within the band 4.7 – 12.8 micrometers carbon dioxide virtually does not absorb infrared radiation of the Earth. It is known that the main spectral window of the atmosphere is within 8–12 micrometers band and that the maximum of the Earth own radiation is around 10 micrometers. Outside the spectral window the Earth radiation is not released to space even with the current concentration of CO_2. Only a minor change of absorption rate near the boundaries of the spectral window is possible.

It should be noticed that not only carbon dioxide does not help global warming, but it is also very useful as it stimulates the development of life on the Earth being a critically essential "food" for the plants — the major cleaners of the nature. Higher concentrations of carbon dioxide accelerates the growth of forests and plants. The evidence of this fact is the so-called "green revolution" — a sharp and global increase in the productivity of agriculture all over the world in XX century. The direct proportionality of agricultural productivity and the concentration of CO_2 is confirmed by a number of experiments. In case the supply of carbon dioxide to the atmosphere ceased, the plants would exhaust its reserve in approximately 10 years. After this, every living thing on the Earth may cease to exist. CO_2 is not toxic! CO_2 does not react with any substance within a human body and it is a harmless gas unlike CO. CO_2 is very important for life.

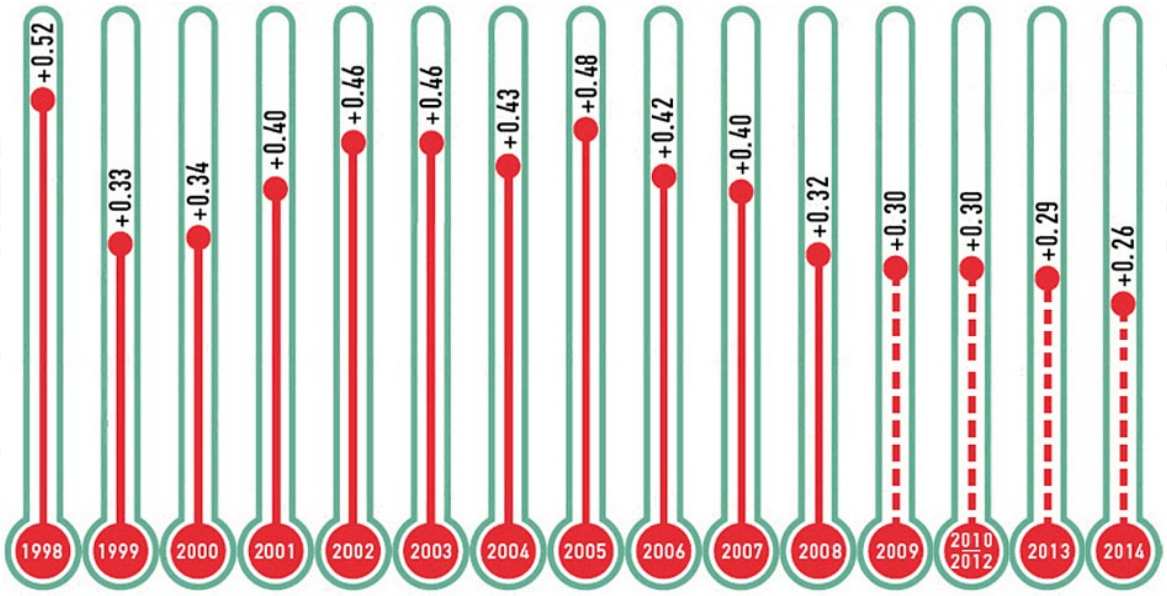
It is important to notice that underlying surface of the Earth and the atmosphere are a shell system. Convective, evaporating and condensation mechanisms of heat exchange play a dominant role in the thermal balance of the Earth and its atmosphere. Taking into account the importance of greenhouse effect, in current condition the variations of greenhouse gases concentrations have a secondary meaning compared to the main defining factors such as changes in the TSI and in albedo (reflection power) of the underlying surface of the Earth.

Changes in the TSI exert a dominating influence on the thermal mode of the Earth. If the TSI fell by 1.0 W/m^2, the temperature of the Earth would fall by up to 0.2 Celsius degrees. The fall of temperature caused by the fall of TSI $S_\odot$ leads to the further additional fall of temperature. If $\Delta S_\odot$ = -1.0 W/m^2 then ΔT = -0.2 degrees which leads to an additional growth of the mean albedo of the Earth by approximately 0.003 and so on. It is important to stress that by our calculations, of all radiation and optical parameters of the Earth surface, the change in albedo of the Earth exerts a dominating influence on the variation of temperature. In the case mean albedo of underlying surface rose by 0.01, the annual average global temperature would fall by approximately 0.7 degrees. Albedo of the Earth is the regulator of the thermal mode of our planet.

According to our calculations and to the calculations of our foreign colleagues, the direct influence of 2-century cyclic variation of the TSI accounts for only about a half of the amplitude of changes in the global Earth temperature. However, it is the main and original source of energy, dictating the whole mechanism of climatic changes. The other half of amplitude of the global temperature change is the effect of influence exerted by 2-century variation of the TSI — a secondary effect: the temperature change causes gradual changes in

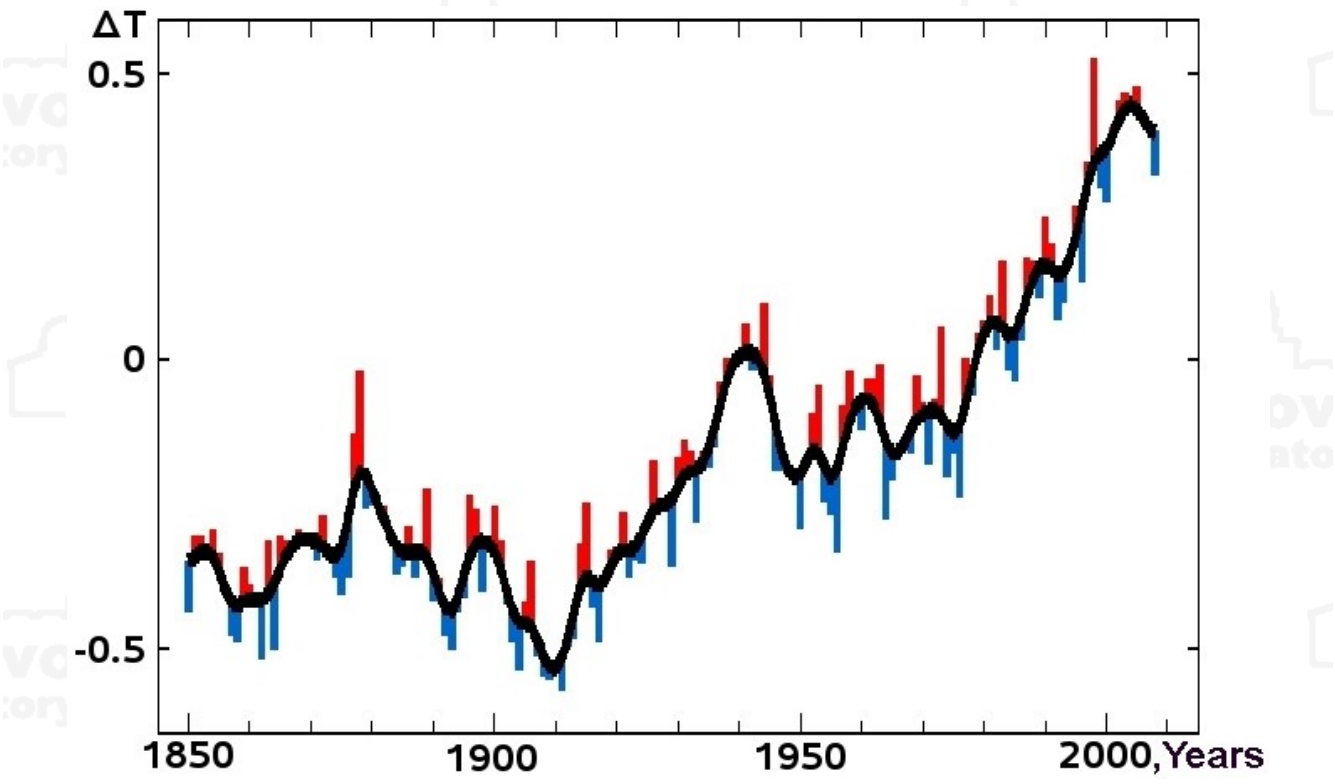
reflection power and absorption capacity of the underlying surface of the Earth and in the physical properties of the atmosphere: the concentration of water vapour (the main greenhouse gas), carbon dioxide and other greenhouse gases. These secondary effects comparable to the direct influence of the TSI variation additionally sharply accelerate the course of global temperature changes on the Earth. Over the last decades the TSI value changed insignificantly, but these changes were accompanied by the rise of concentrations of water vapour and carbon dioxide in the atmosphere due to the global warming caused by a prolonged growth of the TSI, and albedo of underlying surface has been gradually decreasing. Existing data point out the constant decrease of albedo of the Earth over the period 1984–2000. These secondary effects have led to an additional increase of temperature of the Earth.

The TSI has entered a descent phase of the 2-century cycle in early 1990s, but the thermal inertia of the ocean causes the global warming observed during the last years. Our planet had been receiving and collecting an anomalously high thermal energy from the Sun during almost whole XX century. Since the early 1990s it has been giving off the accumulated energy. Suddenly the climatologists found that in 2003 the upper layers of the ocean started to cool down. The heat, accumulated by oceans is unfortunately tailing off. This is an indisputable evidence of the fact that climate changes on the Earth are directly influenced by 2-century variations of solar energy supply and it directly confirms that the Earth has already reached in 1998–2005 the stage of maximal global warming mainly caused by an anomalously high and prolonged increase of the solar energy flux during almost whole XX century.



The observed changes in annual average global temperature since 1998 and the expected tendency of the temperature changes over the period 2009–2014 in relation to the mean temperature of 1961–1990 years which was equal to +14 Celsius degrees.

Nowadays, a few years before the beginning of the upcoming global cooling, we are going through an unstable phase when the temperature will oscillate around the reached maximum without any substantial increase. In 2008 the global temperature on our planet not only did not rise but even fell down due to the decreasing (and record low over 30 years of observations from space) solar luminosity. The stabilization of the global Earth temperature in 1998–2005 and its downward tendency in 2006–2008 is an irrefutable evidence of the fact that our Sun is no longer able to warm the Earth the same way as in the past and that an anthropogenic global warming is a big myth. 1998–2005, being the warmest years for 150 years of weather observations, will stay on the peak of 2-century warming. By the middle of the ongoing century, the new (19th for the last 7500 years) little ice age similar to the Maunder one, will come. The global temperature will fall even without limitation of greenhouse gases emission by industrialized states. That is why the Kyoto treaty is useless so far and should be put off till at least 150 years later. However, climate changes on the planet will spread unevenly depending on the latitude. The fall of temperature will least affect the equatorial region of the Earth and will mostly influence the temperate climate regions. In whole, climate changes are not under the control of humans. A reasonable way to combat these changes is to maintain an economic growth in order to get prepared to alternating coolings and warmings. The coming global cooling will be replaced by a regular 2-century global warming only by the beginning of XXII century.



The known course of global temperature change over the period from 1850 to 2008 in relation to the average temperature of 1961–1990 which was equal to +14 Celsius degrees.

The upcoming cooling will lead to a substantial decrease of concentrations of water vapour (the main greenhouse gas) and carbon dioxide in the atmosphere as these concentrations are directly dependent on the temperature. The global cooling will also lead to the extension of the total area of ice and snow cover — to the rise of the mean albedo of the underlying surface. Due to the above changes, the amount of absorbed solar energy by the whole underlying surface of the Earth and the share of greenhouse effect will considerably decrease. We should expect an additional sharp intensification of cooling due to the above secondary factors which are a direct consequence of a 2-century decrease of the TSI — a global change on the Sun.

That is why we should intensify the research on this most complex problem ever faced by scientists by precise measurements of the global parameters of the Sun, because the amount of solar energy supplied to the Earth is directly dependent on the solar diameter, i.e. on the area of radiating surface of our star. Unfortunately, the image of the Sun, not distorted by the instability of the Earth atmosphere and by oscillatory processes within it, can only be received from airless space. That is why only prolonged special precise (with the error of ± 3–4 km) extra-atmospheric measurements of the temporal variations of the shape and diameter of the Sun, planned by us within the Russia-Ukrainian project Astrometria on the Russian segment of International Space Station, would be able to give a more accurate climate forecast. If the Astrometria project is implemented in time, we will be able to issue a reliable forecast of the time and scale of the upcoming global fall of temperature on the Earth within approximately 8 years by conducting an active research of temporal variations of the shape and diameter of the Sun and of the solar energy flux on-board the ISS during no less than a half of the ongoing 24th "short" 11-year cycle.

Thus, **an exact absolute value of solar radius is the most important fundamental parameter** and it can serve as one of the basic values and as an indicator of both activity level and radiation flux. That is why our prolonged high-precision measurements of the absolute value of solar radius will make possible a more accurate determination of both the TSI and its temporal variations over different periods of time. Here, the spectra of oscillations of the basic properties of the Sun, that is radius, oblateness, integral radiation flux are essential to study its internal structural parameters, because they characterize the changes occurring within the internal layers of the Sun and down into the solar core. The study of spectra and the understanding of the nature of temporal variations of these properties and, consequently, of the structure of the Sun and of its mechanical and thermal instability will make it possible to study the internal global processes inside the Sun which are not directly observable. We will also be able to get a better understanding of radiative transport mechanisms and of the nature of processes occurring deeply inside the stars by using solar-star analogies. Here, the observed long-term variations of the TSI caused by the corresponding variations of diameter is another one poorly studied nexus between the Sun and the stars. That is why **the study of the origin of the long-term variations in the TSI**, i.e. the corresponding variations of radius, is critically important. However, the precise uniform measurements of the absolute value of radius of the Sun, not distorted by the instability of the Earth atmosphere and by oscillatory processes within it, can only be conducted from outside of the atmosphere of the Earth, from airless space. That is why, for a research on the most

important and most urgent basic problems of the solar physics and of the astrophysics in whole and for a more effective and precise research on the origin of the solar constant variations — temporal variations of the shape and diameter of the Sun, we have developed the Astrometria project on the Service Module of the Russian segment of the International Space Station (Abdussamatov H. I. J. Opt. Technol. 2006. **73**, 236); (Abdussamatov H. I. et al.Bulletin of the Russian Academy of Sciences: Physics. 2007. **71**, 596).

The main tasks of the project

- Coordinate and photometric **monitoring of the solar disk diameter and the shape of the solar limb** with the error of 0.005 arc seconds and of its oblateness with the error of around $10^{-6}R_{\odot}$ (by the median of 100 observations) with a frequency of 5 Hz;
- Coordinate and photometric monitoring of **two central and sixteen limb sections of the disk** with spatial resolution around 0.7 arc second with a frequency of 0.05 Hz;
- Coordinate and photometric measurements of angular distances between reference stars $+2.5 \le m_b < +6.5$ with the error of 0.004 arc seconds (by the median of 100 measurements) for image scale calibration and to control the stability of functional parameters of the limbograph as a whole (six times a month);
- Creation of the unique database containing fundamental high-precision series of the above measurements over the period of at lest a half of an 11-year cycle;
- In-flight fine-tuning of the unique scientific instruments providing the above measurements for the further long-term observations of the Sun with the use of unmanned space vehicles.

The main goals of the project

I. The study of global processes occurring deeply inside the Sun and of the related physical processes within the system Sun–Earth:

- The spectrum and nature of disk shape, diameter and oblateness variations and their dependence on the phase of a cycle;
- The internal structure and its dynamics during the cycle; the nature of global processes occurring **deeply inside the Sun and the stars** and of their cyclic variations;
- Physical mechanisms and the nature of a solar cycle; long-term forecasting of the cyclic activity, diameter and TSI variations;
- Direct and indirect influence of the long-term variations of the solar diameter and TSI on the deep changes in the climate of the Earth; forecasting of the time and scale of the upcoming global cooling.

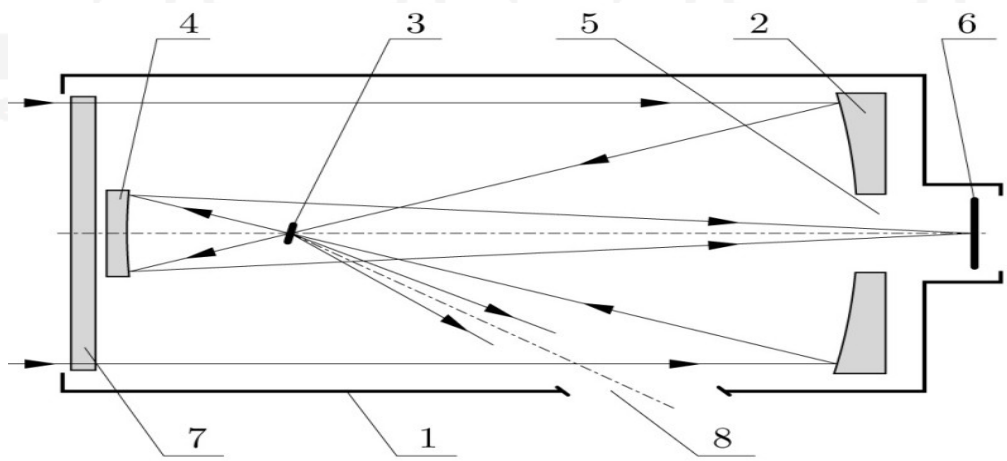
II. The study of cyclic variations of the fine structure of the photosphere:

- The fine structure and dynamics of the active and quiet features and their cyclic

variations; oscillatory processes within the active regions of the Sun;

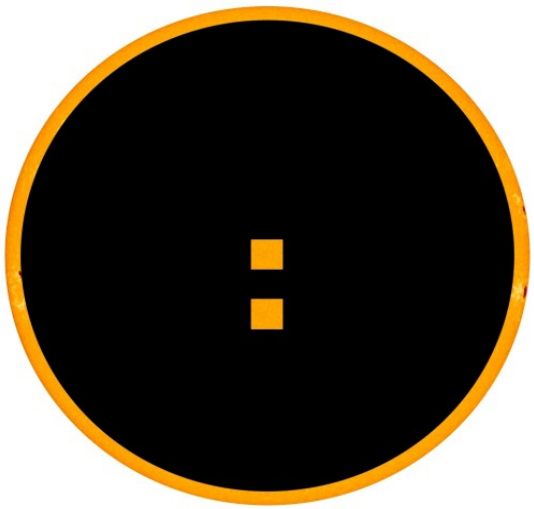
- A very high precision dynamics of the surface convective movements at mesogranular and supergranular scales; the nature of granular, meso- and supergranular structures.
- Physical properties of the photosphere versus depth as the diameter and the phase of the cycle are changing; dynamical properties of the inversion layer, its variability during the cycle;
- Creation of an adequate non-uniform model of the photosphere of the Sun.

To solve technical problems caused by direct influence of the integral solar disk radiation flux on the stability of the optical parameters, mechanical properties of the telescope and the photo detecting block and also in order to get unambiguous and consistent results with the required precision, the unique space-based solar limbograph SL-200 has been developed and patented (Abdussamatov H. I. Patent of Russian Federation No. 2158946 for an invention, 2000). The effective diameter of the primary mirror of this instrument is 200 mm, the instrument simulates an annular solar eclipse. The SL-200 base optical system is a hyper-focal aplanatic Gregory system with an artificial moon 3 mounted in the intermediate focus. The artificial moon covers more than 90% of the central image zone of the solar disk and leaves only a very thin limb edge ring and two central regions of the disk available for observations. The moon is an opaque elliptic shield with transverse angular diameter of at least 1800 arc seconds with two central holes, installed angularly (12° in relation to the plane orthogonal to the optical axes). Solar radiation flux reflected by the mirror surface of the artificial moon is driven out through the aperture 8 in the case of limbograph. SL-200 is equipped with quartz beam (spectral) splitting filter 7 on the entrance pupil which produces more than 100 times reduced solar radiation flux and by a heliophotomicrometer with a special cell photo detector Ø 50 mm located in the focal plane 6 on a special movable padding. The system of Image Quality Analysis (IQA) analyses the variations of granular contrast from the central photo detecting block while the photo detecting block is being slowly moved by the means of an Auto Focusing System (AFS). When the best granular contrast is reached, the AFS fixes the position of CCD photo detector and thus it gets installed in the plane of the best focusing. Calibration of the image scale and control of stability of SL-200 functional parameters are performed by periodical measurements of angular distances between the bright reference stars. During the star observations, the light filter 7 is removed from the pencil of rays and the Ø 200 mm diaphragm becomes an entrance pupil of the system. An equivalent focal distance of the system is 4800 mm.



An optical layout of the limbograph with a ray tracing for an axial beam

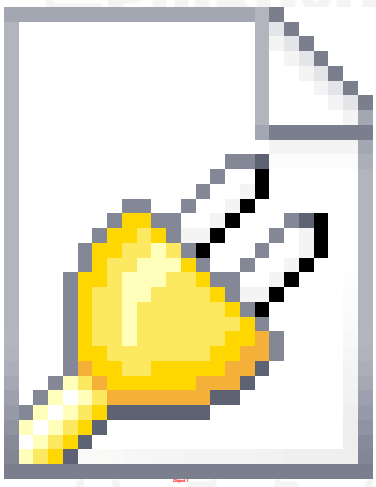
- 1 – The invar case (tube) of the solar limbograph;
- 2 – The concave ellipsoidal primary mirror $Ø_{eff}$200 mm made of silicon carbide (λ /50) with the central hole 5 Ø 49 mm;
- 3 – The flat opaque thermal shield mirror – "an artificial moon" – of elliptical shape with transverse angular diameter of at least 1800 arc seconds with two central holes;
- 4 – The secondary concave elliptic mirror $Ø_{eff}$44 mm made of silicon carbide (λ /50);
- 6 – The heliophotomicrometer – a registering photo detecting device (a special CCD array Ø50 mm) in the focal plane of the limbograph;
- 7 – The mirror light (spectral) splitting filter made of quartz glass KU-1 $Ø_{eff}$188 mm (λ / 50) which defines the aperture of the system during solar observations, being an entrance pupil;
- 8 – The aperture in the case of the limbograph.

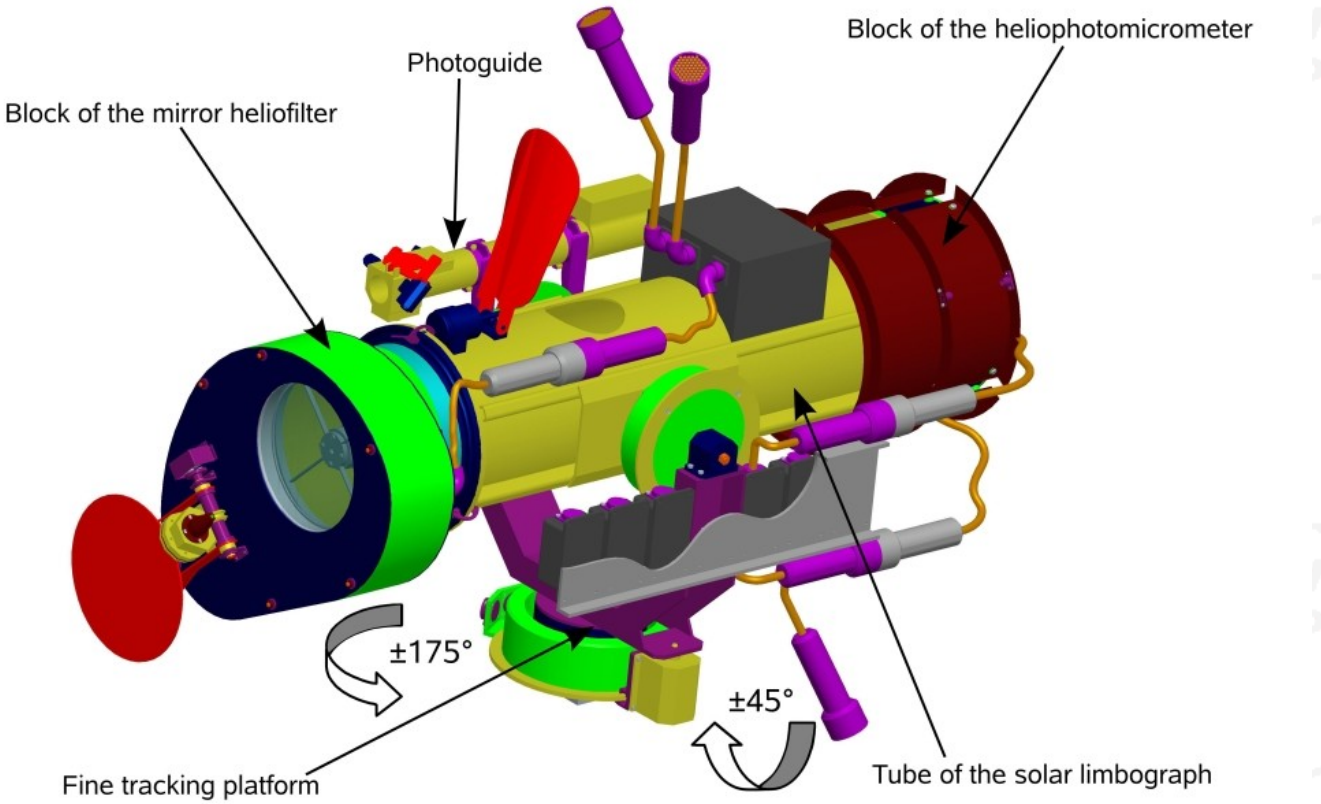


An image of limb and two central regions of the solar disk produced by SL-200, bounded by the edge of field of view Ø35 arc minutes and by the edge of the artificial moon Ø30 arc minutes.

The scientific instruments of the **measuring-research complex of SL-200** consist of two blocks:

- A block of optics and mechanics (BOM) installed in the open space beyond the case of Service Module of the Russian segment of ISS.
- A block of electronics consisting of the internal sub block with a computer installed in the airtight compartment of the Service module and an external sub block with a CPU installed directly on the BOM.





A general view of the block of mechanics and optics (BOM) of the SL-200 complex.

The developed two-loop autonomic thermal regime assuring system (ATRAS) consists of the regulated electric heaters with the total power up to 100 W which ensure the compensation of unadjusted thermal losses of the BOM to the outer space and the vacuum-shielded thermal insulation (VSTI) of its external surfaces. The invar case (tube) of the limbograph is covered by two layers of VSTI (the thickness of each layer is 10 mm) with an additional aluminium pipe between them to ensure equal temperature along the optical axis and inside the invar tube. The passive elements of the ASTS are the system which protects the secondary mirror from the direct solar radiation and from overcooling during the star observations, external radiating panels and thermal buses to remove excessive heat produced by the photodetector and during the solar observations and also the heat protecting annular lens hood installed within the lens case. Thus, a uniformly spread negative external thermal balance of the case-tube of the limbograph is achieved within the range of work temperatures by the means of choosing the radiation parameters, a thermal insulation of the case-tube and the external surfaces of the radiators. Such ATRAS is able to maintain the given thermal mode of the mirrors and the case-tube of the limbograph within the allowed range of 1.0 K given that the temperature difference between the mirrors and the case is not more than 0.5 K and is able to maintain the displacement of the focal plane of the optical system in the cyclical work mode

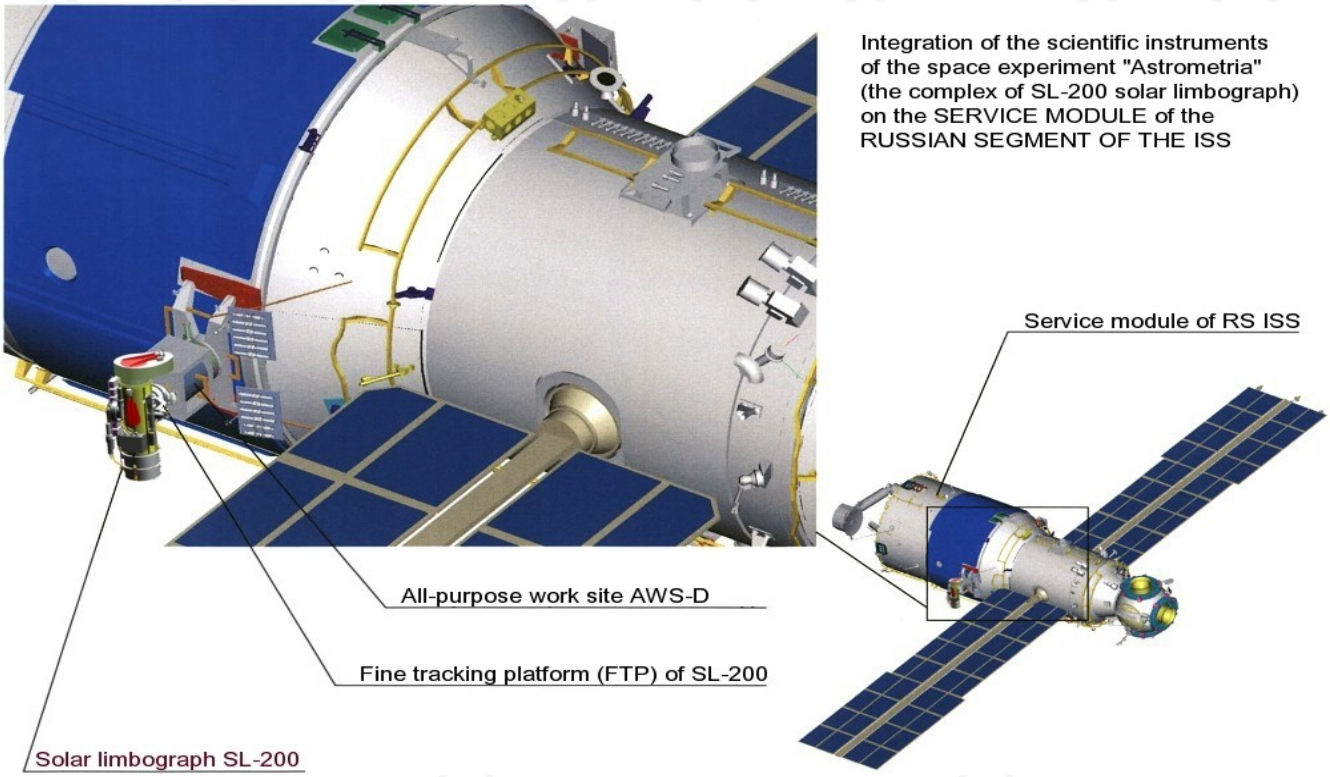
within no more than 25 micrometers (Abdussamatov H. I., Hankov S. I. Journal of Optical technology v. 73, No. 1, p. 29, 2006; v. 73 No. 4, p.37, 2006). Here, to avoid the overcooling of the case-tube of the limbograph, the duty-loop of the ATRAS is permanently switched on. Stability of the limbograph focal plane position can be achieved by adjusting and registration of the mirror and case-tube temperatures:

$$\Delta f = B_{pri} Q_{pri} + B_{sec} Q_{sec} - B_{ct} Q_{ct},$$

where Δf – thermal displacement of the focal plane; Q_{pri}, Q_{sec} and Q_{ct} are the heatings of the primary, secondary mirrors and the case-tube, respectively; B_{pri}, B_{sec} and B_{ct} – transfer coefficients for the primary mirror, secondary mirror and the case-tube, respectively. By the means of this formula and the temperatures of mirrors and of the case-tube, one can determine the thermal displacement of the limbograph focal plane during either solar or bright reference stars measurements and include the corresponding compensating correction to the measured values.

Thermal and mechanical construction of the limbograph SL-200 is worked on the basis of invar case, silicon carbide primary and secondary mirrors, thermal protecting covers and the thermostating of the photo detecting device and of the main optical and mechanical parts. The use of quartz light (spectral) splitting filter on the entrance pupil and of the artificial moon in the intermediate focus of the optical system ensures a stable and high image quality and other through characteristics of the optical and photo detecting block as a whole.

The special fine tracking platform for the instruments of measuring and research complex SL-200 was developed in 2004. The fine tracking platform features the extended rotating angles on vertical (±175°) and horizontal (±45°) axes. The extended rotating angles allow the implementation of the Astrometria project on the SM RS of ISS without the earlier planned use of an intermediate pointing nexus (a two-degree pointing platform (TDPP) and a detachable work site (DWS)). Thus, according to our request, the BOM of the SL-200 complex is to be attached directly to AWS–D (all-purpose work site) located on the external surface of the large-diameter working compartment (WC–2) of the SM along plane IV (starboard) at a distance of about 1000 mm from its case. Thus, large expenses for manufacturing, delivery and operation of the TDPP and DWS during six years are avoided. Additionally, the pointing complex is significantly simplified, the mechanical reliability of the system is increased, the precision of pointing the BOM to the Sun or to a given celestial site containing at least a pair of reference stars and the precision of guidance are also increased.



According to the calculations of the specialists of the Korolev Energia Rocket-Space Corporation (RSC Energia), when the orbital orientation of the ISS is maintained by means of controlling moment gyroscopes (CMG), the system ISS–AWS-D–space–BOM of SL-200 experiences virtually no resilient oscillations since the frequency spectrum of the controlling actions lie outside the range of the natural frequencies of the combined system.

The complex of SL-200 works in five major modes:

- **LIMB MEASUREMENTS:** Coordinate and photometric measurements of the shape of limb and of the diameter of the Sun with a frequency of 5 Hz
- **PHOTOSPHERE MEASUREMENTS:** Coordinate and photometric measurements of the fine structure of the photosphere within 2 central and 16 limb sections of the disk with a frequency of 0.05 Hz.
- **CALIBRATION:** Coordinate and photometric measurements of angular distances between reference stars $+2.5 \leq m_b < +6.5$ for image scale calibration and to control the stability of functional parameters of the limbograph as a whole (six times a month);
- **FOCUSING** of the optical system of SL-200 with a given spatial frequency by the means of image quality analyser (IQA) and automatic focusing system (AFC) when necessary.

- **ADJUSTING** of the instrumental axes of SL-200 in relation to the instrumental axes of two star sensors of the star coordinates block (SCB) of the SM (six times a month).

The mission profile of the experiment is controlled by the on-board equipment control system (OECS) of the SM and by the block of electronics (BE) of SL-200 complex. Systems of the block of optics and mechanics and of the photo detecting device are controlled by BE. Recording of the given lines of the photo detector (during the solar observations) or of a given 2–3 limb sections (during the bright star observations), their processing and registration of the images of solar limb, of the central regions of the solar disk and of the bright stars is also controlled by the BE of SL-200. Registration of the service and control information on the operation of the scientific instruments is also performed by the BE of SL-200. The scientific and service information is efficiently transmitted to the Earth by the corresponding on-board systems of the SM. The results of the experiment recorded to removable hard drives are additionally periodically brought to the Earth.

The implementation of the Astrometria space project on the RS of ISS will particularly make possible an accurate determination of the TSI and of the course of its temporal variations and a more accurate explanation and forecasting of the upcoming global climate changes.

The high importance of the Astrometria project for the solution of the most important fundamental problems and applied tasks makes its implementation during the rising phase of the new solar cycle 24 highly necessary (this period is optimal due to astronomical circumstances). The implementation of this project during the above period will substantially increase its scientific efficiency and output and enhance the scientific prestige of Russia in an important section of the fundamental science.

The design documentation development for BOM and BE of the SL-200 is finished. The blocks and modules for the experimental sample of BE for Leningrad Optical Institute are manufactured. The Korolev Rocket and Space Corporation "Energia" together with CAO RAS have implemented the integration of the scientific instruments of the space experiment Astrometria (the solar limbograph SL-200 complex) on the Service module of the Russian segment of the ISS.

The project Astrometria on the monitoring of temporal variations of the shape and diameter of the Sun and of the fine structure of the active and calm regions of the solar photosphere is included in the federal **"Scientific program of research and experiments planned on the Russian segment of the ISS"** and on 2006-10-14 by an international agreement it was included in the international **"Scientific program of the Russian-Ukrainian research and experiments on the Russian segment of the ISS"** as a top priority task.

Learn more...

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