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The Increase in the Water Vapor Concentration in the Course of Warming Leads to the Decline Climate Sensitivity to a Growth in the Abundance of Carbon Dioxide

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Abstract

Excess TSI in the growth phase of the bicentennial cycle due to thermal inertia will provide a long-term positive the Earth's energy imbalance (EEI), which will lead to a slight increase in temperature by about 0.25K. The warming that has begun due to an increase in solar insolation will increase significantly due to influence multiple long-term feedback effects: mainly due to a natural increase in the amount of water vapor, a decrease in Bond albedo, an increase of carbon dioxide abundance and a narrowing of atmospheric transparency windows. The influence of feedback effects also will continue both during TSI maximum phase, as well as during the short period (about 30 years) of the beginning of its decline phase. Variations in the absorption spectra of the thermal radiation of the surface corresponded to the increase in the general water vapor concentrations in the atmosphere by 7% and the carbon dioxide from 350 to 420 ppm in a warming period were modeled considering the partial overlap of their spectral absorption bands. The physics of increasing carbon dioxide abundance is such that its ability to warm the planet is determined by the ability of increasing carbon dioxide to absorb surface thermal radiation, which decreases as the concentration of water vapor in the underlying near-surface layers sharp increases with warming. As a result, the warming-related sharp increase in the water vapor concentration in the underlying near-surface layers will lower the effect on the temperature increase of the uniform growth of the carbon dioxide abundance in the overlying layers. An accurate understanding difference of the distribution combined increase water vapor and carbon dioxide concentrations with height under warming in the atmosphere is fundamental to assessing and predicting of the future climate change. The data obtained by the Lunar Observatory will make it possible to reliably reveal the physical mechanisms of formation, reasons, and regularities of climate.

Keywords: Bicentennial solar cycle; Climate; Combined impact H_2O and CO_2; Modeling; Thermal inertia; Instability EEI; Lunar observatory

Introduction

One of the most important peculiarities of our parent star is its cyclically alternating periods of growth and fall in the power of the radiated energy with quasi-periods of 11±3 and 200±70 years. With the delay due to thermic inertia, all long-term variations in the physical activity of the Sun are naturally reflected in the state of the near-Earth space environment, the Earth itself. Quantitative measures of climatic characteristics are formed as a result of reflection, scattering, and absorption of the solar radiation by the atmosphere and the surface both of the land and of the World Ocean (hereinafter – Ocean), with its subsequent transformation to the intrinsic thermal radiation of the Earth as a planet, and also due to the vertical and horizontal transfer of energy, air, and water, as well as the movement of minerals and organic compounds in the Ocean. The long-term state of the absolute value of the global Earth's energy imbalance between the it and outer space (EEI), which is never stable and never in equilibrium, and of the thermal state of the entire planet due to the thermal inertia as a whole are determined by the variation of the difference between the energy that the Earth receives from the Sun and the energy that the Earth loses back to outer space, i.e. the difference between the amount of solar energy absorbed by Earth and the amount of energy the planet radiates to space as heat. That's why long-term variations in incoming solar irradiances are potentially influencing the EEI and hence the climate as well as the circulations of sea currents and air masses in the atmosphere and cloud formation. Additionally, solar radiation plays a role in changing carbon dioxide concentration in the atmosphere and water evaporation, humidity, and agricultural and ecological processes, which are interconnected with climate [1-7]. The extremely complex and non-linear climatic system of the Earth depends on the cumulative effect of variations of the set of numerous physical processes, the dynamics and loops of causal feedback effects occurring during the 30-years and longer periods in ocean-land-atmosphere subsystems; these processes are, in turn, subject to a multitude of various factors. The basic and dominating factor affecting all geophysical processes is a bicentennial cyclical variation in the TSI, accompanied by the subsequent substantial manifestations of climatic processes. Moreover, also it is important to study significant impact of the increase in the subsequent effects of the long chain of secondary non-linear cause-and-effect feedback processes in climatic variations, caused by variations in the surface and atmosphere parameters (changes in the Bond albedo, the water vapor and carbon dioxide concentrations, etc.) [7]. Due to the secondary causal feedback effects, even the most insignificant long-term yearly-average TSI variations caused by one hundred thousand-years cyclical oscillations of the shape of Earth's orbit, in correspondence with Milankovitch cycles, result in the Great glacial/interglacial cycles, and, according to Clausius-Clapeyron relation and Henry Law, to substantial natural variations in the abundances of water vapor, carbon dioxide and other greenhouse gases in the atmosphere [7,8]. The significant positive correlation between a solar proxy and climatic records observed during the Holocene can be explained only by the fact that long-term solar radiation changes had a decisive and considerable climatic impact throughout the Holocene at multiple time scales [9-15]. However, a model simulation claim that direct influence of the Sun has a modest climatic effect because in fact the changing of long-term the total solar irradiance direct influence to the Earth's climate insignificantly. While most of the solar effect on climate caused by subsequent nonlinear mechanisms climatic feedback [8]. Indeed, the Sun influence Earth's climate by insignificant direct radiative and by a significant of the climatic feedbacks forcing. Actual the total effect of solar energy together with the influences generated subsequent by climatic feedback on the Earth's climate may be several times greater than the direct effect of TSI alone.

An Energy Imbalance between the Earth and the Cosmic Space

A fundamental index determining the global energy imbalance of the climate system and the thermal state of the entire planet is the long-term (the order of 30 years – period of thermal inertia) EEI, since the climate is determined exceptionally by the long-term variation of the global thermal state (the heat content) of the entire planet. Disbalancing of the energy system of the underlying surface and the atmosphere can result only from consistent variations of the yearly-average EEI during a time of the order of 30 years and more, whatever their reasons may be. To study physical mechanisms of the climate formation and variations it is primarily necessary to determine the reasons for long-term variations of the yearly-average EEI. In the decline (or growth) phase of TSI bicentennial cycle within a period of ~35-65 years the Earth always radiates to space more (or less) energy than it absorbs, since due to the thermal inertia of the Ocean the planet does not have enough time to respectively cool down (or heat up). Naturally, this mechanism provides respectively a negative (or positive) long-term yearly-average EEI as a result of 11-year and quasi-bicentennial TSI variations due to the thermal inertia of the oceans. A disbalanced state in the income and outcome of the entering solar energy in the underlying surface – atmosphere system on the outer border of the atmosphere is the natural state of the climate system because it never stable and never in equilibrium [16,17]. Therefore, the quasi-bicentennial and 11-year TSI variations and the variations of the physical conditions on the surface and in the Earth's, atmosphere related to the long-term effect of TSI variations (primarily the variations of the Bond albedo and the water vapor concentration), taking into account the thermal inertia, are the basic sources of the energy instability and violation of the Earth's thermal balance. The EEI is determined by the difference between the values of the specific power of the solar radiation obtained by the outer layers of the atmosphere on the area of the cross-section of the globe πr^2 (r is the radius of the planet) and the fractions of its reflected and scattered energy outgoing to the space, determined by the Bond albedo of the Earth and also by the intrinsic thermal radiation outgoing from the atmosphere to the space in all directions from the entire surface of the Earth's sphere with the area $4\pi r^2$ [16,17]:

$$E = \frac{\left(S_{\odot} + \Delta S_{\odot}\right)}{4} - \frac{\left(A_{BE} + \Delta A_{BE}\right)\left(S_{\odot} + \Delta S_{\odot}\right)}{4} - \varepsilon\sigma\left(T_p + \Delta T_p\right)^4 \qquad (1)$$

where E is the specific power of the variation of the enthalpy (heat content) of the active oceanic and atmospheric layer (Wm^{-2}) of the planet, $S_{\odot}$ the TSI, $\Delta S_{\odot}$ the TSI increment, A_{BE} the Bond albedo of the Earth, ΔA_{BE} the increment of the Bond albedo of the Earth, ε the rate of emission (blackness degree) of the underlying surface-atmosphere system, σ the Stefan-Boltzmann constant, T_p the thermodynamical planetary temperature (of the Earth's surface and the atmosphere), ΔT_p its increment. The planetary thermodynamical temperature is the temperature*y* averaged over the entire surface of the planet (the Earth's surface and the atmosphere). The temperature increment is determined by long-term increments of the TSI and the Bond albedo of the Earth:

$$\Delta T = \frac{\Delta S_{\odot}\left(1 - A_{BE} - \Delta A_{BE}\right) - \Delta A_{BE} S_{\odot}}{16\varepsilon\sigma T^3} \qquad (2)$$

A natural temperature gradient in BCC determined by the TSI difference for the period from the Maunder minimum phase to the current maximum phase, equal to $\Delta S_{\odot} \approx 4\ W/m^2$ [18-21], without taking into account all other contributions for can only reach

$$\Delta T \approx 0.25°C \qquad (3)$$

A variation of the EEI, independently of reasons for variations of its constituents for the time of the order of 30 years and more, is a basic measure of subsequent climate variations. Such a long-term consistent drop in the Earth's temperature in the decline phase of the bicentennial cycle generates secondary causal feedback effects: an increase in the Bond albedo of the Earth, a substantial

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decrease in the concentrations of greenhouse gases in the atmosphere, according to Clausius-Clapeyron relation and Henry Law, an increase in the atmosphere transmission of the thermal radiation of the Earth's surface to the space, and a decrease in the area of the "dark" surface of the Ocean. These effects will result in an additional decrease in the planet temperature; in turn, this will lead to a long chain of such cycles, which will also retain within the entire phase of the extended Grand minimum of TSI bicentennial cycle, when $\Delta S_{\odot} \approx 0$. Therefore, in the end of the Grand minimum phase, the cooling will reach its maximum. Even in the periods of virtually constant TSI ($\Delta S_{\odot} \approx 0$) during extended maximum and minimum phases of the bicentennial cycle, due to multiple repeated feedback effects, the EEI variation, determined from the equation (1) will persist

$$E = \frac{\Delta S_{\odot}\left(1 - A_{BE} - \Delta A_{BE}\right)}{4} - \varepsilon\sigma\left(T_p + \Delta T_p\right)^4 \quad (4)$$

and the same is true for the temperature increment determined from the equation (2)

$$\Delta T = -\frac{\Delta A_{BE} S_{\odot}}{16\varepsilon\sigma T^3} \quad (5)$$

Consequently, the Bond albedo of the Earth is also a highly important physical parameter in the EEI, as its increment *ΔA* = 0.003 (1.0%) is equivalent to a lowering of the TSI by $\Delta S_{\odot}$ = –5.9W/m^2 (0.435%). In general, the Bond albedo increases to the maximum level with deep cooling and decreases to the minimum level with global warming.

Thus, during extended maximum and minimum phases of a bicentennial solar cycle, gain temperature and EEI variations gain is result from continued secondary cause-and-effect feedback effects under virtually constant TSI. Depending on the long-term (the order of 30 years and more) trend of variations of the absolute value of yearly-average EEI and its sign, one can reliably estimate the excess of the accumulated entered energy (with the positive sign) or its accumulated deficit (with the negative sign) in the Ocean. Consequently, a corresponding direction and the depth of the forthcoming climate variations is determined considering by the thermal inertia of the Ocean and the forecast of the forthcoming TSI variations of the quasi-bicentennial cycle and feedback effects. Note that the combined radiation energy outgoing from the upper part of the atmosphere into the space is one of critically important parameters in studies of climate variations and in the most reliable forecasting of its future variations. In this case, of course, in the climatic system, the role of natural inter-system reasons for short-term temperature variations up to ±0.5^{0}C must also be considered. They are due to volcanic eruptions on land and underwater, the distinction between fluctuations of regional oceanic and atmospheric flows, cloudiness, the surface area of snow and ice covers, etc., and also due to their substantial difference in the North and South hemisphere, taking into account primarily the non-uniform distribution of land on their surfaces (~39% and ~19%, respectively).

The surplus of the incoming solar energy thereby accumulated in the Ocean's active layer during the BCC's growth phase, without considering the effect of all the other factors, resulted in only an insignificant (~0.25K) increase in the planet's temperature. However, the latter triggered a significant change in the physical, optical (the albedo), and radiation characteristics (degrees of emissivity, as well as the transmission of thermal radiation of the Earth's surface into space by the atmosphere) of the Earth's surface and atmosphere and the content of water vapor and carbon dioxide. This also triggered the long-term substantial impact of the long chain of an important secondary feedback mechanism:

a) A substantial decrease around snow-ice covers, variation in the physical parameters of the Earth's surface and atmosphere, and, consequently, a substantial decrease in the lost by Earth fraction of the incoming solar energy due to increased absorbed radiation.

b) A natural increase in the concentration of the basic greenhouse gas, water vapor, and other greenhouse gases in the atmosphere, with the warming according to Clausius-Clapeyron relation and Henry Law, which substantially enhanced the occurred warming due to the noticeable growth in the greenhouse effect.

c) A decrease in atmospheric transmission of the thermal radiation of the Earth's surface to space due to the narrowing of its transparency windows caused by the increase in the concentrations of greenhouse gases in the atmosphere.

d) An increase in the "dark" surface of the Ocean, caused by the increase in the water level, due to deglaciation on land and the thermal expansion of water by warming, which results in a growth in the fraction of the absorbed solar energy.

They led to a further significant increase in warming. The increase of this heating, in turn, has caused additional changes in the physical and optical characteristics of the Earth's surface and atmosphere, forming a re-intensification of temperature change. Increased heating, in turn, has caused additional changes in the physical and optical characteristics of the Earth's surface and atmosphere, which has formed a chain of repeated multiple self-intensification of temperature changes.

The natural substantial self-amplification of the warming in the *XX* century by long chains of those mentioned above secondary cause-and-effect climatic feedback effects additionally continued anomalously for more than 60 years in the very extended phase of the BCC maximum, when the amplitude of the SA and TSI oscillations quasi-stabilized around the maximum level during five 11-year cycles. The natural substantial self-amplification of the warming by long chains of the above-mentioned secondary feedback effects also continued at the beginning of XXI century, an approximately 30-year initial period of the BCC's decline phase. This is precisely the effect of very extended chains of feedback that resulted in the observed natural additional substantial self-amplification of climate warming at the end of the XX and the beginning of the XXI century taking into account powerful eruption of submarine the Hunga Tonga-Hunga Ha'apai volcano, which was also accompanied by the eruption 146 million tons of water vapor

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from the South Pacific Ocean to a height up to 55km, which led to additional warming by increasing the influence of the greenhouse effect due to the sharp growth of water vapor in the atmosphere [22]. This is why climatic variations on the planet accelerated under the influences of feedback effects, which imminently led to substantial multiple additional self-amplification of the started warming. In this case, an extended minor TSI growth (up to 0.3%) is sufficient for starting the insignificant heating and triggering a chain of consistent events of secondary cause-and-effect feedback effects, mutually enhancing each other and resulting in substantial climate variations.

The Increase in the Water Vapor Concentration in the Near-Surface Layers in the Course of Warming Lowers the Sensitivity of the Climate to the Uniform Growth of the Abundance of Carbon Dioxide with Height

The chemical composition of dry air as a whole varies relatively little up to the height of around 100km. However, the most important variable components of the atmosphere are the water vapor, significantly depended on a height changes, which is basically located in the troposphere, and the carbon dioxide, with a constant fraction in the mixture up to the height of the order of 80 km (being uniformly mixed along the height). Their natural concentrations in the atmosphere vary substantially depending on climate variations due to strong positive feedback between them and temperature variation according to Clausius-Clapeyron relation and Henry Law. Main part of the increase in atmospheric CO_2 and all increase H_2O can be attributed to a redistribution of them between the oceans and atmosphere, primarily as a result of changing Ocean temperatures. These concentrations grow to a maximum level during warmings and lower to a minimum level in Ice Ages (in addition, substantially strengthening and weakening the greenhouse effect, respectively) [6]. This results in corresponding variations in physical characteristics of the atmosphere and the surface, and also in the transmission of the thermal radiation of the Earth's surface to the space through the transparency windows of the atmosphere without intermediate absorption and repeated multiple re- radiation. The transmission capability of the atmosphere with respect to the thermal radiation of the Earth surface into the space depends on variations in the abundance of greenhouse gases, primarily of water vapor, and also of carbon dioxide, i.e., on the variation of the fraction of thermal radiation of the Earth's surface absorbed by them in the spectral ranges of the transparency windows of the atmosphere. The most substantial transparency window of the atmosphere stretches from 8 to 13 micron and virtually coincides with the spectral interval of the maximum energy of the Earth's radiation at the wavelength 10.045 micron. The fragmented part of the transparency windows lies within the spectral range 3 to 5.5 micron (Figure 1).

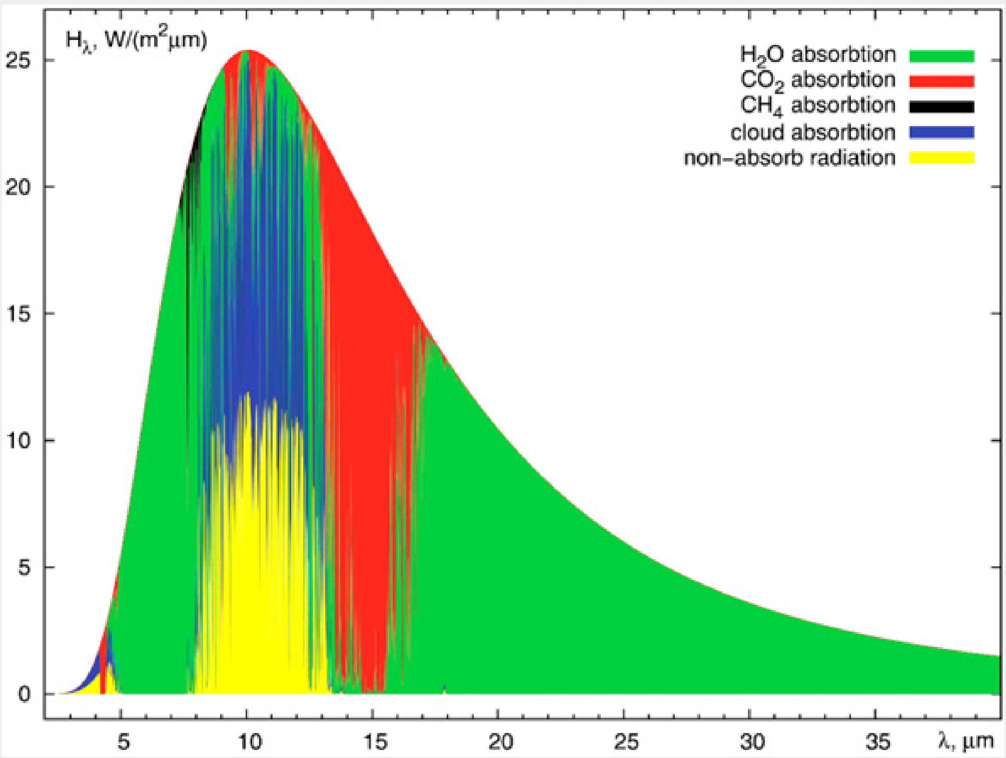

Figure 1: Spectral-flux density of thermal radiation from the Earth's surface as an absolute blackbody and its fractions absorbed by the main greenhouse gases [23,24].

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The widths of the atmosphere transparency windows and the transmission capability of the atmosphere with respect to the thermal radiation of the Earth's surface to the space reach their maximum in the deep freeze periods and decrease to their minima at the stages of warming, since the concentration of greenhouse gases in the atmosphere changes in proportion to changes in temperature according to Clausius-Clapeyron relation and Henry Law. The importance of the transparency windows of the atmosphere in EEI is obvious, since when in the long-term a window narrows, the Earth can heat, and vice versa. Outside the transparency windows of the atmosphere, long-wave radiation of the Earth's surface becomes totally absorbed by the atmosphere and does not emerge to the space even with the current level of the carbon dioxide concentration. The basic absorbed fraction of the power of the thermal radiation from the surface accrues to the spectral bands of absorption of the main greenhouse – the water vapor, and amounts to roughly 68%, while carbon dioxide absorbs only around 12%. This proportion results from partial overlapping of spectral bands of the water vapor and carbon dioxide absorption within the intervals ~4-5, ~9-11 and ~12-18 micron (Figure 1), and also from a specific maximum distribution of the water vapor concentration in the surface layer with its very sharp drop with the height in the troposphere (Figure 2). If no mutual overlap of these absorption bands occurred, the water vapor would absorb about 77% of the thermal radiation of the surface, while carbon dioxide only around 17%.

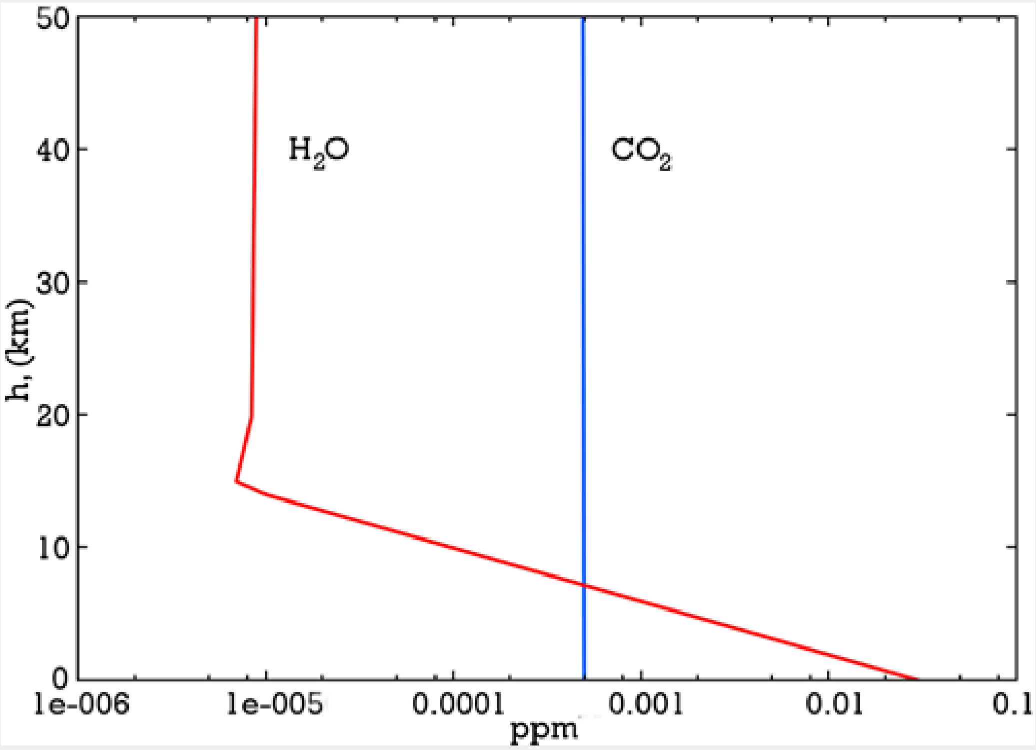

Figure 2: Changes in the concentrations of H_2O and CO_2 with altitude h in the atmosphere [23,24]. The concentrations of H_2O and CO_2 is plotted on a logarithmic scale.

Long-term increase in the TSI level in the growth phase of the bicentennial cycle, equal to about 4W/m^2 [18-21], with a delay of the order of 30 years determined by the thermal inertia of the Ocean, inevitably involves a temperature increase by ~0.25°C (equations 2 and 3) and a correspondinge natural increase in the concentration of both water vapor and carbon dioxide in the atmosphere. However, in this case the increase in the absorption of the thermal radiation of the surface by these gases with an increase in the temperature is not proportional to the increase in their absolute concentrations in the atmosphere. The reason is that, in accordance with vertical profiles of volume concentrations of the water vapor and carbon dioxide in the atmosphere, an insignificant simultaneous increase in their total concentration with warming results in a sharp increase in the water vapor concentration immediately in the lowest near-surface layers of the troposphere, in contrast to a uniform distribution of the growth of the concentration of the carbon dioxide up to the height of the order of 80km (Figure 2). This results from the fact that almost all water vapor is concentrated in the troposphere and displays the maximum concentration immediately in the surface layer of the air, decreasing very sharply with the height in the troposphere and remaining roughly constant in the stratosphere. British and American scientists note that along with the latest 30 years' warming, the level of the air humidity in the surface layers and

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above the ocean surface has grown by 2.2%. Since about 1900, the amount of water vapor has increased according to the Clapeyron-Clausius relation by between 6 and 7% due to a warming of the lower atmosphere of about 1°C. The increase in the concentration of the water vapor in the surface layer as a whole substantially increases the opacity of the atmosphere for infrared radiation. As a result, the relation between the absorption of the thermal radiation of the Earth's surface by the water vapor and that by the carbon dioxide noticeably alters in favor of the water vapor, due to substantial overlapping of their absorption bands within spectral intervals of the transparency windows of the atmosphere. This results in a substantial growth in the absorption of the thermal radiation of the surface by water vapors in the surface layer of the air in the course of warming. In this case, the transparency window of the atmosphere makes it possible for about 10% of the thermal radiation of the land-and-sea surface of the Earth to be transmitted directly through the atmosphere to the space without intermediate absorption and repeated multiple re- radiation, and, consequently, without heating of the atmosphere. Clouds, in the current approximately stable state of their area and their optical density, along with the molecules of other minor greenhouse gases absorb about 10% of the thermal radiation of the Earth's surface.

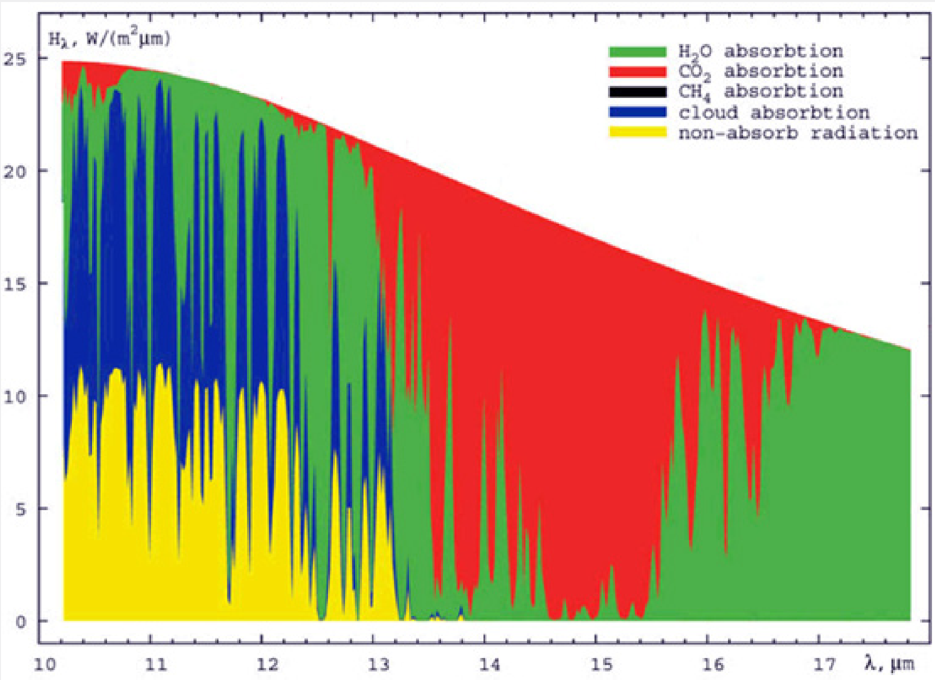

Figure 3: The absorption of thermal radiation flux from the Earth's surface by the main greenhouse gases in the initial state.

Occurring directly within the surface layer of the troposphere, the sharp increase in the ratio of the density of the volume concentrations of the water vapor and the carbon dioxide in the course of warming results in a relative increase in the fraction of the absorption of the thermal radiation of the surface by the water vapor in the overlapping spectral absorption bands within the transparency windows of the atmosphere. Variations in the absorption spectra of the thermal radiation of the surface corresponding to the increase in the general water vapor concentrations in the atmosphere by 7% and the carbon dioxide from 350 to 420 ppm in a warming period were modeled with a fixed cloudiness taking into account the partial overlap of their spectral absorption bands. The constructed one-dimension model of the lower atmosphere (troposphere and stratosphere up to the height of 50km) took into account the radiative transfer in the IR spectral range (1–50 micron) and the convection. The surface radiation was not considered of the blackbody type; instead, it was assumed that the surface radiates as that of slightly heated water. As a result, the sensitivity of the climate to the content (uniformly increasing with the altitude) of the carbon dioxide in the atmosphere decreases with a substantial increase in the relative fraction of the water vapor concentration directly in the lowest near-surface layers of the troposphere. In this case, the transparency window of the atmosphere also narrows and the flow of thermal radiation from the Earth's surface going into space without intermediate absorption and multiple re-radiation is reduced (Figure 3 & 4). Nigmatulin (former director of the Shirshov Institute of Oceanology of the Russian Academy of Sciences) [25] argues that with the warming the carbon dioxide sinks in the water vapor directly in the surface layer of the atmosphere. In this case, the fraction of the thermal radiation of the surface absorbed within the wavelength interval 3.6-12.8 micron

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by the carbon dioxide, which displays relatively weak absorption bands in the overlapping sections of spectral absorption bands of transparency windows of the atmosphere, virtually will be unable to additionally increase the absorption of the thermal radiation of the surface to significant extent.

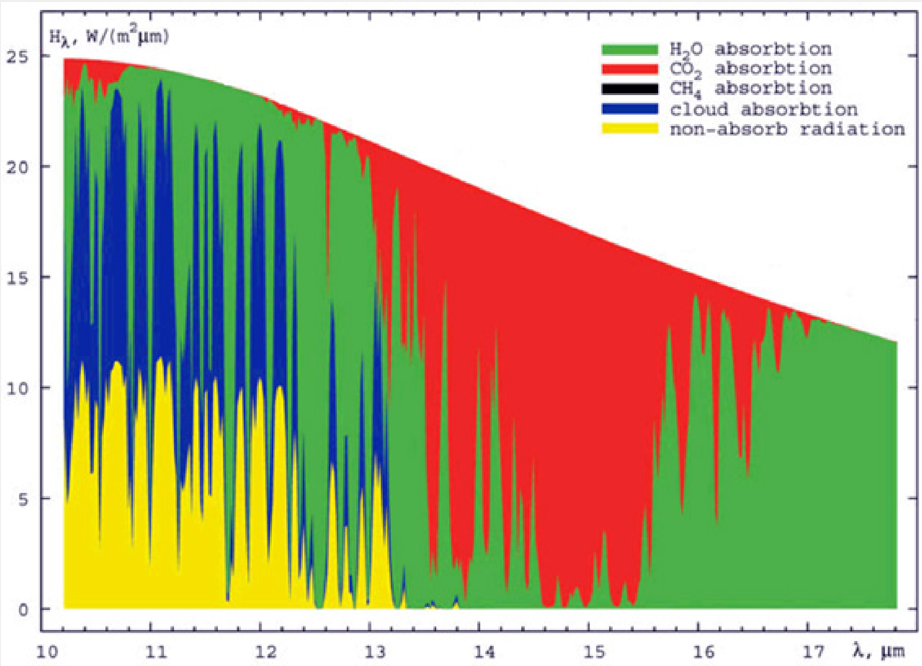

Figure 4: Variation in the absorption of thermal radiation flux from the Earth's surface by the main greenhouse gases after modeling with by corresponding increase in the total water vapor concentration in the atmosphere by 7% and the carbon dioxide from 350 to 420 ppm in a warming period with a fixed cloudiness.

Thereby, in the period of warming (for its current concentration higher than 420 ppm), the climate sensitivity to the absorption by the carbon dioxide in the atmosphere, whose concentration uniformly increased with the altitude, lowers because of a substantial overlapping of its spectral absorption bands with those of the water vapor within the limits of the transparency windows of the atmosphere, and because of the growth of absorption due to sharply increased concentration of the primary greenhouse gas – the water vapor directly in the lowest near-surface layers of the troposphere. This lowers the effect on the planet's thermal regime of the absorption the uniform distribution of the growth of the concentration of the carbon dioxide with height. The reason for that is that in the period of warming directly in the lowest near-surface layers of the troposphere the absorption of the thermal radiation of the surface by sharply grown concentration of the water vapor molecules will simultaneously increase. Because most of the total amount of carbon dioxide molecules will be located above the underlying water vapor molecules in the troposphere.

So, the fraction of the thermal radiation of the surface, absorbed by carbon dioxide, in the period of warming virtually does not increase significantly because of the growth in the absorption by sharply grown water vapor molecules in the lower near-surface layers of the troposphere. This factor decreases the effect of the general increase in the concentration of carbon dioxide in the entire atmosphere on the thermal regime of the planet in the period of warming. Consequently, with a further increase in the concentration of carbon dioxide in the atmosphere (for its current concentration higher than 420 ppm) in the period of warming it is virtually impossible to expect for a substantial additional increase in the absorption by this gas of the thermal radiation of the surface and by its significant role in the climate warming. Therefore, the effect of the growth in the concentration of carbon dioxide gas on the на climate variation is secondary and insignificant compared with consequences of effects of the increasing bicentennial cyclical TSI variations, the growth in the concentration of water vapor in near-surface layers of the troposphere and the other causal feedback effects – the basic factors of temperature variations. According to the data of Nigmatulin [25] "natural flows (CO_2, H_2O, dust) from the ocean and land into the atmosphere (M_{in}) and from the atmosphere (M_{out}) to the ocean and to the land are measured in tens of billions tons per year and exceed manifold ejections of

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these matters into the atmosphere (M_{ant}) as a result of human actions… The total CO_2 content in the ocean is by the factor of 50 larger than that in the atmosphere, and even a weak breath of the Ocean may dramatically alter the level of CO_2 in the atmosphere…, …fiddling effects, which mankind exercises on the atmosphere by the CO_2 emission, yield insignificant consequences". Indeed, the powerful eruption of submarine the Hunga Tonga—Hunga Ha'apai volcanoe has accompanied by the eruption, 146 million tons of water vapor from the South Pacific Ocean to a height up to 55km [22]. By acting as a main and excellent greenhouse gas, this water vapor curtailed heat energy from leaving the Earth's surface, overrode the aerosol effect, and dominate the top of the atmosphere radiative forcing, leading to a net warming of the climate system. Thus, powerful volcanic submarine eruptions have further demonstrated the excellent heating role of water vapor in global warming.

Indeed, the Earth's atmosphere reacted to the sharp decrease in emissions of carbon dioxide related to restrictions on travel and on other sectors of the economy administered by countries all over the world during the pandemics, in a remarkable manner: the substantial reduction in CO_2 anthropogenic emissions unexpectedly showed the important absence of its impact on the atmosphere [26]. The most astonishing result is that, although anthropogenic emissions of carbon dioxide in 2020 reduced by 5.4%, the amount of CO_2 in the atmosphere continued to grow in roughly the same rate as it did in previous years. Despite the fact that the lowering of CO_2 anthropogenic emissions by 5.4% was substantial, the growth of atmospheric concentrations remained within the limits of the normal range of its annual oscillations caused by natural processes [24]. As a result, even an insignificant increase in the total average concentration of the water vapor in the atmosphere in the period of warming substantially enhances the absorption of long-wavelength radiation in the surface layer of the air, thereby decreasing the effect of substantial uniform growth in the carbon dioxide concentration with the altitude on the thermal regime of the planet. Therefore, the variations of the abundance of the water vapor in the atmosphere are an important factor of climate variations, and the water vapor is the most important and principal greenhouse gas. The bicentennial cyclical EEI variation along with the substantial subsequent multiple impact of a long chain of the subsequent cause-and-effect feedback effects is a primary factor that governs and controls the climatic system, determining the corresponding alternation in climate variations. Natural quasi-bicentennial variations in EEI remain a basic factor of climate variations in the past, present and the nearest future. Our research shows that additional emissions CO_2 in the period of warming becomes less effective (when levels are above 420 ppm). The current its abundance content CO_2 indicates that further its increases with warming will cause only little additional warming. Because the warming-related sharp increase in H_2O concentration in the near-surface layers will lower the effect on the temperature increase of the uniform growth of the CO_2 abundance with the altitude.

Lunar Observatory for Simultaneous Continuous Monitoring of Climate and Asteroid Hazard Across the Entire Celestial Sphere

Therefore, to solve the complex of these most important scientific and applied problems we have been developing the Lunar Observatory (LO) project [27]. The LO we are developing is a single system of two identical special optical robotic telescopes located along the equator on the opposite edges of the Moon at the longitudes ±(81±0.1°) (Figure 5a & 5b). At the same time, simultaneously a telescope installed on the night side of the Moon provides monitoring of the energy flux of the share of the TSI reflected by the planet within the shortwave range of 0.2-4 micron and the outgoing intrinsic thermal radiation of the Earth within the LW ranges of 4-50 and 8-13 micron continuously during more than 94% of the lunar day. Break less than 6% in the observations of the night and near-night of the Earth carries a miniscule share of energy. This energy will be reliably interpolated and will not affect the high accuracy of the round-the-clock measurements.

Simultaneously at the same time a telescope located on the day side of the Moon will be continuously monitoring of the asteroid-comet hazard throughout the celestial sphere within the range of 0.2-2 micron during 100% of the lunar day. The measurements the radiation of the Earth's surface in the most significant transparency window of the Earth's atmosphere in the spectral range 8–13 micron is introduced to study the long-term variations of the contribution of the fraction of thermal radiation of the Earth's surface outgoing to space directly through transparency window of the atmosphere without intermediate absorption and repeated re-radiation. This will make it possible to detect and trace time variations in the transmission of the surface thermal radiation through the atmosphere to space and determination of the relative contribution of the variations in the concentration of greenhouse gases in the atmosphere to climatic variations. All these data will make it possible to calibrate and determine the dependence of the absolute value of the annual average EEI on cyclical TSI variations, which serves as a reliable indicator for reconstruction EEI variations for the total period of high-precision space TSI measurements since 1978. This will make it possible to reliably reveal the physical mechanisms of formation, reasons, and regularities of climate change on our planet. The bicentennial cyclicity of TSI and EEI, along with the very important self-enhanced continuous action of the secondary feedback effects, is the basic fundamental reason for corresponding cyclical alternations of the climate from warming to cooling and the main factor that controls the climate system [8].

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Figure 5: Simultaneous continuous functioning of the system of two SOTR-300VM: a telescope installed on the night side of the Moon provides monitoring of the energy flux of the share of the TSI reflected by the planet and the outgoing intrinsic thermal radiation of the Earth continuously during more than 94% of the lunar day; simultaneously at the same time a telescope located on the day side of the Moon will be continuously monitoring of the asteroid-comet hazard throughout the celestial sphere during 100% of the lunar day.

Conclusion

In the growth phase of quasi-bicentennial variations of TSI our planet will absorb the fraction of the consequently increasing average level of the energy radiated by the Sun; however, due to the thermal inertia of the Ocean, the Earth will not respectively heat up and, consequently, during this entire period of time will radiate into the space significantly less energy than that it will absorb. As a result, during the entire growth phase of the bicentennial cycle a positive energy imbalance between the Earth and the cosmic space is provided. This long-term positive energy imbalance results in a natural insignificant (≈0.25K) growth of the temperature and to a corresponding variation in the global physical, optical and radiative parameters of the underlying surface and the atmosphere. These variations will generate a long chain of subsequent continuously repeating causal feedback effects: an decrease in the value of Bond albedo of the Earth, an increase in the concentration of greenhouse gases in the atmosphere according to Clausius-Clapeyron relation and Henri Law, an decrease in transmission of the thermal radiation of the Earth's surface into the space by the atmosphere, and also an increase in the area of the "dark" surface of seas and oceans. These variations also result in a consequent supplementary significant growing of the absorption of the fraction of TSI by the planet and in a growth of positive EEI, which will enhance the arrived insignificant warming by the factor of a few by analogy the significant influence of feedback effects in Milankovitch cycles. This leads to the onset of the warming phase.

It should be noted here that the self-enhancement of climate change by corresponding impacts of the secondary feedback effects, which continuously acted in the growth phase of the

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bicentennial cycle, will still continue due to the thermal inertia during the entire period of maximum phase, when the average TSI value in general virtually does not vary ($(\Delta S_{\odot} \approx 0)$), as well as during short periods exposure at the beginning of slow decline in BCC (order 30 years) due to thermal inertia [8]. This will provide the further self-enhancement corresponding variations of temperature also within of these BBC periods. That's why the natural substantial self-amplification of the warming by long chains of the above-mentioned secondary cause-and-effect climatic feedback effects additionally continued also in the beginning of XXI century in the period exposure to thermal inertia during in the about 30-years, in the period of the beginning BCC decrease phase. This is precisely why in the end of the XX century and at the beginning of the 21st century a natural reinforcement of the global warming was observed in the extended period of relative stability of the maximum TSI level of the bicentennial cycle, as well as at the beginning of its decline.

A sharp increase in the water vapor concentration in the surface layers in the period of warming lowers the impact of a uniform growth in the abundance of carbon dioxide with the altitude on the increase in the Earth's temperature. In addition, as it was established by Nigmatulin [25] the natural flows of carbon dioxide from the Ocean and from the land into the atmosphere (M_{in}) and from the atmosphere (M_{out}) to the в Ocean and to the land multiply exceed the ejections of these matters to the atmosphere (M_{ant}) as a result of the human activity. The climate change results not only from a direct insignificant effect of TSI, but also from other, no less important and significant subsequent causal feedback effects. And these feedback effects, continuously self-enhancing the influence of insignificant direct solar radiation and of temperature variations in the growth phase of the quasi-bicentennial cycle, will still act accordingly in the periods of the maximum phase of the bicentennial cycle and will continue further during short periods (about 30 years) the beginning of its phases of the decline, influencing a further intensification of the corresponding temperature change due to the thermal inertia of the Ocean. As a result, a controlling impact of TSI on climate change, with the initial (primary) insignificant direct radiation effect, is determined and significant impact of feedback mechanisms [8]. Long-term minor direct TSI forcing is the primary solar trigger driving Earth's climate change by launching triggering of a chain of consistent events of secondary cause-and-effect climatic feedback, mutually enhancing each other. Therefore, changes of the Sun total summary influence to have a many times stronger overall impact on the Earth's climate than the TSI direct forcing alone. This explains the decisive and significant influence on climate of long-term cyclical variations in solar radiation power throughout the Holocene at multiple time scales.

Therefore, the physics of increasing CO_2 abundance is such that its ability to warm the planet is determined by ability of increasing CO_2 to absorb surface thermal radiation, which decreases as the concentration of H_2O in the underlying near-surface layers sharp increases with warming. As a result, the warming-related sharp increase in the H_2O concentration in the underlying near-surface layers will lower the effect on the temperature increase of the uniform growth of the CO_2 abundance in the overlying layers. At atmospheric CO_2 concentrations of about 420 parts per million, additional CO_2 has little ability to absorb heat, i.e. at higher concentrations in the future, the ability of future increases to warm the planet will be smaller. More of the atmospheric weak greenhouse gas, CO_2, will can increase temperature, but only slightly. An accurate understanding difference of the distribution combined increase atmospheric water vapor and carbon dioxide concentrations with height under warming is fundamental to an estimate and predicting of climate future variations.

The data obtained by the Lunar Observatory will make it possible to calibrate and determine the dependence of the absolute value of the annual average EEI on cyclical TSI variations, which serves as a reliable indicator for reconstruction EEI variations for the total period of high-precision space TSI measurements since 1978. This will make it possible to reliably reveal the physical mechanisms of formation, reasons, and regularities of climate change on our planet.

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