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Cosmic Rays and Clouds Variations Effect on the Climate is Insignificantly

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Abstract

It is believed that an increase in the area of the cloud cover in the lower atmosphere of the Earth caused by the influence grows of galactic cosmic rays in the period of the Grand minimum of solar activity lead to an increase the reflected part of incoming solar radiation back into space and by that to a cooling of the climate down to the Little Ice Age. We will try to estimate an inverse aspect of simultaneously influence of increase in the area of the cloud cover in to the narrowing of the transmission of the windows of atmospheric transparency, which practically compensates of this cooling by means of accumulation of energy. An increase in the reflection of the thermal radiation of the Earth surface and of the solar radiation reflected from it, as well as the significant amplification of the greenhouse effect, presents an important additional source of heating due to the increase in the area of the cloud cover in the lower atmosphere. The impact of the increase in the area of the cloud cover caused by the influence grows of cosmic rays on the climate is very small.

Keywords: cosmic rays, clouds, atmospheric transparency window, climate, Earth's energy budget

1. Introduction

One of the most important problems faced by humanity is the search of the physical mechanism responsible for global climate changes. The Earth's climate is a highly complex non-linear system affected by numerous factors and feedback loops. The climate system depends on an extremely complex set of long-term (≥ 20 years) physical processes in the ocean-land-atmosphere system, which, in turn, is influenced by diverse, mainly quasi-bicentennial variations in the total solar irradiance (TSI). If we consider only influence the direct quasi-bicentennial variation of TSI at order ~0.4% (Shapiro et al., 2011; Egorova et al., 2018), the increment in the planetary temperature will appear to be insignificant (~0.3 K). However, TSI variations are extremely important as a triggering mechanism of multiple feedback effects that cause substantial variations in the Earth's Bond albedo, in the content of greenhouse gases in the atmosphere, and the transmission of the atmosphere transparency windows (Abdussamatov, 2012a,b, 2015, 2016). It is known that the energy budget of the Earth E is determined by the average annual difference between the energy of TSI incoming to the outer layers of the atmosphere (Figure 1) and the fraction of TSI outgoing to space via reflection and scattering by the planet to all directions (Bond albedo), and also by the energy of the Earth’s long-wave radiation (Abdussamatov 2012a,b, 2015):

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

Here, $S_\odot$ is TSI, $\Delta S_\odot$ the increment of TSI, A_{BE} the global albedo of the Earth (Bond albedo), ΔA_{BE} the increment of the Bond albedo, ε the emissivity of the surface-atmosphere system, σ the Stefan-Boltzmann constant, T_p the planetary thermodynamic temperature, ΔT_p the increment of the planetary thermodynamic temperature, and E the specific power of the variations in the enthalpy of the active oceanic and atmospheric layer (Wm^{-2}).

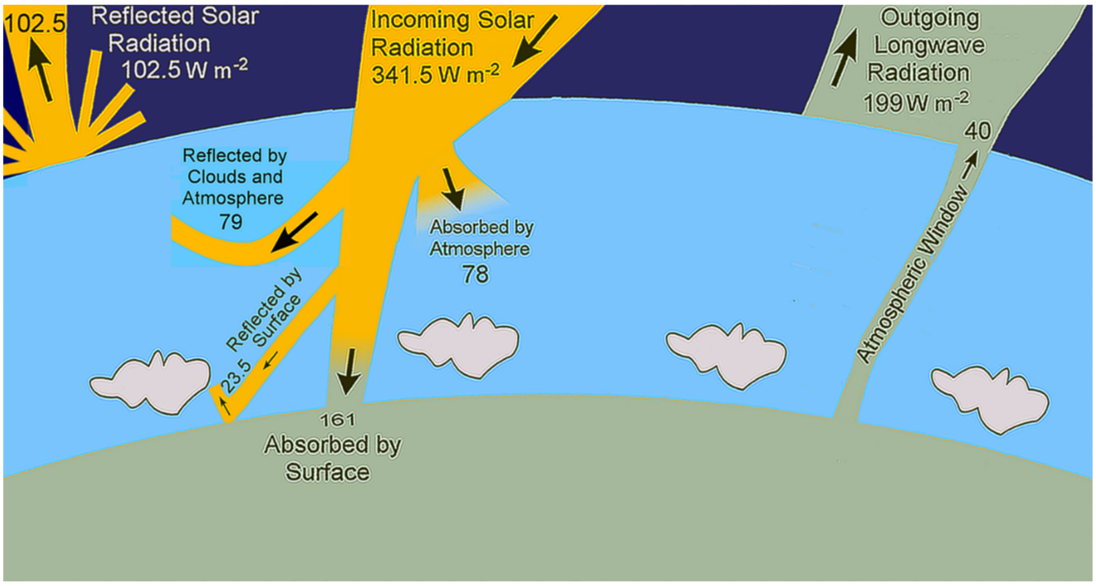

Figure 1. The average annual values of all components of the total energy balance of the Earth as a planet at the outer layers of the atmosphere in the equilibrium state (Trenberth et al., 2009; Abdussamatov, 2016)

2. Cosmic Rays, Clouds and Transmission of the Atmospheric Transparency Window

The area and the optical density of the cloud cover are fundamental parameters for the average annual energy budget of the Earth, and any physical process that can cause their systematic noticeable changes is of undoubted interest. Clouds, in the current approximately stable state of their area and optical density, absorb about 10% of the thermal radiation of the Earth's surface, and some 10% of it are scattered to space through the transparency windows of the Earth's atmosphere (Figure 2). When in the long term (≥ 20 years) the atmospheric transparency window is narrowed, the Earth becomes warmer, and vice versa. However, the bandwidth of the atmospheric transparency window for the outgoing thermal radiation of the Earth's surface particularly depends also on the variations in the area and optical density of the cloud cover, which accordingly alters the reflection and absorption parameters. In other words, both the transmitted fraction of incoming solar radiation and the fraction of outgoing thermal radiation of the Earth's surface depend on the variations in the proportion of radiation reflected and absorbed by the clouds. It is known that the Bond albedo, the width of the windows of atmospheric transparency, and the throughput of the atmosphere for the thermal radiation of the Earth's surface into space reach their maxima at a deep cooling stage and decrease to minima at a global warming stage.

According to the hypothesis Svensmark and Friis-Christensen (1997), Svensmark (2007), Svensmark et al. (2017) and Stozhkov et al. (2017), the ions created by the increase in the flux of galactic cosmic rays during the period of the Grand Minimum of solar activity affect aerosols in the lower atmosphere of the Earth, increasing the cloud cover area and the cloud formation rate. The growth in the optical density and the area of the cloud cover increases the reflected part of the incoming solar radiation and correspondingly the energy leaving back to space, thereby weakening the flux of solar radiation reaching the surface layers below the clouds. The growth of clouds can thereby lead to a deficit in incoming solar energy and to the long-term negative average annual energy budget of the Earth. The hypothesis Svensmark and Friis-Christensen (1997), Svensmark (2007), Svensmark et al. (2017) and Stozhkov et al. (2017) states that the reflecting effect of cloud growth that attenuates the absorbed part of the solar radiation will inevitably lead to a cooling of the climate down to the onset of a Little Ice Age. Within this hypothesis, the global warming is explained by a decrease in the flux of cosmic rays and in the rate of cloud formation, as well as by the growth in the absorbed part of the solar radiation within the Grand Maximum of the solar activity. However, without any reason, this hypothesis totally ignores the influence of the quasi-bicentennial variation of TSI at order ~0.4% (Shapiro et al. 2011; Egorova et al., 2018) and all the changes in the physical processes in the atmosphere, which are due to cause by the growth of clouds. It is obvious that the effect of the variation in the cosmic-ray flux on the change in the area and optical density of the clouds will yield the corresponding variation in the reflection of incoming solar radiation back to space. However, in our opinion, effect of cooling requires further careful study and additional scientific justification (Sloan & Wofendale, 2008, 2011; Erlykin et al., 2013). At the same time, it is extremely topical to assess whether this supposed negative balance of the average annual energy budget of the Earth can play a significant role in the subsequent climate cooling and in the onset of the Little Ice Age within the period of the coming Grand Minimum of the solar activity (Abdussamatov, 2005, 2015, 2016; Nils-Axel, 2015).

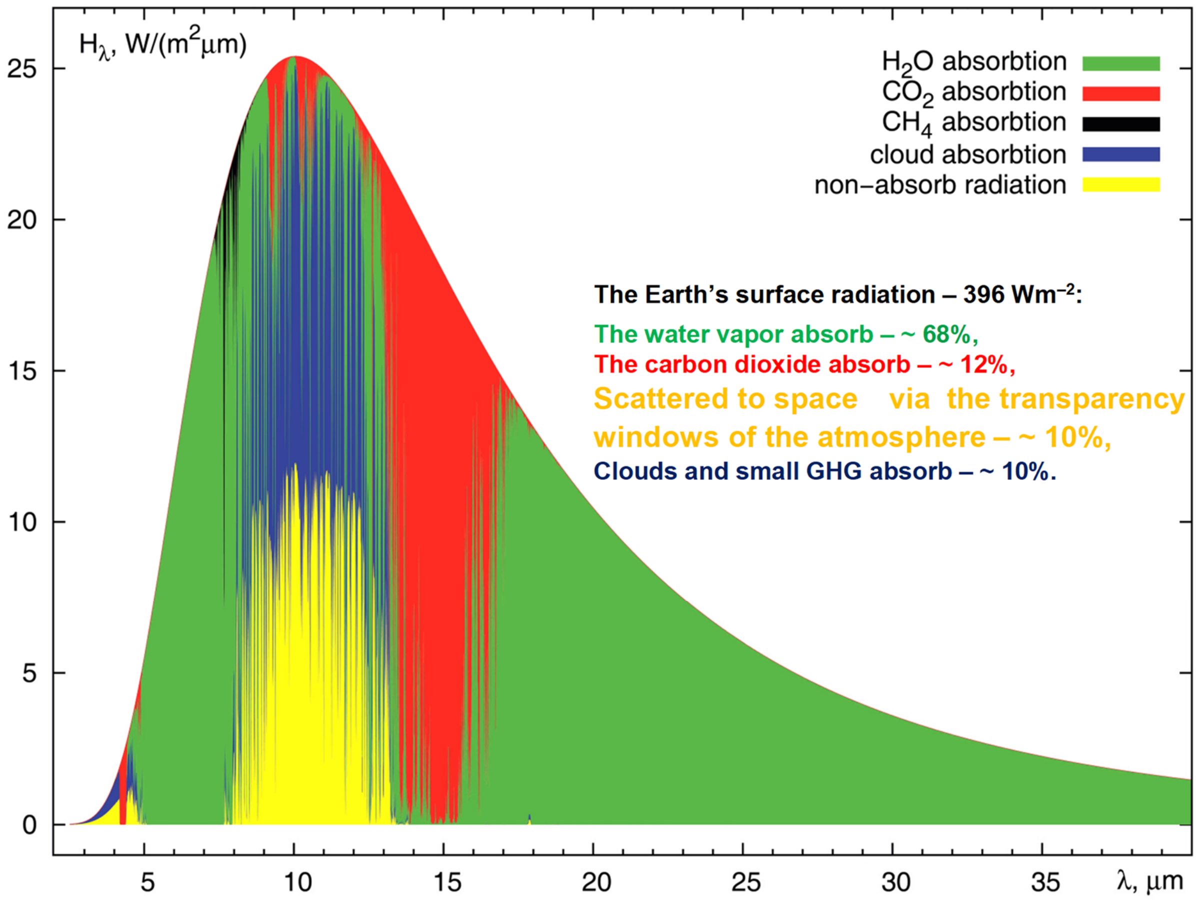

Figure 2. The spectral density of the thermal flow long-wave radiation of the Earth's surface (as a blackbody) (Abdussamatov, 2016)

Despite the indefinite degree of influence of cosmic rays on the cloud cover area, on the balance of the average annual energy budget of the Earth, and on subsequent cooling of the climate (Sloan & Wofendale, 2008, 2011; Erlykin et al., 2013), for the first time we will try to evaluate other unexplored and oppositely directed aspects of the energetical impact of cloud growth on the climate. Since the growth in both the area and optical density of clouds results in simultaneously an inevitable increase in the absorption and reflection of the thermal radiation of the surface, as well as the fraction of the solar radiation reflected from the surface. All these factors promote direct air heating and additional energy release in the atmosphere, and ultimately an increase in the atmospheric temperature due to effective narrowing of the transmission of atmospheric transparency windows. In addition, the growth in the area and in the optical density of the clouds in the lower layers of the atmosphere leads to a significant increase in the greenhouse effect, which will also heat the atmosphere and the planet as a whole even more. The atmosphere heated by the additional energy radiates both into space and backwards to the Earth's surface, thus heating it. All this is due to the fact that thermal radiation of the surface, both its fraction going to space through the transparency windows of the atmosphere, and that absorbed by the clouds, belongs virtually to the same wide spectral band (Figure 2). Therefore, the determination of the degree and role of the oppositely directed influence of the growth in the area and the optical density of the cloud cover on the average annual energy budget of the Earth and its contribution to the subsequent planetary heating is very important. This determination will make it possible to assess the effect of the growth in the area and in the optical density of the cloud cover and in the opposite processes of the global change in the average annual energy budget of the Earth and the climate.

Further in this short note, we will restrict our consideration to the effect of the increase in cloudiness within the Grand Minimum of solar activity on the growth of the reflected part of the incoming solar radiation back to space, on the increase in absorption and reflection of the surface radiation as well as of the solar radiation reflected from the Earth’s surface. We will also consider the joint oppositely directed effects on the variations in the balance of the average annual energy budget of the Earth and on the subsequent global climate change (Svensmark & Friis-Christensen, 1997; Svensmark, 2007; Svensmark et al., 2017; Stozhkov et al., 2017). Due to the growth in the area and the optical density of the cloud cover, the absorbed and reflected (in the direction of the surface) energy of the thermal radiation of the surface within the wide spectral bands of the atmospheric transparency windows increases (Figure 2). As a result, the energy of the unabsorbed thermal radiation of the Earth's surface that emerges into space within the spectral intervals of the atmospheric transparency windows will decrease by almost the same amount due to a decrease in the energy transmission from the atmosphere to space. With an increase in the area and the optical density of the cloud cover, the atmosphere will therefore receive all the energy that has not gone into space due to the narrowing of the transparency windows of the atmosphere. Let's try an approximately to estimate the change in a quantity of initial state the average annual energy budget of the Earth E_o if only the area of the cloud cover grows by 2%. In this case the reflected from clouds portion of the incoming solar radiation back into the space (≈79 Wm^{-2}) also will increase a approximately 2% more (Figure 1). This weakens the flux of solar radiation reaching the surface layers under the clouds and will lead to a decrease in E_o of about at $-0.02 \cdot 79$ $Wm^{-2} = -1.58$ Wm^{-2} and leading to a some cooling. However, at the same time, the thermal radiation from the Earth's surface reflected back in the direction of the surface by the clouds cover will also increase by approximately 2%, and an energy leaving into space through the transparency windows of the atmosphere (≈40 Wm^{-2}), accordingly will be decreased. This grows the flux of energy in the surface layers under the clouds, and will lead to an increase in E_o of approximately on $+0.02 \cdot 40$ $Wm^{-2} = +0.8$ Wm^{-2}. At the same time, the portion of solar radiation reflected from the surface of the Earth that goes into space (≈23.5 Wm^{-2}) also will decreased because its reflected by clouds back in the direction of the surface will an increase at approximately 2%. This will lead to an increase in E_o of approximately at $+0.02 \cdot 23.5$ $Wm^{-2} = +0.47$ Wm^{-2} and heating of air under the clouds and of the planet surface. In addition, the increase in the clouds and area of cloud cover in the lower layers of the atmosphere greatly enhancing the greenhouse effect, which also leads to noticeable an increase in E_o with subsequent heating of the planet. As a result, the new current average annual energy budget of the Earth $E_1 \approx E_o - 1.58$ $Wm^{-2} + 0.8$ $Wm^{-2} + 0.47$ Wm^{-2} + x.xx Wm^{-2} (the contribution from of the growth of the greenhouse effect due to absorbing by clouds in the lower layers of the atmosphere of the additional thermal radiation the Earth's surface and solar radiations). Thereby $\Delta E = E_1 - E_o \approx 0$ or may be $E_1 - E_o > 0$, what definitely does not indicate a noticeable decrease the current value of the average annual energy budget of the Earth E_1 relative to the its initial state E_o. Thereby the growth of flux the cosmic rays, clouds and area of the cloud cover during the period of the Grand Minimum of solar activity has practically no noticeable effect on the magnitude of the change in the average annual energy budget of the Earth. Consequently, the impact of the increase in the area of the cloud cover, caused by the influence of the increase cosmic rays, on the climate is very small. This is ensured by the fact that the cloud cover that absorbs and reflects the radiation of the Earth's surface as well as the solar radiation reflected from the Earth's surface is four times larger than the area of clouds that reflect the incoming solar radiation. Since the incoming flux of solar radiation is reflected by the cloud cover on the cross-sectional area of the terrestrial sphere (circle), while the thermal radiation of the Earth's surface is absorbed by the cloud cover on the area of the entire surface of the terrestrial sphere, which is four times as large. In addition, in accordance with the Clausius-Clapeyron relation, the cooling results in a decrease in the evaporation from the World Ocean and the land, the decrease in the moisture content in the atmosphere; consequently, atmosphere will contains less water vapor, which in turn will reduce the cloud formation and of the total area of the cloud cover.

3. Conclusions

Clouds growth simultaneously leads both to the deficit in the average annual energy budget of the planet, by increasing the reflection of incoming solar radiation back to space and to, a surplus energy budget due to the growth of the absorbed and reflected parts of the thermal radiation of the surface and the solar radiation reflected from the Earth's surface; the greenhouse effect also strengthens significantly. Consequently, an increase in the area and density of the clouds cover in the lower atmosphere simultaneously leads to both a rise and a decrease in the temperature. Such additional oppositely directed an influence a growth of clouds on the change in the total balance of the average annual energy budget of the planet is extremely important for reliable identification of the role and degree of possible influence of the growth of cosmic ray flux in the lower atmosphere on the global climate variation. Determining the predominance of one of these opposite trends (warming or cooling) in climate change presents a difficult problem and requires further research. However, it is known that very small long-term changes in annual average TSI due to long-term cyclic changes in the Earth's orbit forms, known as Milankovich's astronomical cycles, together with the subsequent very important (due to long-term TSI and temperature changes) nonlinear feedback effects lead to the Big Glacial Periods (of about 100,000 years) with glacial/interglacial cycles (Milankovitch, 1941; Abdussamatov, 2016). Big Glacial Periods with a multiple increase in temperature changes of ~10-12° C cyclically occur independently, and without any participation of the corresponding long-term large variations in solar activity, cosmic rays, and clouds. From all above, we can conclude that the relationship between increases in the cosmic ray flux and clouds, on the one hand, and cooling of the climate on the other becomes insignificant and the hypothesis of the dominant role of cosmic-ray flux growth in the formation of deep climate cooling down to a Little Ice Age is not confirmed. The warming of Mars and of virtually the entire Solar System in the end of the 20-th century (Odyssey, 2005; Ravilious, 2007) also does not confirm any significant influence of cosmic rays flux variation on the climate change in contrast to the influence of TSI changes observed in the quasi-bicentennial solar cycle (Shapiro et al., 2011; Abdussamatov, 2016; Fröhlich, 2017; Egorova et al., 2018). Thus, the climatic sensitivity to the growth of the cosmic ray flux in the period of the Grand Minimum of solar activity, which could lead to an increase in the area and optical density of the cloud cover, is very small, i.e. variations of cosmic rays flux and clouds have an insignificant effect on the climate. In this case, it is impossible to expect for any substantial decrease in the Earth's temperature and, especially, the onset of the Little Ice Age due to the influence of the growth of the flux of a galactic cosmic rays and a subsequent increase in the area and optical density of the cloud cover (Sloan & Wofendale, 2008, 2011; Erlykin et al., 2013). The quasi-bicentennial variability of TSI has always been the dominant factor in global warming and now it is leading us towards the global cooling (Abdussamatov, 2012a,b, 2015, 2016; Nils-Axel, 2015).

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