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The change of the solar activity and the temperature conditions in the high latitudes troposphere of the Siberian region*

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Abstract. The results of mathematical modeling, which demonstrate the response of the temperature conditions of the atmosphere of the North hemisphere to the changes of the solar activity, are presented. The calculations with the help of the ECSib climatic model (ICM&MG of SB RAS) were carried out. In the course of calculations, the influence of the solar activity was taken into account on the basis of the model of the solar activity effects on climatic features of the troposphere. According to this model, the intensification of the solar activity brings about an increase in a difference of electrical potential "ionosphere-Earth" and appropriate redistribution of the charged nuclei of condensation in the troposphere, changing the water vapor state and forming the cloudiness. The resulting cloudiness changes the radiation balance. The main attention in the analysis of the results is given to the troposphere response in high latitudes to helio-geophysical perturbations for the cold period. It is shown that a similar mechanism is capable of changing the temperature conditions of the troposphere in high latitudes.

1. Introduction

Currently, the research into the influence of diversity of physical mechanisms on the nature of the atmospheric circulation, its variability has received much attention. An understanding of such mechanisms, which affect natural processes, makes it possible not only to gain some insight into them, but also to evaluate prospects of natural changes. In [1], a concept of constructing a model of the solar activity as related to changes in tropospheric characteristics of the Earth's atmosphere is outlined. The main idea is the following. The external factors, associated with the solar space beams and accompanying magnetospheric perturbations are capable of affecting the climatic system by a energy flux coming into the space from the Earth. Verbatim it is like this. Amplification of the solar geophysical activity (fluxes of the solar space beams, perturbations of the solar wind and an interplanetary field, geomagnetic storms and sub-storms) result in an increase in difference of the Ionosphere-Earth electric potential. Increasing the difference in the potential is accompanied by an increase in the vertical electric field resulting in redistribution in height in the troposphere of charged condensation

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particles, that is, elevation of negatively charged nuclei to large heights. In this case, in the regions, where earlier the concentration of such nuclei was low, the content of water vapor being sufficiently large, the water vapor is condensed and cloudiness is formed. The formed cloudiness brings about a change in the radiation balance. Thus, this mechanism will have the greatest influence on the radiation balance and the thermobaric troposphere in high-latitude regions. This occurs in the absence of an incoming flux of a short-wave radiation from the Sun. The work proposed is aimed at studying the indicated mechanism with the help of numerical modeling.

2. A 1D radiation model

As an initial instrument for studying the mechanism in question, the radiation model from [2] was used. According to [2], the radiation processes are simulated in such a manner that the most probable of them could be distinguished. To them we can refer the short-range processes affecting the atmospheric heat fluxes, such as aerosol-cloudiness absorption effects, scattering effects of aerosols, clouds and such gases as (H_2O, CO_2, O_3), that is, those with a radiating medium considered to be ‘grey’. Gas absorption is regarded as perturbation imposed on the calculated radiation fluxes, caused by the Rayleigh scattering processes as well as scattering and absorption by clouds and aerosols. Radiation fluxes coming through the atmosphere are calculated with the help of a standard procedure of two-fluxes approximation for each atmosphere layer using the method allowing for scattering and absorption effects from all other layers.

In [3], the numerical tests of the sensitivity research of radiation inflows of heat at the account of the cloudiness are presented. It is necessary to note that the spectrum of the long-wave radiation was divided into three intervals, and the cloudiness is represented as an absorptive substance in the form of a liquid water. Calculation of the infrared radiation was performed for the model levels taking into account the distribution of the following characteristics:

- the water vapor mixing ratio,
- the mixing ratio,
- the content of carbonic gas, ozone and aerosol,
- the air temperature,
- the presence of cloudiness in the layers of the atmosphere model.

When calculating the infrared radiation fluxes were used calculated in advance the numerical factors for evaluation of transmission function for each of three intervals of infrared spectrum. The numerical results have shown the high sensitivity of radiation model to presence of cloudiness.

For the numerical experiment we took a certain state of the Atmosphere, which was obtained in the course of the climate simulation based on the model developed in the ICM&MG of SB RAS [4, 5]. This model was incorporated into the climatic model as radiation unit. The day of December 22, of a certain model year was taken. The vertical profiles were constructed for a site corresponding to the Dickson isle, with geographical coordinates 80°E, 73°N. The date and the site were selected from considerations to take into account only the long-wave radiation, neglecting the effect of the short-wave incoming radiation.

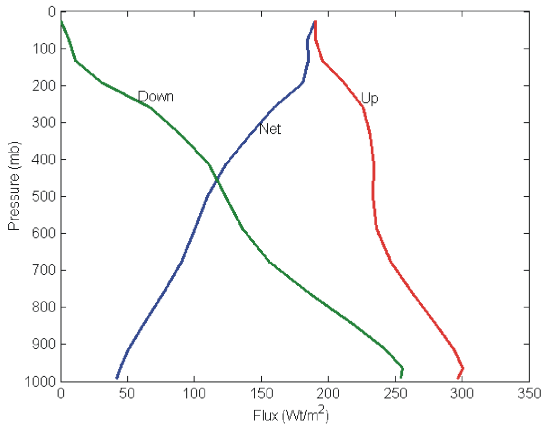

Figure 1. Long-wave radiation fluxes in high latitudes in the winter period: Down is the descending long-wave radiation fluxes; Up is the ascending long-wave radiation fluxes; Net = Up − Down is an effective flux of the long-wave radiation)

It is common knowledge that an effective radiation flux is formed of fluxes of the ascending and the descending radiation $F_{\mathrm{net}} = F^{\mathrm{up}} - F^{\mathrm{down}}$ (Figure 1). In this case, a change in temperature (the radiation cooling rate) is determined from a difference of effective fluxes on the upper and the lower boundaries of the layer $\Delta T \sim \frac{1}{\rho c_p} \frac{F_{z+1} - F_z}{\Delta z}$. A series of experiments was carried out. Some of them seem to be 'exotic', nevertheless, being of a certain interest in terms of the methods used. Below, their description is presented.

Experiment 1. The effective fluxes of infrared radiation and the respective daily temperature change are calculated from the model data (the so-called control experiment on the comparison of it with all other experiments).

Experiment 2. The amount of cloudiness at all levels of the model was set equal the zero with the constant other characteristics of Experiment 1.

Experiment 3. The amount of cloudiness is equal to 1 at all levels of the model with the use of the other characteristics of Experiment 1.

Experiment 4. The dry atmosphere is considered, such a representation allows one to estimate a response of effective fluxes of radiation to the presence of gases (carbonic gas, ozone) and aerosols.

Experiment 5. Effective fluxes and a daily temperature change are calculated with the double amount of cloudiness as related to Experiment 1. The aim of given experiment is to show the influence of the cloudiness increase due to redistribution of aerosol particles on the temperature conditions. The double increase of cloudiness appeared possible because in Experiment 1, the amount of cloudiness does not exceed the value of 0.4. This experiment gives the foundation to assume that with a change in the formation of cloudiness conditions, the amount of cloudiness can twice increase.

Experiment 6. The amount of cloudiness was set equal to zero at all levels except for a level corresponding to 500 mb level, where the cloudiness ball was set equal to unit. The remaining characteristics are the same, as in Experiment 1.

Experiment 7. All characteristics including the amount of cloudiness were chosen the same as in Experiment 1, except for the level of 500mb, where the amount of cloudiness was set equal to 1. This experiment is interesting in terms of the possibility to estimate the potential influence of the formation of additional cloudiness on redistribution of thermal characteristics.

Experiment 8. The atmosphere was set dry at all levels, but at 500 mb level, the amount of cloudiness amount was set equal to 1 (the exclusively methodological case).

Figure 2 presents effective fluxes of the long-wave radiation, calculated according to the description of experiments. Of peculiar interest seems the comparison of the results of the first and the fifth experiments from the standpoint of the objectives of studying a possible influence of the space radiation on a change in electric potential and redistribution of aerosol particles, and as consequence, a change in the cloud cover. The seventh experiment has also a sense, because a maximum cloudiness is, in fact, concentrated at a level of 500 mb. The rest experiments demonstrate 'exotic' situations and testify that the radiation model applied in the calculations is reasonably used. The edge curves in the third and the fourth experiments, the broken lines in the sixth and in the eighth indicate to quite unreal distributions of the characteristics under study. The second experiment with an increased radiation flux is associated with the absence of cloudiness as it is. As a proof to the above-said, Figure 3 shows changes in the vertical temperature distribution (the rates of radiation cooling) only due to the presence of radiation effects, according the above experiments.

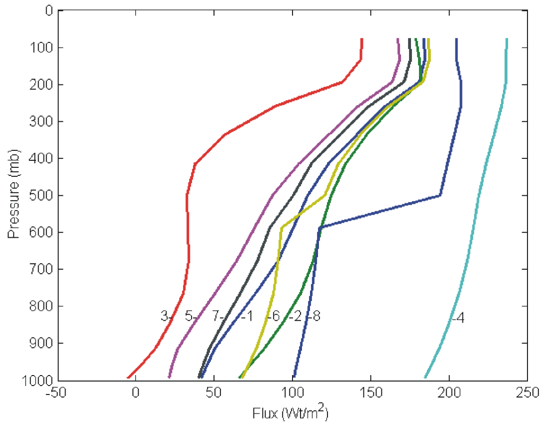

Figure 2. Effective long-wave radiation fluxes, calculated according to the conducted experiments (digits stand for numbers of experiments)

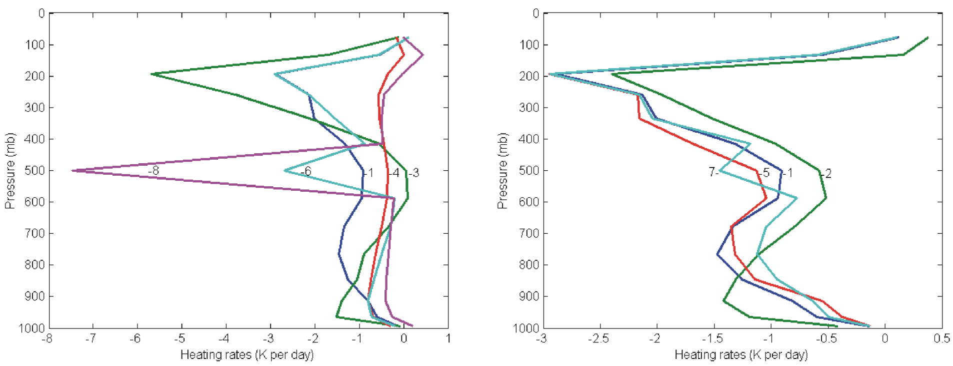

Figure 3. The vertical temperature variation according to our experiments (digits stand for numbers of experiments)

As was expected, increasing the cloudiness amount, on the one hand, brings about a sharp cooling at the stage of formation of additional clouds due to the reflected radiation and, on the other hand, a decrease in radiation cooling over and under clouds due to an increase of the flux of an incoming additional radiation. These are sufficiently complicated nonlinear processes. Let us once again mention that all the experiments were carried out based upon a real temperature distribution, humidity, cloudiness amount, which varied according to the above-said. Since the conducted experiments did not involve the global climatic model with allowance for evaporation processes, condensation, precipitation, interactions with an underlying surface, etc., there arose a necessity to verify the given hypothesis in concert with the climatic model of the ICM&MG.

3. A change in temperature conditions in high latitudes under the solar activity

By means of the general circulation model of the atmosphere, several variants were calculated. Calculations started with some steady (quasi-equilibrium) condition, namely, since December 22. The atmospheric characteristics obtained for this date used as a background for carrying out the first (control) computation with which methodological calculations were compared to the changed cloudiness amount. The computations for all variants have been performed for the some modeling day.

The second variant: during the first day of modeling the cloudiness ball above land to the north of 68°N twice increased in comparison with an initial ball. Further, the cloudiness amount is simulated according to the formulas included in the general circulation model of the atmosphere. This computation allows one to consider the influence of the mechanism of aerosols redistribution and the formation of the additional cloudiness.

Taking into consideration the fact that the formation of additional cloudiness is possible only at the lower levels of a mean stratum, the third calculation was carried out. In this calculation, the cloudiness amount above land top the north of 68°N, increased up to 0.8 at a level of ~700 mb within the first modeling day. A change in the cloudiness ball only above land was set with the aim of research into a modification of temperature on the surface, where there is an immediate interaction with an underlying surface at which the temperature and the humidity are recalculated on the basis of the balance equation (the surface ocean temperature is set into the model).

Figure 4 represents the fields of temperature differences between the anomalous second and the first control experiments at the levels of 1000 mb and 500 mb, respectively, for the Siberia region. It should be noted that if at 100 mb level the temperature still keeps for some time the arisen positive anomaly, at the level of 500 mb, there is no such at all. In this case, for validity, we should mention that there is a certain change in the atmosphere circulation, which is quite natural in introduction of finite perturbations. However, it is doubtful that this can affect the averaged results of the long-term integration. It is sufficient to note that in the integration for several subsequent months, a difference in mean-month values of simulated characteristics does not exceed a natural variability.

Concerning the comparison of the results of the third and the control experiments, it is necessary to note that if cloudiness is increased only at a level of 700 mb, the effect of an increase in temperature as well as on average levels takes place. This is also associated with the fact that with an increase of the amount of clouds, the counter radiation of the atmosphere increases and the effective radiation decreases. The question: where, at what altitudes, in what amounts and under which conditions the cloudiness

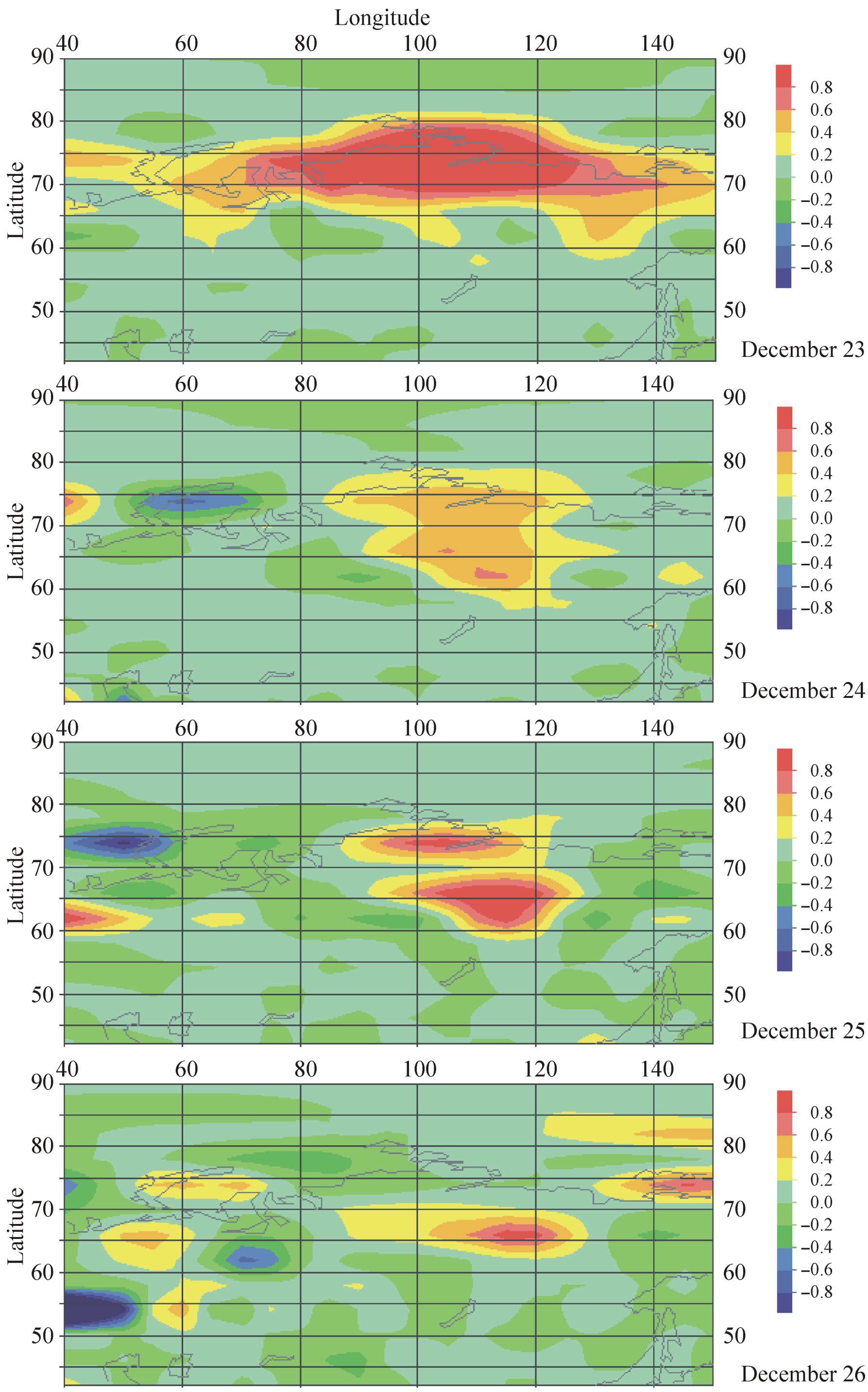

Figure 4. Subsequent temperature variations at 1000 mb level (a difference between Experiments 2 and 1)

can increase due to changes in the solar activity is still open.

The latter remark reduces to the fact that the conducted experiments are really anomalous. They were intended only for supporting the possibility of existence of the mechanism, discussed in Introduction. There are no proofs of the fact that nature considerably responds to changes in the electrical potential by changing cloudiness to a great extent. An increase in the cloudiness amount by 1.5 times but not twice essentially softens the picture.

4. Conclusion

The conducted simple experiments have justified the mechanism of the influence of the solar activity on the atmospheric characteristics in the high troposphere, which is based on the hypothesis of additional cloudiness formation. At least, if such a mechanism actually exists, then it affects the current thermal atmosphere conditions (the weather). This will result in the reorganization of the whole dynamics. Taking into consideration the fact that heat contents of the Earth's climatic system during the decades of years has essentially increased [6], we may conclude that the observed changes of the Earth's climatic system are due to a decrease in the energy flux, radiated by the Earth into space. But, as mentioned in [1], only quasiperiodic variations of the solar constant were observed during the last 40–50 years, a significant trend being absent. Hence, it is early to speak about the effect of the solar activity action on the climate changes. We can speak only about the internal variation due to the indicated factor (the solar activity variations). To provide support for the importance of the influence of the mechanism in question on the change of a current state of the atmosphere, it is necessary to carry out further studies based on the real data. In the case of increasing the solar activity action, it is necessary to analyze a synoptic situation, which accompanies the phenomenon.

References

[1] Zherebtsov G.A., Kovalenko V.A., Molodykh S.I., Rubtsova O.A. Model of solar activity action on climate characteristics of the Earth troposphere // Atmosphere and ocean optics.—2005.—Vol. 18, No. 12.—P. 1042–1050 (In Russian).

[2] Geleyn J.-F., Hollingsworth A. An economical analytical method for the computation of the interaction between scattering and line absorption of radiation contributions to atmospheric physics // Beitr. Phys. Atmosph.—1979.—Vol. 52, No. 1.—P. 1–16.

[3] Kurbatkin G.P., Kurbatskaya L.I. The investigation of sensitivity of radiation heating inflows to the cloudiness account.—Novosibirsk, 1986.—(Preprint / RAN. Sib. Branch. Comp. Cent.; 686) (In Russian).

[4] Fomenko A.A., Krupchatnikov V.N. A finite-difference model of atmospheric dynamics with conservation laws // Bull. Novosibirsk Comp. Center. Ser. Num. Model. in Atmosph., Ocean, and Env. Studies. — Novosibirsk, 1993. — Iss. 1. — P. 17–31.

[5] Fomenko A.A., Krupchatnikov V.N., Yantzen A.G. A finite-difference model of atmosphere (ECSib) for climatic investigations // Bull. Novosibirsk Comp. Center. Ser. Num. Model. in Atmosph., Ocean, and Env. Studies. — Novosibirsk, 1996. — Iss. 4. — P. 11–19.

[6] Zaitseva N.A., Shliakhov V.I. Long-wave radiation in the Antarctic atmosphere // Investigation of the Antarctic climate. — Leningrad: Hidrometeorological Publ., 1980. — P. 27–33 (In Russian).