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The influence of external factors on mathematical modeling of the Siberian regional climate*

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Abstract. The experiments on the research of the influence of the modified external parameters of the atmospheric model to atmospheric characteristics were carried out. Our main interest is in the study of the change of some computed characteristics in the Siberian region.

1. Introduction

The basic objective of the presented experiments with the atmospheric model is estimation of the atmospheric response to a possible change of the external parameters. This is not a climatic response in a general sense, but the nearest response of the climatic parameters. The integration, for example, over 30 years and the subsequent averaging would not possibly single out significant changes in the climatic sense. But changes in time (variations over a few days periods) demonstrate that the external influence on the current atmospheric state may essentially change the weather state. As climate is the average weather state, we should treat carefully with all the above said. If all the summer precipitation fell during the first week in June, it would be a disaster. However, the average seasonal precipitation quantity is normal. It is recommended to pay a special attention to this point.

The experiments on the research into the influence of modified external parameters of the atmospheric model on atmospheric characteristics were carried out as follows. First, a quasi-equilibrium climatic state of the atmosphere on the basis over 15-year integration of the global model was obtained with allowance for the annual behavior of the solar radiation. When integrating, the zenith angle of the sun daily varied depending on a day of a year. The diurnal behavior of the solar radiation was not taken into account. As input parameters, the monthly averaged climatic values of the ocean surface temperature were taken from the AMIP data. The distribution of ice cover, monthly averaged climatic values of temperature and moisture of soil at a certain depth were set. The height of topography in the model is fixed. It is characteristic of the given spatial resolution and the parameter of roughness

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above the land, depending on the type of the surface, urbanization, and topography. The albedo values depend on characteristics of the surface and vary in time with their change.

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2. Description of the model

There are 15 levels in the vertical, which are defined on $\sigma = p/p_s$ levels. The dynamical terms and the physical processes are calculated on Arakawa's C-grid. A spatial difference scheme gives the second order approximation and exhibits the potential enstrophy conservation law at the eddy advection of the horizontal velocity (in a barotropic atmosphere). A special approximation of the hydrostatic equation allows us to construct a vertical angular momentum conservation scheme. The possibility of the long-time integration is provided by the conservation of certain global invariants in a finite difference form, which exists in the differential formulation of the task. Therefore, in the statistical sense, such invariants allow us to approximate the continuous atmospheric dynamics by the discrete model dynamics. The basic integration algorithm construction is a semi-implicit scheme with respect to the linear part of the dynamic operator, an explicit scheme with respect to "slow" physical processes and an implicit scheme with respect to the "fast" ones. There are two variants of the model: global and regional. The global model has horizontal resolution $5°$ in the longitude and $4°$ in the latitude. The regional model has horizontal resolution $1.66°$ in the longitude and $1.25°$ in the latitude and the same parametrization as in the global model. The regional model allows us to obtain more detailed modeling characteristics [1, 2].

The physical parameterizations are the following:

- A linear or a nonlinear forth or second order horizontal diffusion operator applied to velocities and temperature;
- The calculation of surface fluxes is based on the Monin–Obukhov similarity theory, where the wind and the temperature profiles depend on the external parameters and on the surface momentum and heat fluxes. Equations used in the model for the momentum, sensible heat and moisture fluxes are different for the stable and the unstable stratifications of the surface layer. Also, the fluxes over the surface layer are calculated in different ways for stable and unstable stratifications;
- The deep moisture convection parametrization scheme is based on Kuo's method. The main distinction of the scheme used from Kuo's parametrization is that not only convective clouds generated by the air

rising from the Earth's surface are considered, but also clouds being conceived at higher levels, where moisture convergence can also occur;

- In the non-convective cloudiness parametrization scheme, the condensation process occurs when the specific humidity reaches the saturation value, but the liquid water does not fall in the form of precipitation until one of two conditions is fulfilled. The first condition of a fairly cold cloud top is based on the mechanism, which is taken into account that the ice nuclear generation goes more effectively if the temperature is below some threshold temperature. The second condition of a fairly thick cloud is based on the fact that the rain drops coagulation increases if these drops density increases. In this criterion, the cloud water must exceed a certain value;
- At the land, the thin soil layer is singled with a certain heat capacity, which exchanges heat and moisture between the atmosphere and the deep soil. Snow melting is considered every time when snow is present and the land temperature (T_s) exceeds the ice melting temperature, while the incoming energy goes to the snow melting. The moisture over the sea is equal to the saturation value at a given temperature (T_s). The soil moisture and the snow cover are calculated with allowance for precipitation, evaporation, melting water runoff, and moisture diffusion into the soil;
- The solution to the radiation transport equation for the fluxes is very expensive, and we do it only twice a day at every grid point. The solution to the radiation transport equation involves integration over angles, the vertical coordinate, and some intervals of spectrum. We suppose that we can separate the whole spectrum into two intervals: short and long waves, and some spectrum domains (three for the long waves, two for the short waves). We use the interactive scheme of the radiation with 3-layer clouds and the convective tower predicted from the relative humidity [3, 4].

3. Experiments

Based on the obtained climatic state, the following experiments over a two-year period, starting with the last year of integration, were carried out:

1. The control;
2. Solar radiation constant I_0 was increased by 1%;
3. Solar radiation constant I_0 was decreased by 1%;
4. Input solar radiation on the surface was increased by 10% in the north latitudes from 60°N;

5. Output solar radiation on the surface was decreased by 10% in the north latitudes from 60°N;
6. The Arctic surface ocean temperature was increased by 1°.

Our main interest is the study of changes of some atmospheric characteristics in the Siberian region. Globally, the basic changes appear in the tropics. However, the response is not the same, but most probably it is due to variability. It becomes visually apparent in sufficiently non-smooth characteristics such as fluxes and precipitation. For getting the climatic response, it is necessary to do the long-time integration.

The behavior of kinetic energy demonstrates a non-ordinary nature of the Siberian region. In Siberia, it does not repeat the behavior in the global scale. Possibly, the difference is that 2/3 of the Earth is covered with the ocean. But Siberia has a continental climate. Possibly small perturbations practically do not change a climatic picture since the averaging is done over a significant time period. But they may cause serious changes of a current atmospheric state, that one can see directly (floods, droughts, etc.). In the demonstrated pictures, one can really see that the limit of determined predictability is about 10 days. Nevertheless, the averaged characteristics do not essentially differ from each other.

Some results of the integration of the global climatic model are presented in Figures 1–6.

4. Conclusion

The difference in the standard predicted characteristics is not essential. For example, it does not exceed 0.35 K for T_s. An increase in the solar radiation constant produces a small decrease in the surface pressure in the center of Siberian anticyclone and its some displacements. The most remarkable but not essential effects are in the transient seasons (spring, autumn). However, we can not say this about the finer characteristics.

The response of the land (in particular, in Siberia) is more than on the whole of the sphere, because the ocean more inert than the land and T_s is fixed over the ocean.

The difference in the surface characteristics between north and south passing next to 60°N is close to of interest. This is observed in the real data.

The order of magnitude of precipitation is at most 5 mm/day. The difference in experiments is not more than 1 mm/day. The difference in heat fluxes is not more than 10%. The latter seems to be significantly different.

The increase in the solar radiation constant I_0 by 1% results in increase sensible heat fluxes over the surface in West Siberia. Also difference in

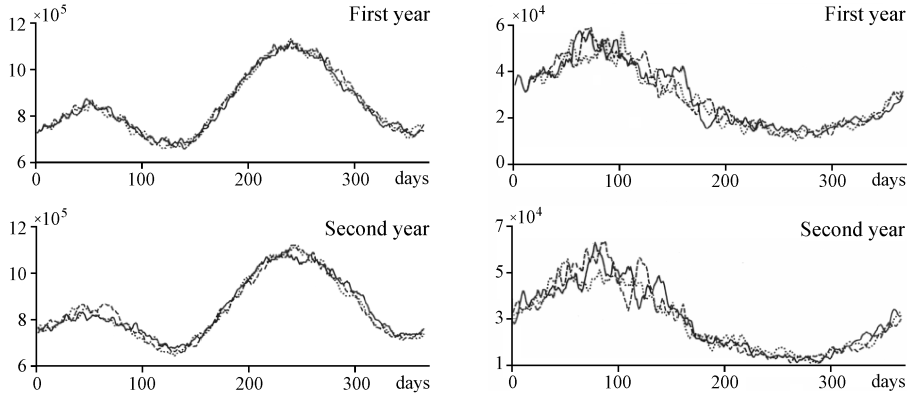

Figure 1. The behavior of the kinetic energy (in conditional units) over the Sphere (left) and over the Siberian region (right): exp. 1 – solid line, exp. 2 – dashed line, exp. 3 – dotted line

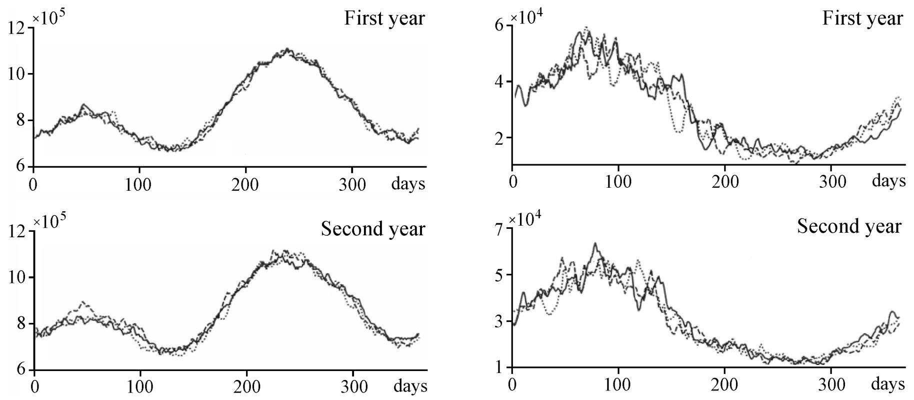

Figure 2. The same as in Figure 1: exp. 1 – solid line, exp. 4 – dashed line, exp. 5 – dotted line

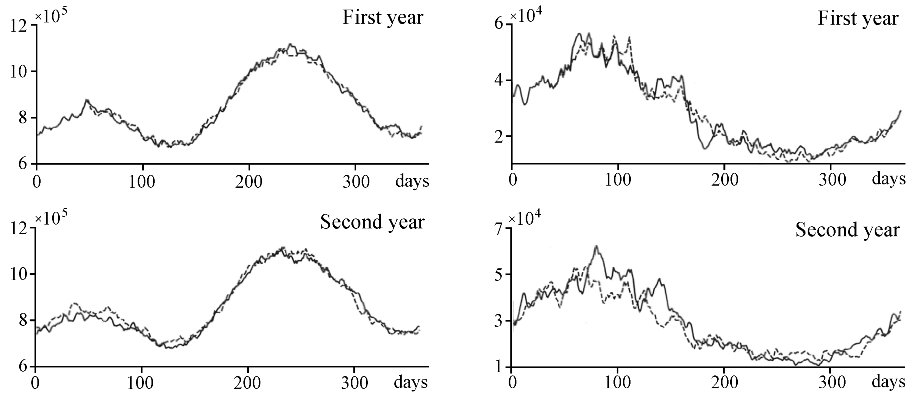

Figure 3. The same as in Figure 1: exp. 1 – solid line, exp. 6 – dashed line

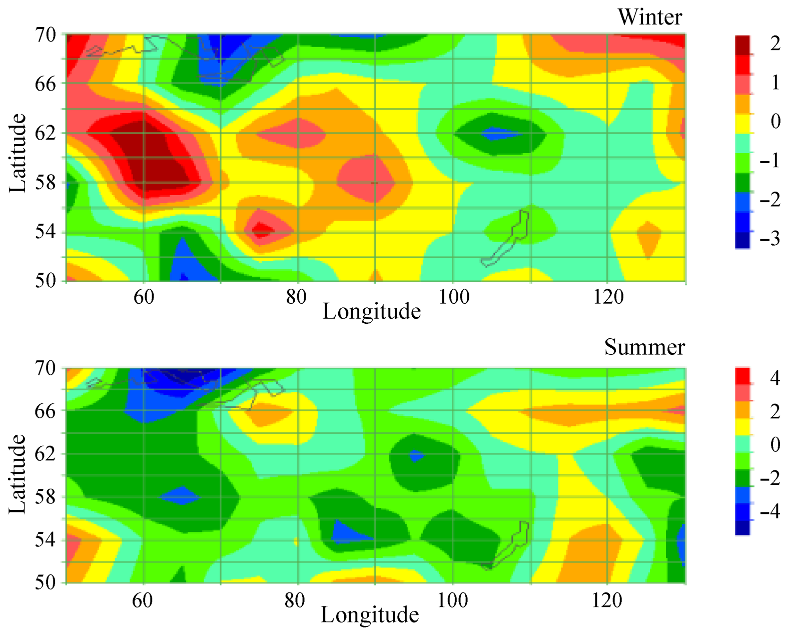

Figure 4. The difference between the sensible heat fluxes (Wt/m^2) for the 2nd and 3rd experiments

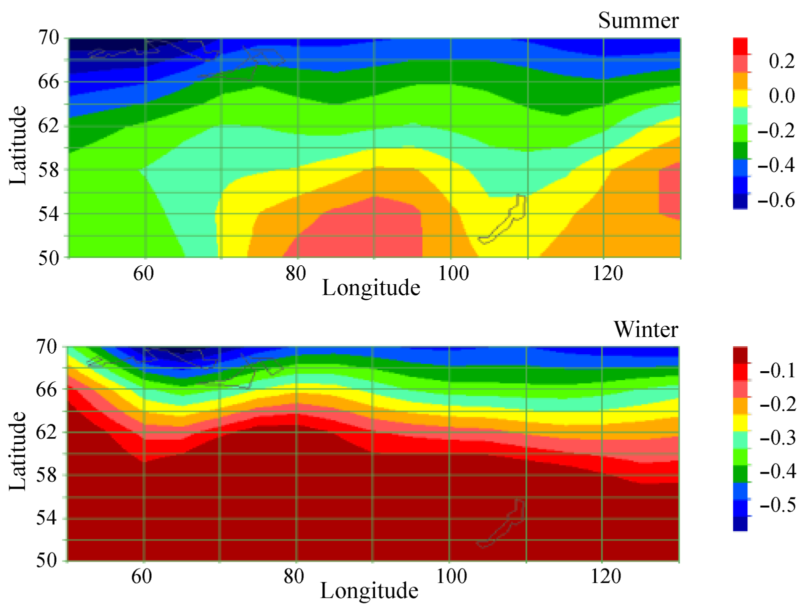

Figure 5. The difference between the surface temperatures (K) for the 1st and 6th experiments

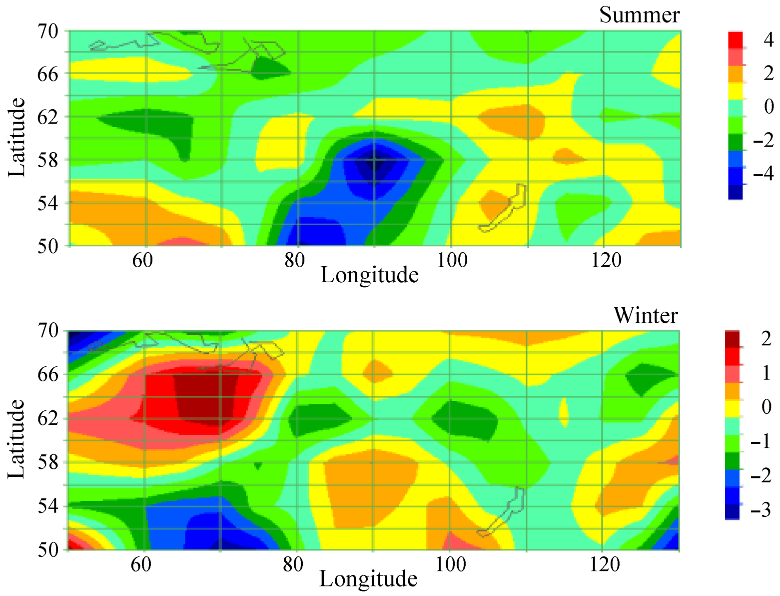

Figure 6. The difference between the sensible heat fluxes (Wt/m^2) for the 1st and 6th experiments

changes in sensible and latent heat fluxes, passing next to 60°N is visible. This distinct is more fact in Ural, West Siberia (east-west transport) and the Far East. A possible explanation of this fact is the contrast between the northern and the southern water masses.

In all the experiments, the response appears to be global, and not always its significance in the Siberian region is congruent with other regions.

The necessity of taking into account the influence of the Arctic Ocean is determined by its significance for the Siberian region. Its influence on Siberia is more significant than on North America [5].

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