Manifestation of isolated heliogeophysical perturbations in the high-latitude troposphere

O.A. Rubtsova, V.A. Kovalenko, and S.I. Molodykh

Institute of Solar-Terrestrial Physics, Siberian Branch of the Russian Academy of Sciences, Irkutsk

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The results are presented of the research into the response of the high-latitude troposphere climatic characteristics to isolated heliogeophysical perturbations (HGP) (space sun beams, geomagnetic storms). It is shown that these disturbances are accompanied by regular changes of the thermobaric field dynamics. It has been found that the typical zonal transfer disturbance, which manifests itself in the fact that there appears "stationarity" of isolated moving structures, takes place after HGP. It is precisely these stationary regions that are of maximal troposphere response to HGP. It has been established that after heliogeophysical disturbances in the isolated high-latitude regions of the lower and middle troposphere, there can be observed a significant (up to 15°) temperature increase, while in the upper troposphere its decrease is observed. The heat content change at latitudes higher 50° related to isolated HGP can reach several per cent of the annual variation amplitude. The revealed regularities are totally explicable on the basis of the model and mechanism of the solar activity influence on the tropospheric climatic characteristics previously suggested by the authors.

Introduction

The question on the contribution of solar activity to the change of climatic characteristics up to now remains open. In most of papers, devoted to the study of the influence of solar activity on the climate, it is suggested that the energy, necessary for the change of climatic characteristics of the troposphere, should be provided from the outside. At the same time, it has been known that the variations of energy flow reaching the Earth's troposphere due to the change of solar activity are small as compared with the energy content in the troposphere, and even with the energy of one baric formation, for example, cyclone. Thus, a signal from heliogeophysical characteristics should be recognized at the background of high-power natural disturbances.

According to a proposed by authors[1–3] physical mechanism of the effect of solar activity on the thermobaric characteristics of the high-latitude troposphere, a connecting link between them is the atmospheric electricity. On the one hand, the parameters of atmospheric electricity of high-latitude regions of the troposphere are subjected to the influence of solar activity, on the other hand, they can by the action on the high-altitude distribution of meteorological aerosols and, accordingly, on the formation of cloudiness, make an impact on the radiation balance in definite areas of the atmosphere.[4]

Note that the energy quantity necessary for such an effect, may be small and is not of fundamental importance.

A basic agent of solar activity, affecting the weather-climatic characteristics of the troposphere, are the parameters of solar wind and interplanetary magnetic field, which determine the geomagnetic activity and affect the variation of electric field of high-latitude atmosphere. Besides, the definite contribution to the variation of electric field of high-latitude troposphere is made by large flows of space sun beams (SSB) generated during solar flares.

Both space sun beams and geomagnetic storms result in the change of electric field intensity in the high-latitude troposphere, in the increase of difference of electric potential "the ionosphere – the Earth," because of this, the redistribution in height of charged condensation centers take place as well as the formation of cloudiness and change of radiation balance.

This mechanism operates most effectively in high-latitude areas, in the dark or at polar night, when the arriving radiation flow from the sun is absent. In this case the formation of cloudiness of any level will lead to the air temperature increase below the level of cloud formation and to the decrease of temperature higher than a given level due to reduction of heat flow from lower atmospheric layers.

It should be noted that the orography, characteristics of underlying surface and atmospheric circulation will make a great impact on the special features of the manifestation in specific regional areas.

This paper shows a complex analysis of the response of thermobaric characteristics of the troposphere to separate heliogeophysical perturbations.

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Analysis of spatiotemporal distribution of the response of thermobaric characteristics of the troposphere on the isolated heliogeophysical perturbations

Based on the data file NCEP/NCAR Reanalysis, the analysis was made of the response of the troposphere to the invasion of anomalously large flows of SSB over a period from 1968 to 2005. It should be noted that, as a rule, 1 or 2 days later after the SSB invasion great geomagnetic storms and substorms are observed.

For every event on a basis of data of NCEP/NCAR Reanalysis we have created daily maps of anomalies of mean temperature of the tropospheric layer (925–450 hPa) for the Northern hemisphere. Based on these maps, the analysis was made of variations of the pressure field and the temperature for standard levels of the high-latitude troposphere during the period of anomalous heliogeophysical perturbations (HGP). In the previous work[5] it has been found that after HGP the variation of a typical zonal transfer is observed, which is manifested in the fact that there appears the "steady state" of separate moving structures. Besides, it turned out that it is precisely the areas of "steady state" are the areas of maximal response of the troposphere to HGP.

As an example, figure 1 shows the characteristics of one of typical events. Anomalously large flow of space sun beams was observed on January 31, 1982. As a reference date (0-day) the day of arrival of SSB flow is chosen. During this period the moderate geomagnetic storm was also observed. This can be seen based on data of indices of geomagnetic activity of Ae and Dst shown in Fig. 1.

This case corresponds to the total influence of two components of heliogeophysical disturbance, which influences the electric field of the high-latitude troposphere – the space sun beam flow and magnitospheric convection. The difference of the response to theses events is only in the localization. For a space sun beam the area of maximal manifestation is the region of geomagnetic pole while for geomagnetic storms this is the area of auroral oval.

Successive variations of altitude profile of deviations of air temperature at standard isobaric levels are given in Fig. 2.

Using the data shown in Fig. 2*a* we can see that during the 1st day after HGP a certain increase of air temperature begins from the Earth's surface to the level of 300 hPa, which reaches maximum during the fourth day (up to 15°) while higher than the level of 300 hPa the temperature decrease is observed.

Analogous regularities of variations of the temperature altitude profile after HGP are typical for another case (November 7, 2004, 0-day), Fig. 2*b*. As distinct from the preceding event, the extremal magnetic storm took place during the second day after the arrival of the space sun beam flow. As in the first case, we observe the air temperature increase from the Earth's surface to the level of 300 hPa and the temperature decrease-higher than this level. Maximal growth of air temperature in the refion of steady state is observed during the fourth day in the layer of 500–700 hPa.

The underlying surface makes a great impact on the characteristics of the manifestation in the specific areas. We observed a significant difference of the response over the dry land and the ocean, which is manifested, first of all, in the variation of the temperature close to the underlying surface over the ocean when the temperature increase is practically insignificant while over dry land the temperature increases greatly exceeding the mean level. This difference is due to the fact that the energy balance in high-latitude areas during cold season is largely provided by the meridian heat flow (heat flow from the low-latitude areas). In the period of HGP impact, in the areas of manifestation, owing to the cloud formation in the upper troposphere, the radiation cooling decreases, the radiation balance changes, in this case the temperature of middle and lower troposphere increases and the heat flow to the Earth grows, which determines the increase of the ground air temperature. A considerable difference in the specific heat of the ocean and dry land leads to the fact that the surface air temperature over the ocean changes slightly.

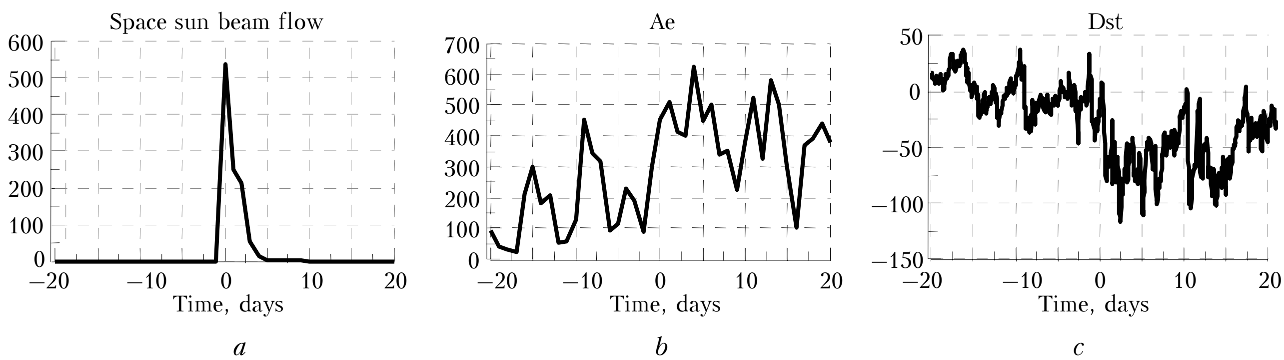

Fig. 1. Characteristics of heliogeophysical perturbation: space sun beam flow (*a*); index Ae (*b*); index Dst (*c*).

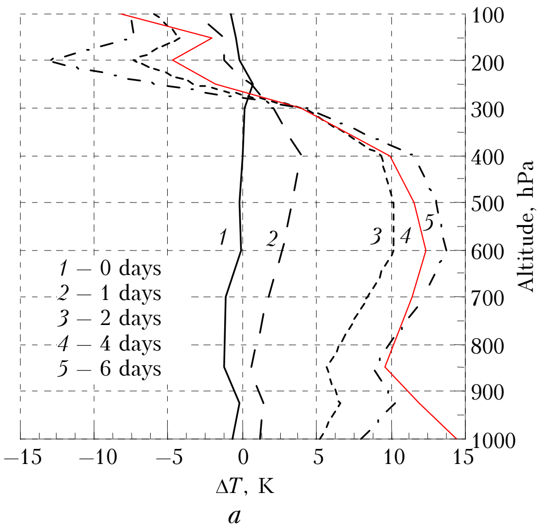

Fig. 2. The altitude profile of deviations of air temperature from the day before the onset of HGP in the region of "steady state" for two events of anomalously large flows of space sun beams: *a*) over a period from January 31 to February 6, 1982 in the region (60–70°N, 140–160°E); *b*) over a period from November 7 to November 12, 2004 in the region (55–65°N, 140–150°E).

Variations of circulation in the high-latitude troposphere during HGP period

The variations in the temperature distribution in the troposphere are accompanied by the appropriate changes of the tropospheric circulation. A detailed analysis of the maps of thermobaric fields during the period of HGP impact shows that after this event there occurs the disturbance of zonal transfer and variation of the profile of the high-altitude frontal zone.

Processes of blocking manifested in the form of strong tropospheric ridges of heat are more pronounced in the region of the north part of the Pacific Ocean (Fig. 3). Besides, in this region in the latitude zone of 40–70N after HGP the decrease of meridian temperature gradients takes place. Prior to HGP the temperature difference at the level of 500 hPa between the latitudes of 40–70 was 15–20° in the region of manifestation. During the fourth day after HGP this difference decreased to 5°.

As a whole, the blocking process extends from 3 to 5 days. Once the meridian exchange by air masses reached maximum, a change of circulation types and reconstruction of zonal transfer take place.

Thus the observed regularities of variations of circulation in the polar latitudes fully correspond to expected ones within the limits of the considered model of HGP effect on the thermobaric field of the troposphere.

Characteristics of heat content variations of high-latitude troposphere after separate HGP

Analysis of the heat content variation of the troposphere of 925–500 hPa in the areas of manifestation and for all the latitude area 50–90°N, produced by separate HGP, has shown that the heat content increase is observed, which can reach several percent from the amplitude of seasonal variation.

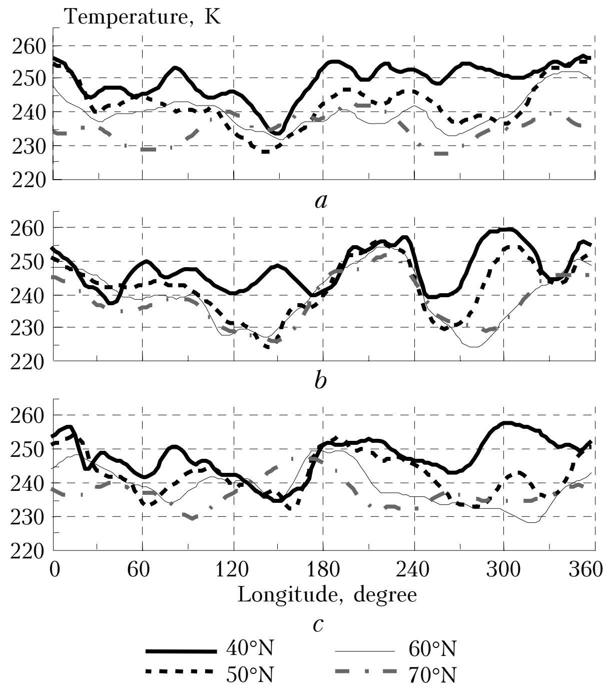

Fig. 3. Zonal distribution of air temperature on the surface of 500 hPa; *a*) during a day preceding HGP on January 30, 1982; *b*) during the fourth day after HGP on the February 4, 1982; *c*) during tenth day after HGP on February 10, 1982.

Figure 4 shows the graphical representation of the variation of anomalies of mean zonal heat content in the area of 50–90°N, obtained by the method of superimposed epoch for 13 events. It is evident that after HGP a significant increase of heat content (up to 2%) is observed.

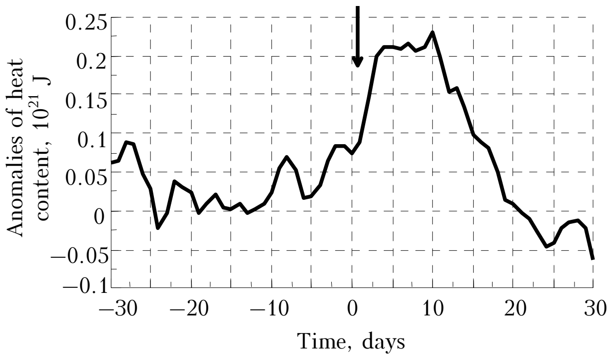

Fig. 4. Deviations of mean zonal heat content in the latitude range of 50–90N for 13 HGP (the superposed epoch method).

It should be noted that the real increase of heat content of climatic system will be much greater because here we did not take into account the heat flows to the underlying surface (especially to the ocean) as well as the latent heat.

Basic results

The complex analysis of the response of thermobaric characteristics of the troposphere to separate heliogeophysical perturbations has shown that these perturbations are accompanied by a regular change of dynamics of a thermobaric field.

It has been found that after HGP the variation of typical zonal transfer occurs, which manifests itself in the fact that “steady state” of separate moving structures takes place.

In separate high-latitude areas of low and middle troposphere a significant (up to 15°) temperature increase is observed while in the upper troposphere the temperature decrease can be observed.

We have revealed the increase of heat content of the atmospheric layer of 925–500 hPa in the areas of “steady state” and the latitude area of 50–90°N reaching several percent of the amplitude of annual variation.

The revealed regularities can be properly explained in the limits of the model and mechanism of the action of solar activity on the climate characteristics of the troposphere suggested by the authors.[1–4]

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