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The effect of solar activity on the Earth's climate changes

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Abstract. There is considered the problem of solar activity influence on the earth's climate. The attention is paid to the role of the atmospheric electric field in helioclimatic interrelations. The electro-optical mechanism of the heliogeophysical factors effect on climate characteristics of troposphere is substantiated and discussed. The main point of this mechanism is the regulation of the energy flux coming from the Earth into space due to changes in radiative cooling conditions in the atmosphere at high latitudes. There is shown, radiative balance and troposphere thermobaric field of polar regions depends on the geomagnetic activity level, and the potential ionosphere-Earth. The changes of the troposphere thermobaric field also have action upon atmosphere circulation.
There was made the testing of the suggested mechanism by means of analyzing the experimental data in anomalous heliophysical event periods.

Key words. Sun: solar activity – Earth: climate changes

1. Introduction

A special attention has been paid in the last few years to studying the nature of the global warming, to its manifestations in the planet's regions and to predicting climate changes (see for example (Ring 2002). Especially vital is the issue of the contribution of solar activity to observed changes in the climate.

This paper presents:

A mechanism of the effect of heliogeophysical factors on the troposphere's climatic characteristics;

Observation data demonstrating clearly the effect of solar cosmic rays and magnetospheric disturbances on atmospheric electricity and thermobaric field parameters;

The main points of the model of solar activity effect on the Earth's troposphere.

2. The electro-optical mechanism of the effect of heliogeophysical factors on the troposphere's climatic characteristics

The authors Zherebtsov et al. (2003) and Zherebtsov, Kovalenko, & Molodykh (2004) have proposed an electro-optical mechanism of the solar activity effect on climatic characteristics and atmospheric circulation via atmospheric electricity.

A schematic representation of the way the electro-optical mechanism operates is displayed in Fig. 1.

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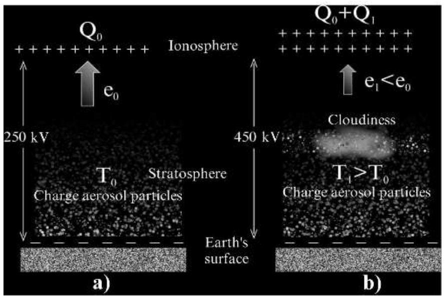

Fig. 1. The scheme of electro-optic mechanism of the heliogeophysical disturbance effect on the troposphere climate characteristics: a) in the absence of heliogeophysical disturbances; b) after geomagnetic disturbances, or invasion of SCR. Q_0 - the charge prior to invasion of charged particles, Q_1 - the charge introduced by the flux of charged particles, the distribution of the condensation nuclei is shown as dots. e_0, T_0 and e_1, T_1 - the outgoing radiative flux and temperature before and after the formation of cloudiness.

With heliogeophysical disturbances absent, the ionosphere-Earth potential is determined by tropical thunderstorms and the intensity of galactic cosmic rays (Fig. 1a).

During periods of heliogeophysical disturbances in high latitudes a considerable contribution into the ionosphere-Earth potential is made by disturbed magnetospheric convection, charged particle flows precipitating from the magnetosphere, and solar cosmic rays (SCR) (Fig. 1b).

Altitudinal re-distribution of condensation nuclei under increased electric field (potential) of the atmosphere can result in water vapour condensing in areas where the concentration of these nuclei has been small, while water vapour content is sufficient. This is accompanied by calorification of latent heat (water vapour phase transition) and clouds formation. Cloudiness leads to changed radiation balance, reduced radiative cooling and altered thermobaric field in the troposphere (Fig. 1b).

Manifestation of heliogeophysical effects in the troposphere will depend on the time of day, year season and atmospheric situation in a given region, viz.:

- altitudinal profile of water vapour content and temperature;

- original altitudinal distribution of condensation nuclei at the moment of disturbance.

3. The effect of solar cosmic rays and magnetospheric disturbances on atmospheric electricity

Let us examine what heliogeophysical characteristics affect the electrical ionosphere - Earth potential. According to measurements data for polar regions, the ionosphere-Earth current rises about two-fold during the arrival of large flows of solar cosmic rays. Fig. 2 shows measurement data of the atmospheric current at Apatity station and of a proton flow with energies in excess of 100 Mev based on Goes-10 satellite data during the 15 April 2001 proton event (Roldugin et al. 2003).

Analogous response of the electric field in the troposphere of polar regions is observed not only during periods of solar cosmic ray invasion, but during geomagnetic disturbances as well (Gurnet & Frank 1973; Sheftel et al. 1994; Michnowski 1998) accompanied by increased magnetospheric convection and particle (proton and electron) precipitation from the magnetosphere in high-latitude regions. An example is shown in Fig. 3 by providing data for electric field variation near the Earth's surface during a magnetic storm.

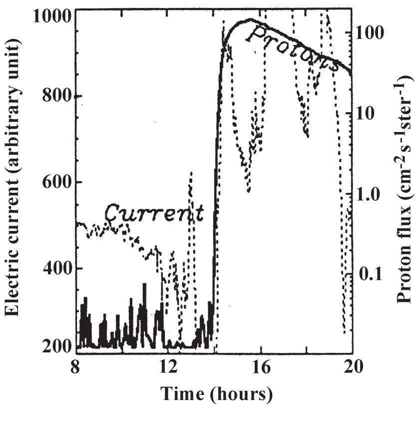

Fig. 2. The change of the ionosphere-Earth electric current in Polar region after invasion of SCR over the period 15 April 2001 (Roldugin et al. 2003).

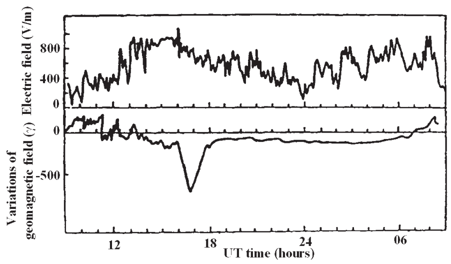

Fig. 3. The change of the vertical component of electric field in Polar region over the period of geomagnetic disturbances (Sheftel et al. 1994).

We would like to emphasise that measurements of the near-Earth electric field and ionosphere-Earth current refer exclusively to so-called "fair-weather" conditions.

Thus, there are three different causes resulting in substantially altered electric field in the Earth's atmosphere of the polar latitudes during heliogeophysical disturbances:

- solar cosmic rays;
- disturbed magnetospheric convection during geomagnetic storms;
- precipitation of protons and electrons from the magnetosphere during geomagnetic disturbances.

4. Manifestations of solar flares in thermobaric characteristics of the troposphere.

Fig. 4 presents measurements data for the vertical temperature profile acquired at the Murmansk obs. from 15 to 18 February 1984 (Shumilov et al. 1996) for the arrival period of solar cosmic rays on 16 February 1984. We can see the increase of temperature at height $< 10km$ and decrease at height $> 10km$ after the invasion. Obviously, the observed variations in the altitudinal temperature profile tally completely with those expected from our model. Convincing confirmation of the electro-optical mechanism in the response of meteorological characteristics to solar flares follows from analysing the data in Schuurmans, & Oort (1969). It was established in Schuurmans, & Oort (1969) that, after solar flares, variations are observed in the altitudinal profiles of pressure and temperature over oceans and in coastal areas within the $40 \div 60^o$ latitude range.

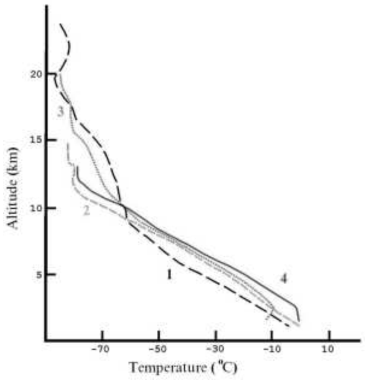

Fig. 4. The change of the height distribution of temperature in high-latitude region of atmosphere after invasion of SCR over the period 15-18 February 1984. The curve 1 is the temperature distribution before the invasion of SCR. The curves 2, 3, 4 are the temperature distributions late 1, 2, 3 days accordingly.

Analysis of the atmosphere's thermobaric field variations for invasion periods of anomalously large SCR flows in August 1972 and July 2000 shows that the 500hPa-level altitude is the most sensitive to invasions of SCR flows (Zherebtsov, Kovalenko, & Molodykh 2004). A well-defined effect of a SCR invasion is manifest in some high-latitude areas of the Southern hemisphere (local winter) within the $50 \div 70^o$ latitude range. Maximum effect is observed on the 3rd - 5th day after the invasion (Zherebtsov et al. 2003; Zherebtsov, Kovalenko, & Molodykh 2004).

Fig. 5 represents in detail temporal variations of the altitude of 500 hPa level for some zones for the period of anomalous SCR flows (Zherebtsov, Kovalenko, & Molodykh 2004). Obviously, the dynamic variations of the 500 hPa isobaric surface level in extensive high-latitude zones occur synchronously, an evidence of these changes being controlled by heliogeophysical factors, not by natural synoptical processes.

The response of atmospheric pressure to geomagnetic disturbances was demonstrated in

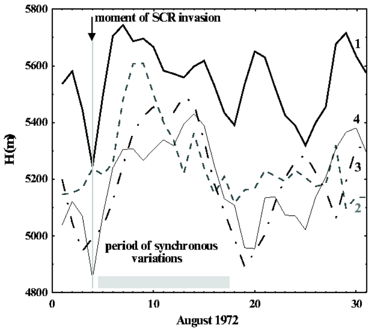

Fig. 5. The height variations in time of the 500 hPa level for separate zones (Zherebtsov, Kovalenko, & Molodykh 2004).

a great number of studies using the superposed epoch analysis (Mustel, Mulukova, & Chetoprud 1990). Moreover, a relationship has been found in (Toth, & Szegedi 2000) between ionospheric disturbances and sea-level pressure over the Arctic.

5. Conclusions

A physical mechanism is proposed and substantiated for the solar activity influence on weather and climate via atmospheric electricity, consisting essentially in regulating (modulating) the energy flux leaving the Earth in high-latitude regions.

We suppose that the proposed physical mechanism can explain great number of the observed relationship between solar activity and the weather and climate characteristics.

In summary we can present the main points of the model of solar activity effect on the Earth's troposphere.

The electro-optical mechanism is most effective in high-latitude areas (in the auroral oval zone during periods of magnetospheric disturbances and in the polar cap area during a SCR invasion), resulting in additional cloud formation (in areas with sufficient water vapour concentration) above oceans in near-coastal areas.

Clouds formation results in changed radiation balance in high-latitude areas: with radiation coming from the Sun (light time of day), the changes in radiation balance may be insignificant, but during the dark time of day or during the polar night, radiative cooling, the most essential component of radiation balance, will fall dramatically.

Thus, with increasing solar activity, the operation of the above mechanism results in reduced energy losses by the Earth climatic system, chiefly in high-latitude areas.

This entails increased temperature in high-latitude areas, leading to changed general circulation and decreased heat outflow from mid-latitude and near-equator areas.

The restructuring of both the local and general circulation in the atmosphere will result in turn in global-scale changes in the thermobaric field of the troposphere.

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