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Mathematical simulation of the atmospheric electric field disturbances caused by a magnetic storm

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It follows from the observational data that during geomagnetic storms, variations of the atmospheric electric field occur. We use a quasi-stationary model of a conductor consisting of the ionosphere and the part of the atmosphere lying below it to calculate the ionospheric and atmospheric electric fields.

To describe the magnetospheric electric field generator, data from the AMPERE satellite on the global distribution of the field-aligned currents for a sequence of time points in increments of 1 hour on March 17 and 18, 2015 were used. First of all, the position of the interface between the regions of closed and open magnetic field lines was clarified by the distributions of the field-aligned currents. The region 2 current system is located in the area of closed magnetic field lines, the rest currents are on open ones: the region 1 current system is on those magnetic field lines which connected to the tail of the magnetosphere, the currents of the cusps are on those magnetic field lines which connected to the magnetopause. During this storm, the total field-aligned current (flowing in total into the Earth's ionosphere, and equal to it flowing into the magnetosphere), according to AMPERE data, reached 45 MA.

The conductivity tensor in the ionosphere is a gyrotropic tensor. In the atmosphere below 50 km, it becomes a scalar. We use the height profile of the conductivity that is some average of known empirical models. Above 65 km (E- and F-layers of the ionosphere) during the day (or 90 km at night), our conductivity model is based on empirical models IRI-2016, MSIS 1990 E, IGRF. A smooth height interpolation of the components of the conductivity tensor between these regions is used. Because of that the field-aligned conductivity is a few orders of magnitude larger than others in the ionosphere a two-dimensional model can be used for the electric current continuity in the ionosphere. Since IRI-2016 does not present auroral enhancement of the electron concentration we are to use Weimer model of the additional Pedersen and Hall conductances in the auroral zones.

As a result of the numerical solution of such a problem, the global distributions of the electric potential are obtained for each moment of time. In particular, the obtained potential difference morning-evening through the polar caps reaches 300 kV, and the average during the storm is about 200 kV. A variation of the electric potential in the ionosphere leads to a variation of the electric field throughout the atmosphere, including its surface layer. During a geomagnetic storm lasting about a day, the observatory in which the atmospheric electric field is measured significantly changes its position relative to the direction to the Sun. This leads to the connection of spatial and temporal variations of the electric field, which must be taken into account when assessing the effect of a geomagnetic storm on the atmospheric electric field when comparing measurement data at a particular observatory with geomagnetic activity indices.

The simulation results showed that during extremely strong magnetic storms, variations in the atmospheric electric field of the same scale as the fair-weather field itself can be formed in some places on the Earth.

For the strong storm on March 17-18, 2015 (the Dst index reached 223 nT), the results of simulations are compared with the disturbances of the fair-weather electric field observed at a number of observatories presented at https://glocaem.wordpress.com, and at Borok Geophysical Observatory of the Schmidt Institute of Physics of the Earth RAS, Complex Geophysical Observatory Paratunka of the Institute of Cosmophysical Research and Radio Wave Propagation FEB RAS, Vostok Observatory (Antarctica).