Ionospheric disturbance caused by the radiation of Chelyabinsk bolide

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In more than three years since the incidence of the Chelyabinsk meteorite on February 15, 2013, numerous works reported seismic, acoustic, magnetic, ionospheric, and optical effects accompanying this phenomenon. The accompanied mechanisms of some of these effects are still under discussion. The hypothesis of the radiation mechanism of the appearance of disturbances in Earth’s lower ionosphere at the stage of flight of the meteoroid was justified and substantiated in [1]. Thermal radiation fluxes impact on the lower ionosphere accompanying the passage of the Chelyabinsk bolide from the 60 km altitude, the corresponding entry in the dense layers of the atmosphere and the beginning of evaporation, to the height of 30 km, corresponding to the separation of a large fragment and disruption of the meteoroid was studied by numerical solution of radiation gas dynamics model. This model includes all necessary physical processes: the deceleration and ablation of the meteoroid in the atmosphere within the framework of physical theory of meteors; radiation gas dynamical processes in the vaporized meteor substance and ambient air as well; the far field thermal radiation transfer in the atmosphere; the excitation of the lower ionosphere described, in turn, by 22 components plasma-chemical model, including the set of minor short-lived constituents. Numerical modeling was performed using tables of thermodynamic and optical characteristics of the air and meteoroid material vapor (LL-Chondrite), calculated based on a mixture of 16 elements: Fe-O-Mg-Si-C-N-H-S-Al-Ca-Na -K-Ti-Cr-Mn-Ni. Verification of the model was evaluated on the luminosity curves in visible and near infrared ranges obtained at different points of ground-based observations and satellite measurements, as well as with the existing integral optical data. The results show that the radiation of the Chelyabinsk bolide in the first 10 seconds of his flight from 60 to 30 km altitude caused the formation in the Earth's ionosphere (80–120 km) of wide ionized region with dimensions of the order of 400 km and the electron density within this region increased to the plasma frequency of 3.5 MHz. This quantitatively coincides with EKB SuperDARN radar system data. The total electron content (TEC) perturbation of 0.1 TECU is consistent with observations at the GPS registration system stations in the Ural region. During this time, meteoroid energy radiation losses is as large as approximately 40% of its total energy (where 15% are in the photon energies range of 1.1–3.1 eV). The numerical models of geophysical effects caused by meteoroid flights in Earth’s upper and middle atmosphere should include radiation effects. The neglect of these processes can result in underestimation of the energy of a meteoroid, which is usually evaluated by comparing the observations of seismic effects with the three-dimensional simulation of gas-dynamic processes in the atmosphere induced by meteoroid impacts.

References

1. T. V. Losseva, b, A. P. Golub’, A. N. Lyakhov, and I. B. Kosarev Radiation Effect of the Chelyabinsk Bolide // JETP Letters, 2016, Vol. 103, No. 11, pp. 680–686.