Numerical simulation of radiative effects in active geophysical rocket experiments

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At the end of the last century, a number of active geophysical rocket experiments (AGRE) were performed. Metallic (Al) plasma was injected into the Earth's ionosphere by an explosive-type generator. The purpose of these experiments was to study the processes of plasma interaction with the geomagnetic field, the generation of ionospheric disturbances with different spatial scales, and the determination of the optical characteristics of the disturbed region. A number of studies were devoted to the numerical simulation of the aluminum jet and metal clouds dynamics. The qualitative and quantitative agreement with evidence on diamagnetic cavern formation at the prompt stage of plasma motion via magnetic field measurements was shown. An alternative way of a model verification is to compare the results of calculations with the optical data, provided by ground-based, satellite and rocket measurements in the wavelength range from UV to far-IR with high temporal and spectral resolution. Solution of such a problem requires the radiation transfer processes incorporation into a numerical model and calculations of optical (radiative) effects at the points of observation. At the prompt stage of metallic plasma expansion into rarefied air, the radiation-gas-dynamic (RGD) model is applicable.

Numerical simulation of the prompt stage of high-speed aluminum jet dynamics and the initial stage of the subsequent expansion of a dense plasma explosion was carried out within the framework of the RGD model [1,2] under conditions corresponding to the experiments Flaxus (140 km) and North Star (300 km). The model takes into account RGD-processes in the plasma and in the air, the long range propagation of thermal radiation emitted by the high-temperature plasma. The excitation of the ionosphere under the action of this radiation was estimated in the framework of the point plasma-chemical model. Numerical simulation was carried out using the tables of thermodynamic and optical properties of metallic plasmas, obtained in these studies, and previously known air tables.

The radiative characteristics of the disturbed region were calculated by independent integration of the radiative transfer equations along a huge set of rays passing through the region with the simulated parameters to the observation point.

The temporal dynamics of the plasma parameters as well as the radiation from plasma cloud in a wide wavelength range (namely the density of radiation fluxes at various observation points and radiation patterns) are obtained. The extra ionization of the surrounding ionosphere under the impact of the emitted radiation was calculated.

References:

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