IONOSPHERIC DISTURBANCES INITIATED BY EXPLOSIVE DISRUPTION OF CHELYABINSK AND TUNGUSKA COSMIC BODIES.

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Introduction: Collisions of cosmic bodies (CBs) with the Earth are able dramatically disturb the atmosphere and cause large-scale disturbances of the ionosphere. The recent Chelyabinsk fall revived our interest in ionospheric effects, as some dynamic characteristics of the ionosphere have been registered after the fall. However, computer modeling of ionospheric disturbances is still a relatively new branch of impact physics. In this paper we present detailed calculations of meteoroid's disruption, vaporization, and deceleration during the entry, initialization of ionospheric disturbances and their horizontal propagation up to a few thousand km from the entry point. Two relatively recent falls, the Tunguska and the Chelyabinsk events differ in energy by nearly two orders of magnitude and the ionospheric response to these events is substantially different.

Methods: The SOVA code [1] is used, first, to model the initial stage of CB penetration, deceleration, and fragmentation. At this step the code treats the body as a liquid droplet (no strength); the thermal conductivity approximation is used to take into account radiative transfer and ablation [2]. Obtained characteristics of the atmosphere are used as initial conditions for the second step – modeling of long-term disturbances in the upper atmosphere. In additional to standard physics, dissipative processes (air viscosity at high altitudes) are included, i.e., Navier-Stokes equations are solved. As the first approximation, we assume that variations of electronic concentration are directly proportional to density variations, i.e., we neglect additional ionization of gases due to heating by shock waves and by the sun.

Results: C*helyabinsk meteoroid.* We calculate ionospheric disturbances using three different approaches: 1) initial conditions correspond to the gasdynamic solution of the most realistic Chelyabinsk entry scenario (e.g., [3]); 2) instead of a highly oblique entry we model a vertical impact; 3) the simplest approach describes the entry as a spherical explosion at an altitude of 20 or 30 km. The resulting ionospheric disturbances differ by 20-40%, i.e., are comparable with variations of the results if different atmospheric models (CIRA, MSISE) are used. For case (3) we compare total electron content (TEC) variations obtained as a resut of numerical simulation with results of studying of TEC [4] compiled from observations and find a reasonable agreement in amplitudes and periods of TEC variations.

Tunguska cosmic body. After an impact of larger bodies, e.g., the Tunguska catastrophe, disturbances differ dramatically: presence of an atmospheric wake leads to plume formation (e.g., [2]). The plume efficiently transports dense gases from the lower atmosphere to high altitudes. At an altitude of ~1500 km the plume decelerates under gravity and begins to fall back generating oscillations of atmospheric densities. This process is accompanied by generation of shock waves which gradually transform the initial plume energy into heat. The heated region also expands laterally. Corresponding disturbances of atmospheric density are much larger than disturbances caused by a spherical explosion at an altitude of 10 km with the same energy. Resulting ionospheric disturbances are an order of magnitude larger than in the Chelyabinsk case.

Generalization of the results. In both cases atmospheric disturbances are most intense at an altitude of ~100 km, where the atmospheric scale height reaches tens of km. At lower altitudes disturbances decay quickly due to the strong density gradient, i.e., smaller value of the scale height.

Conclusions: We are able to calculate dynamic flows in the upper atmosphere up to a few hours after the impact. The simplified model of a spherical explosion works well in case of small bodies (Chelyabinsk). Larger events (Tunguska) require a full-scale numerical modeling of Navier-Stokes equations.

Acknowledgements: The study is supported by Russian Science Foundation, grant 16-17-00107.

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