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Magnetospheric and ionospheric disturbances caused by cosmic body impacts.

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Ionospheric and magnetospheric disturbances caused by impacts of cosmic bodies with sizes 0.3-1 km may have global character (Kovalev et al., 2005; Nemchinov et al., 2005). Descending through the atmosphere these bodies do not become substantially decelerated and deformed by aerodynamic forces. They hit the ground or water of seas and oceans with the velocity and density close to the initial ones. A plume (mixture of cosmic body and target debris and air) is ejected upwards through the rarefied channel formed behind these bodies – though the wake.

At an altitude of about 100-150 km the plume increase its angle of divergence and somehow resembles the ejecta curtain but consisting mainly of the air ejected from the lower dense layers of the atmosphere. Some part of the plume obtain the velocity higher than the escape velocity, and for sufficiently large energy of the high-velocity part of the plume may even pierce the ionosphere and magnetosphere.

For an example, a 400-m stony body, with the initial velocity of 17 km/s (the size and velocity of recently found asteroid 2004 MN4) impacting the ocean with the depth of 4 km penetrate to the depths of about 2 km, and form the plume rising upwards. For the moments of 200-600 s the plume increase the density in the cylinder with radius of 1600-1800 km and altitude up to $\sim$2000 km to the density of 10(-14) g/cm^3, which corresponds to the normal density at an altitude of $\sim$350 km. That changes the recombination rates and increases the ionization due to the solar radiation and cosmic rays. This effect resembles rising the F2 layer of the ionosphere up to altitudes of 1000-2000 km. Radii of the density disturbances at higher altitudes are much larger - they reach 5000-7000 km at an altitude of 1200 km at the same moments of time. At altitudes of about 1000-2000 km the shock wave moves radially with the average velocity of about 5-10 km/s. Low-velocity part of the plume falls back due to gravity and produced intense oscillations of the ionospheric conducting layers propagating to very large distances from the impact point. The disturbances may have global character.

Being heated in the shock wave due to interaction with the air at lower altitudes the plume becomes at least partially ionized and interact with the magnetic field. The most intense interaction occurs for the case when the plume moves perpendicular to the Earth's magnetic field. But even if the plume is directed along the magnetic field (for vertical impacts in the polar regions) the plume expands in the radial direction and interaction with the magnetic field also occurs. Disturbances with the velocity of the order of Alfvenic speed propagate ahead of the plume, reach Van Allen radiation belts and may cause precipitation of trapped particles, and thus produce additional ionization. The ionospheric and magnetospheric disturbances may make the normal work of some technical systems of the modern civilization not possible: they may disrupt radiocommunications, produce great errors in the location by GPS systems and so on. So these effects deserve further thorough studies.

MHD simulation of these processes have been fulfilled to describe all these processes.

Some simplifications has been used at the initial phase of the research, e.g. the degree of ionization was determined in the assumption of thermodynamic equilibrium. There are other effects which should be taken into account in addition to these which are described by the MHD approximation, e.g. at high altitudes the mean free path become comparable or even exceed the characteristic size of the disturbed regions. So some kinetic-type models taking into account nonequilibrium thermodynamics, possibility of mutual penetration of the different types of the particles, formation of 2D and even 3D current systems, acceleration of some particles, and anomalous magnetic diffusion into the diamagnetic cavity. These models could be checked by large-scale modelling experiments, e.g. by ejection of high-velocity jets into the ionosphere at various altitudes (Adushkin et al., 1993; Gavrilov et al., 1999, 2004; Erlandson et al., 2002, 2004).

The jets of explosive type generators reach velocities up to 30-50 km/s, thus covering all the interval of cosmic bodies impacts and upward plume velocities. Release of these jets at various altitudes provide possibility of in-situ study of the interaction of the jet with the background plasma and the Earth's magnetic field at these altitudes. Not only general features of the physical and geophysical processes in the modeling experiments and after natural impacts are the same: the high velocity jet has density much higher than the background plasma, fast magnetohydrodynamic waves and current systems are formed, momentum transfer from the jet to the ambient air and magnetic field occurs qualitatively in the same manner, including the so-called anomalous transport phenomena, but even the coincidence of some quantitative characteristics of the processes take place. As an example, the velocity of the jet may be the same as of the plume in the natural impact. The density and composition of the air at all the altitudes are of course, the same as in the impact events. Amplitude of magnetic field in these experiments coincide with those at the altitude under investigation. Composition and initial temperature of the released air after interaction of the jet with the artificial air cloud with the density of about 150 km approximately corresponds to those reached behind the shock wave at these altitudes, where the wide air jet is formed. The main error in the scaling is the difference in the ratio of the radius of the jet in the modelling experiments (about 0.1-1 km) and in the impact generated plume (10-100 km). Theoretical modeling helps decrease possible discrepancies. Modelling experiments have already been fulfilled at altitudes of 150-350 km, and the results are now analyzed by MHD simulations and more sophisticated models.

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