Numerical model of the Chelyabinsk meteoroid as a strengthless object

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The Chelyabinsk airburst of 15 February 2013 was an extraordinary event due to its large kinetic energy about 500 kt TNT [1-3]. The 20-m-diameter asteroid deposited the most part of its energy in the atmosphere at an altitudes about 50-23 km and produced significant damage and injuries over a large populated area. Many papers considering various effects of the Chelyabinsk event have been published but a rich observational material leaves room for further research. In this study we applied a numerical model, initially developed for simulations of the entry of large (>several tens of meters) meteoroids, to the Chelyabinsk event.

In this model, disruption and deceleration of a meteoroid in the atmosphere and following propagation of a shock wave to long distances are simulated using a two-step approach described in [4]. At the first step, the motion of a meteoroid in the atmosphere is simulated in the coordinate system associated with the moving body, taking into account its deformation, deceleration, destruction, and evaporation. The model, equations, and numerical scheme have been described in [5], [6]. The entering body is treated as a strengthless liquid-like object and its deformation and the flow are described by the hydrodynamic equations.

The distributions of velocity, energy and density in the atmosphere are used as initial data for the second step of simulations. At this step, the propagation of an air shock wave to great distances over the Earth’s surface is simulated in a coordinate system associated with the Earth. We calculate pressures behind the shock wave and compare them with other models and shock effects observed after the Chelyabinsk airburst. Both calculation steps are implemented using the SOVA numerical method [7]. Using the distributions of temperature and density obtained in the first and second steps we calculated radiation fluxes on the Earth's surface and compared the results with the observed light curve of the Chelyabinsk meteoroid. Applicability and limitations of the model will be discussed.

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References

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