NUMERICAL SIMULATION OF DARK FLIGHT TRAJECTORY AND DISPERSION ELLIPSE FOR METEORITES

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Meteorite-producing fireballs pass the Earth's atmosphere in two consequent stages: hypervelocity entry of causing fireball meteoroid and decelerated terminal dark flight. Initial bright part of the trajectory can be considered linear (Gritsevich, 2008), however as the projectile descents into the lower heights, the aerodynamic drag becomes major factor in reducing velocity down to subsonic values. Dark flight estimations are crucial in determining the search area on the ground, since no reliable instrumental means of detection are available at present to follow the survived fragments at this part of the trajectory. The numerical simulation becomes the most robust tool to specify the terminal part of the trajectory.

For the problem of dark flight we consider the model of projectile dynamics, where ballistic objects are called particles and modeled as homogenous spheres with a given bulk density. The motion of a single particle in a gas is governed by the system of ODEs in Lagrange variables. External forces, acting on a particle, are the total drag, Magnus force and gravity. The drag coefficient is defined by Henderson formula. The air properties for Mach and Reynolds numbers can be computed from one of the atmosphere models, e.g. 1976 U.S. Standard Atmosphere.

During the descent each particle presenting meteorite fragment can shatter into smaller pieces if a threshold is met for impact pressure (a difference between stagnation and static pressure for isentropically decelerated compressible flow). Such fragmentation event introduces new particles to the computation. Underlying mathematical model neglects direct inter-particle collisions; however discrete trajectory method is not suitable, since we simulate transverse repulsive forces arising in separation dynamics of two fragments (Passey and Melosh, 1980) and use discrete element method. The corresponding force coefficient is defined according to (Artemieva and Shuvalov, 1996). Each particle is scattered by the sum of repulsive forces from all other particles within effective distance. The ordinary differential equations governing projectile dynamics are integrated by the second order Runge-Kutta scheme, which is sufficient in the presence of input data uncertainties. Since the particles do not interact with each other directly, we implemented parallel computations. The integration of each trajectory is carried out down to the surface, which can be either considered as zero height for the spherical or elliptical Earth model or can be realistically implemented as overlay of digital elevation model on reference ellipsoid WGS84 via one of the GIS, which effectively yields estimation for dispersion ellipse.

References

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