RECOVERY OF METEORITES AFTER LARGE METEORITE FALLS – MASS DEFICIENCY PROBLEM.

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Introduction: The total mass of recovered Chelyabinsk meteorites does not exceed 2000 kg, <0.02% of its pre-atmospheric mass. The largest fragment and its satellites from the Chebarkul lake made about ~800 kg whereas meteorites recovered shortly after the fall from the strewn field are mainly small (<0.1 kg) fragments [1]. Similar problem of "mass deficiency" exists for other recently observed and well-documented large meteorite falls such as Almahata Sitta and Tagish Lake. No one meteorite has been recovered after the Tunguska event – the largest impact of 20-th century. Mass deficiency could be explained by a few reasons: 1) dramatic overestimate of the pre-atmospheric mass; 2) low recovery rate: 3) specific structure of large meteoroids (dusty matrix with embedded solid fragments, e.g. [2-3]); 4) intense ablation during large meteorite falls. The first two reasons could be dismissed as these events have been registered by various methods, their landing sites have been predicted and carefully searched. The third idea will remain speculative until detailed asteroid study in situ. Thus, it seems reasonable to check physics of meteoroid/atmosphere interaction first.

Method: We use the 2D hydrocode SOVA [4] to describe an entry of disrupted cosmic body into the atmosphere. At the beginning the meteoroid is represented by a swarm of fragments with prescribed size-frequency distribution (SFD); all particles have the same velocity along the trajectory and a small perpendicular component describing expansion of the meteoroid after the fragmentation [5]. Each particle is characterized by its mass-dependent strength and may be subjected to subsequent fragmentations. In addition, fragments change their mass due to ablation. The intensity of ablation depends on the radiative flux which is defined in our approach as the maximum between a fraction (heat transfer coefficient C_h) of gasdynamic flux and black-body radiation [5]. This approach describes ablation of both separated fragments and those moving within a hot wake behind the main body.

Results: At an altitude of 20 km a 20-m-diameter meteoroid lost 10% of its pre-atmospheric velocity and 86% of its mass. The majority of mass losses (3/4) are due to vaporization, and 1/4 - due to fragment separation from the swarm. Our prediction of the total mass of 1-cm and larger fragments on the surface is ~6500 kg. The same approach applied to a smaller 1-m-diameter meteoroid revealed that the fragments are quickly dispersed, move independently, and lose their mass according to the standard ablation model.

Conclusions: Whereas meteorite falls are usually described in the frame of the point mass approximation, larger events (Tunguska) require full-scale hydrodynamic modeling. Modeling the Chelyabinsk event allows us to bridge the gap between Tunguska-like airbursts and 'casual' meteorite falls. Still, each small body (<10-30 m) may have the unique entry scenario because of its specific properties (fragment SFD in particular).

References: [1] Ivanova M. et al. 76 *M&PS* 48A: 5366. [2] Goodrich C. et al. 2015. *M&PS* 50: 782-809. [3] Borovička J. et al. 2015. eprint arXiv:1502.03307. [4] Shuvalov V. 1999. *Shock waves* 9:381-390. [5] Artemieva N. and Shuvalov V. 2001. *JGR* 106: 3297-3310.