SCALING RELATIONS FOR SHOCK WAVE EFFECTS FROM LARGE METEOROIDS DECELERATED IN THE EARTH'S ATMOSPHERE.

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Introduction: Damage on the ground produced by pressure pulses of shock waves is one of the most important dangerous effects of asteroid and comet airbursts, and the only one in the case of the Chelyabinsk event. The Chelyabinsk airburst resulted in little structural damage, other than broken windows, window frames and doors [1]. The impact-induced shock wave in the atmosphere is referred to as the air blast or blast wave. The intensity of the blast depends on the energy released during the impact and the height in the atmosphere at which the energy is deposited [2]. The effects of the blast wave may be estimated based on the data on nuclear explosions [3] or based on the especially elaborated model [4]. The atmospheric entry was modelled for ~60 different scenarios in [5]. Based on these simulation results scaling relations for the most important parameters of the shock wave are constructed. Thorough impact risk assessment is a significant computational challenge and motivates the need for simplified approaches and fast damage calculators, which can use suggested scaling relations.

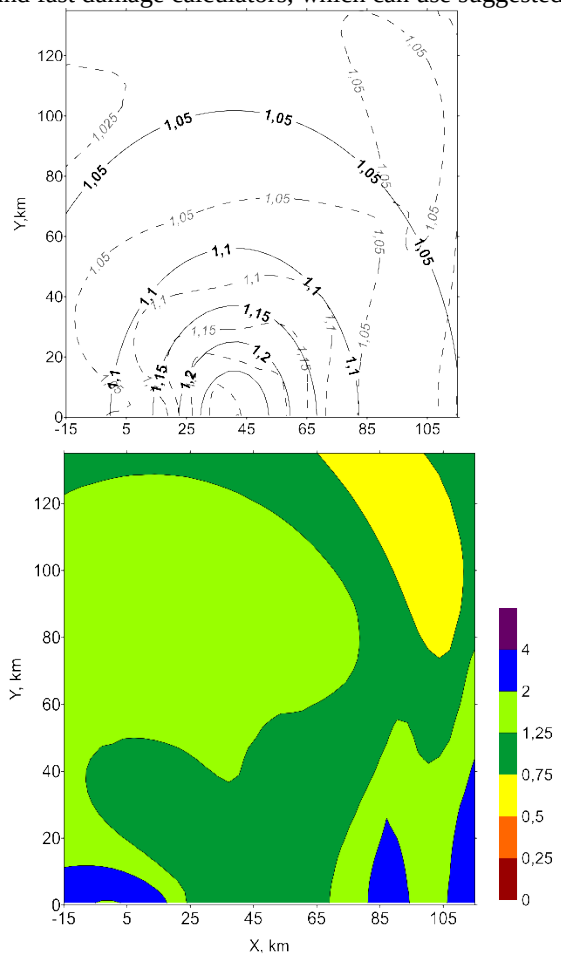

Figure 1. (a) Overpressure distribution according numerical simulations P_{sim} [5] (dashed lines) and according scalng relations P_{scal} (solid lines) for cometary body with D~50 m, entry angle 30^0, V~70 km/s. Relative overpressure values P/P_{atm} are marked on corresponding levels. (b) Distribution of the relative error P_{scal}/P_{sim}.

Estimated parameters. Suggested scaling relations are dependent only on the properties of the entering object (size, density, velocity and entry angle). The important quantities to determine are the peak overpressure, that is, the maximum pressure in excess of the ambient atmospheric pressure P_{atm}, and the ensuing maximum wind speed. Scaling relations allow to determine a surface distribution of the overpressure and wind speed (Fig.1). Besides they allow to estimate an area, at which chosen levels of overpressure is exceeded.

The most part of considered quantities is dependent on the kinetic energy of the body and some effective altitude, which in turn is determined by the entry angle, the size and the density of the impactor. Areas, at which chosen levels of overpressure is exceeded, depend not only on kinetic energy and effective altitude, but also on the entry angle. The surface anisotropy of the overpressure and wind speed distributions is taken into account by including ellepticity. Ellipticity is determined by the entry angle.

These scaling relations can be considered as the first approximation, which takes into account the main features of the distribution with one maximum. They do not take into account the more complex character of the overpressure distribution caused by the destruction and deceleration of the cosmic body, in which local maxima are observed. In addition, levels of small excess pressures of less than 0.025-0.05, outside the central area in question, also require separate consideration.

Suggested scaling relations were tested on data and different modelling efforts for Tunguska and Chelyabinsk events and allowed satisfactory describe the observed/modelled overpressures and wind.

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References: [1] Popova O. et al.(2013) *Science* 342:1069-1073. [2] Shuvalov V.V.et al. (2016) *Solar System Research 50*: 1-12. [3] Collins G.S. et al. (2005) *Meteoritics & Planetary Science* 40: 817–840. [4] Shuvalov V.V. (2017) *Solar System Research 51*: 44-58. [5] Artemieva N. et al. 2017. *Meteoritics & Planetary Science* 32: A6041.