

NUMERICAL MODELING OF IMPACT INDUCED AERIAL BURSTS. V.Shuvalov, I.Trubetskaya, Institute for Dynamics of Geospheres RAS, Leninsky pr. 38-1, 119334 Moscow, Russia, (shuvalov@idg.chph.ras.ru)

Introduction. The Tunguska event [1] occurred in 1908 was the largest aerial burst induced by asteroidal (or cometary) impact and recorded in human history. We use the term aerial burst to define a variety of impacts which do not produce craters, but produce strong atmospheric (radiation, shock waves, acoustic-gravity waves) and possibly surface (devastations and fires) effects. There are good reasons to believe that Tunguska-like and even much larger aerial bursts continuously occurred during geological history.

Wasson and Moore [2], Wasson and Boslough [3] suggested that radiation from aerial bursts could be responsible for production of layered tektites in South East Asia and Libyan Desert Glass found in Western Egypt. Shuvalov [4] suggested that surface impacts of strongly disrupted (during a passage through the atmosphere) projectiles are much more effective from the viewpoint of thermal effects on the ground than Tunguska-like aerial bursts. In such impact most of the kinetic energy is released at the surface, but a crater and shock induced modification of target material are not formed because of low bulk density of the disrupted projectile.

The type of aerial burst depends on projectile material, size, velocity, and trajectory angle. In general three types can be considered: surface impact (when a hot jet or fireball touches the ground), Tunguska-like phenomena (when a jet or fireball do not reach the ground but produce fires and devastation), and meteor-like phenomena (when there is a bright flash but no surface effects). The purpose of this paper is to study numerically an influence of impact angle and projectile velocity on the processes accompanying aerial burst. We modeled an impact of a spherical 50-m-radius cometary projectile at $U=50$ and 20 km/s (impact energy equals 150 and 25 Mt of TNT equivalent respectively). Trajectory angles were 90 , 45 , and 30 degree (to horizon).

Numerical approach. To perform numerical simulations we used the model developed by Shuvalov and Artemieva [5]. For all trajectory angles α we solved numerically a 2D problem with effective atmospheric scale height $H/\cos(\alpha)$, where H is a normal atmospheric scale height. Initial altitude (at $t=0$) was 70 km.

The computational grid consists of 600×300 cells in vertical and horizontal directions. In the region (50×100 cells) around the impactor a spatial resolution was 20 cells across the initial meteoroid radius. The space step increases from this region in order to

describe the wake. A bottom boundary of the computational grid moves downwards with a current impactor velocity.

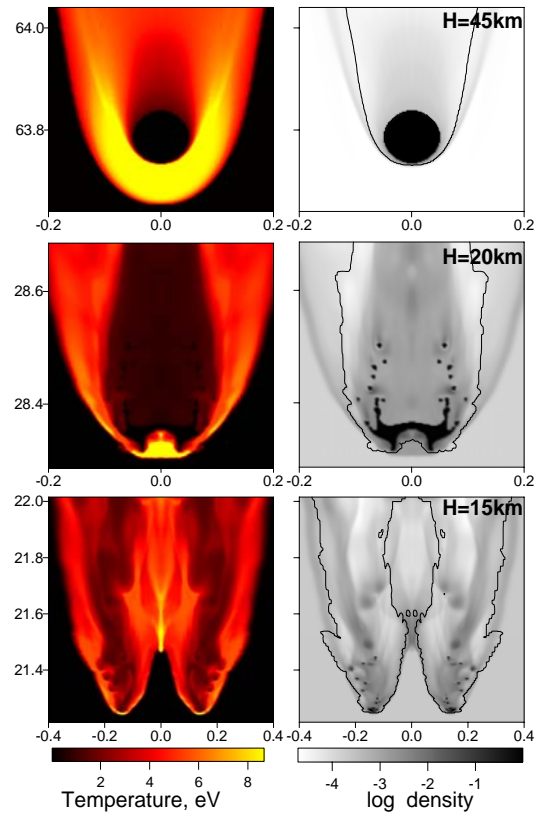


Fig.1. Disruption of a projectile at 45° angle and $U=50$ km/s: temperature and density distribution.

Numerical results. Fig.1 shows a typical process of projectile deformation and disruption (for $U=50$ km/s and $\alpha=45^\circ$). At an altitude of about 35 km the projectile begins to deform under increasing aerodynamic loading. At 20 km altitude a typical pancake-like structure forms, at 15 km altitude the projectile transforms into a debris jet, then into a gaseous jet consisting of vapor and shock-heated air. An important feature is that the disruption and total evaporation of the projectile occurs at high velocity which is close to pre-entry velocity. The projectile decelerates only after its total evaporation and transformation into a gaseous jet. This process is typical for all the angles under consideration.

Fig.2 shows bolide velocity versus altitude for $U=50$ and 20 km/s and $\alpha=45^\circ$. Five runs were performed for each variant. Different runs give slightly

different results, in particular, an altitude of strong deceleration changes in a range of about 5 km. This difference arises from the mechanism of projectile disruption due to development of instabilities. Small perturbations can strongly change a course of disruption. For every impact velocity and angle we also performed five runs and took for further discussion the results which give a middle deceleration altitude.

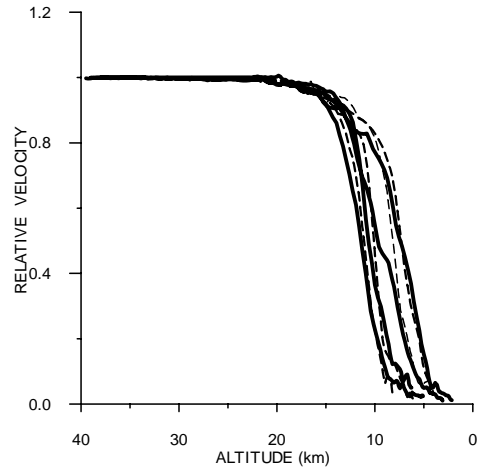


Fig.2. Relative bolide velocity versus altitude of flight for impact angle 45° , impact velocity 50 km/s (solid) and 20 km/s (dashed).

Fig.2 also demonstrates that the results only slightly depend on impact velocity. It is not strange because as a first approximation the time of instability development is proportional to U , the time of a flight down to any fixed altitude is proportional to U^{-1} , therefore the length of trajectory segment till disruption is not dependent on impact velocity. Numerical simulations confirm this conclusion.

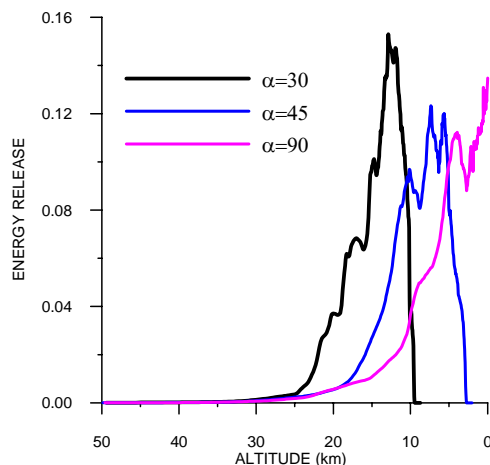


Fig.3. Energy release for different trajectory angle. Impact velocity is 50 km/s. The curves for 20 km/s look very similar.

Fig.3 shows energy release at 5 s for three impact angles. At this time all the projectile material fully decelerates and reaches its lowest position. Later both projectile vapor and shock heated air in the wake accelerate upwards forming an impact plume. In the 90° degree alternative (vertical impact) the projectile totally evaporates at an altitude of about 4 km, transforms into a gaseous jet, but the jet does not have time to decelerate and strikes the ground. The fireball expands along the surface increasing an area exposed to radiation (see Fig.4). In this case both radiation and thermal conductivity can provide strong heating, melting and even evaporation of the upper target layer over an area of about $10\text{-}100\text{ km}^2$.

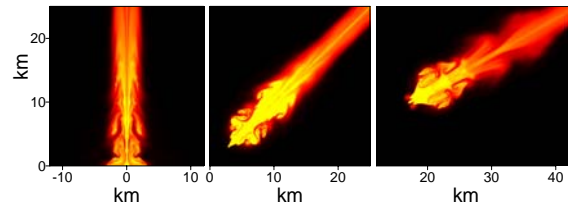


Fig.4. Bolide view at 5 s (when projectile material reaches its lowest position) for different trajectory angle. Impact velocity is 50 km/s. Figures for 20 km/s look very

In the 45° degree alternative the jet totally decelerates at an altitude of about 2-4 km (see Fig.4), then both projectile vapor and hot air move upward through the rarified wake. Shock wave reaches the ground and can produce significant devastation, the radiation is not as high as in the previous case but is intensive enough to produce fires. This 45° degree alternative (at 20 km/s velocity and energy 25 Mt) looks very similar to the 1908 Tunguska event.

In the 30° degree alternative most of the impact energy is released at altitudes above 10 km. Shock wave reaches the ground at rather low overpressure (an order of magnitude lower than at 45° angle) and produce (if does) weaker devastation.

Acknowledgement. This publication is based on work supported by Award No. RUG-2655-MO-05 of the U.S. Civilian Research and Development Foundation.

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