# NUMERICAL MODEL OF AN APOPHIS-LIKE IMPACT AGAINST THE EARTH.

V. V. Shuvalov[1], N.A. Artemieva[1,2], D.O. Glazachev[1], O.P. Popova[1] and V.V. Svettsov[1]. [1]Institute for Dynamics of Geospheres RAS, Moscow. E-mail: shuvalov@idg.chph.ras.ru. [2]Planetary Science Institute, Tucson..

**Introduction:** In 2004 for a short time period the near-Earth asteroid 99942 Apophis was reported as an extremely dangerous object with the probability of the impact on April 13, 2029 as large as 2.7%. Later, additional observations eliminated the 2029 impact threat [1]. However, a possibility remains that the impact will occur in 2036 or later. Since any other projectile of a similar size can impact the Earth in the future, we present a numerical model of such impacts and use it to study the impact consequences including blast waves, formation of an impact crater, ejecta, thermal radiation, and ionospheric disturbances.

**Methods:** Our description of the impact is based on the SOVA multi-material multi-dimensional code [1] Radiative transfer euqations are solved using the radiation heat conduction and volumetric approximations. ANEOS-derived tabular equations of state of dunite and quartz are used to describe the projectile and the target. We performed a suite of numerical experiments to model an impact of a 300-m-diameter spherical body entering the atmosphere at 20 km/s. Impact angles vary from 30° to horizon to 90° (vertical impact).

**Results** show that the projectile experiences strong deformations during its passage through the atmosphere at any impact angle (Fig.1). However, the projectile velocity near the surface is only slightly lower than its pre-atmospheric velocity.

*Crater and ejecta.* The crater size and its shape are identical to the crater created by a spherical projectile. High-velocity ejecta reach an altitude of 200 km; few minutes after the impact almost all ejecta are deposited within the ejecta blanket. Its thickness decreases with distance according to the scaling law: the ejecta blanket is ~100-m-thick near the crater rim, a few meters thick at a distance of 10 km, and ~0.1 m at a distance of 25 km.

*Blast waves* cause an overpressure pulse and strong winds along the surface. A radius of severely damaged area (collapse of buildings and structures) may reach 100 - 150 km. Broken glasses, damage of panel walls and roofs occur within 350-500 km from the impact point. As a rule, a decrease of the impact angle results in an increase of the damaged area. The shape of isobars is circular after a vertical impact and becomes elongated in the direction perpendicular to the trajectory plane after an oblique impact.

*Heating by radiation* is another dangerous consequence of the impact. In good visibility conditions live trees and grass are ignited up to a 200-km-distance from the impact point. At twice smaller distance roofs are burned, rocks and aluminum begin to melt. People can be effected by radiative heating at distance up to 300-400 km.

*Disturbances in ionosphere.* At the late stage of an Apophis-like impact the simulations predict strong ionospheric disturbances at distance up to thousands of kilometers. Density perturbations reach 10-30%, velocities can be as high as 100-300 m/s at altitudes of 100-300 km. These disturbances persist a few hours or even tens of hours.

**Conclusions:** An **i**mpact of a 300-m-diameter asteroid produces regional effects on the surface and global atmospheric disturbances.

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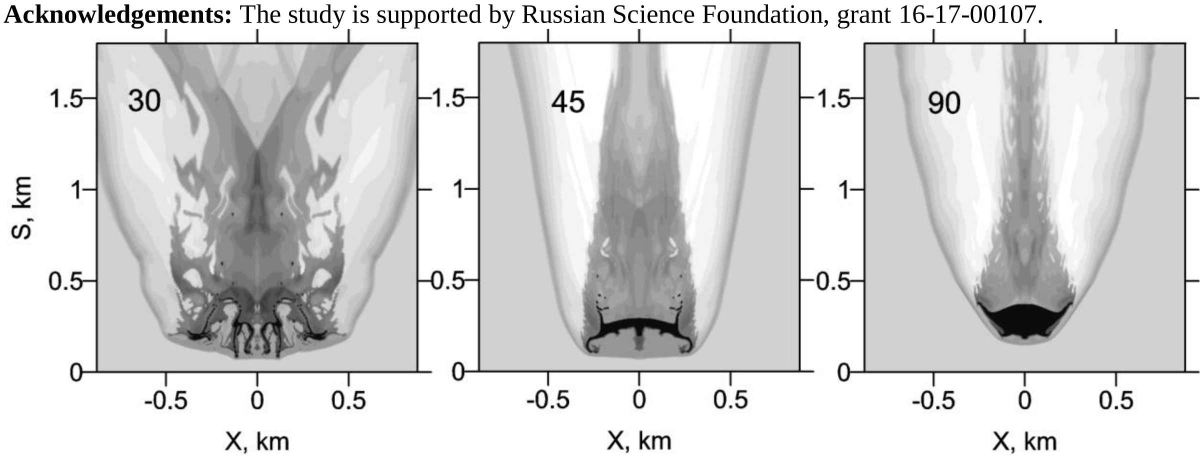


Fig. 1. Fragmentation of a 300-m-diameter asteroid in atmosphere for various entry angles (from left to right: 30°,45°, and 90°). Shades of gray color show the relative agas density; black color corresponds to the non-vaporized projectile material.

**References:** [1] Thuillot W. , Bancelin D. , Ivantsov A. et al. 2015. A&A 583, A59. [2] Shuvalov V. 1999. *Shock waves* 9:381-390.