OBLIQUE IMPACT: ATMOSPHERIC EFFECTS. N.A.Artem'eva, V.V.Shuvalov. Institute for Dynamics of Geospheres, Russian Academy of Sciences, Leninsky prosp., 38-6, Moscow, 117979.

The impacts of asteroids and comets on the Earth cause large-scale disturbances of the Earth's atmosphere. Only 1% or less of the energy of bolides is taken up directly during the passage through the atmosphere, and the vaporized, melted and solid ejecta transfer up to 40% of their energy to the atmospheric air [1]. It may be the reason why the latter effect has been investigated in detail - from the fundamental work [2] to the encyclopedia [3], and the former has received only occasional attention in the literature. For example, O'Keefe and Ahrens [1] mentioned, that the penetration of the bolide produces a short-lived hole in the atmosphere with diameter approximately equal to that of the bolide. The gas in this hole flows radially inward filling the hole and upward propelling the air and ejecta particles to high altitudes. In [4] it was emphasized that the presence of a tail of a highly rarefied cavity promotes the escape of the ejecta to the upper layers of the Venusian atmosphere. The interaction of airblast waves with a thin heated channel and the accompanying reconstruction of the ejecta flow has been investigated numerically in [5], and the more realistic problem has been solved in [6,7] for the case of vertical impact on Mars and on the Earth. The results of the above mentioned computer simulation indicate the powerful upward stream that is many times greater than the well known asymmetry of the "facula" due to the atmospheric inhomogeneity.

Now we have improved the previous model [7] - the real wake, real impact with crater formation, heat and light transfer are taken into account. Fig.1 demonstrates the 50 km/s vertical impact of 1 km silicate body on the Earth. The vapor plume, consisting of the body and surface material, is expanded within the "hole" (rarefied wake). The shape of the plume and blast wave is far from spherical mainly because of the wake influence. Although vertical impact is a convenient object for numerical simulation due to it's cylindrical symmetry, in real situations an impact is most likely to be oblique.

Relatively simple 3DE hydrocode enables us to make computer simulation of the oblique impact of the same asteroid falling with inclination angle 45° onto a silicate Earth covered by atmosphere. For the sake of simplicity we have restricted ourself to the simplest model: the wake can be treated as a time-dependent cylindrical explosion with the energy $V^2/2$ per unit mass of the atmosphere, and the ejecta - as an explosion of a hemisphere that is 10 times as massive and 4 times as great as the asteroid and its thermal energy is equal to the half of the asteroid's kinetic energy. The scale height of the atmosphere is taken to be H=8.4 km.

Fig.2 presents the isolines of the relative density ρ/ρ_z at XZ-section of the flow, where ρ_z is the atmospheric density at the corresponding height z immediately after the impact, Fig.3 presents ρ/ρ_z at 1.25 sec following the impact. As shown in Fig.2, the wake ranges in thickness from 20 km at the height 50 km to 4 km near the surface, and it's density in a thin central channel is ~10 times lower than that of the ambient gas. Fig.3 depicts an absence of strong vertical flow: the blast waves occupy considerably greater region than it has been suspected for an explosion without wake (dashed lines), with strong disturbances toward the wake. Also the velocity is a maximum not on the upper edge of the ejecta flow but within the wake (35 km/s versus 15 km/s).

So the interaction of the atmospheric shock waves generated during the flight and the following impact of the bolide alters the final flow pattern radically. This doesn't mean that the ejecta pathways change dramatically too, but it's not unlikely. The complex spatial flow can modify the mass and velocity distribution of high-energy ejecta, its deposition in the stratosphere and largely influence the long-term consequences of impact phenomena. In our model we do not take into account radiation at all. But it is well known that the fireball is a powerful source of light and heat pulse, that causes fire storms on the Earth's surface. As the fireball is distorted in shape, the area of fires may be significantly increased.

Whereas essentially all impacts are vertical in relation to crater formation except gently inclined ones [3], they are significantly oblique in relation to atmospheric effects. Our simulation is only the first step on the road to extensive studies. At a later time we try to adjust our physical model.

References: [1] O'Keefe J.D., Ahrens T.J. (1982), GSA Special Paper No 190, p.103-120. [2] Zeldovich Ya.B., Raizer Yu.P. (1967), Physics of Shock Waves and High Temperature Hydrodynamic Phenomena, Academic Press, N.Y. [3] Melosh H.J. (1989), Impact Cratering, Oxford Univ. Press, N.Y. [4] Ivanov B.A. et al. (1986), J. Geophys. Res., v.91, No B4, p.413-430. [5] Bergelson V.I. et al. (1987), Meteoritica, No 48, p.137-141 (in Russian). [6] Nemchinov I.V., Shuvalov V.V. (1992), Solar System Research, v.26, No 4, p.333-343. [7] Nemchinov I.V. et al. (1993), LPSC XXIV (abstracts), p.1067-1068.