EFFECTS OF HYDRODYNAMICS AND THERMAL RADIATION IN THE ATMOSPHERE AFTER COMET IMPACTS

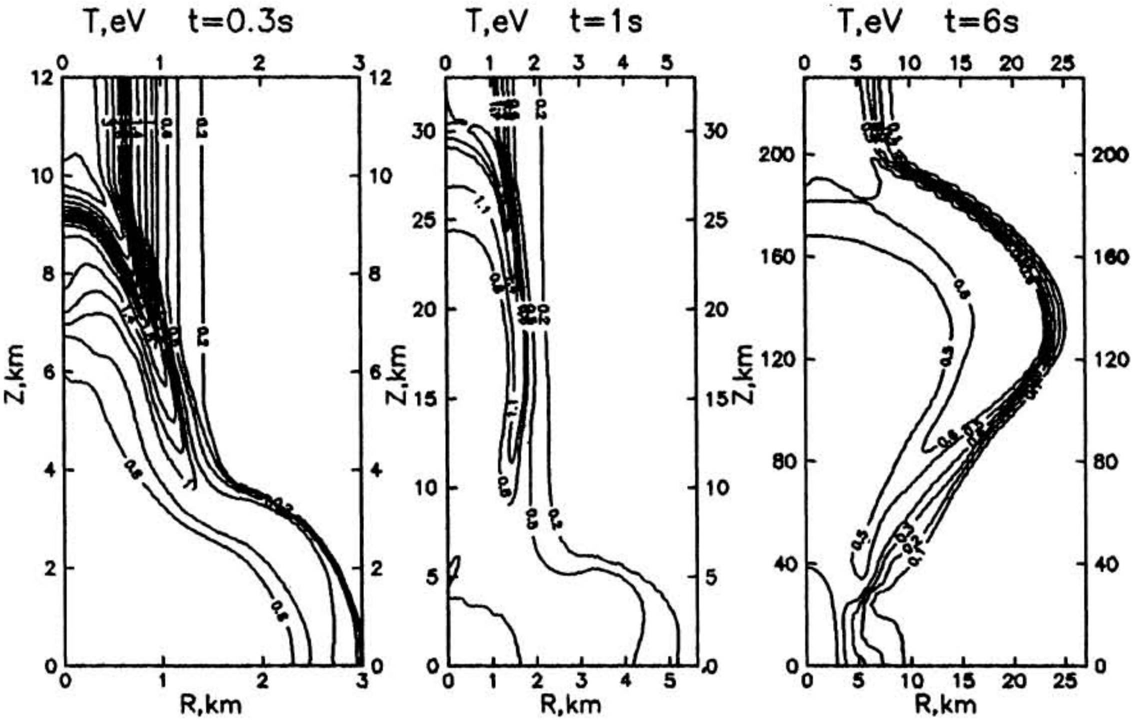
I. V. Nemchinov, M. P. Popova, L. P. Shubadeeva, V. V. Shuvalov, and V. V. Svetsov
(Institute for Dynamics of Geospheres, Moscow, Russia)

Radiation phenomena in the atmosphere after impacts of cosmic bodies have special features in comparison with the surface nuclear explosions. First, initial concentration of energy after the impact is lower, and, second, a wake after the passage of the meteoroid through the atmosphere has a dramatic effect on the atmospheric flow and radiation transfer. Consequently, scaling laws [1] can not be employed for prediction of the flow in the atmosphere and the light flux on the Earth's surface.

If a density of a high-velocity impactor is low relative to the ground, as in a case of a comet impact on rocks, a major part of kinetic energy is converted to internal energy of dense and hot vapors [2]. But radiation effects can be essential even for fairly low velocities of the impactor. To clarify this issue we have undertaken calculations of 100-Mt explosions at the Earth's surface caused by small comets with velocities from 10 to 70 km/sec. That is, the initial concentration of energy has been varied. The calculations have shown that for velocities of the comet greater or about 20 km/sec a portion of energy emitted from the fireball exceeds 20% of the total energy of the explosion and this quantity does not change very much with the velocity. For an absolutely transparent atmosphere the energy of thermal radiation per unit area on the ground would be about 100 J/cm^2 at a distance of 100 km from the point of the impact. This radiation exposure is sufficient to ignite outdoor tinder materials. But atmospheric visibility reduces the radius of ignition to about 10 km for normal atmospheric conditions [3].

It had been shown in [4] that after the impact of a medium-sized comet (with radii from 200 m to 1 km) the light pulse on the Earth's surface is sufficient to ignite mass fires on continent-sized areas. The influence of the wake had not been taken into account. But the radiation flux on the ground in this case by far exceeds the magnitude necessary for ignition, and, hence, even rough estimates could give trustworthy results. In the case of the impact of a small comet (with a radius of about 100 m and smaller) it is a wake that crucially changes the atmospheric flow and enhances efficiency of radiation. We have carried out 2D radiation hydrodynamic calculations of a vertical impact of the comet. The wake was approximated by release of energy and momentum in a cylindrical layer with a radius equal to the radius of the meteoroid. It was assumed that the major part of kinetic energy of the comet was converted to heat.

Figure shows temperature contours in the atmosphere after the impact of a 100-m radius icy body at a velocity of 50



km/sec. The wake expands hydrodynamically (in 1 sec to 2 km in radius) and a great amount of mass and energy is injected into the wake. A velocity of a shock wave travelling upwards along the wake grows with the altitude and is above 40 km/sec in 1 sec after the impact. The temperatures are higher in the wake than near the ground. The plasma at the high altitudes becomes semitransparent and the radiation transfer becomes more effective than in the lower atmosphere. On the other hand, the light source, located very high, is less attenuated by atmospheric absorption. The energy per unit area is greater than 100 J/cm^2 at a distance of 300 km from the point of the impact for a perfect atmospheric visibility. The altitude of the source which emits a major portion of the light pulse is greater than 60 km. This effect severely enhances a hazard of wildfires after the impact of a small comet.

When a shock wave moves along the heated layer on the surface of the Earth, dust will be involved into the whirl inside the plume [5]. Due to the wake more dust is lofted into the upper atmosphere than in the case of the explosion of the equivalent energy.

REFERENCES: 1. Zel'dovich,Ya.B., and Raizer,Yu.P., Physics of shock waves and high temperature hydrodynamic phenomena, Acad. press, N.Y., 1967. 2. O'Keefe,J.D., and Ahrens,T.J., J. Geophys. Res., 87, 6668, 1982. 3. The effect on the atmosphere of a major nuclear exchange, Nat. Acad. press, Washington, D.C., 1985. 4. Nemtchinov,I.V.,and Svetsov,V.V., Adv. Space Res.,11, 6(65), 1991. 5. Artem'ev,V.I., Bergel'son et al., Izv. Akad. Nauk SSSR, Mekh. Zhidk. Gaza, No.2, 158, 1988.