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Impact Effects and Consequence

Entry Angle Effects on the Ground Signature of the Chelyabinsk Superbolide

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ABSTRACT

In 2013, an approximately 20-m diameter chondritic body traveling at 19 km/sec broke up over the Russian city of Chelyabinsk. The breakup rapidly transferred the object's 500 kilotons of kinetic energy into the atmosphere producing a blast wave that shattered windows, damaged structures, and caused approximately 1500 people to seek medical attention. Chelyabinsk's entry angle of 18.3 degrees was shallow in comparison to the most likely entry angle of 45 degrees for asteroids impacting Earth. This shallow entry angle provided more atmospheric shielding causing the object to burst at a higher altitude thus lowering overpressure on the ground.

Here we examine the effect the object's entry angle had on the burst height and the overpressure footprint on the ground using 3D numerical simulation. To model the event, we use the FSISPH solver, part of the open-source adaptive smooth particle hydrodynamics code Spheral, maintained by Lawrence Livermore National Laboratory. Simulations proceed in two steps. First, we model the atmospheric entry of the object to estimate the deposit profiles of mass, momentum, and energy with altitude. We then use those deposits as initial conditions for blast simulations in a hydrostatic atmosphere to model the overpressure footprints. We present results from three simulations, one at the nominal 18.3 degrees and two at steeper entry angles of 45 and 90 degrees. Increasing the entry angle decreases the effective burst height by 10 kilometers in the most extreme case.

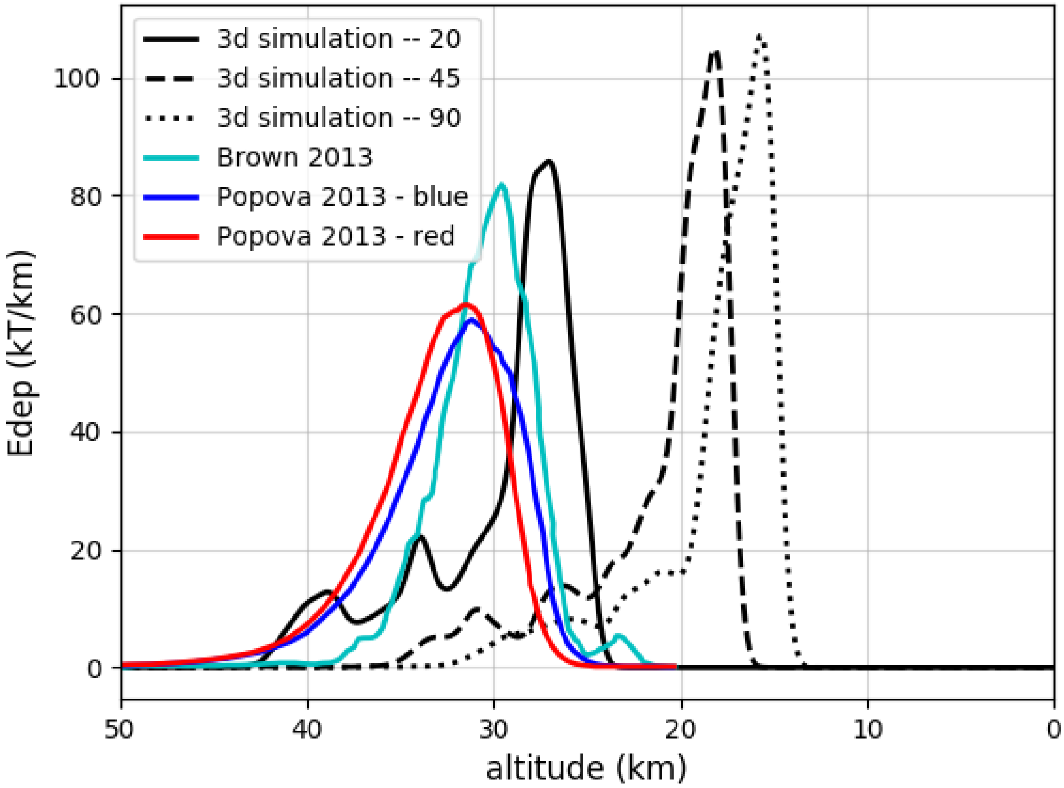

Figure 1: Kinetic energy deposit rate is plotted versus altitude for three 3D simulations of the Chelyabinsk meteor at different entry angles 20, 45, and 90 degrees. Simulated results are compared to the observation derived energy deposit curves from Brown et. al. 2013 and Popova et. al. 2013.

Comments: Prefer oral session

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