ASTEROID TO AIRBURST; COMPARING SEMI-ANALYTICAL AIRBURST MODELS TO HYDROCODES

S. McMullan[1], G. S. Collins[1], and T. M. Davison[1], [1]Impact and Astromaterials Research Centre, Dept. Earth Science and Eng., Imperial College London, SW7 2AZ, UK, email: s.mcmullan16@imperial.ac.uk

Introduction: The 2013 Chelyabinsk event in Russia brought to light the potential hazard a Near-Earth Object (NEO), ~20 m in diameter can have on the Earth's surface [1]. NEOs 1-100m in size are abundant, difficult to observe astronomically, and strike the Earth with little to no warning [2]. There is likely to be at least one significant event in a human lifespan (e.g. Chelyabinsk, Tunguska), so being able to model their potential energy deposition and damage on the ground accurately is imperative. Semi-analytical models are fast predictors of energy deposition but make many assumptions and have several free parameters that are poorly defined [3-5]. These parameters are usually tuned to reproduce a particular event, such as Chelyabinsk [4]. In previous work, we showed that it is possible to tune multiple semi-analytical models to match the Chelyabinsk energy deposition [1], however, when these same models are then applied to a different event, such as Tunguska, the results diverge [6]. Previous studies have shown that shock physics codes are capable of reproducing the fragmentation of meteoroids in the atmosphere and their energy deposition rates [7-9]. They make fewer assumptions than semi-analytical models, so have fewer independent model parameters, but have a higher computational cost. Here we use the iSALE shock physics code [10-12] to simulate the atmospheric entry of meteoroids. From our simulation results, we can produce synthetic energy deposition curves with known initial entry conditions. This provides an additional data set with which to calibrate existing semi-analytical models and develop new approaches for the fast prediction of airburst outcomes.

Modelling Airbursts with iSALE: We have adapted the iSALE shock physics code [10-12] for the purpose of simulating atmospheric fragmentation of a meteoroid. We implemented a dynamic air-inflow bottom boundary condition that allows the atmospheric traverse to be simulated in the reference frame of the meteoroid. This avoids undesirable regridding or advection of the meteoroid through the Eulerian mesh. An example simulation is shown in Figure 1, with initial conditions similar to the Chelyabinsk event (diameter = 20 m, velocity = 19 km/s, density = 3300 kg/m^3). From these simulations, we produce synthetic data sets, including energy deposition curves for comparison with the energy deposition curve inferred from light-curve observations.

Discussion: Comparisons of our preliminary iSALE results with predictions of semi-analytical models show that while the timing and altitude of principal energy deposition are similar, the details of meteoroid spreading and ablation are different. iSALE predicts spreading rates of 2.5 times the initial radius, far lower than those of semi-analytical models which are calculated at 6-9 times the initial radius. This is consistent with previous hydrocode simulations of meteoroid entry [13]. Further simulations will investigate the effect of asteroid strength and porosity on the rate of deceleration and spreading.

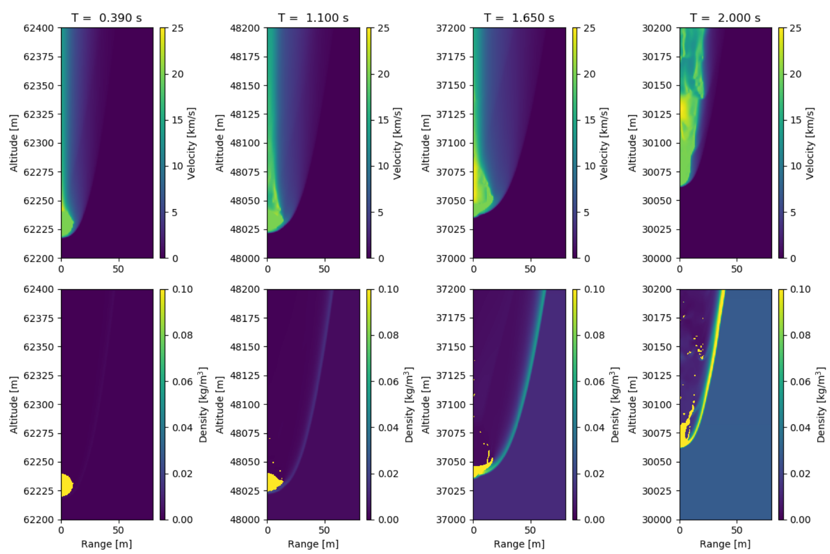

Figure 1: iSALE atmospheric fragmentation simulation, showing the velocity and density profiles at 0.39, 1.1, 1.65 and 2.0 secs.

Acknowledgments: We gratefully acknowledge the developers of iSALE (www.isale-code.de). This work was funded by STFC grant ST/N000803/1.

References: [1] Brown P. G. et al. (2013) *Nature* 503:238-241, [2] Harris A. et al. (2015) *In Asteroids IV, Univ. of Arizona, Texas,* 835-854, [3] Chyba C. F. et al. (1993) *Nature* 361:40-44, [4] Hills J. G. and Goda M. P. (1993) *The Astronomical Journal* 105:1114-1144, [5] Avramenko M. I. et al. (2014) *Journal of Geophysical Research: Atmospheres* 119:7035-7050, [6] McMullan S. and Collins G. S. (2019) *Icarus* 327:19-35, [7] Crawford D.A et al. (1994) *Shock Waves* 4:47-50, [8] Shuvalov and Artemieva (2002) *Planetary and Space Science* 50:181-192. [9] Robertson D. and Mathias D. (2017) *Journal of Geophysical Research: Planets* 122:599-613, [10] Amsden A. et al. (1980) *Los Alamos National Laboratories Report* LA-8095:101p, [11] Collins G. S. et al. (2004) *Meteoritics and Planetary Science* 39:217-231, [12] Wünnemann K. (2006) *Icarus* 180:514-527, [13] Artemieva N. and Pierazzo E. (2009) *Meteoritics & Planetary Science* 44:25-42.