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MODELLING THE BREAK-UP AND RE-ENTRY PROPAGATION OF METEORITES THROUGH A CONTINUUM APPROACH

Abstract

The study of the fragmentation of meteorites re-entering the Earth's atmosphere is of interest to predict the consequences such events can have on the ground. The size and location of the surviving fragments are important and so is the energy deposited in the atmosphere. In fact, the rate at which this energy is deposited through thermal ablation and momentum loss due to aerodynamic drag is fundamental in understanding the risk connected to blast waves generated by the meteorite fragmentation. Existing models for meteoroid fragmentation follow either a pancake approach, where the cloud of fragments resulting from the meteorite explosion expands together in the shape of a disk, or a discrete fragmentation approach, where successive fragmentation events split the bolide into several pieces. Approaches combining these two techniques also exist. In this work, we propose a comprehensive approach in which the fragments resulting from the break-up of a meteorite are modelled using a continuum distribution. A modified version of the NASA Standard Break-up Model is used to generate the fragments distribution in terms of their area-to-mass ratio and ejection velocity. This distribution is then combined with the nominal re-entry state of the meteorite to generate the initial conditions for the entire ensemble of fragments resulting from the break-up. The fragments distribution is then directly propagated using the continuity equation combined with the re-entry dynamics, considering both deceleration and ablation. In this way, we do not propagate single fragments but their spatial density under the effect of the non-linear re-entry dynamics. The result is the evolution of the fragments cloud in time, which is then reconstructed at each time step using a Gaussian mixture model (GMM). This model moves away from the simplified pancake method and has the flexibility to include large fragmentation events for a better physical representation of the re-entry of meteorites. Another advantage of the proposed propagation methodology is its flexibility. It only requires the fragments distribution as an initial condition. This means that improved meteorites fragmentation models can be easily integrated into this framework for better propagation of the trajectory of the fragments. The paper describes the fragmentation models and the generation of the initial distribution of fragments, their propagation using the continuity equation, and the distribution reconstruction at each time step using GMM. The propagation of the fragments density and its reconstruction is first compared against Monte Carlo simulations, and then against real observations.