Numerical Prediction of Meteoric Infrasound Signatures

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Abstract

Infrasound measurements of meteoroids entering the Earth's atmosphere provide independent estimates of luminous efficiency. When combined with optical observations, these estimates help refine our assessment of energy deposition. Moreover, analysis of the infrasound signature may give insight into the shock system and fragmentation characteristics, particularly equivalent blast radius, during the meteor's descent[1].

This paper presents a direct computational approach for predicting infrasound signatures of small meteors. Our focus is on regional events, where the propagation distance through the atmosphere is less then 150 km. We apply techniques from sonic-boom analysis of supersonic aircraft[2] to the propagation of blast waves of hypersonic meteors. The physical domain is divided into a nearfield and a farfield region. In the nearfield, we assume steady inviscid flow in thermochemical equilibrium and use a second-order finite-volume discretization to compute a near-body pressure signature. In the farfield region, the near-body signature is propagated through a stratified atmosphere to the ground using an augmented Burgers equation.

A novel contribution of this work is a thorough validation of the computational predictions. We start by analyzing the entry of the Stardust capsule[3], which is a convenient "artificial" meteor with a well defined geometry, trajectory and infrasound record. The results are used to understand the numerical attenuation of the signature and to account for instrument response. We then consider several cases from the Southern Ontario Meteor Network dataset[1].

Figure 1 shows preliminary results. The first example (top) involves a 7 cm meteor entering the atmosphere at 16 km/s. The left frame shows a model of the body, while the right frame shows a comparison of the predicted infrasound signature with the measured data. The second example (bottom) shows the Stardust entry. The simulations closely agree with the observations in both amplitude and wavelength. The final paper will provide a detailed analysis of the accuracy of the computed signatures, and include a discussion of arrival times and sensitivity to various uncertainties, such as the meteor shape and atmospheric conditions.

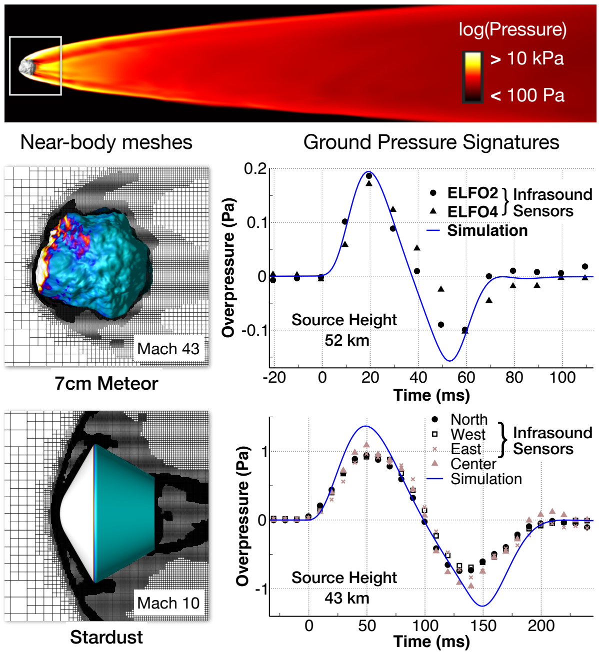

Figure 1: Measured (symbols) and computed (blue lines) infrasound signatures of a meteor-like shape (top) and the Stardust capsule (bottom)

References

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