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A Semi-Analytic Lamb Wave Model for Prediction of Blast Overpressures from Large Asteroid Entries

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Atmospheric entry and disruption of very large bodies produces blast waves with damage radii reaching hundreds or even thousands of kilometers. Recent 3D computational simulations of large impactors (above roughly 1 Gt kinetic energy at entry) demonstrate that these large blasts initially expand roughly spherically and then transition to more cylindrical behavior as the blast essentially “fills up” the entire height of the atmosphere. Since the blast is constrained by the ground, the large pressure disturbances transition to Lamb waves within the troposphere and can propagate many times around the globe. Over water, these pressure disturbances provide atmospheric forcing of Ocean Coupled Airwaves (OCA) that can cause tidal effects and tsunamis far from the blast source, as recently observed after the 2022 eruption of Hunga Tonga–Hunga Ha’apai [Omira, 2022; Nishikawa, 2022; Ren, 2023].

We present a semi-analytic model connecting the Lamb wave overpressure, blast yield energy, and distance from the blast source following the form of Nishikawa et al. [2022] with an extension to airbursts using the relationship between source energy and Lamb wave period from ReVelle & Whitaker [1996]. We also present a simple trigonometric

extension to the wave front propagating around a spherical Earth. Since Lamb waves are essentially cylindrical elastic waves, the large blast model gives overpressure decay rates of *1/r* rather than spherical blast decay rates of $1/r^2$. This slower blast overpressure decay indicates that blast damage (1 psi or greater) could extend even further than predictions from spherical-blast models or height-of-burst (HoB) models [Glasstone & Dolan, 1977]. Importantly, the Lamb wave model also enables fast and inexpensive estimation of the atmospheric forcing for global tsunami simulation even when the impact point is over land or for landlocked bodies of water.

In addition to the mathematical details of the Lamb wave model, we will show how it connects with weapons-heritage HoB methods near the source. We will also present full 3D simulation results focusing on large asteroids with up to 5 Gt of energy at entry. At these scales, overpressures above 2 psi may extend to over 200 km from the point of impact. The new Lamb wave model fills two modeling gaps: accurately predicting overpressures from large blasts at distances where HoB methods lose accuracy, and providing a tool for driving global tsunami simulations directly from the atmospheric energy deposition of large asteroid entries.

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The authors would prefer an oral presentation format for this work.