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Impact Effects & Consequences

Numerical Modeling of Asteroid Ocean Impact: Preparing Pipeline for Future Scenario Modeling

Lauren S. Abrahams [(1)], **Betsy R. Seiffert** [(2)], **Megan Bruck Syal** [(3)], **and Souheil Ezzedine** [(4)]

[(1)] *Lawrence Livermore National Laboratory, L-783, Livermore, CA 4551, +1(925)784-7616, abrahams3@llnl.gov*

[(2)] *Lawrence Livermore National Laboratory, L-030, Livermore, CA 4551, +1(925)422-8841, seiffert2@llnl.gov*

[(3)] *Lawrence Livermore National Laboratory, L-016, Livermore, CA 4551, +1(925)784-7616, syal1@llnl.gov*

[(4)] *Lawrence Livermore National Laboratory, L-043, Livermore, CA 4551, +1(925)-422-0565, ezzedine1@llnl.gov*

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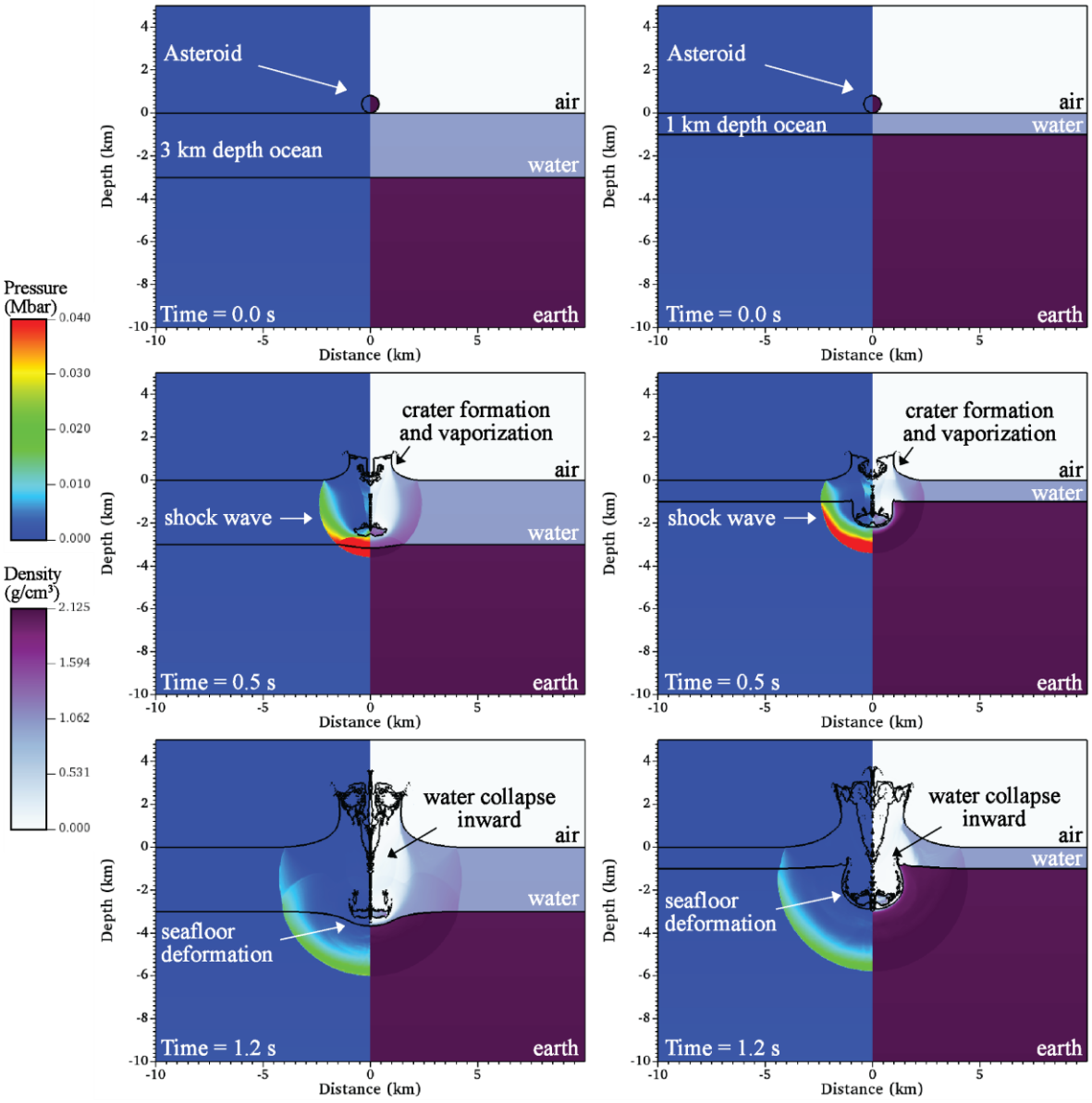
ABSTRACT

Near Earth Objects (NEOs), such as asteroids on an Earth-impact trajectory, are low probability, high consequence natural hazards. To understand and assess these hazards, we rely on numerical simulations of Earth-impacting NEOs to model potential damages. With 71% of Earth covered in water, we focus this work on wave generation and propagation for water impacts. This work aims to establish an operational capability to assess threats and rapidly share results with the broader interagency community through a national planetary defense assessment pipeline. The establishment of such a planetary defense modeling pipeline was a recommendation in the 2023-2032 Planetary Science & Astrobiology Decadal Survey.

The problem geometry includes the atmosphere, ocean, and solid earth. We model a spherical 600 m diameter asteroid impacting deep (5 km), intermediate (3 km), and shallow (1 km) water at both normal (90°) and oblique (45° and 20°) angles to examine symmetrical and asymmetrical impacts. We calculate impact energy conversion to wave energy, pulverization, and water to vapor using ALE3D, a multi-physics hydrocode which uses an Arbitrary Lagrangian-Eulerian (ALE) scheme. Geodyn material models are used for the asteroid and earth. We examine crater formation, shock formation and propagation, and atmospheric effects from asteroid impact. Initial investigation is carried out in 2D axisymmetric geometries, with adaptive mesh refinement (AMR) applied to the area around the asteroid and material interfaces. Impact angle probability distribution scales as ~sin(2θ), where θ is the angle from surface normal, therefore, we extend this problem to more realistic, oblique impacts through 3D modeling without AMR. To allow for wave propagation and coastal inundation further steps include linking the wave generation data from the initial impact to a separate tsunami code.

With limited data available from historical NEOs impacts, numerical models of theoretical impacts can provide us with insight on assessing potential hazard and lead to recommendations for emergency response. If an asteroid is detected with sufficient warning time, consequence calculations may also factor into the decision to fly reconnaissance and/or mitigation missions. Timely and credible consequence assessments, such as water impact assessments, are an essential piece for a successful planetary defense modeling pipeline.



Caption: Time history of pressure and density distributions for an asteroid impacting two different air-water-earth model scenarios (3 km and 1 km water depth, left to right, respectively).

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