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AIRBURST-GENERATED TSUNAMI BY VARIOUS COUPLING MECHANISMS

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ABSTRACT

The effort to prevent or mitigate the effects of an impact on Earth is known as planetary defense. A significant component of planetary defense research involves risk assessment. Much of our understanding of the hazard from near-Earth objects comes from the geologic record in the form of impact craters, but not all asteroid impacts are crater-forming events. Small asteroids explode before reaching the surface, generating an airburst, and most impacts into the ocean do not penetrate the water to form a crater in the sea floor. The hazard from these non-crater-forming ocean impacts and airbursts is difficult to quantify and represents a significant uncertainty in our assessment of the overall risk. We are currently working to better understand impact scenarios that can generate dangerous tsunami.

One of the suggested mechanisms for the production of asteroid –generated tsunami is by direct coupling of the pressure wave to the water, analogous to the means by which a moving weather front can generate a meteotsunami. To test this hypothesis, we have run a series of airburst simulations and used the resulting time-resolved pressure and wind profiles as source functions for tsunami simulations. We used the CTH hydrocode to model the various airburst scenarios to compare to the results of other simulations and provide time dependent boundary conditions as input to shallow-water wave propagation codes. The strongest and most destructive meteotsunami are generated by atmospheric pressure oscillations with amplitudes of only a few hPa, corresponding to changes in sea level of a few cm. The resulting wave is strongest when there is a resonance between the ocean and the

atmospheric forcing. A Proudman resonance takes place when the atmospheric disturbance translational speed (U) equals the longwave phase speed c = $\sqrt{gh}$ of shallow water wave. Coupling is strongest when the Froude number (Fr=U/c) is unity. A weather front propagates much slower than the speed of sound, so meteotsunami are most common and dangerous in shallow bodies of water such as the Mediterranean Sea or Lake Michigan. By contrast, the blast wave from an airburst propagates at a speed faster than a tsunami in the deepest ocean, and a Proudman resonance cannot be achieved even though the overpressures are orders of magnitude greater. However, blast wave profiles are N-waves in which a sharp shock wave leading to overpressure is followed by a more gradual rarefaction to a much longer-duration underpressure phase. Even though the blast outruns the water wave it is forcing, the tsunami should continue to be driven by the out-of-resonance gradient associated with the suction phase, which may depend strongly on the details of the airburst scenario. The open question is whether there are any conditions under which such an airburst-driven tsunami can be dangerous enough to contribute to the overall impact risk.

We have also identified other potential mechanisms for airburst-generated tsunami: 1) reaction force at the surface from the plume ejected into space, which carries significant momentum, 2) expanding toroidal vortices at the surface, which travel more slowly than the shock wave and can generate a Proudman resonance in relatively shallow ocean (such as continental shelf), and 3) steam explosion from seawater ablation by a “Type II” (Libyan Desert Glass-type) airburst in which the hot vapor jet descends to the surface. We will present our simulations of these other possible mechanisms.

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