PDC2023
Vienna, Austria

Impact Effects & Consequences

2023 PDC EXERCISE: GLOBAL TSUNAMI FROM LAND OR OCEAN IMPACT

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Keywords: *Lamb Wave, tsunami, meteotsunami, Proudman resonance*

ABSTRACT

For the 2017 PDC we modeled the production of asteroid–generated tsunami by direct coupling of the pressure wave, analogous to the means by which a moving weather front can generate a meteotsunami. We used the CTH hydrocode to simulate various airburst scenarios to provide time dependent boundary conditions as input to shallow-water wave propagation codes. The strongest and most destructive weather-driven 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 the 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. We concluded that there are conditions under which such an airburst-driven tsunami can be dangerous enough to contribute to the overall impact risk.

The January 15, 2022 explosive eruption of Hunga Tonga–Hunga Ha‘apai and resulting tsunami provided an existence proof for the air pressure wave coupling mechanism we proposed. It also suggests that it can be stronger and more significant

over much greater distances than we contemplated, leading to global tsunami associated with impact events on land as well as in the water. Large atmospheric explosions generate global Lamb waves with larger amplitudes, longer periods, and slower speeds than the local and regional blast waves we modeled in 2017. Each of these differences leads to an increase in coupling efficiency over larger geographic areas. Using the parameters for the impact associated with the 2023 PDC exercise, we simulated the blast and resulting global meteotsunami from land impacts in Dallas and Jebba, Nigeria. We have shown that the resulting global tsunami contribute significantly to the destruction. Because the coupling and focusing of the tsunami depend upon the details of ocean bathymetry and its relationship to the source, the damage can be greatest in unexpected places across the globe. We propose ensemble simulations of Lamb-wave generated tsunami for impact locations spanning the planet to provide maps to enable rapid tsunami warnings in the event of a pending or unexpected NEO impact.

This work was supported by the US Department of Energy through the Los Alamos National Laboratory. Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of U.S. Department of Energy (Contract No. 89233218CNA000001).

Comments:

Prefer oral presentation