TSUNAMI GENERATION BY EARTHQUAKES: SEABED TOPOGRAPHY AND INERTIAL EFFECTS

Robert A. Dalrymple, Johns Hopkins University, rad@jhu.edu
Morteza Derakhti, Johns Hopkins University, derakhti@jhu.edu

The generation of surface gravity waves by a seabed displacement (uplift or subsidence) is a classical problem that arises in the study of earthquake-generated Tsunamis. The pioneer study of Hammack (1973) has elucidated the main dynamics of the generation of surface waves by the uplift or subsidence of a portion of a flat bottom boundary in a two-dimensional domain of a uniform depth. He defined a non-dimensional rise time as

$$\tau = \frac{t_r}{R/\sqrt{gh}}, \qquad (1)$$

where t_r is the characteristic time of the bed motion, R is the radius or half of the width of the moving region, h is the constant ocean depth and g is the gravitational acceleration. Hammack identified three regimes, which he named impulsive ($\tau \ll 1$), transitional ($\tau \sim 1$), and creeping ($\tau \gg 1$), where the generated surface wave height increases with decreasing τ, with the maximum free surface displacement was found to be bounded by the maximum bed displacement.

In practice, the seafloor displacement estimated from seismic characteristics of an earthquake in impulsive regime is usually translated to the free surface as an initial free surface condition along with a zero velocity field as an initial velocity condition for a hydrodynamic propagation model. The physical problem of Tsunami generation, however, is more complex in which the deforming seafloor includes large features such as seamounts and trenches with various heights and shapes. In addition, ignoring the inertial effects during the generation phase may lead to a significant error in the predicted arrival time and height of the generated Tsunami, especially in the near field.

In this presentation, we examine the effects of the shape and height of a moving bed on the generated surface gravity waves using the 3-D Smooth Particle Hydrodynamic model, GPUSPH (Hérault et al., 2010). Further, we investigate the relative importance of the inertial effects on the general characteristics of the generated Tsunami in the near- and far-field for various rates of the bed displacement, ranging from creeping to impulsive regimes. The sensitivity of the inertial effects on the shape of the moving bed is also discussed. Finally, the characteristics of the acoustic waves generated during the various bed displacement scenarios are examined.

Figure 1 shows the 3-D view of the half of the computational domain for three 3-D simulations with a cylindrical, conical and spherical moving beds with the same base radius and volume as well as the adjacent circular ocean. Figure 2 shows an example of the temporal variation of the generated surface waves in various x locations for a transitional ($\tau = 0.33$), and an impulsive ($\tau = 0.08$) bed motions with various bed shapes as shown in Figure 1. The results reveal that the bed shape has a profound effect on the generated wave height within the generation region for the impulsive case. Further, results show that the inertial effects lead to the surface displacement that is considerably greater than the maximum bed displacement, especially in the case with a cylindrical moving bed. A number of 2-D and 3-D simulations at the field scales are presently underway to examine the characteristics of the generated acoustic waves in addition to surface waves for the same bed shapes and displacement scenarios discussed above.

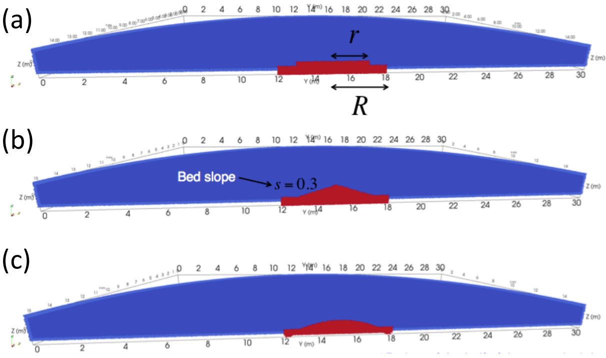

Figure 1 - 3-D view of the half of the computational domain for three 3-D simulations with a (a) cylindrical, (b) conical, and (c) spherical uplift region. The base radius, *r*, and volume of all three upper features of the uplift region are the same. In all cases, the lower part of the uplift region is a cylinder of radius *R*.

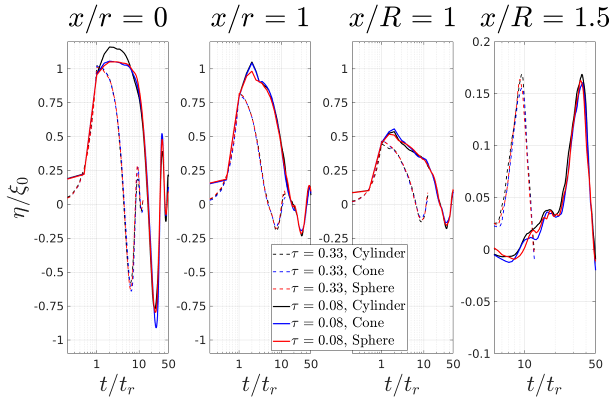

Figure 2 - Temporal variation of the normalized surface gravity waves generated by the uplift of various bed features shown in Figure 1. Here, t_r is the rise time of the uplift motion, and ζ_0 is the maximum bed displacement.

REFERENCES
Hammack (1973), A note on tsunamis: their generation and propagation in an ocean of uniform depth, J. Fluid Mech., 60 (04), 769-799.

Hérault, Bilotta, Dalrymple (2010), SPH on GPU with CUDA, Journal of Hydraulic Research, 48(S1), 74-79.