Numerical Modeling of Hydro-acoustic Waves In Weakly Compressible Fluid

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Low-frequency hydro-acoustic waves are precursors of tsunamis. Detection of hydro-acoustic waves generated due to the water column compression triggered by sudden seabed movement, could therefore significantly enhance the efficiency and promptness of tsunami early warning systems (TEWS), given the recent advances in deep-sea measurement technology. This low frequency waves propagate with the speed of sound in water, which is significantly larger than the long wave tsunami celerity. The records of the faster hydro-acoustic waves can cope with the shortening decision time of spreading the alarm and in principle dramatically enhance the accuracy and trustworthiness of TEWS. Several investigations have been carried out in order to reveal the physical characteristics of acoustic waves generated by bottom sudden displacement, clarifying that there exists a relationship between the tsunami-genic source and the hydro-acoustic waves.

Recent experimental evidence of the existence of low-frequency elastic waves generated by the seabed motion has been found during the Tokachi-Oki 2003 tsunami event (Nosov & Kolesov, 2007). In addition, during occurrence of Haida Gwaii 2012 earthquake, Ocean Network Canada observatories in the southern side of earthquake zone showed low frequency waves collected by bottom pressure gauges few minutes after the event. These two events are the first available records of hydro-acoustic waves with appropriate sampling frequency located on source zone and in the far field respectively.

Here we present 2 numerical models valid in weakly compressible fluids for complete reproduction of these waves. First, a potential flow three-dimensional model is represented to investigate the correlation between hydro-acoustic waves records and dynamic rising mechanism of sea bottom. Second, to overcome the difficulties of expensive 3D model, we have therefore developed a numerical model based on the solution of a hyperbolic mild slope equation, valid in weakly compressible fluids (MSEWC), detailed in Sammarco et al. (2013).

$$\psi_{ntt}\left(\frac{C_n}{c_s^2}+\frac{1}{g}\right)-\nabla(C_n\nabla\psi_n)+\left(\frac{\omega^2}{g}-\beta_n^2\mathrm{C_n}\right)\psi_n=h_tD_n \qquad (1)$$

Equation (1) is expressed in terms of fluid velocity potential at the free-surface $\psi_n(x,y,t)$. The model gave us the opportunity of investigating the propagation of such waves in the far field. The model has been validated against the full three-dimensional weakly compressible model. The results comparison of 3D and 2D models will be presented in the conference. The general characterization of these pressure waves depending on the generation mechanism, the source location, the bottom topography and the depth of the pressure recording point can be identified from simulated hydro-acoustic signals. According to the numerically reproduced scenario results, we shall propose preliminary indications for the implementation of innovative TEWS based on hydro-acoustic wave measurements.

Reference

Nosov, Kolesov, (2007). Elastic oscillations of water column in the 2003 Tokachi-Oki tsunami source: in-situ measurements and 3-D numerical modeling. Nat. Hazards Earth Syst. Sci. 7 (2), 243–249.

Sammarco, Cecioni, Bellotti and Abdolali (2013). Depth-integrated equation for large scale modelling of low-frequency hydroacoustic waves. Journal of Fluid Mechanics, 722(R6), doi:10.1017/jfm.2013.153.