Analytical Estimation of the Maximum Wave Height and the Inundation Distance in East Sri-Lanka Induced during the 2004 Indian Ocean Tsunami

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ABSTRACT

The analytical convolution solution of 1-D fully nonlinear shallow water equations derived by Carrier et al. (2003) is applied to estimate the maximum wave height and the inundation distance during the 2004 Indian Ocean Tsunami. The applied area is in the east coast of Sri Lanka with latitude between 6.8°N and 8°N. The offshore condition for the wave form and vertically-averaged flow velocity are obtained by solving the linear version of the COMCOT tsunami model and has been verified by comparing with the record at Maldives.

By taking the nearshore shelf slope as the constant bottom slope for the analytical solution, the inundation distance in the applied area is between 500m and 2.75 km, and the maximum wave height is between 4.46m and 6.63m. The max tsunami height calculated by the present method agrees very well with the in-situ measurement. Therefore, this method is a very useful tool for tsunami early warning by quickly estimating if the max wave height is more than 50m can be calculated by a numerical tsunami model. With the offshore wave form as the input, its convolution can be calculated numerically and serves as a fast estimation of the tsunami wave force, the run-up height and the inundation distance to the shoreline.

To verify the effectiveness of the methodology, the field survey of Sri Lanka in the Indian Ocean Tsunami is taken as an example. The wave height and the inundation distance from the shoreline are both consistent with the results of the proposed approach. Thus, the efficiency and the accuracy of this methodology are proven by the real tsunami.

METHOD TO ESTIMATE THE NEARSHORE TSUNAMI BEHAVIOR

The solution of nearshore tsunami is the convolution of initial wave profile and flow with an Analytical Green's function (AGF) of a simplified constant slope sea bottom. The detailed derivation can be found in Carrier et al. (2003). After including a convenient horizontal length scale L, dimensional variables (with ') are replaced by nondimensional variables by the following:

\[ u = \sqrt{gL} u', \eta = \alpha L \eta', x = Lx', t = \sqrt{gL} t'. \]

where \( u \) is the horizontal flow velocity normal to the shoreline and \( \eta \) is the free surface elevation, as is shown in Fig. 1. Nondimensionalized 1-D nonlinear shallow water equations for long waves propagating over a flat beach with a uniform slope \( \alpha \) can be written as:

\[ [u(x + \eta)] + \eta_t = 0, \]
\[ u_x + uu_t + \eta_x = 0. \] (2)

Carrier et al. (2003) introduced a distorted coordinate system of \( \lambda \) and \( \sigma \) that are defined as

\[ \lambda = t - u_x, \]
\[ \sigma = \eta_x. \] (3)

where \( q = x + \eta \) is the inundation distance and hence \( \sigma = 0 \) represents the moving shoreline. The unknowns \( u \) and \( \eta \) are transformed to \( \phi \) with

\[ \phi = \int (\lambda \d \lambda + \sigma \d \sigma), \]

\[ \phi_x + \phi_{tt} + \d \int_{0}^{\phi} \eta \d \eta = 0. \] (4)