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Assimilation of Initial Wave of Tsunami Using Adjoint Equation Method

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Tsunami inflicts enormous damage on the wide coastal area. It is important to investigate how to reduce the damage of tsunami. In order to reduce the damage, the understanding of the behavior of the tsunami is indispensable. The purpose of this study is to present an assimilation of the initial wave of tsunami. However, it is very difficult to observe the initial wave of tsunami in a direct way. Initial wave can be assimilated by solving the backward analysis which is based on the observed water elevation obtained on the coast. Therefore, in this research, initial condition of tsunami is assimilated using the adjoint equation method. We introduce the performance function for the assimilation index. The performance function is defined by the square sum of the discrepancy between the computed and the observed water elevation on the observation points. The extended performance function is derived by adding inner products between the adjoint variables and the governing equations to the performance function. The first-order adjoint equation can be derived by the condition that the first variation of the extended performance function should be zero. The weighted gradient method is employed as the minimization method. We can derive the gradient to update the computed initial water elevation by solving the adjoint equations. Behaviors of tsunami can be expressed by the shallow water equation, in case that the horizontal domain is much broader than the water depth. The finite element method based on the linear interpolation function is adapted as the spatial discretization and the two step explicit scheme is adapted as the temporal discretization. The initial wave shape of the water elevation is assimilated by the theory presented in this paper. The assimilation of Tohoku earthquake tsunami is carried out. As the verification, we carried out an assimilation of the sinusoidal wave in simple rectangular model.

Keywords: Shallow Water Equation, Two-step Explicit Scheme, Finite Element Method, Performance Function, First-order Adjoint Equation, Weighting Gradient Method