Numerical Simulation of Tsunami Propagation with Corrected Dispersion Effects in Ocean

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ABSTRACT

A numerical modeling of transoceanic tsunamis has been conducted by solving the linear shallow-water equations with the leap-frog scheme in a staggered grid system. When a tsunami propagates a long distance, the frequency dispersion effects play an important role and should be considered in numerical simulation. Recently, Cho et al. (2007) have developed a practical dispersion-correction scheme to consider frequency dispersion by using numerical dispersion. The model has been verified by comparing numerical results with available analytical solution and field survey data. In this study, in order to reproduce dispersion effects on the actual terrain, propagation of the 2011 East Japan Tsunami is simulated in the Pacific Ocean. Numerical results such as, the arrival time and the leading wave crest elevation at tidal stations are compared with available observed data.

KEY WORDS: tsunami; linear shallow-water equations; dispersion effects; finite difference method;

INTRODUCTION

Tsunamis are probably one of the most devastating ocean disasters in the world. They are long-period oceanic waves generated by underwater earthquakes, submarine landslides or volcanic eruptions. Most of the major tsunamis result from undersea earthquakes and the induced tsunami propagates into all directions from the source region by gravitational force. As a tsunami comes close to the coastal area, the amplitude increases while the wavelength decreases. This process causes a severe flooding and serious damages in coastal areas.

For the last several decades the great earthquakes have been occurring increasingly around the world. For instance, a major tsunami occurred off the Pacific coast of Tohoku, Japan on 11 Mar 2011. A huge damage has occurred along the eastern coast of Japan and many countries on the other side of the Pacific Ocean have also been affected. After the tsunami generated, it is very important to predict changes in water level as soon as possible using numerical simulation.

Numerical modeling of transoceanic tsunamis has been conducted by solving the linear shallow water equations in the staggered grid system (Imamura et al., 1988). When a tsunami propagates a long distance, the frequency dispersion effects play an important role and should be considered in numerical simulation (Kajiura and Shuto, 1990). Recently, Cho et al. (2007) have developed a practical dispersion-correction scheme to consider frequency dispersion by using numerical dispersion. The model has been verified by comparing numerical results with available analytical solution and field survey data.

In this study, propagation of the 2011 East Japan Tsunami is simulated in the Pacific Ocean considering frequency dispersion effects on the actual terrain. First, the governing equations are selected to investigate propagation of transoceanic tsunamis. And the numerical model is employed to simulate propagation of the 2011 East Japan Tsunami. Then numerical results such as, the arrival time and the leading wave crest elevation at tidal stations, are compared with available observed data and detailed analysis is conducted. Finally, summary of the study and concluding remarks will be described.

GOVERNING EQUATION

The linear shallow-water equations were used in the most of the previous studies due to numerical difficulty of using the linear