VERIFICATION AND VALIDATION OF SEC-HY21 MODEL FOR TSUNAMI INUNDATION

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Summary SEC-HY21 is a general-purpose two-dimensional surface-water modelling software package developed in Sinotech. In this study, application of SEC-HY21 on tsunami simulation is introduced with a focus on its verification and validation. An exhaustive series of tests was conducted, including the analytical solutions, the benchmark problems from laboratory and field data suggested by NOAA. The results show that SEC-HY21 can simulate the entire process of tsunami generation, propagation, runup and inundation.

INTRODUCTION

SEC-HY21 is an integrated software package developed by the Sinotech Engineering Group for two-dimensional depth-averaged hydraulic simulations and analyses of surface water flows, pollutant transport, non-uniform sediment transport and morphologic processes. This software can be applied to study dam-breaking, storm surge, tsunami, landslide-generated wave and debris flows. Finite-volume well-balanced Roe/TVD schemes on unstructured grids to solve nonlinear two-dimensional shallow water equations are adopted for simulating tsunami propagation and runup. The developed numerical tsunami model is tested by the exhaustive series of benchmarks suggested by NOAA (Synolakis, *et al*., 2007). We conducted analytical and laboratory benchmarking for the cases of solitary wave runup on a simple beach, solitary wave runup on a composite beach, solitary wave runup on a conical island, landslide-generated waves, and the runup on Okushiri Island, Japan, during the 1993 Hokkaido-Nansei-Oki tsunami. In all conducted benchmark problems, the simulated solutions match the available data very well. Some of the benchmarking results are illustrated below.

Solitary wave runup on a simple beach

Synolakis (1987) conducted a series of laboratory experiments on the solitary wave over a 1:19.85 sloping beach. The cases of non-breaking wave with $H/h_0 = 0.0185$ (i.e. wave height to depth ratio = 0.0185) and breaking wave with $H/h_0 = 0.3$ are simulated. The grid sizes of the two cases are $\Delta x/h_0 = 0.1$ and $\Delta x/h_0 = 0.05$, respectively. Comparison of computed and measured water surface profiles during the runup process is shown in Fig. 1. It can be seen that the numerical results are in good agreement with laboratory data for both cases.

Non-breaking wave with $H/h_0 = 0.0185$ Breaking wave with $H/h_0 = 0.3$

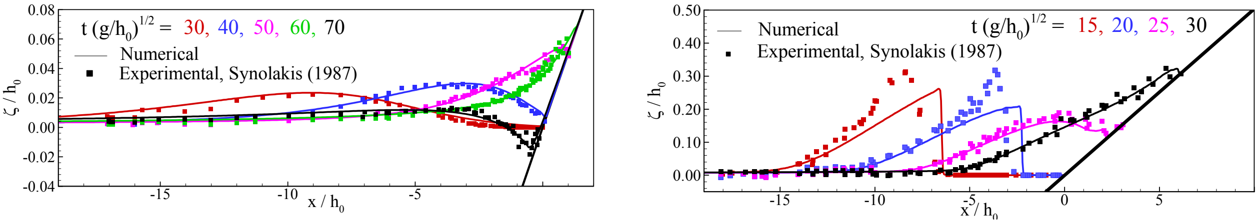

Fig. 1: Comparison of measured and simulated water surface profiles during runup of a non-breaking wave ($H/h_0 = 0.0185$) and a breaking wave ($H/h_0 = 0.3$).

Tsunami wave runup on Okushiri Island

The Hokkaido-Nansei-Oki tsunami of 1993 that struck Okushiri Island, Japan, with extreme runup height of 31.7 m and currents of the order of 10–18 m/sec was a disaster, but provided fortuitous high-quality data. The extreme tsunami runup mark was discovered at the tip of a very narrow gulley within a small cove at Monai. We validate the numerical model using measurements collected in a laboratory experiment that modeled runup near the village of Monai. After comparing computations to laboratory measurements, we simulate tsunami wave runup on Okushiri Island and compare the numerical solution to available field observations.

A laboratory experiment, using a large-scale tank at the Central Research Institute for Electric Power Industry, was focused on modeling runup of a long wave on a complex beach near the village of Monai. The beach in the laboratory wave tank was a 1:400 scale model of the bathymetry and topography around a very narrow gully, where extreme runup was measured. The computational domain, as shown in Fig. 2a, represents a 5.488 m x 3.402 m portion of the wave tank near the shore and is divided into 0.014 m x 0.014 m grid cells. The incident tsunami wave specified at left boundary is shown in Fig. 2b. The other boundaries are treated as wall. The Manning's coefficient n = 0.013 and time step 0.05 s are used in simulation. Fig. 3 shows plots of the computed and measured water level evolution at channels 5, 7, and 9 for the first 50 s. The amplitude and phase of the first maximum shows almost perfect agreement with observations.

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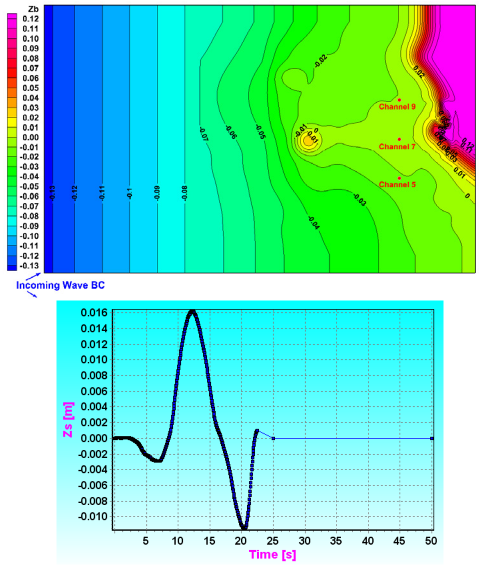

Fig. 2: (a) Computational/experimental domain with bathymetry. Red dots mark wave gage positions; (b) Input tsunami wave.

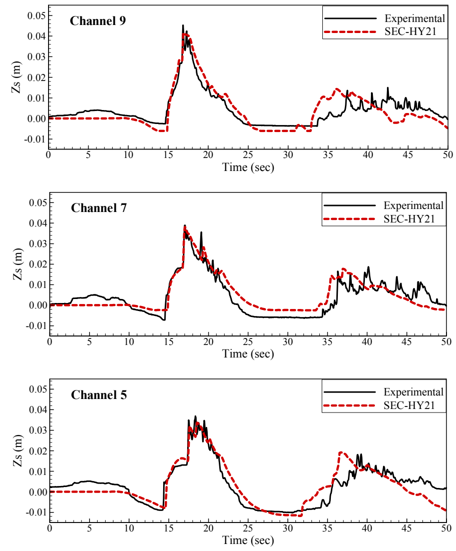

Fig. 3: Water level comparison of experimental data and numerical simulation at three wave gages for the Okushiri laboratory case.

The bathymetry/topography digital elevation model (DEM) for Okushiri Island is provided by the Disaster Control Research Center (DCRC) at Tohoku University, Japan. The data consists of several nested grids of increasing spatial resolution ranging from 450 m to 5 m. The initial wave profile DCRC-17a constructed by DCRC with 4.9 m and 2.2 m uplift and 1.1 m subsidence, as shown in Fig. 4, is used as tsunami source as suggested by NOAA. Fig. 5 shows the computed and observed water level evolution at Iwanai and Esashi tide stations. The arrival time and amplitude of the computed waves match very well with the measurements. We also compare the computed and observed maximum runup around Okushiri Island in Fig. 6. It can be seen that general agreement achieved almost everywhere around the island, although there are several exceptions where the simulated runup underestimates the observations.

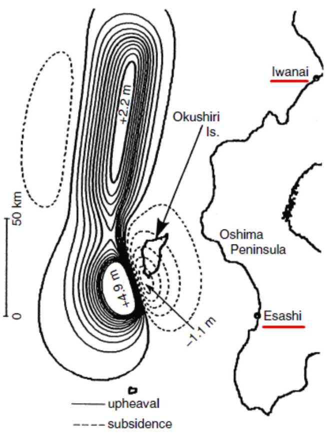

Fig. 4: Initial water surface constructed by the DCRC, Japan. (Takahashi, 1995)

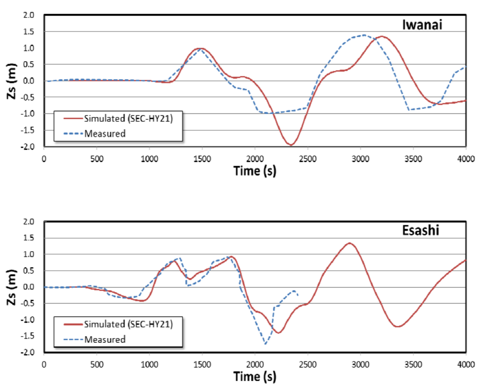

Fig. 5: The computed and measured water level evolution at two tide stations during 1993 Okushiri tsunami.

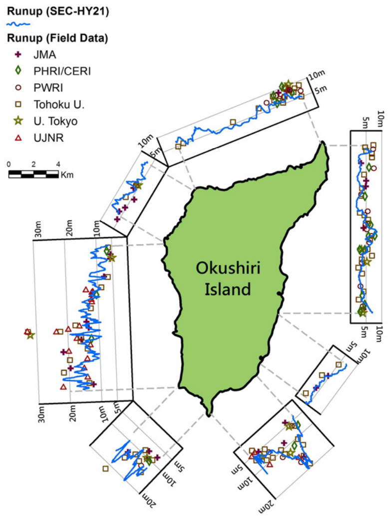

Fig. 6: The computed and observed maximum runup around Okushiri Island after 1993 Okushiri tsunami.

CONCLUSIONS

The SEC-HY21 model is verified and validated using NOAA standards and criteria and it shows that the results match the available data very well and are within established errors proposed by Synolakis et al. (2007). It concludes that SEC-HY21 model can simulate the whole process of tsunami generation, propagation, runup and inundation.

References

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