A Coupled Model of Sediment Transport In Coastal Hazard Events

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Introduction

STRICHE is a new model for simulating **S**ediment **TR**ansport **I**n **C**oastal **H**azard **E**vents, which is coupled with GeoClaw (GeoClaw-STRICHE). Additional to the standard components of sediment transport models, STRICHE also includes modules to reconstruct grain-size trends and the generation of bed forms. STRICHE is verified and validated with a parameter study, flume experiments as well as field data. For the coupling between GeoClaw and STRICHE, a two-way coupling but separately solving system is utilized (Fig. 1).

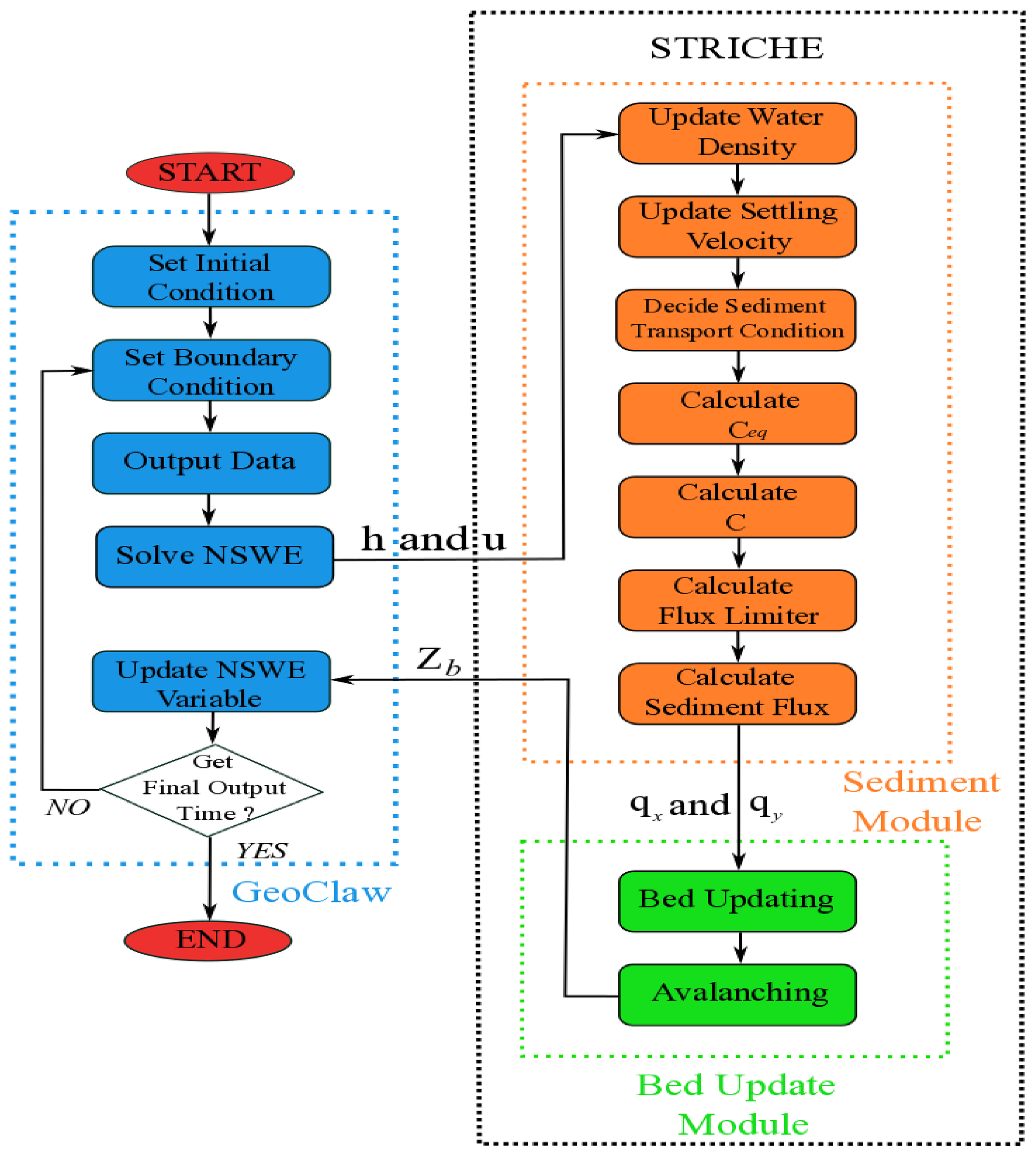

Fig. 1: Flowchart for model algorithm

Flume Experimental Design

STRICHE is tested by simulating six flume experiments for tsunami sediment transport. Figure 2 depicts the experiment and model setting for flume experiments from Johnson et al., 2016.

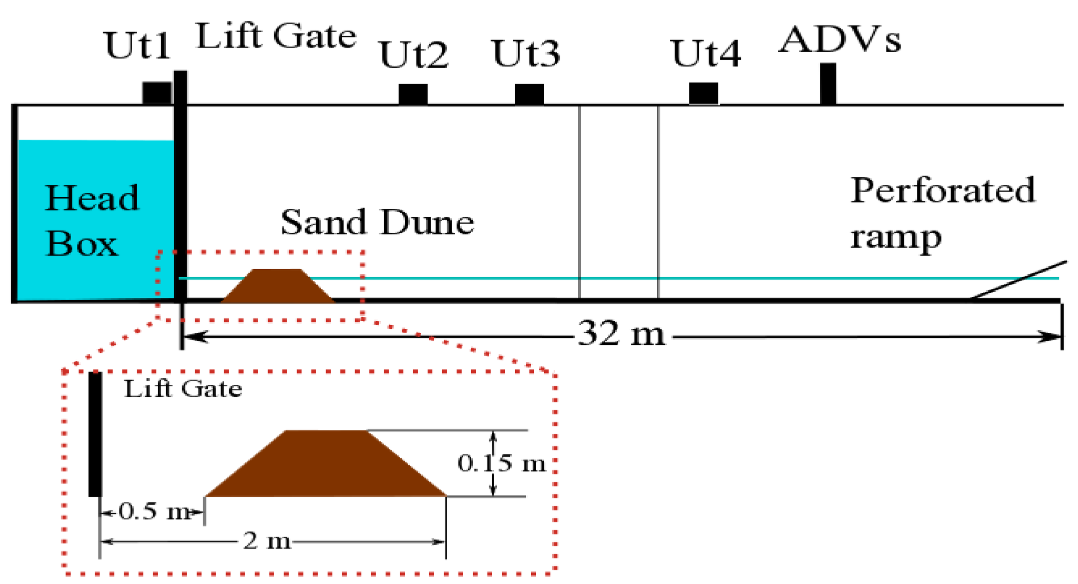

Fig. 2: Schematic diagram for experimental design

Flume Experiment Results

First three cases have the same grain-size distribution of sediment source, but different initial water depths in the water tank (0, 10 and 19 cm). Last three cases setup with the same water depth (8 cm) and different grain-size distributions ($D_{50} = 2.85$, 3.36 and 3.41 mm). Figure 3 compares model and experimental results for sediment thickness. Figure 4 depicts the simulated and experimental D_{10}, D_{50} and D_{95}.

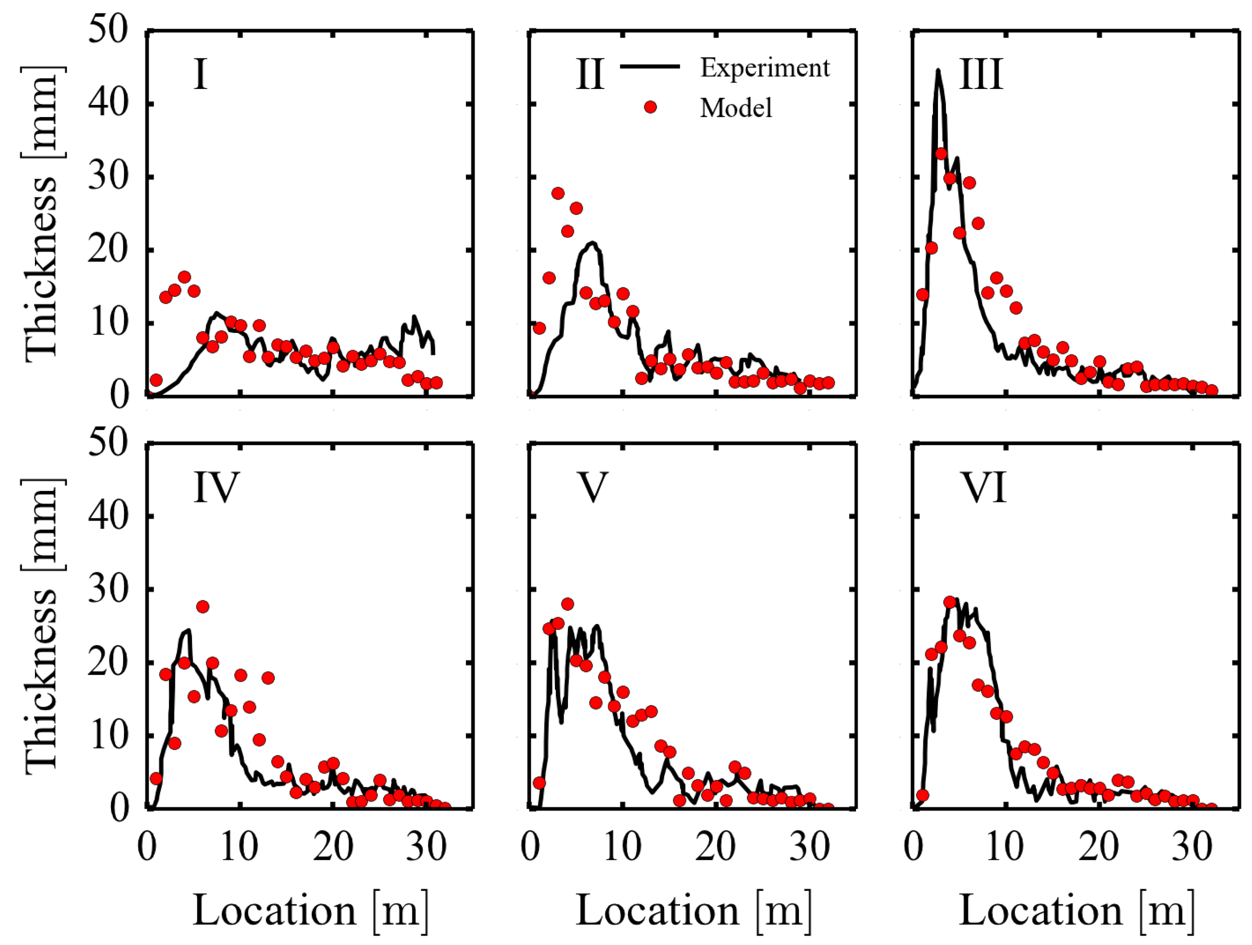

Fig. 3: Model results for sediment thickness

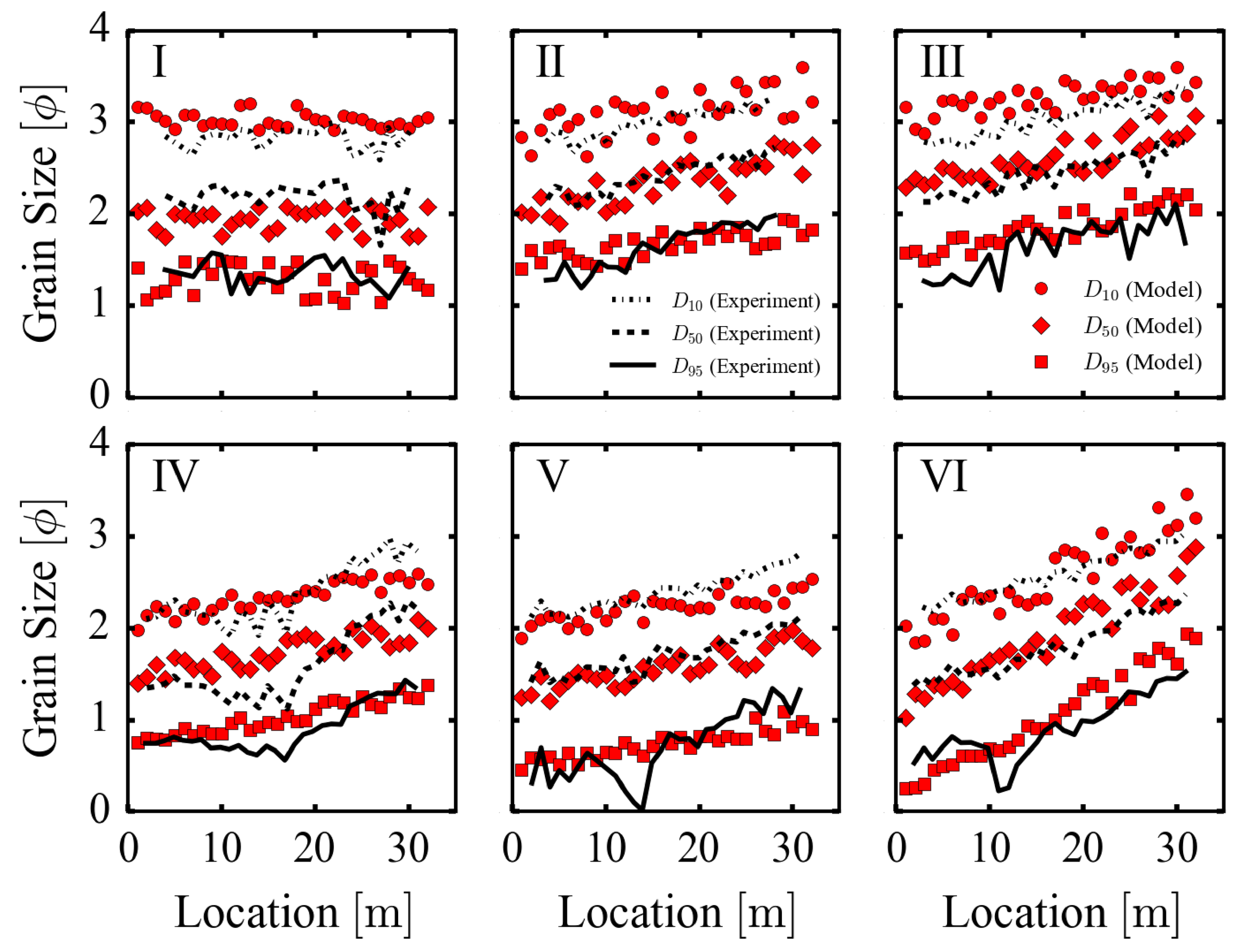

Fig. 4: Model results for D_{10}, D_{50} and D_{95}

Parameter Study Results

In order to study the control factors of deposition ratios, STRICHE was employed to carry a parameter study. The grain size, wave height, and slope are components in the parameter space. The maxima of $\xi_{0.5}$ and ξ_1 are achieved when the steepest slope, the smallest grain size, and the largest amplitude are got.

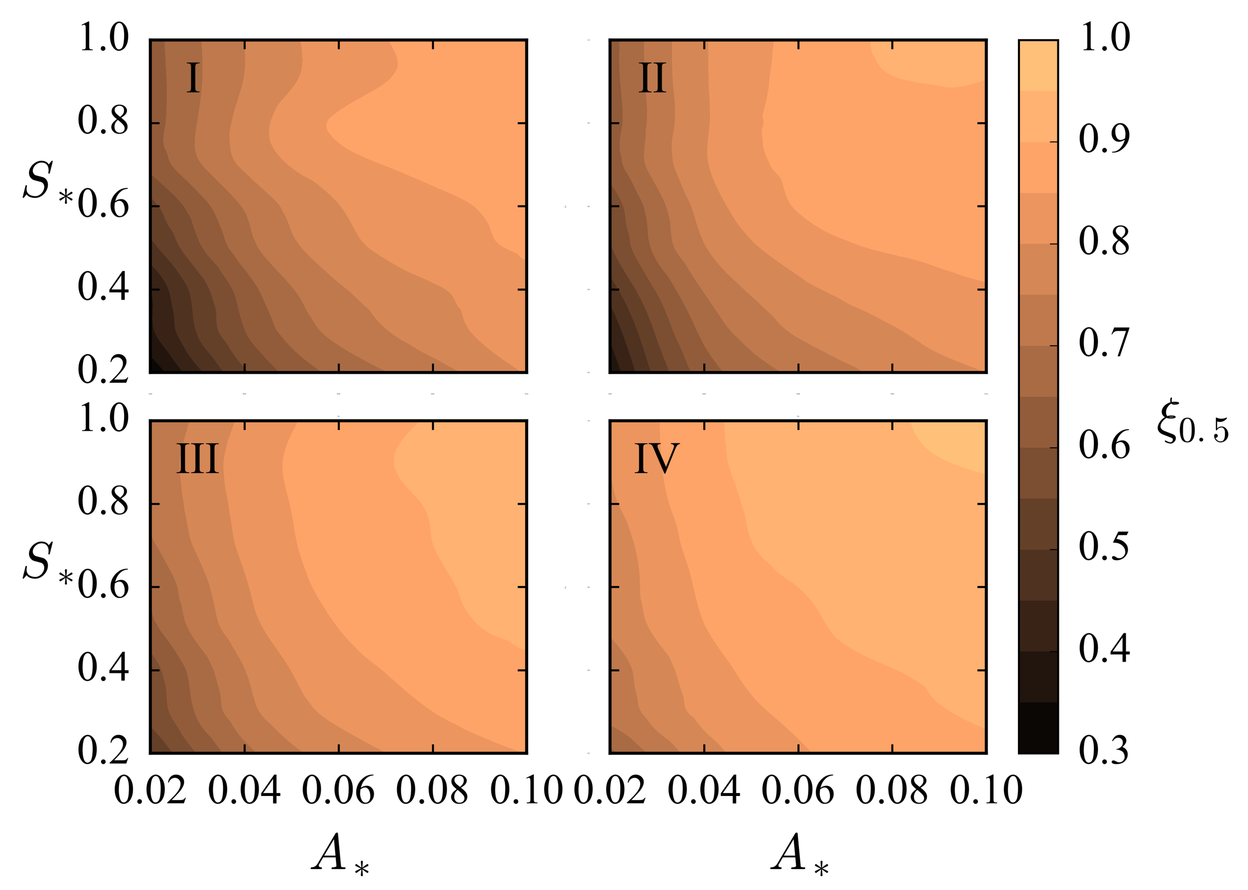

Fig. 6: $\xi_{0.5}$ as a function of S_*, A_*, and grain size

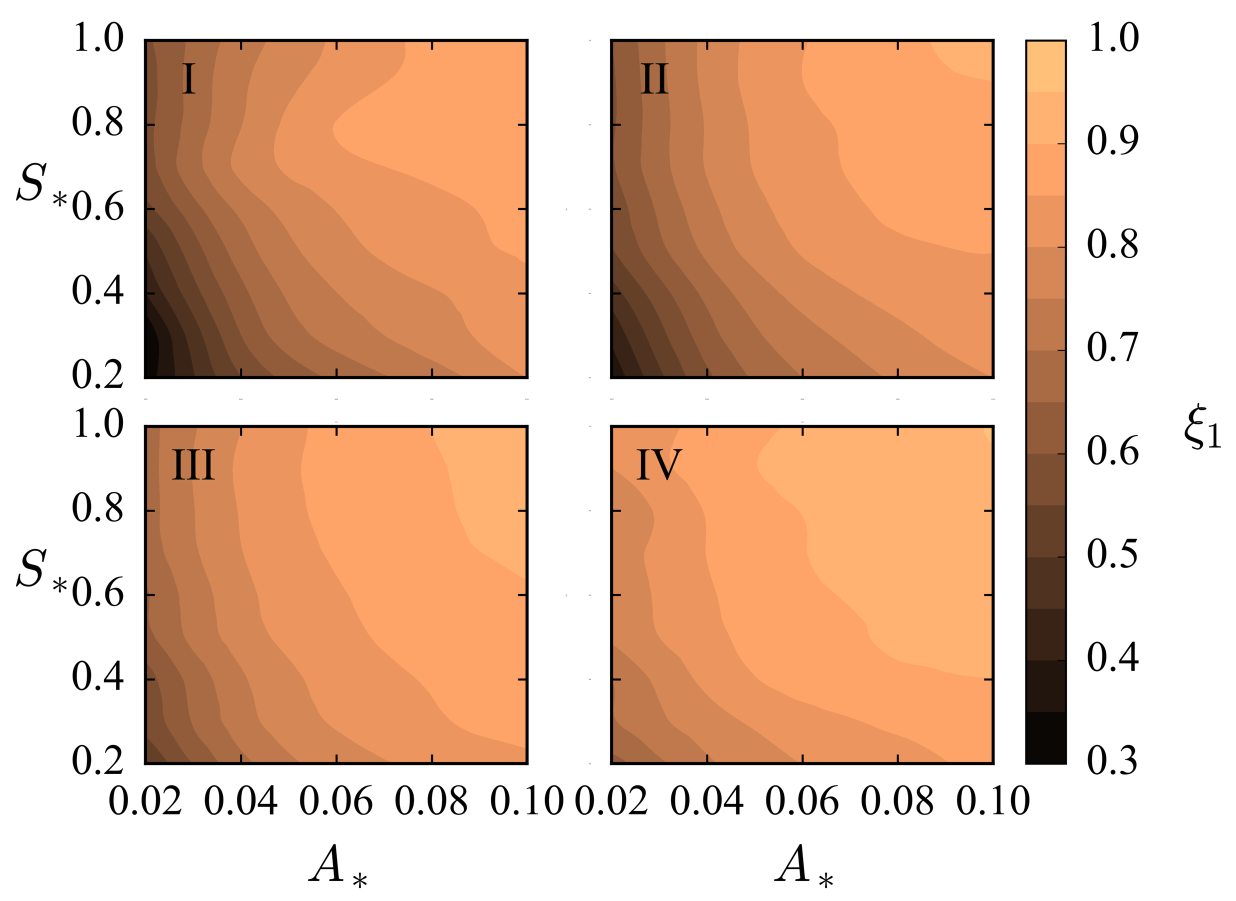

Fig. 7: ξ_1 as a function of S_*, A_*, and grain size

Reference

[1]Apotsos, A., Gelfenbaum,G., Jaffe, B., Process-based modeling of tsunami inundation and sediment transport. Journal of Geophysical Research 116, F01006. [2]Johnson, J. P., Delbecq, K., Kim, W., Mohrig, D. (2016). Experimental tsunami deposits: Linking hydrodynamics to sediment entrainment, advection lengths and downstream fining. Geomorphology, 253, 478-490. [3]Tang, H and Weiss, R. (2016). GeoClaw-STRICHE: A coupled model of Sediment Transport In Coastal Hazard Events, Computational Geosciences (Under Review). [4]Abe, T., Goto, K., & Sugawara, D. (2012). Relationship between the maximum extent of tsunami sand and the inundation limit of the 2011 Tohoku-oki tsunami on the Sendai Plain, Japan. Sedimentary Geology, 282, 142-150.

Parameter Study Model Setting

Figure 5 shows parameter study's bathymetry setup. We define the normalized slope as $S_* = ss_0^{-1}$ and normalized wave height as $A_* = hD^{-1}$. In this study, the deposition ratio is defined as a ratio between tsunami sediment layer extent and inundation limit ($\xi = H_s H_w^{-1}$ or $\xi = L_s L_w^{-1}$).

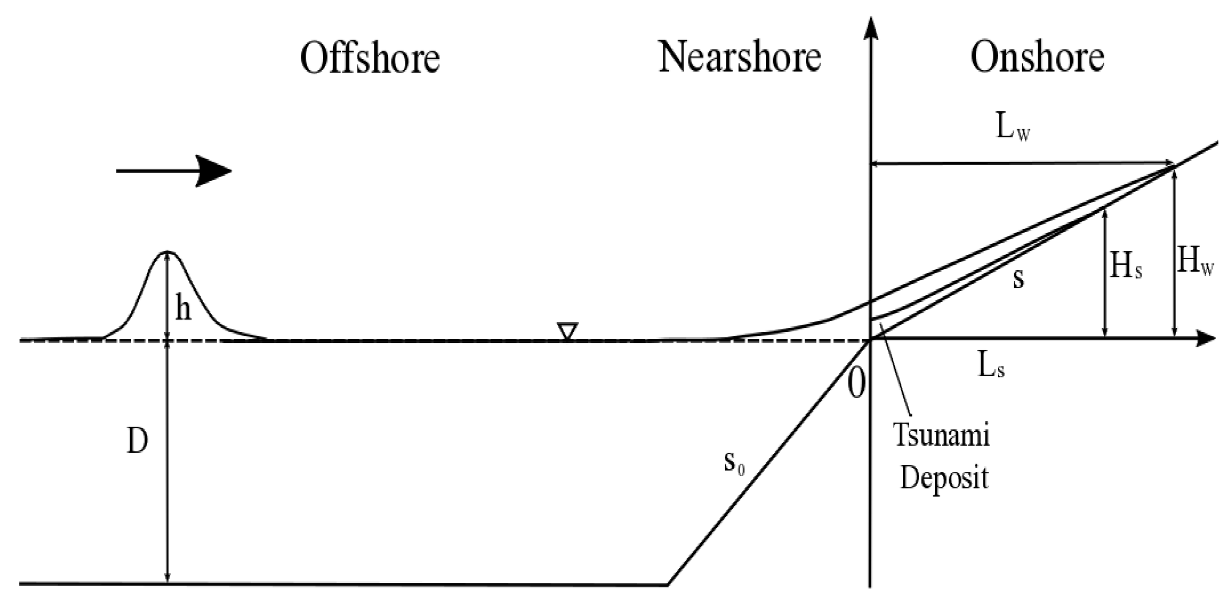

Fig. 5: A sketch of the parameter study setup

2004 Indian Ocean Tsunami Case

STRICHE is validated with field data from the 2004 Indian Ocean tsunami in Kuala Meurisi area. The model setting is same to the case for Delft3D in Apotsos et al., 2011. The model results are compared with data from Delft3D and measurement.

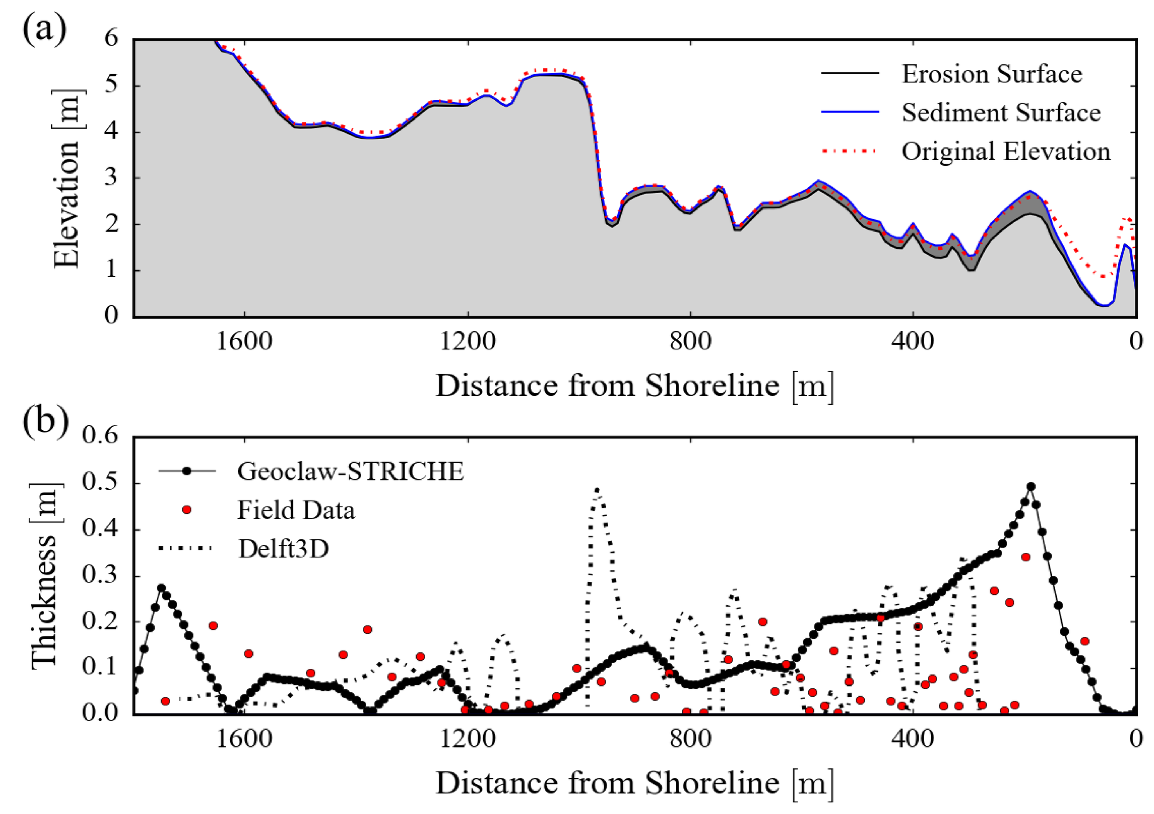

Fig. 8: Model results for the 2004 Indian Ocean tsunami

Conclusions

In this study, we propose a new model for simulating sediment transport in coastal hazard events. The grain size, wave amplitude, and slope affect the deposition ratios. Model results match well with the flume experimental data and field data from the 2004 Indian Ocean tsunami.