Using experimental tsunamis to evaluate sediment deposit characteristics and inverse model predictions

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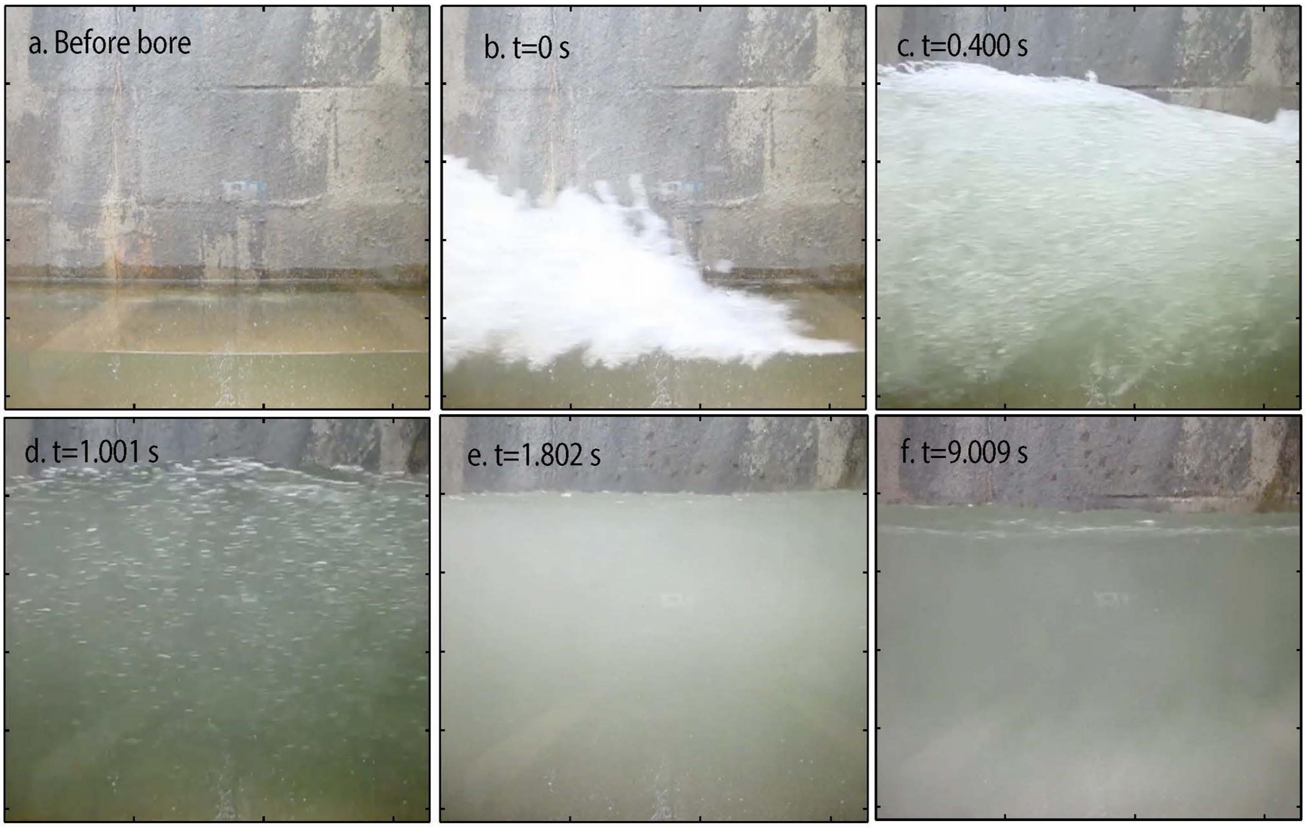
Tsunami deposits can imperfectly record the hydraulic conditions of devastating extreme events. Quantitative models relating sediment characteristics to flow hydraulics hold the potential to improve coastal hazard assessments. However, data from recent natural tsunamis have rarely been accurate enough, over a range of parameter space, to quantitatively test proposed inverse models for predicting flow characteristics. To better understand how to “read” flow depth and velocity from deposits, we conducted controlled and repeatable laboratory flume experiments in which different grain size distributions (GSDs) of sand were entrained, transported and deposited by hydraulic bores. The bores were created by impounding and instantaneously releasing ~6 m^3 of water with a computer-controlled lift gate. The experiments represent 1/10 to 1/100 scale physical models of large events. Both flow characteristics (including Froude numbers) and suspended sediment transport characteristics (including Rouse numbers and grain size trends) scale consistently with documented natural tsunamis.

We use the experimental data to interpret how entrainment, transport and mixing influence deposit GSDs along the flume, and to evaluate an advection-settling model for predicting flow depth and velocity. Suspension-dominated deposits get finer and thinner in the direction of transport. The data show that two key controls on GSDs along the flume are (a) the size distribution of the sediment source, and (b) turbulent dispersion of grains. First, we find that the influence of source GSDs on deposit GSDs is strongest near the sediment source. Size-dependent suspension and settling become increasingly important farther down the flume. Transport distances of 1-2 advection length scales are required for deposit GSDs to be sensitive to flow hydraulics. Second, by looking at the spatial distribution of grains of a given size class along the flume, we show that turbulent dispersion strongly influences local deposit GSDs. By comparing different grain size classes, we interpret that dispersion is more important than resuspension for transporting some grains farther distances than expected based on mean advection and settling rates. Importantly, intermediate deposit grain size percentiles (e.g. D50) are less sensitive to dispersive transport than either the fine or coarse tails of local deposit GSDs. Using deposit GSDs along the flume, an advection-settling model best predicts flow depths and velocities when calculated for intermediate percentiles (e.g. D50), rather than for coarse size fractions (e.g. D95) as has been assumed in previous works. Overall, well-controlled experimental data should be used to improve inverse models for predicting tsunami characteristics from deposits, and to rigorously evaluate the accuracy and uncertainty of model-based hazard assessments.

Keywords: tsunami deposit, inverse model, flume experiment


a. Before bore
b. t=0 s
c. t=0.400 s
d. t=1.001 s
e. t=1.802 s
f. t=9.009 s