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Inverse modeling of onshore tsunami flow speed and depth – examples from the 2004 Indian Ocean and 2006 Java tsunami

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Flow depth and speed are important parameters that describe the overland flow of a tsunami. These parameters are in many cases known for recent events, but are not available for historical or paleo-tsunami.
Inverse modeling uses the thickness, grain-size distribution and grain density of a tsunami deposit to estimate flow speeds and depths necessary to entrain the given sediment. In our study we used TsuSedMod, an inverse model by Jaffe and Gelfenbaum (2007). The model assumes a steady and uniform flow, and an equilibrium distribution of sediment in the water column. Additionally, the model assumes that only 10% of the sediment is transported as bed load and that a typical tsunami sediment is normally graded. An a priori assumption of TsuSedMod is the fact that no erosion by subsequent wave runup or backwash has altered the tsunami deposit in question. This, however, cannot be verified.
We applied TsuSedMod to invert sediments from the 2004 Indian Ocean tsunami in India and Kenya, and of the 2006 Java tsunami in Southern Java. Model results for flow depths and observed field data were compared in order to validate the model. The comparisons show that model outputs appear to reasonably estimate the observed flow parameters along the surveyed tsunami runup sections.
The computed flow depths and speeds of all runup sections show a landward decreasing trend. This is due to the general landward fining and thinning trends of tsunami layers; whereas thicker tsunami layers deposited in morphological depressions or coarser grained swash lines diverge from this general trend. Several subsequent waves of the tsunami wave train interfere close to the shoreline and result in an more scattered distribution of the computed runup parameters. The computed results become more diagnostic farther inland, where only single waves with higher inundation distances leave deposits. In one of the Java runup sections, an abrupt decrease of both flow depth and speed within a short distance can be traced. This decrease is probably the result of the tsunami destroying houses and the associated decrease of tsunami energy.
Our study shows that TsuSedMod gives the best approximation of flow depths for grain-size data gained by settling tube measurements. This is because settling tube results represent hydraulic equivalents while digitally counted grain-size distributions do not include grain shape and density.
Application of TsuSedMod to recent examples shows it to be a valuable tool for calculating flow depths and speeds of ancient tsunami, as long as individual sample parameters are thoroughly evaluated.
Jaffe, B. & Gelfenbaum, G., 2007: A simple model for calculating tsunami flow speed from tsunami deposits. Sed. Geol., 200, 347-361.