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Tsunami-induced boulder transport – combining physical experiments and numerical modelling

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Coasts are crucial areas for living, economy, recreation, transportation, and various sectors of industry. Many of them are exposed to high-energy wave events. With regard to the ongoing population growth in low-elevation coastal areas, the urgent need for developing suitable management measures, especially for hazards like tsunamis, becomes obvious. These measures require supporting tools which allow an exact estimation of impact parameters like inundation height, inundation area, and wave energy. Focussing on tsunamis, geological archives can provide essential information on frequency and magnitude on a longer time scale in order to support coastal hazard management. While fine-grained deposits may quickly be altered after deposition, multi-ton coarse clasts (boulders) may represent an information source on past tsunami events with a much higher preservation potential. Applying numerical hydrodynamic coupled boulder transport models (BTM) is a commonly used approach to analyse characteristics (e.g. wave height, flow velocity) of the corresponding tsunami. Correct computations of tsunamis and the induced boulder transport can provide essential event-specific information, including wave heights, runup and direction. Although several valuable numerical models for tsunami-induced boulder transport exist (e. g. Goto et al., 2007; Imamura et al., 2008), some important basic aspects of both tsunami hydrodynamics and corresponding boulder transport have not yet been entirely understood.
Therefore, our project aims at these questions in four crucial aspects of boulder transport by a tsunami: (i) influence of sediment load, (ii) influence of complex boulder shapes other than idealized rectangular shapes, (iii) momentum transfers between multiple boulders, and (iv) influence of non-uniform bathymetries and topographies both on tsunami and boulder. The investigation of these aspects in physical experiments and the correct implementation of an advanced model is an urgent need since they have been largely neglected.
In order to tackle these gaps, we develop a novel BTM in two steps. First, scaled physical experiments are performed that determine the exact hydrodynamic processes within a tsunami during boulder transportations. Furthermore, the experiments are the basis for calibrating the numerical BTM. The BTM is based on the numerical two-phase mass flow model of Pudasaini (2012) that employs an advanced and unified high-resolution computational tool for mixtures consisting of the solid and fluid components and their interactions. This allows for the motion of the boulder while interacting with the particle-laden tsunami on the inundated coastal plane as a function of the total fluid and solid stresses. Our approach leads to fundamentally new insights in to the essential physical processes in BTM.

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