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Simulation of boulder transport in a flume comparing cuboid and complex-shaped boulder models

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Coasts around the world are affected by high-energy wave events like storm surges or tsunamis depending on their regional climatological and geological settings. Coarse clasts (boulders to fine blocks) deposited on the shore can provide evidence for hazard-prone areas and physical characteristics of the flooding event. In order to better understand the process of boulder transport by tsunamis and to calibrate numerical hydrodynamic models, we conducted physical boulder transport experiments in a Froude-Scale of 1:50 utilizing idealized boulder shapes (cuboids) as well as realistic, complex boulder shapes based on real-world data. Comparing the behaviour of natural shaped with idealized boulders, allows identifying how the boulder shape influences the transport process in terms of transport mode (sliding, shifting, saltation), path and distance.

Experiments are conducted in a 33 m long and 1 m wide flat wave flume ending on an ascending coastal profile. The gradient angle of the ramp changes from 11° to 4° ending on a flat elevated platform resulting in a total length of 4.5 m. The complex shaped boulder model (17.4x9.6x7.6 cm^3) is constructed from photogrammetric data of a coastal boulder on Bonaire in the Dutch Caribbean (BOL2 in Engel and May, 2012), which is assumed to be transported by a tsunami. A cuboid boulder model of equivalent volume and weight (14x8x6 cm^3) is created for comparison. The tsunami is modelled as a broken bore generated by two computer-controlled pumps. Each experimental run set-up was repeated for at least three times.

The results show a significant influence of the boulder shape, in particular regarding the area of the contact surface when the bore approaches the boulder. With increasing contact surface higher transport distances occur. Due to the shape of the complex boulder tends slightly towards a rough ovoid, which is more streamlined than the idealized shape, the effectively acting drag force decreases and leads to reduced transport distances.

The predominant transport mode during the experiments was sliding combined with gentle rotating around the vertical axis. However, in several experimental cases the complex boulder significantly rotates while the idealized does not. Recognizing that the transport distance, presumably due to decreasing ground contact and therefore less friction, increases during rotational transport, it is remarkable that the complex boulder still does not reach the transport distances of the idealized one.

Experiments for boulder-boulder interactions generally show reduced transport distances. The bore-facing boulder generates a “flow shield” preserving the latter boulder from movement. In consequence, the bore-facing boulder hits its neighbour and stops moving. Within the range of our experiments, this boulder-boulder impact does not exceed a necessary energy-threshold for dislocating the second boulder.

Beside further results regarding the influence of the initial water level, increased bottom friction and experiment sensitivity, insights into a numerical model based on these experiments will be presented.

Engel, M.; May, S.M.: Bonaire’s boulder fields revisited: evidence for Holocene tsunami impact on the Leeward, Antilles. Quaternary Science Reviews 54, 126–141, 2012.