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Boulders moved by the 29 September 2009 Tsunami: Flow-Speed Estimates at Taga, Samoa

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On September 29, 2009 at 17:48:10 UTC (local time: UTC-11), an M_w ≈8.1 earthquake struck about 200 km S of the main Samoan Islands chain and 200 km E of Tonga's Niua Group. This is the most significant earthquake on the northern bend of the Tonga trench since 1917.

At Taga, boulders of different sizes were observed; their distribution on the surface did not shore any recognizable pattern. It should be noted that the term 'boulder' in here is not applied to an indicated grain size, but to describe particles that have a size that cannot be neglected compared to the water depth. Taga village is located on south-central Savai'i Island, Samoa. The tsunami flooding reached about 180 m inundation and about 6m maximum runup . The tsunami waves were able to turn a empty water tank upside down and destroyed a house attached to a swimming pool. The flow depth reached 4 m marked by roof damage.

In order to achieve estimates of the flow speed from the boulders on the surface, a few assumptions need to be made. Even though these assumptions simplify the physical problem almost to the level of the spherical cow, and yet they do not violate basic physics. Also, the initiation of motion is not considered, which is complex due to the necessary three-dimensional description of the turbulent flow field and shear-stress distribution around the boulder. Furthermore, the bedding and roughness in vicinity of the boulder is of pivotal importance for the initiation of motion.

The first assumption is that the Froude number can be used to scale between the flow depth and the flow speed. The Froude number is the ratio of the flow speed and square root of gravity times the flow depth. It is classically used to evaluate the influence of inertia on a flow system and for scaling of gravity driven flows. The second assumption is that the boulders are spherical with varying bulk density. The last assumption is that the Rouse number can be employed to retrieve information on the transport mode. The Rouse number is the ratio of the settling velocity and shear velocity times the van Karman's constant. It represents the ratio of gravity and turbulent fluctuations. To compute the settling velocity, we adopt the method as presented in Fergosun and Church (2004). The model resulting from these assumptions cannot be collapsed into one governing equation. Furthermore it is non-linear and an iterative solution scheme is needed.

The grain size is computed that can be transported by a certain flow depth, using the Froude number for velocity scaling, and as function of the Rouse number. It is important to note that the initiation is not considered. Hence, the grain size computed represents the maximum grain size for deposition. The boulder densities are assumed to vary between 1010 and 2000 kg m^{-3}. It is noted that the velocities in the mid rage of the x axis are more realistic because the Froude number is in the vicinity of unity. Furthermore, large Rouse numbers are the probable scenario, stating that the particles are more likely to be transported near the bed than higher up in the flow. The computed flow velocities range from 5 to 7 m/s.