Dynamic Interaction Between a Two-phase Submarine Landslide and a Fluid Reservoir

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1 Introduction

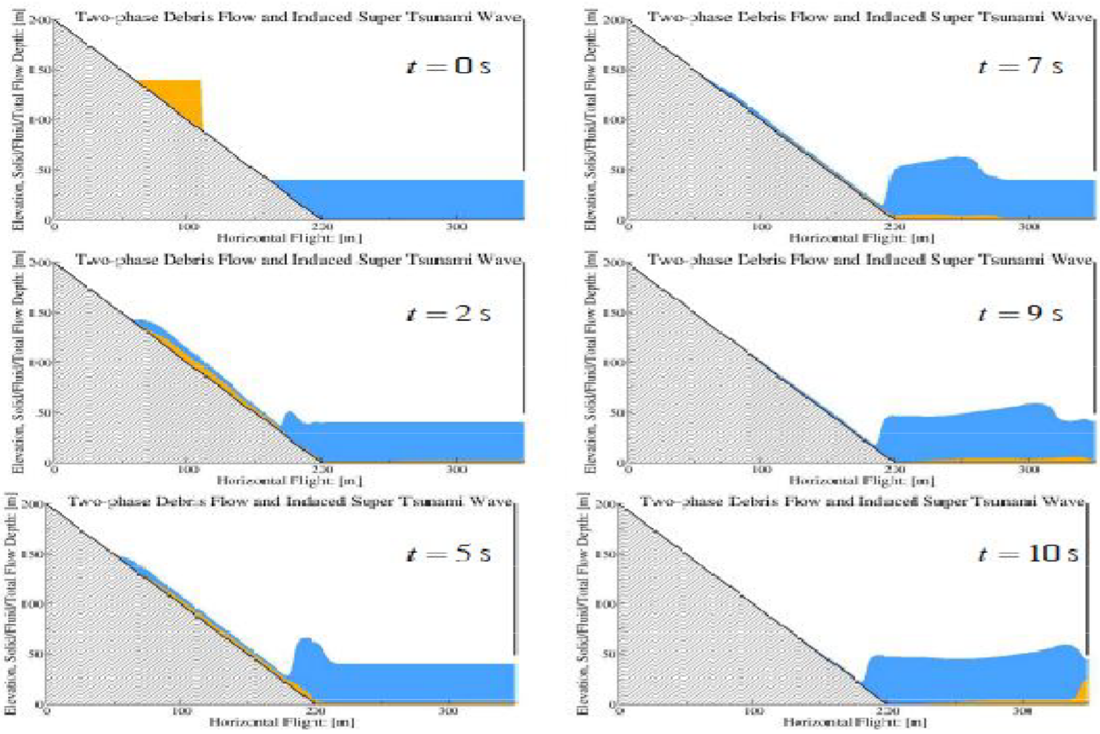
Subaerial and submarine landslides and debris flows are very important sediment transport mechanisms. Examples include sediment transport in hill slopes, in hydraulic channels and submarine environments. These are effectively two-phase flows of solid particles mixed with fluid. Accurate knowledge of the distribution and evolution of the solid and the fluid-phases are very important from the environmental and industrial point of view including the huge landslides in the coastal and mountain areas, and particle transport in mountain lakes, rivers, reservoir and hydro-electric power plants. The information of submarine debris wave speed can be useful for the design of early warning strategies in the coastal regions.

Previous findings substantially increase our understanding of complex multi-phase systems and multi-physics and flows, and allows for the proper modeling of landslide and debris induced tsunami, the dynamics of turbidity currents and sediment transport, and associated applications to hazard mitigation, geomorphology, and sedimentology. Here, we apply the general two-phase debris flow model (Pudasaini, 2012) and advance further by simulating three-dimensional subaerial and submarine debris flows. With an innovative and unified approach, we analyze the mechanics of complex wave generation and interactions between the solid and the fluid phases in the lakes, reservoirs and hydraulic channels. This includes the tsunami generated by the debris impact at reservoirs, lakes and oceans. We focus on the generation, amplification and propagation of super tsunami waves and run-ups along coastlines, debris slide and deposition at the bottom floor, particle transport in hydraulic channels, and the integrity of the reservoir dams, embankments and hydroelectric power plants. Our results can further be applied to properly analyze the stability of reservoir dams, embankments and slopes in response to the fluctuation of the water level (due to landslide impact)in the reservoir and lakes which plays a crucial role in the evolution of the pore-fluid pressure and seepage conditions.

2 Landslides and Tsunami in Dams

To develop insight into the basic features of the complex non-linear equations, the model is applied to three dimensional debris flow and tsunami generation. Here, we focus primarily on the complex dynamics of a two-phase subaerial debris flow sliding down an inclined channel plunging into a fluid dam. The impact produces a tsunami wave while at the same time generates a submarine debris flow along the dam basin. Simulation results show that the amount of grain in the dam plays a significant role in controlling the overall dynamics of the tsunami wave and the submarine debris flow. For very small solid particle concentrations in the dam, the submarine debris flow moves significantly faster than the surface tsunami wave, which may be an observable phenomena in nature. These results demonstrate wide applicability of the model to a wide range of two-phase geophysical mass flows, including particle-laden and dispersive flows, sediment transport, and debris flows.

Figure 1. Two-phase subaerial debris flow hits a fluid dam (t = 2 s), generates tsunami wave, and a submarine debris wave continues to slide down. Orange and blue colors indicate volume fractions of solid and fluid. At t = 5 s, tsunami wave is amplified, leading to an increasing hydrodynamic impact vacuum. There are three complex flows taking place simultaneously: subaerial debris flow in the upstream, submarine debris flow in the downstream and at the dam floor, and the surface tsunami wave. At t = 5 s, the submarine debris hits the horizontal basin of the dam and the tsunami becomes a super wave. At t = 7 s, the submarine debris wave is moving much faster than the tsunami wave. At t = 9 s, a left-going water wave starts,



and the hydrodynamic vacuum is decreasing. A particularly important observation is: the submarine debris already hits the right wall of the dam but the tsunami is still following the debris mass. This time gap can be used in generating early warning signals. At t = 10 s, the submarine debris hits the distal dam wall and a shock wave of debris material is generated that propagates upstream. (*Source*: *Pudasaini and Miller* (*2012*))

2 Concluding remarks

The work has brought new aspects of the complex interactions and waves generated from a two-phase debris flow impacting a fluid dam, and how it penetrates the fluid and finally deposits on the bottom of the basin.Three-dimensional evolution of solid and fluid phases in the dam, interactions between fluid wave, sub-marine debris and dam walls, debris deposition on the bottom of the basin, coastal inundation . The result is used to generate early warning signals in coastal regions, hydropower plants, and also to prevent possible catastrophic dam collapses,and hyper concentrations of solid particles in hydraulic channels, plants, ash floods simulations, mitigations.

References

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