Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

HCG35-12 Room:105 Time:May 27 12:15-12:30

Modeling runout and deposition of dense granular flows and its application to pyroclastic density currents in nature

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Constraining physical parameters of pyroclastic density currents generated by collapsing of lava domes or eruption columns is important to assess volcanic processes and hazards, but is a significant challenge because the mechanics of pyroclastic grains and their interactions are incompletely understood. One approach has been to exploit the thinness of the flows relative to their length by employing a depth-averaged description. A key issue is the granular friction law that is introduced into the models. Recent laboratory studies on granular flows suggest that rheology can be described by friction coefficients. Variation of the friction coefficients related to physical parameters such as shear rate and pressure is captured through dimensionless numbers (e.g., Maeno et al., 2013). Under the shallow water assumption how well the friction models work remains unclear when applied to pyroclastic density currents in nature. In this presentation, I will introduce the shallow water model of granular flows with different types of granular friction laws, and discuss their application to natural system and related issues, taking a case study for Soufriere Hills volcano, Montserrat, Caribbean.

Recent dome collapse events at Soufriere Hills volcano provide good examples to study the dynamics of pyroclastic density currents and to examine granular flow models, because of abundant geological and geophysical data. Here the 20 May 2006 lava dome collapse and resultant deposit are focused. The total collapse volume of the 2006 event was 97 Mm^3, of which about half was dense granular components (Trovimovs et al., 2012). The seismograms showed a prolonged buildup of increasingly large block and ash flows lasting ˜90 min. The most intense phase that produced the main deposit occurred in 35 min with two marked peaks. Based on the collapsed volume and the duration of seismicity, an average collapse rate can be estimated to be $4.7*10^4$ m^3/s. On the other hand, the submarine deposit is characterized by an elongated shape in flow direction and by levee-like facies. The deposit shape was very different from that produced in the 2003 event where collapsed materials 170 M m^3 was released in 2.6 hours with an average collapse rate $1.8*10^4$ m^3/s, and the shape of proximal submarine deposit was characterized by semicylindrical, steep-sided lobes.

To investigate the factors controlling the shape of the deposit in 2006, the 2D shallow water model of granular flows with different types of Coulomb-type friction models is applied to the terrain of the Soufriere Hills. One had a constant friction coefficient, and another had a friction coefficient that depends upon the dimensionless inertial number (I) of the motion. For source condition, a constant mass or a line source with a flux function were used. Parameter studies were carried out within possible ranges of parameters such as volume, grain-size, and friction angles. When the I-dependent friction model was applied with a flux function and specific values of the parameters were used, the characteristics of deposit shape can be reproduced. The I-dependent friction model works better after the flow passing a slope break point where slope angle is equal to the friction angle at zero shear rate. Our results suggest that coupling effects of discharge rates, slope and granular friction properties may explain the different shapes of the deposits produced by dome collapse events at Soufriere Hills volcano.

References: Maeno, F. et al. (2013) Physics of Fluids, 25, 023302, doi:10.1063/1.4792707, Trofimovs, J. et al. (2012) Bull. Volcanol., 74, 391-405.

Keywords: pyroclastic density currents, granular flow, modeling, shallow water theory