Is Coulomb's law suitable to estimate basal friction in rapid mass movements of rock fragments?

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Rapid mass movements of rock fragments (pyroclastic flows and rock avalanches for example) can be considered among the most hazardous natural phenomena because of their large momentum content. Consequently, they cannot be approached during motion and their physical behaviour is not well understood. In particular, the mechanism determining friction at their base and their mobility remain a matter of uncertainty and controversy. We are interested in relatively small-volume flows such as that shown by a previously-unpublished satellite image of the Soufrière Hills volcano in the island of Montserrat, West Indies (Fig. 1). In this figure, the objects are whiter when hotter and darker when colder. It is easy to identify the billowing volcanic plume that is black because it is cold and the round mass of the volcanic dome that is white because hot. The position of the dome corresponds to that of the crater. It is also

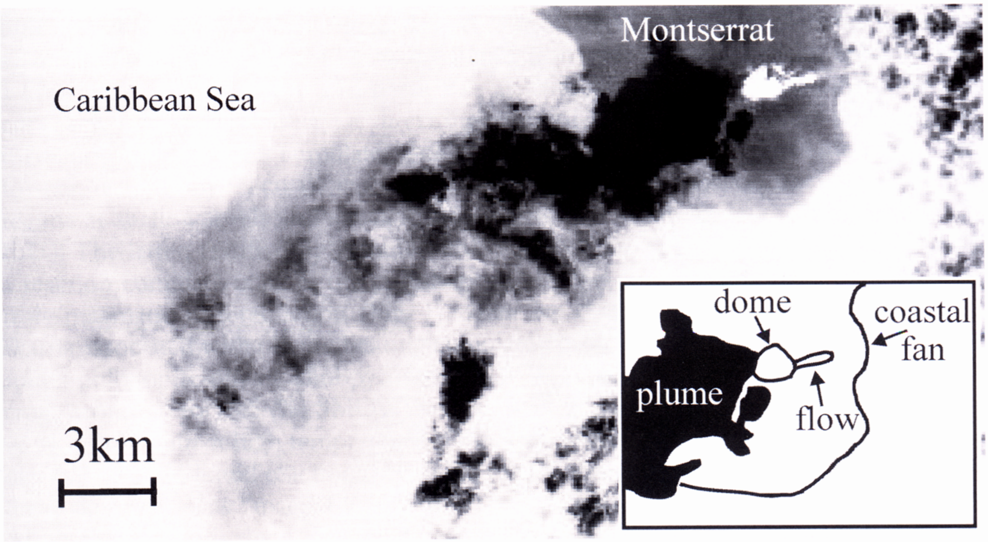

Fig. 1. ASTER image of the 28 December 2000 showing the southern portion of the island of Montserrat (a pixel in the figure is 90 m × 90 m). The elongated thermal anomaly of the flow that is located within the Tar River valley shows that these flows are controlled by topography.

easy to discern a relatively long hot tongue that could be either an eastward moving pyroclastic flow descending the Tar River valley or the thermal anomaly of a recently deposited one (the first interpretation is more likely because the anomalies of dome and tongue are still connected). Thus, this is probably one of the few available satellite images of moving pyroclastic flows. We suggest that slope-normal oscillations of granular mass flows with a quasi-rigid plug can result in reduction of their apparent coefficient of friction. This coefficient is computed as the ratio between drop in elevation and horizontal distance of travel. In our model, the effective friction during a downhill journey is a combination of the friction forces acting on the plug during the ascending and descending parts of its slope normal oscillations. As a consequence of oscillations, the decreased contact with ground surface reduces the apparent coefficient of friction. Channel lateral surfaces can also support a portion of plug weight giving another contribution in the reduction of this coefficient. The support of lateral surfaces requires a relatively narrow channel such as a gully or the presence of levees whereas the reduced basal contact can be important also in larger channels that do not provide lateral support. Our model is able to explain relatively long runout distances as long as the energy dissipated by oscillations is accounted for by the true coefficients of friction that enter the calculations. We conclude that Coulomb's law should be considered an effective friction law that averages the complex phenomena occurring at the base and on the sides of granular mass flows.