Landslide scar geometry effect on flow spreading: Application to Martian landslides.

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Introduction

Landslides take part in weathering and transport processes on Earth as well as on Mars. Prediction of their dynamics remains difficult in spite of many experimental and numerical studies. Numerous numerical works have been carried out on real landslides cases using DTM (Digital Topographic Model) so as to improve our understanding of their development by comparing results with field observations. Many previous studies have been based on runout analysis in relation to mean dissipation calibration via the friction coefficient. The geometry of the landslide scar may also play a role in landsliding and mass spreading but it is usually unknown. We have tried here to reduce the potential error on mean dissipation resulting from the uncertainty on initial scarp geometry. In addition, from field observations of landslide deposits we have tried to retrieve initial landslide parameters such as initial geometry and volume of material involved. The effect of scar geometry on the spreading flow is studied using a numerical model able to take into account the curvature of the bottom topography.

Methodology

Our study is based on both geomorphological analysis and numerical modeling. The first part of this work requieres image and DTM processing using the Integrated Software for Imagers and Spectrometers (ISIS released 3) [1]; [2] and vectorial mapping software as previously described [3]; [4].

Simulation is performed using the numerical model developed by [5] based on the Savage-Hutter equations developed in a reference frame linked to the topography including only the curvature terms in the x and y direction. Debris avalanche is treated here as a single-phase, dry granular flow with Coulomb-type behavior. The Coulomb-type friction law applied on the averaged media has been tested by comparing depth-averaged model Shaltop - 2d with discrete element simulations (DEM) [6] on the collapse of granular column of variable aspect ratio ($a = H_i/R_i$, where H_i and R_i are the initial thickness and radius of the granular column). The main result was that vertical acceleration has to be included in the model if aspect ratio $a < 1$ are deal with. As the focused of this work was to study the geometry effect, our model is an adapted tool for this purpose as it is able to take into account the bottom topography. All natural cases considered in this study meet with this condition allowing authors to use the model in this specific context.

Granular community oftenly perform studies involving 2D narrow channels or axisymetric cylinder geometries in laboratory experiments as well as in numerical studies. Before applying tests on real geophysical cases, we thus perform a few theoretical tests on topographies which are completely controled by equations so as to avoid artefact effects. In this manner, we start here by simple 2D and 3D topographies so as to get closer to experimental conditions. In a third step, we generated some natural alike topographies before applying on real DTM (digital topographic model) on Mars.

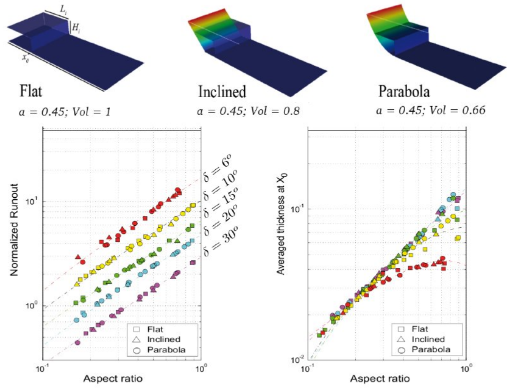

Figure 1: (top) 2D topographies. (bottom-left) Normalized runout as a function of initial aspect ratio (H_i/L_i).(bottom-right) Normalized mean thickness as a function of initial aspect ratio

Results

Our benchmarking analysis involving various theoretical scar geometries in 2-D and 3-D shows that the runout distance and the mean thickness are not affected by the initial shape of the scar, whatever the friction coefficient (fig. 1). In contrast, 3-D tests show that the shape of the final deposits is a function of the scar geometry, which means that information on initial slope failure geometry and initial volume involved in the mass spreading can be retrieved from analysis of final deposit geometry (fig. 2).

These results are validated with terrestrial examples

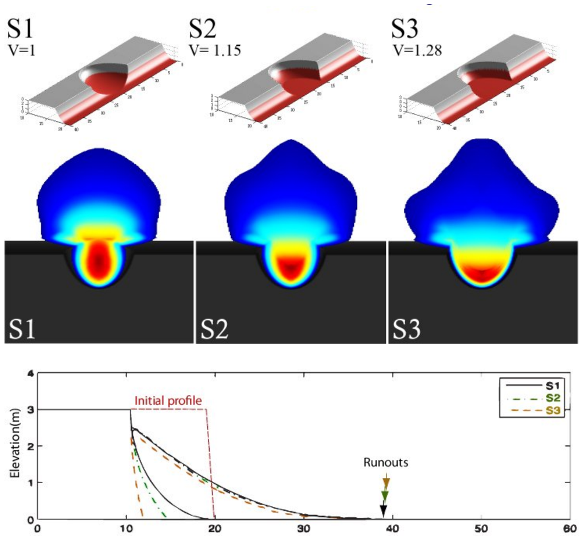

Figure 2: (top) 3D scar geometries used for benchmarking. (middle) Final deposits for each geometry. (bottom) Topographic profils showing that the runout is not affected by the scarp geometry.

for which the scarp geometry and friction coefficient are well known. A feedback analysis of Martian landslides, for which excellent exposures of landslide debris aprons and reasonable hypotheses of initial scarp geometry can be drawn, is then performed (fig. 3). Agreement has been found between geomorphological analysis and modeling, allowing us to explore deeper the initial conditions of landslides on Mars. A feedback analysis method for retrieving the volume and shape of the initial landslide material is given.

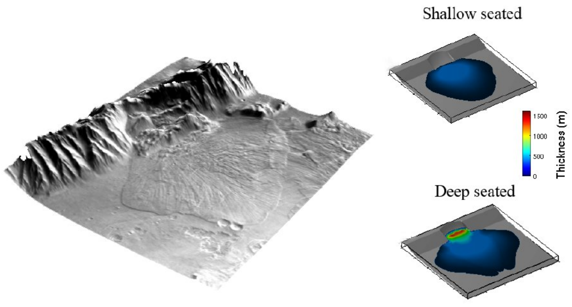

Figure 3: Coprates Chasma landslide compared with two scarp geometries (shallow-seated and deep-seated). The deep-seated geometry allows to get results in better mass distribution and shape of deposits.

Discussions

Previous studies have included calculation of Martian landslide volumes calculation [4]; [7]; [8]. This information is the main point for mass balance assessment. Using the final shape of deposits, we thus obtain constraints on the initial volume. In addition, this method can help retrieve information on slope failure geometry, making feedback analysis of geotechnical parameters of landslide material possible. We will discuss of this two major points and their implications in terms of geology and climate conditions.

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