New Insights Into the Dynamics of Martian Gullies

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Introduction

Recently, bright gully deposits observed by MOC images were subject to debate on their formation [1]; [2]; [3]. Initialy interpreted as evidence of liquid water [1], this flow was modeled and thought to be dry [2] based on geomorphics features. The granular rheology is able to reproduce the "fingers" features observed on the natural example [2].

We focus here on the Centauri Montes example (96^{o}E,-38^{o}N). The deposits are 600 m long and 35 m large and the source seems to be 400m above the upper part of the current deposits. Moreover, the topographic slope angle $\theta < 12^o$ at the front of the deposits (fig. 1). This point questions the value of the mean dissipation (e.g. The friction angle describes the mean dissipation in granular flow) of the gully and thus the behavior of the flow. Indeed, granular media starts to flow when the slope reaches the avalanche angle θ_a and stops when this slope gets repose angle θ_r. Consequently, hysteresis of granular flows occurs when the slope angle $\theta \in [\theta_a, \theta_r]$. In this manner, the friction angle of material involved should be very small ($\delta < 12^o$) regarding to classical values measured experimentally (e.g. friction angle of sand is $\sim 30^o$).

However, the slope angle at the hypothetical source (also proposed by [2]) is above 40^o. Assuming a dry granular behavior, we can question if the inertia is strong enough allowing the mass flowing down below a 20^o slope? Using an up-to-date numerical model, the aim of this study is to go into the dynamics of such mass flows, so as to figure out the balance of forces that occured during the flowing of dry granular media.

Numerical model description

Numerical simulation is performed using the numerical model hereafter called $Shaltop-2d$ based on the classical Savage-Hutter model for granular flows over sloping topography [7] [5] [6]. This model accurately the topography effects [7]. Based on the long wave approximation (given that the length of the flow direction is larger than the thickness of the avalanche) the model describes the balance between inertia, gravity, pressure gradients and friction forces acting on the depth-averaged media [6].

The appropriate law to describe dissipation in dry granular flows is still an open question. In this study, we use an emperical parametrization of the friction law figured out by experimental studies involving dry media spreading over inclined plane [8]. Basically, this law implies the friction coefficient increases with increasing velocity and decreasing thickness. These emperical functions can be deduced by fitting the function relating the slope angle θ of an inclined plane to the thickness staying on the plane $h_{stop}(\theta)$ and the function relating the slope angle θ to the minimum thickness of an initially at rest granular layer $h_{start}(\theta)$ necessary to generate a flow observed in experiments involving dry media [8]; [6].

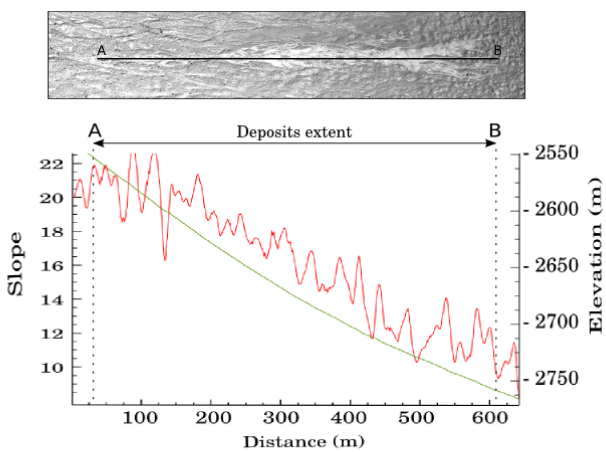

Figure 1: (top) HiRISE image of bright Deposits Gully. (bottom) Topographic and slope profiles (A–B) along bright deposits (data from HiRISE-DTM available in [4]. The front of the deposits lies on 11^o slope.

Dynamics of the flow

Using sand values parameters from experiments in [8] and simulations in [6], the model is not able to reach the observed runout of the deposits (fig 2). The simulated deposits stay at slope angle $\theta \sim 23^o$. Moreover, fingers are reproduced by the model as in [2]. These fingers are clearly related to some pre-existent channels (also present in the DTM given by [4]) and not to the behavior of dry media.

Concerning the dynamics, the total time release of the flow is about 800 secs. During the first stage (0-200 secs), the behavior is essentially governed by inertia,

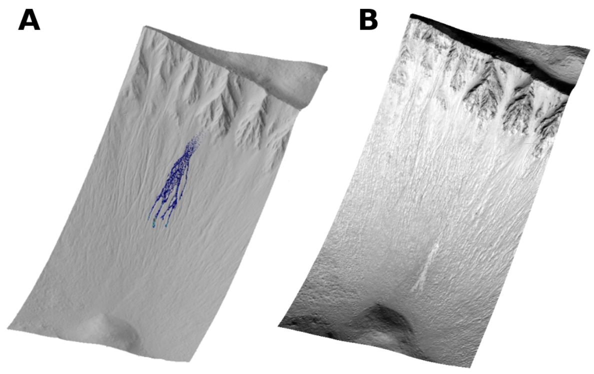

Figure 2: (A) Simulated deposits using parameters calibrated on experiments [8]. The source is taken as the same altitude than in [2]. (B) Deposits as observed by HiRISE camera. (DTM is from [4]). Simulated runout (in A) does not reach the observed one (in B). The total mass stays at upper part of the wallslope compared to the natural case.

gravity and frictionnal forces (fig. 3). During the decceleration phase, it is clear that only frictionnal and gravity forces govern the flow. Inertia equal to 0 after 200 secs. Consequently, a pure dry media behavior is not sufficient to reach the observed runout.

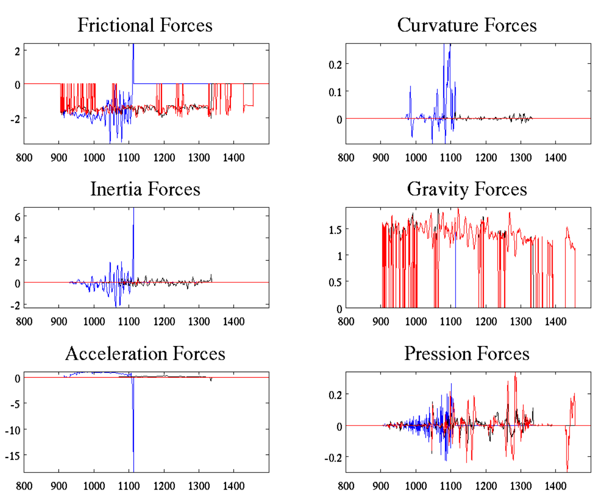

Figure 3: Normalized forces in the slope direction at the middle of the flowing mass and taken at several times: 50 secs (blue lines) - 100 secs (black lines) - 600 secs (red lines).

Discussion

As shown here, pure granular media model (in usual granular settings) does not reproduce the observed deposits. Our dynamics analysis of dry granular flow shows that inertia is not strong enough to push the mass down the slope (e.g. $\theta < \theta_a$). The mean dissipation acting on the acceleration of the gully is clearly smaller than that used in our simulations. Smaller friction coefficients are needed in simulations to catch the runout distance observed on HiRISE images. However, very small particles (diameter $< 10\mu m$) could show unusual frictional behavior not taken into account in our simulations. We will discuss some processes not present in the pure dry granular flow model and could occur in the gully dynamics.

Acknowledgment

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