On the simulation of Large Martian Landslides. A. Lucas[1,2], A. Mangeney[1], D. Mège[2], F. Bouchut[3], [1]Institut de Physique du Globe de paris, UMR CNRS 7154, Université Paris Denis Diderot, France; [2]Laboratoire de Planétologie et de Géodynamique, UMR CNRS 6112, Université de Nantes, France; [3]Département de Mathématiques et Applications, Ecole Normale Supérieur, UMR-CNRS 5881, Paris, France. (lucas@ipgp.fr).

Introduction: Landslide morphologies have been identified on Mars [1-2]. Some similarities between experiments on dry granular spreading and Large Martian Landslides (LML) convey to conlude on dry conditions [3]. However, normalized runout on Mars is twice as large as those observed in laboratory. Numerical simulations on theoretical 2D and real 3D topographies reconstructed from remote sensing data show that slope effects significantly reduce the discrepancy between experimental results and Martian observations [4]. However, topography effects are not strong enough to explain the high mobility of Martian landslides, which requires a very small friction angle ($\delta < 10°$), much smaller than required in dry granular spreading simulations ($\delta = 32°$) [4].

As a result, physical processes such as air cushioning or lubrication by a fluid phase should play a key role in the dynamics of Martian landslides. We investigate landslide mechanics using a new mobility parameter [4] that makes it possible to characterize the flow dynamics regardless of the geometry of the released mass and of the underlying topography.

Model description: Our model, named *Shaltop-2d*, is based on the equations introduced by *Bouchut and Westdickenberg* [2004] developed in a fixed cartesian reference frame with the thin layer approximation (TLA) imposed in the direction perpendicular to the topography. The rigourous asymptotic analysis makes it possible for the first time to account for the whole curvature tensor. Furthermore, the numerical method is of order 2 requiring less refined grid to reach the same precision.

The numerical method is based on the work of F. Bouchut [2004] and preserve the steady states as well as other requirements related to the resolution of hyperbolic equations. *Shaltop-2d* has been used successfully to simulate laboratory experiments of granular collapse [7], levees-channel formation [8] as well as real 3D avalanches in a natural context as it has been recently shown for large Martian landslides [4].

2D numerical tests : 2D numerical tests have been performed. The 2D topography consists in a channel configuration where the shape of the bottom topography on which settles the granular flow (initially as a vertical column) is controled. We generate three kinds of bottom topographies so as to deal with the shape of the scarp below the initial mass (*see figure 1*). The first shape called Topo-1 involves two inclined planes with distinct angle (here we use $\theta_1 = 65°$ and $\theta_2 = 0°$). Topo-2 involves a conique shape below the initial mass. Finally, the third shape, named Topo-3, involves a linear inclined plane as bottom topagraphy.

Figure 1 – Three types of 2D topographies. Red parts are Initial bottom topography which we deal with. Dached black line indicate initial mass. Note that bottom topohraphy shapes have implications on the initial mass volume.

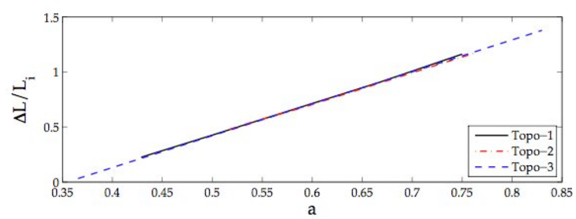

Figure 2 – Normalized runout as a function of the initial aspect ratio ($a = H_i / L_i$) for the three different bottom topographies (*see figure 1*). Runout is not affected by the shape of the bottom topography.

2D tests show that despite of the shape of the bottom topography, runout distance is not affected. Using the topographic reconstruction methodology developed previously by [9], we performed 3D tests on real DTM (Digital Topography Model) and get same observations. The shape of the bottom topography does not affect the runout distance of landslide.

Morphometric parameters of LML: *Quantin et al.* [10] have performed a systematic geomorphology analysis of VM landslides using THEMIS MOC and MOLA data sets. More recently, *Lajeunesse et al.* [3] have performed a morphometric analysis of these landslides. From these studies, some landslide morphometric parameters can be defined (*figure 3*).

From THEMIS, MOLA and MOC data available from PDS [11], we performed a morphometric survey using these parameters on five large Martian landslides (*see figure 4*).

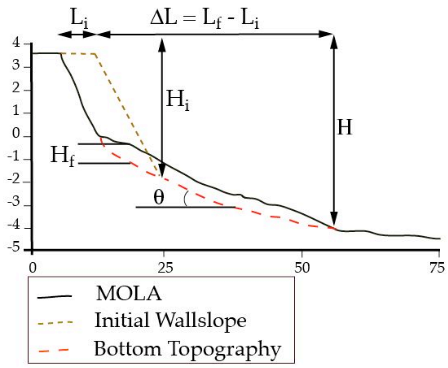

Figure 3 – Morphometrics parameters using in this study.Where L_i is the initial mass length, H_i is the initial mass height, ΔL tha final runout, H is the total height (topographic slope is here taken into account), θ is the slope and H_f is the final thickness of deposits. (*Modified after* [4]).

New Mobility of Martian landslides: The classical mobility is defined as:

$$m_e = \frac{\Delta L}{H},$$

It is volume-dependant. We define instead a new mobility parameter m'_e, which reads [4]:

$$m'_e = \frac{1}{\tan\delta} = \frac{1}{\tan\theta + \alpha \frac{H_i}{\Delta L}},$$

where θ is the bottom slope, and $\alpha = 1.24$ *is* a dimensionless parameter introduced by [12]. The mobility parameter is independent of the initial landslide volume, its aspect ratio, and the underlying topography. This mobility m'_e is thus a function of the friction angle δ. We calculate m'_e for the following landslides:

Landslides	Mobility (m'_e)	δ (°)
Ophir	5.8	9.8
Candor	5.6	9.9
Ganges	6	9.4
Coprates	7.7	7.3
Melas	6.9	8.1

Table 1 – Mobility m'_e and angle of friction δ calculated for a few landslides on Mars.

Mobility m'_e is useful for numerical simulations of Large Martian Landslides. Based on thin-layer a proximation model, we performed a series of simul tions of large Martian landslides in which the topography is taken into account [4,8]. Using the same angle of friction calcultated from our new mobility, we obtained very satisfaying results as shown on figure 5.

Results and discussion: Calculation of the mobility (m'_e) for the 5 Valles Marineris landslides studied give a similar angle of friction. This result is consistent with the similar geological context of these landslides, and the presumed similar composition of the slided material involved. This indicates that the mobility parameter we used is makes sense and provides a good effective friction estimate. The friction angle values do not allow us to conclude as to the presence or not of a liquid phase in the dynamics of the large Martian landslides. We will discuss the implications of the use of this new mobility parameter for large Martian landslide numerical modeling, following the path opened by an earlier Ophir Chasma landslide study [4].

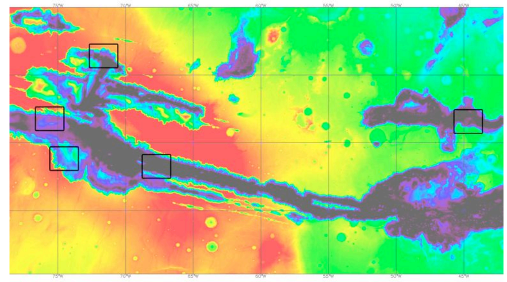

Figure 4 – Valles Marineris Map. Studied landslides are noticed by black squares.

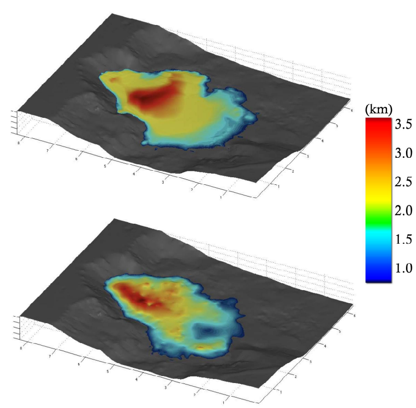

Figure 5 – 3D view of the Ophir landslide deposits for numerical simulations (top) and MOLA (bottom) [4].

References:

[1] Lucchitta, *JGR*, 1979; [2] McEwen, *Geology*, 1989; [3] Lajeunesse et al., *GRL*, 2006; [4] Lucas and Mangeney, *GRL*, 2007; [5] Bouchut and Westdickenberg, 2004; [6] Bouchut et al., *CRAS*, 2004 [7] Mangeney et al., *JGR*, 2005; [8] Mangeney et al., *JGR*, 2007; [9] Lucas et al., *Workshop on Martian Gullies*, 2008; [10] Quantin et al., *PSS*, 2004; [11] *http://pds-geosciences.wustl.edu*; [12] Lube et al., *J. Fluid Mech*, 2004.