Triggering and flow conditions of recent flows in Martian gullies: numerical simulation using RAMMS

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Introduction

Over the last decade new flow deposits have formed in multiple gullies across Mars. These flows can substantially erode the channel and form terraces, transport meter-sized boulders, form new channel segments, migrating sinuous curves and lobate deposits. Moreover, these flows deposit on slopes well below the angle of repose, suggesting fluidization of the flows in the absence of liquid water. Based on these observations, multiple models for the nature of these new flows have been proposed - mostly relying on carbondioxide sublimation fluidizing the flow and thereby enhancing flow runout above typical dry flow runout.

Objectives

Here we model one such recent flow in Hale crater using the RAMMS to determine:

(1) The initial failure volume required to form the new flow;

(2) The rate of fluidization as a result of carbondioxide sublimation;

(3) The typical flow characteristics, such as flow depth and flow velocity.

Methods

We perform our simulation using the RAMMS (RApid Mass Movement Simulation) model. RAMMS uses the Voellmy-Salm fluid model to describe the rheology of the flow debris. The model divides the friction resistance into two parts: a dry-Coulomb type friction (μ) that scales with the normal stress and a velocity-squared drag or viscous-turbulent friction (ξ). The frictional resistance S is then:

$$S = \mu \rho g h \cos(\varphi) + (\rho g u^2)/\xi$$

Entrainment in the RAMMS model is based on a simple shear stress formulation. Flows stop once the initial momentum has declined below a user-defined criterium. We assume that the new flows initiate by a slope failure in the gully-alcoves. We model failure areas of 71 m2 (part of the upper alcove) and 152 m2 (full upper alcove), with failure depths ranging from 0.5 m to 3 m. We let friction values vary from 0.25 to 0.35 for μ and from 100 to 800 for ξ. Stopping occurs at momemtum values of 5-20% of the maximum momentum. We assume a solids-air mixture with a density of 1500 kg/m3.

Plausible scenario

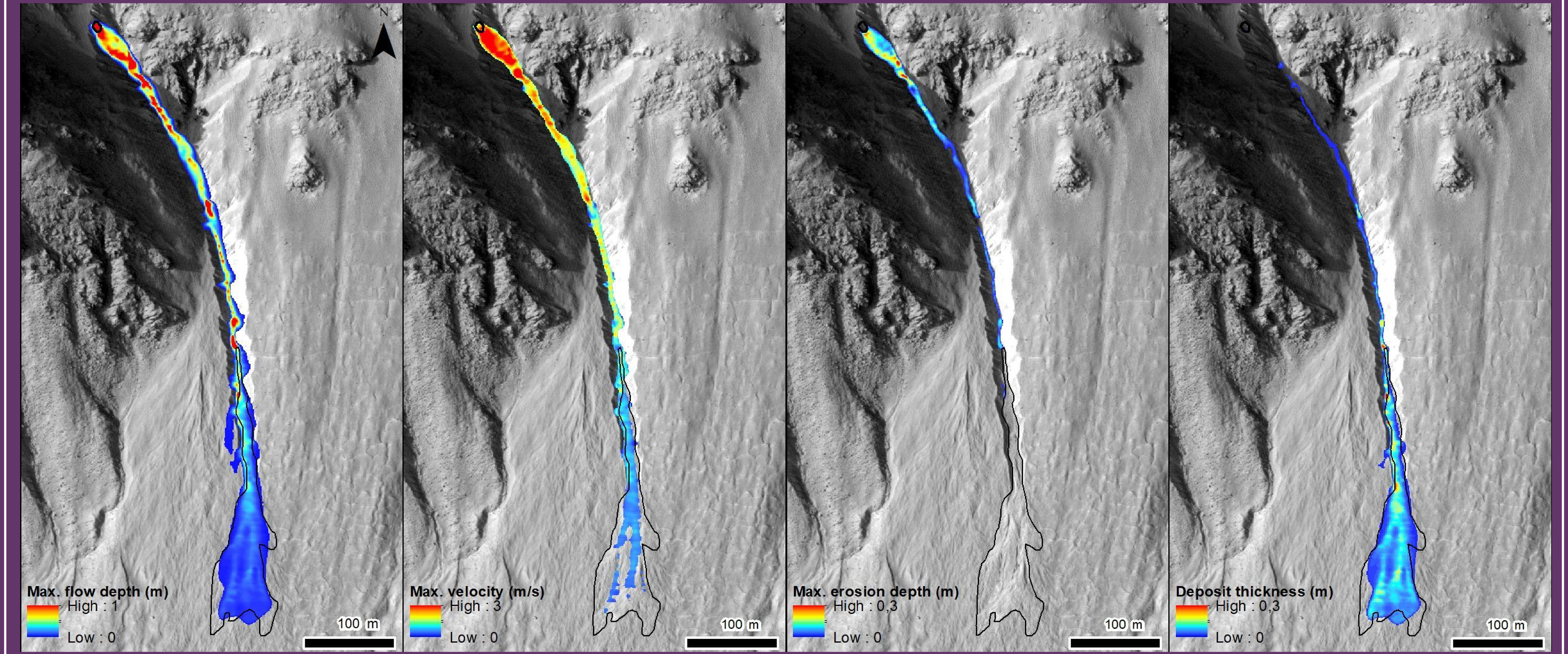

Fig. 1: Maximum flow depth, maximum flow velocity, maximum erosion depth, and deposit thickness of a plausible model scenario - μ = 0.25, ξ = 100, stopping momentum = 10%, initial volume = 210 m3 (see Fig. 2). The thick solid line in the upper gully alcove represents the release area, the solid line on the gully fan represents the observed flow deposit outline. Flow deposit thickness is limited, in the range of a few decimeter on the gully fan, consistent with observation on many recent flow deposits indicating thin deposits. Flow velocity strongly declines from initiation area to deposition area, under influence of decreasing slope.

Reproducing flow runout

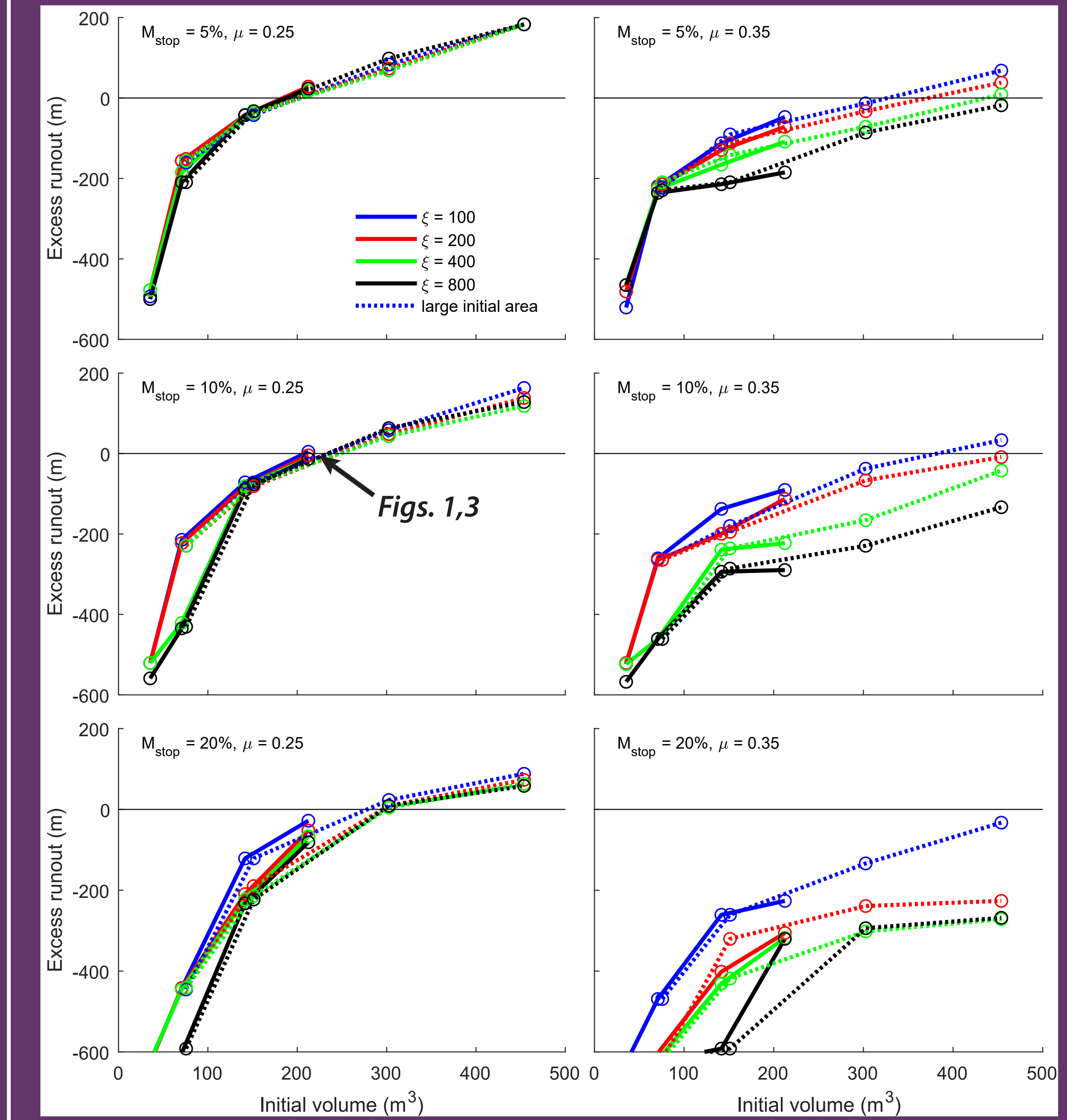

Fig. 2: Modelled excess flow runout (0 means perfect fit to observed runout). The figure panels show results for different combinations of friction parameters μ and ξ and stopping momentum. Multiple parameter combination result in realistic results, but initial volumes should at least exceed 200 m3. Solid and dashed lines result from a 71 m3 and 151 m3 release area, respectively.

Flow development

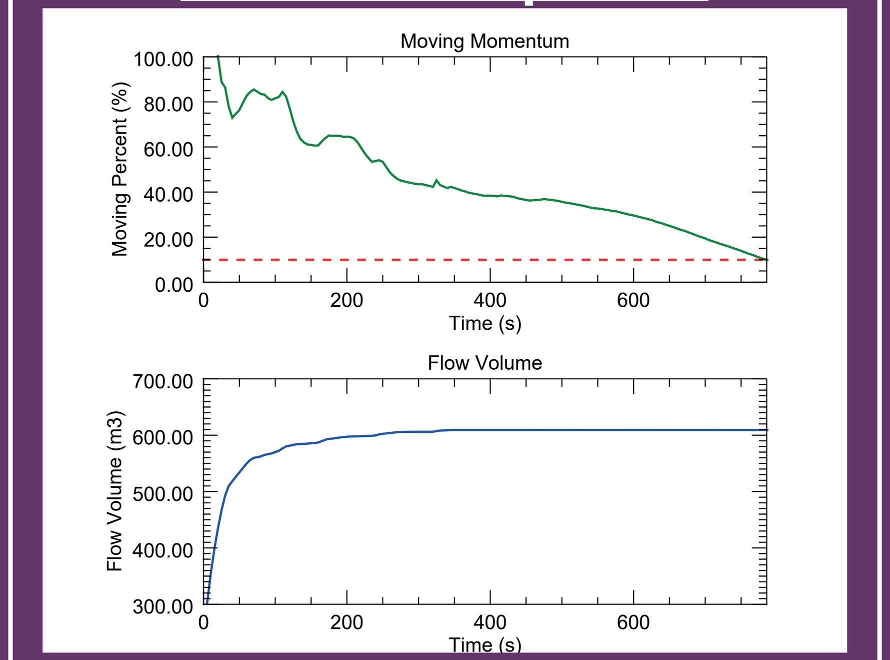

Fig. 3: Flow development for the flow shown in Fig. 1. The flow erodes a substantial amount of sediment from the gully alcove, approximately doubling its initial volume. No erosion and bulking occur on the depositional fan, where the flow decelerates and stops.

Mars vs. Earth

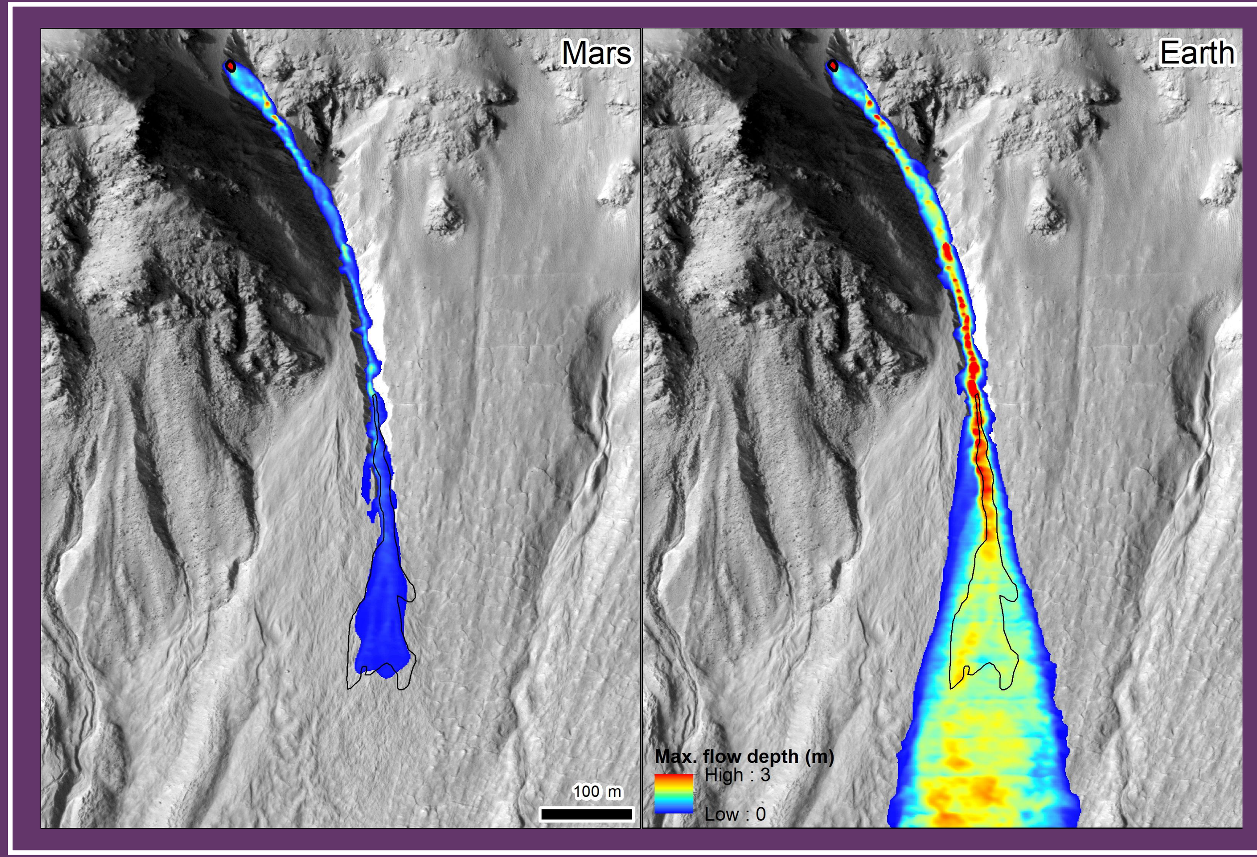

Fig. 4: There is a large difference in flow properties between Mars and Earth gravity. Earth gravity leads to larger flows a a result of the higher driving force, but also due to larger amounts of erosion, enhancing flow bulking. Erosion is a runaway effect, where bulking leads to higher flow depth, and thus further enhanced erosion. This also shows that the model is sensitive to erosion properties and conditions.

Conclusions

(1) Minimum failure volume to reproduce the flow runout is ~200 m3, but may be much larger depending on friction parameters.

(2) Multiple parameter combinations result in plausible flow runout.

(3) Flow deposit thickness on the gully fans is limited, in the order of a few decimeters, consistent with observations.

(4) Flow velocity is high in the gully alcoves (>1 m/s), but decreases to a few decimeters per second on the depositional fan.

Future work: repeat analysis for different martian systems, and compare friction values to known terrestrial flows.