Deciphering the formation processes of linear dune gullies on Mars

Lonneke Roelofs, Simone Visschers, Susan Conway, Tjalling de Haas, Maarten Kleinhans, Matthew Sylvest, Manish Patel

l.roelofs@uu.nl - @RoelofsLonneke

Utrecht University

BSG British Society for Geomorphology

Introduction

Linear dune gullies (Fig 1) are enigmatic active channel features on Martian southern mid-latitude dunes [1-3]. Their channels are straight or sinuous, with distinct levees. The channels lack a clear alcove at the upstream end and often end in pits [1-5].

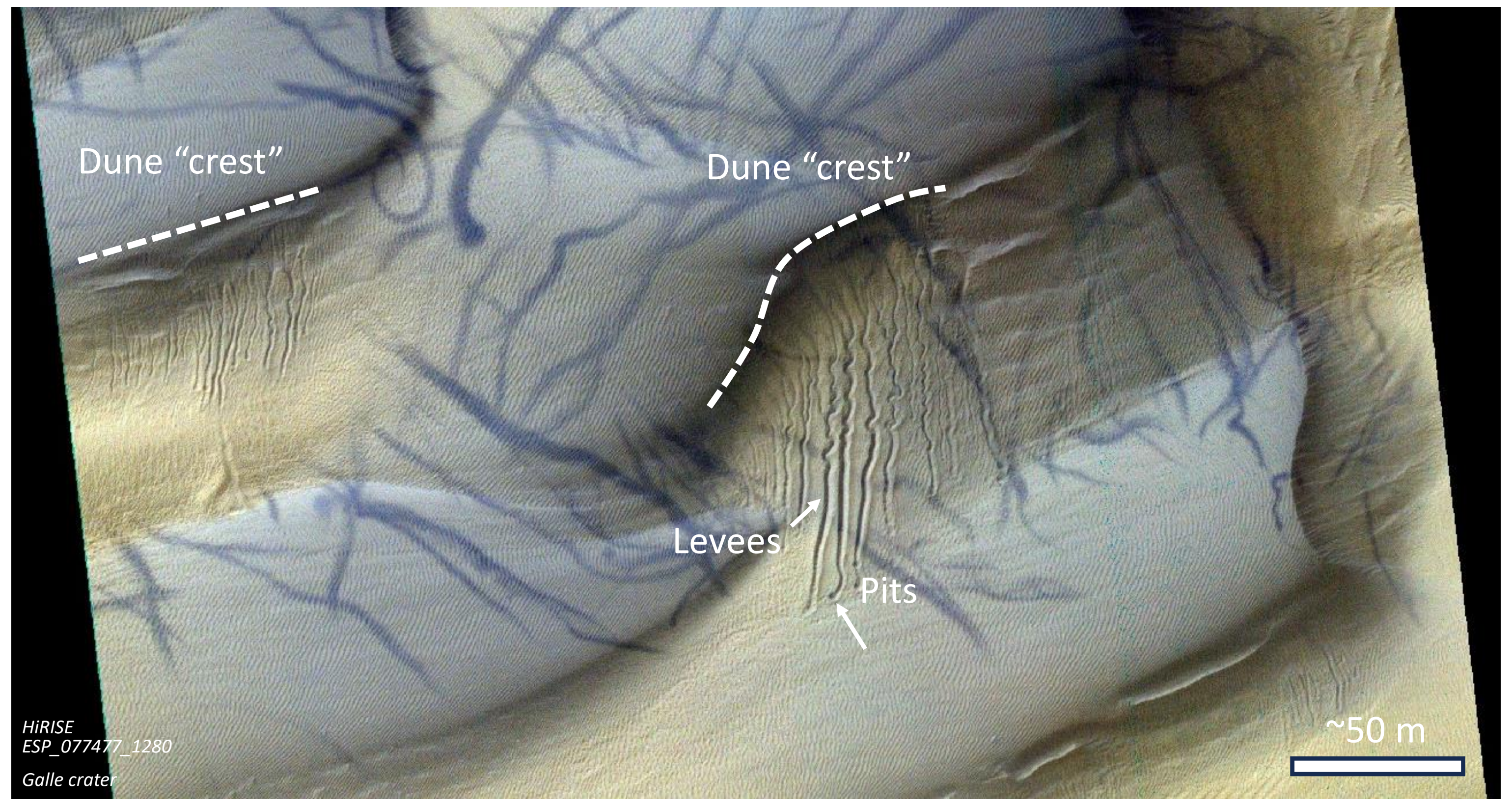

Fig 1 Linear dune gullies on Galle crater dune field. In the image, two fields of linear gullies can be observed. They start at the top of the dune and extend in the downslope (south) direction (north is at the top of the image). The dark blue tracks on the dunes are dust devil tracks.

Current hypothesis

CO_2 ice breaks off in spring and **slides down**, while some slopes are defrosted [2.4].

Fig 2 Snow cornices on Earth as a visual reference

Fig 3 Snowy dunes on Earth as a visual reference

Observational evidence

Linear gullies are active yearly, at the beginning of spring; channels extend, new pits appear, and sediment is actively reworked [1-3]. Also, blocks of **CO_2 ice** have been observed in some linear gullies (mostly on Russell).

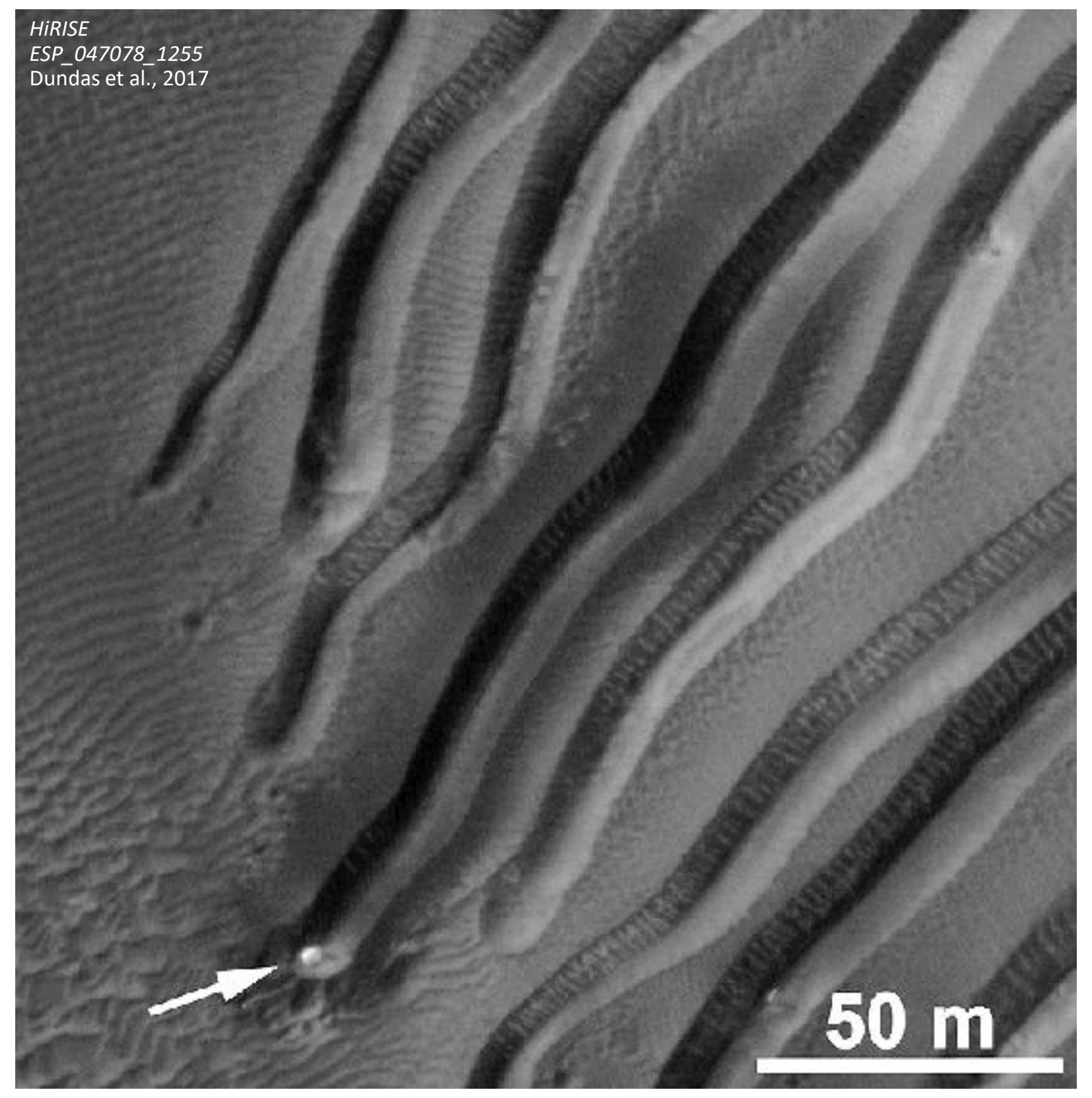

Fig 4 Dune gullies on Russell crater mega dune. The white block indicated with an arrow is CO_2 ice.

Research questions

1. Does the CO_2 sliding-block hypothesis work?
2. What causes the difference in channel morphology around the dune crest vs downslope?
3. What causes the sinuosity?

Methods

We tested the existing hypothesis under Martian atmospheric conditions (8 mbar) by conducting more than 150 small-scale flume experiments in the Mars chamber at The Open University (Fig 5). We constructed a small-scale flume consisting of a sloping tray (1.2x0.4 m) filled with aeolian sand and a release mechanism for CO_2-ice blocks. Experiments were conducted at different slopes angles, with CO_2-ice block size and grain sizes.

Fig 5 Photos of the experimental set-up. Left, the Mars Chamber (The Open University) from the outside (Lonneke for scale). Right, the flume set-up.

Results

Our experiments show that CO_2-ice blocks move downslope by two different modes of transport:
(1) The earlier hypothesised **sliding** (Fig 6b-c,g-h) – on steep slopes and coarse-grained beds.
(2) A newly discovered mechanism of **burrowing** (Fig 6d-e,i-j) – on gentle slopes and fine-grained beds.

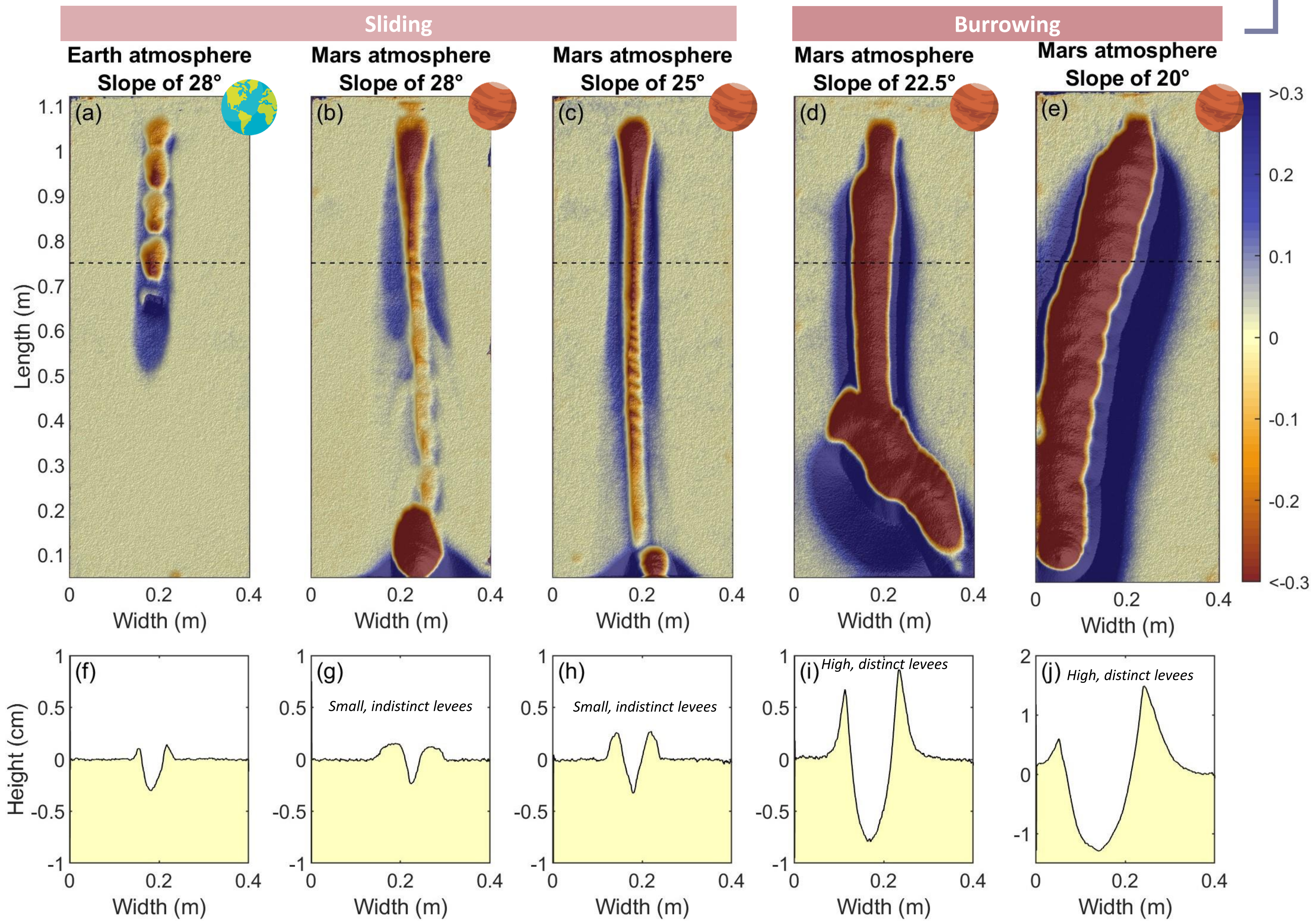

Fig 6 DEMs (a-e) and cross-sections (f-j) of the slopes of four experiments after the CO_2 block has been released and travelled down the slope. Blue indicates deposition of sediment, and red indicates erosion of sediment. Panel (a,f) shows an experiment under terrestrial atmosphere (1020 mbar,) panels (b-e and g-j) represent experiments under Martian atmosphere (8 mbar).

Videos

High speed

Real time

Discussion

- The two transport mechanisms (sliding and burrowing) create distinct gully morphologies that can also be recognized in the linear gullies on Mars, often along one single gully (from up- to downslope), see Fig 1. Upslope, the gully channels do not show distinct characteristics, whereas downslope distinct levees are present together with sinuous curves.
- Both mechanisms are driven by large gas fluxes produced by CO_2-ice sublimation under the Martian atmosphere caused by the contact of the CO_2 ice and the warmer sand. However, the dominating processes and forces causing the block to move in a certain way are different (Fig. 7).

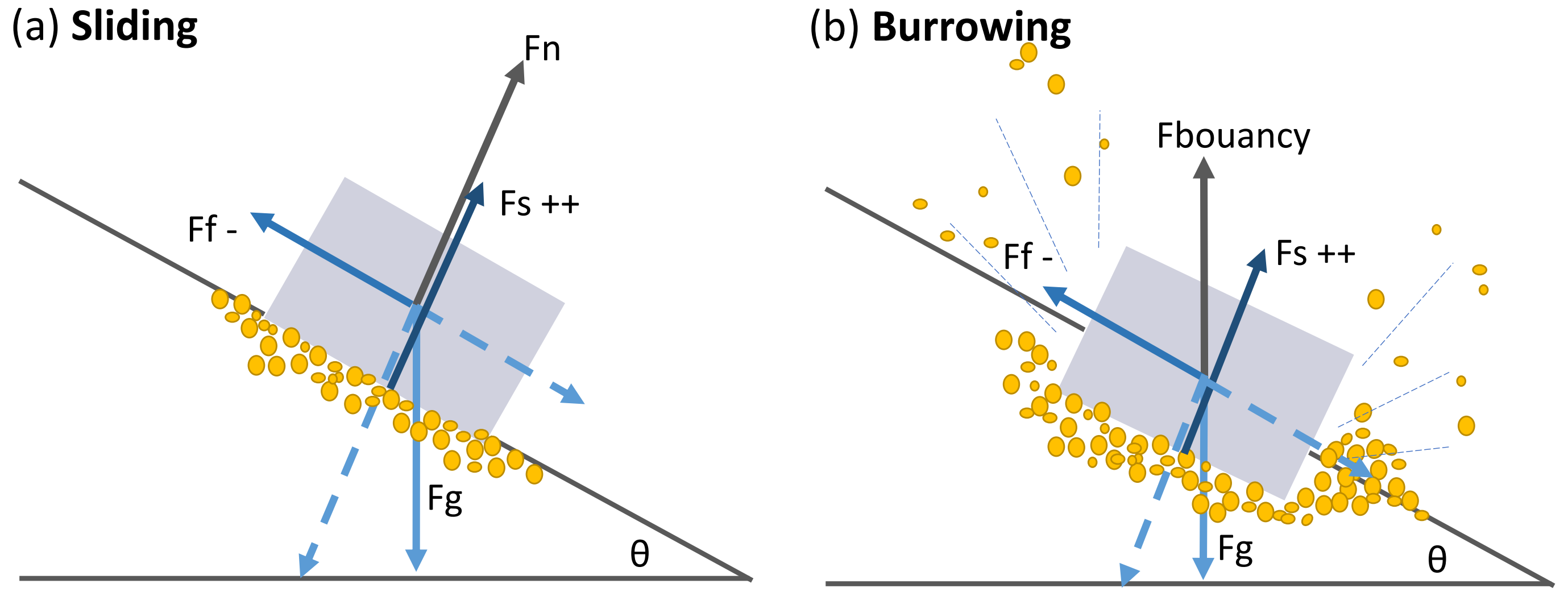

Fig 7 Schematics of the forces and parameters involved in the block movement for the two transport mechanisms (a) sliding and (b) burrowing

Conclusions

1. Sliding and **burrowing** blocks of CO_2 ice carve linear dune gullies on Mars. Depending on the steepness of the slope they slide or burrow.
2. Sliding blocks create gullies with small and indistinct levees. Burrowing blocks create half-pipe-shaped gullies with high and distinct levees.
3. Sinuosity is caused by burrowing blocks that encounter obstacles (either topographic, thermal, or a combination) and therefore change direction.

References
[1] Pasquon, K. et al. (2016). *Icarus*, 274, 195-210. [2] Dundas, C. M., et al. (2012). *Icarus*, 220(1), 124-143.
[3] Pasquon, K. et al. (2019). *Icarus*, 329, 296-313. [4] Diniega, S., et al (2013). *Icarus*, 225(1), 526-537.
[5] Jouannic, G., et al. (2012). *PSS*, 71(1), 38-54.

This presentation participates in OSPP
EGU
Outstanding Student & PhD candidate Presentation contest

Sharing is encouraged

EGU2024