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► **To cite this version:**

Lonneke Roelofs, Simone Visschers, Susan J. Conway, Tjalling De Haas, Maarten Kleinhans, et al..  
Deciphering the formation processes of linear dune gullies on Mars. EGU General Assembly Conference  
Abstracts 2024, Apr 2024, Vienna, Austria. pp.1889, 10.5194/egusphere-egu24-1889 . hal-04759985

**HAL Id: hal-04759985**

**<https://hal.science/hal-04759985v1>**

Submitted on 30 Oct 2024

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EGU24-1889, updated on 30 Oct 2024

<https://doi.org/10.5194/egusphere-egu24-1889>

EGU General Assembly 2024

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## Deciphering the formation processes of linear dune gullies on Mars

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Linear dune gullies are a unique surface feature on Mars of which no Earth analogue exists. They have long and constrained channels, lack an alcove, and often end in circular depressions called pits. Satellite observations have shown that the activity of linear dune gullies is related to the presence of CO<sub>2</sub> ice, which led to the hypothesis that these landforms are carved by blocks of CO<sub>2</sub> ice. Here, we experimentally test this hypothesis under Martian atmospheric conditions and establish a better physical understanding of how this process works. We conducted >100 experiments under Martian atmosphere in which we released CO<sub>2</sub>-ice blocks on a sloping sand bed. Our experiments show that CO<sub>2</sub>-ice blocks move downslope by two different modes of transport, both driven by large gas fluxes produced by CO<sub>2</sub>-ice sublimation under Martian atmosphere. In general, on steep coarse-grained slopes, the blocks slide down, carving narrow and shallow elongated depressions. On gentle fine-grained slopes, the blocks burrow themselves into the sand and slowly carve deep elongated depressions with high and narrow levees, ending in circular pits. These two modes of transport of the CO<sub>2</sub>-ice blocks can explain the different morphologies of linear dune gullies on different locations, with some gullies having very defined levees and some not, as well as the transition in morphology of certain linear dune gullies from steep upper slopes to gentle lower slopes that we observe on Mars. These experiments allow us to reconstruct how linear dune gullies formed based on their morphology, and infer the necessary climatic and topographic conditions allowing these gullies to form: 1) CO<sub>2</sub> ice needs to be preserved at the top of the dune until the beginning of spring, 2) the rest of the dune needs to defrost and heat up to induce sublimation of the CO<sub>2</sub> ice once it has started to move downslope, and 3) the dunes need to be made of material that is fine enough to be propelled away from the block and form levees. The first two conditions should limit the formation of linear gullies to south-facing concave slopes at the beginning of spring, which is also where and when activity in these gullies is observed.