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# Re-analysis of martian gully orientation and slope for comparison with climate model predictions of freeze-thaw and dry-ice sublimation.

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Gullies on Mars are kilometre-scale landforms, comprising an erosional alcove and channel and a terminal debris apron/fan. These landforms are similar to features on Earth carved by the flow of liquid water, or by the action of water rich debris flows. The majority gullies on Mars are believed to be (at most) ~5 Ma old and both erosion and deposition within these features have been observed within the last 10 years of orbital observations. At present liquid water is not thermodynamically stable at the martian surface and many of the recent changes in surface morphology occur during winter and early spring, when temperatures are too low for even metastable liquid water to be produced. Therefore, researchers have proposed an alternative mechanism for gully-formation - the sublimation of solid $CO_2$, which is deposited on the maritan surface every winter.

Previous studies have revealed that gully-density and orientation varies systematically with latitude – a fact that led to the development of many climate-based hypotheses for their formation. Here, we use the global database of martian gullies and extract the orientation and slope-angle of gully-hosting-slopes. We find that gully-orientation is more even strongly controlled by latitude than previous studies, where more sparse data were used. From ~30-40° latitude in both hemispheres, gullies are almost never found on equator-facing slopes, and polewards of 40° gullies have a tendency to be located on equator-facing slopes.

We use a 1D version of the LMD Mars climate model physics to simulate surface temperature on slopes up to 35°, oriented to face north or south, for all latitudes (5° spacing), and for orbital obliquities of 5-55°. We otherwise use current orbital conditions (ellipticity, date of perihelion) and we use a constant thermal inertia of the substrate of 1000 $Jm^{-2}K^{-1}s^{-1/2}$and a bare soil albedo of 0.2. We extracted two pieces of information from a complete annual cycle: (i) The number of hours during which the surface temperature was below the $CO_2$ condensation point of 149K. We use these data as a proxy for where $CO_2$sublimation processes can be active. (ii) The number of sols for which the daily minimum is below 273K and the daily maximum is above 273K. We use these data as a proxy for where ice could be stable and then melt during freeze-thaw cycles.

Our results reveal that neither of these simple modelling cases exactly fits the observational data, therefore we conclude that it is likely that a mixture of $CO_2$ and water related processes are responsible for forming martian gullies. We aim to perform a number of tests to assess both the applicability of these simple proxies and to test a wider range of substrate properties (buried ice) and orbital parameters (perihelion and increased atmospheric pressure at high obliquity) to see if they give better fits to our observations.