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The seasonal evolution of ices on the gullied slopes of Sisyphi Cavi on Mars using CaSSIS and HiRISE orbital images

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Gully systems on Mars were first reported by Malin and Edgett (Science, 2000) and because of their similarity to gullies on Earth were attributed to the action of liquid water. They are generally kilometre-scale systems where tributary alcoves lead into channel(s), which terminate in digitate deposits and/or fans. They are found on almost all steep slopes polewards of 30°N/S and are oriented towards the pole in the interval 30-40°, then occur on all slope-orientations >40° (e.g. Conway et al. 2019). Their latitudinal distribution and trends in orientation are strong indicators of a climatic factor playing a pivotal role in their formation. Repeat orbital observations have revealed changes in up to 20% of monitored gully systems (Dundas et al. 2019). When the timing of the changes can be constrained, they occur at the end of the seasonal defrosting period when carbon dioxide ice is present at the surface rendering the temperatures too cold for liquid water to be involved (Dundas et al. 2015, 2019; Pasquon et al., 2016, 2019a,b; Raack et al. 2015, 2020). Some changes involve resolvable quantities of sediment, including motion of metre-scale boulders and erosion of new channels (Dundas et al. 2015; de Haas et al. 2019; Pasquon et al., 2019a).

Here, we exploit an exceptional time series to monitor the evolution of gullies and the seasonal frost deposits in Sisyphi Cavi (68-74°S, 345°-5°E). We use image data from HiRISE (High Resolution Imaging Science Experiment; 0.25-1 m/pixel), CaSSIS (Colour and Stereo Surface Imaging System; 4.5 m/pixel) and CTX (Context; 6 m/pixel). CaSSIS has four colour filters: BLU, PAN, RED and NIR (centred on 500, 675, 836 and 937 nm respectively); where the BLU filter is particularly useful for picking up surface frosts (Tornabene et al. 2019). We find that gullies and dunes are the last surfaces to defrost in the area. Independent of slope-orientation the alcoves of the gullies defrost first, followed by their channels then their fans. A surprising result considering that intuitively defrosting should progress from the equator-facing alcoves to the equator-facing fans, then from the pole-facing fans to the pole-facing alcoves. We infer that this is a consequence of a) fans and alcoves having contrasting thermal inertia and b) alcoves having slope-facets with a range of local orientations (with some proportion being equator-facing independent of overall orientation).

We observe dark spots, dark flows and dark fans at the metre-to-ten-metre-scale. These features occur when a continuous solid slab of translucent CO2-ice is penetrated and warmed by sunlight at its base. The sublimation drives gas build-up under the slab, ruptures it, entraining dust and then depositing the dust on the surface (e.g. Kieffer et al. 2006) to form spots, flows and/or fans, depending on the context. We find that the recent activity of gullies promotes the formation of dark spots/flows/fans and are investigating the inverse relationship.

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