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How much liquid water was there on Martian dunes?

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Presently, liquid water unlikely to be found on the surface of Mars because of atmospheric pressure/temperature conditions below water's triple-point. However, gullies discovered by Malin and Edgett (2000) suggest that significant amounts of liquid water has flowed on Mars in the recent past. These gullies are among the youngest features on Mars based on the scarcity of cratered gullies (Heldmann et al., 2007) and their superposition on relatively young formations such as dunes. Several hypotheses have been suggested for the formation of gullies: (i) runoff and debris flows with liquid water from groundwater aquifers (Heldmann and Mellon, 2004; Malin et al., 2000), (ii) snow-melt (Christensen, 2003; Dickson et al, 2007), (iii) liquid CO_2 breakout (Musselwhite et al., 2001), (iv) melting of near-surface ground ice (< 1 m meter) at high obliquity (Costard et al., 2002), (v) geothermal-heated aquifers (Gaidos, 2001; Hartmann, 2001), (vi) the presence of brines (Knauth et al., 2000; Knauth and Burt, 2003).

This study focuses on gully morphologies on the Russell megadune (54.5°S; 12.7°E) and in Kaiser crater (46.2°S; 19.1°E) using High Resolution Imaging Science Experiment (HiRISE) images and Digital Terrain Models (DTM). Gullies on terrestrial sand dunes are rare, and their presence on Mars, as well as their mechanical properties, and the quantity of fluid required for their formation currently remain misunderstood. Based on the scenario of ground ice melting in a periglacial environment, we propose to test the hypothesis that Martian gullies on dunes were triggered by the presence of liquid water. The calculated results for Martian gullies are consistent with terrestrial studies on debris flows. Based on a morphological description and on the estimated physical parameters, we propose a model for gully formation on Martian dunes. The melt water from near-surface ground ice is incorporated in the debris flow and water concentration increases during its propagation. The increase of water concentration in the debris flow can be explained by a progressive increase of water/ice content in the permafrost downslope. Consequently, the lack of a final deposit at the front of some gullies tends to demonstrate that the flow became relatively highly concentrated in liquid downstream and all the water could have been lost in the final stage of the flow. Here we quantify the quantity of liquid necessary to form such a morphology.