THE ELEVATION DISTRIBUTION OF MID-LATITUDE GULLIES ON MARS AS A TEST OF CO2 AND H2O FORMATION AND MODIFICATION PROCESSES. J. L. Dickson[1], A. M. Palumbo[2], J. W. Head[2], L. A. Kerber[3], C. I. Fassett[4], M. A. Kreslavsky[5] [1]Caltech, The Murray Lab, Pasadena, CA, USA (jdickson@caltech.edu), [2]Brown University, Providence, RI., [3]Jet Propulsion Laboratory, Pasadena, CA, [4]Marshall Space Flight Center, Huntsville, AL, [5]U.C. Santa Cruz, Santa Cruz, CA.

Introduction: Geologically-recent gullies on Mars exhibit morphologies that resemble H_2O-carved channels and debris fans on Earth [1]. Their distribution is well-constrained in latitude and slope orientation [2], suggesting a relation to climate; however, they are found at high elevations where liquid H_2O is not possible at these locations in the current climate [2-3]. Modification of existing gullies is usually temporally associated with seasonal solid CO_2 sublimation [4-5], suggesting that gullies could form from dry processes, with gully channel deepening due to H_2O sublimation [6].

Mapping of gully activity at high-latitudes shows that contemporary erosion of gully channels is rare. In Sysyphi Cavi, ~98.3% of gullies show no activity, more than half of events are isolated non-erosive boulder movements, and no gullies experienced mappable channel erosion [7], despite occurring where CO_2 jet processes are common [8]. Current activity appears capable of mobilizing loose sediment on steep slopes [4-5], but erosion through ice-cement has not been documented.

It has long been suggested that gullies may have been primarily eroded during Mars' most recent high-obliquity periods [9-12]. At 35° obliquity the mid-latitudes experience net accumulation of H_2O in the form of the latitude-dependent mantle [9, 13-14], an ice-cemented layer that is a potential source for the fluid that carved them [11]. Pasted-on terrain was once at least 20m thicker than present at some locations [15], consistent with predictions of net depletion of near-surface H_2O-ice in the mid-latitudes in the current low-obliquity regime [9]. At 35° obliquity, massive CO_2 slabs currently within the South Polar Residual Cap would sublimate [16] and double the current atmospheric density [17]. This would alter the map of where conditions (atmospheric pressure at the surface and surface temperature) above the H_2O triple point are achieved and therefore metastable liquid water can potentially exist. Aiming to assess where these conditions can be met, we used the 3D LMD GCM [19] to simulate three obliquity values that Mars has experienced in the last 1 million years and assumed present-day eccentricity. Each scenario was performed twice: once with perihelion at northern summer solstice and once with perihelion at southern summer solstice.

Results: At 35° (630K years ago) [20] minimum conditions for melting are achieved at nearly all gully sites in each hemisphere. Each hemisphere experiences increased H_2O-ice accumulation in the mid- and high-latitudes that are recorded in our model. At high latitudes, several gullies are not predicted to surpass the triple point due to H_2O-ice covering being present year-round, thus pinning the surface temperature at 273K; at all other gully locations, conditions above the triple point are achieved.

More than ¾ of gullied landforms on Mars (78.4%) occur between 25°S and 50°S [18], and all of these locations achieve potential melting conditions with 98.2% of them surpassing the triple point for >10% of the year when perihelion occurs during southern summer at 35° obliquity. This latitude range also hosts the highest elevation gullies on Mars, along the southern margin of the Thaumasia Highlands (Fig. 1), and these all experience conditions above the triple point. Our model predicts a rapid increase in potential melting conditions when descending across the ~4500 m contour. The summit of the Warrego Valles watershed experiences potential melting conditions for ~0.6% of the year, while the adjacent lower plains to the south experience melting conditions for ~13.6% of the year (Fig. 1), among the highest values for gullied terrain in the southern mid-latitudes.

This steep gradient between conditions above and below the triple point, defined by the ~4500 m contour, can be traced around the southern extent of the Thaumasia Highlands for ~1700 km and corresponds with the upper elevation extent of gullies on Mars [18]. The abrupt termination of gullies at the ~4500 m contour is challenging to explain by CO_2 processes alone. The cutoff of gullies at ~4500 m is well explained by the metastability of H_2O at high-obliquity, if hyper-localized conditions beyond the resolution of our model are conducive to melting of surface ice, as well. The greatest impediment to meltwater at these locations is the energy loss due to sublimation driving surface temperatures down at ice surfaces, which would require optimal topographic geometries at landform [21] and boulder [22] scales to preserve ice before rapid heating due to exposure to direct insolation, followed by energetic boiling.

Liquid water that boils [23] explains the abrupt high-elevation cutoff at ~4500 m (Fig. 1) and why stratigraphically lower well-preserved gully channels and fans have not been erased by ongoing processes [5-6]. Both CO_2 [5] and H_2O [24] undergo phase transitions today, producing rare [7] localized [5] modifications to existing gully systems, but this does not require erosion through material with strength. Melting and boiling of heavily-sheltered H_2O ice at high-obliquity provides a more energetic mechanism to achieve gully erosion, consistent with the elevation distribution of gullies within the southern highlands.

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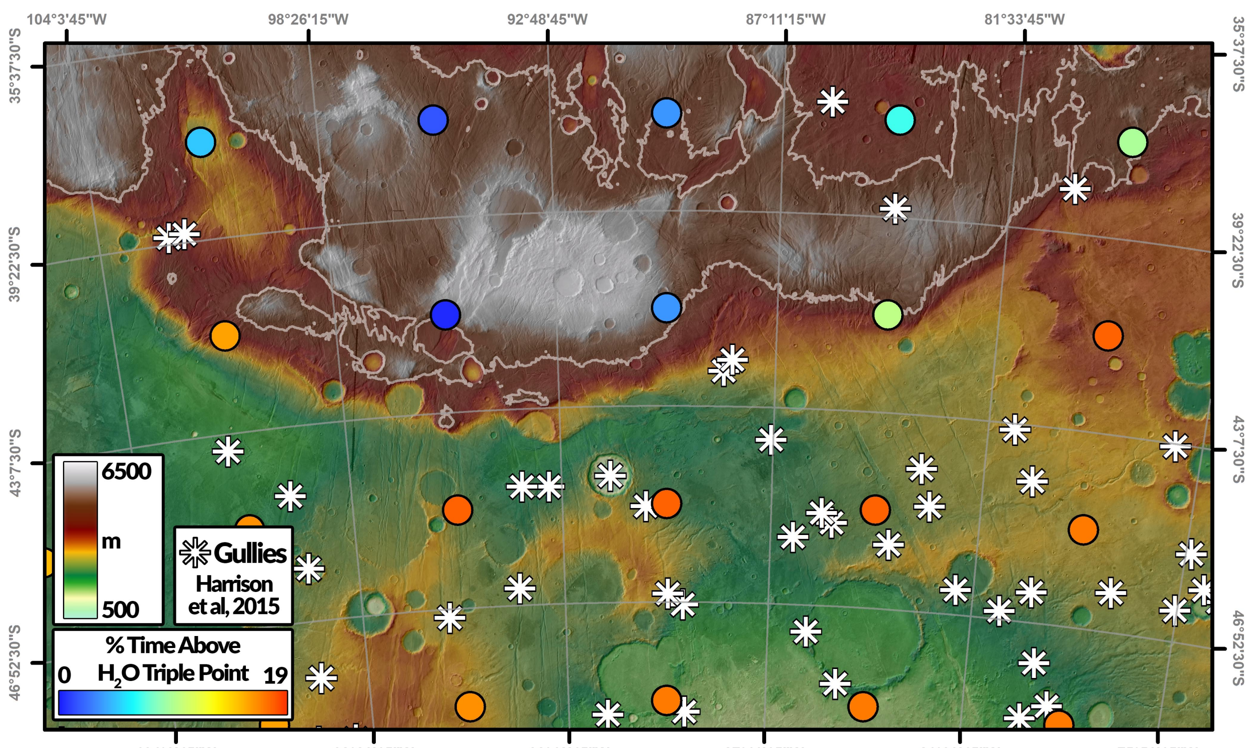

Figure 1. Distribution of gullies (white stars [18]) with 35° obliquity GCM simulation results (colored dots; gridlines represent GCM cell boundaries) that show extensive of periods of the Martian year above the H_2O triple point in the same regions as where gullies are found along the southern margin of the Thaumasia Highlands. Gullies are not observed above the ~4500 m contour. Our models predict minimal time above the H_2O triple point but extensive CO_2 ice emplacement and removal.