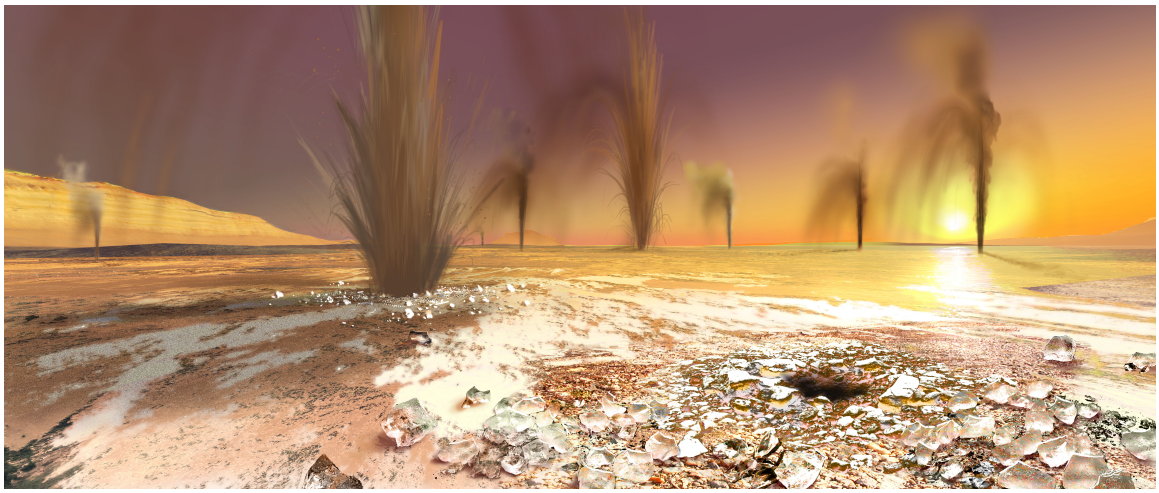
Extensive surface change triggered by seasonal CO_2 frost

Seasonal cycling of surface volatile deposits (mostly CO_2 with some water) on Mars have been known since early telescopic observations, and early orbiters documented seasonal changes in the appearance of those deposits. It has been determined in recent years, however, that seasonal CO_2 frost is capable of triggering significant geomorphologic modifications that leave records within martian landforms, often by counterintuitive mechanisms: erupting plumes of venting CO_2 gas sublimating from beneath seasonal CO_2 slabs in the polar regions during the defrosting phase have been proposed to explain "spider-shaped" markings on the surface of Mars. The markings are comprised of meter-scale-wide, dendritic trough features that collectively produce a persistent patterned ground labelled as araneiform terrains in the southern hemisphere (with temporally corresponding furrows in the northern hemisphere). These features are estimated to a minimum age of ~1,300 martian years, and many are found in association with sand dunes, leading researchers to consider how sand might assist in the scouring process.

Recently, linear gullies on sand dunes, originally thought to be the result of flow processes, have been found in High Resolution Imaging Science Experiment (HiRISE) images to be active during the winter, when water will be present only as ice, and associated with CO_2 frost blocks. The linear gullies are characterized by levéed grooves and terminal pits. An intriguing observation of the displacement of meter-scale CO_2 blocks – perhaps released from dune crests as overhanging CO_2 cornices are eroded by wind and sublimation – suggests that linear gullies form as moving blocks slide or roll down slopes, buoyed by their own venting gas over the warmer sand. This "hovercraft" process has been dramatically reproduced in analog studies using CO_2 blocks on terrestrial dune slopes where even shallow slopes permitted the block to move downslope, carving out a shallow track. Sublimating CO_2 blocks found within linear gullies can also explain the pit features if the sublimation is energetic enough to excavate sand surrounding a stationary block. This seasonal and distinctly martian phenomenon continues to be studied. Martian gully landforms (hourglass-shaped features not to be confused with linear gullies) also undergo activity that appears to be associated with seasonal CO_2 frost occurrence, but the geomorphologic process by which the CO_2 may initiate or sustain the large-scale movement of material or erode into bedrock has not yet been determined.

These observations remind us that Mars has two volatiles, water and carbon dioxide, that can affect the surface environmental conditions during martian history. Previous interpretations of several martian landforms are thus being revisited in light of our new understanding. Recent analysis of surface temperature has suggested that CO_2 frost forms overnight even at low latitudes in dusty areas with low thermal inertia. While these deposits are very thin and vanish with the rising Sun, they may affect regolith cementation, maintaining surface properties conducive to reaching frost-point temperatures, even near the equator. Further study of these active landforms and determination of their formation processes will enable geomorphic studies to contribute significantly towards a quantitative understanding of present-day conditions and processes at the martian surface.



Sand-laden jets shoot into the polar sky in this view by noted space artist Ron Miller. It shows the Martian south polar icecap as southern spring begins. (Image Credit: Arizona State University/Ron Miller).

Diniega, S., C. J. Hansen, J. N. McElwaine, C. H. Hugenholtz, C. M. Dundas, A. S. McEwen, and M. C. Bourke (2013), A new dry hypothesis for the formation of martian linear gullies, Icarus, 225(1), 526-537, doi:http://dx.doi.org/10.1016/j.icarus.2013.04.006.

Portyankina, G., C. J. Hansen, and K.-M. Aye (2017), Present-day erosion of Martian polar terrain by the seasonal CO_2 jets, Icarus, 282, 93-103, doi:http://dx.doi.org/10.1016/j.icarus.2016.09.007.

Piqueux, S., S. Byrne, and M. I. Richardson (2003), Sublimation of Mars' southern seasonal CO_2 ice cap and the formation of spiders, Journal of Geophysical Research-Planets, 108(E8), doi:10.1029/2002je002007.

Piqueux, S., and P. R. Christensen (2008), North and south subice gas flow and venting of the seasonal caps of Mars: A major geomorphological agent, J. Geophys. Res., 113, E06005, doi:10.1029/2007JE003009.

Piqueux, S., A. Kleinböhl, P. O. Hayne, N. G. Heavens, D. M. Kass, D. J. McCleese, J. T. Schofield, and J. H. Shirley (2016), Discovery of a widespread low-latitude diurnal CO_2 frost cycle, and implication for dust mobility on Mars, J. Geophys. Res. Planets 121, 10.1002/2016JE005034.

Dundas, C. M., S. Diniega, and A. S. McEwen (2015), Long-term monitoring of martian gully formation and evolution with MRO/HiRISE, Icarus, 251, 244-263, doi:10.1016/j.icarus.2014.05.013.

Hansen, C. J., S. Diniega, N. Bridges, S. Byrne, C. Dundas, A. McEwen, and G. Portyankina (2015), Agents of change on Mars' northern dunes: CO_2 ice and wind, Icarus, 251, 264-274, doi:10.1016/j.icarus.2014.11.015.

Kieffer, H. H., P. R. Christensen, and T. Titus (2006) CO_2 jets formed by sublimation beneath translucent slab ice in Mars' seasonal south polar cap ice, Nature, 442, 793-796, doi:10.1038/nature04945.

Pilorget C. and Forget F. (2016) Formation of gullies on Mars by debris flows triggered by CO_2 sublimation. Nature Geoscience, 9, 65-69.