MARS GULLY SLOPE CONSTRAINTS FOR SUBLIMATION-INDUCED GRANULAR FLOWS. M. E. Sylvest[1], S. J. Conway[2,3], M. R. Patel[2,4], J. C. Dixon[1], [1]Arkansas Center for Space & Planetary Sciences, Fayetteville, AR (msylvest@uark.edu), [2]Department of Physical Sciences, Open University, Milton Keynes MK7 6AA, UK, [3]LPG Nantes – UMR CNRS 6112, Université de Nantes, France , [4]Space Science and Technology Department, STFC Rutherford Appleton Laboratory, Oxfordshire OX11 0QX, UK, [5]Center for Advanced Spatial Technologies, University of Arkansas, Fayetteville, AR.

Introduction: The role of CO_2 in Mars gully evolution, and formation, is suggested by interpretation of a growing body of observational evidence [1–3]. Recent thermo-physical modeling [4, 5] provides a physical mechanism supporting these interpretations, and consistent with our experimental simulations demonstrating the ability of sublimating CO_2 frost to mobilize regolith under Martian atmospheric conditions [6].

Here we present experimental results constraining the minimum static slope angle for JSC Mars-1 regolith simulant, which may be mobilized the by sublimation of CO_2 surface frost, under current Martian environmental conditions.

Approach: We condensed CO_2 frost, *in situ*, on a slope of JSC Mars-1 Mas regolith simulant. Subsequently, we induced sublimation of the frost by radiant heat, supplied by a 500 W heat lamp mounted above the slope, Fig. 1. Regolith activity was recorded with a matched pair of high definition video cameras, throughout the sublimation procedure, for photogrammetric analysis. See Sylvest et al. [6] for a more detailed description of the apparatus, procedure, and photogrammetric techniques used.

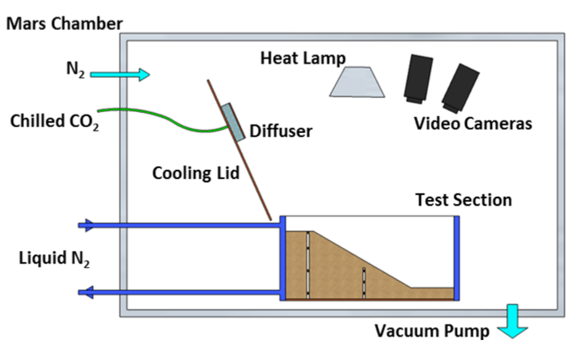

Fig. 1: Schematic diagram of test section layout, with relative positions of test section, pivoting cooling lid, heat lamp and cameras.

Initial Results: We performed 17 experimental runs with JSC Mars-1 regolith simulant slopes, at initial slope angles of 10° to 30°.

10° Initial Slope Angle: 1 Run. Jetting, entrainment of dust by escaping subsurface gas, was present at both near-surface thermocouples (Fig. 1). The slope surface appeared to relax, settling 1 – 3 mm downslope, in response to retreating surface frost. No discrete mass flows were observed.

15° Initial Slope Angle: 3 Runs. As for the 10° run, jetting was present at near-surface thermocouples, and surface relaxation followed frost retreat. However, 1 – 3 discrete mass flows were observed in all three runs, from 1 – 95 min. into the sublimation process. These flows were approximately 1 – 3 mm deep, 10 – 60 mm in dia., with 10 – 30 mm runout. Jetting also ensued in an area exposed by a mid-slope flow.

17.5° Initial Slope Angle: 4 Runs. Jetting was present at near-surface thermocouples. Surface relaxation followed frost retreat. Each run exhibited hundreds of mass flows from 2 – 100 min. from the start of sublimation. These flows were similar in size to the 15° runs, except max. runouts were much larger ~280 mm. Flows with runouts > ~30 mm stirred clouds of dust, some filling the lower half of the test section. Jetting was also observed at the slope toe, as gas escaped through flow deposition. In one run, three ice chunks (2 ~4 mm dia. & 1 ~5 × 10 mm) slid downslope. The two smaller chunks left visible, sinuous trails, ~90 & 180 mm long, on the slope surface. While the large chunk only slid ~15 mm, it did leave behind a slightly curved channel with 1 – 1.5 mm high levees, Fig. 3.

20° Initial Slope Angle: 3 Runs. As for the 17.5° runs, jetting was active at near-surface thermocouples, and became active at the slope toe as flow deposition accumulated. Surface relaxation was more prominent for these runs than any other, moving downslope as much as 20 mm or more, in some instances. At times, relaxation transitioned into locally discrete flows, creating 1 – 6 mm scraps, as they divided from the initial mass. Fewer mass flows are observed than for all lower initial run angles; however, the larger (1 – 6 mm deep, up to 110 mm dia., with runouts to ~220 mm) flow appear to move comparable volumes of regolith.

30° Initial Slope Angle: 5 Runs. Jetting was only observed at the slope toe, after flow deposition accumulated, when it was apparently more vigorous than at lower initial angles. As surface frost retreats, the slope immediately fails, with no observable relaxation phase. The apparent number of mass flows is consequently more comparable to 17.5° runs, than the 20° runs. Most of the flow activity occurs in the first 20 min. of sublimation [6], but continues to a max. of 110 min. Flows sizes were consistent with 17.5° and 20° runs, but with runouts up to ~240 mm. Only 1 – 2 flows generated noticeable dust clouds; although, some clouds completely filled the test section.

Observations for 30° runs: At the crest of the profile, slope-angles were retained, but in both the mid-slope and basal areas, the slope declined over the course of the experiment (Fig. 2). The configuration of the regolith inside the test section did not allow all grain-flows to self-terminate; hence, material built up at the base of the profile (Fig. 2). However, the top of the slope maintained a steep angle, which means the process is not self-terminating; with recharge of CO_2, it could continue.

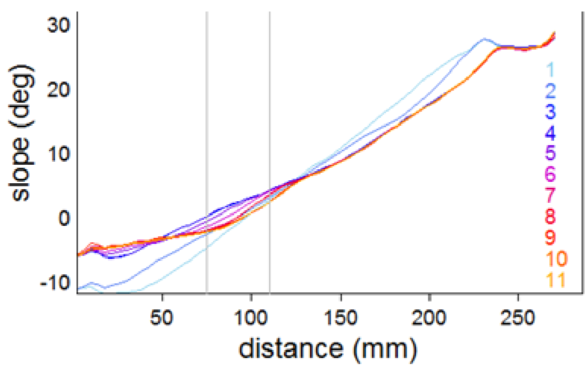

Fig. 2: Topographic long profiles for a 30° initial slope angle run.

Conclusions: Our experiments reveal that sublimation-induced motion can occur at angles much lower than the nominal angle of repose. We do not expect these exact angular limits to apply on Mars, due to the difference in gravitational acceleration; however, this observation shows that the CO_2 sublimation process is feasible beyond the domain of gravity triggered granular flows. Therefore, sublimation could be a more common process on Mars than previously though.

References: [1] Dundas, C. M. et al. (2015) *Icarus* 251, 244–263. [2] Diniega, S. et al. (2013) *Icarus* 255(1), 526–537. [3] Raack, J. et al. (2015) *Icarus* 251, 226–243. [4] Pilorget, C. and Forget, F. (2015) *NGEO* 9, 64–69. [5] Cedillo-Flores, Y. et al. (2011) *Geophys. Res. Lett.* 38(21). [6] Sylvest, M. E. et al. (2015) *LPSC XLVI*, Abstract #2667.

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Fig. 3: Example slope surfaces after sublimation procedure. Left to right, panels are 10°, 15°, 17.5° & 30° initial slope angle runs.