EXPERIMENTAL ANALYSIS OF CO_2 SUBLIMATION AND MARTIAN GULLY MORPHOLOGY.

R. C. Leone[1], M. E. Sylvest[2], and J. C. Dixon[2], [1]Colorado School of Mines, Golden, CO, [2]Arkansas Center for Space & Planetary Sciences, University of Arkansas, Fayetteville, AR.

Introduction: CO_2 frost is speculated to play a role in the formation of Martian gullies [1]. Theories include CO_2 frost acting as an avalanche, dry granular flows of CO_2 block ice, or the ground collapsing on liquid CO_2 aquifers [1,2]. Martian gullies usually occur around mid-latidudes and are often pole facing, especially in the southern hemisphere [3,4]. Martian gullies display distinct morphological features such as an alcove at the head of the gully followed by a channel and debris apron fan at the end [5]. Martian gullies are also known to be geologically young and active [6,7]. An observational analysis was performed on several simulations in order to determine the behavior of Martian slopes when subjected to CO_2 ice sublimation.

Methods: A copper box with sloping sides that was 15 cm wide, 30 cm long, and a height of 13 cm was used as a test section (fig 1). The test section was filled with an approximately 10 cm high column of JSC Mars-1 regolith simulant. The regolith was angled in order to create a slight slope. The regolith was then lightly covered with crushed CO_2 ice and placed in a cold room at approximately 4° C, under a 150 W Halogen lamp. Two webcams were placed above the test section, along with one camcorder at an oblique angle in order to record the experiment. Five thermocouples were placed in the regolith at various depths and one temperature/humidity probe was placed above the test section. Several experiments were run, each lasting from 30-60 minutes, until most observed surface activity had ceased. For some experiments a small wedge was placed under the back of the test section in order to create a steeper slope. Some experiments were also overlain with a mix of CO_2 ice and regolith simulant. The amount of CO_2 ice used was also varied for each experiment.

Photogrammetry: The test section was calibrated by placing 14 control points with a fine point marker around the rim of the box which established the Cartesian corrdinate system for the slope surface relative to the test section. After the experiments were run, stereo image pairs were taken from the webcam videos capturing important mass wasting events, and at several time intervals. The stereo pairs, along with the control point coordinates, were then imported into photogrammetry software to generate Digital Elevation Models (DEM), which were used to analyze the experiments. The DEMs were imported into GIS software where several maps such as the slope, direction, curvature, and elevation changes were generated using a python script.

Figure 1: Test section with regolith and water frost.

Results & Discussion: Multiple surface activities were observed throughout the experiments. Experiments where the test section was steepened showed the most mass wasting, including a small avalanche (fig 2). Experiments with less CO_2 ice placed on the slope showed less slope movement and less changes in morphology. In addition to several small granular flows, the CO_2 ice slumped rather than just subliming.

Figure 2: In this experiment a steeper slope resulted in a small avalanche.

Two experiments showed an approximately 1.3 cm range of elevation change (fig 3). Overall, the maximum total elevation change was 1.57 cm. The observed avalanche resulted in several morphological changes to the slope, such as a small gully-like alcove and debris apron (fig 4).

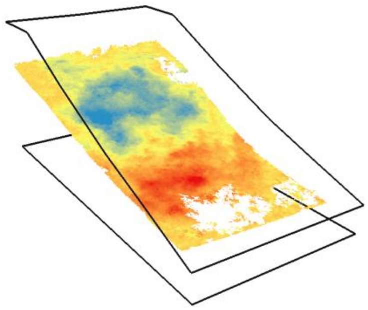

Figure 3: DEM of the elevation change. Blue represents decrease in elevation and red increase.

The slope surface morphology changes can be seen when mapped over time intervals. The last and first time intervals are shown in Figure 4. The maps represent the role of CO_2 sublimation in causing a concentrated area of steep slope angles in the middle of the test section. A significant number of granular flows were observed in this area. This avalanche also created a small debris fan at the end of the slope, similar to debris aprons seen on Martian gullies.

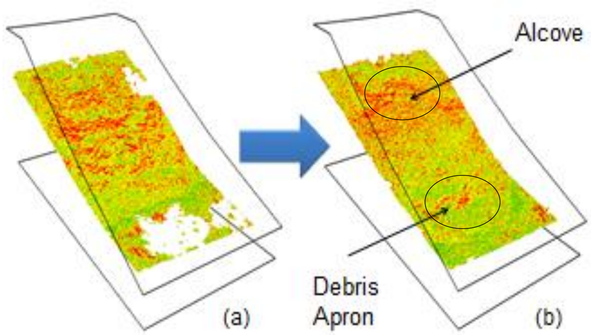

Figure 4: DEM of the slope at the first time interval (a) and the last time interval (b).

The slope and elevation change were calculated on the area in the middle of the test section where the most activity occured. This was done by calculating the mean over several squares on a grid. The normalized mean values are graphed over three time intervals in figure 5, with elevation change as the independent variable.

The graph (fig 5) shows that a steeper slope was observed in the area where the elevation decreased. This corresponds to when the CO_2 ice sublimated or where there was a mass wasting event. The graph also shows how the shallower slopes are mostly where the elevation increased, where the mass wasting was deposited. This correlation was especially seen at the later time intervals and is portrayed in the graph by the increasing slope between the two variables with time. These observations suggest that as the CO_2 ice sublimated, it caused the slope morphology to change, creating the alcoves and aprons seen in the DEM.

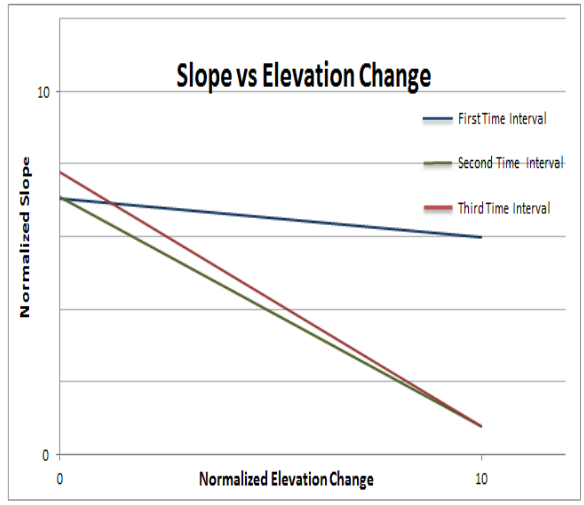

Figure 5: Correlation between elevation change and slope. Note increasing slope with time.

Conclusion: Overall, when the test section had a significant amount of CO_2 ice and was subjected to a steeper slope, sublimation of CO_2 caused mass wasting events and several observed gully morphological characteristics such as alcoves and debris fans. For steeper inital slope angles, increased CO_2 sublimation resulted in local steepness of the the slope. Therefore, sublimation caused steeper slopes while deposition due to mass wasting resulted in shallower slopes. Further work is needed to understand the rate of slope movement and what effect changes in humidity and temperature have on this rate, and the formation of gully morphology.

References: [1] Billingsley, L. (2007) *Proquest Dissertations and Theses*, 1151–1154. [2] Dundas, C. et al. (2012) *Icarus, 220*, 124-125. [3] Heldman, J. et al. (2004) *Icarus, 168*, 285-287. [4] Diniega, S. (2013) *Icarus, 225*, 526-529. [5] Malin, M and Edgitt, K. (2000) *Science, 280,* 2330. [6] Lanza, N. et al. (2010) *Icarus, 205*, 103-105. [7] Kneissl. T. et al. (2010) *Earth and Plantary Science Letters, 294,* 357-359.

Acknowledgements: This project was funded by NSF grant #1157002. We thank C. Owens for laboratory space. Also, thank you A. Barnes, B. Johnston, for advising and providing photogrammetric instrumenttation, and Center for Advanced Spatial Technologies for office space. Also the University of Arkansas REU program.