ROUGHNESS OF SURFACES IN THE ETHIOPIAN DANAKIL FROM REMOTE HANDHELD IMAGE SURVEYS. Rudger H. Dame[1], Jani Radebaugh[1], Ralph D. Lorenz[2], Samuel M. Hudson[1], [1]Department of Geological Sciences, Brigham Young University, Provo, UT (rudgerd@byu.edu), [2]Johns Hopkins University Applied Physics Laboratory, Columbia, MD

Introduction: Remote sensing, especially from Synthetic Aperture RADAR (SAR) imaging, can reveal the roughness of surfaces on the Earth and other planetary bodies. Various geological features and terrains are known to have unique, small-scale topography and can be identified by their roughness in SAR images at the scale of the RADAR wavelength [1, 2]. Validation of the relationship between radar reflectivity and geometric roughness (also relevant for eolian processes [3]) requires measurements in the field. Here we obtain multiple overlapping images with a handheld camera during the Europlanet 2018 campaign [4] to derive a 3D spatial model at several sites a few meters across in a particularly flat, arid region, the Danakil desert of Northeastern Ethiopia.

The presence of vast salt flats in this region from extension and ephemeral fluid filling means that the extensively flat surface may manifest in nonimaging microwave data (such as scatterometer and radiometer observations) to facilitate the interpretation of similar data from planetary missions.

Materials and Methods: A variety of sites across the Danakil were imaged using a handheld digital camera. To obtain local elevation variations at each site, a fiducial marker was placed on the surface and a series of photos were taken 360 degrees around the marker from shoulder height at two different distances from the marker, ~3 m and ~10 m (Fig. 1).

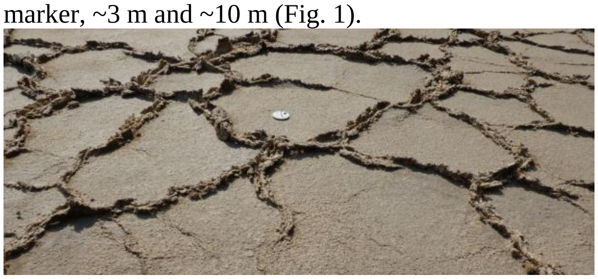

Figure 1: Image of Flat 9

Each image group was then loaded into the software program Agisoft PhotoScan Pro to create digital elevation models (DEM). The shadows that existed in some of the photos were subtracted from the image. The photos were then aligned in Agisoft to position and orient each photo to build a sparse point cloud model, from which a dense point cloud was then built. A coordinate system was created using the image marker, and using the size and shape of the marker, quantitative data could then be extracted from the photos to build an elevation model of each the different surfaces (Fig 2). After subtracting any slope plane from the surface, the dense (x,y,z) point cloud data was exported to MATLAB (Fig.3) to calculate the standard deviation of the z positions as a measure of roughness for each flat [1, 5].

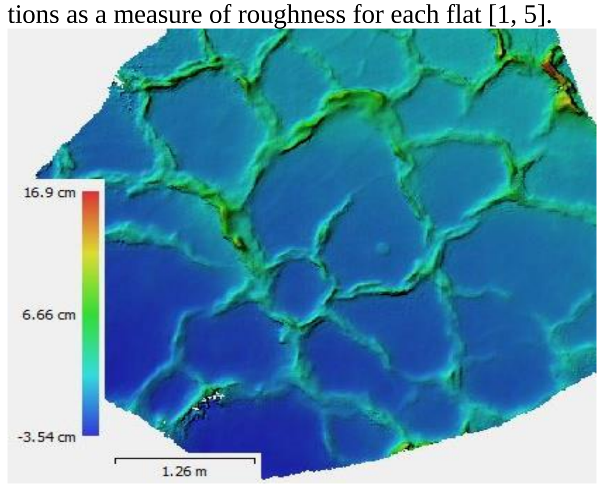

Figure 2: DEM of Flat 9 created in Agisoft PhotoScan.

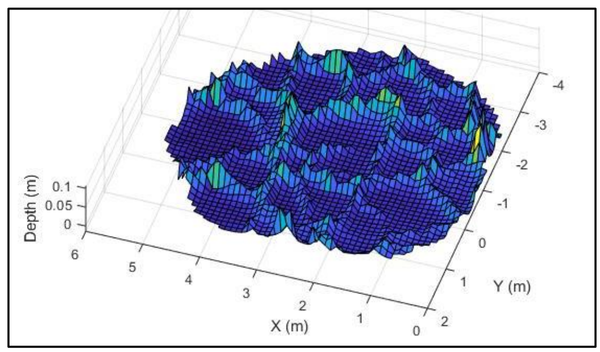

Figure 3: 3-D surface plot, made in MATLAB, using the point cloud of Flat 9.

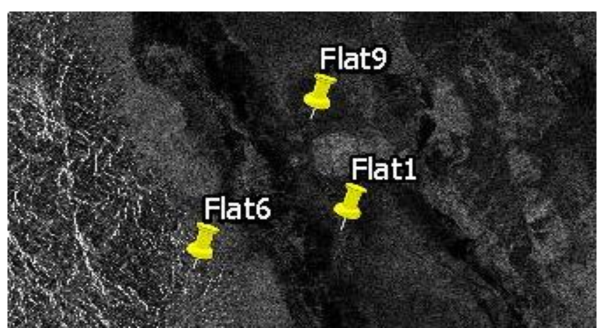

Figure 4: Sentinel – 1B SAR map of a subset of the studied regions in the Danakil Depression

Sentinel-1B SAR images were found of the Danakil Depression (Fig. 4) acquired during the same week in which the handheld images of the flats were taken. The Sentinel-1B images are C-Band frequency, which shows roughness at sizes of 4-7 cm. Raster values or roughness values for each flat were found using these SAR images.

Results: The results and data for four of the 17 studied flats analyzed to date are as follows:

Flat 1: A salt flat that appeared to be slightly rougher visually, and that had a height standard deviation of 0.45 cm (Fig. 5) and a radar C-band raster value of 137.

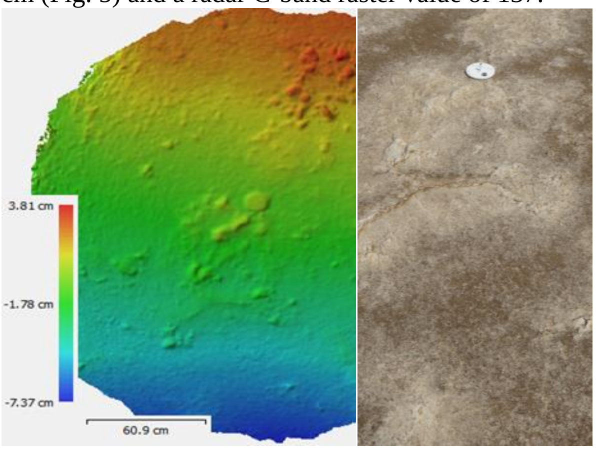

Figure 5: DEM and image of Flat 1.

Flat 6: A rocky, pebbled alluvial fan terrain that had a standard deviation of 2.01 cm (Fig. 6) and a raster value of 172.

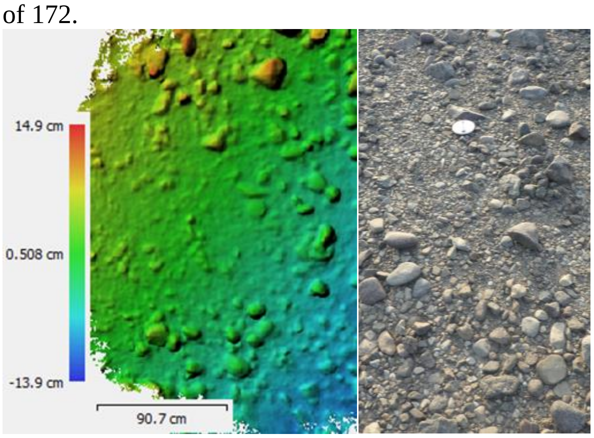

Figure 6: DEM and image of Flat 6.

Flat 9: A salt flat near and similar to Flat 1 with high polygon edges that had a higher standard deviation of 1.8 cm and a raster value of 107. Note the remarkably regular spacing of the ridges, and the very flat surfaces between – casual visual observations show strongly specular reflections from these surfaces at low sun elevations (Fig. 1, 2, 3).

Flat 11: A sandy flat that is generally smooth (Fig. 7) was found to have a height standard deviation of 1.11 cm and a raster value of 131.

Discussion: The roughness seen visually in the field correlates with the calculated roughness based on the DEMs that were made from images from the field. However, the roughness calculated based on the DEMs

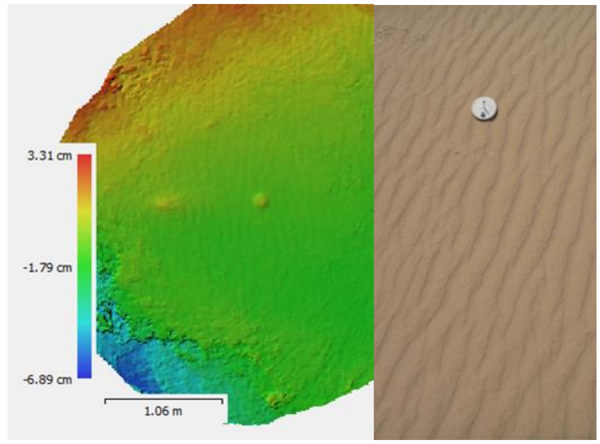

Figure 7: DEM and image of Flat 11

made from images taken in the field and the SAR roughness values in a few cases gave conflicting results. This inconsistency may be due to a few different issues. One factor could be that the method of calculating the height standard deviation of the DEM created from the handheld images assumes that the computer generated terrain is perfectly level. However, if this is not true, the surface may appear to more bright to radar. It also seems that flats with ripples or edges (Fig. 1, 2, 7) appear brighter in radar than what roughness calculations from the field would suggest. This is possibly due to the scattering surface (i.e., ripples or edges) facing the SAR instrument, sending back the radar signal to give the impression of roughness. The inconsistency may also be due to the wavelength range of the RADAR .

Conclusion: Preliminary research shows that the elevation models built from images of these flats in Ethiopia represent and quantify the roughness of the area well. If these roughness calculations are relevant to the geological processes of other planets then this study will give us a better understanding of locations on other planets that we see as flat in remote sensing imagery.

References: [1] Grohmann, C., Smith, M., and Riccomini, C.: Multi-scale Analysis of Topographic Surface Roughness in the Midland Valley, Scotland, IEEE Transactions on Geoscience and Remote Sensing, Vol. 49, pp. 1200-1213, 2011. [2] Campbell, D.B., Black, G.J. Carter, L.M., Ostro S.J.: Radar Evidence for Liquid Surfaces on Titan, Science 302, pp. 431-434, 2003. [3] Marticorena, B., et al., 2006. Surface and aerodynamic roughness in arid and semiarid areas and their relation to radar backscatter coefficient. Journal of Geophysical Research: Earth Surface, 111(F3), doi:10.1029/2006JF000462 [4] Radebaugh, J., R.D. Lorenz, R. Dame, L. Kerber, L. Bandeira, D. Vaz and G. Ori: Danakil Depression Flats as Analogues for RADAR-Smooth Surfaces of Titan, Mars and Venus, EPSC 2018. [5] Hansen, A.: Small-scale Surf Zone Geometric Roughness, Calhoun: The NPS Institute Archive, 2017.