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Danakil Depression Flats as Analogues for RADAR-Smooth Surfaces of Titan, Mars and Venus

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Abstract

Vast, extremely smooth and solid surfaces on Titan, Venus and Mars as seen by RADAR data have been erroneously interpreted as liquids. An analogue site on Earth is the large Danakil Depression of NE Ethiopia. We observed the characteristics and measured the roughness of 16 individual sites in the Danakil in the field and compared the results with satellite RADAR data. The SAR-darkest, or smoothest, regions are dominated by salt flats, firm surfaces generally flat on cm scales, or silty surfaces, while moderately SAR-dark surfaces have smaller salt polygons with rough margins. SAR-bright surfaces in the region are alluvial fans. This reveals the benefit of field studies for interpreting planetary remote sensing observations.

1. Introduction

The solar system has features with improbable characteristics. Radar observations of Titan made with the giant Arecibo radio telescope in 2002-2003 indicated areas on Titan that were tens of km across, but were 'smooth as parking lots' [1]. The simplest interpretation at the time was that these were areas of liquid – i.e. lakes. Subsequent observations by Cassini showed that these areas were solid after all. Additionally, at least one site on Venus showed a quasi-specular reflection in Magellan data [2].

Yet the fact that such large areas of solid surfaces can be so flat can be difficult to explain. An analogue area exists in the inhospitable Danakil Depression of Ethiopia. This region is a deep depression (below sea level) and is the site of rapid sedimentation fed by surrounding alluvial fans. Because it is a closed basin, it cycles climatically between containing ephemeral lakes and evaporite basins, or salt flats. Such regions are relatively flat over many tens of kilometers.

Although there have been in-situ studies of small regions of playas or salt flats (e.g. Death Valley) to compare with imaging radar data (sigma-0, at incidence angles of 15-40 degrees), the Dallol region offers a much larger target area (>10km) of incredibly flat, homogenous terrain that allows meaningful interpretation of nonimaging remote sensing data obtained at much lower spatial resolution, including nadir backscatter, and microwave emissivity. Such data are often obtained on planetary missions (notably, Magellan and Cassini as well as Mars missions) but comparable knowledge of terrestrial analogues does not exist because most locations are heterogeneous on spatial scales smaller than the instrument footprint.

2. Field Methods

We participated in the Europlanet field study of the Danakil and Dallol of Ethiopia in January 2018. Our field measurement campaign entailed the quantification of the microtopography (cm-scale roughness, using digital photography with geometric calibration – e.g. shadow bar and ruler) with a handheld digital camera held at shoulder height, walking around a ~25 m^2 area to obtain an image-derived DEM, at 16 sites in the Danakil. Our measurements also involved characterization of the composition via geological assessment and hand tool trenching. We compared these field measurements with PALSAR 50 m Synthetic Aperture RADAR (SAR) data for the region in L-band, or 15-30 cm.

3. Surfaces of the Danakil

Our field sites were selected based on their appearance in the field (Fig. 1) and their PALSAR characteristics (Fig. 2). Several regions were targeted because they appeared dark in the PALSAR data, which means they are smooth and return little SAR signal. While it is understood that these surfaces may change by flooding, these events are rare enough in this region that we assume the smoothness is a result of the generally present surface that we observed.

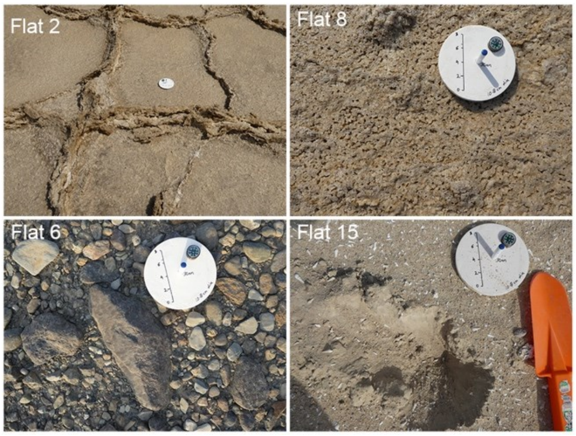

Figure 1: Select field survey regions discussed in text.

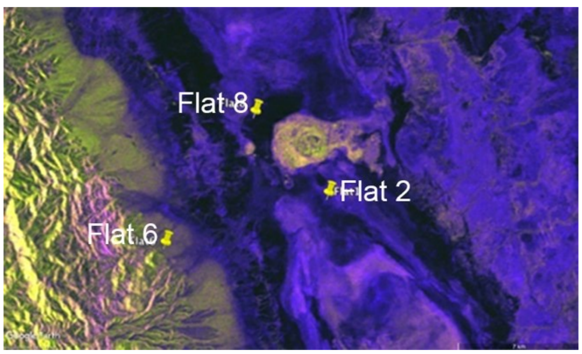

Figure 2: Location of the selected field sites discussed in the text as viewed on PALSAR image (other sites collected here are not shown in this image). Colors are for polarizations of the L-band SAR. Scale bar is 7 km.

Flat 2 was obtained at a salt flat just south of the Dallol hydrothermal area, regionally flat but with some SAR signal return (Figs 1 and 2). Rough edges of salt polygons may affect the signal return, or perhaps there is sub-surface roughness that is seen by the SAR as it penetrates some meters deep at those wavelengths (Fig. 1). Flat 8 was taken in an exceptionally SAR-dark region, where liquids can pond against the valley and the elevated Dallol region (bright circular feature at center of Fig. 2). This site is extremely flat on several to tens of cm scales (Fig. 1). Flat 6 is of an alluvial fan surface, and is noticeably rougher on several to tens of cm scales and is brighter in PALSAR (Fig. 2). Flat 15 was obtained in the south of the Danakil, in the Afdera region. This is a large, SAR-dark region composed of thick, powdery silt related to the retreat of the once larger Lake Afdera.

All regions have characteristics we might predict from a range of possibilities based on the SAR data. We may envision creating a database of possible surfaces that correspond to SAR signal return, so that these could be applied to different geological conditions on Earth and other planets. We are quantifying the roughness of the surfaces using field image-obtained DEMs through elevation profiles and surface height standard deviations [3]. We will quantify the PALSAR signal return sigma0, and will pair each of our 16 measured sites with these data to fully characterize the surfaces in the Danakil.

4. Summary and Conclusions

Our combined study of field measurements and remote sensing observations are providing a set of data against which both simple and sophisticated models of backscatter and emissivity of planetary surfaces can be validated, thereby paving the way for quantitative interpretation of planetary data such as that from Cassini and Magellan but also for potential future missions e.g. Envision.

Acknowledgements

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