EXPLORING THE INNER STRUCTURE OF TITAN'S DUNES: IMPLICATIONS FOR UNDERSTANDING PALEO-WIND REGIMES. P. Sharma[1] , E. Heggy[1,2], T.G. Farr[2] and J. Radebaugh[3], [1]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125; psharma@caltech.edu, [2]Jet Propulsion Laboratory, Pasadena, CA 91109; [3]Brigham Young University, Provo, UT 84602.

Introduction: Images taken by the Cassini Synthetic Aperture Radar (SAR), Visual and Infrared Mapping Spectrometer (VIMS) and Imaging Science Subsystem (ISS) have depicted the manifestation of aeolian or wind-driven processes at work, in the form of extensive dune fields in Titan's equatorial regions [1,2] (Figure 1). These near-parallel, radar-dark, longitudinal dunes on Titan have a typical spacing of ~1-2 km, with heights of ~100-150 m and lengths of many tens of kilometers.

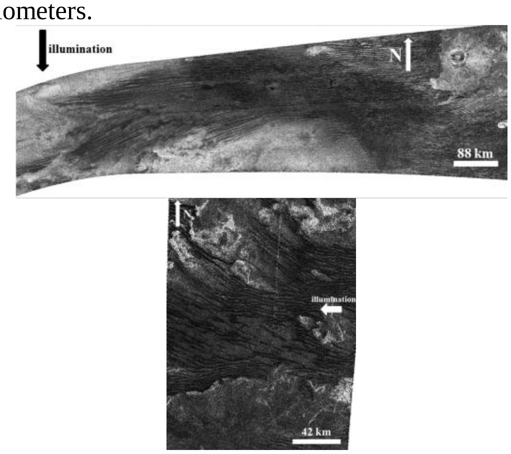

Fig. 1. Linear dunes on Titan observed in Cassini SAR swaths. Planetary photojournal images: (Top) PIA14500 centered at 11°N, 74°W; (Bottom) PIA11802 centered at 19.2°S, 257.4°W.

Although the geomorphology of the dunes has been studied from Cassini SAR images, it has not been possible to investigate their internal structure in detail as of yet. Layering in dunes is an indicator of multiple dune-forming episodes due to changing climate and wind regimes and can be linked to the age of the dunes [3]. The single polarization (HH), Ku-band (2.17cm), Cassini SAR data available for Titan [4], solely does not provide enough information to examine the shallow layering and, consequently, formation history of the dunes on Titan. In this study, we integrate multiple radar datasets, including SAR backscatter data for Titan's and Earth's dunes and Ground Penetrating Radar (GPR)/radar sounding data for terrestrial dunes to investigate the internal structure of Titan's dunes. We relate the SAR backscatter variation with elevation across terrestrial dunes to the layering inferred from radar sounding data. By comparing the backscatter variation with elevation for Titanian dunes with terrestrial dunes, we can deduce the layering and inner structure of the dunes on Titan.

Terrestrial Analog Site: For comparisons with Titan's dunes, we focus on three sites having linear dune fields in the Egyptian desert: 1) Great Sand Sea in central/south-western Egypt (~26.23°N, 26.73°E), 2) Siwa dunes in north-western Egypt (~28°N, 26.17°E) and 3) Qattaniya dunes in north-eastern Egypt; west of Cairo (~30.18°N, 30.2°E) (Figure 2). These large, linear dunes in the Egyptian desert have heights of 50-400 meters, spacing of few kilometers and lengths of ~100 km. They are thus comparable in size and morphology to the longitudinal dunes observed on Titan.

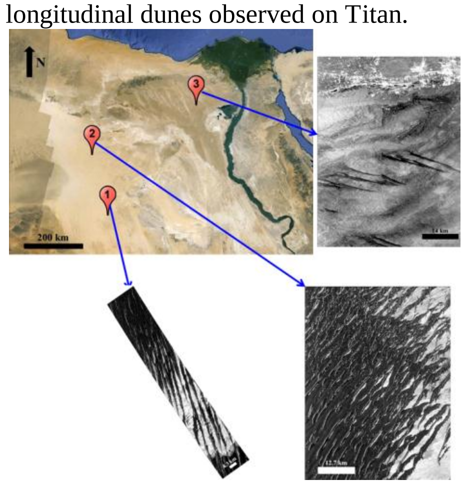

Fig. 2. Google Earth® visible imagery showing locations of three sites of analogous dune fields in Egypt. (1) Great Sand Sea (2) Siwa dunes (3) Qattaniya dunes. Corresponding SIR-C radar backscatter scenes are also shown.

SAR characterization of Titan's and Earth's dunes: For studying the dunes on Titan, we have used backscatter data from the Ku-band (2.17cm) Cassini RADAR instrument [4]. For the analog sites in Egypt, we used C-band (5.8cm) backscatter data from the Spaceborne Imaging Radar (SIR)-C [5]. We have also utilized elevation data with a resolution of 1 arc-second (~30 m) from the Shuttle Radar Topography Mission (SRTM) [6]. We collected Ground Penetrating Radar (GPR)/radar sounding data for the Qattaniya and Siwa dunes in Egypt during a site visit in September 2010. The GPR data collected has a central frequency of 900 MHz, bandwidth of 400 MHz, allowing 5 cm vertical resolution and a penetration depth of 8 meters into the dunes.

Variation of SAR backscatter with elevation for Titan's and Earth's dunes: Based on dielectric mixing models with different assumed dune compositions, we find that the Cassini Ku-band microwaves should be able to penetrate up to ~3 m through Titan's surface, thus interacting with the sub-surface and providing information about the layering in Titan's dunes. This implies that the shallow subsurface properties should impact the observed radar backscatter.

For each of the three terrestrial analog sites, we selected 35 profiles traversing individual dunes and extracted the corresponding backscatter and elevation data (in this abstract, 'profile' refers to a selection of radar backscatter and corresponding elevation measurements). We then examined variation of the normalized C-band backscatter data in HH polarization with elevation across the dunes. In total, we delineated 135 profiles over terrestrial dunes in Egypt: 70 in the Great sand sea, 35 over Siwa dunes and 30 over Qattaniya dunes (figure 3).

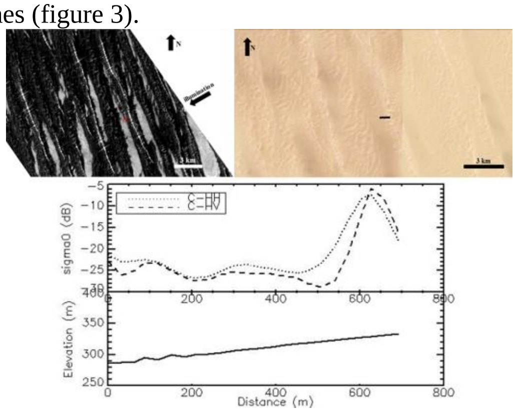

Fig. 3. Example profile across a dune in the Great Sand Sea in Egypt. (Top) SIR-C radar backscatter image and corresponding Google Earth® visible imagery are shown. (Bottom) Variation of normalized radar backscatter and elevation with horizontal distance along the dune profile.

Our backscatter profiles suggest that for the larger, older dunes, like the ones in the Great Sand Sea, with heights of 250-400 m, the normalized surface backscatter shows a strong dependence on elevation, irrespective of the incidence angle. On the other hand, for smaller (50-150 m height), relatively younger dunes like the ones in the Qattaniya dune field, the backscatter shows very weak/almost no variation with elevation (Figure 4). GPR data collected on the Siwa and Qattaniya dune fields show larger dunes are more finely layered than smaller dunes in the first 8 meters of the subsurface. This suggests that the measured surface backscatter from older (and larger) dunes is received from a finely layered medium while the radar backscatter from younger (and smaller) dunes is representative of a more homogeneous medium. Thus, older dunes should exhibit a backscatter-height dependency different than the younger ones, which is what we observe with the analysis of the SIR-C and SRTM data.

We repeated this analysis with each of the four large dune fields on Titan: Fensal, Aztlan, Belet and Shangri-La. We find dunes from all of them to exhibit a very weak, almost negligible dependence of the radar backscatter on elevation (Figure 5). This behavior is similar to the smaller terrestrial dune fields, the Qattaniya dunes, as described above, indicating possibly lesser layering and a relatively younger age for the dunes on Titan.

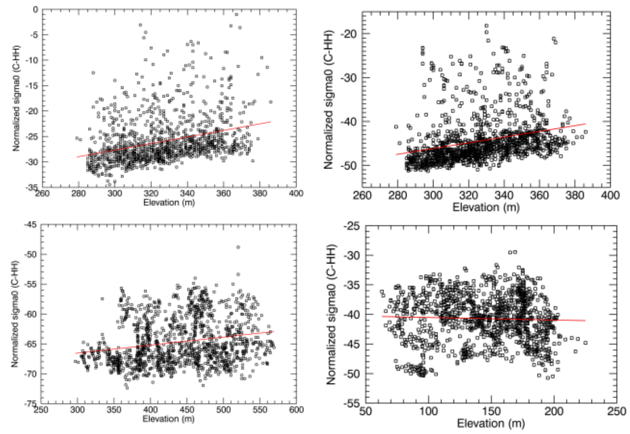

Fig. 4. Variation of SIR-C normalized (C-HH) radar backscatter (σ0 in dB) with SRTM elevation (in meters). (Top left) Great Sand Sea (inc=24.8°); (Top right) Great Sand Sea (inc=50°); (Bottom left) Great Sand Sea (inc=65°); (Bottom right) Qattaniya dunes (inc=54°).

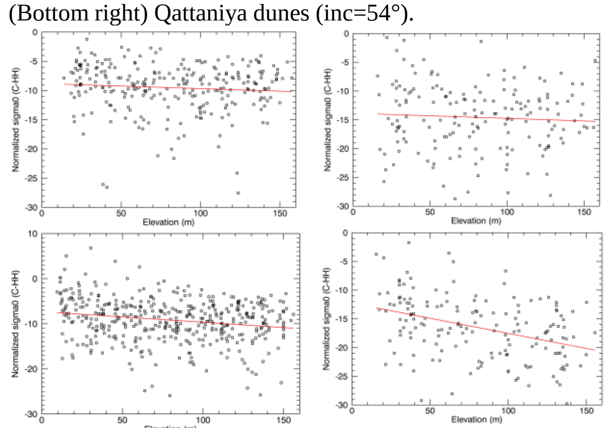

Fig. 5. Variation of Cassini SAR normalized (Ku-HH) radar backscatter (σ_0 in dB) with assumed elevation (in meters). (Top left) Aztlan; (Top right) Fensal; (Bottom left) Belet; (Bottom right) Shangri-La.

We will be presenting the implications of this analysis for understanding paleo-wind regimes on Titan at the conference.

References: [1] Lorenz, R. D. et al. (2006) *Science*, *312*, 724-727. [2] Radebaugh, J. et al. (2008) *Geomorph.*, *121*, 122-132. [3] Bristow, C.S. et al. (2000) *Nature*, *406*, 6791, 56-59. [4] Elachi, C. et al. (2004) *Space Sc. Rev.*, *115*, 71-110 [5] Jordan, R.L. et al. (1995) *IEEE Trans. on Geo. and Remote Sens.*, *33*, 4, 829–839. [6] Farr, T. G. et al. (2007) *Rev. Geophys.*, *45(2)*, RG2004.