EPSC Abstracts
Vol. 6, EPSC-DPS2011-149, 2011
EPSC-DPS Joint Meeting 2011

Modeling the SAR Backscatter of Linear Dunes on Titan

Ph. Paillou and D. Bernard
University of Bordeaux, UMR 5804, Floirac, France (philippe.paillou@obs.u-bordeaux1.fr / Fax: +33-557-776110)

Abstract

We present modeling results of the SAR backscatter of dune regions on Titan. We calibrated our scattering model using SAR data acquired over the linear dunes of the Great Sand Sea on Earth, in order to estimate reasonable values for the surface roughness parameters. The model was then applied to the modeling of the backscattering properties of Titan's linear dunes.

1. Introduction

The Cassini-Huygens mission has been studying the Saturn system since 2004. The Ku-band RADAR instrument, on-board the Cassini spacecraft, has revealed many geological features on the surface of Titan, in particular vast dune fields at the equator [1]. They cover about 10 million km^2 on the surface of Titan and are made of a mixture of tholins and ice material which source is still discussed. Most of dunes on Titan are linear [2], being parallel to the time-averaged direction of winds [3]. The study of the morphology (slope, height, spacing) of dunes yields information about the depositional environment in which they were formed. We started to model the radar response of Titan's dunes, with the aim to extract morphological parameters, based on the study of terrestrial analogs. We considered the linear dunes of the Great Sand Sea, that covers eastern Libya and western Egypt, as representative of the Titan landforms [4]. Topography from the Shuttle Radar Topography Mission (SRTM) is available for these dunes, together with multi-frequency radar data acquired during the Shuttle Imaging Radar mission SIR-C/X-SAR in 1994. The dunes of the Great Sand Sea are composed of pure silicate, which low dielectric constant is very close to the values reported for Titan materials [5]. Data acquired at X-band (9.6 GHz) during the SIR-C/X-SAR mission (see Fig. 1) are also very close in frequency to the Ku-band (13.8 GHz) of the Cassini RADAR instrument.

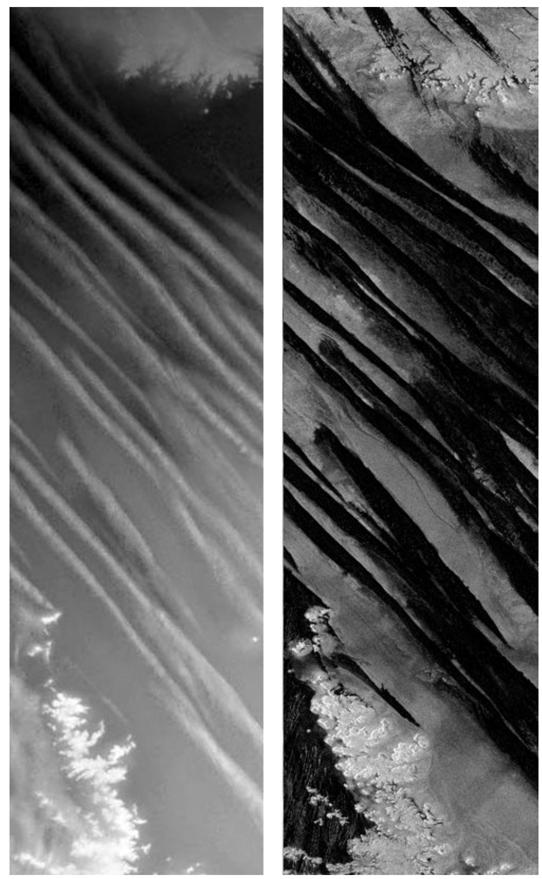

Figure 1: SRTM topography (left) and X-band SAR image of linear dunes in the Great Sand Sea.

2. Modeling the SAR Response of Terrestrial Linear Dunes

Sand dunes usually exhibit a low radar return since the dune's surface is usually smooth and the radar signal is likely to penetrate into sand [6]. The radar response of such natural surfaces can be modeled considering a single surface scattering with possibly a weak volume scattering term [7]. Inter-dunes appear in radar images as brighter features (see Fig. 1), due to a higher surface roughness combined to a possible multi-layer scattering process [7]. As a first step, we only considered the single scattering term of a layer of sand, using either the Integral Equation Model (IEM) [8] or the Physical Optics Model (POM) [9] depending on the roughness conditions.

The IEM can be used for smooth to medium-rough surfaces (the roughness being defined comparatively to the radar wavelength) and is expressed by [8]:

$$\sigma^0_{Spp}(\theta)=\frac{k}{4}e^{-2k^2\cos^2(\theta)\sigma^2}\sum_{n=1}^{\infty}|I^n_{pp}|^2\frac{W^{(n)}(-2k\sin(\theta),0)}{n!} \quad (1)$$

The POM is better suited to rough surfaces and is particularly suited for the Ku-band SAR of Cassini, since most natural surfaces are rough at such a high frequency. It is expressed by [9]:

$$\sigma^0_{Spp}(\theta)=2k^2\cos^2\theta\,\Gamma_{pp}(\theta)\,e^{-(2k\sigma\cos\theta)^2}\cdot \quad (2)$$

$$\sum_{n=1}^{\infty}(4k^2\sigma^2\cos^2\theta)^n/n!\int_0^{\infty}\rho^n(x)J_0(2kx\sin\theta)x\,dx$$

The parameters to be determined in such models are: the radar frequency ν and polarization *pp*, the radar wave incidence angle θ, the surface material dielectric constant ε, and the surface roughness parameters σ and L (we consider here surfaces with a Gaussian auto-correlation function). The incidence angle was derived from SRTM topographic data and we used the dielectric constant of pure silicate (*3.4-0.05j*). In order to derive the surface roughness parameters, we explored the (σ, L) space for the three frequency bands, so that the observed backscattered power over dunes could be reproduced: *-34* dB at L-band, *-26* dB at C-band and less than *-30* dB at X-band. We find a solution in the parameter space for σ=*0.2* cm and L=*3.0* cm (see Fig. 2). Such values correspond to typical numbers reported for the sand ripples height and spacing on terrestrial dunes [10]. It has to be noted that the radar scattering of the linear dunes of the Great Sand Sea could be modeled considering only single surface scattering, i.e. no volume scattering component is needed here. This means that the sediments composing the dunes are likely to be homogenous in composition and compaction.

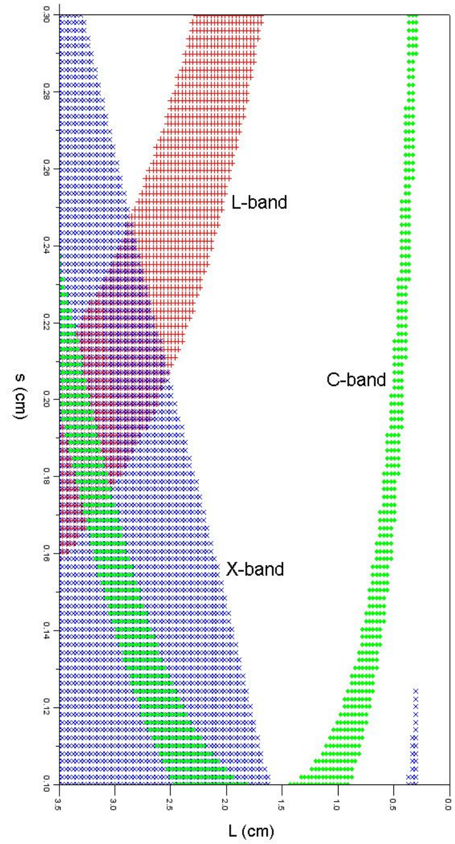

Figure 2: Modeling of the dunes' radar response at L-band (red), C-band (green) and X-band (blue) in the (σ, L) roughness parameter space.

3. Application to the Dunes of Titan

We used the SAR data acquired by the Cassini RADAR instrument during the T8 flyby over Titan, that took place in October 2005. The T8 radar swath is dominated by dunes and covers longitude 186 to 314ºW, over a latitude range from 11 to 7ºS [11]. Dune fields are composed of an alternation of bright and dark lines, dunes being the dark streaks and inter-dunes being the bright streaks (see Fig. 3). As the incidence angle changes during the swath acquisition, we dispose of a measured radar backscatter power at several incidence angles. For the dunes, σ_0 decreases from *-9* dB at θ=*12*º to *-14* dB at θ=*22*º. Considering a mean slope for the dunes of the same order as their terrestrial analogs (i.e. around *5*º), running the Integral Equation Model with the previously obtained roughness parameters and considering the dielectric constant of tholins (*2.3-0.02j*) as major constituents of the dune [5], we compute a backscattered power in the *-8* dB to *-19* dB range, which is quite consistent with the measured values. This implies that the radar response of linear dunes on Titan can be described using a single surface scattering component, i.e. the material constituting the dunes is homogeneous. Our result also support the hypothesis that the mean slope of Titan's dunes should be comparable to the one of linear dunes on Earth [12]. Future work will concern the modeling of the brighter inter-dune radar response.

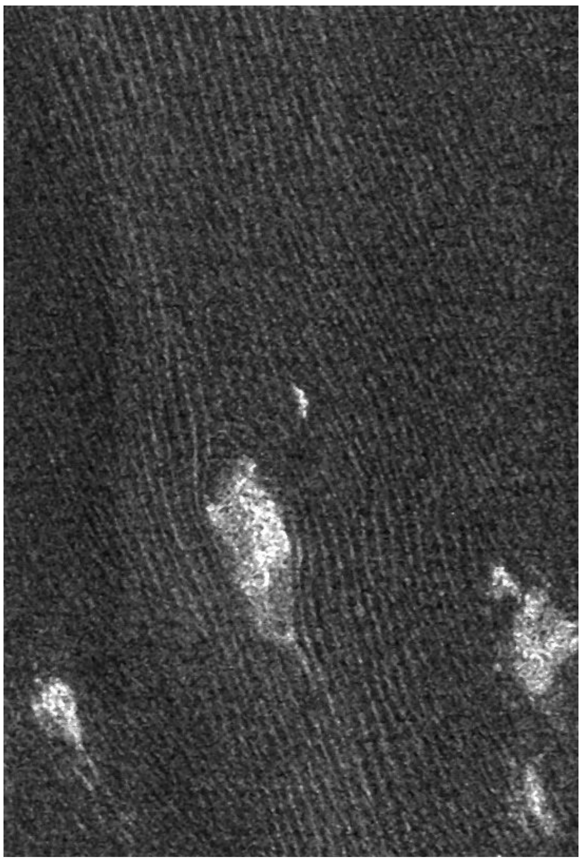

Figure 3: Extract of Cassini RADAR image obtained during the T8 flyby in 2005, showing a linear dunes.

Acknowledgements

The authors would like to thank Ch. Elachi and S. Wall from JPL, Team Leads of the Cassini RADAR instrument, and the French space agency CNES for financial support.

References

[1] Lorenz, R.D., et al., "The Sand Seas of Titan: Cassini RADAR Observations of Equatorial Fields of Longitudinal Dunes", *Science*, vol. 312, pp. 724-727, 2006.

[2] Radebaugh, J., et al., "Dunes on Titan from Cassini RADAR", *Icarus*, vol. 194, pp. 690-703, 2008.

[3] Lorenz, R.D., and J. Radebaugh, "Global pattern of Titan's dunes: Radar survey from the Cassini prime mission", *GRL*, vol. 36, L03202, 2009.

[4] Radebaugh, J., R.D. Lorenz, T. Farr, Ph. Paillou, C. Savage, "Linear dunes on Titan and Earth: Initial remote sensing comparison", *Geomorphology*, vol. 121, pp. 122-132, 2010.

[5] Paillou, Ph., J.I. Lunine, G. Ruffié, P. Encrenaz, S.D. Wall, R.D. Lorenz, M.A. Janssen, "Microwave dielectric constant of Titan-relevant materials", *Geophysical Research Letters*, vol. 35, L18202, 2008.

[6] Farr, T. G., Ch. Elachi, P. Hartl, K. Chowdhury, "Microwave penetration and attenuation in desert soil: A field experiment with the Shuttle Imaging Radar", *IEEE Trans. Geosci. Remote Sensing*, vol. GE-24, no. 4, pp. 590-594, 1986.

[7] Paillou, Ph., M. Crapeau, Ch. Elachi, S. Wall, P. Encrenaz, "Models of SAR backscattering for bright flows and dark spots on Titan", *Journal of Geophysical Research*, vol. 111, E11011, 2006.

[8] Fung, A.K., *Microwave Scattering and Emission Models and their Applications*, Norwood MA, Artech House, 1994.

[9] Ulaby, F.T., R.K. Moore, A.K. Fung, *Microwave Remote Sensing: Active and Passive*, vol. 2, Norwood MA, Artech House, 1982.

[10] Lancaster, N., *Geomorphology of Desert Dunes*, Routledge, 1995.

[11] Lunine, J.I., et al., "Titan diverse landscapes as evidenced by Cassini Radar's third and fourth look at Titan", *Icarus*, vol. 195, no. 1, pp. 415-433, 2008.

[12] Neish, C.D., R.D. Lorenz, R.L. Kirk, L.C. Wye, "Radarclinometry of the sand seas of Africa's Namibia and Saturn's moon Titan", *Icarus*, vol. 208, pp. 385–394, 2010.