INVERSION OF CASSINI RADAR DATA: THE LIQUID CONTRAST METHOD. **M. Mastrogiuseppe[1], V. Poggiali[2], C. Elachi[1] and S. Wall**. [1]Division of Geological and Planetary Sciences, California Institute of Technology, USA (mmastrog@caltech.edu), [2]Cornell Center for Astrophysics and Planetary Science, Cornell University, 104 Space Sciences Building, 14853 Ithaca, New York, USA.

Introduction: Herein we present a method to infer dielectric properties of the solid surface of Titan comparing backscattering measurements acquired by the Cassini RADAR instrument over specific regions where the surface is observed in presence or not of liquid hydrocarbon. The dielectric properties of lake/seas have been previously determined during the mission and allow to invert the observed backscattering contrast of submerged and exposed surfaces into dielectric properties of the solid material. The analysis can be performed directly on SAR images, selecting homogeneous regions in proximity of the shorelines of the seas, where the radar attenuation of the liquid can be neglected or a value can be derived from previous data analysis. Similarly, the technique can be applied to altimetric data acquired over seas/lakes, comparing the backscattering measured at the sea/lake floor with specific regions of exposed solid surface. An example of data inversion applied to SAR data acquired in a region at South of Ligeia Mare is presented. The roughness parameter of the surface/subsurface is further investigated.

Method: Dielectric properties of liquids hydrocarbons of seas and lakes have been determined from radar-altimetry observation of Titan seas and lakes [1-4] and cryogenic laboratory measurements [5]. In particular, the loss tangent of the liquid medium has been derived by using the radar attenuation estimated from subsurface backscattering as function of increasing depths, with a results of eps_r = 1.75 +- 5%

Dielectric properties of the solid surface of Titan are less constrained than liquid : several materials with different dielectric properties such as simple organic material (eps_r = 2 – 2.4), water ice (eps_r = 3.1) or (ethero) polymers or water-ammonia (eps_r = 4.5 – 5.5) could be present [6-8]. This variability makes radar measurements particularly attractive, permitting discrimination and mapping of possible materials present on the moon.

Dielectric studies of the surface of Titan have been performed also using radiometry [9] and scatterometry [10], despite the limited ground resolution scale (tens to hundreds of km) characterizing these datasets. Herein we present a method for estimating the dielectric properties of the solid surface of Titan at a km scale and in proximity of the shorelines of seas/lakes. .

This is done selecting regions where the dielectric properties of the solid surface can be assumed spatially constant. As a first step we assume the composition of the sea floor and surface to be the same and is estimated by comparing the measured backscattering in presence or not of the liquid.

Steps for the Inversion Processing: The steps for applying the inversion technique can be described as follow:

- Area selection close to the shoreline: surface (S) and subsurface (SS);
- Extraction of data (pixel backscattering, incidence angle, noise level, range) for each flyby;
- Estimation of the mean values and delta-backscattering of the two selected areas (S and SS) for each flyby;
- Fitting of the scattering models for roughness estimation at the S and SS;
- Estimation of radar attenuation of the liquid medium at the SS areas using altimetry data (where available);
- Compensation of delta-backscattering from the effects of roughness and attenuation;
- Inversion of delta-backscattering into dielectric properties for (Case 1) homogeneous media and (Case 2) porous media with different values of porosity.

OUTPUT: Dielectric properties of the media (Case 1) or effective dielectric properties of S and SS (Case 2) and roughness at S and SS.

Example of data inversion applied to Ligeia Mare: We selected a Region of Interest (ROI) at South Ligeia, where bathymetric measurements are available (T91 fly-by) and homogeneous areas with abrupt change in radar backscattering (presence of liquid) can be identified. Area selection must be properly performed trying to avoid fluvial features on pixels selection (see Fig.1). Selection of area has been manually performed using MATLAB dedicated software which allow selection of areas and extraction of scientific and ancillary data. We found four available SAR images acquired over the selected area (Fig. 1 bottom panel) having off-nadir look angle less than 30° and suitable for testing the inversion technique.

Estimation of the mean values and delta-backscattering to Ligeia Mare: The delta-backscattering must be properly estimated due to the presence of noise which contaminates the subsurface distribution of the backscattering values in a different way respect to the surface one. In our work we use to fit Rayleigh distribution and find parameters which allow to remove the noise effects.

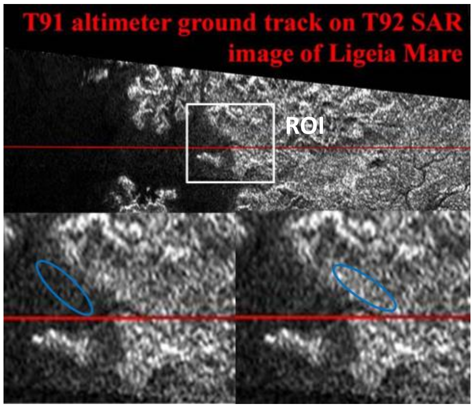

Figure 1. (a) T91 altimeter ground track on T92 SAR observation: region of interest (white box) and selected area at the subsurface (right) and surface (left)selection (blue ellipse).

Roughness parameters (fs&fss) estimation: Surface and subsurface roughness parameters must be properly estimated and compensated in order to invert the backscattering contrast into dielectric properties. In this work we make use of general fractal models calculated for the Hurst exponent (H) equal to 0.5 (i.e. Hagfors Model) and equal to 1 (Geometrical Optic solution (GO)). Fitting these models to the four angular observations, we found that subsurface is few degree smoother than the surface in terms of rms slopes (see fig. 2). In addition we found that both models returns similar values of scattering terms correction (fs/fss) which than are used to compensate the delta backscattering.

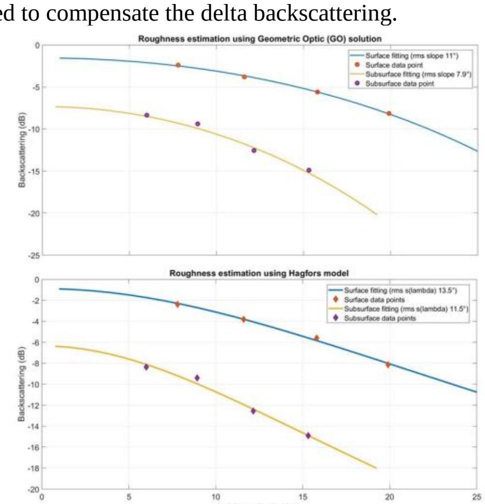

Figure 2. Roughness Estimation using Geometric Optics (GO) (upper panel) and Hagfors (lower panel).

Bathymetry interpolation and depths estimation: The last step of the backscattering compensation before inversion is the attenuation K which must be properly estimated. Herein we use bathymetric measurements in proximity of the selected area, in order to estimated depths and the correspondent total attenuation calculated using the loss tangent estimated in [4]. We found that depths vary between 20-30 m (see fig. 3), which correspond to 2.5/3.5 dB of radar attenuation. This value added to the subsurface backscattering similarly for all observations.

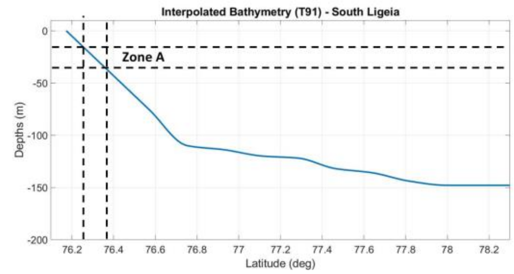

Figure 3. Bathymetric interpolated measurements from T91 dataset.

Data Inversion: After roughness and attenuation compensation, the corrected values of delta-backscattering can be used to retrieve dielectric properties assuming homogeneity of the material or some values of porosity. Here we show a preliminary results for the case of an homogenous media. Results show that for this specific example, values ranges from 2.7 to 3 (see fig.4), consistent with the presence of water ice or mixed organic material. Results shown here are preliminary and subject to some possible slight changes.

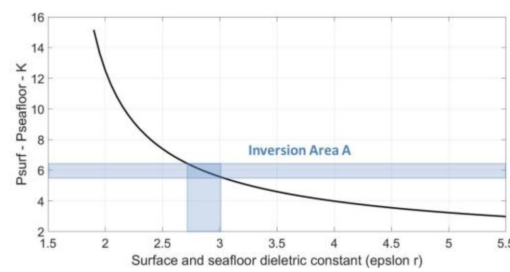

Figure 4. (a) Inversion results for area A

References: [1] Mastrogiuseppe M. et al., *GRL*, *41*, 5, 1432-1437. [2] Mastrogiuseppe M. et al. (2016) *IEEE TGRS*, *54*, 10. [3] Mastrogiuseppe M. et al. (2018) *EPSL*, *496*, 89-95. [4] Mastrogiuseppe et al. (2018) *Icarus*. [5] Mitchell et al. (2015) *GRL*, 42, 1340–1345. [6] Thompson et al. (1990), *Icarus*, Vol. 86, Issue 2, Pages 336-354 . [7] Picardi et al. (2004),Planetary and Space Science, v. 52, iss. 1-3 [SPECIAL ISSUE], p. 149-156. [8] Lunine et al. (1983), Science, 222, 1229–1230. [9] Le Gall et al . (2016), *JGR Planets* [10] Wye et al. (2007), volume 188, Issue 2, Pages 367-385