Backscatter Curves for Specific Morphological Units on Titan. A. R. Nowak[1], A.G. Hayes[2], S.P.D. Birch[2], [1]Winona State University (175 W Mark St. Winona, MN, ANowak14@winona.edu), [2]Cornell University.

Introduction: Titan, the largest moon of Saturn, has proven to be an interesting body to researchers. Titan is home to the only other known place, beside Earth, in our solar system that has resting surface liquid, which is in the form of liquid methane. Titan also contains many other Earth-like geological features including extensive dune fields, plains, and mountain chains. By looking at how different features across Titan's global terrain vary compositionally, we can gain insight into the different geological processes that take place on the Saturnian moon. [2,3]

Because Titan's surface is covered by an extensive atmosphere, probing the surface can prove to be somewhat of a challenge. The Cassini spacecraft was the first instrument to be able to probe the moon's surface from close range using the RADAR instrument [1,4]. At the highest resolution, Cassini was able to capture Titan's surface at 256 pixels per degree.

In this research project I will be using multiple flybys at varying viewing geometries to characterize the surface properties of Titan, including surface composition and surface roughness. The uniqueness of this study is that by using high resolution SAR data we can characterize smaller units without risk of accidentally extending the analysis to undesired regions.

Modeling Procedure: By measuring the backscatter from signals emitted by Cassini, and comparing them at different incidence angles we are able to apply a combination of quasi-specular and diffuse models to characterize the surface parameters [1]. To fit our data we will be using one of three quasi-specular models (shown below):

$$\sigma_H^o(\theta_i) = \frac{\rho C}{2}(\cos^4\theta_i + C\sin^2\theta_i)^{-\frac{3}{2}}$$
$$\sigma_G^o(\theta_i) = \frac{\rho C}{\cos^4\theta_i}\exp(-C\tan^2\theta_i)$$
$$\sigma_E^o(\theta_i) = \frac{3\rho C}{\cos^4\theta_i}\exp(-\sqrt{6C}\tan\theta_i)$$

These models correspond to Hagfor's, Gaussian, and an exponential model, respectively. The diffuse model is a simple cosine power law.

$$\sigma_D^o(\theta_i) = A\cos^n\theta_i$$

The quasi-specular models are important as they tend to dominate at low incidence angles, while the diffuse model tends to dominate at high incidence angles.

ρ in our models is a measure of surface reflectivity, and is related to the dielectric constant by :

$$\epsilon = \left(\frac{1+\sqrt{\rho}}{1-\sqrt{\rho}}\right)^2$$

We can use the dielectric constant to directly measure the surface material. C in our model is a parameter known as the rms surface roughness.

For accuracy in the modeling procedure we will want to look at regions that have been observed at least four times with high resolution data. Each flyby contributes one point to our plots, corresponding to a backscatter value vs. incidence angle of viewing.

Material	Dielectric Constant (ϵ)	Loss Tangent ($\tan\delta$)
Liquid Hydrocarbons	1.6–1.9	10^{-3}
Solid Hydrocarbons	2.0–2.4	$10^{-2} - 10^{-3}$
CO2 Ice	2.2 (1.6)	10^{-3} (10^{-4})
Water Ice	3.1	$10^{-4} - 10^{-5}$
Water-Ammonia Ice	4.5	$10^{-2} - 10^{-3}$
Organic heteropolymers	4.5–5.5	$< 10^{-5}$
Meteoric Material	8.6	0.9

Figure 1:A table depicting known materials and associated dielectric constants from Lauren Wye [1]

Modeling results: While the results are still early, we have shown that our early findings are consistent with what is known of Titan's surface. For example, in our analysis of an equatorial dunes region centered onlatitude 0.796 degrees and longitude 190.152 degree (Figure 2), I have found the dielectric constant to be 1.0709 ± 0.2715 which is consistent with liquid and solid hydrocarbons like methane. The rms surface roughness for this region was found to be 0.9189 ° ± 2.4033.

In another region, in the vicinity of the north polar lakes, centered on 69.403 degrees latitude and 3.622 degrees longitude, I have found the dielectric constant to be 1.7159 ± 0.7727 , which is consistent with liquid methane. The rms surface roughness for this region is 15.7533 ° ± 25.6976.

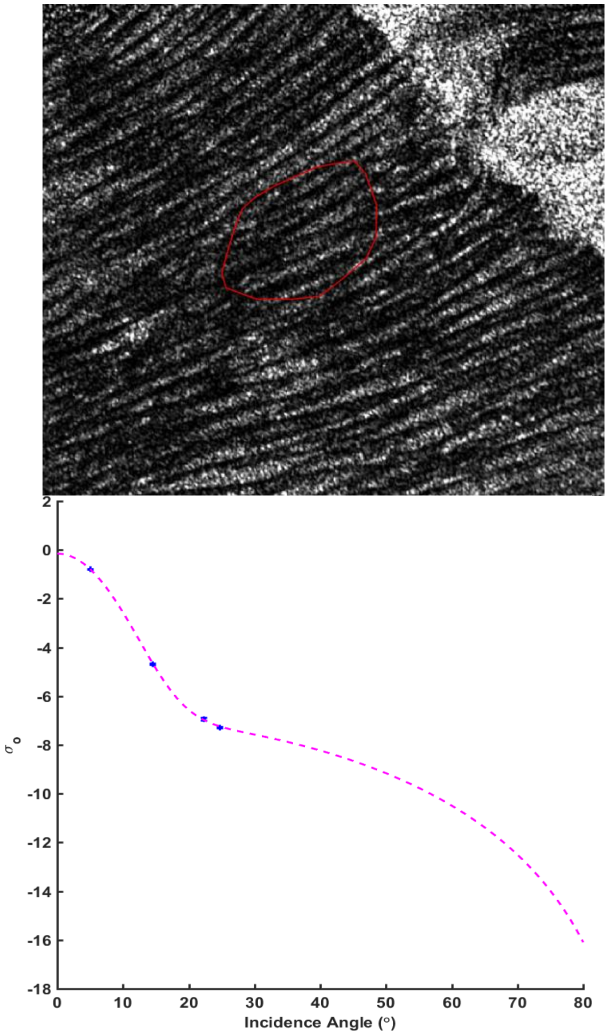

Figure 2: An equatorial dunes unit, analyzed area circled in red, along with the corresponding backscatter curve.

Improvements of results: The findings of this study are still early and much work is left to be done before it is complete. In the future we hope that many more geological morphologies can be analyzed in this method to improve the results. By analyzing more morphologies we will have a better understanding of the differences in similar units across Titan. We will eventually want to extend this procedure to ten or more units across the globe.

Another improvement that can be made is to take into account the effects of the azimuthal angle of observation in the viewing geometry. The azimuthal angle can play a significant role by affecting backscatter values. For example, if we were to look at a mountain from one geometry we might get back one backscatter value. However, this does not guarantee that we will get a reasonable value back from a different azimuthal angle. If one side of the mountain is rather flat and the other covered by steep cliffs, backscatter values may change in an unusual manner depending on from which side of the mountain you viewed from. Future work would be sure to include an analysis of this feature.

This study is in no way complete as only early findings have been analyzed. Further research will hopefully expand on this procedure to produce more complete results.

References: [1] L. Wye (2011). [2] S.P.D. Birch (2017). [3] R. Lopes (2009). [4] R. Michaelides (2014)

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