MODELING TITAN'S SURFACE FROM CASSINI RADAR'S SCATTEROMETER AND RADIOMETER MEASUREMENTS. L. C. Wye[1], H. A. Zebker[1], R. D. Lorenz[2], and the Cassini Radar Team, [1]Stanford University, Department of Electrical Engineering, 350 Serra Mall, Packard Building, Stanford, CA 94305, USA (lcwye@stanford.edu), [2]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, U.S.A.

Introduction: The Cassini Titan Radar Mapper [1] acquired microwave reflectivity and emissivity measurements of Titan's surface using scatterometer and radiometer modes on five recent flybys. The scatterometer uses a 0.38° antenna beam at 13.78 GHz (2.17 cm) in an active, real-aperture mode to produce regional-scale backscatter images across large areas of the surface. Radiation at this wavelength penetrates the thick atmosphere and permits surface measurements at resolutions from 10 to 200 km. Raster scanning achieves large angular coverage of the surface to properly sample the average backscatter function. A backscatter function over a wide range of angles reveals much about the dielectric composition, surface and subsurface scattering properties.

The radiometer mode operates in tandem with the active mode, passively receiving and measuring the brightness of Titan's emission in between the pulsed echoes of the scatterometer data. Thus, it measures emission from the same area of the surface, at the same linear polarization, as the active mode data.

The radar's active and passive modes individually contribute essential information about an area of coverage. Yet, when taken together, the different radar data types reveal a more complete story, providing complementary information on the physical and electrical properties of the surface. Here we present overlapping data collected by the RADAR's scatterometer and radiometer over the Titan observations to-date (denoted Ta-Inbound and Ta-Outbound, October 2004; T3, February 2005; T4, March 2005; T7, September 2005; T8-Inbound and T8-Outbound, October 2005). We present here separate model solutions obtained from the active and passive data in terms of electrical and physical properties. We are now beginning to reconcile the implications of the two using a unified surface model, and include preliminary results of this modeling approach.

Active Model: We use angle diversity to separate a quasispecular surface scattering term from a diffuse volume scattering term in the radar echo. We model the observed backscatter using traditional scattering models: a Hagfors' [2] or Gaussian [3] specular term plus a cosine^n diffuse component (Figure 1). The parameters of the best fit specular component suggest values for the dielectric constant and rms surface slope of the observed area. For much of the surface, we retrieve dielectric constants ranging from 1.5 to greater than 3. Surface slope distributions range from a few degrees rms up to 15 degrees in different regions.

We note that these values represent average measurements over a variety of terrains and it is possible none of the surfaces scatters in this average way. Nonetheless, these results begin to constrain the range of materials and surface conditions that are found on Titan.

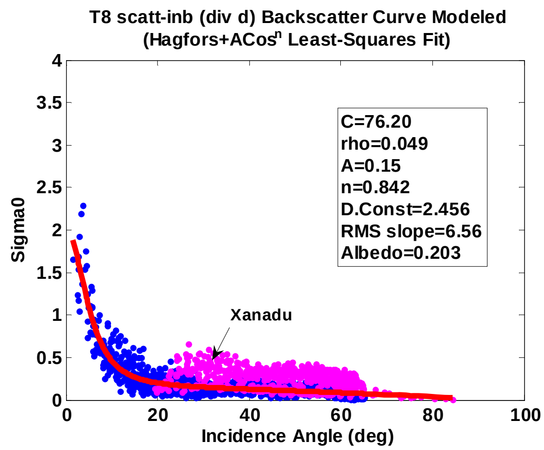

Figure 1. Relative radar cross section is plotted vs. incidence angle. T8-inbound scatterometer data with composite Hagfors-plus-cosine model (red line). Blue data points are from the background surface of the pass. Purple points are return from the radar-bright Xanadu feature and are not considered in the model fitting.

Passive Model: In modeling the observed brightness temperatures, we consider Titan to be a simple emitting sphere covered with a uniform layer of unknown-dielectric lossless material. We use Fresnel's equations to model the magnitude and polarization of signals emitted by a subsurface lossy, and hence emissive, layer, as transmitted through the upper layer and refracted at the surface towards the radar receiver (Figure 2). We fit this simple model to the roughly calibrated radiometry data (where spillover sidelobe errors are not yet taken into account) and estimate the dielectric constant of the layer to average between 1.5 and 2. This results are provisional and complete error analysis has yet to be done.

Dielectric constants retrieved from the modeled radiometer data tend to be systematically lower than those from the scatterometer. This could be do to unresolved calibration issues, but also may likely show limitations of the existing models that consider scatterometer-only or radiometer-only data. For example, this radiometer model does not include the effects of scattering centers within the lossless layer. Our goal is to devise a single model of the surface that satisfies both sets of measurements.

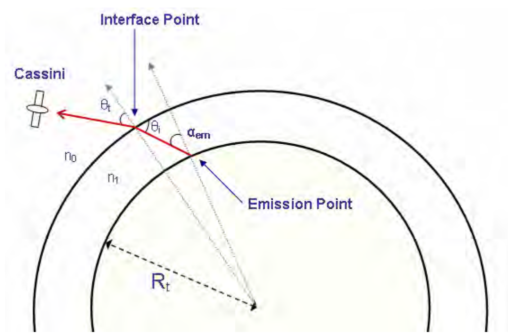

Figure 2. Simple radiometer model showing uniform lossless dielectric layer over an emissive gray body, where n_1 is the index of refraction of the surface material, n_0 is the index of refraction of space, θ_t is the angle of transmission, θ_i is the angle of incidence, and α_{em} is the anisotropic grazing angle.

Titan's Surface Revealed: Comparison of the scatterometer and radiometric measurements reveals that the active and passive microwave observations are anticorrelated and show similar features over most of the imaged regions. We have compared these in seven separate regions on Titan's surface, and present the residual maps from the Ta-inbound pass in Figure 3. The many small scale features seen represent differences observable in both emissivity and reflectivity from the average values, and likely give clues to the nature of the composition of the surface as well as geologic processes.

Despite some systematic differences in detail, the inferred parameters from the backscatter and emissivity models appear to suggest dielectric constants that vary between 1.5 and 3 over the areas observed. Dielectric constants of 1.7 are indicative of hydrocarbon materials such as methane or ethane, while water ice has a dielectric constant of 3.2. If the surface is composed largely of water ice, it would have to be unconsolidated material such as snow where the bulk electrical properties are reduced by the fractional volume of material.

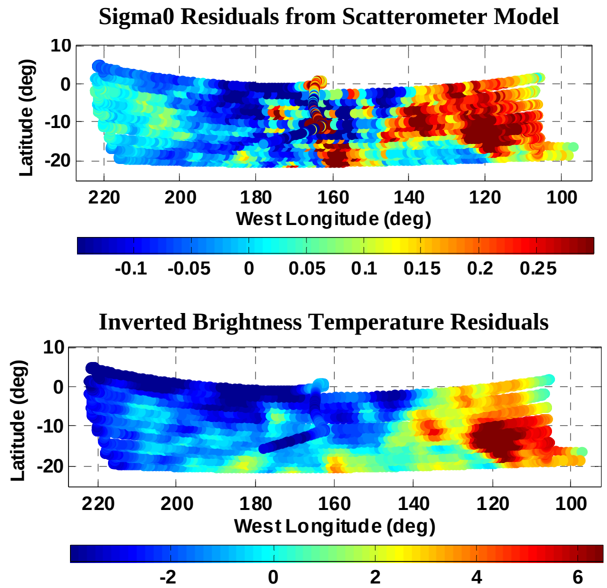

Figure 3. Comparison of the scatterometer model residuals (top) with the inverted radiometer model residuals (bottom) for TA-inbound data reveal the same surface features and demonstrate the anticorrelation of the active and passive radar data. Red means brighter (cooler) than the model, where as blue means darker (warmer) than the model. The optical-bright Xanadu region is on the right and is distinct in both types of data.

Comprehensive Titan Surface Model: We have seen that the independent backscatter and emissivity models tend to support each other, yet still differ in the quantitative inference of surface parameters. Thus, present work is aimed at integrating the passive and active models into a single surface model which can explain Titan's simultaneous high reflectivity and high emissivity. We continue with the layered model approach: a gray body of emissive material is overlain by a nearly lossless but complex icy layer that differs from the previous model by the inclusion of scattering centers within the layer. The lossless layer is required to produce the high radar returns through coherent backscattering, while the absorptive substrate is needed to produce high radiative temperatures. We present here preliminary fits using this new model.

References: [1] Elachi, C. et al. (2004) Space Sci. Rev. 115, 71-110. [2] Hagfors, T. (1964), *JGR*, *69*, 3779-3784. [3] Beckmann, P. and Spizzichino, A. (1963), "The Scattering of Electromagnetic Waves from Rough Surfaces."