COMPOSITION OF TITAN'S SURFACE FEATURES CONSTRAINED THROUGH BACKSCATTER MODELING. L. C. Wye[1], H. A. Zebker[1], M. A. Janssen[2], R. D. Lorenz[3], R. D. West[2], and the Cassini RADAR Team, [1]Stanford University, Department of Electical Engineering, 350 Serra Mall, Stanford, CA 94305, lcwye@stanford.edu, [2]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, [3]Space Department, Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723.

Introduction: The Cassini RADAR is a multi-functional instrument, shifting between four modes as it swings by Titan on a given orbit. Starting at a distance of 100,000 km, it begins in radiometer mode, passively listening to the microwave emission radiating from the surface's disk. Flying closer (9000-25000 km), the scatterometer mode takes over, actively scanning the 4-m high-gain antenna beam over the surface in a raster pattern to cover large areas as well as sample the regional backscatter response. Closer yet, the altimeter mode steers the beam towards nadir and records elevation profiles beneath the spacecraft. And around closest approach, the SAR mode images swaths with resolutions as high as 350 m. Each RADAR mode is primed for a specific science objective and sets up a particular observing geometry to achieve it. Here, we utilize this geometry diversity to create a more complete set of surface backscatter functions for a collection of features than is possible with the scatterometry data alone.

By modeling the backscatter response for individual features rather than the average response over regional areas, we can constrain the composition and structure of specific units on Titan's heterogeneous surface. This will further constrain the processes responsible for the feature's formation and evolution.

The specific features that we model include the dune fields, crater ejecta (Sinlap), bright albedo regions (Tsegihi, Quivira, and Adiri), dark albedo regions (Senkyo, Shangri-la), and bright spots called facula (Shikoku), among others.

Combining Data Sets: The scatterometer uses the 0.37° central antenna beam at 13.78 GHz (2.17 cm) in a real-aperture mode to produce regional-scale backscatter images across large areas of the surface. Observing from distances between 9000 and 25000 km, the typical resolution cell is 90-km by 150-km, as determined by the beam footprint and the pulse length. Raster scanning achieves large angular coverage of the surface to properly sample the average backscatter function over the region. Yet, multi-angle coverage of a particular area, or feature, is lacking unless we have multiple scans overlapping. The 17 scatterometry scans acquired to-date (TAi, TAo, T3, T4, T8i, T8o, T13, T16, T19, T21, T23i, T23o, T25, T28, T29, T30i, T30o) overlap only over eight distinct areas, and just two of these have overlap from more than 2 scans. It is clear that, for a particular feature or area, scatterometer-data alone does not provide adequate backscatter-function sampling.

By applying the real-aperture processing techniques of the scatterometer to the other active radar modes, we can combine datasets to achieve greater angular sampling of a feature's backscatter response. The altimetry data provides the very low angle response (less than 1°), while the SAR data gives the mid-range response (10° to 40°).

Because the scatterometry has already observed close to 80% of the surface (Figure 1), a large portion of altimetry and SAR coverage is coincident with scatterometry. The 15 SAR swaths collected to-date (TA, T3, T7, T8, T13, T16, T17, T18, T21, T23, T25, T27, T28, T29, T30) cover roughly 20% of the surface. The 19 altimeter tracks collected (TAo, T3i, T3o, T8i, T8o, T13, T16, T19i, T19o, T21, T23i, T23o, T25i, T28i, T28o, T29i, T29o, T30i, T30o) cover less than 1%. Together, the multi-angle radar reflectivity coverage is more complete (Figure 2).

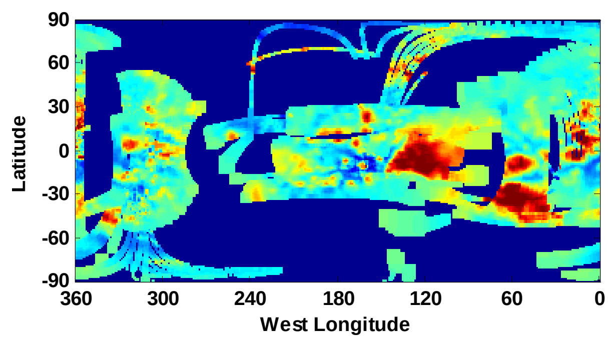

Fig. 1: Global scatterometry map as of May, 2007.

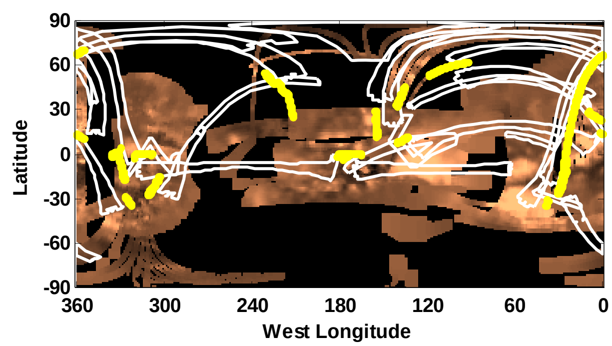

Fig. 2: Coincident radar coverage: SAR (white), altimetry (yellow), scatterometry (pink).

Calibration. The challenge in combining the active mode datasets is verifying that all modes are calibrated to the same scale. Calibration, or conversion from quantized data numbers to watts, is performed by computing the noise power from an equivalent system noise temperature and comparing to the measured noise variance of the data. For two reasons, this is more complex than expected. First, each mode uses a different receiver filter and bandwidth and thus has a different system noise temperature. Engineering tests show that the smaller the receiver bandwidth, the higher the noise temperature, suggesting a narrow-band back-end noise contaminant [1]. Second, each mode cycles through a different set of attenuation factors to account for their different viewing geometries and echo power levels. Typically, the equivalent system temperature is dominated by the front-end gain of the receiver, which is ideally large enough to dampen the effects of gains and losses further down the receiver chain. Yet, the Cassini radar receiver has a noise temperature that is strongly dependent on the leading attenuator value. Thus, in addition to measuring noise temperatures for each mode's bandwidth, we must also cycle through the various attenuation levels to see how the equivalent temperature changes.

Backscatter Modeling: A backscatter function over a wide range of angles reveals much about the dielectric composition, surface and subsurface scattering properties. We separate the backscatter response into two different regimes: surface scatter dominates at low angles and volume scattering dominates at the larger angles. The surface component yields the tightest constraints on dielectric constant and surface slopes, while the volume component is most descriptive of scattering centers such as cracks or inclusions within the near-surface material.

We use traditional facet scattering models to describe the quasi-specular scatter of the surface term, such as Hagfors' or Gaussian laws. We then consider two different approaches to incorporate the volume term. The first approach is to use an empirical cosine-law to model the diffuse volume scatter [2]. This is used solely to measure and eliminate the contribution of the diffuse scatter to the low-angle backscatter, so that the quasi-specular model can be applied more accurately. The cosine-law parameters reveal nothing physical about the sub-surface scattering. An example of this composite model fit to the scatterometry and altimetry points of Shangri-la is shown in Figure 3. Our second approach is to consider a volume scattering model that incorporates the emission measurements collected by the radiometer. While the active modes await receipt of their echoes, the radiometer listens to the natural microwave emission, yielding coincident emission and reflectivity measurements. By assuming the system to be in thermal equilibrium, so that absorption equals emission, and using Kirchhoff's law for thermal radiation (where the sum of reflected plus absorbed energy equals unity), we have derived a model that incorporates both data types under a single set of physical parameters including the surface dielectric constant, wavelength-scale surface roughness, and the size distribution of scattering centers within the near-surface material [3]. The results of both models applied to each feature's backscatter curve are presented.

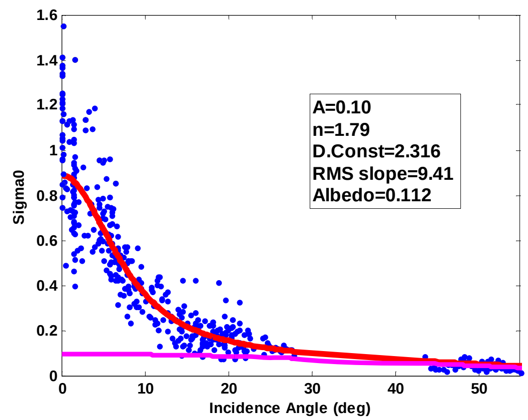

Fig. 3: The results of a composite Hagfors fit (red) using the diffuse cosine law (pink) to the scatterometry + altimetry points over Shangri-la (blue) suggest a dielectric constant around 2.3 and surface slopes on the order of 9°. Dielectric constants between 2 and 2.4 are thought to represent solid hydrocarbons [4].

Identifying Surface Features: We examine the high-resolution SAR and the ISS and VIMS infrared images to identify specific features and feature types from all available Titan passes, and use the locations derived from this catalog to extract the measurements corresponding to each feature type. In this way features that we cannot readily identify in the lower resolution modes of the radar can be extracted reliably. We find sufficient numbers of features at various incidence angles across all of the available Cassini passes, to infer the properties of specific feature types, and determine for instance whether the dune features scatter differently from the mountain or plains features. Determining the dielectric properties of each feature type will also constrain theories about feature formation.

References: [1] West R. et al. (2007), in prep. [2] Wye L. C. et al. (2007) *Icarus, 188,* 367-385. [3] Zebker H. A. et al. (2007) *Icarus,* (submitted). [4] Thompson W. R. and Squyres S. W. (1990) *Icarus, 86,* 336-354.