A COMPREHENSIVE BACKSCATTER MAP OF TITAN FROM THE CASSINI RADAR. L. C. Wye[1], H. A. Zebker[1], R. D. West[2], and the Cassini RADAR Team, [1]Stanford University, Department of Electrical Engineering, 350 Serra Mall, Packard Building, Stanford, CA 94305-9515, USA (lcwye@stanford.edu), [2]Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109.

Introduction: The Cassini RADAR instrument has been measuring the backscatter of Titan at a 2.2-cm wavelength for close to four years, with three passes remaining in the nominal mission (Feb 22, May 12, and May 28) and more to come in the extended mission. Here we present the entire collection of real-aperture results from the five active operational modes of the RADAR. We also develop a method for combining the data into a cohesive global backscatter map, achieving close to global coverage of Titan's surface.

Each active operational mode can be processed in its real-aperture form by summing all received energy within a single burst's beam, ignoring the transmitting waveform characteristics. This yields normalized radar cross-sections (σ^0) values at beamwidth-sized resolutions, allowing us to process all five active modes in a similar manner. Once the σ^0 values are calibrated to the same scale, we can combine them into a single global backscatter map of Titan.

Five Active Operational Modes: Standard operation of the Cassini RADAR consists of four unique data collection strategies. Starting at a distance of 100,000 km, it begins in radiometer mode, passively measuring the microwave emission radiating from the surface's disk. Flying closer (9000-30,000 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 (1000-5000 km), the SAR mode images swaths with resolutions between 300 m and 1 km. This sequence is often reversed on outbound to make a full RADAR Titan pass.

In addition to the three primary active modes listed above (scatterometer, altimeter, and SAR), there are occasionally two other operational modes that can push both SAR and scatterometry functionality out to larger distances than usual. High-altitude SAR mode produces images of 1 to 3 km resolution at altitudes between 10,000 and 25,000 km by using the lowest bandwidth receiver configuration to lengthen the size of the synthetic aperture and balance the azimuth resolution with the range resolution [1]. The second scatterometer operational mode, called the compressed scatterometer mode, can operate at altitudes between 25,000 and 100,000 km by combining the pulse echo data on board the spacecraft into a single echo profile to save data volume. This data collection strategy allows more pulses to be transmitted (>100 pulses as compared to the 8 pulses transmitted in standard scatterometry mode) without requiring more down-linked data volume. More pulses means higher SNR and better data quality. The five active RADAR modes are summarized in Table 1, where the mean resolution values are in parenthesis.

Table 1: Summary of the five active RADAR modes

Active Mode	Altitude (km)	Real-Aperture Resolution	
		Azimuth (km)	Range (km)
Standard Scatterometer	9000-30,000	50-250 (145)	50-350 (180)
Compressed Scatterometer	25,000-100,000	175-500 (300)	200-540 (330)
SAR	1000-5000	6-38 (15)	5-30 (13)
High-Altitude SAR	10,000-25,000	50-250 (158)	75-200 (156)
Altimeter	5000-15,000	30-100 (58)	25-80 (45)

Calibrating the Active Modes: We calibrate the data using a scale factor determined from thecomparison of the measured noise floor (in raw data counts) to the estimated receiver noise power (in watts); thus, we must know the receiver temperature fairly well [2]. The RADAR receiver has four different active bandpass filters, each with its own bandwidth and its own noise temperature characteristic. To complicate matters, there exists a narrow-band back-end noise source in the receiver chain that causes each noise temperature to increase as the back-end attenuation increases [3]. To characterize the variation of noise temperature with attenuator setting, we measure the data's noise floor response to attenuation change and scale it to noise temperature using the engineering tests of West et al. [3], which have determined the receiver noise temperature values for a few sample attenuator settings at each receiver bandwidth. The best-fit polynomial to this scaled noise curve yields the calibration noise temperatures.

Measuring the noise floor in the data can be challenging. For scatterometer mode observations, there are empty intervals at the beginning and end of the receive window that contain only noise samples, making the measurement straightforward. Yet, for the other modes, the noise must be measured between the pulse echoes or using special noise-only bursts. Quantization effects can also distort the measurements and will be considered here.

Merging the Datasets: The real-aperture resolution is a function of geometry, mainly spacecraft altitude and incidence angle. As shown in Table 1, the resolutions vary greatly between the active mode datasets, and even within a single operational mode. The challenge here is to integrate the overlapping data such that all information from the various modes and resolutions is utilized. The simplest procedure would be to overlay the higher-resolution data on top of the lower resolution data. Yet, this method would ignore the accuracy and often higher signal levels of the lower resolution data. On the other hand, one could simply average all datasets together. But this has the disadvantage of decreasing the resolution.

Here we build upon the approach of Yun et al. [4], utilizing a Prediction Error (PE) filter to maintain the spectral content of the high-resolution data while also considering the constraints implied by the underlying lower resolution data.

Example Datasets: We show examples of the various active mode intermediate maps in the figures to the right. The maps represent the variation of real-aperture σ^0 values from surface effects (mainly surface roughness and dielectric properties); incidence angle effects have been removed. Red represents high backscatter return, blue represents low return.

The example maps are shown in order of increasing resolution. We have grouped the data together by operational mode to demonstrate the resolution scales. In actuality, the merging problem is not just an inter-mode problem, but is also intra-mode, and the final image map will reflect that.

Conclusion: In this presentation, we show the real-aperture processing results from the Cassini RADAR's five active operational modes. This is the first time that all data has been processed to the same scale. Specifically, we discuss our calibration of each active operational mode and the method used to seamlessly integrate the data of various resolutions into a single backscatter map.

References: [1] West R. et al. (2006) *AGU Fall Meeting,* Abstract P13A-0151. [2] Wye L. et al. (2007) *Icarus* 188. [3] West R. et al. (2008) In preparation. [4] Yun S. et al. (2005) *IEEE TGRS,* 43(7).

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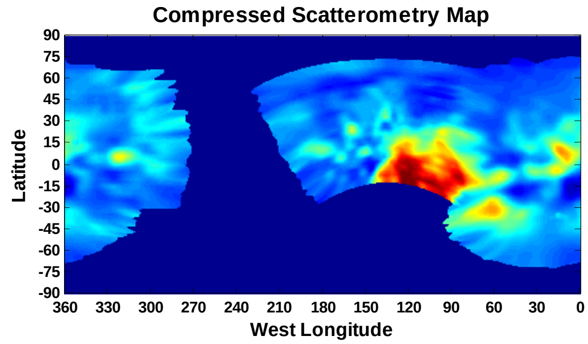

Figure 1: The compressed scatterometry backscatter map (T4, T12, T15, T20).

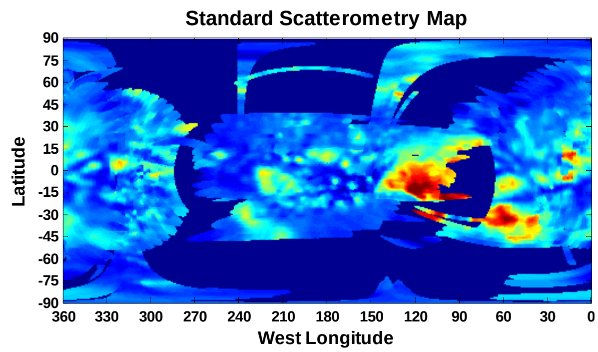

Figure 2: The standard scatterometry real-aperture backscatter map (Ta through T39).

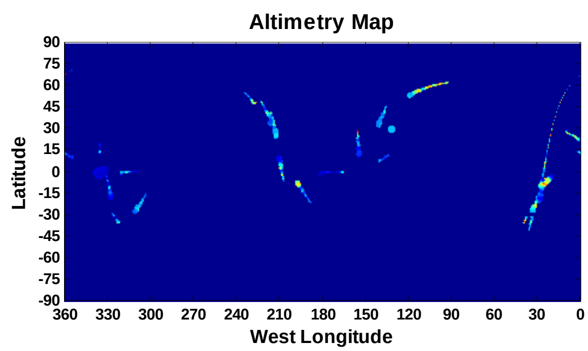

Figure 3: The altimetry real-aperture backscatter map (Ta through T39). In this image, the beam footprint was doubled for easier visualization. Also note that this is a map of raw backscatter values, not corrected for incidence angle since the angles are roughly constant between 0° and 1°.