Cassini RADAR Altimeter Observations of Titan. William T. K. Johnson[1], Philip S. Callahan[1], Yonggyu Gim[1], G. Alberti[2], E. Flamini[3] S. Hensley[1], R. D. Lorenz[4], R. Orosei[5], H. A. Zebker[6], and the Cassini RADAR Operations Team, [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, wtkjohnson@jpl.nasa.gov, [2]Consorzio di Ricerca su Sistemi di Telesensori Avanzati, 80125 Naples, Italy, [3]Agenzia Spaziale Italiana, 00131 Rome, Italy, [4]Space Department, Johns Hopkins University Applied Physics Lab, Laurel, MD 20723, [5]Istituto di Astrofisica Spaziale e Fisica Cosmica, Istituto Nazionale di Astrofisica, 00133 Rome, Italy [6]Stanford University, Stanford, CA 94305

Introduction: During the design of the Cassini RADAR it was recognized that different types of radar data have different value for the purpose of interpreting the properties of the main RADAR target, the haze-enshrouded moon Titan[1-2]. The closest approach time was reserved for Synthetic Aperture Radar (SAR) which provides information about geological features, then altimetry which provides topography of the surface, then scatterometry, and finally radiometry-only modes were allocated successively further out portions of a Titan pass. Altimetry data have now been collected on the inbound and outbound portions of thirteen passes of Titan. While the collection and processing of terrain height data from a spacecraft in a hyperbolic trajectory is a technical challenge the Cassini RADAR altimetry data in particular have shown unusual processing and interpretation obstacles well beyond any previously collected altimetry data. Here we discuss the data collected to date and examine some possibilities of terrain models that might fit the data.

Data Acquired: The altimetry data are generally collected while the spacecraft is between 4000 and 10,000 km (up to 16,000 km on some passes) on the inbound and outbound legs of a Titan pass which usually has a closest approach distance of about 1000 km. The ground tracks of each portion are approximately 600 km in length on the surface of Titan. The distribution on Titan appears somewhat random as the flyby trajectory is governed mainly by the Cassini orbiter tour that reflects the desires of all the instrument teams and navigational constraints such as gravity. Data were collected during Titan passes “A”, 3, 8, 13, 16, 19, 21, 23, 25, 27, 28, 29, and 30. Except for Titan pass 30 (T30), all data were acquired as described above. The acquisition sequence for T30 was specifically designed so that data would be collected over a swath that has previously been imaged by the SAR, providing a much-needed geologic context for the observations. The areas for which both altimetry and SAR are available had been very sparse pre-T30. In this latest pass (12 May 2007) the inbound altimetry portion coincides with nearly 2500 km of the T28 SAR swath so that a much wider range of geometries is available. At the time of this abstract we have completed only a very preliminary survey of the data and a more comprehensive analysis will be presented at this workshop.

Processing: The altimeter return comes from a footprint on the surface that varies with range from about 60 km in diameter at long range (16,000 km) to about 25 km at near range (4000 km) down to about 6 km in T30 which was enabled by operating in the altimeter mode at Cassini’s minimum distance from Titan. The 4.25 MHz bandwidth altimeter signal gives approximately 30 m range resolution when the frequency-encoded pulse is compressed. These reduced radar echoes are combined with spacecraft ephemeris to give an accurate surface height. Navigation solutions for Cassini relative to Titan are throught to be accurate to better than 100 m.

Following pulse compression several different types of altimetry processing have been applied to the data including leading edge detection, tracking the radar echo centroid, and maximum likelihood estimation (MLE). The results from early passes have shown very little terrain relief and some disagreement between the methods. Experience with radar sounder data, such as from the MARSIS instrument on the ESA Mars Express mission [3], suggests that “radargrams” might be useful as a visual aid in determining how best to do the height estimate and what the elevation surface profile might resemble. We present several examples of Cassini radargrams ranging from a smooth flat surface to very complex returns. Features within the radargrams show that removing radar effects such as changing antenna footprint, signal level, Doppler spread, and range rate will be a challenge because some of the effects are dependent on the surface characteristics.

Surface Models: The SAR data [4-6] have revealed several types of surfaces including lakes, dune-like formations, channels, and cryovolcanic features but no obvious Earth-like mountain systems. “Mountains” appear to be low in elevation and limited in spatial extent.

Overall, the altimeter data show the mean radius of Titan to be very close to the nominal value of 2575 km. Typical slopes found over the length of many altimeter tracks are <~0.2 m/km. In edge detected data, only a few features higher than 150 m on approximately 100 km scales have been seen with occasional relief of >500 m. Perhaps, as shown in Figs. 1 and 2, the most intriguing feature of the altimeter echoes is the wide range of "depths" seen.

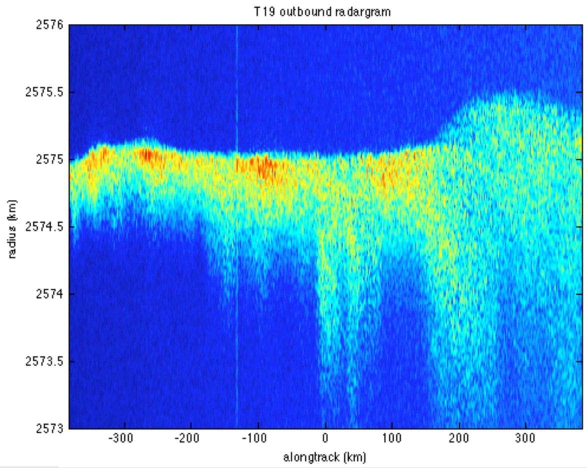

Figure 1: Radargram of T19 altimetry : Red represents strongest signal while the width is related to the surface properties such as material and slope. The spacecraft altitude varies from about 4000 km on the left to 10,000 on the right.

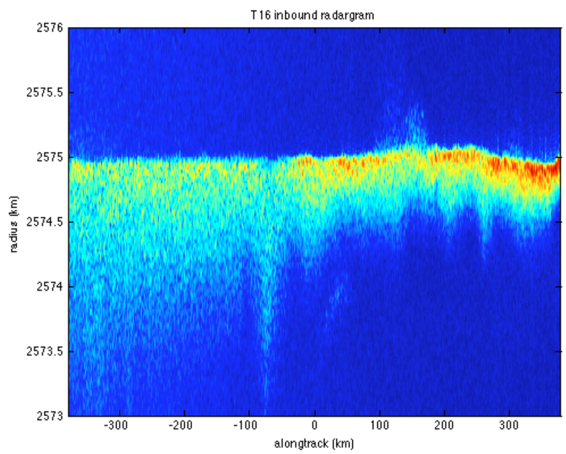

Figure 2: Radargram of T16 altimetry: The altitude variation is opposite that in Fig. 1.

Some data show fairly sharp, hard flat surface returns while other echoes must be from areas which have several hundreds of meters of relief with very few flat areas as the echoes are spread out much more than we expect from beam spreading or other effects. The deep echoes seem to be generally correlated with terrain that is bright either optically or in SAR, but much more overlap between data types will be necessary to validate the models.

References: [1] Elachi, C. et al., 2005, Space Science Rev 117. [2] Elachi, C. et al., 2006, Nature, 441. [3] Picardi, G. et al., 2005, Science 310, [4] Stofan, E. et al., 2006, Icarus 185. [5] Lopes, R. et al., 2007, Icarus 186. [6] Lorenz R. et al., 2006, Science 312

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