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Titan Digital Map Products from the Cassini RADAR in the NASA Planetary Data System

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1. Introduction

The RADAR instrument on board the Cassini spacecraft uses 2.17 cm microwave radiation to map the surface of Titan through the satellite's dense atmosphere [1]. During the Cassini prime mission (2004–2008), RADAR collected data on 22 Titan flybys [2]. The basic data from these encounters, described immediately below, have been archived in the NASA Planetary Data System (PDS) within 6 months of receipt [http://pds-imaging. jpl.nasa.gov/ Admin/resources/cd_cassini_radar.html]. In this abstract, we describe the variety of higher level derived products that have been generated from these basic data sets. Known collectively as Cassini RADAR Digital Map Products (DMPs), these products will be archived in the PDS in their first version (containing data from the full prime mission) in 2010. Subsequent releases will be updated to include extended mission data. These map products should be of significant utility to a wide range of Titan studies, particularly those that involve coregistration and comparison of RADAR data with results from other Cassini instruments.

2. Source Data

RADAR has multiple operating modes [1]. Active modes include synthetic aperture radar (SAR) imaging with resolutions from 0.3-1.4 km near closest approach and real-aperture altimetry profiles [3] and scatterometry scans [4] with 25-200 km resolution at greater distances. Passive-mode radiometric observations are obtained during all these modes and at even greater distances, allowing local to global mapping at 6-500 km resolution [5]. Data from each flyby are processed at JPL and archived to the PDS in two formats. Burst Ordered Data Products (BODPs) are binary table files listing a set of housekeeping, timing, geometric, observed, and reduced data values for each operational "burst" cycle of the instrument [6]. The BODPs contain the complete set of information obtained by RADAR but, although the tabulate quantities include the latitude and longitude observed by each burst, they are not straightforward to use in geospatial studies. Some derived quantities, such as radiometry corrected for sidelobe leakage, altimetry elevations corrected for off-nadir angle, and elevations from "SARTopo" [7] are contained in auxiliary files that must be merged with the BODPs by matching the burst numbers.

SAR data are archived as Basic Image Data Records (BIDRs) [8]. These are raster files at grid spacings of 256 pixels/degree or ~175 m/pixel (plus multiples of the basic resolution for working, browse, and thumbnail use) that can be viewed as images. Map projection information is provided so that the latitude-longitude coordinates of any pixel can be calculated, but data from each flyby are recorded in an Oblique Cylindrical projection that follows the groundtrack of that encounter, making comparison of multiple BIDRs more difficult. The BIDR dataset includes multiple versions of the SAR image (raw, noise-subtracted, normalized to constant incidence angle, and logarithmically scaled) as well as maps of parameters such as incidence angle.

3. Characteristics of the DMPs

All DMPs are raster images with both attached and detached PDS labels containing map projection information that allows the coordinate of any pixel to be calculated [9]. Map projections such as Equirectangular (similar to Simple Cylindrical) and Polar Stereographic that are globally valid and understood by numerous software packages are used, so that multiple datasets can easily be overlaid and compared [10]. Grid spacings of 2^n pixels/degree are used to further facilitate comparisons and a standard scheme of 15 quadrangles is employed [11] with lowest resolution global data also provided in two hemispheric maps. Most DMPs include maps of key observational parameters such as incidence/emission and azimuth angles and resolution, in addition to the primary data. Index maps are also provided to identify the source of each pixel in the DMPs that are created by mosaicking data from multiple flybys.

3.1 SAR Image Products

Mosaicked Image Data Records (MIDRs) are mosaics of multiple SAR images (BIDRs). Separate mosaics are provided for the closest-approach "main swaths" containing the highest resolution image data, lower resolution images from greater distances, and the combination of the two. The images are scaled logarithmically to 8-bit integer format before mosaicking. In addition, Repeat Image Data Records (RIDRs) are provided to facilitate the comparison of overlapping SAR images. These files contain the data from multiple flybys in separate files but (unlike the BIDRs) the same map projection so that the images are easily overlaid. Both 8-bit logarithmic and floating-point noise-subtracted (but not normalized to uniform incidence) versions of the images are provided. The associated maps of incidence and azimuth angles make quantitative analysis of scattering properties, surface change, and stereo topography straightforward.

3.2 Scatterometry Products

Whereas the SAR images and mosaics show high resolution details of the surface backscatter cross-section, these products show the equivalent parameter at the resolution of the full radar beam. Pass Scatterometry Data Records (PSDRs) show data from a single part of a single

flyby. Global Scatterometry Data Records (GSDRs) are mosaics of data from multiple PSDRs. Both floating-point and 8-bit versions of the data are provided, along with maps of resolution, incidence and polarization angles, and an index map showing the source of each pixel in the GSDR.

3.3 Radiometry Products

These rasterized maps of radiometric observations from a single scan of Titan (PRDRs) and mosaics of radiometry data from multiple flybys (GRDRs) are closely analogous to the PSDRs and GSDRs. Maps of the microwave brightness temperature, dielectric constant, and volume-scattering fraction, derived from joint analysis of the full radiometry dataset [5] are also included as part of the GTDR product.

3.4 Topographic Products

The altimetry [3] and SARTopo [7] modes yield topographic profiles along the track of each flyby. The Global Topographic Data Record (GTDR) is a raster map that shows all of these elevation profiles at a grid spacing that captures their $\geqslant$5 km resolution. More detailed topographic information for limited areas will be provided in the form of Digital Topographic Models (DTMs). These are generated by stereoanalysis of overlapping RADAR images, which are available for tens of areas covering >1% of Titan [12] and, for a very few areas where the uniformity of radar scattering properties permits, by two-dimensional radarclinometry (shape from shading) [13]. DTM products are currently preliminary and will not be included in the initial release of DMPs.

3.5 Indices and Extras

A full set of indices describing the DMP dataset will be provided as part of the PDS archive. This will include descriptions of the input data for each product, spatial coverage, resolutions, and the association of basic image data with auxiliary maps of resolution, geometric angles, and so on. Other extras will include detached ISIS 2 labels that will allow opening of the DMP files directly in the USGS ISIS 2 and ISIS 3 software [14] and JPEG/JPEG 2000 versions of the 8-bit scaled data sets.

4. Conclusions

Our intent in delivering the Digital Map Products is to advance the study of Titan by providing a comprehensive set of data from the RADAR investigation in a form that is georeferenced in a simple and consistent way, so that users can easily compare RADAR results from multiple modes and flybys with one another and with results from other instruments.

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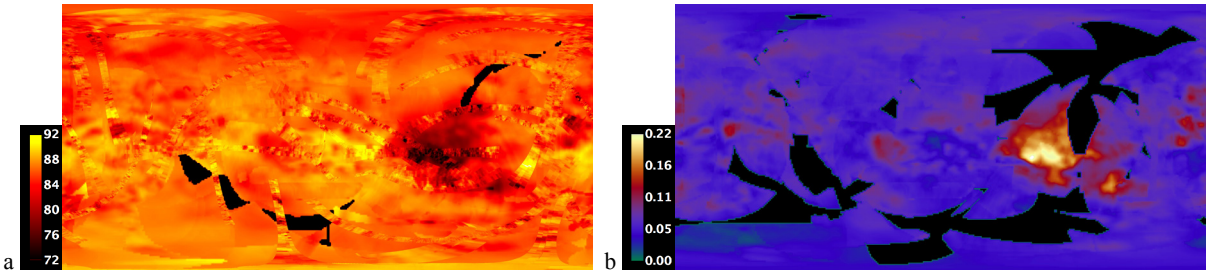

Figure 1: Examples of GRDR radiometry products obtained by joint modeling of all observations, global simple cylindrical projection with north at top, 180° in center. (a) Surface brightness temperature corrected to normal incidence. (b) Fraction of signal derived from volume scattering. Note that these figures have been color-coded with the indicated color scales for display purposes only. Archived data sets contain floating point or 8-bit integer data values, depending on data shown.