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Combining active and passive microwave observations of Titan to learn about its surface

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Abstract

The Cassini spacecraft payload includes a Radar instrument that measures both the backscatter (σ^0) and polarized thermal emission of Titan's surface at 2-cm wavelength. Active and/or passive observations were made during most of the 71 Titan passes in the 6-year span of the Prime and Equinox Cassini tours. The radiometric data have been combined into complementary maps of radiometric brightness and effective surface dielectric constant, each of which now covers almost all of the surface. These will be compared with the radar reflectivity and interpreted in terms of surface properties of Titan's diverse terrains.

1. Introduction

The thermal emission from a planetary surface provides a measure of its physical and chemical properties, and at microwave frequencies it uniquely samples the surface from centimeter to meter depths. Among Solar System bodies Titan's thermal microwave emission is uniquely amenable to interpretation because of the stability of the thermal environment and independent knowledge of physical temperatures across its surface. This allows the emissivity to be obtained with confidence from the brightness map. The active measurements may then be compared with the emissivity through Kirchhoff's law of thermal radiation and inferences drawn about the nature of the surface.

2. Observations

The Radar instrument uses the 4-meter Cassini high-gain antenna to observe in several modes depending on range to the source and incidence angle, as described by Elachi et al. [1]. At close range (<~6000 km) it maps the surface in synthetic aperture (SAR) mode using a five-beam switched feed to sweep the sub-spacecraft ground track, with synthesized map resolutions as high as 300 m. The circular central beam only is used at distances out to 12,000 km to carry out altimetry and single-beam SAR mapping, and out to ~40,000 km to obtain real-aperture scatterometry data. The radiometer channel obtains concurrent radiometry (real aperture) in all active modes, plus in a stand-alone mode that allows radiometry to be obtained at all times in the mission.

3. Radiometric Mapping

The thermal emission from a surface depends on the observational parameters, polarization and emission angle. In the present data set every point on the surface has been observed, usually more than once, at ranges, polarization and emission angles afforded by the geometries of many Titan passes, and observing segments allocated to Radar within these passes. This disparate data set has been organized into two surface maps, one of effective dielectric constant as obtained from the relative brightness variation with polarization and emission angle, and a second consisting of an adjusted absolute brightness temperature derived using the dielectric map to adjust the observed brightnesses to their equivalent value at normal incidence. The procedure for carrying this out, the absolute calibration, and the small residual uncertainties incurred are discussed by Janssen et al [2]. This previous work used only the data available up to the T30 pass of May 2007, comprising about 70 observing segments.

The maps presented here use the same approach but now incorporate over 200 observing segments obtained through the T71 pass in July 2010. The effective dielectric map is shown in Figure 1 and the equivalent brightness map at normal incidence is shown in Figure 2. These are still works in progress and the final maps will be presented at the meeting.

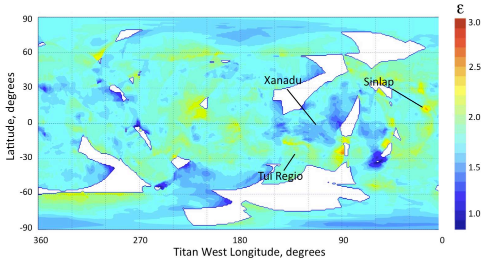

Figure 1: Map of effective dielectric constant.

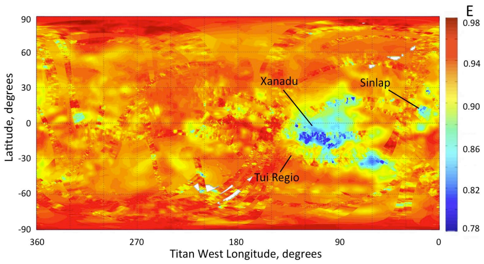

Figure 2: Map of equivalent brightness at normal incidence.

4. Interpretation and Conclusions

The effective dielectric constant of Titan's surface is low, averaging about 1.6, with a only a few places that begin to approach the value of 3.1 for pure water ice; e.g., in the vicinity of the Sinlap crater and the region separating Tui Regio from Xanadu. The low overall value is consistent with a loose, fluffy surface or a porous covering of organic material, with exposed water or ammonia ice appearing in only a few places on the surface.

The brightness map is inconsistent with a simple dielectric surface at its known and approximately uniform temperature, which we have previously interpreted as due to a predominance of volume scattering in radiometrically cold regions [1]. Figure 3 shows a plot of radar backscatter averaged over the real-aperture beam footprints in SAR mode (where we obtain the highest spatial resolutions) plotted against concurrently obtained emissivities for several types of terrain, showing an anticorrelation generally consistent with Kirchhoff's law. The very high reflectivities seen on Titan are hard to understand without resorting to models with coherent scattering structures on scales of a few wavelengths [3]; e.g., rounded "river rocks" in regions identified as of fluvial origin [4]. We will examine the unique regional behaviors of all distinct terrains in more detail, where we will show that the inferred surface properties obtained by comparing active and passive microwave observations have similarly interesting implications for Titan's geology.

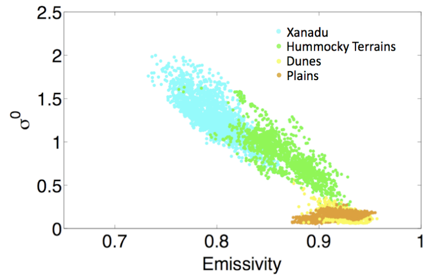

Figure 3: Radar reflectivity vs. emissivity for major terrain types

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