Photometric properties of Titan's surface at 5 µm investigated with Cassini/VIMS hyperspectral images

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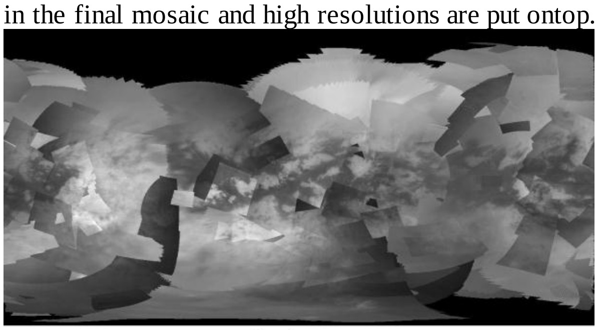
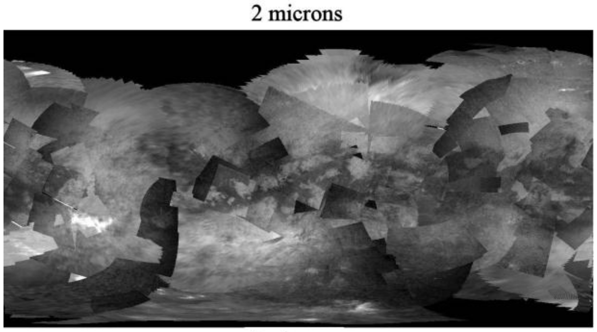
Introduction: Titan is the largest satellite of Saturn, and the only one to have a dense atmosphere. Whereas its surface cannot be seen at visible wavelengths due to the strong absorption and scattering effects of the atmospheric gases (mainly N_2 and CH_4) and aerosols, it can be seen at specific wavelengths in the infrared. We focus here on the global mapping of Titan using the Visual and Infrared Mapping Spectrometer onboard Cassini [1], and investigate the photometric behavior of the surface in the 5 µm window, with the objective to decorrelate atmospheric and surface components.

Methodology: In order to integrate all the available VIMS data cubes acquired during the nominal and extended mission (from T0 to T70) into a single global hyperspectral mosaic, we have automatically sorted the complete list of VIMS cubes (representing more than 20000 cubes of Titan) by increasing spatial resolution. Low resolution images are used as background in the final mosaic and high resolutions are put ontop.



2 microns



5 microns

Figure 1 : global mosaic of VIMS cubes acquired during the nominal and extendend mission at 2 µm (up) and 5 µm (bottom)

A series of filters has been designed to remove pixels acquired with too extreme viewing geometries, which produce strong atmospheric artifacts. Thresholds of 80° have been used for the incidence and emergence angles (i and e respectively), and a threshold of 100° has been used for the phase angle. The mosaic presented in Figure 1 contains only cubes acquired with time exposures in the range 40-240 ms to avoid too noisy images and saturated pixels. It has been produced at a resolution of 4, 8 and 16 pixels per degree, corresponding to spatial resolutions of 11.2, 5.6 and 2.8 km per pixel at the equator.

Investigation of the 5 µm window: The surface of Titan can be seen mainly in seven narrow infrared windows at 1.08, 1.27, 1.59, 2.01, 2.69, 2.78 and 5.0 µm where the few percents of CH_4 present in the atmosphere do not efficiently absorb the solar flux [2,3]. Among these, the 5 µm window is the less affected by the additive component due to the aerosols [4]. We used the 2D-scatter plots shown in figure 2 in order to study the dependence of the signal at 5 µm with the observing geometry. Figure 2 (up) corresponds to the the 5 micron flux plotted versus cos i, which corresponds to a lambertian body. The plot is restricted to the area indicated by the red rectangle, in order to avoid variations at 5 µm due to pure albedo variations. Figure 2 (bottom) corresponds to the 5 micron image plotted versus cos i / (cos i + cos e), which would correspond to a photometric body following the Lommel Seeliger Law.

We see in these plots that the cos i factor provides a better correlation with the 5 µm image than the cos i/ (cos i + cos e) factor. The only points departing from the overall tendency correspond to clouds, or to Tui Regio, which is well known to have an anomalously high signal at 5 µm [5]. The 2D-scatter plot can be fitted using a straight line with the following equation: $R_{5\mu m} = -0.0035 + 0.0407x \cos i$. This means that the surface is at first order following a pure lambertian law and is scattering almost isotropically. A similar result has been obtained by [6] at shorter wavelengths using data from the DISR instrument onboard the Huygens probe. It also indicates that Titan's bright regions have albedos at 5 µm of ~0.04. This is consistent with the findings of [7], who derived a value between 0.03 and 0.05 using a MODTRAN™ 5 radiative transfer code.

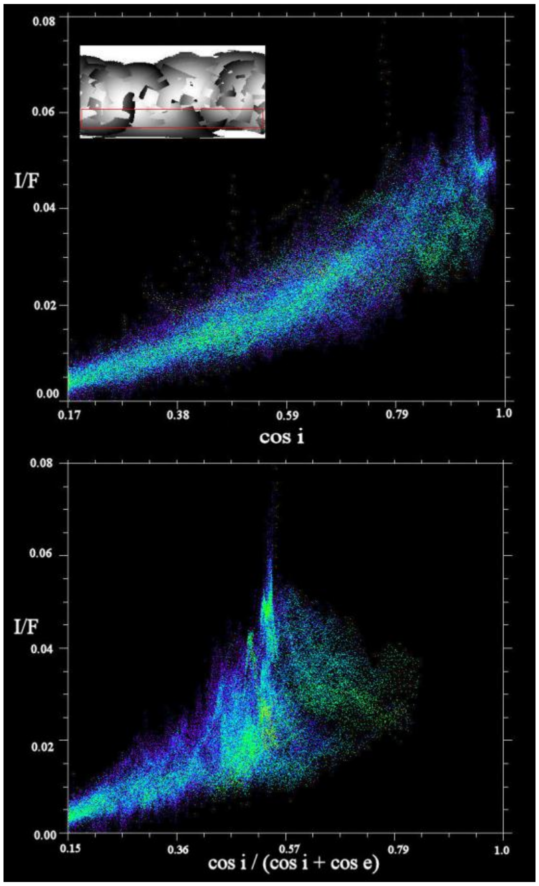


Figure 2 : 2-D scatter plots of the flux at 5 µm versus geometric factors (up : cos i, bottom : cos i/(cos i+cos e))

The correlation seen in figure 2 also means that most of the light reaching the surface at 5 microns corresponds to direct flux. As a consequence, the division by cos i can therefore be used at first order to normalize the viewing geometry in the 5 micron image. This is shown in figure 3. The main discrepancies which are still present between individual images in this mosaic are due to transient phenomenon such as clouds.

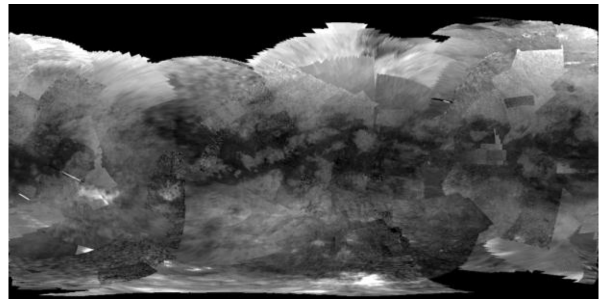


Figure 3 : 5 µm image divided by cosine of the incidence angle

Conclusion and Perspectives : It seems from this test that Titan's surface behaves almost isotropically at 5 µm. We are currently investigating its behavior at shorter wavelength, were the coupling with atmospheric aerosols complicates the correction of the mosaics. A preliminary map at 2µm is shown in figure 4 before correction (left) and after applying an empirical correction of the aerosols and the geometric factor (right).

Bibliography : [1] Brown R.H. et al., The Cassini Visual and Infrared Mapping Spectrometer investigation, *Space Sci. Rev., 115*, pp. 111–168, 2004. [2] Sotin et al., Release of volatiles from a possible cryovolcano from near-infrared imaging of Titan, *Nature*, 435, pp.786-789, 2005. [3] Barnes, J. W., et al., Global-scale surface spectral variations on Titan seen from Cassini/VIMS, *Icarus*, 186, pp. 242–258, 2006. [4] Rodriguez et al., Cassini/VIMS observations of the Huygens landing site on Titan, *Planet. Space Sci.*, 54, pp 1510-1523, 2006. [5] Barnes et al., Cassini observations of flow-like features in western Tui region, Titan, *Geophys. Res. Lett.*, 33, 2006. [6] Schröder and Keller, The unusual phase curve of Titan's surface observed by Huygens' Descent Imager/Spectral Radiometer, *Planet. Space.Sci.*, 57, p1963-1974, 2009. [7] Soderblom et al., The geology of Hotei Regio, Titan: Correlation of Cassini VIMS and Radar, *Icarus*, 610-618, 2009

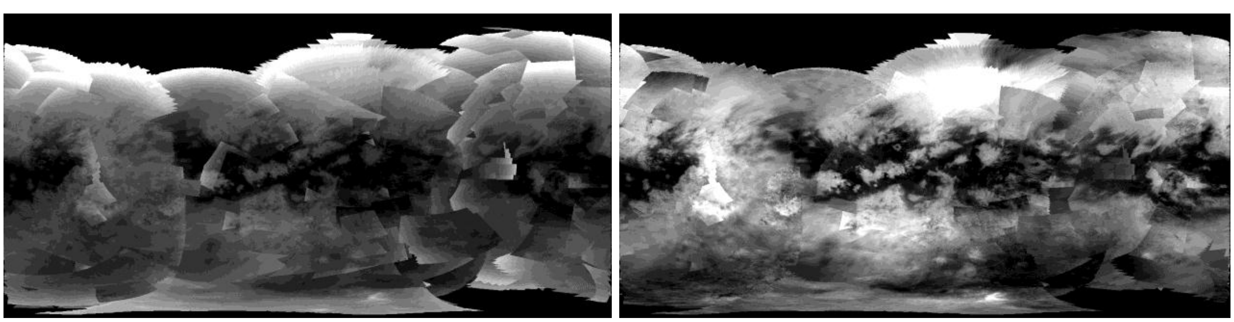


Figure 4: cylindric projection of VIMS data at 2 µm acquired during the nominal and extended Cassini mission (flybys T0 to T70). The left image corresponds to the 2 µm mosaic divided by Cos i. The right image corresponds to the same mosaic for which an empirical aerosol removal has been applied prior to the division by cos i.