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The spectral nature of various Titan surface units: implications on the composition

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Abstract

We investigate both the surface and the atmospheric contributions on Titan from Visual and Infrared Mapping Spectrometer (VIMS) spectro-imaging of near-infrared data by use of a radiative transfer code [1-3]. We focus here on the major geological and albedo major units identified in [4-7]: mountains, plains, labyrinths, maculae, impact craters, dune fields, alluvial fans, and possible cryovolcanic and/or evaporite features. We find that, for some of the regions classified as the same geomorphological unit in SAR, there are significant differences in spectral responses (albedo) from VIMS, depending on location. Conversely, some regions classified from SAR as different geomorphological units show very similar spectral responses in VIMS. The surface albedo differences and similarities among the various units constrain the implications for the geological processes that govern Titan's surface (i.e. aeolian, fluvial, sedimentary, lacustrine etc). Hence, we are able to report on the differences and similarities among the various regions, monitor their temporal evolution, and provide implications for their chemical composition, which lead us to constrain specific processes of origin.

1. Context/Data

In order to unveil Titan's surface nature, it is important to determine the surface composition of different units, along with their morphological expressions. Matching the surface units with specified mixtures of materials can shed light on the interconnection between the interior, surface, and atmosphere. The Cassini VIMS obtained spectro-imaging data of Titan's surface from flybys performed during the last thirteen years, in the 0.8-5.2μm range. The data from the seven narrow methane spectral "windows" centered at 0.93, 1.08, 1.27, 1.59, 2.03, 2.69-2.79 and 5 μm provide some information on the lower atmosphere and the surface parameters. Atmospheric scattering and absorption need to be clearly evaluated before we can extract the surface properties. Here we focus on areas that are in the mid-latitudes and are of geological interest. The geomorphological units and albedo features we analyze are:

i. the undifferentiated plains [5;6],
ii. hummocky/mountainous terrains [4;6],
iii. labyrinth terrains [6],
iv. variable plains [5;6], v. streak-like plains [6],
vi. dunes [4;5],
vii. candidate evaporites [8],
viii. the Huygens Landing site [6],
ix. candidate cryovolcanic sites [3;4],
x. alluvial fans [7], xi. maculae [10],
and xii. impact craters [9]. For most of the geomorphological units and albedo features, we also provide results on the temporal evolution of these surface units for a significant period of time between 2004-2013 [3;11].

2. Methods

Our radiative transfer (RT) method is a 1-D multi-stream RT code based on the open-source solver SHDOMPP [1]. As inputs, we used most of the Huygens Atmospheric Structure Instrument (HASI) and the Descent Imager/Spectral Radiometer (DISR) measurements, as well as new methane absorption coefficients. These are important to evaluate the atmospheric contribution and constrain the real surface alterations by comparing the spectra of these regions. Figure 1 shows the spectral variations of the extracted surface albedos from RT of the regions of interest with the 'ground truth' albedo derived at the Huygens landing site (HLS). We then test the surface albedos against a spectral database of Titan candidate ice and organic constituents and provide some constraints on the possible major material present in every geomorphological unit. We use a new updated material library based on Bernard et al. (2006), Coll et al. (2006) and the GhoSST database (http://ghosst.osug.fr).

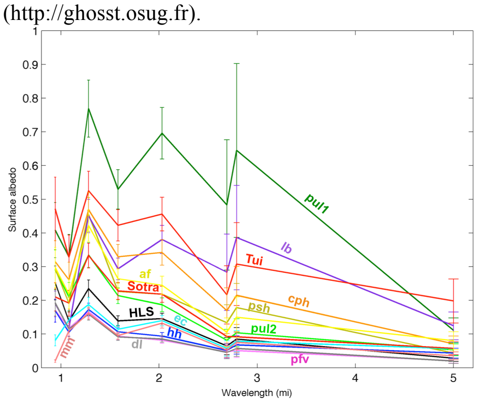

Fig. 1. Weighted averages in the methane windows of the surface albedos of the various geomorphological units: *i)* Undifferentiated plains 1 (pul 1) (green), *ii)* Undifferentiated plains 2 (pul 2) (light green), *iii)* Labyrinth (lb) (violet), *iv)* Streak-like plains (psh) (dark yellow), *v)* Variable plains (pfv) (fuchsia), *vi)* Hummocky (hh) (blue), *vii)* Dunes (dl) (grey), *viii)* Evaporite candidates (ec) (light-blue), *ix)* Tui Regio –cryovolcanic (cc Tui) (red), *x)*,Sotra Patera –cryovolcanic (cc Sotra) (red), *xi)* impact craters (cph) (orange), *xii)* alluvial fans *(af)* (yellow), *xiii)* maculae (mm) (peach), and *xiv)* the Huygens landing site (HLS). For clarity purposes, we have connected the points with straight lines that do not represent real results but help see the spectral behavior as a whole for each unit.

3. Results

From the results of the analysis, we confirm that for the majority of terrains there is a good correlation between the classifications from SAR and VIMS data. Within VIMS data, we have identified 3 main types of albedo response (high, medium, low). The Huygens landing site and the candidate evaporite regions appear to be compositionally similar to one type of plains unit (variable plains), suggesting similar formation mechanisms. By matching the extracted albedos with reflectance spectra of candidate materials for Titan's surface, we find that all regions fall into one of three main types of major candidate constituent: water ice, tholin-like material, or an unknown, very dark material.

From the analysis of the temporal variation Tui Regio (cryovolcanic candidate), which has been initially reported to change in surface albedo from 2005 to 2009 by becoming darker [5], has returned to its initial (2005) brightness in 2015. Furthermore, Hotei Regio, which remained unchanged during 2005 to 2009, retained the same brightness up to 2015. In a previous study [5], we have shown that Sotra Patera (strongest cryovolcanic candidate) became brighter within a year from 2005 to 2006 by a factor of 2, especially at short wavelengths. We therefore show that temporal variations of surface albedo (in chemical composition and/or morphology) exist for some areas on Titan's surface, but that they differ from one region to the other. This could be due to diverse, past and/or ongoing formation processes (endogenic and/or exogenic, possibly cryovolcanic). The surface albedo variations together with the presence of volcanic-like morphological features suggests that the cryovolcanic candidate features are possibly connected to the satellite's deep interior, which could have important implications for the satellite's astrobiological potential. This idea has been recently augmented by the construction of recent interior structure models of Titan and corresponding calculations of the spatial pattern of maximum tidal stresses [14]. However, an explanation attributed to exogenic processes is also possible [15]. Currently, we are working on deriving information on the full chemical compositions of the aforementioned regions from the extracted surface albedos. This will shed light on the potential formation processes.

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