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EPSC Abstracts
Vol. 12, EPSC2018-167, 2018
European Planetary Science Congress 2018

The spectral nature of Titan's major geomorphological surface units: constraints on the composition

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Abstract

We investigate Titan's low-latitude and midlatitude surface using spectro-imaging near-infrared data from Cassini/Visual and Infrared Mapping Spectrometer [1]. We use a radiative transfer code [2-4] to first evaluate atmospheric contributions and then extract the haze and the surface albedo values of major geomorphological units identified in Cassini Synthetic Aperture Radar data, which exhibit quite similar spectral response to the Visual and Infrared Mapping Spectrometer data. We have identified three main categories of albedo values and spectral shapes, indicating significant differences in the composition among the various areas. We compare with linear mixtures of three components (water ice, tholin-like, and a dark material) at different grain sizes. Our fits of the data are overall successful, except in some cases at 0.94, 2.03, and 2.79 µm, indicative of the limitations of our simplistic compositional model and the need for additional components to reproduce Titan's complex surface. Our results show a latitudinal dependence of Titan's surface composition, with water ice being the major constituent at latitudes beyond 30°N and 30°S, while Titan's equatorial region appears to be dominated partly by a tholin-like or by a very dark unknown material. The albedo differences and similarities among the various geomorphological units give insights on the geological processes affecting Titan's surface and, by implication, its interior. We discuss our results in terms of origin and evolution theories.

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 [4; 5], 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. the Huygens Landing site [6],
viii. alluvial fans [7], and ix. crater ejecta [8].

2. Methods

Our radiative transfer (RT) method is a 1-D multi-stream RT code based on the open-source solver SHDOMPP [2]. 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), Brasse et al. (2015) and the GhoSST database (http://ghosst.osug.fr).

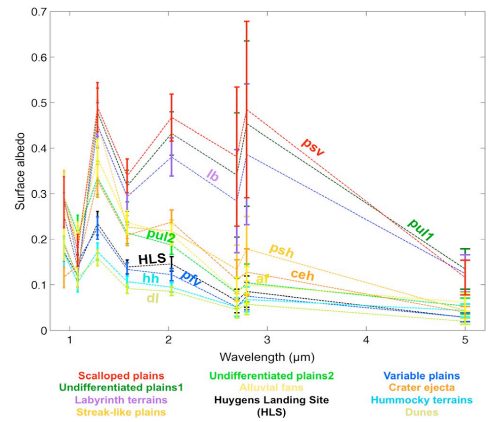

Fig. 1. Weighted averages in the methane windows of the surface albedos of the various geomorphological units: For clarity purposes, we have connected the points with straight lines that do not represent real results but help see the spectral behavior as a whole for each unit.

3. Results

Our results indicate that: i. RoIs with the same geomorphological unit classification also share the same or very similar spectral characteristics, ii. there are three groups of composition mixtures present on Titan's low-latitude and midlatitude surface region. In Figure 2 we plot the regions on an Imaging Science Subsystem global map, and hereafter we compare with previous work and additional insights from geological aspects. Our results suggest the presence of a material compatible with water ice in the areas around high latitudes. The HLS and the variable plains share many albedo characteristics (Figure 1) suggesting that HLS is part of this unit and has an organic origin or is at least coated with organic materials. The same applies to the hummocky terrains and the dunes that are also compatible with an organic surficial composition. The alluvial fans and the crater ejecta units are covered by tholin-like material and seem to be dominated by atmospheric deposits that mask their underlying material. The areas with major constituents spectrally compatible with water ice seem to follow a geographical pattern as all four (northern undifferentiated plains, labyrinths, scalloped plains, and streak-like plains) are located at northern or southern midlatitudes, close to 30°–60°N and 60°S (Figure 11). Hence, Titan's surface composition has a significant latitudinal dependence.

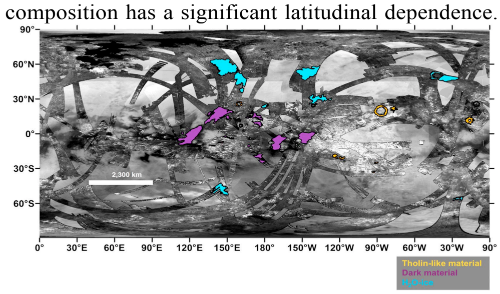

Fig. 2. Implications on the major constituents of Titan regions of interest from Solomonidou et al. 2018 [1].

Taking into consideration our results we provide two possible interpretations: one suggesting that more dark material is being deposited from the atmosphere onto the equatorial regions compared to the higher polar regions and another where we assume that atmospheric deposition is similar in the low-latitude and midlatitude on Titan, but with more rain falling onto the higher latitudes causing additional processing of materials on those regions.

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.

Acknowledgements

This research was supported by the Cassini Data Analysis and Participating Scientists Program (CDAPS) grant NH16ZDA001N to R.L. ©2018 California Institute of Technology. Government sponsorship acknowledged.

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