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The spectral evolution of various Titan geomorphic surface types

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Abstract

We study the various, complex and potentially dynamic mid-latitude geological terrains of Titan. We focus on the geological types identified as possibly active in Lopes et al. (2010, 2015) [1;2] in addition to regions we studied in our recent work [3] where we reported two equatorial regions that present changes in surface albedo with time, such as Tui Regio and Sotra Patera. Here, we study the nature of the various geomorphological unit types (undifferentiated plains, hummocky/mountainous, candidate cryovolcanic sites, labyrinth, dunes, and others) in terms of surface albedo values and their spectral evolution with time (depending on data availability). Hence, we are able to report the differences and similarities among the various regions and provide implications on 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 ten years, in the 0.8-5.2 μm 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 close to the equator and are of geological interest. The geomorphological units we analyze are: i. the Undifferentiated Plains ('Blandlands') [2], ii. Hummocky/mountainous terrains [2;4], iii. Labyrinth terrains [4], iv. Variable Plains, v. Stripe-like plains, vi. Dunes, vii. Candidate evaporates [5], viii. the Huygens Landing site [6], ix. Candidate cryovolcanic sites [7]. For the last four type units we also provide results on the temporal evolution of these surface units for significant period of time between 2004-2013 [6;7].

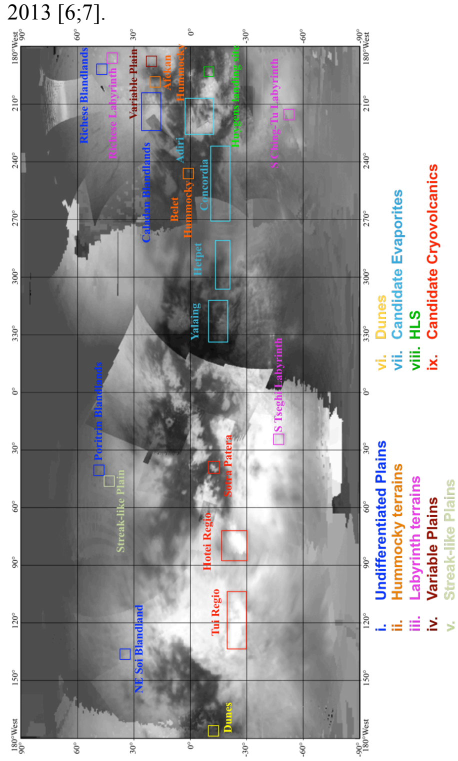

Fig. 1. Studied regions of interest from eleven different geological units on VIMS (2.03μm).

2. Methods

Our radiative transfer (RT) method is a 1-D multi-stream RT code based on the open-source solver SHDOMPP [8]. 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 2 shows the difference of the extracted surface albedos from RT of the regions of interest with the 'ground truth' albedo derived at the Huygens landing site.

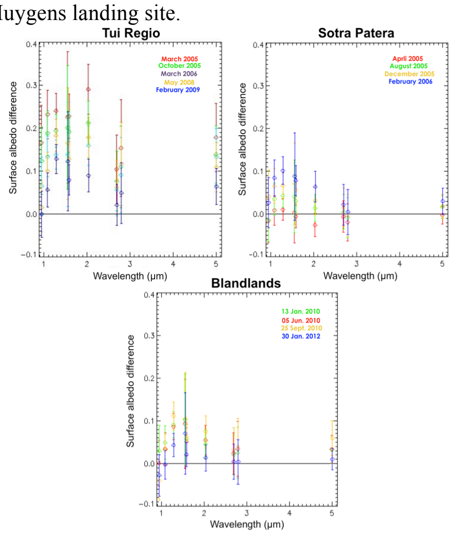

Fig. 2. Surface spectra showing changes in surface albedo shape and values in the near-infrared methane windows as a function of time with respect to the HLS surface albedo. (top left) Tui Regio from 2005-2009, (top right) Sotra Patera from 2005-2006, (bottom) the undifferentiated plains from 2010-2012 (from selective dates). From Solomonidou et al. (2015, Icarus, in press)

3. Results

Tui Regio's (location shown in Fig. 1 red) surface albedo spectrum remains the same with time, only its overall brightness diminished from 2005 to 2009 (Fig. 2). The Sotra Patera (Fig. 1 red) area became brighter within a year from 2005 by a factor of 2, especially at short wavelengths. The tests, for approximately the same periods of time, of three surface reference points that correspond to dune fields (Fig. 1 yellow) show that they did not present similar changes in surface albedo. The undifferentiated plains (Fig. 1 blue) and preliminary results from the evaporite candidates ix (Fig. 1 light blue) do not present any surface albedo changes with time. 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). In addition, in a follow up study we found that the labyrinth terrains (Fig. 1 magenta) and the undifferentiated plains seem to consist of a very similar if not the same material, while the different types of plains show compositional variations (Fig. 1 dark red, light green) The surface albedo variations together with the presence of volcanic-like morphological features suggests that the cryovolcanic candidate features (Fig. 1 red) 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 new interior structure models of Titan and corresponding calculations of the spatial pattern of maximum tidal stresses [9]. However, an explanation attributed to exogenic processes is also possible [10].

Currently, we are working on deriving information on the chemical composition of the aforementioned regions from the extracted surface albedos. This will shed light on the potential formation processes.

Acknowledgements

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