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New processing of Cassini/VIMS data on potentially geologically varying regions

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Abstract

We present a study of Titan's geology with a view to enhance our current understanding of the satellite's potentially geologically varying regions. We apply here a statistical method, the Principal Component Analysis (PCA) [1, 2] and a radiative transfer method [3, 1] on three potentially "active" regions on Titan, i.e. regions possibly subject to change over time (in brightness and/or in color etc) [4] namely Tui Regio, Hotei Regio, and Sotra Facula. With our method of PCA we have managed to isolate specific regions of distinct and diverse chemical composition. Then, with our follow-up RT method, we retrieved the surface albedo of the three isolated regions and of the surrounding terrains with different spectral response. These methods enabled us to evaluate the atmospheric contribution and allowed us to better constrain the real surface alterations, by comparing the spectra of these regions. Finally, the temporal surface variation of Hotei Regio as suggested by Nelson et al. 2009 [5], has been tested through the use of the RT method while we have superimposed this area's Cassini Visual and Infrared Mapping Spectrometer (VIMS) and RADAR data in order to 'view' the morphological potential. Even though we have used exactly the same dataset as Nelson and co-authors in 2009, we did not detect any significant surface albedo variations over time; this led us to revise the definition of "active" regions: even if these regions have not visually changed over the course of the Cassini mission, the determination of the chemical composition and the correlation with the morphological structures [6] observed in these areas do not rule out that past and/or ongoing cryovolcanic processes are still a possible interpretation.

1. Context/Data

The determination of Titan's surface chemical composition is critical in order to unveil its geology and investigate the interactions between the interior, the surface and the atmosphere. The Cassini VIMS obtained data of Titan's surface from flybys performed during the last eight years. In the 0.8-5.2 μm range, these spectro-imaging data showed that the surface consists of a multivariable geological terrain hosting complex geological processes. The data from the seven narrow methane spectral "windows" centered at 0.93, 1.08, 1.27, 1.59, 2.03, 2.8 and 5 μm provide some information on the lower atmospheric context and the surface parameters that we want to determine. Atmospheric scattering and absorption need to be clearly evaluated before we can extract the surface properties. In this study we focus on the following cryovolcanic candidates and potentially varying regions: Tui Regio (20°S, 130°W) [7], a 1500-km long flow-like figure, Hotei Regio (26°S, 78°W) [8], a 700-km wide volcanic-like terrain and Sotra Facula (15°S, 42°W) [9], an area measuring 235-km in diameter. All these regions have high geological interest due to their spectral index, which suggest dynamic geological processes, in addition to their surficial structural expressions.

2. Methods

We are sequentially using two methods in order to acquire the optimal result from the data set. First, the Principal Component Analysis (PCA), which is a statistical method widely used in geophysics studies, decorrelates the features visible on many similar images into a new set of images that show the main

features only, sorted by frequency of appearance (not by brightness). We have tested this method on the previously studied Sinlap crater [10], delimitating compositional heterogeneous areas compatible with the published conclusions by Le Mouélic et al. (2008).

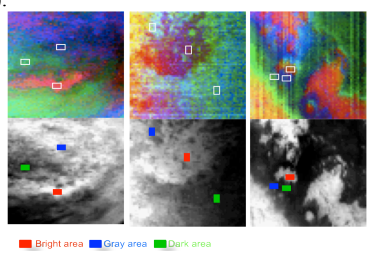

Figure 1: PCA on VIMS data (upper) and false colour composites (lower) of the three cryovolcanic candidate regions. The red spot marks the bright area, the blue the gray area and the green the dark area.

Secondly, the radiative transfer method is a 1-D multi-stream RT code based on the open-source solver SHDOMPP [11]. We have used as input most of the Cassini Huygens Atmospheric Structure Instrument (HASI) and Descent Imager/Spectral Radiometer (DISR) measurements, as well as new methane absorption coefficients [12].

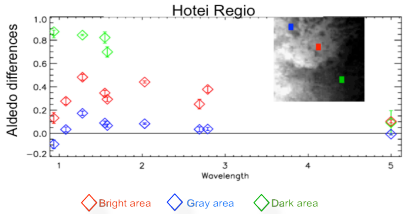

Figure 2: RT on VIMS data at PCA selective regions. Surface albedo differences with VIMS with respect to the Huygens landing site albedo.

As a test case, we used our RT code to verify the varying brightness of Hotei Regio reported by other investigators based on models lacking proper simulation of the atmospheric absorption [5].

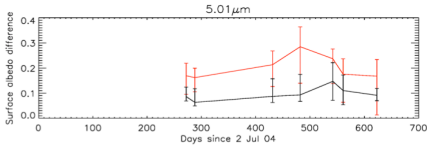

Figure 3. Time variation of the average surface albedo obtained within 5μm methane window. The red and black curves correspond to Hotei and the "grey reference" areas respectively.

3. Results

We have isolated 3 areas in Tui Regio, Hotei Regio and Sotra Facula with PCA (Fig. 1) that have different spectral response as showed by the Radiative Transfer simulation (Fig. 2). The bright areas are brighter at almost all wavelengths/ the dark are darkest at all wavelengths. There seem to be no significant spectral variation in Hotei Regio from 2004 until 2006 (Fig.3). Nevertheless the shape of the region itself, with lobate flows and possible calderas, is compatible with cryovolcanism. We only demonstrated here that its activity, if any, spans far longer than a few months or a few years. Currently we study the chemical composition (species, grain sizes, mixtures) from the surface albedos we derived.

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