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Potentially active regions on Titan: Application of PCA to Cassini/VIMS data and atmospheric subtraction

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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 active zones. We combine here Principal Component Analysis and ”atmosphere substraction” [1;2], as a prelude to “differential spectroscopy” on three potentially active regions on Titan, namely Tui Regio, Hotei Regio, and Sotra Facula. With the statistical method of Principal Component Analysis, we have managed to isolate specific regions of interest of distinct spectral behaviours and hence of diverse chemical composition; then, by means of atmospheric subtraction, we have reduced the effect of the contribution of the atmosphere within the atmospheric methane windows, to better focus on the real alterations in surface composition, by comparing the spectral behaviours of these regions. We present some suggestions for the chemical composition and the correlation with the morphotectonic features [3] within these three cryovolcanic candidate areas.

1. Introduction

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. Cassini/VIMS acquired a large amount of spectra and images taken within the narrow methane spectral windows centered at 0.94, 1.08, 1.27, 1.59, 2.03, 2.79 and 5-μm. However, the surficial imaging is still ambiguous due to haze scattering and particle absorption and needs to be clearly defined. In this study we focus on the following cryovolcanic candidates and potential active regions: Tui Regio (20°S, 130°W) [4], a 1500-km long flow-like figure, Hotei Regio (26°S, 78°W) [5], a 700-km wide volcanic-like terrain and Sotra Facula (15°S, 42°W) [6], 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. The key aim of our study is to apply atmospheric and photometric corrections on the spectral images of both areas, in order to obtain more accurate data that will constrain the analysis of the chemical composition.

2. Method

We are sequentially using two methods in order to acquire the optimal result from the data set. First, the ‘Principal Component Analysis’, 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). Secondly, the ‘Atmosphere Subtraction’ is an empirical method that evaluates the atmospheric contribution through absorption filters in the methane bands and produces surface images by subtracting this atmospheric component from images in the centre of the methane windows. We consider the centre of the methane window as the "surface" image, while the channel from the closest methane "wing" diagnoses best the "atmospheric" contribution. This accounts mainly for the flux reflected by the aerosols in the upper layers of the atmosphere. This method allows us to compensate for most of the atmospheric contribution while focusing on the real shapes of the visible features, something useful for morphology studies. Doing this separately for each window allows us to estimate the relative albedo variation of the surface as a function of wavelength, focusing on a few ‘Regions of Interest’ (RoI) isolated through the PCA: this will enhance their chemical composition discrepancies.

3. Figures

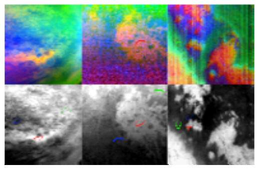

Figure 1: PCA on VIMS data (upper) and false colour composites (lower) of the three cryovolcanic candidate regions. The red line marks the 'cryo' bright area, the green the semi-dark area and blue the dark area (B).

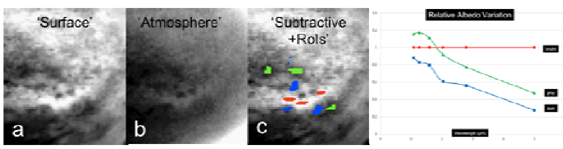

Figure 2: Choice of images in the K band: in the core of the 2.03µm window, the surface features are visible (a), while atmospheric variance is the main feature of the 'atmosphere' image (b). Subtracting the later from the former dampens the atmospheric contribution and enhances the surface features contrast on the resulting 'unaffected image' (c), where RoI are selected. The graph shows the relative albedo curve.

4. Summary and Conclusions

We have used one statistical method and one empirical method on VIMS data, in order to retrieve surface images without the atmospheric contribution at three specific areas. We have applied the Principal Components Analysis in order to delimitate the areas of different compositions. With PCA, we have isolated 3 distinct areas within Tui Regio (Red, Green, Blue), characterized as 'Cryo' bright areas (R), Semi-dark areas (G), and Dark area (B) (Fig. 1). We have treated Hotei Regio and Sotra Facula similarly. Afterwards, using the Regions of Interest (ROIs) as indicated from PCA we have applied an empirical method, to diminish the effect of the atmosphere on the image (Fig. 2). For Tui Regio, the ''cryo bright area'' terrain used as a reference presents high I/F values, but is the very brightest only at longer wavelengths: obvious alterations are expected at 2.03µm, 2.79µm, and 5.02µm (Fig.2). Similarly to Tui Regio, Hotei Regio's spectral graph indicates that the "cryo bright area" presents high I/F values but remains brighter only at long wavelengths. In the case of Sotra Facula, the PCA method returns a slightly different image. To be more specific, for this region, far more reduced in size than the previous ones, PCA is able to differentiate two behaviours within the dark regions. As seen in Fig. 1, the brightest areas are still red-orange, but the gray ones appear as yellow; moreover, the dark fields of Fensal are now splitted into green and blue regions, most certainly related to the fields of dune (green) and the water ice remnants, well known as 'dark brown' and 'dark blue' regions respectively.

Acknowledgements

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