EPSC Abstracts
Vol. 13, EPSC-DPS2019-191-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

A corridor of exposed ice-rich bedrock across Titan's tropical region

Caitlin A. Griffith[1], Paulo F. Penteado[2], Jake D. Turner[3], Catherine D. Neish[4], Giuseppe Mitri[5], Nicholas J. Montiel[1], Ashley Schoenfeld[6], Rosaly M.C. Lopes[2]

[1]Department of Planetary Sciences, LPL, University of Arizona, Tucson, AZ, 85721; Griffith@lpl.arizona.edu, [2]Department of Physics and Astronomy, Northern Arizona University, Flagstaff AZ 86011,currently at [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109 [3]Department of Astronomy, University of Virginia, Charlottesville, VA 22904, USA, [4]Department of Earth Sciences, University of Western Ontario, London, ON, Canada, [5]International Research School of Planetary Sciences, Università d'Annunzio, Pescara, Italy, [6]Department of Earth and Planetary Sciences, UCLA, Los Angeles, CA, 90095

Abstract

Global maps of Titan show great diversity in terrain types, but their association to specific compositions on a large scale are obscured by Titan's thick atmosphere, which shrouds the weak spectral features. Here we develop a Principal Component Analysis (PCA) that enables the identification of subtle spectral features. The PCA was applied to over 13,000 Cassini VIMS spectra that cover half the globe, focused on tropical latitudes. Our analysis detected an ice-rich linear feature, which extends a length equivalent to 40% of Titan's circumference. This corridor is puzzling because it does not correlate with topography nor measurements of the subsurface. Otherwise ice-rich terrains prevail in local regions excavated by craters, or exposed by erosion, suggesting that cryo-volcanism, if active, is currently not widespread. We also find evidence for the diversity of organic sediments, formed by the photolysis of Titan's past atmospheres, which can be investigated with future similar approachesy.

1. Introduction

Titan's density indicates an icy composition, like those of Saturn's other moons, which suggests an icy surface. However, Titan uniquely sports an immense atmosphere composed mainly of N_2 and CH_4, which is photolyzed in the upper atmosphere, thereby producing a plethora of organic molecules that end up as liquid and solid sediments on the surface[1]. Therefore, Titan's surface is expected to have two distinct components, an icy bedrock and the atmospheric-derived organic sediments

2. PCA investigation of Titan's Surface

This project analyzes the composition of half of Titan's surface, that bounded by 30°S and 30°N latitude (Supplementary Figure 1) to study the surface spectral diversity and investigate the exposure of water ice "bedrock" of Titan's tropical surface, despite the ongoing sedimentation of organic material from the atmosphere. Towards this goal, we developed a PCA analysis of the 4 wavelength bands (1.1, 1.3, 1.6, and 2.0 μm) that most clearly view Titan's surface from orbit.

In contrast to radiative transfer analyses, the PCA identifies and deconstructs the major spectral components based on the variance of the data. This approach, as discussed below, identifies the weak surface spectral features on a global scale without prior assumptions regarding the surface composition and atmospheric scattering and absorption, as assumed in RT analyses. A full RT analysis is significantly more time consuming because the assumptions are evaluated at each spatial pixel. Rather than analyzing each spectrum, one at a time in detail, we study the correlations of the M = 4096 spectra of a VIMS "cube", which are recorded over 64 x 64 spatial pixels covering a contiguous region of Titan's surface. This analysis enables the identification of weak features by correlating the spectra. Of the N = 4 wavelength regions considered here, two (1.1 and 1.3 μm) reside outside H_2O absorptions and two (1.6 and 2.0 μm) are regions of H_2O absorptions.

3. Results

Our PCA study indicates that water ice is unevenly, but not randomly, exposed across Titan's tropical surface (Figure 2). Most of the exposed ice-rich material follows a long, nearly linear, corridor that stretches 6300 km from roughly [30°E, 15°N] to [110°W 15°S]. Within this vast linear feature, we find the largest angular offsets between the 2nd and 1st components, indicating the strongest water ice features of Titan's tropical surface The deepest ice absorptions occur in the Sotra complex (Figure 2), a topographically unique region, with a 500 m high mountain (Doom Mons) situated next to a 1500 m deep pit, Sotra Patera, hypothesized to be of cryovolcanic origin[9]. The observations covering Sotra are at zenith viewing and have a high enough signal to noise to detect all 3 water ice bands (1.6, 2.0 and 2.8 μm) in the lowlying dunes surrounding Mohini Fluctus flow deposits (38.5°W, 11.8°S) that appear to emerge from Doom Mons (Supplemental Figure 3).

Titan's global ice feature presents a puzzle. It does not correlate in any obvious way with the Bouguer gravity anomaly, a measure of the gravitation field and therefore the material below the subsurface, nor does it correlate with topography, as measured from Cassini RADAR measurements However, gravity measurements have been conducted only at low spatial resolution, and topography measurements are sparse. The linearity of the icy corridor over a global scale presents the question of whether tectonic processes shaped this feature, thereby manifesting the processes that mold Titan's surface and subsurface on a global scale. However, we find no evidence that Titan is geologically active, consistent with Titan's long wave topography and gravity field, which indicate a thick ice shell that is conductive rather than convective.

References (Examples)

1. Yung, Y. L., Allen, M. & Pinto, J. P., Photochemistry of the atmosphere of Titan – Comparison between model and observations. *Astrophys. J. Suppl.* Ser. **55**, 465–506 (1984).

2. Cruikshank, D. P., Allamandola, L. J., Hartmann, W. K., Tholen, D. J, Brown, R. H., Matthews, C. N., Bell, J. L., Solid C triple bond N bearing material on outer solar system bodies. *Icarus* **94**, 345–353 (1991).

3. Clark, R. N., Curchin, J. M., Barnes, J.~W., Jaumann, R., Soderblom, L., et al. Detection and mapping of hydrocarbon deposits on Titan. Journal of *Geophysical Research (Planets)* **115**, 10005 (2010).

4. Brown, R. H., Baines, K. H., Bellucci, G., Bibring, J.-P., Buratti, B. J., et al. The Cassini Visual and Infrared Mapping Spectrometer (VIMS) Investigation. *Space Science Reviews* **115**, 111–168 (2004).

5. Barnes, J. W., Brown, R. H., Soderblom, L., Sotin, C., Le Mouèlic, S., et al., Spectroscopy, morphology and photoclinometry of Titan's dune fields from Cassini/VIMS. *Icarus*, **57**, 400–414 (2008).

6. Le Gall, A., Janssen, M. A., Wye, L. C. ,Hayes, A. G., Radebaugh, J., et al. Cassini SAR, radiometry, scatterometry and altimetry observations of Titan's dune fields. *Icarus* **213**, 608–624 (2011).

7. Lorenz, R. D., Wall, S., Radebaugh, J., Boubin, G., Reffet, E., et al., The Sand Seas of Titan: Cassini RADAR Observations of Longitudinal Dunes, *Science*, **312**, 724-727 (2006).

8. Soderblom, L. A., Kirk, R. L., Lunine, J. I., Anderson, J. A., Baines, K. H., et al., Correlations between Cassini VIMS spectra and RADAR SAR images: Implications for Titan's surface composition and the character of the Huygens Probe Landing Site. *Planetary and Space Science* **55**, 2025–2036 (2007).

9. Lopes, R.M.C., Kirk, R. L., Mitchell, K. L., Legall, A., Barnes, J. W., et al. Cryovolcanism on Titan: New results from Cassini RADAR and VIMS. *Journal of Geophysical Research (Planets)* **118**, 416–435 (2013).

10. Barnes, J.W., Brown, R. H., Soderblom, L., Buratti, B. J., Sotin, C., et al., Global-scale surface spectral variations on Titan seen from Cassini/VIMS. *Icarus* **186**, 242–258 (2007).

11. Le Mouélic, S., Cornet, T., Rodriguez, S., Sotin, C., Seignovert, B., et al., The Cassini VIMS archive of Titan: From browse products to global infrared color maps *Icarus*, **319**, 121-132 (2019)

12. Solomonidou, A., Hirtzig, M., Coustenis, A., Bratsolis, E., Le Mouélic, S., et al. Surface albedo spectral properties of geologically interesting areas on Titan. *Journal of Geophysical Research (Planets)* **119**, 1729–1747 (2014).