EPSC Abstracts,
Vol. 4, EPSC2009-380, 2009
European Planetary Science Congress,

Combination of VIMS and RADAR data over the surface of Titan: a statistical approach

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Introduction

In this work we have searched through Cassini/VIMS [1] hyperspectral cubes, selecting those data which have convenient viewing geometry and which overlap with Cassini/RADAR [2] footprints having comparable ground resolution, in order to properly look for correlations between the infrared and microwave ranges explored by the two instruments.

In RADAR data we have considered two geophysical quantities: the normalized backscatter cross-section obtained from the scatterometer measurement, corrected for the incidence angle, and the calibrated antenna temperature determined from the radiometer measurement, as found in publicly available data products.

In VIMS data, combining spatial and spectral information, we have selected some infrared wavelengths in the methane windows, which provide the best optical depth to measure surface reflectance.

The two RADAR parameters are combined with the VIMS data, with estimated errors, to produce an aggregate data set, that we process using multivariate classification methods to identify homogeneous taxonomic units in the multivariate space of the samples.

A first analysis has been done with the G-mode method [3], which has been successfully used in the past for the classification of such diverse data sets as lunar rock samples, asteroids and planetary surfaces.

Results

In medium resolution data, sampling relatively large portions of the satellite's surface, regional geophysical units matching both the major dark and bright features seen in the optical mosaic can be identified. In particular, given the VIMS and RADAR data used in this work, the largest homogeneous type is associated with the dark equatorial basins, where the sand dune fields are located. The corresponding pixels show the lowest reflectance levels in all of the sampled atmospheric windows, so these regions appear dark also in the NIR range up to 5 μm; they also have a rather low backscattering coefficient (typically <0.15 on an average) that, excluding geometric effects or dielectric constants very different from the rest of the satellite, is most likely indicative of surfaces being relatively smooth on a regional scale [4]; also, these regions, that are probably rich in hydrocarbons and/or nitriles, are not involved by significant volume scattering processes (see **Figure 1**).

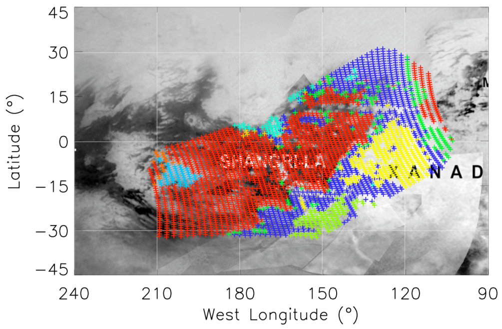

Figure 1: Classification of cube CM_1481607233_1 with 5 variables, overlapped to an ISS mosaic [6].

The calibrated antenna temperature is, on an average, higher than in the rest of the satellite (reaching the highest values in Shangri-La and Atzlan), also consistently with the higher emissivity of the material these basins are filled of [5].

At a medium resolution, the Xanadu bright continental feature is one of the most interesting geophysical units of Titan: this region shows the highest backscattering coefficient of the whole satellite (>0.6 on an average), and a lower temperature. Since this behavior is seen at several incident angles and not only at small incidence angles, it can be excluded that this is due to the peculiar observational geometry: the Xanadu region is rather likely to be microwave-bright because it shows a relevant roughness on a regional scale, or because it is involved by a broad volume scattering effect [4, 5].

This behavior it is not observed in a region located southwest of Xanadu, beyond the Tui Regio, that is bright at 2.69, 2.78 and 5 μm while showing a low σ_0 value measured at small incidence angles and a medium temperature: here the classification returned by the G-mode seems to trace the boundaries of a detached geophysical unit, characterized by a low surface roughness or by a condition where the volume scattering is anyway not prominent.

The major bright features seen on Titan generally do not behave the same way of Xanadu. As an example, from our analysis, the southern Tsegihi feature, the second largest bright feature on Titan (also very bright at 5 μm), shows a low σ_0 backscattering coefficient (≤0.10 on an average), so it could have a low roughness on a regional scale; and it has a nominal temperature, which is some degrees lower than the antenna temperature measured in the close dark basins Fensal and Atzlan (the latter having an inlet that, right on the border of Tsegihi, shows an average antenna temperature as high as that of Shangri-La). The western Adiri feature looks very bright at 2.02 μm and has a high backscattering coefficient. On the other hand, the Dilmun feature, located at northern latitudes and centered in the anti-Saturnian hemisphere, looks rather bright at 2.02, 2.69, 2.78 μm, while not having a significantly high backscattering coefficient, though higher than that of Tsegihi.

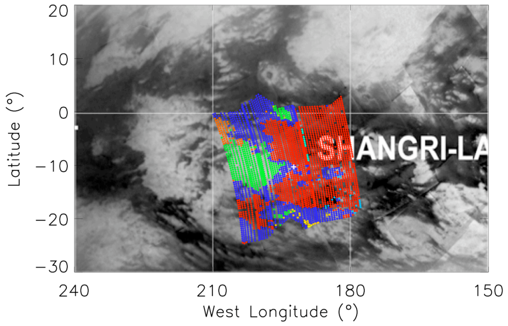

Figure 2: Classification of cube CM_1477490933_1 with 5 variables, overlapped to an ISS mosaic [6].

By selecting a higher spatial resolution for this data analysis, the distinction between bright features and dark terrains is kept; however, here a large homogeneous type is often representative of Titan's ground portions where we find intermediate conditions on the basis of all the meaningful variables (see **Figure 2**). As an example, at a medium-to-high resolution scale, the Huygens landing site, located in between the Adiri eastern border and the Shangri-La dark basin, is in fact classified neither among the darkest terrains nor among the bright features; but it rather sets in an intermediate group. In this spatial resolution range, we also find some homogeneous types made up by a low number of samples, that are indicative of peculiar behaviors with respect to one or more variables (for example, correlations or anti-correlations between the reflectance observed at 2.02 and 5 μm, probably due to a difference in composition).

Acknowledgements: This work was supported by the Italian Space Agency, ASI-INAF grants I/031/05/0 and I/026/05/0.

References: [1] Brown, R.H. et al. (2004) *Space Sci. Rev. 115*, Issue 1-4, 111-168. [2] Elachi, C. et al. (2004) *Space Sci. Rev. 115*, Issue 1-4, 71-110. [3] Coradini, A. et al. (1977) *Comput. Geosci. 3*, 85-105. [4] Wye, L.C. et al. (2007), *Icarus 188*, 367-385. [5] Janssen, M.A., et al. (2009) *Icarus* 200, 222-239. [6] Turtle, E., et al. (2009), *Geophys. Res. Lett.* 36, L02204.