
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 brightness 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. This method can be used without any a priori knowledge of the taxonomic structure of the observations, which is in fact provided by the classification. Furthermore, independence of variables and samples is not required, although the relationship between variables and samples needs to be known.

Data sets and analysis: The scatterometry data from RADAR passes T3, T4, T8, T13 and T16, have been used. In these data, the normalized backscatter cross section σ0, corrected for the incidence angle through a sine law, and the brightness temperature measured along with the scatterometry echoes (not corrected for any effect), are considered. In scatterometry data, regions appear bright if they are of rougher terrain, have slopes facing the radar, are made of more reflective materials, or for a combination of these causes [4]. On the other hand, radiometry data reveal the brightness temperature, which is a function of polarization (in turn related to the emission angle), surface composition (dielectric constant) and roughness [5].

In the case of Titan, VIMS data are mainly affected by the haze scattering involving the atmosphere of the satellite, whose magnitude is a function of both the wavelength and the lightning/observation angles. In this work, the VIMS data ranging from mission sequences S01 to S29 with ground resolution ≤ 200 km and good SNR (IR tem ≥ 160 msec/pixel) have been selected. To have good lightning and viewing conditions, from these data only pixels with phase angle < 40°, and incidence and emission angles < 60°, are selected. Furthermore, in these pixels, we have considered only the infrared I/Fs measured by VIMS in the 2.02, 2.69, 2.78, and 5 μm atmosphere windows, where the haze scattering is less effective and albedo differences due to the surface can be seen.

For any considered VIMS cube, the selected pixels are crossed with the scatterometry data from each of the flybys in order to look for overlappings. If found, the infrared I/Fs in the above wavelengths are extracted and associated to the corresponding values of backscattering coefficient σ0 and brightness temperature, in order to build an aggregate dataset to be processed by the G-mode program.

Results: Preliminary results reveal the variety of behavior of Titan’s surface. On the Xanadu optically bright region, a higher infrared reflectance in both the 2.02 and 5 μm windows is related to a lower backscatter cross-section and a lower brightness temperature (even though the northern border of Xanadu shows a higher backscatter cross-section value). The Tsegihi bright southern region shows a similar behavior: higher I/Fs and lower σ0 and temperature than the average. Samples overlapping the Shangri-La optically dark equatorial basin show lower I/Fs (in any window) and σ0 than the average, while they have a higher brightness temperature. The Aztlan dark equatorial feature also shows a higher temperature, even though the backscattering coefficient here is not significantly different from the average value.

The behavior of the bright regions can be due to volume scattering, whereas the dark areas are probably consistent with smooth surfaces filled by solid or liquid hydrocarbons.
From a methodological point of view, it is generally found that, by keeping a high confidence level, the classification leads to a large first type, representing a ‘background’, or average, behavior of the surface of Titan on the basis of all the variables. One sees that the classification is mostly driven by the 2.02 µm reflectance, and, by removing this variable, the 5 µm window and the backscattering coefficient have more statistical weight whereas the 2.69 and 2.78 µm I/Fs (composing the so-called dirty window) are always less significant. Nonetheless the classification does not change very much: a large first type is anyway representative of the ‘average’ conditions of the Titan surface on the basis of both the 5 µm reflectivity and the backscattering coefficient, while the other homogeneous types show differences related to a correlation or anti-correlation between these two key variables.

By including also the brightness temperature in the classification, more homogeneous types are generally found, which are representative of different surface temperatures. However, since this parameter is not corrected here for the polarization effects, the corresponding results shall be considered and discussed only for small emission angles.

Conclusions and future work: The use of data sets from different instruments onboard the Cassini spacecraft is a necessary step towards understanding the nature and history of Titan, since correlations between different physical processes can be highlighted.

Due to the large number of data, the classification work is still ongoing; nevertheless the obtained results are generally in agreement with previous works devoted both to the analysis of the scatterometry data through physical models [4] and to the correlation between SAR and radiometry data at a high resolution scale [6].

These evidences, evaluated for the first time through a multivariate statistical method, can bring constraints on the geophysical models under development for the Titan surface.

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Fig. 1 Distribution of the homogeneous types revealed by the G-mode on the surface of Titan in the classification of cube V1477467367_1.QUB, overlapping the T13 and T16 scatterometry footprints. The classification is superimposed to a mosaic map of the surface of Titan (with names) obtained by the Imaging Science Subsystem (ISS) in the 0.938 µm wavelength [7].

Fig. 2 Distribution of the homogeneous types on the surface of Titan in the 9-types classification (with temperature) of cube V1514287583_1.QUB, overlapping the T3 scatterometry footprints.