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Comparison between Dione' and Enceladus' terrain units, based on Cassini VIMS data

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Abstract

Saturn's icy satellites were observed several times by the Cassini spacecraft in its nominal and extended mission from 2004 to 2010. We selected 133 Cassini/VIMS (Visual and Infrared Mapping Spectrometer) hyperspectral cubes of Dione in the IR range between 0.85 and 5.1 μm and we applied Spectral Angle Mapper (SAM) clustering technique to classify different surface units on the basis of their spectral properties. We were able to identify nine terrain types for Dione, correlated to specific surface morphologies. The same process is applied to Enceladus VIMS cube, whose terrain units' characteristics are compared with those of Dione.

1. Introduction

Dione has a diameter of 1122 km and a density of ρ = 1.475 g/cm^3. The Voyager spacecrafts observed Dione in 1980 showing a complex surface structure, with both heavily cratered terrains and less cratered plains [2, 3]. Afterwards Dione was observed by the Cassini spacecraft in both its nominal and extended mission from 2004 to 2010. Most of Dione' surface is covered by the heavily cratered terrains, located mainly in the trailing hemisphere and crossed by high-albedo wispy streaks that are likely tectonic features [7]. Enceladus has a mean diameter of 504 km [1] and its surface appears to be completely made up of pure water ice [5]. In 2005, Cassini had a close fly-by of this Saturn's icy moon. Form data acquired during this event, it was observed a present-day geologic activity coming from the South polar region. Plumes of micron-sized particles of water ice erupting from this region represent the major source of the E-ring.

2. Data set and analysis

The *Visual and Infrared Mapping Spectrometer* (VIMS) instrument onboard the Cassini Orbiter is able to acquire hyperspectral cubes in the overall spectral range from 0.35 to 5.1 μm. We select VIMS cubes of Dione and Enceladus in the IR range between 0.85 and 5.1 μm, selecting those data which show at the same time: 1) a spatial resolution better than 100 km; 2) a phase angle in the range 20^o-40^o and 3) a good S/N ratio (essentially driven by exposure time). We normalize all spectra at λ=2.232 μm in order to minimize photometric effects due to different illumination conditions. We apply a clustering technique to the spectra of each cube based on the supervised method Spectral Angle Mapper (SAM) to emphasize the presence of spectral units. The endmembers used by the SAM for the classification of each terrain type, were selected applying the unsupervised clustering technique k-means to the cubes with the highest spatial resolution. In particular, k-means technique identified nine endmembers for Dione, whose spectra are shown in Figure 1 where each terrain unit is coded with a color.

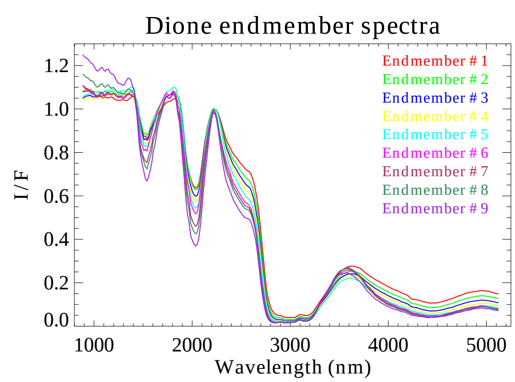

Figure 1: Spectra of Dione's endmember

In the SAM method applied to remote sensing data, each spectrum is represented by a vector in the *n*-dimensional coordinate system, where *n* is the number of spectral channels. In this case, *n* = 256. In order to compare the spectrum of each cube's pixel of the target with the endmembers, the algorithm evaluates an angle θ that represents the angular separation between the vector of the spectrum of each endmember (y_i) and the vector representing each pixel's spectrum (x_i) in the data space (256 dimensions). θ is computed as:

$$\theta = cos^{-1}\left[\frac{\sum_{i=1}^{n} x_i y_i}{\left(\sum_{i=1}^{n} x_i^2\right)^{1/2}\left(\sum_{i=1}^{n} y_i^2\right)^{1/2}}\right] \quad (1)$$

Small values of θ are indicative of a higher degree of similarity. We set θ=0.1^o as the maximum allowed angle value.

3. Results and discussion

To summarize the result of the SAM classification, we projected classified cube's pixels on a Dione's cylindrical map (Figure 2).

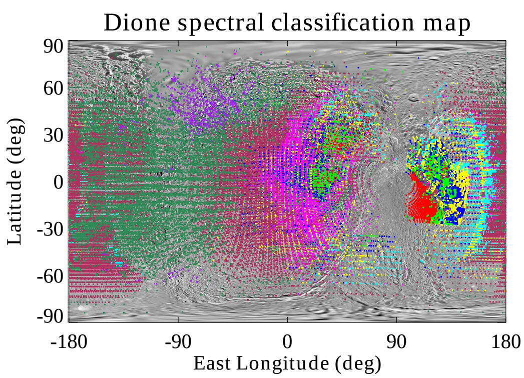

Figure 2: Projection of classified cubes' pixels on a Dione's cylindrical map

For both satellites, the infrared spectrum is dominated by the prominent signatures of H_2O ice /OH bands at 1.5, 2.0 and 3.0 μm. We conclude that a classification method applied to VIMS hyperspectral data is crucial to understand geochemical processes taking place on the surface of the icy satellites. From our analysis we find that several spectral units on the two satellites are characterized by different values of the spectral indices, such as the water ice bands' depth and the reflectance of the 3.6 μm peak, which is an indicator of the water ice grain size: the higher the peak, the finer the grains. Some classes show also a peculiar trend with respect to the phase angle, possibly related to the physical structure of the surface constituents (e.g, average grain size of the surface regolith). Particles of water ice coming from the E-ring, whose origin is Enceladus' south polar activity, deposits on Dione's leading hemisphere since it is tidally locked with Saturn, making this side of its surface brigheter than the trailing hemisphere. Therefor, a comparison between Dione and Enceladus spectra is crucial to quantify the effectiveness of this mechanism.

References

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