SPECTROSCOPIC VARIATION OF WATER ICE ABUNDANCE AND SUB-MICRON ICE GRAINS ACROSS ENCELADUS, MIMAS, AND TETHYS' SURFACE USING CASSINI VIMS DATA.

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Introduction: The surface of Saturn's regular satellites is largely composed by water ice. The Cassini spacecraft has observed present-day geologic activity at the Enceladus' South Polar region (the so-called "Tiger Stripes") in the form of eruptive plumes of volatile gases (H_2O, CO_2, NH_3, CH_4) which are the major source of Saturn's E-ring. Some of this material falls onto Enceladus' surface to form deposits that extend to the north at ~220°E and ~40°E and whose highest concentration is at the south pole.

Mimas and Tethys are Enceladus' orbital neighbours, lying inside and outside Enceladus' orbit respectively. It is therefore likely that Mimas and Tethys surfaces interact with icy particles from the E-ring, resulting in a spectral, color and grain size modification.

The most prominent feature on Mimas surface is crater Herschel with a diameter of 130 km, one-third of the moon itself. Mimas has the most uniform surface among Saturn's principal satellites, with its trailing side just 10% brighter and redder than the leading side. The uniformity of Mimas extends on spectral appearance too. The 1.52 and 2.02 μm H_2O-ice absorption bands are ~10% deeper on the trailing hemisphere.

On Tethys' leading hemisphere, the 400-km crater Odysseus represents ~40% of the diameter of the moon.

Here we present results from our ongoing work mapping the variation of the main water ice absorption bands and sub-micron ice particles across Mimas, Tethys and Enceladus' surfaces using Cassini/VIMS data acquired in the IR range (0.8–5.1 μm).

Data analysis: The Cassini VIMS spectrometer acquires hyperspectral images (`cubes') in the overall 0.3–5.1 μm spectral range. We selected VIMS cubes of Enceladus, Mimas and Tethys in the IR range (0.8–5.1 μm), and minimized photometric effects due to different illumination conditions by normalizing all spectra at 2.23 μm.

For all pixels in the selected VIMS images, we measured the band depths for water-ice absorptions at 1.25, 1.5 and 2.02 μm and the height of the 3.6 μm reflection peak, whose value relates to the grain size.

Moreover, we considered the main spectral indicators in the IR range for ice particles smaller than 1 μm [1]: (i) the 2-μm absorption band is asymmetric and (ii) it has the minimum shifted to longer λ; (iii) the band depth ratio 1.5/2.0 μm decreases; (iv) the reflection peak at 2.6 μm decreases; (v) the Fresnel reflection peak is suppressed; (vi) I/F at 5 μm decreases relative to the 3.6 μm peak.

Since the first part of the VIMS-IR spectrun (0.8-2.5 μm) is sometimes affected by saturation effects, for each cube of the dataset we performed a pixel-by-pixel selection of spectral features to be used: for each pixel, only (totally or partially) unsaturated absorption bands were selected.

To characterize the global variation of water-ice band depths, we sampled the three satellites' surface with a 1°x1° fixed-resolution grid and then averaged the band depths and peak values inside each square cell.

Results: For Mimas and Tethys we find that large geologic features, such as the Odysseus and Herschel craters, do not correlate with water ice's abundance and/or grain size variation.

For Tethys, we found a quite uniform surface on both hemispheres. The only deviation from this pattern shows up on the trailing hemisphere, where we notice two north-oriented, dark areas around 225° and 315°. For Mimas the selected dataset covers just the leading side and a portion of the trailing side. From the analysis, the two hemispheres appear to be quite similar in water ice abundance, the trailing portion having water ice absorption bands slightly reduced than the leading side.

No correlation with the visible-color/thermal anomaly features has yet been found.

For Enceladus, water ice bands depth' variation and all sub-micron ice particle spectral indicators can clearly map plumes deposits on the surface. The highest concentrations occur at Enceladus' South Pole, where the band depths values are the deepest across the entire moon's surface. Our results confirm that plume particles fall in north-oriented patterns at ~40°E and ~220°E, and disappear around ~0°E and ~180°E.

Outside plumes deposits, the value of all spectral indicators considered decreases, meaning that in this region the concentration of sub-micron ice particles is higher and that water ice is more contaminated than on the plumes deposits: since plumes deposits undergo darkening processes for less time than surrounding terrains, they appear brighter meaning that water-ice absorption bands must be deeper.

An example of spectral maps is reported in Figures 1, 2 and 3 for Tethys, Mimas and Enceladus, respectively. In the top panels the variation of the 2.02 μm band depth is mapped, while in the bottom panels the intensity of the 3.1-μm Fresnel peak is traced.

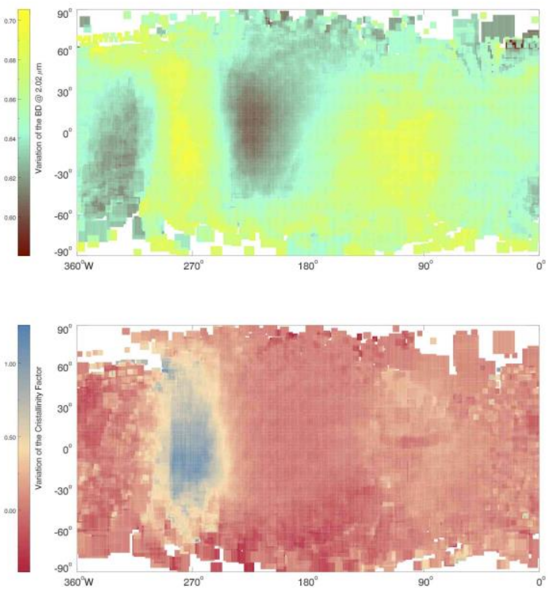

Figure 1: Tethys 2.0 μm (**top**) and 3.1 μm (**bottom**) bands depth variation.

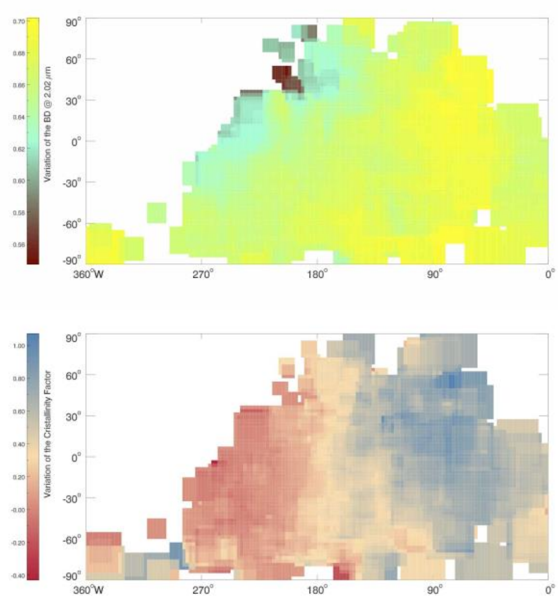

Figure 2: Mimas 2.0 μm (**top**) and 3.1 μm (**bottom**) bands depth variation.

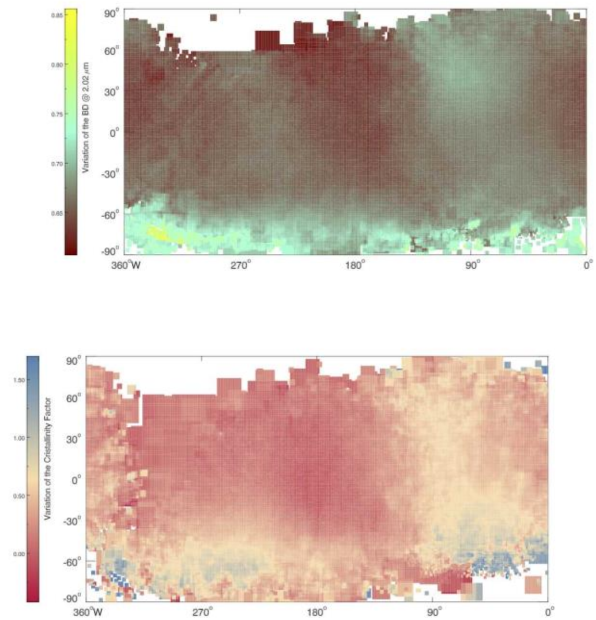

Figure 3: Enceladus 2.0 μm (**top**) and 3.1 μm (**bottom**) bands depth variation.

Conclusions: All spectral indicators considered in this work clearly outline the E-ring plumes deposits on Enceladus surface. Moreover, the global variation of water ice band depths highlighted a bright feature located between 45°-90°W and 30°-60°N, which is not apparently related to any surface feature.

The analysis of the sub-micron ice grains spectral indicators revealed that sub-micron ice particles locate mostly on the trailing hemisphere, while they are not present on the plumes deposits and in the Tiger Stripes region.

For Tethys, we found a deposit of crystalline water ice on the trailing hemisphere superimposed on the dark material deposit, and a gradient of grain size, being bigger on the leading site and on the water ice deposit on the trailing hemisphere.

For Mimas, we found no evidence of the thermal anomaly feature seen on the basis of ISS images.

References:

[1] Clark, R. et al. (2013in The science of Solar System ices, Springer Science+Business Media New York.