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Thermophysical Property Variations on Saturn's icy moons: A system-wide perspective.

C.J.A. Howett (1), J.R. Spencer (1), A. Verbiscer (2) and the Cassini CIRS Team
(1) Southwest Research Institute, Boulder, CO, USA, (2) University of Virginia, Charlottesville, VA, USA

Abstract

Thermal inertia variations have been observed on icy satellite surfaces throughout the Saturnian system, causing night and daytime temperature variations across the satellites. The most notable are the two 'Pac-Man' anomalies on Mimas and Tethys: distinct regions of high thermal inertia at low latitudes on the leading hemisphere of both satellites, which results in warmer nighttime and cooler daytime temperatures (by ~15 K) than their surroundings. Only subtle differences in surface color had previously been observed in the same region [1]. It is believed that the bombardment of the surface by high-energy electrons alters the surface of Mimas and Tethys, resulting in these high thermal inertia regions.

Subtler differences in thermal inertia across other icy satellite surfaces have also been observed. For example: preliminary investigations show Dione may also display a thermal inertia variation that is similar to, but weaker than, Mimas and Tethys' anomalies. Initial investigations have also reveled that the ejecta from Rhea's bright crater Inktomi (14.1 S and 112.1 W) displays higher thermal inertia than its surroundings.

1. Introduction

Changes in a surface's thermal inertia are indicative of structural or compositional surface alteration, and thus provide a tracer for endogenic and exogenic processes. We derive the thermal inertia of Saturn's mid-sized icy satellites by comparing their observed day and night time temperatures to those predicted by a 1-D thermal model [2]. Cassini's Composite Infrared Spectrometer (CIRS) observations provide the surface temperatures, determined by fitting the observed spectra to blackbody emission curves.

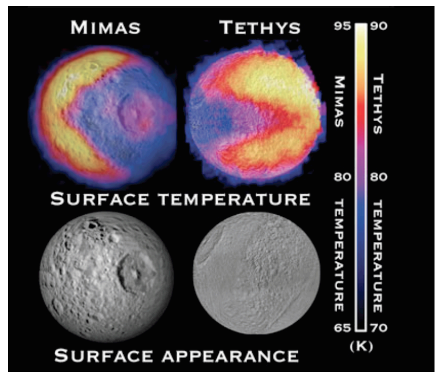

Fig. 1 Surface temperature of Mimas and Tethys, showing their "PacMan" thermal anomalies, compared to the visible surface appearance.

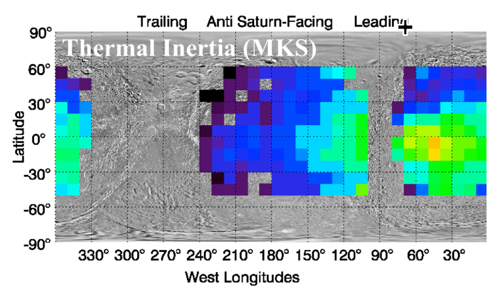

Fig. 2 Thermal inertia variations across Dione, warmer colors indicate higher values. Black cross indicates the location of the Creusa crater.

2. Surface alteration by high-energy electron bombardment.

High thermal inertia regions have been observed on Mimas, Tethys and Dione [Figs. 1 and 2]. Each of these anomalous regions cover different latitudinal extents but they all occur at mid- to low-latitudes on their leading hemispheres. This is the same region that high-energy electrons (MeV) preferentially bombarded their surfaces [3, 4, 1]. We believe that absorption of the electrons by the surface probably causes water ice molecules to be mobilized, increasing the contact areas between the ice grains, thus increasing the thermal conductivity and hence thermal inertia [3]. The magnitude of the thermal inertia increase between the background and the anomalous region is largest on Mimas and smallest on Dione. This follows the same pattern as the high-energy electron intensity, which decreases with distance from Saturn [Fig. 3]. Despite Enceladus' relatively intensive bombardment of high-energy electrons [Fig. 3] it is not expected that its surface will display a similar thermal anomaly, as in-fall from its plumes provides a high resurfacing rate. To date no such anomaly has been observed on Enceladus.

Whilst the albedo of Mimas, Tethys and Dione do vary, with reference to one another and across their surfaces (most notably on Dione), there is no pronounced visible color change on Mimas and Dione and only a slight change on Tethys across their thermal anomaly boundaries. Comparing the boundaries of the thermal inertia variation to contours of high-energy electron flux shows that electron energy fluxes greater than approximately 18 GeV cm^{-2} s^{-1} are required to dramatically alter the thermal inertia of an icy satellite surface [3,4]. It is possible that similar, currently unobserved, anomalies exist on the Jovian icy satellites, which are also known to experience bombardment by high-energy electron fluxes [5].

3. Surface alteration by cratering.

Rhea and Dione both display young, morphologically fresh craters (less than 500 Ma) that are several tens of kilometers across [6]. Two of these craters, Dione's Creusa (49.2° N, 76.3° W) and Rhea's Inktomi (14.1° S, 112.1° W), along with their ejecta blankets, have been shown by Cassini's Visual and Infrared Mapping Spectrometer (VIMS) to be compositionally different to their surrounding terrain [7]. In particular they display strong H_2O ice absorption bands [6]. As such it is likely that both of these craters and their ejecta would display different thermophysical properties to their surroundings.

However, preliminary results show that the thermal inertia of Dione displays very little variation across Creusa [Fig. 2]. Whilst Rhea's thermal inertia increases in the region of Inktomi [Fig. 4]. The reason for this difference is currently unknown.

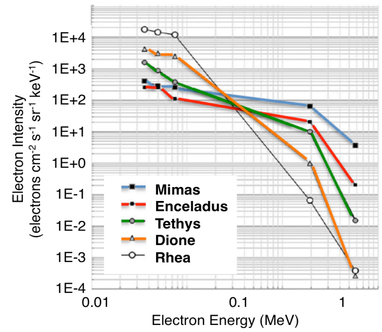

Fig. 3 The energy spectrum of electron bombarding Saturn's mid-sized icy satellites [8].

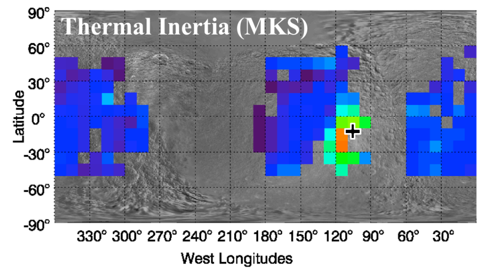

Fig. 4 Thermal inertia variations across Rhea, warmer colors indicate higher values. Black cross indicates location of Inktomi crater.

4. Conclusions.

Thermophysical property variation is observed across all mid-sized icy Saturnian satellites. We link this variation to both the bombardment of the surface by high-energy electrons and to cratering processes.

Acknowledgements

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