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Retrieval of temperatures from near-IR reflectance spectra of water-ice-rich bodies: application to Saturn's satellites and rings

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Crystalline water ice reflectance is characterized by a peak at about 3.6 μm that has temperature-dependent properties (Filacchione et al., 2012). Optical constants measured in transmittance by Mastrapa et al (2009) in the range of temperature between 20 and 150 K show that the peak's position changes with the temperature. The same trend is observed on reflectance measurements realized by Clark et al. (2012) on small grains of pure water ice at standard illumination conditions (phase=30 deg) for temperature of the sample varying between 88 K and 172 K. The analysis of these data demonstrates that the 3.6 μm peak shifts towards shorter wavelengths when the ice is cooled, moving from about 3.675 μm at T=172 K to about 3.58 μm at T=88 K. Starting from this experimental evidence we have used a 4th-degree polynomial fit in the 3.2-3.8 μm range to measure the wavelength at which the peak occurs on laboratory data with the view toward using it as a marker to retrieve similar temperatures of the ring particles and of the regular icy satellites of Saturn. We report about the results obtained after having applied this method to three different datasets: a) a sample of 240 disk-integrated observations of Saturn's regular satellites collected by VIMS between 2004 and 2011 with solar phase in the 20-40 deg range, corresponding to late morning-early afternoon local times. From these observations we have retrieved average temperatures for Mimas (88 K), Enceladus ($<<$88 K), Tethys ($<$88 K), Dione (100 K), Rhea (108 K), Hyperion (113 K), Iapetus trailing (138 K) and Iapetus leading hemisphere ($>$170 K). b) Satellites disk-resolved observations (20-40 km/pixel) which are suitable to map temperature variations across surfaces' features, such as Enceladus' tiger stripes or Tethys and Mimas equatorial dark lenses. c) Ten VIMS ring radial mosaics acquired with solar phase ranging between 5.7 deg and 132.4 deg and elevation angles between -23.5 deg and 2.6 deg (Filacchione et al., submitted). VIMS data indicate that temperature is anticorrelated with the albedo: low-albedo C ring and Cassini division have higher temperatures than A-B rings where albedo is high. Since albedo and optical depth are correlated across rings, we observe a similar anticorrelation between temperature and optical depth too. Furthermore, with the exception of the Cassini division, the temperature decreases with the distance from Saturn. The availability of data taken at different solar elevation angle allows us to follow how seasonal changes influences the ring's temperature. As a general remark we mention that in some cases, like on C ring and Cassini division, the temperatures measured by VIMS with this method are higher than corresponding ones reported by CIRS: this is a consequence of the shallow skindepth (few microns) to which VIMS is sensitive while CIRS measures temperature at greater depth (few millimeters). Grain size and contaminants embedded in water ice may also play a role in the 3.6 μm peak properties and these effects have yet to be investigated. Combining VIMS and CIRS measurements will allow us to better characterize the regolith physical properties and heat transport mechanisms.

References:

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