Measurement and Modeling of Water Ice Spectral Signatures Observed by the MRO CRISM Imaging Spectrometer at 20 Meter Scale Spatial Sampling.

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The Compact Reconnaissance Infrared Spectrometer for Mars (CRISM)[1] is carried on board the NASA Mars Reconnaisance Orbiter (MRO). The primary science phase began for MRO in November 2006. We present here early results from CRISM observation of the Northern polar region of Mars.

The CRISM imaging spectrometer measures the spectral range from 360 nm to 3920 nm in the portion of the electromagnetic light dominated by solar reflected energy. The spectral sampling is nearly constant at 6.55 nm over the complete spectral range. In the visible and near infrared (VNIR), the full-width-at-half-maximum (FWHM) of the spectral response function varies from 8.6 to 10 nm over the range from 360 to 1050 nm. In the short wavelength infrared (SWIR) the FWHM varies from 9.7 to 17.5 nm from 1000 to 3920 nm. A complete spectral calibration image file has been developed for CRISM with the position and FWHM of each spectral-spatail element reported.

These spectral parameters are essential for direct spectroscopic analysis of the CRISM measurements and for analysis with physically based computer models. These computer models are used for atmospheric characterization and correction as well as for inversion of surface parameters such as water ice grain and dust properties.

In full resolution target mode, the spatial sampling of CRISM is 15 to 19 meters per pixel depending on orbit altitude with approximately 600 cross-track imaging elements. The CRISM imaging spectrometer opearates in a pushbroom mode with an entire cross-track row of spectra acquired for each time sample.

A CRISM image of a portion of the Mars north pole layered deposit (data set FRT3509) is shown in figure 1. This image is rendered in image cube format to highlight the underlying spectrum from 400 to 3950 nm available for compositioonal analysis for each spatial element in the image. The spectral range in conjuction with the 20 meter scale spatial resolution of CRISM allow new water related science questions to be pursued across Mars including the polar regions.

Figure 2 shows three extracted spectra from FRT3509. These are uncalibrated CRISM data with only the dark signal subtracted. In these spectra the water ice absorptions at 1250, 1500 and 2000 nm are evident even with instrumental and atmospheric effects present.

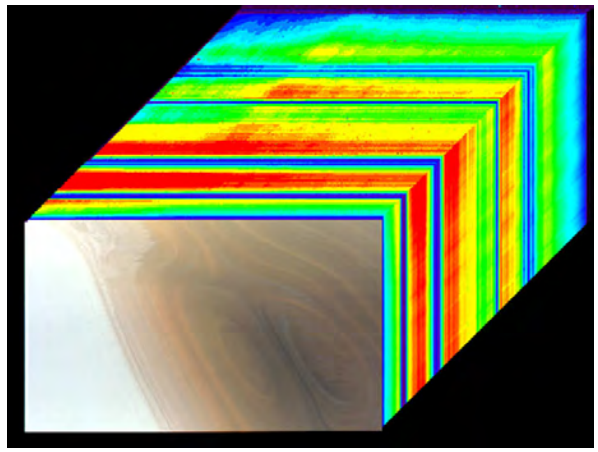

Figure 1. CRISM image FRT3509 of the north polar layered deposits rendered in image cube form.

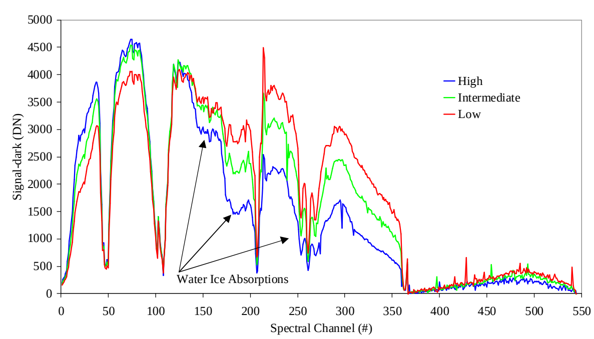

Figure 2. CRISM uncalibrated data from FRT3509 showing water ice absorption.

The instrumental factors of measured CRISM data are compensated by use of the calibration parameters and calibration algorithms. Compensation for the atmosphere may be implemented with parameters from a physically based atmosphere radiative transfer model. A version of the MODTRAN [2] radiative transfer code has been adapted to model the atmosphere of Mars (MarsTRAN). Figure 3 shows a model Mars atmospheric transmittance spectrum at 1 nm spectral resolution from MarsTRAN. These data are convolved to the CRISM spectral calibration characteristics for atmospheric correction.

Application of the calibration parameters and algorithms as well as the atmospheric correction parameter results in a corrected CRISM spectrum of the North polar cap of Mars (FRT3509). Figure 4 shows this corrected spectrum over the range from 400 to 2500 nm. It should be noted, that both the instrument correction and calibration algorithms and the atmospheric correction approaches are evolving rapidly in these early stages of MRO CRISM measurements.

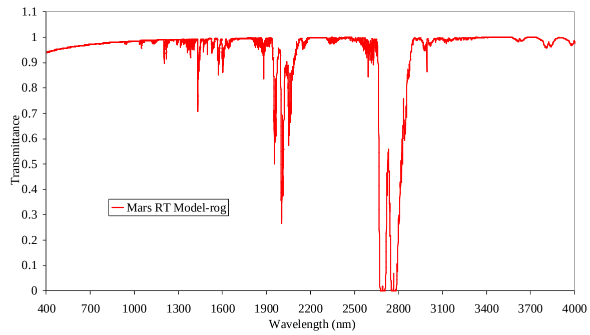

Figure 3. Modeled atmospheric transmittance of Mars with adapted MODTRAN radiative transfer code.

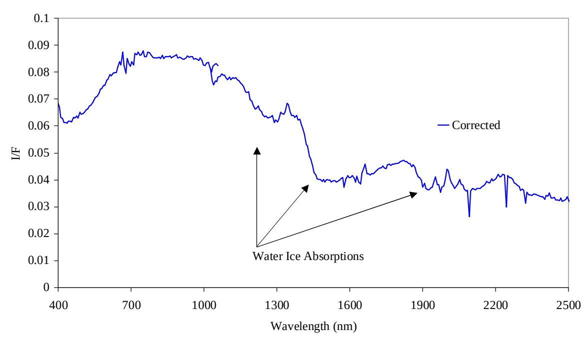

Figure 4. Corrected CRISM spectrum.

To estimate the properties of the water ice spectra recorded by CRISM a series of mie scattering [3] and discrete ordinate radiative transfer (RT) [4] calculations have been performed. The spectral complex refractive index of water ice is the starting parameter for these calculations. The calculations produce model based reflectance spectra for water ice of differing grain sizes. Figure 5 shows a set of the calculated spectra for grain sizes from 10 to 250 microns.

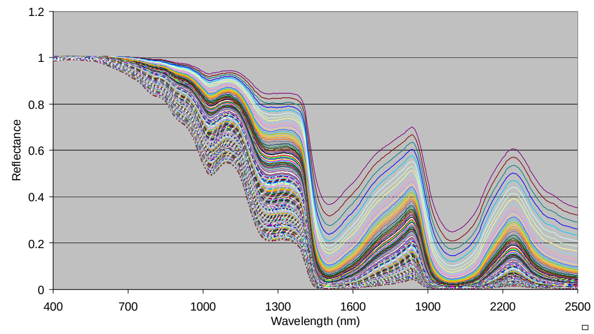

Figure 5. Calculated reflectance spectra for water ice of differing grain sizes from 10 to 250 micron.

Initial comparative analysis between the RT modeled and CRISM measure spectra show a water ice grain size of approximately 100 microns.

This physical model based approach to derivation of grain size will be extended to incorporate dust partical size and concentration parameters. With this model based forward inversion approach detailed maps of the water ice grain size and dust parameters may be obtained at the 20 meter spatial scale of CRISM. The ice and dust parameter will be used to explore questions of the age, movement, sources, and sinks, and of water ice in the polar regions of Mars.

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References 1. Murchie, S. et al. (2006) J. Geophys. Res., in press. 2. Anderson, G.P., M. L. Hoke, J. H. Chetwynd, Jr., A. J. Ratkowski, L. S. Jeong, A. Berk, L. S. Bernstein, S. M. Adler-Golden, et al, MODTRAN4 Radiative Transfer modeling for remote sensing, SPIE, 4049, 176-183, 2000. 3. Wiscombe, W.J., Improved Mie scattering algorithms, Applied Optics, 19 (9), 1505-1509, 1980. 4. Stamnes, K., S.C. Tsay, W.J. Wiscombe, and K. Jayaweera, Numerically stable algorithm for discrete-ordinate-method radiative transfer in multiple scattering and emitting layered media, Applied Optics, 27, 2502-2509, 1988.