CRISM-DERIVED SCATTERING PARAMETERS FOR SURFACES IN THE VICINITY OF OPPORTUNITY MARS ROVER TRAVERSES.

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Introduction: This work focuses on use of data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) on the Mars Reconnaissance Orbiter (MRO) to derive the surface single scattering albedos and phase functions for regions traversed by Opportunity, as well as nearby terrains (Fig. 1). We also compare results to previous ground-based inferences based on multi-filter Opportunity Panoramic Camera (Pancam) data [1]. Opportunity has traversed 26.56 km (as of 1/4/11) in Meridiani Planum and observed various surface units, including bedrock, several types of soil and ripple units, and crater ejecta (Fig 1). During this time, CRISM has taken several Full Resolution Targeted (FRT) observations over Opportunity's traverse (FRTs include a central gimbaled scan and 10 lower resolution frames taken at varying emission angles) that allow derivation of surface Hapke scattering parameters (Eqns 1-3) [2] by simultaneously modeling atmospheric and surface scattering and absorption using Discrete Ordinate Radiative Transfer (DISORT) and the Hapke model, respectively [2].

Procedure: CRISM I/F data from each of the 10 frames as well as the central scan in FRT000028A1 were randomly subsampled (usually 10 points per frame or scan, picked by random number generator). Three wavelengths (0.5663 µm, 1.408 µm, and 2.3641 µm) were picked to span the CRISM wavelength range and avoid major gas bands. The data were modeled for simultaneous surface and atmospheric contributions, with an average atmospheric dust particle radius of 1.5 micrometers based on extensive analysis of CRISM EPF data [3]. We solved for the single scattering albedo (w) and also the asymmetry parameter (b, negative for backscattering, positive for forward scattering) in the Henyey-Greenstein expansion of the single particle phase function (Eqns 1-3).

$$rf = \left(\frac{w}{4}\right)\left(\frac{\mu_0}{\mu_0 + \mu}\right)\left[(p(g) + H(\mu_0)H(\mu) - 1\right] \quad (1)$$

$$p(g) = \frac{(1-b^2)}{\left[1+b^2+2b\cos(g)\right]^{3/2}} \quad (2)$$

$$H(\mu) \sim \frac{1+2\mu}{1+2\sqrt{1-w}\,\mu} \quad (3)$$

For the above equations: rf = radiance factor, p(g) = 1-term Henyey-Greenstein phase function, g = phase angle, H=multiple scattering function, μ_0 is the cosine of the incidence angle, µ is the cosine of the emergence angle [2].

The Levenberg-Marquardt least squares approach was used on a grid of initial values to find local minima; then a grid search was performed to obtain a global minimum in chi-squared space [4]. See Fig. 2 for a comparison of the fit to the original data, as well as several other model curves (this example is for 1.408 micrometers; w is much more highly constrained than b). The spread in the original FRT data is due to the various surface units which are covered by the FRT frames and central scan, including areas to the north of the landing site that have extensive bedrock exposures as opposed to the ripple-covered surfaces at the Opportunity landing site (Fig 1).

Results: Analysis of CRISM data indicates that the area around Opportunity's traverses is moderately backscattering (analysis at multiple wavelengths was conducted to come to this conclusion) and has an average single scattering albedo ranging from 0.39 - 0.48 over the wavelength range 0.57 – 2.36 µm (Fig. 3). As wavelength increases, single scattering albedo increases and the surface becomes more backscattering. CRISM-derived photometric parameters resulting from this investigation are similar to those of both the "ripples" and the hematitic "spherule-rich soil (plains)" units determined from Opportunity data and analyzed by Johnson et al. [1]. However, the trends in the CRISM-derived parameters best match the soil in only two regions: the Valentina/Vostok region and the Heat Shield Area (as analyzed by Johnson et al. [1]). The CRISM-derived single scattering albedo much more closely matches soil regions (w=~0.46) than bedrock regions (w=~0.77) observed with Pancam. This is to be expected considering the relative abundance of soil cover vs. bedrock in the CRISM scene. The backscattering nature of the soil is also clearly seen in both sets of results (Fig. 3). Thus, we have self-consistent results between landed and orbital data.

Future work: We will investigate wavelength bands that are closer to those used by Opportunity's Panoramic Camera (Pancam). We will also continue to explore the trade-off between computation time and amount of subsampling to increase the goodness-of-fit.

We will use the same full radiative model, including the most recently CRISM-derived atmospheric scattering parameters [3] applied in this work to analyze key regions explored by Opportunity. Further, we will partition both data sets by terrain type to facilitate comparisons and retrieve information on grain sizes, packing, and surface roughness.

References:

[1] Johnson et al. (2006), *JGR*, *111*, E12S16.

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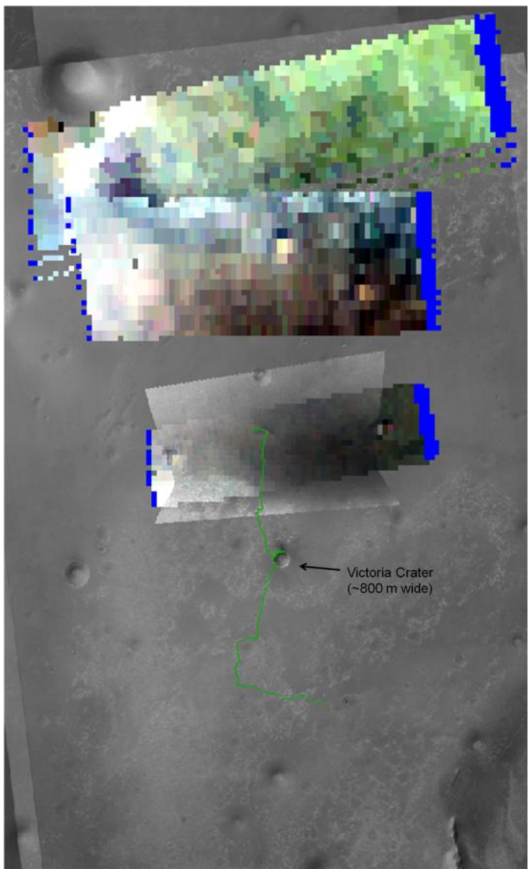

Figure 1. CTX mosaic with CRISM FRT000028A1 and Opportunity traverse overlain. The central, high resolution scan is the hourglass-shaped image in the middle of the figure. It has a center incidence angle of 55.2° and was taken at a solar longitude of 115.3°. The green line shows Opportunity's traverses. Also shown on the image are three of the ten EPF (emission phase function) frames of the FRT. EPF frame 03 (hexadecimal IDs in order of image capture) overlies the central hourglass frame and has a low gimbal angle (i.e. emission angle). The frame just north of it is EPF frame 09 (moderate gimbal angle). The northernmost frame, EPF frame 0D (high gimbal angle), includes regions richer in bedrock than those covered by frame 07.

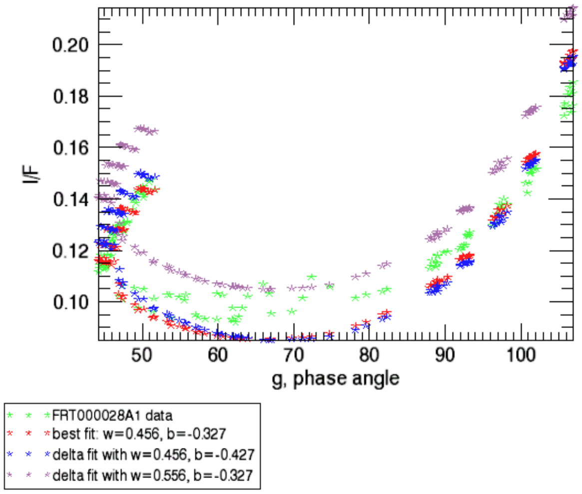

Figure 2. Comparison of model results to original data at 1.408 micrometers. Also included are some offsets from the best fit, one with b decreased from its best fit value by 0.1, and the other with w increased from its best fit value by 0.1.

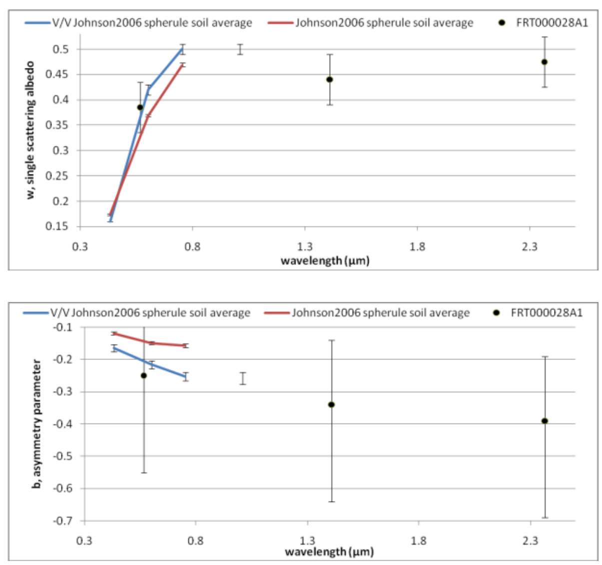

Figure 3. Comparison of results to the findings of [1]. V/V = Valentina/Vostok region. Johnson2006 = Johnson et al. 2006. Despite the conservative error bars (100% chi-squared) shown in this image, the parameter values appear to be quite close to the Opportunity-based results. Future model runs with less subsampling and with separation of terrain units are likely to produce lower error bars.

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