SURFACE UNITS TO BE EXPLORED BY CURIOSITY: INSIGHTS USING HIRISE COLOR MEASUREMENTS.

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Introduction: Previous orbital data analyses at Mount Sharp showed a high diversity of morphologic and mineralogic features [e.g., 1-5]. To provide new constraints on the composition of the stratigraphic sequence, we analyzed the NW flank of Mount Sharp using HiRISE color images. These units are expected to be investigated by Curiosity. Our results could be used to support operations planning and the *in situ* interpretations. Here we present a new methodology that enables us to correct the atmospheric dust contribution to HiRISE brightness and color data.

HiRISE color images: The High Resolution Imaging Science Experiment (HiRISE) [6,7] provides high spatial resolution (up to 25 cm/pixel) color images using 3 bandpasses: the Blue-Green (BG) (<600 nm), the RED (550-850 nm centered at 700 nm) and infrared (IR) filter (>800 nm), with a central swath of color 1.0-1.3 km wide. The quantitative color data can be used to distinguish compositional units, complementary to the information provided by other orbital and in situ instruments.

HiRISE surface reflectance and albedo estimates:

Transfer of solar light through the Mars surface and atmosphere. To correct precisely the dust atmospheric contribution, a robust radiative transfer (RT) model that reproduces the multiple scatterings between the surface and the atmosphere is needed. The main challenge in the top-of-atmosphere (TOA) signal reconstruction is accounting for the light that is anisotropically scattered by atmospheric dust. Thanks to recent improvements in our knowledge about Martian dust aerosols properties [8], we are able to use a sophisticated RT model of the TOA reflectance to reproduce the observed data. We use the same coupled surface-atmosphere 1D RT formulation of the TOA signal as the Multi-angle Approach for Retrieval of Surface Reflectance from CRISM observation (MARS-ReCO) algorithm. MARS-ReCO was developed to correct the dust aerosol scattering contribution in the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) multi-angular observations [9]. The major improvement of this semi-analytical formulation is the use of a Green's function in the RT equation. It is used to model the intrinsic diffuse scattering responses of the atmosphere and a kernel-based scattering model (Ross-Thick Li-Sparse (RTLS) [10]) for the surface that enables us to take into account the non-Lambertian behavior of surface materials [see 9 for more details].

Dust optical thickness. Significant progress has been made recently using the CRISM Emission Phase Function (EPF) observations that enable us to separate the atmospheric and surface contributions. Based on characterization of the surface and dust aerosol scattering behaviors [e.g., 8, 11] we can retrieve the dust aerosol optical thickness (AOT). At least 3700 HiRISE observations have CRISM coordinated EPF observations that we use to estimate the dust AOT.

Surface scattering assumption. HiRISE provides only one photometric geometry per observation, so we cannot derive anisotropic surface scattering functions at this scale. Fortunately, the low emission angles of the HiRISE images limits the anisotropic scattering contribution. We use a Lambertian scattering behavior for the surface in the surface-atmosphere RT model, to correct the dust contribution in order to estimate the surface reflectance.

To get a semi-quantitative surface albedo (i.e. single scattering albedo), we use the Hapke model [12]. Variable surface single scattering albedo ($\omega_{L,}$ assuming Lambert behavior) values (from 0 to 1, step of 0.01) are chosen to mimic variable Mars surface states. For each ω_L value, we estimate the equivalent surface RTLS kernel weights by inverting the surface RTLS model. The surface RTLS kernel weights are essential to calculate the TOA reflectances and they are stored in a look up table (LUT#1) calculated once and used for all HiRISE observations.

Dust atmospheric scattering correction.

- Step 1. Using the geometric conditions from a given HiRISE observation and the dust optical thickness from the coordinated CRISM EPF observation, we calculate the modeled surface and TOA reflectance spectra in the visible range (0.4 to 1.1 µm). We use the atmosphere-surface RT formulation. We calculate the spectra for variable surface ω_L values (from 0 to 1 in steps of 0.01) (using LUT#1). The results are stored in a LUT (LUT#2), specific to the HiRISE observation.
- Step 2. We weigh each TOA reflectance spectrum and surface reflectance spectrum calculated for variable surface ω_L values with the HiRISE spectral response to get the equivalent BG, RED and NIR reflectances. They are stored in a new LUT (LUT#3), specific to the conditions of the HiRISE observation.
- Step 3. For each HiRISE pixel and filter, we search for the modeled TOA reflectance that minimize the deviation with the observed reflectance value that give us the corresponding surface reflectance and ω_L values.

Results and discussion: Fig. 1a presents the 3 studied areas selected from the HiRISE PSP_009149_1750 observation that covers the NW Mount Sharp flank. The areas are located in relatively flat surfaces to limit topographic effects (i.e., surface multiple scattering). The dust scattering contribution has been corrected by using the dust AOT estimated from CRISM FRT#B6F1 observation [8, personal comm.]. Fig. 1b-d present the surface results of the main geological and mineralogical units defined by previous works [1-5]: surface RED (Lambert) reflectance; the derived surface Lambert albedo values related to the grain composition and size [12] and the surface BG/RED color ratio values linked to the composition and sensitive to the ferric- and ferrous-bearing minerals. The results show a high diversity of brightness and color features between the different units:

Surface albedo. The “brightest” unit in RED channel (ω_L=0.75-0.85) corresponds to the layered sulfate materials that suggests less absorption (consistent with the CRISM sulfate spectral signature [2,5]) and/or fine grains. The “darkest” unit (ω_L=0.48-0.52) is associated with the dune materials indicating more absorption (consistent with the CRISM olivine spectral signature, [2]) and/or coarse grains.

Surface color ratios. The most ferrous materials are the dune field also consistent with the CRISM spectral signature [2] whereas the most ferric materials are associated with the ridge in which the uppermost layer is associated with a hematite signature [4,5]. The BG/RED results also indicate an overall ferric signature (BG/RED<0.8) that could be the result of the dust contamination on top or within the surface material. [13] showed a few dust grains within or a layer of one dust grain on top the material can almost completely mask the underlying material brightness.

Albedo and color heterogeneity are also observed thanks to the high spatial resolution within units and highlight surface erosion/exposure, dust covering and/or different material mixture and abundances.

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Figure 1. a. Studied areas in the HiRISE color images. b. Surface RED (Lambert) reflectances and studied minalogical and geomorpholical units. c. Surface Lambert RED albedo. d. Surface BG/RED color ratio.