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Surface photometric properties in Gusev crater from CRISM observation onboard MRO spacecraft

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Abstract

CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) onboard MRO (Mars Reconnaissance Orbiter) acquires observations under varied geometry conditions in visible/near infrared and provides constraints on the surface physical properties in Gusev crater. First, we select appropriate CRISM observations. Second, we applied an original inversion method to retrieve the atmospheric optical thickness considering a non-lambertian surface hypothesis. Third, we estimate the physical parameters using a 2-term phase function Hapke inversion procedure using the retrieved surface reflectance. The present results can be compared to previous photometric studies from orbital and in situ instruments.

1. Introduction

CRISM onboard MRO spacecraft provides the Full Resolution Targeted (FRT) observations, composed of a sequence of 11 images at different emission and phase angles (11 geometries) for each target [1]. Our aim is to derive the surface photometric characteristics and physical properties of the Martian regolith in order to study the geologic processes. An atmospheric correction of multi-angle observation is used to estimate the signal from the surface. The main advance of this method is the consideration of the non-lambertian behavior of the Martian surface. In this work, Gusev crater is selected for the photometric investigation to compare with previous photometric studies made from orbit with the High Resolution Stereo Camera (HRSC) onboard the MEX spacecraft [2] and in situ with the rover Spirit from the Mars Exploration Rovers (MER) mission [3].

2. Methodology

Selection of CRISM observations : One overlapping strip can provide until 11 geometries of the same target at different emission angles. Unfortunately, the narrow range of photometric angles with a single CRISM observation does not contain enough information to determine the physical parameters. To improve the number of observational geometries, more overlapping strips acquired at different times along the mission must be combined in order to enrich the range of the phase angle domain to complete as possible the whole phase function [4]. Three observations with varied geometry conditions (FRTCDA5, FRT8CE1 and FRT3192) have been taken on the landing site of Spirit (West of Columbia Hills). In the following study, the eleven CRISM images of each FRT observation are combined and binned at about 300 meters per pixel.

Retrieval of surface reflectance : The signal from the surface is contaminated by the diffusion and absorption of the dust aerosols in the Martian atmosphere. Consequently, an original inversion method is used to retrieve the surface bidirectional reflectance factor (BRF). This model inverses CRISM multi-angle observation using the non-lambertian surface hypothesis, so considering the anisotropy of the aerosols and the martian surface [5]. Previous studies show that the properties of the surface, usually considered to be a lambertian surface, are more complex than expected.

Retrieval of physical properties : Retrieved reflectance is analyzed using a Hapke radiative transfer model [6] with six parameters: single scattering albedo w, macroscopic roughness θ, particle phase function which is described by a two-term Henyey-Greenstein function that includes the parameter b which represents the asymmetric parameter and c the backscattering fraction, and opposition effect described by its width h and magnitude $B0$ (phase angles greater than 40 degrees, so h and $B0$ are not constrained here, no interpretation should be undertaken). Those parameters were derived from the retrieved reflectance at 750 nm by means of the Hapke inversion procedure of Cord et al. [6] using genetic algorithm.

3. Results and discussion

The strategy is to combine the different FRT observations of the same target, one by one in order to appreciate the impact of the combination on the physical parameters determination. Four regions of interest (ROIs) are used for the photometric study which represent each an area of about 300 x 300 meters, located spatially in the same zone (SW of the landing site of Spirit). The first results (Table 1) are obtained by combining the FRTCDA5 and FRT8CE1 observations and then by combining the three FRT observations for the four ROIs. We note that w is relatively low, that is consistent with the low albedo region in the landing site of Spirit (the dark wind streaks). However, the parameters b and c change when the observation FRT3192 is added, indicating that the estimation is not robust. These parameters will be better constrained by adding more FRT observations but in a first approximation, the low albedo region shows a dominantly backscattering nature of the region near the landing site. Previous orbital investigation by the HRSC [4] provided information of physical parameters in Gusev crater which were determined under some limitation, notably without atmospheric correction (the data were selected with an atmospheric opacity less than 0.9 and for low emission angles) and with a lower spatial resolution of data (1.6 km per pixel). Considering HRSC [4], in the dark wind streaks, the region with the lowest albedo showed higher w (0.69 to 0.74) and lower c (0.4 to 0.5) which could result from the lack of atmospheric correction. The comparison between the two datasets shows that the approximations made by Jehl et al. [2] for the HRSC study are consistent with our determination. Spectrophotometric observations were acquired [3], thanks to the MER mission (Spirit) in order to investigate the surface scattering properties of the rocks and soils in the plains and hills of Gusev crater. It is a good complement for orbital measurements to better determine the regional photometric properties. At nearly 750 nm, the single scattering albedo varies between 0.65 and 0.85 for the different unit classes. However the comparison of our results with b and c provided by Spirit is not straightforward as Spirit provides local measurements (soils, rocks) whereas the orbital instruments like CRISM and HRSC measure an extended area.

4. Summary and conclusions

In this work of the Martian surface photometric investigation, the high spectral and spatial resolutions and the new retrieval method of the surface bidirectional reflectance under the consideration of the surface non-lambertian behavior enable us to estimate realistic surface photometric properties from space. However more investigations must be made to validate this approach by combining more observations and by investigating other target places.

FRT observation	CDA5 and 8CE1	3192, CDA5 and 8CE1
w	0.65 - 0.66	0.69 - 0.72
θ (degrees)	20 - 22	18 - 20
b	0.11 - 0.13	0.22 - 0.25
c	0.66 - 0.74	0.46 - 0.57

Table 1: Physical parameters derived from the photometric inversion in Gusev crater.

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