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Retrieval and validation of photometric properties of Mars surface from multi-angle CRISM/MRO imagery

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Abstract

Retrieval of photometric properties of Mars is carried out using CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) multi-angular observations acquired during the ongoing Mars Reconnaissance Orbiter (MRO) mission. First, retrievals of dust aerosol atmospheric optical thickness (AOT) and surface bidirectional reflectance factor (BRF) are performed using two approaches that use the multi-angle capabilities of CRISM. Second, inversion of a two-term phase function Hapke model is performed to validate the estimated photometric properties of the Martian surface. Present results agree with other independent studies.

1. Introduction

The CRISM instrument aboard the MRO spacecraft is the first imaging spectrometer to operate systematically in multi-angle mode at high spatial resolution around Mars [1]. Each CRISM observation is composed by eleven hyperspectral images (0.36 - 3.92 μm) acquired for a given site of Mars at different viewing geometries. This angular coverage can be used to improve the atmospheric correction of CRISM data in order to retrieve accurate spectrophotometric curves of the surface. The latter help understanding its physical state and discriminating the different types of terrains by their photometric and spectral variability.

A novel strategy to retrieve photometric properties from CRISM data is put forward. First, the dust content of the atmosphere is estimated for a given observation. Second, surface BRF is derived after correction of CRISM top-of-atmosphere (TOA) radiances for atmospheric effects. Finally, the retrieved photometric curves of the surface are fitted by a photometric model. In this study, a CRISM observation over the Gusev crater of Mars is processed to derive the corresponding photometric properties. Results show a good correlation with previous investigations.

2. Retrieval of AOT and BRF

Recently a AOT retrieval algorithm has been developed for CRISM multi-angle observations [2]. This original method is based on the correlation between the intensity of the CO_2 gas absorption band at 2 μm and the amount of aerosols. The strength of radiative coupling between these two atmospheric constituents is expressed by the definition of a new parameter β that can be used to retrieve the AOT in addition to the level of radiance. After the factor β is calculated according to geometry for a given CRISM observation, the AOT is estimated by fitting the resulting curves using a DISORT based model. The main requisite of this method is an optical path length that is large enough so that the aerosol/gas coupling is significant. CRISM observations are suitable for the method in [2] because of their broad angular coverage.

Once the content of aerosols is known, CRISM TOA radiances can be corrected in order to retrieve surface BRF. The correction of remotely sensed images for atmospheric effects is however not straightforward due to the anisotropic scattering properties of the atmospheric aerosols and the materials at the surface. Traditional inversion algorithms are based on reductionist hypothesis that assume that the surface is lambertian [3]. Although this assumption largely simplifies the inverse problem, it critically corrupts the angular shape of the retrieved BRF since solid surfaces are hardly isotropic. Recently, we have proposed an original inversion method to overcome these limitations when treating CRISM multi-angle observations [5]. This inversion algorithm is based on a TOA radiance model that depends on the Green's function of the atmosphere and a semi-analytical expression of the surface BRF. In this way, robust and fast inversions of the model on CRISM TOA radiance curves are performed accounting for the anisotropy of the aerosols and the surface.

3. Photometric inversion

Retrieved BRF is analyzed using a Hapke radiative transfer model [6] considering six parameters: single scattering albedo w, macroscopic roughness θ, the 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, opposition effect described by its width h and magnitude $B0$. These parameters are derived at 750 nm from the retrieved surface BRF at the same wavelength by using the Hapke inversion procedure that is detailed in [7].

The photometric study for validation is focused on the Gusev crater of Mars. CRISM observation CDA5 is selected over the landing site of the Mars Exploration Rover "Spirit" and the photometric inversion is performed on an area of 300×300 m in size. The results of the inversion are shown in Table 1. In addition, phase curves are plotted in Fig. 1. As it can be seen, the Hapke model reproduces successfully the TOA reflectance and the retrieved BRF and low absolute and relative quadratic residuals are found. The retrieved Hapke parameters estimated for the Gusev crater after correcting for the aerosol contribution are consistent with independent studies, namely in terms of w, θ and c (see companion abstract [8]). In [8], overlapping observations under varied geometry conditions are combined as in [4] to better constrain the photometric modeling.

Observation CDA5	TOA reflec.	surface BRF
AOT	0.40	0.40
w	0.69	0.67
θ (degrees)	11	20
b	0.03	0.13
c	0.37	0.70
abs. RMS in BRF	0.00711	0.0065
rel. RMS in BRF	0.2344	0.0218
number of geometries	7/11	7/11

Table 1: Physical parameters derived from the photometric inversion of the CRISM observation CDA5.

4. Summary and Conclusions

Validation of surface BRF retrieval is carried out for a CRISM observation of the Gusev crater. CRISM data are corrected for atmospheric effects considering a non lambertian surface. Photometric inversion using a Hapke model underlines the validity of the retrieved photometric curves at 750 nm.

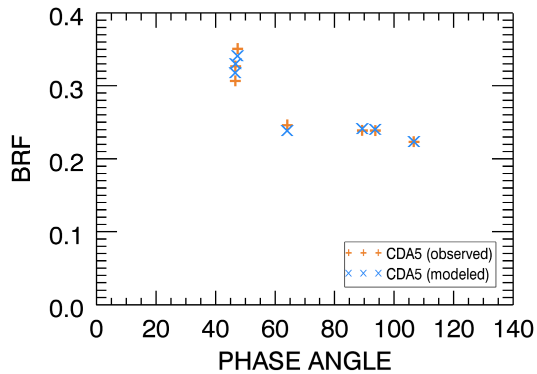

Figure 1: Phase functions of the retrieved surface BRF and modeled data by the photometric inversion.

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