METHODOLOGY TO INVESTIGATE MARS' SURFACE PROPERTIES AND COMPOSITION USING HRSC DATA: FIRST RESULTS. J.-Ph. Combe[1], J. B. Adams[2] and T. B. McCord[1], [1]Space Science Institute, Bear Fight Center, 22 Fiddler's Road, P.O. Box 667, Winthrop, WA 98862, USA. e-mail: jcombe@spacescience. [2]Department of Earth and Space Sciences, University of Washington, Seattle, WA, USA.

Introduction. Mapping of geological units at the surface of Mars with a high spatial resolution requires the knowledge of the mineralogical composition along with information of the surface's structure. This may be performed by using both high-spectral resolution data and high spatial resolution images. The present study is the first step of an investigation involving both color images and panchromatic stereo images from the High-Resolution Stereo Camera (HRSC, [1]) on the Mars-Express spacecraft.

Information about the composition may be derived from spectral analysis of HRSC color data, in complement to high-spectral resolution data from the OMEGA (Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité) imaging spectrometer. However, this analysis is very sensitive to the conditions of illumination and observation. The former depend to the position of the lighting source (solar elevation) and the topography at scales larger or smaller than a pixel that create shading and shadowing in the images [2]. With HRSC stereo images, an area is observed through different geometries of acquisition. This enables to retrieve information about the topography at scales smaller than a pixel. Then, this result may be used as a correction of spectral data, in order to increase the precision of surface component identification or abundance evaluation.

Problematics: minimizing the effects of the observation angle before performing spectral analysis.

Using the four-wavelength spectra of HRSC, the two types of surface color units (bright red and dark bluish material) plus a shade/shadow component can explain most of the variations [3]. The multiple geometry of the color images results in a different amount of shade and shadow for a given area. As a consequence, the shape of the spectra varies in function of the surface albedo, the average slope gradient within each pixel, the solar elevation, the emergence angle and the azimuth of observation with respect to the solar azimuth. The different orientations of observation at different wavelengths create ambiguities, because radiance factor (I/F) variations may be due to changes on the albedo or the amount of shade. The analysis of the color data only is not sufficient to solve this ambiguity. However, the panchromatic images may be used to obtain additional information.

How evaluating the surface roughness? The multiple geometry of remote data acquisition is commonly used by radiative transfer models to derive parameters related to the surface roughness [4, 5, 6, 7] and the atmosphere [4, 5]. The first models [4, 5] were designed for data with a spatial resolution exceeding several tenths of kilometers. As a consequence, they were not recquired to take into account the problem of projected shadows [7]. The latest models [6, 7] are focused on the analysis of spectra taken in the plane of the direction defined by the source of illumination and the surface. Since the HRSC data are acquired even when the sun, the surface and the spacecraft are not aligned, the azimuth of illumination and observation have to be taken into account. The present analysis summarizes the results of an artificial sub-pixel-scale topography that simulates projected shadows and several ranges of azimuth angles between the source of illumination and the instrument.

The HRSC dataset: different types of images and derived products. The HRSC is a multiple instrument. It combines different techniques for mapping details of the geomorphology, the color units (in relation to the composition), the surface roughness and the topography.

Color images: a multispectral dataset with complex geometry of acquisition. The color images are composed of four broadband channels centered respectively at 440, 530, 750 and 970 nm. Each channel is oriented with a different angle to the normal to the surface (-3°, +3°, -16° and +16° respectively). The spatial resolution is usually 100 m or 200 m.

The panchromatic images: different angles of observation at the same wavelength. All the panchromatic images are taken in the same wavelength domain centered at 650 nm. One channel takes images at the nadir at a resolution of 12.5 or 25 m. The other ones are rotated at +/-19° (stereo) and at +/-5° (panchromatic) with respect to the nadir, and their spatial resolution is usually 25 or 50 m.

The derived Digital Elevation Model (DEM). The topography is derived from the stereo images. Standard products have a pixel size about two times larger than color images ; advanced products may reach a spatial resolution of about 50 to 100 m.

Method and results: evaluation of the surface roughness by simulation. The different parameters to be simulated are all those that may induce variations of I/F, independently of the albedo. They are 1) the average gradient slope, 2) the solar elevation, 3) the emergence angle and 4) the azimuth of observation with respect to the solar azimuth. The simulation may include the creation of a synthetic topography (like done by [12]) or the use of a measured Digital Elevation Model as a basis for the surface roughness within a pixel. For a given topography, different values of solar azimuth and solar elevation are chosen. The decrease of illumination light with respect to the incidence angle (shading effect) is calculated through the assumption of Lambertian scattering for each element of the DEM (indicatrix as chosen by [12]). The projected shadows are calculated to identify the areas that are not directly illuminated. Finally, the azimuth of observation and the emergence angle are taken into account to simulate how the surface would look like as seen by the different channels of the HRSC. The complete simulation is displayed in Figure 1. The most meaningful result is the percent of reflectivity recorded by the HRSC color channels that have the most different angle of observation (at 750 and 970 nm). This difference appears on a given column of each graph Emergence angle *versus* Mean gradient slope. It is common the difference reaches 20% or more. As a consequence, spectral analysis of HRSC color data should not be performed before correction of the effect of the surface roughness.

Perspectives: evaluation of the surface roughness and mapping of color units. The next steps include some refinement of the simulation, corrections of the effects of surface roughness and spectral analysis. Any part of the surface may receive some scattered light from the surrounding terrain (as taken into account by 12]) and from the atmosphere. As a consequence, every part of the surface may receive some light from these additional sources of illumination. This may not change the absolute difference of incident light between the areas, but only the ratios of measured I/F values. The comparison of the different panchromatic images with the results of the simulation will allow us to retrieve the average gradient slope within each pixel, which is one type for evaluating the surface roughness. This may complete the information derived from the TES instrument [8]. Then, the color data will be corrected to make the spectral shapes between every parts of the images compatible to perform spectral analysis, in order to map the color units more precisely.

References: [1] Neukum et al., 2004, *ESA-SP 1240*. [2] Adams J. B. And Gillespie A. R., 2006, *Cambridge University Press*, 362 pp. [3] McCord T. B., et al., *submitted to JGR*. [4] Hapke, B., 1981. Bidirectional reflectance spectroscopy. 1. Theory. *JGR. 86*, 3039–3054.[5] Hapke, 1984, *JGR 86*, 3039-3054. [6] Cord et al., 2003, *Icarus 165*, 414-427. [7] Schkuratov et al., 2005, *Icarus 137*, 235-246. [8] Chojnacki et al., 2006, *JGR 111 EO4005*.

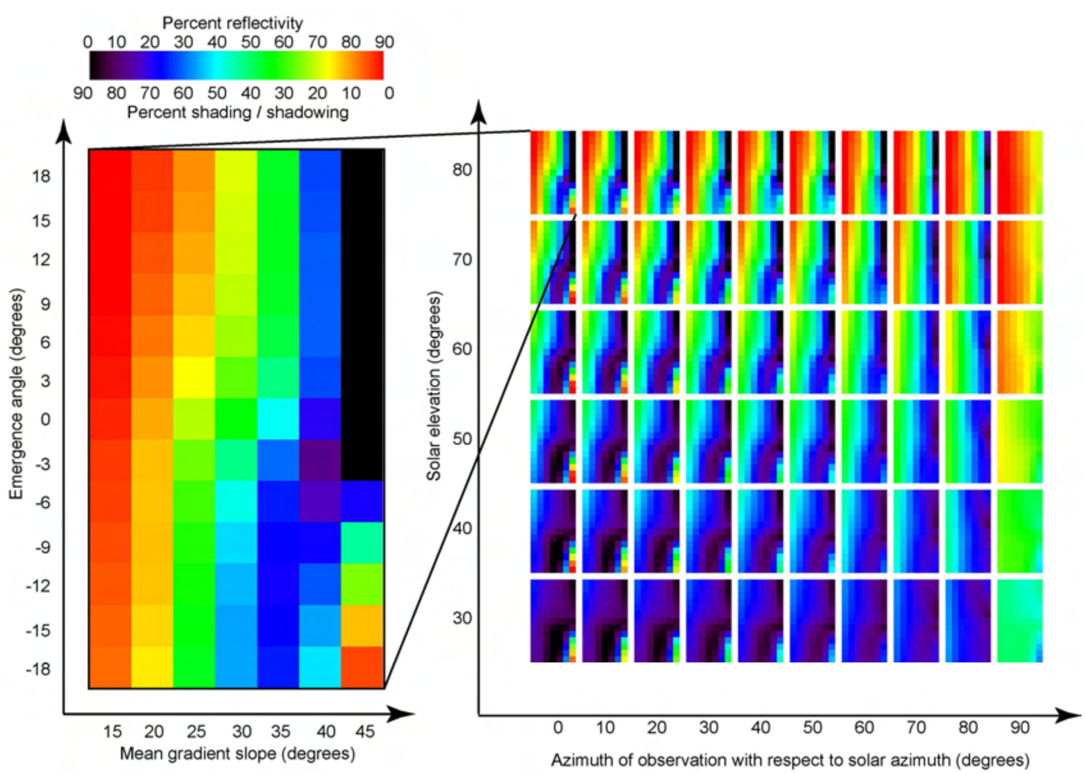

Figure 1. Simulation of the different geometrical parameters describing the surface and the conditions of acquisition of spectral data. The graph on the left is a detail of the complete set of parameters (right).