Correction of HRSC images for atmospheric dust using a simple optical depth retrieval method. O. J. Stenzel[1] and N. M. Hoekzema[1] and W. J. Markiewicz[1] and H. U. Keller[1], [1]Max-Planck-Institut für Sonnensystemforschung, Max-Planck-Straße 2, D-37191 Katlenburg-Lindau, Germany, stenzel@mps.mpg.de

Introduction: The High Resolution Stereo Camera (HRSC) on board Mars Express (MEX) has and still is delivering stunning images of the Martian surface [1]. However the images do not only show surface features but also contributions from the atmosphere due to absorption, and scattering. The light is affected by various atmospheric constitutions and aerosols. In the observed images these influences result in a change (usually reduction) of contrast and and change of color which can be seen in Fig. for the case of a dusty atmosphere. On Mars, the surface is protected from wind erosion neither by vegetation nor by oceans and so the wind is able to transport large amounts of dust up into the atmosphere. In the case of large global storms this can render the atmosphere completely opaque. Usually the dust load is much lower and allows for observations in the visible spectrum, but the optical depth of the atmosphere rarely sinks below $\tau = 0.3$, at least at the position of the Mars Exploration Rover A (Spirit), see Fig. 1 on page 1. Water ice is another important aerosol which affects radiation. This abstract presents a new method to obtain the optical depth of the atmosphere using HRSC images.

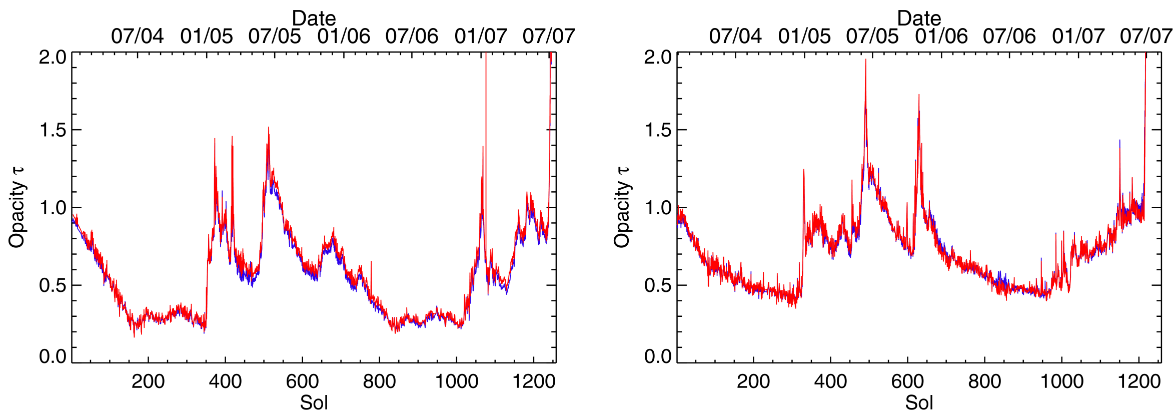

Figure 1: Atmospheric opacity as measured by Spirit (left) and Opportunity (right) at 440 nm and at 880 nm represented by the blue and red lines, respectively. The data was obtained through the MER Analyst's Notebook

Method: The Albedo Method is an iterative scheme to estimate the optical depth for a given HRSC image and to use this optical depth to correct the image to obtain albedo maps and color images. The principle is simple: Different optical depths are used with the radiative transfer model SHDOM [2] until a reasonable result is reached. This is possible because we already know some properties of the Martian surface from the Viking Lander, Mars Pathfinder and Mars Exploration Rover missions. Thus we are able to set upper limits for the Lambert albedo when checking our results. A lower limit is the underexposure of the camera. Figure 2 shows a simplified diagram of the Albedo Method. The scheme can be broken down into three parts. The first part is the data preparation part, marked blue in Fig. 2. The albedo method normally uses Level 4 data in conjunction with Digital Terrain Models (DTMs). The in-file calibration coefficients are used to calculate the I/F ratios from the raw data. After setting an initial optical depth the process continues with the iterative part, marked orange in Fig. 2. The data is passed to a atmospheric dust correction routine. The corrected image is then checked for too high or too low albedos. If the check fails, the optical depth is adjusted the corrections starts again. In case of passing the test, albedo maps or a composite color image can be obtained.

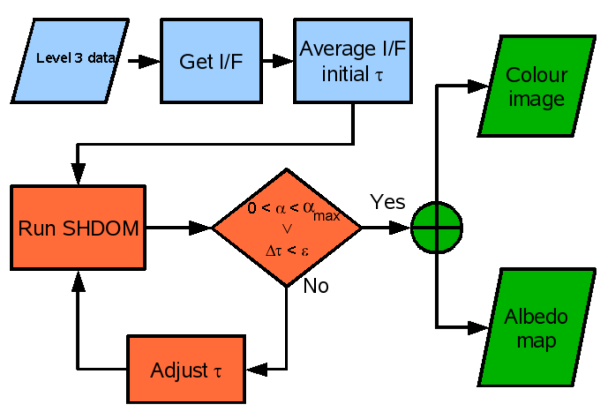

Figure 2: Simplified diagram of the Albedo Method.

Results: With this method we were able to process several hundred HRSC images. The albedos of the corrected images differ considerably form the unprocessed albedos. Figure 3 shows the mean albedo for the nadir channel distribution over the whole frames for both unprocessed (black) and processed (red) data. Albedo are generally shifted to right side, i.e. the surfaces are brighter than they appear in the original images. The atmospheric extinction plays a bigger role here than backscattering. The second thing that is eminent from Fig. 3 is the enhanced contrast between the two local maxima in the histogram.

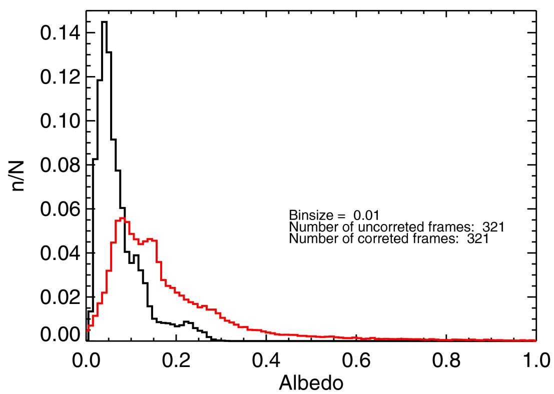

Figure 3: Albedo histogram for the original and corrected nadir channel images.

As the largest part of the Martian surface is covered by bright red dust (BRD), it is not surprising to see the maximum of the histogram on the right side of distribution. However, the maximum is situated at around 0.4 which is higher then the observed albedo of BRD of the lander missions. One reason for this is inherent overestimation of τ. An other explanation for the excess of high albedos and the wide slopes of the histogram in general is the variation of the solar zenith angle through out the frame. The atmospheric mass correction applied to the images is only correct in the center of the frame. Further, ice hazes play an important role for the scattering processes in the Martian atmosphere but are neglected in the current implementation of the albedo method.

References: [1] Neukum, G.; R. Jaumann and the HRSC Co-Investigator and Experiment Team (2004), ESA, SP-1240. [2] Evans, K. F. (1997), *Journal of the Atmospheric Sciences*, 25, 429-446.

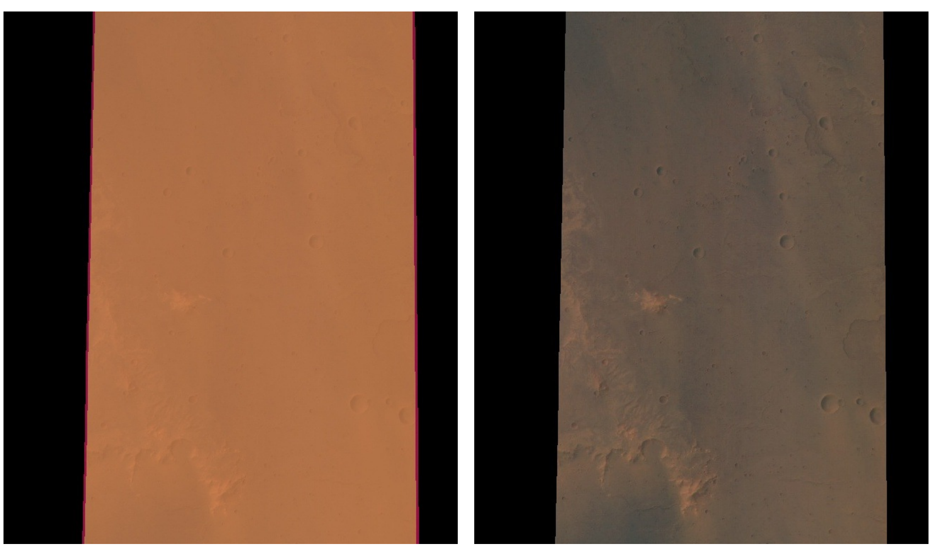

Figure 4: A HRSC color image composed of panchromatic, green and blue channels. The original image is shown on the left side, the corrected image is sown on the right side.