IMAGE-DERIVED ATMOSPHERIC TRANSMISSION FOR ENHANCEMENT OF CRISM VOLCANO SCAN CORRECTION. Y. Itoh[1], M. Parente[1], [1]Department of Electrical and Computer Engineering, University of Massachusetts Amherst MA 01003; yitoh@engin.umass.edu;

Introduction: The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [1] has revealed many aspects of surface mineralogy of Mars thanks to significant efforts made on calibration and atmospheric compensation to retrieve accurate surface reflectance. "Volcano scan" correction was first proposed for atmospheric correction by the OMEGA team [2] and has been used in the pipeline of CRISM data processing to produce high level products [3, 4]. It performs atmospheric correction using transmission spectra derived from the ratio of spectra at the the summit and the base of Olympus Mons. Since the original development of the algorithm, CRISM researchers made significant efforts on improve the quality of the method [5, 6]. The current version of the algorithm selects the optimal atmospheric transmission data from the candidates in the Ancillary Data Record (ADR) to consider the variations of the filter positions and the atmospheric conditions for different scenes. In spite of these efforts, some distortions still remain; we observed in fact that for several Target Reduced Data Record 3 (TRR3) images, all transmittance spectra available in the CRISM processing pipeline produced some sort of artifacts in the resulting I/F spectra. This indicates that such variations are not fully modeled in the current approach. Image-derived atmospheric-transmittance spectra do not suffer from these problems and can be extracted provided that they are successfully separated form surface contributions and their noise are properly handled. We present a methodology to estimate the atmospheric transmission from the image.

Derivation of atmosphere transmission from the image: The contribution of atmosphere is the dominant components in I/F data. In order to extract only atmospheric transmission, it is necessary to isolate the contribution of surface reflectance. Under the model based on the Beer-Lambert law used in the volcano scan correction, I/F is considered to be a surface reflectance multiplied with an exponentially scaled transmission. We consider the logarithm of I/F signal since the transmission and surface reflectance can be linearly separable components in this domain. For the logarithm of the spectrum, we subtract its continuum obtained via an approach described in [7] pixel-by-pixel. Then the continuum removed spectra are de-noised with a simple statistical method.

After the process above, only surface reflectance absorption features and transmission components are present in the signal under the assumption that all the surface reflectance spectra are modeled by the combination of appropriate continua and absorption features. Suppose there exists a pixel with unremarkable spectrum with no absorption features, its continuum removed spectrum only has the contribution of atmosphere. However, it is hard to detect such a spectrum because of the presence of noise and uncertainty in the estimation of the continuum. In addition, the contribution of the atmosphere obscures the surface reflectance a lot. Gray spectra in Figure 1 show all the continuum removed spectra in a column in the same scene. Their variation is mostly governed by the contribution of atmosphere. Therefore, it is reasonable to focus on known possible spectral absorption bands to assess the existence of absorptions. From Figure 1, it is easy to recognize the variation of the spectra around a water band around 1.9μm. Currently we select the spectrum with the least absorption bands in this region as the estimated transmission.

The whole process is performed column-by-column because atmospheric absorption features are different for different columns due to smile effect. This method is theoretically reasonable if the atmosphere signal is uniform along the column. In addition, our method requires the existence of an unremarkable spectrum in every column. It is interesting to note that the transmission may include common multiplicative components of systematic column distortion resulting from small calibration errors and these can be also removed by our method, although the systematic errors cannot be isolated from the atmospheric transmission in our scheme.

Comparison of corrected spectra: We evaluated the performance of the proposed atmospheric compensation approach against the currently available method on several TRR3 images in the CRISM data processing pipeline. Here we illustrate typical results on the scene 94F6 acquired with the Full Resolution Targeted (FRT) mode. We consider the wavelength region between 1.0-2.6μm. Compared are reflectance spectra corrected by volcano scan method with transmission spectra selected by CRISM Analysis Toolkit 7.3.1 (CAT) with the option of empirical optimization. For both transmissions, the 1.980-2.007μm band pair [5] was used and no photometric correction was applied.

Figure 1 showcases one example of the comparison of an estimated transmission, continuum removed spectra in the image, and the transmission spectrum in the ADR selected by CAT for this scene. The estimated transmission and image continuum removed spectra are exponentially scaled so that their 1.98 and 2.007μm bands have the same ratio. Overall, the estimated and ADR

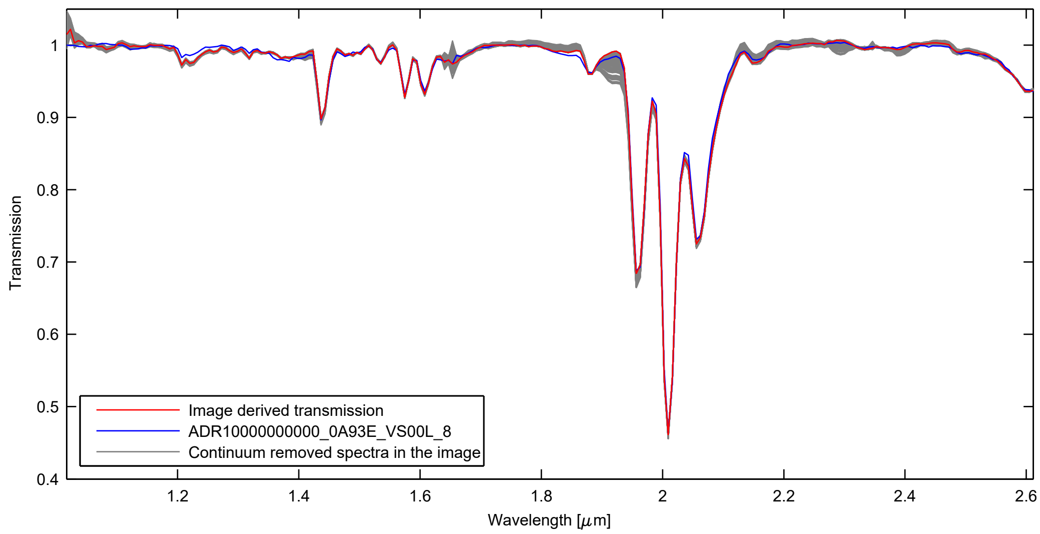

Figure 1: Comparison of transmission spectra (FRT000094F6, column 200)

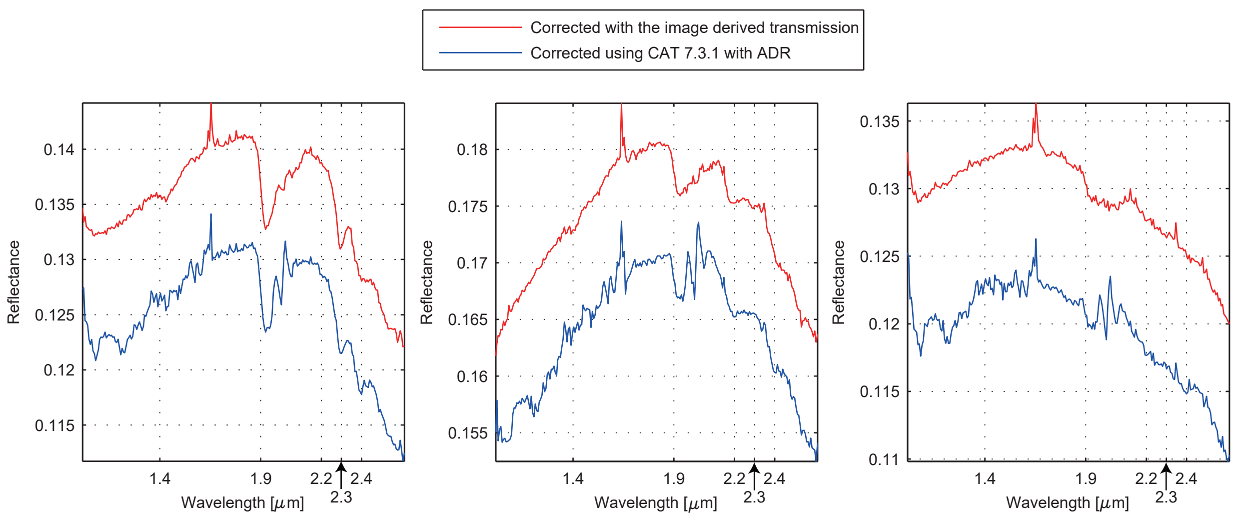

Figure 2: Comparison of processed spectra on the image coordinate (line, column) of (81,200) (left), (92,200) (center) and (102,200) (right) in FRT000094F6. The blue spectra are vertically shifted by -0.01 for clarity in comparison.

transmission spectra closely overlap with each other, while details are different, which we assume are caused by the variation of the atmosphere and wavelength shifts or column dependent calibration errors.

Figure 2 shows three examples comparing the atmospheric compensated spectra estimated by our method versus ones processed with CAT. The small atmospheric residuals over 1.0-1.8μm are significantly reduced, making a water band at 1.4μm visible. In addition, our proposed method reduces the triplet-like atmospheric residual around 2.0μm, indicating more accurate modeling of the transmission on this region. However, the bowl-like shape around 2μm in the right of Fig. 2 can be also interpreted as an artifact described in [8]. Further analysis to validate the average benefit of our approach is necessary. In addition, consideration of more spiky noise will be a future work.

References: [1] S. Murchie, et al. (2007) *J Geophys Res* 112(E5):E05S03. [2] Y. Langevin, et al. (2005) *Science* 307(5715):1584. [3] F. P. Seelos, et al. (2011) *LPSC* 1438. [4] F. P. Seelos, et al. (2016) *LPSC* 1783. [5] P. C. McGuire, et al. (2009) *Planet Space Sci* 57(7):809. [6] F. Morgan, et al. (2011) *LPSC* 2354. [7] Y. Itoh, et al. (2017) *Int Geosci Remote Sens*, to appear. [8] S. Wiseman, et al. (2016) *Icarus* 269:111.