A NEW SIMULTANEOUS ATMOSPHERIC CORRECTION AND DE-NOISING OF CRISM DATA. Y. Itoh[1], M. Parente[1], [1]Department of Electrical and Computer Engineering, University of Massachusetts Amherst MA 01003; yitoh@umass.edu;

Introduction: The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [1] on board of Mars Reconnaissance Orbiter has made significant contributions on revealing many detailed aspects of surface mineralogy of Mars, owing to significant efforts made on calibration and atmospheric correction to retrieve accurate surface reflectance. However, the atmospheric correction algorithm used in the current CRISM data processing pipeline, so called "volcano scan" [2, 3, 4], still leaves some residuals despite of its improvements [5, 6, 7]. In addition, the processed spectra are still sometimes corrupted with moderate to large noise that needs to be addressed. Our previous works [8, 9] tackled the issue of the residual caused by volcano scan using an unmixing technique and improved the signal quality for variety of images. We made a significant upgrade; our new method now considers severe noise and atmospheric correction and de-noising are simultaneously performed. The presence of water ice aerosol is also taken into consideration. Our new method is applicable to wide range of scenes including noisy ones acquired at IR high detector temperature.

Methodology of simultaneous atmospheric correction and de-noising: As in our previous work [9], it is assumed that the light propagation through the atmosphere is modeled by the Beer-Lambert model and that the surface reflectance is approximately modeled by the corrupted linear spectral mixing model [10] in the logarithmic domain. The estimation of atmospheric transmission is performed by a model inversion formulated as a minimization problem, in which a modified version of sparse unmixing with adaptive background [10] is simultaneously conducted to estimate the surface reflectance and model parameters. The sparse unmixing allows us to select endmembers/phases contributing to each spectral signal from a large spectral library and estimate their fractional abundances. In order to take various noise with different magnitude into consideration, we formulate the unmixing in a robust way using ℓ_1-norm. The algorithm to solve the minimization problem is iterative and large noise are detected and removed at each step in the algorithm using hard-thresholding on the residual of modeling. In order to ensure the method to work on variety of scenes with little adjustment, many phases are included for the computation of modeling surface spectra. The 686 candidate phases (endmembers) are selected from CRISM spectral library, RELAB spectral database [11], U.S. Geological Survey (USGS) spectral library (splib06) [12], and CRISM Type Spectra Library [13]. The transmission spectra in the ADR are also used for the initialization of the transmission spectrum to stabilize the optimization algorithm. The absorption efficiency spectra of water ice are also calculated using Mie theory from the optical constants in the Grenoble Astrophysics and Planetology Solid Spectroscopy and Thermodynamics (GhoSST) database[1] and stacked to the library to compensate the absorption by water ice aerosol. Currently, its scattering is not considered. Note that a scaling parameter for the transmission spectrum is also obtained for each pixel as a byproduct, which is then used for removing the effect of transmission by applying the Beer-Lambert law.

The computation is performed column-by-column due to wavelength shift caused by smile effect. The uniformity of the atmospheric transmission over each column is required. Our method works on the wavelength region over 1.0-2.6 μm.

Comparison of corrected spectra: We applied our algorithms on the CRISM images including the ones around the final candidates of the Mars2020 landing site, North East Syrtis, Jezero crater, and Columbia hills. The computational time for processing each image was about one and half to two hours in our environment.

Fig. 1 shows some comparisons of I/F spectra corrected by our algorithm (red) and ones corrected by volcano scan method using the CRISM Analysis Toolkit (CAT) software (version 7.3.1) (blue). The empirical selection of the transmission spectra is used for CAT and photometric correction is not applied. Overall, spiky features on the CAT-corrected spectra are removed on the ones corrected by our method. These spiky features may be artifacts created in the CRISM processing pipeline (including atmospheric correction) or random noise. A depression around 2.0 μm in Fig. 1(c) that seems to be the bowl-shape artifact [14] and a triplet residual in Fig. 1(a) are also clearly removed. Furthermore, absorption features such as hydration bands at 1.4 and 1.9 μm are much more clearly retrieved. Fig. 1(a) shows our corrected spectrum shows much clear Al-smectite bands at 2.2 μm. Our corrected spectra tend to exhibit more small fluctuations, which can be greatly minimized when spatially averaged (Fig. 1(f)), confirming that the small zig-zags on our corrected spectra are not atmospheric residual, but small random noise.

Fig. 2 shows another comparisons where the significant contribution of water ice aerosol is observed. The contribution is confirmed by the kink at 1.5 μm and an

[1]http://ghosst.obs.ujf-grenoble.fr

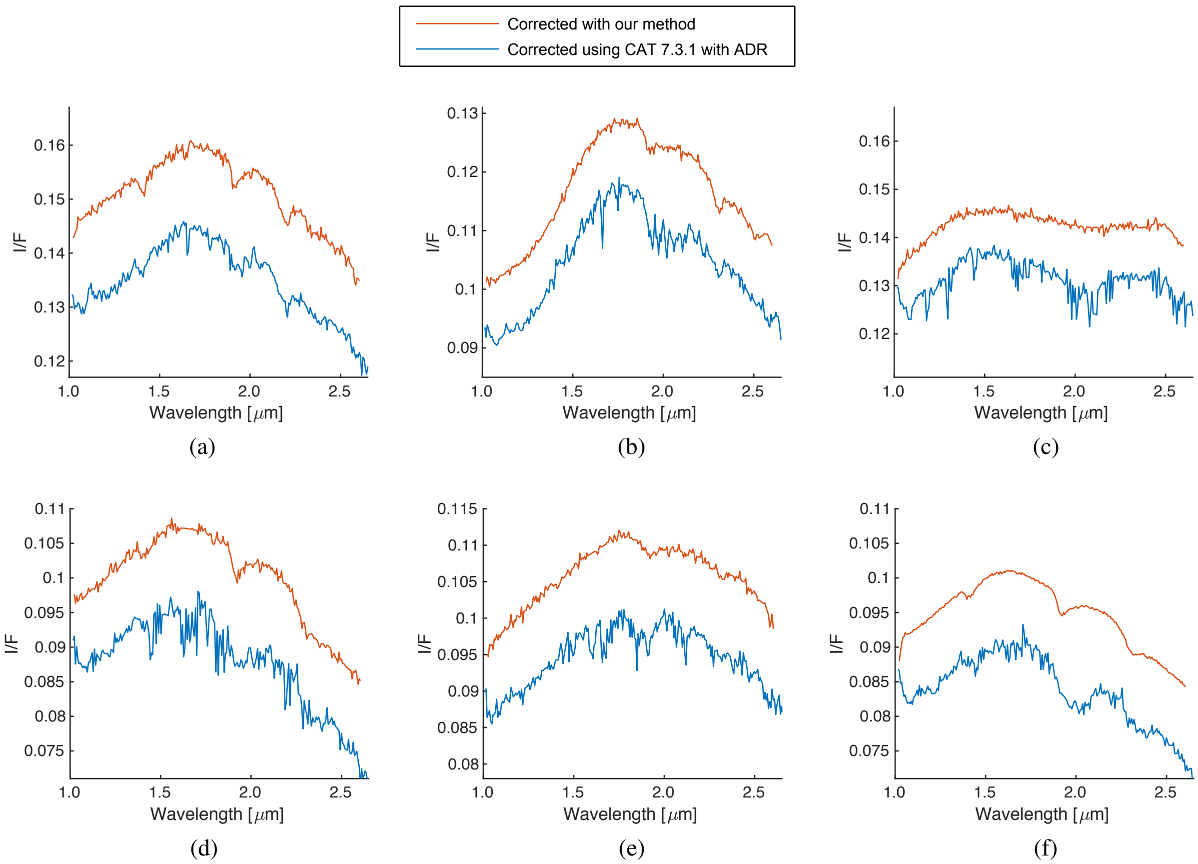

Figure 1: Comparison of corrected I/F spectra by our method (red) and by volcano scan in CAT software (blue); (a) the pixel coordinates (sample,line) of spectra are (235, 31) in FRT00016A73, (b) (191,359) in HRL0002422E, (c) (306,296) in FRT000174F4, (d) (528,367) in FRT00024C1A, (e) (280,167) in FRS00031442, and (f) same as (c) and averaged over 5x5 pixels. Spectra are shifted for clarity.

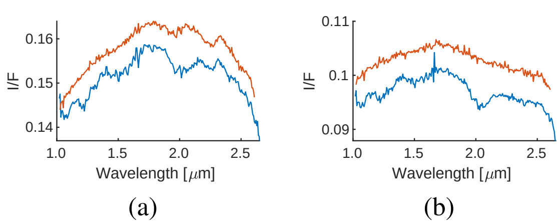

Figure 2: Comparison of corrected I/F spectra by our method (red) with the numerator ones in CRISM Type Spectra Library (blue). The coordiantes are (a) (313,406) and (b) (289,122) in HRL0000B8C2.

absorption around 2.0 μm. The kink may be clearer in the relatively bland spectra shown in Fig. 2(b). It can be seen that our method compensate the absorption induced by water ice aerosol and reveals mineral features.

Future work: We are testing our algorithm on more variety of scenes to examine its applicability and limitations. Our method is still not applicable to polar region. In addition, if the atmospheric transmission spectrum is too different from the ones in ADR, the method may create artifacts.

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