DENOISING CRISM IMAGES: A NEW LOOK M. Parente[1], A.M. Saranathan[1], S. Wiseman[2], B.L. Elhmann[3] and L. Pan[3], [1]Department of Electrical & Computer Engineering, University of Massachusetts, Amherst MA 01003 USA (mparente@ecs.umass.edu), [2]Brown University and [3]California Institute of Technology.

Introduction: The increase in spatial and spectral resolution from OMEGA to CRISM [1] led to new discoveries of water-related minerals and a refined understanding of the history and diversity of Martian aqueous environments. Yet, most CRISM discoveries were made averaging tens of pixels due to the uncertainties in the spectral shapes of single pixels. While great progress in data calibration and reduction have been made in the current version (TRR3) of CRISM data and even the prototype MTRDR [2], challenges still remain especially in regions of lower signal to noise and for observations performed in the last couple of years due to the aging hardware. We focus our attention on these "problematic" scenarios and explore the potential of a novel spectral artifact mitigation technique that is the first step to exploiting the full CRISM inherent resolution. This technique leverages the latest improvements on atmospheric correction based on radiative transfer [3, 4] as an alternative to the currently available "volcano scan" correction. Spectral artifacts in CRISM images are due to residual atmospheric contributions and detector-based effects that are column-dependent and other spatially localized temperature-dependent effects. We are proposing a denoising approach that separately addresses both sources of spectral distortions.

Noise Suppression:
1) Atmospheric Correction using DISORT Modeling: CRISM spectra are atmospherically corrected using the Discrete Ordinate Radiative Transfer (DISORT) [5, 6] code, which is a public domain general purpose Fortran program for discrete-ordinate-method radiative transfer in scattering and emitting layered media. The atmosphere is treated as a plane-parallel medium in which individual layers are homogenous but interlayer properties can be varied. The numerical implementation is discussed in [5] and "front-end" routines optimized for study of the Martian atmosphere in [7]. DISORT is used to calculate I/F for atmospheric conditions relevant to each CRISM image for a series of surface albedos. These forward models are used to generate lookup tables that are then used to convert CRISM I/F to surface albedo (e.g., [8]). DISORT-based atmospheric retrievals have been used to model CRISM and OMEGA spectra [8, 9] and has recently been optimized for the column-dependent spectral sampling and resolution of the CRISM spectrometer [3].
2) Column-Average Based Noise Suppression : We assume that the lambert albedo (or apparent reflectance) $Y(i, j, k)$ obtained by the DISORT stage can be modeled at each CRISM pixel i, j and each spectral channel (band) k can be modeled as a combination of the signal corresponding to the surface contribution $S(i, j, k)$, some detector (column) dependent artifact $n_d(i, j, k)$ and other (random) noise processes $n(i, j, k)$, namely $Y(i, j, k) = S(i, j, k) + n_d(i, j, k) + n(i, j, k)$. Both residual atmospheric distortions [3] and some detector artifacts [10, 11] have a column dependency. We approximate the column-dependent distortions as a scaled version of some fixed detector-specific "noise" profile $n_d(i, j, k) = \alpha(i, j)\tilde{\mu_y}(k)$, where $\alpha(i, j)$ is a scaling factor proportional to the integrated albedo of the signal Y at pixel (i, j). The noise profile $\tilde{\mu_y}(k)$ can be extracted from the average signal over the lines at each sample (column) by considering the residual of a spline fitting to the average spectrum of a given column. This is because such a spectrum is expected to be a combination of the average mineral (surface) contribution in the column, which is a smoother function and the detector specific noise profile (assuming that the other (random) noise processes have 0 mean). We can simply remove the column-dependent distortion $\alpha(i, j)\tilde{\mu}_y(k)$ from the reflectance values $Y(i, j, k)$ by subtraction.
3) Neighborhood based despiking: the remaining noise term $n(i, j, k)$ exhibit high frequency variations in the spectral domain and it is spatially localized. Our approach consists of identifying spectra with unnaturally large intensity differentials $i_D(k) = |y(k)-y(k-1)|+|y(k)-y(k+1)|$, where $y(k)$ is the value of the signal at channel k after the column-dependent noise correction. A spectral region of y is "spiky" if it exhibits intensity differential greater than 115% of the average intensity differential. The spiky region is corrected by estimating the shape of the signal y in that region from the spectral shapes of the non-spiky neighboring pixels in the same region.

Experiments and Results: We consider CRISM cubes acquired by the IR (L) detector and concentrate on the spectral range between 1.1127 to 2.6285μm. Our preliminary observations of the results of the algorithm on images selected from Gale crater and Acidalia Planitia are encouraging. The images were chosen due to the elevated spectral noise. Here we show an example of typical results. The algorithm is applied to the image FRT00017F45 (henceforth 17F45) (version TRR3 of CRISM). Fig. (1) show a comparison of single pixels of the image where the available corrections are made (in red) in comparison to pixel obtained after the noise-suppression pipeline described above was used. The processing lead to significant improvements in the spectral shape. In particular the column average based cor-

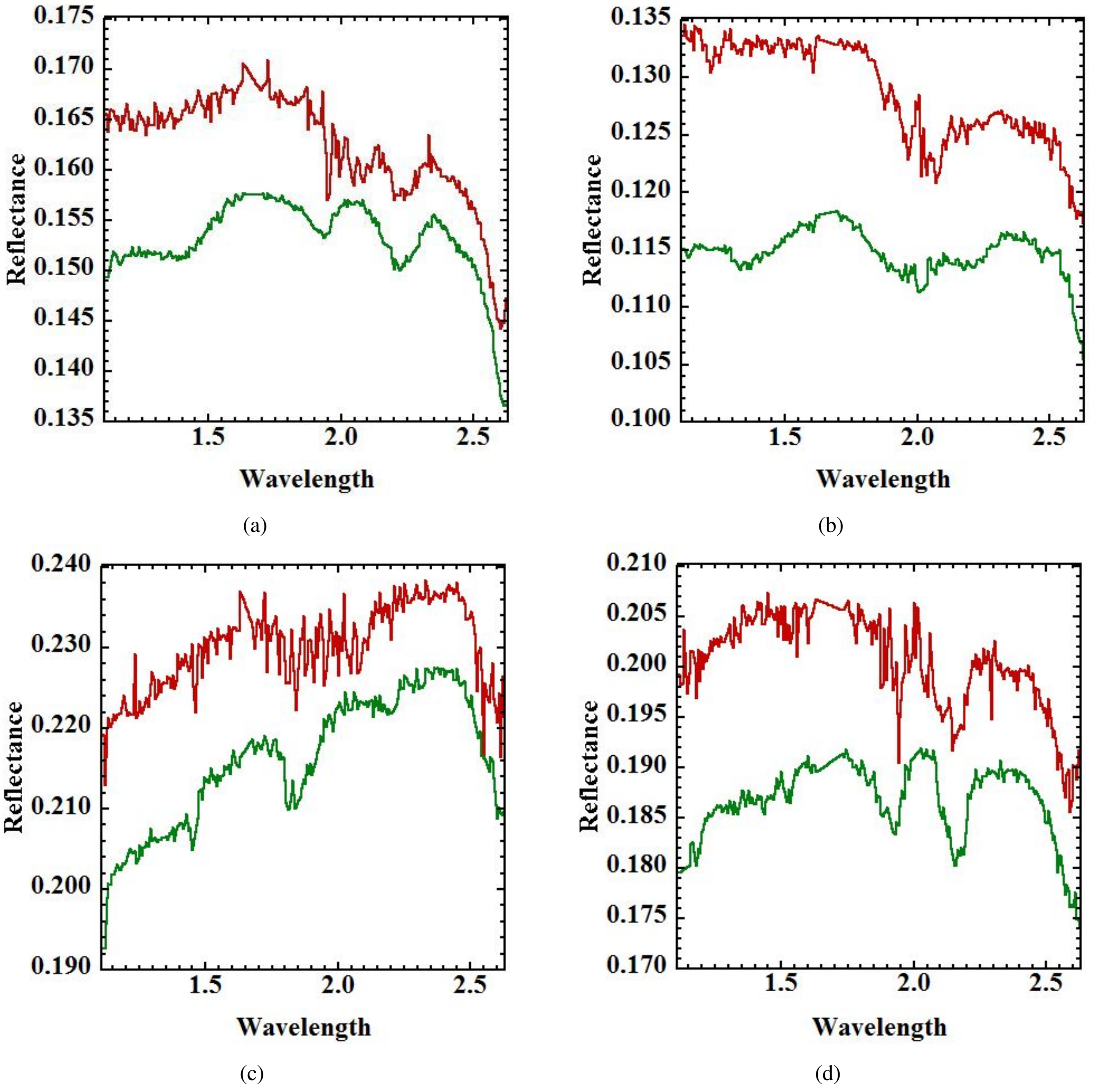

Figure 1: Comparision of the TRR-3 pixel spectra after CAT atmospheric correction (red plots) to the pixel spectra after processing (green plots) for the image 17F45 (a) Pixel at (349 (sample), 198 (line)), (b) Pixel at (563, 112), (c) Pixel at (328, 343) and (d) Pixel at (417, 101)

rections seems to be quite successful at mitigating remaining atmospheric distortions and also seems to generally reduces the detector dependent noise in the signal. Especially in the wavelength range between 1.8 - 2.0 μm the artifacts of atmospheric corrections are removed making the hydration bands more clearly visible $1a$, $1c$ and $1d$). The area is being currently studied in a paper submitted to this conference [**?**]. The proposed approach seems to identify previously undiscovered phases together with confirmed mineral species.

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