IMPLEMENTATION OF A RESIDUAL CORRECTION IN THE MRO CRISM VNIR MAPPING STRIP DATA PROCESSING PIPELINE. K. R. Frizzell1, F. P. Seeles1, D. C. Humm1, S. L. Murchie1, and C. D. Hash2,
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Introduction: The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [1] on the Mars Reconnaissance Orbiter (MRO) [2] has provided reflectance imaging spectroscopy observations leading to key surface spectral and mineralogical discoveries. Over the course of the MRO mission CRISM has acquired data with various spatial and spectral sampling characteristics, ranging from ~180 m/pixel multispectral mapping observations to ~18 m/pixel hyperspectral targeted observations. The Multi-Spectral VNIR (MSV) CRISM mapping data sits in between these operational bounds – with a spatial sampling of ~90 m/pixel, nearly the full CRISM VNIR hyperspectral wavelength set (90 channels from 371 nm to 1016 nm), and a typical footprint of ~11 km cross-track x ~500 km along-track per strip of mapping data. Discussion of the motivation, characteristics, acquisition history, and applications of the CRISM MSV data set is included in a companion abstract [3].

The CRISM Science Operations Center (SOC) is currently adapting the existing CRISM map-ping data processing and map tile (mosaic) assembly processing pipeline [4] to support the unique spatial, spectral, and radiometric characteristics of the MSV data set. This effort recently uncovered a previously unrecognized low-level time-variable calibration residual characterized by a quasi-periodic along-track structure which manifests itself as cross-track banding that persist from a few to a few tens of frames (e.g. Figure 1a). Preliminary MSV mosaic products [5] demonstrated that this ‘frame set residual’ has sufficient amplitude and spatial structure to compromise the scientific utility of some spectral parameterizations, particularly those that score weak spectral features and/or have an inherently low SNR. A prototype Frame Set Correction (FSC) has been developed and added to the existing workflow in order to remediate the cross-track banding residual, and the established data processing procedures are being updated to accommodate the MSV data characteristics.

Observation Independent Workflow: MSV mapping strips are processed individually through a processing pipeline (described in further detail in the MRO CRISM Data Product Software Interface Specification [6]) before being radiometrically reconciled and assembled as an internally consistent map tile mosaic. A data triage and selection pre-processing step omits strips acquired during times of excessive aerosol opacity or that are missing accompanying calibrations.

Frame Set Correction (FSC): The Frame Set Correction is a newly-developed procedure with the purpose of mitigating the quasi-periodic along-track residual structure. The procedure removes spatial row-oriented banding (in sensor space, parallel to single frames within the strip) by gathering adjacent inter-row statistics and constructing an along-track additive aggregate profile from the median values of the inter-row discrepancies. The profiles are accumulated from both along-track directions (+y and -y) and the difference statistics are collected with a +1 and -1 row shift. The aggregate profile is then smoothed with a sliding boxcar median with a length scale of 50 frames (approximately the size of the largest residual structures). The boxcar result is subtracted from the aggregate profile to produce a correction profile for each spectral band. The along-track band-independent correction is then applied to all samples in the input image cube. The application of the frame set correction to a typical MSV strip is shown in Figure 1.

Ratio Shift Correction (RSC): The RSC is a band-independent procedure that was originally developed as part of the targeted hyperspectral observation noise remediation workflow [7] to isolate and mitigate systematic calibration residuals traceable to individual CRISM detector elements. The correction removes spatial column-oriented (in sensor space) residual striping by gathering adjacent inter-column ratio statistics from continuum-normalized spectral data and constructing a cross-track multiplicative aggregate profile from median values of the inter-column ratios. The profiles are created in both cross-track directions with the inter-column ratio statistics collected with both a +1 and -1 column shift. The aggregate profile is then normalized by a low-order Legendre polynomial fit to generate a correction profile for the subject band. The correction profile is applied to all frames in the continuum-normalized spectral cube, and the data are then transformed back into I/F [6]. Although the RSC and FSC operate orthogonally within an image cube, they are functionally similar approaches to the characterization and correction of systematic calibration residuals in imaging spectroscopy data.

Lambertian Photometric Correction (PHT): The spectrum of each spatial pixel in the image cube is divided by the cosine of the solar incidence angle at that pixel [6].

Empirical Smile Correction (ESC): CRISM data exhibit a spatial/spectral structure traceable to spectral
smile, which is an optical artifact whereby the wavelength calibration shifts slightly as a function of cross-track spatial position. This induces a small radiometric calibration residual that appears as a wavelength-dependent cross-track gradient. The Empirical Smile Correction (ESC) remediates these residuals by using a fit of along-track-averaged intra-band wavelength-dependent variation in signal that is constrained to have a cross-track form consistent with the spectral smile. The resulting cross-track correction is normalized to a set of reference columns at the center of the detector [6]. The result of the end-to-end MSV strip-independent workflow is shown in Figure 1.

Mosaic Construction and Optimization: The MSV image cubes that result from the observation-independent processing workflow are suitable for mosaic optimization and assembly. Spatial relationships and associated radiometric discrepancies among the constituent observations are identified and sampled, and an optimization procedure that seeks to minimize the radiometric discrepancy across the mosaic is applied. The optimization results in transform function coefficients for each spectral band of each participating observation.

Figure 1: A section of MSV0003B303_01 covering the Jezero Crater delta showing the data before and after various correction steps. Band 5 (416 nm) is displayed with no corrections (a), the frame set correction (FSC) (b), the result of the full correction pipeline (c), and the ratio between the final corrected MSV and the uncorrected data (d). An RGB image of the corrected MSV is shown on the right (e) with R: 696 nm, G: 592 nm, and B: 520 nm.

Jezero Crater Use Case: With a strong community interest in Jezero crater as the Mars 2020 rover landing site, we are pursuing the assembly of a radiometrically reconciled MSV mosaic for a portion of the Syrtis Major Mars Chart (MC-13) that includes Jezero as well as the large regional spectral and albedo variability for testing and development. A small portion of a preliminary MSV mosaic product centered on Jezero crater is shown in Figure 2.

Conclusion: The current state of the MSV data processing and mosaic assembly workflow, and the in-progress MC-13 / Jezero crater mosaic will be presented. It is expected that the ~90 m/pxl MSV mosaic data products will ultimately provide a near-global framework for the evaluation of surface spectral reflectance across the CRISM VNIR wavelength range, and the integration and comparison of numerous Mars remote sensing data sets.


Figure 2: Preliminary MSV mosaic of the Jezero crater Mars 2020 rover landing and field sites. The mosaic consists of corrected MSV mapping strips that have been radiometrically reconciled by a linear least squares optimization process. The corrected reflectance at 768 nm is shown with a blue-red divergent color ramp.