NEXT GENERATION CRISM MULTISPECTRAL MAP OF MARS: NOISE REDUCTION AND RADIOMETRIC RECONCILIATION.

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Introduction and Motivation. The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [1] is a visible through short-wave infrared hyperspectral imaging spectrometer (VNIR S-detector: 364-1055 nm; IR L-detector: 1001-3936 nm; 6.55 nm sampling) that has been in operation on board the Mars Reconnaissance Orbiter (MRO) [2] since 2006. Over the course of the MRO mission, CRISM has acquired over 276,000 individual observation segments (or mapping strips) with a variety of observing modes and data characteristics (Table 1). Due to the MRO near-polar mapping orbit (inclination ~93 degrees), CRISM mapping coverage density varies primarily as a function of latitude and secondarily due to seasonal and operational considerations. The aggregate VNIR and IR mapping coverage at the equator stand at ~97% and ~78%, respectively, increasing poleward so that at higher latitudes there are typically multiple individual mapping strips that sample a given ground location. The quality of the CRISM VNIR mapping data has not changed substantially over the course of the mission, but the IR mapping data quality has varied significantly as function of the IR detector operating temperature. The CRISM IR detector is actively cooled and as the cryosystem efficiency has decreased with age, the IR detector temperature and associated noise level (e.g. Figure 1A) have increased accordingly. The manifestation of the thermally driven IR noise is more challenging to address in the CRISM mapping data as compared to the hyperspectral targeted observation data. The fraction of affected pixels is amplified and the magnitude of the noise structure is depressed by the 5x or 10x cross-track spatial binning inherent to CRISM mapping observations, and the wavelength subsampling reduces the channel-to-channel correlation that can be leveraged toward noise identification and mitigation.

CRISM Mapping Mosaic Testbed. The variable CRISM IR data quality and the accumulated spatial coverage density have motivated the development of a mapping data processing and mosaicking testbed within the CRISM Science Operations Center (SOC). This supports both the prototyping of data processing procedures for future deliveries of CRISM Planetary Data Systems (PDS) standard data products - e.g. the Multispectral Reduced Data Record (MRDR) map tiles - and the generation of custom mosaicked data products that complement the standard PDS data product suite.

Mapping Data Noise Remediation. A prototype IR mapping data noise remediation procedure has been adapted from the hyperspectral data filtering procedure currently employed in the ground processing of CRISM targeted observations [3] [4]. As with the targeted observation processing, noise structures are partitioned into systematic and stochastic components, where the systematic structures manifest as wavelength-dependent along-track oriented (column-aligned) residuals in the ground plane, and the stochastic structures as isolated data spikes (spatially and spectrally) and/or collections of multiple adjacent pixels with erroneous data values (e.g. Figure 1A). The noise remediation challenges unique to the CRISM IR mapping data necessitated a shift from the evaluation of the stochastic filter sampling kernels in isolation (as for targeted observations with contiguous spectral sampling) to an exchange of information among proximate sampling kernels. The results from a 2D (band-independent) implementation of this approach are illustrated in Figure 1B. The modified procedure adds an additional layer of bookkeeping and iteration control, but allows the procedure to successfully distinguish and retain real spatial/spectral variability in multispectral observations with noise that is more prevalent and more structured than that in lower IR detector temperature observations.

Empirical Radiometric Reconciliation. The current MRDR pipeline includes an explicit correction for the spectral effects of atmospheric gases and aerosols based on radiative transfer modeling that makes use of CRISM- and MARCI- derived measurements of dust and ice opacities [5]. However, the procedure still leaves radiometric residuals that are evident where mapping strips overlap. The accumulated CRISM mapping data sampling density supports an empirical approach to inter-strip radiometric reconciliation and the assembly of self-consistent mapping mosaic data products. The empirical approach leverages both inter-strip spatial overlaps and proximal relationships to construct a graph that encodes the strip-to-strip relationships and radiometric discrepancies, and linear and non-linear least squares optimization to derive a set of strip- and wavelength- specific model parameters for a series of transform functions so the total residual radiometric discrepancy in the optimized mosaic is minimized. An illustration of top-of-atmosphere (TOA) empirical radiometric reconciliation is shown in Figure 2. In this example, the empirical optimization is acting at the individual strip level as a relative atmospheric and photometric correction.

Results and Applications. The IR mapping data noise remediation and inter-strip radiometric reconciliation allow for the generation of mapping mosaic data products that establish a self-consistent spectral / radiometric framework for a given study area. Mapping mosaic testbed map tiles and derivative products that include a selection of the Mars 2020 candidate landing sites will be presented.

Class Type	Pixel Size (m/pxl)	VNIR Bands	IR Bands	Observations [Target IDs]	VNIR Segments	IR Segments
MSP	**~200**	**19**	**55**	**40564**	**61752**	**61834**
MSW	***~100***	***19***	***55***	***2557***	***2565***	***2562***
HSP	~200	107	154	15981	19578	19635
HSV	~200	107	N/A	41008	61571	N/A
MSV	~100	90	N/A	33874	47026	N/A
			Total:	133984	192492	84031

Table 1. *Summary of CRISM mapping data acquired through 2007-009. Observation and segment counts reflect the content of the Experiment Data Record (EDR) archive. The class types in bold were active at the start of the MRO mission. The class type in italics has been suspended.*

References: [1] Murchie S. L. et al. (2007) *JGR, 112,* E05, S03. [2] Zurek R. W. and Smrekar S. E. (2007) *JGR,* E05, S01. [3] Seelos F. P. (2009) *AGU Fall Meeting,* P23A-1234. [4] Seelos F. P. et al. (2016) *LPS XLVII*, Abstract #1783. [5] McGuire et al. (2013) *LPS XLIV*, Abstract #1581.

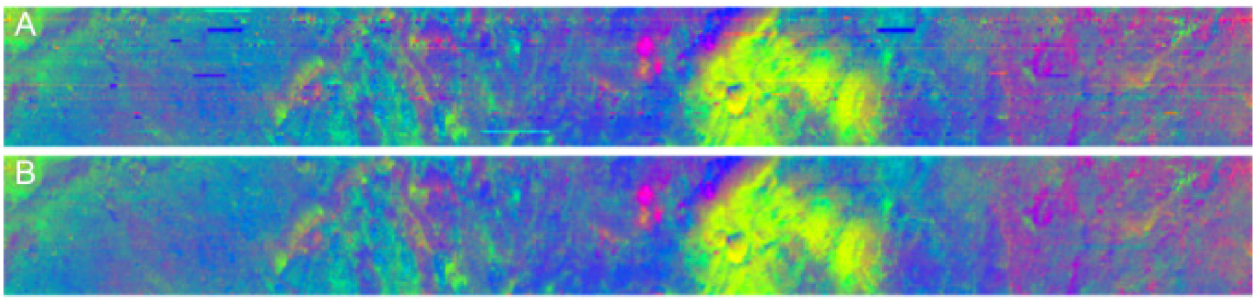

Figure 1. *Illustration of the prototype CRISM mapping data filtering procedure (MSP00002FE4_03). Each image consists of permuted ratios of the standard CRISM IR RGB visualization channels (R: 2529 nm / 1506 nm; G: 1506 nm / 1080 nm; B: 1080 nm / 2529 nm) with a 1% linear stretch calculated from the filtered data product (B) applied to each band. Band ratio composite images emphasize low-level spectral variability as the continuum variation that dominates band composite images is scaled out of the visualization. (A) IR band ratio composite with systematic and stochastic noise structure. The spatially organized collections of spurious pixels are representative of noise structure that challenges the hyperspectral data filtering procedure. (B) IR band ratio composite showing the result of the revised (2D) mapping data stochastic noise filtering procedure.*

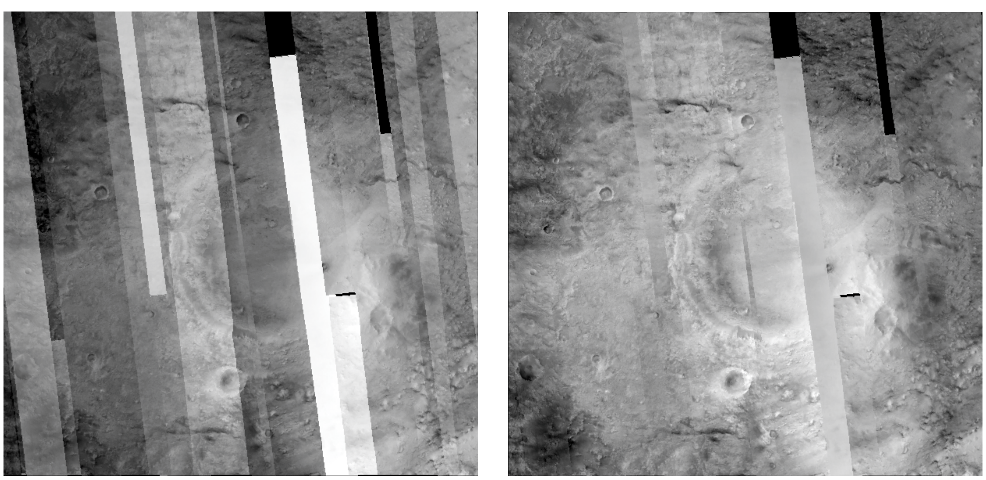

Figure 2. *Illustration of the CRISM mapping data empirical radiometric reconciliation procedure applied to the ~200 m/pxl VNIR class types (MSP, HSP, HSV) for the Jezero Crater Mars 2020 candidate landing site region (~120km x ~120 km). (Left) Initial 770-nm TOA mosaic – acquisition order strip stacking. (Right) 770-nm TOA empirically optimized mosaic – acquisition order strip stacking.*