CRISM DATA PROCESSING AND ANALYSIS PRODUCTS UPDATE – CALIBRATION, CORRECTION, AND VISUALIZATION.

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Introduction: The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) Science Operations Center (SOC) administers two data processing pipelines - a production pipeline which generates Planetary Data System (PDS) standard products such as spectral radiance and reflectance (I/F) image cubes (TRDRs), and a developmental pipeline which is used to prototype upgrades to the radiometric calibration and generate high level analysis and visualization products. The CRISM team recently completed updates to the radiometric calibration for both the visible and near-infrared (VNIR 362-1053 nm) and infrared (IR 1002-3920 nm) detectors, and implemented a custom hyperspectral data filtering procedure suitable for application to PDS-deliverable spectral reflectance data [1]. These advances have been incorporated into the production pipeline and reprocessed data are being delivered to the PDS. The developmental pipeline has also been augmented with new data processing capabilities to support the generation of photometrically, atmospherically, and empirically corrected map-projected hyperspectral image cubes (MTRDRs). The integrated result of this series of improvements is a suite of systematically generated high level CRISM products of enhanced utility to the Mars science community (e.g. Figure 1).

Calibration Pipeline: Modifications to the radiometric calibration for a given detector (VNIR or IR) impact all CRISM spectral data products derived from that detector and are incorporated into parallel versions of the data delivered as radiance on sensor and I/F. In contrast, the data filtering procedure is only applied to full and half resolution I/F data – the central scans of Full Resolution Targeted (FRT), Half Resolution Long (HRL), and Half Resolution Short (HRS) gimbaled observations and Flat Field Calibration (FFC) pushbroom observations.

Radiometric Calibration. The VNIR and IR radiometric calibrations have both been augmented from version 2 to version 3 (TRR2 to TRR3). The most significant improvement corrects for slight shutter/mirror position non-repeatability when viewing an internal calibration reference (integrating sphere). This impacts the diffraction grating sampling and results in a slowly temporally varying calibration error. An explicit correction for this effect improves the VNIR calibration at ~850-1050 nm and the IR calibration at ~1000-1650 nm. As a result, both the consistency of the recovered surface spectral reflectance for repeat observations and the agreement of the VNIR and IR data at ~1000 nm are improved. Specific to the IR detector, the spectrally selective application of a more robust flat field correction better retains fine structure in atmospheric gas absorptions. Improvements to the modeling and subtraction of second-order diffraction reduces an artifact centered at 3180 nm, and a more accurate characterization of responsivity at ~2000 nm better supports the modeling of atmospheric absorptions in this spectral region.

Hyperspectral Data Filter. CRISM has operated with an IR detector temperature between ~107 K and ~127 K. Observations acquired at higher detector temperatures exhibit a marked increase in both systematic and stochastic noise. The primary systematic noise component in CRISM IR and VNIR data appears as along track column-oriented striping. This is addressed by a scene-dependent multiplicative correction frame developed through the serial evaluation of channel-specific inter-column ratio statistics. The dominant CRISM IR stochastic noise components appear as isolated data spikes or column-oriented groups of pixels with erroneous values. Non-systematic noise in the IR data is identified and corrected through the application of an iterative-recursive kernel filter which employs a statistical outlier test as the iteration control and recursion termination criterion. This allows the filtering procedure to make a statistically supported distinction between high frequency (spatial/spectral) signal and high frequency noise based on the information content of a given multidimensional data kernel.

Summary Parameters / Browse Products: Spectral summary parameters are band math calculations that quantify compositionally indicative spectral structure. The standard spectral parameters in use across the CRISM project are configured for multispectral data with non-contiguous spectral sampling. When applied to targeted observations the standard calculations do not take full advantage of the hyperspectral sampling and so are susceptible to propagating optical and calibration residual artifacts. Within the developmental pipeline selected parameter calculations have been revised to appropriately make use of the hyperspectral sampling. The parallel parameter implementations will be included in a future release of the CRISM Analysis Toolkit (CAT).

The majority of the CRISM browse products are RGB composites of thematically related summary parameters. The current standard set shows spectral variations related to ferric and mafic minerals, sulfates, phyllosilicates, and ice. These have all been improved by the revised parameter formulations, and new browse products better conveying information related to ice, carbonates, chlorides, and crystalline ferric minerals are in development.

MTRDR Generation: Additional processing of TRDR I/F data results in a suite of high level analysis products that simplify the investigation of surface spectral properties. The two standard pipeline corrections are a basic photometric (Lambertian) correction, and for IR data the application of an empirically derived atmospheric transmission spectrum. The current implementation of the latter 'volcano scan' correction is described in a companion abstract [2]. The most recent additions to the pipeline are two empirical procedures that address targeted observation characteristics which complicate visualization, intra-scene spectral evaluation, and inter-observation comparisons.

Empirical Geometric Normalization (EGN). CRISM targeted observations are acquired with a continuously varying emission and phase angle geometry due to the requisite gimbal image motion compensation. This typically results in an asymmetric, wavelength-dependent, along-track gradient primarily related to variation in atmospheric path length and aerosol scattering. These effects are addressed by an empirical procedure that characterizes the geometric dependencies across all segments of a targeted observation (central scan bounded by reduced spatial resolution higher emission angle images), and normalizes the central scan to a reference geometry. The data from each spectral band are sampled against the independent (geometric) variables and modeled as a low-order two dimensional polynomial. A forward model is calculated for each spatial pixel in each channel, the model is normalized to the minimum sampled emission angle, and the normalized model is applied to the source data.

Empirical Smile Correction (ESC). Spectral smile is an optical artifact whereby the wavelength calibration shifts as a function of spatial position. The CRISM calibration has a small residual related to spectral smile that appears as a wavelength-dependent cross-track gradient. This is addressed by an empirical correction that characterizes intra-channel wavelength sampling dependencies, and normalizes the data to a reference wavelength vector. Using the wavelength map for a targeted observation central scan, a wavelength sampling histogram is constructed for each spectral channel delineating the spatial columns that fall into each wavelength bin. The spectral data are sampled according to the histogram binning map and the sampled data is modeled as a linear function of wavelength weighted by the histogram counts. A forward model is calculated for the detector wavelength map profile, and the reference wavelength for each channel is used to calculate a reference value. The channel-specific forward model is then normalized to the appropriate reference value and applied to the source spectral data.

Status and Availability: The prototype version 3 calibration, MTRDR generation, and browse product pipelines were used to generate systematic CRISM analysis products for the 4th MSL Landing Site Selection Workshop [3] (available and described in detail at http://crism.jhuapl.edu/msl_landing_sites/). CRISM TRR3 standard products are currently being delivered to the PDS and reprocessing of the full mission archive is underway. The PDS delivery of MTRDRs and their associated browse products will be staged in CY2011.

References: [1] Seelos F. P., Parente M., Clark T., Morgan F., Barnouin O. S., McGovern A., Murchie S. L, and Taylor H. (2009) *American Geophysical Union, Fall Meeting*, P23A-1234. [2] Morgan F. (2011) *this conference*. [3] Seelos F. P. and Barnouin O. S. (2010) *4th MSL Landing Site Selection Workshop.*

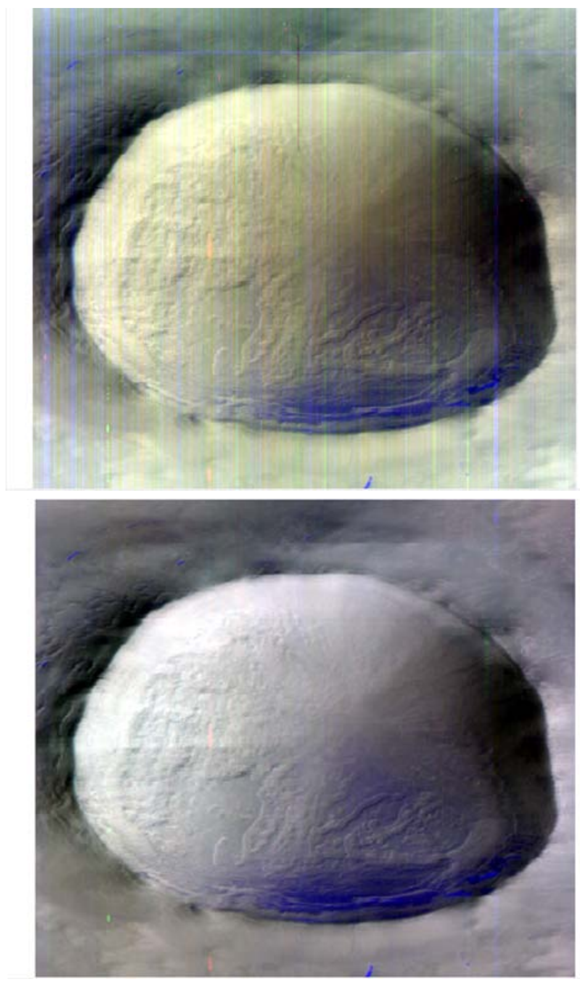

Figure 1. CRISM FRT00017709 IR I/F unprojected RGB composite – Heimdall crater. R:2530 nm, G:1507 nm, B:1080 nm, 0.5% linear stretch. (Top) TRR2. (Bottom) TRR3 with EGN and ESC applied.