

AN ENVI/IDL COLOR AND MULTISPECTRAL PROCESSING TOOLKIT FOR TGO/CaSSIS AND MRO/HiRISE. J. L. Piatek¹, L. L. Tornabene^{2,3} and V. G. Rangarajan⁴ ¹Dept. of Earth & Space Sciences, Central Connecticut State Univ., New Britain, CT (piatekjl@ccsu.edu) ²Dept. Earth Sciences, Univ. Western Ontario, CA, ³Inst. Space & Earth Exploration, Univ. Western Ontario, CA, ⁴DLR Institute of Planetary Research, Berlin, Germany.

Introduction: Mars spacecraft missions, particularly the Trace Gas Orbiter (TGO) and Mars Reconnaissance Orbiter (MRO), continue to return terabytes of high resolution imagery of Mars. Color-infrared images have a significant potential to enhance scientific study of the geologic history of Mars but can be difficult to ingest into common software interfaces for further correction, processing visualization and analysis.

The goal of our ongoing work is to develop a publicly available toolset for the ENVI/IDL Classic interface (currently available from NV5 Geospatial) to facilitate processing and analysis of Visible/Near-infrared (VNIR) multispectral images from the Colour and Stereo Surface Imaging System (CaSSIS) instrument on TGO; a tangential goal is to produce a parallel toolset in ENVI/IDL for processing color images from the High Resolution Imaging Science Experiment (HiRISE) in a similar fashion. The ultimate goal of these tools is to facilitate co-analysis of datasets in a commonly used interface (ENVI/IDL).

CaSSIS is a VNIR color stereo camera that acquires images in up to 4 broadband filters optimized for Mars photometry (BLU: 495 PAN: 678 RED: 836 NIR: 939 nm) [1]; the ~4.5 m/px images are generally ~9.5 km wide and up to ~50 km long, but are resampled to 4 m/px in post-processing [2]. HiRISE provides a narrow VNIR color swath ~1.1-1.2 km in width from a Sun-synchronous orbit as low as 250 km [3] and provides 3 broadband filters (BG: 500, RED: 690, NIR: 870 nm) with a unbinned resolution as high as 0.25 m/pixel after resampling [4].

Method: Our processing steps (illustrated in the flow chart in Fig. 1) begin with images provided by instrument teams in ISIS 3 format: calibrated CaSSIS images are publicly available ~6 months after acquisition (<https://doi.org/10.5270/esa-da0ic0t>). HiRISE unfiltered color images, necessary for a proper Dark Subtraction (DS) method to mitigate time-variable atmospheric scatter, are generated as two halves (COLOR4 and COLOR5), one for each set of IR, RED and BG detector combinations. These are only readily available to HiRISE science team members (not PDS released) or via processing from the raw EDRs in ISIS [5]. The ISIS image cubes are ingested into ENVI and compiled into a final image with bands in increasing wavelength order (as preferred by ENVI and for multispectral analysis). Header (or label file) information is used to

determine map projection and to record image parameters such as solar longitude at the time of acquisition and incidence angle. HiRISE images are converted from integer to float using the base and multiplier from the image header (referred to in Fig. 1 as the gain and offset step). An image mask is generated so subsequent steps can be performed only in pixels that contain image data for all bands. Masking is necessary to exclude background values that inhibit DS correction and cause errors when calculating spectral parameters (e.g., band ratios). The result of this initial masking step is a calibrated "top of atmosphere" image.

The next step is to allow the user to select a method of DS correction, which is highly recommended to better isolate the multispectral response from the surface components. Options for this step were selected after extensive testing to verify that they produced a valid correction with respect to the assumptions of the method [5-10]: the options to determine band minimums include a simple automated [absolute] band minimum, use of user-defined Region of Interest (ROI), or a scaled offset. In the case of the scaled offset, data from the ROIs used for correction are converted to radiance (using information from the instrument characteristics and the image header) to determine the radiance that must be added to the corrected image to avoid negative I/F values that might cause issues in calculating spectral parameters.

After dark subtraction, the user may choose to calculate select band ratios and other spectral parameters. Options for these ratios depend on the wavelengths available in the image: the user may also opt whether to choose from parameters that would highlight bright atmospheric phenomena and/or ices, or just to focus on those relevant non-icy surfaces (a list of ratios for CaSSIS, as noted by [6], appears in Table 1; a similar list for HiRISE provided in [5]). An option also exists, at this stage, to produce a simulated true colour (sRGB) R-G-B product in a similar fashion to HiRISE [2,4]; this also includes an option to filter out speckle noise common observed in CaSSIS BLU filter images.

Finally, the original bands and spectral parameters can either be "stacked" to produce a single multi-band image cube, or may be saved separately as individual files. The user also has the option to repeat the parameter calculations with the "top of atmosphere" image for

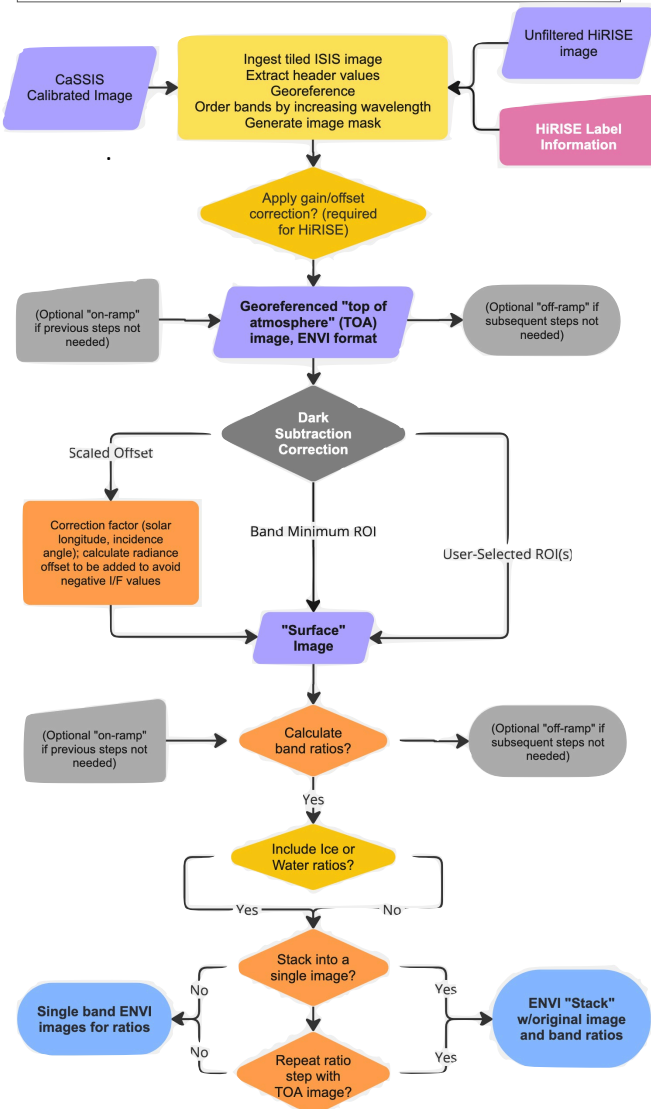
comparison to the DS-corrected, which is recommended for validating the DS correction applied [8].

Dissemination: We intend to make these routines publicly available as part of an upcoming manuscript in the form of plaintext IDL “procedure” (.pro) files, along with instructions for installation use in the ENVI Classic interface. Bug fixes and updates will be available when time allows for development and testing.

References:

[1] Thomas et al. (2017), *Space Sci. Rev.*, 212, 1897. doi: 10.1007/s11214-017-0421-1
[2] Perry et al. (2022), *Plan. & Space Sci.*, 223, 105581, doi: 10.1016/j.pss.2022.105581.

Figure 1. Image processing flowchart, assuming an ISIS cube as the starting point. Places where users could stop or start to avoid repeating unnecessary steps are noted.



[3] McEwen et al. (2007), *JGR Planets*, 112 (E5), doi: 10.1029/2005JE002605.
[4] Delamere et al. (2010), *Icarus*, 205, 38-52. doi:10.1016/j.icarus.2009.03.012.
[5] Rangarajan et al. (2023a), *Icarus*, 419, 115849, doi:10.1016/j.icarus.2023.115849.
[6] Tornabene et al. (2018), *Space Science Rev.*, 214, doi:10.1007/s11214-017-0436-7.
[7] Tornabene et al. (2022), *53rd LPSC*, abs. 2330.
[8] Tornabene et al. (2024) *Space Sci. Rev.*, in prep.
[9] Rangarajan et al. (2023b) *Icarus*, 394, 115443, doi:10.1016/j.icarus.2023.115443.
[10] Tornabene et al. (2024), *10th Int'l Mars Conf.*, abstract #3318.

Table 1. Band ratios for CaSSIS images, as identified by [2]. Atmospheric ratios (ice or water) use the mean of available bands; the denominator for the Ice ratios depends on what bands are available.

CaSSIS Band Ratios		Sensitive to?
Numerator	Denominator	
NIR	Red	Chlorides
Red	Pan	Ferric iron
Pan	Blue	
NIR	Blue	
Red	Blue	
NIR	Pan	Ferrous iron
Pan	NIR	
Pan	Red	
Red	NIR	
Blue	Pan	Ice (atmosphere)
Mean of all bands	NIR / Blue	
Mean of all bands	Red / Blue	
Mean of all bands	NIR / Pan	
Mean of all bands	Pan / Blue	
Blue	Pan	
Mean of visible bands	NIR	Water (atmosphere)