Working with CRISM data

Hari Nair, Kim Seelos, Debra Buczkowski, Frank Morgan, Frank Seelos, Scott Murchie, and the CRISM Science Operations Center

Johns Hopkins University Applied Physics Lab

Presented at the Mars Data Analysis Meeting

ISRO Headquarters, Bangalore

Feb 22-25, 2016

The CRISM Analysis Tool (CAT)

CRISM Analysis Toolkit (CAT)

- The CRISM Analysis Toolkit (CAT) is a series of custom IDL procedures packaged as a plug-in to ENVI, a proprietary remote sensing software available through ITT Exelis.

- To download and install the CAT, go to

http://pds-geosciences.wustl.edu/missions/mro/crism.htm

- You will need CAT Version 7.0 or better to utilize the MTRDRs and related data products.

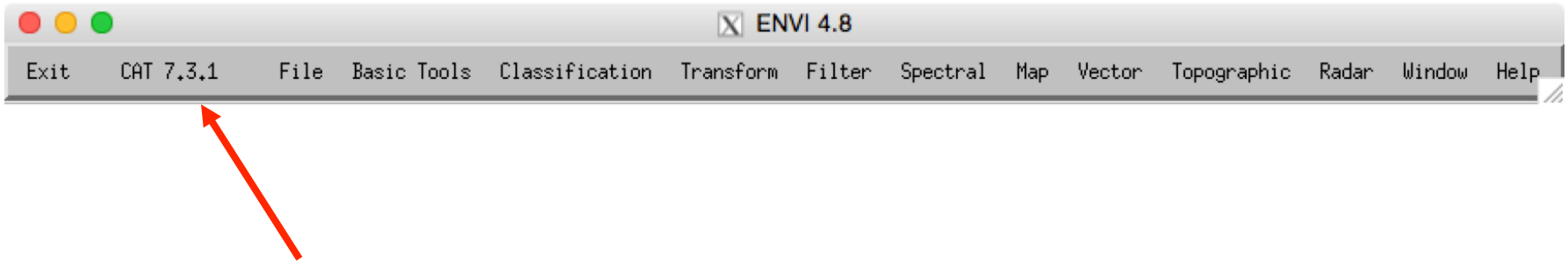
CAT Distribution: File Locations

- IDL/ENVI procedures for CAT are found under:
  - CAT_ENVI/save_add/CAT_programs
- Calibration Data Records (CDR):
  - CAT_ENVI/aux_files/CDRs/
- Ancillary Data Records (ADR):
  - CAT_ENVI/aux_files/ADR/
- User manuals, CRISM SIS:
  - CAT_ENVI/aux_files
- Default CAT output:
  - CAT_ENVI/out
- CAT temporary file output:
  - CAT_ENVI/tmp
    - Nominally CAT will clean up; files may be left in event of a crash; can be deleted after a session

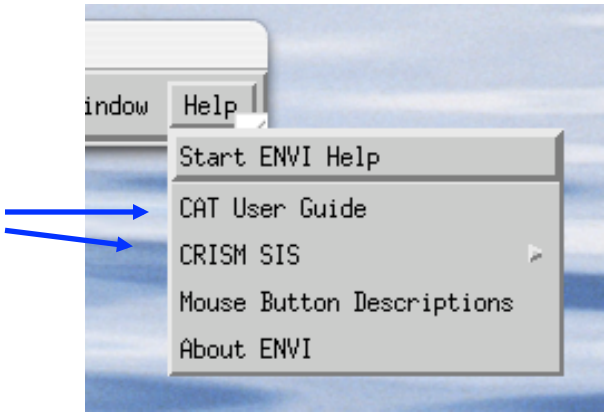
CAT Setup

- ENVI config file:
  - Need envi.cfg in CAT_ENVI
  - Can copy from one of the defaults, envi_win.cfg, envi_unix.cfg according to OS
  - Useful things it specifies: tmp file directory, default output directory, spectral library directory, default data directory (where it looks first to open files)
- CAT config file:
  - CAT_ENVI/catconfigs/crismcat*.cfg
    - Replace * with any text, or omit
    - Can have multiple configs (multiple users, customized analysis, etc)
      - **select at startup, reload during session if desired**
    - Not required
    - PDS path, aux_files path, default volcano scan

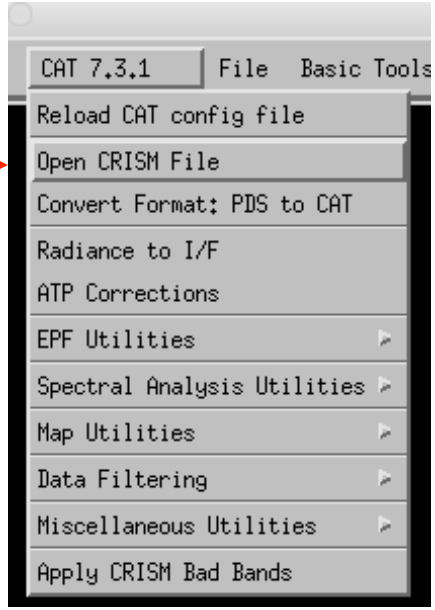
CAT Startup



- When CAT installed, ENVI starts with CAT menu added
  - includes CAT version number
- Additional CAT-specific items added under Help and Display/Tools menus



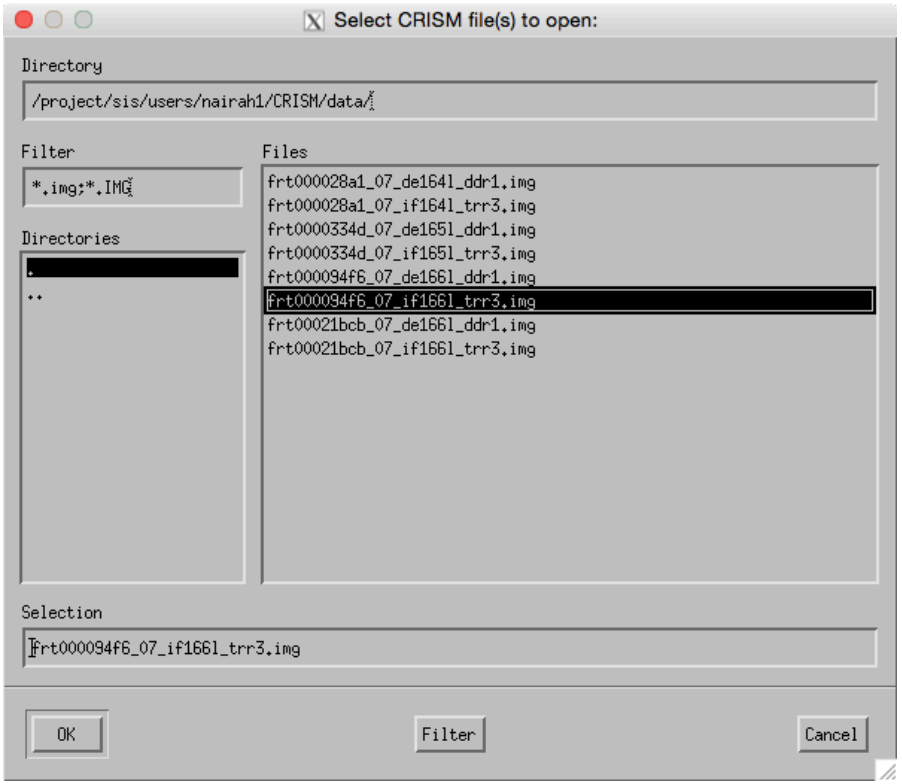
Open CRISM File



INPUT DATA:

- CRISM PDS image file (*.img)
- Corresponding PDS label (*.lbl)
  - example: frt000094f6_07_if166l_trr3.img
    frt000094f6_07_if166l_trr3.lbl

select input file in the ENVI dialog box that pops up



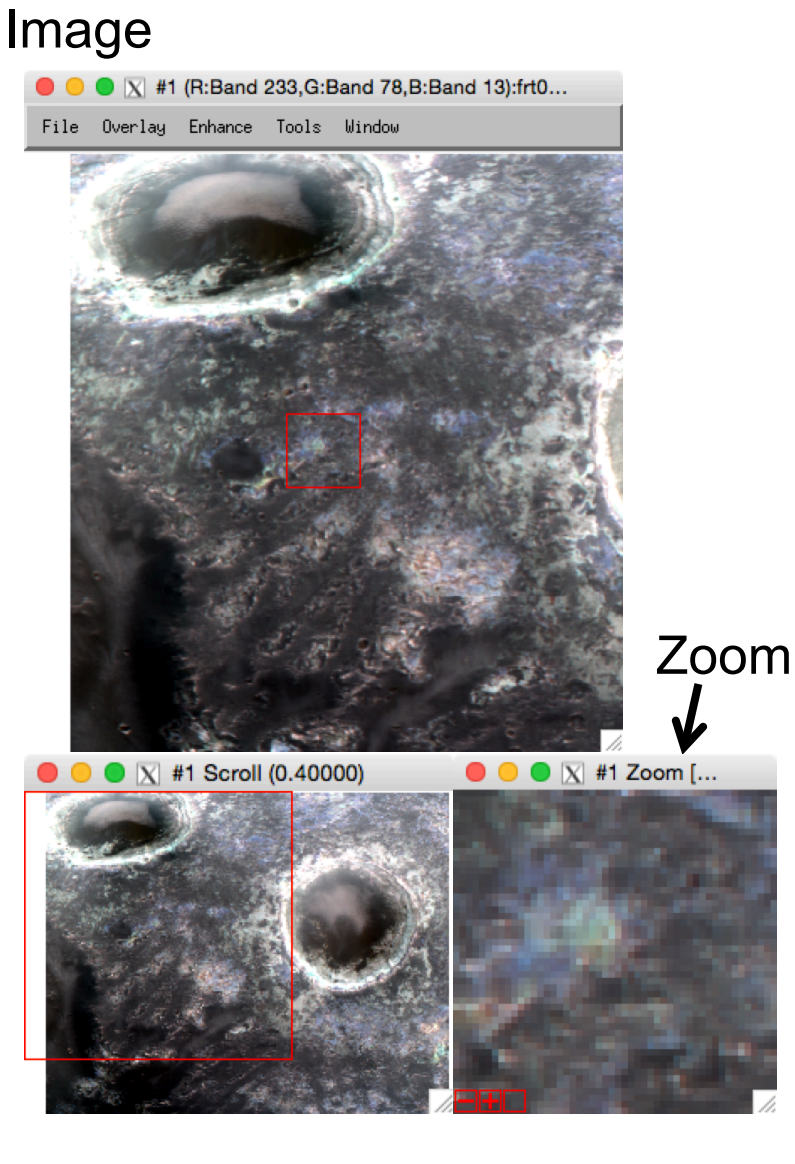
Opens CRISM data in ENVI *Available Bands* and *Display* windows

Initial Display of image cube

- Any image cube is initially opened in ENVI in a cluster of 3 windows.
  - Scroll (shows full spatial extent)
  - Image (full spatial resolution)
  - Zoom (4x resolution subset)

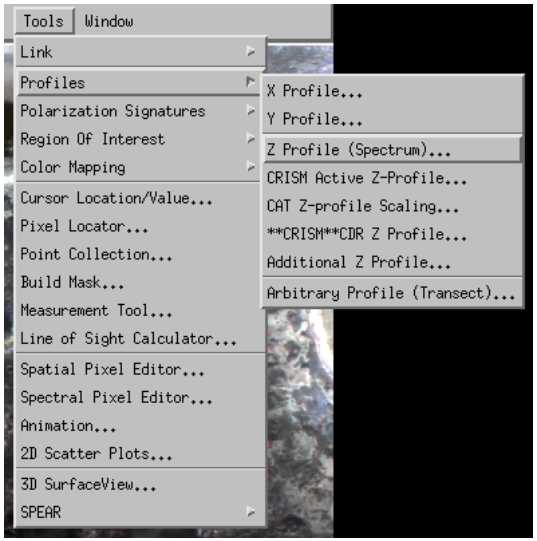
- Red box in the Scroll window shows location of Image window; red box in the Image window shows location of Zoom window.

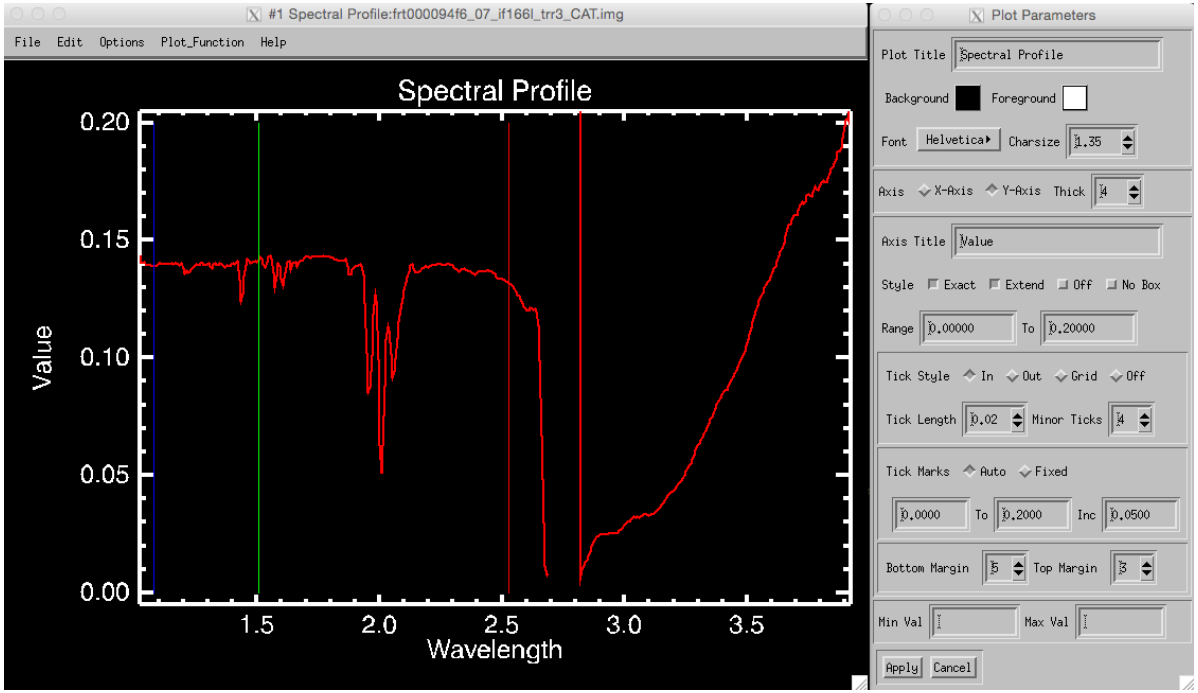
- HINT: For CRISM images, it is usually helpful to maximize the Image window, after which the Scroll window is no longer needed.



Displaying a Spectrum

From the Image window menu, >Tools >Profiles >Z Profile (Spectrum)





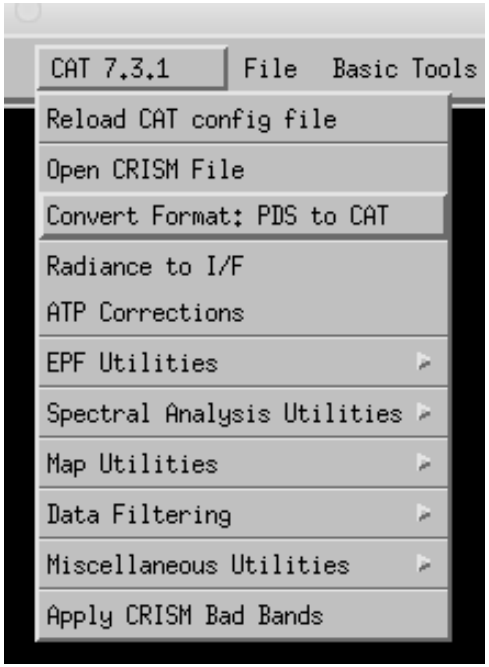
Z-profile extracted at Zoom window location.

Plot parameters can be set from Spectral Profile window, Options > Plot_Parameters

Colored vertical lines on spectral plot indicate RGB wavelength positions – can adjust, reload new combination in Image window.

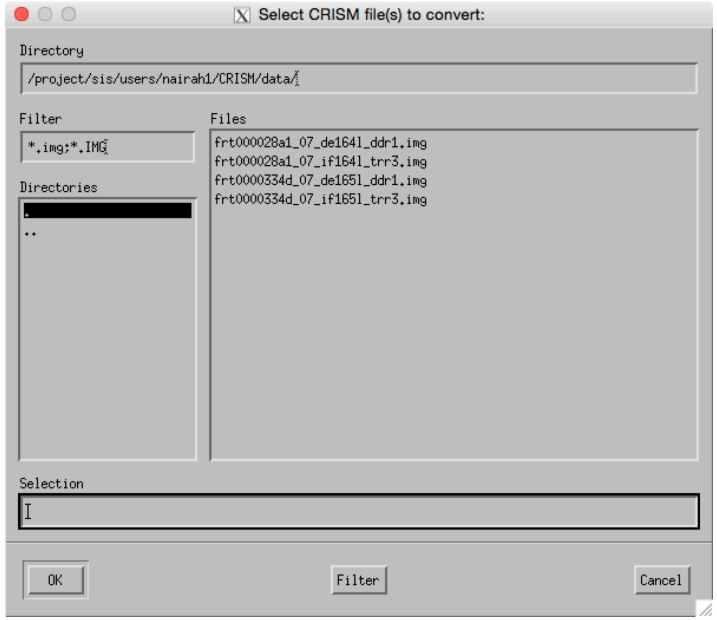
Simple Image Processing and Summary Parameters

CAT: Convert PDS to CAT



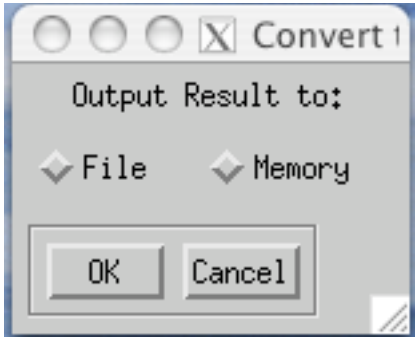
- CRISM PDS data for IR channel:
  - Spectrum stored long-to-short
  - Last wavelength 65535 (CRISM invalid data code)
- Convert Format: PDS to CAT
  - Reverses order of IR spectrum
  - Replaces the 65535 wavelength with 4.0 microns

Select input PDS file to convert here

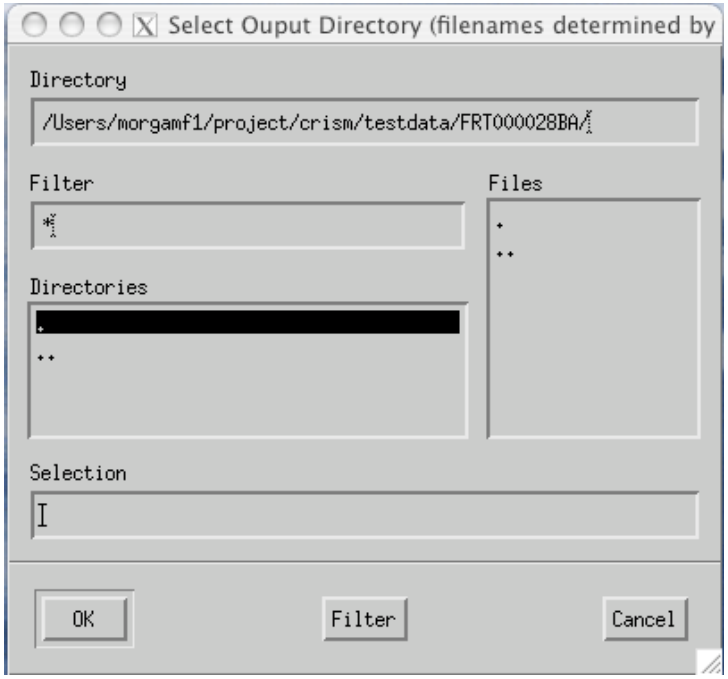


CAT: File or Memory?

Common CAT question: Output to file or memory?



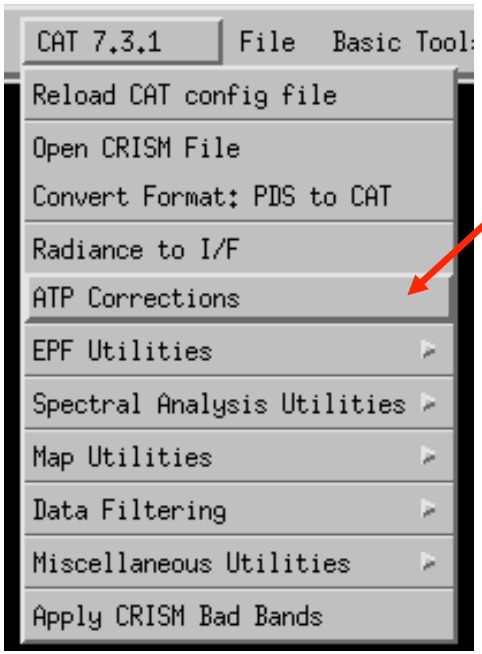
Select “File,” then select an output path and, usually, filename via the ENVI dialog:



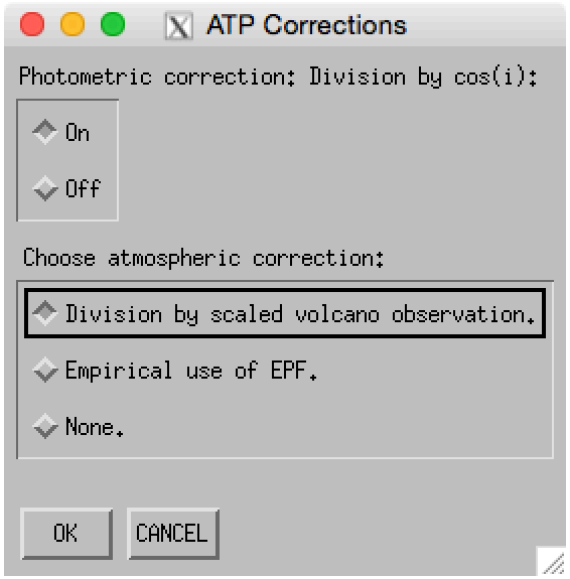
OR…

Select “Memory” and computation proceeds, with output to Available Bands and Display window

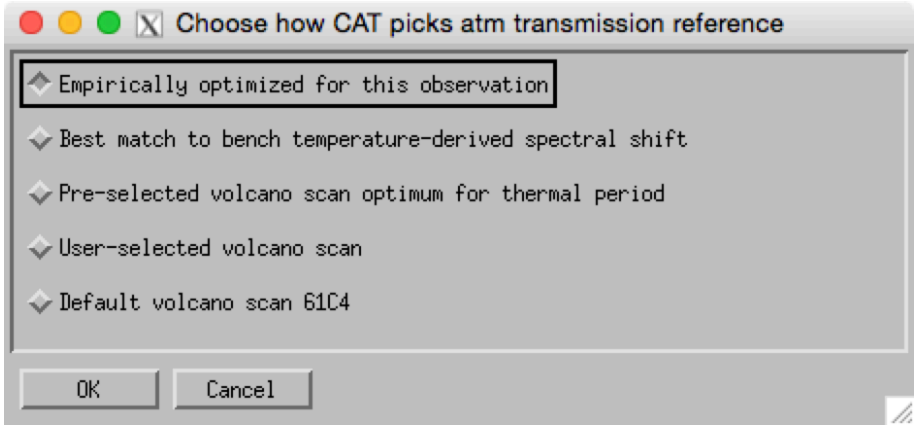
CAT: Photometric & Atmospheric Corrections



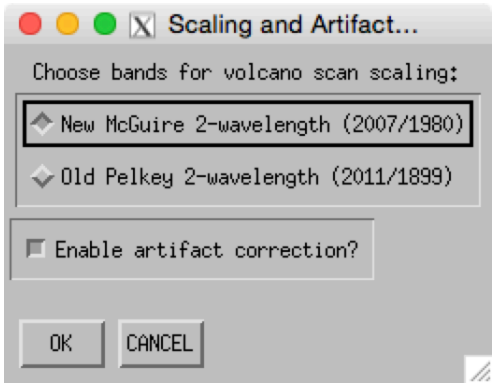
File selection dialog…
then select corrections



Then pick a volcano scan selection method…



Then finally, select scaling wavelengths…

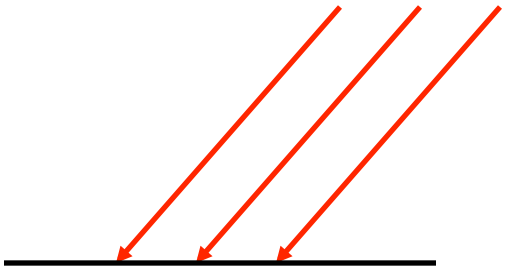


CAT: Photometric Correction Behind the Scenes

Photometric Correction…

First order correction to radiance for non-normal solar incidence:

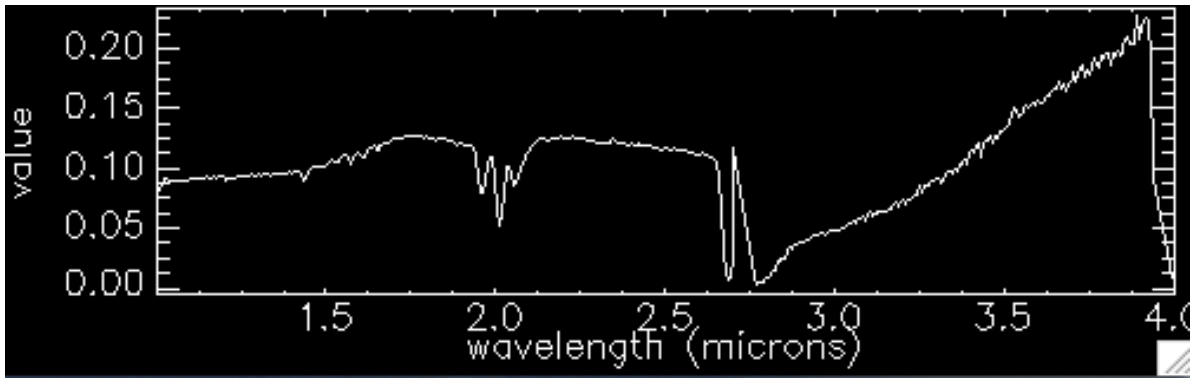
Divide by cos(incidence angle)



Get incidence angle at aeroid from DDR (ancillary data file)

CAT: Atmospheric Correction Behind the Scenes

- Atmospheric Correction: Need to correct spectrum for absorption by CO_2
  - Volcano scan: special observation viewing nadir on traverse across Olympus Mons
  - Estimate atmospheric transmission =
    (base spectrum) / (summit spectrum)
  - Correct a scene spectrum by scaling the volcano scan transmission to match the scene at 2 wavelengths near the CO_2 2-micron band, then divide
    - One near absorption peak, one in wings
    - Adjusts for variable atmospheric optical depth- elevation, season…

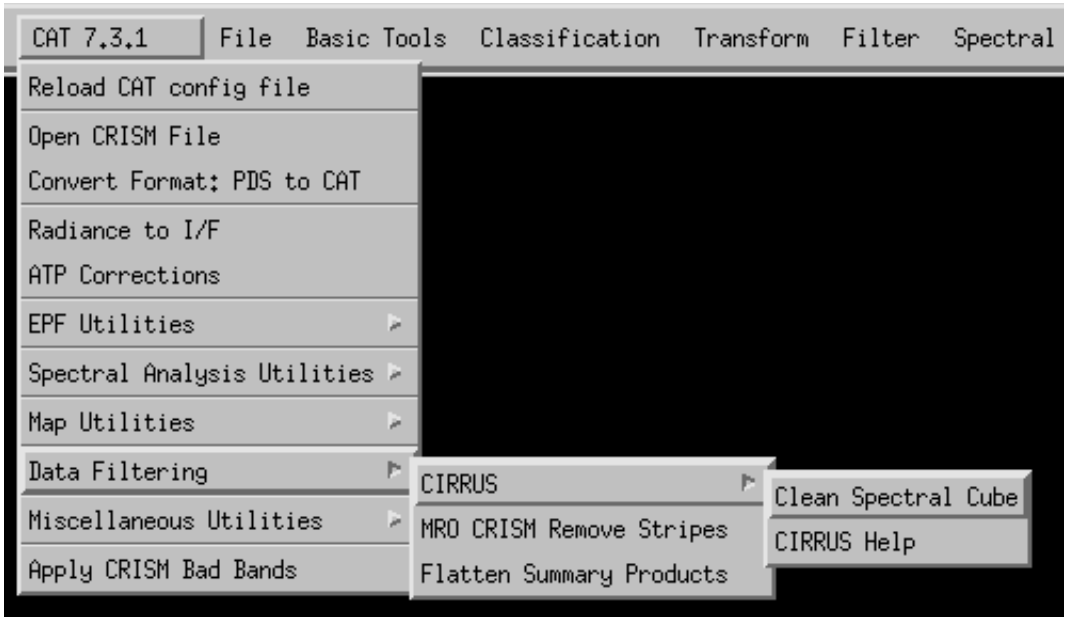


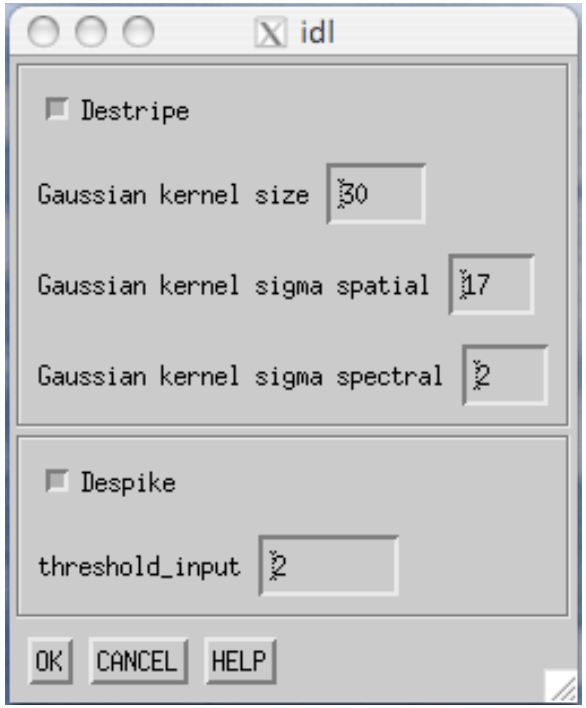
CAT: Atmospheric Correction Behind the Scenes

- Selecting scaling wavelengths: 2 options…
  - McGuire 2-wavelength (2007/1980) [recommended]
    - 2007 nm near absorption peak
    - 1980 nm in wing, but close to 2007 to reduce systematic error in presence of broad mineralogical absorptions near 2 microns
  - Pelkey 2-wavelength (2011/1899)
    - Original wavelengths in CAT
    - Closer match to OMEGA correction
    - Occasional artifacts from scaling errors caused by mineralogical abosrption affecting 2011 but not 1899

CAT: Data Filtering 1

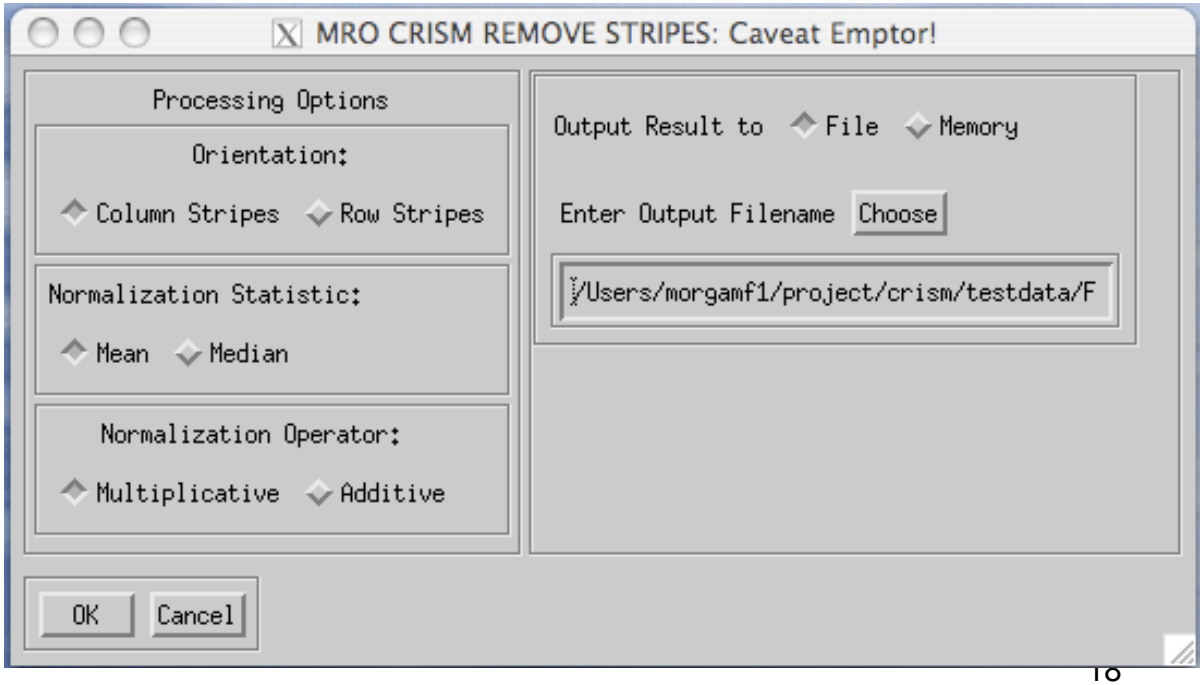
- CIRRUS
  - Despiking (removing isolated noise spikes)
  - Destriping (removing elevated detector columns)



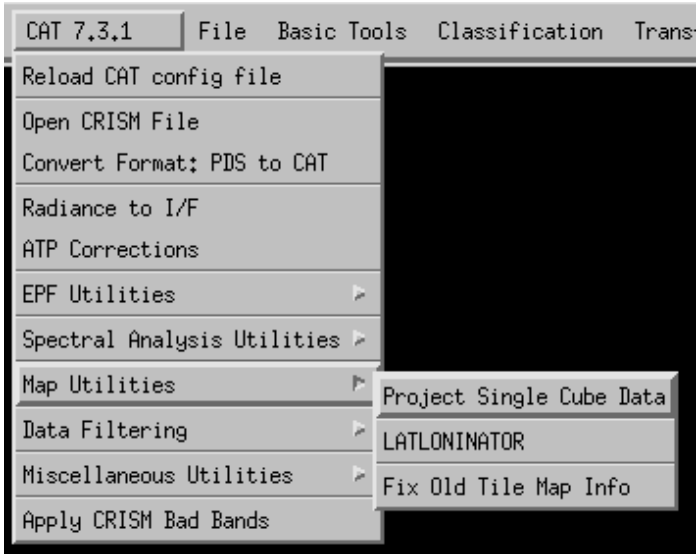


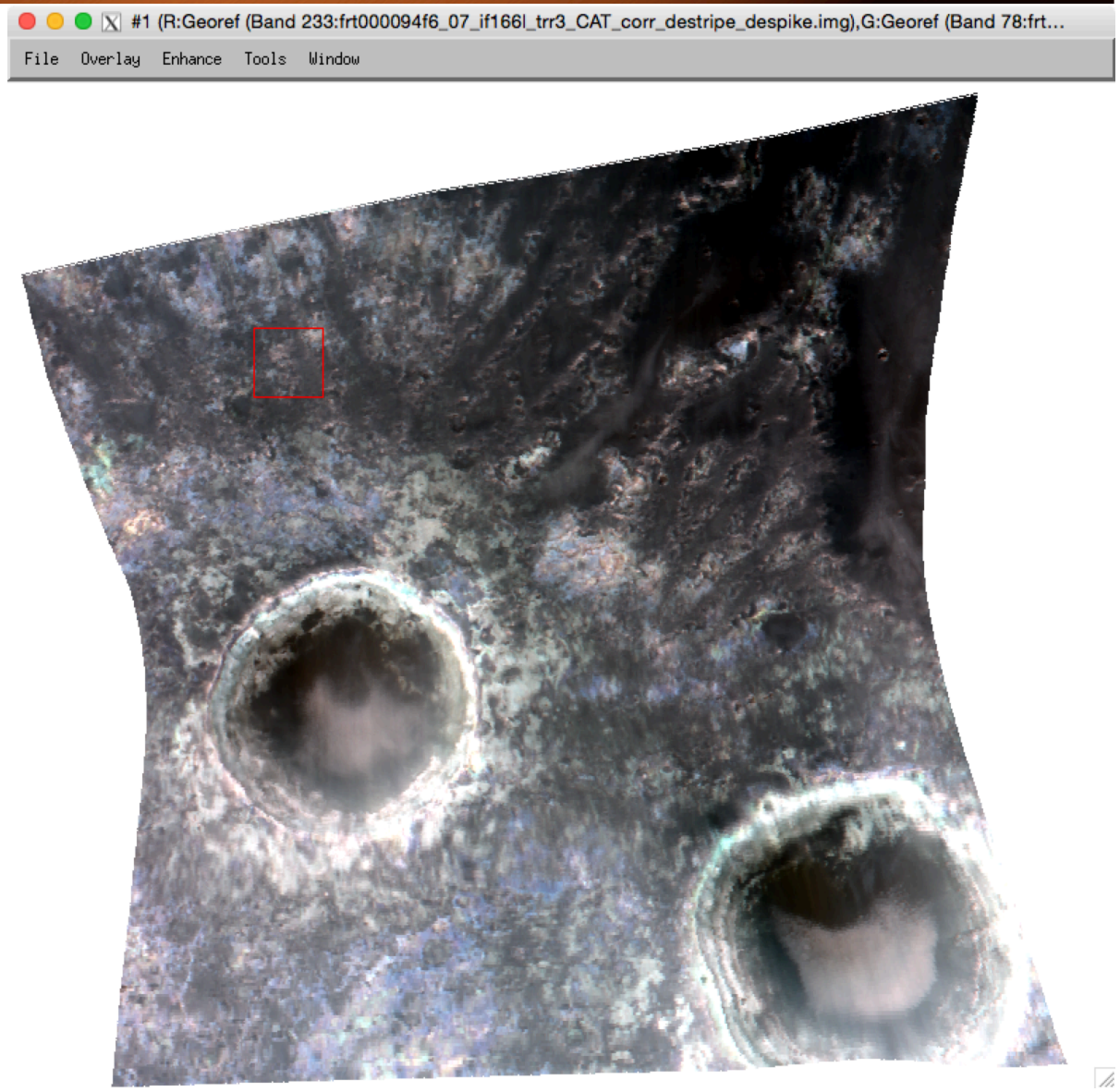
CAT: Data Filtering 2

- ***MRO CRISM Remove Stripes***
  - Alternate stripe removal algorithm
  - Generally, CIRRUS destripe preferred
  - But, Remove Stripes offers control over multiplicative vs. additive correction



Map Utilities





Summary Parameters

Summary Parameters: algebraic measures of the strengths and positions of possible mineral absorptions, and measures of the spectral continuum.

Journal of Geophysical Research: Planets

RESEARCH ARTICLE

10.1002/2014JE004627

Key Points:

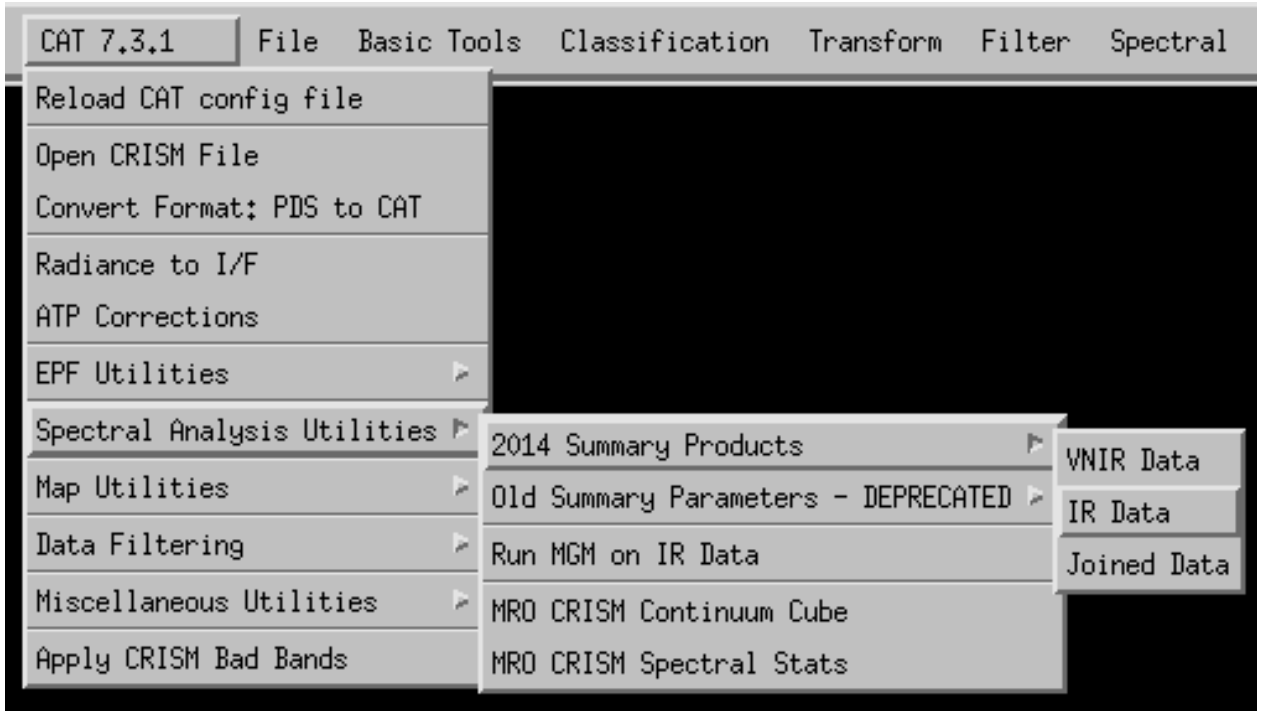
- A revised set of 60 CRISM summary products captures Mars' spectral diversity
- A library of 30 surface type spectra identified using CRISM is presented
- New "browse products" demonstrate surface spectral variability

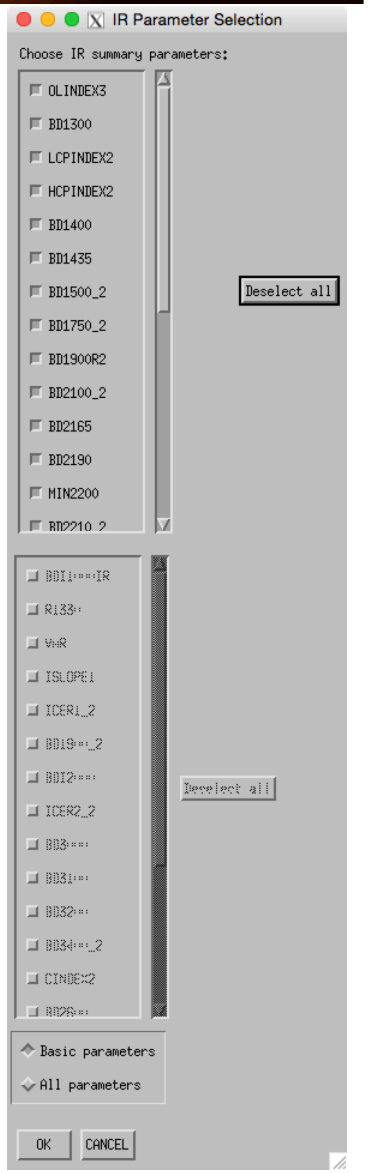
Revised CRISM spectral parameters and summary products based on the currently detected mineral diversity on Mars

Christina E. Viviano-Beck[1], Frank P. Seelos[1], Scott L. Murchie[1], Eliezer G. Kahn[1], Kimberley D. Seelos[1], Howard W. Taylor[1], Kelly Taylor[2], Bethany L. Ehlmann[3,4], Sandra M. Wisemann[5], John F. Mustard[5], and M. Frank Morgan[1]

[1]Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland, USA, [2]Corning Inc., Corning, New York, USA, [3]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California, USA, [4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA, [5]Geological Sciences, Brown University, Providence, Rhode Island, USA

Spectral Analysis Utilities





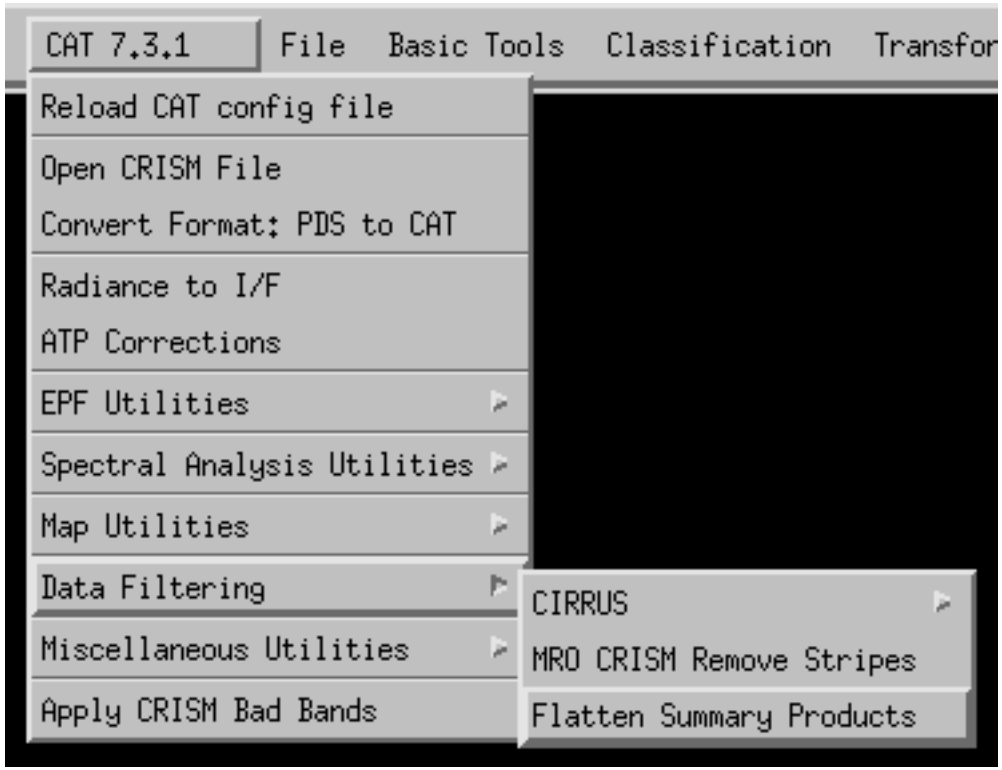
Summary Parameters

Table 2. Updated Summary Products[a]

#	Name	Status[b]	Parameter	Formulation	Kernel Width[c]	Rationale	Caveats
1	R770	√	0.77 μm reflectance	$R770$	R770: 5	Higher value more dusty or icy	Sensitive to slope effects, clouds
2	RBR	√	Red/blue ratio	$R770/R440$	R440: 5 R770: 5	Higher value indicates more npFeOx	Sensitive to dust in atmosphere
	BD530	x	0.53 μm band depth	$1-\left(\frac{R530}{a*R716+b*R440}\right)$	–	–	–
3	BD530_2	√	0.53 μm band depth	$1-\left(\frac{R530}{a*R614+b*R440}\right)$	R440: 5 R530: 5 R614: 5	Higher value has more fine-grained crystalline hematite	–
	SH600	x	0.6 μm shoulder height	$1-\left(\frac{a*R530+b*R709}{R600}\right)$	–	–	–
4	SH600_2	√	0.6 μm shoulder height	$1-\left(\frac{a*R533+b*R716}{R600}\right)$	R533: 5 R600: 5 R716: 3	Select ferric minerals (especially hematite and goethite) or compacted texture[d]	Sensitive to high opacity in atmosphere
5	SH770	√	0.77 μm shoulder height	$1-\left(\frac{a*R716+b*R860}{R775}\right)$	R716: 3 R775: 5 R860: 5	Select ferric minerals, less sensitive to LCP than SH600_2	Sensitive to high opacity in atmosphere
	BD640	x	0.64 μm band depth	$1-\left(\frac{R648}{a*R600+b*R709}\right)$	–	Select ferric minerals (especially maghemite)	Obscured by VNIR detector artifact
6	BD640_2	√	0.64 μm band depth	$1-\left(\frac{R624}{a*R600+b*R760}\right)$	R600: 5 R624: 3 R760: 5	Select ferric minerals (especially maghemite)	Obscured by VNIR detector artifact
	BD860	x	0.86 μm band depth	$1-\left(\frac{R860}{a*R800+b*R984}\right)$	–	–	–
7	BD860_2	√	0.86 μm band depth	$1-\left(\frac{R860}{a*R755+b*R977}\right)$	R755: 5 R860: 5 R977: 5	Select crystalline ferric minerals (especially hematite)	–
	BD920	x	0.92 μm band depth	$1-\left(\frac{R920}{a*R800+b*R984}\right)$	–	–	–
8	BD920_2	√	0.92 μm band depth	$1-\left(\frac{R920}{a*R807+b*R984}\right)$	R807: 5 R920: 5 R984: 5	Crystalline ferric minerals and LCP	–
9	RPEAK1 *	√	Reflectance peak 1	Wavelength where first derivative = 0 of fifth-order polynomial fit to reflectances at all valid VNIR wavelengths	–	Fe mineralogy (<0.75 suggests olivine, ~0.75 pyroxene, and >0.8 dust)	–
10	BDI1000VIS	√	1 μm integrated band depth; VNIR wavelengths	Divide reflectances from R833 to R1023 by the modeled reflectance at RPEAK1, then integrate over (1 − normalized radiances) to get integrated band depth	–	Olivine, pyroxene, or Fe-bearing glass	–

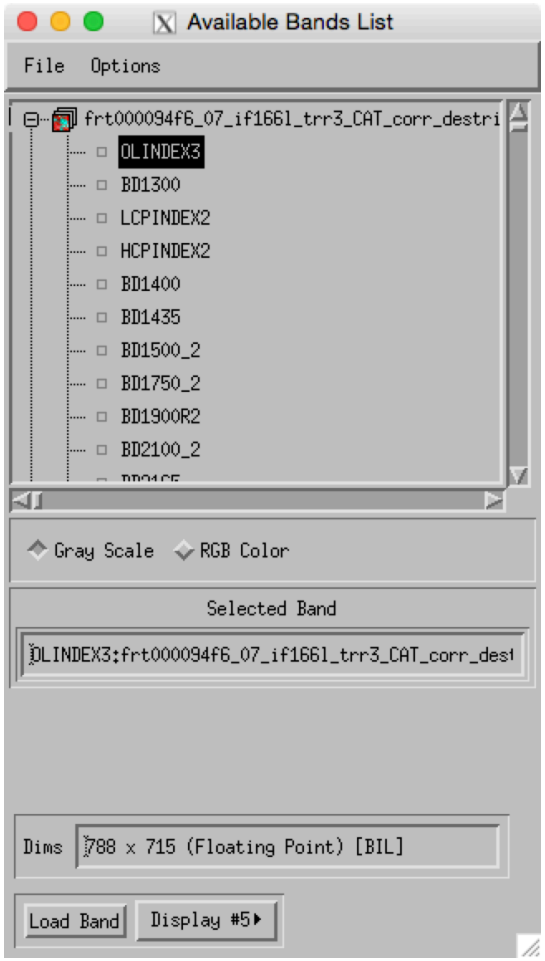
CAT: Data Filtering 3

- ***Flatten Summary Products***
  - Removes banding along lines in summary product images



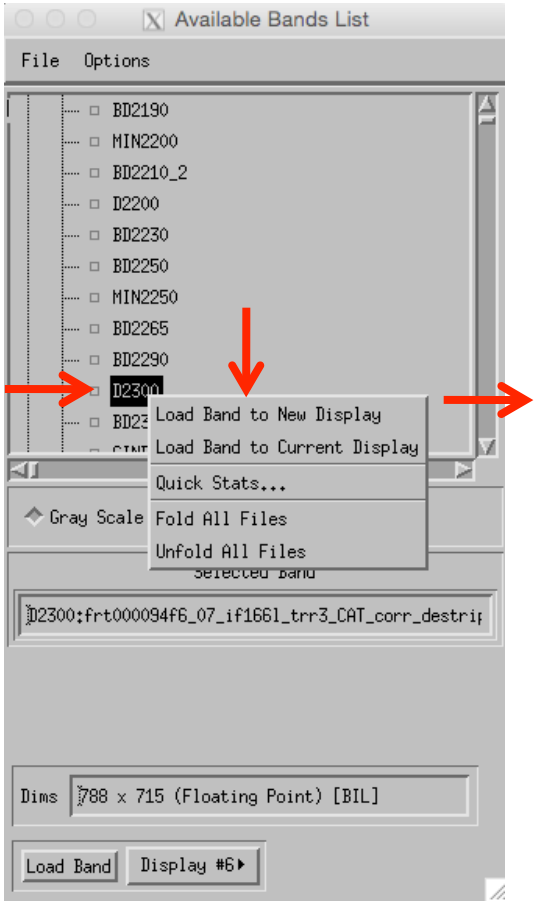
Working with Summary Parameters

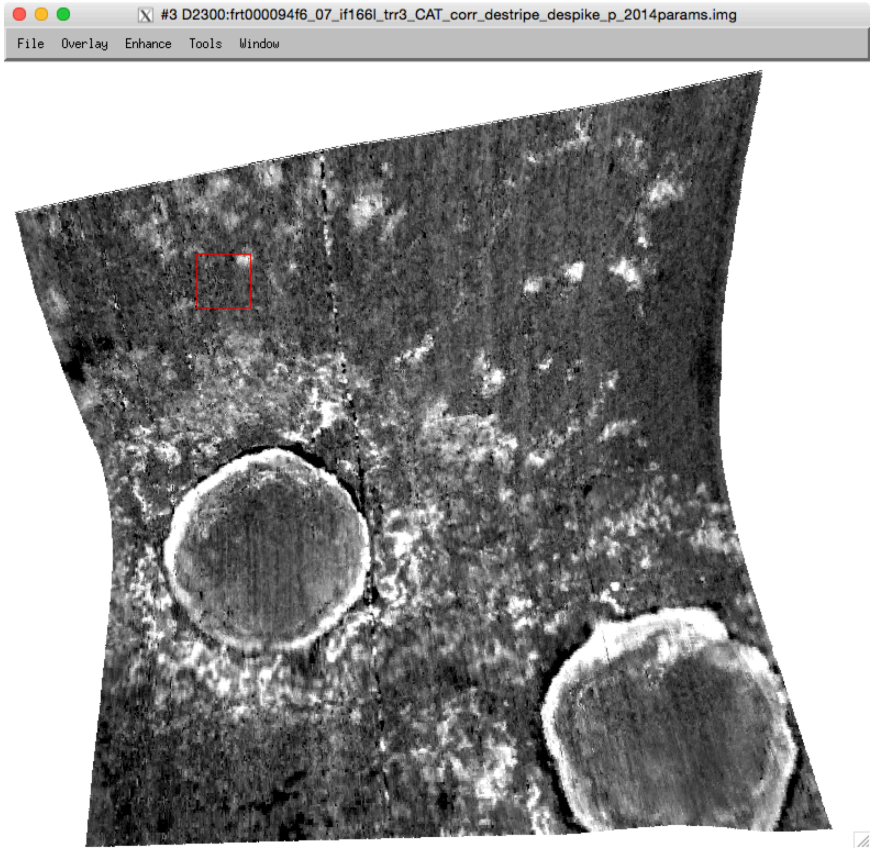
All parameters displayed in Available Bands List for summary parameter file.



Single Band Display

- Load the D2300 parameter: from Available Bands List, right click on D2300 and select Load Band to New Display

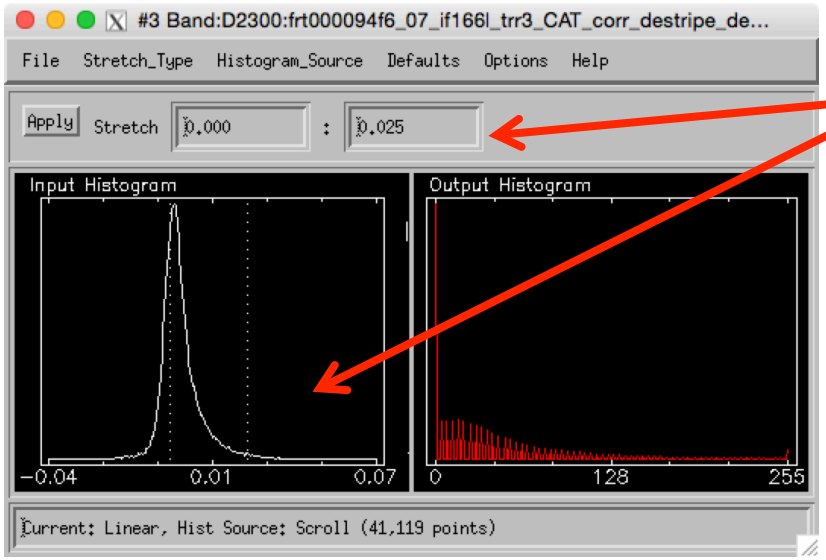




- Default Linear 2% stretch includes unrealistic parameter values less than zero

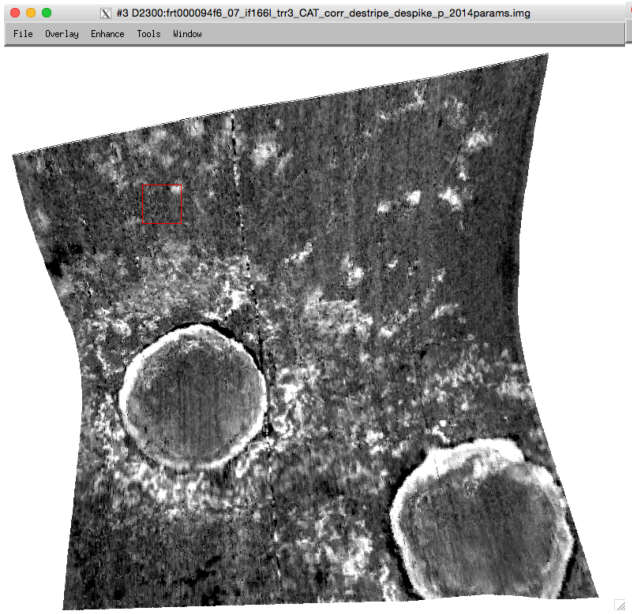
Apply Appropriate Stretch

- For most band depth and similar measures of absorption,
  - Zero is the minimum realistic value
  - The 99th percentile is typically a good maximum, although there is a empirically-determined "minimum maximum" that varies by parameter (e.g., 0.02 for D2300)
- From Image window, go to >Enhance >Interactive Stretching

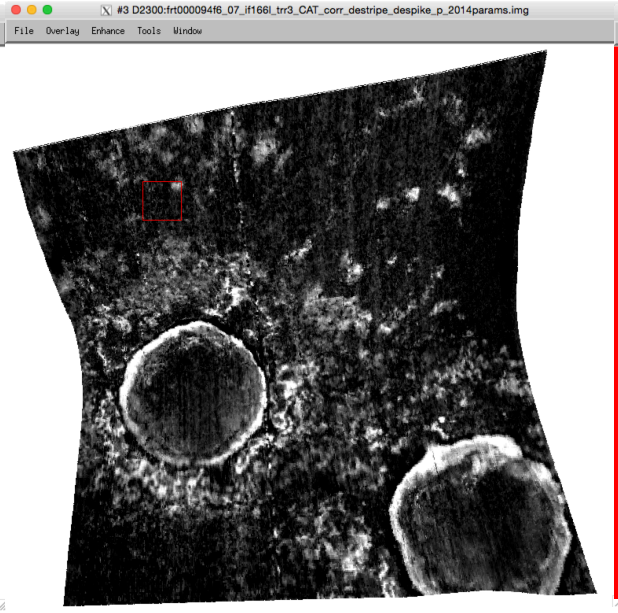


- Type min and max values or slide dashed bars until at correct percentile values (will display along bottom)
- If needed, modify the histogram binning and range under >Options >Histogram Parameters

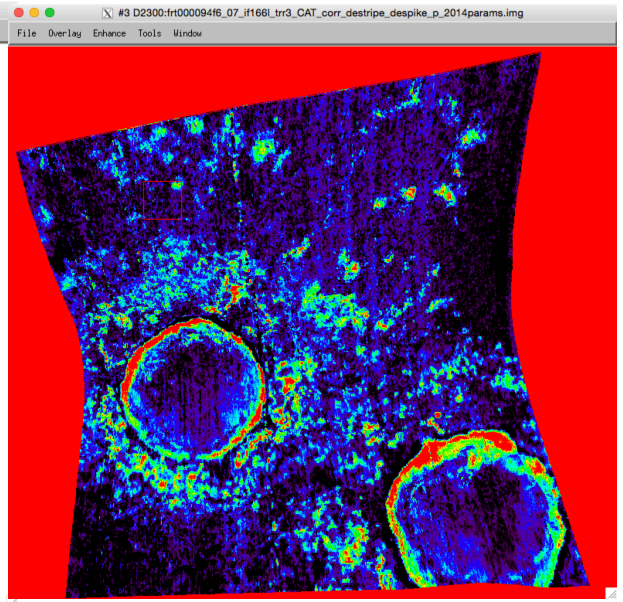
D2300 Display Comparison



Default Stretch
(-0.007 to 0.021)



Optimized Stretch,
Grayscale
(0.0 to 0.027)



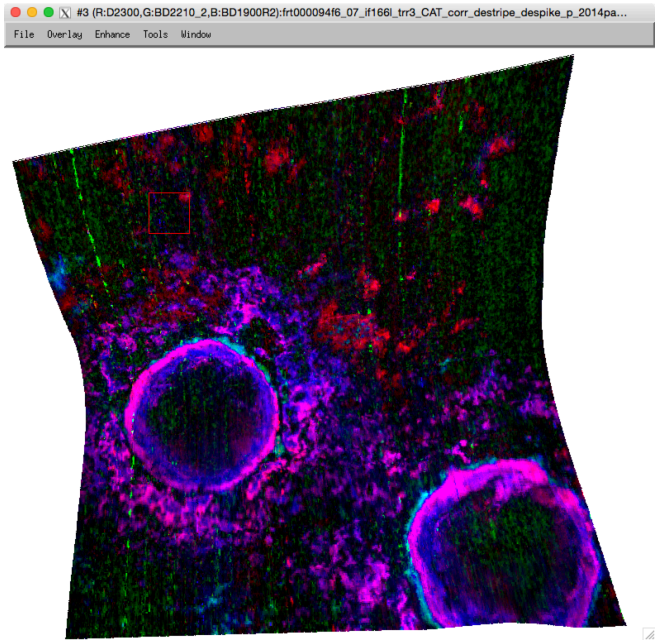
Optimized Stretch,
Rainbow Color Ramp
(0.0 to 0.027)

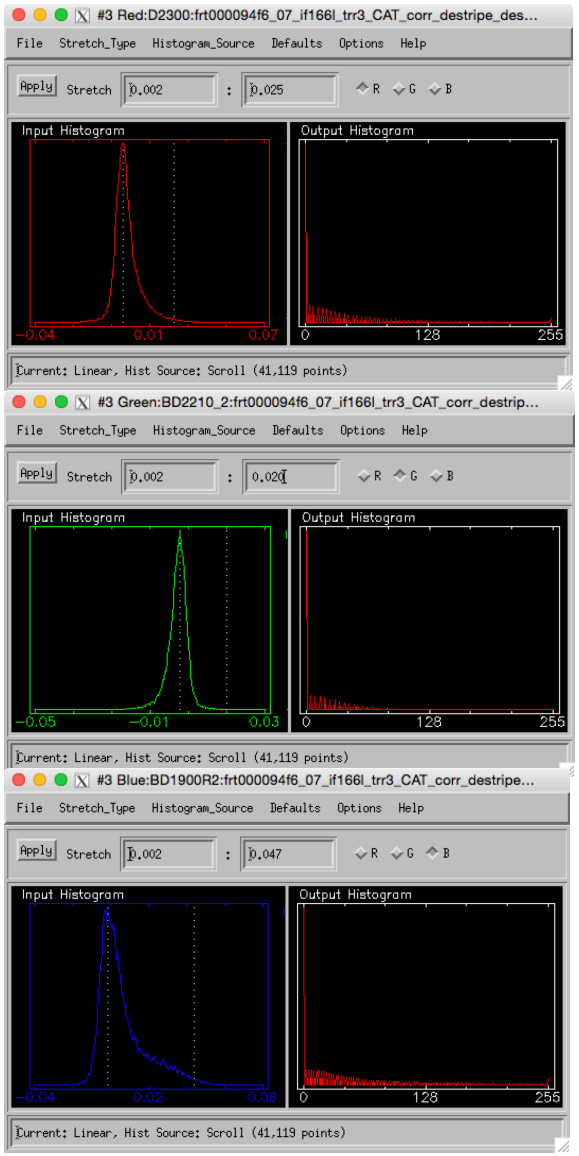
- To apply color ramp, go to >Tools >Color Mapping > ENVI Color Tables

RGB Display and Stretch

- Load PHY from Available Bands List: >Select RGB Color >click on D2300, BD2210_2, and BD1900R2 to fill in RGB fields >New Display from drop-down >Load RGB
- Optimize stretch of each band from Image window: >Enhance >Interactive Stretching

PHY Browse Product Result:





D2300

Min: 0.002 (distribution peak)

Max: 0.025 (99th percentile)

BD2210_2

Min: 0.002 (distribution peak)

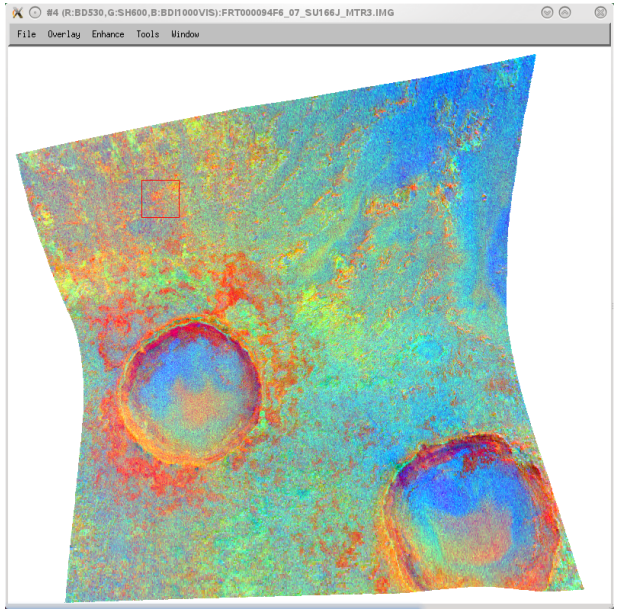
Max: 0.020 (“minimum maximum”)

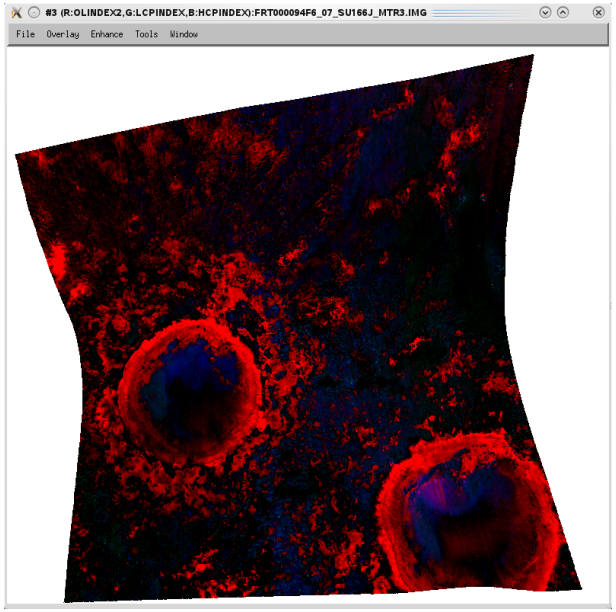
BD1900R2

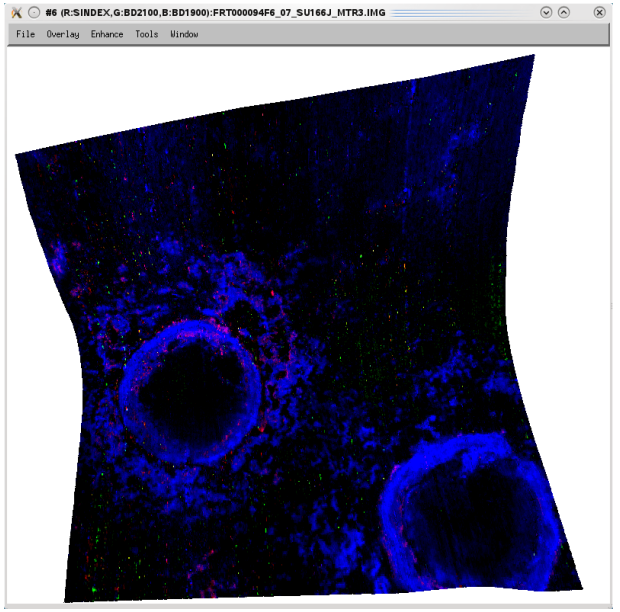
Min: 0.002 (distribution peak)

Max: 0.047 (99th percentile)

Other Browse Products for 94F6







FEM

R: BD530_2

G: SH600_2

B: BDI1000VIS

MAF

R: OLINDEX3

G: LCPINDEX2

B: HCPINDEX2

HYD

R: SINDEX2

G: BD2100_2

B: BD1900_2

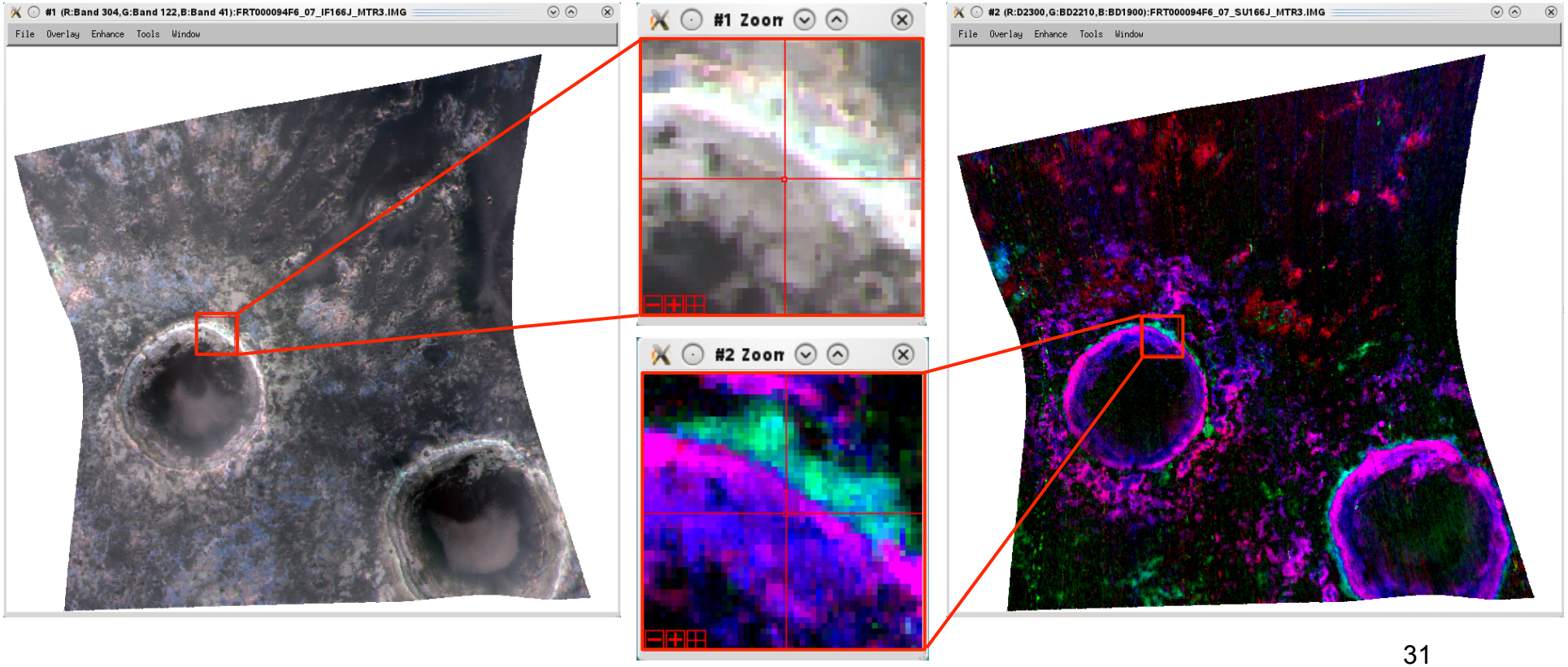
Browse Products

From Table 3, Viviano-Beck, et al. (2014)

		IR Browse Products
IRA	R1300 R1300 R1300	From "IR albedo." Shows photometrically corrected I/F at 1330 nm and may be used to correlate spectral variations with morphology.
FAL	R2529 R1506 R1080	From "false color." An enhanced infrared false color representation of the scene. The wavelengths chosen highlight differences between key mineral groups. Red/orange colors are usually characteristic of olivine-rich material, blue/green colors often indicate clay, green colors may indicate carbonate, and gray/brown colors often indicate basaltic material.
MAF	OLINDEX3 LCPINDEX2 HCPINDEX2	From "mafic mineralogy." Shows information related to mafic mineralogy. Olivine and Fe-phyllosilicate share a 1.0–1.7 μm bowl-shaped absorption and will appear red in the MAF browse product. Low- and high-Ca pyroxene display additional ~2.0 μm absorptions and appear green/cyan and blue/magenta, respectively.
HYD	SINDEX2 BD2100_2 BD1900_2	From "hydrated mineralogy." Shows information related to bound water in minerals. Polyhydrated sulfates have strong 1.9 μm and 2.4 μm absorption bands, and thus appear magenta in the HYD browse product. Monohydrated sulfates have a strong 2.1 μm absorption and a weak 2.4 μm absorption band, and thus appear yellow/green in the HYD browse product. Blue colors are indicative of other hydrated minerals (such as clays, hydrated silica, carbonate, or zeolite).
PHY	D2300 D2200 BD1900r2	From "phyllosilicates." Shows information related to hydroxylated minerals including phyllosilicates. Fe/Mg-OH bearing minerals (e.g., Fe/Mg-phyllosilicates) will appear red, or magenta when hydrated. Al/Si-OH bearing minerals (e.g., Al-phyllosilicates or hydrated silica) will appear green, or cyan when hydrated. Blue colors are indicative of other hydrated minerals (such as sulfates, hydrated silica, carbonate, or water ice).

Linking Spectral and Summary Parameter Cubes

- From either Image window, >Tools >Link then one of
  - >Link Displays for pixel-location based link (requires exactly same size images; allows blinking and transparency), -OR-
  - >Geographic Link for map projected link (can be different spatial coverage or resolutions)



Spectral Analysis

Spectral Analysis Methods

- In general, there are 3 steps to spectral analysis:
  1. Locate interesting material(s)
     - Summary parameters are a good start
  2. Collect best possible spectra (scene “endmembers”)
     - Pixel average, Region of Interest (ROI), etc.
  3. Interpret endmember spectra
     - E.g., comparison to laboratory mineral spectra
- This is what ENVI is designed to do…
  - There are many analysis tools/options available within the ENVI software environment.
  - Not all of them work well with CRISM data.

CRISM Pixel-based Endmember Extraction (1/2)

- As an example, let's find an endmember spectrum for the D2300-bearing material in FRT000094F6.

- Load D2300 as single band and stretch to emphasize highest realistic D2300 values.
- Link D2300 with corrected TRDR spectral cube and PHY browse (optional, but useful)

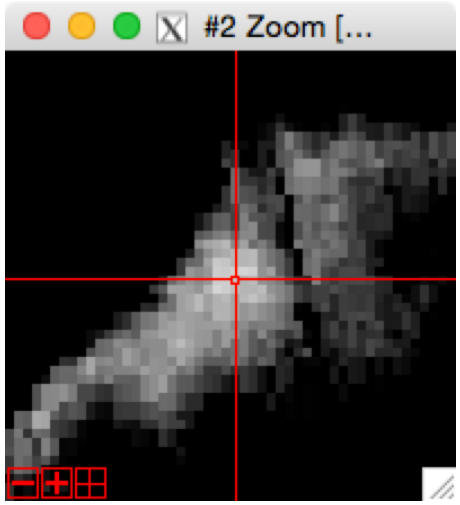
Emphasized Stretch (0.04 to 0.05)

Spectral Cube RGB

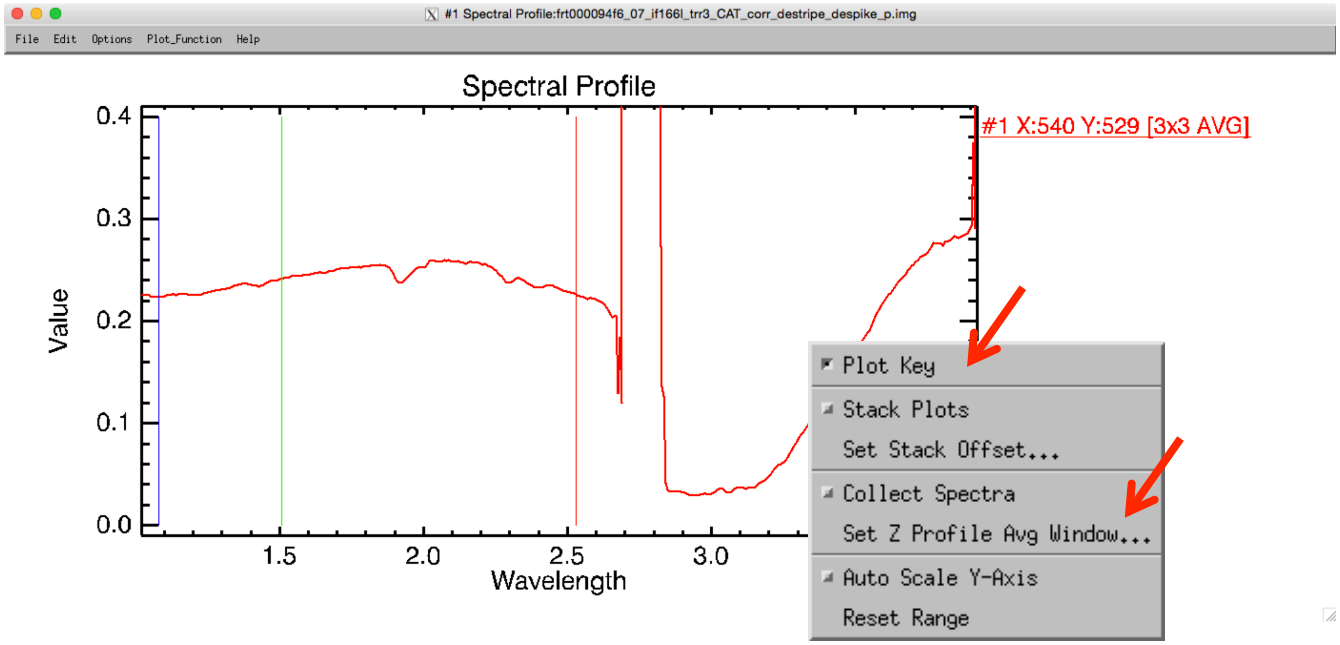
PHY Browse

Pixel-based Endmember Extraction (2/2)

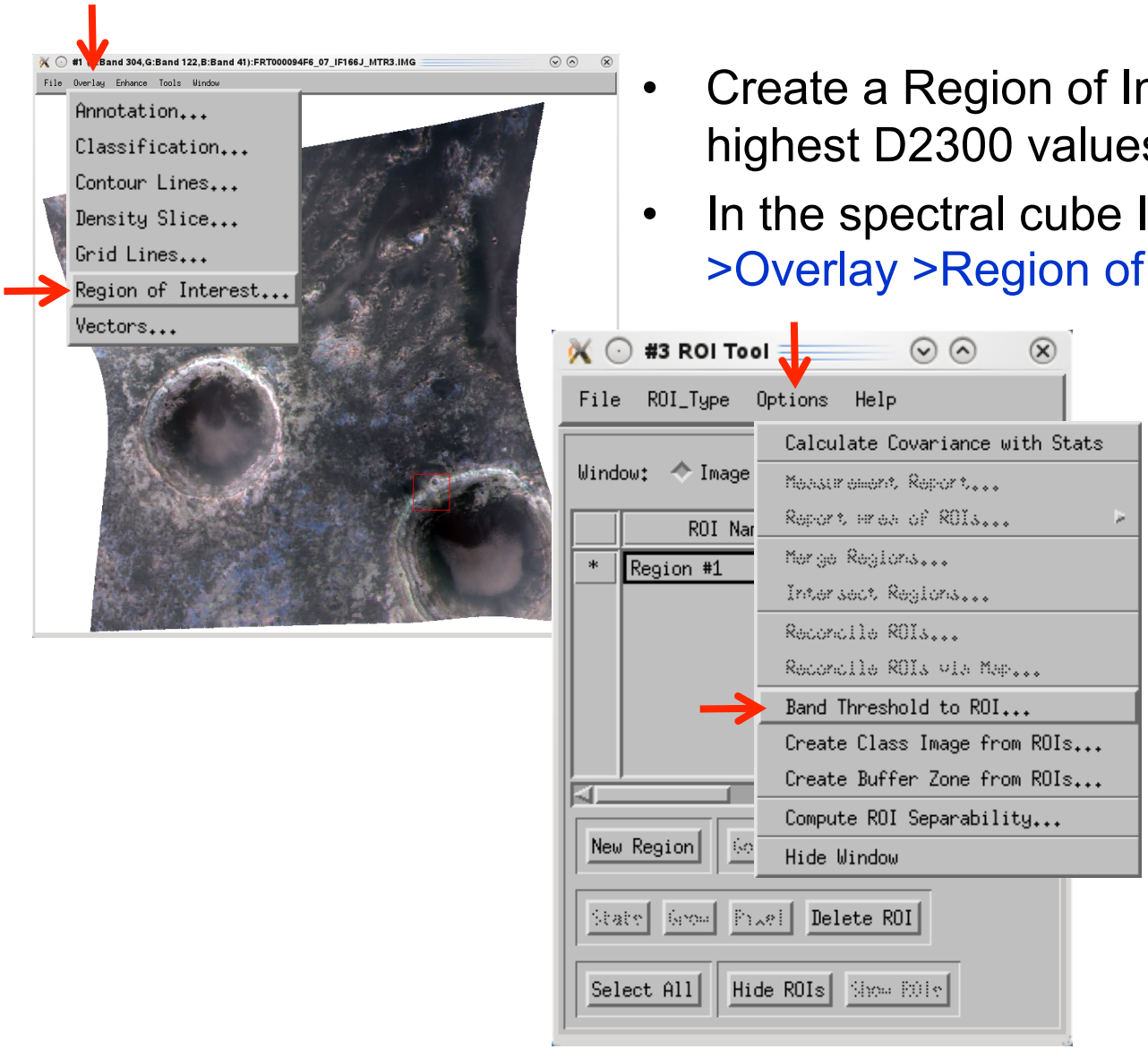
- From the linked spectral cube Image window, extract a Z-profile (Spectrum)
- In the spectral plot window
  - Go to >Edit >Plot Parameters to adjust y-axis (65535 values skew the range)
  - Right click anywhere to view Plot Key and set Z-profile Avg Window to 3x3 pixels
  - Preserve this spectrum for later use under >Options >New Window: with Plots…



Spectral Cube RGB

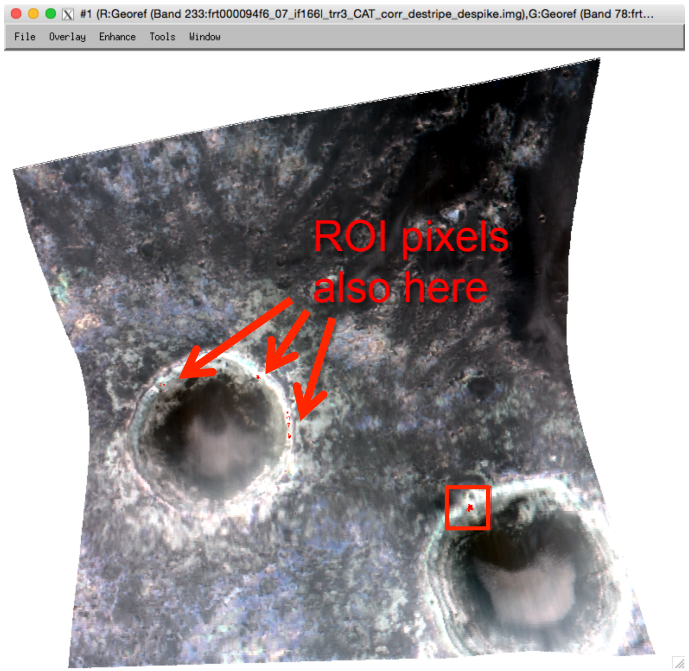


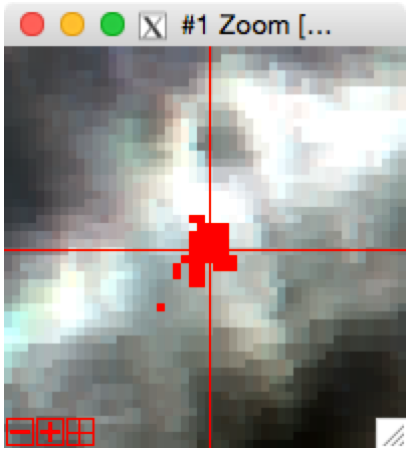
CRISM ROI-based Endmember Extraction (1/3)



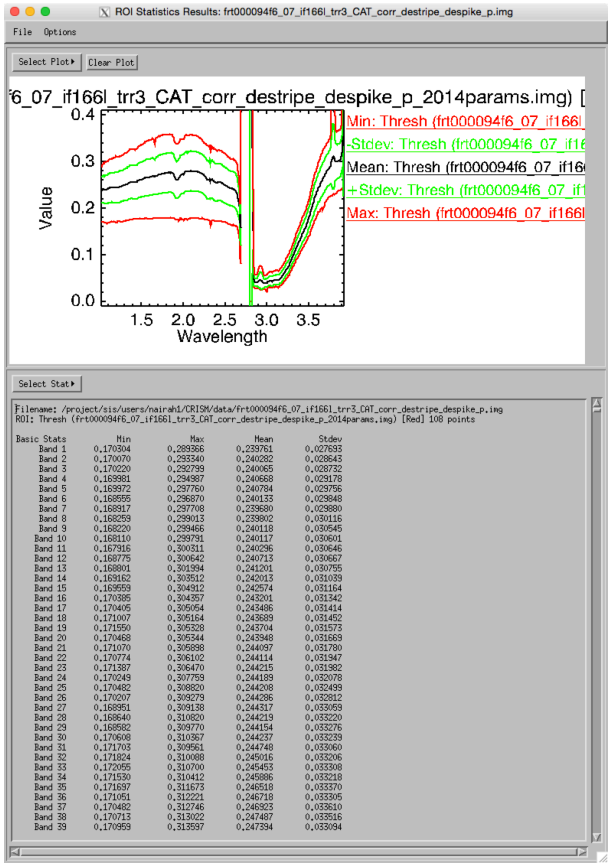
- Create a Region of Interest (ROI) from the highest D2300 values throughout the scene
- In the spectral cube Image window, go to >Overlay >Region of Interest
- In the ROI Tool, >Options >Band Threshold to ROI
- Select the D2300 band from the summary parameter file
- Type in min and max values of 0.04 and 0.05, respectively
- Should get a result of 108 pixels
- May want to refine threshold range to get fewer pixels

ROI-based Endmember Extraction (2/3)





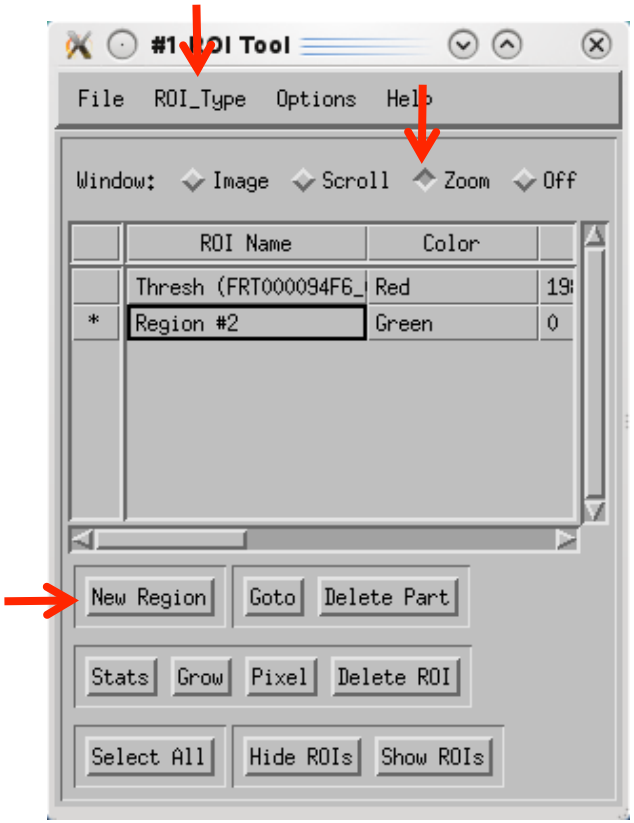
- The ROI appears as red pixels in the displayed window
- In the ROI Tool, calculate the average of the pixels by clicking >Stats



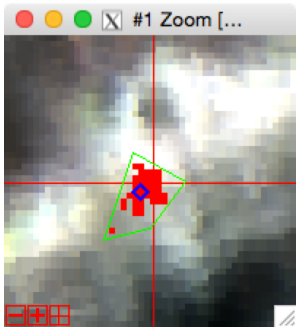
- Right click within the Stats Results plot area to adjust Plot Parameters and view Plot Key
- Click and drag the Mean spectrum to the previously-created spectral plot containing the pixel-based endmember spectrum

CRISM ROI-based Endmember Extraction (3/3)

- A third method would be to define a polygon ROI…

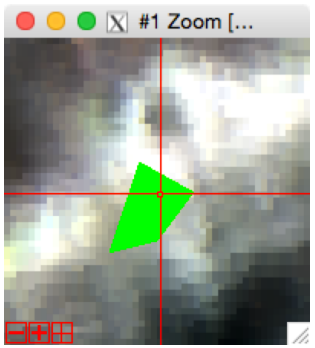


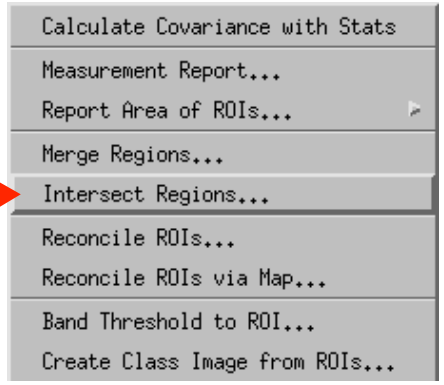
- In the ROI Tool, select >ROI_Type >Polygon
- Create New Region and select Zoom as the active window



- Calculate statistics on the polygon-ROI as before
- The polygon ROI can be used alone or (e.g.) to spatially constrain the band threshold ROI: >ROI Tool > Options >Intersect Regions

right click to finalize

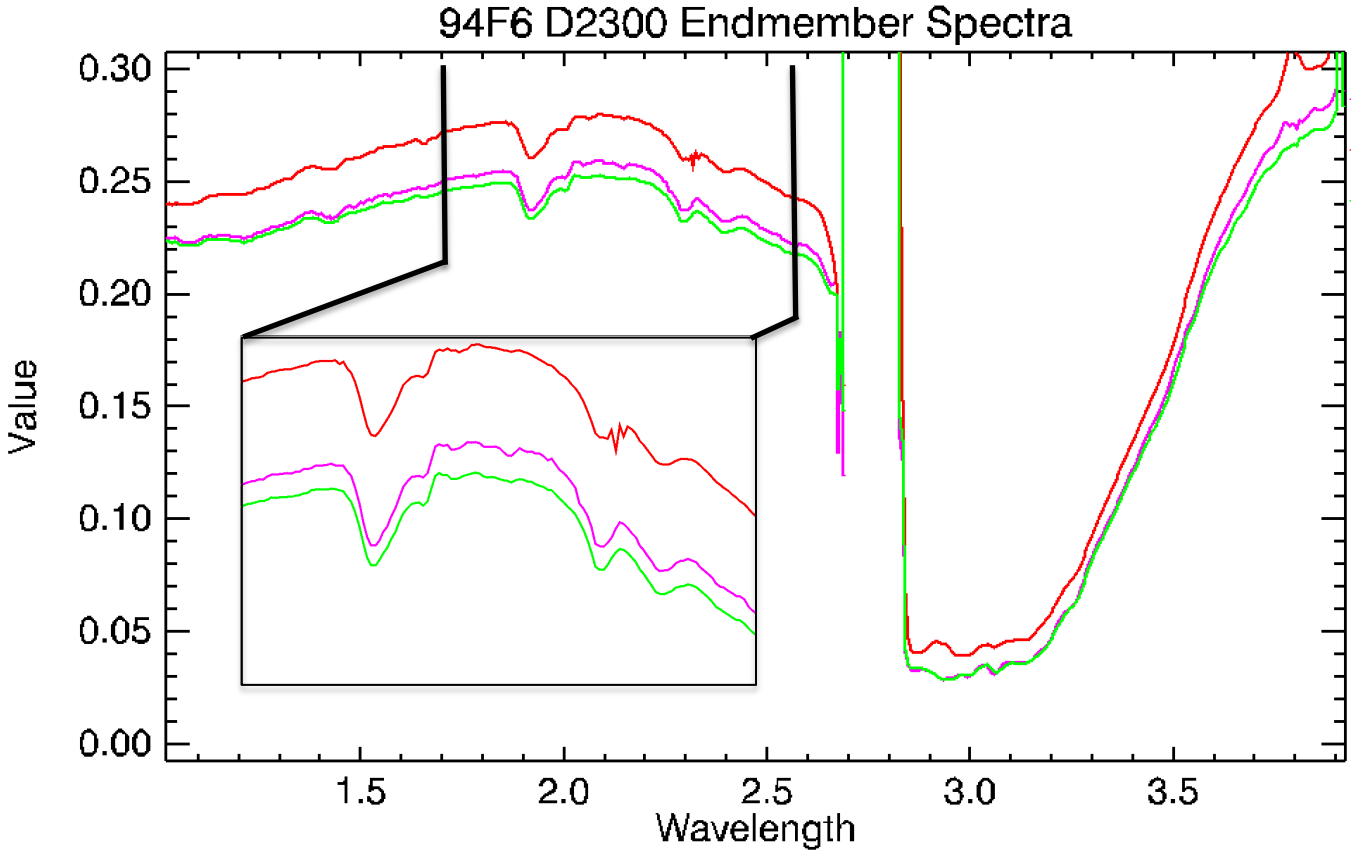




CRISM Example Endmember Spectra – D2300

- Three D2300 spectra were extracted using the methods discussed in previous slides: **1)** 3x3 pixel average, **2)** band threshold, and **3)** polygon.

- In this scene, there are no huge differences between the spectra.
- In general, more pixels = less spectral noise.



3x3 AVG

Mean: Thresh 108 points

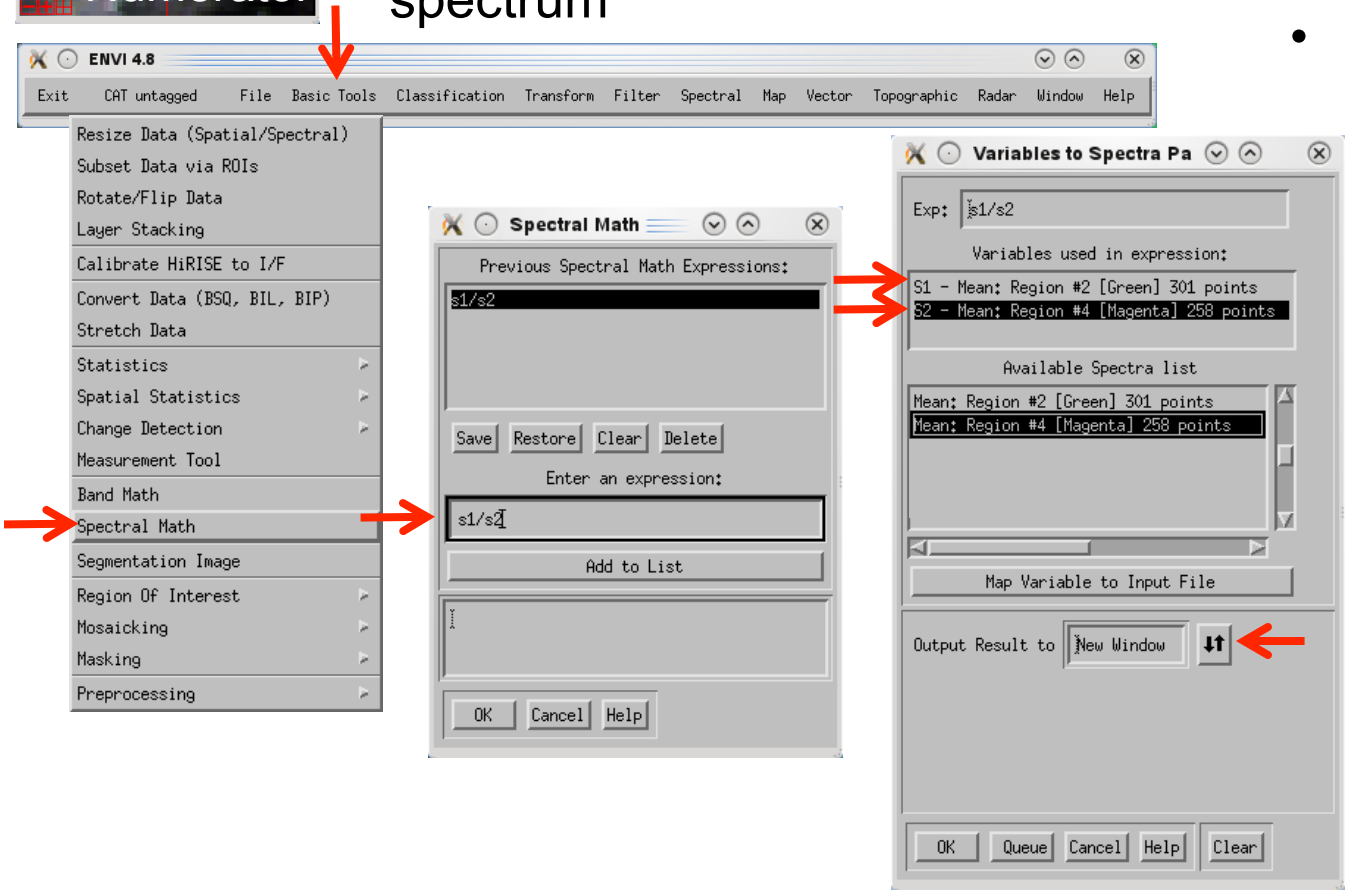
Mean: Polygon 105 points

Enhancing Spectral Features

- There are two widely accepted ways to enhance spectral features to aid with interpretation:
  - Ratio to a spectrally neutral area in the same scene
  - Continuum removal
- Benefit to using a ratio is that you may cancel out detector noise or spikes
- However, if your denominator spectrum is not truly neutral you may introduce unintended spectral shape, e.g., from:
  - Broad features from mafics like olivine or pyroxene
  - Spectral slope
  - VNIR variability from ferric oxide-related features
- Continuum removal is not recommended over the entire CRISM wavelength range, either
  - Best results when focused on relatively narrow range bracketing the feature(s) of interest

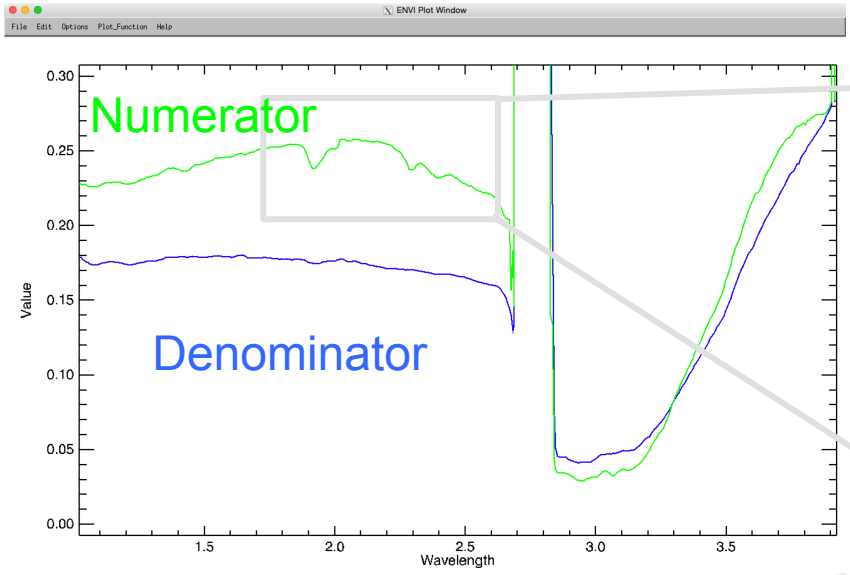
Ratioing (1/2)

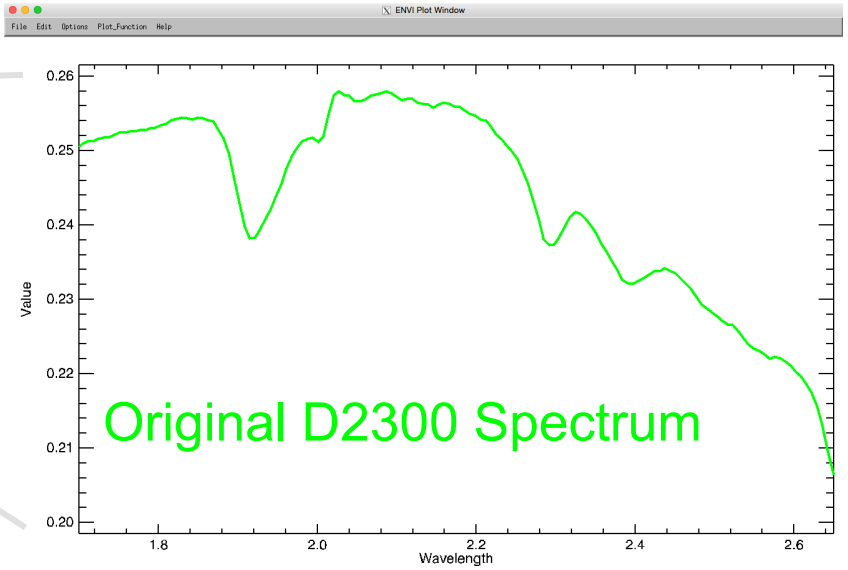
- Numerator: let's use the D2300 spectrum with the least noise - the average from the green polygon ROI.
- Denominator: Create a similar-sized polygon in the nearby spectrally bland dark material and calculate its average spectrum

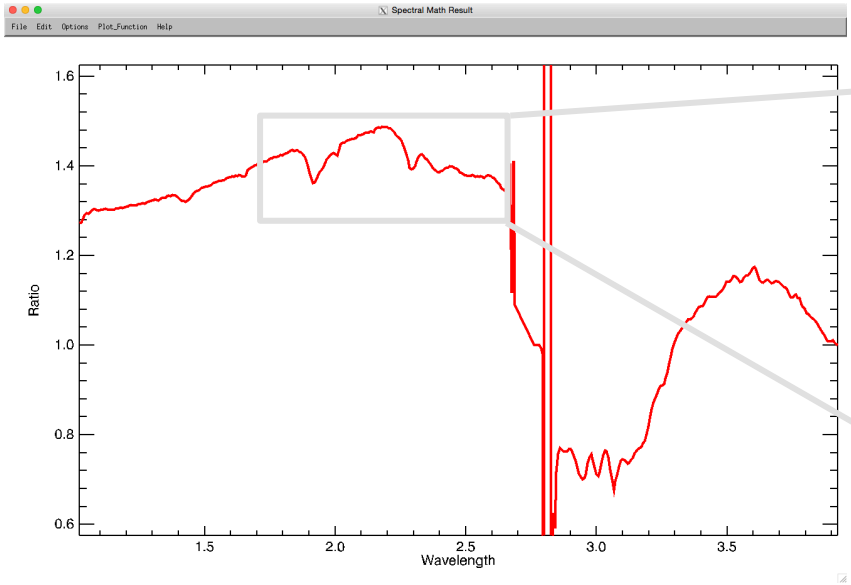


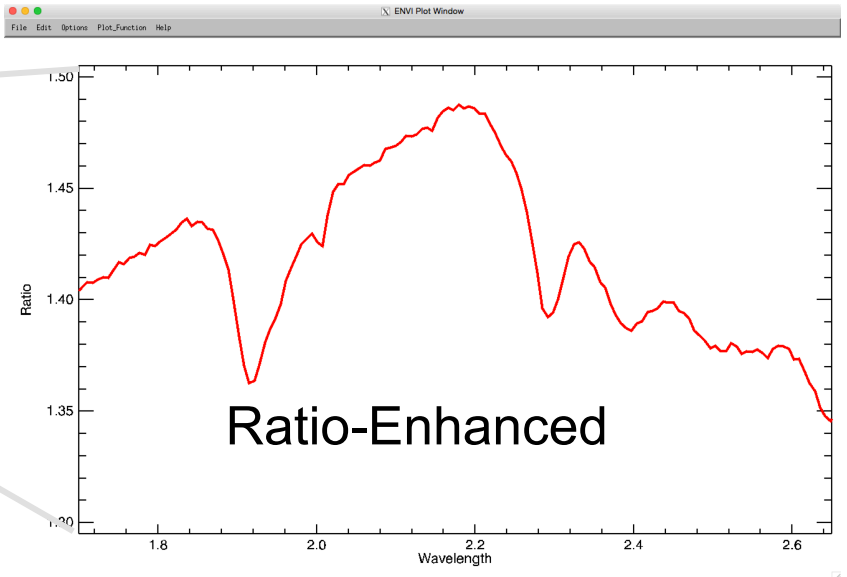
- From the ENVI main menu, go to >Basic Tools > Spectral Math
  - Enter the expression: s1/s2
  - Map the numerator (s1) and denominator (s2) to the Available Spectra List
  - Output to New Window

Ratioing (2/2)


ENVI Plot Window
File Edit Options Plot_Function Help
Numerator
Denominator
Value
Wavelength


ENVI Plot Window
File Edit Options Plot_Function Help
Original D2300 Spectrum
Value
Wavelength


Spectral Math Result
File Edit Options Plot_Function Help
Ratio
Wavelength

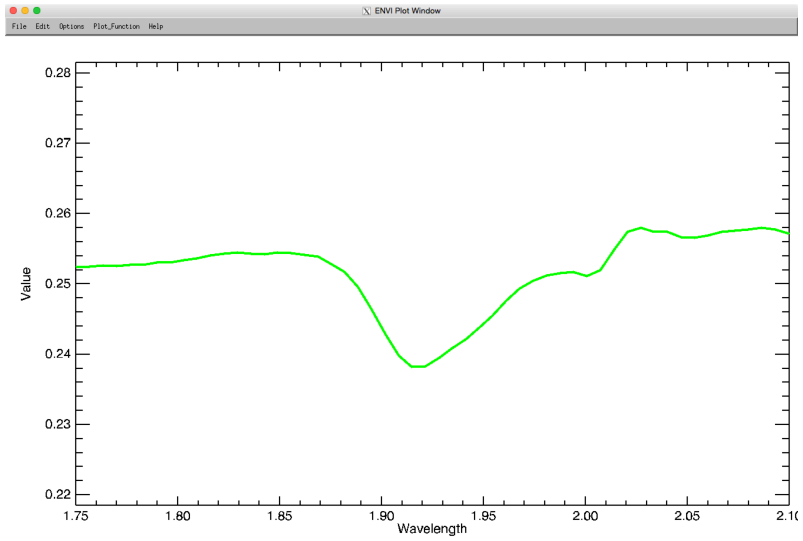

ENVI Plot Window
File Edit Options Plot_Function Help
Ratio-Enhanced
Ratio
Wavelength

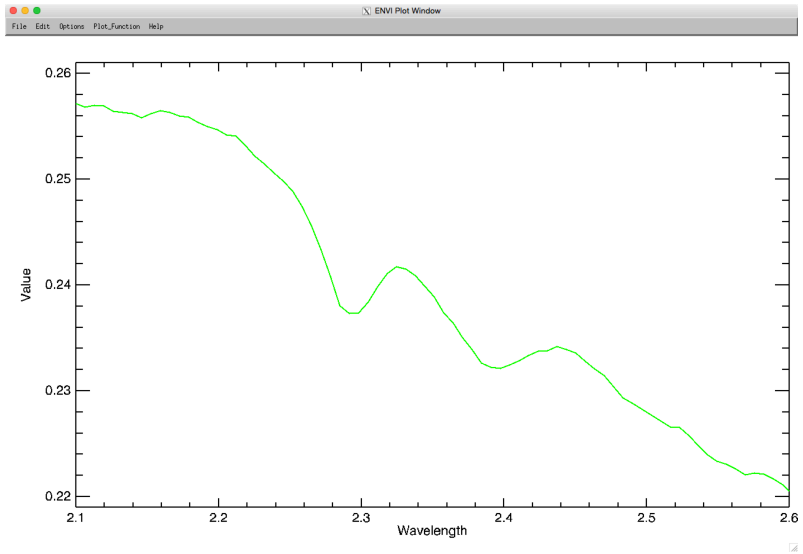
Continuum Removal (1/2)

- In >Edit >Plot Parameters, subset the x-axis range to bracket the feature of interest
- Then choose Plot_Function > Continuum Removed as the display method
- You will likely have to rescale the y-axis in the continuum removed-plot

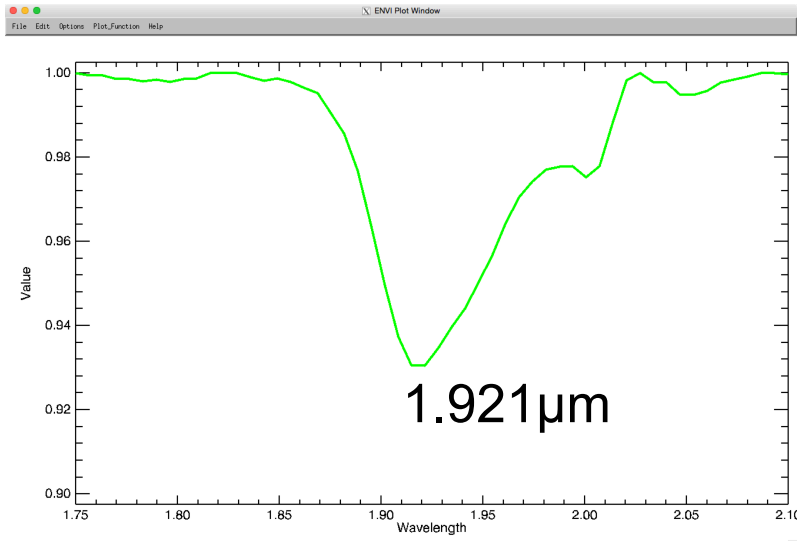
Continuum Removal (2/2)

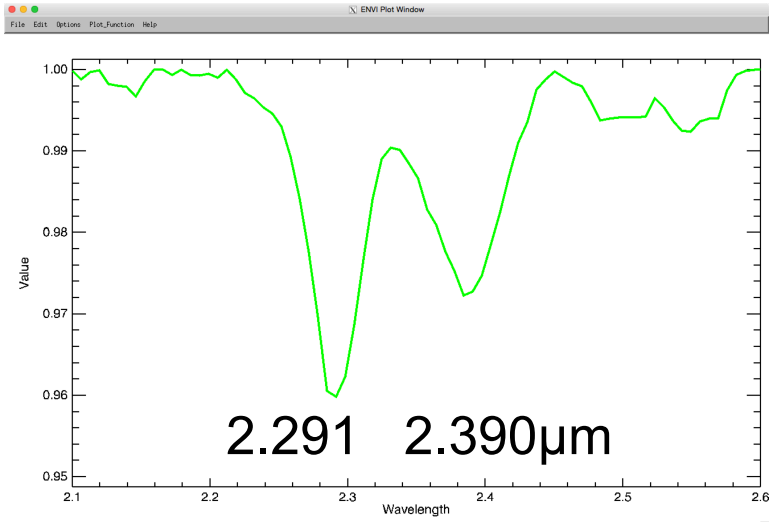
Normal



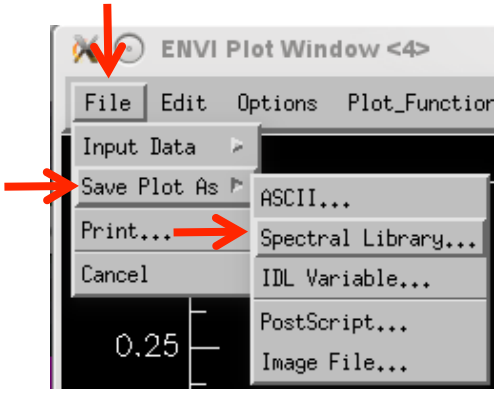


Continuum Removed

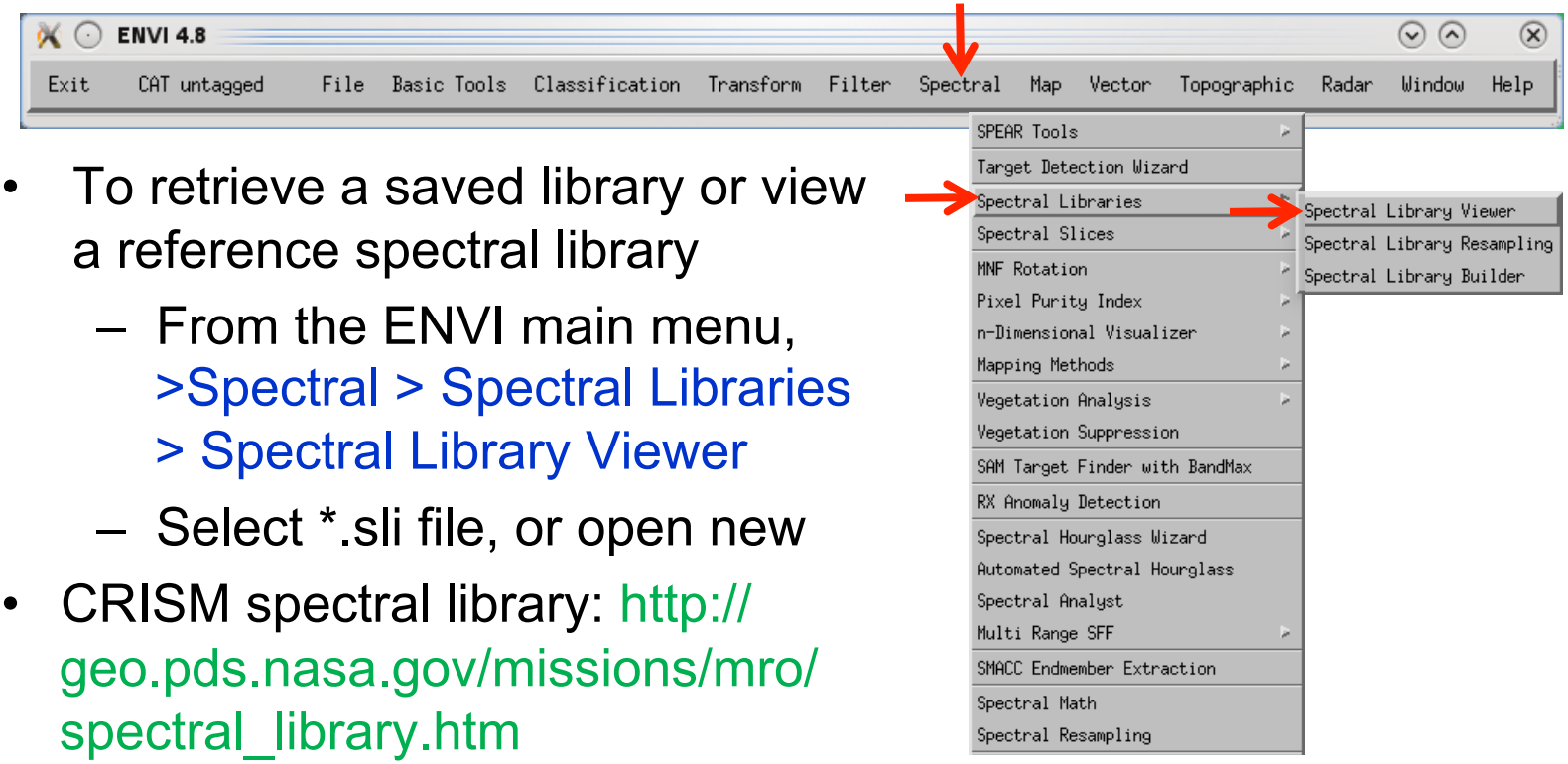




Spectral Libraries

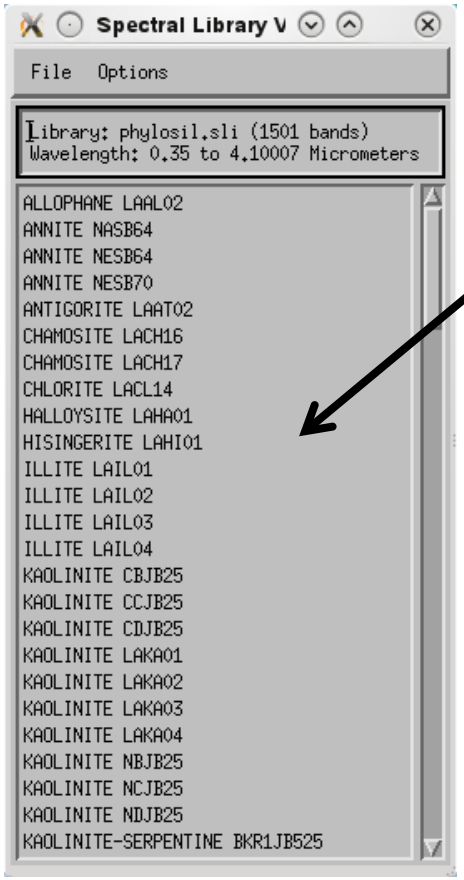


- Save spectra as ENVI spectral libraries (*.sli), or export as ASCII text file
  - From a spectral plot window, >File >Save Plot As > Spectral Library
  - HINT: Line colors are not preserved; make sure you rename the spectra appropriately

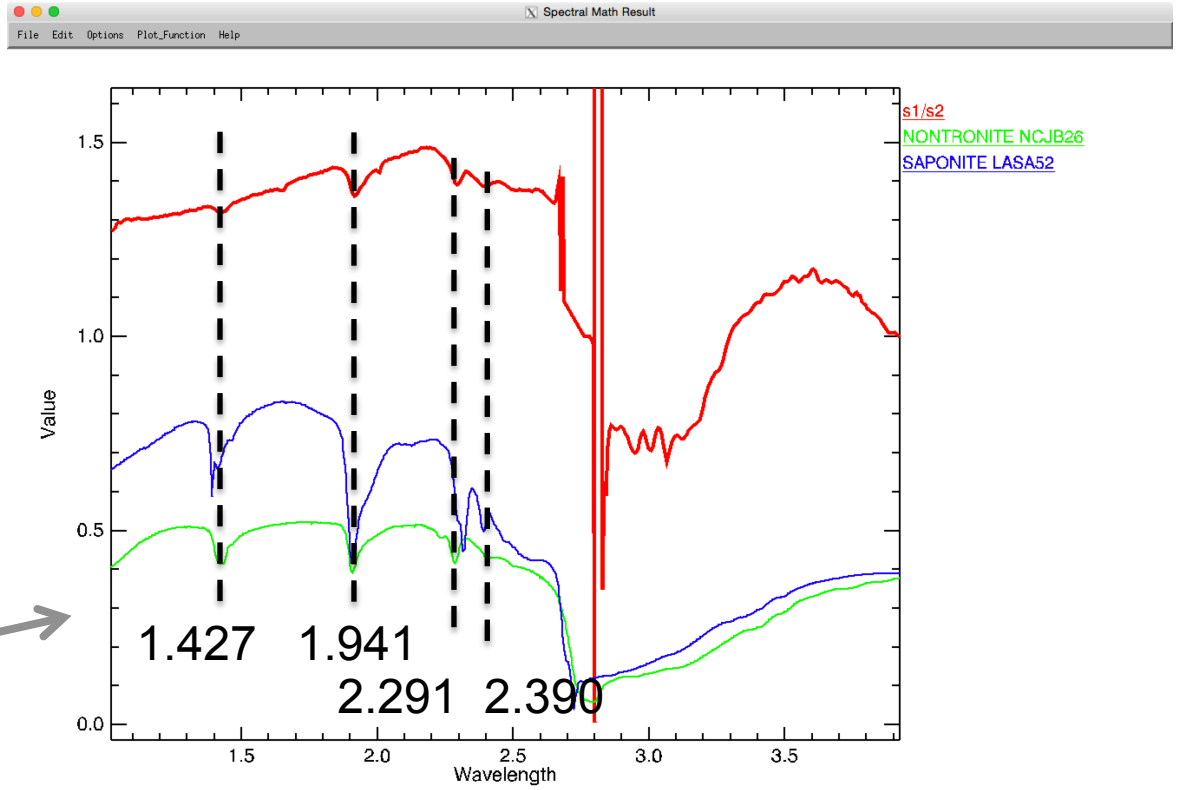


- To retrieve a saved library or view a reference spectral library
  - From the ENVI main menu, >Spectral > Spectral Libraries > Spectral Library Viewer
  - Select *.sli file, or open new
- CRISM spectral library: http://geo.pds.nasa.gov/missions/mro/spectral_library.htm

Interpretation



- Compare the enhanced spectra to laboratory reference spectra to locate the best mineralogic match(es).
- For the D2300 endmember example, open a library containing phyllosilicate spectra and load candidate reference spectra to examine absorption band positions in detail…



Diagnostic bands match best with nontronite.

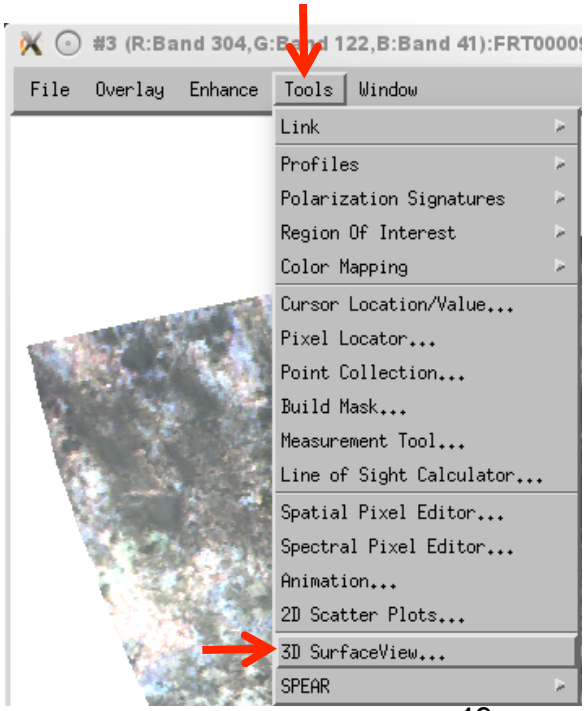
Interpretation Guidelines

- Common sense rules apply to spectral interpretation:
  - All major absorption features in the spectrum of the proposed reference mineral should be present or otherwise accounted for
  - Relative strengths and shapes of spectral features of the proposed reference mineral should be replicated in the CRISM spectrum
- Even a single CRISM pixel (~20m) is unlikely to comprise a single pure mineral, i.e.,
  - Spatial mixing is likely
  - Intimate mixtures can also occur
  - Geochemically intermediate phases are also possible
- So, simple explanations are usually best, but complexity happens. It's real geology, after all!

VISUALIZATION

3-D Rendering (1/3)

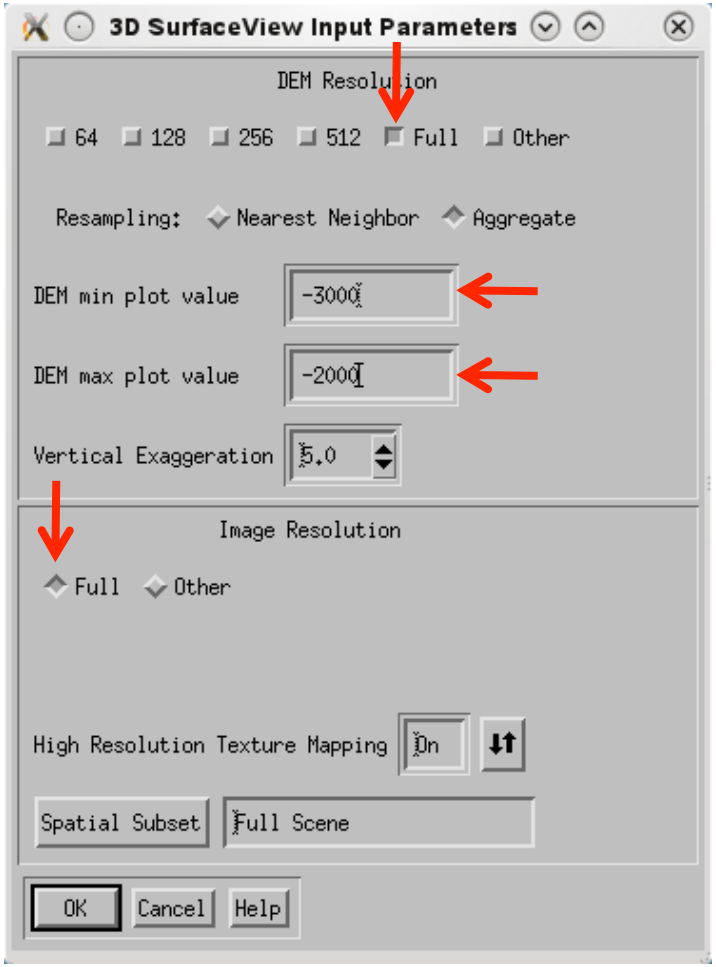
- 3-D visualization can be helpful for understanding relationships between different units.
- First, open the DDR cube (frt000094f6_07_de166l_ddr1.img) and load the Elevation band
  - Highest resolution MOLA gridded data is oversampled to match CRISM spatial scale; co-registration is good but interpolation in sparse areas can lead to feature mismatch
  - Note the approximate elevation range under >Enhance >Interactive Stretching

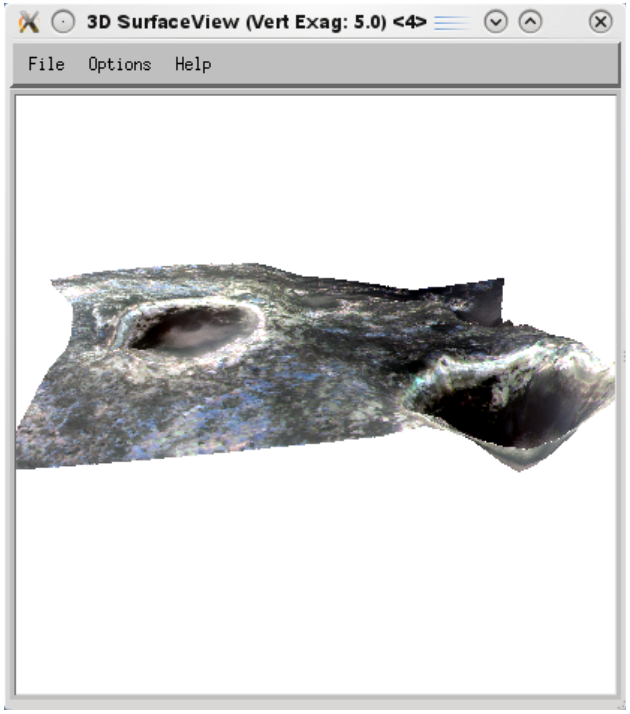


- Load and stretch the band or RGB composite that you want to view in 3D
- From the Image window, go to >Tools >3D Surface View

3-D Rendering (2/3)

- In the 3D SurfaceView Input dialog
  - Indicate Full DEM Resolution
  - Type in min and max elevation values that bracket the actual range
  - Indicate Full Image Resolution

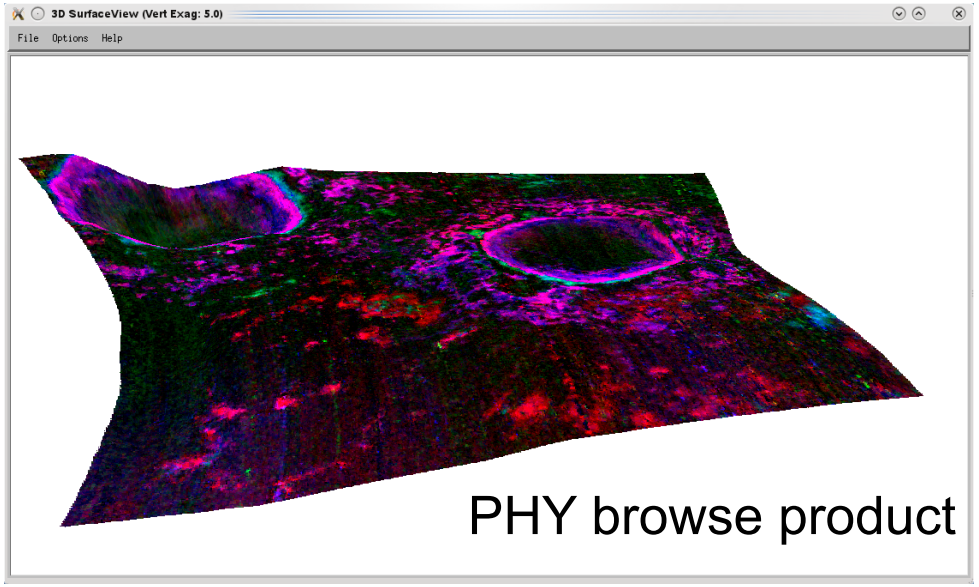




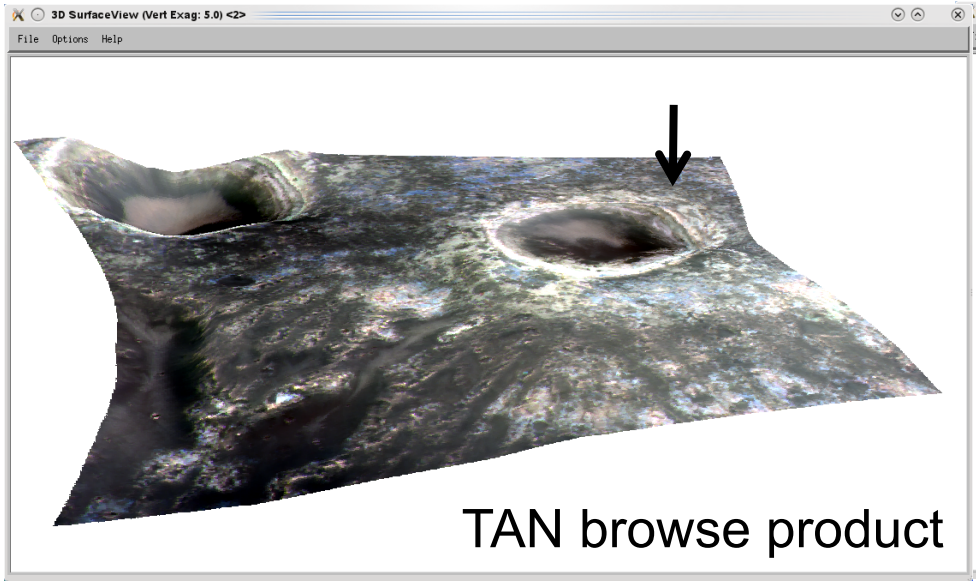
Initial 3D view

3-D Rendering (3/3)

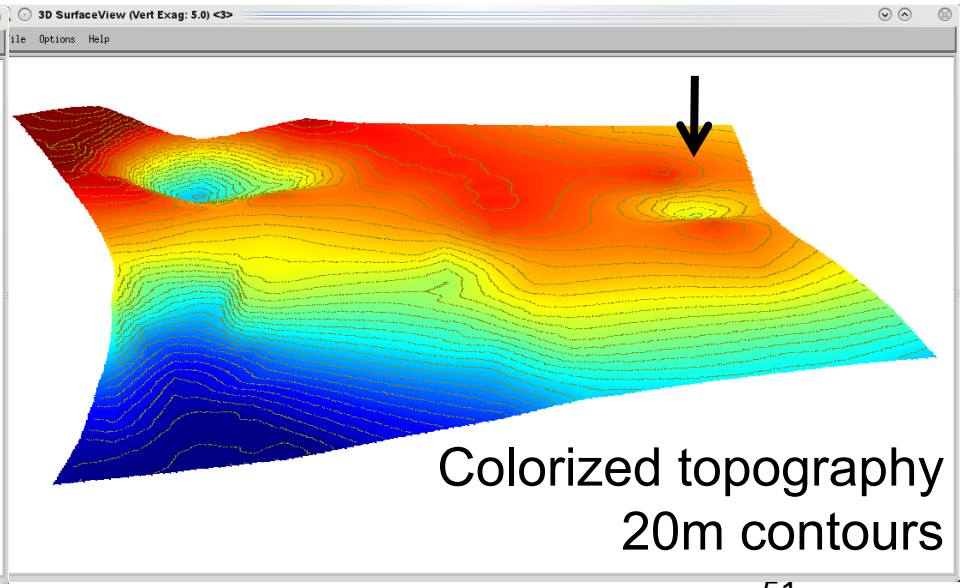
- Use mouse buttons to navigate, or use >Options >Surface Controls
- Perspective view here is looking south (5x vertical exaggeration)
- Note that the lowest point for the western crater (right side, arrows) is offset from the crater's center due to sparseness of the interpolated MOLA tracks



PHY browse product



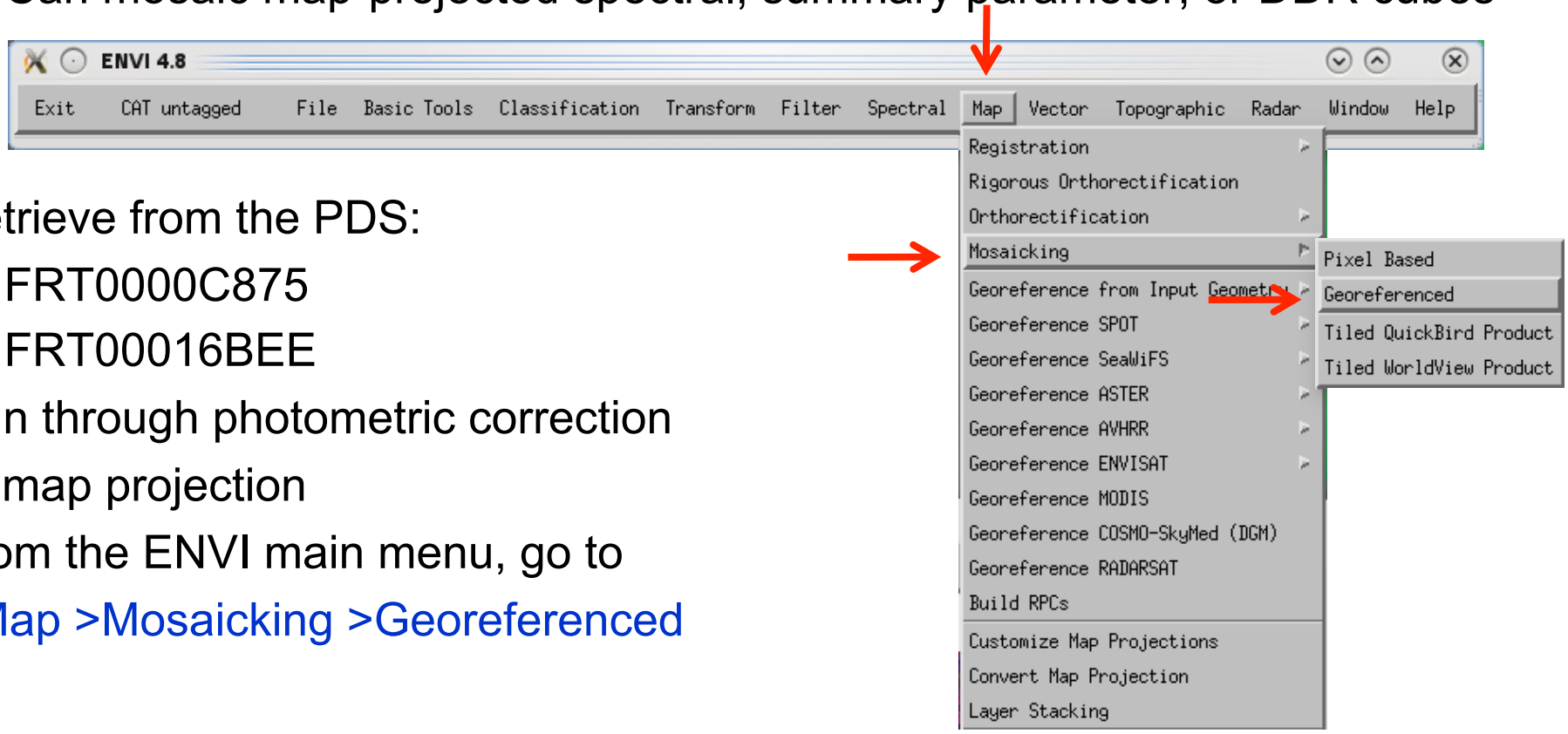
TAN browse product



Colorized topography
20m contours

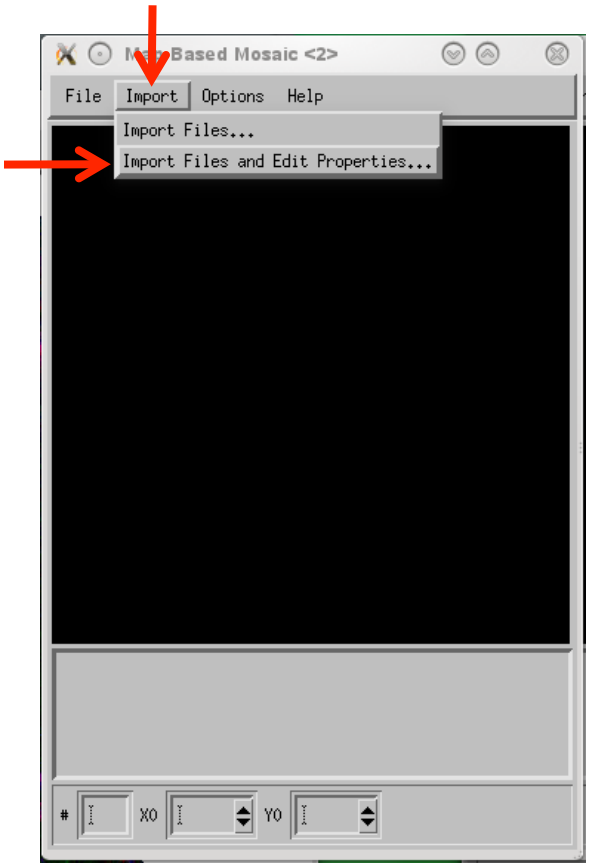
Mosaicking (1/4)

- Mosaicking multiple CRISM cubes together allows broader geographic context for inferred mineralogy.
  - Can mosaic map-projected spectral, summary parameter, or DDR cubes



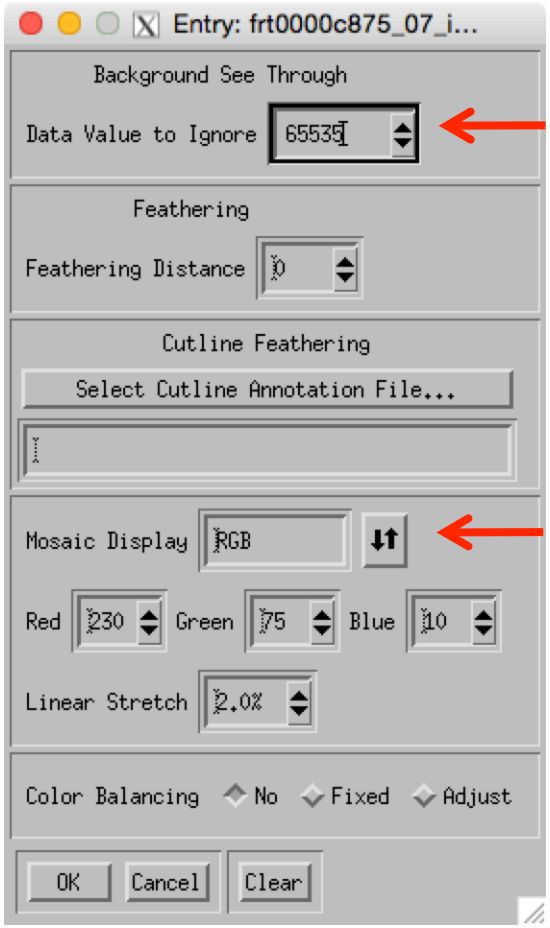
- Retrieve from the PDS:
  - FRT0000C875
  - FRT00016BEE
- Run through photometric correction and map projection
- From the ENVI main menu, go to >Map >Mosaicking >Georeferenced

Mosaicking (2/4)

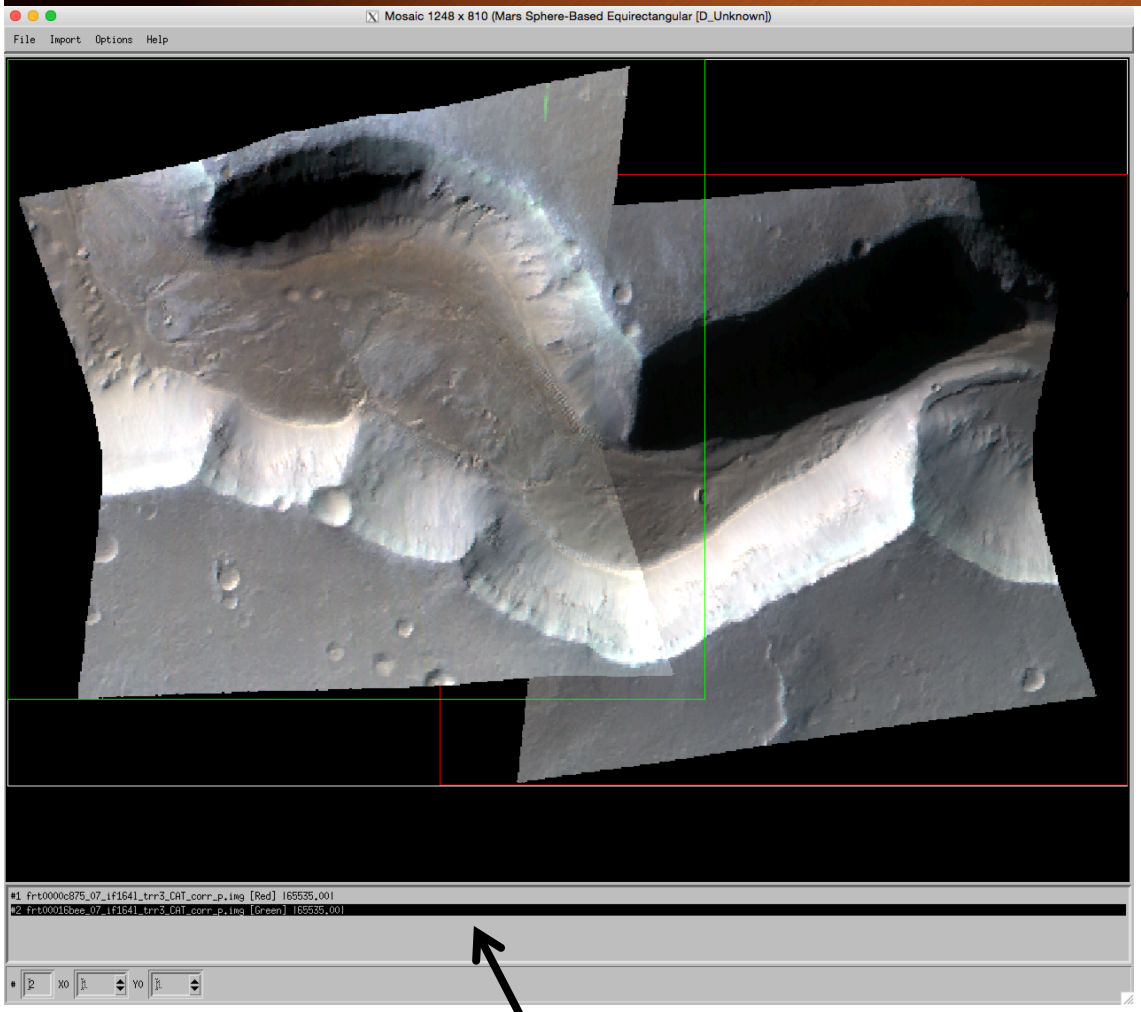


- In the Mosaic dialog box, go to >Import >Import Files and Edit Properties
  - Select the two cubes you wish to mosaic

- For each file, indicate a Data Ignore Value of 65535 and default RGB bands at 230, 75, and 10.



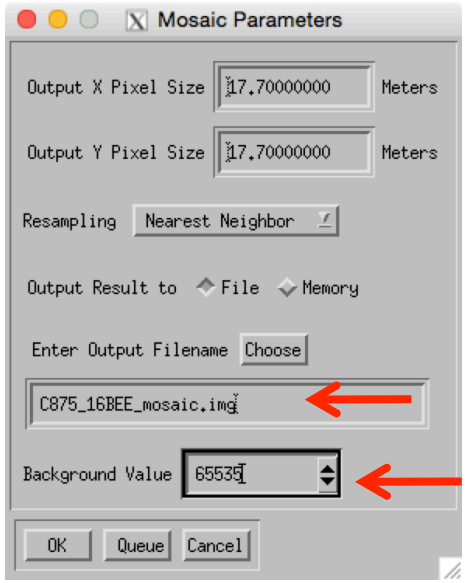
Mosaicking (3/4)



To adjust layering order or edit display properties, right click on filename here

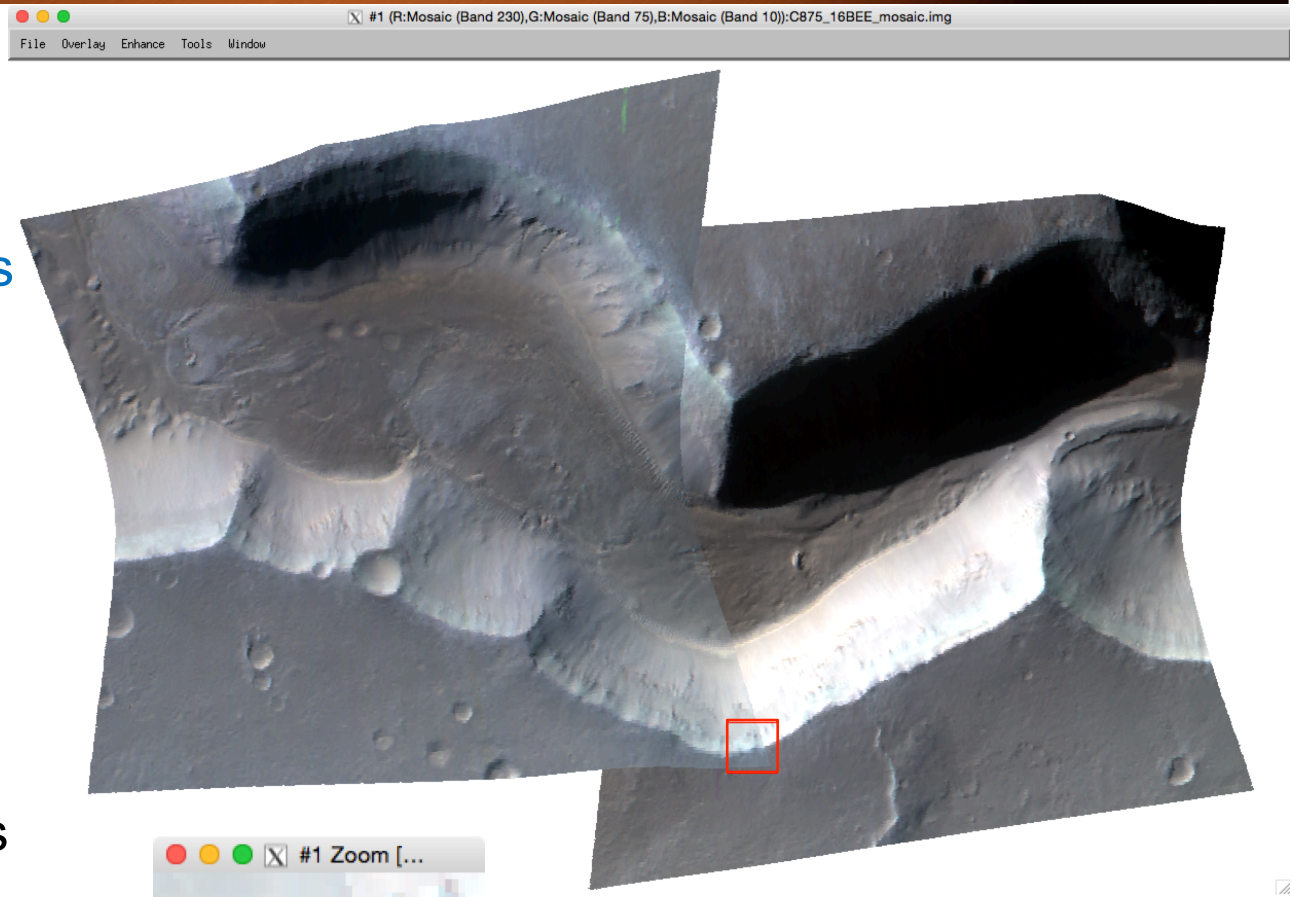
To save, go to >File >Apply

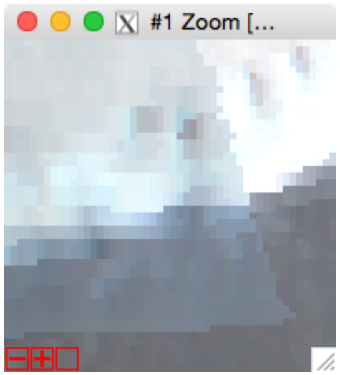
– Indicate filename and include a background value of 65535.



Mosaicking (4/4)

- Load a mosaic just like any other file
- Go to >File >Edit ENVI Header >Edit Attributes to set Data Ignore Value (65535) and reapply band names if desired

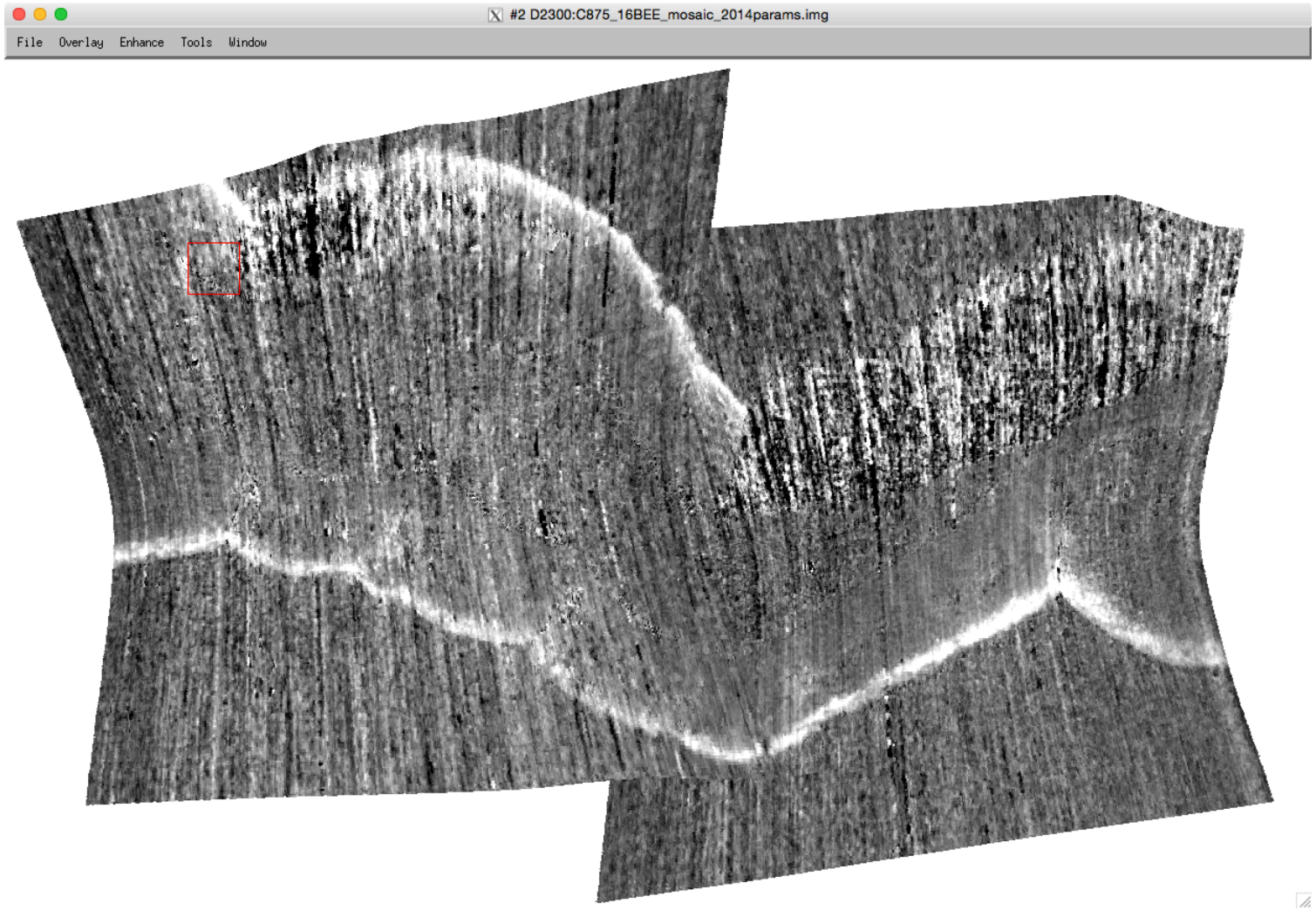




- Difficult to avoid seams in mosaic due to varying atmospheric/ illumination/geometric conditions.

More Mosaic Results

- Load the mosaic file and generate the D2300 summary parameter:



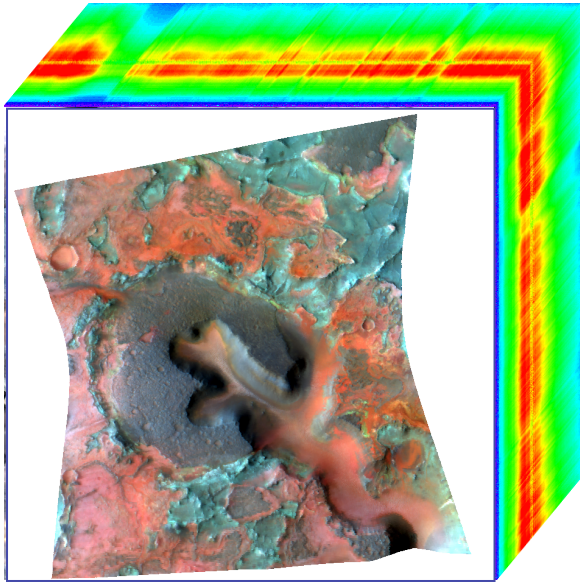
What is an MTRDR?

1) An image cube of I/F from a TRR3 for a targeted observation's central swath, with additional processing:
   - The best current correction for atmospheric gases
   - Lambertian photometric correction
   - First-order empirical normalization of atmospheric opacity to the nearest-nadir geometry
   - Residual cross-track optical distortions ("spectral smile") fitted and normalized
   - VNIR data reprojected to IR data in sensor space
   - "Bad bands" removed
   - Map projected to a global standard (equirectangular, rolling center latitude of projection)
2) An image cube of spectral indices ("summary products") derived from these corrected, normalized data
3) An image cube of map-projected geometric information from the DDRs

- **Our current, best, "whole image" correction to what an idealized version of CRISM would see if it only pointed an nadir**

MTRDR Nomenclature

- **FRT =** Class Type
  - FRT (Full Resolution Targeted Observation)
  - HRL (Half Resolution Long Targeted Observation)
  - HRS (Half Resolution Short Targeted Observation)
- **00003E12** = 8-digit hexadecimal Observation ID
- **07** = Hex counter for image within observation
- **IF166** = Processing, internal command macro used
  - IFnnn – I/F / Macro#
  - SUnnn – Summary products / Macro#
  - DEnnn – Derived data / Macro#
- **J** = Sensor ID
  - J for joined (for IF and SU)
  - L for IR (for DE)
- **MTR3** = MTRDR, calibration version = 3
- **IMG** = file extension
  - IMG for binary image data
  - LBL for detached ASCII PDS label



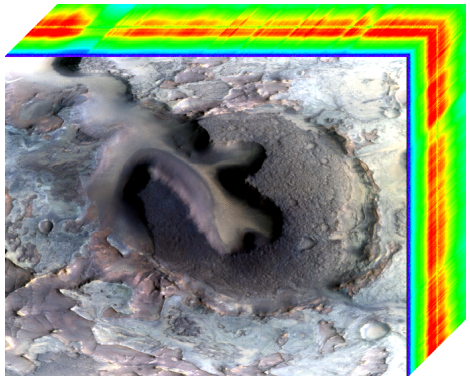
Full-resolution target
Observation 3E12
Counter
Calibrated to I/F
Joined VNIR+IR data
Software version 3

FRT00003E12_07_IF166J_MTR3.IMG

The file name describes the type of data, an overview of the processing, and gives the unique ID and counter

We're Also Delivering a non-Map Projected Version of the Corrected Data

Scene I/F, unitless



Multiband image of corrected I/F; VNIR re-projected to IR; "bad bands" STILL PRESENT

```
SPACECRAFT_ID                = MRO
INSTRUMENT_NAME              = "COMPACT RECONNAISSANCE IMAGING
                                SPECTROMETER FOR MARS"
INSTRUMENT_ID                = CRISM
TARGET_NAME                  = MARS
PRODUCT_TYPE                 = MPTARGETED_RDR
PRODUCT_CREATION_TIME        = 2010-11-21T17:44:07
START_TIME                   = 2008-08-21T17:20:57.794
STOP_TIME                    = 2008-08-21T17:22:57.529
SPACECRAFT_CLOCK_START_COUNT = "4/0903806478.04596"
SPACECRAFT_CLOCK_STOP_COUNT  = "4/0903806597.52710"
ORBIT_NUMBER                 = "NULL"
OBSERVATION_TYPE             = "FRT"
OBSERVATION_ID               = 16#00003E202#
MRO:OBSERVATION_NUMBER       = 16#07#
MRO:ACTIVITY_ID              = "IF165"
MRO:SENSOR_ID                = "J"

/* Detector and FPE temperature refer to IR component of observation */

MRO:DETECTOR_TEMPERATURE     = -152.306
MRO:OPTICAL_BENCH_TEMPERATURE = -52.938
MRO:SPECTROMETER_HOUSING_TEMP = -76.728
MRO:SPHERE_TEMPERATURE       = -52.672
MRO:FPE_TEMPERATURE          = 0.718
PRODUCT_VERSION_ID           = 3
```

Detached PDS label describing the source files, corrections performed

TER = Targeted Empirically-corrected Data Record

- **FRT =** Class Type
  - FRT (Full Resolution Targeted Observation)
  - HRL (Half Resolution Long Targeted)
  - HRS (Half Resolution Short Targeted)
- **00003E12** = 8-digit hexadecimal Observation ID
- **07** = Hex counter within observation
- **IF166** = Processing, internal macro used
  - IFnnn – I/F / Macro#
- **J** = Sensor ID
  - J for joined
- **TER3** = TER, calibration version = 3
- **IMG** = file extension
  - IMG for binary image data
  - LBL for detached ASCII PDS label

Full-resolution target
Observation 3E12
Counter
Calibrated to I/F
Joined VNIR+IR data
Software version 3

FRT00003E12_07_IF166J_TER3.IMG

Each Type of I/F File is Accompanied by a Table of Wavelengths Present

```
0,196,  436.13
0,197,  442.63
0,198,  449.14
0,199,  455.64
0,200,  462.15
0,201,  468.65
0,202,  475.16
0,203,  481.67
0,204,  488.17
0,205,  494.68
0,206,  501.19
0,207,  507.70
0,208,  514.21
0,209,  520.72
0,210,  527.23
0,211,  533.74
0,212,  540.25
0,213,  546.76
0,214,  553.27
0,215,  559.78
0,216,  566.29
0,217,  572.81
0,218,  579.32
0,219,  585.83
0,220,  592.35
0,221,  598.86
0,222,  605.38
0,223,  611.89
0,224,  618.41
0,225,  624.92
0,226,  631.44
0,238,  709.68
0,239,  716.20
0,240,  722.72
0,241,  729.25
0,242,  735.77
0,243,  742.30
0,244,  748.82
```

ASCII table of image band numbers and wavelengths

```
INSTRUMENT_NAME                = "COMPACT RECONNAISSANCE IMAGING
                                   SPECTROMETER FOR MARS"
INSTRUMENT_ID                  = CRISM
TARGET_NAME                    = MARS
PRODUCT_TYPE                   = MPTARGETED_RDR
PRODUCT_CREATION_TIME          = 2012-03-14T03:47:40
START_TIME                     = "N/A"
STOP_TIME                      = "N/A"
SPACECRAFT_CLOCK_START_COUNT   = "N/A"
SPACECRAFT_CLOCK_STOP_COUNT    = "N/A"

PRODUCT_VERSION_ID             = "3"
PRODUCER_INSTITUTION_NAME      = "JOHNS HOPKINS UNIVERSITY
                                   APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME                  = "mtrdr_pipeline"
SOFTWARE_VERSION_ID            = "1.0"

/*    A listfile including detector row numbers and wavelengths in the */
/*    Targeted Empirical Record and Map-Projected Targeted RDR images. */

OBJECT                         = WAVELENGTH_SOURCE_TABLE
  NAME                         = "CRISM JOINED WAVELENGTH TABLE"
  INTERCHANGE_FORMAT           = "ASCII"
  ROWS                         = 674
  COLUMNS                      = 3
  ROW_BYTES                    = 14
  DESCRIPTION                  = "CRISM JOINED WAVELENGTH table"
  OBJECT                       = COLUMN
    COLUMN_NUMBER              = 1
    NAME                       = SPECT_ID
    DATA_TYPE                  = ASCII_INTEGER
    START_BYTE                 = 1
    BYTES                      = 1
    DESCRIPTION                = "Spectrometer identifier; 0 = IR; 1 = VNIR"
  END_OBJECT                   = COLUMN
  OBJECT                       = COLUMN
    COLUMN_NUMBER              = 2
    NAME                       = ROWNUM
```

Detached PDS label describing the table

- **FRT =** Class Type
  - FRT (Full Resolution Targeted Observation)
  - HRL (Half Resolution Long Targeted)
  - HRS (Half Resolution Short Targeted)
- **00003E12** = 8-digit hexadecimal Observation ID
- **07** = Hex counter within observation
- **IF166** = Processing, internal macro used
  - IFnnn – I/F / Macro#
- **J** = Sensor ID
  - J for joined
- **TER3** = Product type and calibration version
  - TER, calibration version = 3
  - MTR, calibration version = 3
- **TAB**= file extension
  - TAB for table of wavelengths
  - LBL for detached ASCII PDS label

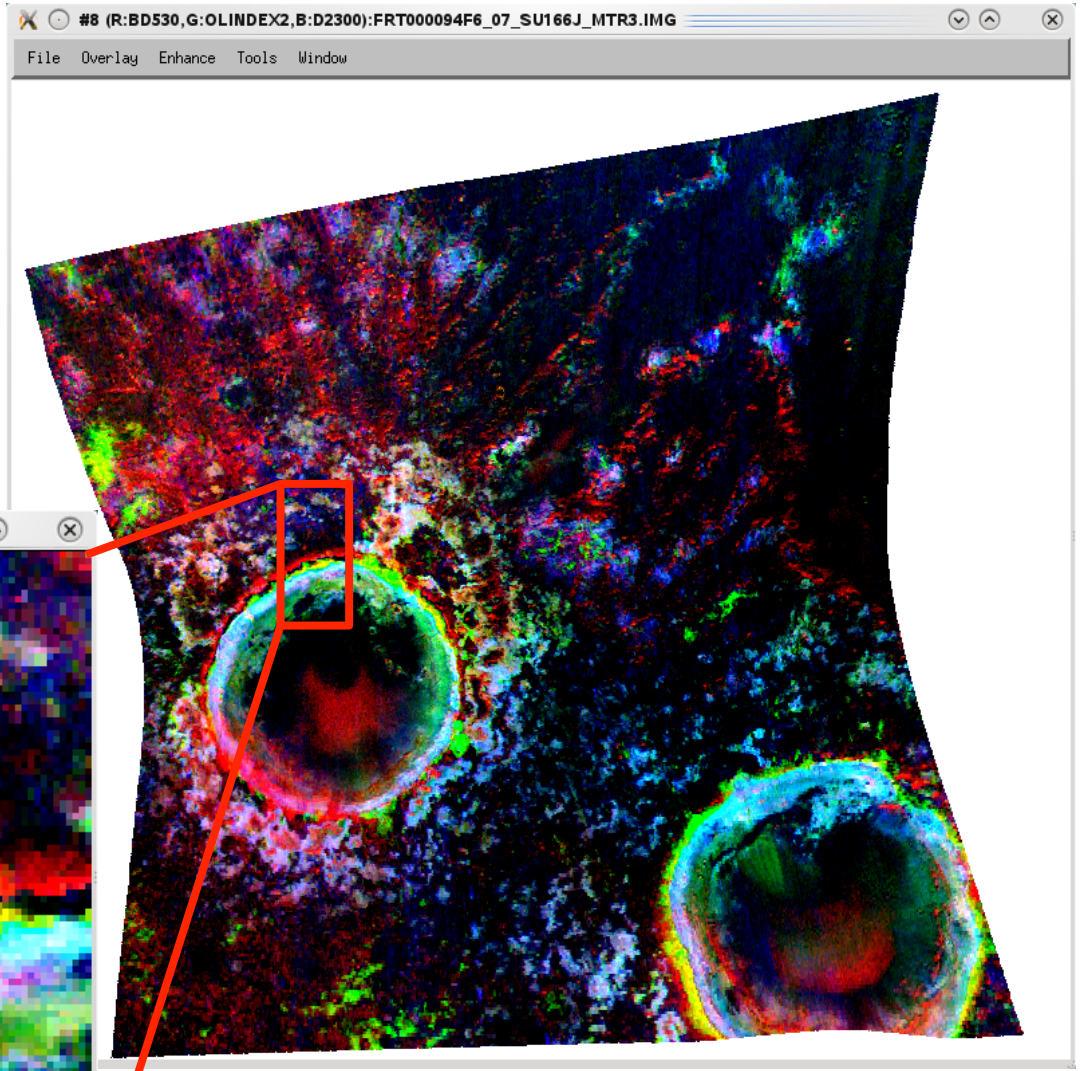
Full-resolution target
Observation 3E12
Counter
Wavelength table
Joined VNIR+IR data
Software version 3

FRT00003E12_07_WV166J_TER3.TAB

Custom Composites

- Custom RGB composites and browse products can take advantage the joined nature of the MTRDR summary parameter cube.

- Example at right shows ferric, ferrous, and clay variability.
- MANY color units to follow-up on!!



R: BD530 G: OLINDEX2 B:D2300

QUESTIONS?

Please also visit the PDS forum: http://geoweb.rsl.wustl.edu/community/index.php?/forum/20-mrocrism-data-users-workshop-2012/