

Generation and Evaluation of Systematic CRISM Mineral Indicator Maps

4th MSL Landing Site Selection Workshop
MSL CDP
09/27/2010

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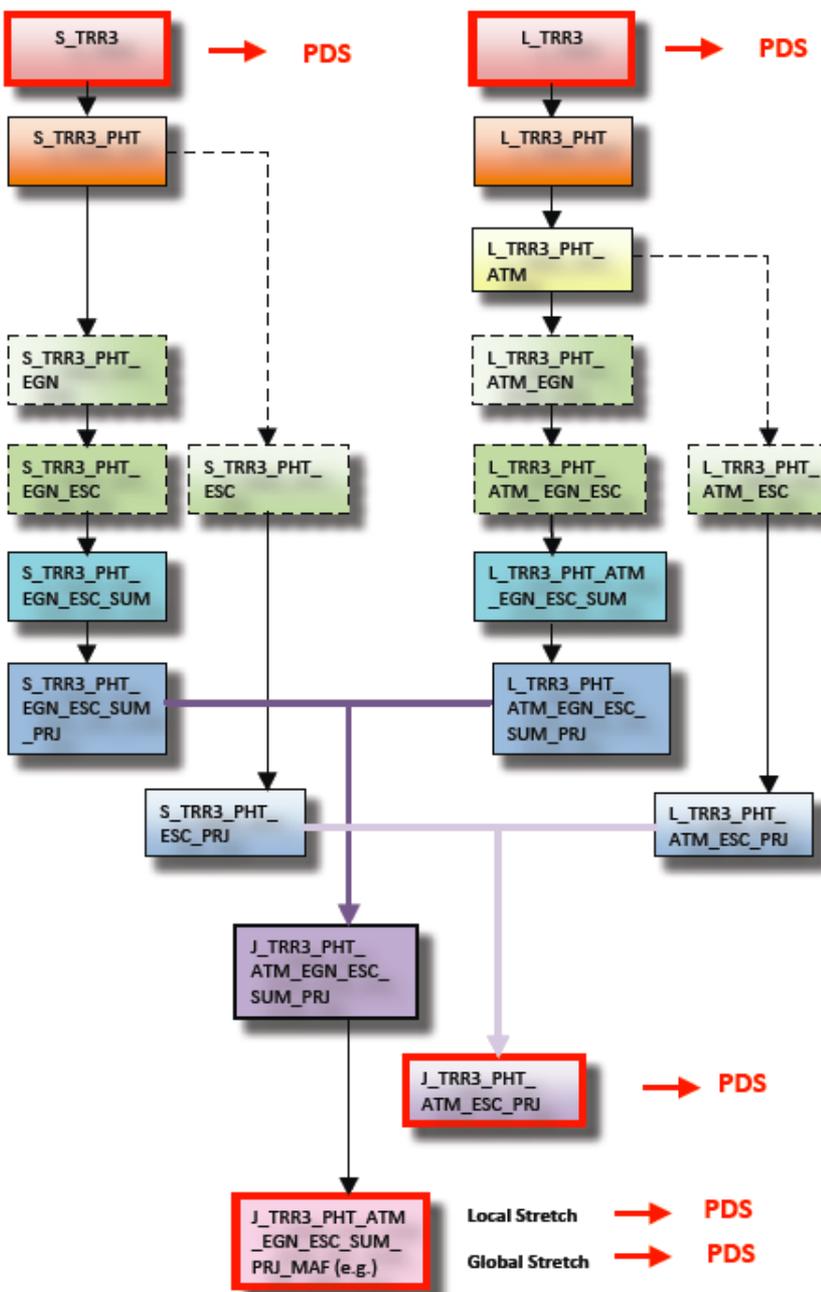
- CRISM data processing and product description
 - Updated radiometric calibration (TRR2 → TRR3)
 - Systematic spectral processing
 - Revised summary parameters and browse products
- MSL candidate landing sites – CRISM web site
 - Active online community resource
 - 170 targeted observations of the MSL candidate landing sites presented
 - CRISM prototype TRR3 I/F image cubes
 - Systematic browse products, false color composites, etc.
- Representative observations and derived analysis products
 - Mawrth Vallis
 - Holden Crater
 - Eberswalde Crater
 - Gale Crater

- A major upgrade of the CRISM data processing pipeline is nearing completion
 - Non-map projected hyperspectral data, calibration version 3 (TRR3s)
 - Radiance ('RA') cubes – output from radiometric calibration version 3
 - I/F cubes – TRR3's processed though custom filtering procedures
 - IR: kernel filter to remove stochastic noise
 - VNIR+IR: mitigation of systematic column-oriented noise
 - Map-projected filtered hyperspectral data
 - Upgraded atmospheric correction
 - Correction for observation geometric/photometric effects
 - Correction for spectral smile effect
 - Browse versions of the data with the above corrections
 - Reformulated to show more phases, reduce artifacts
- 1st release for MSL candidate landing sites - via CRISM web site
- Redelivery of other data will begin with next PDS delivery

VNIR (S)

IR (L)

- Input Data (TRR3)
- Photometric Correction (PHT)
- Atmospheric Correction (ATM)
- Empirical Geometric Normalization (EGN)
- Empirical Smile Correction (ESC)
- Summary Parameters (SUM)
- Map project (PRJ)
- Summary parameter cube
- Spectral data
- Combine VNIR and IR cubes (S+L = J)
- Summary parameters
- Spectral data
- Browse products & RGB composites (e.g., FEM, MAF, PHY)



→ PDS

→ PDS

← Calibration upgrade and noise filtering

← Upgraded atmospheric correction

← Empirical normalization of geometric dependencies

← Empirical correction of systematic calibration residual

← Revised summary products

← Map projection using MRO conventions

← Combine VNIR+IR remove bad channels

← PNG versions of summary product composites (browse products)

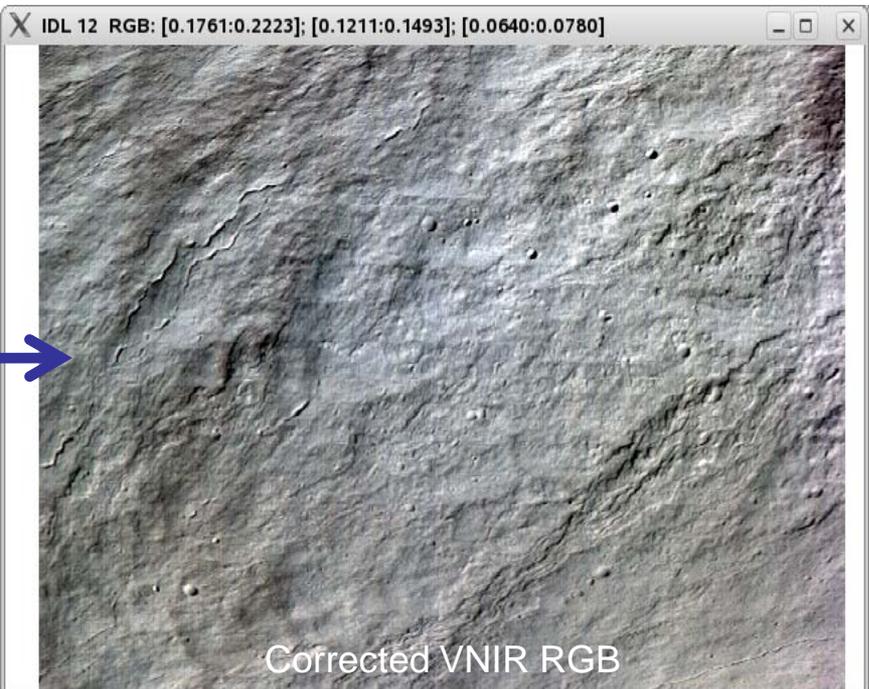
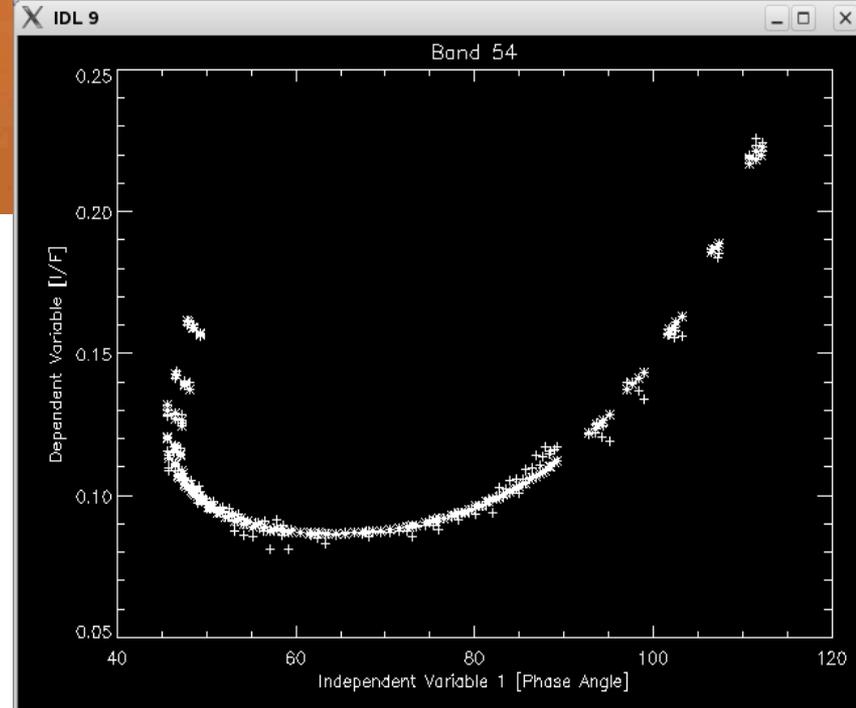
Local Stretch → PDS

Global Stretch → PDS

(reference Mike Wolff opacity in label and as dust-o-meter)

The TRR3 data still exhibit two effects

- Along-track brightness variations
 - Due to continuously varying gimbal angle
 - Processing fits variation as a function of observing geometry in the central scan and accompanying EPF segments
 - Data is normalized to minimum emission angle
- Cross-track brightness variations (optical artifact)
 - Fits cross-track variations using a function constrained in form to follow spectral smile
 - Data is normalized to center of the FOV

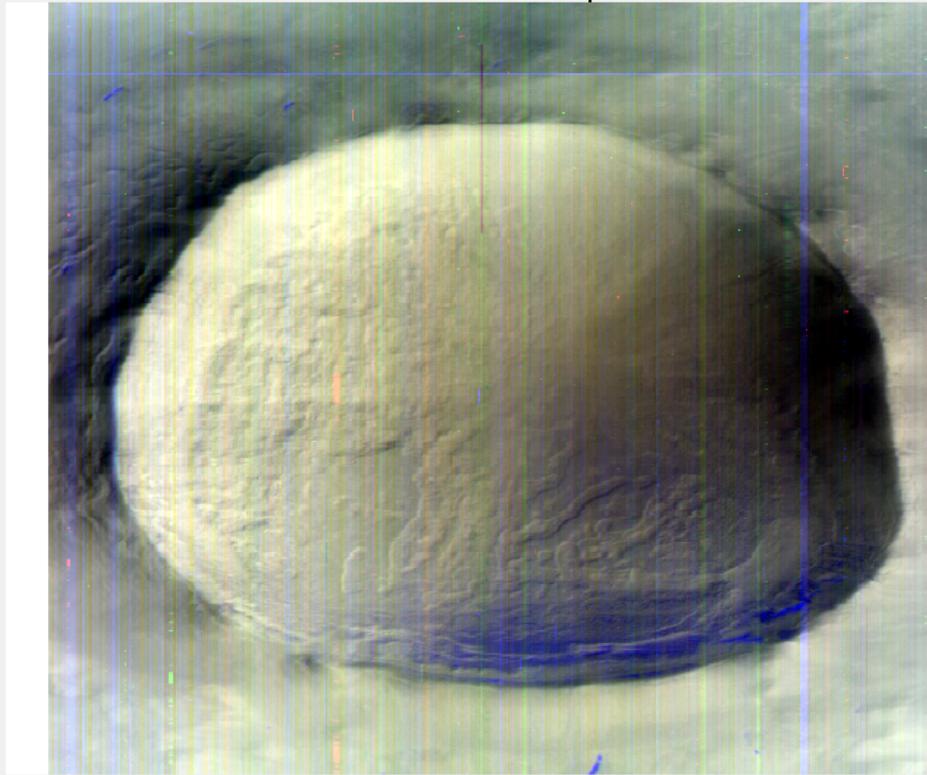
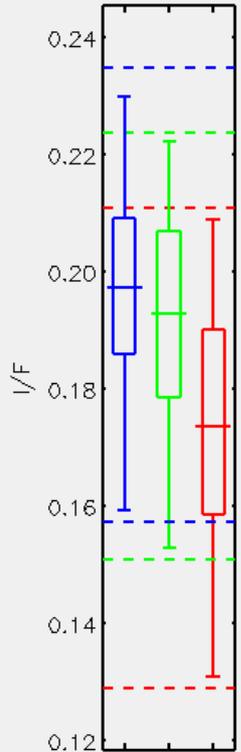




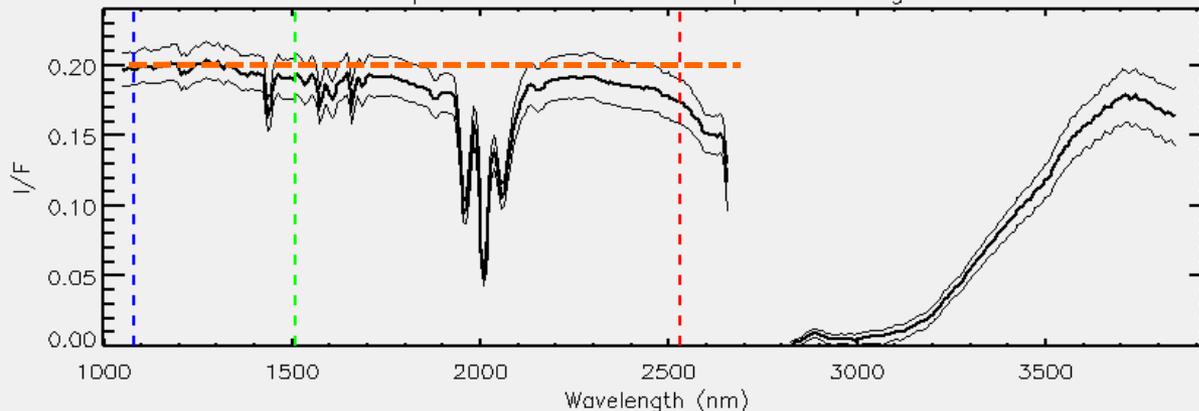
CRISM Data Processing Progression: Heimdal



FRT00017709 CRISM IR Composite



Spectral Median & Interquartile Range



TRR2

Current I/F PDS deliverable

False color IR RGB composite;
 0.5% linear stretch on each
 displayed band; spectral
 median plot with
 interquartile envelope and
 RGB wavelengths indicated;
 boxplots show data
 distribution of RGB bands

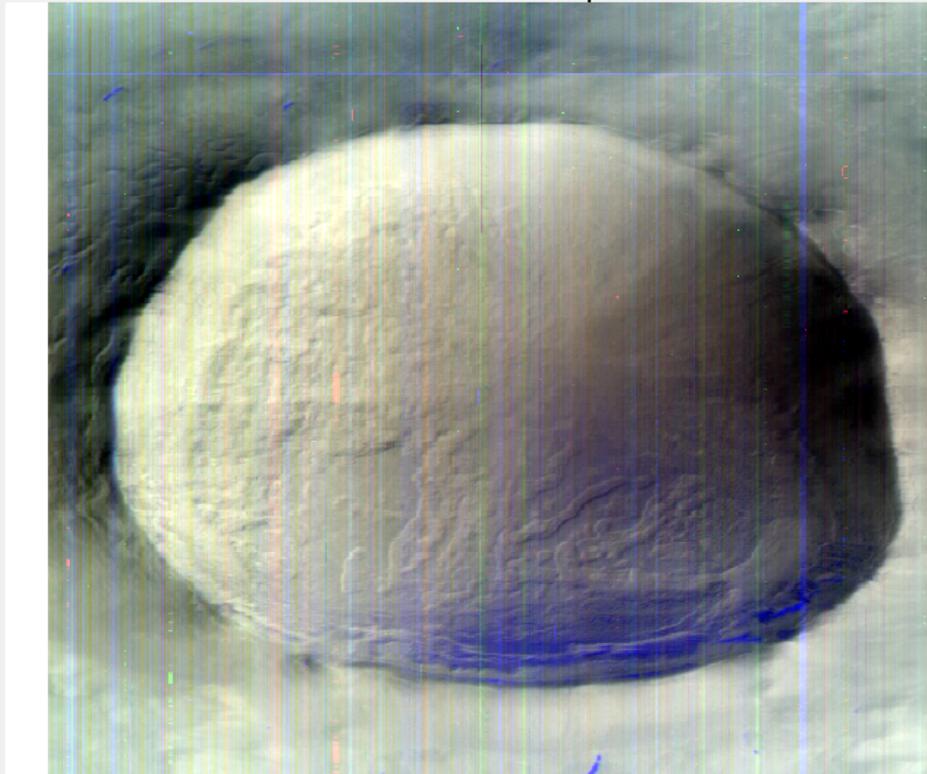
Note IR spectral slope and
 noise components



CRISM Data Processing Progression: Heimdal



FRT00017709 CRISM IR Composite

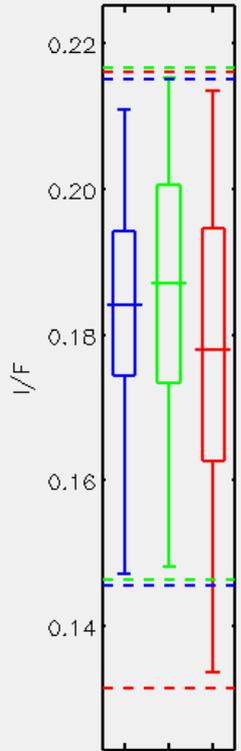


TRR3 – Unfiltered

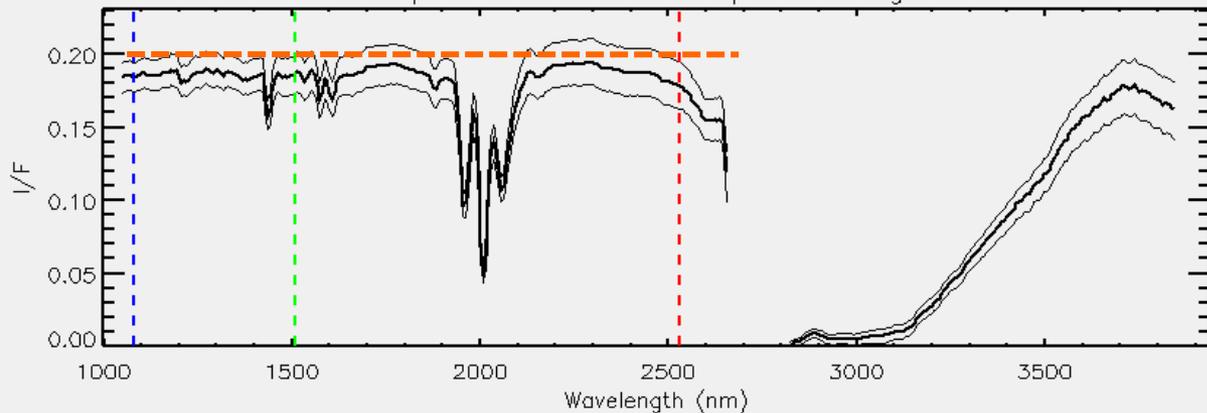
Spectral artifact at $< 1.7 \mu\text{m}$ corrected

Improved flat-field

Minor change to systematic noise component; stochastic component effectively unchanged

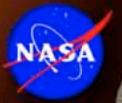


Spectral Median & Interquartile Range

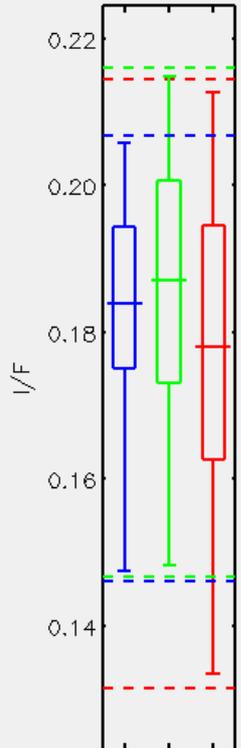
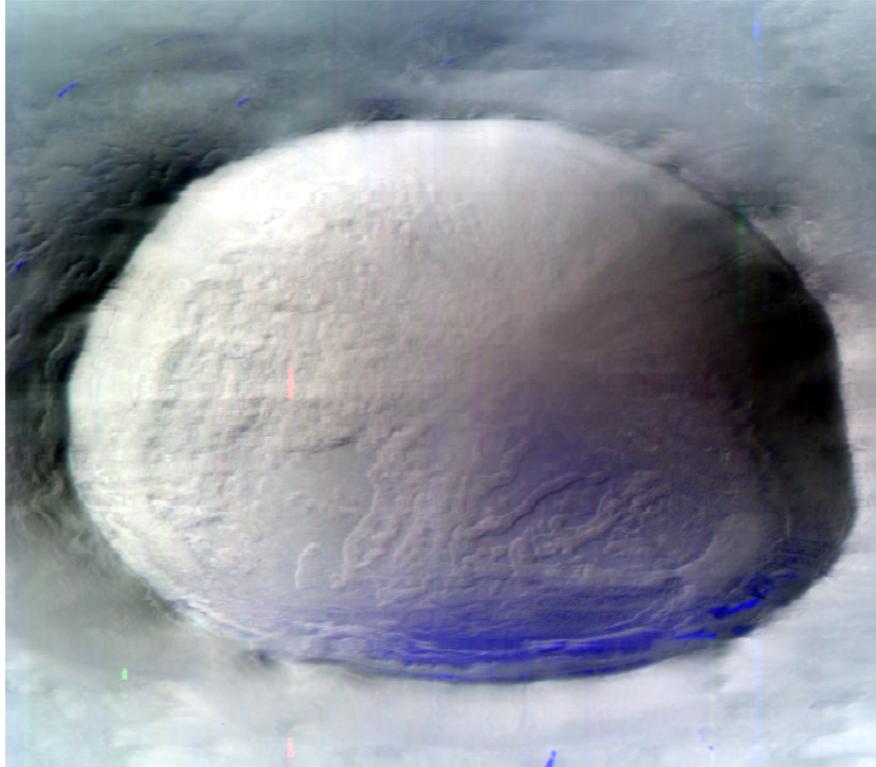




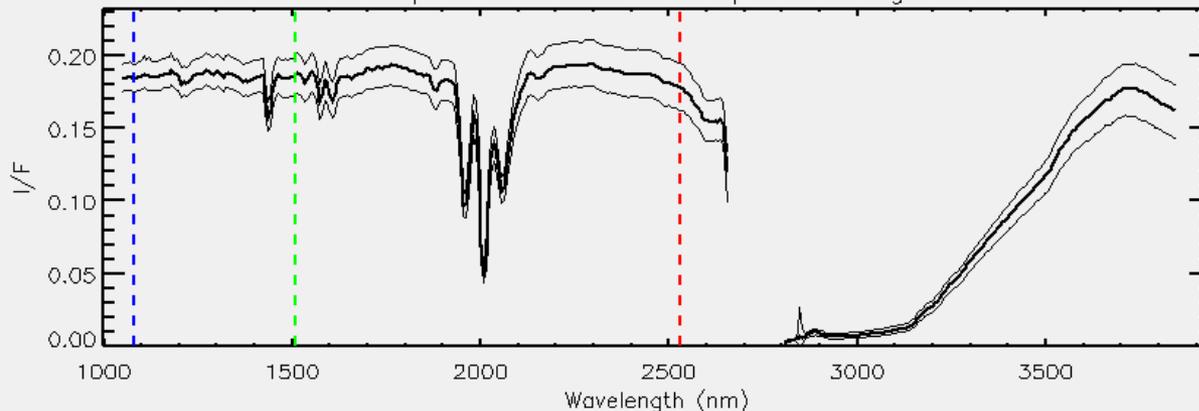
CRISM Data Processing Progression: Heimdal



FRT00017709 CRISM IR Composite



Spectral Median & Interquartile Range



TRR3 – Filtered

Systematic and stochastic noise removed - spectral shape intact

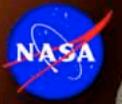
TRR3 I/F PDS deliverable

Prototype TRR3 data for MSL candidate landing sites available as an early release

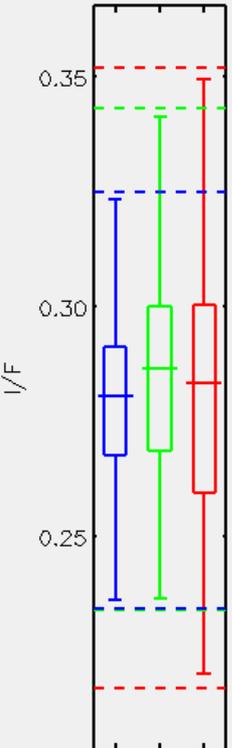
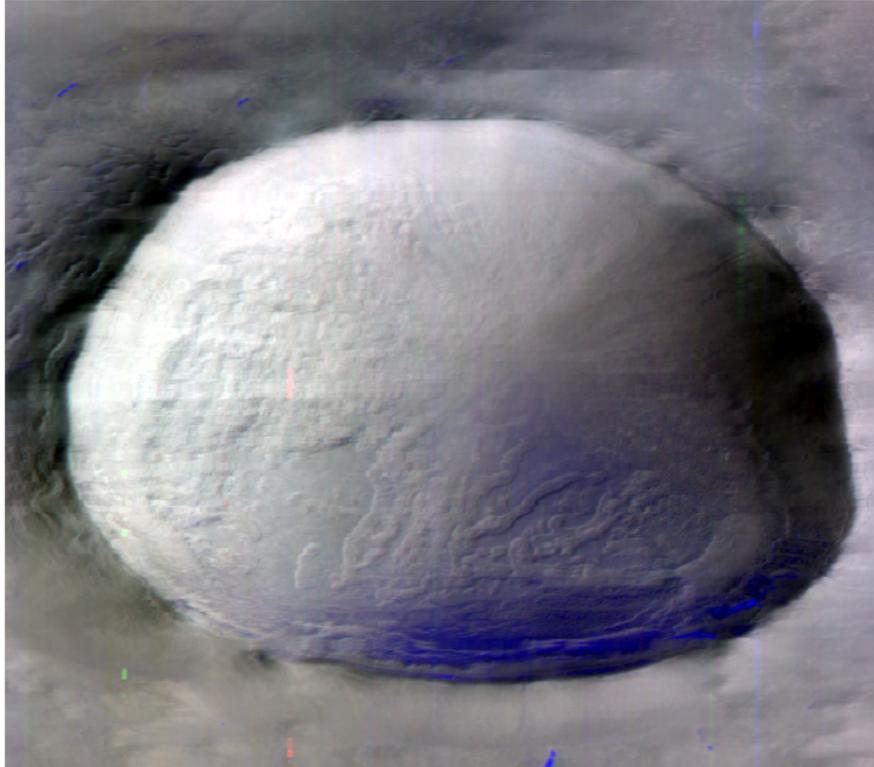
Note photometric effects at the top and bottom of the scene



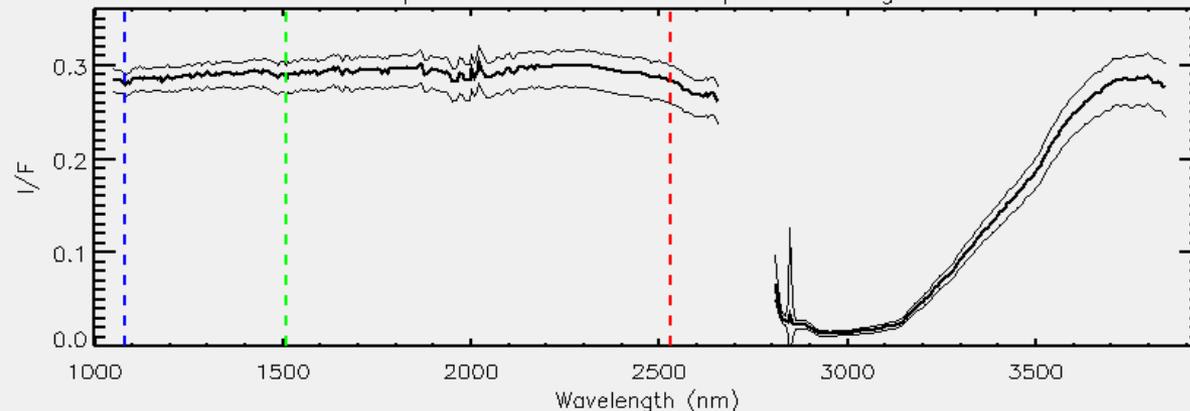
CRISM Data Processing Progression: Heimdal



FRT00017709 CRISM IR Composite



Spectral Median & Interquartile Range



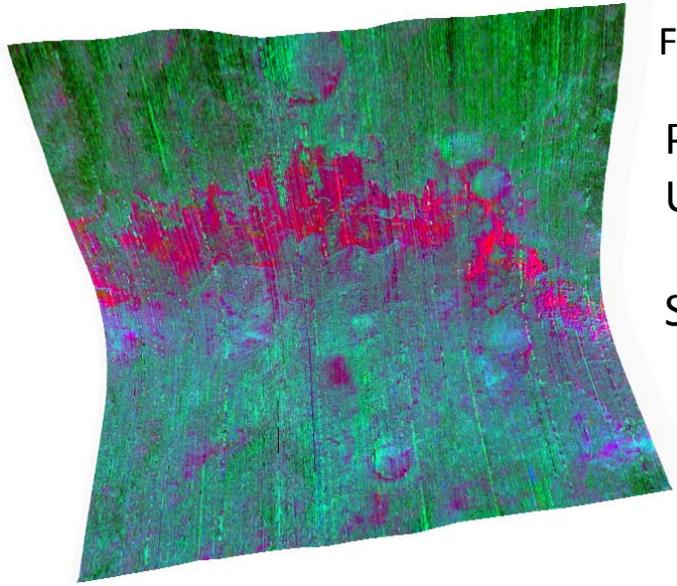
TRR3 – Filtered & Corrected

Simple photometric ($\cos(i)$) and atmospheric (“volcano scan”) corrections

Empirical normalization of the data to the minimum sampled emission angle observing geometry

Empirical spectral smile residual correction

Corrected data used in the calculation of spectral summary parameters and browse products

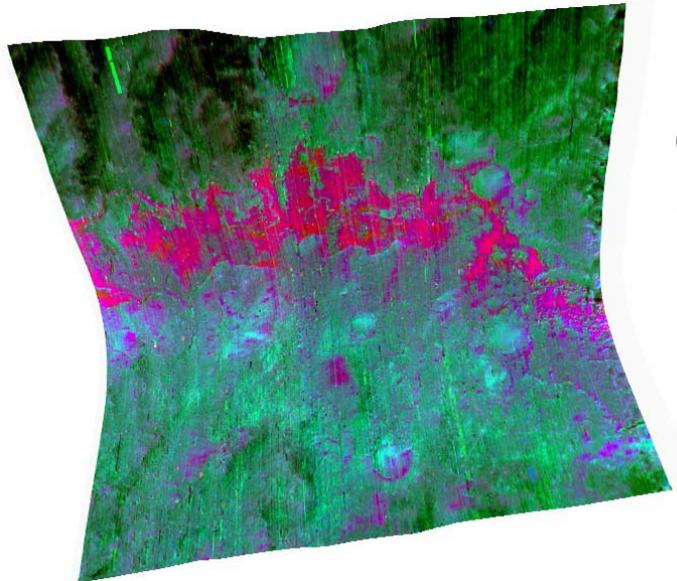


FRT00007D87 - TRR2

Previous:

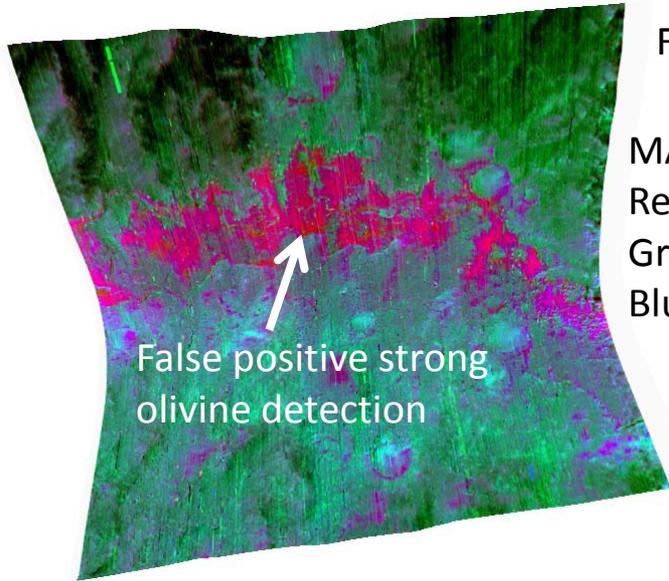
Use only 72 channels present in both multispectral and hyperspectral data for spectral parameter calculation
Spectral noise propagated into parameter

MAF -
Red: OLINDEX
Green: LCPINDEX
Blue: HCPINDEX



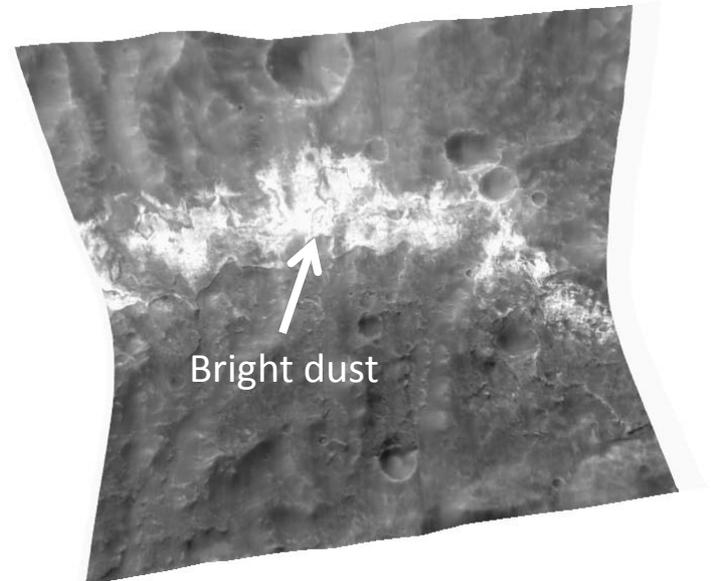
Current:

Evaluate spectral data in channels near wavelengths used in parameter calculations
Mitigates propagation of spectral artifacts

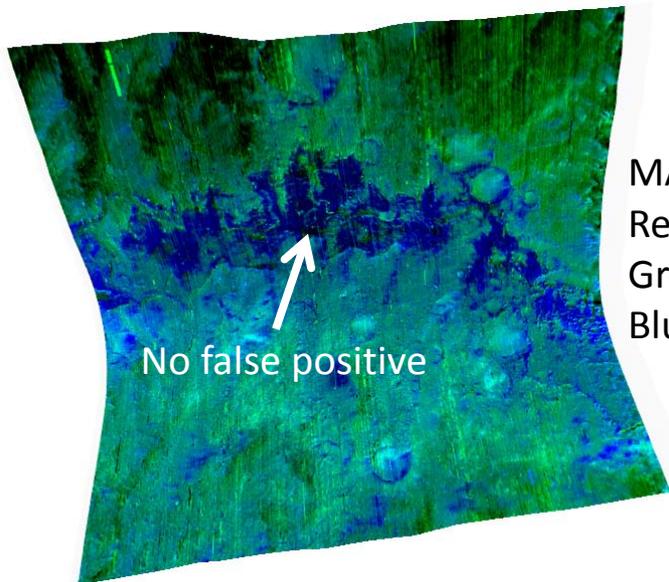


FRT00007D87 - TRR2

MAF (previous) -
Red: OLINDEX
Green: LCPINDEX
Blue: HCPINDEX



IRA - Corrected brightness at 1.3 μm



MAF (current) -
Red: OLINDEX2
Green: LCPINDEX
Blue: HCPINDEX

OLINDEX2 – Mitigates spectral continuum effects in parameter calculation

CRISM Web Site

http://crism.jhuapl.edu/development/msl_land

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CRISM Web Site

CRISM

Compact Reconnaissance Imaging Spectrometer for Mars

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MRO CRISM - MSL Landing Site Selection

This web site contains browse versions of CRISM hyperspectral, targeted observations of the four finalist candidate MSL landing sites, and links to the hyperspectral data. CRISM observations shown here have been newly reprocessed to include several upgrades from previous version of the data:

- Calibration has been upgraded to correct most systematic instrumental artifacts (the data are "TRR3s", replacing earlier "TRR2s");
- An iterative kernel filter has been applied to IR data to mitigate semi-random artifacts due to pixels with elevated noise levels;
- A correction has been applied for effects within individual observations resulting from systematic instrument optical characteristics uncorrected by radiometric calibration;
- The [emission phase function accompanying each targeted observation](#) has been used to model scattering effects of atmospheric aerosols, and normalize all parts of each observation to the nearest-to-nadir geometry present within the observation; and
- "Browse" version of the data have been modified to minimize effects of solar illumination and shadows, and new informative products have been added

Contents:

- (1) [MRO Support of MSL Landing Site Selection](#)
- (2) [An Overview of CRISM Observations of the Candidate MSL Landing Sites](#)
- (3) [An Overview of CRISM Browse Images of Candidate MSL Landing Sites](#)
- (4) [Interpreting the Browse Products](#)
- (5) [Links to CRISM Browse Images of Candidate MSL Landing Sites](#)
- (6) [Additional Resources](#)

(1) MRO Support of MSL Landing Site Selection:

The [MRO](#) project and the [CRISM](#), [HIRISE](#), and [CTX](#) science and operations teams support the [MSL landing site selection process](#) through the acquisition of high resolution panchromatic, color, and hyperspectral orbital remote sensing data. The [first MSL landing site selection workshop](#) was held in May, 2006. At that workshop [30+ candidate landing sites](#) were proposed by the Mars science community. Following the [second MSL landing site selection workshop](#) in October 2007, the number of sites considered was reduced to [10 sites](#). The [third landing site selection workshop](#) was held in September 2008, following which the list was narrowed to 7 sites. The list was further narrowed to 4 finalists based on engineering considerations:

- [Holden crater](#) (contains a deltaic deposit whose lower beds contain phyllosilicate minerals)
- [Eberswalde crater](#) (contains another deltaic deposit whose lower beds contain phyllosilicate minerals)
- [Gale crater](#) (contains an interior sedimentary deposit grading upward from phyllosilicate- to sulfate-containing beds)
- Plains surrounding [Mawrth Vallis](#) (covered by a deposit with interbedded Fe/Mg phyllosilicates, Al-phyllosilicates, silica, and ferric minerals)

(2) An Overview of CRISM Observations of the Candidate MSL Landing Sites:

The characteristics of the [standard CRISM hyperspectral targeted observations](#) covering MSL landing sites are listed below.

New MSL candidate landing site CRISM browse products

Brief explanation of systematic data processing

Product overview

CRISM Web Site

http://crism.jhuapl.edu/development/msl_land

Most Visited

CRISM Web Site

example, IR_PHY and IR_HYD can have bluish colors due to spectral effects of water ice hazes. Illumination geometry or atmospheric dust and ice hazes can create artifacts in VNIR_FEM, IR_MAF, IR_PHY, and IR_HYD. IR_PHY and VNIR_FM2 are most susceptible to detector artifacts.

More detailed information is available on:

- [Interpreting the Browse Products](#)
- [Visible and Near-infrared \(VNIR\) Browse Products](#)
- [Infrared \(IR\) Browse Products](#)

An excellent reference describing the underlying parameters used in constructing browse products is:

Pelkey, S. M., J. F. Mustard, S. Murchie, R. T. Clancy, M. Wolff, M. Smith, R. Milliken, J.-P. Bibring, A. Gendrin, F. Poulet, Y. Langevin, and B. Gondet, CRISM multispectral summary products: Parameterizing mineral diversity on Mars from reflectance, J. Geophys. Res., 112, E08S14, doi:10.1029/2006JE002831, 2007.

(5) Links to CRISM Browse Images of Candidate MSL Landing Sites

Click on the name of a site below to see locations of CRISM images covering it or to view the high resolution browse images.

SITE NAME	LOCATION	ELEVATION	KEY FEATURES
Holden Crater	26.37°S, 325.10°E	~1.9km	Fluvial layers, phyllosilicates
Eberswalde Crater	23.86°S, 326.73°E	~1.5km	Delta
Gale Crater	4.49°S, 137.42°E	~4.4km	Layered Sulfates, Phyllosilicates
Mawrth Vallis	24.01°N, 341.03°E	~2.2km	Noachian Layered Phyllosilicates

(6) Additional Resources:

[CRISM Home Page](#)

[HiRISE MSL Image Catalog](#)

[MARSOWEB](#)

[THEMIS support for MSL landing site selection](#)

MSL Landing Site Selection Committee Contacts:

Contact	Role
M. Golombek	Mars Landing Site Steering Committee Co-Chair
J. Grant	Mars Landing Site Steering Committee Co-Chair

CRISM MSL Landing Site Selection Contacts:

Contact	Role
S. Murchie	CRISM PI
J. Mustard	CRISM Deputy-PI; MSL Landing Site Selection Committee Member

http://crism.jhuapl.edu/
msl_landing_sites/



Detailed information on the browse products, parameter stretches, products interpretation, and caveats

Click on the site name to access product the library

CRISM Web Site

http://crism.jhuapl.edu/development/msl_land

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CRISM Web Site

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[Return to Candidate MSL Landing Sites List >](#)

MSL Landing Site Selection - Mawrth Vallis

FRT00003BFB - FRT000094F6 FRT000096DA - FRT0000A600 **FRT0000A955 - FRT0000B3B6** FRT0000B643 - FRT0000C18E FRT0000C596 - FRT000119DC FRT00012D3C - FRT00017229

FRT0001763B - FRT00019F4E HRL0000285A - HRL00011CCD HRS0000307A - HRS00018EB8 Mosaics

FRT0000A955 FRT0000AB94 FRT0000AC83 FRT0000AD81 FRT0000B141 FRT0000B273 FRT0000B3B6

Context Image

Observation Quality

[IR detector temperature \(left\) and atmospheric opacity \(right\)](#)

Composite VNIR Images

VNIR_RGB

Enhanced visible color

red = 592 nm
green = 533 nm
blue = 442 nm

[View Details](#) [View Details](#) [View Details](#) [View Details](#) [View Details](#) [View Details](#) [View Details](#)

http://crism.jhuapl.edu/
msl_landing_sites/

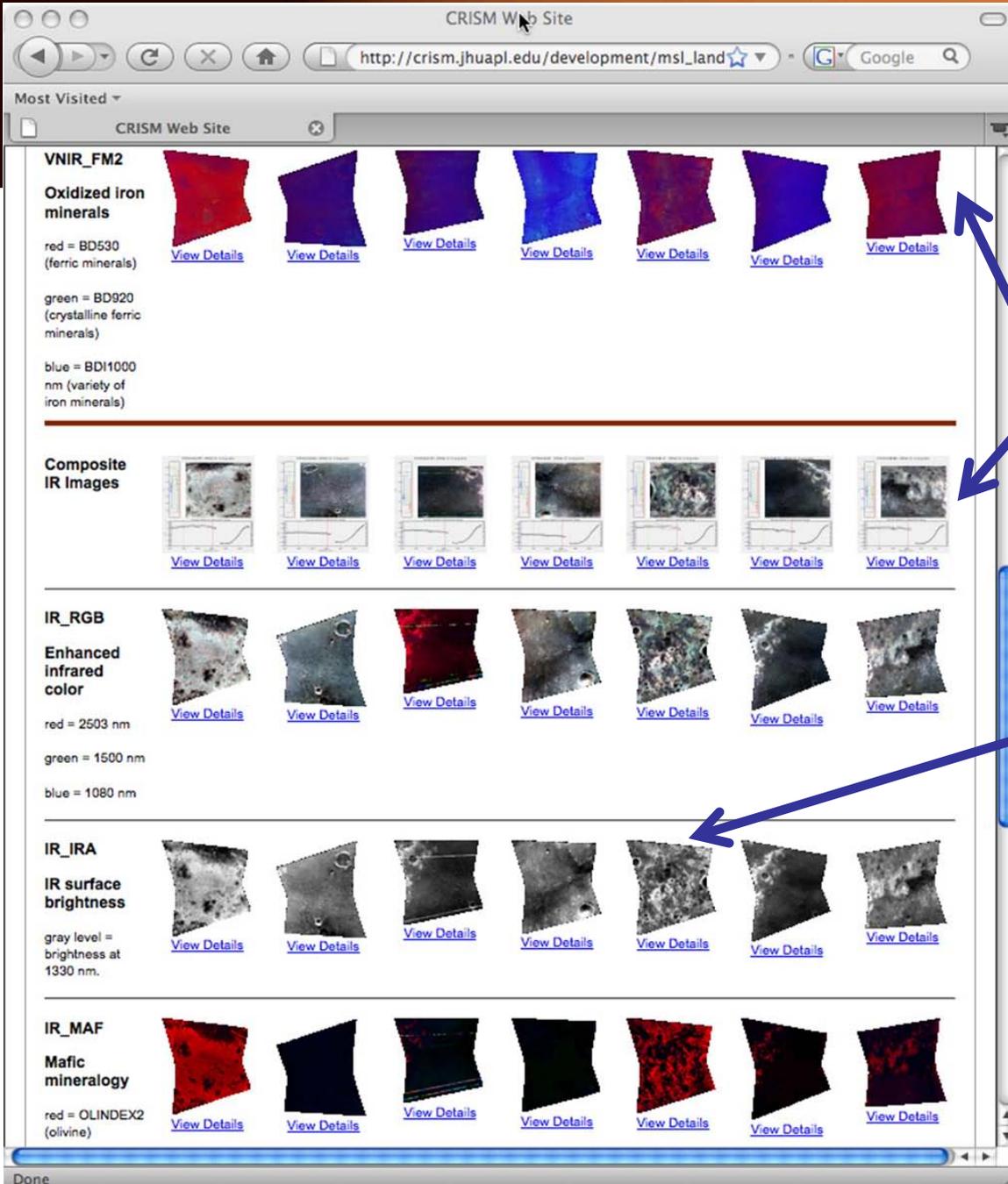


Observations organized into tabs by type and time order

1 column = 1 observation

1 row = 1 product type

Data quality metrics –
IR detector temperature
Atmospheric opacity



http://crism.jhuapl.edu/msl_landing_sites/



Each product type emphasizes one way to visualize the observation information content: context image showing footprint, Fe minerals, mafic minerals, phyllosilicates, etc.

Click on a thumbnail to access full-resolution version

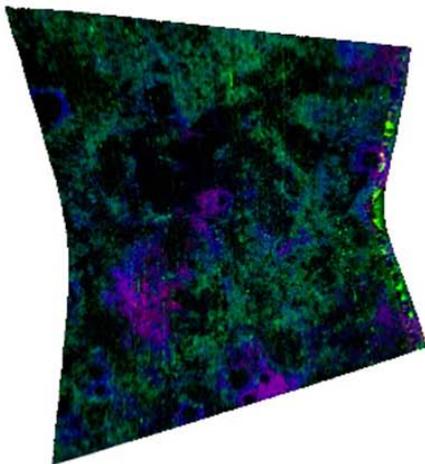
CRISM Web Site

http://crism.jhuapl.edu/development/msl_land

Most Visited

CRISM Web Site

UNIFORM STRETCH ACROSS ALL SITES



ACCESS TO MRO DATA IN THE PDS

The following links provide direct access to the PDS archive of calibrated CRISM data for this observation if the data have already been archived, as well as to CTX or HIRISE images coordinated with it.

- [VNIR image data, calibrated to units of I/F](#)
- [VNIR geometric information, in several units](#)
- [IR image data, calibrated to units of I/F](#)
- [IR geometric information, in several units](#)
- [Accompanying CRISM emission phase function data, and CTX and HIRISE coordinated images](#)

ACCESS TO PROTOTYPE TRR3 CRISM DATA

These prototype TRR3 data products are being made available prior to PDS release to support MSL landing site studies. Permission for use is for that purpose. PDS labels for TRR3 products are under development. The labels here are "PDS-compliant" labels from radiance images used to calculate I/F, and some of the label information is mismatched (e.g., units). However these labels are adequate to support ingestion of TRR3s into CAT.

- [VNIR image cube](#)
- [VNIR label](#)
- [IR image cube](#)
- [IR label](#)

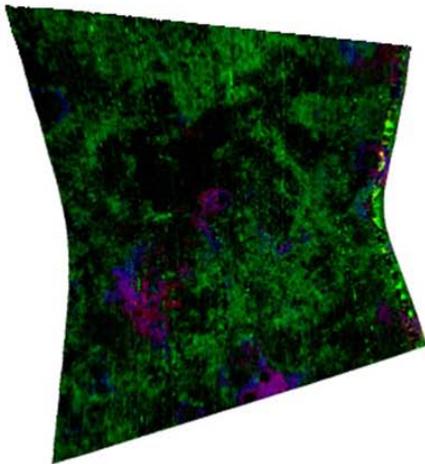
DOWNLOADS

- [Uniform Stretch PNG](#)
- [Uniform Stretch PNG w/ geo. grid](#)
- [Site Stretch PNG](#)
- [Site Stretch PNG w/ geo. grid](#)

OBSERVATION DETAILS

File	FRT0000B141_07_IF167L_TRR2.LBL
Comment	23002 Characterize surface hazards and science of possible MSL rover landing site Future Exploration/Landing Sites
Year/Day of Year	2008_166
Observation Type	FRT
Observation ID	0000B141
Image Count	

SITE STRETCH



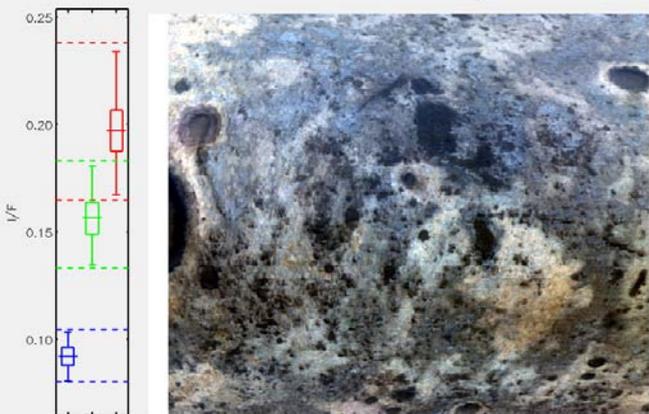
Separate 'global' and regional stretches for site-to-site comparison and to highlight local heterogeneity

Links to version of data already in the PDS (TRR2)

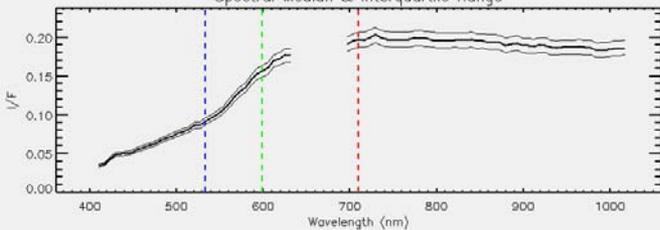
Links to early release of TRR3s

Links to full resolution versions of the browse products with and without geographic grid

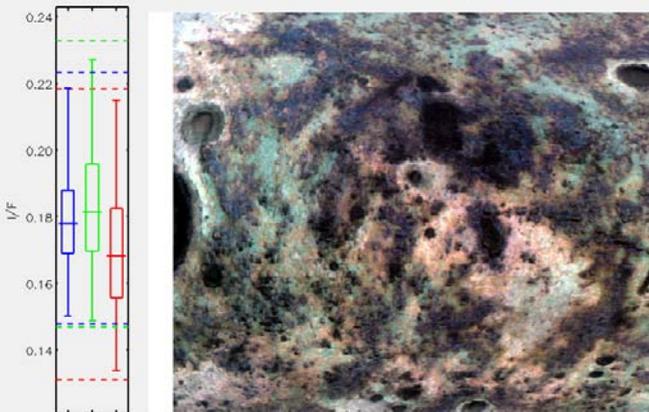
Detailed breakdown of observation and data set characteristics: lat/lon/L_s, i/e/g, lines/samples/bands, etc.



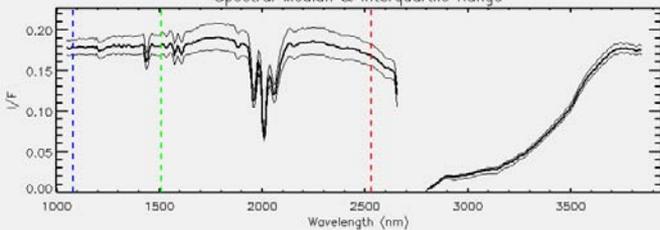
Spectral Median & Interquartile Range



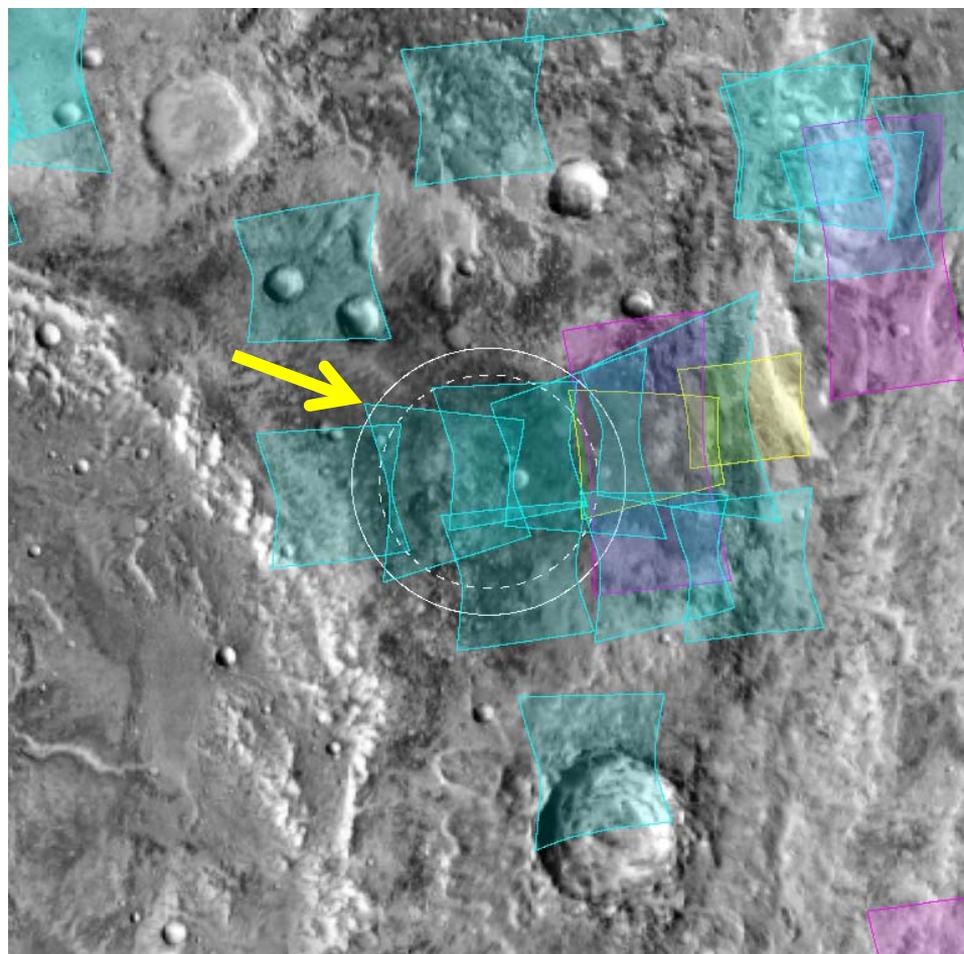
FRT0000B141 CRISM IR Composite



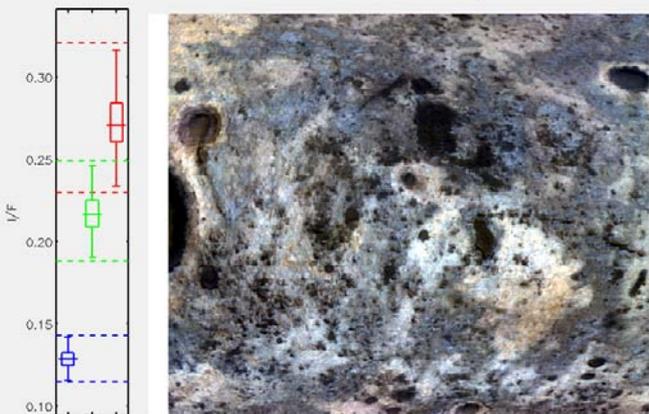
Spectral Median & Interquartile Range



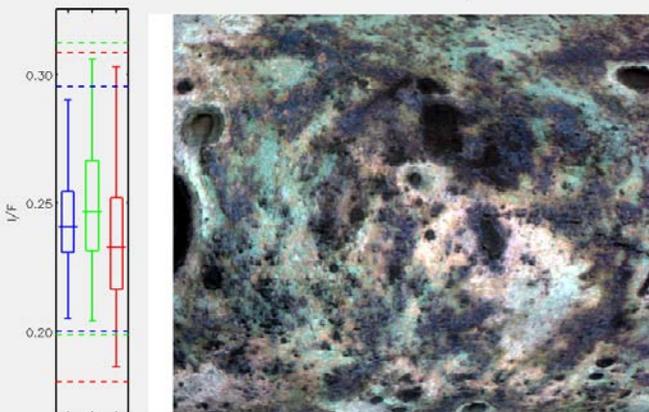
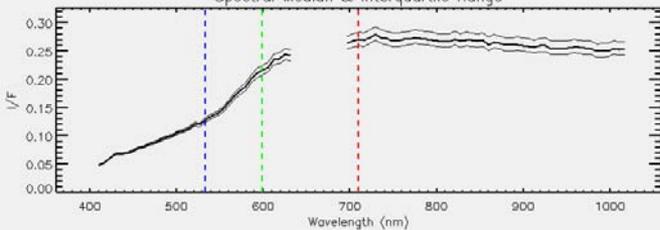
Mawrth Vallis – FRT0000B141



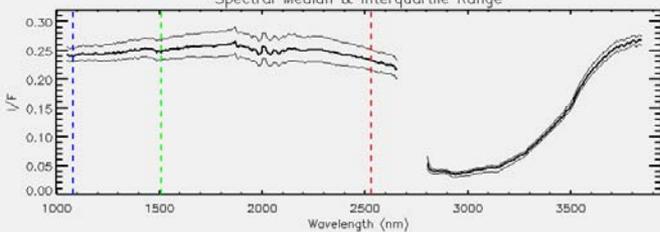
FRT
HRL
HRS



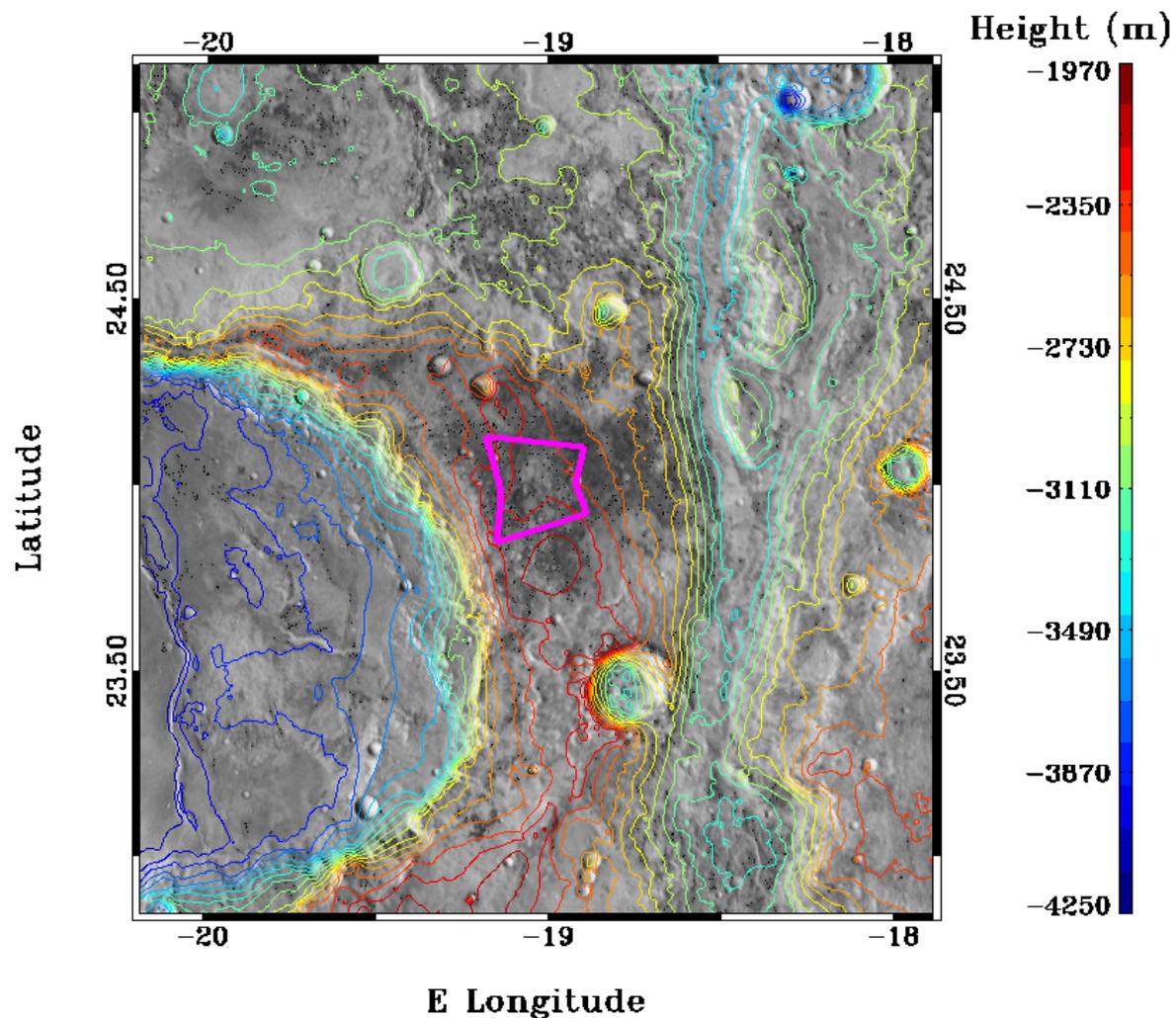
Spectral Median & Interquartile Range

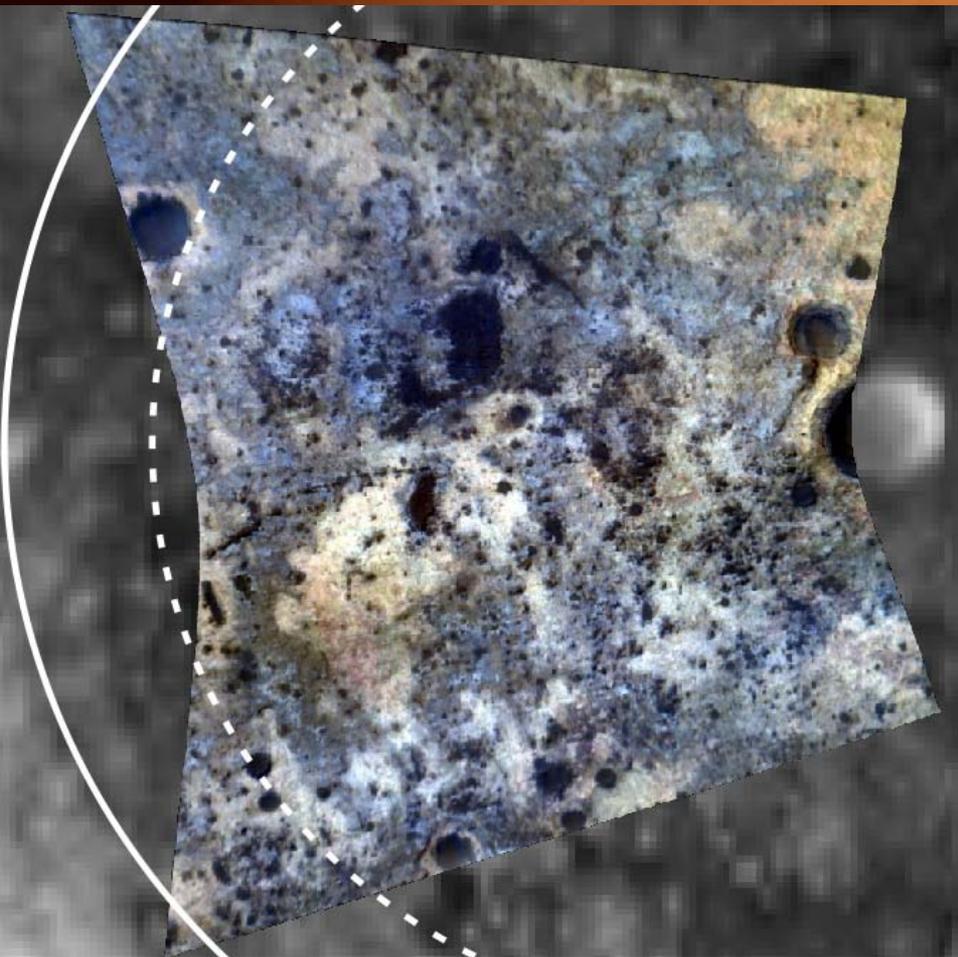


Spectral Median & Interquartile Range

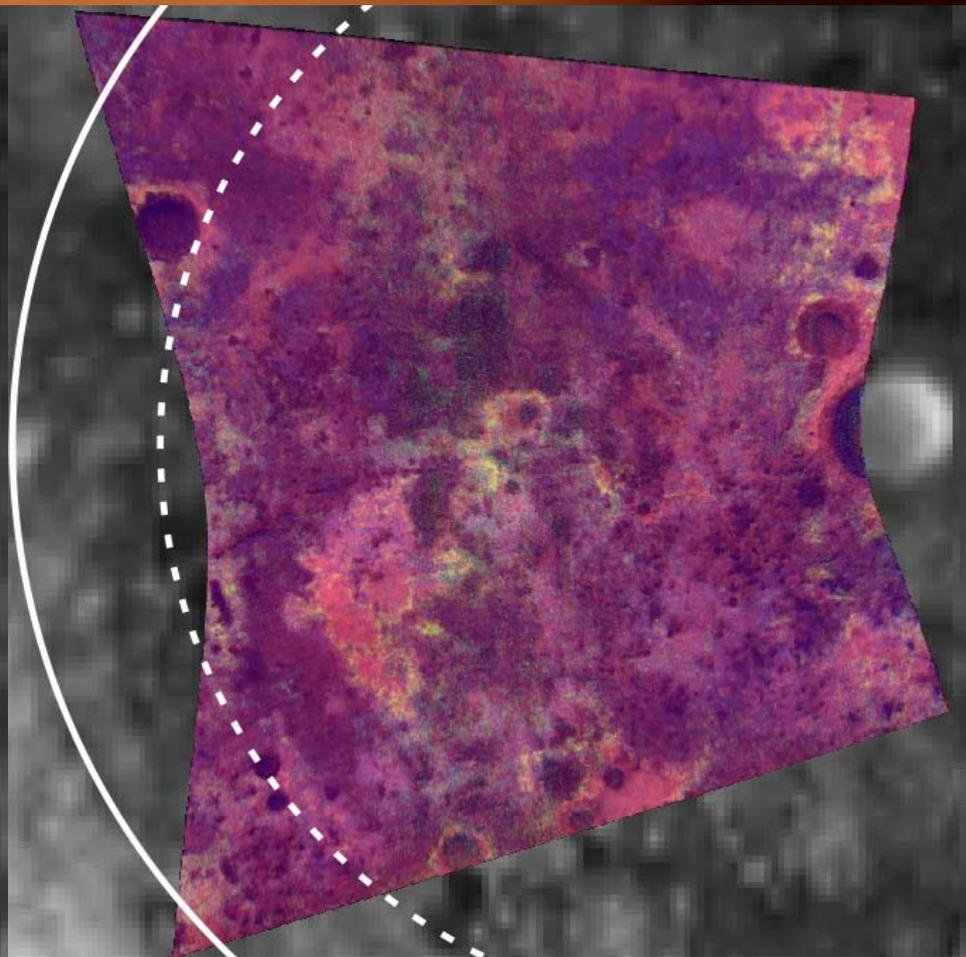


Mawrth Vallis – FRT0000B141





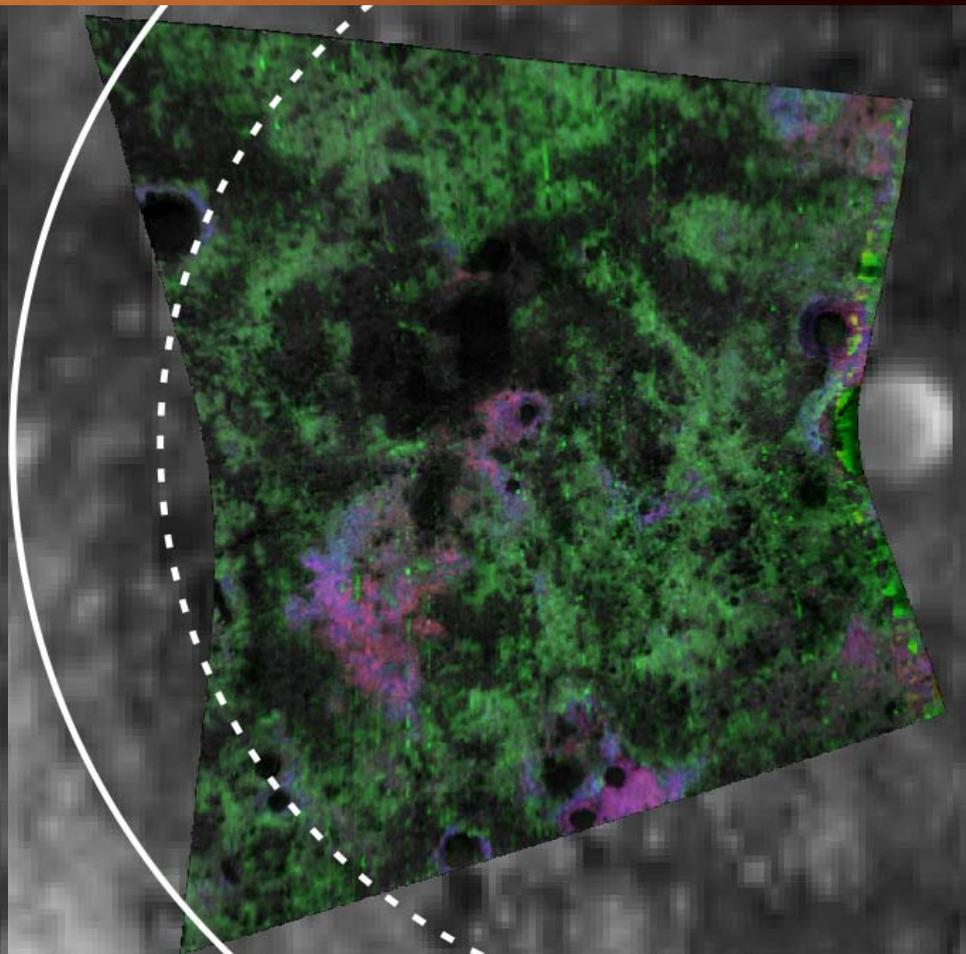
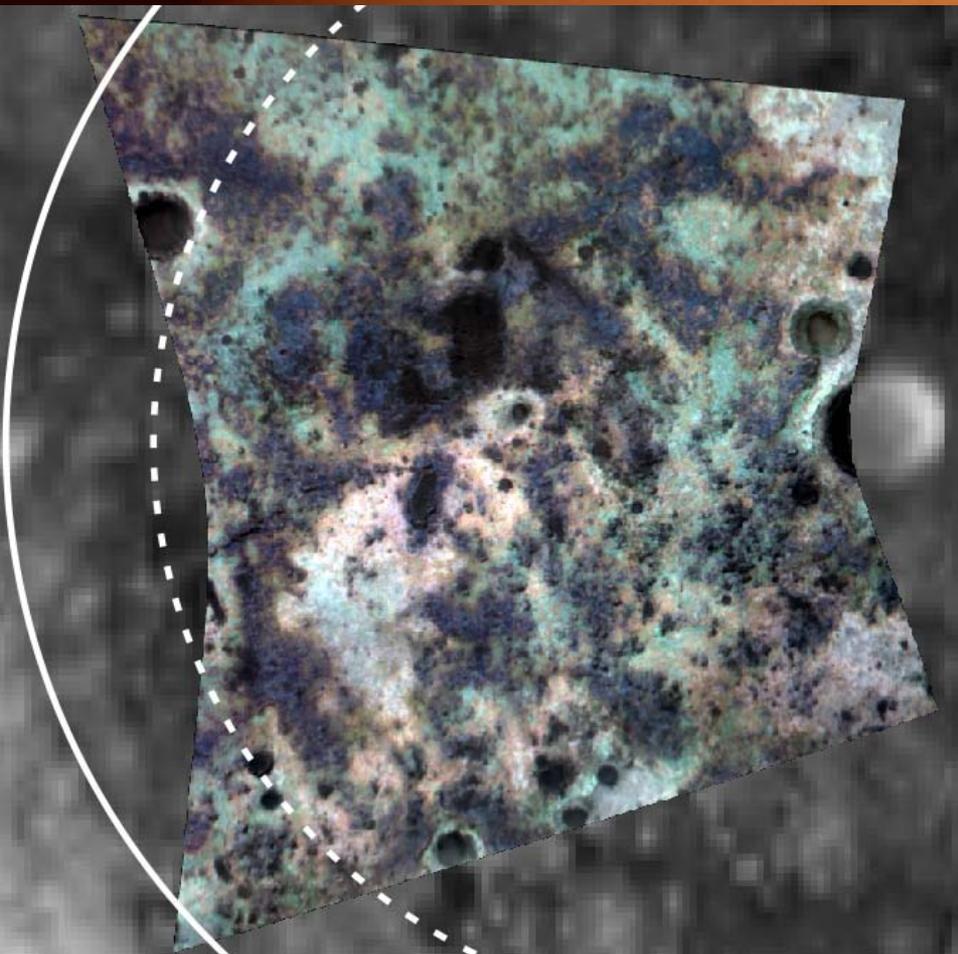
VNIR RGB



VNIR FM2

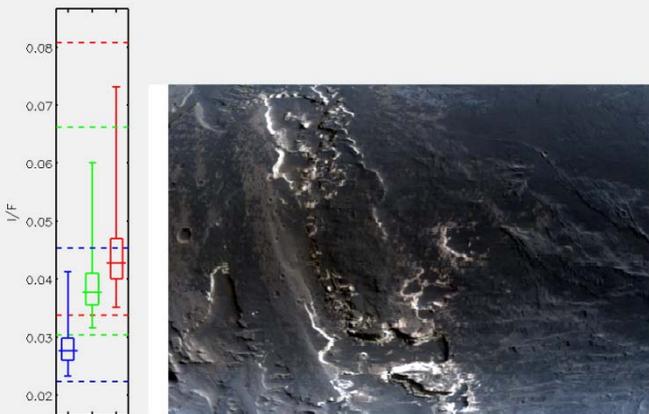
VNIR spectral variability – Fe mineralogy

R: BD530
G: BD920
B: BDI1000

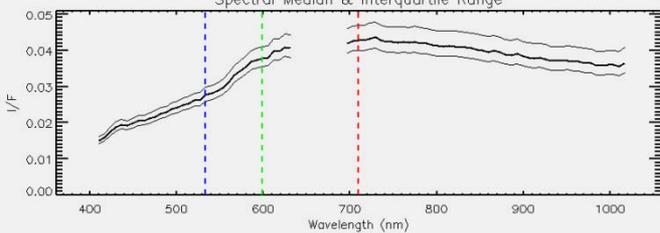


Western portion of the ellipse dominated by Al-phyllsilicate signatures

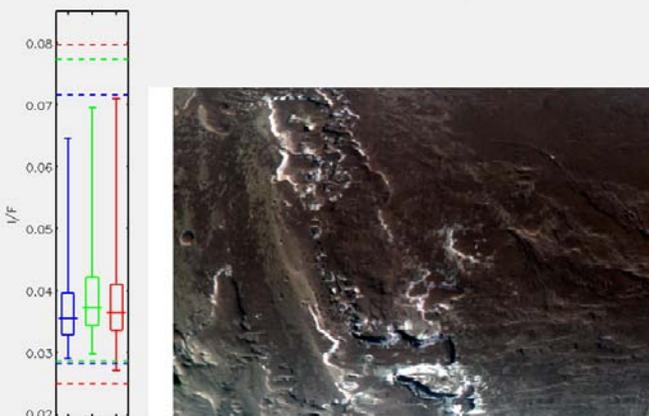
R: D2300
G: BD2210
B: BD1900



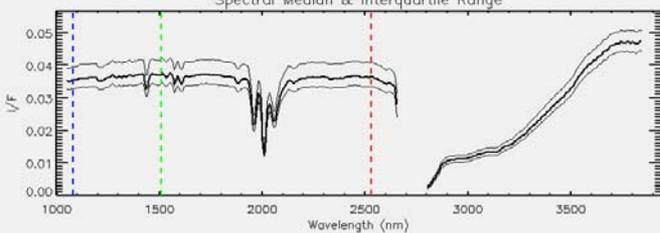
Spectral Median & Interquartile Range



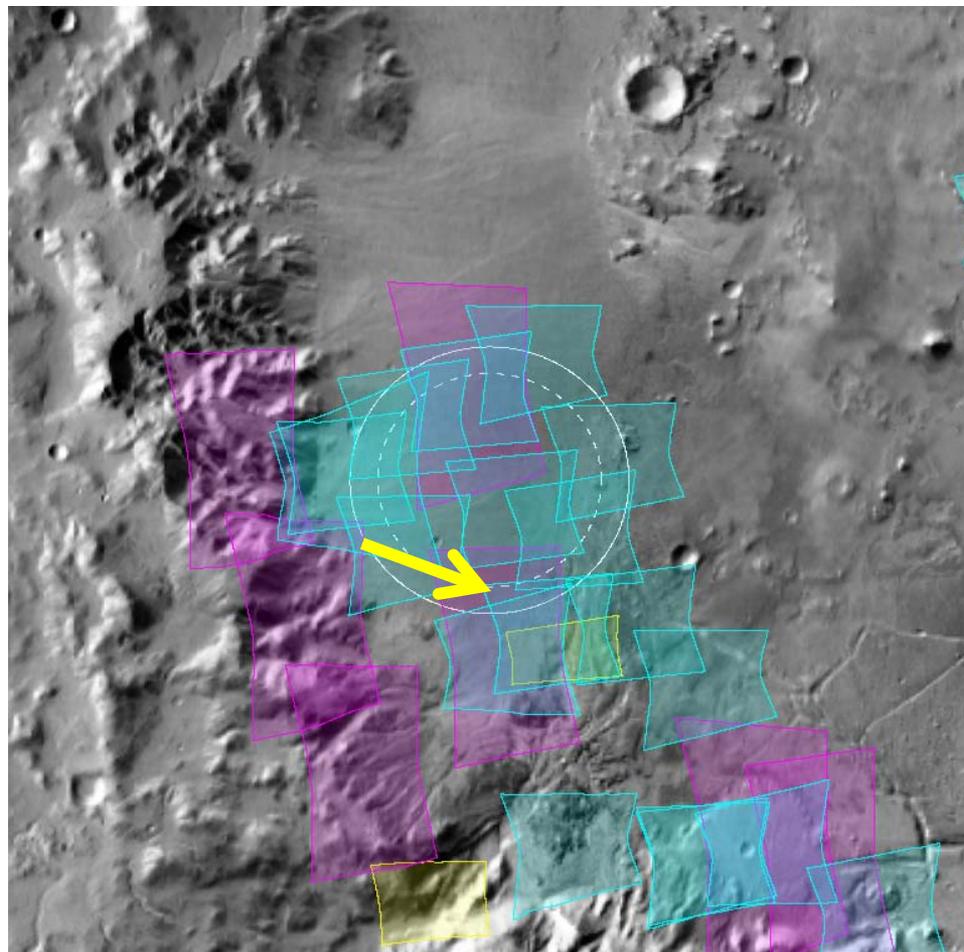
FRT0000C1D1 CRISM IR Composite



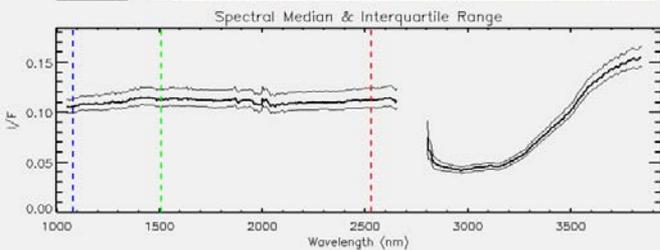
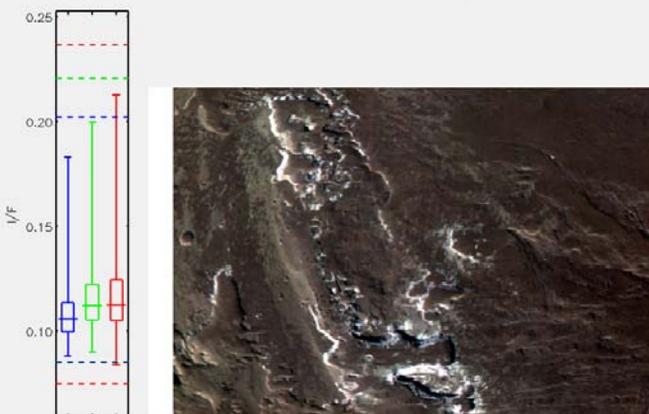
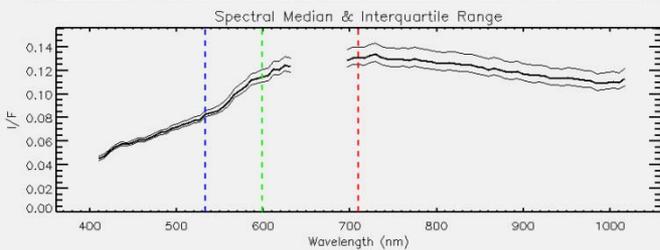
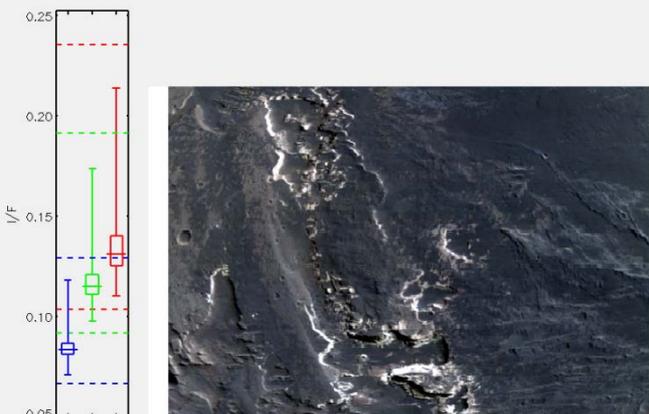
Spectral Median & Interquartile Range



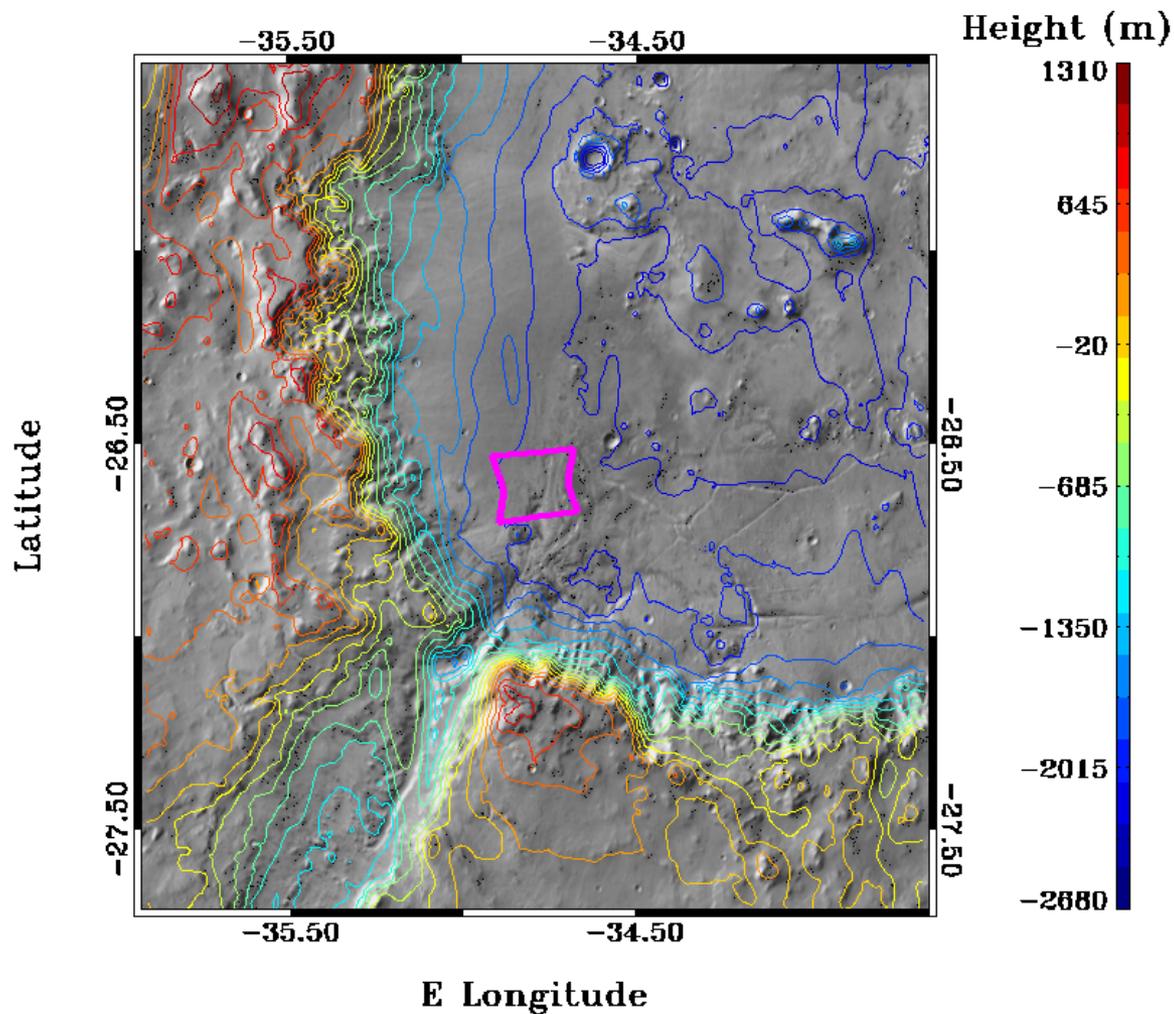
Holden Crater – FRT0000C1D1

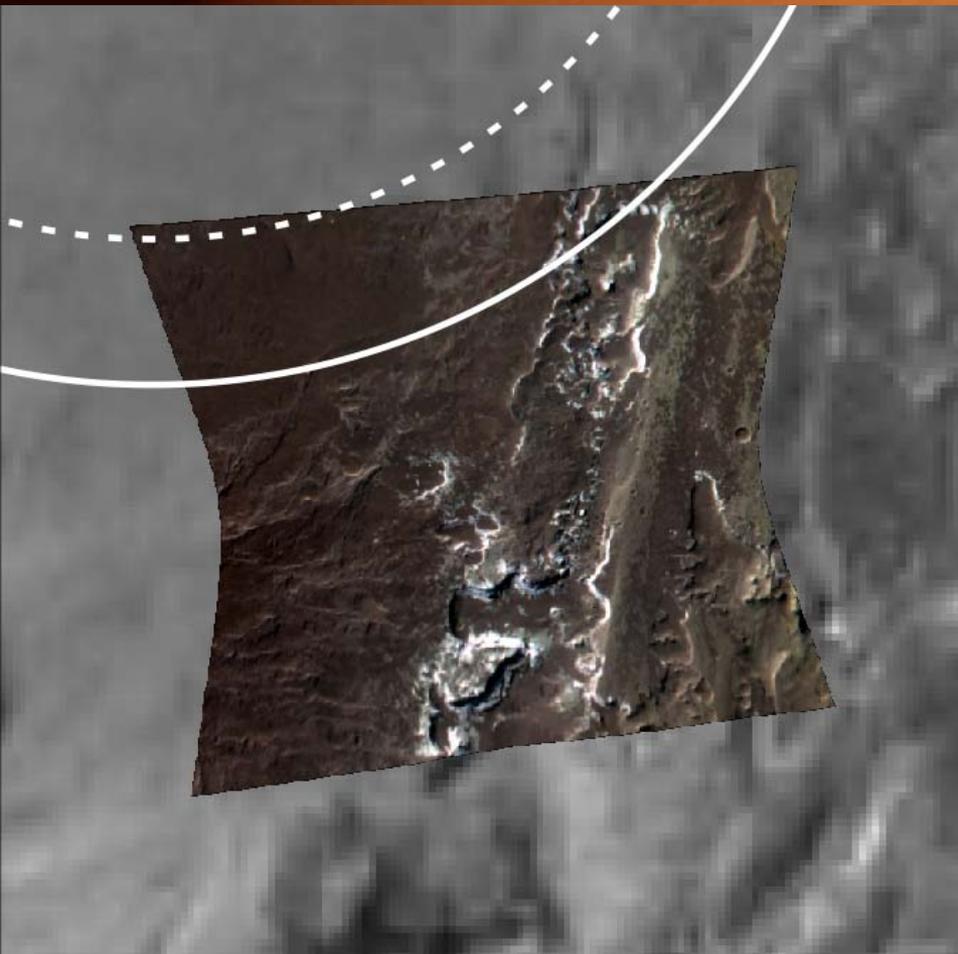


FRT
HRL
HRS

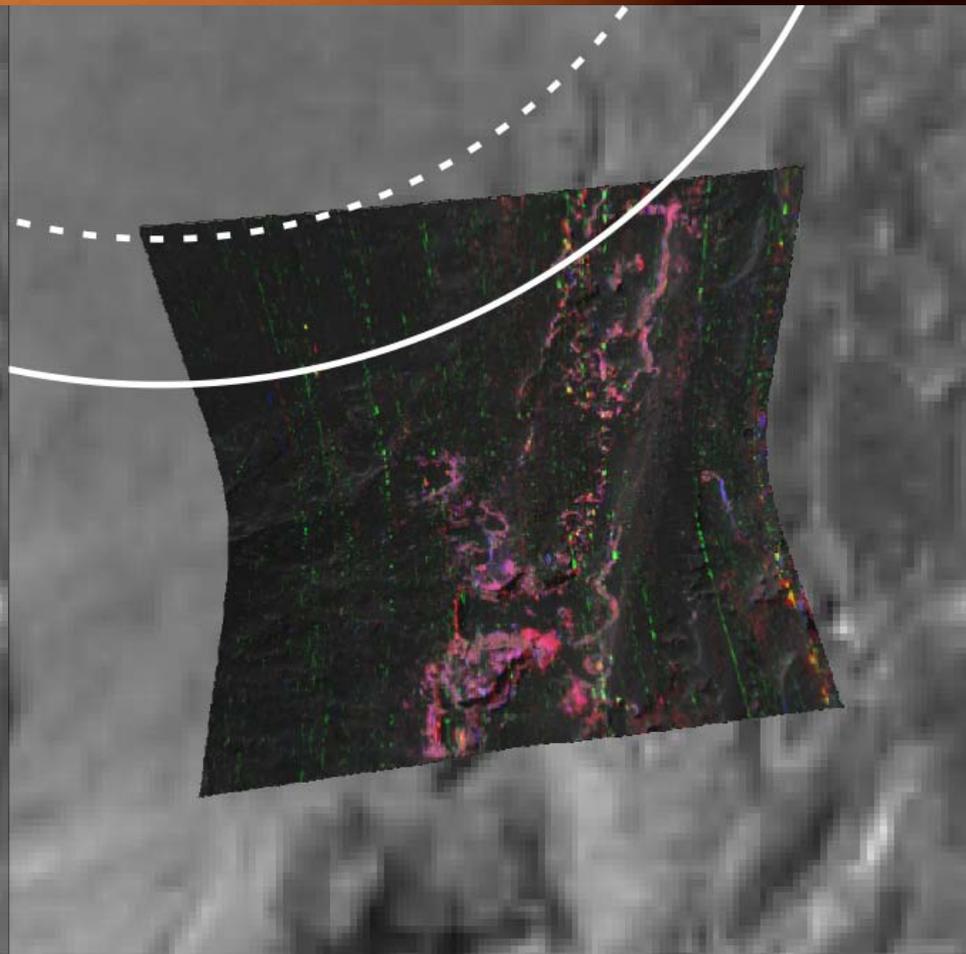


Holden Crater – FRT0000C1D1





IR RGB



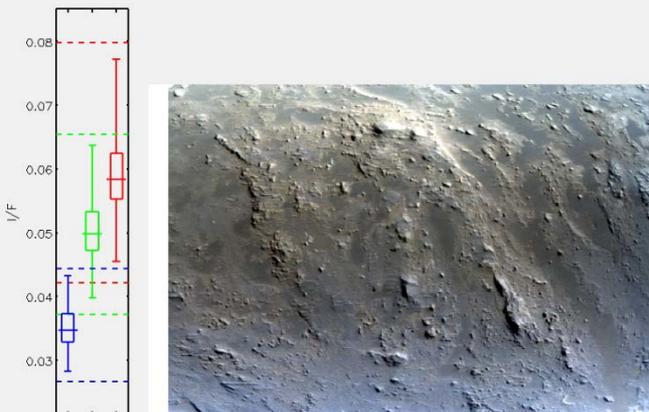
IR PHY

R: D2300

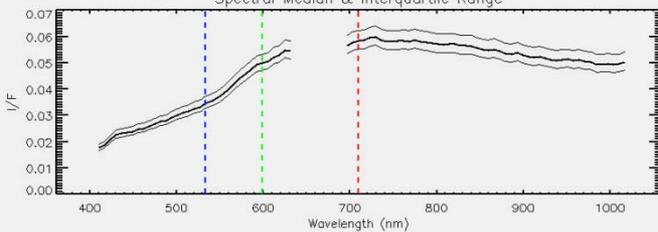
G: BD2210

B: BD1900

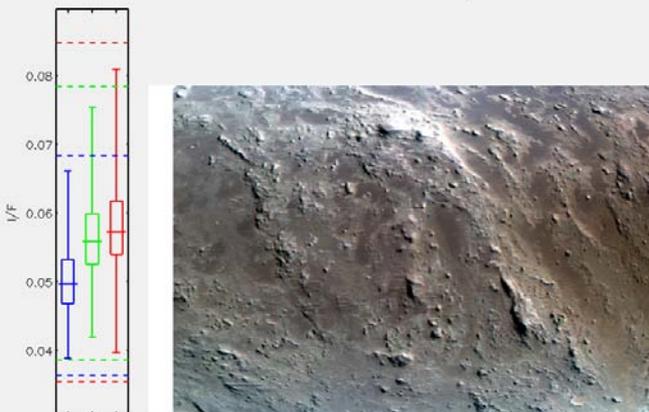
Light toned deposits in IR RGB image correspond to enhanced D2300 and BD1900 spectral indices (magenta pixels – Fe/Mg phyllosilicate) in IR PHY browse product



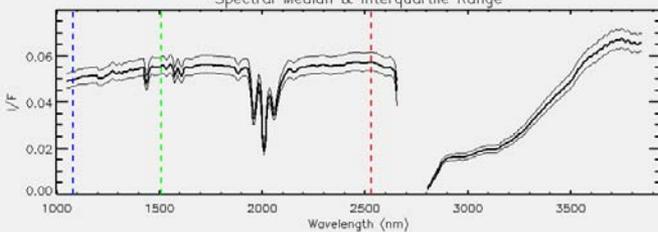
Spectral Median & Interquartile Range



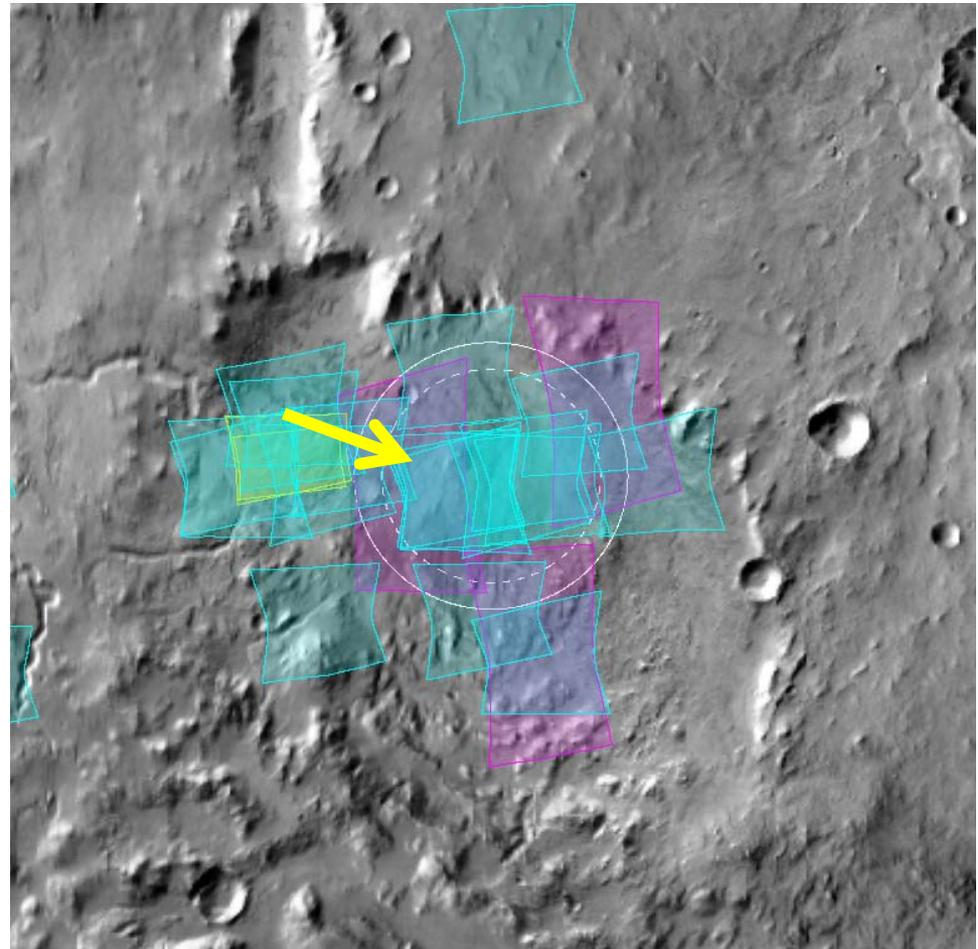
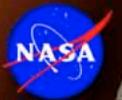
FRT0000AADE CRISM IR Composite



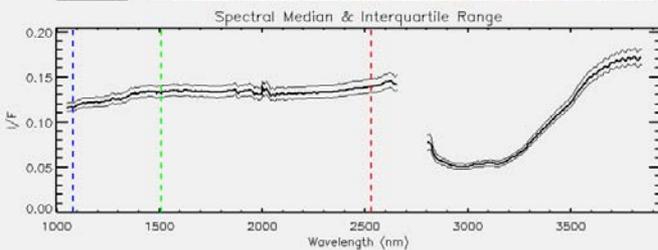
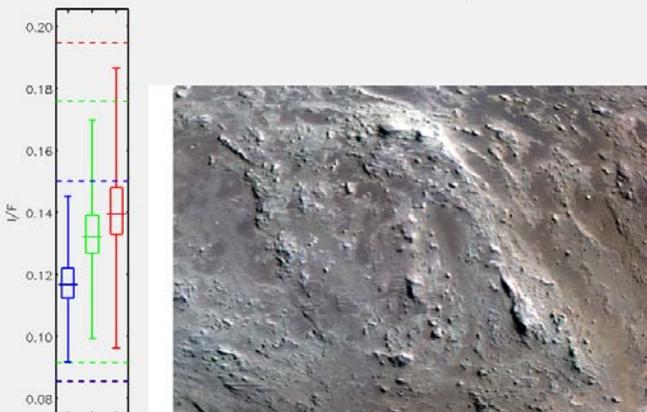
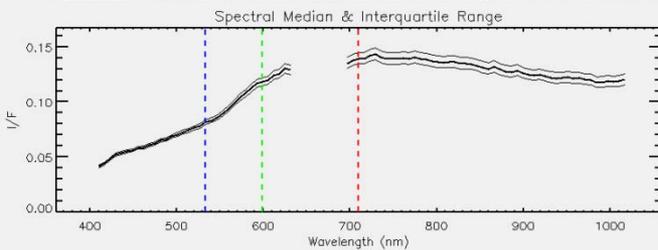
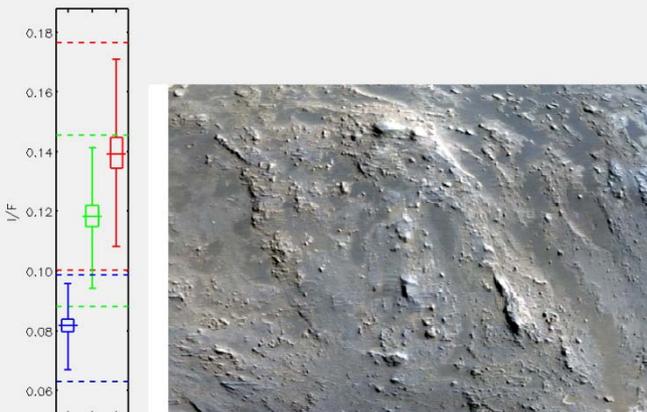
Spectral Median & Interquartile Range



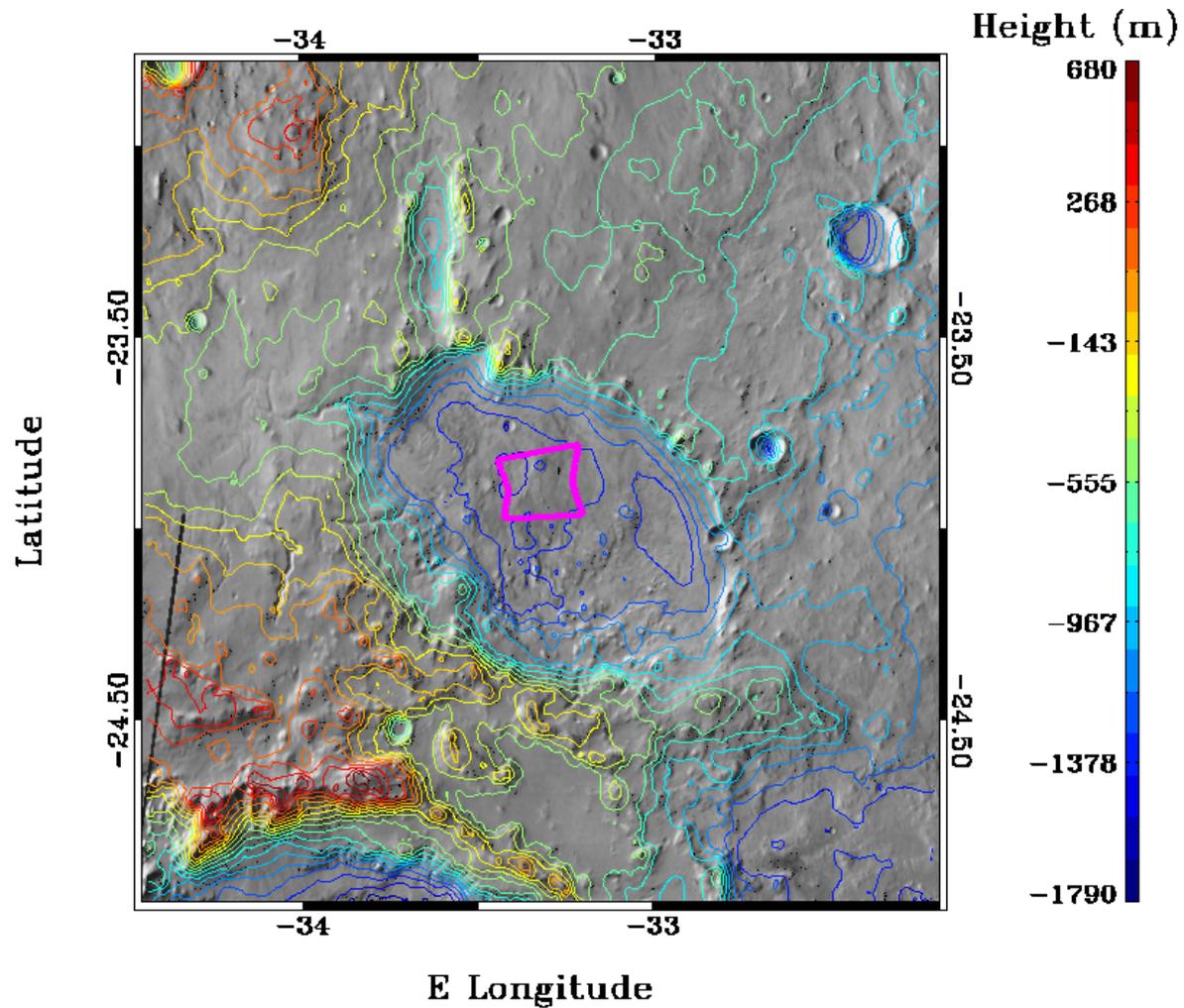
Eberswalde Crater – FRT0000AADE

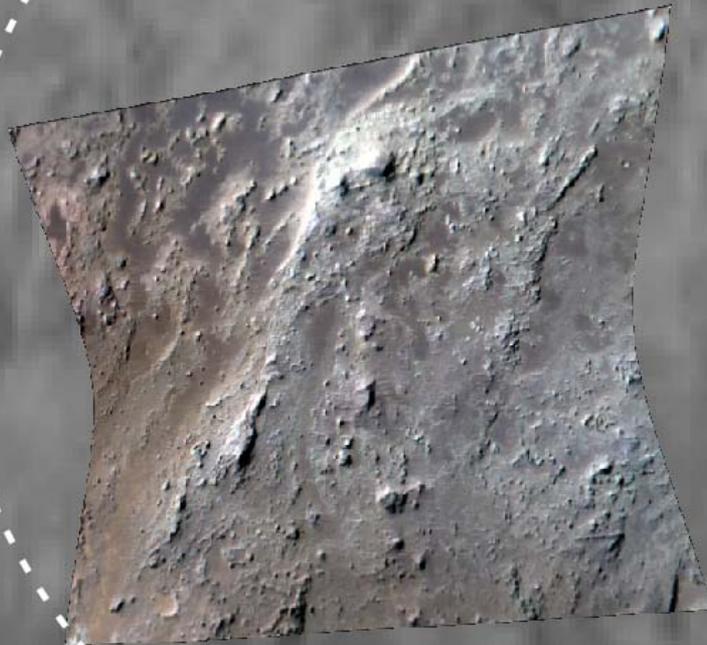


FRT
HRL
HRS

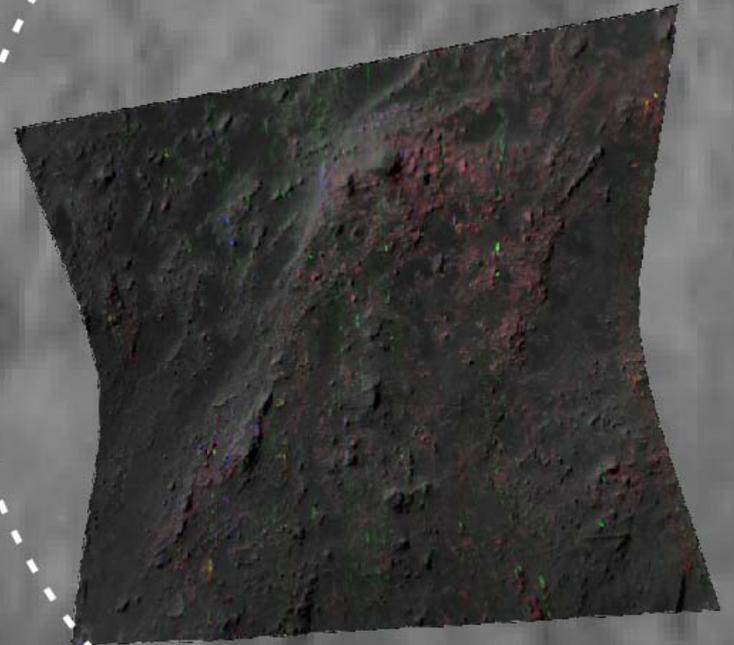


Eberswalde Crater – FRT0000AADE





IR RGB



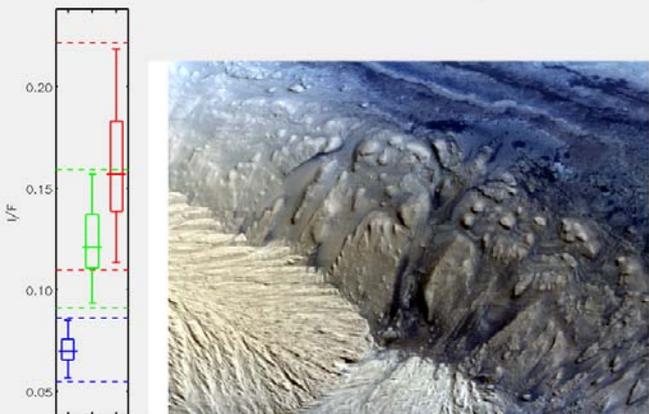
IR PHY

Fe/Mg-Phyllosilicate detection - magenta pixels in IR PHY brose product – restricted to small knobs/outcrops

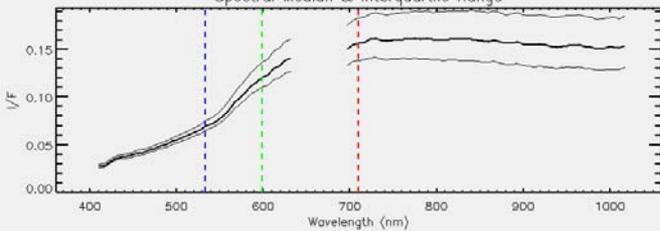
R: D2300

G: BD2210

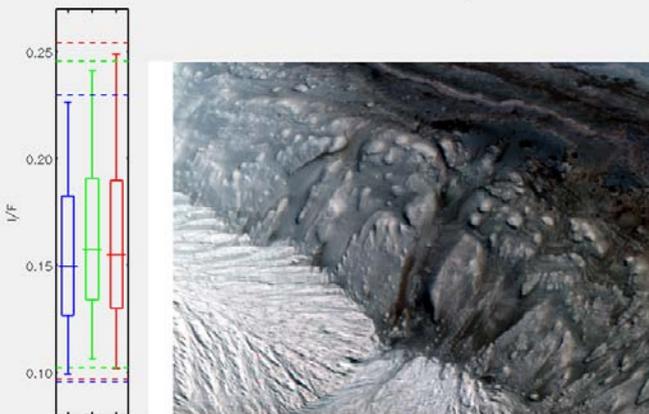
B: BD1900



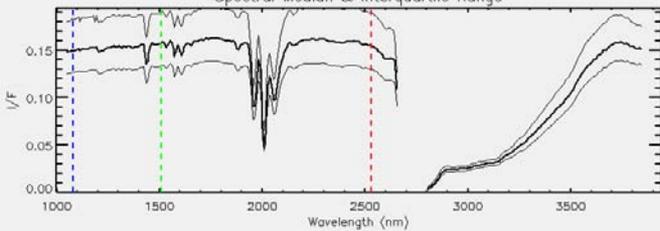
Spectral Median & Interquartile Range



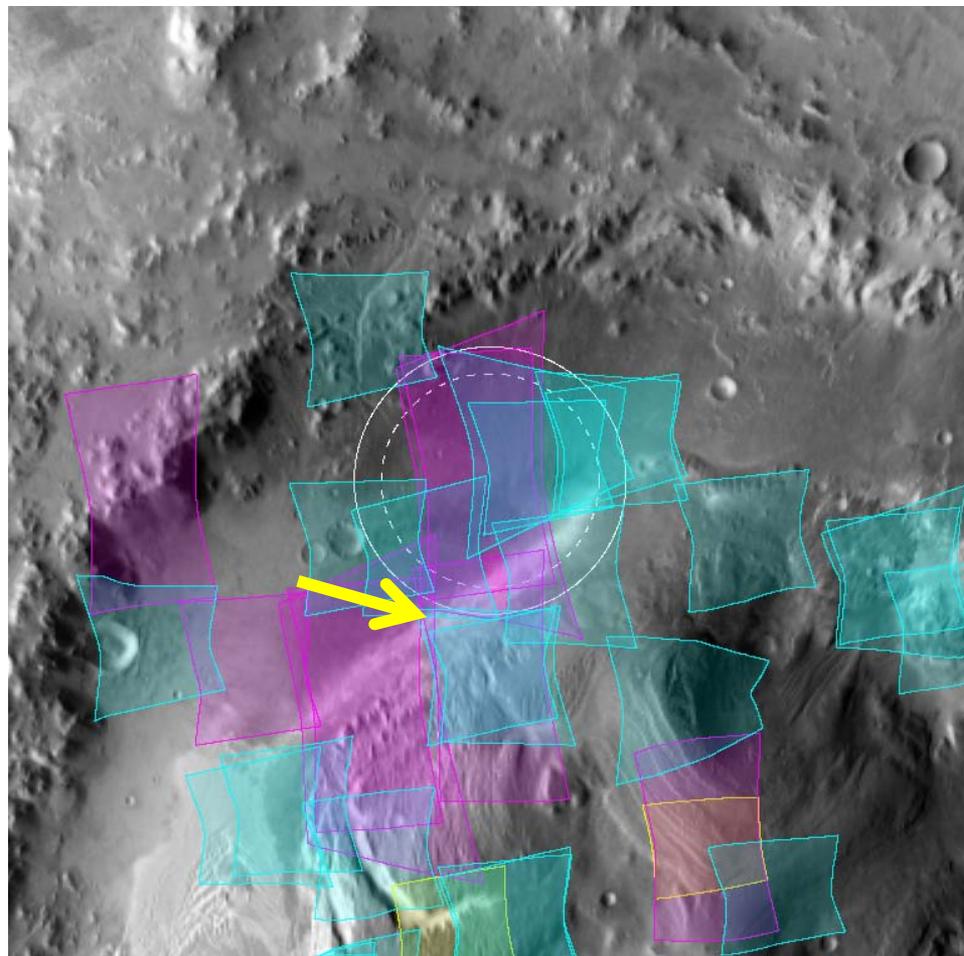
FRT0000B6F1 CRISM IR Composite



Spectral Median & Interquartile Range

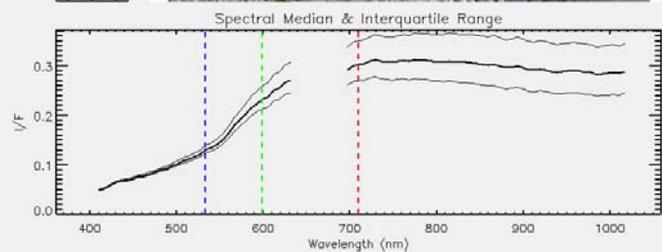
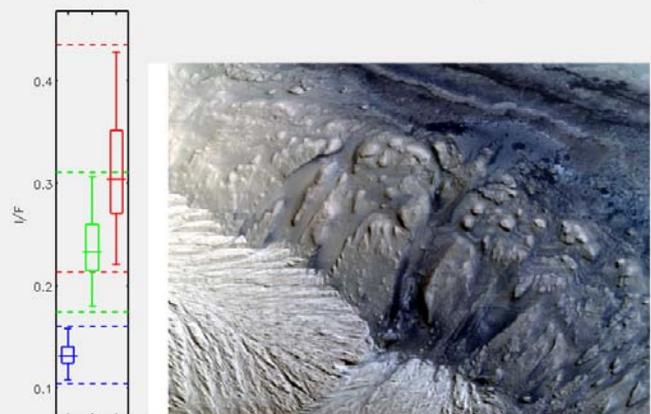


Gale Crater – FRT0000B6F1

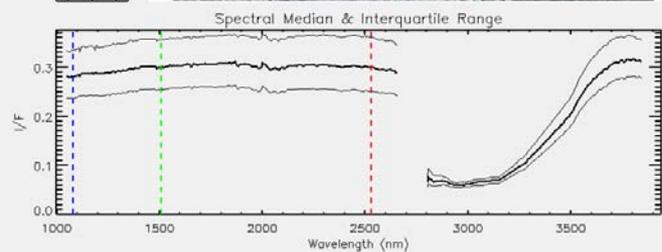
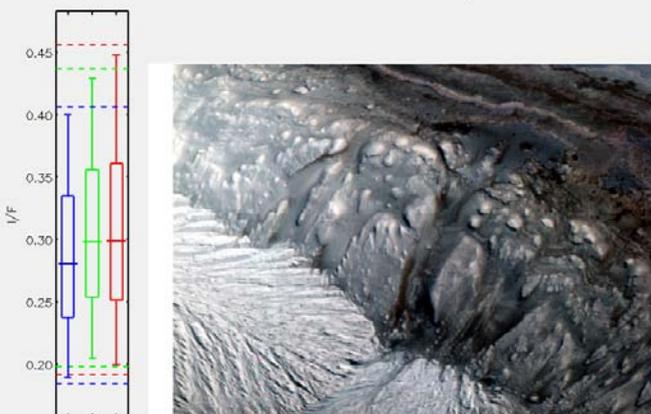


FRT
HRL
HRS

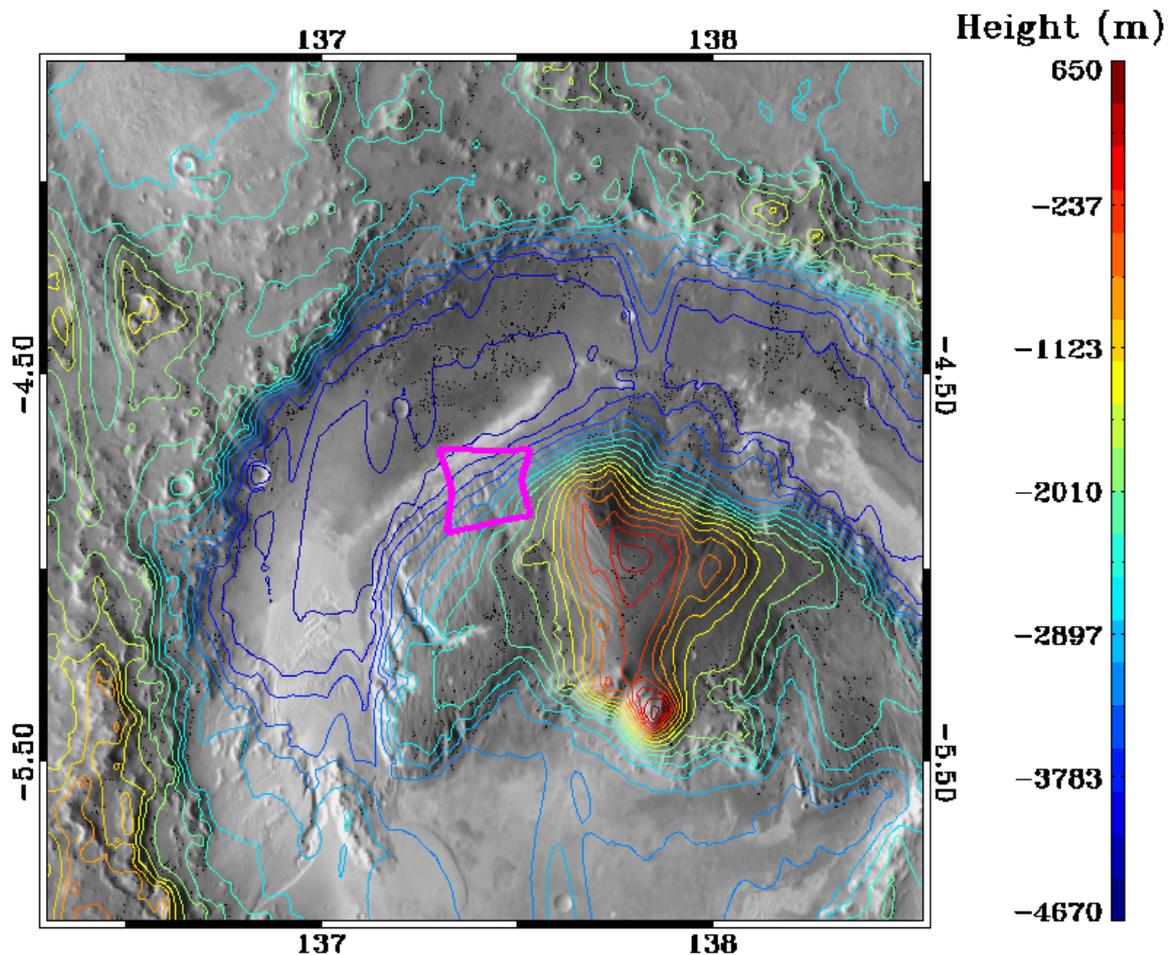
Gale Crater – FRT0000B6F1



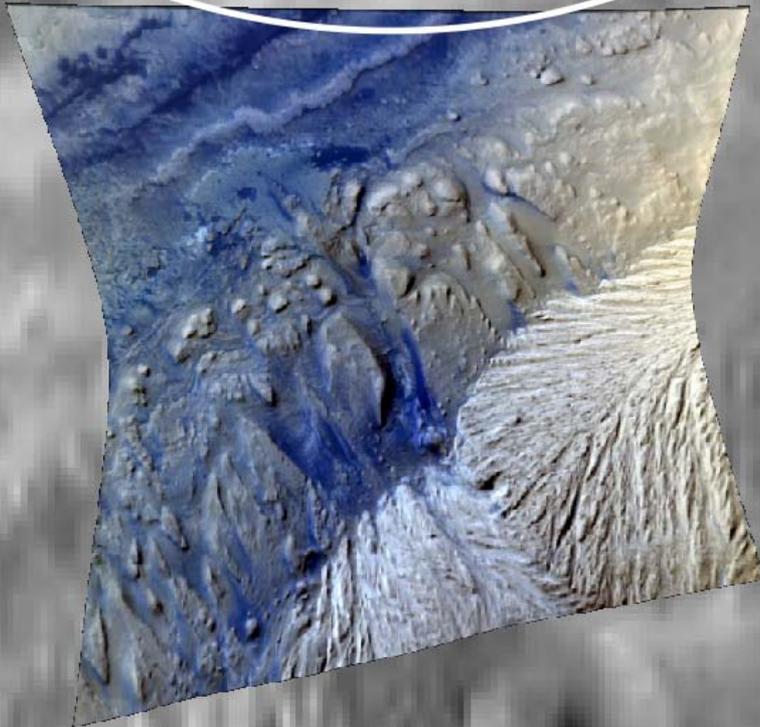
FRT0000B6F1 CRISM IR Composite



Latitude

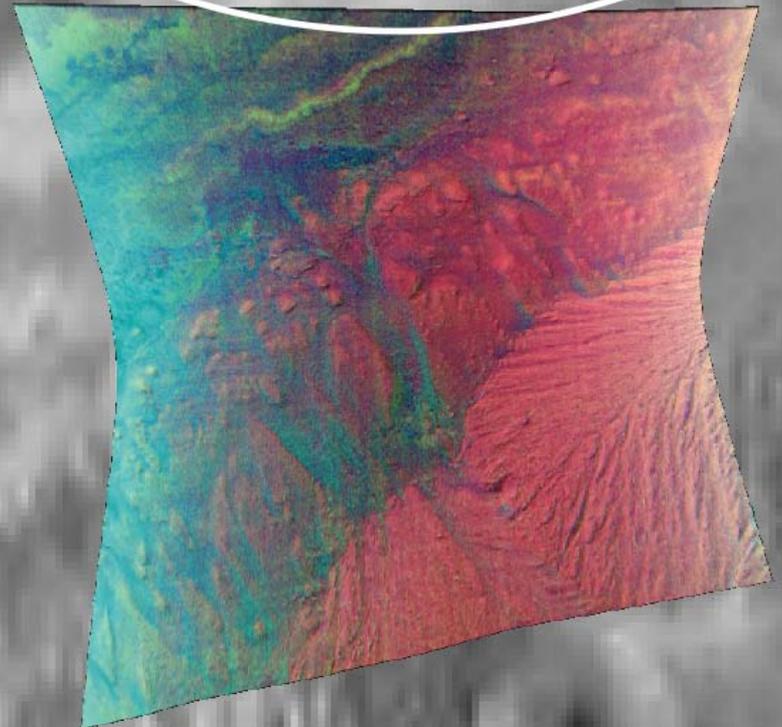


E Longitude



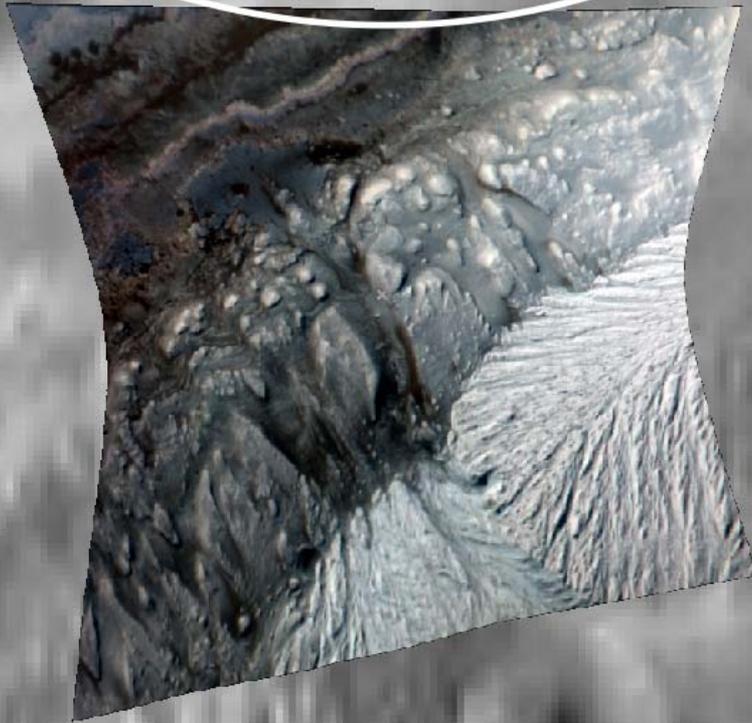
VNIR RGB

Distribution of ferric/ferrous iron phases

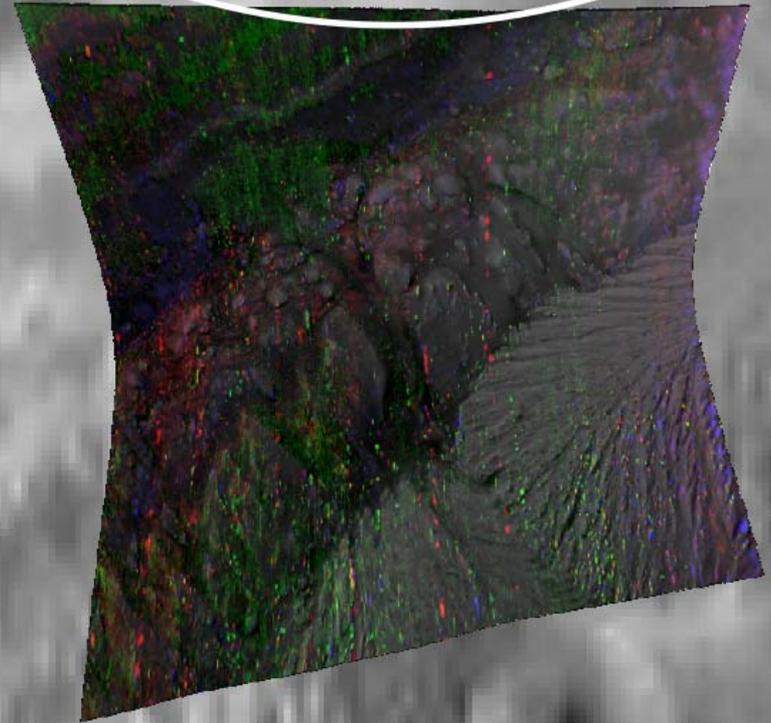


VNIR FM2

R: BD530
G: BD920
B: BDI1000



IR RGB



IR HYD

Hydrated sulfate signature correlated with pyroxene signature

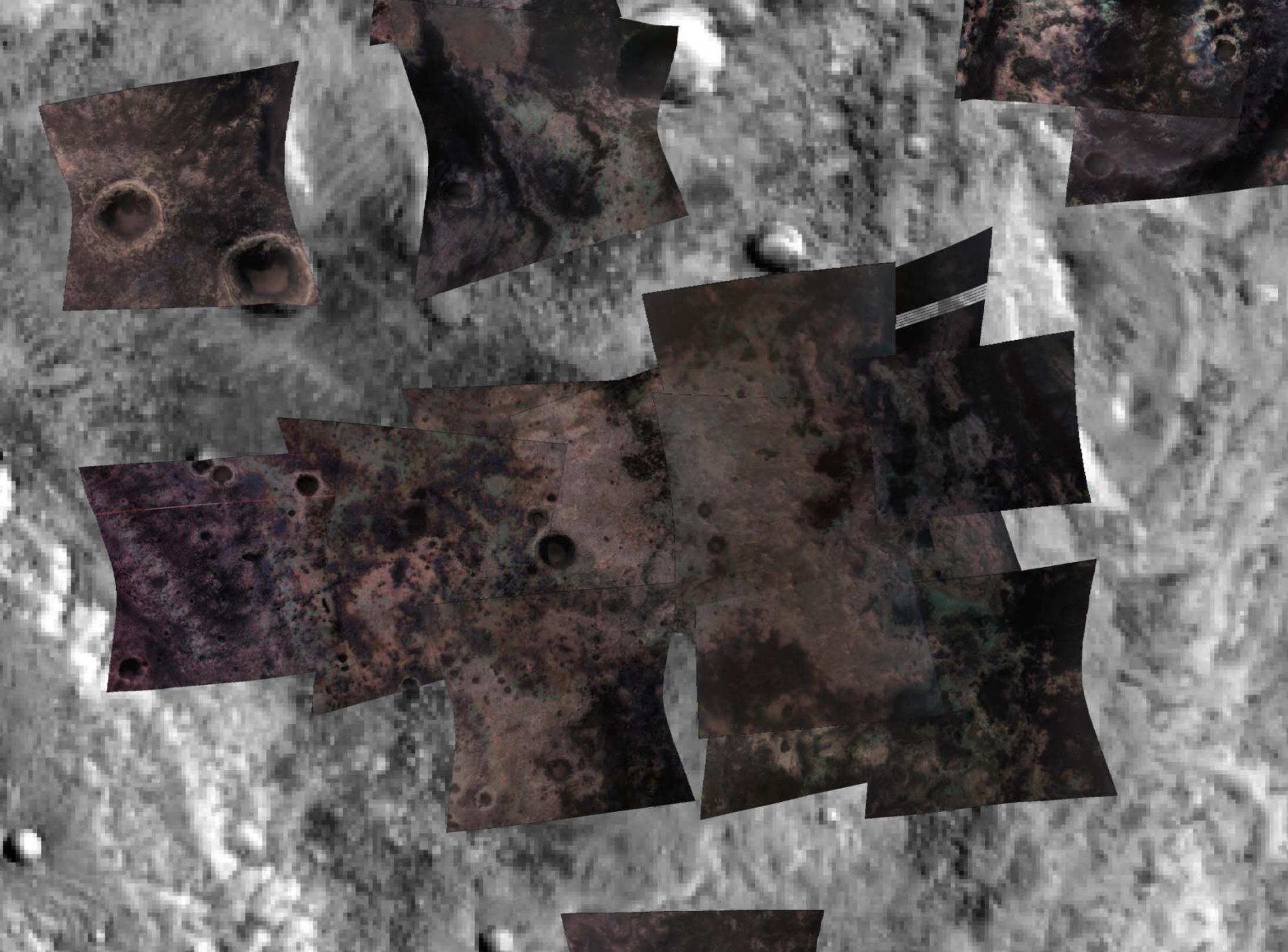
R: SINDEXT
G: BD2100
B: BD1900

CRISM support for MSL landing site selection:

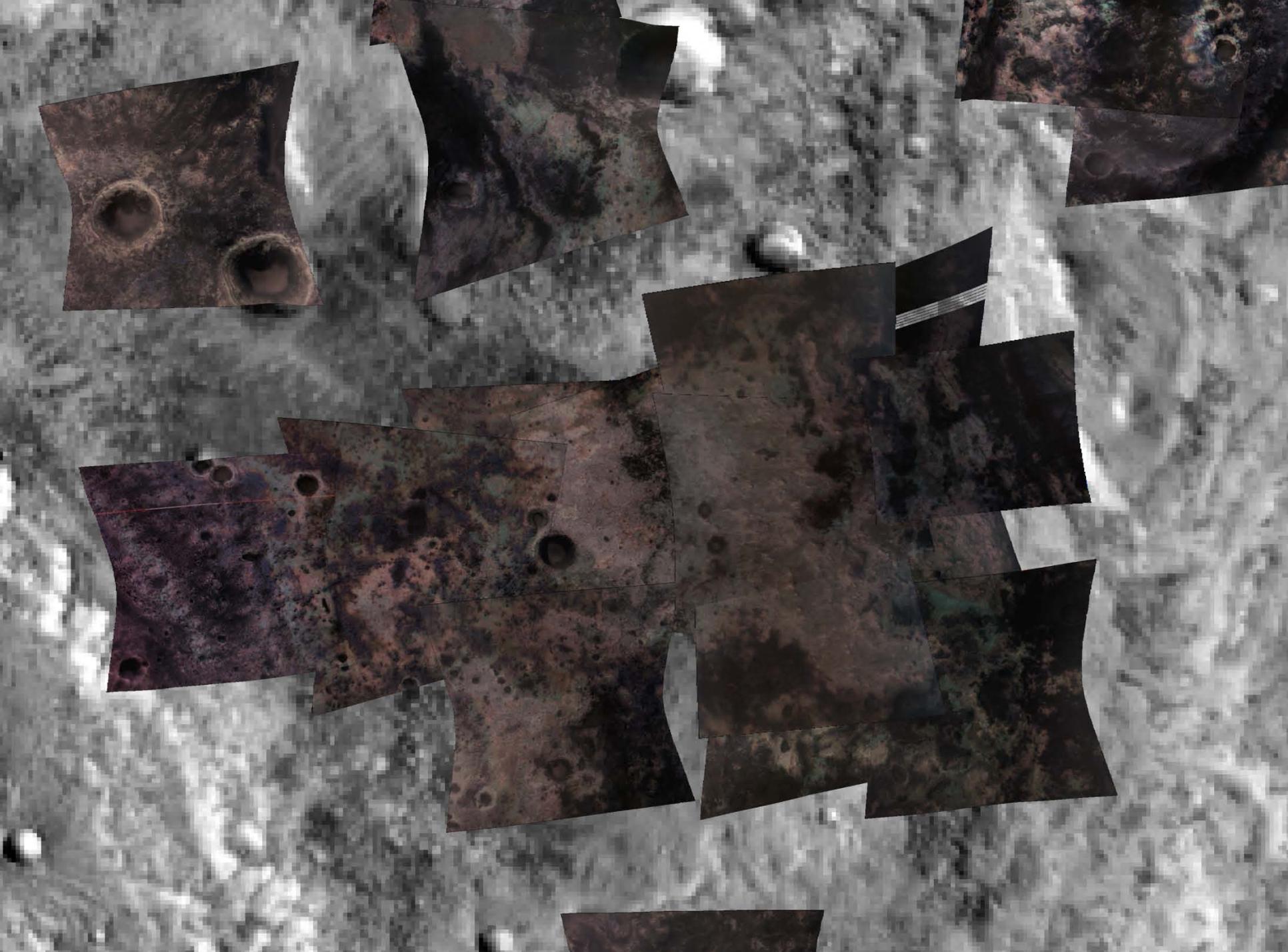
http://crism.jhuapl.edu/msl_landing_sites/

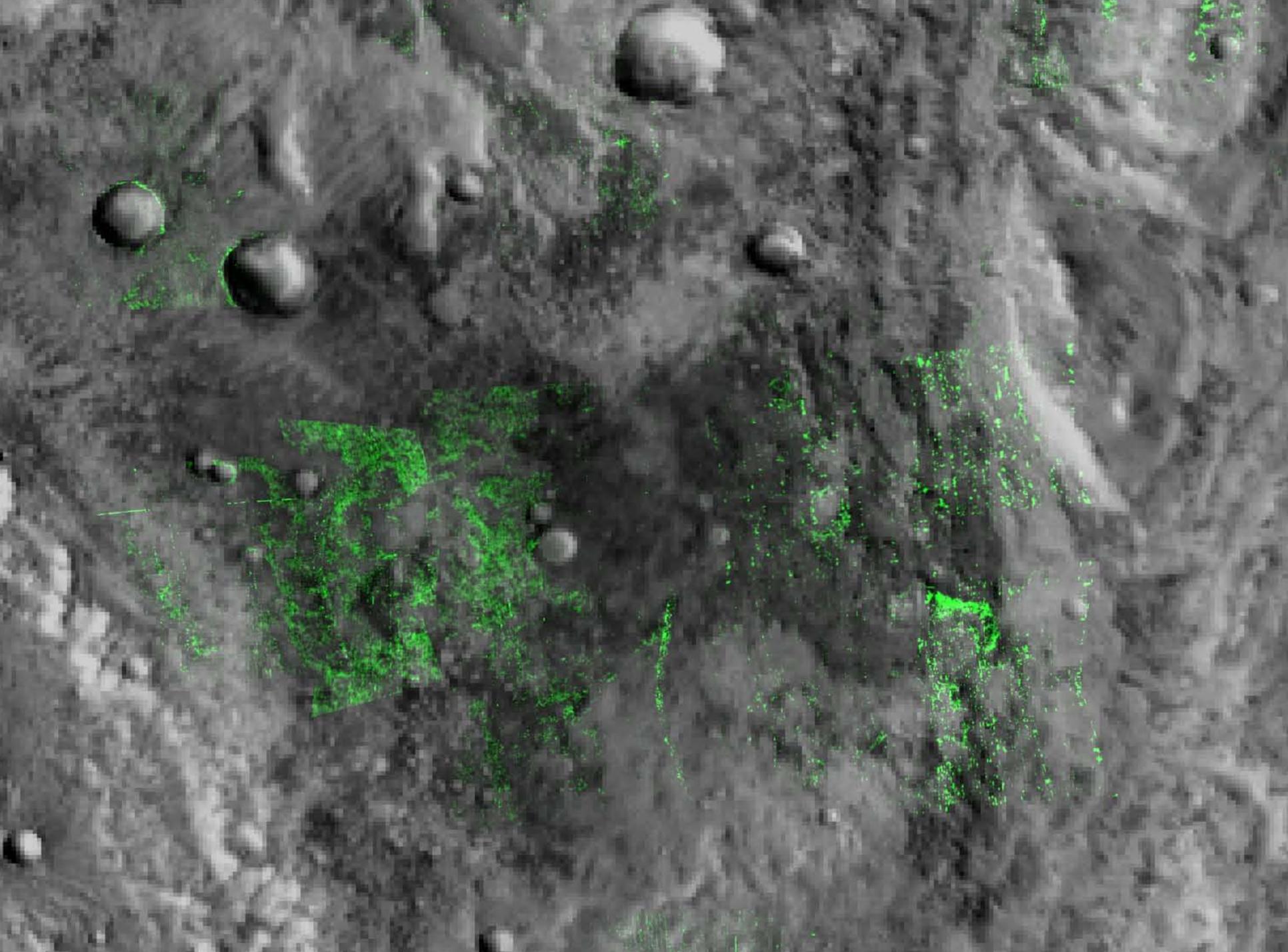
- The systematic set of derived CRISM analysis products provides an objective framework for the evaluation and comparison of the spectral signatures at each candidate site
- CRISM prototype TRR3 I/F data available for MSL candidate landing sites via the website

Future Attractions – Systematic Product Mosaics

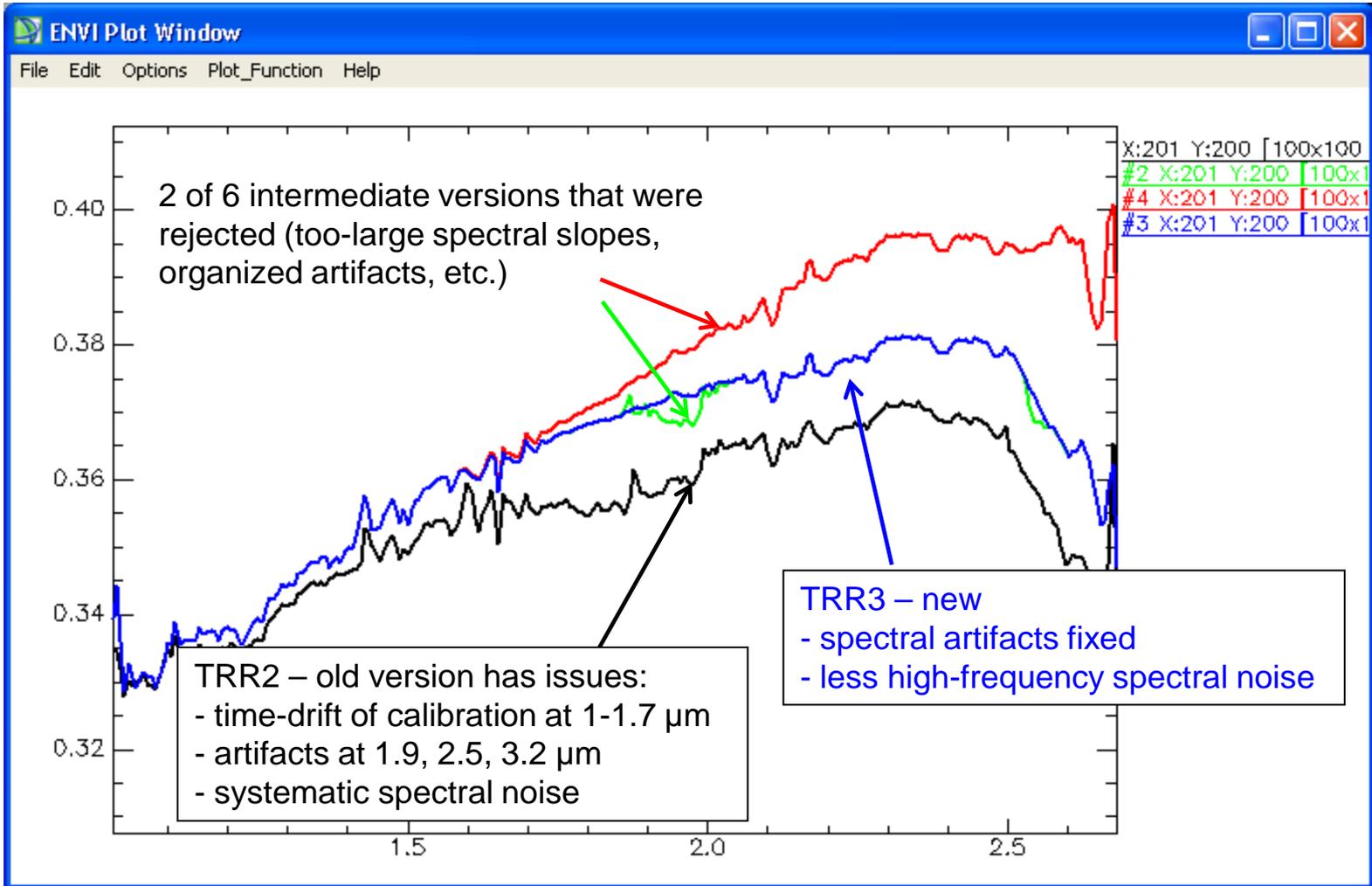


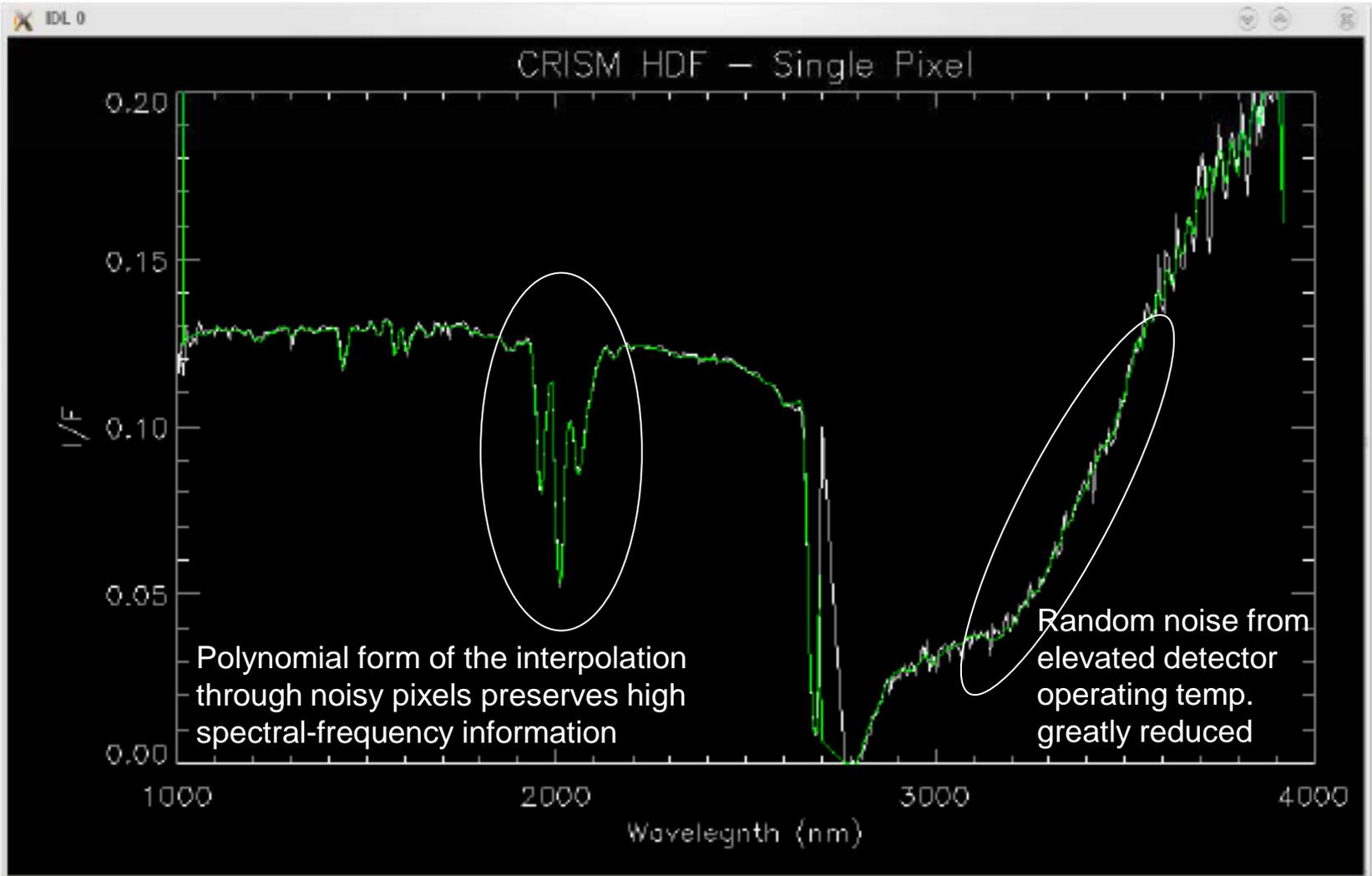




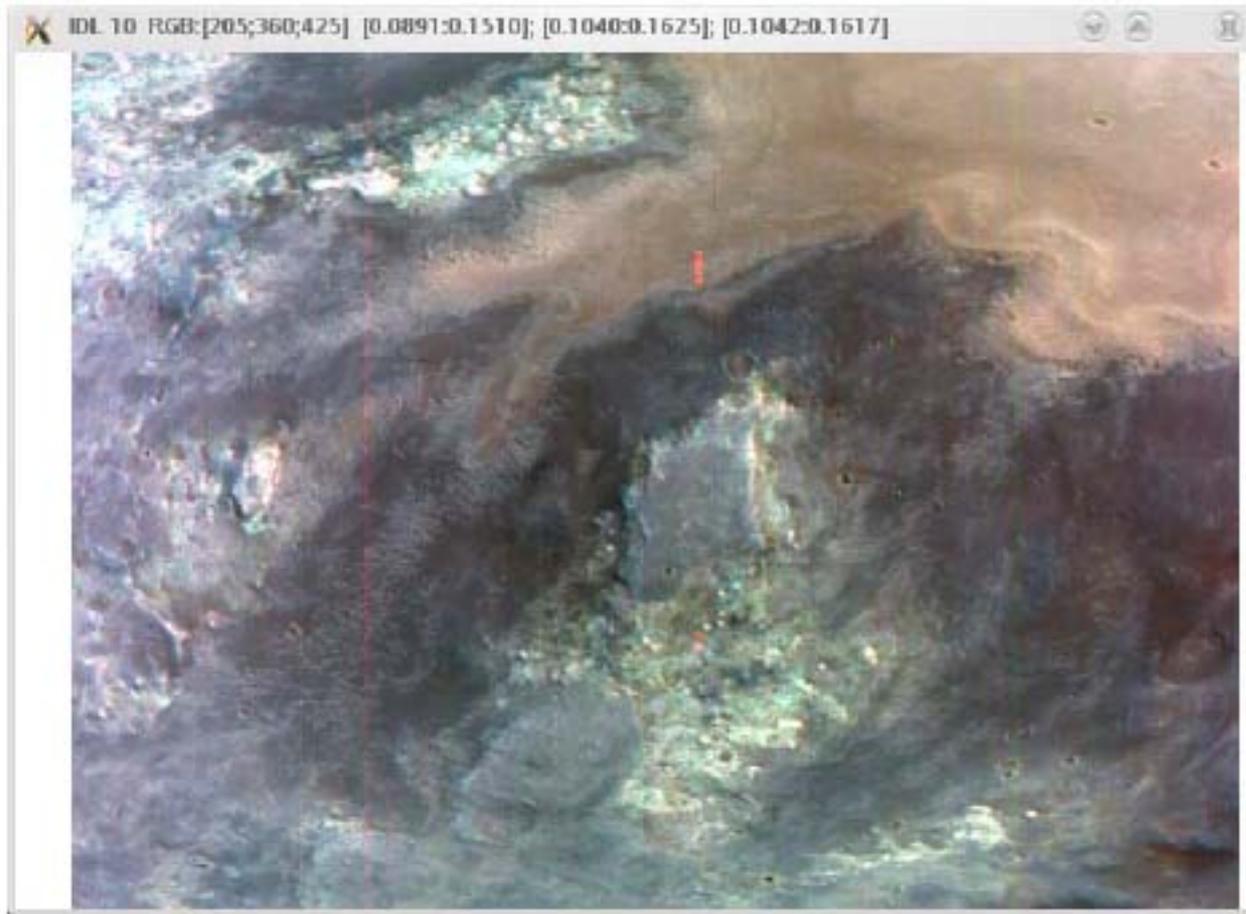


CRISM TRR3 Calibration - Additional Material

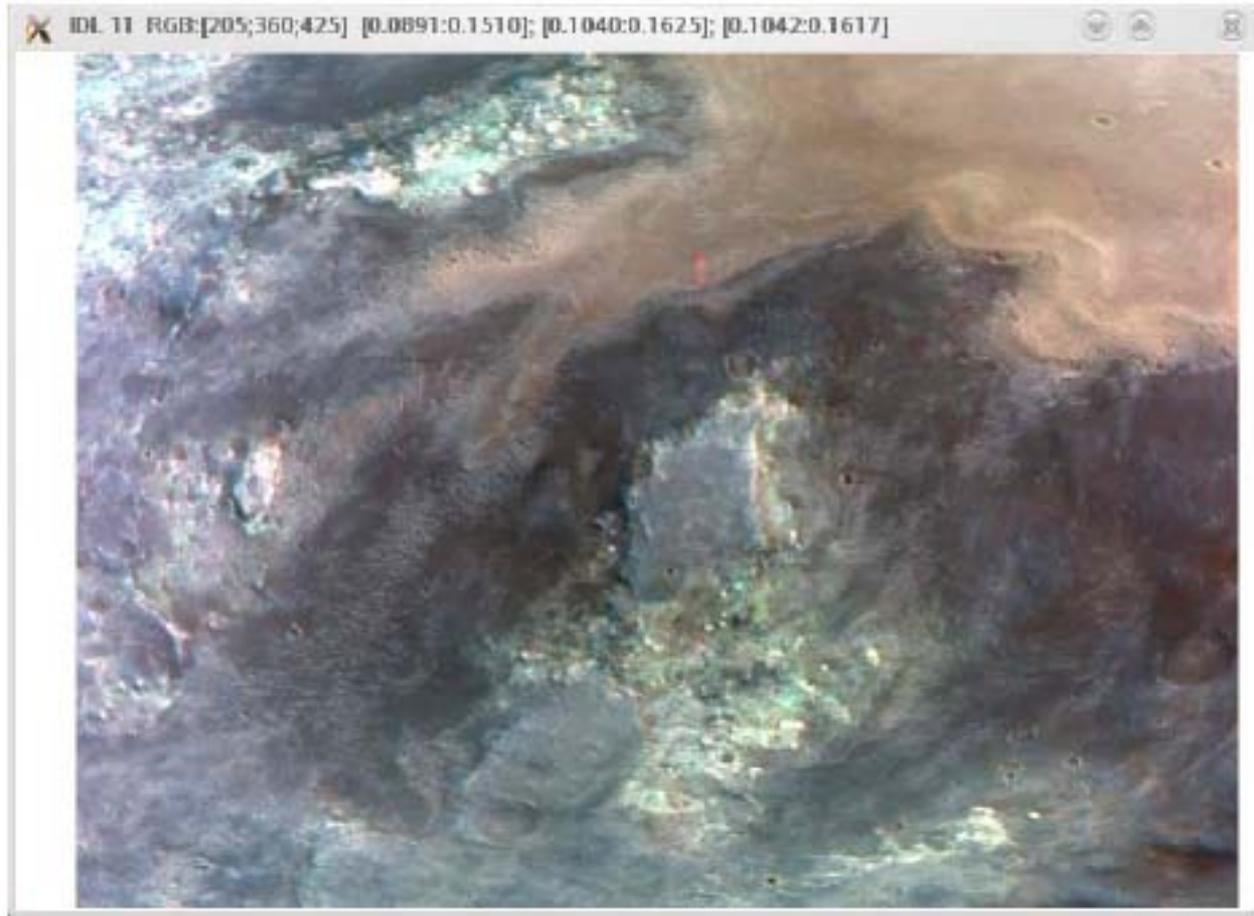




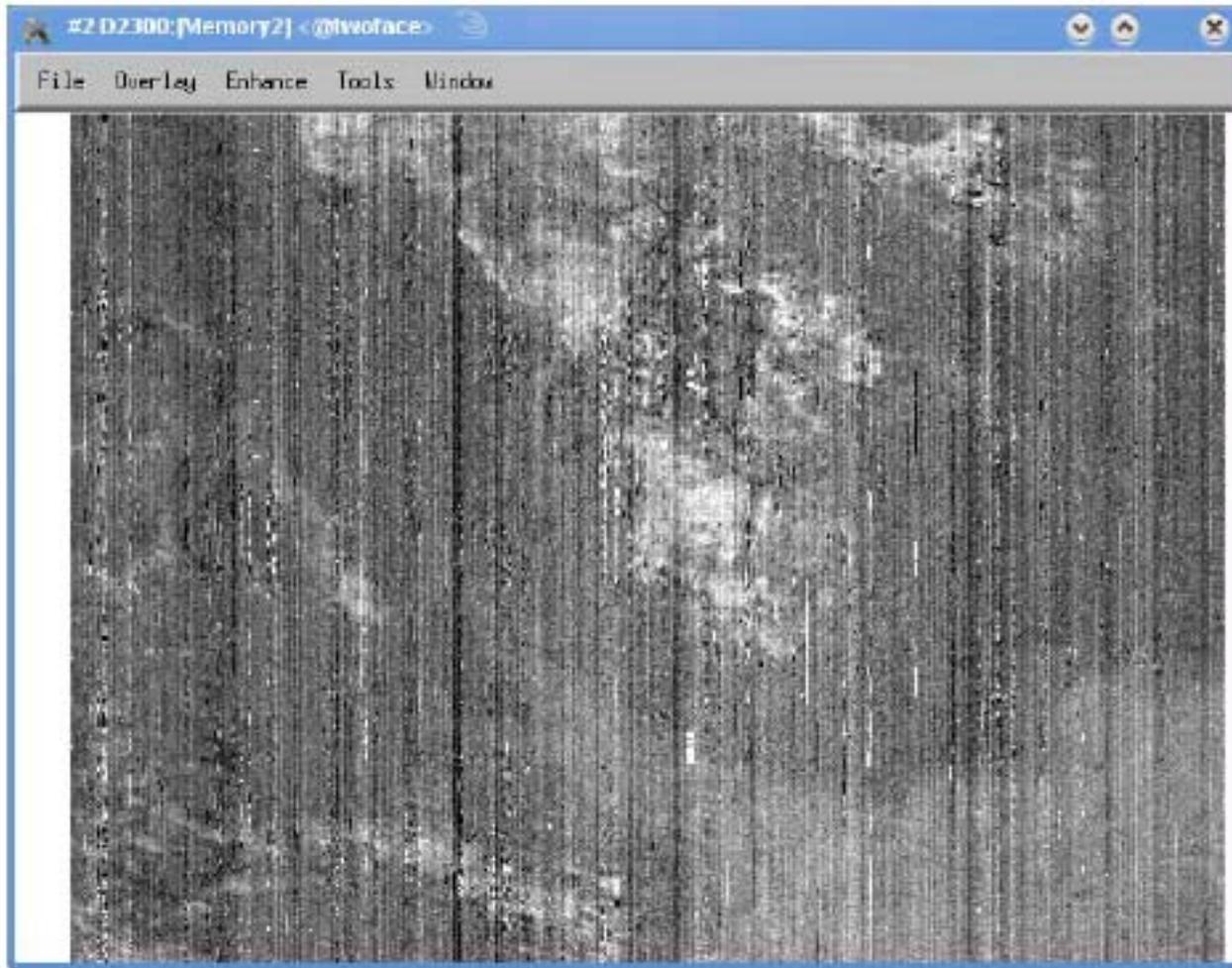
TRR2 vs. TRR3



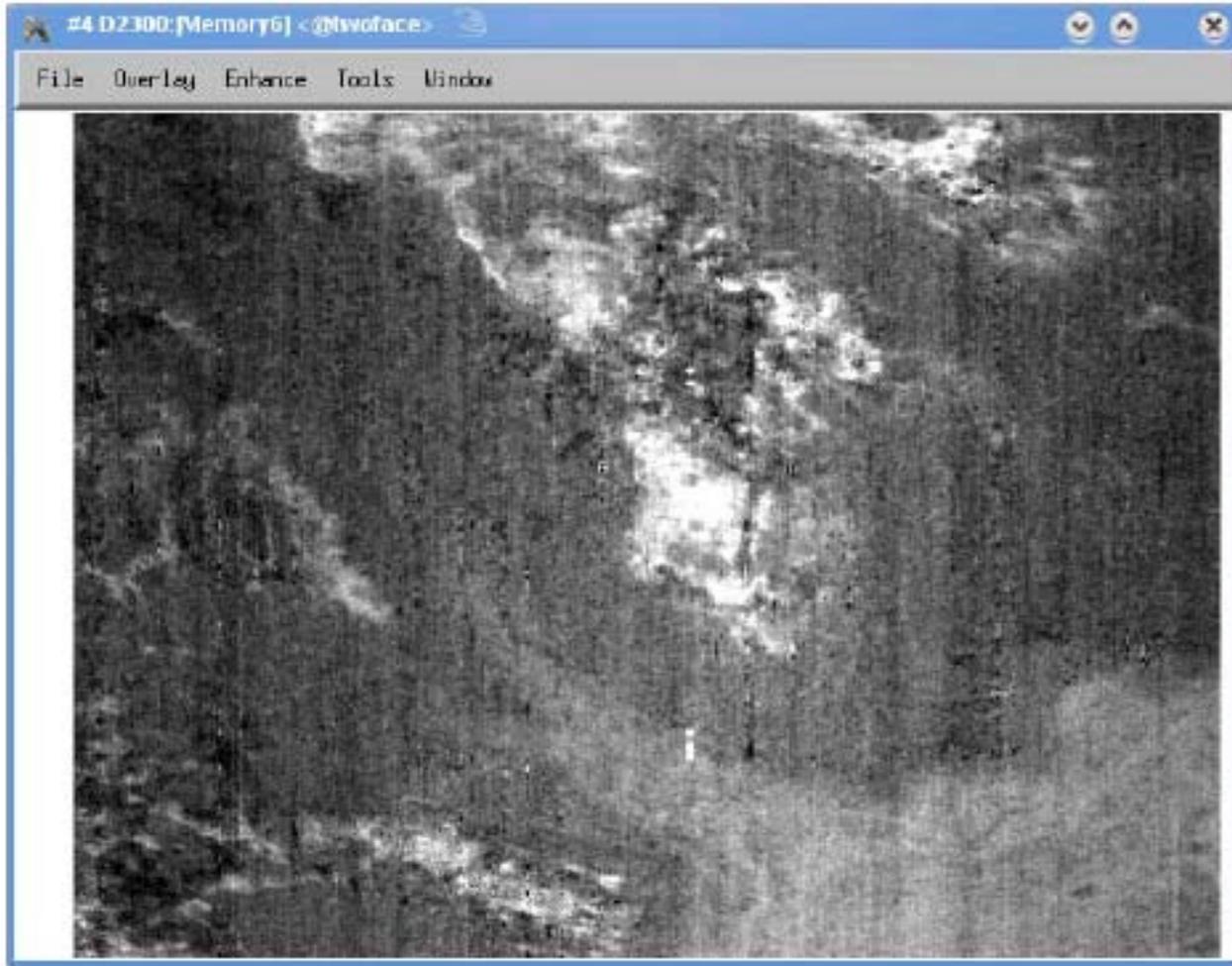
TRR2 vs. TRR3



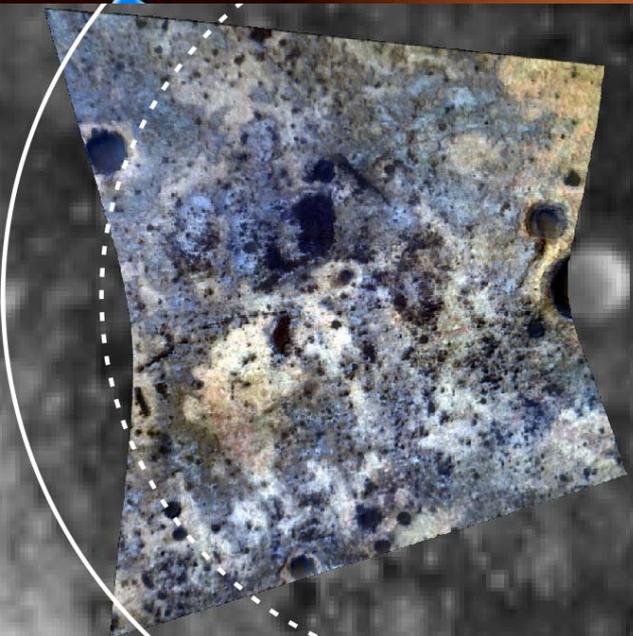
2.3- μm Phyllosilicate Band TRR2 vs. TRR3 (1% stretch)



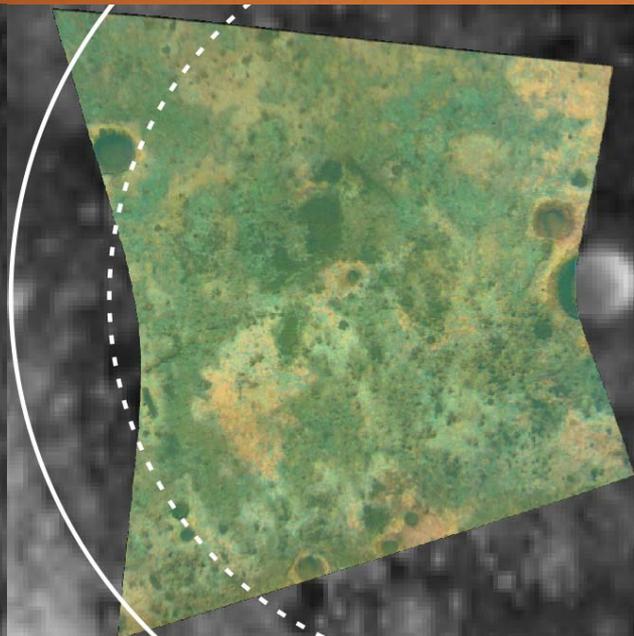
2.3- μm Phyllosilicate Band TRR2 vs. TRR3 (1% stretch)



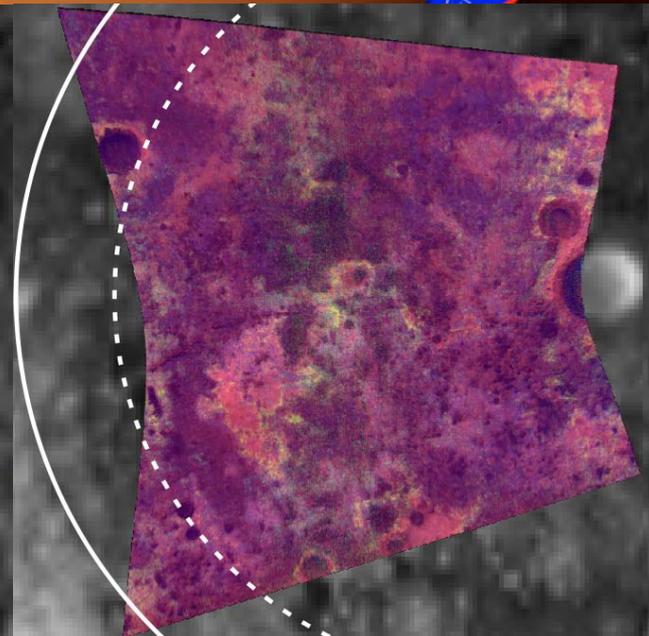
MSL Systematic CRISM Browse Products Gallery



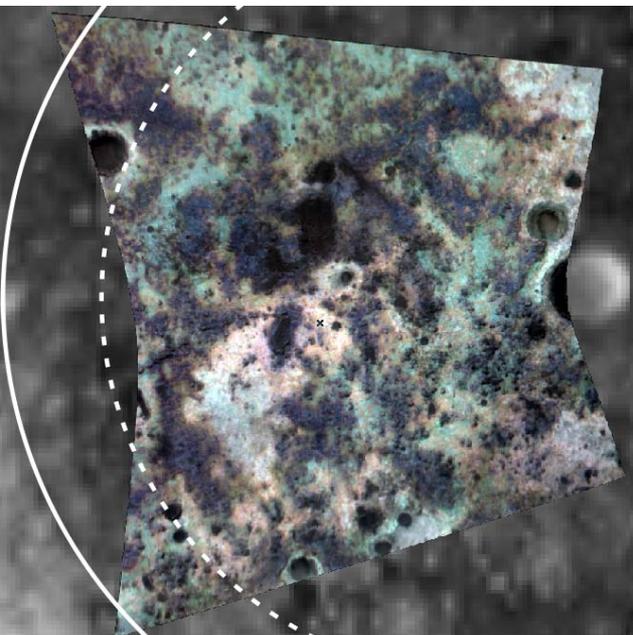
VNIR RGB



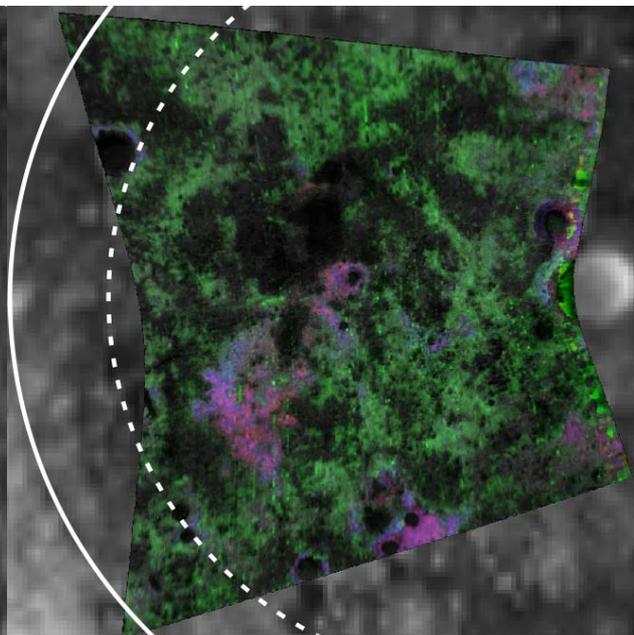
VNIR FEM



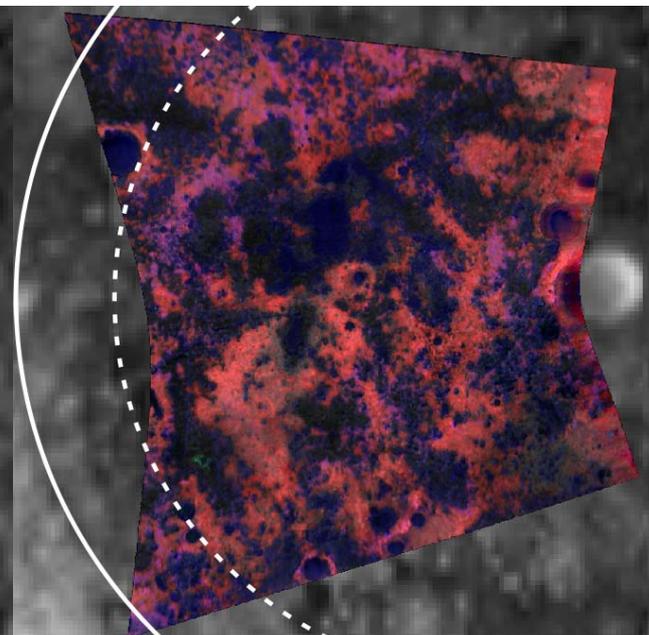
VNIR FM2



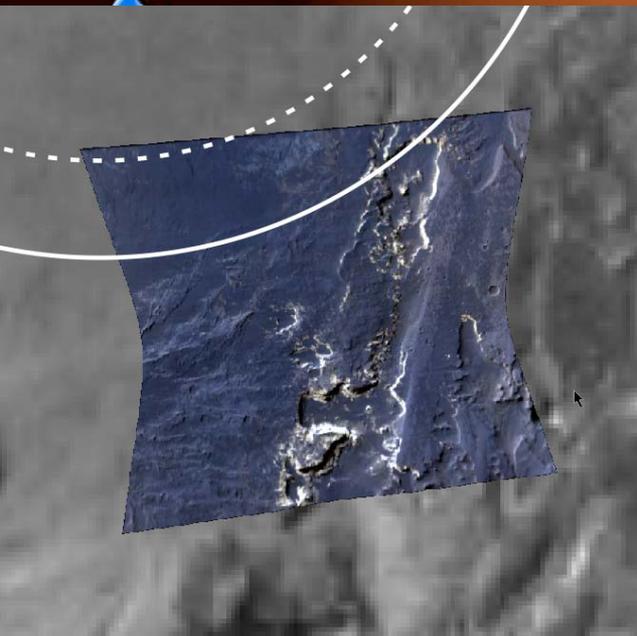
IR RGB



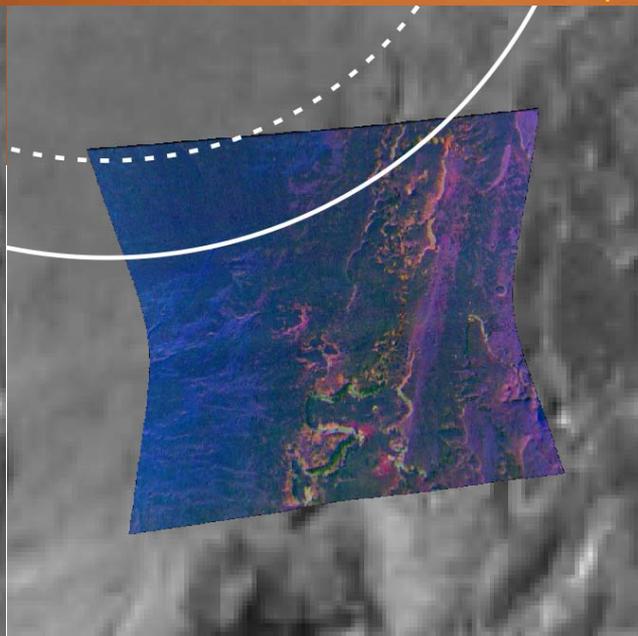
IR PHY



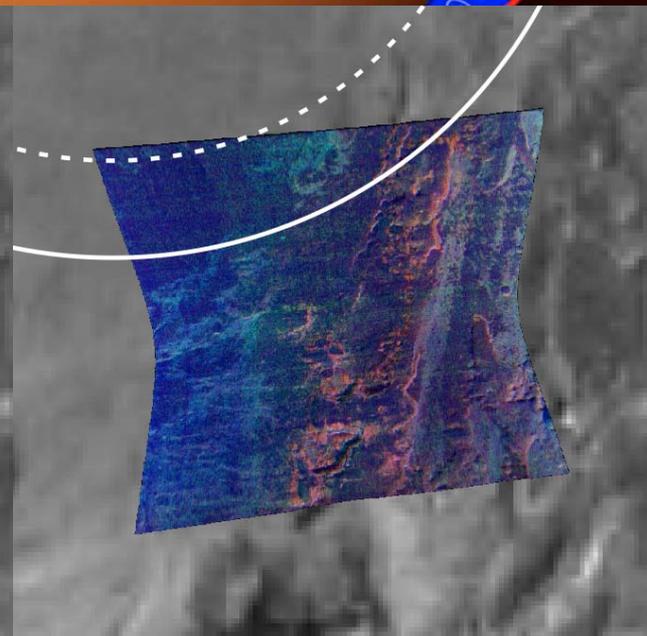
IR MAF



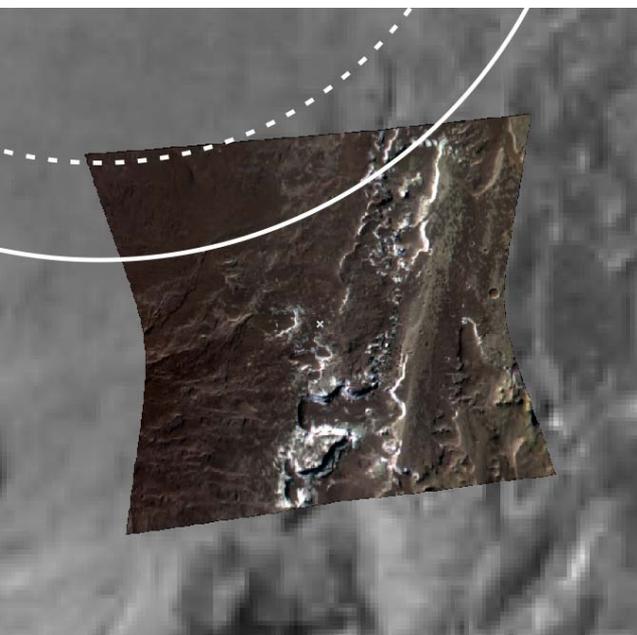
VNIR RGB



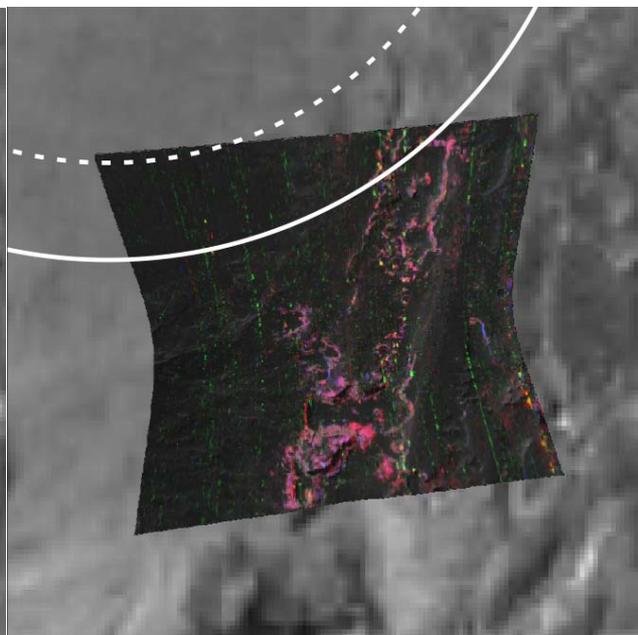
VNIR FEM



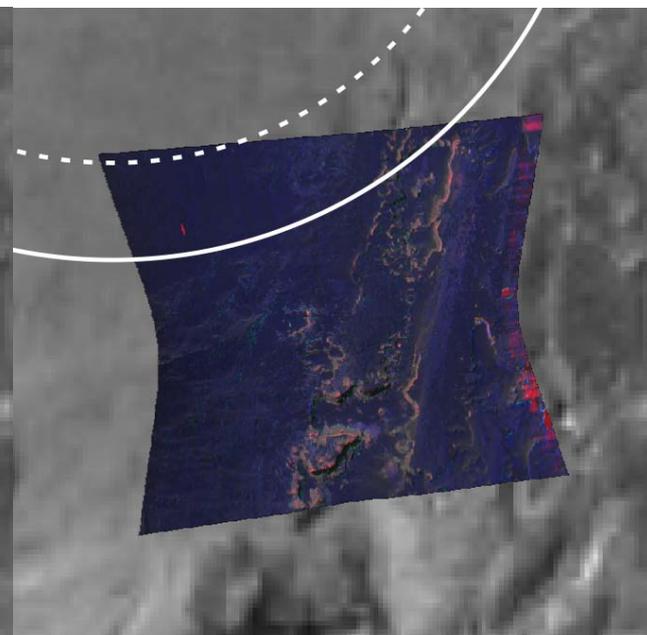
VNIR FM2



IR RGB



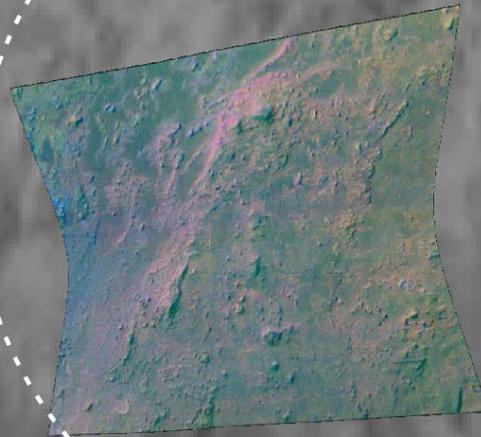
IR PHY



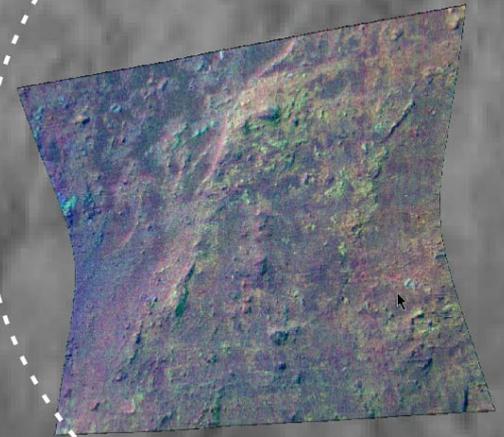
IR MAF



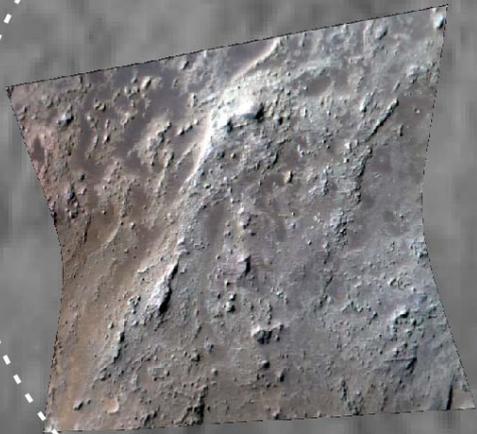
VNIR RGB



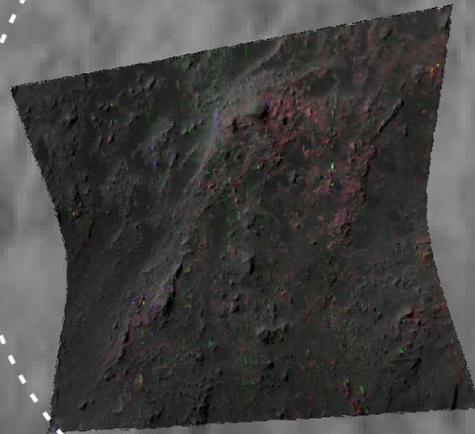
VNIR FEM



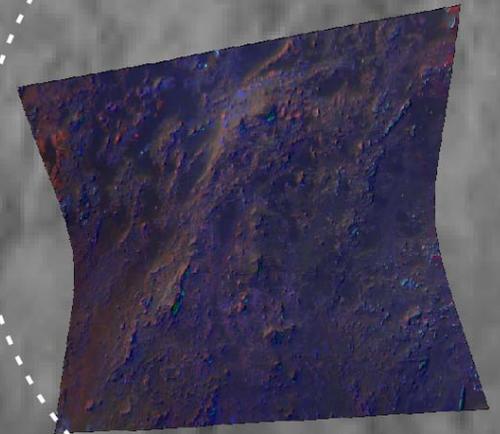
VNIR FM2



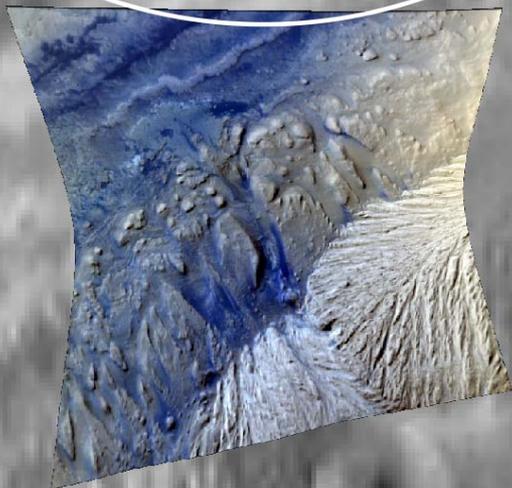
IR RGB



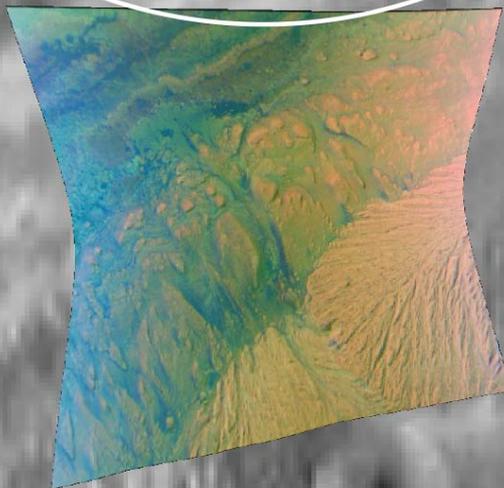
IR PHY



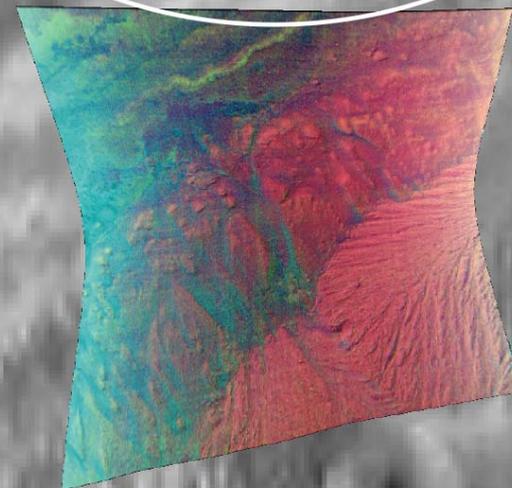
IR MAF



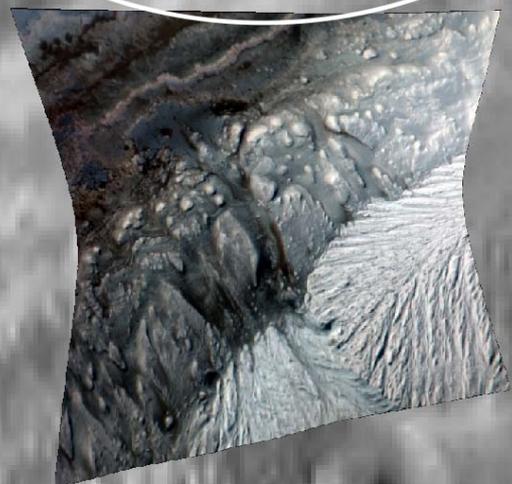
VNIR RGB



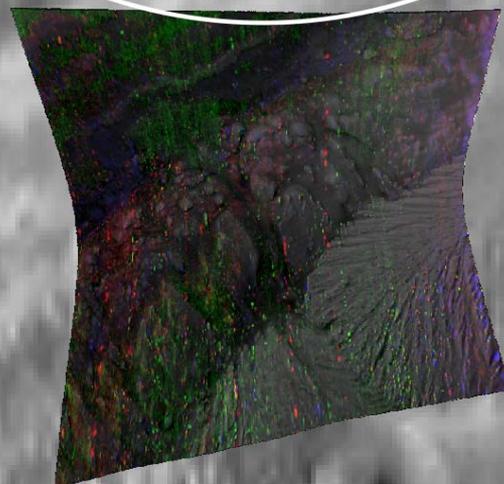
VNIR FEM



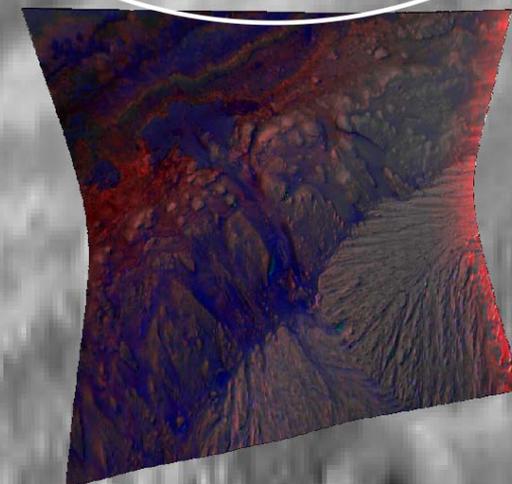
VNIR FM2



IR RGB



IR HYD



IR MAF