New Horizons Encounter with the Pluto System: Global Color Maps, Image Cubes, and Absorption Band Maps – Overview

This data set contains global color maps, image cubes, and absorption band maps created from calibrated data taken during the PLUTO mission phase by the Linear Etalon Imaging Spectral Array (LEISA) instrument and the Multispectral Visible Imaging Camera (MVIC) instrument on the New Horizons spacecraft. Image cubes are provided per instrument and target body, covering the surfaces of Pluto, Charon, Nix, Hydra, and Kerberos. Color maps and absorption band maps for N2, CO, CH4, and H2O are provided for both Pluto and Charon.

Instrument Description

MVIC has 4 filters with identifiers and wavelengths listed here:

```
name    identifier   wavelengths(nm)
-------------------------------
BLUE     mc1         400 – 550
RED      mc0         540 – 700
NIR      mc2         780 – 975
CH4      mc3         860 – 910
-------------------------------
```

Each filter is affixed to a separate CCD array with dimensions [5024,32]. The instrument is operated by sweeping all four arrays across the field of view together, with scan motion being perpendicular to the long axis of the arrays. The CCDs are read out during the scan at a rate matched to the scan motion so as to operate in time delay integration mode. Much more information on the instrument is published in Reuter, et al. (2008) and in the instrument catalog file in this dataset.

Level 2 MVIC color data consist of separate frames for each of the four filters, with units of DN. Header keywords are provided to enable users to convert to flux units according to procedures described in Howett, et al. (2017).

LEISA operates at infrared wavelengths, and its etalon (a wedged filter with a narrow spectral bandpass that varies linearly in one dimension) is bonded to the illuminated side of the IR detector. As a result, each row of detector pixels receives only light of a particular wavelength. Spectral maps are produced by sweeping the FOV of the instrument across a scene, sequentially sampling each point in the scene at each wavelength.

The LEISA filter comprises two bonded segments. The first is a high spectral resolution segment with Wavelength/dWavelength = 560 covering a wavelength range from 2100 to 2250 nm, The second is a low spectral resolution segment with Wavelength/dWavelength = 240 covering a wavelength range from 1250 to 2500 nm.

Though overlapping spectrally, the filter segments are separate and adjacent spatially. Plots of wavelength and delta-Wavelength per pixel row across the complete filter show discontinuities at the bond joint between the segments.

See the instrument catalog file, Reuter, et al. (2008), and the SOC to Instrument Interface Control Document (ICD) for more information.

Processing

Mosaics: Pluto and Charon Global Color Maps

Mosaics are composed of all MVIC color scans between MET (Mission Elapsed Time) 0298652198 and 0299178098 for Pluto and MET 0298891588 and 0299176438 for Charon. Each scan was photometrically converted to normal albedo by means of a photometric model McEwen, et al. (1991) with parameter L=0.65 applied for both Pluto and Charon.

All scans were geometrically registered to the Long-Range Reconnaissance Imager (LORRI) base map, and then mosaiced into a single map.

Cylindrical Global Color Map Observations

Color images were taken with the MVIC instrument, which is part of the Ralph instrument Reuter, et al. (2008) on the New Horizons spacecraft. MVIC is equipped with 6 Time-Delay Integration (TDI) CCDs (Charge-Coupled Device), four of which are used for color observations. The other two are redundant panchromatic TDI CCDs (400-975nm). During observations, data are recorded from all 4 color TDI arrays simultaneously Olkin, et al. (2017), with bands centered at 895, 870, 625, and 475 nm Schenk, et al. (2017) Schenk, et al. (2018).

For Pluto, the best mapping and stereo imaging scans were at pixel scales of ~0.65 km/pixel at phase angles of ~38 degrees. Pluto approach imaging had coarser resolutions at 15 deg phase angles. The phase angle remained essentially constant at ~15 degrees until the final hours of the Pluto encounter, facilitating production of a global map with generally uniform illumination quality.

For Charon, the best mapping and stereo imaging covered the illuminated Pluto-facing hemisphere of Charon. Due to the high encounter velocity (~15 km/s) and the slow rotation of the two bodies (6.4 days), mapping resolution with longitude varied from ~35 to 0.15 km/pixel, while terrains south of about -38 degrees were in darkness due to polar obliquity at the time of encounter.

Cylindrical Global Color Map Data Processing

To produce photometrically uniform maps of the normal reflectance of the surface, wherein the brightness of different regions can be compared at least in a relative sense, a simplified photometric correction is applied to each image or mosaic to correct for emission and incidence angle variations across the surface before they are assembled into the global map.

We used the combined lunar-Lambertian photometric function, formulated by McEwen, et al. (1991) and encoded in ISIS3 software (Integrated Software for Imagers and Spectrometers) Sides, et al. (2017), wherein the relative degree of lunar and Lambertian photometric qualities,

L, is a function of phase angle. This empirical function is used to produce maps of the effective bidirectional reflectance of the surface of Pluto and Charon, normalized to common viewing conditions across the surface, in this case, the approach phase angle of 15 deg. For both bodies, the optimal value of L(15) was empirically derived to be ~0.65.

The lower resolution 4-color global mosaic was created separately using the same procedures and then merged with the panchromatic base map using the technique of McEwen, et al. (1991) to produce a global 4-color full-resolution map of Pluto and Charon.

Uncertainties
A description of the uncertainties may be found in Howett, et al. (2017).

Color Image Cubes: 4-color Image Cubes for Pluto and All Satellites
These products contain MVIC data converted to I/F and reprojected to the perspective view of the target as seen from the spacecraft at the mid-scan header time for the BLUE filter scan, for each MVIC color scan where the target is well resolved and well lit.

For each scan, the reprojected spatial resolution is selected to be somewhat higher than the resolution of the raw data, so as not to lose detail in the reprojection. After all 4 filters have been reprojected to the same geometry, they are stacked into an IMG file with dimensions [nx,ny,4] where nx and ny are spatial dimensions oriented such that north is up, and the four filters are in the order listed in the instrument description above.

An additional correction was applied to the CH4 filter, relative to that described in the Howett et al. paper, of 0.938, empirically determined from the Charon scans to make CH4 I/F match that of NIR. This correction was based on the understanding that Charon's Pluto- facing hemisphere is neutral in color at MVIC's NIR and CH4 wavelengths, as reported in Fink, et al. (1988).

File naming convention
Target identity is indicated by the letters 'pl' for Pluto or 'ch' for Charon in the filename. The 0x545 and 0x536 tags identify the raw packet id (ApID). Scan identity is indicated by MET unique identifiers (10-digit integers indicating mission elapsed time in seconds). In many cases, a single scan covers Pluto and Charon, leading to two sets of products. The observations included in this dataset are listed here:

MET_id	Descriptive_name	Target
298719172	PC_MULTI_MAP_B_5	Pluto
298766872	PC_MULTI_MAP_B_6	Pluto
298824437	PC_MULTI_MAP_B_8	Pluto
298853042	PC_MULTI_MAP_B_9	Pluto
298853042	PC_MULTI_MAP_B_9	Charon
298853212	PC_MULTI_MAP_B_9	Pluto
298853212	PC_MULTI_MAP_B_9	Charon
298891582	PC_MULTI_MAP_B_11	Pluto
298891582	PC_MULTI_MAP_B_11	Charon
298939122	PC_MULTI_MAP_B_12	Pluto
298939122	PC_MULTI_MAP_B_12	Charon

```
298939292    PC_MULTI_MAP_B_12        Pluto
298939292    PC_MULTI_MAP_B_12        Charon
298995294    PC_MULTI_MAP_B_14        Pluto
298995294    PC_MULTI_MAP_B_14        Charon
299025872    PC_MULTI_MAP_B_15        Pluto
299025872    PC_MULTI_MAP_B_15        Charon
299064592    PC_MULTI_MAP_B_17        Pluto
299064592    PC_MULTI_MAP_B_17        Charon
299079022    PC_MULTI_MAP_B_18        Pluto
299079022    PC_MULTI_MAP_B_18        Charon
299104952    PCNH_Multi_Long_1d1_01   Pluto
299104952    PCNH_Multi_Long_1d1_01   Charon
299127622    PC_Multi_Long_1d2        Pluto
299127622    PC_Multi_Long_1d2        Charon
299147977    PC_Color_TimeRes         Pluto
299147977    PC_Color_TimeRes         Charon
299162512    PC_Color_1               Pluto
299162512    PC_Color_1               Charon
299176432    C_COLOR_2                Charon
299178092    P_COLOR2                 Pluto
```

The highest resolution Pluto and Charon products from this dataset have also been presented in Grundy, et al. (2016a), Stern, et al. (2015), Moore, et al. (2016), and Grundy, et al. (2016b), but this dataset was created from later MVIC products using the most recent SPICE kernels.

(SPICE is a toolkit provided by the Jet Propulsion Laboratory Navigation and Ancillary Information Facility, and it stands for Spacecraft ephemeris, Planet or any target body ephemeris and physical constants, Instrument information, C-matrix attitude and orientation information, and Events information).

Processes for converting to I/F and mutually registering the separate color channels for Pluto and Charon are the same as described in the references above. A different process was used for the smaller moons and is described below.

To co-register cubes for Nix and Hydra using MVIC scans, three well-resolved color scans from the raw dataset were converted into cubes:

```
SAPNAME      File_Root                Power_Side
H_Color_Best 0299165322_0x536_eng.fit 0
N_COLOR_BEST 0299166912_0x536_eng.fit 0
N_Color_2    0299171078_0x536_eng.fit 1
```

The engineering files were then debiased, electronic stripe noise was removed, and the data was flat-fielded. The following flat fields were applied, from the calibrated dataset:

mc0_flat_20160120.fits
mc1_flat_20160120.fits
mc2_flat_20160120.fits
mc3_flat_20160120.fits

The destriped, flat-fielded files were then windowed to approximately 5x the width of the target. These windowed files were co-registered across the four MVIC color filters (Blue, Red, NIR, and CH4) at a sub-pixel level using the following approach.

Each of the files from a given scan were scaled up in dimension by a factor of 6 using bilinear interpolation. The upscaled, windowed Red band image for each scan were chosen as the template for co-registration. For each of the other three frames to be co-registered to the Red frame, a mean flux scaling factor, F_s, was determined by computing the sum of the given channel to the sum of the Red channel. The best integer x and y pixel offsets for channel i was determined by brute-force minimizing:

$$CHI = sum((F_s*Im\_Red - shift(Im\_i, x, y))^2 / (Im\_i + eps))$$

In the formula above, shift(Im, x, y) is the channel i image after linear integer pixel shifts of x and y, and eps is a small flux offset to account for noise from removed sky and read noise. For these scans, eps was set to 5.0 DN.

Once the upscaled images were co-registered, the images were re-sampled with a mean block-reduce function to their original pixel scale. The resulting co-registered images from a given scan were assembled into a FITS cube with the original file headers included in each extension. Units are in native MVIC DN.

No power side correction was applied to N_Color_2, as tests comparing it to N_COLOR_BEST indicate that the NIR channel gain drift amplitude was <1 percent for this scan.

No attempt was made to match PSFs between the four channels; as such, there are limb artifacts in RGB composites of the cubes due to the narrower PSF of the Blue channel with respect to the longer-wavelength channels.

Uncertainties
A description of the uncertainties may be found in Howett, et al. (2017).

Spectral Cubes: 1.25-2.5 Micron Image Cubes for Pluto and Satellites
This dataset contains spatial - spectral I/F cubes of scans across Pluto, Charon, Nix, Hydra, and Kerberos from the LEISA instrument in three dimensions, nx, ny, and nw. The first two dimensions (nx and ny) are spatial dimensions to cover the mid-scan-time field of view centered on the target. The third axis (nw) has 256 channels across the wavelength range of 1.25 to 2.5 microns, with a high resolution section in channels 200 to 255 for wavelengths between 2.10 and 2.25 microns. The associated wavelength product is needed when using this data because the wavelength response of each row of LEISA pixels is slightly curved, referred to as the spectral smile. Associated geometry products contain the approximate geometry as of the mid-scan time. The starting MET of the scan is included as part of the filename. On LEISA there is a glue bond between the high resolution segment and the low resolution segment. There is scattered light off of the glue bond that affects the signal that reaches channels 199-207 (the last channel of the low resolution section and the first 8 channels of the high resolution segment). The scattered light pattern is not uniform across the detector because there are

chips along the glue bond that make it not uniform. Observations were designed to have the target avoid the worse areas of scattered light.

LEISA operates in a pushbroom fashion, where each row of the LEISA frame is a different wavelength. The LEISA frames are used to construct an image cube where each plane of the cube represents a single wavelength.

LEISA's 256x256 HgCdTe detector array has linear-variable interference filters affixed to it that cover wavelengths from 1.25 to 2.5 microns. The filters are oriented such that one axis of the detector array is mostly spatial and the other axis is both spatial and spectral. The field of view is swept across the scene of interest while recording frames at a rate of approximately one frame per pixel of motion. The resulting sequences of frames are provided as level 1 and level 2 data.

Making optimal use of the lower level data requires knowledge of the time history of the spacecraft orientation. This history is incorporated to produce the higher level data products in this directory. These products are produced using the USGS's Integrated Software for Imagers and Spectrometers, ISIS3, which accounts for camera geometry and for spacecraft orientation as a function of time during the spectral scan, providing a footprint on-or-off of the target for each pixel of each LEISA frame. These footprints are reprojected by the software to the mid-scan view from the spacecraft to produce spectral cubes, as tabulated below.

Scans of Pluto:

```
MET         Scan name          UT date and time     Range(km) SubSClon&lat
-------------------------------------------------------------------------
0299026199  PC_MULTI_MAP_B_15  2015-07-12 17:01:49  2123418   247.35 42.92
0299064869  PC_MULTI_MAP_B_17  2015-07-13 03:46:32  1589686   222.26 42.86
0299079314  PC_MULTI_MAP_B_18  2015-07-13 07:46:25  1391154   212.94 42.82
0299105209  PCNH_MULTI_LONG_1d1 2015-07-13 14:59:33 1032784   196.19 42.70
0299127869  PC_MULTI_LONG_1d2  2015-07-13 21:18:58   718986   181.68 42.49
0299144829  P_LEISA             2015-07-14 02:01:50   468610   170.42 42.12
0299169338  P_LEISA_Alice_1a    2015-07-14 08:48:06   149717   158.78 39.72
0299170159  P_LEISA_Alice_1b    2015-07-14 09:00:36   139431   158.66 39.42
0299172014  P_LEISA_Alice_2a    2015-07-14 09:33:05   112742   158.62 38.52
0299172889  P_LEISA_Alice_2b    2015-07-14 09:48:16   100297   158.81 37.91
0299176809  P_LEISA_HIRES       2015-07-14 10:56:19    45222   164.17 30.73
-------------------------------------------------------------------------
```

Scans of Charon:

```
MET         Scan name          UT date and time     Range(km) SubSClon&lat
-------------------------------------------------------------------------
0299026199  PC_MULTI_MAP_B_15  2015-07-12 17:01:49  2129381    66.70 42.78
0299064869  PC_MULTI_MAP_B_17  2015-07-13 03:46:32  1600665    41.64 42.49
0299079314  PC_MULTI_MAP_B_18  2015-07-13 07:46:25  1403516    32.38 42.35
0299105209  PCNH_MULTI_LONG_1d1 2015-07-13 14:59:33 1046821    15.83 42.00
0299127869  PC_MULTI_LONG_1d2  2015-07-13 21:18:58   733569     1.67 41.46
0299146219  C_LEISA             2015-07-14 02:21:50   483075   351.00 51.55
0299171308  C_LEISA_LORRI_1     2015-07-14 09:20:28   137829   342.40 34.15
0299175509  C_LEISA_HIRES       2015-07-14 10:32:06    80651   346.38 27.17
-------------------------------------------------------------------------
```

Each of the above scans is converted to an array with dimensions [nx,ny,nw] where nx and ny are spatial dimensions to cover the mid-scan-time field of view centered on the target at 2 to 3 times the native LEISA resolution. The third axis nw is LEISA's 256 wavelength channels. Values in the arrays are I/F for pixels that fall on the target, or -3.4028235e-38 for pixels that are off the target or are bad for other reasons (unpatchable cosmic rays, dead pixels, etc.). Channels 0-196 cover wavelengths from 1.25 to 2.5 microns at low spectral resolution. Channels 200-255 cover wavelengths from 2.10 to 2.25 microns at higher spectral resolution, but with highly uncertain flux calibration, mostly due to confusion from light scattering through the glue bond between the low res and high res wavelength segments.

Accompanying each Pluto/Charon I/F cube is a wavelengths array with the same [nx,ny,nw] dimensions providing the wavelength for each pixel. This array is needed because the wavelength response of each row of LEISA pixels is not quite constant, but exhibits a slight curvature, referred to as the spectral smile. To account for this effect, use the wavelengths from the accompanying wavelengths array.

A third array describes the geometry as of the mid-scan time (the times in the table above). This array has dimensions [nx,ny,ng], where the number of geometry planes ng is 5, in this order: phase angle, emission angle, incidence angle, latitude, and longitude (all angles in degrees). The finite duration of the scan means the geometry array is only approximate. If you need the exact geometry for each pixel, then this product is not what you need. Instead, go back to the level 1 or level 2 data along with the spacecraft orientation time history data recorded in the relevant SPICE kernels.

For Nix, Kerberos, and Hydra, the LEISA images taken at the listed MET were used for these data products:

MET (s)	Target	Date (UT)	MidObsTime (UT)	Distance (km)	Duration (s)	ExpTime (s)	PixScale (km/pix)	Phase (deg)
0299153775	Kerb.	2015-07-14	04:27:16.375	394,000	359	0.868	24.2	24.81
0299154901	Hydra	2015-07-14	04:46:51.875	369,000	458	0.969	22.7	26.48
0299164549	Hydra	2015-07-14	07:28:01.876	239,000	502	0.854	14.7	33.05
0299166335	Nix	2015-07-14	07:56:26.876	163,000	340	0.676	10.0	8.65
0299173908	Nix	2015-07-14	10:04:04.376	60,000	509	0.579	3.7	9.65

The images for Nix, Hydra, and Kerberos are processed differently from the Pluto and Charon scans and do not include geometry information. They are cube FITS files with the data in the first object plus 4 extensions. From extension number 1 to 4, they are the wavelength, estimated error, gains and flat field.

New Horizons made LEISA observations of all small satellites of Pluto except Styx. This dataset contains observations covering the near-IR range from 1.25 to 2.5 microns at a resolving power of ~260, and from 2.10 to 2.25 microns at a resolving power of ~520. Each LEISA frame has been flat-fielded using the v4 LEISA flat field, corrected for background pattern noise and calibrated to I/F.

The processing uses the pointing history of the spacecraft, from housekeeping data, to correct for the target's motion within the LEISA frames.

Uncertainties

A description of the uncertainties may be found in Schmitt, et al. (2017).

Absorption Maps: Reprojected LEISA Absorption Maps of Pluto

This dataset includes four band depth and spectral indicator maps of Pluto from the LEISA hyperspectral imager, in simple cylindrical projection:

- CH4 integrated band depth maps of the band group around 1.7 micrometers
- N2 integrated band depth maps of the 2.150 micrometer band
- CO integrated band depth maps of the 1.578 micrometer band
- H2O spectral indicator (2.06 / 1.39 micrometers)

They are respectively provided in the files:

- leisa_809-889-014_band-ch4_i89.img
- leisa_889-014_band-n2_i88.img
- leisa_889-014_band-co_i88.img
- leisa_809-889-014_si-h2o_norm_i89.img

Values outside valid ranges have been set to '-99'.

Band depths & spectral indicator calculations are in their native observation geometry, with 2 km/pix (at image center) re-sampled data for both P_LEISA_Alice_2a/b observations and 1 km/pix for P_LEISA_HIRES.

The maps were then projected as simple cylindrical maps with a common 0.0482 degrees/pix resampling corresponding to 1 km/pix sampling at the equator. The data were then mosaicked with the high resolution swath overlaid over the two others.

The observations included in these maps are:

```
    MET_id      Descriptive_name  Target  Resolution  Maps
    ---------------------------------------------------------------
    0299172014  P_LEISA_Alice_2a  Pluto   6.95 km     CH4, N2, CO, H2O
    0299172889  P_LEISA_Alice_2b  Pluto   6.20 km     CH4, N2, CO, H2O
    0299176809  P_LEISA_HIRES     Pluto   2.75 km     CH4, H2O
```

This dataset uses calibration version 'v5', with flat field '4x'. The two first observations together cover most of the illuminated hemisphere of Pluto at the time just before the closest flyby while the high resolution swath covers a strip about 700 km wide and 2700 km long, going from the SSE of the illuminated hemisphere to its W side. In the CH4 and H2O maps, this high resolution swath is overlaid over the two others.

Note: In some of the maps residual calibration artifacts inside the observations and small mismatches in intensity between the individual observations, with a linear structure in the

original projection, produce the curved structures seen in the cylindrical maps, mostly apparent in the N2 and CO maps (weak bands), and very faintly in the CH4 map. The flat was made from a sideways scan across Pluto, so Pluto's spectral features have to be removed from it.

Details follow.

CH4 map

This map plots the integrated CH4 band depth between 1.589 and 1.833 micrometers (um) over a group of 3 CH4 bands at about 1.67, 1.72, and 1.79 um. Its integrate the reflectance factor between a continuum estimated around Wavelength_1=1.589 um (5 bands average) and around Wavelength_2=1.833 um (3 bands average). The full equation is provided in eq. 1 of Schmitt, et al. (2017) and also here: (where lam = lambda = wavelength):

$$BD(CH4) = 1 - Integral(from\ lam1\ to\ lam2)\ RF(lam)dlam\ /$$
$$Integral(from\ lam1\ to\ lam2)\ Cont(lam)dlam$$

The CH4 band depth intensity of the high resolution map (P_LEISA_HIRES) has been slightly shifted (8 percent) and stretched (10 percent) to best fit the values of the other observations.

The signal-to-noise ratio has been greatly improved using the global principal component analysis (PCA) covering most of the LEISA spectral range and spectrum reconstruction with inverse PCA. This analysis has been limited to incidence and emergence angles below 89 degrees. Since the band is very strong, the signal to noise ratio (S/N) is very high and the band depth is very sensitive, a minimum detection threshold of 0.0 is safe to use. Negative values means no CH4 was detected, although some very weak CH4 bands are still detected in H2O-dominated or Red material-dominated areas down to band depth, about -0.05. The maximum value in the image is about 0.55.

N2 map

This map plots the integrated N2 band depth between 2.136 and 2.160 micrometers over the N2 band at about 2.15 um. The full equation is provided in eq. 2 of Schmitt, et al. (2017) and reproduced here:

$$BD(N2) = 1 - [RF(2.136um) + RF(2.144um) +$$
$$RF(2.152um) + RF(2.160um)]\ /\ [RF(2.121um) + RF(2.1285um) +$$
$$RF(2.1675um) + RF(2.1755um)].$$

The signal-to-noise ratio has been greatly improved using a specific PCA around the 2.15 micrometer band and spectrum reconstruction with inverse PCA. This analysis has been limited to incidence angles below 88 degrees and emergence angles below 89 degrees. This band being weak, the S/N is low, and a global minimum detection threshold of about 0.025 should be used. The local detection threshold can be lower (~0.01). Negative values mean no N2 was detected. The maximum value in the image is 0.228.

As demonstrated in details in Schmitt, et al. (2017), the N2 band depth depends on the fraction of the pixel covered by N2 ice but does not depend on the proportion of N2 (mostly over 95-99 percent). This band depth is sensitive to the grain size, but is inversely sensitive to the amount

of CH4 dissolved in it, and can be hidden completely when more than about 1 percent of CH4 is present. So a significant part of Pluto's surface still contains N2 ice but cannot be mapped with the N2 band depth.

CO map

This map plots the integrated CO band depth between 1.566 and 1.578 micrometers (um) over the CO band at about 1.58 um (2 nu).

The full equation is:

$$BD(CO) = 1 - [RF(1.5665um) + RF(1.572um) + RF(1.578um)] / [1.5 * [RF(1.561um) + RF(1.583um)]]$$

(Eq. 3 in Schmitt, et al. (2017)), but this calculation has been shifted to have a center at 1.572 um instead of 1.578 um (one spectel) to try to overcome the smile effect.

A specific PCA around the 1.578 micrometer band and spectrum reconstruction with inverse PCA has greatly improved the signal-to-noise ratio. This analysis has been limited to incidence angles below 88 deg and emergence angles below 89 deg. However, this band is very weak and narrow, its intensity is very sensitive to the 'spectral smile' affecting the data (not yet corrected) and the relative intensity of the band at large scale can be very strongly perturbated. The CO locations are relatively fiable but some areas, especially to the E of Pluto may be missing. A minimum threshold of about 0.005 should be used as the signal to noise is also low. Negative values means no CO was detected.

- H2O map:

This map plots a specially designed H2O spectral indicator using 10 wavelength bands around each of 1.39 and 2.06 micrometers as defined in eq. 4 of Schmitt, et al. (2017) to improve the signal to noise ratio, given here again:

$$SI(H2O) = 1 - SUM[RF(2.022um) \text{ to } RF(2.090um)] / SUM[RF(1.365um) \text{ to } RF(1.410um)]$$

It was found the most sensitive for separating H2O from the signature of the Red material and also for maximizing the contrast with CH4 ice.

This spectral indicator, mainly spanning the [-0.25 - 0.65] range, has been normalized between [0 - 1] for easier use. Negative values means no H2O was detected. The initial detection threshold of the high resolution map (P_LEISA_HIRES) has been slightly upshifted to -0.20 before normalization, to best fit the values of the other observations.

The presence of red material may affect the low values (< 0.25) of this normalized H2O spectral indicator. This map did not use the MVIC 'red slope' to conservatively remove this effect (see Schmitt et al. 2017) as this slope indicator is not yet available as a global map.

More detailed information is provided in Schmitt, et al. (2017).

Uncertainties

A description of the uncertainties may be found in Howett, et al. (2017).

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