Chandrayaan-2

IIRS PDS4 Data Products

User Guide

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Chandrayaan-2 IIRS PDS4 Data Products User Guide

Document Change History

*A: Addition; M: Modification; D: Deletion

Version No.	Date	Section No.	A/M/D *	Description of change
V 1.0	Nov 21, 2019	All	A	Initial draft Version
V 2.0	October 28, 2020	All	M	Initial feedback and comments
		3.3	A	Data file formats
		Annexure IV and V	A	Conversion factor and central wavelength
V3.0	January 8, 2021	Annexure VI	A	Added Band Validity List
V4.0	13 July 2021	Annexure VII	A	Added Radiance to Reflectance Conversion
V5.0	16 July 2021	Annexure IV and VI	D	Deleted as mentioned in DP SIS
		Annexure IV	A	Added Coverage Map
		5	A	Added Disclaimer
V 6.0	23 August 2021	4.5	A	Added the Data Product Acknowledgment Statements

Technical Content Approvals

	Name & Function
Reviewed by	Amitabh DPD (Optical P/L DP) Chandrayaan-2 Satadru Bhattacharya PI, IIRS, Chandrayaan-2
Approved by	T P Srinivasan Alternate Chairman, Chandrayaan-2 PDS4 Working Group SAC – ISRO, Ahmedabad

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1. Introduction

1.1 Purpose and Scope

The purpose of this user guide document is to bring about the details of the PDS4 Data Products from the user's perspective. It lists out the number of data products, types and formats available for the users to work with PDS4 data products.

1.2 Audience

This document is meant for the staff of archiving authority (ISSDC for ISRO), data processing team, PI science team, and users from scientific community.

1.3 Acronyms, Abbreviations & Definitions

Table 1 brings out the list of definitions, acronyms & abbreviations used in this report.

Table 1. Acronyms, Abbreviations & Definitions

Acronyms/ Abbreviations	**Description**
PDS	Planetary Data System
ISRO	Indian Space Research Organization
ISSDC	Indian Space Science Data Centre
ISDA	ISRO Science Data archive
SAC	Space Applications Centre
DP	Data Processing
IIRS	Imaging Infrared Spectrometer
SPICE	Spacecraft Planet Instrument Camera Event
ICD	Interface Control Document
Kernel	Primary SPICE data sets
DPD	Deputy Project Director

Acronyms/ Abbreviations	Description
PI	Principal Investigator
CODMAC	Committee on Data Management and Computation
EOM	Electro Optical Module
MTF	Modulation Transfer Function
SNR	Signal-to-Noise Ratio
GSD	Ground Sampling Distance
OSF	Order Sorting Filter

1.4 Applicable Document

1. Chandrayaan-2 – Imaging Infrared Spectrometer (IIRS) PDS4 Data Products and Archive Software Interface Specifications (Chandrayaan-2/DP/SAC/SIPG/HRDPD/TR-07/July 2020)

2. Chandrayaan-2 PDS4 data archive

Chandrayaan-2, India's second mission to the Moon was launched by GSLV-MKIII in July 2019. Mission carries 8 scientific payloads on Orbiter. Orbiter is presently orbiting moon under 100 km x 100 km circular orbit.

The data collected from the instruments from the orbiter is received, processed and archived in Indian Space Science Data Center (ISSDC) for dissemination and use by scientific community in India and abroad.

The data from Chandrayaan-2 instruments are archived in such a way that they are easily accessible by internet through simple interfaces similar to those that are being used elsewhere for similar missions.

PDS4 is the international standard for long term archival of planetary science data. For all the scientific payloads, PDS4 data products types were identified as shown in **Table 2**.

Each of the PDS4 data products types were mapped to the ISRO Levels and CODMAC Level shown in below **Table 2**.

Table 2. Chandrayaan-2 PDS4 CODMAC mapping

PDS4 Level	PDS4 Level Description	ISRO Level	CODMAC Level
Raw	Original data from an instrument after initial pre-processing like decompression, reformatting, packetization etc. The archived data are in a PDS approved archive format.	0	2
Calibrated	Data converted to physical units, which makes values independent of the instrument (Radiometrically corrected & seleno-tagged).	1	3
Derived	Results that have been distilled from one or more calibrated data products (for example, maps, gravity or magnetic fields, or ring particle size distributions). Supplementary data, such as calibration tables or tables of viewing geometry, used to interpret observational data should also be classified as 'derived' data if not easily matched to one of the other three categories (higher level products like ortho, DEM).	2	4+

3. Archive Structure

Archive structure is designed both at instrument level and data products level.

3.1 Instruments Collection and Data Products

Under each instrument wise data collection, data is organized under each directory defined by PDS4. Data is organized based on the levels of data processing and data products definitions. To handle requirement of archiving the data products for 12 orbits in a day, data products are organized into year-month-day format as yyyymmdd. Figure 1 shows the details of instrument wise collection structure.

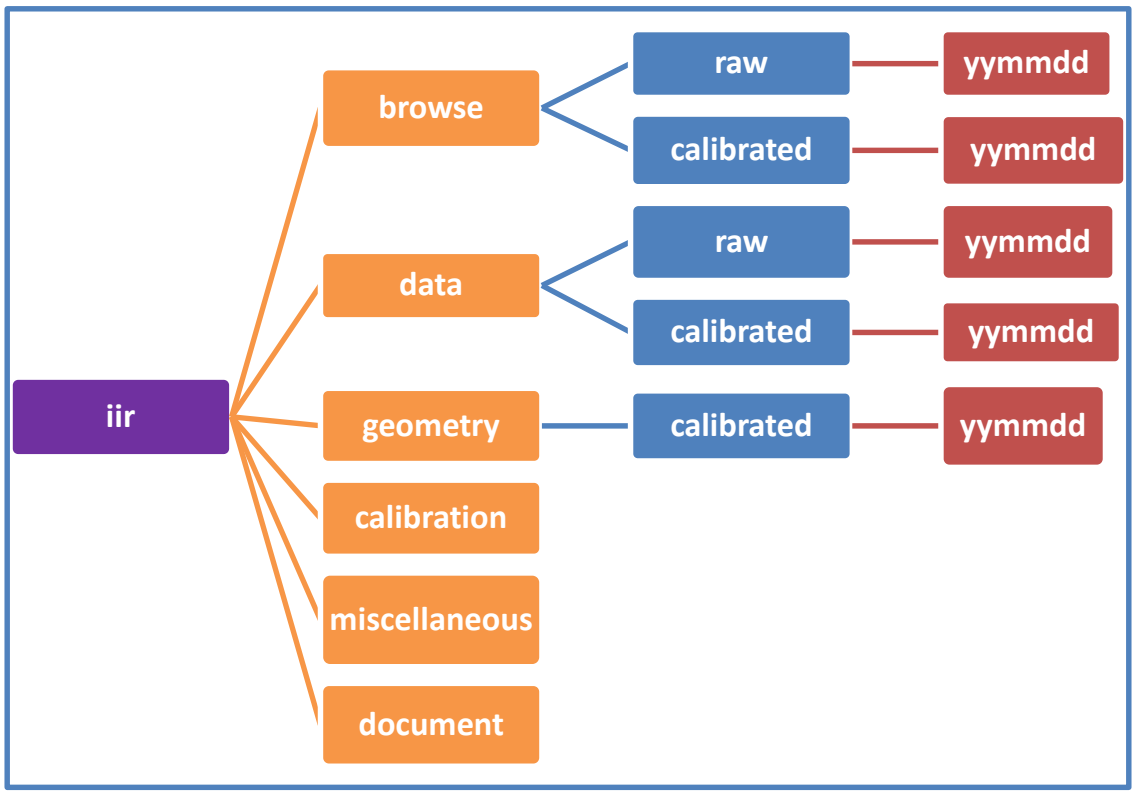


Figure 1. Instrument Collection and Data Products

4. IIRS PDS4 Data Products

A PDS product consists of one or more digital and/or non-digital objects, and an accompanying PDS label file. The labeled digital objects are classified as data products (i.e. electronically stored files).

Labeled non-digital objects are physical and conceptual entities which have been described by a PDS label. These labels provide identification and description information for labeled objects. The PDS label defines a Logical Identifier (LID) by which any PDS labeled product is referenced throughout the system.

PDS4 labels are XML formatted ASCII files. More information on the formatting of PDS labels is provided in DP and Archive SIS document.

The PDS4 data products for IIRS are defined based on the data processing levels as Raw (L0) and Calibrated (L1) data products. **Table 3** shows the data products definitions for each level of data processing. The details of the descriptions about the raw and calibrated data product mentioned in **Table 3** are given in the following sub sections.

Table 3. Chandrayaan-2 IIRS Data Products Definitions

Data Products Levels	**Level-0**	**Level-1**	**Level-2***
Data Products Definition	Raw qube data without any data processing correction along with system level corner coordinates	Radiometrically corrected qube data, refined corner coordinates tagged and grid data	Thermally and Photometrically Corrected reflectance qube data
PDS4 Level	Raw	Calibrated	Derived

Note* - Level-2 Data Products are under development

The detail description about the Raw Data Product and Calibrated Data Product mentioned in above Data Products Definition in **Table 3** are described in the following sub sections

4.1 Raw Data Products

Raw data products contain the raw image qube data (raw count) which is dark data* subtracted without any correction along with the system level corner coordinates. In the imaging season 1 (December 2019 – February 2020) and 2 (May 2020 – July 2020), for each acquisition of image, pre and post-dark sessions were acquired from the non-illuminated side of the Moon. Based on the analysis of both the sessions, pre-imaging dark data was found to have the minimal variations (from average dark count). Hence, data processing chain currently uses pre-imaging dark data for dark estimation.

Note*: If there are changes in dark estimation in due course of time (because of better understanding of payload behavior), it will be notified and DPSIS will be updated in future version of release.

For each payload observation, PDS4 data products are generated (based on product id and sensor id derived from file name (for details refer Annexure-I), zipped and organized under year-month-day wise collection directory defined under instrument collection structure shown in Section 6.4. For example, if the user has downloaded a zip product as,

- ch2_iir_nri_20200701T1351524657_d_img_d18.zip

unzipped structure of IIRS raw data product at user end will be as shown

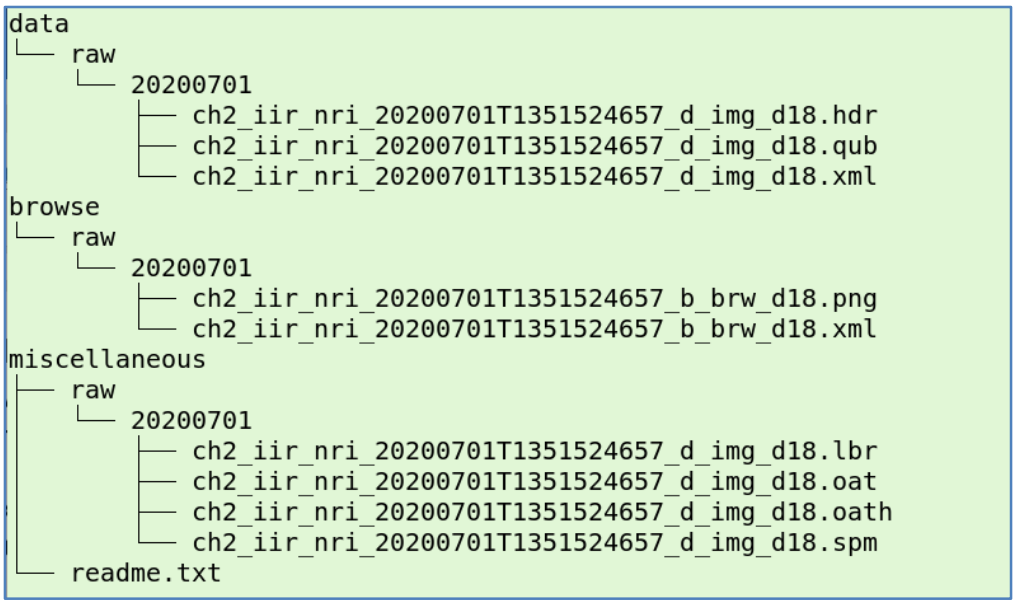


Figure 2. IIRS Raw Data Archive

The details of individual data products along with the data formats present inside the zip product are shown in **Table 4**. To visualize the data products please refer Annexure II.

Table 4. IIRS Raw Data Products

PDS4 data product levels	PDS4 data products	Data formats	Description	Visualization tools available
Raw	Data raw image	Binary	The PDS raw data in qube form in generic binary format	Any binary image viewer – imageJ, Envi, Erdas etc. Provide image width, image height, number of bands and data type from label file
	Data raw label	XML	The PDS label product contains description about the raw product.	PDS4 viewer or any web browser
	Browse raw image	PNG	Sub-sampled browse raw image of band no. 40	Any image viewer can be used to load the png file
	Browse raw label	XML	The PDS label product contains description about the browse raw product.	PDS4 viewer or any web browser
	Miscellaneous data (non-PDS data)	Text	Contains four files such as orbit & attitude (oat), orbit & attitude header (oath), liberation angle (lbr), sun parameter file (spm)	Any text viewer software will be able to load the data

4.2 Calibrated Data Products

Calibrated Data Products contain radiometrically corrected data along with the refined corner coordinates. The radiometrically corrected data is generated from raw data by subtracting the dark data as the first step. The detector non-uniformity is corrected by applying Look Up Table (LUT) and then destriping is applied to reduce the residual non-uniformity. The resultant output of the above steps is converted into radiances and then post processing is carried out. This includes keystone correction, radiance adjustment in OSF regions (applied only in OSF regions), radiance corrections at the start and end of the spectral regions. Above mentioned post processing steps improve the accuracy of radiances. This calibrated data is converted to physical units (mWcm-2sr-1µm-1) and stored as 32-bit floating point numbers in generic binary BSQ format.

The user may find differences in radiances converted using the raw data, look up table and formula provided in Appendix-F with respect to the calibrated data provided as part of PDS4 archive. The differences in radiances values are due to the post processing steps mentioned above. All OSF region bands, bands in the beginning and end are marked as bad bands/low confidence bands as described in Appendix-H.

Apart from radiometrically corrected image qube product, there is another geometrically gridded data product that is generated in DP software which takes Orbit, Attitude and Time (OAT) from level-0 as an input. All these files are generated at level-0 using SPICE kernel as an input. The SPICE Archive (hosted on ISSDC Pradan web application) can be accessed through the following link- https://pradan.issdc.gov.in/pradan/protected/browse.xhtml?id=spice.

For each payload observation, PDS4 data products are generated (based on product id derived from file name (for details refer Annexure-I), zipped and organized under year-month-day format collection directory defined under instrument collection structure as shown in section 6.4. For example, if the user has downloaded the zip product as

- ch2_iir_nci_20200701T1351524657_d_img_d18.zip

unzipped structure of IIRS raw data product at user end will be as shown in **Figure 3**.

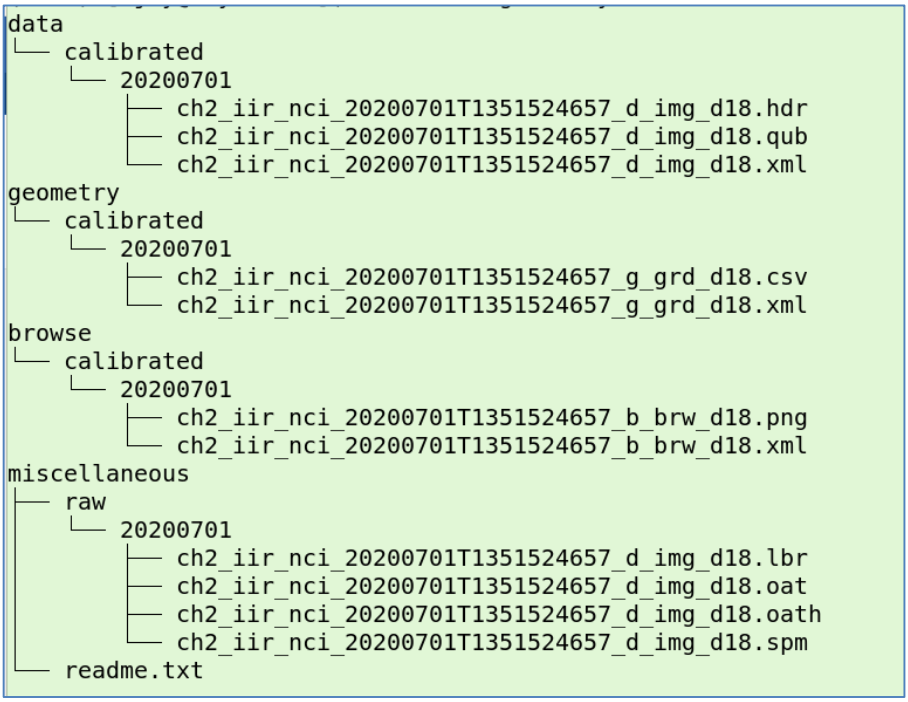


Figure 3. IIRS Calibrated Data Archive

The details of individual data products along with the data formats present inside the zip product are given in **Table 5.**

Table 5. IIRS Calibrated Data Products

PDS4 data product levels	PDS4 data products types	Data formats	Description	Visualization tools available
Calibrated	Data calibrated image	Binary	The PDS radiometrically corrected data in qube form in generic binary format	Any binary image viewer – imageJ, envi, erdas, etc. Provide image width, image height, number of bands and data type from label file
	Data calibrated label	XML	The PDS label product contains description about the calibrated product.	PDS4 viewer or any web browser

PDS4 data product levels	PDS4 data products types	Data formats	Description	Visualization tools available
	Browse calibrated image	PNG	Sub-sampled browse calibrated image of band no. 40	Any image viewer can be used to load the png file
	Browse calibrated label	XML	The PDS label product contains description about the browse calibrated product.	PDS4 viewer or any web browser
	Geometric calibrated grid	CSV	A grid file containing longitude, latitude, scan and pixel numbers as four columns alongwith the data	Any text editor, MS Excel can be used to load the csv file.
	Geometric calibrated grid label	XML	The PDS label product contains description about the geometry calibrated product.	PDS4 viewer or any web browser
	Miscellaneous data (non-PDS data)	Text	Contains four files orbit & attitude (oat), orbit & attitude header (oath), liberation angle (lbr), sun parameter file (spm)	Any text viewer software will be able to load the data

4.3 Data File Formats

IIRS instrument is a hyperspectral imaging payload. The primary data collected from instrument is raw image in cube format. The IIRS imager has 256 bands. For a single scene both primary as well as secondary data sets are defined that contains data product levels, types and formats shown in **Table 6**.

Table 6. IIRS PDS4 Data Products Format

Sensors	**PDS4 Data Product Levels**	**PDS4 Data Products Types**	**Data Formats**	**Data type***
Hyperspectral	Raw	Image	Binary Spectral Qube	UnsignedLSB2
	Raw	Browse	PNG	UnsignedByte
	Calibrated	Image	Binary Spectral Qube	IEEE754LSBSingle
	Calibrated	Browse	PNG	UnsignedByte
	Calibrated	Geometry	CSV	ASCII Text
	Derived	Image	Binary Spectral Qube	IEEE754LSBSingle

Note*:

UnsignedLSB2 is UInt16 (Unsigned Integer of 16-bit length)

SignedLSB2 is Int16 (Signed Integer of 16-bit length)

Unsigned Byte is 8-bit unsigned integer

IEEE754LSBSingle is floating point of 32-bit length

4.4 Data Product Acknowledgment

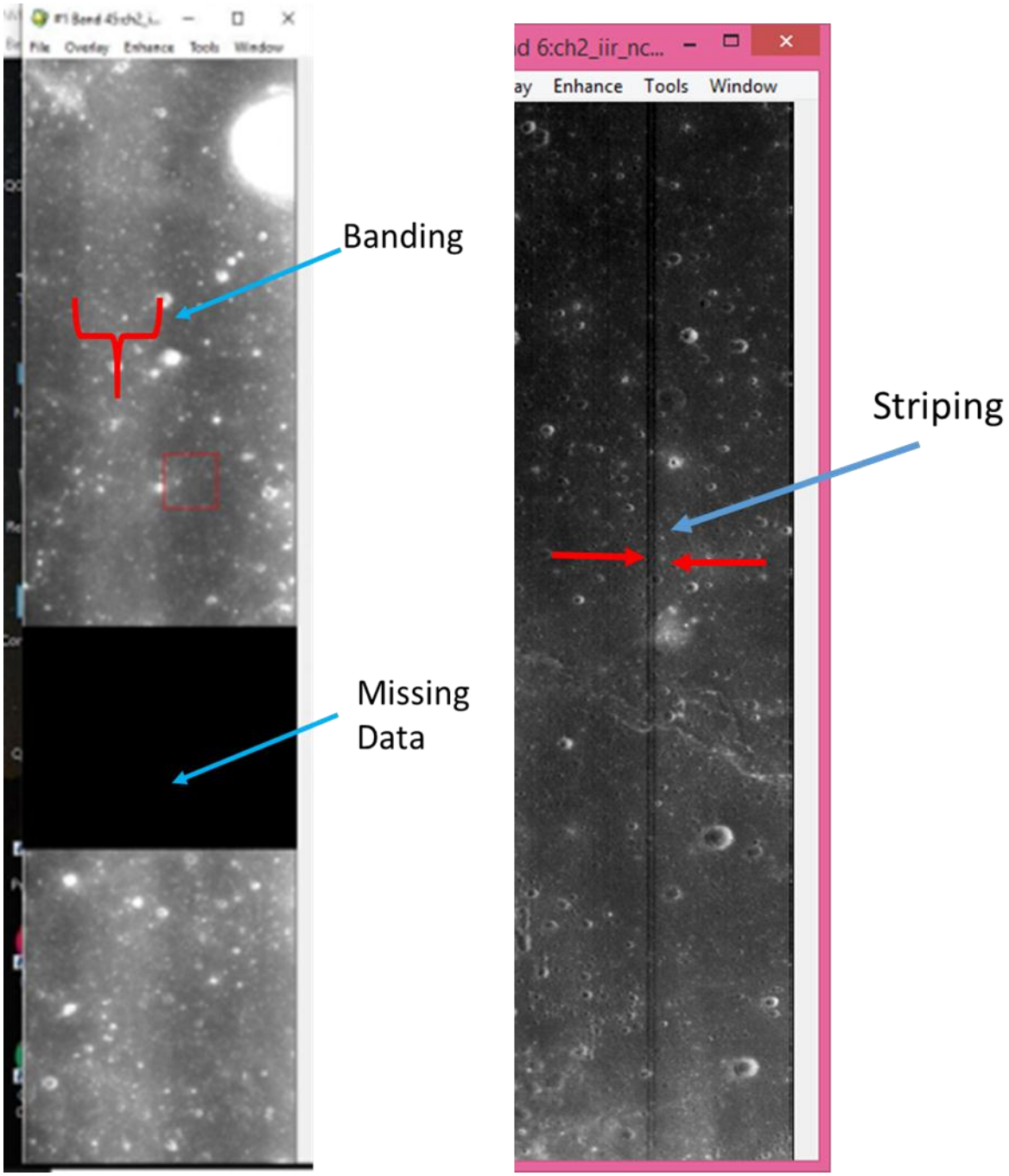
- The users will make available to the scientific community the salient results of the data analysis through publication in appropriate journals.
- When publishing a paper using the Chandrayaan-2 data, please
    - mention about “Chandrayaan-2” in abstract and
    - include the following statement in acknowledgement - "We acknowledge the use of data from the Chandrayaan-2, second lunar mission of the Indian Space Research Organisation (ISRO), archived at the Indian Space Science Data Centre (ISSDC)"
- If you are using the results of Chandrayaan-2 which are already published and carrying out further interpretation or modeling, please include the following statement in acknowledgement - "The research is based partially / to a significant extent **(whichever is applicable)** on the results obtained from the Chandrayaan-2, second lunar mission of the Indian Space Research Organisation (ISRO), archived at the Indian Space Science Data Centre (ISSDC)"
- ISRO reserves the right to use the published results in its reports and publications with due reference to the publication. If the reports or publications are copyrighted, ISRO will have a royalty-free right under the copyright to reproduce, distribute and use the copyrighted works for their purposes.
- Any print of the data/ data products supplied by ISRO should carry the mark "© reserved ISRO" mark in legible letters.

5. Disclaimer

This data is provided on an experimental as is basis, because the in-orbit calibration-validation exercises are ongoing as image acquisition over calibration sites are in progress. These datasets will be updated as and when the newer/better processing steps are added. The user is requested to ascertain the utility of the datasets of interest before any publication of results derived from these datasets.

It is also brought to the notice of the user that the instrument principal investigator (PI) or Department of Space/Indian Space Research Organization (DOS/ISRO) is not responsible for any dispute/disrepute that may arise due to the use of this dataset. The user should neither redistribute the data to third party nor it be used for any commercial purpose without the knowledge of Department of Space/Indian Space Research Organization (DOS/ISRO).

Note: Few data sets may contain vertical stripping/banding and missing data at sporadic places. Also, the spectral region in longer wavelengths (dominated by thermal emission- Band 155 and beyond) domain may contain problematic radiance values. Users are requested to use such data with caution.



Examples of Vertical Stripping/Banding and Missing Data

Annexure–I: File Naming Conventions & Formats

This section describes the naming convention used for science data files for the mission. **Table 7** shows the detail description about the following file naming conventions designed for the data products.

ch2_<inst>_<mtc>_<YYYYMMDDTHHMMSSssss>_<p>_<prd>_<stn>.fff

Table 7. File Naming Conventions

Code	Description
ch2	It denotes the mission name whose value is fixed as ch2.
inst	It denotes the Instrument ID, it can have following value: = iir (refers to the IIRS)
m	It denotes the mission phase name. It can have following values: = e (refers to the Earth Bound Phase - ebp) = n (refers to the Normal Operations Phase - nop)
t	It denotes the data type. It can have following values: = r (referes to raw data) = c (referes to clibrated data) = d (referes to derived data)
c	It denotes the imaging mode/camera id/band. It can have the following value: = i (referes to Imaging InfraRed Spectrometer (IIRS))
YYYYMMDDTHHMMSSssss	It denotes the observation/imaging start time and has the following format: YYYY stands for year MM stands for month DD stands for day T stands for time. HH stands for hour MM stands for minute SS stands for seconds ssss stands for 1/10 millisecond or 100 microsecond

Code	Description
p	It denotes the PDS data products categories. Its value can be any of the following: = d (referes to data products under data directory) = b (referes to browse data products under browse directory) = g (referes to gridded data products under geometry directory)
prd	It denotes the PDS data product name. Its value can be any of the following: = img (referes to the image data product) = brw (referes to the browse data product) = grd (referes to the gridded data product)
stn	It denotes the station id from which data was acquired. Its value can be any of the following: = d32 (ISSDC, Bangalore) = d18 (ISSDC, Bangalore) = gds (Gold Stone, USA) = cnb (Canberra, Australia)
fff	It denotes the standard file type extension. It can have any one of the following values: = img (PDS image data file) = qub (PDS image qube data file) = hdr (Envi header file) = xml (PDS detached label file) = jpg (PDS browse data file) = csv (PDS geometry data file) = tif (PDS geotiff data for derived products)

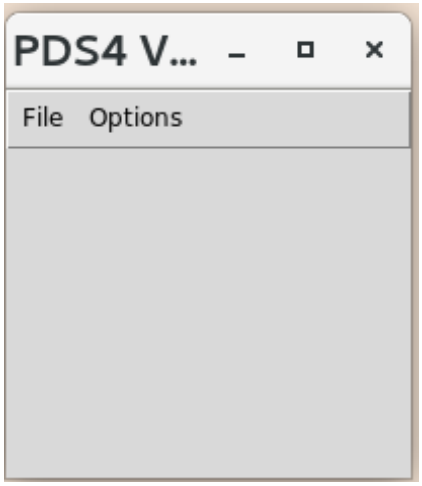
All underscore characters '_' are mandatory and separate the different fields.

Annexure–II: Visualize PDS4 Data Products using PDS4 Viewer

There are many PDS tools are available for opening the Raw/Calibrated Data products such as PDS4Viewer. PDS4Viewer is a simple display tool for visualizing data contained in the PDS4 data standard. PDS4Viewer tool can be downloaded from internet using link "http://sbndev.astro.umd.edu/wiki/PDS4_Viewer". This Software is available for both Linux as well as window platform. The given data sets can be opened using PDS4Viewer.

The instructions to open the data using PDS4Viewer are as follows:

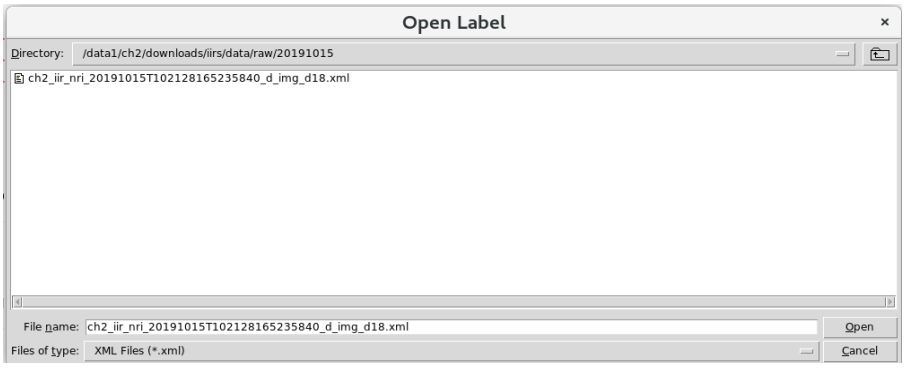
1. Download the PDS4Viewer tool from internet location "http://sbndev.astro.umd.edu/wiki/PDS4_Viewer". There will be zip files (for both Linux/Windows) which contain the PDS4Viewer.
2. Extract the Zip file into any location.
3. Go to the extracted directory and run the pds4_viewer executable file. The PDS4Viewer GUI will come up on the screen, as shown below.



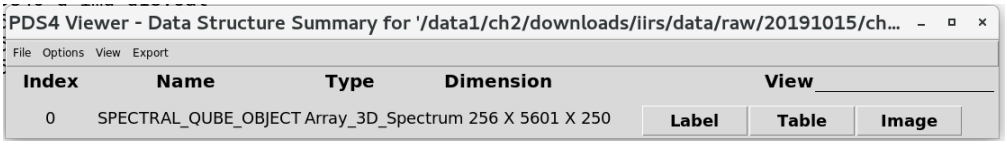
Opening PDS4 Raw/Calibrated Image Product

==========

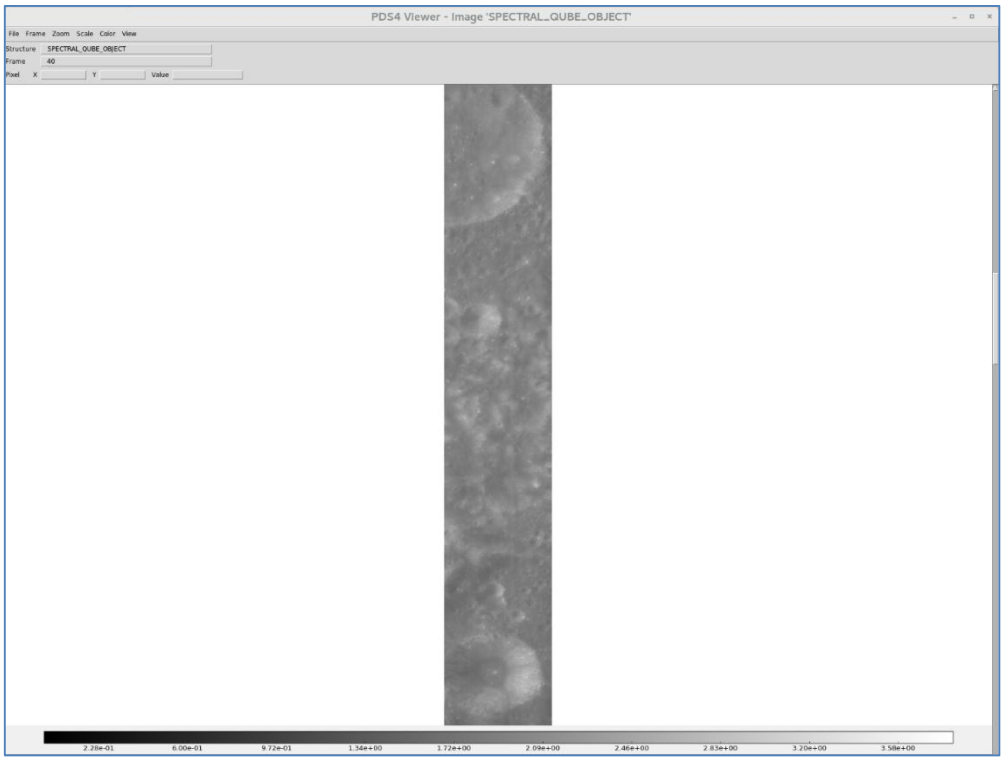
1. After opening the PDS4Viewer display tool. Click on the <File> menu and select <Open> object.
2. From the dialog box (shown below) and select a label file (xml file) and click <Open> button.



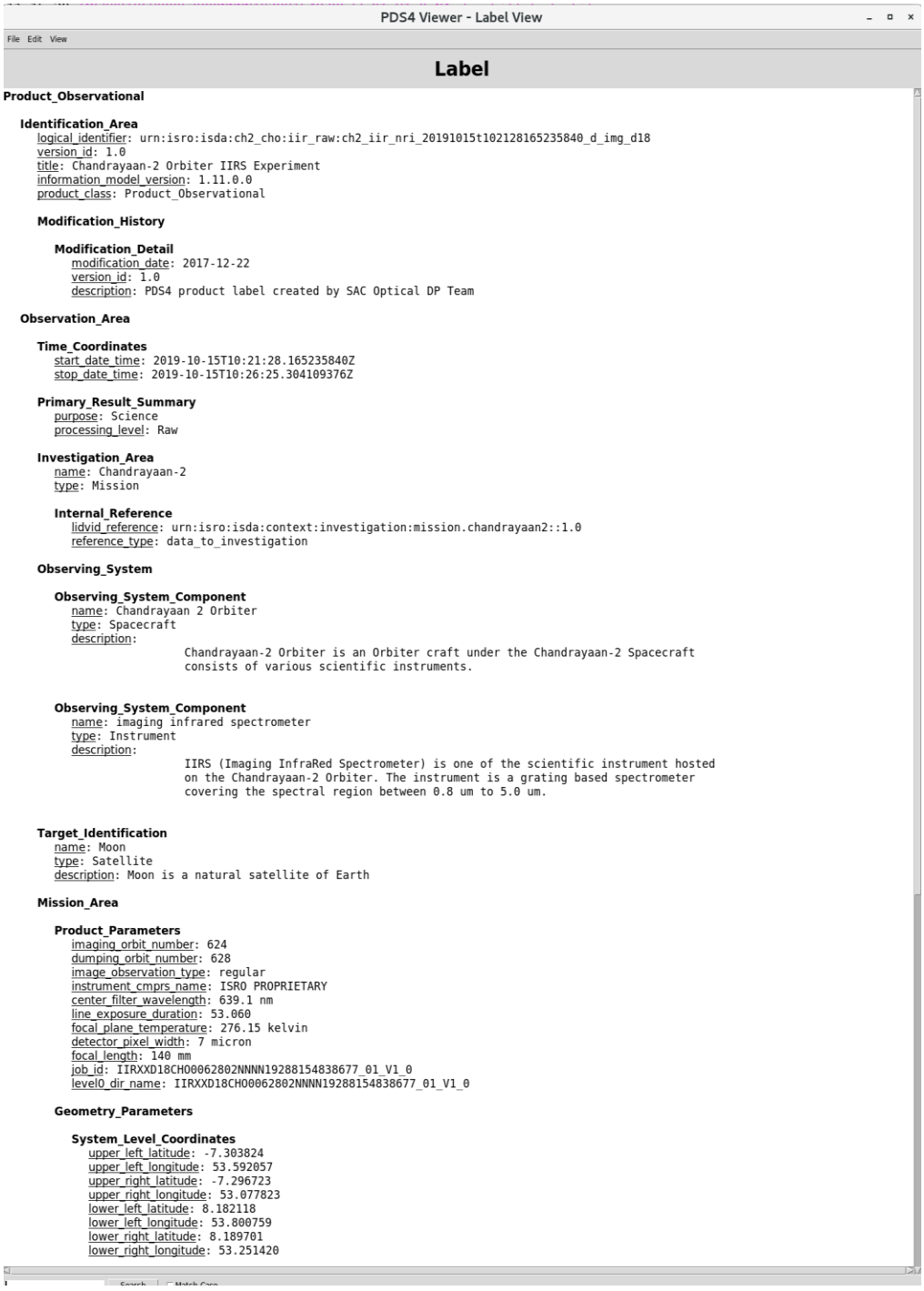
3. After clicking <Open> button, the data will be loaded in the PDS4Viewer as shown below:



4. For opening an image, click on the <Image> button as shown on the figure in step 3. The following figure shows the image from the IIRS payload data that will open.



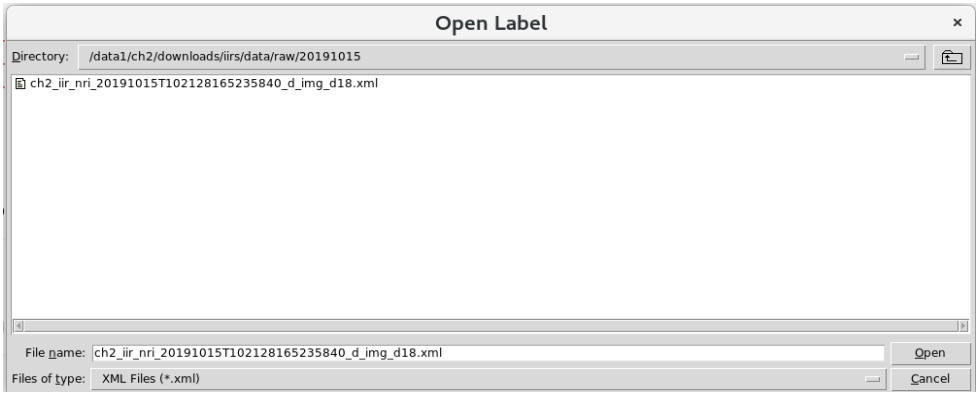
5. For opening a label, click on the <Label> button shown in step 3. The figures below show the label file as label view.



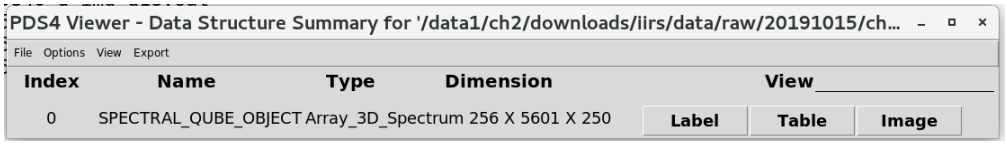
Opening PDS4 Geometry Grid Data Product

==========

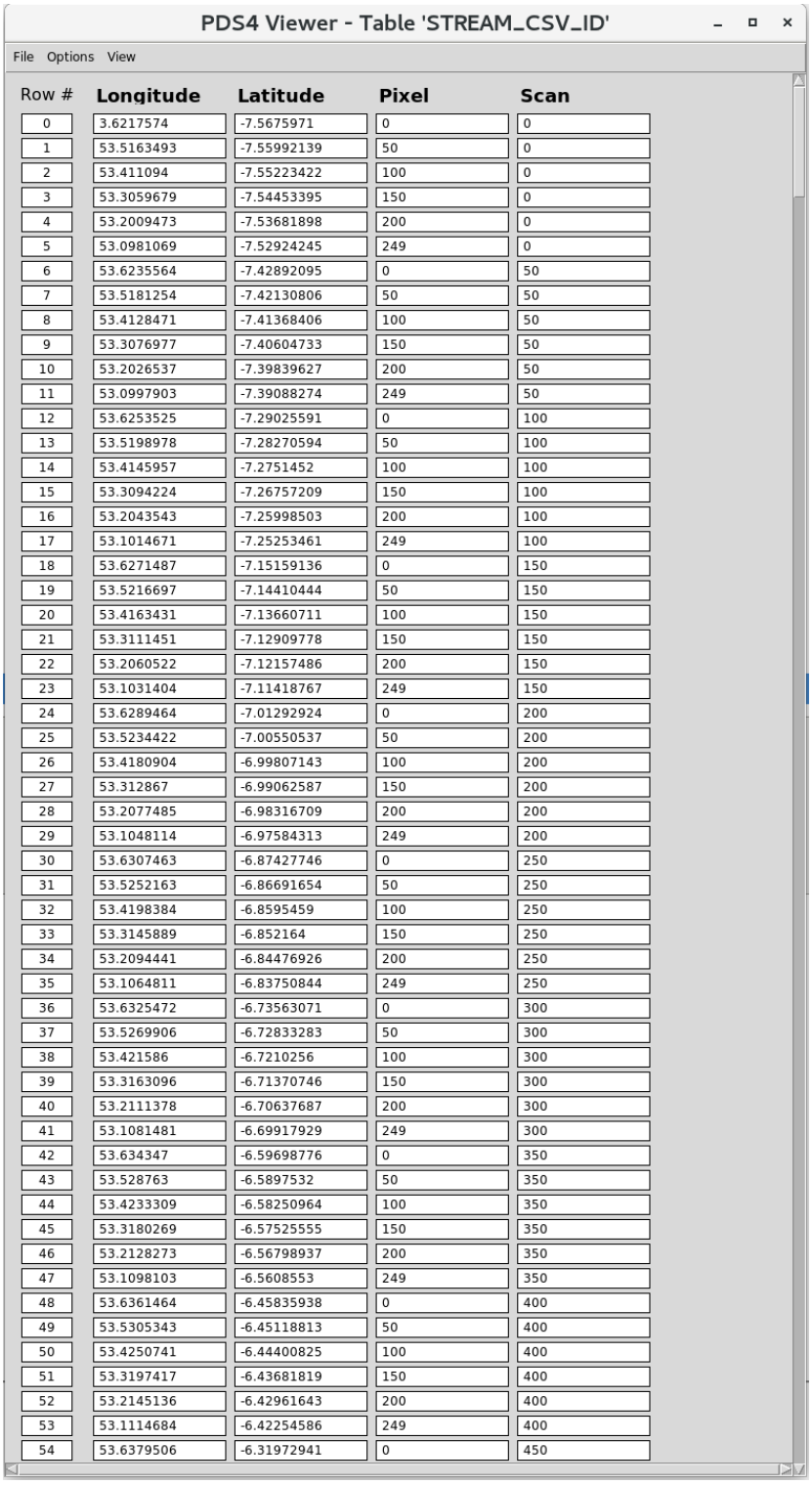
1. After opening the PDS4Viewer display tool. Click on the <File> menu and select <Open> object.
2. From the dialog box (shown below) and select a label file (xml file) and click <Open> button.



3. After clicking <Open> button, the data will be loaded in the PDS4Viewer as shown below:



4. For opening grid file, click on the <Table> button shown on the figure in step 3. The figure below shows the grid file from the IIRS payload data.

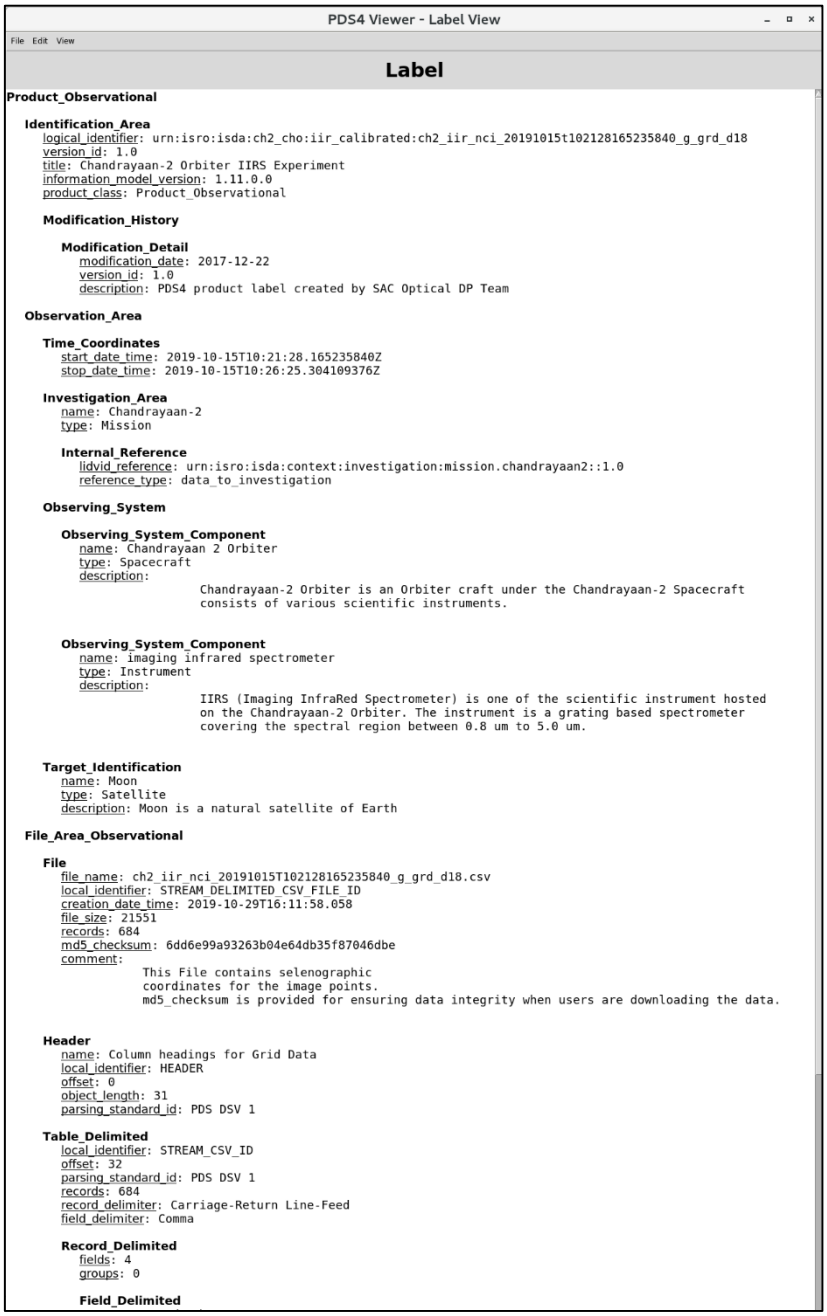


PDS4 Viewer - Table 'STREAM_CSV_ID'

File Options View

Row #	Longitude	Latitude	Pixel	Scan
0	3.6217574	-7.5675971	0	0
1	53.5163493	-7.55992139	50	0
2	53.411094	-7.55223422	100	0
3	53.3059679	-7.54453395	150	0
4	53.2009473	-7.53681898	200	0
5	53.0981069	-7.52924245	249	0
6	53.6235564	-7.42892095	0	50
7	53.5181254	-7.42130806	50	50
8	53.4128471	-7.41368406	100	50
9	53.3076977	-7.40604733	150	50
10	53.2026537	-7.39839627	200	50
11	53.0997903	-7.39088274	249	50
12	53.6253525	-7.29025591	0	100
13	53.5198978	-7.28270594	50	100
14	53.4145957	-7.2751452	100	100
15	53.3094224	-7.26757209	150	100
16	53.2043543	-7.25998503	200	100
17	53.1014671	-7.25253461	249	100
18	53.6271487	-7.15159136	0	150
19	53.5216697	-7.14410444	50	150
20	53.4163431	-7.13660711	100	150
21	53.3111451	-7.12909778	150	150
22	53.2060522	-7.12157486	200	150
23	53.1031404	-7.11418767	249	150
24	53.6289464	-7.01292924	0	200
25	53.5234422	-7.00550537	50	200
26	53.4180904	-6.99807143	100	200
27	53.312867	-6.99062587	150	200
28	53.2077485	-6.98316709	200	200
29	53.1048114	-6.97584313	249	200
30	53.6307463	-6.87427746	0	250
31	53.5252163	-6.86691654	50	250
32	53.4198384	-6.8595459	100	250
33	53.3145889	-6.852164	150	250
34	53.2094441	-6.84476926	200	250
35	53.1064811	-6.83750844	249	250
36	53.6325472	-6.73563071	0	300
37	53.5269906	-6.72833283	50	300
38	53.421586	-6.7210256	100	300
39	53.3163096	-6.71370746	150	300
40	53.2111378	-6.70637687	200	300
41	53.1081481	-6.69917929	249	300
42	53.634347	-6.59698776	0	350
43	53.528763	-6.5897532	50	350
44	53.4233309	-6.58250964	100	350
45	53.3180269	-6.57525555	150	350
46	53.2128273	-6.56798937	200	350
47	53.1098103	-6.5608553	249	350
48	53.6361464	-6.45835938	0	400
49	53.5305343	-6.45118813	50	400
50	53.4250741	-6.44400825	100	400
51	53.3197417	-6.43681819	150	400
52	53.2145136	-6.42961643	200	400
53	53.1114684	-6.42254586	249	400
54	53.6379506	-6.31972941	0	450

5. For opening a label, click on the <Label> button shown in step 3. The figure below shows the label file as label view.

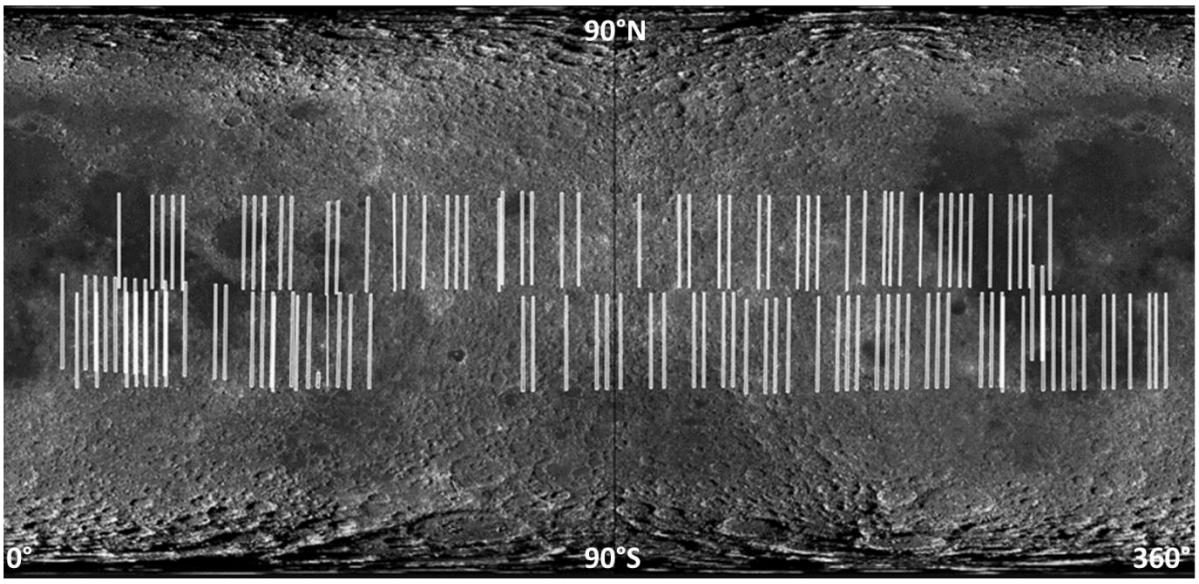


Annexure – III Team: Contact Information

Teams	Person Name	Contact	Email Id
Operations Team @ ISSDC IDSN Bylalu, Bengaluru	Sri. Sreenath	+91-80-2809-4416/17/18 (SCC), 2809-4419 (MOX), 2202-9173/74 (ISSDC-IDSN)	sreenath@istrac.gov.in
Principal Investigator (PI) Team @ SAC Ahmedabad	Sri. Satadru Bhattacharya	+91-079-26914361	satadru@sac.isro.gov.in

Annexure–IV: Coverage Map

This Annexure shows the IIRS coverage map of first imaging season from Dec. 2019 to Feb. 2020 in the figure below.



IIRS First Imaging Season Coverage Map

Note*: Some of the data sets may not be available publicly due to data quality constraints.

Annexure–V: Central Wavelengths for IIRS bands

Table 8 shows IIRS central wavelength and Band width for every bands.

Table 8 IIRS Central Wavelength and Band Width

Band number	Center wavelength (nm)	Band width (nm)
1	712.3	19.8
2	729.2	19.9
3	746	20
4	762.9	20.1
5	779.7	20.2
6	796.6	20.3
7	813.4	20.4
8	830.3	20.4
9	847.2	20.5
10	864	20.5
11	880.9	20.6
12	897.7	20.6
13	914.6	20.6
14	931.4	20.7
15	948.3	20.7
16	965.1	20.8
17	982	20.8
18	998.8	20.9
19	1015.7	20.9

Band number	Center wavelength (nm)	Band width (nm)
20	1032.5	20.9
21	1049.4	21
22	1066.2	21
23	1083.1	21.1
24	1099.9	21.1
25	1116.8	21.1
26	1133.6	21.2
27	1150.5	21.2
28	1167.3	21.2
29	1184.2	21.3
30	1201.1	21.3
31	1217.9	21.3
32	1234.8	21.4
33	1251.6	21.4
34	1268.5	21.4
35	1285.3	21.4
36	1302.2	21.5
37	1319	21.5
38	1335.9	21.5
39	1352.7	21.5
40	1369.6	21.6
41	1386.4	21.6
42	1403.3	21.6

Band number	Center wavelength (nm)	Band width (nm)
43	1420.1	21.6
44	1437	21.7
45	1453.8	21.7
46	1470.7	21.7
47	1487.5	21.7
48	1504.4	21.7
49	1521.2	21.8
50	1538.1	21.8
51	1555	21.8
52	1571.8	21.8
53	1588.7	21.8
54	1605.5	21.8
55	1622.4	21.9
56	1639.2	21.9
57	1656.1	21.9
58	1672.9	21.9
59	1689.8	21.9
60	1706.6	21.9
61	1723.5	21.9
62	1740.3	21.9
63	1757.2	22
64	1774	22
65	1790.9	22

Band number	Center wavelength (nm)	Band width (nm)
66	1807.7	22
67	1824.6	22
68	1841.4	22
69	1858.3	22
70	1875.1	22
71	1892	22
72	1908.9	22
73	1925.7	22
74	1942.6	22
75	1959.4	22
76	1976.3	22
77	1993.1	22
78	2010	22
79	2026.8	22
80	2043.7	22
81	2060.5	22.1
82	2077.4	22.1
83	2094.2	22.1
84	2111.1	22.1
85	2127.9	22.1
86	2144.8	22.1
87	2161.6	22.1
88	2178.5	22.1

Band number	Center wavelength (nm)	Band width (nm)
89	2195.3	22.1
90	2212.2	22.1
91	2229	22.1
92	2245.9	22
93	2262.8	22
94	2279.6	22
95	2296.5	22
96	2313.3	22
97	2330.2	22
98	2347	22
99	2363.9	22
100	2380.7	22
101	2397.6	22
102	2414.4	22
103	2431.3	22
104	2448.1	22
105	2465	22
106	2481.8	22
107	2498.7	22
108	2515.5	22
109	2532.4	22
110	2549.2	22
111	2566.1	22

Band number	Center wavelength (nm)	Band width (nm)
112	2582.9	22
113	2599.8	22
114	2616.7	22
115	2633.5	21.9
116	2650.4	21.9
117	2667.2	21.9
118	2684.1	21.9
119	2700.9	21.9
120	2717.8	21.9
121	2734.6	21.9
122	2751.5	21.9
123	2768.3	21.9
124	2785.2	21.9
125	2802	21.9
126	2818.9	21.9
127	2835.7	21.9
128	2852.6	21.9
129	2869.4	21.8
130	2886.3	21.8
131	2903.1	21.8
132	2920	21.8
133	2936.8	21.8
134	2953.7	21.8

Band number	Center wavelength (nm)	Band width (nm)
135	2970.6	21.8
136	2987.4	21.8
137	3004.3	21.8
138	3021.1	21.8
139	3038	21.8
140	3054.8	21.8
141	3071.7	21.8
142	3088.5	21.8
143	3105.4	21.8
144	3122.2	21.7
145	3139.1	21.7
146	3155.9	21.7
147	3172.8	21.7
148	3189.6	21.7
149	3206.5	21.7
150	3223.3	21.7
151	3240.2	21.7
152	3257	21.7
153	3273.9	21.7
154	3290.7	21.7
155	3307.6	21.7
156	3324.5	21.7
157	3341.3	21.7

Band number	Center wavelength (nm)	Band width (nm)
158	3358.2	21.7
159	3375	21.7
160	3391.9	21.7
161	3408.7	21.7
162	3425.6	21.7
163	3442.4	21.7
164	3459.3	21.7
165	3476.1	21.7
166	3493	21.7
167	3509.8	21.7
168	3526.7	21.7
169	3543.5	21.7
170	3560.4	21.7
171	3577.2	21.7
172	3594.1	21.7
173	3610.9	21.7
174	3627.8	21.7
175	3644.6	21.7
176	3661.5	21.7
177	3678.3	21.7
178	3695.2	21.7
179	3712.1	21.7
180	3728.9	21.7

Band number	Center wavelength (nm)	Band width (nm)
181	3745.8	21.7
182	3762.6	21.7
183	3779.5	21.7
184	3796.3	21.7
185	3813.2	21.7
186	3830	21.7
187	3846.9	21.7
188	3863.7	21.7
189	3880.6	21.7
190	3897.4	21.7
191	3914.3	21.7
192	3931.1	21.7
193	3948	21.8
194	3964.8	21.8
195	3981.7	21.8
196	3998.5	21.8
197	4015.4	21.8
198	4032.2	21.8
199	4049.1	21.8
200	4066	21.8
201	4082.8	21.9
202	4099.7	21.9
203	4116.5	21.9

Band number	Center wavelength (nm)	Band width (nm)
204	4133.4	21.9
205	4150.2	21.9
206	4167.1	21.9
207	4183.9	22
208	4200.8	22
209	4217.6	22
210	4234.5	22
211	4251.3	22
212	4268.2	22
213	4285	22.1
214	4301.9	22.1
215	4318.7	22.1
216	4335.6	22.1
217	4352.4	22.2
218	4369.3	22.2
219	4386.1	22.2
220	4403	22.2
221	4419.9	22.3
222	4436.7	22.3
223	4453.6	22.3
224	4470.4	22.4
225	4487.3	22.4
226	4504.1	22.4

Band number	Center wavelength (nm)	Band width (nm)
227	4521	22.4
228	4537.8	22.5
229	4554.7	22.5
230	4571.5	22.5
231	4588.4	22.6
232	4605.2	22.6
233	4622.1	22.7
234	4638.9	22.7
235	4655.8	22.7
236	4672.6	22.8
237	4689.5	22.8
238	4706.3	22.8
239	4723.2	22.9
240	4740	22.9
241	4756.9	23
242	4773.8	23
243	4790.6	23.1
244	4807.5	23.1
245	4824.3	23.2
246	4841.2	23.2
247	4858	23.3
248	4874.9	23.3
249	4891.7	23.4

Band number	Center wavelength (nm)	Band width (nm)
250	4908.6	23.4
251	4925.4	23.5
252	4942.3	23.5
253	4959.1	23.6
254	4976	23.6
255	4992.8	23.7
256	5009.7	23.8

*As per design 250 bands corresponds to intended wavelength range of around 0.8 – 5 um. Out of 256 bands, band numbers 1 to 5 and 256 have very low radiometric response thus recommended not to use.

Annexure–VI: Radiance to Reflectance Conversion

Level 1 calibrated radiance data can be used to estimate the reflectance by dividing with a solar spectrum and the cosine of the incidence angle, and normalizing with the solar distance (eqn. 1).

The formula for calculating apparent surface reflectance is given in equation (1).

$$\rho_{ap}(\lambda) = \frac{L(\lambda)}{\cos(i) \times \frac{F_0(\lambda)}{\pi}} \times \left(\frac{1}{d_{AU}}\right)^2 \qquad (1)$$

where, ρ_{ap} is the apparent surface reflectance, λ is wavelength, L(λ) is the calibrated radiance measured by IIRS (Level 1 radiance product), i is the solar zenith angle, $F_0(\lambda)$ is the solar irradiance at one Astronomical Unit (AU), d_{AU} is the distance from surface to the sun in AU. Once the data is converted into the apparent surface reflectance, further scientific analyses can be carried out to detect and map the surface mineralogy and hydration features on the Moon.

The spectral solar irradiance ($F_0(\lambda)$), provided as the file under miscellaneous directory (path iir/miscellaneous/), is the top of the atmosphere solar flux (F_o) convolved with the relative response function (RSR) of the IIRS instrument. The F_o values are taken from the National Oceanic and Atmospheric Administration Climate Data Record (NOAA CDR). The F_o is the average of the values from 2010 to 2019.

The users are free to use any other available solar irradiance spectrum that covers the spectral range of Chandrayaan-2 IIRS for IIRS radiance measurements or to convert IIRS derived products as required.

References

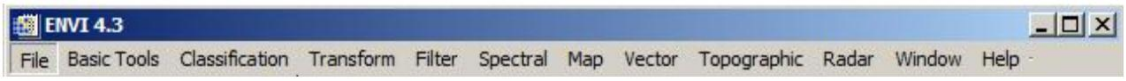
Coddington, O., J. L. Lean, P. Pilewskie, M. Snow, D. Lindholm, A Solar Irradiance Climate Data Record, BAMS, 2015, doi:10.1175/BAMS-D-14-00265.1.

Odele Coddington, Judith Lean, Doug Lindholm, Peter Pilewskie, and Martin Snow and NOAA CDR Program (2015): NOAA Climate Data Record (CDR) of Solar Spectral Irradiance (SSI), Version 2.1. [s1610-e2019]. NOAA National Centers for Environmental Information. doi:10.7289/V53776SW [26/02/2020]

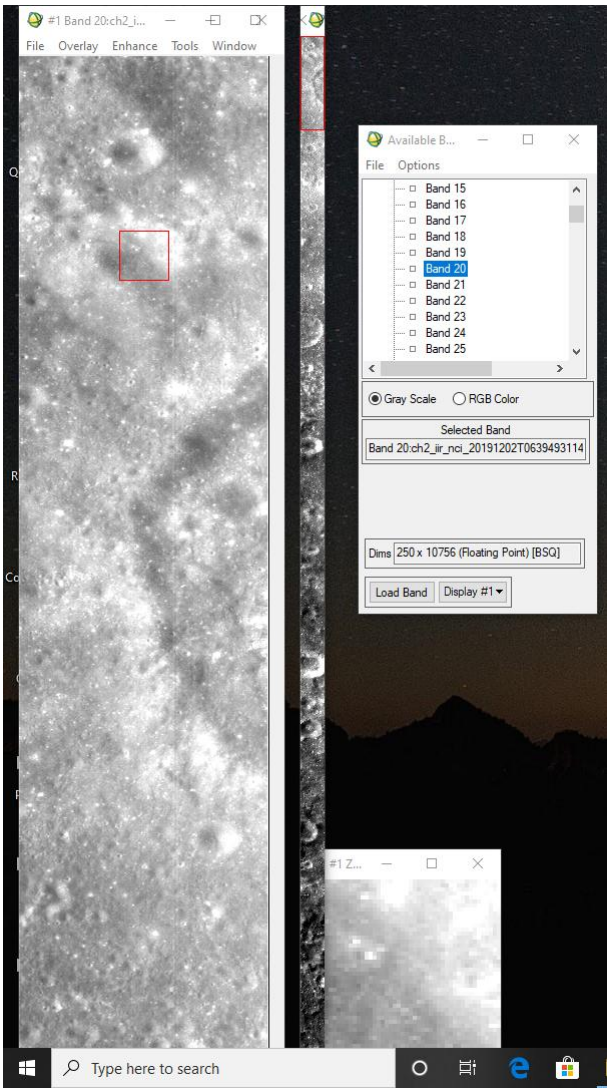
Annexure-VII: Working with IIRS data in ENVI

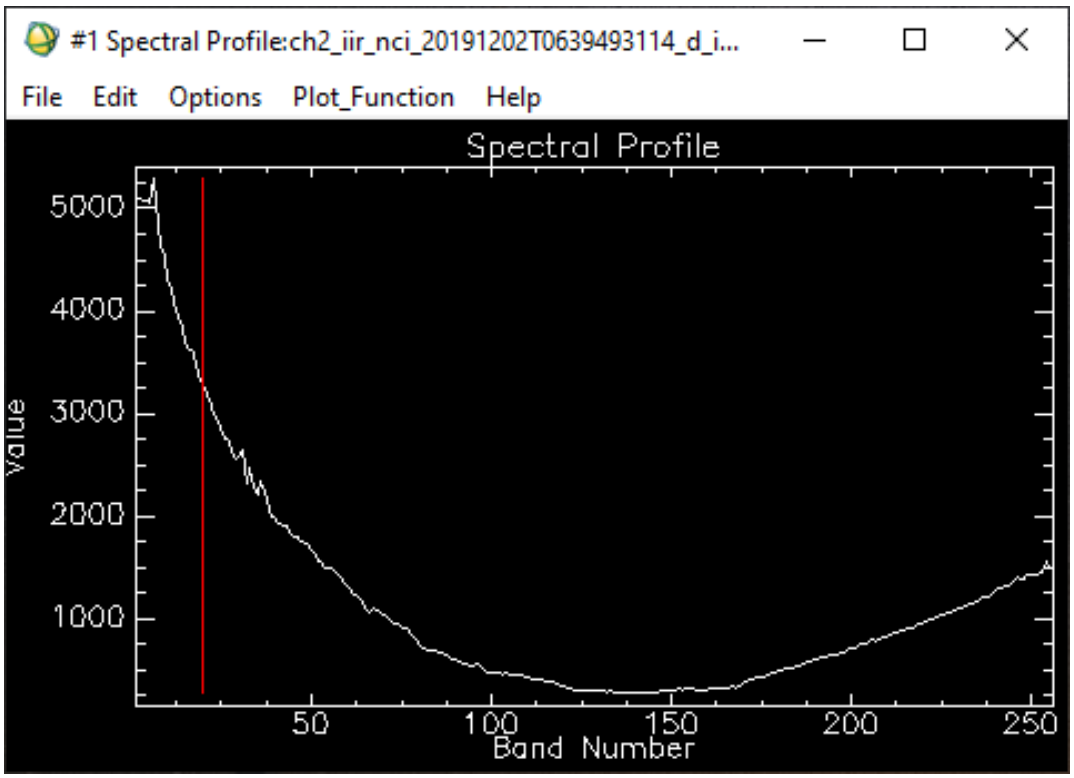
Loading of Level 1 IIRS PDS4 data in ENVI

1. Double click on ENVI  icon.
2. ENVI main menu bar will open.

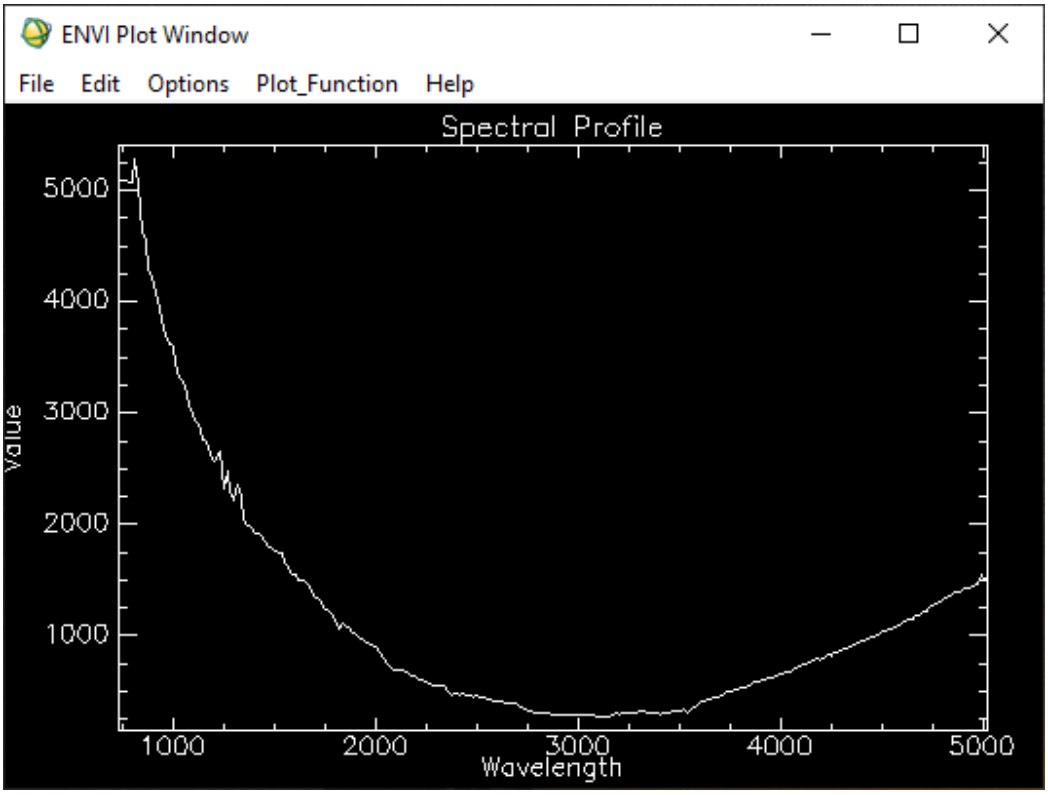


3. From the ENVI main menu bar, select File ⟶ Open Image File.
4. Navigate to the folder where IIRS data have been kept and select the *.qub file and click to open.



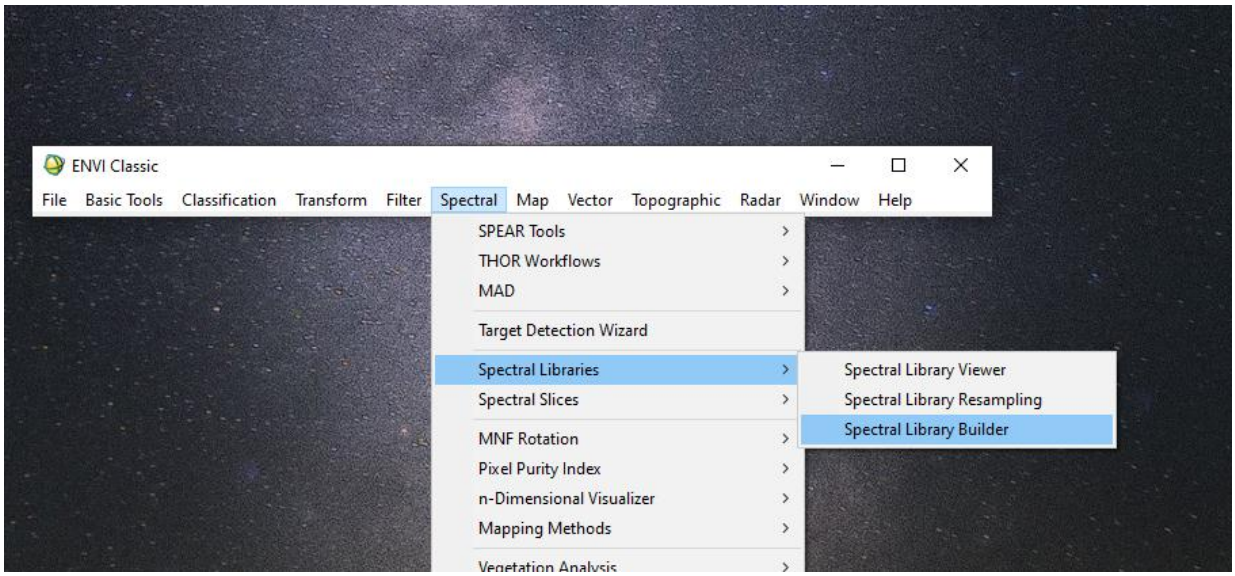


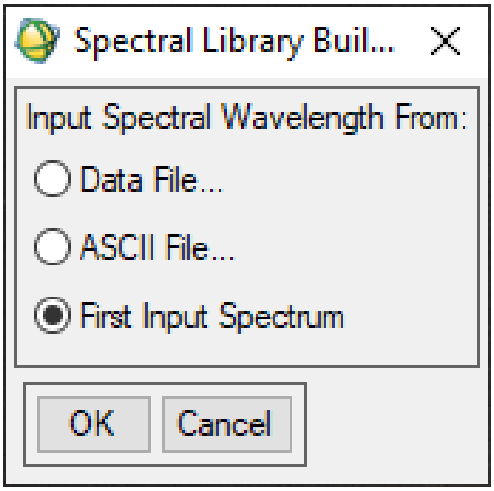
Radiance vs Spectral channels plot

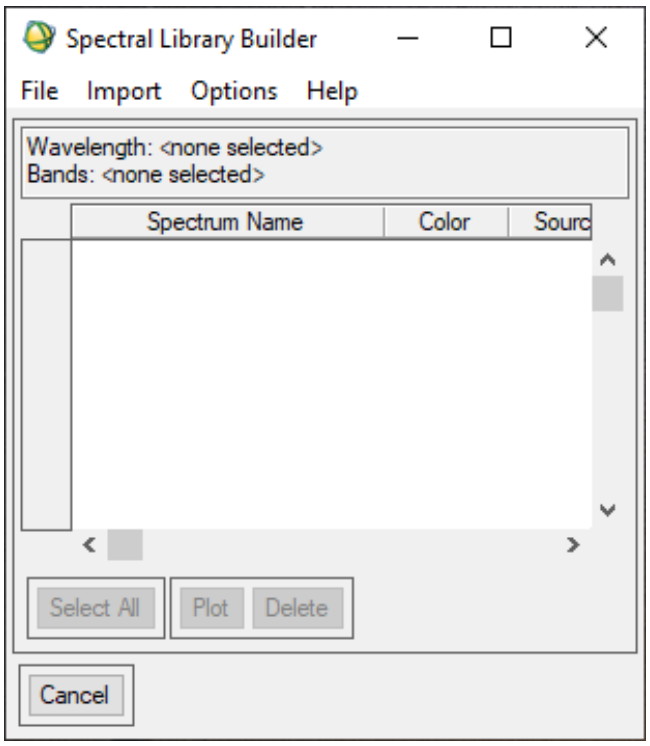


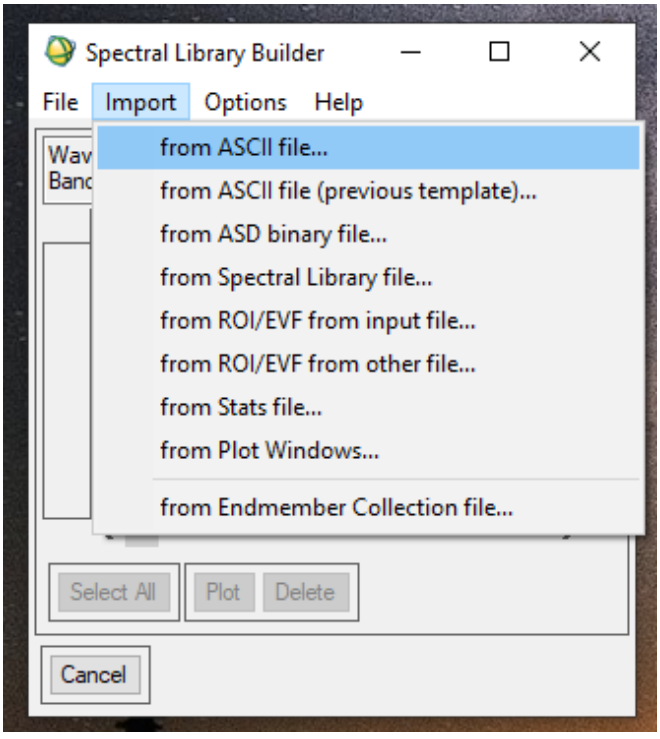
Radiance vs Wavelength (nm) plot

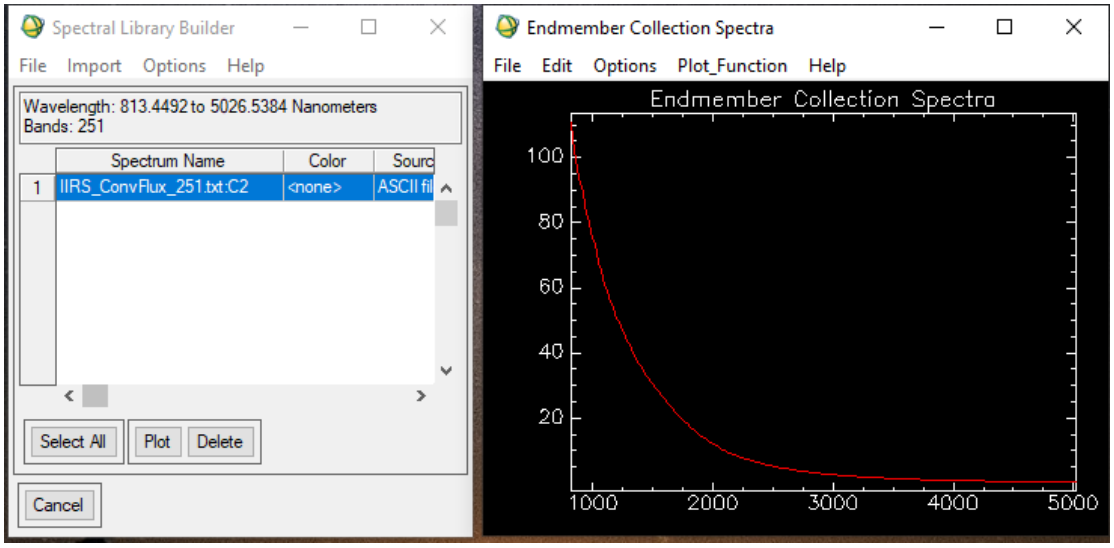
Steps for opening solar flux in ENVI:





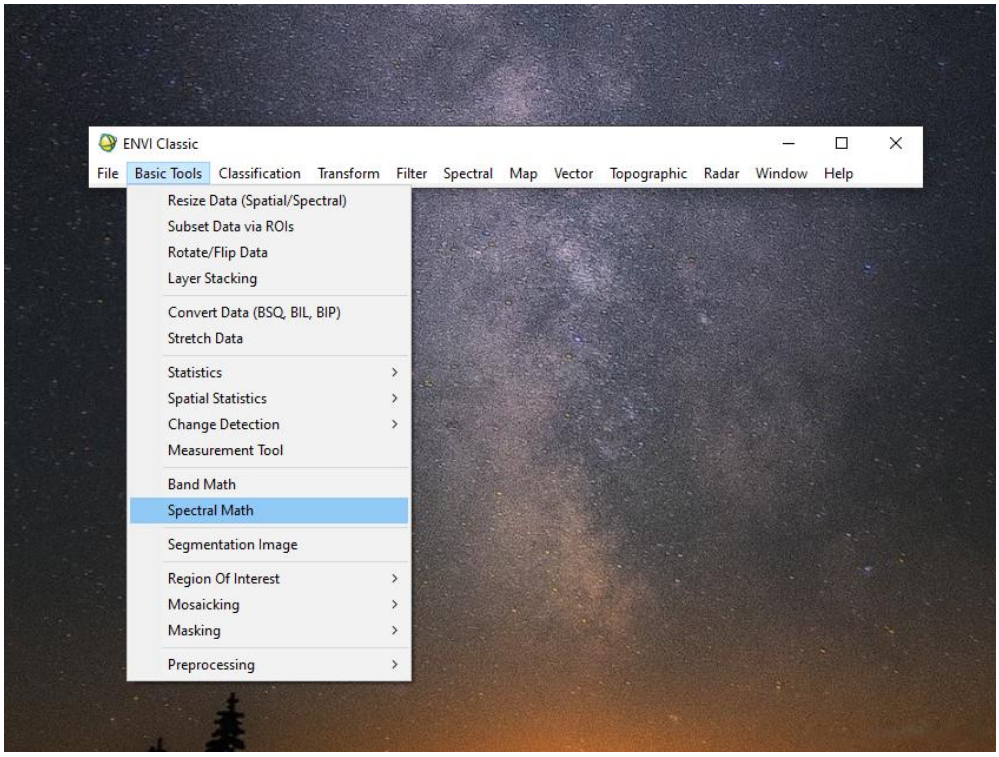

Spectral Library Builder
File
Import
Options
Help
Wavelength: <none selected>
Bands: <none selected>
Spectrum Name
Color
Sourc
Select All
Plot
Delete
Cancel

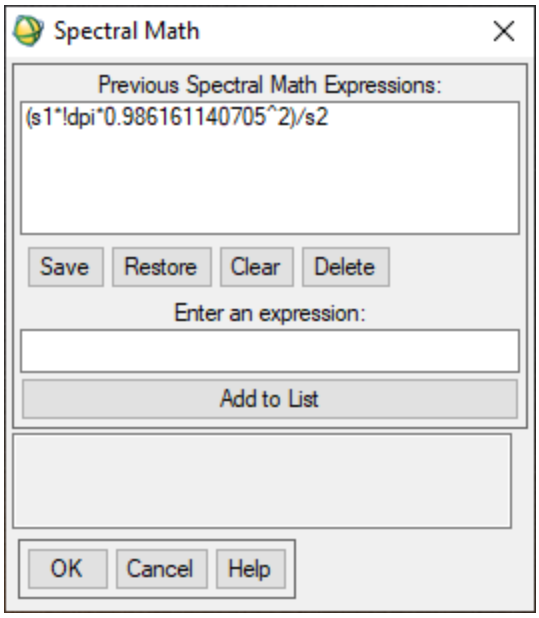

Spectral Library Builder
File
Import
Options
Help
from ASCII file...
from ASCII file (previous template)...
from ASD binary file...
from Spectral Library file...
from ROI/EVF from input file...
from ROI/EVF from other file...
from Stats file...
from Plot Windows...
from Endmember Collection file...
Select All
Plot
Delete
Cancel



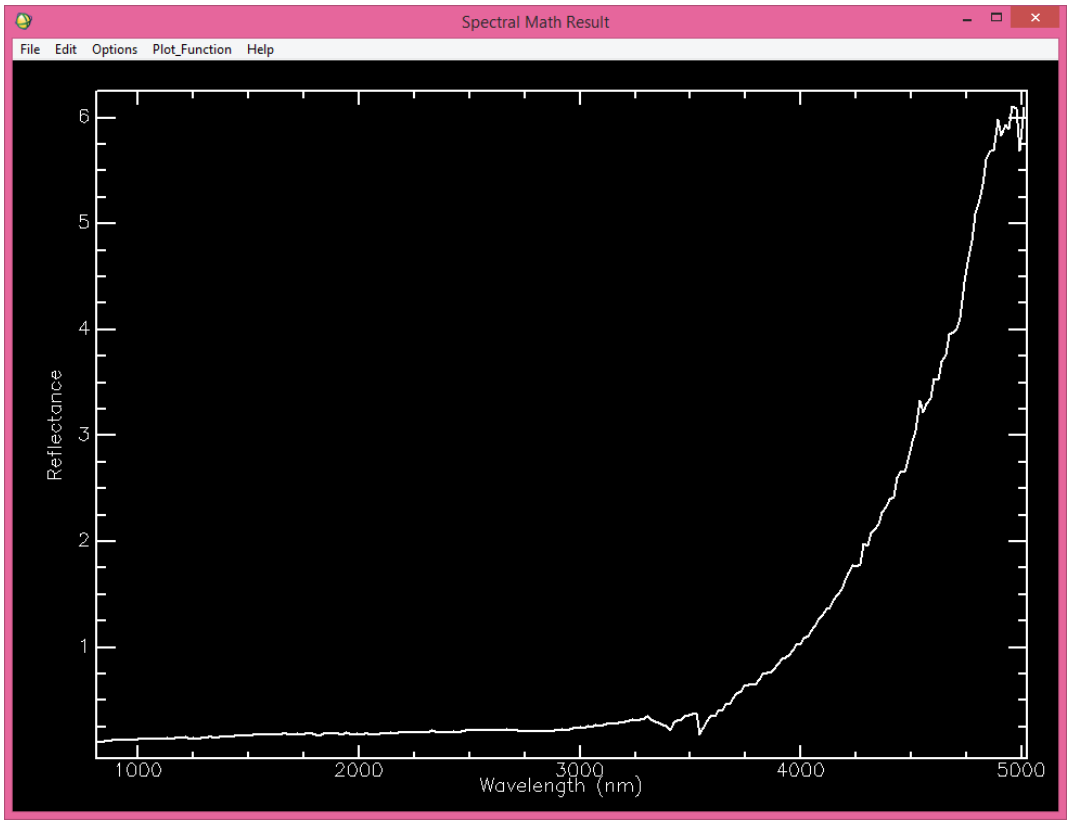
Solar flux convolved w.r.t. IIRS spectral channels (wavelength in nm)

Spectral Math Expression for converting radiance to reflectance:

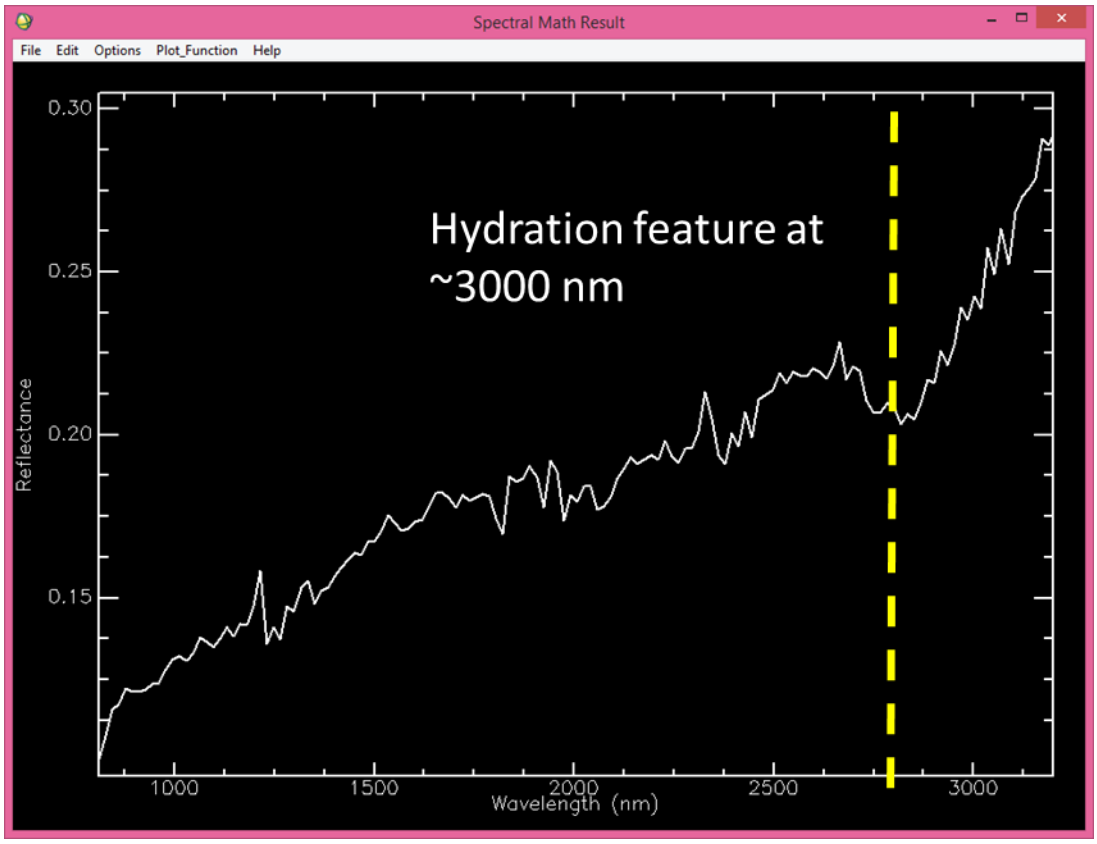




Define s1 as the radiance file and s2 as the convolved solar flux. This will convert the radiance into I/F (reflectance). d_{AU} = 0.986161140705 is for example only and this value changes from one orbit to another but remains near 1.



Reflectance spectra covering 800-5000 nm spectral range of IIRS. Thermal emission effect is clearly visible as the reflectance values are above 1 in longer wavelengths.



Reflectance spectra covering 800-3200 nm spectral range of IIRS. Hydration feature at ~3000 nm is shown by yellow dashed line.