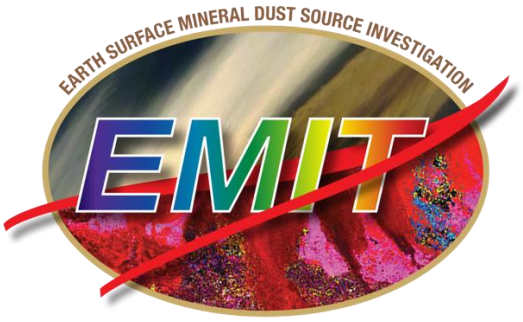

Earth Surface Mineral Dust Source Investigation (EMIT)

Level 2B Data Product User Guide

Draft v01

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Change Log

Date	Sections Changed	Reason for Change	Revision
03/09/2022	All	All	Pre-release
06/07/2023	All	Revised product definition	Initial Release

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1 Introduction

1.1 Identification

This document describes information about the file structure and datasets provided in the EMIT Level 2BMIN data product. The algorithms and data content of the Level 2BMIN data products are described briefly in this guide, with the purpose of providing the user with sufficient information about the content and structure of the data files to enable the user to access and use the data, in addition to understanding the uncertainties involved in the products.

1.2 Overview

The EMIT Project will deliver space-based measurements of surface mineralogy of the Earth's arid dust source regions. These measurements are used to initialize Earth System Models (ESM) of the dust cycle, which describe the generation, lofting, transport, and deposition of mineral dust. Earth System Models incorporate the dust cycle to estimate the impacts of mineral dust on the optical and radiative properties of the atmosphere, and a variety of environmental and ecological processes. During its one-year mission, EMIT on the ISS will make measurements over the sunlit Earth's dust source region that occur in the range of ±52° latitude. EMIT will schedule up to five visits (three on average) of each arid target region and only cloud-free acquisitions are downlinked. EMIT-based maps of the relative abundance of source minerals will advance our understanding of the current and future impacts of mineral dust in the Earth system.

The EMIT instrument is a Dyson imaging spectrometer that uses contiguous spectroscopic measurements in the visible to short wavelength infrared region of the spectrum to resolve absorption features of dust-forming minerals. From the instrument's focal plane array, on-board avionics reads out raw detector counts at 1.6 Gbps, then digitizes and stores this data to a high-speed Solid-State Data Recorder (SSDR). From there, the avionics software reads the raw uncompressed data, packages this data into frames of 32 instrument lines, screens for cloudy pixels within the frames, and performs a lossless 4:1 compression of the frame's science data before storing the processed, compressed data back onto the SSDR. The data is later read from the SSDR, wrapped in CCSDS packets and then formatted as ethernet packets for transmission over the International Space Station (ISS) network and downlinked to the EMIT Instrument Operation System (IOS). Once on the ground, the EMIT IOS delivers the raw ethernet data to the SDS where Level 0 processing removes the Huntsville Operations and Support Center (HOSC) ethernet headers, groups CCSDS packet streams by APID, and sorts them by course and fine time.

The Level 2BMIN data product contains EMIT data pertaining to the mineral identification, band depths, and corresponding uncertainties. In addition, the geolocation of all pixel centers is included as well as the calculation of observation geometry and illumination angles on a pixel-by-pixel basis. Each image line of the Level 2BMIN data product is also UTC time-tagged.

All EMIT products are provided as Network Common Data Form (NetCDF) files (further information can be found at https://www.unidata.ucar.edu/software/netcdf/).

1.3 File Formats

1.3.1 1.3.1. Metadata Structure

EMIT is operating from the ISS, orbiting Earth approx.16 times in a 24-hour day period. EMIT starts and stops data recording based on a surface coverage acquisition mask. The top-level metadata identifier for EMIT data is an orbit, representing a single rotation of the ISS around Earth. Within an orbit, a period of continuous data acquisition is called a scene and is identified by a scene number. An orbit contains multiple scenes, where each scene can cover up to thousands of kilometers down-track, depending on the acquisition mask map. Each scene is broken into granules of 1280 lines down-track. The last granule in a scene is merged into the one before, making the last granule to be between 1280 and 2560 lines down-track. Granules can be downloaded as NetCDF files, and are identified by a date-time string in the NetCDF file name.

The EMIT Mineral Spectral Abundance collection (EMITL2BMIN) contains 2 NetCDF files (Spectral Abundance, Spectral Abundance Uncertainty), and 1 quicklook PNG file (Browse). with file content described in Table 1-1.

Table 1-1: EMITL2BMIN collection file list and naming convention

Collection: EMITL2BMIN	
	Spectral Abundance: EMIT_L2B_MIN_<VVV>_<YYYYMMDDTHHMMSS>_<OOOOO>_<SSS>.nc
	Spectral Abundance Uncertainty: EMIT_ L2B_MINUNCERT_<VVV>_<YYYYMMDDTHHMMSS>_<OOOOO>_<SSS>.nc
	Browse: EMIT_L2B_MIN_<VVV>_<YYYYMMDDTHHMMSS>_<OOOOO>_<SSS>.png

<VVV> gives the software version number, e.g., 001
<YYYYMMDDTHHMMSS> is a time stamp, e.g., 20220101T083015
<OOOOO> is the orbit identification number, e.g., 12345
<SSS> is the scene identification number, e.g., 007

1.3.2 L2BMIN Data Products

The EMIT L2B Estimated Mineral Identification and Band Depth collection contains estimated mineral identification and band in spatially raw, non-orthocorrected, format. In addition to the spectral abundance datasets, the Reflectance NetCDF file contains geometric lookup table (GLT), latitude, longitude and elevation datasets.

Table 1-1: EMIT L2B Data Products Summary

Earth Science Data Type	Product Level	Data Dimension	Spatial Resolution	Swath Width	Map Projection
Collection	*EMITL2BMIN*				
Spectral Abundance	L2	1242 cross-track, 1280 down-track, 11 bands	60 m*	72 km*	Not ortho-rectified, latitude and longitude tagged (WGS-84)

* Nominal at equator

1.4 Product Availability

The EMIT L2BMIN products will be available at the NASA Land Processes Distributed Active Archive Center (LP DAAC, https://lpdaac.usgs.gov/) and through NASA Earthdata (https://earthdata.nasa.gov/).

2 Minerals' Spectral Identification and Band Depth

EMIT's Level 2BMIN is a mineral identification and band depth product for each pixel. Mineral identification is performed on two different (spectral) groups, with simultaneous identifications commonly occurring. The spectral depth of the absorption feature (band depth) is also provided for each match. For convenience, these data are reported in four condensed bands: the Group 1 mineral identification, Group 1 band depth, Group 2 mineral identification, and Group 2 band depth. This product provides the basis for quantifying mineral spectral abundance, which will be provided in a subsequent data product. EMIT L2BMIN is generated based off EMIT's Level 2A reflectance values. The calculations are built off of Tetracorder system, as described in Clark et al. (2013). EMIT Level 2B ATBD provides a more complete description of this algorithm.

3 File Structure

3.1 Dimensions and Global Attributes

The NetCDF files contain metadata information describing the dimensions of the datasets (downtrack, cross track, bands, ortho_y, and ortho_x), where downtrack and cross track describe the dimensions of the not-orthocorrected datasets, and whereas ortho_y and ortho_x describe the dimensions of the orthocorrected (lat\lon projected) GLT bands.

Each NetCDF file contains a list of global attributes describing mission relevant information.

3.2 Mineral Identification and Band Depth

The following table provides the EMIT L2B Estimated Mineral Identification and Band Depth bands contained in the NetCDF file.

Table 3-1: EMIT_L2B_MIN File Structure and Content

Field Name	Type	Units	Comments
Group	***root***		
group_1_band_depth	float32	N/A	Group 1 Band Depth
group_1_mineral_id	int16	N/A	Group 1 Mineral ID
group_2_band_depth	float32	N/A	Group 2 Band Depth
group_2_mineral_id	int16	N/A	Group 2 Mineral ID
Group	***location***		
GLT-X	int32	Index	
GLT-Y	int32	Index	
Lat	float64	Decimal Degree	
Lon	float64	Decimal Degree	
Elevation	float64	Meters	
Group	***/mineral_metadata***		
mineral_metadata/index	uint32	N/A	Index matching the Group 1 or Group 2 Mineral ID
mineral_metadata/record	uint32	N/A	Record in the associated spectral library
mineral_metadata/name	str	N/A	Mineral Name
mineral_metadata/url	str	N/A	Link to USGS Spectral Library 7 Description (if available)

mineral_metadata/group	uint32	N/A	Which mineral spectral group the index belongs to (1 or 2)
mineral_metadata/library	str	string	Spectral library index corresponds to

3.3 Mineral Identification and Band Depth Uncertainty

The following table provides the EMIT L2B Estimated Mineral Identification and Band Depth Uncertainty bands contained in the NetCDF file.

Table 3-2: EMIT_L2B_MINUNCERT File Structure and Content

Field Name	Type	Units	Comments
Group	***root***		
group_1_band_depth_unc	float32	N/A	Group 1 Band Depth Uncertainty
group_1_fit	float32	N/A	Group 1 Fit Score
group_2_band_depth_unc	float32	N/A	Group 1 Band Depth Uncertainty
group_2_fit	float32	N/A	Group 2 Fit Score
Group	***location***		
GLT-X	int32	Index	
GLT-Y	int32	Index	
Lat	float64		
Lon	float64	Decimal Degree	
Elevation	float64	Meters	

3.3.1 Geometry Lookup Table (GLT)

EMIT's Reflectance data are provided in non-orthocorrected spatially raw format (termed 'original'). To project the original data onto a gridded geographical map we use a geometry lookup

table (GLT) approach. The provided GLT dataset is an orthocorrected product with a fixed pixel size projected into a North-up WGS-84 system that contains the information about which original pixel occupies which output pixel in the final product. The GLT file contains two parameters – original sample number (GLT Sample Lookup, column index) and original line number (GLT Line Lookup, row index). These two numbers provide the column and row location indexes of pixels in the original file, and their placement in the GLT dataset is the new location in the orthocorrected spatial format.

Table 3-3: GLT File Structure and Content

Field Name	Type	Units	Comments
GLT Sample Lookup	int32	Index	
GLT Line Lookup	int32	Index	

3.3.2 Location

EMIT data product files contain location information in spatially raw format. The following location data are provided: latitude, longitude, elevation. The latitude and longitude coordinates are given in EPSG:4326 (coordinates on the WGS-84 ellipsoid). The longitude values are Easing (values increasing Eastward from Greenwich. The elevation dataset is sourced from the Shuttle Radar Topography Mission (SRTM), and is resampled to EMIT's spatial resolution.

Table 3-4: Location File Structure and Content

Field Name	Type	Units	Comments
Latitude	float64	Degree	Degrees increasing Eastward from Greenwich
Longitude	float64	Degree	Degrees increasing from the equator
Elevation	float64	Meters	Estimated ground elevation at pixel center

4 References

Appendix A: Acronyms

Term	Definition
ADC	Analog to Digital Converter
APID	Application Identifier
ASCII	American Standard Code for Information Interchange
BIL	Band Interleaved by Line
CCSDS	Consultative Committee for Space Data Systems
DAAC	Distributed Active Archive Center
DCID	Data Collection Identifier
DN	Digital Number
EMIT	Earth Mineral dust source InvesTigation
ENVI	Environment for Visualizing Images
ESDIS	Earth Science Data and Information System
ESM	Earth System Model
FPA	Focal Plane Array
FPGA	Field Programmable Gate Array
FPIE	Focal Plane Interface Electronics
FPIE-A	Focal Plane Interface Electronics - Analog
FSW	Flight Software
Gbps	Gigabits per second
GLT	Geometry Lookup Table
HOSC	Huntsville Operations and Support Center
ICD	Interface Control Document
IOS	Instrument Operations System
ISS	International Space Station
JPL	Jet Propulsion Laboratory
kHz	Kilohertz
L0	Level 0 (compressed, raw packets)
L1A	Level 1A (reconstructed, uncompressed data reassembled into scenes)
L1B	Level 1B (calibrated radiances with geolocation parameters)
L2A	Level 2A (atmospherically-corrected surface reflectance)
L2B	Level 2B (mineral feature depth maps)
L3	Level 3 (gridded global map of mineral composition and abundances)
L4	Level 4 (model runs of GISS ModelE2 and NCAR CESM)
LP DAAC	Land Processes Distributed Active Archive Center
LSB	Least Significant Bit
MSB	Most Significant Bit
NASA	National Aeronautics and Space Administration
NetCDF	Network Common Data Format
PGE	Product Generation Executable
PLRA	Program Level Requirements Appendix
ROIC	Readout Integrated Circuit
SDS	Science Data System
SIS	Software Interface Specification

SSDR	Solid State Data Recorder
UTC	Universal Time Coordinated