Lunar Reconnaissance Orbiter

Diviner Lunar Radiometer Experiment
Reduced Data Record and Derived Products Software Interface Specification

Version 1.21

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CHANGE LOG

DATE	SECTIONS CHANGED	REASON FOR CHANGE	REVISION
9/09/07	All	First draft	1.0
1/31/08	2.4.3	Updated Coordinate Systems	1.1
3/27/08	1.3, 2.1.1, 2.2, 2.3.2, 2.3.3, 2.3.4, 2.4.3, 3.1, 3.2, 3.3, 4.1, Appendix A, Appendix B	Review changes	1.2
4/7/09	2.1.1, 2.2, 2.3.4, 2.4.5, 3.2, 3.3, Appendix A, B, C	Three new quality flags replace "qual", and other edits	1.3
6/1/09	1.3, 2.1.1, 2.3.4, 2.4.5, 2.4.6, 3.1, 3.3, 4.1, Appendix A, Appendix B	Minor edits	1.4
7/23/09	2.1.1, 2.4.5, 3.2, 3.3, Appendix A, Appendix B	Minor edits	1.5
12/01/09	3.2, 3.3, Appendix B, Appendix C	Minor edits	1.6
05/16/10	2.4.3, 3.2, Appendix B, Appendix C	Minor edits	1.7
10/19/10	Appendix C	Added two flags to qmi	1.8
11/4/10	1.3, 2.2, 2.3.*, 2.4.4, 5.*, 6.*, 7.*, Appendix D and E.	GDR, PRP Specification	1.9
3/10/11	1.3, 2.2, 2.3.*, 2.4.4, 5.*, 6.*, 7.*, Appendix D and E.	Post-review fixes	1.10
5/8/11	5.3	Minor edits	1.11
11/8/11	6.1, 6.2	Minor edits	1.12
3/4/13	5.3	Added new map cycles	1.13
1/9/2017	8, Appendix F	Added sections for Global Cumulative Product (GCP)	1.14
5/22/2020	2.2, 2.3.1, 2.3.4, 2.4.4, 9, Appendix G	Added sections for Polar Cumulative Product (PCP)	1.15

6/24/2021	1.3, 2.2, 2.3.1, 2.3.2, 2.3.4, 2.4.4, 10, Appendix H	Added sections for Regional Cumulative Product (RCP)	1.16
12/15/21	1.3, 2.2.8, 10.4, Appendix H	Revised for PDS4 for RCP Peer Review	1.17
02/28/22	2.3.4.6, 10.1, and 10.2 . Deleted Appendices A, C, D, E, F, G, H as they were all label examples.	Revised for review liens	1.18
07/22/22	1.4, 2.2.7, 2.3.4.5,9.1 9.2	Added section for Polar Cumulative Products (PCP) seasonal	1.19
08/03/22	1.3, 2.3.4.5, 2.4.1	Revised for PDS4 version of PCP	1.20
10/25/23	1.4, 2.2.9, 2.3.1, 2.3.2, 2.3.4.7, 2.4.1, 11	Added section for Global High-Resolution Mosaics (GHRM)	1.21

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ACRONYMS AND ABBREVIATIONS

ASCII	American Standard Code for Information Interchange
CF	Christiansen Feature
CODMAC	Committee on Data Management and Computation
DLRE	Diviner Lunar Radiometer Experiment
EDR	Experiment Data Record
GB	Gigabytes
GCP	Global Cumulative Product
GDR	Gridded Data Record
GHRM	Global High-Resolution Mosaic
ICD	Interface Control Document
JPL	Jet Propulsion Laboratory
LOLA	Lunar Orbiter Laser Altimeter
LRO	Lunar Reconnaissance Orbiter
NASA	National Aeronautics and Space Administration
ODL	Object Description Language
PCP	Polar Cumulative Product
PDS	Planetary Data System
PPD	Pixels Per Degree
PRP	Polar Resource Product
RCP	Regional Cumulative Product
RDR	Reduced Data Record
RMS	Root Mean Square
SIS	Software Interface Specification
SOC	Science Operations Center
TBD	To Be Determined

GLOSSARY

TERM	DEFINITION
Meta-Data	Selected or summary information about data. PDS catalog objects and data product labels are forms of meta-data for summarizing important aspects of data sets and data products.
Profile	The vertical distribution, as a function of atmospheric altitude, of some physical property, such as temperature or water vapor amount

1 INTRODUCTION

1.1 Purpose and Scope

The purpose of this data product Software Interface Specification (SIS) is to provide users of the Diviner Lunar Radiometer Experiment (DLRE or “Diviner”) Reduced Data Record (RDR) and derived products with a detailed description of the products and a description of how they were generated, including data sources and destinations. The document is intended to provide enough information to enable users to understand the Diviner higher level data products. The users for whom this document is intended are software developers of the programs used in generating the products and scientists who will analyze the data, including those associated with the Lunar Reconnaissance Orbiter (LRO) Project and those in the general planetary science community.

1.2 Contents

This data product SIS describes how the LRO Diviner instrument acquires its data, and how the data are processed, formatted, labeled, and uniquely identified. This document discusses standards used in generating the products and software that may be used to access the products. The data product structure and organization are described in sufficient detail to enable a user to read the products.

1.3 PDS4 Update

LRO Diviner products were originally archived using the PDS3 archive standard. All previously released Diviner products have now been migrated to the PDS4 standard. Newly created product types will also be archived using PDS4.

This document is a hybrid PDS3 and PDS4 version. New sections have been added to describe the new Diviner RCP and GHRM data products, both archived solely as PDS4 data products. The sections pertaining to the Diviner PCP have been revised, as the new seasonal PCPs are archived solely as PDS4 data products and the diurnal PCPs have been migrated to PDS4. The other Diviner datasets (GCP, GDR, PRP, and RDR) have been migrated to PDS4, however the sections describing them have not been changed, and therefore still refer to the PDS3 standard. Users are asked to refer to the *notes* documents in the document collections of the Diviner calibrated and derived bundles for migration information.

Both PDS3 and PDS4 reference documents are listed in the Applicable Documents section below.

1.4 Applicable Documents and Constraints

This data product SIS is responsive to the following documents:

1. Lunar Reconnaissance Orbiter Project Data Management and Archive Plan, K. North, LRO Document 431-PLAN-00182.
2. Diviner Lunar Radiometer Experiment Telemetry Dictionary, S. M. Loring, JPL D-33198.
3. Lunar Reconnaissance Orbiter Diviner Science Team and PDS Geosciences Node Interface Control Document (ICD), S. Slavney, Nov. 16, 2006.
4. Diviner Lunar Radiometer Experiment Data Record Software Interface Specification, Version 1.8, M Sullivan, December 10, 2009.
5. Planetary Data System Archive Preparation Guide, Version 1.4, JPL D-31224, April 1, 2010 (PDS3).
6. Planetary Data System Data Standards Reference, Version 3.8, JPL D-7669, Part 2, February 27, 2009 (PDS3).
7. Planetary Science Data Dictionary Document, JPL D-7116, November 24, 2010 (PDS3).
8. Planetary Data System Standards Reference, version 1.16.0.0, April 21, 2021, https://pds.nasa.gov/datastandards/documents/sr/. (PDS4)
9. Planetary Data System Data Provider's Handbook, version 1.16.0.0, April 21, 2021, https://pds.nasa.gov/datastandards/documents/dph/. (PDS4)
10. PDS4 Information Model Specification, version 1.16.0.0, April, 2021, https://pds.nasa.gov/datastandards/documents/im/. (PDS4)
11. Diviner Lunar Radiometer Experiment Archive Volume Software Interface Specification, Version 1.11, M Sullivan, March 10, 2011.
12. Diviner Lunar Radiometer Observations of Cold Traps in the Moon's South Polar Region, D. Paige et al, Science, Vol. 330, p479-482, 2010.
13. Lunar Surface Rock Abundance and Regolith Fines Temperatures Derived From LRO Diviner Radiometer Data, J. Bandfield et al, Journal of Geophysical Research, Vol. 116, E00H02, 2011.
14. The Global Surface Temperatures of the Moon as a Measured by the Diviner Lunar Radiometer Experiment, J.-P. Williams et al, Icarus, Vol. 283, p300-325, 2017.
15. A Standardized Lunar Coordinate System for the Lunar Reconnaissance Orbiter and Lunar Datasets, LRO Project and LGCWG White Paper, Version 5, Goddard Space Flight Center, October 1, 2008.
16. Seasonal polar temperatures on the Moon, J.-P. Williams et al., Journal of Geophysical Research, Vol. 124, p2505-2521, 2019.
17. Temperatures of the Lacus Mortis region of the Moon, J.-P. Williams et al., Earth and Space Sciences, 9, e2021EA001966, 2022.
18. Mapping of ice storage processes on the Moon with time-dependent temperatures, N. S. Schorghofer and J.-P. Williams, Planetary Science Journal, 1, 54, 2020.

19. High-resolution nighttime temperature and rock abundance mapping of the Moon using the Diviner Lunar Radiometer Experiment with a model for topographic removal, T. M. Powell et al, Journal of Geophysical Research: Planets, 128, e2022JE007532, 2023.

1.5 Relationships with Other Interfaces

The products described in this SIS are used in the production of other archived products of the Lunar Reconnaissance Orbiter (LRO) mission, so that changes to their content and format may result in an interface impact.

2 DATA PRODUCT CHARACTERISTICS AND ENVIRONMENT

2.1 Instrument Overview

The Diviner Lunar Radiometer Experiment is in most respects a copy of the Mars Climate Sounder (MCS) instrument on Mars Reconnaissance Orbiter. Both instruments observe radiation with 21 detectors in each of nine spectral bands. MCS is primarily an atmospheric limb sounder that measures temperature, pressure, water vapor, dust, and condensates at Mars' atmospheric limb. In contrast, Diviner is a surface pushbroom mapper that measures emitted thermal radiation and reflected solar radiation from the surface of the moon. Two Diviner solar channels measure 0.3-3 μm reflected solar radiation. Three Diviner channels near 8 μm classify regolith mineralogy by mapping the location of the Christiansen feature. The remaining four Diviner channels measure surface temperature in four spectral bands ranging from 12.5 μm to beyond 200 μm.

2.1.1 Hardware Overview

The Diviner Lunar Radiometer Experiment is a nine-channel infrared radiometer employing filter radiometry. These channels are distributed between two identical, boresighted telescopes, and an articulated elevation/azimuth mount allows the telescopes to view the lunar surface, space, and calibration targets. The instantaneous field-of-view (FOV) response of each channel is defined by a linear, 21-element, thermopile detector array at the telescope focal plane, and its spectral response is defined by a focal plane bandpass filter.

The Diviner instrument is shown in Figure 1. The Diviner structure consists of an instrument optics bench assembly (OBA), an elevation/azimuth yoke, and a base. The OBA contains all of the instrument optical subassemblies and is suspended from the yoke (Figure 1). Elevation and azimuth motors mounted on the yoke drive instrument articulation. The OBA can be temperature controlled, and internal temperature gradients are minimized by design. Radiometric calibration is provided by views of blackbody and solar targets mounted on the yoke. The electronics subassemblies control signal processing, instrument operation and articulation, command processing, and data processing. These electronics are distributed between the OBA, the yoke, and the Diviner Remote Electronics Box (DREB).

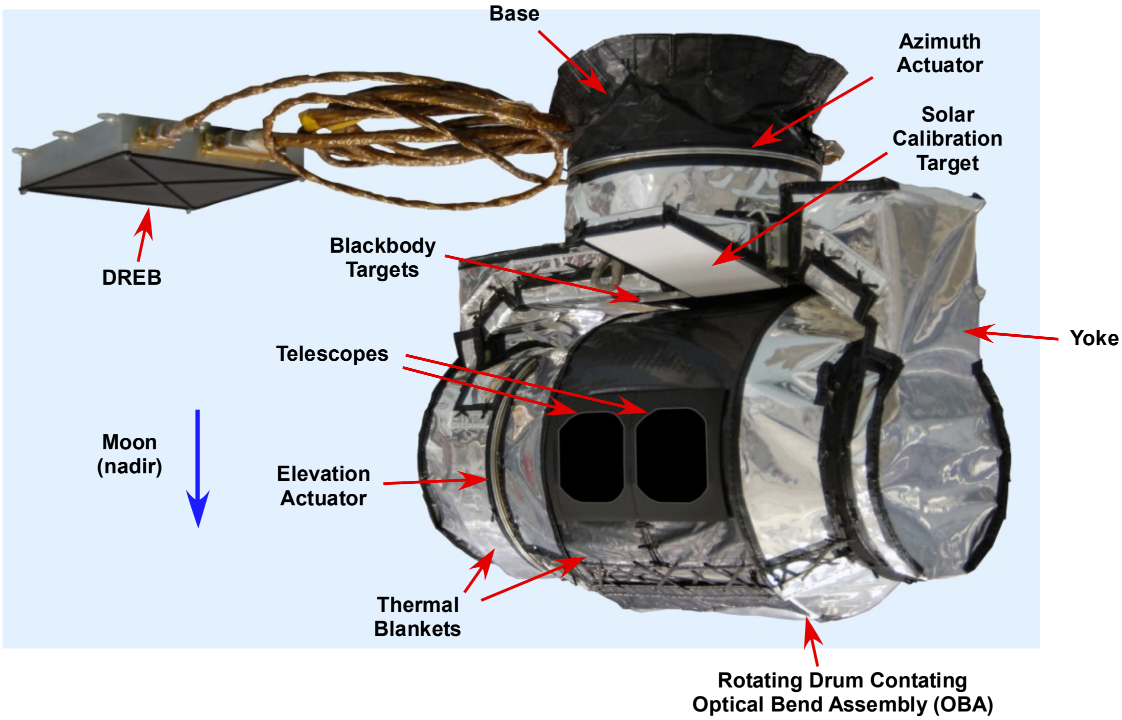

Figure 1: Diviner instrument.

Table 1 lists some key instrument characteristics and Table 2 lists the spectral channel characteristics.

Parameter	Property
Instrument Type	Infrared and solar radiometer
Spectral Range	0.35 to 400 µm in nine spectral channels
Telescopes	Two identical three-mirror, off-axis, f/1.7 telescopes with 4cm apertures,
Detectors	Nine 21-element linear arrays of uncooled thermopile detectors Pixel size 240 µm x 480 µm
Fields of view	Detector Geometric IFOV: 6.7 mrad in-track 3.4 mrad cross track 320 m on ground in track for 50 km altitude 160 m on ground cross track for 50 km altitude Swath Width (Center to center of extreme pixels): 67 mrad; 3.4 km on ground for 50 km altitude
Instrument Articulation	Two-axis azimuth/elevation, Range 270º, resolution 0.1º
Operating Modes	Single operation mode, 0.128 s signal integration period
Observation Strategy	Primarily nadir pushbroom mapping

Table 1: Diviner instrument characteristics

Channel Number	Channel Type	Channel Name	Passbands µm	Measurement Function
1 (A1)	Solar	High Sensitivity Solar	0.35-2.8	Reflected solar radiation, high sensitivity
2 (A2)	Solar	Reduced Sensitivity Solar	0.35-2.8	Reflected solar radiation, reduced sensitivity
3 (A3)	8 µm	7.8 µm	7.55-8.05	Christiansen feature
4 (A4)	8 µm	8.25 µm	8.10-8.40	Christiansen feature
5 (A5)	8 µm	8.55 µm	8.38-8.68	Christiansen feature
6 (A6)	Thermal	13-23 µm	13-23	Surface Temperature (most sensitive channel for >178 K)
7 (B1)	Thermal	25-41 µm	25-41	Surface Temperature (most sensitive channel for 69-178K)
8 (B2)	Thermal	50-100 µm	50-100	Surface Temperature (most sensitive channel for 43-69 K)
9 (B3)	Thermal	100-400 µm	100-400	Surface Temperature (most sensitive channel for <43 K)

Table 2: Diviner channel spectral characteristics

Figure 2 shows a schematic diagram of the optical layout. Each off-axis telescope has three optical elements, and baffles in front to reduce stray light.

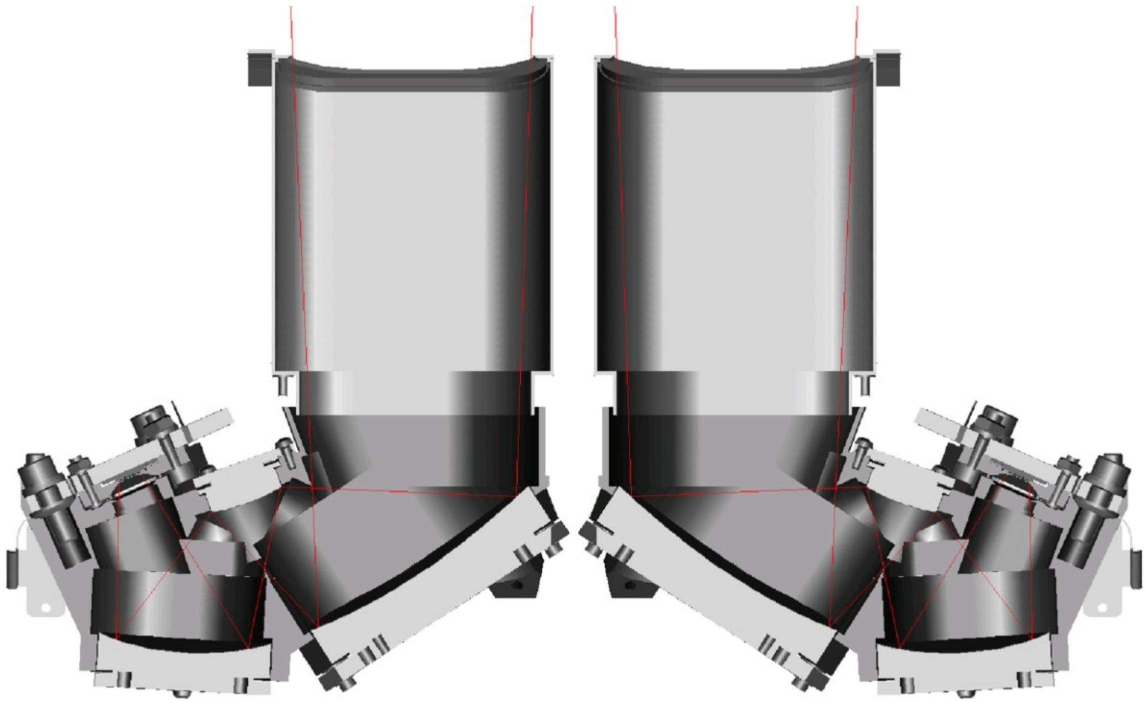

Figure 2: Optical Layout. Telescope A (left) and Telescope B (right)

Table 2 lists the channel bandpasses and functions. The detector arrays for channels A1 through A6 are located in the focal plane of telescope A. The detector arrays for channels B1 through B3 are located in the focal plane of telescope B. Each Diviner spectral channel has 21 FOVs defined by the individual detectors of the corresponding linear array. Figure 3 shows the layout of the two focal planes.

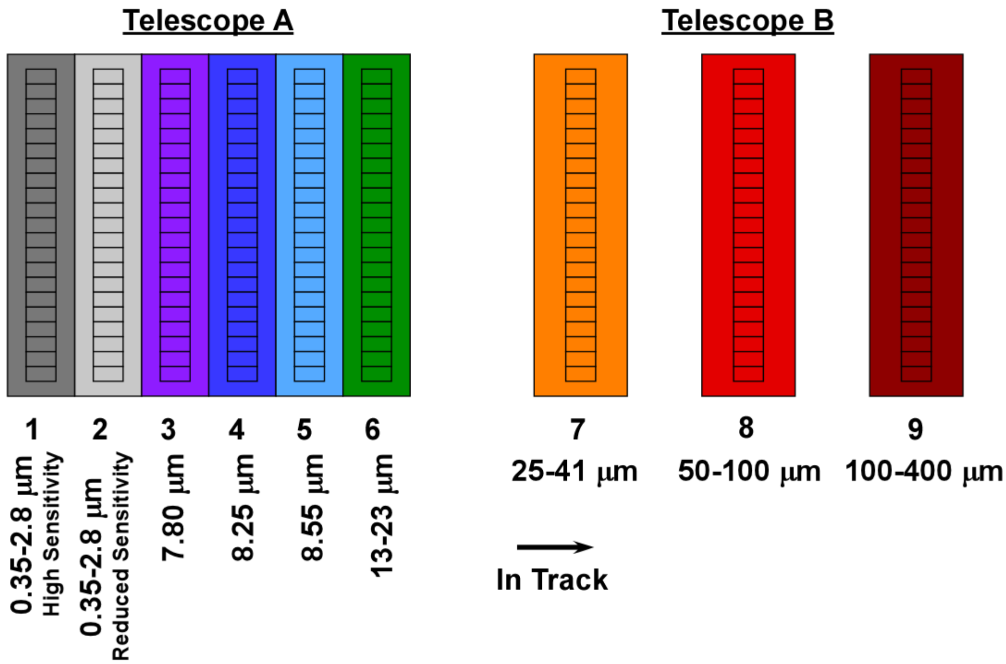

Figure 3: Detector and Filter Layout

2.2 Data Product Overview

2.2.1 Reduced Data Records (RDRs)

Every 2.048 seconds Diviner collects a data “frame” containing the following:

- 16 sets of science data, with each set containing 192 sixteen-bit science measurements from the focal plane interface electronics obtained over integration periods of 0.128 seconds
- A single set of instrument engineering and housekeeping measurements (or “engineering data”) acquired during the 2.048 second interval

The data are downlinked to the LRO Ground Data System (GDS) and are pushed to the Diviner SOC at the end of each downlink pass. Diviner software assembles the telemetry files into EDR (Experiment Data Record) data tables, each covering a one-hour time period. The RDR data tables are produced directly from the EDR data tables using Diviner software, geometry, and ephemeris data provided by the LRO project.

Each Diviner RDR data product consists of two files. The first file is an ASCII formatted detached PDS label. The second file is the ASCII data table file. Unlike the EDR data tables, which contain values for each of the 189 detectors in a single record (every 0.128 seconds), the RDR data tables have one record per detector. Therefore, for every EDR record there are 189 detector-specific RDR records, each with the same “date” and “utc” time as the original EDR record.

Due to the size of the RDR dataset, each RDR data table covers ten minutes of time, one-sixth of the EDR data tables. In order to save space on disk and to facilitate faster downloading, the RDR data tables are compressed using Info-ZIP (a freely available utility).

Each RDR record contains 340 bytes. Each ten-minute Diviner RDR ASCII data table is up to approximately 296 MB uncompressed (112 MB compressed). The daily volume of the RDR data product is up to approximately 42 GB uncompressed (16 GB compressed).

The RDR data product is considered to be foremost of scientific interest, and thus contains a minimal representation of engineering and housekeeping data needed to verify instrument status and data quality.

2.2.2 Level 2 Gridded Data Records (GDRs)

The Diviner GDR data products are derived directly from the RDR data product. They directly mimic the format and intent of the Lunar Orbiter Laser Altimeter (LOLA) GDR data product for maximum compatibility with LOLA and other products.

NASA Level 2 Diviner GDR products include solar reflectances, brightness temperatures, and time-related values such as local time and Julian Date that are binned and averaged according to 27-day LRO mapping cycles. Each averaged product is further split into daytime (local time 06:00 to 18:00) and nighttime (local time 18:00 to 06:00) data products.

For each averaged gridded product, an analogous pair of count and error estimate products is created. Count files simply contain the number of measurements in each bin. The purpose of the error estimate products is to provide the end user with information regarding the uncertainties in the gridded quantities based on the signal to noise ratios of the Diviner channels, and the number of observations in each bin. Error estimates in local time and Julian Date are determined by computing the standard deviation in these quantities.

Unlike the LOLA GDR data products, which use interpolation to create continuous global grids, Diviner GDR data products include data gaps in grid cells where no observations were acquired.

The Level 2 GDR data products are gridded in cylindrical longitude and latitudinal space and in polar stereographic space (to +/- 75 degrees latitude) at varying resolutions.

Cylindrical maps are provided at resolutions of 128, 64, 16, 4, and 1 pixels per degree (ppd). This last resolution value produces global lon/lat maps during the LRO primary mission with minimal low-latitude gores.

Polar stereographic maps are provided at a single resolution of 126.347 ppd, which corresponds to a map scale of 240 meters per pixel (m/pix).

Only nadir-pointing data are used in these datasets (RDR activity flag 110 – on moon, standard nadir). The thermal channel data are further constrained to brightness temperature values of 10 to 450 K as anything outside this range contains bad data. Observations with excessive noise are also culled. The finite field of view of the Diviner footprints is also taken into account to produce the master maps, which avoids resolution aliasing problems at higher latitudes. All footprints are projected by locating the fields of view in three dimensions onto a LOLA digital elevation model of the Moon.

See section 5 for further details on Level 2 GDRs.

2.2.3 Level 3 Gridded Data Records (GDRs)

NASA Level 3 Diviner GDR products include Christiansen Feature (CF) position, Rock Abundance, Soil Temperature, and Root Mean Square (RMS) fitting errors between measured and modeled radiances.

The CF position is the wavelength of a major mid-infrared emissivity peak near 8-microns. It is a measure of silicate composition and shifts to shorter wavelengths for feldspathic lithologies (e.g. highlands) and longer wavelengths for mafic lithologies (e.g. maria). The CF position is also correlated with geochemical composition (generally shorter CF position for higher Si, Na, Ca and longer for higher Fe, Mg). The CF position is calculated from Diviner channels 3, 4, and 5 radiances. Each radiance is binned and averaged and then converted to brightness temperature. The three point brightness temperature spectrum is solved quadratically to determine the maximum brightness temperature. Emissivity values are then calculated for channels 3, 4, and 5. The emissivity spectrum is solved quadratically to determine the CF position.

Two types of CF maps will be created:

(1) Standard CF: CF calculated using a quadratic fit to the three 8-micron channels to determine the wavelength location of the emissivity peak. This map includes the best time of day data available for each longitude.

(2) Normalized to Equatorial Noon (NEN) CF: Standard CF normalized to equatorial noon by the "best effort" of the Diviner science team.

Rock Abundance and Soil Temperature are derived from nighttime Diviner Channel 6, 7, and 8 observations. The maps are derived by fitting the measured radiances to a two-component model that assumes that the observed scene consists of an unknown mixture of soil and rock. The temperature of the rock component taken from thermal model results assumes a semi-infinite rock thermal inertia of 1000 (MKS units) and the rock fractional coverage and the soil temperature are fitted parameters.

RMS fitting errors are with respect to measured and modeled Diviner radiance in channels 6, 7, and 8 using the rock abundance and soil temperature determination technique described in Bandfield et al. 2011 [10].

For CF Position, a single map for each is produced. For Rock Abundance, Soil Temperature, and RMS fitting error, ten lunar-hourly maps spanning the local time range of 19:30 to 5:30 are produced. All maps are simple cylindrical projections covering the latitude range -60 to 60 degrees at 32 ppd resolution.

See section 6 for further details on Level 3 GDRs.

2.2.4 Level 2 and 3 GDR Similarities

All GDRs consist of images employing scaled binary 16-byte integers with the extension IMG, and associated geotagged JPEG2000 format files with the extension JP2, as well as a sample low-resolution JPEG image with the extension .JPG, for easy viewing. Each format has a detached PDS label that describes their contents and includes useful metadata. The label has the extension LBL.

See section 5 and 6 for a discussion of GDR file sizes.

2.2.5 Level 4 Polar Resource Products (PRPs)

The Diviner NASA Level 4 Polar Resource Products (PRPs) are produced from thermal model fits to Diviner north and south polar observations from the first year of mapping orbit as described in Paige 2010 [9]. The derived quantities are: annual average surface temperature, annual maximum surface temperature, and depth to water ice permafrost. The results for the north and south polar regions are contained in separate ASCII files. Each line of the file corresponds to a triangular mesh element in a north or south polar digital elevation model derived from the Kaguya laser altimeter experiment results (Araki et al., Science 223, 897, 2009). The mesh consists of 2880000 triangles and covers a square region centered on the pole to 80 degrees latitude as shown in Figure 1 of [9].

See section 7 for further details on Level 4 Polar Resource Products.

2.2.6 Level 4 Global Cumulative Products (GCPs)

The Global Cumulative Products are derived from Diviner Level 1 RDR radiances binned at 2 ppd and 0.25 hours of local time from a compilation of all nadir observations acquired from 5-July-2009 to 1-April-2015 as described in Williams et al., Icarus 283, 300 – 325, 2017. Each file contains a single header line followed by a line for each bin containing brightness temperatures derived from the binned radiance for the seven infrared channels and the bolometric brightness temperature as described in Paige et al., Science 330, 479, 2010. Each line represents the mean brightness temperature for each latitude, longitude bin and solar local time bin. The data set is global and split into 18 files representing 10° bands of latitude (e.g. 0° to 10° N, 10° to 20° N, and so on), and all longitudes from -180°E to +180°E. Bins that contained no data are represented with a MISSING_CONSTANT = -9999.

2.2.7 Level 4 Polar Cumulative Products (PCPs)

The Polar Cumulative Products (diurnal) are derived from Diviner Level 1 RDR radiances binned at 240 m pix^{-1} and either 0.25 hours of local time or 3.75° of subsolar longitude providing 96 bins of diurnal temperatures from a compilation of all nadir observations acquired from 5-July-2009 to 17-Feb-2019 as described in Williams et al., J. Geophys. Res. 124, 2505 – 2521, 2019. Each file contains a single header line followed by a line for each bin containing distances from the pole (x,y) normalized by the mean radius 1737.4 km, the longitude and latitude, and the bolometric brightness temperature derived from the binned radiances of the seven infrared channels. The data set covers a 10° latitude cap at each pole (i.e. -90° to -80° S and 80° to 90° N) and is divided between summer and winter defined by the subsolar latitude being above or below the equator. Each file represents a single local time bin, or a single subsolar longitude bin. Bins that contained no data are excluded. This version of the Polar Cumulative Products emphasizes the diurnal temperatures (PCP diurnal).

Additionally, Diviner Level 1 RDR radiances from a compilation of all nadir observations acquired from 5-July-2009 to 15-Mar-2020 were binned at 240 m pix^{-1} and 15° of subsolar longitude (24 bins of diurnal temperatures) and 60° of ecliptic longitude (L_s) (6 bins of seasonal temperatures) for a 10° latitude cap at the south pole (i.e. -90° to -80° S) as described in Schorghofer and Williams, Planet. Sci J. 1, 54, 2020. L_s is defined by the right ascension of the apparent position of the Sun as seen from the Moon in the reference frame of the ecliptic north pole and the Moon's pole providing an angular description (0°–360°) of the draconic time of year, with 0° being when the Moon crosses the ascending node (i.e. spring equinox in the northern hemisphere). Each file contains a single header line followed by a line for each bin containing distances from the pole (x,y) normalized by the mean radius 1737.4 km, the longitude and latitude, the solar local time, and the bolometric brightness temperature derived from the binned radiances of the seven infrared channels. Bins that contained no data are excluded. This version of the Polar Cumulative Products emphasizes the seasonal temperatures (PCP seasonal).

2.2.8 Level 4 Regional Cumulative Products (RCPs)

The Regional Cumulative Products are derived from Diviner Level 1 RDR radiances binned at 128 ppd and 0.1 hours of local time from a compilation of all observations with emission angles <20° acquired from 5-July-2009 to 1-March-2021 as described in Williams et al., Earth Space Sci., 9, e2021EA001966, 2022. Each file contains a single header line followed by a line for each bin containing brightness temperatures derived from the binned radiance for the seven infrared channels and the bolometric brightness temperature as described in Paige et al., Science 330, 479, 2010. Each line represents the mean brightness temperature for each latitude, longitude bin and solar local time bin. The data set includes the Lacus Mortis region (22.5° E to 31.5° E, 41.5° N to 48.5° N) and split into 63 files representing 1° tiles of latitude and longitude. Files are 'sparse' in that bins that contain no data are excluded.

2.2.9 Level 4 Global High-Resolution Mosaics (GHRMs)

The Level 4 Global High-Resolution Mosaics are cylindrical maps gridded at 128 ppd spanning 70˚S to 70˚N latitude. These products include:

- Channel 6-9 brightness temperature (e.g., tb6), bolometric temperature (tbol), and regolith temperature (treg). These are each calculated at midnight (m) and slope adjusted midnight (sam)
- Derived rock abundance (ra) at slope-adjusted midnight.
- Bolometric temperature and regolith temperature anomaly at slope adjusted midnight (anom).

The production of these products is described in detail in Powell et al., JGR: Planets, 128, e2022JE007532, 2023.

The channel 6-9 brightness temperature maps are derived from Diviner Level 1 RDR radiances for observations with emission angles <15˚ acquired from 5-July-2009 to 01-August-2022. Data are gridded at 128 ppd and 0.25 hours of local time. For each spatial bin and channel, empirical fitting is used to calculate the brightness temperature at midnight and slope-adjusted midnight. Slope-adjusted midnight is a local time that is shifted from midnight by the east-west component of the slope angle.

Bolometric temperatures are derived from the channel 6-9 brightness temperatures as described in Paige et al., Science 330, 479, 2010. Rock abundances and regolith temperatures are derived from fitting the channel 6, 7, and 8 brightness temperatures to a two-component model that assumes each spatial bin is composed of an unknown mixture of rock and regolith, as described in section 2.2.3, as well as Bandfield et al., JGR: Planets, 116, E00H02, 2011 and Powell et al., JGR: Planets, 128, e2022JE007532, 2023.

Temperature anomaly is the difference between the Diviner temperature at slope-adjusted midnight and the expected temperature for typical regolith, as determined by a thermophysical model. The thermophysical model accounts for effects such as latitude, slope, scattering and emission from surrounding terrain, and shadowing by topography. This model is described in Powell et al., JGR: Planets, 128, e2022JE007532, 2023.

2.3 Data Processing

2.3.1 Data Processing Level

The Diviner RDR data products are derived directly from the Diviner EDR data products and are considered "Diviner Level 1". It is similar to CODMAC Level 3 (NASA Level 1A) in that the data are reversibly calibrated and located in space, yet the content resembles more traditional CODMAC Level 4 (NASA Level 1B) data. GDRs, PRPs, GCPs, PCPs, RCPs, and GHRMs are CODMAC Level 5

(GDRs are NASA Level 2 and 3, and PRPs, GCPs, PCPs, RCPs, and GHRMs are NASA Level 4). Refer to the following table for descriptions of processing levels.

Processing Levels for Science Data Sets

PDS4 Processing Level	PDS4 Processing Level Description	Old PDS3 CODMAC Level	Old PDS3 NASA Level
Telemetry	An encoded byte stream used to transfer data from one or more instruments to temporary storage where the raw instrument data will be extracted. PDS does not archive telemetry data.	1	0
Raw	Original data from an instrument. If compression, reformatting, packetization, or other translation has been applied to facilitate data transmission or storage, those processes will be reversed so that the archived data are in a PDS approved archive format. Often call EDRs (Experimental Data Records).	2	1A
Partially Processed	Data that have been processed beyond the raw stage but which have not yet reached calibrated status. These and more highly processed products are often called RDRs (Reduced Data Records).	2	1A
Calibrated	Data converted to physical units, which makes values independent of the instrument.	3	1B
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.	4+	2+

2.3.2 Data Product Generation

The Diviner RDR data products and labels are generated by the Diviner Instrument Team at JPL. The RDR data products are derived from the EDR data products, merged with geometry and ephemeris data provided by the LRO Project, and formatted according to this SIS.

The GDRs, GCPs, PCPs, RCPs, PRPs, and GHRMs are derived from the RDR data products and are produced by the Diviner UCLA SOC.

2.3.3 Data Flow

After an initial data validation period, the Diviner team at JPL transfers the RDR data tables and labels to the UCLA SOC, which assembles the archive volumes and transfers them to the PDS Geosciences Node. The Diviner RDR archive is made available via data releases scheduled at three month intervals as specified in the Lunar Reconnaissance Orbiter Project Data Management and Archive Plan (see Applicable document #1).

GDRs and PRPs are archived five months after the first complete year of mapping orbit and may be completely reprocessed in the future as necessary.

2.3.4 Labeling and Identification

2.3.4.1 RDR

The PDS3 data set ID provided by the PDS for the Diviner RDR data product is: LRO-L-DLRE-4-RDR-V1.0. The version number is incremented should the entire RDR data set be revised. The PDS3 data set name is “LRO DLRE 4 CALIBRATED RADIANCE V1.0”.

The file naming convention for the RDR data products is in the form of an 8-digit date in the format YYYYMMDD, plus a two-digit hour and a two-digit minute, e.g. “200707082000_RDR.TAB". The hour and minute represent the beginning of the ten-minute time period in which the data were taken.

Because the data tables will be compressed using Info-ZIP, they have a .ZIP suffix in the archive, e.g. “200707082000_RDR.ZIP”. See section 4 “Applicable Software” for more.

Each Diviner RDR data product has a detached PDS label in a separate file of the same name, extension .LBL: e.g. “200707082000_RDR.LBL”. The PDS format file for each RDR data product is DLRE_RDR.FMT.

2.3.4.2 GDR

The PDS3 data set ID for the GDR data product is: LRO-L-DLRE-5-GDR-V1.0. The version number is incremented should the entire GDR data set be revised. The PDS3 data set name is “LRO DLRE 5 GRIDDED DATA RECORD”.

The naming convention for GDRs is much more detailed and is explained in sections 5 and 6. The projection types are described in DSMAP.CAT (cylindrical) and DSMAP_POLAR.CAT (polar stereographic). The JPEG2000 format and usage is further described in JPINFO.TXT, which is found in the same directory as the JPEG2000 files and labels.

2.3.4.3 PRP

The PDS3 data set ID for the Polar Resource Product is: LRO-L-DLRE-5-PRP-V1.0. The version number is incremented should the entire data set be revised. The PDS3 data set name is “LRO DLRE 5 POLAR RESOURCE PRODUCT”.

The file names for each PRP are:

DLRE_PRP_NORTH.TAB
DLRE_PRP_SOUTH.TAB

Each file has a detached PDS label accompanying it in the same directory, with the same filename except for the suffix which is .LBL. The format is described in the format file DLRE_PRP.FMT.

2.3.4.4 GCP

The PDS3 data set ID for the GCP data product is: LRO-L-DLRE-5-GCP-V1.0. The version number is incremented should the entire data set be revised. The PDS3 data set name is “LRO DLRE 5 GLOBAL CUMULATIVE PRODUCT”.

The file names for each GCP are of the format:

GLOBAL_CUMUL_AVG_CYL_[MINLAT][MAXLAT]_[RES].TAB

Where MINLAT and MAXLAT are the minimum and maximum latitudes of the grid band. They are two-digit numbers followed by either an N for North or an S for South. For example, the southernmost latitude band uses “90S80S”.

RES is a three-digit number indicating the resolution of the data in pixels per degree. Currently the GCP product contains only 002 pixels per degree.

Each file has a detached PDS label accompanying it in the same directory, with the same filename except for the suffix which is .LBL. The format is described in the format file DLRE_GCP.FMT.

2.3.4.5 PCP

The PCP data products have been migrated to the PDS4 standard. They are part of a collection within a PDS4 bundle of Diviner derived products. The collection’s Logical Identifier with Version Identifier (LIDVID) is
urn:nasa:pds:lro_diviner_derived1:data_derived_pcp::1.0.
The name of the collection is the Lunar Reconnaissance Orbiter Diviner Polar

Cumulative Product (PCP) Collection.

The file names for each PCP (diurnal) are of the format:

PCP_AVG_[VAL]_[PROJ]_[SEASON]_[TYPE][NUM]_[RES].TAB

The file names for each PCP (seasonal) are of the format:

PCP_AVG_[VAL]_[PROJ]_LS[NUMLS]_[TYPE][NUM]_[RES].TAB

Where:

- VAL is the binned value which is always “TBOL”, the average bolometric brightness temperature (degrees Kelvin).
- PROJ is the projection, either “POLN” for north polar stereo, or “POLS” for south polar stereo.
- SEASON is either “SUM” for summer, or “WIN” for winter season.
- NUMLS is the bin center for the ecliptic longitude value in degrees where bin edges are +/-30 degrees.
- TYPE is either “LTIM” and “SLON” for the local time or subsolar longitude.
- NUM is a number (1 – 96) for the 96 local time steps or 96 solar longitude increments. The translation from NUM to the lower LTIM is LTIM=(NUM-1)*0.25 with the value of 1 corresponding to LTIM 0 to 0.25. The translation from NUM to lower SLON is SLON=(NUM-1)*3.75 with the value of 1 corresponding to SLON 0 to 3.75.
- RES is a three digit number indicating the resolution of the data in meters per pixel. Currently the PCP product contains only 240 meters per pixel.

Each .TAB file has a detached PDS label accompanying it in the same directory, with the same filename except for the suffix which is .XML.

The original diurnal PDS3 data product labels (suffix .LBL) remain available. The format is described in the format file DLRE_PCP.FMT.

2.3.4.6 RCP

The RCP data product is archived using the PDS4 standard. It is a collection within a PDS4 bundle of Diviner derived products. The collection’s Logical Identifier with Version Identifier (LIDVID) is
urn:nasa:pds:lro_diviner_derived1:data_derived_rcp::1.0.
The name of the collection is the Lunar Reconnaissance Orbiter Diviner Regional Cumulative Product (RCP) Collection.

The file names for each RCP are of the format:

REGION_[NAME]_CUMUL_AVG_CYL_[CENLAT][CENLON]_[RES].TAB

Where NAME is an identifier based on the regional nomenclature. Currently the RCP product contains only “LACUS_MORTIS”.

CENLAT and CENLON are the center latitudes and center longitudes of the 1° × 1° data tile. The center latitude is a two-digit number followed by either an N for North or an S for South. The center longitude is a three-digit number followed by either an E for East or W for West. For example, “42N023E”.

RES is a three-digit number indicating the resolution of the data in pixels per degree. Currently the RCP product contains only 128 pixels per degree.

Each file has a detached PDS label accompanying it in the same directory, with the same filename except for the suffix which is .XML.

2.3.4.7 GHRM

The GHRM data products are archived using the PDS4 standard. They are in a collection within a PDS4 bundle of Diviner derived products. The collection’s Logical Identifier with Version Identifier (LIDVID) is
urn:nasa:pds:lro_diviner_derived1:data_derived_ghrm::1.0.
The name of the collection is the Lunar Reconnaissance Orbiter Diviner Global High-Resolution Mosaic (GHRM) Collection.

The files names for each GHRM follow the format:

dghrm_[VAL]_[TYPE]_[MINLAT][MAXLAT]_[FORMAT].[FORMAT]

Where VAL is the gridded value which can either be:

- Channel 6, 7, 8, or 9 brightness temperature: “tb6”, “tb7”, “tb8”, or “tb9”
- Bolometric temperature: “tbol”
- Regolith temperature: “treg”
- Rock abundance: “ra”

TYPE can be “m” for midnight, “sam” for slope-adjusted midnight, or “anom” for anomaly at slope-adjusted midnight.

MINLAT and MAXLAT are the minimum and maximum latitudes of the map. They are two-digit numbers followed by either “n” or “s” for North or South, respectively. Currently, all GHRMs products use “70s70n”.

FORMAT indicates the file type, which is either “tif” or “img”.

Each file has a detached PDS label accompanying it in the same directory, with the same filename except for the suffix which is .XML.

2.4 Standards Used in Generating Data Products

2.4.1 PDS Standards

Diviner RDR, GDR, PRP, GCP, and PCP (diurnal) data products were originally archived in compliance with the PDS3 standards for file formats, directory names, and PDS labels, as specified in the PDS Standards Reference [6] and the Planetary Science Data Dictionary Document [7]. These product types have now been migrated to the PDS4 standard specified in Applicable Documents [8], [9], and [10].

Diviner RCP, PCP (seasonal), and GHRM data products were originally archived in compliance with the PDS4 standard.

2.4.2 Time Standards

The PDS label for Diviner data uses keywords denoting time values, such as start time, stop time, start spacecraft clock count, and stop spacecraft clock count. Each time value standard is defined according to the PDS keyword definition.

In the data product label, Start Time and Stop Time values are stored in PDS compliant UTC date format, in the pattern YYYY-MM-DDTHH:MM:SS.SSS (four digit year, two digits for month, day, hour, minute and second, and three digits for decimal fractional second). Spacecraft clock start and stop count time values are stored in decimal seconds from the epoch January 1, 2001 00:00:00 UTC.

2.4.3 Coordinate Systems

Lunar Reconnaissance Orbiter (LRO) data use lunar planetocentric/body-fixed coordinates with east-positive longitude from 0 to 360 degrees. A mean Earth/polar axis (ME) reference system (also called the mean Earth/rotation system) is used, with the z axis being the mean rotational pole and with the prime meridian (zero degrees longitude) defined by the mean Earth direction.

The ME reference system is used for all LRO archival data. This LRO standard is documented in “A Standardized Lunar Coordinate System for the Lunar Reconnaissance Orbiter, LRO Project White Paper, 451-SCI-000958, Version 3, January 30, 2008”. Using coordinates in the ME system is consistent with recommendations from the International Astronomical Union (IAU)/International Association of Geodesy (IAG) Working Group on Cartographic Coordinates and Rotational Elements.

A Jet Propulsion Laboratory (JPL) planetary and lunar ephemeris and corresponding Euler angle set are used to define an ME frame to which the LRO data are registered. The LRO Data Working Group (LDWG) determines which ephemeris and Euler angle set should be used. Alternatively, LRO data can be registered to an existing or new reference frame in the ME system, via ties to surface points known in the frame (examples include Lunar Laser Ranging (LLR) retroreflectors, points in images and Digital Elevation Models).

When a JPL planetary and lunar ephemeris is used, the JPL Navigation and Ancillary Information Facility (NAIF) provides the necessary lunar ephemeris file (SPK) and binary lunar orientation file (PCK) in a Principal Axes (PA) reference frame for use with the SPICE Toolkit. NAIF also provides the frames kernel (FK) used for accessing the PA orientation in the PCK and for transforming from the PA frame to the ME frame.

Alternatively, the JPL lunar ephemeris information is available in an ASCII format not requiring the use of the SPICE Toolkit. This information is available from a JPL website: http://ssd.jpl.nasa.gov.

Whenever the planetary surface is referenced, unless otherwise specified, a simple sphere is used. This sphere is defined in the label by the fields A_AXIS_RADIUS (also the x-axis), B_AXIS_RADIUS (y), and C_AXIS_RADIUS (z), in kilometers, with all three having the same value. Typically the radius of this sphere is 1737.4 kilometers.

2.4.4 Data Storage Conventions

The Diviner RDR data files are stored as fixed-length fixed-format ASCII tables. The detached PDS labels for Diviner RDRs are stored as ASCII text. Each record is terminated with a carriage return followed by a line feed.

The GDR IMG data files are stored as 16-bit signed binary integers in least-significant-byte (LSB) order. These integers are scaled representations of the actual values, which are derived using the label elements SCALING_FACTOR and OFFSET (see section 5.5). The GDR JPEG2000 files are derived directly from the IMG files. Separate PDS ASCII labels accompany and describe each file format.

The Diviner PRP, GCP, PCP, and RCP data files are stored as fixed-length fixed-format ASCII tables. The detached PDS labels are stored as ASCII text. Each record is terminated with a carriage return followed by a line feed.

The Diviner GHRM data files are stored as 32-bit floating-point IMG and GEOTIFF files. Each file is accompanied by a separate XML label file.

2.4.5 Channel and Detector Order

The RDR channel names and detector order have been changed from the method used in the Diviner EDR dataset. Figures 4 and 5 show the difference in channel and detector labeling.

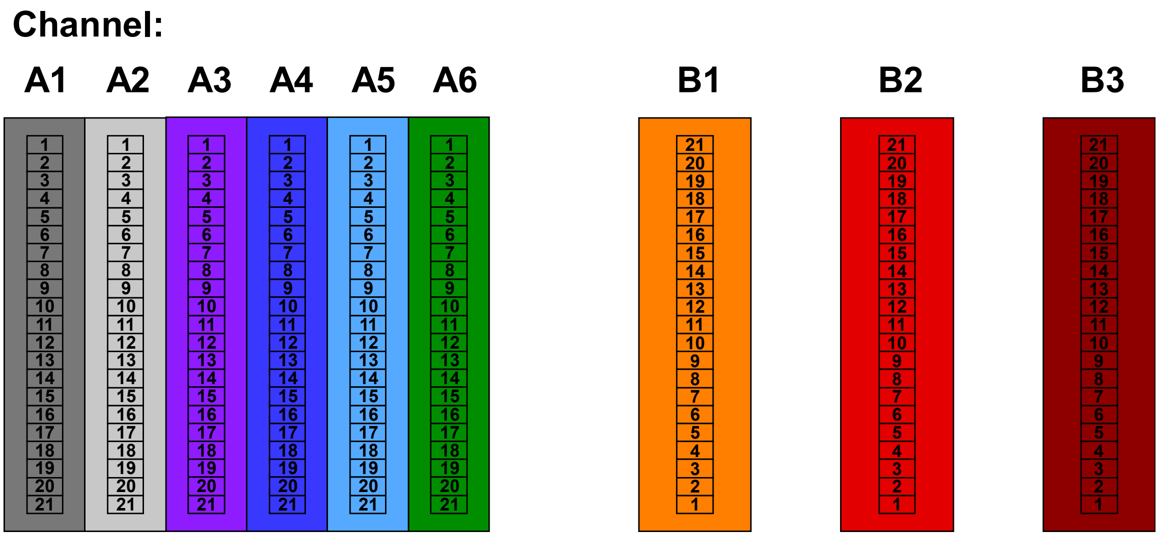

Figure 4: Diviner EDR Order

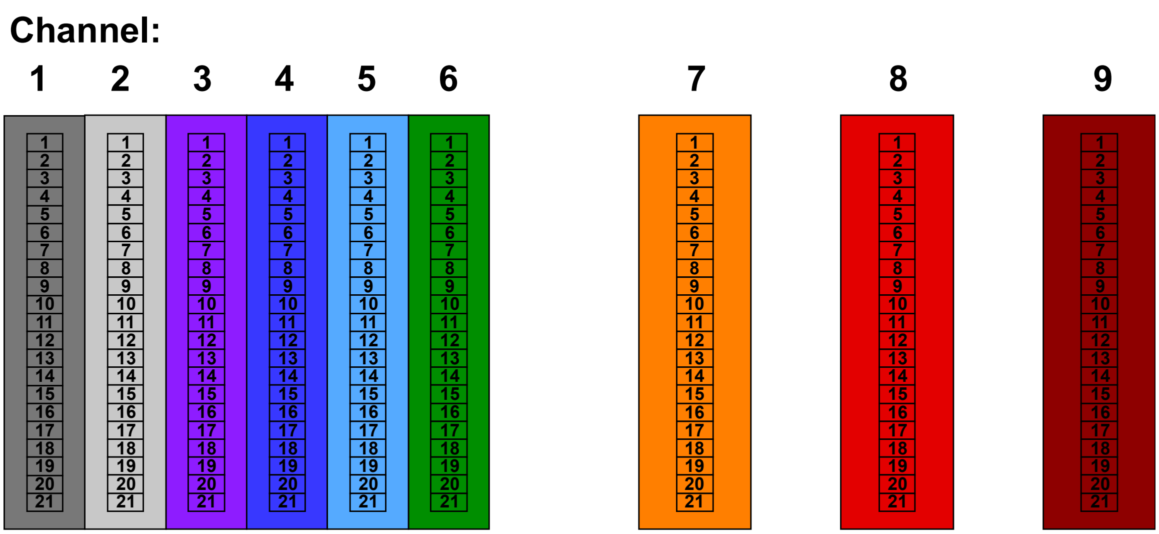

Figure 5: Diviner RDR Order

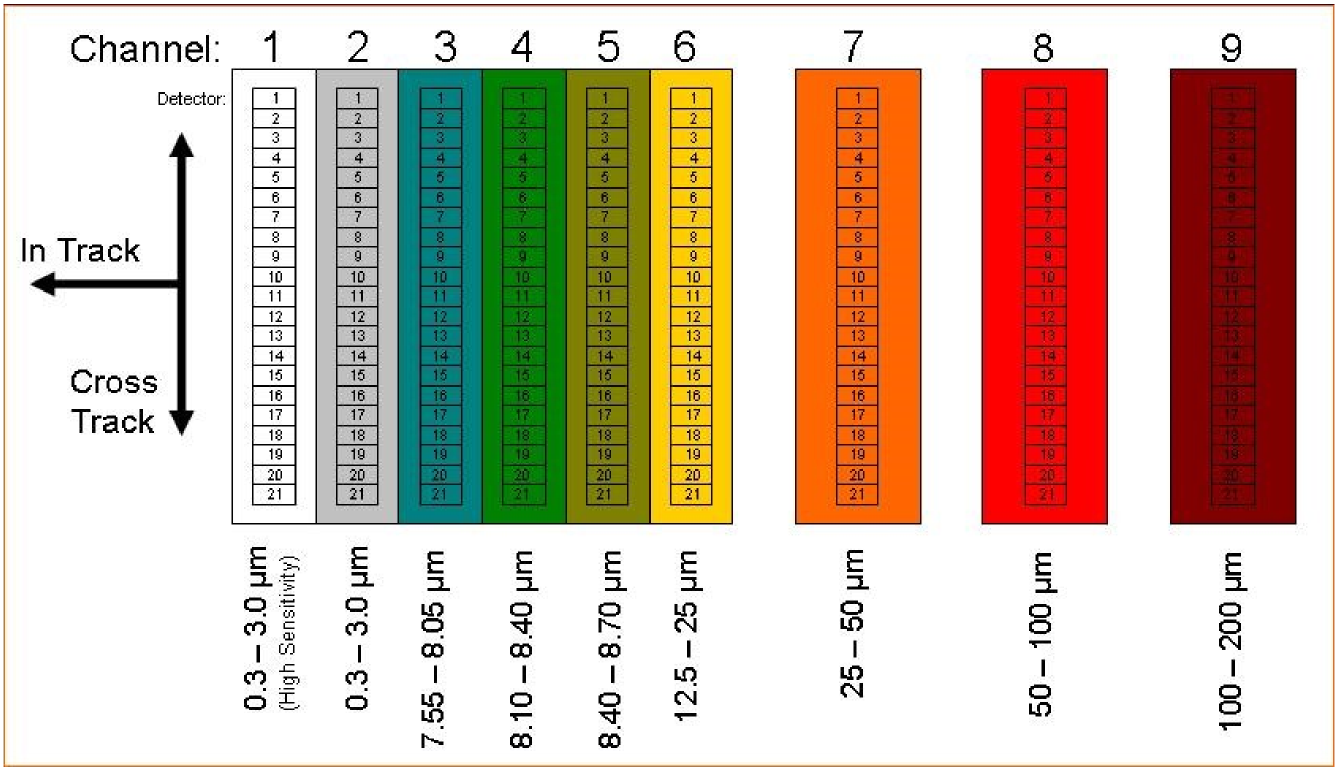

Figure 6: Diviner RDR Order, detailed

Note that the EDR channels A1-A6 correspond to RDR channels 1-6, and that EDR channels B1-B3 correspond to RDR channels 7-9. It should also be noted that while the EDR channels B1-B3 have their detector numbers *reversed* with respect to the EDR channels A1-A6, no such reversal occurs in the RDR channels. In other words, the RDR channel detectors are all numbered from 1 to 21 in the same cross track direction. Thus, the detectors 21-1 (descending) for EDR channels B1-B3 correspond to detectors 1-21 (ascending) for RDR channels 7-9.

Channels 1-6 and channels 7-9 represent separate focal planes that are approximately boresighted. Therefore channel 1 roughly overlays with channel 7, and channel 6 roughly overlays channel 9.

The EDR method of detector numbering was inherited from MCS. The RDR method was developed primarily from a desire to have all detectors numbered in the same direction, which makes things easier to understand geometrically and programmatically, as well as easier for the user to visualize.

2.4.6 Calibration

A full set of ground calibration and characterization testing was performed on the Diviner instrument, including measurements of radiometric response, spectral response, and the instantaneous field of view of every pixel. Radiometric response was measured by scanning the instrument between a cold blackbody target and a second blackbody target that was varied in temperature between 20 and 415 K. Spectral response in channels 1-7 was measured with a collimated signal from a monochromator in the spectral range 0.3 to 50 microns. Spectral response in channels 8-9 was determining by using a Fourier-transform spectrometer to measure the filter passbands. To measure pixel field of views, a slit in front of a hot source was collimated and scanned across the field of view of the instrument.

Data used to perform calibration are archived with the RDR dataset. Details are outlined in the Diviner Lunar Radiometer Experiment Archive Volume Software Interface Specification [11].

2.5 Data Validation

Diviner data products are validated before being released to the PDS. Validation is accomplished in two parts: validation for scientific integrity and validation for compliance with PDS standards. Diviner Team members conduct validation for scientific integrity in the course of their analysis of the products. Science validation is meant to ensure that data products contain the expected measurements and that they are otherwise suitable for analysis. The details of the science validation process are the responsibility of the Diviner Team.

Validation for PDS compliance is performed by the PDS Geosciences Node and is meant to ensure that data products conform to PDS standards and to the specifications in this SIS.

A data set passes a peer review before it is accepted by PDS. The Diviner Team and the PDS Geosciences Node convene a peer review committee made up of scientists and data engineers. The committee examines the data set to make sure it is complete and meets the product specifications as defined in the SIS. The committee includes a PDS representative to ensure that the data set is in compliance with PDS standards.

3 RDR DETAILED DATA PRODUCT SPECIFICATIONS

3.1 Data Product Structure and Organization

The RDR data products are located in the DATA directory of the volume. The files are grouped into directories with one directory per day. Each directory name is in the format YYYYMMDD. Within each directory there are up to 144 compressed data product files and their labels, with each file/label corresponding to a ten-minute time period. The labels point to the corresponding data files and contain a pointer to the format file detailing the column layout of the data files. The data product file names are in the format YYYYMMDDHHMM_RDR.ZIP for the data tables, and YYYYMMDDHHMM_RDR.LBL for the labels.

3.2 Data Format Descriptions

The Diviner RDR data product file is a fixed record-length ASCII table. Descriptions of the data contained within the table columns are provided below. For descriptions of starting byte and column lengths, please see the format file included within the volume.

A note on the width of character fields: The width of each character field is listed as **including** the beginning and ending double quotes. Thus the first field “date” (Character width 13) begins with a double quote, followed by 11 characters for the date, followed by the closing double quote, for a total of 13 bytes.

The PDS3 format file, however, **does not include** quotes in the width (or BYTES), so it lists the START_BYTE as byte 2 and the BYTES as 11. This inconsistency has been allowed here so that this SIS can be consistent with its predecessor versions, including those of MCS.

RDR Fields and Descriptions

#	Field name	Data Type and Width[.Precision]	Description
1	date	Character 13	Date at the midpoint of observation (SCET, UTC). E.g. "25-Jun-2009"
2	utc	Character 14	Time at the midpoint of observation (SCET, UTC). E.g. "19:35.37.440"
3	jdate	Real 17.9	Julian Date at the midpoint of observation (SCET, UTC). E.g. 2454102.123456789
4	orbit	Integer 5	Orbit number. 0 to 99999
5	sundist	Real 7.5	The distance from the center of the moon to the sun (AU). E.g. 1.00001
6	sunlat	Real 8.5	Subsolar Latitude (deg). -1.7 to 1.7 degrees.
7	sunlon	Real 9.5	Subsolar East Longitude (deg). 0.00000 to 360.00000
8	sclk	Real 16.5	Spacecraft clock at midpoint of observation (seconds.subseconds). The seconds are relative to the 2001 epoch. The numbers to the right of the decimal point are not decimal fraction of a second but rather subseconds. Each second is divided into 65536 subseconds, thus the range for subseconds is 0 – 65535. Example: 123456789.00001
9	sclat	Real 9.5	Subspacecraft Latitude (deg). -90.00000 to 90.00000
10	sclon	Real 9.5	Subspacecraft East Longitude (deg). 0 to 360.00000
11	scrad	Real 11.5	Distance from the center of moon to the spacecraft (km). E.g.: 11000.00000
12	scalt	Real 11.5	Distance from the surface of the moon to the spacecraft (km). E.g.: 11000.00000. Uses spherical moon approximation as described in Section 2.4.3.
13	el_cmd	Real 7.3	Last Elevation Command (deg). 0 to 270.000
14	az_cmd	Real 7.3	Last Azimuth Command (deg). 0 to 270.000
15	af	Integer 4	Activity Flag. Range is -999 to 999. See Appendix B of DLRE RDR SIS for description

16	orientlat	Real 9.5	Orientation Latitude (deg). The latitudinal component of the "orientation vector", a vector from the center of the moon in the direction of the detector array direction (defined as from detector 21 to detector 1). Provides angular orientation of the FOV's. -90.00000 to 90.00000
17	orientlon	Real 9.5	Orientation Longitude (deg). The east longitudinal component of the "orientation vector", a vector from the center of the moon in the direction of the detector array direction (defined as from detector 21 to detector 1). Provides angular orientation of the FOV's. 0 to 360.00000
18	c	Integer 1	Diviner Channel Number. 1 to 9
19	det	Integer 3	Diviner Detector Number. 1 to 21
20	vlookx	Real 9.6	The X component of the Diviner Look Unit Vector, using the lunar coordinate system described in Section 2.4.3. -1.0 to 1.0
21	vlooky	Real 9.6	The Y component of the Diviner Look Unit Vector, using the lunar coordinate system described in Section 2.4.3. -1.0 to 1.0
22	vlookz	Real 9.6	The Z component of the Diviner Look Unit Vector, using the lunar coordinate system described in Section 2.4.3. -1.0 to 1.0
23	radiance	Real 10.4	Calibrated Radiance (W m^{-2} sr^{-1}). The realistic range of radiance is -1000.0000 to 1000.0000, but this number can be as high as 99999.9999 during spacecraft or instrument anomalies.
24	tb	Real 8.3	Calibrated Brightness Temperature (K). Except for Channels 1 and 2, which is radiance relative to normally illuminated Lambert surface at sun-moon distance. The realistic range of tb is -450.000 to 450.000, but this number can be as high as 9999.999 during spacecraft or instrument anomalies. Negative values correspond to negative radiances.
25	clat	Real 9.5	Latitude of FOV center (deg). Undefined if off planet. Uses spherical moon approximation as described in Section 2.4.3. -90.00000 to 90.00000
26	clon	Real 9.5	East longitude of FOV center (deg). Undefined if off planet. Uses spherical moon approximation as described in Section 2.4.3. 0 to 360.00000
27	cemis	Real 9.5	Emission Angle at FOV center (deg). This is the angle between the vector from the surface FOV center to Diviner and a “normal” vector drawn perpendicular to the Moon’s surface. Undefined if off planet. Uses spherical moon approximation as described in Section 2.4.3. 0 to 90.00000
28	csunzen	Real 9.5	Solar Zenith angle at FOV center (deg). This is the angle between the vector from the surface FOV center to the Sun and a "normal" vector drawn perpendicular to the Moon's surface. Undefined when off planet except during solar calibrations when it is defined as the angle between the vector to the Sun and the normal vector of the solar calibration target. Uses spherical moon approximation as described in Section 2.4.3. 0 to 180.00000
29	csunazi	Real 9.5	Solar Azimuth Angle at FOV Center (deg). 0 degrees when aligned with the solar vector and measured counterclockwise when looking down at the planet. Undefined when off planet except during solar calibrations when it is defined as the angle between

			the projection of the vector to the sun onto the solar calibration target plane and the X-axis of the solar calibration target reference system (STS). The X-axis direction of the STS is roughly parallel to the outward edge of the solar calibration target panel. Uses spherical moon approximation as described in Section 2.4.3. 0 to 360.00000
30	cloctime	Real 8.5	Local time at FOV Center (hours past midnight). Undefined if off planet. Uses spherical moon approximation as described in Section 2.4.3. 0 to 24.00000
31	qca	Integer 3	Quality Flag for Calibration. A 3-digit decimal integer representing an 8-bit binary quality flag. Bits set to 1 represent various conditions which compromise data quality. A value of zero represents best quality and increasing values indicate lower quality. Range is 0 to 255. See Appendix C of the RDR SIS for more details.
32	qge	Integer 3	Quality Flag for Geometry. A 3-digit decimal integer representing an 8-bit binary quality flag. Bits set to 1 represent various conditions which compromise data quality. A value of zero represents best quality and increasing values indicate lower quality. Range is 0 to 255. See Appendix C of the RDR SIS for more details.
33	qmi	Integer 3	Quality Flag for Miscellaneous. A 3-digit decimal integer representing an 8-bit binary quality flag. Bits set to 1 represent various conditions which compromise data quality. A value of zero represents best quality and increasing values indicate lower quality. Range is 0 to 255. See Appendix C of the RDR SIS for more details.

3.3 Label and Header Descriptions

Each Diviner RDR data product is described by a detached PDS3 label in a separate file with the same name, extension ".LBL". A label file is stored in the same directory as the data file it describes.

A PDS3 label is object-oriented and describes the objects in the data file. The PDS3 label contains keywords for product identification and for data object definitions. The label also contains descriptive information needed to interpret or process the data objects in the file.

PDS3 labels are written in Object Description Language (ODL) [6]. PDS label statements have the form of "keyword = value". Each label statement is terminated with a carriage return character (ASCII 13) and a line feed character (ASCII 10) sequence to allow the label to be read by many operating systems. Pointer statements with the following format are used to indicate the location of data objects in the file:

^TABLE = filename,location

where the caret character (^, also called a pointer) is followed by the name of the specific data object. The 'location' is the starting record number (counting from one) for the data within the file, e.g.

^TABLE = ("200811300400_RDR.TAB", 5)

The data files themselves will usually contain some rows of embedded headers, marked by the '#' symbols, which are used for file comments.

The PDS3 label also includes a pointer to another file that contains the table column definitions, in order to avoid repeating the lengthy definitions in every label. The column definition file has the extension ".FMT" and is stored in the LABEL directory of the archive.

PDS3 Label Elements and Definitions for RDR Products

Name	Data_Type	Description
PDS_VERSION_ID	IDENTIFIER	The version number of the PDS standards documents that is valid when the label is created. Examples: PDS3, PDS4
RECORD_TYPE	IDENTIFIER	The record format of a file. For RDR, this will be FIXED_LENGTH.
RECORD_BYTES	INTEGER	The number of bytes in a physical file record, including record terminators (carriage return and line feed).
FILE_RECORDS	INTEGER	The number of physical file records, including both header records and data records.
MISSING_LINES	INTEGER	The number of data record lines of data missing from the file.

LRO:PARTIAL_LINES	INTEGER	The number of data record lines that contain partial data due to missing packets.
LRO:COMPLETE_LINES	INTEGER	The number of data record lines that are complete, i.e. not missing any expected data.
LRO:TOTAL_LINES	INTEGER	The total number of data record lines in the file. Is equal to PARTIAL_LINES + COMPLETE_LINES. Does not include MISSING_LINES.
DESCRIPTION	CHARACTER	A free-form description of the data.
DATA_SET_ID	IDENTIFIER	This unique identifier describes the mission, instrument, data level and archive version (the archive version starts at V1.0 and only ever gets bumped up in the event that the entire dataset needs to be re-archived). Example: "LRO-L-DLRE-4-RDR-V1.0"
FILE_NAME	CHARACTER	The name of either the compressed or uncompressed data file, depending on where this occurs in the label. In the OBJECT that describes the compressed file, this is "200906251200_RDR.ZIP" for example. In the OBJECT that describes the uncompressed file, this would be "200906251200_RDR.TAB".
FILE_STATE	CHARACTER	Indicates whether the data file contains possibly corrupted data. Either CLEAN or DIRTY. DIRTY means only that the file was prematurely closed during output, e.g. during a program crash. A CLEAN file may still contain missing or partial records, as long as all available records are written successfully.
MISSION_NAME	CHARACTER	Major planetary mission or project. Always "LUNAR RECONNAISSANCE ORBITER".
MISSION_PHASE_NAME	CHARACTER	The mission phase at the time of the beginning of the file. For LRO, possible values include: "COMMISSIONING", "NOMINAL MISSION", and "EXTENDED MISSION".
INSTRUMENT_HOST_NAME	CHARACTER	Full name of the spacecraft on which the instrument is based. Always "LUNAR RECONNAISSANCE ORBITER".
INSTRUMENT_HOST_ID	CHARACTER	Unique identifier for the spacecraft on which the instrument is based. Always "LRO".
INSTRUMENT_NAME	CHARACTER	The full name of the instrument. Always "DIVINER LUNAR RADIOMETER EXPERIMENT".
INSTRUMENT_ID	CHARACTER	Unique identifier for the instrument. Always "DLRE".
PRODUCT_TYPE	CHARACTER	Descriptive title of the product, refers to both the instrument and the processing level. Always "RDR".
PRODUCT_ID	CHARACTER	A permanent, unique identifier assigned to a data product. Here it is the base name of the data product file, e.g.: "200811300400_RDR.TAB".
FLIGHT_SOFTWARE_VERSION_ID	CHARACTER	An unordered set of flight software versions used to acquire the telemetry data. Example: {"1.1","1.2"}
LRO:DREB_FLIGHT_SOFTWARE_VER_ID	CHARACTER	An unordered set of DREB flight software versions used to acquire the telemetry data.

		Example: {“1.1”,”1.2”}
LRO:CALIBRATION_SOFTWARE_VER_ID	CHARACTER	The version of calibration software used to generate a dataset.
SOFTWARE_VERSION_ID	CHARACTER	The version of ground software used to generate this data product. Example: “1.1”.
TARGET_NAME	CHARACTER	The name of the mission or project target. Always “MOON”.
START_TIME	TIME	The beginning UTC time of the first observation in the data product. This is equal to the midpoint time given in the first record minus one-half of the exposure time (0.128 sec).
STOP_TIME	TIME	The ending UTC time of the last observation in the data product. This is equal to the midpoint time given in the last record plus one-half of the exposure time (0.128 sec).
SPACECRAFT_CLOCK_START_COUNT	CHARACTER	The value of the spacecraft clock in the first record of the data product.
SPACECRAFT_CLOCK_STOP_COUNT	CHARACTER	The value of the spacecraft clock in the last record of the data product.
PRODUCT_CREATION_TIME	TIME	The UTC system format time when this product was created.
PRODUCT_VERSION_ID	CHARACTER	The version number of the archived data product. If the data needs to be modified and re-archived, this number is incremented. “1” means first revision, “2” means second, and so on.
LRO:DLRE_DATE_MIN	CHARACTER	The minimum recorded value of date.
LRO:DLRE_DATE_MAX	CHARACTER	The maximum recorded value of date.
LRO:DLRE_UTC_MIN	CHARACTER	The minimum recorded value of utc.
LRO:DLRE_UTC_MAX	CHARACTER	The maximum recorded value of utc.
LRO:DLRE_JDATE_MIN	REAL	The minimum recorded value of jdate.
LRO:DLRE_JDATE_MAX	REAL	The maximum recorded value of jdate.
LRO:DLRE_ORBIT_MIN	INTEGER	The minimum recorded value of orbit.
LRO:DLRE_ORBIT_MAX	INTEGER	The maximum recorded value of orbit.
LRO:DLRE_SUNDIST_MIN	REAL	The minimum recorded value of sundist.
LRO:DLRE_SUNDIST_MAX	REAL	The maximum recorded value of sundist.
LRO:DLRE_SUNLAT_MIN	REAL	The minimum recorded value of sunlat.
LRO:DLRE_SUNLAT_MAX	REAL	The maximum recorded value of sunlat.
LRO:DLRE_SUNLON_MIN	REAL	The minimum recorded value of sunlon.
LRO:DLRE_SUNLON_MAX	REAL	The maximum recorded value of sunlon.
LRO:DLRE_SCLK_MIN	REAL	The minimum recorded value of sclk.
LRO:DLRE_SCLK_MAX	REAL	The maximum recorded value of sclk.
LRO:DLRE_SCLAT_MIN	REAL	The minimum recorded value of sclat.
LRO:DLRE_SCLAT_MAX	REAL	The maximum recorded value of sclat.
LRO:DLRE_SCLON_MIN	REAL	The minimum recorded value of sclon.
LRO:DLRE_SCLON_MAX	REAL	The maximum recorded value of sclon.
LRO:DLRE_SCRAD_MIN	REAL	The minimum recorded value of scrad.
LRO:DLRE_SCRAD_MAX	REAL	The maximum recorded value of scrad.
LRO:DLRE_SCALT_MIN	REAL	The minimum recorded value of scalt.
LRO:DLRE_SCALT_MAX	REAL	The maximum recorded value of scalt.
LRO:DLRE_EL_CMD_MIN	REAL	The minimum recorded value of el_cmd.

LRO:DLRE_EL_CMD_MAX	REAL	The maximum recorded value of el_cmd.
LRO:DLRE_AZ_CMD_MIN	REAL	The minimum recorded value of az_cmd.
LRO:DLRE_AZ_CMD_MAX	REAL	The maximum recorded value of az_cmd.
LRO:DLRE_ORIENTLAT_MIN	REAL	The minimum recorded value of orientlat.
LRO:DLRE_ORIENTLAT_MAX	REAL	The maximum recorded value of orientlat.
LRO:DLRE_ORIENTLON_MIN	REAL	The minimum recorded value of orientlon.
LRO:DLRE_ORIENTLON_MAX	REAL	The maximum recorded value of orientlon.
LRO:DLRE_VLOOKX_MIN	REAL	The minimum recorded value of vlookx.
LRO:DLRE_VLOOKX_MAX	REAL	The maximum recorded value of vlookx.
LRO:DLRE_VLOOKY_MIN	REAL	The minimum recorded value of vlooky.
LRO:DLRE_VLOOKY_MAX	REAL	The maximum recorded value of vlooky.
LRO:DLRE_VLOOKZ_MIN	REAL	The minimum recorded value of vlookz.
LRO:DLRE_VLOOKZ_MAX	REAL	The maximum recorded value of vlookz.
LRO:DLRE_CLAT_MIN	REAL	The minimum recorded value of clat.
LRO:DLRE_CLAT_MAX	REAL	The maximum recorded value of clat.
LRO:DLRE_CLON_MIN	REAL	The minimum recorded value of clon.
LRO:DLRE_CLON_MAX	REAL	The maximum recorded value of clon.
LRO:DLRE_CEMIS_MIN	REAL	The minimum recorded value of cemis.
LRO:DLRE_CEMIS_MAX	REAL	The maximum recorded value of cemis.
LRO:DLRE_CSUNZEN_MIN	REAL	The minimum recorded value of csunzen.
LRO:DLRE_CSUNZEN_MAX	REAL	The maximum recorded value of csunzen.
LRO:DLRE_CSUNAZI_MIN	REAL	The minimum recorded value of csunazi.
LRO:DLRE_CSUNAZI_MAX	REAL	The maximum recorded value of csunazi.
LRO:DLRE_CLOCTIME_MIN	REAL	The minimum recorded value of cloctime.
LRO:DLRE_CLOCTIME_MAX	REAL	The maximum recorded value of cloctime.
LRO:DLRE_QCA_SOLAR_MIN	INTEGER	The minimum recorded value of qca for solar channels.
LRO:DLRE_QCA_SOLAR_MAX	INTEGER	The maximum recorded value of qca for solar channels.
LRO:DLRE_QCA_THERMAL_MIN	INTEGER	The minimum recorded value of qca for thermal channels.
LRO:DLRE_QCA_THERMAL_MAX	INTEGER	The maximum recorded value of qca for thermal channels.
LRO:DLRE_QGE_MIN	INTEGER	The minimum recorded value of qge.
LRO:DLRE_QGE_MAX	INTEGER	The maximum recorded value of qge.
LRO:DLRE_QMI_MIN	INTEGER	The minimum recorded value of qmi.
LRO:DLRE_QMI_MAX	INTEGER	The maximum recorded value of qmi.
LRO: DLRE_CH1_RADIANCE_MIN	REAL	The minimum recorded value of radiance for channel 1.
LRO: DLRE_CH1_RADIANCE_MAX	REAL	The maximum recorded value of radiance for channel 1.
LRO: DLRE_CH2_RADIANCE_MIN	REAL	The minimum recorded value of radiance for channel 2.
LRO: DLRE_CH2_RADIANCE_MAX	REAL	The maximum recorded value of radiance for channel 2.
LRO: DLRE_CH3_RADIANCE_MIN	REAL	The minimum recorded value of radiance for channel 3.
LRO: DLRE_CH3_RADIANCE_MAX	REAL	The maximum recorded value of radiance for channel 3.

LRO: DLRE_CH4_RADIANCE_MIN	REAL	The minimum recorded value of radiance for channel 4.
LRO: DLRE_CH4_RADIANCE_MAX	REAL	The maximum recorded value of radiance for channel 4.
LRO: DLRE_CH5_RADIANCE_MIN	REAL	The minimum recorded value of radiance for channel 5.
LRO: DLRE_CH5_RADIANCE_MAX	REAL	The maximum recorded value of radiance for channel 5.
LRO: DLRE_CH6_RADIANCE_MIN	REAL	The minimum recorded value of radiance for channel 6.
LRO: DLRE_CH6_RADIANCE_MAX	REAL	The maximum recorded value of radiance for channel 6.
LRO: DLRE_CH7_RADIANCE_MIN	REAL	The minimum recorded value of radiance for channel 7.
LRO: DLRE_CH7_RADIANCE_MAX	REAL	The maximum recorded value of radiance for channel 7.
LRO: DLRE_CH8_RADIANCE_MIN	REAL	The minimum recorded value of radiance for channel 8.
LRO: DLRE_CH8_RADIANCE_MAX	REAL	The maximum recorded value of radiance for channel 8.
LRO: DLRE_CH9_RADIANCE_MIN	REAL	The minimum recorded value of radiance for channel 9.
LRO: DLRE_CH9_RADIANCE_MAX	REAL	The maximum recorded value of radiance for channel 9.
LRO: DLRE_CH1_TB_MIN	REAL	The minimum recorded value of tb for channel 1.
LRO: DLRE_CH1_TB_MAX	REAL	The maximum recorded value of tb for channel 1.
LRO: DLRE_CH2_TB_MIN	REAL	The minimum recorded value of tb for channel 2.
LRO: DLRE_CH2_TB_MAX	REAL	The maximum recorded value of tb for channel 2.
LRO: DLRE_CH3_TB_MIN	REAL	The minimum recorded value of tb for channel 3.
LRO: DLRE_CH3_TB_MAX	REAL	The maximum recorded value of tb for channel 3.
LRO: DLRE_CH4_TB_MIN	REAL	The minimum recorded value of tb for channel 4.
LRO: DLRE_CH4_TB_MAX	REAL	The maximum recorded value of tb for channel 4.
LRO: DLRE_CH5_TB_MIN	REAL	The minimum recorded value of tb for channel 5.
LRO: DLRE_CH5_TB_MAX	REAL	The maximum recorded value of tb for channel 5.
LRO: DLRE_CH6_TB_MIN	REAL	The minimum recorded value of tb for channel 6.
LRO: DLRE_CH6_TB_MAX	REAL	The maximum recorded value of tb for channel 6.
LRO: DLRE_CH7_TB_MIN	REAL	The minimum recorded value of tb for channel 7.
LRO: DLRE_CH7_TB_MAX	REAL	The maximum recorded value of tb for channel 7.
LRO: DLRE_CH8_TB_MIN	REAL	The minimum recorded value of tb for channel 8.
LRO: DLRE_CH8_TB_MAX	REAL	The maximum recorded value of tb for channel 8.
LRO: DLRE_CH9_TB_MIN	REAL	The minimum recorded value of tb for channel 9.
LRO: DLRE_CH9_TB_MAX	REAL	The maximum recorded value of tb for channel 9.
LRO:DLRE_ORIENTATION	CHARACTER	An unordered set of all orientations recorded from af. Possible values include “ON MOON”, “NEAR LIMB”, “OFF MOON”, and “ELEVATION ACTUATOR HOMED”
OBSERVATION_TYPE	CHARACTER	An unordered set of all observation types recorded from af. Possible values include “STANDARD NADIR”, “ROTATED NADIR”, “SPACE CALIBRATION”, “SOLAR CALIBRATION”, “BLACKBODY CALIBRATION”, and “STOWED”

INSTRUMENT_MODE_ID	CHARACTER	An unordered set of all instrument modes recorded from af. Possible values include “NOMINAL”, “SMALL ROLL”, “LARGE ROLL”, “FREEZING”, “FROZEN”, “SAFING”, “SAFED”, and “MOVING”.
SPICE_FILE_NAME	CHARACTER	A list containing the NAIF SPICE Toolkit version (as the first element), followed by all the SPICE data files/kernels used to create the dataset. Example: {"V.N0060", "naif0008.tls", "pck00008.tcp", "de414.bsp", "c-kernel.bc"}
START_ORBIT_NUMBER	REAL	The orbit number of the first observation in the dataset.
STOP_ORBIT_NUMBER	REAL	The orbit number of the last observation in the dataset.
START_SOLAR_LONGITUDE	REAL	The subsolar east longitude at the first observation in the dataset, in degrees.
STOP_SOLAR_LONGITUDE	REAL	The subsolar east longitude at the last observation in the dataset, in degrees.
A_AXIS_RADIUS	REAL	The radius of the “A” axis of the Moon used in geometry calculations, in kilometers. See section 2.4.3, “Coordinate Systems”, for more.
B_AXIS_RADIUS	REAL	The radius of the “B” axis of the Moon used in geometry calculations, in kilometers. See section 2.4.3, “Coordinate Systems”, for more.
C_AXIS_RADIUS	REAL	The radius of the “C” axis of the Moon used in geometry calculations, in kilometers. See section 2.4.3, “Coordinate Systems”, for more.

4 RDR APPLICABLE SOFTWARE

4.1 Utility Programs

The data table files are compressed using Info-ZIP, a freely available utility. In order to uncompress the files into ASCII format, Info-ZIP is recommended but not required as many generic unzipping programs will suffice. For example, to uncompress a file named 200707082000_RDR.ZIP from the command line, simply type the command:

```
unzip 200707082000_RDR.ZIP
```

This will create the file 200707082000_RDR.TAB in the current directory. The ZIP file may then be deleted to save space. On graphically-based desktops, it may be sufficient to simply open the file’s icon in order to begin the unzipping process.

Because the Diviner RDR products are formatted as columnar ASCII data, they can be read and manipulated by standard, public-domain software. For this reason, no special utilities are provided.

4.2 Applicable PDS Software Tools

PDS3-labeled data products can be viewed with the program NASAView, developed by the PDS and available for a variety of computer platforms from the PDS web site http://pds.nasa.gov/tools/software_download.cfm. There is no charge for NASAView.

PDS4-labeled data products can be viewed with the program PDS4 Viewer, available at https://sbnwiki.astro.umd.edu/wiki/PDS4_Viewer. The underlying Python library from which the PDS4 Viewer is build is also available. There is no charge for either the standalone PDS4 Viewer program or the Python library.

5 Level 2 GDR Detailed Data Product Specifications

5.1 Gridded Values

The following table lists the values in each gridded data product:

Value	Description
VB1	Channel 1 Visual Brightness
VB2	Channel 2 Visual Brightness
TB3	Channel 3 Brightness Temperature
TB4	Channel 4 Brightness Temperature
TB5	Channel 5 Brightness Temperature
TB6	Channel 6 Brightness Temperature
TB7	Channel 7 Brightness Temperature
TB8	Channel 8 Brightness Temperature
TB9	Channel 9 Brightness Temperature
TBOL*	Bolometric Temperature
LTIM	Local Time (binned using “circular” averaging)
JD	Julian Date

5.2 File Names

All gridded values have associated files with binned averages, errors, and counts, with the exception of TBOL which has just binned averages. The format of each file name is:

DGDR_[VAL]_[BTYPE]_[PROJ]_YYYYMMDD[DN]_[RES]_[SUF].[SUF]

* TBOL is now considered a NASA Level 3 product, but because its structure is similar to that of the other Level 2 products, it is described here.

Each item in the file name is explained in the following table:

Filename Component	Description
VAL	The value binned. E.g. VB1
BTYPE	The bin type. One of AVG (average), ERR (error), or CNT (count).
PROJ	Projection. One of CYL (cylindrical) or POL[N or S] (polar).
YYYYMMDD	The date beginning the mapping cycle.
DN	Either D (daytime) or N (nighttime)
RES	For cylindrical maps, the resolution in pixels per degree. For polar maps, the map scale in meters per pixel.
SUF	File suffix. Either “IMG” (16-bit LSB binary integers), “JP2” (JPEG2000), “JPG” (JPEG), or “LBL” (detached PDS label). The extra “_SUF” in the base name is to keep all label names unique in order to avoid name clashes, which allows one to store all labels in the same directory.

An example file name for a cylindrical GDR binning average visual brightness for Channel 1:

DGDR_VB1_AVG_CYL_20090915D_128_IMG.IMG

An example file name for a polar GDR binning average local time for Channel 1:

DGDR_LTIM_AVG_POLN_20090915D_240_IMG.IMG

5.3 Date Coverage

Each Level 2 GDR covers a 27-day lunar mapping cycle. The dates are partitioned to give -180 to 180 degrees longitude global coverage with the “seam” (jump in local time between maps) at +/- 180 degrees. This seam will shift by 180 degrees longitude between the day and night maps so that said day and night maps will be staggered in time to ensure that the discontinuity in local time occurs at +/- 180 for both types of map. Dates and times are at the time of the anti-meridian crossing as seen by channel 1, detector 11.

In addition to the 27-day cycle maps, a map of observations covering the time when the instrument was first powered on up until the first mapping cycle will also be produced. This covers less than a 27-day cycle and is considered to be useful data.

Here are the dates and hours where the seams occur at +/- 180 degrees longitude.

Daytime map cycle start dates:

Julian Date	UTC: YYYY-MM-DDTHH:MM:SS.FFF	Length (days)	Notes
2455018.208333	2009-07-05T17:00:00.000	21.92	First light
2455040.123414	2009-7-27T14:57:42.974	27.26	
2455067.383935	2009-8-23T21:12:51.961	27.23	Orbit change: Commissioning to circular
2455094.615567	2009-9-20T2:46:24.99	27.36	
2455121.977083	2009-10-17T11:26:59.972	27.27	
2455149.247576	2009-11-13T17:56:30.574	27.34	
2455176.585863	2009-12-11T2:3:38.557	19.91	
2455196.496982	2009-12-30T23:55:39.21	21.05	Dusk/dawn
2455217.546602	2010-1-21T1:7:6.454	27.33	
2455244.879318	2010-2-17T9:6:13.068	27.33	
2455272.212094	2010-3-16T17:5:24.902	27.26	
2455299.474241	2010-4-12T23:22:54.444	27.33	
2455326.806141	2010-5-10T7:20:50.606	27.33	
2455354.137644	2010-6-6T15:18:12.472	22.89	
2455377.028358	2010-6-29T12:40:50.102	17.98	Dusk/dawn
2455395.010996	2010-7-17T12:15:50.014	27.33	
2455422.340784	2010-8-13T20:10:43.771	27.33	
2455449.668488	2010-9-10T4:2:37.405	27.25	LRO begins extended mission
2455476.919978	2010-10-7T10:4:46.058	27.32	
2455504.244922	2010-11-3T17:52:41.233	27.33	
2455531.574725	2010-12-1T1:47:36.207	26.41	
2455557.985825	2010-12-27T11:39:35.291	14.52	Dusk/dawn
2455572.509009	2011-1-11T0:12:58.355	27.33	
2455599.837961	2011-2-7T8:6:39.838	27.33	
2455627.167342	2011-3-6T16:0:58.389	27.26	
2455654.423540	2011-4-2T22:9:53.84	27.24	
2455681.665763	2011-4-30T3:58:41.891	27.34	
2455709.000871	2011-5-27T12:1:15.223	27.88	
2455736.881263	2011-6-24T9:9:1.135	13.00	Dusk/dawn
2455749.878963	2011-7-7T9:5:42.439	27.33	
2455777.212442	2011-8-3T17:5:54.95	27.25	
2455804.465019	2011-8-30T23:9:37.636	27.26	
2455831.723639	2011-9-27T5:22:2.381	27.34	
2455859.062417	2011-10-24T13:29:52.854	27.22	

2455886.282860	2011-11-20T18:47:19.136	27.61	Orbit change: Circular to elliptical.
2455913.892548	2011-12-18T9:25:16.154	13.44	Dusk/dawn
2455927.334640	2011-12-31T20:1:52.884	27.47	
2455954.801858	2012-1-28T7:14:40.57	27.05	
2455981.855420	2012-2-24T8:31:48.262	28.63	
2456010.481023	2012-3-23T23:32:40.355	25.98	
2456036.459697	2012-4-18T23:1:57.794	27.30	
2456063.762061	2012-5-16T6:17:22.048	27.21	
2456090.976088	2012-6-12T11:25:33.965	13.61	Dusk/dawn
2456104.581960	2012-6-26T1:58:1.376	27.37	
2456131.955511	2012-7-23T10:55:56.15	27.21	
2456159.163566	2012-8-19T15:55:32.131	27.29	
2456186.448704	2012-9-15T22:46:8.022*		

Nighttime map cycle start dates:

Julian Date	UTC: YYYY-MM-DDTHH:MM:SS.FFF	Length (days)	Notes
2455018.208333	2009-07-05T17:00:00.000	8.20	First light
2455026.409428	2009-7-13T21:49:34.593	27.34	
2455053.747675	2009-8-10T5:56:39.132	27.29	
2455081.038099	2009-9-6T12:54:51.775	27.30	Orbit change: Commissioning to circular
2455108.341417	2009-10-3T20:11:38.436	27.27	
2455135.611278	2009-10-31T2:40:14.45	27.35	
2455162.959704	2009-11-27T11:1:58.415	27.33	
2455190.292700	2009-12-24T19:1:29.271	13.63	Dusk/dawn
2455203.919146	2010-1-7T10:3:34.22	27.33	
2455231.252376	2010-2-3T18:3:25.256	27.25	
2455258.505751	2010-3-3T0:8:16.849	27.33	
2455285.840694	2010-3-30T8:10:35.934	27.26	
2455313.100780	2010-4-26T14:25:7.405	27.33	
2455340.432755	2010-5-23T22:23:10.037	27.33	
2455367.761889	2010-6-20T6:17:7.251	13.62	Dusk/dawn
2455381.386611	2010-7-3T21:16:43.192	27.33	
2455408.715985	2010-7-31T5:11:1.062	27.33	
2455436.045292	2010-8-27T13:5:13.232	27.25	LRO begins extended mission
2455463.293482	2010-9-23T19:2:36.87	27.33	
2455490.623850	2010-10-21T2:58:20.666	27.32	
2455517.948383	2010-11-17T10:45:40.293	27.25	
2455545.195909	2010-12-14T16:42:6.539	13.61	Dusk/dawn
2455558.809584	2010-12-28T7:25:48.034	27.32	
2455586.133886	2011-1-24T15:12:47.733	27.33	

2455613.461428	2011-2-20T23:4:27.363	27.26	
2455640.717303	2011-3-20T5:12:54.993	27.32	
2455668.041496	2011-4-16T12:59:45.274	27.25	
2455695.294208	2011-5-13T19:3:39.571	27.33	
2455722.626074	2011-6-10T3:1:32.785	15.28	Dusk/dawn
2455737.902038	2011-6-25T9:38:56.115	25.68	
2455763.585414	2011-7-21T2:2:59.786	27.26	
2455790.840473	2011-8-17T8:10:16.849	27.33	
2455818.172002	2011-9-13T16:7:40.97	27.26	
2455845.432524	2011-10-10T22:22:50.104	27.30	
2455872.734132	2011-11-7T5:37:8.986	27.28	
2455900.012136	2011-12-4T12:17:28.508	18.02	Dusk/dawn. Orbit change: Circular to elliptical.
2455918.028841	2011-12-22T12:41:31.877	22.83	
2455940.863474	2012-1-14T8:43:24.167	27.30	
2455968.165219	2012-2-10T15:57:54.922	27.30	
2455995.467038	2012-3-8T23:12:32.095	27.30	
2456022.769215	2012-4-5T6:27:40.151	27.22	
2456049.988785	2012-5-2T11:43:51.042	27.30	
2456077.291307	2012-5-29T18:59:28.942	19.64	Dusk/dawn
2456096.930189	2012-6-18T10:19:28.335	21.34	
2456118.266664	2012-7-9T18:23:59.753	27.29	
2456145.557515	2012-8-6T1:22:49.292	27.29	
2456172.847033	2012-9-2T8:19:43.622*		

* The last two Daytime and Nighttime dates represent the end of the previous mapping cycles, not the start of new mapping cycles.

5.4 Footprints and Geometry

At the Diviner UCLA SOC various programs known informally as “pipes” are used to determine instrument footprints and calculate geometry. The program “pfootprint” determines if multiple lat/lon bins fell within the Diviner footprint. This routine takes the “orientlat” and “orientlon” parameters to determine the detector array orientation relative to North. Once this angle of rotation is determined, the field of view for the along track (6.7 rad) and across track (3.4 rad) is used along with the spacecraft altitude to determine the rectangle on the surface of a smooth Moon that represents a Diviner footprint. Currently the routine adds eight points surrounding the central point representing the +/- X directions, +/- Y directions and the four corners of the rectangle all rotated by the angle of the detector array relative to North. These additional points that outline the extent of the footprint are added to the pipes data stream and further processed along with the rest of the data. This populates additional bins with data that fall within a footprint.

A more specific description of what the routine does is as follows:
Define a plane using the vector defined by the center lon,lat of the Diviner

observation <clon,clat,radius> and the vector of the North Pole <0,0,radius>. Then define a line (vector) defined by the detector array orientation <orientlon,orientlat,1>. The approach here is to determine the angle between this plane which goes through the North Pole and the vector describing the detector orientation. This requires determining the normal of the plane. The plane normal is determined from the cross product of the two vectors used to define the plane (<clon,clat,radius>x<0,0,radius>). This unit vector is then right angles to North. Using the dot product of this normal vector and the detector array orientation vector gives the angle between these two vectors and then subtracting the angle from 90 degrees gives us the angle between the detector array orientation and North. This angle is then used to rotate the along track and across track FOV's to get the rectangle oriented on the lunar surface to define where the eight surrounding points are located.

The program "p3lonlatalt_09" then ray traces all the data points to recalculate the geometry (now including both original data and new points added by pfootprint). This gives tlon – target longitude and tlat – target latitude which is then what is binned with the pipes program "pbin3dsparse".

5.5 File Sizes

The following is an estimate of the size of the IMG files. It is unknown at this time what the size of the JP2 will be due to uncertainties of how well the IMG files will compress. The sample JPG images will be very small and won't factor into this either.

For cylindrical projections, the size of each IMG at master resolution (128 pixels per degree) will be:

360 (degrees longitude) * 180 (degrees latitude) * 128 (subdivisions of deg lon) * 128 (subdivisions of deg lat) * 2 (bytes per value) = 2.12 GB

For polar projections, the size of each IMG at master resolution (roughly 126 pixels per degree) will be:

30 (degrees horizontal) * 30 (degrees vertical) * 126 (subdivisions of deg horizontal) * 126 (subdivisions of deg vertical) * 2 (bytes per value) = 0.029 GB

5.6 Label and Header Descriptions

The GDR label elements are described below.

PDS3 Label Elements and Definitions for GDR Products

Name	Data Type	Description
PDS_VERSION_ID	IDENTIFIER	The version number of the PDS standards documents that is valid when the label is created. Examples: PDS3, PDS4
RECORD_TYPE	IDENTIFIER	The record format of a file. For GDR, this will be FIXED_LENGTH.
RECORD_BYTES	INTEGER	The number of bytes in a physical file record. This is the number of bytes that make up a “row” in the image.
FILE_RECORDS	INTEGER	The number of physical file records, including both header records and data records. For a simple IMG file, this is the number of “rows” in the image.
ENCODING_TYPE	CHARACTER	For JPEG2000/JPEG files only, the type of compression or encryption used for data storage. E.g. “JP2”.
INTERCHANGE_FORMAT	CHARACTER	For JPEG2000 files only, the manner in which data items are stored. Should always be “BINARY”.
UNCOMPRESSED_FILE_NAME	CHARACTER	For JPEG2000 files only, this is a reference to the uncompressed IMG file name.
REQUIRED_STORAGE_BYTES	CHARACTER	For JPEG2000 files only, the number of bytes required to store the uncompressed IMG file.
DESCRIPTION	CHARACTER	A free-form description of the data.
DATA_SET_ID	IDENTIFIER	This unique identifier describes the mission, instrument, data level and archive version (the archive version starts at V1.0 and only ever gets bumped up in the event that the entire dataset needs to be re-archived). Example: “LRO-L-DLRE-5-GDR-V1.0”
FILE_NAME	CHARACTER	The base file name of data file.
MISSION_NAME	CHARACTER	Major planetary mission or project. Always “LUNAR RECONNAISSANCE ORBITER”.
MISSION_PHASE_NAME	CHARACTER	The mission phase at the time of the beginning of the mapping cycle. For LRO, possible values include: “COMMISSIONING”, “NOMINAL MISSION”, and “EXTENDED MISSION”.

INSTRUMENT_HOST_NAME	CHARACTER	Full name of the spacecraft on which the instrument is based. Always “LUNAR RECONNAISSANCE ORBITER”.
INSTRUMENT_HOST_ID	CHARACTER	Unique identifier for the spacecraft on which the instrument is based. Always “LRO”.
INSTRUMENT_NAME	CHARACTER	The full name of the instrument. Always “DIVINER LUNAR RADIOMETER EXPERIMENT”.
INSTRUMENT_ID	CHARACTER	Unique identifier for the instrument. Always “DLRE”.
PRODUCT_ID	CHARACTER	A permanent, unique identifier assigned to a data product. Here it is the base name of the image, minus the suffix that denotes the file format type.
SOURCE_PRODUCT_ID	CHARACTER	The full filename of the source IMG used to make a derived product such as a JPEG2000 or JPG. “NONE” if this is an IMG.
TARGET_NAME	CHARACTER	The name of the mission or project target. Always “MOON”.
START_TIME	TIME	The UTC time of the first observation in the data product.
STOP_TIME	TIME	The UTC time of the last observation in the data product.
PRODUCT_CREATION_TIME	TIME	The UTC system format time when this product was created.
PRODUCT_VERSION_ID	CHARACTER	The version number of the archived data product. If the data needs to be modified and re-archived, this number is incremented. “1” means first revision, “2” means second, and so on.
A_AXIS_RADIUS	REAL	The radius of the “A” axis of the Moon used in geometry calculations, in kilometers. See section 2.4.3, “Coordinate Systems”, for more.
B_AXIS_RADIUS	REAL	The radius of the “B” axis of the Moon used in geometry calculations, in kilometers. See section 2.4.3, “Coordinate Systems”, for more.
C_AXIS_RADIUS	REAL	The radius of the “C” axis of the Moon used in geometry calculations, in kilometers. See section 2.4.3, “Coordinate Systems”, for more.
PRODUCER_ID	CHARACTER	The identifier of the instrument team that

		produced the data product. Always "LRO_DLRE_TEAM"
PRODUCER_FULL_NAME	CHARACTER	The name of the Principal Investigator of the instrument team.
PRODUCER_INSTITUTION_NAME	CHARACTER	Where the data products were produced.
LINES	INTEGER	The number of lines or "rows" in the image.
LINE_SAMPLES	INTEGER	The number of pixels per line in the image.
SAMPLE_TYPE	CHARACTER	The data type used to store a pixel sample. Should be "LSB_INTEGER".
SAMPLE_BITS	CHARACTER	The number of bits used to store the SAMPLE_TYPE. Should be 16.
UNIT	CHARACTER	The units represented by the numbers in the data. Varies depending on which quantity is being gridded.
SCALING_FACTOR	REAL	The factor used to convert the data numbers to their actual values. E.g. if "0.5", multiply all numbers by 0.5 to get their actual values, then add the OFFSET described below.
OFFSET	REAL	The offset used to convert the data numbers to their actual values. After multiplying by the SCALING_FACTOR, add the OFFSET to get their actual values.
MAP_PROJECTION_TYPE	CHARACTER	Which projection is being used. Either "SIMPLE CYLINDRICAL" or "POLAR STEREOGRAPHIC".
KEYWORD_LATITUDE_TYPE	CHARACTER	Which type of latitude is used in this projection. Should always be "PLANETOCENTRIC".
MAP_RESOLUTION	INTEGER	The resolution of the grid, in number of pixels per degree.
POSITIVE_LONGITUDE_DIRECTION	CHARACTER	The direction in which values of longitude increase. By LRO standard, always "EAST".
CENTER_LATITUDE	REAL	The latitude at the center of the grid.
CENTER_LONGITUDE	REAL	The longitude at the center of the grid.
LINE_FIRST_PIXEL	INTEGER	The line number of the first pixel in the image. Should always be 1.

LINE_LAST_PIXEL	INTEGER	The line number of the last pixel in the image. Should always be equal to LINES.
SAMPLE_FIRST_PIXEL	INTEGER	The sample number of the first pixel in the image. Should always be 1.
SAMPLE_LAST_PIXEL	INTEGER	The sample number of the last pixel in the data set. Should always be equal to LINE_SAMPLES.
MAP_PROJECTION_ROTATION	REAL	Provides the clockwise rotation, in degrees, of the line and sample coordinates with respect to the map projection origin (LINE_PROJECTION_OFFSET, LINE_PROJECTION_OFFSET). This parameter is used to indicate where 'up' is in the projection. For example, in a polar stereographic projection does the zero meridian go center to bottom, center to top, center to left, or center to right? The polar projection is defined such that the zero meridian goes center to bottom. However, by rotating the map projection, the zero meridian can go in any direction. Note: 180 degrees is at the top of the North Pole and 0 degrees is at the top of the South Pole. For example, if 0 degrees is at the top of the North Pole than the MAP_PROJECTION_ROTATION would be 180 degrees.
MAP_SCALE	REAL	Identifies the scale of a given map. The scale is defined as the ratio of the actual distance between two points on the surface of the target body to the distance between the corresponding points on the map (km).
MINIMUM_LATITUDE	REAL	The lowest (most southerly) latitude represented in the map.
MAXIMUM_LATITUDE	REAL	The highest (most northerly) latitude represented in the map.
WESTERNMOST_LONGITUDE	REAL	The lowest (most westerly) longitude represented in the map.
EASTERMOST_LONGITUDE	REAL	The highest (most easterly) longitude represented in the map.
LINE_PROJECTION_OFFSET	REAL	The line offset value of the map projection origin position from the line and sample 1,1 (upper left).
SAMPLE_PROJECTION_OFFSET	REAL	The sample offset value of the map projection origin position from the line

		and sample 1,1 (upper left).
COORDINATE_SYSTEM_TYPE	CHARACTER	Which type of coordinate system is used for this projection. Always "BODY-FIXED ROTATING".
COORDINATE_SYSTEM_NAME	CHARACTER	The name of the coordinate system used for this projection. Always "MEAN EARTH/POLAR AXIS OF DE421".
LRO:LOLA_DEM_VERS	CHARACTER	The version of LOLA digital elevation model used to locate Diviner footprints.
LRO:DLRE_GEOM_VERSION_ID	CHARACTER	The version of Diviner geometry and averaging software used to generate this product.
LRO:CALIBRATION_SOFTWARE_VER_ID	CHARACTER	The version of the calibration software used to generate the input RDR data.
LRO:DLRE_JDATE_MIN	REAL	The earliest Julian Date for data in this product.
LRO:DLRE_JDATE_MAX	REAL	The latest Julian Date for data in this product.
LRO:DLRE_CLOCTIME_MIN	REAL	The earliest local time for locations on the Moon's surface used in this product. This is measured at the equator for cylindrical maps and at +/- 75 degrees for polar maps. For nighttime maps, MIN may be greater than MAX as nighttime is defined as 18:00 to 06:00.
LRO:DLRE_CLOCTIME_MAX	REAL	The earliest local time for locations on the Moon's surface used in this product. See the note above for LRO:DLRE_CLOCTIME_MIN.
MISSING_CONSTANT	INTEGER	The "exclude" value for no data, applies to average and error products. Count products will use zero as expected.
DERIVED_MINIMUM	REAL	The minimum derived value in the product. Derived values are computed by taking the digital numbers and multiplying by SCALING_FACTOR, then adding OFFSET.
DERIVED_MAXIMUM	REAL	The maximum derived value in the product. Derived values are computed by taking the digital numbers and multiplying by SCALING_FACTOR, then adding OFFSET.
MINIMUM_WAVELENGTH	REAL	The minimum wavelength at which observations were made by this channel, in microns.

MAXIMUM_WAVELENGTH	REAL	The maximum wavelength at which observations were made by this channel, in microns.

5.7 GDR Applicable Software

The IMG data products were converted to JPEG2000 using the Geospatial Data Abstraction Library (www.gdal.org). GDAL software may be used to convert the IMG products to other formats. JPEG2000, which uses a lossless compressed file format, is compatible with many Geographical Information Systems such as ArcGIS (www.arcgis.com).

Please note that it is recommended that ArcGIS version 10 or later be used to avoid bugs when displaying JPEG2000 products.

Also please note: Many GDAL-supported products such as ArcGIS require an auxiliary XML file for viewing JPEG2000 products correctly. These XML files must reside in the same directory as the JP2 and must adhere to a strict naming scheme, which is to take the filename of the JP2 and append ".AUX.XML" to it.

XML files for each JP2 image may be found in the EXTRAS/ subdirectory of the archive, under GDR_L2/ and GDR_L3/.

6 Level 3 GDR Detailed Data Product Specifications

6.1 Gridded Values

The following table lists the values in each gridded data product:

Value	Description
STD_CF	Standard Christiansen Feature position. One cumulative map.
NEN_CF	Normalized to Equatorial Noon Christiansen Feature position. One cumulative map.
RA	Rock Abundance. A ratio from 0 to 1. Nighttime hourly, and all hours averaged together.
ST	Soil Temperature. Average temperature in degrees Kelvin. Nighttime hourly, and all hours averaged together.
STN	Soil Temperature normalized to remove local latitudinal variations. Average temperature in degrees Kelvin. All hours averaged together.
RMS	Root Mean Square fitting errors between measured and modeled radiances. Nighttime hourly only.

Note: TBOL (Bolometric Temperature) is also a Level 3 product, but is described in the Level 2 section 5.

6.2 File Names

Unlike the Level 2 GDRs which are binned averages, errors, and counts, Level 3 GDRs contain calculated values. The format of each file name is:

DGDR_[VAL] _[BTYPE]_[PROJ]_[HHMM]_[RES]_[SUF].[SUF]

Each item in the file name is explained in the following table:

Filename Component	Description
VAL	The value binned. CF, RA, or ST.
BTYPE	Bin type. One of CLC (calculated), AVG (average), CNT (count), or ERR (error).
PROJ	Projection. Always CYL.
HHMM	For RA, ST, and RMS only, the beginning local time of the lunar hour in hours and minutes, e.g. 1930.
RES	Resolution in pixels per degree.
SUF	File suffix. Either “IMG” (16-bit LSB binary integers), “JP2” (JPEG2000), “JPG” (JPEG), or “LBL” (detached PDS label). The extra “_SUF” in the base name is to keep all label names unique in order to avoid name clashes, which allows one to store all labels in the same directory.

An example CF file:

DGDR_NEN_CF_CLC_CYL_32_IMG.IMG

An example RA file:

DGDR_RA_CLC_CYL_1930_32_IMG.IMG

An example ST file:

DGDR_ST_CLC_CYL_1930_32_IMG.IMG

An example RMS file:

DGDR_RMS_CLC_CYL_1930_032_IMG.IMG

6.3 File Sizes

The following is an estimate of the size of the IMG files. It is unknown at this time what the size of the JP2 will be due to uncertainties of how well the IMG files will compress.

For cylindrical CF maps, the size of each IMG at master resolution (32 pixels per degree) will be:

360 (degrees longitude) * 180 (degrees latitude) * 32 (subdivisions of deg lon) * 32 (subdivisions of deg lat) * 2 (bytes per value) = 0.13 GB

For cylindrical RA, ST, and RMS maps, the size of each IMG covering -60 to 60 degrees latitude at master resolution (32 pixels per degree) will be:

360 (degrees longitude) * 120 (degrees latitude) * 32 (subdivisions of deg lon) * 32 (subdivisions of deg lat) * 2 (bytes per value) = 0.09 GB

6.4 Label and Header Descriptions

The Level 3 GDRs will use the same label specification as the Level 2 GDRs, which is described in section 5.5. Some keywords in the accompanying table may be specific to either Level.

6.5 GDR Applicable Software

Please see the details in section 5.7.

7 Level 4 PRP Detailed Data Product Specifications

7.1 Gridded Values

As stated in section 2.2, Polar Resource Products are produced from thermal model fits to north and south polar observations from the first year of mapping orbit. The format of both files (north and south) is simple ASCII text. Each line in the file represents the vertices of a triangle in a triangular digital elevation model, along with the longitude, latitude, and altitude of the triangle’s center. The calculated annual average temperature, annual maximum temperature, and water ice depth are also listed according to the following format:

PRP Fields and Descriptions

#	Field Name	Data Type and Width.Precision	Description
1	tri1_x	Real 12.5	The x coordinate of triangle vertex 1 in a Moon-centered frame (km)
2	tri1_y	Real 12.5	The y coordinate of triangle vertex 1 in a Moon-centered frame (km)
3	tri1_z	Real 12.5	The z coordinate of triangle vertex 1 in a Moon-centered frame (km)
4	tri2_x	Real 12.5	The x coordinate of triangle vertex 2 in a Moon-centered frame (km)
5	tri2_y	Real 12.5	The y coordinate of triangle vertex 2 in a Moon-centered frame (km)
6	tri2_z	Real 12.5	The z coordinate of triangle vertex 2 in a Moon-centered frame (km)
7	tri3_x	Real 12.5	The x coordinate of triangle vertex 3 in a Moon-centered frame (km)
8	tri3_y	Real 12.5	The y coordinate of triangle vertex 3 in a Moon-centered frame (km)
9	tri3_z	Real 12.5	The z coordinate of triangle vertex 3 in a Moon-centered frame (km)
10	tri_clon	Real 15.9	The planetocentric east longitude of the center of the triangle (degrees)
11	tri_clat	Real 15.9	The planetocentric latitude of the center of the triangle (degrees)
12	tri_calt	Real 15.9	The altitude of the center of the triangle relative to a 1737.4 km radius sphere (km)
13	temp_avg	Real 8.3	The annual average temperature (K), calculated at a depth of 2 cm below the surface.
14	temp_max	Real 8.3	The annual maximum temperature (K), calculated at the surface.
15	ice_depth	Real 11.5	The calculated depth at which water ice would be sublimated at a rate of 1 kg m-2 per billion years (m). Notes: If the calculated depth at which water ice would be sublimated at a rate of 1 kg m-2 per billion years is zero, then water ice is stable to sublimation at the surface. Also, ff the calculated depth at which water ice would be sublimated at a rate of 1 kg m-2 per billion years is greater than 2.8738 meters, then the MISSING_CONSTANT (-32768) is reported.

7.2 File Names

The file names for each PRP are:

DLRE_PRP_NORTH.TAB
DLRE_PRP_SOUTH.TAB

Each has an associated detached PDS label with the suffix .LBL.

7.3 File Sizes

The size of each TAB will be 210 characters/line * 2880000 lines = 0.6 GB

7.4 Label and Header Descriptions

The PRP label elements are described below.

PDS 3 Label Elements and Definitions for PRP Products

Name	Data Type	Description
PDS_VERSION_ID	IDENTIFIER	The version number of the PDS standards documents that is valid when the label is created. Examples: PDS3, PDS4
RECORD_TYPE	IDENTIFIER	The record format of a file. For PRP, this will be FIXED_LENGTH.
RECORD_BYTES	INTEGER	The number of bytes in a physical file record.
FILE_RECORDS	INTEGER	The number of physical file records, including both header records and data records.
DESCRIPTION	CHARACTER	A free-form description of the data.
DATA_SET_ID	IDENTIFIER	This unique identifier describes the mission, instrument, data level and archive version (the archive version starts at V1.0 and only ever gets bumped up in the event that the entire dataset needs to be re-archived). Example: “LRO-L-DLRE-5-PRP-V1.0”
FILE_NAME	CHARACTER	The base file name of either the TAB or LBL file.

MISSION_NAME	CHARACTER	Major planetary mission or project. Always “LUNAR RECONNAISSANCE ORBITER”.
MISSION_PHASE_NAME	CHARACTER	The mission phase at the time of the beginning of the mapping cycle. For LRO, possible values include: “COMMISSIONING”, “NOMINAL MISSION”, and “EXTENDED MISSION”.
INSTRUMENT_HOST_NAME	CHARACTER	Full name of the spacecraft on which the instrument is based. Always “LUNAR RECONNAISSANCE ORBITER”.
INSTRUMENT_HOST_ID	CHARACTER	Unique identifier for the spacecraft on which the instrument is based. Always “LRO”.
INSTRUMENT_NAME	CHARACTER	The full name of the instrument. Always “DIVINER LUNAR RADIOMETER EXPERIMENT”.
INSTRUMENT_ID	CHARACTER	Unique identifier for the instrument. Always “DLRE”.
PRODUCT_ID	CHARACTER	A permanent, unique identifier assigned to a data product.
TARGET_NAME	CHARACTER	The name of the mission or project target. Always “MOON”.
START_TIME	TIME	The UTC time of the first observation in the data product.
STOP_TIME	TIME	The UTC time of the last observation in the data product.
PRODUCT_CREATION_TIME	TIME	The UTC system format time when this product was created.
PRODUCT_VERSION_ID	CHARACTER	The version number of the archived data product. If the data needs to be modified and re-archived, this number is incremented. “1” means first revision, “2” means second, and so on.
A_AXIS_RADIUS	REAL	The radius of the “A” axis of the Moon used in geometry calculations, in kilometers. See section 2.4.3, “Coordinate Systems”, for more.
B_AXIS_RADIUS	REAL	The radius of the “B” axis of the Moon used in geometry calculations, in kilometers. See section 2.4.3, “Coordinate Systems”, for more.
C_AXIS_RADIUS	REAL	The radius of the “C” axis of the Moon used in geometry calculations, in kilometers. See section 2.4.3,

		“Coordinate Systems”, for more.
PRODUCER_ID	CHARACTER	The identifier of the instrument team that produced the data product. Always “LRO_DLRE_TEAM”
PRODUCER_FULL_NAME	CHARACTER	The name of the Principal Investigator of the instrument team.
PRODUCER_INSTITUTION_NAME	CHARACTER	Where the data products were produced.
LRO:CALIBRATION_SOFTWARE_VER_ID	CHARACTER	The version of the calibration software used to generate the input RDR data.
LRO:DLRE_JDATE_MIN	REAL	The earliest Julian Date for data in this product.
LRO:DLRE_JDATE_MAX	REAL	The latest Julian Date for data in this product.

8 Level 4 GCP Detailed Data Product Specifications

8.1 Gridded Values

Global Cumulative Products are a compilation of all Diviner nadir observations from 5-July-2009 to 1-April-2015. They are produced by binning Diviner RDR (Level 1b) radiance measurements for each IR channel (channels 3-9) in 0.5-degree bins in longitude and latitude, and 0.25 hours of local time to determine the mean brightness temperatures on a global cylindrical grid. Additionally, the mean radiance values for all the channels were used to determine the bolometric brightness temperatures for each bin. The data set is global (longitudes span -180° to +180° E longitude) and is split into latitude bands of 10 degrees each. The format of the files is simple ASCII text with empty bins indicated with a MISSING_CONSTANT = -9999. Each line in the file represents a bin center with the longitude, latitude, local time, brightness temperatures (channels 3 through 9), and the bolometric temperature listed according to the following format:

GCP Fields and Descriptions

#	Field Name	Data Type and Width.Precision	Description
1	clon	Real 7.2	The longitude of the grid center (degrees)
2	clat	Real 6.2	The latitude of the grid center (degrees)
3	ltim	Real 6.2	The bin centered local solar time (hours)
4	t3	Real 9.4	The Diviner channel 3 average brightness temperature (degrees Kelvin)
5	t4	Real 9.4	The Diviner channel 4 average brightness temperature (degrees Kelvin)

6	t5	Real 9.4	The Diviner channel 5 average brightness temperature (degrees Kelvin)
7	t6	Real 9.4	The Diviner channel 6 average brightness temperature (degrees Kelvin)
8	t7	Real 9.4	The Diviner channel 7 average brightness temperature (degrees Kelvin)
9	t8	Real 9.4	The Diviner channel 8 average brightness temperature (degrees Kelvin)
10	t9	Real 9.4	The Diviner channel 9 average brightness temperature (degrees Kelvin)
11	tbol	Real 9.4	The average bolometric brightness temperature (degrees Kelvin)

8.2 File Names

The file names for each GCP are:

GLOBAL_CUMUL_AVG_CYL_00N10N_002.TAB
GLOBAL_CUMUL_AVG_CYL_10N20N_002.TAB
GLOBAL_CUMUL_AVG_CYL_10S00S_002.TAB
GLOBAL_CUMUL_AVG_CYL_20N30N_002.TAB
GLOBAL_CUMUL_AVG_CYL_20S10S_002.TAB
GLOBAL_CUMUL_AVG_CYL_30N40N_002.TAB
GLOBAL_CUMUL_AVG_CYL_30S20S_002.TAB
GLOBAL_CUMUL_AVG_CYL_40N50N_002.TAB
GLOBAL_CUMUL_AVG_CYL_40S30S_002.TAB
GLOBAL_CUMUL_AVG_CYL_50N60N_002.TAB
GLOBAL_CUMUL_AVG_CYL_50S40S_002.TAB
GLOBAL_CUMUL_AVG_CYL_60N70N_002.TAB
GLOBAL_CUMUL_AVG_CYL_60S50S_002.TAB
GLOBAL_CUMUL_AVG_CYL_70N80N_002.TAB
GLOBAL_CUMUL_AVG_CYL_70S60S_002.TAB
GLOBAL_CUMUL_AVG_CYL_80N90N_002.TAB
GLOBAL_CUMUL_AVG_CYL_80S70S_002.TAB
GLOBAL_CUMUL_AVG_CYL_90S80S_002.TAB

Each will have an associated detached PDS label with the suffix .LBL.

The structure of each file name is described in section 2.3.4, but in short the first block of numbers and letters stands for the latitude band, e.g. 80N90N means 80 degrees north to 90 degrees north, and the 002 refers to resolution in pixels per degree.

8.3 File Structure and Size

The data tables are composed of one header line followed by 1382400 record lines. Each line represents a record of size 113 characters, including the carriage return (CR) and line feed (LF) characters. The total file size is 156 MB.

1382401*113 = 156211313 Bytes

8.4 Label and Header Descriptions

The GCP label elements are described below.

PDS3 Label Elements and Definitions for GCP Products

Name	Data Type	Description
PDS_VERSION_ID	IDENTIFIER	The version number of the PDS standards documents that is valid when the label is created. Examples: PDS3, PDS4
RECORD_TYPE	IDENTIFIER	The record format of a file. For GCP, this will be FIXED_LENGTH.
RECORD_BYTES	INTEGER	The number of bytes in a physical file record.
FILE_RECORDS	INTEGER	The number of physical file records, including both header records and data records.
DESCRIPTION	CHARACTER	A free-form description of the data.
DATA_SET_ID	IDENTIFIER	This unique identifier describes the mission, instrument, data level and archive version (the archive version starts at V1.0 and only ever gets bumped up in the event that the entire dataset needs to be re-archived). Example: “LRO-L-DLRE-5-GCP-V1.0”
FILE_NAME	CHARACTER	The base file name of either the TAB or LBL file.
MISSION_NAME	CHARACTER	Major planetary mission or project. Always “LUNAR RECONNAISSANCE ORBITER”.
INSTRUMENT_HOST_NAME	CHARACTER	Full name of the spacecraft on which the instrument is based. Always “LUNAR RECONNAISSANCE ORBITER”.
INSTRUMENT_HOST_ID	CHARACTER	Unique identifier for the spacecraft on which the instrument is based. Always

		"LRO".
INSTRUMENT_NAME	CHARACTER	The full name of the instrument. Always "DIVINER LUNAR RADIOMETER EXPERIMENT".
INSTRUMENT_ID	CHARACTER	Unique identifier for the instrument. Always "DLRE".
PRODUCT_TYPE	CHARACTER	A permanent, unique identifier assigned to the data product type. Always "GCP".
PRODUCT_ID	CHARACTER	A permanent, unique identifier assigned to a data product.
LRO:CALIBRATION_SOFTWARE_VER_ID	CHARACTER	The version of the calibration software used to generate the input RDR data.
PRODUCER_ID	CHARACTER	The identifier of the instrument team that produced the data product. Always "LRO_DLRE_TEAM"
PRODUCER_FULL_NAME	CHARACTER	The name of the Principal Investigator of the instrument team.
PRODUCER_INSTITUTION_NAME	CHARACTER	Where the data products were produced.
A_AXIS_RADIUS	REAL	The radius of the "A" axis of the Moon used in geometry calculations, in kilometers. See section 2.4.3, "Coordinate Systems", for more.
B_AXIS_RADIUS	REAL	The radius of the "B" axis of the Moon used in geometry calculations, in kilometers. See section 2.4.3, "Coordinate Systems", for more.
C_AXIS_RADIUS	REAL	The radius of the "C" axis of the Moon used in geometry calculations, in kilometers. See section 2.4.3, "Coordinate Systems", for more.
TARGET_NAME	CHARACTER	The name of the mission or project target. Always "MOON".
START_TIME	TIME	The UTC time of the first observation in the data product.
STOP_TIME	TIME	The UTC time of the last observation in the data product.
SPACECRAFT_CLOCK_START_COUNT	CHARACTER	The value of the spacecraft clock in the first record of the data product.
SPACECRAFT_CLOCK_STOP_COUNT	CHARACTER	The value of the spacecraft clock in the last record of the data product.
PRODUCT_CREATION_TIME	TIME	The UTC system format time when this

		product was created.
PRODUCT_VERSION_ID	CHARACTER	The version number of the archived data product. If the data needs to be modified and re-archived, this number is incremented. “1” means first revision, “2” means second, and so on.
MINIMUM_LATITUDE	REAL	The minimum latitude of the data.
MAXIMUM_LATITUDE	REAL	The maximum latitude of the data.
WESTERNMOST_LONGITUDE	REAL	The westernmost longitude of the data.
EASTERNMOST_LONGITUDE	REAL	The easternmost longitude of the data.
POSITIVE_LONGITUDE_DIRECTION	REAL	The direction in which longitude values increase. Always “EAST”.

9 Level 4 PCP Detailed Data Product Specifications

9.1 Gridded Values

Polar Cumulative Products (diurnal) are a compilation of all Diviner nadir observations from 5-July-2009 to 17-Feb-2019. They are produced by binning Diviner RDR (Level 1b) radiance measurements for each IR channel (channels 3-9) in 240-meter bins of a polar stereo projected grid to determine the mean bolometric brightness temperatures. Diurnal PCPs are binned in increments of 0.25 hours of local time, or 3.75 degrees of subsolar longitude over a 10-degree latitudinal cap covering each pole. The data set is additionally divided between summer and winter halves of the draconic year defined by the subsolar latitude being either above or below the equator. The format of the files is simple ASCII text with empty bins excluded. Each line in the file represents a bin center with a distance (x,y) normalized by the mean radius 1737.4 km, the longitude, latitude, and the bolometric temperature listed according to the following format:

PCP (diurnal) Fields and Descriptions

#	Field Name	Data Type and Width.Precision	Description
1	x	Real 9.6	The distance from the grid center (normalized)
2	y	Real 9.6	The distance from the grid center (normalized)
3	clon	Real 11.6	The longitude of the grid center (degrees)

4	clat	Real 10.6	The latitude of the grid center (degrees)
5	tbol	Real 10.6	The average bolometric brightness temperature (degrees Kelvin)

Polar Cumulative Products (seasonal) are a compilation of all Diviner nadir observations from 5-July-2009 to 15-Mar-2020. Seasonal PCPs are binned in increments of 15 degrees of subsolar longitude and 60 degrees of ecliptic longitude over a 10-degree latitudinal cap covering the south pole. The format of the files is simple ASCII text with empty bins excluded. Each line in the file represents a bin center with a distance (x,y) normalized by the mean radius 1737.4 km, the longitude, latitude, the local time, and the bolometric temperature listed according to the following format:

PCP (seasonal) Fields and Descriptions

#	Field Name	Data Type and Width.Precision	Description
1	x	Real 9.6	The distance from the grid center (normalized)
2	y	Real 9.6	The distance from the grid center (normalized)
3	clon	Real 11.6	The longitude of the grid center (degrees)
4	clat	Real 10.6	The latitude of the grid center (degrees)
5	ltim	Real 7.4	The local time (hours)
6	tbol	Real 10.6	The average bolometric brightness temperature (degrees Kelvin)

9.2 File Names

The file names for PCP (diurnal) are:

PCP_AVG_[VAL]_[PROJ]_[SEASON]_[TYPE][NUM]_[RES].TAB

The file names for PCP (seasonal) are:

PCP_AVG_[VAL]_[PROJ]_LS[NUMLS]_[TYPE][NUM]_[RES].TAB

Each item in the file name is explained in the following table:

Filename Component	Description
VAL	The value binned. This is always TBOL, the average bolometric brightness temperature (degrees Kelvin) for the PCP product.

PROJ	The projection, polar stereo south, POLS, or north. POLN.
SEASON	Either summer, SUM, or winter, WIN.
NUMLS	Bin center for fixed ecliptic longitude value in degrees where bin edges are +/-30 deg.
TYPE	For fixed local time, LTIM, or fixed subsolar longitude, SLON.
NUM	For PCP (diurnal), number increment 1 to 96 for the 96 files of local time (24 hr/0.25 hr = 96) or subsolar longitude (360 deg/3.75 deg = 96). The translation from NUM to the lower LTIM is LTIM=(NUM-1)*0.25 with the value of 1 corresponding to LTIM 0 to 0.25. The translation from NUM to lower SLON is SLON=(NUM-1)*3.75 with the value of 1 corresponding to SLON 0 to 3.75. For PCP (seasonal), number increments 1 to 24 for the 24 files of subsolar longitude (360 deg/15 deg = 24). The translation from NUM to the lower SLON=(NUM-1)*15 with the value of 1 corresponding to SLON 0 to 15.
RES	A three-digit number indicating the resolution of the data in meters per pixel. Currently the PCP product contains only 240 meters per pixel.

An example PCP (diurnal) file:

PCP_AVG_TBOL_POLS_WIN_SLON02_240.TAB

An example PCP (seasonal) file:

PCP_AVG_TBOL_POLS_LS030_SLON02_240.TAB

Each will have an associated detached PDS label with the suffix .XML.

9.3 File Structure and Size

The data tables are composed of one header line followed by a variable number of record lines as empty bins are omitted. Each line represents a record of size 59 characters, including the carriage return (CR) and line feed (LF) characters. The total file sizes are approximately 170 to 190 MB each.

9.4 Label and Header Descriptions

PCP data products have PDS4 labels. A PDS4 label is a separate file with the same name as the file it describes, but with the extension ".xml". It is text file that can be viewed in a text editor. A PDS4 label is written using XML (Extended Markup Language), a widely used standard for information exchange [8].

Although users who are new to PDS4 may find the XML labels hard to read at first, they are easily read by many available software tools. The use of an XML-aware text editor is recommended. Some commonly used XML-aware editors are Notepad++, Visual Studio Code, UltraEdit, xmplify, and Oxygen.

The content of PDS4 XML labels is strictly controlled by the core PDS4 Data Dictionary and other PDS-managed dictionaries. The dictionaries are provided in the form of XML schema, available online at https://pds.nasa.gov/datastandards/dictionaries/, and as HTML and PDF documents at https://pds.nasa.gov/datastandards/documents/. PDS provides a dictionary lookup tool for both PDS3 and PDS4 metadata at https://pds.nasa.gov/tools/dd-search/.

In addition to the PDS4 labels, the diurnal PCP data products are also accompanied by the older PDS3 labels for users who are accustomed to working with them. The PCP PDS3 label elements are described below.

PDS3 Label Elements and Definitions for PCP Products

Name	Data Type	Description
PDS_VERSION_ID	IDENTIFIER	The version number of the PDS standards documents that is valid when the label is created. Examples: PDS3, PDS4
RECORD_TYPE	IDENTIFIER	The record format of a file. For PCP, this will be FIXED_LENGTH.
RECORD_BYTES	INTEGER	The number of bytes in a physical file record.
FILE_RECORDS	INTEGER	The number of physical file records, including both header records and data records.
DESCRIPTION	CHARACTER	A free-form description of the data.
DATA_SET_ID	IDENTIFIER	This unique identifier describes the mission, instrument, data level and archive version (the archive version starts at V1.0 and only ever gets bumped up in the event that the entire dataset needs to be re-archived). Example: "LRO-L-DLRE-5-GCP-V1.0"

FILE_NAME	CHARACTER	The base file name of either the TAB or LBL file.
MISSION_NAME	CHARACTER	Major planetary mission or project. Always “LUNAR RECONNAISSANCE ORBITER”.
INSTRUMENT_HOST_NAME	CHARACTER	Full name of the spacecraft on which the instrument is based. Always “LUNAR RECONNAISSANCE ORBITER”.
INSTRUMENT_HOST_ID	CHARACTER	Unique identifier for the spacecraft on which the instrument is based. Always “LRO”.
INSTRUMENT_NAME	CHARACTER	The full name of the instrument. Always “DIVINER LUNAR RADIOMETER EXPERIMENT”.
INSTRUMENT_ID	CHARACTER	Unique identifier for the instrument. Always “DLRE”.
PRODUCT_TYPE	CHARACTER	A permanent, unique identifier assigned to the data product type. Always “PCP”.
PRODUCT_ID	CHARACTER	A permanent, unique identifier assigned to a data product.
LRO:CALIBRATION_SOFTWARE_VER_ID	CHARACTER	The version of the calibration software used to generate the input RDR data.
PRODUCER_ID	CHARACTER	The identifier of the instrument team that produced the data product. Always “LRO_DLRE_TEAM”
PRODUCER_FULL_NAME	CHARACTER	The name of the Principal Investigator of the instrument team.
PRODUCER_INSTITUTION_NAME	CHARACTER	Where the data products were produced.
A_AXIS_RADIUS	REAL	The radius of the “A” axis of the Moon used in geometry calculations, in kilometers. See section 2.4.3, “Coordinate Systems”, for more.
B_AXIS_RADIUS	REAL	The radius of the “B” axis of the Moon used in geometry calculations, in kilometers. See section 2.4.3, “Coordinate Systems”, for more.
C_AXIS_RADIUS	REAL	The radius of the “C” axis of the Moon used in geometry calculations, in kilometers. See section 2.4.3, “Coordinate Systems”, for more.
TARGET_NAME	CHARACTER	The name of the mission or project target. Always “MOON”.

START_TIME	TIME	The UTC time of the first observation in the data product.
STOP_TIME	TIME	The UTC time of the last observation in the data product.
SPACECRAFT_CLOCK_START_COUNT	CHARACTER	The value of the spacecraft clock in the first record of the data product.
SPACECRAFT_CLOCK_STOP_COUNT	CHARACTER	The value of the spacecraft clock in the last record of the data product.
PRODUCT_CREATION_TIME	TIME	The UTC system format time when this product was created.
PRODUCT_VERSION_ID	CHARACTER	The version number of the archived data product. If the data needs to be modified and re-archived, this number is incremented. “1” means first revision, “2” means second, and so on.
MINIMUM_LATITUDE	REAL	The minimum latitude of the data.
MAXIMUM_LATITUDE	REAL	The maximum latitude of the data.
WESTERNMOST_LONGITUDE	REAL	The westernmost longitude of the data.
EASTERNMOST_LONGITUDE	REAL	The easternmost longitude of the data.
POSITIVE_LONGITUDE_DIRECTION	REAL	The direction in which longitude values increase. Always “EAST”.
MINIMUM_WAVELENGTH	REAL	The minimum wavelength at which observations were made by this channel, in microns.
MAXIMUM_WAVELENGTH	REAL	The maximum wavelength at which observations were made by this channel, in microns.
LRO:DLRE_SUNLON_MIN	REAL	The minimum recorded value of sunlon.
LRO:DLRE_SUNLON_MAX	REAL	The maximum recorded value of sunlon.
LRO:DLRE_CLOCTIME_MIN	REAL	The minimum recorded value of cloctime.
LRO:DLRE_CLOCTIME_MAX	REAL	The maximum recorded value of cloctime
MAP_PROJECTION_TYPE	CHARACTER	Which projection is being used. Always “POLAR STEREOGRAPHIC”.
KEYWORD_LATITUDE_TYPE	CHARACTER	Which type of latitude is used in this projection. Should always be “PLANETOCENTRIC”.
MAP_RESOLUTION	REAL	The resolution of the grid, in number of pixels per degree

MAP_SCALE	REAL	Identifies the scale of a given map.

10 Level 4 RCP Detailed Data Product Specifications

10.1 Gridded Values

Regional Cumulative Products are a compilation of all Diviner observations from 5-July-2009 to 1-March-2021 with emission angles <20°. They are produced by binning Diviner RDR (Level 1b) radiance measurements for each IR channel (channels 3-9) in 0.0078125-degree bins in longitude and latitude, and 0.1 hours of local time to determine the mean brightness temperatures on a regional cylindrical grid. Additionally, the mean radiance values for all the channels are used to determine the bolometric brightness temperatures for each bin. The data set is regional and covers the Lacus Mortis region (22.5° E to 31.5° E, 41.5° N to 48.5° N) and is split into 1 degree data tiles. The format of the files is simple ASCII text. Empty bins are excluded. Each line in the file represents a bin center with the longitude, latitude, local time, brightness temperatures (channels 3 through 9), and the bolometric temperature listed according to the following format:

RCP Fields and Descriptions

#	Field Name	Data Type and Width.Precision	Description
1	clon	Real 13.8	The longitude of the grid center (degrees)
2	clat	Real 12.8	The latitude of the grid center (degrees)
3	ltim	Real 5.2	The bin centered local solar time (hours)
4	t3	Real 10.6	The Diviner channel 3 average brightness temperature (degrees Kelvin)
5	t4	Real 10.6	The Diviner channel 4 average brightness temperature (degrees Kelvin)
6	t5	Real 10.6	The Diviner channel 5 average brightness temperature (degrees Kelvin)
7	t6	Real 10.6	The Diviner channel 6 average brightness temperature (degrees Kelvin)
8	t7	Real 10.6	The Diviner channel 7 average brightness temperature (degrees Kelvin)
9	t8	Real 10.6	The Diviner channel 8 average brightness temperature (degrees Kelvin)
10	t9	Real 10.6	The Diviner channel 9 average

			brightness temperature (degrees Kelvin)
11	tbol	Real 10.6	The average bolometric brightness temperature (degrees Kelvin)

10.2 File Names

The file names for RCP are:

REGION_[NAME]_CUMUL_AVG_CYL_[CENLAT][CANLON]_[RES].TAB

Each item in the file name is explained in the following table:

Filename Component	Description
NAME	An identifier based on the regional nomenclature. Currently the RCP product contains only “LACUS_MORTIS”.
CENLAT	The center latitude of the 1-degree data tile consisting of a two-digit number followed by either N for north or S for south.
CENLON	The center longitude of the 1-degree data tile consisting of a three-digit number followed by either E for east or W for west.
RES	A three-digit number indicating the resolution of the data in pixels per degree. Currently the RCP product contains only 128 pixels per degree.

An example RCP file:

REGION_LACUS_MORTIS_CUMUL_AVG_CYL_42N023E_128.TAB

Each file will have an associated detached PDS label with the suffix .XML.

10.3 File Structure and Size

The data tables are composed of one header line followed by a variable number of record lines as empty bins are omitted. Each line represents a record of size 132 characters, including the carriage return (CR) and line feed (LF) characters. The total file sizes are approximately 147 to 173 MB each.

10.4 Label and Header Descriptions

RCP data products have PDS4 labels. A PDS4 label is a separate file with the same name as the file it describes, but with the extension “.xml”. It is text file that can be viewed in a text editor. A PDS4 label is written using XML (Extended Markup Language), a widely used standard for information exchange [8].

Although users who are new to PDS4 may find the XML labels hard to read at first, they are easily read by many available software tools. The use of an XML-aware text editor is recommended. Some commonly used XML-aware editors are Notepad++, Visual Studio Code, UltraEdit, xmplify, and Oxygen.

The content of PDS4 XML labels is strictly controlled by the core PDS4 Data Dictionary and other PDS-managed dictionaries. The dictionaries are provided in the form of XML schema, available online at https://pds.nasa.gov/datastandards/dictionaries/, and as HTML and PDF documents at https://pds.nasa.gov/datastandards/documents/. PDS provides a dictionary lookup tool for both PDS3 and PDS4 metadata at https://pds.nasa.gov/tools/dd-search/.

11 Level 4 GHRM Detailed Data Product Specifications

11.1 Gridded Values

The production of the Global High-Resolution Mosaics is described in section 2.2.9. Each product is gridded at 128 ppd, and values are calculated for midnight or slope-adjusted midnight. Values are in single precision floating-point format. The following table lists the values in each gridded product:

Value	**Description**
tb6	Channel 6 brightness temperature (degrees kelvin)
tb7	Channel 7 brightness temperature (degrees kelvin)
tb8	Channel 8 brightness temperature (degrees kelvin)
tb9	Channel 9 brightness temperature (degrees kelvin)
tbol	Average bolometric brightness temperature (degrees kelvin)
treg	Derived regolith temperature (degrees kelvin)
ra	Derived rock abundance (a fraction between 0 and 1).

11.2 File Names

The format of each file name is:

dghrm_[VAL]_[TYPE]_[MINLAT][MAXLAT]_[FORMAT].[FORMAT]

Each item in the file name is explained in the following table:

Filename Component	Description
VAL	The gridded value. This can be tb6, tb7, tb8, tb9, tbol, treg, or ra.
TYPE	This can be midnight (m), slope-adjusted midnight (sam), or anomaly at slope-adjusted midnight (anom).
MINLAT	The minimum latitude bound. Currently, all GHRM products have a minimum bound of 70s.
MAXLAT	The maximum latitude bound. Currently, all GHRM products have a maximum bound of 70n.
FORMAT	The file format of the product. This can be either tif or img.

The file names for each GHRM are:

dghrm_tb6_m_70s70n_tif.tif
dghrm_tb6_sam_70s70n_tif.tif
dghrm_tb7_m_70s70n_tif.tif
dghrm_tb7_sam_70s70n_tif.tif
dghrm_tb8_m_70s70n_tif.tif
dghrm_tb8_sam_70s70n_tif.tif
dghrm_tb9_m_70s70n_tif.tif
dghrm_tb9_sam_70s70n_tif.tif
dghrm_tbol_m_70s70n_tif.tif
dghrm_tbol_sam_70s70n_tif.tif
dghrm_tbol_anom_70s70n_tif.tif
dghrm_treg_m_70s70n_tif.tif
dghrm_treg_sam_70s70n_tif.tif
dghrm_treg_anom_70s70n_tif.tif
dghrm_ra_sam_70s70n_tif.tif

Each file is associated with a detached PDS label with suffix .XML.

11.3 File Structure and Size

The data products are cylindrical maps gridded at a resolution of 128 ppd spanning 180˚W to 180˚E longitude and 70˚S to 70˚N latitude. The values are in single-precision floating point format. Each file is approximately 3.3 GB.

11.4 Label and Header Descriptions

GHRM data products have PDS4 labels. A PDS4 label is a separate file with the same name as the file it describes, but with the extension ".xml". It is text file that can be viewed in a text editor. A PDS4 label is written using XML (Extended Markup Language), a widely used standard for information exchange [8].

Although users who are new to PDS4 may find the XML labels hard to read at first, they are easily read by many available software tools. The use of an XML-aware text editor is recommended. Some commonly used XML-aware editors are Notepad++, Visual Studio Code, UltraEdit, xmplify, and Oxygen.

The content of PDS4 XML labels is strictly controlled by the core PDS4 Data Dictionary and other PDS-managed dictionaries. The dictionaries are provided in the form of XML schema, available online at https://pds.nasa.gov/datastandards/dictionaries/, and as HTML and PDF documents at https://pds.nasa.gov/datastandards/documents/. PDS provides a dictionary lookup tool for both PDS3 and PDS4 metadata at https://pds.nasa.gov/tools/dd-search/.

12 APPENDIX B – ACTIVITY FLAG

The Activity Flag (“af”) represents a combination of the orientation, observation type, and instrument mode. It is given by a three-digit integer which is sometimes negative (a negative value denotes “moving”) for a total of four characters.

The first, or hundredth’s, digit of af denotes the orientation:

First Digit	Orientation
1xx	On moon
2xx	Near limb (absolute value of limb angle is 10 degrees or less)
3xx	Off moon
4xx	Elevation actuator homed
9xx	Not applicable/Unknown

The second, or tenth’s, digit of af denotes the observation type:

Second Digit	Observation Type
x0x	Stowed
x1x	Standard nadir
x2x	Rotated nadir
x5x	Space view
x6x	Solar calibration target view
x8x	Blackbody view
x9x	Not applicable/Unknown

(Note: Standard nadir refers to the instrument pointing along track in “normal” position, i.e. leading with Channel 1 and Channel 7. Rotated nadir refers to the instrument pointing along track in “reverse” position, i.e. leading with Channel 6 and Channel 9. See the “Figure 6: Diviner RDR Order, detailed” in section 2.4.5)

The third, or one’s, digit of af denotes the instrument mode:

Third Digit	Instrument Mode
xx0	Nominal (< 4 degrees)
xx1	Small roll (between 4 and 10 degrees)
xx2	Large roll (> 10 degrees)
xx3	Freezing
xx4	Frozen
xx5	Safing
xx6	Safed

xx9	Not applicable/Unknown

For the instrument mode, Diviner defines spacecraft pointing with respect to the angle between the spacecraft +z axis and a vector between the spacecraft and the center of the moon. This parameter does not consider Diviner's pointing independent of the spacecraft. Nominal pointing includes angles less than 4 degrees where emission phase effects are negligible. Small rolls are angles between 4 and 10 degrees where emission phase effects are small. Large rolls are angles greater than 10 degrees where emission phase effects could be moderate or large.

It should also be noted that "moving" is considered a special instrument mode that overlaps with all other instrument modes. Therefore, we denote a negative number to represent moving.

By combining the presence or absence of a negative sign and the three digits, one can interpret the full Activity Flag. Here are some examples:

Example af	Description
121	On moon, rotated nadir, small roll
-202	Moving, near limb, large roll
404	Elevation actuator homed, frozen
485	Elevation actuator homed, blackbody calibration, safing

13 APPENDIX C – QUALITY FLAGS

This appendix provides details for the three quality flags in the RDR record. Each flag is a three decimal digit integer which represents an 8-bit binary flag. Each bit represents a condition which, when set to one, represents the presence of that condition in a record. Lower (or less significant) bits are considered less severe than higher (or more significant) bits. Therefore, the higher the value of a quality flag, the lower quality of the data record.

Certain bit flags are left blank for future expansion of the list of conditions.

A simple formula for determining whether a certain bit is set is given by:

```
bit_set(int quality_flag,int bit) =
   if(quality_flag & (2^bit)) then
      return TRUE
   else
      return FALSE
   endif
```

This is pseudo code. The "&" here represents bitwise-and.

For example, a flag that has a decimal value of “3” has a corresponding bit flag of 00000011, indicating that only the two least significant bits (bits 0 and 1) were set to one for this flag.

The three quality flags represent Calibration, Geometry, and Miscellaneous. Below are tables which describe each bit in the flags.

31) qca – Quality Flag for Calibration

Bit	Flag Name	Description
0	Interpolated but out of bounds	Interpolate to get offsets and gains for the measurement using the offsets and gains from the two surrounding calibration markers for the channel type - except when the opposing channel type has one or two closer calibration markers. In that case, the interpolation to derive offsets for the measurement is based on the offsets in those closer calibration markers. One or more calibration markers are out of bounds.
1	Nearest Marker Method	Use gain from nearest calibration marker for the channel type. Use offset from the closest of 1) the marker where gain came from or if it exists 2) the nearest calibration marker for the opposing channel type that lies between the time of the measurement you are calibrating and the time of the marker where gain came from.
2	Nearest Marker Method but out of bounds	Use gain from nearest calibration marker for the channel type. Use offset from the closest of 1) the marker where gain came from or if it exists 2) the nearest calibration marker for the opposing channel type that lies between the time of the measurement you are calibrating and the time of the marker where gain came from. One or more calibration markers are out of bounds.
3	Constants only	Constants used for gains and offsets, since extrapolation is not feasible
4	Reserved	Reserved for future use
5	Reserved	Reserved for future use
6	Reserved	Reserved for future use
7	Reserved	Reserved for future use

A calibration marker is considered "out of bounds" if it occurs more than a nominal time difference (initially 12.5 minutes for thermal channels and 2.5 hours for solar channels) from a calibration point. This generally occurs if one or more of the calibration sequences for the channel type (solar, thermal) are missing near the time of the measurement.

Channel types for the Calibration Quality Flags are defined to be either solar (channels 1-2) or infrared (channels 3-9). Therefore, when calibrating a solar channel, closer calibration markers from the opposing infrared channels will be used if found and when calibrating an infrared channel, closer calibration markers from the opposing solar channels will be used if found.

This quality flag is defined to be zero (all bits unset) when we have an interpolated measurement that is not out of bounds.

32) qge – Quality Flag for Geometry

Bit	Flag Name	Description
0	Reserved	Reserved for future use
1	Reserved	Reserved for future use
2	Definitive but not reprocessed Pointing	Tracking data used to generate pointing geometry
3	Definitive but not reprocessed Ephemeris	Tracking data used to generate ephemeris geometry
4	Predict Pointing	Predictive SPICE kernels used to generate pointing geometry
5	Predict Ephemeris	Predictive SPICE kernels used to generate ephemeris geometry
6	No Pointing	No predictive SPICE kernels available to generate pointing geometry
7	No Ephemeris	No predictive SPICE kernels available to generate ephemeris geometry

Reprocessed geometry is considered the best quality level, in which updated lunar models in addition to tracking data are used to generate geometry. For either pointing or ephemeris, if all corresponding bits are zero then that type of geometry is considered Reprocessed. Thus, the best overall value for this flag is zero, in which both pointing and ephemeris geometry are Reprocessed.

33) qmi – Quality Flag for Miscellaneous

Bit	Flag Name	Description
0	Reserved	Reserved for future use
1	Eclipse	Moon is in eclipse at this time

2	Turn-on Transient	The instrument has been recently turned on or stowed, therefore measurements are considered unreliable
3	Abnormal Instrument Thermal State	The blackbody or optics bench temperature is more than a tolerable difference from their nominal values, or the focal plane temperature differs from that of the blackbody by more than a tolerable difference
4	Abnormal Instrument Temperature Drifts	The temperature drifts of one or both focal planes exceed a tolerable value
5	Noise	Data collected during a time period that was identified as containing noisy data
6	Channel 1 Saturation	A Channel 1 detector has gone above the threshold value.
7	Moving	An actuator moved during acquisition of data

Here the best possible value of the quality flag is zero, indicating none of these conditions are present.