Magellan ARCDR User's Guide
for the PDS4 Dataset
01/19/24

1.0 Introduction

This document is a quick start guide to the updated Magellan ARCDR (Altimetry and Radiometry Composite Data Record) archive. This updated ARCDR dataset was created by the Planetary Data System's (PDS) Geosciences Node as part of the Node's effort to migrate all its holdings to the PDS4 standard (pds.nasa.gov/datastandards/documents/current-version.shtml). The ARCDR dataset consists of estimates of planetary radius, Fresnel reflectivity, surface roughness, brightness temperature, and emissivity of Venus derived from Magellan altimeter and radiometer data acquired along the spacecraft orbit-track during the first three mapping cycles. The updated version of this dataset was migrated to the PDS4 standard from the set of nineteen CD-ROMs originally submitted to PDS by Magellan team members from MIT. The original dataset has four types of data files for each orbit. As described in later sections, the new archive has migrated three of these file types. The fourth type is a copy of spacecraft ephemeris data, which is already available from the PDS NAIF node. The PDS4 archive also has new JPEG browse products that can be easily opened for quick-look display of selected parameters in the ARCDR data. This document will help users understand what is in the PDS4 version of the archive, how it was created, and how it is different from the original dataset.

2.0 Magellan Mission

The Magellan Radar Mapping mission produced the first detailed datasets for topography and surface properties of Venus, along with global, high-resolution SAR (Synthetic Aperture Radar) images. The spacecraft was launched on May 4, 1989. It arrived at Venus on August 10, 1990, and began systematic mapping of the Venus surface on September 15, 1990. The main goals of the Magellan mission were geologic mapping with SAR imaging and determining the topography of Venus. The properties of surface materials at microwave (12.6 cm) wavelengths were also mapped.

Magellan mission operations were divided into several mapping cycles, each being 243 Earth days in duration. This was the time it took Venus to rotate once under Magellan's orbit. The first three mapping cycles concentrated on collecting the altimetry and radiometry data about surface properties, along with SAR images. The fourth and fifth cycles were devoted to mapping the planet's gravity field. The final cycle occurred after the spacecraft orbit was lowered to collect better gravity data near the poles. The mission completed on October 13, 1994, after the spacecraft was commanded to drop into the Venusian atmosphere.

The Magellan spacecraft orbit was elliptical (294 by 8543 km) and nearly polar with an 85.5° inclination. Periapsis was located at about 10° N latitude. The orbit period was 3.25 hours. The SAR imaging and altimetry and radiometry data collection occurred on each orbit as the spacecraft traveled from north to south. Data collection started after Magellan passed near the North Pole and the High-Gain Antenna (HGA) was pointed toward the Venusian surface and continued to about 57°S latitude. In the intervening orbits, data collection started at about 70°N and extended to 74°S latitude. Altimetry and radiometry footprint sizes ranged from about 10 to 50 km. On the second part of the orbit when the spacecraft was moving from south to north, the HGA was used to transmit the data to Earth in two sessions before and after apoapsis [Saunders, *et al.*, 1990; 1992].

3.0 Altimetry and Radiometry Data

The primary parameters in the ARCDR dataset are along orbit-track estimates of planetary radius, Fresnel reflectivity, surface roughness, brightness temperature, and emissivity. Altimetry and radiometry data were collected in-between SAR transmit and receive bursts through the HGA. After the last SAR echo in a burst was received, the system was switched to the altimeter mode that used the separate horn antenna to transmit a set of seventeen nadir-directed pulses to measure the topography. Once the last altimeter echo was received the system used the HGA in its side-looking mode for about 50 ms to receive the naturally emitted microwave energy from the planet surface. Therefore, the nadir pointing altimeter data and the side-looking radiometry data are offset in time and location along each orbit.

Planetary radius, surface Fresnel reflectivity, and RMS surface slopes were extracted simultaneously from the altimeter mode echoes. Radius was determined by subtracting both the estimated spacecraft range to the surface and an atmospheric correction from the length of the spacecraft position vector relative to the center of mass for the planet. Intensity and time dispersion of the horn antenna echoes were used to estimate RMS slopes and Fresnel power reflection coefficients by fitting the echoes to Hagfors' radar backscatter model templates [Ford and Pettengill, 1992; Pettengill *et al.*, 1991].

The HGA was also used with the radar transmitter turned off to measure the passive emissions from the surface at a 12.6 cm wavelength. The surface emissions were used to determine surface brightness temperature and thus emissivity using an estimated value of the surface physical temperature [Pettengill *et al.*, 1992]. The radiometry measurements had the same geometry (i.e., emission angles) as the SAR data and varied with latitude and spacecraft altitude. The footprint size of radiometry data also varied with latitude and spacecraft altitude.

4.0 Original PDS Dataset

The original ARCDR data were derived from the ALT-EDR dataset (pds-geosciences.wustl.edu/mgn/mgn-v-rdrs-2-alt-edr-v1/) using a software processing system developed by Magellan team members at MIT. ARCDR files were initially stored on highdensity magnetic tape. The ARCDR Software Interface Specification (SIS) document, which is included in the document collection of this PDS4 archive, describes how the ARCDR products were generated from the ALT-EDR data, the magnetic tape format, and the format of the original ARCDR data files [Ford, 1991]. The ARCDR products were subsequently transferred from magnetic tape to a set of 19 CD-ROMs, which were delivered to the PDS Geosciences Node and the interested science community.

ARCDR products on CD-ROM are stored as four separate tables with binary records. However, the binary files on the CD-ROMs use a VAX binary format for floating-point values, a format that is not widely used by the science community today. The VAX format binary data files have been converted to the commonly used IEEE 754 floating-point format in generating the PDS4 version. Besides the VAX binary format issue with the original ARCDR dataset, the CD-ROM dataset was created using an early form of PDS standards at the same time that the standards were being developed and evolving. Some of these early standards are not compatible with the current PDS4 standard. Also, the organization and content of the CD-ROMs changed over the time period that the dataset was being produced because the PDS standards were evolving. Both the out dated VAX binary format, and the old and changing archive standards, and the changing CD-ROM organization provide the rationale for migrating the ARCDR dataset to the current PDS4 standard.

Data from the original set of ARCDR CD-ROMs are available on the Geosciences Node's online repository at:

pds-geosciences.wustl.edu/missions/magellan/arcdr

These data are the source of the new PDS4 ARCDR dataset. The CD-ROMs typically have four data files for each Magellan orbit that collected altimetry and radiometry data. The four file types are altimetry, spacecraft ephemeris, orbit parameters, and radiometry data files. Orbits on the CD-ROMs are grouped into directories containing data for about 20 orbits.

5.0 PDS4 Archive Organization

The new ARCDR dataset described in this document was created using the PDS4 standard. This section describes the organization of the new dataset according to PDS4 standards. The highest level of organization for a PDS4 dataset is called a ***bundle***. A bundle is a set of one or more related ***collections*** that can be of different types. A collection is a set of related ***basic products***, which are typically all of the same type (e.g., raw, calibrated, or derived data, documents; etc.). Each basic product in PDS4 contains one or more digital objects (tables, images, etc.) and its label. Bundles and collections are logical structures, not necessarily tied to any physical directory structure, although the physical organization of a PDS4 dataset usually follows the bundle and collection structure. PDS4 labels are formatted as XML files.

All items in a PDS4 archive are considered products including bundles, collections, and basic products. A PDS4 product consists of a PDS4 label and the item or items that the label describes. All PDS4 labels are stored in an XML file separate from the items that the label describes. PDS4 products typically consist of one label file and the one file described by the label, however, a PDS4 label can describe more than one file if the content consists of multiple files. An example PDS4 product for an image product would be both the image file and the label that (a) describes the format of that image and (b) provides metadata about the image. The exception is a bundle product, which is a single XML file that lists the metadata about the bundle and the collections that belong to that bundle. Bundle products can also reference an optional readme text file that describes an introduction to the nature and contents of the bundle. Collection products consist of a PDS4 label and a separate CSV file that lists the inventory of all basic products in the collection.

Each PDS4 product is uniquely identified by a string in its label called a Logical Identifier (or LID). A LID consists of four to six tokens, each separated by a colon. The first three are fixed for datasets archived by the PDS. These first three tokens are: ***urn:nasa:pds***. The fourth token is the bundle identifier. In this case the bundle identifier is ***magellan_arcdr***. The fifth token, if present, is a collection identifier, whereas the sixth token for basic products is a product identifier. This formation rule generates a unique LID across all of PDS because the bundle identifier has to be unique across the PDS, the collection identifier has to be unique within the bundle, and finally the product identifier has to be unique within its collection. As an example, the ARCDR product LID for the altimetry product from orbit 1141 is:

urn:nasa:pds:magellan_arcdr:data_altimetry:adf01141_3

The product identifier token is usually based on the product file name without the file extension. The file name formation rule for ARCDR products is described in the next section. The LID is an attribute in the label of each product.

If there are multiple versions of a PDS4 product, these can be distinguished by version identifier (VID), which has the form M.n, with M indicating the major version (starts with 1) and n noting minor version revisions such as label updates (starts at 0 for each major version). The VID is an attribute listed in the PDS4 label. The LID and the VID can be combined to refer to a specific product version by concatenating the LID and VID with two colons. This is known in PDS4 as a LIDVID. For example, the LIDVID of version 1.0 of the product above would be:

urn:nasa:pds:magellan_arcdr:data_altimetry:adf01141_3::1.0

The ARCDR PDS4 bundle has six collections – ***data_altimetry***, ***data_radiometry***, ***data_orbit_header***, ***browse***, ***document***, and ***miscellaneous***. Each collection is described below in more detail.

The three data collections of the PDS4 bundle are mixed together within the directory structure because the physical arrangement of data products is organized by spacecraft orbit. This organization is similar to that of the original CD-ROMs. There is a data subdirectory named ***data*** in the bundle root directory. Under the data directory are additional subdirectories containing data for about 20 orbits. The subdirectory naming pattern is xxxx_yyyy where xxxx is the four-digit value of the first orbit and yyyy is the value of the last orbit for data in that subdirectory. Within these subdirectories are altimetry, radiometry, and orbit_header data files and their PDS4 labels. Browse collection files are stored in a directory named ***browse*** in the bundle root directory with the same organization as for data collections. Document and miscellaneous collections are in their own subdirectories under the bundle root directory.

5.1 Data Collections

There are three data collections because these data files each have their own set of parameters and thus formats. Altimetry products containing planetary radius, Fresnel reflectivity and surface roughness, along with several other fields, such as the latitude and longitude for the center of each footprint, are in the ***data_altimetry*** collection. Radiometry products with emissivity and brightness temperature estimates and other associated fields are in the ***data_radiometry*** collection. Products in the ***data_orbit_header*** collection contain fields with timing information for the start and stop of mapping within an orbit, start and stop times of orbits and parameters about the orbit characteristics. Orbit_header data are stored in binary format to preserve the precision of the original data. A summary of the orbit parameters from all orbits is also included in the miscellaneous collection as an ASCII file for easy reading and comparison of orbits. As noted, spacecraft ephemeris files have not been included in this PDS4 bundle because the ARCDR ephemeris files on the CD-ROMs are copies of the same files in the ALT-EDR dataset and because the same files are also available at the PDS NAIF node.

There are cases where a given orbit does not have data for all three types of ARCDR products. These cases are documented in the ***acumcomm.txt*** and ***arcdr_processing_notes.txt*** files in the document collection. In addition, there are orbits with no data, which are also documented in the ***acumcomm.txt*** file.

Each ARCDR data product consists of two files: the binary data file (**.dat*) and the PDS4 file (**.xml*). File names have the following formation rules:

Data File Types	File Name Format
Altimetry	adfnnnnn_v.dat
Radiometry	rdfnnnnn_w.dat
Orbit Header	ohfnnnnn_x.dat

Where ***nnnnn*** is the five-digit orbit number, and ***v***, ***w***, and ***x*** are the file version numbers from the original CD-ROMs. An example file name for an altimetry file is:

adf01141_3.dat

The file name without the ***dat*** extension is used as the product identifier in the product LID.

5.2 Browse Collection

The browse collection contains a series of graphs with altimetry and radiometry parameters from each orbit plotted versus latitude. The collection identifier is ***browse*** in all the LIDs within the collection. There are a set of browse products for each orbit with data. The graphs plot data points of planetary radius and Fresnel reflectivity from the altimetry data files and emissivity from the radiometry data files. The graphs also show red points that are a median filter determined from an 11-footprint window centered on each data point. The median filter is included because data from some orbits are noisy. The x-axes of all graphs extend from 90° south to 90° north latitude even though orbits do not cover the full range of latitude. The y-axis of a given parameter is constant in all graphs of that type. Thus, data can be more easily compared from orbit to orbit. Browse products are stored as JPEG images. Each JPEG file has a corresponding PDS4 label containing metadata about the browse product, along with a reference to the altimetry or radiometry product from which the data in the graphs were derived. This reference can be found in the Reference_List of the browse label and looks like this:

```
<Reference_List>
  <Internal_Reference>
    <lid_reference>urn:nasa:pds:magellan_arcdr:data_altimetry:adf01141_3</lid_reference>
    <reference_type>browse_to_data</reference_type>
  </Internal_Reference>
</Reference_List>
```

The <lid_reference> is the LID of the corresponding full data product.

File names for browse products have a similar formation rule as file names for altimetry and radiometry products, but with an added suffix (see table below) indicating the type of graph. An example browse file name would be:

adf01141_3_radius.jpg

The product identifier in a browse product LID is the browse file name without the ***jpg*** extension.

Graph Parameter	**File Name Suffix**
Planetary Radius	radius
Fresnel Reflectivity	refl
Emissivity	emiss

5.3 Document Collection

The document collection contains documentation about the ARCDR PDS4 bundle. The collection identifier is ***document*** in all the LIDs within the collection. Some of the documents have been imported from the CD-ROM version of the dataset and several are new to the PDS4 bundle. There are ASCII text files that describe the radar instrument that collected the data (***rdrsinst.txt***), the Magellan spacecraft (***insthost.txt***), and the mission (***mission.txt***). These documents are the PDS catalog files migrated from the original CD-ROMs. The ARCDR SIS is also included as an ASCII text file (***arcdr_sis.txt***). As noted, the SIS describes the original process for generation and storage of ARCDR products on magnetic tape [Ford, 1991]. This documentation was largely written in the 1990s by Magellan project personnel and science team members.

The final document copied from the CD-ROM set is named ***acumcomm.txt***. It is an ASCII text file that lists issues and other comments about the ARCDR data products. The version in the

PDS4 bundle was taken from the final CD-ROM volume (PDS volume_id mg_2019). The comments/issues are organized in reverse CD-ROM volume_id order and comments/issues are noted by orbit number within each section about a CD-ROM volume. The comments/issues can be correlated to the PDS4 products by the orbit number in the product file name. In addition, the PDS4 labels also list the original CD-ROM volume_id from where the data came.

There are two new documents in the document collection. First is this user's guide, included as a PDF file named ***arcdr_user_guide.pdf***. The second new document is ***arcdr_processing_notes.txt***. This document is an ASCII text file containing observations about any issues or other comments found while generating the PDS4 bundle. Observations in the processing notes file are organized by orbit number.

5.4 Miscellaneous Collection

The miscellaneous collection in PDS4 typically contains supplemental information useful for interpretation and use of the data in the bundle. The miscellaneous collection in the ARCDR bundle contains three products with the collection identifier of ***miscellaneous***. These products are formatted as CSV ASCII tables. The file ***arcdr_catalog.csv*** lists selected metadata about altimetry and radiometry files extracted from their PDS4 labels. The table has fields such as the number of records in the data file, the start and stop times covered by the data, the start and stop latitudes and longitudes for the footprints in the data file, and the source CD-ROM volume_id. The ***arcdr_ephemeris.csv*** file contains selected items extracted from original PDS labels of ephemeris files, such as the orbit start and stop times, the mapping start and stop times, command upload ID and navigation solution ID. The ***arcdr_orbit_parameters.csv*** file is a composite of all orbit header files listed as ASCII text. As mentioned, the orbit header files are stored as binary records to preserve the precision of the data. The composite version in the miscellaneous collection provides an easy way to view a summary of orbit parameters on all orbits in one file. Note that there is some overlap in the fields of the three products to provide context for the unique fields of each product.

6.0 Detailed Data Product Descriptions

The subsections below describe how the new PDS4 versions of the ARCDR products were generated, their structure, and their PDS4 labels.

6.1 Data Products

As noted, the original ARCDR data files are stored on CD-ROM using VAX binary format for floating-point values. Binary floating-point data in the PDS4 version are stored using the IEEE 754 standard, which can be read by most current computer systems. The conversion was done by reading the ARCDR files on the Geosciences Node online repository using the IDL (Interactive Data Language) version 8.8.1 (www.nv5geospatialsoftware.com/Products/IDL) built-in function for reading VAX formats and converting the values to IEEE 754. The converted IEEE 754 data in memory were written as binary records to a new file. All fields in the original records were included in the new files. The only item removed from the original files was the SFDU header found at the beginning of each file. The SFDU header was removed because the information is available in the PDS4 labels. The first field in each file record has its own SFDU and this field has been copied to the new PDS4 data files.

The PDS4 data products are described as ***Table_Binary*** objects. As such, the fields within each record have the same width and data type from record to record. The data types in the new PDS4 data files are the same as in the original data files, but using single- or double-precision IEEE 754 format for floating-point values. Integer values are stored in single-byte or 4-byte fields. All integer and floating-point fields except for Signal_Quality_Indicator field in the altimetry files are stored in least-significant-byte (LSB) first order. The Signal_Quality_Indicator field is a floating-point value that was stored in most-significant-byte (MSB) first order in the original data files. It has been left as a MSB value in the new PDS4 data files. Field descriptions in the PDS4 labels have been copied from the original CD-ROM labels with minor editing in some cases.

Validation of the PDS4 conversion were checked in several ways. A preliminary check of the format conversion from VAX to IEEE floating-point was done by comparing profiles of primary parameters from several converted altimetry and radiometry files to corresponding areas of the global maps in the GxDR dataset (pds-geosciences.wustl.edu/missions/magellan/gxdr; doi: 10.17189/kv67-gt18). Results of the comparison show that the conversion method works because the converted test profiles were in good agreement with the global maps. In addition, converted orbit header files were read and output as ASCII text in the ***arcdr_orbit_parameters.csv*** file. The converted orbit parameters are consistent with expected values.

Each PDS4 altimetry and radiometry data file were checked by outputting the minimum and maximum values of selected parameters and reviewing these minimum and maximum values for obvious anomalies in their range. All browse products were also visually displayed to look for anomalies such as rapid departures from the general trend of the data. Additional graphs were generated that are not part of the bundle to check parameters, such as spacecraft range above the surface, footprint size, incidence angle, and latitude versus longitude locations of footprints. These additional graphs were visually reviewed for any anomalous jumps in the trends. Any anomalies were checked by reviewing comments and errata documented in the ***acumcomm.txt*** file found in the document collection.

6.2 Browse Collection

Browse products are created with an IDL script to plot planet radius (field 13) and reflectivity (field 15) from the altimetry files and emissivity (field 17) from the radiometry files versus latitude at the center of each footprint. The data values are plotted as black points. A second set of points in red on all graphs are results of a median filter derived from a 11-footprint wide window around each data point. The median filter points are shown because data in some files are noisy. As mentioned, all graphs use a constant x-axis range from 90°S to 90°N latitude. The y-axis range for a given graph type is also constant for all orbits. Graphs are stored as JPEG image files with names similar to the altimetry or radiometry file used to generate the graph. Browse file names have an added suffix indicating the parameter plotted in the graph.

Each browse JPEG image file is accompanied by a PDS4 label as a separate XML file. The label has the same base name as the browse image, but with an extension of *.xml. The browse label is similar to the label for the data product, but simpler. It contains the basic identifying information standard to all PDS4 labels and information on the physical structure of the browse file, in this case noting that it is a JPEG file. The label also has a pointer to the altimetry or radiometry data product from which the plotted data were derived.

7.0 Displaying Data from the Binary Files

The ***PDS4_Viewer*** tool, provided by the PDS Small Bodies Node, is a simple tool for visualizing the binary ARCDR data files as ASCII. The tool uses the information in the PDS4 label to read and interpret the binary fields and displays the data in an ASCII table. PDS4_Viewer is available at:

sbnwiki.astro.umd.edu/wiki/PDS4_Viewer

PDS4_viewer is available for Windows, MacOS, and Linux systems. Installation instructions and other information about the tool's capabilities are included on the site. Source code is also available.

PDS4_viewer can export binary tables as ASCII tables in several formats. Use the "Export" menu item after opening an ARCDR data file. The options for exporting the data are "Fixed Width Columns", "Comma-Separated Columns", "Tab-Separated Columns", or a user defined separator. Select an export method and click the "Save" button. A window will open to specify the name and location for the output file. Finally selecting the "Save" from this window will output the data in the desired format. The export method was tested on version 1.3.

The PDS Engineering Node also provides a tool, ***Transform***, to convert a PDS4 binary table file into an ASCII CSV file. The tool is available for download at:

nasa-pds.github.io/transform/

The command to do the conversion is:

transform <path>/<namefile> -f csv

<Path> is the directory path with the file to convert and <namefile> is the name of the PDS4 label file. This tool requires Java to run. See the information at:

nasa-pds.github.io/transform/install

for tool requirements and installation instructions.

8.0 References

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