Mars Global Surveyor/Thermal Emission Spectrometer
Atmospheric Column Dust and Water Ice Optical Depth
Planetary Data System Bundle

USER'S GUIDE

Luca Montabone
Space Science Institute (Boulder, CO, USA)

Michael D. Smith
NASA Goddard Space Flight Center (Greenbelt, MD, USA)

Michael J. Wolff
Space Science Institute (Boulder, CO, USA)

Bruce A. Cantor
Malin Space Science Systems (San Diego, CA, USA)

lmontabone@spacescience.org
lmontabone@paneureka.org

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1 Introduction

This User's Guide describes the format and content of the Mars Global Surveyor/Thermal Emission Spectrometer (MGS/TES) Atmospheric Column Dust and Water Ice Optical Depth data archive on the Atmospheres Node of the Planetary Data System (PDS). It includes descriptions of the data products and associated metadata, as well as the archive format, content, and generation pipeline.

1.1 Document Change Log

Version	Change	Date	Affected portion
Issue 1	Initial document	12/21/2021	All
Issue 2	Revised document	08/31/2023	All

Table 1: Document change log

1.2 Acronyms and Abbreviations

Acronym	Meaning
ASU	Arizona State University
CDOD	Column Dust Optical Depth
CODMAC	Committee On Data Management And Computation
CRISM	Compact Reconnaissance Imaging Spectrometer for Mars
CSV	Comma-Separated Values
CWIOD	Column Water Ice Optical Depth
DSV	Delimiter-Separated Values
EPF	Emission Phase Function
IR	Infrared
IWB	Iterative Weighted Binning
JPL	Jet Propulsion Laboratory
L_S	Areocentric solar longitude
MCD	Mars Climate Database
MGS	Mars Global Surveyor
MOC	Mars Orbiter Camera
MRO	Mars Reconnaissance Orbiter
MY	Martian Year
NAIF	The Navigation and Ancillary Information Facility
NASA	National Aeronautics and Space Administration
PDS	Planetary Data System
PDS4	Planetary Data System Version 4
SSI	Space Science Institute
SOY	Sol-of-Year
SPICE	Spacecraft, Planet, Instrument, Camera-matrix, Events
TES	Thermal Emission Spectrometer
TW	Time Window
VIS	Visible
XML	eXtensible Markup Language

Table 2: Acronyms, abbreviations, and their meanings

1.3 Glossary

We separate the glossary in two parts, one specific to the datasets described in this User's Guide, and one specific to PDS4 concepts.

1.3.1 Dataset-specific glossary

Column Optical Depth – This quantity is related to how much radiation at a specific wavelength would be removed from the vertical component of a beam during its path through the atmosphere by absorption and scattering (i.e. extinction) due to aerosols.

Emission phase function – An orbiting satellite viewing geometry where a fixed spot of the surface is viewed at a wide range of scattering/emission angles as the spacecraft passes over the spot.

Gridding – The process of creating uniformly-spaced data (i.e. a regular grid) from irregularly-spaced (scattered) data.

Invariable plane – For a planetary system, it is the plane passing through its barycenter (center of mass) perpendicular to its angular momentum vector.

Martian Year – A Martian year has about 668.6 mean solar days (sols) and corresponds to about 687.0 Earth solar days. It is a common convention to enumerate Martian Years starting on April 11, 1955 (MY 1), see Clancy et al. (2000).

Nadir – Direction pointing directly below a particular location. In the case of an orbiting satellite, it refers to the downward-facing viewing geometry such as is employed during remote sensing of the atmosphere.

Retrieval – In the context of atmospheric science, the retrieval is the inverse problem of extracting atmospheric state parameters (temperature, aerosol optical depths, etc.) from the observed radiance spectra.

1.3.2 PDS-specific glossary

Definitions related to the PDS4 are taken from Appendix A of the PDS4 Concepts Document v1.16.0. The reader is referred to that document for more detailed information. We just recall here the following definitions used throughout this User's Guide:

Archive – A place in which public records or historical documents are preserved. It also defines the material preserved – often used in plural. The term may be capitalized when referring to all of PDS holdings – the PDS Archive.

Basic Product – The simplest product in PDS4; one or more data objects (and their description objects), which constitute (typically) a single observation, document, etc. The only PDS4 products that are *not* basic products are collection and bundle products.

Bundle Product – A list of related collections. For example, a bundle could list a collection of raw data obtained by an instrument during its mission lifetime, a collection of the calibration products associated with the instrument, and a collection of all documentation relevant to the first two collections.

Class – The set of attributes (including a name and identifier) which describes an item defined in the PDS Information Model. A class is generic – a template from which individual items may be constructed.

Collection Product – A list of closely related basic products of a single type (e.g. observational data, browse, documents, etc.). A collection is itself a product (because it is simply a list, with its label), but it is not a *basic* product.

Data Object – A generic term for an object that is described by a description object. Data objects include both digital and non-digital objects.

Data Product – It is a set of measurements resulting from a science observation, usually stored in one file.

Data Set – It is a collection of related data products, usually data products acquired by a particular instrument and processed in a certain way.

Derived Data – The term derived data (or derived file, or derived product) refers to data, products or files derived from other science products.

Description Object – An object that describes another object. As appropriate, it will have structural and descriptive components. In PDS4 a 'description object' is a digital object – a string of bits with a predefined structure.

Digital Object – An object which consists of real electronically stored (digital) data.

Identifier – A unique character string by which a product, object, or other entity may be identified and located. Identifiers can be global, in which case they are unique across all of PDS (and its federation partners). A local identifier must be unique within a label.

Label – The aggregation of one or more description objects such that the aggregation describes a single PDS product. In the PDS4 implementation, labels are constructed using XML.

Logical Identifier (**LID**) – An identifier that identifies the set of all versions of a data product.

Versioned Logical Identifier (LIDVID) – The concatenation of a logical identifier with a version identifier, providing a unique identifier for each version of product.

Metadata – Data about data – for example, a 'description object' contains information (metadata) about an 'object.'

Object – A single instance of a class defined in the PDS Information Model.

PDS Information Model – The set of rules governing the structure and content of PDS metadata. While the Information Model (IM) has been implemented in XML for PDS4, the model itself is implementation-independent.

Product ID – Each data product has a "Product ID". The Product ID is a permanent, unique identifier assigned to a data product within a data set. The Product ID is a character string up to 40 characters in length. Information about the product can be embedded in the Product ID.

Product Type – Each data product is of a single "Product Type". A product type identifies the type or category of a data product within a data set. For example, DOCUMENT, CALIBRATION, ANCILLARY, etc.

XML schema – The definition of an XML document, specifying required and optional XML elements, their order, and parent-child relationships.

2 Overview of Mission, Instrument, and Data Products

2.1 Mars Global Surveyor Mission

NASA's Mars Global Surveyor spacecraft, which operated on Mars from September 12 (UTC), 1997 to November 2, 2006, was designed to study the composition of Mars, map its topography and monitor weather patterns. MGS started its science mapping phase in March 1999 ($L_S \approx 104°$, MY 24), after a lengthy period of aerobraking during which its orbit was very elliptical and its orbit period much longer than the nominal 2-h mapping phase orbit. The mission was officially ended in January 2007. MGS was in a near-polar, sun-synchronous (local time ~02:00 and 14:00 hours) orbit with the ascending node at 14:00 hours.

The MGS mission achieved the following six science objectives during its primary mission (quoted from the MGS website): 1) Characterize the surface features and geological processes on Mars; 2) Determine the composition, distribution and physical properties of surface minerals, rocks and ice; 3) Determine the global topography, planet shape, and gravitational field; 4) Establish the nature of the magnetic field and map the crustal remnant field; 5) Monitor global weather and the thermal structure of the atmosphere; 6) Study interactions between Mars' surface and the atmosphere by monitoring surface features, polar caps that expand and recede, the polar energy balance, and dust and clouds as they migrate over a seasonal cycle.

During its extended mission, it continued to observe the atmosphere, monitor changes on the surface due to wind and ice, image possible landing sites for landers/rovers, and observe key sites of geological interest.

It carried a payload including five scientific instruments, which were furnished by NASA centers as well as universities and industry: the Mars Orbiter Camera (MOC), the Mars Orbiter Laser Altimeter (MOLA), the Thermal Emission Spectrometer (TES), the Electron Reflectometer, and the Radio Science experiment. In addition to the science instruments, the spacecraft carried an ultra-high frequency (UHF) antenna to relay communication from rovers and landers to Earth.

2.2 Thermal Emission Spectrometer Instrument

TES instrument was used to study the atmosphere and map the mineral composition of the surface by analyzing the infrared radiation emitted from the surface of Mars throughout all phases of the MGS mission, collecting over 206 million infrared spectra (Christensen et al., 2001).

TES was a thermal infrared interferometer/spectrometer with additional broadband visible and thermal channels (bolometers). Six detectors in a three-by-two array simultaneously took spectra covering the spectral range from 201.6 to 1708.9 cm^{-1} (~6-50 µm), with a selectable spectral resolution of either 5 or 10 cm^{-1}. The acquisition time of each group of six spectra is about 2-4 seconds, depending on the spectral resolution (Christensen et al., 2001). A pointing mirror allowed TES to observe the atmosphere from nadir to above both the forward and aft limbs (i.e. without direct contribution from the surface). Each pixel in the detectors subtended an 8.3-mrad field of view. TES data, therefore, have a spatial resolution of 3 km across-track and 10–20 km along track (because of smear caused by spacecraft motion).

The primary mode of TES data acquisition was nadir viewing. However, every 10°–20° of latitude around the orbit, a sequence of limb-geometry observations was taken with the field-of-view pointed to observe the atmosphere above the limb. TES also had the capability to produce thermal IR spectra and solar-band observations taken as EPF sequences. As reported in Clancy et al. (2003), the angular, seasonal, and spatial coverages of the TES EPF observations evolved over the MGS primary mission. In the first part of the mission, they were taken once per orbit, incremented in 15°

latitude between 60° north and south latitudes, with irregular and sparse longitudinal coverage, and for three emission angles of ±75°, ±55°, and 0°. In the second part, TES EPF sequences were obtained twice per orbit, incremented in 7.5° latitude between 90° north and south latitudes, with improved but still nonuniform longitudinal coverage, and for five emission angles of ±75°, ±65°, ±55°, ±30°, and 0°. Note that these two modes of observation do not have different duration time, just different number of samples in between start and end. Any difference in retrieval quality should be reflected in the uncertainty of the retrieval itself. Because TES scanned only within the orbit plane, the rotation of Mars during the one minute period of the −75° to +75° emission angle coverage of TES leads to several degree longitudinal spread in each TES EPF sequence.
During the science mapping phase, TES operated from L_S = 103.6° in MY 24 to L_S = 82.5° in MY 27. After this date (corresponding to August 2004), the number and quality of TES observations rapidly decreased. Given the characteristics of the MGS orbit, one day of TES data gives two sets of twelve narrow strips of observations spaced roughly 29° apart in longitude. These are centered around either ~02:00 h LTST (descending node, nighttime observations) or ~14:00 h LTST (ascending node, daytime observations) at most latitudes, except when the orbit crosses high latitudes, providing a larger local time span. Note that the equation of time causes the LTST to drift by about +/- 1 hour over the Martian year.

2.3 Infrared Column Dust and Water Ice Optical Depth Retrievals from MGS/TES Nadir Observations

We have developed an improved retrieval for column aerosol (dust and water ice) optical depth using TES thermal IR spectra obtained in nadir viewing geometry (note that the six TES spectra are averaged before carrying out a retrieval). MGS limb observations as well as EPF observations when the emission angle is larger than 10° are skipped (aerosol opacities are not retrieved). When the central EPF observation is used, retrievals are reported as normal column optical depths and not explicitly flagged, as the geometry is similar to true nadir. The retrieval algorithm is based on the TES retrievals originally delivered to the PDS (Smith, 2004), but has several key improvements that increase the latitude coverage and the accuracy of valid retrieved values for dust and water ice optical depth. Specifically, the criterion for performing a retrieval has been changed from a strict minimum surface temperature to a numerical determination of the sensitivity of each observation to a change in the aerosol optical depth. This new approach is more physically based, allows a greater latitude range of observations to be retrieved, and enables a meaningful uncertainty to be estimated for each individual retrieval. In addition, an error in the original TES retrieval algorithm has been isolated and fixed that had caused biases in retrieved optical depth when surface temperatures were cool. The new uncertainty estimate is based on the inverse of the thermal contrast and scaled by an estimate of the instrument noise, providing an objective constrain about quality and reliability of the data. Aerosol optical depth retrievals provided in this archive have absolute uncertainties between 0.02 and 0.5. An absolute uncertainty of 0.5 is considered as an upper threshold for meaningful retrievals, and all aerosol optical depths lower than or equal to 0.2 have a fixed, minimum uncertainty of 0.02. All non-negative aerosol optical depths have a minimum relative uncertainty of 10% (see Section 5.1 for discussion about negative values). Note that, at the mid-latitude local time of TES, the uncertainty in the retrieved absorption column dust optical depth at 9.3 µm is similar to (or slightly larger than) the uncertainty in the retrieved absorption column water ice optical depth at 12.1 µm. Therefore we only provide the former in this archive, to be used as a conservative estimate of the latter.
The novel retrievals cover latitudes of the planet previously unexplored by TES at certain seasons. The extension to cold surfaces allows mapping dust and clouds at the edge of the polar night,

therefore extending the multiannual record of dust and water ice clouds and enabling studies of possible interannual variability. The current IR dataset delivered to PDS spans the range $L_S \approx 104°$ in MY 24 to $L_S \approx 81°$ in MY 27. Absorption CDOD and CWIOD (scattering is not modeled) are reported at reference wavelengths of, respectively, 1075 cm^{-1} (9.3 µm) and 825 cm^{-1} (12.1 µm). Nighttime observations (i.e. those at local time ~02:00 h) were not considered here, because 1) the nighttime spectra have lower signal-to-noise, 2) near-surface nighttime inversions in the boundary layer potentially cause relatively larger uncertainties in the retrieved temperature profile near the surface, and 3) differences in thermal inertia at scales smaller than a TES pixel cause a large mixture of surface temperature.

2.4 Visible Column Dust Optical Depth Retrievals from MGS/TES Solar Band EPF Sequences.

Although solar band EPF sequences taken by MGS/TES in 1999-2001 have already been used to retrieve aerosol optical depths and sizes (Clancy et al., 2003), they have not been previously used to systematically retrieve VIS CDOD over the entire span of the TES mission. We have developed a retrieval algorithm, based upon the methodology of Wolff et al. (2009), and initially applied to MRO/CRISM EPF sequences. Briefly, it employs the DISORT radiative transfer program as the forward model and MPFIT optimization algorithm to model the TES solar band observations. While the six TES IR spectra are averaged before carrying out a retrieval, the entire EPF sequence of solar band observations including all the detectors are used as part of the fit. The retrieval uses a Hapke function for modelling surface reflectance of regolith (e.g., Wolff et al., 2009), and a Lambert function for the icy surfaces of the polar regions. The surface parameter that we obtain is a fitted value. To minimize the aliasing of water ice opacity into the retrieved dust column, the water ice optical depth is included – but held as fixed parameter – using the contemporaneous TES thermal IR aerosol retrievals. This is particular important for periods when water ice clouds are an important atmospheric feature (e.g. during the aphelion cloud belt in northern spring and summer). The ice treatment scales the TES IR water ice optical depth to the TES solar band regime using an absorption IR to VIS extinction factor of 2.6, which is based on an assumption of an effective radius of 2 µm for the ice particle size. The current VIS dataset spans the range $L_S \approx 109°$ in MY 24 to $L_S \approx 80°$ in MY 27. Obviously, the VIS dataset only involves daytime observations (i.e. those at local true solar time around 14:00 h).

Note that, because of the large temporal and spatial intervals covered by each EPF sequence, in this dataset we also provide start/end times, minimum/maximum longitude/latitude and standard deviation of the longitude/latitude interval for improving the localization of such observations.

2.5 Daily Global Column Dust Optical Depth Gridded Maps from IR Retrievals

Montabone et al. (2015, 2020) have developed an iterative weighted binning (IWB) methodology to reconstruct daily gridded maps of CDOD from satellite observations, which also works for Sun-synchronous satellites such as MGS. This methodology has already been applied to previous CDOD retrievals from MGS/TES observations (Montabone et al., 2015). In this new dataset, we use the new IR retrievals described in Section 2.3 to reconstruct daily gridded maps of CDOD from SOY = 227 ($L_S \approx 105°$) in MY 24 to SOY = 174 ($L_S \approx 81°$) in MY 27, according to the sol-based Martian calendar described in Section 3.1.1.1. Note that we do not use VIS retrievals because 1) the factor to convert VIS optical depths to IR optical depths in absorption at 9.3 µm varies significantly with dust particle size, and 2) the number of VIS retrievals is small compared to the number of IR retrievals. Nevertheless, VIS CDOD retrievals as well as visible images from MGS/MOC are very useful for validation of the IR map products, in term of relative if not absolute values.

The gridding methodology produces incomplete global maps on a regular grid of 60x60 longitude-latitude grid points. Each valid grid point value corresponds to the average of CDOD retrievals within defined space-time windows, weighted in space, time, and retrieval uncertainty. If certain defined criteria are not satisfied, a grid point is considered invalid and a large negative value is assigned to it. The IWB parameters used to produce the gridded maps in this dataset are the same as those used to reconstruct the TES-only maps described in Montabone et al. (2015), see first line of Table 1 therein. We summarize them here in Table 3 for reference. Using the same parameters allows verifying the direct impact of the new retrievals on the CDOD maps, without introducing possible indirect effects due to changes in the gridding methodology.
The field names and definitions used in Montabone et al. (2015) and reported in Appendix 2 therein coincide with the names and definitions used here, see Appendix A: Long Descriptions of Variables in Data Products. We just remind that the reliability value of a grid point, calculated as the weighted average of the reliability values of the single retrievals (i.e., 1.0 - relative uncertainty, or 0.9 if the CDOD is ≤ 0.5, as in Montabone et al., 2015), has an effective range of 0.08-0.90 in the dataset described here. Small values indicate less reliable grid point averages, which mostly occur during dust storms with larger optical depths. Note that the upper cut-off of 0.9 is due to the fact that all non-negative TES IR CDOD single retrievals have a minimum relative uncertainty of 10%.

Spatial grid (lon-lat)	TW (sols)	Lon_{cutoff} (degrees)	Lat_{cutoff} (degrees)	S_{min} (10^2 km)	S_{max} (10^2 km)	d_{thr} (10^2 km)	N_{thr}
6° x 3°	1, 3, 5, 7	6^{1}, $9^{2,3,4}$	3^{1}, $4.5^{2,3,4}$	$1.5^{1,2,3,4}$	1.5^{1}, $3^{2,3,4}$	2^{1}, $3^{2,3,4}$	$3^{1,2,3,4}$

Table 3: List of parameters used in the current IWB methodology to produce gridded CDOD maps. See Montabone et al. (2015) for their definitions. The superscripts indicate the IWB iteration number with a given TW ('1' being the first iteration, and so on)

3 Data Products

We have produced three types of data products based on observations from MGS/TES spanning the overall period between February 28, 1999 (L_S ≈ 104° in MY 24) and August 31, 2004 (L_S ≈ 81° in MY 27). All three data products are derived data, see Table 4 for CODMAC and NASA processing levels. All data are written as space-separated values in ASCII format files (fixed-width tables).

Instrument and view mode	Product	CODMAC level	NASA level
MGS/TES (nadir)	IR CDOD and CWIOD retrievals	Derived Level 5	Level 2
MGS/TES (EPF)	VIS CDOD retrievals	Derived Level 5	Level 2
MGS/TES (nadir)	IR CDOD gridded maps	Derived Level 5	Level 3

Table 4: Data products and processing levels

For the IR CDOD gridded maps product we include two additional archival products: supplementary "ancillary" information, and browse "thumbnail" images. The former are fixed-width ASCII format files that provide some ancillary information for each gridded map (see Section 5.1 for more details) and are located in the same directory, while the latter are JPEG files that can be used as image thumbnails to visualize the information of each gridded map and are located in a separate browse_map collection (see Section 4 for more details). Note that, in the document collection where this Users' Guide is located, we also provide an animation of the same image thumbnails in MPEG-4 format where each frame shows the gridded maps for all available years at the same Sol-of-Year (see time standards in the next Section).

3.1 Standards used in generating data products

Data products and labels in this archive comply with Planetary Data System standards, including the PDS4 data model as specified in the relevant documentation available at NASA's PDS webpage: https://pds.nasa.gov/datastandards/documents/

3.1.1 Time standards

This document and the data products use the following time standards summarized in Table 5.

Time Standard	Definition
SCLK	**Spacecraft clock**. The value of the MGS spacecraft clock, given in seconds since 12:00 a.m. on January 1, 1980.
OCK	**Orbit counter keeper**. Sequential count of the number of orbital revolutions of the MGS spacecraft since orbit insertion; unique throughout the entire MGS mission. This number is identical to the MGS project orbit number up until the beginning of the Mapping Phase (OCK=1684) when the MGS Project reset its orbit count to 1.
L_S	**Areocentric solar longitude**. The longitude of the Sun as viewed from the center of Mars. The areocentric solar longitude is measured in the interval [0°, 360°] eastwards from the Martian northern spring equinox (southern autumn equinox) point, defined as L_S = 0°. It follows that L_S = 90° is the start of northern summer/southern winter, L_S = 180° is the start of northern autumn/southern spring, and L_S = 270° is the start of northern winter/southern summer. The areocentric solar longitude is also equivalent to the angle between the position of Mars on its orbit, the Sun, and the orbital position of the Martian northern spring equinox. We provide it with a precision of about two seconds (five decimal digits) for the single-retrieval datasets.
UTC	**Coordinated Universal Time**. It is the system of Earth time keeping that gives a name to each instant of time, based on the International Atomic Time (TAI) system with leap seconds added at irregular intervals to compensate for the accumulated difference between TAI and time measured by Earth's rotation. The format used for UTC in metadata labels and data includes year, month, day, hour, minutes and seconds: YYYY-MM-DDThh:mm:ssZ (Example: `1999-03-12T03:47:53Z`).
LTST	**Local True Solar Time**. It is the time corresponding to the actual planet-centered position of the Sun in its sky at a given location (e.g. LTST=12.0 corresponds to the time when the Sun is highest in the sky). It is expressed in decimal Martian hours (hh.ffff), with the Martian solar day divided into 24 equal hours (24 Mars-hour clock). We provide it with a precision of about three seconds (four decimal digits) for the single-retrieval datasets.
SOY	**Sol of Year**. It is the integer sol number starting from sol 1 as first day of the Martian year. A *sol* is the mean solar day on Mars (24 hours, 39 minutes, 35.244 seconds). We follow the convention to define the start and end of a sol with reference to the prime meridian passing over the Airy-0 crater. A sol therefore starts at 00:00 and ends at 24:00 hours at 0° longitude. The SOY is calculated accordingly.

MY	**Martian Year.** A Martian year can be defined in term of areocentric solar longitude or in term of mean solar days (sols). In term of L_S, a Martian year is defined as the period between two successive northern spring equinoxes (L_S = [0°, 360°]). This is the definition we use for the IR and VIS single retrieval products. In term of sols, a Martian Year has a fractional value of 668.5921 sols or, with good approximation, 668.6 sols. It is more convenient to have an integer number of sols in a year, so a Martian sol-based calendar needs to be defined first, in order to avoid de-synchronization with respect to the L_S-based calendar. The Martian sol-based calendar we use for the IR daily map product is specifically described in Section 3.1.1.1. In both cases, we follow the convention introduced by Clancy et al. (2000) for which MY 1 starts on April 11, 1955.

Table 5: Time standards and definitions

The Coordinated Universal Time, areocentric solar longitude, and local true solar time have been calculated using NASA's NAIF SPICE Toolkit kernels specific for the MGS spacecraft, available at: https://naif.jpl.nasa.gov/pub/naif/pds/data/mgs-m-spice-6-v1.0/mgsp_1000/
The Martian Year is either calculated from the areocentric solar longitude or according to the sol-based calendar defined in the next Section 3.1.1.1, together with the Sol-of-Year.
All other ancillary temporal information (including spacecraft clock and orbit counter keeper) is extracted from TES products on NASA's PDS Geoscience Node ("Vanilla" files, maintained at ASU).

3.1.1.1 Used sol-based Martian calendar

Our gridded map product uses the sol as reference time coordinate, since we provide one map per sol (as detailed above, a sol starts when it is 00:00 hours and ends when it is 24:00 hours LTST at the prime meridian). It is therefore convenient to use a sol-based Martian calendar rather than a L_S-based one, knowing that the conversion between sol and L_S can be calculated.
Appendix A in Montabone et al. (2015) describes the basic concepts of the Martian calendar used in that work, based on cycles of five Martian years with different number of sols: 669, 668, 669, 668, and 669 sols. The main advantage of using a 5-year cycle defined in that way is that, with good approximation (i.e. within 1/25 sol), the number of sols can be considered as integer (3343 sols), and the solar longitude at the beginning of one cycle is very close to the one at the beginning of the following cycle. The two cycles including TES observations starts respectively on MY 21 and MY 26. According to Table 2 in Appendix A of Montabone et al. (2015), MY 24 has a total number of 668 sols and starts at L_S=359.98°, MY 25 and 26 have 669 sols and start respectively at L_S=359.67° and L_S=359.88°, MY 27 has 668 sols and starts at L_S=0.08°.
In this archive, we extend the use of the same sol-based calendar, including the separation of the daily gridded maps into monthly folders. Years with 668 sols can be divided into 8 months of 56 sols and 4 months of 55 sols. For years with 669 sols, one of the month has 57 instead of 56 sols. This separation in months closely follows the terrestrial "Gregorian" calendar, which has 7 months of 31 days, 4 months of 30 days, and one month of 28 or 29 days depending on the total number of days of the year. While in the terrestrial "Gregorian" calendar a year starts on January 1 (during the northern hemisphere winter season), in our sol-based Martian calendar a year starts with the sol that is closest in time to the northern hemisphere spring equinox (L_S = 0°). Our Martian "month 1", therefore, corresponds to terrestrial "March" rather than "January". Note that we do not assign names to the Martian months, but we rather identify them by their sequential number in the year.
The separation of sols in Martian months, compared to the separation of days in the terrestrial "Gregorian" calendar, is summarized in the following Table 6. In this table we also show the SOY

intervals of each month and the approximate length of the solar longitude interval, which changes every month because of the elliptical Mars' orbit. The seasonal correspondence between Mars' and Earth's months is, therefore, only approximate (note that, for Earth, the seasonal response lag of the ticker atmosphere contributes to desynchronize Earth's and Mars' seasons). Nevertheless, the separation in months that we introduce for Mars in this archive has clear mnemonic advantages, and is useful for assigning a Martian "date" to specific events included in the daily gridded CDOD maps (such as the occurrence of large dust storms) as well as for producing monthly, sol-balanced averages.

Martian months	1	2	3	4	5	6	7	8	9	10	11	12
Number of sols	56	55	56	55	56	56	55	56	55	56	56	56 or 57
SOY interval	1 / 56	57 / 111	112 / 167	168 / 222	223 / 278	279 / 334	335 / 389	390 / 445	446 / 500	501 / 556	557 / 612	613 / 668 or 669
Approximate L_S length	28°	25°	25°	25°	27°	29°	31°	35°	36°	36°	33°	30° or 31°
Terrestrial "Gregorian" months	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Number of days	31	30	31	30	31	31	30	31	30	31	31	28 or 29

Table 6: Martian months compared to terrestrial "Gregorian" months

3.1.2 Spatial Coordinate System

The spatial coordinate system we use throughout this archive is the Areocentric (or Mars-centered Mars-fixed) coordinate system, i.e. the three-dimensional, right-handed Cartesian coordinate system that models Mars as a three-dimensional object, measuring locations from its center of mass, along x, y, and z axes aligned with the equator and the prime meridian. The geographical coordinates we use are summarized in the following Table 7. Because this archive only involves vertically-integrated atmospheric optical depth values (i.e. limited to two degrees of freedom), we use two-dimensional coordinates.

Geographical coordinate	**Definition**
LON	**(Areocentric) longitude**. The angle between the prime meridian and another meridian passing through a point of interest. There is no distinction between areocentric and areographic longitudes, as the vertex of the angle is always the center of the planet. It is expressed in degrees within the range [0°, 360°], unless otherwise stated (e.g., it is expressed within the range [-180°, +180°] in

	the gridded map product). In the right-handed Areocentric coordinate system, areocentric longitude increases to the East.
LAT	**Areocentric latitude**. The angle between the equatorial plane and the radius from the center of mass of the planet to a point of interest, measured from the equatorial plane. It is expressed in degrees within the range [-90°, +90°]. Positive values are for the northern hemisphere, defined as being the same celestial hemisphere relative to the invariable plane of the Solar System as Earth's North Pole.

Table 7: Geographical coordinates and definitions

All ancillary spatial information (including areocentric longitude and latitude) is extracted from TES products on NASA's PDS Geoscience Node ("Vanilla" files, maintained at ASU).

3.1.3 Data Storage Conventions

The data products of this archive are composed of a detached XML file with PDS labels and a data file. Label keywords will provide necessary information to determine the size and organization of the records in the data file.

The data file is stored as an ASCII table with fixed-width columns separated by spaces. This format is generally known as Delimiter-Separated Values (DSV) format (the Comma-Separated Values format, or CSV, is a subset of DSV format using a comma as delimiter). The first line of a data file contains column names. Each line is terminated by ASCII carriage-return and line-feed characters.

All three data products of the data set described in this document can be loaded into any software that can interpret ASCII DSV files, such as spreadsheet programs, and use them to display plots or any other kind of data analysis.

4 Data Archive Organization

This section describes the basic organization of the MGS/TES Column Aerosol Optical Depth data archive under the PDS4 Information Model (IM). The relevant document with specifications is available at the previously cited NASA's PDS webpage. We briefly describe the naming conventions used for the bundle, collection, and product unique identifiers, the naming conventions for the data product files, and then we provide details about the structure of the data archive.

4.1 Logical Identifiers

Every product in PDS4 has an identifier that allows it to be uniquely identified across the system. This identifier is referred to as a Logical Identifier or LID. A LIDVID (Versioned Logical Identifier) includes product version information, and allows different versions of a specific product to be uniquely referenced. LID and VID are defined as separate attributes in the product label, and are formed according to the conventions described in the following sections. LIDs take the form of a Uniform Resource Name (URN). LIDs are restricted to ASCII lower case letters, digits, dash, underscore, and period. Colons are also used, but only to separate prescribed components of the LID. Within one of these prescribed components dash, underscore, or period are used as separators. LIDs are limited in length to 255 characters.

4.1.1 LID Formation

LIDs in this archive are formed according to the following conventions:

- Bundle LID is formed by appending a bundle specific ID (`mgs_tes_atmos_dust-ice`) to the base ID `urn:nasa:pds` to create `urn:nasa:pds:mgs_tes_atmos_dust-ice`
  This archive has only one bundle.
- Collection LIDs are formed by appending a collection specific ID to the collection's parent bundle LID to create `urn:nasa:pds:mgs_tes_atmos_dust-ice:<collection ID>`
  There are seven different collections in this archive, corresponding to the different collection types (e.g. "browse", "data", "document", etc.). Additional descriptive information may be appended to the collection type (e.g. "data_derived_ir", "data_derived_vis", etc.) to insure that multiple collections of the same type within the bundle have unique LIDs. Here is the list of collection LIDS:
  browse_maps: `urn:nasa:pds:mgs_tes_atmos_dust-ice:browse-maps`
  context: `urn:nasa:pds:mgs_tes_atmos_dust-ice:context`
  document: `urn:nasa:pds:mgs_tes_atmos_dust-ice:document`
  data_IR_Aerosol_Optical_Depth:
  `urn:nasa:pds:mgs_tes_atmos_dust-ice:data_derived_ir-aerosol-optical-depth`
  data_IR_Dust_Optical_Depth_Maps:
  `urn:nasa:pds:mgs_tes_atmos_dust-ice:data_derived_ir-dust-optical-depth-maps`
  data_VIS_Dust_Optical_Depth:
  `urn:nasa:pds:mgs_tes_atmos_dust-ice:data_derived_vis-dust-optical-depth`
  xml_schema: `urn:nasa:pds:mgs_tes_atmos_dust-ice:xml_schema`
- Basic product LIDs are formed by appending a product specific ID to the product's parent collection LID to create `urn:nasa:pds:mgs_tes_atmos_dust-ice:<collection ID>:<product_ID>`
  Product LIDs are based on the collection LIDs, which are unique across PDS, so the only additional condition is that a product ID must be unique across a collection. Product IDs in this archive are set to have additional descriptive information derived from the specific data file name to which they are associated.
  Example: `urn:nasa:pds:mgs_tes_atmos_dust-ice:data_derived_ir-aerosol-optical-depth:my24_ls240_ls270`

4.1.2 VID Formation

Product Version IDs consist of major and minor components separated by a "." (M.n). Both components of the VID are integer values. The major component is initialized to a value of "1", and the minor component is initialized to a value of "0". The minor component resets to "0" when the major component is incremented. The PDS Standards Reference document at the previously cited NASA's PDS webpage specifies rules for incrementing major and minor components.

4.2 Data File Naming Convention

In this archive, files including data products are named according to the following conventions:
For single retrievals: <Instrument>_<Product>_<Wavelength>_<MY>_<Start_L_S>_<End_L_S>.dat
For derived maps: <Instrument>_<Product>_<Wavelength>_<MY>_<SOY>.dat
In this archive, <Instrument> is always "TES" and <Product> can be either "COD" or "CODMAP". <Wavelength> can be either "IR" or "VIS". <MY> is the Martian Year (defined in term of L_S for the single retrieval products, and in term of sol/SOY for the derived map product), <Start_L_S> and

<End_L_S> represent the areocentric solar longitude interval (30° interval) for the single retrieval products, and <SOY> is the Sol-of-Year for the derived map product.
Specifically, the names for the files related to the three distinct data products are the following:

- IR CDOD and CWIOD retrievals: TES_COD_IR_ <MY>_<Start_L_S>_<End_L_S>.dat
  Example: `TES_COD_IR_MY26_Ls270_Ls300.dat`
- VIS CDOD retrievals : TES_COD_VIS_ <MY>_<Start_L_S>_<End_L_S>.dat
  Example : `TES_COD_VIS_MY27_Ls030_Ls060.dat`
- IR CDOD maps: TES_CODMAP_IR_ <MY>_<SOY>.dat
  Example: `TES_CDODMAP_IR_MY24_SOY231.dat`

Note that:

1. Supplementary files related to the IR CDOD maps (including some ancillary information such as UTC of first/last used IR CDOD retrieval, Martian year, Sol-of-Year and solar longitude) have the same file naming convention as for the maps but with the `.txt` extension replacing the `.dat` extension;
2. Browse products related to the IR CDOD maps (i.e. thumbnails of the maps) have the same file naming convention as for the maps but preceded by a `browse_` prefix and with the `.jpg` extension replacing the `.dat` extension.

4.3 Data Archive Structure

The highest level of organization for a PDS archive is the bundle. A bundle is a set of one or more related collections which may be of different types. A collection is a set of one or more related basic products which are all of the same type. Bundles and collections are logical structures, not necessarily tied to any physical directory structure or organization. The inventory file of each collection includes the list of LIDVIDs for the basic products belonging to the collection. It is a Comma-Separated Value (CSV) file with extension ".csv".
As previously mentioned, in this archive there is only one bundle (MGS/TES Atmospheric Column Dust and Water Ice Optical Depth) and seven collections, which in our case also correspond to directories:

1. **browse_maps**: This collection of type "Browse" includes thumbnails of the global maps of atmospheric CDOD (at a reference IR wavelength of 9.3 µm in absorption and normalized to the reference pressure of 610 Pa) reconstructed from MGS TES single retrievals.
2. **context**: This is the "Context" type collection for the atmospheric column optical depth data for dust and water ice as well as the daily maps of CDOD, derived from thermal IR and solar band observations of the MGS/TES instrument.
3. **document**: This collection of type "Document" includes the documentation for the atmospheric column optical depth data for dust and water ice as well as for the daily maps of column dust optical depth, derived from observations of the MGS/TES instrument. In particular, in the corresponding directory the user can find the present "User's Guide" as well as an MP4 animation of multiannual thumbnails of available CDOD maps, shown in 669 frames (i.e. 669 SOYs. Each frame is a multiannual composite of the same single CDOD maps in the browse_maps collection).
4. **data_IR_Aerosol_Optical_Depth**: This collection of type "Data" includes atmospheric IR CDODs and CWIODs retrieved from MGS TES observations. Absorption IR optical depths are retrieved from thermal IR observations in nadir-viewing mode and reported at a reference wavelength of 9.3 µm for the dust and 12.1 µm for the water ice.
5. **data_IR_Dust_Optical_Depth_Maps**: This collection of type "Data" includes daily global maps of atmospheric IR CDOD reconstructed from MGS TES single retrievals. Maps provided at a

reference infrared wavelength of 9.3 µm in absorption are reconstructed from single retrievals of CDOD from thermal IR observations in nadir-viewing mode.

6. **data_VIS_Dust_Optical_Depth**: This collection of type "Data" includes atmospheric VIS CDODs retrieved from MGS TES observations. VIS optical depths are retrieved from solar band emergence phase function sequences and reported at a reference wavelength of 0.67 µm.
7. **xml_schema**: This is the "XML Schema" type collection for the atmospheric column optical depth data for dust and water ice as well as the daily maps of CDOD, derived from thermal IR and solar band observations of the MGS/TES instrument.

The structure of the directory tree is represented below. IR Aerosol Optical Depth and VIS Dust Optical Depth data products are separated in sub-directories corresponding to Martian Years, whereas IR Dust Optical Depth Maps data products and Browse Maps products are separated in sub-directories corresponding to Martian Years and Months, according to the sol-based calendar described in Section 3.1.1.1. Note that for data products and browse products, only the generic names of the basic products and corresponding label files for the first subdirectory are explicitly shown in the directory tree below.

```
mgs_tes_atmos_dust-ice:
|   bundle_mgs_tes_atmos_dust-ice.xml
|   README.txt
|
+---browse_maps
|   |   collection_mgs_tes_atmos_dust-ice_browse-maps.xml
|   |   collection_mgs_tes_atmos_dust-ice_browse-maps_inventory.csv
|   |
|   +---MY24
|   |   +---month_05
|   |   |       browse_TES_CDODMAP_IR_<MY>_<SOY>.xml
|   |   |       browse_TES_CDODMAP_IR_<MY>_<SOY>.jpg
|   |   |
|   |   +---month_06
|   |   +---month_07
|   |   +---month_08
|   |   +---month_09
|   |   +---month_10
|   |   +---month_11
|   |   \---month_12
|   +---MY25
|   |   +---month_01
|   |   +---month_02
|   |   +---month_03
|   |   +---month_04
|   |   +---month_05
|   |   +---month_06
|   |   +---month_07
|   |   +---month_08
|   |   +---month_09
|   |   +---month_10
|   |   +---month_11
|   |   \---month_12
|   +---MY26
|   |   +---month_01
|   |   +---month_02
|   |   +---month_03
|   |   +---month_04
|   |   +---month_05
```

```
|   |   +---month_06
|   |   +---month_07
|   |   +---month_08
|   |   +---month_09
|   |   +---month_10
|   |   +---month_11
|   |   \---month_12
|   \---MY27
|       +---month_01
|       +---month_02
|       +---month_03
|       \---month_04
+---context
|       collection_mgs_tes_atmos_dust-ice_context.xml
|       collection_mgs_tes_atmos_dust-ice_context_inventory.csv
|
+---document
|       collection_mgs_tes_atmos_dust-ice_document.xml
|       collection_mgs_tes_atmos_dust-ice_document_inventory.csv
|       animation_allyears_TES_CDODMAP_IR.xml
|       animation_allyears_TES_CDODMAP_IR.mp4
|       user_guide_TES_COD.xml
|       user_guide_TES_COD.pdf
|
+---data_IR_Aerosol_Optical_Depth
|   |   collection_mgs_tes_atmos_dust-ice_data_derived_ir-aerosol-optical-
depth.xml
|   |   collection_mgs_tes_atmos_dust-ice_data_derived_ir-aerosol-optical-
depth_inventory.csv
|   |
|   +---MY24
|   |       TES_COD_IR_<MY>_<Start_Ls>_<End_Ls>.xml
|   |       TES_COD_IR_<MY>_<Start_Ls>_<End_Ls>.dat
|   |
|   +---MY25
|   +---MY26
|   \---MY27
+---data_IR_Dust_Optical_Depth_Maps
|   |   collection_mgs_tes_atmos_dust-ice_data_derived_ir-dust-optical-
depth-maps.xml
|   |   collection_mgs_tes_atmos_dust-ice_data_derived_ir-dust-optical-
depth-maps_inventory.csv
|   |
|   +---MY24
|   |   +---month_05
|   |   |       TES_CDODMAP_IR_<MY>_<SOY>.xml
|   |   |       TES_CDODMAP_IR_<MY>_<SOY>.dat
|   |   |       TES_CDODMAP_IR_<MY>_<SOY>.txt
|   |   |
|   |   +---month_06
|   |   +---month_07
|   |   +---month_08
|   |   +---month_09
|   |   +---month_10
|   |   +---month_11
|   |   \---month_12
|   +---MY25
|   |   +---month_01
|   |   +---month_02
```

```
|    |    +---month_03
|    |    +---month_04
|    |    +---month_05
|    |    +---month_06
|    |    +---month_07
|    |    +---month_08
|    |    +---month_09
|    |    +---month_10
|    |    +---month_11
|    |    \---month_12
|    +---MY26
|    |    +---month_01
|    |    +---month_02
|    |    +---month_03
|    |    +---month_04
|    |    +---month_05
|    |    +---month_06
|    |    +---month_07
|    |    +---month_08
|    |    +---month_09
|    |    +---month_10
|    |    +---month_11
|    |    \---month_12
|    \---MY27
|         +---month_01
|         +---month_02
|         +---month_03
|         \---month_04
+---data_VIS_Dust_Optical_Depth
|    |    collection_mgs_tes_atmos_dust-ice_data_derived_vis-dust-optical-
depth.xml
|    |    collection_mgs_tes_atmos_dust-ice_data_derived_vis-dust-optical-
depth_inventory.csv
|    |
|    +---MY24
|    |         TES_COD_VIS_<MY>_<Start_Ls>_<End_Ls>.xml
|    |         TES_COD_VIS_<MY>_<Start_Ls>_<End_Ls>.dat
|    |
|    +---MY25
|    +---MY26
|    \---MY27
\---xml_Schema
          collection_mgs_tes_atmos_dust-ice_xml_schema.xml
          collection_mgs_tes_atmos_dust-ice_xml_schema_inventory.csv
```

5 Data Archive Product Formats

Data in the described archive are formatted in accordance with PDS4 specifications. In this section, we provide details on the formats specifically used for each of the products included in the archive.

5.1 Data Product Formats

Single IR and VIS retrieval data are time ordered using SCLK. Other four time references are provided in the data files for single retrieval data: OCK, LTST, L_S, and UTC, see Section 3.1.1 for definitions. For VIS retrieval data, the SCLK values at the beginning and end of an EPF sequence are also provided. Each IR and VIS retrieval data product contains values within 30° of areocentric solar longitude in

one of the four available Martian Years (24 to 27). Note that the first available range in MY 24 is L_S = [90°, 120°], and the last available range in MY 27 is L_S = [60°, 90°].
In the IR single retrieval data products, there are some negative values of CDOD and CWIOD. These values are such that, if summed to their uncertainty, the result is non-negative. Although a single negative opacity has no physical meaning, we have decided to leave these values in the dataset to prevent statistical biases when averaging many values together.
IR daily maps gridded using single retrievals are time ordered using the MY and SOY. The L_S value calculated when it is noon at the prime meridian is also provided in the supplementary ancillary files (same names as data files, but with ".txt" instead of ".dat" extension), as well as the UTC of the first and last used retrieval. Each daily map product covers one sol, from 00:00 to 24:00 hours at 0° longitude. Nevertheless, note that the IWB procedure uses an iterative process with retrievals within time windows that can span more than one sol. Map products are separated in sub-directories corresponding to Martian years and months, as discussed in Section 3.1.1.1. The first available SOY is in MY 24, month 5 (SOY 227), and the last available SOY is in MY 27, month 4 (SOY 174).
The grid in the IR maps is regular: 60 x 60 grid points, respectively separated by 6° in longitude and 3° in latitude. Nevertheless, not all grid points have valid values of CDOD, as pointed out in Section 2.5. We use the missing values of -999 (integer) or -999.99 (floating point) for variables when grid points do not have valid CDOD values.
In the three following Tables, we show the variables (with units) included in each data product, their position in the record line, and provide a short description of them. For longer descriptions of these variables, see labels in corresponding ".xml" files or Appendix A in this User's guide.

#	Name	Short description	Unit	Type	Position	Length
1	SCLK	Spacecraft Clock	s	Integer	1	9
2	OCK	Orbit Counter Keeper	N/A	Integer	11	5
3	UTC	Earth Date and Time	N/A	Date_Time_YMD_UTC	17	20
4	LON	East Longitude	deg	Real	38	6
5	LAT	Latitude	deg	Real	45	6
6	L_S	Solar Longitude	deg	Real	52	9
7	LTST	Local True Solar Time	h	Real	62	7
8	IR_CDOD	Column Dust Optical Depth at 9.3 μm	N/A	Real	70	5
9	IR_CDOD_UNC	Uncertainty in Column Dust Optical Depth at 9.3 μm	N/A	Real	76	4
10	IR_CWIOD	Column Water Ice Optical Depth at 12.1 μm	N/A	Real	81	5
11	TSURF	Surface Temperature	K	Real	87	6
12	SPEC	Spectrum Type	N/A	Integer	94	2
13	PSURF	Calculated* Surface Pressure	Pa	Real	97	4

*Table 8: Variables, descriptions, and formats for the IR single retrieval product. *Calculated, in this context, means "not retrieved".*

#	Name	Short description	Unit	Type	Position	Length
1	SCLK	Spacecraft Clock	s	Integer	1	9
2	OCK	Orbit Counter Keeper	N/A	Integer	11	5

3	UTC	Earth Date and Time	N/A	Date_Time_YMD_UTC	17	20
4	LON	East Longitude	deg	Real	38	6
5	LAT	Latitude	deg	Real	45	6
6	L_S	Solar Longitude	deg	Real	52	9
7	LTST	Local True Solar Time	h	Real	62	7
8	SCLK_MIN	Minimum Spacecraft Clock	s	Integer	70	9
9	SCLK_MAX	Maximum Spacecraft Clock	s	Integer	80	9
10	LON_MIN	Minimum East Longitude	deg	Real	90	6
11	LON_MAX	Maximum East Longitude	deg	Real	97	6
12	LON_STD	East Longitude Standard Deviation	deg	Real	104	6
13	LAT_MIN	Minimum Latitude	deg	Real	111	6
14	LAT_MAX	Maximum Latitude	deg	Real	118	6
15	LAT_STD	Latitude Standard Deviation	deg	Real	125	4
16	VIS_CDOD	Column Dust Optical Depth at 0.67 µm	N/A	Real	130	4
17	VIS_CDOD_UNC	Uncertainty in Column Dust Optical Depth at 0.67 µm	N/A	Real	135	4
18	VIS_CWIOD	Calculated* Column Water Ice Optical Depth at 0.67 µm	N/A	Real	140	4
19	LAMB	Lambert Switch	N/A	Integer	145	1
20	SURF_PARAM	Surface Parameter	N/A	Real	147	4
21	SURF_PARAM_UNC	Uncertainty in Surface Parameters	N/A	Real	152	4
22	PSURFMCD	MCD Surface Pressure	Pa	Real	157	4

*Table 9: Variables, descriptions, and formats for the VIS single retrieval product. *Calculated, in this context, means "not retrieved".*

#	Name	Short description	Unit	Type	Position	Length
1	LON	East Longitude	deg	Real	1	6
2	LAT	Latitude	deg	Real	8	5
3	CDODNUM	Number of Averaged CDOD Retrievals	N/A	Integer	14	4
4	CDODTW	Time Window	Sol	Integer	19	4
5	CDODREL	Reliability Value	N/A	Real	24	7
6	CDOD610	CDOD at 9.3 µm and 610 Pa	N/A	Real	32	7
7	CDOD610UNC	Uncertainty in CDOD at 9.3 µm and 610 Pa	N/A	Real	40	7
8	CDOD610RMSD	RMSD of CDOD at 9.3 µm and 610 Pa	N/A	Real	48	7
9	CDODTOT	CDOD at 9.3 µm	N/A	Real	56	7
10	CDODTOTUNC	Uncertainty in CDOD at 9.3 µm	N/A	Real	64	7

Table 10: Variables, descriptions, and formats for the IR gridded map product.

5.2 Document and Browse Product Formats

Text documents in this archive (such as the present User's Guide) are provided as PDF/A, an ISO-standardized version of the PDF specialized for use in the archiving and long-term preservation of electronic documents. If no special formatting is required (e.g. for README files), plain ASCII text is used.
This archive also include an animation in the MPEG-4 format, an ISO-standardized method of defining compression of audio and visual digital data.
Thumbnails of CDOD maps in the Browse Collection are provided in JPEG format, a lossy image compression standard and digital image format.

5.3 PDS Labels

Each data product is accompanied by a PDS4 label. PDS4 labels are ASCII text files written in the eXtensible Markup Language (XML). Product labels are detached from the files they describe (with the exception of the Product_Bundle label). There is one label for every product. A PDS4 label file has the same name as the data product it describes, except for its specific ".xml" extension. See the directory tree reproduced in Section 4.3 for the list of names of the PDS labels.

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Appendix A: Long Descriptions of Variables in Data Products

Name	Long description
SCLK	See Section 3.1.1 for the general definition. For the IR single-retrieval dataset, it is the MGS spacecraft clock at the beginning of a nadir observation; for the VIS single-retrieval dataset, it is the value at the first observation with minimum emergence angle of an EPF sequence.
OCK	See Section 3.1.1 for the general definition.
UTC	See Section 3.1.1 for the general definition. It is calculated from the spacecraft clock value using NASA's NAIF SPICE Toolkit.
LON	See Section 3.1.2 for the general definition. For the IR single-retrieval dataset, it is the areocentric East longitude of the nadir observation, in [0, 360] degrees; for the VIS single-retrieval dataset, it is the average areocentric East longitude of the observations within an EPF sequence, in [0, 360] degrees; for the IR gridded-map dataset, it is the areocentric East longitude of a grid point, in [-180, +180] degrees.
LAT	See Section 3.1.2 for the general definition. For the IR single-retrieval dataset, it is the areocentric latitude of the nadir observation; for the VIS single-retrieval dataset, it is the average areocentric latitude of the observations within an EPF sequence; for the IR gridded-map dataset, it is the areocentric latitude of a grid point. They are all in [-90, +90] degrees.
L_S	See Section 3.1.1 for the general definition. It is calculated from the spacecraft clock value using NASA's NAIF SPICE Toolkit.
LTST	See Section 3.1.1 for the general definition. It is calculated from the spacecraft clock value and longitude value using NASA's NAIF SPICE Toolkit.
SCLK_MIN	The value of the Mars Global Surveyor spacecraft clock at the first observation of an EPF sequence, given in seconds since 12:00 a.m. on January 1, 1980.
SCLK_MAX	The value of the Mars Global Surveyor spacecraft clock at the last observation of an EPF sequence, given in seconds since 12:00 a.m. on January 1, 1980.
LON_MIN	Minimum areocentric East longitude of the observations within an EPF sequence, in [0, 360] degrees.
LON_MAX	Maximum areocentric East longitude of the observations within an EPF sequence, in [0, 360] degrees.
LON_STD	Standard deviation of the areocentric East longitudes of the observations within an EPF sequence.
LAT_MIN	Minimum areocentric latitude of the observations within an EPF sequence, in [-90, +90] degrees.
LAT_MAX	Maximum areocentric latitude of the observations within an EPF sequence, in [-90, +90] degrees.
LAT_STD	Standard deviation of the areocentric latitudes of the observations within an EPF sequence.
IR_CDOD	Column-integrated absorption optical depth due to dust, retrieved from the infrared observation at nadir and reported at a reference wavelength of 9.3 μm (1075 cm^{-1}). It is a dimensionless quantity.

IR_CDOD_UNC	Uncertainty estimate in retrieved absorption column dust optical depth at 9.3 µm. It can also be used as an estimate of the uncertainty in retrieved absorption column water ice optical depth at 12.1 µm. It is a dimensionless quantity.
IR_CWIOD	Column-integrated absorption optical depth due to water ice, retrieved from the infrared observation at nadir and reported at a reference wavelength of 12.1 µm (825 cm^{-1}). It is a dimensionless quantity.
TSURF	Best fit of surface temperature, in Kelvin, retrieved from the infrared observation at nadir.
SPEC	Type of observed TES spectrum: 10 = 10 cm^{-1} spectral resolution, full spectrum (all channels returned); 11 = 10 cm^{-1} spectral resolution, partial spectrum (most, but not all channels returned); 20 = 5 cm^{-1} spectral resolution, full spectrum (all channels returned); 21 = 5 cm^{-1} spectral resolution, partial spectrum (most, but not all channels returned).
PSURF	Atmospheric pressure at the surface of Mars, in Pascal. It is calculated from the altitudes given by the MGS/MOLA 1/4° x 1/4° topographic map, using the hydrostatic law and assuming a 10 km scale height. It includes an adjustment for the seasonal CO_2 sublimation cycle. Proper normalization is obtained by fitting the pressures observed by the Viking and Pathfinder landers. This is the surface pressure used in the retrieval of the infrared column aerosol optical depth and is provided here for possible normalization of the IR column optical depth to a given reference pressure.
VIS_CDOD	Column-integrated optical depth due to dust, retrieved from the solar-band emission phase function sequence and reported at a reference wavelength of 0.67 µm. It is a dimensionless quantity.
VIS_CDOD_UNC	Uncertainty estimate in retrieved column dust optical depth at 0.67 µm. It is a dimensionless quantity.
VIS_CWIOD	Column-integrated optical depth due to water ice at 0.67 µm, calculated (not retrieved) from the infrared absorption column water ice optical depth at 12.1 µm by scaling. The used scaling factor is VIS/IR=2.6 for 2-µm particle size, where 1.22 is the absorption to extinction factor, and 2.13 the IR to VIS conversion factor. It is a dimensionless quantity.
LAMB	Binary value corresponding to the use of the Hapke model (0) or the Lambertian reflectance (1) for the derivation of surface reflectance. It is unitless.
SURF_PARAM	They correspond to the Hapke w parameter (single-scattering albedo) if LAMB=0 (Lambert switch variable) or to Lambertian reflectance if LAMB=1. The Hapke w parameter is used together with the other constant Hapke parameters (asymmetry parameter b=0.26, forward scattering fraction c'=0.30, opposition effect magnitude B0=1.00, opposition effect width h=0.06, and macroscopic roughness thetabar=15.00) to calculate the Hapke bidirectional reflectance of the surface (see Johnson et al., 2006a, 2006b, and Hapke, 1984) when the Lambertian reflectance is not used. Both single-scattering albedo and Lambertian reflectance are unitless.
SURF_PARAM_UNC	Uncertainty in surface parameters, i.e. either in the Hapke w parameter (single-scattering albedo) if LAMB=0 (Lambert switch variable) or in the Lambertian reflectance if LAMB=1. It is unitless.
PSURFMCD	Atmospheric pressure at the surface of Mars, in Pascal. It is calculated from the Mars Climate Database version 5.3 (http://www-

	mars.lmd.jussieu.fr/mars/access.html) using the pres0 routine. In order to derive high resolution surface pressure from the lower resolution dataset output, this routine uses a normalization correction of the global atmospheric mass to match the Viking Lander 1 surface pressure records (smoothed to remove thermal tides and transient waves), combined with an altitude correction to that given by the MGS/MOLA 32-px x 32-px topographic map using the hydrostatic law with a scale height based on the temperature at 1km above the surface (Spiga et al, 2007). Surface pressure is provided here for possible normalization of the VIS column optical depth to a given reference pressure.
CDODNUM	The number of averaged Column Dust Optical Depth retrievals that contributed to the corresponding valid grid point (see also Montabone et al., 2015). It is a dimensionless quantity.
CDODTW	The minimum time window in sols within which averaged Column Dust Optical Depth retrievals provided a valid grid point (see also Montabone et al., 2015).
CDODREL	The reliability value of the grid point, calculated as the weighted average of the reliability values of the Column Dust Optical Depth retrievals (see also Montabone et al., 2015). It is a dimensionless quantity.
CDOD610	Absorption Column Dust Optical Depth at a reference wavelength of 9.3 μm (1075 cm^{-1}) normalized to the reference pressure of 610 Pa (see also Montabone et al., 2015). It is a dimensionless quantity.
CDOD610UNC	Combined uncertainty of absorption Column Dust Optical Depth at a reference wavelength of 9.3 μm (1075 cm^{-1}) normalized to the reference pressure of 610 Pa (see also Montabone et al., 2015). It is a dimensionless quantity.
CDOD610RMSD	Root mean squared deviation of absorption Column Dust Optical Depth at a reference wavelength of 9.3 μm (1075 cm^{-1}) normalized to the reference pressure of 610 Pa (see also Montabone et al., 2015). It is a dimensionless quantity
CDODTOT	Absorption Column Dust Optical Depth at a reference wavelength of 9.3 μm (1075 cm^{-1}). This value corresponds to the total atmospheric column (see also Montabone et al., 2015). It is a dimensionless quantity.
CDODTOTUNC	Combined uncertainty of absorption Column Dust Optical Depth at a reference wavelength of 9.3 μm (1075 cm^{-1}). This value corresponds to the total atmospheric column (see also Montabone et al., 2015). It is a dimensionless quantity.

Table 11: Long Descriptions of Variables in Data Products

Appendix B: Cognizant Persons

Data Producer Team		
Name	**Affiliation**	**Email**
Luca Montabone	Space Science Institute	lmontabone@spacescience.org lmontabone@paneureka.org
Michael D. Smith	NASA Godard Space Flight Center	michael.d.smith@nasa.gov
Michael J. Wolff	Space Science Institute	mjwolff@spacescience.org
Bruce A. Cantor	Malin Space Science Systems	cantor@msss.com
PDS Atmospheres Node		
Name	**Affiliation**	**Email**
Lyle Huber, Archive Manager	New Mexico State University	lhuber@nmsu.edu
Nancy Chanover, Node Manager	New Mexico State University	nchanove@nmsu.edu
Lynn Neakrase, Science Infusion Manager	New Mexico State University	lneakras@nmsu.edu

Table 12: Cognizant Persons