MODIS/Aqua Snow Cover Daily L3 Global 0.05Deg CMG, Version 6

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

Hall, D. K. and G. A. Riggs. 2016. *MODIS/Aqua Snow Cover Daily L3 Global 0.05Deg CMG, Version 6.* [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/MODIS/MYD10C1.006. [Date Accessed].

FOR QUESTIONS ABOUT THESE DATA, CONTACT NSIDC@NSIDC.ORG

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/MYD10C1

National Snow and Ice Data Center

TABLE OF CONTENTS

1 DETAILED DATA DESCRIPTION

This data set is generated from Normalized Difference Snow Index (NDSI) snow cover in the MYD10A1 data set. Snow covered land typically has a very high reflectance in visible bands and very low reflectance in the shortwave infrared; the NDSI reveals the magnitude of this difference. MYD10A1 observations at 500 m are mapped into 0.05° (approx. 5 km) CMG cells, binned by observation type (e.g. snow, snow-free land, cloud, etc.), and tallied. Snow and cloud cover percentages are generated by computing the ratio of the number of snow or cloud observations to the total number of land observations that were mapped into the CMG cell.

As of August 2023, this data set is retired and no longer available for download. We recommend using MODIS/Aqua Snow Cover Daily L3 Global 0.05Deg CMG, Version 61 as an alternative.

Note: Version 6 incorporates a recently developed Quantitative Image Restoration (QIR) technique that restores Aqua MODIS band 6 data to scientific quality. Thus, the snow detection algorithms are now the same for Aqua and Terra. See “Section 3.4 | Derivation Techniques and Algorithms” for additional details.

1.1 Format

Data files are provided in HDF-EOS2 (V2.17). JPEG browse images are also available.

HDF-EOS (Hierarchical Data Format - Earth Observing System) is a self-describing file format based on HDF that was developed specifically for distributing and archiving data collected by NASA EOS satellites. For more information, visit the HDF-EOS Tools and Information Center.

1.2 File Naming Convention

Example File Name:

```
MYD10C1.A2003001.006.2016062201451.hdf

MYD[PID].A[YYYY][DDD].[VVV].[yyyy][ddd][hhmmss].hdf
```

Refer to Table 1 for descriptions of the file name variables listed above.

Table 1. Variables in the MODIS File Naming Convention

Variable	Description
MYD	MODIS/Aqua
PID	Product ID
A	Acquisition date follows

Variable	Description
YYYY	Acquisition year
DDD	Acquisition day of year
VVV	Version (Collection) number
yyyy	Production year
ddd	Production day of year
hhmmss	Production hour/minute/second in GMT
.hdf	HDF-EOS formatted data file

Note: Data files contain important metadata including global attributes that are assigned to the file and local attributes like coded integer keys that provide details about the data fields. In addition, each HDF-EOS data file has a corresponding XML metadata file (.xml) which contains some of the same internal metadata as the HDF-EOS file plus additional information regarding user support, archiving, and granule-specific post-production. For detailed information about MODIS metadata fields and values, consult the MODIS Snow Products Collection 6 User Guide.

1.3 File Size

Data files are approximately 5 MB.

1.4 Spatial Coverage

Coverage is global. Aqua's sun-synchronous, near-polar circular orbit is timed to cross the equator from south to north (ascending node) at approximately 1:30 P.M. local time. Complete global coverage occurs every one to two days (more frequently near the poles). The following sites offer tools that track and predict Aqua's orbital path:

- Daily Aqua Orbit Tracks, Space Science and Engineering Center, University of Wisconsin-Madison
- NASA LaRC Satellite Overpass Predictor (includes viewing zenith, solar zenith, and ground track distance to specified lat/lon)

1.4.1 Spatial Resolution

0.05°

1.4.2 Projection

MODIS CMG data sets are produced in a Geographic Lat/Lon projection. This simple projection treats geographical longitude and latitude degrees as if they were x- and y-coordinates in a plane. The following figure shows the geographical lat/lon projection known as Plate Carrée:

Plate Carree geographical latitude longitude projection

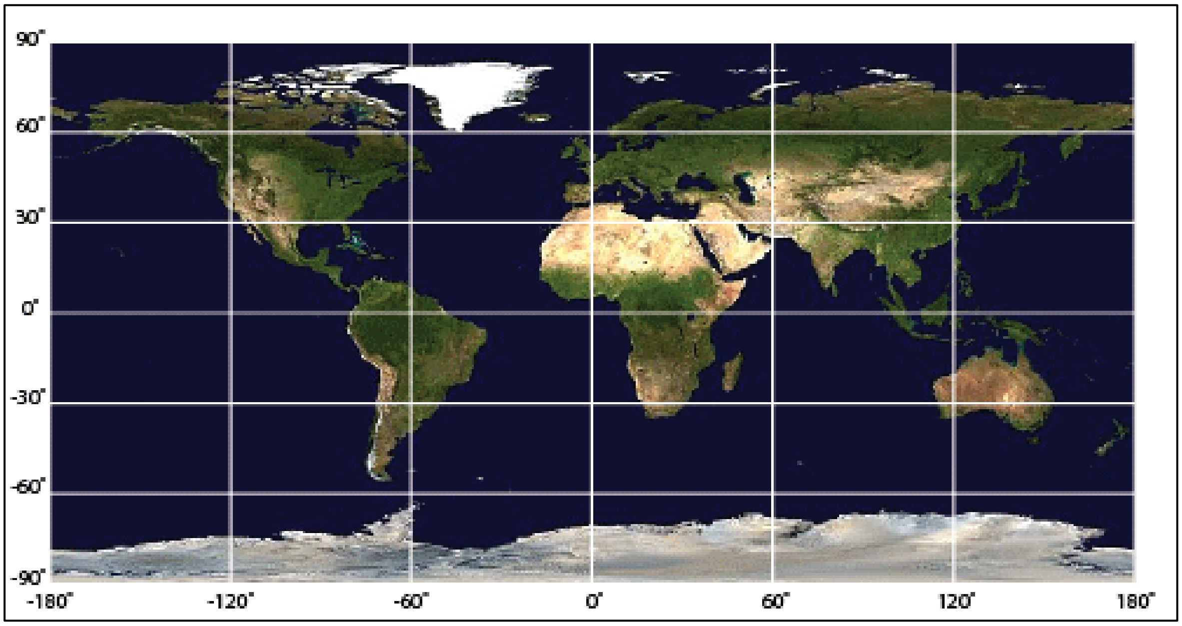

Figure 1. Plate Carrée projection. Longitude and latitude degrees are plotted on the x and y axes, respectively.

1.4.3 Grid

The MODIS Climate Modeling Grid (CMG) consists of 7200 columns by 3600 rows. Each cell has a resolution of 0.05° (approximately 5 km). The upper-left corner of the upper-left cell is -180.00° longitude, 90.00° latitude. The lower-right corner of the lower right cell is -180.00° longitude, -90.00° latitude. For additional details about the MODIS Climate Modeling Grid, see the NASA MODIS Lands | MODIS Grids Web page.

The following resources can help you select and work with gridded MODIS data:

- HDF-EOS to GeoTIFF Conversion Tool (HEG)

1.5 Temporal Coverage

MODIS Aqua data are available from 4 July 2002 to 25 February 2023. However, because the NDSI depends on visible light, data are not produced when viewing conditions are too dark. In addition, anomalies over the course of the Aqua mission have resulted in minor data outages. If you cannot locate data for a particular date or time, check the MODIS/Aqua Data Outages Web page.

1.5.1 Temporal Resolution

Daily

1.6 Parameter

Note: The `Day_CMG_Confidence_Index` variable in Version 5 has been replaced with `Day_CMG_Clear_Index`. See Table 2 for details.

Snow cover percentage, cloud cover percentage, and data quality metrics are written to the HDF-EOS formatted data files as Scientific Data Sets (SDSs) according to the HDF Scientific Data Set Data Model. The SDSs for this data set are described in the following table:

Table 2. Scientific Data Sets and Descriptions

Scientific Data Set	Description
Day_CMG_Snow_Cover	Snow cover percentage plus other results. Value = the ratio of MYD10A1, 500 m snow cover observations to the total number of land observations that were mapped into the CMG cell. Possible values are: 0–100: snow cover percentage 107: lake ice 111: night 237: inland water 239: ocean 250: cloud obscured water 253: data not mapped 255: fill Note: Antarctica deliberately mapped as snow. Snow cover percentage set to 100.
Day_CMG_Cloud_Obscured	Cloud cover percentage plus other results. Value = the ratio of MYD10A1, 500 m cloud cover observations to the total number of land observations that were mapped into the CMG cell. Possible values are: 0–100: cloud cover percentage 107: lake ice 111: night 237: inland water 239: ocean 250: cloud obscured water 252: Antarctica mask 253: data not mapped 255: fill Note: Antarctica deliberately mapped as snow. Cloud cover percentage set to 252 (masked).

Scientific Data Set	Description
Day_CMG_Clear_Index	Percentage of clear-sky land observations plus other results. Value = the ratio of MYD10A1, 500 m clear-sky observations to the total number of land observations that were mapped into the CMG cell. Low values indicate cells with suspect snow cover fractions due to extensive cloud cover. Possible values are: 0–100: clear index 107: lake ice 111: night 237: inland water 239: ocean 250: cloud obscured water 253: data not mapped 255: fill Note: Antarctica deliberately mapped as snow. Clear index set to 100 (clear).
Snow_Spatial_QA	Basic QA plus other results. Value = the most frequently occuring MYD10A1, 500 m basic QA value mapped into the CMG cell. Possible values are: 0: best 1: good 2: OK 3: poor 4: other 237: inland water 239: ocean 250: cloud obscured water 252: Antarctica mask 253: data not mapped 254: no retrieval 255: fill Note: Antarctica deliberately mapped as snow. QA set to 252 (masked).

2 SOFTWARE AND TOOLS

2.1 Get Data

Data are available via HTTPS.

2.2 Software and Tools

The following sites can help you identify the right MODIS data for your study:

- NASA's Earth Observing System Data and Information System | Near Real-Time Data
- NASA Goddard Space Flight Center | MODIS Land Global Browse Images

The following resources are available to help users work with MODIS data:

- The HDF-EOS to GeoTIFF Conversion Tool (HEG) can reformat, re-project, and perform stitching/mosaicing and subsetting operations on HDF-EOS objects.
- HDFView is a simple, visual interface for opening, inspecting, and editing HDF files. Users can view file hierarchy in a tree structure, modify the contents of a data set, add, delete and modify attributes, and create new files.
- What is HDF-EOS? an NSIDC FAQ
- The MODIS Conversion Toolkit (MCTK) plug-in for ENVI can ingest, process, and georeference every known MODIS data set, including products distributed with EASE-Grid projections. The toolkit includes support for swath projection and grid reprojection and comes with an API for large batch processing jobs.

3 DATA ACQUISITION AND PROCESSING

3.1 Mission Objectives

MODIS is a key instrument onboard NASA's Earth Observing System (EOS) Aqua and Terra satellites. The EOS includes satellites, a data collection system, and the world-wide community of scientists supporting a coordinated series of polar-orbiting and low inclination satellites that provide long-term, global observations of the land surface, biosphere, solid Earth, atmosphere, and oceans. As a whole, EOS is improving our understanding of the Earth as an integrated system. MODIS plays a vital role in developing validated, global, and interactive Earth system models that can predict global change accurately enough to assist policy makers in making sound decisions about how best to protect our environment. For more information, see:

- NASA's Earth Observing System
- Aqua Earth-observing satellite mission
- NASA MODIS | Moderate Resolution Imaging Spectroradiometer

3.2 Data Acquisition

The MODIS sensor contains a system whereby visible light from Earth passes through a scan aperture and into a scan cavity to a scan mirror. The double-sided scan mirror reflects incoming light onto an internal telescope, which in turn focuses the light onto four different detector assemblies. Before the light reaches the detector assemblies, it passes through beam splitters and spectral filters that divide the light into four broad wavelength ranges. Each time a photon strikes a detector assembly, an electron is generated. Electrons are collected in a capacitor where they are eventually transferred into the preamplifier. Electrons are converted from an analog signal to digital data, and downlinked to ground receiving stations. The EOS Ground System (EGS) consists of facilities, networks, and systems that archive, process, and distribute EOS and other NASA Earth science data to the science and user community.

3.3 Data Processing

The MODIS science team continually seeks to improve the algorithms used to generate MODIS data sets. Whenever new algorithms become available, the MODIS Adaptive Processing System (MODAPS) reprocesses the entire MODIS collection—atmosphere, land, cryosphere, and ocean data sets—and a new version is released. Version 6 (also known as Collection 6) is the most recent version of MODIS snow cover data available from NSIDC. NSIDC strongly encourages users to work with the most recent version.

Consult the following resources for more information about MODIS Version 6 data, including known problems, production schedules, and future plans:

- MODIS Snow Products Collection 6 User Guide
- The MODIS Snow and Sea Ice Global Mapping Project
- NASA Goddard Space Flight Center | MODIS Land Quality Assessment
- Product Quality Documentation for MYD10C1, C6

3.4 Derivation Techniques and Algorithms

3.4.1 Processing Steps

Fifteen of the 20 band 6 detectors on the Aqua MODIS failed shortly after launch, a 75 percent signal loss that has precluded using this band for snow detection through Version 5. However, a Quantitative Image Restoration (QIR) technique was recently developed (Gladkova et al., 2012) that restores Aqua MODIS band 6 data to scientific quality. In Version 6, the MODIS Aqua swath-level data set (MYD10_L2) incorporates this technique to produce an intermediate, calibrated radiances product with band 6 restored. Aside from this step, the snow detection algorithm is the same for the Aqua and Terra 500 m data sets used as input to the CMG.

The CMG algorithm maps 500 m MYD10A1 observations into 0.05° (approx. 5 km) CMG cells and bins and counts each observation by type, for example snow cover, cloud cover, and snow-free land. For the purpose of counting, the binning algorithm converts NDSI snow cover to a snow/no snow flag assuming that an NDSI > 0 indicates the presence of at least some snow. Snow and cloud cover extent are computed as the ratio of the number of snow or cloud observations to the total number of land observations that were mapped into the CMG cell. These ratios are expressed as percentages in the SDSs.

The snow map also includes lake ice coverage. The number of inland water body observations are counted using the water flag in the MYD10A1 `NDSI_Snow_Cover_Algorithm_Flags_QA` SDS. If the water body has more lake ice observations than open water, it is interpreted as lake ice and a value of 107 is set in the output. Lakes that are cloud obscured are output as cloud obscured with a value of 250.

A CMG-specific, 0.05° land mask is used with the binning algorithm. This land mask was derived from the University of Maryland 1km Land Cover data set. CMG cells which contain 12% or greater land are considered land and analyzed; cells with less than 12% land are considered ocean. This threshold was selected as a balance between remaining sensitive enough to map snow along coasts and minimizing snow detection errors in these regions.

Viewing conditions in the CMG cell, relative to cloud cover, are represented by the Clear Index (CI). This value reports the percentage of all land observations in the cell that were clear, thus providing an estimate of the amount of land surface that was observable. Though calculated independently from observation counts, the clear index is essentially 100 minus the percentage of cloud cover and can be used to assess the quality of that cell's snow cover value. A high CI indicates predominantly clear-sky conditions; low values correspond to cells with extensive cloud cover and indicate that the snow cover estimate was derived from a partial view of the land surface.

Polar darkness extent is based on the latitude of the CMG cell nearest the equator that is full of night observations. All CMG cells poleward of that latitude are filled as night. This approach was adopted so that a neat demarcation of night and day is visible in the CMG.

Antarctica has been masked as 100% snow covered to improve the visual quality of data. As such, this data set cannot be used to map snow in Antarctica. For users who wish to evaluate Antarctica, the MYD10_L2 data set offers a higher resolution and contains more data and information about accuracy and error.

Finally, a global mask is applied at the end of the algorithm to eliminate erroneous snow cover detections in regions where snow is extremely unlikely, such as the Amazon, the Sahara, and the Great Sandy Desert. The presence of snow cover in these regions stems from erroneous snow detections in the MYD10_L2 data set which are carried forward through the processing chain to the CMG. The mask is specifically designed to eliminate extremely unlikely snow cover in the CMG while allowing it in regions where snow may be a rare event.

3.4.2 Version History

See the MODIS | Data Versions page for the history of MODIS snow and sea ice data versions.

3.4.3 Error Sources

The NDSI technique has proven to be a robust indicator of snow cover. Numerous investigators have utilized MODIS snow cover data sets and reported accuracy in the range of 88% to 93%. The daily CMG offers a synoptic view of snow cover extent, with cloud cover and optionally the clear index which can be added to construct a synoptic view of snow cover with the cloud mask overlaid. Snow cover and cloud cover are written to separate data arrays so that users may interpret or combine the data which is most relevant to their research or applications. Snow commission errors are typically associated with cloud cover and thus snow errors may appear on any day in conjunction with cloud cover. Users should consider how best to interpret and use the snow cover data, or whether to combine it with the cloud cover data.

Because of the great difficulty in discriminating between clouds and snow over Antarctica in the swath-level snow detection and cloud mask algorithms, data quality is low over Antarctica and thus masked as 100% snow cover. Although masking improves the visual quality of the image, this approach excludes using the data for scientific study in Antarctica. In addition, to reduce erroneous snow cover detections in regions of the world that climatologically should never have snow, a putative snow “impossible” mask is applied in the algorithm. This mask improves the synoptic quality of the product, but at the expense of detecting unprecedented snowfall with this data set. The MOD10_L2/MYD10_L2 and MOD10A1/MOD10A1 data sets should be used to investigate such an event.

Snow errors ultimately propagated from MYD10_L2 to MYD10A1 and then into this data set. For more detail about potential error sources in the input data, see the Derivation Techniques and Algorithms section in the MYD10_L2 documentation and the MODIS Snow Products Collection 6 User Guide.

3.5 Instrument Description

The MODIS instrument provides 12-bit radiometric sensitivity in 36 spectral bands ranging in wavelength from 0.4 µm to 14.4 µm. Two bands are imaged at a nominal resolution of 250 m at nadir, five bands at 500 m, and the remaining bands at 1000 m. A ±55 degree scanning pattern at an altitude of 705 km achieves a 2330 km swath with global coverage every one to two days.

The scan mirror assembly uses a continuously rotating, double-sided scan mirror to scan ±55 degrees, and is driven by a motor encoder built to operate 100 percent of the time throughout the six year instrument design life. The optical system consists of a two-mirror, off-axis afocal telescope which directs energy to four refractive objective assemblies, one each for the visible, near-infrared, short- and mid-wavelength infrared, and long wavelength infrared spectral regions.

The MODIS instruments on the Terra and Aqua space vehicles were built to NASA specifications by Santa Barbara Remote Sensing, a division of Raytheon Electronics Systems. Table 3 contains the instruments' technical specifications:

Table 3. MODIS Technical Specifications

Variable	Description
Orbit	705 km altitude, 1:30 P.M. ascending node (Aqua), sun-synchronous, near-polar, circular
Scan Rate	20.3 rpm, cross track
Swath Dimensions	2330 km (cross track) by 10 km (along track at nadir)
Telescope	17.78 cm diameter off-axis, afocal (collimated) with intermediate field stop
Size	1.0 m x 1.6 m x 1.0 m
Weight	228.7 kg
Power	162.5 W (single orbit average)
Data Rate	10.6 Mbps (peak daytime); 6.1 Mbps (orbital average)
Quantization	12 bits
Spatial Resolution	250 m (bands 1-2) 500 m (bands 3-7) 1000 m (bands (8-36)
Design Life	6 years

3.5.1 Calibration

MODIS has a series of on-board calibrators that provide radiometric, spectral, and spatial calibration of the MODIS instrument. The blackbody calibrator is the primary calibration source for thermal bands between 3.5 µm and 14.4 µm, while the Solar Diffuser (SD) provides a diffuse, solar-illuminated calibration source for visible, near-infrared, and short wave infrared bands. The Solar Diffuser Stability Monitor tracks changes in the reflectance of the SD with reference to the sun so that potential instrument changes are not incorrectly attributed to changes in this calibration source. The Spectroradiometric Calibration Assembly provides additional spectral, radiometric, and spatial calibration.

MODIS uses the moon as an additional calibration technique and for tracking degradation of the SD by referencing the illumination of the moon since the moon's brightness is approximately the same as that of the Earth. Finally, MODIS deep space views provide a photon input signal of zero, which is used as a point of reference for calibration.

For additional details about the MODIS instruments, see NASA's MODIS | About Web page.

4 REFERENCES AND RELATED PUBLICATIONS

Hall, D.K., and G.A. Riggs. 2011. Normalized-difference snow index (NDSI). Encyclopedia of Snow, Ice and Glaciers, Encyclopedia of Earth Sciences Series. 779-780. doi: http://dx.doi.org/10.1007/978-90-481-2642-2_376.

Derksen, C. and R. Brown. 2012. Spring snow cover extent reductions in the 2008-2012 period exceeding climate model projections. *Geophysical Research Letters* (39). Art. #L19504. doi: http://dx.doi.org/10.1029/2012GL053387.

Gladkova, I., M., Bonev G. Grossberg, P. Romanov, and F. Shahriar. 2012. Increasing the accuracy of MODIS/Aqua snow product using quantitative image restoration technique. *IEEE Geoscience and Remote Sensing Letters* 9(4):740-743. doi: http://dx.doi.org/10.1109/LGRS.2011.2180505.

Klein, A.G. and J. Stroeve. 2002. Development and validation of a snow albedo algorithm for the MODIS instrument. *Annals of Glaciology* 34:45-52. doi: http://dx.doi.org/10.3189/172756402781817662.

Masuoka, E., A. Fleig, R.E. Wolfe, and F. Patt. 1998. Key characteristics of MODIS data products. *IEEE Transactions on Geoscience and Remote Sensing* 36(4):1313-1323.

Riggs, George A. and Dorothy K. Hall. 2016. *MODIS Snow Products Collection 6 User Guide*. https://nsidc.org/sites/nsidc.org/files/files/MODIS-snow-user-guide-C6.pdf.

Salomonson, V.V. and I. Appel. 2004. Estimating the fractional snow covering using the normalized difference snow index. *Remote Sensing of Environment* 89(3):351-360. doi: http://dx.doi.org/10.1016/j.rse.2003.10.016.

Salomonson, V.V. and I. Appel, 2006: Development of the Aqua MODIS NDSI fractional snow cover algorithm and validation results, *IEEE Transactions on Geoscience and Remote Sensing* 44(7):1747-1756. doi: http://dx.doi.org/10.1109/TGRS.2006.876029.

Tekeli, A.E., A. Sensoy, A. Sorman, Z. Akyürek, and Ü. Sorman. 2006. Accuracy assessment of MODIS daily snow albedo retrievals with in situ measurements in Karasu basin, Turkey. *Hydrological Processes* 20:705–721. doi: http://dx.doi.org/10.1002/hyp.6114.

Wolfe, R.E., D.P. Roy, and E. Vermote. 1999. MODIS land data storage, gridding and compositing methodology: level 2 grid. *IEEE Transactions on Geoscience and Remote Sensing* 36(4):1324-1338.

Wolfe, R.E. 2006. MODIS Geolocation. Earth Science Satellite Remote Sensing, Eds. Qu J.J, Wei, G, Menas, K, Murphy, R.E. and Salomonson, VV. Springer Berlin Heidelberg. 50-73. doi: http://dx.doi.org/10.1007/978-3-540-37293-6_4.

Wolfe, R.E. and M. Nishihama. 2009. Trends in MODIS geolocation error analysis. *Proc. SPIE 7452*, Earth Observing Systems XIV, 74520L (August 24, 2009). doi: http://dx.doi.org/10.1117/12.826598.

4.1 Published Research

See MODIS | Published Research for a list of studies that used MODIS data from NSIDC.

4.2 Related Data Sets

- MODIS/Aqua Snow Cover Daily L3 Global 500m Grid, Version 6 (MYD10A1)
- MODIS/Aqua Snow Cover 5-Min L2 Swath 500m, Version 6 (MYD10_L2)
- MODIS/Terra Snow Cover Daily L3 Global 0.05Deg CMG, Version 6 (MOD10C1)
- MODIS Data Sets @ NSIDC

4.3 Related Websites

- MODIS @ NASA Goddard Space Flight Center
- The MODIS Snow and Sea Ice Global Mapping Project

5 CONTACTS AND ACKNOWLEDGMENTS

5.1 Principal Investigators

Miguel O. Román
NASA Goddard Space Flight Center
Mail Code: 619
Greenbelt , MD 20771

Dorothy K. Hall
NASA Goddard Space Flight Center

Mail Code 615
Greenbelt, MD 20771

George A. Riggs
NASA Goddard Space Flight Center
Science Systems and Applications, Inc.
Mail stop 615
Greenbelt, MD 20771

6 DOCUMENT INFORMATION

6.1 Document Creation Date

February 2004

6.2 Document Revision Dates

August 2007

June 2016

December 2021

August 2023