MODIS/Terra Snow Cover Daily L3 Global 0.05Deg CMG, Version 5

USER GUIDE

How to Cite These Data

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

Hall, D. K., V. V. Salomonson, and G. A. Riggs. 2006. *MODIS/Terra Snow Cover Daily L3 Global 0.05Deg CMG, Version 5*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/EI5HGLM2NNHN. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/MOD10C1

NSIDC National Snow and Ice Data Center

TABLE OF CONTENTS

1 DETAILED DATA DESCRIPTION 3
1.1 Format 3
1.1.1 External Metadata File 4
1.2 File Naming Convention 5
1.3 File Size 5
1.4 Spatial Coverage 5
1.4.1 Latitude Crossing Times 6
1.4.2 Spatial Resolution 6
1.4.3 Projection 6
1.4.4 Grid 6
1.5 Temporal Coverage 6
1.5.1 Temporal Resolution 6
1.6 Parameter or Variable 6
1.6.1 Parameter Description 6
1.6.2 Parameter Range 7
2 SOFTWARE AND TOOLS 7
2.1 Data Access Aids 7
2.2 Data Analysis Tools 7
3 DATA ACQUISITION AND PROCESSING 8
3.1 Theory of Measurements 8
3.2 Data Acquisition Methods 8
3.2.1 Source or Platform Mission Objectives 8
3.2.2 MODIS Snow and Sea Ice Global Mapping Project Objectives 8
3.2.3 Data Collection System 8
3.2.4 Data Acquisition and Processing 9
3.3 Derivation Techniques and Algorithms 9
3.3.1 Processing Steps 9
3.3.2 Error Sources 10
3.3.3 Quality Assessment 10
3.4 Sensor or Instrument Description 11
3.4.1 Principles of Operation 11
3.4.2 Technical Specifications 11
3.4.3 Spectral Bands 12
3.4.4 Sensor or Instrument Measurement Geometry 12
3.4.5 Manufacturer of Sensor or Instrument 12
3.4.6 Calibration 12
4 REFERENCES AND RELATED PUBLICATIONS 13
4.1 Related Data Collections 14
5 CONTACTS AND ACKNOWLEDGMENTS 14

5.1 Principle Investigators 14
6 DOCUMENT INFORMATION 15
6.1 Publication Date 15
6.2 Date Last Updated 15

1 DETAILED DATA DESCRIPTION

This data set contains snow cover and Quality Assessment (QA) data, latitudes and longitudes in compressed Hierarchical Data Format-Earth Observing System (HDF-EOS) format, and corresponding metadata. This data set consists of 7200 columns by 3600 rows of global arrays of snow cover in a 0.05 degree Climate Modeling Grid (CMG). MODIS snow cover data are based on a snow mapping algorithm that employs a Normalized Difference Snow Index (NDSI) and other criteria tests. No major changes were made to MOD10C1 V005 data from the previous version.

Please visit the following sites for more information about the V005 data, known data problems, production schedule, and future plans:

- MODIS Snow Products User Guide to Collection 5
- NASA Goddard Space Flight Center: MODIS Adaptive Processing System (MODAPS) Services
- The MODIS Snow and Sea Ice Global Mapping Project: Project Description
- NASA Goddard Space Flight Center: MODIS Land Quality Assessment
- MODIS Land Team Validation: Status for Snow Cover/Sea Ice: MOD10/29

Algorithms that generate snow cover products are continually being improved as limitations become apparent in early versions of data. As a new algorithm becomes available, a new version of data is released. Users are encouraged to work with the most current version of MODIS data available, which is the highest version number.

1.1 Format

MODIS snow products are archived in compressed HDF-EOS format, which employs point, swath, and grid structures to geolocate the data fields to geographic coordinates. This data compression should be transparent to most users since HDF capable software tools automatically uncompress the data. Various software packages, including several in the public domain, support the HDF-EOS data format. See section 2.0 Software and Tools for details. Also, see the Hierarchical Data Format - Earth Observing System (HDF-EOS) Web site for more information about the HDF-EOS data format, as well as tutorials in uncompressing the data and converting data to binary format.

Data can also be obtained in GeoTIFF format from Reverb | ECHO, NASA's Next Generation Earth Science Discovery Tool.

MOD10C1 V005 consists of 7200 columns by 3600 rows of global arrays of snow cover. The MOD10C1 product was created by assembling MOD10A1 daily tiles and binning the 500 m cell observations to the spatial resolution of the CMG cells. Each data granule contains the following HDF-EOS local attribute fields, which are stored with their associated Scientific Data Set (SDS).

Each data granule also contains metadata either stored as global attributes or as HDF-predefined fields, which are stored with each SDS.

The Day CMG Confidence Index field represents an estimate of confidence in each cell's data value. The index indicates how confident the algorithm is that snow percentage in a cell is correct based on which data, snow, snow-free land, cloud, or unknown, were binned into the grid cell.

Snow percentage in each cell of the Day CMG Snow Cover field is calculated using 500 m totals of the number of snow observations and count of land observations in that cell for the day. The percentage of snow-covered land is based on the clear-sky view of land in the CMG cell. Thus, the amount of snow observed in a CMG cell is based on the cloud-free observations mapped into the CMG grid cell for all land in that cell.

```
percent snow = 100 * count of snow observations/count of land
```

In V005 data, snow cover ranges from 0-100 percent.

Cloud percentage in each cell of the Day CMG Cloud Obscured field is calculated in the same way as the percentage of snow, except that the count of cloud observations is used. Data from the Day CMG Snow Cover and Day CMG Cloud Obscured fields can be used together to better understand the observed snow. For example, if MODIS views a snow-covered region and no clouds obstruct the view on that day, then the percentage of snow cover is 100 percent. If there is 30 percent cloud cover for that day, then the percentage of snow cover is 70 percent.

```
percent cloud obscured = 100 * count of cloud observations/count of land
```

The Snow Spatial QA field provides additional information on algorithm results for each pixel within a spatial context and is used as a measure of usefulness for snow-cover data. The QA data are stored as coded integer values and tell if algorithm results were nominal, abnormal, or if other defined conditions were encountered for a pixel.

1.1.1 External Metadata File

A separate ASCII text file containing metadata with a .xml file extension accompanies the HDF-EOS file. The metadata file contains some of the same metadata as in the product file, but also includes other information regarding archiving, user support, and post-production QA relative to the granule ordered. The post-production QA metadata may or may not be present depending on whether or not the data granule was investigated for quality assessment. The metadata file should be examined to determine if post-production QA was applied to the granule.

1.2 File Naming Convention

The file naming convention common to all MODIS products is

`MOD10C1.A2000062.005.2006254085832.hdf`

Refer to Table 1 for an explanation of the variables used in the MODIS file naming convention.

Table 1. Variable Explanation for MODIS File Naming Convention

Variable	Explanation
MOD	MODIS/Terra
10C1	Type of product
A	Acquisition date
2000	Year of data acquisition
062	Day of year of data acquisition (day 62)
005	Version number
2006	Year of production (2006)
254	Day of year of production (day 254)
085832	Hour/minute/second of production in GMT (09:11:04)
hdf	HDF-EOS data format

1.3 File Size

Data files are typically between 0.5 - 6.0 MB using HDF compression.

New in V005, MOD10C1 data files now use HDF data compression. The extent to which compression reduces the file size varies from image to image, but generally it is a factor of 10 or more.

1.4 Spatial Coverage

Coverage is global; however, snow cover is calculated for only tiles that include land. A ±55 degree scanning pattern at 705 km altitude achieves a 2330 km swath with global coverage every one to two days. The following resources can help you select and work with MOD10C1 tiles:

- HEG HDF-EOS to GeoTIFF Conversion Tool
- MODIS Land Discipline Group (MODLAND) Tile Calculator

1.4.1 Latitude Crossing Times

The local equatorial crossing time of the Terra satellite is approximately 10:30 A.M. in an descending node with a sun-synchronous, near-polar, circular orbit.

1.4.2 Spatial Resolution

Gridded resolution is 0.05 degrees.

1.4.3 Projection

MOD10C1 is in a 0.05 degree CMG.

1.4.4 Grid

The CMG products contain global snow cover arrays of 7200 columns by 3600 rows. Each cell is 0.05 degree resolution. For more information about the CMG, see the MODIS Land | MODIS Grids Web page.

1.5 Temporal Coverage

MODIS data extends from 24 February 200 to 1 January 2017.

Over the course of the Terra mission, there have been a number of anomalies that have resulted in dropouts in the data. If you are looking for data for a particular date or time and can not find it, please visit the MODIS/Terra Data Outages Web page.

1.5.1 Temporal Resolution

Temporal resolution is daily.

1.6 Parameter or Variable

1.6.1 Parameter Description

The snow mapping algorithm for CMG products classifies pixels as snow, snow-free land, cloud, night, masked (Antarctica), or no data. Snow extent is the primary variable of interest in this data set.

1.6.2 Parameter Range

Refer to the MOD10C1 and MYD10C1 Global and Local Snow Cover Attributes, Version 5 document for a key to the meaning of the coded integer values in the Day CMG Snow Cover Field, the Day CMG Confidence Index Field, the Day CMG Cloud Obscured Field, and the Snow Spatial QA Field.

2 SOFTWARE AND TOOLS

2.1 Data Access Aids

The following sites can help you select appropriate MODIS data for your study:

- MODIS Rapid Response System
- NASA Goddard Space Flight Center: MODIS Data
- Space Science and Engineering Center (SSEC): Aqua Orbit Tracks GLOBAL Web site

2.2 Data Analysis Tools

- Land Processess Distributive Active Archive Center: MODIS Swath Reprojection Tool Distribution Page: Software tools that read HDF-EOS files containing MODIS swath data and produce native binary HDF-EOS Grid or GeoTIFF files of gridded data in different map projections.
- HEG HDF-EOS to GeoTIFF Conversion Tool: This free tool converts many types of HDF-EOS data to GeoTIFF, native binary, or HDF-EOS grid format. It also has reprojection, resampling, subsetting, stitching (mosaicing), and metadata preservation and creation capabilities.
- NCSA HDFView: The HDFView is a visual tool for browsing and editing the National Center for Supercomputing Applications (NCSA) HDF4 and HDF5 files. Using HDFView, you can view a file hierarchy in a tree structure, create a new file, add or delete groups and datasets, view and modify the content of a dataset, add, delete, and modify attributes, and replace I/O and GUI components such as table view, image view, and metadata view.
- Hierarchical Data Format - Earth Observing System (HDF-EOS): NSIDC provides more information about the HDF-EOS format, tools for extracting binary and ASCII objects from HDF, information about the hrepack tool for uncompressing HDF-EOS data files, and a list of other HDF-EOS resources.
- The MODIS Conversion Toolkit (MCTK): A free plugin for ENVI that can ingest, process, and georeference every known MODIS data product using either a graphical widget interface or a batch programmatic interface. This includes MODIS products distributed with EASE-Grid projections.

3 DATA ACQUISITION AND PROCESSING

3.1 Theory of Measurements

For information regarding the theory for snow mapping and fractional snow cover, please see the Theory of Measurements section in the MODIS/Terra Snow Cover 5-Min L2 Swath 500m, Version 5 guide document (MOD10_L2).

3.2 Data Acquisition Methods

3.2.1 Source or Platform Mission Objectives

MODIS is a key instrument aboard the Terra satellite, a core component of NASA's Earth Observing System (EOS). The EOS includes a series of satellites, a data system, and the world-wide community of scientists supporting a coordinated series of polar-orbiting and low inclination satellites for long-term global observations of the land surface, biosphere, solid Earth, atmosphere, and oceans that together enable an improved understanding of the Earth as an integrated system. MODIS is playing a vital role in the development of validated, global, and interactive Earth system models able to predict global change accurately enough to assist policy makers in making sound decisions concerning the protection of our environment.

3.2.2 MODIS Snow and Sea Ice Global Mapping Project Objectives

Within this overall context, the objectives of the MODIS snow and ice team are to develop and implement algorithms that map snow and ice on a daily basis, and provide statistics of the extent and persistence of snow and ice over eight-day periods. Data at 500 m resolution enables sub-pixel snow mapping for use in regional and global climate models. A study of sub grid-scale snow-cover variability is expected to improve features of a model that simulates Earth radiation balance and land-surface hydrology.

3.2.3 Data Collection System

The MODIS sensor contains a system whereby visible light from the 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 created. 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.

3.2.4 Data Acquisition and Processing

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. For example, ground stations provide space to ground communication. The EOS Data and Operations System (EDOS) processes telemetry from EOS spacecraft and instruments to generate Level-0 products, and maintains a backup archive of Level-0 products. The MODIS Adaptive Processing System (MODAPS) is currently responsible for generation of Level-1A data from Level-0 instrument packet data. These data are then used to generate higher level MODIS data products. MODIS snow and ice products are archived at the NSIDC Distributed Active Archive Center (DAAC) and distributed to EOS investigators and other users via external networks and interfaces. Data are available to the public through a variety of interfaces.

3.3 Derivation Techniques and Algorithms

The MODIS science team is responsible for algorithm development. The MODAPS is responsible for product generation and transfer of products to NSIDC.

3.3.1 Processing Steps

In the MOD10C1 product, a binning algorithm maps MOD10A1 daily snow cover data at 500 m resolution into the corresponding cell of a 0.05 degree CMG and computes snow and cloud percentages, QA, and a confidence index based on the mapping results. The algorithm generates these parameters based on the total number of observations of a class (snow, cloud, land, and others) and the total number of land observations mapped into a cell of the CMG. The objective of the algorithm and output product is to provide the user with an estimate of snow cover observed in a CMG cell, an estimate of how much of the land surface was obscured by clouds, and an index that determines the confidence of the estimates.

The binning algorithm places the different classes of observations into categories for each class. The MODIS snow algorithm analyzed all land pixels to determine if snow was present during Level 2 processing. The snow algorithm processed only land pixels using the MOD03 land/water mask. A land bin sums all the observations made over land (snow, land, cloud, and others). This sum of land counts is the basis for expressing the percentage of snow, cloud, and the confidence index for each CMG cell.

A 0.05 degree land mask, derived from the University of Maryland's 1 km Global Land Cover product, is used with the binning algorithm. If a CMG cell contains 12 percent or greater land, then it is classified as land and analyzed. If a cell contains less than 12 percent land, it is classified as ocean. This threshold was selected to minimize snow errors along coasts while being sensitive enough to map snow along coasts.

Because Antarctica's surface is typically less than one percent snow-free, a value less than the global error rate for MODIS snow mapping, the algorithm classifies Antarctica as completely snow-covered. This also reduces confusion with cloud signatures (Riggs, Hall, and Salomonson 2006).

3.3.2 Error Sources

As with any upper level product, the characteristics of and/or anomalies in input data may carry through to the output data product. The following product is input to the algorithms used to create the MOD10C1 product:

- MOD10A1 - MODIS/Terra Snow Cover Daily L3 Global 500m Grid, Version 5

3.3.3 Quality Assessment

Quality indicators for MODIS snow data can be found in the following places:

- AutomaticQualityFlag and the ScienceQualityFlag metadata objects and their corresponding explanations: AutomaticQualityFlagExplanation and ScienceQualityFlagExplanation located in the CoreMetadata.0 global attributes
- Custom local attributes associated with each SDS, for example, snow cover
- Snow Spatial QA field.

These quality indicators are generated during production or in post-production scientific and quality checks of the data product. For more information on local and global attributes, go to one of the following links:

- MOD10C1 and MYD10C1 Global and Local Snow Cover Attributes, Version 5

The AutomaticQualityFlag is automatically set according to conditions for meeting data criteria in the snow mapping algorithm. In most cases, the flag is set to either Passed or Suspect, and in rare instances, it may be set to Failed. Suspect means that a significant percentage of the data were anomalous and that further analysis should be done to determine the source of anomalies. The AutomaticQualityFlagExplanation contains a brief message explaining the reason for the setting of the AutomaticQualityFlag. The ScienceQualityFlag and the ScienceQualityFlagExplanation maybe updated after production, either after an automated QA program is run or after the data product is inspected by a qualified snow scientist. Content and explanation of this flag are dynamic so it should always be examined if present in the external metadata file.

The algorithm tests for a variety of anomalous conditions and sets the pixel value accordingly if such conditions are detected. Summary statistics about missing data, the percent cloud cover, the percent of good or other quality data, and snow cover percent are calculated and placed in the metadata for each product.

The Snow Spatial QA data field provides additional information on algorithm results for each pixel within a spatial context, and is used as a measure of usefulness for snow-cover data. The QA information tells if algorithm results were nominal, abnormal, or if other defined conditions were encountered for a pixel.

The NASA Goddard Space Flight Center: MODIS Land Quality Assessment Web site provides updated quality information for each product.

3.4 Sensor or Instrument Description

3.4.1 Principles of Operation

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 a 705 km altitude 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, 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 wave-infrared, and long wave-infrared spectral regions.

3.4.2 Technical Specifications

Table 2. Technical Specifications

Orbit	705 km, 1:30 p.m. descending node (Terra), 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 x 1.6 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	Six years

3.4.3 Spectral Bands

For information on the 36 spectral bands provided by the MODIS instrument, see the MODIS Spectral Bands Table.

3.4.4 Sensor or Instrument Measurement Geometry

The MODIS scan mirror assembly uses a continuously rotating double-sided scan mirror to scan ±55 degree, with a 20.3 rpm. The viewing swath is 10 km along track at nadir, and 2330 km cross track at ±55 degree.

3.4.5 Manufacturer of Sensor or Instrument

MODIS instruments were built to NASA specifications by Santa Barbara Remote Sensing, a division of Raytheon Electronics Systems.

3.4.6 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 shortwave infrared bands. The Solar Diffuser Stability Monitor (SDSM) 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 (SRCA) 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.

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4.1 Related Data Collections

See MODIS Data | Data Sets for a complete list of MODIS snow and sea ice products available from NSIDC.

5 CONTACTS AND ACKNOWLEDGMENTS

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6 DOCUMENT INFORMATION

6.1 Publication Date

February 2004

6.2 Date Last Updated

October 2006