MODIS/Terra Snow Cover Monthly 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. 2015. *MODIS/Terra Snow Cover Monthly 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/MOD10CM.006. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/MOD10CM

National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

This data set is generated from Normalized Difference Snow Index (NDSI) snow cover. 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. Monthly averages for each CMG cell are calculated from the corresponding 28 – 31 days of observations in the MOD10C1 daily maximum snow cover extent data set. The input data are filtered to utilize only the clearest surface views in the average and to remove low magnitude snow cover fractions in the output that likely reflect erroneous snow detections.

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:

- MOD10CM.A2000061.006.2016063065826.hdf
- MOD[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
MOD	MODIS/Terra
PID	Product ID
A	Acquisition date follows
YYYY	Acquisition year
DDD	Day of year, first day of data month. See Table 2.
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

File names for this data set refer to calendar dates as a day of the year. The following table lists the first day of each of each month along with its corresponding day of the year, for both common (non-leap) and leap years:

Table 2. Day of year, First Day of Month for Common and Leap Years

Year Type	Jan 1	Feb 1	Mar 1	Apr 1	May 1	Jun 1	Jul 1	Aug 1	Sep 1	Oct 1	Nov 1	Dec 1
Common	001	032	060	091	121	152	182	213	244	274	305	335
Leap	001	032	061	092	122	153	183	214	245	275	306	336

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 1.3 MB.

1.4 Spatial Coverage

Coverage is global. Terra's sun-synchronous, near-polar circular orbit is timed to cross the equator from north to south (descending node) at approximately 10:30 A.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 Terra's orbital path:

- Daily Terra 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. Figure 1 shows the Geographical lat/lon projection known as Plate Carrée, which plots longitude and latitude degrees as coordinates on the x and y axes, respectively:

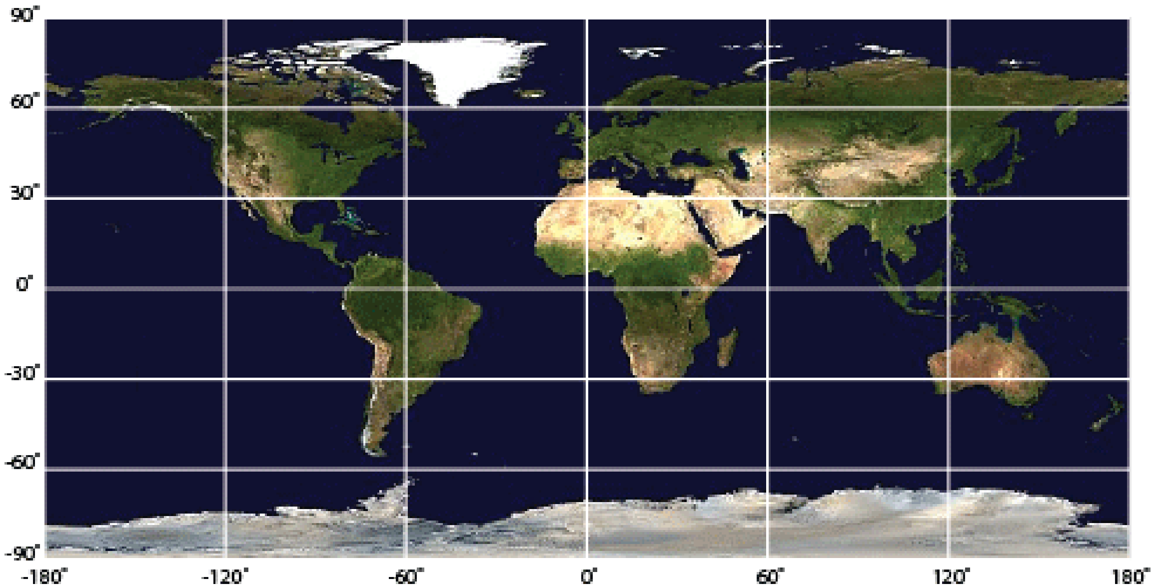

Figure 1. Plate Carrée projection. Longitude and latitude degrees are plotted on the x and y axes, respectively.

1.4.3 Grid

The MODIS CMG consists of 7200 columns by 3600 rows. Each cell has a resolution of 0.05 degrees (approximately 5 km). The upper-left corner of the upper-left cell is -180.00 degrees longitude, 90.00 degrees latitude. The lower-right corner of the lower right cell is -180.00 degrees longitude, -90.00 degrees 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 Information

MODIS Terra data are available from 24 February 2000 to present. 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 mission have resulted in minor data outages. If you cannot locate data for a particular date or time, check the MODIS/Terra Data Outages web page.

1.5.1 Temporal Resolution

Monthly

1.6 Parameters

Monthly average snow cover and basic QA 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 3. Scientific Data Sets and Descriptions

Scientific Data Set	Description
Snow_Cover_Monthly_CMG	Monthly average snow cover percentage plus other results. Possible values are: 0–100: snow cover percentage 211: night 250: cloud 253: no decision 254: water mask 255: fill Note: Antarctica deliberately mapped as snow. Snow cover percentage set to 100.
Snow_Spatial_QA	Basic QA plus other results. QA = good or other quality. Possible values are: 0: good quality 1: other quality 252: Antarctica mask 254: water mask 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.
- 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.
- NSIDC's Hierarchical Data Format | Earth Observing System (HDF-EOS) web page contains information about HDF-EOS, plus tools to extract binary and ASCII objects, instructions to uncompress and geolocate HDF-EOS data files, and links to obtain additional HDF-EOS resources.

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
- NASA Terra | The EOS Flagship
- 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 MOD10CM, C6

3.4 Derivation Techniques and Algorithms

3.4.1 Processing Steps

Average snow cover is calculated using the clearest views of the surface from the 28 – 31 days of MOD10C1 observations for the month. To screen for cloudiness, the algorithm reads each daily observation's corresponding Clear Index (CI)—the percentage of clear-sky, 500 m observations used to estimate snow cover in the CMG cell—and excludes those with a CI < 70. Monthly average snow cover is only computed for cells which have at least one daily observation with a CI ≥ 70. Cells which fail this restriction are reported as no decision.

Daily observations with CI ≥ 70 contribute to the monthly average as follows:

```
Daily contribution to monthly average =
(100/CI) * observed snow percentage
```

Examining this equation, if a daily observation was completely unobscured by clouds (CI = 100), its contribution to the monthly mean equals its observed snow cover percentage. For daily observations that were partially obscured by clouds (70 ≤ CI < 100), the contribution is scaled by a factor of 100/CI, or a value between 1 and approximately 1.43. This approach assumes that the presence of clouds obscures some fraction of a cell's snow cover and thus its contribution should be increased proportionally.

For example, the contribution of a cell with 25 percent snow cover and CI = 75 would be:

```
Daily contribution to monthly average = (100/75) * 25% = 33%
```

After the monthly average is computed, a second filter is applied to identify cells whose averages were derived predominantly from daily observations below 10 percent. These low magnitude snow cover fractions often reflect erroneous snow detections in the MOD10_L2 swath-level data set that propagate downstream through the other products in MODIS snow cover collection. As such, this filter sets a cell to 0 percent snow cover for the month if its average, non-zero daily snow cover fraction < 10%.

For example, for a cell that has 20, CI = 100 days, 10 with 100 percent snow cover and 10 with no snow, the monthly average snow cover would be:

```
Monthly snow cover = (10*100 + 10*0) ÷ 20 = 50%
```

The second filter would be then be applied as follows:

```
Average daily snow cover percentage = (days with snow * snow percentage)
÷ days with snow

Average daily snow cover percentage = (10*100) ÷ 10 = 100%
```

The monthly average in this cell would be retained because its average daily contribution was > 10 percent. However, given a cell that has 20 days with CI = 100, 10 of which have 5 percent snow and 10 which have 0 percent, the second filter would return:

```
Average daily snow cover percentage = (10*5) ÷ 10 = 5%
```

In this case, the cell's monthly snow cover would be set to 0 percent because it's average non-zero daily snow cover percentage was 5 percent.

Antarctica has been masked as 100 percent 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 MOD10_L2 data set offers a higher resolution and contains more data and information about accuracy and error.

Minimal QA is applied to this data set. By default, the QA is set to good quality and only changed if all the input data are bad.

3.4.2 Version History

See the MODIS web page 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 percent to 93 percent. Snow errors are ultimately propagated from the first data set in the MODIS snow suite of products, MOD10_L2, into MOD10A1, MOD10C1, and then this data set. For more detail about potential error sources in the input data, see the Derivation Techniques and Algorithms section in the MOD10_L2 documentation and the MODIS Snow Products Collection 6 User Guide.

Based on visual and qualitative analysis, these data appear to reasonably represent mean monthly snow cover when compared with other sources that produce global and regional monthly snow maps. However, notable spurious snow cover has been observed in places without snow, likely the result of compounding daily snow commission errors over the course of a month. Alternately, these errors may in certain situations indicate anomalous surface conditions or recurring confusion between snow and clouds. Users may opt to reduce likely snow commission errors by screening out low snow cover percentages at a value of their choosing or choose to interpret the data in other ways that relate to their specific research interest. Although these data are currently validated at Stage 1, their maturity level may change in the future based on further evaluation and analysis.

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 4 contains the instruments' technical specifications:

Table 4. MODIS Technical Specifications

Variable	Description
Orbit	705 km altitude, 10:30 A.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 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

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4.1.1 Published Research

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

4.1.2 Related Data Sets

- MODIS/Terra Snow Cover Daily L3 Global 0.05Deg CMG, Version 6 (MOD10C1)
- MODIS/Aqua Snow Cover Monthly L3 Global 0.05Deg CMG, Version 6 (MYD10CM)
- MODIS/Terra Snow Cover 5-Min L2 Swath 500m, Version 6 (MOD10_L2)
- MODIS Data Sets @ NSIDC

4.1.3 Related Websites

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

5 CONTACTS AND ACKNOWLEDGMENTS

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6 DOCUMENT INFORMATION

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