MODIS/Terra Snow Cover Monthly L3 Global 0.05Deg CMG, Version 61

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. 2021. *MODIS/Terra Snow Cover Monthly L3 Global 0.05Deg CMG, Version 61*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/MODIS/MOD10CM.061. [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

TABLE OF CONTENTS

1 DATA DESCRIPTION

This global data set is generated by compositing 28-31 days of MOD10C1 daily observations on the 0.05° MODIS CMG. Snow cover is detected using the Normalized Difference Snow Index (NDSI) in a preceding product (MOD10_L2), which is ultimately carried forward to this product. 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. The Scientific Data Sets (SDSs) included with this product are described in Table 1 and a sample image of the data is shown in Figure 1.

The terms “Version 61” and “Collection 6.1” are used interchangeably in reference to this release of MODIS data.

1.1 Parameters

Table 1. SDS Details

Parameter	Description	Values
`Snow_Cover_Monthly_CMG`	Monthly mean snow cover percentage per CMG.	0-100: percent of snow in cell 211: night 250: cloud 253: no decision 254: water mask 255: fill
`Snow_Spatial_QA`	Basic quality assurance indicator.	0: good quality 1: other quality 252: Antarctica mask 254: water mask 255: fil
`Lat`	Upper left X coordinate for each grid cell in degrees north.	Coordinate value range: 90.0º to - 90.0º
`Lon`	Upper left Y coordinate for each grid cell in degrees east.	Coordinate value range: -180.0º to 180.0º

1.2 Sample Data File

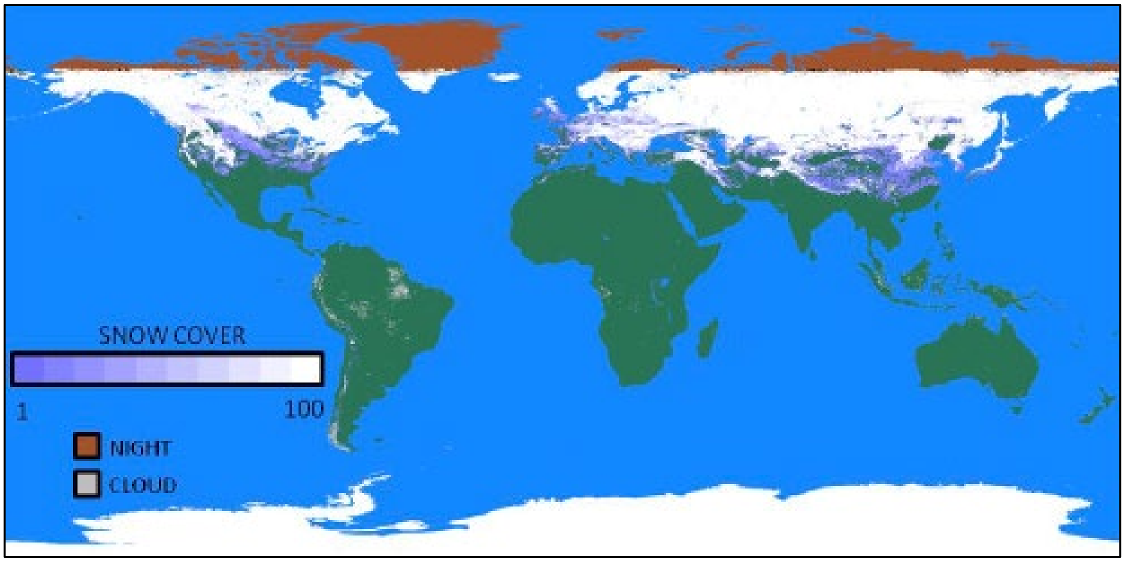

Figure 1. This figure shows MOD10CM monthly mean snow cover mapped to a CMG, for January 2003.

1.3 File Information

1.3.1 File Format

Data are provided in HDF-EOS2 format and are stored as 8-bit unsigned integers. For software and more information, visit the HDF-EOS website.

1.3.2 File Contents

As shown in Figure 2, each data file includes one data field (`Snow_Cover_Monthly_CMG`), one data quality field (`Snow_Spatial_QA`), two geolocation fields (`Lat` and `Lon`), and three metadata fields (`ArchiveMetadata.0`, `CoreMetadata.0`, and `StructMetadata.0`).

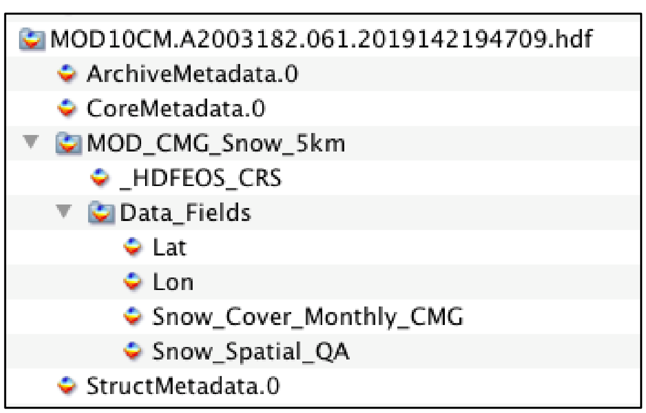

Figure 2. This figure shows the fields included in each data file as displayed with Panoply software.

1.3.3 Ancillary Files

A browse image file (`.jpg`) and metadata file (`.xml`) are provided with each data file.

1.3.4 Naming Convention

Files are named according to the following convention and as described in Table 2.

File naming convention:

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

Table 2. File Name Variables

MOD	MODIS/Terra
PID	Product ID
A	Acquisition date follows
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

File name example

`MOD10CM.A2003182.061.2019142194709.hdf`

File names for this data set refer to calendar dates as a day of the year. Table 3 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 3. 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.

1.4 Spatial Information

1.4.1 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)

1.4.2 Projection

MODIS CMG data sets are provided in geographic latitude/longitude coordinates. For additional details about the MODIS CMG see the NASA MODIS Lands | MODIS Grids web page.

1.4.3 Resolution

0.05°

1.4.4 Geolocation

The following tables provide information for geolocating this data set.

Table 4. Projection Details

Region	Global
Geographic coordinate system	WGS84
Projected coordinate system	Geographic Lat/Lon
Longitude of true origin	0°
Latitude of true origin	0°
Scale factor at longitude of true origin	1.0
Datum	WGS 84
Ellipsoid/spheroid	WGS 84
Units	degrees
False easting	0°
False northing	0°
EPSG code	4326
PROJ4 string	+proj=longlat +datum=WGS84 +no_defs
Reference	https://epsg.io/4326

Table 5. Grid Details

Region	Global
Grid cell size (x, y pixel dimensions)	0.05°
Number of rows	3600
Number of columns	7200
Nominal gridded resolution	0.05°
Grid rotation	N/A
Geolocated upper left point in grid	-180.0°(x), 90.0°(y)
Geolocated lower right point in grid	180.0°(x), -90.0°(y)

1.5 Temporal Information

1.5.1 Coverage

This data is available from 1 March 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 Terra 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.

1.5.2 Resolution

Monthly

2 DATA ACQUISITION AND PROCESSING

2.1 Background

This data set provides monthly average maps of global snow cover extent. Monthly averages for each CMG cell are calculated using 28 – 31 days of MOD10C1 observations. The input data are filtered to utilize only the clearest surface views and to remove low magnitude snow cover fractions that likely reflect erroneous snow detections. These filters ensure that only the most relevant days of snow cover are used to calculate the monthly average.

2.2 Acquisition

MODIS scans the entire globe every one to two days. As such, most locations on Earth are imaged at least once per day and more frequently where swaths overlap, such as near the poles. Terra's sun-synchronous, near-circular polar orbit is timed to cross the equator from north to south (descending node) at approximately 10:30 A.M. local time.

Ongoing changes in the Terra orbit
The Terra flight operations team conducted Terra’s last inclination adjust maneuver to maintain Terra’s orbit in February 2020. The inclination adjust maneuvers were used to control the platform’s 10:30 AM mean local time (MLT) equator crossing. Terra will continue to drift and is expected to reach a 10:15 AM MLT in October 2022. At that time, the flight operations team will have Terra exit the Earth Sciences Constellation and lower Terra to an altitude of 694 km by performing two retrograde maneuvers. MLT will continue to drift after these maneuvers, reaching 9:00 AM around December 2025. Terra MODIS will remain operational and generate the full suite of products until the end of the mission in December 2025.
Earlier crossing times for a morning platform like Terra mean lower solar elevations leading to more prevalent shadows. This decrease in orbit altitude alters the spatial coverage of the sensor including possible gaps in spatial sampling, decreased spatial coverage, and higher spatial resolution. Products are mostly expected to be science quality except for reduced grid size (from lower altitude) and without a strict 16-day repeat of observations (from drift and changing orbit).
Details on the impact of the Constellation Exit on the quality of the product are being compiled and will be posted when available.

2.3 Sources

Table 6 lists the data set and parameter inputs to the MODIS CMG binning algorithm.

Table 6. Inputs to the MOD10C1 CMG Binning Algorithm

Product ID	Long Name	Parameter
MOD10C1	MODIS/Terra Snow Cover Daily L3 Global 0.05Deg CMG, Version 61	Day_CMG_Snow_Cover Day_CMG_Cloud_Obscured Day_CMG_Clear_Index

2.4 Processing

The MOD10CM algorithm calculates the monthly mean snow cover percentage for CMG cells. The processing steps are described below.

1. Filter for cloudiness.

Monthly mean snow cover is calculated using the clearest views of the surface from 28 – 31 days of MOD10C1 observations. To screen for cloudiness, the algorithm reads the Clear Index (CI) for each daily observation and excludes observations with a CI ≤ 70. There must be at least one day in the month for each cell with the CI > 70 for the mean snow cover to be computed for that cell.

2. Calculate the daily contribution to the monthly mean snow cover percentage.

The daily snow contribution to the monthly mean snow-cover percent, for cloud free observations, is the grid cell value from the input MOD10C1 'Day_CMG_Snow_Cover' array. However, for daily observations of mixed snow and cloud (70 < CI < 100) the contribution to the monthly mean will be greater than the daily snow observation as follows.

$$Daily\ contribution\ to\ monthly\ mean = \left({}^{100}/_{CI}\right) * observed\ snow\ \%$$

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. Daily observations with a CI ≤ 70 are assigned as 'cloud', 'night', or 'no decision'.

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

$$Daily\ contribution\ to\ monthly\ mean = \left({}^{100}/_{75}\right) * 25\% = 33\%$$

3. Calculate the monthly mean snow cover percentage.

The formula below shows how the monthly mean snow cover percentage is calculated from two groups of valid observation days. As stated above (process step 1) the algorithm filters for cloudiness by only considering observations from days with a CI > 70. In the formula below, valid observation days (CI > 70) are expressed as ‘obs days.’

$$Monthly\ mean\ Snow\ Cover\ \% = \frac{obs\ days_i * snow\ \%_i + obs\ days_j * snow\ \%_j}{obs\ days}$$

For example, consider a cell that has 20 observations (days) with a CI of 100, 10 days with 100% snow and 10 days with 0% snow. Given this scenario the monthly average snow cover would be:

$$Monthly\ mean\ Snow\ Cover\ \% = \frac{10 * 100 + 10 * 0}{20} = 50\%$$

4. Filter out low magnitude snow cover.

After the monthly average is computed, a low magnitude 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 MOD10_L2 which propagate downstream through the MODIS snow cover products. As such, this filter sets a cell to 0 percent snow cover for the month if its average, non-zero daily snow cover fraction is < 10 percent.

The low magnitude filter is calculated as follows:

$$Average\ daily\ Snow\ Cover\ \% = \frac{days\ with\ snow * snow\ \%}{days\ with\ snow}$$

Given the example from step 3; where a cell has 20 observations (days) with a CI of 100, 10 days with 100% snow and 10 days with 0% snow.

$$Average\ daily\ Snow\ Cover\ \% = \frac{10 * 100}{10} = 100\%$$

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 a CI of 100, 10 days with 5% snow and 10 days with 0% snow.

$$Average\ daily\ Snow\ Cover\ \% = \frac{10 * 5}{10} = 5\%$$

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 < 10 percent.

Note: To improve the visual quality of the data, Antarctica has been mapped as 100% snow. As such, this data set should not be used to map snow in Antarctica. For users who wish to evaluate Antarctica, the MOD10_L2 data set offers higher resolution and contains more data and information about accuracy and error.

2.5 Quality Information

The 'Snow Spatial QA' data array provides a quality indicator based on the final snow value for a cell. If the final snow value is in the valid_range (0-100), the cell value is set to 'good'. If the final snow value is not in the valid range and is not one of the mask values, the cell value is set to 'other'.

2.6 Accuracy

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.

2.7 Errors

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 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 by choosing 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.

2.8 Instrumentation

2.8.1 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 five refractive objective assemblies, one each for the visible, near-infrared, shortwave infrared, middle-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 7 contains the instruments' technical specifications.

Table 7. 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

2.8.2 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.

3 VERSION HISTORY

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

4 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
- MODIS Land Discipline Group (MODLAND) Tile Calculator
- Tile Bounding Coordinates for the MODIS Sinusoidal Grid

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.

5 RELATED WEBSITES

The following resources provide additional information about MODIS Version 6.1 data, including known problems, production schedules, and future plans:

- The MODIS Snow and Sea Ice Global Mapping Project
- NASA LDOPE | MODIS/VIIRS Land Product Quality Assessment
- MODIS Land Team Validation | Status for Snow Cover/Sea Ice (MOD10/29)

6 CONTACTS AND ACKNOWLEDGMENTS

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7 REFERENCES

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Riggs, G.A., Hall, D.K. and Roman, M.O. 2015. VIIRS Snow Cover Algorithm Theoretical Basis Document (ATBD). NASA Goddard Space Flight Center, Greenbelt, MD. (See PDF)

Riggs, G.A., Hall, D.K. and Roman, M.O. 2019. MODIS Snow Products Collection 6.1 User Guide. NASA Goddard Space Flight Center, Greenbelt, MD. (See PDF)

8 DOCUMENT INFORMATION

8.1 Publication Date

March 2021

8.2 Date Last Updated

December 2021