MODIS/Terra Snow Cover Daily 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 Daily 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/MOD10C1.061. [Date Accessed].

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

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

National Snow and Ice Data Center

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1 DATA DESCRIPTION

This global data set is produced by mapping daily MOD10A1 tiles to the MODIS Climate Modeling Grid (CMG). MOD10A1 observations at 500 m are mapped into 0.05° CMG (~ 5 km) grid cells, binned by observation type (e.g. snow, cloud, ocean), and counted to identify the most frequently occurring feature type. 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 in 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
`Day_CMG_Snow_Cover`	The percentage of snow-covered land mapped in the CMG cell.	0-100: percent of snow in cell 107: lake ice 111: night 237: inland water 239: ocean 250: cloud obscured water 253: data not mapped 255: fill
`Day_CMG_Cloud_Obscured`	The percentage of cloud-covered land mapped in the CMG cell.	0-100: percent of cloud in cell 107: lake ice 111: night 237: inland water 239: ocean 250: cloud obscured water 252: Antarctica mask 253: data not mapped 255: fill

Parameter	Description	Values
Day_CMG_Clear_Index	Percentage of clear-sky land observations mapped in the CMG cell.	0-100: clear index value 107: lake ice 111: night 237: inland water 239: ocean 250: cloud obscured water 253: data not mapped 255: fill
Snow_Spatial_QA	Basic quality assurance indicator.	0: best 1: good 2: ok 3: poor 4: other 237: inland water 239: ocean 250: cloud obscured water 252: Antarctica mask 253: not mapped 254: no retrieval 255: fill
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 Image

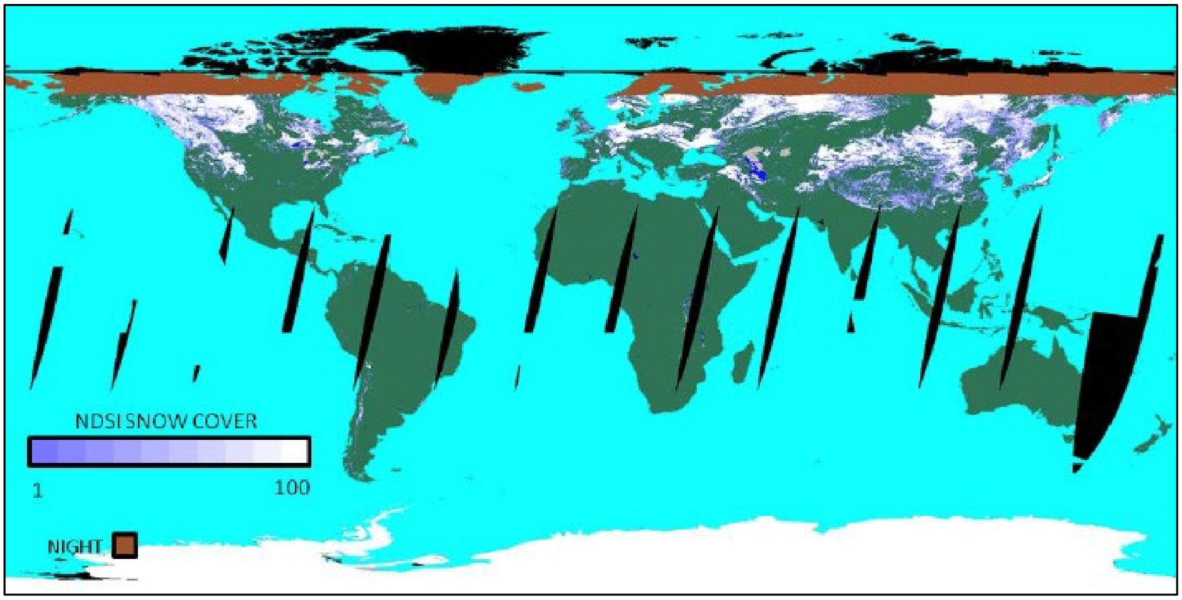

Figure 1. This MOD10C1 snow map shows the percent of snow cover mapped to a 0.05° CMG (approx. 5 km). The data was acquired 9 January 2003.

1.3 File Information

1.3.1 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 Data File

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

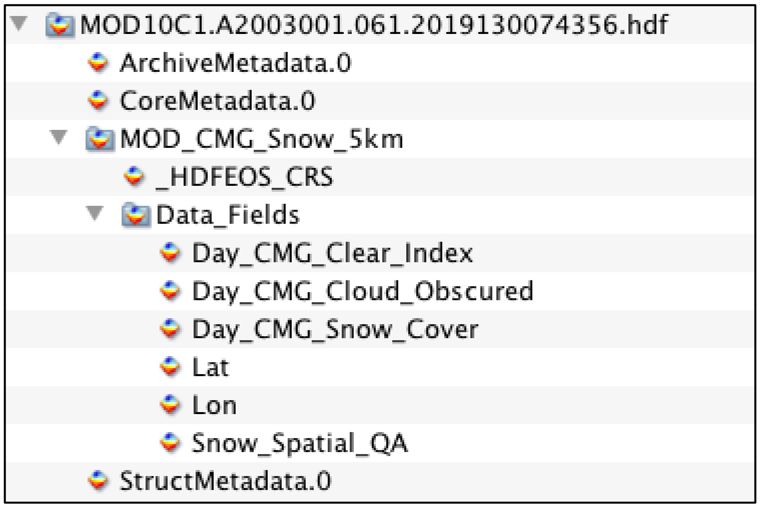

Figure 2. This figure shows the fields included in each data file as displayed with Panoply software.

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

`MOD10C1.A2003001.061.2019130074356.hdf`

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 3. 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 4. 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

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 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

Daily

2 DATA ACQUISITION AND PROCESSING

2.1 Background

This data set provides daily global maps of the snow cover extent, cloud cover extent, and clear index extent. Snow cover extent and cloud cover extent are provided as the percentage of snow-covered land or cloud-covered land mapped in the CMG cell. The clear index extent is provided as the percentage of all land observations in the cell that were clear, thus producing an estimate of the amount of land surface that was observable.

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

Table 5. Inputs to the MOD10C1 CMG Binning Algorithm

Product ID	Long Name	Parameters
MOD10A1	MODIS/Terra Snow Cover Daily L3 Global 500m SIN Grid, Version 6.1	NDSI_Snow_Cover NDSI_Snow_Cover_Algorithm_Flags_QA NDSI_Snow_Cover_Basic_QA

2.4 Processing

The MOD10C1 CMG binning algorithm is used to calculate the snow cover extent, cloud cover extent, and associated quality values mapped to CMG grid cells. The algorithm maps 500 m MOD10A1 'NDSI_Snow_Cover' observations into 0.05° (approx. 5 km) CMG cells. Approximately, 100 MOD10A1 'NDSI_Snow_Cover' observations are mapped into each CMG cell. The mapped observations are binned by feature type (snow, cloud, night, ocean, etc.) and counted to identify the most frequently occurring feature type in the CMG cell. The observation counts are then used to determine the feature type assigned to the CMG cell. Specific details are provided below.

2.4.1 Snow Cover Extent

The percent of snow cover mapped to each CMG cell is calculated by computing the ratio of MOD10A1, 500 m snow cover observations to the total number of land observations that were mapped into the CMG cell. To assist with counting, the binning algorithm converts NDSI snow cover values to a binary snow/no snow flag, with NDSI > 0 indicating the presence of at least some snow. The result is expressed as the percentage of snow observations mapped in the CMG cell. The valid range of snow cover extent is 0-100%.

2.4.2 Cloud Cover Extent

The percent of cloud cover mapped to each CMG cell is calculated by computing the ratio of MOD10A1, 500 m cloud cover observations to the total number of land observations that were mapped into the CMG cell. The result is expressed as the percentage of cloud observations mapped in the CMG cell. The valid range of cloud cover extent is 0-100%.

2.4.3 Clear Index Extent

The clear index reports the fraction of all land observations in the cell that were observed under clear sky conditions. 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 the cell's snow cover value. A high clear index 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.

2.4.4 Inland Water

Inland water bodies are identified using the inland water bit flag in the MOD10A1 'NDSI_Snow_Cover_Algorithm_Flags_QA' array. The number of water body observations in a CMG grid cell are counted and tallied. If the water body has more lake ice observations than open water observations it is interpreted as lake ice. In the output data arrays, pixels with inland water are assigned a value '237', pixels with lake ice are assigned a value '107', and cloud obscured lakes are assigned a value of '250'.

2.4.5 Ocean

A CMG-specific land mask was made for use with the binning algorithm. The 0.05° land mask was derived from the University of Maryland 1km global land cover data set. If a CMG cell contains 12% or greater land then it is considered land and analyzed; if less than 12% it is considered ocean. This threshold was selected as a balance that minimized snow errors along coasts yet was sensitive to mapping snow along coasts.

2.4.6 Night

The 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.

2.4.7 Antarctica

To improve the visual quality of data, Antarctica has been masked as 100% snow covered using the MODIS land/water mask. 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.

2.4.8 Global Mask

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 MOD10_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.

2.5 Quality Information

The 'Snow_Spatial_QA' parameter contains quality assurance (QA) values mapped from the MOD10A1 'NDSI_Snow_Cover_Basic_QA' field. These values provide a qualitative estimate of the algorithm result, for each pixel, based on the input data and solar zenith data. The QA value applied to a CMG cell is the most frequently occurring MOD10A1 'NDSI_Snow_Cover_Basic_QA' value mapped into the cell. The binning algorithm returns the most frequent QA value for each CMG cell, and if there is a QA value tie, the highest QA value of the tied values is reported in the 'Snow_Spatial_QA' SDS. For a detailed description of the QA values, see the MOD10A1 user guide.

2.6 Errors

NDSI 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%. Snow commission errors (detecting snow where there is no snow) 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.

To reduce erroneous snow cover detections in regions of the world that climatologically should never have snow, a global 'snow impossible' mask is applied in the algorithm. This mask improves the synoptic quality of the data set, but at the expense of not detecting highly unusual snowfall. If a highly unusual snowfall event occurs, the MOD10_L2 and MOD10A1 products should be used to investigate the event.

Snow errors are ultimately propagated from MOD10_L2 to MOD10A1 and then into this data set. For additional details, regarding potential error sources in the input data, see the 'MODIS Snow Products Collection 6.1 User Guide' (Riggs et al. 2019).

2.7 Instrumentation

2.7.1 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 6 contains the instruments' technical specifications.

Table 6. 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

2.7.2 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