MODIS/Terra Snow Cover Daily L3 Global 500m Grid, 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 500m SIN Grid, Version 5*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/63NQASRDPDB0. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/mod10a1

National Snow and Ice Data Center

TABLE OF CONTENTS

1 DETAILED DATA DESCRIPTION

This data set contains snow cover, snow albedo, fractional snow cover, and Quality Assessment (QA) data in compressed Hierarchical Data Format-Earth Observing System (HDF-EOS) format along with corresponding metadata. MOD10A1 consists of 1200 km by 1200 km tiles of 500 m resolution data gridded in a sinusoidal map projection. The Moderate Resolution Imaging Spectroradiometer (MODIS) snow cover data are based on a snow mapping algorithm that employs a Normalized Difference Snow Index (NDSI) and other criteria tests. New in V005 is fractional snow cover, where the percent snow cover is estimated on a pixel by pixel basis. The snow albedo data array added in Version 4 (V004) continues with a provisional status.

Please visit the following sites for more information about the V005 data, known data problems, the production schedules, 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

This data set is retired and no longer available for download. The most up-to-date version of this data can be accessed on the NSIDC website here.

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 the Software and Tools section 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.

MOD10A1 consists of 2400 x 2400 cells of tiled data in a sinusoidal projection. Each data granule contains the following HDF-EOS local attribute fields, which are stored with their associated Scientific Data Set (SDS):

- Snow Cover Daily Tile Field
- Snow Albedo Daily Tile Field
- Snow Spatial QA Field
- Fractional Snow Cover Field

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

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 following file naming convention is common to all Level 3 MODIS Land products:
`MOD10A1.A2003141.h03v06.005.2006.143091104.hdf`

Refer to the following table 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
10A1	Type of product
A	Acquisition date
2003	Year of data acquisition
141	Day of year of data acquisition (day 141)
h03v06	Horizontal tile number and vertical tile number. See the MODIS Sinusoidal Grid (SIN) as a reference.
005	Version number

Variable	Explanation
2006	Year of production (2006)
143	Day of year of production (day 143)
091104	Hour/minute/second of production in Greenwich Mean Time (GMT) (09:11:04)
hdf	HDF-EOS data format

1.3 File Size

Data files are typically between 0.8 - 7.6 MB using HDF compression.

New in V005, MOD10A1 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 five or more.

1.4 Spatial Coverage

Coverage is global, but only tiles over land are produced for MOD10A1. The following resources can help you select and work with MOD10A1 tiles:

- MODIS Tile Bounding Coordinates for the MODIS SIN
- MODIS MODLAND Tile Calculator
- HDF-EOS to GeoTIFF Conversion Tool (HEG)
- Hierarchical Data Format - Earth Observing System (HDF-EOS): Geolocating HDF-EOS Data

1.4.1 Latitude Crossing Times

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

1.4.2 Spatial Resolution

Gridded resolution is 500 m.

1.4.3 Projection and Grid Description

1.4.3.1 Projection

MOD10A1 V005 data are georeferenced to an equal-area sinusoidal projection. The following Web sites provide links to the software tools that either read data in a sinusoidal projection or convert sinusoidal to other projections:

- Earth Observing System Data and Information System (EOSDIS) Core System Project: Science Data Processing Toolkit Home Page
- LP DAAC: MODIS Reprojection Tool Distribution Page
- HEG HDF-EOS to GeoTIFF Conversion Tool

In the sinusoidal projection, areas on the data grids are proportional to the same areas on the Earth, and distances are correct along all parallels and the central meridian. Shapes are increasingly distorted away from the central meridian and near the poles. Finally, the data are neither conformal, perspective, nor equidistant.

Meridians are represented by sinusoidal curves except for the central meridian, and parallels are represented by straight lines. The central meridian and parallels are straight lines of true scale. Specific parameters are listed in Table 2:

Table 2. Sinusoidal Projection Parameters

Earth radius	6371007.181000 meters
Projection origin	0° latitude, 0° longitude
Orientation	0° longitude, oriented vertically at top
Upper left corner point (m)	-20015109.354(x), 10007554.677(y)
Lower right corner point (m)	20015109.354(x), -10007554.677(y)
True scale (m)	463.31271653(x), 463.31271653(y)

1.4.3.2 Grid

The MOD10A1 daily product is gridded in equal area tiles. Each tile consists of a 1200 km by 1200 km data array, which corresponds to 2400 by 2400 pixels at 500 m resolution. Although this product is referred to as having a 500 m grid, the true pixel resolution is 463.31271653 m in both X and Y directions. This allows for 2400 pixel by 2400 pixel tiles, each tile covering exactly 10 degrees of latitude vertically.

The MODIS MODLAND Tile Calculator converts between MODIS tile image/coordinates or map coordinates in meters and latitude/longitude coordinates.

1.5 Temporal Coverage

Data extend from 24 February 2000 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 cannot 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 classifies pixels as snow, snow-covered lake ice, cloud, water, land, or other. Snow extent, fractional snow cover, and snow albedo are the primary variables of interest in this data set.

1.6.2 Parameter Range

Refer to the MOD10A1 and MYD10A1 Local Snow Cover Attributes document for a key to the meaning of the coded integer values in the Snow Cover Daily Tile Field, the Fractional Snow Cover Field , and the Snow Albedo Daily Tile 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 Land Global Browse Images
- MODIS: MODLAND Tile Calculator

2.2 Data Analysis Tools

- Land Processes Distributive Active Archive Center: MODIS Reprojection Tool: Software tools that reproject MODIS data to other projections.
- HDF-EOS to GeoTIFF Conversion Tool (HEG): 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 (mosaicking), and metadata 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 ENVI plugin (available as of 08/04/2016 via GitHub) 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

MOD10A1 V005 data granules include a snow albedo data array. Albedo refers to the percentage of incident solar radiation reflected back by an object. The albedo measured by MODIS is specifically termed a directional-hemispheric reflectance as the incident irradiance is considered a directional collimated beam, and the reflected radiance is integrated over the upward hemisphere.

Snow albedo is an important parameter for understanding global energy-balance as well as local- and basin-scale snow melt runoff. Four conversions are needed in order to derive broadband albedo from satellite measurements:

- Satellite sensor calibration
- Correction for atmospheric effects
- Correction for surface effects including slope, solar aspect, and reflectance anisotropy
- Conversion to a spectrally integrated albedo (Klein and Stroeve 2002).

For more information regarding the theory for snow mapping and fractional snow cover, please see “Section 3.1 | Theory of Measurements” 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, the flagship 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, including MOD10A1. 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. MODAPS is responsible for product generation and transfer of products to NSIDC.

3.3.1 Processing Steps

Please see "Section 3.3.1 | Processing Steps" in the MODIS/Terra Snow Cover 5-Min L2 Swath 500m, V005 guide document for a discussion of the processing steps used to generate the MOD10_L2 product. A day's worth of MOD10_L2 data is processed into a single MOD10_L2G product for each day by mapping each pixel in each MOD10_L2 swath to a grid all in the MODIS sinusoidal map projections. Thus, the MOD10_L2G product is not archived, but is used as the input to MOD10A1 processing.

In MOD10A1, a daily snow cover map is constructed by examining the multiple observations acquired for a day that are mapped to each grid cell. For V005 data, a scoring algorithm based on pixel location, distance from nadir, area of coverage in a grid cell, and solar elevation, selects an observation for the day. The object of scoring is to select the observation nearest to nadir with greatest coverage at the highest solar elevation that was mapped into the grid cell (Riggs, Hall, and Salomonson 2006). The scoring algorithm is represented by the following equation:

score = 0.5 * (solar elevation) + 0.3 * (distance from nadir) + 0.2 * (observation coverage)

Results of the snow cover algorithm are used to create a daily snow map, and are stored in the Snow Cover Daily Tile Field. The corresponding fractional snow cover observation is stored in the Fractional Snow Cover field. Gridded snow cover data are stored as coded integer values with values being the same as assigned for MOD10_L2.

3.3.2 Snow Albedo

The prototype MODIS snow albedo algorithm for MOD10A1 V005 granules is described in detail in (Klein and Stroeve 2002) and (Klein 2003). The observation selected by the scoring algorithm described above is used by the albedo algorithm for a cell. Albedo is calculated only for areas identified as cloud-free by the MODIS cloud mask and as snow-covered by the MODIS snow algorithm. If the pixel meets these criteria, atmospherically corrected surface reflectances are retrieved from the MODIS/Terra Surface Reflectance Daily L2G Global 500m SIN Grid product, available from the LP DAAC (Klein and Stroeve 2002). Land cover type, retrieved from the MODIS/Terra Land Cover Type Yearly L3 Global 500 m SIN Grid is also available from the LP DAAC (Klein and Stroeve 2002), and is used to correct non-forested pixels for the anisotropic reflectance of snow using a static Anisotropic Response Function (ARF).

3.3.3 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 products are input to the algorithms used to create the MOD10A1 product:

Note: NSIDC does not archive or distribute the following products, and does not maintain the links to these products. Thus, if a link does not work, please contact the MODAPS or the LP DAAC.

- MOD10L2G Land Level 2G Snow Cover, Version 5
- MODMGGAD - Geolocation Angles Daily L2G Global 1km Day, Version 5
- MODPTHKM - MODIS/Terra Observation Pointers Daily L2G Global 500m SIN Grid, Version 5
- MOD09GHK - Surface Reflectance Daily L2G Global 500m, Version 5
- MOD12Q1 - MODIS/Terra Land Cover Type Yearly L3 Global 1km SIN Grid, Version 5
- GTOPO30 Global 30-Arc Second Digital Elevation Data Set

The Snow Albedo Daily Tile Field Local Attribute was released as a beta product in V004 data, and it progressed to a status of provisional in V005 data. Validation and evaluation of the snow albedo is ongoing and is estimated to be within 10 percent of surface measured snow albedo based on studies in the literature. However, those estimates are based on best conditions for the algorithm. Where it is difficult to calculate snow albedo, such as in steep mountainous terrain, the error in calculated albedo is likely to be large.

Snow albedo retrieved from MODIS is sensitive to a variety of atmospheric effects such as errors in modeling the ARFs used to correct the MODIS reflectances into a hemispheric albedo, and the conversion from narrow-band albedos to a broadband albedo (0.3 - 3.0 microns). In terms of atmospheric effects, excluding clouds, uncertainties in atmospheric aerosols have the largest impact on derivation of surface albedo from visible and near infrared satellite observations and (Greuell and Oerlemans 2005). Since it is impossible to retrieve aerosols over bright surfaces such as snow and ice, climatologies of aerosols are used in the polar regions. In the MODIS atmospheric correction for snow-covered and ice-covered regions, the aerosol optical depth at 550 nm is set at 0.05. However, there are many locations and times of the year that the aerosol optical depth exceeds this value. Thus, for pixels with viewing angles less than 50 degrees, variation in aerosol optical depth impacts the albedo by less than 0.01. For viewing angles greater than 50 degrees, the impact will be larger; however, it is not clear as to how large (Greuell and Oerlemans 2005).

Erroneous albedo values also occur wherever clear-sky conditions are misidentified. However, in general, the MODIS cloud mask is conservative, classifying clear sky pixels as cloudy. In the ARF conversion, the model assumes a constant snow grain size of 250 microns and ignores diffuse sky radiation assuming only direct radiation (Klein and Stroeve 2002). The ARFs under real sky conditions are slightly different depending on the ratio of direct to diffuse sky radiation, and it is a potential error source in the ARF values used in the derivation of the albedo. Another potential error source is the fact that snow grain size is variable, and different ARFs are needed depending on how fine or coarse the snow grain size is. Thus, fine-grain snow has a small backscattering peak at viewing angles of 50 degrees, whereas medium snow grain sizes do not. The narrow-to-broadband conversion also depends on atmospheric effects, and may not be suitable for atmospheric conditions different from the assumptions used in developing the narrow-to-broadband conversion model (Painter and Dozier 2004). Finally, accurate instrument calibration is essential in order to provide high-quality scientific data sets. There are uncertainties in MODIS albedo as a result of calibration problems, around two percent for the MODIS instrument based on comparisons made using data in Greenland (Greuell and Oerlemans 2005), which is similar to that reported by (Justice 2002).

The snow albedo product in MOD10A1 and MYD10A1 is subject to a different land/water mask mismatch. The albedo algorithm requires as input a global Digital Elevation Model (DEM) from which slopes and aspects are computed. The GTOPO30 DEM is used for this purpose, and it has a land/water mask that does not precisely match the MODIS land/water mask. Pixels where there is a mismatch between the GTOPO30 and MODIS masks are flagged as such in the data.

3.4 Quality Assessment

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

- MOD10A1 and MYD10A1 Local Snow Cover Attributes, Version 5
- MOD10A1 and MYD10A1 Global 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 (Riggs, Hall, and Salomonson 2006).

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

3.5 Sensor or Instrument Description

3.5.1 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.

3.5.2 Technical Specifications

Table 3. Technical Specifications

Orbit	705 km, 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 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

3.5.3 Spectral Bands

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

3.5.4 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.

3.5.5 Manufacturer of Sensor or Instrument

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

3.5.6 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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4.2 Related Data Sets

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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