Documentation for MODIS/Aqua Snow Cover 5-Min L2 Swath 500m, 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/Aqua Snow Cover 5-Min L2 Swath 500m, Version 5*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/R90VAMI75N22. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/MYD10_L2

National Snow and Ice Data Center

TABLE OF CONTENTS

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. Latitude and longitude geolocation fields are at 5 km resolution while all other fields are at 500 m resolution.

MYD10_L2 V005 data has both a binary snow cover map and a map of fractional snow coverage per pixel. A second snow map based on a more liberal cloud mask that was added in Version 4 (V004) was removed from V005. As in V004, the thermal mask threshold used to distinguish between cloud and snow is 283.0 K rather than 271.0 K as in Version 3.

MYD10_L2 data has two separate snow fields. The first field, snow cover, classifies each cloud-free land or inland water body pixel as snow-covered or snow-free, the second field, fractional snow cover, provides the percent of snow cover within each pixel for land and inland water bodies. MODIS snow cover data are based on a snow mapping algorithm that employs a Normalized Difference Snow Index (NDSI) and other criteria tests.

Please visit the links listed under Related Websites for more information about the V005 data, known data problems, the production schedules, and future plans.

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 Section 2.0 Software 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 are produced in five minute segments of the orbital swath, which corresponds to approximately 203 scans. With 20 lines per scan, individual products have approximately 4060 pixels in the along track direction and 2708 pixels in the cross track direction. At the Earth's surface, the coverage of a single MOD10_L2 data granule is approximately 2030 km along track by 2330 km cross track.

MYD10L2 V005 consists of 500 m resolution snow cover and fractional snow cover data with 5 km resolution latitude and longitude geolocation fields. Also, in V005, the bit encoded Snow Cover Pixel QA Field was replaced by coded integer values. Each data granule contains HDF-EOS local attribute fields, which are stored with their associated Scientific Data Set (SDS) listed under Related Data Sets.

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

Figure 1 illustrates how the latitude and longitude fields are mapped to the Snow Cover, Fractional Snow Cover, and Snow Cover Pixel QA data fields using increment, offset, and fractional offset.

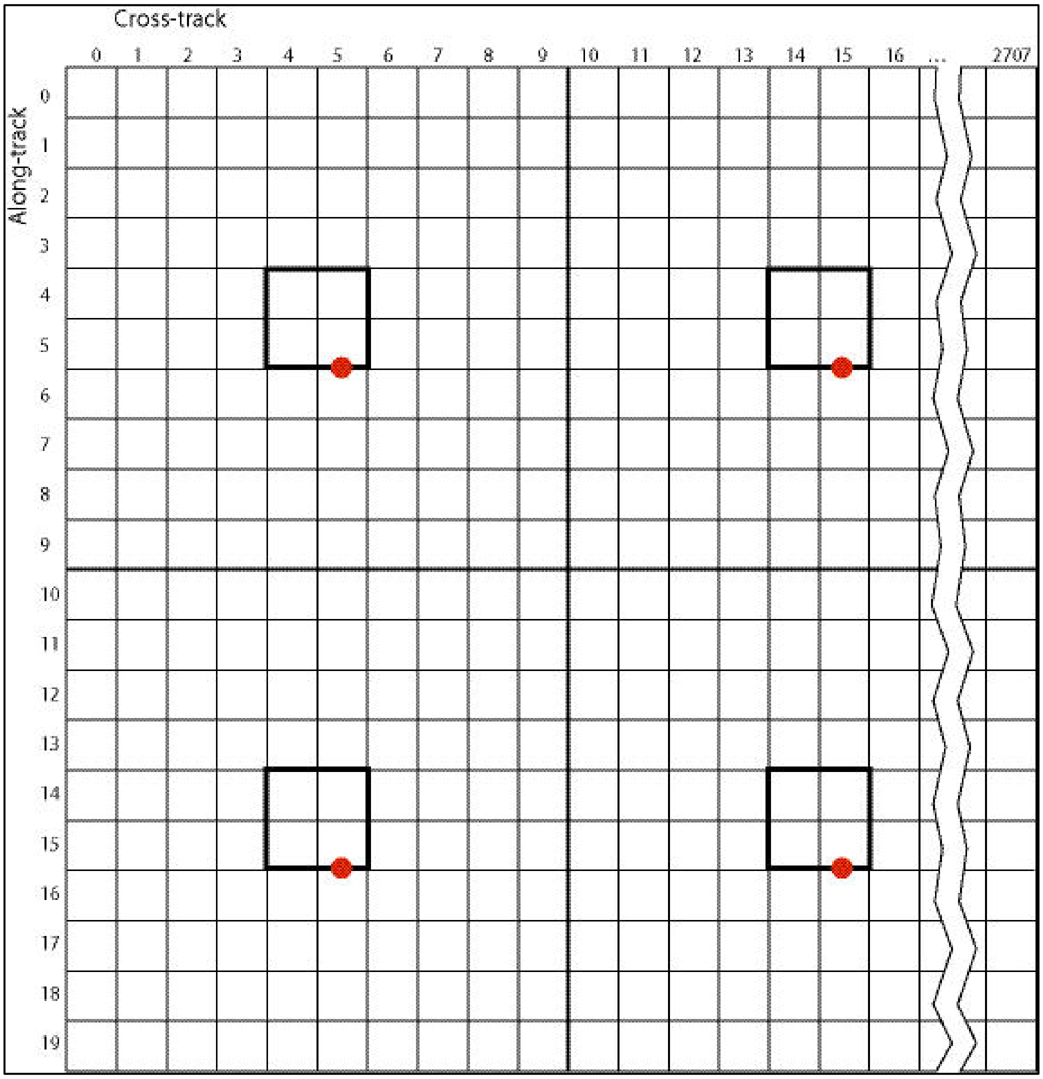

Figure 1. Latitude and longitude Mapping Fields

HDF-EOS dimension maps consisting of offsets and increments are used to associate geolocation information with each data array. As shown in Figure 1, the offset indicates how far to move along a data dimension until reaching the first point with a corresponding entry along the geolocation dimension. The increment tells how many points to travel along the data dimension before the next point is found for which there is a corresponding entry along the geolocation dimension. For MYD10_L2, in the StuctMetadata.0 gobal attribute, which holds the dimension mapping, the first element (0,0) in the latitude or longitude field maps to the element (5, 5.5) in any of the data fields, for example Snow Cover. Increments of 10 pixels in the cross track or along track direction in the data field map to consecutive elements in the geolocation array. For more information on dimension maps and how geolocation field offsets work, please consult Section 5.1.4 Dimension Maps, page 27 of the HDF-EOS Library User's Guide, Volume 1 and see Geolocating HDF-EOS Data.

Unfortunately, the HDF-EOS specification only allows integer offsets in dimension maps while MODIS 500 m data products such as MYD10_L2 require fractional offsets in order to be correctly geolocated. In V005, two new metadata elements HDFEOS_FractionalOffset_Along_swath_lines_500m_MOD_Swath_Snow and HDFEOS_FractionalOffset_Cross_swath_pixels_500m_MOD_Swath_Snow, have been added to the HDF-EOS metadata to record the offsets needed. Additional offsets of .5 in the along swath direction and 0 in the cross track direction are needed for MYD10_L2 data. However, the HDF-EOS library recognizes only the dimension mapping specified in the StructMetadata.0 global attribute. These attributes are supplied for users who wish to apply the correct dimension mapping outside the HDF-EOS library.

1.2 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 Quality Assessment (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 (Riggs, Hall, and Salomonson 2006).

1.3 File Naming Convention

The file naming convention common to all MODIS products is `MYD10_L2.A2003141.0000.005.2006.143091104.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
MYD	MODIS/Aqua
10_L2	Type of product
A	Acquisition date
2003	Year of data acquisition
141	Day of year of data acquisition (day 141)
0000	Hour and minute of data acquisition in Greenwich Mean Time (GMT) (00:00)
005	Version number
2006	Year of production (2006)
143	Day of year of production (day 143)

091104	Hour/minute/second of production in GMT (09:11:04)
hdf	HDF-EOS data format

1.4 File Size

Data files are typically between 0.5 - 10 MB using HDF compression

New in V005, MYD10L2 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

1.5 Spatial Coverage

Coverage is global. A ±55 degree scanning pattern at 705 km altitude achieves a 2330 km swath with global coverage every one to two days and more frequent coverage near the poles.

1.5.1 Latitude Crossing Times

The local equatorial crossing time of the Aqua satellite is approximately 1:30 P.M. in a descending node with a sun-synchronous, near-polar, circular orbit.

1.5.2 Spatial Resolution

Resolution at nadir is approximately 500 m (at the equator) for the data fields and 5 km (at the equator) for the latitude and longitude geolocation fields.

1.5.3 Swath Description

A MYD10_L2 scene is a five-minute segment of an orbital swath, which corresponds to approximately 203 scans. At 500 m resolution there are 20 lines per scan, yielding approximately 4060 pixels in the along track direction in each data record. In the cross track direction there are 2708 pixels. At the Earth's surface, the coverage of a single MYD10_L2 scene is approximately 2030 km along track by 2330 km cross track. Approximately 144 data granules are acquired during the daylight portions of a days worth of orbits. Visit the Space Science and Engineering Center (SSEC): Aqua Orbit Tracks GLOBAL website listed under Related Websites to help select appropriate swath data for your study.

1.6 Temporal Coverage

Data extend from 4 July 2002 to 2 January 2017.

Over the course of the Aqua 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/Aqua Data Outages website listed under Related Websites.

1.6.1 Temporal Resolution

Data are produced in five-minute segments. The time between repeat coverage of a given point on the earth depends on latitude with multiple pass coverage near the poles, and at least daily coverage of locations poleward of ±30 degrees latitude. The nominal repeat period of the satellite is 16 days. Note that the snow cover products are only produced under sunlit conditions; therefore, they are not produced during the night time portions of each orbital period, nor over portions of the polar regions during their respective fall and winter season when the viewing conditions are too dark.

1.7 Parameter or Variable

1.7.1 Parameter Description

The snow mapping algorithm classifies pixels as snow, snow-covered lake ice, cloud, water, land, or other. Snow cover and fractional snow cover are the primary variables of interest in this data set. Snow cover reduced cloud is no longer included in the snow mapping algorithm.

1.7.2 Parameter Range

Refer to the MOD10_L2-and-MYD10_L2-V5-Global-and-Local-Snow-Cover-Attributes document listed under Technical References for a key to the meaning of the coded integer values.

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

2.2 Data Analysis Tools

The following software tools can help you analyze the data:

- 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

Satellites are well suited to the measurement of snow cover because the high albedo of snow presents a high contrast with most other natural surfaces except clouds. Spectral reflectivity of snow depends on grain size and shape, impurity content, liquid water content, depth, surface roughness, and solar elevation angle (Hall and Martinec 1985). Reflectance of fresh snow is very high in the visible wavelengths, but decreases in the near-infrared wavelengths especially as grain size increases. Because of natural aging and other factors such as soot or volcanic ash deposition, reflectance of snow decreases over time. Fresh snow can have a reflectance up to about 80 percent, but its reflectance may decrease to below 40 percent after snow crystals metamorphose (Hall et al. 1998).

Snow and Cloud Discrimination

Snow and cloud discrimination techniques are based on differences between cloud and snow/ice reflectance and emittance properties. Clouds typically have high reflectance in visible and near-infrared wavelengths, while reflectance of snow decreases in near-infrared wavelengths.

Special Considerations for Dense Forests

The mapping of snow cover becomes limited in areas where snow cover is obscured by dense forest canopies. A forested landscape is never completely snow-covered because tree branches, trunks, and canopies may not be covered with snow. Often, in boreal forests, snow that falls on the coniferous tree canopy will not stay on the canopy for the entire winter because of sublimation. Thus, even in a continuously snow-covered area, much of the forested landscape will not be snow-covered. Furthermore, snow that falls onto the ground through the canopy may not be visible from above.

A canopy reflectance model (GeoSAIL) for discontinuous canopies is the basis for determining the fraction of sunlit crown, sunlit background, crown reflectance, canopy transmittance, shadowed crown, and shadowed background within a forest stand. Reflectances for the sunlit snow are calculated using the Wiscombe and Warren (1980) model, while reflectances from other components were measured from direct observations. A significant difference exists between the high reflectance of snow and the low reflectance of soil, leaves, and bark. Depending on the vegetation type, snow may also cause a decrease in the mid-infrared reflectance of the forest stand. In addition, reflectance in the visible spectrum often increases with respect to the near-infrared reflectance. This lowers the Normalized Difference Vegetation Index (NDVI), a complement to the NDSI.

The NDSI and NDVI are used together to discriminate between snow-free and snow-covered forests (Klein, Hall, and Riggs 1998). Forested pixels have higher NDVI values compared with non-forested pixels. Thus, by using the NDSI and NDVI in combination, it is possible to lower the NDSI threshold in forested areas without compromising the algorithm performance in other land covers (Hall et al. 1998).

3.2 Data Acquisition Methods

3.2.1 Source or Platform Mission Objectives

MODIS is a key instrument aboard the Aqua satellite, a 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. (NASA's MODIS Web Site 2006), (NASA's Aqua Web Site 2006), and (NASA's EOS Web Site 2006)

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 (Hall et al. 1998).

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 down linked 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 NASA Goddard Space Flight Center: MODIS Adaptive Processing System (MODAPS) Services 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 MYD10_L2. 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 MODIS Data Processing System (MODAPS) is responsible for product generation and transfer of products to NSIDC.

The snow-mapping algorithm, based on the NDSI, identifies the presence of snow by reflectance or radiance properties in each 500 m pixel. The NDSI is a ratio of the difference in reflectance of snow in the visible and near-infrared wavelengths. The NDSI partially compensates for a number of illumination conditions including atmospheric effects. The algorithm uses MODIS Bands 4 (0.55 µm) and 6 (1.6 µm) from MYD02HKM to calculate the NDSI (Hall et al. 1998).

NDSI = (Band 4 - Band 6) / (Band 4 + Band 6)

The fractional snow cover map is based on the regression technique of (Salomonson and Appel 2004). The fractional area (in percent) of each pixel covered by snow is calculated for both land and inland water bodies not covered by cloud and over the range of NDSI values from 1-100. Fractional snow may be mapped over the whole NDSI range indicative of snow (Salomonson and Appel 2006).

Snow Fraction = -0.01 + 1.45 * NDSI

3.3.1 Processing Steps

Analysis for snow in a MODIS swath is constrained to pixels that:

- have nominal Level-1B radiance data
- are in daylight
- are over land or inland water
- are unobstructed by clouds
- have an estimated surface temperature less than 283 K

Constraints are applied in the order listed. Only pixels having a daylight, clear-sky view of the land surface are then analyzed for snow. The NDSI can generally separate snow from most obscuring cumulus clouds, but it cannot always discriminate optically-thin cirrus clouds from snow. Instead, clouds are masked using data from the MODIS Cloud Mask data product (MYD35_L2). If the cloud mask algorithm was not applied to a MYD10_L2 pixel, the snow algorithm proceeds while assuming that the pixel is unobstructed by cloud (Hall and Riggs 2006).

V005 data uses the summary cloud result field and the unobstructed field-of-view flag from MYD35_L2 to generate a single cloud mask for the snow algorithm. In some cases, MYD35_L2 identifies snow as clouds, which prevents the snow algorithm from mapping true snow extent.

A 1 km resolution land/water mask within the MODIS geolocation product (MYD03) is used to mask oceans and inland water. Ocean pixels are not analyzed for snow. Inland water pixels are analyzed for the condition of snow-covered inland water (primarily lakes).

MYD02HKM Level-1B data are screened for missing and unusable data. Unusable data result if sensor radiance data fail to meet acceptable criteria during processing. If unusable data are encountered, then a no decision result is written for the affected pixels. Similarly, pixels are labeled missing data if missing data are encountered.

Snow detection is achieved through the use of two groups of criteria tests for snow reflectance characteristics in the visible and near-infrared regions. One group is for detection of snow under a wide range of conditions. A pixel is identified as snow if all the following conditions are met:

- (Band 4 - Band 6) / (Band 4 + Band 6) is greater than or equal to 0.4
- Band 2 reflectance is greater than 0.11
- Band 4 reflectance is greater than 0.10

Another group of criteria tests is used to better detect snow in dense vegetation, such as forests. In this case, a pixel is identified as snow if the following conditions are met:

- The pixel has NDSI and NDVI values in a defined polygon in a scatter plot of the two indices
- Band 1 reflectance is greater than 0.10
- Band 2 reflectance is greater than 0.11

This last set of criteria is applied without regard to the ecosystem, so it should not be interpreted strictly as snow-covered forest. Snow-covered ice on inland water is determined by applying the first group of criteria tests used for snow detection to pixels mapped as inland water by the land-water mask.

Intermediate checks for theoretical bounding of reflectance data and the NDSI ratio are made in the algorithm. In theory, reflectance values should lie within the 0-100 percent range, and the NDSI ratio should lie within the -1.0 to +1.0 range. Summary statistics are kept for pixels that exceed these theoretical limits; however, the test for snow is done regardless of violations of these limits.

The snow algorithm also identifies missing data and reports them in the output product. Certain expected anomalous conditions may exist with the input data, such as a few missing lines or unusable data from the MODIS sensor. In these cases, the snow algorithm makes no snow decision for an affected pixel. The pixel value is set to missing data or no decison and the algorithm moves to the next pixel. The Valid EV Obs Band x and Saturated EV Obs Band x local attributes are propogated from the MYD02HKM input product to assist in QA and analysis (Riggs, Hall, and Salomonson 2006).

3.3.2 Error Sources

The snow mapping algorithm incorporates tests for known anomalous conditions. If input data are missing, the snow mapping algorithm indicates that in the output product. Where dead detectors are found, the result is a no decision result. No averaging or other processing is done for dead detectors. If other known anomalous conditions are encountered, the snow mapping algorithm makes no decision for that pixel.

As with any upper level product, the characteristics of and anomalies in input data may carry through to the output data product. The following products are input to the snow mapping algorithm:

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.

- MYD02HKM - MODIS/Aqua Calibrated Radiances 5-Min L1B Swath 500m, Version 5
- MYD021KM - MODIS/Aqua Calibrated Radiances 5-Min L1B Swath 1km, Version 5
- MYD03 - MODIS/Aqua Geolocation Fields 5-Min L1A Swath 1km, Version 5
- MYD35_L2 - MODIS/Aqua Cloud Mask and Spectral Test Results 5-Min L2 Swath 250m and 1km, Version 5

Errors may exist in the reflectance calculations used to determine whether snow is present due to the anisotropy of snow and ice. Snow is not a Lambertian Reflector because snow reflects more in a forward direction. As snow ages, its anisotropy increases. The increase in forward scattering with snow age is greater in the near infrared wavelengths, relative to the visible wavelengths. Such errors will likely be greater at larger angles, 30 percent or more off nadir, as the amount of reflected solar irradiance varies with view angle. Additionally, errors in precise reflectance value due to anisotropy related to topographic variability is inherent in the data (Hall et al. 2001a).

The snow-mapping algorithm is sensitive to small changes in NDSI or Normalized Difference Vegetation Index (NDVI) particularly over dark, dense vegetation. Since this can result in erroneous snow detection, particularly over the dark, dense forests of the tropics, a thermal threshold of 283 K is used. If the surface has an estimated temperature greater than 283 K, then it will not be mapped as snow. This threshold is several degrees above the melting temperature of snow since the effective brightness temperature of a pixel may be high due to mixed contributions in the field of view, for example, warm tree crowns in a snow-covered region or sun warmed rock in regions of patchy snow. Thus, bright warm surfaces that have similar spectral characteristics as snow are removed because of the screen.

Errors with the snow mapping algorithm are lowest in tundra and prairie regions. The maximum expected errors are 15 percent for forests, 10 percent for mixed agriculture and forest, and 5 percent for other land covers. Estimating snow cover is difficult in forests because trees partially or completely conceal underlying snow. The expected maximum monthly and annual errors in Northern Hemisphere snow-mapping methods from the algorithm have been estimated. The maximum monthly errors are expected to range from 5 percent to 9 percent for North America, and from 5 percent to 10 percent for Eurasia. The maximum aggregated Northern Hemisphere snow mapping error is estimated to be 7.5 percent. The error is highest, around 9 percent to 10 percent, when snow covers the Boreal Forest roughly between November and April (Hall and Riggs 2006).

3.3.3 Quality Assessment

Quality indicators for MODIS snow data can be found in 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 Cover Pixel QA data field.

These quality indicators are generated during production or in post-production scientific and quality checks of the data product.

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 snow algorithm identifies missing data and reports them in the output product. Certain expected anomalous conditions may exist with the input data such as a few missing lines or unusable data from the MODIS sensor. In these cases, the snow algorithm makes no snow decision for an affected pixel. Summary statistics are calculated for these conditions and reported as Valid EV Obs Band x percent and Saturated EV Obs Band 1 percent local attributes (Riggs, Hall, and Salomonson 2006). In addition to these data values, the product contains quality information at the pixel level.

The Snow Cover Pixel QA data field provides additional information on algorithm results for each pixel within a MODIS scene 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 (Riggs, Hall, and Salomonson 2006). For example, intermediate checks for theoretical bounding of reflectance data and the NDSI ratio are made in the algorithm. In theory, reflectance values should lie within the 0-100 percent range, and the NDSI ratio should lie within the -1.0 to +1.0 range. Summary statistics are kept for pixels that exceed these theoretical limits; however, the test for snow is done regardless of violations of these limits.

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 705 km altitudes achieve 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, and infrared spectral regions.

3.4.2 Technical Specifications

Table 2. Technical Specifications

Orbit	705 km altitude, 1:30 P.M. descending node (Aqua), 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 Spectral Bands Table on NASA's MODIS Specifications Web page.

3.4.4 Sensor or Instrument Measurement Geometry

The MODIS scan mirror assembly uses a continuously rotating double-sided scan mirror to scan ±55 degrees with a 20.3 rpm cross track. 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 short wave 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.

4 REFERENCES AND RELATED PUBLICATIONS

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4.1 Related Data Sets

MODIS/Terra Snow Cover 5-Min L2 Swath 500m, Version 5
MODIS Data Sets @ NSIDC

4.2 Related Websites

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
Space Science and Engineering Center (SSEC): Aqua Orbit Tracks GLOBAL
MODIS/Aqua Data Outages
MODIS @ NASA Goddard Space Flight Center

The MODIS Snow and Sea Ice Global Mapping Project

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6 DOCUMENT INFORMATION

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