MODIS/Aqua Snow Cover 5-Min L2 Swath 500m, Version 61

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

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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

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1 DATA DESCRIPTION

Snow-covered land typically has very high reflectance in visible bands and very low reflectance in shortwave infrared bands. The Normalized Difference Snow Index (NDSI) reveals the magnitude of this difference. The MODIS snow cover algorithm calculates NDSI for all land and inland water pixels in daylight using Aqua MODIS band 4 (visible green) and band 6 (shortwave near-infrared). The Scientific Data Sets (SDSs) included in this product are listed in the Table 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
`NDSI`	Raw NDSI values (i.e. prior to screening).	NDSI values are scaled by 1 x 10^4. -10000 to 10000: valid values -32768: fill value
`NDSI_Snow_Cover`	NDSI snow cover and data flag values.	NDSI snow cover values and data flags values, stored as 8-bit unsigned integers. 0–100: NDSI snow cover 200: missing data 201: no decision 211: night 237: inland water 239: ocean 250: cloud 254: detector saturated 255: fill

Parameter	Description	Values
`NDSI_Snow_Cover Algorithm_Flags_QA`	Algorithm-specific bit flags set for data screens and for inland water.	Bit flag values: Bit 0: Inland water screen Bit 1: Low visible screen failed, snow detection reversed to no snow Bit 2: Low NDSI screen failed, snow detection reversed to no snow Bit 3: Combined temperature/height screen failed • brightness temperature ≥ 281 K, pixel height < 1300 m, flag set, snow detection reversed to not snow, OR; • brightness temperature ≥ 281 K, pixel height ≥ 1300 m, flag set, snow detection NOT reversed. Bit 4: High Shortwave IR (SWIR) reflectance screen • Snow pixel with SWIR > 0.45, flag set, snow detection reversed to not snow, OR; • Snow pixel with 0.25 < SWIR ≤ 0.45, flag set to indicate unusual snow condition, snow detection NOT reversed Bit 5: Cloud possible screen, probably cloudy Bit 6: Cloud possible screen, probably clear Bit 7: Uncertain snow detection due to low illumination
`NDSI_Snow_Cover _Basic_QA`	A general estimate for the quality of the algorithm result.	Quality assessment flag values: 0: best 1: good 2: ok 3: poor (not used) 4: other (not used) 211: night 239: ocean 255: unusable input or no data
`Latitude`	Coarse resolution (5 km) latitudes for geolocating the SDSs.	Values correspond to the pixel center of 5 km x 5 km blocks in the data array.
`Longitude`	Coarse resolution (5 km) longitudes for geolocating the SDSs.	Values correspond to the pixel center of 5 km x 5 km blocks in the data array.

1.1.1 Interpreting the parameter: NDSI_Snow_Cover_Algorithm_Flags_QA

Pixels determined to have some snow present are subjected to a series of screens that have been specifically developed to alleviate snow commission errors (detecting snow where there is no snow) and to flag uncertain snow detections. In addition, snow-free pixels are screened for very low illumination to prevent possible snow omission errors. Screen results, as well as the location of inland water, are stored as bit flags in the 'Algorithm_Flags_QA' SDS. Refer to the Appendix of this document for a detailed description of the Algorithm QA Flags.

To identify bit flag values, convert the decimal grid cell value to its binary equivalent. Bit values default to 0 and are set to 1 if the screen result is true. A visual example of the bit flag format for the decimal value '129' is provided in Figure 1.

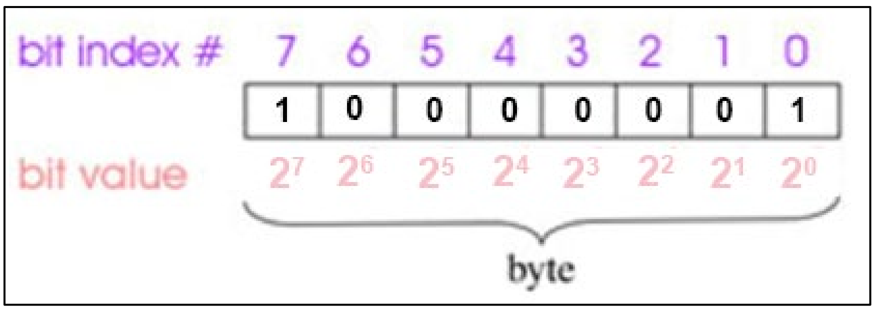

Figure 1. Bit flag format. The bit index positions are numbered from right (bit index 0) to left (bit index 7), and each index stores the result of a screen test. The bit values from right to left solve respectively to 1, 2, 4, 8, 16, 32, 64, and 128. In this example, bit index 0 and bit index 7 are set to true (1) with corresponding bit values 2^0 and 2^7 equaling '1' and '128', which, when summed equal '129'.

1.2 File Information

1.2.1 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.

1.2.2 Data File

As shown in Figure 2, each data file includes two data fields (`NDSI_Snow_Cover` and `NDSI`), two data quality fields (`NDSI_Snow_Cover_Basic_QA` and `NDSI_Snow_Cover_Algorithm_Flags_QA`), and two geolocation data fields (`Latitude` and `Longitude`).

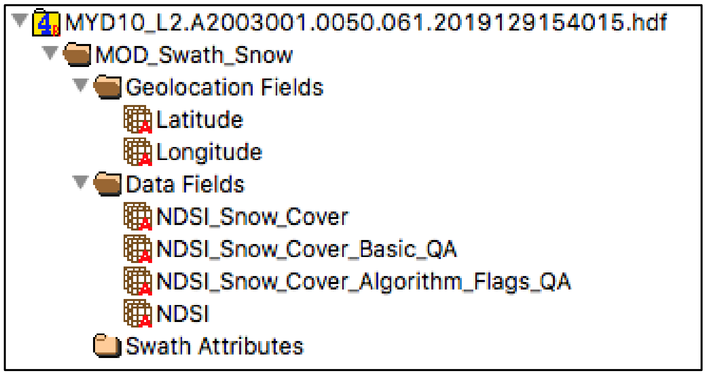

Figure 2. This figure shows the fields included in each data file as displayed with Panoply software.

1.2.3 Ancillary Files

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

1.2.4 Naming Convention

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

File naming convention:

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

Table 2. File Name Variables

`MYD`	MODIS/Aqua
`PID`	Product ID
`A`	Acquisition date follows
`YYYY`	Acquisition year
`DDD`	Acquisition day of year
`HHMM`	Acquisition hour and minute in GMT
`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:

`MYD10_L2.A2003001.0050.061.2019129154015`

Note: Data files contain important metadata including global attributes that are assigned to the file and local attributes like coded integer keys that provide details about the data fields. In addition, each HDF-EOS data file has a corresponding XML metadata file (`.xml`) which contains some of the same internal metadata as the HDF-EOS file plus additional information regarding user support, archiving, and granule-specific post-production. For detailed information about MODIS metadata fields and values, see the MODIS Snow Products Collection 6.1 User Guide (Riggs et al., 2019).

1.3 Spatial Information

MYD10_L2 data files contain five minutes of swath data, known as a swath scene. Five minutes of MODIS swath data typically comprise 203 full scans of the MODIS instrument and occasionally 204. With an along-track viewing path of 10 km, each scan acquires 20 pixels in the 500 m bands, and thus a scene typically contains 4060 pixels in the along-track direction and occasionally 4080. The instrument's ±55 degree scanning pattern yields 2708 pixels per scene in the cross-track direction. In general, 144 5-minute scenes are acquired during daylight.

1.3.1 Coverage

Coverage is global. Aqua's sun-synchronous, near-polar circular orbit is timed to cross the equator from south to north (ascending node) at approximately 1:30 P.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 Aqua's orbital path:

- Daily Aqua 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)

1.3.2 Projection

This data set is not projected. Swaths are georeferenced using the 5 km latitude and longitude array fields, which are based on GPS measurements, and reference the WGS84 datum.

1.3.3 Resolution

500 m (at nadir) for data fields

5 km for geolocation fields

1.3.4 Geolocation

The 'StructMetadata.0' metadata object contains a dimension map that specifies how each dimension of each geolocation field relates to the corresponding dimension in each data field.

When a data field and a geolocation field share a named dimension, no explicit map is needed. However, for MODIS data sets in which the resolution of the geolocation dimension (5 km) differs from the resolution of the data dimension (500 m), two additional metadata objects, 'Offset' and 'Increment' are needed to fully define the mapping.

'Offset' specifies the location along the data dimension of the first data point with a corresponding entry along the geolocation dimension. 'Increment' then specifies the number of steps between subsequent points with corresponding entries along the geolocation dimension. For MODIS 500 m data sets, 'Offset' = '5' and 'Increment' = '10'.

Unfortunately, HDF-EOS specifications only allow integer offsets in dimension maps, and MODIS 500 m data sets require fractional offsets to be correctly geolocated. Two product-specific metadata attributes were created to accommodate this additional mapping requirement:

'HDFEOS_FractionalOffset_Along_swath_lines_500m_MOD_Swath_Snow' and
'HDFEOS_FractionalOffset_Cross_swath_pixels_500m_MOD_Swath_Snow'.

These elements contain fractional offsets of '0.5' in the along-track direction and '0.0' in the cross-track direction that must be added to the integer offset stored with the dimension map. Thus, the combined along-track offset of '5.5' indicates that the first element (0,0) in the latitude and longitude fields maps to (5, 5.5) in any of the data fields. Subsequent elements in the geolocation arrays then map to locations in the data fields at 10-pixel increments in the both the along-track and cross-track directions.

1.4 Temporal Information

1.4.1 Coverage

MODIS Aqua data are available from 4 July 2002 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 Aqua mission have resulted in minor data outages. If you cannot locate data for a particular date or time, check the MODIS/Aqua Data Outages web page.

1.4.2 Resolution

Each data file contains five minutes of swath data (one scene).

1.5 Sample Data Image

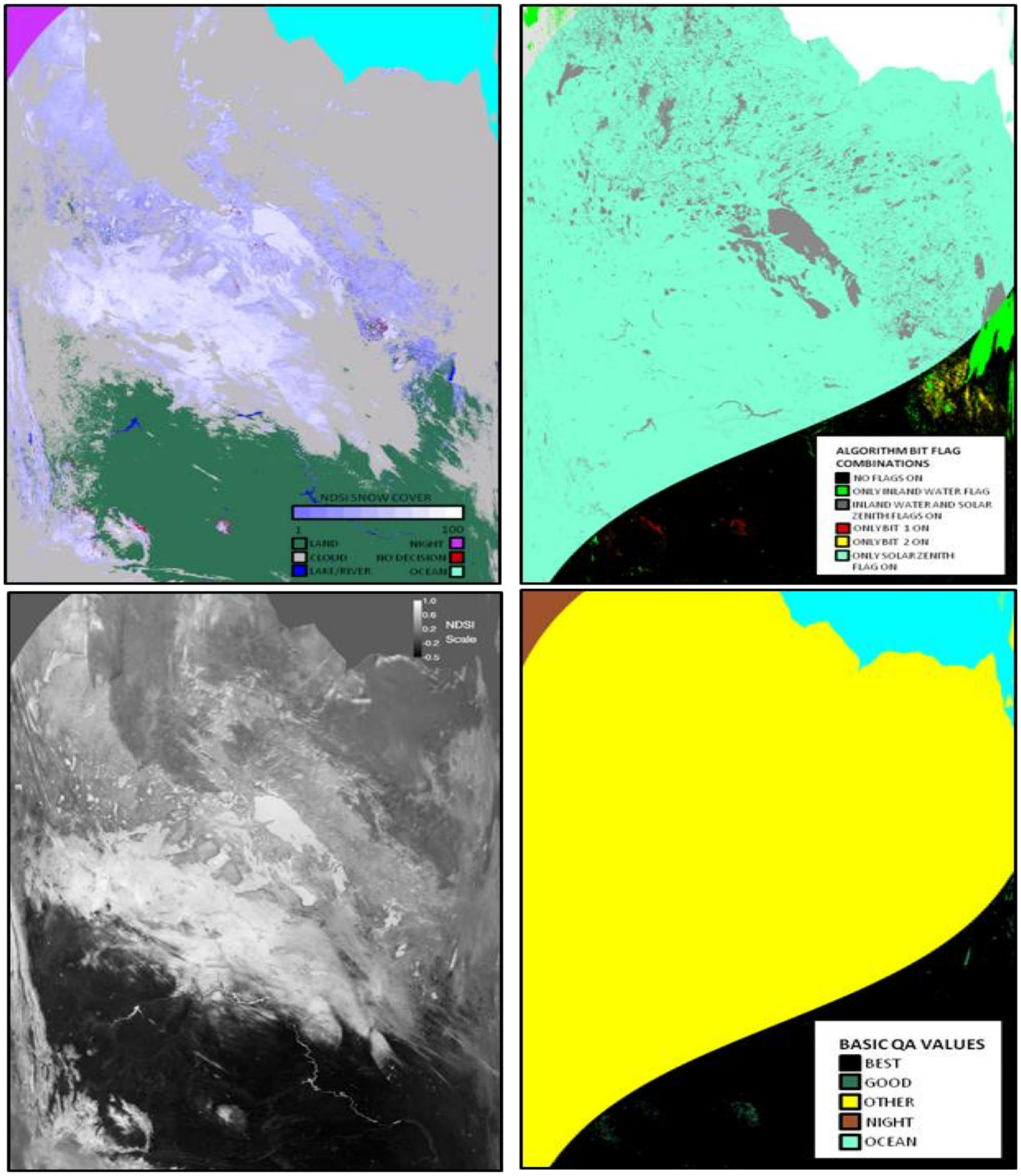

Figure 3**.** This figure shows the MOD10_L2 data arrays from Terra MODIS acquired on 10 January 2003. The four data arrays in the product are: NDSI_Snow_Cover (upper-left), algorithm QA bit flags (upper-right), NDSI (lower-left), and basic QA values (lower-right). This sample image was acquired from MODIS Terra but provides a representative sample of the same data acquired from MODIS Aqua.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

The objective for the MODIS snow cover algorithm in Collection 6.1 (C6.1) is to minimize snow cover detection errors of omission and commission for the purpose of mapping snow cover extent (SCE) accurately on the global scale. The algorithm is the same as used in Collection 6.0 (C6.0) with minor revisions made for the low visible reflectance screen and to the quality information flags. Specific updates to the snow cover algorithm in C6.1 include:

- The low visible reflectance screen for snow cover using bands 2 and 4 was lowered to 0.07 reflectance from 0.10 in C6.0.
- Two algorithm bit flags are set in the MYD35_L2 cloud mask and confidence flags of 'probably cloudy' and 'probably clear' are set in the algorithm flags QA SDS.

Based on these algorithm enhancements, users should expect to see fewer 'no decision' results in C6.1 data sets. In general, the lowering of the visible reflectance screen has been observed to change 'no decision' results to 'snow' or 'not snow', with 'no decision' results found for very low, < 0.07 reflectance situations. The MODIS cloud mask (MYD35_L2) flags for 'probably cloudy' and 'probably clear' are now included in the 'NDSI_Snow_Cover_Algorithm_Flags_QA' SDS so they can be used to evaluate possible cloud/snow confusion situations.

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 (e.g. near the poles). Aqua's sun-synchronous, near-circular polar orbit is timed to cross the equator from south to north (ascending node) at approximately 1:30 P.M. local time.

Ongoing changes in the Aqua orbit
The Aqua flight operations team completed mission manuevers related to maintaining a 1:30 PM MLT equator crossing and 705 km orbit altitude on March 18, 2021. In July 2021, Aqua began drifting to a later MLT. In January 2022, Aqua will begin its constellation exit by stopping all maneuvers except collision avoidance maneuvers and will exceed a 1:45 PM MLT crossing in February 2023. MLT will continue to drift after this, reaching 3:50 PM around August 2026. Aqua MODIS will remain operational and generate the full suite of products until the end of the mission in August 2026.
Later crossing times for an afternoon platform like Aqua 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 3 lists the MODIS C6.1 products used as inputs to the snow detection algorithm. For a detailed description of the MODIS snow detection algorithm, see the Algorithm Theoretical Basis Document (Hall et al., 2001). For a revised explanation of the NDSI snow cover algorithm theory, see the NASA VIIRS Snow Cover ATBD (Riggs et al., 2015). The MODIS and VIIRS snow cover algorithms both use the NDSI snow detection algorithm, albeit adjusted for sensor and input data product differences.

Table 3. Inputs to the MODIS snow algorithm

Product ID	Long Name	Data Used
MYD02HKM	MODIS/Aqua Calibrated Radiances 5-Min L1B Swath 500m	Band 1 (0.645 µm); Band 2 (0.865 µm); Band 4 (0.555 µm); Band 6 (1.640 µm)
MYD021KM	MODIS/Aqua Calibrated Radiances 5-Min L1B Swath 1km	Bands: 31 (11.03 µm)
MYD03	MODIS/Aqua Geolocation Fields 5-Min L1A Swath 1km	Land/Water Mask; Solar Zenith Angle; Latitude; Longitude; Geoid Height
MYD35_L2	MODIS/Aqua Cloud Mask and Spectral Test Results 5-Min L2 Swath 250m and 1km	Unobstructed Field of View Flag; Day/Night Flag

Note: MODIS C6.0 and C6.1 utilize a land/water mask derived from the University of Maryland Global Land Cover Facility's UMD 250m MODIS Water Mask. To maintain continuity between MODIS C5.0 and C6.x products, the 'UMD 250m MODIS Water Mask' was converted from a 250 m two-class map to a 500 m seven-class map for use in all MODIS products. The conversion is detailed in Development of an Operational Land Water Mask for MODIS Collection 6.

2.4 Processing

Fifteen of the twenty band 6 detectors on Aqua MODIS failed shortly after launch, resulting in a 75% signal loss that has precluded using band 6 for snow detection. However, a Quantitative Image Restoration (QIR) technique was implemented (Gladkova et al., 2012) that restores Aqua MODIS band 6 data to scientific quality. This technique produces an intermediate, calibrated radiances product with band 6 restored: MYD02HKM_QIR (this product is not retained). Aside from this step, the snow detection algorithm is the same for Aqua and Terra.

2.4.1 Snow Cover

The MODIS snow cover algorithm calculates snow cover using the NDSI technique. This technique and the processing are described below:

NDSI Background

The MODIS snow cover algorithm detects snow by computing the NDSI (Hall and Riggs, 2011) from MODIS Level 1B calibrated radiances. Snow typically has a very high reflectance in visible bands (VIS) and very low reflectance in shortwave infrared bands (SWIR). The relative difference between the two is used to detect and distinguish snow-covered from snow-free land and from most cloud types.

NDSI Limitations

The NDSI is effective at detecting snow cover on the landscape when skies are clear, and viewing geometry and solar illumination are good. Snow cover always has an NDSI > 0.0 but not all surface features with NDSI > 0.0 are snow cover. Some surface features, such as salt pans, or cloud-contaminated pixels at edges of cloud, can have NDSI > 0.0 and be erroneously detected as snow cover, which results in a snow commission error.

NDSI Processing

The MYD10_L2 algorithm processes land and inland water bodies observed during daylight for snow detection or ice/snow on water detection. The algorithm inputs include Level 1B reflectance data from MYD02HKM_QIR and Level 1B radiance data from MYD021KM, geolocation data and land/water mask from MYD03, and the cloud mask and day/night flag from MYD35_L2.

The MYD021KM radiance data is used to provide a rough estimate of the surface temperature and is applied as a screen later in the algorithm. The algorithm performs pixel by pixel processing and uses the land/water mask to control the processing. First, the MYD02HKM_QIR reflectance data are read and the land/water mask and day/night flag are applied to identify ocean and night pixels. Pixels identified as ocean are labeled ‘ocean’ and pixels identified as night are labeled ‘night’. The reflectance data is then screened for valid values and the cloud mask is applied. Pixels identified as cloud-covered are labeled ‘cloud’. The NDSI is then computed for all daytime observed land and inland water pixels using the NDSI ratio of the difference in VIS and SWIR reflectance as follows:

$$NDSI = \frac{band\ 4 - band\ 6}{band\ 4 + band\ 6}$$

A pixel with NDSI > 0.0 is considered to have some snow present. A pixel with NDSI <= 0.0 is a snow free land surface (Riggs et al., 2016).

Data Screens

As mentioned above, some surface features may be erroneously detected as snow cover which results in a snow commission error. Data screens are used to reverse snow cover detection or to flag uncertain, lower quality snow cover detection situations. Other data screens are applied to all pixels to flag situations that may affect the overall quality of the data or for supporting interpretation and use of the data. For a detailed description of the data screens, see the Appendix section of this document.

2.4.2 Lake Ice

The lake ice/snow covered detection algorithm is the same as the NDSI snow cover algorithm, except that the low visible reflectance screen thresholds were kept at the C6.0 settings, where band 2 ≤ 0.10 or band 4 ≤ 0.11. Inland water bodies are flagged by setting bit 0 in the 'NDSI_Snow_Cover_Algorithm_Flags_QA' SDS. Lake ice is inland water detected to have snow/ice cover with an NDSI in the range of 1-100. Inland water that does not have ice detected has a value of '237'. The inland water mask (bit 0) should be used with the 'NDSI_Snow_Cover' SDS to find inland water bodies that were detected as snow/ice covered.

The lake ice/snow covered detection algorithm relies on the basic assumption that a water body is deep and clear and therefore absorbs all of the solar radiation incident upon it. Water bodies with algal blooms, high turbidity, or other relatively high reflectance conditions may be erroneously detected as snow/ice covered. See the 'MODIS Snow Products Collection 6.1 User Guide' (Riggs et al., 2019) for additional details regarding lake ice quality.

2.4.3 Cloud Masking

The 'Unobstructed FOV Quality Flag' from MYD35_L2 is used to mask clouds. The 1 km cloud mask is applied to the four corresponding 500 m pixels. If the cloud confidence flag is 'confident cloudy' then the pixel is masked as 'cloud.' If the cloud confidence flag is set 'confident clear,' 'probably clear' or 'probably cloud' it is interpreted as 'clear' in the algorithm. In C6.1 the cloud confidence flags of 'probably cloudy' and 'probably clear' are set in bits 5 and 6 in the 'NDSI_Snow_Cover_Algorithm_Flags_QA' SDS. These cloud confidence flags are included so that they can be used to investigate cloud/snow confusion situations. See the 'MODIS Snow Products Collection 6.1 User Guide' (Riggs et al., 2019) for additional details regarding cloud/snow confusion situations.

2.4.4 Abnormal Condition Rules

If MODIS L1B radiance data from MYD02HKM are missing in any of the bands used in the algorithm, that pixel is set to 'missing data' in the 'NDSI_Snow_Cover' SDS and is not processed for snow cover. Unusable radiance data are set to 'no decision' in the 'NDSI_Snow_Cover' SDS.

2.5 Quality Information

2.5.1 Basic Quality Assurance

Basic quality assurance (QA) values are stored in the 'NDSI_Snow_Cover_Basic_QA' SDS. These values provide a qualitative estimate of the algorithm result for a pixel based on the input data and solar zenith data. The basic QA value is initialized to 'best' and then adjusted as needed based on the quality of the MYD02HKM input radiance data and the solar zenith angle screen. If the MYD02HKM data (TOA reflectance) lie outside the range of 5% to 100% but are still usable, the QA value is set to 'good'. If the solar zenith angle (SZA) is in range of $70° \leq SZA < 85°$, the QA is set to 'ok' to indicate the increased uncertainty stemming from low illumination. If the input data are unusable, the QA value is set to 'other'. Features that are masked, like 'night' and 'ocean', use the same values as the 'NDSI_Snow_Cover' SDS.

2.5.2 Bit Flags

Bit flags are stored in the 'NDSI_Snow_Cover_Algorithm_Flags_QA' SDS and are used to report data screen results. Bit flags can be used to investigate results for all pixels which have been processed for snow. By examining the bit flags, users can determine if any of the data screens: a) changed a pixel's initial result from 'snow' to 'not snow'; or b) flagged snow cover in a pixel as uncertain. Refer to the Appendix of this document to see how each data screen should be interpreted, and to the 'MODIS Snow Products Collection 6.1 User Guide' (Riggs et al., 2019) for more details.

2.6 Errors

2.6.1 Bright Surface Features

Surface features such as salt flats, bright sands, or sandy beaches that have visible and shortwave infrared reflectance characteristics similar to snow may be detected as snow cover based solely on the NDSI value, thus resulting in errors of commission. Screens specifically for bright surfaces were not developed for C6.1, but the screens in C6.1 can reduce the occurrence of snow commission errors in some situations. See the Appendix for a description of the data screens.

2.6.2 Land/water Mask

In MODIS C6.0 and C6.1 the land/water mask is derived from the 'UMD 250m MODIS Water Mask' data set (University of Maryland (UMD) Global Land Cover Facility). The location of lakes and rivers is greatly improved compared to the land/water mask used in C5.0. This improvement can be seen by the increase in the number of lakes mapped, especially in small lake regions, such as northern Minnesota to the Northwest Territories and via the continuity of many larger rivers.

2.6.3 Geolocation Accuracy

Geolocation accuracy for MYD10_L2 is 50 m or less. Geolocation uncertainty is not evident in MODIS Level-2 products when viewed independently. However, when mapped to projections or to other maps, feature mismatches may occur (Lin et al., 2019).

2.6.4 Antarctica

Antarctic data must be carefully scrutinized for accuracy and quality. The Antarctic continent is nearly ice and snow covered year round, with very little annual variation. The snow cover map may show areas of no snow cover, which is an obvious error. That error is related to the difficulty in identifying clouds over Antarctica’s ice/snow cover. The similarity in reflectance and lack of thermal contrast between clouds and ice/snow cover and thermal inversions are challenges to accurate snow/cloud discrimination. In situations where the cloud mask fails to identify 'confident cloudy,' the snow algorithm assumes a cloud-free view and either identifies the surface as not snow covered or identifies the cloud as snow. In either case the result is incorrect.

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 4 contains the instruments' technical specifications:

Table 4. MODIS Technical Specifications

Variable	Description
Orbit	705 km altitude, 1:30 P.M. ascending 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 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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8 DOCUMENT INFORMATION

8.1 Publication Date

March 2021

8.2 Date Last Updated

December 2021

APPENDIX - DATA SCREENS

This appendix provides a description of the data screen tests applied in the 'NDSI_Snow_Algorithm_bit_flags_QA' SDS.

INLAND WATER SCREEN: BIT 0

Inland water bodies are identified using bit 0. The pixels identified by this flag are set to '237' in the 'NDSI_Snow_Cover' SDS.

LOW VISIBLE REFLECTANCE SCREEN: BIT 1

This screen is used to prevent errors from occurring when the reflectance is too low for the algorithm to perform well. The screen is applied to non-cloud pixels with NDSI ≥ 0.0. If the visible reflectance from MODIS band 2 or band 4 is < 0.07, bit 1 is set and a value of 'no decision' is set for pixels in the 'NDSI_Snow_Cover' SDS.

LOW NDSI SCREEN: BIT 2

This screen is used to prevent errors from occurring where the difference between visible and shortwave reflectance is very small, thus resulting in very low but positive NDSI values. Uncertain snow detections or snow commission errors are common when 0.0 ≤ NDSI < 0.1. Therefore, if NDSI < 0.1 a snow detection is reversed to 'not snow', and bit 2 is set. This flag can be used to find pixels where snow cover detections were reversed to 'not snow'.

ESTIMATED SURFACE TEMPERATURE AND SURFACE HEIGHT SCREEN: BIT 3

This screen serves a dual purpose by linking estimated surface temperature with surface height. It is used to alleviate errors of commission at low elevations that appear spectrally similar to snow but are too warm. It is also used to flag snow detections at high elevations that are warmer than expected. Using the estimated MODIS Band 31 brightness temperature (Tb), if snow is detected in a pixel with height < 1300 m and Tb ≥ 281 K, the pixel is reversed to 'not snow' and bit 3 is set. If snow is detected in a pixel with height ≥ 1300 m and Tb ≥ 281 K, the pixel is flagged as 'unusually warm' and bit 3 is set.

HIGH SWIR REFLECTANCE SCREEN: BIT 4

This screen also serves a dual purpose by: a) preventing non-snow features that appear similar to snow from being detected as snow; b) allowing snow to be detected where snow cover shortwave infrared reflectance (SWIR) is anomalously high. Snow typically has a SWIR reflectance of less than 0.20; however, this value can be higher under certain conditions, like a low sun angle. The SWIR reflectance screen thus utilizes two thresholds. Snow pixels with SWIR reflectance > 0.45 are reversed to 'not snow' and bit 4 is set. Snow pixels with 0.25 < SWIR ≤ 0.45 are flagged as having an 'unusually high SWIR' and bit 4 is set.

CLOUD POSSIBLE SCREENS: BITS 5 & 6

This screen is utilized to identify cloud conditions using the 'Unobstructed FOV Quality Flag' from the MOD35_L2 product. If the MOD35_L2 quality flag is 'confident cloudy' the pixel is masked as 'cloud' and bit 5 is set to 'probably cloudy'. If the MOD35_L2 quality flag is set 'confident clear,' 'probably clear' or 'probably cloud' the condition is interpreted as 'clear' by the algorithm and the bit 6 flag is set to 'probably clear'. These cloud confidence flags are included to enable the snow cover to be evaluated with respect to cloud/snow confusion situations.

SOLAR ZENITH SCREEN: BIT 7

This screen is utilized to identify low illumination conditions. When solar zenith angles exceed 70°, the low illumination challenges snow cover detection. As such, pixels with solar zenith angles > 70° are flagged by setting bit 7. This solar zenith mask is set across the entire swath. **Note**: night is defined as a solar zenith angle ≥ 85°. Night pixels are assigned a value '211' in the 'NDSI_Snow_Cover_Algorithm_Flags_QA' SDS and the 'NDSI_Snow_Cover' SDS.