MODIS/Aqua CGF Snow Cover Daily L3 Global 500m SIN Grid, Version 61

USER GUIDE

How to Cite These Data

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

Hall, D. K. and G. A. Riggs. 2020. *MODIS/Aqua CGF Snow Cover Daily L3 Global 500m SIN Grid, Version 61.* [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/MODIS/MYD10A1F.061. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/MYD10A1F

National Snow and Ice Data Center

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1 DATA DESCRIPTION

This data set (MYD10A1F) is a daily cloud-gap-filled (CGF) version of the MODIS/Aqua Snow Cover Daily L3 Global 500m SIN Grid (MYD10A1) product. Grid cells in MYD10A1 which are obscured by cloud cover are filled by retaining clear-sky views of the surface from previous days (Hall et al., 2010). A separate parameter is provided which tracks the number of days in each cell since the last clear-sky observation.

MYD10A1 snow cover is detected using the Normalized Difference Snow Index (NDSI). Snow-covered land typically has very high reflectance in visible bands and very low reflectance in shortwave infrared bands; the NDSI reveals the magnitude of this difference.

1.1 File Information

1.1.1 File Format

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

1.1.2 File Contents

As shown in the following figure, each data file includes three Scientific Data Sets (CGF_NDSI_Snow_Cover, Cloud Persistence, and MYD10A1_NDSI_Snow_Cover) and two quality fields (Basic_QA and Algorithm_Flags_QA). In addition, three HDFEOS global attributes (StructMetadata.0, CoreMetadata.0, and ArchiveMetadata.0) are embedded in the file.

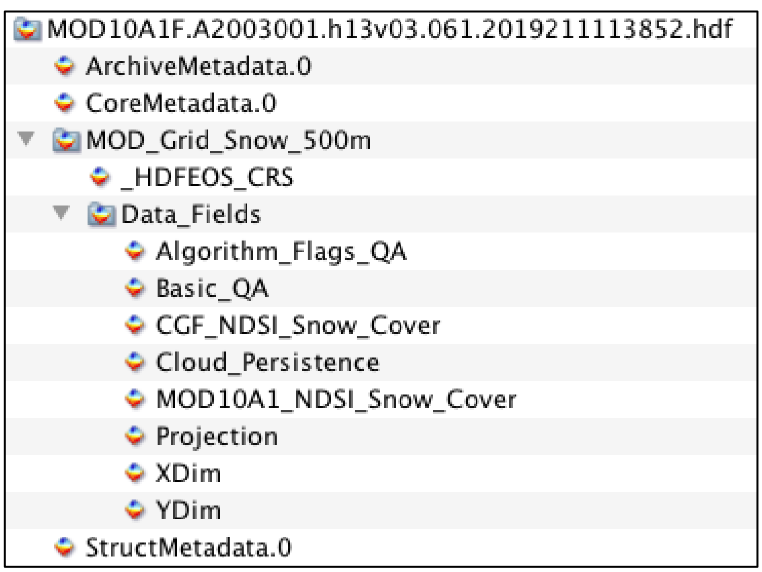

Figure 1. This figure shows the fields included in each MYD10A1F data file as displayed with Panoply software.

The following table describes the Scientific Data Sets (SDSs) included in this product.

Table 1. SDS Details

Parameter	Description	Values
CGF_NDSI_Snow_Cover	Cloud-gap-filled NDSI snow cover.	NDSI snow cover values and data flags values, stored as 8-bit unsigned integers. 0 - 100: NDSI snow cover (no snow to completely snow covered) 200: missing data 201: no decision 211: night 237: inland water 239: ocean 250: cloud 254: detector saturated 255: fill
Cloud_Persistence	The number of consecutive days with cloud cover preceding the current day.	Cloud persistence values. 0 - 254: valid data range 255: fill
MOD10A1_NDSI_Snow_Cover	Gridded NDSI snow cover from the current day.	NDSI snow cover values and data flags values, stored as 8-bit unsigned integers. 0 - 100: NDSI snow cover (no snow to completely snow covered) 200: missing data 201: no decision 211: night 237: inland water 239: ocean 250: cloud 254: detector saturated 255: fill

Parameter	Description	Values
Algorithm_Flags_QA	Data screens applied to identify false or uncertain snow detections.	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) refectance 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 conditon, 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
Basic_QA	General quality estimate for pixels processed for snow.	Quality assessment flag values 0: best 1: good 2: ok 3: poor-not used 4: other-not used 211: night 239: ocean 255: unusable
Projection	Sinusoidal projection attributes.	n/a

Parameter	Description	Values
XDim	Projected upper left X coordinate for each pixel in km	Coordinate value range for data set -20015.109354 to 20015.109354
YDim	Projected upper left Y coordinate for each pixel in km	Coordinate value range for data set -10007.554677 to 10007.554677

1.1.3 Interpreting 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 decode bit flag values, convert the grid cell's 8-bit integer value to its binary equivalent (For example, the decimal value 129 converted to binary is 10000001). Bit values are initialized to 0 and set to 1 if the result of the corresponding screen is true. The following figure shows the bit flag representation of the decimal value '129':

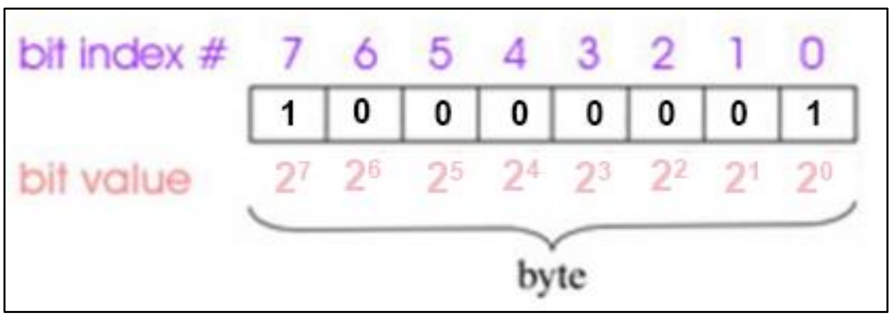

Figure 2. This figure shows the decoded bit flag for the 8-bit integer value 129. Bit positions are numbered from right (bit 0) to left (bit 7), and each bit stores the result of a screen. In this example, bit 0 (inland water) and bit 7 (low illumination) are set to true (1).

1.1.4 File Naming Convention

Date files are named according to the following convention and as described in Table 2:

Example:

MYD10A1F.A2000055.h32v10.061.2020037174024.hdf

MYD[PID].A[YYYY][DDD].h[NN]v[NN].[VVV].[yyyy][ddd][hhmmss].hdf

Table 2. File Name Variables

Variable	Description
MYD	MODIS Aqua
PID	10A1F
A	Acquisition date follows
YYYY	Acquisition year
DDD	Acquisition day of year
h[NN]v[NN]	Horizontal tile number and vertical tile number (`See Grid Section below`)
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

Note: Data files contain important metadata including global attributes that are assigned to the file and local attributes like coded integer keys that provide details about the data fields. In addition, each HDF-EOS data file has a corresponding XML metadata file (.xml) which contains some of the same internal metadata as the HDF-EOS file plus additional information regarding user support, archiving, and granule-specific post-production.

1.1.5 Ancillary Files

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

1.2 Spatial Information

1.2.1 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)

1.2.2 Projection

This data set is georeferenced to an equal-area sinusoidal projection. Areas on the grid are proportional to the same areas on Earth and distances are correct along all parallels and the central meridian. Shapes become increasingly distorted away from the central meridian and near the poles. The data are neither conformal, perspective, nor equidistant. Meridians, except for the central meridian, are represented by sinusoidal curves and parallels are represented by straight lines. The central meridian and parallels are lines of true scale.

1.2.3 Grid

As shown in Figure 3, data are gridded using the MODIS Sinusoidal Tile Grid, which comprises 460 non-fill tiles that each cover 10° by 10° at the equator or approximately 1200 km by 1200 km. Each data granule covers one tile and consists of 2,400 rows and 2,400 columns at a nominal spatial resolution of 500 m and a true per pixel resolution of 463.31271653 meters in both the X and Y directions. Tiles are labeled with horizontal (h) and vertical (v) indices, starting in the upper left corner with tile h00v00 and proceeding rightward and downward to tile h35v17 in the bottom right corner.

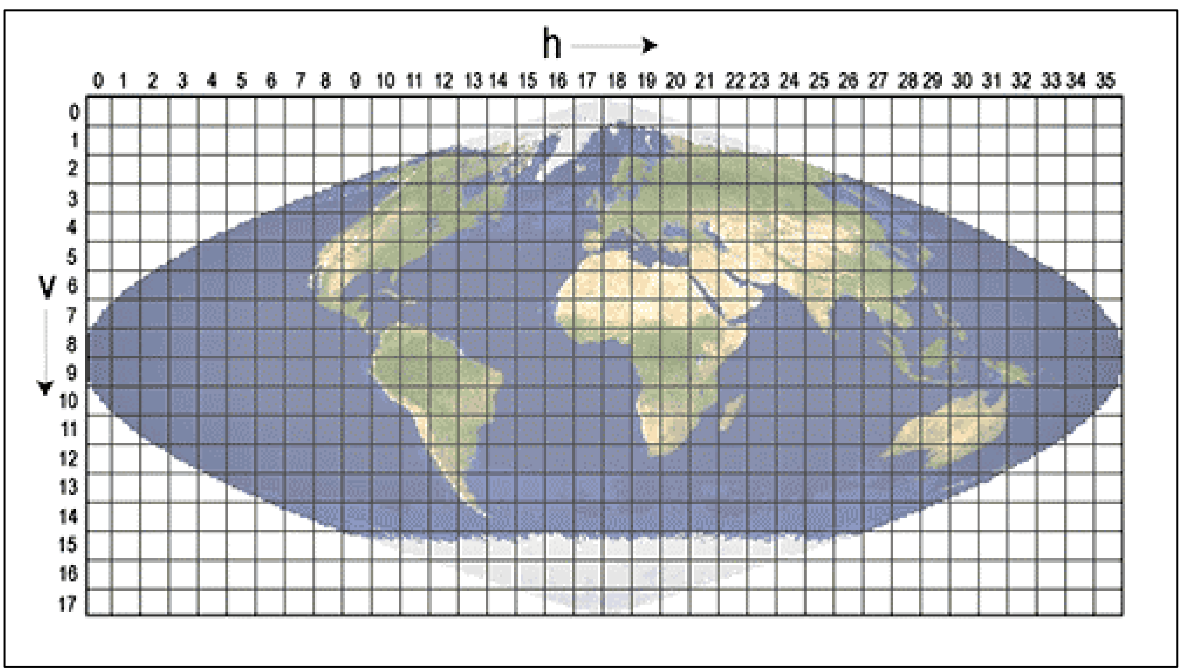

Figure 3. MODIS Sinusoidal Tile Grid

The following resources can help you select and work with gridded MODIS data:

- Tile Bounding Coordinates for the MODIS Sinusoidal Grid
- MODIS Land Discipline Group (MODLAND) Tile Calculator
- Earth Observing System Data and Information System (EOSDIS) Core System Project: Science Data Processing (SDP) Toolkit Home Page
- HDF-EOS to GeoTIFF Conversion Tool (HEG)

1.2.4 Resolution

The nominal spatial resolution is 500 meters.

1.2.5 Geolocation

The following tables provide information for geolocating this data set.

Table 3. Projection Details

Region	Global
Geographic coordinate system	WGS84
Projected coordinate system	Sinusoidal Grid
Longitude of true origin	0°
Latitude of true origin	0°
Scale factor at longitude of true origin	1.0
Datum	WGS 84
Ellipsoid/spheroid	6371007.181000 meters
Units	Meter
False easting	0°
False northing	0°
SR-ORG code	6974
PROJ4 string	+proj=sinu +lon_0=0 +x_0=0 +y_0=0 +ellps=WGS84 +datum=WGS84 +units=m +no_defs
Reference	https://spatialreference.org/ref/sr-org/6974/html/

Table 4. Grid Details

Region	Global
Grid cell size (x, y pixel dimensions)	500 m
Number of rows	2400
Number of columns	2400
Nominal gridded resolution	500 m
Grid rotation	N/A
Geolocated upper left point in grid	-20015109.354(x), 10007554.677(y)
Geolocated lower right point in grid	20015109.354(x), -10007554.677(y)

1.3 Temporal Information

1.3.1 Coverage

MODIS Aqua data are available from 04 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.

1.3.2 Resolution

Daily

1.4 Sample Data Image

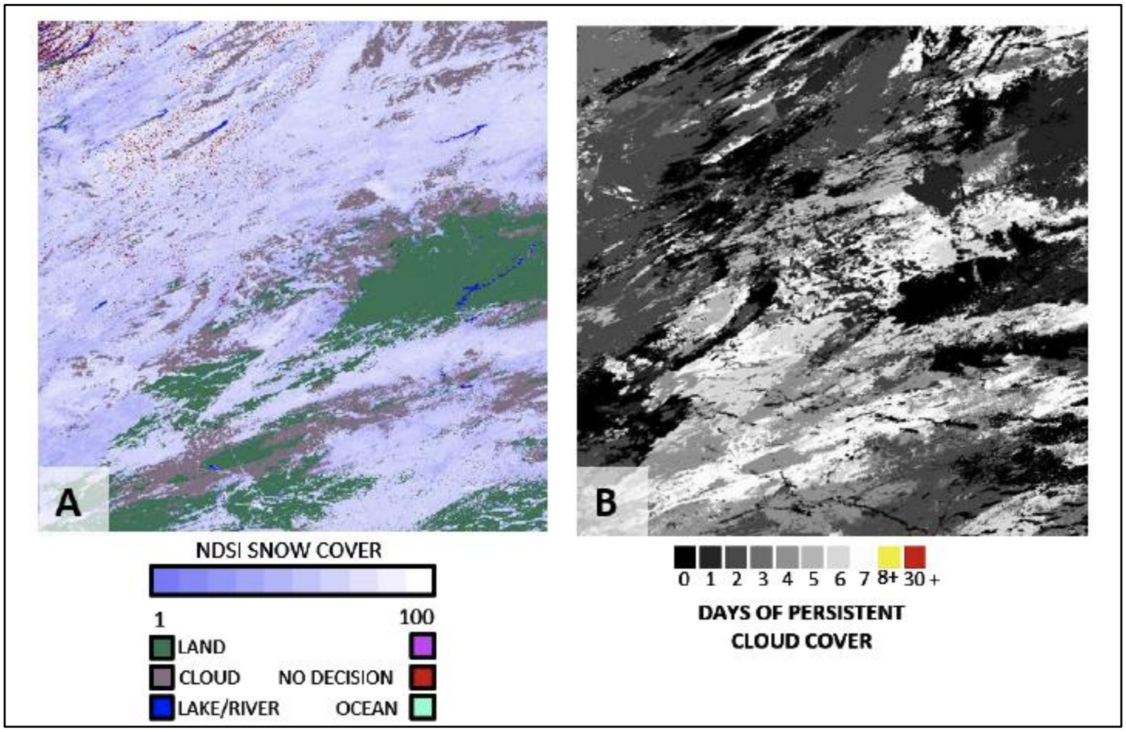

Figure 4. This figure shows CGF_NDSI_Snow_Cover (A) and cloud persistence (B) from MOD10A1F, tile h10v04, (26 December 2017, MODIS/Terra). The region shown extends from southern Nebraska to northern Montana. The unlabeled purple square in the legend represents 'Night'.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

The purpose of the daily CGF snow cover product (MYD10A1F) is to provide a daily 'cloud-free' map of snow cover extent. The CGF snow cover parameter provides an estimate of the snow cover that might exist under current cloud cover.

2.2 Acquisition

The data source for the MYD10A1F V61 product is the MYD10A1 Version 61 product.

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.

2.3 Processing

The MODIS CGF algorithm inputs the current day MYD10A1 snow cover and MYD10A1F snow cover from the previous day. The current day CGF snow cover field is generated by replacing the current day's MYD10A1 cloud-covered observations with MYD10A1F non-cloud (clear view) observations from the previous day. Cloud persistence is tracked by incrementing or resetting the count of consecutive days of cloud cover in each cell in the Cloud_Persistence parameter. When a cloud-free observation occurs, the cloud persistence count is reset to "0" to indicate a cloud-free observation occured on the current day. A cloud persistence value of "1" indicates that the current day was cloudy. A cloud persistence value greater than "1" specifies the number of consecutive cloud-obscured observations in the cell (on that day).

As a result of this approach, the first day of MYD10A1F production the CGF snow cover values will be the same as the corresponding MYD10A1 snow cover values. Over time the MYD10A1F gap-filled cloud cover will eventually decline to zero, as non-cloud observations replace cloud observations. Typically, it takes five to seven days to reach a nearly cloud free map, but this depends on the season and location.

The CGF snow cover product is produced as a 12-month sequence corresponding to the United States Geological Service (USGS) "water year," which begins on 1 October and ends on 30 September. The USGS water year period is maintained for each year, except for the first year which began on 19 January 2012. On the first day of the water year (or first day of temporal coverage) MYD10A1F snow cover is produced as a copy of the MYD10A1 snow cover and cloud persistence values are set to '1' for grid cells that include cloud cover.

A user can determine if MYD10A1F is the first day of a time series or a day in the series by reading the global attribute "First_Day_of_series." This attribute is set to "Y" for the first day in a time series and to "N" for all other days in the time series. The global attribute "Time_Series_Day" stores the count of days in the series since the first day.

Fill data originating from orbit gaps or missing parts of MOD10_L2 swaths (passed on to MYD10A1) is replaced with a non-fill data value from the previous day's MYD10A1F snow cover and the cloud persistence count is incremented by one. Users will note that some MYD10A1 tiles are missing for certain days in the data record. When a missing tile is encountered, the MYD10A1F algorithm uses the previous day's MYD10A1F snow cover as the current day and increments the cloud persistence count by one for all cells. The global attribute "Missing_days_MODIS_10A1_tile_count" reports the number of missing day for the tile.

2.4 Quality

CGF snow cover can be evaluated relative to MYD10A1 Version 61 snow cover by comparing the CGF snow cover to the current day of MYD10A1, which is stored on this product in the "MYD10A1_NDSI_Snow_Cover" parameter.

The 'Basic_QA' field provides general snow cover quality assessment and the 'Algorithm_Bit_Flag_QA' field provides algorithm specific data screen results. These fields are copied from MYD10A1 Version 61 for non-cloud observations and from previous day MYD10A1F for cloud-covered observations. Both the 'Basic_QA' and 'Algorithm_Bit_Flag_QA' were set during MOD10_L2 processing and passed on to MYD10A1. For a detailed description of the accuracy, uncertainty, and errors associated with MOD10_L2 Snow Cover, see the MODIS Snow Products Collection 6.1 User Guide (Riggs et al. 2019).

2.5 Instrumentation

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 5. 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)

Variable	Description
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

2.5.1 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 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

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.
- 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.
- NSIDC's Hierarchical Data Format | Earth Observing System (HDF-EOS) Web page contains information about HDF-EOS, plus tools to extract binary and ASCII objects, instructions to uncompress and geolocate HDF-EOS data files, and links to obtain additional HDF-EOS resources.

4 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 Goddard Space Flight Center | MODIS Land Quality Assessment
- MODIS Land Team Validation | Status for Snow Cover/Sea Ice (MOD10/29)

5 CONTACTS AND ACKNOWLEDGMENTS

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6 REFERENCES

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Masuoka, E., A. Fleig, R.E. Wolfe, and F. Patt. 1998. Key characteristics of MODIS data products. *IEEE Transactions on Geoscience and Remote Sensing* 36(4): 1313-1323. https://dx.doi.org/10.1109/36.701081

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Riggs, G.A. and D.K. Hall. 2020. Continuity of MODIS and VIIRS snow cover extent data products for development of an Earth Science Data Record. Remote Sensing, 12(22): 3781. https://doi.org/10.3390/rs12223781. (PDF)

Wolfe, R.E., D.P. Roy, and E. Vermote. 1998. MODIS land data storage, gridding and compositing methodology: Level 2 grid. *IEEE Transactions on Geoscience and Remote Sensing*, 36(4):1324-1338. https://doi.org/10.1109/36.701082

7 DOCUMENT INFORMATION

7.1 Publication Date

5 October 2019

7.2 Date Last Updated

19 October 2020

APPENDIX A – DATA SCREENS

This appendix provides a description of the data screen tests applied in the 'Algorithm_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 MOD10A1 'NDSI_Snow_Cover' SDS.

LOW VISIBLE REFLECTANCE SCREEN: BIT 1

This screen is used to prevent errors from occuring 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 MYD10A1 'NDSI_Snow_Cover' SDS.

LOW NDSI SCREEN: BIT 2

This screen is used to prevent errors from occuring 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 NDSI is 0.0 ≤ NDSI < 0.1. Therefore, if the NDSI is < 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 about 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 'Algorithm_Flags_QA' SDS and the MOD10A1 'NDSI_Snow_Cover' SDS.