# MODIS/Terra Snow Cover 8-Day L3 Global 0.05Deg CMG, Version 61

## USER GUIDE

**How to Cite These Data**

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

Hall, D. K. and G. A. Riggs. 2021. *MODIS/Terra Snow Cover 8-Day L3 Global 0.05Deg CMG, Version 61.* [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/MODIS/MOD10C2.061. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/MOD10C2

National Snow and Ice Data Center

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# 1 DATA DESCRIPTION

This global data set is produced by mapping eight-day MOD10A2 tiles to the MODIS climate modeling grid (CMG). MOD10A2 observations at 500 m are mapped into 0.05° CMG (~ 5 km) grid cells, binned by observation type (e.g. snow, cloud, ocean), and counted to identify the most frequently occurring feature type. Snow cover is detected using the Normalized Difference Snow Index (NDSI) in a preceding product (MOD10_L2), which is ultimately carried forward to this product. Snow-covered land typically has a very high reflectance in visible bands and very low reflectance in the shortwave infrared; the NDSI reveals the magnitude of this difference. The Scientific Data Sets (SDSs) included with this product are described in Table 1 and a sample image of the data is shown in Figure 1.

The terms “Version 61” and “Collection 6.1” are used interchangeably in reference to this release of MODIS data.

## 1.1 Parameters

Table 1. SDS Details

| Parameter | Description | Values |
|---|---|---|
| `Eight_Day_CMG_Snow_Cover` | The maximum 8-day percentage of snow cover mapped in the CMG cell. | 0-100: eight-day, maximum snow cover percentage<br>107: lake ice<br>111: night<br>237: inland water<br>239: ocean<br>250: cloud obscured water<br>253: data not mapped<br>255: fill |
| `Eight_Day_CMG_Cloud_Obscured` | The percentage of persistent 8-day cloud clover mapped in the CMG cell. | 0-100: percent of cell obscured by clouds<br>107: lake ice<br>111: night<br>237: inland water<br>239: ocean<br>250: cloud obscured water<br>253: data not mapped<br>255: fill |

| Parameter | Description | Values |
|---|---|---|
| `Eight_Day_CMG_Clear_Index` | The percent of non-cloud observations mapped to the CMG cell. Note: A clear index of '0' does not indicate cloud-free conditions, but rather indicates that none of the MOD10A2 input cells were completely cloud obscured. | 0-100: clear index<br>107: lake ice<br>237: inland water<br>239: ocean<br>250: cloud obscured water<br>253: data not mapped<br>255: fill |
| `Snow_Spatial_QA` | Basic quality assurance indicator | 0: good quality<br>1: other quality<br>237: inland water<br>239: ocean<br>252: Antarctica mask<br>253: not mapped<br>255: fill |
| `Lat` | Upper left X coordinate for each grid cell in degrees north. | Coordinate value range 90.0º to - 90.0º |
| `Lon` | Upper left Y coordinate for each grid cell in degrees east. | Coordinate value range -180.0º to 180.0º |

## 1.2 Sample Data File

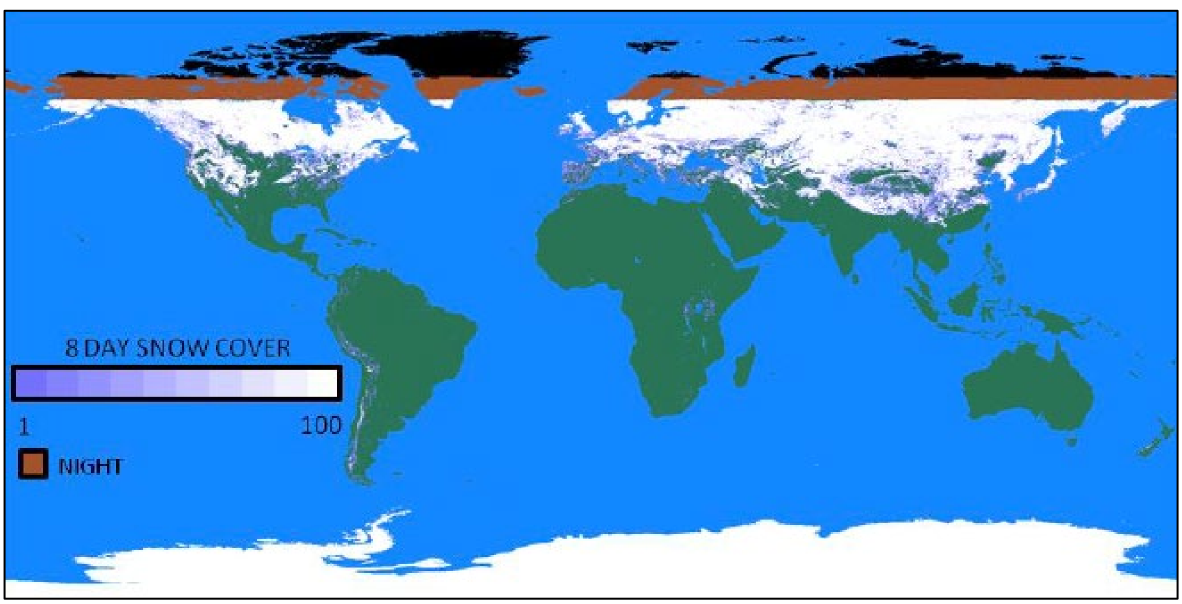


Figure 1. This MOD10C2 snow map shows the maximum percentage of eight-day snow cover mapped to a 0.05° CMG. The data was observed from 1 Jan thru 8 Jan 2003.

## 1.3 File Information

### 1.3.1 Format

Data are provided in HDF-EOS2 format and are stored as 8-bit unsigned integers. For software and more information, visit the HDF-EOS website.

### 1.3.2 Data File

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

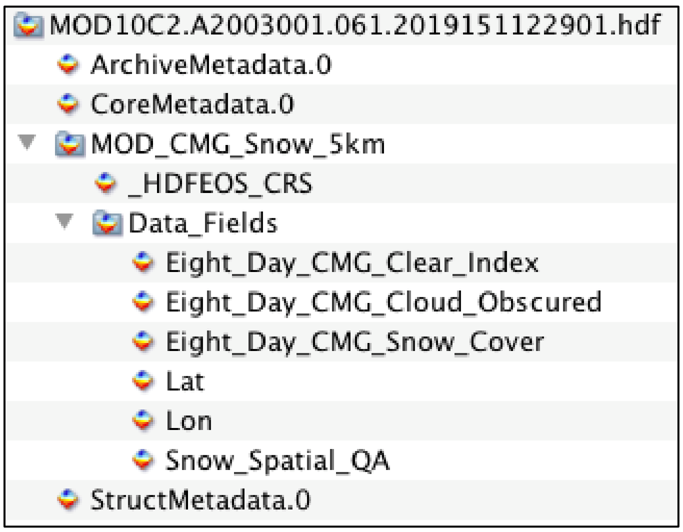


Figure 2. This figure shows the fields included in each data file as displayed with Panoply software.

### 1.3.3 Ancillary Files

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

### 1.3.4 Naming Convention

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

**File naming convention:**

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

Table 2. File Name Variables

| | |
|---|---|
| MOD | MODIS/Terra |
| PID | Product ID |
| A | Acquisition date follows |
| YYYY | Acquisition year |
| DDD | Acquisition day of year |
| VVV | Version (Collection) number |
| yyyy | Production year |
| ddd | Production day of year |
| hhmmss | Production hour/minute/second in GMT |
| .hdf | HDF-EOS formatted data file |

**File Name Example**

`MOD10C2.A2003001.061.2019151122901.hdf`

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

## 1.4 Spatial Information

### 1.4.1 Coverage

Coverage is global. Terra's sun-synchronous, near-polar circular orbit is timed to cross the equator from north to south (descending node) at approximately 10:30 A.M. local time. Complete global coverage occurs every one to two days (more frequently near the poles). The following sites offer tools that track and predict Terra's orbital path:

- Daily Terra Orbit Tracks, Space Science and Engineering Center, University of Wisconsin-Madison
- NASA LaRC Satellite Overpass Predictor (includes viewing zenith, solar zenith, and ground track distance to specified lat/lon)

### 1.4.2 Projection

MODIS CMG data sets are provided in geographic latitude/longitude coordinates. For additional details about the MODIS CMG see the NASA MODIS Lands | MODIS Grids web page.

### 1.4.3 Resolution

0.05°

### 1.4.4 Geolocation

The following tables provide information for geolocating this data set.

Table 3. Projection Details

| | |
|---|---|
| **Region** | Global |
| **Geographic coordinate system** | WGS84 |
| **Projected coordinate system** | Geographic Lat/Lon |
| **Longitude of true origin** | 0° |
| **Latitude of true origin** | 0° |
| **Scale factor at longitude of true origin** | 1.0 |
| **Datum** | WGS 84 |
| **Ellipsoid/spheroid** | WGS 84 |
| **Units** | degrees |
| **False easting** | 0° |
| **False northing** | 0° |
| **EPSG code** | 4326 |
| **PROJ4 string** | +proj=longlat +datum=WGS84 +no_defs |
| **Reference** | https://epsg.io/4326 |

Table 4. Grid Details

| | |
|---|---|
| **Region** | Global |
| **Grid cell size (x, y pixel dimensions)** | 0.05° |
| **Number of rows** | 3600 |
| **Number of columns** | 7200 |
| **Nominal gridded resolution** | 0.05° |
| **Grid rotation** | N/A |
| **Geolocated upper left point in grid** | -180.0°(x), 90.0°(y) |
| **Geolocated lower right point in grid** | 180.0°(x), -90.0°(y) |

# 1.5 Temporal Information

## 1.5.1 Coverage

MODIS Terra data are available from 18 February 2000 to the present. However, because the NDSI depends on visible light, data are not produced when viewing conditions are too dark. In addition, anomalies over the course of the Terra mission have resulted in minor data outages. If you cannot locate data for a particular date or time, check the MODIS/Terra Data Outages web page.

Note: The start date for MOD10C2 C6.1 begins 8-days earlier then the start date for MOD10C2 C6.0. This was done in order to align the MOD10C2 C6.1 start date with the full eight-day compositing period, as described in Table 5. However, the actual days with data are the same for both collections.

## 1.5.2 Resolution

The temporal resolution is eight-days. Tiles are composited from data acquired during eight-day windows. Each year is comprised of 43 compositing periods. The first period begins on the first day of the year; the last period begins on day 361 and extends either two or three days into the following year (leap years vs non-leap years). Table 5 lists the days covered by each compositing period:

Table 5. Eight-day Compositing Periods

| Period | Days | Period | Days | Period | Days | Period | Days |
|---|---|---|---|---|---|---|---|
| 1 | 1-8 | 13 | 97-104 | 25 | 193-200 | 37 | 289-296 |
| 2 | 9-16 | 14 | 105-112 | 26 | 201-208 | 38 | 297-304 |
| 3 | 17-24 | 15 | 113-120 | 27 | 209-216 | 39 | 305-312 |
| 4 | 25-32 | 16 | 121-128 | 28 | 217-224 | 40 | 313-320 |
| 5 | 33-40 | 17 | 129-136 | 29 | 225-232 | 41 | 321-328 |
| 6 | 41-48 | 18 | 137-144 | 30 | 233-240 | 42 | 329-336 |
| 7 | 49-56 | 19 | 145-152 | 31 | 241-248 | 43 | 337-344 |
| 8 | 57-64 | 20 | 153-160 | 32 | 249-256 | 44 | 345-352 |
| 9 | 65-72 | 21 | 161-168 | 33 | 257-264 | 45 | 353-360 |
| 10 | 73-80 | 22 | 169-176 | 34 | 265-272 | 46 | 361-368[1] |
| 11 | 81-88 | 23 | 177-184 | 35 | 273-280 | — | — |
| 12 | 89-96 | 24 | 185-192 | 36 | 281-288 | — | — |
| [1]Includes 2 or 3 days from the next year. | | | | | | | |

# 2 DATA ACQUISITION AND PROCESSING

## 2.1 Background

This data set provides global maps of eight-day snow cover, eight-day cloud cover, and eight-day clear index. The snow map and cloud map represent the maximum percentage of snow cover and persistent cloud cover observed in each CMG cell during the eight-day period. The clear index map reports the fraction of non-cloud observations, thus providing an estimate of the amount of land surface that was observable during the eight-day period.

## 2.2 Acquisition

MODIS scans the entire globe every one to two days. As such, most locations on Earth are imaged at least once per day and more frequently where swaths overlap, such as near the poles. Terra's sun-synchronous, near-circular polar orbit is timed to cross the equator from north to south (descending node) at approximately 10:30 A.M. local time.

**Ongoing changes in the Terra orbit**

The Terra flight operations team conducted Terra's last inclination adjust maneuver to maintain Terra's orbit in February 2020. The inclination adjust maneuvers were used to control the platform's 10:30 AM mean local time (MLT) equator crossing. Terra will continue to drift and is expected to reach a 10:15 AM MLT in October 2022. At that time, the flight operations team will have Terra exit the Earth Sciences Constellation and lower Terra to an altitude of 694 km by performing two retrograde maneuvers. MLT will continue to drift after these maneuvers, reaching 9:00 AM around December 2025. Terra MODIS will remain operational and generate the full suite of products until the end of the mission in December 2025.

Earlier crossing times for a morning platform like Terra mean lower solar elevations leading to more prevalent shadows. This decrease in orbit altitude alters the spatial coverage of the sensor including possible gaps in spatial sampling, decreased spatial coverage, and higher spatial resolution. Products are mostly expected to be science quality except for reduced grid size (from lower altitude) and without a strict 16-day repeat of observations (from drift and changing orbit).

Details on the impact of the Constellation Exit on the quality of the product are being compiled and will be posted when available.

## 2.3 Sources

Table 6 lists the data set and parameter inputs to the MODIS CMG binning algorithm.

Table 6. Inputs to the MOD10C2 CMG Binning Algorithm

| Product ID | Long Name | Parameter |
|---|---|---|
| MOD10A2 | MODIS/Terra Snow Cover 8-Day L3 Global 500m SIN Grid, Version 61 | Maximum_Snow_Extent |

## 2.4 Processing

The MOD10C2 CMG binning algorithm is a revised version of the MOD10C1 binning algorithm (see the MOD10C1 User Guide for more details) that has been adapted to utilize MOD10A2 eight-day data as input. The MOD10C2 algorithm calculates the maximum snow cover extent, persistent cloud cover extent, and associated quality values mapped to CMG grid cells for an eight-day period. The MOD10C2 algorithm maps 500 m MOD10A2 'Maximum_Snow_Extent' observations into 0.05° (approx. 5 km) CMG cells. Approximately 100 MOD10A2 'Maximum_Snow_Extent' observations are mapped into each CMG cell. The mapped observations are binned by feature type (snow, cloud, ocean, etc.) and counted to identify the most frequently occurring feature type in the CMG cell. The observation counts are then used to determine the feature type assigned to the CMG cell. Parameter processing details are provided below.

### 2.4.1 Eight-Day CMG Snow Cover

The maximum extent of snow cover mapped to each CMG cell is calculated by computing the ratio of MOD10A2, 500 m snow-cover observations to the total number of land observations that were mapped into the CMG cell. The result is expressed as the percentage of maximum snow observations mapped in the CMG cell. The valid range of snow cover extent is 0-100%.

### 2.4.2 Eight-Day CMG Cloud Obscured

The extent of cloud cover mapped to each CMG cell is calculated by computing the ratio of MOD10A2, 500 m cloud-cover observations to the total number of land observations that were mapped into the CMG cell. The result is expressed as the percentage of persistent cloud observations mapped in the CMG cell. The valid range of cloud cover extent is 0-100%. Note: MOD10A2 cells only report cloud if the cell was obscured by clouds on all eight days of the period.

### 2.4.3 Eight-Day CMG Clear Index Extent

The clear index is calculated by computing the fraction of all land observations in the cell that were observed under clear sky conditions. The index measures the amount of persistent cloud that was present in a grid cell for eight consecutive days. A high clear index indicates that relatively few input cells were completely cloud obscured. Low values indicate low confidence in the snow cover fraction due to extensive, persistent cloud cover. Note: the MOD10A2 algorithm infers a surface condition if any clear-sky views are available. A clear index = '0' does not indicate cloud-free conditions, but only that none of the MOD10A2 input cells were completely cloud obscured.

### 2.4.4 Inland Water

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

### 2.4.5 Ocean

A CMG-specific land base mask was used with the binning algorithm. This 0.05° land mask was derived from the University of Maryland 1km global land cover data set. If a cell contains less than 12% land cover, it is considered ocean. That threshold was selected as a balance that minimized snow errors along coasts yet was sensitive to mapping snow along coasts.

### 2.4.6 Night

The polar darkness extent is based on the latitude of the CMG cell nearest the equator that is full of night observations. All CMG cells poleward of that latitude are filled as night. This approach was adopted so that a neat demarcation of night and day is visible in the CMG.

### 2.4.7 Antarctica

To improve the visual quality of the data, Antarctica has been mapped as 100% snow. As such, this data set should not be used to map snow in Antarctica. For users who wish to evaluate Antarctica, the MOD10_L2 data set offers higher resolution and contains more data and information about accuracy and error

## 2.5 Quality Information

The 'Snow_Spatial_QA' data array indicates if the input data are valid (within the valid data range) or invalid (outside the valid data range) or if a special condition like polar darkness existed. The quality assurance (QA) value is determined by a count of valid and invalid values tallied in a grid cell. This simple method of estimating QA is used because there is no QA data generated or stored in the MOD10A2 product. The default QA value is 'good quality'; if the majority of observations in a grid cell contain invalid data, the QA value is set to 'other quality'.

## 2.6 Errors

The NDSI technique has proven to be a robust indicator of snow cover. Numerous investigators have utilized MODIS snow cover data sets and reported accuracy in the range of 88% to 93%. This data set provides a synoptic view of maximum snow cover extent during eight-day windows, plus persistent cloud cover and optionally the clear index. Snow cover and cloud cover are written to separate data arrays so that users can consider how best to interpret and use the snow cover map and whether to combine it with the cloud cover data.

Snow commission errors (detecting snow where there is no snow) are typically associated with cloud cover and may appear on any day in conjunction with clouds. These errors may spread in spatial extent over the course of eight days and manifest as low-percentage, maximum snow fractions. A majority of the snow commission errors can be filtered by interpreting snow cover with a value of NDSI < 20 as snow-free. However, this approach may mask out actual snow along the periphery of snow-covered regions.

The algorithm for this data set does not screen for errors; QA values are only provided to indicate whether the input data were valid or invalid or if a special condition like polar darkness was encountered. Users should analyze the snow cover map and choose for themselves an interpretation that minimizes the most probable errors and yet applies the data in a reasonable manner to track maximum snow cover extent.

Snow errors are ultimately propagated from MOD10_L2 to MOD10A1 to MOD10A2, and then into this data set. For more information about potential error sources in the input data, see the 'MODIS Snow Products Collection 6.1 User Guide' (Riggs et al., 2019).

## 2.7 Instrumentation

### 2.7.1 Description

The MODIS instrument provides 12-bit radiometric sensitivity in 36 spectral bands ranging in wavelength from 0.4 µm to 14.4 µm. Two bands are imaged at a nominal resolution of 250 m at nadir, five bands at 500 m, and the remaining bands at 1000 m. A ±55 degree scanning pattern at an altitude of 705 km achieves a 2330 km swath with global coverage every one to two days.

The scan mirror assembly uses a continuously rotating, double-sided scan mirror to scan ±55 degrees and is driven by a motor encoder built to operate 100 percent of the time throughout the six-year instrument design life. The optical system consists of a two-mirror, off-axis afocal telescope which directs energy to five refractive objective assemblies, one each for the visible, near-infrared, shortwave infrared, middle-wavelength infrared, and long-wavelength infrared spectral regions.

The MODIS instruments on the Terra and Aqua space vehicles were built to NASA specifications by Santa Barbara Remote Sensing, a division of Raytheon Electronics Systems. Table 7 contains the instruments' technical specifications:

Table 7. MODIS Technical Specifications

| Variable | Description |
|---|---|
| Orbit | 705 km altitude, 10:30 A.M. descending node (Terra), sun-synchronous, near-polar, circular |
| Scan Rate | 20.3 rpm, cross track |
| Swath Dimensions | 2330 km (cross track) by 10 km (along track at nadir) |
| Telescope | 17.78 cm diameter off-axis, afocal (collimated) with intermediate field stop |
| Size | 1.0 m x 1.6 m x 1.0 m |
| Weight | 228.7 kg |
| Power | 162.5 W (single orbit average) |
| Data Rate | 10.6 Mbps (peak daytime); 6.1 Mbps (orbital average) |
| Quantization | 12 bits |
| Spatial Resolution | 250 m (bands 1-2)<br>500 m (bands 3-7)<br>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

**George Riggs**
NASA Goddard Space Flight Center (GSFC)
Greenbelt, MD

**Dorothy Hall**
ESSIC / University of Maryland
College Park, MD

**Miguel Roman**
NASA Goddard Space Flight Center (GSFC)
Greenbelt, MD

# 7 REFERENCES

Hall, D.K., Riggs, G.A. and Salomonson, V.V. 2001. Algorithm Theoretical Basis Document (ATBD) for MODIS Snow and Sea Ice-Mapping Algorithms. Guide. NASA Goddard Space Flight Center, Greenbelt, MD.

Riggs, G.A., Hall, D.K. and Roman, M.O. 2015. VIIRS Snow Cover Algorithm Theoretical Basis Document (ATBD). NASA Goddard Space Flight Center, Greenbelt, MD. (See PDF)

Riggs, G.A., Hall, D.K. and Roman, M.O. 2019. MODIS Snow Products Collection 6.1 User Guide. NASA Goddard Space Flight Center, Greenbelt, MD. (See PDF)

# 8 DOCUMENT INFORMATION

## 8.1 Publication Date

March 2021

## 8.2 Date Last Updated

December 2021