Multilayer Greenland Ice Surface Temperature, Surface Albedo, and Water Vapor from MODIS, Version 1

USER GUIDE

How to Cite These Data

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

Hall, D. K. and N. DiGirolamo. 2019. *Multilayer Greenland Ice Surface Temperature, Surface Albedo, and Water Vapor from MODIS, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/7THUWT9NMPDK. [Date Accessed].

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

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

National Snow and Ice Data Center

TABLE OF CONTENTS

1 DATA DESCRIPTION

This multi-layer data set includes a swath data file, a daily averages data file, and a monthly averages data file. The parameters for each of these files are shown in tables 1, 2, and 3. Users should refer to Hall et al. (2018) for a more detailed data description. The temporal coverage for this data set spans 1 March 2000 through 31 December 2019, with the exception of the IST data, which has been extended through 31 Aug 2021.

1.1 Parameters

Table 1 describes the parameters included in the swath data file. All available swaths covering Greenland for each day (24-hour period) are provided. The swath observation time is indicated in the file naming convention, as described in Section 1.2.4 below.

Table 1. Swath Parameters

Parameter	Description	Values
Albedo (`Albedo`)	Note, this parameter includes daily averages, not swath observations. **This field in each of the swath files is identical to the one provided in the respective daily file.**	See the albedo parameter in Table 2.
Cloud Mask (`Cloud_Mask_QA`)	Cloud mask swath flags for specifying the likelihood of cloudy skies or clear skies.	0: Confident Cloudy 1: Probably Cloudy 2: Probably Clear 3: Confident Clear
Ice Surface Temperature (`Ice_Surface_Temperature`)	IST produced from swath observations, in kelvins (K).	0: No data 1: Indeterminate 25: Land 39: Open Ocean 50: Cloud Cover 210-313: Expected IST range 655.35: Fill value
Quality Assurance Flag (`Quality_Assurance_Near_Infrared_b0`)	Runtime quality assurance flags. Refer to the Appendix of this User Guide for details on how to use it.	0-255: Valid data range 255S: Fill value
Water Vapor (`Water_Vapor_Near_Infrared_b0`)	Water vapor swath observations, in centimeters (cm).	Valid data range: 0-20 Fill value: -9.999

Table 2 describes the parameters included in the daily averages data file.

Table 2. Daily Parameters

Parameter	Description	Values
Albedo (Albedo)	Daily gridded albedo, presented as a percentage (%).	1–100: snow albedo 101: no decision 111: night 125: land 137: inland water 139: ocean 150: cloud 151: cloud detected as snow 250: missing 251: self-shadowing 252: land mask mismatch 253: BRDF failure * 254: non-production mask 255: fill value
Ice Surface Temperature Mean (Ice_Surface_Temperature_Mean)	Daily mean gridded IST in kelvins (K).	0: No data 50: Cloud Cover 243-273: Expected IST range -999: Fill value
Surface Melt (Ice_Surface_Temperature_Melt_NoMelt)	Daily gridded maximum surface melt, in kelvin (K).	0: No data 1: No melt 2: Melt 50: Cloud
Swath Tracker (Number_of_Swaths_and_Hour_Tracker)	Gridded field for specifying the number of swath temperatures observations that were mapped to each grid cell, as well as the hour(s) for which temperature data were mapped for the day.	Key1 = Bits 0 to 23, set to 1 if swath data was mapped in a cell during an hour: Bit 0 represents hour starting 0Z, Bit 1: hour starting 1Z, Bit 23: hour starting 23Z. Key2 = Bits 24 to 31, comprise an 8-bit word containing the number of swaths that were mapped in a cell.
Water Vapor Mean (Water_Vapor_Near_Infrared_Mean)	Daily mean gridded water vapor, in centimeters (cm).	0-20: Valid data range -9.999: Fill value
* Bidirectional Reflectance Distribution Function (Klein and Stroeve, 2002)		

Table 3 describes the parameters included in the monthly averages data file.

Table 3. Monthly Parameters

Parameter	Description	Values
Albedo (Albedo)	Monthly mean gridded albedo, presented as a percentage (%).	1–100: snow albedo 101: no decision 111: night 125: land 137: inland water 139: ocean 150: cloud 151: cloud detected as snow 250: missing 251: self-shadowing 252: land mask mismatch 253: BRDF failure 254: non-production mask 255: fill value
Ice Surface Temperature Mean (Ice_Surface_Temperature_Mean)	Monthly mean gridded IST, in kelvin (K).	0: No data 50: Cloud Cover 243-273: Expected IST range -999: Fill value
Water Vapor Mean (Water_Vapor_ Near_Infrared_Mean)	Monthly mean gridded water vapor, in centimeters (cm).	0-20: Valid data range -9.999: Fill value
Albedo Number of Days (Albedo_Ndays)	Number of days that contributed to developing the monthly mean Albedo field.	The valid data range is 0-31.
Ice Surface Temperature Mean Number of Days (Ice_Surface_Temperature _Mean_Ndays)	Number of days that contributed to developing the monthly mean IST field.	The valid data range is 0-31.
Surface Melt Number of Days (Ice_Surface_Temperature _Melt_Ndays)	Number of melt days that occurred in the month.	The valid data range is 0-31.
Water Vapor Mean Number of Days (Water_Vapor_ Near_Infrared_Mean_Ndays)	Number of days that contributed to developing the monthly mean Water Vapor Near Infrared field.	The valid data range is 0-31.

In addition to the data parameters shown above, this data set includes ancillary parameters in the area masks file and *LatLon* file (which can be found in the first day of data directory, 2000.03.01). A description of the parameters included in each of these files is provided in Table 4 and Table 5, respectively.

Table 4. Area Mask Parameters

Parameter	Description	Values
Basins Mask (`Basins_Mask`)	Gridded basin mask for delineating drainage divides in Greenland.	Nineteen drainage basins have been identified for Greenland. Basin mask data have a scale factor of 10. Each drainage basin is identified by values ranging from 0 to 82.
Digital Elevation Model (`DEM`)	Gridded Digital Elevation Model (DEM) displaying the elevation, in meters (m), for each grid cell.	DEM data have a scale factor of 1.0. The valid data range is -10 to 3343.
Land Ice Water Mask (`Land_Ice_Water_Mask`)	Gridded mask for delineating land, ice, and water in Greenland.	0: Water 1: Ice 2: land
Pixel Area (`Pixel_Area`)	Area of each pixel in kilometers (km^2)	The valid data range is 0.556685 to 0.646100.

Table 5. LatLon Parameters*

Parameter	Description	Values
Latitude	Latitude coordinate at the center of each pixel.	The valid coordinate range is 58.4673 to 84.6922
Longitude	Longitude coordinate at the center of each pixel.	The valid coordinate range is -94.5383 to 12.0320
* An ancillary file containing the latitude and longitude coordinates is provided in the same directory as the first day of data, i.e. 2000.03.01.		

1.2 File Information

1.2.1 Format

Data are provided in NetCDF 16-bit integer and 32-bit floating-point format. For more information about working with NetCDF formatted data, visit the UCAR Unidata Network Common Data Form website.

1.2.2 Directory Structure

The directory structure for the data includes subdirectories for each day of data beginning 2000.03.01. All directories include both swath and daily files. Monthly files are included in directories for the first day of each month. The two ancillary files are provided in the first day of data directory, which is 2000.03.01.

1.2.3 Naming Convention

The five data files included with this data set are named according to the following convention and as described in Table 6.

File naming convention:

`MODGRNLD.YYYYDDD.HHMM.TYPE.VVV.nc`

Example file names:

`MODGRNLD.2008144.0015.swath.v01.1.nc`

`MODGRNLD.2008144.daily.v01.1.nc`

`MODGRNLD.200805.monthly.v01.1.nc`

`MODGRNLD.ancillary.areamasks.v01.1.nc4`

`MODGRNLD.ancillary.latlon.v01.1.nc4`

Table 6. File Name Variables for Standard MODIS Convention

Variable	Description
`MODGRNLD`	MODIS Greenland
`YYYY`	Acquisition year
`DDD`	Acquisition day of year
`HHMM`	Acquisition hour and minute in Greenwich Mean Time (GMT)
`TYPE`	Type of data. Valid values include `swath`, `daily`, `monthly`, `ancillary.areamasks`, or `ancillary.latlon`.
`VVV`	Data set version number (currently `v01.1`)
`.nc` or `.nc4`	NetCDF formatted data file

1.3 Spatial Information

1.3.1 Coverage

Southernmost Latitude: 58.4673° N

Northernmost Latitude: 84.6922° N

Westernmost Longitude: 94.5583° W

Easternmost Longitude: 12.0320° E

1.3.2 Resolution

The nominal spatial resolution is 780 m or 0.78 km. However, because the polar stereographic grids are not equal-area, the actual resolution varies by latitude.

1.3.3 Geolocation

The following tables provide information for geolocating this data set

Table 7. Projection Details

Region	Greenland
Geographic coordinate system	Unspecified datum based upon the Hughes 1980 ellipsoid
Projected coordinate system	NSIDC Sea Ice Polar Stereographic North
Longitude of true origin	-45° W
Latitude of true origin	90° N
Standard parallel	70° N
Scale factor at longitude of true origin	1.0
Datum	N/A (based on Hughes 1980 ellipsoid)
Ellipsoid / spheroid	Hughes 1980
Units	Meter
False easting	0
False northing	0
EPSG code	3411
PROJ4 string	+proj=stere +lat_0=90 +lat_ts=70 +lon_0=-45 +k=1 +x_0=0 +y_0=0 +a=6378273 +b=6356889.449 +units=m +no_defs
Reference	http://epsg.io/3411

Table 8. Grid Details

Grid cell size (x, y pixel dimensions)	781.25 m
Number of rows	2000
Number of columns	3600
Nominal gridded resolution	780 m
Grid rotation	180° (see warning note below)
ULX, ULY – x-axis and y-axis map coordinates of the center of the upper-left pixel	-675000.0, -575000.0
LRX, LRY – x-axis and y-axis map coordinates of the center of the lower-right pixel	887500.0, -3387500.0

NOTE: The upper-left and lower-right coordinates specified in Table 8 and in the file-level metadata refer to the grid when oriented in the north/top – south/bottom position. Because the grid has a 180° rotation, the user should flip the Y-axis in order to apply the given x and y coordinates.

1.4 Temporal Information

1.4.1 Coverage

The temporal coverage of this data set extends from 01 March 2000 to 31 December 2019 for most data and from 01 March 2000 to 31 August 2021 for IST data.

1.4.2 Resolution

This data set includes daily swath fields, daily averaged fields, and monthly averaged fields. The temporal resolution is specified in the file naming convention.

1.5 Sample Data Image

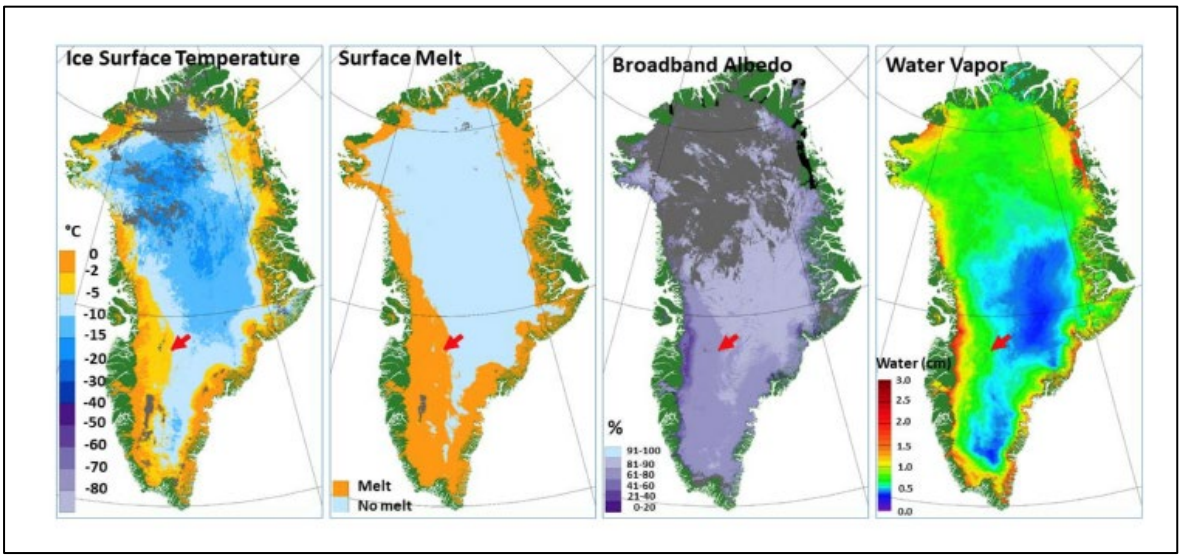

Figure 1. This figure shows 4-day composites from 10-13 July 2014 of the daily IST, surface melt, albedo, and water vapor maps.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

This data set has been developed using standard MODerate-resolution Imaging Spectroradiometer (MODIS) data sets from the Terra satellite. To meet the needs of the ice sheet modeling community, this data set is provided in a polar stereographic projection in NetCDF format, and includes MODIS Collection 6.1 IST and derived melt maps, as well as ancillary data and MODIS Collection 6.0 snow albedo, and water vapor maps.

This data set provides all parameter fields on the same grid, thus enabling the complex relationships between IST, surface melt, albedo, and water vapor to be evaluated; therefore, saving users the effort of performing data access and reprocessing operations. This data set also provides a complementary resource to other MODIS snow and ice data sets. A grid resolution of 0.78 km was selected to enable the data set to be continued in the future using VIIRS data.

The input sources for the IST, albedo, water vapor and surface melt parameters are specified below, and a brief summary of the derivation techniques applied to these sources is provided.

2.2 Sources

Table 9. Source Information for Data Set Parameters

Data Set	Input Sources
Ice Surface Temperature (IST)	The source for the IST swath fields is the MODIS/Terra Sea Ice Extent 5-Min L2 Swath 1km, Version 6 (MOD29). The daily average IST fields are calculated from all the swaths that cover Greenland for that day, and the monthly average IST fields are calculated from the daily IST fields.
Albedo	The source for the daily snow albedo fields is the MODIS/Terra Snow Cover Daily L3 Global 500m Grid, Version 6 (MOD10A1). The monthly average albedo fields are calculated from the daily albedo average fields.
Water Vapor	The source for the water vapor swath fields is the Collection 6 MODIS Near-Infrared Total Precipitable Water (MOD05). The daily average water vapor fields are calculated from all the swaths that cover Greenland for that day, and the monthly average water vapor fields are calculated from the daily water vapor fields.
Surface Melt	The daily surface melt fields are derived from the MODIS/Terra Sea Ice Extent 5-Min L2 Swath 1km, Version 6 (MOD29), and the monthly average fields are calculated from the daily average fields.

2.3 Derivation Techniques for Ice Surface Temperature

Daily IST parameter fields are produced by averaging the ISTs in each pixel for all of the Terra swaths covering Greenland over a 24-hour period. These ISTs are then mapped to a 0.78 km polar stereographic grid. Grid cells that are cloudy, according to the cloud mask, do not provide IST, and are therefore not used to calculate the value reported in that grid cell. The daily fields are averaged for each grid cell to create monthly fields for each month of the MODIS Terra time series. From the swath, daily, or monthly fields, mean annual clear-sky IST maps can be created by a user.

2.4 Derivation Techniques for Snow Albedo

Daily albedo tile data from the MODIS Collection 6.0 MOD10A1 data set was mapped and resampled to a 0.78 km Polar Stereographic grid. The MOD10A1 albedo algorithm is based on a model of bidirectional reflectance of snow to correct for anisotropic scattering effects over non-forested surfaces (Klein and Stroeve 2002).

2.5 Derivation Techniques for Water Vapor

Daily water vapor data are produced by averaging the water vapor in each pixel for all of the Terra swaths covering Greenland over a 24-hour period. These water vapor estimates are then mapped to a 0.78 km polar stereographic grid. The algorithm used to develop the daily MODIS water vapor data set (MOD05) relies on observations of attenuation of near-infrared (IR) solar radiation reflected by surfaces and clouds using ratios of water vapor absorbing channels. The column water vapor is derived from transmittances that are based on theoretical calculations and look-up tables. This data set is available during all sky conditions except for darkness. For clear pixels, the water vapor retrievals are made above clear surfaces. For cloudy pixels, the water vapor retrievals are made above clouds. Water vapor below clouds is not seen by MODIS near-infrared channels; this could result in biases when using a time series of water vapor data.

2.6 Derivation Techniques for Surface Melt

Daily surface melt data is calculated from the daily IST using non-cloud-obscured pixels. If an IST grid cell is $\geq$ -1º C then it is considered 'melt'. The melt threshold of $\geq$ -1º C is used instead of $\geq$ 0º C for three reasons: (1) The accuracy of the IST data set is $\pm$1º C and, therefore, melt would be missed if a threshold of 0º C was used. (2) This melt threshold yields a map that is closer to other remotely sensed maps. (3) Melt can occur while temperatures are slightly below freezing if the solar radiation is strong. However, a user may select any threshold value desired to create a melt map from the IST data. Daily and monthly maximum melt data sets are provided. From the swath, daily, or monthly fields, a user can create annual maps of maximum surface melt. For additional melt map information see Hall. et al (2013).

2.7 Quality

See Hall et al. (2018) for a detailed data description, data validation information, and data quality comparison information.

2.8 Limitations

The accuracy of the albedo data set has not been completely validated and may have high errors for times and locations of large solar zenith angles.

2.9 Instrumentation

For a detailed a description of the MODIS instrument, refer to the MODIS instrument specifications page.

3 SOFTWARE AND TOOLS

Unidata maintains an extensive list of freely available Software for Manipulating or Displaying NetCDF Data.

4 VERSION HISTORY

Table 10. Version History Summary

Version	Release Date	Description of Changes
V1	February 2019	Initial release
V1.1	December 2020	Changes to this version include: • Extension of time series • Corrected projection information in metadata • Renaming of files to include "v01.1".
V1.1	April 2023	Changes to this version include: • Extension of time series (for IST files only)

5 CONTACTS AND ACKNOWLEDGMENTS

Dorothy Hall
ESSIC / University of Maryland
College Park, MD

Nicolo DiGirolamo
SSAI, Lanham, MD
Cryospheric Sciences Laboratory
NASA Goddard Space Flight Center

6 REFERENCES

Gao, B.C. and Y. J. Kaufman. 2003. Water vapor retrievals using Moderate Resolution Imaging Spectroradiometer (MODIS) near-infrared channels. *Journal of Geophysical Research: Atmospheres*, 108(D13), 4389–4398. https://doi.org/10.1029/2002jd003023

Hall, D. K., J. C. Comiso, N. E. DiGirolamo, C. A. Shuman, J. E. Box, and L. S. Koenig. 2013. Variability in the surface temperature and melt extent of the Greenland ice sheet from MODIS. *Geophysical Research Letters*, 40(10), 2114–2120. https://doi.org/10.1002/grl.50240

Hall, D. K., R. I. Cullather, N.E. DiGirolamo, J. C. Comiso, B. C. Medley, and S. M. Nowicki. 2018. A multilayer surface temperature, surface albedo, and water vapor product of Greenland from MODIS. *Remote Sensing,* 10(4): 555, https://doi.org/10.3390/rs10040555.

Klein, A. and J. C. Stroeve. 2002. Development and validation of a snow albedo algorithm for the MODIS instrument. *Annals of Glaciology,* 10: 45-52, https://doi.org/10.3189/172756402781817662

Riggs, G.A., D.K. Hall, and V. V. Salomonson. 2006. MODIS Sea Ice Products User Guides, https://modis-snow-ice.gsfc.nasa.gov/?c=userguides

7 DOCUMENT INFORMATION

7.1 Publication Date

February 2019

7.2 Date Last Updated

April 2023

APPENDIX: Unpacking the Quality_Assurance_Near_Infrared_B0 Flag

Each pixel in the Quality_Assurance_Near_Infrared_b0 SDS is assigned a 5 byte (40 bit) array. Individual bits or groups of bits are set to denote various quality run-time characteristics for that pixel.

All bit and byte numbering depicted in Table will start with 0.

Bits	Field Description	Bit Interpretation Key
Byte #0		
0	IR Water Vapor QA	0 = Not Useful 1 = Useful
1-3	IR Water Vapor Confidence QA (1km)	0 = Fill (Bad or Cloudy) 1 = Best Quality 2-7 = Not Used
4-7	(spares)	n/a
Byte #1		
0-7	Number of Cloudy Pixels within 5x5 km box	valid range: 0 to 25
Byte #2		
0-7	Number of Clear Pixels within 5x5 km box	valid range: 0 to 25
Byte #3		
0-7	Number of Missing Pixels within 5x5 km box	valid range: 0 to 25
Byte #4		
0-1	IR Water Vapor Retrieval Method Used	0 = Split Window (11-12) 1 = Moisture Profile Integration 2 = Other 3 = No Retrieval
2-7	(spares)	n/a