Greenland Ice Sheet Melt Characteristics Derived from Passive Microwave Data, Version 1

USER GUIDE

How to Cite These Data

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

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National Snow and Ice Data Center

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1 DATA DESCRIPTION

The Greenland ice sheet melt extent data, acquired as part of the NASA Program for Arctic Regional Climate Assessment (PARCA), is a daily (or every other day, prior to August 1987) estimate of the spatial extent of wet snow on the Greenland ice sheet since 1979. It is derived from passive microwave satellite brightness temperature characteristics using the Cross-Polarized Gradient Ratio (XPGR) of Abdalati and Steffen (1997). It is physically based on the changes in microwave emission characteristics observable in data from the Scanning Multi-channel Microwave Radiometer (SMMR) and the Special Sensor Microwave/Imager (SSM/I) instruments when surface snow melts. It is not a direct measure of the snow wetness but rather is a binary indicator of the state of melt of each SMMR and SSM/I pixel on the ice sheet for each day of observation. It is, however, a useful proxy for the amount of melt that occurs on the Greenland ice sheet. The data are provided in a variety of formats including raw data in ASCII format, gridded daily data in binary format, and annual and complete time series climatologies in gridded binary and GeoTIFF format. All data are in a 60 x 109 pixel subset of the standard Northern Hemisphere polar stereographic grid with a 25 km resolution and are available via FTP.

1.1 Parameters

The parameter of the Greenland Ice Sheet Melt Characteristics data set is snow melt. In this data set, snow melt is characterized by a threshold value derived from the Cross-Polarized Gradient Ratio (XPGR) of Abdalati and Steffen (1997). Refer to Equation 2. All values above this threshold are considered to be wet snow and therefore experiencing melt and those below the threshold are considered dry (that is, frozen).

1.1.1 Daily Melt Location Files

The daily melt location files contain a list of pixel coordinates (X,Y) on the Greenland ice sheet showing melt for the date specified in the title of the file. That is, the files only contain the coordinates of the pixels that have a value higher than the XPGR threshold value. For details on the processing of these files, see Processing. The range of the data for the daily melt location files is 0 to 59 for X values (left column) and 0 to 108 for Y values (right column) indicating the X,Y location of the pixel showing melt. Note: The pixels have these values because they apply to a 60 x 109 sub-image of the standard Northern Hemisphere polar stereographic grid. For detailed information on the format of these files, see the Format section.

1.1.2 Daily Gridded Melt Status Files

The daily gridded melt status files contain a 60 x 109 array of values indicating the melt status of a pixel on the Greenland ice sheet. For details on the processing of these files, see the Processing section of this document. Pixels with a value of 1 indicate snow melt, and pixels with a value of 0 in the interior of the ice sheet indicate no snow melt. Other pixels, those outside the boundaries of the Greenland ice sheet, including areas along the coastline or mixed pixels only partly covering the ice sheet are not included in the assessment for melt conditions and are set to -999 in the files. For more information on the gridded format of these files, see Format section below.

1.1.3 Annual Melt Number Files

1.1.3.1 Binary Format

The data in the gridded binary annual melt data files are the total number of days that melt occurred at that pixel during a single melt season (acquired from the daily gridded melt status files). For example, if a pixel has a value of 85, that pixel was recorded as showing melt for 85 days that year. For more information about the processing of these files, see the Processing section of this document.

1.1.3.2 GeoTIFF Format

The data in the GeoTIFF annual melt data files are the total number of days that melt occurred at that pixel during a single melt season. For example, if a pixel has a value of 85, that pixel was recorded as showing melt for 85 days that year. In the image, the brighter the pixel the more days of melt there were for that pixel for the year stated in the file name. For more information about the processing of these files, see the Processing section of this document.

1.1.3.3 Climatology Files

The values represent the number of days that the pixel experienced melt on average from 1979 to 2007. For more information about the processing of these files, see the Processing section of this document. The GeoTiff climatology file wa.

1.2 File Information

1.2.1 Format

Below is a detailed description of the format of the daily melt location files, the daily gridded melt status files, and the climatology files.

1.2.1.1 Daily Melt Location Files

The Greenland Ice Sheet melt characteristics raw data files are provided in ASCII text format and contain a list of pixel coordinates showing melt on the Greenland ice sheet for the date specified in the title of the file. The pixel coordinates are listed in each file in two columns of numbers; the first column is the X location, and the second column is the Y location. Be aware, however, that these X and Y values apply to a 60 x 109 sub-image of the standard Northern Hemisphere 304 x 448 Polar Stereographic grid. To convert these numbers back to the standard PS grid, add 129 to all of the X values and 260 to all of the Y values. For example, the first element of the Greenland subset is the 129th X value and the 260th Y value in the standard PS grid; and the last element of the Greenland subset corresponds to the 189th X value and the 369th Y value. Tools for working with these data files are available in the Software and Tools section of this document.

Note: The index transformation from the Greenland subset to the standard PS grid depends on whether the first element on the PS grid is called 0,0 (as in C or IDL) or 1,1 (as in FORTRAN). For example, using a one-based index (1,1 is the first element) in the standard grid, the first element in the Greenland subset is 129,260 in the standard grid. However, using a zero-based index (0,0 is the first element) in the standard grid, the first element in the Greenland subset is 128,259 in the standard grid.

1.2.1.2 Daily Gridded Melt Status Files

The Greenland Ice Sheet melt characteristics gridded data files are provided in flat binary, 2-byte unsigned format (little-endian). The data were gridded to a 60 x 109 pixel subset of the standard Northern Hemisphere 304 x 448 Polar Stereographic grid to make a product that could be easily displayed as an image. To convert these numbers back to the standard PS grid, add 129 to all of the X array values and 260 to all of the Y array values. For example, the first element of the Greenland subset is the 129th X array value and the 260th Y array value in the standard grid; and the last element of the Greenland subset corresponds to the 189th X array value and the 369th Y array value. Tools for working with these data files are available in the Software and Tools section of this document.

Note: The index transformation from the Greenland subset to the standard PS grid depends on whether the first element on the PS grid is called 0,0 (as in C or IDL) or 1,1 (as in FORTRAN). For example, using a one-based index (1,1 is the first element) in the standard grid, the first element in the Greenland subset is 129,260 in the standard grid. However, using a zero-based index (0,0 is the first element) in the standard grid, the first element in the Greenland subset is 128,259 in the standard grid.

1.2.1.3 Annual Melt Number Files

Both the complete time series and annual time series files are provided in flat binary, 2-byte unsigned (little-endian) format and GeoTIFF format. The gridded binary files consist of a 60 x 109 pixel subset of the Northern Hemisphere polar stereographic projection. See the Daily Gridded Melt Status Files format, above, for more information on this subset. See the Processing section of this document for more information about how the GeoTIFF files were created. Tools for working with the binary annual data files are available in the Software and Tools section of this document, and tools for working with the GeoTIFF data files are available in the Software and Tools section of this document.

1.2.1.4 Climatology Files

Both the complete time series and annual time series files are provided in flat binary, 2-byte unsigned (little-endian) format and GeoTIFF format. The gridded binary files consist of a 60 x 109 pixel subset of the Northern Hemisphere polar stereographic projection.

Table 1. File Type and Sizes

File Type	Size	Total Volume
Daily Melt Location Files	0 KB to 16 KB each. Note: 0 KB files with no data in them indicate no melt for that day.	67 MB
Daily Gridded Melt Status Files	16 KB each	67 MB
Annual Melt Number Files	Binary: 16 KB each GeoTIFF: 16 KB each.	976 KB
Climatology Files	19792007climatology_melt.dat: 16 KB 19792007climatology_melt.tif: 16 KB	36 KB

1.2.2 File Contents

Daily Gridded Melt Status Files

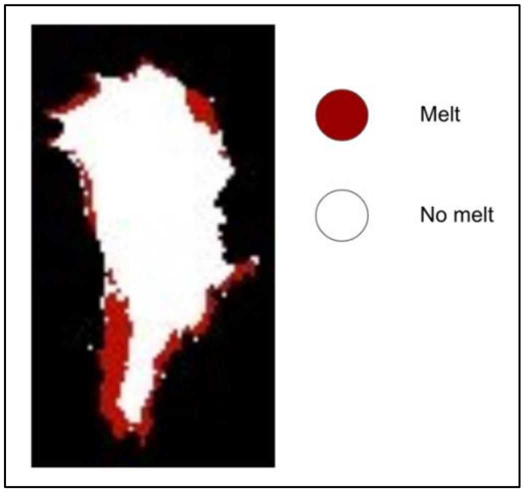

Figure 1. Sample image for one day of the gridded binary data.

Annual Melt Number Files

Figure 2. Sample image of an annual melt data GeoTIFF file.

1.2.3 Directory Structure

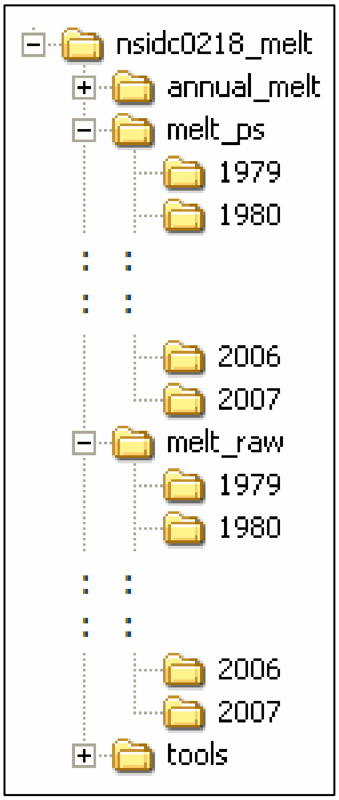

Figure 3. Directory Structure

The data are available on the FTP site in the nsidc0218_melt directory. Within this directory, there are four subdirectories as described here:

Table 2. Directory Descriptions

Directory	Description
annual_melt	Contains all of the annual melt number files and the climatology files in both binary and GeoTIFF formats.
melt_ps	Contains directories labeled by the year that the data were acquired. Each year directory contains the daily gridded melt status files for that year.
melt_raw	Contains directories labeled by the year that the data were acquired. Each year directory contains the daily melt location ASCII text files for that year.
tools	Contains IDL procedures, masks, and geolocation tools for accessing the data files.

1.2.4 Naming Convention

Raw files are named according to the following convention and as described here:

yyyydddiii.meltpts

Where:

Table 3. Daily Melt Location Files

Variable	Description
yyyy	4-digit year
ddd	3-digit day of year
iii	Instrument (smr: SMMR, f08: SSM/I F8, f11: SSM/I F11, and f13: SSM/I F13)
meltpts	Indicates that this file contains the pixel (x,y) location of cells showing melt

The gridded files are named according to the following convention and as described here:

yyyydddiii.dat

where:

Table 4. Daily Gridded Melt Status Files

Variable	Description
yyyy	4-digit year
ddd	3-digit day of year
iii	Instrument (smr: SMMR, f08: SSM/I F8, f11: SSM/I F11, and f13: SSM/I F13)

The annual time series melt files are named according to the following convention:

`yyyyannual_melt.ext`

Where:

Table 5. Annual Melt Number Files

Variable	Description
yyyy	4-digit year
annual_melt	Indicates that this file contains the annual number of melt days per grid cell
.ext	Extension (.dat: binary, .tif: GeoTIFF)

Climatology Files: The complete time series climatology binary and GeoTIFF files are named 19792007climatology_melt.dat and 19792007climatology_melt.tif, respectively.

1.3 Spatial Information

1.3.1 Coverage

The corner points of the Greenland subset of the Northern Hemisphere polar stereographic grid (rounded to the nearest hundredth) are listed in Table 6. For exact corner points, please use the geolocation files provided: Nps.mpp and green_ps.gpd.

Table 6. Spatial Coverage Corner Points

Corner	Latitude	Longitude
Upper left	81.69	-90.00
Upper right	80.31	7.72
Lower left	59.36	-55.81
Lower right	58.98	-30.91

Note: Melt characteristics are only indicated for pixels completely within the boundaries of the Greenland ice sheet as digitized from the Quaternary Map of Greenland produced by the Geological Survey of Greenland (1:2,500,00 scale) (Abdalati and Steffen 1995).

1.3.2 Resolution

The resolution of all data files is 25 km.

1.3.3 Geolocation

1.3.3.1 Projection

The gridded data and the climatology files are gridded on a Greenland subset of the Northern Hemisphere polar stereographic projection. NSIDC chose the Hughes ellipsoid in constructing the polar stereographic grid. The Hughes ellipsoid assumes a radius of 6378.273 km and an eccentricity (e) of 0.081816153 (or e**2 = 0.006693883). For more information on polar stereographic projection, see the Polar Stereographic Projections and Grids Web page.

1.3.3.2 Grid Description

The Greenland subset of the 304 x 448 25 km Northern Hemisphere polar stereographic projection is a region starting at column 128, row 259 (0-based) that contains 60 columns and 109 rows.

1.4 Temporal Information

1.4.1 Coverage

This data set currently spans 02 April 1979 - 31 October 2007. Processing is ongoing, and new data will be added as it becomes available.

1.4.2 Resolution

From 1979 to August 1987, data were recorded every other day; and from September 1987 to the most current processing, data were recorded every day.

2 DATA ACQUISITION AND PROCESSING

2.1 Acquisition

Due to the harsh environment and inaccessibility of the Greenland Ice Sheet, remotely sensed data is ideal as it allows the scientist access to an environment that would otherwise be unattainable. Passive microwave sensors are uniquely adequate for the study of melting snow for several reasons: the amount of change in microwave emission when liquid water forms in the snow is dramatic and therefore, easily detected; microwave radiation can pass through cloud cover; measurements can be taken at night; and coverage of the Greenland Ice Sheet is frequent with these wide-swath instruments (Abdalati and Steffen 1997).

The input source data for the daily melt location files are brightness temperatures from the SSM/I and SMMR instruments from the horizontal 19GHz channel (18GHz for SMMR) and the vertical 37GHz channel. They were acquired from the DMSP SSM/I Daily Polar Gridded Brightness Temperatures data set produced at NSIDC.

2.2 Processing

Data are derived from passive microwave satellite brightness temperature characteristics using the XPGR equation of Abdalati and Steffen (1997). Refer to Equation 2. A mask was applied to the Greenland Ice Sheet data to extract only those pixels that lie fully on the ice sheet so that no mixed pixels of land and snow or ocean cause false melt results. Consequently, approximately six percent of the ice sheet along its perimeter is omitted (Abdalati and Steffen 1997).

Microwave brightness temperatures can be characterized by the Rayleigh-Jeans approximation as shown in Equation 1 and as described here:

Equation 1: Raleigh-Jeans Approximation

$$T_b(\lambda) = \varepsilon T_p$$

Where:

Table 7. Equation 1: Rayleigh-Jeans Approximation Equation Description

Variable	Description
$T_b(\lambda)$	Microwave brightness temperature for a given wavelength (λ)
ε	Microwave emissivity
T_p	Effective physical temperature of the snow

As dry snow melts and transitions to wet snow, there is a sharp increase in the brightness temperature. These increases are dependent on frequency and polarization such that as snow melts there is a greater increase in the horizontal brightness temperatures than the vertical ones at the same frequency. The XPGR technique is an enhanced gradient ratio technique. It is useful because it utilizes both frequency and polarization in its calculation. When snow melts, there is a depolarization effect; the differences between the vertical and horizontal signal lessen. When the vertical 37 GHz channel and the horizontal 19 GHz channel are subtracted, the difference is greater than when the same polarization is used, thus making the distinction between frozen and melting snow easier (Abdalati and Steffen 1995). Using this relationship, a threshold value can be determined; all values below this threshold represent dry snow (frozen) and those above it represent wet snow (melting). The XPGR values determined during this investigation are listed here (Abdalati and Steffen 2001):

Table 8. XPGR Melt Classification Threshold Values

Instrument	Threshold Value
SMMR	-0.0265
SSM/I F08	-0.0158
SSM/I F11	-0.0158
SSM/I F13	-0.0154

Equation 2 shows the cross-polarized gradient ratio (XPGR) of Abdalati and Steffen and is described here:

Equation 2: XPGR

$$XPGR = \frac{T_b(19H) - T_b(37V)}{T_b(19H) + T_b(37V)}$$

Where:

Table 9. XPGR Equation Description

Variable	Description
$T_b(19H)$	Microwave brightness temperature for the 19 GHz horizontal channel (18 GHz for SMMR)
$T_b(37V)$	Microwave brightness temperature for the 37 GHz vertical channel

2.2.1 Daily Melt Location Files

Since the data were acquired from multiple instruments, cross calibrations must be applied for consistency of the data. To account for the transition between instruments, the calibration coefficients of Jezek (1991) were employed for the SMMR data, those of Abdalati and Steffen (1995) were employed for SSM/I F-11 and F-13 data, and the SSM/I F-8 coefficients were used as the baseline standard.

The daily melt location files were processed using the following steps:

1. Data from the SMMR instrument were smoothed with a 5-day running mean.
2. The brightness temperature on a given day is an average of the scans from two days before and two days after that day.
3. The XPGR value is then computed and a pixel is determined to be showing melt or no melt based on that value. For a discussion on how the XPGR values are computed see the Derivation Techniques and Algorithms section of this document.
4. If a pixel showed melt, it was recorded to the file.

Note: During years when two instruments were acquiring measurements, for example, in 1987 both SMMR and SSM/I f08 were acquiring data, files for both instruments are provided.

2.2.2 Daily Gridded Melt Status Files

The daily gridded melt status files were processed using the following steps:

1. A subset of the data is taken for the Greenland ice sheet using the mask file icemask_60x109.byte.
2. Pixels were given a value depending on if they are showing melt, no melt, or were outside the Greenland ice sheet boundary.
3. Then the program writes each gridded file to the .dat files.

Note: During years when two instruments were acquiring measurements at the same time, for example, in 1987 both SMMR and SSM/I f08 were acquiring data, files for both instruments are provided.

2.2.3 Annual Melt Number Files

2.2.3.1 Binary

1. The binary melt files were processed using the following steps:
2. The files were derived directly from the 60 x 109 daily gridded melt status files.
    a. Note: Since the SMMR instrument only acquired measurements every other day, dummy files were created to make a complete daily time series. The dummy files are copies of the data file for the previous day.
3. Each gridded daily file for a particular year was queried to determine how many days of melt were recorded that year for a certain pixel - all pixels that had a value of 1.
4. These sums were then written to the binary files.

Note: During years when two instruments were acquiring measurements, for example, in 1987 both SMMR and SSM/I f08 were acquiring data, the data acquired from the newer instrument was used.

2.2.3.2 GeoTIFF

The GeoTIFF melt files were processed using a data format converter to convert the binary melt files to GeoTIFF format.

2.2.4 Climatology Files

The data in the binary climatology file are an average of all the data for each pixel in the annual melt number files from 1979 to 2007. The GeoTIFF climatology file was processed using a data format converter to convert the binary climatology file to GeoTIFF format.

2.3 Quality, Errors, and Limitations

As with any satellite data, atmospheric conditions and variability can introduce errors in the data. Water vapor in the atmosphere or severe weather can lessen the microwave signal, possibly causing melting snow to go undetected. However, the normalization in the XPGR technique helps to alleviate this (Abdalati and Steffen 1997). An occasional spurious melt pixel may occasionally occur due to bad weather or a bad scan. These occur a couple of times a year on the ice sheet.

Another possible source of error occurs when the snow refreezes. Because two frequencies are used in this method, emission depths must be considered. Generally, when snow is melting, the emission depths of the two frequencies vary by only a few centimeters because the temperature of the emitting layers is close to 0 °C. In the case of refreeze, the surface temperature is lower than the temperature at depth, thus, possibly causing a melt signal even when surface is frozen. This source of error is not thought to impact the results for annual melt extent maps but may need further study when applied to surface melt shorter time scales (Abdalati and Steffen 1995).

For a discussion of error sources in the SMMR brightness temperatures, see the Nimbus-7 SMMR Pathfinder Daily EASE-Grid Brightness Temperatures guide document.

For a discussion of error sources in the SSM/I brightness temperatures, see the DMSP SSM/I Pathfinder Daily EASE-Grid Brightness Temperatures guide document.

2.4 Instrumentation

2.4.1 Description

The instruments used to acquire this data set were the SMMR instrument on the Nimbus 7 satellite and the SSM/I instruments on the Defense Meteorological Satellite Program (DMSP) F-8, F-11, and F-13 satellites.

See the SMMR Instrument Description for more information about that instrument. Also, see the SSM/I Instrument Description and the DMSP Satellite F8, DMSP Satellite F11, and DMSP Satellite F13 platform descriptions for further information on those platforms.

3 SOFTWARE AND TOOLS

The tools needed to read the data differ as a function of format: ASCII, binary, or GeoTIFF. All tools are available via FTP in the tools directory.

3.1 ASCII Files

The gridded ASCII files are readable in any text editing program and can also be imported into spreadsheet programs. NSIDC has created an ASCII lookup table for converting the x and y values of the grid to latitude and longitude coordinates. The lookup table is available via FTP in the tools directory and is explained here:

Table 10. ASCII Lookup Table Description

<table>
<tr><th>File Name</th><th>Description</th></tr>
<tr><td>green_lats_lons.txt</td><td>Provides the latitude and longitude that corresponds to the x and y values of the grid. The table uses 1,1 as the index of the first element. To make the table 0,0 based, subtract one from each x and y value. The file contains four columns as described below.
<table>
<tr><th>Column</th><th></th><th>Description</th></tr>
<tr><td>1</td><td></td><td>X value</td></tr>
<tr><td>2</td><td></td><td>Y value</td></tr>
<tr><td>3</td><td></td><td>Latitude (corresponds to the X value)</td></tr>
<tr><td>4</td><td></td><td>Longitude (corresponds to the Y value)</td></tr>
</table>
</td></tr>
</table>

3.2 Binary Files

NSIDC provides tools for reading, plotting, and geolocating the binary gridded data and the binary climatology files. The tools for reading and plotting the data are written in the Interactive Data Language (IDL) and are explained in Table 11, and the geolocation tools are explained in Table 12. The tools are available via FTP in the tools directory.

3.3 IDL Procedures

The IDL procedures for reading and plotting the binary data are explained in Table 8. They are available via FTP in the tools directory.

Table 11. IDL Procedures

Procedure	Description
read_melt.pro	Reads and plots the binary gridded files and optionally outputs a .tif file. Pixels that are red are showing melt, white pixels are not melting, and black pixels are outside the Greenland ice sheet boundary.
read_annual_melt.pro	Reads and plots the binary melt files and optionally outputs a .tif file. The brighter the pixel the more days melt was seen for that pixel for the year stated in the file name.

3.4 Geolocation Tools

To geolocate this data, a map projection parameter (.mpp) file, a grid parameter definition (.gpd) file, and an ice mask file (.byte) are provided in the tools directory on the FTP site. Table 9 lists the geolocation tools available.

Table 12. Geolocation Tools

Procedure	Description
Nps.mpp	A map projection parameters file to be used with the data.
green_ps.gpd	Grid definition file that can be used with the gridded data files.
icemask_60x109.byte	A mask file of Greenland that can be used with either the raw ASCII or gridded binary data files.

For information on using the .mpp and .gpd files refer to the Points, Pixels, Grids, and Cells: A Mapping and Gridding Primer web page.

3.5 GeoTIFF Files

The GeoTIFF files can be opened and viewed with GIS software and applications for displaying and analyzing geospatial data.

Note: Not all image reading software, such as common photo editors, are able to correctly interpret or open the GeoTIFF files. NSIDC recommends only using an application for displaying and analyzing geospatial data.

4 RELATED DATA SETS

- Program for Arctic Regional Climate Assessment (PARCA)
- DMSP SSM/I Daily Polar Gridded Brightness Temperatures
- Scanning Multi-channel Microwave Radiometer (SMMR)
- Special Sensor Microwave Imager (SSM/I)
- Defense Meteorological Satellite Program (DMSP)
- View NSIDC Data on Virtual Globes: Google Earth

5 CONTACTS AND ACKNOWLEDGMENTS

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6 REFERENCES

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7 DOCUMENT INFORMATION

7.1 Publication Date

August 2007

7.2 Date Last Updated

19 May 2021