Global EASE-Grid 8-day Blended SSM/I and MODIS Snow Cover, Version 1

USER GUIDE

How to Cite These Data

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

Brodzik, M. J., R. Armstrong, and M. Savoie. 2007. *Global EASE-Grid 8-day Blended SSM/I and MODIS Snow Cover, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/KIGGFNVROX9V. [Date Accessed].

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

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National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

This data set comprises global, 8-day Snow-Covered Area (SCA) and Snow Water Equivalent (SWE) data from 2000 through 2008. Global SWE data are derived from the Special Sensor Microwave Imager (SSM/I) and are enhanced with MODIS/Terra Snow Cover 8-Day Level 3 Global 0.05 degree Climate Modeling Grid (CMG) data. Global data are gridded to the Northern and Southern 25 km Equal-Area Scalable Earth Grids (EASE-Grids). These data are suitable for continental-scale time-series studies of snow cover and snow water equivalent.

1.1 Format

The data files are in Network Common Data Form (netCDF, "`.nc`") format. Each netCDF file contains a full year of 8-day data. The files contain data arrays with dimensions of 721 columns by 721 rows. Browse images of snow data in Portable Network Graphics (PNG) format are also included.

1.2 File and Directory Structure

Data are on the FTP site in the `nsidc0321_blended_ssmi_modis` directory. Within this directory, there are two subdirectories – `North` and `South` – each containing netCDF files for the Northern and Southern Hemisphere, respectively, as well as a `browse` directory that contains the PNG browse image files.

1.3 File Naming Convention

1.3.1 netCDF Files

The netCDF files are named according to the convention depicted below and in Table 1:
`[GG].[YYYY].nsidc0321v[XX].nc`

Table 1. NetCDF File Naming Convention

Variable	Description
`GG`	Projection and Grid, where: `NL`: Northern Hemisphere, 25 km EASE-Grid `SL`: Southern Hemisphere, 25 km EASE-Grid
`YYYY`	4-digit year
`nsidc0321`	NSIDC data set ID for this data set
`vXX`	Version (`v01`: version 1)
`.nc`	Identifies this file as a netCDF file

1.3.2 Browse Image Files

The browse image files are named according to the convention depicted below and in Table 2:
`[GG].[YYYYMMDD-YYYYMMDD].nsidc0321v[XX].png`

Table 2. PNG File Naming Convention

Variable	Description
`GG`	Projection and Grid, where `NL`: Northern Hemisphere, 25 km EASE-Grid `SL`: Southern Hemisphere, 25 km EASE-Grid
`YYYYMMDD-YYYYMMDD`	4-digit year, 2-digit month, 2-digit day for the starting and ending date of the 8-day period
`nsidc0321`	NSIDC data set id for this data set
`vXX`	Version (v01: version 1)
`.png`	Identifies this file as a portable network graphics (PNG) image file

1.4 Spatial Coverage

These data are provided in two different spatial coverages: Northern and Southern Hemispheres. Please see the Grid Extent Table on the EASE-Grid: A Versatile Set of Equal-Area Projections and Grids Web page for specific latitude and longitude values.

1.4.1 Spatial Resolution

This data set is derived from multiple sources. While the files are gridded at 25-kilometer spatial resolution, the actual resolution of the component data, SWE or SCA, depends on the input remote sensing data. For SWE data, the satellite passive microwave sensors at the frequencies used for these algorithms have sampling resolutions of 25 km. For SCA data, the spatial resolution of the MODIS/TERRA Snow Cover 8-Day L3 Global CMG (MOD10C2) data are 0.05 degrees, itself derived from 1 km MODIS data.

1.4.2 Projection and Grid Description

These data are stored in the Northern and Southern Hemisphere EASE-Grids. For more information about EASE-Grids, please see All About EASE-Grid.

1.5 Temporal Coverage and Resolution

This data set ranges from 05 March 2000 to 24 January 2008 and has an 8-day resolution.

1.6 Parameters

The parameters of this data are SWE and SCA. SWE is a measurement of the amount of water contained within a snowpack. The SWE data for this data set are derived from DMSP SSM/I-SSMIS Pathfinder Daily EASE-Grid Brightness Temperatures. SCA, as the name implies, is the total area of land covered by snow. The SCA data used to enhance this data set are derived from the MODIS/Terra Snow Cover 8-Day L3 Global 0.05Deg CMG (MOD10C2) data, regridded to the NL and SL EASE-Grid.

1.6.1 Parameter Description

Table 3 describes the values of the SWE variable found in the netCDF files, while Table 4 describes the values of the SCA variable.

Table 3. SWE Value Descriptions

Data Value	Description
>0	Microwave-derived SWE (mm)
0	No snow
-100 to -1	SWE from shallow microwave algorithm, scaled by -1; a value of -25 represents 25 mm SWE.
-150	No passive microwave brightness temperatures were available at this pixel, and no visible snow was detected during the 8-day period.
-200	Static value for corners (locations outside Northern Hemisphere in NL grids, outside the Southern Hemisphere in SL grids)
-250	Static value for ocean pixels
-300	Static value for permanent ice sheets and large glaciers
-350	No microwave SWE, but visible SCA > 25%

Table 4. SCA Value Descriptions

Data Value	Description
0	No snow
1 to 100	Percent MODIS snow-covered area
-200	Static value for corners (locations outside Northern Hemisphere in NL grids, outside the Southern Hemisphere in SL grids)
-250	Static value for ocean pixels
-300	Static value for permanent ice sheets and large glaciers

1.7 Version History

V01 was initially released on 15 January 2008.

1.8 Notes and Limitations

This dataset has not been thoroughly validated with reference measurements or other independent gridded SWE products. It is a standalone passive microwave algorithm with static coefficients so it has uncertainties related to the limitations listed above, which have not been explicitly quantified.

This data set is intended for studies of continental- to hemispheric-scale seasonal fluctuations of SCA and SWE. Due to the lack of in situ validation data for SWE at the spatial scale of the microwave sensors, SWE derived from satellite passive microwave sensors should be considered with caution. The effective field of view of these passive microwave sensors yields radiometric information from an area that is larger than 625 square kilometers. The gridded value represents a mean SWE for this large area; therefore, this value cannot capture localized maxima or minima. The large sensor footprint and other limitations of microwave sensors result in decreased confidence in the SWE reliability and possible underestimation in the following circumstances:

- Mountainous areas with large topographic variability return low mean SWE values. Brightness temperatures in these areas may include mixed emission from deep snow on north-facing slopes, snow-free south-facing slopes, wind-scoured Alpine areas, etc.
- Forested areas return low mean SWE values because the mixed signal includes emission from trees and the snow canopy as well as the underlying surface.
- Areas near coastlines return low or no SWE values because the mixed signal includes frozen and unfrozen water and possibly snow-free land.
- Areas containing melting snow or wet snow packs typical of maritime snow conditions return low or no SWE values because the microwave emission from liquid water overwhelms scattering from the snow pack.
- Shallow or intermittent snow during fall and early winter typically does not result in sufficient microwave scattering to reliably detect SWE. See the Processing Steps section of this document for shallow snow improvement used in this data set.

Lower confidence in SWE reliability due to overestimation may also occur in the following circumstances:

- Areas with significant depth hoar formation. The conditions for depth hoar formation involve the combination of shallow snow exposed to strong temperature gradients driven by cold air temperatures over a period of weeks to months. This results in a snow cover with large grains that enhance the microwave scattering signal and cause overestimation when a particular algorithm has been tuned to a smaller mean grain size. A typical region prone to this type of snow texture is Eastern Siberia. The seasonal snow cover consistently begins to form in this region as early as September, and then relatively shallow snow remains on the ground as air temperatures begin to approach the extremely cold conditions of winter. The SWE values in this data set indicate greater values for Eastern Siberia than for Western Siberia, although some climate models indicate the opposite. There could be some degree of overestimation by the microwave algorithm in this region due to the persistent presence of depth hoar. Unfortunately, the investigators currently do not possess sufficient surface measurements of SWE to determine with any certainty which pattern is correct.

- Areas of extremely high elevation. Current passive microwave snow retrieval algorithms are empirically based and were typically developed using data from lower elevations. The investigators are currently developing an atmospheric correction for regions of extremely high elevation on the Tibetan Plateau (Armstrong 2004) (Savoie 2007), which they expect to implement in the next revision of this data set.

There is a persistent pattern of relatively high SWE values that develops during the winter season in a large portion of the Canadian Arctic, stretching roughly from the Western edge of Hudson's Bay to the North Slope of Alaska. Unfortunately, this is an area with few ground observing stations. Although a large-scale field experiment begun in the 2003-2004 winter season by Derksen and MacKay (2006) indicates that the SWE gradient across this area appears to be real and measurable, it is not as large a gradient as the microwave algorithm indicates and should be treated with caution.

2 DATA ACQUISITION AND PROCESSING

2.1 Processing Steps

The netCDF data files for each hemisphere and year contain 2 EASE-Grid data layers for each 8-day period, derived as follows:

1. The SCA layer is derived from the 8-day MOD10C2 data, regridded to the NL or SL EASE-Grid. An output 25 km grid cell is the drop-in-the-bucket (equally weighted) average of percent SCA from the component 0.05 degree cells with snow detected by MODIS. Input cells classified as cloud, night, or missing are ignored. At the time of processing, the MOD10C2 Version 4 (V004) data are being reprocessed to Version 5 (V005). V005 data are used if they are available, otherwise V004 data are used. The string variable `bpInfoin` the netCDF file contains the identifier `MOD10C2.005` or `MOD10C2.004` for each layer depending on the input used to derive that layer. The SCA data layer includes percent SCA for all grid cell locations regardless of passive microwave returns at this location. Microwave and visible data are blended in the SWE data layer as described in Step 3.
2. Input passive microwave data are daily, cold pass, DMSP SSM/I-SSMIS Pathfinder Daily EASE-Grid Brightness Temperatures. These data are generally available three to six months after acquisition. If, at the time of processing the blended data, brightness temperatures from this data set are not yet available, then a near-real-time substitute is used. The near-real-time data differ from the DMSP SSM/I-SSMIS Pathfinder Daily EASE-Grid Brightness Temperatures in two ways: (i) Input swath data are obtained from the

Global Hydrology Resource Center (GHRC), rather than from Remote Sensing Systems (RSS); (ii) Regridding from swath to grid space is done with an inverse-distance square interpolation, rather than the Backus-Gilbert interpolation. Two microwave algorithms to derive SWE are used.

A. Deep SWE is derived from 19 and 37 GHz brightness temperatures:
   a. Daily SSM/I brightness temperatures are adjusted to SMMR brightness temperatures via regression data at selected stable targets (Brodzik 2005):
      - `SMMR_ADJ(18H) = 0.925 * SSMI(19H) + 10.110`
      - `SMMR_ADJ(37H) = 0.936 * SSMI(37H) + 10.74`
   b. Daily SWE is derived considering
      - `SWE (mm) = 4.77 (SMMR_ADJ(18H) - SMMR_ADJ(37H))` - (Chang, Foster, and Hall 1987) with the assumption of a constant snow density of 300 kg m^{-3}.
   c. Daily SWE is adjusted for surface forest cover (Chang, Foster, and Hall 1996) using the 25 km EASE-Grid version of BU-MODIS Land Cover (Knowles 2004):

```
Let forest_percent = {
0 : no forest,
0.01-0.49 : 1-49% total forest,
0.50 : >= 50% total forest }
Then:
Forest-Adjusted SWE (mm) = SWE / (1.00 - forest_percent)
```

   d. Forest-Adjusted SWE values less than 7.5 mm are considered unreliable and are set to zero (Chang, Foster, and Hall 1987)
   e. In the Northern Hemisphere, false SWE signals from lower latitude features such as deserts are filtered using frequency climatologies derived from the Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 3 data from 1966-2005 (Armstrong and Brodzik 2005). Pixels where Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 3 data never recorded snow in the given month are set to zero SWE. In the Southern Hemisphere, false SWE signals from tropical atmospheric phenomena are filtered using a monthly SWE frequency climatology derived from SSM/I. The Southern Hemisphere SWE frequency climatology limits legitimate SWE data to the Andes Mountains region and New Zealand.
   f. Daily SWE files for the eight days that correspond to the MOD10C2 data are combined using the maximum at each grid cell for the component eight days.

B. Shallow SWE is derived from vertically-polarized 19, 37, and 85 GHz SSM/I cold pass brightness temperatures according to Nagler and Rott (1992). The day with the most cloud-free brightness temperatures for the component 8-day period is determined at each grid cell as the maximum positive temperature difference (37V - 85V). The brightness temperatures for the most cloud-free day are used to derive snow depth (cm) as:

   a. A grid cell is considered snow-covered if and only if:
      - 19V <= 266 K
      - (19V - 37V) >= 4K or (37V - 85V) >= 3K
   b. In a grid cell that is classified as snow-covered, snow depth is:
      - Depth (cm) = (-2.41 + 1.2 * (19V - 37V) - 0.16 * (37V - 85V))
   c. Snow depth is converted to SWE by multiplying depth (cm) by a factor of 3, which assumes a constant snow density of 300 kg m-3

3. The SWE layer in the netCDF files is derived from a series of steps to combine the deep and shallow microwave SWE with the visible data in a reasonable way, based on our knowledge of the relative strengths and reliability of each algorithm. Refer to Table 3 for SWE values and Table 4 for SCA values.
4. Grid cells classified as permanent ice such as ice sheets, ice shelves, and large glaciers are determined using a 50 percent threshold for permanent ice from the 25 km EASE-Grid version of the BU-MODIS Land Cover data (Knowles 2004).

2.1.1 Forest Percent Mask

The forest percent map is derived from NSIDC's EASE-Grid version of the BU-MODIS Land Cover data set. Data values represent the sum of the percent area classified as any of the International Geosphere-Biosphere Programme (IGBP) forest categories. These include:

- Evergreen Needleleaf Forest
- Evergreen Broadleaf Forest
- Deciduous Needleleaf Forest
- Deciduous Broadleaf Forest
- Mixed Forest

Any pixels with forest percent higher than fifty percent are set to the fifty percent threshold, thereby bounding the forest correction of the SWE value to a maximum factor of two.

2.1.2 Permanent Ice Masks

Areas with permanent ice such as ice sheets, ice shelves, and large glaciers are masked using a fifty percent threshold for permanent ice from the 25 km EASE-Grid version of the BU-MODIS Land Cover data.

2.1.3 Snow Frequency Climatologies

Snow frequency climatologies for the Northern Hemisphere processing are derived from Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 3 data, covering the period 1966-2003. For the Southern Hemisphere, they are derived from SSM/I-derived SWE frequency of occurrence for the period 1987-2003. Areas with “likely snow” are limited to the Andes

Mountains region and New Zealand. Frequency thresholds are a function of month, for example, twenty percent for October through May and seven percent for June through September.

3 REFERENCES AND RELATED PUBLICATIONS

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3.1 Related Data Collections

- Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 3
- DMSP SSM/I-SSMIS Pathfinder Daily EASE-Grid Brightness Temperatures
- EASE-Grid Version of Boston University's MODIS Land Cover Characterization
- MODIS/Terra snow cover 8-day L3 global 0.05deg CMG V005 (MOD10C2)

4 CONTACTS AND ACKNOWLEDGMENTS

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5 DOCUMENT INFORMATION

5.1 Publication Date

November 2007

5.2 Date Last Updated

March 2021