Global Monthly EASE-Grid Snow Water Equivalent Climatology, Version 1

USER GUIDE

How to Cite These Data

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

Armstrong, R., M. J. Brodzik, K. Knowles, and M. Savoie. 2005. *Global Monthly EASE-Grid Snow Water Equivalent Climatology, Version 1.* [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/KJVERY3MIBPS. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/NSIDC-0271

National Snow and Ice Data Center

TABLE OF CONTENTS

1 DETAILED DATA DESCRIPTION

This data set is comprised of global, monthly satellite-derived Snow Water Equivalent (SWE) climatologies from November 1978 through May 2007, with periodic updates released as resources permit. Global data are gridded to the Northern and Southern 25 km Equal-Area Scalable Earth Grids (EASE-Grids). Global snow water equivalent is derived from Scanning Multichannel Microwave Radiometer (SMMR) and selected Special Sensor Microwave/Imagers (SSM/I). Northern Hemisphere data are enhanced with snow cover frequencies derived from the Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 2 data (these data were not produced for the Southern Hemisphere). These data are suitable for continental-scale time-series studies of snow cover and water equivalent.

1.1 Format

Data files contain flat, binary arrays of gridded values. Browse images of snow data in PNG format are also included. Many browsers and graphics applications display this file type.

Each monthly binary data file with the file extension ".NSIDC8" contains a flat, binary array of 16-bit signed, little-endian (LSB) integers, 721 columns by 721 rows (row-major order, i.e. the top row of the array comprises the first 721 values in the file, etc.).

Data values are:

Table 1. Description of Data Values

Data Value	Description
>0	Northern Hemisphere: Microwave-derived SWE (mm) at pixels where visible snow was observed in the Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 2 data at least once during the month. Southern Hemisphere: Microwave-derived SWE (mm) at pixels where snow was considered likely.
0	No snow
-100 to -1	Northern Hemisphere: The negative of the percent frequency of visible snow derived from weekly data of visible snow, only for those pixels with no microwave-derived SWE; a value of -25 represents 25 percent visible snow, or 1 out of 4 weeks in this month were classified as snow-covered in the Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 2 data, and no microwave-derived SWE was detected. Southern Hemisphere: This data range was not used because no visible snow data were available.
-150	No passive microwave brightness temperatures (Tbs) were ever available at this pixel, and no visible snow was detected in the month
-200	Fixed value for corners (locations outside Northern Hemisphere in NL grids, outside the Southern Hemisphere in SL grids)
-250	Fixed value for ocean pixels
-300	Fixed value for permanent ice sheets and large glaciers

Other data files have the file extensions ".num" and ".stdev".

- .num - These 16-bit integer files contain the number of days in the month with SWE data to average. If no SWE was available, the value is 0.
- .stdev - These files are 32-bit IEEE floating point values that contain the standard deviation of SWE. If no SWE was available, the value is 0.

Long-term monthly statistics files are also included in the stats subdirectory for each hemisphere and sensor. Statistics directories contain three binary files (.NSIDC8, .num, and .stdev) for each month. These files are the same format as the individual year/month (.NSIDC8, .num, and .stdev) files, except that the data values represent long-term averages for the enclosing span of years, rather than statistics for a single year.

1.2 File and Directory Structure

Text goes here The directory nsidc0271_monthly_ease_grid_swe contains two subdirectories named north and south for the hemispheres. Each of these directories contains three subdirectories; one that contains SMMR data from 1978-1987, one that contains SSM/I data from 1987-2003, and a third directory with SSM/I updates since 2003. Please see 2.3 section for details.

The following table shows the directory structure of the data.

Table 2. Directory Structure

north			
	1978-1987		(Contains three binary files (.NSIDC8, .num, and .stdev) and two image files per month and year)
		stats	(Contains three (.NSIDC8, .num, and .stdev) files with long-term statistics for each month for the respective range of years. A 12-month composite .png image is also included.)
	1987-2003		(Contains three binary files (.NSIDC8, .num, and .stdev) and two image files per month and year)
		stats	(Contains three (.NSIDC8, .num, and .stdev) files with long-term statistics for each month for the respective range of years. A 12-month composite .png image is also included.)
	2003-xxxx		(Updated data since 2003. No statistics are included for updates.)
south			
	1978-1987		(Contains three binary files (.NSIDC8, .num, and .stdev) and one image file per month and year.)
		stats	(Contains three (.NSIDC8, .num, and .stdev) files with long-term statistics for each month for the respective range of years. A 12-month composite .png image is also included.)
	1987-2003		(Contains three binary files (.NSIDC8, .num, and .stdev) and one image file per month and year.)
		stats	(Contains three (.NSIDC8, .num, and .stdev) files with long-term statistics for each month for the respective range of years. A 12-month composite .png image is also included.)
	2003-xxxx		(Updated data since 2003. No statistics are included for updates.)

1.3 File Naming Convention

This data set provides monthly data (time period) files and averages (statistics) over the years covered.

1.3.1 Time Period Files

The following conventions apply to the files of each type (NSIDC8, .num, and .stdev) contained in the time period directories (for example, 1978-1987). An example file name is:

```
hLyyyymm.vxx.ext
```

Where:

Table 3. Time Period File Naming Conventions

File name element	Description
hL	file contains data in the NSIDC Northern Hemisphere (NL) or Southern Hemisphere (SL) "low" (i.e. 25 km) resolution EASE-Grid
yyyy	4-digit year
mm	2-digit month (for example, January = 01)
.vxx	"v" indicates version, "xx" indicates the two-digit version number
ext	.NSIDC8 files contain algorithm "NSIDC8" output .num files contain the number of days in the month with SWE data to average. If no SWE was available, the value is 0. .stdev files contain the standard deviation of SWE. If no SWE was available, the value is 0.

PNG image files named *.BP_VIS35.PNG render the microwave-derived SWE in color (in greens-browns-blues), with additional locations (Northern Hemisphere only) where visible snow was detected for two or more weeks in the month (red). PNG image files named *.BP_PCENT20.PNG render the microwave-derived snow-covered area (in gray), with additional locations indicating visible snow frequency of occurrence (in blues). No *.BP_PCENT20.PNG files are included for the Southern Hemisphere.

1.3.2 Statistics Files

Statistics (stats) directories contain monthly average files of each type (NSIDC8, .num, and .stdev) for the periods 1978-1987 and 1987-2003. For example, there is one file that contains the average for the month of January for the entire time period of 1978 through 1987. The naming convention for these files is:

```
hL.mm.yyyymm-yyyymm.vxx.ext
```

Where:

Table 4. Statistics File Naming Conventions

File name element	Description
hL	file contains data in the NSIDC Northern Hemisphere (NL) or Southern Hemisphere (SL) "low" (i.e. 25 km) resolution EASE-Grid
mm	Month of the average (for example, 01 = January, 02 = February)
yyyymm-yyyymm	Beginning four-digit year and two-digit month to ending four-digit year and two-digit month (for example, 197811-198707)
.vxx	"v" indicates version, "xx" indicates the two-digit version number
ext	.NSIDC8 files contain NSIDC8 algorithm long-term averages. .num files contain the number of years with SWE data to average. .stdev files contain the standard deviation of long-term SWE.

1.4 File Size

Binary files are approximately 4 MB per month per hemisphere, and PNG files are approximately 100 KB.

1.5 Volume

The total uncompressed volume is 2.6 GB.

1.6 Spatial Coverage

This data set covers the Northern and Southern Hemispheres, as shown in Figures 1 and 2.

1.6.1 Spatial Coverage Map

Figure 1. Northern Hemisphere

Figure 2. Southern Hemisphere

1.6.2 Spatial Resolution

This data set is derived from multiple sources. While the climatology files are gridded at 25-kilometer spatial resolution, the actual resolution of the component data (SWE or frequency of occurrence) depends on the input remote sensing data. The satellite passive microwave sensors at the frequencies used for these algorithms have sampling resolutions of 25 km, but the -3dB footprints vary by sensor and frequency, ranging from SMMR 18GHz at 55 x 41 km and SMMR 37 GHz at 27 x 18 km to both of the SSM/I frequencies re-sampled to the 19 GHz footprint at 69 x 43 km. The spatial resolution of the snow cover frequency of occurrence data derived from the Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 2 product ranges from 16,000 to 42,000 square kilometers.

1.6.3 Projection

These data are stored in the NL and SL EASE-Grids.

1.6.4 Grid Description

See EASE Grids for more detail

1.7 Temporal Coverage

1978 - 2007 monthly, with additional dates provided as updates. Please see 2.2.4 Section Temporal Resolution

These data are provided as monthly composites

1.8 Parameter or Variable

Parameters are snow water equivalent and snow cover frequency of occurrence, number of days in the month with SWE data contributing to the average, and the monthly standard deviation of SWE

1.8.1 Parameter Description

Snow water equivalent (SWE) data was derived from the following data sets:

- Nimbus-7 SMMR Pathfinder Daily EASE-Grid Brightness Temperatures
- DMSP SSM/I-SSMIS Pathfinder Daily EASE-Grid Brightness Temperatures

The data were then enhanced with Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent, Version 2.

Sample Data Records

1.8.2 Northern Hemisphere

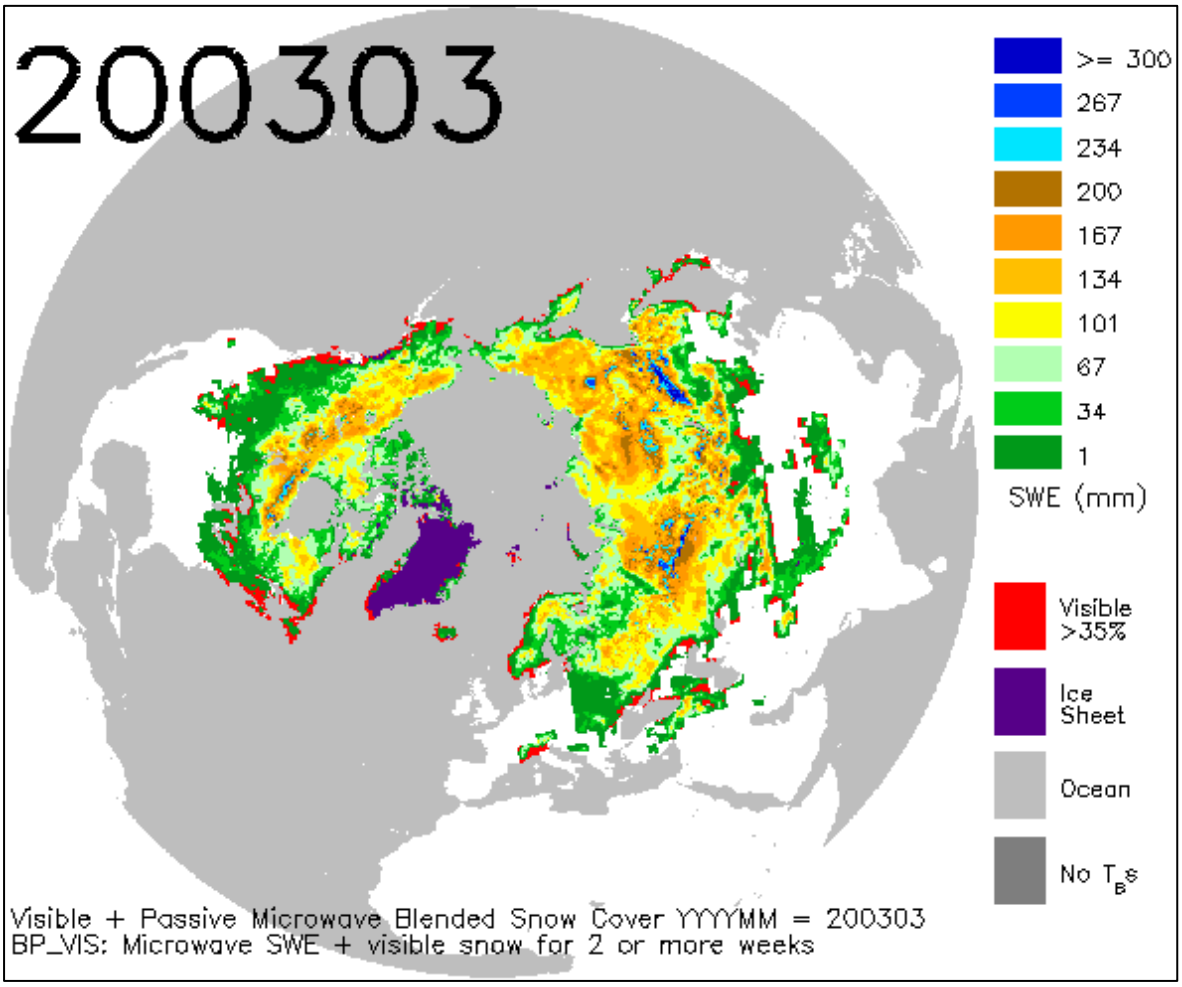

Figure 3. Northern Hemisphere average snow water equivalent (mm) from passive microwave, with additional area indicated as snow by Northern Hemisphere EASE-Grid weekly snow cover in red, March, 2003.

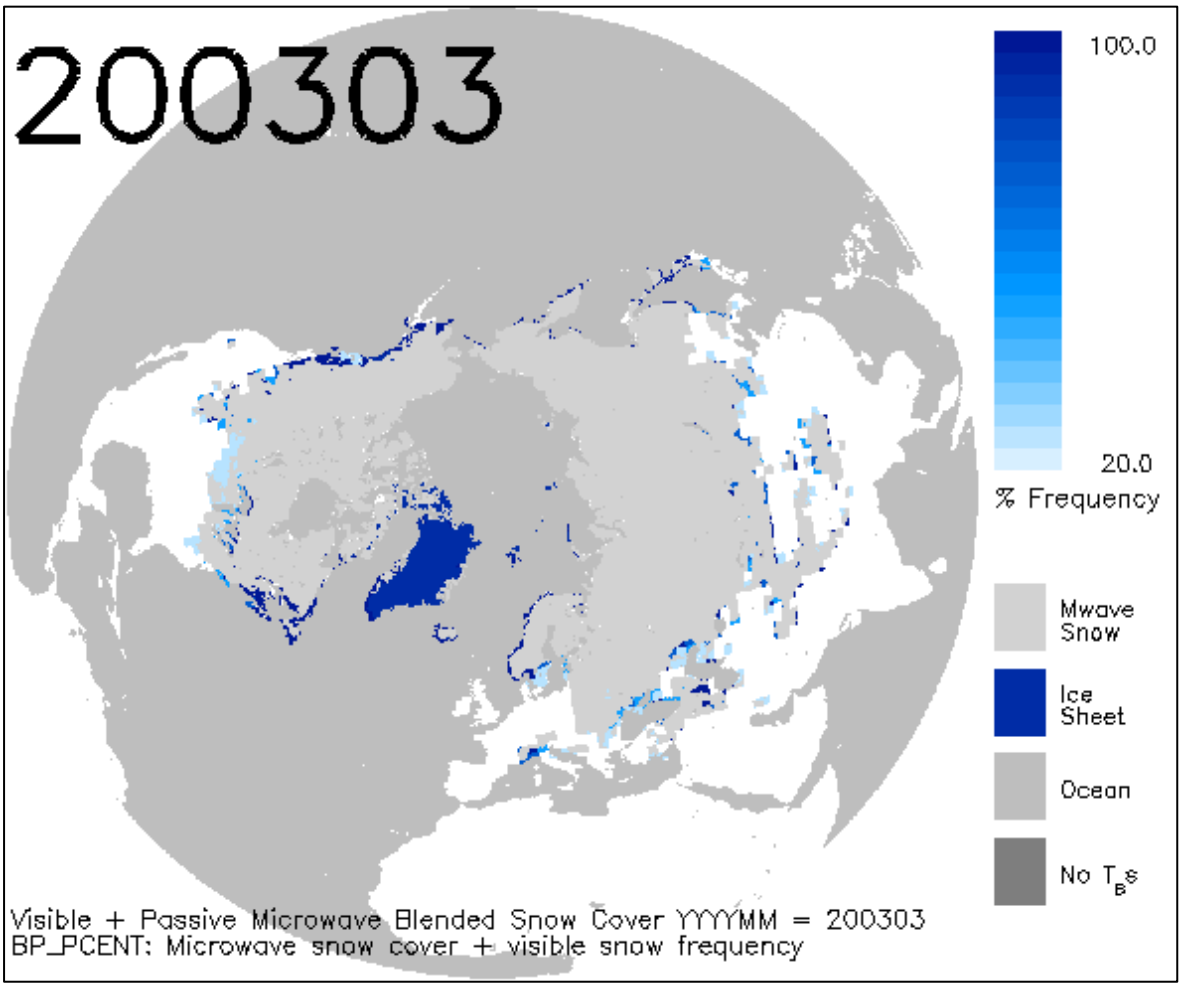

Figure 4. Northern Hemisphere snow extent from passive microwave (gray), with snow-cover frequency for the month from Northern Hemisphere EASE-Grid weekly snow cover (blue shades), March, 2003.

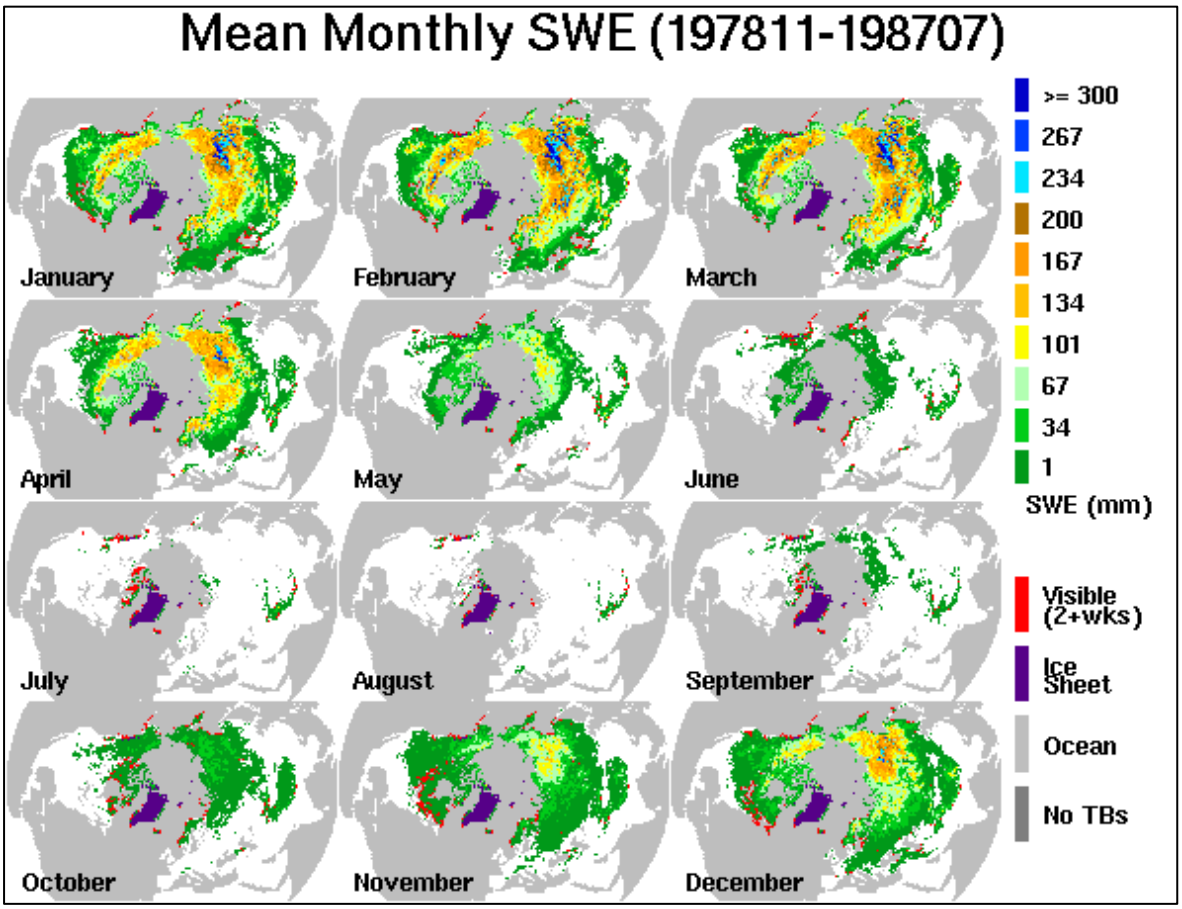

Figure 5. Northern Hemisphere monthly long-term average snow water equivalent (mm) from SMMR, with additional area indicated as snow by Northern Hemisphere EASE-Grid weekly snow cover in red, (November 1978 - July 1987).

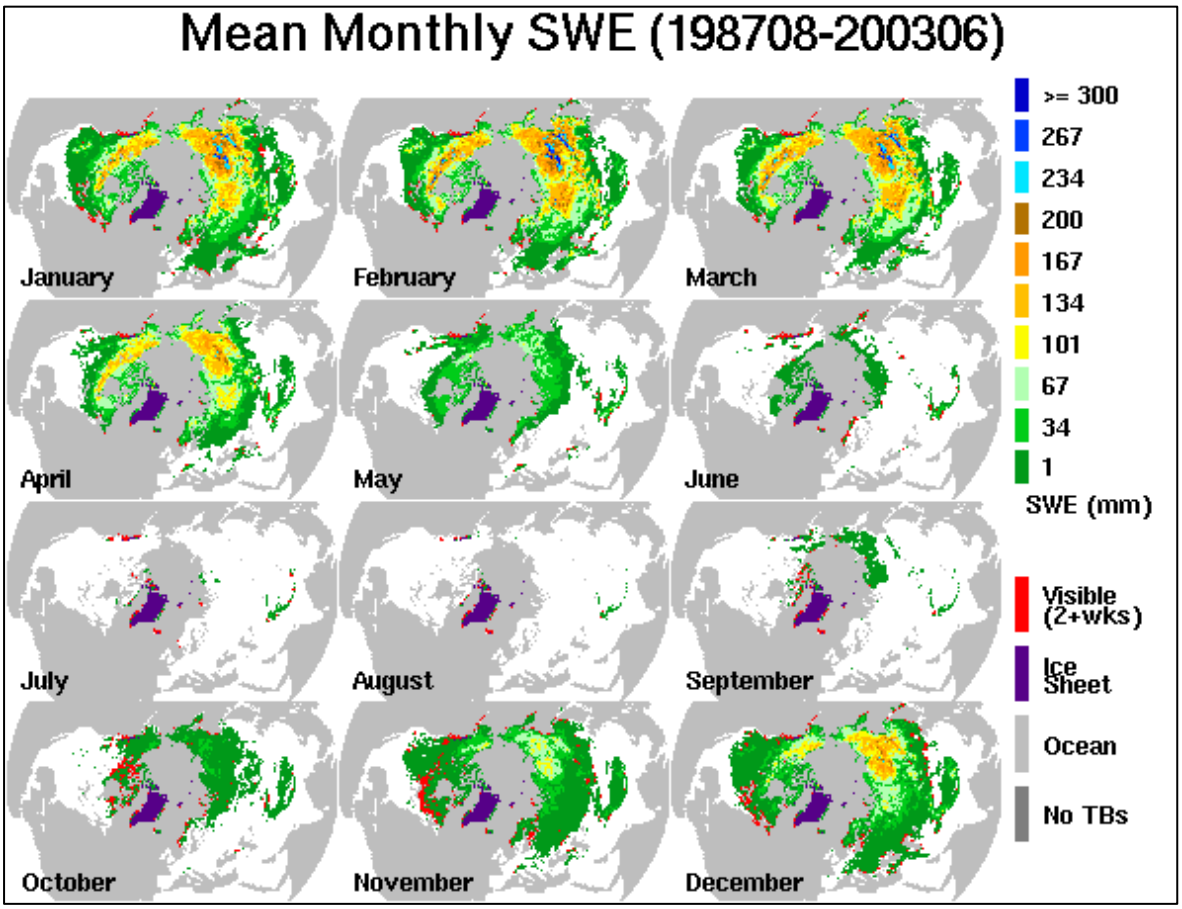

Figure 6. Northern Hemisphere monthly long-term average snow water equivalent (mm) from SSM/I, with additional area indicated as snow by Northern Hemisphere EASE-Grid weekly snow cover in red, (August 1987 - June 2003).

1.8.3 Southern Hemisphere

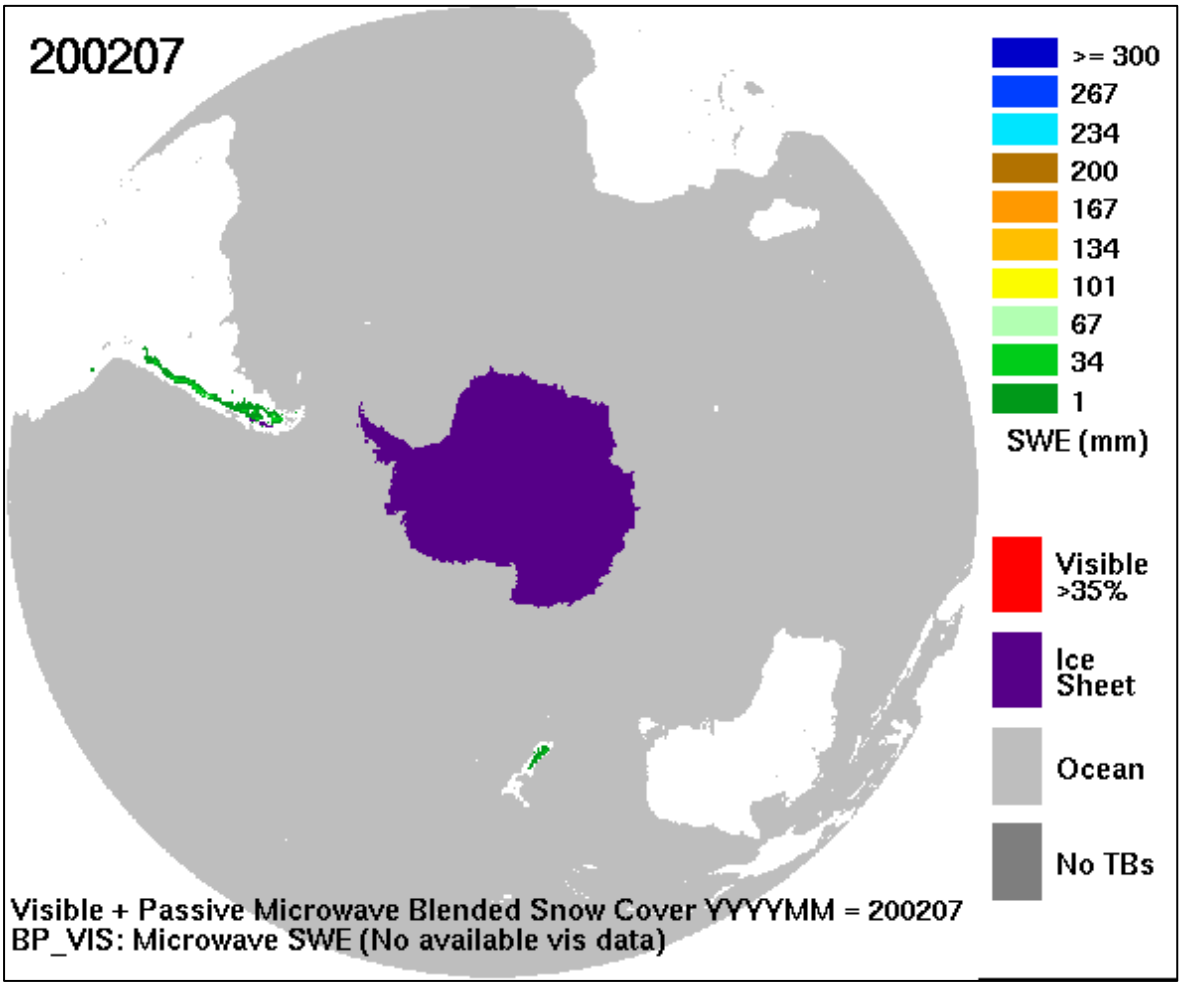

Figure 7. Southern Hemisphere average snow water equivalent (mm) from passive microwave, July, 2002.

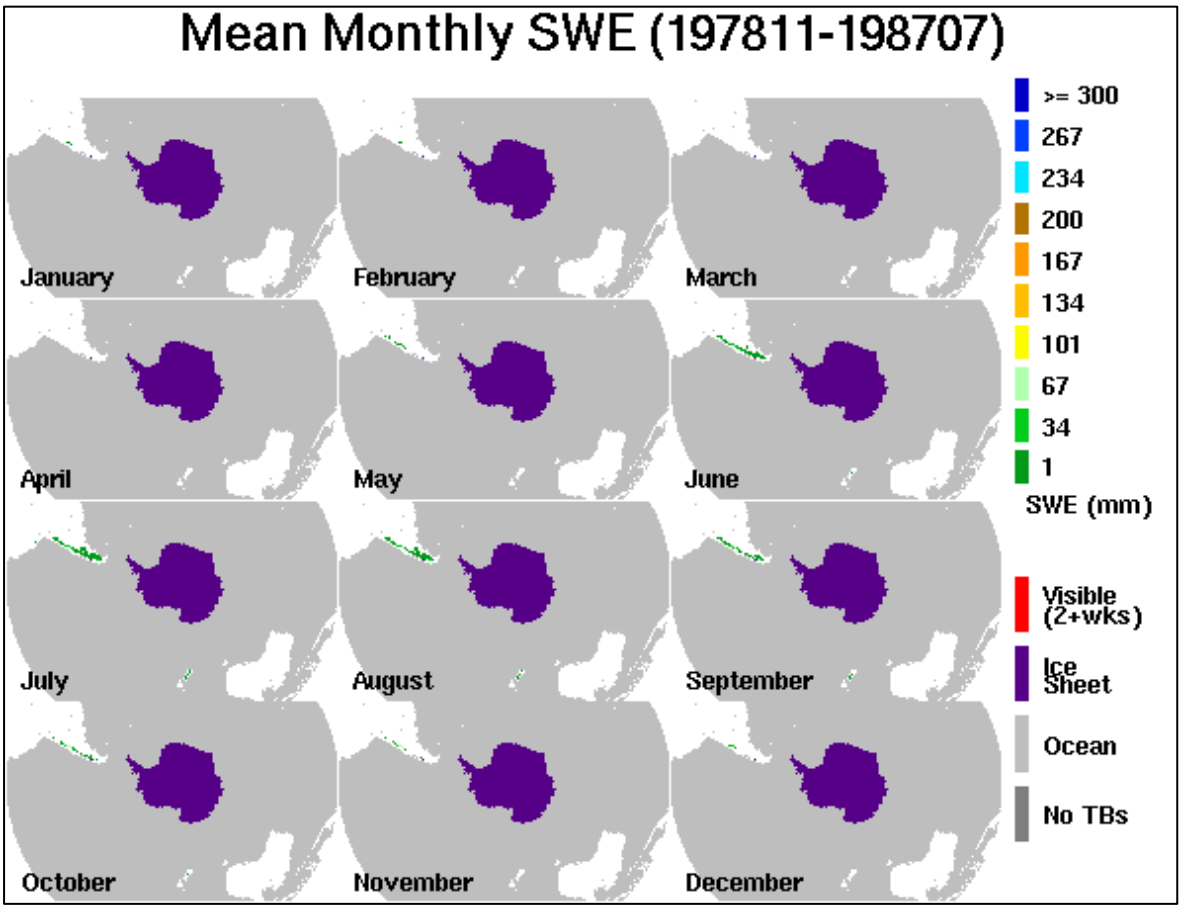

Figure 8. Southern Hemisphere monthly long-term average snow water equivalent (mm) from SMMR, (November 1978 - July 1987).

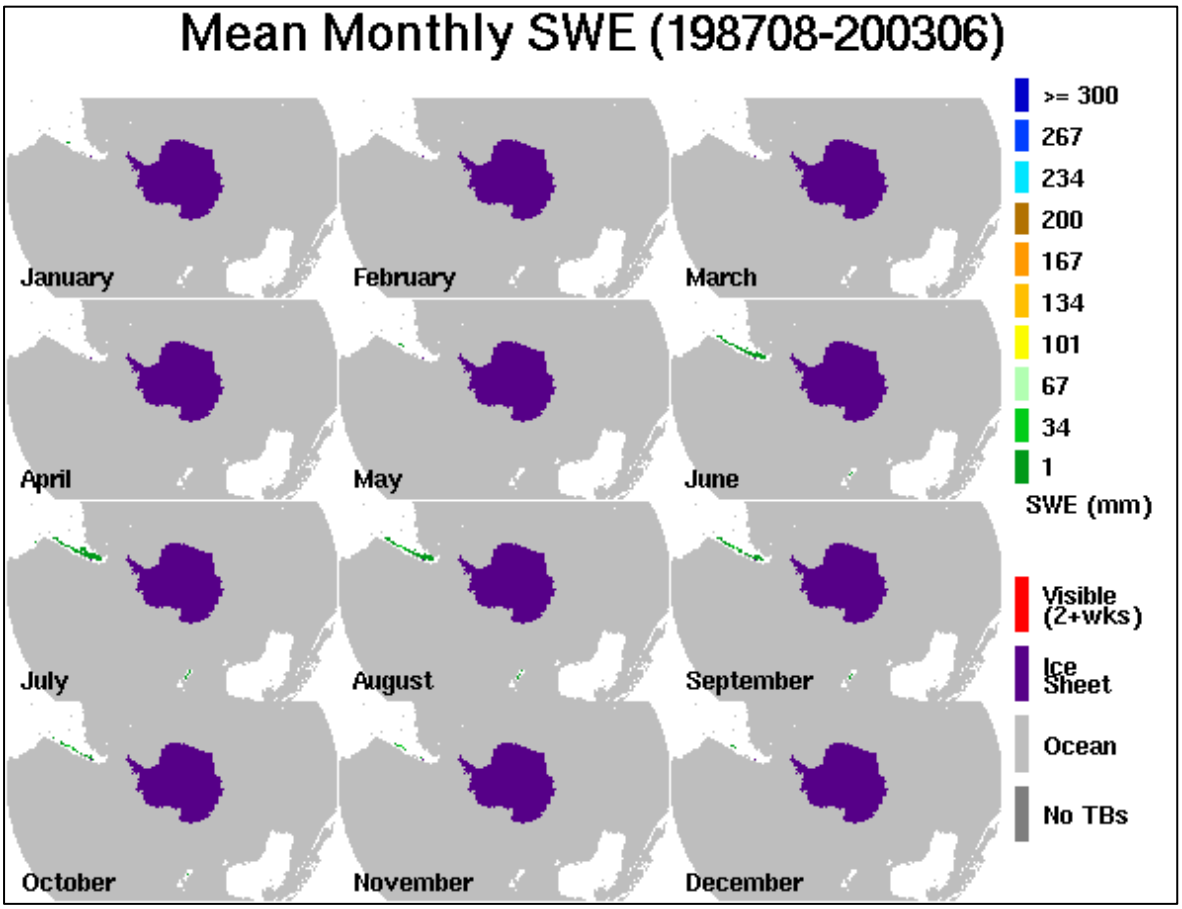

Figure 9. Southern Hemisphere monthly long-term average snow water equivalent (mm) from SSM/I,

2 DATA ACQUISITION AND PROCESSING

2.1 Processing Steps

The data files, designated "NSIDC8", contain microwave-derived SWE enhanced with visible snow frequency for a given month, derived as follows:

1. Input data are daily, "cold" pass, SMMR or SSM/I EASE-Grid brightness temperatures.
2. Daily SWE is derived from the horizontally polarized difference algorithm appropriate for the time period (Chang, Foster and Hall, 1987; Armstrong and Brodzik, 2001):
   - SMMR: SWE (mm) = 4.77 (18H - 37H)
   - SSM/I: SWE (mm) = 4.77 (19H - 37H - 5)
3. Daily SWE is adjusted for surface forest cover (Chang, Foster and Hall, 1996) using the 25 km EASE-Grid Land Cover Classifications Derived from Boston University MODIS/Terra Land Cover Data:
   - Let forest_percent = { 0: no forest, 0.01-0.49: 1-49% total forest, 0.50: >= 50% total forest}
   - Then: Adjusted SWE (mm) = SWE / (1.00 - forest_percent)
4. SWE values less than 7.5 mm are considered unreliable and are set to zero.

5. In the Northern Hemisphere, false SWE signals from lower latitude features such as deserts are filtered using the frequency climatologies derived from the Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 2 data (1966-2003); pixels where Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 2 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 SWE frequency climatology limits legitimate SWE data to the Andes Mountains region and New Zealand.
6. Areas with permanent ice (ice sheets, ice shelves, and large glaciers) are masked using a 50 percent threshold for permanent ice from the 25 km EASE-Grid version of the BU-MODIS Land Cover data.
7. (SSM/I, August 1987 and later, only): Noise in the SWE signal caused by temporary atmospheric phenomena (e.g. warm, precipitating weather fronts) are removed via a five-day persistence filter. A non-zero SWE signal on the third day is removed if and only if the maximum SWE of the surrounding days is zero. In those cases, the non-zero SWE value is considered too transient to be reliable.
8. Missing data caused by satellite swath coverage is interpolated from the surrounding days, using piece-wise linear interpolation across gaps of six missing days at the most.
9. Monthly average SWE is calculated from interpolated daily SWE. Number of days with data to average and standard deviation are saved in separate files.
10. Northern Hemisphere monthly average SWE is blended with Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 2 data for the given month. (Similar data are not available for the Southern Hemisphere.) The maximum extent of visible snow cover for the month is considered the true boundary of snow extent. Within that boundary, save either a) the microwave-derived SWE, or b) the visible snow frequency of occurrence for the month, if no SWE was detected.
11. Fixed values are set for corner, ocean, and permanent ice pixels.

2.2 Ancillary Data

2.2.1 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:

1. EVERGREEN NEEDLELEAF FOREST
2. EVERGREEN BROADLEAF FOREST
3. DECIDUOUS NEEDLELEAF FOREST
4. DECIDUOUS BROADLEAF FOREST
5. MIXED FORESTS

Any pixels with forest percent higher than 50% are set to the 50% threshold, thereby bounding the forest "correction" of the SWE value to a maximum factor of 2.

Click on the samples in Figures 10 and 11 to view larger images.

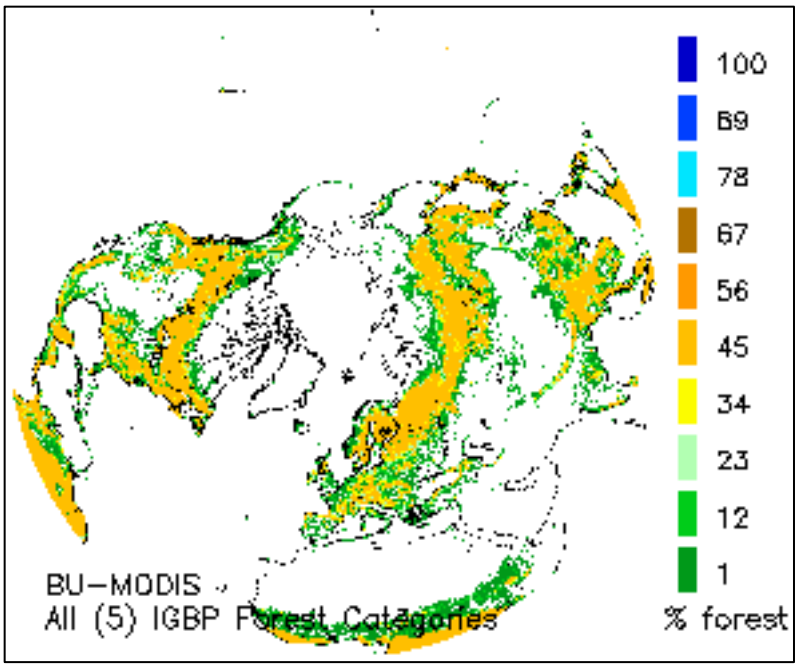

Figure 10. Northern Hemisphere forest percent mask, derived from BU-MODIS Land Cover data

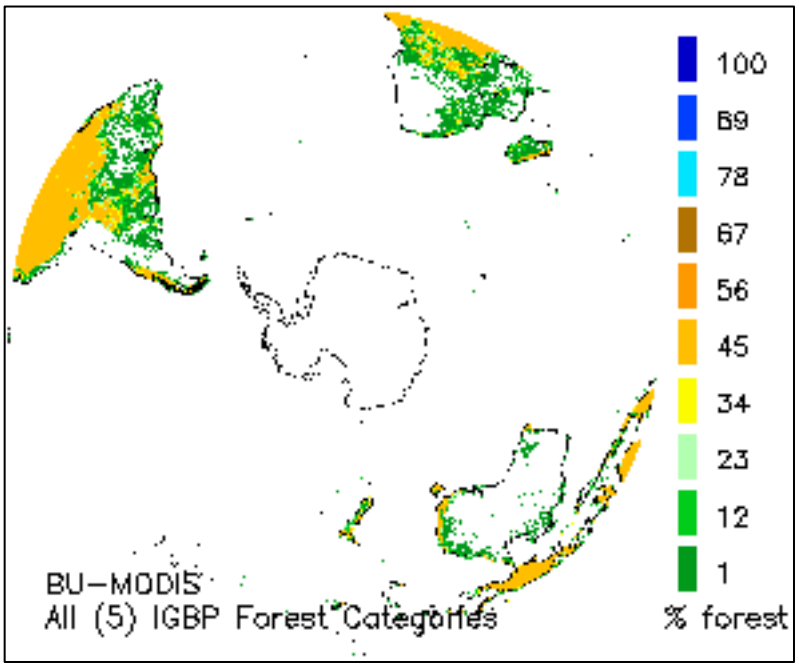

Figure 11. Southern Hemisphere forest percent mask, derived from BU-MODIS Land Cover data

2.2.2 Permanent Ice Masks

Areas with permanent ice (ice sheets, ice shelves, and large glaciers) are masked using a 50 percent threshold for permanent ice from the 25 km EASE-Grid version of the BU-MODIS Land Cover data.

Click on the samples in Figures 12 and 13 to view larger images.

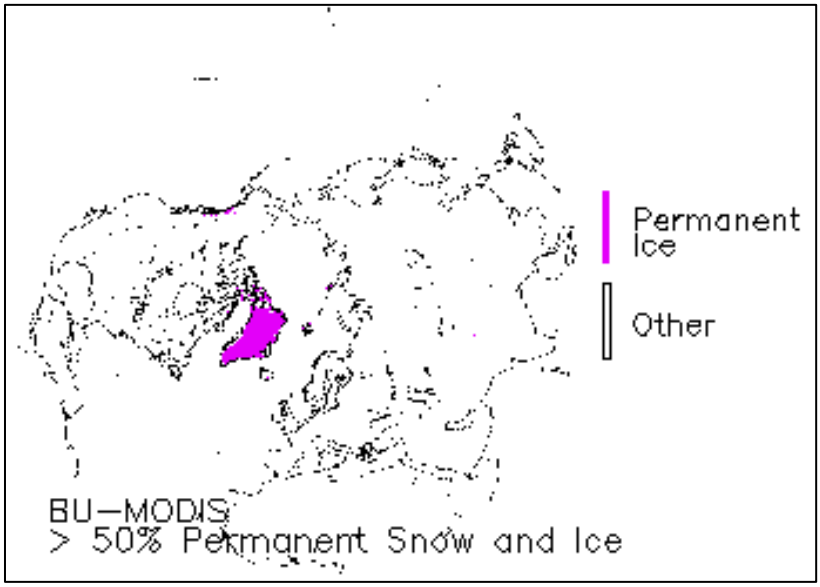

Figure 12. Northern Hemisphere permanent ice mask, derived from BU-MODIS land cover data.

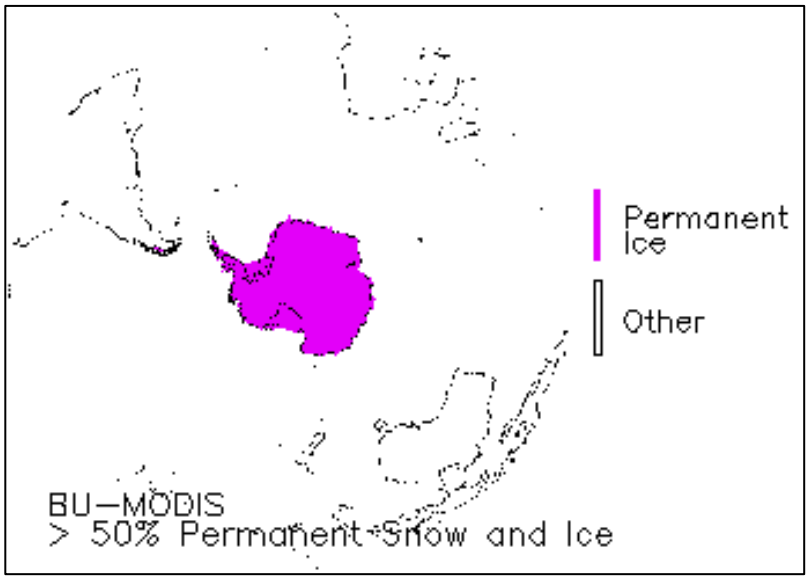

Figure 13. Southern Hemisphere permanent ice mask, derived from BU-MODIS land cover data.

2.2.3 Snow Frequency Climatologies

The snow frequency climatologies are shown in Figures 14 and 15.

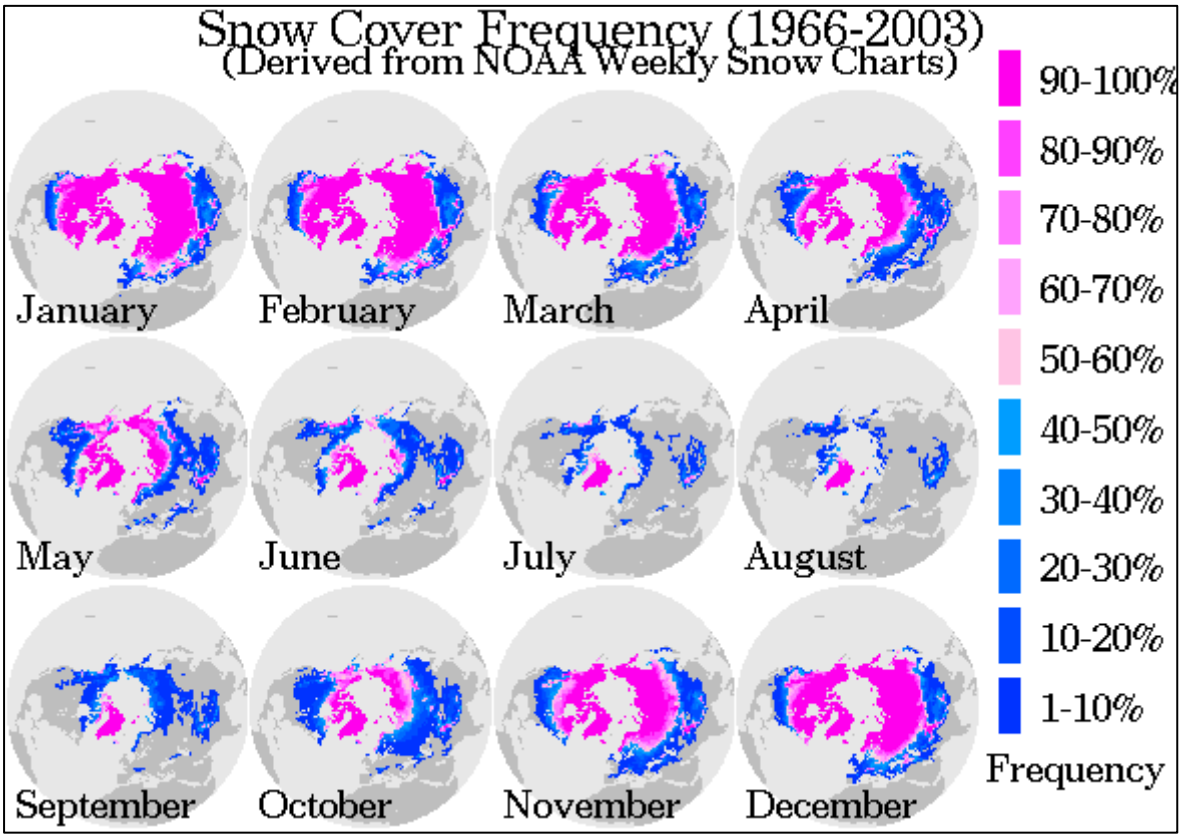

Figure 14. Long-term snow cover frequencies (1966-2003) derived from Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 2 data, used for Processing Steps, Step 5.

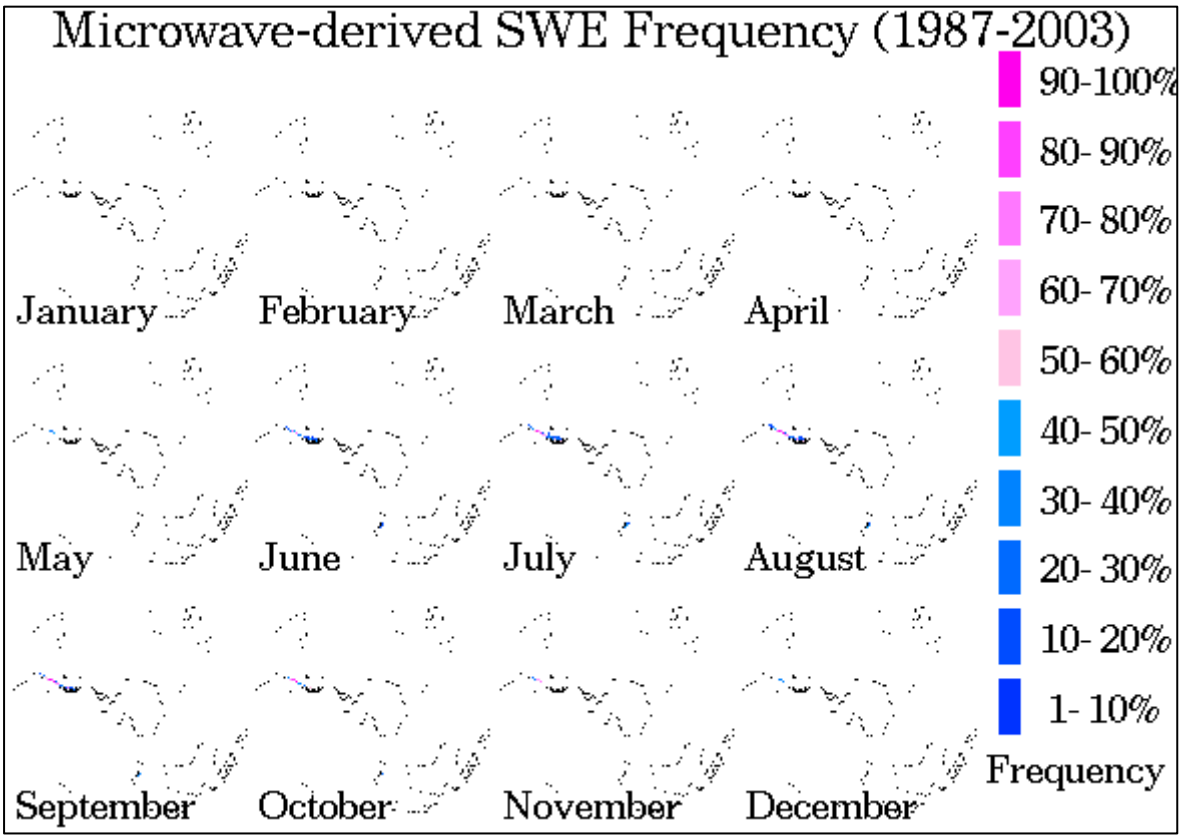

Figure 15. Southern Hemisphere long-term snow cover frequencies (1987-2003) derived from SSM/I-derived SWE frequency of occurrence. Areas with "likely" snow are limited to the Andes Mountains region and New Zealand. Frequency thresholds are a function of month (20% for October through May, 7% for June through September). These frequency maps are used for Southern Hemisphere Processing Steps, Step 5.

2.2.4 Data Set Release History

Table 5 describes the release history for this data set.

Table 5. Release History

Date Released	Version	Summary of Version Changes
1 February 2008	V01	Update released, data from April 2005 to May 2007; all processing was the same as for v01 original release, except that visible data were derived from Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 3 (original v01 release used Version 2 of this data set). No long-term statistics files were generated for this update.
20 September 2005	V01	Update released, data from July 2003 to March 2005; all processing was the same as for v01 original release, except that visible data were derived from Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 3 (original v01 release used Version 2 of this data set). No long-term statistics files were generated for this update.
1 May 2005	V01	Original v01 release, data from November 1978 to May 2003.

2.3 Errors 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 snow cover and SWE. Due to the lack of in situ validation data for SWE at both the spatial scale and resolution of the microwave sensors, snow water equivalent 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. In theory, 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 undermeasure in the following circumstances:

1. Mountainous areas with large topographic variability return low SWE values. Samples from these areas contain a mixed signal from a large footprint that may include deep snow on north-facing slopes, snow-free south-facing slopes, wind-scoured Alpine areas, etc.
2. 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.
3. Areas near coastlines return low or no SWE values, because the mixed signal includes frozen and unfrozen water and land.
4. 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.

5. Shallow or intermittent snow during fall and early winter typically does not result in sufficient microwave scattering to reliably detect SWE.

Lower confidence in SWE reliability due to overmeasure may occur in 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 overmeasure 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 climatology indicate greater values for Eastern Siberia than for Western Siberia, although some climate models indicate the opposite. There could be some degree of overmeasure 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 sow depth to determine with any certainty which pattern is correct.

Lower confidence in SWE reliability due to overmeasure may also occur in 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, which they expect to implement in the next revision of this data set (Armstrong, et al. 2004).

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 others (C. Derksen, personal communication, May 2004) indicates that the SWE gradient across this area appears to be real and measurable, if not as large a gradient as the microwave algorithm indicates, and should be treated with caution.

The passive microwave sensors used for this data set (SMMR and various SSM/I sensors) are all conically-scanning passive microwave radiometers. However, there are enough differences between SMMR and the SSM/I sensors used for this data set to raise doubts as to the validity of time-series analysis of SWE across the sensor break (July to August of 1987). NSIDC recommends that users view the SWE data sets derived from SMMR (1978 to July 1987) and from SSM/I (August 1987 to 2007) as separate time series, with a potential discontinuity in the summer of 1987.

3 REFERENCES AND RELATED PUBLICATIONS

Armstrong, R. L. and M. J. Brodzik. 2001. Recent Northern Hemisphere Snow Extent: A Comparison of Data Derived from Visible and Microwave Sensors. *Geophysical Research Letters*, 23(19):3673-3676.

Armstrong, R. L. and M. J. Brodzik. 2002. Hemispheric-scale Comparison and Evaluation of Passive Microwave Snow Algorithms, *Annals of Glaciology*, 34:38-44.

Armstrong, R. L., M. J. Brodzik, J. R. Wang, M. H. Savoie, O. Frauenfeld, T. Zhang. 2004. Solutions to the Snow Cover Mapping Anomaly over the Tibetan Plateau (poster). *Eos Trans. AGU*, 85(47), Fall Meet. Suppl.Abstract C31A-0282.

Brodzik, M. J. and K. W. Knowles. 2002. "EASE-Grid: A Versatile Set of Equal-area Projections and Grids" in M. Goodchild (Ed.) *Discrete Global Grids. Santa Barbara, California*, USA: National Center for Geographi Information & Analysis.

Chang, A. T. C., J. L. Foster, D. K. Hall. 1987. Nimbus-7 SMMRDerived Global Snow Cover Parameters. *Annals of Glaciology*, 9:39-44.

Chang, A. T. C., J. L. Foster, D. K. Hall. 1996. Effects of Forest on the Snow Parameters Derived from Microwave Measurements during the BOREAS Winter Field Campaign. *Hydrological Processes,* 10:1565-1574.

3.1 RELATED DATA COLLECTIONS

- Armstrong, R. L. and M. J. Brodzik. 2002. Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 2. Boulder, Colorado, USA: National Snow and Ice Data Center.
- Armstrong, R. L., K. W. Knowles, M. J. Brodzik and M. A. Hardman. 1994, updated 2005. DMSP SSM/I-SSMIS Pathfinder daily EASE-Grid brightness temperatures. Boulder, Colorado USA: National Snow and Ice Data Center.
- Knowles, K. W., E. G. Njoku, R. L. Armstrong, and M. J. Brodzik. 2002. Nimbus-7 SMMR Pathfinder daily EASE-Grid brightness temperatures. Boulder, Colorado USA: National Snow and Ice Data Center.
- Knowles, K. 2004. EASE-Grid Land Cover Classifications Derived from Boston University MODIS/Terra Land Cover Data, Version 1. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center.

4 CONTACTS AND ACKNOWLEDGMENTS

Richard L. Armstrong, Mary Jo Brodzik, Ken Knowles, Matt Savoie
National Snow and Ice Data Center
CIRES, 449 UCB
University of Colorado
Boulder, CO 80309-0449
USA

5 DOCUMENT INFORMATION

5.1 Publication Date

September 2017

5.2 Date Last Updated

18 February 2021.

APPENDIX A – APPENDIX A TITLE

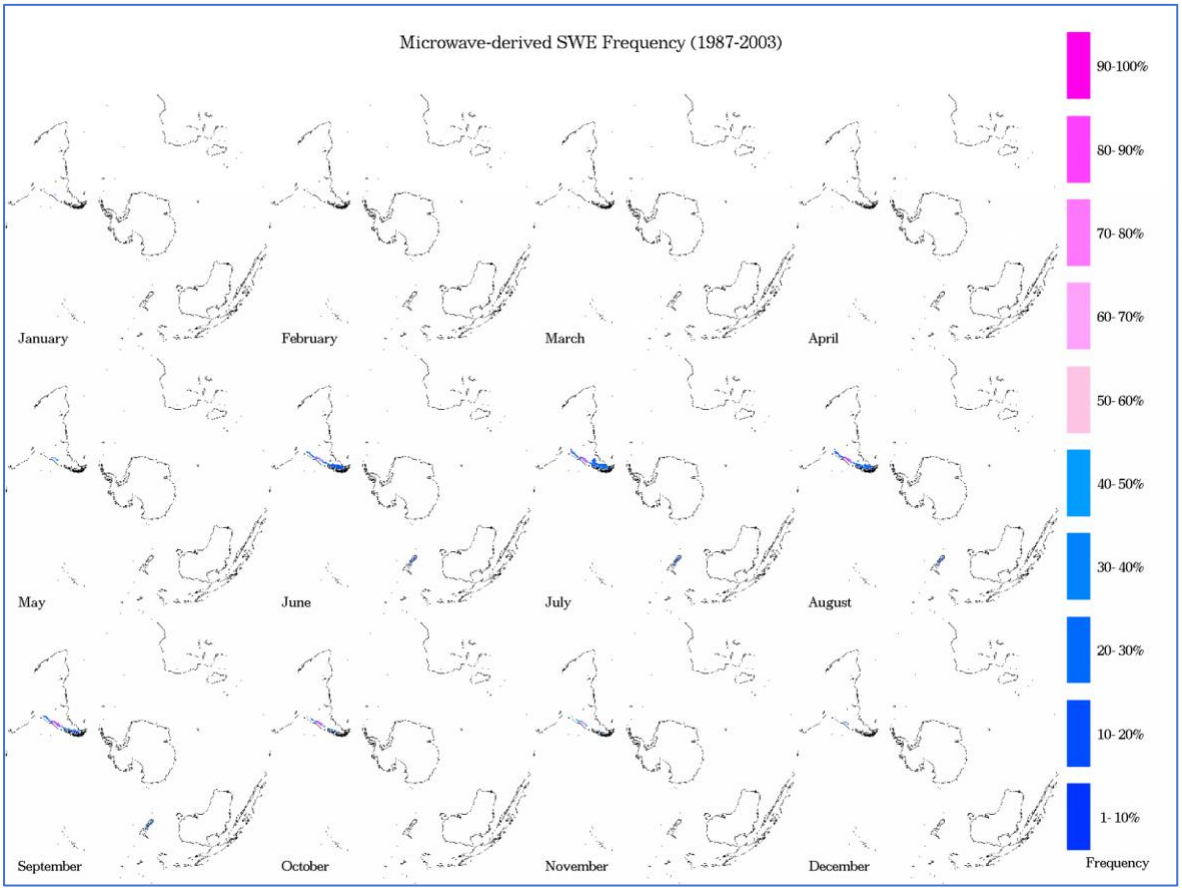

Figure A- 1