Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS, Version 2

USER GUIDE

How to Cite These Data

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

Comiso, J. C. 2000, updated 2015. *Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/J6JQLS9EJ5HU. [Date Accessed].

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National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

This sea ice concentration data set was derived using measurements from the Scanning Multichannel Microwave Radiometer (SMMR) on the Nimbus-7 satellite and from the Special Sensor Microwave/Imager (SSM/I) sensors on the Defense Meteorological Satellite Program's (DMSP) -F8, -F11, and -F13 satellites. Measurements from the Special Sensor Microwave Imager/Sounder (SSMIS) aboard DMSP-F17 are also included. The data set has been generated using the Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) Bootstrap Algorithm with daily varying tie-points. Daily (every other day prior to July 1987) and monthly data are available for both the north and south polar regions. Data are gridded on the SSM/I polar stereographic grid (25 x 25 km) and provided in two-byte integer format.

Note: Users should acquire the entire Version 2 data set in order to update their time series. For more information, refer to the Version History section of this document.

1.1 Format

Data files are stored in the original Goddard Space Flight Center (GSFC) flat binary two-byte integer format, use the little-endian byte order convention, and are scaled by a factor of 10. An individual image of daily or monthly averaged data constitutes a granule in the Bootstrap sea ice concentration time series.

1.2 File and Directory Structure

Data are available on the FTP site in the `ftp://sidads.colorado.edu/pub/DATASETS/nsidc0079_gsfc_bootstrap_seaice/` directory. Within this directory there is one main folder, `final-gsfc` and within the main folder there are two subfolders, `north` and `south`. Within the subfolders there is a: `daily` folder and `monthly` folder. The `daily` folders are further subdivided into yearly folders. Monthly files are located in the `monthly` directory with no further subdivision. Figure 1 shows the directory structure.

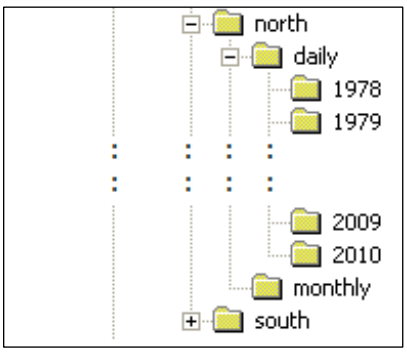

Figure 1. File Organization

1.3 File Naming Convention

1.3.1 Daily Files

This section explains the daily file naming convention used for this product with an example.

Example File Name: `bt_20060901_f13_v02_n.bin`

`bt_YYYYMMDD_SSS_vVV_H.bin`

Refer to Table 1 for the valid values for the file name variables listed above.

Table 1. Daily Files Naming Convention

Variable	Description
bt	indicates that this file was created using the bootstrap algorithm
YYYY	4-digit year
MM	2-digit month
DD	2-digit day
SSS	3-character sensor name: `n07` for Nimbus-7 SMMR `f08, f11,` or `f13` for DMSP SSM/I sensors `f17` for the DMSP SSMIS sensor
VV	2-digit version number (for example, 02)
H	Hemisphere: `n` for Northern `s` for Southern
.bin	indicates that this file is in binary format

1.3.2 Monthly Files

This section explains the monthly file naming convention used for this product with an example.

Example File Name: `bt_200609_f13_v02_n.bin`

`bt_YYYYMM_SSS_vVV_H.bin`

Refer to Table 2 for the valid values for the file name variables listed above.

Table 2. Monthly Files Naming Convention

Variable	Description
bt	indicates that this file was created using the bootstrap algorithm
YYYY	4-digit year
MM	2-digit month
SSS	3-character sensor name: `n07` for Nimbus-7 SMMR `f08`, `f11`, or `f13` for DMSP SSM/I sensors `f17` for the DMSP SSMIS sensor
VV	2-digit version number (for example, 02)
H	Hemisphere (`n` for Northern, `s` for Southern)
.bin	indicates that this file is in binary format

1.4 Spatial Coverage

Data set coverage includes the northern and southern polar regions. For a detailed description, see the Polar Stereo web site.

SSM/I and SSMIS instrument coverage is global, except for circular sectors centered over the North Pole, 311 km in radius, located poleward of 87.2°. These sectors are never measured due to orbit inclination. The 50° scan pattern provided a swath width of 780 km at the Earth's surface. The spatial resolutions at the various frequencies ranged from approximately 27 km at 37 GHz to 148 km at 6.6 GHz. For more information, see the Summary of SMMR, SSM/I, and SSMIS Sensors web page. The measurement footprint size or effective field of view (FOV) varies by frequency, as shown in the following table.

Table 3. SSM/I-SSMIS

Frequency	Footprint Size
19.3 GHz	70 x 45 km
22.2 GHz	60 x 40 km
37.0 GHz>	38 x 30 km

SMMR instrument coverage is global, except for circular sectors centered over the North Pole, approximately 611 km in radius, located poleward of 84.5°. These sectors are never measured due to orbit inclination. The 50° scan pattern provided a swath width of 780 km at the Earth's surface. The spatial resolutions at the various frequencies ranged from approximately 27 km at 37 GHz to 148 km at 6.6 GHz. For more information see the Summary of SMMR, SSM/I, and SSMIS Sensors web page. The measurement footprint size varies by frequency, as shown in the following table.

Table 4. SMMR

Frequency	Footprint Size
6.6 GHz	148 x 95 km
10.7 GHz	91 x 59 km
18.0 GHz	55 x 41 km
21.0 GHz	46 x 30 km
37.0 GHz	27 x 18 km

1.4.1 Spatial Resolution

Sea ice concentrations are provided at a resolution of 25 km.

1.4.2 Projection and Grid Description

For more information, refer to the Polar Stereo pages. The grid size varies depending on the hemisphere, as shown in the following table.

Table 5. Grid Size

Region	Columns	Rows
North	304	448
South	316	332

1.5 Temporal Coverage

Bootstrap sea ice concentration data are available for 26 October 1978 through 31 December 2015.

1.5.1 Temporal Resolution

SMMR data were collected every other day. (The scanner operated only on alternate days, due to spacecraft power limitations). Major data gaps occurred in August 1982 (4, 8, and 16 August) and 1984 (13 through 23 August) for both polar regions. Monthly means are generated by averaging all available files for each individual month, excluding pixels of missing data. Data were interpolated where missing pixels were present so that no areas of missing data remained.

SSM/I and SSMIS data are collected daily. Ice concentrations are provided for each day of data and as monthly means. Monthly mean files are generated by averaging all available daily files for each individual month, excluding pixels of missing data. A major data gap in the SSM/I data occurs from 03 December 1987 to 13 January 1988.

1.6 Parameter or Variable

The data set consists of sea ice concentration derived from gridded brightness temperatures. Sea ice concentrations range from 0 to 100 percent. Please see the Parameter Range section for more details

1.6.1 Parameter Range

Data are stored as two-byte integers representing sea ice concentration values. The sea ice concentration data values are packed into integer format by multiplying the original sea ice concentration values by 10 (divide stored value by 10 to get the percent). The sea ice concentration values range from 0 to 1000. Land is registered as 1200 and the Northern Hemisphere hole (a region of the North Pole that is not measured due to orbit inclination) is registered as 1100. Refer to the Spatial Coverage section.

1.6.2 Sample Data Record

The following is a sample data record from the Northern Hemisphere monthly data.

```
 837  887  924 971  971 992 980 975 974 964 980 965 936 972 968 986
 982  987  978 984  988 965 980 972 981 985 992 988 989 983 993 986
 985  984  982 983  982 981 974 990 982 983 978 977 983 987 981 992
 985  979  978 982  981 969 966 972 977 984 973 976 980 970 972 977
 980  984  980 982  977 973 973 969 968 972 980 951 887 877 928 936
1200 1200 1200 969 1200 951 956 980 980 980 975 982 982 961 937 863
 791  710  706 706  678
```

2 SOFTWARE AND TOOLS

The NSIDC DataViewer, written in IDL, is also available for use with this data set. The DataViewer is an interactive tool for viewing and displaying satellite images from select NSIDC passive microwave data sets. For more information and access to this tool, refer to the `dataviewer.tar.gz` section of the Polar Stereo Web page.

Table 6 lists the tools that can be used with this data set. For a comprehensive list of all polar stereographic tools, see the Polar Stereo Web page.

Table 6. Tools for this Data Set

Tool Type	Tool File Name(s)
Data Extraction	extract_ice.pro
Data Display	dataviewer.tar.gz
Geocoordinate	dataviewer.tar.gz
	locate.for
	mapll.for and mapxy.for
	psn25lats_v3.dat and pss25lats_v3.dat
	psn25lons_v3.dat and pss25lons_v3.dat
Pixel-Area	psn25area_v3.dat and pss25area_v3.dat
Land Masks	gsfc_25n.msk and gsfc_25s.msk
	coast_25n.msk and coast_25s.msk
	ltln_25n.msk and ltln_25s.msk
	pole_n.msk
Region Masks	region_n.msk and region_s.msk

2.1 Quality Assessment

Although most bad data are easily identifiable and removed with little ambiguity, human judgments must be made and applied consistently to the time series data. While efforts were made to minimize errors in judgment and inconsistencies, the resulting data set is not perfect. Nevertheless, the data provider feels that these maps are suitable for some types of research studies, such as basin-scale trend analysis, model inputs, and some regional studies. They are less useful in evaluating conditions on a specific day in a localized region.

NSIDC staff visually checked the entire set of data files, including file structure, comparisons to existing SMMR- and SSM/I-derived sea ice concentration grids, and information files and examination of data quality.

Please note that in this document, a large fraction of the text was supplied by the data set provider. It may include qualitative judgments and statements by the provider and does not necessarily represent endorsements or imply that independent assessments have been performed by NSIDC staff.

2.1.1 Limitations of the Data

Basic limitations arise from the sensor resolution, temporal coverage, and algorithm assumptions and characteristics. Users should review the information provided on fields of view, temporal sampling, and algorithm characteristics.

Particular care is needed in interpreting the sea ice concentrations during summer when melt is underway and in regions where new sea ice makes up a substantial part of the sea ice cover. As noted, some residual errors remain due to sensor differences and to weather effects along with mixing of ocean and land area within the sensor field of view.

No data coverage is available for regions poleward of 84.5° N for SMMR and 87.2° N for SSM/I or SSMIS due to the inclination of the orbits. SMMR data were acquired every other day, while SSM/I data were acquired daily. SSMIS data are also acquired daily.

3 DATA ACQUISITION AND PROCESSING

Satellite passive microwave sensors provide global radiance measurements that may be used to map, monitor, and study Arctic and Antarctic polar sea ice. The microwave data used for this sea ice concentration data set spans over 25 years, starting with the launch of the SMMR instrument on NASA's Nimbus-7 in 1978 and continuing with the DMSP SSM/I series beginning in 1987.

Sea ice concentrations are generated using brightness temperatures derived from SMMR and SSM/I radiances. The goal in the creation of the data set is to produce a long-term, consistent data set in which sea ice extent and area differences between the sensors are reduced that could serve as a baseline for future measurements. The Bootstrap data set provides improved consistency between sensors and enhanced removal of weather and land contamination.

The Bootstrap data set includes gridded daily and monthly averaged sea ice concentrations (every-other-day for the SMMR data) for both the north and south polar regions beginning 26 October 1978 through the most current processing.

Algorithms designed to estimate sea ice concentration using passive microwave data frequently do not work well over open ocean. When applied, instead of predicting the expected zero value, the algorithms predict sea ice concentration values as high as 35 percent, particularly in regions with excessive winds and stormy weather. A climatological sea surface temperature mask was applied to remove pixels from regions where the ocean surface is above freezing. Also, land contamination (false ice along the coast due to pixels containing a mixture of land and ocean) were removed using a filter adapted from Cho et al. (1996). Even with these quality-control measures, some residual sea ice concentrations remain in the open ocean and along the coast.

3.1 Theory of Measurements

The SMMR and SSM/I instruments are dual-polarized and multi-frequency microwave radiometers that sense emitted microwave radiation at an incidence angle of about 53° and an altitude of about 800 km. At microwave frequencies, the observed radiance varies linearly with the temperature of

the emitting material, according to the Rayleigh-Jeans law, and is usually expressed in terms of brightness temperature. The constant of proportionality in the linear relationship is the emissivity, which provides information about the electrical and physical properties of the material itself. The observed brightness temperatures come primarily from the Earth's surface with some contributions from the atmosphere and outer space. Depending on frequency and polarization, the brightness temperature is affected by changing surface, subsurface, and atmospheric conditions. The multichannel capability allows for the discrimination of different surfaces and atmospheric effects and allows for the development of algorithms that provide a range of geophysical information about the surface.

3.2 Data Acquisition Methods

Four sets of satellite data are used to create the Bootstrap sea ice data stream:

- Nimbus-7 SMMR, data range: 26 October 1978 through 20 August 1987
- DMSP-F08 SSM/I, data range: 9 July 1987 through 18 December 1991
- DMSP-F11 SSM/I, data range: 3 December 1991 through 31 December 1996
- DMSP-F13 SSM/I, data range: 5 May 1995 through 31 December 2007
- DMSP-F17 SSMIS, data range: 1 January 2008 through the most current processing

3.2.1 SMMR

Sea ice concentrations were processed by GSFC using SMMR brightness temperatures. The SMMR brightness temperatures were processed and quality checked at GSFC (Gloersen et al. 1992).

3.2.2 SSM/I-SSMIS

Bootstrap sea ice concentrations were processed at GSFC using DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures from NSIDC. Processing of DMSP-F17 brightness temperatures is ongoing. For more information on the brightness temperatures, see the DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures documentation.

3.3 Derivation Techniques and Algorithms

Sea ice concentrations for this data set were derived from a revised Bootstrap algorithm which uses a different set of tie-points and adjustments. For algorithm background, please see the Enhanced Sea Ice Concentrations from Passive Microwave Data document (Comiso and Nishio 2008).

3.3.1 Processing Steps

With Version 2 of the data set released on September 2007, adjustments were made to the tie-points to make the ongoing SMMR-SSM/I time series consistent with the AMSR-E Bootstrap algorithm product. Refer to the Enhanced Sea Ice Concentrations from Passive Microwave Data for further information. In addition to the inter-calibration of the SMMR-SSM/I with AMSR-E, the algorithm was adjusted in the Antarctic to remove negative bins of a few percent ice concentration. Other minor changes were also made for Version 2. Full documentation of the Version 2 data is available in the Enhanced Sea Ice Concentrations from Passive Microwave Data document. Users should thoroughly examine the Version 2 documentation before using the data.

3.3.2 Interpolation

Data were interpolated in areas with missing pixels according to the following steps. First, data were spatially interpolated only for isolated empty pixels. An empty pixel was replaced by the average of four good surrounding pixels, or if four good pixels were not available, then a smaller number of pixels was selected. Second, a time interpolation was applied to the spatially interpolated map. Time interpolation was based on a weighting scheme; the closer the good data were in time, the higher the weighted value. For each empty pixel, the algorithm searched forward in time for a good pixel, and backward in time for a second good pixel. The algorithm determined how many days ahead and behind the two good pixels occurred and calculated the weight of each pixel. A weighted average of the two good pixels was then calculated, and the result was used for the empty pixel. During the SSM/I period, most temporal interpolations were conducted using only adjacent days. During the SMMR period, particularly in 1986 when larger gaps were present, temporal interpolations had separations of more days.

3.3.3 Version History

Table 7 outlines the processing and algorithm history for this product.

Table 7. Description of Version Changes

Version	Date	Description
V2	September 2007	Changes to this version include: • Adjusted tie-points to be consistent with the AMSR-E Bootstrap algorithm • Adjusted Southern Hemisphere land mask to account for changes in extent and positions of ice shelves • Reprocessed entire SMMR-SSM/I time series Important: Because Version 2 is inter-calibrated with AMSR-E, it is not compatible with Version 1 of this data set. Users should acquire the entire Version 2 data set in order to update their time series. This product is also not consistent with the NSIDC-produced Bootstrap Product, the DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures. For further information on Version 2 data processing, see Enhanced Sea Ice Concentrations from Passive Microwave Data.
V1	January 1996	Original version of data. For information on the Version 1 data processing, see the Descriptions of and Differences between the NASA Team and Bootstrap Algorithms Web page.

3.3.4 Error Sources

Sensitivity analysis of potential errors associated with the retrieval of sea ice products were discussed previously. For example, see Comiso et al. 1997 and other references associated with the NASA Team Algorithm sea ice products. Sea ice concentration errors are difficult to quantify because sea ice is an evolving ice cover and does not have uniform physical and radiative characteristics throughout the ice pack. The emissivity of sea ice is known to change as the ice cover develops from grease ice to nilas, pancake to young ice, or first year ice to multiyear ice. The line AD in the scatter plot that provides the sea ice tie-point in the Bootstrap Algorithm corresponds to 100 percent ice for the relatively thick ice types such as first year or multiyear ice. Areas with 100 percent of thinner ice types are often estimated to have ice concentrations as low as 80 percent due to lower emissivities (Comiso et al. 1992). In the summer, retrievals in the Arctic could have biases caused by meltponding effects (Comiso and Kwok 1996).

Inside the ice pack, observations from helicopter and aircraft flights typically show very high sea ice concentrations with some 5 to 10 percent of the leads covered by nilas or pancake ice. The frequency distribution of sea ice concentration in highly consolidated ice areas has a standard deviation of about 3 percent, which includes sea ice cover with concentrations of less than 100 percent. Overall, retrieval accuracy is estimated to be approximately 5 to 10 percent except in

some unusual cases, such as the presence of a large fraction of thin ice or meltponding within the pixel and the presence of stormy weather conditions, especially near the ice edge. Limited comparative analysis with high resolution instruments and other measurements confirm this, but more extensive validation in a greater number of places over all of the seasons would provide more accurate error assessments.

For information describing the rough error/differences between each sensor (F8, F11, F13, F17) during the sensor overlap time period, refer to the following documentation: Comiso et al. 2008, Comiso et al. 2009, and Comiso et al. 2010.

3.4 Sensor or Instrument Description

Please refer to the following documents for details on sensors and platforms:

3.4.1 Sensors

Scanning Multi-channel Microwave Radiometer (SMMR)
Special Sensor Microwave Imager (SSM/I)
Special Sensor Microwave Imager (SSMIS)

3.4.2 Platforms

Nimbus 7 Spacecraft System
Defense Meteorological Satellite Program (DMSP) Satellite F8
Defense Meteorological Satellite Program (DMSP) Satellite F11
Defense Meteorological Satellite Program (DMSP) Satellite F13
Defense Meteorological Satellite Program (DMSP) Satellite F17

4 REFERENCES AND RELATED PUBLICATIONS

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4.1 Related Data Collections

- Sea Ice Trends and Climatologies from SMMR and SSM/I-SSMIS
  NSIDC provides a suite of value-added products to aid in investigations of the variability and trends of sea ice cover. These products provide users with information about sea ice extent, total ice covered area, ice persistence, monthly climatologies of sea ice concentrations, and ocean masks.
- DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures
  NSIDC produces daily gridded brightness temperature data from orbital (swath) data generated by SSM/I mounted on the DMSP F8, F11, and F13 platforms. The gridded brightness temperatures are distributed in polar stereographic projection.
- Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data
  This data set is generated from brightness temperature data derived from the Nimbus-7 SMMR and DMSP F8, F11, and F13 SSM/I radiances at a grid cell size of 25 x 25 km. The data are provided in the polar stereographic projection.
- Sea Ice Index
  The images in the Sea Ice Index data set depict average ice conditions, estimated using satellite passive microwave data for the most recent month available, as well as snapshots of trends and anomalies that compare these recent conditions with the mean for the month.
- Sea Ice Data
  This site offers a summary of sea ice data derived from passive microwave sensors and other sources and is useful for users who want to compare characteristics of various sea ice products to understand their similarities and differences. This site also provides links to tools for passive microwave data and a list of other sea ice resources.

4.2 Related Documents and Websites

- Descriptions of and Differences between the NASA Team and Bootstrap Algorithms
- Polar Stereographic Projections and Grids
- SMMR, SSM/I, and SSMIS Sensors Summary

5 CONTACTS AND ACKNOWLEDGMENTS

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6 DOCUMENT INFORMATION

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