NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 5

USER GUIDE

How to Cite These Data

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

Meier, W. N., F. Fetterer, A. K. Windnagel, J. S. Stewart, and T. Stafford. 2024. *NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 5*. [Indicate subset used]. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center https://doi.org/10.7265/10.7265/rjzb-pf78. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/G02202/

TABLE OF CONTENTS

1 DATA DESCRIPTION

1.1 Summary

This data set provides sea ice concentration estimates at a 25 km spatial resolution derived from passive microwave data that are produced in conformance with NOAA Climate Data Record (CDR) program criteria (NRC 2004). These criteria emphasize transparent and reproducible processing.

The sea ice concentration (SIC) CDR algorithm output is a rule-based combination of ice concentration estimates from two well-established algorithms: the NASA Team (NT) algorithm (Cavalieri et al. 1984) and NASA Bootstrap (BT) algorithm (Comiso 1986). The SIC CDR algorithm blends the NT and BT output concentrations by selecting, for each grid cell, the higher concentration estimate value. The algorithm capitalizes on the strengths of each contributing algorithm to produce ice concentration fields that should be more accurate than those from either algorithm alone. This statement is based on SIC CDR algorithm logic and the literature of NT and BT validation studies. Comprehensive validation of CDR ice concentration fields has not taken place. However, Meier et al. (2014) provide a detailed analysis of the spatial distributions of differences between the SIC CDR fields and ice concentration from NT and BT. They find that the SIC CDR and BT fields are quite similar in both hemispheres. There are larger differences between the SIC CDR and NT concentrations, with the SIC CDR (and BT) finding more ice overall. Trends in area and extent for all three products, computed over 1988-2007, have only small differences. This document summarizes important information about this data set including data file information and organization, spatial and temporal resolution, and data acquisition and processing. For full details on the algorithms, filters, interpolations, and error sources, see the Climate Algorithm Theoretical Basis Document (C-ATBD): Sea Ice Concentration, Rev. 11 (Meier et al., 2024).

The SIC CDR begins in October 1978 with NASA Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR) instrument and continues to the present with the Defense Meteorological Satellite Program (DMSP) F-17 Sensor Microwave Imager and Sounder (SSMIS) sensor.

Addition of AMSR2 Prototype Sea Ice Concentration

With the release of the SIC CDR Version 5, a prototype sea ice concentration record is also supplied. The prototype uses the AMSR2 instrument onboard the Japan Aerospace Exploration Agency (JAXA) Global Change Observation Mission - W1 (GCOM-W1) satellite. This record starts 1 January 2013. Because the DMSP satellites are aging, it is important to ensure the continuation of a quality-controlled sea ice concentration time series. We added this new sea ice concentration record to begin preparing for the eventual failure of the DMSP instruments. Furthermore, the AMSR2 instrument is a next-generation sensor with better spatial resolution than its predecessor SSM/I and SSMIS instruments. The better resolution suggests that an AMSR2 sea ice concentration field represents sea ice more accurately than the same ice represented in an SSMIS ice concentration field. This is true even after the AMSR2 field – whose native resolution is 12.5 km – is down-sampled to match the 25 km SSMIS grid. This is discussed further in Section 4.2.2 of the C-ATBD (Meier et al., 2024). However, differences between SSMIS and AMSR2 fields suggest extending the CDR with AMSR2 ice concentration requires first intercalibrating the DMSP record for consistency with the more-accurate AMRS2 record. Differences are slight (leading to a less than 2% difference in sea ice extent, for example) but significant for a climate data record. Until that work can be done, the AMSR2 record can be used to investigate shorter term regional and hemispheric variability within the AMSR2 time-period and will provide higher effective spatial resolution.

We have designated the AMSR2 record a prototype sea ice concentration to make clear that it is not the sea ice concentration climate data record. Because of the discontinuity between records, the AMSR2 prototype should not be used in conjunction with the earlier NOAA/NSIDC SIC CDR for long-term climate studies.

1.2 Parameters

The parameter of this data set is sea ice concentration which is the fraction of ocean area covered by sea ice. Sea ice concentration represents an areal coverage of sea ice. For a given grid cell, the parameter provides an estimate of the fractional amount of sea ice covering that cell, with the remainder of the area consisting of open ocean.

1.3 File Information

1.3.1 Format

These data are provided in netCDF4 file format and are compliant with the Climate and Forecast (CF) Metadata Convention CF-1.11 and the Attribute Convention for Data Discovery (ACDD) 1.3.

The data are provided in two temporal resolutions: daily and monthly averages. These are structured in two ways: as single files and as aggregated files. For the daily data, users can access a single file for each day of the time series or a yearly aggregated file that contains a year’s worth of daily data in a single file. For the monthly averaged data, users can access a single file for each month of the time series or a single aggregated file with all monthly data spanning the entire period of record. The data variables in both the daily and monthly netCDF files are described in section 1.3.4 File Contents.

1.3.2 Directory Structure

The netCDF data files are organized by hemisphere (north and south) and divided into daily, monthly, and aggregate subfolders as described below and shown in Figure 1.

The top-level directory contains three folders:

1. **ancillary**: Contains ancillary data files that may be useful when working with the sea ice CDR.
2. **north**: Contains the Northern Hemisphere netCDF data files.
3. **south**: Contains the Northern Hemisphere netCDF data files.

The **north** and **south** directories are further subdivided into four folders:

1. **aggregate**: Contains daily data compiled into yearly files and monthly data combined into a single file spanning the entire period of record.
2. **checksums**: Contains md5 checksums of the individual daily and monthly data files and the aggregated daily and monthly data files to ensure accuracy in data transfer. It is divided into three folders: aggregate, daily, and monthly, which correspond to structure of the netCDF data files.
3. **daily**: Contains individual files for each day, organized by year.
4. **monthly**: Contains individual files for each month of every year.

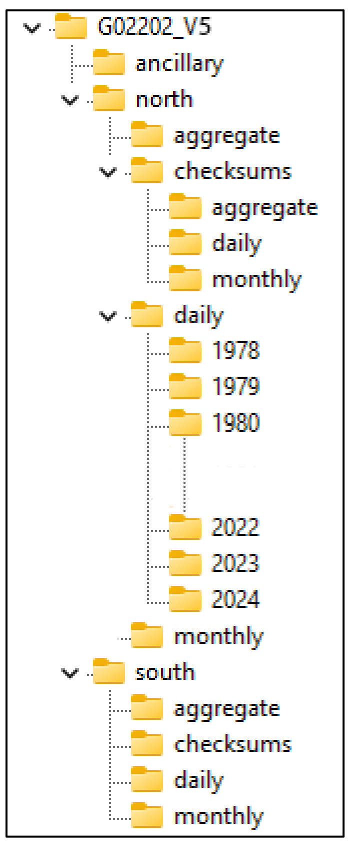

Figure 1. Directory Structure

1.3.3 Naming Convention

The file naming convention for the daily and monthly files is listed below and described in Table 1:

Individual daily files: `sic_ps[h]25_[yyyymmdd]_[sat]_[vXXrXX].nc`

Yearly aggregated daily files: `sic_ps[h]25_[yyyymmdd]-[yyyymmdd]_[vXXrXX].nc`

Individual monthly files: `sic_ps[h]25_[yyyymm]_[sat]_[vXXrXX].nc`

Period-of-record aggregated monthly files: `sic_ps[h]25_197811_[yyyymm]_[vXXrXX].nc`

Where:

Table 1. File Naming Convention

Variable	Description
sic	Identifies files containing sea ice concentration data
ps	Indicates files are gridded to the polar stereographic grid
h	Hemisphere (n: North, s: South)
25	Indicates that the data in these files have a spatial resolution of 25 km.
yyyy	4-digit year (for aggregate files, first instance is start year and second is end year)
mm	2-digit month
dd	2-digit day of month
sat	Source satellite (n07: Nimbus 7, F08: DMSP F8, F11: DMSP F11, F13: DMSP F13, and F17: DMSP F17)
vXXrXX	Version and revision number of the data file (e.g. v05r00: Version 5, Revision 0)
.nc	Denotes a netCDF file
.nc.mnf	Identifies an md5 checksum file

1.3.4 File Contents

Each daily and monthly netCDF file has a variable for the concentration product, as well as variables containing standard deviation, quality flags, and projection information. These are described in further detail below in sections organized by the temporal resolution: 1.3.4.1 Daily File Variable Description and 1.3.4.2 Monthly File Variable Description.

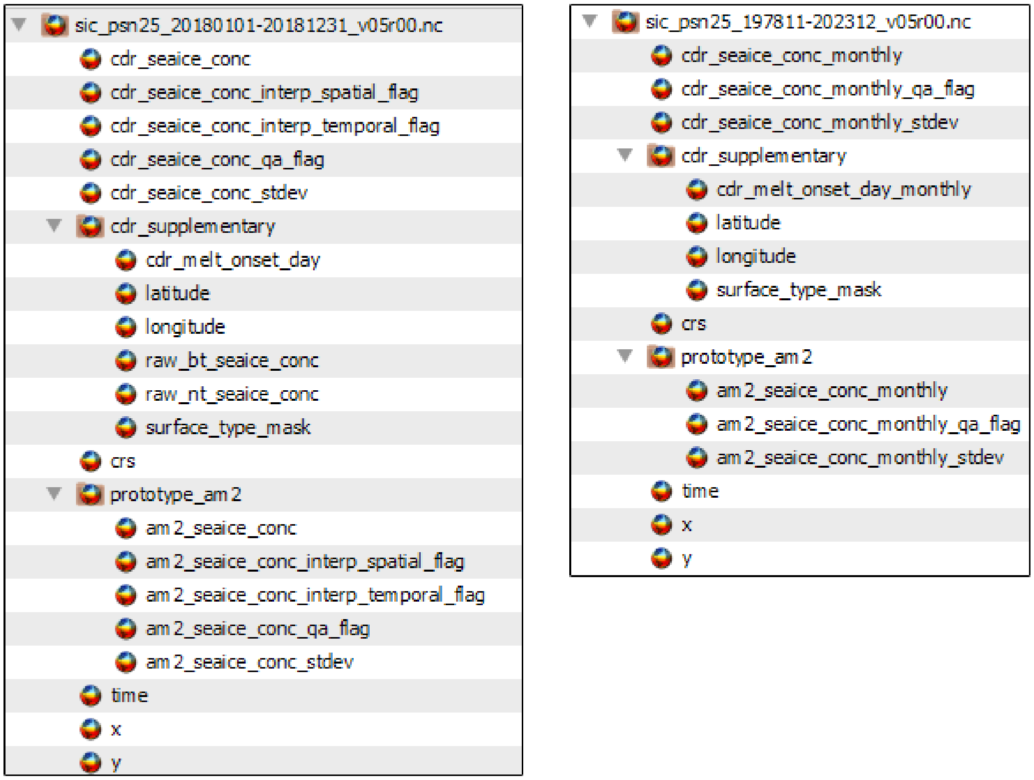

Figure 2. File Contents of a Northern Hemisphere daily aggregated NetCDF file (left) and Northern Hemisphere monthly aggregated NetCDF file (right).

1.3.4.1 Daily File Variable Description

The daily netCDF4 files contain the variables and groups shown in Figure 2 (left) and listed in Table 2, along with a brief description. The sections below the table provide more detailed information about each variable.

Table 2. List of Daily Variables

Variable Name	Brief Description
cdr_seaice_conc	NOAA/NSIDC daily sea Ice concentration CDR.
cdr_seaice_conc_interp_spatial_flag	Indicates the NOAA/NSIDC CDR grid cells that were spatially interpolated.
cdr_seaice_conc_interp_temporal_flag	Indicates the NOAA/NSIDC CDR grid cells that were temporally interpolated.
cdr_seaice_conc_qa_flag	Quality flags for the cdr_seaice_conc variable.
cdr_seaice_conc_stdev	Standard deviation of the daily NOAA/NSIDC CDR sea ice concentration (cdr_seaice_conc).

Variable Name	Brief Description
cdr_melt_onset_day	Day of year when melting sea ice was first detected in each grid cell for the daily NOAA/NSIDC CDR (applies to the Northern Hemisphere only). Located in the cdr_supplementary group.
latitude	Latitude in degrees north of the projection grid centers (aggregated files only). Located in the cdr_supplementary group.
longitude	Longitude in degrees east of the projection grid centers (aggregated files only). Located in the cdr_supplementary group.
raw_bt_seaice_conc	NSIDC-processed Bootstrap daily sea ice concentrations. Located in the cdr_supplementary group.
raw_nt_seaice_conc	NSIDC-processed NASA Team daily sea ice concentrations. Located in the cdr_supplementary group.
surface_type_mask	Provides a mask of different Earth surface types. Located in the cdr_supplementary group.
crs	Projection information for the data.
am2_seaice_conc	Prototype daily sea ice concentration from the AMSR2 instrument. Present only in data files from 2013 onward. Located in the prototype_am2 group.
am2_seaice_conc_interp_spatial_flag	Indicates the prototype AMSR2 grid cells that were spatially interpolated. Present only in data files from 2013 onward. Located in the prototype_am2 group.
am2_seaice_conc_interp_temporal_flag	Indicates the AMSR2 grid cells that were temporally interpolated in the am2_seaice_conc variable. Present only in data files from 2013 onward. Located in the prototype_am2 group.
am2_seaice_conc_qa_flag	Quality flags for the am2_seaice_conc variable. Present only in data files from 2013 onward. Located in the prototype_am2 group.
am2_seaice_conc_stdev	Standard deviation of the AMSR2 sea ice concentration (am2_seaice_conc variable). Present only in data files from 2013 onward. Located in the prototype_am2 group.
time	Date of the data (days since 1970-01-01).
x	Projection grid x centers in meters.
y	Projection grid y centers in meters.

cdr_seaice_conc

Description NOAA/NSIDC CDR sea ice concentrations representing the fraction of ocean area covered by sea ice that span 25 October 1978 through most recent processing. This variable is computed from the NASA Team and Bootstrap processed sea ice concentrations using the CDR Algorithm. For a description of the algorithm used to merge these, see section 2.3.3 SIC CDR Algorithm.

Data Type Unsigned byte array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Yearly aggregated daily files have a time dimension of either 365 or 366, corresponding to the number of days in a year.

Valid Range 0 to 100. Note: Byte values are stored in the files from 0 to 100 but are typically presented by netCDF readers as values ranging from 0 to 1 due to a scaling factor attribute (scale_factor) of .01.

Fill Value 255

Units Unitless

cdr_seaice_conc_interp_spatial_flag

Description Provides details on the CDR grid cells that were spatially interpolated. Spatial interpolation occurs on the brightness temperature channels. See Table 3 for a list of the flag values and the C-ATBD (Meier et al., 2024) for details. If a grid cell was not spatially interpolated, its value is set to zero. Grid cells meeting multiple criteria contain the sum of all applicable flag values.

Data Type Unsigned byte array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Yearly aggregated daily files will have a time dimension of either 365 or 366, corresponding to the number of days in a year.

Valid Range 0 to 63

Fill Value 0

Units Unitless

Table 3. Spatial interpolation flag values. A grid cell that satisfies multiple criteria contains the sum of all applicable flag values.

Condition	Flag Value	Label in NetCDF Variable
19 GHz vertical brightness temperature spatially interpolated	1	19v_tb_value_interpolated
19 GHz horizontal brightness temperature spatially interpolated	2	19h_tb_value_interpolated

Condition	Flag Value	Label in NetCDF Variable
22 GHz vertical brightness temperature spatially interpolated	4	22v_tb_value_interpolated
37 GHz vertical brightness temperature spatially interpolated	8	37v_tb_value_interpolated
37 GHz horizontal brightness temperature spatially interpolated	16	37h_tb_value_interpolated
Pole hole spatially interpolated (Arctic only)	32	pole_hole_spatially_interpolated_(Arctic_only)

cdr_seaice_conc_interp_temporal_flag

Description Provides details on the CDR grid cells that were temporally interpolated. Temporal interpolation is performed on the sea ice concentrations. See the Sea Ice Concentration Temporal Interpolation section of the C-ATBD (Meier et al., 2024) for details. The flag value is a 1- or 2-digit number showing which sea ice concentration data points were used in the interpolation. For example:

- 24: Missing grid cell interpolated from data two days prior and four days in the future.
- 30: Missing grid cell filled with data from three days prior.
- 1: Missing grid cell filled with data from one day in the future.
- 0: No temporal interpolation applied.

Data Type Unsigned byte array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Yearly aggregated daily files have a time dimension of either 365 or 366, corresponding to the number of days in a year.

Valid Range 0 to 55

Fill Value 0

Units Unitless

cdr_seaice_conc_qa_flag

Description Quality flags for the daily NOAA/NSDIC CDR sea ice concentration (cdr_seaice_conc). See Table 4 for a list of the flags.

Note: Grid cells meeting multiple conditions will have a value equal to the sum individual condition values. For example, a grid cell where both the Bootstrap weather filter (BT_weather_filter_applied, value 1) and land spillover (Land_spillover_filter_applied, value 4) are applied will have a flag value of 5.

Data Type	Unsigned byte array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: The yearly aggregated daily files have a time dimension of either 365 or 366, corresponding to the number of days in a year.
Valid Range	Northern Hemisphere files: 0 to 255, Southern Hemisphere files: 0 to 127
Fill Value	0
Units	Unitless

Table 4. Daily QA Flag Values. A grid cell that satisfies multiple criteria will contain the sum of all applicable flag values.

Condition	Flag Value	Label in NetCDF Variable	Description
BT weather filter applied	1	BT_weather_filter_applied	Indicates that the Bootstrap weather filter was applied to this grid cell. This means that sea ice concentration was set to zero (open ocean).
NT weather filter applied	2	NT_weather_filter_applied	Indicates that the NT weather filter was applied to this grid cell. This means that sea ice concentration was set to zero (open ocean).
Land spillover applied	4	Land_spillover_filter_applied	Indicates that a land-spillover correction (either BT or NT2) was applied to this grid cell. This means that sea ice concentration was set to zero (open ocean).
No T_B input data available	8	No_input_data	Indicates that no input brightness temperature data was available for this grid cell.
Invalid ice mask applied	16	invalid_ice_mask_applied	Indicates that this grid cell has been designated as ocean (sea ice concentration set to zero) via an ocean mask or invalid ice mask.
Spatially interpolation applied	32	spatial_interpolation_applied	Indicates that this grid cell was spatially interpolated. For more information, see the cdr_seaice_conc_interp_spatial_flag variable.
Temporal interpolation applied	64	temporal_interpolation_applied	Indicates that this grid cell was temporally interpolated. For more information, see the cdr_seaice_conc_interp_temporal_flag variable.

Condition	Flag Value	Label in NetCDF Variable	Description
Start of Melt Detected (Northern Hemisphere files only)	128	melt_start_detected	Indicates that the ice in this grid cell has shown signs of melting, potentially reducing the reliability of sea ice concentration values. The melt onset test begins on day 60 of the year, approximately when sea ice extent reaches its annual maximum. Once a grid cell is flagged as melting, it retains this status throughout summer until day 244, around the time when extent reaches its minimum. The flag turns off when sea ice concentration drops to zero. For the exact date melting began, refer to the cdr_melt_onset_day variable.

cdr_seaice_conc_stdev

Description	Standard deviation for the daily NOAA/NSIDC CDR sea ice concentration. This value is the standard deviation of a given grid cell along with its eight surrounding grid cells (nine values total) from both the NASA Team and Bootstrap data. The standard deviation is therefore computed using a total of 18 values: nine from the raw NSIDC NASA Team data and nine from the raw NSIDC Bootstrap data. Grid cells with high standard deviations indicate values with lower confidence levels. See the C-ATBD (Meier et al., 2024) for details.
Data Type	Float array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Yearly aggregated daily files have a time dimension of either 365 or 366, corresponding to the number of days in a year.
Valid Range	0.0 to 1.0
Fill Value	-1.0
Units	Unitless

cdr_melt_onset_day

Description	Contains the day of year when melting sea ice was first detected for the sea ice CDR in each grid cell. It is located in the cdr_supplementary group. Once detected, this value remains constant for the rest of the melt season. For example, if a grid cell begins melting on day 73, the value for that cell will be 73 for that day and all subsequent days until the end of the melt season. The melt onset day is only calculated during the melt season: day of year 60 (March 1/February 29 for leap years) through 244 (September 1/August 31 for leap years), inclusive. At the start of the melt season, a value of 0 indicates sea ice

	concentration below 50%. Values of 60 to 244 (inclusive) indicate the day of year when melting on sea ice is detected, while 255 indicates no melt detected, including non-ocean grid cells. Before and after the melt season, the value is 255. Note that grid cells initially set to 0 at the melt season's start may develop ice later, which then melts due to advection or ice growth, and are assigned a melt date. Once set, a melt value remains unchanged. This variable applies to Northern Hemisphere files only.
Data Type	Unsigned byte array with dimensions [1, 448, 304] (North), representing time, y, and x, respectively. Note: Yearly aggregated daily files have a time dimension of either 365 or 366, corresponding to the number of days in a year.
Valid Range	0 to 255
Fill Value	N/A
Units	Unitless

latitude

Description	Latitude in degrees north of the projection grid centers. It is located in the cdr_supplementary group and appears only in the aggregated files.
Data Type	Double array with dimensions [448, 304] (North) and [332, 316] (South), representing y and x, respectively.
Valid Range	31.10 to 89.84 for northern hemisphere files, and -89.84 to -39.36 for southern hemisphere files.
Fill Value	NaN
Units	Degrees north

longitude

Description	Longitude in degrees east of the projection grid centers. It is located in the cdr_supplementary group and appears only in the aggregated files.
Data Type	Double array with dimensions [448, 304] (North) and [332, 316] (South), representing y and x, respectively.
Valid Range	-180.0 to 180.0
Fill Value	NaN
Units	Degrees east

raw_bt_seaice_conc

Description	NSIDC-processed Bootstrap daily sea ice concentrations from 25 October 1978 through the most recent processing. It is located in the cdr_supplementary group. These data values are raw BT concentrations, that is, no weather filters, land spillover corrections, or invalid ice masks have been applied. Note: While physically impossible, sea ice concentration values can exceed 100% due to the nature of the BT algorithm and brightness temperature data. For transparency, these values are left as is in the raw BT

	variable. However, all values over 100% are converted to 100% after they go through the CDR algorithm.
Data Type	Unsigned byte array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Yearly aggregated daily files have a time dimension of either 365 or 366, corresponding to the number of days in a year.
Valid Range	0 to 254. Note: Byte values are stored in the files from 0 to 254 but are presented by most, but not all, netCDF readers as values ranging from 0 to 2.54 because of a scaling factor attribute (scale_factor) for this variable of .01 that is applied by most netCDF readers.
Fill Value	255
Units	Unitless

raw_nt_seaice_conc

Description	NSIDC-processed NASA Team daily sea ice concentrations from 25 October 1978 through the most recent processing. It is located in the cdr_supplementary group. These data values are raw NT concentrations, that is, no weather filters, land spillover corrections, or invalid ice masks have been applied. Note: While physically impossible, sea ice concentration values can exceed 100% due to the nature of the NT algorithm and brightness temperature data. For transparency, these values are left as is in the raw NT variable. However, all values over 100% are converted to 100% after they go through the CDR algorithm.
Data Type	Unsigned byte array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Yearly aggregated daily files have a time dimension of either 365 or 366, corresponding to the number of days in a year.
Valid Range	0 to 254. Note: Byte values are stored in the files from 0 to 254 but are presented by most, but not all, netCDF readers as values ranging from 0 to 2.54 because of a scaling factor attribute (scale_factor) for this variable of .01 that is applied by most netCDF readers.
Fill Value	255
Units	Unitless

surface_type_mask

Description	This variable provides a mask for different Earth surface types. It is located in the cdr_supplementary group. The mask values are listed in Table 5.
Data Type	Unsigned byte array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Yearly aggregated

	daily files have a time dimension of either 365 or 366, corresponding to the number of days in a year.
Valid Range	50 to 250
Fill Value	N/A
Units	1

Table 5. Flag Values for Surface Mask Variable

Flag Name	Value
Ocean	50
Lakes	75
Pole hole	100
Coast	200
Land	250

crs

Description	Provides details about the polar stereo projection information for the data. See section 1.4.2 Projection and Grid Description for more information.
Data Type	Int
Valid Range	N/A
Fill Value	N/A
Units	Meters

am2_seaice_conc

Description	Prototype AMSR2 sea ice concentrations represent the fraction of ocean area covered by sea ice from 1 January 2013 through the most recent processing. It is located in the prototype_am2 group. This variable is computed from the NASA Team and Bootstrap processed sea ice concentrations using the CDR Algorithm. For a description of the algorithm used to merge these, see section 2.3.3 SIC CDR Algorithm.
Data Type	Unsigned byte array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Yearly aggregated daily files have a time dimension of either 365 or 366, corresponding to the number of days in a year.
Valid Range	0 to 100. Note: Byte values are stored in the files from 0 to 100 but are typically presented by netCDF readers as values ranging from 0 to 1 due to a scaling factor attribute (scale_factor) of .01.
Fill Value	255
Units	Unitless

am2_seaice_conc_interp_spatial_flag

Description	Provides details on the AMSR2 grid cells that were spatially interpolated. Spatial interpolation occurs on the brightness temperature channels. It is located in the prototype_am2 group. See Table 3 for a list of the flag values and the C-ATBD (Meier et al., 2024) for details. Grid cells not spatially interpolated are assigned a value of zero.
Data Type	Unsigned byte array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Yearly aggregated daily files have a time dimension of either 365 or 366, corresponding to the number of days in a year.
Valid Range	0 to 63
Fill Value	0
Units	Unitless

am2_seaice_conc_interp_temporal_flag

Description	Provides details on the AMSR2 grid cells that were temporally interpolated. Temporal interpolation is performed on the sea ice concentrations. It is located in the prototype_am2 group. See the Sea Ice Concentration Temporal Interpolation section of the C-ATBD (Meier et al., 2024) for details. The flag value is a 1- or 2-digit number showing which sea ice concentration data points were used in the interpolation. For example: • 24: Missing grid cell interpolated from data two days prior and four days in the future. • 30: Missing grid cell filled with data from three days prior. • 1: Missing grid cell filled with data from one day in the future. • 0: No temporal interpolation applied.
Data Type	Unsigned byte array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Yearly aggregated daily files have a time dimension of either 365 or 366, corresponding to the number of days in a year.
Valid Range	0 to 55
Fill Value	0
Units	Unitless

am2_seaice_conc_qa_flag

Description	Quality flags for the daily prototype AMSR2 sea ice concentration (am2_seaice_conc). It is located in the prototype_am2 group. See Table 4 for a list of the flags. Note: Grid cells meeting multiple conditions will have a value equal to the sum individual condition values. For example, a grid cell where both the Bootstrap weather filter (BT_weather_filter_applied, value 1) and land spillover (Land_spillover_filter_applied, value 4) are applied will have a flag value of 5.

Data Type	Unsigned byte array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Yearly aggregated daily files have a time dimension of either 365 or 366, corresponding to the number of days in a year.
Valid Range	0 to 255
Fill Value	0
Units	Unitless

am2_seaice_conc_stdev

Description	Standard deviation for the daily prototype AMSR2 sea ice concentration. It is located in the prototype_am2 group. This value is the standard deviation of a given grid cell along with its eight surrounding grid cells (nine values total) from both the NASA Team and Bootstrap data. The standard deviation is therefore computed using a total of 18 values: nine from the raw NSIDC NASA Team data and nine from the raw NSIDC Bootstrap data. Grid cells with high standard deviations indicate values with lower confidence levels. See the C-ATBD (Meier et al., 2024) for details.
Data Type	Float array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Yearly aggregated daily files have a time dimension of either 365 or 366, corresponding to the number of days in a year.
Valid Range	0.0 to 1.0
Fill Value	-1.0
Units	Unitless

time

Description	Time in days since 1970-01-01 00:00:00.
Data Type	Long with a dimension of 1. Note: The yearly aggregated daily files will have a time dimension of either 365 or 366 for the number of days in a year.
Valid Range	N/A
Fill Value	N/A
Units	Days since 1979-01-01 00:00:00

x

Description	X-offset in meters of the projection grid centers.
Data Type	Double array with dimension [304] (North) and [316] (South)
Valid Range	-3850000.0 to 3750000.0 (North) and -3950000.0 to 3950000.0 (South)
Fill Value	NaN
Units	Meters

y

Description	Y-offset in meters of the projection grid centers.
Data Type	Double array with dimension [448] (North) and [332] (South)
Valid Range	-5350000.0 to 5850000.0 (North) and -3950000.0 to 4350000.0 (South)
Fill Value	NaN
Units	Meters

1.3.4.2 Monthly File Variable Description

The monthly netCDF4 files contain variables and groups shown in Figure 1 (right) and listed in Table 6 along with brief descriptions. The sections below this table provide more detailed information.

Table 6. List of Monthly Variables

Variable Name	Brief Description
cdr_seaice_conc_monthly	NOAA/NSIDC monthly sea ice concentration CDR.
cdr_seaice_conc_monthly_qa	Quality flags for the cdr_seaice_conc_monthly variable.
cdr_seaice_conc_monthly_stdev	Standard deviation of monthly NOAA/NSIDC CDR sea ice concentration (cdr_seaice_conc_monthly).
cdr_melt_onset_day_monthly	Day of year when melting sea ice was first detected in each grid cell for the monthly NOAA/NSIDC CDR (applies to the Northern Hemisphere only). Located in the cdr_supplementary group.
latitude	Latitude in degrees north of the projection grid centers (aggregated files only). Located in the cdr_supplementary group.
longitude	Longitude in degrees east of the projection grid centers (aggregated files only). Located in the cdr_supplementary group.
surface_type_mask	Provides a mask of different Earth surface types. Located in the cdr_supplementary group.
crs	Projection information for the data
am2_seaice_conc_monthly	Prototype monthly sea ice concentration from the AMSR2 instrument. Present only in data files from 2013 onward. Located in the prototype_am2 group.
am2_seaice_conc_monthly_qa	Quality flags for the am2_seaice_conc_monthly variable. Present only in data files from 2013 onward. Located in the prototype_am2 group.

Variable Name	Brief Description
am2_seaice_conc_monthly_stdev	Standard deviation of the monthly AMSR2 sea ice concentration (am2_seaice_conc_monthly variable). Present only in data files from 2013 onward. Located in the prototype_am2 group.
time	Date of the data (days since 1970-01-01).
x	Projection grid x centers in meters.
y	Projection grid y centers in meters.

cdr_seaice_conc_monthly

Description	Monthly average of daily NSIDC-produced CDR sea ice concentrations (`cdr_seaice_conc`). For a description of the algorithm used to create these, see section 2.3.3 SIC CDR Algorithm.
Data Type	Byte array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Period-of-record aggregated monthly files have a time dimension spanning from November 1978 through the most recent processing, measured in months.
Valid Range	0 to 100. Note: Byte values are stored in the files from 0 to 100 but are typically presented by netCDF readers as values ranging from 0 to 1 due to a scaling factor attribute (scale_factor) of .01.
Fill Value	255
Units	Unitless

cdr_seaice_conc_monthly_qa

Description	Quality flags for the monthly NSIDC CDR sea ice concentration variable (`cdr_seaice_conc_monthly`). See Table 7 for a list of the monthly QA flags. Note: Grid cells meeting multiple conditions will have a value equal to the sum of the individual condition values. For example, if both spatial interpolation was performed and melt detection occurred then the value will be 160 (32 + 128).
Data Type	Byte array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Period-of-record aggregated monthly files have a time dimension spanning from November 1978 through the most recent processing, measured in months.
Valid Range	0 to 127
Fill Value	0
Units	Unitless

The QA flags listed in Table 7 include the following conditions:

- Average concentration exceeds 15%, which is commonly used to define the ice edge and can be used to easily quantify the total extent.
- Average concentration exceeds 30%, which is a commonly used alternate ice edge definition. It may be desired to remove lower concentration ice that tends to have higher errors.
- At least half the days have a concentration greater than 15%. This provides a monthly median extent, which may be a better representation of the monthly ice presence because an average conflates the spatial and temporal variation through the month.
- At least half the days have a concentration greater than 30%. This also provides a monthly median extent, but this higher percentage may leave out questionable or erroneous ice.
- A cell was masked by the invalid ice mask.
- Spatial or temporal interpolation was performed.
- Melt was detected during the month. Since melt tends to bias concentrations lower, this flag gives a sense of whether melt has any effect on the monthly concentration estimate and whether it is having a dominating effect.

Table 7. Monthly QA Flag Values. A grid cell that satisfies more than one criteria will contain the sum of all applicable flag values.

Condition	Flag Value	Label in NetCDF Variable
Average concentration exceeds 15%	1	average_concentration_exceeds_0.15
Average concentration exceeds 30%	2	average_concentration_exceeds_0.30
At least half the days have sea ice conc > 15%	4	at_least_half_the_days_have_sea_ice_conc_exceeds_0.15
At least half the days have sea ice conc > 30%	8	at_least_half_the_days_have_sea_ice_conc_exceeds_0.30
Invalid ice mask applied	16	invalid_ice_mask_applied
At least one day during month has spatial interpolation	32	at_least_one_day_during_month_has_spatial_interpolation
At least one day during month has temporal interpolation	64	at_least_one_day_during_month_has_temporal_interpolation
Melt detected (at least one day of melt occurred during the month >= 1) (Northern Hemisphere files only)	128	at_least_one_day_during_month_has_melt_detected

cdr_seaice_conc_monthly_stdev

Description	Standard deviation of the monthly NOAA/NSIDC CDR sea ice concentration variable (`cdr_seaice_conc_monthly`), calculated from all daily values for the month at each grid cell.
Data Type	Float array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Period-of-record aggregated monthly files have a time dimension spanning from November 1978 through the most recent processing, measured in months.
Valid Range	0.0 to 1.0
Fill Value	-1.0
Units	Unitless

cdr_melt_onset_day_monthly

Description	Contains the day of year when melting sea ice was first detected in each grid cell, taken from the last day of the month in daily files. Located in the cdr_supplementary group and applies to Northern Hemisphere files only. See the description of the daily cdr_melt_onset_day variable for more details on the values.
Data Type	Byte array with dimensions [1, 448, 304] (North), representing time, y, and x, respectively. Note: Period-of-record aggregated monthly files have a time dimension spanning from November 1978 through the most recent processing, measured in months.
Valid Range	0 to 255
Fill Value	255
Units	Unitless

latitude

Description	Latitude in degrees north of the projection grid centers. Present only in the aggregated files and located in the cdr_supplementary group.
Data Type	Double array with dimensions [448, 304] (North) and [332, 316] (South), representing y and x, respectively.
Valid Range	31.10 to 89.84 for northern hemisphere files, and -89.84 to -39.36 for southern hemisphere files.
Fill Value	NaN
Units	Degrees north

longitude

Description	Longitude in degrees east of the projection grid centers. Present only in the aggregated files and located in the cdr_supplementary group.
Data Type	Double array with dimensions [448, 304] (North) and [332, 316] (South), representing y and x, respectively
Valid Range	-180.0 to 180.0
Fill Value	NaN
Units	Degrees east

surface_type_mask

Description	This variable provides a mask for different Earth surface types. Located in the cdr_supplementary group. The mask values are listed in Table 5.
Data Type	Byte array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Period-of-record aggregated monthly files have a time dimension spanning from November 1978 through the most recent processing, measured in months.
Valid Range	50 to 250
Fill Value	N/A
Units	1

crs

Description	Provides details about the polar stereo projection information for the data. See section 1.4.2 Projection and Grid Description for more information.
Data Type	Int
Valid Range	N/A
Fill Value	N/A
Units	Meters

am2_seaice_conc_monthly

Description	Monthly average of the daily prototype AMSR2 sea ice concentrations (`am2_seaice_conc`). For a description of the algorithm used to create these, see section 2.3.3 SIC CDR Algorithm.
Data Type	Byte array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Period-of-record aggregated monthly files have a time dimension spanning from November 1978 through the most recent processing, measured in months.
Valid Range	0 to 100. Note: Byte values are stored in the files from 0 to 100 but are typically presented by netCDF readers as values ranging from 0 to 1 due to a scaling factor attribute (scale_factor) of .01.

Fill Value	255
Units	Unitless

am2_seaice_conc_monthly_qa

Description	Quality flags for the monthly prototype AMSR2 sea ice concentration variable (`am2_seaice_conc_monthly`). See Table 7 for a list of the monthly QA flags. Note: Grid cells meeting multiple conditions will have a value equal to the sum of the individual condition values. For example, if both spatial interpolation was performed and melt detection occurred, then the value will be 160 (32 + 128).
Data Type	Byte array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Period-of-record aggregated monthly files have a time dimension spanning from November 1978 through the most recent processing, measured in months.
Valid Range	0 to 255
Fill Value	0
Units	Unitless

am2_seaice_conc_monthly_stdev

Description	Standard deviation of the monthly prototype AMSR2 sea ice concentration variable (`am2_seaice_conc_monthly`), calculated from all daily values for the month at each grid cell.
Data Type	Float array with dimensions [1, 448, 304] (North) and [1, 332, 316] (South), representing time, y, and x, respectively. Note: Period-of-record aggregated monthly files have a time dimension spanning from November 1978 through the most recent processing, measured in months.
Valid Range	0.0 to 1.0
Fill Value	-1.0
Units	Unitless

time

Description	Time in days since 1970-01-01 00:00:00.
Data Type	Long with a dimension of 1. Note: Period-of-record aggregated monthly files have a time dimension spanning from November 1978 through the most recent processing, measured in months.
Valid Range	N/A
Fill Value	N/A
Units	Days since 1970-01-01 00:00:00

x

Description	X-offset in meters of the projection grid centers.
Data Type	Double array with dimension [304] (North) and [316] (South)
Valid Range	-3850000.0 to 3750000.0 (North) and -3950000.0 to 3950000.0 (South)
Fill Value	N/A
Units	Meters

y

Description	Y-offset in meters of the projection grid centers.
Data Type	Double array with dimension [448] (North) and [332] (South)
Valid Range	-5350000.0 to 5850000.0 (North) and -3950000.0 to 4350000.0 (South)
Fill Value	N/A
Units	Meters

1.3.4.3 Ancillary Files

This data set is accompanied by four ancillary files – two for the Northern Hemisphere and two for the Southern Hemisphere. These comprise the CDR V5 ancillary files and the SMMR invalid ice files, which are described below. These ancillary files are located in the data archive at https://noaadata.apps.nsidc.org/NOAA/G02202_V5/ancillary/.

CDR V5 Ancillary Files

Two CDR V5 ancillary files (one per hemisphere) contain the land mask, latitude, longitude, land adjacency mask, pole hole masks, and invalid ice masks used in processing the sea ice CDR: G02202-ancillary-psn25-v05r00.nc and G02202-ancillary-pss25-v05r00.nc. Table 8 describes the contents of these files.

Table 8. CDR V5 Ancillary Files Content Description

Variable	Description
adj123	Land adjacency mask indicating an ocean pixel's distance from land. 0: Not near land (>3 grid cells) 1: One grid cell from land 2: Two grid cells from land 3: Three grid cells from land
crs	Coordinate reference system description of the polar stereographic projection.

Variable	Description
invalid_ice_mask	Twelve monthly masks denoting areas that should or should not contain sea ice based on climatological analyses of seasonal sea ice locations. Used in combination with the month variable to differentiate the monthly masks. 0: Valid seaice location 1: Invalid seaice location
l90c	Mask defining the coast (land adjacent to water) as 90% sea ice concentration, used in NT2 land spillover correction calculations.
latitude	Latitude of each grid cell in degrees north.
longitude	Longitude of each grid cell in degrees east.
month	The 12 months of the year, used with invalid_ice_mask to differentiate monthly masks.
polehole_bitmask (Northern Hemisphere file only)	Bitmask indicating different pole hole sizes for each satellite/sensor used in the CDR. Used to mask out the northern hemisphere pole hole (an area of the earth that is not measured by the sensor due to the satellite orbit). Because this is a bitmask, the values are additive. For example, the AMSR2 pole hole is the smallest of the pole holes so it fits inside the others. Therefore, it's value is 127 which is the sum of all the bitmask values. The values for each bit are the following: 1: Nimbus 7 SMMR pole hole 2: DMSP F08 SSM/I pole hole 4: DMSP F11 SSM/I pole hole 8: DMSP F13 SSM/I pole hole 16: DMSP F17 SSMIS pole hole 32: Aqua AMSR-E pole hole (not used in this product) 64: GCOM-W1 AMSR2 pole hole
surface_type	Land surface type mask: 50: ocean 75: lake 200: coast (land adjacent to ocean) 250: land
x	The x coordinate of the projection.
y	The y coordinate of the projection.

SMMR Daily Climatology Invalid Ice Masks

Two SMMR daily climatology invalid ice mask files contain a daily climatology ice mask denoting areas that should or should not contain sea ice for the SMMR era: G02202-ancillary-psn25-daily-invalid-ice.nc and G02202-ancillary-pss25-daily-invalid-ice.nc. These are day-of-year climatology invalid ice masks derived from the Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS data (NSIDC-0079). These are needed for the older SMMR era data to remove weather effects in the absence of the 22 GHz channel used for weather filtering in other sensors. Table 9 describes the contents of these files.

Table 9. SMMR Daily Climatology Ice Masks Contents

Variable	Description
crs	Coordinate reference system description of the polar stereographic projection.
doy	Day of year (including 366 for the leap year day)
invalid_ice_mask	Mask indicating where sea ice will not be found on this day based on climatology from NSIDC-0079. 0: Valid seaice location 1: Invalid seaice location
x	The x coordinate of the projection.
y	The y coordinate of the projection.

1.4 Spatial Information

1.4.1 Coverage and Resolution

These data cover both the Northern and Southern polar regions at a 25 km x 25 km grid cell size. Note: While resolution and grid cell size are often used interchangeably with regards to satellite data, there is an important distinction. Resolution refers more accurately to the instantaneous field of view (IFOV) of a particular sensor frequency. That is, resolution is the spot size on the ground that the sensor channel can resolve. The IFOV of some of the passive microwave channels used for processing can be as large as 70 km x 45 km. See Table 2 in the C-ATBD (Meier et al., 2024) for a complete list of IFOVs by channel and sensor.

Since these data are gridded onto a 25 x 25 km grid and the sensor's IFOV is coarser, the sensors obtain information from up to a 3 x 2 25 km grid cell (~75 km x 50 km) region, but place that signature into a single grid cell. This results in spatial "smearing" across several grid cells. Furthermore, because a simple drop-in-the-bucket gridding method is used, some grid cells do not coincide with the center of a sensor footprint and, thus, lack a directly assigned brightness temperature despite being partially covered by at least one footprint. Higher frequency channels have finer resolution, but because the sea ice concentration algorithms use data from the 19 GHz channel, the sea ice concentration estimate is affected by the makeup of the surface over an area considerably larger than the nominal 25 km resolution.

The spatial coordinates for the Northern and Southern polar region are the following:

Northern Hemisphere

Northernmost Latitude: 89.92° N
Southernmost Latitude: 31.04° N
Easternmost Longitude: 180° E
Westernmost Longitude: 180° W

Southern Hemisphere

Northernmost Latitude: 31.04° S
Southernmost Latitude: 89.92° S
Westernmost Longitude: 180° W
Easternmost Longitude: 180° E

Note that for the Arctic, there is a region around the pole that is not imaged by the passive microwave sensors. This area, called the Arctic Pole Hole, changes size over time depending on the instrument used. See Table 10 for these sizes.

This area is filled by spatial interpolation rather than missing values. However, one cannot assume the concentration value in the Arctic pole hole, especially in late Arctic summer and early autumn. NSIDC advises caution when using the interpolated data in long-term trends or climatology analyses. See the C-ATBD (Meier et al., 2024) for more details.

Table 10. Arctic Pole Hole Size by Instrument

Instrument	Pole Hole Area (million km^2)	Minimum Latitude
SMMR	1.193	84.12° N
SSM/I F08	0.318	86.72° N
SSM/I F11	0.318	86.72° N
SSM/I F13	0.318	86.72° N
SSMIS F17	0.0292	89.02° N
AMSR2	0.0286	89.07° N

1.4.2 Projection and Grid Description

The sea ice concentration data are displayed in a polar stereographic projection. For more information on this projection, see the NSIDC Polar Stereographic Projections and Grids Web page. Note that the polar stereographic grid is not equal area; the latitude of true scale (tangent of the planar grid) is 70 degrees. Geolocation and grid details are given in Table 11 and Table 12.

Table 11. Geolocation Details

Geographic coordinate system	Hughes 1980
Projected coordinate system	Northern Hemisphere: NSIDC Sea Ice Polar Stereographic North Southern Hemisphere: NSIDC Sea Ice Polar Stereographic South
Longitude of true origin	Northern Hemisphere: -45°

	Southern Hemisphere: 0°
Latitude of true origin	Northern Hemisphere: 70° Southern Hemisphere: -70°
Scale factor at longitude of true origin	1
Datum	Hughes 1980
Ellipsoid/spheroid	Hughes 1980
Units	meters
False easting	0°
False northing	0°
EPSG code	Northern Hemisphere: EPSG 3411 Southern Hemisphere: EPSG 3412
PROJ4 string	Northern Hemisphere: +proj=stere +lat_0=90 +lat_ts=70 +lon_0=-45 +k=1 +x_0=0 +y_0=0 +a=6378273 +b=6356889.449 +units=m +no_defs Southern Hemisphere: +proj=stere +lat_0=-90 +lat_ts=-70 +lon_0=0 +k=1 +x_0=0 +y_0=0 +a=6378273 +b=6356889.449 +units=m +no_defs

Table 12. Grid Details

Grid cell size	25 km x 25 km
Grid size (y, x pixel dimensions)	Northern Hemisphere: 448 x 304 Southern Hemisphere: 331 x 316
Geolocated lower left point in grid (km)	Northern Hemisphere: (-3850, -5350) Southern Hemisphere: (-3950, -3950)
Nominal gridded resolution	25 km
Grid rotation (degrees)	Northern Hemisphere: -45 Southern Hemisphere: 0
ulxmap – x-axis map coordinate of the center of the upper-left pixel (km)	Northern Hemisphere: -3,837.5 Southern Hemisphere: -3,937.5
ulymap – y-axis map coordinate of the center of the upper-left pixel (km)	Northern Hemisphere: 5,837.5 Southern Hemisphere: 4,337.5

1.5 Temporal Coverage and Resolution

The CDR sea ice concentrations (`cdr_seaice_conc` and `cdr_seaice_conc_monthly`) span 25 October 1978 through the most recent processing, provided at both daily and a monthly averaged resolutions. For the monthly averaged data, at least 20 days (10 for SMMR) of data must be available for a month to calculate an average. Table 13 lists the dates that each passive microwave instrument acquired data. A gap in the data exists from 03 December 1987 through 12 January 1988 due to satellite issues, resulting in no daily or monthly data for that period. Additional gaps due to corrupt or missing data are noted in Table 14. While data files exist for these dates, they are filled with a fill value. In addition, dates with partially missing data are listed in Table 15 for reference. These partial data gaps could cause issues in time-series analyses, as they are missing large areas of data that may make calculations of sea ice extent appear artificially low. Most of these data gaps occurred during the SMMR era, which experienced operational issues. See NSIDC Special Report 20 (Windnagel et al., 2021) for details on these corrupt and missing data.

Table 13. Time Period Each Instrument is Used in the CDR. See Table 13 for a list of missing dates.

Platform and Instrument	Time Period
Nimbus-7 SMMR	25 October 1978 – 09 July 1987
DMSP-F8 SSM/I	10 July 1987 - 02 December 1991 Note: There are no data from 3 December 1987 through 13 January 1988 due to satellite problems.
DMSP-F11 SSM/I	03 December 1991 - 30 September 1995
DMSP-F13 SSM/I	01 October 1995 - 31 December 2007
DMSP-F17 SSMIS	01 January 2008 - most recent processing
AMSR2	01 January 2013 - most recent processing

Table 14. Daily and monthly dates with no data due to corrupt or missing data for the Arctic and Antarctic

Arctic	
Missing Daily	03 Jul 1984 - 04 Aug 1984 12 Aug 1984 - 24 Aug 1984 04 Dec 1986 - 10 Dec 1986 03 Dec 1987 - 13 Jan 1988 26 Dec 1990 - 27 Dec 1990
Missing Monthly	Jul 1984 Dec 1987 Jan 1988
Antarctic	
Missing Daily	12 Aug 1984 - 24 Aug 1984 05 Aug 1985 - 09 Aug 1985 04 Dec 1986 - 10 Dec 1986 03 Dec 1987 - 13 Jan 1988
Missing Monthly	Dec 1987 Jan 1988

Table 15. Dates of partial CDR fields due to corrupt or missing data for the Arctic and Antarctic. Note: Only dates where missing data affect sea ice concentration are noted here.

Arctic	
Partial Missing Daily	07 Jun 1979 - 17 Jun 1979 18 Mar 1986 - 11 Apr 1986
Antarctic	
Partial Missing Daily	31 Jul 1982 - 08 Aug 1982 25 Aug 1984 04 Aug 1985 30 Mar 1986 - 05 Apr 1986

2 DATA ACQUISITION AND PROCESSING

2.1 Input Data

The input data for the SIC CDR and AMSR2 prototype SIC variables are listed in Table 16. The dates that each sensor is used is listed in Table 13.

Table 16. Brightness Temperature Input Data

Sensor	**Input Data Set Name**	**Data Set Id**
SMMR	*Nimbus-7 SMMR Polar Gridded Radiances and Sea Ice Concentrations, Version 1*	NSIDC-0007
SSM/I and SSMIS	*DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures, Version 6*	NSIDC-0001
AMSR2	*AMSR-E/AMSR2 Unified L3 Daily 25 km Brightness Temperatures & Sea Ice Concentration Polar Grids, Version 1*	AU_SI25

2.2 Acquisition

The input gridded brightness temperatures used for creating the daily NOAA/NSIDC CDR sea ice concentrations (`cdr_seaice_conc`) are archived at NSIDC in two data sets listed in Table 15. For a complete description of input data processing, see the Data Acquisition and Processing sections in each data set user guide using the links in Table 15. The input data for the monthly CDR concentration (`cdr_seaice_conc_monthly`) are the daily sea ice concentration CDR data.

2.3 Derivation Techniques and Algorithms

2.3.1 Overview

NSIDC processes the input brightness temperatures (Table 16) into two intermediate sea ice concentrations using two GSFC-developed algorithms: the NASA Team (NT) algorithm (Cavalieri et al., 1984) and the Bootstrap (BT) algorithm (Comiso, 1986). These intermediate NSIDC NT and BT sea ice concentrations are used in the NOAA/NSIDC CDR algorithm described in further detail in the section 2.3.3 SIC CDR Algorithm.

The passive microwave channels employed for the sea ice concentration product are vertical (V) and horizontal (H) polarizations at 19 GHz (18.0 GHz for SMMR; 19.35 GHz for SSM/I and SSMIS; 18.7 GHz for AMSR2), vertical 22 GHz (22.2 GHz for SSM/I-SSMIS, 23.8 for AMSR2), and vertical and horizontal 37 GHz (37.0 for SMMR, SSM/I, and SSMIS, 36.5 for AMSR2). For simplicity, this document denotes the channels as 19 (V/H), 22V, and 37 (V/H). Table 17 lists the channels used for each algorithm and the channels used for the weather filters. For a complete description of the channels for each sensor and the weather filters, see the C-ATBD (Meier et al., 2024).

Table 17. NASA Team and Bootstrap Algorithm Channels

	NASA Team	**Bootstrap**
Algorithm Channels	19H, 19V, and 37V	37H, 37V, and 19V
Weather Filters	37V and 19V (SMMR, SSM/I, SSMIS) 22V and 19V (SSM/I, SSMIS)	37V and 19V (SMMR) 22V and 19V (SSM/I and SSMIS)

Since this data set uses multiple sensors over time, the sea ice algorithms are intercalibrated at the product (concentration) level. Thus, the brightness temperature source is less important because the intercalibration adjustment includes any necessary changes due to differences in brightness temperature across sensors. Both the NASA Team and Bootstrap algorithms employ varying tie-points to account for changes in sensors and spacecraft. These tie-point adjustments are derived from regressions of brightness temperatures during overlap periods. The adjustments are made at the product level by adjusting the algorithm coefficients to ensure the derived sea ice concentration fields are as consistent as possible.

The NASA Team approach uses sensor-specific hemispheric tie-points for each transition (Cavalieri et al., 1999; Cavalieri et al., 2011). Tie-points were originally derived for the SMMR sensor, and subsequent transitions to the different SSM/I and SSMIS instruments adjusted the tie-points to be consistent with the original SMMR record. The Bootstrap algorithm uses daily varying hemispheric tie-points, derived via analysis on clusters of brightness temperature values of the relevant channels (Comiso, 2009; Comiso and Nishio, 2008).

2.3.2 Automated Quality Control

Automated quality control measures are implemented on the NOAA/NSIDC SIC CDR. Two weather filters, based on ratios of channels sensitive to enhanced emission over open water, are used to filter weather effects. The Bootstrap and NASA Team 2 land-spillover corrections are used to filter out much of the error due to mixed land/ocean grid cells. Finally, to screen out errant retrievals of ice in regions where sea ice never occurs, invalid ice masks are applied to the Northern Hemisphere and climatological ocean masks are applied to the Southern Hemisphere. In addition, temporal and spatial gap filling have been implemented. For a complete description of the automated filters, masks, and gap filling, see the C-ATBD (Meier et al., 2024).

2.3.2.1 Temporal Gap Filling Notes

Data gaps can occur for various reasons including issues with the satellite, instrument, or ground stations collecting the data. Missing brightness temperature data can manifest as no data for a day or more, entirely missing swath orbits, a few scans from a swath, or a few grid cells. To address these gaps and enhance the temporal and spatial completeness of the sea ice concentration CDR record, we have employed a temporal gap-filling approach described below, along with guidelines for using the gap-filled data and an example of the method's effects.

Two methods of temporal gap filling are performed on the data: two-sided and one-sided. The two-sided method, attempted first, linearly interpolates missing data with weighted values from up to five days on either side of the missing date. These days do not have to be evenly spaced as the method searches for the closest available days to the missing date. For example, a missing grid cell can be interpolated from corresponding grid cells one day in the past and one day in the future if those data exist; or the method may search further into the past or future to find values for interpolation, such as two days in the past and four days in the future. Once past and future values are found, the method stops searching. The interpolation is weighted, with data closer to the missing date (e.g. 1 day away) given more weight than data further away (e.g. 5 days away). If data are unavailable within five days before or after a date, the one-sided method is applied. This simpler approach fills a missing grid cell with a copy of the data value from the closest corresponding grid cell from up to three days on either side of the date.

We chose five days for the two-sided interpolation and three days for the one-sided interpolation based on experience, though these choices were somewhat arbitrary. If neither method can be applied, the grid cell is marked as missing.

A flag called cdr_seaice_conc_interp_temporal_flag marks the grid cells that were temporally interpolated. This flag uses one- or two-digit numbers to indicate the known data points used in the interpolation. For two-sided gap filling, it is always a 2-digit number where the first digit indicates the number of days in the past, while the second digit indicates the number of days in the future from which the data point came from, with a maximum of five days in either direction. For example, a flag value of 24 indicates that the missing grid cell was linearly interpolated using sea ice concentration data from two days prior and four days in the future. In the two-sided method, the flag values range from 11 to 55 but exclude 10, 20, and 30. For the one-sided gap filing, where only one day is used, the value can be one or two digits with possible values of 1, 2, 3, 10, 20, and 30. Two-digit values indicate that data in the past were used, while single digit values indicate that data in the future were used. For example, a value of 30 indicates that data from three days in the past was copied.

Guidelines for Using Temporally Interpolated Data

The cdr_seaice_conc_interp_temporal_flagis provided as a way for users to screen for temporally gap-filled data. While the interpolation aims to provide the most complete fields possible, users can decide how much (if any) interpolation they wish to use based on the flag values. Here are some guidelines to consider when using the temporally interpolated data:

- The farther away from the day in question (i.e., the longer time period one is interpolating across) the less reliable the estimate.
- An asymmetry in the interpolation can also make the estimate less reliable (e.g. using data from 1 day in the past and 3 days in the future). Sea ice tends to grow linearly, so symmetrically weighted interpolation (i.e., same size gap before and after) typically yields reasonably good results. However, asymmetric, or especially one-directional, interpolation is less reliable.
- Another aspect is what spatial scale one is looking at. If one is looking at total extent or area for the entire Arctic or Antarctic, there is less sensitivity to interpolation because effects will average out. But if one is looking at a smaller region, then the interpolation could produce some odd-looking results.

Temporal Interpolation Example

Below is one example of how temporal gap filling works, combining both the two-sided and one-sided methods.

An issue with the DMSP F17 satellite resulted in missing data for seven days from 19 March to 25 March 2008, with 26 March 2008 also missing some data. The code attempts to fill this gap using temporal interpolation. Since this gap exceeds five days, a combination of two-sided and one-sided interpolation is applied. As noted above, the cdr_seaice_conc_interp_temporal_flag variable keeps track of the grid cells that were interpolated and is filled with a value depending on the type of interpolation. The following breakdown and Figure 3 describe the process for each day during this March 2008 gap:

- **March 18** has a full day of real data, so no interpolation is needed. The cdr_seaice_conc_interp_temporal_flag is set 0 for all grid cells.
- **March 19** is missing all data. There is no data within five days into the future but there is data within 3 days of the past (March 18). So, the one-sided gap filling technique is used and the grid cells for that day are a copy of March 18 data. The cdr_seaice_conc_interp_temporal_flag is set to 10 for all grid cells indicating that the missing grid cells were filled with a copy of the data from one day in the past.
- **March 20** is missing all data. There is no data within five days into the future but there is data within 3 days of the past (March 18). So, the one-sided gap filling technique is used and the grid cells for that day are also a copy of March 18 data. The cdr_seaice_conc_interp_temporal_flag is set to 20 for all grid cells indicating that the missing grid cells were filled with a copy of the data from two days in the past.
- **March 21** is missing all data. Most of the grid cells on that day have data within five days on either side, so they are gap filled using the two-sided method. They are linearly interpolated with data from 3 days in the past (March 18) and 5 days in the future (March 26). The cdr_seaice_conc_interp_temporal_flag is set to 35 for those grid cells. Due to 26 March missing some data, there are grid cells for March 21 that do not have any data within five days of either side, so they must be filled with the one-sided gap filling. The data for those grid cells are a copy of the data from March 18. The cdr_seaice_conc_interp_temporal_flag is set to 30 for those grid cells, indicating that the missing grid cells were filled with the data from three days in the past.
- **March 22** is missing all data. It does have data within five days on either side, so it is gap filled using the two-sided method. Most of the grid cells on that day have data 4 days on either side, so they are linearly interpolated with data from 4 days in the past (March 18) and 4 days in the future (March 26). The cdr_seaice_conc_interp_temporal_flag is set to 44 for those grid cells. Due to 26 March missing some data, there are a small number of grid cells that must be interpolated from 4 days in the past (March 18) and 5 days in the future (March 27). The cdr_seaice_conc_interp_temporal_flag is set to 45 for those grid cells.
- **March 23** is missing all data. It does have data within five days on either side, so it is gap filled using the two-sided method. Most of the grid cells on that day have data from 5 days in the past (March 18) and 3 days in the future (March 26), so they are linearly interpolated with data from those dates. The cdr_seaice_conc_interp_temporal_flag is set to 53 for those grid cells. Due to 26 March missing some data, there are a small number of grid cells that must be interpolated from 5 days in the past (March 18) and 4 days in the future (March 27). The cdr_seaice_conc_interp_temporal_flag is set to 54 for those grid cells.
- **March 24** is missing all data. There is no data within five days into the past but there is data within 3 days of the future (March 26 and March 27). So, the one-sided gap filling technique is used and the most of grid cells for that day are a copy of March 26 data, except where March 26 is missing data and then March 24 is a copy of March 27. The cdr_seaice_conc_interp_temporal_flag is set to 2 for all grid cells that were a copy of March 26 indicating that the missing grid cells were filled with a copy of the data from two days in the future. It is set to 3 for all grid cells that were a copy of March 27 indicating that the missing grid cells were filled with a copy of the data from three days in the future.
- **March 25** is missing all data. There is no data within five days into the past but there is data within 3 days of the future (March 26 and March 27). So, the one-sided gap filling technique is used and the most of grid cells for that day are a copy of March 26 data, except where March 26 is missing data and then March 24 is a copy of March 27. The

cdr_seaice_conc_interp_temporal_flag is set to 1 for all grid cells that were a copy of March 26 indicating that the missing grid cells were filled with a copy of the data from one day in the future. It is set to 2 for all grid cells that were a copy of March 27 indicating that the missing grid cells were filled with a copy of the data from two days in the future.

- **March 26** has some missing some data. There is no data within five days into the past but there is data within 3 days of the future (March 27). So, the one-sided gap filling technique is used. The small number of missing grid cells are filled with a copy of data from March 27. The cdr_seaice_conc_interp_temporal_flag is set to 1 for these grid cells indicating that the missing grid cells were filled with a copy of the data from one day in the future.
- **March 27** has a full day of real data, so no interpolation is needed. The cdr_seaice_conc_interp_temporal_flag is set 0 for all grid cells.

Note that there is a jump from March 20 to March 21 since March 20 is a copy of March 18, but March 21 is linearly interpolated from data on March 18 and March 26.

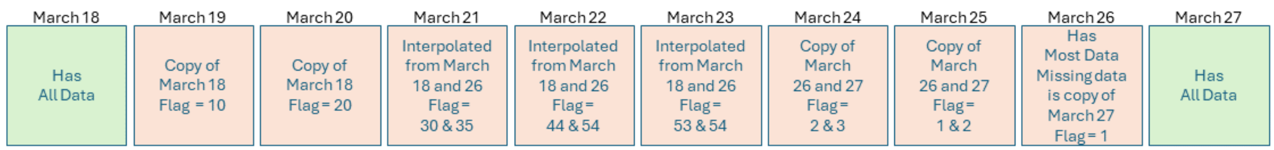

Figure 3. Temporal gap filling for the 7-day gap from 19 - 25 March 2008.

2.3.3 SIC CDR Algorithm

Various algorithms exist for computing sea ice concentration from brightness temperature data. Two widely used GSFC-developed algorithms – NASA Team (Cavalieri et al., 1984) and Bootstrap (Comiso, 1986) – are described in sections 2.3.4 and 2.3.5, respectively. Each algorithm has its own advantages and limitations. For this SIC CDR data set, NSIDC processes input brightness temperatures into two intermediate NASA Team and Bootstrap sea ice concentration fields following the way NASA produces their NASA Team and Bootstrap data sets with a few small differences. See the Theoretical Description section of the C-ATBD (Meier et al., 2021) for full details. The NASA-produced products are available from NSIDC as the *Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data* and the *Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS*.

The NASA Team-derived and Bootstrap-derived sea ice concentrations are then merged into a single ice concentration estimate. The SIC CDR algorithm steps are as follows:

- The Bootstrap algorithm's sea ice concentrations estimates are analyzed first. Any grid cell with a concentration estimate of 10% or greater is considered valid ice in the final product.
- For each grid cell that passes the Bootstrap threshold, the concentration values from both NASA Team and Bootstrap algorithms are compared; the higher value is selected as the CDR value.
- Any concentration values exceeding 100% are capped at 100%.

The resulting SIC CDR field has sea ice concentration values as low as 10% and as high as 100%.

Numerous studies, some noted below, have shown that passive microwave-based algorithms tend to underestimate true ice concentration. While both NASA Team and Bootstrap algorithms underestimate, the NASA Team algorithm does so to a greater extent. The basis of the SIC CDR algorithm is that when compared, the algorithm estimate that is the highest concentration for a given grid cell is likely to be the more accurate estimate. The Bootstrap algorithm runs first because it generally performs better at detecting ice in low concentration areas and where the ice is thin.

The NASA Team algorithm, using a ratio of brightness temperatures, tends to cancel out any physical temperature effects. In contrast, the Bootstrap algorithm uses relationships between two brightness temperatures that depend on physical temperature. Thus, physical temperature changes can affect Bootstrap estimates. Errors occur primarily in regimes with very low temperatures: winter in the high Arctic and near the Antarctic coast (Comiso et al., 1997), where the Bootstrap algorithm can underestimate concentration and give a lower value than the NASA Team algorithm. During winter conditions with more moderate temperatures, NASA Team concentrations also tend to have more of a low bias (Kwok, 2002; Meier, 2005). During melt conditions, both algorithms tend to underestimate concentration; with the effect more pronounced in the NASA Team algorithm (Comiso et al., 1997; Meier, 2005; Andersen et al., 2007).

While these algorithm characteristics are generally true, ice conditions and algorithm performance can vary from grid cell to grid cell. In some cases, this approach of choosing the larger value will result in an overestimation of concentration (Meier, 2005). However, using the higher concentration between the two algorithms tends to reduce the overall underestimation of the SIC CDR estimate (Meier et al., 2014). For a more in-depth discussion on the reasoning behind the algorithm, see the Theoretical Description section of the C-ATBD (Meier et al., 2021).

2.3.4 NASA Team Algorithm

The NASA Team algorithm uses brightness temperatures from the 19 GHz V, 19 GHz H, and 37 GHz V channels. The methodology is based on two brightness temperature ratios, the polarization ratio (PR) of the 19 GHz V and H channels (Equation 1) and the spectral gradient ratio (GR) of the 19 GHz V and 37 GHz V channels (Equation 2).

$PR(19) = [T_B(19V) - T_B(19H))]/[T_B(19V) + T_B(19H)]$ **(Equation 1)**

$GR(37V/19V) = [T_B(37V) - T_B(19V)]/[T_B(37V) + T_B(19V)]$ **(Equation 2)**

Where:

Table 18. NASA Team Algorithm Variable Descriptions

Variable	Description
PR(19)	Polarization ratio of the 19 GHz vertical and horizontal channels
$T_B(19V)$	Brightness temperature at the 19 GHz vertical channel
$T_B(19H)$	Brightness temperature at the 19 GHz horizontal channel
GR(37V/19V)	Gradient ratio of the 37 GHz vertical channel and the 19 GHz vertical channel
$T_B(37V)$	Brightness temperature at the 37 GHz vertical channel

For a detailed description of the NASA Team algorithm, see the NASA Team Algorithm section of the C-ATBD (Meier et al., 2024). Further details are also available in the Descriptions of and Differences Between the NASA Team and Bootstrap Algorithms FAQ and the NASA Technical Memorandum 104647 (Cavalieri et al., 1997).

2.3.5 Bootstrap Algorithm

Like the NASA Team algorithm, the Bootstrap algorithm is empirically derived based on brightness temperatures relationships at different channels. It uses two combinations: 37 GHz H versus 37 GHz V and 19 GHz V versus 37 GHz V. The Bootstrap method uses the fact that scatter plots of different sets of channels show distinct clusters corresponding to two pure surface types: 100 percent sea ice or open water. This is described by Equation 3.

$$C = (T_B - T_O)/(T_I - T_O) \quad \textbf{(Equation 3)}$$

Where:

Table 19. Bootstrap Algorithm Variable Descriptions

Variable	Description
C	Sea ice concentration
T_B	Observed brightness temperature
T_O	Reference brightness temperatures for open water
T_I	Reference brightness temperatures for sea ice

For a detailed description of the Bootstrap algorithm, see the Bootstrap Algorithm section of the C-ATBD (Meier et al., 2024). Further details are also available in the Descriptions of and Differences Between the NASA Team and Bootstrap Algorithms FAQ.

2.4 Processing Steps

Below are the processing steps for both the daily and monthly data files. Figure 4 shows an overview. In addition, the source code is provided for transparency of the algorithm and processes used in creating the SIC CDR. You can access the code from the NOAA National Centers for Environmental Information (NCEI) Climate Data Record Program's Sea Ice Concentration CDR web page or from NSIDC's GitHub repository:

- seaice_ecdr: https://github.com/nsidc/seaice_ecdr
- pm_icecon: https://github.com/nsidc/pm_icecon
- pm_tb_data: https://github.com/nsidc/pm_tb_data

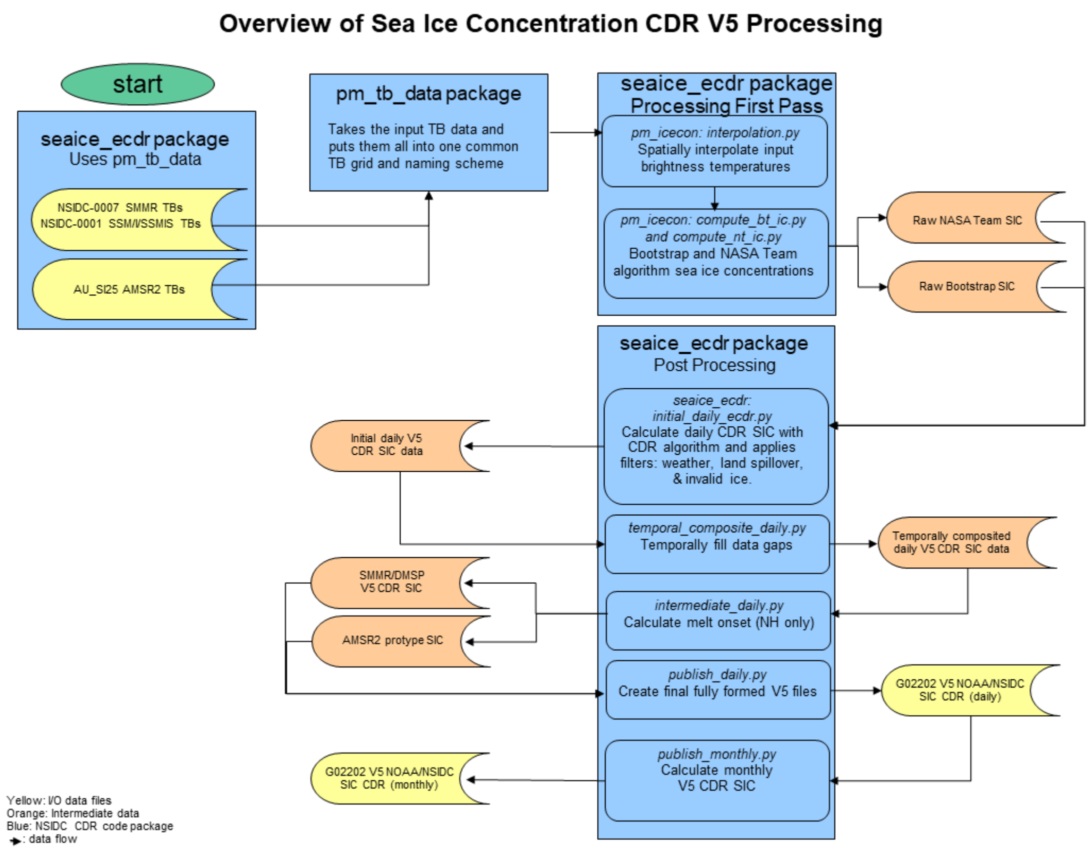

Figure 4. Overview of the Daily and Monthly CDR Processing

2.4.1 Daily Files

The following are the general steps NSIDC uses to produce the daily NOAA/NSIDC SIC CDR product. See Figures 2, 3, and 4 in the C-ATBD (Meier et al., 2024) for a high-level conceptual visualization of the daily data flow. Note that these steps below refer to the authoritative sea ice concentration CDR (cdr_seaice_conc). For the prototype AMSR2 sea ice concentration (am2_seaice_conc), all steps are the same except no melt onset is calculated for that variable.

1. Obtain input brightness temperature data from NSIDC. See Table 15 for a list of these input data sets, and Table 16 for a list of passive microwave channels used.
2. Consolidate the input brightness temperature data into one common brightness temperature grid and naming scheme.
3. Spatially interpolate each brightness temperature channel. Fill the `cdr_seaice_conc_interp_spatial_flag` variable. See the C-ATBD (Meier et al., 2024) for details on how the spatial interpolation is performed.
4. Process the brightness temperatures into two intermediate, raw sea ice concentration products using both the NASA Team and Bootstrap algorithms: `raw_nt_seaice_conc` and `raw_bt_seaice_conc`, respectively.
5. Merge the raw NASA Team and Bootstrap data into the CDR using the SIC CDR algorithm to create an initial CDR sea ice concentration. See section 2.3.3 SIC CDR Algorithm of this document for more information.
6. Apply weather filters, land-spillover corrections, and invalid ice masks.
7. Set initial QA flags (`cdr_seaice_conc_qa_flag`) based on the filters in step 6.
8. Temporally interpolate the CDR sea ice concentrations. See the C-ATBD (Meier et al., 2024) for details on how temporal interpolation is performed.
9. For the Arctic, spatially interpolate the pole hole. See the C-ATBD (Meier et al., 2024) for details on how this interpolation is performed.
10. Apply a day-of-year invalid climatology ice mask for the SMMR era to the sea ice concentration CDR.
11. Compute the CDR sea ice concentration standard deviation (`cdr_seaice_conc_stdev`) and the final QA flag values (`cdr_seaice_conc_qa_flag`).
12. Calculate melt onset (`cdr_melt_onset_day`) and add melt-indicator flag to the QA variable (`cdr_seaice_conc_qa_flag`) via a post-processing step.
13. Populate the daily netCDF variables with both the authoritative sea ice concentration CDR (`cdr_seaice_conc`) and the AMSR2 prototype sea ice concentration (`am2_seaice_conc`) and create the .nc files.

2.4.2 Monthly Files

The following are the general steps NSIDC uses to produce the monthly NOAA/NSIDC SIC CDR product. See Figure 5 in the C-ATBD (Meier et al., 2024) for a high-level conceptual visualization of the monthly data flow.

1. Read the input daily CDR sea ice concentration data (`cdr_seaice_conc`) and the prototype AMSR2 sea ice concentration (`am2_seaice_cdr`).
2. Compute the monthly mean concentration for each grid cell for a given month from the daily values. A minimum of 20 days (10 for SMMR) of data is required to create a monthly average.
3. Populate the `cdr_seaice_conc_monthly` and the `am2_seaice_conc_monthly` variable.
4. Compute the standard deviation and quality flags and fill those variables (`cdr_seaice_conc_monthly_stdev`, `cdr_seaice_conc_monthly_qa_flag`, `am2_seaice_conc_monthly_stdev`, `am2_seaice_conc_monthly_qa_flag`).
5. Set melt onset day (value from the last day of the month), fill the `cdr_melt_onset_day_monthly` variable, and add melt onset flag to the

`cdr_seaice_conc_monthly_qa_flag` variable. This applies to the Northern Hemisphere sea ice CDR only.

6. Write to the .nc files.

2.5 Error Sources

Several studies over the years have assessed ice concentration estimates from the NASA Team and Bootstrap algorithms. These assessments typically use coincident airborne or satellite remote sensing data from optical, thermal, or radar sensors, generally at a higher spatial resolution than the SSM/I and SSMIS instruments but with only local or regional coverage. Several assessments, including those using AMSR sensors, indicate an accuracy of approximately 5% during mid-winter conditions away from the coast and ice edge (Steffen et al., 1992; Gloersen et al., 1993; Comiso et al., 1997; Meier et al., 2005; Andersen et al., 2007; Belchansky and Douglas, 2002; Meier et al., 2017; Kern et al., 2019). Other assessments suggest concentration estimates are less accurate. Kwok (2002) found that passive microwave overestimates open water by three to five times in winter. Partington et al. (2003) conducted a study with the SSM/I instruments and found a difference with operational charts that was relatively low in winter but rose to more than 20% in summer. A more recent study by Kern et al. (2020) compared AMSR sensors with MODIS and found similar results. For further details of error sources and assessments, see the C-ATBD (Meier et al., 2024).

2.6 Instrumentation

For the NOAA/NSIDC CDR data, NSIDC uses brightness temperatures from the SMMR sensor on Nimbus-7 satellite, SSM/I sensors on the DMSP-F8, -F11, and -F13 platforms, and the SSMIS sensor on DMSP-F17. For the prototype AMSR2 sea ice concentrations, NSIDC uses brightness temperatures from the AMSR2 sensor on GCOM-W1. The rationale for using only these satellites was to maintain consistent equatorial crossing times, minimizing potential diurnal effects of data from sun-synchronous orbits. For a description of orbital parameters of the different satellites, see Table 1 in the C-ATBD (Meier et al., 2024). For a list of the footprint size of each sensor by channel, see Table 2 in the C-ATBD (Meier et al., 2024).

3 VERSION HISTORY

Table 20. Version History

Version	Release Date	Description of Changes
v05r00	December 2024	Release of Version 5 Revision 0 For a complete description of these changes see NSIDC Special Report 26 (Windnagel et al., 2024). • Added a prototype AMSR2 sea ice concentration. • Using the NASA Team 2 land spillover correction instead of the original NASA Team corrections. • Improved the Arctic pole hole filling. • Implemented a new land mask • The concentration variable (cdr_seaice_conc) has concentration values only (no land mask) • Added a separate surface type variable (surface_type_mask) • Improved spatial interpolation of TBs • Raw NT (raw_nt_sesaice_conc) and BT (raw_bt_seaice_conc) will keep full range of values instead of being clipped at 100% for provenance and transparency. • Updated the layout and names of variables. Added netCDF groups to improve organization. • Clip CDR values below 10%. • Fixed a bug in the way the BT tie points were being calculated. • Fixed a bug in the way the one-sided temporal interpolation was being calculated.

v04r00	June 2021	Release of Version 4 Revision 0
		• Added SMMR data to the period of record so that the daily Climate Data Record (CDR) sea ice variable now spans 25 October 1978 through to the most recent processing, and the monthly CDR variable will span from November 1978 through to the most recent processing.
		• Added NSIDC-produced daily and monthly NASA Team (NT) and NASA Bootstrap (BT) variables:
		  ○ nsidc_nt_seaice_conc
		  ○ nsidc_bt_seaice_conc
		  ○ nsidc_nt_seaice_conc_monthly
		  ○ nsidc_bt_seaice_conc_monthly.
		• Gap filling implemented using spatial and temporal interpolation. Two new flag variables (spatial_interpolation_flag and temporal_interpolation_flag) indicate when interpolation has been done.
		• Arctic pole hole filled by spatial interpolation.
		• NSIDC's BT algorithm has been updated to use Goddard's BT version 3.1 algorithm, the current version for the BT product.
		• Updated the NASA Team GR3719 weather filter threshold from 0.053 to 0.057 for the Southern Hemisphere F17 and F18 SSMIS instruments and updated it from 0.07 to 0.076 for the Southern Hemisphere SMMR instrument.
		• In CDR V4, both the NT and BT weather and land spillover filters were applied where as in V3, only the BT filters were applied.
		• The following variables have been renamed:
		  ○ seaice_conc_cdr → cdr_seaice_conc
		  ○ melt_onset_day_seaice_conc_cdr → melt_onset_day_cdr_seaice_conc
		  ○ stdev_of_seaice_conc_cdr → stdev_of_cdr_seaice_conc
		  ○ qa_of_seaice_conc_cdr → qa_of_cdr_seaice_conc
		  ○ seaice_conc_monthly_cdr → cdr_seaice_conc_monthly
		  ○ melt_onset_day_cdr_seaice_conc_monthly → melt_onset_day_cdr_seaice_conc_monthly
		  ○ stdev_of_seaice_conc_monthly_cdr → stdev_of_cdr_seaice_conc_monthly
		  ○ qa_of_seaice_conc_monthly_cdr → qa_of_cdr_seaice_conc_monthly
		• Removed the following Goddard-produced variables:
		  ○ goddard_merged_seaice_conc
		  ○ goddard_nt_seaice_conc
		  ○ goddard_bt_seaice_conc

Version	Release Date	Description of Changes
		○ goddard_merged_seaice_conc_monthly ○ goddard_nt_seaice_conc_monthly ○ goddard_bt_seaice_conc_monthly • In addition to the individual daily and monthly netCDF files, yearly aggregated files containing daily data and period-of-record aggregated files containing monthly data are available for download. • Land masks merged into one composite land mask.
v03r01	October 2018	The data have been processed through 31 December 2017. The input data to the Goddard BT variables have been versioned up from v3.0 to v3.1 for 2017 data onward. This change does not affect the sea ice concentration CDR data variables.
v03r01	December 2017	Release of Version 3 Revision 1 Incorporated a new version of the input data product, Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS, Version 3. With this new version of the Bootstrap data, the data providers made some modifications to the Bootstrap algorithm. See the Bootstrap documentation for a description of these modifications. Note that the sea ice CDR product has not been updated to incorporate these modification, so the Bootstrap algorithm used to produce the CDR and the one used to produce the Bootstrap data product are currently inconsistent. NSIDC will be address this inconsistency in a future version of the CDR product. In addition, the Bootstrap data providers chose to remove a section of data from 02 December 1987 through 13 January 1988 that is of poor quality due to issues with the satellite during that time period. This time period had already been removed by the data providers of the NASA team data product, Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data. However, NSIDC had continued to provide data files for this time period because Bootstrap data were still being provided. Because the Bootstrap data providers have decided to remove this time period from their product, NSIDC has removed all daily and monthly data files for this time period for the sea ice CDR, as well, since there is no data for that time period. Further, the Bootstrap data providers also chose to change the start date of their data set from 26 October 1978 to 01 November 1978. Since there are no longer bootstrap data for October 1978, the sea ice CDR data set now also begins 01 November 1978. Fixed a bug in the code that was causing some sections of the time series to not produce output files. The data have been processed through 28 February 2017. Updated the data that use the SSMIS instrument (01 January 2008 to present) to also use the SSMIS pole hole mask. In previous versions, the larger SSM/I pole hole mask was being used for these data, which was cutting out a section of valid data.
v03r00	August 2017	Release of Version 3 Revision 0 The mask to remove spurious ice was updated for the Northern Hemisphere from the NH climatology ocean masks to the Polar Stereographic Valid Ice Masks Derived from National Ice Center Monthly Sea Ice Climatologies.
v02r00	August 2015	The production code was refactored and modularized to improve its internal structure, however, the data were not changed or affected by this update to the code. Data from 1978 through 2013 were processed with the non-modularized version of the code, and 2014 data were processed with the new modularized code.

Version	Release Date	Description of Changes
v02r00	June 2013	Release of Version 2 Two new variables were added to the data set netCDF4 files: • `melt_onset_day_seaice_conc_cdr` • `melt_onset_day_seaice_conc_monthly_cdr` Calculation of `melt_start_detected` flag in the `qa_of_seaice_conc_cdr` variable was updated.
v01r00	September 2011	Initial release of sea ice CDR.

4 RELATED DATA SETS

- *NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 4*
- *Near-real-time NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 2*
- *DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures*
- *Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data*
- *Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I*
- *Multi-sensor Analyzed Sea Ice Extent (MASIE)*
- *Sea Ice Index*
- *Gridded Monthly Sea Ice Extent and Concentration, 1850 Onward*
- *AMSR-E/AMSR2 Unified L3 Daily 25 km Brightness Temperatures & Sea Ice Concentration Polar Grids*

5 RELATED WEBSITES

- NOAA's National Climatic Data Center (NCDC) Climate Data Record (CDR) program
- EUMETSAT Ocean & Sea Ice Satellite Application Facility
- Sea Ice Concentration: NOAA/NSIDC Climate Data Record: Provides an overview of the data product's strengths and weaknesses (Meier and NCAR, 2014).

6 CONTACTS AND ACKNOWLEDGMENTS

Walt Meier, CDR algorithm author

Florence Fetterer, PI, Sea Ice Concentration TCDR (01B-11) and ICDR (01B-11A)

Ann Windnagel, data manager

National Snow and Ice Data Center (NSIDC)

Boulder, Colorado USA

6.1 Acknowledgments

The development of this product was supported by the NOAA NCEI Climate Data Record Program, under a CIRES Cooperative Agreement with NOAA, grant number NA17OAR4320101. Production of original NASA Team and Bootstrap algorithm estimates was supported by the NASA Polar Distributed Active Archive Center. The sea ice concentration algorithms were developed by Donald J. Cavalieri, Josefino C. Comiso, Claire L. Parkinson, and others at the NASA Goddard Space Flight Center in Greenbelt, Maryland, USA.

7 REFERENCES

Andersen, S., Tonboe, R., Kaleschke, L., Heygster, G., and Pedersen, L. T. (2007). Intercomparison of Passive Microwave Sea Ice Concentration Retrievals over the High-Concentration Arctic Sea Ice. *J. Geophys. Res.*, 112(C08004). doi: 10.1029/2006JC003543.

Belchansky, G. I., and D. C. Douglas. (2002). Seasonal Comparisons of Sea Ice Concentration Estimates Derived from SSM/I, OKEAN, and RADARSAT Data. *Rem. Sens. Environ.*, 81: 67-81.

Carsey, F. D. (Ed.). (1992). Microwave Remote Sensing of Sea Ice. *American Geophysical Union*, 462 pp.

Cavalieri, D., C. Parkinson, N. DiGirolamo, A. Ivanov (2011). Intersensor calibration between F13 SSM/I and F17 SSMIS for global sea ice data records. *IEEE Geosci. Remote Sens. Lett*., 9(2), 233-236, doi:10.1109/LGRS.2011.2166754.

Cavalieri, D., C. Parkinson, P. Gloersen, J. Comiso, and H. J. Zwally (1999). Deriving Long-term Time Series of Sea Ice Cover from Satellite Passive-microwave Multisensor Data Sets. *J. of Geophys. Res.*, 104(C7):15,803-15,814.

Cavalieri, D. J., C. L. Parkinson. (1997). Arctic and Antarctic Sea Ice Concentrations from Multichannel Passive-Microwave Satellite Data Sets: October 1978 - September 1995 - User's Guide. *NASA Technical Memorandum* 104647. NASA Goddard Space Flight Center, Greenbelt, Maryland.

Cavalieri, D. J., P. Gloersen, and W. J. Campbell. (1984). Determination of Sea Ice Parameters with the NIMBUS-7 SMMR. *J. Geophys. Res*., 89(D4): 5355-5369.

Comiso, J.C., R.A. Gersten, L.V. Stock, J. Turner, G.J. Perez, and K. Cho. (2017). Positive Trend in the Antarctic Sea Ice Cover and Associated Changes in Surface Temperature. *J. Climate*, 30, 2251–2267. doi: 10.1175/JCLI-D-16-0408.1.

Comiso, J. C. (2009). Enhanced Sea Ice Concentrations and Ice Extents from AMSR-E Data. *J. Rem. Sens. of Japan,* 29(1):199-215.

Comiso, J. C., and F. Nishio. (2008). Trends in the Sea Ice Cover Using Enhanced and Compatible AMSR-E, SSM/I, and SMMR Data. *J. Geophys. Res.*, 113, C02S07. doi:10.1029/2007JC0043257.

Comiso, J. C., D. Cavalieri, C. Parkinson, and P. Gloersen. (1997). Passive Microwave Algorithms for Sea Ice Concentrations: A Comparison of Two Techniques. *Rem. Sens. of the Environ*., 60(3):357-384.

Comiso, J. C. 1986. Characteristics of Arctic Winter Sea Ice from Satellite Multispectral Microwave Observations. *J. Geophys. Res*., 91(C1): 975-994.

Fetterer, F., M. Dorfman, B. R. Brasher, and A. Windnagel. Edge of Antarctica: Two Differing Perspectives on Where Ice and Water Mix. Poster presented at: American Meteorological Society 101st Annual Meeting, 10-15 January 2021, virtual. Retrieved from https://ams.confex.com/ams/101ANNUAL/meetingapp.cgi/Paper/381502

Fetterer, F., and N. Untersteiner. (1998). Observations of Melt Ponds on Arctic Sea Ice. *J. Geophys. Res*., 103(C11): 24,821-24,835.

Ivanova, N., Pedersen, L. T., Tonboe, R. T., Kern, S., Heygster, G., Lavergne, T., Sørensen, A., Saldo, R., Dybkjær, G., Brucker, L., & Shokr, M. (2015). Inter-comparison and evaluation of sea ice algorithms: towards further identification of challenges and optimal approach using passive microwave observations. *The Cryosphere*, 9: 1797–1817. doi: 10.5194/tc-9-1797-2015.

Kern, S., Rösel, A., Pedersen, L. T., Ivanova, N., Saldo, R., & Tonboe, R. T. (2016). The impact of melt ponds on summertime microwave brightness temperatures and sea-ice concentrations. *The Cryosphere*, 10: 2217–2239. doi: 10.5194/tc-10-2217-2016.

Kern, S., Lavergne, T., Notz, D., Pedersen, L. T., Tonboe, R. T., Saldo, R., & Sørensen, A. M. (2019). Satellite passive microwave sea-ice concentration data set intercomparison: closed ice and ship-based observations. *The Cryosphere*, 13: 3261–3307. doi: 10.5194/tc-13-3261-2019.

Kern, S., Lavergne, T., Notz, D., Pedersen, L. T., & Tonboe, R. (2020). Satellite passive microwave sea-ice concentration data set inter-comparison for Arctic summer conditions. *The Cryosphere*, 14: 2469–2493. doi: 10.5194/tc-14-2469-2020.

Kwok, R. (2002). Sea Ice Concentration Estimates from Satellite Passive Microwave Radiometry and Openings from SAR Ice Motion. *Geophys. Res. Lett*., 29(9): 1311. doi:10.1029/2002GL014787.

Meier, W. N., Windnagel, A., & Stewart, S. (2024). Sea Ice Concentration - Climate Algorithm Theoretical Basis Document (C-ATBD), NOAA Climate Data Record Program CDRP-ATBD-0107, Rev. 11. NOAA NCEI CDR Program. https://nsidc.org/sites/default/files/documents/technical-reference/cdrp-atbd-rev11-sic-cdrv5-final.pdf.

Meier, W. N., Stewart, J. S., Windnagel, A., and Fetterer, F. M. (2022). Comparison of Hemispheric and Regional Sea Ice Extent and Area Trends from NOAA and NASA Passive Microwave-Derived Climate Records. *Remote Sens.* 14(3), 619. doi: https://doi.org/10.3390/rs14030619.

Meier, W.N., J.S. Stewart, Y. Liu, J. Key, and J. A. Miller. (2017). An operational implementation of sea ice concentration estimates from the AMSR2 sensor. *IEEE J. Sel. Topics Appl. Earth Obs. & Rem. Sens.* 10(9) doi: 10.1109/JSTARS.2017.2693120.

Meier, W. N., G. Peng, D. J. Scott, and M. H. Savoie. (2014). Verification of a new NOAA/NSIDC passive microwave sea-ice concentration climate record. *Polar Research* 33. doi: 10.3402/polar.v33.21004.

Meier, W. N. and the National Center for Atmospheric Research (NCAR) Staff (Eds). (2014). "The Climate Data Guide: Sea Ice Concentration: NOAA/NSIDC Climate Data Record." Retrieved 04 June 2015 from https://climatedataguide.ucar.edu/climate-data/sea-ice-concentration-noaansidc-climate-data-record.

Meier, W. N., and S. J. S. Khalsa. (2011). Intersensor Calibration between F13 SSM/I and F17 SSMIS Near-Real-Time Sea Ice Estimates. *Geoscience and Remote Sensing* 49(9): 3343-3349.

Meier, W. N. (2005). Comparison of Passive Microwave Ice Concentration Algorithm Retrievals with AVHRR Imagery in Arctic Peripheral Seas. IEEE Trans. *Geosci. Remote Sens*., 43(6): 1324-1337.

Partington, K., T. Flynn, D. Lamb, C. Bertoia, and K. Dedrick. (2003). Late Twentieth Century Northern Hemisphere Sea-Ice Record from U.S. National Ice Center Ice Charts. *J. Geophys. Res*. 108(C11): 3343. doi:10.1029/2002JC001623.

Peng, G., A. Arguez, W. N. Meier, F. Vamborg, J. Crouch, P. Jones. (2019). Sea Ice Climate Normals for Seasonal Ice Monitoring of Arctic and Sub-Regions. *Data* 4(3) 122. https://doi.org/10.3390/data4030122.

Peng, G., W. N. Meier, D. J. Scott, and M. H. Savoie. (2013). A long-term and reproducible passive microwave sea ice concentration data record for climate studies and monitoring. *Earth Syst. Sci. Data* 5: 311-318. doi: 10.5194/essd-5-311-2013.

Steffen, K., J. Key, D. J. Cavalieri, J. Comiso, P. Gloersen, K. St. Germain, and I. Rubinstein. (1992). The Estimation of Geophysical Parameters using Passive Microwave Algorithms, in "Microwave Remote Sensing of Sea Ice." F.D. Carsey, ed., American Geophysical Union Monograph 68, Washington, DC:201-231.

National Research Council of the National Academies. (2004). Climate Data Records from Environmental Satellites: Interim Report. National Academies Press, Washington, D.C., 150 pp.

Windnagel, A., Meier, W., Stewart, S., Fetterer, F., & Stafford, T. (2024). NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration Version 5 Updates. NSIDC Special Report 26. Boulder CO, USA: National Snow and Ice Data Center.

Windnagel, A., Meier, W., Stewart, S., Fetterer, F., & Stafford, T. (2021). NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration Version 4 Analysis. *NSIDC Special Report 20*. Boulder CO, USA: National Snow and Ice Data Center.

8 DOCUMENT INFORMATION

8.1 Author

Ann Windnagel
National Snow and Ice Data Center (NSIDC)
Boulder, CO USA

8.2 Publication Date

This guide was first published in July 2011, when CDR V1.0 was published. The current version was published December 2024.

8.3 Revision History

October 2024: A. Windnagel updated the document to reflect changes with the release of Version 5 Revision 0.
May 2021: A. Windnagel updated the document to reflect changes with the release of Version 4 Revision 0.
October 2018: A. Windnagel updated the version history section to note the release of the 2017 data and added a technical note about the Bootstrap data to the Input Data section.
December 2017: A. Windnagel updated the version history section to note the changes and

updates to Version 3 Revision 1.

August 2017: A. Windnagel updated the document to represent Version 3 Revision 0 changes and updates.

May 2016: A. Windnagel updated the document with the Variables at a Glance tables and made other minor edits.

August 2015: A. Windnagel updated the flow chart diagrams and the version history to reflect the new modularization done to the code.

June 2015: A. Windnagel added the Differences in the NOAA/NSIDC Concentration CDR Variables and the Merged GSFC-Produced Concentration Variables section to clarify which variable to use.

July 2014: A. Windnagel updated the temporal coverage to reflect the new 2013 data that was processed.

March 2013: A. Windnagel updated the document to describe the new Version 2 Revision 00 of these data. Added new processing flowcharts, new melt variable description, and updated the description of the melt detection QA flag. Also added that the temporal coverage now spans through 2012.

May 2012: A. Windnagel added the monthly file information and put the document into the new guide doc style.