NOAA/NSIDC Climate Data Record of Passive Microwave 12.5 km Sea Ice Concentration, Version 5

USER GUIDE

Beta Release

How to Cite These Data

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

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

National Snow and Ice Data Center

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1 DATA DESCRIPTION

Notice: This is a beta release of the SIC CDR Version 5 12.5 km product. The data set has not been thoroughly validated so there may be some inaccuracies, especially in the older portion of the record that uses the SMMR, SSM/I, and SSMIS sensors. Data from these sensors were regridded from their original 25 km grid size to the new 12.5 km grid to match the resolution of the AMSR series. Some discontinuities exist at the sensor transitions that still require adjustments and bias corrections. We encourage users to explore the product and provide feedback for any errors they may find to nsidc@nsidc.org.

NSIDC recommends continuing to use Version 4 (https://nsidc.org/data/g02202/versions/4) for analyses. If you decide to use Version 5, do so with caution until NSIDC has finished validating the product. Once validation is complete, the beta release designation will be removed. Any issues found will be fixed, and the data set will be formally released. If you would like to be notified when validation of Version 5 is complete and you are not already a registered user of the Version 4 product, you can subscribe to announcements by clicking the SUBSCRIBE button from the web site: https://nsidc.org/data/g02202.

1.1 Summary

This data set provides passive-microwave-derived sea ice concentration estimates 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 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. 10 (Meier et al., 2024).

The SIC CDR begins in 1978 with NASA Nimbus-7 SMMR instrument and, with the release of version 5, continues to the present with the GCOM-W1 AMSR2 instrument. For a complete list of the sensors used for this product see Section 2.1 Input Data. This data set goes through 2023.

Daily and monthly resolution sea ice concentration values are provided in NetCDF files organized in two ways: 1) one file for each day of the year and one file for each month of the year for each hemisphere and 2) daily data aggregated into yearly files and monthly data aggregated into one period-of-record file for each hemisphere. Each file has a variable for the concentration product, as well as variables containing standard deviation, quality flags, and projection information. With the release of version 5, the nominal grid resolution has been improved from a 25 km grid to a 12.5 km grid. Because of this improvement, version 5 is sometimes referred to as the enhanced CDR (ECDR) in this document.

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. Land areas are coded with a land mask value.

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 variables in both the daily and monthly NetCDF files are described in the sections 1.3.2.1 Daily File Variable Description and 1.3.2.2 Monthly File Variable Description, respectively.

1.3.2 File Contents

1.3.2.1 Daily File Variable Description

The daily netCDF4 files contain the variables listed in Table 1, which provides a brief description of each. The sections below this table provide more detailed information.

Table 1. List of Daily Variables

Variable Name	Brief Description
cdr_seaice_conc	NOAA/NSIDC daily sea Ice concentration CDR
crs	Projection information for the data
melt_onset_day_cdr_seaice_conc	The day of year on which melting sea ice was first detected in each grid cell for the daily NOAA/NSIDC CDR (applies to the Northern Hemisphere only)
qa_of_cdr_seaice_conc	Quality flags related to the cdr_seaice_conc variable
raw_bt_seaice_conc	NSIDC-processed Bootstrap daily sea ice concentrations
raw_nt_seaice_conc	NSIDC-processed NASA Team daily sea ice concentrations
spatial_interpolation_flag	Marks the grid cells that were spatially interpolated
stdev_of_cdr_seaice_conc	Standard deviation for the daily NOAA/NSIDC CDR sea ice concentration
surface_type_mask	Provides a mask of different Earth surface types
temporal_interpolation_flag	Marks the grid cells that were temporally interpolated
time	The date of the data (days since 1970-01-01)
x	The projection grid x centers in meters.
y	The projection grid y centers in meters.
latitude	Latitude in degrees north of the projection grid centers (aggregated files only)
longitude	Longitude in degrees east of the projection grid centers (aggregated files only)

cdr_seaice_conc

Description	NOAA/NSIDC CDR sea ice concentrations which is 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 processed sea ice concentrations 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 CDR Algorithm.
Data Type	Byte array with dimensions [608, 896, 1] (North) and [632, 664, 1] (South), which are the x, y, and time, respectively. 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	0 to 100. Note: Byte values are stored in the files from 0 to 100 but are presented by most, but not all, netCDF readers as values ranging from 0 to 1 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

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	String
Valid Range	N/A
Fill Value	N/A
Units	Meters

melt_onset_day_cdr_seaice_conc

Description	Contains the day of year on which melting sea ice was first detected in each grid cell. Once detected, the value is retained for the rest of the year. For example, if a grid cell started melting on day 73, the variable for the grid cell on that day will be 73, as will all subsequent days until the end of the year. The melt onset day is only calculated for the melt season: days 60 through 244, inclusive. Before melting is detected or if melt is never detected for that grid cell, the value will be 255. NOTE: This variable applies to Northern Hemisphere files only.
Data Type	Byte array with dimensions [608, 896, 1] (North), which are the x, y, and time, respectively. 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	60 to 244
Fill Value	255
Units	Unitless

qa_of_cdr_seaice_conc

Description	Different quality flags related to the daily NOAA/NSDIC CDR sea ice concentration. See Table 2 for a list of the flags. Note: Grid cells that meet multiple conditions will have a value that is the sum of the values of each individual condition. For example, where the Bootstrap weather filter (`BT_weather_filter_applied`) and NT2 land spillover (`land_spillover_filter_applied`) are applied, the flag value will be 5 (1 for BT weather plus 4 for NT2 land spillover).
Data Type	Byte array with dimensions [608, 896, 1] (North) and [632, 664, 1] (South), which are the x, y, and time, respectively. 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	0 to 255
Fill Value	0
Units	Unitless

Table 2. Daily QA 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).
NT2 land spillover applied	4	Land_spillover_filter_applied	Indicates that the NT2 land-spillover correction 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 there was no input brightness temperature available.
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.

Condition	Flag Value	Label in NetCDF Variable	Description
Spatially interpolation applied	32	spatial_interpolation_applied	Indicates that this grid cell was spatially interpolated. For more information, see the `spatial_interpolation_flag` variable.
Temporal interpolation applied	64	temporal_interpolation_applied	Indicates that this grid cell was temporally interpolated. For more information, see the `temporal_interpolation_flag` variable.
Start of Melt Detected (Arctic only)	128	melt_start_detected	Indicates that the ice in this grid cell has shown evidence of starting to melt, so values may be less reliable. The melt onset test is used starting on day of year 60, around the time when the maximum sea ice extent is reached each year. Once a grid cell is flagged as melting, it remains so through the rest of the summer until day of year 244, roughly the time when extent reaches its minimum value. When the sea ice concentration is zero, the flag will be turned off. For the specific date that melt started, see the `melt_onset_day_cdr_seaice_conc` variable.

raw_bt_seaice_conc

Description NSIDC-processed Bootstrap daily sea ice concentrations from 25 October 1978 through most recent processing. These data values are the raw BT concentrations, that is, no weather filters, land spillover corrections, or invalid ice masks have been applied.

Data Type Byte array with dimensions [608, 896, 1] (North) and [632, 664, 1] (South), which are the x, y, and time, respectively. 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 0 to 100. Note: Byte values are stored in the files from 0 to 100 but are presented by most, but not all, netCDF readers as values ranging from 0 to 1 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 most recent processing. These data values are the raw NT concentrations, that is, no weather filters, land spillover corrections, or invalid ice masks have been applied.
Data Type	Byte array with dimensions [608, 896, 1] (North) and [632, 664, 1] (South), which are the x, y, and time, respectively. 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	0 to 100. Note: Byte values are actually stored in the files from 0 to 100 but are presented by most, but not all, netCDF readers as values ranging from 0 to 1 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

spatial_interpolation_flag

Description	Provides details on the 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, then the value in this variable is set to zero for that grid cell.
Data Type	Byte array with dimensions [608, 896, 1] (North) and [632, 664, 1] (South), which are the x, y, and time, respectively. 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	0 to 63
Fill Value	0
Units	Unitless

Table 3. Spatial interpolation 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
19 GHz vertical brightness temperature spatially interpolated	1	19v_tb_value_interpolated
19 GHz horizontal brightness temperature spatially interpolated	2	19h_tb_value_interpolated
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_value_interpolated

stdev_of_cdr_seaice_conc

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 (for nine values total) from both the NASA Team and Bootstrap data. This means that the standard deviation is computed using a total of 18 values: nine from the intermediate NISDC NASA Team data and nine from the intermediate 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 [608, 896, 1] (North) and [632, 664, 1] (South), which are the x, y, and time, respectively. 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	0.0 to 1.0
Fill Value	-1.0
Units	1

surface_type_mask

Description This variable provides a mask for different Earth surface types. The mask values are listed in Table 4.

Data Type Byte array with dimensions [608, 896, 1] (North) and [632, 664, 1] (South), which are the x, y, and time, respectively. 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 50 to 250

Fill Value N/A

Units 1

Table 4. Flag Values for Surface Mask Variable

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

temporal_interpolation_flag

Description Provides details on the 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 value for each flag is a 1- or 2-digit number indicating the data points used in the interpolation. For example, if the flag value is 24, then the missing grid cell was interpolated from sea ice concentration data from a grid cell from two days prior and four days in the future. If the value is 30, then the missing grid cell was filled with the sea ice concentration value from three days prior. If the value is one, then the missing grid cell was filled with the sea ice concentration value from one day in the future. If a grid cell was not temporally interpolated, then the value in this variable is set to zero for that grid cell.

Data Type Byte array with dimensions [608, 896, 1] (North) and [632, 664, 1] (South), which are the x, y, and time, respectively. 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 0 to 55

Fill Value 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 [608] (North) and [632] (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 [896] (North) and [664] (South)
Valid Range	-5350000.0 to 5850000.0 (North) and -3950000.0 to 4350000.0 (South)
Fill Value	NaN
Units	Meters

latitude

Description	Latitude in degrees north of the projection grid centers. This variable is only in the aggregated files.
Data Type	Double array with dimensions [608, 896] (North) and [632, 664] (South)
Valid Range	0.0 to 90.0 for northern hemisphere files, and -90.0 to 0.0 for southern hemisphere files.
Fill Value	NaN
Units	Degrees north

longitude

Description	Longitude in degrees east of the projection grid centers. This variable is only in the aggregated files.
Data Type	Double array with dimensions [608, 896] (North) and [632, 664] (South)
Valid Range	-180.0 to 180.0
Fill Value	NaN
Units	Degrees east

1.3.2.2 Monthly File Variable Description

The monthly netCDF4 files contain the variables listed in Table 5, which provides a brief description of each. The sections below this table provide more detailed information.

Table 5. List of Monthly Variables

Variable Name	Brief Description
cdr_seaice_conc_monthly	NOAA/NSIDC monthly sea ice concentration CDR
crs	Projection information for the data
melt_onset_day_cdr_seaice_conc_monthly	The day of year on which melting sea ice was first detected in each grid cell for the monthly NOAA/NSIDC CDR. This applies to the Northern Hemisphere only.
qa_of_cdr_seaice_conc_monthly	Quality flags related to the cdr_seaice_conc_monthly variable
stdv_of_cdr_seaice_conc_monthly	Standard deviation for the monthly NOAA/NSIDC CDR sea ice concentration
surface_type_mask	Provides a mask of different Earth surface types
time	Time in days since 1601-01-01 00:00:00.
x	X-offset in meters of the projection grid centers.
y	Y-offset in meters of the projection grid centers.
latitude	Latitude in degrees north of the projection grid centers (aggregated files only)
longitude	Longitude in degrees east of the projection grid centers (aggregated files only)

cdr_seaice_conc_monthly

Description	The monthly average of the daily NSIDC-produced CDR sea ice concentrations (`cdr_seaice_conc`). For a description of the algorithm used to merge these, see section 2.3.3 CDR Algorithm.
Data Type	Byte array with dimensions [608, 896, 1] (North) and [632, 664, 1] (South), which are the x, y, and time, respectively. Note: The period-of-record aggregated monthly files will have a time dimension of the number of months since November 1978 through most recent processing.
Valid Range	0 to 100. Note: Byte values are stored in the files from 0 to 100 but are presented by most, but not all, netCDF readers as values ranging from 0 to 1 because of a scaling factor attribute (scale_factor) for this variable of .01 that is applied by most netCDF readers. Flag values range from 251 to 255.
Fill Value	255
Units	Unitless

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	String
Valid Range	N/A
Fill Value	N/A
Units	Meters

melt_onset_day_seaice_conc_monthly_cdr

Description	Contains the day of year on which melting sea ice was first detected in each grid cell. Once detected, the value is retained for the rest of the year. For example, if a grid cell started melting on day 73, the variable for the grid cell on that day will be 73, as will all subsequent days until the end of the year. The melt onset day is only calculated for the melt season: days 60 through 244, inclusive. Before melting is detected or if melt is never detected for that grid cell, the value will be 255. Note: This variable applies to Northern Hemisphere files only.
Data Type	Byte array with dimensions [608, 896, 1] (North), which are the x, y, and time, respectively. Note: The period-of-record aggregated monthly files will have a time dimension of the number of months since November 1978 through most recent processing.
Valid Range	60 to 244
Fill Value	255
Units	Unitless

qa_of_cdr_seaice_conc_monthly

Description	Different quality flags related to the monthly NSDIC CDR sea ice concentration variable (`cdr_seaice_conc_monthly`). See Table 6 for a list of the monthly QA flags. Note: Grid cells that meet multiple conditions will have a value that is the sum of the values of each individual condition. For example, if spatial interpolation was performed and melt detected then the value will be 160 (32 + 128)
Data Type	Byte array with dimensions [608, 896, 1] (North) and [632, 664, 1] (South), which are the x, y, and time, respectively. Note: The period-of-record aggregated monthly files will have a time dimension of the number of months since November 1978 through most recent processing.
Valid Range	0 to 255
Fill Value	0
Units	Unitless

The QA flags listed in Table 6 include whether the average concentration exceeds 15%, which is commonly used to define the ice edge and can be used to easily quantify the total extent. Another flag indicates when 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. Another flag indicates whether 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. Additionally, there is a flag that indicates whether 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. There are flags to show if a cell was masked by the invalid ice mask and whether spatial or temporal interpolation was performed. Finally, there is a flag to note whether 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 6. Monthly QA 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

Condition	Flag Value	Label in NetCDF Variable
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	region_masked_by_ocean_climatology
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) (Arctic only)	128	at_least_one_day_during_month_has_melt_detected

stdev_of_cdr_seaice_conc_monthly

Description	Standard deviation for the monthly NOAA/NSIDC CDR sea ice concentration variable (`cdr_seaice_conc_monthly`). This value is the standard deviation of the concentration of all daily values for the month at that grid cell.
Data Type	Float array with dimensions [608, 896, 1] (North) and [632, 664, 1] (South), which are the x, y, and time, respectively. Note: The period-of-record aggregated monthly files will have a time dimension of the number of months since November 1978 through most recent processing.
Valid Range	0.0 to 1.0
Fill Value	-1.0
Units	Unitless

surface_type_mask

Description	This variable provides a mask for different Earth surface types. The mask values are listed in Table 4.
Data Type	Byte array with dimensions [608, 896, 1] (North) and [632, 664, 1] (South), which are the x, y, and time, respectively. Note: The period-of-record aggregated monthly files will have a time dimension of the number of months since November 1978 through most recent processing.
Valid Range	50 to 250
Fill Value	N/A
Units	1

time

Description	Time in days since 1970-01-01 00:00:00.
Data Type	Long with a dimension of 1. Note: The period-of-record aggregated monthly files will have a time dimension of the number of months since November 1978 through most recent processing.
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 [608] (North) and [632] (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 [896] (North) and [664] (South)
Valid Range	-5350000.0 to 5850000.0 (North) and -3950000.0 to 4350000.0 (South)
Fill Value	NaN
Units	Meters

latitude

Description	Latitude in degrees north of the projection grid centers. This variable is only in the aggregated files.
Data Type	Double array with dimensions [608, 896] (North) and [632, 664] (South)
Valid Range	0.0 to 90.0 for northern hemisphere files, and -90.0 to 0.0 for southern hemisphere files.
Fill Value	NaN
Units	Degrees north

longitude

Description	Longitude in degrees east of the projection grid centers. This variable is only in the aggregated files.
Data Type	Double array with dimensions [608, 896] (North) and [632, 664] (South)
Valid Range	-180.0 to 180.0
Fill Value	NaN
Units	Degrees east

1.3.2.3 Ancillary Files

There are a total of six ancillary files that accompany this data set, three for the Northern Hemisphere and three for the Southern Hemisphere. They are described below.

ECDR Ancillary Files

There are four ECDR ancillary files that contain the land mask, latitude, longitude, land adjacency mask, pole hole masks, and invalid ice masks used in processing the sea ice ECDR. There are two for the 12.5 km grid and two for the 25 km grid based on hemisphere: ecdr-ancillary-psn12.5.nc, ecdr-ancillary-psn25.nc, ecdr-ancillary-pss12.5.nc, ecdr-ancillary-pss25.nc. Table 7 describes the contents of these files.

Table 7. ECDR Ancillary Files Content Description

Mask/Grid	Description
adj123	Land adjacency mask that describes how far an ocean pixel is from land. The options are 1 grid cell from land, 2 grid cells from land, 3 grid cells from land, or not near land (>3 grid cells).
crs	Coordinate reference system description of the polar stereographic projection.
invalid_ice_mask	An invalid ice mask that denotes areas of the grid that should not contain sea ice based on climatological analyses of seasonal sea ice locations. There are 12 masks (one for each month). This variable is used in combination with the month variable to differentiate the different monthly masks.
l90c	A mask that defines the coast (land adjacent to water) as 90% sea ice concentration. This mask is needed in the calculation of the NT2 land spillover correction.
latitude	Latitude of each grid cell in degrees north.
longitude	Longitude of each grid cell in degrees east.

Mask/Grid	Description
min_concentration	A minimum concentration matrix that is used for a land spillover correction. Not currently used in the calculation of the ECDR.
month	The 12 months of the year. Used in combination with the invalid_ice_mask variable to differentiate the different monthly masks.
polehole_bitmask	This is a bitmask that denotes the different pole holes for each satellite/sensor used in the creation of the ECDR. This is used for masking out the northern hemisphere pole hoe (an area of the earth that is not measured by the sensor due to the earth incidence angel). 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 64: GCOM-W1 AMSR2 pole hole
surface_type	This is a land surface type mask. It defines the following surface types: 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

There are two SMMR daily climatology invalid ice mask files: ecdr-ancillary-psn25-smmr-invalid-ice.nc and ecdr-ancillary-pss25-smmr-invalid-ice.nc. These are day-of-year climatology invalid ice masks derived from the Goddard Bootstrap algorithm NSIDC-0079 data. These are needed for the older SMMR era data to remove weather effects because the 22 GHz channel that is used for weather filtering for the other sensors is not accessible for SMMR.

1.3.3 Directory Structure

The data files are organized in the archive into two main directories by hemisphere: `north` and `south`. The top-level directory also contains an `ancillary` directory that holds ancillary data files that may be useful when working with the sea ice ECDR. Within each of the hemisphere directories, there are four sub-directories: `aggregate`, `checksums`, `daily`, and `monthly`. The `aggregate` directory contains the yearly aggregated daily files and the period-of-record aggregated monthly files. The `checksums` directory 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. The `daily` directory contains the individual daily data files and is further sub-divided into directories labeled by the 4-digit year (YYYY) beginning with 1978; the daily files reside within their respective year directory. All individual monthly files reside directly in the `monthly` directory.

1.3.4 Naming Convention

The file naming convention for the daily and monthly files is listed below and described in Table 8:

Individual daily files: `sic_psh12.5_yyyymmdd_sat_vXXrXX.nc`
Yearly aggregated daily files: `sic_psh_yyyymmdd-yyyymmdd_vXXrXX.nc`
Individual monthly files: `sic_psh_yyyymm_sat_vXXrXX.nc`
Period-of-record aggregated monthly files: `sic_psh_197811_yyyymm_vXXrXX.nc`

Where:

Table 8. File Naming Convention

Variable	Description
sic	Identifies files containing sea ice concentration data
ps	Identifies the files as being grided to the polar stereographic grid
h	Hemisphere (n: North, s: South)
yyyy	4-digit year (for the aggregate files the first instance is the start year and the second is the end year of the data in the file)
mm	2-digit month
dd	2-digit day of month
sat	Satellite the data came from (n07: Nimbus 7, f08: DMSP F8, f11: DMSP F11, f13: DMSP F13, f17: DMSP F17, ame: AMSRE, am2: AMSR2)
vXXrXX	Version and revision number of the data file (v04r00: Version 4, Revision 0)
.nc	Identifies a NetCDF file
.nc.mnf	Identifies this as an md5 checksum file

1.4 Spatial Information

1.4.1 Coverage and Resolution

These data cover both the Northern and Southern polar regions at a 12.5 km x 12.5 km grid cell size. Note: While resolution and grid cell size are often used interchangeably with regards to satellite data, there is an important difference. Resolution refers more properly 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 are 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 12.5 x 12.5 km grid and the IFOV of the sensor is coarser than this, some sensors (SMMR, SSM/I, SSMIS) are obtaining information from up to a 6 x 4 12.5 km grid cell (~75 km x 45 km) region, but that signature is placed into a single grid cell. This results in a spatial "smearing" across several grid cells. Further, 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, do not have a brightness temperature directly assigned to them even though they are 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 12.5 km resolution.

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

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

Note that for the Arctic, there is a region around the pole that is not imaged by the passive microwave sensors. This area is called the Arctic Pole Hole. Depending on the instrument used, the size of this area changes over time as the instrument changes. See Table 9 for these sizes.

This area is filled by spatial interpolation instead of being filled with missing values. Note, one cannot assume what the concentration is in the Arctic pole hole, especially in late Arctic summer and early autumn. Thus, we would advise caution in using the interpolated data in long-term trends or climatology analyses. See the C-ATBD (Meier et al., 2024) for more details.

Table 9. 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
AMSR-E	0.0341	88.94° N
AMSR2	0.0286	89.07° N

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

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

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 10 and Table 11.

Table 10. 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 11. Grid Details

Grid cell size	12.5 km x 12.5 km
Grid size (x, y pixel dimensions)	Northern Hemisphere: 896 x 608 Southern Hemisphere: 664 x 632
Geolocated lower left point in grid (km)	Northern Hemisphere: (-3850, -5350) Southern Hemisphere: (-3950, -3950)
Nominal gridded resolution	12.5 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: -3,843.75 Southern Hemisphere: -3,943.75
ulymap – y-axis map coordinate of the center of the upper-left pixel (km)	Northern Hemisphere: 5,843.75 Southern Hemisphere: 4,343.75

1.5 Temporal Coverage and Resolution

The CDR sea ice concentrations (`cdr_seaice_conc` and `cdr_seaice_conc_monthly`) span 25 October 1978 to through most recent processing provided at both a daily resolution and a monthly averaged resolution (Table 12). For the monthly averaged data, at least 20 days (10 for SMMR) of data must be available for a month for an average to be calculated. There is a gap in the data from 03 December 1987 through 12 January 1988 due to satellite issues during that time, so no daily or monthly data are available for that period. There are additional gaps in the data due to corrupt or missing data that are noted in Table 13. Data files exist for these dates; however, they are filled with a missing data value of 255. In addition, dates of data that have partially corrupt data files are listed in Table 14 for reference, as they could cause issues in analyses of the time series because they contain values that look like sea ice concentration but that are clearly erroneous. Most of these data gaps occurred during the SMMR era, which had some operational issues. See NSIDC Special Report 20 (Windnagel et al., 2021) for details on these corrupt and missing data.

The most recent two weeks of data are a preliminary near-real-time version of this. Preliminary data is meant as interim data to fill the period before the final CDR is processed and to provide data up to the present. The preliminary data does not go through the same quality control measures that the final CDR does, so it should be treated as such.

Table 12. Time Period Each Instrument is Used in the CDR

Platform and Instrument	**Time Period**
Nimbus-7 SMMR	25 October 1978 – 09 July 1987 Note: There are no data from 17 – 19 August 1984 due to satellite problems
DMSP-F8 SSM/I	10 July 1987 - 02 December 1991 Note: There are no data from 3 December 1987 through 12 January 1988 due to satellite problems.
DMSP-F11 SSM/I	03 December 1991 - 30 September 1995
DMSP-F13 SSM/I	01 October 1995 - 31 May 2002
AMSR-E	1 June 2002 – 03 October 2011
DMSP-F17 SSMIS	04 October 2011 – 02 July 2012
AMSR2	03 July 2012 to most recent processing

Table 13. Daily and monthly dates with no data due to corrupt or missing data

Arctic **Daily: YYYY/MM/DD** **Monthly: Month Year**	**Antarctic** **Daily: YYYY/MM/DD** **Monthly: Month Year**
1984/07/03 - 1984/08/04 July 1984	1984/08/12 - 1984/08/24 Note: August 1984 is included but the average is calculated with less than half the days of the month available.
1984/08/12 - 1984/08/24	1985/08/05 - 1985/08/09
1986/12/04 - 12/10/1986	1986/12/04 - 1986/12/10
1987/12/03 – 1988/01/13 December 1987 and January 1988	1987/12/03 – 1988/01/13 December 1987 and January 1988
1990/12/26 – 1990/12/27	2002/08/02
2002/08/02	2002/08/04
2002/08/04	

Table 14. Dates of partial CDR fields due to corrupt or missing data
Note: Only dates where missing data affect sea ice concentration are noted here.

Arctic (YYYY/MM/DD)	Antarctic (YYYY/MM/DD)
1979/06/07 - 1979/06/20	1982/08/04 - 1982/08/09
1986/03/28 - 1986/04/18	1984/08/25 - 1984/08/26
1990/12/25	1985/08/04
	1985/08/10 - 1985/08/11
	1986/03/30 - 1986/04/08
	1986/12/11 - 1986/12/12
	1990/12/26 – 1990/12/27

2 DATA ACQUISITION AND PROCESSING

2.1 Input Data

The input data for the SIC CDR variables are listed in Table 15. The dates that each sensor is used is listed in Table 12.

Table 15. 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
AMSR-E	*AMSR-E/Aqua Daily L3 12.5 km Brightness Temperature, Sea Ice Concentration, & Snow Depth Polar Grids, Version 3*	AE_SI12
AMSR2	*AMSR2 Unified L3 Daily 12.5 km Brightness Temperatures, Sea Ice Concentration, Motion & Snow Depth Polar Grids, Version 1*	AU_SI12

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 four data sets listed in Table 15. For a complete description of how the input data are processed, 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 15) 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 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 AMSR-E and AMSR2), vertical 22 GHz (22.2 GHz for SSM/I-SSMIS, 23.8 for AMSR-E and AMSR2), and vertical and horizontal 37 GHz (37.0 for SMMR, SSM/I, and SSMIS, 36.5 for AMSR-E and AMSR2). For simplicity in this document, the channels are denoted as simply 19 (V/H), 22V, and 37 (V/H). Table 16 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 16. 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 them. 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 so that 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). Note: For this beta release, we are using the initial tie points and other parameters as provided by Goddard for the AMSR2 AU_SI12 product. We may adjust those for later releases, pending science review.

2.3.2 Automated Quality Control

Automated quality control measures are implemented independently on the intermediate NASA Team and Bootstrap outputs. Two weather filters, based on ratios of channels sensitive to enhanced emission over open water, are used to filter weather effects. The NASA Team 2 land-spillover correction is 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).

2.3.3 CDR Algorithm

Different algorithms exist for computing sea ice concentration from brightness temperature data. The two widely used GSFC-developed NASA Team (Cavalieri et al., 1984) and Bootstrap (Comiso, 1986) algorithms are described in sections 2.3.4 and 2.3.5, respectively. Both algorithms have their own inherent advantages and limitations. For the SIC CDR data set, the NASA Team-derived sea ice concentrations are merged with the Bootstrap-derived sea ice concentrations using the SIC CDR algorithm into a single ice concentration estimate. The CDR algorithm steps are as follows:

- First, the sea ice edge is defined using only the Bootstrap-derived data with a 10 percent concentration threshold cutoff. In other words, any grid cell near the ice edge showing a concentration of less than 10 percent in the Bootstrap data is set to open water in the CDR; otherwise, it is set to the Bootstrap-derived concentration. Bootstrap is used for the edge because of the ambiguity and potential inconsistencies between how the edge is detected by the NASA Team and Bootstrap algorithms (Meier et al., 2014). Note that because of the temporal interpolation that is applied during post processing, concentrations less than 10 percent can occur in the daily fields.
- Second, at each sea ice grid cell within the ice cover, the concentration value given by the NASA Team algorithm and that given by the Bootstrap algorithm are compared; whichever value is greater is selected as the CDR value. This is done because both algorithms tend to underestimate ice concentration, however the source of this bias differs between algorithms (Meier et al., 2014).

- The monthly average is computed at each grid cell by averaging all available daily values in the month for that grid cell. A minimum of 20 days (10 for SMMR) is required for a valid monthly value. If a grid cell has fewer than 20 days with non-missing data, that grid cell is assigned the missing flag in the monthly field. No concentration threshold is used in the monthly fields – i.e., unlike the daily fields, monthly concentration values of less than 10 percent may occur because the average of a grid cell for a month may be lower.

NSIDC processes the input brightness temperatures into the two intermediate NASA Team and Bootstrap sea ice concentrations. The processing for these intermediate concentrations for the sea ice CDR is modeled after the way NASA produces their NASA team and Bootstrap data sets. Both data sets 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*. There are a few small differences in the processing done by NSIDC and NASA. See the C-ATBD (Meier et al., 2024) for more information.

The NASA Team algorithm, because it uses a ratio of brightness temperatures, tends to cancel out any physical temperature effects. The Bootstrap algorithm uses relationships between two brightness temperatures that are dependent 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; but the effect is more pronounced in the NASA Team algorithm (Comiso et al., 1997; Meier, 2005; Andersen et al., 2007).

While these characteristics of the algorithm are true in an overall general sense, ice conditions and algorithm performance can vary from grid cell to grid cell; and 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 will tend to reduce the overall underestimation of the CDR estimate (Meier et al., 2014). For a more in-depth discussion on the reasoning behind the algorithm, see the C-ATBD (Meier et al., 2024).

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 17. 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

When PR and GR are plotted against each other, brightness temperature values tend to cluster in two locations, an open water (zero percent ice) point and a line representing 100 percent ice concentration, roughly forming a triangle. The concentration of a grid cell with a given GR and PR value is calculated by a linear interpolation between the open water point and the 100 percent line segment. See Figure 1.

For a detailed description of the NASA Team algorithm, please see the Descriptions of and Differences Between the NASA Team and Bootstrap Algorithms FAQ and the NASA Technical Memorandum 104647 (Cavalieri et al., 1997) that includes information about differences (for example, tie points) between the original algorithm and the revised NASA Team algorithm, and the NASA Team Algorithm section of the C-ATBD (Meier et al., 2024) for a table of tie-point values.

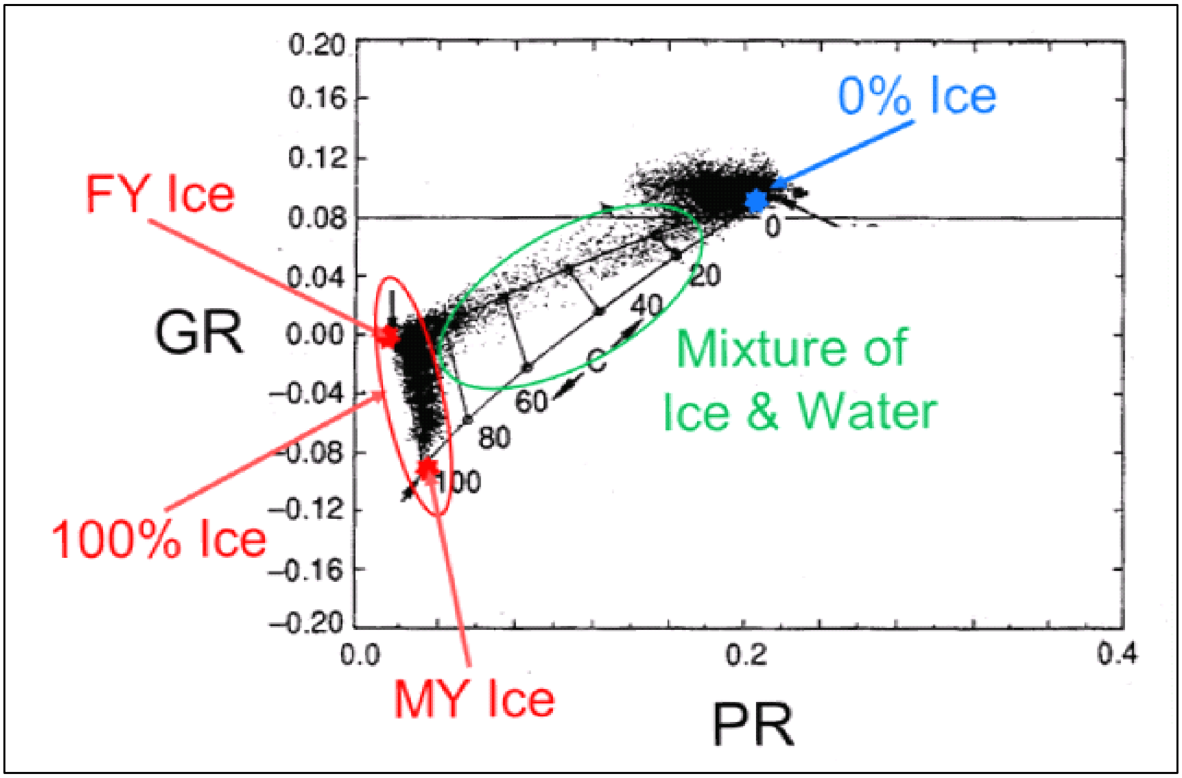

Figure 1. Sample plot of GR vs. PR with typical clustering of grid cell values (small dots) around the 0% ice (open water) point (blue star) and the 100% ice line (circled in red). Points with a mixture of ice and water (circled in green) fall between these two extremes. Adapted from Figure 10-2 of Steffen et al. (1992).

2.3.5 Bootstrap Algorithm

Like the NASA Team algorithm, the Bootstrap algorithm is empirically derived based on relationships of brightness temperatures at different channels. The Bootstrap method uses the fact that scatter plots of different sets of channels show distinct clusters that correspond to two pure surface types: 100 percent sea ice or open water.

Figure 2 shows a schematic of the general relationship between two channels. Points that fall along line segment AD represent 100 percent ice cover. Points that cluster around point O represent open water (zero percent ice). Concentration for a point B is determined by a linear interpolation along the distance from O to I where I is the intersection of segment OB and segment AD. This is described by Equation 3.

$C = (T_B - T_O)/(T_I - T_O)$ **(Equation 3)**

Where:

Table 18. 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

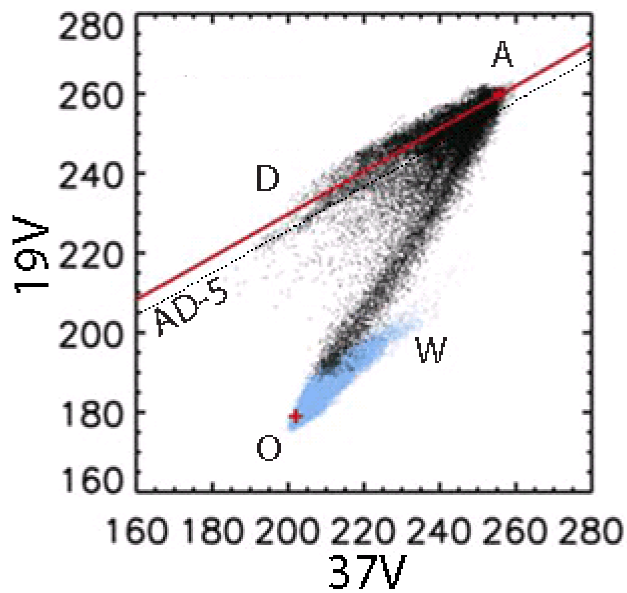

Figure 2. Example of the relationship of the 19V vs. 37V T_B (in Kelvin) used in the Bootstrap algorithm. Brightness temperatures typically cluster around the line segments AD (representing 100% sea ice) and OW (representing 100% open water). For points that fall below the AD-5 line (dotted line), Bootstrap uses T_B relationships for 37H vs. 37V. Adapted from Comiso and Nishio (2008).

The Bootstrap algorithm uses two such combinations, 37 GHz H versus 37 GHz V and 19 GHz V versus 37 GHz V, denoted as HV37 and V1937, respectively. Points that fall within 5 K of the AD segment in a HV37 plot, corresponding roughly to concentrations greater than 90 percent, use this approach. Points that fall below the AD-5 line, use the V1937 relationship to derive the concentration. Slope and offset values for line segment AD were originally derived for each hemisphere for different seasonal conditions (Table 2 in Comiso et al., 1997). However, a newer formulation, employed in this CDR, was developed where slope and offsets are derived for each daily field based on the clustering within the daily brightness temperatures (Comiso and Nishio, 2008). For a detailed description of the Bootstrap algorithm, please see 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 3 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 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

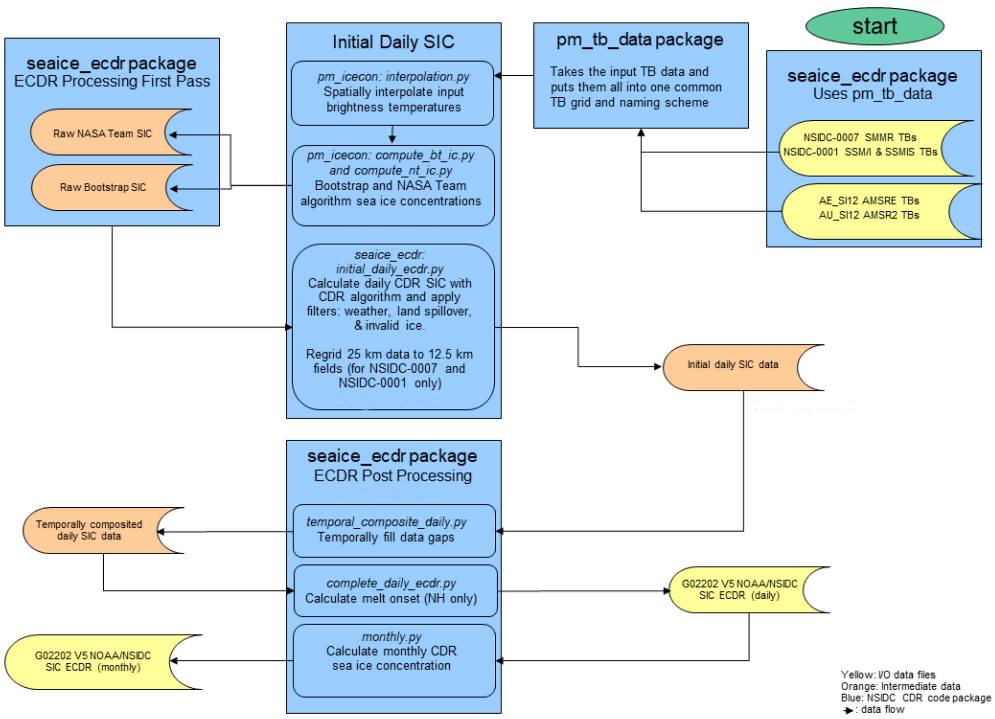

Figure 3. Overview of the Daily and Monthly ECDR Processing

2.4.1 Daily Files

The following are the general steps NSIDC uses to produce the daily NOAA/NSIDC SIC ECDR product. See Figure 4 for an overview diagram of the data flow.

1. Obtain input brightness temperature data from the NSIDC. See Table 15 for a list of these input data sets, and see Table 16 for a list of passive microwave channels used.
2. Spatially interpolate each brightness temperature channel. Fill the `spatial_interpolation_flag` variable. See the C-ATBD (Meier et al., 2024) for details.
3. Process the brightness temperatures into two intermediate, raw sea ice concentration products using both the NASA Team and Bootstrap algorithms.

4. Merge the raw NASA Team (`raw_nt_seaice_conc`) and Bootstrap (`raw_bt_seaice_conc`) data into the CDR using the SIC CDR algorithm and populate the `cdr_seaice_conc` variable. See section 2.3.3 CDR Algorithm of this document for more information.
5. Apply weather filters, land-spillover corrections, and invalid ice masks.
6. Set some initial QA flags (`qa_of_cdr_seaice_conc`) based on the filters in step 5.
7. Temporally interpolate the CDR sea ice concentrations. See the C-ATBD (Meier et al., 2024) for details.
8. For the Arctic, spatially interpolate the pole hole. See the C-ATBD (Meier et al., 2024) for details.
9. Apply a day-of-year invalid climatology ice mask for the SMMR era to the sea ice concentration CDR.
10. Compute the CDR sea ice concentration standard deviation (`stdev_of_cdr_seaice_conc`) and the final QA flag values (`qa_of_cdr_seaice_conc`).
11. Calculate melt onset (melt_onset_day_cdr_seaice_conc) and add melt-indicator flag to the QA variable (`qa_of_cdr_seaice_conc`) via a post-processing step.
12. Populate the daily netCDF variables and create the .nc files.

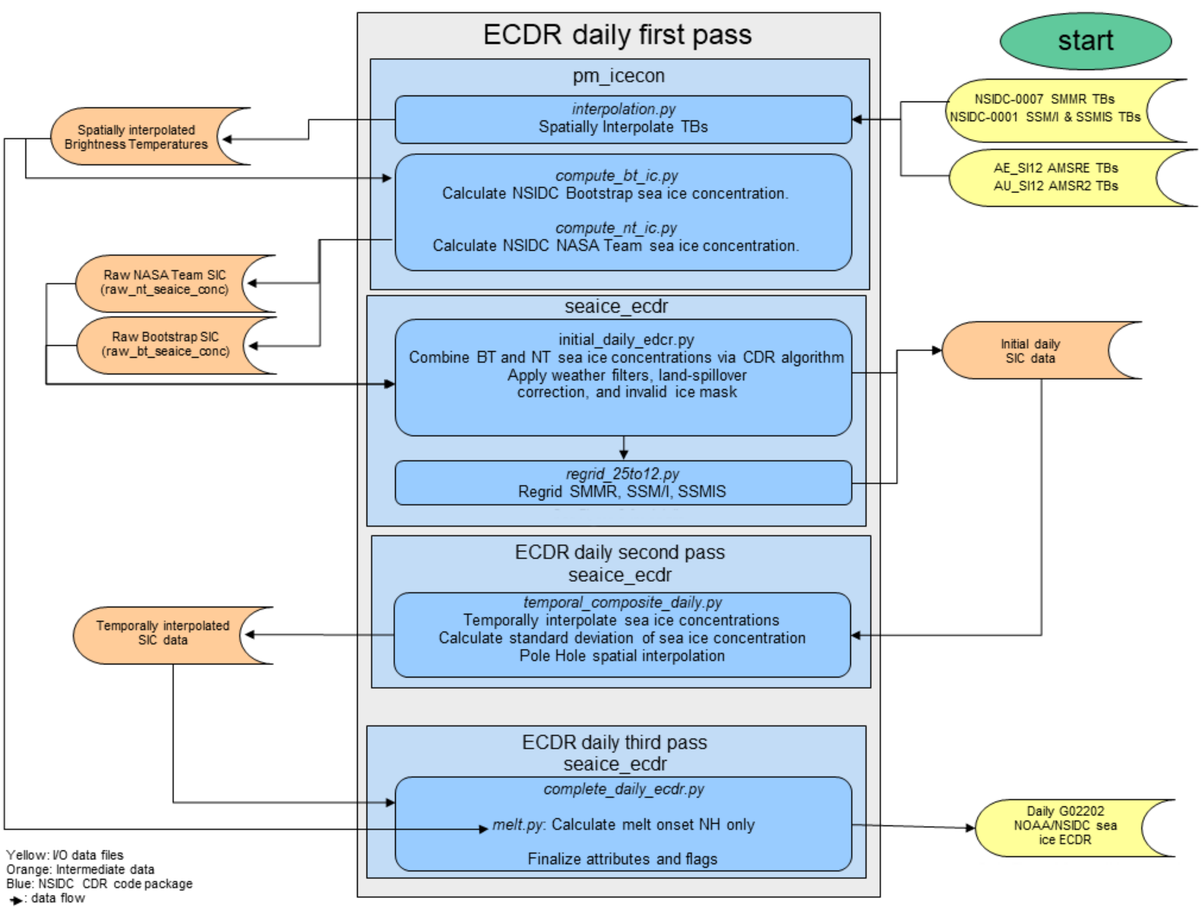

Figure 4. Flow of Data through the Daily CDR Processing.

2.4.2 Monthly Files

The following are the general steps NSIDC uses to produce the monthly NOAA/NSIDC SIC ECDR product. See Figure 5 for a diagram of the data flow.

1. Read the input daily ECDR sea ice concentration data (`cdr_seaice_conc`).
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` variable.
4. Compute the standard deviation and quality flags and fill those variables (`stdev_of_cdr_seaice_conc_monthly` and `qa_of_cdr_seaice_conc_monthly`).
5. Set melt onset day (value from the last day of the month) and fill the `melt_onset_day_cdr_seaice_conc_monthly` variable and add melt onset flag to the `qa_of_cdr_seaice_conc_monthly` variable.
6. Write to the .nc files.

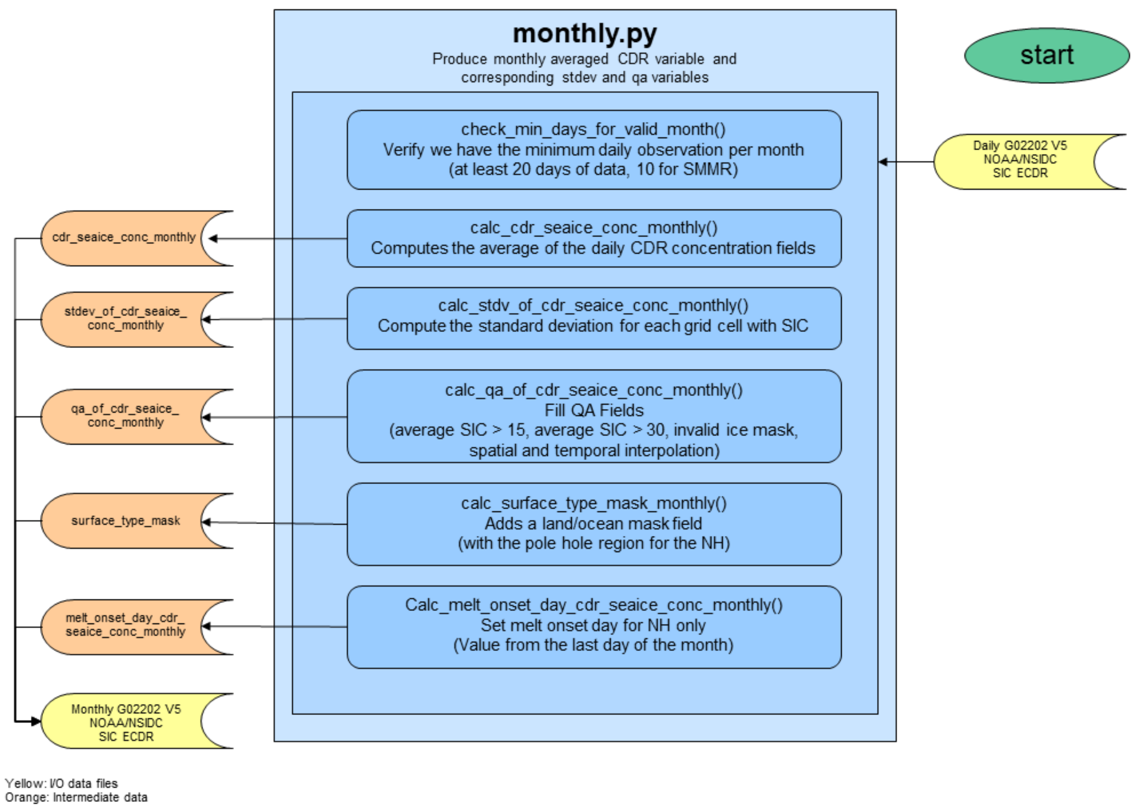

Figure 5. Flow of Data through the Monthly CDR Processing.

2.5 Errors Sources

Several studies over the years have assessed ice concentration estimates from the NASA Team and Bootstrap algorithms. These assessments have typically used 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 ones that use the AMSR sensors, indicate an accuracy of approximately 5% during mid-winter conditions away from the coast and the 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) performed a study with the SSM/I instruments and found a difference with operational charts that was relatively low in the winter but rose to more than 20% in summer. A more recent study done 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, the SSMIS sensor on DMSP-F17, AMSR-E sensor on Aqua, and the AMSR2 sensor on GCOM-W1. The rationale for using only these satellites was made to keep the equatorial crossing times as consistent as possible to minimize potential diurnal effects of data from sun-synchronous orbits of the satellites. 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 19. Version History

Version	Release Date	Description of Changes
v05r00	February 2024	Release of Version 5 Revision 0 • Added AMSR-E and AMSR2 sensors • Changed grid from 25 km to 12.5 km • Regridded the legacy SMMR, SSM/I, and SSMIS sensors from 25 km to 12.5 km • Using the NASA Team 2 land spillover correction instead of the original NASA Team and Bootstrap corrections • Adjusted Bootstrap weather filter coefficients for AMSR2 • Improved the Arctic pole hole filling

Version	Release Date	Description of Changes
v04r00	June 2021	Release of Version 4 Revision 0 1. 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. 2. 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. 3. 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. 4. Arctic pole hole filled by spatial interpolation. 5. NSIDC's BT algorithm has been updated to use Goddard's BT version 3.1 algorithm, the current version for the BT product. 6. 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. 7. 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. 8. 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 9. Removed the following Goddard-produced variables: • goddard_merged_seaice_conc • goddard_nt_seaice_conc • goddard_bt_seaice_conc • goddard_merged_seaice_conc_monthly • goddard_nt_seaice_conc_monthly • goddard_bt_seaice_conc_monthly 10. 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. 11. 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. See the **Error! Reference source not found.** for more information. This change does not affect the sea ice concentration CDR data variables.

Version	Release Date	Description of Changes
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.
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 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/Aqua Daily L3 12.5 km Brightness Temperatures, Sea Ice Concentration, & Snow Depth Polar Grids*
- *AMSR-E/Aqua Daily L3 25 km Brightness Temperatures & Sea Ice Concentration Polar Grids*
- *AMSR-E/AMSR2 Unified L3 Daily 12.5 km Brightness Temperatures, Sea Ice Concentration, Motion & Snow Depth 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

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8 DOCUMENT INFORMATION

8.1 Author

A. Windnagel

8.2 Publication Date

July 2011

8.3 Revision History

February 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.