NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 3

USER GUIDE

How to Cite These Data

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

Meier, W. N., F. Fetterer, M. Savoie, S. Mallory, R. Duerr, and J. Stroeve. 2017. *NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 3*. [Indicate subset used]. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center https://doi.org/10.7265/N59P2ZTG. [Date Accessed].

We also request that you acknowledge the author(s) of this data set by referencing the following peer-reviewed publication:

Peng, G., W. N. Meier, D. Scott, and M. 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. https://doi.org/10.5194/essd-5-311-2013.

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

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

National Snow and Ice Data Center

TABLE OF CONTENTS

1 DATA DESCRIPTION

Notice: A near-real-time version of this data set also exists to fill the gap between the time that this data set is updated through to the present. The data set is called the *Near-Real-Time NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration* (G10016).

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 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 CDR algorithm blends the NT and BT output concentrations by selecting, for each grid cell, the higher concentration value. The CDR 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 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 CDR fields and ice concentration from NT and BT. They find that the CDR and BT fields are quite similar in both hemispheres. There are larger differences between CDR and NT, with the CDR (and BT) finding more ice overall. Trends in area and extent for all three products, computed over 1988-2007, have only small, insignificant differences.

The NT and BT algorithms run at NSIDC as part of CDR processing. Separately, NASA Goddard Space Flight Center (GSFC) produces ice concentrations using the NT and BT algorithms that are distributed by the NSIDC DAAC as the following data sets: *Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data* (NSIDC-0051) and *Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS* (NSIDC-0079), respectively. These products have some manual quality control applied and therefore do not meet CDR standards for reproducibility. However, we include the GSFC output here as a convenience for users who may wish to compare these different ice concentration products.

The CDR begins in 1987 with DMSP SSM/I passive microwave data, rather than in 1978 with NASA Nimbus-7 SMMR data, because the complete processing history of SMMR brightness temperatures cannot be traced and therefore the CDR program requirement for transparency is not met. Yet, many users want consistently processed records that are as long as possible. For this reason, we include merged ice concentrations that are produced with the CDR algorithm using NT and BT from GSFC. This merged product covers the same period of record as do data sets

NSIDC-0051 and NSIDC-0079, beginning with NASA Nimbus-7 SMMR data in 1978. Peng et al. (2013) have shown that the CDR and the merged product are virtually identical for the period of overlap.

In all, there are four ice concentration products included with this data set. The CDR product, with the variables `seaice_conc_cdr` for daily and `seaice_conc_monthly_cdr` for monthly, begins in 1987. The other three products; NT (`goddard_nt_seaice_conc` for daily and `goddard_nt_seaice_monthly_conc` for monthly), BT (`goddard_bt_seaice_conc` for daily and `goddard_bt_seaice_monthly_conc` for monthly), and merged (`goddard_merged_seaice_conc` for daily and `goddard_merged_seaice_monthly_conc` for monthly); begin in 1978. This data set is updated approximately every year, after the NSIDC DAAC has updated NSIDC-0051 and NSIDC-0079 with the most recent delivery of data from GSFC. The closely-related *Near-Real-Time NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration* fills the gap between the end date of this data set and present.

Daily and monthly resolution sea ice concentration values are provided in NetCDF files with one file for each day of the year and one file for each month of the year for each hemisphere. Each file has a variable for each of the four concentration products, as well as variables containing standard deviation, quality flags, and projection information. All data are on a 25 km x 25 km grid.

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-1.6 (Eaton et al. 2010).

Both the daily and monthly files contain 13 variables that are described in the sections 1.3.2.1 Daily File Variable Description and 1.3.2.2 Monthly File Variable Description.

1.3.2 File Contents

1.3.2.1 Daily File Variable Description

The daily netCDF4 files contain 13 variables. Table 1 provides a quick look at these variables.

Table 1. Daily Variables at a Glance. Click Variable Name for More Information.

Variable Name	Brief Description	Variable Name	Brief Description
seaice_conc_cdr	NOAA/NSIDC daily sea Ice CDR from 1987 to most recent processing.	projection	Projection information for the data.
goddard_merged_seaice_conc	Merged GSFC NASA Team/Bootstrap daily sea ice concentrations from 1978 through most recent processing.	time	Time in days since 1601-01-01 00:00:00.
goddard_nt_seaice_conc	GSFC NASA Team daily sea ice concentrations sea ice concentrations from 1978 through most recent processing.	xgrid	X-offset in meters of the projection grid centers.
goddard_bt_seaice_conc	GSFC Bootstrap daily sea ice concentrations sea ice concentrations from 1978 through most recent processing.	ygrid	Y-offset in meters of the projection grid centers.
stdev_of_seaice_conc_cdr	Standard deviation for the daily NOAA/NSIDC CDR sea ice concentration.	latitude	Latitude in degrees north of the projection grid centers.
melt_onset_day_seaice_conc_cdr	The day of year on which melting sea ice was first detected in each grid cell for the daily NOAA/NSIDC CDR. This applies to the Northern Hemisphere only.	longitude	Latitude in degrees north of the projection grid centers.
qa_of_seaice_conc_cdr	A number of different quality flags related to the daily NOAA/NSDIC CDR.		

seaice_conc_cdr

Description NOAA/NSIDC CDR sea ice concentrations which is the fraction of ocean area covered by sea ice that span 1987 through most recent processing. This variable is merged 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. Note that the 1978 to 1987 data files contain this variable, but they are populated with a fill value of 255. See Table 2 for a list of all flag values.

Data Type Byte array with dimensions [304, 448, 1] (North) and [316, 332, 1] (South), which are the xgrid, ygrid, and time, respectively.

Valid Range 0 to 1. 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.

Attributes `_FillValue, valid_range, _Unsigned, long_name, standard_name, units, scale_factor, coordinates, flag_values, flag_meanings, datum, grid_mapping, reference, ancillary_variables`

Fill Value 255

Units Unitless

Table 2. Flag Values for Sea Ice Concentration Variables

Flag Name	Value
Northern Hemisphere pole hole (the region around the pole not imaged by the sensor)	251
Lakes	252
Coast/Land adjacent to ocean	253
Land	254
Missing/Fill	255

stdev_of_seaice_conc_cdr

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.

Data Type	Float array with dimensions [304, 448, 1] (North) and [316, 332, 1] (South), which are the xgrid, ygrid, and time, respectively.
Valid Range	0.0 to 1.0
Attributes	`_FillValue, valid_range, long_name, units, coordinates, missing_value, datum, grid_mapping`
Fill Value	-1.0
Units	1

melt_onset_day_seaice_conc_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 -1 (missing / fill value). NOTE: This variable applies to Northern Hemisphere files only. However, the variable does appear in the Southern Hemisphere files, but it is always filled with zeroes.
Data Type	Integer array with dimensions [304, 448, 1] (North), which are the xgrid, ygrid, and time, respectively.
Valid Range	60 to 244
Attributes	`_FillValue, valid_range, _Unsigned, long_name, standard_name, units, coordinates, missing_value, datum, grid_mapping`
Fill Value	-1
Units	Unitless

qa_of_seaice_conc_cdr

Description	A number of different quality flags related to the daily NOAA/NSDIC CDR sea ice concentration. See Table 3 for a list of the flags. Note 1: Grid cells that meet multiple conditions will have a value that is the sum of the values of each individual condition. For example, if the byte value for a cell is 129, both the `melt_start_detected` flag and `BT_source_for_CDR` flag have been set. Note 2: If the value from the Bootstrap algorithm and the NASA Team algorithm for a cell are equal, then the byte value for that cell is set to 3 (`BT_source_for_CDR` + `NT_source_for_CDR`).
Data Type	Byte array with dimensions [304, 448, 1] (North) and [316, 332, 1] (South), which are the xgrid, ygrid, and time, respectively.

Valid Range	1 to 255
Attributes	`_FillValue, valid_range, _Unsigned, long_name, standard_name, units, coordinates, flag_masks, flag_meanings, missing_value, datum, grid_mapping`
Fill Value	0
Units	Unitless

Table 3. Daily QA Flag Values

Condition	Flag Value	NetCDF Variable Name	Description
BT source for CDR (BT > NT)	1	BT_source_for_CDR	Indicates that the value from the Bootstrap algorithm was greater than the NASA Team algorithm, thus the Bootstrap value was used for this grid cell.
NT source for CDR (NT > BT)	2	NT_source_for_CDR	Indicates that the value from the NASA Team algorithm was greater than the Bootstrap algorithm, thus the NASA Team value was used for this grid cell.
Region masked by ocean climatology	4	no_ice_allowed_per_climatology	Indicates that this grid cell has been designated as ocean via an ocean mask or valid ice mask.
Grid cell near the coast	8	grid_cell_near_to_coast	Indicates that this grid cell is located near the coastline, so it may be less reliable and of lower quality than cells further from the coast.
Concentration < 50%	32	concentration_below_fifty_percent	Indicates that the concentration value for this grid cell is under 50%. This is important because the NASA Team and Bootstrap algorithms do not pick up low concentration ice very well and also confuse low concentration with thin ice. Therefore, these grid cells have a lower confidence level.

Condition	Flag Value	NetCDF Variable Name	Description
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 March 1 (DOY=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 September 1 (DOY=244), roughly the time when extent reaches its minimum value. When the sea ice concentration is zero, the flag will be turned off.

goddard_merged_seaice_conc

Description	Merged GSFC NASA Team/Bootstrap daily sea ice concentrations from 1978 through most recent processing. This variable is merged from the `goddard_nt_seaice_conc` and the `goddard_bt_seaice_conc` variables. For a description of the algorithm used to merge these, see section 2.3.3 CDR Algorithm. For a list of flag values for this variable, see Table 2.
Data Type	Byte array with dimensions [304, 448, 1] (North) and [316, 332, 1] (South), which are the xgrid, ygrid, and time, respectively.
Valid Range	0 to 1. 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.
Attributes	`_FillValue, valid_range, _Unsigned, long_name, standard_name, units, scale_factor, coordinates, flag_values, flag_meanings, datum, grid_mapping, reference, ancillary_variables`
Fill Value	255
Units	1

goddard_nt_seaice_conc

Description	GSFC NASA Team daily sea ice concentrations sea ice concentrations from 1978 through most recent processing. These values come from the daily portion of the *Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data* (NSIDC-0051). For a list of flag values for this variable, see Table 2.
Data Type	Byte array with dimensions [304, 448, 1] (North) and [316, 332, 1] (South), which are the xgrid, ygrid, and time, respectively.
Valid Range	0 to 1. 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.
Attributes	`_FillValue, valid_range, _Unsigned, long_name, standard_name, units, scale_factor, coordinates, flag_values, flag_meanings, datum, grid_mapping, reference, ancillary_variables`
Fill Value	255
Units	1

goddard_bt_seaice_conc

Description	GSFC Bootstrap daily sea ice concentrations sea ice concentrations from 1978 through most recent processing. These values come from the daily portion of the *Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS* (NSIDC-0079) data set. For a list of flag values for this variable, see Table 2.
Data Type	Byte array with dimensions [304, 448, 1] (North) and [316, 332, 1] (South), which are the xgrid, ygrid, and time, respectively.
Valid Range	0 to 1. 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.
Attributes	`_FillValue, valid_range, _Unsigned, long_name, standard_name, units, scale_factor, coordinates, flag_values, flag_meanings, datum, grid_mapping, reference, ancillary_variables`
Fill Value	255
Units	1

projection

Description	Provides details about the polar stereo projection information for the data.
Data Type	Char array with dimension [304] (North) and [316] (South)
Valid Range	N/A
Attributes	`grid_boundary_top_projected_y, grid_boundary_bottom_projected_y, grid_boundary_right_projected_x, grid_boundary_left_projected_x, parent_grid_cell_row_subset_start, parent_grid_cell_row_subset_end, parent_grid_cell_column_subset_start, parent_grid_cell_column_subset_end, spatial_ref, proj4text, srid, GeoTransform, grid_mapping_name, latitude_of_projection_origin, standard_parallel, straight_vertical_longitude_from_pole, longitude_of_projection_origin, scaling_factor, false_easting, false_northing , semimajor_radius, semiminor_radius, units`
Fill Value	N/A
Units	Meters

time

Description	Time in days since 1601-01-01 00:00:00.
Data Type	Double
Valid Range	N/A
Attributes	`standard_name, units, long_name, calendar, axis`
Fill Value	N/A
Units	Days since 1601-01-01 00:00:00

xgrid

Description	X-offset in meters of the projection grid centers.
Data Type	Float array with dimension [304] (North) and [316] (South)
Valid Range	-3.85000e+006 to 3.75000e+006
Attributes	`valid_range, units, long_name, standard_name, axis`
Fill Value	N/A
Units	Meters

ygrid

Description	Y-offset in meters of the projection grid centers.
Data Type	Float array with dimension [448] (North) and [332] (South)
Valid Range	-5.35000e+006 to 5.85000e+006
Attributes	`valid_range, units, long_name, standard_name, axis`
Fill Value	N/A
Units	Meters

latitude

Description	Latitude in degrees north of the projection grid centers.
Data Type	Double array with dimensions [304, 448] (North) and [316, 332] (South)
Valid Range	0.0 to 90.0 for northern hemisphere files, and -90.0 to 0.0 for southern hemisphere files.
Attributes	`standard_name, long_name, units, valid_range, _FillValue`
Fill Value	-999.0
Units	Degrees north

longitude

Description	Longitude in degrees east of the projection grid centers.
Data Type	Double array with dimensions [304, 448] (North) and [316, 332] (South)
Valid Range	-180.0 to 180.0
Attributes	`standard_name, long_name, units, valid_range, _FillValue`
Fill Value	-999.0
Units	Degrees east

1.3.2.2 Monthly File Variable Description

The monthly netCDF4 files contain 13 variables. Table 4 provides a quick look at these variables with links to more detailed information.

Table 4. Monthly Variables at a Glance. Click Variable Name for More Information.

Variable Name	Brief Description	Variable Name	Brief Description
seaice_conc_monthly_cdr	NOAA/NSIDC monthly sea Ice CDR from 1987 to most recent processing.	projection	Projection information for the data.
goddard_merged_seaice_conc_monthly	Merged GSFC NASA Team/Bootstrap monthly sea ice concentrations from 1978 through most recent processing.	time	Time in days since 1601-01-01 00:00:00.
goddard_nt_seaice_conc_monthly	GSFC NASA Team monthly sea ice concentrations sea ice concentrations from 1978 through most recent processing.	xgrid	X-offset in meters of the projection grid centers.
goddard_bt_seaice_conc_monthly	GSFC Bootstrap monthly sea ice concentrations sea ice concentrations from 1978 through most recent processing.	ygrid	Y-offset in meters of the projection grid centers.
stdev_of_seaice_conc_monthly_cdr	Standard deviation for the monthly NOAA/NSIDC CDR sea ice concentration.	latitude	Latitude in degrees north of the projection grid centers.

Variable Name	Brief Description	Variable Name	Brief Description
melt_onset_day_seaice_conc_monthly_cdr	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.	longitude	Latitude in degrees north of the projection grid centers.
qa_of_seaice_conc_monthly_cdr	A number of different quality flags related to the monthly NOAA/NSDIC CDR.		

seaice_conc_monthly_cdr

Description The monthly average of the NSIDC-produced CDR sea ice concentrations (`seaice_conc_cdr`) that span 1987 through most recent processing. Note that the 1978 to 1987 data files contain this variable, but they are populated with a fill value of 255. See Table 2 for a list of flag values used in this variable.

Data Type Byte array with dimensions [304, 448, 1] (North) and [316, 332, 1] (South), which are the xgrid, ygrid, and time, respectively.

Valid Range 0 to 1. 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.

Attributes `_FillValue, valid_range, _Unsigned, long_name, standard_name, units, scale_factor, coordinates, flag_values, flag_meanings, datum, grid_mapping, reference, ancillary_variables`

Fill Value 255

Units Unitless

stdev_of_seaice_conc_monthly_cdr

Description	Standard deviation for the monthly NOAA/NSIDC CDR sea ice concentration variable (`seaice_conc_monthly_cdr`). 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 [304, 448, 1] (North) and [316, 332, 1] (South), which are the xgrid, ygrid, and time, respectively.
Valid Range	0.0 to 1.0
Attributes	`_FillValue, valid_range, long_name, units, coordinates, missing_value, datum, grid_mapping`
Fill Value	-1.0
Units	Unitless

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 -1 (missing / fill value). **NOTE**: This variable applies to Northern Hemisphere files only. However, the variable does appear in the Southern Hemisphere files, but it is always filled with zeroes.
Data Type	Integer array with dimensions [304, 448, 1] (North), which are the xgrid, ygrid, and time, respectively.
Valid Range	60 to 244
Attributes	`_FillValue, valid_range, _Unsigned, long_name, standard_name, units, coordinates, missing_value, datum, grid_mapping`
Fill Value	-1.0
Units	Unitless

qa_of_seaice_conc_monthly_cdr

Description	A number of different quality flags related to the monthly NSDIC CDR sea ice concentration variable (`seaice_conc_monthly_cdr`). See Table 5 for a list of the monthly flags. **Note 1**: Grid cells that meet multiple conditions will have a value that is the sum of the values of each individual condition. For example, if the byte value for a cell is 129, both the `melt_detected_greater_than_half_month` flag and `BT_majority_algorithm_for_monthly_CDR` flag have been set.

Note 2: If the number of days used for the monthly average of a cell comes equally from the Bootstrap algorithm and from the NASA Team algorithm, then the byte value for a cell is set to 3 (`BT_majority_algorithm_for_monthly_CDR` + `NT_majority_algorithm_for_monthly_CDR`).

Data Type Byte array with dimensions [304, 448, 1] (North) and [316, 332, 1] (South), which are the xgrid, ygrid, and time, respectively.

Valid Range 1 to 255

Attributes `_FillValue, valid_range, _Unsigned, long_name, standard_name, units, coordinates, flag_masks, flag_meanings, missing_value, datum, grid_mapping`

Fill Value 0

Units Unitless

Table 5. Monthly QA Flag Values

Condition	Flag Value	NetCDF Variable Name	Description
Number of BT > Number of NT	1	BT_majority_algorithm_for_monthly_CDR	Indicates that the majority of the values used for the monthly average, at this grid cell, are from the Bootstrap algorithm.
Number of NT > Number of BT	2	NT_majority_algorithm_for_monthly_CDR	Indicates that the majority of the values used for the monthly average, at this grid cell, are from the NASA Team algorithm.
Region masked by ocean climatology	4	no_ice_allowed_per_climatology	Indicates that this grid cell has been designated as ocean via an ocean mask or valid ice mask.
Grid cell near the coast	8	grid_cell_near_to_coast	Indicates that this grid cell is located near the coastline, so it may be less reliable and of lower quality.
Ice present < 50%	32	ice_present_less_half_of_month	Indicates that for this grid cell ice was present less than half of the month, so the value is more likely due to a temporal difference of the concentration than a spatial one.

Condition	Flag Value	NetCDF Variable Name	Description
melt detected >= 1	64	melt_detected_at_least_one_day	Indicates that for this grid cell melt was detected at least one day during the month, so it may be less reliable and of lower quality.
Melt detected > 50%	128	melt_detected_greater_than_half_month	Indicates that for this grid cell melt was detected at least half of the days during the month, so it may be even less reliable and of lower quality than for those with melt detected less than half the month or not at all.

goddard_merged_seaice_conc_monthly

Description Merged GSFC NASA Team/Bootstrap monthly sea ice concentrations from 1978 through most recent processing. This variable is merged from the `goddard_nt_seaice_conc_monthly` and the `goddard_bt_seaice_conc_monthly` variables. For a description of the algorithm used to merge these, see section 2.3.3 CDR Algorithm. For a list of flag values for this variable, see Table 2.

Data Type Byte array with dimensions [304, 448, 1] (North) and [316, 332, 1] (South), which are the xgrid, ygrid, and time, respectively.

Valid Range 0 to 1. 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.

Attributes `_FillValue, valid_range, _Unsigned, long_name, standard_name, units, scale_factor, coordinates, flag_values, flag_meanings, datum, grid_mapping, reference, ancillary_variables`

Fill Value 255

Units Unitless

goddard_nt_seaice_conc_monthly

Description	GSFC NASA Team monthly sea ice concentrations from 1978 through most recent processing. These values come from the monthly portion of the *Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data*. For a list of flag values for this variable, see Table 2.
Data Type	Byte array with dimensions [304, 448, 1] (North) and [316, 332, 1] (South), which are the xgrid, ygrid, and time, respectively.
Valid Range	0 to 1. 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.
Attributes	`_FillValue, valid_range, _Unsigned, long_name, standard_name, units, scale_factor, coordinates, flag_values, flag_meanings, datum, grid_mapping, reference, ancillary_variables`
Fill Value	255
Units	Unitless

goddard_bt_seaice_conc_monthly

Description	GSFC Bootstrap monthly sea ice concentrations from 1978 through most recent processing. These values come from the monthly portion of the *Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS* data set. For a list of flag values for this variable, see Table 2.
Data Type	Byte array with dimensions [304, 448, 1] (North) and [316, 332, 1] (South), which are the xgrid, ygrid, and time, respectively.
Valid Range	0 to 1. 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.
Attributes	`_FillValue, valid_range, _Unsigned, long_name, standard_name, units, scale_factor, coordinates, flag_values, flag_meanings, datum, grid_mapping, reference, ancillary_variables`
Fill Value	255
Units	Unitless

projection

Description	Provides details about the polar stereo projection information for the data.
Data Type	Char array with dimension [304] (North) and [316] (South)
Valid Range	N/A
Attributes	`grid_boundary_top_projected_y, grid_boundary_bottom_projected_y, grid_boundary_right_projected_x, grid_boundary_left_projected_x, parent_grid_cell_row_subset_start, parent_grid_cell_row_subset_end, parent_grid_cell_column_subset_start, parent_grid_cell_column_subset_end, spatial_ref, proj4text, srid, GeoTransform, grid_mapping_name, latitude_of_projection_origin, standard_parallel, straight_vertical_longitude_from_pole, longitude_of_projection_origin, scaling_factor, false_easting, false_northing , semimajor_radius, semiminor_radius, units`
Fill Value	N/A
Units	Meters

time

Description	Time in days since 1601-01-01 00:00:00.
Data Type	Double
Valid Range	N/A
Attributes	`standard_name, units, long_name, calendar, axis`
Fill Value	N/A
Units	Days since 1601-01-01 00:00:00

xgrid

Description	X-offset in meters of the projection grid centers.
Data Type	Float array with dimension [304] (North) and [316] (South)
Valid Range	-3.85000e+006 to 3.75000e+006
Attributes	`valid_range, units, long_name, standard_name, axis`
Fill Value	N/A
Units	Meters

ygrid

Description	Y-offset in meters of the projection grid centers.
Data Type	Float array with dimension [448] (North) and [332] (South)
Valid Range	-5.35000e+006 to 5.85000e+006
Attributes	`valid_range, units, long_name, standard_name, axis`
Fill Value	N/A
Units	Meters

latitude

Description	Latitude in degrees north of the projection grid centers.
Data Type	Double array with dimensions [304, 448] (North) and [316, 332] (South)
Valid Range	0.0 to 90.0 for northern hemisphere files, and -90.0 to 0.0 for southern hemisphere files.
Attributes	`standard_name, long_name, units, valid_range, _FillValue`
Fill Value	-999.0
Units	Degrees north

longitude

Description	Longitude in degrees east of the projection grid centers.
Data Type	Double array with dimensions [304, 448] (North) and [316, 332] (South)
Valid Range	-180.0 to 180.0
Attributes	`standard_name, long_name, units, valid_range, _FillValue`
Fill Value	-999.0
Units	Degrees east

1.3.3 Directory Structure

The data files are organized on the FTP site into two main directories by hemisphere: north and south. Within each of these, there are three sub-directories: `checksums`, `daily`, and `monthly`. The `checksums` directory contains md5 checksums of the daily and monthly data files to ensure accuracy in data transfer. The daily directory 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 of the 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 6:

Daily: `seaice_conc_daily_hh_sat_yyyymmdd_vXXrXX.nc`

Monthly: `seaice_conc_monthly_hh_sat_yyyymm_vXXrXX.nc`

Where:

Table 6. File Naming Convention

Variable	Description
seaice_conc	Identifies files containing sea ice concentration data
daily	Identifies files containing daily sea ice concentration
monthly	Identifies files containing monthly sea ice concentration
hh	Hemisphere (nh: North, sh: South)
sat	Satellite the data came from (n07: Nimbus 7, f08: DMSP F8, f11: DMSP F11, f13: DMSP F13,f17: DMSP F17)
yyyy	4-digit year
mm	2-digit month
dd	2-digit day of month
vXXrXX	Version and revision number of the data file (v03r01: Version 3, Revision 1)
.nc	Identifies a NetCDF file
.nc.mnf	Identifies this as an md5 checksum file

Warning: When reading in the 1987 data files with some NetCDF readers, there is an issue with the order the data files are being read in. The older SMMR data, 1978 to 1987, are designated in the filename as *n07*; while the first SSMI data, starting in July 1987, are denoted in the filename as *f08*. Unfortunately, this sensor designation comes before the date in the filename. Thus, if you do a simple list of the files in alphabetical order for 1987, the newer SSMI files are listed first before the older SSMR data, which causes some readers to swap the months of July to December with January to June. To alleviate the problem rename the SMMR data files. A future version of the CDR will have this naming convention corrected to alleviate this issue.

1.3.5 File Size

File sizes are shown in Table 7.

Table 7. File Size

	Northern Hemisphere	Southern Hemisphere
Daily	2.5 MB - 3.7 MB each	1.8 MB - 2.5 MB each
Monthly	3.4 MB each	2.6 MB - 2.7 MB

1.4 Spatial Information

1.4.1 Coverage and Resolution

These data cover both the Northern and Southern polar regions at a 25 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 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 SSM/I channels used are the 19 GHz vertical, the 19 GHz horizontal, and the 37 GHz vertical. The IFOV of the 19 GHz SSM/I passive microwave channel is approximately 70 km x 45 km. See Table 18 for a complete list of IFOVs by channel.

Since these data are gridded onto a 25 x 25 km grid and the IFOV of the sensor is coarser than this, the sensor is obtaining information from up to a 3 x 2 grid cell (~75 km x 45 km) region, but because a simple drop-in-the-bucket gridding method is used, that signature is placed in a single grid cell. This results in a spatial "smearing" across several grid cells. Also, some grid cells do not coincide with the center of the sensor footprint and are thus left as missing even though there is brightness temperature information available at that region. 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 polar region are the following:

Northernmost Latitude: 31.10° N
Southernmost Latitude: 89.84° 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 8 for these sizes.

Table 8. Arctic Pole Hole Size

Instrument	Pole Hole Area (million km^2)	Pole Hole Radius (km)	Pole Hole Latitude
SMMR	1.19	611	84.5° N
SSM/I	0.31	311	87.2° N
SSMIS	0.029	94	89.18° N

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

Southernmost Latitude: 89.84° S

Northernmost Latitude: 39.36° 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. The grid size varies depending on the region, as shown in Table 9.

Table 9. Polar Stereo Grid Size

Region	Columns	Rows
North	304	448
South	316	332

1.5 Temporal Coverage and Resolution

The primary NOAA/NSIDC CDR sea ice concentrations (`seaice_conc_cdr` and `seaice_conc_monthly_cdr`) span 09 July 1987 to through most recent processing provided at both a daily resolution and a monthly averaged resolution. 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 data files or monthly data files are available for that time period.

The merged GSFC NASA Team/Bootstrap sea ice concentrations (`goddard_merged_seaice_conc` and `goddard_merged_seaice_conc_monthly`), that are analogous to the NOAA/NSIDC CDR sea ice concentrations, adds 01 November 1978 through 08 July 1987 data to the record at an every-other-day resolution. The two reference GSFC NASA Team and GSFC Bootstrap sea ice concentrations are also available for that time period. The Bootstrap GSFC-produced sea ice concentrations are provided at a daily resolution from 09 July 1987 to through most recent processing. The NASA team GSFC-produced sea ice concentration and the merged GSFC-produced sea ice concentration are provided at a daily resolution from 21 August 1987 through most recent processing. **Note:** Data files for the 1978 to 1987 time period still contain a variable for the primary CDR data (`seaice_conc_cdr` for daily file, `seaice_conc_cdr_monthly` for monthly file), but it is populated with a fill value of NaN. See Table 10 for a list of the dates that each of the different instruments were used for the CDR, Table 11 for the instruments used for the Goddard NT ancillary variables, and Table 12 for the instruments used for the Goddard BT ancillary variables. Also note that when there are no data for the Goddard NT ancillary variables but there are data for the Goddard BT ancillary variables, the merged version of the two variables (`goddard_merged_seaice_conc`) are filled with `NaN`. In addition, for the monthly averaged data when there is a change in instruments within that month that correspond to a change in Arctic pole hole size, the larger of the holes is used to process the data. See Table 8 for a list of these sizes.

In addition, a preliminary near-real-time version of this product is also available. The NRT CDR is meant as an interim data set to fill the time period between updates of the final CDR and to provide data up to the present. The NRT CDR is preliminary and does not go through the same quality control measures that the final CDR does, so it should be treated as such. You can access this interim product here: *Near-real-time NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration*.

Table 10. Time Period Each Instrument is Used in the CDR variables (seaice_conc_cdr and seaice_conc_monthly_cdr)

Platform and Instrument	Time Period
DMSP-F8 SSM/I	09 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 December 2007
DMSP-F17 SSMIS	01 January 2008 - most recent processing Note: There are no daily data from 19 March 2008 through 25 March 2008 and 30 October 2008 due to satellite problems.

Table 11. Time Period Each Instrument is Used in the Goddard NASA Team Ancillary Variables (goddard_nt_seaice_conc and goddard_nt_seaice_conc_monthly)

Platform and Instrument	Time Period
Nimbus-7 SMMR	01 November 1978 - 20 August 1987
DMSP-F8 SSM/I	21 August 1987 - 18 December 1991 Note: There are no data from 3 December 1987 through 12 January 1988 due to satellite problems.
DMSP-F11 SSM/I	19 December 1991 - 29 September 1995
DMSP-F13 SSM/I	30 September 1995 - 31 December 2007
DMSP-F17 SSMIS	01 January 2008 - most recent processing

Table 12. Time Period Each Instrument is Used in the Goddard Bootstrap Ancillary Variables (goddard_bt_seaice_conc and goddard_bt_seaice_conc_monthly)

Platform and Instrument	Time Period
Nimbus-7 SMMR	01 November 1978 - 31 July 1987
DMSP-F8 SSM/I	01 August 1987 - 17 December 1991 Note: There are no data from 3 December 1987 through 13 January 1988 due to satellite problems.
DMSP-F11 SSM/I	18 December 1991 - 09 May 1995
DMSP-F13 SSM/I	10 May 1995 - 31 December 2007
DMSP-F17 SSMIS	01 January 2008 - most recent processing

2 DATA ACQUISITION AND PROCESSING

2.1 Input Data

The input data for the sea ice CDR variables, the NASA team sea ice variables, and the Bootstrap sea ice variables are described in Table 13.

Table 13. Variable Input Data

Variable Name	Input Data Set Name	Input Data Set Version
seaice_conc_cdr and seaice_conc_monthly_cdr	*DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures*	Version 2: 09 July 1987 - 13 December 2006 Version 4: 14 December 1987 - most current processing
goddard_nt_seaice_conc and goddard_nt_seaice_conc_monthly	*Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data*	Version 1.1: 01 November 1978 - most current processing
goddard_bt_seaice_conc and goddard_bt_seaice_conc_monthly	*Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS*	Version 3.1: 01 January 2017 - most current processing Version 3.0: 01 November 1978 - 31 December 2016 (See 2.1.1 Bootstrap Data Technical Note for information on these versions.)

2.1.1 Bootstrap Data Technical Note

Beginning with January 2017 data, the Sea Ice Concentration CDR uses version 3.1 of the Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS data set (NSIDC-0079) as input to the following NetCDF variables: `goddard_bt_seaice_conc`, `goddard_bt_seaice_conc_monthly`, `goddard_merged_seaice_conc`, and `goddard_merged_seaice_conc_monthly`. All data prior to January 2017 use version 3.0 of the NSIDC-0079 data set.

Version 3.1 of the NSIDC-0079 ice concentrations computes sea ice concentration with an open water identifier that is calculated daily for the months of May and October. In version 3.0, this value was calculated using a single monthly value for May and a single monthly value for October. For complete details on the NSIDC-0079 version changes, please see the Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS, Version 3 documentation [https://nsidc.org/data/nsidc-0079].

Due to this change, users should note that there may be a small discontinuity in the variables mentioned above for data before and after January 2017 occurring in the months of May and October. Other months, as well as the sea ice CDR variables themselves, `seaice_conc_cdr` and `seaice_conc_monthly_cdr`, are not affected by this change.

2.2 Acquisition

2.2.1 NOAA/NSIDC CDR Sea Ice Concentrations

The input gridded brightness temperatures used for creating the daily NOAA/NSIDC CDR sea ice concentrations (`seaice_conc_cdr`) come from NSIDC in the *DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures* data set. These gridded brightness temperatures are produced by NSIDC from swath data obtained from Remote Sensing Systems (RSS). For a complete description of how NSIDC obtains and processes the input data, see the Data Acquisition Methods section of the *DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures* data set guide document. The input for the monthly CDR concentration (`seaice_conc_cdr_monthly`) is the daily CDR variable.

Note that the NOAA/NSIDC CDR does not currently include the SMMR product because full provenance and documentation of the SMMR brightness temperatures and processing methodology (for example, manual filtering of bad grid cells) cannot be assured, and thus, does not fulfill the CDR standards set forth by NRC (2004).

2.2.2 GSFC Sea Ice Concentrations

The data for the GSFC-produced sea ice concentrations are created by GSFC but are archived at NSIDC. NSIDC uses the archived products as input for these variables. The input data for the `goddard_nt_seaice_conc` and `goddard_nt_seaice_conc_monthly` variables are the *Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data*. This data set is also called the NASA Team sea ice concentration data set because the values are computed using the NASA team algorithm. See section 2.3.4 NASA Team Algorithm for a description of this algorithm.

The input data for the `goddard_bt_seaice_conc` and `goddard_bt_seaice_conc_monthly` variables are the *Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-*

SSMIS data. This data set is also called the Bootstrap sea ice concentration data set because the values are computed using the Bootstrap algorithm. See section 2.3.5 Bootstrap Algorithm for a description of this algorithm. Note that Goddard has recently released Version 3 of their Bootstrap product. They have made minor adjustments to the Bootstrap algorithm that are described in Comiso et al. (2017). NSIDC has not made these adjustments to our processing of the bootstrap algorithm but will do so in a future release of this product.

Note: These data are processed almost identically to the intermediate NSIDC-produced NASA Team and Bootstrap sea ice concentrations used in the CDR concentration estimates but are produced at NASA GSFC and include manual quality control. This hand editing removes spurious ice in grid cells that are not removed through automated filtering methods and any other bad data discovered through the manual inspection. However, the hand-editing process has not been documented and, thus, is not traceable, which means that they do not pass the traceability recommendations for CDRs from NRC (2004). In addition, older versions of the RSS brightness temperatures were used as input for some parts of the record, though these differences are small. Therefore, while the GSFC products do not have full traceability, they do result in a better overall quality record. In addition, they also include sea ice estimates from the NASA Nimbus-7 SMMR sensor, which predates DMSP and extends the total time series to late 1978 with every-other-day concentration estimates. The input data for the merged GSFC sea ice concentration variables (`goddard_merged_seaice_conc` and `goddard_merged_seaice_conc_monthly`) are the NASA Team and Bootstrap variables mentioned above. For a description of the algorithm used to merge the data, see section 2.3.3 CDR Algorithm.

2.3 Derivation Techniques and Algorithms

2.3.1 Overview

NSIDC processes the input brightness temperatures into two different intermediate sea ice concentrations using two GSFC-developed algorithms: NASA Team (Cavalieri et al. 1984) and Bootstrap (Comiso 1986). These intermediate NSIDC NASA Team and Bootstrap 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 the 19 GHz, 22 GHz, and 37 GHz frequencies. Table 14 lists the channels used for each algorithm and the channels used for the weather filters. For a complete description of the weather filters, see the Climate Algorithm Theoretical Basis Document (C-ATBD): Passive Microwave Sea Ice Concentration document (Meier, Savoie, and Mallory 2011).

Table 14. NASA Team and Bootstrap Algorithm Channels

	NASA Team	Bootstrap
Algorithm Channels	19H, 19V, and 37V	37H, 37V, and 19V
Weather Filters	22V and 19V	22V

Since this data set uses multiple sensors over time, the sea ice algorithms are intercalibrated at the product (concentration) level by NASA GSFC. 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 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 instruments adjusted the tie-points to be consistent with the original SMMR record. The Bootstrap algorithm uses daily varying hemispheric tie-points, derived via linear regression analysis on clusters of brightness temperature values of the relevant channels (Comiso 2009, Comiso and Nishio 2008). Also, in contrast to the NASA Team, Bootstrap tie-points for SMMR and SSM/I are derived from matching fields from the AMSR-E sensor, which is newer and more accurate.

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. Separate land-spillover corrections are used for each of the algorithms 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, valid ice masks are applied to the Northern Hemisphere and climatological ocean masks are applied to the Southern Hemisphere.

For a complete description of the automated filters and masks, see the C-ATBD (Meier, Savoie, and Mallory 2011).

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 describe below. Both of these algorithms have their own inherent advantages and limitations. For this CDR data set, the NASA Team-derived sea ice concentrations are merged with the Bootstrap-derived sea ice concentrations using the 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).
- 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).

NSIDC processes the input brightness temperatures into the two intermediate NASA Team and Bootstrap sea ice concentrations. The processing for the intermediate NASA Team concentrations for the sea ice CDR is nearly the same as the GSFC-processed *Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data* with two known differences. First, NSIDC uses a new brightness temperature version for the F8 period from what GSFC processed. Second, NSIDC uses a corrected version of brightness temperatures for F11 and F13, while GSFC used the uncorrected version. Spatial and temporal interpolation is done by GSFC, and they also perform an additional manual QC step. In comparisons between the two, there are occasional unexplained small differences.

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, Savoie, and Mallory 2011).

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 15. 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, Savoie, and Mallory 2011) for a table of tie-point values.

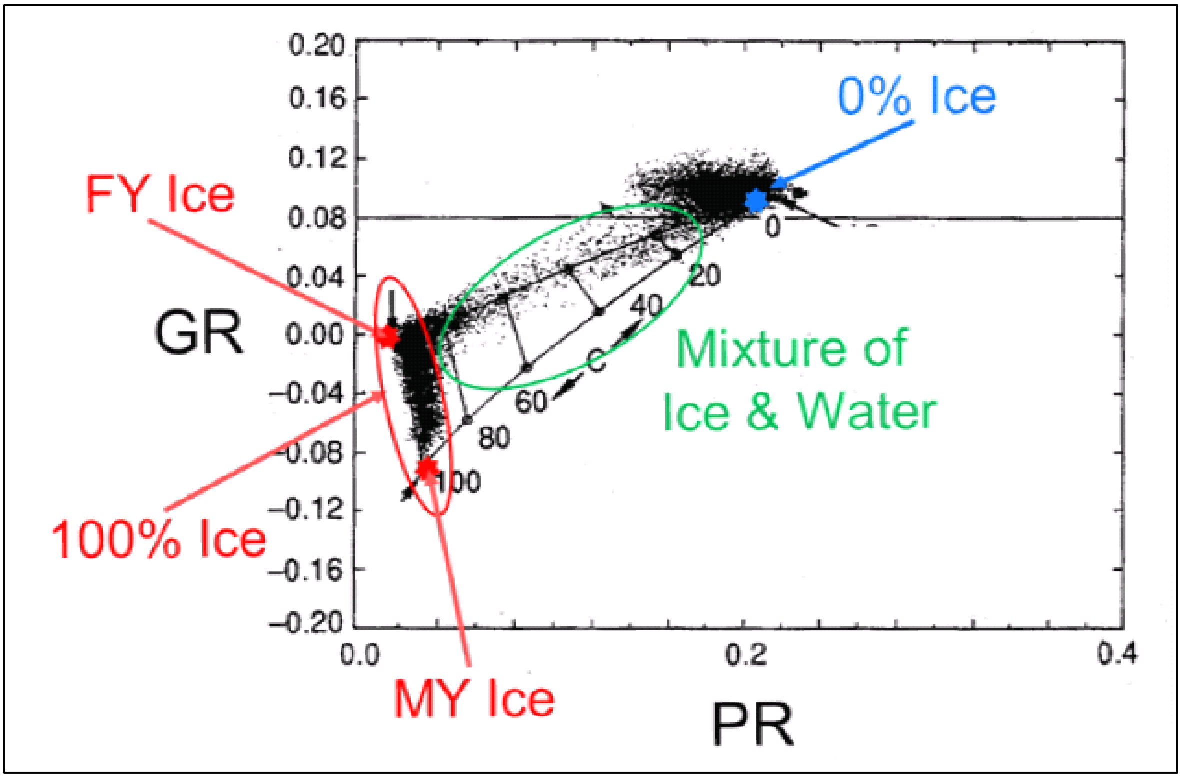

Figure 1. Sample plot of GR vs. PR with typical clustering of grid cell values (small dots) around the 0% ice (open water) point (blue star) and the 100% ice line (circled in red). Points with a mixture of ice and water (circled in green) fall between these two extremes. Adapted from Figure 10-2 of Steffen 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 16. 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

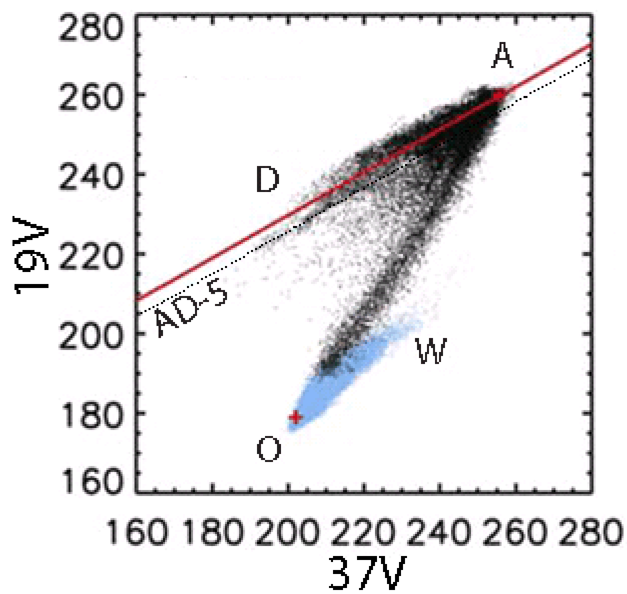

Figure 2. Example of the relationship of the 19V vs. 37V T_B (in Kelvin) used in the Bootstrap algorithm. Brightness temperatures typically cluster around the line segments AD (representing 100% sea ice) and OW (representing 100% open water). For points that fall below the AD-5 line (dotted line), Bootstrap 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. In addition, the source code is provided for transparency of the algorithm and processes used in creating the sea ice CDR. This source code is for reference only and is not intended to be portable to any computer system beyond that of the original CDR producer's environment. You can access the code from the NOAA Climate Data Record Program's Operation CDR Web page under the Oceanic CDRs section.

2.4.1 Daily Files

The following are the general steps NSIDC uses to produce the daily NOAA/NSIDC CDR sea ice concentration product. See Figure 3 for a diagram of the data flow.

1. Obtain input brightness temperatures from the NSIDC *DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures* (NSIDC-0001) data set. See Table 14 for a list of channels used.
2. Process the brightness temperatures into two intermediate sea ice concentration products using both the NASA Team and Bootstrap algorithms — the two orange objects towards the bottom of the middle blue panel in Figure 3.
3. Merge the intermediate NSIDC NASA Team and Bootstrap data into the final CDR using the CDR algorithm and populate the `seaice_conc_cdr variable`.
4. Compute the CDR sea ice concentration standard deviation (`stdev_of_seaice_conc_cdr`) and flag values (`qa_of_seaice_conc_cdr`).
5. Populate the `goddard_nt_seaice_conc` variable with the GSFC NASA Team daily data: *Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data* (NSIDC-0051).
6. Populate the `goddard_bt_seaice_conc` with the GSFC Bootstrap daily data: *Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS* (NSIDC-0079).
7. Merge the GSFC NASA Team and GSFC Bootstrap sea ice concentrations using the CDR algorithm to create the merged variable (`goddard_merged_seaice_conc`).
8. Add melt-indicator flag to the QA variable (`qa_of_seaice_conc_cdr`) via a post-processing step.

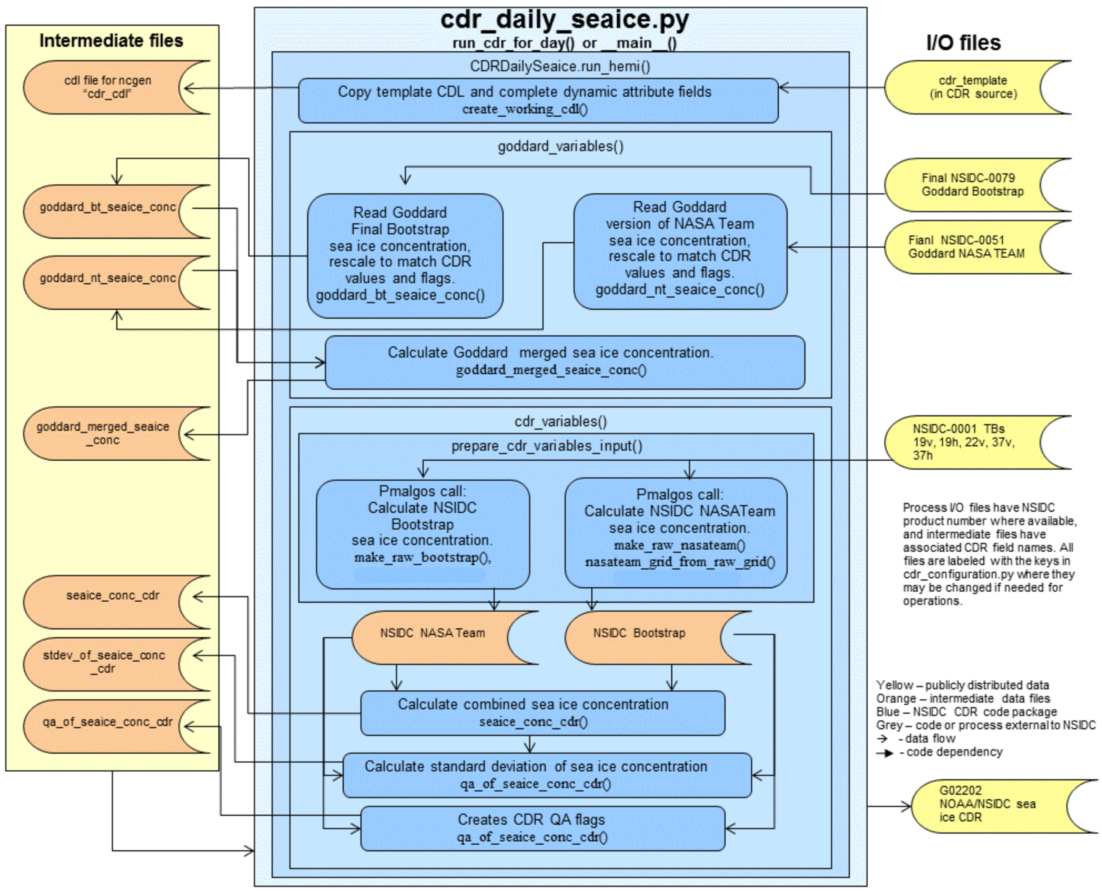

Figure 3. Flow of Data through the Daily CDR Processing. Click for larger view.

2.4.2 Monthly Files

The following are the general steps NSIDC uses to produce the monthly NOAA/NSIDC CDR sea ice concentration product. See Figure 4 for a diagram of the data flow.

1. Read the input data: CDR daily sea ice concentration (`seaice_conc_cdr`).
2. Compute the monthly mean concentration for each grid cell for a given month from the daily values.
3. Compute the standard deviation and quality flags.
4. Obtain the monthly NASA Team sea ice concentrations from the *Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data* data set, used to fill the `goddard_nt_seaice_conc_monthly` variable.
5. Obtain the monthly Bootstrap sea ice concentrations from the *Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS* data set, used to fill the `goddard_bt_seaice_conc_monthly` variable.
6. Use the CDR algorithm to merge the GSFC NASA Team and Bootstrap data for the `goddard_merged_seaice_conc_monthly` variable.
7. Populate the monthly netCDF variables and create the files.

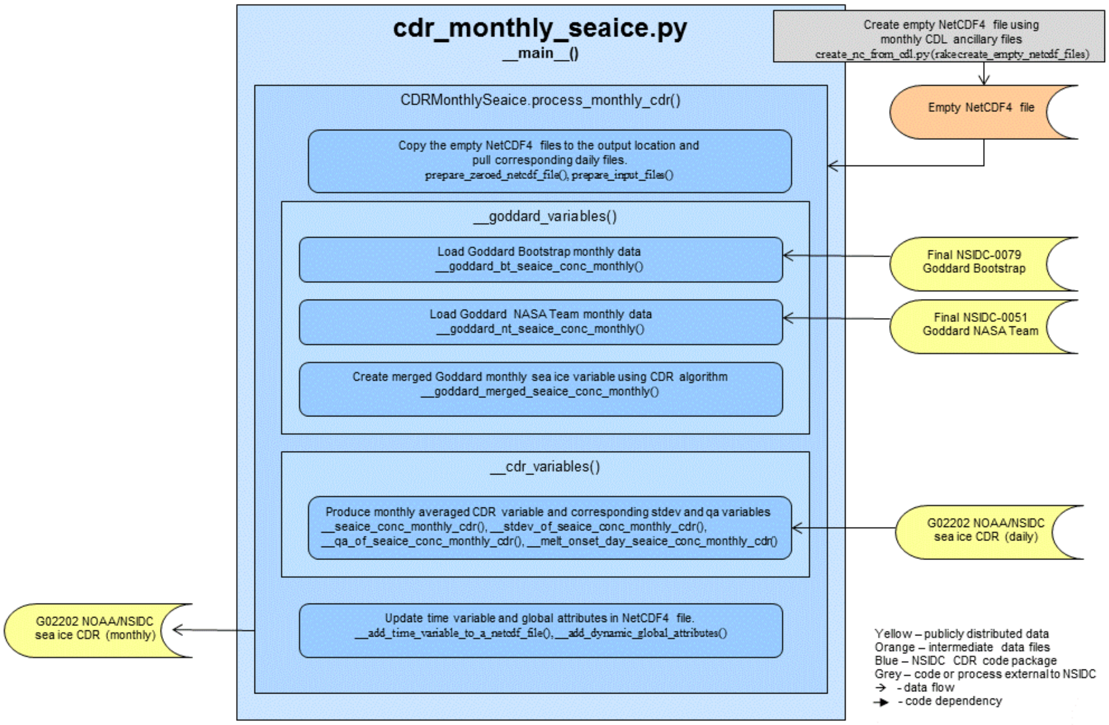

Figure 4. Flow of Data through the Monthly CDR Processing. Click for larger view.

2.5 Errors Sources

Several studies over the years have assessed sea 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 instrument but with only local or regional coverage. Several assessments indicate an accuracy of approximately five percent 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). 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) found a difference with operational charts that was relatively low in the winter, but rose to more than 20 percent in summer.

Researchers can assess and improve a CDR by comparing it with operational products — real-time products that help ships cross the sea ice. Absolute error can be approximated via comparison to operational sea ice products, such as those produced by the U.S. National Ice Center (NIC) or the Canadian Ice Service, but it is important to keep in mind that such products have an operational focus different from the climate focus of the CDR, and the two are not expected to be consistent with each other. The documentation for the daily *Multi-Sensor Analyzed Sea Ice Extent* (MASIE), distributed by NSIDC in cooperation with NIC, gives a summary of how satellite passive microwave CDRs differ from operational products.

Errors can come from problems with the sensor, from weather effects, and from inadequacies in the algorithm. A satellite's orbit may drift over time, for example, which may degrade the data quality of an instrument. Most SSM/I instruments were used long past their designed lifetime expectancy. Atmospheric water vapor is a weather effect that can modulate the passive microwave signature of the surface, particularly at the 19 GHz frequency, causing ice concentration to be overestimated. The emissivity of sea water is generally stable, except under strong winds that cause waves to form. The emissivity of sea ice varies considerably depending on many factors including age, thickness, and surface roughness. When one considers that algorithms must arrive at a single number for ice concentration, taking into account the varying brightness temperatures of all the different surface types that may fill the footprints of the 19 GHz and 37 GHz channels, and that those footprints differ in size and shape across the instrument swath, one can appreciate the difficulty of the problem. Microwave Remote Sensing of Sea Ice, edited F. Carsey, provides a comprehensive overview of the subject (Carsey 1992).

Another potential sensor error results from the transition between sensors on different platforms. The brightness temperature regression and tie-point adjustment corrects for this, though small artifacts remain (Cavalieri et al. 1999; Comiso and Nishio 2008). Comparison of ice extent estimates from sensor overlap periods indicate that the adjustments yield agreements that are on the order of 0.05 percent or less and about 0.5 percent for sea ice area (Cavalieri et al. 1999; Cavalieri et al. 2011). Short overlap periods of early sensor transitions (SMMR to F8 and F8 to F11) may not account for the full seasonal variability (Meier and Khalsa 2011b; Cavalieri et al. 2011) and differences may be higher in some cases. However, differences appear to be well below the sensitivity of the instrument, thus, providing confidence in the robustness of the intercalibrated algorithms through the time series.

When melt ponds form on the surface of ice floes in the summer, the ice concentration appears to decline when in fact the true concentration may not have changed (Fetterer and Untersteiner 1998). Melt state is a surface effect that may in itself contain a climate trend, which could influence sea ice concentration trend estimates. This and other concentration error sources have been examined to some extent in Andersen et al. (2007), and their influence appears to be small compared to the estimated sea ice trends, but such effects should be kept in mind when using these data.

The netCDF4 files contain a variable called `qa_of_seaice_conc_cdr` to help data users assess the quality of a given data value. Table 3 gives a list of the flags, their values, and their meaning. Values less than eight indicate that conditions for high error are not present — though errors could still be high — and also denotes the algorithm source (NASA Team or Bootstrap) or area covered by a climatological ocean mask or valid ice mask. Values greater than or equal to eight indicate that conditions exist that could increase error, with higher values generally indicating greater uncertainty and hence less confidence in the CDR concentration estimate. **Note**: Grid cells that meet multiple conditions will have a value that is the sum of the values of each individual condition.

For a more complete description of error sources and assessments, see the C-ATBD (Meier, Savoie, and Mallory 2011).

2.6 Differences in the NOAA/NSIDC Concentration CDR and the Merged GSFC-Produced Concentration

The NOAA/NSIDC concentration CDR variables (`seaice_conc_cdr` and `seaice_conc_monthly_cdr`) are very similar to the merged GSFC-produced concentration variables (`goddard_merged_seaice_conc` and `goddard_merged_seaice_conc_monthly`). Although the differences are subtle, they are important.

The GSFC-merged concentrations are produced from the final, fully quality-controlled NASA Team and Bootstrap concentrations produced at GSFC. These fields include thorough quality control, including manual correction/replacement of bad values (for example, false ice due to weather effects over the ocean), and spatial or temporal interpolation to fill in missing values. It encompasses the entire SMMR-SSM/I-SSMIS record from late 1978 to present.

The NOAA/NSIDC CDR concentrations are based on the same NASA Team and Bootstrap algorithms at Goddard, but run in-house at NSIDC. There is no spatial/temporal interpolation and there is no manual quality control. It encompasses only the SSM/I-SSMIS record from mid-1987 to present. SMMR was not processed because NSIDC had never processed sea ice algorithms on SMMR and there is a need for considerable manual checking of SMMR to obtain "clean" sea ice fields.

The CDR parameter was created to meet the NOAA CDR Program criteria - most notably fully transparent and reproducible processing. The GSFC-merged data do not meet this requirement because of the manual quality control aspect. However, in terms of overall quality, the GSFC-merged data are better because the quality control cleans up erroneous retrievals and also interpolates for missing data, so the fields are complete.

For more details on the differences between the two different concentration products, see Meier et al. (2014) and Peng et al. (2013) which compare the two and show that the differences at the total extent/area level are mostly in the noise and there is very little difference in terms of trends.

2.7 Instrumentation

For the NOAA/NSIDC CDR data (`seaice_conc_cdr`), NSIDC uses brightness temperatures from SSM/I sensors on the DMSP-F8, -F11, and -F13 platforms and from the SSMIS sensor on DMSP-F17. See Table 17 for a description of orbital parameters of the different platforms. 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 DMSP satellites. Note that the SMMR sensor on the Nimbus-7 platform is used for the merged GSFC NASA Team/Bootstrap data (`goddard_merged_seaice_conc`), the GSFC NASA Team data (`goddard_nt_seaice_conc`), and the GSFC Bootstrap data (`goddard_nt_seaice_conc`) from 1978 to 1987.

Table 17. Comparison of Orbital Parameters

Parameter	Nimbus-7	DMSP-F8	DMSP-F11	DMSP-F13	DMSP-F17
Nominal Altitude*	955 km	860 km	830 km	850 km	850 km
Inclination Angle	99.1 degrees	98.8 degrees	98.8 degrees	98.8 degrees	98.8 degrees
Orbital Period	104 minutes	102 minutes	101 minutes	102 minutes	102 minutes
Ascending Node Equatorial Crossing (local time)	~ 12:00 p.m.	~ 6:00 a.m.	~ 5:00 p.m.	~ 5:43 p.m.	~5:31 p.m.
Algorithm Frequencies*	18.0, 37.0 GHz	19.4, 37.0 GHz	19.4, 37.0 GHz	19.4, 37.0 GHz	19.4, 37.0 GHz
Earth Incidence Angle*	50.2	53.1	52.8	53.4	53.1
3 dB Beam Width (degrees)*	1.6, 0.8	1.9, 1.1	1.9, 1.1	1.9, 1.1	1.9, 0.4

*Indicates sensor and spacecraft orbital characteristics of the three sensors used in generating the sea ice concentrations.

Table 18 lists the footprint size of the SSM/I instrument.

Table 18. SSM/I Footprint Size

Frequency (GHz)	SSM/I IFOV (km)
19.350	70 x 45
22.235	60 x 40
37.000	38 x 30

For a complete description of these instruments, see the SMMR, SSM/I, and SSMIS Sensors Summary.

3 SOFTWARE AND TOOLS

There are a number of netCDF file readers available to read/view netCDF files. For a list of some of these tools, please see the NetCDF Resources at NSIDC: Software and Tools Web page.

You can also visualize, subset, and download data via NOAA's Polar Watch web site.

4 VERSION HISTORY

Table 19. Version History

Version	Release Date	Description of Changes
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 Bootstrap Data Technical Note for more information. This change does not affect the sea ice concentration CDR data variables.
v03r01	December 2017	Relese 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 futrue version of the CDR product. In addtion, 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.

Version	Release Date	Description of Changes
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. See the C-ATBD (Meier, Savoie, and Mallory 2011) for complete details on the use of these masks.
v02r00	September 2016	Data are now available through 2014.
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. As of June 2013 with the release of the Version 2 data, the Version 1 data is no longer available. However, if you still have v1 data, the old documentation can be found here: NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 1.

5 RELATED DATA SETS

- *Near-real-time NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration*
- *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*

6 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).

7 CONTACTS AND ACKNOWLEDGMENTS

Walt Meier (PI)

Florence Fetterer (Co-I)

Julienne Stroeve (Co-I)

National Snow and Ice Data Center (NSIDC)

Boulder, Colorado USA

7.1 Acknowledgments:

The development of this product was supported in part by a grant NA07OAR4310056 from the NOAA NCDC Climate Data Record Program. Production of original NASA Team and Bootstrap algorithm estimates 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. It is maintained at NSIDC with support from the NOAA National Centers for Environmental Information.

8 REFERENCES

Andersen, S., R. Tonboe, L. Kaleschke, G. Heygster, and L. T. Pedersen. 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, https://doi.org/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. of 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.

Eaton B., J. Gregory, H. Centre, B. Drach, K. Taylor, and S. Hankin. 2010. NetCDF Climate and Forecast (CF) Metadata Conventions Version 1.5. Programs for Climate Model Diagnosis and Intercomparison. 81 pp. http://cf-pcmdi.llnl.gov/documents/cf-conventions/1.5/cf-conventions.pdf. Accessed Sep. 2011.

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

Gloersen, P., W. J. Campbell, D. J. Cavalieri, J. C. Comiso, C. L. Parkinson, and H. J. Zwally. 1993. Arctic and Antarctic Sea Ice, 1978-1987: Satellite Passive-Microwave Observations and Analysis. NASA Spec. Publ. 511, 290 pp.

Gloersen, P. and D. J. Cavalieri. (1986). Reduction of weather effects in the calculation of sea ice concentration from microwave radiances. *Journal of Geophysical Research: Oceans* 91(C3): 3913-3919.

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., 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., M. Savoie, and S. Mallory. 2011, updated 2017. CDR Climate Algorithm and Theoretical Basis Document: Sea Ice Concentration, Rev 6. ed. F. Fetterer and A. Windnagel. NOAA NCDC CDR Program.

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.

9 DOCUMENT INFORMATION

9.1 Author

A. Windnagel

9.2 Publication Date

July 2011

9.3 Revision History

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.