National Snow and Ice Data Center

ADVANCING KNOWLEDGE OF EARTH'S FROZEN REGIONS

NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration Version 4 Analysis

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1. Summary

The NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration (G02202) was updated to Version 4 in June 2021. This data set provides a Climate Data Record (CDR) of sea ice concentration from passive microwave data from the Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR); the DMSP F08, F11, and F13 Special Sensor Microwave Imager (SSM/I); and the DMSP F17 and F18 Special Sensor Microwave Imager/Sounder (SSMIS). This document describes the changes that were made to create Version 4. In addition, the near-real-time (NRT) counterpart to the sea ice concentration CDR, the Near-Real-Time NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration (G10016), which uses the same code base but with NRT input data, was also updated to Version 2. The changes noted in this document also pertain to that data set.

The goal with the Version 4 product was to create a sea ice concentration data set that, in an automated way, is as consistent as possible with the Goddard NASA Team (NT) and Bootstrap (BT) sea ice concentration products: 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). These two Goddard products have been manually corrected by NASA investigators to them to make them spatially and temporally complete and consistent data sets. However, the manual corrections are not tracked (thus not reproducible) and do not conform to the NOAA Climate Data Record (CDR) program criteria (NRC 2004). To be considered a CDR, a data product must be fully automated, reproducible, and fully documented. To that end, the Version 4 CDR is created using open-source code that performs a number of spatial and temporal interpolations and applies weather, land spillover, and valid ice filters so that the CDR data comport with the Goddard products. This document describes these procedures and provides a comparison of the Version 4 sea ice CDR with the Goddard products as well as a comparison with the Version 3 CDR.

2. Overview of Changes

Following are the major changes implemented in the Version 4 sea ice concentration CDR. These are described further in later sections of this document and in complete detail in the Sea Ice Concentration CDR C-ATBD document (Meier, Windnagel, & Stewart, 2021).

1. Added SMMR data to the period of record so that the daily CDR sea ice variable now spans 25 October 1978 through to the most recent processing, and the monthly CDR variable spans from November 1978 through to the most recent processing. See section 3 for more information.

2. Added NSIDC-produced daily and monthly NASA Team (NT) and NASA Bootstrap (BT) variables:
    - nsidc_nt_seaice_conc and nsidc_nt_seaice_conc_monthly
    - nsidc_bt_seaice_conc and 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. See sections 4 and 5 for more information.

4. Arctic pole hole filled by spatial interpolation. See section 4.2 for more information.

5. NSIDC's BT algorithm has been updated to version 3.1, the current version for the Goddard 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. See section 6 for more information.

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. Variables have been renamed as shown in Table 1.

Table 1. List of Version 4 Variable Names that Changed

Applicable File	Old V3 Variable Name	New V4 Variable Name
Daily	seaice_conc_cdr	cdr_seaice_conc
Daily	melt_onset_day_seaice_conc_cdr	melt_onset_day_cdr_seaice_conc
Daily	stdev_of_seaice_conc_cdr	stdev_of_cdr_seaice_conc
Daily	qa_of_seaice_conc_cdr	qa_of_cdr_seaice_conc
Monthly	seaice_conc_monthly_cdr	cdr_seaice_conc_monthly
Monthly	melt_onset_day_cdr_seaice_conc_monthly	melt_onset_day_cdr_seaice_conc_monthly
Monthly	stdev_of_seaice_conc_monthly_cdr	stdev_of_cdr_seaice_conc_monthly
Monthly	qa_of_seaice_conc_monthly_cdr	qa_of_cdr_seaice_conc_monthly

9. Removed the following Goddard-produced variables (see section 7):
- goddard_merged_seaice_conc and goddard_merged_seaice_conc_monthly
- goddard_nt_seaice_conc and goddard_nt_seaice_conc_monthly
- goddard_bt_seaice_conc and 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. Individual land masks have been merged into one composite land mask for easier reference and use in processing.

3. SMMR Era Data

Prior to Version 4, the sea ice concentration CDR did not include the SMMR era (Oct. 1978 to Jul. 1987) in its time series. This was due to the poor quality of the SMMR instrument data. The NASA Goddard NT and BT sea ice concentration products (NSIDC-0051 and NSIDC-0079, respectively) were able to include the SMMR era because Goddard investigators performed extensive manual edits to the SMMR input brightness temperature (T_B) data and/or the output concentration fields.

To create the version 4 sea ice concentration CDR, care had to be taken with processing the SMMR data to remove false ice detections due to weather effects or land spillover and to alleviate bad concentration data due to bad or corrupted brightness temperature data. We arrived at a fully automated process for doing so by adjusting weather filters, applying a day-of-year climatology "valid ice" mask, and removing bad data that escaped these steps using a thresholding method. We judged success by the degree to which Arctic- and Antarctic-wide ice extent derived from automatically-produced concentration fields matched extent derived from the concentration fields of a Goddard Merged product (created from the Goddard manually QC-ed NT and BT fields). The remainder of this section describes the process in more detail. Section 8 describes the differences between CDR V4 and the Goddard Merged product that remain in the ice extent record.

SMMR data were highly influenced by weather effects – locally higher brightness temperature due to atmospheric emission (particularly from precipitating clouds) and/or wind-roughening of the ocean surface – as well as land spillover (false ice along the coast). These led to substantial spurious ice in open ocean regions. At Goddard, researchers interactively removed false ice based on expert assessment. For the CDR, as much spurious ice as possible was removed by applying both NT and BT weather filters (described further in section 6) and a land-spillover correction routine. A day-of-year valid sea ice climatology mask was applied, and ice detected outside of the day's mask was removed. This day-of-year climatology mask was derived from the Goddard BT (NSIDC-0079) product. For each day of the year, the maximum extent (i.e., every grid cell where ice occurred on that day in any year of the SMMR era) was used for the day-of-year mask.

SMMR era data have numerous data gaps through the record. One reason is that the SMMR instrument collected data every other day. CDR V4 processing creates a daily resolution product by temporally interpolating to fill in concentrations for the missing days. In addition, the SMMR instrument often had technical difficulties that led to missing swaths of brightness temperature data. Temporal and spatial interpolation was performed to fill in as many of the resulting gaps in ice concentration data as possible. Any remaining grid cell values that could not be filled by interpolation were flagged as missing. See sections 4 and 5 for details of the interpolation.

Care in applying weather filters and using interpolation to fill many gaps improved the degree to which the CDR V4 ice extent record matched that of the Goddard Merged record. On some days, however, large differences in ice extent remained; and we suspected that the fields of brightness temperature data being used as input to CDR processing included corrupt data or large amounts of missing data. Visual examination of a number of cases confirmed this – brightness temperature fields showed missing data or obvious artifacts in emissivity that were clearly not due to changes in ice concentration or weather. See Figure 1.

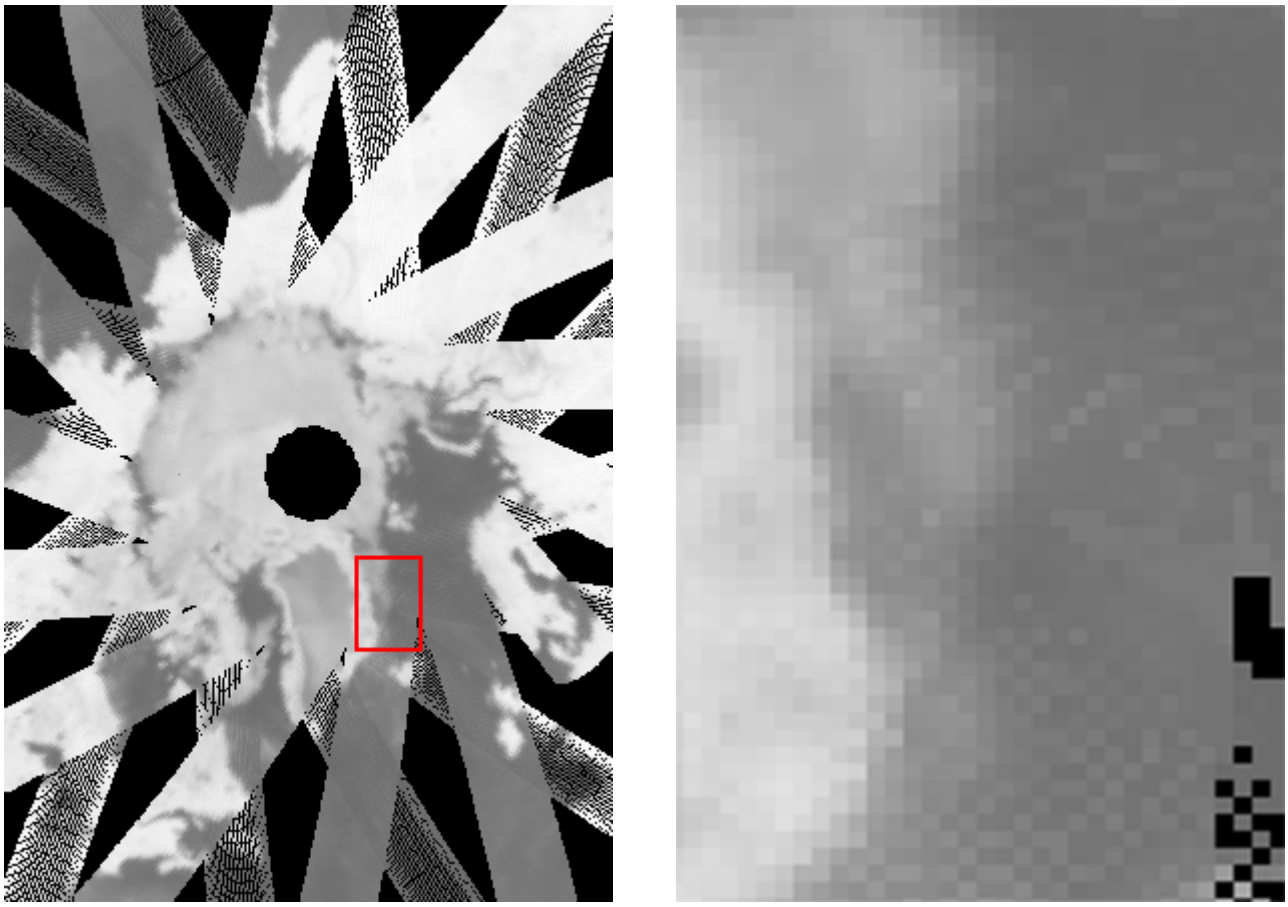

Figure 1. The image on the left shows an example of corrupt SMMR data for 18 July 1984. Note the differences in quality and coverage between ascending and descending swaths. The data have a "checkerboard" pattern over many Arctic pixels that results in erroneous sea ice estimates. The image on the right is a close up of the red box in the image on the left to show the detail in the corrupt data.

If corrupt data permeated a large region, the difference in extent with Goddard Merged was large, if only small areas had bad or missing data, extent differences were not as large. Based on this analysis, and through manual inspection of graphs of the extent difference like those in Figure 2 and Figure 3, thresholds were set to permit or exclude days for which the difference in ice extent fell below or above some number of square kilometers. The threshold for the Arctic was set to extent difference values less than -0.6 million sq km or greater than 0.4 million sq km; and for the Antarctic, values less than -0.4 million sq km and greater than 0.4 million sq km. Days with extent differences outside of these bounds were either defined as containing too much corrupt or missing data to be useable and were removed from the processing stream (Table 2) or flagged as containing corrupt or missing data but that may still be useable in some instances (Table 3).

Table 2 lists the dates removed using the thresholding procedure. In the process of visually inspecting fields to arrive at thresholds, we noted that some dates only have small amounts of corrupt or missing data, but the automated process was unable to fill these in by interpolation. These were left in the data record since most of the data on these days are usable, but they are noted in Table 3 for reference, as they could cause issues in analyses of the time series. Note that even with this automated thresholding method of removing bad or missing data, there may be cases that escaped our detection.

Table 2. Dates removed from the CDR due to corrupt or missing SMMR data

Arctic	Antarctic
7/3/1984 - 8/4/1984	8/12/1984 - 8/24/1984
8/12/1984 - 8/24/1984	8/5/1985 - 8/9/1985
12/4/1986 - 12/10/1986	12/4/1986 - 12/10/1986

Table 3. Dates of partial CDR fields due to corrupt or missing SMMR data

Arctic	Antarctic
6/7/1979 - 6/20/1979	8/4/1982 - 8/9/1982
3/28/1986 - 4/18/1986	8/25/1984 - 8/26/1984
	8/4/1985
	8/10/1985 - 8/11/1985
	3/30/1986 - 4/8/1986
	12/11/1986 - 12/12/1986

4. Spatial Interpolation Description

Two different spatial interpolations were applied to the Version 4 CDR. The first was applied to the input brightness temperatures to fill small gaps and the second was applied to the Arctic pole hole to estimate sea ice concentration in that region. These two interpolation schemes were added to make CDR V4 as spatially complete as possible. See the sections below for details.

4.1 Brightness Temperatures

The input brightness temperatures that are used to produce the sea ice CDR sometimes contain small gaps in the data fields. These empty grid cells result from the drop-in-the-bucket method of gridding swath data to the polar stereographic grid. The empty cells are generally isolated, that is, 1 or 2 missing grid cells surrounded by cells with valid brightness temperature values. These missing grid cells are filled by bilinear interpolation, i.e., a missing grid cell in the brightness temperature field is filled with the average of the four grid cells that surround it: one above, one below, one to the left, and one to the right. If four cells with valid values are not available, three may be used, but no fewer. A variable in the NetCDF files called spatial_interpolation_flag marks the channels that were interpolated. If a grid cell was not spatially interpolated, then the value in that variable for that grid cell is zero. See Table 4 for a description of the flag values.

Table 4. Flag value description for spatial_interpolation_flag variable

Condition	Flag Value	Label in NetCDF Variable
19 GHz vertical T_B spatially interpolated	1	19v_tb_value_interpolated
19 GHz horizontal T_B spatially interpolated	2	19h_tb_value_interpolated
22 GHz vertical T_B spatially interpolated	4	22v_tb_value_interpolated
37 GHz vertical T_B spatially interpolated	8	37v_tb_value_interpolated
37 GHz horizontal T_B spatially interpolated	16	37h_tb_value_interpolated
Pole hole spatially interpolated	32	pole_hole_value_interpolated

4.2 Pole Hole

A polar orbit and wide swath provides near-complete coverage at least once per day in the polar regions except for a small region around the North Pole called the pole hole. A spatial interpolation has been applied to the concentration field to fill this pole hole area. The method involves averaging all sea ice concentration grid cell values that surround the hole and then filling the missing grid cells within the hole with that average. Thus, all grid cells within the pole hole have the same concentration value. The spatial_interpolation_flag variable for these cells is set to 32, identifying this region as being interpolated.

5. Temporal Interpolation Description

To fill larger gaps in the data such as missing swaths or missing days of data, a temporal interpolation is implemented on the sea ice concentration data. Areas of missing concentration on a given date are filled using a linear interpolation of concentrations in that region from surrounding days. Specifically, data are interpolated with sea ice concentration values from each side of the missing data (both before and after, up to five days on either side). If this paired interpolation fails, i.e., if there are no values before and after within five days, then a one-sided interpolation is performed where the single closest value within three days (before or after) is chosen and copied to the missing grid cell.

A variable in the NetCDF files called temporal_interpolation_flag marks the data that were interpolated. The value for each flag is a 1- or 2-digit number indicating the data points used in the interpolation. The first number indicates how many days in the past the data point came from, and the second number indicates how many days in the future the data point came from, with a max of five days in either direction for the paired interpolation and three days on either side for the one-sided 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 did was not temporally interpolated, the value in this variable for that grid cell is zero. The minimum flag value for this variable is zero and the maximum is 55.

Note: Even after temporal interpolation has been applied, there are still occasional missing data due to large data gaps or bad input data that were too great for the interpolation to cover. See the Temporal Coverage section of the sea ice CDR user guide for a list of these gaps.

6. Weather Filter Thresholds and Intersensor Calibration

Both the NASA Team and Bootstrap algorithms implement weather filters – thresholds of brightness temperatures or ratios of brightness temperatures – to prevent artifacts of false ice in ocean regions where sea ice clearly does not exist. These artifacts arise due to atmospheric emission or wind roughening of the ocean surface, which increases microwave emission to the point where the algorithms interpret it as sea ice. Weather filters essentially remove low concentration ice that is likely not ice, but rather weather contamination.

The Bootstrap weather filter uses thresholds in the 37 GHz versus 19 GHz T_Bs and (for SSM/I and SSMIS only) the 22 GHz minus the 19 GHz T_B difference versus 19 GHz T_Bs. The NASA Team algorithm includes two weather filters that are gradient ratio (GR) thresholds of the 37 GHz and 19 GHz vertical (V) polarization (GR3719) and (for SSM/I and SSMIS only) the 22 GHz and 19 GHz V polarization (GR2219).

In the previous version of the CDR (version 3), the BT and NT algorithms, including their individual weather and land-spillover filters, were run independently. Then their concentrations were combined while using the BT concentration to define the ice edge in the CDR. Specifically, the CDR parameter included ice only where BT included ice. However, in developing the automated processing, it was found that the BT weather filter left many false ice artifacts, particularly in the SMMR fields. The NT weather filters, particularly the GR3719, were found to be more effective at removing weather artifacts. So, for Version 4 of the CDR, the NT and BT algorithms were run to derive concentration and then both of their weather and land-spillover corrections were applied. If any of the correction filters removed ice, then the ice was removed from the CDR.

When a data product time series extends over multiple satellite instruments, calibration must be performed to align the data from each instrument so that consistency is maintained across each satellite transition (Cavalieri et al., 1999). Over the period of overlap, ice concentrations and extents from one instrument should match ice concentrations and extents from the follow-on instrument. To accomplish this, adjustments need to be made to account for differences in the input passive microwave brightness temperatures from different sensors. This is done through the adjustment of “tiepoints” or coefficients representing pure surface types (i.e., 100% ice or 100% ocean). This adjustment also includes the weather filter because the weather filter essentially sets a threshold, based on the brightness temperatures, where valid ice concentrations are allowed. Thus, the weather filter thresholds have sometimes been adjusted to produce optimal consistency between sensors.

For the Southern Hemisphere SMMR data, the Goddard NASA Team found that a GR3719 threshold of 0.07 created a smooth transition from SMMR to SSM/I. For the Southern Hemisphere SSMIS data, a threshold of 0.053 was found to create a smooth transition from

SSM/I to SSMIS. During the creation of CDR V4, however, a discontinuity in the sea ice concentration values was noted in the Southern Hemisphere at the boundary of the SMMR to SSM/I transition and the SSM/I to SSMIS transition. This was due to the application of both the NT and BT weather filters, which created discontinuities compared to their use only in their respective algorithms. So, adjustment in some weather filter threshold values in the Southern Hemisphere was needed to produce optimal consistency in the CDR. After testing a range of threshold values, it was found that setting the SMMR GR3719 threshold to 0.076 and the SSMIS GR3719 threshold to 0.057 alleviated much of the discontinuity in CDR V4. For complete details on these weather filters, see the Sea Ice Concentration C-ATBD (Meier, Windnagel, & Stewart, 2021).

7. Reason for Removal of Goddard Produced Variables

The Goddard produced variables were removed from the Version 4 sea ice concentration CDR for the following reasons:

- They were initially included because they span a longer time series of November 1978 to present, whereas CDR V3 began in July 1987. With CDR V4, the CDR time series now begins on 25 October 1978, so the Goddard products are no longer needed to fill that time period.
- They do not conform to the definition of a CDR; and thus, do not belong in a CDR data product.
- Due to the latency of the input data for these products of up to a year, it caused the updating of the CDR product to also lag by a year. Without the Goddard variables in the CDR V4 product, the latency of CDR V4 will be only three to six months.
- The variables goddard_nt_seaice_conc, goddard_nt_seaice_conc_monthly, goddard_bt_seaice_conc, and goddard_bt_seaice_conc_monthly contained exact copies of data products that are available as their own data products from NSIDC. Therefore, it was redundant to have them in the CDR product and keeping these variables in sync with their data product was a challenge. They were originally provided as a courtesy to users, however, with CDR V4, we provide the NSIDC produced NT and BT variables, which are more useful to the understanding of how the CDR variable was created. For access to these Goddard data sets, see NSIDC-0051 for the NT product and NSIDC-0079 for the BT product.

8. Difference Between CDR V4 and Goddard Merged Product

As part of the Version 3 sea ice concentration CDR data files, a Goddard product was included. This so called “Goddard Merged V3” product was analogous to the CDR data because it used the same approach to merge concentrations derived from the NASA Team and Bootstrap algorithms. However, in contrast to the fully-automated CDR processed by NSIDC, the merged product was derived from the Goddard NASA Team (NSIDC-0051) and Bootstrap (NSIDC-0079) manually corrected data sets created at Goddard. This Goddard Merged field was used as the benchmark for CDR V4. This section analyzes the differences between the total sea ice extent of CDR V4 and the Goddard Merged field to quantify the quality of NSIDC’s Version 4 sea ice concentration CDR. The total sea ice extent is calculated by summing up all the grid cells that have a concentration higher than 15% and multiplying by the area of each grid cell.

8.1 Northern Hemisphere

Table 5 lists key statistical information about the difference between the CDR V4 and Goddard Merged extent values for the Arctic. Figure 2 shows the difference in the daily Arctic extent values between the two data sets (CDR V4 minus Goddard Merged). Note that only complete CDR fields were used for the calculations shown in Table 5 and Figure 2, i.e., partial fields noted in Table 3 were excluded because they resulted in erroneously low extent values due to missing data. Note that CDR Version 4 Arctic extent is consistently lower than the Goddard Merged extents from Version 3. This is due to the use of the newer version of the Bootstrap algorithm and the adjustments to the weather and land-spillover corrections noted above.

Table 5. Northern Hemisphere extent difference statistics (CDR V4 minus Goddard Merged V3). Statistics are derived from a sample size of N=13678 days spanning Nov. 1979 –Jan. 2020.

Statistic	Value (Mil sq km)
Mean extent difference	-0.162
Standard deviation	0.129
Maximum extent difference	0.398
Minimum extent difference	-0.6

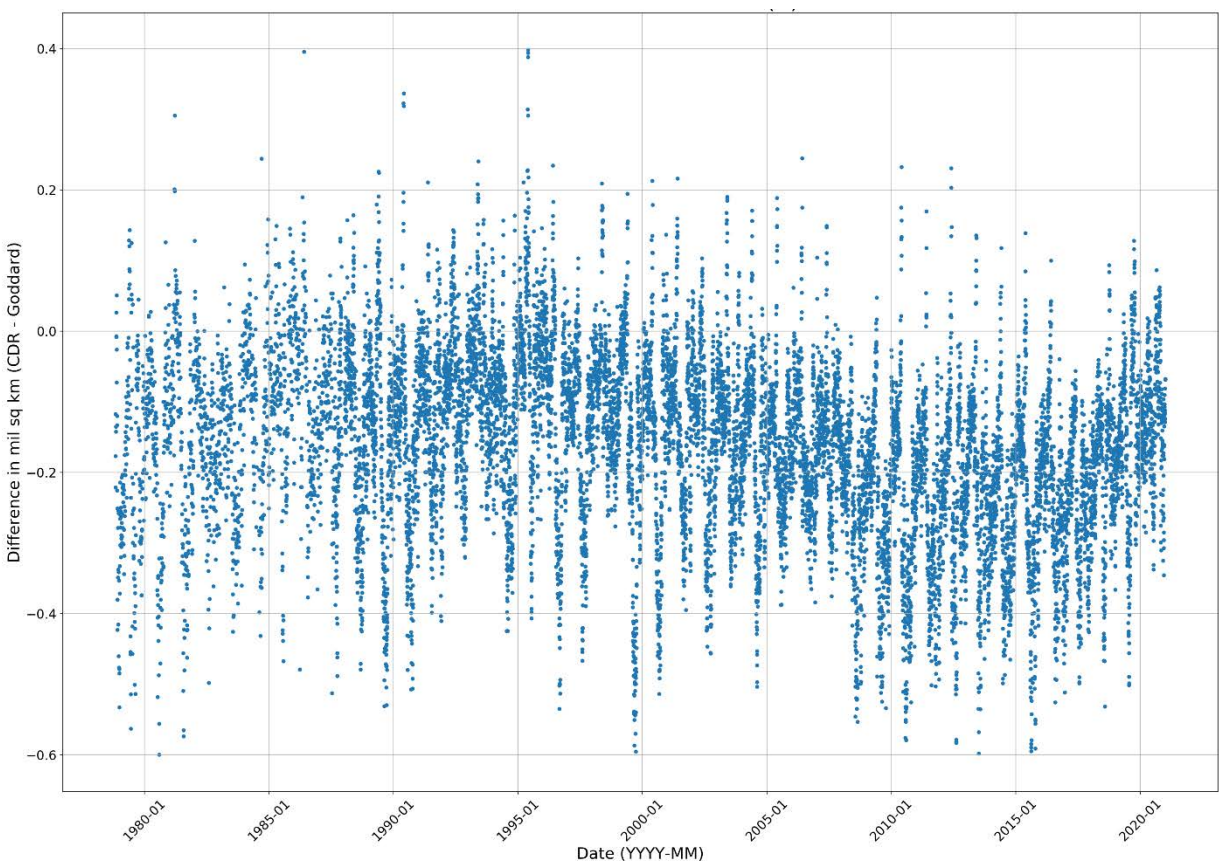

Figure 2. Northern Hemisphere daily extent differences in millions of sq km (CDR V4 minus Goddard Merged V3)

8.2 Southern Hemisphere

Table 6 lists key statistical information about the difference between the CDR V4 and Goddard Merged extent values for the Antarctic. Figure 3 shows the difference in the daily Antarctic extent values between the two data sets (CDR V4 minus Goddard Merged). Note that only complete CDR fields were used for the calculations shown in Table 6 and Figure 3, i.e., partial fields noted in Table 3 were excluded because they resulted in erroneously low extent values due to missing data. Note that the SMMR record shows some drift in the differences through the SMMR years of the record which will be investigated more in the future. Trend analysis that includes SMMR will be slightly affected by this drift. As noted in section 6, the GR3719 weather filter was adjusted so that there is not a discontinuity in the July 1987 SMMR-SSM/I transition.

Table 6. Southern Hemisphere extent difference statistics (CDR V4 minus Goddard Merged V3). Statistics are derived from a sample size of N=13727 days spanning Nov. 1979 –Jan. 2020.

Statistic	Value (Mil sq km)
Mean extent difference	0.007
Standard deviation	0.084
Maximum extent difference	0.332
Minimum extent difference	-0.398

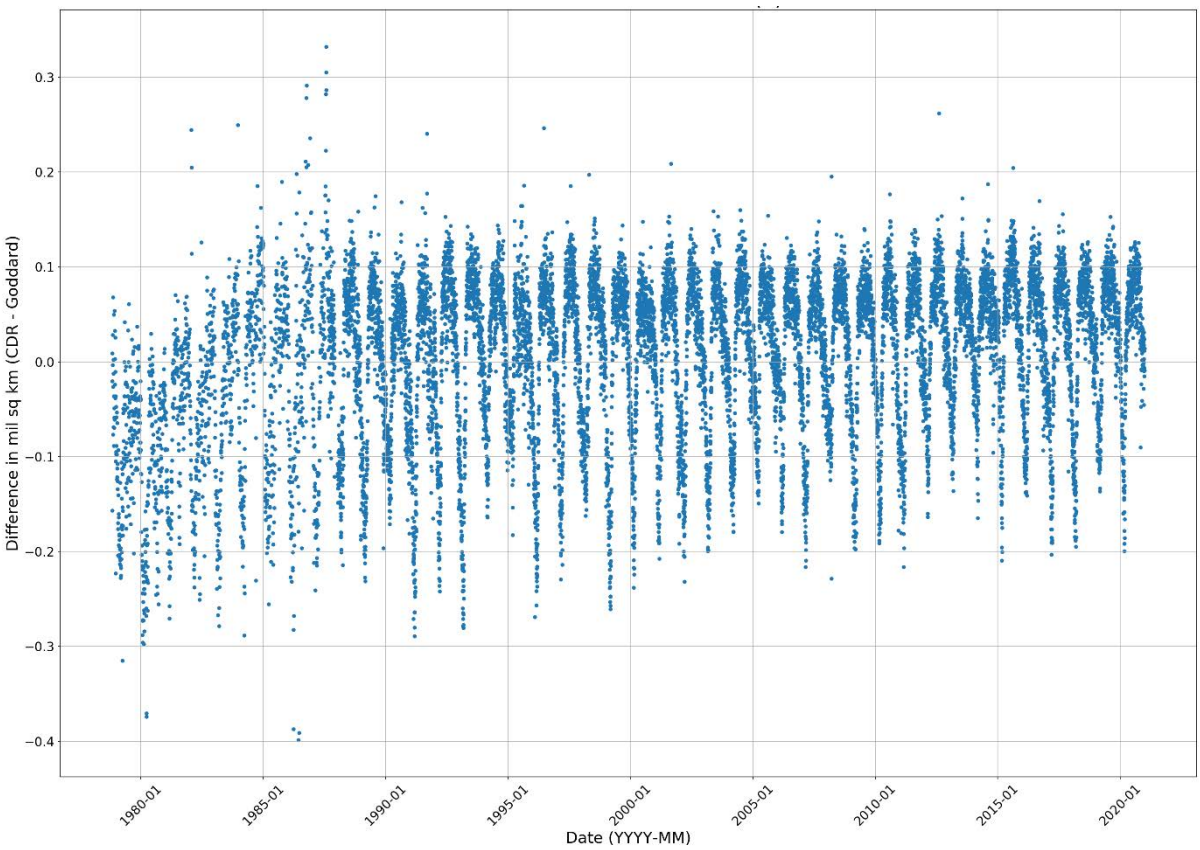

Figure 3. Southern Hemisphere daily extent differences in millions of sq km (CDR V4 minus Goddard Merged V3)

9. Analysis of the differences between CDR V4 and CDR V3

This section shows the differences between the CDR V4 data product and the CDR V3 data product.

9.1 Northern Hemisphere

Figure 4 shows the complete time series of differences of CDR Version 4 minus CDR Version 3 for the Arctic. Due to lots of missing data in CDR V3, especially at the beginning of the record, the CDR V3 extent values tended to be erroneously low, thus causing the high difference values seen in the graph. This has been corrected with the gap filling done in CDR V4.

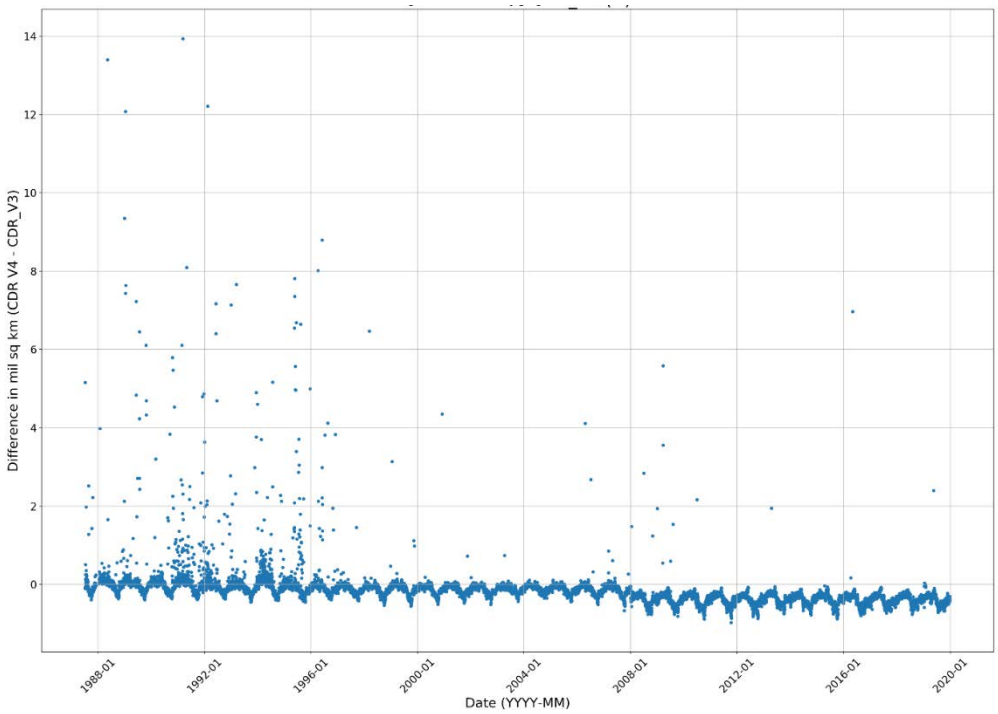

Figure 4. Northern Hemisphere daily extent difference in millions of sq km (CDR V4 minus CDR V3)

Figure 5 shows a scatter plot of the extent values for the Arctic from CDR V4 (orange) and CDR V3 (green) plotted together for the year 2019. Goddard extent values (blue) were included as well to show the full comparison of the products.

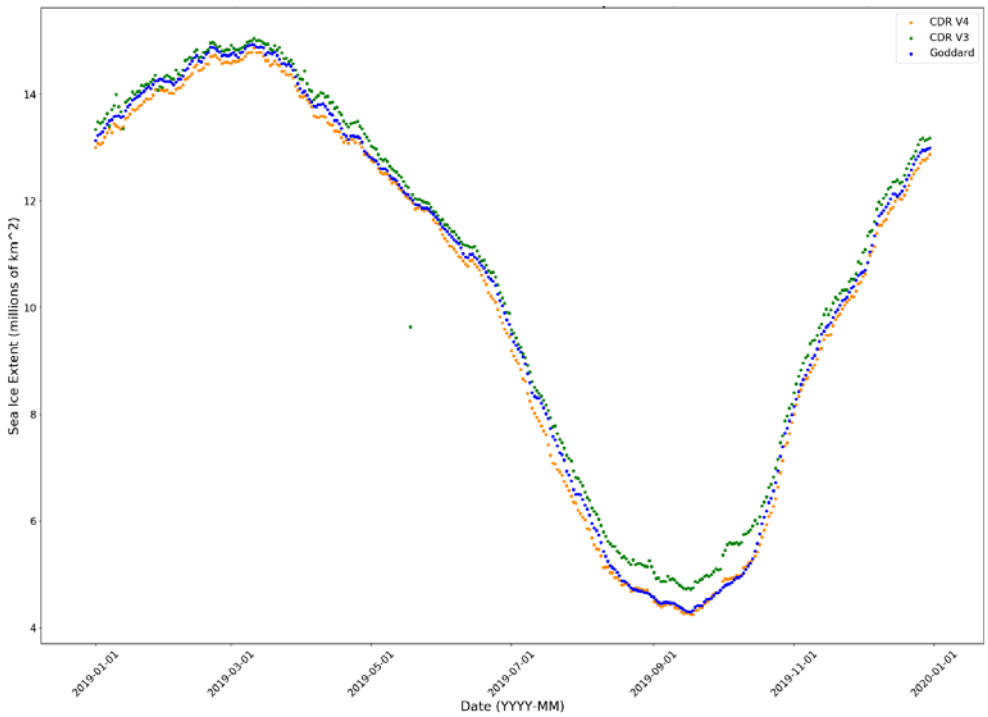

Figure 5. Northern Hemisphere CDR V4, CDR V3, and Goddard Merged extent plot for 2019

Table 5 shows the number of missing grid cells per day for CDR V4 for the Northern Hemisphere from 1979 through 2020. The highest values (~35,000) are for days where there is no data at all. The vast majority of days have no missing data; and of the days with missing data, most have less than 100 missing grid cells. Out of 15,341 days, 525 days in the Northern Hemisphere have missing data. This in contrast to CDR V3, where almost every day has missing data.

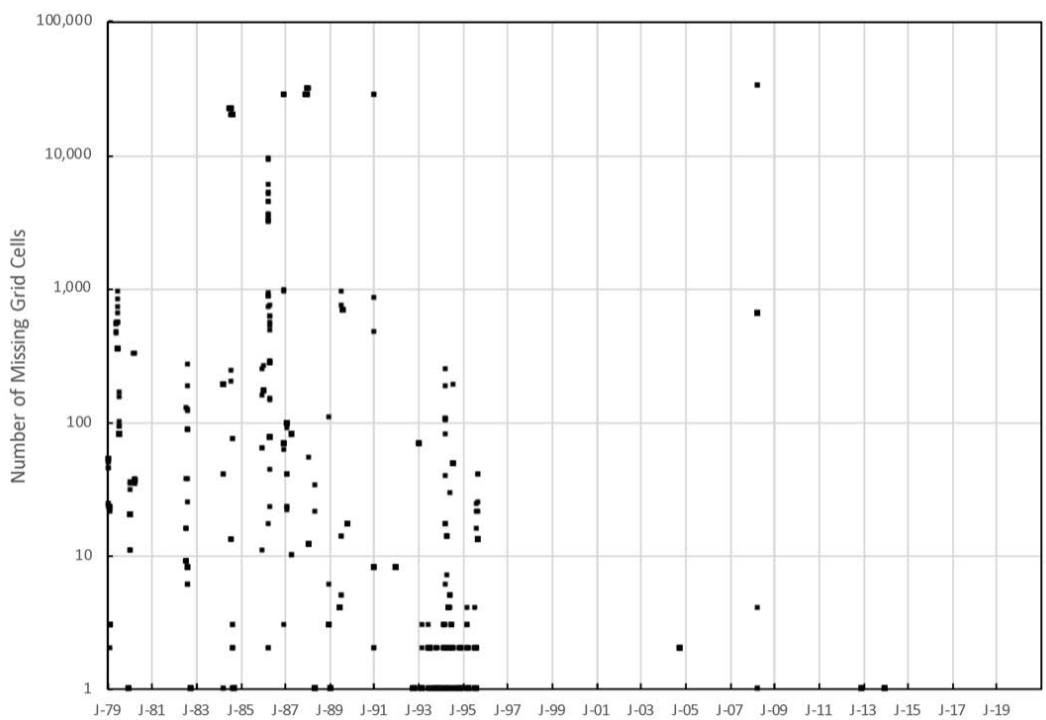

Figure 6. Northern Hemisphere missing grid cells for CDR V4 (y-axis is on a log scale)

9.2 Southern Hemisphere

Figure 7 shows the complete time series of differences of CDR Version 4 minus CDR Version 3 for the Antarctic. Due to lots of missing data in CDR V3, especially at the beginning of the record, the CDR V3 extent values tended to be erroneously low, thus causing the high difference values seen in the graph. This has been corrected with the gap filling done in CDR V4.

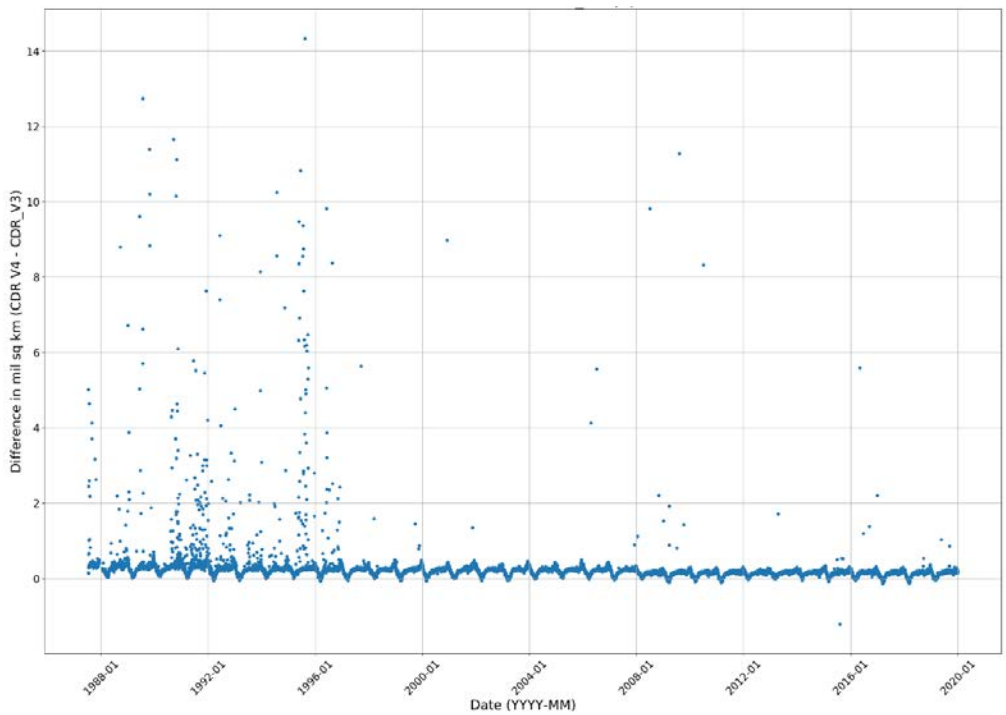

Figure 7. Southern Hemisphere daily extent difference in millions of sq km (CDR V4 minus CDR V3)

Figure 8 shows a scatter plot of the extent values for the Antarctic from CDR V4 (orange) and CDR V3 (green) plotted together for the year 2019. Goddard extent values (blue) were included as well to show the full comparison of the products.

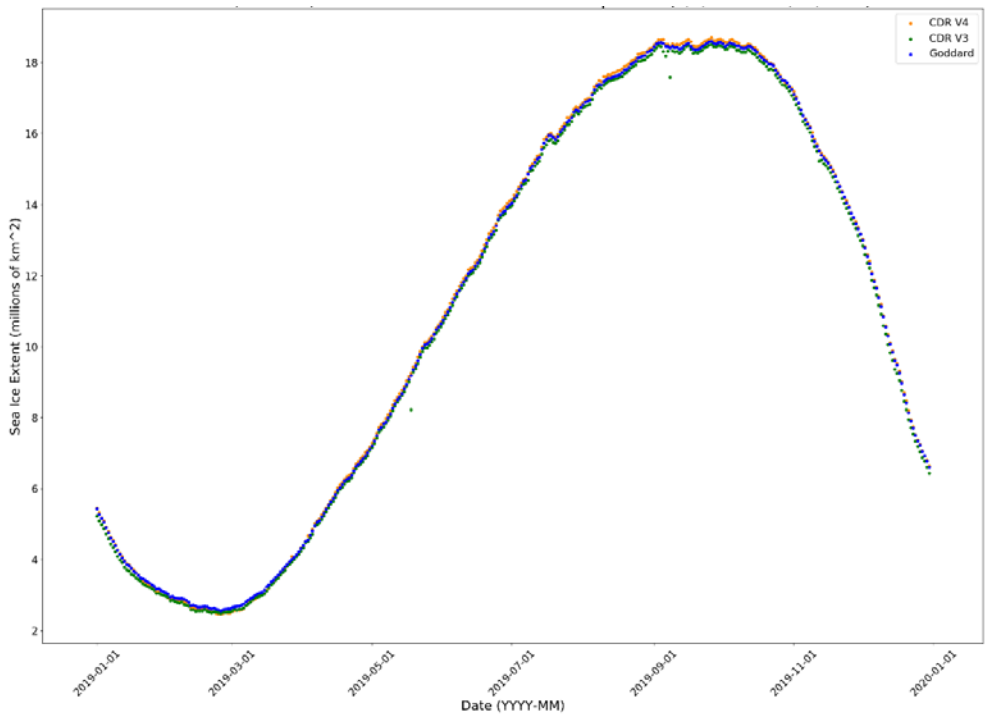

Figure 8. Southern Hemisphere CDR V4, CDR V3, and Goddard Merged extent plot for 2019

Figure 9 shows the number of missing grid cells per day for CDR V4 for the Southern Hemisphere from 1979 through 2020. The highest values (~35,000) are for days where there is no data at all. The vast majority of days have no missing data; and of the days with missing data, most have less than 100 missing grid cells. Out of 15,341 days, 194 days in the Southern Hemisphere have missing data, contrasted to CDR V3, where almost every day has missing data.

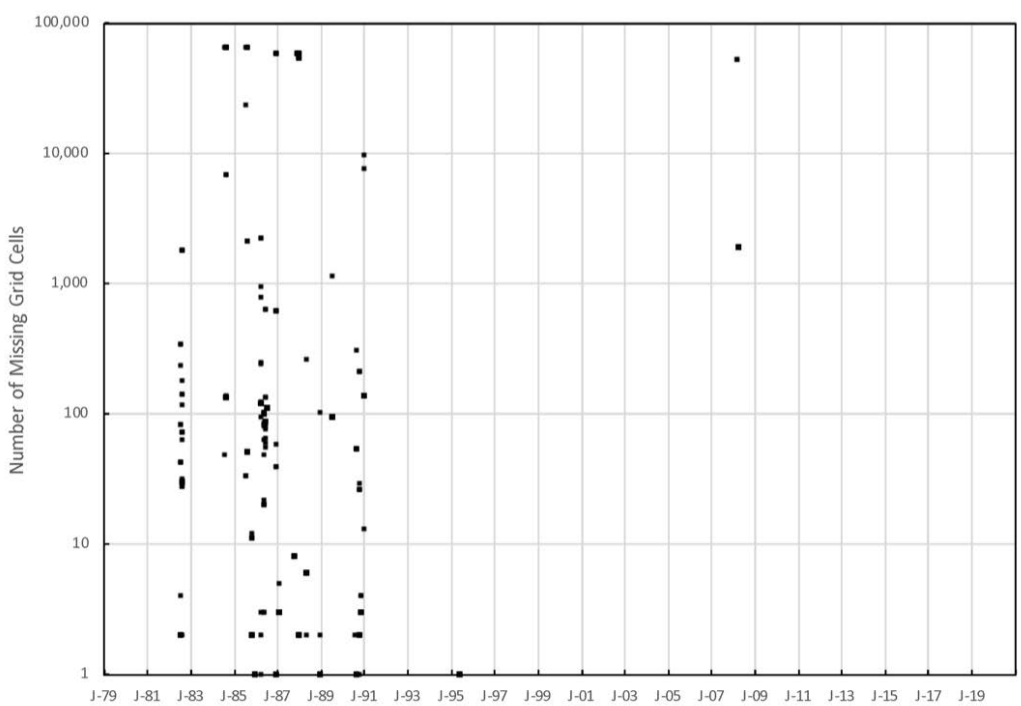

Figure 9. Southern Hemisphere missing grid cells for CDR V4 (y-axis is on a log scale)

10. Conclusions

The enhancements in Version 4 of the Sea Ice Concentration CDR were made to address specific issues in Version 3. The most significant of these was the omission of the SMMR part of the record, which limited the CDR V3 parameter to a record beginning in mid-1987 instead of late-1978. Another issue was the substantial amount of missing data – nearly every day of V3 had at least some missing data. The spatial and temporal interpolation followed a similar approach as that used by Goddard to gap-fill nearly all missing data, creating near-complete concentration fields. In addition, the interpolation approach was also used on the "empty" days during the bi-daily SMMR era to provide daily concentration fields for 1978 to 1987; this is not done in the Goddard fields. Finally, the pole hole in the Arctic was filled to create a complete field of concentration over all ice-covered regions. All interpolation is documented in flag fields, allowing users to recover the "raw" un-interpolated fields if desired. The NASA Team algorithm and the latest version of the Bootstrap algorithm were obtained from NASA Goddard so that the CDR processing is consistent as possible with the historical Goddard fields.

Version 4 of the Sea Ice Concentration CDR is a near-complete, consistent long-term passive microwave sea ice concentration record that is fully automated and reproducible and meets CDR standards for data and metadata. This CDR will meet a variety of user needs for investigating Arctic and Antarctic sea ice and its changes and variability over the past 40+ years.

11. References

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