Supplement of

A new sea ice concentration product in the polar regions derived from the FengYun-3 MWRI sensors

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S1 Processing steps of the MWRI-ASI SIC product

Figure S1 shows the steps of producing the MWRI-ASI SIC. First, we acquired and pre-processed the swath FY-3 MWRI TB data from 2010 to 2019. Second, the initial tie points were generated referring to the SSMI-ASI SIC. The initial SIC was computed based on the initial tie points using the ASI algorithm. Then, we selected tie-point samples to obtain the daily dynamic tie points. The swath SIC was calculated using the daily dynamic tie points based on the ASI algorithm. After filtering weather effects, the swath SIC was averaged to daily SIC. Finally, the SIC product was generated after the monthly maximum ice extent filter.
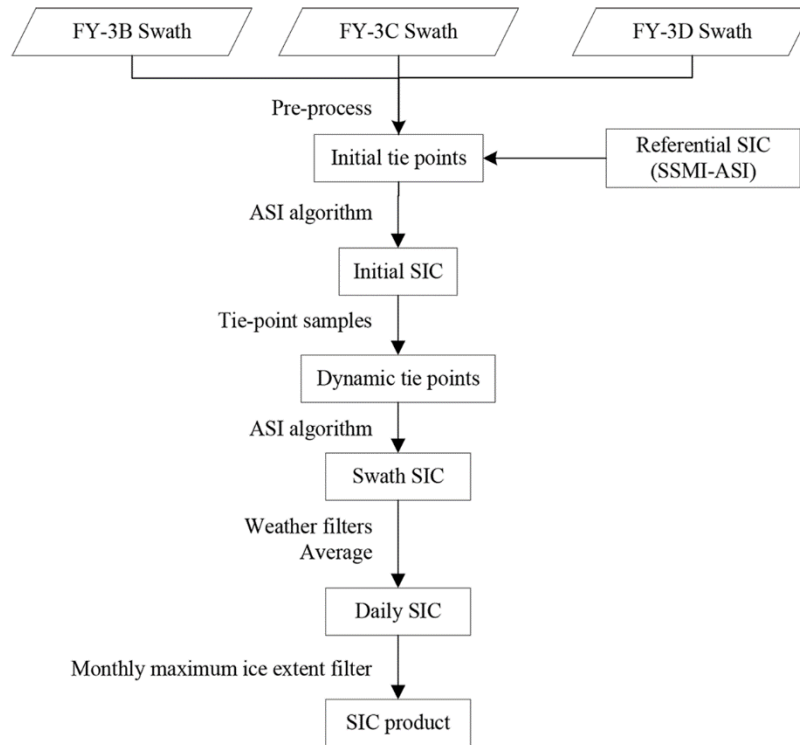
**Figure S1: The flow chart of the processing steps of the MWRI-ASI SIC product.**

S1.1 Pre-process of the re-calibrated MWRI TB

We acquired the main Science Datasets, i.e., "Latitude", "Longitude" and "EARTH_OBSERVE_BT_10_to_89 GHz", of the re-calibrated MWRI TB from the original HDF files. The five frequencies used for the MWRI-ASI SIC product, i.e., at 18.7, 23.8, and 36.5 GHz with V-polarization and at 89 GHz with V- and H-polarization, were derived from the "EARTH_OBSERVE_BT_10_to_89 GHz". The polarization difference defined as V-polarization minus H-polarization was calculated at 89 GHz, which was the main parameter of the ASI algorithm. All the frequencies were projected onto the 12.5-

km polar stereographic grid true at 70 degrees by the "Latitude" and "Longitude" using the "ReprojectGLT" of Envitask in the IDL software and the "Project Raster" of "ArcToolbox" in the ArcGIS software. Figure S2 shows an example of the re-calibrated swath MWRI TB projected onto the 12.5-km polar stereographic grid.

The code of the "ReprojectGLT" of Envitask in the IDL software is shown as follows:

```
e = envi(/headless)
lat_raster = e.openraster(file_lat)
lon_raster = e.openraster(file_lon)
tb_raster = e.openraster(file_tb)
Task = envitask('ReprojectGLT')
Task.latitude_raster = lat_raster
Task.longitude_raster = lon_raster
Task.input_raster = tb_raster
Task.output_raster_uri = file_geo
Task.execute
```
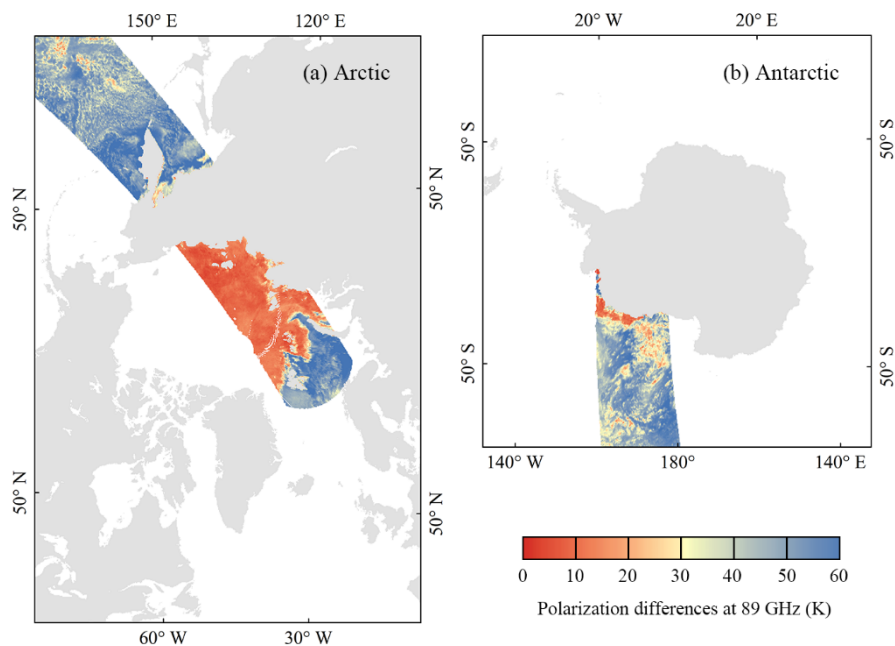

Figure S2: Polarization differences at 89 GHz of the swath FY-3D started at 01:24 am on 1 January 2019 in the Arctic (a) and Antarctic (b).

S1.2 Initial tie points

We selected the daily SSMI-ASI SIC in 2018 as the referential SIC to estimate the initial tie points, including the following steps:

1) Choose one pair of tie points (P_1 and P_0). The selected range of P_1 is from 6.0 to 12.0 K and that of P_0 is from 47.0 to 57.0 K with an interval of 0.1 K, in a total of 6000 pairs of tie points.
2) Calculate the SIC from the swath MWRI TB using the ASI algorithm based on the tie points selected in step 1.
3) Average all the swath MWRI-ASI SIC in one calendar day into daily MWRI-ASI SIC.
4) Conduct the line regression between the daily MWRI-ASI SIC and referential SSMI-ASI SIC. Get the slope, intercept, bias, and Std.
5) Repeat steps 1 to 4. The 6000 pairs of tie points are corresponding to 6000 groups of the slope, intercept, bias, and Std.
6) Determine initial tie points by satisfying the requirements with a slope closer to 1, intercept closer to 0, and relatively low bias and Std.

According to the above procedures, the initial P_1 and P_0 were determined as 7.1 and 50.3 K in the Arctic (Table S1). The Std between the MWRI-ASI SIC based on the initial tie points and referential SSMI-ASI SIC are 8% in the Arctic. In the Antarctic, the initial P_1 was 7.3 K, and the initial P_0 was 55.9 K. The Std between the MWRI-ASI SIC based on the initial tie points and referential SSMI-ASI SIC is 9% in the Antarctic.

The code of line regression in the IDL software is shown as follows:

coe = linfit(MWRISIC, SSMISIC)

slope = coe[0]

intercept = coe[1]

Std = stddev(MWRISIC - SSMISIC)

Table S1: The initial tie points for the Arctic and Antarctic. The results of the linear regression between the MWRI-ASI SIC based on the initial tie points and referential SSMI-ASI SIC.

	P_1 (K)	P_0 (K)	slope	intercept	Std (%)
Arctic	7.1	50.3	1.03	0.97	8
Antarctic	7.3	55.9	1.02	0.98	9

S1.3 Initial SIC

We calculate the initial SIC using the initial tie points applied to all the swath MWRI TB from 2010 to 2019. The third-order polynomials to calculate the initial SIC are shown as Eq. (S1) for the Arctic and Eq. (S2) for the Antarctic:

$$SIC = 2.10 \cdot 10^{-6}P^3 - 0.000215P^2 - 0.0170P + 1.13 \tag{S1}$$

where the coefficients of the polynomial were computed by the Arctic initial tie points (P_1 = 7.1 K, P_0 = 50.3 K).

$$SIC = 6.69 \cdot 10^{-7}P^3 - 0.0000759P^2 - 0.0182P + 1.14 \qquad \text{(S2)}$$

where the coefficients of the polynomial were computed by the Antarctic initial tie points (P1 = 7.3 K, P0 = 55.9 K), and the P is the polarization difference at 89 GHz.

The code for calculating the coefficients of the polynomial in the IDL software is as follows:

```
A = make_array(4, 4)
row0 = [p0^3, p0^2, p0, 1]
row1 = [p1^3, p1^2, p1, 1]
row2 = [3*p0^3, 2*p0^2, p0, 0]
row3 = [3*p1^3, 2*p1^2, p1, 0]
A[*, 0] = row0
A[*, 1] = row1
A[*, 2] = row2
A[*, 3] = row3
A = transpose(A)
B = [0, 1, -1.14, -0.14]
X = IMSL_LUSOL(B, A)
```

S1.4 Dynamic tie points

The dynamic tie-point samples were generated daily under the following conditions:

1) Arctic sea ice tie-point samples: the initial SICs of grids are larger than 95%, the grids are south of 87° N, within the monthly minimum ice extent, and 100 km away from the coast.

2) Arctic open water tie-point samples: the initial SICs of grids fall within the range [-10%, 10%], the grids are north of 50° N, away from the monthly ice edge by 200–350 km, and away from the coast by 100 km.

3) Antarctic sea ice tie-point samples: the initial SICs of grids are larger than 95%, the grids are within the monthly minimum ice extent, and 100 km away from the coast.

4) Antarctic open water tie-point samples: the initial SICs of grids fall within the range [-10%, 10%], the grids are away from the monthly ice edge by 200–350 km, and away from the coast by 100 km.

Finally, we calculated the average of the tie-point samples in a central sliding window (±7 days, in a total of 15 days) as the tie points of the central day. Figure S3 shows the daily dynamic tie points from 2010 to 2019, and one day has two pairs of tie points corresponding to the Arctic and Antarctic, respectively.

The code for selecting tie-point samples in the IDL software is as follows:

data_sample_Arctic_ice = data_landmask100 * data_minicemask * data_initialsic * data_87n

data_sample_Arctic_water = data_landmask100 * data_maxicemask * data_initialsic * data_50n

data_sample_Antarctic_ice = data_landmask100 * data_minicemask * data_initialsic

data_sample_Antarctic_water = data_landmask100 * data_maxicemask * data_initialsic
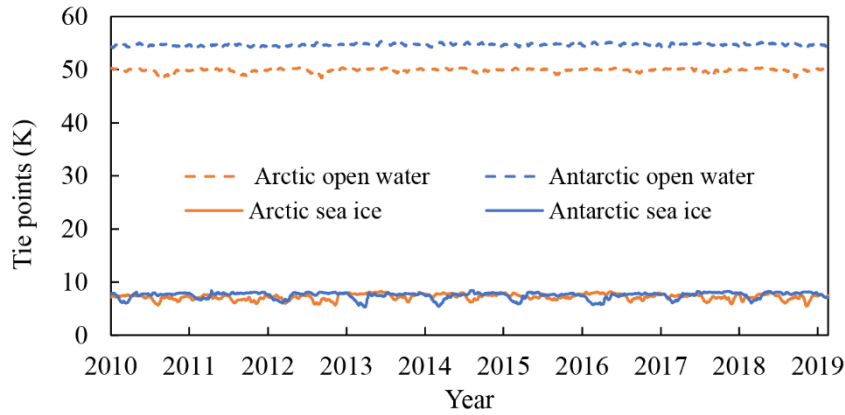
Figure S3: Daily dynamic sea ice and open water tie points in the Arctic and Antarctic from 2010 to 2019.

S1.5 Swath SIC

The daily dynamic tie points were applied to swath MWRI TB on a corresponding day to calculate the swath SIC. For example, on 1 January 2019, the tie points P_1 and P_0 were 7.1 and 50.1 K in the Arctic, and 6.5 and 54.7 K in the Antarctic, respectively. The third-order polynomials based on the two pairs of tie points are Eq. (S3) and (S4).

$$SIC = 2.18 \cdot 10^{-6} P^3 - 0.000223 P^2 - 0.0169 P + 1.13 \qquad (S3)$$

$$SIC = -3.81 \cdot 10^{-7} P^3 - 0.0000422 P^2 - 0.0220 P + 1.14 \qquad (S4)$$

Eq. (S3) was applied to all the swath MWRI TB on 1 January 2019 to calculate the Arctic SIC, and Eq. (S4) was used to calculate the Antarctic SIC. One day has two equations used to calculate the SIC, which are corresponding to the Arctic and Antarctic, respectively. Examples of the swath MWRI-ASI SIC are presented in Figures S4a and S4c.

S1.6 Weather filters

To remove the spurious sea ice over open water, we used two weather filters, i.e., the GR(36.5/18.7) and GR(23.8/18.7):

$$GR(36.5/18.7) = \frac{TB_V(36.5) - TB_V(18.7)}{TB_V(36.5) + TB_V(18.7)} \qquad (S5)$$

$$GR(23.8/18.7) = \frac{TB_V(23.8) - TB_V(18.7)}{TB_V(23.8) + TB_V(18.7)} \qquad (S6)$$

where $TB_V(36.5)$, $TB_V(23.8)$, and $TB_V(18.7)$ is the TB at 36.5 GHz, 23.8 GHz and 18.7 GHz with V- polarization, respectively. The thresholds of the GR(36.5/18.7) and GR(23.8/18.7) are 0.05 and 0.045, respectively. If the values of

GR(36.5/18.7) exceed 0.05 or those of GR(23.8/18.7) were larger than 0.045, the SIC was set to 0% (open water). Figure S4b and S4d show that most of spurious sea ice over open water was removed after using these two weather filters.

The code of weather filters in the IDL software is as follows:

```
gr_36_18 = (data_36V-data_18V)/(data_36V+data_18V)
gr_36_18[where(gr_36_18 ge 0.05)] = 2
gr_36_18[where(gr_36_18 lt 0.05)] = 1
gr_36_18[where(gr_36_18 eq 2)] = 0
sic_1 = gr_36_18 * data_sic
gr_23_18 = (data_23V-data_18V)/(data_23V+data_18V)
gr_23_18[where(gr_23_18 ge 0.045)] = 2
gr_23_18[where(gr_23_18 lt 0.045)] = 1
gr_23_18[where(gr_23_18 eq 2)] = 0
sic_2 = gr_23_18 * sic_1
```

S1.7 Average swath SIC to daily SIC

All the swath MWRI-ASI SIC on one calendar day was averaged as the daily MWRI-ASI SIC.

The code for averaging swath SIC to daily SIC in the IDL software is as follows:

```
total_data = total_data + tmp_data
n_data = n_data + tmp_n_data
avg_data = total_data / n_data
```

S1.8 Maximum ice extent filter

To remove the residual spurious sea ice at low latitudes, we used the monthly maximum ice extent from NSIDC, which is available at https://nsidc.org/data/nsidc-0192/versions/3. The SIC was set to 0% when the location is out of the monthly maximum ice extent.

The code of the maximum ice extent filter in the IDL software is as follows:

```
maxice_filter [where(maxice_filter eq 254)] = 0
maxice_filter [where(maxice_filter eq 253)] = 0
maxice_filter [where(maxice_filter ne 0)] = 1
sic = data_sic*maxice_filter
```
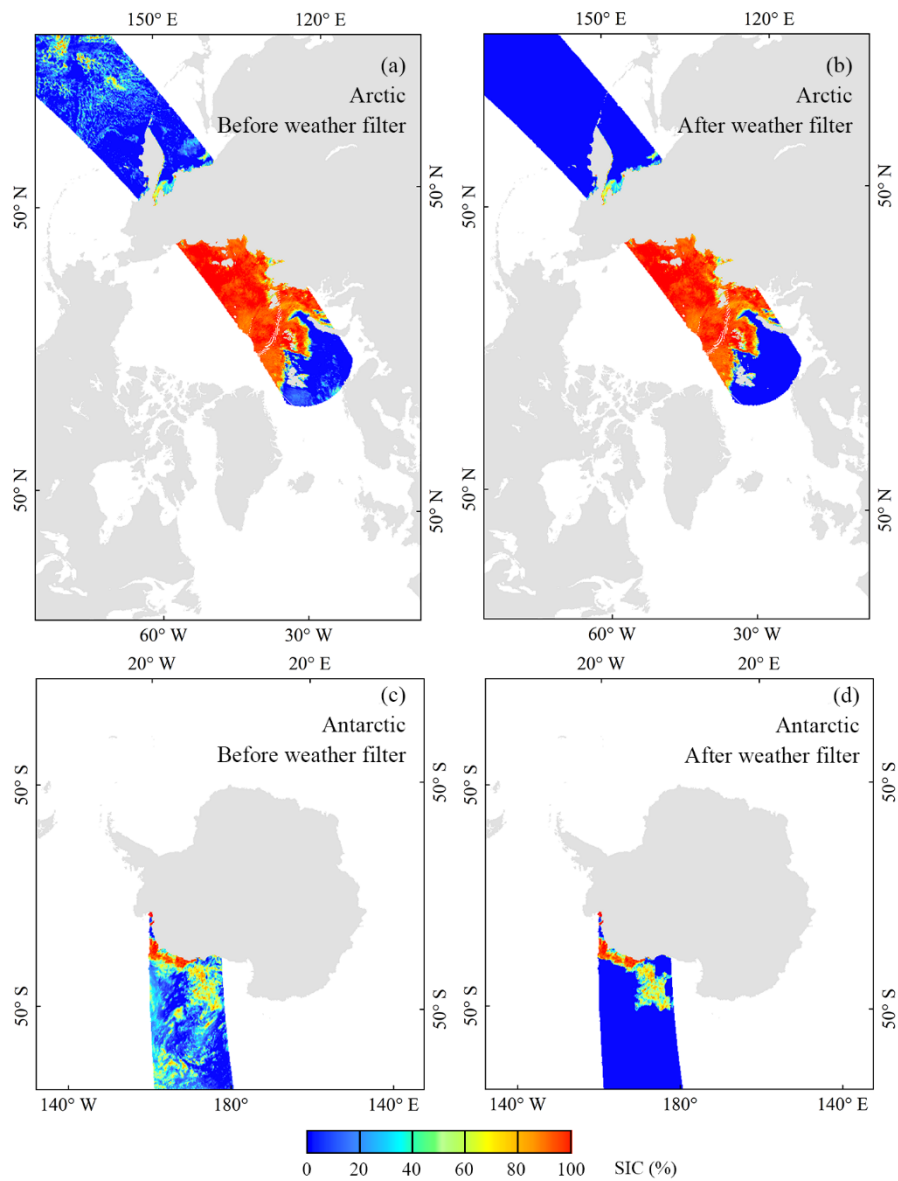
Figure S4: SIC of the swath FY-3D started at 01:24 am on 1 January 2019 before (left) and after (right) the weather filters in the Arctic (top) and Antarctic (bottom).

S2 Differences in TB and SIC with different snow depths

Table S2: MADs between the MWRI-ASI SIC and other two SICs with the snow depth of 0-0.1 m, 0.1-0.4 m, and 0.4-0.6 m in the Arctic and Antarctic from 2010 to 2019.

	Arctic (%)			Antarctic (%)		
	0-0.1 m	0.1-0.4 m	0.4-0.6 m	0-0.1 m	0.1-0.4 m	0.4-0.6 m
SSMI-ASI	7	2	2	6	3	2
AMSR-ASI	9	4	3	8	5	3

Table S3: MADs in the polarization difference at 89 GHz between the MWRI sensor and other two PM series sensors with the snow depth of 0-0.1 m, 0.1-0.4 m, and 0.4-0.6 m in the Arctic and Antarctic from 2010 to 2019.

	Arctic (K)			Antarctic (K)		
	0-0.1 m	0.1-0.4 m	0.4-0.6 m	0-0.1 m	0.1-0.4 m	0.4-0.6 m
SSMI	2.7	1.3	1.2	2.6	1.5	1.3
AMSR	2.4	1.1	1.0	2.3	1.3	1.0