P2.21 Sea Ice Data Derived from Microwave Radiometer for Climate Monitoring

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1. Introduction

Nowadays, it is required for JMA to monitor near realtime sea ice data, for JMA monitors the state of the global atmospheric, oceanic and terrestial climate system focussing on atmospheric circulation, convection, ocean condition and snow/ice coverage based on numerical objective analyses and satellite observation. These monitoring results provide useful information for the global climate changes. Recently, JMA requires monitoring sea ice from the satellite observation.

For refinement of sea surface temperature (SST) analysis in high latitudes, SST is usually estimated from sea ice data(Rayner et al.,1996).

Historical SST is analyzed with this sea ice dataset. An SST analysis named COBE-SST by Ishii et al. (2005) is used for climate monitoring at JMA. In this SST analysis, a historical sea ice dataset (Walsh and Chapman, 2001) is used for their SST analysis before 1978, in which sea ice data are available only in the Arctic Ocean from 1901. For the period from 1978 to the present, a sea ice analysis is made from satellite-derived data.

In this presentation, processing of satellite sea ice data at JMA is introduced.

2. Sea Ice Concentration Algorithm

A near real-time analysis of sea ice concentration (SIC) has been carried out using satellite observations by microwave radiometer: Scanning Multichannel Microwave Radiometer (SMMR) and Special Sensor Microwave/Imager (SSM/I). The NASA team algorithm (Cavarieli et al.,1984,1991) is adopted to compute SIC from brightness temperatures by Microwave Imager (Table 1).

Table 1: Satellites used in sea ice analysis for COBE-SST

Sensor	Satellite	Period
SMMR	Nimbus-7	1978 Oct. 25 - 1987 Jul. 31
SSM/I	DMSP	1987 Aug. 1 - Present

Table 2: SMMR data used in sea ice analysis

Frequency	Poralization	Resolution
18GHz	H , V	$69 \times 43km$
37GHz	V	$37 \times 29km$

The SMMR sensor was on board NIMBUS-7 spacecraft which was launched by NASA in October, 1978.

Vertically and horizontally polarized brightness temperature of SMMR 18GHz and 37GHz channels were used in the sea ice analysis(Table 2).

The SSM/I sensors were on board Defense Meteorological Satellite Program(DMSP)(Table 2): F08, F10, F11, F13, F14 and F15 (Table 3).

3. Bias Correction between the satellites

Before the sea ice analysis, differences in the brightness temperature data between the SSM/I satellites are adjusted by using Wentz's decode 4 algorithm (Wentz, 1991, 1993).

Differences between SSM/I and SMMR are adjusted by using a method proposed by Cavarieli et al.(1999).

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Table 3: Seried of DMSP satellite

Sat	Period	Note
F08	1987 Jul.25 - 1993 Sep.13	1987 Dec.2 - 1998 Jan. 12 not in operation
F10	1990 Feb.11 - 1997 Nov.14	orbit had high eccentricity
F11	1991 Dec.3 - 2000 May 16 2000 May 16	
F13	1995 May 3 - Present	
F14	1997 May 7 - Present	
F15	2000 Jan.14 - Present	

Table 4: DMSP SSM/I data. Letters H and V represent horizontally polarized and vertically polarized, respectively.

Frequency	Polarization	Resolution
19GHz	H , V	$69 \times 43km$
22GHz	V	$50 \times 40km$
37GHz	H , V	$37 \times 29km$
85GHz	H , V	$15 \times 13km$

Since data from one DMSP satellite occasionally cannot cover whole region of the earth, data from plural DMSP satellites were used simultaneously.

4. SSM/I Error Data

4a. *85GHz Data Error*

Hollinger et al. (1991) reported that noise-equivalent delta temperature of the 85GHz channel increased from 0.8K to 2.1K and reached 5K in January 1989. Afterward, 85GHz sensor of F08 could not be used. Figure 1 shows a image of noisy 85GHz data.

So thin ice algorithm is not used in making COBE sea ice.

Sea of Okhotsk is so called thin ice area. Thin ice is calculated lower concentration than the sea ice analyzed by analyst So, the thin ice algorithm in use of 85GHz frequency is developed by Cavarieli, 1994. The improvement is confirmed by National Ice Center(Partington and Bertoia,Figure 2 1999).

Generally, the sea ice derived from microwave imager has lower concentration than the sea ice by analyst(Walsh and Chapman, 2001).

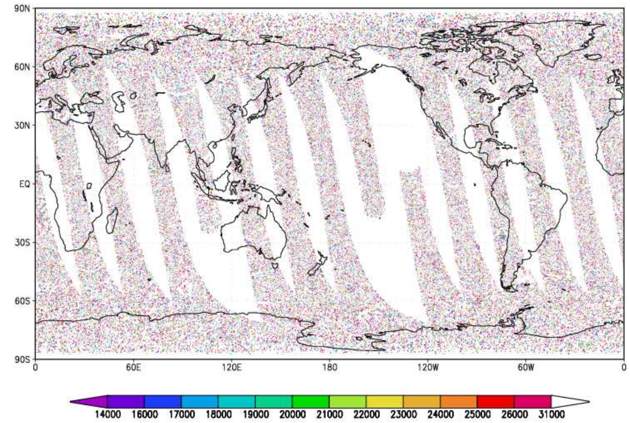

Figure 1: The SSM/I 85GHz vertical image on 1991 Jul.21. Almost everywhere in this figure covered with noise.

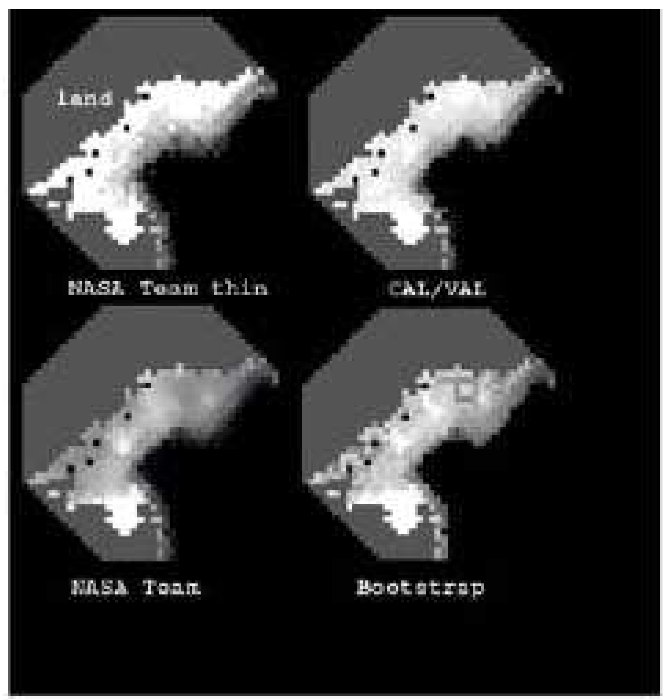

Figure 2: The comparison of NASA original algorithm and Thin ice algorithm : Upper left is thin ice algorithm, upper right is CAL/VAL, left below is NASA team and right below is Bootstrap(Partington and Bertoia, 1999).

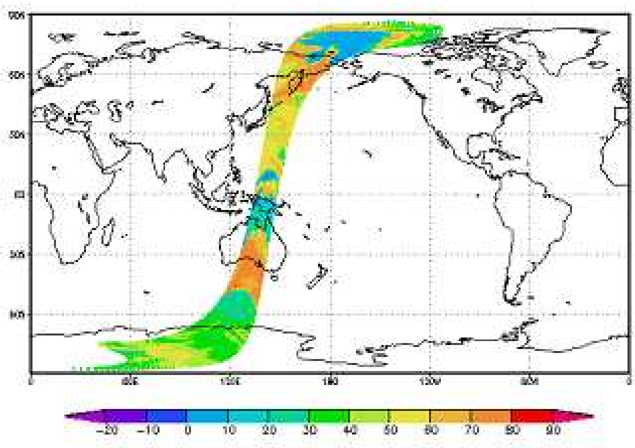

Figure 3: Bad allocation sample on 1991 Jul. 20. Australia is located on New Guinea, and Siberia is on Arctic Ocean.

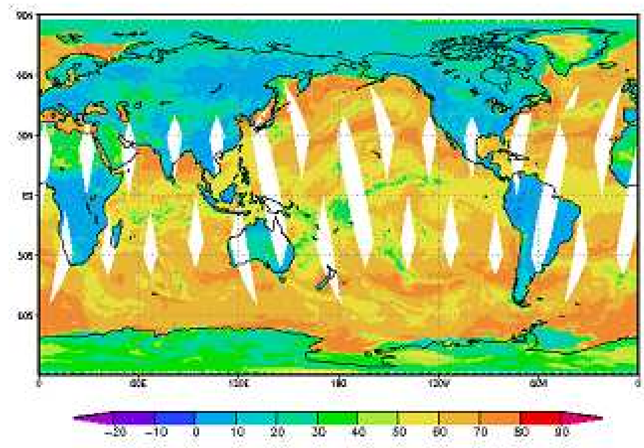

Figure 4: The image of the differrence Tb(19V)- Tb(19H) on 1991 Jan. 31. Tb difference is above 70K almost everywhere in sea area, and is below 30K almost everywhere in land area.

4b. *Date Error*

There are date error on Dec.31, 1996. The filename conversion is errored from the leap year date. These data are not included in sea ice analysis.

4c. *Bad Allocation*

Most likely error is this type (Figure 3). In sea area, the horizontally polarized brightness temperature is going down owing to the change of emissivity. Land area is not so going down. So, there are large brightness temperature difference between sea area and land area. From this point of view, if the data of latitude and longitude are recorded incorrectly, the bad allocation error occurs.

Figure 4 is the differrence between Tb_{19V} and Tb_{19H}. Here, Tb_{19V} is brightness temperature of 19GHz vertically polarized data, and Tb_{19H} is brightness temperature of 19GHz horizontally polarized data. The difference on sea is almost above 70K, and that on land is almost smaller than 30K.

If the difference is more than 40K, the data can be with bad allocation error. And these data are not used in sea ice analysis.

5. Land Data for Sea Ice Analysis

Spurious sea ice is eliminated by using a spill-over correction proposed by Cavalieri et al.(1994). A land data set, GTOPO30 is used in this processing, which contains land data and snow ice index classified by the Global Land Cover Characteristics(GLCC) data from USGS(Loveland et al.,1999).

The Land data (Figure 5) used in this process was made by GTOPO30 land data and Snow Ice index classified by the Global Land Cover Characteristics (GLCC) data from USGS(Loveland et al.,1999).

The GTOPO30 data are defined on a 0.25-degree grid. And land data from GTOPO30 is merged with snow ice index of the vegetation data by JMA.

6. Feature of Sea Ice

It is shown in Figure 6 the difference of sea ice analysis and the land data used in sea ice analysis on winter season in the Arctic. This figure shows that in the thin ice area, such that sea of Okhotsk, COBE sea ice has lower concentration than Hadley sea ice(Rayner et al. 1994), and almost the same as NCEP sea ice(Reynolds et al., 2002). But NCEP sea ice has higher concentration in the arctic than COBE sea ice.

It is shown in Figure 7 the difference of sea ice analysis and the land data used in sea ice analysis on winter season in the Antarctic. Figure 7 shows the handling of iceshelves and land data are different.

Figure 8 shows seasonal change of sea ice analysis in the Arctic of each center. This figure shows that the SIC of COBE and NCEP are closely related, but Hadley is considarably higher than COBE.

Figure 9 shows seasonal change of sea ice analysis in

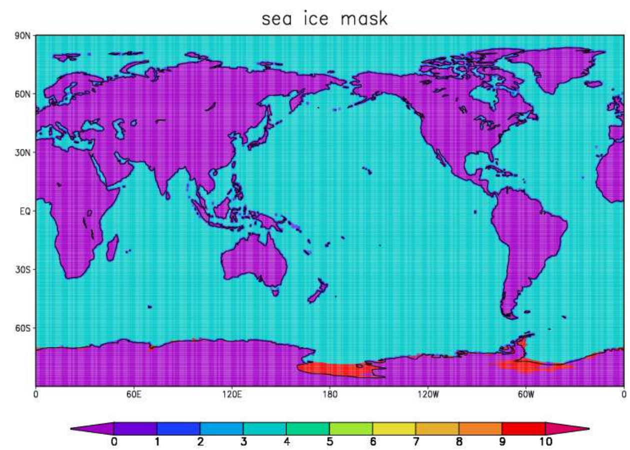

Figure 5: Land data used in sea ice analysis 1: Land, 2-3: Coast, 4: Sea , 10: Iceshelves . Land data is slightly larger than correct Land area for sea ice analysis.

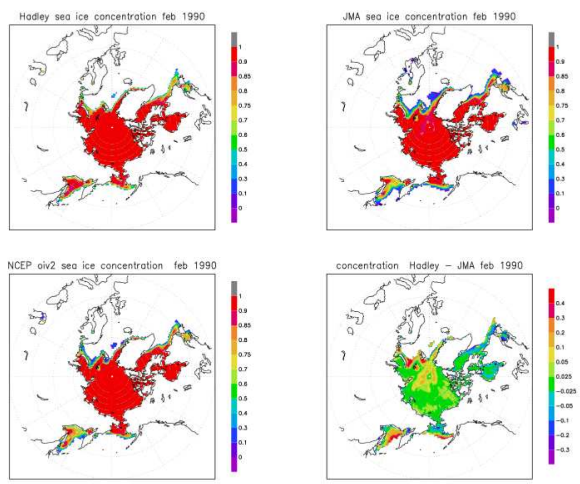

Figure 6: Sea ice concentration of the Arctic in COBE with those of the other centers on February, 1990 : The chart of upper left is Hadley center, that of upper right is COBE, that of left below is NCEP and right below is the difference between Hadley and COBE.

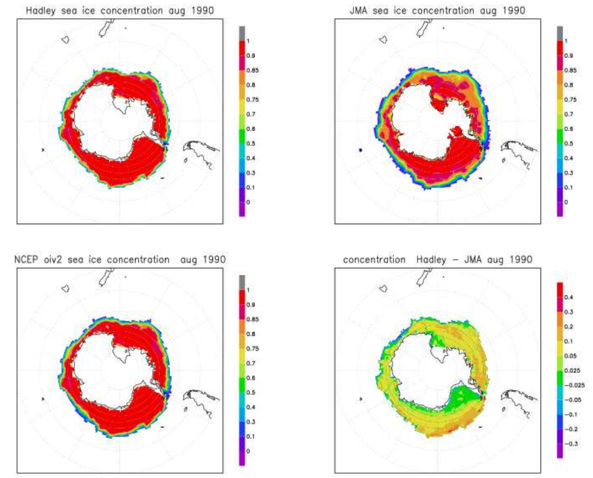

Figure 7: Sea ice concentration of the Antarctic in COBE with those of the other centers on August, 1990 : The chart of upper left is Hadley center, that of upper right is COBE, that of left below is NCEP and right below is the difference between Hadley and COBE.

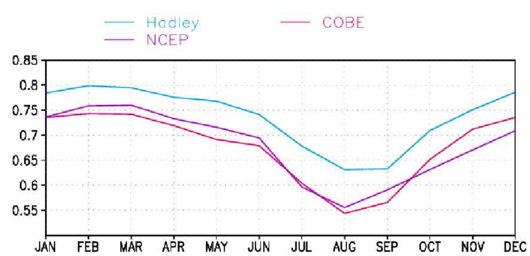

Figure 8: Comaprison of sea ice seasonal change of the arctic in COBE with those of the other centers : The red line expresses COBE, the blue line is Hadley and the purple line is NCEP.

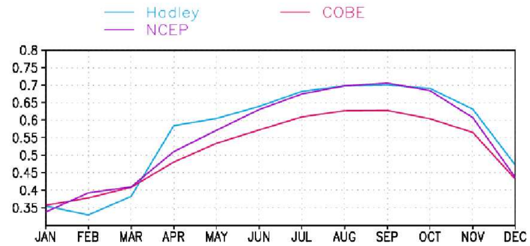

Figure 9: Comaprison of sea ice seasonal change of the Antarctic in COBE with those of the other centers : The red line expresses COBE, the blue line is Hadley and the purple line is NCEP.

the Antarctic of each center. This figure shows that the SIC of Hadley and NCEP are closely related in winter season, and that of COBE and NCEP are closely related in summer season.

From these point of view, the sea ice in COBE has the lowest concentration in the three sea ice data sets.

Figure 10 shows the time series shown are of SIC averages only at grid points where SIC is above 50%.

These figures shows that the feature of sea ice between the Arctic and Antarctic Ocean are quite different. In the Antarctic Ocean ,the sea surface current is around Antarctica and this is the main reason why the formation of the stratification is weak. In the Antarctic Ocean ,the sea surface current is around Antarctica and this is the main reason why the formation of the stratification is weak. So, the sea ice of the Arctic is formed rigidly in winter season, but that of the Antarctic is weaker connection and generated polynyas and lead by strong wind and sea surface current, and SIC of the Antarctic in winter season is lower than the arctic from microwave characteristics.

7. Operational processing

At JMA, DMSP SSM/I TDR data are operationally processed with a delay of one day, and the sea ice analysis is used in COBE-SST.

The sea ice data are evaluated by the COBE-SST, again, and therefore SST and sea ice analyses are in-

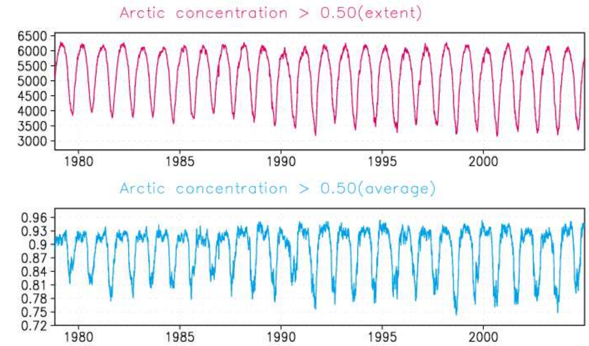

Figure 10: Sea Ice Interannual Change in the Arctic Ocean : The Arctic Ocean is surrounded by the continents. So, sea ice consentration in the Arctic has distinguished seasonal trend.

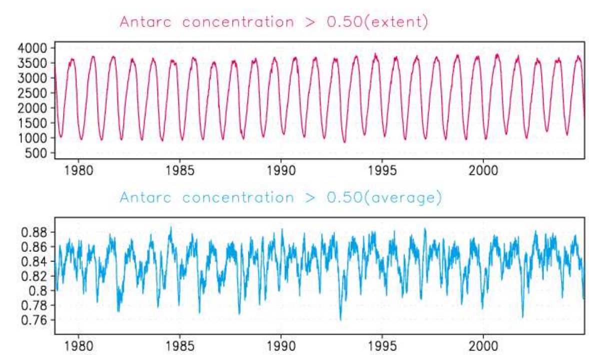

Figure 11: Sea Ice Interannual Change in the Antarctc Ocean : In winter season, sea ice concentration are not so high as in the arctic.

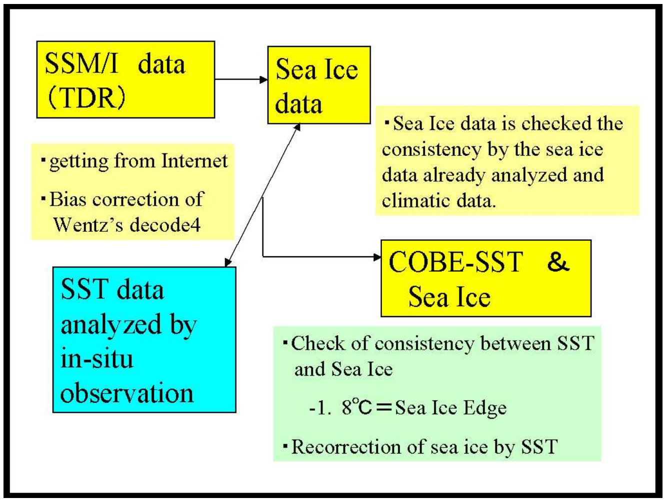

Figure 12: SST and SEA Ice analysis flow chart : This is operational process for climate monitoring.

tended to keep consistency between the two analysis (Figure 12).

The COBE dataset contains analyses and errors and the analysis is available throughout the 20th century. The analysis is based on only in-situ observations exchanged bia the Global telecommunication System and available in the International Comprehensive Ocean and Atmosphere Data Set and the Kobe Collection. The both SIC and SST analyses are utilized in the Japanese 25-year Reanalysis (JRA-25) and the JMA Climate Data Assimilation System (JCDAS).

8. conclusion

The SIC in COBE has the lowest of the three centers, that is Hadley, NCEP and COBE, and the seasonal change is not so clear in the Antarctic as Hadley.

The higher concentration is calculated by the thin ice. For near real time use, it would be introduced in the sea ice process in COBE.

9. Acknowledgement

SMMR data were acquired from National Snow and Ice Data Center. SSM/I data have been acquired from CLASS (NCDC and SAA) by the convenience of Dr. Axel Graumann.

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