Comparison of SSM/I Sea Ice Concentration with Kompsat-1 EOC Images of the Arctic and Antarctic

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Abstract— **We have compared Kompsat-1 EOC images (6.6m resolution, panchromatic) of the Arctic and Antarctic sea ice with SSM/I Sea Ice Concentration (SIC). EOC images were obtained from 10 orbits (624 scenes) across the Arctic sea ice edges from July to August and 11 orbits (676 scenes) across the Antarctic continental edges from September to November, all in year 2005. By applying supervised classification and visual identification to about 12% usable images out of the total scenes, we have classified various sea ice types such as Multi-year ice and First-year ice (M+F), Young ice (Y), and New ice (N). EOC SIC were derived and compared with SSM/I SIC calculated by NASA Team Algorithm (NTA). In summertime of the Arctic, the correlation coefficient between EOC SIC (M+F+Y+N) and SSM/I SIC were low (0.671) due to rapid temporal and spatial variation of sea ice. For springtime in the Antarctic, EOC SIC (M+F+Y, excluding N) and SSM/I SIC have shown the highest correlation coefficient (0.873). We have concluded that the NTA-derived SSM/I SIC includes Y as well as M+F, but not N.**

I. INTRODUCTION

The Arctic and Antarctic regions are very sensitive to global climate change. Particularly, the rapid decrease of sea ice in recent years has been a prime indicator of the climate change possibly from global warming and sea level rise. Satellite passive microwave sensors have been widely used for the polar research because they are not affected by solar radiation or atmosphere conditions. Since 1972, passive microwave sensors such as ESMR, SMMR and SSM/I have been used for sea ice observation. Particularly, SSM/I has been providing the daily Sea Ice Concentration (SIC) of the Arctic and Antarctic from 1987 to present, which is a unique and valuable resource for the research of sea ice fluctuation [1].

Middle to low-resolution satellite sensors such as Landsat TM, ETM+, MODIS, and various SAR systems, combined with field investigations have been used extensively for the calibration and validation of the SSM/I SIC data [2], but there were few comparative study of more detailed ice type and distribution by using a sensor with spatial resolution higher than 10m largely due to the high cost, low solar zenith and cloudy polar weather problems.

Sea Ice can be divided into Multi-year ice (survived the summer melt, > 3m thickness), First-year ice (30cm~2m), Young ice (white nilas, 10~30cm) and New ice (dark nilas, grease ice, frazil ice, less than 10cm) according to their ages, types and thickness, respectively [3].

During July to November 2005, we have obtained high resolution sea ice images of the Arctic and Antarctic using the EOC sensor onboard Kompsat-1 (KOrea Multi-Purpose SATellite) launched in 1999. We classified various sea ice types and calculated SIC thus to compare it with SSM/I SIC to see how each ice type is represented to SSM/I daily SIC archives.

II. EOC and SSM/I Data

EOC is a 6.6m-resolution, 18km-swath panchromatic push-broom sensor with data storage of up to two minute imaging (800km) in a single ascending orbit. The image data is later dumped to a receiving station at KARI (Korean Aerospace Research Institute) in Daejeon, Korea.

We have obtained 624 scenes (18km x 18km each) from 10 orbits for the Arctic sea ice edge from July to August 2005 (Fig. 1a). In this Arctic summer time, floating sea ice types were mainly observed along the melting ice edge (Fig. 2a). The temporal and spatial variations of the sea ice concentration were very high. We could use 85 cloud-free scenes (14% of the total scenes) for further analysis (Table 1).

In the Antarctic, we obtained 676 scenes from 11 orbits for the Antarctic continental edges (Fig. 1b) from September to November 2005. This season was a spring time in the Antarctic when sea ice began to decrease slowly after the peak extension of ice regime during winter. Most sea ice blocks were covered with snow and had narrow cracks and leads that were filled by refrozen new (N) and young ice (Y) in the temporarily open sea. We used 71 cloud-free images (11% of the total) for further analysis (Table 1).

The Arctic		The Antarctic	
Date	Scenes(used)	Date	Scenes(used)
2005/07/12	62(4)	2005/09/25	60(14)
2005/07/15	63(3)	2005/10/01	62(0)
2005/08/05	61(13)	2005/10/02	62(0)
2005/08/06	64(5)	2005/10/05	61(41)
2005/08/07	62(28)	2005/10/07	61(0)
2005/08/11	62(4)	2005/10/08	61(6)
2005/08/14	62(0)	2005/10/21	62(0)
2005/08/22	63(2)	2005/10/24	61(0)
2005/08/25	64(15)	2005/10/27	62(0)
2005/08/27	61(11)	2005/10/30	61(0)
		2005/11/04	63(10)
Total	624(85)	Total	678(71)

Table 1. List of Kompsat-1 EOC images.

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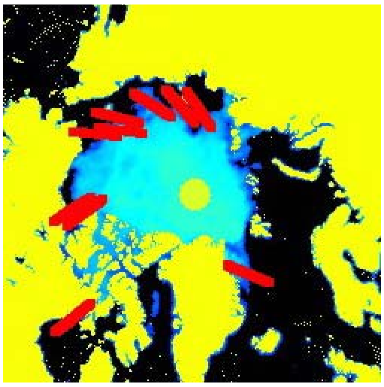
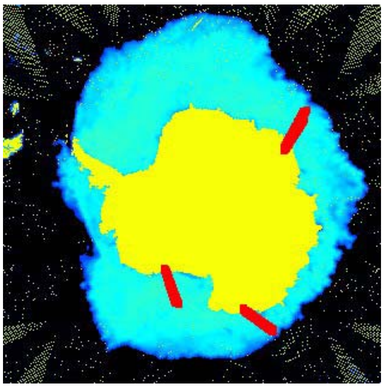
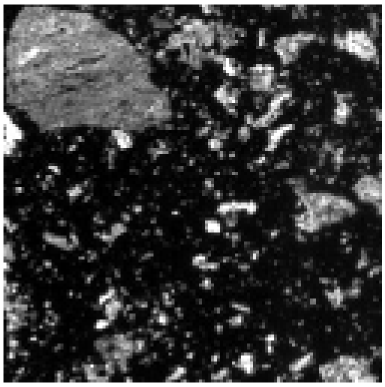


(a) The Arctic (SSM/I: 2005. 8. 5, 6350km x 6350km)

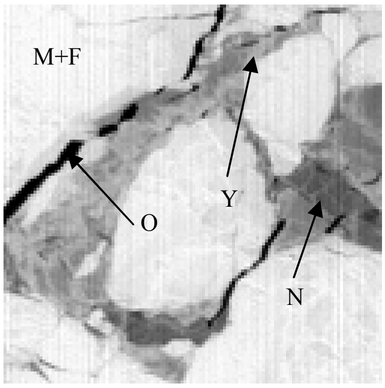


(b) The Antarctic (SSM/I: 2005. 9. 25, 7900km x 7900km)

Figure 1. Kompsat-1 EOC orbits of the Arctic and Antarctic overlying SSMI sea ice concentration image.



(a) The Arctic (2005. 8. 5, 1.8km x 1.8km)



(b) The Antarctic (2005. 10. 5, 1.8km x 1.8km)

Figure 2. Examples of Kompsat-1 EOC images of the Arctic and Antarctic

Using supervised classification, we classified the sea ice types in each image into White Ice (M+F), Grey Ice (Y), Dark-grey Ice (N) and Ocean (O) according to the grey-level characteristics of the panchromatic EOC images (Fig. 2). Errors of supervised classification caused by atmospheric effect and CCD anomaly of the sensor have been corrected by visual inspection.

SSM/I is passive microwave sensor composed of 19, 37, 85GHz dual polarized channels and 22GHz vertically polarized channel, which measures radiation intensity of the sea ice. The daily SIC is derived from the combinations of SSM/I channels using NASA Team Algorithm (NTA) and Bootstrap Algorithm (BTA). We used SSM/I SIC calculated by NTA, which has 25km resolution and is the sum of M and F [4]. We extracted SSM/I SIC of the observation date and location of EOC images, computed standard deviation of cubic pixels including the days before and after and neighboring pixels to see the temporal and spatial instability of the SIC.

III. COMPARISON of EOC with SSM/I SIC

Fig. 3 shows the relationship between SSM/I SIC and EOC SIC (M+F+Y+N) of the Arctic. The vertical error bar of each data point indicates the standard deviation of SSM/I cubic pixels as mentioned above. The SIC of more than 15% data were shown here as it is conventionally used as a criterion for existence of sea ice. The correlation coefficient between two SIC data set is low (0.671). This is because of the temporal and spatial variation of sea ice caused by floating ice and icebergs in the ice edge area. Also this error may have originated from the NTA as it may recognize wet sea ice surface as ocean when the ice surface varies dramatically by weather condition [5].

Fig. 4 shows the relationship between SSM/I SIC and EOC SIC (M+F+Y+N) of the Antarctic. Most SIC in this Antarctic spring shows the value higher than 70%. Generally, EOC SIC shows less than SSM/I SIC and the correlation coefficient was 0.727. Considering relatively stable sea ice condition in this season, the difference between two SIC data set is very large. It is thought that N and Y in the cracks and leads do not respond to SSM/I SIC as NTA calculates SIC with the sum of M and F. Therefore we compared EOC SIC (M+F) with SSM/I SIC of the Antarctic (Fig. 5), but the correlation coefficient was not improved at all.

When we compared EOC SIC (M+F+Y) excluding N with SSM/I SIC (Fig. 6), the correlation coefficient was improved to 0.873. Therefore, it is considered that the Antarctic SSM/I SIC calculated by NTA includes not only M and F but also Y, but not to N.

IV. COCLUSION

For the calibration and verification of SSM/I sea ice concentration, especially the new ice and young ice which are important to interpret the decadal variation of sea ice from SSM/I SIC data, we have analyzed 156 cloud-free, panchromatic Kompsat-1 EOC scenes (out of 1304 scenes) of the Arctic and Antarctic sea ice. It is found that that the 6.6m resolution EOC sensor, which is relatively a high resolution sensor in the polar research, is very useful to classify the detailed ice types such as New Ice, Young Ice, First-year Ice and Multi-year Ice. Although the success rate of cloud-free image acquisition was just over 10% and it was relatively expensive operation, such high-resolution optical images are superior to even SAR image in that SAR can not discriminate N or Y of which surface roughness are similar with each other.

Direct comparison of the SIC calculate from EOC with those from SSM/I using NASA Team Algorithm have shown that EOC SIC did not correlated very well (0.671) to SSM/I SIC in the Arctic summer because of high spatio-temporal variation of sea ice edge. In the Antarctic spring, EOC SIC (M+F+Y) excluding N matches up to SSM/I SIC well with correlation coefficient of 0.873. It is concluded that SSM/I SIC calculated by NTA responds not only to M and F but also Y, but it do not respond to N.

For more detailed Cal/Val of SSM/I SIC, especially for N and Y type along sea ice edge, a series of dedicated Kompsat-1 EOC imaging is scheduled in 2006 during the ice-growing season: April to June for the Antarctic and September to November for the Arctic. Along with various ongoing satellite-based polar researches, such high-resolution optical sensing accompanied with ground observation onboard a polar research vessel could be another option for more detailed SSM/I SIC Cal/Val and for various satellite-based polar research.

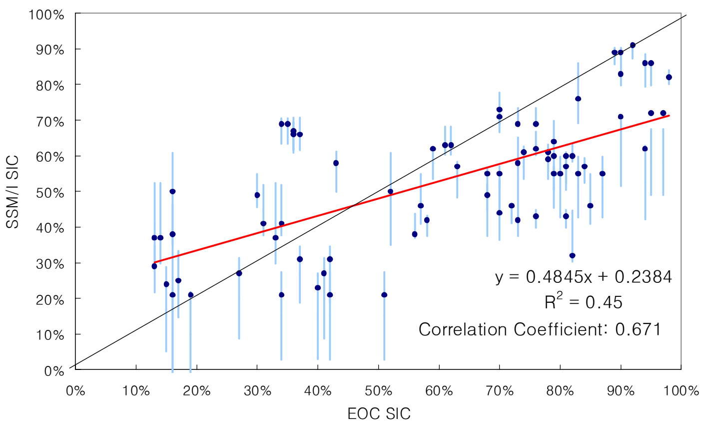


Figure 3. Relationship between EOC SIC (M+F+Y+N) and SSM/I SIC of the Arctic (Correlation Coefficient: 0.671)

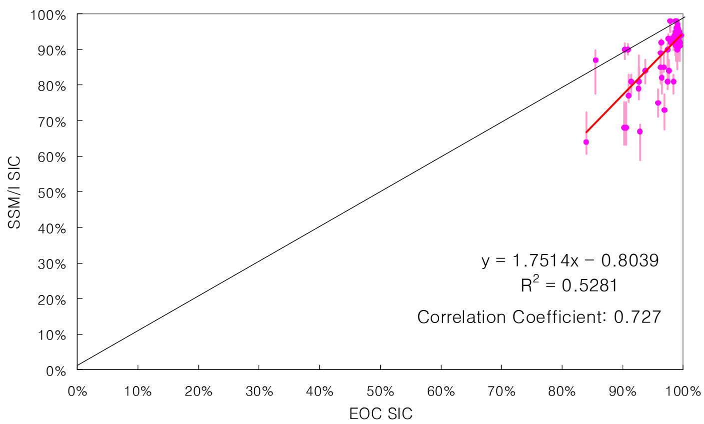


Figure 4. Relationship between EOC SIC (M+F+Y+N) and SSM/I SIC of the Antarctic (Correlation Coefficient: 0.727)

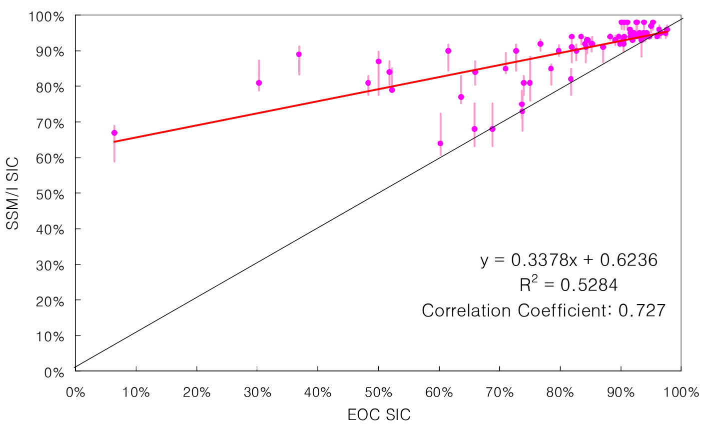


Figure 5. Relationship between EOC SIC (M+F) and SSM/I SIC of the Antarctic (Correlation Coefficient: 0.727)

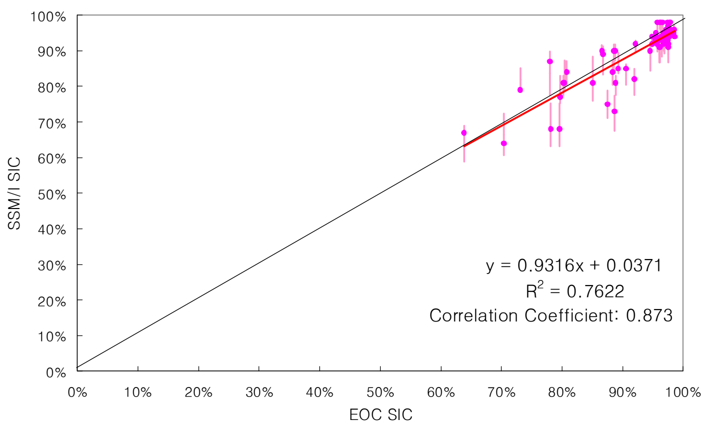


Figure 6. Relationship between EOC SIC (M+F+Y) and SSM/I SIC of the Antarctic (Correlation Coefficient: 0.873)

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