THIN ICE AREA EXTRACTION USING AMSR-E DATA IN THE SEA OF OKHOTSK

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Abstract: Passive microwave sensors onboard satellites, such as SSMI or AMSR-E, can penetrate clouds and can monitor the global sea ice distribution on daily basis. However, since the footprint size of passive microwave sensors are rather large, approx. 38x30km for SSM/I 37GHz and approx.8x14km for ASMR-E 37GHz, extraction of sea ice thickness with passive microwave sensors is not easy. In this study, we have developed a method to detect thin ice area using scatter plots of AMSR-E 19GHz polarization difference(V–H) vs 37GHz V polarization. The result comparison with simultaneously collected MODIS images for the Sea of Okhotsk proved the effectiveness of this method. The interannual variation of total sea ice area and thin ice area in the Sea of Okhotsk is also discussed in this study.

1. INTRODUCTION

Sea ice has an important role of reflecting the solar radiation back into space. However, the reduction of ice cover due to the global warming decreases the earth albedo, and increases the amount of solar energy absorption leading to more global warming. This phenomena is called "ice albedo feedback". This means that the trend of global warming is likely to be enhanced in sea ice area. Passive microwave sensors onboard satellites can penetrate clouds and can monitor the global sea ice distribution on daily basis. On September 16, 2012, the observation by the passive microwave sensor AMSR2 on board satellite GCOM-W1 of JAXA indicated that the Arctic sea ice extent shrunk to 3.49 million square kilometers, the smallest record in the passive microwave sensor observation history from space since 1979. The importance of sea ice monitoring is increasing. Ice concentration is the most fundamental parameter of sea ice which can be calclated from brightness temperatures measured by passive microwave sensors. There are number of sea ice concentration algorithms including NASATeam Algorithm (Cavarieli et. al., 1984), Bootstrap Algorithm (Comiso, 1995), and ASI Algorithm (Spreen et. al., 2008). Sea ice extent and sea ice area can easily be calculated from the sea ice concentration data. Ice thickness is another important parameter of sea ice. The heat flux of thin ice is strongly affected by the ice thickness difference (Maykut, 1978). However, sea ice thickness estimation from passive microwave sensor data is not easy. Martin et. al.(2004) have developed an algorithm for estimating thin ice thickness using the ratio of the vertically(V) and horizontally (H) polarized SSM/I 37 GHz channels. The result suggested the possibility of estimating thin sea ice thickness in Chukchi Sea Alaskan coast polynya with passive microwave observation. However, considering the large footprint size of passive microwave sensors and the spatial variability of sea ice thickness, the authors do not think it is possible to verify the possibility of estimating thin sea ice thickness with passive microwave sensors at least in the Sea of Okhotsk along the coast of Hokkaido. In this study, the authors have developed a method to detect thin ice area using scatter plots of AMSR-E 19GHz polarization difference(V–H) vs 37GHz V polarization. The result comparison with simultaneously collected MODIS images for the Sea of Okhotsk proved the effectiveness of this method. The interannual variation of total sea ice area and thin ice area in the Sea of Okhotsk is also discussed in this study.

Figure1. Test site

2. TEST SITE

In this study, the Sea of Okhotsk was selected as the test site for the detailed evaluation of thin ice area extraction. Figure 1 show the maps of the test site. The

Sea of Okhotsk is located in the north side of Japan, and is one of the most southern seasonal sea ice zones in the northern hemisphere. Since many thin ice area can be found in the Sea of Okhotsk, the sea is suitable for this study. The in situ measurements of ice thickness were performed at the Monbetsu Bay and Saroma Lake along the coast of Hokkaido, Japan.

3. ANALYZED DATA

As for the passive microwave sensor data, data of AMSR-E onboard Aqua satellite were used. AMSR-E was developed by JAXA and operated from 2002 to 2011. In order to identify thin ice area, optical sensor MODIS data were used. Since MODIS is also on the same Aqua satellite, both data were simultaneously collected. Table 1 and 2 show the specifications of AMSR-E and MODIS. As for MODIS, only the Band 1 and 2 which have the 250m resolution were used in this study.

Table 1. Specifications of AMSR-E

Frequency (polarization)	IFOV	Swath	Incident angle
6.925GHz（V,H)	43×75 k m	1445km	55deg
10.65GHz(V,H)	9×51 k m		
18.7GHz（V,H)	16×27 k m		
23.8GHz（V,H)	18×32 k m		
36.5GHz（V,H)	8.2×14.4 k m		
89.0GHz (a)	3.7×6.5 k m		
89.0GHz (b)	3.5×5.9 k m		

Table 2. Specifications of MODIS

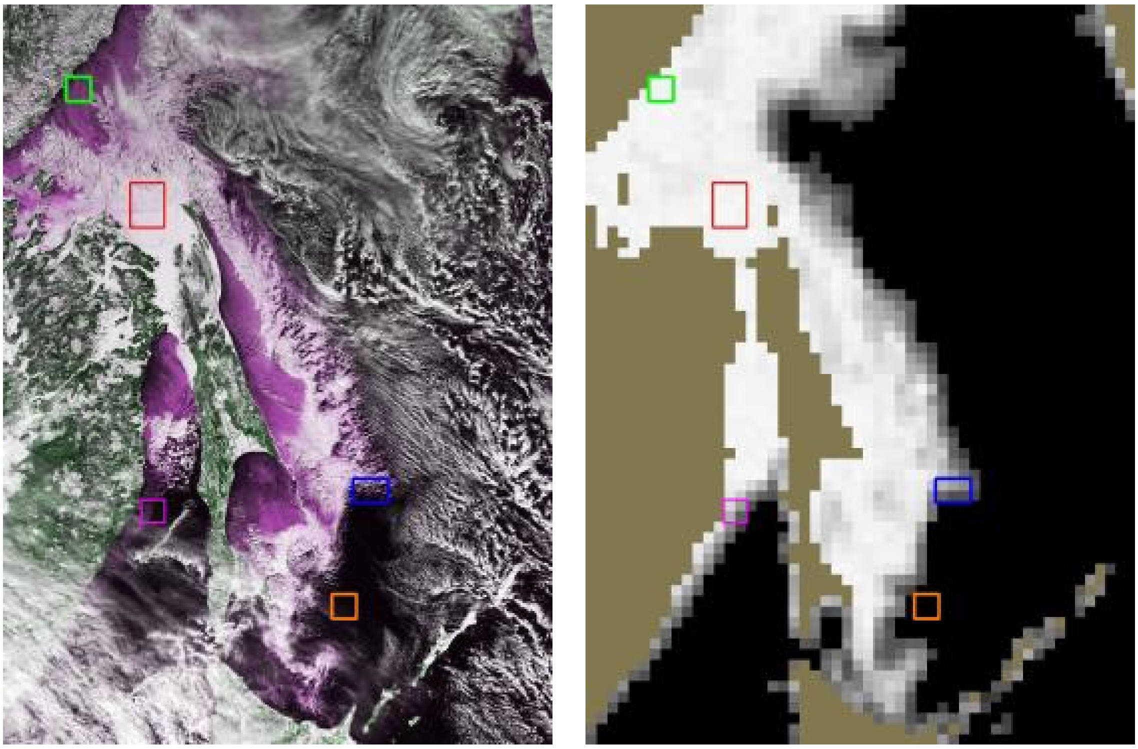
Sensor	Band	Wavelength	IFOV	Swath
MODIS	1	0.620-0.670μm	250m	2330km
	2	0.841-0.876μm		

*The MODIS data of IFOV=500m and 1km are not used in this study.

4. TEST AREA EXTRACTION

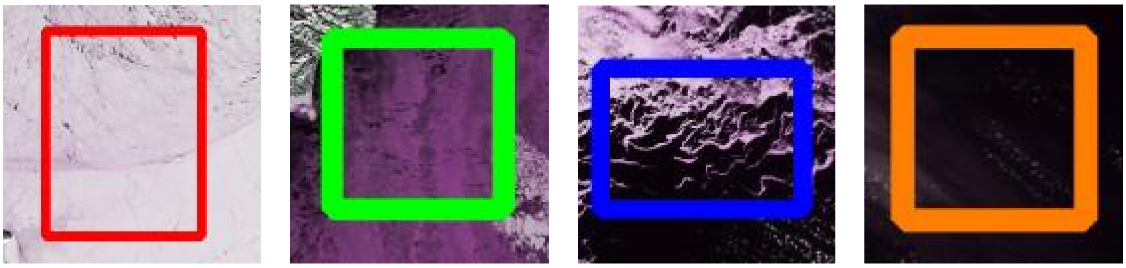
Under the cloud free condition, high resolution optical sensors onboard satellites are quite useful for monitoring the detailed condition of sea ice. Basically, the albedo increases as the ice thickness increases. Through the comparison of the in situ ice thickness measurements with optical sensor data of RSI and MODIS, the authors have verified that under the less snow and cloud free condition, thin sea ice area ,where the ice thicknesses are around or less than 15cm, can be identified in MODIS images (Cho et. al., 2012). In this study, the color composite images of MODIS (Band 1 to blue and red, Band 2 to green) were used for extrtacting test area of thin sea ice, big ice floe, open water and mixed sea ice. In thin ice area, since the surface and around of thin ice are rather wet, the albedo of Band 2(near infrared) decrease greater than Band 1(visible) and appear in purple in the color composite image of MODIS.

Figure 2(a) shows MODIS color composite image and Figure 2(b) shows AMSR-E sea ice concentration image of the Sea of Okhotsk taken on February 7, 2009. The ice concentration image was derived using AMSR-E Bootstrap Algorithm (Comiso, 2009). In Figure 2(a), dark purple area can be seen along the coast of Russia. As explained in the previous chapters, dark purple area in MODIS image can be estimated as thin ice area. In order to examine the brightness temperature characteristics of big ice floe, thin ice, mixed ice, and open water, the sample area of each item was selected in the MODIS image as shown on Figure 3. Then the sample areas are overlaid on the AMSR-E image, and the AMSR-E data of the sample areas were extracted.



(a) MODIS image (b) AMSR-E ice concentration

Figure 2. Comparison of MODIS and AMSR-E images.
(Sea of Okhotsk, February 7, 2009)



(a)Big ice floe (b) Thin ice (c) Mixed ice (d) Open water

Figure 3. Sample area of different ice types extracted from MODIS image
(Sea of Okhotsk, February 7, 2009)

5. THIN ICE AREA EXTRACTION ALGORITHM

Figure 4 shows scatter plot of AMSR-E 19GHz V versus 37GHz V for the sample areas. This characteristic domain is used for calculating ice concentrations in Bootstrap Algorithm. It is clear that the thin ice area ( ) can't be identified with the big ice floe(consolidated ice■) in this scatter plot. So, the authors have introduced the scatter plot of AMSR-E(19GHzV-19GHzH)versus 37GHzV as shown on Figure 5. Since thin ice areas are likely to be wet, the polarization difference of 19GHz brightness temperature in thin ice area increases than big ice floe (consolidated ice). As a result, the thin ice area( ) could be discriminated from big ice

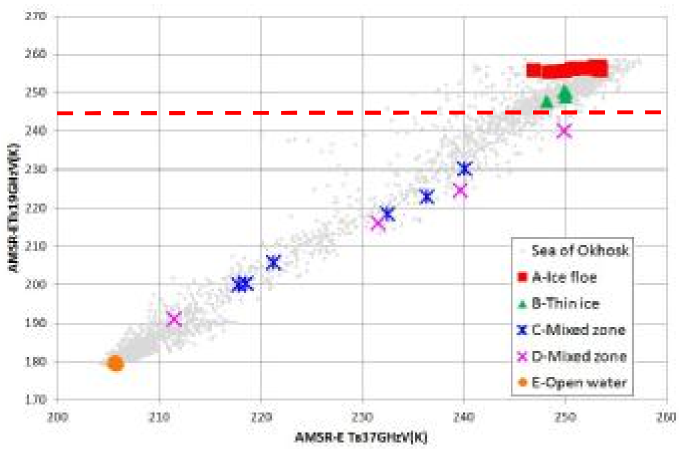


Figure.4 Scatter plots of 19GHz vs 37GHz at V polarization
(Sea of Okhotsk, February 7, 2009)

floe(■) in the scatter plot on Figure 5. The authors have introduced following equation for extracting thin ice area.

TB(19GHzV － 19GHzH) ＋ TB(37GHzV) ＞300K (1)

The meshed area represents the area extracted with equation (1). However, in this case, not only thin ice area( ) but also mixed ice area(X) will be extracted. Considering the large footprint size of passive microwave sensors, it is impossible to discriminate thin sea ice from thick sea ice and water mixed low ice concentration area. So, in this study authors decided to extract only the thin sea ice area with 80% or higher sea ice concentration using the following equation (See also Figure 4).

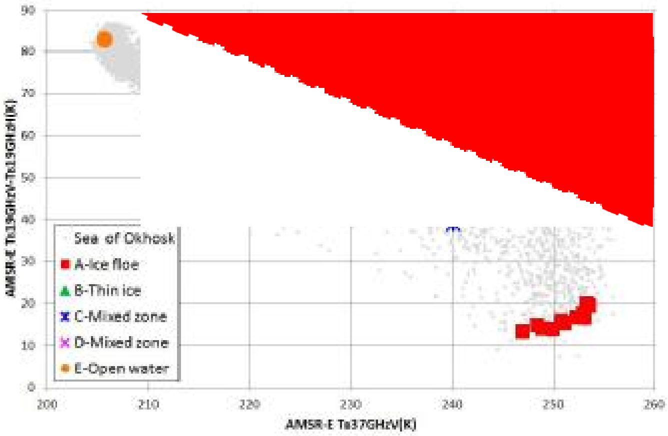
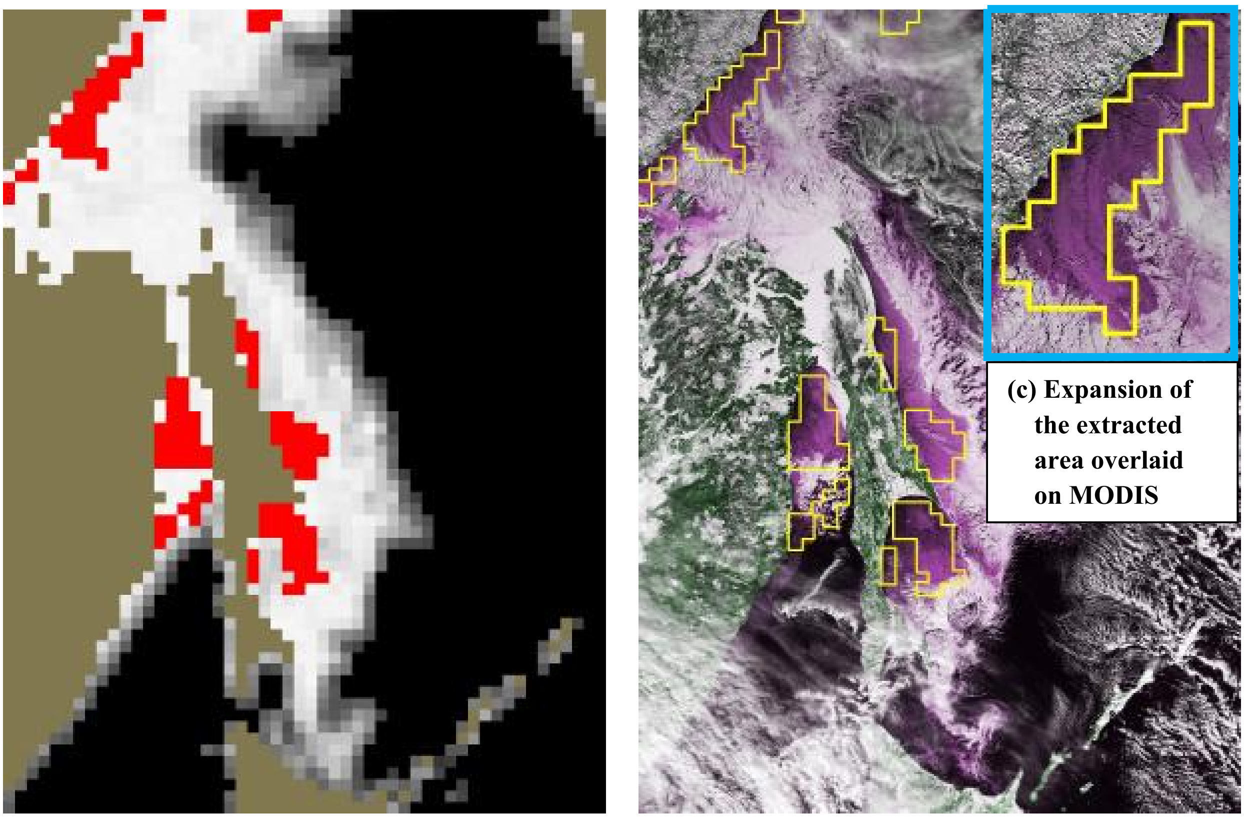


Figure 5 Scatter plots of T_B(19GHzV-19GHzH) versus T_B(37GHzV) (Sea of Okhotsk, February, 7, 2009)

TB(19GHzV)>245K (2)

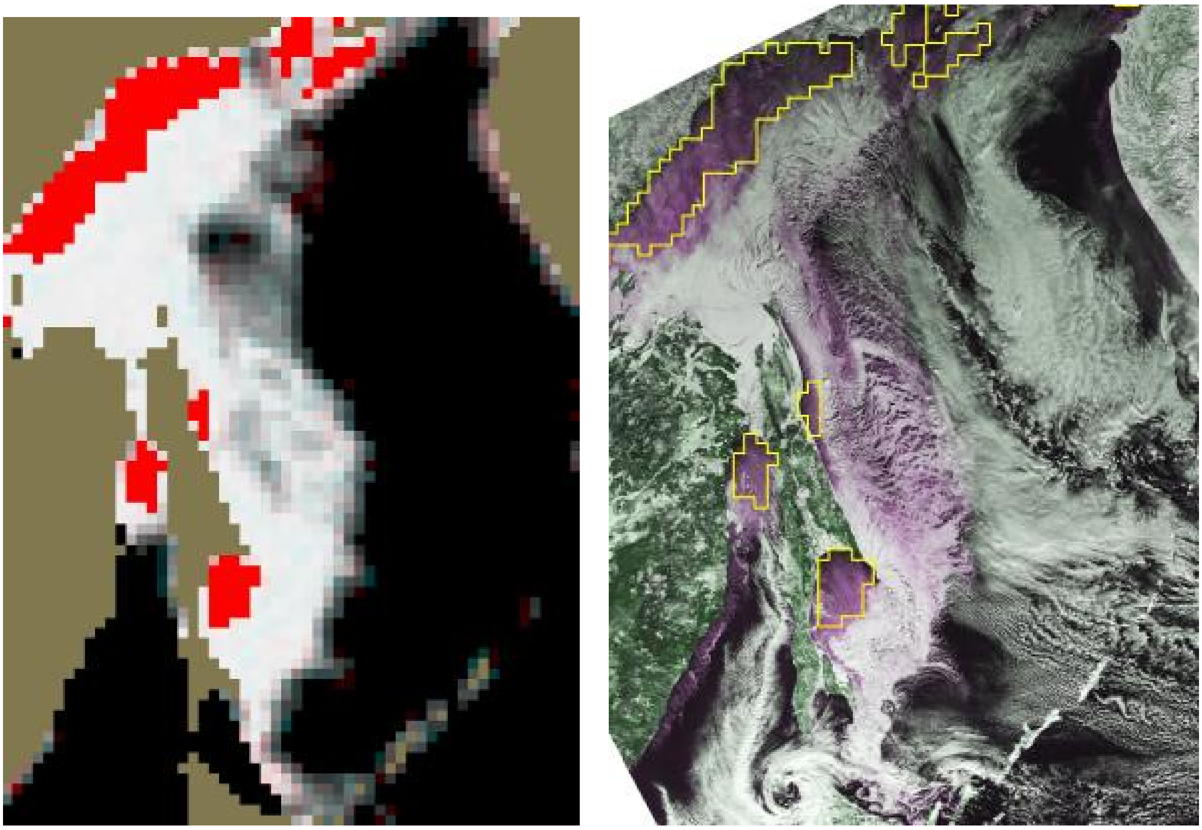
6. RESULT

The red area in Figure 6(a) are the "thin ice areas" extracted using ASMR-E data using equations (1) and (2). The extracted areas were overlaid on the MODIS image for evaluation as shown on Figure 6(b) and (c). It shows that not all but most of the thin ice areas which are appearing in dark purple in the MODIS image are extracted with the proposed method. Figure 7 show another example of February 7, 2004. Up to now, we have applied this method to around ten AMSR-E scenes for the Sea of Okhotsk with acceptable result.



(a)AMSR-E image (Red: extracted area) **(b)MODIS image**

Figure 6 Thin ice area extraction result (Sea of Okhotsk, February 7, 2009)



(a)AMSR-E image (Red: extracted area) (b)MODIS image

Figure 7 Thin ice area extraction result (Sea of Okhotsk, 2004/02/09)

The daily thin sea ice area and total sea ice area of the Sea of Okhotsk were calculated for January and February, 2008. Figure 8 shows the result. It is interesting to see that thin ice area is increasing gradually from the middle of January to middle of February.

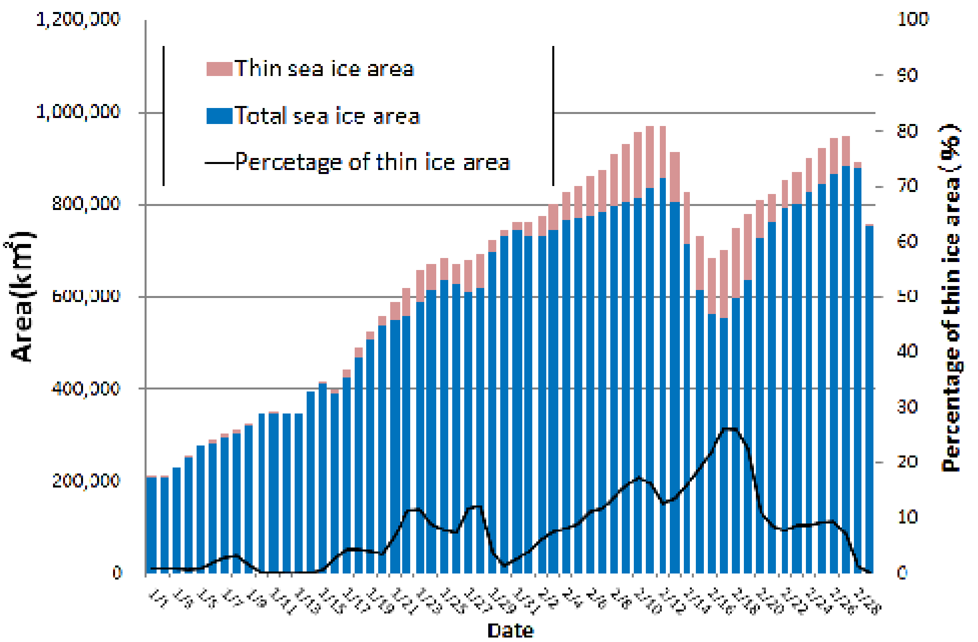


Figure 8. Trend of daily thin sea ice area and total sea ice area derived from AMSR-E data (Sea of Okhotsk, January and February, 2008)

7. CONCLUSIONS

In this study the authors have investigated the possibility of extracting thin ice area from passive microwave AMSR-E data. MODIS images were used to select sample areas of thin ice. By comparing AMSR-E brightness temperatures characteristics of thin ice area with other sea ice type areas, the authors have introduced the scatter plots of AMSR-E (19GHz V-19GHz H) versus 37GHzV for extracting thin sea ice area. The extracted thin sea ice areas were validated by comparing with MODIS images. The result proved the effectiveness of this methodology. However it should noted that, so far, the target will be focused only to seasonal sea ice zones such as Sea of Okhotsk to reject the influence of multi-year ice. Thus, the data will only be calculated before the melting season to reduce the effects of flooding. The authors also recognize the importance of tuning the parameters of the algorithm. The authors are also examining the possibility of applying this methodology to the other sea ice zones.

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