THIN ICE AREA EXTRACTION ALGORITHM USING AMSR2 DATA FOR THE SEA OF OKHOTSK

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ABSTRACT

Passive microwave radiometers, such as AMSR-E and AMSR2, onboard satellites can penetrate clouds and can monitor the global sea ice distribution every day. Usually, by using the big brightness temperature difference between sea ice and open water, sea ice concentrations of the sea ice areas are calculated from brightness temperature data acquired from passive microwave radiometers. On the other hand, considering the radiometric property of sea ice and the large footprint size of passive microwave radiometers, it is not easy to extract sea ice thickness using passive microwave radiometer. However, in 2012, the authors have developed an algorithm to detect thin ice area using the brightness temperature scatter plots of AMSR-E 19GHz versus 37GHz V polarizations and 19GHz polarization difference(V–H) versus 37GHz V polarization (Cho et. al., 2012). It worked quite well in the Sea of Okhotsk. However, recently, the authors have revised the algorithm for AMSR2, the successor of AMSR-E, by using the brightness temperature scatter plots of AMSR-2 19GHz polarization difference(V–H) versus 19GHz V polarization (Cho et. al., 2014). In this study, the authors have evaluated the advantage of the new algorithm against the previous algorithm by comparing the result with simultaneously collected MODIS images.

Keywords: Passive microwave radiometer, Ice thickness, GCOM-W1, MODIS

1. INTRODUCTION

The Fifth Assessment Report (AR5) of the IPCC provided a clear view of the current status of global warming (IPCC, 2013). The sea ice extent reduction graph of the Arctic derived from time series of satellite passive microwave observation was used in the report as one of the evidence of global warming. Ice concentration is the most fundamental parameter of sea ice which can be calclated from brightness temperatures measured by passive microwave radiometers onboard satellites (Cavarieli et. al., 1984, Comiso, 1995, Spreen et. al., 2008). Ice thickness is another important parameter of sea ice. In thin ice areas, the heat flux of ice is strongly affected by the ice thickness difference (Maykut, 1978). However, considering the radiometric property of sea ice and the large footprint size of passive microwave radiometers onboard satellites, it is not easy to extract sea ice thickness using passive microwave radiometer from space.

The passive microwave radiometer AMSR-E onboard Aqua satellite was launched in May 2002 and operated until October 2011. The authors have developed an algorithm to detect thin ice area using scatter plots of AMSR-E 19GHz polarization difference(V–H) versus 37GHz V polarization (Cho et. Al, 2012). It worked quite well in the Sea of Okhotsk. However, AMSR-E terminated its' operations on October 4, 2011. Following AMSR-E, on May 18, 2012, AMSR2 onboard GCOM-W1 was launched by JAXA (JAXA, 2013). Basic specifications of AMSR2 are similar to those of AMSR-E with enlargement of the diameter of the main reflector from 1.6m to 2.0m. The enlargement of the main reflector improved the spatial resolution of the sensor for about 20% which provided the highest spatial resolution as a passive microwave radiometer in space. In the process of applying our thin ice area extraction algorithm to AMSR2, the authors have revised the argorithm by using the brightness temperature scatter plots of AMSR-2 19GHz polarization difference (V–H) versus 19GHz V polarization. In this study, we compare the both algorithms and verify the advantages of the new algorithm by comparing the results with simultaneously collected MODIS images for the Sea of Okhotsk.

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 with AMSR2 data. Figure 1 show the maps of the test site. The Sea of Okhotsk is one of the most southern seasonal sea ice zones in the northern hemisphere where all the sea ice melt in summer season. In winter, many thin ice areas can be found along the coast of Russia in the Sea of Okhotsk. Thus the sea is suitable for this study.

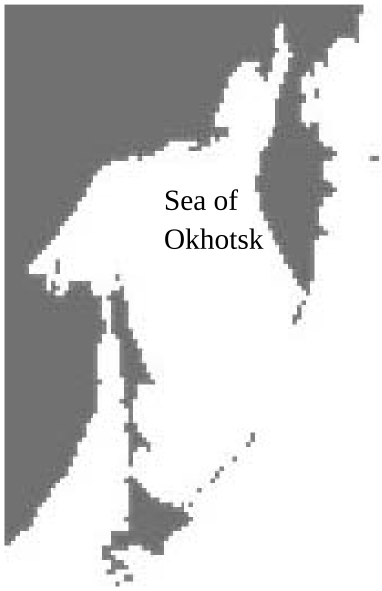


Figure 1. Test site

3. ANALYZED DATA

The brightness temperature data derived from the passive microwave sensor AMSR2 onboard GCOM-W1 satellite were analyzed in this study. The sea ice concentration data derived from AMSR2 data were also used. In order to verify the thin sea ice area derived from AMSR2 data, data collected by the optical sensor MODIS onboard Aqua satellite were used. Since both satellites are in the same orbital track under the frame work of A-Train (NASA, 2012), MODIS onboard Aqua observes almost the same area four minutes after the observation of AMSR2 onboard GCOM-W1. Therefore, MODIS data is one of the most effective validation data for AMSR2 data. Table 1 and 2 show the specifications of AMSR2 and MODIS. As for MODIS, only the Band 1 and 2 which have the highest resolution of 250m were used in this study.

Table 1. Specifications of AMSR2

Frequency (polarization)	IFOV	Swath	Incident angle
6.925GHz（V,H）	35×62ｋｍ	1450km	55deg
10.65GHz(V,H)	24×42ｋｍ		
18.7GHz（V,H）	14×22ｋｍ		
23.8GHz（V,H）	15×26ｋｍ		
36.5GHz（V,H）	7×12ｋm		
89.0GHz（V,H）	3×5ｋｍ		

Table 2. Specifications of MODIS

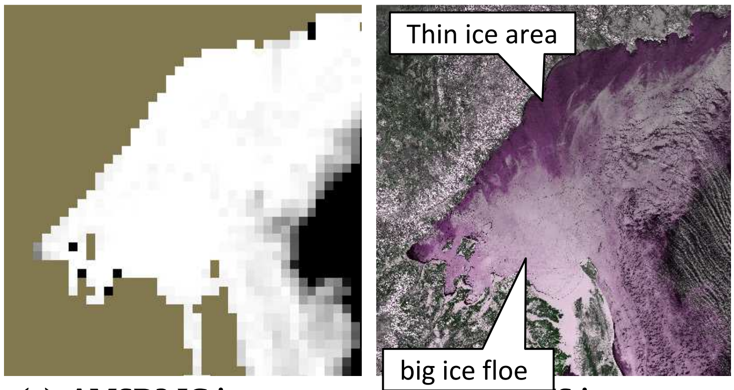
Band	Wavelength	IFOV	Swath
1	0.620-0.670μm	250m	2330km
2	0.841-0.876μm		

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

4. TEST AREA EXTRACTION

Since the spatial resolution of satellite passive microwave radiometers such as AMSR2 are rather low compared with optical sensors such as MODIS (see Table 1 and 2), it is difficult to identify ice types from images derived from passive microwave radiometers. Under the cloud free condition, high resolution optical sensors onboard satellites are quite useful for identifiying the detailed condition of sea ice. Figure 2 show the comparison of simultaniously collected AMSR2 ice concentration image and MODIS image taken on March 4, 2013. The AMSR2 ice concentrations were derive using AMSR2 Bootstrap Algorithm (Comiso et. Al., 2013). The AMSR2 ice concentration image clearly shows the distribution of sea ice in the Sea of Okhotsk. However, it is quite difficult to identify ice thickness differences or thin ice areas from the image. Even though the ice thickness is low, if the area is covered with ice, the ice concentration will be 100% sea ice. In other word, we cannot get ice thickness information from the ice concentration images of AMSR2. On the other hand, in the MODIS image of Figure 2(b), more detailed sea ice distributions can be observed. Basically, the albedo increases as the ice thickness increases. Through the comparison of the in situ ice thickness measurements with data collected by optical sensor on board satellites, 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, blue and red are assigned to MODIS Band 1 and green to Band 2 for making the MODIS color composite images. Usually, the reflectance of thin ice area is lower than thick ice area. Moreover, since the surface and around of thin ice are rather wet, the reflectance of Band 2 (near infrared) decrease greater than Band 1 (visible) in the thin ice area. As a result, thin ice areas are likely to appear in dark purple in the color composite images of MODIS. In this study, we defined these dark purple sea ice areas in the MODIS images as thin ice areas.

In order to examine the microwave brightness temperature characteristics of big ice floe (100% ice), 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 were overlaid on the AMSR2 image and the AMSR2 brigthness temperature data of the sample areas were extracted.



(a) AMSR2 IC image **(b) MODIS image**

Figure 2. Comparison of AMSR2 and MODIS images.
(Sea of Okhotsk, March 4, 2013)

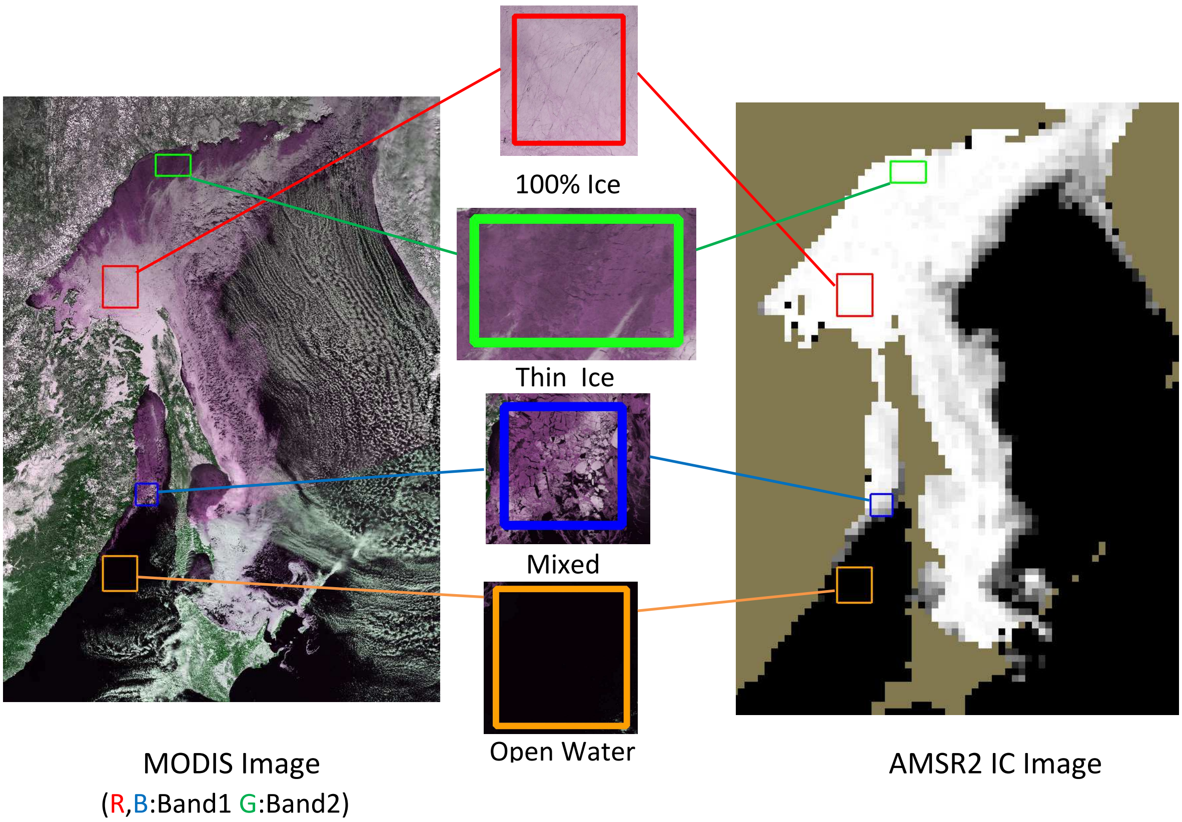


Figure 3. Extraction of sample areas from MODIS and AMSR2 images.
(Sea of Okhotsk, March 4, 2013)

5. THIN ICE AREA EXTRACTION ALGORITHM

5.1 The Original Algorithm

In low ice concentration sea ice areas, verious thickness sea ice and open water are mixed within one pixel of AMSR2. Accordingly, it is impossible to estimate whether the sea ice area is thin ice area or low concentration area. So, in this study, the thin ice area are only extracted within high ice concentration areas. Figure 4 shows the scatter plots of AMSR2 19GHz V versus 37GHz V for the Sea of Okhotsk observed on March 4, 2013 as shown on Figure 3. In this scatter plots, ▲ represents thin ice and ■ represents big ice floe. In our original thin ice algorithm, firstly we use the following equation to extract thin sea ice area with 80% or higher sea ice concentration.

(Tb19GHzV) > 245K (1)

However, Since thin ice area and big ice floa are closely located in this scatter plot, it is difficult to identify thin ice area from big ice floa only with this equation. So, the authors have introduced the scatter plot of AMSR2(19GHzV-19GHzH)versus 37GHzV as shown on Figure 5.

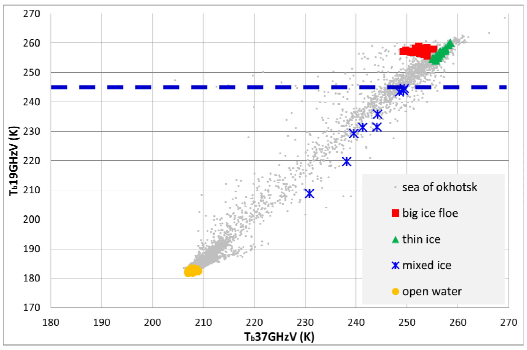


Figure.4 Scatter plots of 19GHz vs 37GHz at V polarization (Sea of Okhotsk, March 4, 2013)

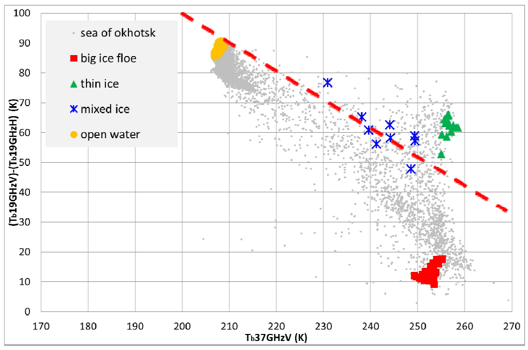


Figure.5 Scatter plots of (T_b19GHzV- T_b 19GHzH) versus (T_b37GHzV) (Sea of Okhotsk, March 4, 2013)

The microwave brightness temperasture of waters are much higher in V polarization than that of H polarization. Since thin ice areas are likely to be wet, the polarization difference(V-H) of 19GHz brightness temperature in thin ice area are much higher than big ice floe (consolidated ice). As a result, the location of thin ice area(▲) could be discriminated from big ice floe(■) in the scatter plots on Figure 6. The authors have introduced following equation for extracting thin ice area.

(Tb19GHzV－Tb19GHzH) ＞ (300K-Tb37GHzV) (2)

The meshed area represents the area extracted with equation (2). In this case, not only thin ice area(▲) but also mixed ice area(✱) will be extracted. However, by the combination of equation (1) and equation (2) only thin ice areas can be extracted.

5.2 Modified Algorithm

By comparing Figure 4 and 5, the authors came to the conclusion that we may extract thin ice areas by using only one AMSR2 brightness temperature scatter plots of (19GHz Vertical polarization(V) – 19GHz Horizontal polarization (H)) versus 19GHz V. Figure 6 shows the scatter plot of AMSR2 brightness temperature for the Sea of Okhotsk observed on March 4, 2013. In this scatter plot, ▲ represents thin ice, ■ represents big ice floe, X represents mixed ice and ● represents open water. Open water(IC=0%) comes to the right top and big ice floe comes to the right bottom on the scatter plot. The middle concentrated ice area comes to in between according to

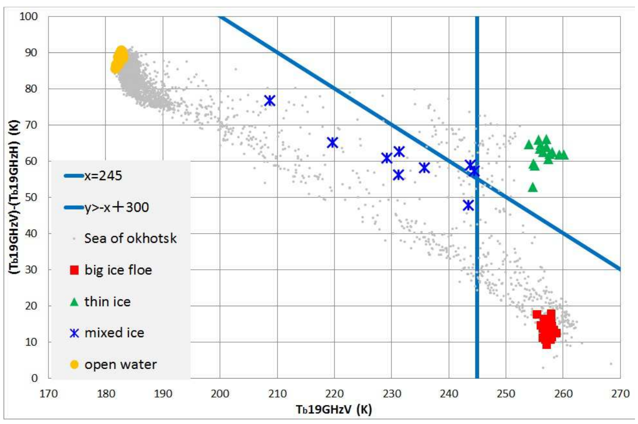


Figure 6. Scatter plot of (T_b19GHzV- T_b 19GHzH) versus (T_b19GHzV) (Sea of Okhotsk, March 4, 2013)

the rate of ice concentration. In our thin ice algorithm, firstly we use the following equation to extract thin sea ice area with 80% or higher sea ice concentration.

(Tb19GHzV) > 245K (3)

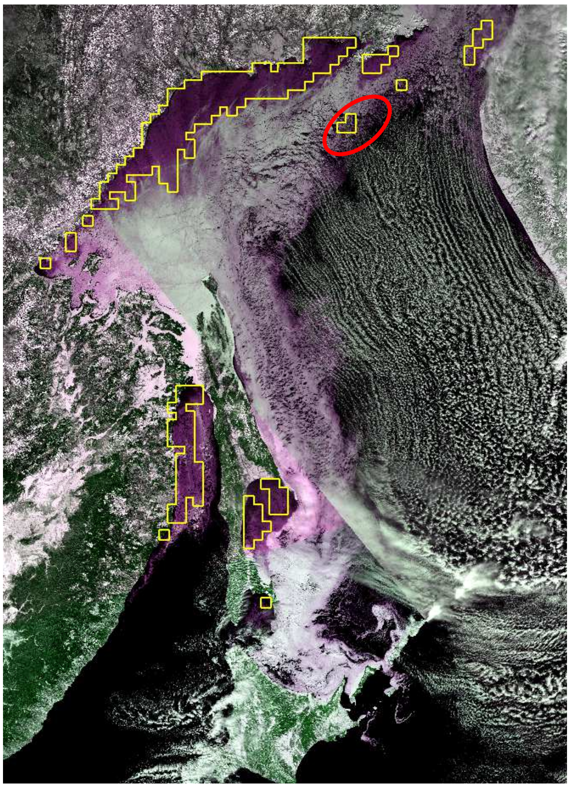
The microwave brightness temperature of waters are much higher in V polarization than that of H polarization. Since thin ice areas are likely to be wet, the polarization difference(V-H) of 19GHz brightness temperature in thin ice area are much higher than big ice floe (consolidated ice). As a result, the location of thin ice area(▲) could be discriminated from big ice floe(■) in the scatter plots on Figure 6. The authors have introduced following equation for extracting thin ice area.

(Tb19GHzV- Tb19GHzH)> 300K-(Tb19GHzV) (4)

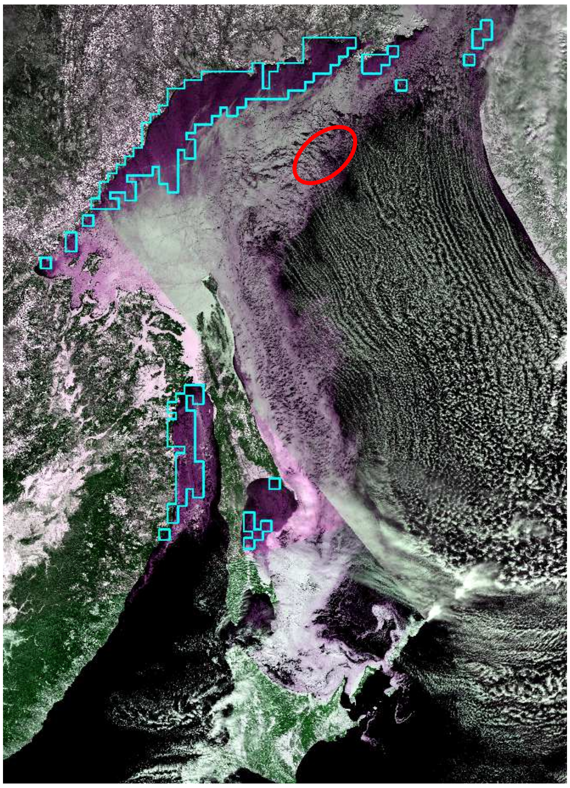
The meshed area represents the "thin ice area" extracted with equation (3) and (4).

6. RESULT

The authors have applied the both algorithms to extract thin ice areas using AMSR2 data in the Sea of Okhotsk. Figure 7(a) shows the examples of the thin ice areas extracted using the original algorithm overlaid on MODIS image of March 4, 2013**.** Figure 7(b) shows the thin ice areas extracted using the modified algorithm overlaid on the same MODIS image**.** Figure 7(a) shows that not all but most of the thin ice areas which are appearing in dark purple in the MODIS image were extracted with the original method. However, some non-thin sea ice areas were also extreacted as thin ice area with the original algorithm (see the red cercle area in Figure 7(a)) . Figure 7(b) shows that most of the thin ice areas extracted by the original algorithm were also extracted by the modified algorithm. Moreover, the wrong thin ice areas extracted by the original algorithm were not extracted in the modified algorithm.



(a) Original Amgorithm



(b) Morified Algorithm

Figure 7 Thin ice area extraction result overlaid on MODIS image (Sea of Okhotsk, March 4, 2013)

7. CONCLUSION

In this study the authors have investigated the possibility of extracting thin ice area from passive microwave radioneter AMSR2 data using the original and modified thin ice area extraction algorithm developmed by our team. The extracted thin sea ice areas were validated by comparing with cloud free MODIS images. The result suggested the advantages of the modified thin ice extraction algorithm against the original algorithm. However it should be noted that, so far, the target areas are focused only to seasonal sea ice zones such as Sea of Okhotsk to reject the influence of multi-year ice. The authors are now examining the possibility of applying this algorithm to AMSR2 in the other sea ice zones.

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