EXTRACTION OF THIN ICE AREA IN THE SEA OF OKHOTSK USING MODIS DATA

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ABSTRACT: Ice thickness is one of the most important parameters of sea ice. However, estimation of ice thickness with satellite remote sensing is very difficult. In this study, the authors have developed a method to extract thin ice area in the Sea of Okhotsk using data of MODIS onboard Terra and Aqua satellites. The reflectance of thin sea ice area is rather low in visible to near-infrared wavelength. The near-infrared region is quite sensitive to water, and the reflectance dramatically reduces with the existence of water. Since the surface of thin sea ice is likely to be wet, the reflectance of near-infrared channel (MODIS Band 2) is lower than that of visible channel (MODIS Band 1) in thin sea ice areas. Considering these characteristics, the authors have developed a method to extract thin sea ice areas by using the scatter plots of MODIS Band 1 and 2 data. By using three equations in the MODIS Band 1 and 2 domain, most of the thin ice area could be extracted in the Sea of Okhotsk. We have verified the method by comparing the extracted result with a high resolution World View image in the Sea of Okhotsk.

1. INTRODUCTION

Sea ice have an important role of reflecting the solar radiation back into space. However, once sea ice melt due to the global warming, the exposed dark water absorbs the solar radiation and causes more warming. This means the effect of global warming is likely to be enhanced in sea ice area. Thus, the importance of sea ice monitoring is increasing. Remote Sensing is a powerful tool for monitoring the global distribution of sea ice. Especially, long term monitoring of sea ice with passive microwave sensors on-board satellites are allowing us to monitor the trend of global sea ice distribution (Parkinson et al., 1999; Comiso and Nishio, 2008; IPCC, 2014).

Ice thickness is one of the important parameters of sea ice. Certain number of studies have been applied on ice thickness estimation from passive microwave data (Martin et al. (2004) and Tamura et al. (2007) etc.). However, since the spatial resolution of passive microwave sensors onboard satellites are rather low (10 to 30km or more), the validation of the ice thickness estimation is not easy. The use of active microwave sensors (Kwok et al., 1995, Toyota et al., 2009) has an advantage in spatial resolution. However, it is quite difficult to detect thin sea ice area or to estimate thin ice thickness with active microwave sensors. Under the cloud free condition, optical sensors are quite useful for monitoring the detailed condition of sea ice. Various studies on estimating ice thickness with optical sensors onboard satellites have been performed in the past (Such as Allison, 1993, Perovich et al., 1982, and Grenfell, 1983). Cho et al. (2011, 2012) has done a detailed study on comparing the ice thickness measurement result with optical sensor RSI and MODIS data. The result suggested that if the ice thickness is less than 20cm, the ice thickness difference can be detected with optical sensors such as MODIS. Since the heat flux of ice is strongly affected by the ice thickness (Maykut, 1978), extracting thin ice area is quite important. In this study, the authors have developed a method to extract thin ice area in the Sea of Okhotsk using data of MODIS onboard Terra and Aqua satellites.

2. TEST SITE

The authors have selected the Sea of Okhotsk as the test site of this study. Figure 1 show the maps of the test site. The Sea of Okhotsk is located in the north side of Hokkaido, Japan, surrounded by the Island of Sakhalin and eastern Siberian coast, Kamchatka Peninsula and Kuril Islands. The sea 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.

Figure 1. Map of the test site.

3. SATELLITE DATA

For evaluating the possibility of extracting thin ice area with optical sensors, MODIS on board Terra and Aqua satellites were analyzed in this study. Table 1 shows the specifications of MODIS. In order to utilize the highest spatial resolution of MODIS, we used only Band 1 and 2 which have 250m resolution.

Table.1 Specifications of optical sensor MODIS

	Band	Wavelength[μm]	IFOV	Swath
MODIS	1	0.620 - 0.670	250m	2330km
	2	0.841 - 0.876		
	3 -7	0.459 - 2.155	500m	
	8 – 36	0.405 - 14.385	1000m	

4. TEST AREA EXTRACTION

The reflectance of thin sea ice area is rather low in visible to near-infrared wavelength. The near-infrared region of the spectrum is quite sensitive to water, and the reflectance dramatically reduces with the existence of water. Since the surface of thin sea ice is likely to be wet, usually the reflectance of near-infrared channel (MODIS Band 2) is lower than that of visible channel (MODIS Band 1) in thin sea ice areas (Cho et al., 2012). Figure 2 shows a color composite image of MODIS assigning blue & red to band 1(visible) and green to band 2(near infrared). Since the reflectance of ice reduces in band 2 when the ice is covered or surrounded by water, the thin ice areas are likely to appear in purple in the MODIS image. In order to investigate the possibility of extracting thin ice area using MODIS data, the authors have selected the test area of thin ice, open water, cloud, and big ice floe from the MODIS image as shown on Figure 2.

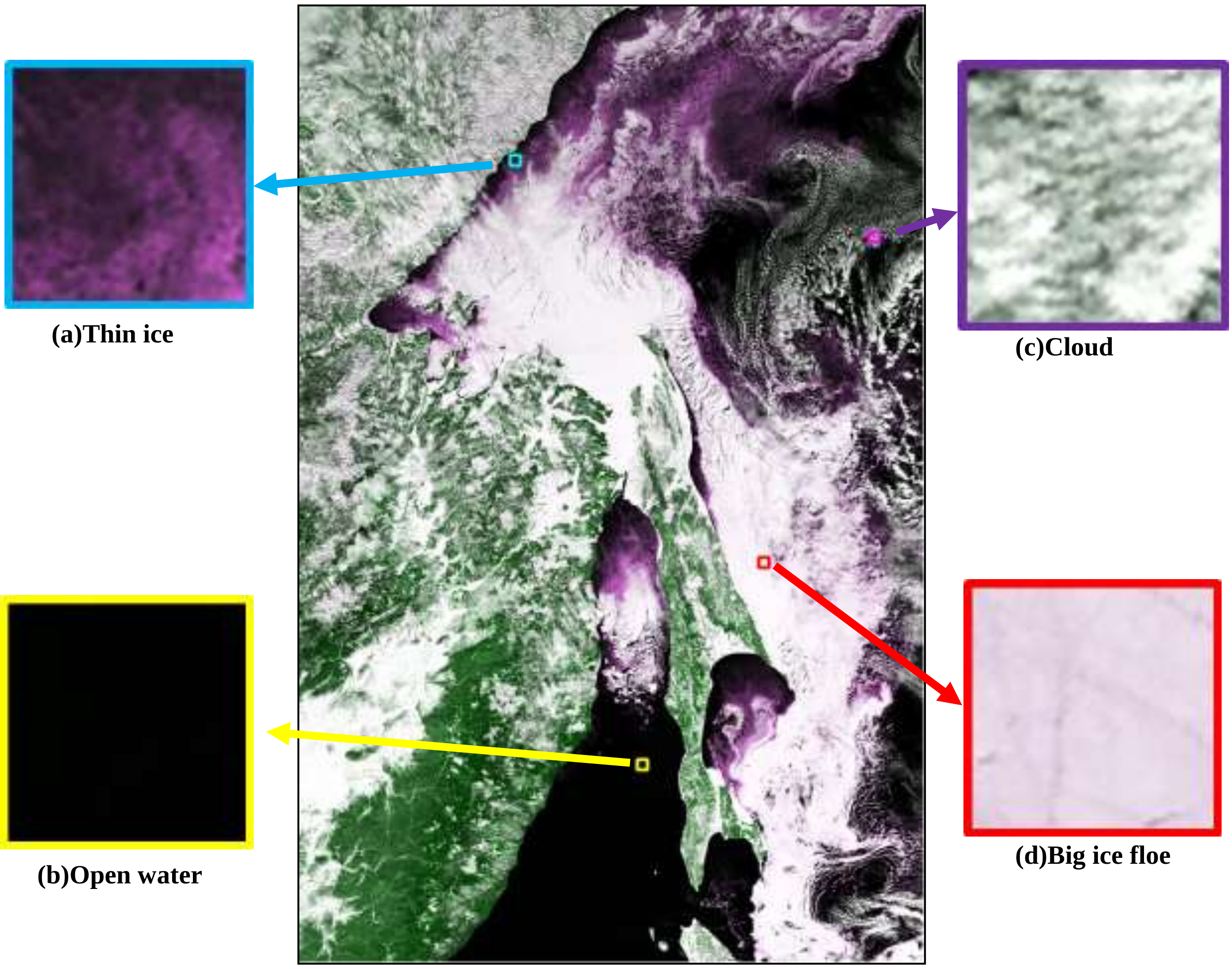


Figure 2. Extraction of test area from the MODIS image.
(Sea of Okhotsk, February 23, 2014)

5. THIN ICE AREA EXTRACTION ALGORITHM

Figure 3 show the scatter plot of each test area, big ice floe(■), Thin ice(▲), cloud(◆), and open water(●) plotted on the Band1 VS Band2 diagram. The gray dots(■) correspond the hole distribution of the Sea of Okhotsk. The numerical values are the digital values of MODIS data. Considering the distribution of each item in Figure 3, the authors have derived the following three equations to extract the thin ice area.

$B2<1.4\times B1+600$ ………………………………. (1)
$B1>610$ ……………………………………….(2)
$B2<2.0\times B1-800$ ………………………………...(3)
B1: Digital value of MODIS Band 1
B2: Digital value of MODIS Band 2

The pixels which are plotted in the red meshed area in Figure 4 are classified to thin ice area in this algorithm.

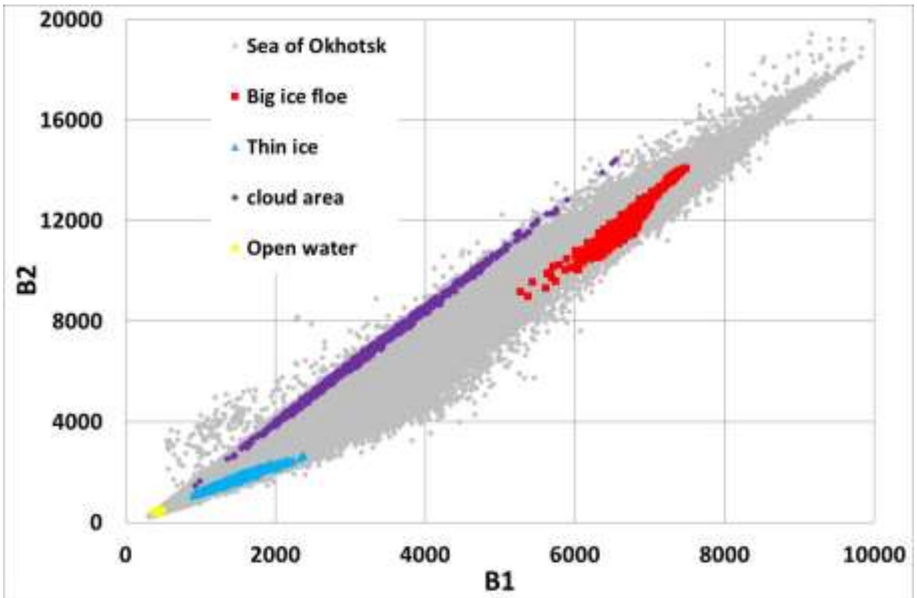


Figure 3. Scatter plots of MODIS Band 1 vs Band 2
(Sea of Okhotsk, February 23, 2014)

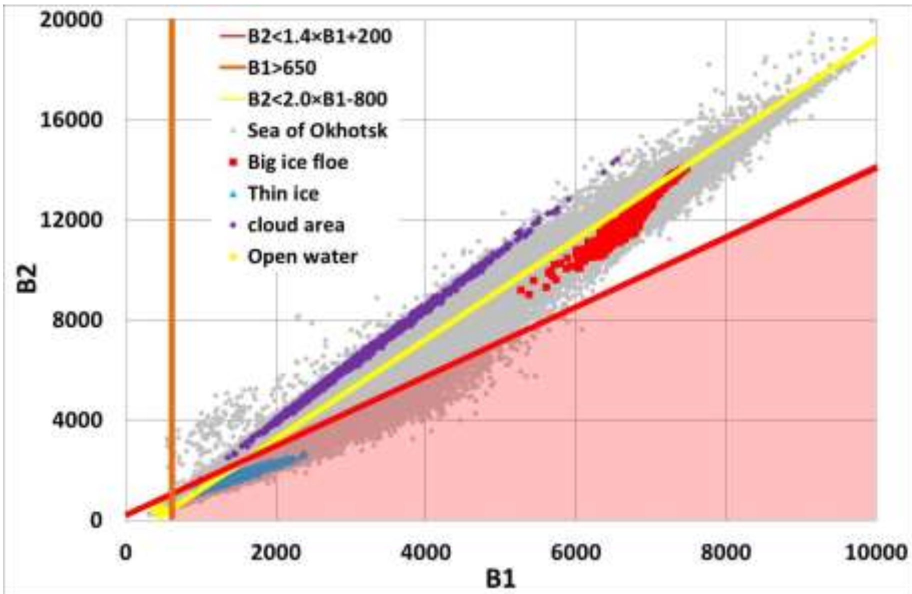
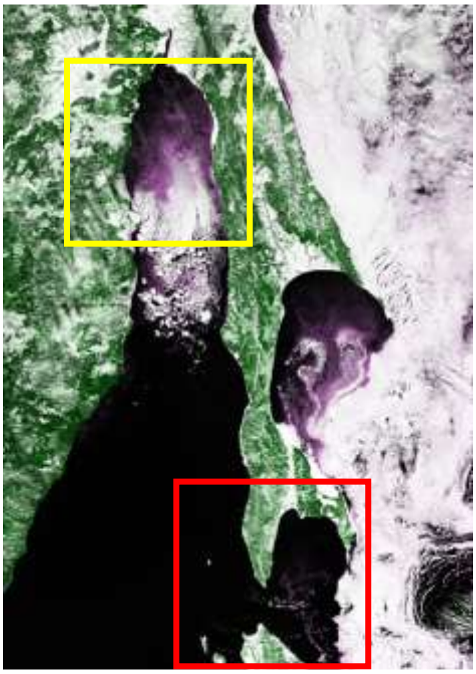


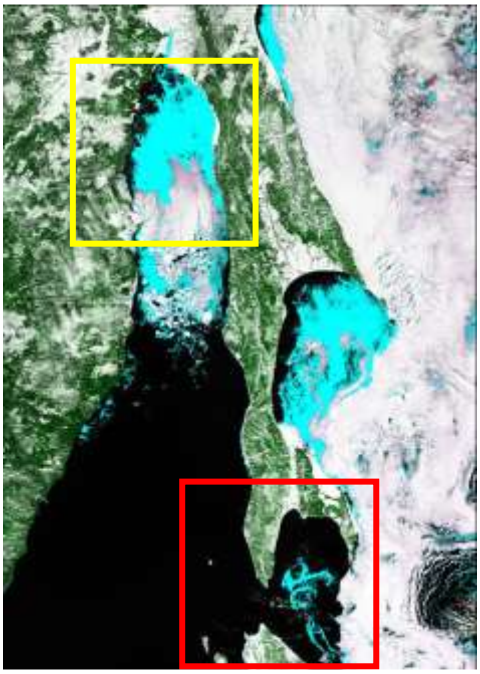
Figure 4. Concept of thin ice area extraction using the scatter plot of MODIS Band 1 and Band 2
(Sea of Okhotsk, February 23, 2014)

6. EXTRACTED RESULT

The MODIS data of the Sea of Okhotsk observed on February 23, 2014 was processed by using the equation (1) to (3) for thin ice area extraction. The extracted thin ice areas are overlaid on MODIS image in cyan color as shown on Figure 5. The most of the thin ice area in the MODIS image were well extracted with this algorithm. Especially, the identification of cloud and thin sea ice are very good as shown on Figure 5(e) and (f).



(a) MODIS image

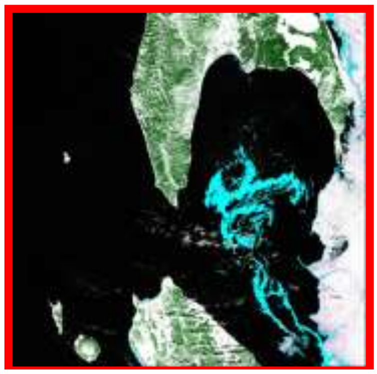


(b) Extracted result

(c) MODIS image (zoom up of area1)

(d) Extracted result (zoom up of area1)

(e) MODIS image (zoom up of area2)



(f) Extracted result (zoom up of area2)

Figure 5. Thin ice area extraction result from MODIS image.
(Sea of Okhotsk, February 23, 2014)

5. CONCLUSION

In this study, the authors have developed a method to extract thin sea ice areas by using the scatter plots of MODIS Band 1 and 2 data. By using the three equations in the MODIS Band 1 and 2 domains, most of the thin ice areas were well extracted in the Sea of Okhotsk. The identification of clouds was also very good. The authors are now verifying the method by comparing the extracted result with high resolution satellite images in the Sea of Okhotsk. We may need some more case study for tuning of the parameters of the algorithm. The authors are now developing thin ice area extraction algorithm using passive micro wave sensor AMSR2 data as well. Since the resolution of MODIS data is much higher than that of AMSR2 data, the result of the thin ice area extraction from MODIS data in this study may be used as the verification data in the study of AMSR2 thin ice area extraction.

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