IDENTIFICATION OF LARGE ICEBERGS USING SATELLITE PASSIVE MICROWAVE RADIOMETER AMSR-E

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Abstract: The U.S. National Ice Center (NIC) is an inter-agency center for sea ice analysis and forecasting. One of the roles of NIC is to provide the location and size information of large icebergs calved from Antarctica which sizes are larger than 15 nautical miles(approx. 28km). The large icebergs are usually monitored by optical sensors such as AVHRR, MODIS or active microwave sensor SAR. In this study, authors have examined the possibility of identifying large icebergs with the passive microwave radiometer AMSR-E band images by comparing with optical sensor MODIS images observed at the same time. The microwave radiation characteristics of icebergs, open water and clouds were also examined. Considering the spatial resolution and microwave radiation characteristics of each band, color composite images of 18GHz V(green) & H(red) and 36GHz H(blue) were used for identifying icebergs. Finally, the authors have confirmed that icebergs larger than 30km could be identified with AMSR-E images.

1. INTRODUCTION

In recent years, calving of massive icebergs from Antarctica has been occasionally reported. The U.S. National Ice Center (NIC) is an inter-agency center for sea ice analysis and forecasting. One of the roles of NIC is to provide the location and size information of large icebergs calved from Antarctica which sizes are larger than 15 nautical miles(approx. 28km). The optical sensor MODIS on board Terra and Aqua satellites are mainly used for monitoring the large icebergs. However, heavy clouds prevent daily monitoring of icebergs with optical sensors. In this study, authors have examined the possibility of using passive microwave sensor AMSR-E on board Aqua satellite for monitoring large icebergs. The spatial resolution of AMSR-E is much lower than MODIS. But, AMSR-E can penetrate clouds and may increase the opportunities of monitoring large icebergs.

2. ANALYZED DATA

The iceberg information which NIC provides to users includes date, location and size information of the icebergs identified with satellite images. The sensor names of the satellite images are also attached. By using the NIC iceberg information, the authors have picked up a number of icebergs calved from Antarctica for our study which are shown on Table 1. As for the satellite images, images from optical sensor MODIS and passive microwave sensor AMSR-E onboard Aqua satellite were used in this study. Table 2 and 3 show the specifications of MODIS and AMSR-E. As for MODIS, only 250m resolution bands were used in this study.

Table 1. Iceberg data used in this study

ID	Date	Lat	Lon	size(km)	sensor
B-17B	2009/3/3	58.09	90.2	48x20	MODIS
C-19A	2007/1/31	62.55	162.01	163x31	MODIS
C-20	2005/10/2-4	56	79.31	25x20	MODIS
D-15	2006/1/13	66.5	81.53	102x57	MODIS

Table 2. Main spec of the MODIS

band	wavelength	resolution	swath width
1	0.620~0.670μm	250m	2330km
2	0.841~0.876μm		
3~7	0.459~2.155μm	500m	
8~36	0.405~14.385μ	1,000m	

Table 3. Specification of AMSR-E

frequency	resolution	polarization	swath width
6.9 GHz	43km	Vertical Horizontal	1450km
10.65 GHz	29km		
18.7 GHz	16km		
23.8 GHz	18km		
36.5 GHz	8.2km		
89 GHz	3.5km		

Figure 1 shows the location of the icebergs analyzed in this study plotted on the map of Antarctica. NIC divides the Antarctic Ocean to four regions (quadrants) which are named A, B, C and D. Serial numbers are given to the large icebergs calved from each quadrant. For an example, B-17B means that the iceberg is the 17th iceberg tracked by NIC calved from Quadrant B. The last B means that B-17 iceberg has split in to two(A & B) or more pieces(C,D,E…).

Figure 2 show comparison of MODIS band1 images and AMSR-E 89GHz horizontal(H) polarization images of iceberg B-17B, C-19A and D-15 observed on same day respectively. Since the spatial resolution of AMSR-E changes with the frequency, 89GHz with highest spatial resolution of 3.5km was used to make the images. Difference in appearance of icebergs in MODIS and AMSR-E images are quite clear. In case of Figure 2(3), the iceberg D-15 is captured in sea ice.

3. METHODS

3.1 Identification of smallest size of icebergs which can be recognized in AMSR-E images

In order to identify smallest size of icebergs which can be recognized in AMSR-E images, authors have collected MODIS and AMSR-E images of iceberg C-19A in different sizes. Since the size of icebergs reduces with time, we have chosen images of January 31, 2007(size: 163x31km), March 10 (size: 30x6km) and 28(size: 15x5km), 2009 for comparison.

3.2 Brightness temperature evaluation

Color composite is one of the effective ways to enhance multi band images in remote sensing. In order to optimize the color combination of AMSR-E bands for identifying icebergs, the brightness temperature characteristics of icebergs, open water and clouds were evaluated. The AMSR-E image of around the iceberg D-15 near Antarctica taken on December 18, 2005, January 7, 13, 16 and February 4, 2006 were used for evaluation. Simultaneously collected MODIS images were used to extract sample area of icebergs, open water and clouds.

3.3 Band combination evaluation

Following the result of the AMSR-E brightness temperature evaluation, the authors have produced a number of color composite images of AMSR-E multiple band images. The color composite images were compared with MODIS images for evaluating the best band combination for identifying icebergs.

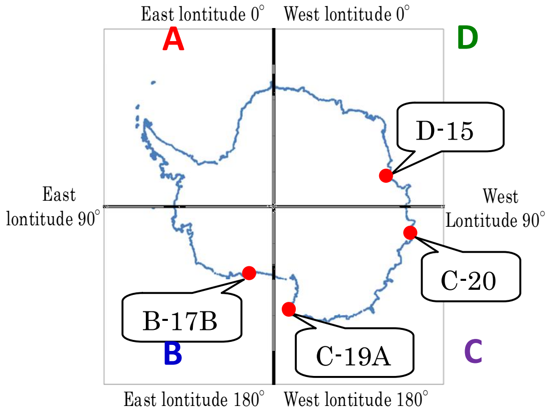
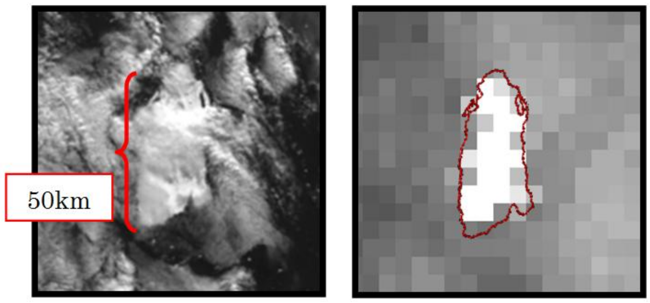
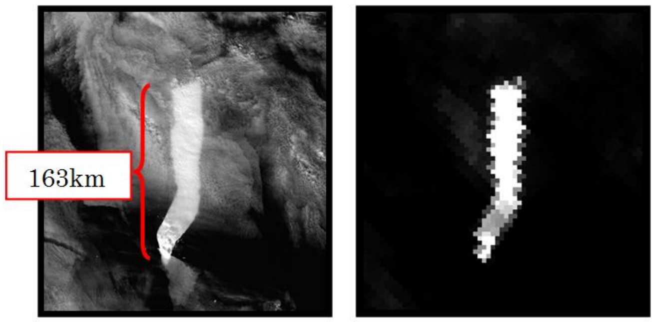


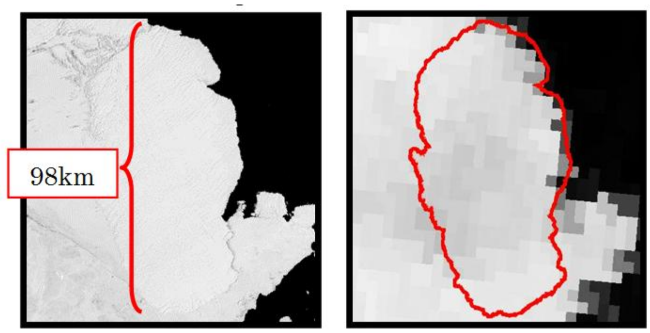
Figure 1. Location of the icebergs



(a) MODIS(band 1) (b) AMSR-E(89GHzH)
(1) B-17B(March 3, 2009)



(a) MODIS(band 1) (b) AMSR-E(89GHzH)
(2) C-19A(March 18, 2007)



(a) MODIS(band 1) (b) AMSR-E(89GHzH)
(3) D-15(January 13, 2006)

Figure 2. Comparison of MODIS and AMSR-E

4. RESULTS

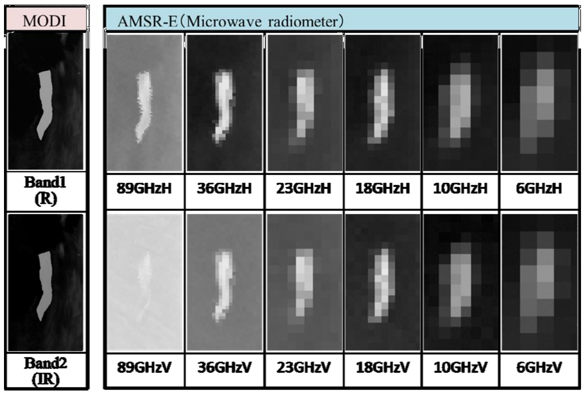
4.1 Identification of smallest size of icebergs which can be recognized in AMSR-E images

Figure 3 show MODIS and AMSR-E band images of icebergs taken on the January 31, 2007, March 10, and 28, 2009. The resolution of AMSR-E band images reduces as the frequency goes down. The difference between vertical(V) and horizontal(H) polarization images are also clear. In case of Figure 3(a) with the iceberg length of 163km, the iceberg could clearly be identified in all AMSR-E band images except 89GHzV. In case of Figure 3(b) with the iceberg length of 30km, the iceberg could be identified with 18GHz, 23GHz and 36GHzV & H images. 89GHzH image is also useful. But, in case of Figure 3(c) with the iceberg length of 15km, the iceberg could barely be identified in 36GHzH and 89GHzH images but not in the other band images. From these result it may be fair to say that icebergs larger that 30km could be identified with AMSR-E images.

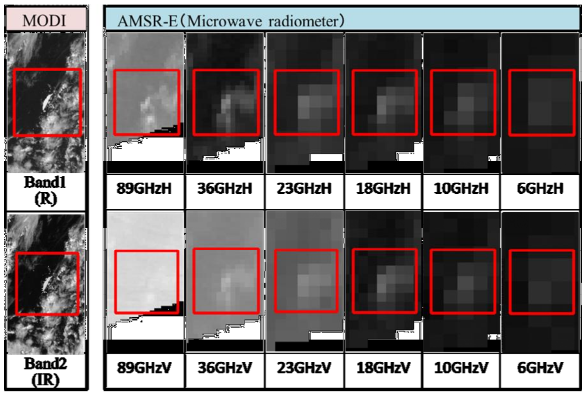
4.2 Brightness temperature evaluation

Figure 4 shows the AMSR-E brightness temperature characteristics of icebergs, open water and clouds in the sea ice area near Antarctica taken on December 18, 2005, January 7, 13, 16 and February 4, 2006. The brightness temperatures were averaged for the five days.

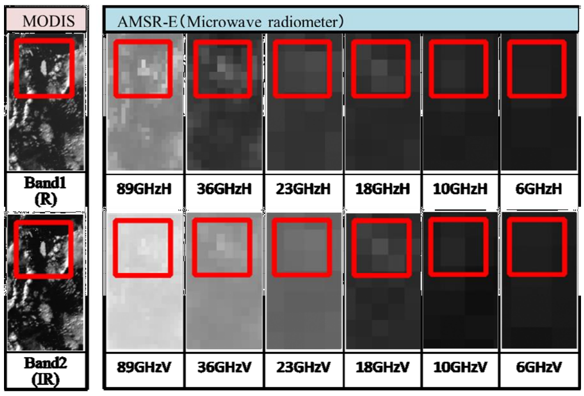
If we look at polarization differences, in all three targets and frequencies, brightness temperature of V polarization is higher than H polarization. But, the brightness temperature difference between V and H polarization are small for icebergs, and are big for open water and clouds in all frequencies. The brightness temperatures of icebergs are around 240K for 6GHz for both V and H polarization. The brightness temperatures of clouds and open water are both around 150K for 6GHzV, and around 80K for 6GHzH. The brightness temperatures of icebergs increase a little from 6GHz to 18GHz, but gradually decrease from 18GHz to 89GHz. On the other hand, the brightness temperature of clouds and open water increase as the frequency increase. However, the increase trend of clouds is higher than open water. So, in 89GHz, the brightness temperatures of icebergs become lower than that of clouds and open water for V polarization. The high spatial resolution of 89GHz is useful for identifying icebergs. But it should be noted that, since the brightness temperature of clouds become similar to that of icebergs in 89GHz, the identification of icebergs may become difficult in 89GHz under the cloudy condition.



(a) Iceberg length: 163km, Date: January 31, 2007



(b) Iceberg length: 30km, Date: March 10, 2009



(c) Iceberg length: 15km, Date: March 28, 2009

Figure 3. Comparison of the visibility of icebergs in MODIS and AMSR-E images.

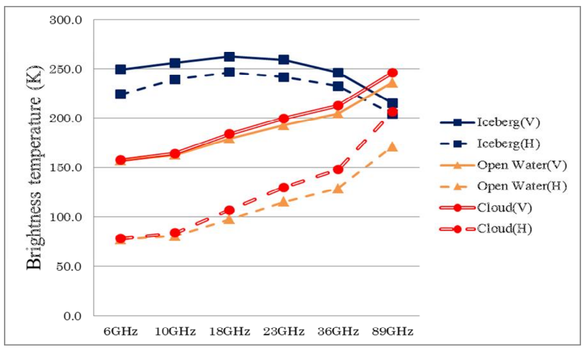


Figure 4. Characteristics of brightness temperatures of iceberg for open water and clouds.

4.3 Band combination selection

By evaluating the result of Section 4.2, band combination selection was performed for producing effective color composite images for iceberg identification. Figure 5(a)-(f) show images of AMSR-E 18GHz, 36GHz, 89GHz for V and H polarization. Considering the spatial resolution and brightness difference between icebergs and the other two, the authors finally selected 18GHz V & H and 36GHz H for color composite. Figure 6 show comparison of the color composite image of AMSR-E (R: 18GHzH, G:18GHzV, B:36GHzH) with MODIS image.

4.4 Advantages of using AMSR-E

By using the color composite images of AMSR-E, authors have evaluated advantages of using AMSR-E for large iceberg tracking. Figure 7 show a comparison of tracking results of iceberg B-17B using MODIS images and AMSR-E images during February 3 to May 12, 2009. Due to the cloudy conditions, B-17B was observed in only four images (days) in MODIS observation. But, for AMSR-E, B-17B was observed in around 30 images (days).

5. CONCLUSIONS

In this study, authors have analyzed the difference in the appearance of the large icebergs in the passive microwave radiometer AMSR-E band images by comparing with optical sensor MODIS images observed at the same time. By investigating the brightness temperature characteristics of these icebergs, clouds and open water, authors have examined the useful band combination for composing AMSR-E band images for the iceberg identification. The authors have confirmed that icebergs larger than 30km could be identified with AMSR-E images.

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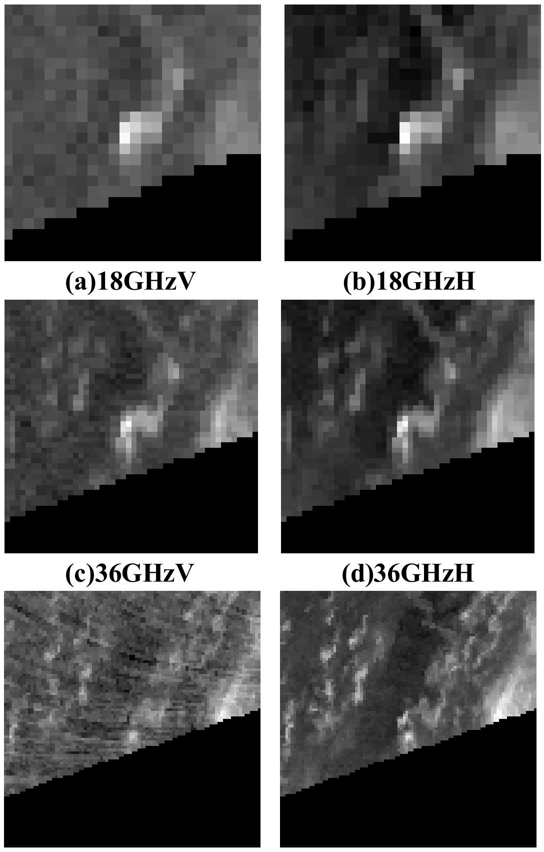
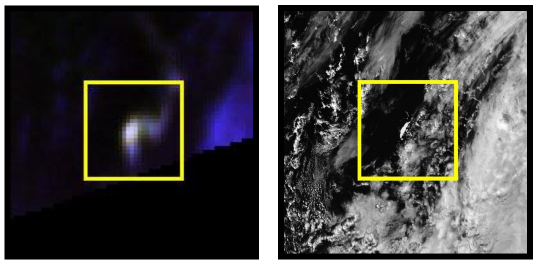


(a)18GHzV (b)18GHzH

(c)36GHzV (d)36GHzH

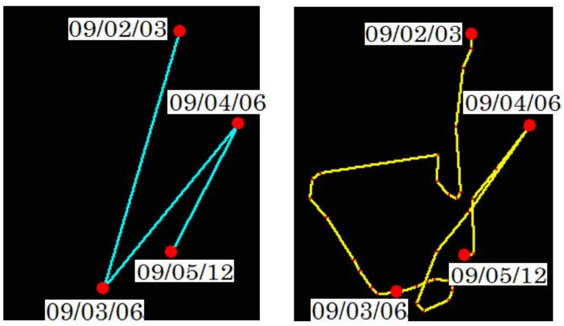
(e)89GHzV (f)89GHzH

Figure 5. Band images of AMSR-E (March 10, 2009)



(a)R:18H, G:18V, B:36H (b)MODIS image

Figure 6. AMSR-E color composite & MODIS images comparison(March 10, 2009)



(a) MODIS (b) AMSR-E

Figure 7. Tracking of iceberg B-17B with MODIS and AMSR-E images (February 3 to May 12, 2009)