A STUDY ON CLOUD EFFECT REDUCTION FOR EXTRACTING SEA ICE AREA FROM PASSIVE MICROWAVE SENSOR DATA

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ABSTRACT:

Due to the global warming issue, the trend analysis of sea ice area is becoming quite important. Passive microwave sensors on board satellites can monitor the global distribution of sea ice on daily basis. In extracting sea ice concentrations from passive microwave sensors onboard satellites, atmospheric effects mainly caused by the presence of atmospheric water vapor, cloud liquid water, rain and sea surface roughening by winds are likely to estimate certain sea ice concentrations at the open water area. We call this kind of area as “false sea ice area”. To solve the problem, usually, weather filters are applied. The basic idea of weather filters is to differentiate clouds over open water from sea ice in the characteristic domain derived from brightness temperatures, and reject clouds by using thresholds. However, it is known that sometimes clouds over open water and sea ice are overlapped in the characteristic domain. So, sea ice concentrations less than 15% are often rejected when counting sea ice extent or sea ice area from sea ice concentration data derived from passive microwave sensors data. Here we call this as 15% rejection method. But, it is also known that sometimes more than 15% sea ice concentrations are calculated when open water are covered with heavy clouds etc. Moreover, 15% rejection method also rejects true low concentration sea ice. In this study, authors have applied three days minimum method for reducing the false sea ice area. The algorithm is to take the minimum sea ice concentration value within the three days observation as output of each pixel. The basic idea of the algorithm is that heavy clouds may not stay in one place for more than three days, and sea ice may be more stable than heavy clouds. The result showed that the proposed method can effectively reduce the false sea ice area than 15% rejection method. Moreover, when calculating sea ice extent, the proposed method could calculate more than 15% rejection method. This suggests the effectiveness of the new method for reducing the cloud effect for calculation sea ice extent..

1. INTRODUCTION

Since longer wavelength microwave can penetrate clouds, passive microwave sensors on board satellites are powerful tools for monitoring the global distribution of sea ice on daily basis. However, passive microwave sensors are not completely cloud free. More or less, microwave signals are affected by atmosphere. It is known that due to the atmospheric effects, sometimes certain sea ice concentrations are estimated at the open water area when calculating sea ice concentration from passive microwave data[1)]. In this study, we call this kind of area as “false sea ice area”. The atmospheric effects are caused by the presence of atmospheric water vapor, cloud liquid water, rain and sea surface roughening by winds.

To solve the problem, usually, weather filters are applied. The basic idea of weather filters is to differentiate clouds over open water from sea ice in the characteristic domain of certain parameters derived from brightness temperatures, and reject clouds by using thresholds. However, since clouds over open water and sea ice sometimes overlaps in the characteristic domain, weather filter is not always effective.

So, when calculating sea ice area from sea ice concentration data derived from passive microwave sensors, sea ice concentrations less than 15% are often rejected. However, this means that true sea ice concentration area less than 15% are also rejected. In order to detect the sign of global warming, more effective ways to reduce the weather effects are required. In this study, authors have proposed three days minimum composite method for reducing the false sea ice area.

2. TEST SITE AND ANALYZED DATA

In this study, the Sea of Okhotsk was selected as the test site for the detailed evaluation of the algorithm. Figure 1 shows the map 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 false sea ice area is often found in the Sea of Okhotsk, the sea is suitable for this study. As for the data analysis, sea ice concentration data derived from SSM/I passive microwave data. The sea ice concentrations were calculated using NASA Team Algorithm[1), 2)]. The optical sensor MODIS image was also used to sea the detailed condition of the sea ice.

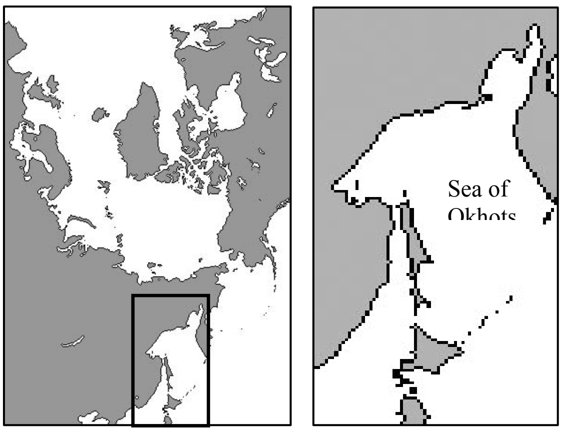
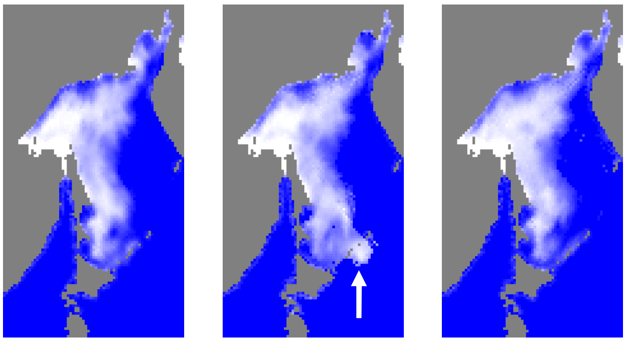


Figure 1. Location of the test site

Figure 2 shows the SSM/I sea ice concentration images of the test site for the continuous three days. It is clear that certain sea ice area (indicated by an arrow) is observed on the second day image which does not exist on the first day or on the third day image. This is the “false sea ice area” where certain sea ice concentrations were calculated over open water due to atmospheric effects. Figure 3 shows the MODIS image of a part of the Sea of Okhotsk for April 4, 2000. There is no sea ice in the right hand bottom part of the sea. It is impossible that sea ice appears widely in this area within one day(April 5) and disappear by the next day(April 6).



(a)April 4,2000 (b) April 5,2000 (c) April 6,2000

Figure 2. SSM/I sea ice concentration images of the Sea of Okhotsk

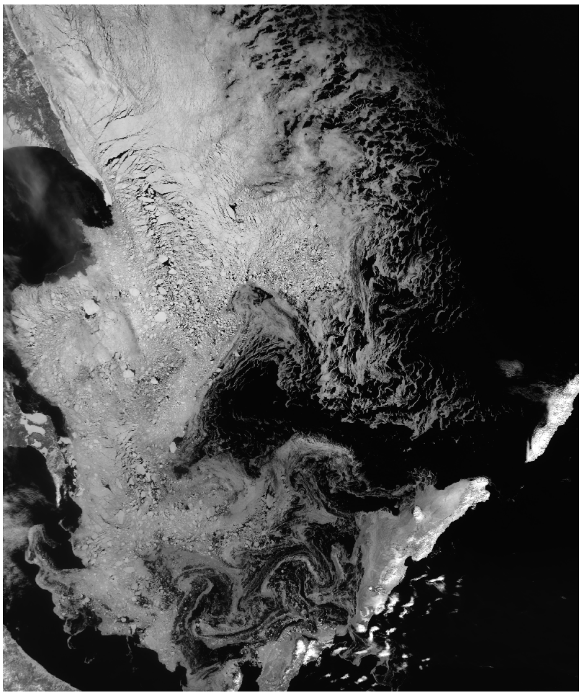


Figure 3. MODIS image of the Sea of Okhotsk for April 4, 2000.

3. METHODOLOGY

3.1 Previous Methods

3.1.1 Weather filter

In sea ice concentration algorithms, such as NASA Team Algorithm or Bootstrap Algorithm[4),5)], weather filters are applied to reduce the atmospheric effects. The basic idea of weather filters is to set the sea ice concentration of a pixel to zero when the pixel meets certain condition. In NASA Team Algorithm, if the pixel meets the either of the following equations, the sea ice concentration of the pixel will be set to zero.[6)]

$$GR(37/19)=(TB37V-TB19V)/(TB37V+TB19V) > 0.05 \quad (1)$$
$$GR(22/19)=(TB22V-TB19V)/(TB22V+TB19V) > 0.045 \quad (2)$$

Where TB37V, TB22V, TB19V are brightness temperatures of the vertical polarizations of 37GHz, 22GHz and 19GHz, respectively. The weather filter does work well in some cases but not always. Figure 4 shows the SSM/I sea ice concentration image of the Sea of Okhotsk for April 5, 2000, the same image of Figure 2(b). In this image, area A was selected as true sea ice area and area B as false sea ice area. Figure 5 shows the scatter plot of the both area in GR(37/19) and GR(22/19) domain. The scatter plot clearly shows that the weather filter cannot reject most of the false sea ice in this case.

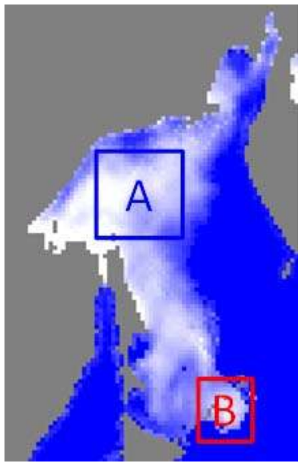


Figure 4. Extraction of sea ice area(A) and false sea ice area(B) in the SSM/I sea ice concentration image of the Sea of Okhotsk. (April 5, 2000)

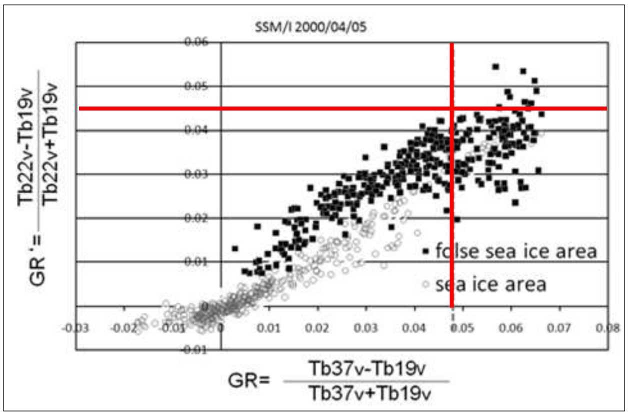


Figure 5. Scatter plot of GR(37/19) and GR(22/19) (Sea of Okhotsk, SSM/I April 5, 2000)

3.1.2 15% rejection

In order to reduce the atmospheric effects which more or less remains even after the weather filter, usually 15% rejection is applied for calculating sea ice area from sea ice concentration derived from passive microwave data. But, this method cannot reject false sea ice area which concentrations are more than 15%. Moreover, 15% rejection method also rejects true sea ice area which concentrations are less than 15%.

3.2 Proposed method

In this study, we propose three days minimum method. The basic idea of this method is to take the lowest sea ice concentrations of the continuous three days of the same pixel and replace the concentration of the mid day with it. Figure 6 shows the concept. If the sea ice concentrations of the continuous three days of a pixel were 5(one day before), 20(target day) and 0(one day after), we take 0 as the new sea ice concentration of the pixel. Since the atmospheric effects are likely to change day by day, three days minimum may reduce most of the atmospheric effects which cause false sea ice. On the other hand, since we can expect that daily variation of sea ice concentrations are more stable than atmospheric condition, the under estimation of the sea ice concentration by the three days minimum may not be so serious.

10	0	0
5	**5**	0
15	15	0

One day before

10	30	25
10	**20**	30
40	30	50

Target day

15	0	0
10	**0**	0
10	10	0

One day after

(a) Input sea ice concentrations of continuous three days

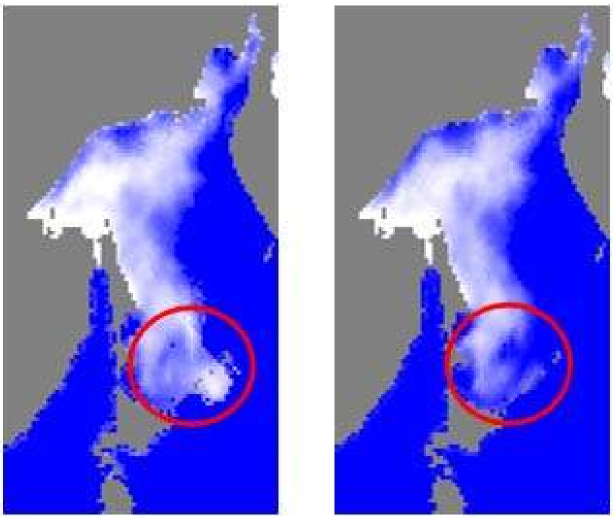
10	0	0
5	**0**	0
10	10	0

(b) Output sea ice concentrations of the target day
Figure 6. Concept of the three days minimum method

4. RESULT

4.1 Reduction effect of false sea ice

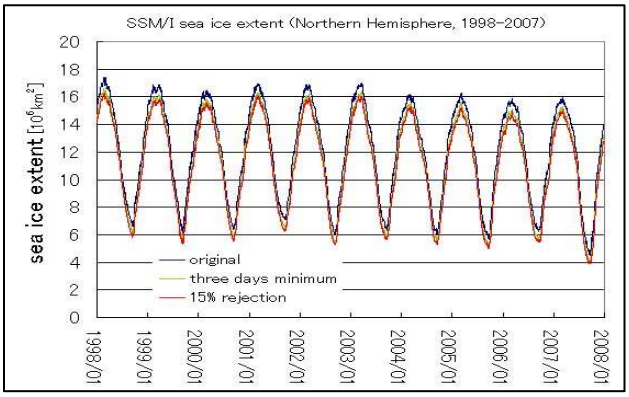
Figure 7 shows the comparison of the false sea ice reduction effects of the 15% rejection method(a) and the three days minimum method(b). Since the most of the sea ice concentrations of the false sea ice area in the Sea of Okhotsk for April 5, 2000 were higher than 15%, the 15% rejection method could not reject most of the false sea ice area of the image. On the other hand, it is clear that the three days minimum method has effectively rejected most of the false sea ice area without much rejection of the concentrations of the true sea ice area.



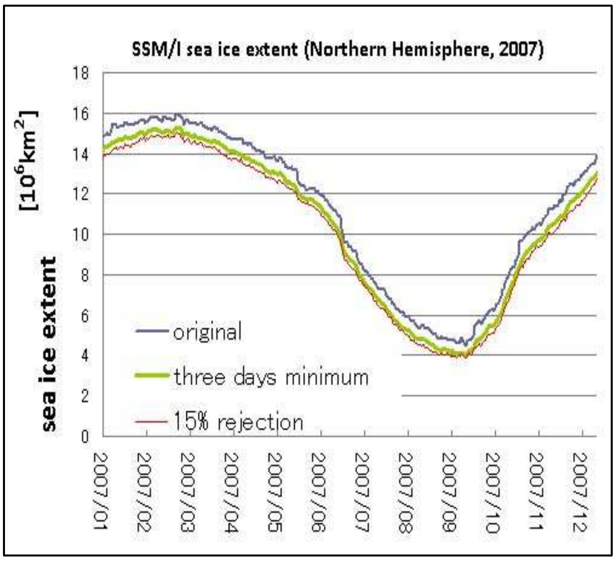
(a) 15% rejection **(b) Thee days minimum**
Figure 7. Comparison of false sea ice reduction effect (Sea of Okhotsk, SSM/I April 5, 2000)

4.2 Sea ice extent calculation

Sea ice concentrations derived from passive microwave sensors are often used for calculating total sea ice extent of certain sea ice zone or of the both Hemisphere. In the IPCC Forth Assessment report published in 2009, sea ice extent trend derived from passive microwave data are used as important observation result of climate change [7)]. Total sea ice area is defined by adding the area of each pixel multiplied by the ice concentration of each pixel. While total sea ice extent is defined by adding the area of pixels which include some sea ice. In order to reduce the atmospheric effects or other errors, usually 15% rejection method is used for calculating sea ice area or sea ice extent. However, since 15% rejection method reject all the pixels of which sea ice concentrations are less than 15%, the sea ice area or sea ice extent are likely to be under estimated.
Figure 8(a) shows the sea ice extent trend graphs of the Northern Hemisphere from 1998 to 2007 derived from SSM/I data. The seasonal changes of 2007 for the Northern Hemisphere and the Sea of Okhotsk are shown on Figure 8(b) and Figure 9 respectively. In Figure 8 and 9, the top curve shows the sea ice extent of the original data. The second curve shows the sea ice extent after applying three days minimum. The bottom curve shows the sea ice extent after applying 15% rejection.



(a) Sea ice extent of Northern Hemisphere (1998-2007)



(b) Sea ice extent of Northern Hemisphere (2007)
Figure 8. Comparison of sea ice extent difference between each method for the Northern Hemisphere.

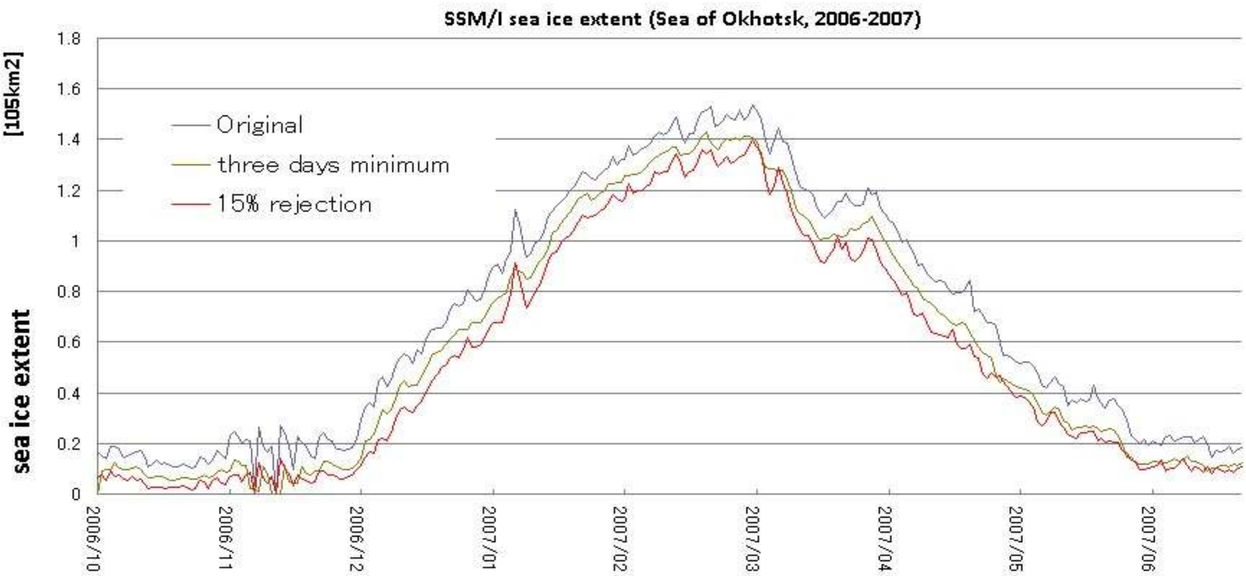


Figure 9. Comparison of the sea ice extent difference between each method for the Sea of Okhotsk (2006-2007).

Since both three days minimum method and 15% rejection method reduce the sea ice concentration of the original data, it is a matter of course that sea ice extent calculated after applying either of the algorithms is lower than the original sea ice extent. But if we compare sea ice extent of three days minimum and 15% rejection, it is clear that in most cases, sea ice extent derived using 15% rejection was smaller than sea ice extent derived using three days minimum. This result suggests the advantage of using three days minimum method for reducing weather effects.

5. CONCLUSIONS

In this study, authors have applied three days minimum composite method for reducing the weather effects. The result showed that the new method can effectively reduce the false sea ice area than 15% rejection method. Moreover, when calculating sea ice extent, the proposed method could calculate more than 15% rejection method. This suggests the effectiveness of the new three days minimum method for reducing the atmospheric effects in calculating sea ice extent from passive microwave sensor data. Since the low concentration sea ice area mainly appears in the marginal sea ice zone, the method may contribute to the improvement of the accuracy of sea ice extent estimation.

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