Estimating sea ice mass derived from AMSR-E data

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1. Introduction

1-1. background

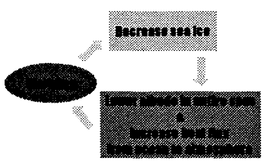
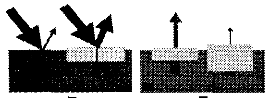


Fig.1 Ice albedo feedback

When sea ice is decreased once due to warming and so on, ocean will get more heat(Fig.2(a)). Then, sea ice will be decreased again. After that, ocean will conduct more heat to atmosphere (Fig.2(b)). Finally, the global warming will make progress. This phenomenon is called "ice albed feedback". The relationship between sea ice and climate is close. Since sea ice variability can be a good indicator as a climate change, we need to monitor entire quantity of sea ice.



Depends on … → Sea ice area → Bootstrap & NASA Team

Sea ice thickness → Not yet…

Fig.2 The two properties of sea ice for interaction between ocean and atmosphere
(a) Reflect solar radiation strongly because of high albedo
(b) High thermal insulation between ocean and atmosphere

The motion equation of sea ice

$$M_{ice}\frac{dV_{ice}}{dt} = t_a + t_w + D + G + R \quad (1)$$

t_a: wind stress; t_w: ocean current stress; D: Coriolis force; G: sea surface gradient force; R: internal ice force

Based on the motion equation(equation.1), "adding a same force to two sea ice witch has different mass, a momentum of more weighted sea ice is less than of the other". In other words, sea ice mass has a relationship with sea ice motion. Therefore, we tried to estimate sea ice mass from sea ice motion.

1-2. Object

In order to estimate entire sea ice mass over a wide range , we developed the method estimated sea ice motion with the template matching with AMSR-E data. AMSR-E has a huge range of observations and high frequency observation, so it is the best for this study to use AMSR-E data. In addition, AMSR-E has a few other advantages(refer to chapter 2). The template matching has been used to estimate sea ice motion for a long time. For example, Emery 1991, Kimura and Wakatsuchi 2000 and so on. In order to solve the problem that microwave radiometer has a coarse resolution and advance accuracy of estimation, we suggest the algorithm which estimate sea ice motion down to sub-pixel.

2. About data

Data for computing sea ice motion

AMSR-E	©NSIDC http://nsidc.org/		
2003/2/18	19GHz	H pol	12.5km Grids
2003/2/19	19GHz	H pol	12.5km Grids
2003/2/20	19GHz	H pol	12.5km Grids

Data for verification

Terra/MODIS	©JAXA		
2003/2/18			1km Grids
2003/2/20			1km Grids
NCEP/NCAR Reanalysis Data	©NOAA http://www.cdc.noaa.gov/cdc/reanalysis/		
2003/2/18	sigma995	u-wind	2.5°Grids
2003/2/18	sigma995	v-wind	2.5°Grids

The characteristic of AMSR-E

- All weather
- High frequency observation (every 12h)
- Covering the earth
- Higher resolution than the other satellite microwave radiometers

3. The method of computing sea ice motion

3-1. Template matching(SSDA)

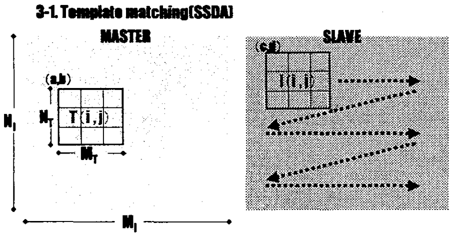


Fig.3 Template matching (SSDA)

Make a template with a focus on a certain pixel.

↓

Calculate similarity index (Dc) with the equation (2) and Displace a template every one pixel over slave data.

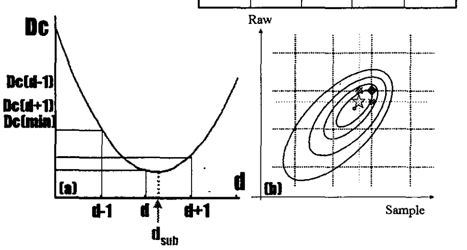
↓

Finally, the pixel which has the lowest "Dc" will be the matching point down to pixel .

$$Dc_{(c,d)} = \sum_{i=0}^{M_T-1}\sum_{j=0}^{N_T-1} | I_{(c,d)}(i,j) - T_{(a,b)}(i,j) | \quad (2)$$

3-2. Parabola fitting

Pixel No.	…	d−1	d	d+1	…
similarity index	▪▪▪	$Dc_{(d-1)}$	Dc_{min}	$Dc_{(d+1)}$	▪▪▪



Implement the template matching. And calculate "Dc".

↓

Apply a quadratic curve to Dc(min), Dc(d-1) and Dc(d+1) in a sample(or raw) direction.

↓

The x-coordinate of the quadratic curve apex will be the matching point down to sub-pixel (d_{sub}) .

↓

calculate "d_{sub}" in an other direction. Finally, two-dimensional matching point down to sub-pixel will be decided.

Fig.4 Parabola fitting
(a) one-dimensional fitting (b) composed matching point with two one-dimensional fittings

4. Computed sea ice motion

Fig.5 The result of computing sea ice motion on Feb, 18, 2003

Computed sea ice motion most probably agreed with the wind direction of NCEP/NCAR.

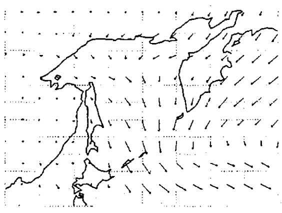


Fig.6 The wind direction near ground level on Feb, 18, 2003

5. Validation methodology

We estimated sea ice motion from MODIS data(Feb,18,2003 and Feb,20,2003) by identifying sea ice witch can be tracked through inspection. Then, we compared directions and migration length of computed sea ice motion from AMSR-E with estimated sea ice motion from MODIS.

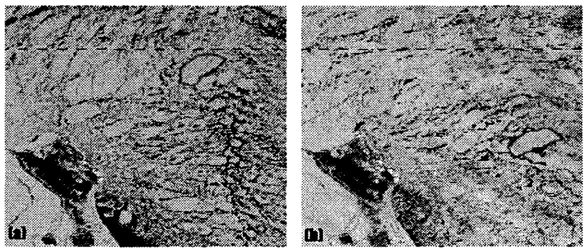


Fig.7 (a) MODIS image of the northern sea of Okhotsk on Feb, 18, 2003
(b) MODIS image of the northern sea of Okhotsk on Feb, 20, 2003

6. Results

Fig.8 Sea ice motion which was estimated from MODIS.

- Estimation regarding direction of sea ice motion was almost matching well.
- Estimation regarding migration distance of sea ice motion was not matching well. There were some miss estimation near polynya.
- Applying parabola fitting, the regression line approached 1:1 line, and the correlation coefficient was increased. However, the huge miss estimation was remained.

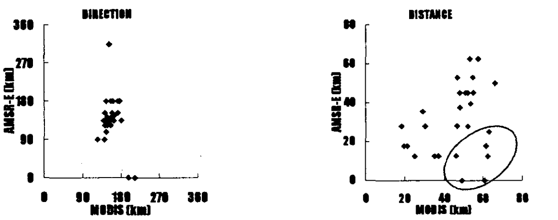


Fig.9 The scatter plot of estimated sea ice motion from AMSR-E data and MODIS data with non-parabola fitting
(a) Direction (b) Migration distance

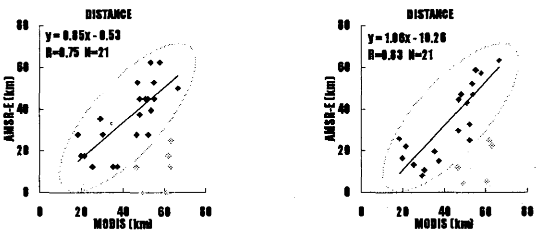


Fig.10 The scatter plot of estimated sea ice motion from AMSR-E data and MODIS data about migration distance
(a) non-parabola fitting (b) parabola fitting

7. Conclusion

- Based on momentum of sea ice, we tried to estimate sea ice mass from the relationship between sea ice mass and motion.
- In order to estimate sea ice mass, we developed the algorithm which calculate accurate sea ice motion from AMSR-E with the template matching.
- There is a miss estimation in a polynya (a polynya is a significant low concentration area).
- We was able to estimate sea ice motion by sub-pixels with the parabola fitting. As a result, the difference between migration distance estimated from AMSR-E and MODIS was decreased.