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Area of a polynya at Amery Ice Shelf derived from AMSR-E 89 GHz sea ice concentrations and MODIS images

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Abstract—**Polynyas are persistent openings and/or thin ice in the ice cover. They play an important role in the air-sea interaction. Their accurate detection, including an estimate of shape and area, is therefore important. There is a polynya at the front of the Amery Ice Shelf (AIS). In this paper, a threshold of 70% of AMSR-E sea ice concentrations is selected to define a polynya and to calculate the area. In addition, the polynya is recognized from cloud free MODIS images. Comparing the area obtained from two different methods, a polynya is well simulated from AMSR-E sea ice concentration data and the correlation is 85%. This supplies another way to analyse the small polynya at the front of the AIS, including characteristics and interannual variability of area of this polynya, especially in winter when MODIS data can not be used.**

Keywords-Amery Ice Shelf; polynya; MODIS; AMSR-E

I. INTRODUCTION

As persistent and recurrent areas of open water and/or thin ice, polynyas occur at locations in the ice cover, where a more consolidated and thicker ice cover would be climatologically expected [1].

The Prydz Bay is the third largest embayment in Antarctica and the AIS is the largest ice shelf in East Antarctica [2]. Zhongshan Station (69° 22′ 24″ S, 76° 22′ 40″ E) of China is located at the coastline of the Prydz Bay (Figure 1), one of the main observation regions of the Chinese Antarctic expedition, and Prydz Bay is speculated as a source of the Antarctic Bottom Water [3], which is the densest water mass in the world ocean and the most important source of the abyssal circulation. However, no field data are available until now to support this hypothesis because ship observation could not be conducted in the freezing season. Satellite remote sensing images show a quite large polynya occurring at the front of the AIS during the freezing season. The large continental shelf plays an important role in the formation of bottom water [4]. Our study focus on the polynya at the front of the AIS.

One method to monitor polynyas is the Polynya Signature Simulation Method (PSSM) developed by Markus and Burns [5]. This method uses an iterative classification of a combination of resolution-enhanced Special Sensor Microwave/Imager(SSM/I) 37 and 85 GHz data to identify thick and/or compact ice, thin and/or loose ice and open water. Such maps were used to derive a time-series of the polynya extent for 1995-2004, which has subsequently been analysed,
and compared to model data to learn more about the relation

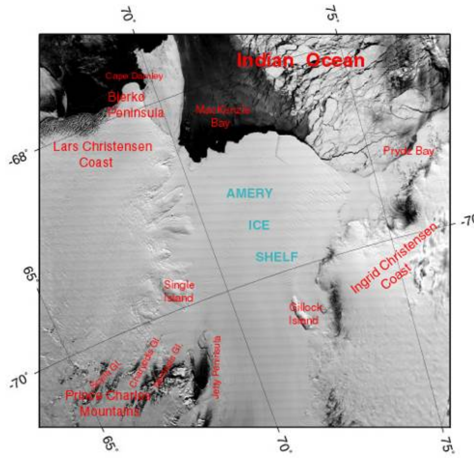

Figure. 1 Amery Ice Shelf and its peripheral (MODIS image of 17th, March, 2002 supplied by NSIDC)

of polynya dynamics in and ice export out of the Kara Sea [6]. By applying the PSSM to single overpass SSM/I data, an analysis was made of the polynyas in the Ross Sea and off the Adelie Coast for the winters (April–September) of 2002–2005 [7]. But because of the spatial resolution of the standard sensor SSM/I at 85 GHz (15×13 km), this method is not adaptable to be used for small polynyas.

An alternative method developed by Martin et al. [8] uses an empirical relationship between ice thickness values derived from Advanced Very High Resolution Radiometer (AVHRR) IR-imagery, numerical model data and the brightness temperature (TB) ratio at SSM/I 37 GHz to get information about the thin ice area and thickness within a polynya. Martin et al. [9] also showed that the method can be adapted to the AMSR 36-GHz channels. Nihashi et al. [10] have developed a thin ice thickness algorithm using the polarization ratio of Advanced Microwave Scanning Radiometer-EOS (AMSR-E) brightness temperature at a 36.5 GHz channel for the Okhotsk Sea coastal polynyas. Tamura et al. [11] have proposed an algorithm that estimates thin ice thickness and detects fast ice based on the SSM/I 85- and 37-GHz polarization ratios (PR85 and PR37) in the Antarctic

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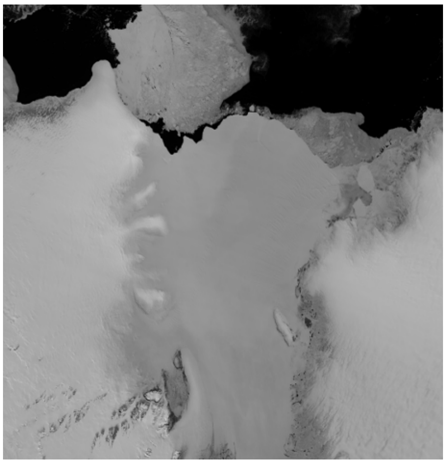
coastal polynyas. But when using this method to calculate the ice thickness, some assumptions are made (e.g. without snow on the ice) and the spatial resolution of the SSM/I data is a restriction for small polynyas.

Obtaining the polynya area using SSM/I based sea ice concentrations with a threshold of 75%, Massom et al. [12] conducted a study of polynya characteristics in East Antarctica for the period July 1987-August 1994. Also, a threshold of 70% of AMSR-E sea ice concentrations was selected to define polynyas and to observe the Terra Nova Bay polynya [13].

Although the polynya at the front of the AIS is very important, few scientists focus on this small polynya. Because of the low spatial resolution of SSM/I data, this polynya is frequently missed by the two described methods. The purpose of this paper is to retrieve the polynya at the front of the AIS using MODIS images and AMSR-E data with higher spatial resolution.

II. DATA AND TECHNIQUES

A. MODIS images



(a)

(b)

Figure 2. Before (a) and after (b) comparison of MODIS images of 9th, December, 2005 of AIS

In [14], a method was established to distinguish sea ice and water from MODIS images in Figure 2(b) by using a threshold individually fixed for each image. Two different gray-values are used to represent water and ice. As a result, water and ice can be distinguished successfully, a polynya is recognized (Figure 2(b)) and the area of this polynya can be calculated. This method requires cloud free MODIS images. It is a disadvantage of the method, but the results can be regarded as a possible comparison with results from other remote sensing data. Using this method, without cloud MODIS images from 2003 to 2007 are picked up to be calculated the area of the polynya.

B. AMSR-E sea-ice concentrations

AMSR-E's 89 GHz channels offer today's highest spatial resolution of passive microwave datasets and cover daily the complete Antarctic. Such datasets obtained from the AMSR-E on board NASA's Aqua satellite are used to calculate sea-ice concentrations on a polar stereographic grid with 6.25 km resolution. Sea ice concentration data calculated with the ARTIST (Arctic Radiation and Turbulence Interaction Study) sea ice (ASI) concentration algorithm using AMSR-E 89 GHz TB [15]. The geoloclation of the AMSR-E Level 1 data has been corrected [16] and sea ice concentrations have been validated compared with Landsat-7 ETM+ and SAR Imagery [17].

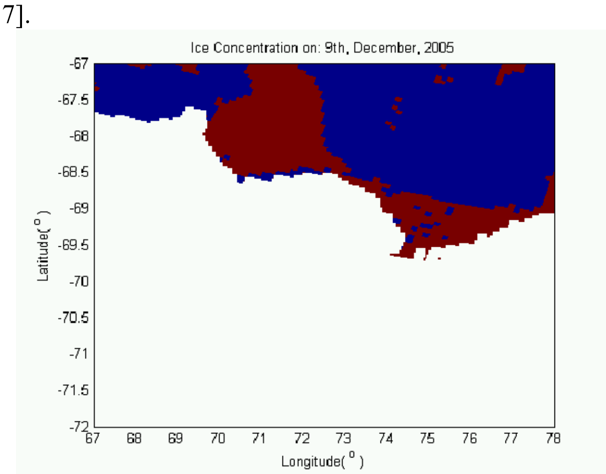


Figure 3. A polynya retrieved from AMSR-E ASI 6.25 km sea ice concentration data (blue: open water, red: sea ice, white: ice shelf and land)

Using the AMSR-E ASI 6.25km sea ice concentration data, a threshold of 70% of AMSR-E sea ice concentrations is selected to define a polynya (Figure 3) and area of this polynya is calculated. When using sea ice concentration data for small areas, the attention must be paid to the landmask of the datasets. The AMSR-E sea ice concentration data is calculated for all Antarctic ocean and Arctic ocean, the landmask is not very accurate for small areas and a new landmask must be calibrated to the old landmask for more exact result. Envisat images are used to make an accurate landmask of Prydz Bay. The detailed method is described in [18].

III. COMPARISONS

From Figure 3, We see that the shape of the polynya retrieved from AMSR-E ASI 6.25 km sea ice concentration data is similar to the shape of polynya retrieved from MODIS images Figure 2(a) and Figure 2(b) at the same day. This shows it is feasible to use a threshold 70% of AMSR-E sea ice concentrations to define a polynya, which exists at the front of the AIS.

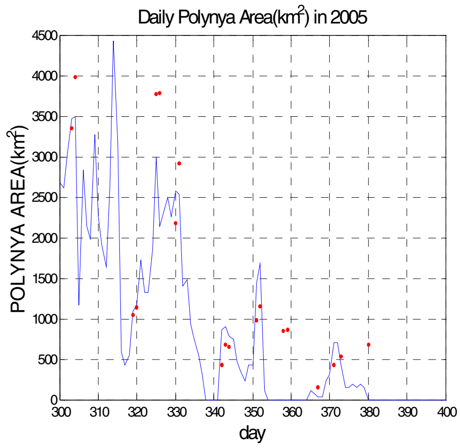


Figure 4. Polynya area comparison obtained from AMSR-E sea ice concentration data and MODIS images in 2005(solid: area obtained from AMSR-E, red: area obtained from MODIS)

MODIS images only can be obtained during daylight, in the Antarctic from about September to March. The resulting areas of 2005 are shown in Figure 5. We choose the year of 2005 results because of the highest polynya in this year. Below 1500 km^2 the results from AMSR-E are nearly the same as those obtained from MODIS. There are some extreme values more than 3000 km^2 and among these several days, the area changes irregularly because of high variability strong katabatic winds from one day to the next.

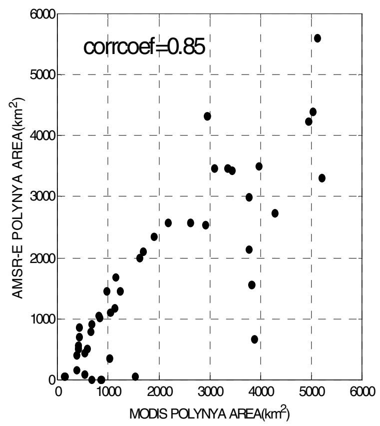


Figure 5. Polynya area comparison obtained from AMSR-E sea ice concentration data and MODIS.

Figure 5 is the polynya area comparison obtained from AMSR-E sea ice concentration data and MODIS images. Some of the points present differences between the two methods and the correlation is 85%. From the figure, we see that when the area is over 3000 km^2, the agreement of the area obtained from the two datasets is poor. Two reasons can lead to the large area. As mentioned, on some days strong katabatic wind blows from the shelf to the ocean and drives the sea ice to the open ocean and those days the area become very large. But at the same day, the area maybe a bit smaller calculated by sea ice concentration data, this may be caused by the threshold value.

CONCLUSIONS

In this paper, based on two different remote sensing datasets, shape and area of polynya at the front of the AIS obtained from AMSR-E sea ice concentration and MODIS images are compared. The two results show a visual agreement and the correlation is 85%. This supplies another way to analyse the small polynya at the front of the AIS, especially in winter when MODIS data are not available. This method also can be applied to the other small polynyas near the ice shelf in Antarctic ocean. In order to obtain spatial distribution and interannual variability of the area of polynyas, AMSR-E sea ice concentrations are more reliable, not only because of higher spatial resolution, but continuously available data. In addition, the results obtained from AMSR-E sea ice concentrations also should be compared with other more remote sensing data (SAR images and so on). This is the focus of future work.

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