CLASSIFICATION OF LAND-FAST SEA ICE TYPES IN THE GREENLAND, ARCTIC BY USING MULTIFREQUENCY SAR IMAGES

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Abstract: Recently, the extent of sea ice is gradually decreased that causes the global warming. The albedo of the Arctic is higher than the equator which means the ice reflects the sun light so that maintains the temperature. There are difficulties to get the field data for monitoring the Arctic, therefore, using the satellite images are preferred. Synthetic Aperture Radar (SAR) images are not affected the cloud cover and the polar nights without the midnight sun which are suitable to observe the polar region. There were previous studies for the sea ice classification using the SAR images; however, classification is affected by the resolution. In this study, the higher resolution SAR images and the field data are used to classify. The study area is the land-fast sea ice in the Greenland of the Arctic and the using data were Radarsat-2 and ENVISAT ASAR images. After pre-processing the images, to define the georeference is required to set the images for same pixels and place. There are many algorithms for unsupervised classification that includes k-means algorithm which we used, and maximum likelihood algorithm was used for supervised classification.

INTRODUCTION

The Arctic is mostly composed of the continental shelf and has an effect on the earth environment such as climate, weather and ocean currents. If the albedo is higher, it reflects the sunlight for reducing the earth temperature. The extent of the sea ice has been decreased because of the Global warming. Small area of the sea ice causes lower albedo; it does not reflect the sunlight to cause the warm temperature. The extent of the Arctic sea ice is the biggest in the winter even the airplane can land on the surface of the sea ice, and the smallest in summer. First year ice melts in summer and grows in winter, however, multiyear ice does not melt in summer. The average thickness of multiyear ice grows 4~5m, consequently, multiyear ice is more dangerous than first year ice especially shipping through the Arctic (Walker *et al.*, 2006). In the middle of the sea ice, there is a large part of multiyear ice.

To study the sea ice of the Arctic, sea ice observation is needed, however, the Arctic is covered with the ice; it requires an icebreaker to get the observation data. Also, it only has the data for small area and cannot effectively observe the change of the Arctic. Remote sensing gives us data for the wide areas and it is useful to observe the inaccessible area such as the Polar Regions for short time. Remote sensing obtains data through the platform of sensors. There are two types of sensors, one is passive sensors mostly uses for remote sensing, and the other is active sensors that are SAR using the microwave and LIDAR and so on. Passive sensors only detect when it is daytime because it uses the natural sunlight energy. However, Active sensors can detect anytime even it is night by using the wavelengths that does not need the sunlight. If we use the passive sensors for the study of the Arctic, there is a polar nights without the midnight sun, so that may not obtain the data for winter. Synthetic aperture radar (SAR) is one of the active sensors that used for this study and we used Radarsat-2 and ASAR.

There are many previous studies by using SAR images in the Arctic. Determining sea ice thickness is studied by Haverkamp *et al.*, (1995), they developed the algorithm for ice thickness classification combined with algorithmic and heuristic methods. Studying multiyear ice for summer is projected by Eicken *et al.*, (1995). They examined the thickness, structure and properties of level multiyear ice. Ning *et al.*, (2009) studied the sea ice thickness in the Bohai Sea, China, by using the MODIS and TM data. Those studies show different way to measure the sea ice thickness. Jung *et al.*, (2011) studied the polarmetric scattering of sea ice. L-band image is affected by the snow which is difficult to distinguish the sea ice and land. Classification is the way to classify the sea ice for various kind of the sea ice that shows the individual characteristics. It has many algorithms to calculate, but if it is classified with the training data, it is called supervised classification and if it does not need the training data, it is unsupervised classification. Hara *et al.,* (1995) classified by using Neural Networks with SAR images, classified first year ice, multiyear ice and boundary. Bogdanov *et al.*, (2005) studied the classification of sea ice images that classified with smooth first year ice, medium deformation first year ice, deformed first year ice, young ice, nilas and open water. It was subdivided the classes, but spatial resolution was 100m and 200m. Studying sea ice thickness or polarmetric scattering, classification is needed because it shows the characteristics of sea ice.

We suggest the classification by using with Radarsat-2 and ENVISAT Advanced SAR (ASAR); each spatial resolution is 25m and 150m. Those SAR images have different spatial resolution that may influence each other for the better results. We compare the result of Radarsat-2 image, ASAR image and Radarsat-2 and ASAR image. K-means algorithm will be used for unsupervised classification and maximum likelihood algorithm will be used for supervised classification. Also, those two algorithms will be compared with the results.

DATA AND METHOD

DATA

We used the SAR images from Radarsat-2 and ASAR, both are active sensors. Table1 was summarized about using data. Radarsat-2 was designed the following Radarsat-1, and was launched 14 December 2007. It operates at C-band and spatial resolution what we used, is 25m with standard mode (Morena *et al.*, 2004). We used the Radarsat-2 image of cross-polarizations (HH + HV and VV + VH). ENVISAT was launched 1 March 2002, ASAR operates at C-band. It has variety of resolution to cover the global oceans (Mouche *et al*., 2005). We used image mode (IMM), wide swath mode (SWM).

Table 1: Summarized SAR sensors in this study

Date	Sensor	Wavelength	Polarization	Spatial resolution	Incidence angle (°)
2009.04.28	Radarsat-2 (Standard)	C-band (5.41 GHz)	HH, HV	25 m	33.5 ~ 39.7
2009.04.30			VV, VH	25 m	41.2 ~ 46.5
2009.05.10	ASAR (IMM)	C-band (5.3 GHz)	HH	150 m	25
2009.05.13	ASAR (WSM)		HH	150 m	36

Study area is land-fast sea ice in the north of the Greenland. Also, there is a camp to get the observational data (83°38.622N and 32° 14.245W). There are first year ice, multiyear ice that is also divided moderately deformed ice and highly deformed ice, and ridges.

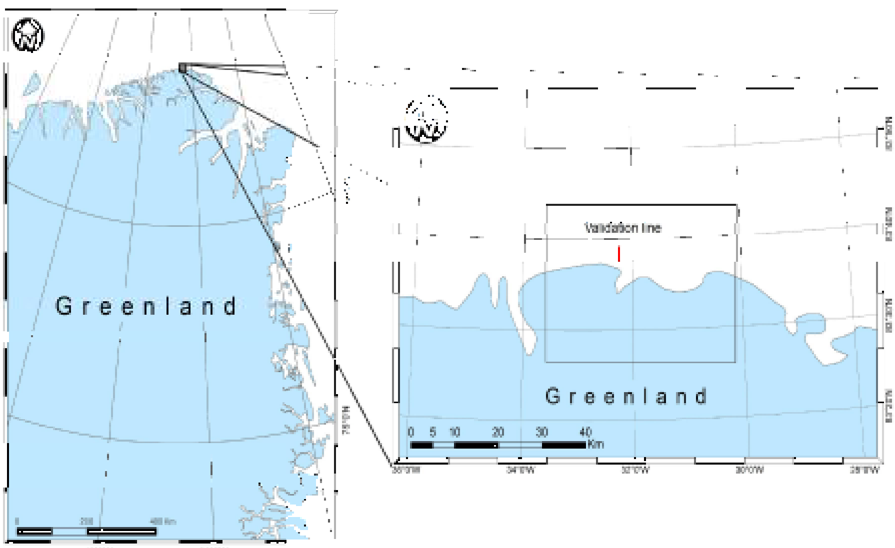

Figure 1: Study Area. There is a line showing validation line where was located the ice camp.

METHOD

SAR image has the speckle noises that reduce the quality. It looks like sprinkled pepper on the image. To remove them, we used the mean filters sized 3 x 3. If it detected same area but different time, or used the different product, it needed to calibrate the radiometric correction. It corrects all of the images for having same radiometric quantities. After the radiometric correction, calculates the geometric correction. It removes the geometric distortion in the images and places the SAR images to same area. Also it needs to set the same coordinates. Figure 2 shows the flowing chart for this study. After that, classify the images by using a K-means algorithm for unsupervised classification and using a maximum likelihood algorithm for supervised classification.

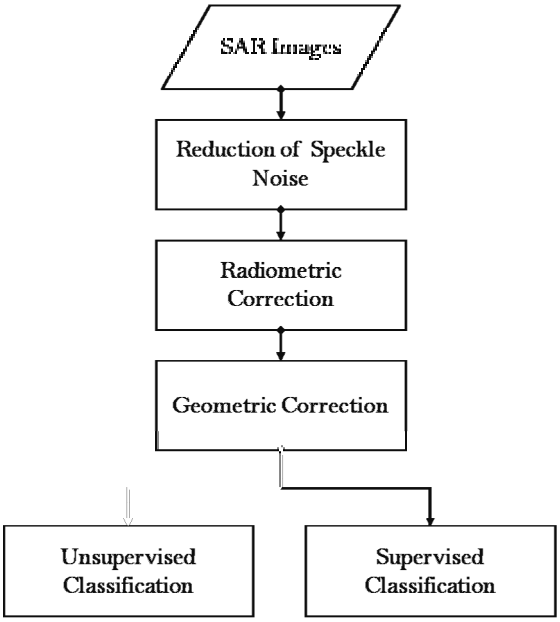

Figure 2: Flowing chart of this study.

RESULTS AND CONSIDERATIONS

K-MEANS

At first, we used the SAR image data of Radarsat-2 and ASAR for classification by using K-means algorithms. It calculates without the training data. We used the 4 clusters for FYI, ridge, moderately deformed ice and highly deformed ice. It was iterated 5 times. We used various combinations for the better results, but the overall accuracy of the K-means results were 57.8 ~ 42.4 %. The best result was slightly over the half percents. Table 2 shows the overall accuracy of the SAR images.

Table 2: Overall accuracy of the K-means results

SAR Sensor(s)	Overall accuracy
Radarsat-2	57.8
ASAR Radarsat-2	55.7
ASAR	42.4

MAXIMUM LIKELY HOOD

Maximum likelihood algorithm is one of the supervised classifications. It calculates a probability distribution by using training data for each pixel. After that, calculate the probabilities of each pixel to belong the most likely classes (Richard and Jia, 1999). We used this algorithm for classification and each class description was referenced by WMO (2004). Table 3 shows the general description about the class and training vectors and test vectors.

Table 3: Description about sea ice type and the number of training vectors and test vectors

Sea ice type	Description	Training vectors	Test vectors
FYI	Not more than one winter's growth from young ice	52	49
Ridge	Rectilinear conglomeration of ice fragments by strong pressure	9	9
Moderately deformed ice	With snow cover, bottom of rough surface becomes smooth	42	41
Highly deformed ice	Non-uniform melting of multi-year ice	47	52

We combined variety of sensors. Table 4 shows the overall accuracy. Using Radarsat-2 VV and VH images were the best result of 81.4%. Combined ASAR, Radarsat-2 HH, HV, VV and VH were 80.1 %. If Radarsat-2 VV and VH polarization included the combination of the images, it has the better result than others because the incidence angle of 45° and VH polarization has the better ice accuracy (Mäkyen and Hallikaien, 2004).

Table 4: The result of overall accuracy and kappa coefficient

SAR sensor(s)	Overall accuracy
Radarsat-2 VV, VH	81.4
ASAR, Radarsat-2 HH, HV, VV, VH	80.1
ASAR, Radarsar-2 VV, VH	76.1
ASAR, Radarsat-2 HH, HV	65.3

Table 5 and 6 shows the confusion matrix of each result. It was hard to classify the ridge because it was narrowing distributed and there were not much data. Table 5 shows that using Radarsat-2 VV and VH polarizations were good at detecting ridge area. Also, it was classified highly deformed ice for 93.57 %. Table 6 shows that detecting ridge was 16.26 %. Most of the ridge was distinguished by highly deformed ice for 64.50%. FYI, moderately deformed ice and highly deformed ice are accounted for 61.16%, 70.94% and 85.10% respectively.

Table 5: The result of confusion matrix using Radarsat-2 VV and VH polarizations

	FYI	Ridge	Moderately deformed ice	Highly deformed ice	Total
FYI	72.65	0.00	8.76	0.30	7.73
Ridge	6.17	72.25	1.74	5.78	26.91
Moderately deformed ice	21.18	0.00	79.47	0.35	22.90
Highly deformed ice	0.00	27.25	10.04	93.57	42.45
Total	100.00	100.00	100.00	100.00	100.00

Table 6: The result of confusion matrix using ASAR and Radarsat-2 with HH, HV, VV and VH polarizations

	FYI	Ridge	Moderately deformed ice	Highly deformed ice	Total
FYI	61.16	0.00	0.32	0.29	4.02
Ridge	0.00	16.26	0.26	2.13	1.57
Moderately deformed ice	32.50	19.24	70.94	12.48	27.68
Highly deformed ice	6.34	64.50	28.48	85.10	66.72
Total	100.00	100.00	100.00	100.00	100.00

CONCLUSIONS

We classified the sea ice in the north of the Greenland by using Radarsat-2 and ASAR images. Radarsat-2 was standard mode with HH, HV and VV, VH polarizations. ASAR were image mode and wide swath mode with HH polarization. FYI, ridge, moderately deformed ice and highly deformed ice were used for sea ice types. The overall accuracy of using K-means algorithm was 57.8 ~ 42.4 % with variety combinations which was about half percents. Unsupervised classification does not need the training data so we can easily classify compared with supervised classification. However, maximum likelihood algorithm which is supervised classification was better results between 81.4% and 65.3%. Using Radarsat-2 VV and VH polarization was better result than using variety combinations such as ASAR and Radarsat-2 with HH, HV, VV, VH or ASAR and Radarsat-2 with VV and VH polarizations.

Ridge is was difficult to classify. We used Radarsat-2 and ASAR sensors which are C-band, but have different spatial resolution. If we use different SAR sensors, for example, TerraSAR - X with X-band (9.6 GHz) or ALOS-PALSAR with L-band, it will be enhanced.

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