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Study on Sea Ice Extraction and Area Correction Model Based on MODIS and GF Data

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Abstract: To gain correct sea ice data, high time resolution (MODIS) and high spatial resolution (GF-2) materials are combined to achieve wide-range high precision monitoring of sea ice area in Liaodong Bay. This article takes GF-2 sea ice area as the baseline, intercepts corresponding MODIS sea ice monitoring scope, establishes a sea ice area correction model, and conducts long time series' analysis of sea ice area change. Here's the result: spectral observation result shows that comparing with CH2 channel, spectral reflectance of the snow-covering sea ice, ice-water mixture, seawater and sea ice in CH1 are with a greater difference value and easier to distinguish. Comparing with the accuracy of 3 extraction methods of MODIS sea ice, the optimal method is CH1 single channel extraction.This paper takes the sea ice area extracted by GF-2 satellite as the benchmark data, then establishes a MODIS sea ice area correction model. The model's correlation coefficient is 0.96. The monitoring error after correction is reduced from 39% to 10%. Sea ice area change in long time sequence shows that the sea ice area of Liaodong Bay is in slight downtrend. The inter-annual variation is featured with 4 years' periodical change. In every winter, sea ice area is in unimodal change, and reaches the maximum value in about early Feb.

1. Introduction

In *National* M*eteorological Disaster Prevention Plan* (2009-2020), as one of the 6 strategic zones, coastal areas take sea ice as the focus of meteorological disaster prevention [1]. Bohai rim is the gold coast of maritime in northern China, and plays an important role in coastal development strategy in China's opening-door policy [2]. However, various degrees of sea ice forms in each winter, which is especially serious in Liaodong Bay waters. Besides serious sea ice disaster years, there're nearly severe sea ice disasters in local waters every year [3]. Driven by wind and flow and together with its own expansion pressure, sea ice generates a strong pushing and impact force which affects ocean freight, oil-gas exploration, offshore facility and aquaculture to certain degrees. When the ice condition was serious, it once caused major sea ice disasters such as oil platform collapse, cargo ship standing and damage, and ocean freight interruption etc., and caused huge personal injury, social loss and environmental damage [4-5]. In 2010, Bohai Sea suffered from the most serious sea ice disaster in recent 30 years. The direct economic loss reached 6.318 billion RMB. And Liaodong Bay suffered the heaviest loss, covering 55% of the total economic loss [6]. Currently, sea ice disaster is mainly prevented by real-time monitoring of sea ice, issuing ice condition forecast timely, and conducting decision prevention after proving disaster status and forecast information to related authorities [7-8]. Therefore, monitoring study on sea ice appears to be more important.

2. Data and Method

2.1 Study Area

Liaodong Bay locates in the northernmost of Bohai in inverted "U" shape. This article studies Liaodong Bay waters in coastal of Liaoning. Its submarine topography is complex, and influence of climate on freezing status is different. So method of partitioning evaluation is adopted to divide the area into 3 morphologic regions: northwest region (I), mid-west region (II) and east region (III) (figure 1) [9].

Northwest region (I): Submarine topography is flat. It inclines from northeast to southwest, with less than 0.2‰ slope and below 20m deep water.

Midwest region (II): The topography of the coastal area is obvious. As the offshore distance increases, it tends to be flat with 0.37‰ to 0.19‰ slope and less than 41m deep water;

East region (III): The topographic relief is much more obvious than mid-west region (II).It's with a relatively large slope change, and there's a super large tidal ridge in the south. The large wavelength can reach 5,000m, and relative elevation difference is about 15m.

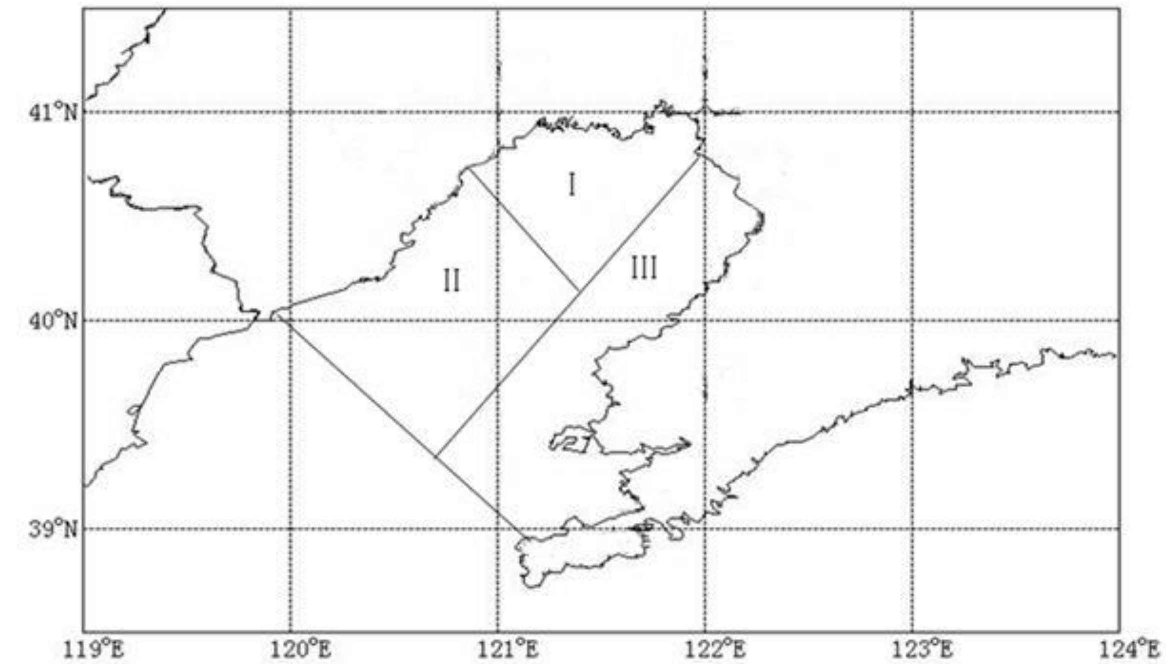

Figure 1. Submarine Topography Partition and Coastal Meteorological Stations Distribution.

2.2Data Source

The 28 scenes of GF-2 satellite data during Jan to Feb from 2015 to 2016 (3.24m multi-spectral, and 0.81m panchromatic) come from China Centre for Resources Satellite Data and Application. EOS/MODIS data in the same period (250m, 500m and 1km multi-spectral) is from CMACast broadcast distribution system, and used for correction study on sea ice area model. In Feb 2016, FieldSpec Pro portable spectrometer of American ASD Company was adopted for spectral observation in Bayuquan district Yingkou, Baisha Bay Gaizhou and Wafangdian Dalian, to analyze the sensitive

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channel where MODIS sea ice is extracted.

2.3 Sea Ice Area Extraction

MODIS sea ice area extraction is divided into 3 steps: land and sea separation, ice and water separation and area statistics [10].

Step1 land and sea separation: ENVI remote sensing image processing software is used to cut the land from remote sensing image according to boundary information.

Step2 ice and water separation: According to reflectance spectral characteristics of sea ice, sea ice and seawater can be visually interpreted and divided by combination of the 3 extraction methods below.

$$\text{MODIS:} \quad \begin{array}{c} ① R_1 < CH1 < R_2 \\ ② R_3 < CH2 < R_4 \\ ③ \begin{cases} NDSI = \frac{CH4-CH6}{CH4+CH6} \\ NDSI > 0.4 \cap CH1 > 0.1 \cap CH2 > 0.11 \cap LST < R_5 \end{cases} \end{array} \tag{1}$$

$$\text{GF-2:} R_6 < \frac{B2}{B4} < R_7 \tag{2}$$

In this formula, CH1, CH2, CH4 and CH6 are the reflectivity of the first, second, fourth and sixth channel of MODIS satellite. B2 and B4 are the reflectivity of 2^{nd} and 4^{th} channel of GF2 satellite. R_1, R_2, R_3, R_4, R_5, R_6 and R_7 are reference threshold to distinguish parameters.

Step3 area statistics: extract sea ice according to ice and water separation steps. Pixel number multiplies by unit pixel area, then there comes sea ice area.

$$S = n * S_i \tag{3}$$

3. Result and Analysis

3.1Spectral Features of Sea Ice and Similar Ground Object.

It shows in ASD spectrum image that the spectral reflectivity can be ranked in descending order as snow-covering sea ice > sea ice> ice-water mixture >sea water. Reflectivity of ground objects shows the maximum value between 500 to 800nm. Reflection peak value of snow-covering sea ice is 80%, sea ice 55%, ice-water mixture 19%, and seawater 10%. Though ground object spectrum near infrared channels can be distinguished, but the difference is not that obvious as in visible light (390-770 nm) channel. To calculate the difference value of the spectral reflectivity of snow-covering sea ice, ice-water mixture, seawater and sea ice separately, to find out the channel with most obvious ground object spectral reflectivity. The result shows that all of the 3 kinds of ground objects have a relatively large difference value between 450 to 850 nm. But spectral reflectivity in CH3 and CH4 are just 500m, not that advantageous as 250m resolution ratio in CH1 and CH2. Value difference in CH1 is greater than in CH2, which is easier to distinguish the sea ice information.

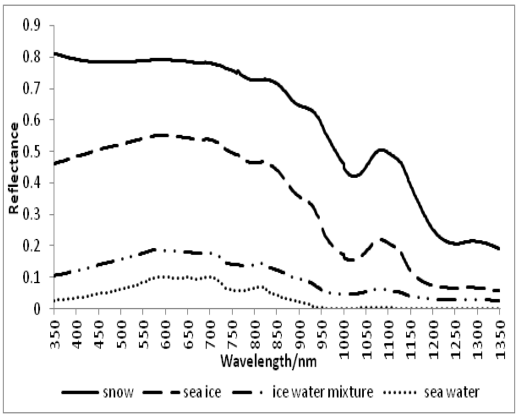

Figure 2. Spectrum Curve of Sea ice and Similar Ground Object.

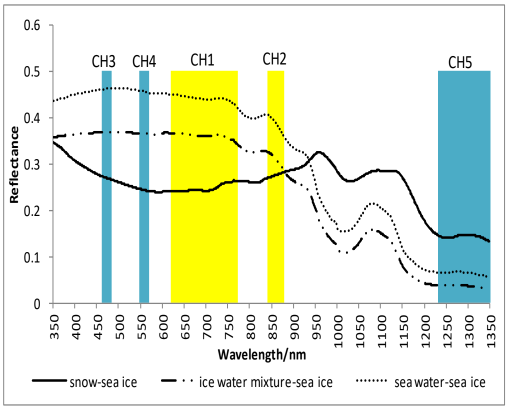

Figure 3. Spectral Difference Value of Sea Ice and Similar Ground Object.

3.2 Sea Ice Extraction with GF-2 Satellite

High-resolution satellite data is processed by ENVI software. After the image is pretreated by radiometric calibration, atmospheric correction, orthographic rectification and geometric correction etc., adopt the data extraction method in formula (2), to achieve rapid remote sensing interpretation of high-resolution satellite sea ice. 28 scenes of data are processed in this project, as shown in formula 1. Figure 4a is the colorful resultant image. Figure 4b is the density slicing drawing to evaluate index calculation. Figure 4c is the sea ice information extracted by decision-tree classification method (figure 5). Specific value 8 to 20 is sea ice pixel. Blue is ocean. Black is seawater and background. It preliminarily realizes separation of sea ice and other ground objects such as seawater etc.

Table 1. Data usage of GF-2.

Year	Data	Landscape number
2015	Jan.22	5
	Jan.27	3
	Feb.1	1
	Feb.11	3
2016	Jan.22	1
	Jan.27	5
	Feb.1	7
	Feb.16	3

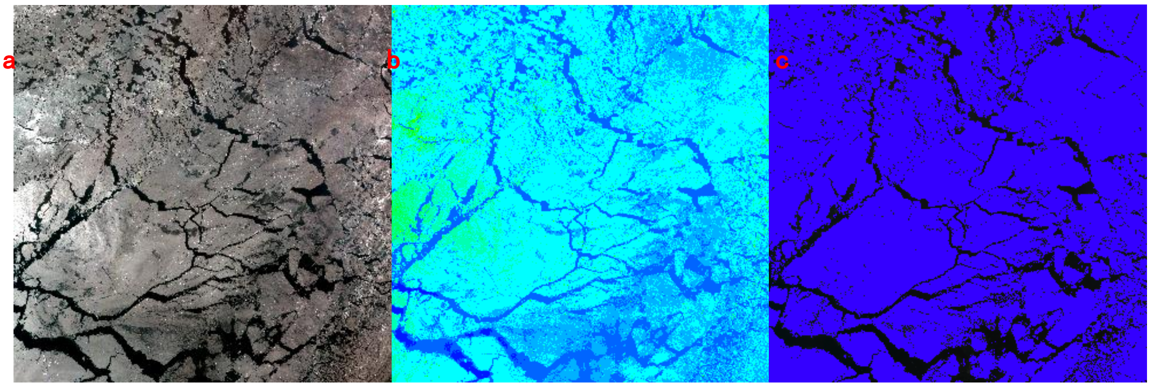

Figure 4. Sea ice extraction process for GF-2.

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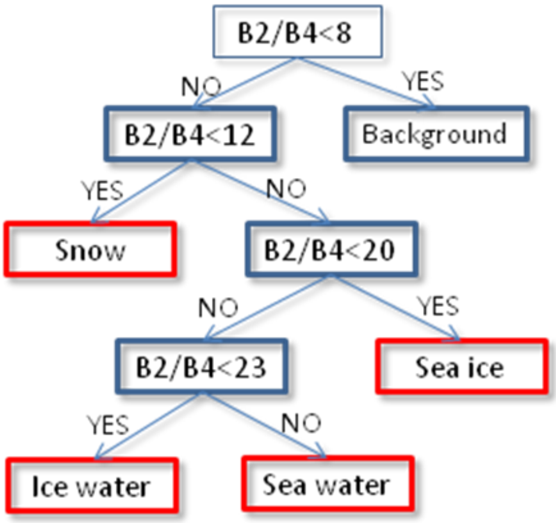

Figure 5. Decision Tree Classification Model.

3.3 MODIS Sea Ice Area Correction

EOS/MODIS is a data source essential for wide-range sea ice monitoring, but its spatial resolution is relatively low and it's mixed with lots of mixed pixels. So GF-2 satellite data with 3.24m spatial resolution is combined to correct the sea ice area. The range of influence of one scene and high resolution satellite is as shown in square area in figure 6a. Corresponding region size (figure 6b) in MODIS image is intercepted according to high resolution satellite latitude and longitude scope (figure 6b). Extract sea ice (figure 6c) with the 3 methods in formula (I), and make use of Formula (3) to calculate the sea ice area. The result shows that method I is with the best correlation, with R to be 0.96. Error is reduced from 39% to 10% after model correction. Method II follows. Error is reduced from 42% to 14% after model correction. Method III is with the worst correlation. There's an erroneous judgement in extracting sea ice in Liaodong Bay, thus it's not applicable (figure7). Therefore, method I shall be used for MODIS sea ice area correction. Here's the correction formula:

$$y = 0.694x + 17 \tag{4}$$

In this formula, y is the MODIS sea ice area after correction, and x is the MODIS sea ice monitoring area

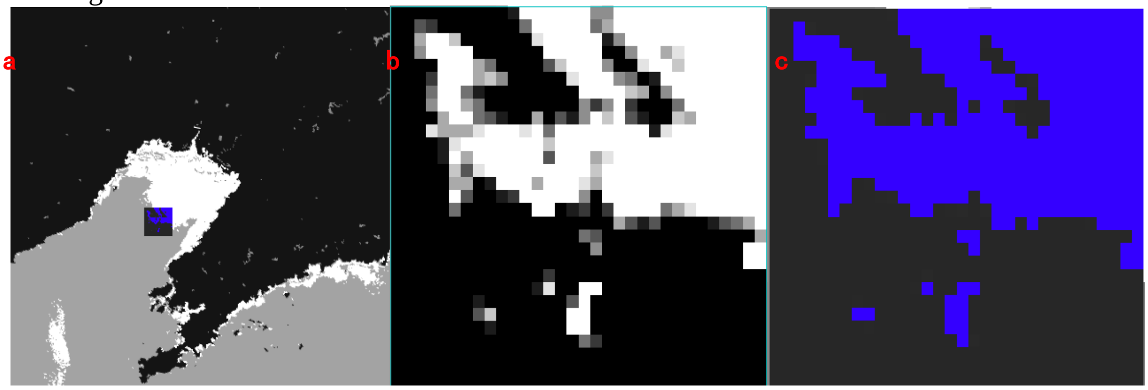

Figure 6. Sea ice extraction process for MODIS.

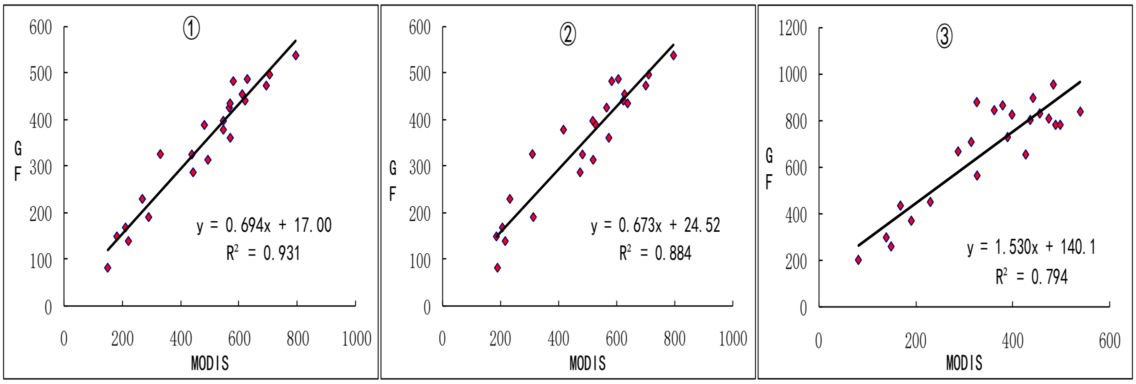

Figure 7. Sea ice area correction for MODIS.

3.4 Sea Ice Area Change during 2004 to 2017

Data from early Dec to early March next year during 2004 to 2017 are used to analyze the area change of sea ice in Liaodong Bay(figure 8). The sea ice area is in slight downtrend. But the inter-annual variation is with obvious stage features. During 2005 to 2008, the sea ice area apparently reduced. During 2009 to 2012 it's in a trend to increase. Then it was in reduction trend again during 2013 to 2016 (except for 2015). Basically 4 years' periodic change appears in sea ice in Liaodong Bay. Analyze the variation of sea ice within the year according to long years' average data shown in the curve, and we can see that basically the sea ice of Liaodong Bay reaches the maximum value as 10,014 km^2 in early Feb, which is changing in unimodal type.

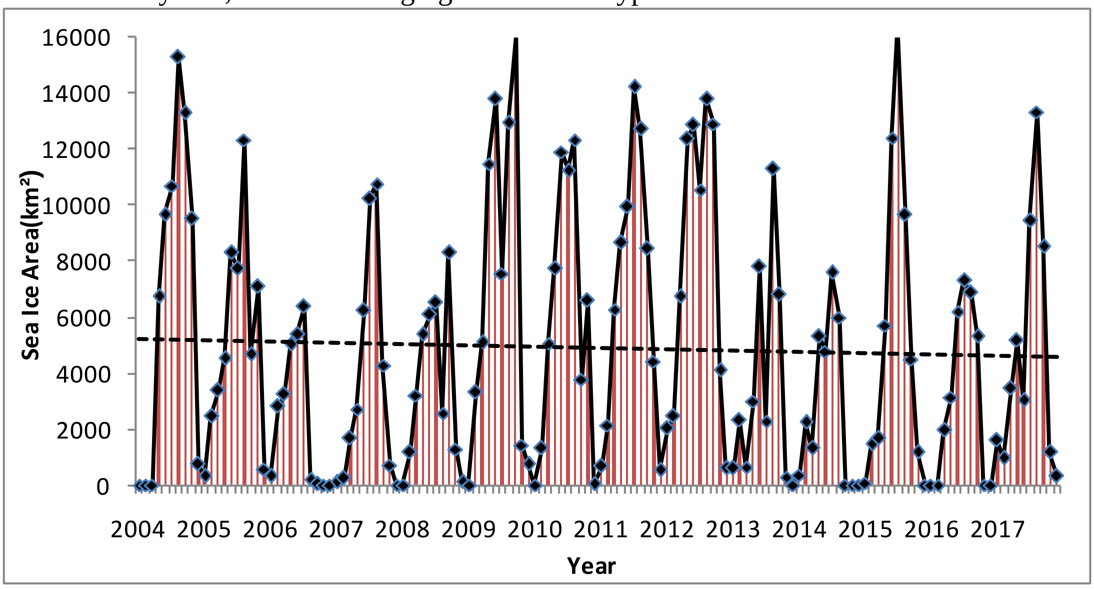

Figure 8. Area change of sea ice in Liaodong Bay.

4. Conclusion and Discussion

Sea ice correction model is established in Liaodong Bay based on the polar-orbiting satellite data (MODIS) with high time resolution and high-resolution satellite data (GF-2) with high spatial resolution. It achieves wide-range and high precision monitoring of sea ice area. Compared the precision of 3 extraction methods of MODIS sea ice, we can find CH1 single channel extraction is the optimal method, which is consistent to the result of spectral observation. The spectrum result also shows that comparing with CH2 channel, snow-covering sea ice, ice-water mixture and seawater and sea ice in CH1 channel has a greater difference value of spectral reflectivity and is easier to distinguish. Here the sea ice area extracted by GF-2 satellite is taken as the benchmark data, and a linear model is established to correct MODIS sea ice area with model correlation coefficient as 0.96. The monitoring error is reduced from 39% to 10% after correction.

Make use of the correction model to correct the sea ice monitoring area from early Dec to early March next year during 2004 to 2017, then analyze the sea ice area change in Liaodong bay. The result shows that the sea ice area is in slight downtrend. The inter-annual variation is featured with 4 years' periodical change. In every winter, sea ice area is in unimodal change, and reaches the maximum value in about early Feb.

After area correction, sea ice monitoring information can be more precise, and extraction precision of sea ice area can be further improved. It's essential to historical data about sea ice study. To accurately grasp sea ice's periodic change and its change features in each winter is of a great significance to the monitoring and forecast of sea ice.

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References
[1] Yuan Ben-kun,Cao Cong-hua,Jiang Chong-bo,etal. Journal of Catastrophology. 2016,31(2):42
[2] Emergency office of the China Meteorological Administration, Emergency management in China..2015,3.
[3] Wang Ning. Important parameters extraction and detection system for sea ice in Bohai based on MODIS data. Ocean University of China. 2009,1-7
[4] Li Yan-qing. Inversion of sea ice visible light remote sensing data in Bohai and assimilation and analysis of waiting time series.Ocean University of China.2013,1-7
[5] Ke Chang-qing.Xie Hong-jie,Lei Rui-bo,etal.Spectral features analysis of sea ice in the Arctic ocean. Spectroscopy and Spectral Analysis,2012,32(4):1081-1084
[6] Liu Yu-cheng,Gu Wei,Li Lan-tao,etal.Acta Oceanologica Sinica.2013,35(3):113-118
[7] Wu Long-tao,Wu Hui-ding,Sun Lantao,etal. Periodical of Ocean University of China.2006.36(2)：173-179
[8] Hong Sungwook. Remote sensing of Environment.2010,114(5):1136-1140
[9] Chen Yan-hong,Liu rui-min,Long Hui. Bulletin of Surveying and Mapping,2015(9):83-86.
[10] Zhou Bin,Zhang Zi-li,Yu Hai-yan. The applied research of Bohai sea ice trends and characters based on the EOS/MODIS.Environmental Monitoring and Forewarning.2013,5(1):11-14