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The Quantitative Evaluation of Sea-ice Disaster in the Bohai Sea based on the GOCI and Sentinel-1 Data

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1. INTRODUCTION

Sea ice is a major marine hazard to the Bohai Sea in the winter. It is very important to evaluate the sea-ice damaging effects quantitatively, which has not been studied and analyzed systematically using long-term data so far. In this paper, the different sea-ice-hazard indexes are defined quantitatively for different hazard-bearing bodies of the marine transportation and the offshore constructions in the Bohai Sea from 2011 to 2017.

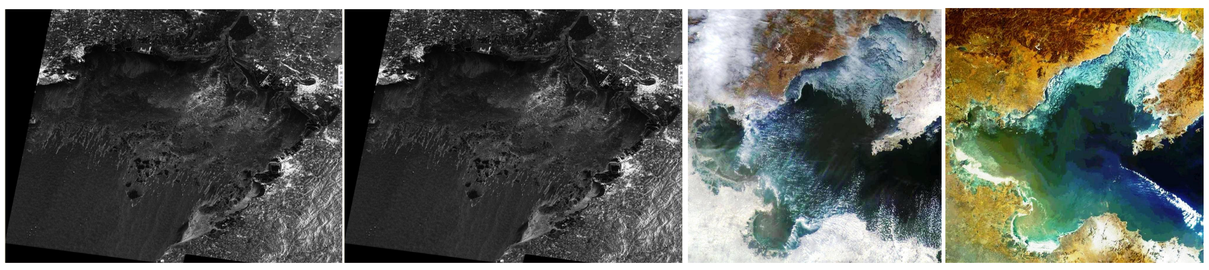
2. DATA SOURCES

(1) Sentinel-1

Sentinel-1 performs C-band synthetic aperture radar imaging and provides single- and dual-polarization images in the Bohai Sea from 2014 to 2017.

(2) GOCI (Geostationary Ocean Color Imager)

GOCI is the first geostationary sensor, which covers the whole Bohai Sea with a spatial resolution of about 500 m of 8 images for one daytime from 2011 to 2017 provided by the Korea Ocean Satellite Center (KOSC).



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The Sentinel-1 images *The GOCI images*

3. SEA-ICE PARAMETERS INVERSION

Sea-ice parameters should be inversed for the sea-ice-hazard evaluation, including the sea-ice concentration, thickness and velocity. According to the Sea-ice-hazard Emergency Plan, Sea-ice-hazard Bulletin from the State Oceanic Administration People's Republic of China (SOAPRC), the sea-ice parameters can be divided to four grades.

The grades of the sea-ice parameters

Sea-ice parameters	Grade 1: Non hazard	Grade 2: Low hazard	Grade 3: Mild hazard	Grade 4: Severe hazard
Concentration	0-15%	15-50%	50-80%	80-100%
Thickness	0-0.1 m	0.1-0.2 m	0.2-0.3 m	>0.3 m
Velocity	0-0.2 m/s	0.2-0.4 m/s	0.4-0.6 m/s	>0.6 m/s

(1) Sea-ice thickness

The sea-ice thickness (H_i) is retrieved using the sea-ice optical information of GOCI in the Bohai Sea [1]. The sea-ice shortwave albedo changes with the variation of sea ice thickness [2].

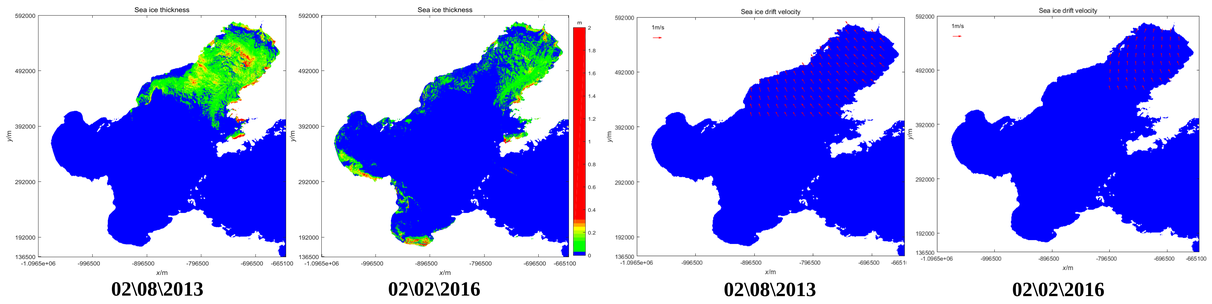
$$\alpha_{short} = \alpha_{max}\,[1-k\exp(-\mu_\alpha H)]$$

The equation of α_{short} calculated by 8 visible infrared spectra of GOCI was proposed [1][3][4]:

$$\alpha_{short} = -0.136\alpha_1-0.270\alpha_2+1.409\alpha_3-0.328\alpha_4-0.081\alpha_5+0.620\alpha_6-0.147\alpha_7-0.0268\alpha_8-0.046$$

(2) Sea-ice velocity

The sea-ice velocity (V_i) is extracted using the GOCI images, which has employed the Maximum Cross-correlation (MCC) method for daily 1-hour sea ice drift tracking in the Bohai Sea [5].



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Sea-ice thickness results by GOCI *Sea-ice velocity results by GOCI*

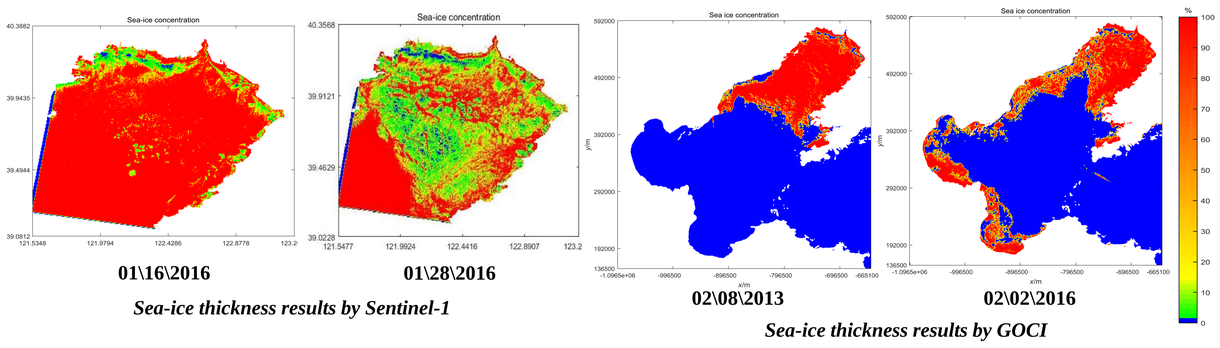
(3) Sea-ice concentration

➢ ***Sea-ice concentration calculated by Sentinel-1***

The sea ice and the sea water are identified using the threshold method based on the Sentinel-1 [6]. Sea-ice concentration can be extracted using the classified results of the Sentinel-1 images.

➢ ***Sea-ice concentration calculated by GOCI***

The sea ice and the sea water can be recognized by the above sea-ice thickness results using GOCI data. Sea-ice concentration can be extracted using the sea ice recognization results of the GOCI images.



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Sea-ice thickness results by Sentinel-1 *Sea-ice thickness results by GOCI*

4. SEA-ICE-HAZARD EVALUATION

(1) For the marine transportation (I_1)

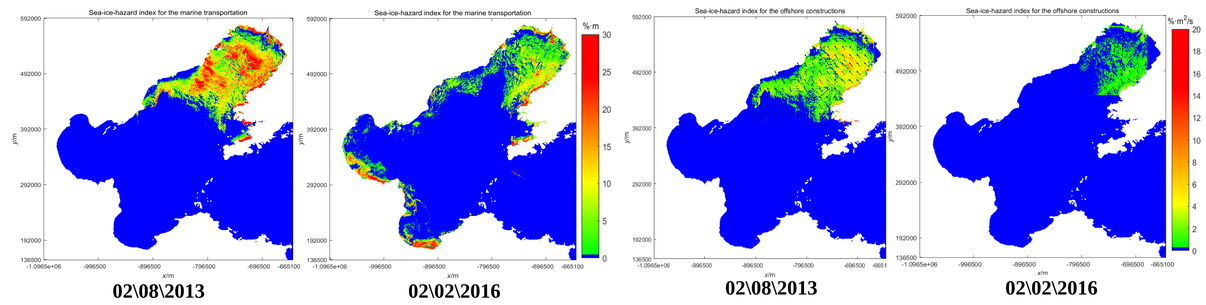
For the marine transportation, its sea-ice-hazard index is equal to multiplying the sea-ice concentration (C_i) by the sea-ice thickness (H_i), which is defined by I_1: $I_1 = C_i \times H_i$ (unit: %·m).

(2) For the offshore constructions (I_2)

For the offshore constructions (e.g. the oil platform), its sea-ice-hazard index is equal to multiplying I_1 by the sea-ice velocity (V_i), which is represented by I_2 : $I_2 = I_1 \times V_i = C_i \times H_i \times V_i$ (unit: %·m²·s⁻¹).

The grades of the sea-ice-hazard indexes

unit	Grade 1: Non hazard	Grade 2: Low hazard	Grade 3: Mild hazard	Grade 4: Severe hazard
% · m	0-1.5	1.5-10	10-24	>24
%·m²·s⁻¹	0-0.3	0.3-4	4-14.4	>14.4



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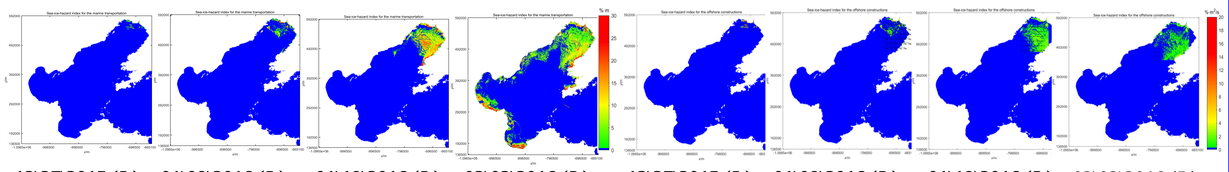
Sea-ice-hazard indexes for the marine transportation *Sea-ice-hazard indexes for the offshore constructions*

(3) The analysis on sea-ice disaster

➢ **Annual analysis**

According to the sea-ice-hazard indexes for the marine transportation and the offshore constructions from 2011 to 2017, the variability and their features of the sea-ice disaster distribution are analyzed in the Bohai Sea in one year. The sea-ice-hazard indexes were often smaller in the November and December, then became increasing from January to February, and were usually larger in February. Finally, sea ice disappeared in March.

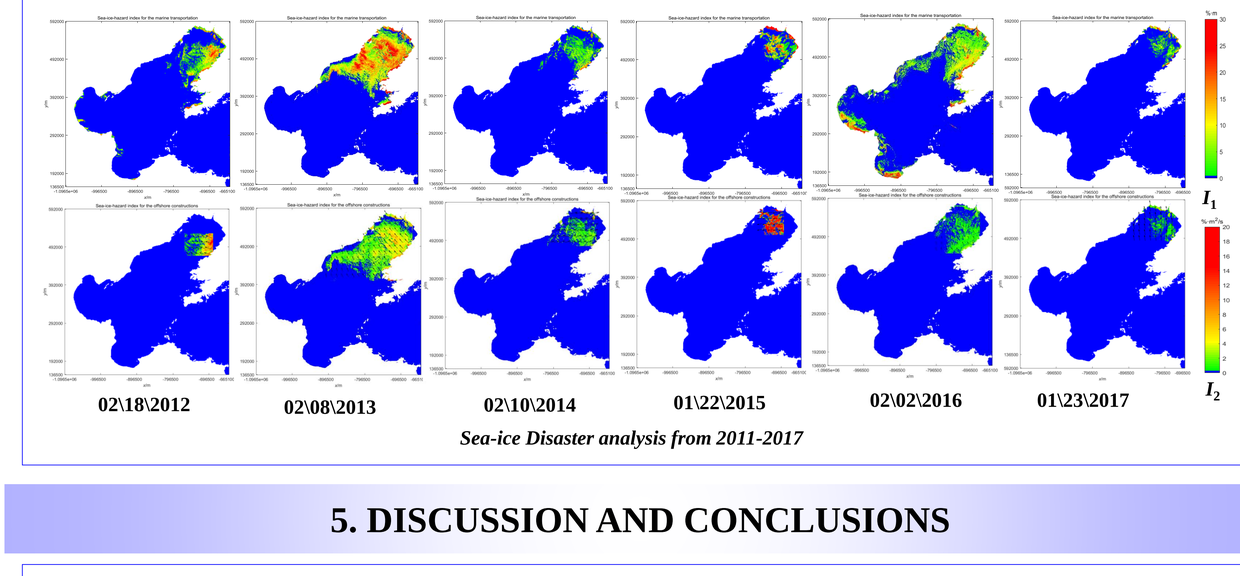


12\27\2015 (I_1) 01\09\2016 (I_1) 01\19\2016 (I_1) 02\02\2016 (I_1) 12\27\2015 (I_2) 01\09\2016 (I_2) 01\19\2016 (I_2) 02\02\2016 (I_2)

Sea-ice Disaster analysis in 2015/2016

➢ **Inter-annual analysis**

According to the sea-ice-hazard indexes for the marine transportation and the offshore constructions, the changes and their features of the sea-ice disaster distribution are analyzed in the Bohai Sea from 2011 to 2017. The sea-ice-hazard indexes were heavier in the 2012\2013 and 2015\2016, milder in the 2011\2012 and 2014\2015, and lighter in the 2013\2014 and 2016\2017.



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Sea-ice Disaster analysis from 2011-2017

5. DISCUSSION AND CONCLUSIONS

In the Dragon-4 programme, the sea-ice-hazard indexes I_1 and I_2 for the marine transportation and the offshore constructions respectively, are quantitatively illustrated the space-time distribution features of the sea-ice disaster in the Bohai Sea from 2011-2017, which can satisfy the request of the sea-ice disaster prevention and reduction and provide the reference of the monitoring and research on the sea-ice disaster.

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