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# Analysis of Influence Factors of GF-4 Registration Accuracy on Sea Ice Drift in the Bohai Sea

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## 1. ABSTRACT

The "GF-4" satellite is China's first high resolution geostationary optical remote sensing satellite. It has the unique advantages of short imaging time interval (20s) and high resolution (50m). In order to analyze the effect of GF-4 satellite image registration accuracy on sea ice drift in Bohai Sea, firstly, the orthorectification of the 28 image data available from August 2016 to March 2018 in the Bohai Sea area was carried out. Then we select the sea-land edge points as control points, and registration of two images which have the same time interval. Next, we recorded the marked same name points which searched from the bottom of Liaodong bay, east of Liaodong bay and west of Liaodong bay respectlly. Statistics the direction and frequency of land point offset sub-regionally and created the rose plots. And maked histogram of the offset of land point. The results show that, when the time interval is 4 hours and 24 hours, the dominant migration direction in the three regions in Liaodong bay is east; when the time interval is 1 minute, the dominant migration direction in Liaodong Bay bottom and Liaodong Bay west coast land is south, Followed by east and southeast respectively; the dominant migration in Liaodong Bay East Coast is north, followed by east; When the time interval is 3 hours, the dominant migration direction in west of Liaodong Bay, bottom of Liaodong Bay and east of Liaodong bay are east, west and south respectively, followed by southeast, east, southeast respectively. The land offset in three regions is major centralized distribution in a range which is from 60m to 80m. That is to say, the offset of land is basically equal to 1.2 times of pixels, and the maximum land offset is less than 2 times of pixels. Through statistical analysis, it can be seen that with the increase of time interval, the land offset will not change much. This study also paves the way for the study of the drift of sea ice.

## 2 INTRODUCTION

The drift of sea ice and sea ice has caused major economic losses to China's economy, such as the destruction of sea structures, the blocking of shipping and the destruction of ships. Therefore, it is necessary to carry out relevant researches on sea ice drift monitoring in Bohai Sea. At present, scholars at home and abroad have carried out research on sea ice drift monitoring based on a variety of satellite images. The remote sensing data commonly used for polar sea ice monitoring include Microwave Scatterometers, Microwave Radiometers, and Synthetic Aperture Radar (SAR) [1-5]. Due to the severe seawater movement in the Bohai Sea, sea ice deformation is likely to occur. The re-visit period of Microwave Scatterometers, Microwave Radiometers, and SARs is relatively long and cannot meet the demand for sea ice drift monitoring in the Bohai Sea. Some scholars have also conducted sea ice research using Moderate Resolution Imaging Spectroradiometer (MODIS) and Geostationary Ocean Color Imager (GOCI) data, and successfully applied the data to the sea ice drift monitoring in the Bohai Sea. However, the "GF-4" satellite imaging time interval is 20s and the resolution is 50m. It has a higher time resolution and spatial resolution and is more suitable for sea ice drift tracking. Xiao-ying Chen based on GF-4 satellite do the green tide extraction research drift velocity in Yellow Sea, Libo Yao studied ship target tracking based on GF-4 satellite [6], Zhong-ting Wang using GF-4 data monitoring "beijing-tianjin-hebei region aerosol [7].There is little research on sea ice monitoring by the GF-4 satellite, and no one has performed error analysis. However, the error will lead to inaccurate sea ice drift velocity. This paper focuses on the analysis of the factors affecting the sea ice drift in the Bohai Sea by the accuracy of GF-4 satellite image registration.

## 3 DATA SETS AND METHOD

### *(1) Study area*

The Bohai Sea is located at latitude 37° 07′-41° 0′N and longitude 117° 35′-121° 10′E. which is composed of Liaodong Bay, Laizhou Bay, Bohai Bay and the central Bohai Sea, with varying degrees of freezing phenomenon each winter [8-9] .Liaodong Bay is the most frozen region in the north of China. It is also the earliest area of sea ice in Bohai Sea. The research area of this paper is the Liaodong Bay area of Bohai Sea , as shown in Fig. 1.

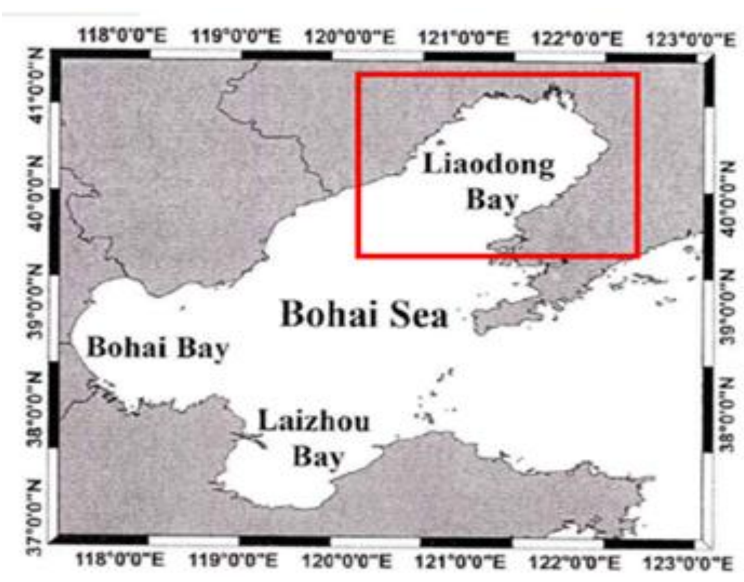



Fig.1 Research area

### *(2) GF-4 data*

The GF-4 satellite was successfully launched in December 2015 and officially put into use in June 2016. It is China's first high-resolution optical satellite in geostationary orbit.It can perform large-scale observations on about one-third of the earth's surface and can continuously observe a certain area for a long period of time. The GF-4 satellite has configuration of the largest aperture array staring camera in our country, and the first large-area array infrared detector developed. It has four working modes: census, gaze, area, and motor patrol. Visible light near-infrared channel pixel resolution ( The point below the star) has reached 50m with four bands of blue, green, red and near-infrared, and the resolution of the mid-wave infrared channel pixel has reached 400m. Compared with traditional geostationary orbit satellites which has only 100 meters' observation capability, its rate has increased dramatically. In addition, its time resolution is up to 20s, and its high spatial-temporal resolution provides better data support for faster dynamic sea ice drift monitoring. The technical indicators of GF-4 satellite load are shown in Table 1.

Table 1 Main technical inenxes of GF-4 satellite and its playloads

| Content | Indicators |
|---|---|
| Satellite orbit | Geostationary orbit |
| Orbital altitude/km | 36000 |
| Designated location | 106.5° |
| Revisit time /s | 20 |
| Remote sensor spectrum | Visible light near infrared channel：0.45～0.90μm，0.45～0.52μm，0.52～0.60μm，0.63～0.69μm，0.76～0.90μm； |
| | Medium wave infrared channel：3.5～4.1μm |
| Image ground pixel resolution. /m | Visible light near infrared channel：50； |
| | Medium wave infrared channel：400 |

From China resources satellite application center land observation satellite data service platform for the August 2016 to March 2018 can constitute a time series of sunny weather, high visibility, cloudless 28 scene GF - 4 satellite image as the research data of this paper (Table 2).

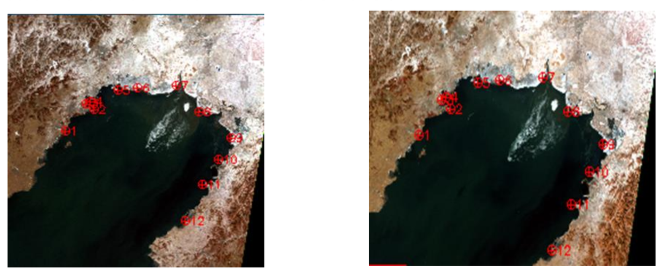
Table 2 Information of the selected GF-4 images

| The time interval | Date of imaging | Imaging time (Beijing time) | |
|---|---|---|---|
| 1min | 2017.1.18 | 11:04:25 | 11:05:34 |
| | | 11:05:34 | 11:06:44 |
| | 2017.3.3 | 11:10:41 | 11:11:48 |
| | | 11:12:55 | 11:14:01 |
| 3h | 2017.1.10 | 11:31:58 | 14:31:58 |
| | | 11:33:37 | 14:33:37 |
| 4h | 2017.1.6 | 10:31:58 | 14:31:58 |
| | | 10:33:37 | 14:33:37 |
| | 2017.1.9 | 10:32:13 | 14:33:37 |
| | | 10:33:52 | 14:31:58 |
| 24h | 2017.1.9 | 14:31:58(1.9) | 14:31:58 (1.10) |
| | 2017.1.10 | 14:33:37(1.9) | 14:33:37 (1.10) |
| | 2018.2.3 | 10:00:42 | |
| | 2018.2.4 | 10:00:42 | |
| | 2018.2.5 | 10:00:42 | |
| | 2018.2.6 | 10:00:42 | |

### *(3) Method*

The method used in this paper mainly includes two steps: (1) Ortho-rectification of 28 scene images respectively, and the corrected image adopts WGS-84 coordinate system and UTM projection. (2) Registration of the corrected image, the accuracy of registration is less than 0.5 pixels.

Take the images of the two moments at 10:33:52 and 14:31:58 on January 9, 2017 (about 4 hours apart) as an example. As shown in Fig. 2, there are two images on January 9 after the orthorectification has been performed. Twelve control points were evenly selected for registration on the land edges of the two images. The total root mean square error of all control points was 0.422795, and the residuals and root mean square errors of the control points during the registration were as shown in Table 3.



(a) The image at 10:33:52 (b) The image at 14:31:58

Fig.2 Image on January 9

Table 3 The Residual error and root-mean-square error of the two image control points at 10:33:52 and 14:31:58 on January 9

| Point | BaseX | BaseY | Warp X | Warp Y | PredictX | PredictY | ErrorX | ErrorY | RMS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 628 | 1261 | 523 | 1068 | 522.92 | 1067.89 | -0.08 | -0.11 | 0.14 |
| 2 | 935 | 1031 | 829.75 | 837.5 | 829.62 | 837.47 | -0.13 | -0.03 | 0.13 |
| 3 | 850.5 | 959.5 | 745.5 | 765.75 | 745.02 | 765.94 | -0.48 | 0.19 | 0.52 |
| 4 | 896.5 | 934 | 790.75 | 740.5 | 791 | 740.41 | 0.25 | -0.09 | 0.26 |
| 5 | 1199.75 | 813.75 | 1094.5 | 620.25 | 1094.23 | 620.06 | -0.27 | -0.19 | 0.33 |
| 6 | 1413.5 | 787.25 | 1307.25 | 593.5 | 1308.05 | 593.55 | 0.8 | 0.05 | 0.81 |
| 7 | 1840 | 765.75 | 1734.5 | 571.75 | 1734.74 | 572.08 | 0.24 | 0.33 | 0.41 |
| 8 | 2088.25 | 1057 | 1983.25 | 863 | 1983.08 | 862.97 | -0.17 | -0.03 | 0.17 |
| 9 | 2435.25 | 1333.25 | 2330.5 | 1139 | 2330 | 1138.55 | -0.5 | -0.45 | 0.67 |
| 10 | 2301 | 1571.25 | 2195.5 | 1376 | 2195.69 | 1376.29 | 0.19 | 0.29 | 0.35 |
| 11 | 2120.25 | 1846.5 | 2015.25 | 1651.5 | 2014.98 | 1651.42 | -0.27 | -0.08 | 0.28 |
| 12 | 1934 | 2244 | 1828.5 | 2048.75 | 1828.89 | 2048.86 | 0.39 | 0.11 | 0.41 |

## 4 PRECISION ANALYSIS

Based on the above two images, the Liaodong Bay is divided into three areas: the bottom of Liaodong Bay, east coast of Liaodong Bay and west bank.

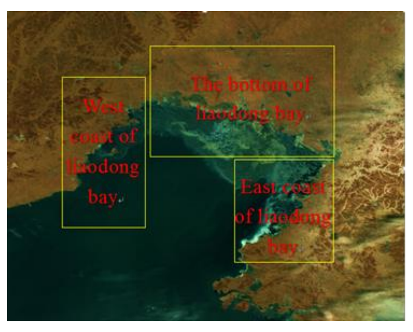
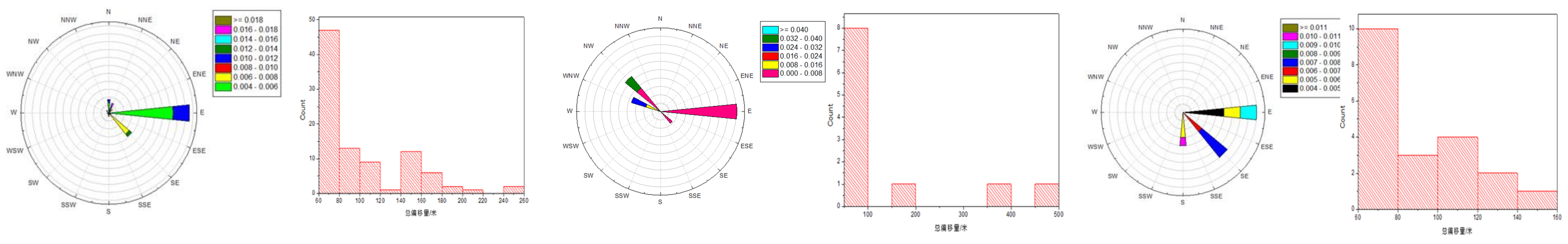


Fig.3 Three areas of Liaodong Bay

In each of the three regions, it is easy to identify the distinctive feature points, such as the intersection of the road and the corner of the field, etc. Recorded the coordinate information of the same feature point in the two images, and counted the differences in the X direction and Y direction as well as the total offset, offset direction and angle. Summarized all the statistical information of 4 hours inteval, and make the rose diagram for the direction and frequency of the land point excursion,as shown in Fig. 3, and make histogram of the total offset of the land point, as shown in Fig. 4. The information statistics steps at intervals of 1min, 3h, and 24h are the same as those that are separated by 4h, and statistical analysis of the error distribution of land offsets is performed.



(a)The bottom of Liaodong Bay (b)The west bank of Liaodong Bay (c)East coast of Liaodong Bay

Fig.4 Rose diagram and histogram of land point offset in Liaodong Bay, four hours apart

The offset direction and offsets of land points in three areas of Liaodong Bay at different time intervals are shown in the table 4 and Table 5. Through statistical analysis, it can be seen that: when the time interval is 4 hours and 24 hours, the dominant migration direction in the three regions in Liaodong bay is east; when the time interval is 1 minute, the dominant migration direction in Liaodong Bay bottom and Liaodong Bay west coast land is south, Followed by east and southeast respectively; the dominant migration in Liaodong Bay East Coast is north, followed by east; When the time interval is 3 hours, the dominant migration direction in west of Liaodong Bay, bottom of Liaodong Bay and east of Liaodong bay are east, west and south respectively, followed by southeast, east, southeast respectively. The land offset in three regions is major centralized distribution in a range which is from 60m to 80m. That is to say, the offset of land is basically equal to 1.2 times of pixels, and the maximum land offset is less than 2 times of pixels.

Table 4 Offset direction of land points in Liaodong Bay at different time intervals

| The time interval | The west bank of Liaodong Bay | The bottom of Liaodong Bay | The east coast of Liaodong Bay |
|---|---|---|---|
| 1min | S | S | N |
| 3h | W | E | S |
| 4h | E | E | E |
| 24h | E | E | E |

Table 5 Offsets of land points in Liaodong Bay at different time intervals

| Area | The interval of 1 min | The interval of 3h | The interval of 4h | The interval of 24h |
|---|---|---|---|---|
| The bottom of Liaodong Bay | 0-100 meters | 0-100 meters | 60-80 meters | 70-80 meters |
| The east coast of Liaodong Bay | 65-75 meters | 60-80 meters | 60-80 meters | 70-80 meters |
| The west bank of Liaodong Bay | 0-100 meters | 0-100 meters | 50-100 meters | 70-80 meters |

## 5 DISCUSSION AND CONCLUSIONS

### (1) *Discussion*

GF-4 satellites are mainly used for military purposes rather than civilian use. Therefore, although the revisiting cycle of GF-4 satellite is 20 seconds, it is not collected every 20 seconds. And GF-4 satellite imagery with good weather, high visibility, and cloudlessness should be selected as experimental data. At present, there are few data sources with a time interval of 3 hours, and there may be errors in the error analysis of 3 hours interval, which still needs further study. In addition, it is necessary to strengthen coordination with polar-orbiting satellites in data acquisition and application in order to increase the application range and efficiency of GF-4 satellite data.

### (2) *Conclusions*

To accurately quantified the tracking error of GF-4 image to sea ice drift, we used the 28 images which acquired from GF-4 between August.2016 to March.2018 to correction, registration and mathematical statistics. And we analyzed the direction, angle and offset of land points in three areas of Liaodong Bay with the different time intervals.

By statistical analysis of the datasets which have time interval of 1min、3h、4h and 24h respectively. We found that the direction of the offset of land points in Liaodong bay are usually east, some of land points are southeast, other direction could be ignored. Furthermore, the quantity of the offset would not change much, and stay around the size of two pixels with the increase in time interval. This research result allows us to have a deeper understanding of the error of GF4 satellite image tracking of sea ice drift, and it also paves the way for the study of sea ice drift behind.