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Research on Fast Extraction Method of Sea Ice Boundary in Arctic Channel Based on MODIS Data

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Abstract. In order to study the distribution of sea ice in the Arctic Channel, sea ice along the Arctic Channel was extracted based on MODIS remote sensing data. Supervised classification method is used to establish a noise removal method for short time series to obtain the sea ice distribution boundary. From this, the navigability of the Arctic waterway is analyzed. The results show that although MODIS data contain more noise effects, more accurate sea ice distribution information can be obtained by effective noise removal methods, which provides support for the judgment of navigation capacity of Arctic waterway.

1. INTRODUCTION

The Arctic Channel is a sea lane that crosses the Arctic Ocean and connects the Atlantic Ocean to the Pacific Ocean. In general, the Arctic Channel usually consists of two parts: the “northwest channel” in the waters of the Canadian Arctic archipelago and the “northeast channel” in the northern part of Russia([1]). Most of the northeast channel is located in the offshore waters of the Arctic Ocean on the northern coast of Russia([2]).

The key obstacle to the opening of the Arctic Channel is the existence of sea ice, which brings great hidden dangers to navigation safety. The first problem to be solved is the time period of navigation, which can barely be navigable for only a few months in a year; the second is the danger of the Channel. Even after the melting of sea ice, there are often ice floes, even icebergs and sea ice, which bring great hidden dangers to navigation safety.

In order to solve the above problems, a continuous short-time sequence spatial superposition method for noise removal is proposed by using MODIS P1D29([3]) sea ice reflectance data, based on the supervised classification technology of remote sensing mainstream. And therefore the sea ice distribution boundary of the Arctic channel is quickly extracted. The results can be used to monitor the annual variation of sea ice, obtain the navigation time of Arctic waterway, forecast the distribution of sea ice for naval vessels, provide technical support for ice-breaking operations and route planning, and provide theoretical support for urgent tasks such as naval vessels.

2. RESEARCH AREA AND DATA INTRODUCTION

2.1 Introduction of the study area

The research area selected in this paper is mainly along the northeast channel. The channel starts from



Iceland via the Barents Sea along the northern part of Eurasia to the Bering Strait. It is a high-latitude maritime transport corridor connecting the Eurasian continent.

In the scope of the waterway, the Russian official limited the Arctic northeast waterway to the north of the latitude of 66 degrees 05 minutes, from the west to the east of the 68 degrees 35 points of the Hotaniye corner, east to the west longitude 168 degrees 58 minutes. The distribution range is shown in Fig.1.

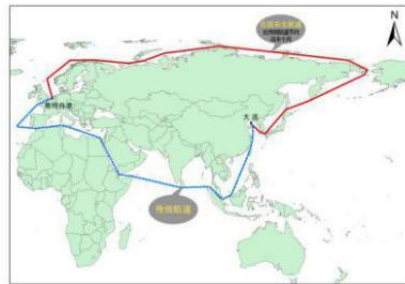


Fig.1. Distribution of Northeast Arctic Channel

2.2 Introduction of MODIS data

NASA successfully launched two polar orbital satellites, Terra and Aqua, in December 1999 and May 2002. MODIS is an important sensor loaded on both satellites, is used to observe global organisms And instruments for physical processes in the EOS program. MODIS continuously provides day and night spectral image data of anywhere on the Earth, including visible and infrared spectral data of the observations of land, sea and atmosphere([4]). The MODIS P1D29 data is an L3 data product, mainly used for sea ice monitoring. The data is Lambert's equal area azimuth projection, the time resolution is 1 day, the data spatial resolution is 1km, the single image data is small with 1200km*1200km coverage, which can meet the requirements of large-scale data fast acquisition and continuous time period data acquisition([5]).

Therefore, this paper uses MODIS L3 data- MODIS P1D29 to study the rapid extraction of sea ice boundaries. The data is to correct the edge distortion generated by the remote sensor imaging process based on the processing of the 1B data, and it is the reflectance data. The mosaic result of MODIS sea ice reflectivity data in the northeastern Arctic channel is shown in Fig.2.

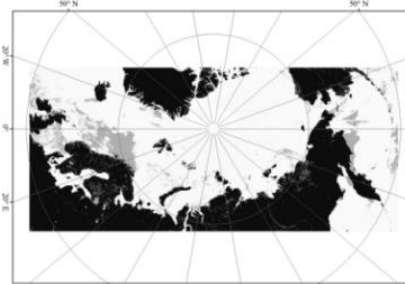


Fig.2. Mosaic results of MODIS data in the study area

3. STUDY ON RAPID EXTRACTION METHOD OF SEA ICE

3.1 Image Mosaic

The Arctic Channel covers a wide area, with 36 data acquisitions to achieve full coverage of the study area. MODIS P1D29 data is mainly used to monitor sea ice. There are fewer species in the polar region. The images mainly include sea ice, sea water, land and cloud. MODIS P1D29 data has been processed by radiation correction and geometric correction. Therefore, it is not necessary to consider the color consistency and physical integrity of image edges in the process of mosaic. It can be mosaic directly to achieve image mosaic.

3.2 Supervised classification

MODIS P1D29 data is L3 data, which has been positioned and calibrated. It is mainly used to study the reflectivity data of sea ice. In this paper, the supervised classification maximum likelihood method is directly used to classify the mosaic data and extract sea ice.

Supervised classification, also known as training site method, is based on the theory of establishing statistical recognition function and classifying according to typical sample training methods. That is to say, according to the samples provided by the known training area, by selecting the characteristic parameters, the characteristic parameters are obtained as decision rules, and the discriminant function is established to classify the images to be classified([6,7]). It is a method of pattern recognition. The training area is required to be typical and representative. If the criterion satisfies the requirement of classification accuracy, the criterion will be established. On the contrary, the decision rules of classification need to be re-established until the requirement of classification accuracy is met.

3.3 Sea ice boundary extraction algorithm

MODIS data acquires visible and infrared band data, and there is a lot of noise in the data. On the one hand, noise comes from data itself, on the other hand, it is the influence of cloud. As shown in Fig.3a, the supervised classification results obtained by using MODIS data of a certain day are presented. We know that the Arctic Circle is covered by sea ice all the year round. There are obvious deviations in the analysis results and the accuracy of the calculation results is not high. Therefore, this paper proposes a method of removing noise based on short-term continuous sequence space superposition analysis to realize the rapid extraction of sea ice distribution boundary. The basic idea of the algorithm is: generally, sea ice melting does not produce sudden changes. The sea ice distribution data of short time series can be obtained, and the spatial overlay analysis can be carried out to realize the rapid extraction of sea ice boundary([8]). In this paper, 10 consecutive short time series are taken. The results are shown in Fig. 3b.

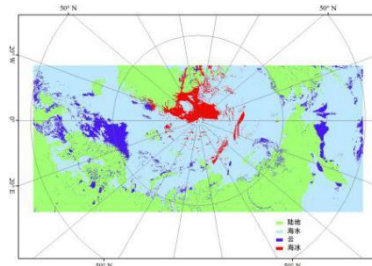


Fig. 3a. Analysis of single-day sea ice distribution

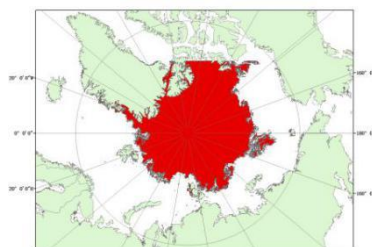


Fig.3b. Distribution of sea ice after noise removal

3.4 Design of rapid extraction process for sea ice boundary

Based on the above technology, this paper uses the flow of Figure 4 to extract the sea ice boundary.

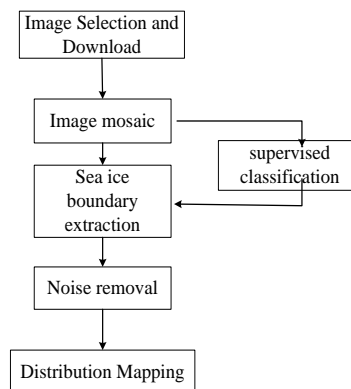


Fig. 4. Flow chart for fast extraction of sea ice boundary

(1) Data download and image mosaic: download MODIS image data of Arctic Channel coverage area, and image mosaic (see <https://modis.gsfc.nasa.gov/>)

(2) Based on remote sensing supervised classification of sea ice boundary extraction: using remote sensing supervised classification method, using different reflectance values of sea water, sea ice, land and clouds, image classification is carried out to obtain sea ice boundary and get the range of sea ice distribution vector.

(3) Noise removal. Using the above method, the vector data of sea ice distribution range for ten consecutive days are obtained, and the spatial superposition analysis is carried out to remove the influence of noise as the result of sea ice distribution on that day.

(4) Navigation time is obtained. The method uses sea ice distribution data for ten consecutive days for spatial overlay analysis. Therefore, in order to obtain the navigation time, this paper chooses to obtain the distribution of sea ice every day in the first, middle and last three decades of each month, and then get the navigation time and accessible area of the Arctic channel.

4.RESULT ANALYSIS

According to the above method, the sea ice boundary is quickly extracted, and the distribution of sea ice in September 2018 is shown in Fig. 3b. The green part of the way is land, the blank area is sea water, and the red area is sea ice. It can be seen from the figure that in September, there is only a small amount of sea ice distribution along the Arctic route, which can be used to plan a safer route. It can be seen from the figure that in September, there is only a small amount of sea ice distribution along the Arctic route, which can be used to plan a safer route.

An analysis of the distribution of sea ice throughout the year of 2018 shows that the current transit time of the northeastern Arctic channel is two to three month. Fig.3b and Fig.5 show the distribution of sea ice in September, November and March, respectively. The chart shows the distribution and variation of seashore in different time periods.

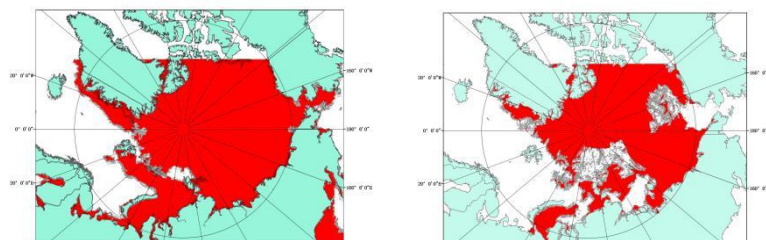


Fig. 5. Distribution of sea ice in different months

5.CONCLUSION

In this paper, MODIS P1D29 data and the remote sensing supervised classification method is used to quickly extract the sea ice boundary. By superimposing the continuous short time series sea ice data to remove the noise influence, improve the extraction accuracy, the sea ice boundary rapid extraction

model is established, and the navigation time of the northeastern northeast channel method is obtained by this method. The MODIS data is easy to obtain, and the L3 data has a small amount of data. After radiometric calibration and geometric calibration, no pre-processing is required, and the data is quickly extracted for the sea ice boundary.

The method can be applied to the rapid extraction of sea ice distribution boundaries in the Arctic channel, and provides decision support for sudden actions. At the same time, it can also provide sea ice distribution forecast for ship navigation, and provide technical support for ice breaking action and navigation route planning. It is able to monitor the annual variation of sea ice and obtain the navigation time of the northeastern Arctic channel.

This method can quickly extract sea ice boundaries, but there are still many problems left for further research.

(1)The spatial resolution of MODIS data is 1km and the resolution is relatively low. Therefore, the obtained sea ice distribution results are only suitable for navigation route planning and sea ice prediction, which can play a role in supporting decision support and cannot be used as navigation route map.

(2)This method only uses MODIS data for sea ice extraction, and no other data is used for result verification. Multivariate data fusion method should be used in the future, such as SAR data, should be used to extract sea ice boundaries to improve accuracy and credibility.

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