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Enhancing the Early Identification and Prevention of Marine Fog Meteorological Disasters by Utilizing Satellite Data

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Abstract:

This paper explores the methods and significance of enhancing the early identification and prevention of marine fog meteorological disasters through the use of satellite data. By analyzing the current application status of satellite remote sensing technology in marine fog monitoring and combining relevant data to illustrate the hazards of marine fog and the necessity of early identification, it further proposes strategies for the early identification and prevention of marine fog based on satellite data, aiming to improve the early warning capability and prevention effect of marine fog meteorological disasters and reduce their adverse impacts on marine activities and coastal areas.

Keywords:

Satellite data
Marine fog
Early identification
Prevention

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1. Introduction

Marine fog is a common marine meteorological disaster that seriously affects maritime transportation, fishery production, marine energy development and other activities, and may also cause many adverse effects on the ecological environment and residents' lives in coastal areas. According to statistics, 50% to 70% of ship collisions or grounding accidents in China's coastal waters are related to marine fog. Therefore, strengthening the early identification and prevention of marine fog meteorological disasters has important practical significance. With the continuous development of satellite technology, satellite data provides strong support for the monitoring and early warning of marine fog. Utilizing satellite data to enhance the early identification and prevention of marine fog meteorological disasters has become an important topic in current meteorological research and marine disaster prevention and mitigation fields.

2. Application status of satellite remote sensing technology in marine fog monitoring

2.1. Visible light and infrared satellite data

Visible light satellite images have the advantages of high resolution and low acquisition cost, as well as clear color and texture features. However, they are easily affected by weather conditions and may lead to false detection or missed detection of ship targets in complex backgrounds or when there is fog or cloud cover. Infrared satellite images have lower resolution than visible light satellite images and the edges of ship targets are not clear, but they have the advantages of being less affected by interference, all-weather observation, and strong cloud and fog penetration capabilities. Visible light satellite data can present the real-time state of the ocean surface in an intuitive form. However, when applied to marine fog monitoring practice, due to the data acquisition principle being highly dependent on sunlight conditions, this type of data has inherent limitations in fog monitoring scenarios. In contrast, infrared satellite data, with its unique technical characteristics, has the outstanding advantage of not being constrained by light conditions, thus enabling continuous monitoring of the target area day and night. From a technical detail perspective, by using the brightness temperature data collected through the infrared channel, the subtle temperature differences presented by the marine fog coverage area compared to the surrounding environment can be identified with high precision. Based on this, through professional algorithms and models, the spatial coverage and intensity levels of the fog can be accurately defined.

2.2. Microwave satellite data

Microwave satellite data, with its unique electromagnetic frequency band characteristics, has excellent cloud and fog penetration capabilities and shows unique advantages in the marine fog monitoring workflow. Especially when encountering extreme meteorological conditions with extremely high fog concentrations, causing visible light and infrared satellite data to be limited by cloud and fog cover and unable to accurately capture effective monitoring information, microwave satellite data, with its penetration advantage, can stably provide more reliable key information for fog monitoring, effectively filling the information gap exposed by visible light and infrared satellite data in complex fog environments, and providing strong support for precise monitoring of fog conditions.

2.3. Fusion of multi-source satellite data

Implementing a fusion strategy for different types of satellite data can fully exploit the potential advantages of each data source and significantly improve the accuracy and reliability of marine fog monitoring work. Taking the fusion of visible light, infrared, and microwave satellite data as an example, in this process, by comprehensively utilizing the rich information contained in multi-source data, it is possible to analyze the physical characteristics of fog from multiple dimensions more deeply and comprehensively, accurately grasp its dynamic development trend and precisely depict its spatial distribution pattern, thereby building a solid data foundation for the early precise identification and timely early warning and forecasting of fog phenomena, and providing a more detailed and in-depth information support system.

3. Hazards of marine fog and the necessity of early identification

3.1. Impact on maritime transportation

Marine fog, as a highly hazardous marine meteorological disaster, can cause a sharp decline in sea surface visibility, posing a serious threat to the safety of ship navigation. Numerous authoritative statistics show that under foggy weather conditions, the frequency of various navigation accidents such as ship collisions, grounding, and running aground has significantly increased, imposing a heavy economic burden on the maritime transportation industry. For instance, during the continuous foggy weather in the Qiongzhou Strait from February 15 to 25, 2018, the fog was so thick that ferry operations were disrupted, with more than ten forced suspensions and a total suspension time of over 70 hours. Such a long suspension directly led to a large number of passengers being stranded in Haikou and vehicles queuing up near the port, not only seriously disrupting people's travel plans but also causing a break in the maritime transportation chain and a series of economic and social problems [1].

3.2. Impact on fisheries production

As an important disruptive factor in marine meteorology, foggy weather has many negative impacts on fishery production. On the one hand, it seriously interferes with the visibility range of fishermen at sea, making it difficult for them to accurately judge the accuracy of operations such as net casting and ship navigation, greatly increasing the difficulty and potential risks of fishing operations. Under the low visibility of fog, accidents such as ship collisions and fishing gear loss occur frequently. On the other hand, fog may also indirectly affect fishery production by influencing the marine ecological environment. The water vapor and particles in the fog mix with seawater, changing its physical and chemical properties, and thereby altering the original distribution pattern and activity rules of fishery resources. Fishermen find it difficult to fish based on experience, ultimately leading to a significant reduction in fishery production efficiency and causing economic losses to fishery workers [2].

3.3. Impact on marine energy development

Under foggy weather conditions at sea, key marine energy activities such as offshore wind power generation and marine oil and gas development are all subject to varying degrees of adverse effects. From the perspective of offshore wind power generation, the high humidity and low light conditions created by fog can cause changes in air density, thereby interfering with the normal operation of wind turbine blades and significantly reducing their power generation efficiency. At the same time, the tiny particles in the fog adhere to the surface of the blades, not only increasing their weight but also damaging their aerodynamic performance, further reducing power generation efficiency.

In the field of marine oil and gas development, foggy weather severely limits the field of vision of workers, making key operations such as equipment inspection, maintenance, and material transportation on offshore oil and gas platforms much more difficult, greatly increasing operational risks. This risk not only threatens the lives of front-line workers but may also cause major accidents such as oil and gas leakage, directly affecting the stable supply of energy and the safe and orderly conduct of production activities.

4. Early identification methods of marine fog based on satellite data

4.1. Threshold method

In the process of accurately identifying foggy areas using satellite data, scientifically setting thresholds for key physical quantities such as brightness temperature and reflectance plays a decisive role. Taking the analysis of infrared satellite images as an example, the parameter of brightness temperature is of great monitoring value. The unique thermodynamic and optical characteristics of fog cause the brightness temperature of the covered area to decrease [3]. When the satellite image shows that the brightness temperature of a certain area is significantly lower than that of the surrounding sea surface and is lower than the threshold precisely determined based on meteorological professional theory, combined with long-term historical observation data and multiple experimental verifications, according to strict discrimination criteria, it can be initially determined that the area is likely to be covered by fog. Similarly, the reflectance index should not be underestimated. Fog interferes with the reflection pattern of surface light, causing the reflectance in specific bands to deviate from the normal range. Once it exceeds the corresponding threshold, combined with other meteorological information for comprehensive consideration, the foggy area can be accurately located, providing strong support for multi-field early warning.

4.2. Texture analysis method

The thick fog presents distinct and unique texture features on satellite images, with a particularly smooth and fine appearance. From a professional image analysis perspective, texture, as a key element reflecting the spatial distribution patterns and surface characteristics of ground objects, is of great significance for fog identification. By using advanced texture analysis methods, researchers can conduct detailed processing and in-depth analysis of satellite images. With the help of techniques such as the gray-level co-occurrence matrix and wavelet transform, the specific texture feature information of fog, such as directionality, periodicity, and roughness, can be accurately extracted [4]. By rigorously comparing the extracted features with the preset fog texture model and comprehensively analyzing multiple information such as the surrounding geographical environment and meteorological conditions, precise identification and real-time monitoring of fog can be achieved, providing a solid data foundation for meteorological forecasting, traffic control, and many other fields.

5. Machine learning method

In the field of fog monitoring, the application of cutting-edge machine learning algorithms has become a key breakthrough. Advanced algorithms such as support vector machines and neural networks have injected strong impetus into fog identification. Researchers collect a vast amount of satellite data and match it with corresponding on-site fog observation data, using this as the basic material to input into the algorithm model for in-depth learning and fine training. During this process, the model continuously optimizes parameters, accurately capturing the intrinsic relationship between the features of satellite images and the actual situation of fog. The fog identification model constructed through deep training has a powerful automatic recognition ability, not only accurately locating fog areas in satellite images but also predicting the development trend of fog based on historical data patterns and real-time dynamic information, greatly enhancing the accuracy and efficiency of early identification and providing a solid basis for fog response strategies in multiple fields [5].

6. Marine fog prevention strategies based on satellite data

6.1. Strengthen satellite data monitoring and sharing

We are committed to building a comprehensive and efficient satellite data monitoring network system, significantly increasing the frequency and coverage of satellite observations to greatly improve the temporal and spatial resolution of data, ensuring that the collected information is highly accurate and real-time. At the same time, we actively promote the deep integration and sharing of data among different departments such as meteorology and oceanography, breaking down information barriers to ensure that all stakeholders can obtain and efficiently utilize satellite data resources in real time. This measure will provide a solid data foundation for the early and precise identification and effective early warning of marine fog, contributing to the safety and environmental protection of our oceans.

6.2. Enhance the timeliness and accuracy of warning information release

Based on the early identification results from satellite data, we adopt a comprehensive approach that integrates numerical weather prediction models with various observational data to achieve the fastest speed and highest accuracy in the release of marine fog warning information [6]. We are dedicated to ensuring that warning information is both timely and accurate, so that ships at sea, fishery workers, and coastal residents can quickly receive these warnings and take effective preventive measures in a timely manner, thereby effectively reducing the risks brought by fog.

6.3. Improve marine fog emergency response plans

We have meticulously compiled a comprehensive and detailed marine fog emergency response plan, clearly defining the specific responsibilities and key tasks of each relevant department in the process of responding to fog disasters, and establishing a sound and efficient emergency rescue system. We continuously strengthen the professionalization of emergency rescue teams and significantly enhance the modernization level of emergency rescue equipment to ensure that in the event of sudden fog disasters, we can respond promptly, accurately formulate and implement rescue strategies, and carry out rescue operations efficiently, minimizing the losses caused by disasters.

6.4. Strengthen publicity, education, and training

Actively utilize various communication channels such as television, radio, and the Internet to promote comprehensive and multi-angle publicity and education on marine fog meteorological disasters. The aim is to significantly enhance the public's awareness of the potential dangers of fog and strengthen their proactive prevention consciousness. Through extensive dissemination via these channels, efforts are made to build a well-known and widely participated fog prevention network [7]. For key groups directly exposed to fog risks, such as maritime workers and meteorological observers, a series of specialized training courses have been designed. These courses not only teach practical emergency handling skills in foggy conditions but also focus on enhancing self-protection awareness, with the goal of comprehensively improving the emergency response and survival capabilities of these personnel in complex meteorological environments.

Through this comprehensive training and education, the aim is to establish a more robust fog disaster response mechanism, ensuring that in the event of sudden fog incidents, the public can effectively protect themselves and professionals can promptly and accurately take measures, jointly building a solid defense line and minimizing the negative impact of fog disasters on social life and economic operations.

7. Conclusion

Utilizing satellite data to enhance the early identification and prevention of marine fog meteorological disasters is a systematic project with significant practical significance and application value. By fully leveraging the advantages of satellite remote sensing technology and continuously optimizing early identification methods and prevention strategies, the early warning capability and prevention effect of marine fog meteorological disasters can be improved, ensuring the safety of maritime activities and the stability of the economy and society in coastal areas. In the future, with the continuous advancement of satellite technology and the development of meteorological science, we should further strengthen the application research of satellite data in marine fog monitoring, continuously improve the early identification and prevention system, and make greater contributions to the cause of marine disaster prevention and mitigation.

Disclosure statement

The author declares no conflict of interest.

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