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Analysis of Marine Oil Spill Pollution Monitoring Based on Satellite Remote Sensing Technology

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Abstract: In recent years, the number of marine oil spill accidents has been increasing, which is very harmful. It is urgent to develop an efficient monitoring technology for marine oil spills . This paper summarizes the types of satellite remote sensing that can detect marine oil spills. The advantages and disadvantages of marine oil spill monitoring based on medium resolution MODIS data, spaceborne infrared data, hyperspectral data, multi-source multi-temporal multispectral data, and satellite radar data, and offshore oil spill monitoring systems based on remote sensing data and their research progress are described. The shortage of marine oil spill monitoring is also analyzed. Finally, the prospect is put forward in order to provide technical reference for related research.

1. Introduction

In recent years, with the rapid development of industry, marine pollution has become increasingly serious, among which oil leakage is the most prominent. Marine oil spill is characterized by difficulty in recovery, wide pollution range and inflammability [1], which has great harm to marine ecological environment. Traditional monitoring technologies cannot identify oil spill areas in a timely and efficient manner. Remote sensing technology has become increasingly sophisticated, and it can widely realize the timely monitoring of offshore oil monitoring. The use of remote sensing technology to monitor oil spills abroad began in the late 1960s and early 1970s. The study on marine oil spill monitoring in China started late. The First Institute of Oceanography of the State Oceanic Administration and Dalian Maritime University first began the experimental work of China's aviation remote sensing monitoring of oil spill pollution on the sea.

2. Research status of remote sensing monitoring of oil spill pollution at home and abroad

Satellite remote sensing has the characteristics of wide range, high speed and simultaneous continuous monitoring, making it an irreplaceable monitoring tool. Due to remote sensing technology is used to monitor the oil spill, rely mainly on remote sensing data. Therefore, the development of remote sensing monitoring of marine oil spills at home and abroad has progressed with the continuous improvement of remote sensing data. At present, remote sensing monitoring of marine oil spill pollution mainly includes: monitoring of oil spills based on medium-resolution remote sensing data, monitoring of oil spills based on infrared data, monitoring of oil spills based on hyperspectral data, and multi-source and multi-temporal remote sensing data Oil spill monitoring and marine oil spill monitoring based on satellite radar data.

2.1. Marine oil spill monitoring based on medium resolution MODIS data

Traditional satellite optical sensors (such as NOAA/AVHRR, SeaWiFS, etc.) obtained better applications in the 1990s. However, due to the limited spatial resolution of oil spill detection, high spatial resolution optical sensors (such as Landsat, SPOT, IKONOS, etc.) are expensive, have few spectral channels and low time resolution, and cannot provide daily observation data. Moderate Resolution Imaging Spectroradiometer (MODIS) can make up for the shortcomings of the above sensors and provide 4 high-resolution data every day. Han Kun [2] extracted the spectral characteristics of oil spill areas based on MODIS data and established a method for identifying oil spill areas. Adamo et al. [3] combined MODIS and MERIS data to estimate the drift speed of oil spills. Chen Hui et al. [4] used the MODIS data on the EOS-Aqua/Ferra satellite to perform spectral analysis and research on four accidents, including the oil spill in the Yangtze Estuary and the Maracaibo Lake in Venezuela. Hou Yufeng [5] constructed an oil spill area identification method based on MODIS data and inverted the oil spill in the Bohai Bay and the Gulf of Mexico oil spill accident. The results show that this method can accurately identify the oil spill area. Through the analysis of the above studies, the following conclusions can be drawn:

(1) The wavelength band used for monitoring oil spill characteristics is suitable for reflecting infrared (1000 nm to 2000 nm), followed by near-infrared, then in the visible light band, and finally thermal infrared band. However, when the oil film leaks to the surface of the sea, the solar film absorbs the solar energy during the daytime so that the brightness temperature of the oil film area in the thermal infrared band is higher than that of the background seawater.

(2) There are about 14 to 19 bands out of the 22 bands in the reflection band, and there are only 3 (20, 22, 23) channels in the 16 bands of the emission band, and the remaining 13 bands. The accident site has no obvious features.

(3) The spectral contrast ratio image of the reflection band can enhance the contrast of oil and water. The visible light region below 400-800 nm can have a large contrast ratio using the spectral ratio method, and the original brightness image between 800 and 2130 nm is more appropriate. In addition to the influence of external environmental factors, the characteristics of oil spill spectrum have a close relationship with oil spill types and oil film thickness.

MODIS data contains rich multispectral information, but due to the low spatial resolution of multispectral data, it can be used as ancillary information for high spatial resolution images. Considering the oil-water contrast of the spilled oil is particularly noticeable in the reflected infrared, a high-resolution sensor can be installed in these bands when launching satellites for daily monitoring of spilled oil.

2.2. Marine oil spill monitoring based on satellite-borne infrared data

When the wavelength is constant, the temperature difference caused by the difference in emissivity between the two objects with the same actual temperature is known from the Stephen Boltzmann formula. The emissivity of the oil film (0.972) is slightly lower than that of seawater (0.993) when the temperature is 300K. Theoretically, it is calculated that the radiation temperature is 1.6K lower than that of seawater. Therefore, it shows dark features of low temperature on satellite images. According to the above principles, Yang Na et al [6]uses NOAA satellite data (AVHRR) to analyze and study the oil spill events of the "ABO" and the "Tasman Sea". The imagery enhancements such as stretching and color synthesis were performed on the satellite data in the area of the accident, highlighting the characteristics of the oil on the images. Based on the physicochemical properties, the algorithm was designed to automatically identify the oil pollution. Finally, the accident was estimated. The amount of oil provided a good basis for investigation and evidence collection after the accident.

The above research shows that the 1.1-km ground resolution of the NOAA satellite (AVHRR) restricts its research on marine oil spill pollution. However, in the research of large and medium-sized accident oil spills, the abundant data volume and low price make it has great potential for application in this direction. Taking into account China's current economic and scientific research status, mainly based on NOAA satellite data (AVHRR), supplemented by other high-resolution satellite data is a good strategy for offshore oil spill research.

2.3. Marine oil spill monitoring based on hyperspectral data

Hyperspectral, with its high spectral resolution and large amounts of data information, has become a leading edge technology in remote sensing applications. It can acquire very narrow bands at many wavelengths in the visible, near-infrared, mid-infrared, and thermal infrared bands. Consecutive image data, the so-called "map synthesis." With the continuous maturation of hyperspectral technology, the application of hyperspectral sensors to detect oil spills at sea has received increasing attention. It has great potential in quantitatively monitoring oil film types, areas, and oil spill volumes, and make up for the deficiency of the existing sensor effectively.

Scholars such as Foudan [7] used hyperspectral remote sensing techniques to conduct experiments on velocity prediction, automatic identification of oil spill types, and direction of spilled oil spills, and speculated on the oil spill diffusion speed and accurately extracted oil species information. Chao et al. [8] proposed an oil film pixel calculation method based on hyperspectral image data. The results show that the oil spill volume can be accurately calculated. Zhou Kai et al. [9] used AISA hyperspectral data to perform differential operations to extract the sensitive bands of the oil film's spectral features. Relevant studies have shown that due to environmental conditions, data characteristics, etc. by means of remote sensing for marine oil spill information extraction is a very complicated work. However, the application of hyperspectral data is still in its infancy, and there are still many deficiencies. Using hyperspectral data to extract information on oil spills from the sea, although the information on oil spills can be extracted at present, the method used is still at a preliminary stage of research. The accuracy of the results still needs to be improved.

2.4. Marine oil spill monitoring based on multi-source and multi-temporal multispectral data

Landsat satellites have a high spatial resolution of TM images (30m), but their temporal resolution is relatively low. A single ocean can be monitored in 16 days. The NOAA weather satellite AVHRR image has a high temporal resolution and can be monitored four times a day in a certain sea area. However, its spatial resolution is poor (1.1km). Therefore, it can be considered to combine the two to complement each other and achieve satisfactory effect. Li Qi et al. [10] used the TM and AVHRR data to conduct a method test study on the oil spill accident of the old Tieshan waterway. Liu Bingxin [11] took the oil spill accident caused by the explosion of the Lebanese power plant in 2006 and the crude oil pollution accident caused by the explosion of the oil platform in the Gulf of Mexico in 2010 as the research object, taking the data of MODIS, AVHRR and MERIS as research objects, and separately performing the oil spill information solution. According to the characteristics of each data and the characteristics of oil spill incidents, the feasibility of MODIS, AVHRR and MERIS data monitoring for oil spills is evaluated.

The above research shows that the use of multispectral Landsat TM and AVHRR data combined with remote sensing technology to monitor oil spill pollution at sea has proved to be feasible in theory and practice, and has the advantages of saving funds, timely, synchronous, rapid and continuous large-scale monitoring. No difference is the inevitable means to achieve comprehensive monitoring of the ocean in the future. However, the following problems still exist:

(1) At present, Landsat and NOAA satellite data received by China are passive remote sensing. The band is limited to the visible light and the near-middle-infrared band. The clouds, fog and atmospheric humidity, etc. in the air will affect the information effect and cannot be monitored throughout the day.

(2) Oil spill monitoring needs to track dynamic monitoring. When Landsat satellites are in phase, it is difficult to complete timely tracking and monitoring. The NOAA satellites have good phases, but their accuracy is poor, and small-scale emissions are difficult to monitor. This contradiction needs to be solved step by step by updating the remote sensor of the meteorological satellite platform and improving the satellite earth station's ability to receive multiple terrestrial resource satellites.

(3) The monitoring of oil spillage is very important and involves the determination of the oil pollution treatment plan. However, the amount of contamination must be determined from the area and thickness of the oil film mask. According to the color and brightness of the image, the relative thickness of the oil

film can only be determined. However, the absolute thickness must be determined after extensive experiments using microwave remote sensing. The work in this area needs to be done a lot of experiments and research work.

2.5. Monitoring of spilled oil based on satellite radar data

There are two main types of radars used for oil spill detection and environmental detection: Synthetic Aperture Radar (SAR) and Side View Airborne Radar (SLAR). Synthetic aperture technology is based on the principle of Doppler effect, relying on short antennas to achieve high spatial resolution. At present, spaceborne radars are synthetic aperture radars, capable of large-scale imaging, and capable of imaging the sea surface at night or in severe weather conditions with cloudiness, and play an important role in the monitoring of oil spills at sea.

In 1999, researchers from the University of Hamburg, Germany conducted analysis of 660 ERS-2 SAR images in three sea areas (Baltic Sea, North Sea and Gulf of Lions). For example, Wu Yi et al. [12] used the oil spill accident in the Bohai Bay area in March 2006 as an example to use the Environmental Satellite (Envisat) Synthetic Aperture Radar System (ASAR) image data of the European Space Agency to delineate contaminated oil film. The above research shows that spaceborne radar is currently the most effective remote sensor to provide large-scale all-weather oil spill monitoring, and will be an important business development direction. At the present stage, the limitation of SAR application is that satellites have long ground coverage periods and low resolution. Therefore, the real-time monitoring performance is poor, and it is difficult to monitor small-scale oil spills. The future development trend is to make full use of sensors and computer technologies to form multi-remote sensor real-time data collection and fusion, and combine it with GIS and numerical models to establish an emergency response integrated system for data comprehensive processing and analysis and prediction. The analysis of oil spill accidents, the formulation of emergency response plans, and damage assessment provide evidence and technical support. The application of SAR in the detection of oil film mainly has three directions:

(1) SAR performance should be improved to reduce wavelength, increase SAR image resolution, and reduce false alarm rate.

(2) The SAR image oil film database should be improved, and the relationship should be further explored between the occurrence of oil film and season, geographical location, and natural environment to accumulate experience for accurate classification, so as to further reduce the false alarm rate.

(3)Method of automatic detection should be in-depth researched and developed of oil film on the ocean surface of SAR images, such as automatic detection of target detection and oil film classification.

2.6. Construction of offshore oil spill monitoring system based on remote sensing data

With the rise and development of computer technology, automation and intelligence have become the focus of attention in the world today. Computers have been rapidly developed in other fields because of their high computing speed and accuracy. All these have laid a technical foundation for the development of marine oil spill monitoring systems. The United States established the Aviation Offshore Oil Membrane Monitoring System (AOSS) in 1974; In 1998, the NOAA Environmental Satellite Data and Information Center (NESDIS) in the United States used NOAA series satellites to establish a marine oil spill warning system based on satellites monitoring coastlines, ocean currents, eddies, upwellings, red tides, and oil spill accidents. Su Weiguang[13] used ENVISAT-1 and MODIS data to process and analyze the marine oil spill pollution in the Bohai Sea area of China. Based on the Windows XP environment, the IDL language-based marine oil spill remote sensing monitoring prototype system was used to use the system for MODIS and ASAR data. Processed and extracted marine oil spills, and estimated the oil spilled area. Using the developed marine oil spill remote sensing monitoring prototype system, processing and analysis of MODIS satellite remote sensing data and ASAR radar satellite remote sensing data were completed. The marine oil spill monitoring in Caofeidian sea area has been monitored remotely and good monitoring results have been obtained.

The above study shows that the monitoring capabilities of marine oil spill systems can be further improved in the following aspects:

(1) Further the understanding of the spectral characteristics of various oil films should be improved. According to the imaging characteristics of each sensor, more effective and useful data can be selected to complete the monitoring of marine oil spills.

(2) Data can be conducted rapidly and intelligently. Once a marine oil spill accident occurs, the data can be quickly processed and analyzed to provide support for decision-making departments.

(3) Based on the microwave spectral characteristics of oil film and the principle of SAR imaging, a method for the automatic detection of marine oil film was established to rapidly extract information on oil spills on the sea.

(4) The joint use of remote sensing image data of different temporal resolutions and spatial resolutions, especially the combination of optical remote sensing technology and microwave remote sensing technology, can not only provide a large amount of data to determine oil spill pollution, but also improve the accuracy of monitoring. At the same time, they will exert their respective advantages and conduct real-time dynamic monitoring of oil spill pollution.

3. Conclusion

In summary, remote sensing technology has the characteristics of high efficiency, timely, large-scale monitoring, and has great application value in monitoring areas such as oil spills on the sea. Although remote sensing technology has made great progress, there are still some deficiencies that need to be developed and researched: 1 The sensor is bulky, the cost is high, and the sensitivity is low; 2 The spaceborne radar has low resolution, long cycle, and poor real-time performance. 3 Hyperspectral technology is not mature enough. In the future research, the accuracy of atmospheric correction should be improved, basic guarantees should be made for quantitative information extraction, multiple classification methods should be applied to classification and suitable and effective classification methods should be chosen by comparison.

Sensors and computer technology are used fully to form real-time data collection and fusion of multiple remote sensors. GIS and numerical models should be combined to establish an emergency response integrated system for comprehensive data processing and analysis and prediction. This will provide basis and technical support for analysis of oil spill accident, formulation of emergency response plan and damage assessment.

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