# REMOTE SENSING APPLICATIONS FOR PETROLEUM RESOURCE EXPLORATION IN OFFSHORE BASINS OF CHINA

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## ABSTRACT

In this paper, a new approach for detecting and analyzing sea surface slicks caused by hydrocarbon seepage of offshore petroleum accumulations has been developed. This approach uses remote sensing radar technology and geophysical exploration techniques and has been developed based on hydrocarbon seepage theory. In this study, Synthetic Aperture Radar (SAR) data were used as the main data source. These data were integrated with gravity data inversed from satellite altimeter data, geophysical abnormal data from airborne magnetic data, and geological data of oil- and gas-bearing basins. Using the geographical information system, the oil and gas accumulating areas were outlined by the prospect models. This approach for the exploration and evaluation for offshore petroleum accumulations has been applied to two study areas in offshore petroleum basins in China: the Bohai Sea and Pearl River Mouth basins. By comparing the drilling outcomes and relative materials, our results show that the application of this integrated method is very effective.

***Keywords***: hydrocarbon seepage, remote sensing, petroleum exploration, offshore basins

## 1. INTRODUCTION

In many field surveys, the hydrocarbon seepage of offshore petroleum accumulations produces distinct alterations to discrete areas of the sea floor and sea surface. The geology of these sites suggests that the hydrocarbon seepage of offshore petroleum accumulations tends to persist at specific locations for at least hundreds of years [1][2]. Hydrocarbon seepage detection is an ideal technique for evaluating large offshore basins.

According to the theory of hydrocarbon seepage, almost all known oil provinces in the world seep. In offshore basins, oil seeps that escape from petroleum accumulations arrive at the sea surface, usually in the form of oil-coated gas bubbles [3]. They then produce distinctive sea surface slicks that are identifiable by satellite [4].

The basic principle for detecting surface slicks from Synthetic Aperture Radar (SAR) images is well established. SAR is sensitive to sea surface roughness because of the presence of short waves. Surface slicks on the sea surface cause reduced air-sea interactions, resulting in the dampening of the capillary waves. The dampening effect reduces the backscattering coefficient of the sea surface, yielding a darker area in the SAR image than other areas of the sea surface [5].

Identification of petroleum resources through the detection of oil seepage using radar remote sensing is a preferred technique used by international petroleum companies. This technique has been used for pre-exploration in early stage petroleum accumulation prospecting since space-borne SAR satellites were launched. Numerous studies have been conducted over the last twenty years to develop methods for hydrocarbon detecting using multi-temporal SAR images from around the world [6][7][8][9].

In this paper, a new data fusion approach to detect and analyze sea surface slicks caused by the hydrocarbon seepage of offshore petroleum accumulations has been developed. This approach uses remote sensing radar technology and diverse geophysical exploration techniques and was developed based of hydrocarbon seepage theory. This approach is aimed at searching for and locating the target areas of potential petroleum accumulations during the exploration of large, frontier offshore basins in China. In this study, SAR data were used as the main data source.

SAR data were integrated with gravity data inversed from satellite altimeter data, geophysical abnormal data from airborne magnetic data, and the geological, seismic, and logging data of oil- and gas-bearing basins. Using the geographical information system, the oil- and gas-accumulating areas have been outlined and evaluated with the prediction models. Finally, this approach of exploration for offshore petroleum accumulations has been applied in two study areas in offshore petroleum basins in China -- the Bohai Sea and Pearl River Mouth basins.

## 2. METHODOLOGY

The proposed data fusion approach involves three basic procedures: slick segmentation, slick classification, and comprehensive prospect analysis.

### 2.1 Slick Segmentation

First, the automatic and semi-automatic segmentation process was developed and applied to determine oil slick boundaries by the partial differential equation (PDE) level set and the fast level set method [10][11].

In image segmentation, the image intensity gradient is utilized as the impetus and direction for oil slick propagation. The integration of the intensity driven speed and curvature flow into the method allows the front interface to propagate naturally with topological changes, significant protrusions and narrow regions, giving rise to a stable and smooth boundary, especially for the low contrast, noisy Ocean images.

In addition, because wind and ocean current conditions affect the feasibility and reliability of seepage detection and influence the search for the seepage origin from the SAR images, a method of real-time inversing of the wind speed by CMOD4 from SAR images was developed to obtain the parameters of wind speed.

### 2.2 Slick Classification

Slick classification is regarded as an important process in slick detection. To classify slicks, characteristics such as the backscatter, texture, morphology of surface slicks (identified from the SAR images), geological data, geophysical data, geochemical data, and geographical data were considered for slick classification to distinguish the hydrocarbon seepage from the accumulation location. These characteristics were also used to distinguish seepage and accumulation from other detections, such as oil pollution or natural biological processes (e.g., fish or other marine animals) also shown on the SAR images by the analytic-hierarchic process fusion model.

### 2.3 Comprehensive Prospect Analysis

The slick classification results, geological data, geophysical data, geochemical data, and geographical data were entered into the geographic information system. The data were overlaid for comprehensive prospect analysis.

## 3. EXAMPLES AND DATA ANALYSIS

In the study, we used many multi-temporal ERS-2 SAR and ENVISAT ASAR images from 1996 to 2007, along with other geospatial data, to identify the optimal set of parameters for detecting hydrocarbon seepage in the study areas of the Bohai Sea and Pearl River Mouth basins. The petroleum remote sensing analysis system was established specifically for the offshore basins in the Bohai Sea and Pearl River Mouth basins.

Maps of oil slick distribution and classifications, as well as confidence level estimates, were created. The spatial analysis techniques were combined with the detected surface slicks in order to find their relationship to geological structures and other relative petroleum accumulation data. Therefore, the prediction models allowed for the target areas of potential petroleum accumulations to be located. Additionally, the target areas and explored reservoirs were analyzed.

Figure 1 shows prospective maps created by remote sensing comprehensive analysis for offshore petroleum exploration in the Bohai Sea study area. The study area is indicated by a red rectangle. Polygons with red edges are uplifts and polygons with green edges are sags. The red, yellow, and green regions represent different levels of potential for high-confidence oil slicks that repeatedly occur in the gravity and airborne magnetic anomaly regions. The black triangles are drills.

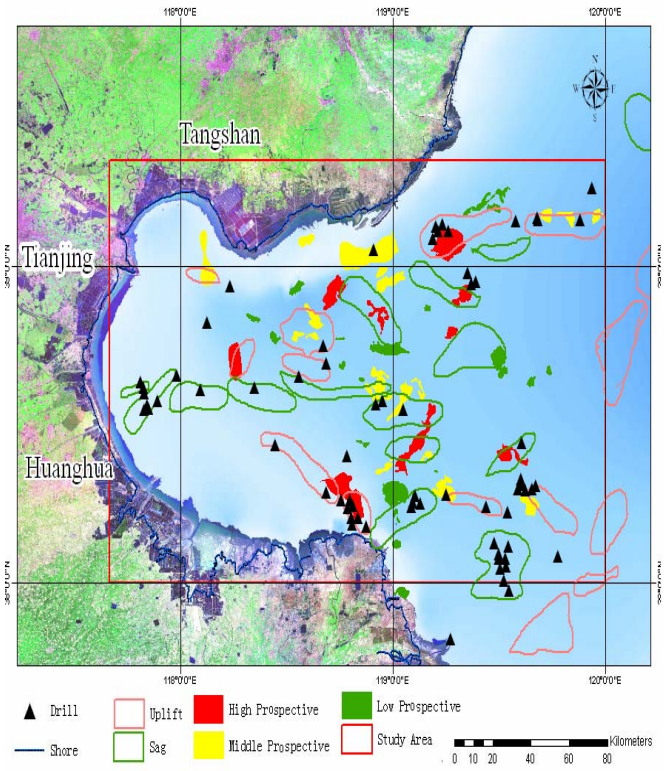


Figure 1. Prospective map created by remote sensing comprehensive analysis for offshore petroleum exploration in the Bohai Seas study area

## 4. CONCLUSIONS

By comparing the drilling outcomes and the resulting materials, our results of the Bohai Sea and Pearl River Mouth basins show that the integrated remote sensing method of hydrocarbon seepage detection is a quick and effective approach of the exploration and evaluation of prospective, large, frontier petroleum resources for offshore basins in China.

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