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Observation of Oil Spills through Landsat Thermal Infrared Imagery: A Case of Deepwater Horizon

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Abstract

In the accidental oil spills of Deepwater Horizon at the Gulf of Mexico in 2010, cold plume of initial oil cover with the apparent surface temperature lower than the surrounding sea surface temperature by 0.6 K, was detected; and away from the initial leakage location, the apparent temperature of oil film was found higher than the surrounding sea surface water temperature with a maximum difference of 3.2 K. Both the cold and hot oil patches had relatively thicker film, but the cold patches were due to the initial low temperature during the crude oil upwelling from deep water while the hot ones were caused by sun heating. This suggests that thermal infrared imagery has the potential in locating the leakage place of crude oil spill upwelling especially from deep water and identifying thick oil aggregations.

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Keywords: *Crude oil spill; deep sea oil rig; sea surface temperature; thermal infrared imagery; Landsat; deepwater horizon; the Gulf of Mexico*

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1. Introduction

Due to the increasing activities of marine oil resource exploitation, oil spill has become very dangerous to marine ecosystem, e.g., the Deepwater Horizon oil gush (Klemas, 2010) at the Gulf of Mexico in April-July, 2010, and the oil leakage of Penglai oil rig platform at the Bohai Sea China since June, 2011. Remote sensing techniques can provide information on the location of ocean oil spills, the rate and direction of oil patches movement, and input to prediction model and may help to the management of clean-up and control.

Optical and microwave remote sensing techniques are mostly used to monitor marine oil spill (Jha et al., 2008). Optical detection techniques include passive and active visible remote sensing, e.g., LANDSAT, MODIS visible imagery, and laser fluorescence. Passive optical sensors can not work at night when there is no sunlight; active ones, e.g., laser fluorescence, can be used to monitor oil spill in daytime and night. However, clouds, fogs and haze may have negative impacts on the passive optical remote sensing as well as the laser fluorescence in the application of oil spill remote sensing. Microwave can see through clouds, and work at daytime and night; SAR sensors on the basis of microwave can image oil spills. However, application of SAR is highly dependent on sea surface wind speed: the low wind speed area may be mistaken as oil spill, and oil spills in the very high wind speed area may be not detected.

Oil film differs from sea water in thermal characteristics and absorption of sun ray energy. Thermal infrared radiation can see though haze and thin fog, and can work in daytime and night. Thermal infrared remote sensing technique is a very important tool for oil spill remote sensing. Using AVHRR data, Tseng and Chiu (1994) observed hot spots of oil spill with the apparent temperature 2-4 ^{o}C higher than the surrounding sea surface temperature, SST in daytime during the 1991 Persian Gulf War, and these hot spots weakened or disappeared at night. Cai et al (2007) used high resolution thermal infrared imagery of ASTER to detect the possible oil regions in the Yinggehai area of Hainan Province, China. As the modeling by Shih and Andrews (2008a,b), differential heating of the oil film and water during daytime can lead to the infrared radiance contrast reversal.

For monitoring oil spill, our work aims to study the thermal dynamics on the basis of Landsat thermal infrared imagery.

2. Data and Methods

The largest accidental marine oil spill in the history of the petroleum industry happened on April 20, 2010 at the Gulf of Mexico, Fig.1. The spill stemmed from a sea-floor oil gusher with a water depth 4992 feet, 1521.6 meters, and the location is more than 100 Km away from the nearest land, BP Exploration and Production Inc., 2009. This accident was used as a case study. Landat-7 ETM+ and Landsat-5 TM data were acquired at about 10:18 AM, local time in the morning to map the oil spill. Radiance, and apparent temperature retrievals were based on the work of Xing et al (2006a, b): converting digital number, DN, dimensionless to at-satellite radiance, L_λ, W m^{-2} sr^{-1} µm^{-1} as the following equation:

$$L_\lambda = \text{gain} \times DN + \text{offset} \,, \quad 1$$

where the value of gain and offset can be found or calculated from parameters provided in the header file of data; then, we can get the at-satellite brightness temperature as Eq. 2 which is an approximation to Planck’s radiance function:

$$T_B = \frac{K_2}{\ln(k_1 / L_\lambda + 1)} \,, \quad 2$$

where k_1 and K_2 are calibration constants.