MERGED APPLICATION OF MULTI-FREQUENCY SAR IMAGES AND SIMULATION SAR IMAGES FOR OIL SPILL MONITORING

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***Abstract* –In recent years, the oil spill detection over sea surface and similar oil material filtration are attracting much attention from the ecological point of view, and synthetic aperture radar (SAR) is considered as an effective way of monitoring such phenomenon due to the day-and-night and all weather observation capability. In this paper, results of the oil slick detection experiment by multi-frequency space borne SARs are reported. On December 7, 2007, an oil tanker was wrecked in the Yellow Sea off the Korean west coast, spilling over 12,000 tons of crude oil, and causing considerable damage on the coastal environment. In order to analyze the impact of the oil spill, we acquired 4 sets of multi-frequency spaceborne SAR images, including TerraSAR-X X-band data, ENVISAT ASAR and RADARSAT-1 C-band data, and ALOS-PALSAR L-band data. We also computed, as a preliminary study, the backscatter radar cross sections (RCS) based on the Integral Equation Method (IEM) and the Method of Moments at three microwave frequencies for different wave damping ratios by oil slick. In this paper, we describe the present status of the study on oil slick detection, and suggest the possible future direction to be taken.**

Keywords: Multifrequency SAR, oil spill, coastal environment, oil spill detection, radar cross section (RCS), Integral Equation Method (IEM), Method of Moments

1. INTRODUCTION

Oil spills are a principal factor of the ocean pollution. The complicated problems involved in detecting oil spills are usually due to varying wind and sea surface condition such as ocean wave and current. On the coast of Yellow Sea in South Korea (36°47′04″ N, 126°03′12″ E), the Hebei Spirit accident was happened and a massive oil spill occurred (Figs. 1 & 2). More than 12,000 tons of crude oil was spilled in the sea after a crane barge collided with the anchored Hebei Spirit oil tanker, known to be carrying 260,000 tons of crude oil at that time. In Fig. 2, a spilled oil stripe appears in both KOMPSAT-2 optical image and an aerial photograph. The aim of this work is to improve the detection and classification performance in order to define a more accurate training set and identifying the feature of oil spill region from SAR.

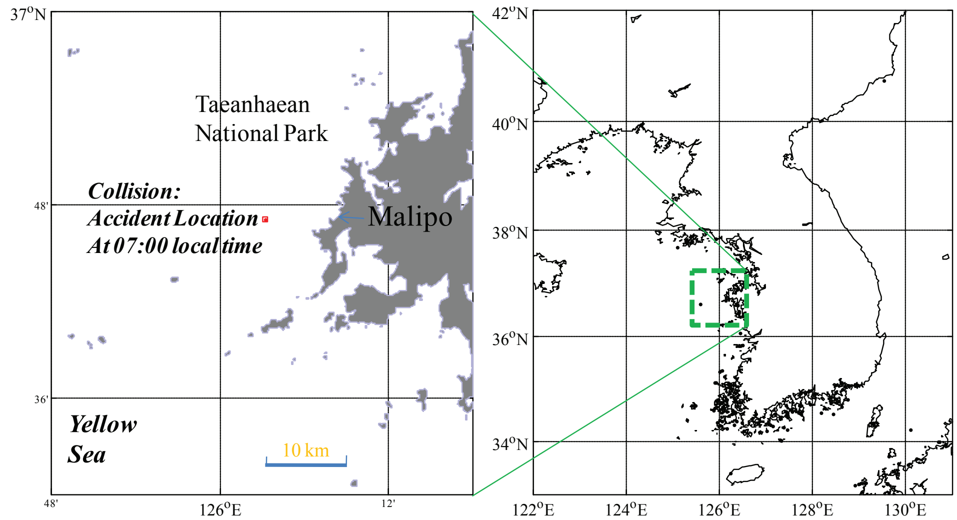

Fig. 1 Map of the accident location for the Hebei Spirit oil spills on December 7, 2007 (LT).

Fig. 2 Spilled oil stripe viewed from an aerial photograph and optic satellite image

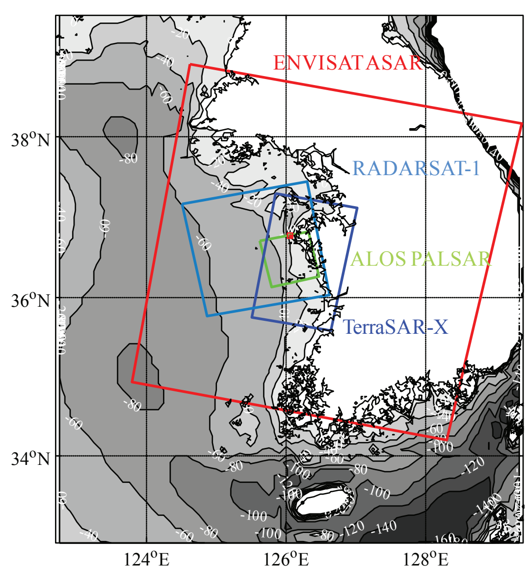

Fig. 3 Location map with the coverage area for 4 SAR images from Dec. 11 to 12, 2007.

Table 1 List of SAR modes and wind and wave

SAR	Acquisition Time(UTC)	Mode	Pol.	Wind Speed/ Direction	Wave, Hs(m)
ENVISAT ASAR	2007.12.11 01:41	Wide Swath	VV	4.8m/s 27.4°	0.2
RADARSAT-1	2007.12.11 09:30	Wide	HH	4.8m/s 32.3°	0.4
ALOS PALSAR	2007.12.11 13:46	Polarimetric	FULL	1.5m/s 48.5°	0.3
TerraSAR-X	2007.12.12 21:43	ScanSAR	VV	0.9m/s 109.6°	1.1

Figure 3 shows coverage of images observed by ENVISAT ASAR, RADARSAT-1, ALOS PALSAR and TerraSAR-X around the accident area during the period from 11 to 12 December 2007. Detailed information of those data are listed in Table 1 with wind and wave measurements at the same time. Since simultaneous observation of multi-frequency SAR is not available, SAR data obtained in a short time are used here to minimize a weathering effect of spilled oils in detecting the areas using C-, X-, L-bands SAR images of different acquisition time.

There are some limitations in the application of only SAR imagery to detect oil spill because it is not easy to distinguish between oil slicks and look-alikes[1]. To make an integrated system merging SAR and the backscatter radar cross section (RCS) models in the future, as a preliminary study, the backscatter radar cross section (RCS) based on Integral Equation Method (IEM) and the Method of Moments is considered here at three microwave frequencies for different wave damping ratios by oil slick. In this paper, we describe the present status of the study on oil slick detection, and suggest the possible future direction to be taken.

2. BACKSCATTER RADAR CROSS SECTION (RCS) MODELS

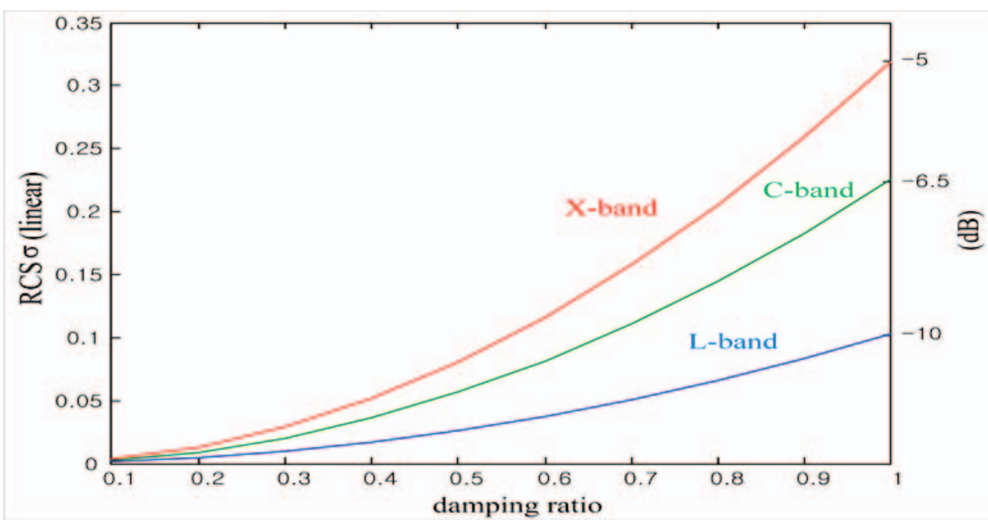

Fig. 4 RCS calculated from the IEM model in terms of the wave damping ratio by oil slick

There are several practical models to describe the radar backscatter from ocean surface, including Kichhoff (Physical Optics) Model, Composite Surface (Two-Scale) Model, Bragg Model, perturbation mode, and integral equation model. IEM that has large range for application is available for various wind direction and speed conditions. The model includes the polarization dependence and the effects of oil types and thickness on the growth of small-scale waves.

Fig.4 shows the RCS in terms of the wave damping ratio by oil slick, computed by the IEM theory described above. The damping ratio is the multiplicative factor on the waveheight spectrum. The damping ratio of 1.0 means the case of ambient sea, and the ratio of 0.5 corresponds to the waveheight spectrum reduced by 0.5 times. It can be seen that the difference in RCS between the ambient sea surface and the surface with oil slicks is largest for X-band at 23◦ incidence angle and VV polarization under wind speed of 5 m/s, i.e., the detection accuracy of oil slicks is higher at X-band than other lower frequency bands. It is, of course, very unlikely that oil slicks damp the waveheight spectrum uniformly, but rather shorter waves are damped more than longer waves. A weight should, therefore, be applied to the damping ratio according to the observation and/or theoretical basis.

Next, a precise numerical computation is tested of the radar backscatter of various shapes of oil spills on ocean surfaces. At first, the randomly rough dielectric surface with two-scale roughness is generated based on the wins speed on the ocean surface. A two layered medium is generated by adding a thin oil layer on the rough sea surface (Morchin, 1993; Oh, 1996). Then, the electric fields scattered from the oil spilled ocean surface are computed by the Method of Moments (Oh, 1998).

3. CONCULDING REMARKS

SAR is the most applicable sensor for operational oil spill detection as it covers wide areas and operates at all-weather, day and night. As the quantity of the SAR data increases rapidly there is a big need for semi or fully automatic methodologies to detect and identify dark formations as oil spills, fast and accurate. South Korea will launch KOMPSAT-5 with X-band SAR in 2010.
There are several methodologies proposed in the literature but their results are under discussion. For an effective oil spill methodology we suggest a merging system of SAR and scattering modeling. In SAR application for oil detection, multi-polarization and multi-frequency SAR analysis should be added to a single polarization method.

4. ACKNOWLEDGEMENTS

This research is funded by Korea Research Council of Fundamental Science & Technology (PG47271) and Korea Ocean Research & Development Institute (PE98333).

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