OIL-SLICK OBSERVATION USING SINGLE LOOK COMPLEX TERRASAR-X DUAL-POLARIZED DATA

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1. INTRODUCTION

Sea oil pollution originated from ships and/or oil-platforms is one of the major environmental threats of the Earth's Ocean. Even though, tanker accidents and accidentally oil-spillage from offshore platforms, are locally an important source of pollution, the largely amount of oil released over the sea surface is due to routine oil tanker and ship operations. Also if only the 5 percent of oil pollution is due to tanker accident one big spill can disrupt both sea quality and productivity and shore life for miles producing severe financial consequences for the people living in the polluted coastal area. [1].

A synoptic sea oil spill monitoring, based on remotely sensed data, is recognized as a key tool to contrast illicit vessel discharges, to have an early warning system in case of environmental disaster, to assist law enforcements [1]. In particular, microwave sensors are often preferred to optical sensors due to the all-weather and all-day capabilities. The Synthetic Aperture Radar (SAR) is commonly accepted as the most important remote sensor to accomplish such monitoring applications [1]-[3]. It is well known that oil films floating on the sea surface, damping the Bragg waves responsible for the signal backscattered to the radar antenna, generate a low backscatter area which, in the SAR image plane, appears as a dark patch. However, since there are other natural phenomena (e.g. biogenic slicks, low wind areas) which produce dark areas in SAR images [4], SAR oil slick observation is not a trivial task [2]-[3].

There is a general consensus that the extra information provided by SAR polarimetry is very suitable for classifying the scattering behaviour of the observed scene. However, the real benefit of SAR polarimetric information, which can be extracted once a proper electromagnetic model is available, is considered mainly for land applications.

Recently it has been shown that polarimetric information, once properly modeled, can be successfully exploited to observe oil slicks in L- and C-band dual-polarized SAR data [5]-[6].

Nowadays, there is an increasing interest towards X-band polarimetric SAR measurements, witnessed by the German TerraSAR-X and the Italian Cosmo SkyMed missions. As a matter of fact, in this study the usefulness of

X-band polarimetric SARs for sea oil slick observation purposes is explored. Within this context the TerraSAR-X measurements, gathered in dual polarimetric mode, can serve as a useful data source.

In this study, a physically-based electromagnetic approach, based on the phase difference between the complex HH and VV channels (CPD), is firstly applied on dual-polarized TerraSAR-X Single Look Slant Range Complex (SSC) products, to observe sea oil slicks.

Experiments, accomplished over a meaningful data set in which both certified oils and look-alikes are present, show that X-band dual-polarimetric SAR data are suitable for sea oil slicks observation purposes and witness the paramount importance of the TerraSAR-X dual-polarimetric mode for such application.

2. ELECTORMAGNETIC MODEL

In this study, a physically-based electromagnetic approach, based on the CPD, which has been demonstrated to be suitable to observe sea oil spill in C-band SAR data [5], is firstly applied to read in physical terms dual-polarized TerraSAR-X data for such applications.

In particular, the standard deviation σ of the CPD probability density function (pdf) can be exploited to obtain information about the sea scattering mechanism with and without surface slicks. In fact, σ, being related to the correlation between the HH and VV complex channels [5], can be exploited as a measure of the departure from the Bragg scattering. Under low to moderate wind conditions and assuming the small-scale ripples follow the Bragg scattering, two cases must be distinguished.

In case of slick-free sea surface, since the Bragg scattering is characterized by a high correlation between the co-polarized channels [7], a low σ value is expected.

In case of oil-covered sea surface, the ripple waves responsible for the Bragg scattering are damped and a non-Bragg mechanism has been demonstrated to be in place [5]. The latter is characterized by a low correlation between the co-polarized channels and, therefore, a high σ value is expected.

Different is the case of some Oil Look-Alikes (OLA) which, characterized by weak damping properties, still call for a Bragg scattering and, therefore, are expected to be indistinguishable from the surrounding sea in terms of σ [5].

3. EXPERIMENTAL RESULT

In this section a meaningful experiments, accomplished on dual-polarimetric SLC TerraSAR-X data in which both certified oil slicks and weak-damping Oil Look-Alikes (OLA) are present, are shown. The data set has been processed by using a simple and very effective filtering technique which estimates σ through a 3x3 moving window.

The first data set is relevant to the acquisition of 16 November 2007 at 03:52 UTC. On November 11, stormy seas and gale-force winds in the narrow Kerch Strait have smashed a Volganeft-139 Russian oil tanker in two

parts, spilling at least 2,000 metric tonnes of fuel oil (see Fig. 1(a)). Analyzing the experimental results (see Fig. 1(b)), in which the measured σ is represented in gray tones, it is possible deduce that the polarimetric CPD model applied in X-band SAR data is able to recognize the different scattering mechanism (Bragg and non-Bragg) of slick-free and slick-covered sea surface. In fact, Fig.3(b) means that the scattering mechanism is everywhere the Bragg one but within the oil-covered sea surface. Moreover, form an operational viewpoint, it can be noted that the CPD approach acts as an emphasis filter, when applied to SAR data in which oil slicks are present. Fig.1(b) witnesses that the oil slick has bee emphasized with respect to the surrounding sea, if compared to Fig.1(a).

The second data set is relevant to the acquisition of 28 July 2009, 04:18 UTC in Black Sea. Figure 2(a) shows an excerpt of the X-band VV power SAR image in which the ship and the illicit vessel oil discharge are visible. The estimated σ, shown in Fig. 2(b), clearly shows features related to the spillage. The result confirms the capability of the proposed approach to highlights fresh spillage from vessel

The third data set is relevant to the acquisition of 05 June 2009, 05:19 UTC near the Ischia harbour, Italy, in which two weak damping OLA, due to a ship wakes, are present (see Fig. 3(a)). In this case the CPD processing, shown in Fig.3(b), does not show any remarkable feature related to the dark areas of Fig.3(a). This means that, although dark areas are visible in Fig.3(a), the scattering mechanism is everywhere the Bragg one.

4. REFERENCES

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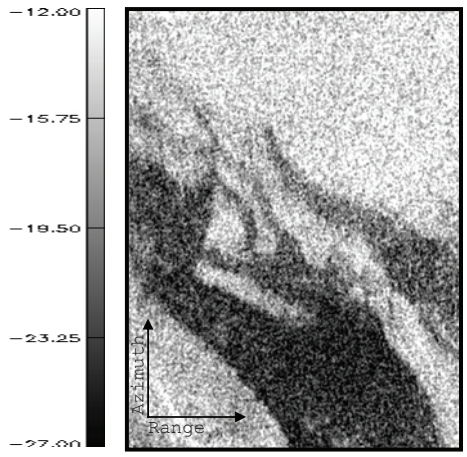
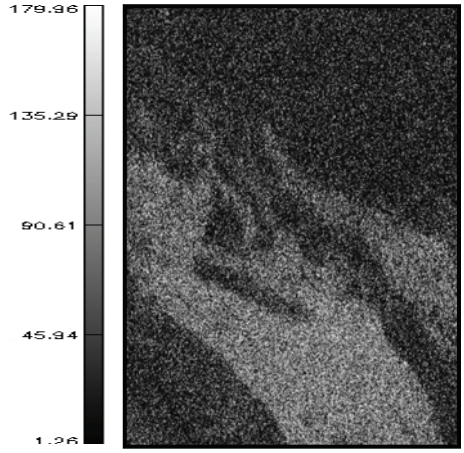
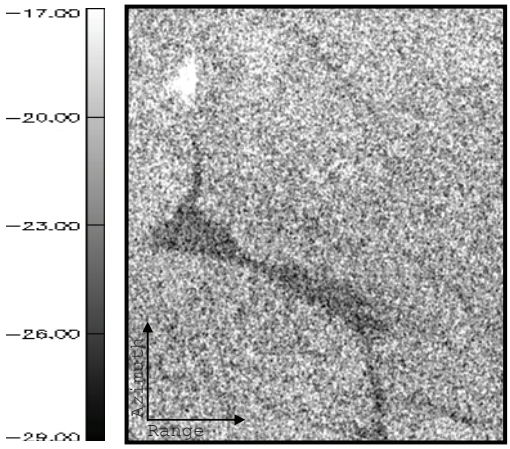


(a) VV power image (dB)

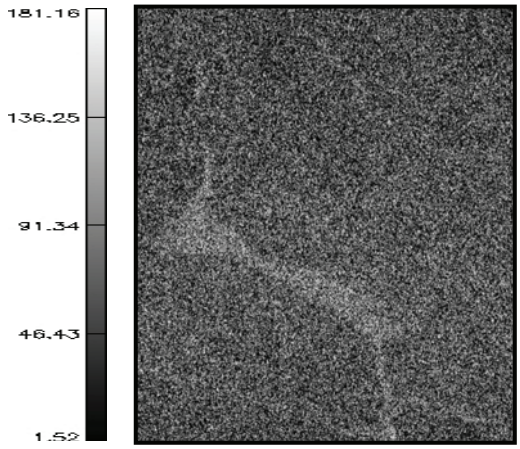


(b) σ CPD image (°)

Figure 1. X-band SAR data relevant to the acquisition of 16-11-2007 at 03:52 UTC, (a) shows an excerpt of the VV power image in which part of the oil spillage is visible, (b) the estimated CPD standard deviation image (grey tones)

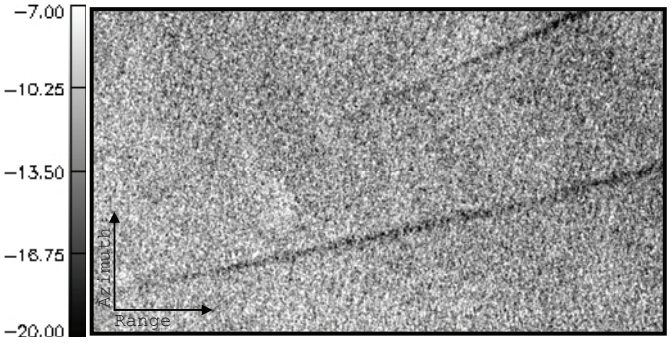


(a) VV power image (dB)



(b) σ CPD image (°)

Figure 2. X-band SAR data relevant to the acquisition of 28-07-2009 at 04:18 UTC, (a) shows an excerpt of the VV power image in which illicit vessel oil discharge is clearly visible, (b) the estimated CPD standard deviation image (grey tones)



(a) VV power image (dB)

(b) σ CPD image (°)

Figure 3. X-band SAR data relevant to the acquisition of 05-06-2009 at 05:19 UTC, (a) shows an excerpt of the X-band VV power SAR image in which two Oil Look Alikes (OLA, (b) the estimated CPD standard deviation image (grey tones)