METALLIC OBJECTS AND OIL SPILL DETECTION WITH MULTI-POLARIZATION SAR

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1. INTRODUCTION

Within the National Environmental Satellite, Data, and Information Service (NESDIS) of the National Oceanic and Atmospheric Administration (NOAA), multi-platform SAR imagery is being used to aid post-hurricane response efforts in the Gulf of Mexico. The main areas of interest after passage of hurricane are: 1) identify oil pipeline leaking and other oil spills, and 2) provide first hand information on potential oil drilling infrastructure damage. SAR-amplitude-based oil spill algorithms have been developed using the neural network [1] and fuzzy logic methodologies among others [2].

A lot of efforts have been spent on tuning the algorithm with known oil spills. For metallic objects detection, a statistically-based constant false alarm rate (CFAR) algorithm [3] has been used to derive locations of these objects in a pre-operational environment. It is found that this algorithm can detect almost all targets that are at least longer than the image pixel size. When ship size is smaller than image pixel size, the algorithm can only detect about 50% of the targets.

With the advance of synthetic aperture radar (SAR) sensors, multi-polarization data become available from both ENVISAT ASAR and ALOS PALSAR. The purpose of this study is: To use the polarization information contained in SAR data to develop a physically-based image processing algorithm to identify both oil slicks and metallic objects in the SAR images with minimum false alarm caused by other look-alike features. A combination of using statistically-based (single-channel SAR amplitude data) and physically-based (SAR multi-polarization data) approaches will help operational agencies to improve post-hurricane survey in the heavy oil production area, i.e., Gulf of Mexico.

2. METHODOLOGY

In this study the sea surface scattering mechanism with and without oil slicks and metallic objects is analyzed to develop a physically-based filtering technique for target detections in the SAR image. Both metallic objects and oil slicks are characterized by scattering mechanisms which, under low to moderate wind condition, are completely different from the sea surface one.

The slick-free sea surface scattering is well-modeled by the Bragg scattering mechanism, i.e at microwave frequency the signal scattered towards the radar antenna is mainly due to the small-scale sea surface ripples.

The presence of an oil film deployed over the sea surface, damps the Bragg resonant waves, and thus generates a low backscatter area (damping phenomenon) which, in the SAR image plane, appears as a dark patch. Following this rationale both image- and statistically-based approaches have been exploited to detect oil slicks. Due to other look-alike features contained in the SAR image, i.e., low wind area, island shadows, upwelling etc., these algorithms usually result in relatively high false alarm rate [4]. Recently, polarimetric models exploiting full scattering mechanism from oil-slick-covered sea surface have been developed [5]-[6]. Following this rationale, the presence of oil slick has been demonstrated to call for a non-Bragg scattering mechanism whose polarimetric features are summarized in Table I.

The presence of a metallic object (e.g. a ship or a oil rig) over the sea surface calls for a backscattering which is determined by several scattering mechanisms including direct reflection from areas perpendicular to the radar beam, corner reflections and multiple reflections from the ship and sea surface, which cause a high coherent microwave response. In the SAR image plane, the object appears as a bright spot. Following this rationale both image- and statistically-based approaches have been exploited to detect ships in SAR images. Typically, all algorithms operate on multi-look SAR images, i.e. SAR data in which the speckle noise is reduced at the expense of spatial resolution. As a result, these algorithms will miss small target detections. Recently, an electromagnetic model is developed. This approach considers ships as dominant scatterers characterized by a strong and coherent backscattered signal, which contains sub-pixel information, i.e. the speckle [7]. This approach, in theory, will improve ship detection especially for small ships.

In this study,following above-,mentioned theoretical rationale, we develop an electromagnetic-based polarimetric approach to tackle the problem of oil and metallic object detection by using both dual- and full-polarimetric SAR data.

With respect to oil slick observation, polarimetric approaches use the characteristics of polarimetric features summarized in Table I to separate oil-spill pixels from the free sea surface.

With respect to metallic object observation, two approaches will be applied. 1) A single-polarization approach. It uses full-resolution speckled data and highlights the larger coherent response due to a metallic object; and 2) A dual-polarization approach. It measures the correlation between the HH and VV complex channels and distinguishes the sea-surface Bragg scattering from the complex scattering due to the metallic objects. It uses dual-polarized SAR.

Type of sea surface	Scattering mechanisms that enhance certain polarimetric features
Free surface	High correlation between the complex like-polarized channels. Low cross-polarized return.
Oil-covered	Low correlation between the complex like-polarized channels.
Metallic objects	High coherent scattering

3. PRELIMINARY RESULTS

Preliminary results, relevant to the metallic objects detection, obtained processing the ASAR Alternate Polarization Product (APP) data are shown and compared to the known ground truth in Fig. 1a.

Fig.1(a) shows the HV power relevant to the ASAR APP data taken on August 8, 2003 at 20:31:48 GMT. The result obtaining processing the HV channel by using a physically-based approach which highlights the coherent component in the scattered signal, is shown in Fig.1(b). For the purpose of this study a 3x3 moving window has been employed to estimate the coherent component. There are 3 ships detected using this approach and the 3 ships are confirmed in the ground truth data set (Fig.1C).

Oil slick detection algorithms have been developed [5]-[6],[8]. We have approved proposals to obtain dual-polarized and fully-polarized data from Radarsat-2 and ALOS-PLASAR for research purposes. Validation work will be performed when these data become available.

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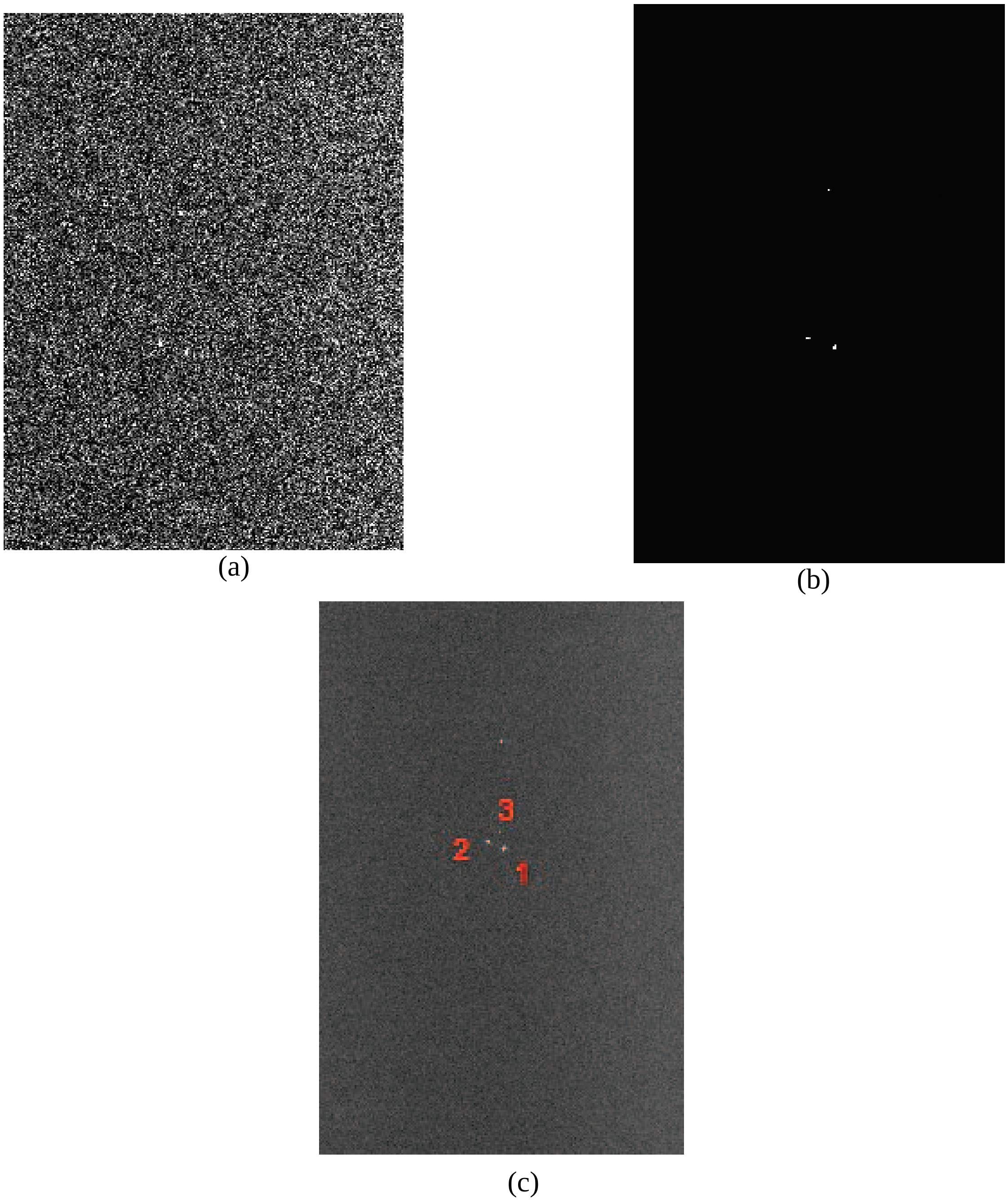

Figure 1. ENVISAT ASAR APP data. (a)Excertpt of the HV image in which three ships are present. (b)Processing results. (c) Ground truth.