ANALYSIS OF THE BACKSCATTER SIGNAL IN ALOS-PALSAR IMAGES COLLECTED OVER OFFSHORE ENVIRONMENTS AND THEIR USE IN OIL FILM DETECTION

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ABSTRACT

The applicability of L-band Synthetic Aperture Radar (SAR) to identify and extract information from oil spills in marine environments has been studied. Although the extraction of this type of information is possible, is necessary to analyze the backscatter signal from the targets of interest, i.e., water and oil. This study aims to make a preliminary analysis of the adequacy of data collected by the Phased Array L-band SAR (PALSAR) sensor, on board the Advanced Land Observing Satellite (ALOS), to discriminate oil films yielded by seepages or spills in offshore environments of the Gulf of Mexico. The results show that the HH and VV polarizations have a signal decreasing trend when the incidence angle increases. This trend is clearly observed for incidence angles above 25^o, which is related to the tilted Bragg scatter mode. Furthermore, were verified that the HH and VV polarizations acquired on PLR acquisition mode and HH acquired on FBD acquisition mode are suitable to discriminate oil spills films from oceanic water. The opposite was verified about HV polarization in both acquisition modes.

Index Terms— Oil detection, Offshore, Bragg model, ALOS-PALSAR

1. INTRODUCTION

The society dependency for energy sources, especially petroleum and its derivatives, is increasing nowadays. Investigate areas for petroleum extraction became an extremely important economic activity. Furthermore, oil slick monitoring, detection and characterization may help on continence and mitigation environmental plans.

Due to the nature and spatial dimensions on investigations of this type, imaging satellites are an adequate source of information. These sensors provide information in a repetitive and synoptic view of large areas [1] at a low cost compared to traditional methods of exploration, such as seismic inference and drilling [2].

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A limitation about the use of optical sensors is that the data collection depends on the sunlight and the presence of adverse atmospheric conditions, i.e., cloud covering over the imaged region, blocks the reflected radiance from the sea surface. An alternative is the use of Synthetic Aperture Radar (SAR) sensors, once they do not have limitations in data acquisition under adverse atmospheric conditions.

With the advent of polarimetric SAR systems, the applicability of this kind of data got increased with respect to the detection and inferences about the thickness and characteristics from emulsion of offshore oil slick, as shows in [3].

Recent studies have shown the applicability of the Synthetic Aperture Radar (SAR) L-band images to identify and extract information from oil spills in marine environments [3] [4] [5]. Although the extraction of this type of information is possible, it is first necessary to analyze the σ^0 backscatter signal of the targets of interest (water and oil). This is an important procedure to verify the relationship between Normalized Radar Cross Sections (NRCS) and the Noise Equivalent Sigma Zero (NESZ), which impacts on oil detection.

Therefore, this paper aims to do a preliminary analysis of the adequacy of data collected by the Phased Array L-band SAR (PALSAR) sensor, on board the Advanced Land Observing Satellite (ALOS), in PLR and FBD acquisition modes, to discriminate oil films yielded by seepages or spills in offshore environments of the Gulf of Mexico.

2. MATERIALS AND METHODS

Three ALOS-PALSAR images were used in this study, two acquired in Fine Beam Dual (FBD) mode (HH and HV polarization) and one in Polarimetric (PLR) mode (HH, HV and VV polarization). These images were acquired on 10^{th} January (PLR), May 20^{th} (FBD) and July 18^{th} (FBD) of 2008, over the Northwestern sector of the Mexican Gulf, where seepage events are well documented [6]. All three images were acquired during weak to moderate wind speed conditions (5 to 8 ms^{-1}) [7]. This is a key feature since oil seepage identification using SAR images in offshore environments is mostly possible under the above conditions [5].

To be able to extract information from targets of interest in SAR images, the σ^0 backscatter signal of these images must be greater than the NESZ. Therefore, proper interpretation of the ALOS-PALSAR dataset can only be achieved if the NRCS extracted from the imagery shows a signal above this threshold.

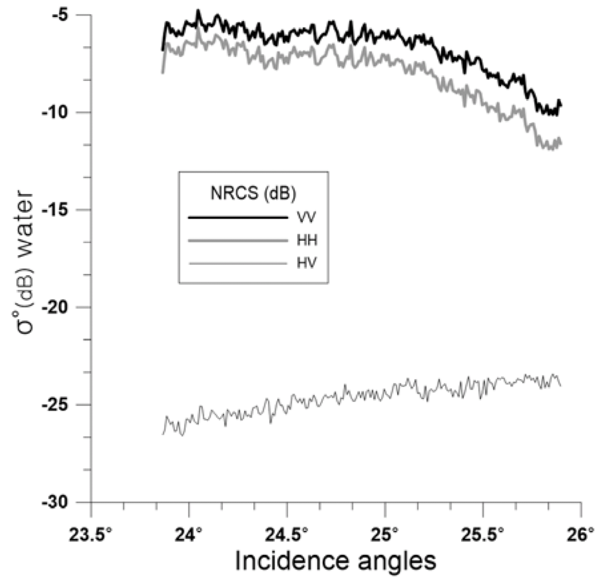
The averaged σ^0 signal was analyzed in transects crossing oil-free oceanic and areas where oil films are clearly visible, according to the incidence angle of the signal emitted by the SAR sensor during the imaging. To evaluate the ability of each polarization (HH, HV and VV) to discriminate oil-free from oil-present areas, representative NRCSs extracted from ALOS-PALSAR PLR image were used. In the ALOS-PALSAR FBD image acquired on July 18^{th} 2008, a representative transect comprising oil-free pixels was produced, whereas an archetype transect of oil film was yielded from the ALOS-PALSAR FBD acquired on May 20^{th} 2008.

3. RESULTS

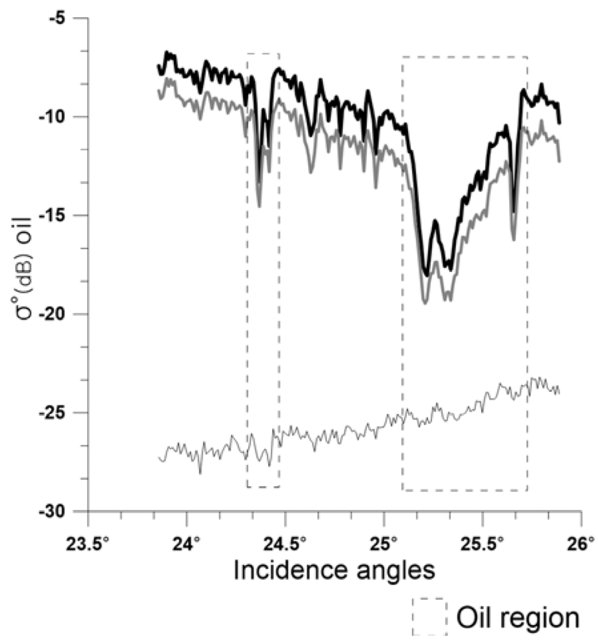
Figure 1 shows the results obtained from the PLR image. It is observed that for oil-free areas (Figure 1(a)) all polarizations showed NRCS higher than the NESZ, which are $-30\ dB$ for HH and VV polarizations and $-34\ dB$ for the HV polarization [8]. The HH and VV polarizations display a similar σ^0 backscatter signal behavior in oil-free areas. These results are in agreement with those found by [5], which showed that the HH and VV polarizations are highly correlated in offshore environments. The HH and VV polarizations showed a decreasing trend in the σ^0 signal with an increasing incidence angle. This trend is clearly observed for incidence angles above 25^o. Researches indicate that this σ^0 behavior may be related to the tilted Bragg scatter model [4] [9]. The HV polarization has a σ^0 signal along the NRCS lower than the HH and VV polarizations but higher than the NESZ ($-34\ dB$). For this polarization, the σ^0 signal increases with increasing incidence angle; this behavior was opposite to that observed in the HH and VV polarizations.

The region of PLR image which oil films are present (Figure 1(b)), the HH and VV polarizations display a similar behavior to that observed in oil-free, i.e., the σ^0 signal decreases with increasing incidence angle. These two polarizations proved highly suitable to discriminate oil seepages in offshore environments. The areas highlighted in the Figure 1(b) with dashed lines showed a considerable reduction in σ^0 signal in comparison to the oil-free transect (Figure 1(a). According to [10], this is the expected behavior for the σ^0 signal of oil spills in SAR images. The HV polarization σ^0 signal was less affected by the oil films than the HH and VV polarizations, which means that HV polarizations have a lower capacity to discriminate oil spills from the background.

Figure 2 shows the results obtained for the FBD images. For this image acquisition mode, the HH polarization showed a σ^0 signal higher than NESZ along the NRCS ($-32\ dB$). Conversely, the HV polarization showed a lower σ^0 signal compared to NESZ along the NRCS. This behavior was observed for both situations examined (i.e., oil-free and oil-present transects).

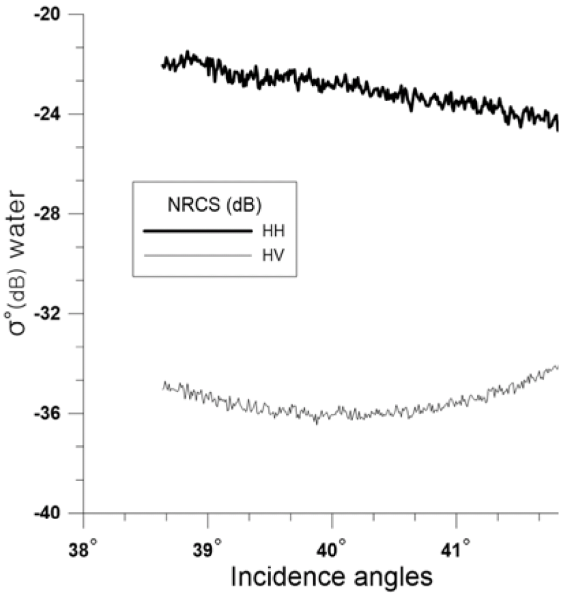


(a) Oil-free

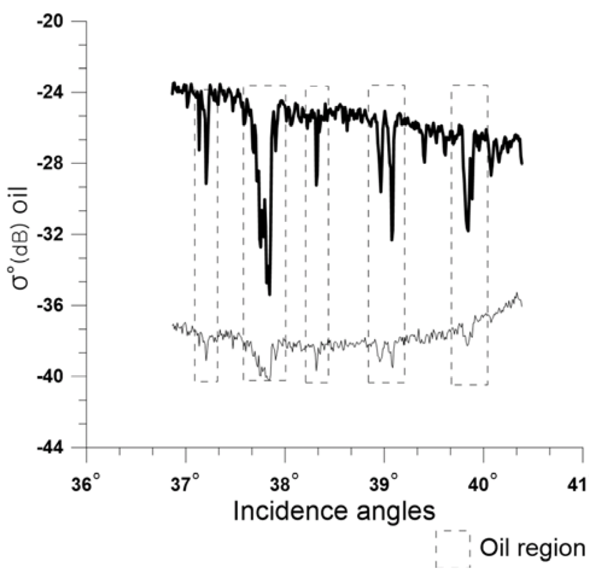


(b) Oil-present

Fig. 1. NRCS extracted from ALOS-PALSAR PLR image.



(a) Oil-free



(b) Oil-present

Fig. 2. NRCS extracted from ALOS-PALSAR FBD image.

Figure 2(b) indicates that the HH polarization acquired on FBD mode is highly adequate to discriminate oil seepages in offshore environments. In the areas highlighted in the Figure 2(b), the σ^0 signal showed a considerable reduction in comparison to the oil-free transect (Figure 2(a)). As observed in the image acquired on PLR mode, the HH polarization acquired on FBD mode also showed a decreasing trend in the signal with increasing incidence angles. This behavior was also presented in [4] and can be related to the tilted Bragg scatter model. The σ^0 signal of HV polarization was less affected by the oil spill than the HH polarization, which means that HV polarization is less suitable to discriminate oil films from the background in the FBD acquisition mode.

4. CONCLUSIONS

This study analyzed the ability of ALOS-PALSAR images to identify oil films in offshore environments. Images acquired in HH and VV polarizations and in PLR and FBD acquisition modes showed to be suitable to discriminate oil spills films from oceanic water in the background. The opposite was verified for HV polarization.

The HH and VV polarizations from the PLR image showed a decreasing trend in the signal with an increasing incidence angle. This trend is clearly observed for incidence angles above 25^o. As observed in the image acquired in PLR mode, the HH polarization acquired in FBD mode also showed a decreasing trend in the signal with increasing incidence angles. This behavior may be related to the tilted Bragg scatter mode. However, additional studies should be conducted to confirm this hypothesis.

It is important to mention that current and future L-band SAR sensors continue to provide worldwide imagery in offshore environments both in HH and VV polarizations, bringing benefits to petroleum exploration and environmental monitoring.

5. REFERENCES

[1] J. R. Jensen, *Remote Sensing of the Environment: An Earth Resource Perspective*, Prentice Hall, 2007.

[2] T. Lammoglia and C. R. Souza Filho, “Spectroscopic characterization of oils yielded from brazilian offshore basins: Potential applications of remote sensing,” *Remote Sensing of Environment*, vol. 115, no. 10, pp. 2525 – 2535, 2011.

[3] B. Minchew, “Determining the mixing of oil and sea water using polarimetric synthetic aperture radar,” *Geophys. Res. Lett.*, vol. 39, no. 16, pp. 1–6, Aug. 2012.

[4] B. Minchew, Jones C. E., and B. Holt, “Polarimetric analysis of backscatter from the deepwater horizon oil spill using l-band synthetic aperture radar,” *IEEE T. Geoscience and Remote Sensing*, vol. 50, no. 10, pp. 3812–3830, 2012.

[5] C. Brekke, B. Holt, Cathleen Jones C. E., and S. Skrunes, “Discrimination of oil spills from newly formed sea ice by synthetic aperture radar,” *Remote Sensing of Environment*, vol. 145, pp. 1 – 14, 2014.

[6] M. Migliaccio, F. Nunziata, and A. Gambardella, "On the co-polarized phase difference for oil spill observation," *International Journal of Remote Sensing*, vol. 30, no. 6, pp. 1587–1602, 2009.

[7] M. Shimada, O. Isoguchi, T. Tadono, and K. Isono, "Palsar radiometric and geometric calibration," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 47, no. 12-1, pp. 3915–3932, 2009.

[8] P. Trivero and W. Biamino, "Geoscience and remote sensing new achievements," 2010, Tech. Report.

[9] C. Hu, X. Li, W. G. Pichel, and F. E. Muller-Karger, "Detection of natural oil slicks in the nw gulf of mexico using modis imagery," *Geophysical Research Letters*, vol. 36, no. 1, 2009.

[10] National Oceanic and Atmospheric Administration's, "National data buoy center.," 2013, Accessed: Dec. 20^{th} 2013.