An overview of polarimetric SAR-based monitoring of sea oil slicks

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Among all maritime applications, oil pollution monitoring is a hot topic from both an operational and scientific perspective. Marine oil pollution is mainly due to i) illegal polluters that discharge oil-waste products, ii) accidental oil spills from oil rigs/platforms, iii) natural oil seeps, i. e., stocks of hydrocarbons that naturally come from the bottom of the oceans [1]. In this context, the use of microwave remote sensing is of paramount relevance. In fact, the synthetic aperture radar (SAR) is characterized by an almost all-weather and all-day capability of imaging Earth’s surface offering fine spatial resolution and wide area coverage. The latter represent key requirements for an effective sea oil slick observation, that consists of i) detection of oil slicks over the sea surface, ii) discrimination between oil slicks and look-alikes, i. e., biogenic films, low-wind areas, ship’s wakes, etc., and iii) mapping of physical properties that characterize sea oil slicks, i. e., damping [1].

Considering single-polarization SAR, the use of intensity information only limits the detection capability and does not allow sea oil slick discrimination/characterization. This is due to the fact that single-polarization SAR-based approaches for sea oil slick monitoring mostly rely on supervised image processing techniques that require external information including suitable thresholds, training samples, ancillary data and/or trained personnel [1]. Nowadays, a large set of polarimetric SAR (POLSAR) data is available in a wide range of imaging modes, frequencies and polarizations. The physical information they offer on the observed scene allows developing new robust and efficient algorithms that are able to address all the above-mentioned tasks in an unsupervised way. The capability of POLSAR-based approaches to perform sea oil slick observation relies on the fact that sea surface scattering, under low-to-moderate wind conditions and at intermediate incidence angles (AOI), is well described by the almost deterministic Bragg scattering model, while oil slicks are characterized by a completely different scattering behavior. Following the same rationale, a broad class of look-alikes, i. e., surfactants calling for weak-damping properties, can be automatically distinguished from oil slicks since they are characterized by a Bragg-like scattering mechanism. However, POLSAR-based approaches need suitable electromagnetic models to properly interpret the scattering mechanisms of the observed scene [1, 2].

Nevertheless, operational use of POLSAR architectures is limited due to the fact that fully-polarimetric (FP) architecture is characterized by reduced swath and limited range of acceptable AOI if compared to single-/dual-polarized SAR. The latter may be operationally attractive, but conventional HH-HV/VV-VH dual-polarized architectures do not offer additional information useful for sea oil slick observation with respect to single-polarization SAR [1, 3].

Recently, a new POLSAR generation has been developed, namely Compact-polarimetry (CP), that represents a good compromise between polarimetric information content and area coverage. They are coherent dual-polarized architectures that receive in an orthogonal H-V basis while transmitting a circularly-polarized or slant linearly-polarized wave, i. e., Hybrid-Polarity (HP) and \(\pi/4\) mode, respectively [2, 3]. Although there exist space missions operating in CP mode and further space missions equipped with CP SAR are already planned for forthcoming years, actually a consistent and reliable SAR dataset of CP measurements collected over sea oil slicks is still not available [1].
CP SAR architectures promise obtaining performance very close to FP SAR for sea oil slick observation purposes, although the physical information they carry on represents only a subset of the polarimetric information provided by FP SAR [4]. However, a common reference framework is needed to quantitatively assess the performance of CP architectures and to undertake a fair comparative analysis with FP SAR. Slight differences over both sea surface and oil slicks can be found between CP and FP SAR architectures and among CP mode, and they can be physically explained through the different mapping of FP-CP eigenvalues into the corresponding polarimetric observables, i.e., FP coherency matrix and CP wave coherency matrix.

REFERENCES:


