On the use of compact-polarimetric SAR features for the monitoring of a crashed aircraft in the western part of King George Island, Antarctica

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Abstract. Synthetic Aperture Radar (SAR) is an active, all-day and all-weather, high-resolution microwave sensor able to measure the electromagnetic field backscattered off the observed scene. Antarctic environment presents very hard imaging conditions for optical imagery, and sometimes they are challenging even for SAR observations. However, full-polarimetric (FP) SAR features can provide useful information for characterizing man-made targets in different types of ice. This study aims at exploiting polarimetric features extracted from compact-polarimetric (CP) SAR architectures, e. g., circular transmitting/linear receiving (CTLR) and linear transmitting/linear receiving (LTLR), that have been shown to be operationally attractive due to the doubled area coverage they offer with respect to FP SAR architectures.
CP SAR data are here emulated using actual FP SAR measurements to both detect the dominant scattering mechanism that characterizes man-made targets, and classify them accordingly. As a study case, an aircraft crashed on November 2014 off the Chilean military base area in the western of King George Island (Antarctica) and actually placed close to the gravel airstrip, is considered. At all, three Radarsat-2 FPSAR data were acquired over the test site. In this study, as first results, a single SAR acquisition was explored due to the availability of ground truth relevant to the crashed aircraft and other airdrome structures position. The achieved preliminary results have encouraged future work that will deal with the exploration of different responses from a wide range of inland and sea ice.

Keywords: synthetic aperture radar, compact polarimetry, target detection, antarctica.

1. Introduction

Synthetic Aperture Radar (SAR) is an active, all-day and all-weather, high-resolution microwave sensor able to measure the electromagnetic field backscattered off the observed scene. SAR provides fine spatial resolution (lower than tenth m) and large spatial coverage (tenths to hundreds km^2) observations of the Earth and, hence, it represents a strategic remote sensing tool. Antarctic environment presents very hard imaging conditions for optical imagery, and sometimes they are challenging even for SAR observations Rees (2006). However, full-polarimetric (FP) SAR features can provide useful information for characterizing man-made targets in different types of ice. Nakamura et al (2005); Mendes Júnior et al (2010); Kim et al, (2014); Paes et al (2015a). This study aims at exploiting polarimetric features extracted from compact-polarimetric (CP) SAR architectures, e. g., circular transmitting/linear receiving (CTLR) and linear transmitting/linear receiving (LTLR), that have been shown to be operationally attractive due to the doubled area coverage they offer with respect

to FP SAR architectures. CP SAR data are here emulated using actual FP SAR measurements to both detect the dominant scattering mechanism that characterizes man-made targets, and classify them accordingly Raney (2007); Paes et al (2016). As a study case, an aircraft crashed on November 2014 off the Chilean military base area in the western of King George Island (Antarctica) and actually placed close to the gravel airstrip, is considered. The aircraft is a completely metallic structure whose sizes are about 30m in length, 11.6m in height and 40m in width (considering the wingspan).
Three C-band Radarsat-2 FP single-look complex (SLC) data, collected with about 5m spatial resolution, with an incidence angle spanning from 19° up to 25°, in right-looking ascending pass, right looking, were acquired on different dates from March, 4th 2015 to March, 28th 2015, over the Chilean military base area called "Base Presidente Eduardo Frei Montalva", in the western part of King George Island (Antarctica). Nevertheless, for the present work, only that one acquired on March, 21st 2015 was explored due to the availability of ground truth relevant to the crashed aircraft and other airdrome structures position. More details on the SAR dataset and ground truth information are shown in Figure 1 and 2.

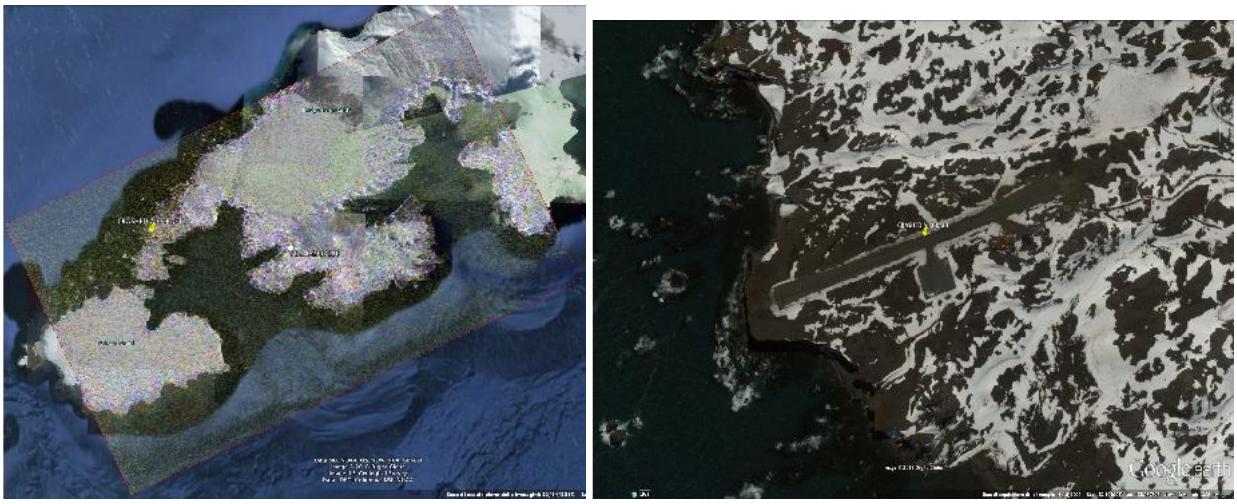


Figure 1. The processed SAR image overlapped on Google Earth® optical image (on the left). Ancillary optical image zoomed on the airdrome area (on the right). The position of the aircraft is highlighted by the yellow pin.

Figure 2. Airdrome infrastructure: air traffic tower and shelters (on the left), hangar (on the center); source: Panoramio®. Crashed aircraft placed onto airdrome parking (on the right); source G1 website.

2. Methodology

Methodology is proposed to effectively combine CP features in order to extract scattering information for characterizing man-made targets Raney (2007); Paes et al (2015b). A CP SAR belongs to the class of coherent dual-polarimetric SARs, i. e., a single polarization is transmitted while a coherent receiving system is implemented according to a linear horizontal (h) - vertical (v) polarization basis. However, when dealing with most of natural scenarios which satisfy reflection symmetry property, conventional dual-polarimetric SARs do not offer additional information if compared to single-polarization SAR architectures since the relative phase between the two measured polarimetric channels, i. e., hh-hv or vh-vv, is practically uninformative.
As a matter of fact, the underpinning idea of CP SAR architectures is to transmit/receive a polarization different from the conventional h-v ones. Several CP architectures can be implemented according to the adopted transmitting and receiving combinations. In this study, circular transmitting/linear

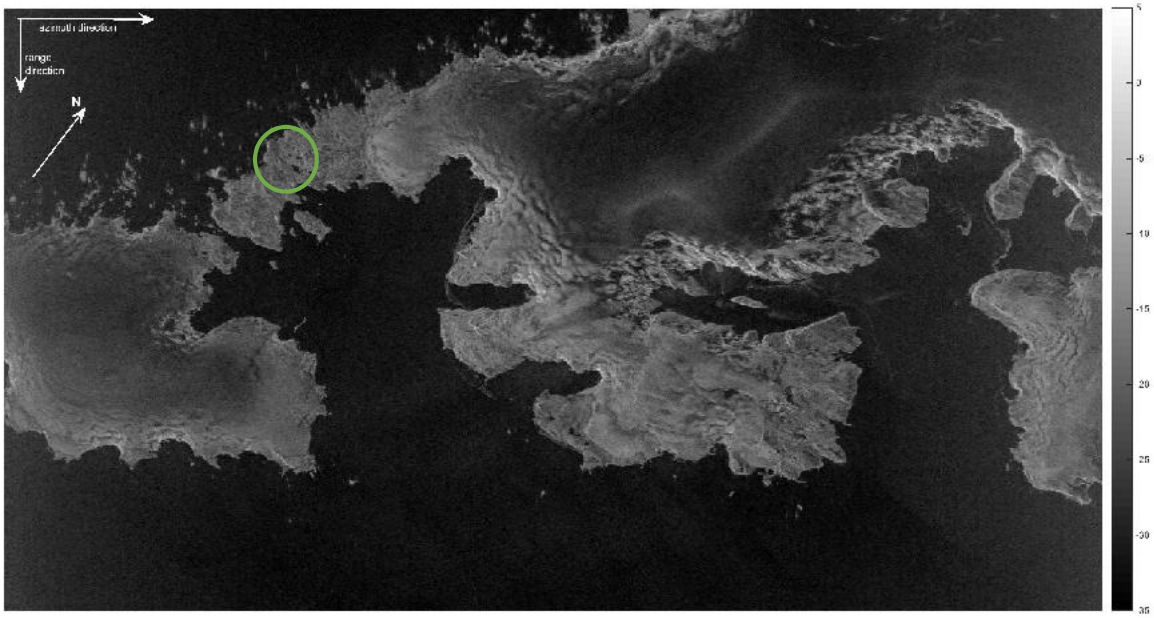
receiving (CTLR) is considered that consists of transmitting a circularly polarized wave while coherently receiving according to a linear h-v basis. The latter, transmitting a circularly polarized wave, retains the rotational invariance against the observed scenario that characterizes radar systems using circular polarizations in both transmitting and receiving operations. However, due to the linear h-v receiving basis, it turns out to be much simpler in terms of hardware requirements. The other CP SAR mode considered in this study is the linear transmitting/linear receiving (LTLR), which consists of transmitting a linearly polarized wave oriented at 45° in the h-v plane, while coherently receiving according to a linear h-v basis Raney (2007); Raney et al (2011).
Then, CP features are derived and interpreted according to wave polarimetry concepts (see Table 1): the degree of polarization, P; the phase difference between the orthogonal components of the received wave, δ_{hv}; the circular polarization ratio, μ_c; the conformity index, μ; and the ellipticity parameter, $sin2\chi$. Accordingly to this wide set of CP features, reliable samples were collected from the aircraft, sea surface, glacier and gravel airstrip, in order to perform a fair comparison.

Table 1 – The considered set of CP features and their expected behavior over the targets.

CP feature	Polarimetric information	Range of values	Expected value (man-made targets)
μ	Single-bounce predominance over other elementary scattering mechanisms	$-1 \leq \mu \leq 1$	$\mu < 0$
δ_{hv}	Correlation between the orthogonal components of received wave	$-180° \leq \delta_{hv} \leq +180°$	$\delta_{hv} \approx 90°$
P	Degree of polarization of the wave	$0 \leq P \leq 1$	$P << 1$
$sin2\chi$	Single-bounce predominance over other elementary scattering mechanisms	$-1 \leq sin2\chi \leq 1$	$sin2\chi < 0$
μ_c	Circular polarization ratio	$\mu_c \geq 0$	$\mu_c > 1$

3. Experimental results

As a showcase, an experiment is relevant to the C-band Radarsat-2 FP SAR scene collected on March, 21st 2015 over the King George Island (Antarctica), is undertaken. Incidence angle ranges between 21° and 25°. CP features relevant to the considered SAR scene are shown in Figure 3, where the wavelet filter is applied to reduce speckle, together with the hv-polarized intensity image used as a reference. It can be noted that, as expected, CP features exhibit a completely different behaviour when evaluated over man-made targets with respect to the surrounding areas. In Figure 4, the polarimetric response of airdrome and aircraft is seen in detail. It can be noted that, differently from the other CP features, P does not offer a significant discrimination capability. Furthermore, $sin2\chi$ offers a target/background contrast larger than μ even though they carry on a very similar information.



Grey-tone hv-polarized intensity SAR image, in dB scale.

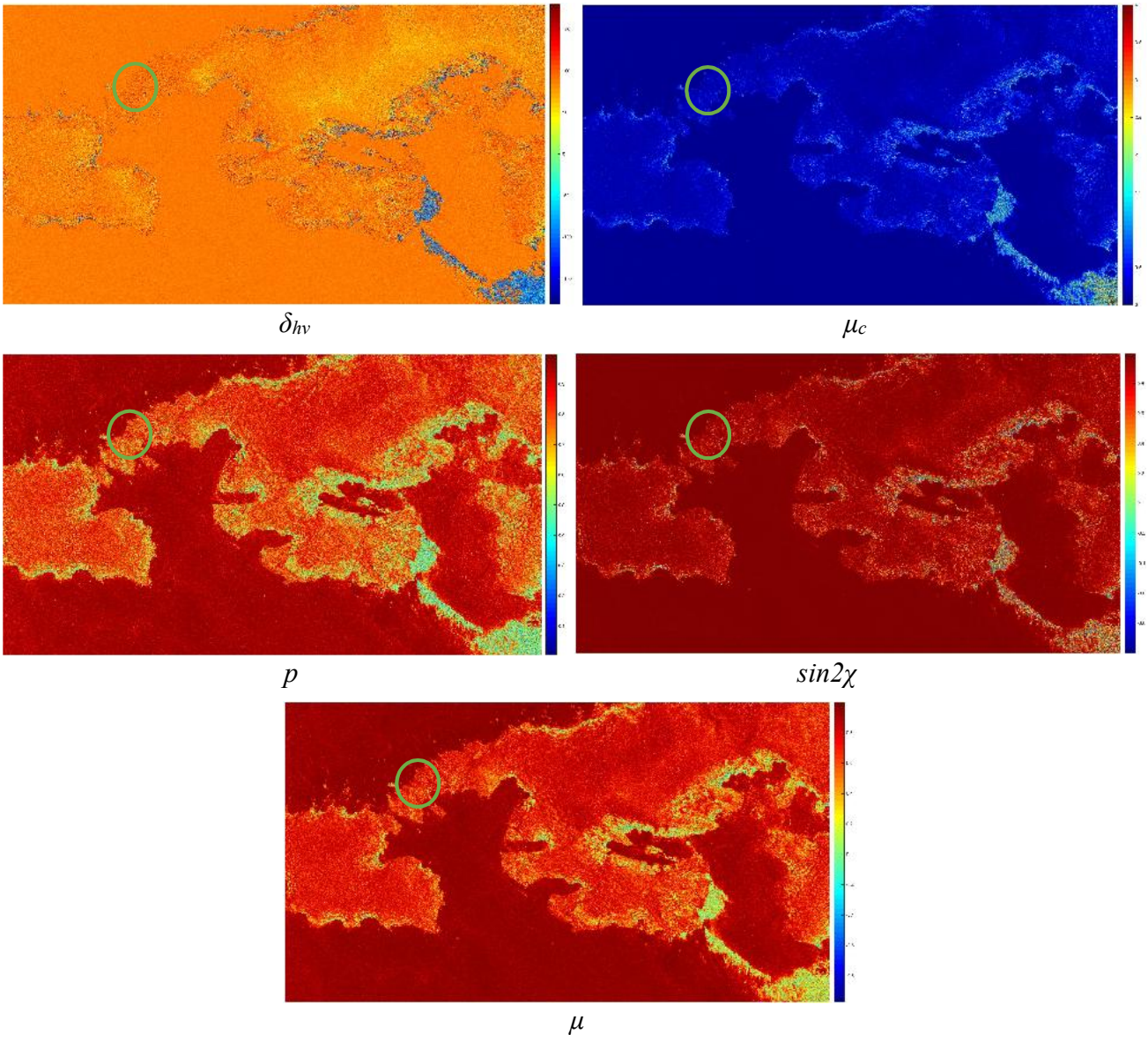
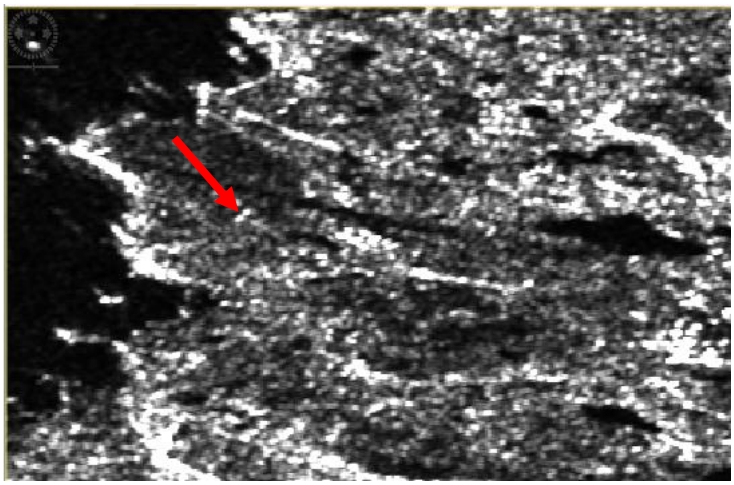
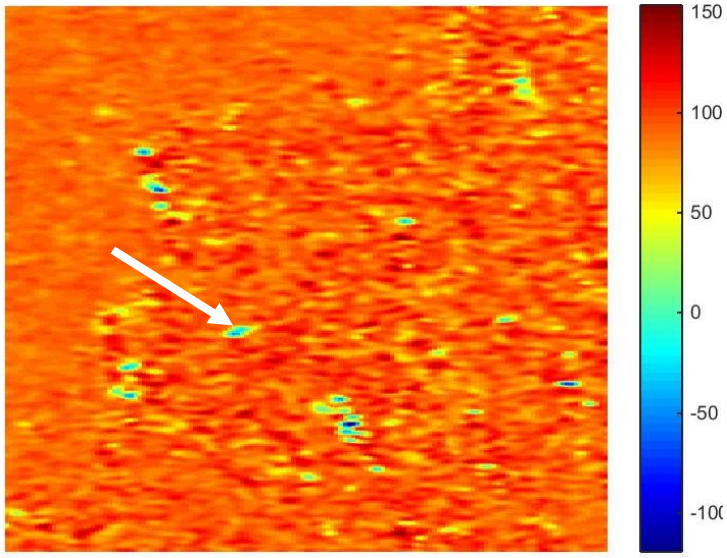


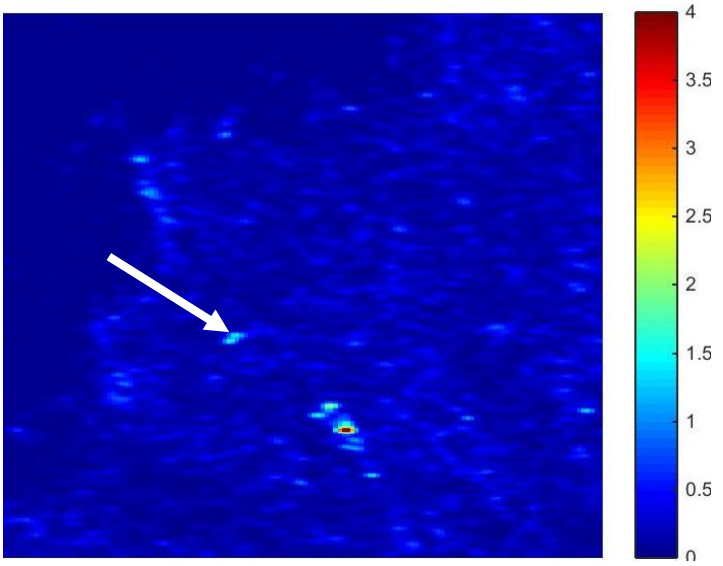
Figure 3. Radarsat-2 SAR image and CP features: overall viewing. The area of interest is marked with a green circle.



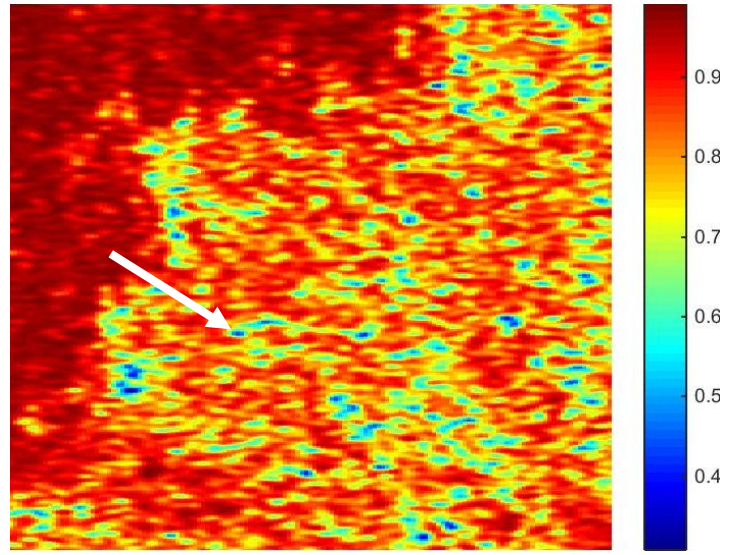
Grey-tone hv-polarized intensity SAR image, in dB scale.



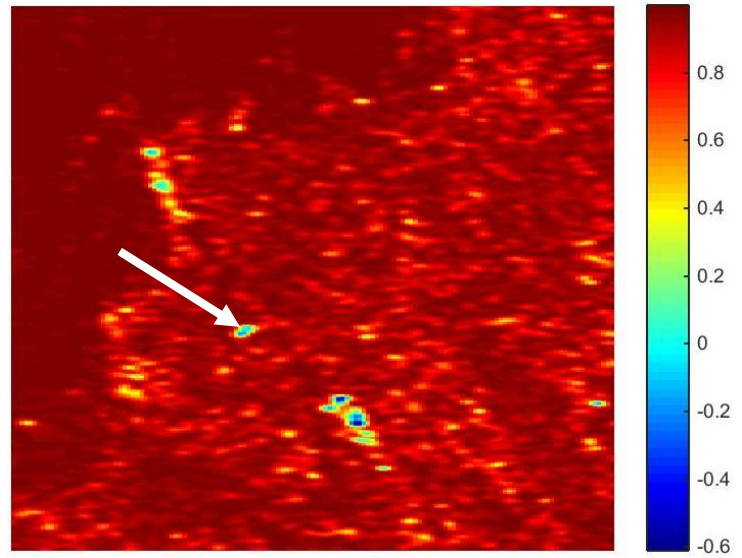
δ_{hv}



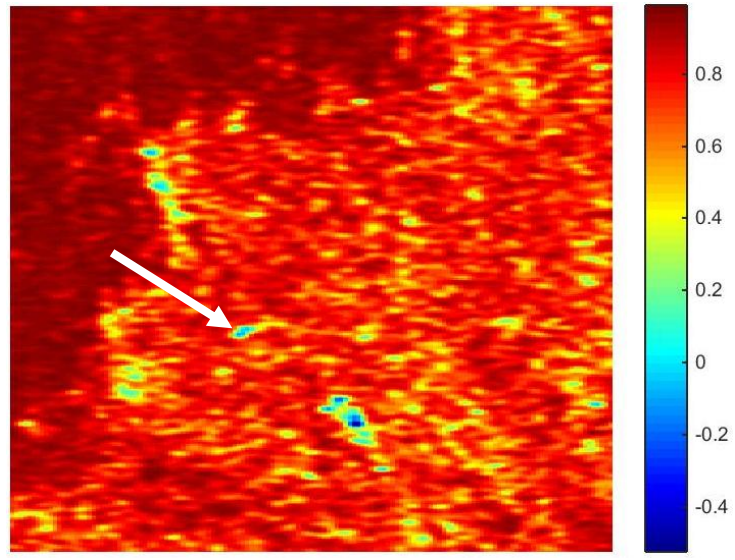
μ_c



p



sin2χ



μ

Figure 4. CP features zoomed over the area of interest. The aircraft position is marked with a with arrow.

4. Conclusions

In this study, CP features are exploited to both detect and classify polarimetric behavior of man-made targets within a complex Antarctic environment. Experiments undertaken on CTLR and LTLR measurements emulated from actual C-band Radarsat-2 FP SAR data confirm the soundness of the proposed approach. The achieved preliminary results have encouraged future work that will deal with the exploration of different responses from a wide range of inland and sea ice. Present research is very promising to the situational awareness enhancement for eventually operational flights on Antarctica.

Acknowledgments

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