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► **To cite this version:**

Paillou Nathan, Laetitia Thirion-Lefevre, Regis Guinvarc'H. Interest of Temporal Methods over Spatial Methods in Order to Detect Small Targets. IGARSS 2020 - 2020 IEEE International Geoscience and Remote Sensing Symposium, Sep 2020, Waikoloa, France. pp.1767-1769, 10.1109/IGARSS39084.2020.9324539 . hal-03616697

**HAL Id: hal-03616697**

**<https://hal.science/hal-03616697v1>**

Submitted on 22 Mar 2022

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# INTEREST OF TEMPORAL METHODS OVER SPATIAL METHODS IN ORDER TO DETECT SMALL TARGETS

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## ABSTRACT

Target detection is an important part of research in SAR. However, the detection of small targets has always been complicated as most of the methods are spatial and based on the use of information from neighbouring pixels to characterise more precisely the studied pixel. In addition, data are often filtered to reduce the noise which results in an additional loss of spatial information. In the frame of small targets detection, this loss has to be avoided and to do so we propose to use temporal methods. Instead of using neighbouring pixels, one can use the different values of the pixels over time which allow not to wipe out small targets. The aim of this preliminary study is to show the advantages of temporal methods over spatial methods and to highlight the points to be further investigated in temporal methods. Promising results on intensity and entropy have been obtained.

**Index Terms**— SAR, Spatial, Temporal, Detection, Polarimetry, Small Targets

## 1. INTRODUCTION

Since the beginning of radar, studies have been carried to correct the noise on images [1]. Indeed, the noise can hide the response of targets one is trying to detect, and this is why many filters have been created [2]. In particular, for small targets detection, a complex filter has to be used so that they are not wiped out [3]. These small targets can also disappear from the SAR image when one calculates some classical variables, as the intensity, the entropy, the coherence or any other property. These methods often use the information contained within pixels closed to the one whose value is calculated. Therefore, the detection of small targets in filtered data using spatial methods can become a difficult task. For example, to calculate precisely the entropy it is recommended to use at least a 7 by 7 multi-look as shown in [4]. Even more, [5] shows that with 95% pixels from surface scattering and 5% pixels from volume scattering, the calculated entropy will be closer to the entropy from a volume scattering than from a surface scattering. As a consequence, we do not expect to detect a thin road in a forest using the regular entropy, because of the multi-look. Temporal methods could be a solution and

the purpose of this study is to investigate their potential benefit. Thus, as there are now temporal stacks available, it is possible to replace the information given by the neighbouring pixels by the information given by the same pixel, but from different temporal acquisitions. For example, in classification, it has been demonstrated in [6] that the use of a temporal estimation of entropy gives better results in most of situations than with spatial estimation. In this article it will be shown that temporal methods, as the temporal estimation of entropy, gives better results for small target detection. As for spatial methods for neighbouring pixels, we assume that the studied physical properties of the pixel do not change over time. The data are presented in the next section, while our methodology is explained in section (3). Then we present and discuss the results on intensity and entropy.

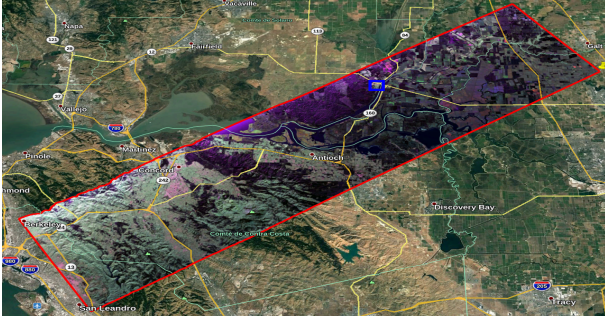
## 2. DATA PRESENTATION

We used UAVSAR data provided by the Jet Propulsion Laboratory and collected over the Sacramento-San Joaquin Delta. They are L-band SAR images, full-polarized (HH, HV, VH, VV) and acquired in PolSAR mode with a resolution of 0.6 m in azimuth and 1.6 m in range. The temporal stack is composed of 69 acquisitions, obtained between July 18, 2009 and November 14, 2017. For this study, we selected the area indicated within the small blue rectangle near Rio Vista in Figure (1). We chose this area as it contains various environments, as shown in Figure (2). There is a part of Sacramento on the top right of the image, a forest in the middle, fields and urban areas. There are several roads and paths of different sizes, orientations, and materials between fields, urban areas and forests. They will constitute the group of objects we aim to detect.

## 3. METHODOLOGY

It is important to note first that these data are coregistered and calibrated in phase and amplitude, which is a crucial step to allow the study of the evolution of pixels over time.

Acknowledgement: UAVSAR data courtesy NASA/JPL-Caltech.



**Fig. 1:** Area covered by UAVSAR over Sacramento-San Joaquin Delta with studied area inside the blue rectangle (Google Earth Image and Pauli kmz)



**Fig. 2:** Zoom on the studied area of Rio Vista (Google Earth image)

### 3.1. Intensity

The intensity can be calculated by averaging the value across the temporal dimension and not the spatial one. The result presented below has been obtained thanks to Eq. (1).

$$\sigma_{i,j}^{qp \text{ temporal}} = \frac{1}{N} \sum_{n=1}^N |qp_{i,j}^n|^2 \quad (1)$$

where  $\sigma_{i,j}^{qp \text{ temporal}}$  is the temporal intensity corresponding to the qp polarization for the pixel (i,j), with q and p equal to h or v, N is the total number of temporal acquisitions used and  $qp_{i,j}^n$  is the complex backscattered coefficient for the qp polarization for the pixel (i,j) for the nth acquisition.

### 3.2. Entropy

The spatial entropy as defined in [7] is derived using a multi-look calculation of the coherency matrix T. Like for the intensity, the spatial averaging can be replaced by a temporal averaging which allows to calculate a temporal entropy as shown in [6]. Eq. (2) and Eq. (3) have been used to obtain the temporal coherency matrix  $T_{i,j}^{\text{temporal}}$  for a pixel (i,j). The temporal entropy is then computed just as the spatial entropy, calculating the eigenvalues of the matrix  $T_{i,j}^{\text{temporal}}$  and the Shannon Entropy corresponding to these eigenvalues.

$$T_{i,j}^{\text{temporal}} = \frac{1}{N} \sum_{n=1}^N k_{i,j}^n k_{i,j}^{n*} \quad (2)$$

$$k_{i,j}^n = \begin{pmatrix} hh_{i,j}^n + vv_{i,j}^n \\ hh_{i,j}^n - vv_{i,j}^n \\ 2hv_{i,j}^n \end{pmatrix} \quad (3)$$

## 4. RESULTS

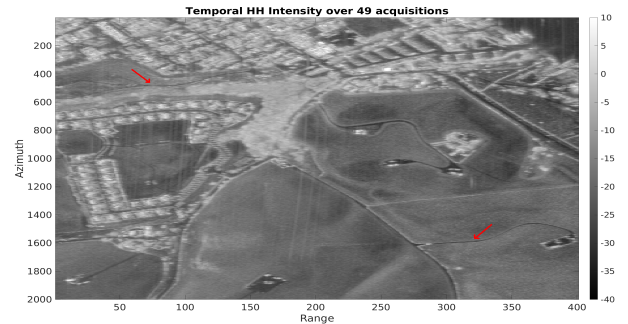
The difference between temporal and spatial methods is presented for HH intensity and for the entropy.

### 4.1. Intensity

In Figure (3) is presented the HH intensity obtained using a Lee Sigma Filter with a 7 by 7 window. This result is compared to the one presented in Figure (4) obtained using the temporal method described previously with 49 acquisitions instead of 69, in order to keep the same number of values.



**Fig. 3:** HH intensity obtained using a Lee Sigma Filter with a 7x7 window in dB

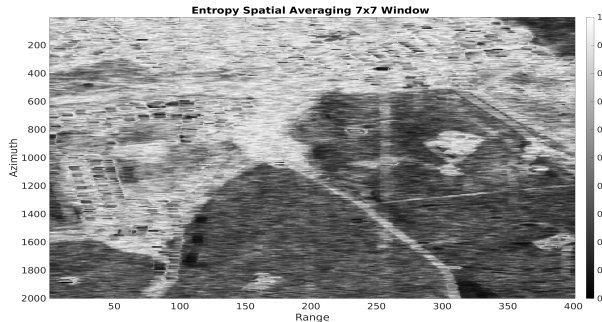


**Fig. 4:** HH intensity using a temporal average over 49 acquisitions in dB

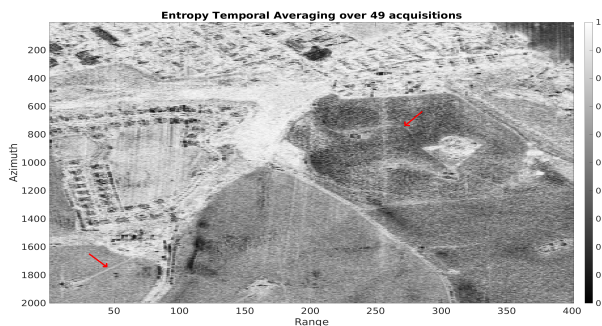
As we can see, it is easier to distinguish the roads (See for instance the two roads indicated by the red arrows) and the details in the urban areas in the image obtained using the temporal method.

## 4.2. Entropy

In Figure (5) is presented the entropy calculated using a 7 by 7 window and in Figure (6) the temporal entropy computed using 49 acquisitions.



**Fig. 5:** Spatial entropy calculated using PolSARpro with a 7x7 window



**Fig. 6:** Temporal entropy calculated using 49 acquisitions

Again, in Figure (6), one can observe more details than in Figure (5). In particular, the roads are easier to distinguish. We note also that the values for the temporal entropy seems to be higher than for the spatial entropy.

## 5. DISCUSSION

The previously shown results suggest that temporal methods are better than spatial ones for the detection of small targets, as there is no loss of spatial information. However, before being able to conclude on the effectiveness of these methods, further investigations have to be performed on various points. First, what is the correct way to average complex data over time? Next, do the parameters have the same meaning? For example, the temporal entropy is a little higher than the spatial one; is it due to the way the temporal entropy is calculated or is it that these two parameters do not refer to the same physical property?

## 6. CONCLUSION

The purpose of the study was to evaluate the interest of temporal methods over spatial ones. Through the study of the HH intensity and the entropy for L-band SAR data, it has been shown that temporal methods are promising. Indeed the detection of small targets is easier as there is no loss of spatial information for the temporal HH intensity and the temporal entropy. However, it is important to note that further investigations have to be performed to better understand the physical content of these new variables.

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