

# HYDRO-ECOLOGICAL MONITORING OF COASTAL MARSH USING HIGH TEMPORAL RESOLUTION SENTINEL-1 TIME SERIE

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## 1. INTRODUCTION

In wetlands, hydrological regimes determine values of functions and ecosystem services. If hydrological regimes of wetlands are now widely handled by environmental managers, its impacts on both floods and vegetation dynamics are still unexplored. Simultaneously, the new Earth observation Sentinel-1 constellation, allowing all weather radar acquisitions with high temporal and spatial resolution appears as a promising opportunity for the monitoring of wetlands. In the same time, this study aims at (i) evaluating the ability of a Sentinel-1 time for the detection and monitoring of flood areas at 1:50 000 scale across a 100 000 hectares marsh; (ii) exploring the relation between the hydrological dynamic and ecological processes.

## 2. STUDY SITE AND DATA SETS

The study is carried out on the Regional Natural Park of the Marais-Poitevin, next to the French Atlantic coastline. The Marais-Poitevin is a large area of marshland (about 100 000 ha) resulting of the building of several polders. The elevation is between 1.5 and 3.5 meters above the sea for the most part of the marsh. Marsh is seasonally flooded mostly thanks to precipitations. The drainage system are structured by hydrological compartments, and principally managed by farmers and environmental managers [1].

The radar data have been acquired by the SAR sensor on board the Sentinel-1 satellite which operates at C band ( $\lambda=6$  cm). 14 acquisitions have been acquired in ascending pass, in dual-polarization (VV/HV), over the study period, extending from December 2014 to May 2015. They have been realized in IW mode (Interferometric Wide swath), and are delivered either in GRDH or SLC products according their acquisition date prior or after March 2015 respectively. The spatial resolution is about 5 m x 20 m in ground range and azimuth. The pixel size is 2.3 x

17.4m in range and azimuth for the SLC products, while it is 10 x 10 m for GRDH products [2]. The study site ranges between 36° and 42° of incidence angle.

In order to train and validate the analysis of Sentinel-1 time series, ancillary data were gathered in the data set: (i) a micro-topography map (Litto 3D, IGN) derived from LIDAR acquisitions is available with a 1.0 meter grid size and a 0.10 m elevation accuracy; (ii) the water table levels were measured by using a set of 14 piezometric probes located in various grasslands sites.

### 3. METHODS AND FIRST RESULTS

This section details the different steps performed to extract the floods periods. First, the envelope corresponding to the potential flooded areas over the entire time period is estimated through a 2-class classification method. Then, within the resulting envelope, for each acquisition, the flooded areas are estimated through a 3-class classification method. In particular, emphasis is put to discriminate between open water and flooded vegetated areas. This allows the production of a floods duration map.

A supervised classification method is retained in this study: the Random Forest algorithm which gave similar results while less time consuming than the SVM (Support Vector Machine) method. Each classification performed in this study involves 3 radar attributes;  $\sigma_{VV}^0$ ,  $\sigma_{VH}^0$  and  $\sigma_{VH}^0/\sigma_{VV}^0$ .

The polygons required to define training samples have been visually delineated from one radar and one optical LANDSAT data acquired with a 5 day interval (12<sup>th</sup> and 17<sup>th</sup> March respectively). Over both images, several identical flooded areas are easily discernible without any ambiguities. Then, a subset of 1000 training samples is randomly chosen from these polygons to train the classifier.

#### 3.1. Pre-processing

Important issues are the preservation of spatial resolution (despite the speckle noise affecting the radar data) to obtain an accurate segmentation of the water areas, whatever the presence of vegetation or not. The Mean shift algorithm [3] gave the best results among the different filtering tested methods ([4], [5]) in order to reduce the speckle noise while preserving the spatial resolution. An illustration is given in Fig. 1.

#### 3.2 Delineation of the floodplain areas envelope

The delineation of the floodplain areas envelope is performed by the use of a supervised classifier: the Random Forest algorithm. 2 classes have been retained: water / non water following the processing detailed above. The model classifier is estimated for the 12<sup>th</sup> March radar acquisition. It is then applied for each of the 13 other radar acquisitions. Finally, the maximum open water envelope is estimated by merging the different open water areas discriminated for each acquisition. An illustration of the classification result over a 5 x 3 km<sup>2</sup> sub-area is given in Fig. 1. It can be seen that the method is able to extract continuous and patchy open water areas (Fig. 1).

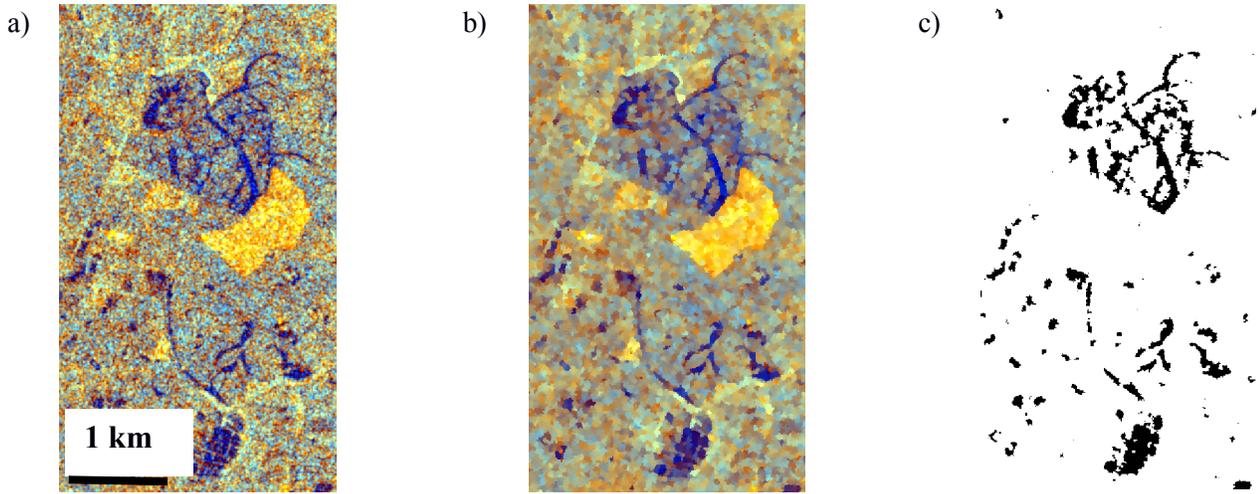


Figure 1: a) 2015/02/04 Sentinel-1 acquisition color composite image over wetland areas: R:  $\sigma^{0}_{VV}$  - G:  $\sigma^{0}_{VH}$  - B:  $\sigma^{0}_{VH}/\sigma^{0}_{VV}$  polarisation. b) same as a) after MeanShift filter processing. c) Water area estimation.

### 3.3. Flood monitoring

Within the envelope of floodplain areas, for each acquisition, both open water and flooded vegetation areas are estimated by the use of a Random Forest classifier algorithm. Here 3 classes are concerned: Dry areas, Flooded vegetation and Open water. Here again, the training samples are defined following the same protocol detailed above. The classification model computed for the 12<sup>th</sup> March acquisition is applied to the 13 others acquisitions.

## 4. RESULTS AND DISCUSSION

Fig 2 shows an illustration of the results obtained over a 5 x 3 km<sup>2</sup> sub-area for the 12<sup>th</sup> March acquisition. For each classification, the results have been confronted to 15 *in situ* measurements made with piezometric probes. When compared with the whole set of probes, the overall accuracy is ranging between 50% and 93% for each of the 14 classifications. These results will be deeply commented as additional analyses have to be made when comparing these located piezometric measurements with spatial classification.

It appears that this method gives better results than other based only on the threshold of the radar backscattering coefficient  $\sigma^{0}_{VH}$ ,  $\sigma^{0}_{VV}$ , and/or  $\sigma^{0}_{VV}/\sigma^{0}_{VH}$ . The addition of other polarimetric indices such as the H/A/ $\alpha$  decomposition [6], the Shannon entropy [7], the degree of coherence between VV and VH polarization have to be deeply analyzed, first results shows that it doesn't improve the results.

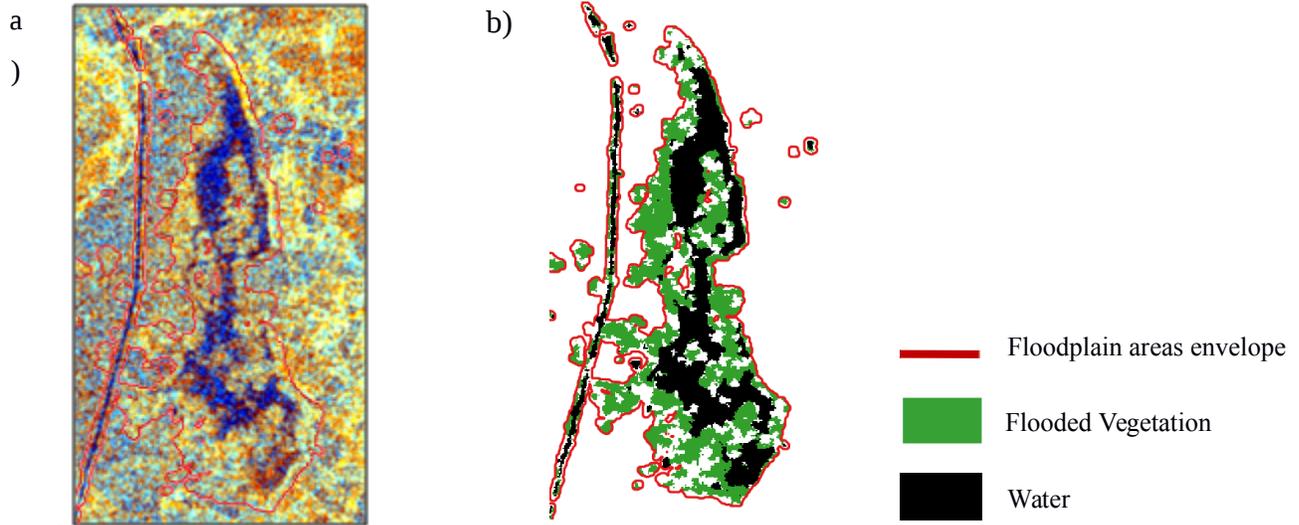


Figure 2 : a) Flooded areas extracted from the 2015/03/12 Sentinel1-A acquisition: Color composition: R:  $\sigma_{VV}^0$  – G:  $\sigma_{VH}^0$  – B:  $\sigma_{VH}^0/\sigma_{VV}^0$  polarization channels, b) Classification of the flooded areas

Finally, the combination of the results obtained for each of the 14 acquisitions, allow us to perform a flood duration map which is shown in Fig. 3. It highlights that Western part of the Poitevin marsh is longer flooded than the Eastern part.

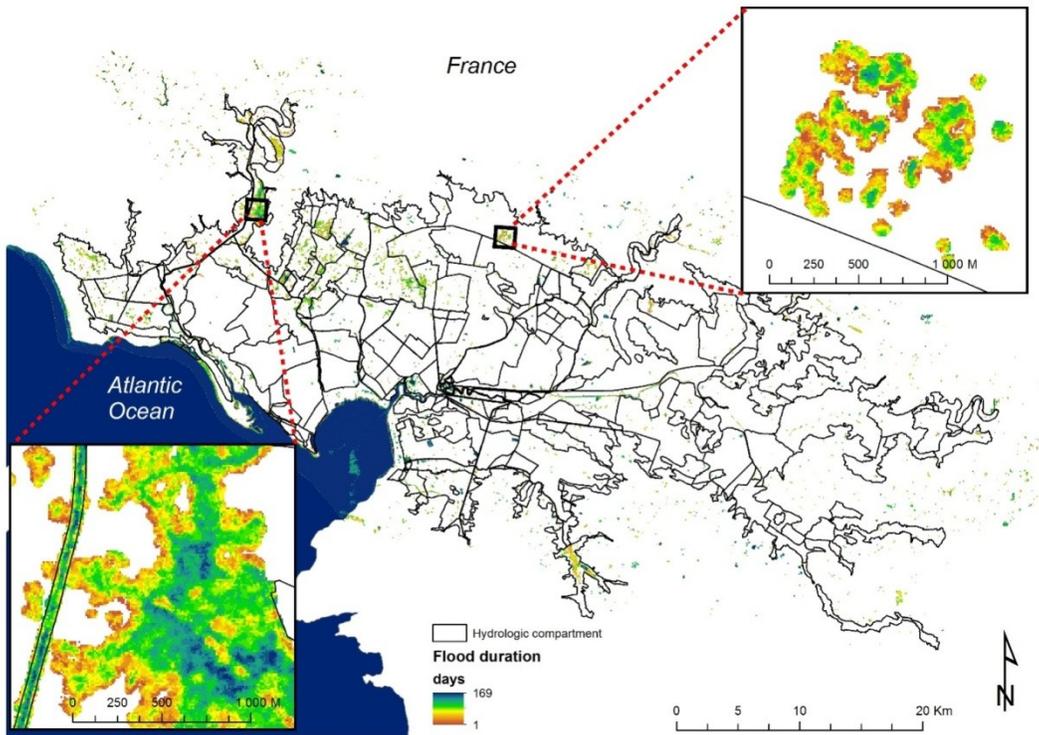


Figure 4 : Map of flood duration in the Poitevin marsh between December 2014 and May 2015, derived from the analysis of a Sentinel-1 time series

#### 4. PERSPECTIVES

This paper presents preliminary results about the monitoring of marshlands using a SENTINEL-1 time series consisting of 14 acquisitions in IW mode between December 2014 and May 2015. The flood duration map derived from Sentinel-1 increases the knowledge about hydrological regime characterization in the Poitevin marsh. Since hydrological regime is a driver of plant and fauna biodiversity, this map provides to environmental managers useful information in the framework of ecosystem service issues.

The proposed method, which is based on the Random Forest supervised classifier, allows to discriminate in a first step the floodplain envelope. Then, the flooded vegetation and open water areas are discriminated, allowing to produce a flooded duration map over the whole 100.000 ha area of marshland. When compared to 15 located piezometric probes, this method shows an overall accuracy ranging between 50 and 93%. These results need additional analyses. In particular, the combination of these results with the LIDAR-derived DTM has to be investigated. At a first glance a close correspondence can be noticed between the floods duration map and the DTM.

## 5. REFERENCES

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