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HIGH FREQUENCY MONITORING OF THE SHORELINE/BARLINE EVOLUTION OF AN OPEN SANDY BEACH, THE EXAMPLE OF BISCARROSSE BEACH (FRANCE)

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Abstract

One year of high frequency DGPS surveys (January 2016 to January 2017) completed by the inner bar position extracted from video monitoring are analyzed to study the evolution of the open sandy beach of Biscarrosse (SW of France). The purpose of this work is not only to characterize the seasonal dynamics of the shore but also to look after the evolution of different shore proxies (e.g. dune foot, lower/higher beach, etc…) at short scales as energetic event scales. According to our dataset, the tide is a key component in beach morphology changes and sandbar position. Indeed, during the winter 2016 clusters provoked beach and dune erosion because of spring tide periods whereas neap tide isolated events seems to reconstruct the beach. Moreover, we observed a significant alongshore variability in beach response to energetic and calm conditions probably linked to beach management and the inner bar shape (presence of RIP channels).

Key words: sandy beach, sediment transport, morphodynamics, clusters, recovery periods, barline position.

1. Introduction

Predicting the shoreline evolution is a recurring issue in coastal management. The increase of human pressures on coastal environments associated to the possible effects of "global warming" could impact the natural fluctuations of the coastline. Understand the sediment exchanges at different timescales are thus a key component to predict the shoreline variability and vulnerability. With nearly 250 km of long strait sandy coastline, the Aquitanian coast (S-W of France) is recognized as a touristic hotspot fully opened to the North Atlantic swell. Previous studies (*e.g.* Senechal *et al*., 2009) have shown that both seasonal and storm event scales are key components in the shoreline dynamics. Moreover, Boak & Turner (2005) highlighted the importance in the chosen proxy to describe the shoreline dynamics pointing that, for example, the dune foot will react differently to same factors than the lower beach. This work trends towards a better understanding of the impact of short scale dynamics on the seasonal variations by including not only erosive events (*e.g.* storms or cluster of storms) but also calm periods (relative to storms) generally considered in the literature as being 'recovery' periods (*e.g.* Splinter *et al*., 2011).

2. Methods

2.1. *Field area*

Biscarrosse beach, South West of France (fig.1), is a meso to macrotidal double-barred open sandy beach previously described as a typical example of the Aquitanian beaches' morphology (Castelle *et al.,* 2007b; Almar, 2009). Oriented about 280.5° due to the North, Biscarrosse is totally opened to the North Atlantic swell, associated to mean annual Hs of 1.4m and Tp equals to 6.5s (Butel *et al.,* 2002). However, a strong seasonality in the wave climate is observed with waves that can exceed 10 m during winter storms (from November to March). The mean spring tide in this area is 3.7m against 1.8m during neap tide.

Composed by medium sand, 350 µm median grain size (Ba & Senechal, 2013), Biscarrosse beach

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morphology is both driven by cross-shore exchanges and a strong longshore drift (from North to South). This beach is classified as an intermediate beach, according to the classification of Wright & Short (1984), mostly dominated by TBR and LTT states (Peron & Senechal, 2011).
Over the past years, several studies illustrated the intertidal sandbar morphologies and migrations (e.g. Lafon *et al.,* 2002; Apoluceno *et al.,* 2003; Senechal *et al.,* 2009). Almar (2009) showed that even if the inner bar generally presents a TBR type associated with wavelengths around 400m, all intermediate states can be observed. The outer bar is currently crescentic with a typical wavelength about 700m, but its geometry can be modifed by the wave incidence and the subtidal sandbar sometimes exhibits an asymmetric shape (Lafon *et al.,* 2004; Castelle *et al.,* 2007b).

Another remarkable point about Biscarosse is the different management strategies deployed on the beach. Indeed the back dune is covered by grass, the southern part of the shoreline is fixed by seawalls and the northern part of the dune is protected by windbreakers (fig.1).

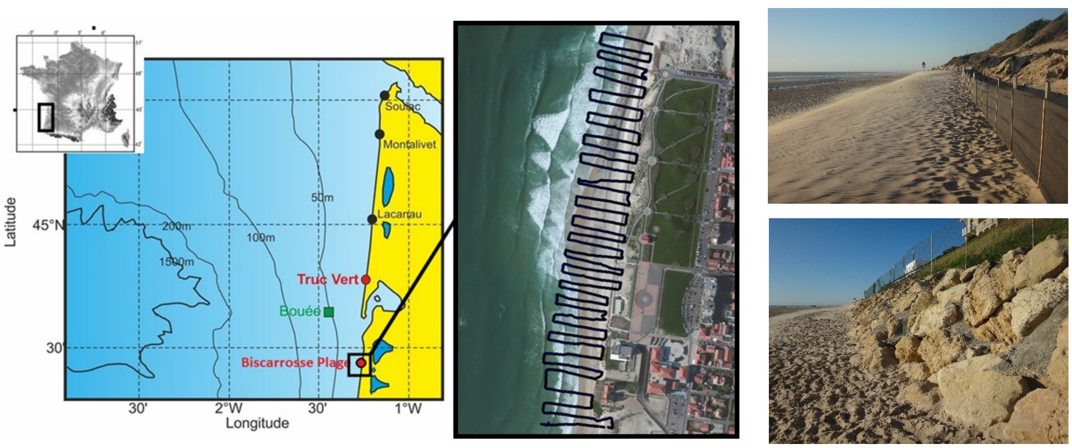

Figure 1: Biscarrosse beach location and DGPS typical transects over the beach. Right images: top: windbreakers; bottom: seawalls.

2.2. *DGPS surveys and barline extraction*

From November 2015 until February 2017, more than ninety DGPS surveys have been done on Biscarrosse beach. With at least two surveys a week (excepting during summer), this high frequency dataset allows us to access the beach and dune variability at really short scale, as storm event. Covering 700m of longshore beach (fig.1), thirty cross-shore transects are recorded from the dune to the low tide mark. Actually, even the inner bar can be reached during summer spring tide.

The barline position has been monitored through a modified CamEra system, developed in the first time by the NIWA and revised by V. Marieu (EPOC, France). Four color cameras are fixed on a 15m high structure located on the top of the dune. The video system overlooks about 2km longshore and 1km cross-shore (Ba & Senechal, 2013), providing 4 images per hour (Almar *et al*., 2009). Because of technical failure, only images from the middle of January 2016 until the end of March 2016 (the first winter period) have been used in this paper. Moreover, because of poor images quality (rain, reflections, etc…) only 32 days have been exploited that is half of the time period. The bar position has been digitized using rectified averaged images, obtained by a 10 minute time-exposure video (Senechal *et al.,* 2015). Predominant wave breaking is used as a proxy to identify the submerged surfzone sandbar (Lippman & Holman, 1989; Van Enckevort & Ruessink, 2001). In order to avoid tide and wave shift, the mean wave breaking (γ) has been fixed according to the Equation 1 (Desmazes, 2005), where Hs is the significant wave height and η the water level, and the images extractions done according to this coefficient.

$$\gamma = Hs/\eta = 0.8 \tag{1}$$

3. Preliminary results

3.1. *Hydrodynamic conditions*

The wave dataset was extracted from the WaveWatch3 model provided by Previmer. The offshore waves were modeled by 50m deep and offshore the Cap Ferret sandy spit (fig. 1, green square on the map). Tide data were obtained by the tide model developed by the SHOM institute. According to previous studies (e.g. Dolan & Davis, 1994), a storm event could be described by two different thresholds, one for the significant wave height and one for the storm duration. Those thresholds are typical to each environment. For the Biscarrosse beach, and more generally the Gironde coast, hydrodynamic conditions are considered as storms when the Hs are superior to 4m (H95%) during more than a tide cycle (12hrs). Following this characterization Biscarrosse endured nine different storms during the winter 2016 (from the 5th of January 2016, beginning of DGPS surveys). The first storm recorded was the 2nd of January 2106, associated to a max Hs equals to 6.1m and a duration over 20 hrs. During the second one (4th to 7th January), waves reached 6.5m with a mean Hs about 5m. The third one occurred during a spring tide period, from the 11th to the 12th January, and the maximum Hs was 7.3m. In view of the small interval (< 5 days) between those 3 storms, they could be considering as a same cluster event. Thus the winter 2016 could be described by three clusters respectively composed by 3 and 2 storms, and two isolated events (fig. 2).

Figure 2: First panel: significant wave height; Second panel: Pic periods; Third panel: Wave Incidence; Forth panel: Tide height. Blue box: Clusters; Red Box: Single storm.

3.2. *Beach morphology*

The first results seems to present a classical seasonal schema with a global beach and dune erosion during winter and a recovery period associated to a berm reconstruction during summer (fig. 3). But, an alongshore variability in the beach response to events is observable. Actually, when looking to winter results (fig. 3, 1st panel) a major erosion of the southern end of the beach is obvious. Moreover, cross-shore profiles were extracted from DGPS surveys in order to access the impact of clusters and storms on the two ends of the beach (fig. 4, top panels). Concerning the northern end, the maximum of erosion is reached at the end of the 2nd cluster (17/02), associated with a retreat about 15 m of the dune foot and a steeper dune/beach slope at the end of winter (fig.4, Top left panel). Plus, the first isolated event (29/01 to 01/02) appeared to initiate a reconstruction of the higher part of the beach meaning that recovery could takes place during high hydrodynamic conditions. The southern end began to have a steeper dune only after the first cluster (22/01). The maximum dune foot retreat about 25m and is attained the 17/02 (fig.4, Top right panel).

At the end of winter an erosion of the lower beach around 1m is observable.

This alongshore variability is also significant during calm conditions and recovery periods. According to the figure 3 (bottom panel) the berm looks higher (2m against 0.6m) and wider in the south part on the beach than in the north. In the north, the first berm reformation began around the 19th of April 2016. The berm migrated toward the dune until the beginning of June, when it stabilized. Its amplitude was about 2m but an erosion of the berm started at the end of summer. In contrast, the first berm reconstruction in the south is later than in the north and took place in August. Its amplitude is less important but the structure was still stable at the end of summer.

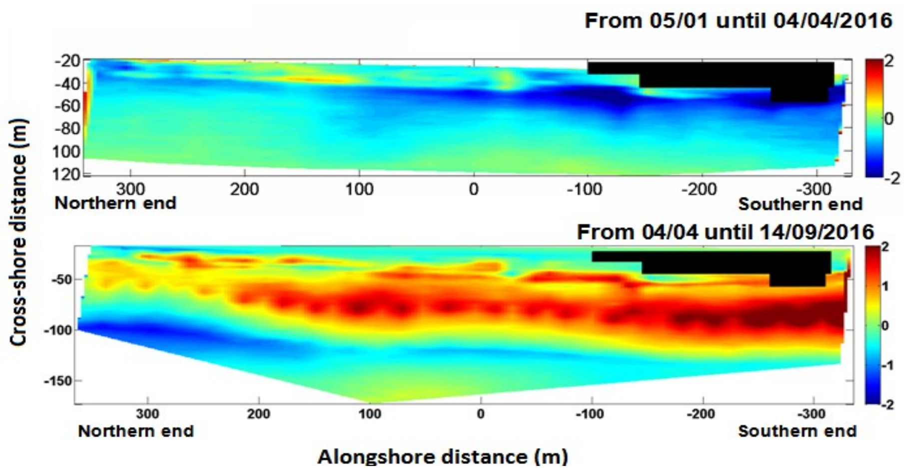

Figure 3: Beach morphodynamics. Top panel: Beach changes during winter 2016. Bottom panel: Beach changes during summer 2016

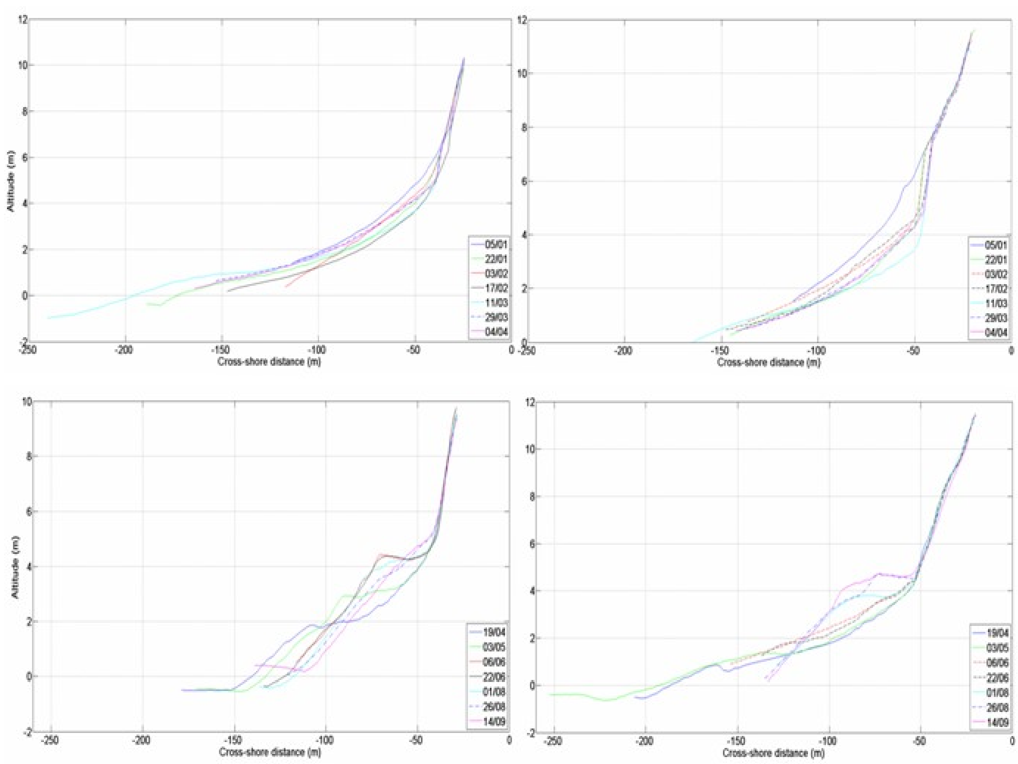

Figure 4: Extracted cross-shore profiles. Top: Winter; Bottom: Summer. Left: Northern end of the beach; Right: Southern end of the beach.

In order to look at the response of the different part of the beach, in term of proxies as dune foot, higher beach or lower beach, isocontours were extracted form topographic surveys. According to our results for winter 2016, beach response to storms is highly variable and cannot be resumed to a single factor. For example, the figure 5 illustrates no erosion of the isocontours Z=1, 2.5 and 9m during the first isolated storm, despite high values of Hs (> 5m). Moreover, recovery periods could be observed between two consecutive storms of a cluster, but not necessarily (e.g. storms during the 1st cluster vs. the 2nd one, figure 5). Furthermore, the figure 5 also shows that an offset exists between the pic of an event (energetic or calm) and the dynamic of the beach (erosion or accretion): the beach is still in erosion after the end of the 2nd cluster, while conditions are calm. The opposite can be noticed for the 3rd cluster: the beach is always in recovery periods during the first storm of the cluster.

In addition, following the proxy Z= 1m, the seasonal recovery period associated to more calm conditions seems to begin in the first days of April against the middle of April for the proxy Z=2.5m. From May 2016, the lower part of the beach starts a landward movement whereas calm hydrodynamic conditions. This is not the signature of an erosion of the beach but of the reconstruction of the berm and the increase of the beach slope.

Thos preliminary results show that different proxies allow us to make different interpretations for a same beach and a same event, and there are both cross-shore and longshore variability in the seasonal beach response to high or calm conditions.

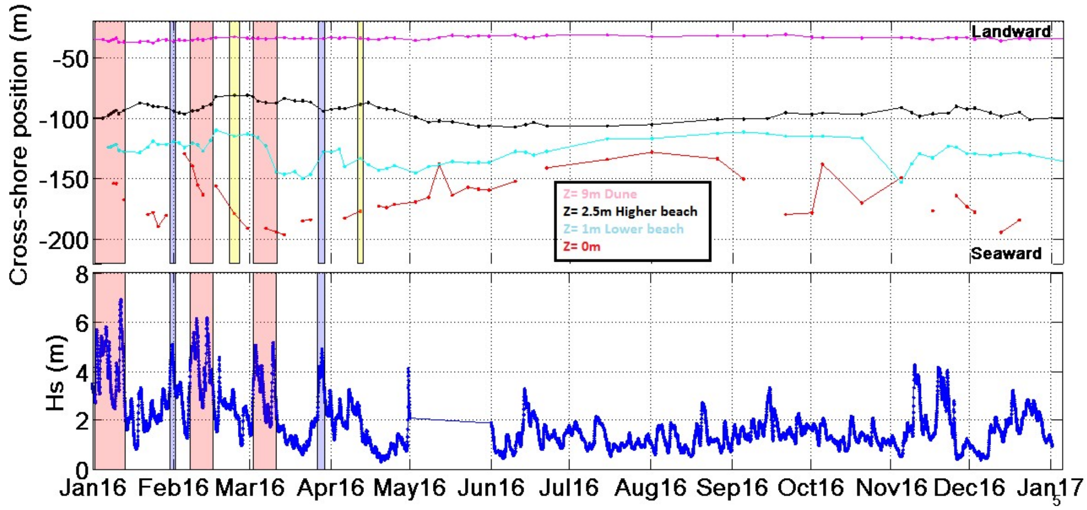

Figure 5: Different isocontours (top panel) compared to significant wave height (bottom panel). Pink boxes: Clusters. Blue boxes: Isolated storms. Yellow boxes: Re-sanding

3.3. *Inner bar positions*

The first point to notice is that the first cluster has not been taking into account because of a failure in the video system. But, we suppose that the very important hydrodynamic conditions can explain the offshore position of the inner bar at the start of this study (fig. 6). The relatively calm conditions of the last 15 days of January allowed the initialization of an inshore movement of the barline (from 340m to 300m le 26th of January). More generally, there is a correlation between Hs conditions and the barline position: during high conditions, the sandbar initiates an offshore movement with the purpose to protect the beach to high wave energy. In contrast, during calm conditions the inner bar in moving toward the beach. Thos results are conformed to previous studies (e.g. Almar *et al.,* 2009; Ba & Senechal, 2013).

Moreover, changes in the bar morphology can also be observed thanks to video monitoring. Thus, the 3D patterns are smoothed during storms and could be reformed during more calm conditions (compared to storm conditions).

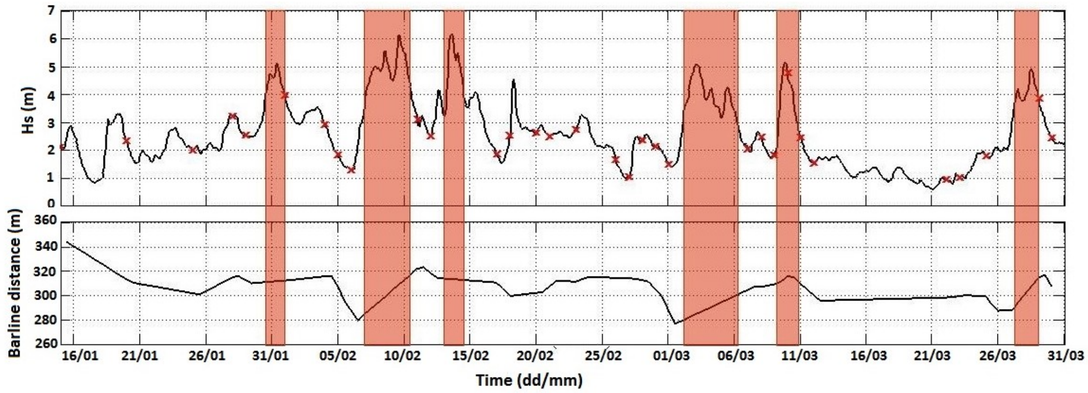

Figure 6: Top panel: Significant wave height. Bottom panel: Inner sandbar position.

4. Discussions

Masselink & Short (1993) supposed that the tide is a fundamental parameter driving the beach morphodynamics and that not only the wave parameters have to be taking into account. According to our results, the tide is a key component in Biscarrosse cross-shore exchanges. Actually, clusters look to have a major influence on all beach cross-shore profile compared to single events. One reason could simply be the fact that we always had a storm associated to spring tides during each cluster. In contrast, every single event occurred during neap tide meaning that only the lower part of the beach could be reached and eroded. Moreover, during isolated storms observations show that the higher part of the beach is in reconstruction supposing a possible sediment transfer from the lower part (fig. 5, Z=1m) to the higher part of the beach (fig. 5, Z=2.5m). The opposite is remarkable during clusters because the dune foot is attacked when high waves are correlated to spring tide. This time, the higher part is eroded and the available sediment used to enrich the lower part (fig. 5, end of the first cluster, and second one).

The tide has not only an influence on beach morphodynamics but also on the inner bar position (Almar *et al.,* 2010). Looking to the figure 6, the first event occurred during a neap tide period and no significant change is noticeable in the bar position. But, throughout the second event (1st storm of the 2nd cluster) a major offshore movement happened linked to high wave conditions and a spring tide period. This tendency is confirmed all along the winter 2016, even for the 3rd cluster: the sandbar retreat highlight a tide transition from neap to spring tide.

Even if our results cannot really provide a direct link between the barline position and beach response to storm events, the position of RIP channels seems to be a key to understand the alongshore variability. In fact, two principal parameters could play a role in this case. The first one is the beach strategy management. The southern end of the beach is characterized by a seawall protecting two old and emblematic houses (fig. 1). In 1988, Pilkey and Wright described seawalls effects according to three categories: beach width reduce, passive and active erosion. In Biscarrosse beach, an active erosion associated with an “end-of-wall effect” (McDougal, 1987) is recorded. Nevertheless, a strong active RIP channel situated in front of the seawall (fig. 7), and potentially linked to its placement, could also explain the massive erosion in the southern and of the beach, and the delay in the berm reconstruction.

The last point the authors would like to discuss is the reconsideration of the simple model based on the fact that erosion occurs only during strong hydrodynamic conditions and recovery during calm conditions. It is clear that the field reality is not as binary. We observed reconstruction during single events and erosion after the apex of storms (fig. 5). Recently, Scott *et al.* (2016) pointed that post-storm recovery could happened during energetic condition and even that wave events look essential to initiate the recovery. That point will be discussed in a future paper focused on short term beach variations.

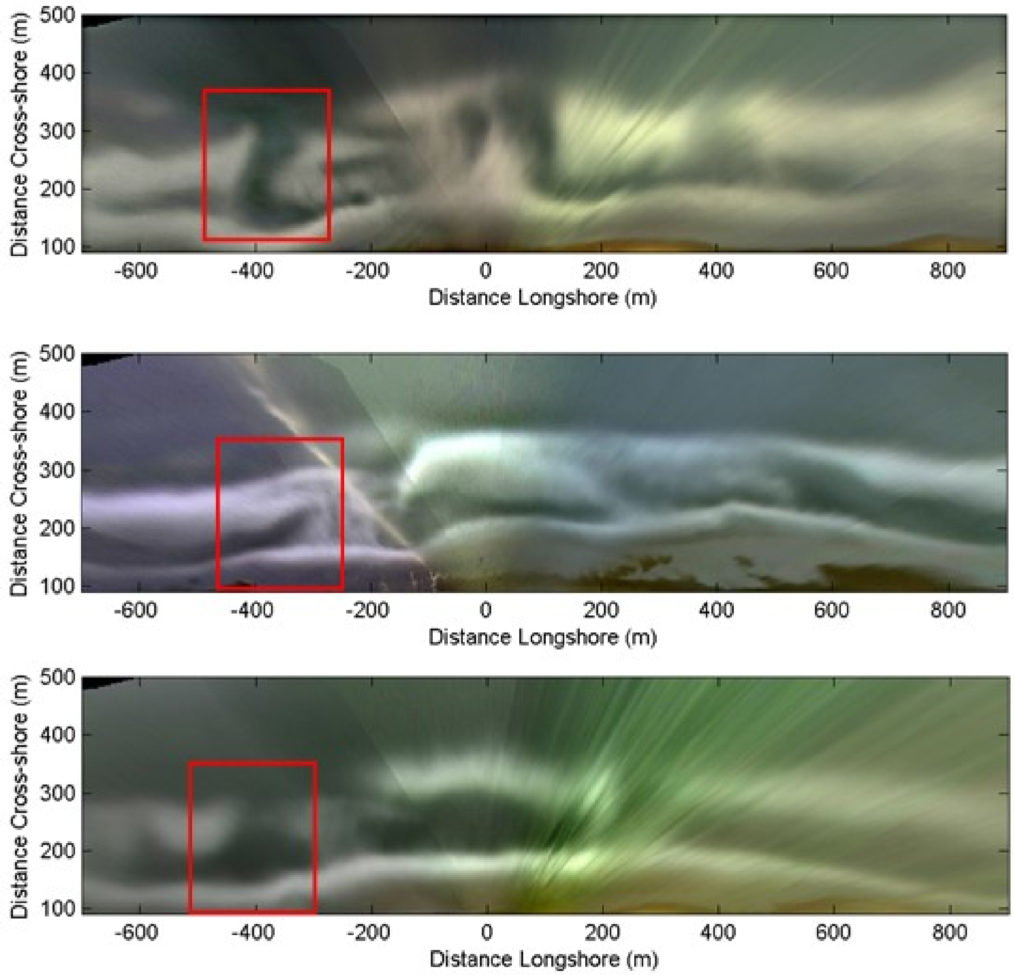

Figure 7: Rip channel in front of seawall (20/01; 17/02; 25/03)

5. Conclusions

High frequency DGPS surveys associated to video monitoring allowed us to access short term beach and dune variability and seasonal trends. We found that the beach morphology is submitted to factors as wave energy (or significant wave height), storm duration or tide. Moreover those factors could influence the various part of the beach in completely different ways. Storm events and spring/neap tides transitions also play a role in the inner bar position. The bar migrates offshore during energetic conditions protecting the beach to wave energy, and its movement is amplified when correlated to spring tide periods. The bar shape and the presence of RIP currents are also an important element to look after when talking about sediment exchanges. In the case of Biscarrosse beach, the double impact of seawalls and stable RIP channel accelerate the beach lowering in front of the structure, and the dune foot retreat on each side of the wall. On summer, the recovery and the berm reconstruction are also impacted by those two complex factors. The question now is which factors initiate the recovery and erosion of the beach since it appears that both tendencies could happen for calm or energetic hydrodynamic conditions.

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