Morpho-sedimentary evolution of the intertidal zone in tidal cycle on the Jacqueville coast (Southern Côte d'Ivoire)

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Abstract : This study on the morpho-sedimentary evolution of part of the Jacqueville coast aims to understand the behaviour of the beach during a tidal cycle. Several methods were used to carry out this study. The topographic survey method shows overall fattening of the study portion. The sediment reworking method, in a tidal cycle, gives a fattening morphology on both profiles A and B with amplitudes of sedimentary movements reaching 38.5 cm. The coastline is indeed stable. The beach adopts each of the two morphological states. While one portion is getting fatter, another is eroding.

Index terms : Amplitude, beach, coastline, cycle, Jacqueville, profiles, topographic

1. INTRODUCTION

Côte d'Ivoire has a coastal strip oriented WSW-ENE that stretches over 566 km. It consists of rocky capes from Tabou to Sassandra and sandy ridges from Sassandra to the Ghanaian border [1] and contains natural resources (water, wildlife, minerals) and fragile ecosystems (lagoon, coastal forest, mangroves). This façade is inhabited by more than 4.000.000 inhabitants unevenly distributed between the West and East [1] and has important infrastructure for the country's economy (ports, industry, tourist sites, hotels). The concentration of populations and their activities in Abidjan and its surroundings (Jacqueville) has an impact on coastal dynamics. They exert, in the same way as the sea, an influence that can upset the balance of this environment. In Côte d'Ivoire, coastal erosion is evident along almost the entire coastline. It is characterized by the retreat of the coastline, very pronounced in some places and the destruction of material assets (infrastructure, habitats, tourist sites...). For several years, studies have been conducted to better understand the kinematics of the coastline, which is more dynamic in places [2-3-4-5-6-7-8-9-10]. In response to this situation, the Oceanological research Centre of Abidjan (C.R.O.) has been monitoring the seafront since 1980. This monitoring is reduced by:

- diachronic analysis of topographic surveys, maps and aerial photos to detect beach dynamics in the short, medium and long term;
- the analysis of the sediments involved in this process.

The main objective of this study is to determine the maximum amplitude of sediment movement or mobile layer of sediment at the scale of the tidal cycle along the foreshore of the Jacqueville coastal area.

2. DATA ACQUISITION METHODS

2.1. Presentation of the study area

The tests took place on the Jacqueville coast located in the southwestern part of the Ivorian sedimentary basin (Figure 1). In Jacqueville, the profiles have a convex appearance and reflect an area favourable to accumulation. This sector is gaining sandy equipment estimated at more than 2300 m^3. This results in an estimated coastline advance of 13.5 m. Like sandbars, which play an essential role in beach dynamics, particularly with respect to erosion and coastal changes during storms [11], continuous rock banks at the underwater beach at Jacqueville should mitigate the effect of waves and confirm this hypothesis.

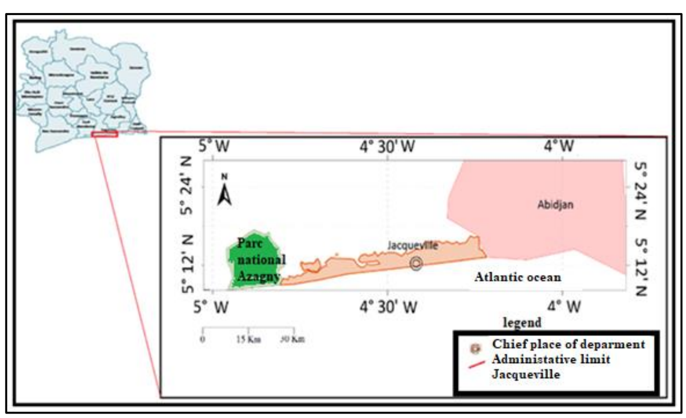

Figure 1 *: Geographical location of the study area*

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2.2. Acquisition of hydrodynamic forcing data

2.2.1. Tide

The theoretical water levels were extracted from the simulations of the Marine Hydrographic and Oceanographic Service (SHOM) on behalf of the Port of Abidjan. The difference in water level between a high water mark (HW) and a consecutive low water mark (LW) that corresponds to the theoretical tidal range was calculated for the experimental days.

2.2.2. Swell

The wave data were extracted from the ERA 40 or NOAA WAVE WATCH program. For this study the significant height was the focus of interest. Every six or three hours data are extracted depending on the program. Thus with ERA 40 four daily swell values are obtained. With NOAA WAVE WATCH, eight values are obtained. An average of these values is made per day.

2.3. Altimetric monitoring of the submerged foreshore

The dynamics of the beach is related to the amount of sediment brought into the action of the up rush and their departure in the backwash. These two upward and downward wave movements occur in an uneven sediment ratio so that the altimeter level is constantly changing. Altimetric monitoring therefore consisted in measuring the height of the stakes placed in the foreshore at wave crossings. The time for two consecutive post height readings is 5 min. This time allows the foreshore to ensure some settlement before the next measurement and also to prevent the action of a large number of waves on the foreshore from escaping. The stakes are placed equidistantly; either every two metres or every three metres depending on the width of the swash area materialized by the level of the last levee. A total of ten to sixteen stakes are implanted.

3. RESULTS

3.1. Morphological construction process of a beach point

3.1.1. At the bottom of the foreshore

The analysis of the sand movements on profile A and B shows that all the points were visited by the waves during the tidal cycle (Figure 2).

For profile A

The extreme values for RrI/5 min are between -9 cm at the upper range and 15 cm at the lower range. This means that a wave can pull up to 9 cm of sediment at depth and also bring up to 15 cm of sediment. The extreme values for Rr/C are -7.5 cm at the upper range and 31 cm at the lower range. This means that on the A-profile the maximum depth reached by the waves is 7.5 cm and the maximum input is 31 cm.

For profile B

The extreme values for RrI/5 min are between -9 cm at the upper range and 8 cm at the lower range. This means that a wave can pull up to 9 cm of sediment at depth and also bring up to 8 cm of sediment. The extreme values for Rr/C are -4 cm at the upper range and 13 cm at the lower range. This means that on the B-profile the maximum depth reached by the waves is 4 cm and the maximum input is 13 cm.

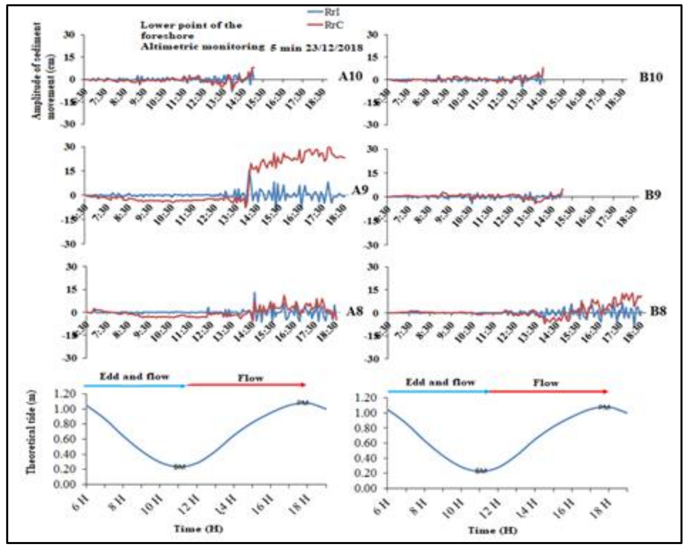

***Figure 2**: Continuous altimeter monitoring curve (5 min) of the lower estran points of profiles A and B on Jacqueville beach (23/12/2018)*

3.1.2. At the middle of the foreshore

Analysis of the sand movements on the A and B profiles shows that at mid-forest the posts A4, A5, A6, A7, A7, B4, B5, B6 and B7 show a slight fattening in the open sea until the next low water mark (Figure 3). This part of the foreshore is only submerged during the flow phase. This part of the foreshore receives the waves just after they fall. Wave energy is still well conserved and causes large amounts of sediment to move. It is a mi estran that grows fatter in the flow as well as in the lower estran.

For profile A

The extreme values for RrI/5 min are between -9.5 cm at the upper range and 7.5 cm at the lower range. This means that a wave can pull up to 9.5 cm of sediment at depth and also bring up to 7.5 cm of sediment.
The extreme values for Rr/C are -10.5 cm at the upper range and 8 cm at the lower range. This means that on the profile A the maximum depth reached by the waves is 10.5 cm and the maximum input is 8 cm.

For profile B

The extreme values for RrI/5 min are between -10 cm at the upper range and 9 cm at the lower range. This means that a wave can pull up to 10 cm of sediment at depth and also bring up to 9 cm of sediment. The extreme values for Rr/C are -4.5 cm at the upper range and 22 cm at the lower range. This means that on the B-profile the maximum depth reached by the waves is 4.5 cm and the maximum input is 22 cm.

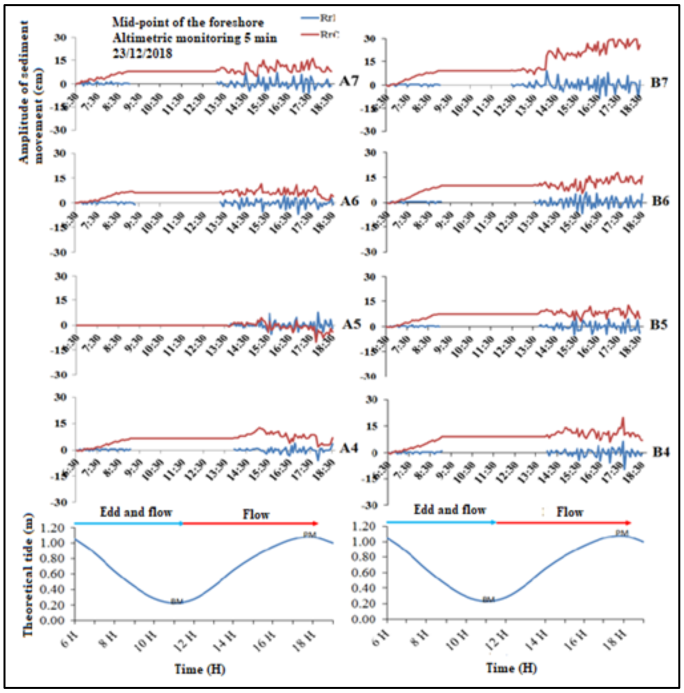

***Figure 3**: Continuous altimeter monitoring curve (5 min) of the mid-shore points of profiles A and B on Jacqueville beach (23/12/2018)*

3.1.3. At the top of the foreshore

Analysis of the sand movements on the A and B profile shows that at high foreshore, at low tide the stakes A1, A2, A3, B1, B2 and B3 are not affected by the waves (Figure 4). When we reach the sea plain these poles are submerged and we notice that the poles A2, A3, B2 and B3 have a fattening phase. This part is only visited by waves during high seas.

<u>For profile A</u>

The extreme values for RrI/5 min are between -4.5 cm at the upper range and 4 cm at the lower range. This means that a wave can pull up to 4.5 cm of sediment at depth and also bring up to 4 cm of sediment. The extreme values for Rr/C are 0 cm at the upper range and 9 cm at the lower range. This means that on the A-profile the maximum depth reached by the waves is 0 cm and the maximum input is 9 cm.

<u>For profile B</u>

The extreme values for RrI/5 min are between -5 cm at the upper range and 3.5 cm at the lower range. This means that a wave can pull up to 5 cm of sediment at depth and also bring up to 3.5 cm of sediment. The extreme values for Rr/C are -0.5 cm at the upper range and 7.5 cm at the lower range. This means that on the B profile the maximum depth reached by the waves is 0.5 cm and the maximum input is 7.5 cm.

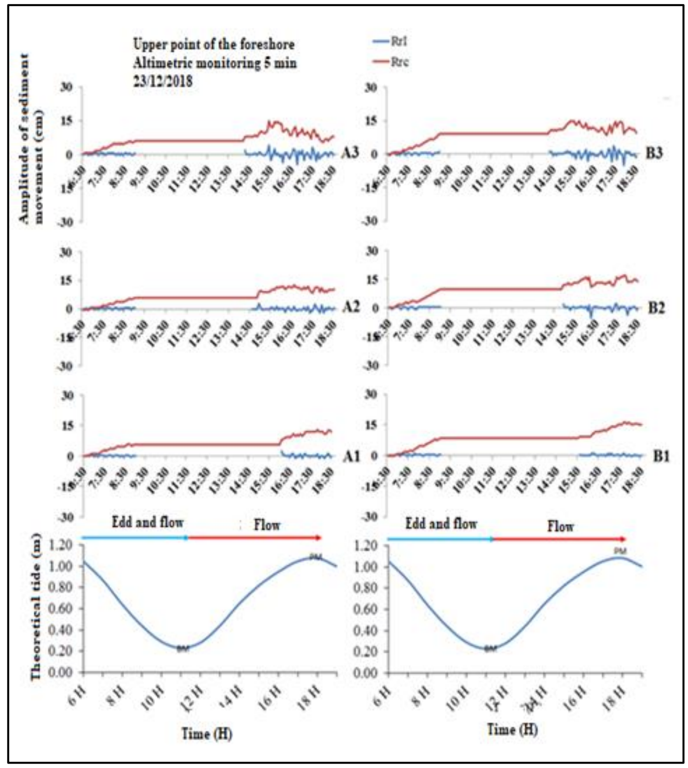

***Figure 4:** Continuous altimeter monitoring curve (5 min) of the points Upper foreshore of the A and B profiles on Jacqueville beach (23/12/2018)*

3.2. Morphological evolution in the tidal cycle of Jacqueville beach

The profile of 23/12/2018 was lifted at 13:00 (Figure 5), we note that :

For profile A, -6h before the profile survey we see a fattening, - 3h before the profile survey we see an erosion, while 6h and 3h after we see a fattening. For profile B, -6h and -3h before the profile survey we find no movement of the profile. While 6h and 3h after the profile survey we see a fattening. Beaches do not have the same behaviour even though they are subjected to the same hydrodynamic condition but react differently. Altimetric monitoring helps to understand that the morphological state of a beach originates from the tidal cycle. Fattening and erosion coexist with dominance of one of the two states depending on the marine seasons and hydrodynamic forcing conditions. On each of the two profiles A and B, it can be seen that the general fattening on the different points is better perceived. Both profiles generally become fatter during the tidal cycle. This fattening gives way to erosion 3 hours before the survey in ebb time.

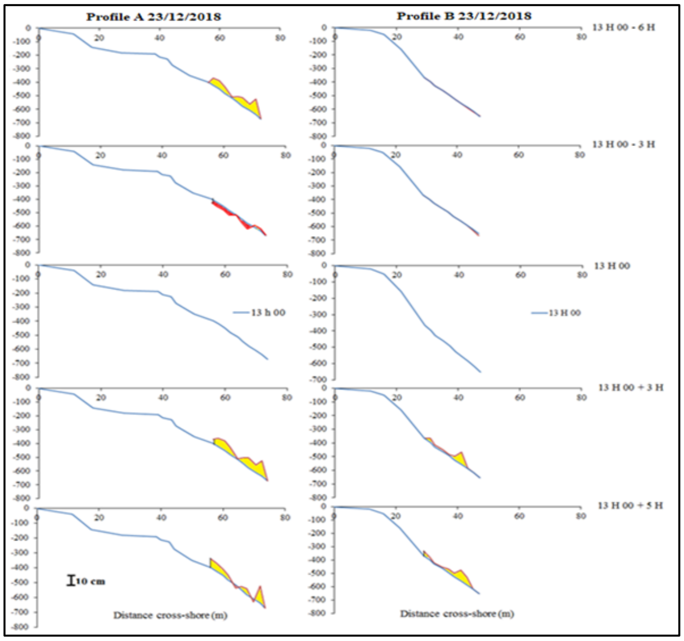

Figure 5: *Morphological evolution of beach profile in a tidal cycle*

3.3. Maximum amplitudes of sediment movement

The instantaneous and cumulative wave action is limited to a reduced envelope towards the upper beach points and fairly uniform for the other parts of the foreshore (Figure 6). This envelope results in maximum amplitudes dominated either by the RrI values or by the RrC values. The maximum amplitudes resulting from the RrI and RrC values of the A and B profiles (Table 1 and 2) are generally increasing from the upper foreshore to the mid foreshore. These amplitudes decrease towards the bottom of the foreshore. The large amplitude obtained is at point A9 with a value of 38.5 cm.

Table 1 : *Maximum amplitudes of the RrI and RrC of the points of profile A*

	A1	*A2*	*A3*	*A4*	*A5*	*A6*	*A7*	*A8*	*A9*	*A10*
RrI Amplitude	*3,5*	*5*	*8,5*	*10*	*17*	*11,5*	*13*	*19,5*	*24*	*14,5*
RrC Amplitude	*7,5*	*6,5*	*11*	*7*	*15*	*5,5*	*11*	*17*	*38,5*	*15*
Max Amplitude	*7,5*	*6,5*	*11*	*10*	*17*	*11,5*	*13*	*19,5*	*38,5*	*15*

Table 2: *Maximum amplitudes of the RrI and RrC of the points of profile B*

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
RrI Amplitude	1,5	7,5	8,5	16,5	10,5	13	18	17	7	11
RrC Amplitude	7,5	7	6,5	14	9,5	12,5	24	13	9	10
Max Amplitude	7,5	7,5	8,5	16,5	10,5	13	24	17	9	11

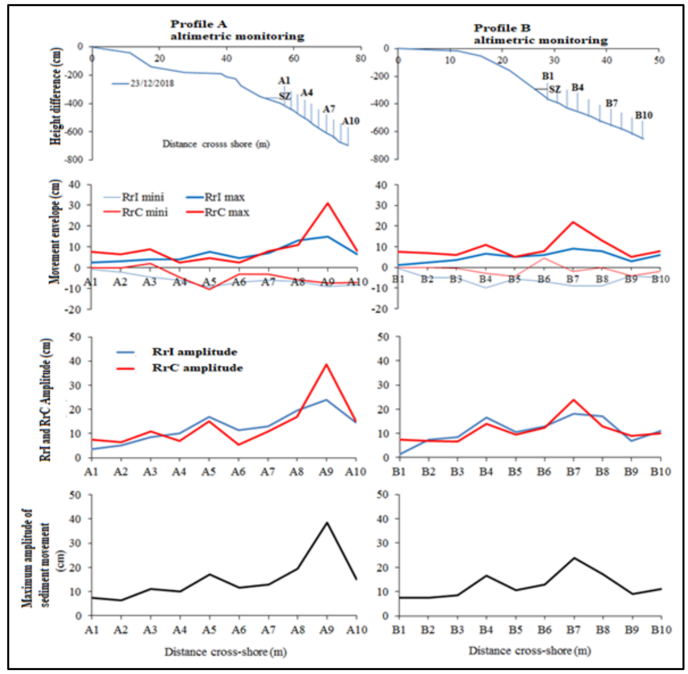

Figure 6*: Envelope and amplitude of RrI and RrC on profiles A and B in the tidal cycle for 5 min altimetric monitoring on 23/12/2018 in Jacqueville*

4. DISCUSSION

The study of sedimentary reworking at Jacqueville shows beach mobility through the different amplitudes of reworking. The amplitudes vary between 6.5 cm and 38.5 cm for profile A and between 7.5 cm and 24 cm for profile B. These amplitudes are more accentuated at the BE. The ebb phase has more erosion phases. On the other hand, in the flow phase, HE, ME and BE get fatter. These results are in line with those of [12] on San-Pedro beach, showing that the ebble phase has more erosion series and at the flow phase, the ME is eroding in favour of the BE which is becoming fatter. It also shows that the thickness of the moving layers is much greater at the BE level. Our results showed that the amplitude of sedimentary movements increases from the upper foreshore to the lower foreshore. This work is in line with the work of [13] in Port-Bouët, which revealed that the effective redesign is decreasing from the BE to the HE. Our work showed that using the continuous monitoring method and the coloured sand tracing method, the moving layer is between 6.5 and 11 cm for the HE, 10 and 17 cm for the ME and 15 and 38.5 cm for the BE. These results are in the same order as those of [14], which applied the same method on Port-Bouet beach. It shows that the amplitudes are between 4 and 13 cm for the HE, 13 and 25 cm for the ME and more than 26 cm for the BE. The work of [11-14] showed that using the method of tracing using coloured sand buried at the bottom of the stakes makes it possible to determine the effective reworking. This effective reworking gives the actual amplitude of the thickness of the sediment layers actually reworked and those when the measurement period is more restricted (2 min, 5 min). Our work gives the highest amplitudes to the BE, these results are similar to those of [15] on the beach of Grand-Bassam. Saimon [10] work for 2015 on Port-Bouët Airport beach in a context of low agitation shows amplitudes that increase from the upper foreshore to the mid foreshore, before decreasing to the lower foreshore. The maximum amplitude obtained by this author is 45 cm at mid-forest, while ours is 38.5 cm at the bottom.These results are qualitatively similar to ours when we refer to the direction of growth of the movements although the beaches are physically distinct. Indeed, Port-Bouët beach is equipped with steep slopes subjected to high energies and Jacqueville beach is equipped with medium slopes subjected to moderate wave energies.

5. CONCLUSION

The study of the sedimentary dynamics of the Jacqueville coastline was considered from the point of view of redesign. This study allowed us to know the thickness of sand displaced per tidal cycle during the period of low wave agitation. It also made it possible to characterize the morphological evolution and size of the reworked grains. The results mainly concern: The morphological evolution of Jacqueville's beaches.The morphological evolution of the beach is known from beach topographic profile surveys. These reveal that the coastal perimeter of Jacqueville is a complex area, especially since for the same period while some beaches are becoming fatter and others are being eroded

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