Estuarine bedforms and Hydrodynamic of the Piranhas-Açu River Mouth, Northeast of Brazil.

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Abstract

Estuaries are important transitional areas as scientific as economic and environmental point of view. This study presents estuarine bedforms mapping associated with hydrodynamic data of the Piranhas-Açu River Mouth, where the river splits in three estuaries (Açu, Cavalos and Conchas), on the northern littoral of Rio Grande do Norte State, northeast of Brazil. The methodology used consisted of hydrodynamic and sonographic data acquisition in November of 2010, during the dry season, in spring tide. The main estuarines bedforms identified were: flat bed, small and medium 2D dunes and 3D dunes, produced in a lower regime, at depths range from 1 .5m to 8.0m with average speed flows from 0.2m/s to 1 .0m/s. The average speed flow on flood tide is around 0.5 m/s, and on ebb tide average between 0.8 and 0.6 m/s.

Introduction

According to Cameron & Pritchard (1963), an estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage. For Boyd et al (2006), estuaries receive sediment from both fluvial and marine sources, commonly occupy the seaward portion of a drowned valley, contain facies influenced by tide, wave, and fluvial processes, and are considered to extend from the landward limit of tidal facies at their heads to the seaward limit of coastal facies at their mouths.

The objective of this study is the estuarine bedforms and hydrodynamic characterization of the Piranhas-Açu River Mouth, where it splits in three estuaries: Açu, Cavalos, and Conchas.

The study area is inserted in a coastal environment, dominated by mixed processes of waves and tides, under semidiurnal and mesotidal regime. It is constituted by tidal flats, mangrove ecosystems, sand bars, dunes, barrier-spit systems and sand beaches (Figure 01). The mouth of these estuaries constituted the debouchment of the River basin Piranhas Açu-RN, the largest of this area, covering 34.7% (IDEMA 2009).

The Oil industry is the main socio-economic activity in this region, where units are installed on land and at sea, and so it is under high risk to oil spills. Other activities, such as salt production, shrimp farm, fishing, agriculture and tourism are also observed. Moreover the area is under constant action of coastal processes. Because of this environmental monitoring is necessary.

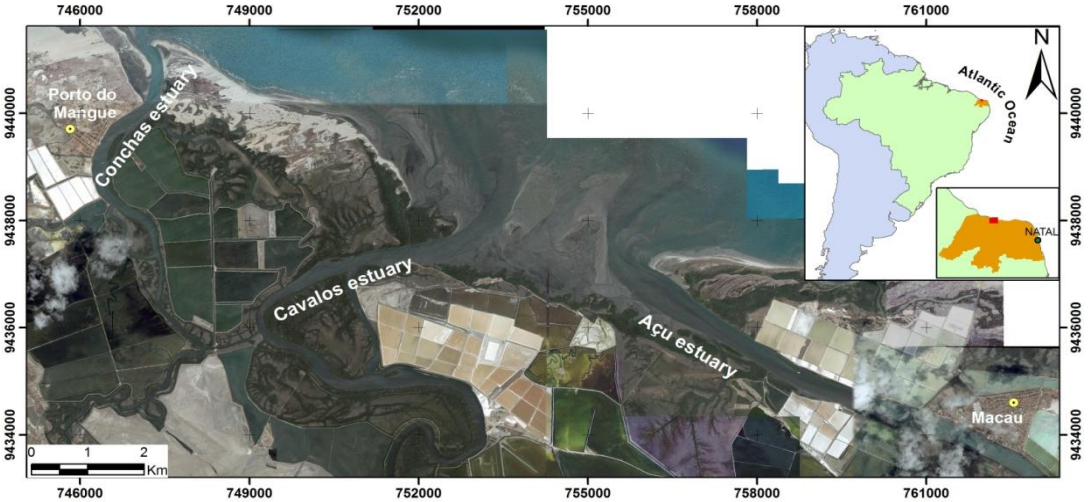

Figure 01 - Location Map of the studied area. Image: Google Earth (2010).

Geology Settings

The study area is inserted on geologic context from Cretaceous to Quaternary of the Potiguar Basin. It involves Cenozoic sedimentary rocks (Tibau, Barreiras and Potengi Formation) superimposed of Tidal flat, Alluvium, barrier-spits, Vegetated and Beach Aeolian quaternary deposits. The Cenozoic evolution in this region (Fonseca, 1996), is assigned for the reactivation of ancient fault systems, modeling the present surface and coastal sedimentation.

Method

Field work was developed in the 2010 dry season (November), during the spring tide. Hydroacoustic data (side scan sonar and ADCP) were acquired simultaneously during continuous 13 hours in each estuary (Açu, Cavalos and Conchas), in order to correlate the flow intensity with the subaqueous features.

The side scan sonar was an Edgetech model 272-TD with 500 kHz frequency and the current profiler Doppler effect (ADCP) a RD Instruments with 600kHz frequency. Bedforms were classified according to Ashley (1990), described by their shape and size based on spacing (Table 01). Sediment samples were collected with van-veen bottom grab where the sonar image different textures.

On their shape, if the flow pattern persist relatively unchanged in third dimension, the bedform produced is straight crested, termed 2D dune, and if the flow structure varies significantly in the third dimension the bedform reflects this as sinuous crested, and is termed 3D dune.

Table 01 – Classification of shape and size bedforms.

Classification scheme recommended by the SEPM Bedforms and Bedding Structures Research Symposium
Subaqueous Dune
First Order Descriptors (Necessary)
Size { Spacing / Height* } Small { 0.6 - 5 m; / 0.075 - 0.4 m; } Medium { 5 - 10 m; / 0.4 - 0.75 m; } Large { 10 - 100 m; / 0.75 - 5m; } Very large { >100 m / >5 m
Shape [2 Dimensional / 3 Dimensional
Second Order Descriptors (Important)
- Superposition: simple or compound (sizes and relative orientation)
- Sediment characteristics (size, sorting)
Third Order Descriptors (Useful)
- Bedform profile (stoss and lee slope lengths and angles)
- Fullbeddedness (fraction of bed covered by bedforms)
- Flow structure (time-velocity characteristics)
- Relative strengths of opposing flows
- Dune behavior-migration history (vertical and horizontal accretion)

* Height calculated using the equation $H = 0.0677\ L^{0.8098}$ (Flemming 1988) in Ashley (1990)

Results

In the Açu, Cavalos and Conchas estuaries, the main bedforms identified were: flat bed, small and medium 2D dunes and 3D dunes, produced in a lower regime, at depths range from 1 .5m to 8.0m with average speed flows from 0.2m/s to 1.0m/s.

The flat bedforms (Figure 02 and 03) were identified near of margin areas or upstream, where they are generated on the conditions of low speeds of the currents.

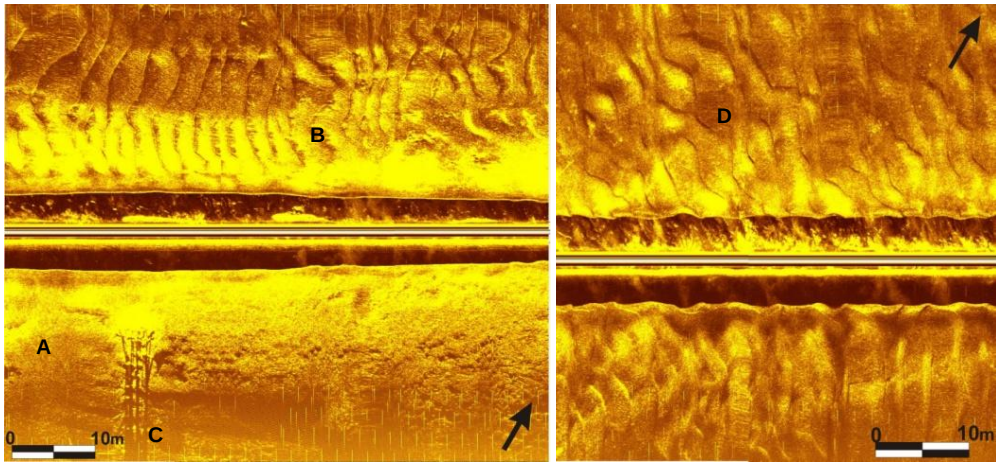

Figure 02 – Bedforms in Açu estuary. In A, flat bed area on the left margin. In B, 2D dunes superposed area with 2m to 5m of length and average high of 30cm. In C, fishing net marks. In D, 3D dunes area with 1m to 3m of length and average high of 20cm. The arrows indicate the North direction.

The subaqueous dunes, small and medium 2D and 3D (Figure 02 and 03), are generated near the mouth where there has abundant supply of material, as also in main channel, where the flow has a higher intensity for the mobilization of sediment. The source of sediments near the mouth is related to aeolian deposits and marine currents that transport material available on the coastline.

The three estuaries presents a similar behavior regarding the flow speed at flood tide (Figure 04A). In the upstream levels the flow is low (~0.2 m/s), then increasing (~ 1 m/s) until decreasing again, as a cyclical movement. From the center to downstream they show higher values, ranging gradually, except the Conchas estuary that decreasing at the mouth.

During ebb tide (Figure 04B) the estuaries showed the highest rates in the center, decreasing closer to the mouth, mainly to Cavalos (0.8 to 0.3 m/s) and Conchas (1 to 0.4m/s).

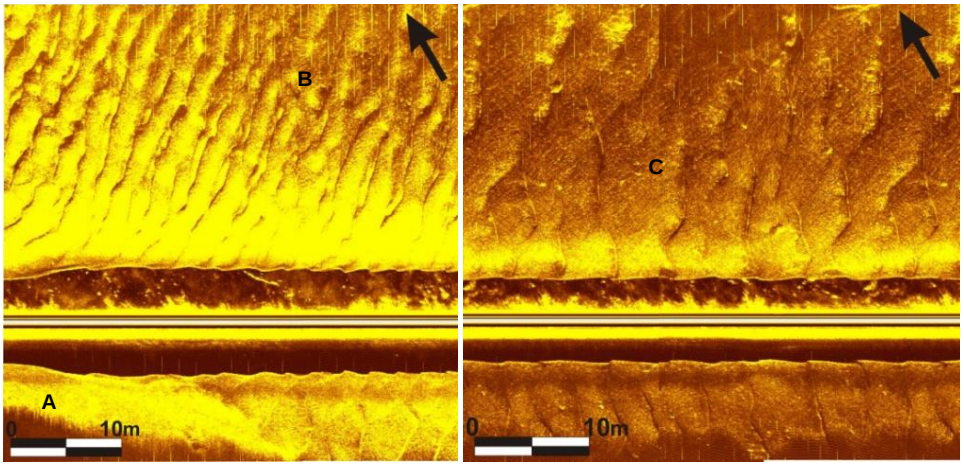

Figure 03 – Bedforms in Cavalos and Conchas estuaries. In A, flat bed area on the left margin of Cavalos estuary and in B, 2D dunes area with 2m to 3m of length and average high of 30cm. In C, 3D dunes area in Conchas estuary with 2m to 6m of length and average high of 15cm. The arrows indicate the North direction.

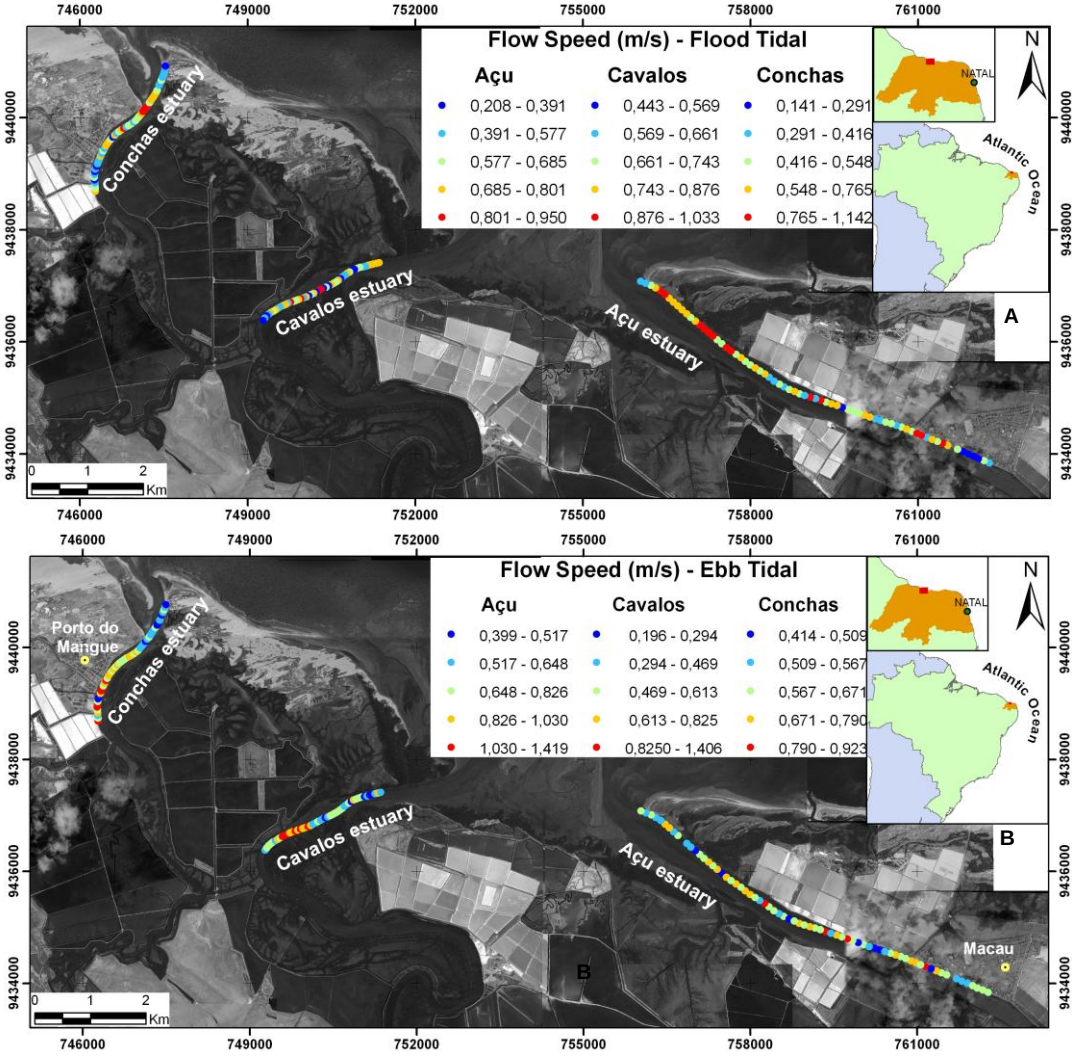

Figure 04 – Map of main speed flow values during the flood tide in **A**, and ebb tide in **B** for Açu, Cavalos and Conchas estuaries.

The flow direction during flood tide (Figure 05A) indicates the estuaries material input. In Açu, the main direction is SE, to Cavalos is W-NW and to Conchas is W-SW.

The flow direction during ebb tide (Figure 05B) shows the estuaries material output.

In Açu, the main direction is N-NW, to Cavalos is E-SE and to Conchas is E. In both tides, the direction of flow is influenced by the estuaries shape.

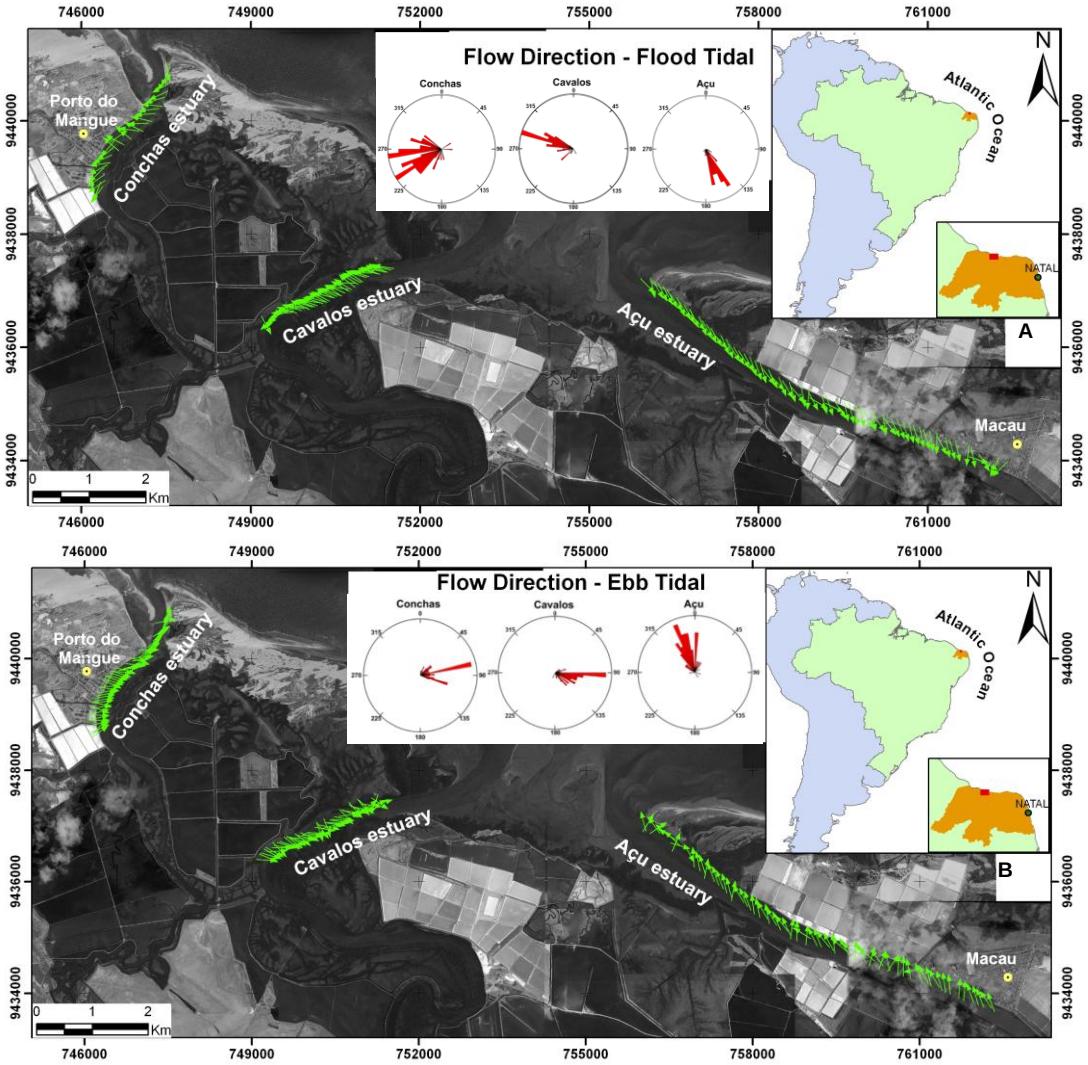

Figure 05 – Map of flow direction showing, in **A** the flood tide and in **B** ebb tide for Açu, Cavalos and Conchas estuaries.

Conclusions

The estuaries are inserted in a coastal region where the coastal processes are strongly active, that is noticed mostly by the dynamics morphological structures changes. And knowing the substrate of estuaries and their transport dynamics is fundamental importance for the construction of evolutionary models mainly where all socio-economic activities are dependent on these estuaries.

In the Açu, Cavalos and Conchas estuaries, were identified four different bedforms: flat bed, ripples, 2D dunes and 3D dunes, produced in a lower regime, at depths ranging from 1 .5m to 8.0m with average speed flows from 0.2m/s to 1.0m/s.

The average speed flow during flood tide is 0.6m/s to Açu, 0.7 m/s to Cavalos and 0.5m/s to Conchas. During ebb tide the average speed flow is 0.8m/s to Açu, 0.7m/s to Cavalos and 0.6m/s to Conchas.

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