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Environmental Hydrodynamic Modeling and Sediment Transport in Maputo Bay

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Abstract: In Maputo Bay, located in south of Mozambique, it is important to know the hydrodynamics circulation due to tides and local winds, as well as the sediment dynamics processes, to auxiliary the maritime navigation.For this work, a finite element modelling system has been adopted, this being employed SisBaHiA®, which is the acronym for Base System for Environmental Hydrodynamics in Portuguese. Simulations have been done using a 2DH hydrodynamic model coupled with a sediment transport model, forced with local winds, river discharges and tides.

This work presents results foran environmental hydrodynamic and sediment transport study, focused on the Maputo harbor area and close to the border open(near the Inhaca Island) in order to assess the trend of the drift of sediment.

The results showed that the tides are the physical process that dominates the circulation on the bay. The tidal current is highest in the central part of the bay than in eastern and western. As expected, current velocitiesare more intense during spring tidesthan during neap tides.It has not been identified any seasonal variations in tidal current intensities. In most parts of the bay,variations in bathymetry due to sediment transport showed small differences from summer to winter.

Key words: Tidal waves, Tidal currents, Hydrodynamic and Sediment Transport Model

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1. Introduction

Estuaries are coastal water bodies with great economic and biological importance. Are ecosystems rich in natural resources but with many features that make the study of these water bodies an extremely complex task. This complexity in terms of hydrodynamic circulation, fate of contaminants and sediment transport processes are becoming from the interaction constraints as river flow, tidal, irregular bottom topography, and surface tensions caused by wind.

In Maputo Bay, located in south of Mozambique, it is important to know the hydrodynamic circulation due to tides and local winds, as well as the sediment dynamics processes, to assist maritime navigation. This work presents results for an environmental hydrodynamic and sediment transport numeric study, focused on the Maputo harbor area and close to the open boundary (near the Inhaca Island) in order to assess the trend of sediment drifts.

The general objective was to assess the generation of the deployment to tidal currents in nautical charts, derived from sediments in Maputo bay and the specific objectives were to evaluate the change of tidal currents and assess through a bathymetric change the sediment transport model in Maputo bay after dredging;

Figure 1 shows the location of Maputo Bay, as well as stations selected to analyze the data obtained using hydro sedimentological models. The sations were named with the following names, A1-Tide gauge Location, A2-Midle of the Bay, A3 e A4-bundaries open locations.

2. Methodology

For this work, a finite element modelling system has been adopted, this being SisBaHiA®, which is the acronym for Base System for Environmental Hydrodynamics in Portuguese (Rosman,2015). Simulations have been done using a 2DH hydrodynamic model coupled with a sediment transport model, forced with local winds, river discharges and tides.

The bathymetry data were got from Chart of National Institute for Hydrography and Navigation in Mozambique and these data were reference to local Hydrographic Zero.

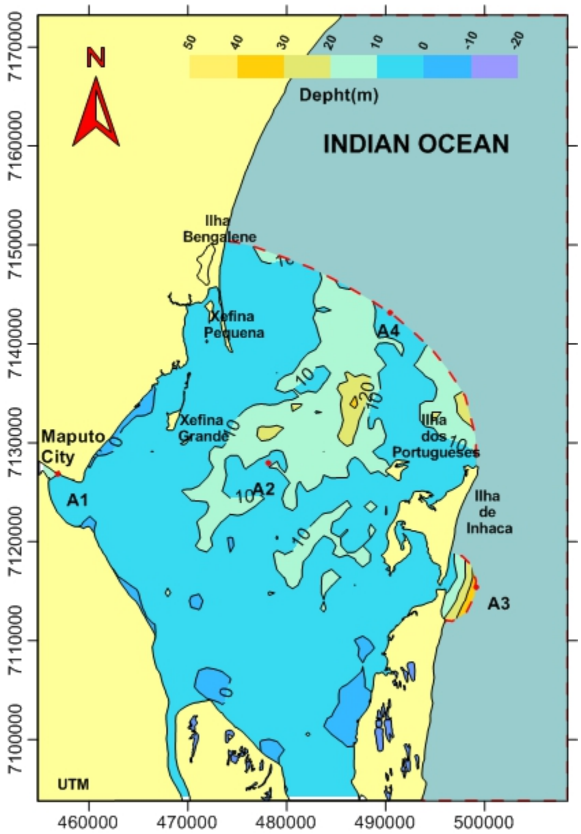

Figure 1. Location map of Maputo Bay showing bathymetry contours and control stations to analyze the tide variation from the open boundary (A4) until the tide gauge (A1).

For calibration of the hydrodynamic model, water surface elevation measurements have beenused collected using a pressure tide gauge, WLR (Water Level Record), installed in Maputo Harbor Station, figure 1.

The sediment data used as input for the model, to simulate the transport sediment into the bay,were collected byAchimo (2000). In this study, Achimo concluded that on average the sediments in Maputo bay are siliciclastic and sand-dominated because the depositional energy conditions are very high due to large scale reworking.

Addition to the data above mentioned, wind, river dischares and tide data have beenused to force the model. Wind data measurements have time step interval of one hour.

The figure 2, represents the typical wind for winter.

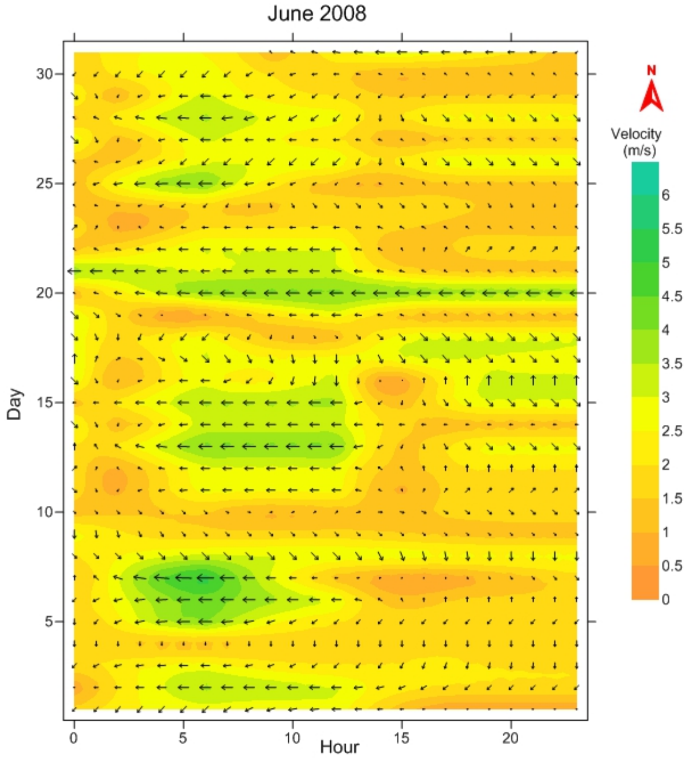

Figure 2. Winter wind representation for station situated near Maputo Bay.

2.1 Hydrodynamic Calibration Model

The hydrodynamic model was calibrated using data measured in Maputo Harbor tide gauge station. The data measured corresponds to an interval starting from June 22th, 2015, until August the 4th, 2015; with time step of 1800s.

The phase constant of 900s and reduction factor of 0.8 were used and imposing on the boundary open. The constant phase indicate that the tides from boundary open the reveal that is an increase in phase delay of wave propagation tide toward the coast.

Figure 3 shows the comparison between measured data and model results. As it can be seen from the graph, compared data shows a good agreement.

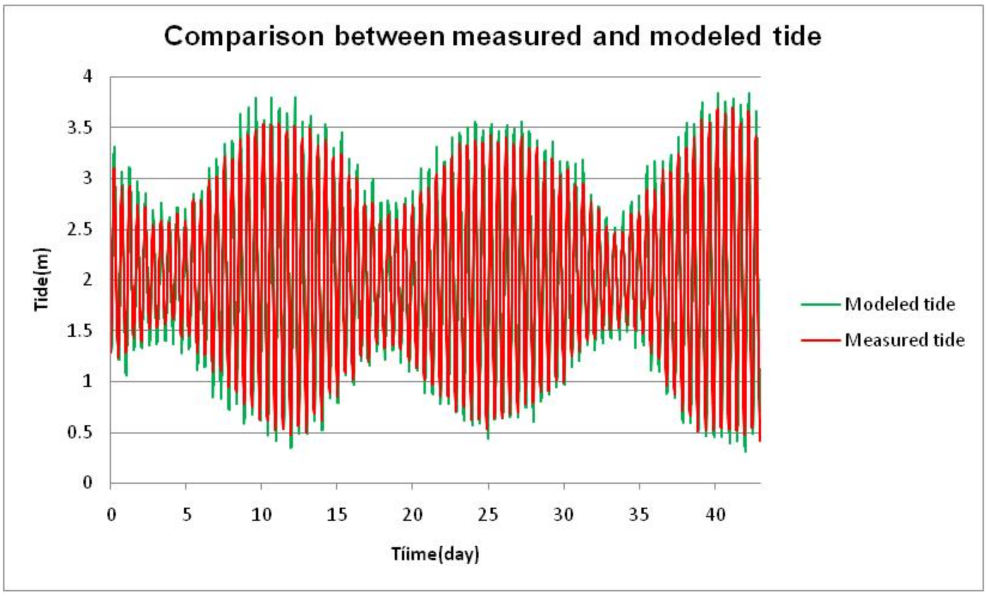

Figure 3. Comparison between measured tides in tide gauge and model results.

3. Results and Discussion

The data analyses were made using the stations A1. A2, A3 and A4 for neap and spring tides. An interval of fifteen days was selected to discuss the results obtained.

3.1 Hydrodinamic Characterization

The model was run using the measured tidesin Maputo tide guage in about 42 days and can be observed both tides, spring and neap. The model wasconfiguredto generate Spatial and Temporal results in 900-seconds time interval enabling the visualization of the spatio-temporal alterations.

Figure 4, shows the data details considering 15 days for transitions period between neap and spring tide for tide mensured and model results.

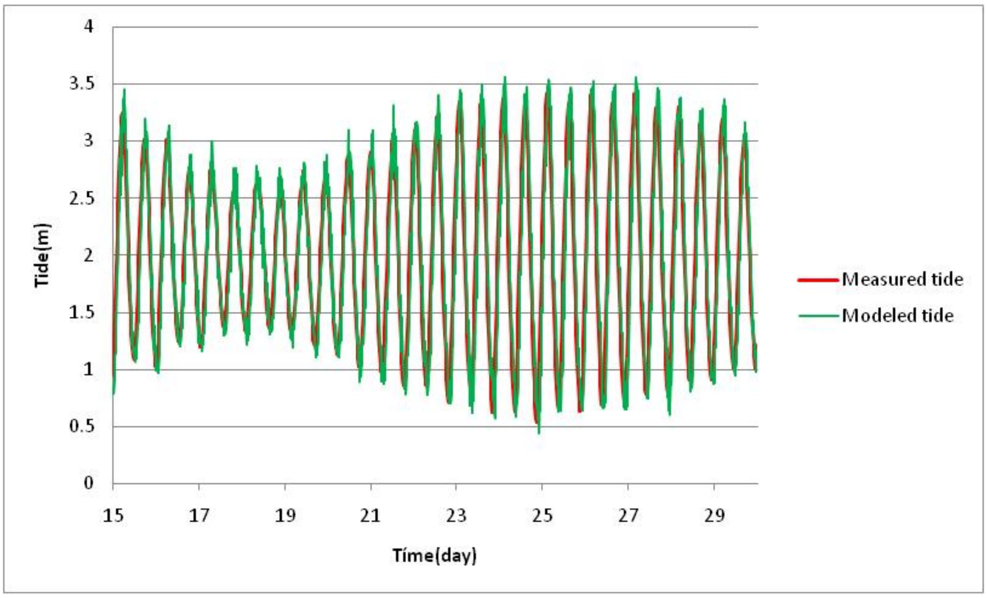

Figure 4. Details of tide measured and model results during 15 days for spring and neap tides.

The interval of the numerics simulation is approximately of two months, from June to August, 2015; as this is the period that was possible to get the data measurements from the tide gauge. For data analyse considering neap and spring tide were extracted from Figure 4 two days periods for both as showed in Figures 5 and 6.

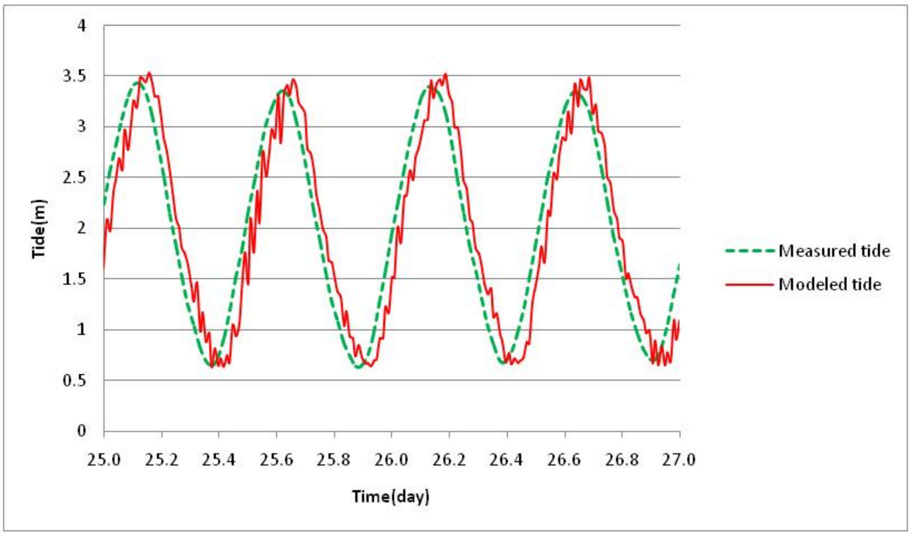

Figure 5. Comparison between measured tides in tide gauge and model results, spring tide.

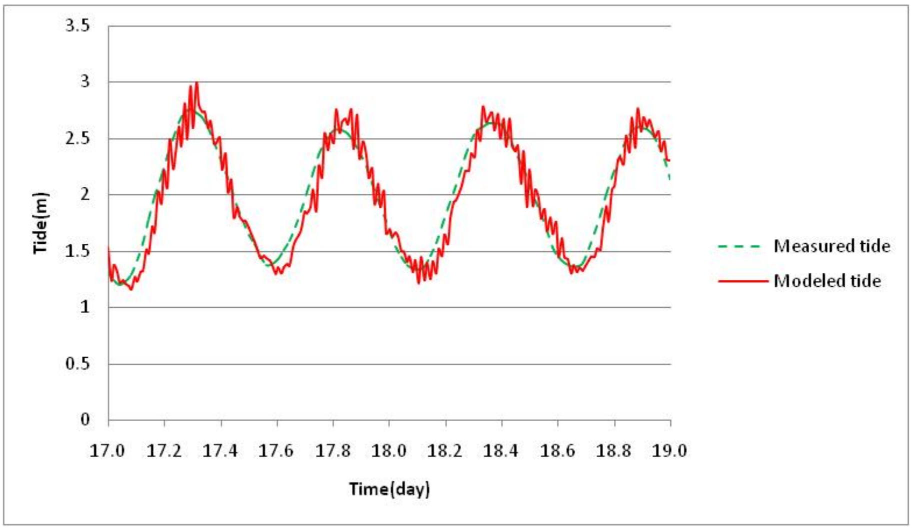

Figure 6.Comparison between measured tides in tide guage and model results ,neap tide.

The results in Figures 5 and 6 show the difference of phase for model and measured tide, it happened because the tidal wave to propagate toward the coast slows as result of decrease in depth near the tide gauge. The delay of tidal wave intensified when the tide propagation along the channels due to the significant effect of the friction. In study of Maputo Bay hydrodynamics, Canhanga (2004), concluded that phases of diurnal and semidiurnal constituents inside Maputo bay reveal that is an increase in phase delay of wave propagation tide toward the coast. During spring tide, amplitudes are greater than during neap tide.

After comparison made between Figure 5 and 6 was plotted Figure 7 with four stations from West(A1) to East (A4) as ilustred in Figure 1 with objective of analyse the behavior inside of Bay.

To more details were selected from Figure7, tide neap (day 17 to 19) and spring tide (day 25 to 27) , the illustration ofdata is only to winter period as showed in figure 2 .

Was concluded that the tide wave is very high from station A1 and decrease going to East bay, station A4. There is phase discrepancy from east to west bay.

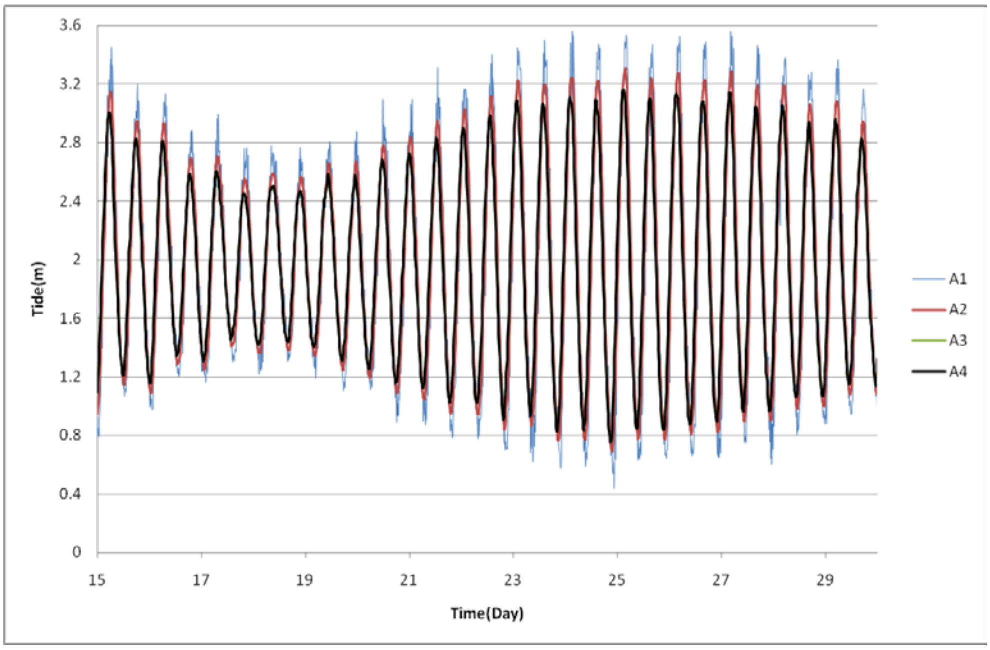

Figure 7. Water level time series comparison for all station during 15 days.

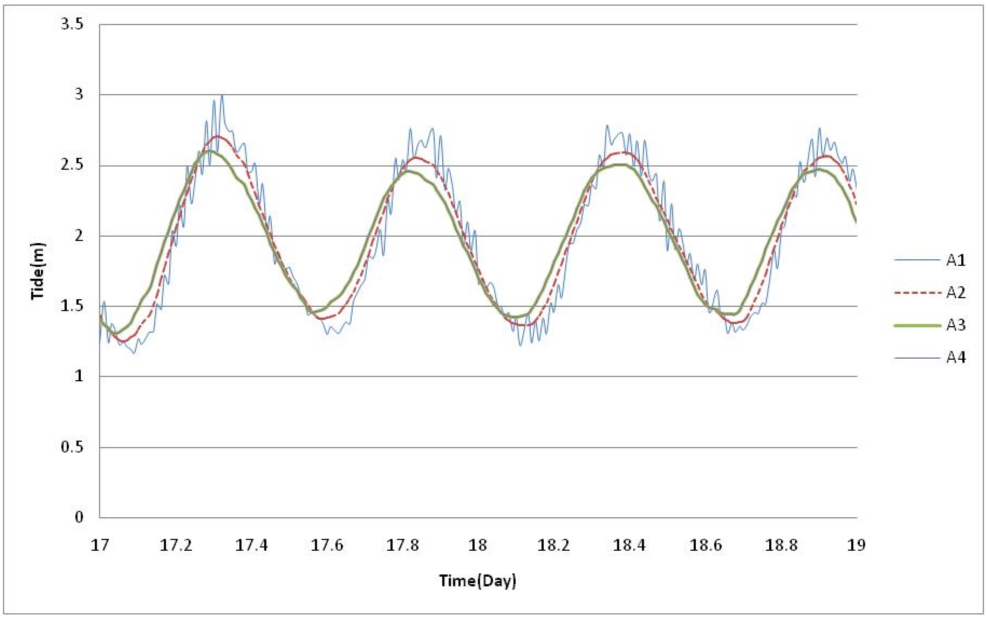

Figure 8. Water level time series comparision for all stations during neap tide. Station A1 corresponds to the tide gauge.

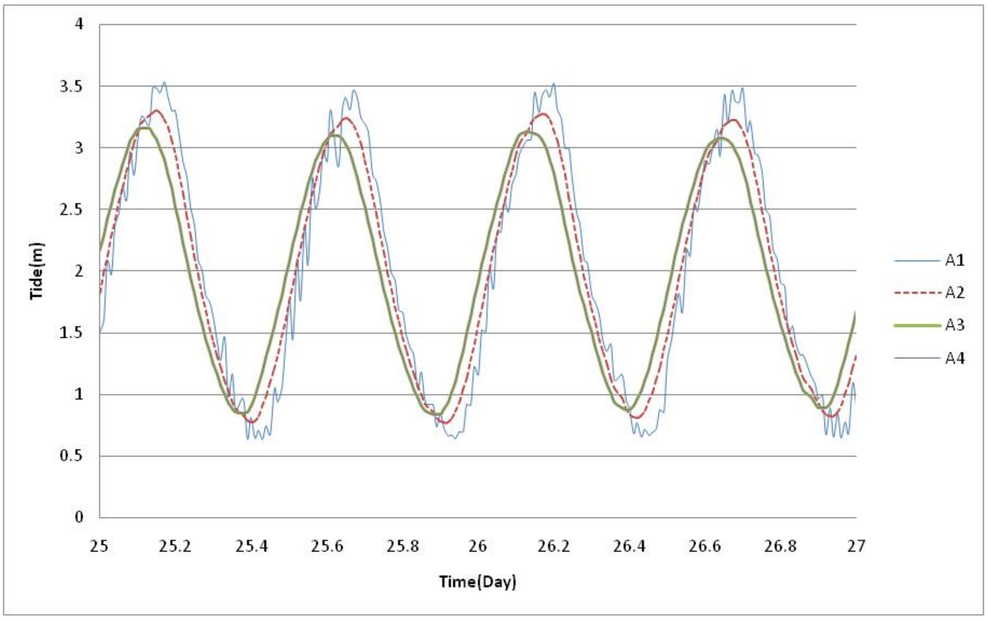

Figure 9. Water level time series comparision for all stations during spring tide. Station A1 corresponds to the tide gauge.

3.2 Tidal Currents

According Canhanga (2004), few studies on tidal currents were made on Maputo Bay and tidal currents vary from place to place,with maximum speeds ranging from 1.3m / s and 1.5 m/s during the dry season.

The tidal currents in Maputo bay were obtained from numeric simulation (2DH), through the velocity vectors with horizontal resulting components (u_x and u_y) of current velocities, prome diatedalong the water column. The vectors allow to evaluate the mean flow inside the bay.

In the first was plotted Figure 10 to analyse the behavior of progressive and stationary tide . Were plotted graphs of currents and tide for spring tide only where we have high tides and was concluded that the tide is typical stationary where the maximum velocity occurs near half tide ebb and flood and is became zero in low and high tide.

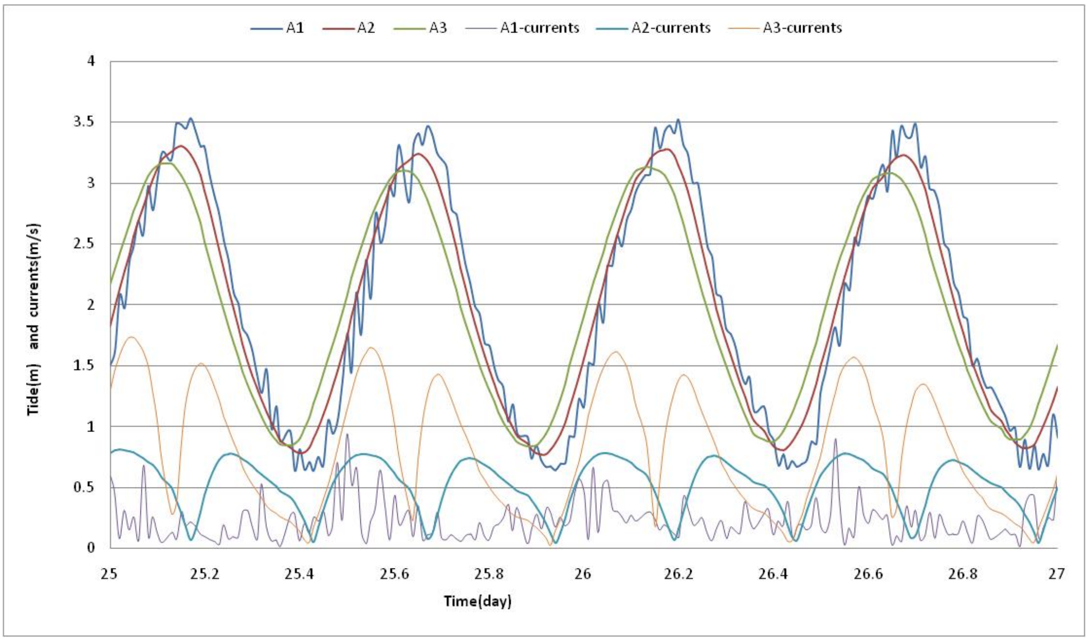

Figure 10. Graphics showing tide and currents in three stations selected.

The Figures 11 and 12 show graphics depict currents velocity variations in selected stations.Note that the greatest current speeds occur in spring tide, Figure 12, in neap tide the currents are not so intense, Figure 11.

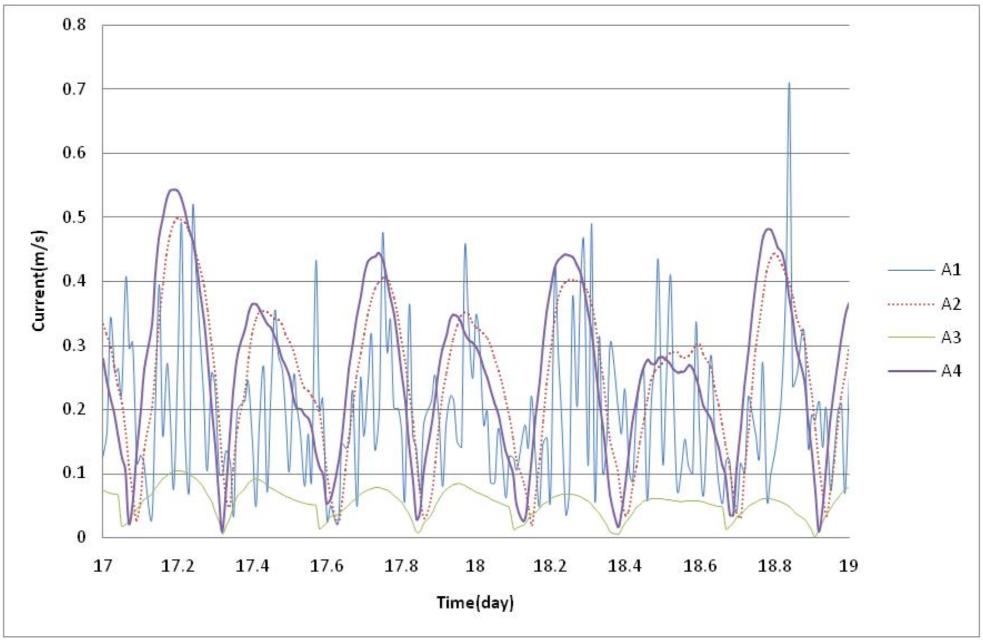

Figure 11.Currents velocities during neap tide.

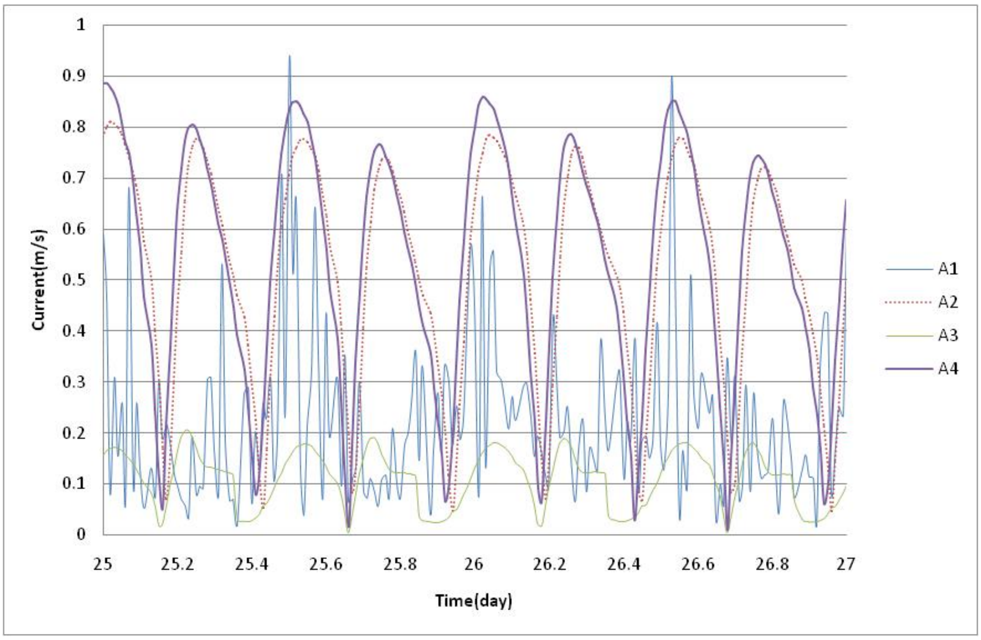

Figure 12. Currents velocities during spring tide.

3.3 Sediment Characteristic

The results of the bed bathymetry changes were computed using a sediment transport model coupled with an hydrodynamic model. The figures below illustrate bathymetric changes (delta h) after the simulation corresponding period of, about 42 days and forced winter winds.

It should be noted that there are displayed only graphs illustrating bathymetric changes in Tide Gauge location (A1), Midle of the Bay (A2), bundaries open locations(A3 e A4).The posite and negative signal indicate erosion and silting, respectively.

In both graphics the results show that the bathymetry alterations were insignificant for erosion and sedimentation after the simulated period.

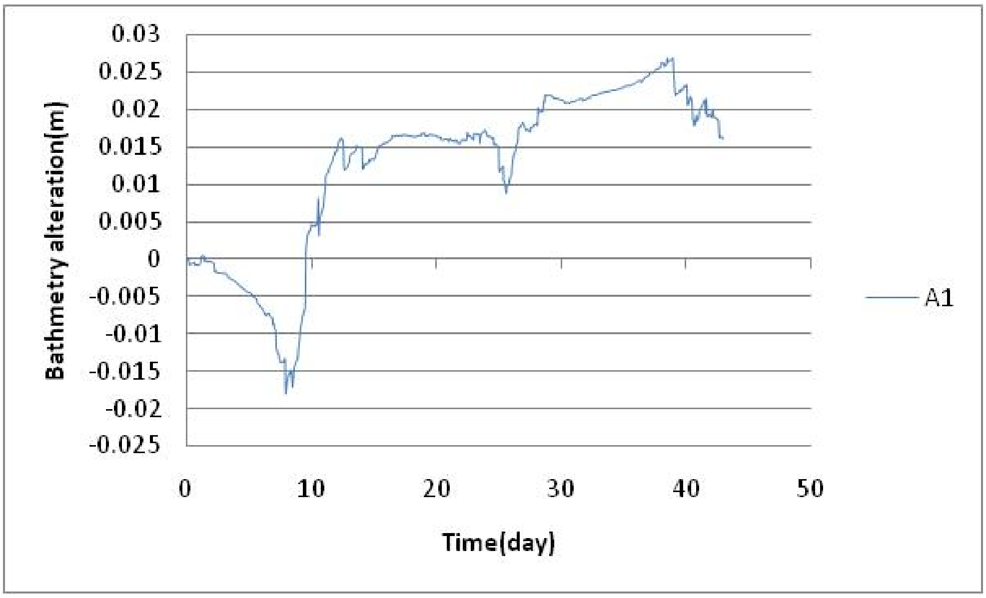

Figure 13.Bathmetry alteration near Tide Gauge Station.

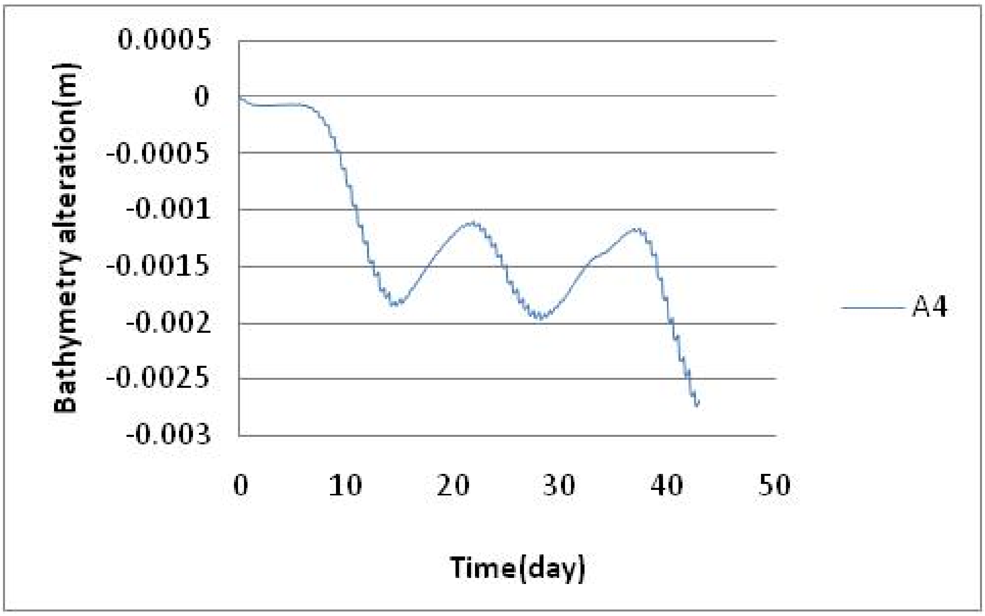

Figure 14.Bathmetry alteration near boundary open

4. Conclusions

The results confirm that the Maputo bay is dominated by the action of the tide, this fact confirms the results presented in studies passed by Canhanga (2004). Using the hydrodynamic and sediment transport model as a tool for understanding the hydro-sedimentological results occurring in Maputo bay,was possible to understand the effects of the forcing agents on the system.

About hydrodynamic circulation, the results showed that the tide variation is more intense at the station A1, West of the bay and became lessintense near the model open boundary (A4). The phase difference is due to performed calibration.

Results show that the tide isthemain physical process that dominates the hydrodynamic circulation on the bay. Tidal currents are stronger in the central part of the bay than in the Eastern and Westernparts. As expected, current velocities are more intense during spring tides than neap tides. It has not been identified any seasonal variations in tidal current intensities. In stations A1 and A4,variations in bathymetry due to sediment transport showed small differences in winter**.**

Acknowledgment

Has experience in Geosciences with an emphasis on Synoptic Meteorology in Coastal and Ocean Engineering and topography. Acts primarily in the areas of hydrodynamic modeling and sediment transport.

Experience in topography (leveling in local access to main and secondary ports of Mozambique) and oceanography at the National Institute of Hydrography and Navigation.

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