

Modelling Test of Marine Submersion applied to Port-Bouet and Grand-Bassam Coasts (Côte d'Ivoire)

Jacques André Tiemélé¹, Eric Valère Djagoua², Brice Abaka Mobio³, Jean Baptiste Kassi⁴

PhD Student, Department of Climate, Environment and Sustainable Development, University Center for Research and
Application of remote Sensing, Abidjan, Côte d'Ivoire¹

Associate Professor, Department of Climate, Environment and Sustainable Development, University Center for
Research and Application of Remote Sensing, Abidjan, Côte d'Ivoire²

Associate Professor, Department of Climate, Environment and Sustainable Development, University Center for
Research and Application of Remote Sensing, Abidjan, Côte d'Ivoire³

Associate Professor, Department of Climate, Environment and Sustainable Development, University Center for
Research and Application of Remote Sensing, Abidjan, Côte d'Ivoire⁴

ABSTRACT: In order to face the series of storms occurred in recent years on the Ivorian coast, environmental, socio-economic and human resources damaging of the coastal zone allowed to take modelling test of submersion marine applied on the more vulnerable coasts, such as Port-Bouët and Grand-Bassam. This study aims to understand the temporal and spatial evolution of sea level occurred from 25 to 26 August 2011 night. Numerical simulations using DELFT 3D were made at high resolution on a 12 h period for 0.5 min time step. From an hour simulation, the elevation increases exponentially to about 3 m to 12 hours of simulation. The resulting wave setup meanwhile, are between 0.01 and 1.84 m, resulting in an average of 0.66 m. Intense hydrodynamic activity created by the tide in a position of ebb out of the Vridi channel coupled to significant wave height (2.92 m) and wind speeds (4.2 m/s) and the natural grau closure of Grand-Bassam could explain water level on these coasts.

KEYWORDS: Modelling test, Marine submersion, DELFT 3D, Wave setup

I.INTRODUCTION

Sea-level rise is one of the major consequences of global warming, which threatens many low coastal areas and small islands, heavily populated. In these areas, sea-level rise is amplified by constraints due to natural phenomena (for example, the subsidence in deltaic areas induced by sedimentary loading, vertical movements of the ground due to plate tectonics, volcanism and the post-glacial rebound, etc) or / and human activities (for example, the land subsidence due to groundwater pumping and/or extraction of oil, urbanization, etc.). In addition, tide observations of the last century, and sea level measures from space missions of altimetry, for decades, have shown that sea-level rise was not uniform, instead showed strong regional variabilities, Becker and al. [1]. In the Gulf of Guinea, local storms were locally observed in May 1997, July 1998, August 1999, September 2001, September 2006, July and October 2007, September 2008 and may 2009 [2]. They are usually of short duration, from a few hours to a day. Those classified as regional were observed in August 1996, 2002, 2007, 2011 and 2012. They are the most prominent due to their impact on the entire region and their relatively long duration (1 to 2 days). In Côte d'Ivoire, the storm event of August 2011 has caused erosion and an exceptional flooding of Port-Bouet and Grand-Bassam coasts. It began on August 25, 2011 and ended August 26, 2011, marked by a significant wave height of 3.11 m.

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II. PRESENTATION OF THE MAIN CONTRIBUTION OF THE PAPER/SCOPE OF RESEARCH

A lack of scientific knowledge on this problem that occurred on these ivorian coasts justify this work namely measures insufficiently accurate or incomplete of sea level on these coasts; a lack of knowledge on the temporal evolution of waves height and a gap in understanding, the high-resolution modeling and prediction of the wave setup, flooding factor in the short term. Simulating test for the wave setup during the events of August 2011 appear necessary to understand and improve the accuracy in the prediction of currents and water levels on these sensitive ivorian coasts. Between 3 and 5°N North and 3.5 and 4.8 ° N West, (Fig. 1), the length coast between Port-Bouët to Grand-Bassam is about 42 km. Port-Bouët coast is interrupted by the Vridi Canal, which connects the Ebrié Lagoon to the Atlantic ocean. The east part is represented by Phare, Derrière Warff, Adjouffou, Modest and FHB international Airport areas. Grand-Bassam area is a tourist attraction with its many resorts which some are located in areas of Coconut village and Mondoukou. Fishing activities are strongly practised in these sectors, including Awankro, camp of fishermen.

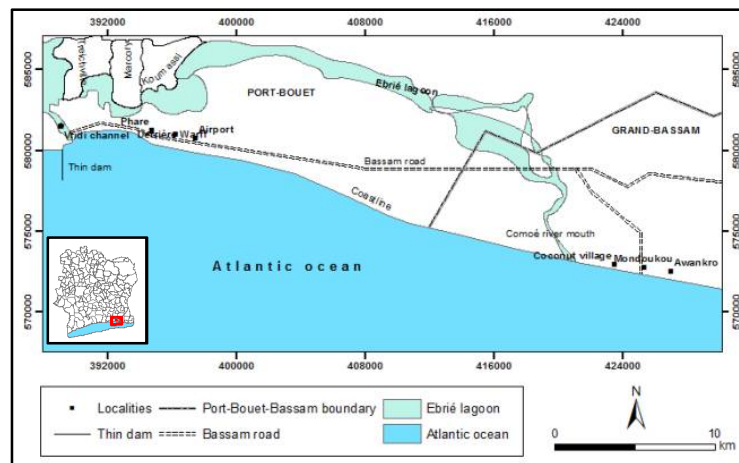


Figure 1 : Location of study area

III. METHODOLOGY PROPOSED

III.1 Data and Methodological Approach

Material used for numerical simulation testing is the DELFT 3D software. It is a model that uses the finite difference numerical method for solving hydrodynamic equations in coastal, estuarine areas and artificial environments such as bridges and ports.

Tidal daily data were acquired on the site <http://www.shom.fr/les-services-en-ligne/predictions-de-maree/presentation/> and significant waves height and winds on the site las.aviso.altimetry.fr/las/getUI.do/ for the period from September 2009 to August 2011. Simulations of water heights scenarios were possible by statistical processing of time series of the data used. The propagation of waves at the coast model has been studied to determine the wave setup.

III.2 Mesh Size of the Study Area

The mesh used for the simulations has been generated using the mesh RGFGRID generator built into Delft3D. It helped define 74 'grid' points in cartesian coordinates in the horizontal direction (direction M) and 99 'grid' points in the

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vertical direction (direction N). The spatial resolution is 100 m and 59 m respectively in the M and N directions. The refinement is 2 * 2 in the surf-zone (fig.2).

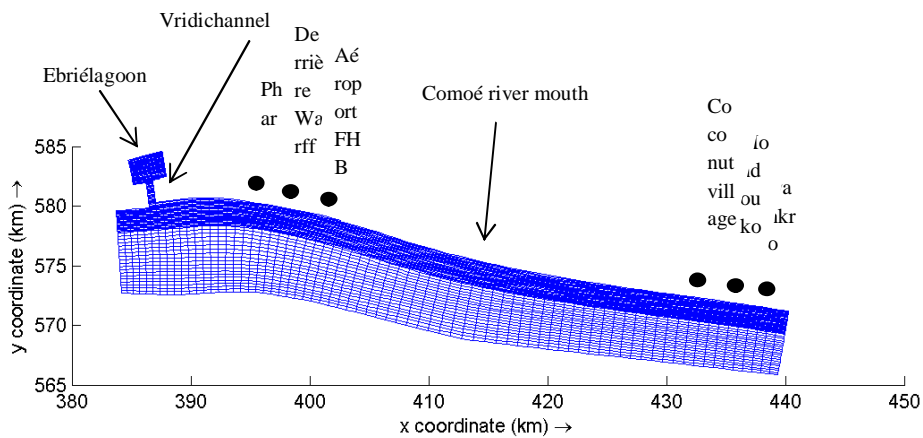


Figure 2 : .Mesh of studyarea

III.3 Bathymetry

The bathymetry of the study area has been reconstructed from about 50 points. Depths (between 0 and - 140 m) input data are entered on the grids through nodes and then interpolated by triangulation using interpolation model Delft3D-QUICKIN tool. Calculated water height results from the average depths of 4 nodes in the mesh (fig. 3).

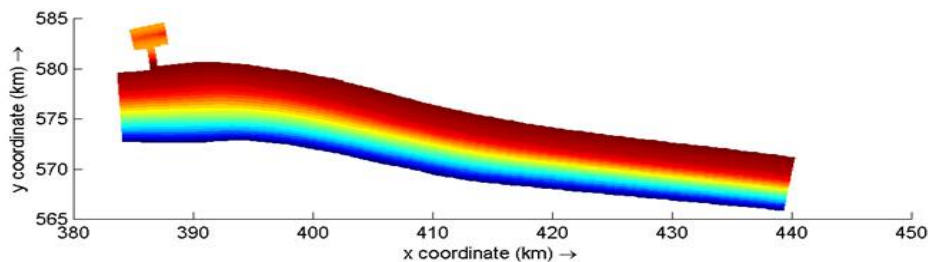


Figure 3 :.Bathymetry of study area (m)

III.4 Initial Conditions

In this study, the data used to prepare scenarios of simulations of tidal/wave /vents are used in Flow and Waves of the DELFT 3D software modules. These are data from tide, waves and winds, the physical parameters (roughness, water density, gravity, viscosity), the thin dam, the time step.

III.5 Boundary Conditions

The boundary conditions are given for each of the border points of the field of study. They describe the types of open boundary: level water and Neumann. The southern boundary of the ocean, the western of Vridi Canal area, the east boundary of Grand-Bassam area and the northern area of Ébrié lagoon. The forcing type is the harmonic type.

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III.6 Time Step

The time step used was calculated using the relationship power-Friedrichs-Lewy number (CFL), which had been recommended by the manual for model Delft3D-FLOW user:

$$CFL = \frac{\Delta t (gH)^{1/2}}{(\Delta x, \Delta y)}$$

Δt : time step (min). g : gravity (m/s²); H : total water depth (m); $(\Delta x, \Delta y)$: minimum value of the size of mesh in the lateral and longitudinal directions, CFL: number of current (≤ 10).

IV. EXPERIMENTAL RESULTS

IV.1 Temporal Evolution of Sea level during the Simulation

The results of the simulation from 25 August 2011 to 26 August 2011 were able to predict simultaneously a sea level-rise between 1.08 and 3 m. Between 0 and 2 h, sea level-rise varies very little and lies between 1.08 and 1.1 m. From 2 hours, the variation becomes exponential for the duration of the simulation to reach 3 m (fig.4).

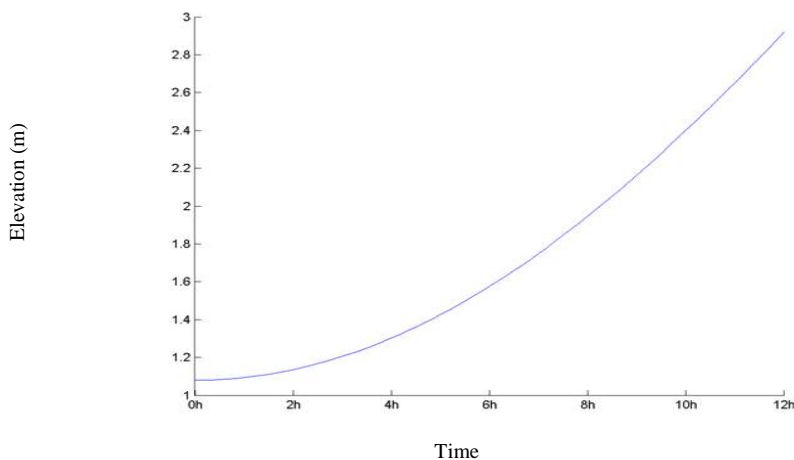


Figure 4: Temporal evolution of sea level during the Simulation

Comparing changes in observed and modelled sea level-rise, are deduced the wave setup. Up to 2 hours, there is a coincidence of observed and modelled data. It is from this time that changes were distinct. Observed data ranged from 0.48 m to 0.88 m while those modelled lie between 0.73 and 2.64 m. The resulting wave setup meanwhile, are between 0.01 and 1.84 m, resulting in an average of 0.66 m (fig.5).

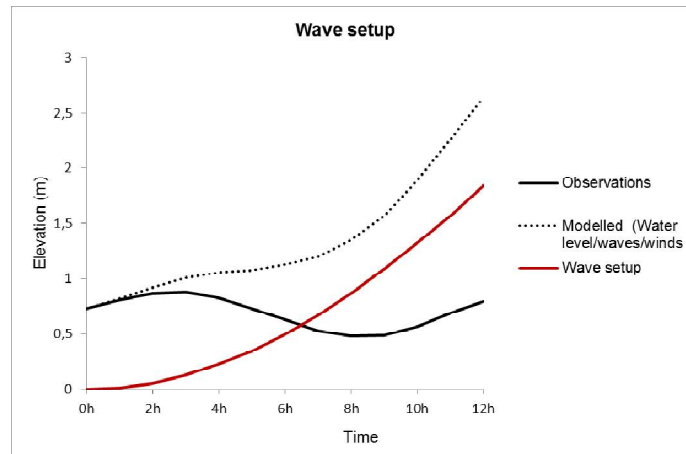
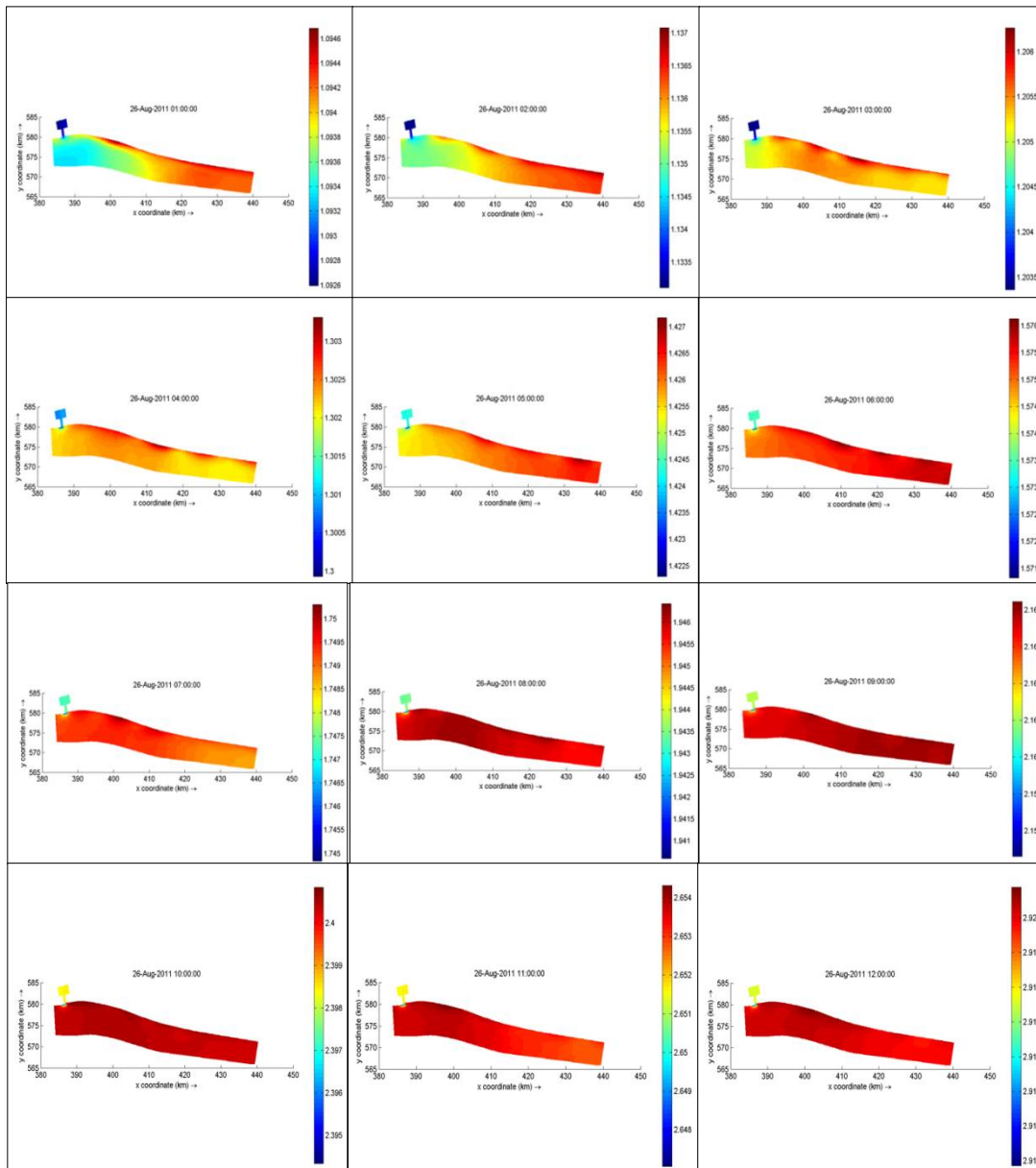


Figure 5: Wave setup observed

IV.2 Spatial evolution of Sea level during the Simulation

1 h of the simulation, the sea level rise from 1.08 to 1.09 m on Port-Bouet and Grand-Bassam coasts. Phare, Derrière Waff, FHB Airport, Coconut village, Mondoukou and Awankro localities undergo elevation of 1.094 m whereas at Canal Vridi, it is 1.093 m. At 2h, this increase oscillates between 1.133 and 1.137 m, an increase of 43 mm. This increase is gradually done towards the east of the study area and the towns of Mondoukou and Awankro seem most affected. A 3h and 4h of simulation, water levels become larger and reach respectively 1.2 and 1.3 m, representing increases 12 and 22 cm on the coast. The water level in the Vridi canal reached 1.4 m at 5h of simulation and elevation is again towards the east of the study area to reach 1.427 m on the coasts and Mondoukou Awankro. This rise is intensifying around 6h, reaching 1.5 m and mostly at the output of Port Bouet in the area of the mouth of the Comoé River and Grand-Bassam with water levels 1.576 m. At 7 h, water levels reached 1.7 m but the situation is reversed. Only the Port-Bouet coasts undergo heights of 1.75 m while those of Grand-Bassam remain relatively less affected. This scenario is almost the same at 8h but with higher heights oscillating around 1.946 m in the area of the mouth of the Comoé river and Port-Bouet coasts. At 9 h, the water level is 2.1 m and the areas of FHB Airport and Grand Bassam are the most affected with heights of 2.164 m. Between 10 h and 11 h, elevations become maximum and are between 2.4 and 2.6 m with a greater tendency on the coast of Port-Bouet (2.5 to 2.654m). It is 12 h the coast of Port-Bouet undergo elevation about 3 m while those of Grand-Bassam remained at 2.9 m.

Fig. 6 shows spatial evolution of sea level during the simulation.



V.DISCUSSION

Analysis of the deterministic principle of wave setup of our study appears to rely on the techniques used for the estimation of risk of marine flooding and/or mapping of flood areas on most low coasts. Clearly, this principle is adopted by some authors [3]; [4], Pirazzoli and al. [5]; Benavente and al. [6]; Caspar and al. [7] who believe that the greatest wave setup generally occur during storms that generate strong waves. Suanez and al. [8] investigated the wave setup by statistical analysis of extreme sea levels to assess the risk of flooding of low coasts applied to the beach of Vougot, Brittany (France).

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These waves setup vary between 0.431 m ($T = 2$ years) and 0.794 m ($T = 100$ years) and have been obtained from tide gauge data and waves (Hmo and Tpic) simulated digitally over the period 1979-2002 at a point off the coast of Brittany using TOMAWAC. This concerned the project of construction of a coastal and Sea Ocean Atlas Digital of States along the Atlantic coast and the North Sea. To understand the extreme sensitivity of these coasts, other high-resolution digital waves and tides propagation models were made by Chaumillon and al. [9] for wave setup study on the night from 23 October 1999 to 24 October 1999 to the ports of La Pallice (0.2 m) and Chapus (0.1 m) taking into account the non-linear interactions between the tides, the waves and the wind. These wave setup calculated in these areas are less than that determined in our study. Intense hydrodynamic activity created by the tide on the Port-Bouet and Grand-Bassam coasts due to the closure of the natural groyne of Grand-Bassam and the artificial channel Vridi since 1950 could explain these differences. To resolve this issue, the river Comoé outlet in Grand-Bassam was opened by numerical simulation using TELEMAC 2D by Mondé and al. 2011 in order to quantify the transfers of water between the Atlantic ocean and the Ébrié lagoon. The simulations allowed to show a decrease in the quantity of water and the effect of flushing in Grand-Bassam ; in Vridi area, the effect of flushing and ebb currents are most important.

VI. CONCLUSION

Ultimately, tests of hydrodynamic numerical simulations were needed to understand the prediction and accuracy of storm wave setup during the events of August 2011 on the Port-Bouet and Grand-Bassam coasts. The numerical modelling of marine submersion using the DELFT 3D software allowed to monitor spatial and temporal high-resolution variations of the sea-level rise.

The simulated average wave setup of 0.66 m expresses the sea-level that would cause the coasts submersion with a 2/3 contribution. These models of marine submersion test should lead to decision-making regarding the establishment of a sustainable management of the coastal development of the ivoirian coasts.

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