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Delft3d Model of The Estuarine Area of The Ebrié Lagoon In The Low Water Period

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Abstract:*The FLOW module of Delft3D software was used to simulate the 3D hydrodynamic processes during the low water in the estuarine area of the Ebrié lagoon. We choose this area because in term of hydrodynamics it's the most active area of the lagoon. This study was carried out to simulate and therefore to understand the current behaviour across the water column.he calibration focused on bottom rugosity, water viscosity and the time step. We chose the good value of this parameters after comparing three statistic indicators of each test: root mean square error (RMSE), coefficient of correlation (r) and coefficient of determination (R^2).*

This study highlighted results from others studies such the current velocities are low (<2.5 m/s) and their regime depends of the shape of the considered area. Currents have an alternative regime in tight areas and a giratory regime in wide areas. We also highlighted vortexes in the central basin that appear during the flow.

Finally, this simulation showed that current velocities decrease with depth and water has a synchronous movement along the water column.

Keywords *: Delft3D, 3D model, Ebrié lagoon, current, low water, hydrodynamic, estuary, water column.*

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I. Introduction

Likeany lagoon environment, the Ebrié lagoon is a transition area between Atlantic ocean and the town of Abidjan in ivory coast where it crosses several municipalities. The estuarine area of this lagoon (figure 1) is under the full influence of the tide at sea and so is very active hydrodynamically.In order to understand the hydrodynamism of this lagoon, a lot of studies have been carried out, amongothersVarlet (1978), Lemasson et *al* (1981), Wango (2002),Affian (2003) et Yao (2010). The development of computer sciences and specially numerical modelisation allow today a better understanding of hydrodynamic processes and a sustainable management of these environments. Many hydrodynamic processes modelisations of this lagoon have been carried out (Pouvreau, 2002; Brenon et *al.* 2004; Monde (2004) et Wango (2009)).

These models allowed a better understanding of hydrodynamic processes of the Ebrié lagoon. However, these models have the common particularity to be in two dimensions (2D). This kind of model implies that there is no variation along the water column while Yao (2010) proved that there are velocity and directions variation of current along the water column.The purpose of this project is to propose an additional parameter such as variation along the water column to the previous models. This study is to do a 3D model, it will appreciate the behavior of water along the water column.

Figure1 : localisation of the study area on the Ebrié lagoon

II. METHODOLOGY

The study was undertaken with Delft3D developed by The Dutch research institute “Deltares”. It’s a model who contains several modules (figure 2). The module used in our study is FLOW/MOR. It treats the water circulation in 2D, 3D and the sediment transport.

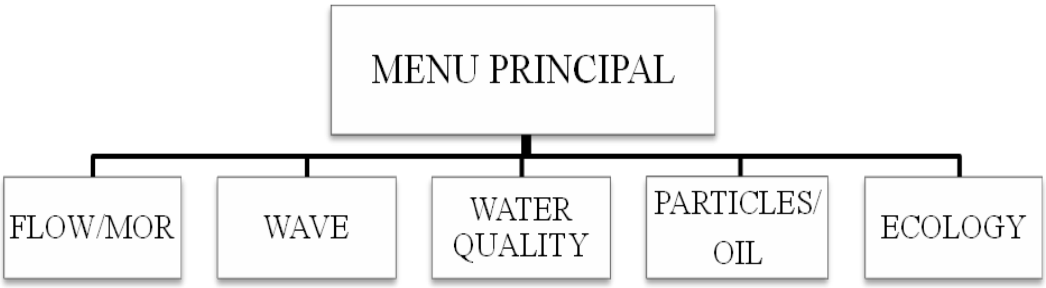

Figure 2 : Delft3D system architecture

The flow module is based on the resolution of Navier-Stokes equations that can be summarized by this three equations :

$$\frac{\partial u}{\partial t}+\frac{u}{\sqrt{G\xi\xi}}\frac{\partial u}{\partial \xi}+\frac{v}{\sqrt{G\eta\eta}}\frac{\partial u}{\partial \eta}+\frac{\omega}{d+\zeta}\frac{\partial u}{\partial \sigma}-\frac{v^2}{\sqrt{G\xi\xi}}\frac{1}{\sqrt{G\eta\eta}}\frac{\partial\sqrt{G\eta\eta}}{\partial \xi}+\frac{uv}{\sqrt{G\xi\xi}}\frac{1}{\sqrt{G\eta\eta}}\frac{\partial\sqrt{G\xi\xi}}{\partial \eta}-fv=$$
$$-\frac{1}{\rho 0\sqrt{G\xi\xi}}P\xi+F\xi+\frac{1}{(d+\zeta)^2}\frac{\partial}{\partial \sigma}\left(v_{\mathrm{v}}\frac{\partial u}{\partial \sigma}\right)+M\xi, \quad (1)$$

$$\frac{\partial v}{\partial t}+\frac{u}{\sqrt{G\xi\xi}}\frac{\partial v}{\partial \xi}+\frac{v}{\sqrt{G\eta\eta}}\frac{\partial v}{\partial \eta}+\frac{\omega}{d+\zeta}\frac{\partial v}{\partial \sigma}-\frac{uv}{\sqrt{G\xi\xi}}\frac{1}{\sqrt{G\eta\eta}}\frac{\partial\sqrt{G\eta\eta}}{\partial \xi}-\frac{u^2}{\sqrt{G\xi\xi}}\frac{1}{\sqrt{G\eta\eta}}\frac{\partial\sqrt{G\xi\xi}}{\partial \eta}+fu=$$
$$-\frac{1}{\rho 0\sqrt{G\eta\eta}}P\eta+F\eta+\frac{1}{(d+\zeta)^2}\frac{\partial}{\partial \sigma}\left(v_{\mathrm{v}}\frac{\partial v}{\partial \sigma}\right)+M\eta, \quad (2)$$

$$\frac{\partial \zeta}{\partial t}+\frac{1}{\sqrt{G\xi\xi}\sqrt{G\eta\eta}}\frac{\partial((d+\zeta)u\sqrt{G\eta\eta})}{\partial \xi}+\frac{1}{\sqrt{G\xi\xi}\sqrt{G\eta\eta}}\frac{\partial((d+\zeta)\,v\sqrt{G\xi\xi}}{\partial \eta}+\frac{\partial \omega}{\partial \sigma}=$$
$$(d+\zeta)(q_{in}-q_{out}) \quad (3)$$

2.1 The Grids

Our model is in 3D, therefore we have two grids : one in the horizontal plane and the second in the vertical plane.The grid in the horizontal plane is curvilinear because the shape of our study area is irregular. Meshes are more refined in the Vridi chanel than the rest of the study area because hydrodinamically it’s the most active area due to its proximity with the sea.The grid in the vertical plane is a σ-grid. With this grid, we cut the water column in four (04) layers named from the top to the bottom C1, C2, C3 and C4 and each of the total depth at each point. This choice is done according to Yao (2010) who worked on five (05) layers but showed that the variation is in four steps.

2.2 Boundary condition

We have three (03) opened boundaries : the entry of the Vridi chanel to the South, the outlet of the river Agneby to the West and the outlet of the river Comoé to the East. The conditions imposed on those opened limits are time-series of total discharge at the rivers outlets and a time-series of water level variation at the entry of Vridi chanel. The values of total discharge at the outlets of the rivers Comoé and Agneby are respectively0.840 m^3/s et 0.051 m^3/s. to these limits, we added data of wind with a direction of 220 degree and a velocity of 3m/s.

2.3 Calibration

As well as any other model, we needed to calibrate our model before to launch the simulation. The calibration permitted to determine the appropriate values of bottom rugosity, viscosity and diffusivity of the model in our study area. The results are in the table I.

Table I : calibration results

Bottom rugosity	Horizontal Viscosity, Diffusivity	Vertical Viscosity, Diffusivity
n = 0.05 $m^{-1/3}s$	v_H =1 m^2/s, D_H = 1 m^2/s	v_V = D_V= 5.10^{-5} m^2/s

The time step of the simulation is 1 min.

III. Results Et Interpretation

Figures 3 and 4 show the current evolution at two (02) period of the tide in the ocean: the high tide (PM) and the low tide (BM) in the four (04) layers of the water column.

At the low tide (figure 3), current in the estuarine area are directed towards the sea, we are in the ebb flow. Flood velocity falls with depth. The highest velocities worth 1.4 m/s and are located at the surface of the water in Vridi channel.Currents are fasters in the tight areas than the wide areas. Current have the same direction along the water column.

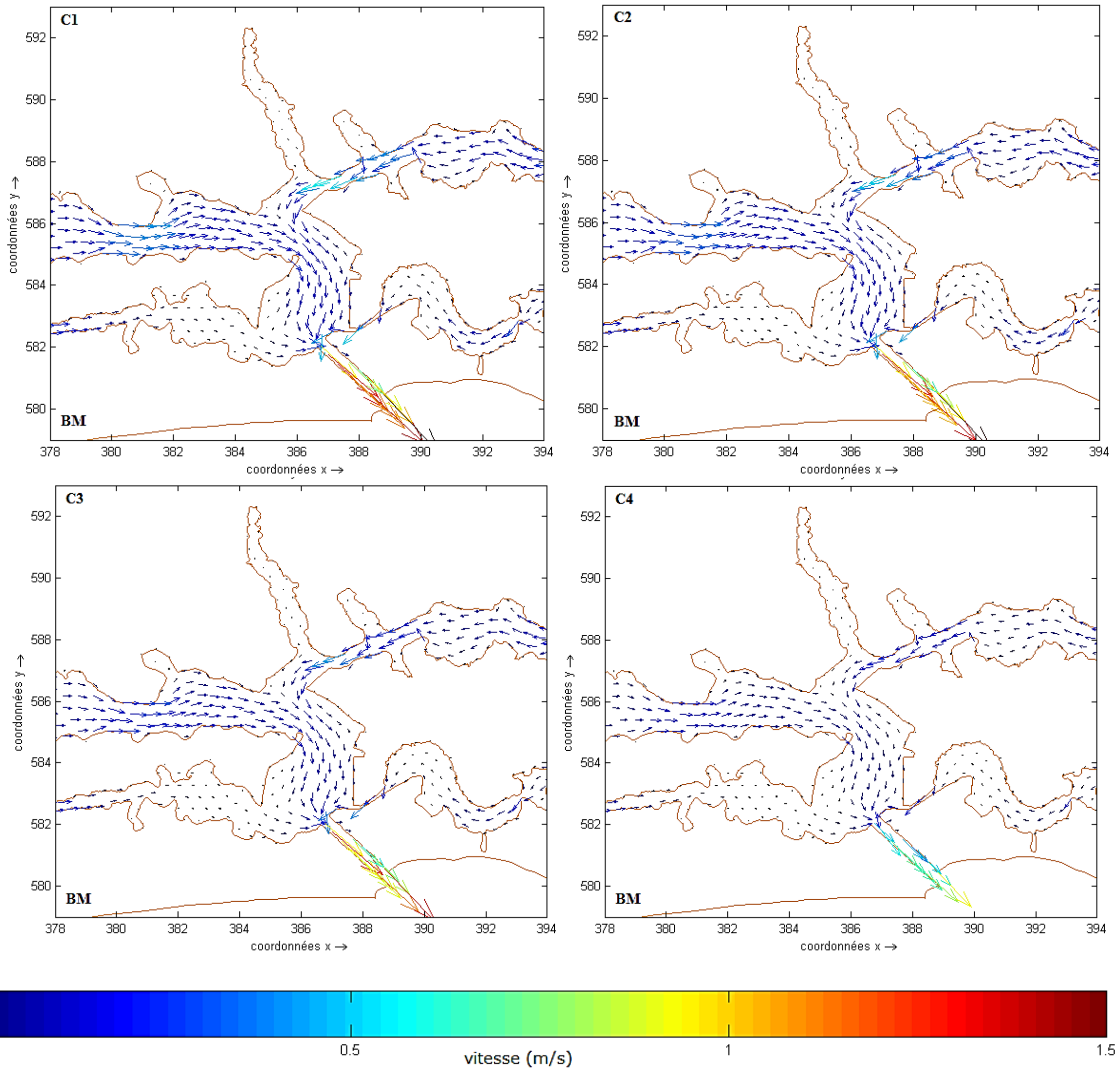

Figure 3 : current behaviour along the water column at low tide

At the high tide (figure 4), current are directed towards the lagoon, we are in flood flow. Current velocities are high than in the ebb flow with 2.4 m/s at the surface in Vridi chanel. Current movement is the same along the water column. As in the ebb flow, currents are accelerated in the tight areas.The Currents form two vortex in the central basin : One on the right and the other on the left.The one on the right is clockwise and the one of the left is in the opposite direction.Current velocity decrease with the depth. In the bays, velocities are very low, almost zero.

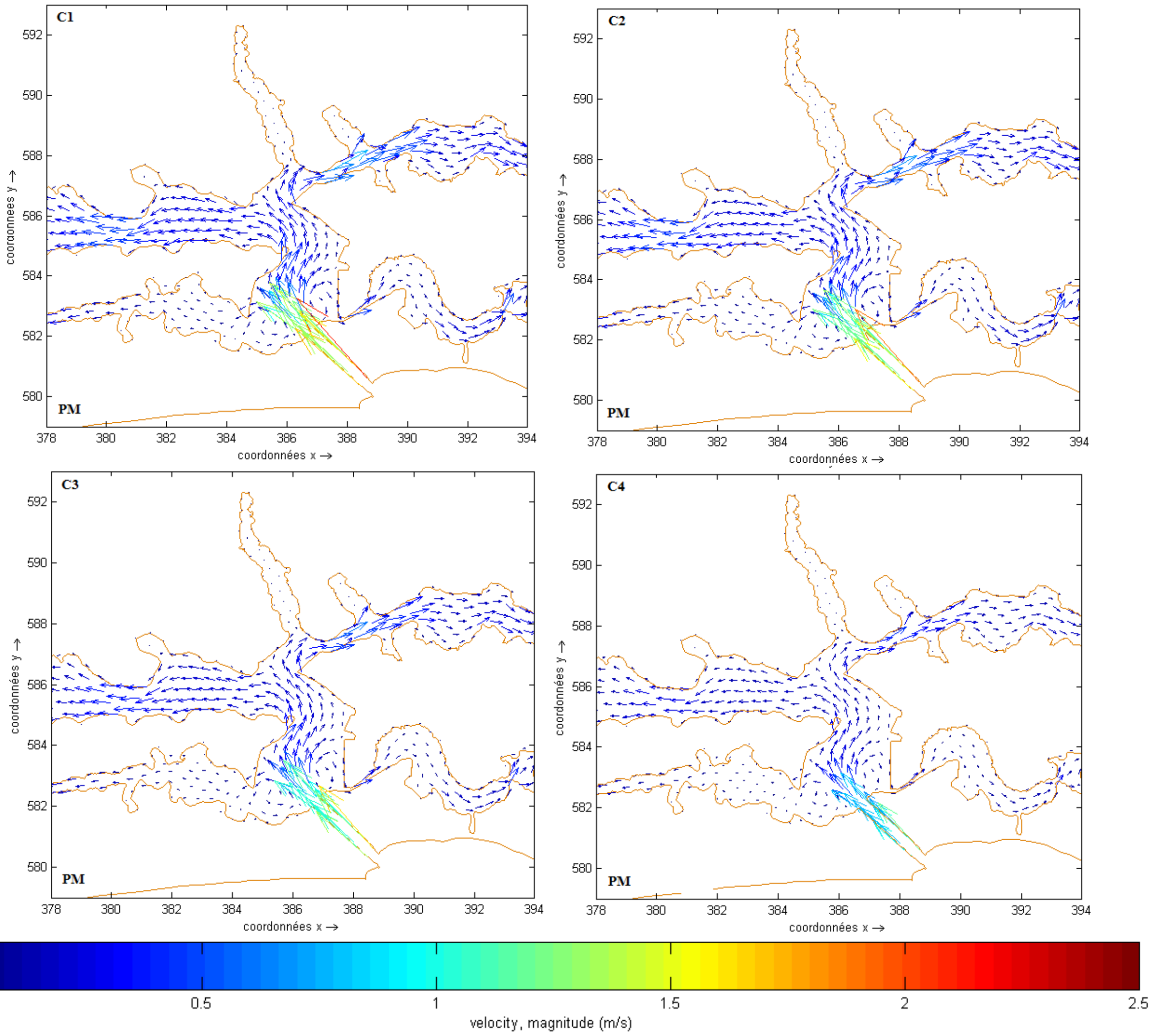

Figure 4 : currentbehaviouralong the water column at high tide

IV. Discussion

The analysis of the behaviour of currents as revealed in our study, shows that the current velocities are relatively low on the lagoon during low flow (< 2.5 m/s). Wind has an important influence on the circulation of surface water.The highest speeds are in the Vridi channel and currents are accelerated in tight areas.

These results were already revealed by Guiral and Lanusse (1984), Durand and Guiral (1994), Wango (2002), Affian (2005) and Yao (2010).The current velocity decreasing with depth is due to the effects of turbulent flow on the bottom (Yao, 2010).The analysis of the current during the ebb flow and the flood flow shows that except the central basin where currents have a gyratory regime. They have an alternative regime in all the rest of the lagoon. This result confirms those of Yao (2010) who deduced that the currents are giratories in the wides areas and alternatives in tights areas.Our study has highlighted vortexes formed by the currents from either side of exit of the channel. These vortexes have already been highlighted by Pouvreau (2002), Monde (2004) and Wango (2009). Note that the vortexes are visible only at the high tide and along the water column.Studying the current behaviour at each layer and at the same time, we observe that the water movement is synchronous in our entire study area. This result differs from that of Yao (2010). Who highlighted shear in the water column at some point of the lagoon. This difference would be due to the scale of study area. In fact, Yao (2010) worked on some of the lagoon (small scale) while we worked on a surface of the lagoon (large scale).

V. CONCLUSION

This study showed the behaviour of current in the estuarine area of the Ebrié lagoon. In fact this study showed that water has a synchronous movement along the water column and the current velocity decrease with the depth.It also attested some results of previous studies as the current regime that is giratory in the wide areas and alternative in the tight areas.At the end of our study, we notice that the 3D simulation with delft3D strengthen most of previous studies results. It permitted to understand the behaviour of current along the water column.

These results showed that a well calibrated model can reflect reality and so a better understanding of hydrodynamic processes.

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