INTERNATIONAL JOURNAL OF
MARITIME TECHNOLOGY

JMT Vol.3/ Winter 2015 (61-65)

Available online at: http://ijmt.ir/browse.php?a_code=A-10-392-1&sid=1&slc_lang=en

TECHNICAL NOTE

A Survey on Precision of Nested Water Level Data Derived From Delft3D Model

Maryam Rahbani [1]

[1] *Faculty of Marine Science and Technology, Hormozgan University, Bandar Abbas, Iran; maryamrahbani@yahoo.com*

ARTICLE INFO

Article History:
Received: 4 Jan. 2014
Accepted: 13 Jan. 2015
Available online: 20 Jun. 2015

Keywords:
model
nesting
open boundary condition
water level
wind

ABSTRACT

One of the troublesome aspects of numerical modeling is to determine open boundaries for a model and to make sure that the boundary conditions employed at the open boundaries are compatible with physical processes being simulated within the interior of the model domain. In this investigation the accuracy of the water level data derived from delft3D employing nesting procedure were studied. These water level data were prepared to apply at open boundaries of a tidal channel model. This method was employed due to the lack of measuring stations in the proper geographical positions at the site. There was however three gauges inside the area, in which their records were used for the calibration of the model. Primary water level data derived from the model were compared with those derived from the in situ gauge. Observing dissimilarity between these two time series was the reason to search for the possible reasons. The importance of wind and/or bathymetry on the water level results also was studied. It was found that unreliable results were the outcome of using unjustified data at the boundaries. It is therefore, suggested that the boundary conditions to be verified and if necessary to be justified before applying at open boundaries. Several reasons, explaining the necessity of the justification, are presented.

1. Introduction

Numerical models are one of the most powerful tools for simulating the nature. They help us to know more about our planet, earth. These tools are also widely used to simulate the ocean characteristics. The availability of the field data for the open boundaries however, is one main problem in such an area. One solution to determine appropriate conditions for open boundaries of a model is to apply nesting procedure. Results derived from this procedure however, might be contained some errors which can affect the final simulation. It is therefore, suggested that the conditions provided by the nesting procedure to be verified before applying at open boundaries.

Simulating hydrodynamic of a tidal channel system locates in the southeastern part of the North Sea was the subject of this investigation. Water level data was decided to be used as boundary conditions of the model. As in situ data was not available, the use of nesting procedure was suggested. Comparing water level data derived from the nesting procedure and from a tidal gauge, a phase log was detected. It is therefore, concluded that the data derived from nesting procedure should be justified.

2. Study area

The hydrodynamic of the Piep tidal channel system located in the southeastern part of the North Sea was the subject of this study (Figure 1). The area is confined from the north by the Eider estuary and from the south by the River Elbe.

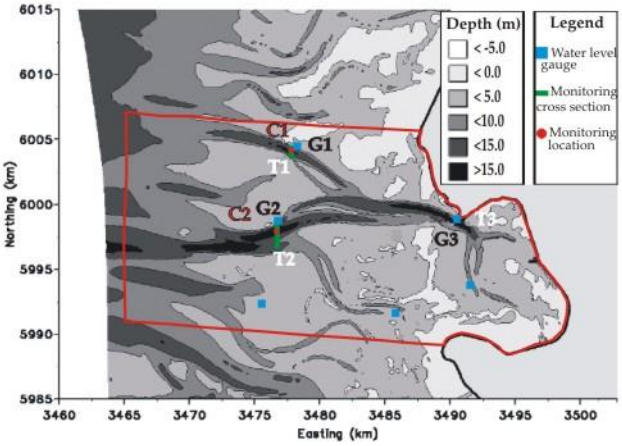

Figure 1. Area under investigation (red line shows the boundary of the model)

The most dominant morphological features of the area are tidal flats, tidal channels and sand banks over the outer region. Semi-diurnal tide with a mean tidal range of about 3.2m is prevailed in the area. Under moderate conditions the maximum mean water depth in the tidal channels is about 18m, and approximately 50% of the domain falls dry at low tide.

3. Investigation method

The first step in modeling the hydrodynamic of an area is to prepare a proper grid map of the area and suitable boundary condition for the model [1]. For this study Delft3d model was used to simulate the hydrodynamic of the area. As the projected area for the study was the tidal channel called Piep tidal channel system, and is shown in Figure 1, the boundaries of the model have been chosen far from the area of interest, namely the Piep tidal channel system. This has ensured that the boundary conditions will not affect the hydrodynamics at the monitoring points (Figure 1). The model consists of a closed land boundary at the east and three open boundaries in the north, west, and south.

For the open boundary input data in terms of water levels were considered. It was the decision due to the availability of long time data collected for the entire North Sea. The nested procedure provided by the package was used to prepare the astronomic water level data for the tidal channel model. The challenge at this level was to prepare boundary conditions for open boundaries [2].

To derive water level values for the open boundaries of the tidal channel model two consecutive nesting procedures were carried out. The First overall model was the north-west European Continental Shelf Model (CSM). This model has a grid spacing of about 9 km and implements two-dimensional depth-integrated flow approximations based on the DELFT3D modelling system developed by Delft Hydraulics in the Netherlands [3]. The 10 main harmonic tidal constituents (M2, S2, N2, K2, O1, K1, Q1, P1, NU2, and L2) were prescribed along the open sea boundaries of the CSM [4]. In order to improve the description of water level along the boundaries a middle model nesting procedure was adopted (Figure 2). That is, the CSM was nested with the German Bight Model (GBM), which has a grid spacing ranging from 0.5 km to 1.9 km [5]. Within this procedure water level data for the boundary conditions of the GBM derived from the CSM as monitoring points (Figure 2).

Similar procedure was executed to impose water level data from the GBM onto the open boundaries of the Meldorf Bight Model (MBM) (Figure 2). The size of the grid cells are approximately 150 m for the tidal channels, and 250 m for the tidal flats. Grid lines preferably follow the tidal channel axes which reduce the magnitude of the convective accelerations and therefore the associated non-linearity. The sensitivity analysis for the regional mesh modelling could be found in the work by the author [6]. A quick glance at the grid sizes of the three models, it could be found the reason for the use of two nesting procedures.

Using water level data derived from the above mentioned procedure at open boundaries of the model incorporate with bathymetry data from the Federal Maritime and Hydrographic Agency (BSH) in Hamburg (Figure 3), the model has been executed [7]. Several tidal gauges located in the area (G1 to G3 in Figure 1) are used for the verification of the boundary conditions derived from the final nesting consequences.

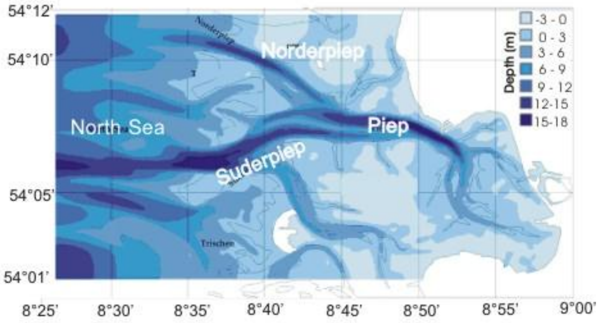

Figure 3. Model bathymetry (Escobar 2007)

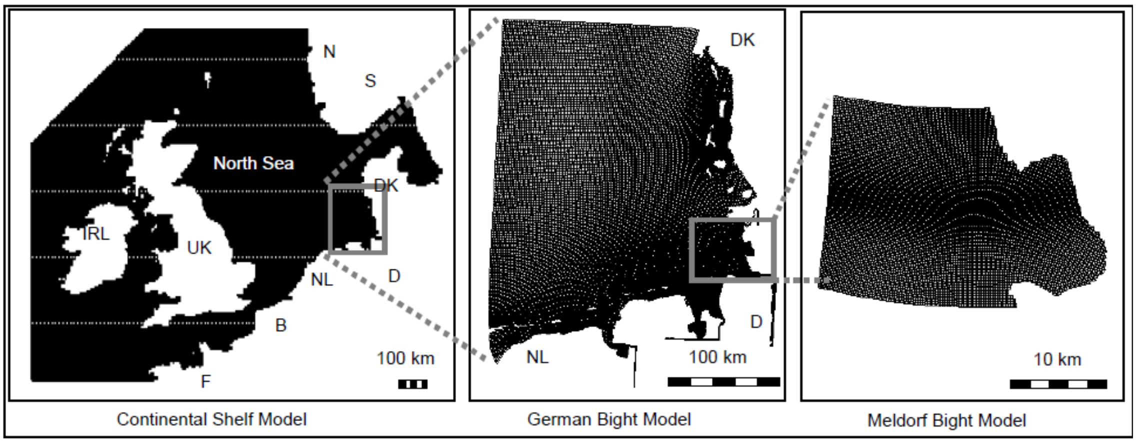

Figure 2. Nesting sequence for generating open boundary conditions

4. Model results

The model was executed using pure water level data derived from the nesting procedure as boundary conditions. To be able to verify the accuracy of the boundary conditions, observation points with the exact geographical location of tidal gauges were defined to the model.

For the same period of model simulations, water level data records from the tidal gauges located near the western open sea boundary (G1 in Figure 1) were used for the comparison. Figure 4 shows a comparison of measured and computed water level time series at G1. The graph shows very similar trend of variations for computed and measured water level. However, it can be seen that in spite of the ability of the model to describe the tidal variations, some discrepancies exist between the model results and the field data in terms of the height and the phase.

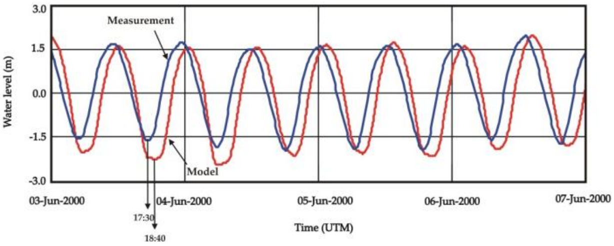

Figure 4: Comparing water level time series derived from the model (red) and recorded by the gauge at G1

In the Figure the computed values show a phase lag of up to about one hour from the measured values. It can also be seen that model is unable to reproduce the tidal range accurately.

Further investigations were carried out to determine the possible sources for the discrepancies. Re-examination of the model bathymetry, the verification of the effect of waves on the water level time series, and the accuracy of the open sea boundary conditions assigned to the model were the terms which have been examined.

4.1. Examination the accuracy of the model bathymetry

Bathymetric surveys comprise of sample depths with a variable spatial resolution. As the measuring locations usually do not coincide with the coordinates of the model grid, interpolations are needed. The interpolation procedure sometimes results in deviation between the actual hydrographic surveys and the interpolated results.

In order to check the accuracy of the model bathymetry, comparisons of the model and measured bed elevations covering the entire domain were carried out. Figure 5 shows the differences in bed elevations between the two bathymetries obtained from all the available measurements and the ones obtained by interpolation of the measurements on the model grid. It can be seen that in general the agreement on the tidal flats and channels is reasonable. The differences are on the average in the order of a few centimeters. But along the margins of the Piep tidal channel system discrepancies of up to about 2 meters can be seen.

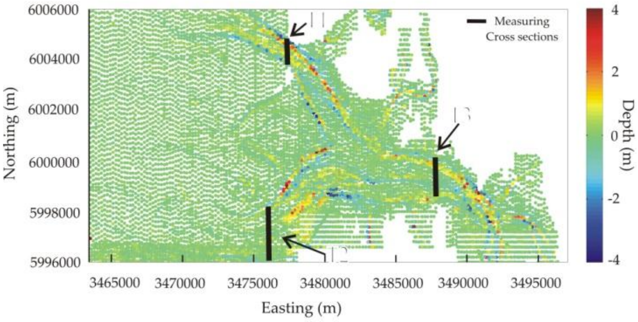

Figure 5: Difference between bathymetries in m (measurements– model)

Despite the differences in the bed elevations along the margins of the tidal channels, it was concluded that the actual bathymetry is well represented in the model and thus is not the source for the discrepancies in the simulated water levels.

4.2. Waves superimposed on water levels

To advance the understanding of the effect of waves on water levels, additional model executed implementing the coupled flow and wave modules. Simulations were carried out using moderate wind condition. The period was used characterized by tidal ranges of about 3.7m and wind velocities up to 11 m/s**.** Figure 6 shows comparisons of the modelled water level time series with and without the consideration of wave at monitoring point C3 (see Figure 1).

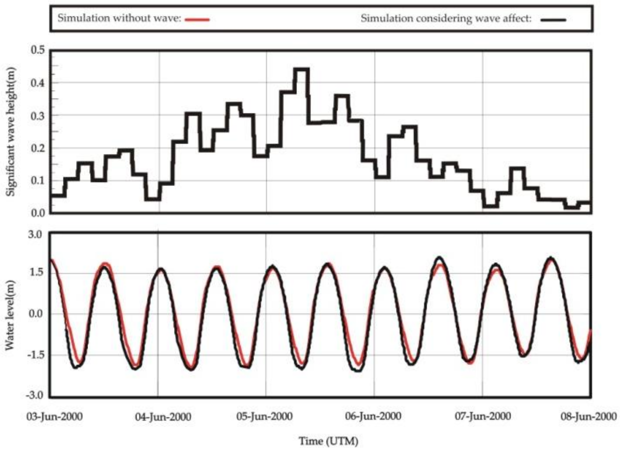

Figure 6. Comparing water level time series computed from simulations with and without wave at Station

It can be seen that there are almost no differences between the water level time series with and without the wave consideration. This is in good agreement with the findings of previous researchers on the area (see [8], [9], and [10]).

4.3. Water level time series along the open sea boundaries

The precise specification of the conditions along the open sea boundaries is important in the accuracy of results from the flow model [11]. It is also reported that the height and phases lag of water level time series derived from the nesting sequence are not always in good agreement with the observed values. It is therefore proposed that the following adjustments to the height and the phase of the water level time series derived from the model should be imposed [12].

$$H_{adj} = \frac{1}{\overline{\Delta A}} H_{nest} - \overline{\Delta H} \qquad (1)$$

$$t_{adj} = t_{nest} - \overline{\Delta t} \qquad (2)$$

in which H_{adj} is the corrected water level, $\overline{\Delta A} = A_{nest} / A_{meas}$ is the average amplitude ratio, H_{nest} is the water level obtained from the nesting sequence, $\overline{\Delta H} = H_{nest} - H_{meas}$ is the average difference in the peak water levels, t_{adj} is the adjusted peak occurrence time, t_{nest} is the peak occurrence time derived from nesting sequence, and $\overline{\Delta t} = t_{nest} - t_{meas}$ is the average difference in the peak occurrence time [6].

In this study the procedure proposed above was adopted to adjust the phase and the height of the nested water level data. To test the effectiveness of these corrections, simulations for a wide range of tidal conditions were carried out. Table 1 presents the results of the simulations covering five periods with tidal ranges between 2.3m (neap tide) and 4.0m (spring tide). Referring to the Table, corrections required to the phase vary from 30 to 52 minutes for the tidal ranges of 2.3 to 4, respectively. The results show that increasing the tidal range from neap to spring tide was associated with the increase of phase lag. The results of corrected height also show a clear dependency with the tidal range. Adjustments of up to -17cm and +16cm are required respectively for the spring (4.0 m) and neap (2.3 m) tidal cycles.

The comparisons of the measured and the computed water level time series at point G1 with and without applying the corrections are shown in Figure 7, Figure 8, and Figure 9. These are respectively for spring, neap and mid tidal cycles. Significant improvement can be seen in all of the Figures which were as a result of applying corrections in the water level time series derived from nesting procedure.

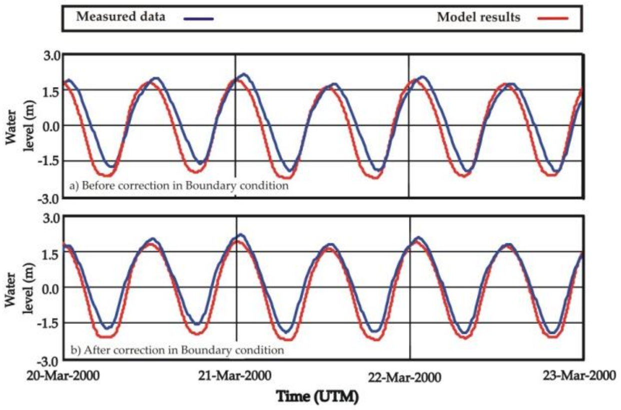

Figure 7. Comparing measured and computed water level time series at station G1 before (a) and after (b) applying the corrections to the open sea boundary conditions–Spring tide, March 20-25, 2000

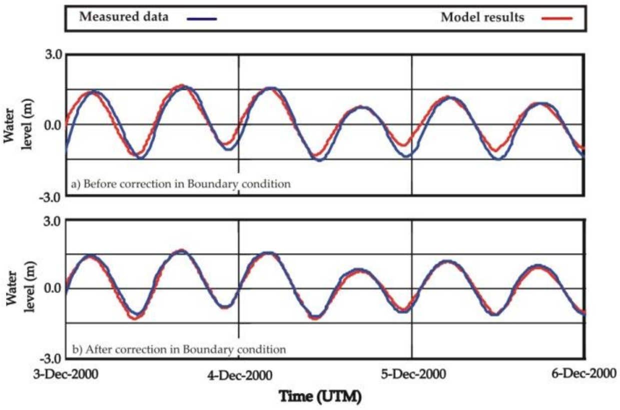

Figure 8. Comparing measured and computed water level time series at station G1 before (a) and after (b) applying the corrections to the open sea boundary conditions– Neap tide, Dec 3 to 8, 2000

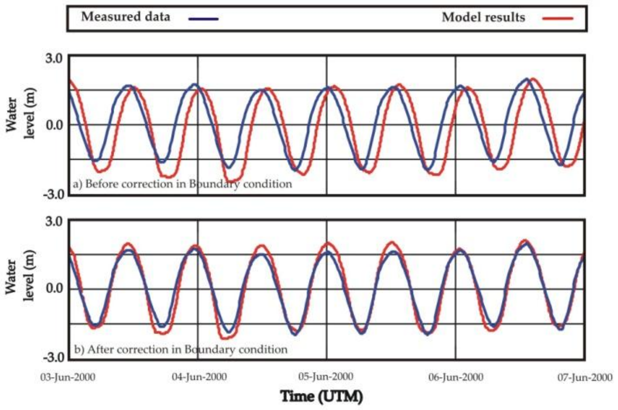

Figure 9. Comparing measured and computed water level time series at station G1 before (a) and after (b) applying the corrections to the open sea boundary conditions– Mid tide, June 3 to 7, 2000

Table 1. Correction factors applied to the water levels along the open sea boundaries

Date	Tidal range (m)	Correction to the phase (min)	Correction to the amplitude (m)
March 21 to 23, 2000	4.0	$t_{nest}-52$	$H_{nest}-0.17$
June 5 to 6, 2000	3.7	$t_{nest}-41$	$H_{nest}-0.13$
September 5 to 6, 2000	3.2	$t_{nest}-40$	$0.98H_{nest}$
September 12 to 13, 2000	3.0	$t_{nest}-40$	$0.98H_{nest}$
December 5 to 6, 2000	2.3	$t_{nest}-30$	$0.9H_{nest}+0.16$

5. Conclusions

The water level time series at the boundaries derived from the nesting procedure were evaluated to find the ability of the model to calculate the water level time series during various tidal cycles. Following results are derived:

- The model was able to describe the trend of tidal variations reasonably well. There are however, some amplitude dissimilarity and phase lags of up to about 1 hour, in comparison with the field data.
- The effect of bathymetry and waves on values of the water level at open boundaries was examined. It was found that under the moderate condition neither of them affect the water level time series derived from the nesting procedure.
- Significant improvement was achieved using adjustments in the phase and amplitude of the open boundary water level time series.

6. Acknowledgment

I would like to thank Prof. Dr. Roberto Mayerle, for his supervision and full support during my Ph.D research. Furthermore I would also like to acknowledge with much appreciation the crucial role of the staff of Coastal Research Laboratory of Kiel University for their warm hospitality during my stay in Germany.

8. References

1- Choi, J. Y., Park, J. Y., Cho, K. H., Hyun, S. K., Yoo, J., Lee, D. Y., & Jun, K. C. (2013), *Field observation and modeling of wave set-up on a macrotidal beach: the Malipo Experiment*. JOURNAL OF COASTAL RESEARCH, 183-188.

2- Rahman, M. M., Paul, G. C., & Hoque, A. (2013), *Nested numerical scheme in a polar coordinate shallow water model for the coast of Bangladesh*. Journal of Coastal Conservation, 17(1), 37- 47.

3- Verboom, G. K., De Ronde, J. G., & Van Dijk, R. P. (1992), *A fine grid tidal flow and storm surge model of the North Sea*. Continental Shelf Research, 12(2), 213-233.

4- Mayerle, R., J. Wilkens, C. Escobar, and W. Windupranata, (2005), *Hydrodynamic Forcing Along the Open Sea Boundaries of Small-Scale Coastal Models*. Die Kuste, 69, 203-228.

5- Hartsuiker, G., Deutsche Bucht and Dithmarschen Bucht, (1997), *Set-up and calibration of tidal flow models*, Delft Hydraulics, report no. H1821.

6- Rahbani, M., (2011), *Numerical modelling of the coastal processes in Dithmarschen Bight incorporating field data*, Ph.D. Thesis, Coastal Research laboratory, University of Kiel, Germany.

7- Escobar, C.A., (2007), *Modelling of Sediment Dynamics in the Dithmarschen Bight, German North Sea Coast*, Ph.D. Thesis, Coastal Research laboratory, University of Kiel, Germany, 208 pp.

8- Wilkens, J., (2004), *Medium Scale Morphodynamics of the Central Dithmarschen Bight*, Ph.D. Thesis, Coastal Research Laboratory, University of Kiel, Germany.

9- Wilkens, J., I. Junge, and H. Hoyme, (2005), *Modelling of Waves in a Tidal Flat Area in the South-Eastern German Bight*, Die Kuste, 69, 175-202.

10- Mayerle, R., & W. Zielke, (2005), *PROMORPH – Predictions of Medium-Scale Morphodyanimcs: Project Overview and Executive Summary*, Die Kuste, 69, 1-24.

11- Mayerle, R., J. Wilkens, C. Escobar, and W. Windupranata, (2005), *Hydrodynamic Forcing along Open Sea Boundaries of Coastal Models*, Die Kuste, 69, 203-228.

12- Echeverry, J., (2004), *Assessment of performance of the Dithmarschen Bight model using the RMAE parameter on cross section measurements*, Master of Science Thesis, Coastal Research laboratory, University of Kiel, Germany, 98 pp.