2D Tidal Current and Water Level Prediction for The Arabian Gulf KGulf Model

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Abstract

Hydrodynamic models (HD) represent the core of any simulation for water quality, siltation, and morphology studies. In this study a KGulf model was developed and setup for the Arabian Gulf to predict the tidal currents and tidal water level variations. A grid constituents values was setup for Arabian Gulf waters and refined grids inside Kuwaiti territorial Waters. The model was setup in two dimensional mode with an element size varying from 11 km within the Arabian Gulf to less than 50 m inside the Kuwaiti territorial waters for refined grid. The model was shown to provide good results for the water level variations and the tidal currents with very short computer simulation time.

Keywords

Hydrodynamic model, Arabian Gulf, Tidal currents, water level.

Introduction

Hydrodynamic models (HD) represent the core of any simulation for water quality, siltation, and morphology studies. HD models vary from fully three dimensional (3D) to simpler one dimensional (1D) models. For such models they may differ in the choice of the numerical grid, the discritization method, the time difference scheme, the solution technique, and the treatment of boundary conditions. Finite difference models using Cartesian grids require the application of several nested models in order to model a certain area with a fine grid. Finite element models have the advantage that an unstructured grid can be used thus providing fine grid resolution in the areas of interest only. But the disadvantage with this method is that the computation takes much time for simulation.

Many researchers have modeled the Arabian Gulf (e.g., Blain, 2000; AlHajri et al., 1997, Chu et al., 1988, and Proctor et al. 1994). It is essential for Kuwait to have its own HD model for the Arabian Gulf. Lo and Al-Salem (1999) attempted to develop such a model for the Kuwait Institute for Scientific Research (KISR) by setting up two models. The two models they used however were based on the finite difference technique and thus require the use of nested models to provide a finer grid resolution in the Kuwaiti territorial waters.

A new Tidal Current prediction technique is developed for hind-cast, now-cast and forecasting of Tidal current conditions over the Kuwaiti territorial water and the Arabian gulf. It is an interactive, online model. The computer simulation time required for this model technique for Tidal Current history prediction in very little. The present technique is validated with RMA 10 model and measured data. Model was named as **KGulf model** as shown in (Fig. 1).

In this study a KGulf model is setup to predict the water level variations and the currents induced by tides. The grid resolution is finer in the Kuwaiti territorial waters to be able to provide useful data for Kuwait.

Model Description

In this study, the KGulf model was developed and set up for the Arabian Gulf and Kuwait territorial waters. The KGulf model is a two dimensional (2D) and is based on the calculated grid constituents values, which is stored and linked as database to the model. The model is capable of simulating 2D tidal current and water level at any selected grid inside the Arabian Gulf waters starting from the year 1970 to 2035 with hourly output results.

Model Setup

A grid was generated covering the Arabian Gulf from the Hormoz inlet till the upper part of the Gulf (Fig. 2). The grid spacing is about 11 km in the Arabian Gulf as show in (Fig. 2) with a total of 3692 wet grid inside the Gulf. For some local areas in Kuwait the refined grid spacing reached about less than 50 m (Fig. 3 and 4) with total wet refined grid of about 9696 and 7346 grids.

Fig. 1. KGulf Model for Arabian Gulf and Kuwaiti Territorial Water Region.

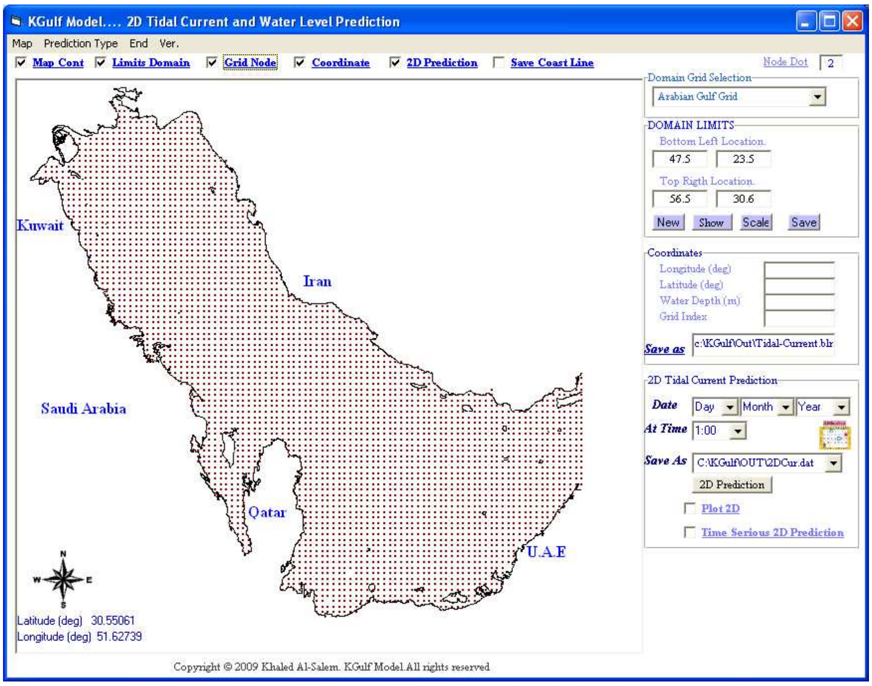


Fig. 2. KGulf Grid Covering the Arabian Gulf.

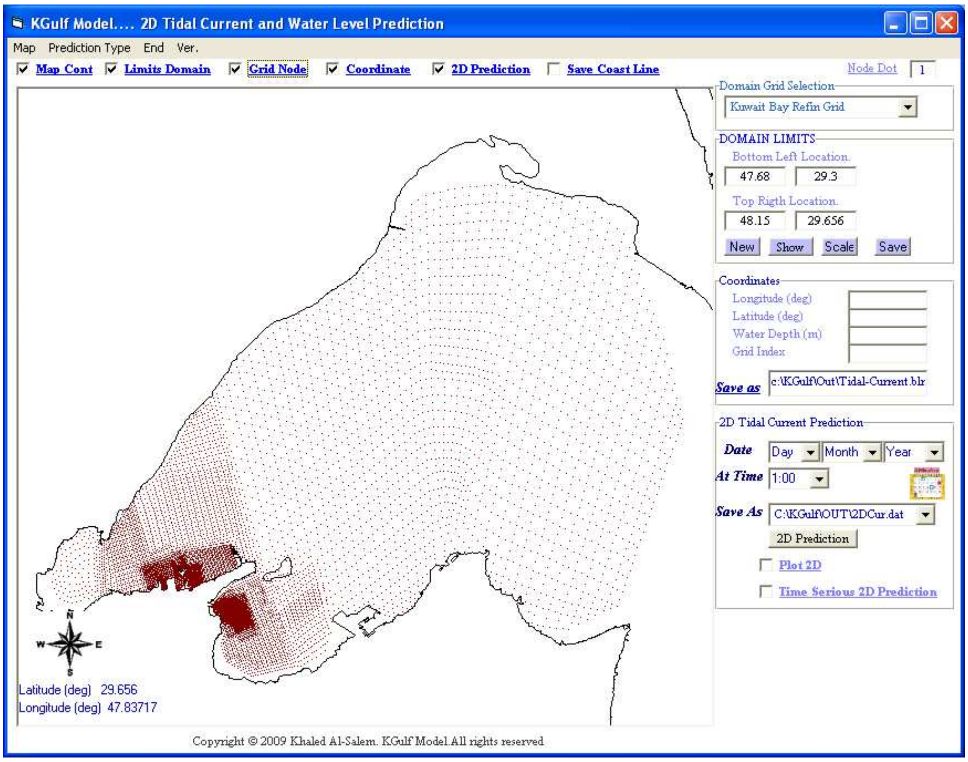


Fig. 3. KGulf Refined Grid for the Kuwait Bay as a Part of the Arabian Gulf.

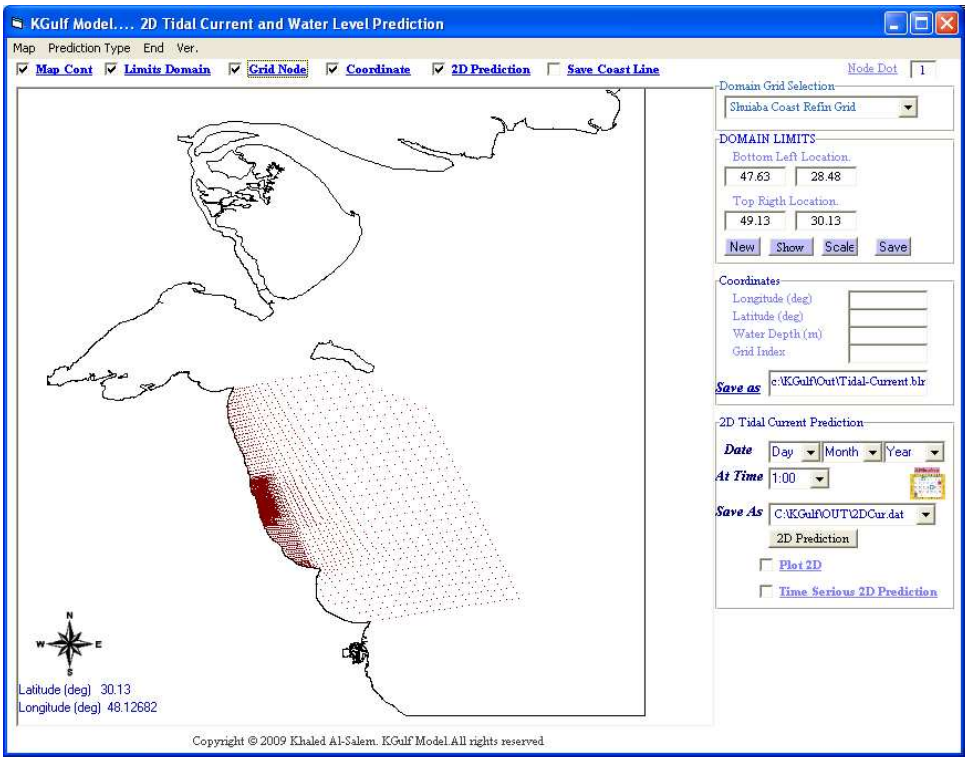


Fig. 4. KGulf Refine Grid for the Kuwaiti territorial water as a Part of the Arabian Gulf.

Model Calibration/Validation

The KGulf Model was calibrated/validated with RMA-10 model, which is a three dimensional finite element HD model (King 1988) and tidal water level data obtained from a tidal model TIDECALC and RMA model. The TIDECALC software is a version of the tidal prediction program developed by the UK's Hydrographic Office for publication in the Admiralty Tide Tables. This model was used by KISR in many projects and found to provide good predictions for the water level variations in Kuwait. Figure 5 provides the location of the stations that were used to validate the KGulf Model and Table 1 provides the location for these stations.

Table 1. Stations used to Validate the KGulf Model

Station No.	Station Name	Longitude	Latitude
2	Mina Saud (AzZour), Kuwait	48° 24'	28° 44'
3	Mina Al-Shuwaikh, Kuwait	47° 55'	29° 21'
10	Khowr E-Musa Bar, Iran	49° 03'	30° 00'
11	Jazerih Ye Khark, Iran	50° 20'	29° 16'
13	Jazireh-ye Lavan, Iran	53° 23'	26° 48'
17	Bandar Misha'b, Saudi Arabia	48° 38'	28° 07'
18	Ju'aymah Boat pier, Saudi Arabia	49° 54'	26° 52'
19	Mina Salman, Bahrain	50° 36'	26° 14'
20	Musay'id outer channel, Qatar	51° 39'	25° 01'
22	Jazirat Das, U.A.E.	52° 53'	25° 09'

The predicted tidal currents and water levels using KGulf for all the above locations were compared with the predicted values using RMA10 and TideCalc and KGulf presented in Fig. 6 to 14. These figures show that the KGulf model is capable of predicting the tidal water level variations and tidal current very well for stations within the Gulf. A period of 14 days is provided in all these figures representing a complete spring and neap cycle.

Figure 15 shows the part of a refined grid in Kuwaiti territorial waters and the node where the data was extracted (Node coordinates longitude $48^{o}10^{'}00.0^{"}$ E and latitude $29^{o}04^{'}00.0^{"}$ N). Figure 16 provides a comparison between KGulf model results and RMA-10 Model for this nodal point.

Figure 17 provides a comparison between actual measurements for water levels recorded at Offshore of Al-Khiran using (Aanderaa Water Level Sensor), extracted from the study of Lo et al. 1994 and Al-Salem et al. 2003). The measurements provided in Figure 17 are for grid located at Longitude $48^{o}29^{'}10.3^{"}$ E and Latitude $28^{o}34^{'}22.1^{"}$ N. It can be seen that the KGulf model have a good prediction for water level as shown in Fig.18. Table 2 shows a comparison of the time consumed for computer simulation for KGulf and RMA-10 model at same model input. It can be seen that the KGulf model consumed very short time in simulation comparing to RMA 10 model. This is the major advantage of KGulf and the user can save significant order of time for getting the water level and tidal levels with same accuracy of RMA-10 model.

Conclusions

In this study the KGulf model based on the grid constituent's values was developed and setup to model the tidal currents and water level variations in the Arabian Gulf. The model is two dimensional mode. The element size varied from 11 km to less than 50 m in the territorial water of Kuwait.

The model was validated using a tide prediction (TIDECALC) model, RMA-10 HD model and using some field measurements. The model results showed that the model is capable of predicting the tidal currents and water level variations well with a very short of computer simulation time.

The KGulf model was setup to run in window operation system and internet system at linked address as (http://www.hceatkuwait.net) for public use.

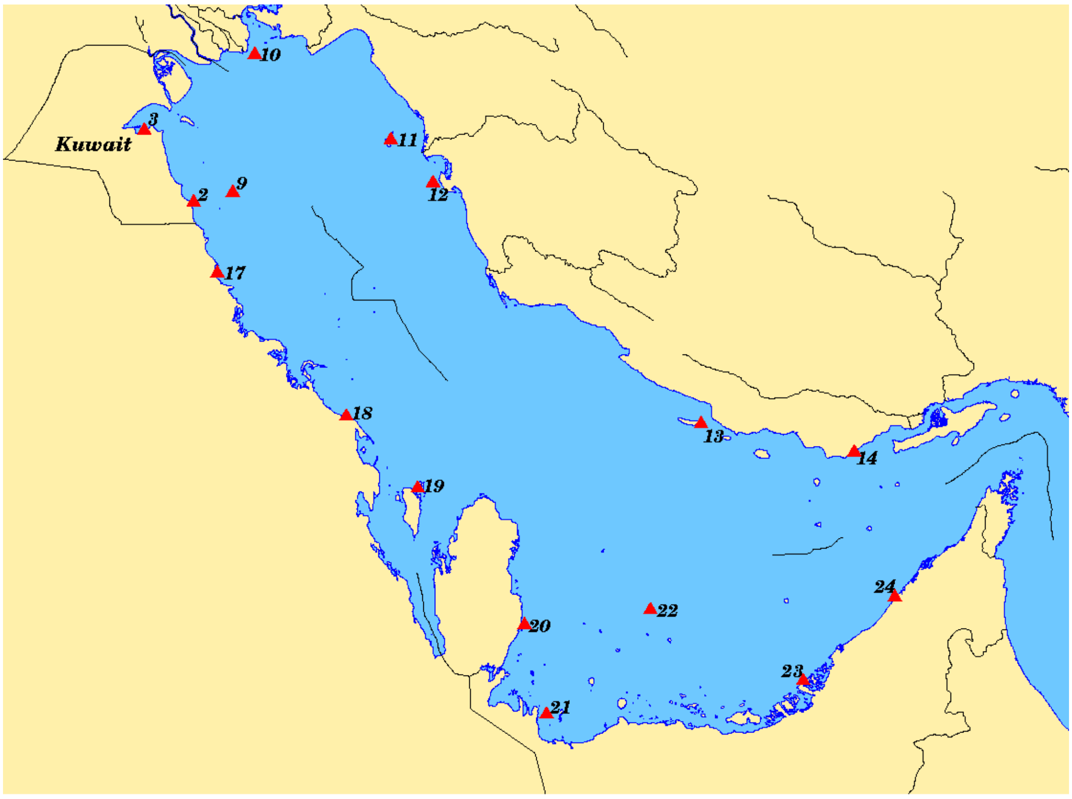
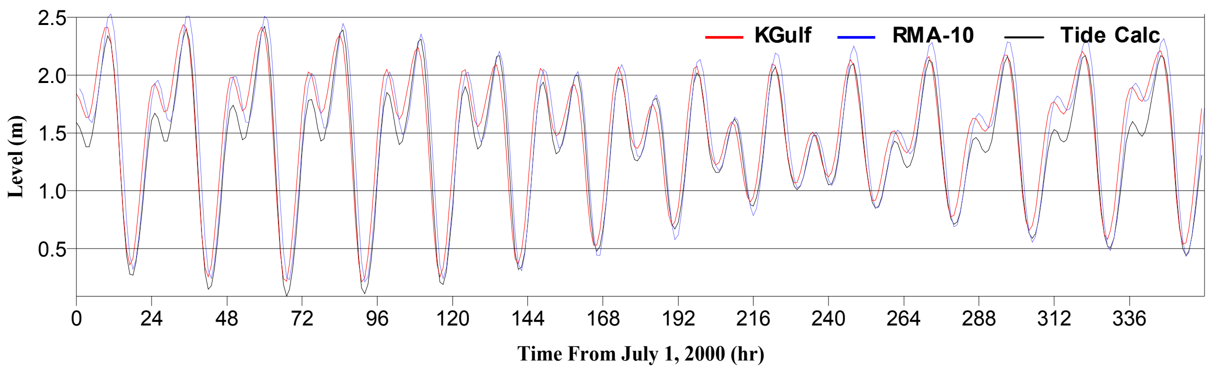


Fig. 5. Location of Stations Used to Verify the RMA Arabian Gulf Model.



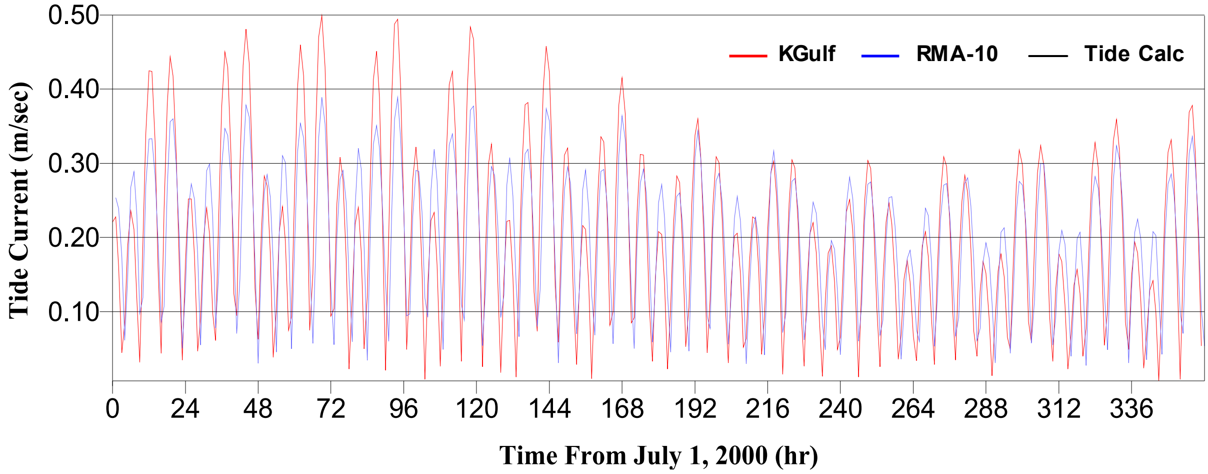


Fig. 6. Tidal Current and Water Level Predictions at Az-Zour (St. 2).

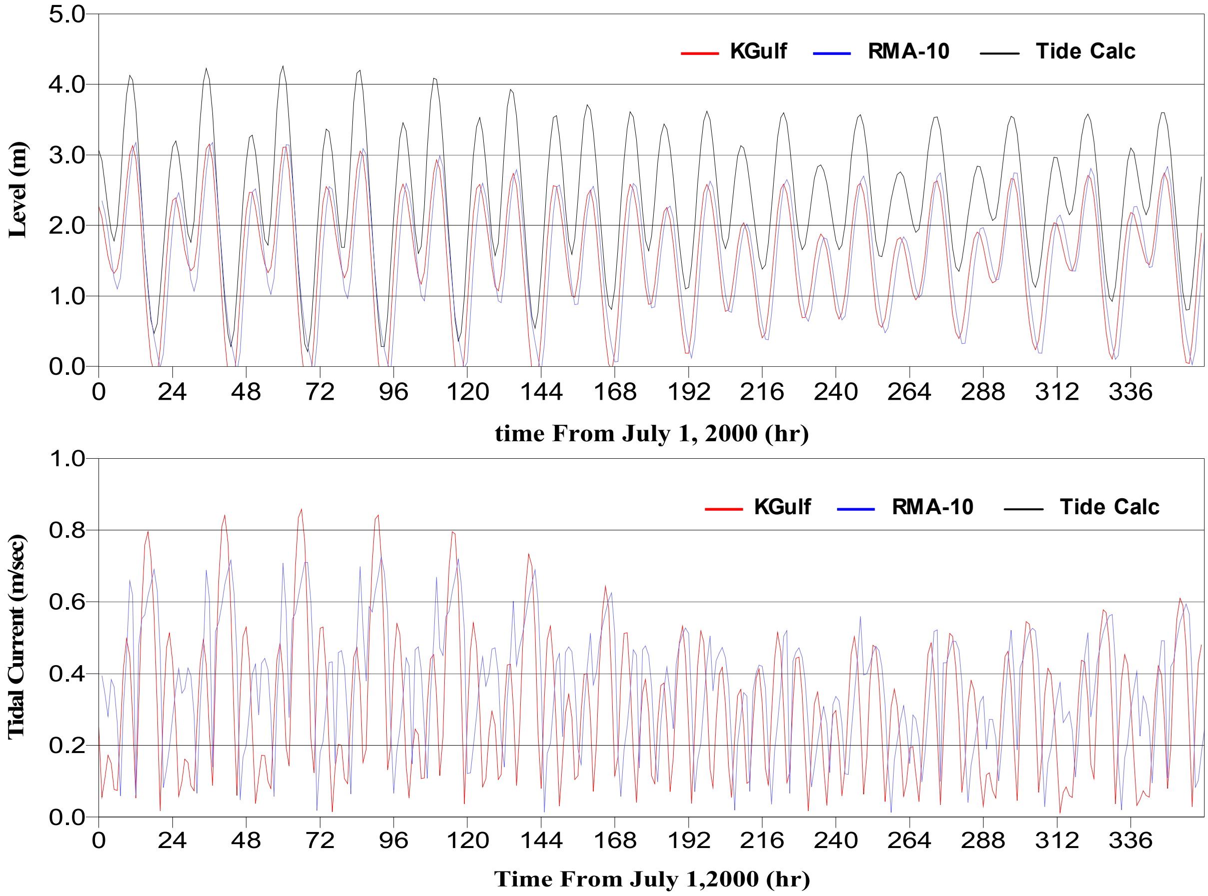


Fig. 7. Tidal Current and Water Level Predictions at Al-Shuwiakh (St. 3).

KGulf RMA-10

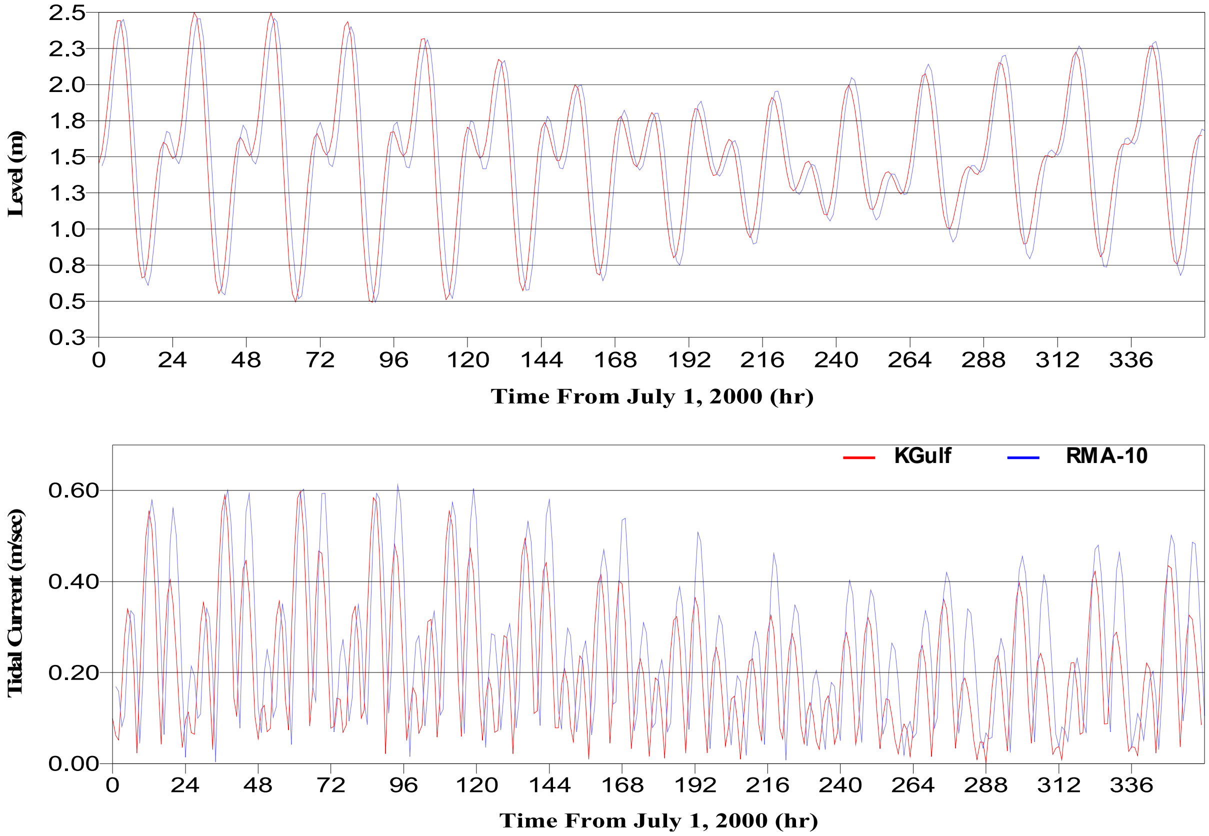


Fig. 8. Tidal Current and Water Level Predictions at Jazira Ye Khark (St. 11).

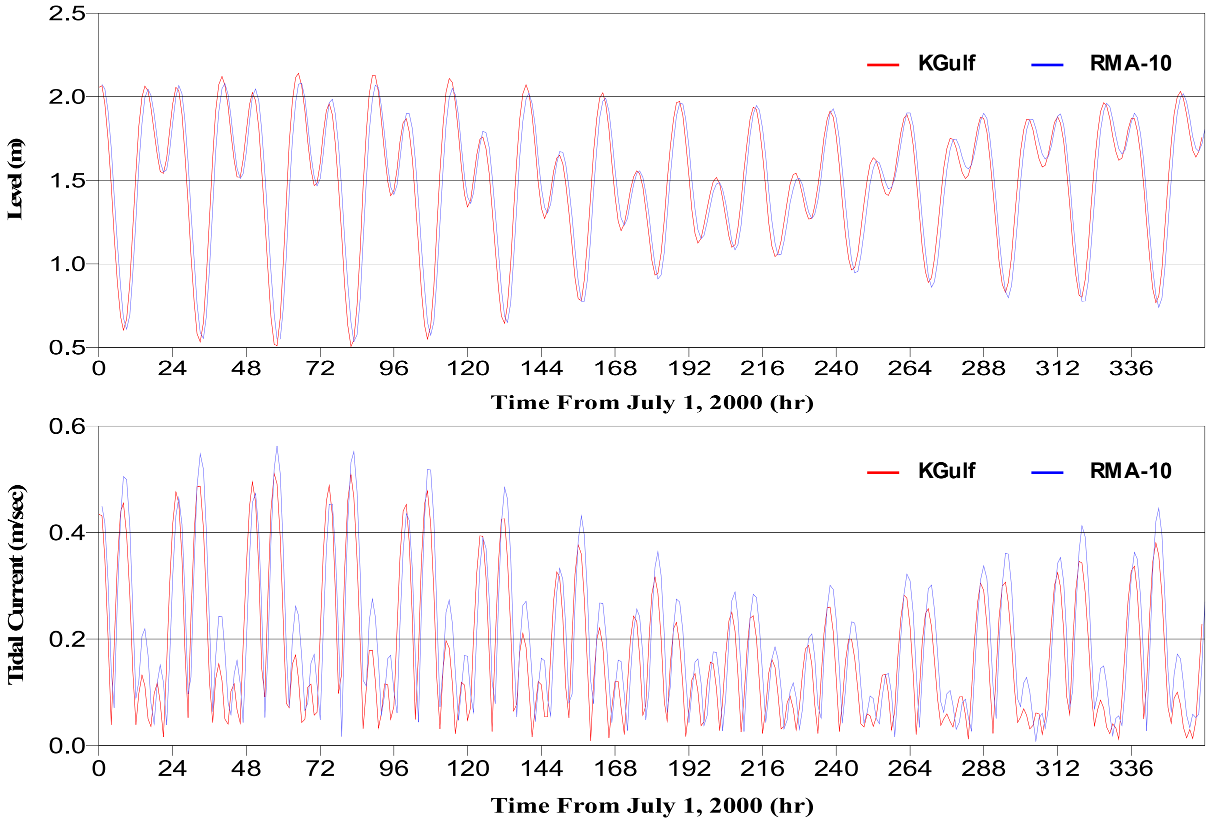


Fig. 9. Tidal Current and Water Level Predictions at Jazira Ye Lavan (St. 13).

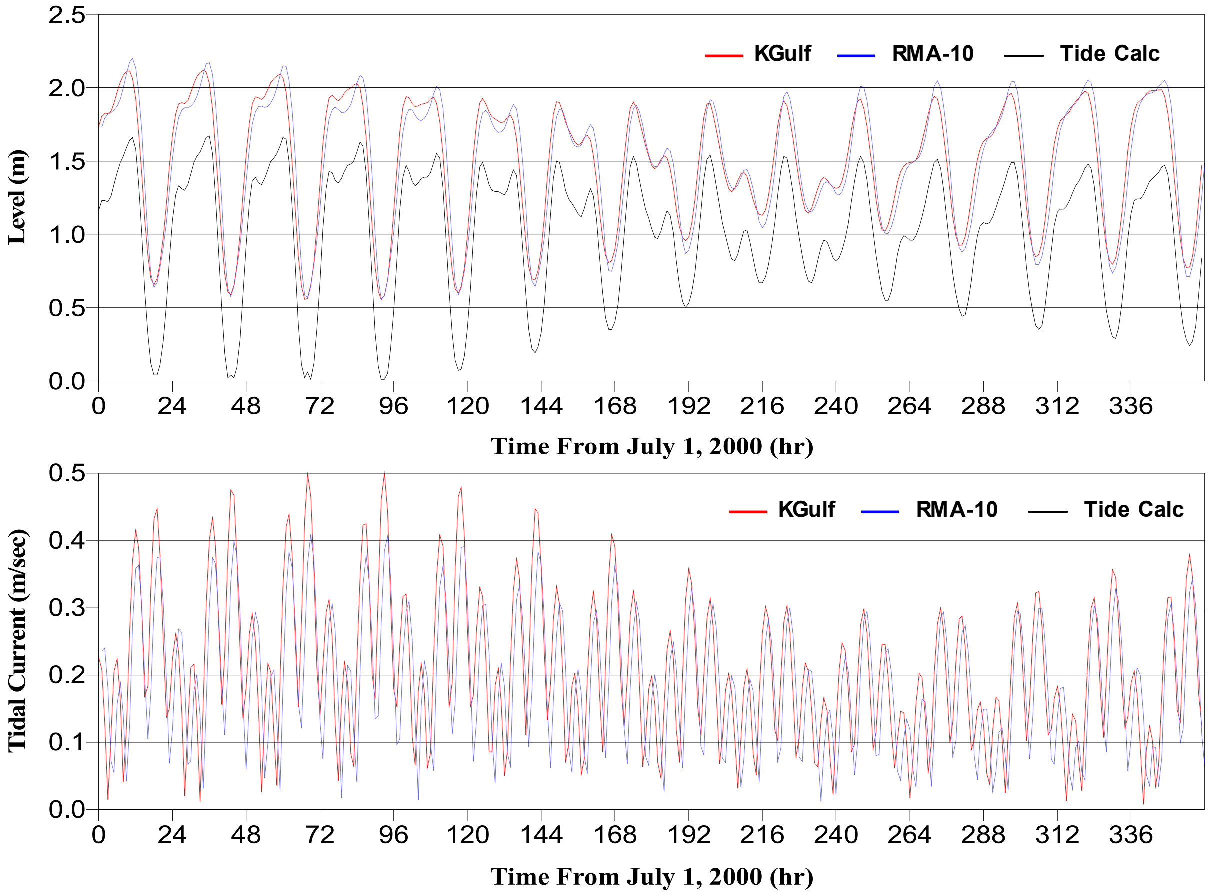


Fig. 10. Tidal Current and Water Level Predictions at Ras Al-Mishaab (St. 17).

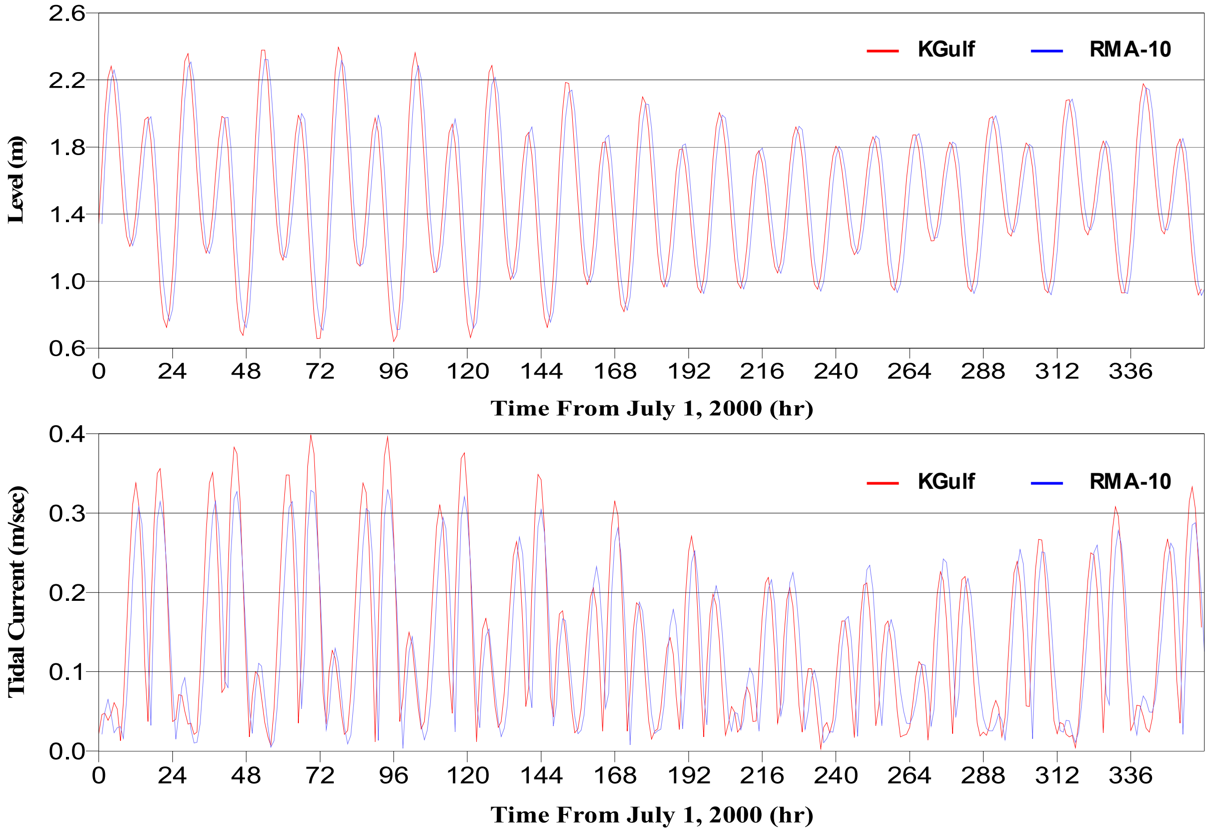


Fig. 11. Tidal Current and Water Level Predictions at Jumayah Boat Pier (St. 18).

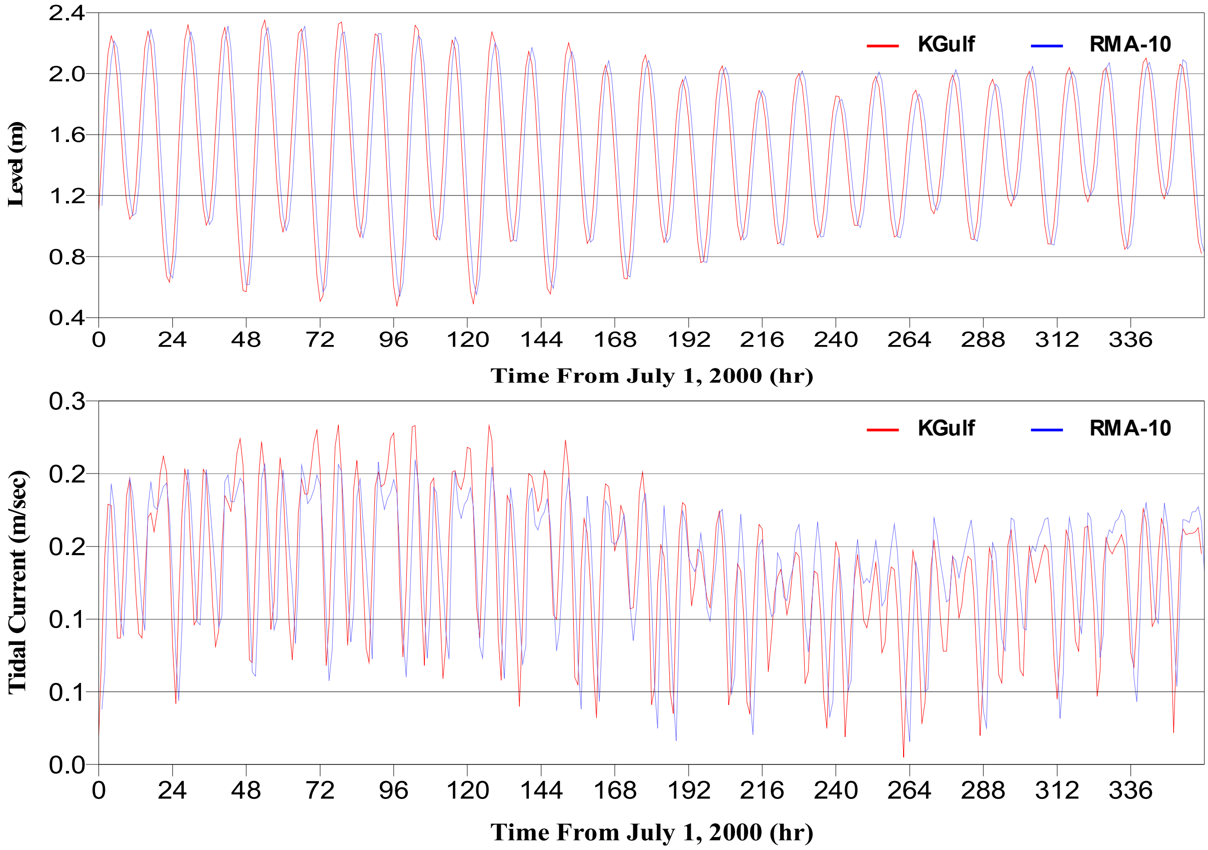


Fig. 12. Tidal Current and Water Level Predictions at Mina Salman (St. 19).

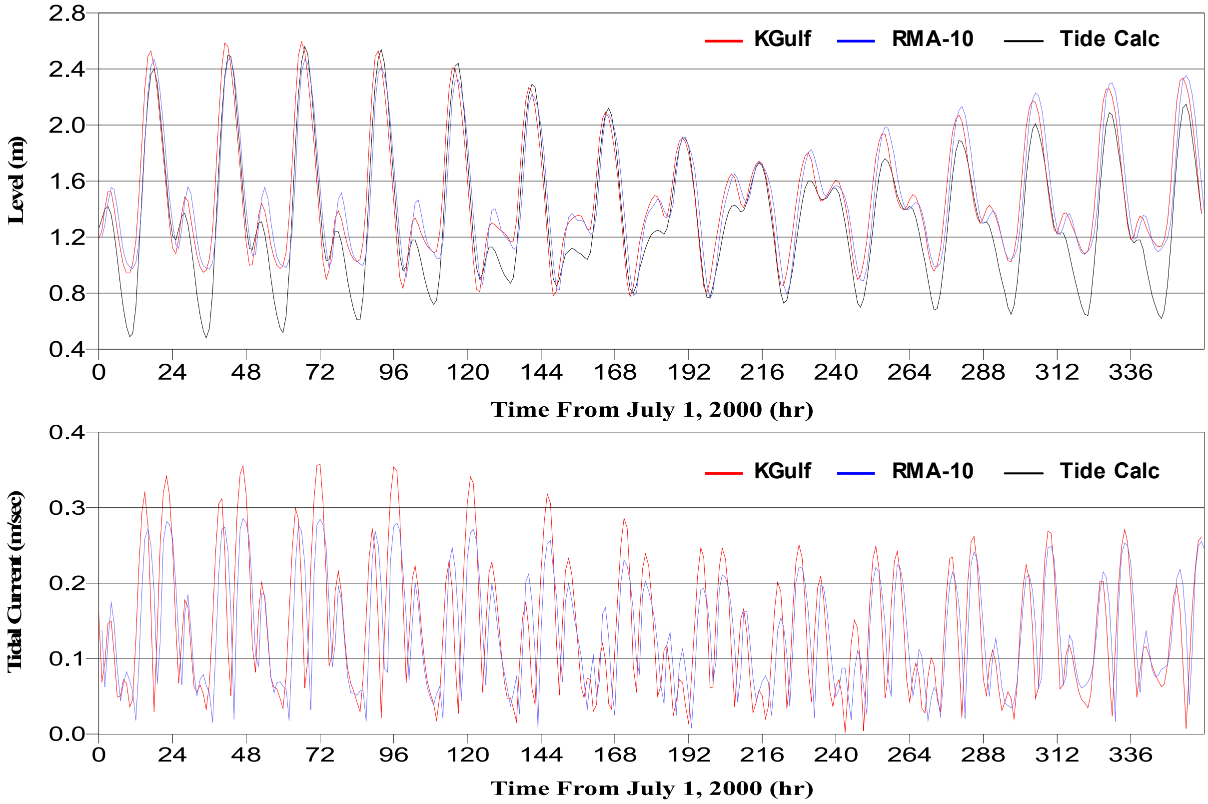


Fig. 13. Tidal Current and Water Level Predictions at Musayid (St. 20).

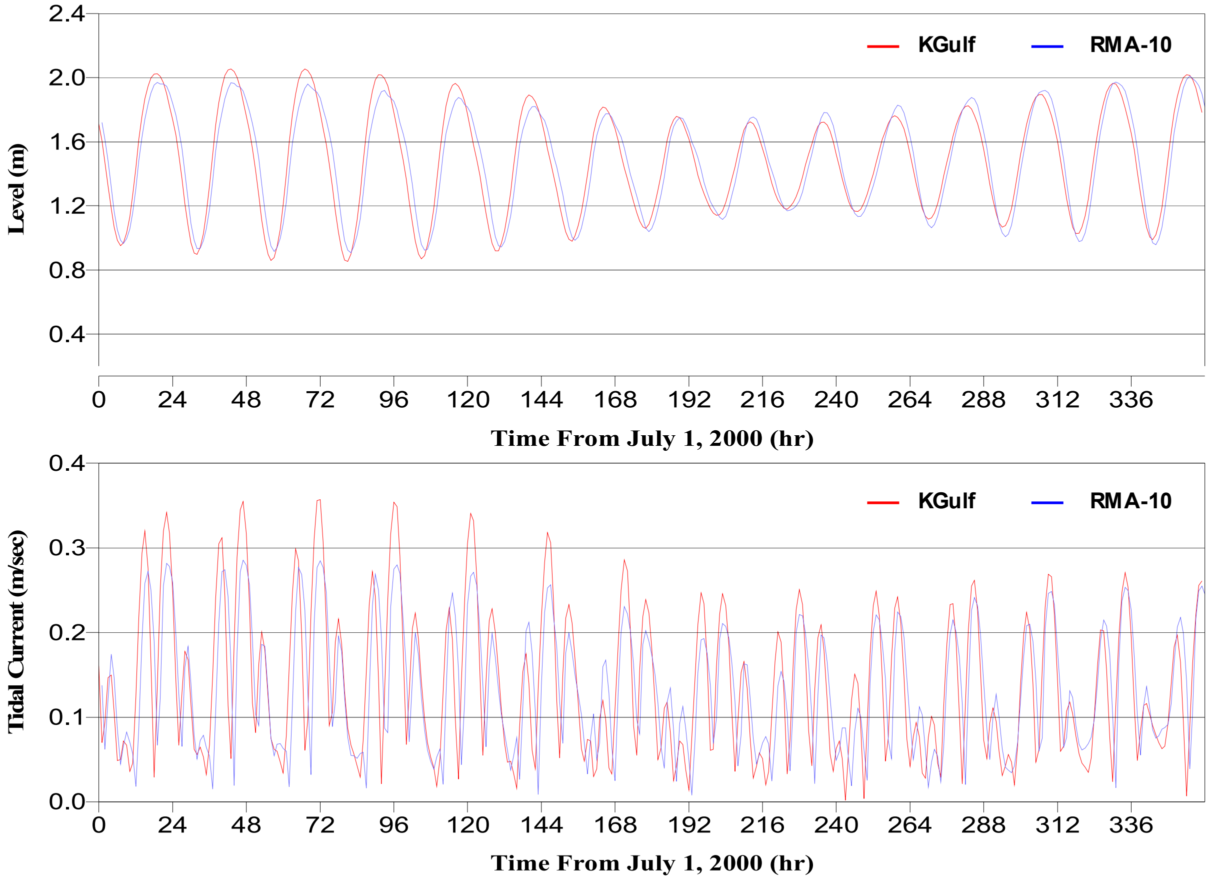


Fig. 14. Tidal Current and Water Level Predictions at Jazirat Das (St. 22).

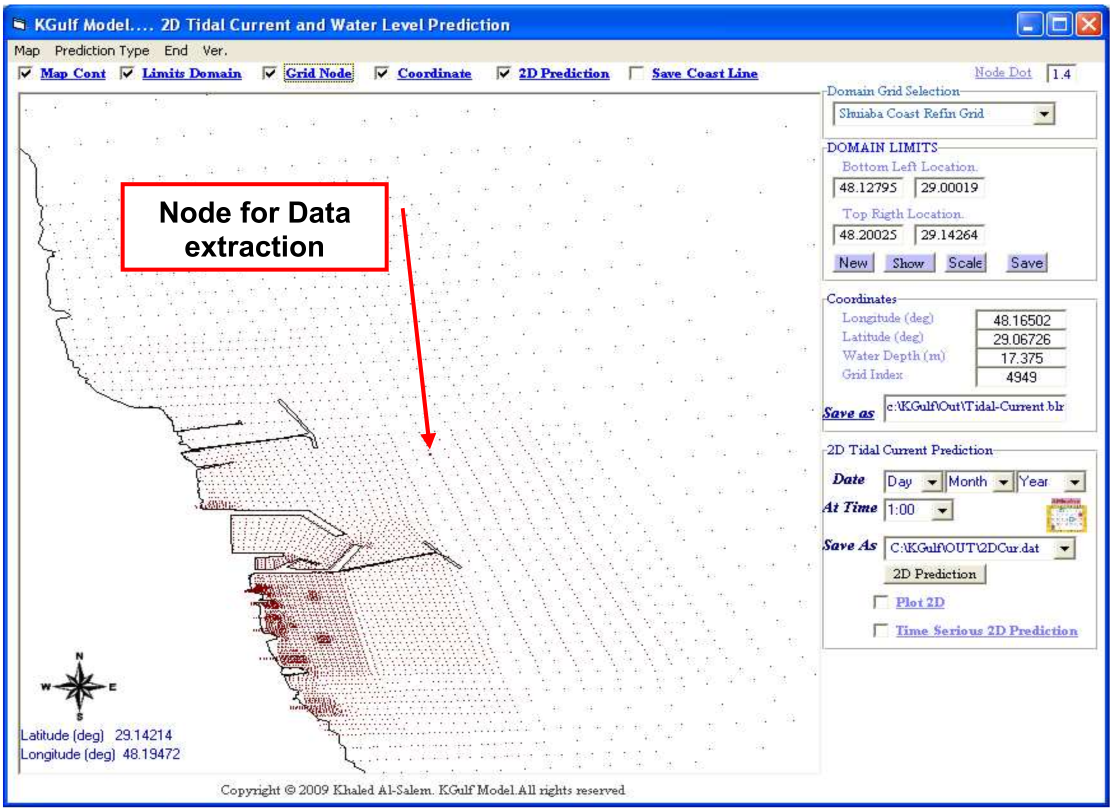


Figure 15. Location of Node where data was predicted and extracted.

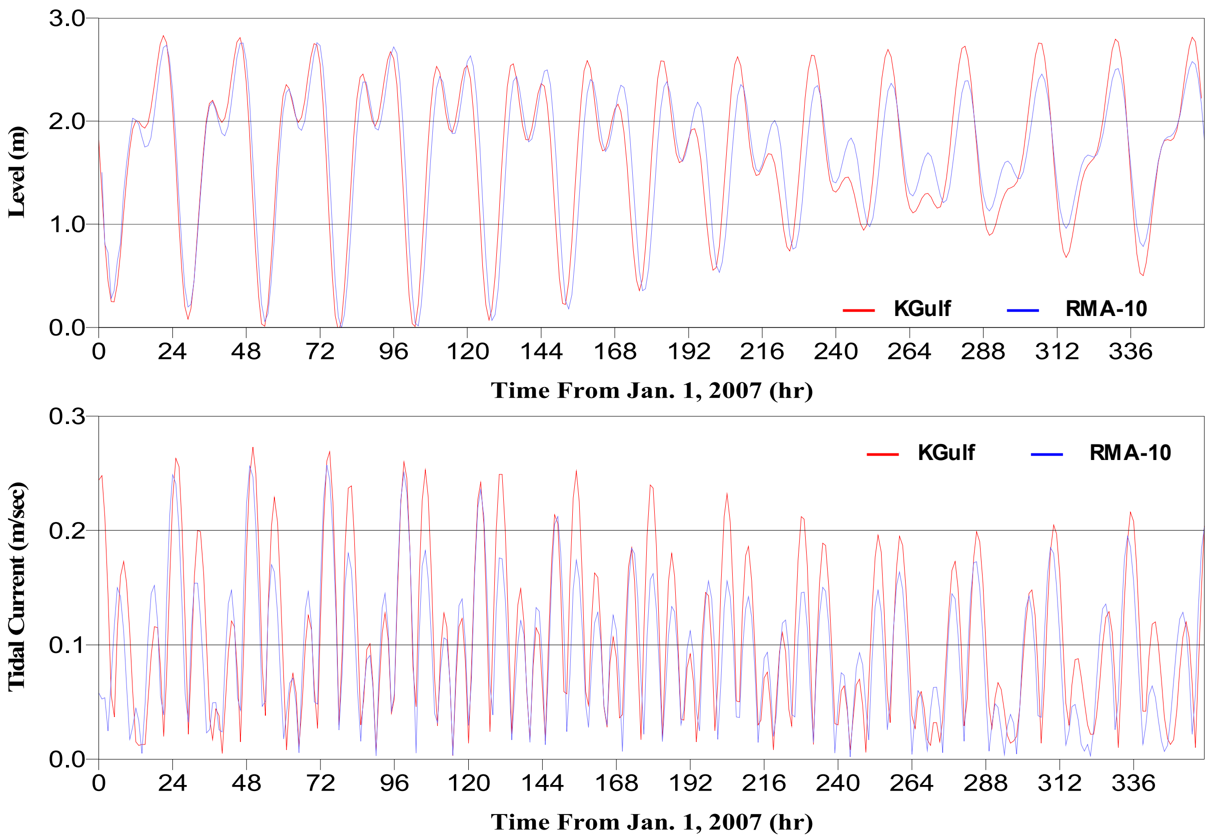


Figure 16. Tidal Current and Water Level Predictions at Node Coordinate (Longitude $48^{o}10^{'}00.0^{''}$ E and Latitude $29^{o}04^{'}00.0^{''}$ N)

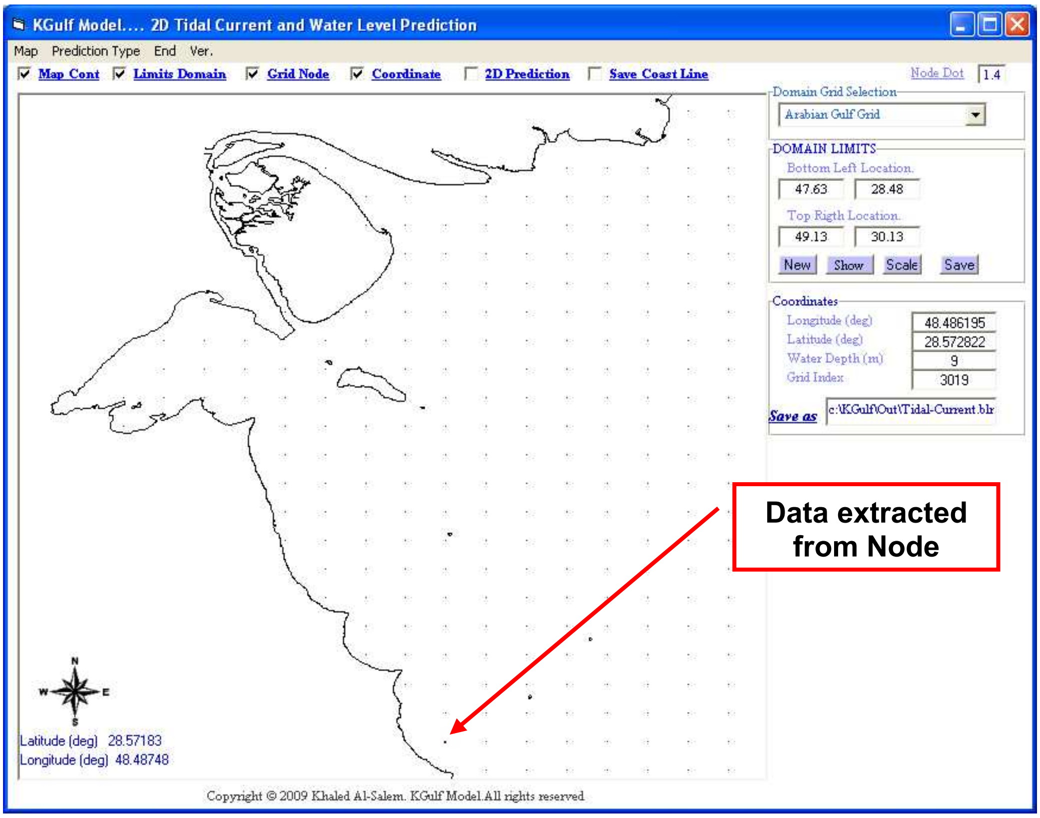


Figure 17. Location of Node where measurements for water levels were Recorded at Offshore of Al-Khiran using Aanderaa Water Level Sensor during Nov. 1, 1999.

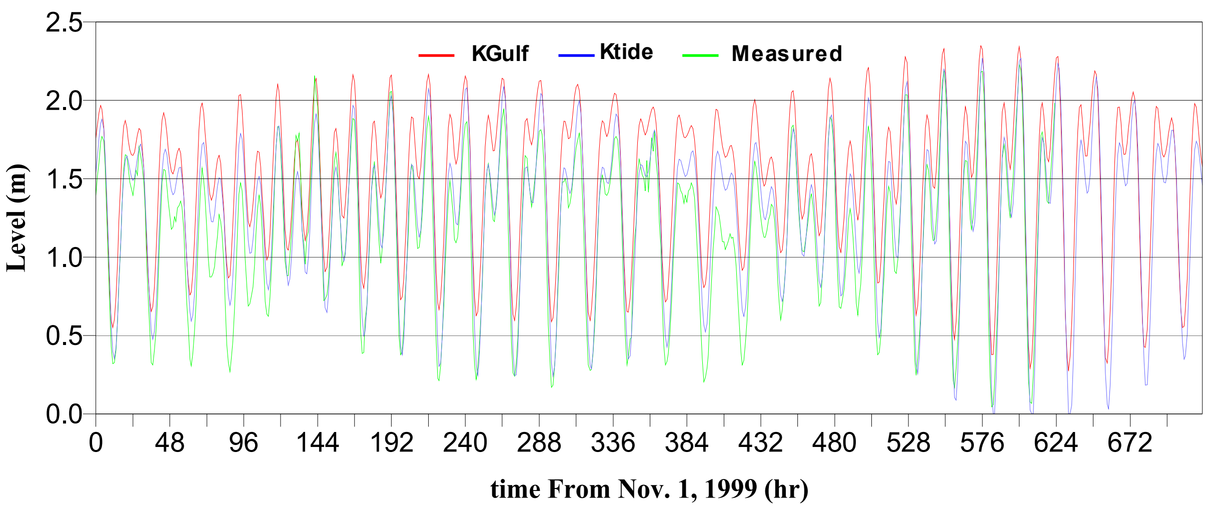


Figure 18. Model Validation against Measurements of Water Level at the Node Coordinate (Longitude $48^{o}29^{'}10.3^{''}$ E and Latitude $28^{o}34^{'}22.1^{''}$ N)

Table 2. Comparison of the time consumed for computer simulation for KGulf and RMA-10 model

Total simulation Time

Model Name	15 Days	30 Days
RMA-10	10 hr	24 hr
KGulf	4 min	8 min

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