NUMERICAL SIMULATION FOR PREDICTION OF OIL SLICK SPREAD IN PERSIAN GULF

Key words: Oil slick, Persian Gulf, Numerical modeling, prediction, forecast

Introduction

Study of oil slick spreading in marine environments is important for preserving natural assets from possible environmental damages. When oil spills occur, one of the first questions is "Where will the oil go?" Pollutants, such as oil, float on the surface and move through and along with the water. Computer models are tools that help predict the path of pollutants. They help minimize oil spill impacts by estimating the landfall and movement of oil. Plans for protecting the environment, society, and the economy require reliable forecasts that predict where oil will spread in the event of a spill.

In this paper, three numerical models are combined to predict the behavior of oil slick spreading after spillage. To verify the model results they are compared with an oil spill field data near the coast of Saudi Arabia and Kuwait.

Hydrodynamic Model

A developed 2-D depth-averaged hydrodynamic model is applied here to simulate the tidal currents as the basic modeling component of oil slick spreading in the Persian Gulf.

Wind and Wave Forecast Data

The wind and wave data during oil slick was adopted from the outputs of a new forecast model at Ports and Maritime organization (PMO) for the Persian Gulf. Using the results of an ensemble prediction system developed for the Weather Research and Forecasting (WRF) model to predict surface wind over the Persian Gulf

This work is devoted to present the results of an ensemble prediction system developed for the Weather Research and Forecasting (WRF) model to predict surface wind over the Persian Gulf.

The waves are simulated by introducing the modeled wind field to the wave generation/propagation model. The existing data of 10 historical data stations and 3 recent data stations were collected in this study. Version 4.18 of the third generation WW3 model was implemented for the generation and propagation of waves in the Persian Gulf. A structured mesh is developed to resolve the bathymetry within the computational domain. The mesh size is $0.05°\times0.05°$ and general time-step was set to be 12 minutes. The main parameters of the model were assigned based on comprehensive sensitivity analyses. Calibration and verification of the model was performed for about 30 individual selected events, based on the available historical and new data. Regarding the peak wave heights, the model showed a very good performance for 65% of the high waves but 23% of the peaks were overestimated (up to 20% of the recorded wave heights) and the remaining 12% of simulated results were about 15% lower than the recorded values. Altogether, it can be concluded that the results of the forecast system for the Persian Gulf are reliable for practical applications.

The hydrodynamic model is applied here to simulate the tidal currents in the Persian Gulf.

Simulation and Prediction of Spillage

The oil trajectory model is run for 26 days from Jan 24th to Feb 18th, 1991 where the tidal currents are derived from the outputs of hydrodynamic model. The effects of wind, wave and tidal currents are taken into account. An oil spill size of 240 million gallons was assumed at or near Al-Ahmadi terminal. The effects of wind, wave and tidal currents are taken into account.

The outputs of the model, extracted on 27th January, 12th February and 18th February, are compared with the observations of oil slick.

Figure 1 shows the predicted location of oil slick on 27th of January, 1991. Similarly, the model results on 12th and 18th of February are presented by figures 2 and 3, respectively. The arrows reveal the Northwest to Southeast movement of oil slick. The presented results of figures 1 and 3 are comparable with the actual observed data. The predicted location of oil slick at 12th of February also agrees with the reported track of oil slick, i.e. 173 km toward Southeast direction, based on satellite images [27]. The accumulative distribution of oil slick during total simulation period (26 days) of spillage has been presented in figure 4.

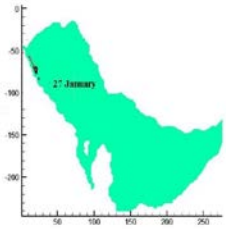


Fig. 1- Predicted location of oil slick from Jan 24th to 27th, 1991(4 days)

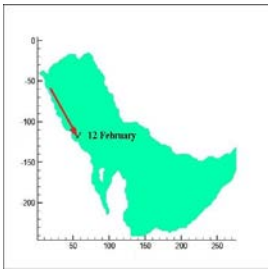


Fig. 2- Predicted location of oil slick from Jan 24th to Feb 12th, 1991(20 days)

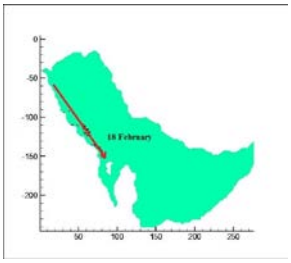
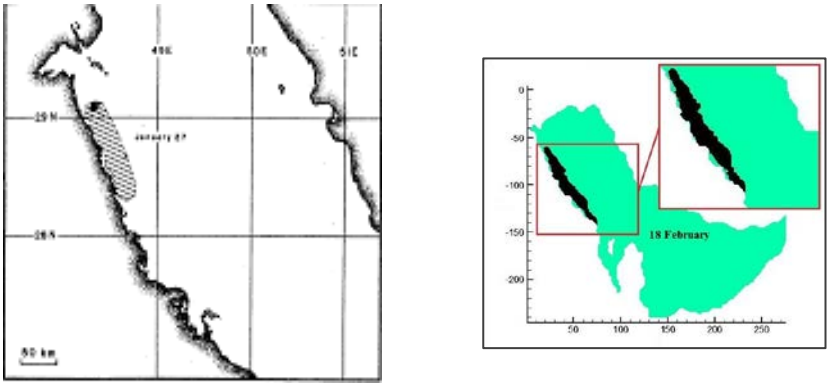


Fig. 3- Predicted location of oil slick from Jan 24th to Feb 18th, 1991(26 days)



(a) (b)

Fig.4. (a) Sketch of the Mina Al- Ahmadi oil spill (b) Predicted location of oil slick from Jan 24th to Feb 18th, 1991

Conclusion

A numerical model was developed for the simulation of the fate of oil spills in shallow water bodies. The predicted results were used to predict the OIL SLICK SPREAD IN PERSIAN GULF and calibrated for the Persian Gulf. The comparisons between the numerical results and the observed oil slick transport in the Persian Gulf shows a very good agreement for the case of oil spill that occurred at Al-Ahmadi oil terminal.

Sensitivity analysis using the developed numerical model clearly shows that tidal currents contribute very little to long-term net transport of oil spills. On the other hand, it is clear that wind-driven currents are the governing factor for the oil transport. For the case of Al-Ahmadi oil slick, the relative contributions of wind, wave and current forces are 80%, 15% and 5%, respectively.

Considering the frequency of famous Shamal winds in the Persian Gulf, the general movement of oil slicks under wind and resultant wave actions will be from northwest to southeast direction.

Despite the cases where the spillage is very close to Iranian borders, the danger of oil slicks approaching Iranian borders is small. However, this fact is true for the main land and it can not be extended to the islands of the Persian Gulf. Moreover, it should be noted that although the southern winds are not frequent, they can result in a significant oil transport towards Iranian shores. Introducing the future wind field and wave forecast to the developed numerical model, it can successfully be used to predict the short term fate of oil spills in any scenario of oil spillage in the Persian Gulf.

The developed oil spill trajectory model can be improved to simulate continuous spills. However, the Fay's spreading criteria should be changed since it is valid only for the lumped spills. Long term weathering processes have to be included for long term simulations too.