Assessment of Tide Models in Shallow waters and Data Fusion in Tidal Prediction

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Introduction

Among the considerations to determine the top level of marine structures in the engineering design, the periodic sea level variation –oceanic tide is a primary factor, which has been a serious concern for the safety of marine activity for the public. In light of this, the accurate prediction of tide deserves some special attention, particularly in the field of marine engineering and transportation. In the standard protocol, it demands the sea level records observed at a tidal gauge to reconstruct the tidal signals. Harmonic analysis is often adopted to study characteristics of tidal constituents and astronomical tides. Numerical models are often applied also to compute tidal signal at mesh grids.

Harmonic analysis has been developed for more than a century (Darwin, 1907). It is a trustworthy tool for engineers and scientists due to its accuracy on astronomical tidal parameters determination. Groves and Reynolds (1975) further developed convolution method to overcome the deficiency of harmonic analysis when the tidal records are insufficient in length, which often leads to the problem of large error. However, these two methods are single-point prediction, namely that tidal signal processing is confined at the station where observation is available.

Some techniques were consequently proposed to solve the problem. The satellite altimeters provide much complete data coverage over ocean globally. Hydrodynamic models realize the possibility to predict tidal signals at any given location and any given time (Cartwright and Ray, 1990) (Matsumoto, et al., 1995, 2000). Chang and Hwang (2001) assessed the prediction performance of NAO.99b for 3 stations of different tide types around Taiwan by comparing with harmonic analysis with 9 constituents.

The ambiguity in sea bottom topography and the non-linear effect disturbed in shallow waters turn out to be challenge in tidal prediction. To overcome this difficulty, we keep the hydrodynamic component implemented by the tide model, and evaluate the residuals of observed tidal height and this model prediction component at tidal gauges, and then a correction reference is obtained through spatial interpolation over these residuals.

Ministry of Interior, Taiwan developed a new tide model (MOI) optimized for area around Taiwan by introducing the assimilation and feedback techniques. A validation for the model accuracy assessment was carried out based on tidal records in 2012 from all the tidal gauges maintained by Central Weather Bureau around the coast of Taiwan. It shows that the root mean squared errors of the model prediction are as high as 0.15-0.17m for the tidal gauges around the middle-south of west coast, but averagely the errors are about 0.05-0.11m for gauges anywhere else in Taiwan.

The goal of this study is to assess the discrepancy between prediction and observation for tide model NAO.99b and MOI around the coast of Taiwan, and propose a data fusion based tidal prediction technique to cope with the difficulties presented around the shallow water area of Taiwan west coast, which had the unsatisfactory model performance in terms of prediction accuracy.

This study selected 2016 data record 22 tide stations along Taiwan coast to assess the accuracy performance of NAO.99b and MOI model. MOI tidal prediction, when compared with observation, has lower RMSE than NAO.99b at all 22 tide gauges. The RMSE is quite homogeneous along the east coast, about 11.1cm. Along the west coast, the RMSE decrease from north to south, and are significantly larger than that along the east coast. This study analyzed the residuals of observation and model prediction in the vicinity of Waisanding and concludes that for the MOI model the residuals show high spatial correlation. We therefore propose a data fusion based interpolation technique to improve the model prediction. It shows that the improvement can reach 1.6-6.4cm, or at the rate of 11.28%-37.92%. If the optimal combination is considered, the accuracy can be further improved, reaching the rate up to 15.35%-55.94%. However, the NAO.99b does not have strong spatial correlation in terms of its residuals, which ended up some bad result. This study concludes that MOI is suitable for model prediction around Taiwan. If data fusion technique is applied, accuracy can be further improved.

Keywords: tide model, data fusion, model assessment, correlation coefficient, harmonic analysis