TIDAL DYNAMICS OF THE ADRIATIC SEA USING HIGH RESOLUTION 3D FINITE ELEMENT MODEL AND IN SITU OBSERVATIONS

Ivica Janekovic* and Milivoj Kuzmic

Center for Marine and Environmental Research, Rudjer, Boskovic Institute, Bijenicka c 54, 10002 Zagreb, Croatia - * ivica@irb.hr

Abstract

In the present work we explore the impact of assimilating local tide gauge on the quality of predicting seven major Adriatic tidal harmonics. To that end we compute optimal tidal open boundary conditions for a 3D high-resolution finite element model using inverse modeling technique. Derived harmonic constants from original time series from 10 tide gauges are assimilated and the results are analyzed with literature available values. RMSE for observed and modeled amplitudes are less than 1cm. The model output is also successfully validated with current data, not used in the assimilation.

Keywords: Tides, numerical model, data assimilation, Adriatic Sea

Introduction

The need for accurate tidal correction of altimetric signal has revived interest in tidal modelling of marginal seas. In case of the Adriatic, estimation of tidal dynamics is primarily dependent to determination of boundary conditions along one open boundary. Complexity of flows in the basin resulting from the elaborate coastline and bottom topography makes the problem interesting and challenging. In a recent modelling study [1] the Adriatic tides were addressed as a part of the larger, Mediterranean solution. Similar 3D model was used [2] to simulate co-oscillation of four Adriatic harmonics while data assimilation technique, for the first time, was used in [3] to study major Adriatic harmonics (M2 and K1). The goal of the present study is to explore further dynamics for seven major tidal harmonics by assimilating data from 10 local tidal gauges.

Data

One type of used data are original tide gauge time series for 10 stations (squares on Figure 1). The data were collected simultaneous with record length of approx. two months (28/2/1982 – 30/4/1982). Tidal analyses were done for 38 harmonics and only seven of the most energetic ones (M2, S2, K2, N2, O1, P1 and K1) were used in the study. The other data source is harmonic constants compiled and verified from available literature (dots on Figure 1). The current data used in verification were obtained with 6 Aanderaa RCM-4 current meters deployed at 2 mooring stations in the Northern Adriatic (stars in Figure 1). Useful deployment period was about one month, from December 2nd 1986 till January 4th 1987.

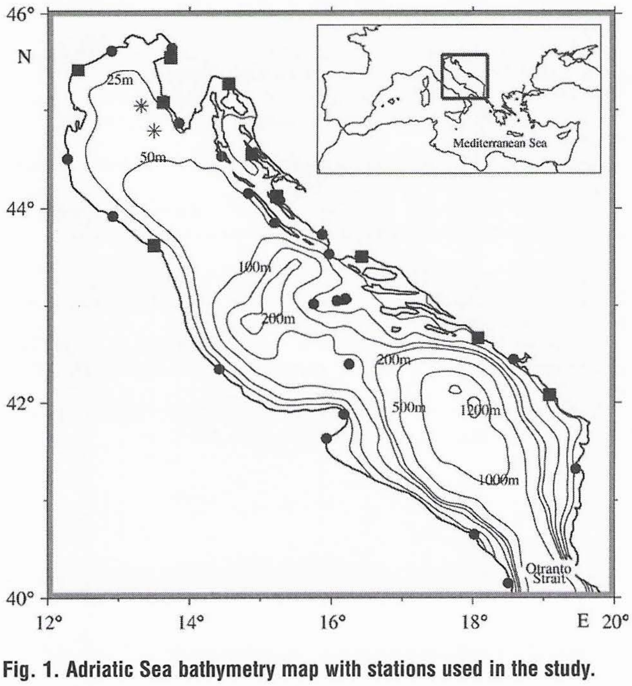

Fig. 1. Adriatic Sea bathymetry map with stations used in the study.

Method and models

Although the Adriatic Sea has only one short open boundary along the Straits of Otranto this appears to be a difficult one as there has been no published data on the bottom pressure covering the boundary. We used 3D finite element linear model and its inverse in order to obtain open boundary conditions for each tidal harmonic separately. Inversion is based on the best fit of the model to the observations, in the least squares sense. Three-dimensional forward model [4] is a finite element model based on the 3D non-linear shallow water equations. The finite element grid consists of 23055 nodes and 37200 elements with the nodal distances varying from about 500m in coastal areas up to 44 km in the largest triangle (deep parts of domain). With this mesh we have been able to include in our simulations 77 major islands and recognise realistic topography and lateral geometry better than in any previous Adriatic tidal model. The model is forced only by time varying sea level boundary conditions along 40°N resulting from the output of data assimilative models.

Results and conclusions

Using the mentioned method we were able to obtain open boundary values for seven major harmonics in dynamically consistent way. The two most energetic harmonics M2 and K1 obtained in previous study [3] showed good agreement with values in this study (although a different inverse models and technique were used). Obtained open boundary amplitude structure shows small values (<2 cm) for harmonics other than 3 major ones (M2, S2 and K1). By assimilating higher amplitude values at the northern part of domain (where tidal signal is stronger) we succeeded to reproduce small values at the open boundary. The phase structure is characterised by 2 groups: diurnal with values between 40° and 55°, and semidiurnal with phases ranging between 90° and 110°. For semi-diurnal harmonics basin-wide solutions show well known cyclonically rotating amphidromic system; diurnal solutions exhibit narrow phase sweep (20° to 25°) in cross-basin direction (northeast to southwest) with amplitude rise along the central axis (southeast to northwest). Comparison of modelled amplitudes with those obtained via harmonic analyses generated small RMSE (M2 ~0.8cm, S2 ~0.2cm, K2 ~0.4cm, N2 ~0.3cm, K1 ~0.5cm, P1 ~0.2cm, O1 ~0.3cm).

Verification of model with measured currents produced rather agreeable result. At two locations and at three depths the model was able to reproduce both the major and minor semi-axes in close agreement with measured data (not used in data assimilation procedure). RMSE for major (M2 ~1.4cm/s, S2 ~1.2cm/s, K1 ~0.9cm/s) and minor semi-axis (M2 ~0.9cm/s, S2 ~0.5cm/s, K1 ~0.3cm/s) are close to observed RMSE (1.8cm/s and 1.5cm/s for major and minor semi-axis).

References

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