ADRIATIC SEA TIDES IN THE ERA OF SATELLITE ALTIMETRY

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Abstract

This study addresses the question of how well some recent model solutions fit the established image of the Adriatic Sea tides. To that end harmonic constants for 33 stations have been compiled and compared to the same output from a purely hydrodynamic (HD) model, and two models incorporating satellite altimetry on a global scale. The comparison shows that the pure HD model produces better agreement with the perimeter gauges. The two global models, despite inherent disadvantages, apparently can produce Adriatic results generally in accord with the pure HD solution and the gauge data, except at anomalous locations largely on the east Adriatic side.

Key-words: tides, models, remote sensing, Adriatic Sea

Introduction

Satellite altimetry has reached such a level of precision that it allows direct evaluation of marine tides, but also demands accuracy for the tidal correction to avoid the contamination of other parts of the oceanographic signal. The marginal shallow seas provide both the need for predicting a rapidly changing and spatially complex tidal environment, and a challenge to researchers to show the utility of altimetry and/or altimetry-adjusted models.

Although the Mediterranean Sea is not known for pronounced tides, in some of its parts shallow topography contributes to harmonic amplitudes of appreciable magnitude. Such is the case of the Adriatic Sea, an elongated basin spanning more than 800 km between the Strait of Otranto, and the Gulf of Trieste (Fig. 1). Common understanding of the Adriatic tides, developed earlier in this century (1) and reinforced in more recent works (2,5), pictures a basin co-oscillating with the Ionian Sea with only minor correction arising from the direct action of the tide generating potential.

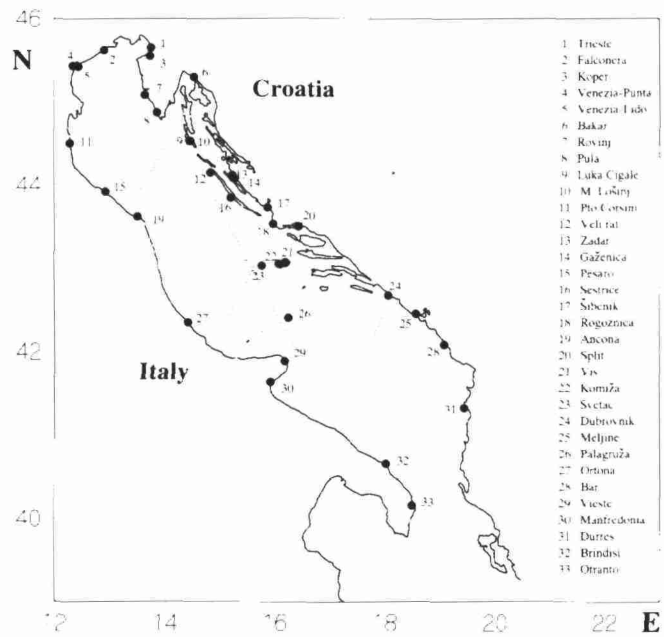

Figure 1. Location and names of the Adriatic tidal gauge stations and Topex/Poseidon track segments.

In this study we aim to assess how well some recent tidal models fit the established image, and to glean how successful altimetry can be in extracting a relatively weak tidal signal over a narrow basin with complex topography.

Gauge data and mathematical models

We have compiled harmonic constants from the available literature for 33 Adriatic coastal and island gauge stations as depicted in Fig 1. These empirical data have been compared to the same output generated by 3 tidal models, one purely hydrodynamic while the other two include Topex/Poseidon (T/P) altimetry on a global scale, but seek to accomodate the tidal complexities of the Mediterranean Sea in different ways.

The POL model (2) is a high resolution (1/12 x 1/12 degrees), non-linear, two-dimensional, pure HD model of the Mediterranean Sea forced only by the equilibrium tide inside and the actual tides at the Strait of Gibraltar. The CSR3.0 model (3) is a global tidal solution referenced to the high resolution Grenoble HD model (4) in which long wavelength accruacy is sought by fitting altimeter residuals from this and a Mediterranean (5) model to tide harmonics through a response formalism, and broadly smoothing the resulting corrections. In the FES95.2 model (3) improvement on global scale is sought through statistical assimilation of a pure altimetric solution (CSR2.0) into the same global reference HD model (4). In the Mediterranean however, FES95.2 is completed by adding the same local gauge-constrained HD model (5) resampled on a coarser grid. All models compute at least the 4 major constituents we have considered in the present study (M2, S2, K1, and O1).

Results and conclusions

Two parameters are used to aid the comparisons. One is the magnitude of the vectorial difference (distance d) between observed (o) and modeled (m) harmonic constants (H, G - phase lag relative to Greenwich) calculated as:

$$d = \sqrt{(H_o\cos G_o - H_m\cos G_m)^2 + (H_o\sin G_o - H_m\sin G_m)^2} \qquad (1)$$

and the other is the classic Form number:

$$F = (K1 + O1)/(M2 + S2) \qquad (2)$$

While the gauge values provide a useful test generally, the comparisons with particular gauges which have site problems may not be representative. Thus the larger distances to some gauges do not necessarily imply an inferior model. One should also bear in mind that binning and smoothing applied in CSR3.0 or coarse resampling in FES95.2 inevitably distort their solutions, particularly at the margins where the gauges are located. The hope for CSR3.0 has been that the altimeter data in the mid-basin would provide some positive effect, while FES95.2 results should gauge the penalty for subsampling. Some of the observed behavior with respect to the gauges is captured in Fig 2.

Comparing model performance in two parts of the basin we note that all experience difficulties in the shallower northern part. An example is a pronounced discrepancy at Trieste, the most studied station with particularly reliable constituent estimates. We note in passing that station 4 inside the Venice Lagoon is understandably beyond the reach of the three models. Judging the ability to predict the overall diurnal and semi-diurnal tide behavior, we find problems for all models along the island-rich eastern Adriatic coast, and along both coasts close to the amphidromic center. There, the solutions are particularly vulnerable to numerical noise, and the distances can reach or surpass the M2 amplitude.

Comparing the pure HD (POL) with the 2 global model solutions we find that the two ways of accomodating the Mediterranean tides produce solutions that depart from POL in a similar fashion. This clearly testifies to their common hydrodynamical background in the Mediterranean (5) and to the ineffectiveness of the small and broad altimetric adjustment. Preliminary analysis of solutions along Adriatic T/P tracks (not shown) suggests there are similar deviations of both global model solutions from POL in the open areas of the sea as well, with somewhat better CSR3.0 performance. A notable exception is Ancona station where CSR3.0 and FES95.2 largely differ in predicting diurnal and semi-diurnal waves as well as their ratio (see Table I). It is worth noting that Ancona is one of the five gauge stations (and the only one in Adriatic) providing empirical constraint to the model on