

Tidal Estimation in the Atlantic and Indian Oceans

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Abstract An estimation technique has been developed to extrapolate tidal amplitudes and phases over entire ocean basins using existing gauge data and the altimetric measurements which are now beginning to be provided by satellite oceanography. The technique was tested previously in the Lake Superior basin by Sanchez et al. (1985). The method has now been developed and applied in the Atlantic-Indian ocean basins using a $6^\circ \times 6^\circ$ grid to test its essential features.

The functions used in the interpolation are the eigenfunctions of the velocity potential (Proudman functions), which are computed numerically from a knowledge of the basin's bottom topography, the horizontal plan form, and the necessary boundary

conditions. These functions are characteristic of the particular basin.

The gravitational normal modes of the basin, computed as part of the investigation, are used to obtain the theoretical forced solutions for the tidal constituents. The latter provide the simulated data for testing of the method and serve as a guide in choosing the most energetic functions for the interpolation. The results of the estimation of the M_2 and K_1 tidal constituents indicate the possibility of recovering the tidal signal with a degree of accuracy well within the error bounds of present satellite techniques.

Introduction

The accurate modeling of oceanic tides is very important for the interpretation of oceanic measurements from spaceborne altimeters. The tides not only introduce errors into the determination of geostrophic velocity but are of considerable interest in their own right. Tidal investigations of ocean basins with realistic topography and coastal boundaries are still in the development stage.

Ocean tidal studies have a long history. Several comprehensive reviews can be found in the literature (i.e., Hendershott and Munk, 1970; Cartwright, 1977; Hendershott, 1973, 1977, 1981; Schwiderski, 1980). Hendershott (1977) summarized the efforts to solve the Laplace tidal equations (LTEs) for global tides for semidiurnal and diurnal components up to that time.

More recent efforts have been directed to incorporate the results of loading and self-attraction. Accad and Pekeris (1978) solve the LTEs for the M_2 and S_2 tides in the world oceans on the basis of a knowledge of the tidal potential alone. Tidal dissipation was taken to be limited to the coastline. The main purpose of their investigation was to determine the effects of tidal self-attraction and of tidal loading. An iterative method was developed to evaluate these secondary effects. The resulting change is of the order of 10% and better agreement is obtained between the theoretical and observed tides. Parke and Hendershott (1980) obtained global solutions to the LTEs for the M_2 , S_2 , and K_1 tides. They addressed the problem of divergence of the near-resonance modes by means of test functions which are used to interpolate between island data

in the least-squares sense. These test functions are derived by solving the LTEs with ocean loading and self-gravitation in an iterative manner. The resulting representations of the global tide are stable over at least a $\pm 5\%$ variation in the mean depth of the model basin and they conserve mass.

Schwiderski (1980) computed the M_2 global tide by solving the LTEs directly, using a finite difference scheme in space and time; the strictly mathematical solution was modified by means of an interpolation technique which incorporates over 2000 tide data collected at continental and island stations. The interpolation is accomplished by adjusting the bottom friction coefficient and by allowing inflow or outflow across the mathematical ocean boundary. No direct comparison of observed and computed data is feasible since the model incorporates essentially all known data, although it is possible to evaluate the smoothness with which the computed tide accepts or rejects data. It was found that the interpolation technique permits a check of the reality of both the tide model and the tidal data input.

Platzman (1978, 1981, 1984) has computed a range of normal modes for the world oceans. He used them to synthesize some of the diurnal and semidiurnal tides. He decomposed the transport vector by means of the Stokes/Helmholtz potentials but did not determine the velocity potential and stream function eigenfunctions explicitly (as in this paper), but proceeded directly to the normal-mode solution of the LTEs. The linearized primitive equations were discretized by means of first-order, piecewise-linear finite elements with an average grid triangle area equal to that of a 4.54° equatorial square. His synthesized tides incorporated dissipation by means of energy flux across the domain boundary, and no tidal loading or self-attraction was included.

Simulation studies by Estes (1980) using numerical solutions of the LTEs to generate the observed measurements (based on simulated 4-day SEASAT orbits over a 200-day interval) indicate that when the rms amplitude error is less than 10 cm for the M_2 tide, virtually all the structure is recovered. For rms errors between 12 and 15 cm, all large-scale features are retained; for 1.5- to 20-cm rms errors, the high-amplitude structure is recovered. These results were obtained by utilizing long arc intersection or crossover point