TIDE CORRECTIONS FOR COASTAL ALTIMETRY: STATUS AND PROSPECTS

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1. INTRODUCTION

Knowledge of global oceanic tides has markedly advanced over the last two decades, in no small part because of the near-global measurements provided by satellite altimeters, and especially the long and precise Topex/Poseidon time series e.g. [2]. Satellite altimetry in turn places very severe demands on the accuracy of tidal models. The reason is clear: tides are by far the largest contributor to the variance of sea-surface elevation, so any study of non-tidal ocean signals requires removal of this dominant tidal component.

Efforts toward improving models for altimetric tide corrections have understandably focused on deep-water, open-ocean regions. These efforts have produced models thought to be generally accurate to about 2 cm rms. Corresponding tide predictions in shelf and near-coastal regions, however, are far less accurate. This paper discusses the status of our current abilities to provide near-global tidal predictions in shelf and near-coastal waters, highlights some of the difficulties that must be overcome, and attempts to divine a path toward some degree of progress.

There are, of course, many groups worldwide who model tides over fairly localized shallow-water regions, and such work is extremely valuable for any altimeter study limited to those regions, but this paper considers the more global models necessary for the general user. There have indeed been efforts to patch local and global models together, but such work is difficult to maintain over many updates and can often encounter problems of proprietary or political nature. Such a path, however, might yet prove the most fruitful, and there are now new plans afoot to try again.

As is well known, tides in shallow waters tend to be large, possibly nonlinear, and high wavenumber. The short spatial scales mean that current mapping capabilities with (multiple) nadir-oriented altimeters often yield inadequate coverage. This necessitates added reliance on numerical hydrodynamic models and data assimilation, which in turn necessitates very accurate bathymetry with high spatial resolution. Nonlinearity means that many additional compound tides and overtides must be accounted for in our predictions, which increases the degree of modeling effort and increases the amounts of data required to disentangle closely aliased tides.

2. STATUS OF CURRENT MODELS

To ascertain the accuracies of global tidal models in shallow-water regions, some effort has recently been devoted to constructing a high-quality set of validation, or "ground truth," measurements. A similar validation dataset has proven useful for assessing deep-water models. The new dataset now comprises well over one hundred stations, and the search for additional stations is on-going. Most of the stations are from bottom pressure recorders sitting on the shelf floor. Some are standard tide gauges located on small islands. Since most bottom-pressure data have been collected in but a few select regions, the distribution of these data is far from ideal.

One application is given in Figure 1, which shows that our altimeter-based tidal models [2] have been continually improving in shallow-water regions, even though most efforts have been oriented toward the deep ocean. This progress is the result of several factors: increasing amounts of altimeter data, improved model spatial resolutions, improved methods of data assimilation, and improved numerics and realism of the underlying hydrodynamic models.

As a rough assessment of current capabilities, Table 1 gives the rms differences (in cm) between both our deep-ocean and shallow-water test stations and the altimeter-based model GOT00.2, an update to [3]. Included in Table 1 are the main eight diurnal and semidiurnal constituents which most modelers provide. An additional column accounts for other constituents within the diurnal and semidiurnal bands (e.g., tides $2N_2$, L_2, etc.) which are typically accounted for in tidal prediction by inference

Table 1. RMS differences (cm) of model GOT00 with validation gauge data

	Q_1	O_1	P_1	K_1	N_2	M_2	S_2	K_2	Inferred minors	Error of Omission	Total RSS
Deep water	0.28	0.86	0.37	1.02	0.63	1.45	0.93	0.42	0.28	—	2.37
Shallow water	0.88	1.20	0.59	1.58	2.12	8.01	4.35	1.65	0.94	6.62	11.83

methods. Another column accounts for completely missing constituents, which in the GOT00 model would be all compound tides (more recently released models—FES2004, GOT4.7, TPXO.7—now at least include the overtide M_4).

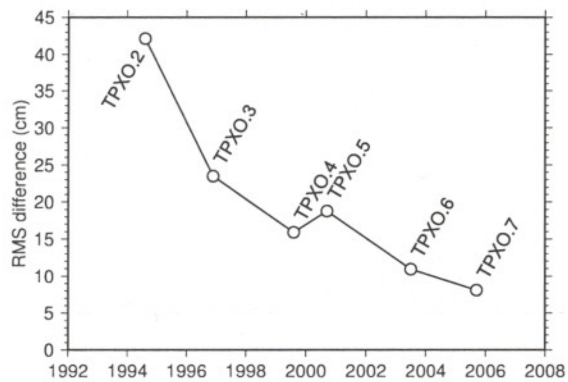

Fig. 1. M_2 tide RMS differences between a set of shallow-water tide-gauge stations and six successive releases of the TPXO series of global inverse models [2]. The continued improvement over time is clear.

Table 1 emphasizes the differences in our capabilities for tidal prediction in deep versus shallow water. The larger constituents are a factor of 4 or more worse in shallow seas, and the overall root-sum-of-squares exceeds 10 cm. Note, however, that while these deep-water values are thought to be a legitimate assessment, the shallow-water values should be taken with a grain of salt—they are highly dependent on the locations of our test stations. It would be easy to find examples in shallow water where our tidal predictions are better than 12 cm, or much, much worse than that. Moreover, the shallow-water diurnal values in Table 1 are probably too small (i.e., too optimistic) to represent a global mean, owing to an over-abundance of bottom-pressure stations in the Atlantic Ocean where the diurnal tides are very small.

3. PROSPECTS

Both near-term and longer-term improvements in shallow-water tidal modeling can be anticipated. However, some problems may prove intractable without additional measurements, such as those envisioned by a wide-swath altimeter mission.

The series of empirical GOT models can be improved in the near future by employing higher spatial resolutions (GOT00 is 0.5° resolution, which is too coarse for most shallow seas). However, the existing coverage of altimeter data places an inherent limit on the achievable resolution until a wide-swath or similar mission is flown.

Numerical modeling of compound tides can evidently be improved by some new approaches. For example, a standard approach relies on time-stepping the nonlinear hydrodynamical equations and extracting both linear and nonlinear tides; errors in the former induce large errors in the latter. Reformulation of the nonlinear equations based on having reliable prior inverse solutions of the linear tides appears to show considerable promise.

Of course, lacking sufficient tidal measurements, our inversions must rely more heavily on hydrodynamic modeling. The major impediment to progress in many regions is a lack of accurate, high-resolution bathymetry data. Constructing grids from multiple sources, eliminating obvious errors, and refining resolution are very time-consuming tasks, even when data can be obtained—and in many cases data cannot be. Several international groups, and most notably the French LEGOS group led by F. Lyard, are attacking the difficult and tedious tasks of modeling individual shallow seas, one by one. By such work, we expect to see slow, but significant, progress. More and denser satellite data would help considerably in these efforts.

4. REFERENCES

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