Altimetric studies of ocean tidal dynamics

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The accurate global measurements of the ocean tides by TOPEX/POSEIDON and Jason-1 allow a number of longstanding questions about tidal dynamics to be addressed in a serious way. Among them are the problems of tidal energy dissipation, the dynamics of long-period tides, and the nature of internal tides. Ocean cotidal charts themselves also continue to improve as the altimetry time series grows longer. We intend to periodically release new global tide models of benefit to other altimeter users and to the wider geophysical community.

Improved Tide Models

Improving our knowledge of the ocean tides continues to be an important task for the TOPEX/POSEIDON and Jason-1 missions. The applications of improved tide models are widespread throughout geodesy and oceanography, and, of course, none is more crucial than the application to altimetry itself. Following the rapid and marked improvements made early in the TOPEX/POSEIDON mission, later advances are understandably more incremental. Our recent global solutions, dubbed GOT99.2, GOT00.2, and TPXO.5, are nonetheless clearly more accurate than our earlier global models, especially in shallow seas. Figure 1 shows one recent solution for the principal lunar diurnal tide O1.

A judicious use of data from ERS-1, ERS-2, GFO, and coastal tide gauges, combined with hydrodynamic models, will serve as valuable supplements to T/P and Jason-1 data. We expect that further incremental improvements to global tide models will continue throughout the Jason-1 mission.

Internal Tides

The discovery of internal tide signals in satellite altimeter data opens up an exciting new approach to the study of these waves. Internal tides can be observed in altimetry as small (usually less than 2 cm), short-wavelength (150 km) modulations in the tidal surface elevations. They are therefore most easily observed in along-track tidal estimates. Because of their tiny amplitudes, very long time series of sea level observations are required to extract them from a background of larger oceanographic signals and noise. Jason-1 data will considerably refine our maps of internal tides. So too will the T/P and Jason tandem mission, which will improve the spatial resolution in our estimates.

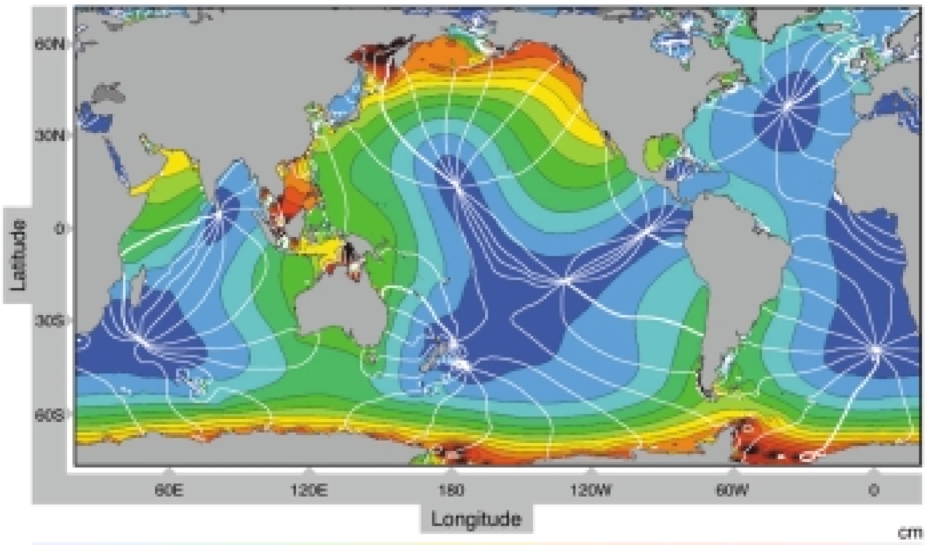

Figure 1: The principal lunar diurnal tide O1 from the TPXO.5 global assimilation solution. White lines delineate tidal phases with an interval of one lunar hour.

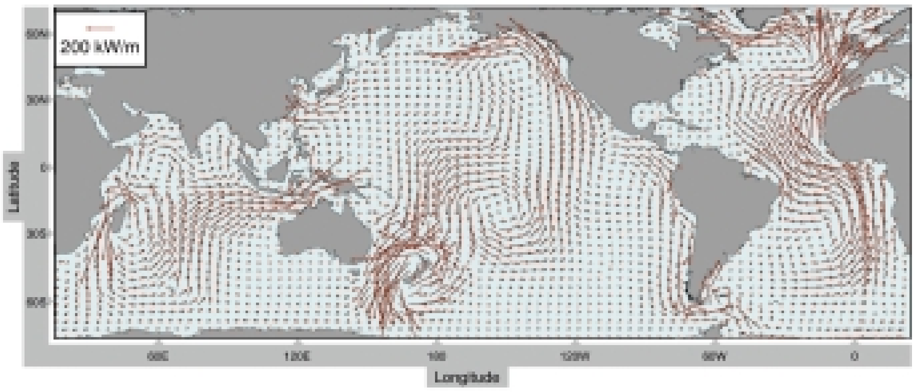

Figure 2: Mean tidal energy fluxes of the M2 barotropic tide, determined from TOPEX/POSEIDON altimeter measurements.

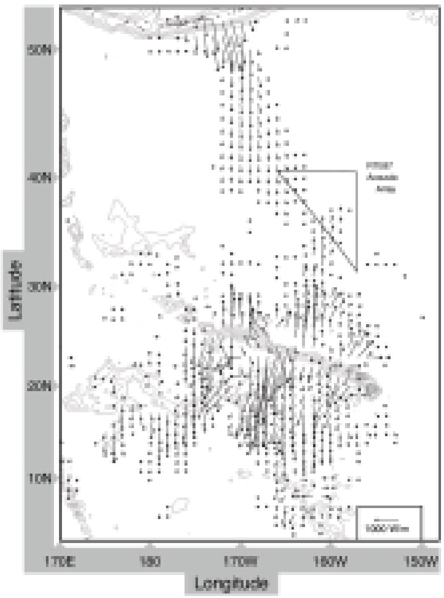

Figure 3: Mean tidal energy fluxes of the temporally coherent M2 internal tide, averaged over ocean bins of size 4 x 3 degrees [Ray and Cartwright, 2001]. Flux vectors smaller than 100 W/m are not shown. Bathymetry contours are given every 1000 m.

Tidal Energetics

The advances in tidal mapping afforded by TOPEX/POSEIDON have finally allowed us to begin to answer some longstanding questions about tidal energetics, specificically the nature and the location of tidal energy dissipation. We have recently reported some initial findings [Egbert and Ray, 2000]. Analyses of the altimeter-derived cotidal charts reveals that most tidal energy is dissipated in shallow seas, as most oceanographers have long thought. However, about 25 to 30% of the global energy dissipation, or about 1 terawatt, occurs in the open ocean, generally near rugged bottom topography. The mechanism at work is almost certainly the scattering of surface wave energy into internal tides and other baroclinic motions. It is thus conceivable that the dissipation of tidal energy is intimately related to the vertical mixing of the ocean and to its thermohaline circulation.

Figures 2 and 3 show two examples of deciphering the flow of energy in the surface tide and internal tide, respectively. Such charts can often immediately reveal the sources and sinks of tidal energy. The barotropic energy fluxes of figure 2 show considerable energy flowing into various shallow seas; the major energy sinks are clearly evident. The subtle deep-ocean dissipation is revealed by computing the divergence of figure 2 and subtracting the work done by the moon on the ocean. As energy leaves the surface tide, it can sometimes be seen to reappear in the internal tide, as figure 3 shows for central North Pacific Ocean. Internal wave energy is observed flowing both north and south from the Hawaiian Ridge, sometimes in remarkably narrow beam patterns. A very localized source along the Aleutian Ridge generates waves that propagate southwards over 2000 km.

As the TOPEX/POSEIDON time series grows longer and as it is supplemented by the Jason-1 time series, these data only grow more valuable for tide studies. We expect to see many new and intriguing results over the next several years.

References

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