NORTH AUSTRALIAN TROPICAL SEAS CIRCULATION STUDY (PHASE IV)

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The goal of our TOPEX/POSEIDON Extended Mission (TPEM) project is to investigate applications of TOPEX radar altimetry to studies of regional and coastal circulation in northern Australian marginal seas. To this end we are developing regional tidal models for computing accurate tidal corrections in coastal settings. The residual low frequency sea level variations and associated currents are compared with *in situ* observations. These residuals will ultimately be assimilated into regional hydrodynamic models, to serve chiefly as an input to ecological studies.

Introduction

The outstanding performance of TOPEX radar altimetry in deep ocean studies is well demonstrated by recent studies of tidal and sub-tidal SSH variability. However, several issues arise in using altimetry to observe circulation of marginal seas and continental shelves, particularly in the topographically-complex domain of NE Australia. Examples include: obtaining accurate tidal corrections; coping with data dropouts due to islands and reefs; resolving continental shelf waves; and avoiding land contamination in side lobes. Our TPEM project seeks to resolve such issues. We are presently using high-resolution regional numerical hydrodynamic models to determine appropriate tidal corrections for use in the Western Coral Sea (WCS) /Great Barrier Reef (GBR), Australian NW Shelf (NWS) and the Gulf of Maine (GOM), and are seeking to minimize data losses by improved screening and interpolation of the altimeter and ancillary data during the correction phase.

Once the issues are resolved we will use the corrected altimetry signals to study mesoscale and low-frequency coastal current variability. In future, we will use coastal-trapped and internal wave models to identify and remove these wave signals from the altimeter-derived coastal SSH fields since these are under-sampled (aliased) by the 10-day repeat cycle. The resulting low-frequency signals will be used to study coupling between deep ocean flows and the time-varying alongshelf drift. This drift is responsible for dispersing larvae such as those of the coral predator, the Crown-of-Thorns Starfish, which periodically damages large sections of the GBR.

Objectives and methods

Our objectives are to acquire relevant long-term sea level and current data, to develop regional circulation models of the marginal seas, to study mesoscale circulation patterns and their interactions with adjoining continental shelves, and to assimilate *in situ* and satellite altimeter data into the regional models.

To achieve these objectives we maintain long-term current meter moorings and tide gauges on the NE and NW Australian continental shelf and slope, and near off-shelf reefs. These provide 'sea truth' data for verifying the altimeter-derived sea level and current variations, for setting boundary conditions, and for verifying numerical models.

We also develop and apply 2D and 3D finite-difference hydrodynamic model codes [Bode et al., 1997; Black, 1995]. These are used to predict tidal and low-frequency surface heights and currents. Special numerical schemes have been developed to improve circulation predictions in the topographically-complex Great Barrier Reef (GBR). These work by embedding analytical models that represent sub-grid scale flows through reef passages [Bode et al., 1997]. Selected models will ultimately be run in assimilation mode.

Finally, we acquire and maintain an archive of NOAA AVHRR imagery and other active radar remote sensing data (eg., ERS-1/2 Synthetic Aperture Radar, and Wind/Wave Scatterometry). These provide supplementary data on specific phenomena. As part of this effort, we plan to merge ERS-1&2 altimetry with the TOPEX data to enhance resolution of mesoscale circulation features, such as those revealed by SST imagery (Figure 1).

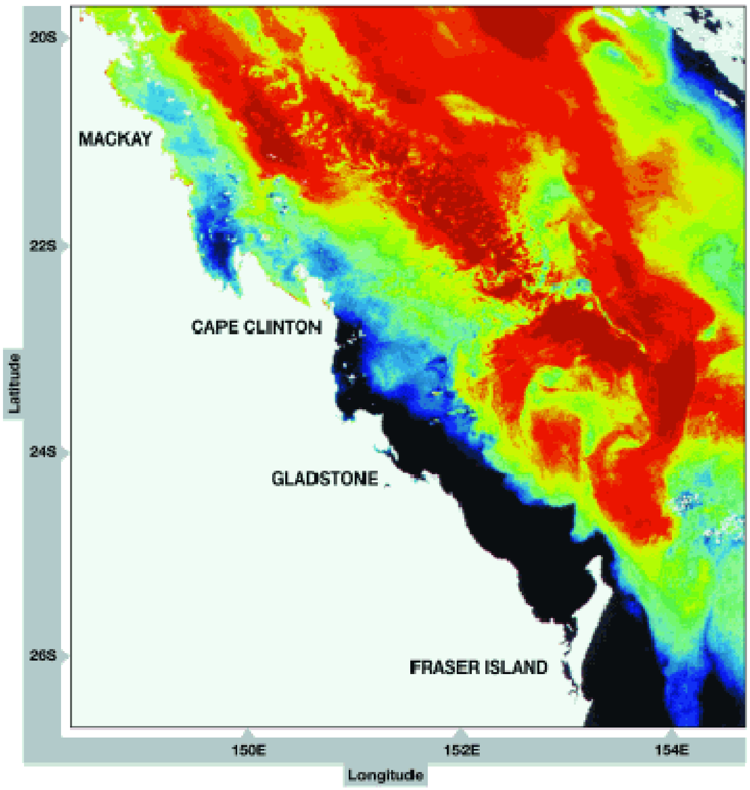

Figure 1
SST in the SGBR NOAA/AVHRR SST image (T_B/Ch.4) of the SGBR. The southward flowing EAC (warm/cold red/blue) leaves the SE tip of the GBR, crosses the Capricorn channel and spins up a clockwise circulating 'lee eddy' north of Fraser Island. Image provided by W. Skirving, AIMS Remote Sensing Manager)

Results

Our initial focus has been to obtain high accuracy tidal predictions in marginal seas of Northern Australia and the North Eastern USA. These are required to correct the TOPEX altimetry for aliased tidal components. Once the altimetry is corrected for such effects, the low-frequency (i.e. weather-related, seasonal and/or inter-annual) variations in SSH and surface current should emerge.

In our previous TOPEX Primary Mission project we found that predictions of the standard TOPEX global tidal models (FES95.2, CSR3.0) compared well with *in situ* tide gauge data, and with output from a regional tidal model of the Coral Sea. However, a similar inter-comparison for TPEM of a high resolution regional tidal model of the continental shelf and slope region of the SGBR (having 1' x 1' or ~1.85 km resolution, Figure 2) [Bode et al., 1997] showed the predictive skill of the regional model was outstanding. Average deviations from *in situ* M2 amplitude and phase were 2 cm and 2.4 deg, respectively. This significantly exceeded the skill of the global models which resolve the coastal seas poorly, especially in topographically-complex domains (eg GBR).

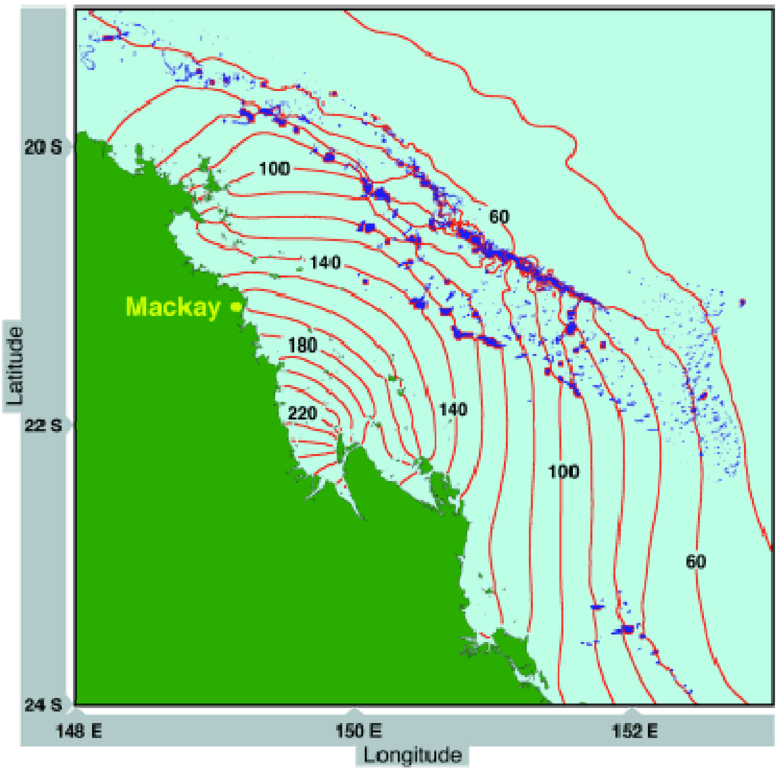

Figure 2
Predicted M2 tide of the SGBR (in meters). Amplitude of the M2 tide from the regional tidal model [Bode et al., 1997]. Both the modelled and observed tides are amplified by convergence from the north and east around the outer GBR and the funnelling by Broad Sound (22°S, 150°E).

We are presently working in three contrasting domains to assess the influence of topography on model performance and resulting corrections. All three regions, the WCS/GBR, the NWS and GOM, exhibit enhanced surface and internal tides due to standing wave effects and resonant amplification, and only modest levels of mesocale variability in the low-frequency circulation. The resulting low 'signal to noise' ratio provides a significant challenge, and a stringent test of our ability to remove tidal signals from the altimeter data.

The regions differ in shape, coastal orientation and topographic complexity, with the highest complexity exhibited by the WCS/GBR. The GOM (see Figure 4) is an interesting intermediate case, with channeling of flow around Georges Bank and resonant amplification in the Bay of Fundy (BOF). We presently model the GOM/BOF using a 5x 5 km resolution 2D finite-difference model, which we plan to convert to 3D mode (using 3DD, Black [1995]). We are now verifying this model using *in situ* data [Moody, 1984], and plan to compare its performance with that of a 3D finite-element model developed by the Dartmouth modelling group [Naimie and Lynch et al.].

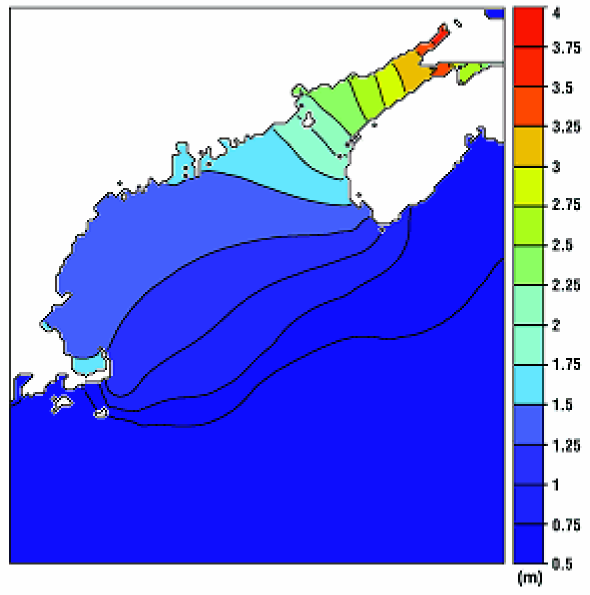

Figure 4

Predicted M2 tide of the GOM (in meters). The M2 Amplitude from analysis of 28 day simulation of the GOM tidal model reveals the well known resonant amplification of the GOM and BOF system. Results agree well, qualitatively, with Moody et al. [1984].

We have applied corrections from the regional SGBR tidal model to the altimetry and have computed the rms variability of the residual low frequency SSH variations Figure 3). These show a maximum along the descending track (#1439, running along-shelf) of 18 cm compared with 45 cm for corrections from the 'best' global tidal model. A local rms minimum appears at the track intersection in the Swains Reefs (cf. Figure 1). We associate most of the remaining variability with fluctuations in the mesoscale structure of the East Australian Current (EAC) and associated lee eddies and frontal structures in the SGBR (Figure 1) [Burrage et al., 1996].

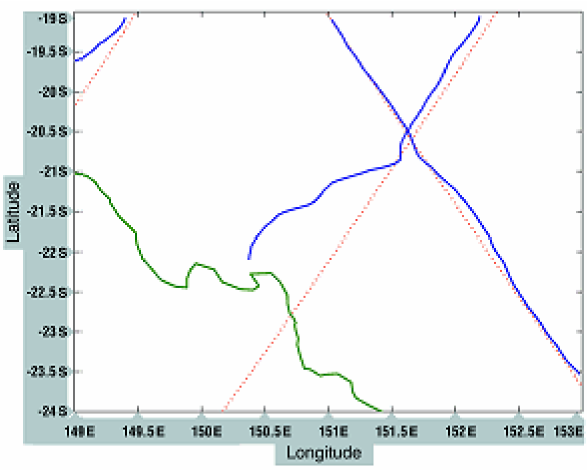

Figure 3

Rms SSH variability from the TOPEX Altimeter. Along-track profiles of rms SSH from altimetry corrected using the SGBR tidal model. SSH scale is 0.025 deg Lat/cm and profiles (solid lines) intersect corresponding ground-tracks (dashed) at 15 cm rms level. A distinct minimum with rms height < 25 cm is seen off shore in the GBR where the tracks intersect near 21°S, 152°E, while a maximum of 50 cm rms occurs near Cape Clinton at 22°S, 151°E (cf Figure 1).

In contrast to the SGBR model, which is forced solely by strategically located *in situ* tide gauge data, the GOM model (Figure 4) is forced almost exclusively by open boundary data obtained from the TOPEX global tidal model, CSR 3.0 (we used only one coastal tide gauge on each across-shelf boundary). The model performs surprisingly well in comparison with *in-situ* data. Thus, with careful choice of boundaries and limited use of *in-situ* data, it appears possible to extrapolate the global tidal results to the coast with acceptable accuracy, using a high-resolution regional tidal model.

Future work and conclusions

Outstanding tasks include testing and tuning the available tidal models using residual rms minimization criteria. Models of coastally-trapped waves will be used to further reduce the rms variability. Finally, the resulting products will be assimilated into low-frequency numerical hydrodynamic models and used to address ecological dispersal problems.

Early results suggest the prospects for use of altimetry in coastal settings are good, but that success will depend on particular applications and geographical domains. Our long-term goal is to develop operational models for predicting coastal and regional circulation for a variety of scientific, engineering and resource management applications.

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