Subtidal Modulation of Tidal Currents on the Northeast Brazilian Shelf

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Introduction

The sharp increase in the exploitation of ocean resources of the northeast Brazilian continental shelf in the last two decades creates a demand for the development of methods for efficient assessment and prediction of the impacts that ocean circulation variability may cause in the environment. Among these impacts, we may cite the effects of coastal erosion and sand deposition affecting beaches, oil and gas pipelines related to production in the Potiguar Basin, sand deposition at port entrances, large bedform movement and bedform stability over the shelf, benthic ecosystem changes, the fate of oil spills, and impacts on marine biota and lobster fishing activities.

Geographical Setting

- Large tidal ranges are observed (3m amplitudes);
- Easterly winds are steady (6-12 m/s) over most of the year;
- Very shallow continental shelf, with the shelf edge having depths of the order of 50 m, at 50 to 100 km distances from the coast.
- Only one analysis of current measurements reported to date in the open literature Signorini and Miranda (1983). Study based on a 40 day mooring line with current meters at three depths, near the shelf break, at a local depth of 41 m. Currents were dominated by semidiurnal tides, with mostly cross-shore variance, and subtidal unidirectional longshore flow.

Present Work

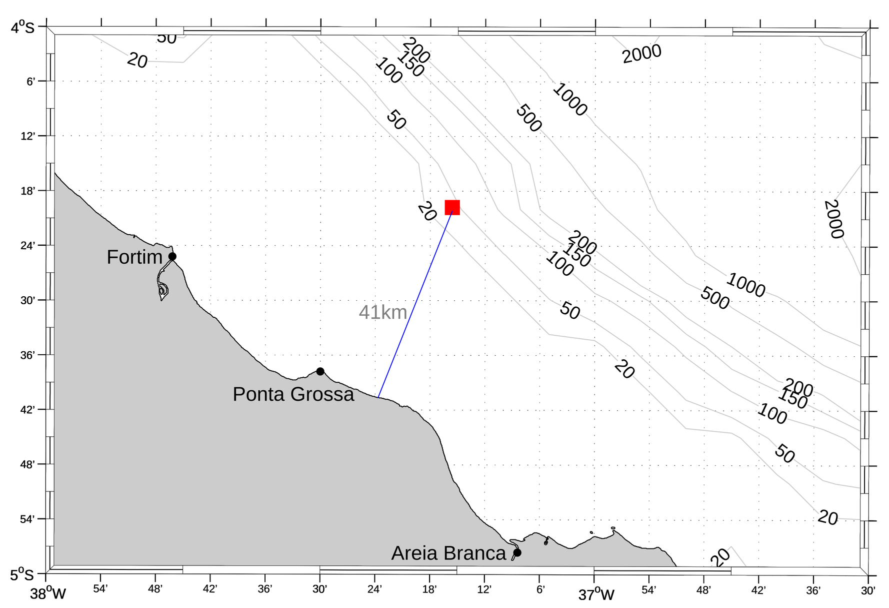

Figure 1: Site map

- Present work reports part of a first effort to close this gap of knowledge of an important equatorial shelf circulation pattern, concentrating on the tidal current regime. It is based on data from one of the ADCP bottom-mounted moorings deployed and maintained by the authors near the shelf edge at 30 m depth between September 2000 and November 2001.

The ADCP Data Set

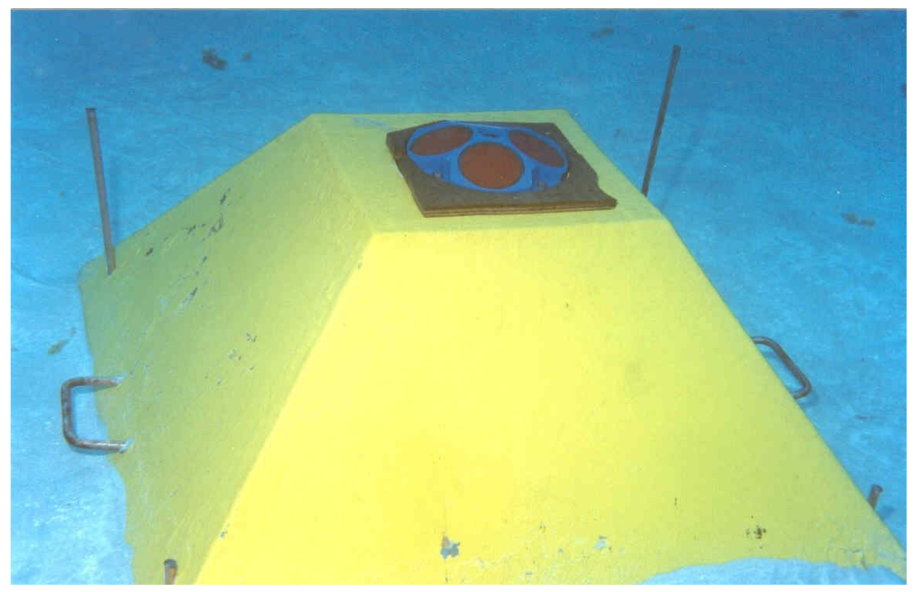

Figure 2: ADCP just after deployement

A RDI 300 KHZ Workhorse Sentinel ADCP (figure 2) was positioned by the authors at the site(figure 1) by diving. This site was chosen with the help of a image-assisted mapping of the area, using TM-LANDSAT imagery of the seafloor, in the same way as reported by Vianna et al. (1991), Vianna et al. (1993) and Santos (1999). Maintenance and data retrieval was done in a 3-month basis by diving, as shown in figure 3.

The instrument was programmed to record profile data at each half hour (GMT) with 240 0.5 s pings, 0.5 m bins, giving a total of useful 50 bins for this 27-30 m depth site (around 3 m of tidal amplitude), and 410 days of good current profile time series was obtained.

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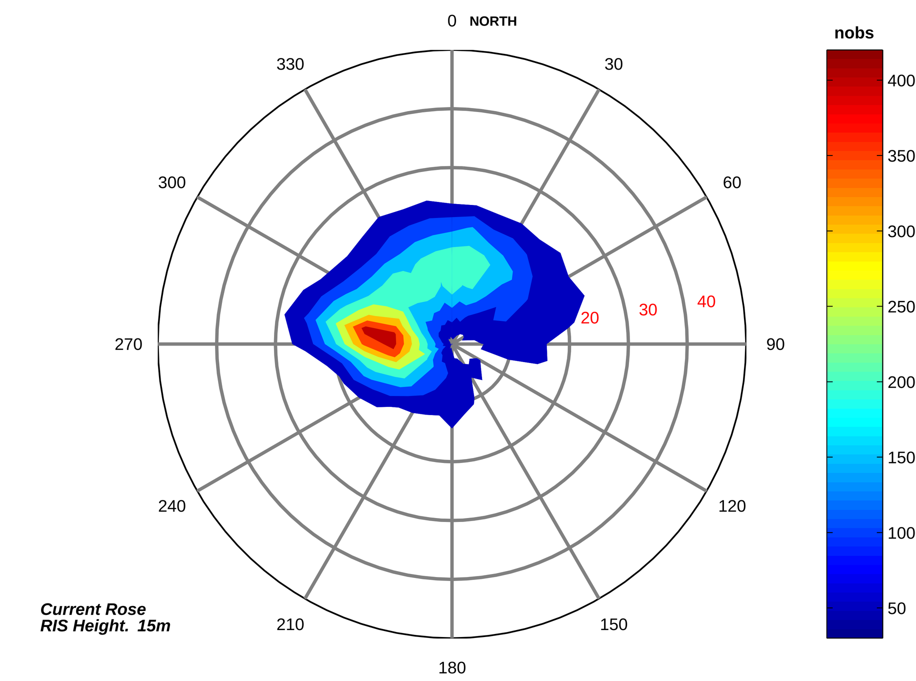
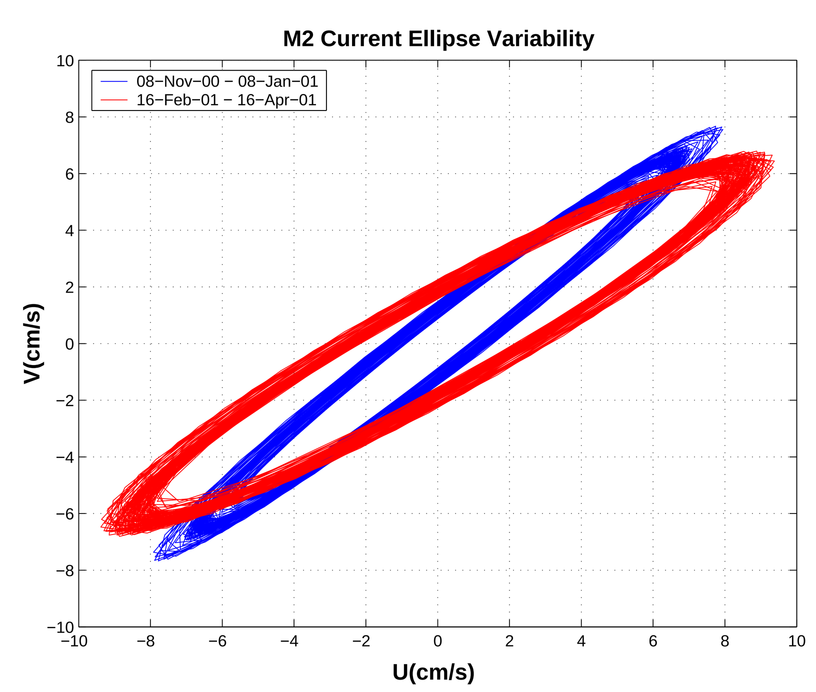
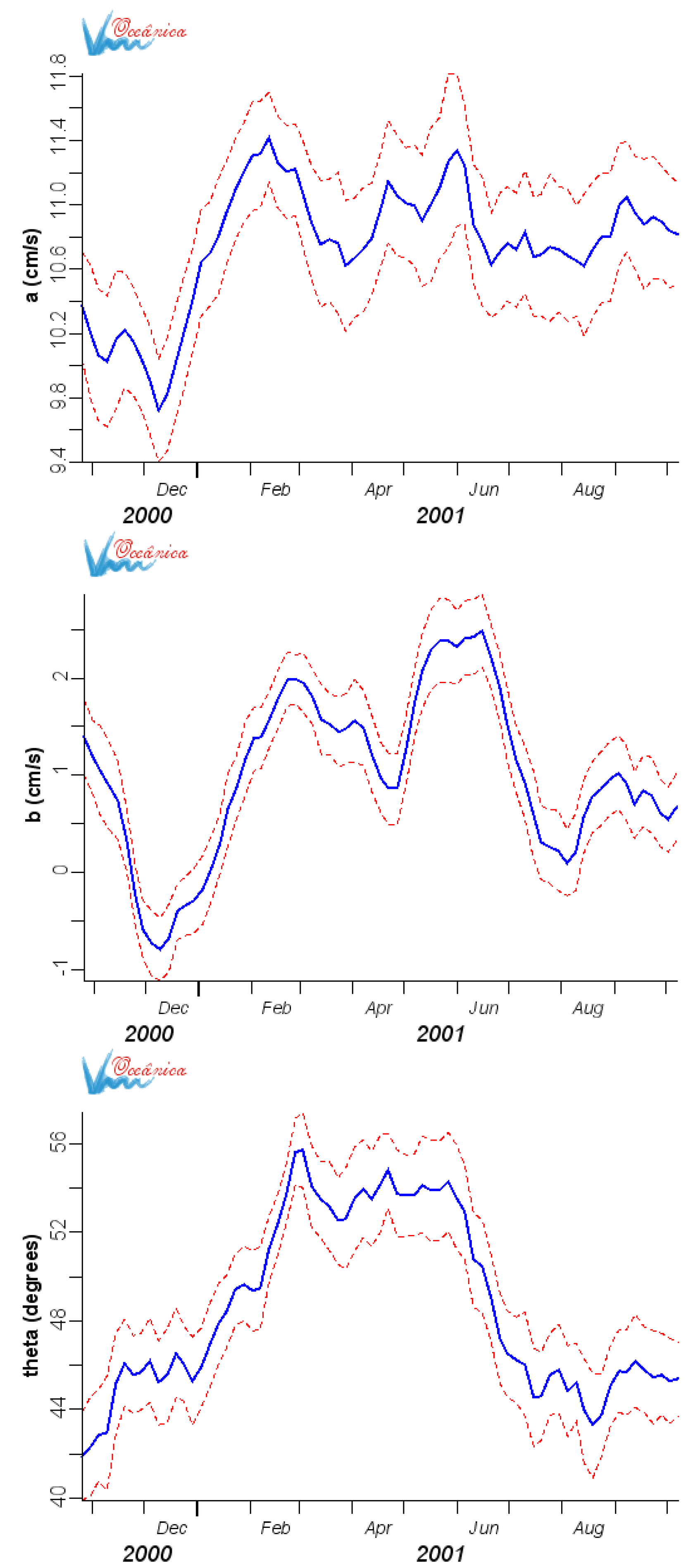
Figure 3: Clear water and rocky reefs near ADCP site



Methods of Analysis

- The main question to be addressed here refers to what advantage do we gain by determining *a priori* the significant tidal frequencies and modulations empirically from the record, and this suggests another question: Can we first efficiently separate the signal from noise before attempting to analyze the data and fit it to the harmonic representation? Yes!
- The use of wavelet analysis has been recently introduced to do this job, and support non-stationary tidal current studies, and in this connection a good reference is Jay and Kukulka (2003).
- However, since the signals of interest have a large multiply periodic component in the total variance due to tidal signals, it seems more appealing to explore Multichannel Singular Spectrum methods (e.g., Ghil et al. (2002)), as was done by us in analogy for a altimeter-derived circulation study of the western equatorial Atlantic Vianna and Menezes (2003).
- Things get simpler if a two-step analysis is made:
  - First, one develops some orthogonal empirical mode representation for each of the vector components, as exemplified by the Singular Spectrum Analysis Reconstructed Modes (RC's) Ghil et al. (2002).
  - In the next step, an accurate determination of the few dominant spectral peaks present in each mode is made. The empirical orthogonal mode expansions in the time domain have the advantage of being capable of decomposing the signal into a sum of component RC modes ordered in a decreasing sequence of variances explained by each one. Each mode contains only a few spectral dominant peaks, and this includes projections of linear and nonlinear trends contained in the signal either into independent orthogonal modes, or embedded as nonlinear modulations in each mode
- The spectral lines present in each mode can easily be identified by all-pole spectral estimation methods, and the Yule-Walker Autorregressive Spectrum Estimation method (YWARS), which is the same as the Maximum Entropy Method.
- The great advantage of the freedom to chose a window length parameter by this methodology is more than academic: it permits the easy determination of non-stationary low frequency modulations, that would otherwise be dependent on availability of very lengthy time series, and presents very high resolving power in spectral analysis.
- We address this matter in the present work by separating the tidal from the non-tidal variability, by determining the tidal ellipse constituents, and by describing the sub-seasonal modulation of these constituents from the ADCP currents obtained in the highly barotropic shallow northeastern Brazilian shelf.
- Tidal analysis of overlapping 60-day segments on the separated *Tidal Band*, by running a 60-day window with a 5-day time step: we found non-random variations in the ellipse axes(e.g.M2) **a** (major) and **b** (minor), and the angle (**theta**) of **a** with the east direction. The variability in **theta** is dominated by the annual cycle.





Conclusions

- Initial analysis comparing tidal ellipses from two deployments at the same site exhibited differing major axis directions, suggestive of bad compass stability or poor calibrations, with impact on expected error bars. Our long-term data analysis proved that the tidal ellipses were actually veering due to nonlinear longshore subtidal-tidal current interactions, not due to instrument performance or calibration.
- We showed that using both empirical orthogonal methods and classical tidal analysis is more adequate than using only one method for analysis of current profile data. This can also help to better asses performance and flexibility features in different ADCPs and better determine circulation fine structure.

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