

MULTISENSOR REMOTE SENSING DATA APPLIED TO COASTAL PROCESSES AND BEDFORM DYNAMICS RELATIONSHIP ANALYSIS AT NE BRAZILIAN CONTINENTAL SHELF

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Abstract: The NE Brazilian Continental Shelf near Calcanhar Cape is a very dynamic region in terms of the interaction of coastal processes and sediment transport. The main aspects of the study area are: a shallow and wide shelf; a mesotidal regime; high transparency waters; large siliciclastic quartz and carbonate sand deposits; presence of sand ribbons and subaqueous dune fields; presence of coral and calcareous algae reefs; important area for lobster fishing and oil exploration (Potiguar Basin). The methods used in this study are based on a combination of remote sensing data from different sensors, in situ data regarding currents and sediment sampling, and modelling. Basically the approaches are: data related to wave parameters (direction, significant wave height, wavelength): through ERS-1/2-SAR and TOPEX-POSEIDON; wind data were obtained from ERS-1/ERS-2 scatterometers and from meteorological stations; bathymetry: echosounding and modelling using TM- Landsat data; bedform migration patterns from 1984 to 1997 via TM data; sediment transport pattern characterization from Landsat images, sediment sampling, current meter data and modelling. Bathymetric modelling allowed the comparison of bathymetric patterns, showing a transport trend towards offshore, with sediment deposition over the 25 m depth and the increase of the bedforms heights. The presence of an open shelf ridge was reported for the first time, being covered by a series of transverse bedforms orthogonally oriented with the open shelf ridge axis. A five months comparison of a specific dune, showed changes on its borders, with intense accretion and erosion on its baseline. Current data showed that the unidirectional North Brazil Current is the main transport vector, combined with the tidal currents, and the NW flow is dominant. The sediment transport pathway is also presented.

Keywords: coastal processes, sediment dynamics, continental shelf, remote sensing, tropical environments.

Resumo: A plataforma continental na região frontal ao Cabo Calcanhar, Rio Grande do Norte, Brasil, é uma área de intensa dinâmica, no que se refere ao regime hidrodinâmico e meteorológico. Os principais aspectos desta área são: uma plataforma rasa e larga; amplitude de maré - mesotidal; alta transparência da água; extensos depósitos de areia siliciclástica e carbonática; presença de 'sand ribbons' e campos de dunas submersas; presença de recifes de coral e de algas calcáreas; importante área para pesca lagosteira e proximidade de área de exploração petrolífera (Bacia Potiguar). Os métodos empregados neste trabalho são baseados na combinação de dados de sensoriamento remoto de distintos sensores, dados correntométricos e sedimentológicos coletados in situ; e modelagem de transporte de sedimentos. Dados de onda foram obtidos através de 'imagettes' do sensor SAR à bordo dos satélites ERS-1 e ERS-2 e séries históricas do altímetro TOPEX/POSEIDON; dados de vento foram obtidos através de série histórica do escatêrometro à bordo dos satélites ERS-1/ERS-2 e estações meteorológicas; dados batimétricos foram extraídos através de modelagem batimétrica através de imagens Landsat e pontos de controle no campo; migração de dunas submersas foram analisadas através de série de imagens Landsat desde 1984, dados correntométricos foram obtidos através de instalação de correntômetro instalado na isóbata de 20 m. A modelagem batimétrica possibilitou a comparação e evolução de processos deposicionais e erosivos, mostrando tendência de transporte para 'offshore' ao norte do campo de dunas. A presença de uma 'open shelf ridge' é reportada pela primeira vez, sendo coberta por uma série de 'bedforms' transversais ao eixo da 'ridge'. Os padrões de migração de dunas foram analisados, e dados correntométricos mostraram o efeito sinérgico entre as correntes de maré e da Corrente Norte do Brasil, esta predominante. Os padrões de transporte sedimentar são apresentados.

Palavras-chave: processos costeiros, dinâmica sedimentar, plataforma continental, sensoriamento remoto costeiro, ambientes tropicais.

1. Introduction

The NE Brazilian Continental Shelf near Calcanhar Cape (Figure 1) is a very dynamic region in terms of the interaction of coastal processes and sediment transport. The area has a combination of unique characteristics which allow the development of extensive bedform deposits and, in the other hand, it allows the investigation using a combination of remote sensing and in situ data and modelling. The main aspects of the study area are:

- a shallow and wide shelf;
- under the effect of trade winds;
- under the effect of an unidirectional SE-NW current throughout the year;
- a mesotidal regime (average amplitude = 2.4 m);
- high transparency waters;
- large siliciclastic quartz and carbonate sand deposits;
- presence of sand ribbons and subaqueous dune fields positioned in a cross-shore gradation;
- presence of a long open shelf ridge (30 km);
- presence of coral and calcareous algae reefs;
- important area for lobster fishing and oil exploration (Potiguar Basin)

The main objectives of the study are:

- Characterisation of the main sedimentary features present in the area;
- Investigation of the bedform characteristics that reflect control by the hydrodynamic processes;
- Study of the bedform dynamics in short (4 months) and long (15 years) time scale;
- Characterisation of an open shelf ridge and related bedforms.

2. Methodology

The methods used in this study are based on a combination of remote sensing data from different sensors, in situ data regarding currents and sediment sampling, and modelling. Basically the approaches are:

- Data related to wave parameters (direction, significant wave height, wavelength): through ERS-1/2 SAR Wave mode and TOPEX-POSEIDON Altimeter;
- Bathymetric characterisation: echosounding and modelling using TM-Landsat data;
- Bedform migration patterns from 1984 to 1997 via TM data;
- Sediment transport pattern characterization from Landsat images, sediment sampling, current meter data and modelling.

Thirteen Landsat images were used, covering 1984 to 1999. Wind and wave data were extracted from different sources: wind data from ERS-1 and ERS-2 scatterometers (from 1992 to 1999), in situ data from Calcanhar Lighthouse Brazilian Navy meteorological station (from 1997-1999); wave data from ERS-2 imagerettes and in situ observation.

Current data were collected from a currentmeter mooring deployed at 22 m depth, from July to December 1997. Bathymetric data were collected during a field work campaign (July/August 1997). Sediment sampling was also carried out during July/August 1997 campaign. Previous sediment data analysis were also used in the discussion, basically those showed in Vianna et al (1991), Vianna et al (1993) and Testa (1996). Bathymetric modelling were carried out based on the Lyzenga (1977) approach, modified by Cabral (1993) as follows:

$$L_i(\mathbf{a}) = L_{si} + c(\mathbf{a}) R_{bi} \exp[-k_i f_z(\mathbf{a})],$$

where, L_i = radiance band I, L_{si} = radiance deep area, $f = \sec \theta + \sec \phi$,
 $c(\alpha)$ = atmosphere irradiance, R_{bi} = reflectance depth, k_i water attenuation
 coefficient for band I, $z(\alpha)$ = depth

Assuming,

$$r_{bi} = c(\mathbf{a}) R_{bi} \text{ and } x_i = \ln(L_i - L_{si}) \text{ (after Lyzenga, 1979)}$$

$$Z = \frac{Rb2 - Rb1}{f(k_2 - k_1)} + \frac{1}{f(k_2 - k_1)} x_1 - \frac{1}{f(k_2 - k_1)} x_2$$

k_1 and k_2 = water attenuation coefficient for band 1 and band 2, respect.
 $Rb1$ and $Rb2$ = apparent reflectance for bands 1 and 2 respectively.

3. Results and Discussion

Bathymetric modelling allowed the comparison of bathymetric patterns in different periods. Figure 2 shows the 3D bathymetry for two periods showing and intense transport trend towards offshore, with sediment deposition over the 25 m depth and the increase of the bedforms heights.

Figure 3 shows two bathymetric profiles over the open shelf ridge. This feature is the first of that nature to be report in the southern hemisphere. The open shelf ridge is covered by a series of transverse bedforms mainly orthogonally oriented with the open shelf ridge axis. The depth profiles indicates a more sharp bathymetric in the SE part of the ridge, with a more smooth profile in NW part.

Figure 4 shows a 5 months comparison of a specific dune, showing changes on its geometry, mainly related to the borders, with intense accretion an erosion on its baseline.

Current data showed that the unidirectional North Brazil Current is the main transport vector, combined with the tidal currents, and the NW flow is dominant. Figure 5 shows the proposed sediment transport pathways for the continental shelf. The main trend is toward NW from 10 o 25 m isobaths. Between 5 to 15 m a residual transport is also present due to the effect of tidal currents. In the coastal areas (up to 5m), a longitudinal transport is present towards NW.

4. Conclusions

- TM-images co-registration did show slow bedform migration along 15 years.
- The sandwave field as whole moved 1.5 km northwestward.
- During austral winter period sandwaves changed geometry, mainly width and length.
- An open shelf ridge in the area is reported for the first time, showing long main axis long main axis (25 km), with height from 8 to 10 m, and a series of bedforms \ positioned on its landward side. The seaward side present step slope with sediment transport northeastward.
- Calculations of bedload transport and estimation of net transport are been performed.

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5. References

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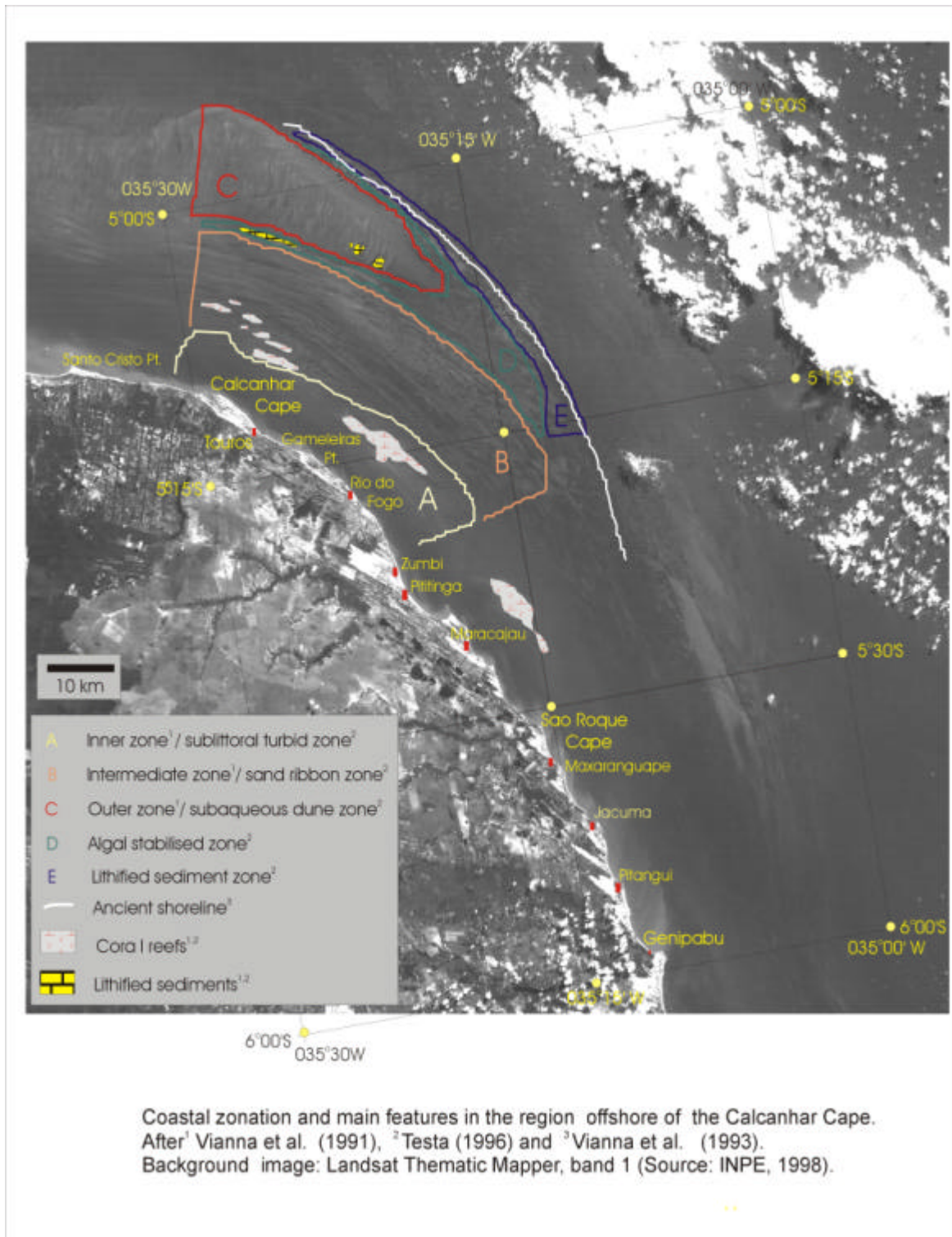


Figure 1 – Overview of the study with the main deposition zones.

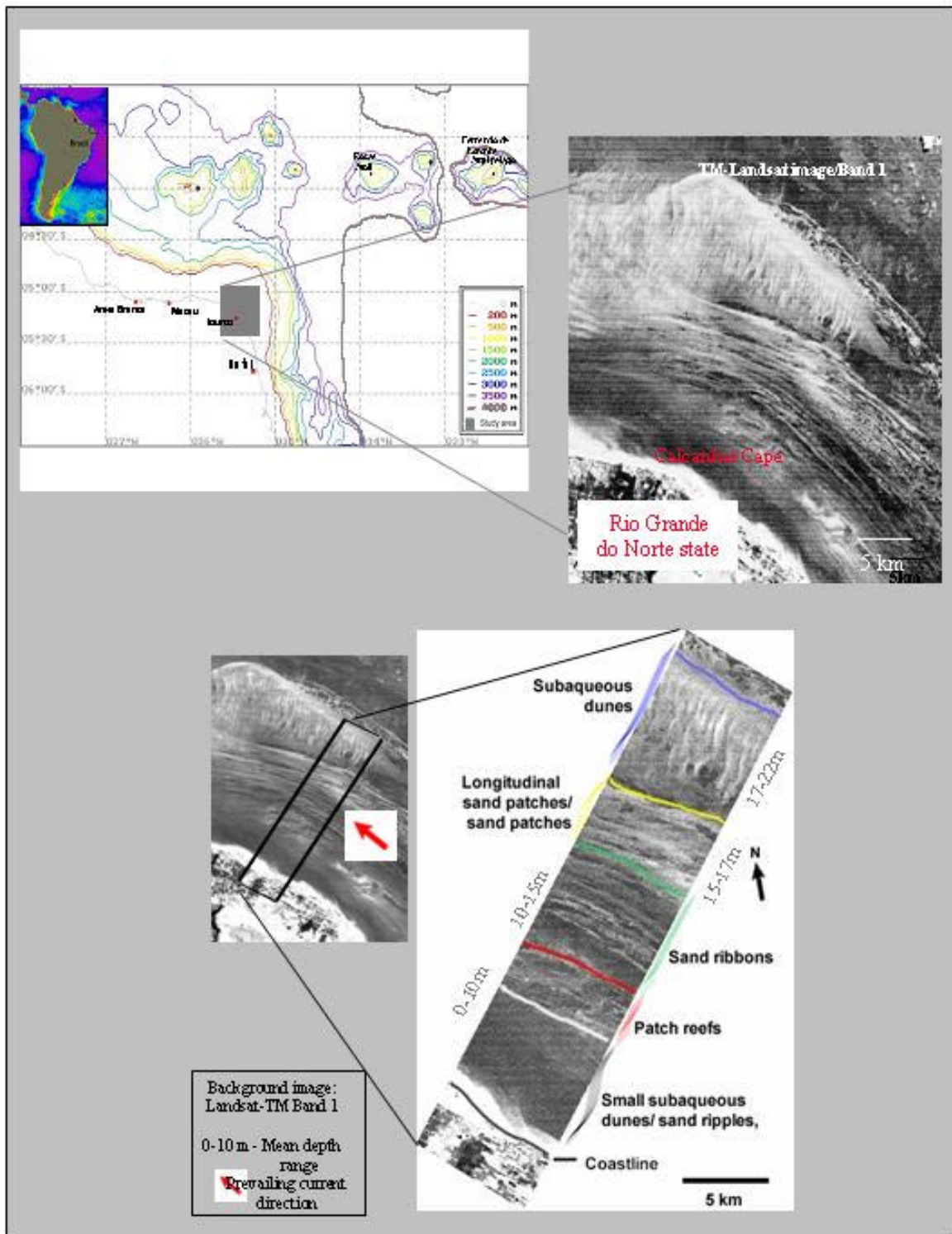


Figure 2 – Study area with the main bedform deposits.

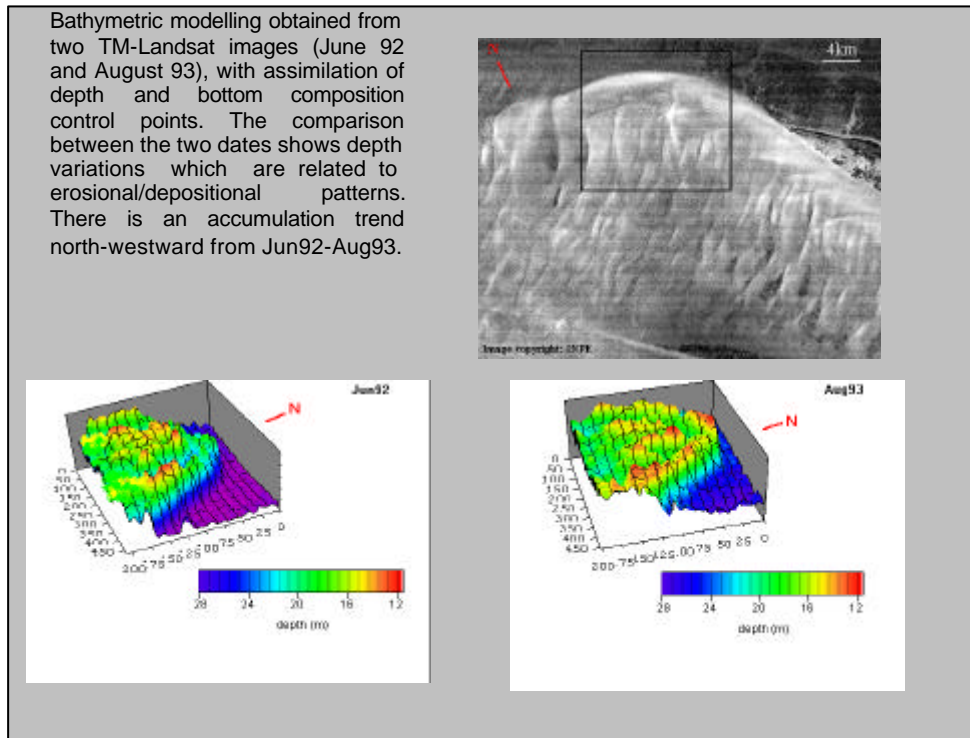


Figure 3 – Results from bathymetric modelling over a one year period, showing the depth variation caused by erosional and depositional patterns.

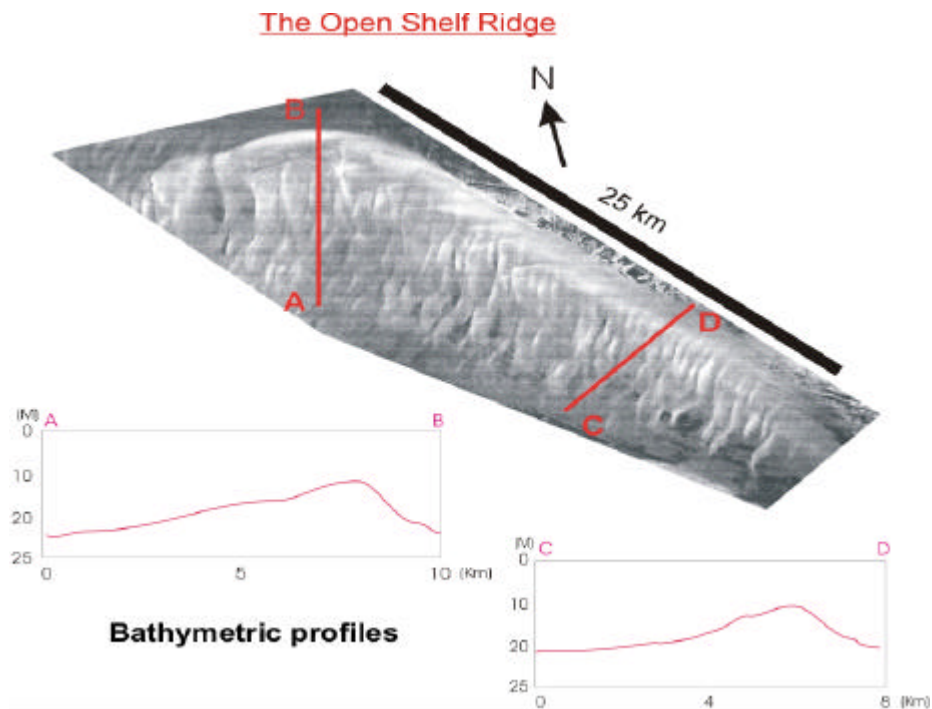


Figure 4- Bathymetric transects across the open shelf ridge.

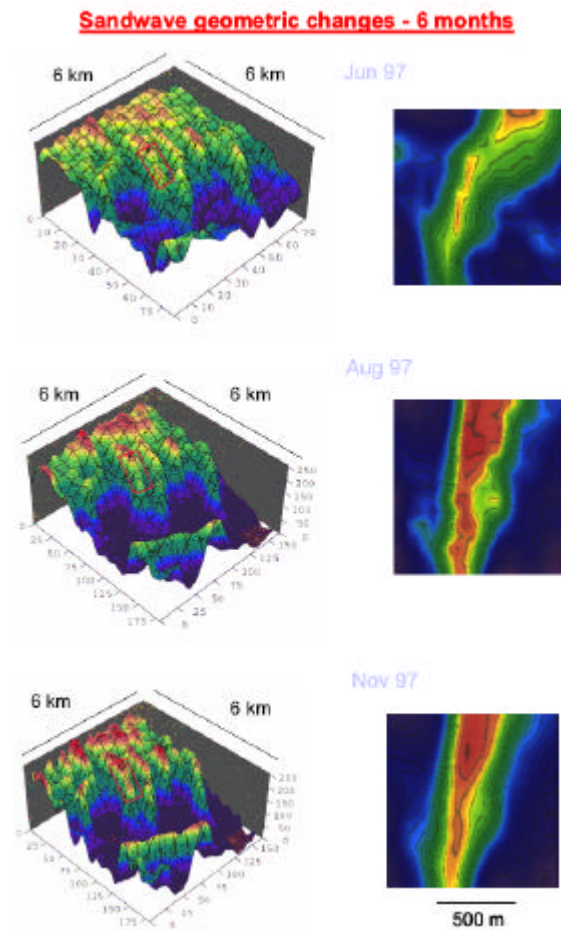


Figure 5 – Bedform geometric changes over a 6 months period.

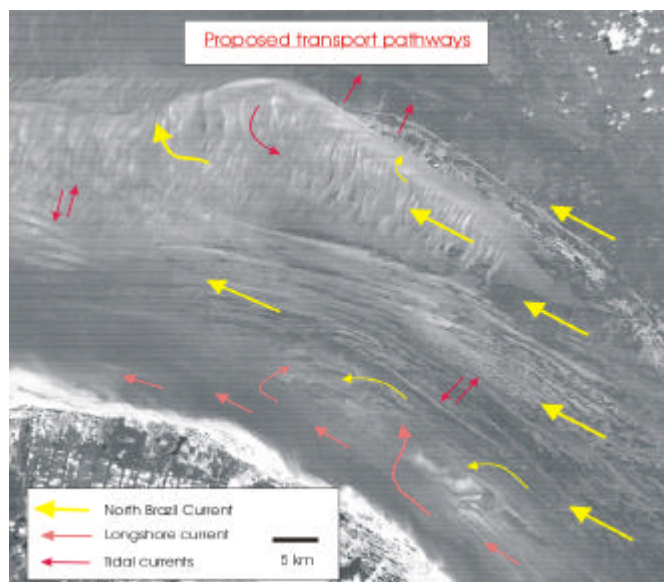


Figure 6 – Proposed sediment pathways in the study area.