MONITORING CHANGES IN COASTAL BATHYMETRY USING GROUND BASED MARINE RADAR

Paul S Bell (Proudman Oceanographic Laboratory, Liverpool, L3 5DA) psb@pol.ac.uk
Jon J Williams (School of Geography, University of Plymouth, PL4 8AA)

ABSTRACT

Maps of the sea bed in the region of a tidal inlet have been produced using a novel analysis of image sequences of waves recorded from a land based marine radar. The sea bed changes determined using these maps and occurring over a four year period, have shown how such inlets interrupt the transport of sediment by longshore drift, directly contributing to the erosion of the downdrift coastline.

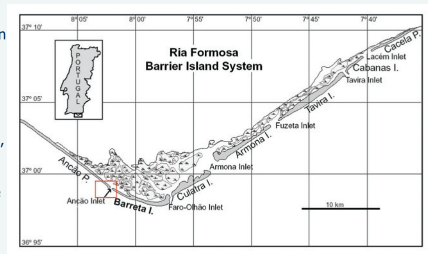

Figure 1. The barrier island and tidal inlet chain of the Ria Formosa in Portugal. The barrier islands are natural features that protect intertidal salt marshes and associated industries, such as shell fisheries, from the force of the waves. The red rectangle corresponds to the analysis area shown in later figures.

BACKGROUND

Beginning in 1999, an international team of researchers joined forces in a three year EU funded project: the Inlet Dynamics Initiative Algarve (INDIA) [1]. The aim of this was to try to measure and understand the processes driving the natural migration of tidal inlets. The barrier islands and inlets of the Algarve (Figure 1) are typical of such systems around the world. Such islands are often heavily populated and of significant economic importance because the associated inlets allow easy access between the sheltered waters behind the barrier islands and the open ocean.

Figure 2. Left: The radar mounted on a jack-up barge during the winter of 1999 within the Ancao inlet. **Right:** The radar mounted on a scaffold tower on the beach overlooking the ancao inlet in 2003. Note that these locations are within a few metres of each other - the inlet had migrated more than 300m during the four years separating the photographs

OBSERVATIONS

During the 1999 INDIA experiment, a marine radar was mounted on a jack-up barge that acted as a mobile base for a range of experiments within the tidal inlet (Figure 2). A further set of data were recorded during a return visit to the site in 2003, this time by mounting the radar on a scaffold tower on the beach, the INDIA project and hence the barge deployment having finished.

An example of a single radar image from one of the sequences recorded in 2003 is shown in Figure 3. The darker areas correspond to strong radar echos. By analysing a sequence of such images using a Fourier transform based technique it is possible to map the wavelength of the waves over a range of different wave periods.

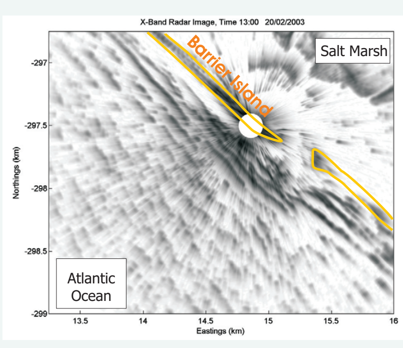

Figure 3. A single radar image recorded during 2003. Darker areas correspond to areas of stronger radar backscatter. The waves at this time were predominantly swell coming in off the Atlantic. The significant waveheight during this record was 2m peak-trough.

THEORY

Waves slow down and hence reduce their wavelength as they travel from the open ocean into shallower coastal waters. If the wavelength, period and height of the waves can be determined from images of the sea surface then the water depth (Figure 4) causing that wave behaviour can be calculated using the following equation [2]:

Water depth $$d = \frac{L}{2\pi}\tanh^{-1}\frac{2\pi L}{gT^2} - \frac{H_S}{2\sqrt{2}}$$

Where L = wavelength of the ocean waves
T = wave period
H_S = significant wave height (the average of the highest third of the waves)
g = gravity

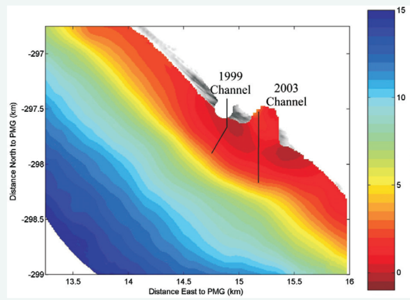

Figure 4. The bathymetric (water depth) map determined by analysing the wave image sequences recorded in 2003. The colour represents water depth in metres relative to mean sea level minus 2m (the local datum). The accuracy of these water depths has been shown to be +/-0.5m or better [4].

RESULTS

Calculation of volume changes between the bathymetric maps generated from the radar data collected during 1999 and 2003 show areas of erosion and deposition as shown in Figure 5. These results show that the coastline downdrift of the inlet in area C lost 85% of the sand that would have been supplied by longshore drift [3] during that time. 65% of that lost sand was shown to be sequestered in the ebb delta in area B [4], with the remainder of the lost sand probably located on the flood delta behind the barrier beach, out of range of the radar.

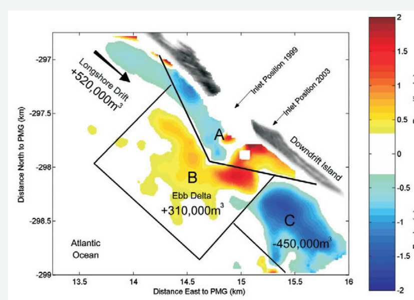

Figure 5. Changes in water depth calculated from the radar derived bathymetric maps of 1999 and 2003. The red and blue areas represent accretion and erosion respectively. Area A encompasses the immediate area of the inlet and shows no overall change in sediment volume. Area B, the ebb delta, shows significant deposition of sand, while area C in front of the downdrift island shows extensive erosion.

Independent evidence of the erosion of the downdrift island is illustrated by the photographs in Figure 6. On the left is an aerial photograph of the downdrift island from 1999 showing it to be about 100m wide and vegetated. On the right is a photograph taken on that island in 2003 showing it to be no more than 15m wide and with very little remaining vegetation.

Figure 6. Left: An aerial photograph of the downdrift island in 1999. **Right:** A photograph looking along the downdrift island in 2003.

REFERENCES

[1] Williams, J.J., O'Connor, B.A., Arens, S.M., Abadie, S., Bell, P., Balouin, Y., Van Boxel, J.H., Do Carmo, A.J., Davidson, M., Ferreira, O., Heron, M., Howa, H., Hughes, Z., Kaczmarek, L.M., Kim, H., Morris, B., Nicholson, J., Pan, S., Salles, P., Silva, A., Smith, J., Soares, C. and Vila-Concejo, A., 2003a, "**Tidal inlet function: field evidence and numerical simulation in the INDIA Project**". Journal of Coastal Research, 19 (1), 189-211.
[2] Hedges, T.S., 1976, "**An empirical modification to linear wave theory**". Proc. Inst. Civ. Eng., 61, 575-579.
[3] Balouin, Y. & Howa, H., 2002, "**Sediment transport pattern at the Barra Nova inlet, south Portugal: a conceptual model**". Geo-Marine Letters 21, 226-235.
[4] Bell, P.S., 2005, "**Remote determination of bathymetric changes using ground based radar**". PhD thesis, University of Wales, Bangor.

ACKNOWLEDGEMENT

The INDIA project was funded by The Commission of the European Directorate General for Science, Research and Development under contract MAS3-CT97-0106, and also in part by the UK Environment Research Council and by the national governments and universities of the partners' institutes.

Proudman Oceanographic Laboratory
NATURAL ENVIRONMENT RESEARCH COUNCIL