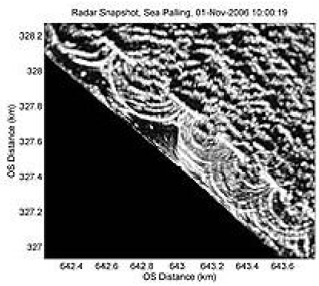
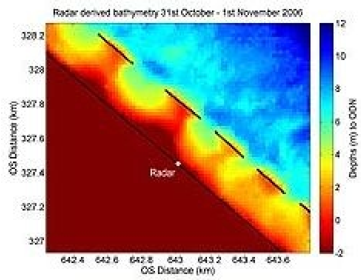
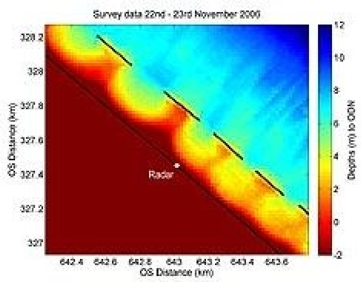
USING A STANDARD MARINE X-BAND RADAR

Coastal Mapping Around Shore Parallel Breakwaters





Surveying very shallow coastal areas can be a logistically difficult and time-consuming process. Mapping the embayments around a series of shore parallel breakwaters at Sea Palling on the south-east coast of England has proven an interesting challenge for a new radar-based remote mapping technique. This technique uses the wave behaviour visible as sea clutter on a marine radar to infer the underlying water depth that caused the observed wave behaviour, allowing large areas of the seabed to be mapped without having to deploy boats or people. View Larger Map



When new breakwaters at Sea Palling proved more effective than expected, it prompted a study to investigate this. Here we describe how an X-band marine radar was successfully used to map the embayments.

Historic Perspective

During the 1953 storm surge at Sea Palling in East Anglia (Figure 1, right), the sea overtopped the dunes and seven people drowned. Following that event, a sea wall was built to protect the village from further risk. In recent years, however, the sea has begun to undercut these defences, and a series of shore parallel breakwaters were installed in conjunction with beach recharge in an attempt to protect the earlier sea wall (Figure 2). These new breakwaters were designed to better retain the sand and hence continue the protection to that part of the coast. However, they have performed better than expected at this site and the first breakwater on the northern updrift end of the structures now has a permanent tombolo linking the breakwater to the shore, interrupting the flow of sediment down the coast.

Research Project

In 2005, the UK Engineering and Physical Sciences Research Council (EPSRC) funded LEACOAST2 (Liverpool-East Anglia Coastal Study Phase 2), a collaborative research project to study the hydrodynamics and sediment processes around these breakwaters that followed on from the earlier LEACOAST project. The aim was to improve the understanding of how such structures interact with their environment and hence improve future design guidelines.

Teams from the Universities of East Anglia, Plymouth and Liverpool and from the Proudman Oceanographic Laboratory (POL) began work in 2006 with a wide range of equipment for monitoring waves, currents and sediment dynamics (Figure 3). In addition, an ARGUS video system to study the near-shore processes and an X-band marine radar for looking over longer ranges were installed. Surveys of the beaches and embayments were conducted at regular intervals both on foot and by boat by the University of East Anglia team.

Standard Radar System

A Kelvin Hughes marine X-band radar with a 2.4m rotating antenna was deployed on the roof of the Sea Palling Inshore Lifeboat Station overlooking the offshore breakwaters and associated embayments (Figure 3). This was coupled to a PC-based digitisation system, allowing 10-minute animations of the sea surface to be recorded automatically every hour. Summary images of each record were produced and sent via a broadband link to the POL website so that the status of the system could be monitored via the internet, including radar snapshots (Figure 4) of the sea surface and time-lapse images, which show persistent features very well. Waves tend to be visible on the radar images only when the wave height is larger than about 1m, so in contrast to more conventional surveying techniques this method of mapping is only appropriate during wave events. However, this would allow the bathymetry of an area to be monitored during storms when large changes might be expected.

Anaysing Images

The data analysis has been developed over a number of years and works by determining the wavelength and direction of the ocean waves in a small window on the ocean for a range of wave frequencies. As the analysis approach is based on Fourier methods, the wave behaviour must be assumed to be uniform within that small window. The size of this window is selectable depending on the area being studied, but the aim is to have between one and four wavelengths of the dominant waves present within the window. An equation representing the theoretical behaviour of the waves is then fitted to the measured values, yielding a water depth and, if selected, a current vector for that small area. The window is moved across the study area and hence a map of the inferred water depth is produced.

Local Datum

In order for such maps to be useful in the longer term, they must be related to a local datum, and so the tidal level measured using a tide gauge is subtracted from the derived water depth maps to produce a map that is relative to the desired datum. In this case, the pressure records for the experiment are still being analysed, and so the surge component of the tide was identified from the nearest UK National Tide and Sea Level Facility gauges at Cromer and Lowestoft, and this surge component was added to the predicted tide levels for Sea Palling to provide the vertical reference.

Stable Maps

There are, of course, a number of possible sources of error in such water depth estimates, including tidal slope, the effect of tidal currents on wave behaviour, and variable wave heights over the study area. Corrections for some of these are under development but despite the many simplifications assumed by the analysis it is possible to produce remarkably stable bathymetric maps with only a few hours of data. Even a single record is sufficient to produce a reasonable approximation of the bathymetry provided strong wave patterns are present in the radar data.

Wave Event

Hourly records spanning a 24-hour period during a wave event from 31 October to 1 November 2006 from the Sea Palling radar were processed. In order to highlight the capabilities of the technique in areas of complex bathymetry around the breakwaters and embayments, a window size of only 80m was selected. This window was then translated across the study area at a quarter of this spacing, hence giving measurements on a 20m grid spacing. Usually, a much larger window size of several hundred metres would be selected for areas of less complex bathymetry. In this case, however, it was interesting to see how far the technique could be pushed in such a challenging environment. The results from each of these records have been corrected to Ordinance Datum Newlyn, using the tide predictions plus the observed surge component, and combined to give the bathymetric map shown in Figure 5. The upper limit of the colour scale corresponds approximately to mean sea level, and peak spring tides have a range of approximately 4m.

Traditional Surveys

Beach and bathymetry surveys conducted three weeks after the storm have also been combined to produce a comparable map of the same area shown in Figure 6. These surveys were carried out by researchers at the University of East Anglia, using a real-time kinematic GPS system for absolute positioning combined with the addition of a single-beam sonar for the boat surveys.

Severe Storms

The two maps show a clear agreement both in overall pattern and in absolute elevations. Some subtle discrepancies can be observed, particularly in the location of the shore face, which the radar shows to be slightly shorewards compared to the survey. However, this is consistent with known beach behaviour at the site, where severe storms routinely reduce the height of the beach by up to 2-3m, before recovering rapidly within about 48 hours after the storm subsides. The depth of the embayments also shows a corresponding slight shallowing, perhaps indicating the location of the temporarily eroded material. Some discrepancies are also evident offshore of the breakwaters, particularly in the eastern half of the data where the radar indicates deeper water than the survey by about 1-2m. It is unclear at this stage whether this is a real deepening or an artefact of the processing; however, the survey track lines (marked as black dots in

Figure 6) are separated by 200m in this area and so the apparent difference may simply be an artefact of gridding insufficiently dense survey data.

Tracking Dune Fields

Interestingly, the region directly offshore of the breakwaters is also characterised by a field of sub-tidal dunes that, according to both survey data and other radar-based observations, are migrating to the south-east, in line with the prevalent direction of longshore drift. An investigation of these previously unobserved features and their behaviour during the 30-month radar deployment will be published in due course.

One might expect the system to be used in the future at a port located in an area of mobile sand banks, where the radar-derived maps could be used as an early warning system, detecting whether a sandbank is migrating in the direction of a navigation channel.

Strength of Technique

The ability to map complex areas of bathymetry using data recorded from standard marine radar has been clearly demonstrated. While this technique will never be able to match the accuracy of modern survey techniques, its strength lies in the ability to monitor large areas of shallow water as often as there are sufficient waves to be seen on the radar. Since the method uses the shoaling of waves to derive water depths, it is obviously unsuitable for deep (>20m) areas, but could be used operationally to monitor the movement of sandbanks in areas where this might be of commercial importance. â€žÃ

Acknowledgements

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Further Reading

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