The use of video in the study of sandbar dynamics

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Abstract

This contribution demonstrates the utility of video imaging techniques for nearshore studies with particular reference to the measurement of nearshore sandbar dynamics. The system is capable of obtaining quantitative measurements over a broad range of length scales (10^1 to 10^3m) and time scales (days to decades). Data is presented from a video site located at the mouth of an estuary at Teignmouth (S. Devon, England). This environment is characterised by the cyclical evolution of a sandbar system in the mouth of the estuary. External forcing factors for the sandbar evolution includes tides (meso- to macrotidal), wind-driven waves and to a lesser extent fresh water discharge from the Teign river. Ongoing video measurements beginning in February 1999 allow a qualitative representation of the dynamics of this sandbar system. Dramatic changes in the morphology of the ebb delta have occurred within the last nine months including the rapid accretion of sediment on two outer sandbars around the main channel. The appearance of these sandbars was accompanied by the simultaneous evolution of another sandbar system close to the beach, which is cross-shore oriented in February and long-shore oriented in November. Quantification of these processes is currently under investigation with the objective of studying the coastal evolution over several months.
The technique described in this work can be applied to other specified studies such as independent bedform dynamics in intertidal or subtidal environments.

Introduction

The dynamic nearshore environment is a valuable social and economic resource. As a result of this the acquisition of high quality field measurements of nearshore morphology has become a common preoccupation for scientists and coastal managers. Remotely sensed video imagery potentially provides a powerful mode of monitoring the nearshore environment and the dynamics of sandbars. The video imaging system provides a means of evaluating dynamic physical processes (Holland *et al*., 1997) over a wide range of spatial (centimetres to kilometres) and temporal (seconds to years) scales. The remote nature of the acquisition procedure is less time-consuming and cheaper than more traditional methods of survey.
The pioneering work of Lippmann and Holman (1989) in the quantification of nearshore morphology with video imagery was the catalyst for an international network of monitoring stations: the ARGUS programme. The estuary at Teignmouth (Devon, England) is the eleventh site of this network.
The aim of this work is to present video-based techniques for the study of the sediment dynamics in nearshore environments, and to apply it to study the evolution of intertidal sandbars. Firstly, a description is given of the field site at Teignmouth. This is followed by a description of the video surveying method and some provisional qualitative results for this site in term of sandbar dynamics.

Site description

The beach and estuary system of Teignmouth lie on the south coast of Devon, England at the mouth of the River Teign, an incised valley filled with sediment. The topography of the mouth is characterised by a main channel that is 800m long, 350m wide and 5m deep in the narrowest section. This channel is surrounded to the north by Sprat Sands and to the south by the Permian breccia cliff, the Ness (Figure 1). The tidal regime is semi-diurnal with a tidal range varying between 1.7m to 4.2m.

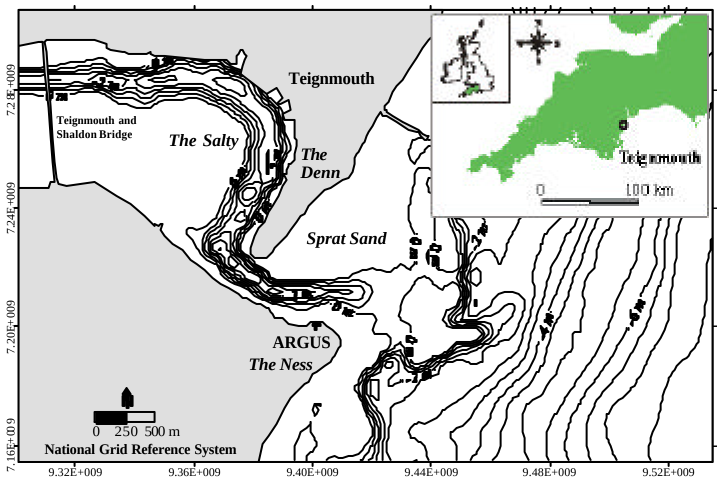


Figure 1: The field site

The Teign river discharge is less than 20m^3/s in summer with peaks of 50-100m^3/s in autumn and winter. Wave heights greater than 0.5m are representative for 10% of the year, being wind-driven and due to easterly gales. The predominant wind directions are 20.6% from the WSW, 22.6% from the NW and 20% from the NE or ENE.
The beach slope is dissipative at low water (<1°) and is steeper at high water mark (≈7°). The sediment is composed mainly of fine sand in the offshore region (0.2mm), coarsening to medium sand in the approaches of the beach (0.4mm), although stones and gravel sizes (5-50mm) are also present. In the vicinities of the ebb channel and in the Ness Pole stone and gravel sizes are dominant.
A cyclic movement of the sandbars within the ebb-delta has been observed by Robinson (1975). It is suggested that the period of the cycle is of the order of 5-7 years. Today the main channel is dredged to maintain shipping traffic activities. Accurate, long-term, and large-scale measurements of these processes in the approaches to the harbour and estuary at Teignmouth is, therefore, fundamentally important in developing an understanding of the periodic pattern of shoreline genesis and morphologic change.

General video techniques

Since February 1999, five video colour cameras are installed in the Ness (50m above ordinance datum, Figure1) aiming northward and offering a panoramic view of the estuary (Figure 2).

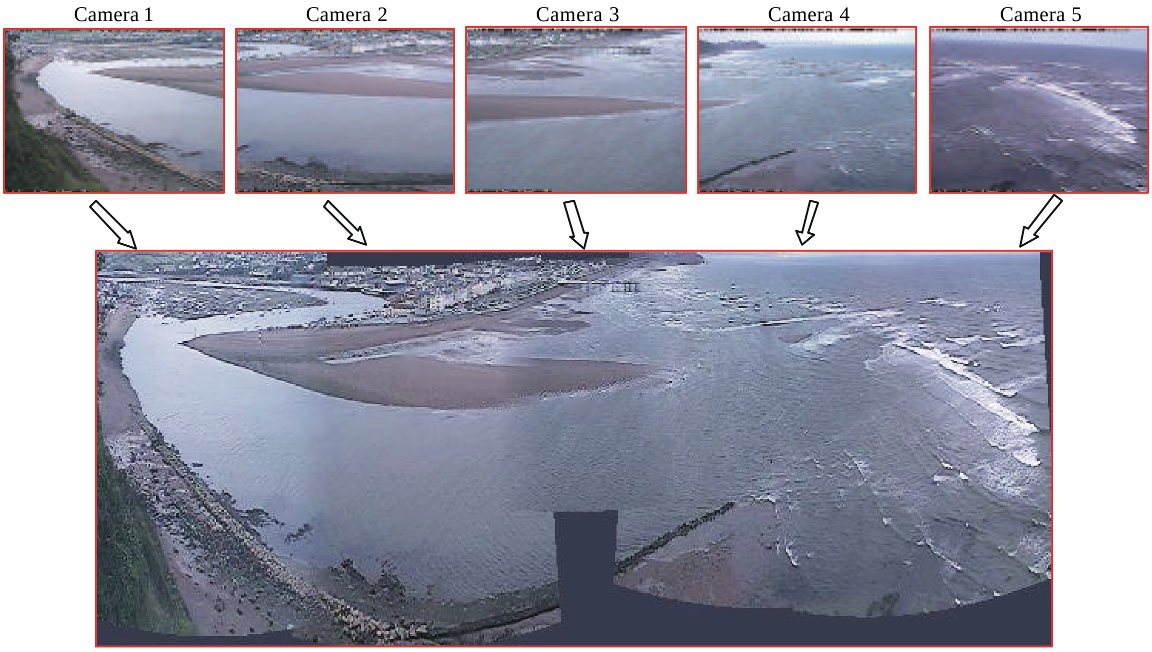


Figure 2: Views from the individual five cameras in the top, merged in the bottom at low-tide (17 May 1999, 14:00).

Each of the cameras hourly record three types of images, including a snapshot, a time-exposure and a standard deviation image (Figure 3).

Figure 3: Different types of images including: snapshot, time-exposure and standard deviation images recorded by camera 5. All show the breaking waves in the outer bar.

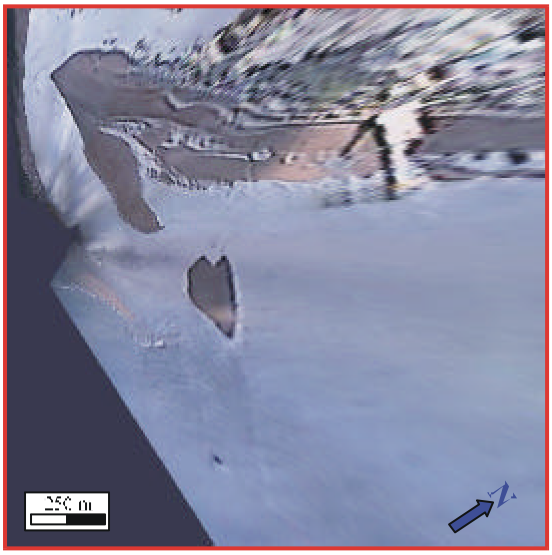


Figure 4: A rectified view of merged images for the 27 October 1999 14:00

Time-exposure and standard deviation images are commonly used to define high intensity pixel values which characterise swash zones in the intertidal beach and wave breaking areas in subtidal sandbars (Holman *et al*. 1991; Kingston *et al*., 1999).

Ground-truth survey data (ground control points) enable the application of steorographic techniques allowing the merging of simultaneous images from the five cameras (Figure 2) or rectifying oblique views to plan views (method described by Holman *et al*. 1991; Figure 4). As these techniques require the mean water level variation to compute the correct geometry, an estimate is obtained from a tidal prediction model. The vertical accuracy of pixel resolution is around 0.1% of the distance from the camera (Holman *et al*. 1991). For example, the vertical error along the pier of Teignmouth which is 800m away from the cameras, is estimated to be around 0.8m.

Evolution of sandbar in Teignmouth

A first analysis of nine months of data set of the Teignmouth site gives a good qualitative representation of the sandbar system evolution. Figure 5 shows four combined and merged time exposure images of the estuary in February, May, August and November 1999 for similar tide levels.

For ease of interpretation here the four main sandbars have been given a reference number (1 to 4). In February, the sandbar 1, close to the beach, is cross-shore oriented. Within the last nine months this sandbar is adopting a long-shore morphology, creating in November a bar along the beach. Simultaneously, the two outer bars, 3 and 4, forming the ebb-delta and surrounding the main channel are formed. Bar no.3 adopts a triangular shape with the apex oriented in an offshore direction in May and August, and starts to migrate west. In November the base of this triangular form is filled with sediment. The outer bar (no.4) is initially more linear and accretes rapidly, moving onshore, adopting a more triangular shape in November. The morphology of the sandbar no.2 (Sprat Sands) forming the limit between the main channel and the beach does not seem to change dramatically.

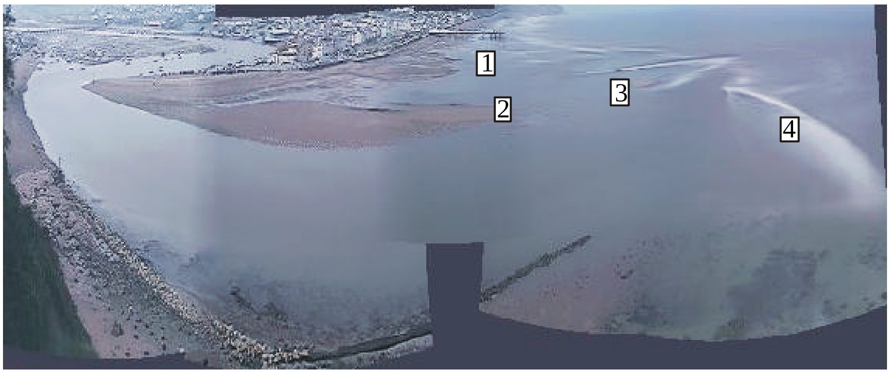
At the time of writing, these observations remain qualitative. However, quantitative studies are in progress. Quantifying these sandbars movements will involve the implementation of intertidal bathymetric mapping methods.

Video methods of intertidal bathymetry mapping

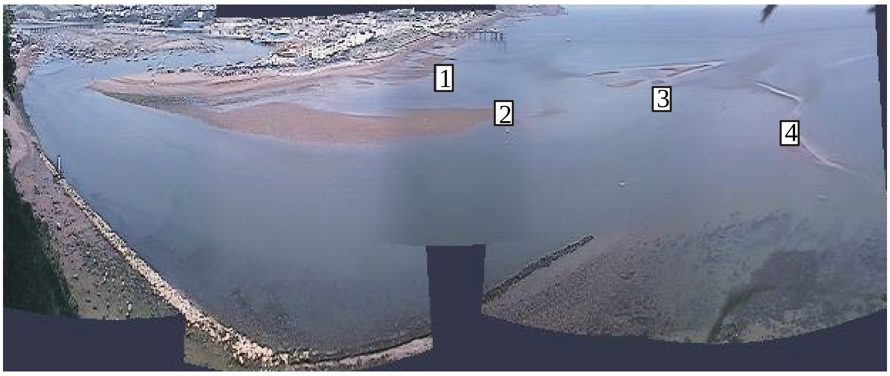
The video methods of intertidal bathymetry mapping consists on the detection of the shoreline location at a number of instances during a tidal cycle. If the vertical level of the shoreline is known it effectively strikes a contour across the beach. A combination of these contour lines yields an estimate of the intertidal bathymetry. Plant and Holman (1996) mapped the ShoreLine Intensity Maximum (or SLIM) and related this feature to the mean sea level. Davidson *et al*. (1997) used rectified spatial differential of time-exposure images as a shoreline feature. Aarninkhof and Roelvink (1999) quantified shoreline location from the hue, saturation and value derived from colour video image.

The large variety of techniques used for estimating the shoreline position is in part a reflection of the fact that the principle of video imagery is a relatively new concept. However, the diversity is also due to the fact that in general these methods are highly site dependent. For example, analysis of the Teignmouth data using the aforementioned methods of shoreline detection present the inconvenience that the “white line” defining the upper limit of the swash zone does not appear in fair weather condition.

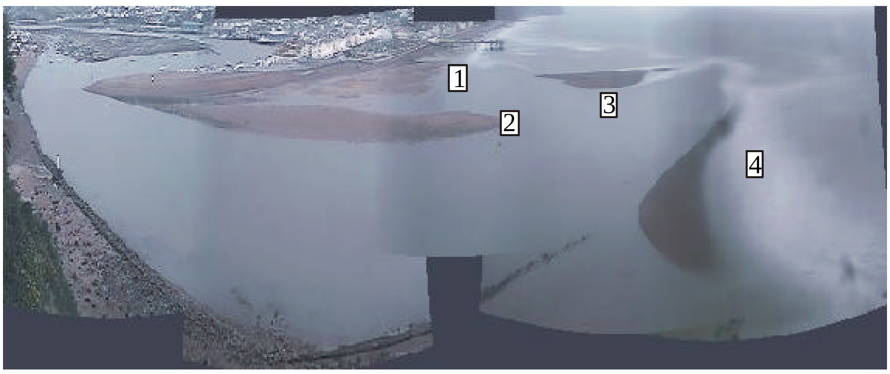
20 February 1999 15:00, 0.5m



18 May 1999 14:10, 0.4m



12 August 1999 12:10, 0.9m



26 November 1999 14:10, 0.7m

Figure 5: Merging of oblique time exposure images showing the evolution of the sandbars at similar low tides from February to November 1999 (label numbers correspond to sandbar locations and are indexed in the text).

Moreover, the complexity of the shoreline characterised by outer bars and non-linear morphologic features does not allow a rectilinear track of the coastline as used in some techniques. Finally, the previous methods were developed with greyscale images even though new sites are recording colour images. The difference between greyscale and colour scales implicates that not only pixel intensity is considered but also red, green and blue intensities allowing a better definition of the images.
Natural characteristics of the studied site also play an important role. In Teignmouth for example where the colour of the sand is red which strongly contrasts with the sea colour.

The Aarninkhof and Roelvink (1999) method is very promising for quantifying the dynamics of the sandbars in Teignmouth. Nonetheless, this technique seems to be very specific to the studied site. One of the principle aims of this work is to derive a more generic method of quantifying the nearshore morphology.

Conclusion

Time series of video images of the Teignmouth Estuary have been used to study the long-term dynamics of inter-tidal sandbars. So far, qualitative observations since February 1999 from the video imagery show the development of two outer sandbars forming part of the ebb-delta. It is observed that the morphology of the ebb delta changes dramatically with the formation of two outer sandbars and the simultaneously evolution of a sanbar closer to the shore. This bar is oriented in a cross-shore sandbar in February and a longshore direction in November.

To quantify these dynamic processes, new techniques of shoreline definition are under investigation.

In this work, video imagery measurements and post-processing analysis are used to study the long-term evolution of sandbar at Teignmouth. However, similar methods of video monitoring could also be applied in other environments and to other applications. For example, to measure the evolution of the boundaries of an intertidal sandwave fields or even to quantify the displacement of individual bedform evolution over several tidal cycles. Video imagery techniques are applicable to both intertidal or subtidal nearshore environments.

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