Coastal Sediment Transport: the COAST3D Project

R L Soulsby[1]

Abstract

The MAST-III RTD project COAST3D started in October 1997. A consortium of 11 partners including hydraulic laboratories, universities and national regulatory authorities from five EU states (UK, Netherlands, France, Spain and Belgium) will undertake this three-and-a-half year project. The project will make field measurements of waves, currents, sediment transport and morphodynamics at two contrasting sites. The results will be used to valid existing morphodynamic computational models, and lead to coastal zone management tools.

Introduction

Coastal management and engineering decisions rely increasingly heavily on predictions made by computational numerical models of hydrodynamic and sediment-dynamic processes and the resulting morphodynamic changes to the coastline and sea bed. Yet such models are rarely tested adequately against real data from coastal field measurements. This is largely because the many field experiments made to date have been designed to elucidate the physical processes rather than to evaluate numerical models. In addition, the most detailed data-sets are from North American sites, which are fundamentally different to European conditions. Evaluation of numerical models makes special requirements of the data, such as detailed measurement at the boundaries, and a dense spatial coverage of measurements within the modelled area. At the same time, improvements to numerical models are mainly made through improved understanding of the processes, so it is important to measure and interpret these also. The knowledge and models also need to be taken beyond the domain of the scientist, and put into a framework of guidelines and methodologies to be of direct value for coastal zone management.

[1] Manager, Marine Sediments Group
HR Wallingford, Howbery Park, Wallingford, OX10 8BA, UK

Sandy coasts can be classified as 2-dimensional (uniform in the coastwise direction), 2.5-dimensional (as 2D, but with natural non-uniformities such as rip-channels), and 3-dimensional (with irregular features such as headlands and tidal inlets). One of the best ways of gaining insights into the complex 2- or 3-dimensional development and behaviour of sandy coastal systems is by simulating their structure, organisation and functioning by using numerical models. Nowadays, morphodynamic models especially have become important tools for coastal zone management to predict and evaluate the evolution in coastal morphology in response to environmental change and engineering works.

Numerical morphodynamic models are generally of two types: Coastal Profile (CP) Models, suitable for 2D coasts, and Coastal Area (CA) Models, suitable for 3D coasts, with certain variants of both being applicable to 2.5D coasts. The understanding and modelling of notionally 2D coasts is reasonably well advanced, but the question is being raised whether any natural coast is sufficiently uniform to enable 2D modelling techniques to make successful predictions. Hence the focus is now turning to understanding the three-dimensional aspects.

Objectives

The purpose of the COAST3D project is

- to improve understanding of the physics of coastal sand transport and morphodynamics
- to remedy the present lack of validation data of sand transport and morphology suitable for testing numerical models of coastal processes
- to test a representative sample of numerical models for predicting coastal sand transport and morphodynamics against this data
- to develop validated modelling tools, and methodologies for their use, in a form suitable for coastal zone management

This will be achieved by making field measurements purpose-designed for numerical model evaluation, with adequate boundary conditions and a dense horizontal array of measurement points, in conditions typical of the European coastline. Previous coastal experiments in Europe and elsewhere have placed their main emphasis on hydrodynamics; an innovative feature of the present project is that the emphasis throughout is on sand transport and morphodynamics.

Another distinctive feature is that the focus is on non-uniform (3D) coasts, rather than on the relatively well understood (but possibly unrealistic) uniform 2D case. Experiments will be performed at two contrasting sites: a quasi-uniform (2.5D) stretch of the Dutch coastline, and a fully 3D site on the UK coast. This phased

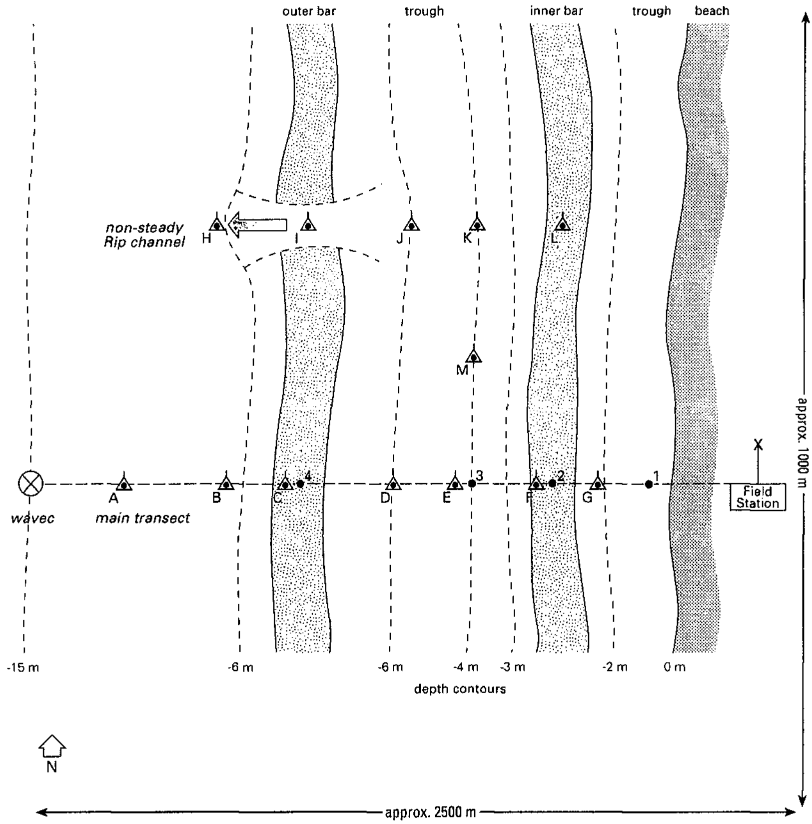

Figure 1. Schematic layout of instruments for Egmond experiment

approach will allow both the process information and the performance of the numerical models to be more easily interpreted.

Innovative techniques will be used in the experiments. Numerical modellers will work interactively with the experimenters, at the planning, experiment, and evaluation phases. Participants from national regulatory authorities will ensure that the project is focused on practical tools for coastal zone management.

Sites have been chosen in:

- the Netherlands for the 2.5D case, which is typical of the quasi-uniform sandy beaches dominated by breaker bars found on much of the coastlines of northeast France, Belgium, the Netherlands, western Germany, western Denmark, and eastern England.

- the UK for the 3D case, which is typical of the irregular coastlines featuring tidal inlets, river and estuary mouths, headlands, and coastal structures, often without breaker bars, found in western and southern Britain, Ireland, northern and western France, northern Spain, Portugal, and Norway.

A large proportion of the coastline of Europe falls into these two categories. The remainder comprise the micro-tidal coasts of the Mediterranean and the Baltic. These latter seas fall within the remit of the ongoing MAST-3 FANS project, based on an experiment in the Mediterranean to measure water, sediment and nutrient fluxes in three domains: the nearshore, the shelf and the continental slope. Another complementary MAST-3 project, INDIA, will study the morphodynamic behaviour of tidal inlet entrances and adjacent coastlines at a site in Portugal. Links will be forged between COAST3D, INDIA and FANS, through the presence of common partners, so that a wide variety of different European environments will be covered by these three projects.

Experiments

The first experiment will take place at Egmond on a quasi-uniform stretch of the Dutch coast (Fig.1), starting with a pilot experiment in spring 1998 followed by the main experiment in autumn 1998. Although the coastline and bathymetric contours appear on charts to be nearly straight, it is known from earlier work that the natural three-dimensionality produced by rip-channels intersecting a bar system has a major effect on the hydrodynamics and sediment dynamics of the coast. The site is regarded as "2.5–dimensional" as a result of these sedimentary non-uniformities, and the departures from 2-dimensionality are an important aspect of this experiment.

The second experiment, scheduled for 1999, will take place at Teignmouth on the south coast of England (Fig.2), where a rocky headland and a river mouth provide a

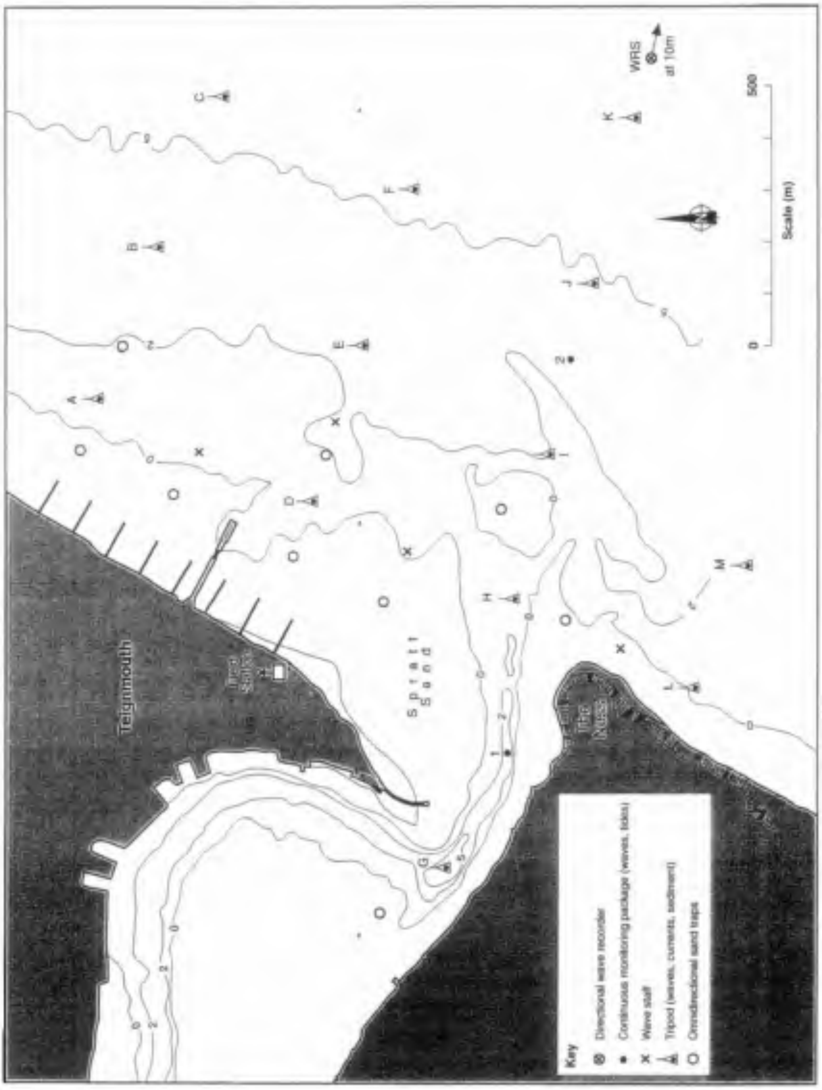

Figure 2. Schematic layout of instruments for Teignmouth experiment

strong three-dimensionality. A complicated re-curving spit is very active morphodynamically. This site, which additionally has a wide range of grain-sizes, will stretch the capabilities of present day coastal morphodynamic numerical models to their limits, and will provide a very exacting test of these and future models.

At each site a small number of permanent instruments will monitor conditions over at least 12 months. The main experimental work, however, will take place over an approximately 6 week period in the autumn (when beach conditions change most rapidly) at first the Dutch, and then the UK, site. The vast majority of the instruments are already owned by the partners, and will be deployed at both sites in succession, thereby making optimum use of the instruments, the logistics, the cooperative working practices, and the data management scheme. Instruments will be deployed in an array designed to meet the needs of numerical model evaluation, and to provide the more detailed process information. A pilot experiment of about two weeks duration will take place in the spring preceding each main experiment, to maximise the chances of success in the autumn.

The use of the innovative devices WESP and CRIS, which have been recently designed and constructed specifically for coastal experiments, is an important aspect of the implementation of the research programme. The WESP is a 10m high motorised tripod on wheels with a platform at the top supporting the engine and a cabin with facilities. Surveys can be conducted from the beach out to water depths of 6m in wave heights up to 2m (moderate storms). The WESP will tow a sledge (CRIS) carrying an intensive array of instruments wired in to the WESP cabin. This arrangement will ensure that the flow disturbance around the WESP does not influence the instruments.

The WESP is valuable for the collection of sand transport data, because it allows on-line measurements of short duration (30 min), and simultaneous collection of calibration samples by pumping systems. The availability of the WESP will allow a greater flexibility during the measurements by increasing the number of operational hours, by reducing ship time and the reaction time after an event and by deploying instruments at sites which are otherwise difficult to reach. The WESP will be used for measuring the 3-dimensional bathymetry of the nearshore zone, for placing and relocating instruments and for taking samples. The WESP can be dismantled to be able to carry it to various sites in Europe.

A crucial aspect of the experiments is the large number of instruments which will be deployed. In many ways this is what distinguishes COAST3D from previous field campaigns, and makes the resulting data-set of so much value for evaluating numerical models. Most of the instruments are already owned and used by the participants, and in many cases have been specially developed by them.

Modelling

A representative selection of numerical models of coastal hydrodynamics, sediment dynamics, and morphodynamics developed by the partners will be used at various stages throughout the project, most particularly for:

- preliminary runs to aid the design of the experiment. The models will be set up for the study area and run with representative inputs. Areas with strong spatial variations of the modelled parameters (waves, currents, sediment transport), and those areas where the models markedly disagree among themselves, will be identified for intensive instrumentation

- on-site modelling at a "modellers' week" midway through each experiment. Deficiencies in the experimental set-up can be remedied for the remainder of the experiment, and initial indications of the performance of the models obtained. The modellers' weeks will be open to modellers from outside the project to participate

- evaluation of the models after the full data validation, calibration and reduction. This will be the largest modelling effort, and will contribute towards the validation and accreditation of the models used.

The models used range from research models exploring the detailed physical processes (mainly at the universities) to fully operational models used routinely for consultancy applications (mainly at the hydraulic institutes).

Comparisons of the models with the data will be made in two distinct ways, by two distinct groups.

A diagnostic modelling group, made up of the university partners, will compare the measurements of individual physical processes with their representation by the models. It will identify: which models include the important processes, which of these give the best agreement with the data, how they can be improved, and how the improved algorithms can be included in the other models.

A practical modelling group, made up of the hydraulic institutes and regulatory authority partners, will test the overall capability of the models to reproduce the main trends in the data. They will address issues such as ease of setting up and driving the models, computational speed, stability and robustness, ease of plotting and interpreting results, as well as establishing an objective measure of "skill" in the models' performance against data. Best features will be further improved and included in all the models. Further, the group will decide on recommended procedures for the use of numerical models in coastal applications, and embody these in guidelines for use in coastal zone management.

Process Interpretation

The use of the data to further the understanding of the processes taking place in the coastal zone is every bit as important as the use for model validation. Accordingly, the experiments have been designed to accommodate both uses of the data.

For the 2.5D experiment one of the major questions which will be addressed is the growth, development and migration of nearshore bars in the surfzone and its impact on the behaviour of the coast, as well as the role of rip channels on bar behaviour. In many surfzones nearshore bars are the main morphological phenomena and their behaviour is still only partly understood and forms a good test case for the models. To measure the different processes and parameters a main cross-shore array of instruments will be installed covering the entire shoreface from a depth of about 20 m to the high tide levels on the beach. A number of instruments will be mounted to one side of the main line, to quantify the effects of rip channels on longshore nonuniformity (Figure 1).

For the 3D experiment the main emphasis is on the variations in the measured parameters in the two horizontal dimensions, particularly identifying horizontal circulation patterns of currents and sediments. A wide range of depths is necessary to identify the differing processes which re-distribute sediment in offshore areas and in the surf-zone. Some emphasis on the vertical distributions is also necessary. To measure the different processes and parameters a main array of instruments will be installed along intersecting cross-shore and longshore transects as shown schematically in Figure 2. Instruments will be located at the offshore and lateral boundaries of the studied region, to provide boundary conditions for the numerical models.

In both cases, it must be emphasised that the layout of instruments in the figures are schematic, and the exact layout will be determined by consultation between all the partners at an early stage of the project, after initial runs of the numerical models have been made.

Data Management and Availability

Good data management is a vital part of the project. A Data Management Group will oversee and specify:

- the synchronisation, record lengths and file formats of the logged data,
- the validation, calibration and basic analysis of the data,
- the design of a suitable data-base system,
- the storing of the data in the data-base,
- the public dissemination of the data through the Internet and CD-ROMs.

This will ensure uniformity of procedures between partners.

The data will be publicly available six months after the end of the project in two distinct forms:

(a) the complete data-set for study of physical processes,
(b) a condensed data-set of the basic variables for running and evaluating numerical models.

Coastal Zone Management

One of the most important products of the project is a set of tools and guidelines for practical coastal zone management (CZM). The production of these CZM tools will be guided particularly by the Rijkswaterstaat and Environment Agency partners, having regard to the following considerations.

Tools available to the coastal zone manager for solving problems are:

- data analysis
- measurement and monitoring
- (numerical) modelling.

Guidelines for using these tools should answer the following basic questions:

- WHEN to use,
- WHAT tools, and
- HOW to use these.

Answering the WHEN question first of all, requires an analysis of the CZM problem(s), leading to the definition of measurable:

- CZM objective(s), [eg maintenance of the coastline over a well defined length and for a well defined period of time],
- CZM parameter(s), [eg sand content of a well defined control volume],

and on this basis the definition of the most important

- temporal and spatial scale(s), and
- physical parameters.

Then, the answer to the question WHAT tools to use is depending on

- the availability of data,
- the possibilities for monitoring and measurements,
- the availability and (more important) the validity of numerical models, considering the spatial and temporal scales of interest.

Finally, the question HOW to use the tools may lead to guidelines for each individual tool, eg

- statistical analysis techniques (minimum data demands etc),
- monitoring and measurement schemes (parameters, instrumentation, frequency and spatial distribution, accuracy etc),
- methodology and procedures for applying individual numerical models.

For practical use however, it is just as important to develop guidelines on the combined use of the tools, answering:

- how to interpret measurement data,
- how to interpret model results, and
- how to draw conclusions in relation to the CZM problems.

Partners

The partners and contact names for further information are as follows:

Partner	Country	Contact	Email
HR Wallingford (Coordinator)	UK	RL Soulsby	rls@hrwallingford.co.uk
Univ. of Utrecht	NL	P Hoekstra	p.hoekstra@frw.ruu.nl
Rijkswaterstaat	NL	R Spanhoff	R.Spanhoff@rikz.rws.minvenw.nl
Delft Hydraulics	NL	LC van Rijn	Leo.vanRijn@wldelft.nl
Plymouth Univ.	UK	DA Huntley	D.Huntley@plymouth.ac.uk
Liverpool Univ.	UK	BA O'Connor	price@liverpool.ac.uk
Proudman O Lab	UK	P Thorne	pdt@pol.ac.uk
Université de Caen	FR	F Levoy	levoy@neptune.msh.unicaen.fr
CIIRC, Barcelona	ES	A S-Arcilla	arcilla@etseccpb.upc.es
MAGELAS	BE	J Lankneus	jean.lankneus@skynet.be
Environment Agency	UK	M W Owen c/o M Smalls	martin.smalls@environment-agency.gov.uk

Up to date news can be found on the project web-site: http://www.hrwallingford.co.uk/projects/COAST3D

The EU responsible scientific officer is C. Fragakis (christos.fragakis@dg12.cec.be).

Conclusions

The COAST3D project will

- make measurements at two contrasting sites, one typical of 2.5D and one of 3D conditions

- store the data in a properly managed data-base, and make them publicly available in two forms:

    (a) the complete data-set for study of physical processes, and

    (b) a condensed data-set of the basic variables needed for running numerical models, to provide definitive test-cases against which present and future models can be evaluated

- interpret the data to provide an increased understanding of the physical processes operating in the coastal zone

- make an evaluation of a representative sample of present-day European morphodynamic numerical models, in terms of both their ability to represent individual processes (diagnostic), and their overall usability and performance (practical)

- present the models and methods in a form suitable for coastal zone management, for example by providing a series of guidelines.

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