iCOASST Final Report

Background

Coastal erosion was widespread around the United Kingdom during the 20th Century and is expected to become even more pervasive through the 21st Century due to sea-level rise and climate change. Erosion is a direct hazard for coastal residents and it also makes it more likely that natural and artificial defences will fail during storms. This in turn increases the risk of coastal flooding, which is considered by the UK Cabinet Office as one of the biggest national threats. We can predict erosion and flooding during a specified coastal storm with some skill, but as we look further into the future, our ability to predict possible changes in risk diminishes significantly. Much of this difficulty is due to our inability to quantitatively predict coastal and estuarine morphological changes over management time scales of decades to centuries (the mesoscale).

The NERC-funded iCOASST (integrating COAstal Sediment SysTems) project (www.icoasst.net) comprised a consortium of UK Universities, Research Laboratories and Engineering Consultants, partnered by the Environment Agency, who considered how best to predict coastal morphological change at the mesoscale required to inform long-term coastal decision-making, such as shoreline management and strategy studies. This is a difficult problem, not least because the erosion and/or accretion of a coastal landform such as a beach is influenced by interaction with adjacent coastal landforms, be they cliffs, saltmarshes, tidal deltas, etc. The problem is further complicated by the role of soft and hard human interventions, which also exert a pervasive control on coastal evolution. In the UK, the legacy of such intervention is universal, and even if we abandon defences in the future, this declining human control must still be considered.

Accordingly, the iCOASST project took a system level perspective to the understanding and prediction of coastal and estuarine change. The research included two contrasting demonstration case studies of Liverpool Bay and the Suffolk coast, comprising coasts with large estuaries and small estuaries, respectively. Within these study areas, detailed model applications took place on the Sefton to Blackpool coast, including the Ribble Estuary (Liverpool Bay) and the Deben estuary and its environs (Suffolk).

The iCOASST project also included an active and ongoing engagement with local stakeholders to explore the realism and utility of our results. In a novel and successful arrangement, the Environment Agency (EA) were the key embedded stakeholder and actively involved in the project design and implementation throughout. The EA provided access to a wealth of valuable datasets and also greatly facilitated our engagement with a diverse set of coastal stakeholders through the project. The iCOASST team made a conscious decision to adopt a participatory modelling approach, and this evolved and become more important as the project progressed. This reflects a growing realisation that the iCOASST approaches and modelling tools could not be successfully developed and applied without stakeholder participation and acceptance. Further, stakeholder input was also valuable in improving our understanding of the coast in many locations. This is an important lesson for future coastal analysis and modelling in the UK.

The iCOASST Approach

The iCOASST approach is founded on a set of linked components that are outlined below and illustrated in Figure 1. There are five key components, including data. These are discussed below.

Component 1: A new Coastal and Estuarine System Mapping (CESM) framework, supported by a GIS-based software tool (CESMapper), for describing and mapping the interactions between coast, estuary and inner shelf landforms and the extent to which these are constrained by human interventions. CESM provides a basis for the formalisation of diverse sources of knowledge and for developing a shared understanding between scientists, stakeholders and policy makers concerning the most important processes, sediment pathways and human interventions that govern landform

behaviour. It has been demonstrated in Liverpool Bay and along the Suffolk Coast, but the method is generic and can be applied in any setting in the world with an appropriate coastal ontology.

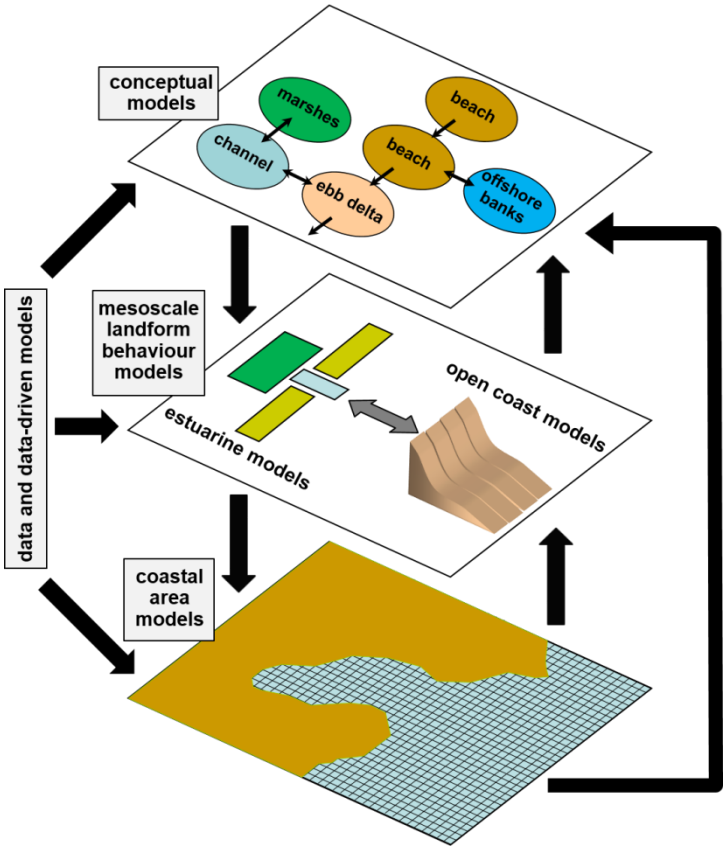

Figure 1. The iCOASST Framework

Component 2: Well-validated hydrodynamic and sediment transport shelf models (POLCOMS and TELEMAC), applied at the scale of UK territorial continental shelf waters, and more locally where appropriate, to calculate currents, waves and net sediment movement for a representative year (2008). These model outputs define broad-scale sediment pathways and identify locations where there is likely to be active inner shelf-coast interaction in terms of sediment exchange. Regional analyses were conducted, together with more focused analyses based on the two case study regions. In the case of Liverpool Bay, the main shelf-coast interaction is an onshore feed of sand. In Suffolk, the shelf provides a pathway for fine-grained sediment, some of which is deposited in the estuaries. The complex shelf bathymetry also significantly influences the wave climate, and a set of transfer functions were developed explicitly to drive the coastal models in Suffolk based on offshore wave data products.

Component 3: New and improved landform behaviour models were developed and applied within iCOASST. These models describe the processes shaping coastal evolution at annual to decadal (and even centennial) scales at an appropriate level of complexity. Their tractable formulations and computational efficiency allow relatively large ensembles of simulations, which are needed to explore the large parameter and climate change / management scenario space. For open coasts, the SCAPE model of shore platforms and soft cliffs was substantially developed and generalised, including complete recoding into a new model, SCAPE+. This allows for a much wider range of situations to be simulated. For estuary inlets, a new model -- MESO_i – was developed and applied to the complex tidal delta shoals of the Suffolk estuaries. While this worked well for these cases, we recognise that a generic inlet model remains elusive. Lastly, a new estuary model – ESTEEM – was developed based on observations of strengths and weaknesses of earlier spatial models such as SLAMM that use simple rules to define the pattern of change in intertidal landforms and habitats. ESTEEM embraces the appropriate complexity concept, combining a physically-complete treatment of tidal channel hydrodynamics with a more highly parameterized representation of intertidal flat and marsh morphological change under the influence of locally-generated wind waves and sediment budget constraint. Collectively, these models provide a significantly improvement to our capacity to simulate a broad range of coastal landforms. In addition to these new models the existing Unilinea and ASMITA shoreline and estuary models were applied in part of Liverpool Bay.

Component 4: Groups, or 'compositions', of coastal and estuarine landform models, which exchange information at run-time, thereby integrating the three previous elements. The model compositions are designed based on the CESM results, which identify the key landform

complexes, as well as stakeholder input. Linkages with the inner shelf are specified as look-up tables or transfer functions based on the POLCOMS and TELEMAC results. Linking such models at run-time is a difficult task that has hardly ever been achieved previously for quantitative predictions of coastal morphological change. The iCOASST project used the Open Model Interface (or OpenMI) standard for this purpose and conducted case studies in our two case study sites. As a proof of concept, we are also demonstrating an alternative way of linking models at the conceptual stage – the Coastal Modelling Environment – or CoastalME – which maps the different models on to a common data structure (http://www.coastalme.org.uk).

Component 5: Coastal data, which are fundamental to the conceptualisation and quantification of coastal change, and the validation and effective application of landform behaviour models. Coastal monitoring data are increasingly available in the public domain (e.g. from the Channel Coastal Observatory at http://www.channelcoast.org) and this is also stimulating the development of a new models and data-driven analyses. As datasets continue to develop, extend over longer time spans and become more comprehensive in scope, a fusion with the modelling systems being championed in iCOASST will emerge.

An ultimate goal is multiple simulations of coastal evolution to explore sensitivity and uncertainties in future decadal-scale coastal response, including the effects of climate change and the wide range of possible management choices. The iCOASST project has produced important demonstrations of this type of application, including stakeholder reaction to the results. The stakeholders were all very impressed with the achievements of iCOASST, but it was also acknowledged that the iCOASST results challenged stakeholder thinking and more experience of these type of modelling studies and their outputs will be needed before they could be fully utilised in coastal-decision making.

The iCOASST Results

Demonstration case studies for Liverpool Bay and Suffolk have established an active and ongoing engagement with stakeholders in both regions that has allowed us to evaluate the realism, relevance and utility of our results. This has identified the critical importance of defining appropriate coastal state indicators, and other aspects of model output, that have practical utility for specific activities such as shoreline management planning. Building on this, iCOASST has adopted a participatory modelling approach that includes all interested stakeholders, including the public. Stakeholders bring valuable knowledge and contribute to structuring the problem and the formulation of an agreed modelling approach, rather than merely being ‘consulted’ on simplified outputs from a modelling process led purely by ‘experts’.

The results from the Liverpool Bay from Formby Point to Blackpool using a two-model (open coast and estuary) composition demonstrate the importance of sediment exchange between the Ribble Estuary and the adjacent open coast. One implication of this is that large-scale instantaneous managed realignment could cause serious problems. The existing ASMITA model is a useful tool for experts, but its output is highly aggregated and hence difficult to communicate to stakeholders. Hence, it is recommended that ASMITA is best used as an exploratory tool by expert users.

In Suffolk, workshops based around discussion of CESM outputs captured valuable stakeholder knowledge that prompted a reassessment of the regional littoral drift system. The previous assumption was of a more-or-less continuous southwards sand and gravel transport. New data and model analyses showed that the system is more finely balanced with localised sediment transport reversals. Additional work stimulated by stakeholder knowledge also highlighted the importance of inter-annual variation in wave climate and the potential for significant drift reversals. This makes analysis and prognosis of coastal behaviour in Suffolk much more difficult. A detailed study of south Suffolk used a composition of three models (SCAPE+, MESO_i and ESTEEM) to simulate the coupled behaviour of the Deben estuary inlet shoals and the adjacent coast.

Further results on the iCOASST project can be found at http://www.channelcoast.org/iCOASST/introduction/.

The iCOASST Legacy

The iCOASST Project has a full and open legacy that goes beyond what has hitherto been the norm for NERC-funded research. The project been fully archived on the Channel Coastal Observatory (CCO) web site at http://www.channelcoast.org/iCOASST/introduction/ to maximise dissemination to relevant coastal managers, consultants and other endusers who utilise this site routinely. This web site includes the background to the project, a description of all the methods and models and their application to the case study areas. The tools developed in the project, as well as all models that were applied in iCOASST are all open source and are available for download via this site. Demonstration CESM maps of all of Liverpool Bay and Suffolk are available within the overall CCO databases, demonstrating the utility of the method. Development and application of these models is outgoing within the partner organisations, building on the ideas and concepts generated during the duration of the project itself. Links are provided to these on-going model development projects.

Beyond iCOASST, the links with the EA have been important to maintain development and application of the iCOASST results. The joint Defra/EA Flood and Coastal Erosion Risk Management R & D programme has funded a package of work to encourage uptake of the iCOASST deliverables and lessons into practice. This is mainly focused on the Suffolk case study. The main output from this work is a package of end user focused reporting and guidance that clearly sets out the work of the iCOASST consortium and how its deliverables can be used to deliver operational shoreline management benefits to the Environment Agency, Natural Resources Wales and coastal risk management authorities. General lessons and advice about modelling coastal morphological evolution over decades or longer are also included. This reporting includes guidance on:

a. The generation and use of the Coastal and Estuarine Systems Mapping (CESM) approach and products;

b. Selection and use of Coastal State Indicators to improve management decision making;

c. The set up and running of the mesoscale landform modelling software;

d. Guidance on mesoscale model selection, applicability, benefits over existing approaches in shoreline management planning and coastal / estuarine strategy studies.

The ambition is for the guidance to serve three levels of user:

1. The generally interested member of the coastal management community including local stakeholders and coastal risk management authority managers;

2. Coastal engineers, who are not experts in modelling and may not use the models themselves, but need to understand the concepts, methodology, pilot site and outputs and how they might be used to improve decision making; and

3. The coastal modelling community who want a user guide on how to run the models and generate outputs.

Further ongoing work to disseminate the iCOASST results to practise, funded by the Environment Agency, is in progress.