Dynamic Humber

Department of Geography, Environment and Earth Sciences

Investigating the long-term impact of environmental change on the physical, social and economic state of the Humber estuary and East coastal margin.

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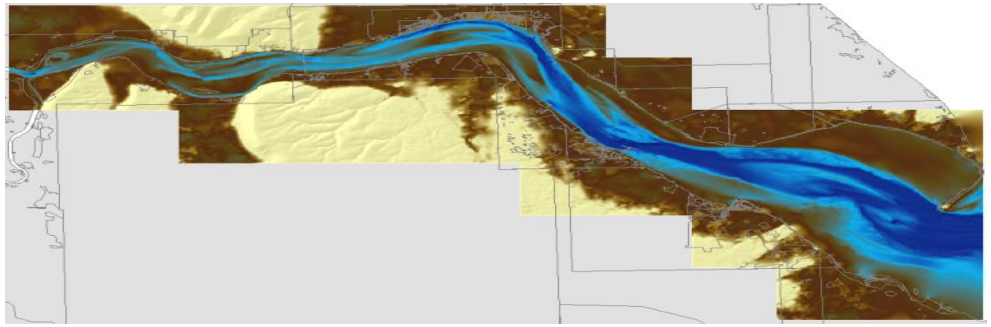
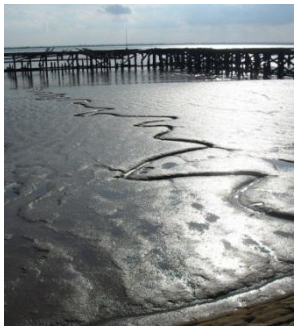
Aims

1. Creating long-term, high resolution observations and model simulations of physical fluxes within the Humber estuary and East coastal margin.


2. Forecasting the influence of future environmental change on physical, social and economic flows in the Humber estuary over the long- term (2000 - 2100).

3. Working with local communities, businesses, organisations and institutions to be more aware and better prepared to adapt to, compensate, mitigate and manage environmental change in the region.


Objectives

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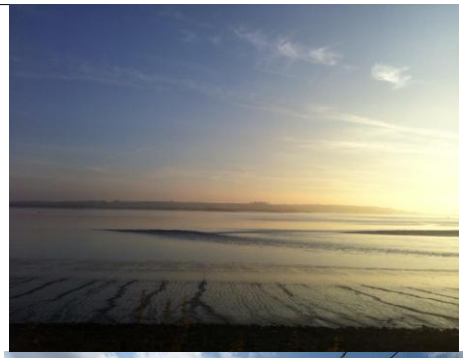
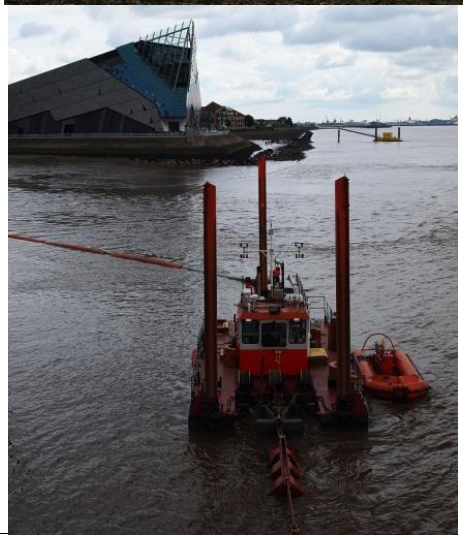
1. Understand past and present sediment fluxes in the estuary and build capacity to produce high definition field surveys with state-of-the-art equipment



2. Develop novel numerical modelling simulations to forecast the influence of future environmental change

3. Use the developed capacity and numerical model to engage with stakeholders, and evaluate the impacts of current estuarine dynamics and future environmental change on the commercial and social demands of the Humber



4. Develop novel approaches for the management of estuaries to ensure the provision of ecosystem services in the face of future anthropogenic, climatic and environmental change.

One Project, Three strands –

1. **Socioeconomic**

   How might the future physical changes influence economic activity of the region, and what impact does this have on social processes

2. **Morphodyanamics**

   What are the physical properties of the estuary and how might these be influence by future environmental or anthropogenic changes

3. **Numerical Modelling**

   Developing a novel numerical model to simulate likely physical changes in the estuary over the next century

One Project, Three strands –

1. **Socioeconomic**

   How might the future physical changes influence economic activity of the region, and what impact does this have on social processes

A new approach to estuary management

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- Key ecosystem services

- Face current and future pressures (climatic, environmental and anthropogenic change)
- Current management practises: the ecosystem approach

  Requires a comprehensive understanding of ecosystem functioning and its driving forces, and connectivity to all adjoining ecosystems and catchment basins.

  "*Formulating an operational definition of the ecosystem in question and establishing boundary limits is recognised as a key scientific challenge……. as ecosystems and their boundaries are often difficult to delimit and are defined in such a way that limit practical applicability in terms of fixed lines for research and management" (DEFRA, 2007).*

A new approach to estuary management

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- The problem with current definitions and boundary delineations: Structural/static boundaries based on historical delineations and physicochemical parameters . Fragment function and process. Ineffective and incomplete management programmes. Predictions of long-term change.

- The need for a new approach: 'what an estuary is' & 'what an estuary does'. Addressing the estuarine ecosystem as a functioning unit.

A functional approach to management

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- Benefits of this approach: provision of ecosystem services, ecosystem resilience & sustainability.
- Difficulties:

- Unbounded Boundaries



- Moving Baselines




Development:

Functional definition - *'An estuary is an ecosystem that is dependent upon its connectivity to both tidal marine and freshwater sources for energy transfer, but is bounded by the limits of its internal functioning. Maintenance of these limits and connectivity are essential to ensure estuarine ecological integrity and thus the provision of ecosystem services'*

Functional Boundaries - *'the smallest scale capable of delineating the current and future functioning of the ecosystem in such a way that ecosystem services and ecological integrity are preserved while appropriate human use and options for livelihood are sustained to ensure long-term resilience and sustainability'*

A series of generalisations (followed by an individualised approach) of estuarine ecosystem function that can be applied to estuaries worldwide to help define the ecosystem and delineate ecosystem boundaries using a functional approach.

One Project, Three strands –

2. Morphodyanamics

What are the physical properties of the estuary and how might these be influence by future environmental or anthropogenic changes

Measuring the morphological evolution of estuaries

- The University of Hull owns a high resolution multi-beam echo sounder designed to survey river beds
- This equipment enables us to quantify morphological evolution using repeat surveys of an area of interest
- Together with flow vectors and suspended sediment measurements obtained with our other instruments this enables us to paramaterise and evaluate our numerical models
- We have considerable expertise in field deployment of this equipment and the development of novel methods to derive suspended sediment fluxes from multi-beam backscatter

Multibeam Echo-Sounder

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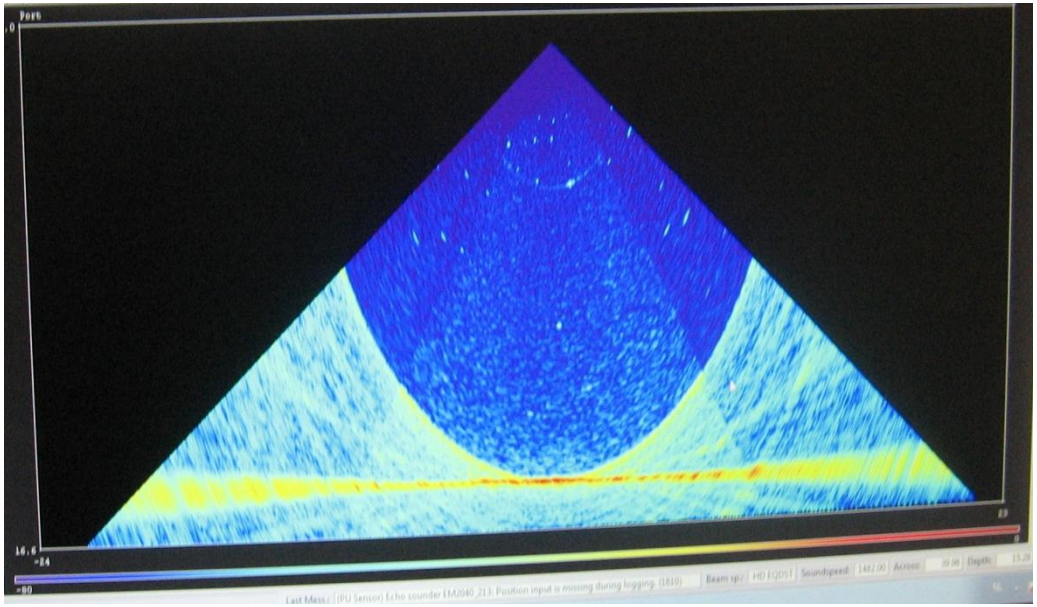
Reson SeaBat 7125 multi-beam echo sounder

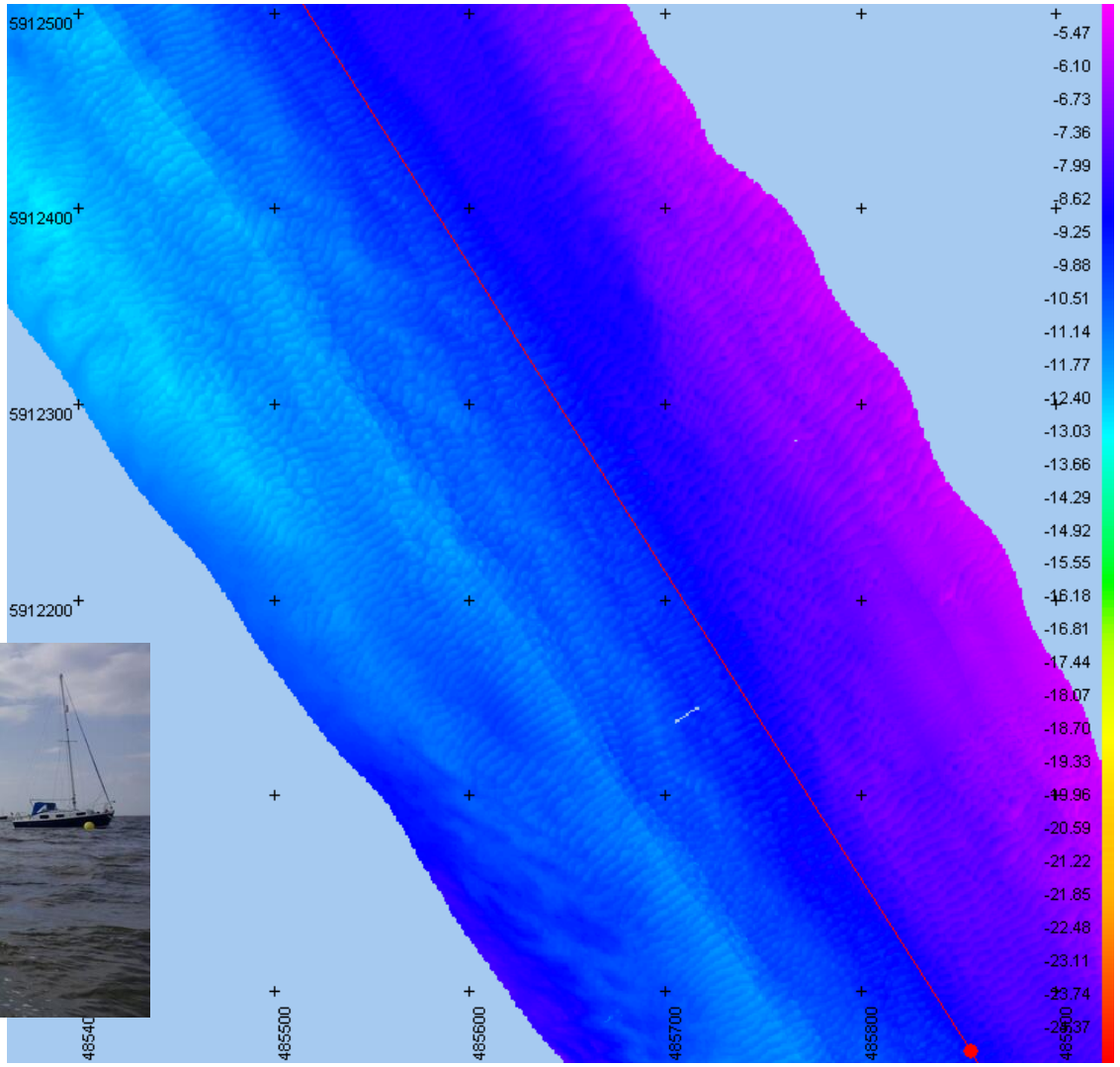
- Ultrasonic
- Centimetric resolution of the depth to the bed
- 512 depth soundings per acoustic pulse
- Up to 50 acoustic pulses per second



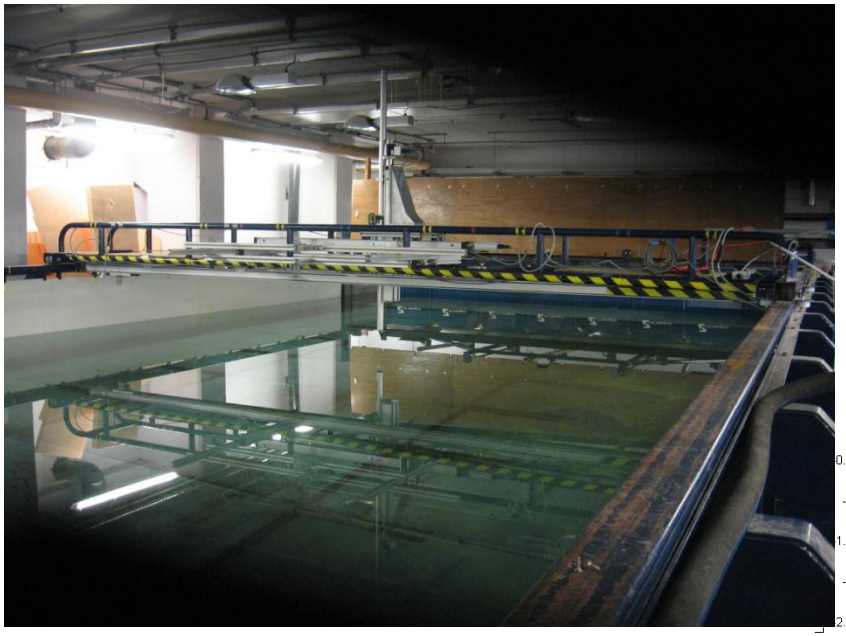
Multibeam image showing the bed, suspended sediment backscatter (and fish!)

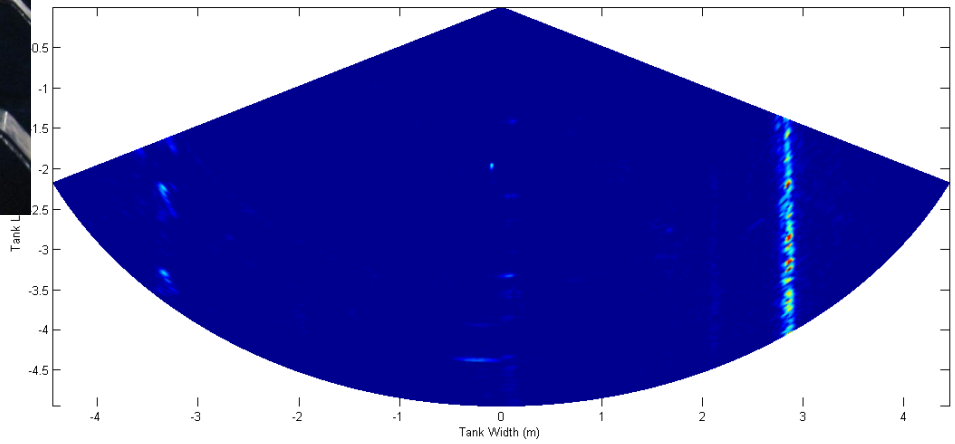
COHBED – Dee Estuary

Predicting how natural mudflats and beaches respond to the changing forces of the tides, wind and waves.



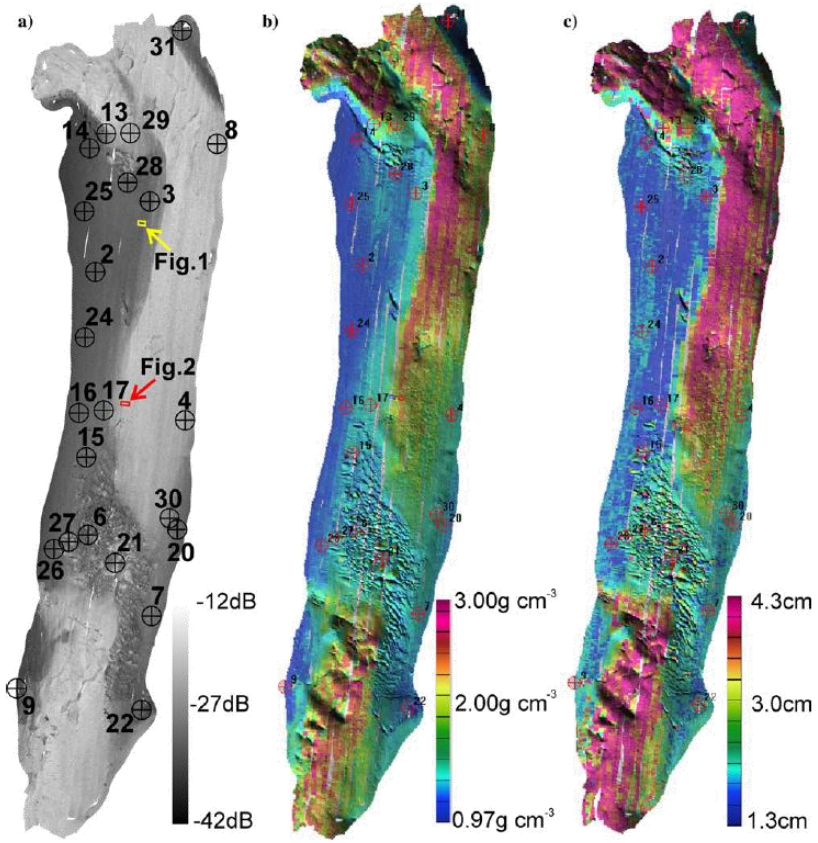
Calibration at the Total Environment Simulator, the Deep





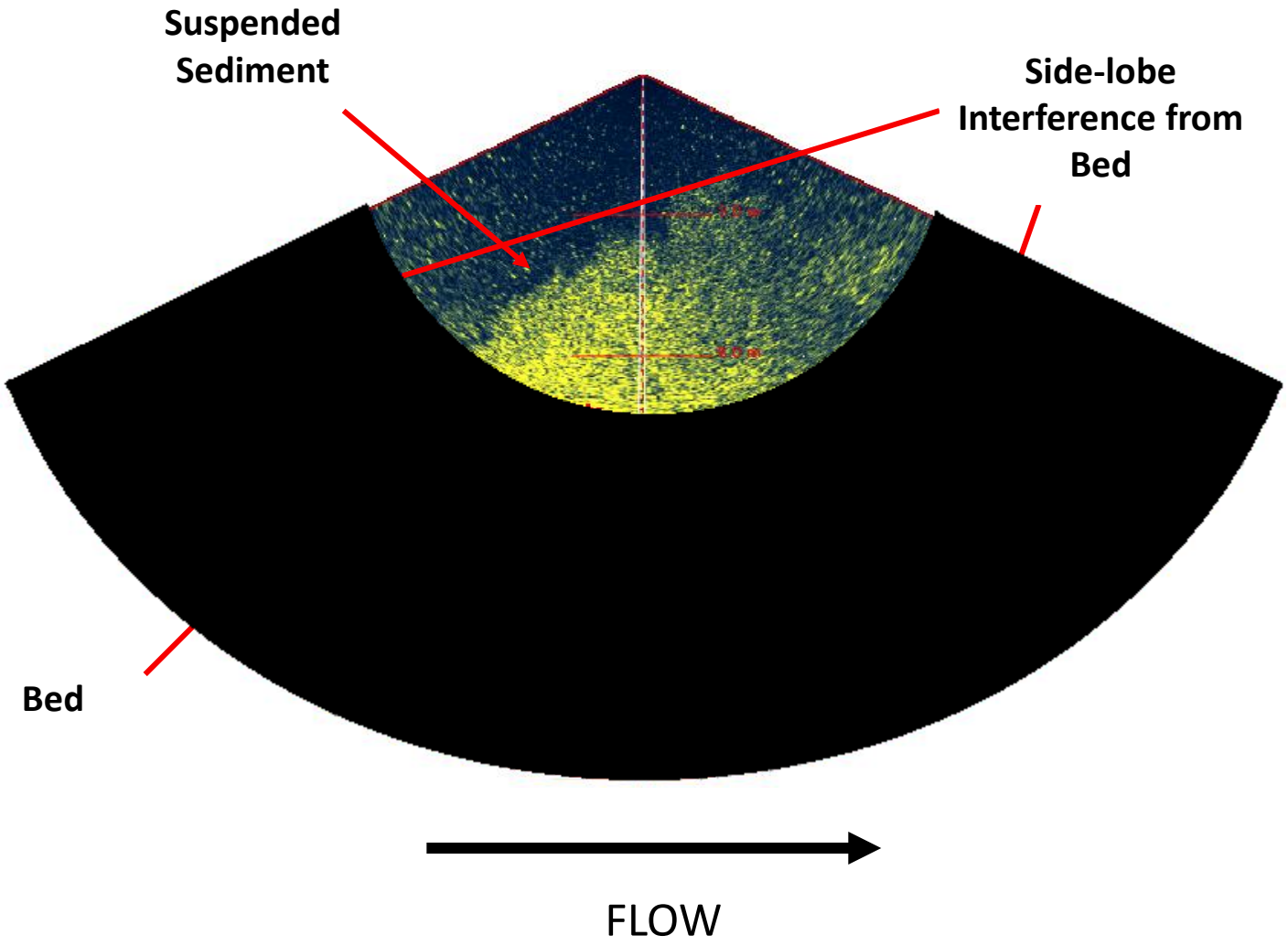
Effect of surface roughness on acoustic backscatter

- Sediment bulk density and surface roughness determined through analysis of backscatter angular variation.
- Measurements can be used to improve numerical model

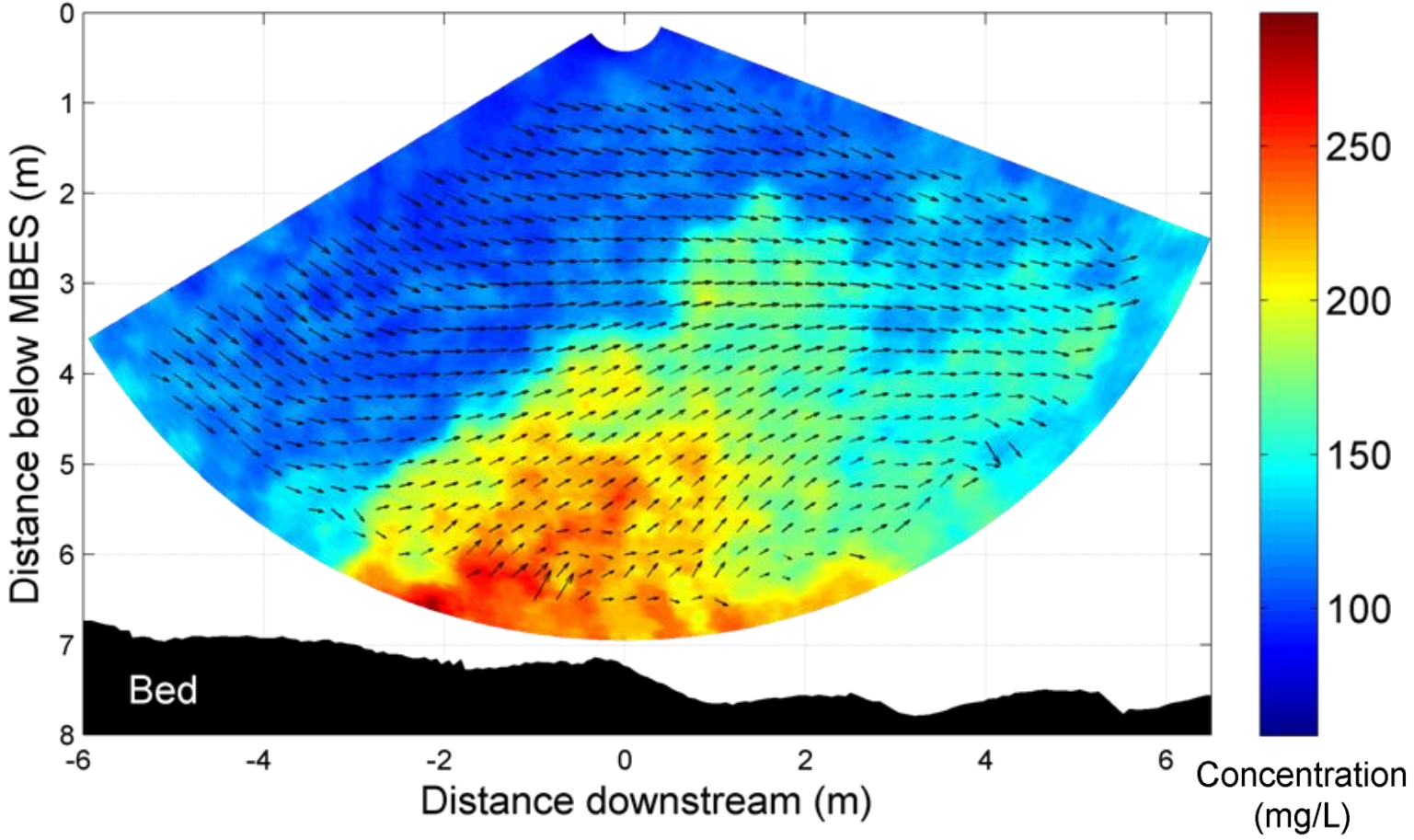


Fonseca & Mayer 2007

Suspended sediment plume, Mississippi



Mean components of velocity averaged over 9 pings (10Hz rate). Vert. scale x5 and rel. to mean



Mekong Delta, Cambodia

Understanding the importance of climatic and autogenic controls in determining the transfer of sediment from source-to-sink within a large river system.

Hull University:

- Has considerable expertise and capacity to undertake large-scale field measurements of sediment transport processes
- This ability is being exploited to inform and improve predictive models of the effect of natural and man-made controls on sediment transport and bed morphology on a number of current projects

Humber Estuary Measurements: Forthcoming collaborations with

- Precision Marine Survey Limited
- ABP

One Project, Three strands –

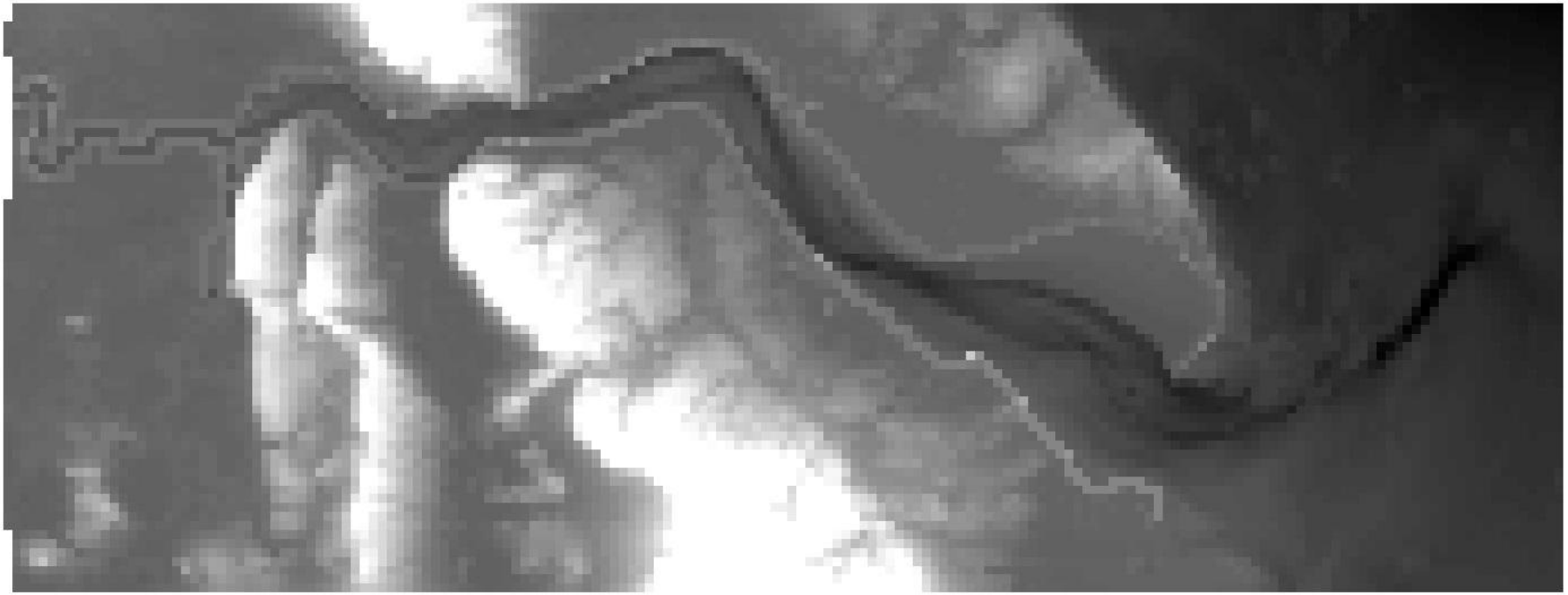
3. Numerical Modelling

Developing a novel numerical model to simulate likely physical changes in the estuary over the next century

Motivation and Model

- There exists a gap between 1D landscape evolution models (100s to 1,000,000s of years, and complex 3D models (up to 10s of years), such as Delft-3D, when modelling estuarine environments
- The modelling gap exists for timeframes of 10s to 1000s of years, which would be computationally expensive for 3D models, but require more detail than provided by a 1D model
- CAESAR-Lisflood has the potential to fill this gap, but a reduced-complexity cellular-automata model has yet to be successfully applied to a real-world estuary
- The union of two established 2D numerical models
- CAESAR – a landscape evolution model
- Lisflood-FP – a 2D flow model
- Although CAESAR has long been established for the modelling of fluvial evolution, the flow model was not suitable for tidal regions
- With combination with Lisflood, this limitation has been removed

Setting up the model



Data used in making the DEM –

LiDAR from the EA
Bathymetry from ABP
Elevations from the OS

Flood defences from EA recently added

Tidal gauge data provided by ABP

This is used to both drive and test the model's performance

As far as possible all data is from 2010

Running the model

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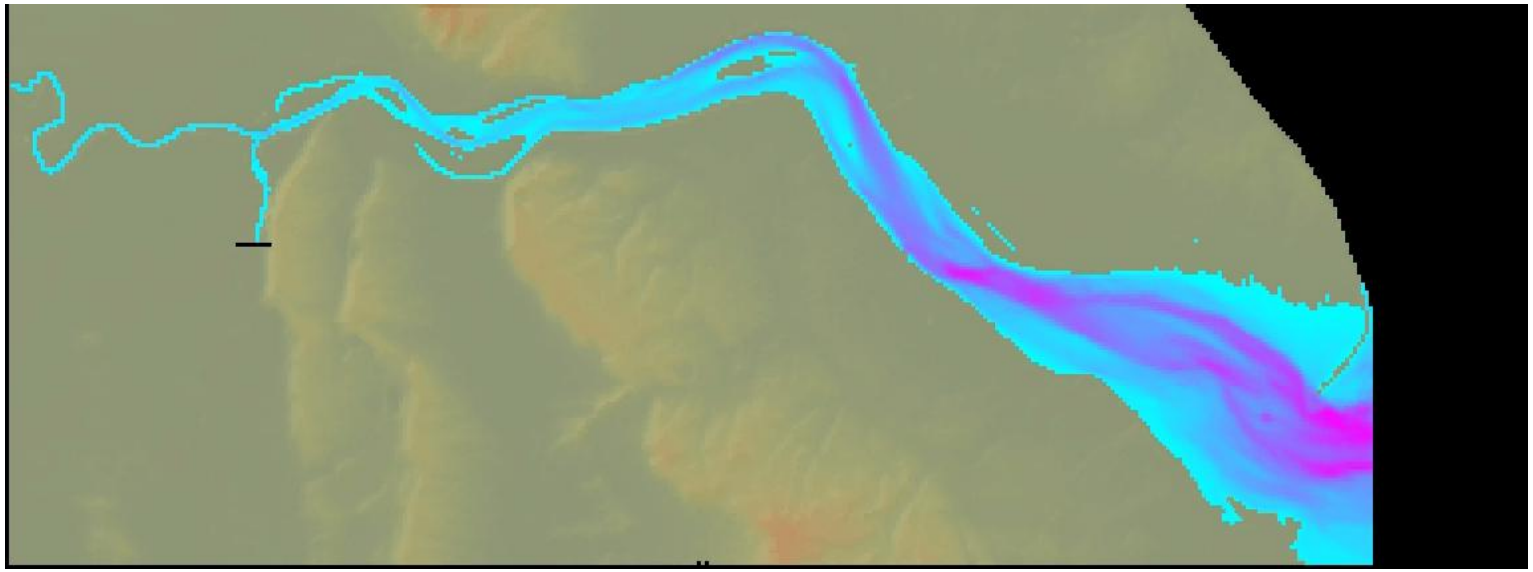
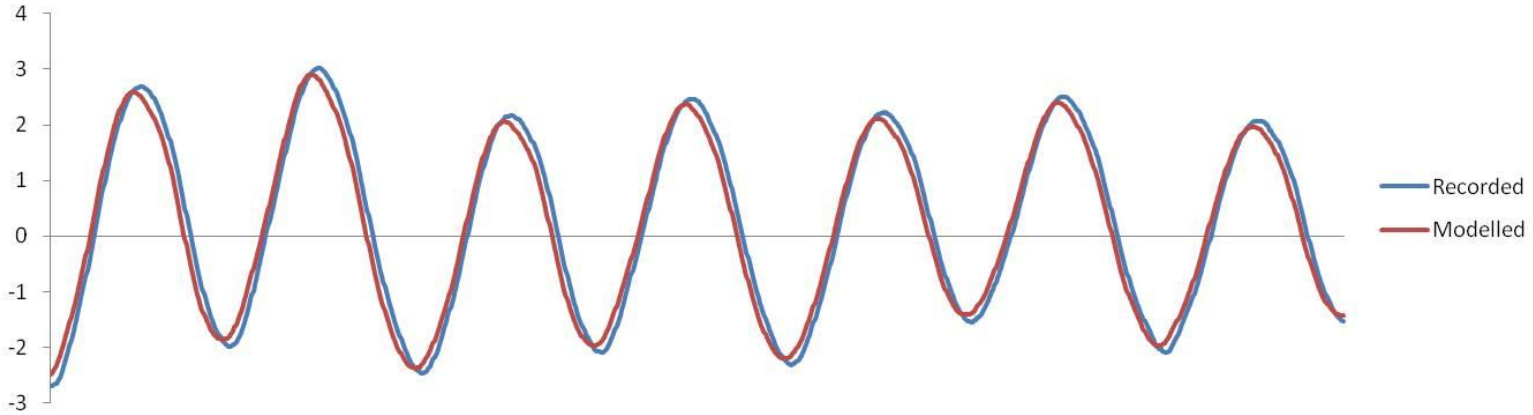
Simulation of tides



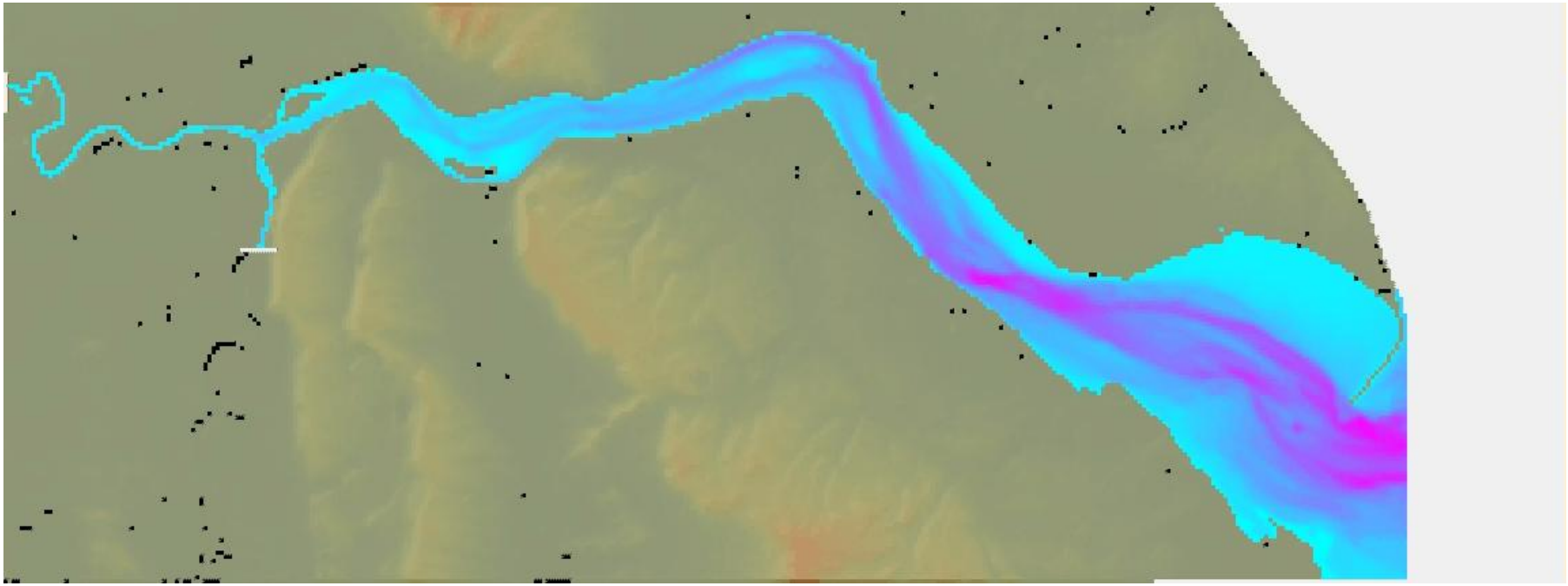
Tidal heights at Immingham



The 1953 Surge

Using data collected during the storm surge in 1953, it was possible to predict how the region would cope with present day defences.

The model suggested that the defences would cope well.

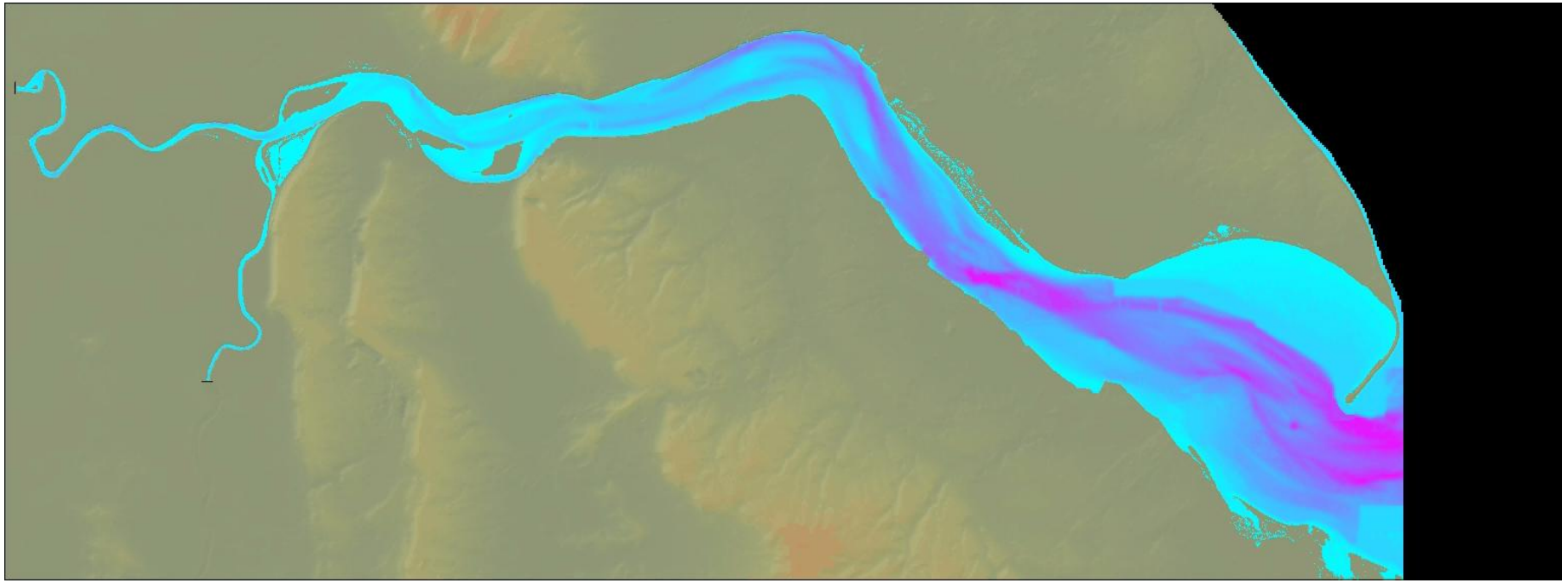


The 2013 Surge

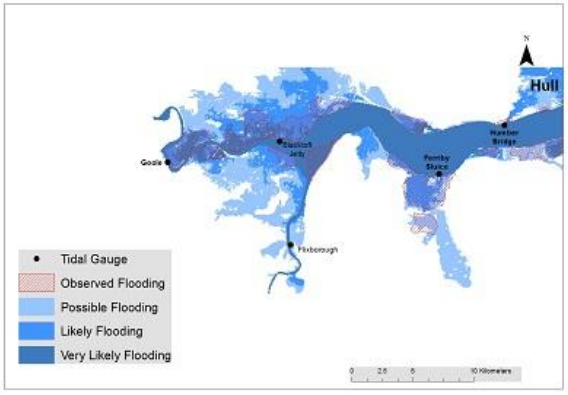
The flooding seen on 5th December was more than would have been expected from a repeat of the 1953 event

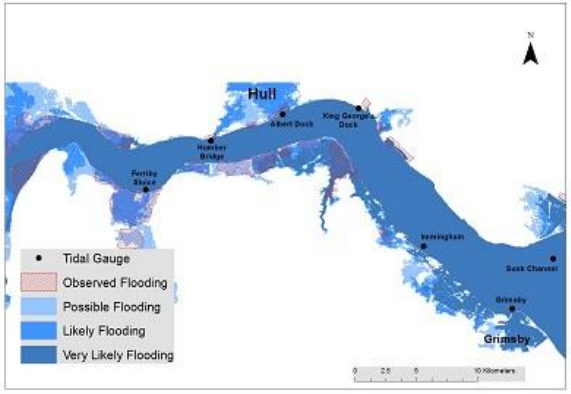
Overall, the defences coped ok but were pushed to their limits in places

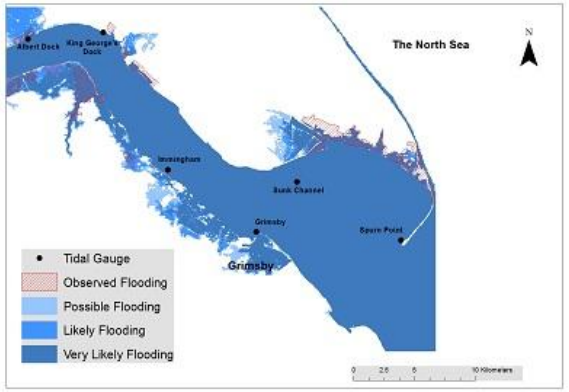
Data from the event provided by ABP and the EA allowed further testing of the model



Flood Extents

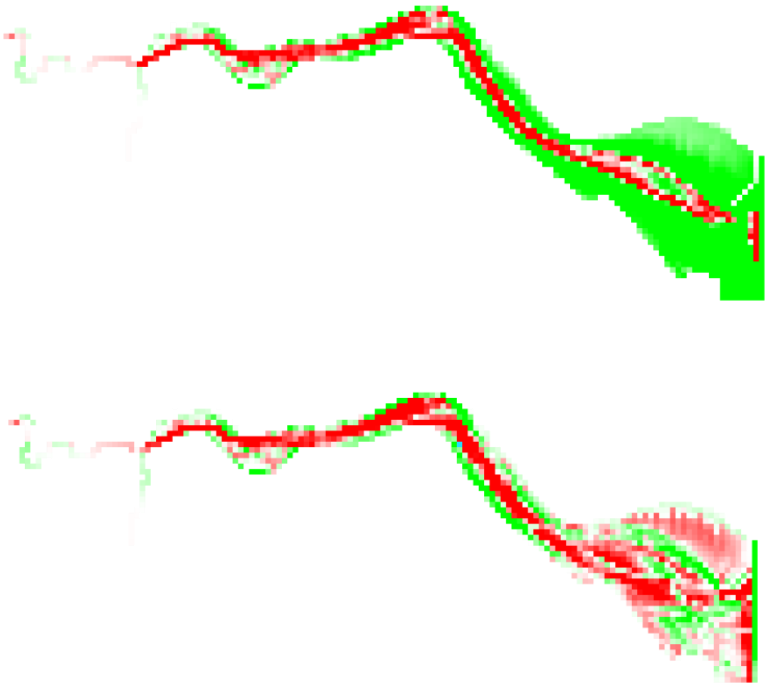






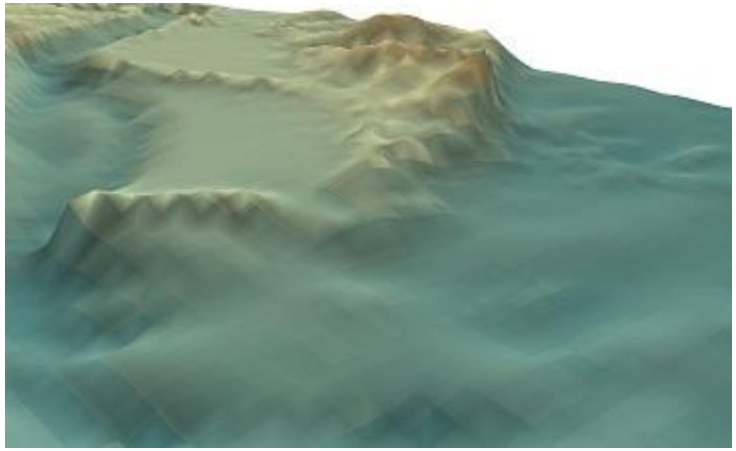
Future Changes

- With the model set up and validated for tidal hydraulics, it was possible to start modelling morphodynamic changes
- This was performed by adjusting the existing erosion/deposition processes in CAESAR-Lisflood
- Model calibrated by altering the suspended sediment concentration (SSC) in the incoming tide
- The model output is very sensitive to this

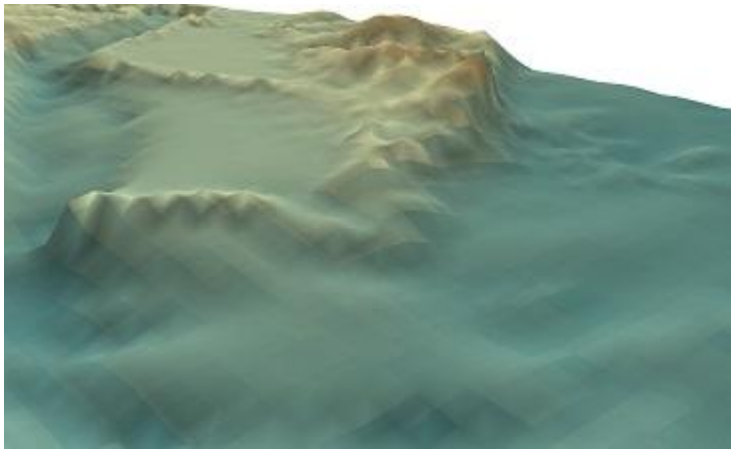


Model outputs from 100year simulation.
Green shows deposition, Red show erosion.
Top output shows 1000mg.l^{-1}
Bottom shows 100mg.l^{-1}

Future Changes



Spurn breach after 25years



Spurn breach after 50years

- Having the model in a state of equilibrium, it is possible to apply perturbations and model possible future changes
- Applying a 1m sea level rise over 100years results in more than double the amount of sediment deposited
- Work beginning to model the impacts of the breach at Spurn Point it is left unrepaired

Future plan

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1. Ascertain critical sediment properties in the Humber estuary (bed sediment type, suspended sediment concentration and flow velocity)
2. Fully integrate sediment properties into the numerical model
3. Model future sediment fluxes within the Humber estuary
4. Make probabilistic predictive forecasts based on a range of scenarios
5. Engage with local communities and estuary stakeholders to assess and mitigate the impacts of future environmental change in the region
6. Develop follow-on projects through collaborative cross-discipline grants/bids with industry, government and institutions
7. Develop a functional approach to defining, delineating and managing estuaries



To finish....

Information on the project, including news, photos, preliminary results and output will be available through the website and twitter feed.

www.dynamic-humber.org.uk

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