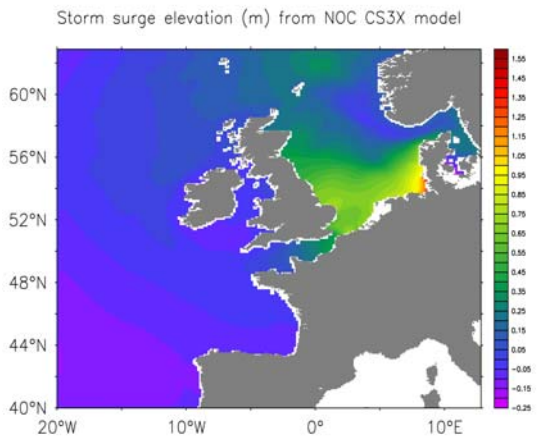
Inundation Modelling – Coastal Flooding
Improved Storm Surge Forecasting

FRMRC2 has produced:
- New modelling techniques and improved forcing datasets that will help to understand and reduce storm surge forecast errors

Intended readership:
- Storm surge and inundation modellers
- Government agencies
- Emergency planners

Where to find more information:
- http://www.pol.ac.uk/ntslf/model.html
- http://mitgcm.org
- http://www.enm.bris.ac.uk/ai

Summary



Hindcasts of storm surges provide boundary conditions for overtopping and inundation models

Novel adjoint modelling and artificial intelligence techniques are developed for storm surge forecasting to be used to explore sources of forecast errors.

Forecast errors depend on uncertainty in model physics, initial conditions and boundary conditions such as meteorological forcing. Traditional techniques like ensemble modelling are inefficient at determining the sensitivity of the forecast to multiple, interdependent parameters and conditions.

Adjoint Modelling is an efficient way to find the relative sensitivity of the forecast to specific factors, including their inter-dependence and spatial structure. For example, whether the maximum surge height depends more on uncertainty in the wind forcing over a particular region or on the bottom drag coefficient in another region in the surge model.

Artificial Intelligence provides an alternative predictive tool that potentially reduces forecast errors by making few or no physical assumptions, but instead uses algorithmic learning on training data.

Both techniques can help determine which sources of forecast uncertainty are of greatest relative importance, thus guiding where resources should be focussed for improved forecasting.

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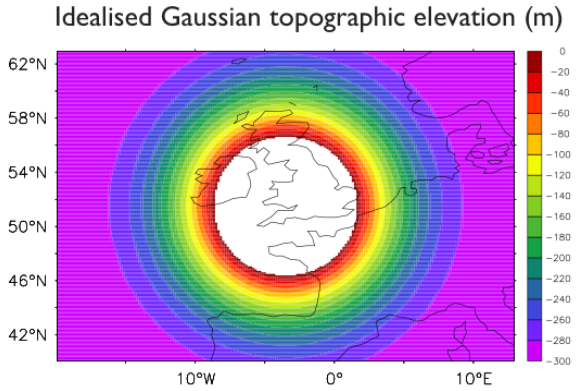
Construction and Testing of the Adjoint Model

The MITgcm model is well established in a variety of ocean applications and is uniquely constructed to allow calculation of the 'adjoint' of the forward model via 'automatic differentiation' of the code. The adjoint contains information about the sensitivity of a cost function (e.g. maximum sea level in a given region) to a set of inputs, which may include initial and boundary conditions as well as model physical parameters (e.g. frictional drag at the sea bed or the drag coefficient of wind stress).

Previously MITgcm has been used in this way to study how large-scale ocean heat transport depends on the three-dimensional temperature and density structure. However, the model has had limited prior application to three-dimensional storm surge modelling. We constructed and tested the model, first for idealised experiments to compare the forward and adjoint modelling techniques.



Idealised pressure distribution (representing a depression) used as MITgcm model input

Artificial Intelligence Techniques

'Linguistic regression trees' provide an alternative, low dimensional, model to predict storm surges at one location based on tide gauge observations at other locations. This type of model does not explicitly require any physical assumptions, so has the potential to improve forecast skill by avoiding errors due to model physics.

The forecast surge at Sheerness is modelled as a function of input surge at other east coast ports, Wick, Whitby, Immingham and Lowestoft. The linguistic regression tree is built from a set of IF-THEN fuzzy rules, e.g. if the surge at Wick is between low and very low and the surge at Whitby is high, then there is an 80 percent probability that the surge at Sheerness is high. Linear regression on high quality training data gives the model predictive skill.

Hindcast Storm Surge Dataset

The NOC CS3X model is run from 1960-2001, forced by 1°lon x1°lat ERA-40 meteorology.

Other sources of information

The storm surge hindcast dataset provides vital input to WP 2.1: Coastal Modelling.

UK operational storm surge forecasts use the NOC CS3X model, integrated at the Met Office and with results transmitted to the Environment Agency.

Research Team

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- Northern Ireland Rivers Agency

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