Tide-Surge Interaction in Generating Extreme Water Levels in a Hypertidal Estuary

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Introduction

The accurate prediction of extreme water levels within estuaries is essential for the planning of future coastal settlements, industry and infrastructure, particularly energy infrastructure associated with existing and new nuclear energy assets. New nuclear stations must be designed to cope with a 1 in 10,000 year event (0.0001 probability), whilst decommissioned sites in their Care and Maintenance phase are still required to be resilient to a 1 in 100 year extreme water level. Work undertaken in association with the nuclear energy sector has revealed a fundamental weakness in the translation of extreme level data from the nearest primary tide gauge or standard port to any particular location up-estuary, particularly in relation to tidal asymmetry and attenuation, morphological controls on surge propagation, and the capacity for the estuary floodplain to accommodate the surge once it exceeds the confining sea defences. Huge spatial variability in water level is known to occur between tide gauges and that a small increase in elevation can cause significant changes to inundation extent (Lewis et al., 2011). Based on observations and model simulation for the extreme water level at the estuary mouth, the research aims to provide validated models of estuarine surge propagation, tide-surge-wave-river interaction and flood water accommodation to provide more accurate assessments of extreme water levels up-estuary to the tidal limit. Tide-surge interaction is well understood for shelf seas (Horsburgh and Wilson, 2007) and dominates the signal in lower estuary elevation (Brown et al., 2013). We aim to develop this methodology for the Severn estuary using the examples of Oldbury-on-Severn and Berkeley as sites of current and future nuclear operations, liaising with colleagues at Magnox, Horizon Energy, the ONR and the EA in terms of their critical information needs.

Example from the Tohuku earthquake of an extreme water level exceeding the capacity of present-day sea defences. Current nuclear fleet and new build have to meet ONR stress test regulations in demonstrating resilience to such rare events.

Source: http://www.nytimes.com/2011/03/14/world/asia/14seawalls.html?pagewanted=all&_r=0

Project Summary

The project will focus first on setting up a combined bathymetric/topography domain for the Severn estuary and floodplain, and on establishing the boundary conditions (available extreme water level and surge data, operational model projections). POLCOMS-WAM will be set up at 1.8 km resolution for the Bristol Channel/Severn Estuary to model tide-surge-wave propagation and interaction within the estuary over the tidal cycle, establishing an effective interaction between hydrodynamics and intertidal morphology. Up-estuary
‘blocking’ of river flow by high water will also be incorporated to consider the nonlinear impacts of river-tide-surge events in the region (Maskell et al., 2014). Modelling of sea defence overtopping and flood risk will be undertaken at high resolution (50 m, and nested to 2 m where necessary) using LISFLOOD-FP (Bates et al., 2010). Model hindcasts will be validated against tide gauge data for Avonmouth, Newport, Severn Bridge and Sharpness (where and for which time period data permit, e.g. 2009) to correct extreme water level predictions from tide gauge locations for wetting & drying and tidal attenuation. These are substantial research challenges as wetting-drying and the up-estuary shallow regions are not yet handled within POLCOMS for this dynamic region that experiences the largest UK tidal range.

A further element of the research uses a mass-balance approach in tandem with the POLCOMS-WAM and LISFLOOD-FP simulations and river flow data to deliver a series of flood risk projections that take into account surface roughness, tranquil/shooting flow effects as the water level exceeds the sea defences (see opposite), and the capacity of the floodplain to reduce the surge height up-estuary as water is diverted from the channel (see examples from Tohoku earthquake above). For example, existing projections of the 1 in 10,000 extreme water level exceeds the sea defences as Oldbury, but will already have exceeded the lowest sea defence height down-estuary. Hence, are the floodplain capacity and defence overtopping flow sufficient to prevent the storm surge substantially exceeding the height of the lowest defences?

Whilst this methodology will be developed and tested for the Bristol Channel and Severn Estuary, the various components of the methodology will be sensitivity tested on different idealized estuary morphologies and defence options – thus scoping its broader applicability and its capacity for modelling future mitigation options.

Work plan:
- Formulation of key research questions and modelling challenges based on critical review of literature, state-of-the-art knowledge, and available methods/models.
- Research training; including project management, hypothesis testing, data acquisition and analysis, research methods, model set-up and design, testing and validation, dissemination and working with stakeholders etc.
- Data gathering; including input data and modelled boundary conditions, bathymetry/topography for model domain, interpretation/interpolation/processing of data, model set-up and validation.
- Data exploration; including re-analysis of datasets and downscaling, use of appropriate statistical tools, use of model outputs and data for hypothesis testing.
- Outputs and dissemination; including writing reports, presentations, posters, papers and PhD thesis, presentation of conference papers and posters, writing of policy briefs for stakeholders and non-specialists.

References


