Spatial variability of extreme water levels in a hypertidal estuary

Charlotte Lyddon [a,b] *, Andy Plater [a], Jenny Brown [b], Nicoletta Leonardi [a]

[a] Department of Geography and Planning, University of Liverpool, UK. [b] National Oceanography Centre Liverpool, UK.

* c.e.lyddon@liverpool.ac.uk

1. Background and Objectives

Coastal zones worldwide are subject to short term, local variations in sea level, particularly communities and infrastructure developed on estuaries (Quinn et al., 2014). The Severn Estuary is prone to frequent storm surges, where nuclear assets are located.

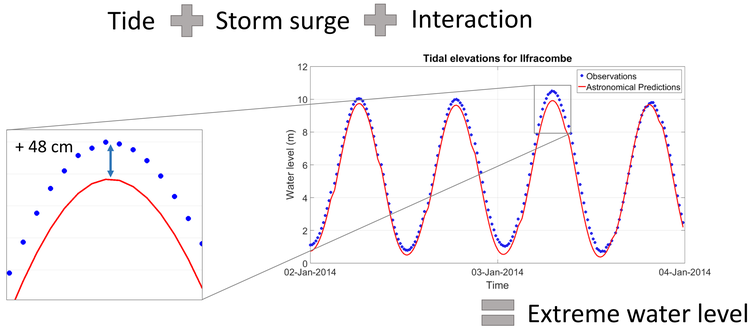

Figure 1: Extreme water level at Ilfracombe, 2 – 3 January 2014 *(Source: NTSLF, 2016)*

This project uses Delft3D-FLOW in a sensitivity study to investigate the influence of
- the timing of the peak of the storm surge relative to tidal high water
- asymmetry of the storm surge component with time
- and locally generated tide-surge interaction (Horsburgh and Wilson, 2007)

on extreme water level in the Severn Estuary. The results provide quantitative guidance on how to improve resilience of coastal energy infrastructure to extreme water levels.

2. Methods

Delft3D-FLOW, a 2D-horizontal hydrodynamic model (Lesser et al. 2004), is used to simulate barotropic tide-surge-river propagation and interaction to access spatial variability in extreme water levels for historical events of varying severity in the Severn Estuary.

Historical tide gauge data from Ilfracombe and Mumbles is used to generate a series of 4 extreme water level events. The storm surge component of each event is classified using skewness, a measure of asymmetry, a novel approach.
- Positive skewness indicates a longer falling limb.
- Negative skewness indicates a longer rising limb.

A low pass filter is applied to each storm surge component to separate out the time-varying meteorological residual and tide-surge interaction. The filtered surge is recombined with the tide in series of time shifted configurations.

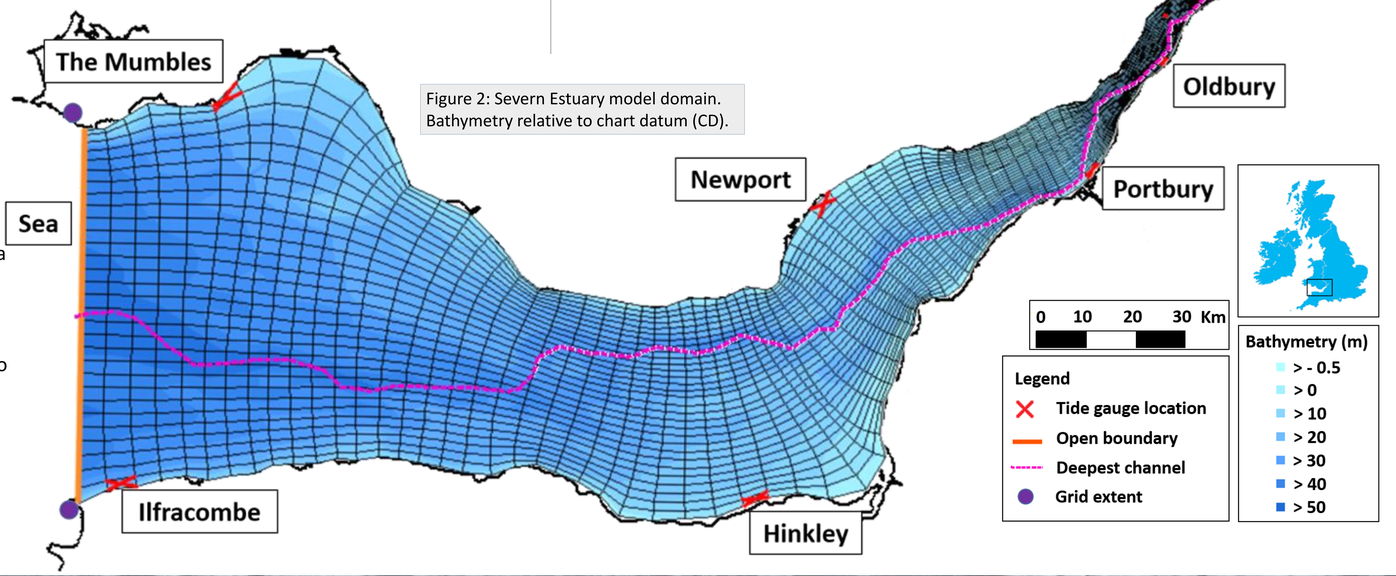

Figure 2: Severn Estuary model domain. Bathymetry relative to chart datum (CD).

3. Results

3.1 Maximum water level in deepest channel

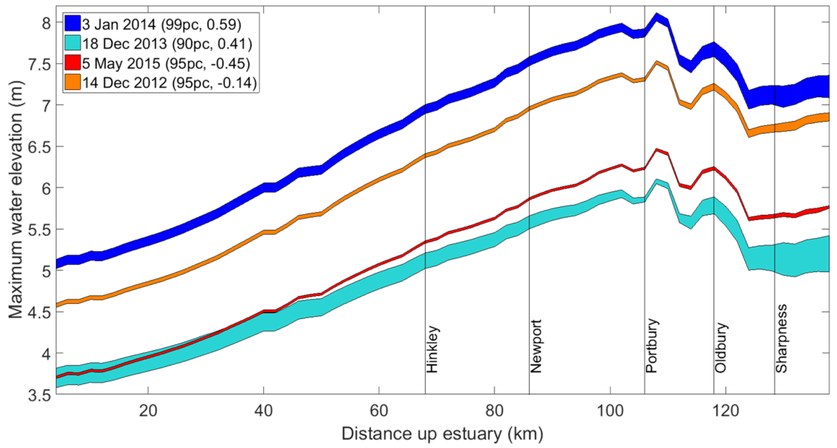

Figure 3: Maximum modelled water levels along the deepest channel of the Severn Estuary for 4 historic, extreme water level events. Each event is classified based on event severity and storm surge skewness.

- Maximum modelled water levels are stacked as a function of the severity of the extreme water level event.
- A storm surge with a positive skewness has extended influence after tidal high water, and produces a greater range of modelled maximum water levels.
- A storm surge with a negative skewness has extended influence before tidal high water, and constrains maximum water levels.
- Tipping point between funnelling and friction effect near Portbury.

3.2 Flood hazard proxy

Figure 4 & 5 show changes in flood hazard up-estuary at each tide gauge location up-estuary, compared to tide only, as a function of change in timing of the surge peak.

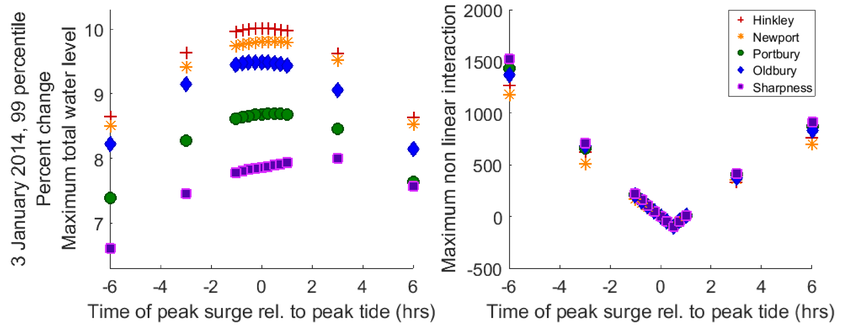

Figure 4: 3 January 2014 (99th percentile, 0.59 skewness). Percent change in i) maximum water level; ii) maximum non-linear interactions ((total water level) – (tide + filtered surge))

- Fig. 4 suggests locations in lower estuary experience greatest % change in maximum water, noticeably when the peak of the surge and tidal high water coincide (0).
- Locations up-estuary show greatest % change in maximum water when surge occurs 3 hours after high water (+3), indicating sensitivity to timing of the peak of the surge.
- Greatest positive change in non-linear interaction when surge occurs significantly before or after tidal high water. Limited interaction around high water.

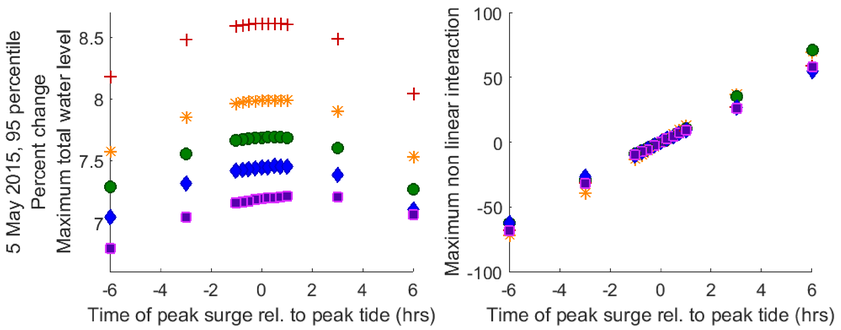

Figure 5: 5 May 2015 (95th percentile, -0.45 skewness). Percent change in i) maximum water level; ii) maximum non-linear interactions ((total water level) – (tide + filtered surge))

- Fig. 5 suggests greater spatial variability in % change maximum water level between locations, with a smaller extent of change than the 99th percentile event.
- Linear trend; greatest positive change in non-linear interaction when surge occurs significantly before high water. Limited interaction around high water.

4. Summary

- Severity of event and skewness value of surge can cause spatial-temporal variability of EWLs in Severn Estuary.
- Results for changes in water level can be used in an operational, forecasting context, for example nuclear infrastructure of interest to the ARCoES project.
- This methodology could be applied to other hypertidal estuaries worldwide.
- Next Delft3D will be coupled with WAM to investigate defence breaching & overtopping.

References

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Lesser, G.R. et al., 2004. Development and validation of a three-dimensional morphological model. *Coastal Engineering*, 51(8–9), pp.883–915.

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