Flood hazard assessment for a hyper-tidal estuary and river as a function of tide – surge – morphology interaction

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Hyper-tidal estuary

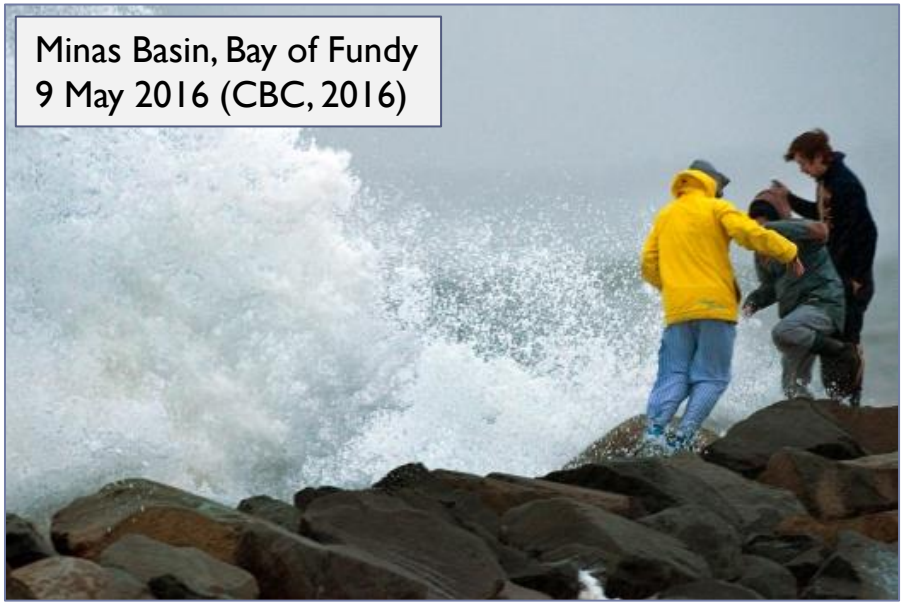
- Hyper-tidal: Tidal range exceeds 6 metres
  - Bay of Fundy, Canada
  - Severn Estuary, SW England

Hyper-tidal estuary

- Hyper-tidal: Tidal range exceeds 6 metres
  - Bay of Fundy, Canada
  - Severn Estuary, SW England
- Tidal amplification
  - Near resonance
  - Channel convergence
- Surge amplification
  - Reduced hydraulic drag

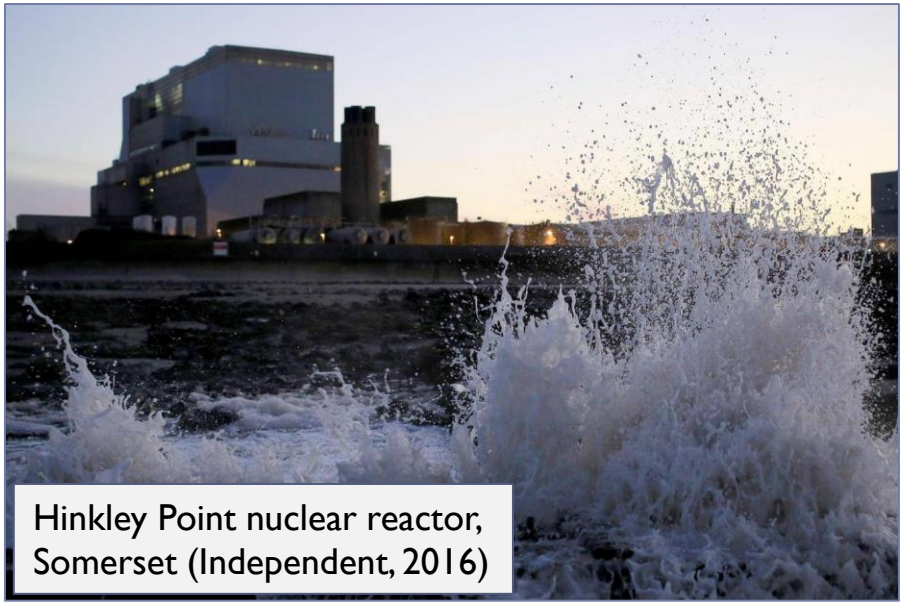
Flood hazard in a hyper-tidal estuary

- Tide – surge concurrence can be catastrophic



Flood hazard in a hyper-tidal estuary

- Tide – surge concurrence can be catastrophic



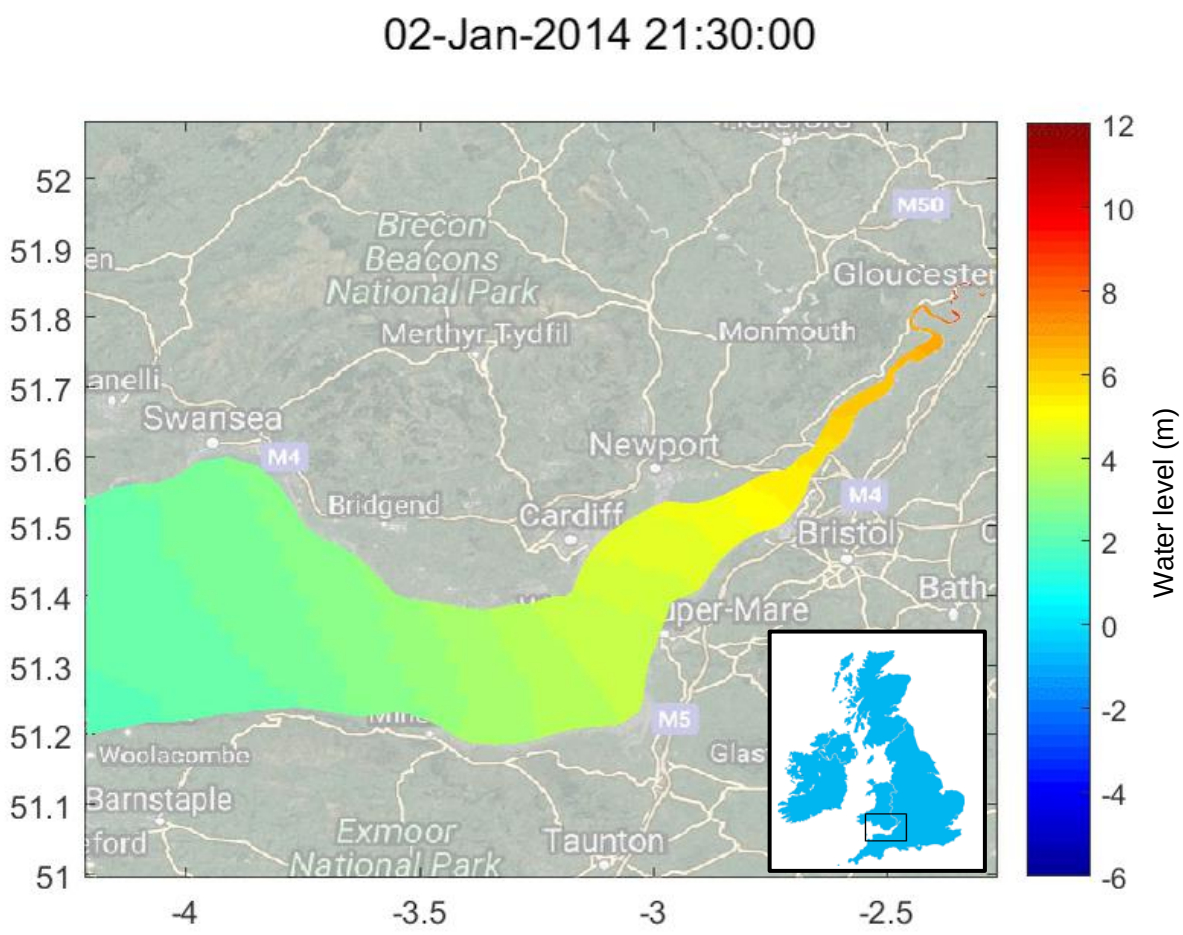
Hinkley Point nuclear reactor, Somerset (Independent, 2016)

Ilfracombe, Somerset (Telegraph, 2014)

- Accurate prediction of extreme water level and its timing is essential for storm hazard mitigation in heavily populated and industrialized, hyper-tidal estuaries

Flood hazard in a hyper-tidal estuary

- Combined factors controlling magnitude and variability of extreme water levels in a hypertidal estuary
  - Event severity
  - Storm surge timing and shape
  - Estuary morphology



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Background
- Coastal flood hazard
- Project aim

Methods
- Model domain
- Boundary conditions

Results
- Water level along thalweg

Application

Summary

This logo will bring you back here

Background

Coastal flood hazard

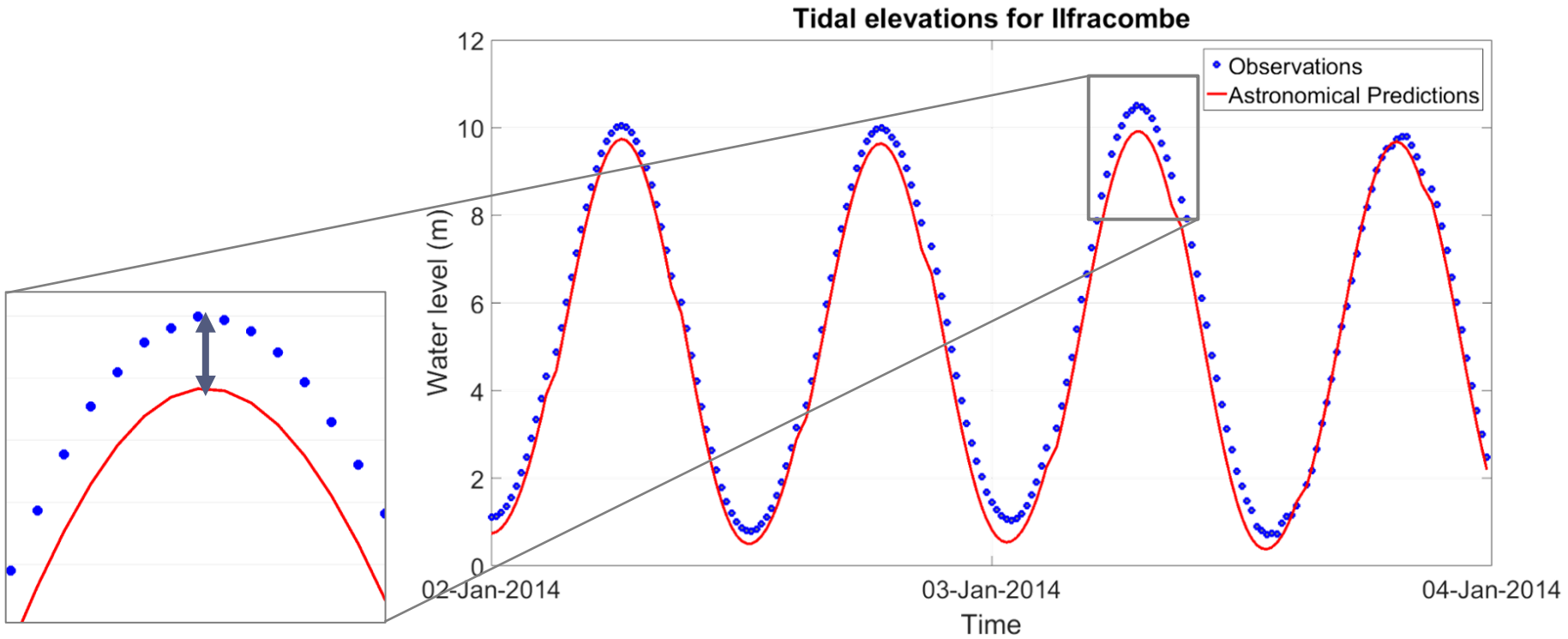
- Coastal zones worldwide are subject to short term, local variations in sea-level, particularly communities and industries developed on hyper-tidal estuaries.
  - Tidal amplification and extreme surge development means tide-surge concurrence can be catastrophic.

Coastal flood hazard

- Tide-surge concurrence in the Severn Estuary, SW England, where tidal range can exceed 12.2 m, can cause very high water levels.
- Images show the most extreme event on record, 3 January 2014

Extreme water level, 3 January 2014

Tide + Storm surge + Interaction



+ 48 cm mismatch between observed and predicted tide

= Extreme water level

Horsburgh and Wilson, 2007
Data source: NTSLF, 2016

Aim

- Accurate prediction of extreme water level and its timing is essential in heavily populated and industrialized estuaries and tidal rivers
  - Essential for storm hazard mitigation
- Incorporate spatial and temporal variability of the combined flood hazard in flood risk assessments

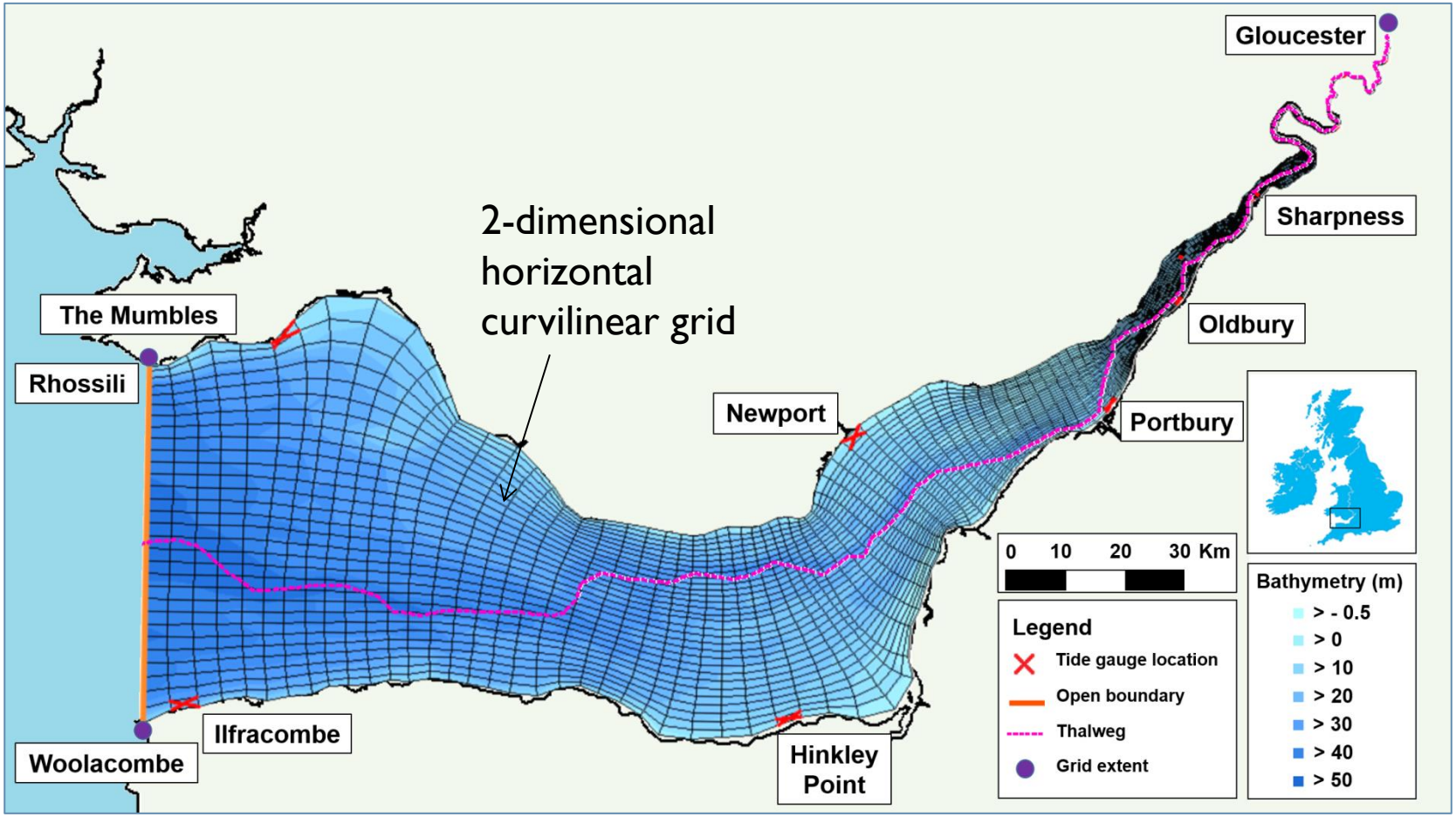
Oldbury-on-Severn, U.K

Gloucester, U.K

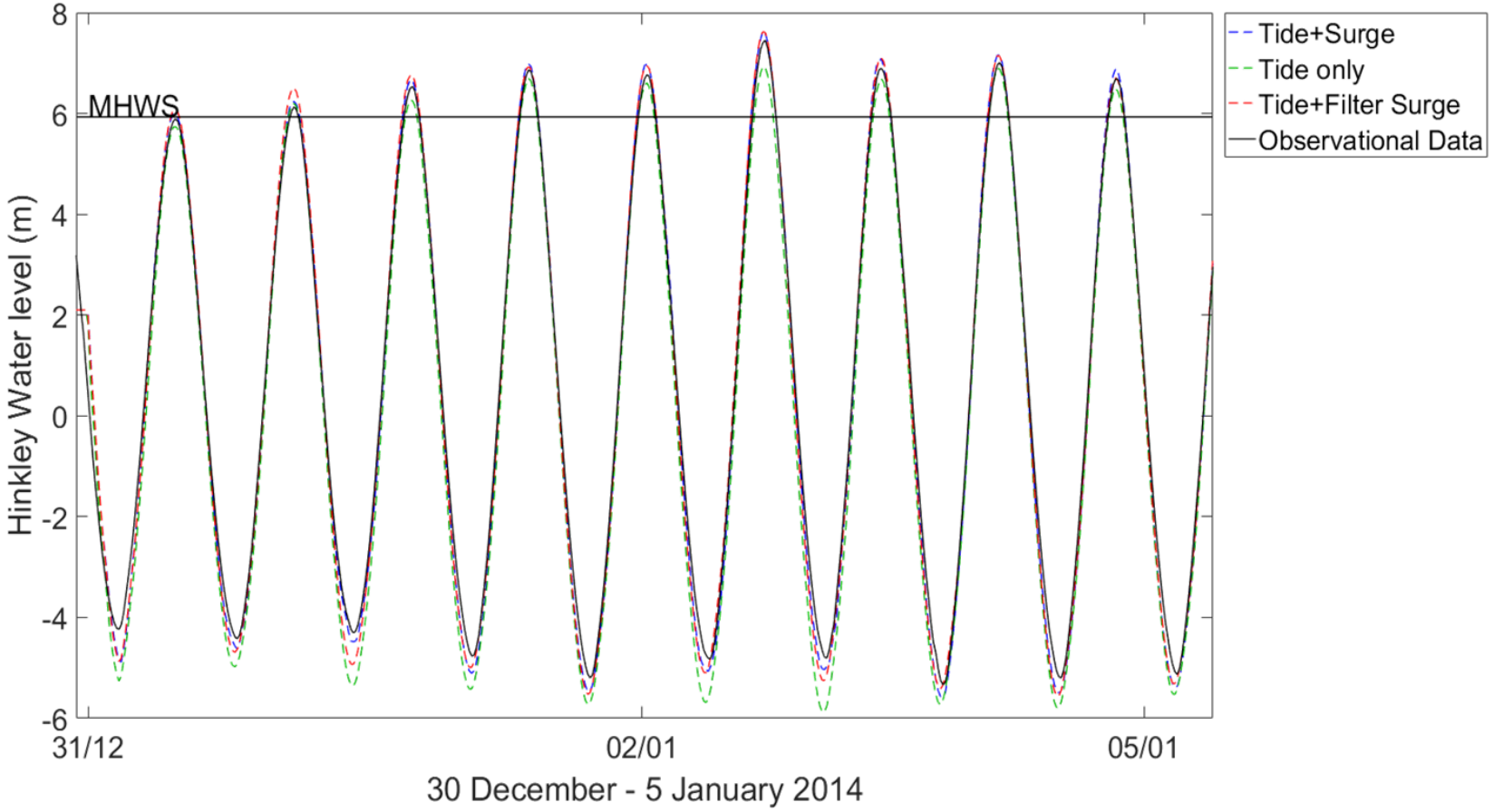
Royal Portbury Dock, U.K.

Methods

Model setup - Delft3D-FLOW



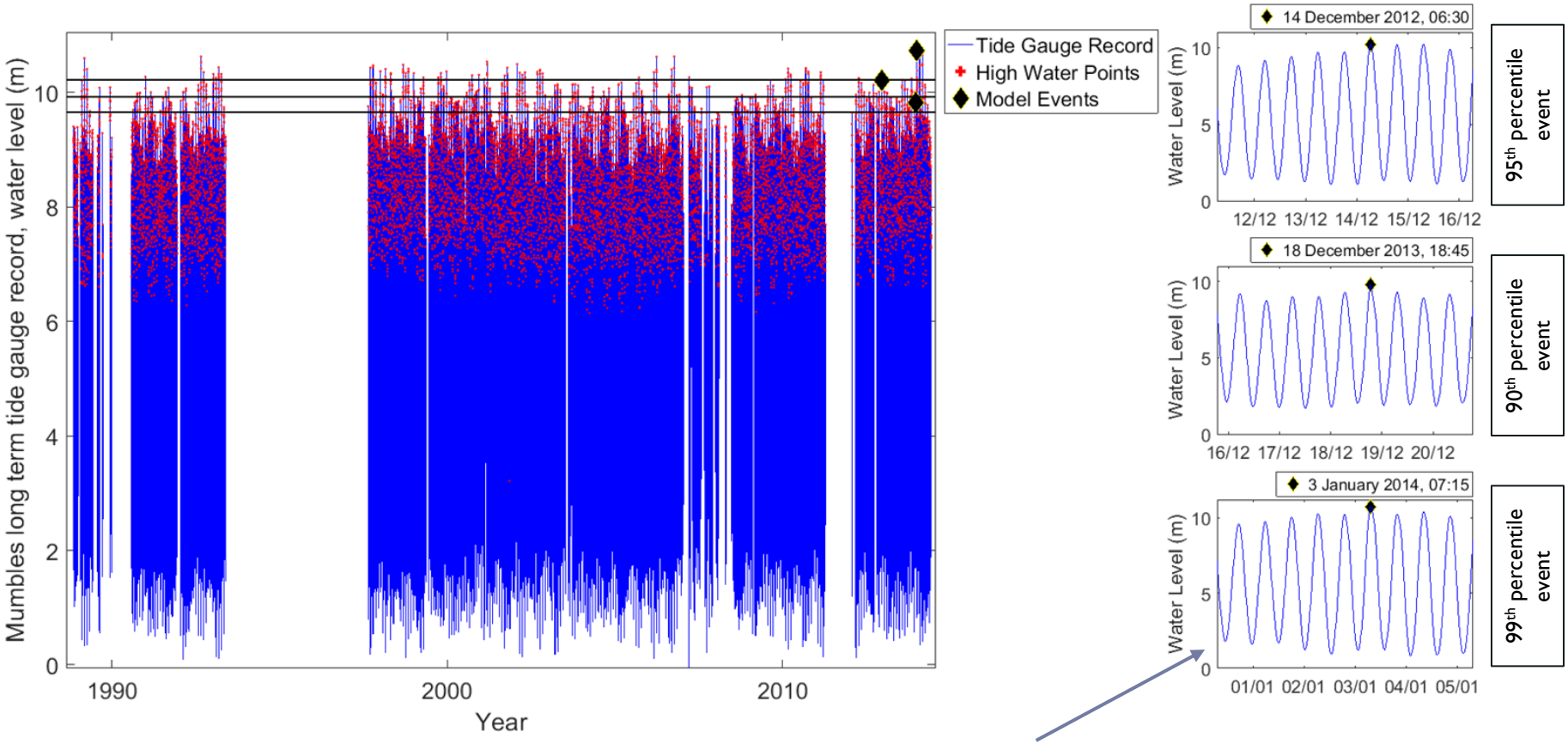
Model validation – 3 January 2014



	Tide + Surge	Tide only	Tide + Filter Surge
R squared	0.99	0.91	0.95
Wilmott Index of Agreement	0.97	0.91	0.95

Long term tide gauge record

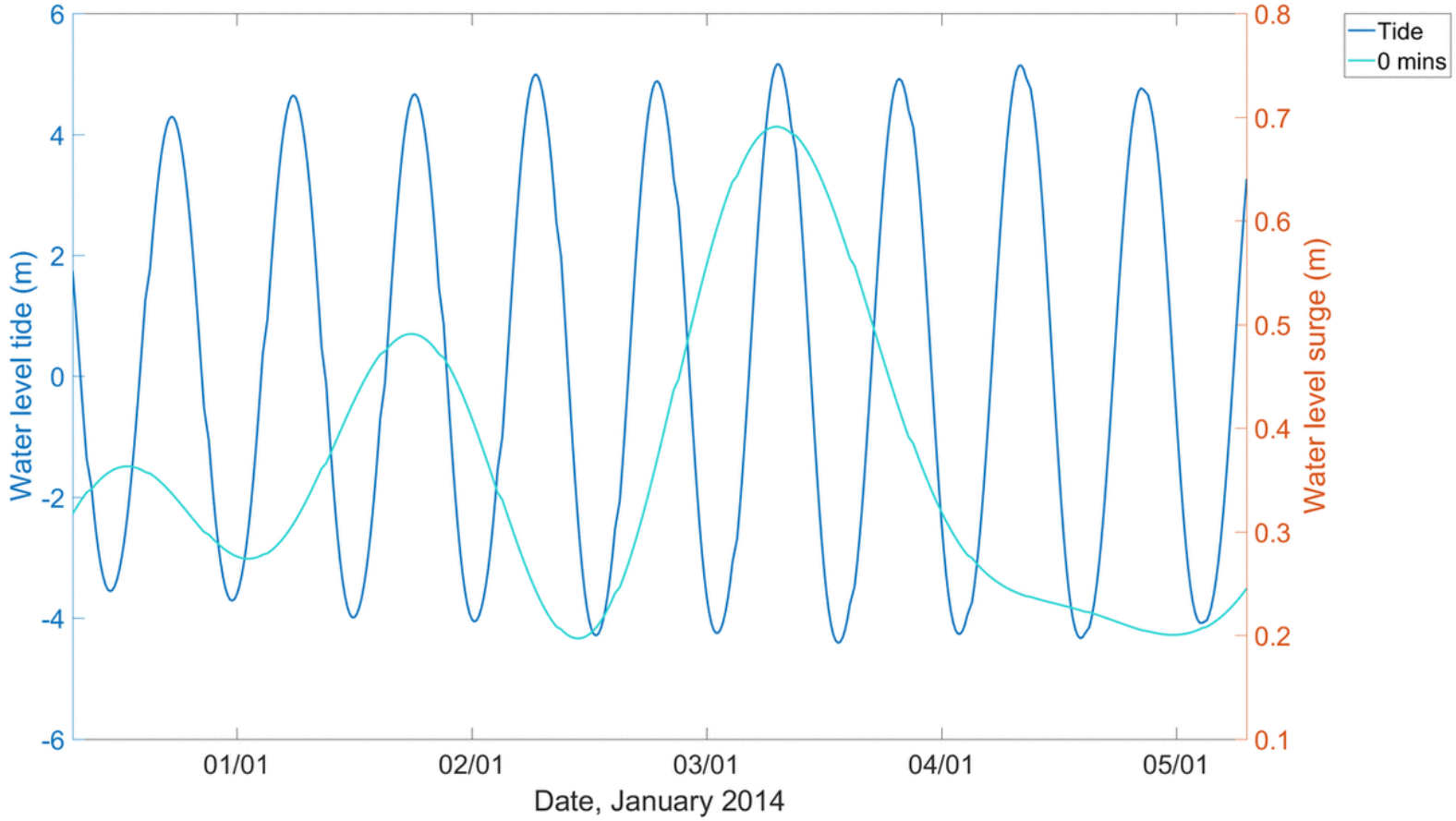
- Long-term tide gauge records from Ilfracombe and the Mumbles are used to generate a series of extreme water level events, of varying severity, to force the model boundary.



- The most severe event on records, 3 January 2014 is simulated first to ensure that extreme water levels can be predicted with confidence.

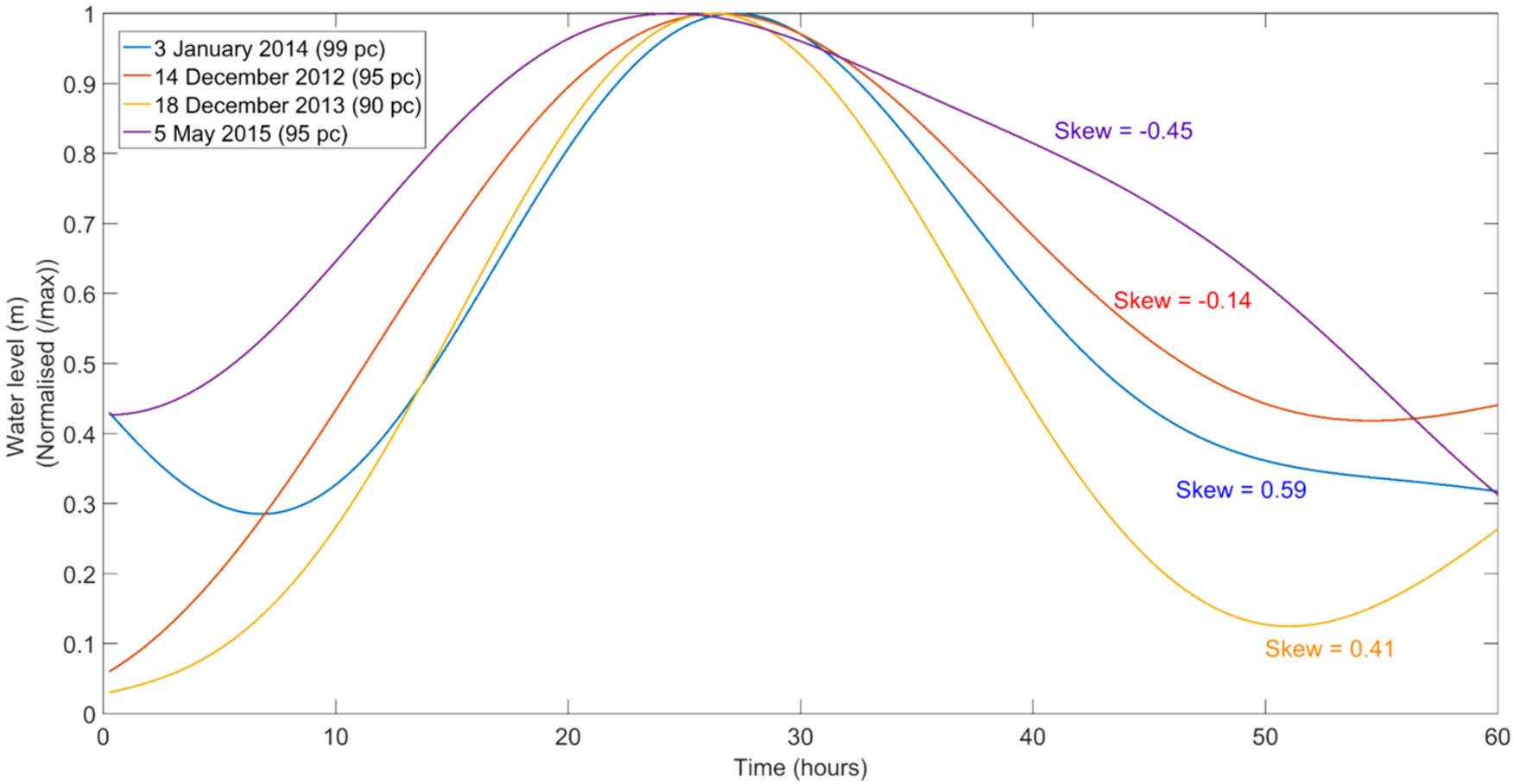
Timing of surge – 3 January 2014

- A filtered surge component is recombined with the tide in a series of time shifted configurations. The peak of the surge changes in time relative to the peak of tidal high water to investigate the influence of the timing of the surge on the extreme water levels.



Surge characteristic - skewness

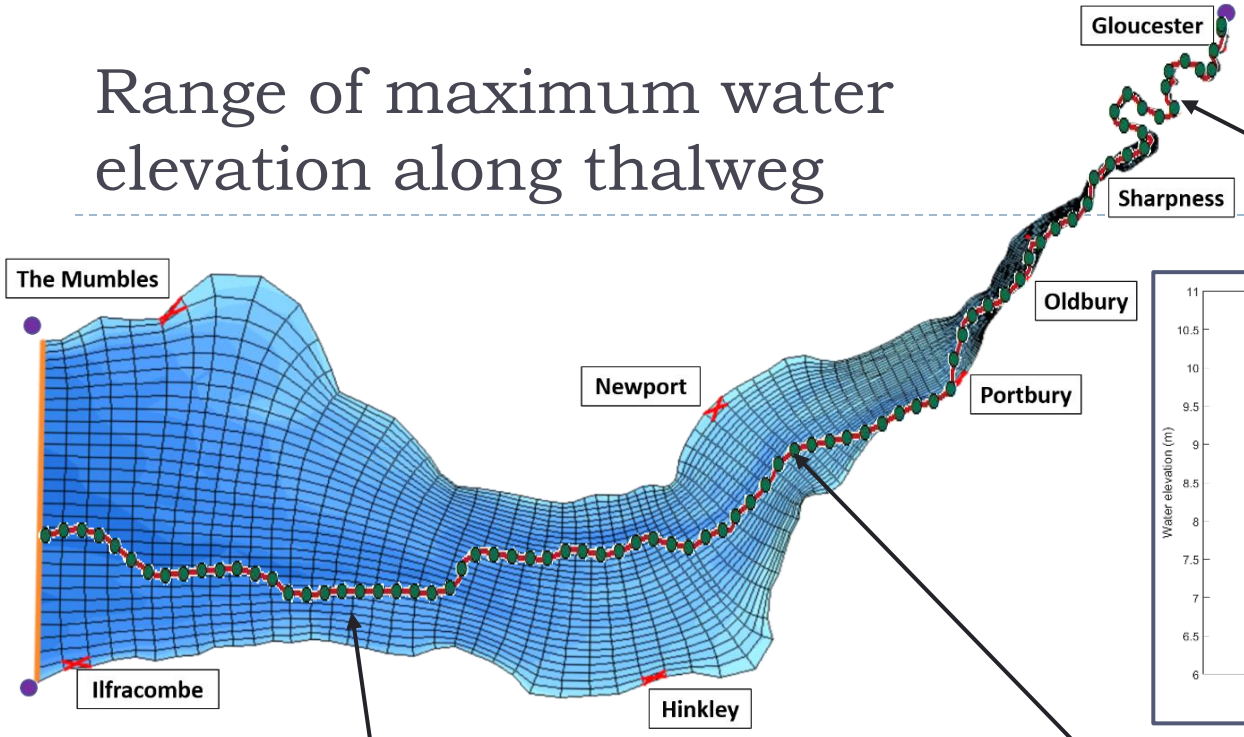
- The shape of each filtered storm surge component is classified using skewness, a measure of asymmetry.

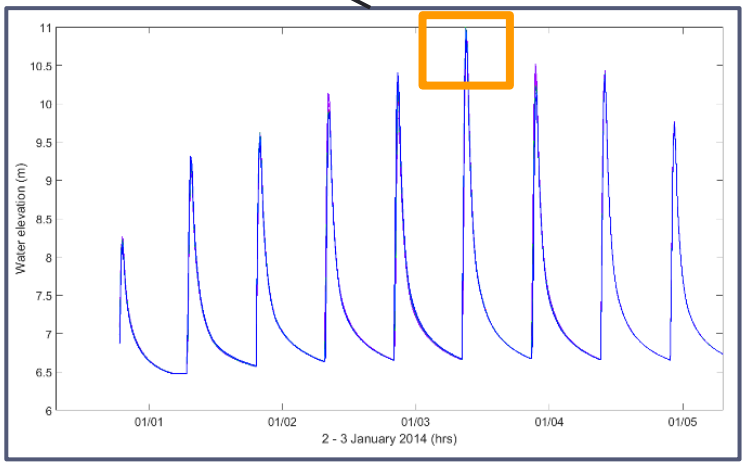


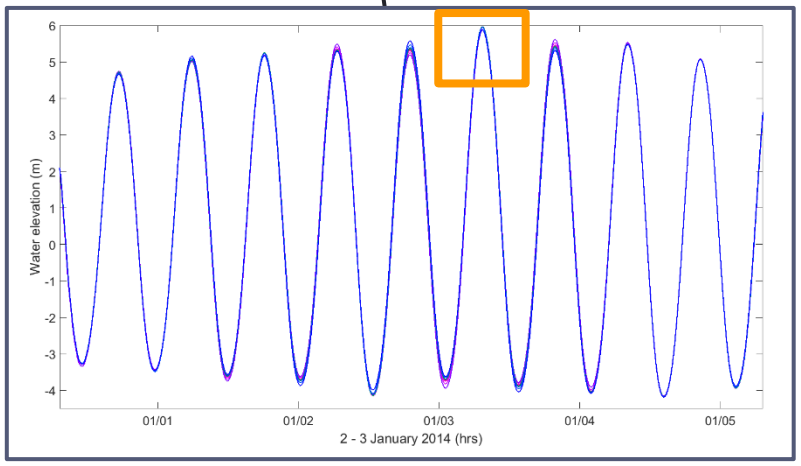
Results

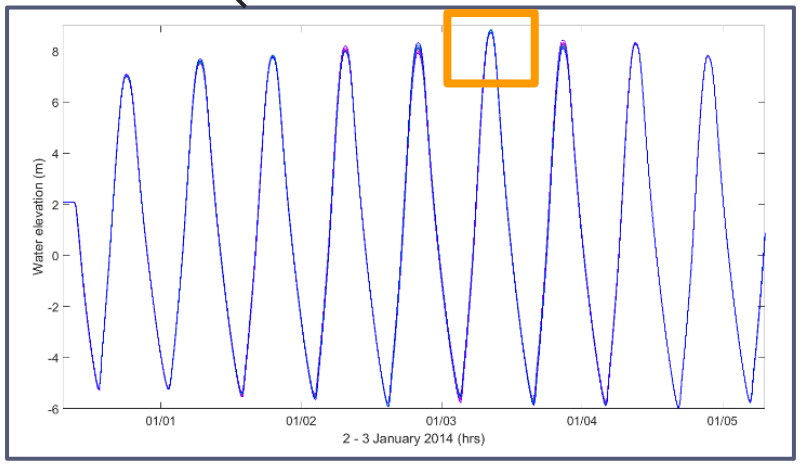
Range of maximum water elevation along thalweg

Maximum water elevation identified every 2 km along thalweg



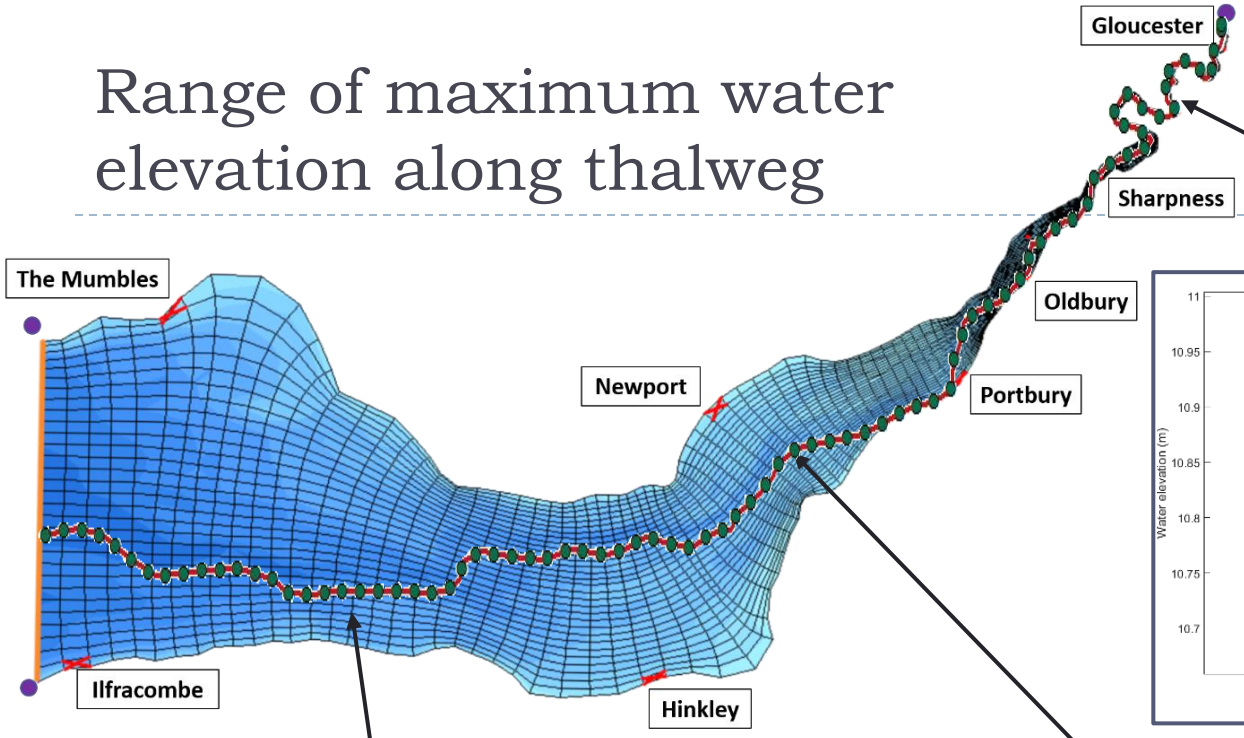


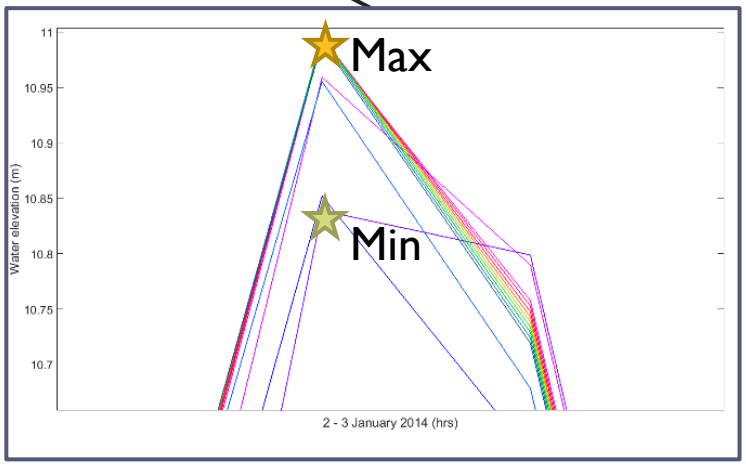


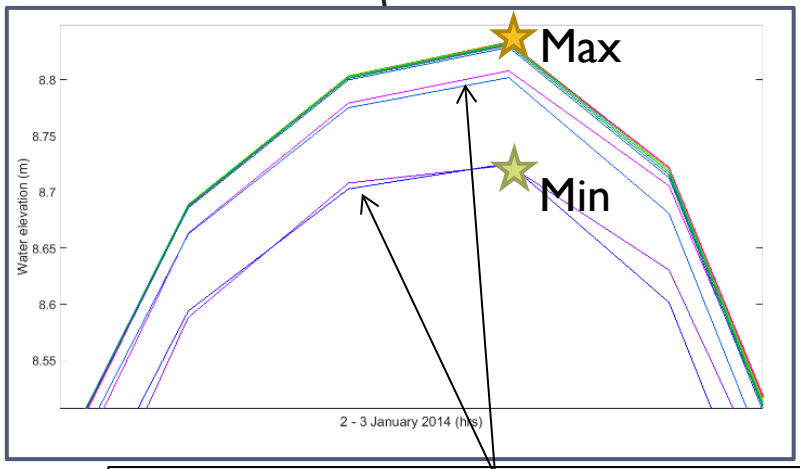


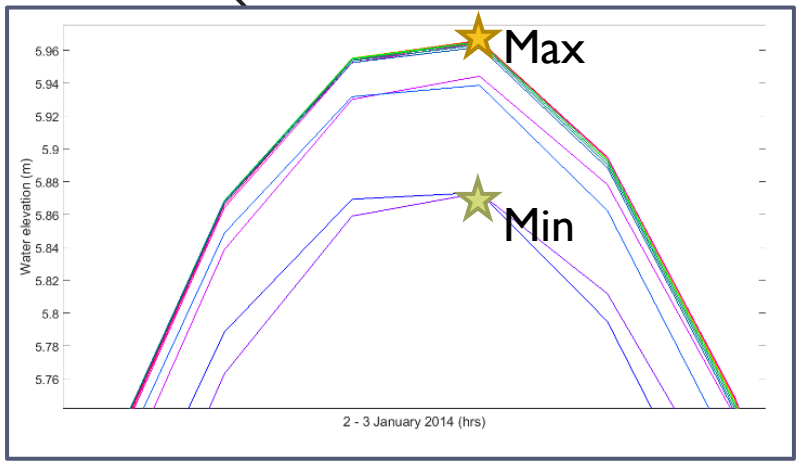
Range of maximum water elevation along thalweg

Identify maximum and minimum water elevations within the 5 day maximum



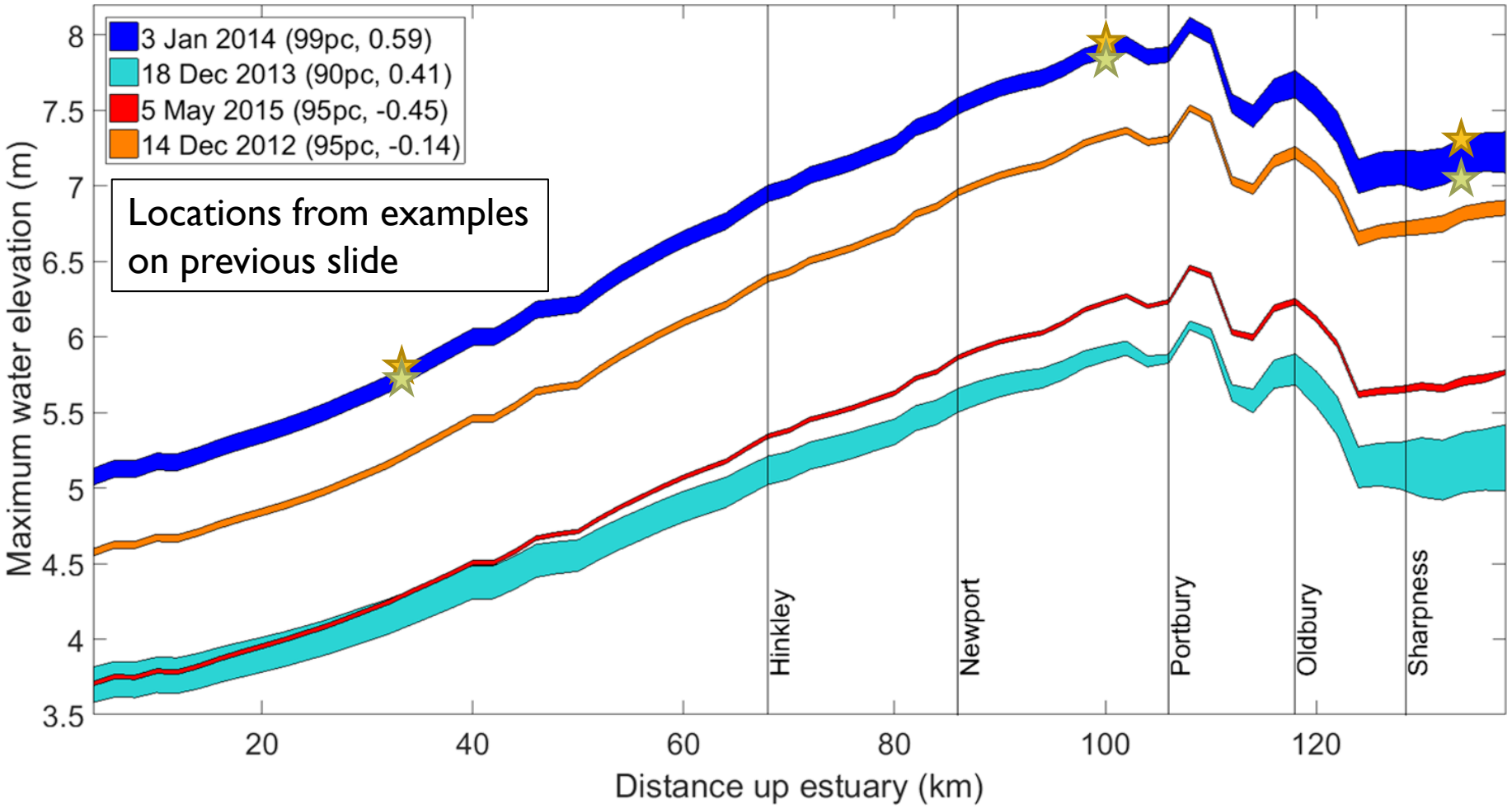




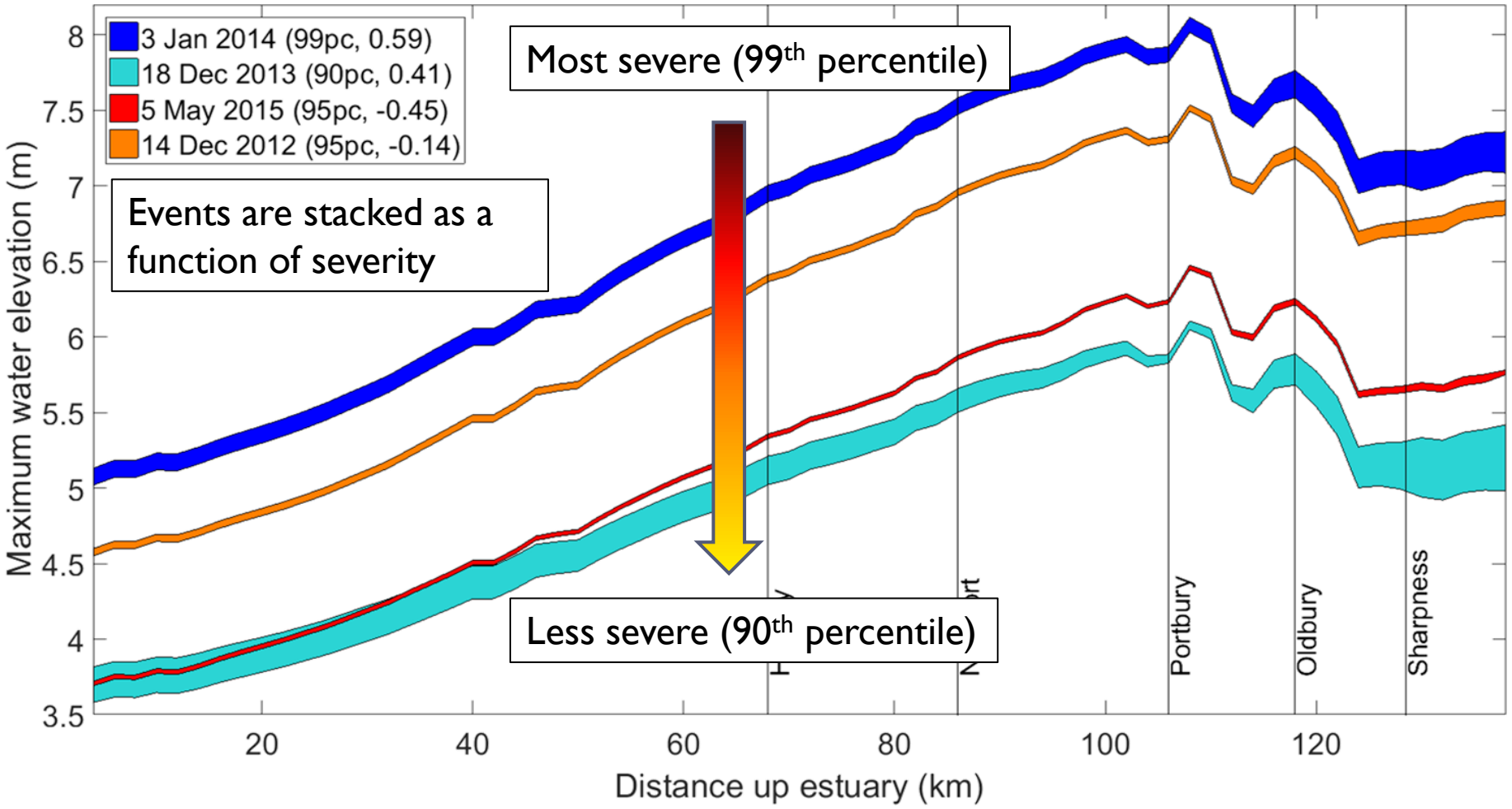


Each line represents a change in the timing of the surge relative to tidal high water.

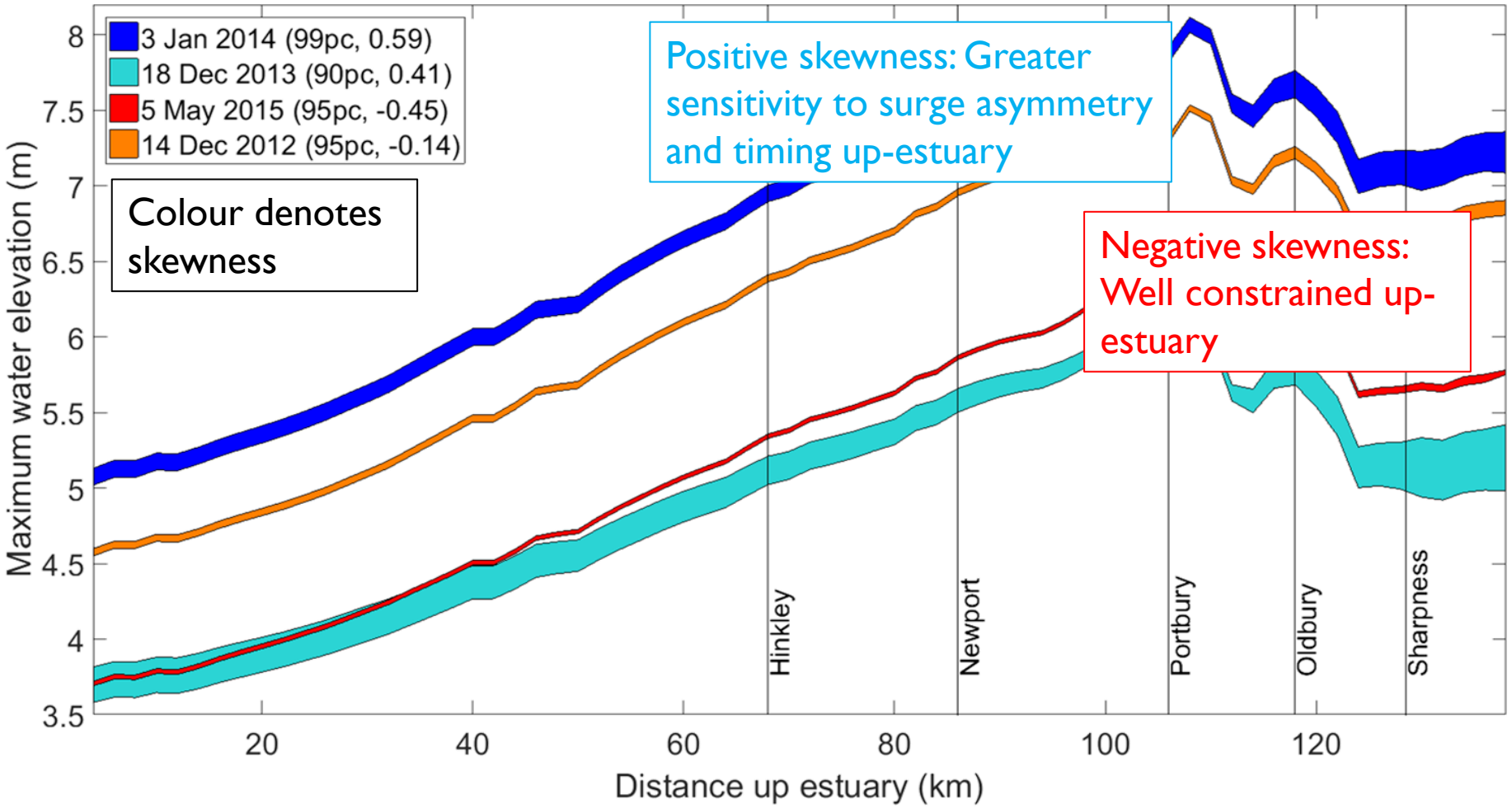
Range of maximum water elevation along thalweg



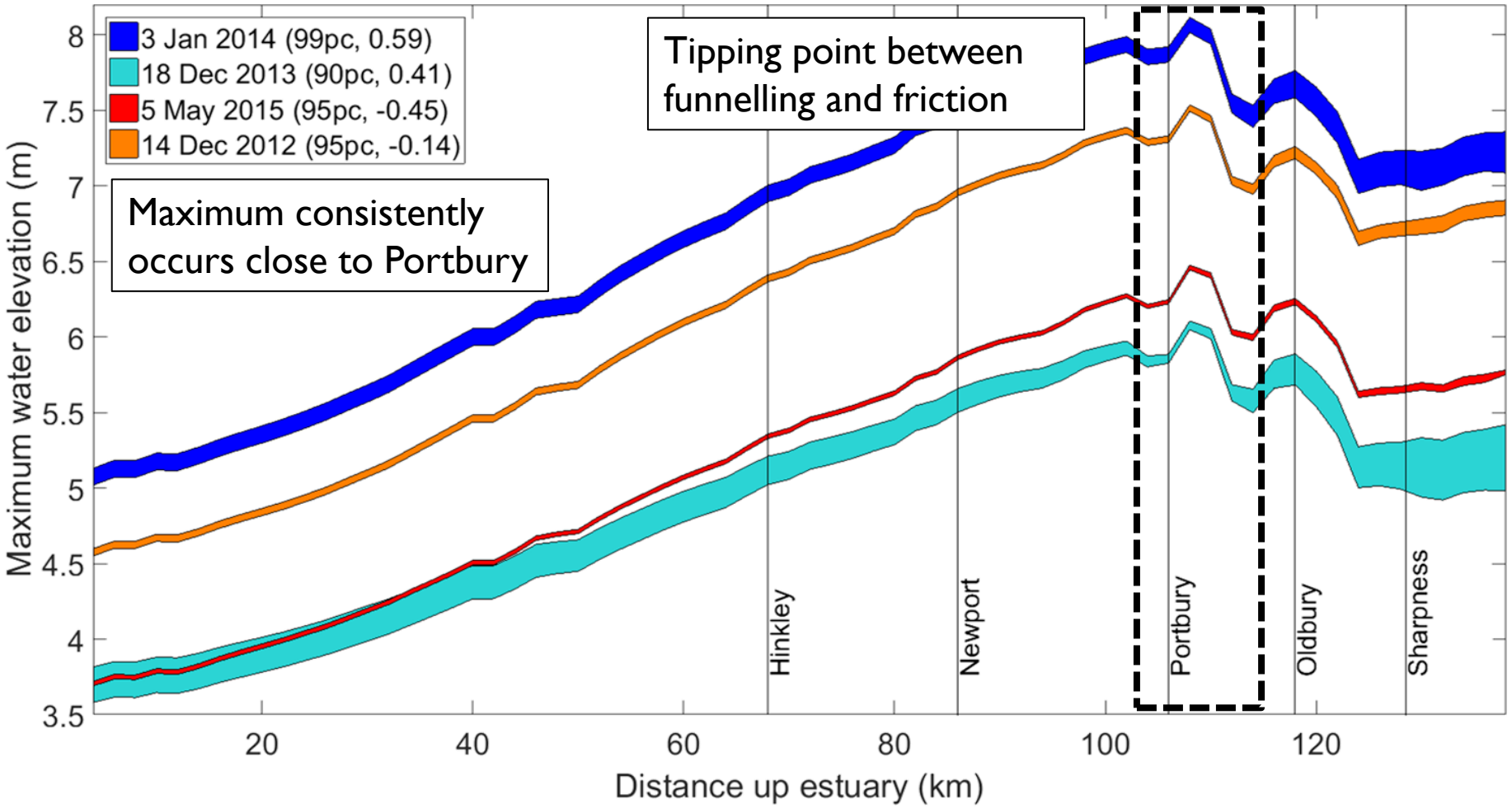
Influence of event severity on maximum water elevation along thalweg



Influence of surge skewness and timing on maximum water elevation along thalweg



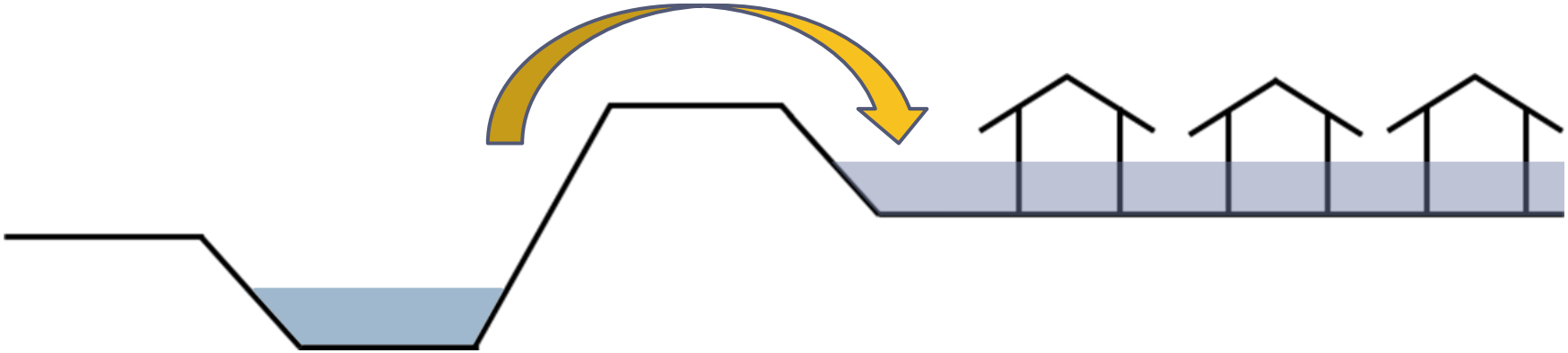
Influence of channel morphology on maximum water elevation along thalweg



Application

Source-Pathway-Receptor-Consequence

The SPRC model identifies the combined sources which contribute to extreme water levels and increase flood hazard.

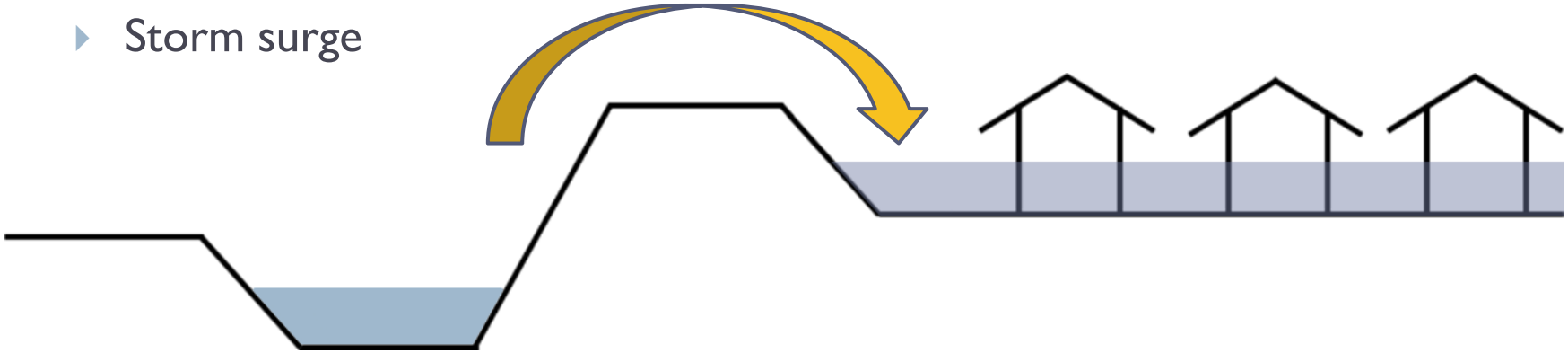


HR Wallingford, 2001

Source-Pathway-Receptor-Consequence

Storm surge severity, shape (asymmetry) and timing combine to increase flood hazard in a hyper-tidal estuary

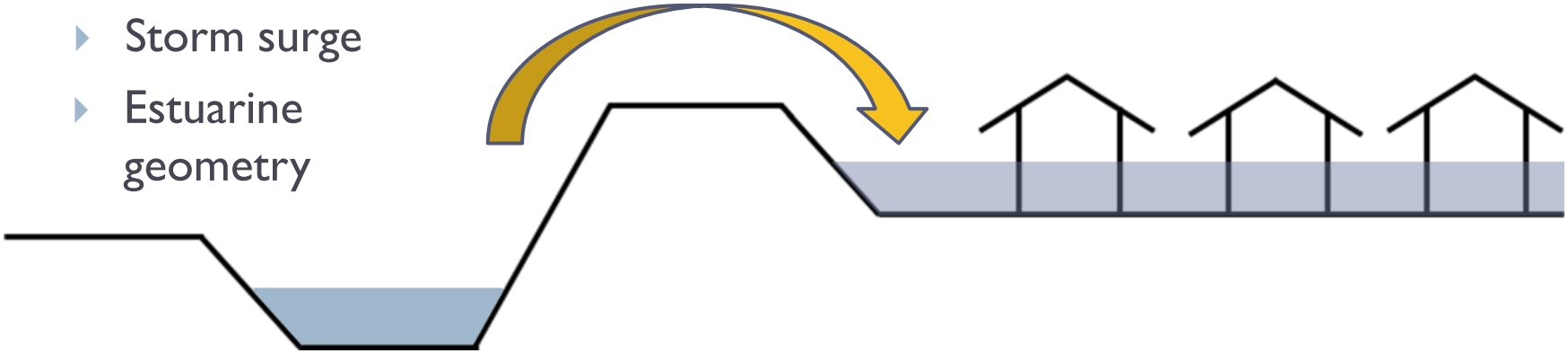
- Source
  - Storm surge



HR Wallingford, 2001

Source-Pathway-Receptor-Consequence

- Source
  - Storm surge
  - Estuarine geometry
- Pathway
  - Estuarine geometry



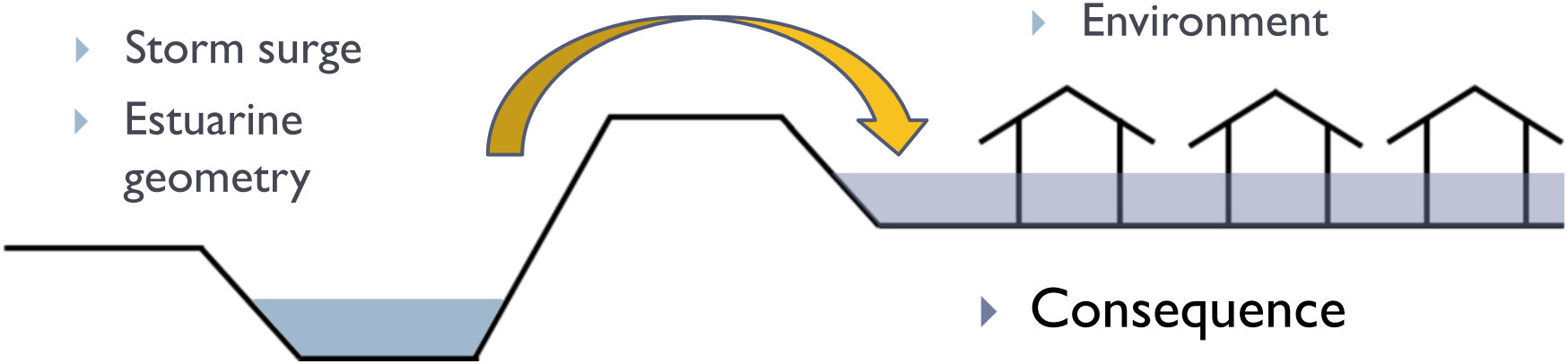
The complex geometry of a hyper-tidal estuary is a 'source' or 'pathway' in itself, influencing how floodwaters are conveyed through the system.

HR Wallingford, 2001

Source-Pathway-Receptor-Consequence

Site specific impacts

- **Source**
  - Storm surge
  - Estuarine geometry
- **Pathway**
  - Estuarine geometry
- **Receptor**
  - Communities
  - Industries & infrastructure
  - Environment



- **Consequence**
  - Material damage
  - Environmental degradation

HR Wallingford, 2001

Summary

Summary

- Delft3D-FLOW is used to understand combined mechanisms controlling extreme water levels in the Severn Estuary.
- When modelling a local area, severity of an event is most important when assessing flood hazard.
  - **Timing** of the surge and **skewness** of the surge also act in combination to alter magnitude and variability of extreme water levels.
  - **Morphology** results in maximum water levels in certain locations due to funnelling effect.

Hopewell Rocks, Canada

Meghna Delta, Bangladesh

Summary

- Site specific results can address local management needs.
- Methodology can be applied to other hypertidal and macrotidal estuaries worldwide.

- Lyddon, C.E., Brown, J.M., Leonardi, N., Plater, A.J. (2018) Flood hazard assessment for a hyper-tidal estuary and river as a function of tide – surge – morphology interaction. *Estuaries and Coasts*.

Hopewell Rocks, Canada

Meghna Delta, Bangladesh

Thank you for watching

- Questions?

- Email: C.E.Lyddon@liverpool.ac.uk

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