New Storm Surge Catastrophe Model for Great Britain and Beyond

Richard Yablonsky, Mohammad Keshtpoor, and Austen Blair

33rd Conference on Hurricanes and Tropical Meteorology

American Meteorological Society

18 April 2018

AIR Worldwide
131 Dartmouth, Boston, MA 02116

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Countries where AIR models catastrophes around the globe (s = storm surge catastrophe model)

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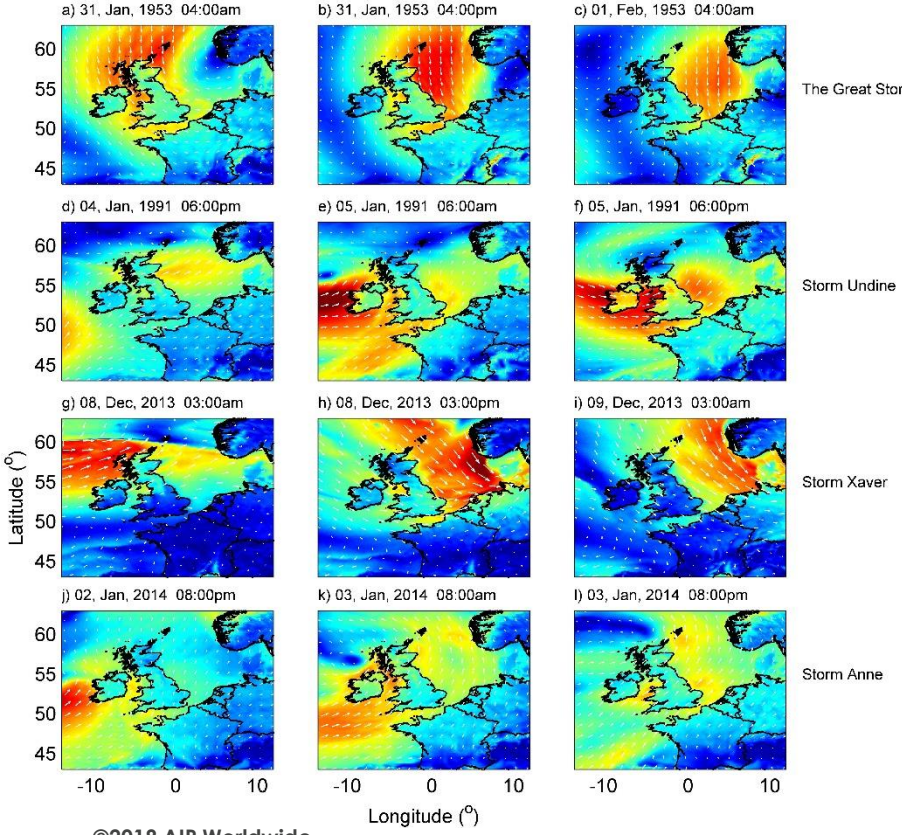
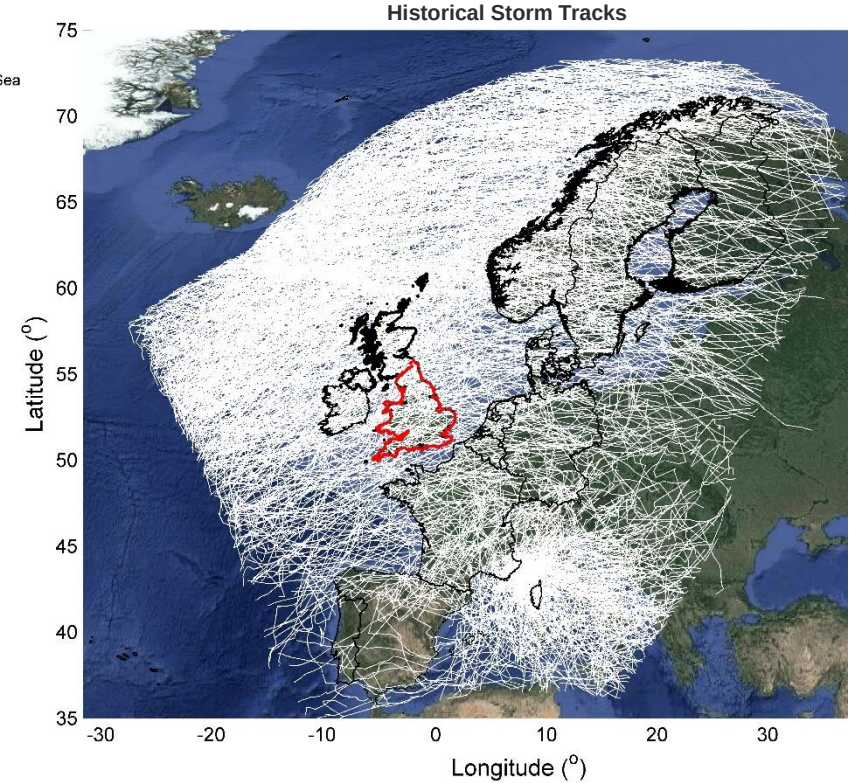
Extratropical cyclones (not tropical cyclones) generate storm surge in Great Britain





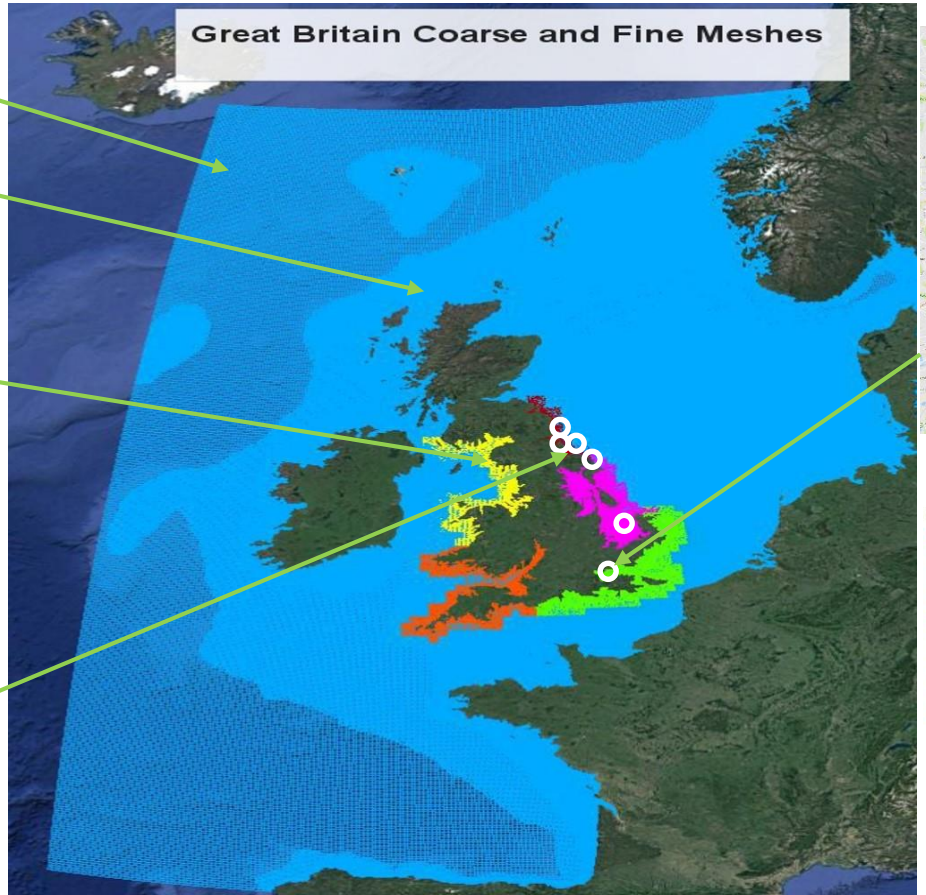
Xaver wind = HIRLAM; other storms = ERA-Interim reanalysis → WRF 16-km; Charnock-based C_D

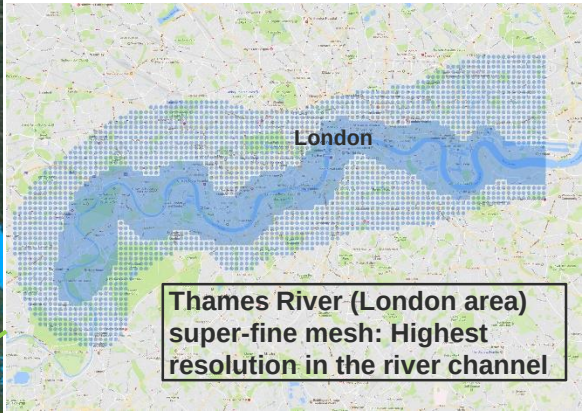
Delft3D Flexible Mesh computational domains for hydrodynamic storm surge modeling (Great Britain)

Coarse mesh (blue) is Deltares' Dutch Continental Shelf Model: Deep water resolution ~8 km; Refines to ~2 km near coast

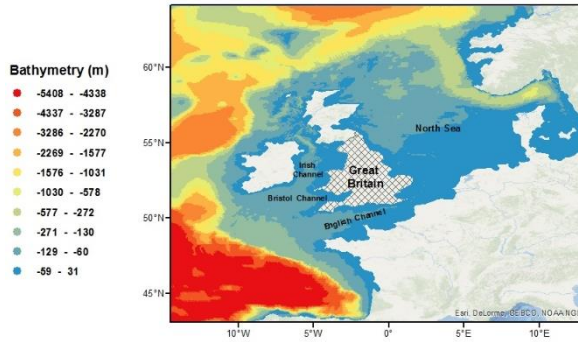
AIR's 5 fine meshes (yellow, orange, green, pink, & red): Offshore resolution ~2 km to match coarse mesh boundary condition; refines to ~220 m at coast and onshore up to 20-m topographic contour

AIR's 6 super-fine meshes target important areas up tidal rivers with resolution as high as ~35 m: London, Boston, Middlesbrough, Newcastle-upon-Tyne, Blythe, & Warkworth





Thames River (London area) super-fine mesh: Highest resolution in the river channel



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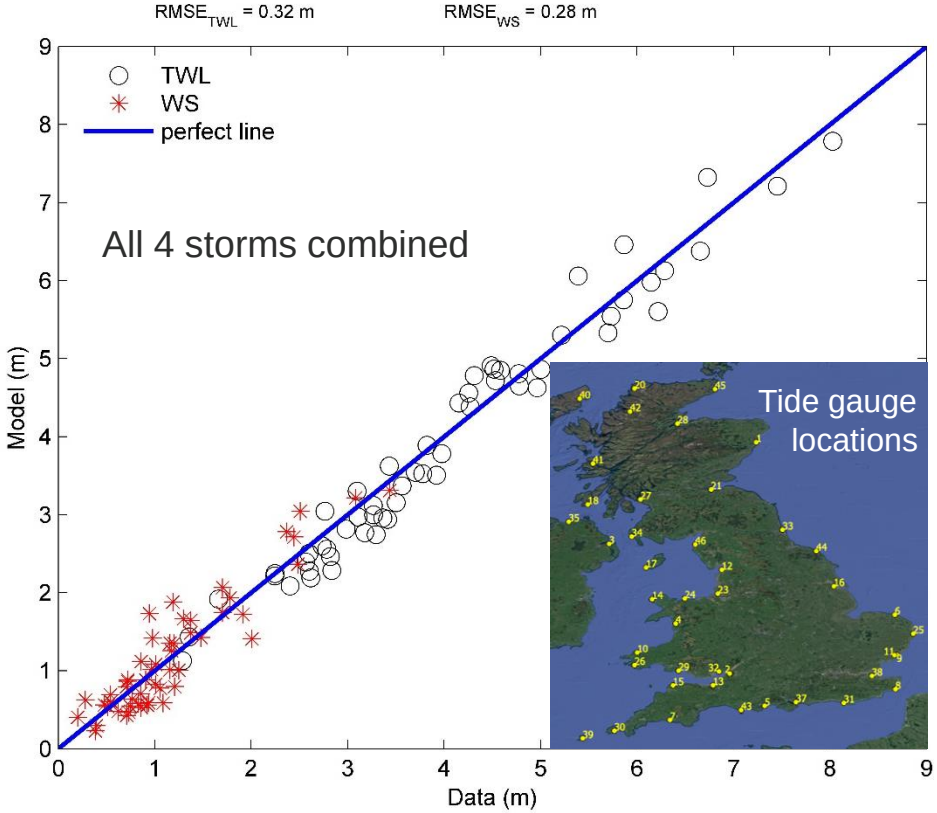
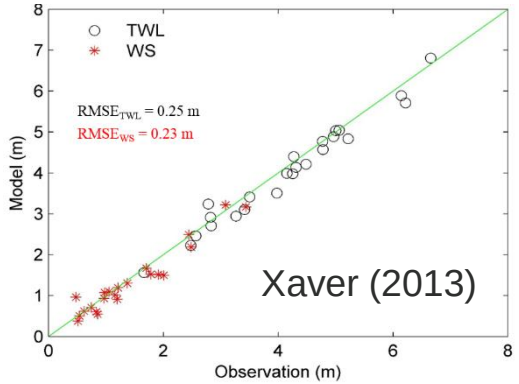
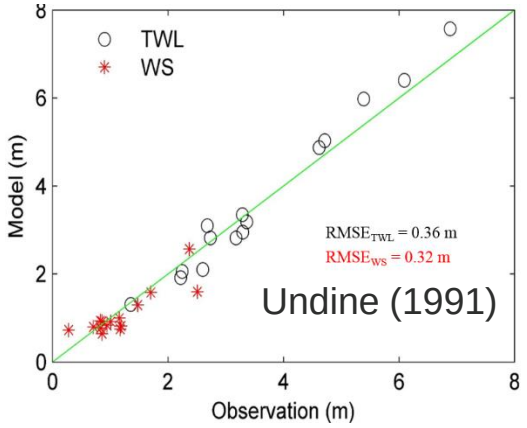
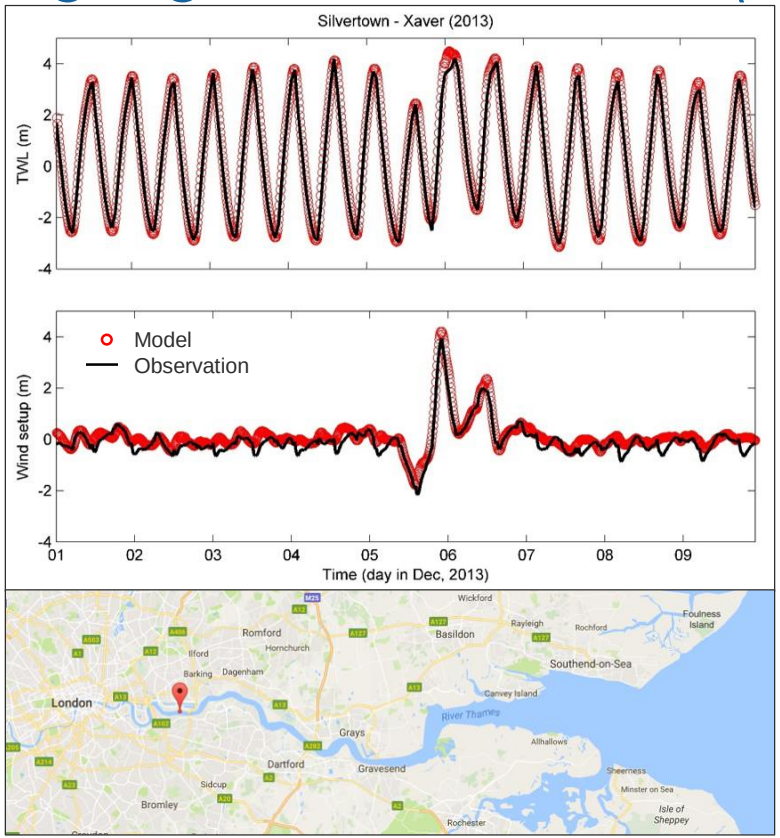
Storm surge model validation at Great Britain tide gauges for 4 storms: 1953, Undine, Xaver, & Anne

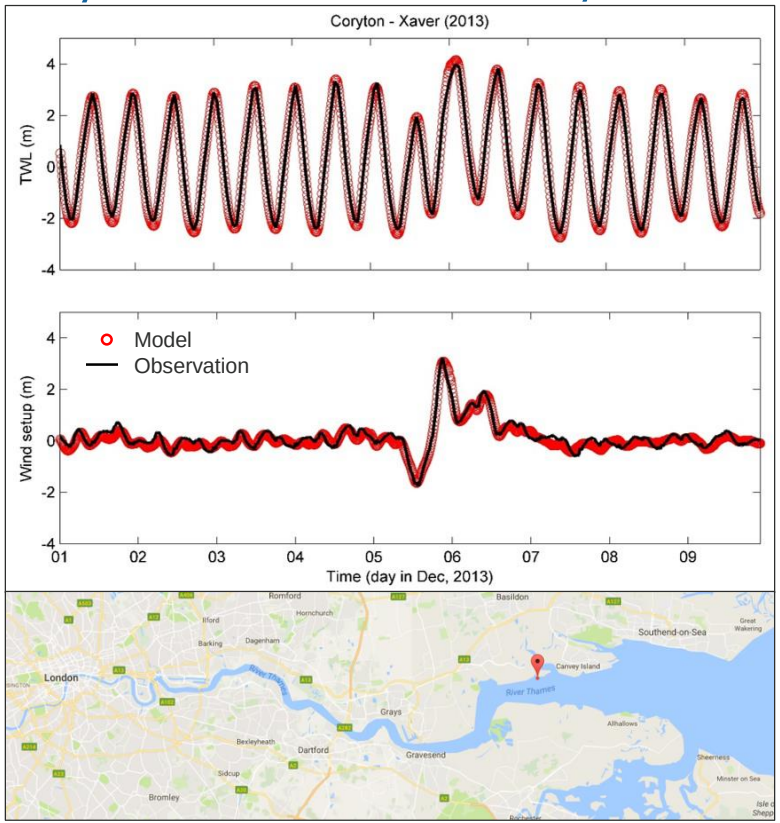




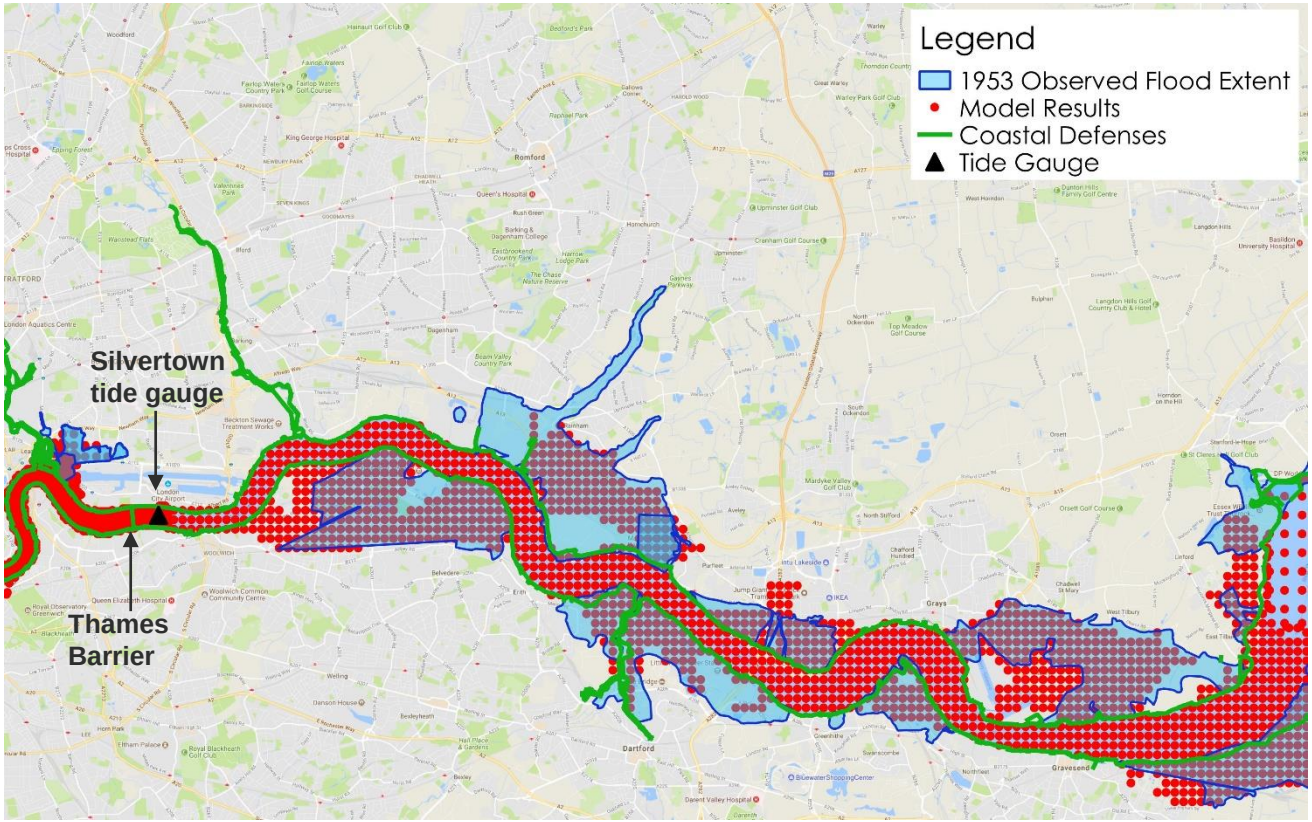


Storm surge model validation at Thames River tide gauges for Storm Xaver (2013): Time series analysis

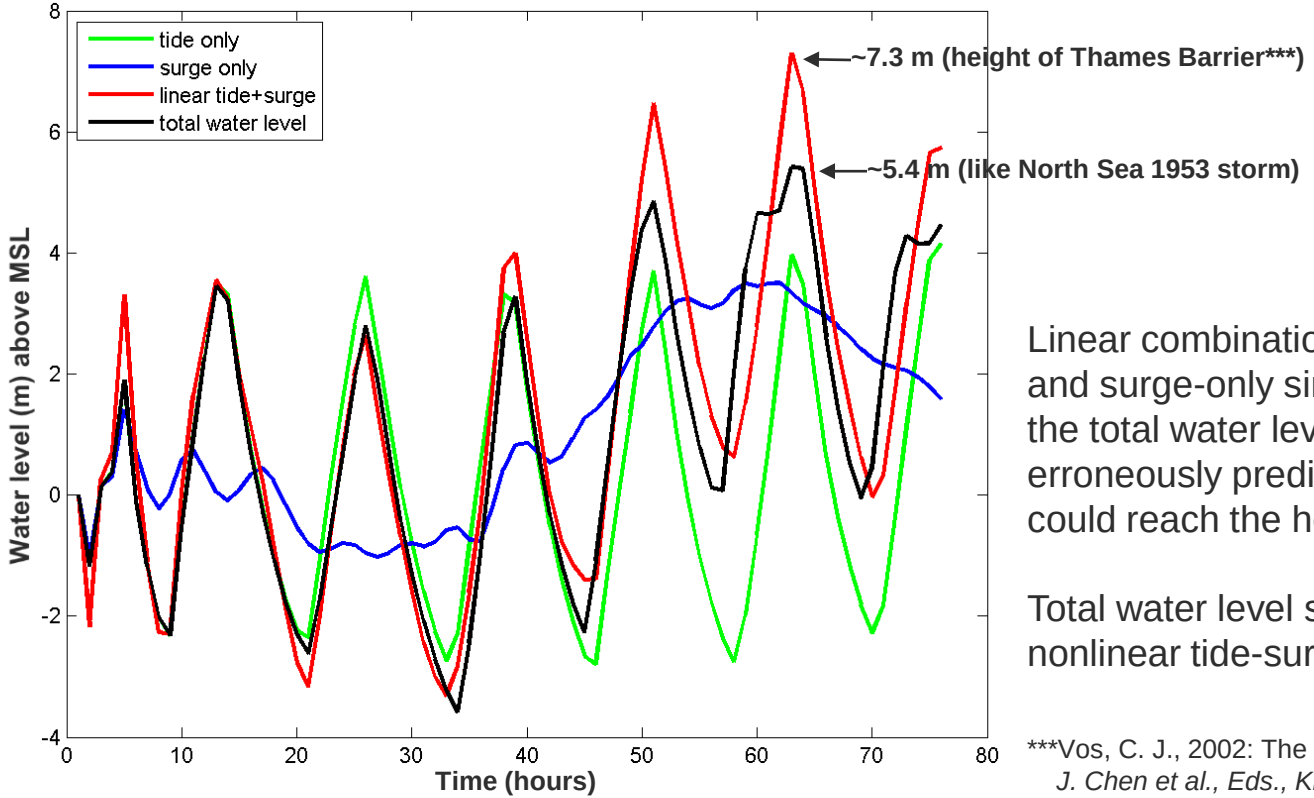




Storm surge model flood footprint validation along Thames River for North Sea 1953 storm



Modeled water level near Thames Barrier (Silvertown) from a North Sea 1953-like storm

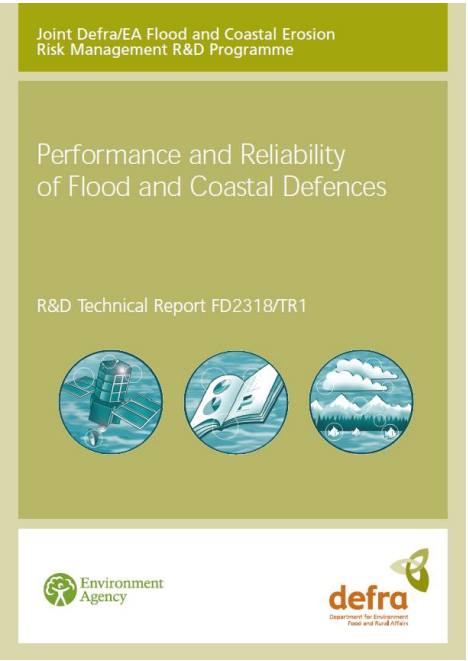


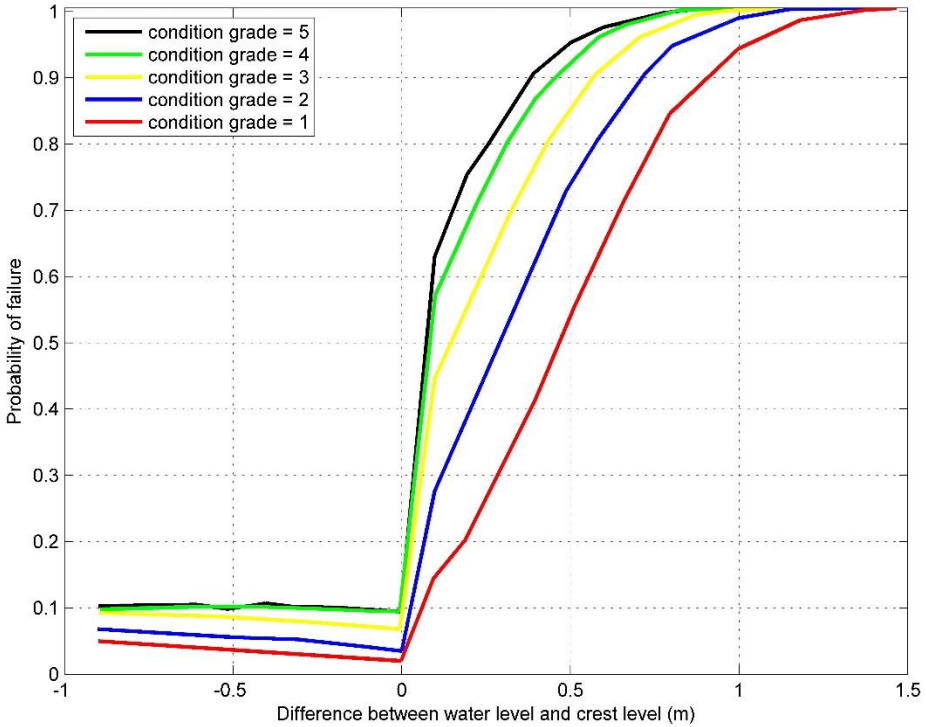
Linear combination of tide-only simulation and surge-only simulation overestimates the total water level by ~2 m and erroneously predicts that a 1953-like storm could reach the height of Thames Barrier.

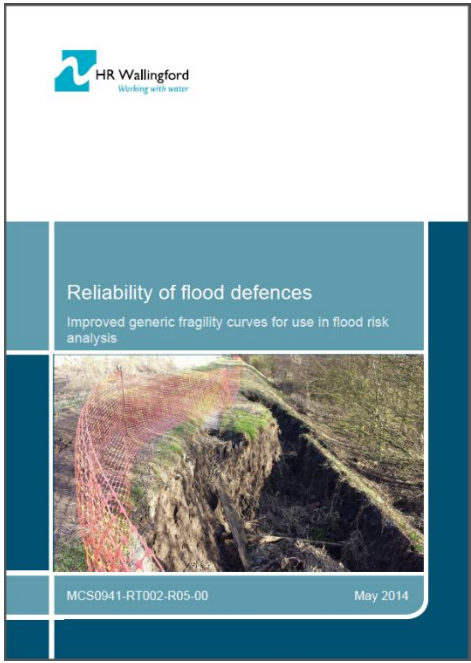
Total water level simulation accounts for nonlinear tide-surge interaction.

***Vos, C. J., 2002: The Thames Barrier. *Engineered Coasts, J. Chen et al., Eds., Kluwer Academic Publishers,* 291-308.

In addition to overtopping, levees can fail (breach)







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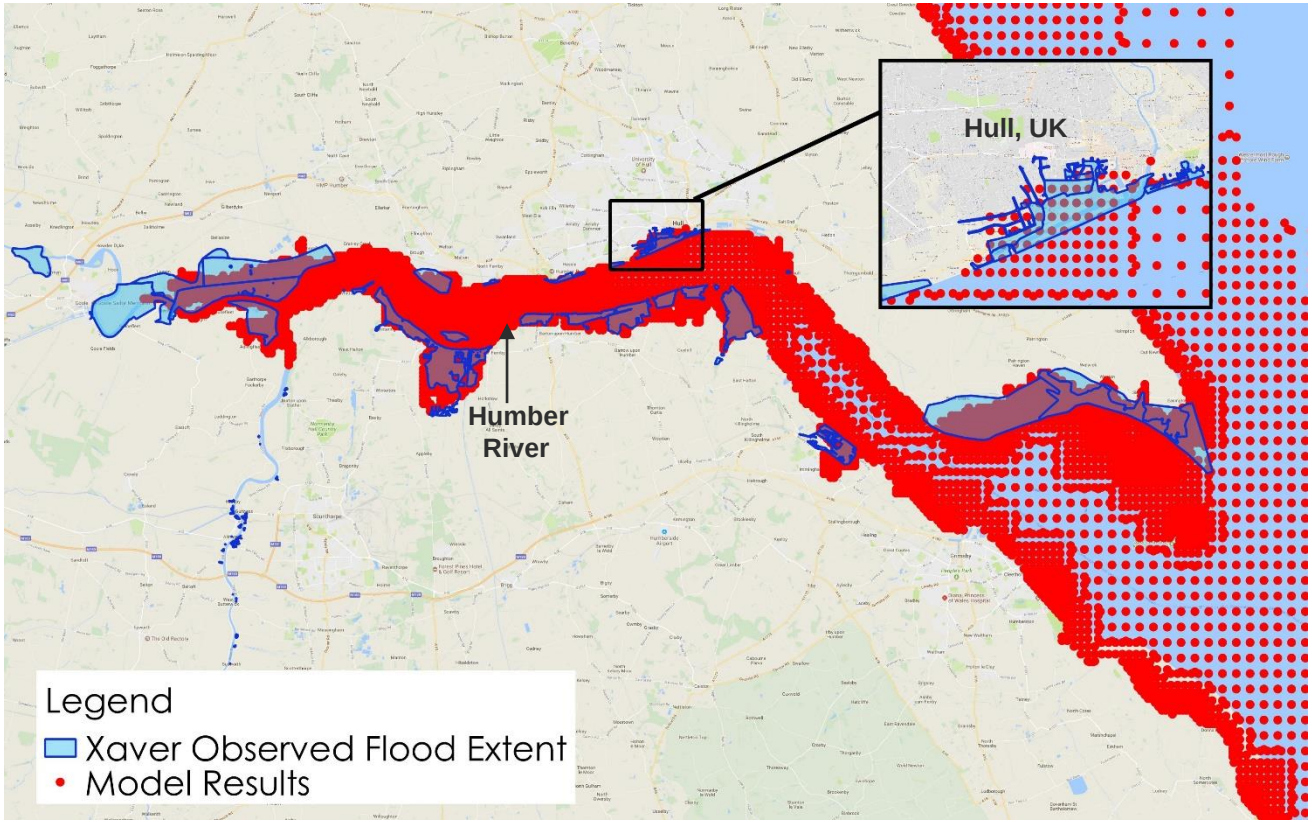
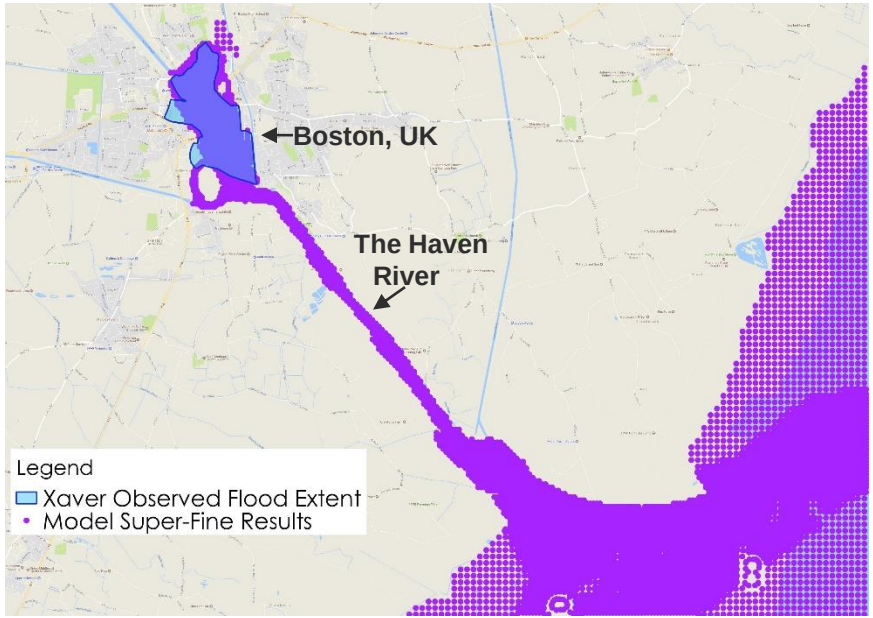
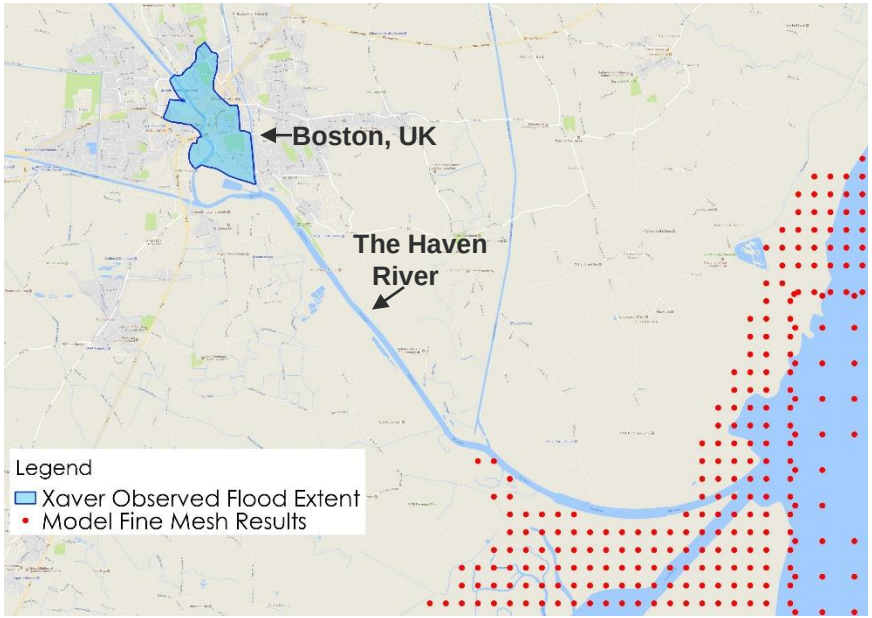
Storm surge model flood footprint validation along Humber River for Storm Xaver (2013)



Storm surge model flood footprint validation for Xaver in Boston, UK with & without super-fine mesh



Sufficient resolution (up to 35 m) for water to reach Boston, UK



Insufficient resolution (~220 m) for water to reach Boston, UK

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Stochastic catalog of surge-producing extratropical cyclones in Great Britain

- Perturb 1750 historical seed storms from ~35 years to obtain ~500K stochastic storms in 10K years
- Use a regression model based on DCSM numerical simulation of the 1750 historical seed storms to select ~100K surge-producing stochastic storms***
- Use 2-year water level return period threshold at tide gauges to reduce to ~45K stochastic storms
- Numerically-simulate storm surge on Delft3D-FM (super)-fine meshes for remaining stochastic storms

***Keshtpoor, M., I. Carnacina, and R. M. Yablonsky, 2018: A new statistical approach to select surge-producing extratropical cyclones from a 10,000-year stochastic catalog. *Nat. Hazards,* in review.

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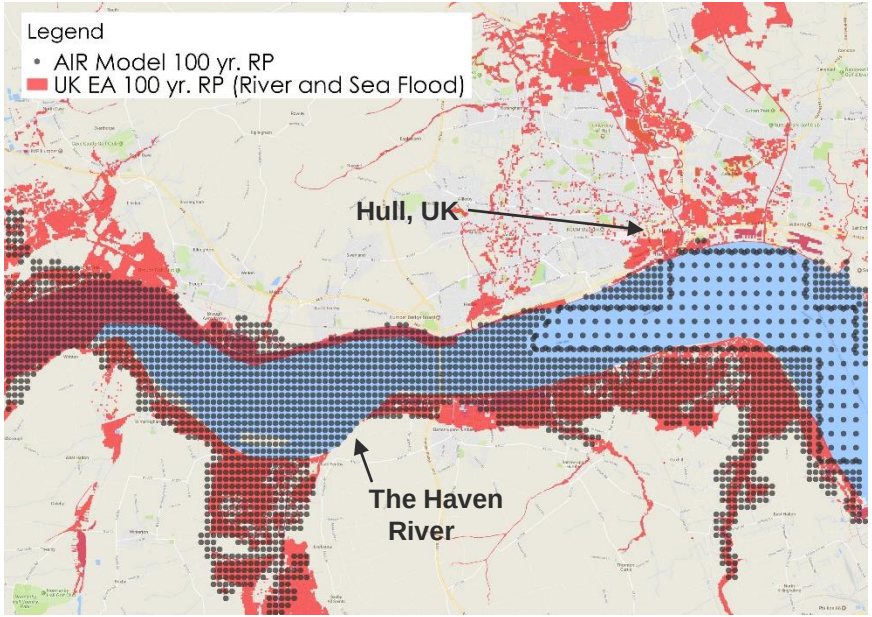
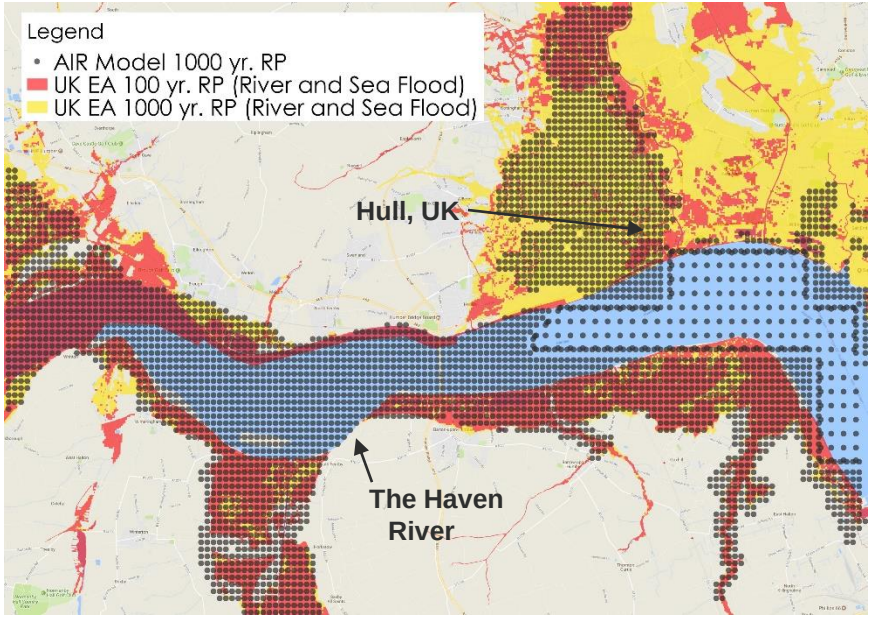
Storm surge model flood footprint validation along Humber River based on return period analysis





UK Environmental Agency (EA) return periods are used to help validate AIR's stochastic return period model results, but perfect agreement Is not expected because of differing model assumptions, and EA's return periods include precipitation-induced flooding as well.

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Summary and Future Work

- Storm surge in Great Britain generated by extratropical cyclones is modeled with Delft3D-FM.
- Calibration and validation of historical events utilizes tide gauges records and observed flood extents.
- Nonlinear tide-surge interaction is important for capturing the total water level.
- Modeling inundation requires accurate levee characteristics, including probability of failure.
- Very high resolution is required to model surge up narrow rivers.
- Validation of stochastic surge results utilizes return period analysis.
- A similar Delft3D-FM-based modeling framework can be used to simulate the storm surge hazard from tropical cyclones in other parts of the world (as a component of a full catastrophe model).