Using a wave model derived estimate of momentum stress to improve storm surge forecast for the UK

Clare O'Neill[1], Nieves Valiente[2], Breogan Gomez[1]

[1] Met Office, UK

[2] Now at University of Plymouth, UK

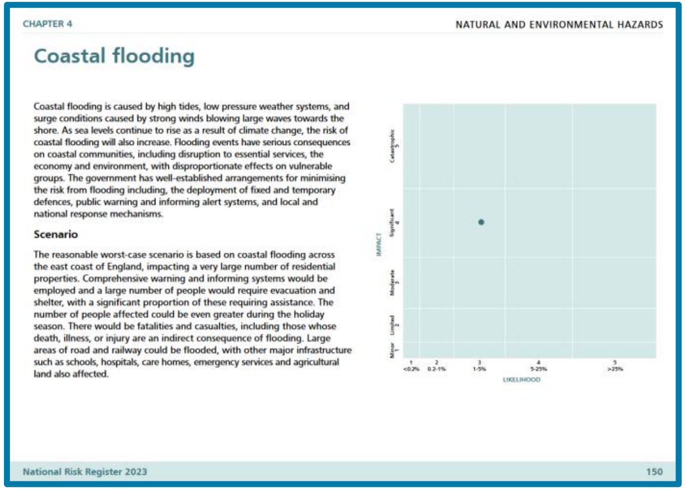
Outline

- Background
- Applying winds to surge model
- Results
- Summary

Storm surge forecasting for the UK

Motivation

- Coastal flooding is a significant impact risk in UK National Risk Register
- Tides are significant, doesn’t need to be a very large surge to cause flooding if at high tide
- Met Office runs operational surge forecast system to mitigate the risk


CHAPTER 4 NATURAL AND ENVIRONMENTAL HAZARDS

Coastal flooding

Coastal flooding is caused by high tides, low pressure weather systems, and surge conditions caused by strong winds blowing large waves towards the shore. As sea levels continue to rise as a result of climate change, the risk of coastal flooding will also increase. Flooding events have serious consequences on coastal communities, including disruption to essential services, the economy and environment, with disproportionate effects on vulnerable groups. The government has well-established arrangements for minimising the risk from flooding including, the deployment of fixed and temporary defences, public warning and informing alert systems, and local and national response mechanisms.

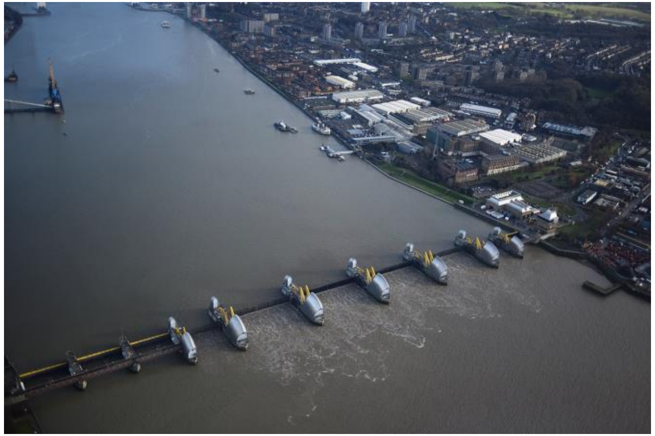
Scenario

The reasonable worst-case scenario is based on coastal flooding across the east coast of England, impacting a very large number of residential properties. Comprehensive warning and informing systems would be employed and a large number of people would require evacuation and shelter, with a significant proportion of these requiring assistance. The number of people affected could be even greater during the holiday season. There would be fatalities and casualties, including those whose death, illness, or injury are an indirect consequence of flooding. Large areas of road and railway could be flooded, with other major infrastructure such as schools, hospitals, care homes, emergency services and agricultural land also affected.

National Risk Register 2023 150

Motivation

- Surge forecast is important for Thames Barrier operations



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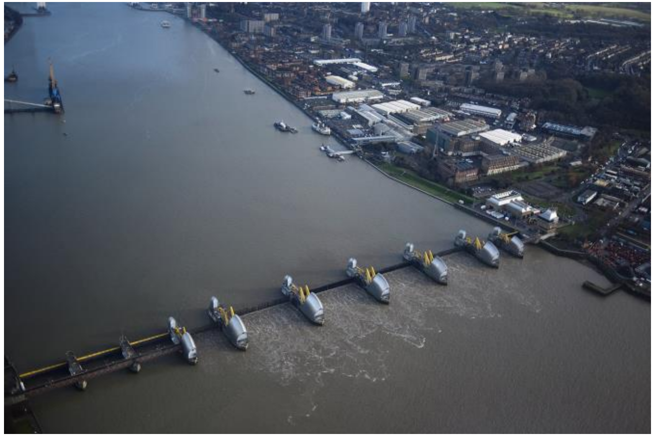

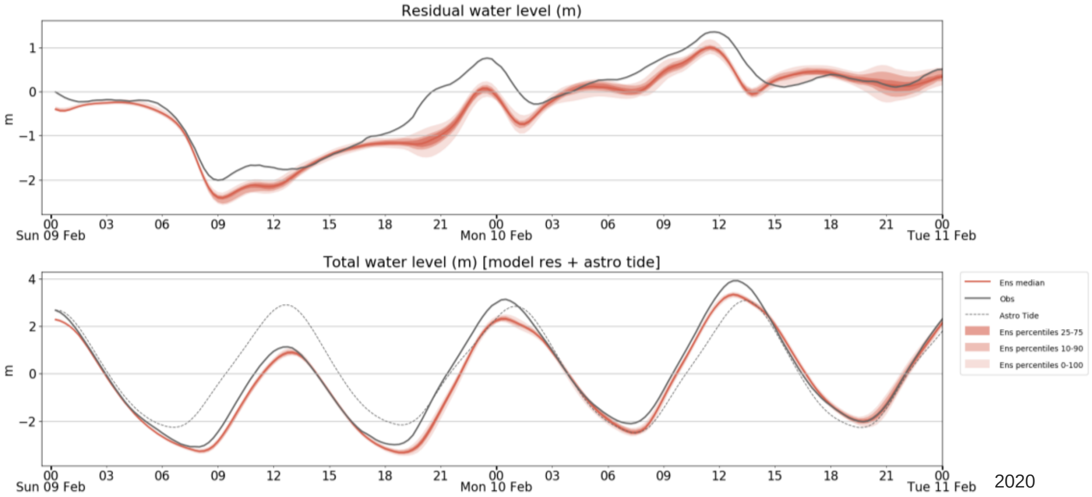

2020

Motivation

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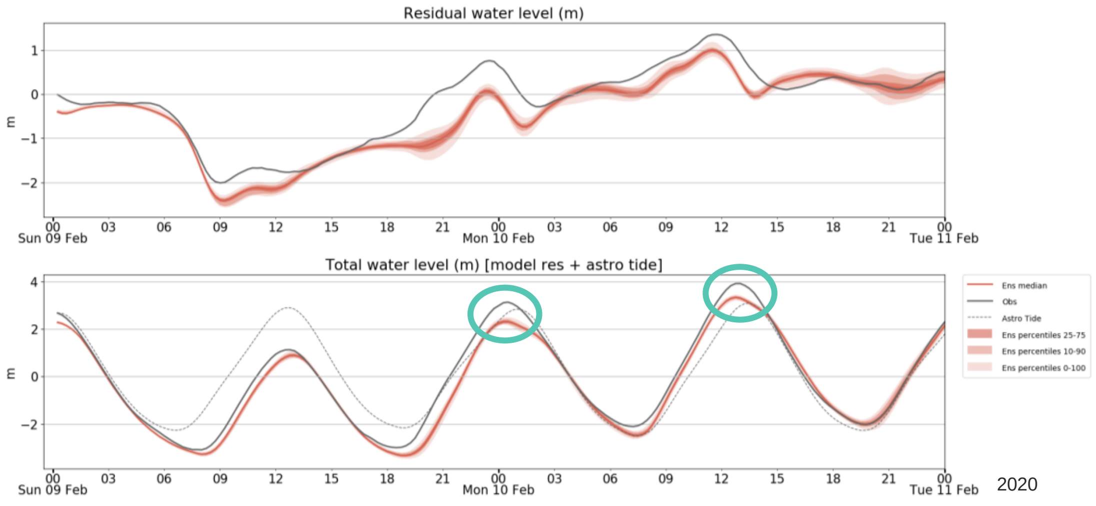
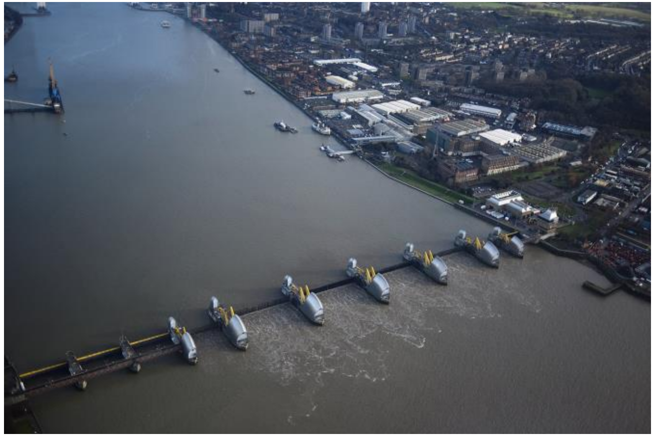
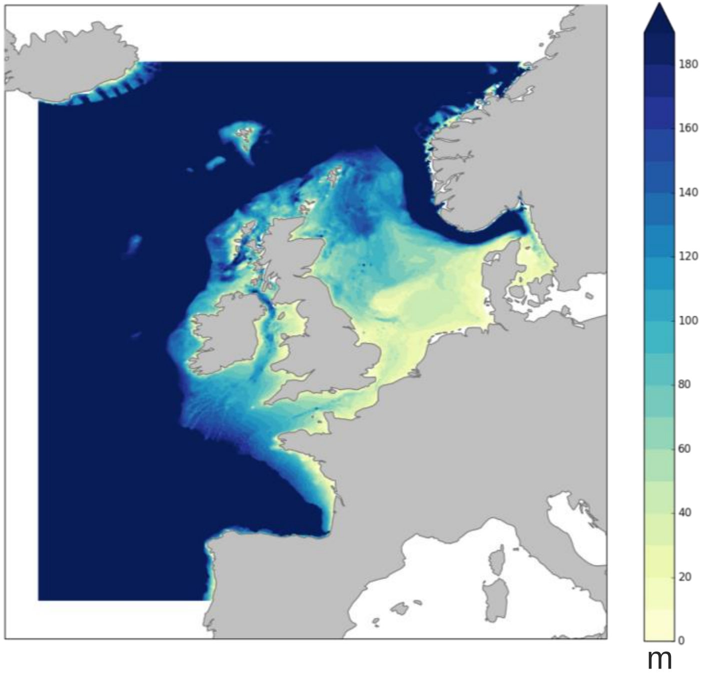


2020

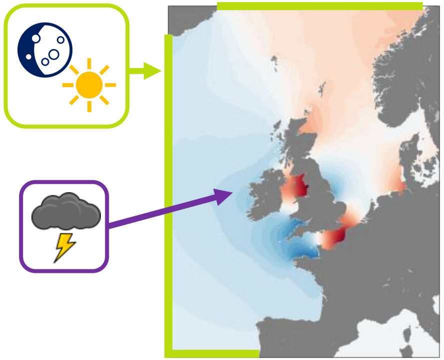


UK's operational surge forecast system

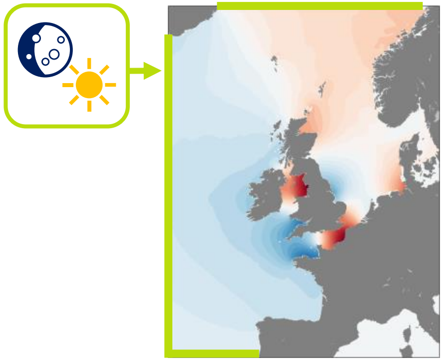
- NEMO3.6 surge model
- 2D
- ~7km resolution
- Inputs:
  - Tides at open boundaries, applied as harmonic constituents
  - 10m wind and surface air pressure from NWP (Met Office global models)
- Runs 4x daily, deterministic + ensemble



UK's operational surge forecast system

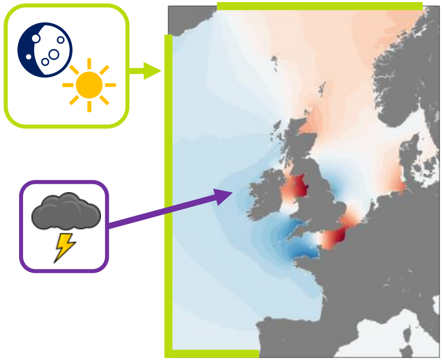


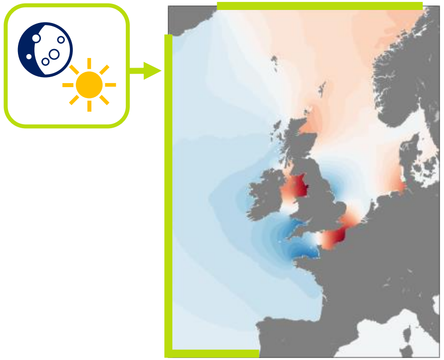
Forced model run



tide only model run

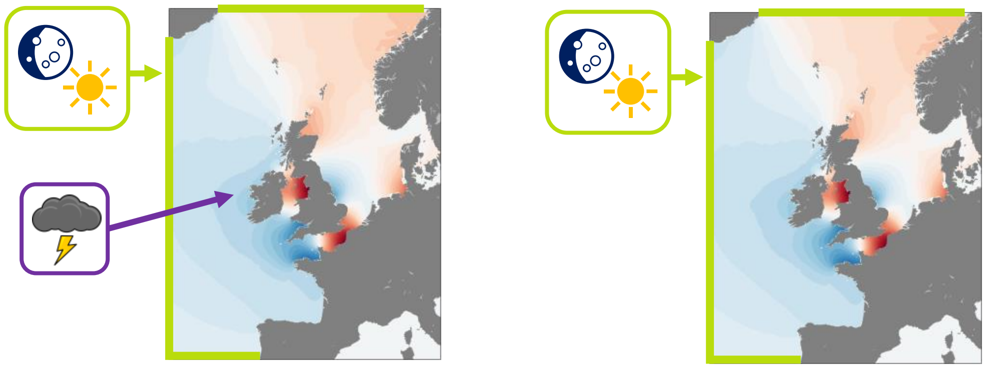
UK's operational surge forecast system





Forced model run - tide only model run = model surge

UK's operational surge forecast system



Forced model run - tide only model run = model surge

Model surge + harmonic tide prediction = water level forecast

Wind stress on the ocean

Current setup

$$\tau_a$$

Total wind stress
at ocean surface

Current setup

$$\tau_a$$

Total wind stress at ocean surface

$$\tau_a = \rho_a C_D |U_{10}| U_{10}$$

Current setup

$$\tau_a$$

Total wind stress at ocean surface

$$\tau_a = \rho_a C_D |U_{10}| U_{10}$$

$$z_0 = \frac{\alpha u_*^2}{g}$$

Current setup

$$\tau_a$$

Total wind stress at ocean surface

Charnock parameter: 0.0275

$$\tau_a = \rho_a C_D |U_{10}| U_{10}$$

$$z_0 = \frac{\boxed{\alpha} u_*^2}{g}$$

Better option?

$$\tau_{oc} = \tau_a - \tau_{aw} + \tau_{woc}$$

Stress felt by the Eulerian ocean

Total wind stress at ocean surface

Stress used for wave growth

Momentum released by wave breaking/dissipation

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Better option?

$$\tau_{oc} = \tau_{a} - \tau_{aw} + \tau_{woc}$$

Stress felt by the Eulerian ocean

Total wind stress at ocean surface

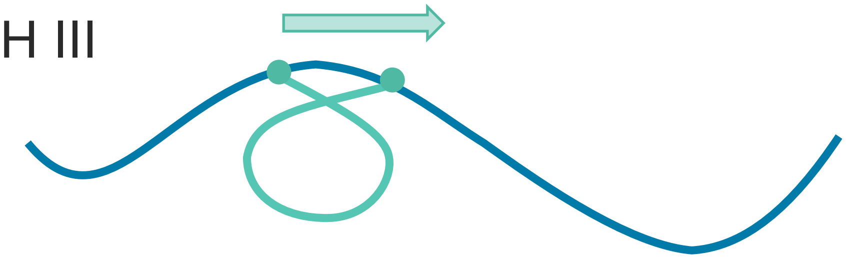
Stress used for wave growth

Momentum released by wave breaking/dissipation

- Give NEMO the τ_{oc} field from WAVEWATCH III (run offline)
- More physically realistic
- Avoid issues caused by having a high tuning for Charnock parameter?

Experiments

- Wind forced as in operational setup
- τ_{oc} from WAVEWATCH III
- τ_{oc} and Stokes drift from WAVEWATCH III

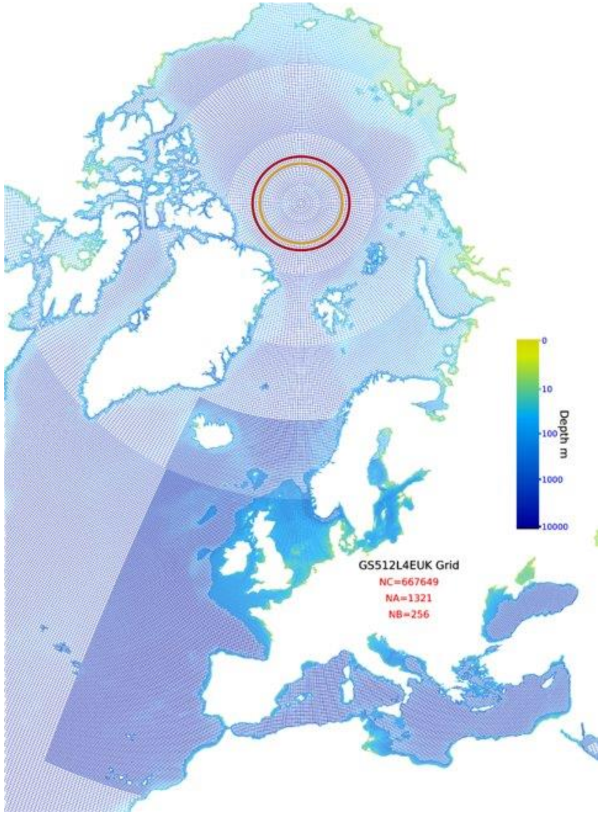


- 2013-2021 hindcast style run
- Shorter run with full forecast cycling (deterministic): Dec 2019-Feb 2020

NEMO 4.0.4 used to include updates to Stokes drift option

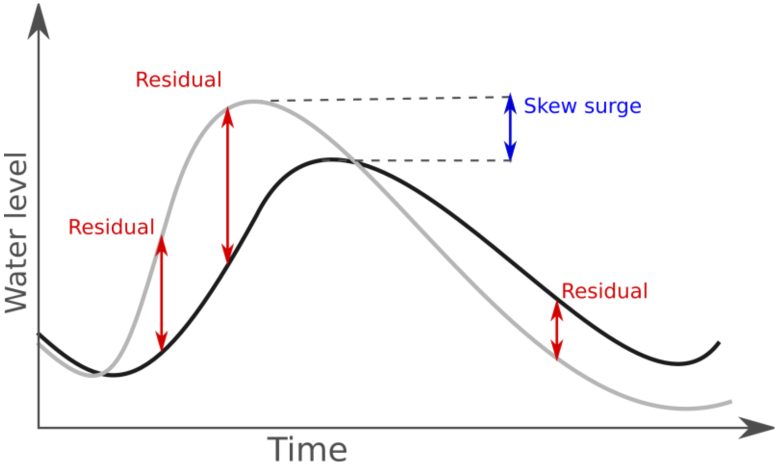
WAVEWATCH III model setup

- Global variable resolution grid
- ST4 (Ardhuin et al., 2010) source terms (wave growth and dissipation) with Met Office tunings
- Discrete Interaction Approximation (DIA) non-linear wave-wave interactions
- Battjes & Janssen bottom friction
- 2nd order advection scheme on Spherical Multi Cell grid.
- Shallow water physics accounted for (depth induced refraction, shoaling and breaking)



Experiments

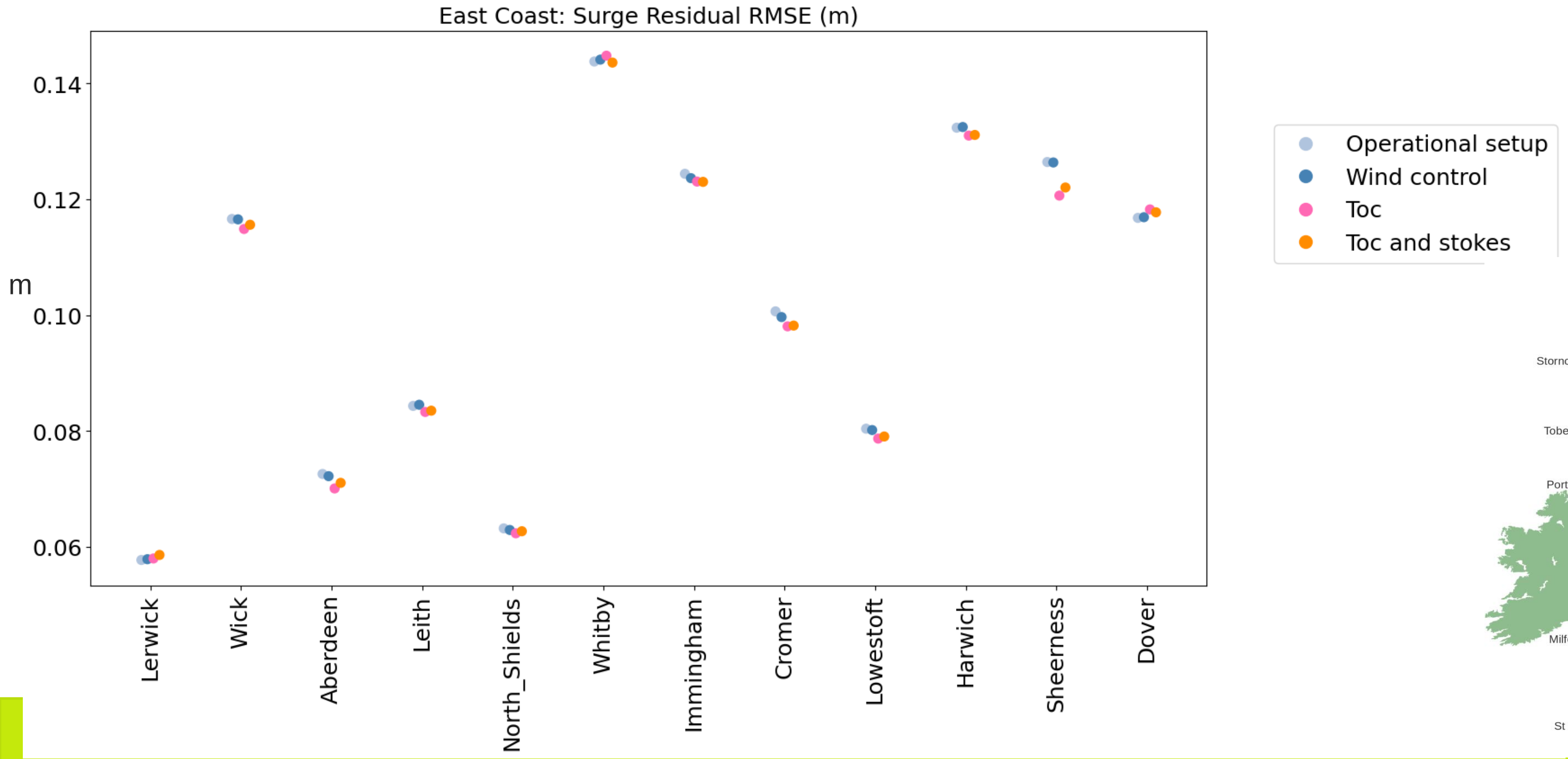
Residual and skew surge compared against tide gauge observations

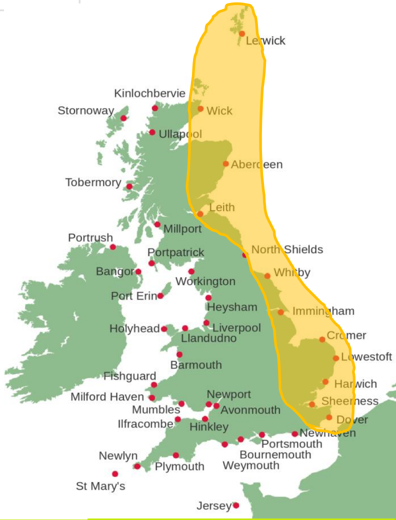


Results

Results from long hindcast run

Overall statistics, east coast





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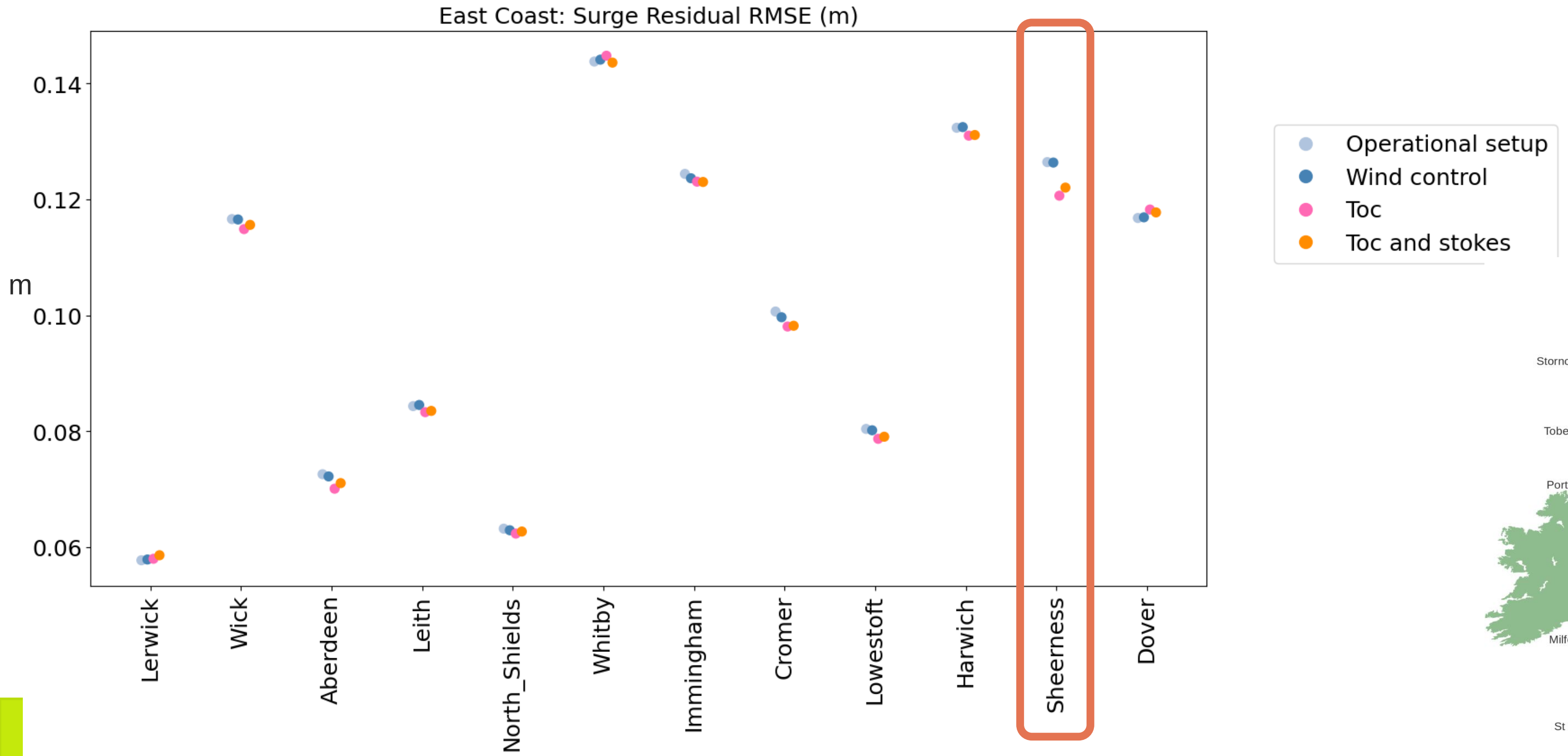

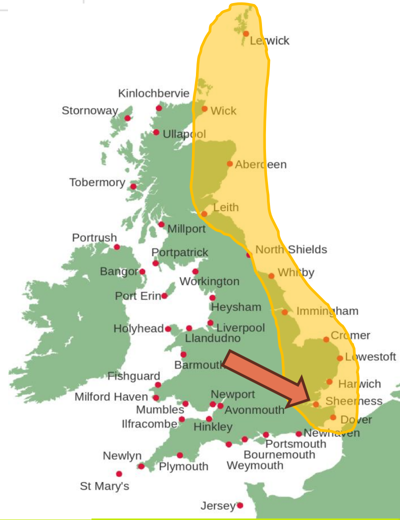

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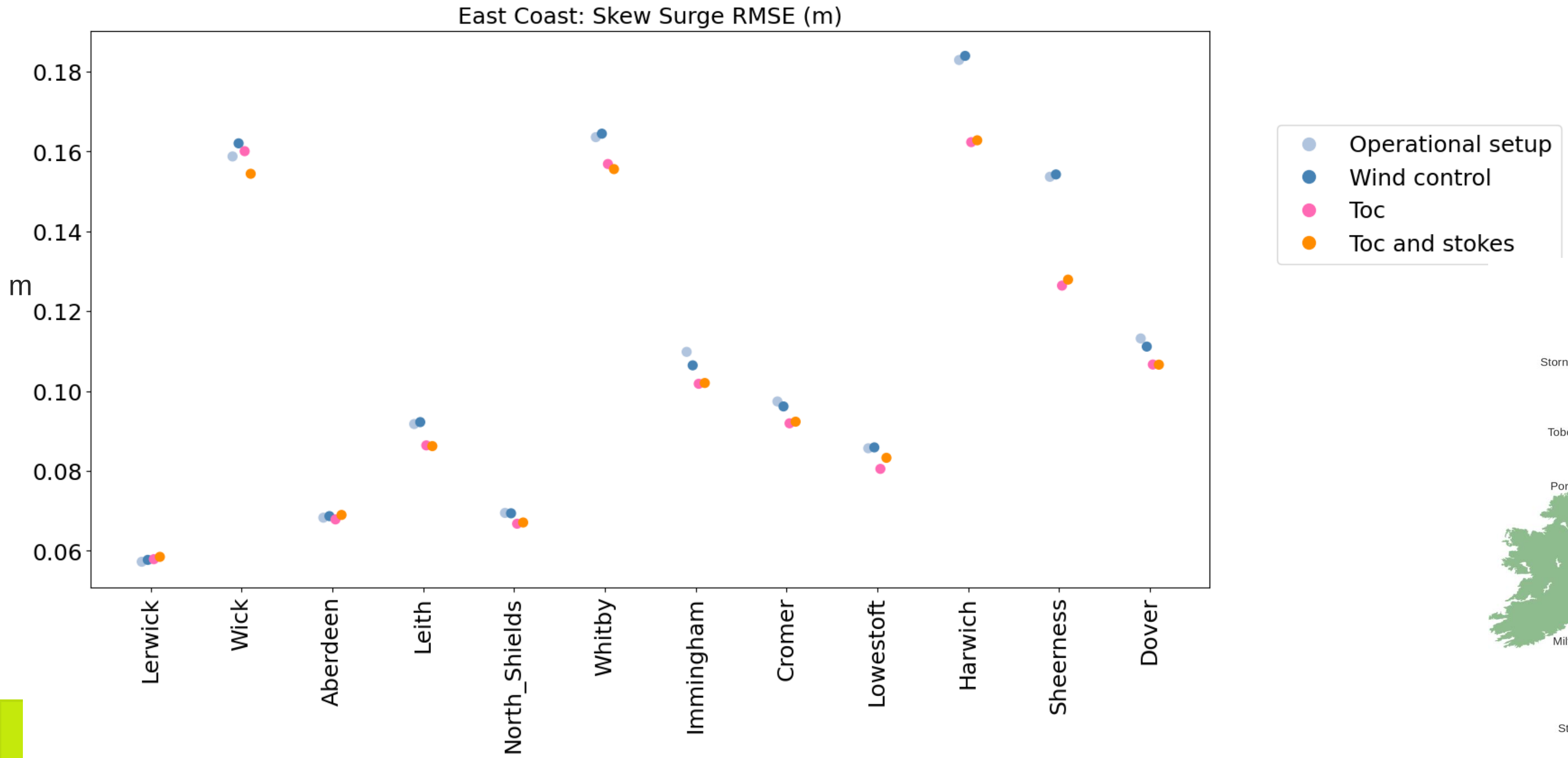

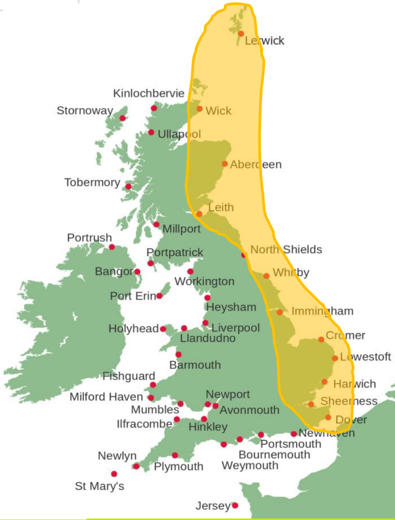

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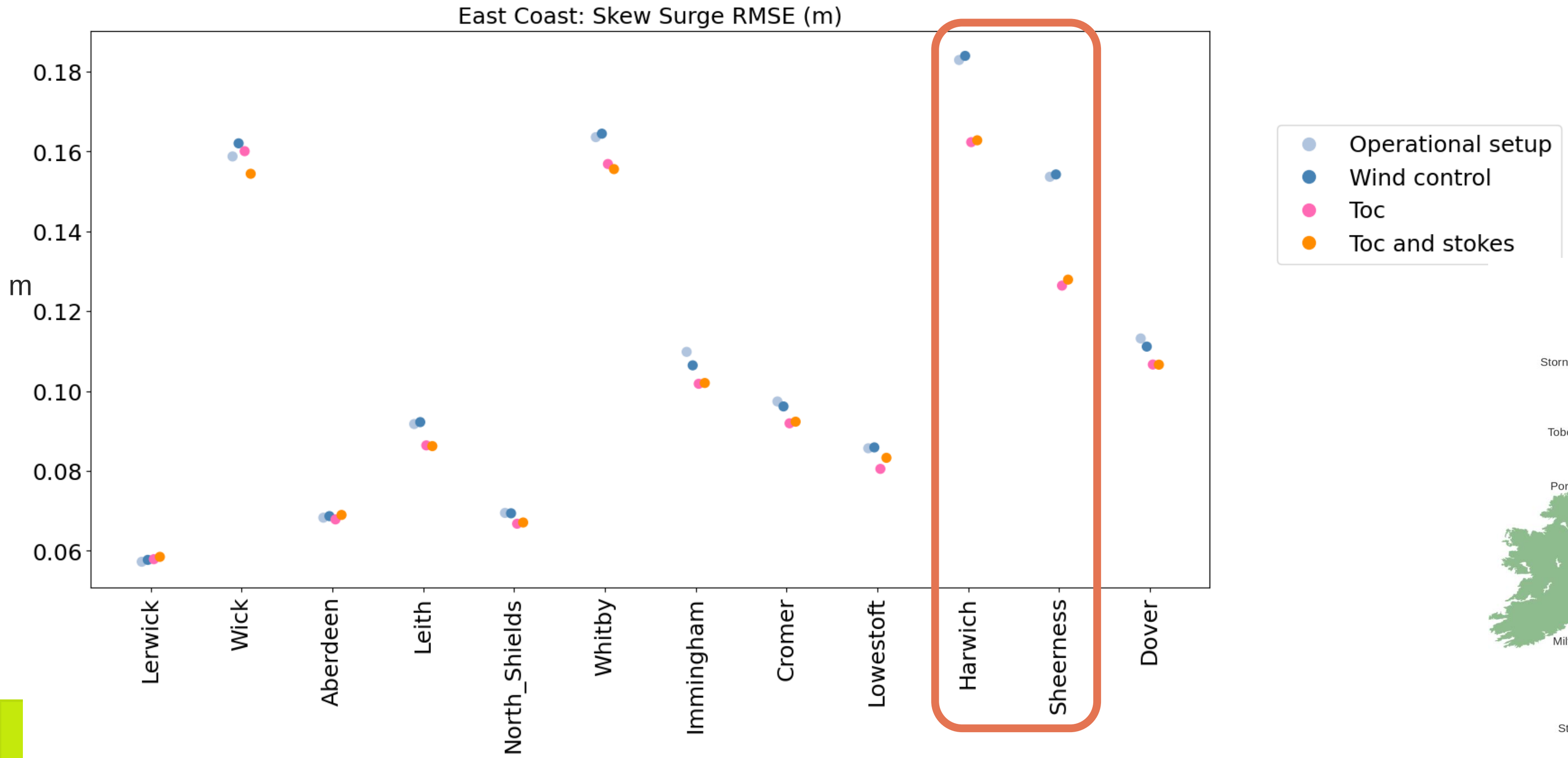

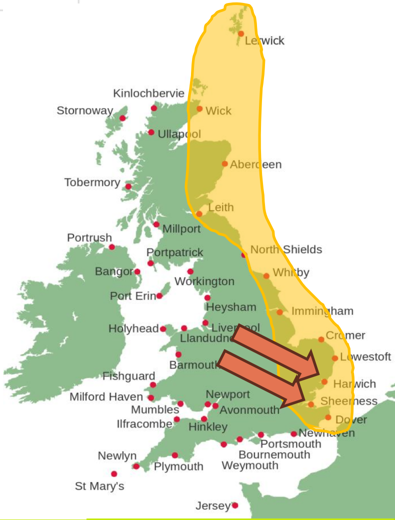

Results from long hindcast run

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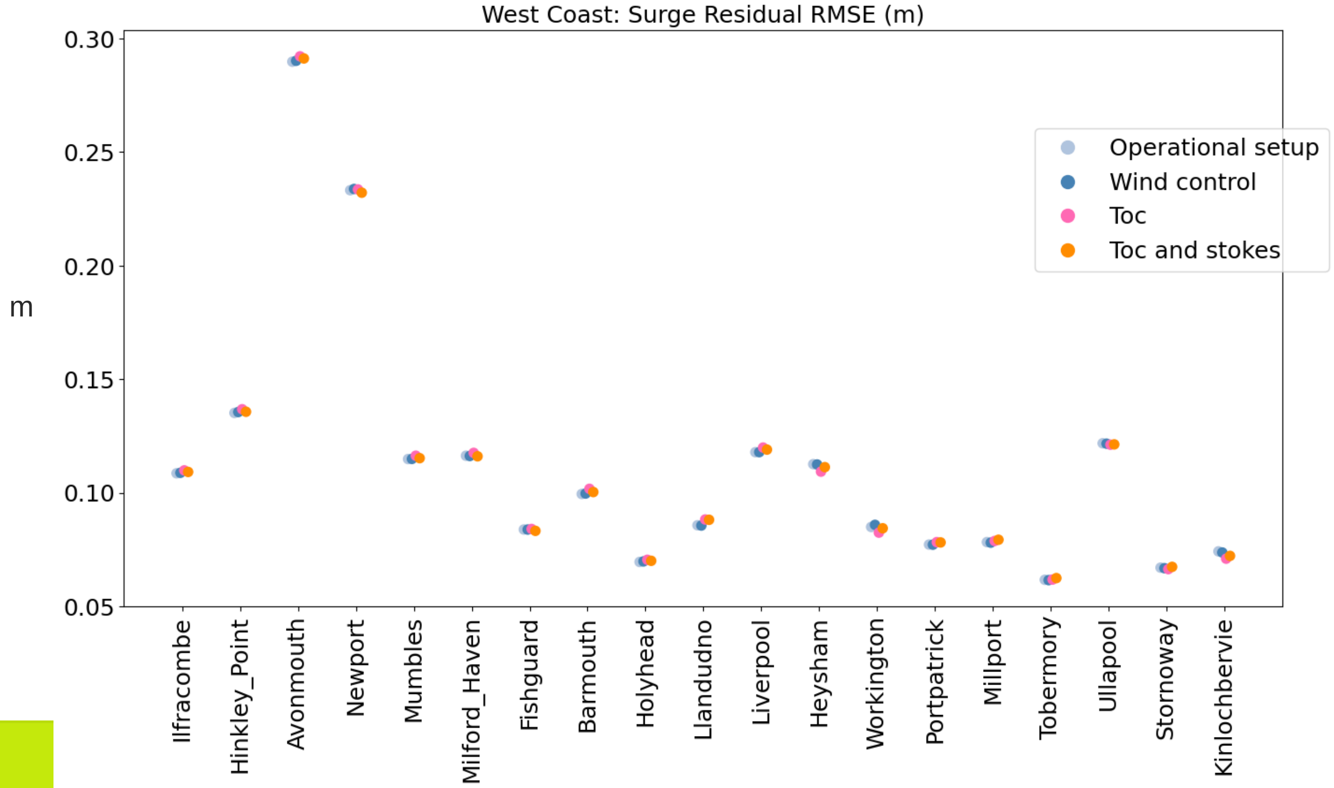

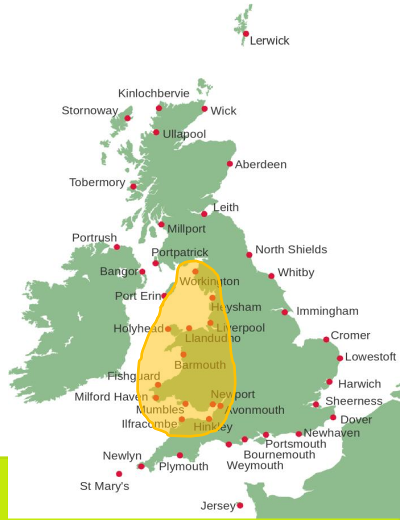

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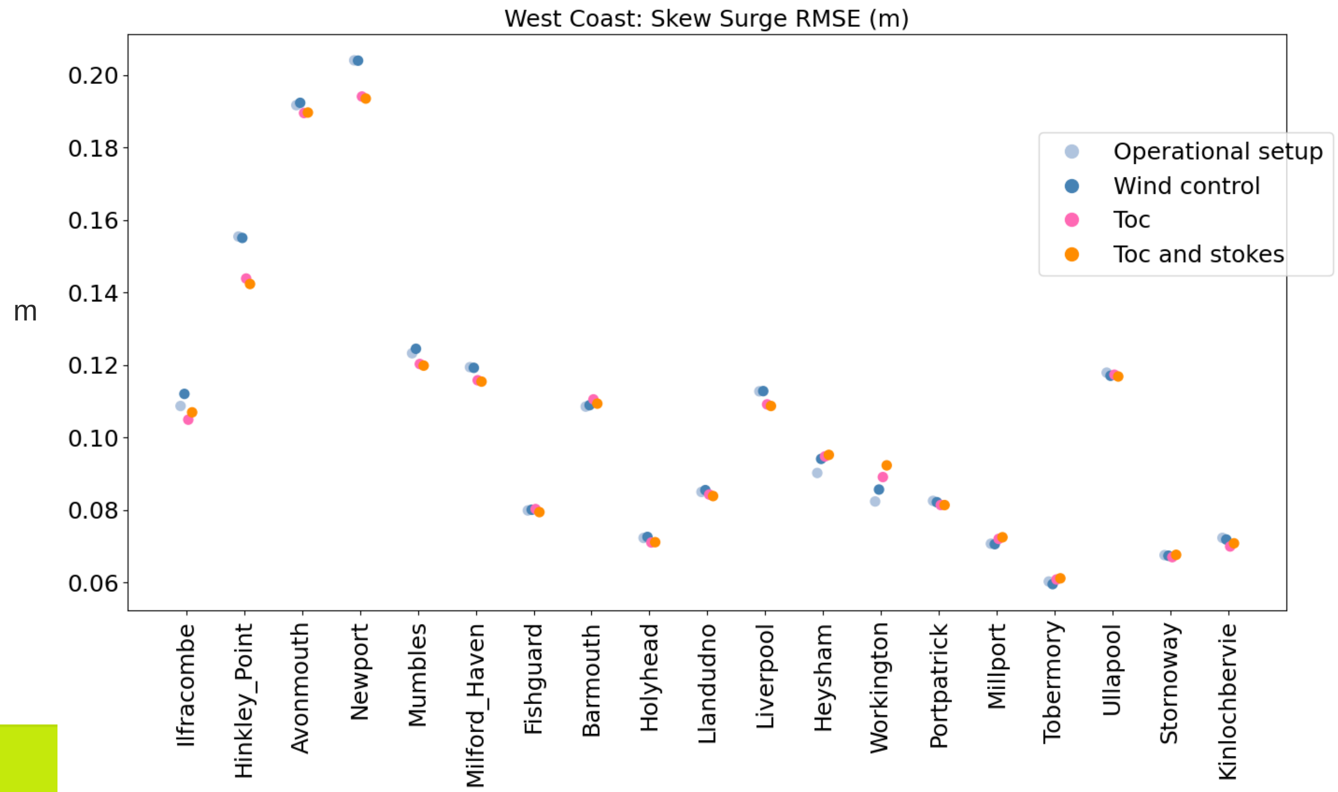

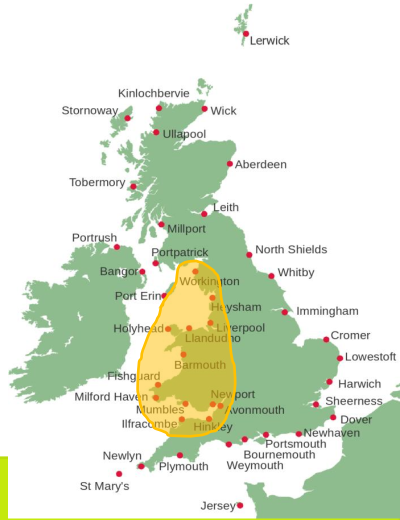

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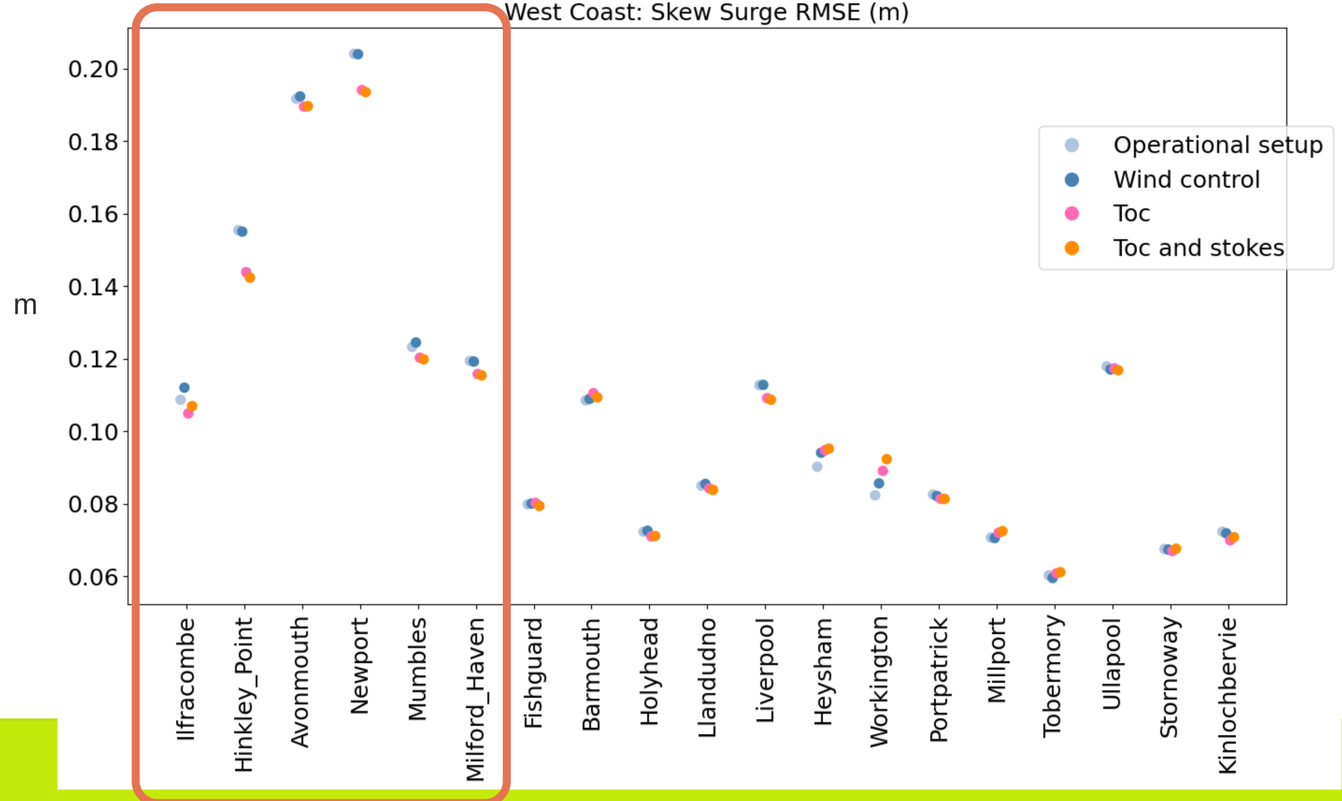

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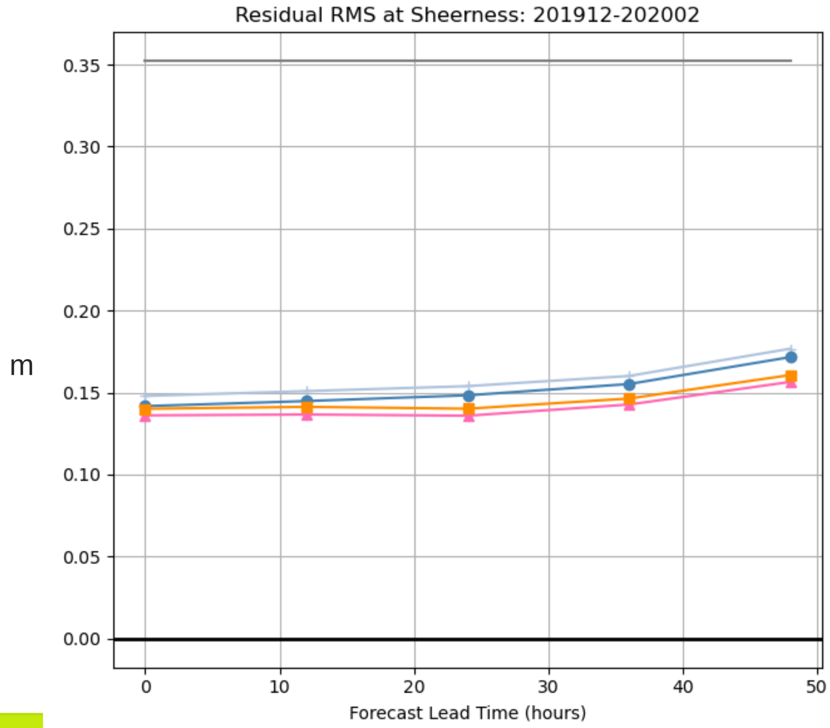
Results from 3 months of forecasts

Forecast statistics, Sheerness



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Results from 3 months of forecasts

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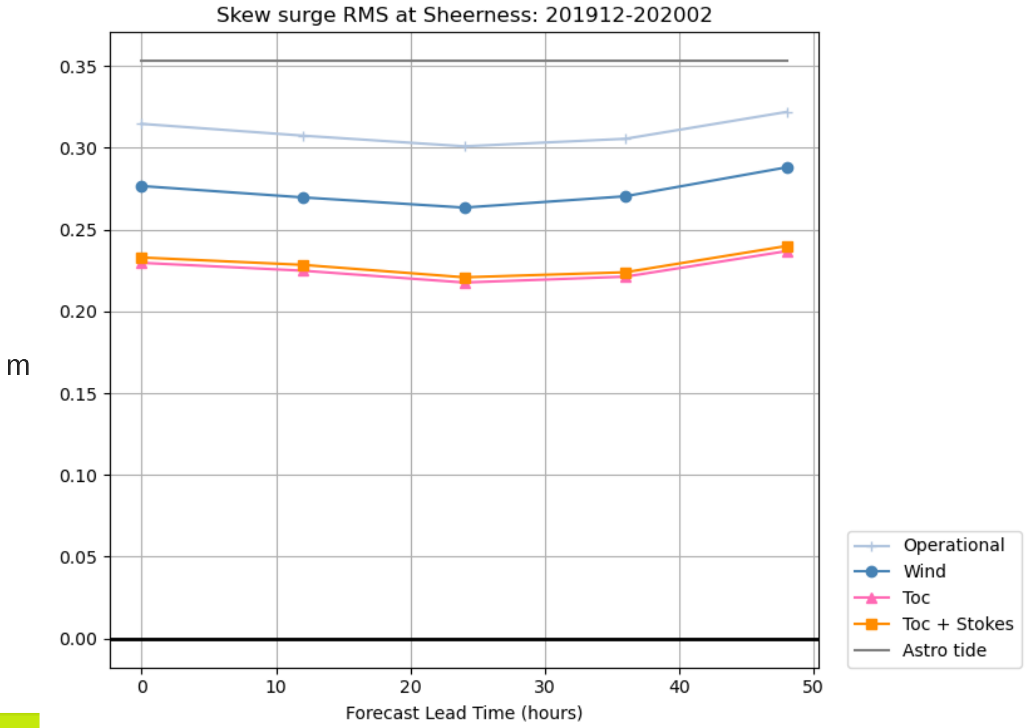

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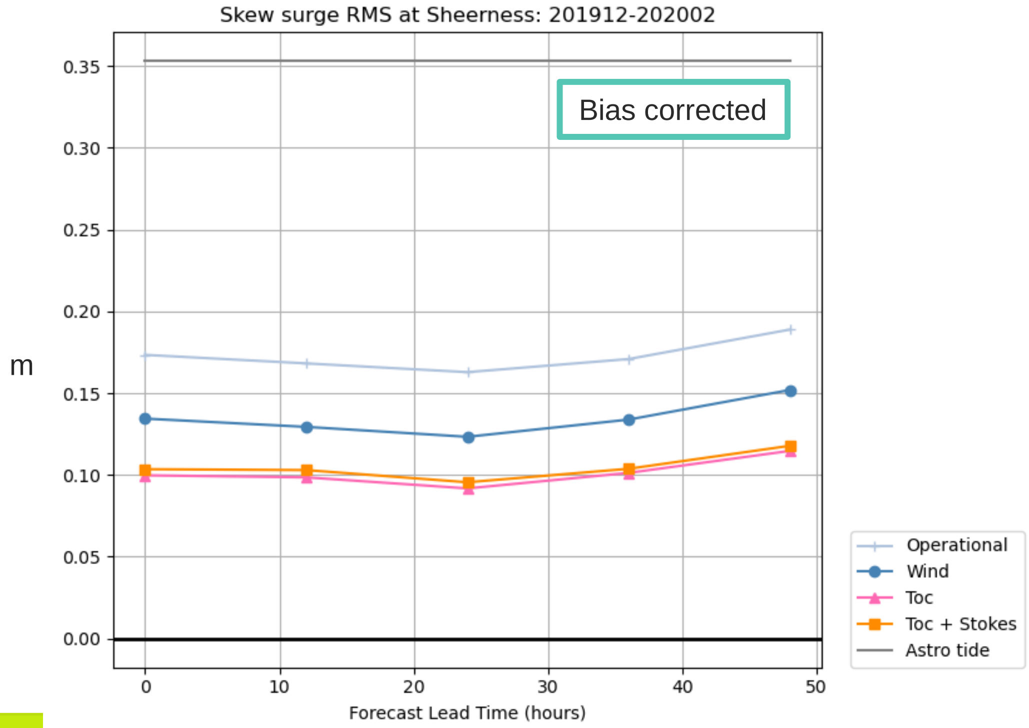
Results from 3 months of forecasts

Forecast statistics, Sheerness



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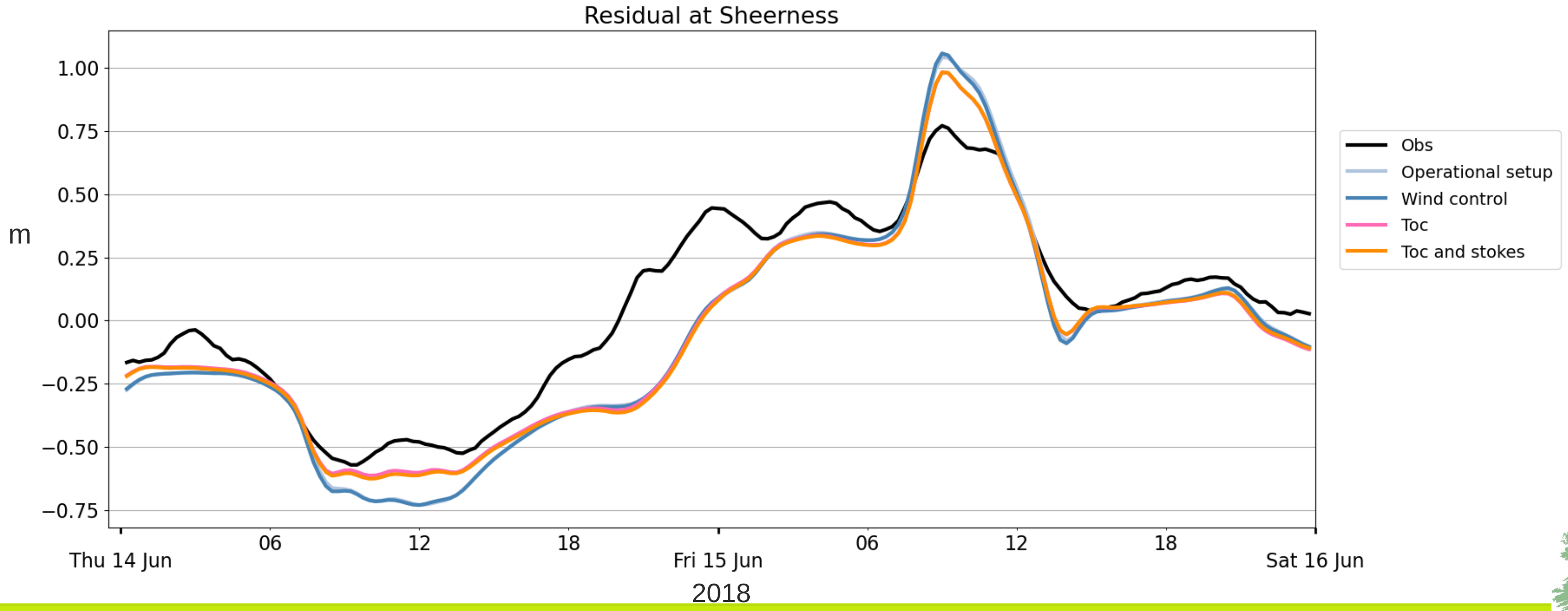
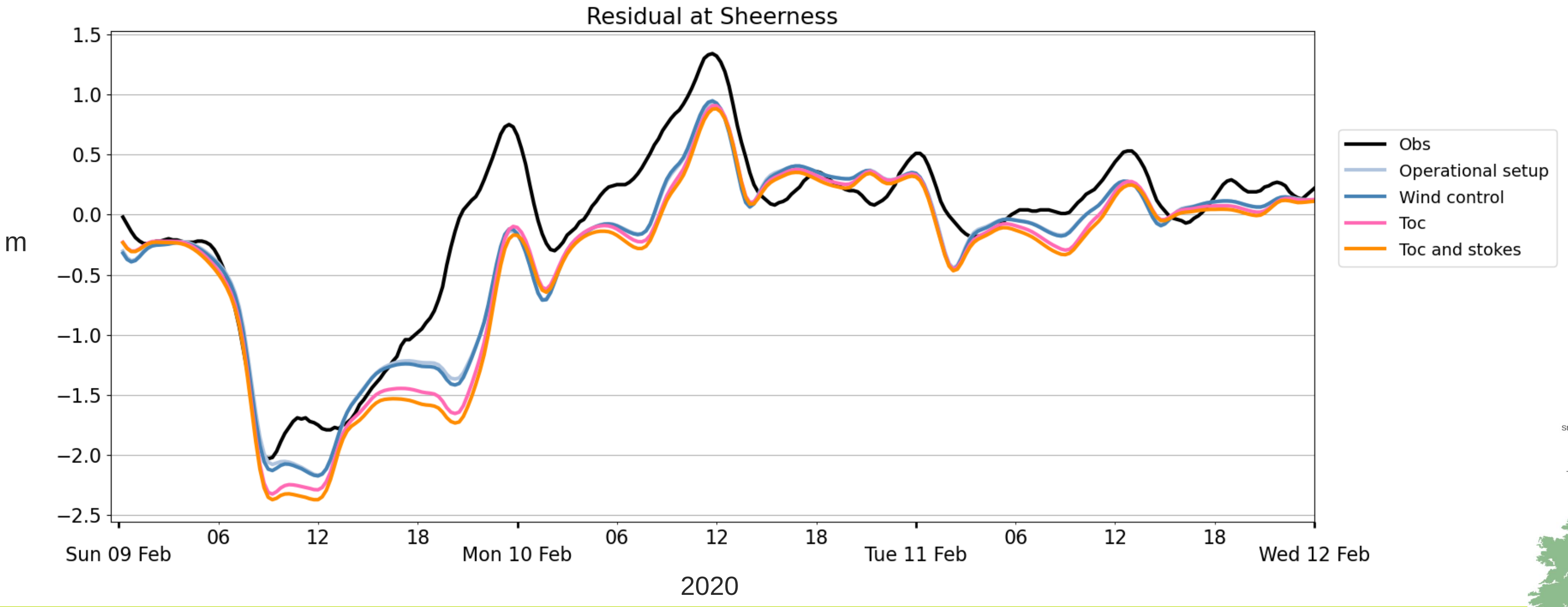
Case study – storm Hector (Jun 2018)



Case study – storm Ciara (Feb 2020)



Summary

Summary

- NEMO surge model has been run forced by modified wind stress provided by an offline wave model
- Using the modified stress improves the statistical performance at the target location (Sheerness), particularly for skew surge
- But not always an obvious improvement in case study timeseries
- Surge model is not sensitive to adding the effect of Stokes drift
- Still TBD whether to add this to the operational system

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Questions?

Contact: clare.oneill@metoffice.gov.uk