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National Oceanography Centre

Sources of uncertainty in coastal overtopping forecasts

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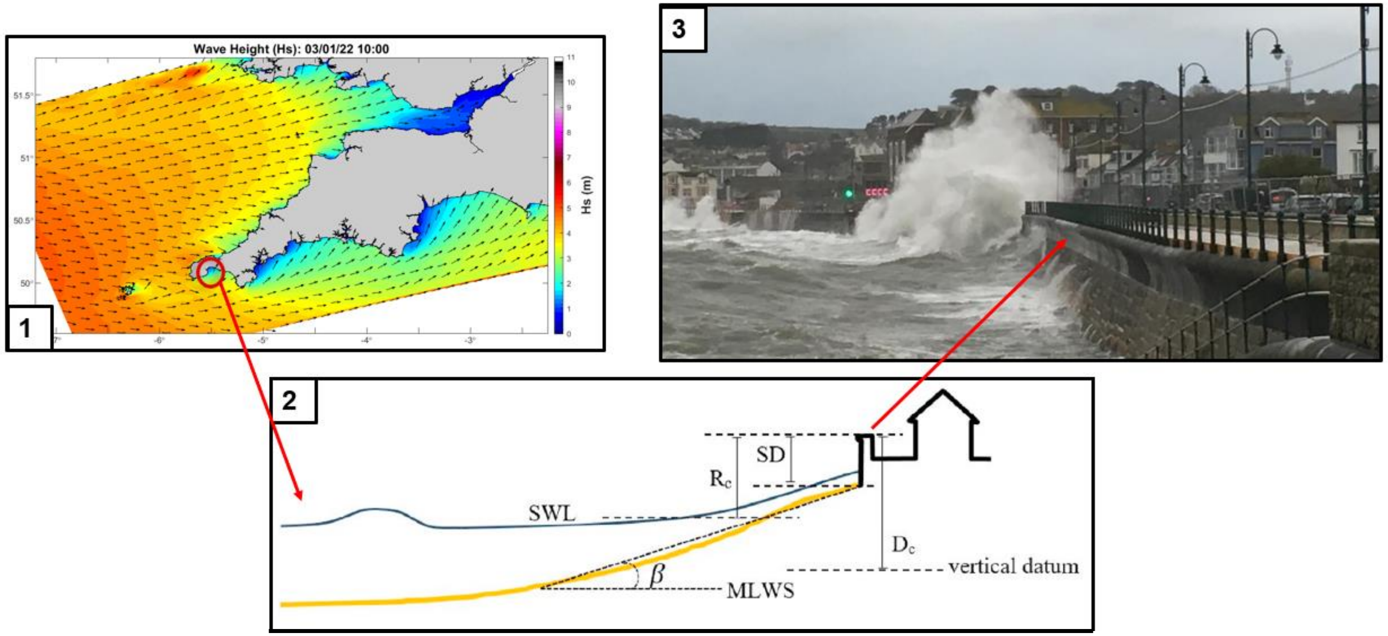
Sources of uncertainty in coastal overtopping forecasts

- Motivation for research
- OWWL overtopping forecast
- CREAM-T field measurements
- Uncertainty due to wave and water level
- Uncertainty due to beach profile
- Uncertainty due to wind
- Other sources of uncertainty
- Conclusions



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Motivation for research

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- 10 cm of sea level rise is expected to occur by 2030–2050 and could double the frequency of extreme flooding events*

- Reducing flooding risk requires:
  - prevention (engineering hard or soft sea defences)
  - mitigation (preventing development or relocating communities)
  - preparedness (having forewarning of a flood event)

* Vitousek, S., Barnard, P.L., Fletcher, C.H., Frazer, N., Erikson, L., Storlazzi, C.D., 2017. Doubling of coastal flooding frequency within decades due to sea-level rise. Sci. Rep. 7 (1), 1399.

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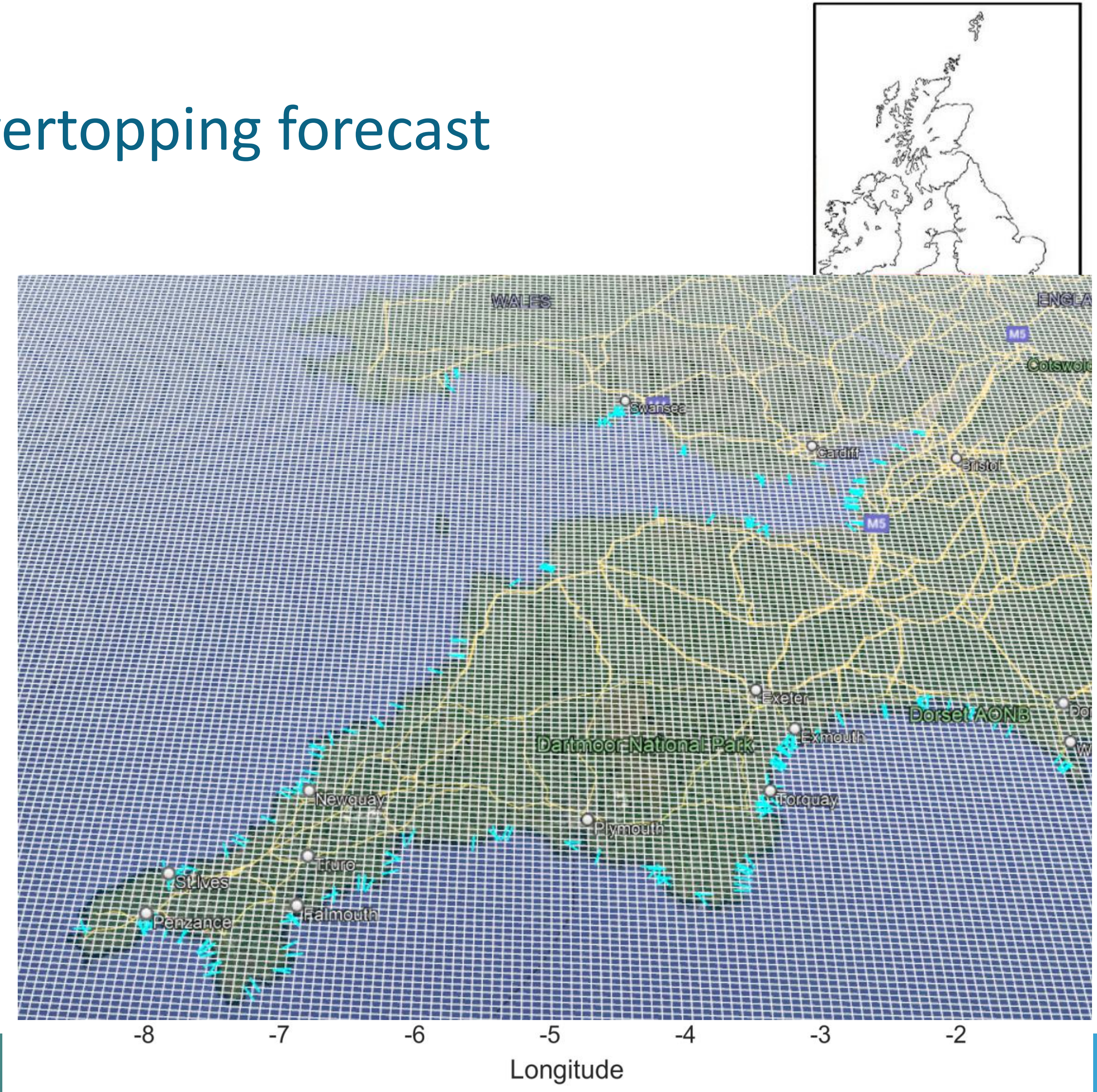
sweep OWWL Operational Wave & Water Level Model

overtopping forecast

2017-2022: OWWL-D3D

2022-present: OWWL-CMEMS

- Uses wave and water level model (DELFT3D)
- Uses 1.5 km AMM15 CMEMS wave and flow forecast product
- UK Met Office boundary data
- Potential to roll out across UK
- Automatically runs a 3-day forecast
- Automatically runs a 5-day forecast
- Model output in shallow water
- Empirical, depth-limited shoaling into the shore
- Monitored coastal profiles used to predict runup and overtopping at >200 locations
- 3 different empirical approaches to predict overtopping



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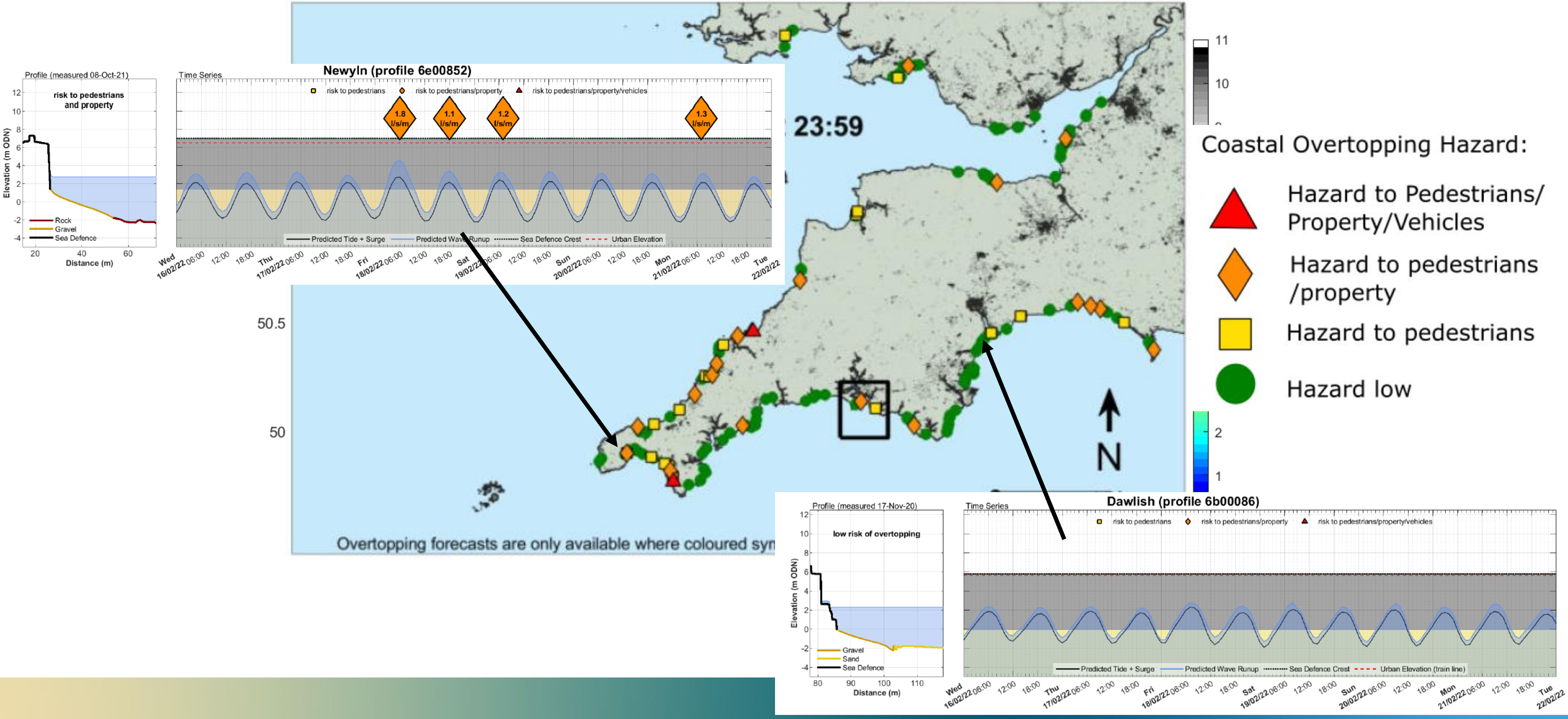
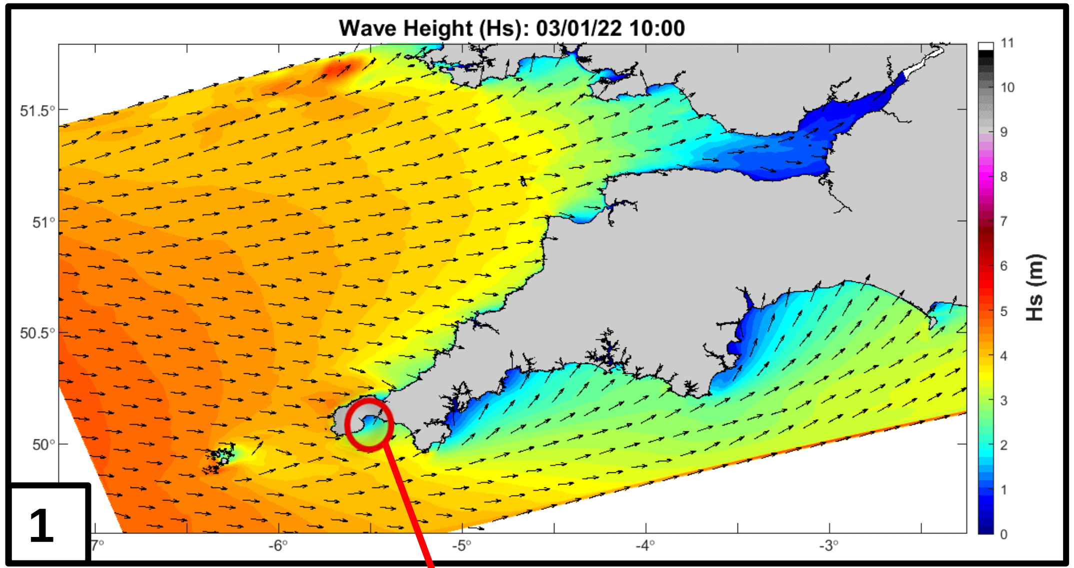
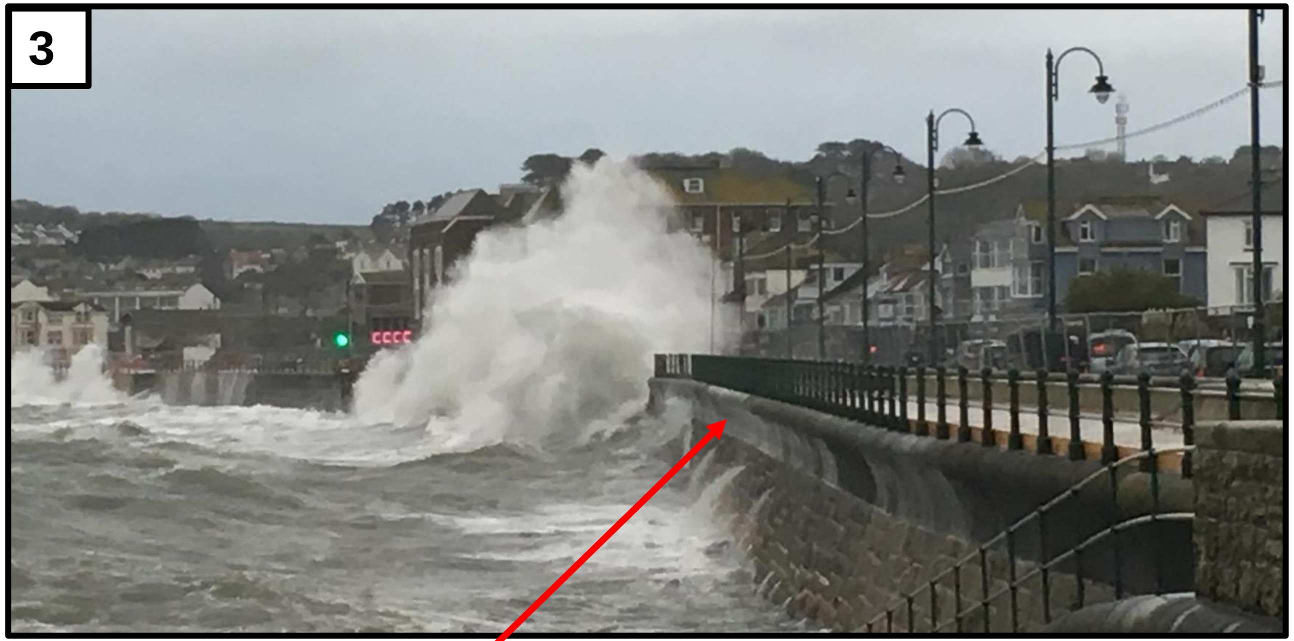
SWEEP OWWL Operational Wave & Water Level Model

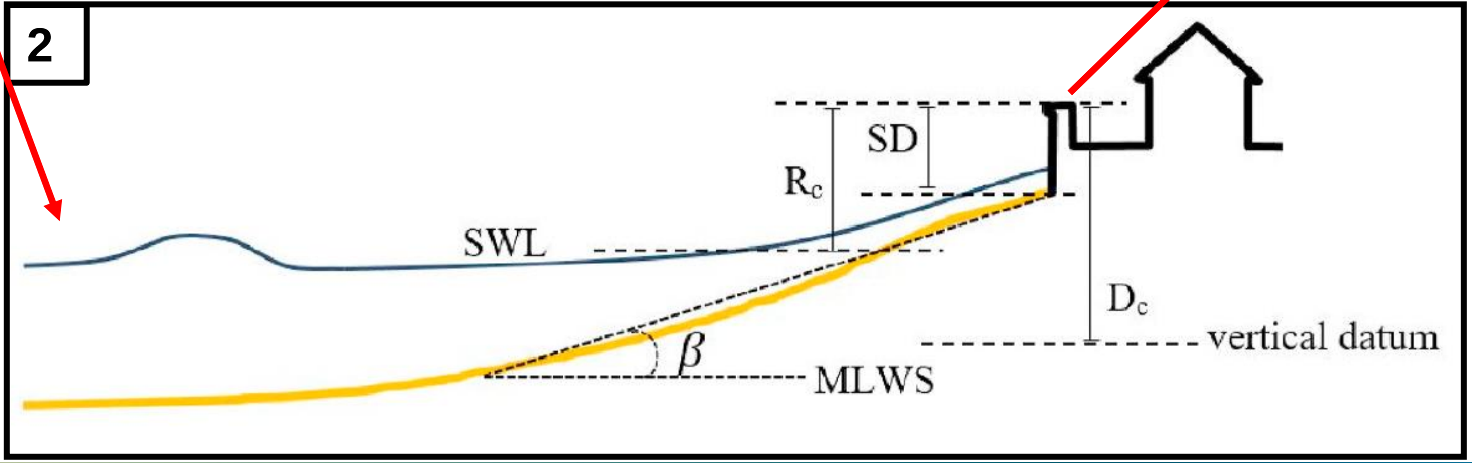
overtopping forecast



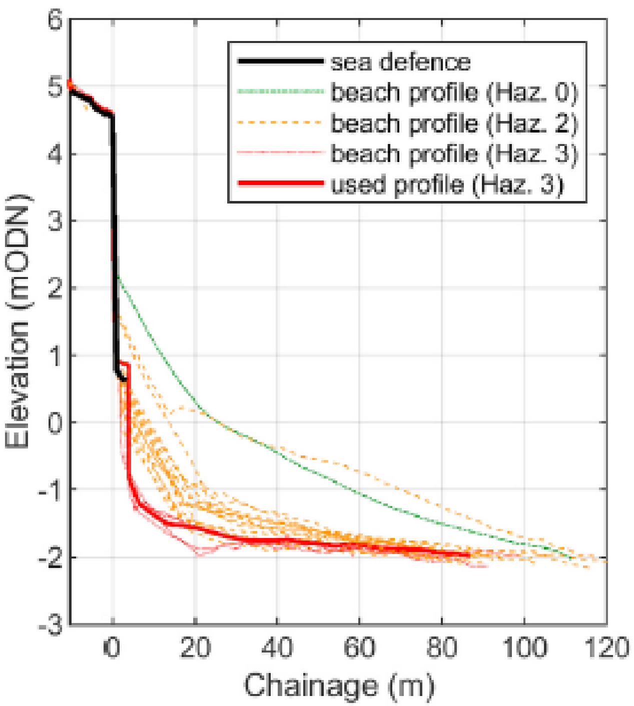
overtopping forecast

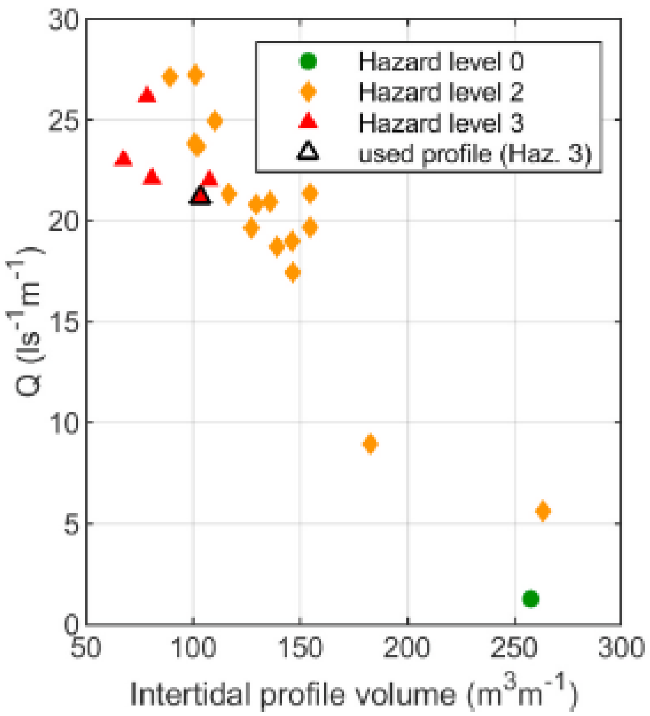




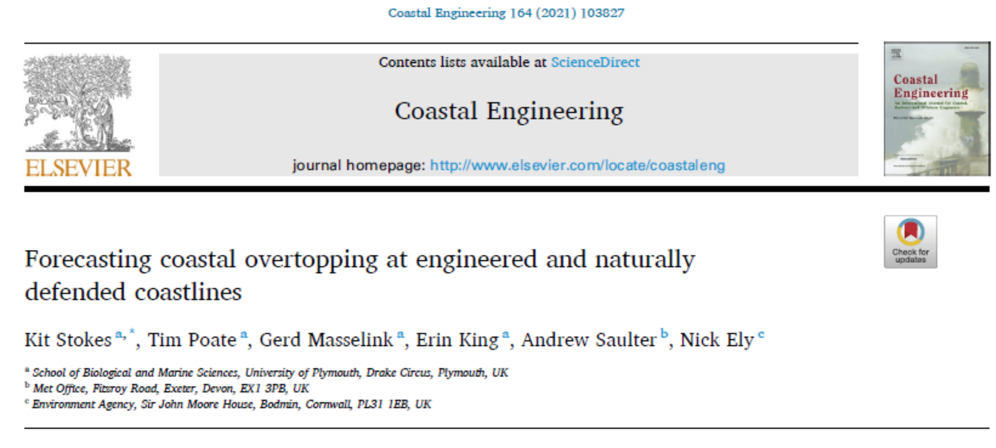


overtopping forecast





- Profile variation at the coast is highly important to overtopping
- For a given storm, beach level influences overtopping discharge by an order of magnitude



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ELSEVIER

Forecasting coastal overtopping at engineered and naturally defended coastlines

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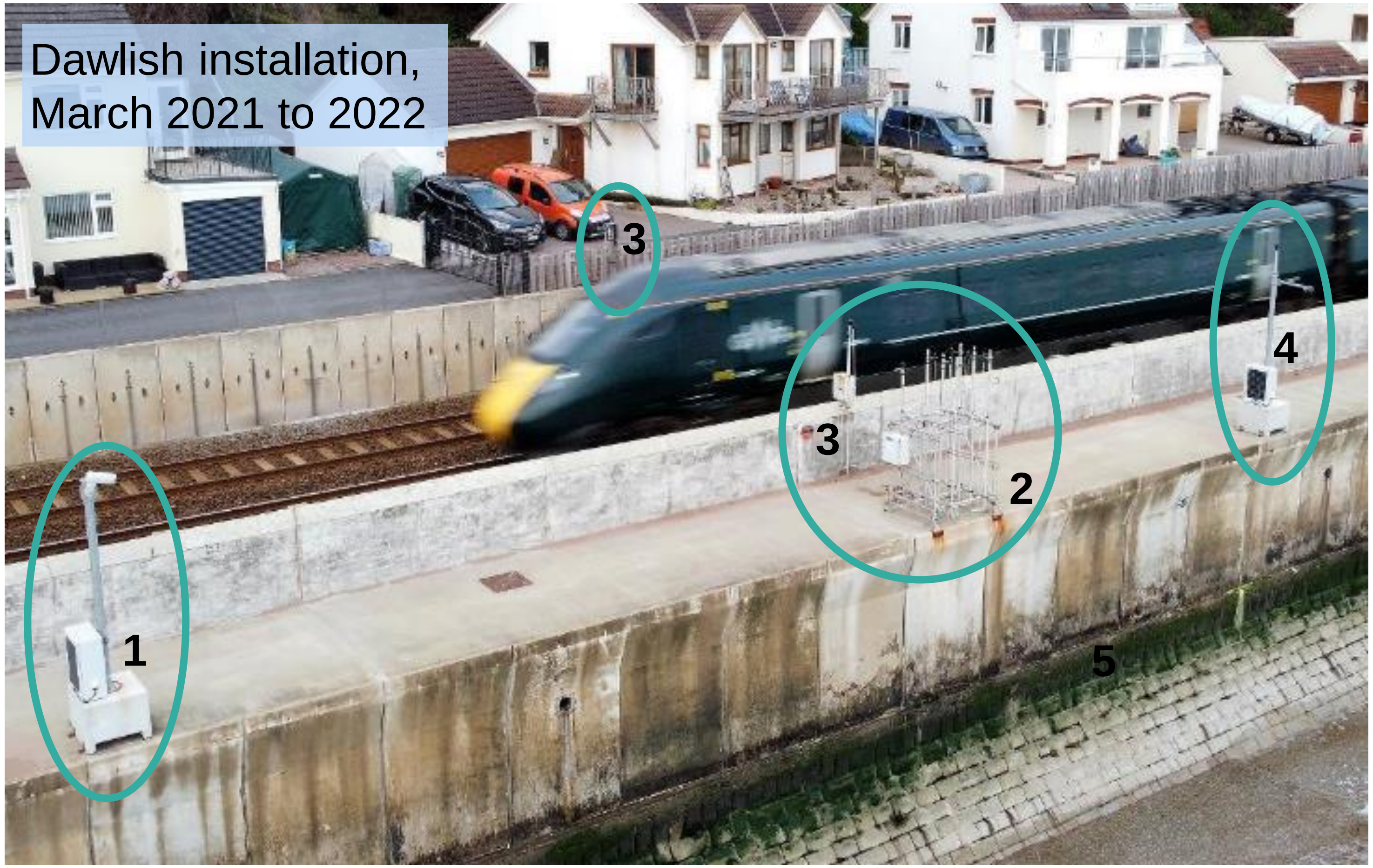
CREAM-T field measurements

1) Camera
2) WireWall
3) WireWands
4) B-Scan with anemometer



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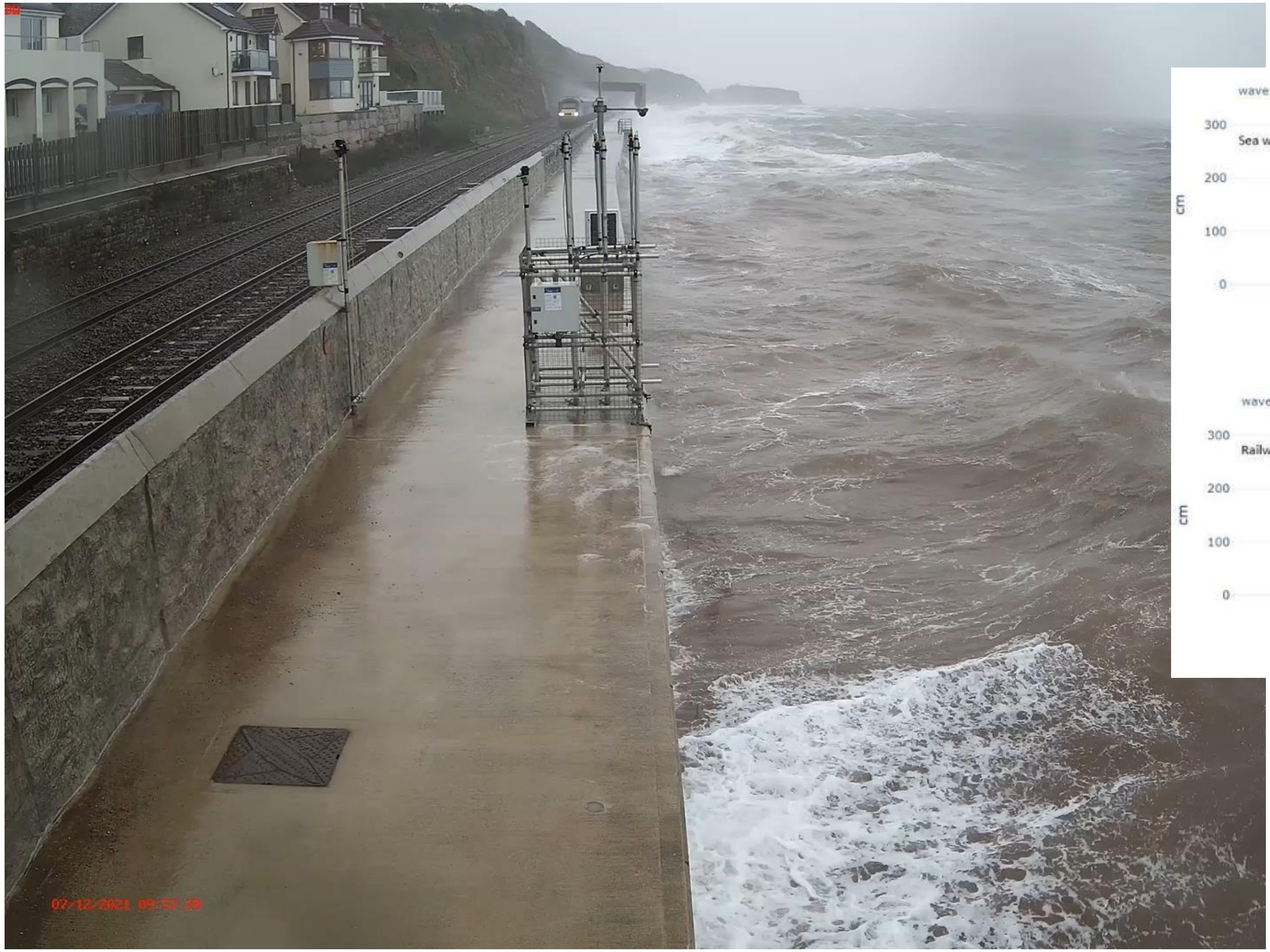
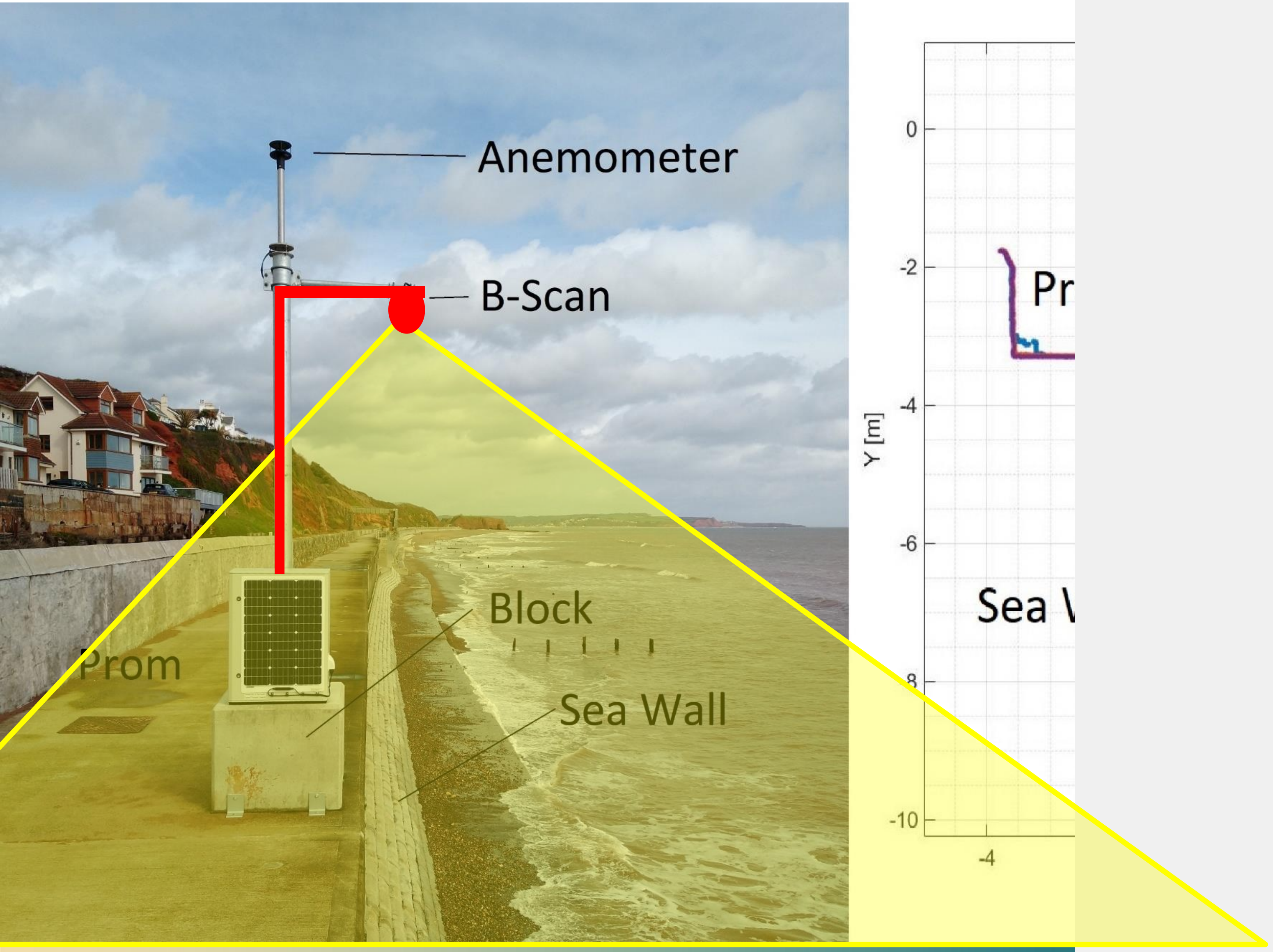
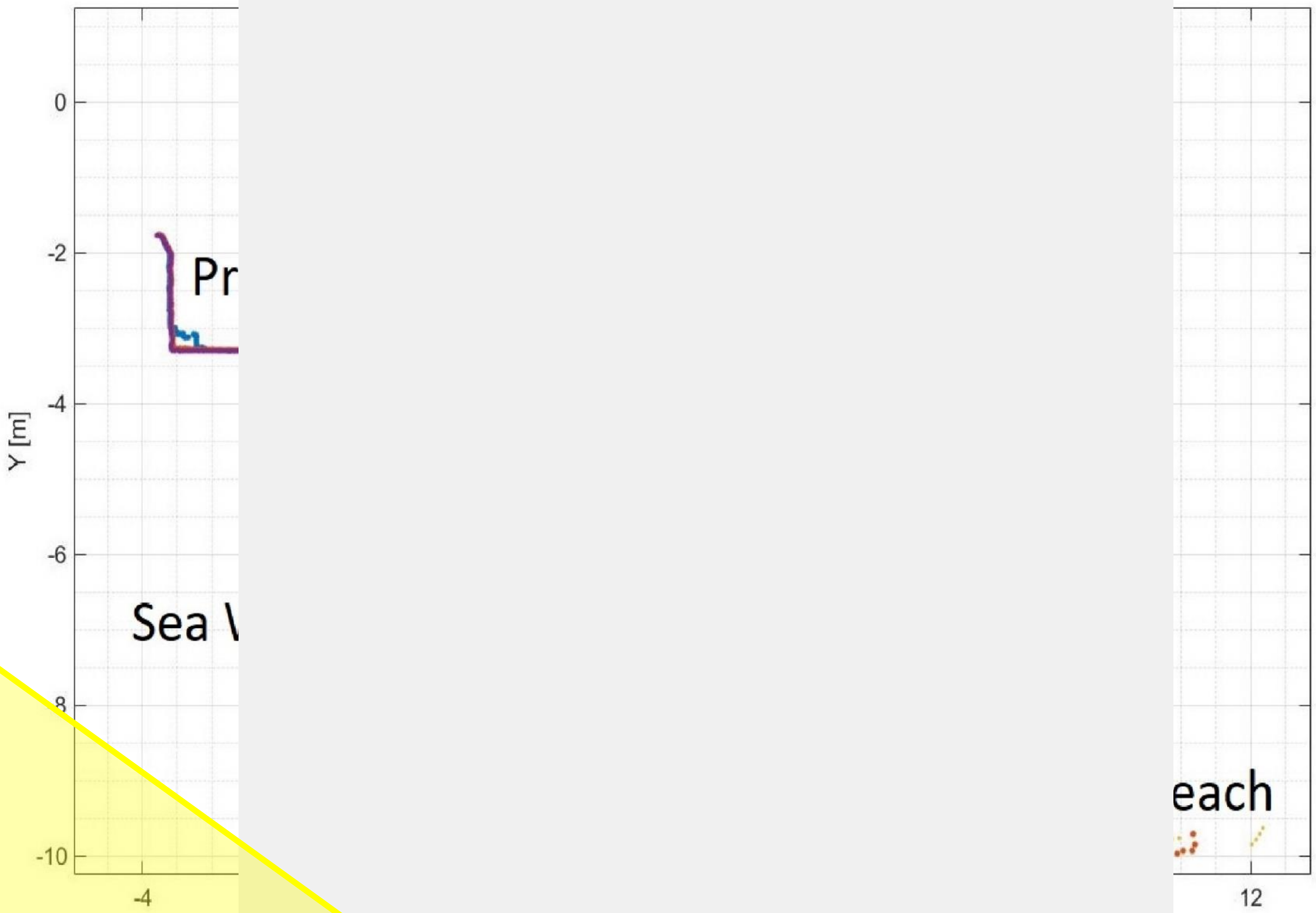
CREAM-T field measurements

National Oceanography Centre



CREAM-T field measurements





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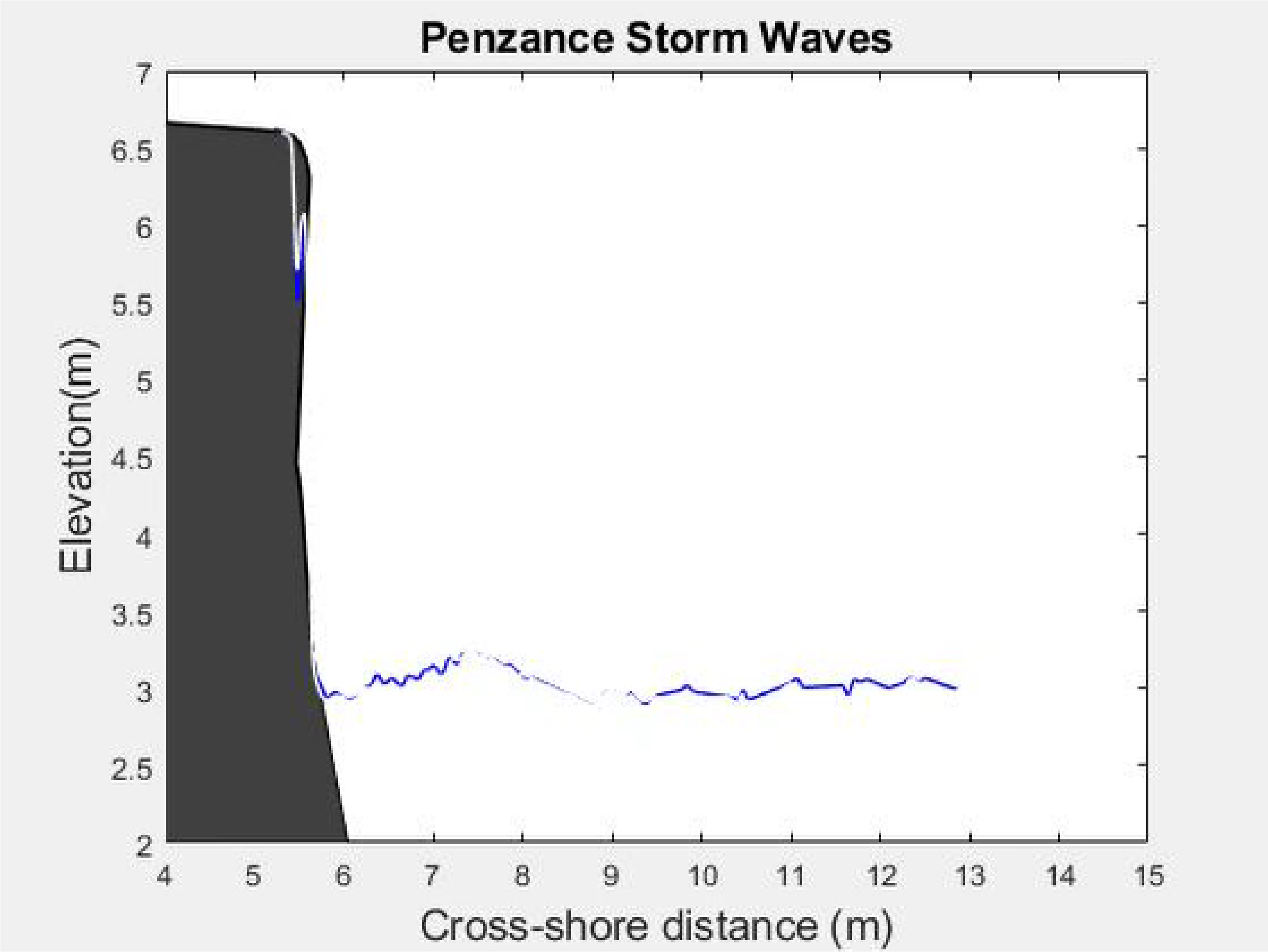
CREAM-T field measurements

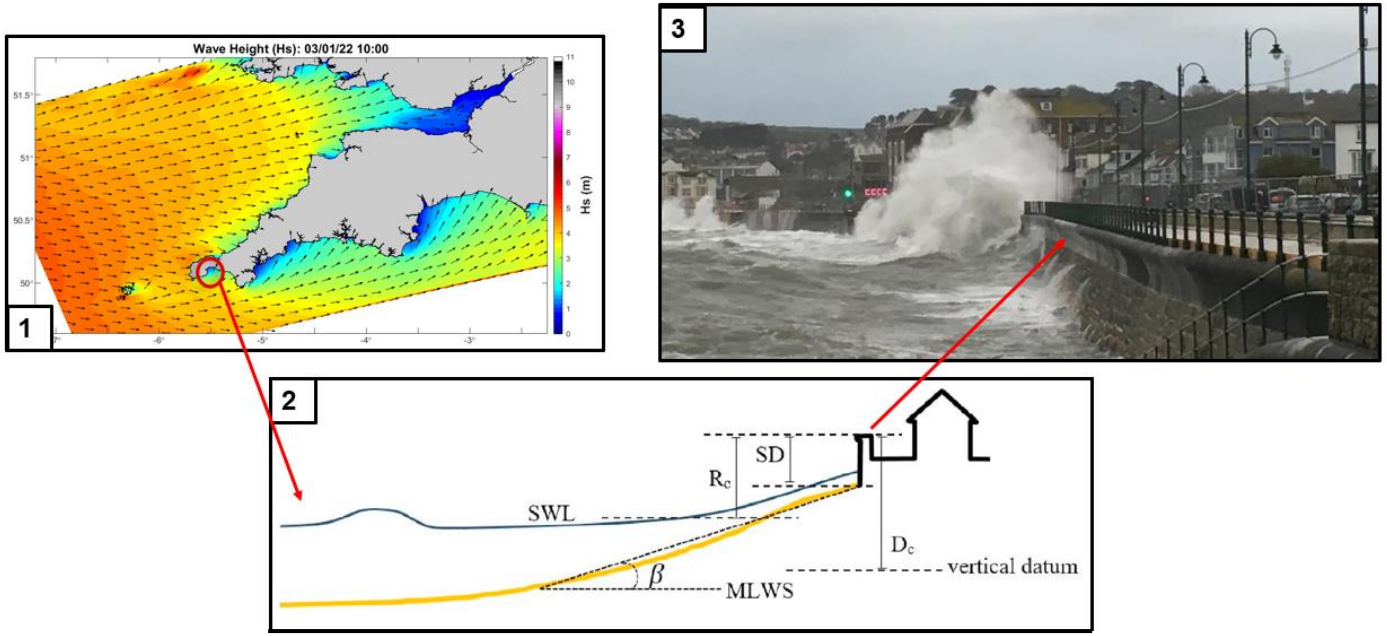
B-SCAN
Remote Beach-Level Sensor



Sources of uncertainty when forecasting overtopping

- Multi-model approach needed to predict overtopping rate, Q

- Dynamic natural variables influence Q:
  - Waves
  - Water level
  - Bathymetry
  - Wind
  - Currents



- Static variables also influence Q:
  - Sea defence type and geometry
  - Location along sea defence
  - Choice of overtopping equation

- Various sources of error in predicting/defining these parameters, and therefore also in predicting Q

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uncertainty due to wave forcing

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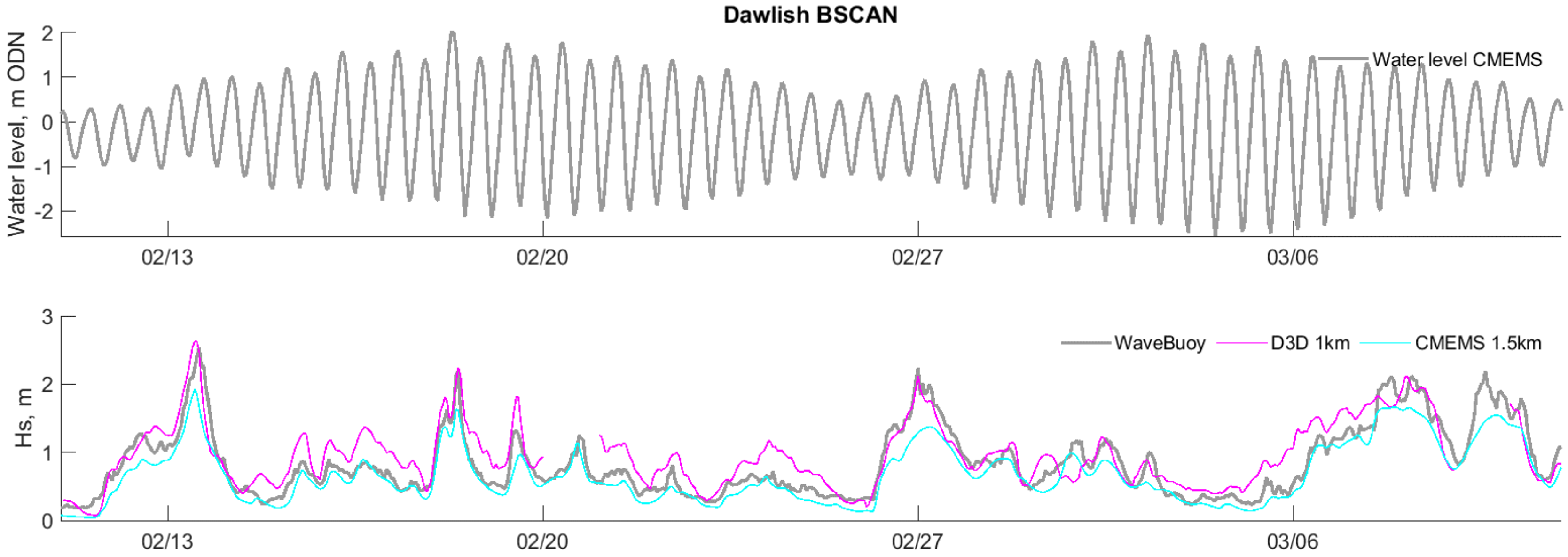
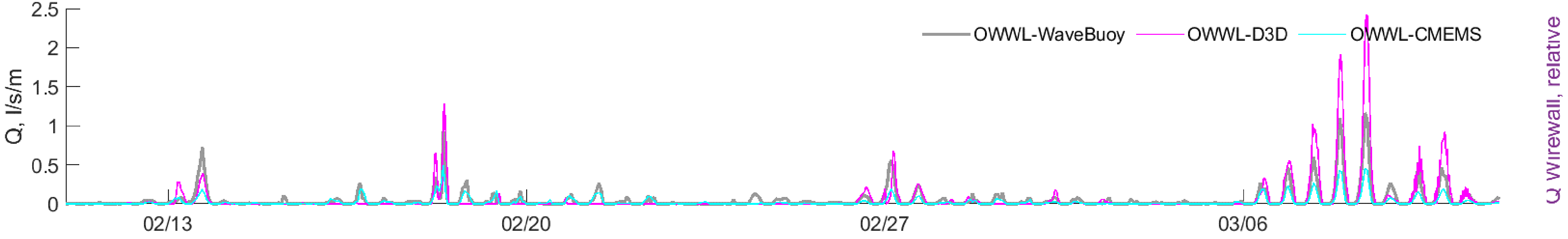
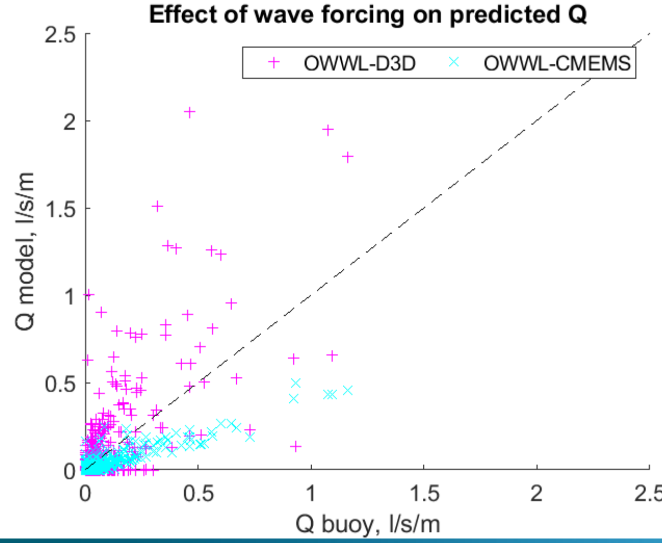


- Wave forcing clearly important to overtopping prediction
- OWWL D3D wave height (Hs) mean error in SW England +/- 40 cm (30 cm bias)
- CMEMS – similar?

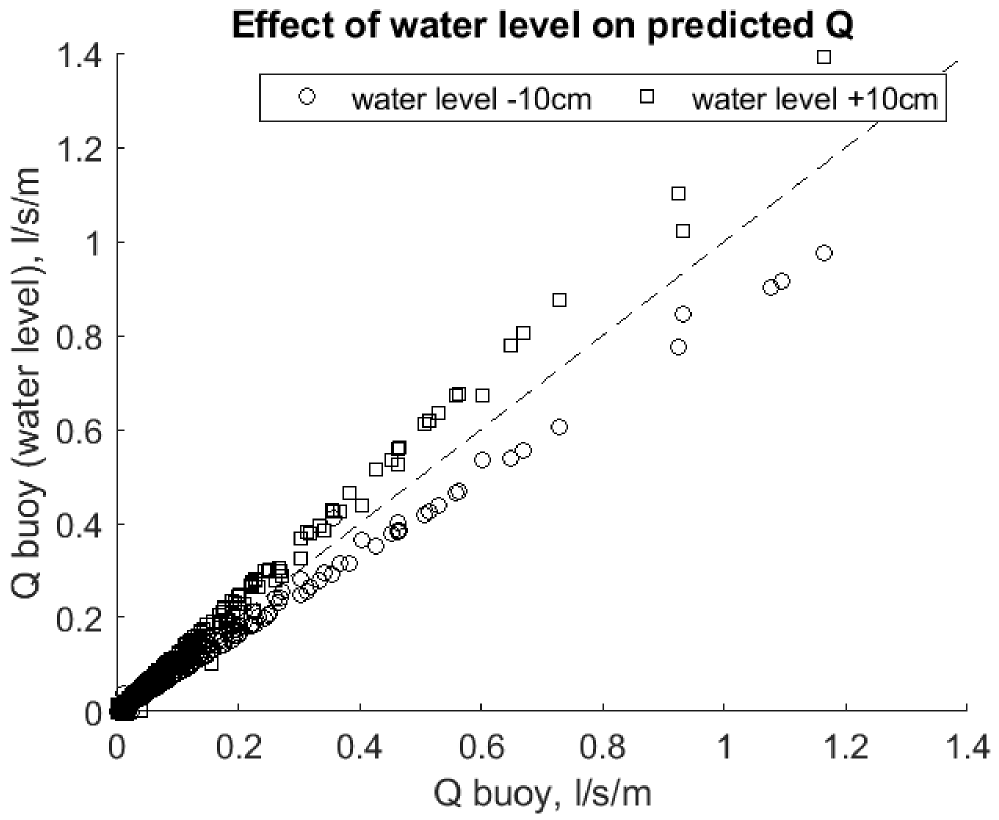
uncertainty due to wave forcing



- Regardless of wave forcing used, OWWL reproduced the timing and shape of measured overtopping events well
- Choice of wave model influenced Q by 2-4 times (compared to using wave buoy data)

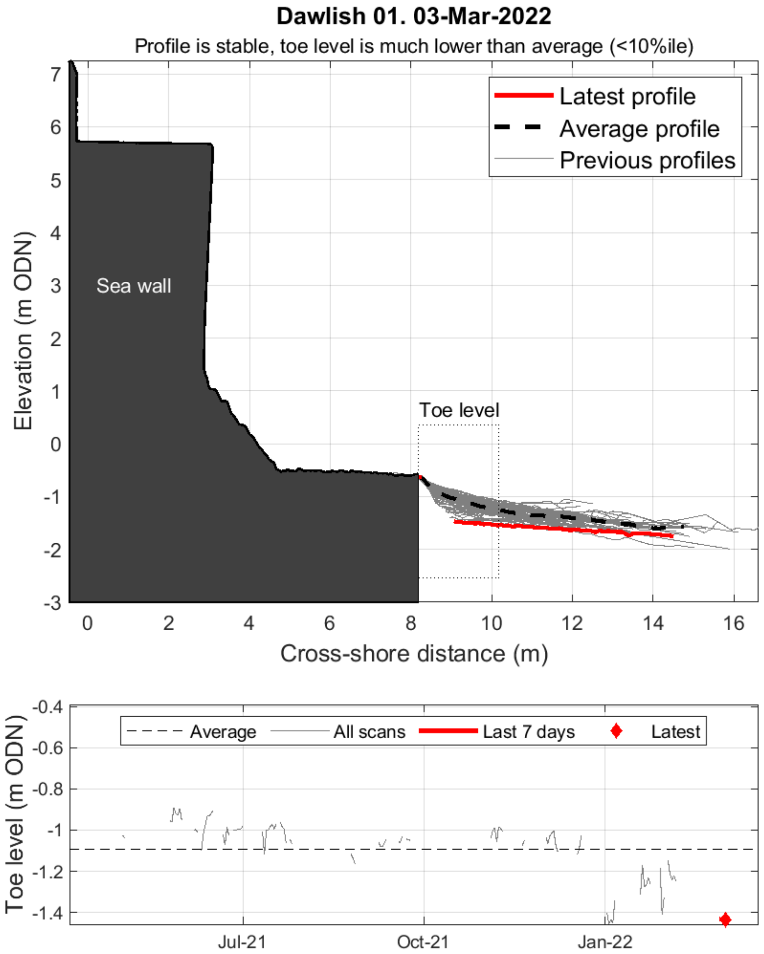


uncertainty due to water level



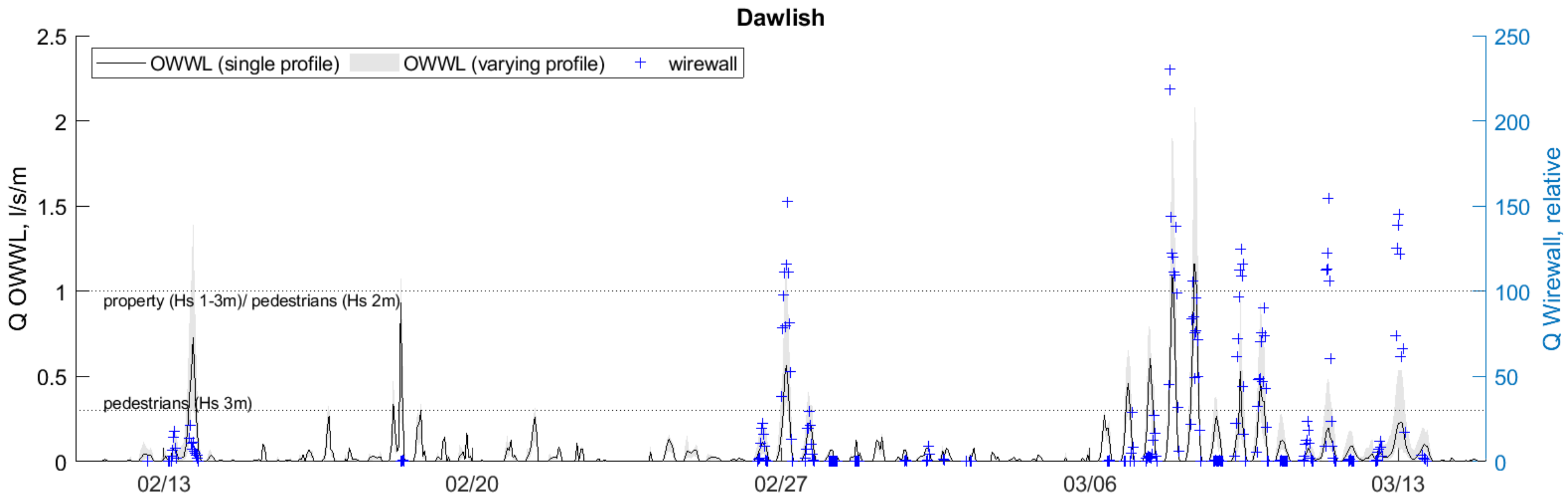
- OWWL's Delft3D model reproduces tide gauge data to within approx. 10 cm
- To test impact of this, water level varied by +/-10cm
- This varied overtopping discharge, Q by +/- 0.15 times

Uncertainty due to beach profile



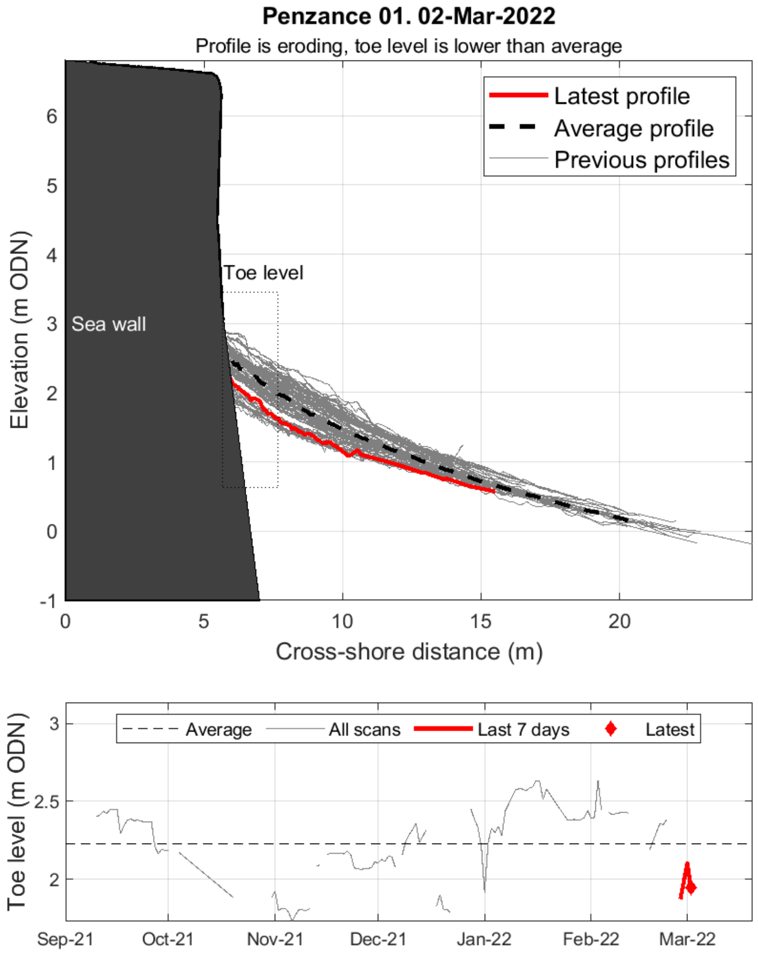
- At Dawlish, a 'toe mound' on the seawall limited the detectable beach area
- Beach level in front of the toe varied by approx. +/- 0.5 m
- 4 reliable scans of the low tide beach were achieved between 11/02/22 – 11/03/22
- For OWWL, the missing 'subtidal' part of the profile is interpolated out to the depth of wave forcing

Uncertainty due to beach profile



- Predicted Q at Dawlish was on average 1-2 times higher when toe level was at its lowest than at its highest
- Beach level variation was enough to alter the hazard warning by at least one level on each major event

Uncertainty due to beach profile



- At Penzance, a greater length of beach was measured
- Beach level in front of the toe varied by approx. +/- 1 m
- 16 reliable scans of the low tide beach were achieved between 11/02/22 – 11/03/22
- For most tides, an ‘emergent’ (dry) seawall toe meant no reliable EurOtop prediction could be made, despite considerable overtopping occurring
- Calibrating an overtopping equation for a dry seawall toe would be a useful contribution from the present data set

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Uncertainty due to wind

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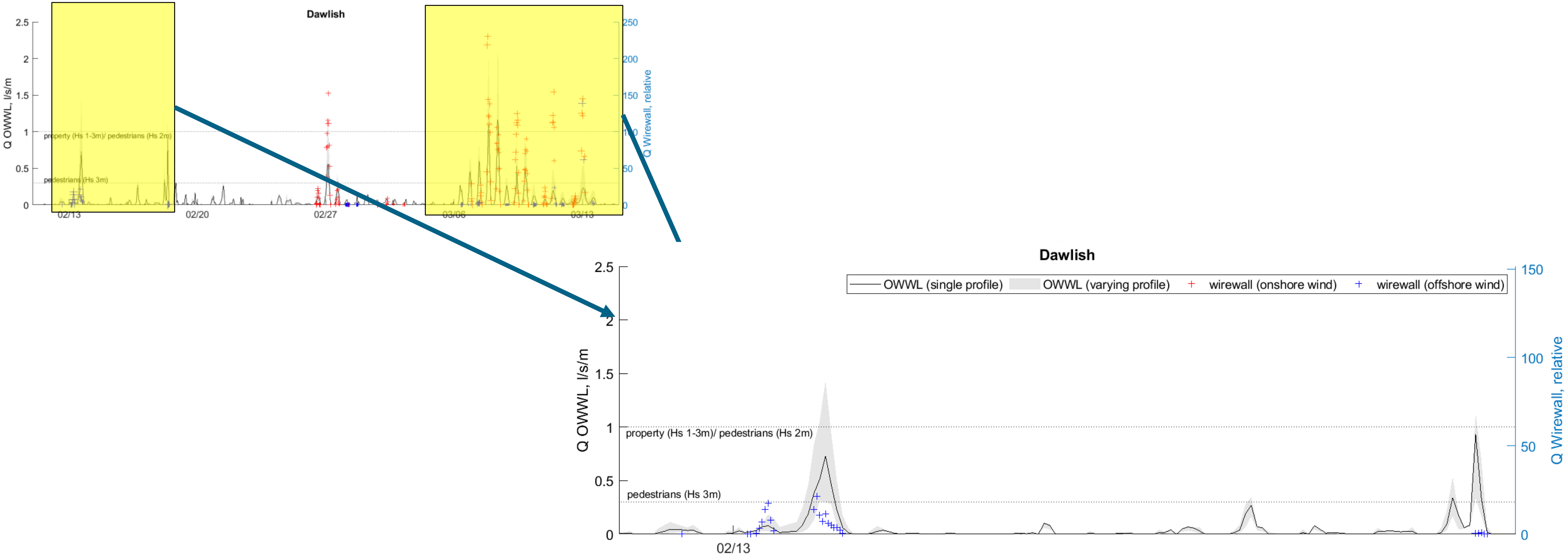

- No reliable wind influence factors currently available for EurOtop equations
- Measured overtopping magnitude appears to be 2-4 times higher (lower) than predicted when wind is blowing onshore (offshore)

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Other sources of uncertainty

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- Subtidal profile
- Nearshore wave shoaling
- Choice of EurOtop equation
- Alongshore variation – huge difference!

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Conclusions

- Forecasting wave overtopping hazard will be increasingly important as sea levels rise to help communities prepare for nuisance and extreme coastal flooding events

- A multi-model approach is required to forecast wave overtopping discharge/hazard, which incurs various sources of uncertainty

- Using novel field measurements we have started to look at the relative importance of these uncertainties on the predicted overtopping rate, Q:

    - *Wave forcing* (2-4 times variation in Q over study period)
    - *Water level forcing* (0.15 times variation in Q over study period)
    - *Coastal profile* (1-2 times variation in Q over study period, order of magnitude for older profiles)
    - *Onshore/offshore wind* (2-4 times variation in Q over study period)

- Real time field measurements complement forecast systems:
    - will help to quantify and reduce these uncertainties
    - and can provide real-time warnings at key locations