Rogue waves in UK coastal waters

Investigating the nature and dynamical properties of rogue waves

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Background

Rogue waves are wind-generated surface waves which are much larger than the background waves.

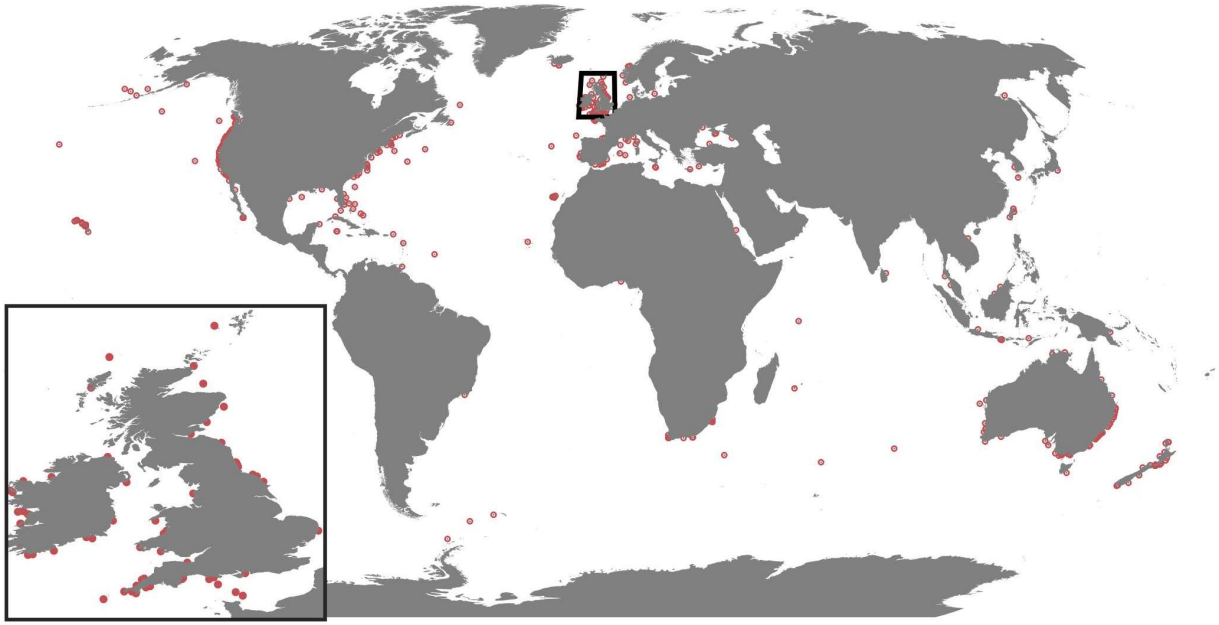
What is a rogue wave?

A wave whose maximum height exceeds twice the significant wave height (H_s or H_{m0}):

$$\frac{H_{max}}{H_s} > 2$$

Rogue waves are a marine hazard

Extreme heights, steep wave fronts, and groups - no accurate forecast



2005-2021 - (Didenkulova et al., 2022)

Past research

In 1995, the first reliable measurement of a rogue wave was made – the Draupner wave.

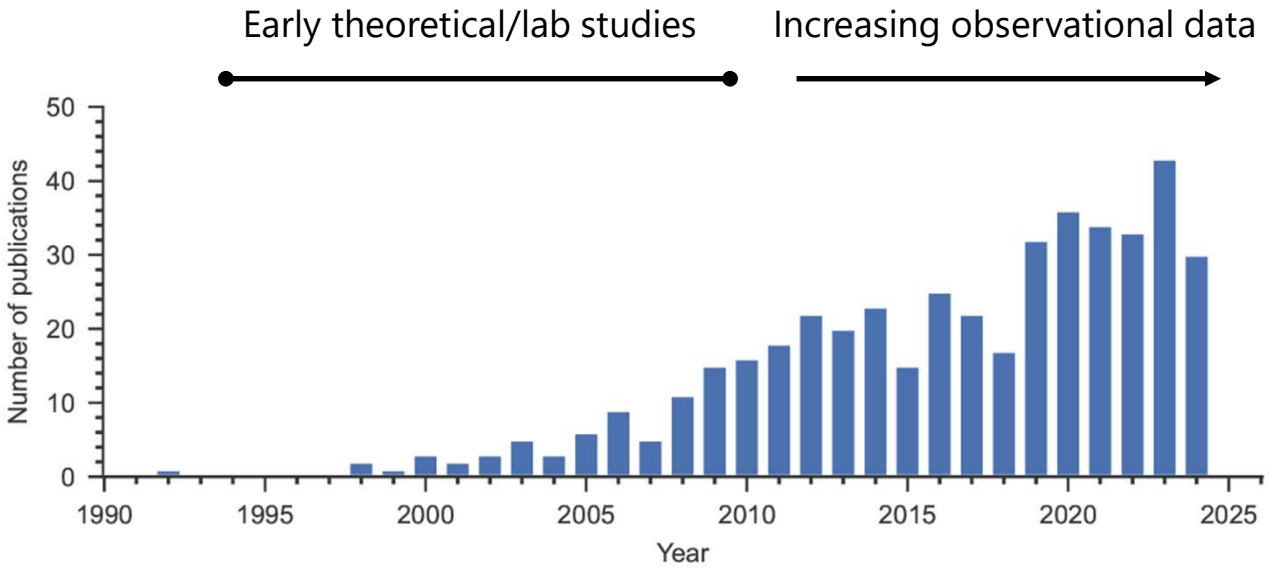
*Environmental factors e.g. Wave-current interaction

Generation mechanisms?

Linear superposition (dispersive focussing) vs. non-linear (modulation instability)*

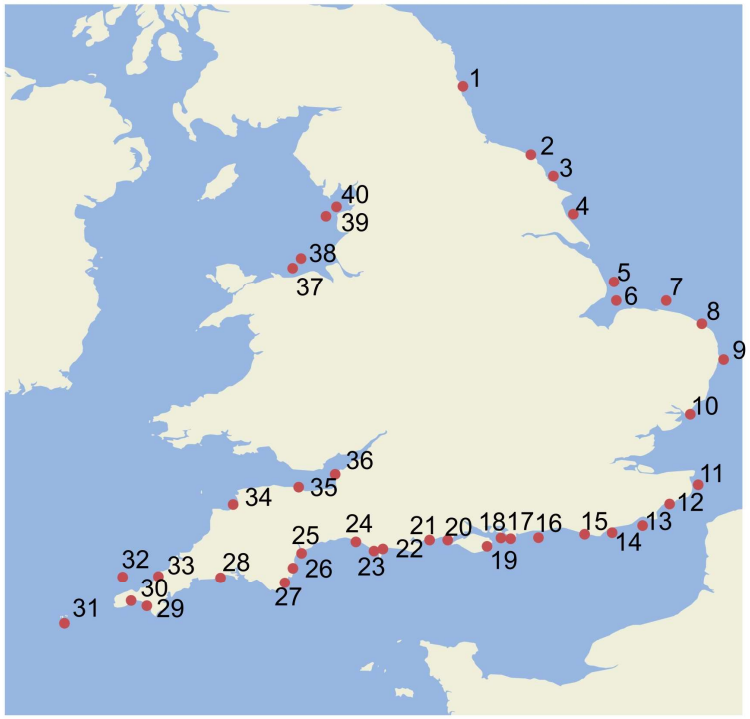
Linear dispersive focussing is thought to be dominant (Christou & Ewans, 2014; Fedele at al. 2016; Hafner et al. 2021; Teutsch & Weisse, 2023)

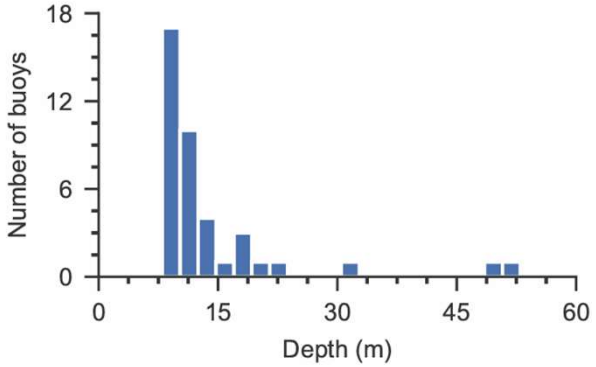
Sea state parameters rogue wave occurrence

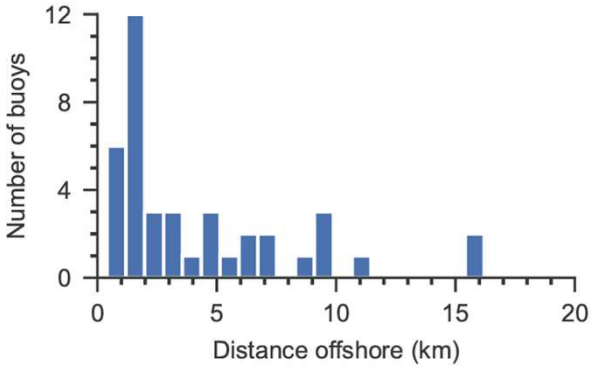


Dataset – Channel Coastal Observatory

Better understand coastal rogue waves (occurrence & generation mechanisms)







Methodology

1

Preprocessing

Combine raw data into structured netCDF format

2

Processing

Complete wave-by-wave analysis and compute sea state statistics

3

Postprocessing

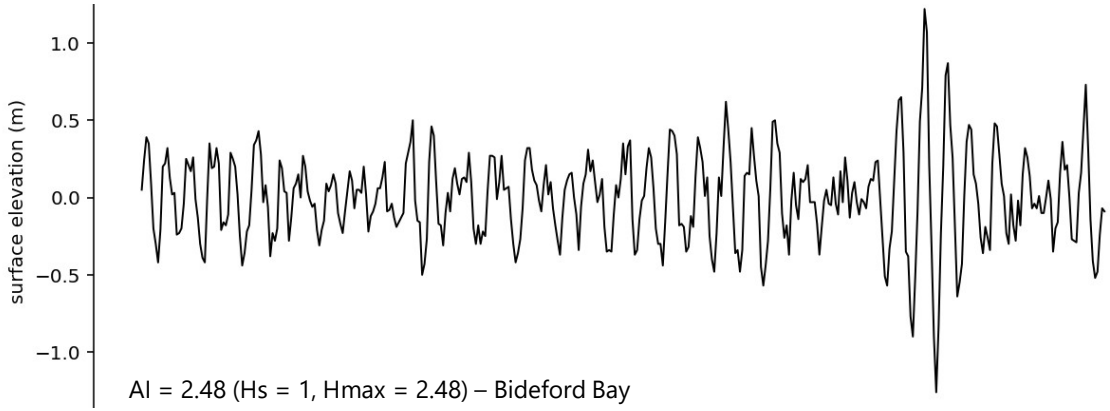
Filter waves

4

Analysis

Look for relationships between sea states and rogue waves

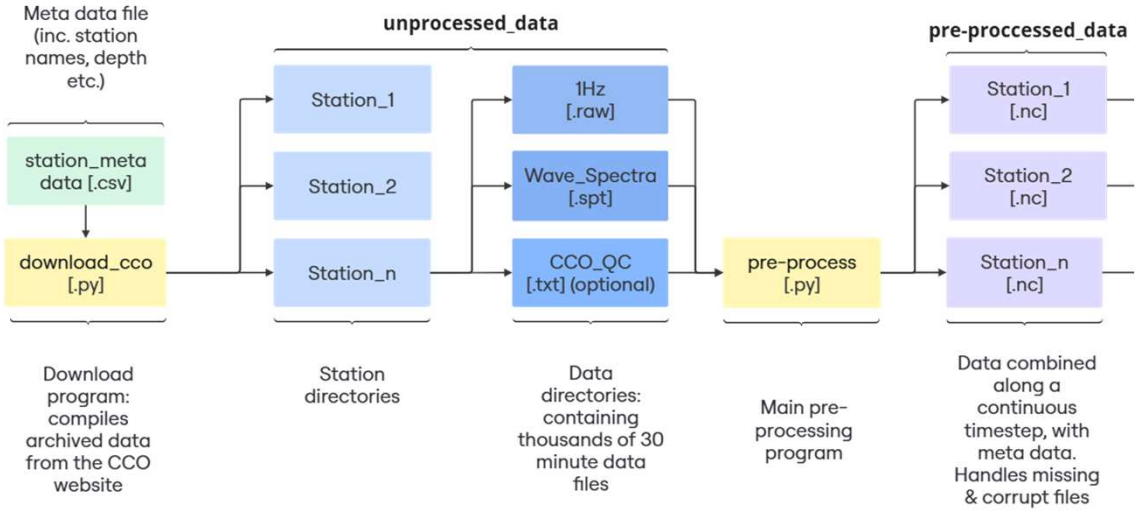
In progress...

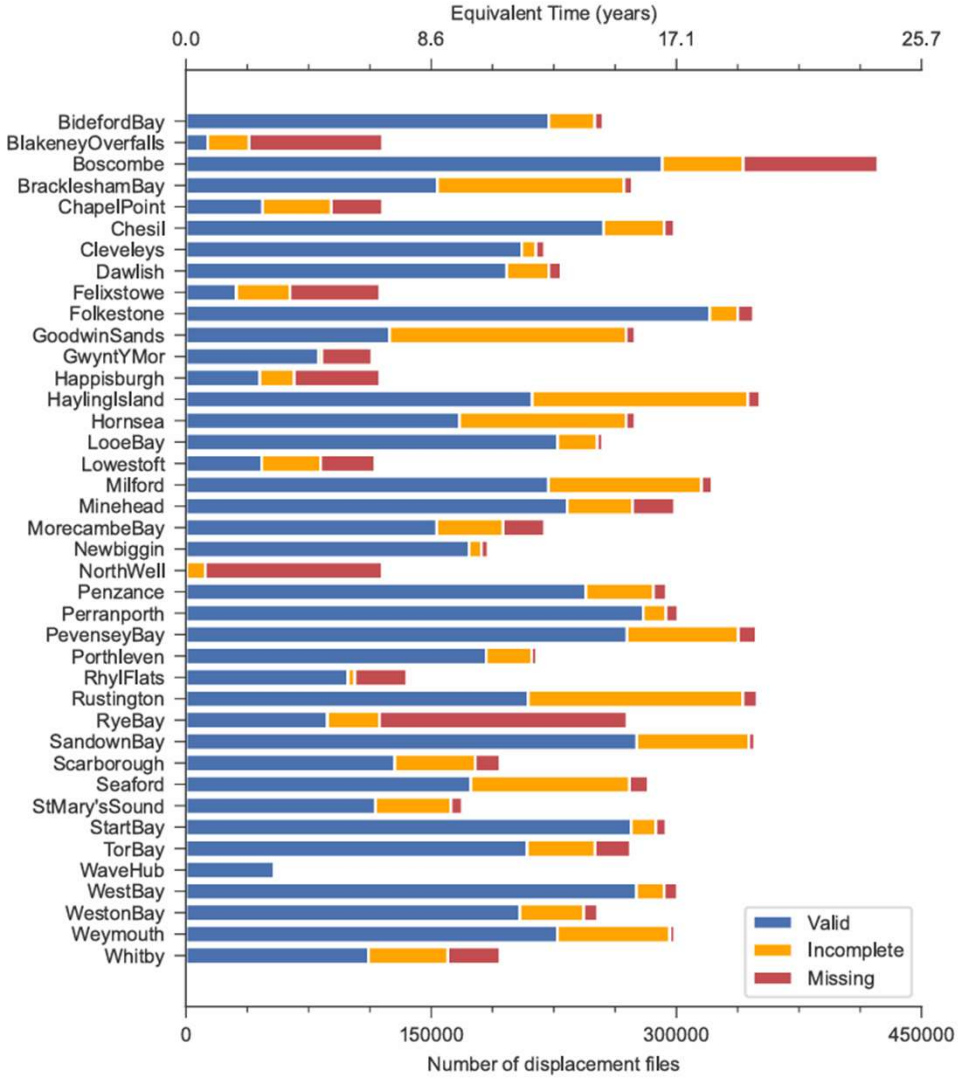


Preprocessing

- 8.5 million .raw (30-min) displacement files (480 years)
- 9 million .spt spectra files

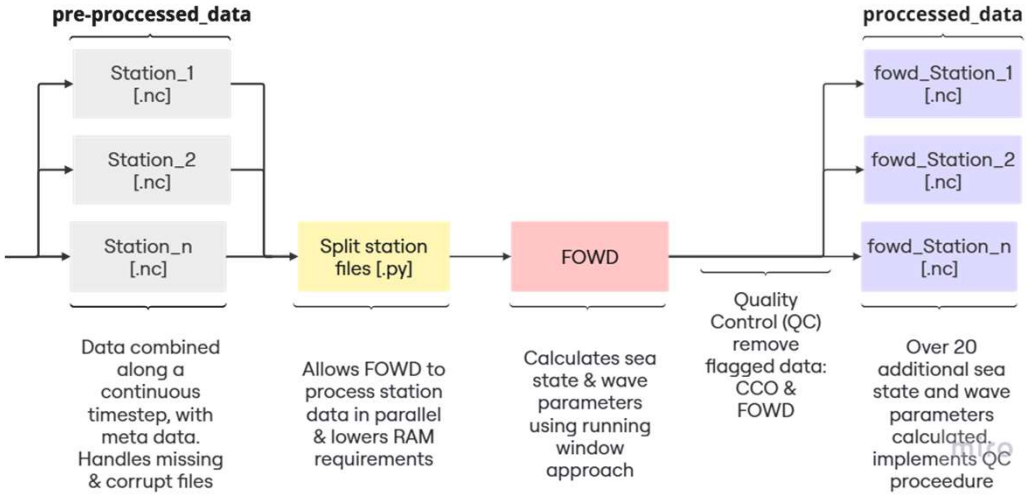
- 21% are incomplete
- 10% are missing

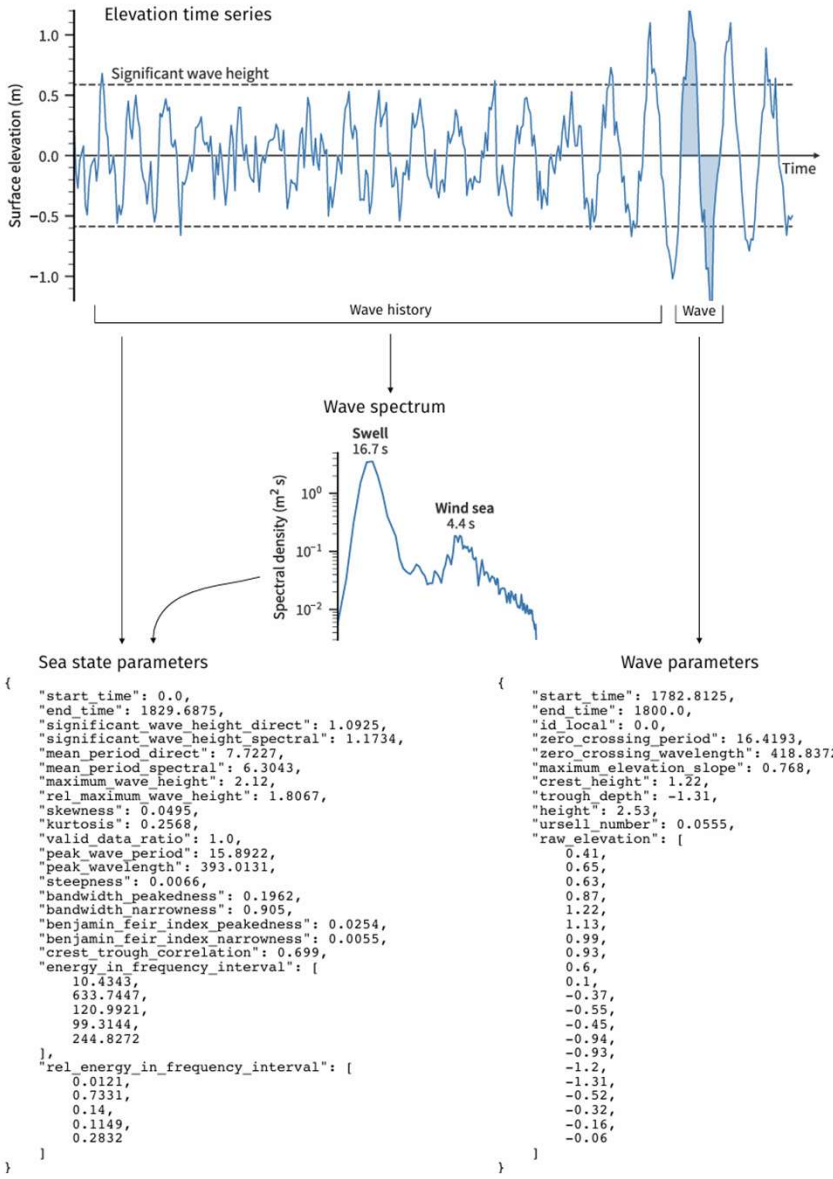




Processing

- Wave-by-wave analysis (Free Ocean Wave Dataset processing tool - Hafner et al. 2021)
- Running window approach (10 min, 30 min, dynamic)

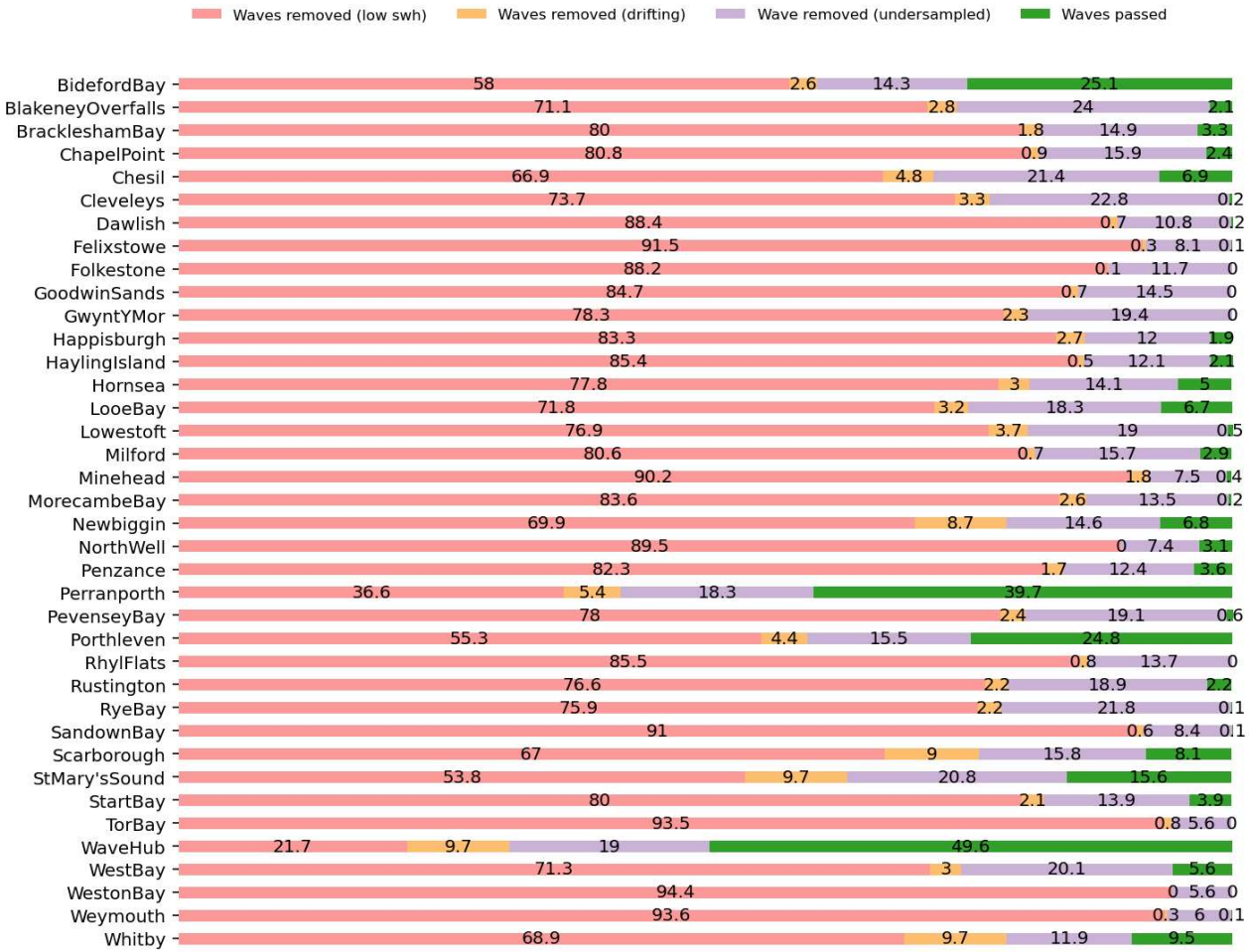




Postprocessing

Filters:

1. Hs less than 1 m
2. Mean period less than 5 s (Nyquist frequency)
3. Relative energy of low frequency band exceeds 10% of the total energy



Initial results

WAVE PROCESSED

2.37 bn

Across 38 stations

REMAIN AFTER FILTERING

5%

120 million waves

ROGUE WAVES

9,436

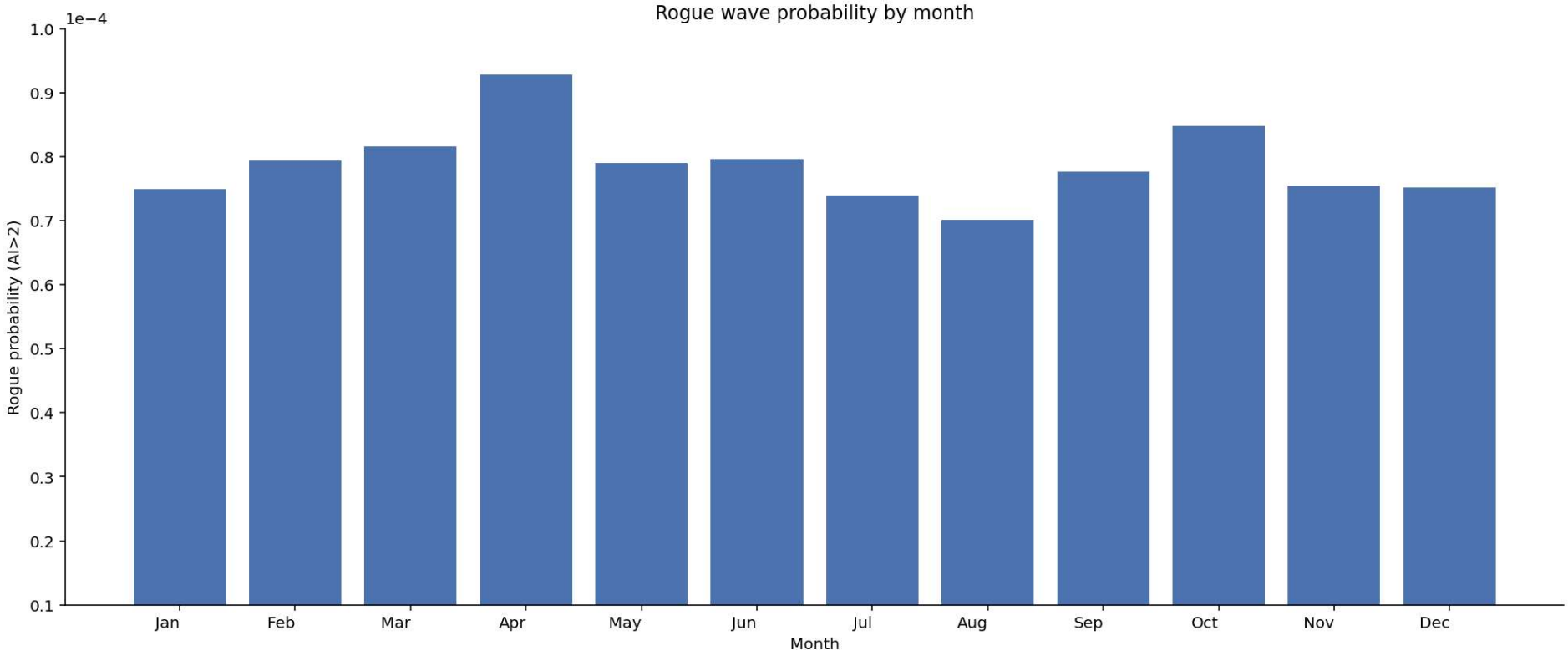
1 in 13,000 waves are rogue

1 in 3,000 (linear theory)

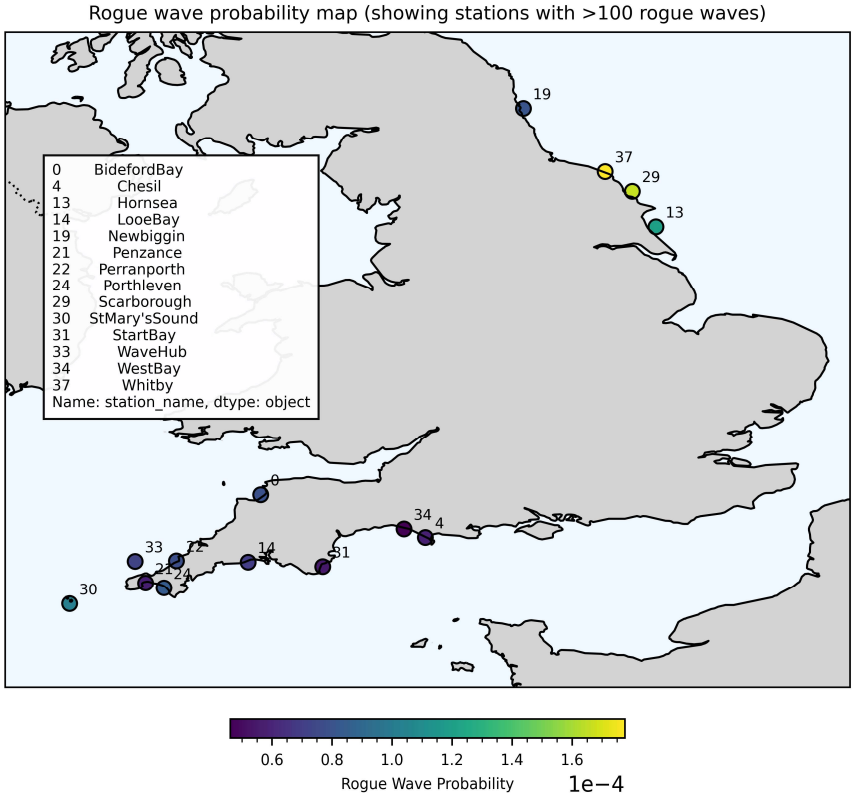
1 in 8,000 (James & Panchang, 2025)

1 in 15,000 (Hafner et al. 2021)

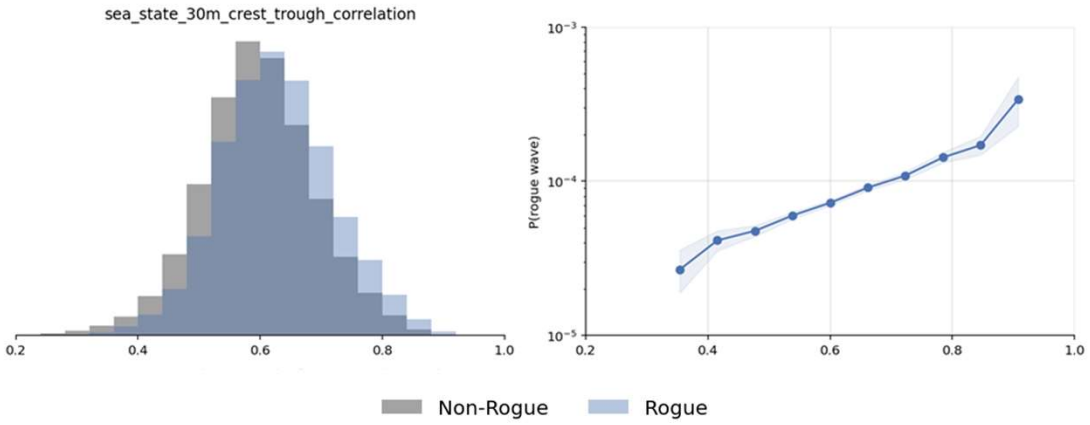
Temporal analysis



Analysis



- Probabilities vary by 2x
- Crest-to-trough correlation remains a strong predictor



Summary

- 1 in 13,000 waves are rogue (AI>2)
- 13 sites with over 100 rogue waves
- Most data on SW coast
- Crest-to-t
  strong pre

Future work

- Temporal evolution of parameters
- Look for other predictors
- Stratify data by region, wave conditions

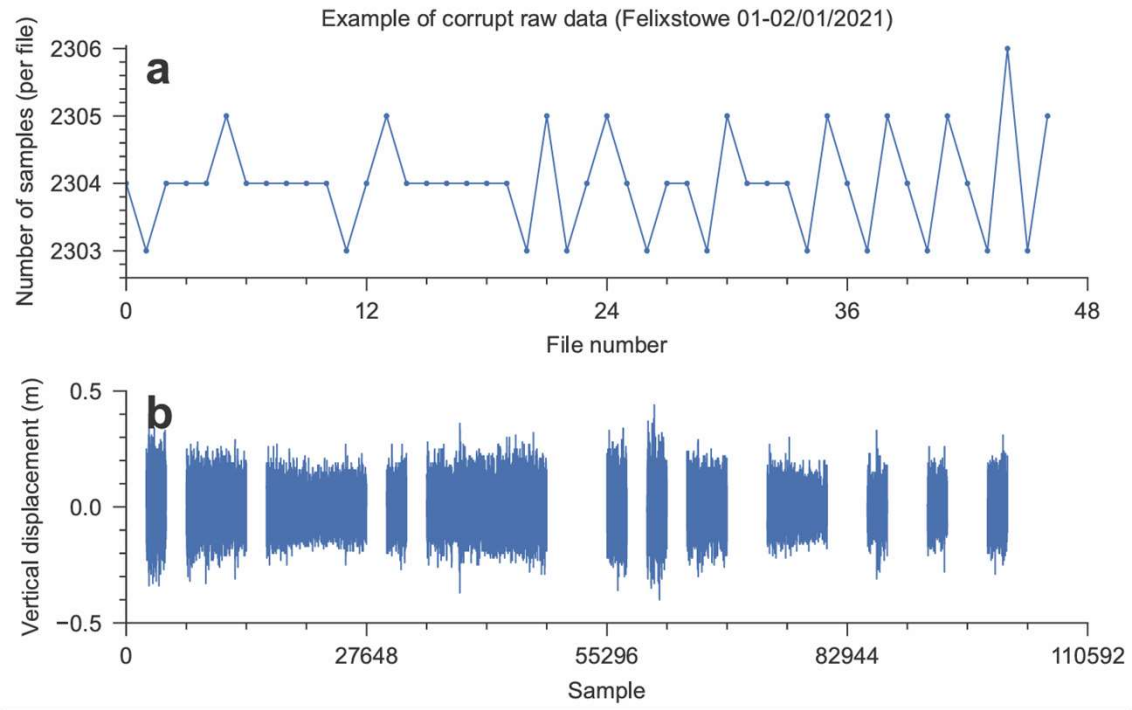
Thank you for listening

Further analysis & write-up in progress… (full & filtered processed dataset will be published)

Extra slides…

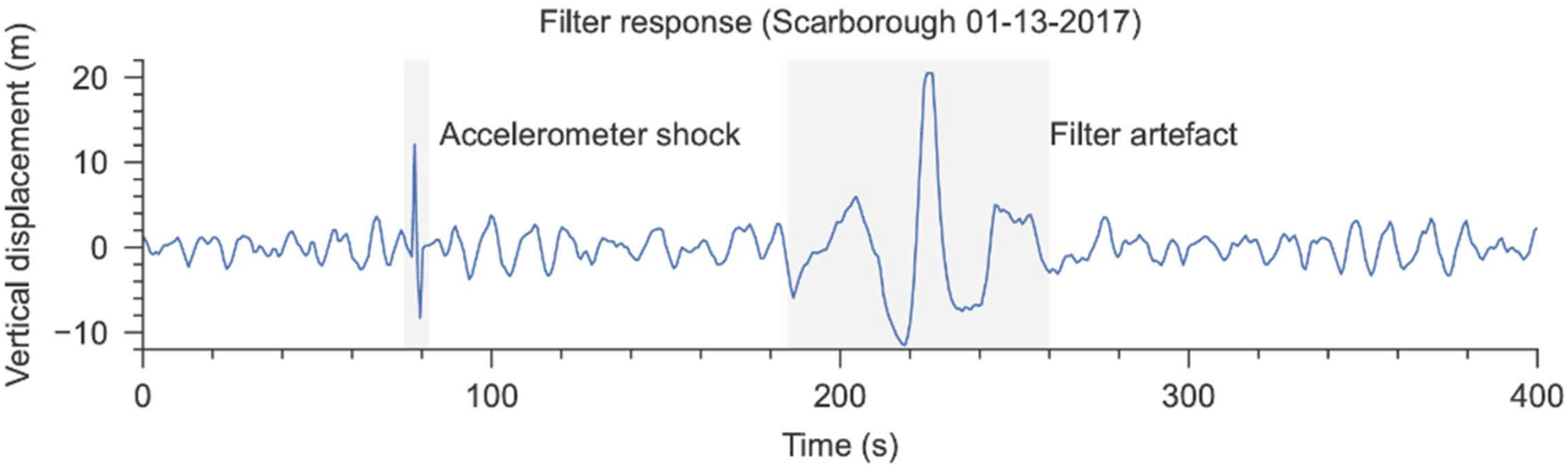
Challenges (1)

High frequency radar transmission (from wave buoy to receiver) can result in missing data.
Solution: These files with missing data are replaced with NaN values.

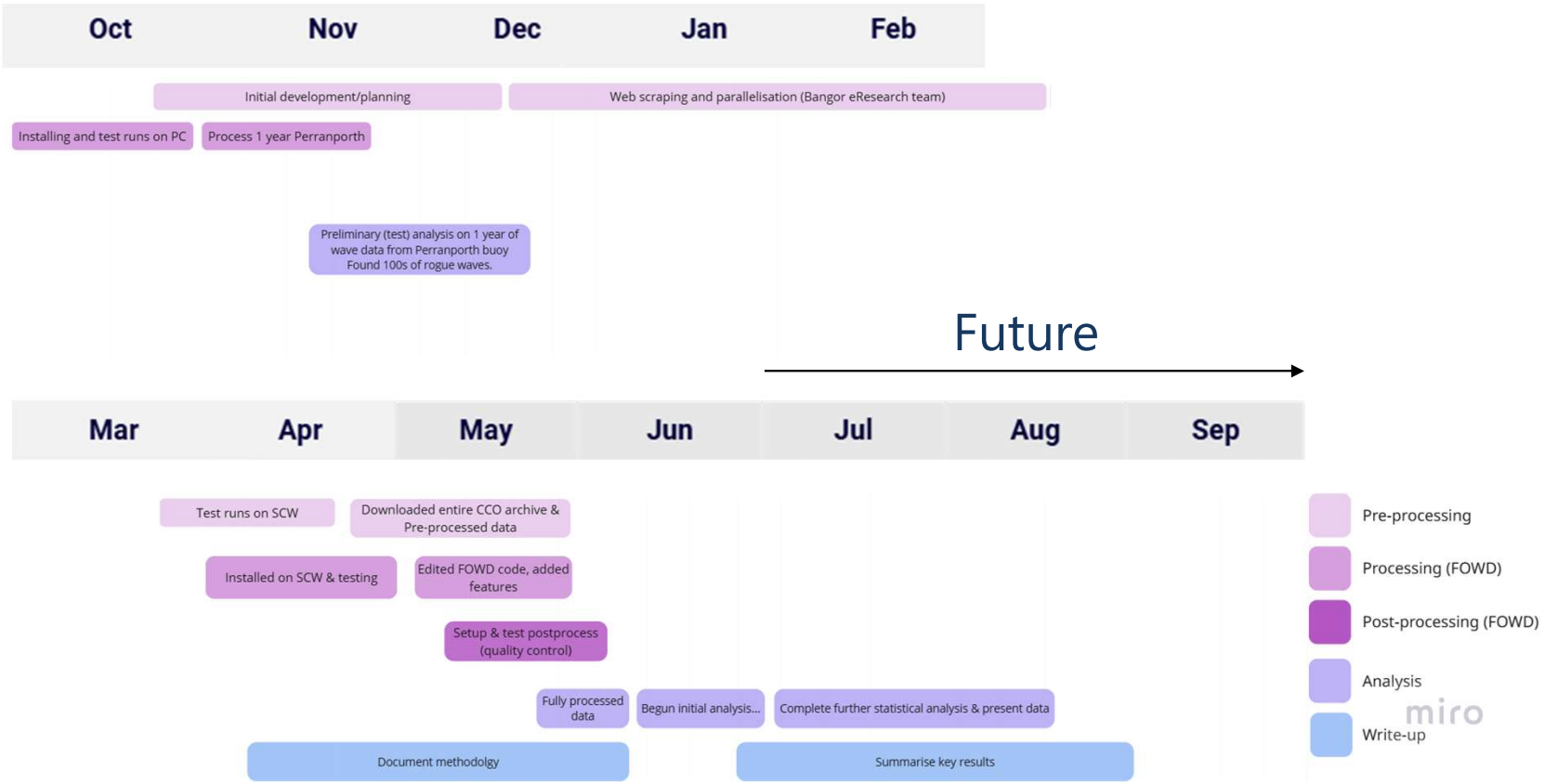


Challenges (2)

A common issue with raw data from the Datawell Waverider buoys is the **filter artefact**
Solution: We attempt to remove these data points in QC
… However, some remain in the processed data.



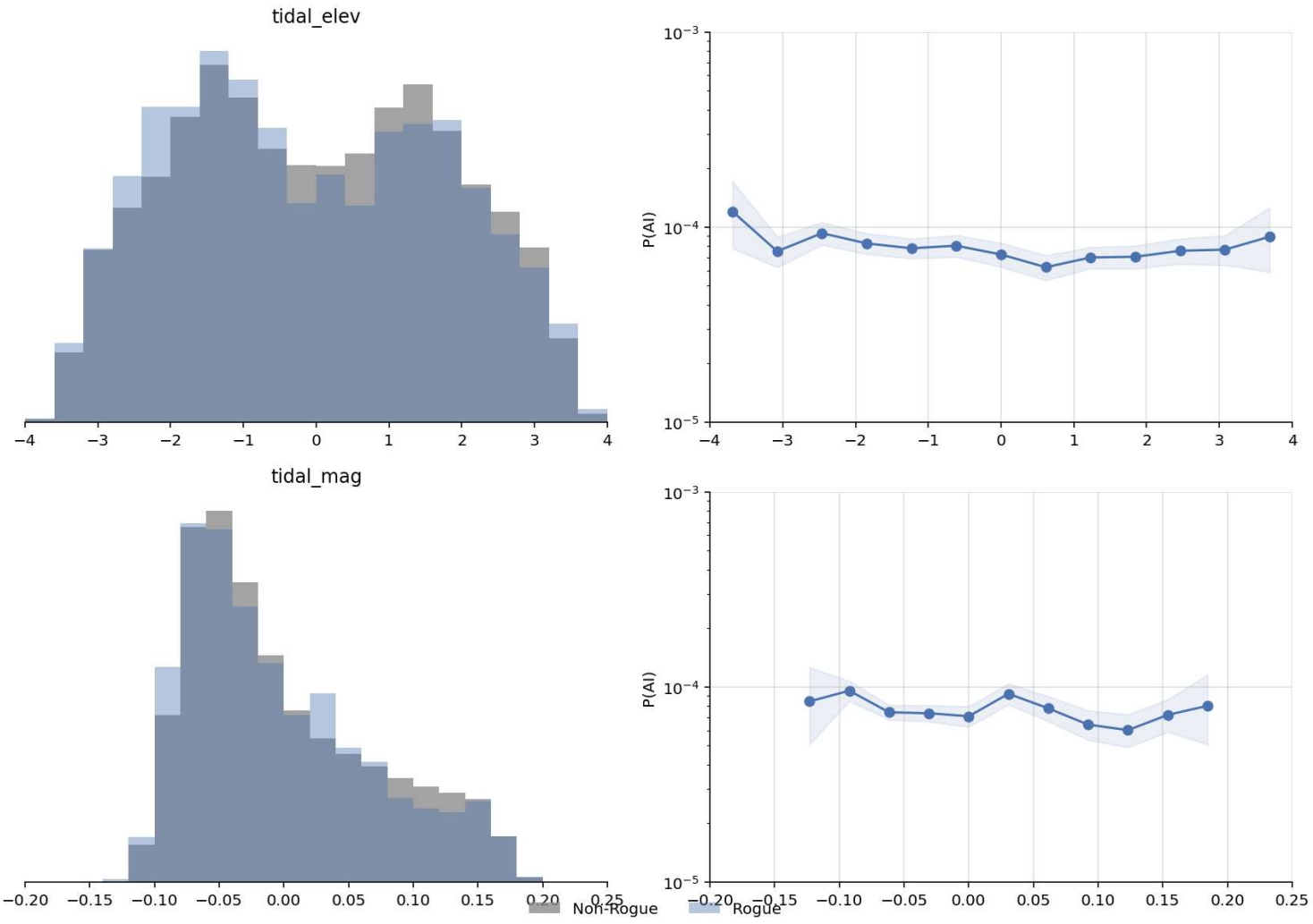
Progress timeline

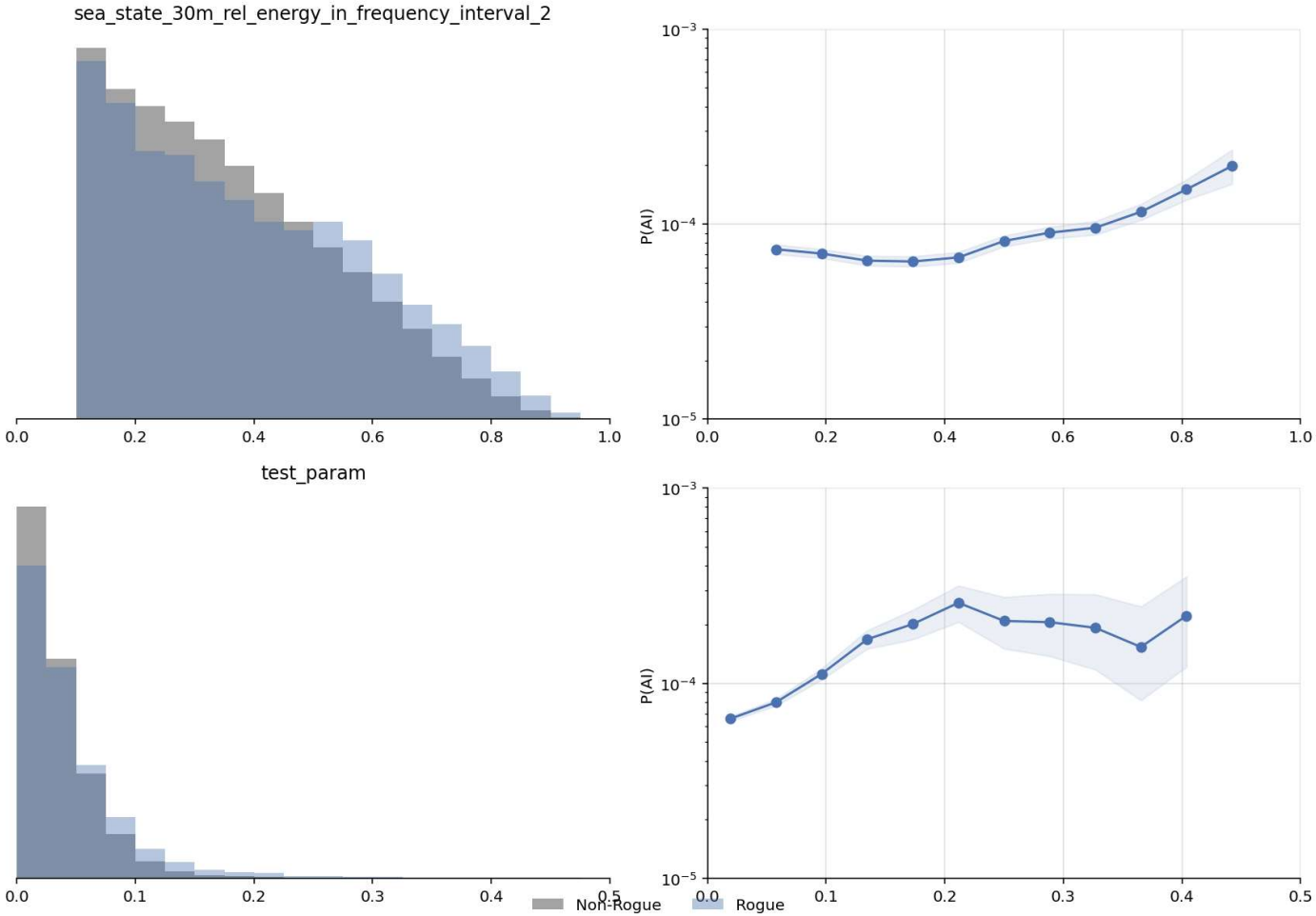


An investigation of rogue waves in UK coastal waters (James & Panchang, 2025)

- Data spanned from 2014.01 - 2020.12
- Sea state parameters are calculated from the preceding 30-minute sample. Then the probability of a rogue wave occurring in the next sample is used.
- No wave-by-wave analysis
- Found 1 in 8,000 waves were rogue
- Found that relative depth is a strong predictor – we did not find this to be true in our analysis.

Perranporth tidal test – ran a harmonic prediction from 30 model timeseries




sea_state_30m_rel_energy_in_frequency_interval_2
test_param
P(AI)
P(AI)
Non-Rogue
Rogue