10 September 2025

MAKING A SPLASH: HOW DIGITAL TOOLS ARE REVOLUTIONISING WAVE OVERTOPPING PREDICTION

National Oceanography Centre

Magda Juarez Olaya, RSE; Colin Sauze, Senior RSE

CONTENTS OVERVIEW

01 Section 1

Wave Overtopping

This section includes:

02 Section 2

What we do about this?

This section includes:

03 Section 3

Wave overtopping prediction with SPLASH

This section includes:

WAVE OVERTOPPING PREDICTION WITH SPLASH

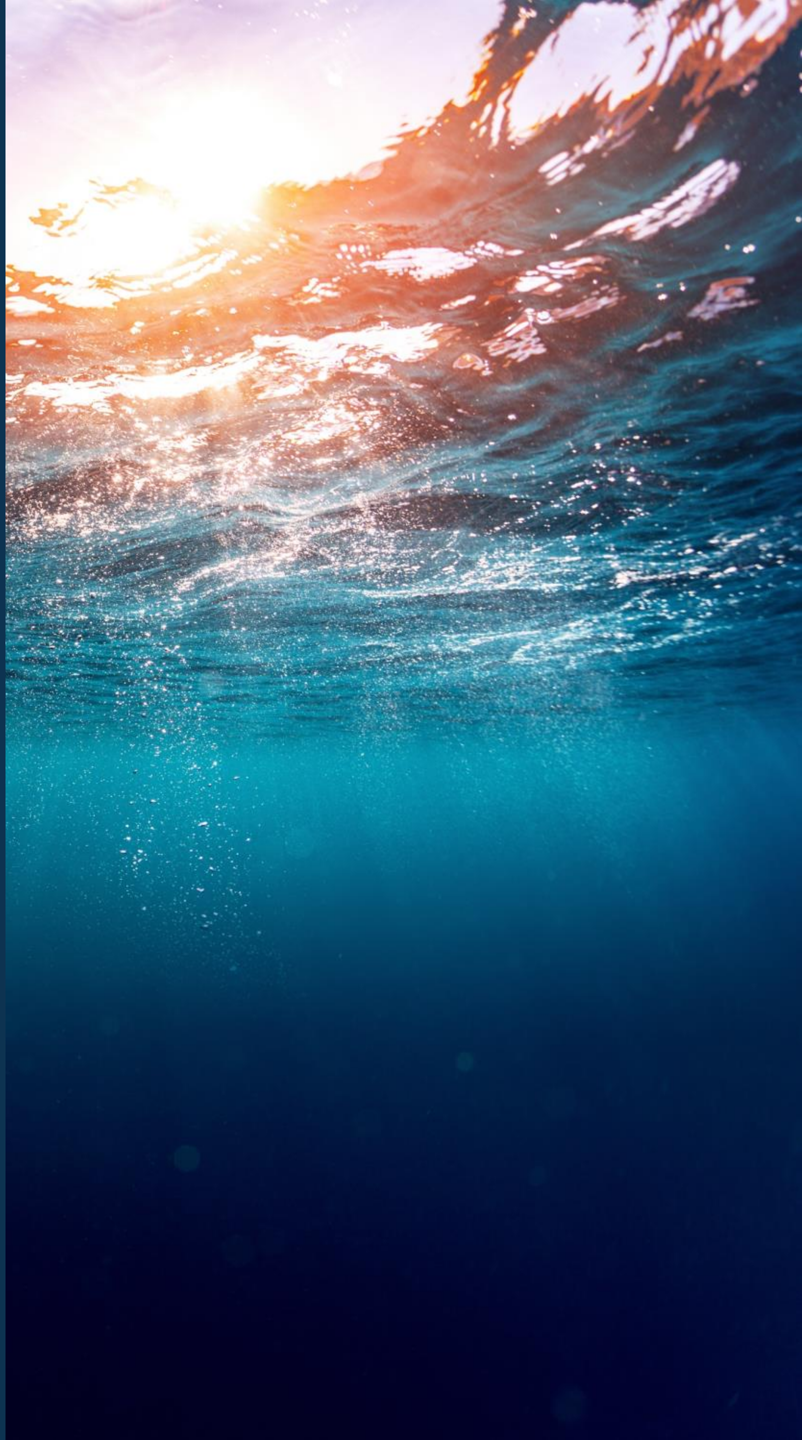
SPLASH

DIGITAL APPROACHES TO PREDICT WAVE OVERTOPPING HAZARDS

plotly

- SPLASH dashboard is an **environmental digital twin** able to forecast and visualise wave overtopping events to support coastal communities in high-risk flooding areas.
- This dashboard **predicts wave overtopping** events in **Dawlish** and **Penzance** from today up to 5 days ahead.
- This rich interactive web-based visualisation was built by using **Plotly Dash** library.

WAVE OVERTOPPING



WAVE OVERTOPPING - A MORE FREQUENT HAZARD

Flooding is probably one of the most destructive environmental hazards. Impacts include damage to homes, businesses and infrastructure near the shore like roads, railways and potential risks to safety and wellbeing.

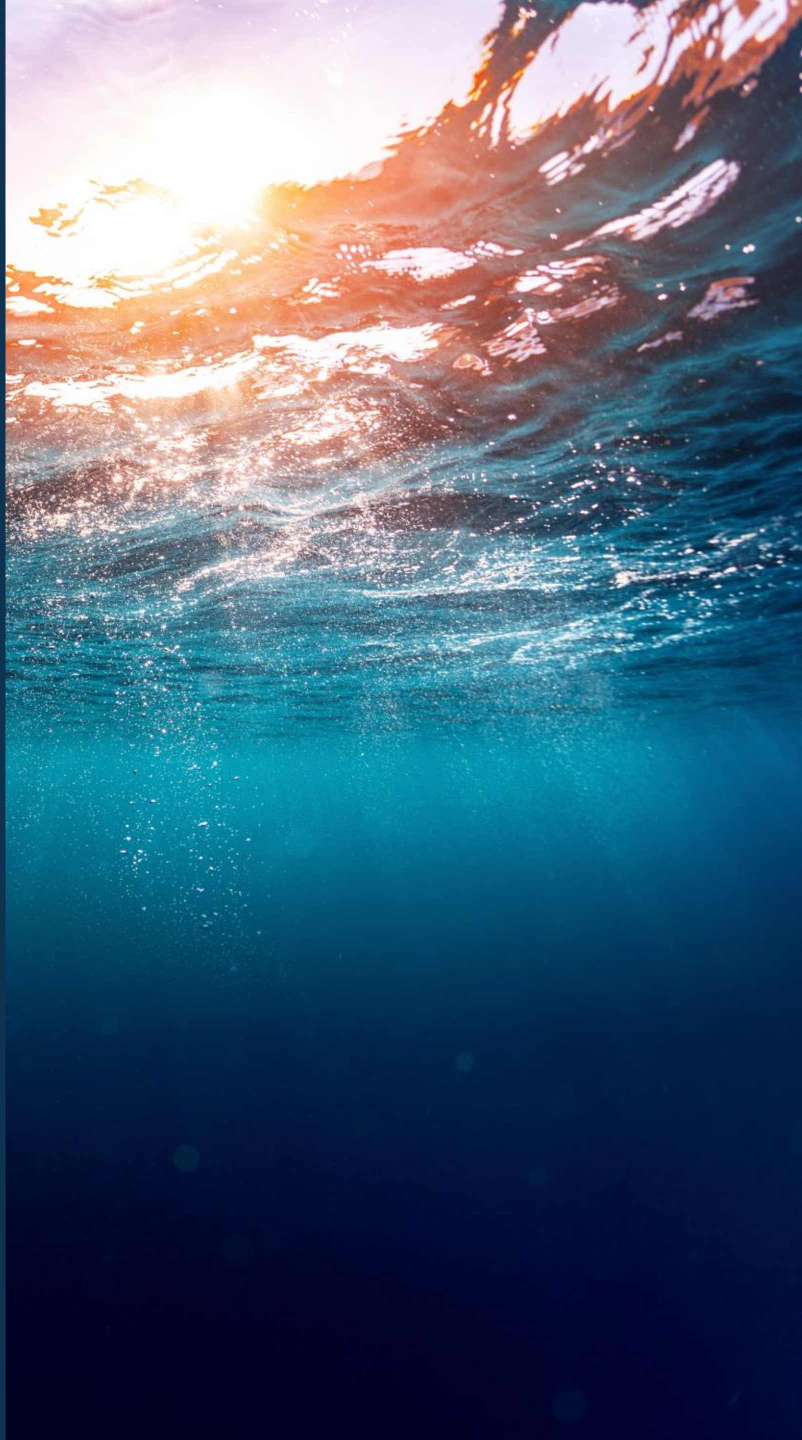
WAVE OVERTOPPING - A MORE FREQUENT HAZARD

Storms in the UK	Affected Area	Impacts
Petra (4th - 5th of February 20214)	Newlyn, St Mawes Perranporth, Looe, Kingsand, Cawsand, Plymouth, Torcross, Dawlish, Exmouth, Devon and Cornwall.	• Up to 150ft (46m) of railway track has been destroyed and Dawlish station has also been damaged. • £50 million in infrastructure damage.
Babet (16th – 21st October 2023)	Easter Scotland, Northern Ireland and northern England	• Damage cost exceeded £495 million.
Gerrit (27th – 28th December 2023)	Wales, northwest England and Scotland.	• Major railways disruptions and motorway closures. • 3 fatalities • £21 million transport losses.
Agnes (27th – 28th September 2024)	Cumbria and south-west Scotland	• Thousands without power, many homes and businesses flooded.

WAVE OVERTOPPING - A MORE FREQUENT HAZARD

Storms around the world	Affected Area	Impacts
Hurricane Milton (October 10th 2024)	Florida, USA	• 14 fatalities • 3.5 million power outages • £85 billion in infrastructure damages.
Typhoon Haikui (27th of August – 6th of September)	Taiwan	• 16 fatalities • $683 million damages

WHAT DO WE DO ABOUT THIS?



CURRENT CHALLENGES IN WAVE OVERTOPPING PREDICTION

01

Empirical and process-based modelling approaches to predict wave overtopping discharge at seawall.

CURRENT CHALENGE

Wind effects are oversimplified due to insufficient empirical understanding.

EurOtop

SWASH
Simulating WAves till SHore

02

Systems to forecast and forewarn against coastal overtopping

CURRENT CHALENGE

These models are computationally expensive. OWWL does not include wind speeds for overtopping prediction.

sweep OWWL Operational Wave & Water Level Model

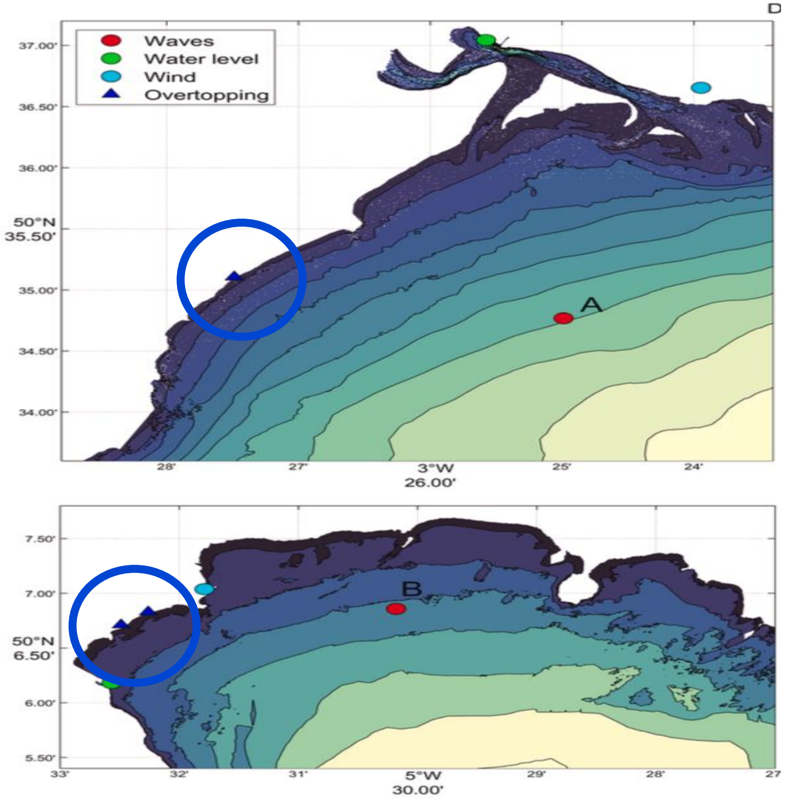
RISC-KIT Toolkit

THE WIRE-WALL AND AI MODELS

- WireWall is an in-situ system developed by NOC (National Oceanography Centre) that records field observations of wave overtopping.

https://www.youtube.com/watch?v=dd6QHjHuHYc

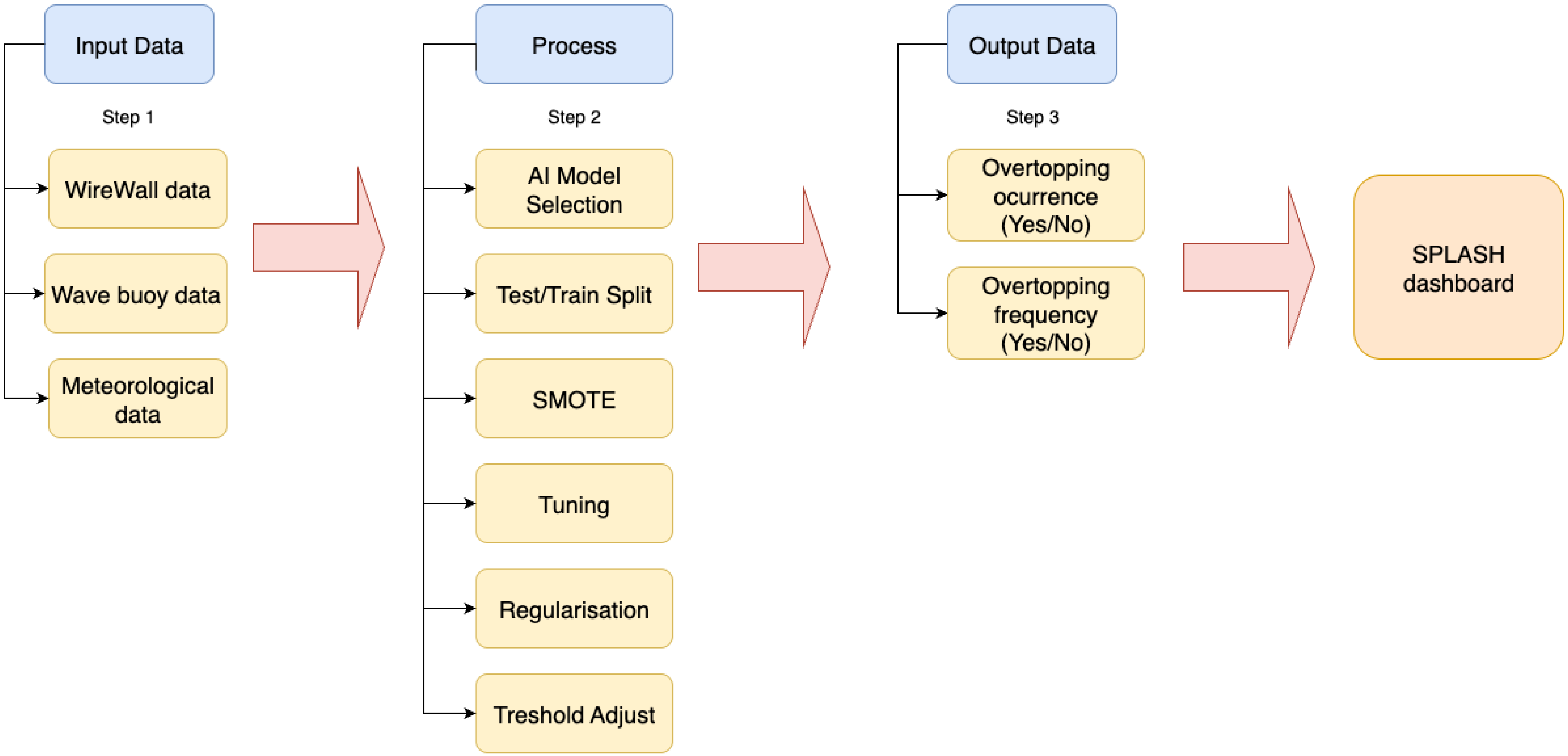
- Dawlish and Penzance are exposed to frequent wave overtopping and flooding.
- WireWall was installed on both locations.



- Several studies have investigated training AI models to predict wave overtopping but these rely on datasets used by EUROTOP.

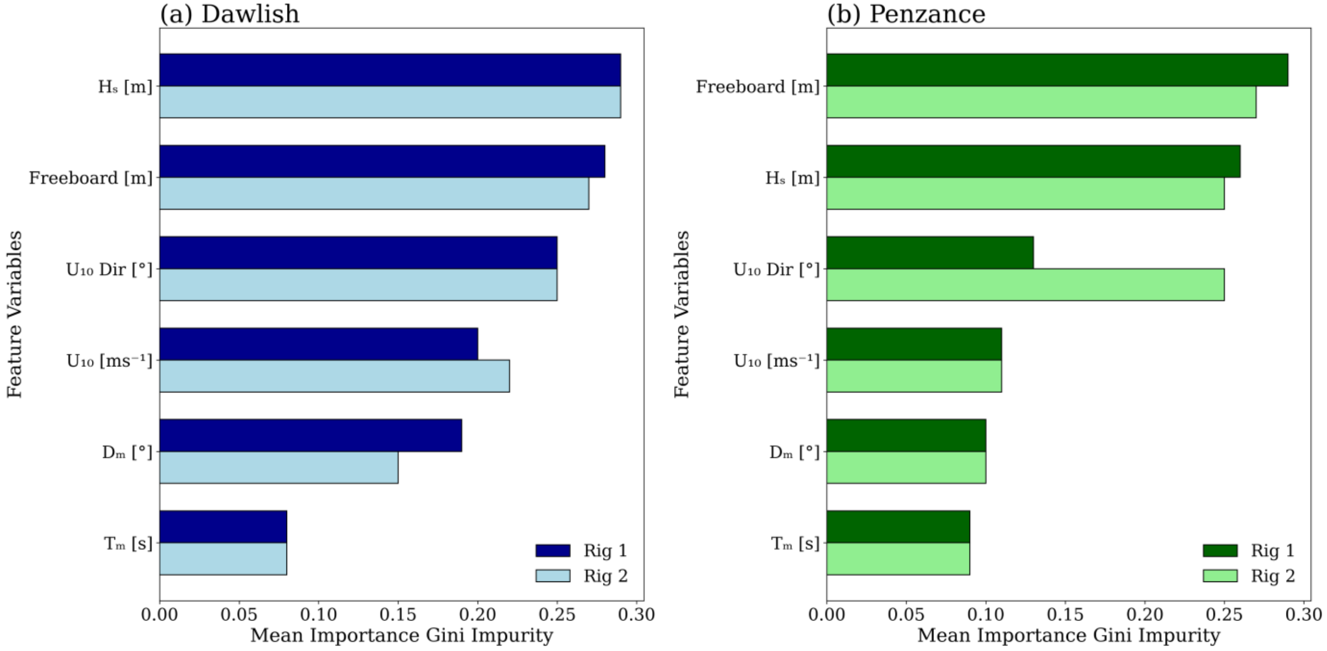
WHAT ARE WE DOING ABOUT THIS?

OUR APPROACH



STEP 1 – DATA PROCESSING

- Random forest variable importance metric (VIM) was used to determine any relevant feature variables to predict wave overtopping.
- The AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion) assessed the effectiveness of different AI models.



Hs: Significant wave height
Freeboard: Tidal level
U10 Dir: Wind direction
U10: Wind speed
Dm: Mean wave direction
Tm: Mean wave period

Reference: Michael McGlade, Nieves G. Valiente, Jennifer Brown, Christopher Stokes, Timothy Poate (2025), Investigating appropriate artificial intelligence approaches to reliably predict coastal wave overtopping and identify proces s contributions (https://www.sciencedirect.com/science/article/pii/S1463500325000137)

STEP2 - AI MODEL RESULTS: BINARY MODEL

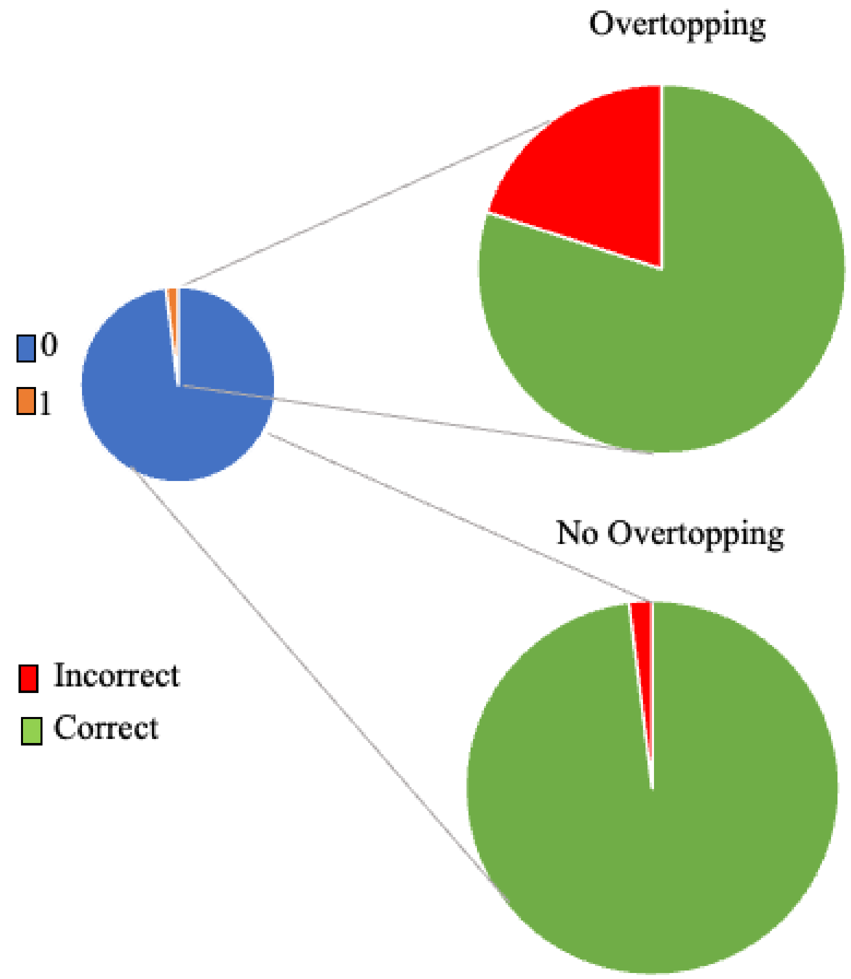


Table 1. AI performance metrics for estimating overtopping occurrence in Dawlish.

Rig	Model	AIC	BIC	F1	Precision	Recall	Accuracy	MMC	Brier Score
	Random Forest	**421**	**467**	**0.83**	**0.85**	**0.80**	**96%**	**0.79**	**0.031**
1	XGBoost	394	345	0.81	0.82	0.79	94%	0.77	0.032
	Neural Network	400	354	0.70	0.72	0.67	93%	0.77	0.032
	Random Forest	**345**	**433**	**0.80**	**0.79**	**0.81**	**97%**	**0.76**	**0.011**
2	XGBoost	367	400	0.78	0.74	0.80	95%	0.71	0.019
	Neural Network	342	361	0.72	0.70	0.74	93%	0.70	0.034

Table 2. AI performance metrics for estimating overtopping occurrence in Penzance.

Rig	Model	AIC	BIC	F1	Precision	Recall	Accuracy	MMC	Brier Score
	Random Forest	**489**	**476**	**0.86**	**0.86**	**0.86**	**97%**	**0.81**	**0.006**
1	XGBoost	467	460	0.85	0.88	0.82	95%	0.80	0.025
	Neural Network	386	311	0.74	0.64	0.87	93%	0.64	0.089
	Random Forest	**345**	**433**	**0.75**	**0.65**	**0.85**	**95%**	**0.71**	**0.032**
2	XGBoost	411	423	0.71	0.77	0.66	92%	0.71	0.023
	Neural Network	364	334	0.59	0.70	0.74	84%	0.70	0.034

Reference: Michael McGlade, Nieves G. Valiente, Jennifer Brown, Christopher Stokes, Timothy Poate (2025), Investigating appropriate artificial intelligence approaches to reliably predict coastal wave overtopping and identify proces s contributions (https://www.sciencedirect.com/science/article/pii/S1463500325000137)

STEP 2 - AI MODEL RESULTS: REGRESSION MODEL

Predictions are satisfactory for linear statistical tests:

We use non-linear L1 norm stats: The Euclidean distance < 12%

Table 3. AI model performance for estimating wave overtopping frequency in Dawlish.

Rig	Model	R^2	RMSE	MSE	MAE	Mean Bias	T-Test
1	**Random Forest**	**0.81**	**3.05**	**9.28**	**0.66**	**0.11%**	**t = 1.37; p = 0.17**
	XGBoost	0.77	3.28	10.7	0.69	0.01%	t = 0.15; p = 0.88
	Neural Network	0.45	5.1	26	2.43	0.83%	t = 6.42; p = < 0.01
2	**Random Forest**	**0.76**	**1.90**	**3.62**	**0.23**	**0.08%**	**t = 0.55; p = 0.58**
	XGBoost	0.53	2.65	7	0.30	0.16%	t = 1.03; p = 0.30
	Neural Network	0.45	2.85	8.14	1.08	0.83%	t = 5.57; p = 0.675

Table 4. AI model performance for estimating wave overtopping frequency in Penzance.

Rig	Model	R^2	RMSE	MSE	MAE	Mean Bias	T-Test
1	**Random Forest**	**0.84**	**7.87**	**6.91**	**2.53**	**0.35%**	**t = 2.33; p = 0.434**
	XGBoost	0.81	8.70	7.54	2.74	0.44%	t = 0.12; p = 0.322
	Neural Network	0.52	13.7	18.9	6.22	1.22%	t = 1.33; p = < 0.01
2	**Random Forest**	**0.84**	**15.3**	**2.33**	**11.8**	**0.07%**	**t = 3.42; p = 0.233**
	XGBoost	0.80	9.88	9.71	8	0.33%	t = 5.66; p = 0.122
	Neural Network	0.92	1.22	1.22	3	0.18%	t = 2.22; p = 0.543

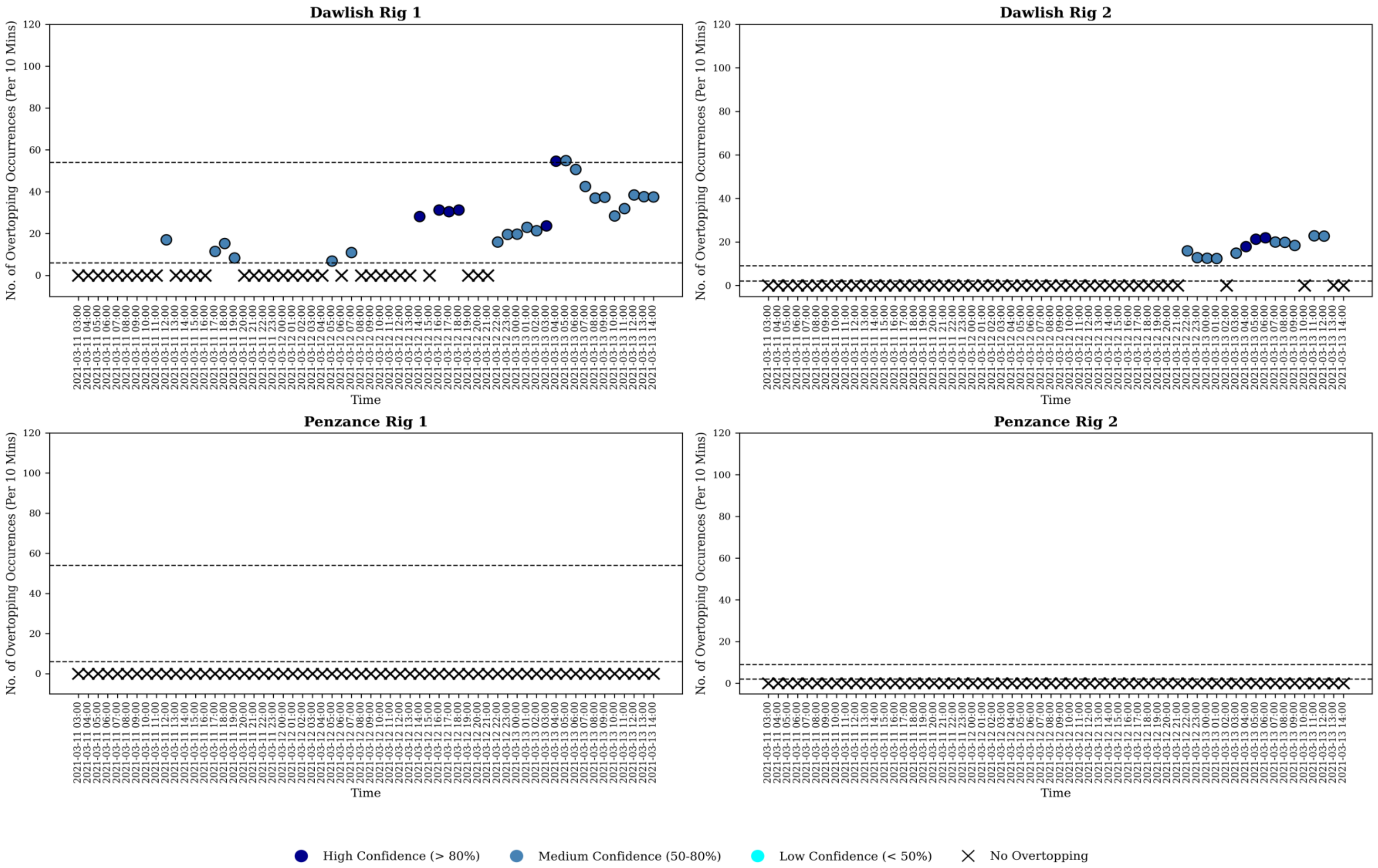
Reference: Michael McGlade, Nieves G. Valiente, Jennifer Brown, Christopher Stokes, Timothy Poate (2025), Investigating appropriate artificial intelligence approaches to reliably predict coastal wave overtopping and identify process contributions (https://www.sciencedirect.com/science/article/pii/S1463500325000137)

STEP 3 – RESULTS : WAVE OVERTOPPING PREDICTION

Formulates 60 hourly predictions:
(~ 4-5 seconds)

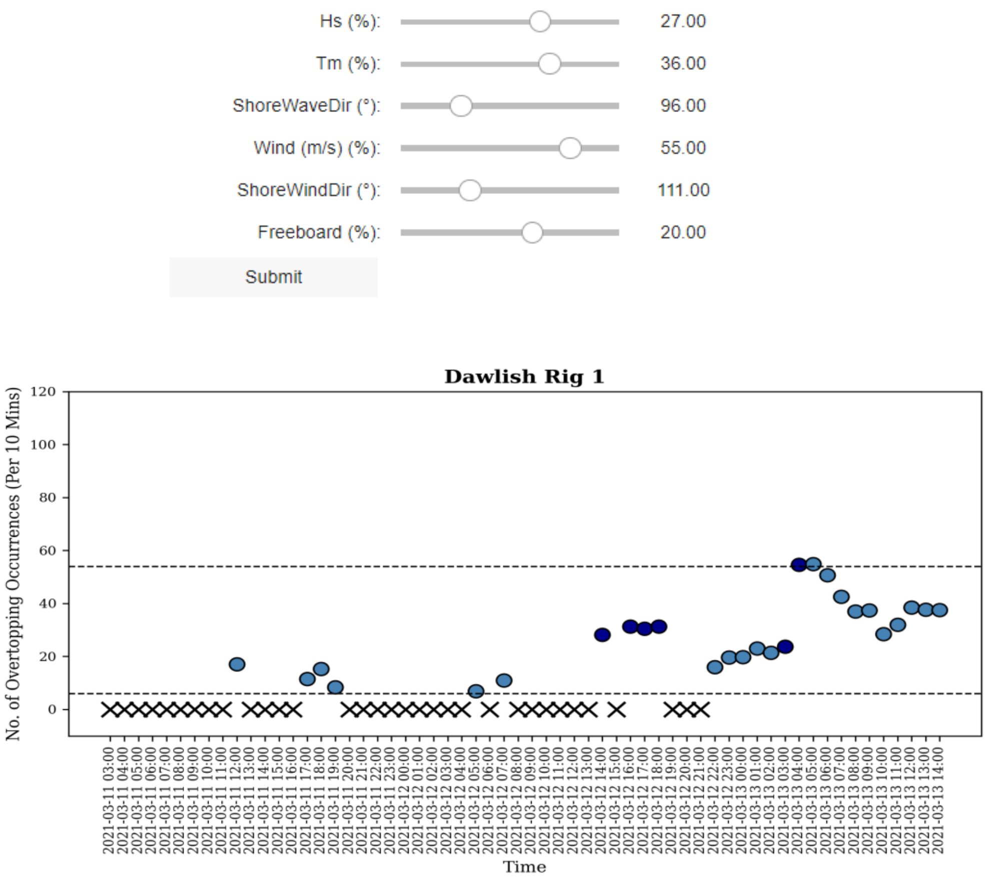
Hs (%):		27.00
Tm (%):		36.00
ShoreWaveDir (°):		96.00
Wind (m/s) (%):		55.00
ShoreWindDir (°):		111.00
Freeboard (%):		20.00

Submit

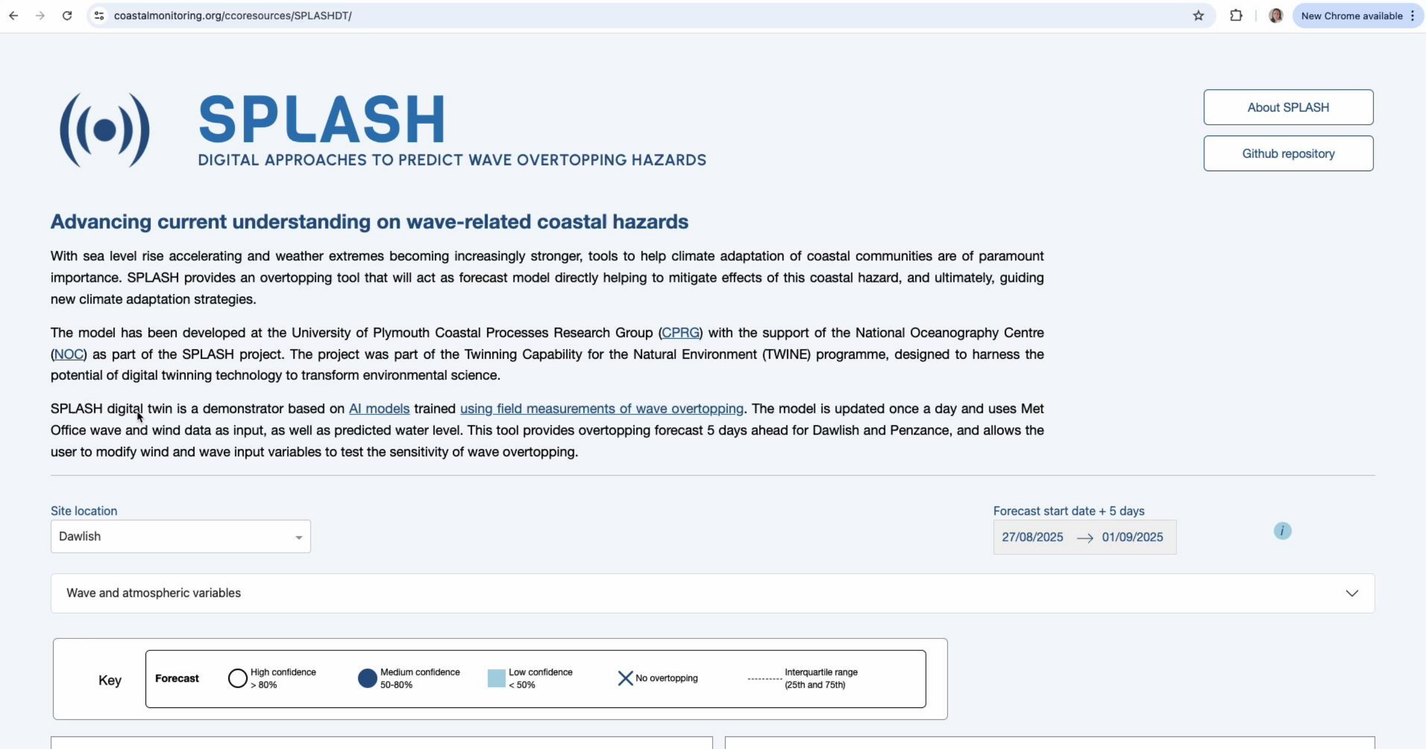


RESULTS - JUPYTER NOTEBOOK VS SPLASH

JUPYTER NOTEBOOK



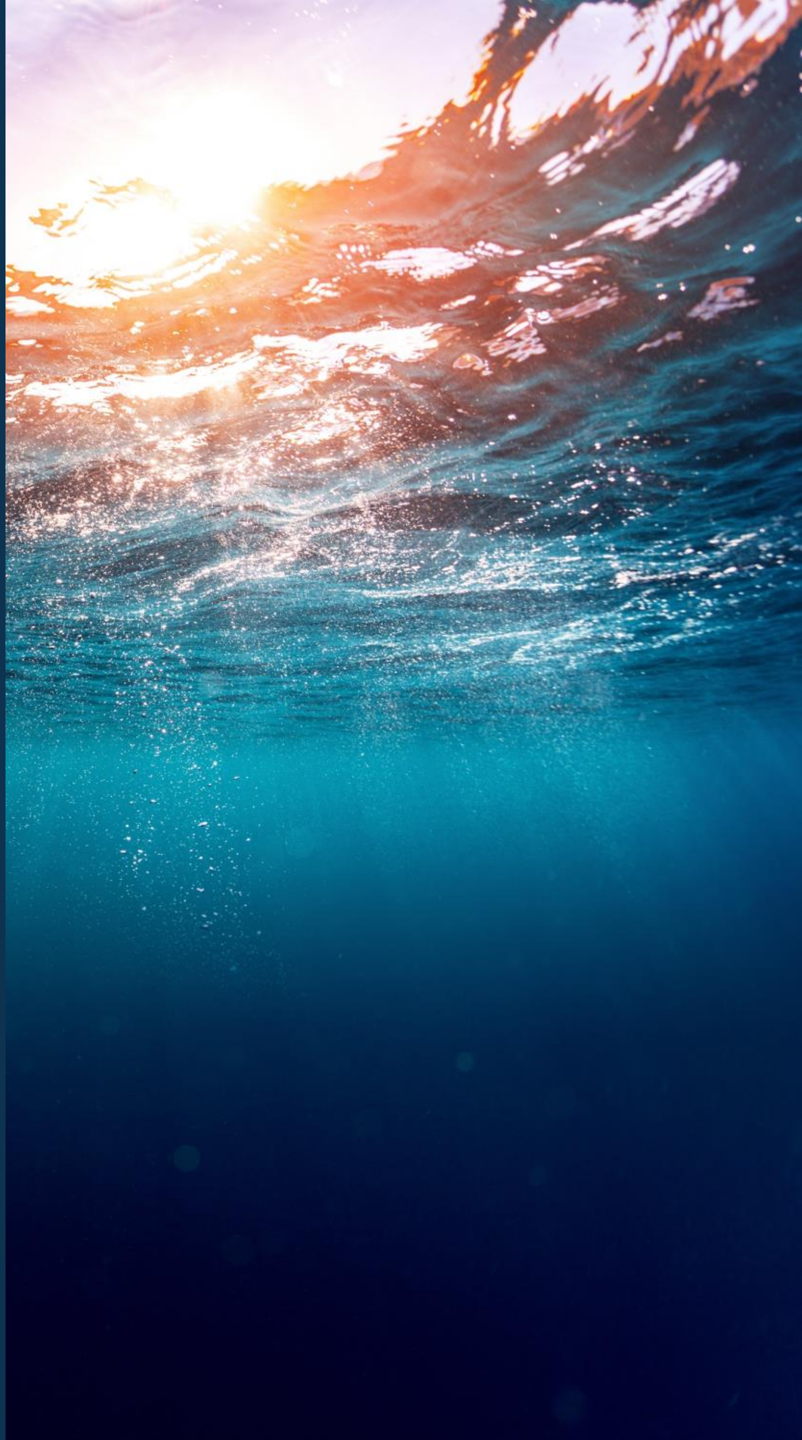
SPLASH DASHBOARD



https://www.youtube.com/watch?v=Vqm9yhseZPM

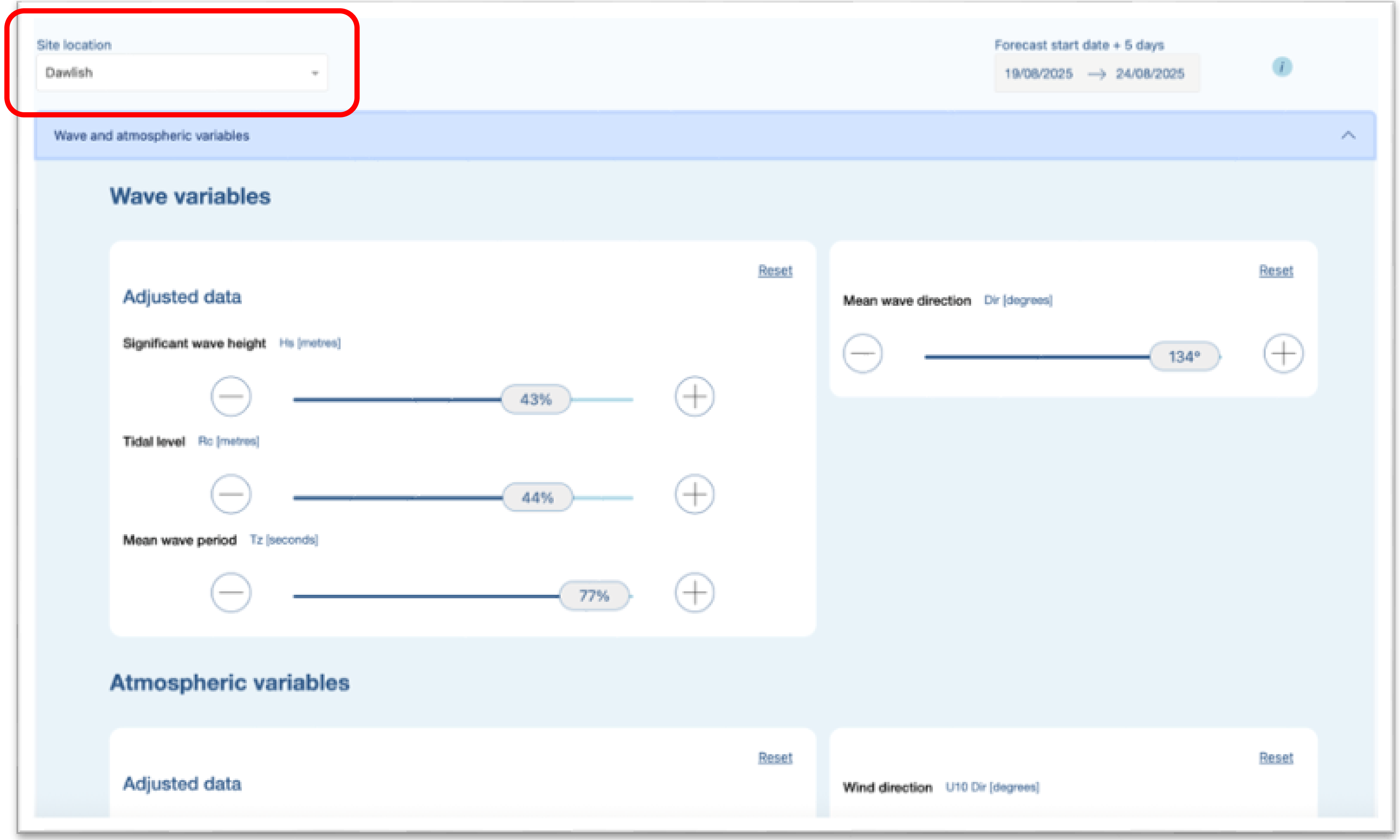
UNIVERSITY OF PLYMOUTH · National Oceanography Centre · UKRI Natural Environment Research Council · Met Office

WAVE OVERTOPPING PREDICTION WITH SPLASH



WAVE OVERTOPPING PREDICTION WITH SPLASH

- User could select a site location like Dawlish/Penzance overtopping to forecast overtopping events by a specific location.
- It allows user to adjust the wave, water level and atmospheric variables to predict new overtopping scenarios.



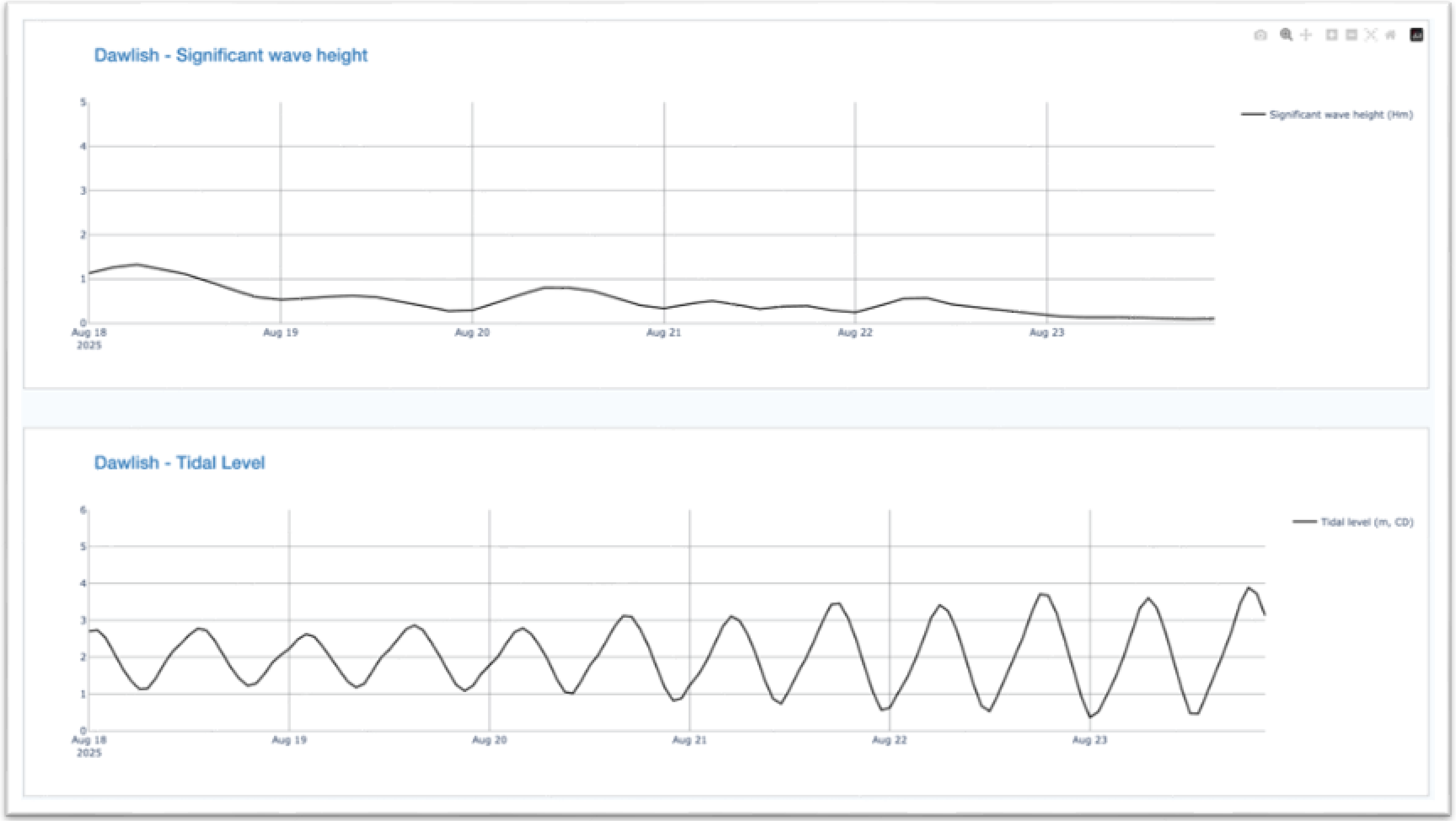
LINK TO APP: https://coastalmonitoring.org/ccoresources/SPLASHDT/

WAVE OVERTOPPING PREDICTION WITH SPLASH

Once a user has submitted any meteorological and/or atmospheric variables, plot graphs with overtopping and non-overtopping events are shown.

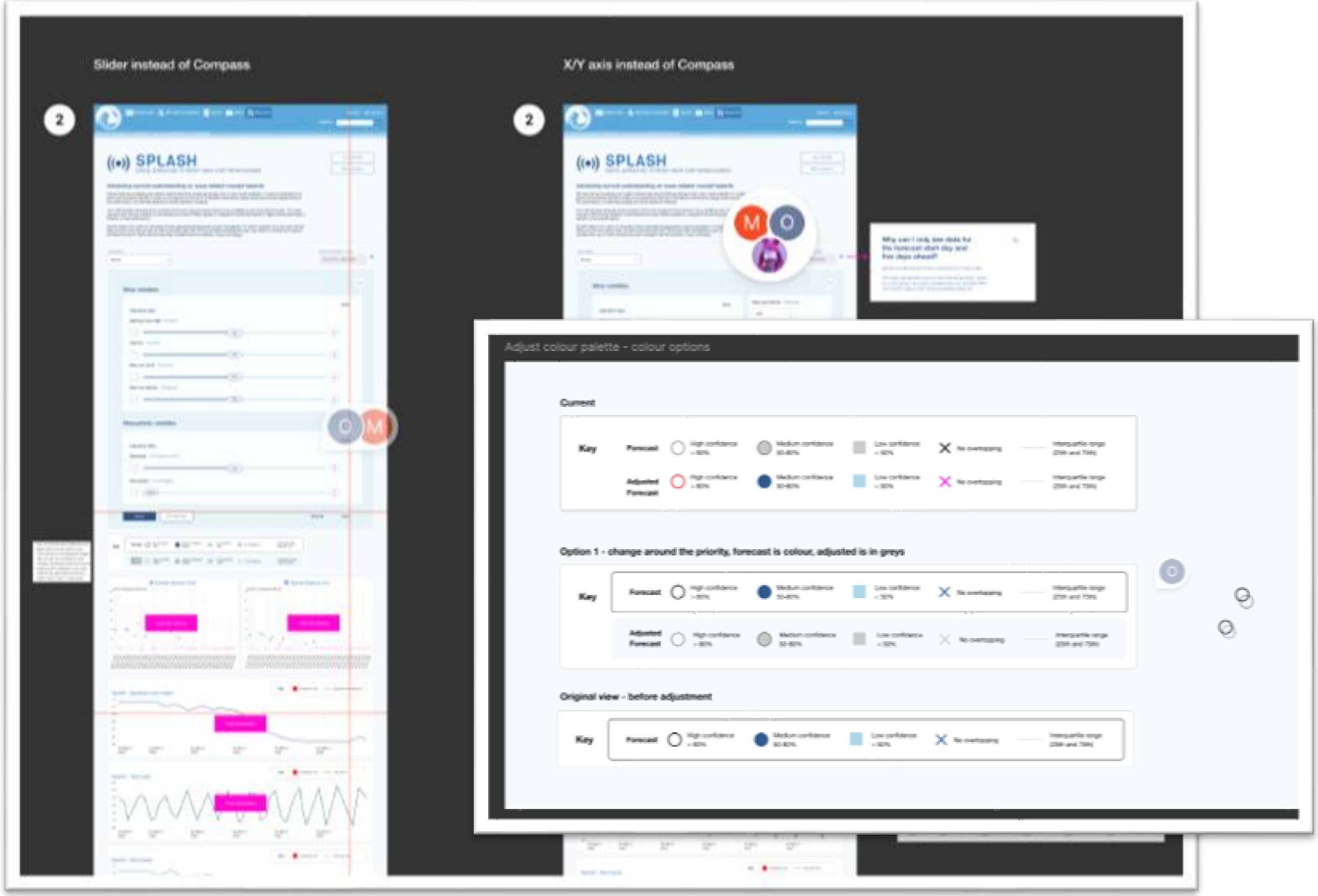
WAVE OVERTOPPING PREDICTION WITH SPLASH

Trends graphs of some of meteorological/atmospheric variables are part of the dashboard results.

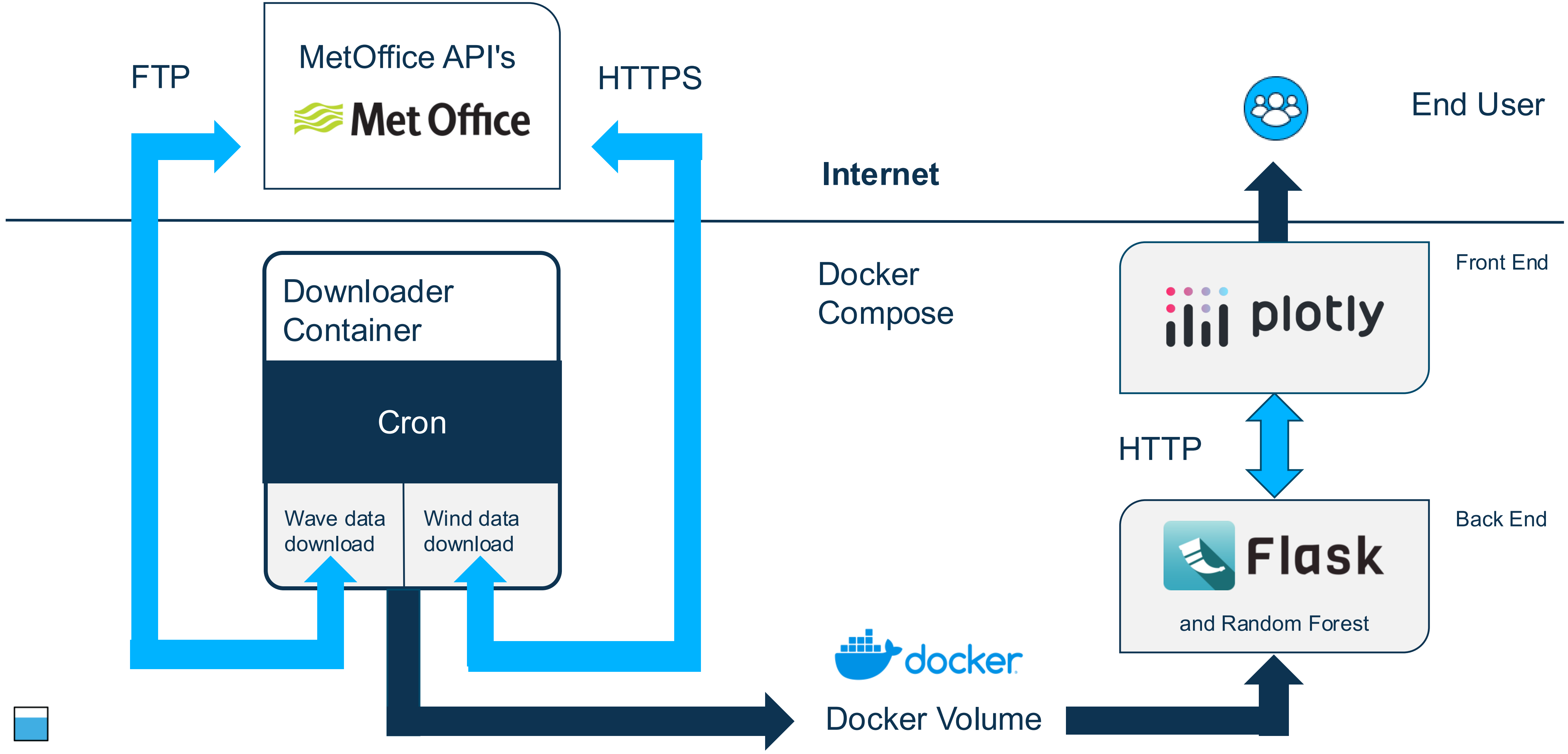


WAVE OVERTOPPING PREDICTION WITH SPLASH

- The user interface was designed using best practice accessibility recommendations, ensuring the colour contrasts used on the charts and graphs meet an AA contrast ratio (WCAG 2.2).
- The design process was iterative with the Stakeholders of the project.
- Figma was used for the design of the UI interface, and supported collaboration.



APPLICATION ARCHITECTURE



WAVE OVERTOPPING PREDICTION WITH SPLASH

- SPLASH utilises Random Forest (RF) models trained on Wire-Wall data, wave buoy data and meteorological data as input to predict overtopping.
- RF models only take a few seconds to execute and are run when a user loads the dashboard's page.
- Digital twin scripts for Dawlish and Penzance were refactored to incorporate it to SPLASH backend source code.
- This application downloads wave and wind data daily from Met Office server using a cron job.

WAVE OVERTOPPING PREDICTION WITH SPLASH

- SPLASH application was containerised with Docker and deployed on servers run by Channel Coastal Observatory.
- There are three containers:
    - Downloader – Runs the cron jobs and download scripts.
    - Backend – Runs the Random Forest
    - Frontend – Runs the dashboard.
- The downloader and backend share a Docker volume for the latest wave and wind data.
- The Backend and Frontend communicate via an HTTP API to a Flask server running in the backend container.
- The frontend is written in Plotly.

WAVE OVERTOPPING PREDICTION WITH SPLASH - DEMO

- Link to SPLASH dashboard: https://coastalmonitoring.org/ccoresources/SPLASHDT/
- Source code https://github.com/SPLASHDT/splash-docker
- Follow README instructions to download synthetic datasets
  https://github.com/SPLASHDT/splash-dashboard-backend/tree/main

WAVE OVERTOPPING PREDICTION WITH SPLASH – USES

Unique visitors this year since launch

557

SPLASH supports STEM outreach and academic training

Aligns with NERC Digtal Strategy

NERC

Supports early warning and hazard management, transforming environmental science through digital twins.

Educational tool

MSc

Used in course in coastal management at University of Southampton

Shared with industry (Network Rail)

A vs B

SPLASH was shared with Network Rail for forecasting comparison.

WAVE OVERTOPPING PREDICTION WITH SPLASH – NEXT STEPS

- Watch for an opportunity to collect more data nationally to then provide large scale predictions.
- Make the Random Forests models more generalisable so SPLASH dashboard could be used broadly around UK. Now the RFs are trained using data from Dawlish and Penzance only.

QUESTIONS?

National Oceanography Centre

THANK YOU

National
Oceanography
Centre