**ASX ANNOUNCEMENT**

24 September 2020

Release of Wave Predictor Video and Webinar

- New video explaining and promoting Carnegie's Wave Predictor released
- Blue Economy CRC webinar conducted including Wave Predictor
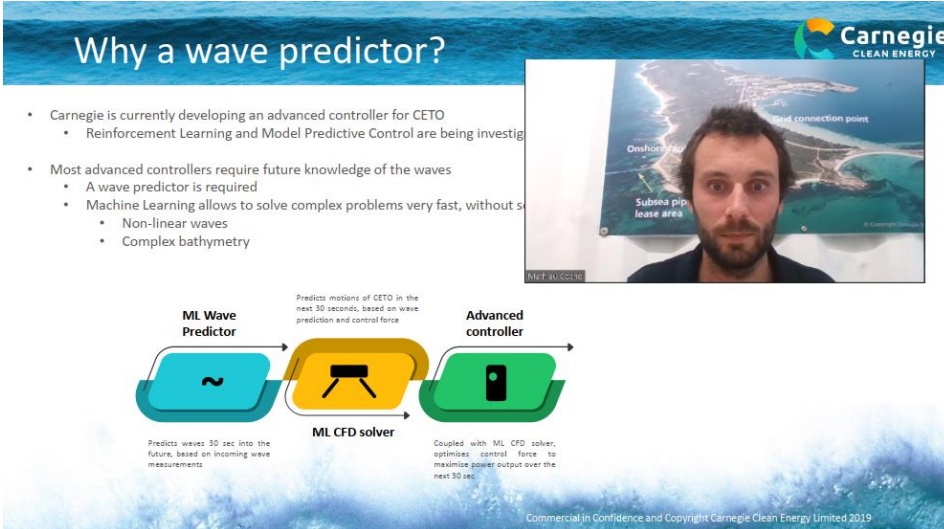
Wave Predictor Video

Carnegie is pleased to announce the release of a new video related to its recently developed Wave Predictor technology. The video provides a high-level explanation of how it works, the benefits to Carnegie's CETO technology and what it offers other marine industries. The video has been released on the company's website and will also be posted on social networks such as Twitter, LinkedIn and Youtube.
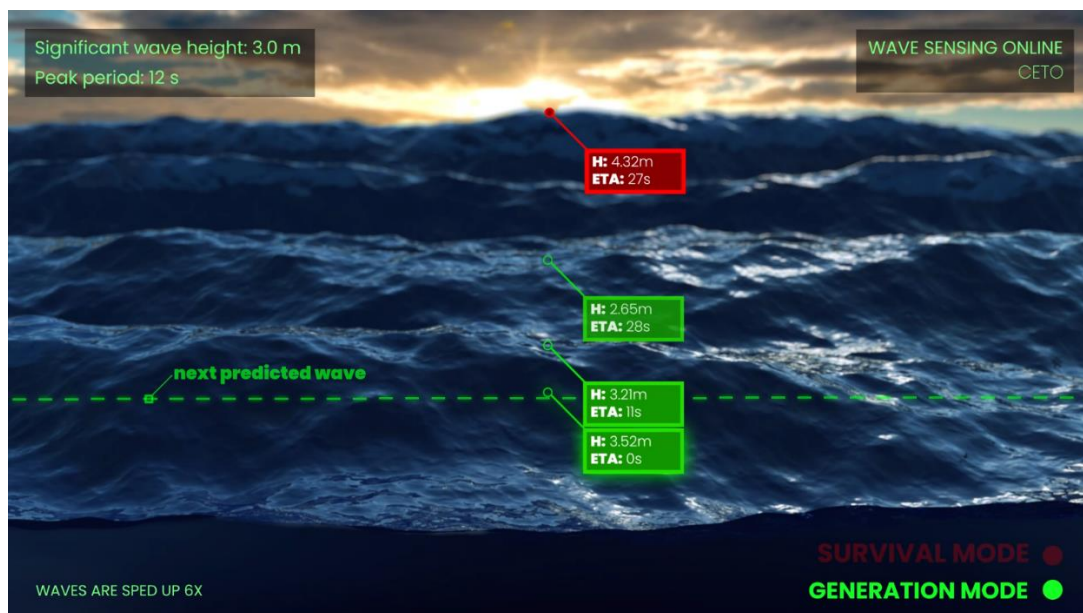
A snapshot from the Wave Predictor video showing oncoming predicted wave peaks with an extreme peak 27 seconds into the future

Blue Economy CRC Webinar "Machine Learning – adding power to the toolbox"

Yesterday Carnegie's Data Analyst made a presentation about the Wave Predictor during a webinar coordinated by the Blue Economy Cooperative Research Centre (CRC). The topic of the webinar centred on the application of machine learning in the blue economy, in particular seafood production and marine renewable energy. A copy of the slides presented are provided as an appendix to this announcement.

Screen capture from the webinar with Carnegie's Data Analyst presenting

About the Wave Predictor

Carnegie's Wave Predictor is a piece of machine learning software, along with an array of wave sensors, which can predict waves 30 seconds into the future. By using neural networks (akin to an artificial brain), the tool is able to understand and predict complex waves in a fraction of a second. This prediction can allow the CETO intelligent controller to make much better decisions resulting in greater capture of wave energy.

Aside from its relevance for wave energy sector, the Wave Predictor has potential applications in many offshore industries where operations are limited by wave conditions. Indeed, prediction of large waves travelling towards a floating platform, such as a fish farm or an oil rig, can be used to support decisions, increasing operational safety and reliability. Equally, in semi-exposed ports, where ore-loading equipment or ships can be interrupted by exceptionally large waves, use of the Wave Predictor is likely to offer an economic benefit.

For more information

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CETO Wave Predictor

23rd Sept 2020

Who is Carnegie Clean Energy?

- Australian Stock Exchange (ASX) listed

- 11,000 shareholders, mostly retail

- One of the leaders in wave energy technology. 15 years of CETO development including tank testing, rapid small scale prototyping and large commercial scale prototypes and array:
- Multiple small prototypes deployed at Rous Head (Fremantle) Research Facility
- CETO 3 Unit deployed off Garden Island in 2011
- Perth Wave Energy Project completed in 2016 to demonstrate the CETO 5 technology. A grid-connected wave energy project over four seasons, with thousands of in-ocean operating hours, broke world records

- Experienced team covering engineering, analysis, corporate, commercial, offshore, operations, maintenance, electrical, mechanical capabilities

- Deep engagement with global supply chain and Wave Energy Converter (WEC) and subsystem developers
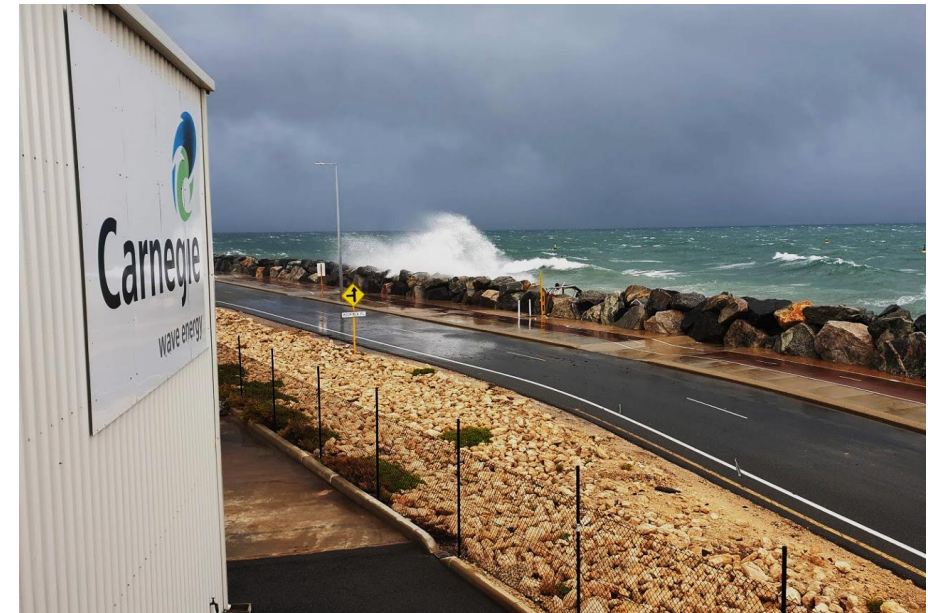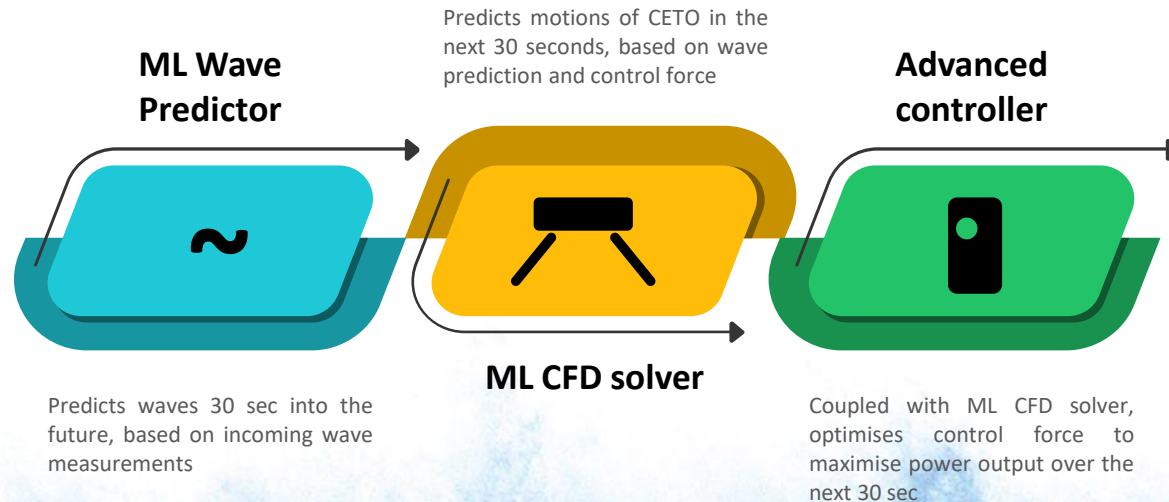
What is CETO?

- The technology has been in development for over 15 years.
- Now mainly captures the 'heave' and 'surge' motions form the waves
- Sits ~2 m below the sea surface.
- Installed in depths > 20 m.

| CETO 2	CETO 3	CETO 4	CETO 5	CETO 6
2008	2011	2013	2014	
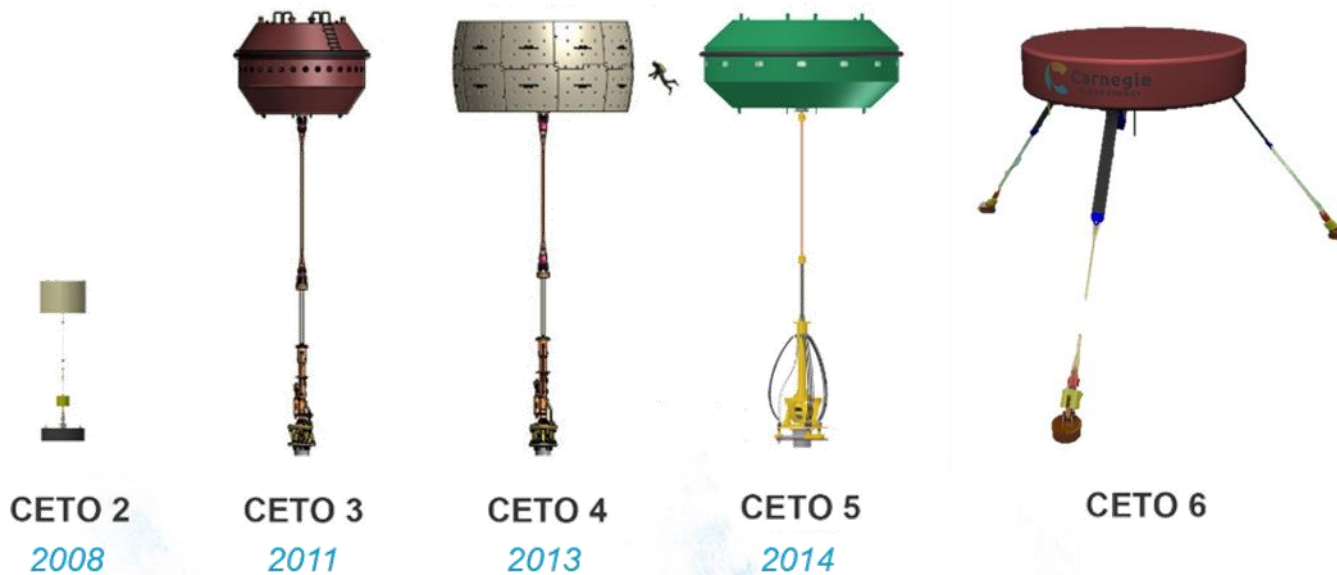
Why a wave predictor?

- Carnegie is currently developing an advanced controller for CETO
  - Reinforcement Learning and Model Predictive Control are being investigated

- Most advanced controllers require future knowledge of the waves
  - A wave predictor is required
  - Machine Learning allows to solve complex problems very fast, without solving the physics
    - Non-linear waves
    - Complex bathymetry

ML Wave Predictor

Predicts motions of CETO in the next 30 seconds, based on wave prediction and control force

Advanced controller

ML CFD solver

Predicts waves 30 sec into the future, based on incoming wave measurements

Coupled with ML CFD solver, optimises control force to maximise power output over the next 30 sec
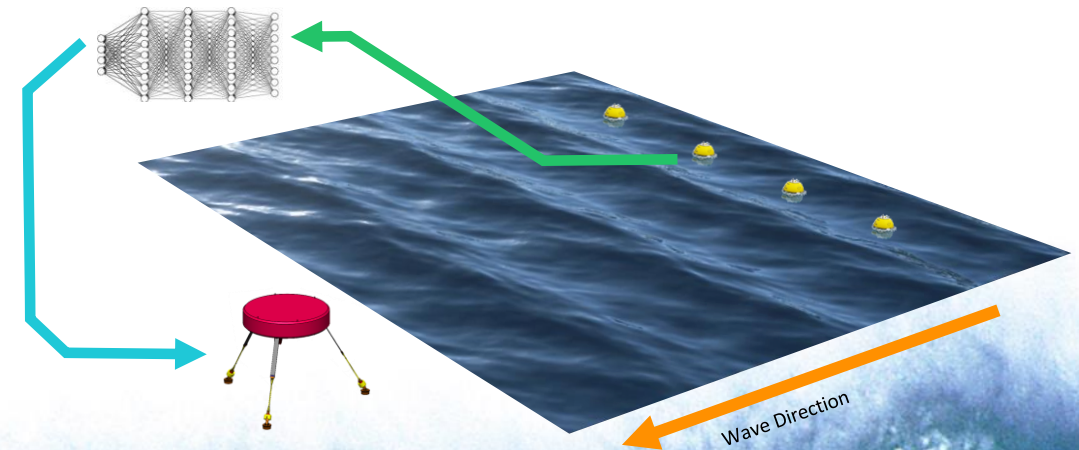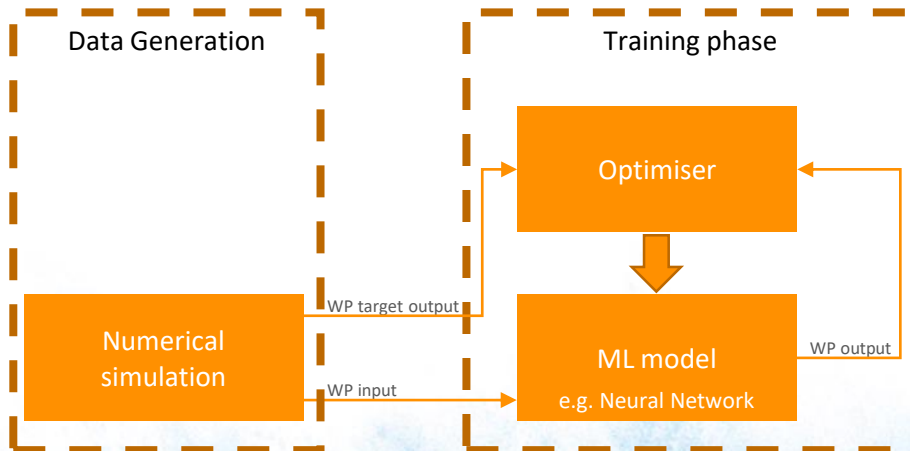
Wave Predictor development steps

- Development steps:
  - Long / Short crested linear waves: data generated on a laptop
  - Short crested non-linear waves: data generated on Pawsey Supercomputers
  - Tank testing: data generated over 10 days of testing
 - Real ocean
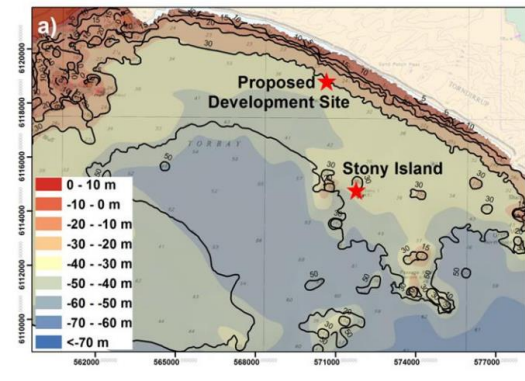
Wave Predictor description

- Objective: Predict waves 30 s into the future, in all conditions at the deployment site
- Prediction based on up-wave measurements
- Dataset contains ML model input data, and output data (labels, or truth)

Data Generation

Training phase

Numerical simulation

WP target output

WP input

Optimiser

ML model

e.g. Neural Network

WP output

Wave Direction

Feature Engineering

- WP inputs: surface elevation @ wave sensor, from X s into the past until now
- WP output: surface elevation @ CETO system, 30 s into the future
- Distance and lookback parameters are dictated by wave travel velocity
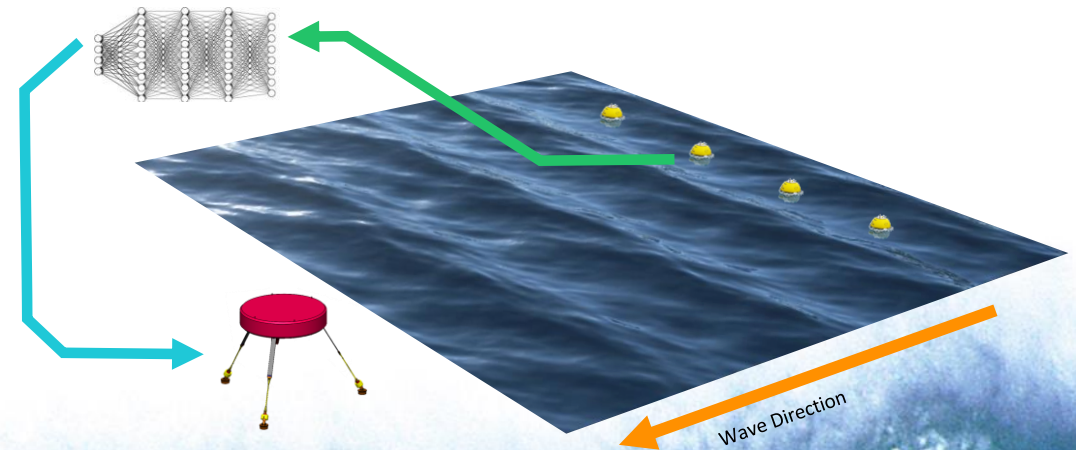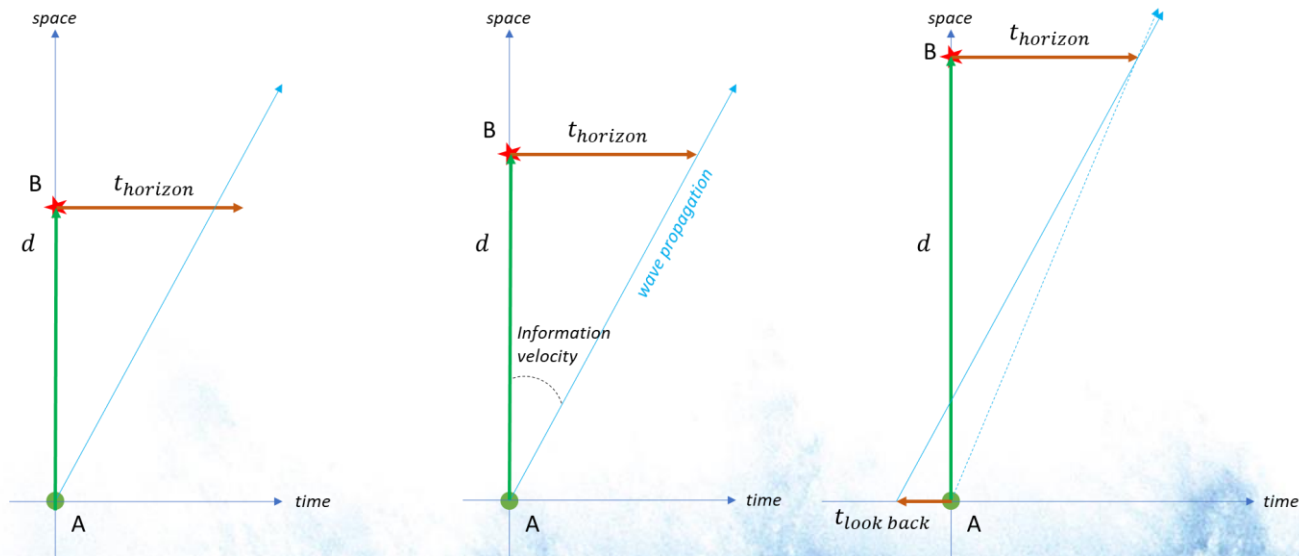
Feature Engineering

- Design parameters
    - Number and spacing of sensors
    - Distance from prediction point
    - Network architecture
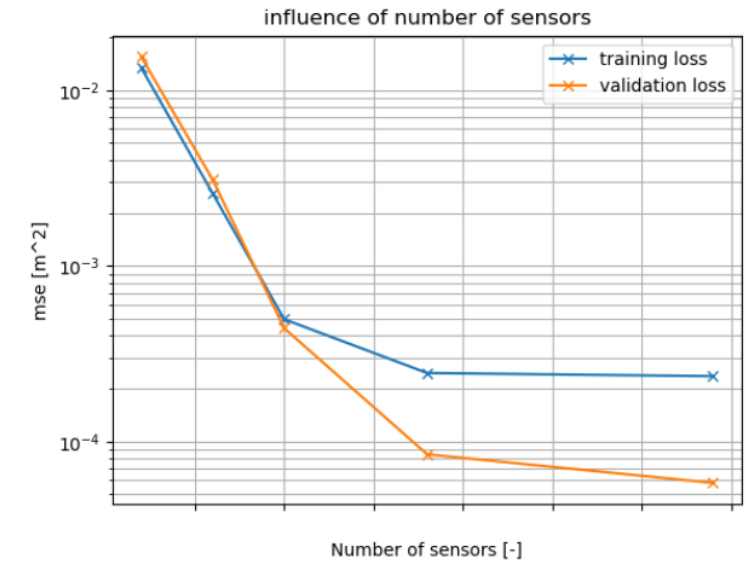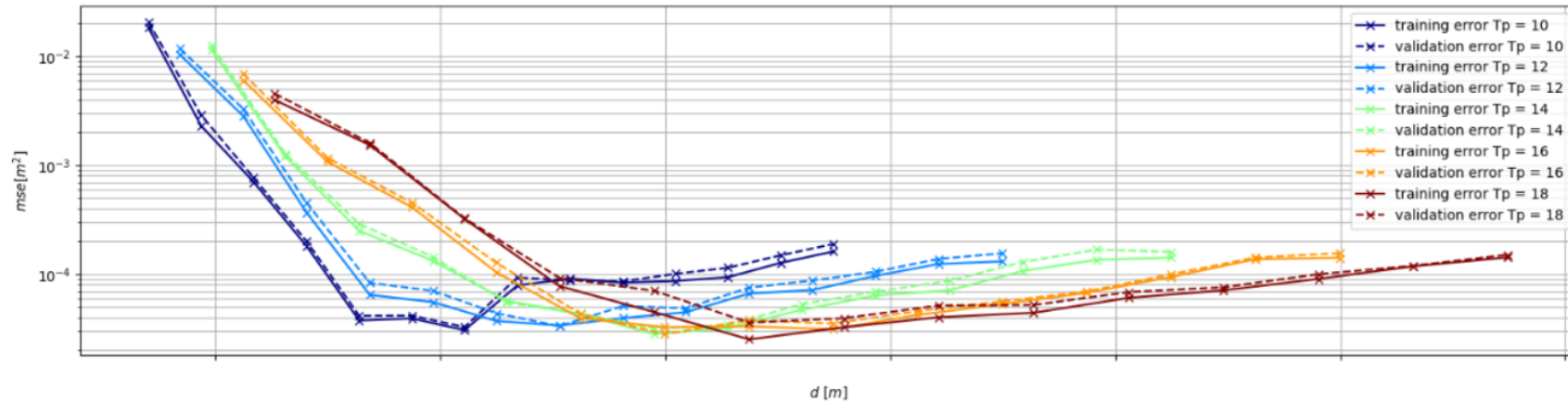
Wave predictor performance

- The WP performs very well on synthetic data
- The WP is able to generalise to unseen sea states, provided they fall within the envelope of the training set
- Currently in the process of validating it on tank data, with promising early indicators

Elevation prediction in time

Surface elevation prediction error for different predictor architectures

Surface elevation prediction
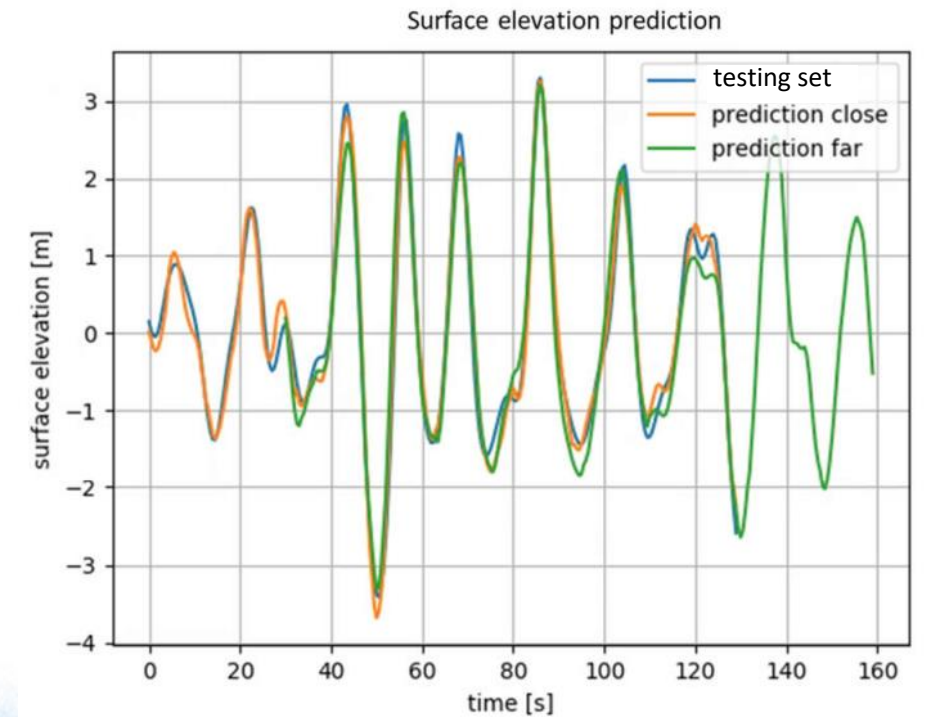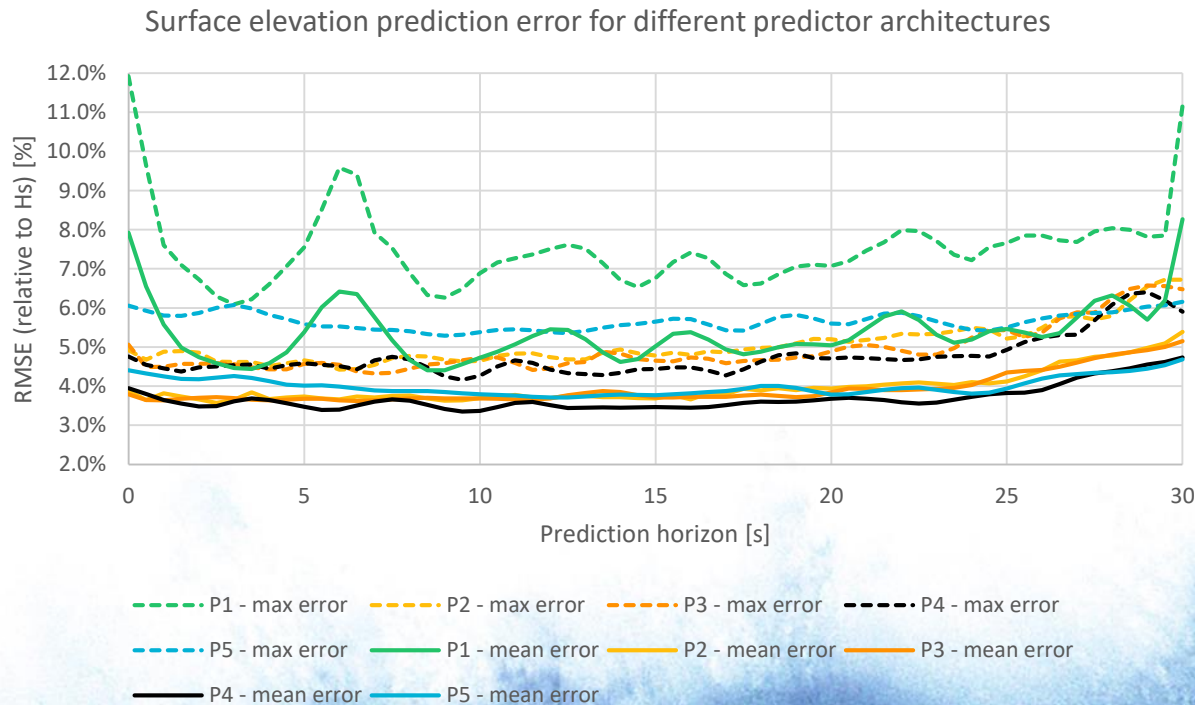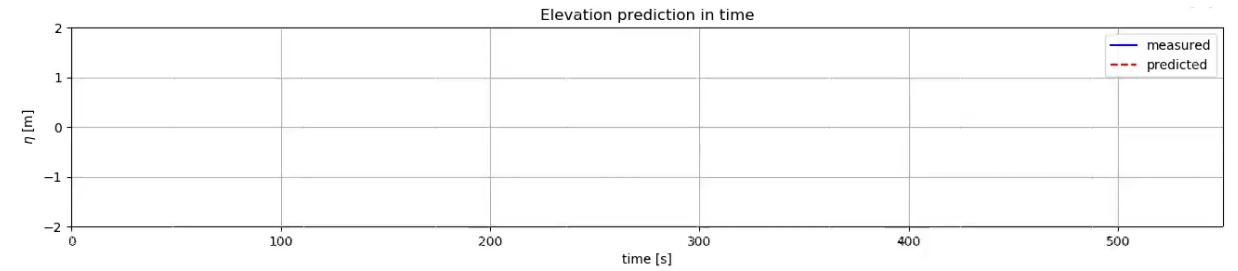
Applications outside of wave energy

- The WP can increase safety and operational envelope of activities where large waves are a limiting factor
  - Boarding / outboarding of sea vessels
  - Offshore lifting

- The use of X-Band radar will increase the application range of the wave predictor

Thank you!

Questions ?