Accounting for Current in Wave Buoy Measurements

Project summary

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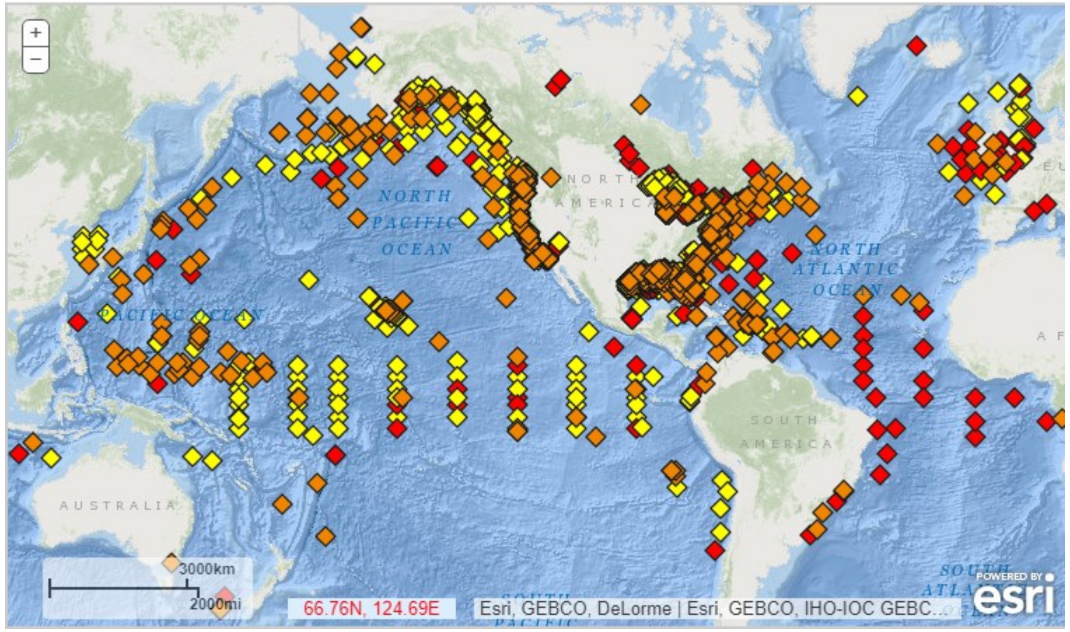
Background

- Buoys provide a vital source of wave information
  - Often used directly in design of offshore systems and ORE devices

- Buoy measurements used to calibrate and validate wide-area numerical models
  - Subsequently used for extreme and fatigue load calculations as well as power production (wave energy)

- Buoys do not (usually) measure current and assume there is no current
  - Wave parameters incorrect
  - Buoy response affected, unknown and unaccounted for



Source: https://www.ndbc.noaa.gov/

Motivation

Objectives

1. Quantify errors introduced by current

2. Account for current in buoy analysis approach

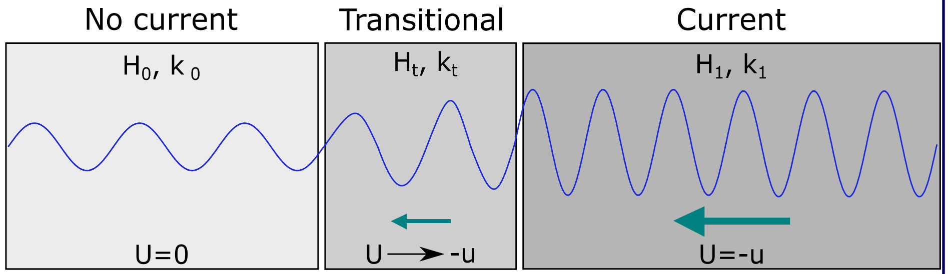
Motivation

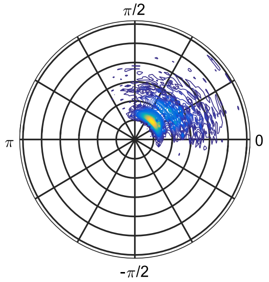
Unknown current introduces 3 types of errors:

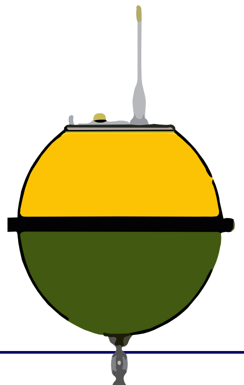
1. Wave climate misrepresented
   - Errors in assumed wavelengths, steepness, power

2. Errors in wave direction
   - Errors in mean direction and spreading

3. Alteration to buoy dynamics and ability to surface track
   - Transfer functions in current unknown





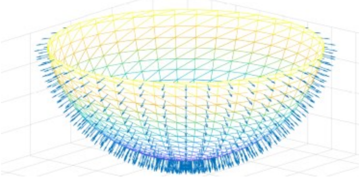


Project overview

WP1: Obtain buoy transfer functions in current

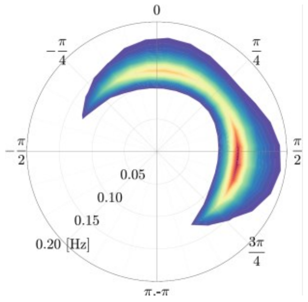
- Tank testing
  - Regular waves in current
  - 2 x buoy diameter
  - 2 x mooring stiffness

- Frequency domain model developed
  - Accounts for doppler shift and modified draught and mooring
  - Nemoh for hydrodynamic coefficients.



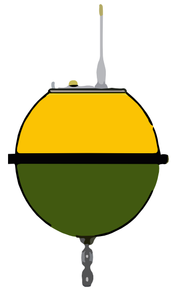
WP2: Develop new buoy analysis approach to account for current

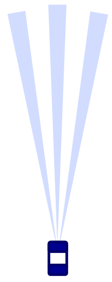
- Method developed to correct wave parameters and estimate current velocity
  - Optimisation approach
- Considers current modification to wavenumber
  - Wavenumbers formulated as a function of angle relative to (unknown) current field



WP3: Validate developed method

- Method validated using simulated datasets
  - Predicts current velocity, directional spectra and corrects sea state parameters
- Preliminary validation using experimental data
- Plan to validate on full-scale data
  - ADCP near to wave buoy



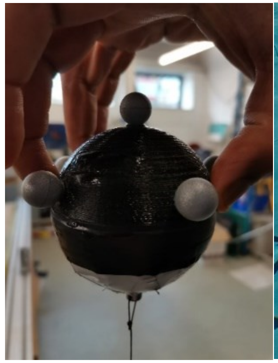


WP1: Obtain buoy transfer functions in current

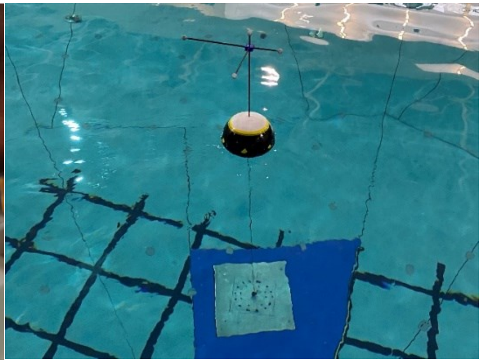
Experimental campaign

- 2 x buoy models manufactured
- 2 x moorings (for each buoy)
- Testing:
  - Current only (0 – 0.35 m/s)
  - Collinear waves and currents
  - Oblique waves and currents
  - Directionally spread waves and currents

Small buoy



Large buoy

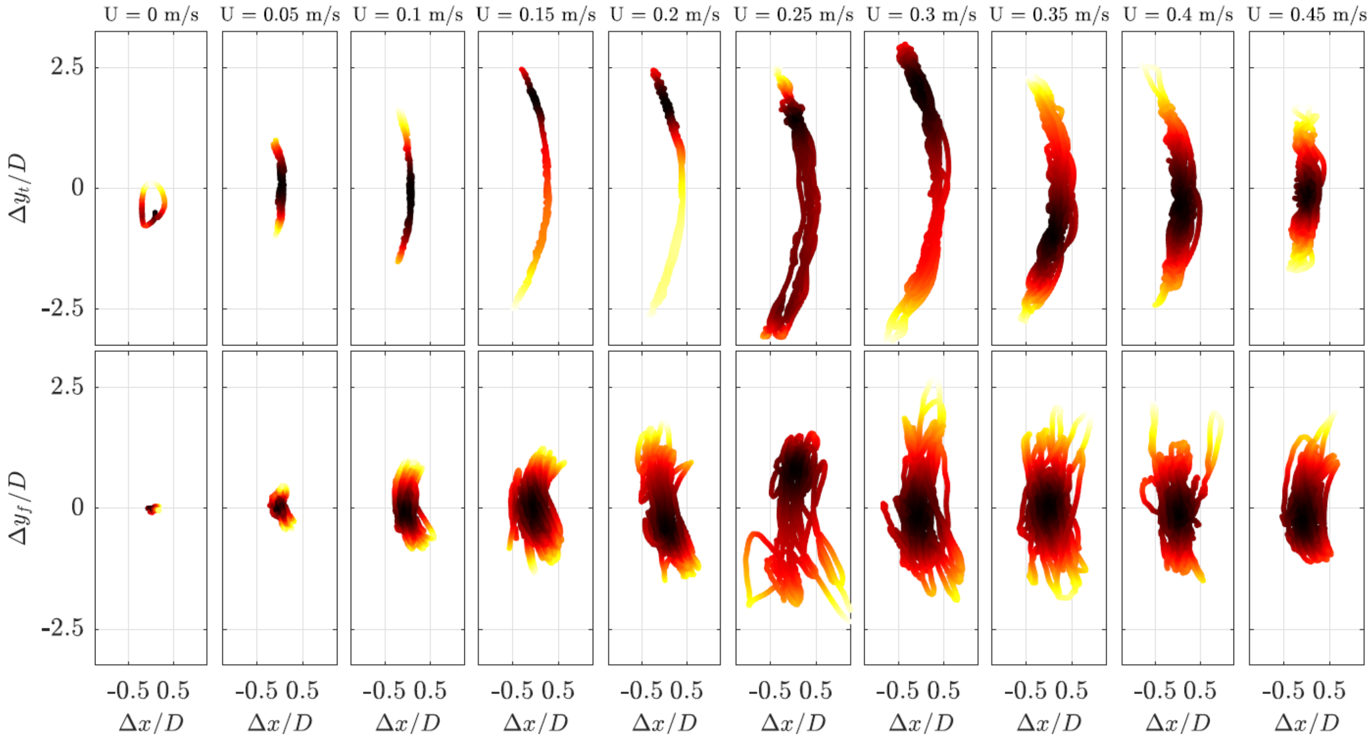


Key findings 1: Vortex induced motions

- Vortex-induced motions significant
- Significantly lower frequency than waves
  - Amplitudes of wave-induced motions of buoy not affected by VIM

Taut line

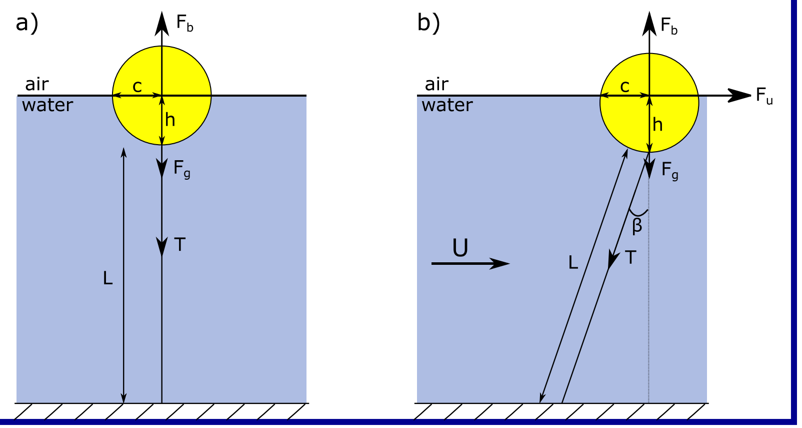
Flexible line



WP1: Obtain buoy transfer functions in current

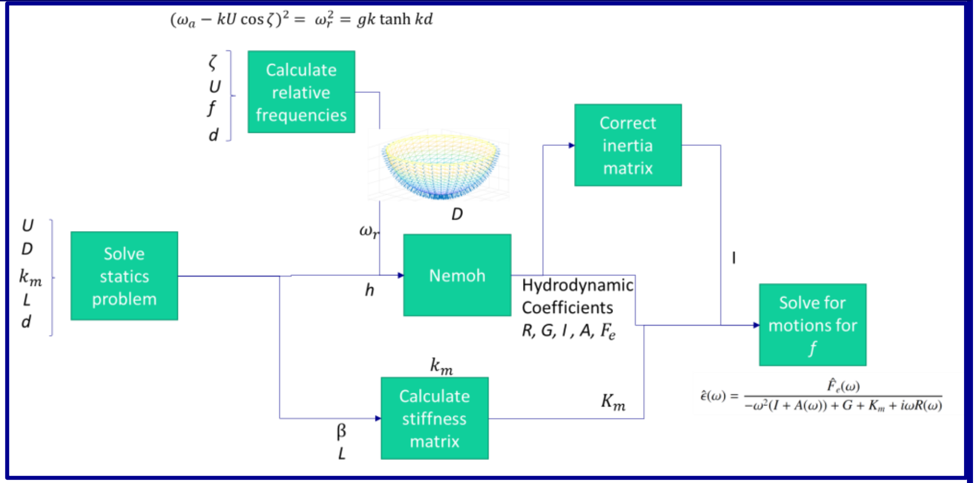
Numerical modelling

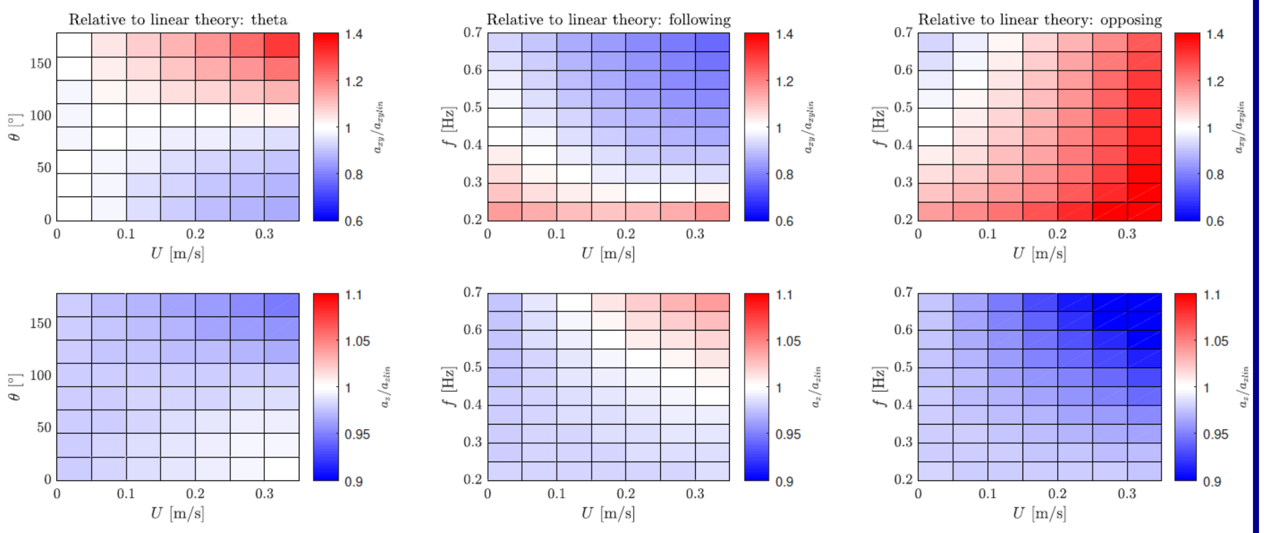
- Frequency-domain model developed to predict transfer functions
- Accounts for doppler shift, modified draught and mooring dynamics



Key findings 2: Predicting wave-induced buoy response

- Transfer functions developed to predict deviation from linear wave-current theory
- Function of:
    - Relative angles
    - Frequency
    - Velocity





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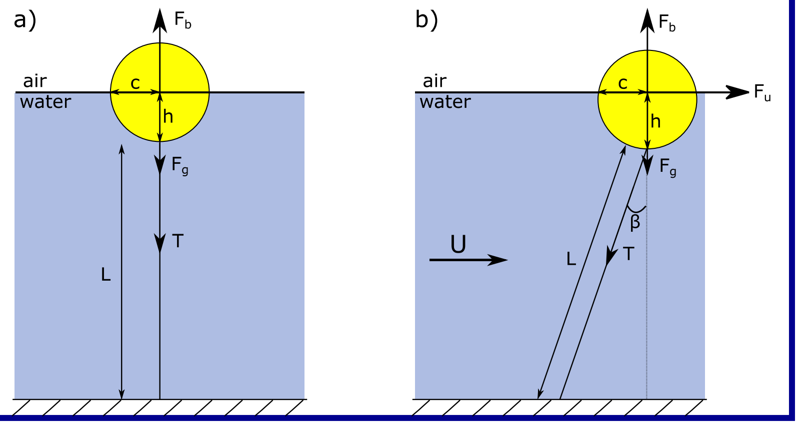


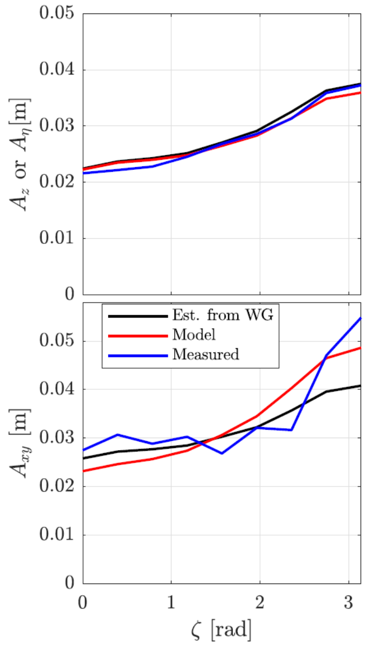
Key findings 3: Wave-induced buoy response

- Buoy response deviates from linear wave-current theory in current
- Transfer functions (red) improve on predictions made by linear wave-current theory (black) compared to experiments (blue)
- (to be) incorporated into analysis framework

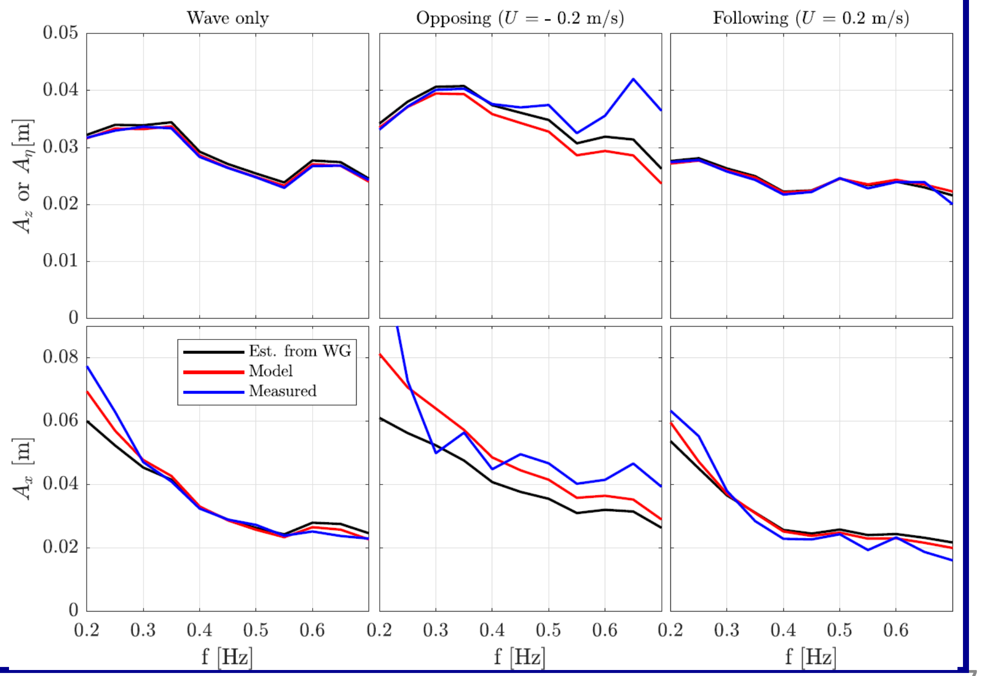
Heave

Surge

Oblique



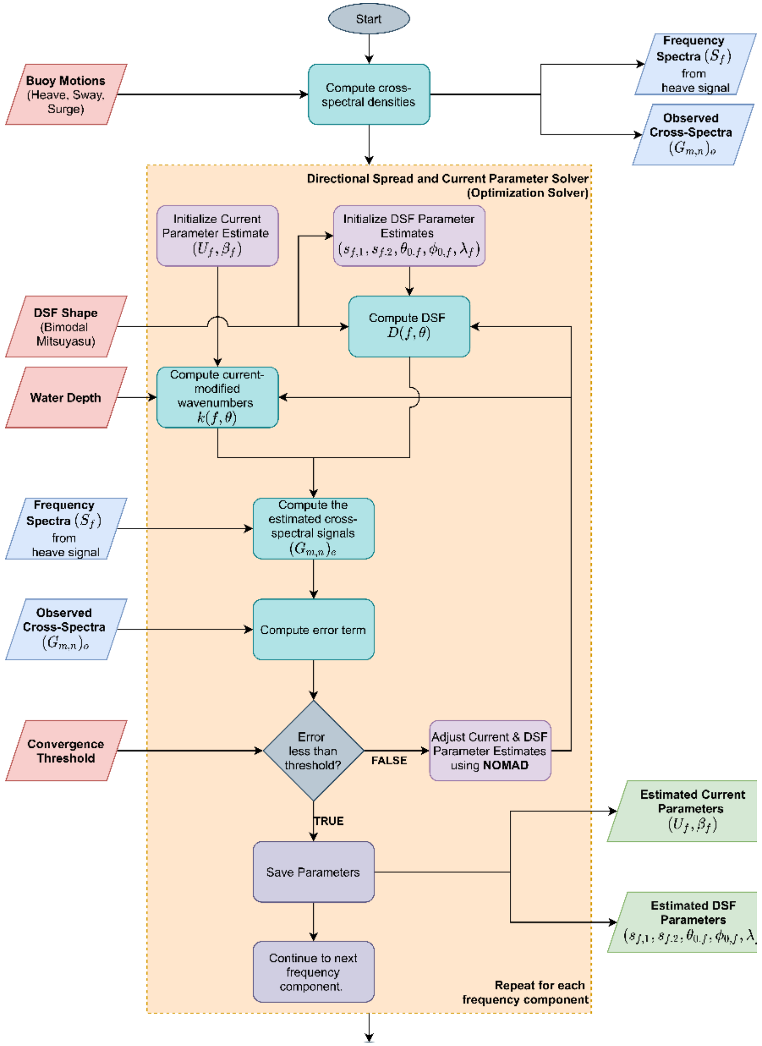
Collinear



WP2: Develop new buoy analysis approach to account for current

Framework

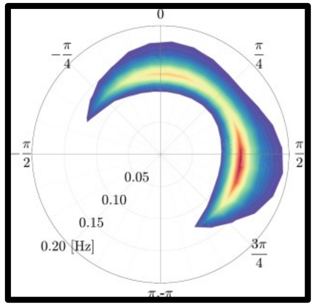
- Formulated as a parameter estimation problem
    - Solve for unknown wave and current parameters, incorporating current
- Using a mesh adaptive direct search (MADS) algorithm



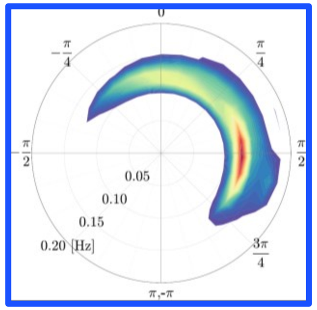
Testing on simulated data

- Can effectively resolve directional spectra
    - Including bi-modal

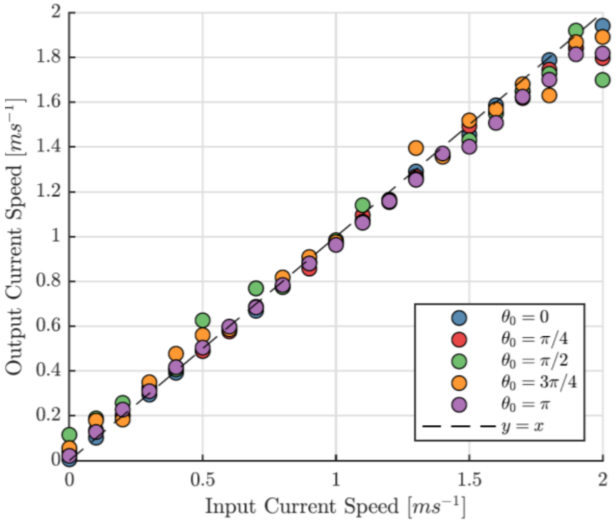
Target



Optimisation approach



- Can predict current velocity
    - and correct sea state parameters



WP3: Validate developed method

Tank data

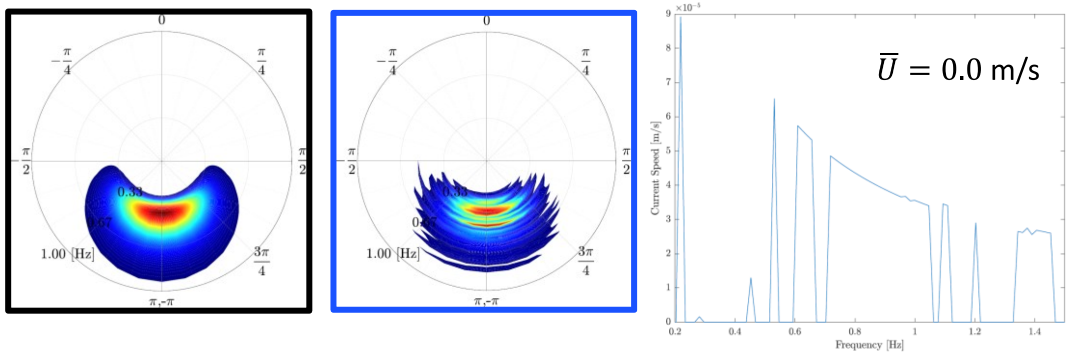
- Preliminary analysis suggests method is performing well on experimental data
- Further tuning required (in progress) to improve estimates
- Transfer functions from WP1 not yet included, which will further improve performance

$\bar{U} = 0.0$ m/s

Target

Optimisation approach

Current estimate

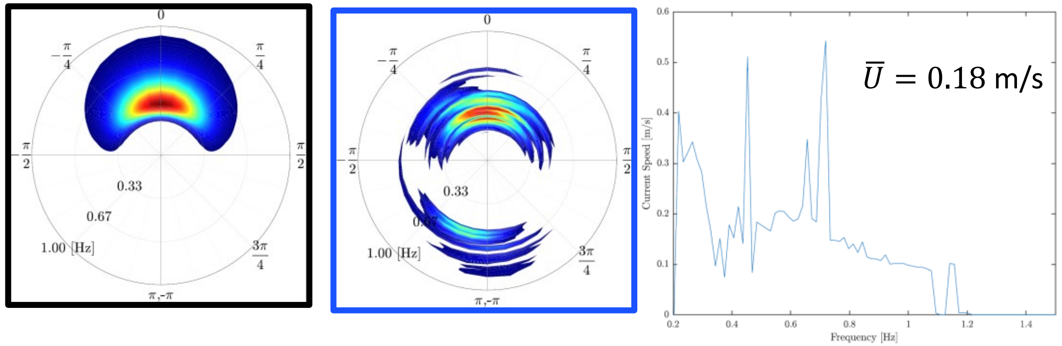


$\bar{U} = 0.15$ m/s

Target

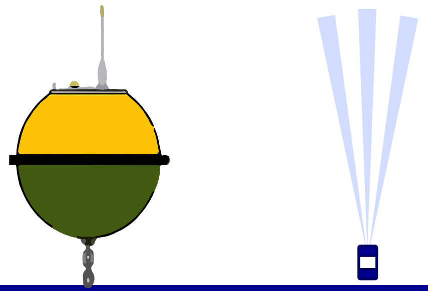
Optimisation approach

Current estimate



Full-scale data

- Data obtained
  - Wave buoy with ADCP nearby to validate current estimates
- Data processing begun
- No validated tests carried out to date



Key impacts and follow on work

Key impacts

- Errors associated with the effect of current on wave buoys quantified
- Method developed to account for the presence of current
  - Can correct historic datasets
  - Improved estimates of wave parameters + estimate of current
- Numerical modelling approach developed to predict modified buoy response in current
  - Can improve estimates further
  - Expand understanding of, and correction for, different buoys and mooring configurations

Further work

- Validation on real ocean datasets
- Development of time-domain model to capture non-linearities associated with buoy response

Future project options

- Large-scale correction of historic buoy datasets
  - Subsequent large-scale assessment of wave-current interaction
- Validation of coupled wave-current models with corrected buoy datasets (improved approach)
- Development of robust open-source code, including all buoy configurations, for improved analysis

Funding opportunities: EPSRC, NERC