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Analysis of turbulence parameters in prospective tidal energy sites in Australia




AUSTEn Project

Tidal energy is:

- Clean
- Predictable and reliable
- Reduced visual impacts

- **Australian Renewable Energy Agency (ARENA)**
- **AUSTEn Project →** investigate the potential and feasibility for **tidal stream energy generation** in Australia
  - Sediment transport dynamics
  - Physical characteristics of the flow + biological activity
  - Hydrodynamic models of flows
  - Economic feasibility
  - Potential hybrid farms: tidal + solar/ tidal + wind energy
  - **Study of turbulence at the sites**

Prospective tidal energy sites identified by **AUSTEn: Banks Strait, TAS and Clarence Strait, NT**

Challenges faced by developers

Device longevity of **approx. 25 years**

- Large waves
- Shear
- High levels of turbulence

→ Large load fluctuations on turbine blades

(Photo taken during field campaign in Banks Strait, TAS)

Challenges to **estimating turbulence** parameters:

- Wave-turbulence interaction
- No international guidelines
- Lack of studies with long-term turbulence measurements

Site assessment guidelines

- Existing international guidelines:
  - 2009: European Marine Energy Centre (EMEC): **Assessment of Tidal Energy Resource**

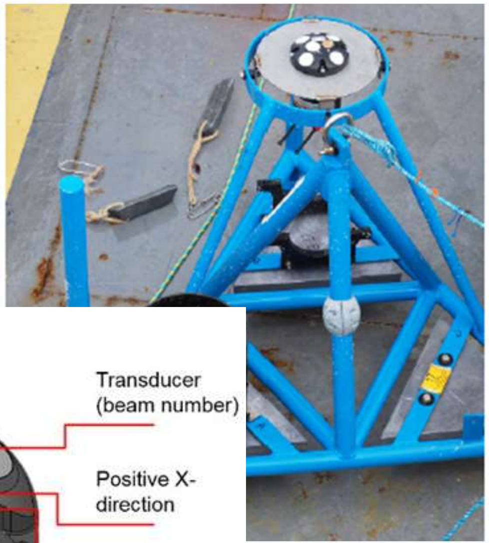
    Barely addresses turbulence importance and its parameters ✗
    Does not provide clear guidelines for turbulence measurements ✗
    Does not address wave-turbulence interaction ✗

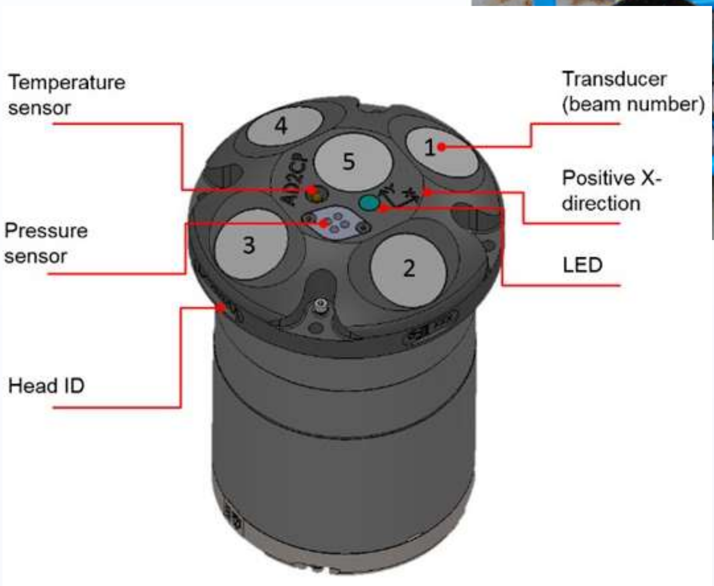
  - 2015: International Electrotechnical Commission (IEC) guidelines: **Tidal energy resource assessment and characterization**

    Recognizes the importance of turbulence ✓
    Does not provide clear guidelines for turbulence measurements ✗
    Does not address wave-turbulence interaction ✗

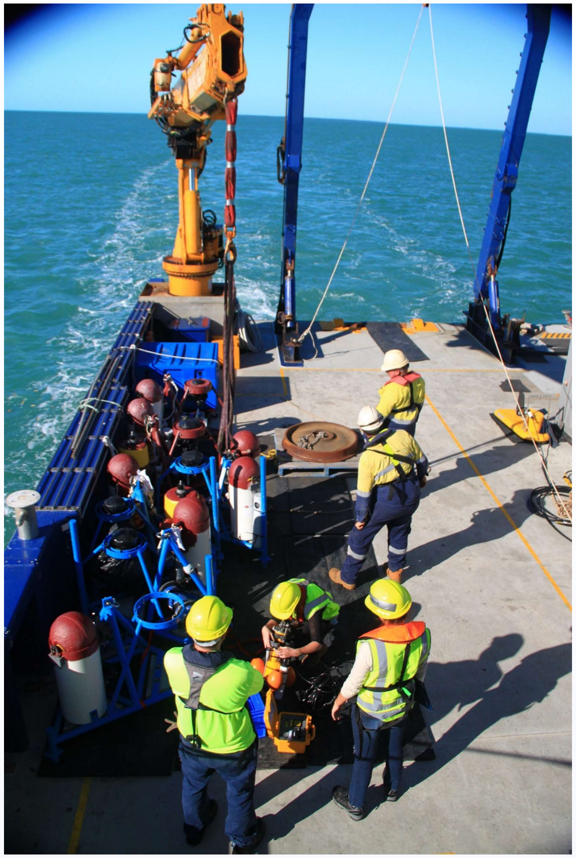
Instrument of preference: ADCP

- Acoustic Doppler Current Profilers
- Provide information across the **entire water column**
- Low frequencies compared to other instruments
- **AD2CP Nortek Signature** series:
  - Higher frequencies
  - 5 beams





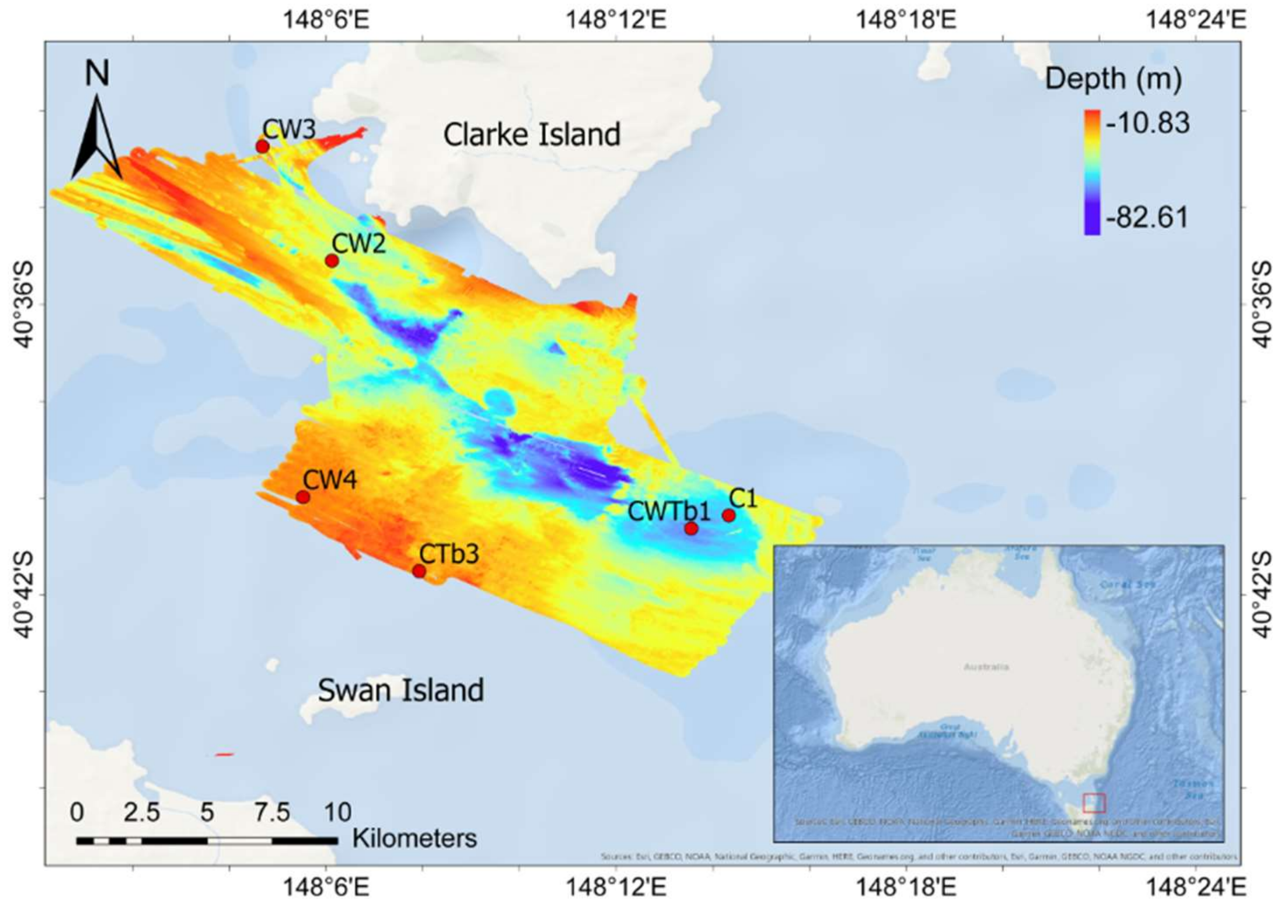
Overall work goals



- Deploy several instruments (ADCPs) at the study sites:
  - **Long-term variability** of resource and conditions
  - Assess **spatial variability** across the channels
  - Use different **instrument configurations**
- **Characterize** wave climates and turbulence parameters
- Test, develop and compare **wave-turbulence decomposition** methods applied to tidal energy sites
- Model **turbine performance** under unsteady conditions

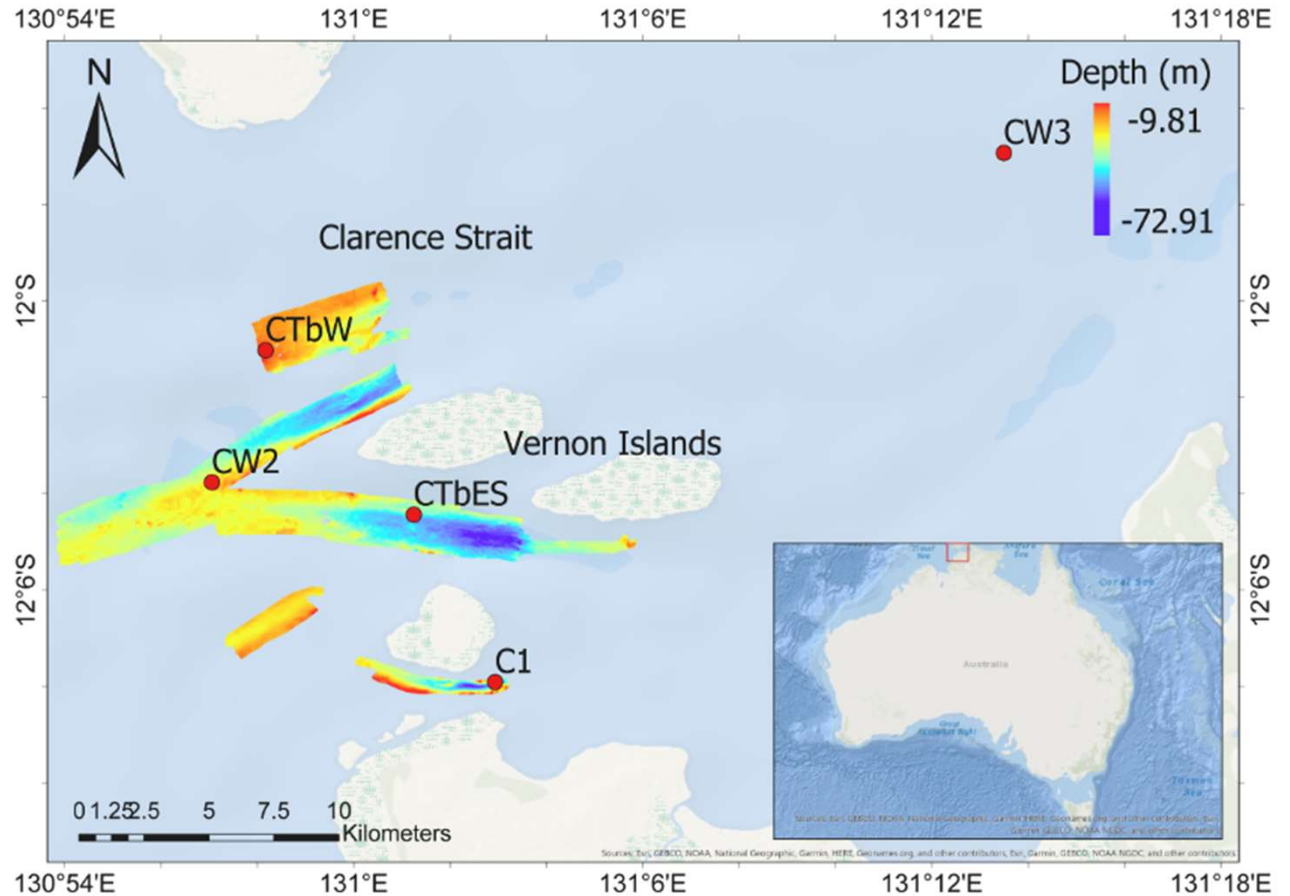
Study site 1: Banks Strait, TAS

- 16 km wide
- 25 m – 60 m, deep pockets of over 70 m
- Mean current speed: 0.7 m/s – 1.0 m/s
- Maximum current speed: 2.3 m/s
- Mean wave period: 7 s – 12 s
- Mean Hs: 1 m – 2 m
- Maximum Hs: > 5 m



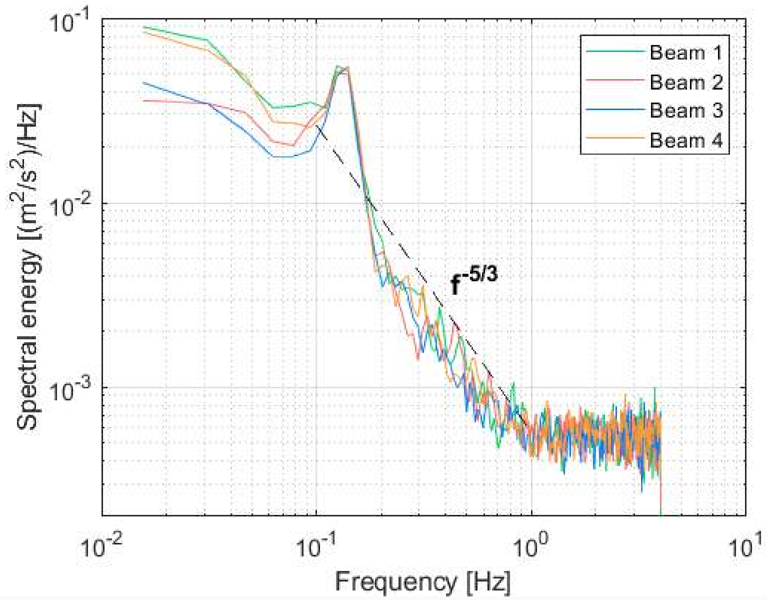
Study site 2: Clarence Strait, NT

- Narrow channels off the coast of Darwin – approx. 3 km
- 20 m – 40 m, deep pockets of 60 m
- Mean current speed:
  - Howard Channel: 1.0 – 1.1 m/s
  - North Channel: 0.8 m/s – 1.0 m/s
  - South Channel: 1.0 – 1.2 m/s
- Maximum current speed: 2.8 m/s
- Mean wave period: 2 s – 3 s
- Mean Hs: 0.2 m – 0.5 m
- Maximum Hs: approx. 1 m



Wave-turbulence interaction

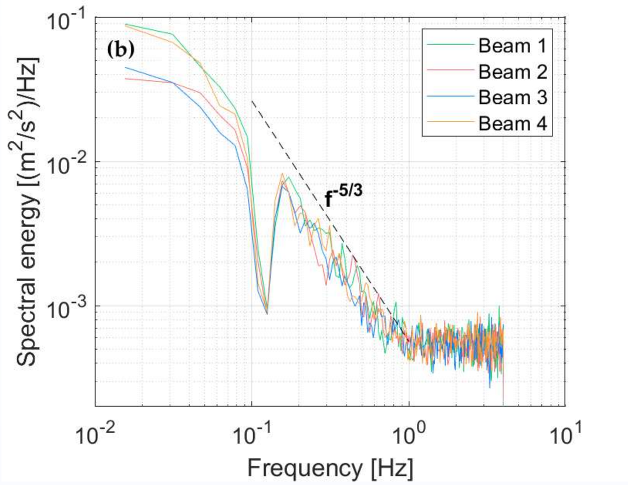
- **Superposition** of wave orbital velocities and turbulent fluctuations
  - Common in prospective tidal energy sites
  - Lead to inaccurate estimations of turbulence
- Strong and constant characteristic of Banks Strait, TAS
- Tested several methods to decompose: Synchrosqueezing Wavelet Transform (SWT)
  - The technique was later applied to other sites in Europe
  - Further development



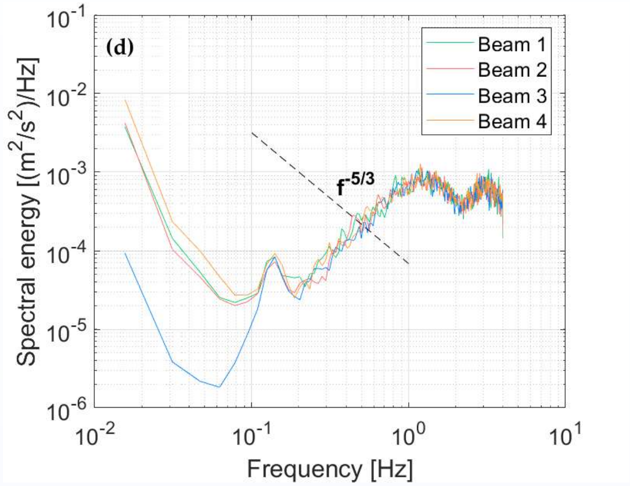
(Perez et al. 2020)

Wave-turbulence decomposition

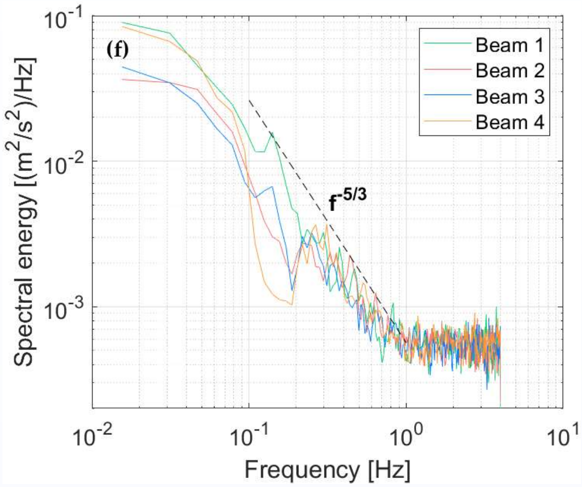
- Some techniques tested:



Stopband filter



Moving average filter



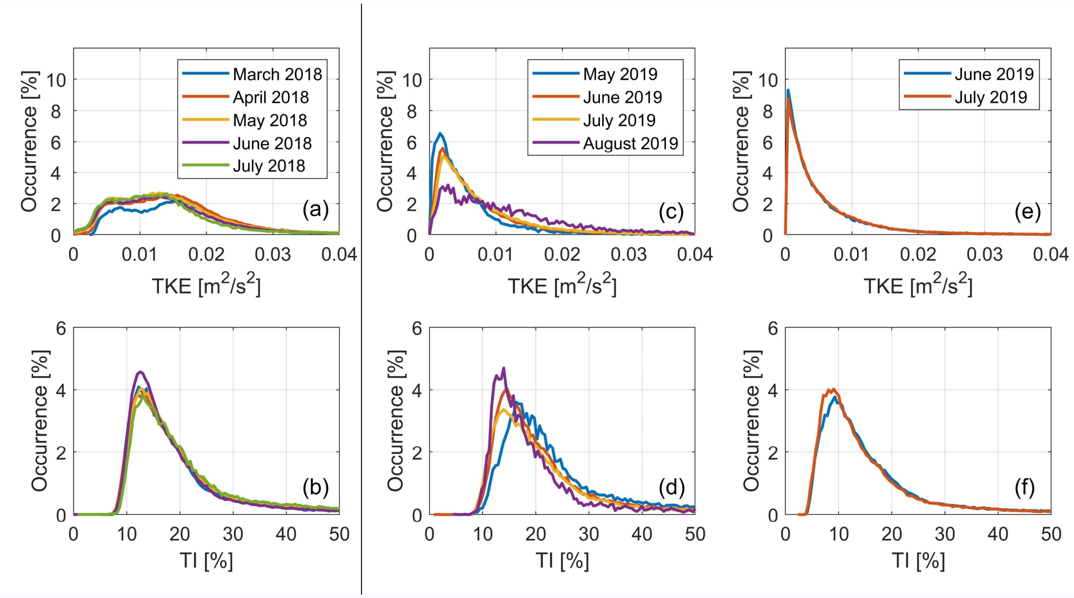
SWT

Turbulence characterization

- 2 – 3 months long datasets (sampling rates 4 Hz – 8 Hz)
- Application of SWT method to Banks Strait data
- Wave climates and mean currents
- Estimation of turbulence parameters at both study sites:
  - Turbulence intensity
  - TKE
  - TKE production rates
  - TKE dissipation rates
  - Integral length scales
- Investigation of parameters variability:
  - Tidal cycle
  - Wave climates

Banks Strait, TAS

Clarence Strait, NT



(Perez et al. 2021)

Tidal turbine performance

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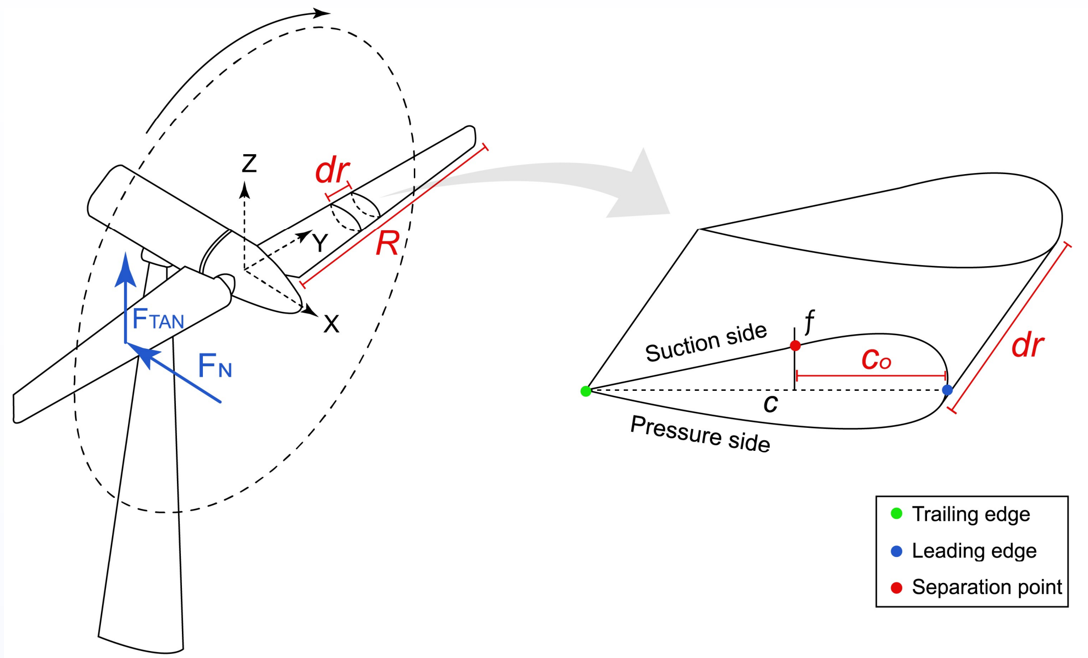
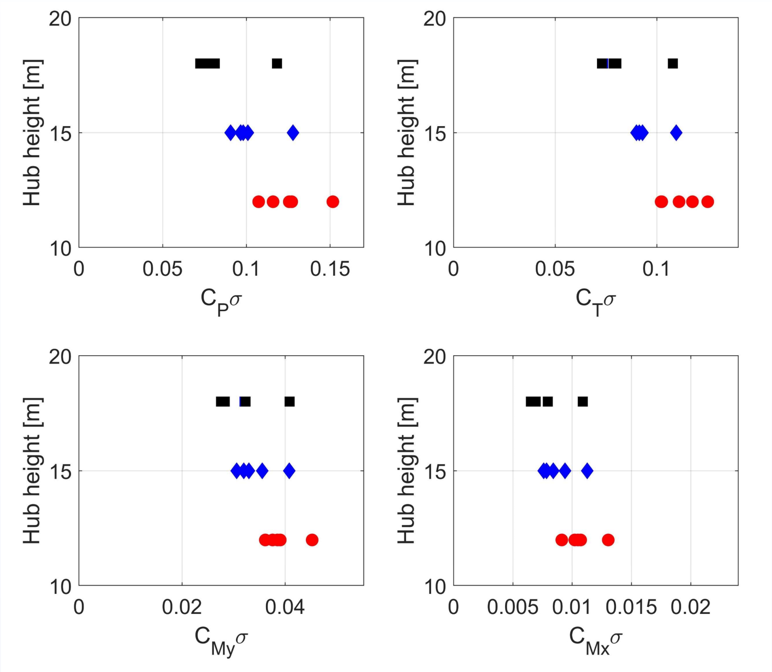
- High-frequency field **ADCP data to feed BEM model**
  - Model uses the velocity field measured at the sites
- Verification of **impacts to device performance** induced by:
  - Hub submergence depth
  - Large waves
  - Various levels of turbulence

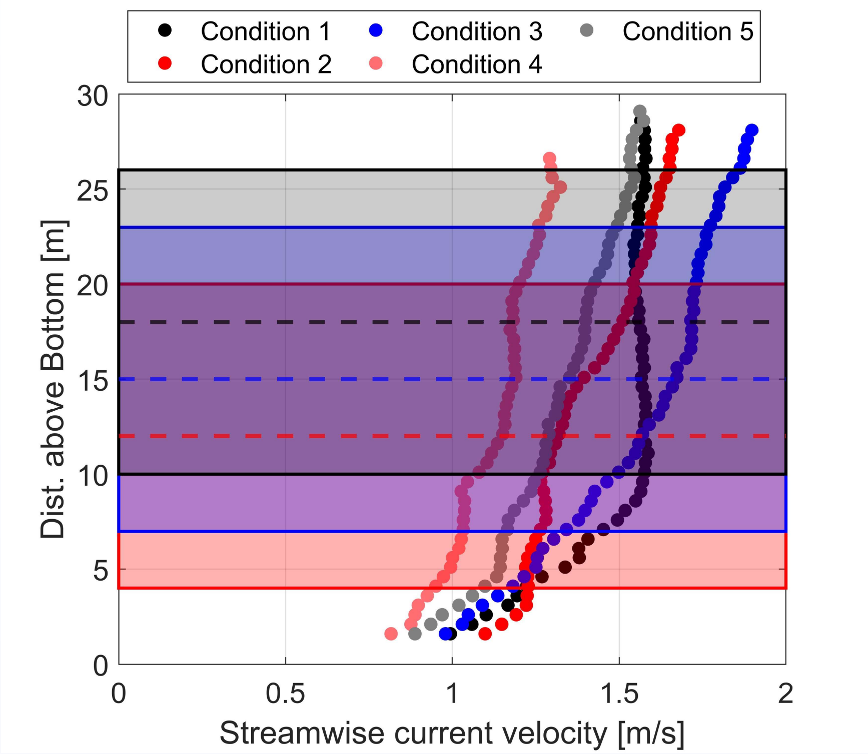


(Perez et al. 2022)

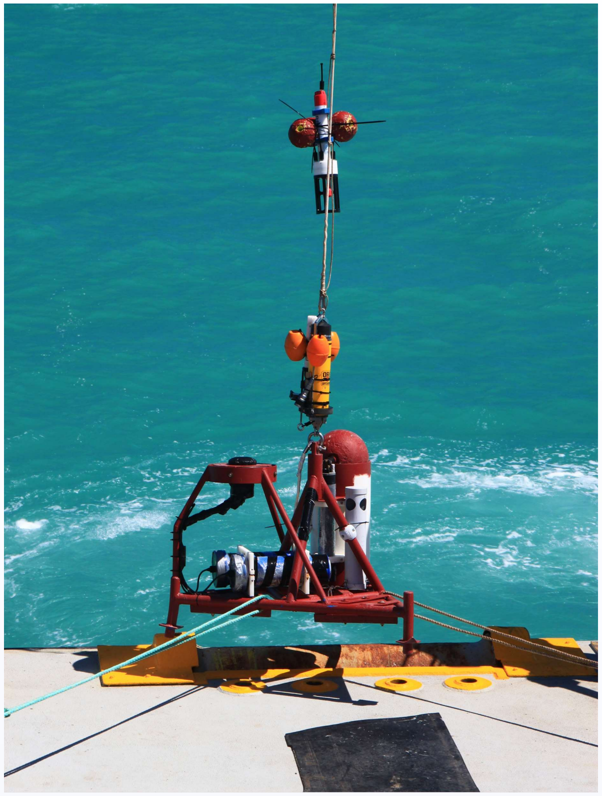
Tidal turbine performance

- Large standard deviations in pronounced shear profiles
- Impact of **hub height variations**





Main research outcomes



- Different wave-turbulence decomposition methods have been discussed
- Quantification of turbulence parameters in sites previously unexplored
  - Long datasets now publicly available
  - Investigation of turbulence parameters at both sites:
    - Different instrument configurations
    - Estimation of several metrics
- Investigation of turbine performance using field data from sites never studied

Thank you

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