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Tidal Energy in Australia

Assessing resource and feasibility to Australia's future energy mix

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Acknowledgements

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Project Lead

Research Partners

Funding Agency

Industry Participants

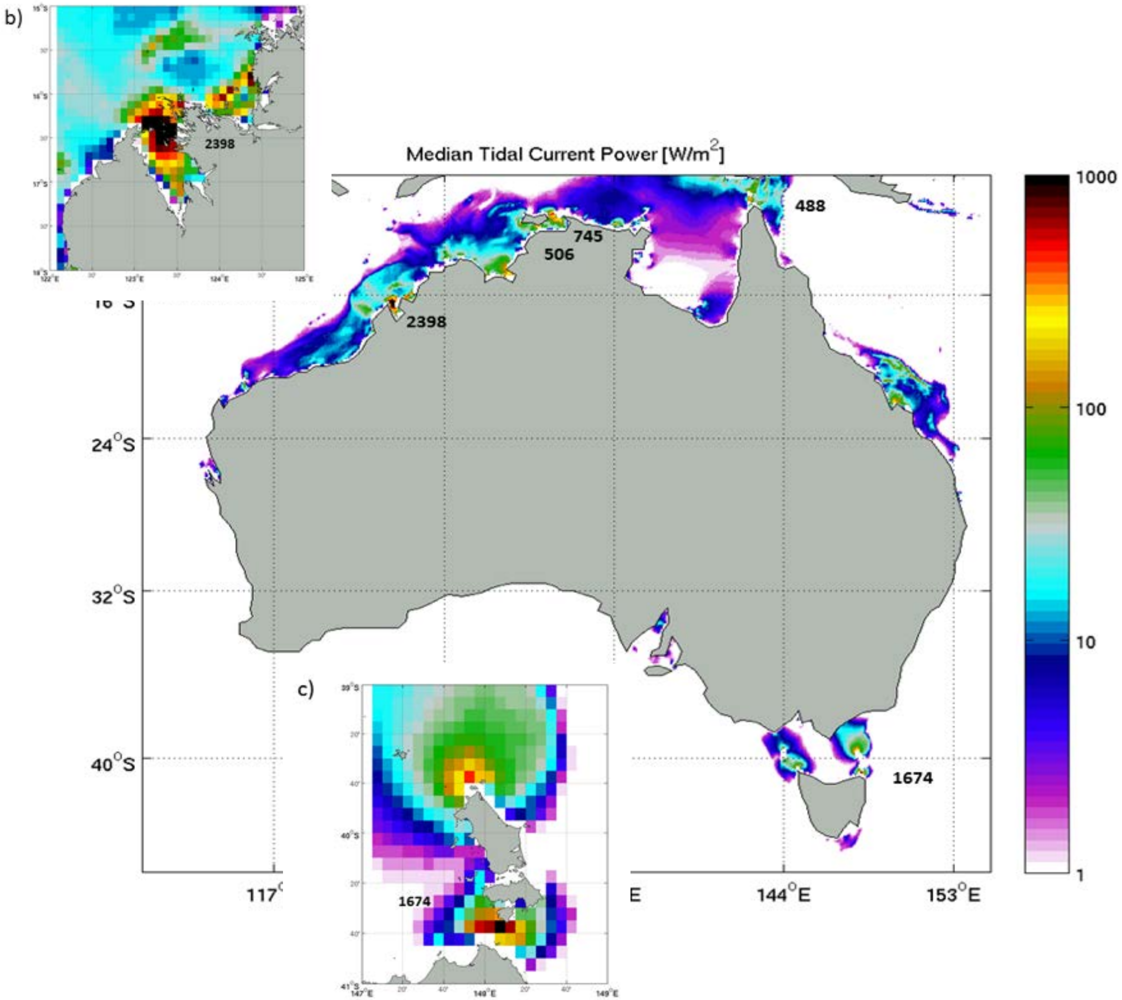
International Collaborators

Where is there tidal resource in Australia?

Clarence Strait: 200 MW (~1.75 TWh/yr; flux of 500 W/m^2, over a 20km channel 20m deep).
Dundas Strait: 1.2 GW (~10 TWh/yr; flux of 750 W/m^2, over a 25 km channel 60 m deep).

Together could deliver to the whole Northern Territory electricity demand (~3.5 TWh/yr in 2013/2014).

King Sound: 1.5 GW (~13 TWh/yr; flux of 2400 W/m2, over a 25 km channel, 25 m deep).



Time-averaged tidal current power, based on the 1/12 degree (~10km) tidal model (CSIRO, 2012).

Torres Strait (QLD): 500 MW (~4.4 TWh/yr; flux of 500 W/m2 over a 100 km channel, 10 m deep) grid and off-grid applications.

Banks Strait (TAS): 350 MW (3 TWh/yr; flux of 1650 W/m2, over a 10 km wide channel, 25 m deep) grid and off-grid applications.
Tasmania's electricity consumption in 15/16 was 10.2 TWh/yr.

Despite technology advancement and Australia being home to some of the largest tides in the world, the quality of information is not sufficient for companies to attract investors.

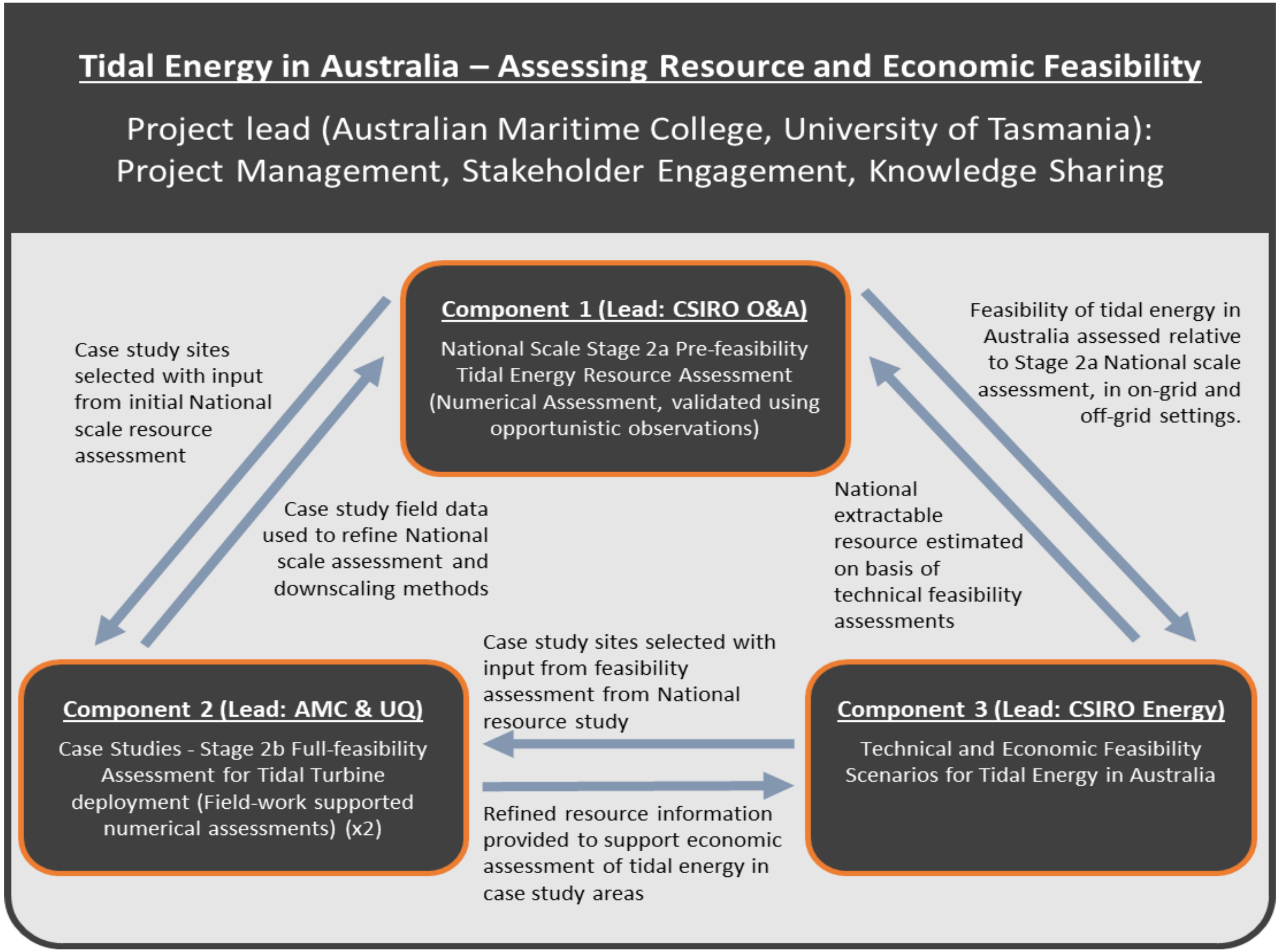
How can we access greater granularity of data to help refine our understanding of the scale and distribution of tidal resources in Australia, to attract and underpin investment?

How well suited are Australian sites for tidal energy development and what potential for viable energy generation exist at these sites?

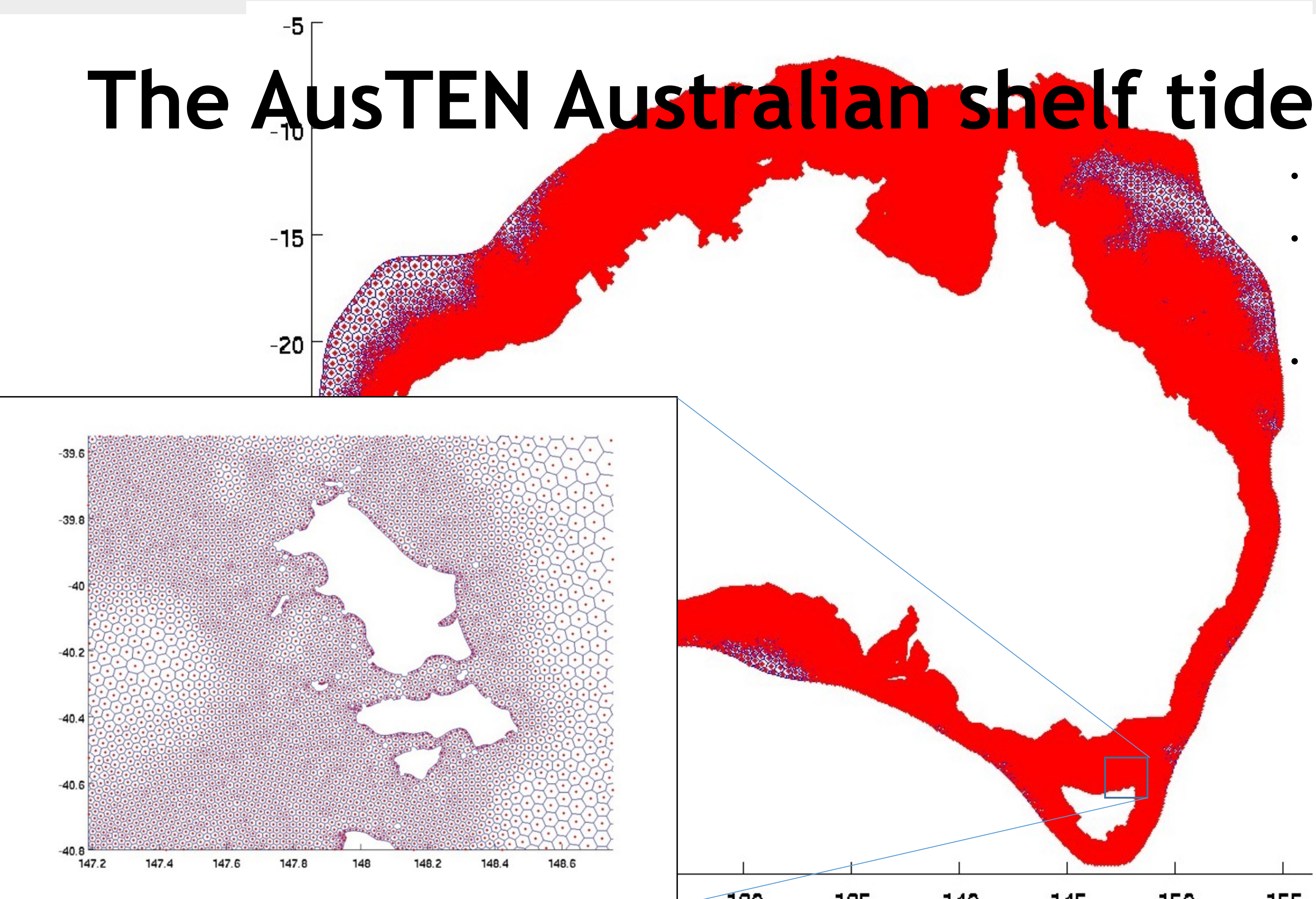
Project Outcomes

- Increased understanding of **Australia's national tidal energy resource**.
- Detailed understanding of **two case-study sites**.
- **Sharing** of high quality research into the **technical and economic feasibility of tidal energy generation in Australia**, addressing conditions specific to Australia.
- Timely data that is correct and of sufficient quality to support accurate calculation of the **LCOE** of proposed tidal energy converter technologies.
- **Reduced cost & risk** for prospective tidal energy developers.
- Improved awareness and understanding of tidal energy to the public, investors and collaborators.
- Improved skills, capacity and knowledge to support further development of Australia's ocean renewables industry.
- Improved collaboration across the Universities, Government (including ARENA funded projects) and Industry to support development of Australia's ocean renewable energy industry.

Project Structure



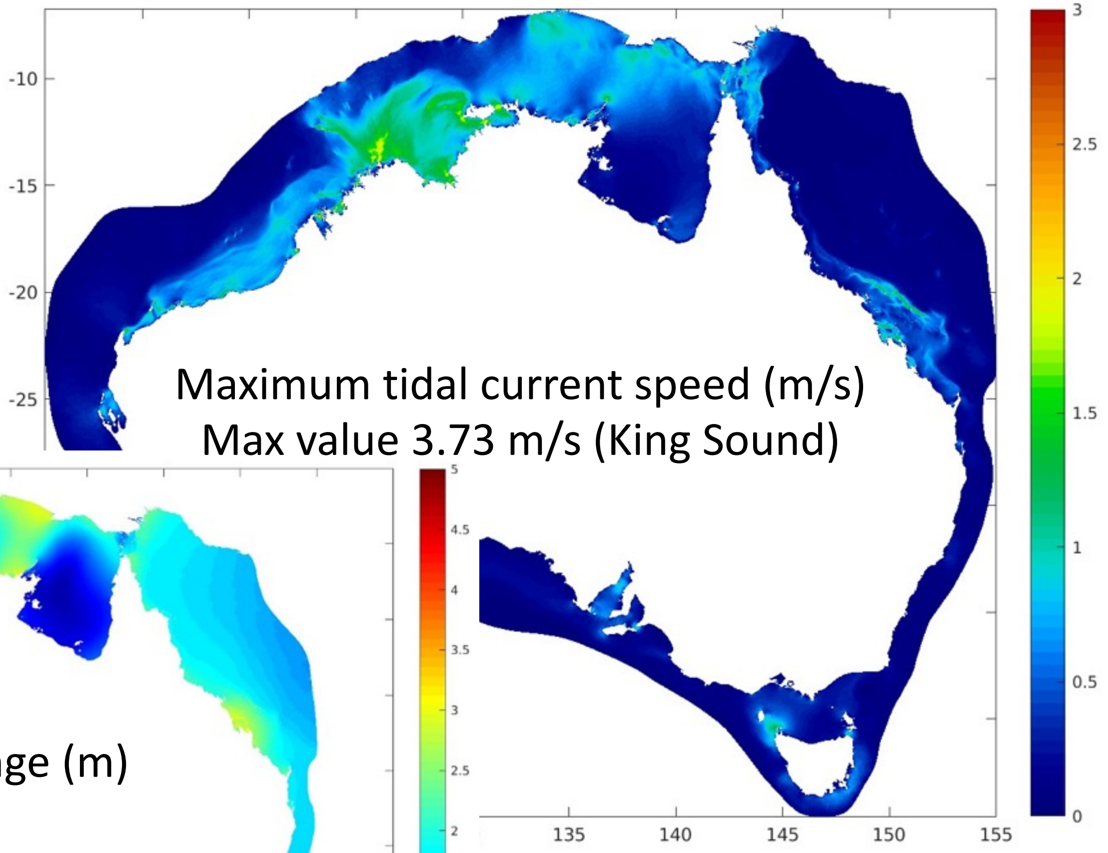
The AusTEN Australian shelf tide model

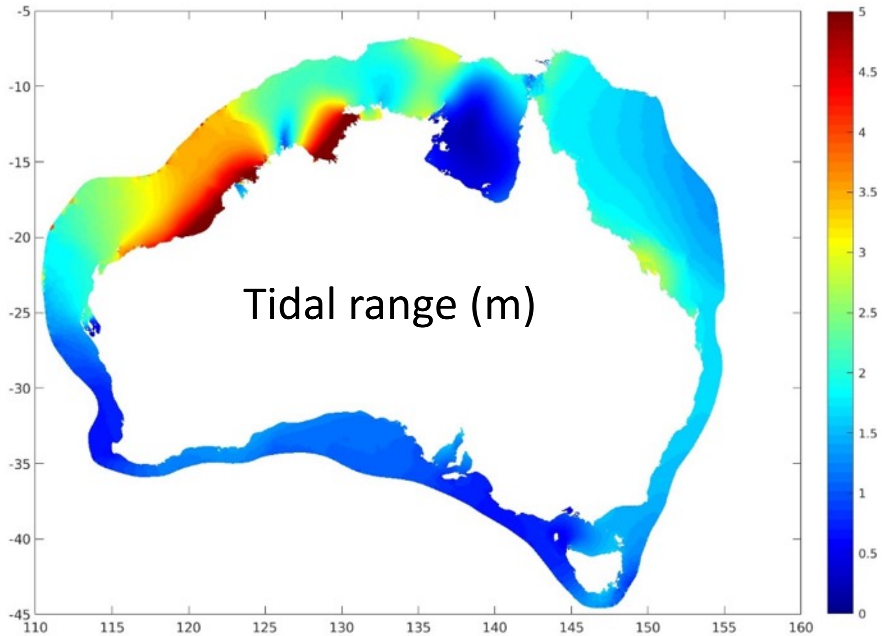


- ARENA project is to deliver tidal sea level and currents around Australia,
- Weighting function is a combination of tide and bathymetry (e.g. shallow areas with high amplitude get high resolution),
- A national 3D model would probably use a different weighting function.

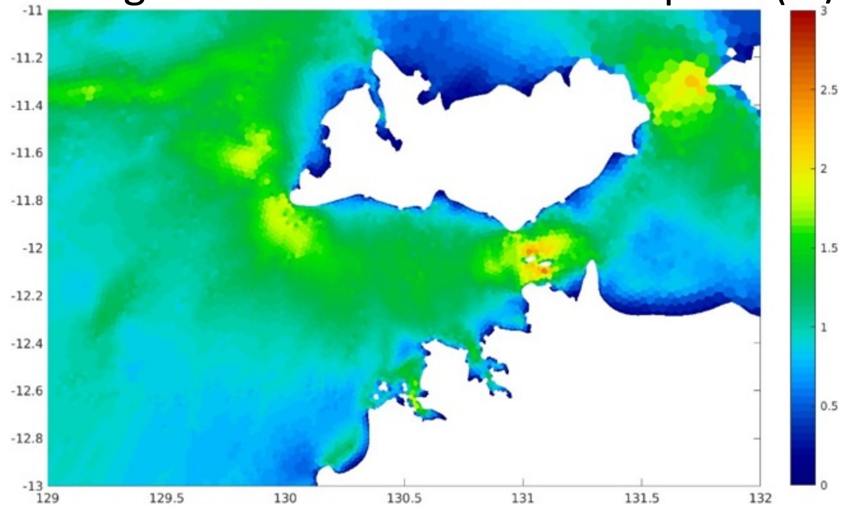
Number of 2D wet cells = 212686
Number of 3D wet cells = 2322647
52 vertical layers
Mean horizontal edge length = 4162.61 m
Mean distance between centres = 2394.27 m
Min. distance between centres = 445.25 m
Max. distance between centres = 54501.19 m
Mean cell area = 23.23 km^2

Preliminary simulation results

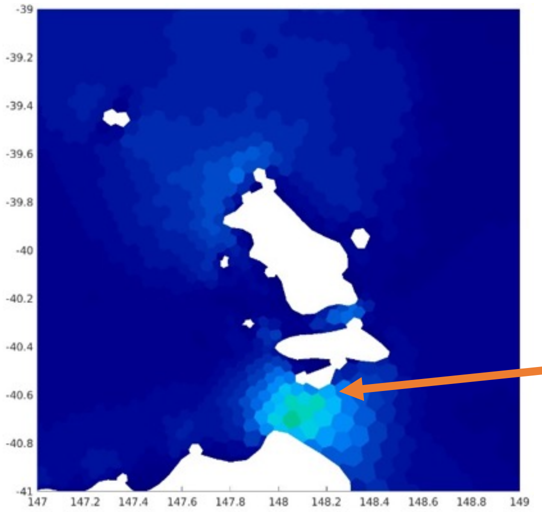




Beagle Gulf: Max tidal current speed (m/s)



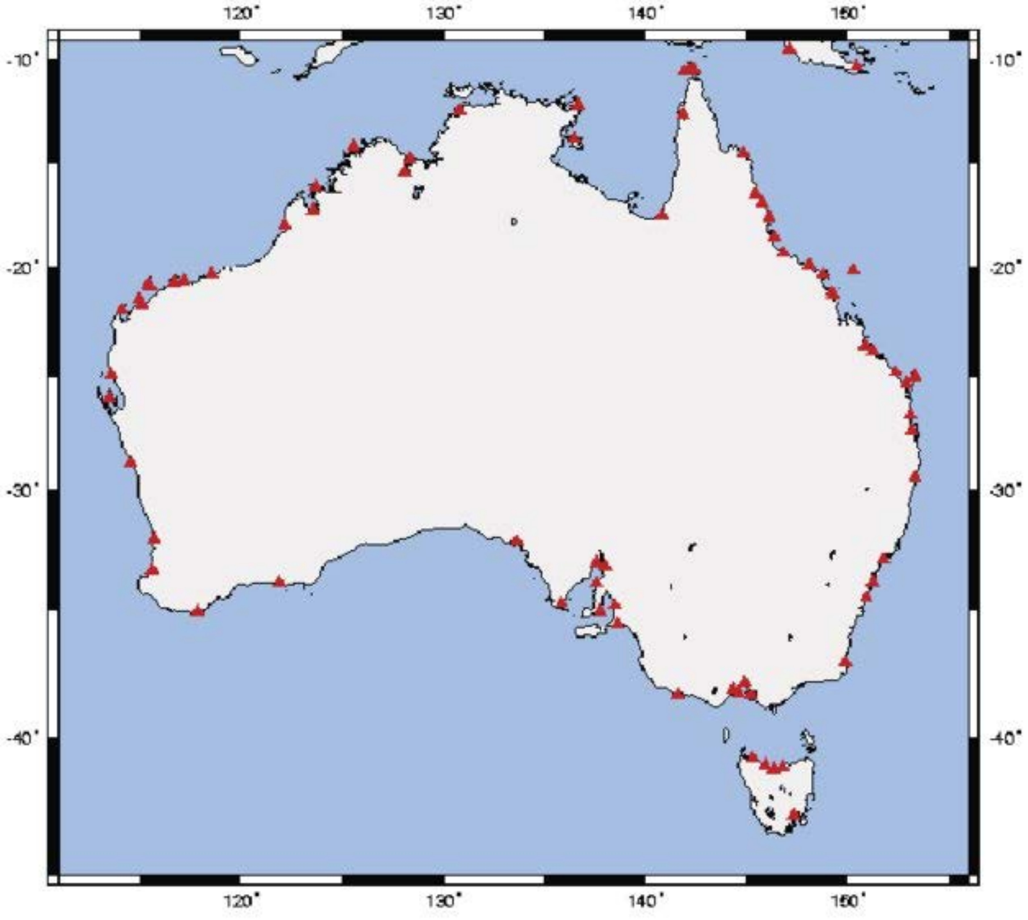
Banks Strait: Max tidal current speed (m/s)



Grid needs iteration
Tidal range NOT tidal velocity dependence

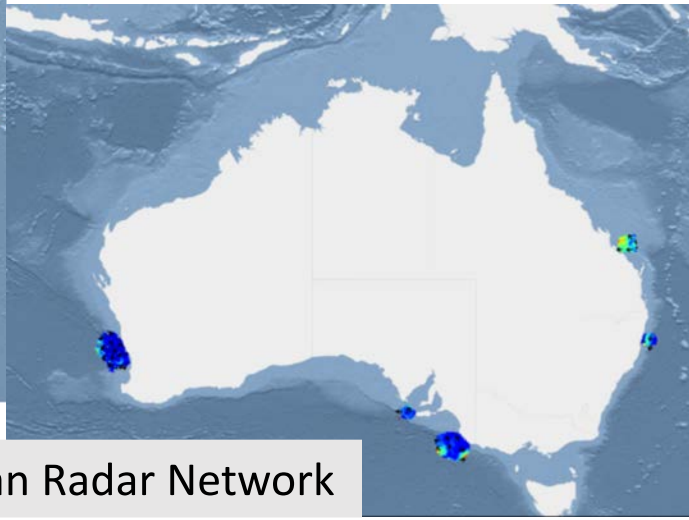
Calibration/Validation Data

Elevations / Tide gauges
(National Tide Centre, Bureau Met.)



Available tidal velocity data
(Australian Ocean Data Network, IMOS)

Australian National Mooring Network



Australian Coastal Ocean Radar Network

Component 2 data needed for validation in high energy regions

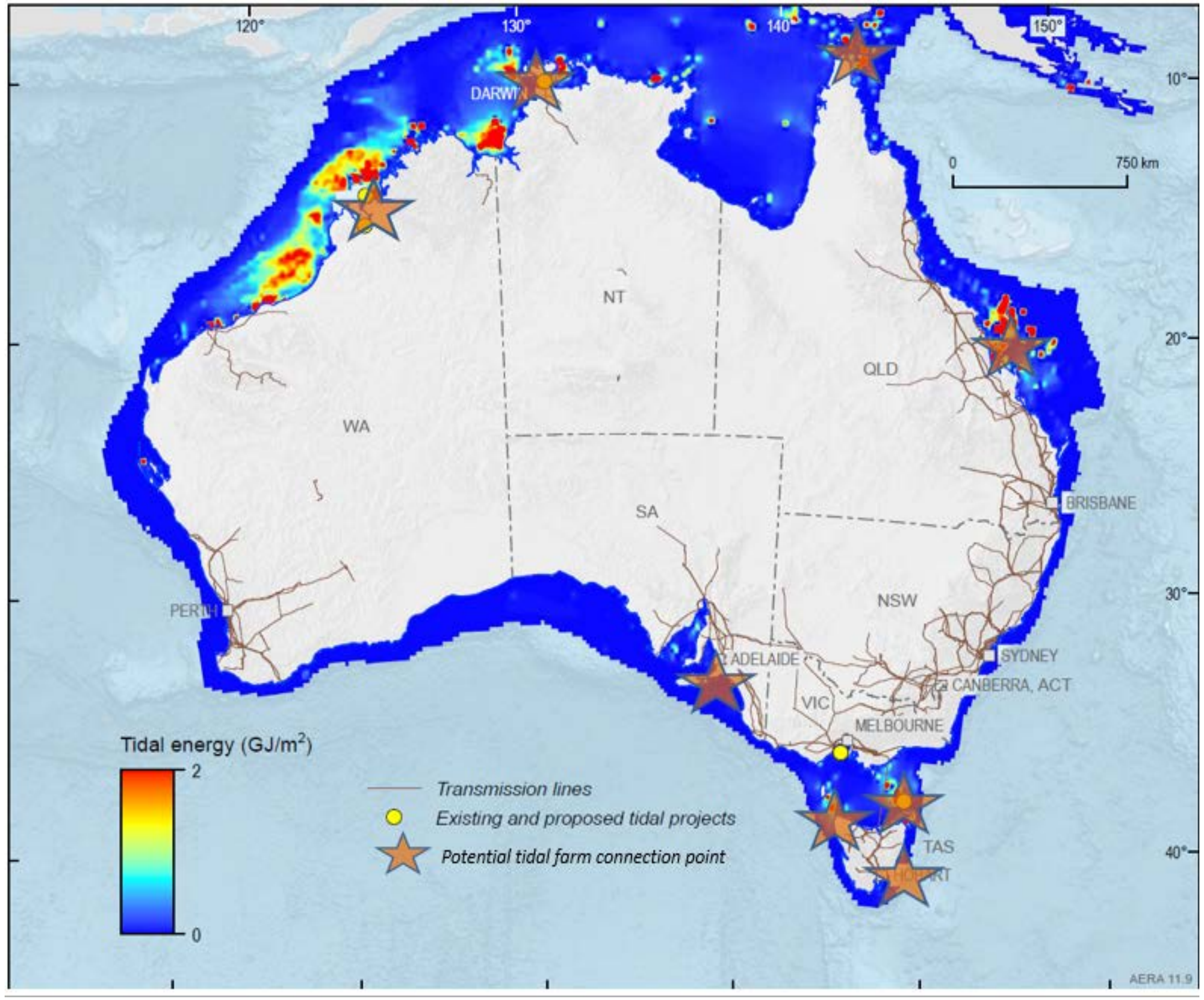
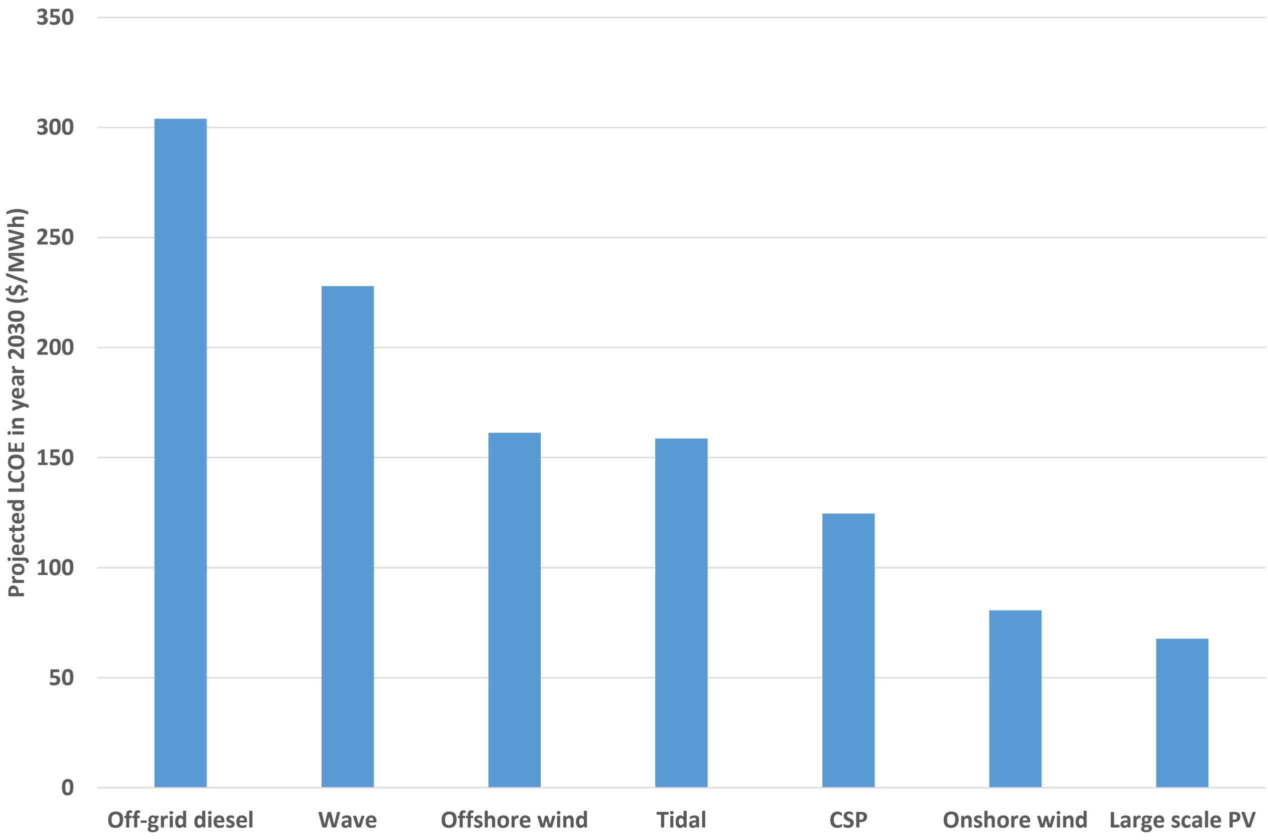


Fig. 1 Tidal energy resources and potential connection point in Australia (**Source:** Geoscience Australia)

No.	Major potential tidal farm locations
1	Southern Tasmania
2	Northeast Tasmania
3	Northwest Tasmania
4	Kangaroo Island
5	Mid-North Queensland
6	Far North Queensland
7	Clarence Strait (Darwin)
8	King Sound (Western Australia)

Table 2. Potential tidal farm location

Tidal energy LCOE comparable with offshore wind by 2030



Projected LCOE of renewable electricity generation technologies.
Source: CSIRO's Global and Local Learning Model (GALLM)

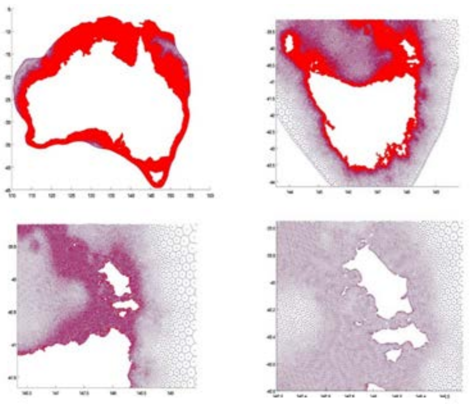
- Tidal has added advantage that highly predictable
- Tidal has half the LCOE of off-grid diesel and can work in a hybrid power system
- Installed tidal energy generation capacity in Australia could easily exceed 1.5GW with current LCOE estimates of AU $158 /MWh achievable by 2030.

How can we identify suitable tidal energy sites?

- Resource size is always performed
- But what about…

  -electricity demand, distances to grid connection, distance to electricity generators, distance to coastlines, distance to ports distance to population, environmental restrictions, locations of pipelines, slope of bathymetry, flow restrictions that induce turbulence or blockage, cable laying routes, economic costs, shipping density and tracks, biological restrictions, remoteness of site, water depth, other users, land title rights, turbine array spacing, turbine design, maximum capacity of electricity network, maximum capacity of electrical substations, intermittency, energy generation mix, noise restrictions, community support, blah blah blah…!

- **Multi-Criteria Assessment Model**



CSIRO National Tidal Model

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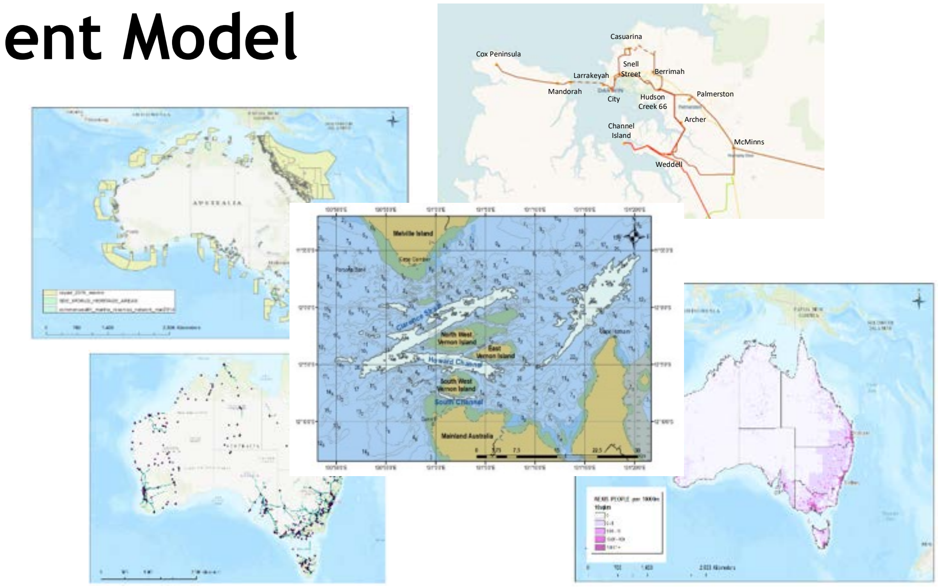

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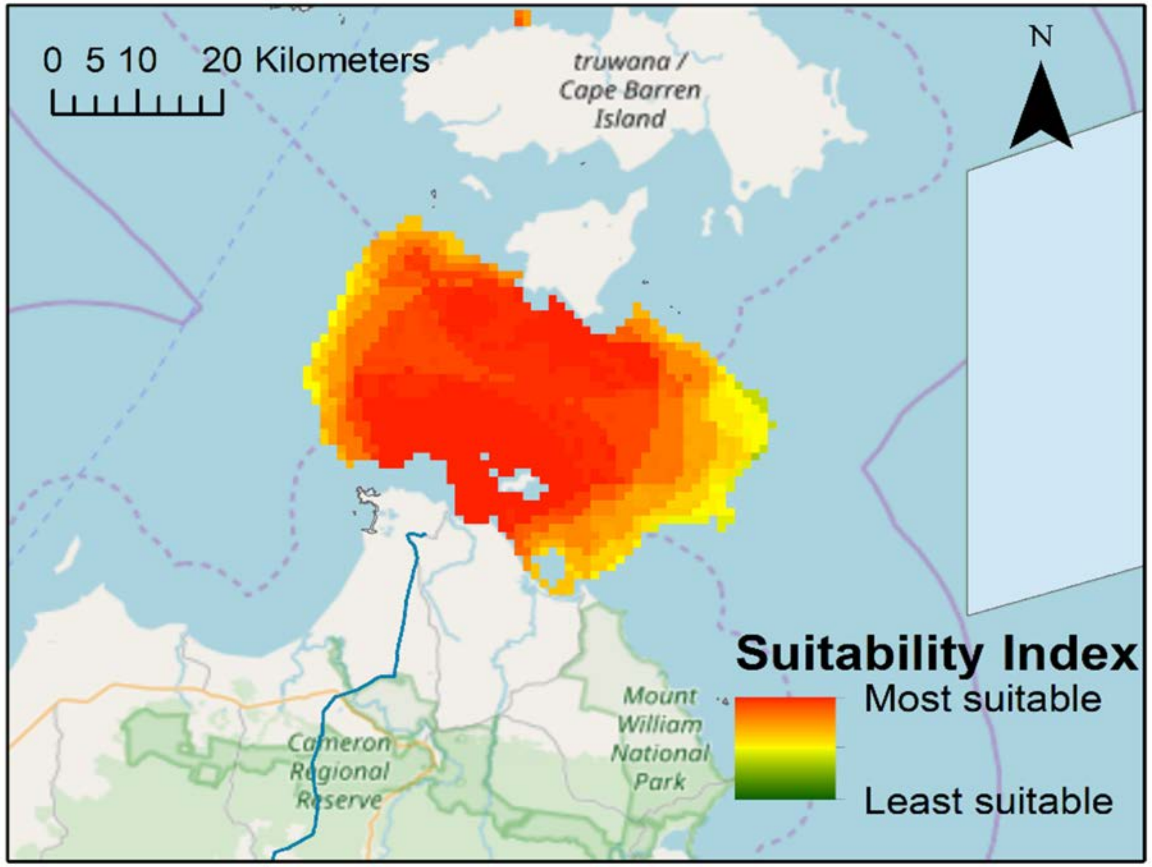
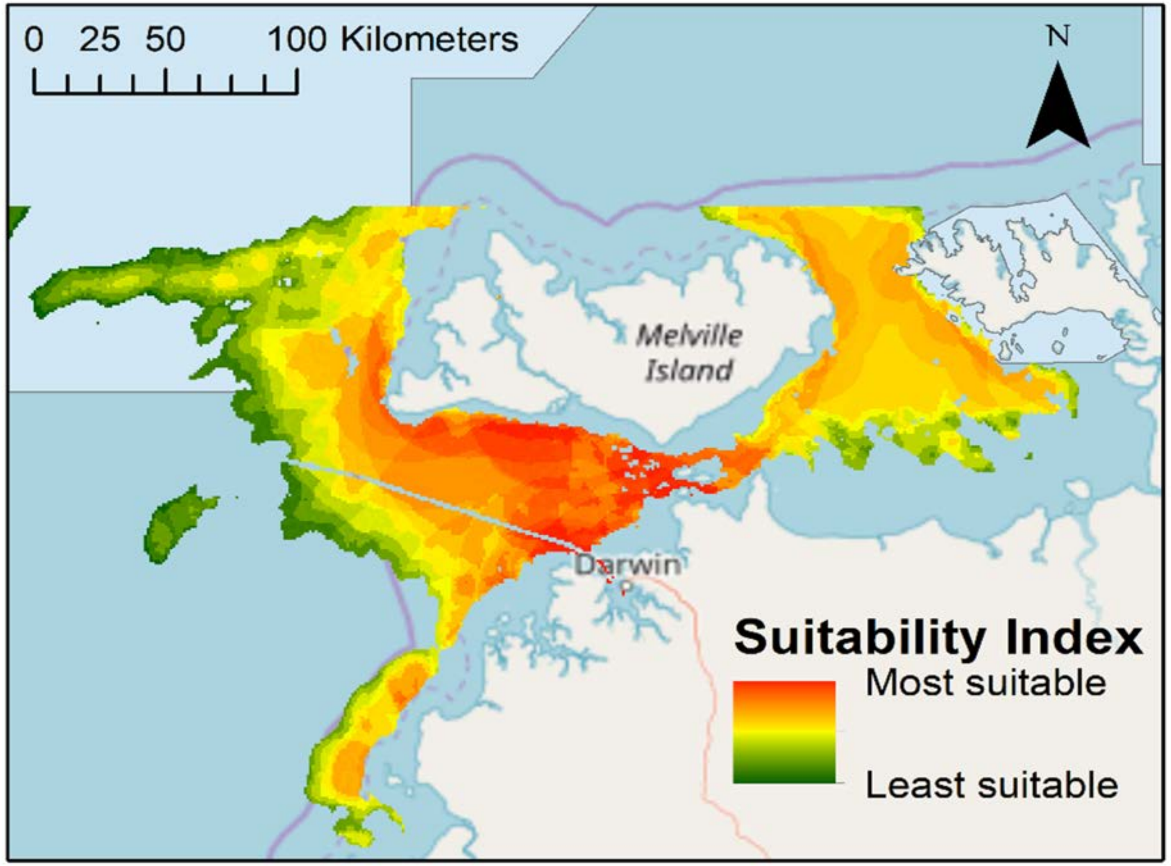
Site Suitability

MCA Site Suitability Index



Banks Strait Region



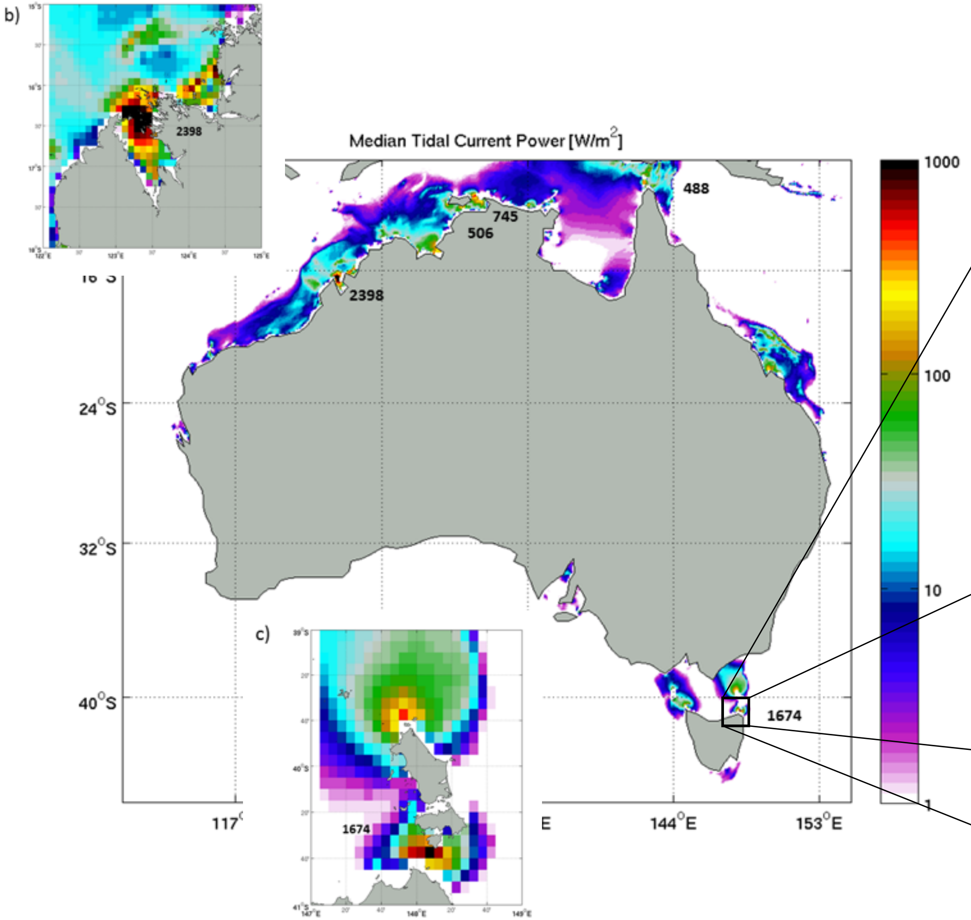
Darwin Region

Component 2

Focussed case studies at two promising locations for energy extraction, involving rigorous field based and high-resolution numerical site assessments.

One site is specified (Eastern Bass Strait, TAS) and second chosen on basis of work completed in components 1 and 3 (Clarence Strait, NT).

Site 1 Location: Banks Strait, Tasmania



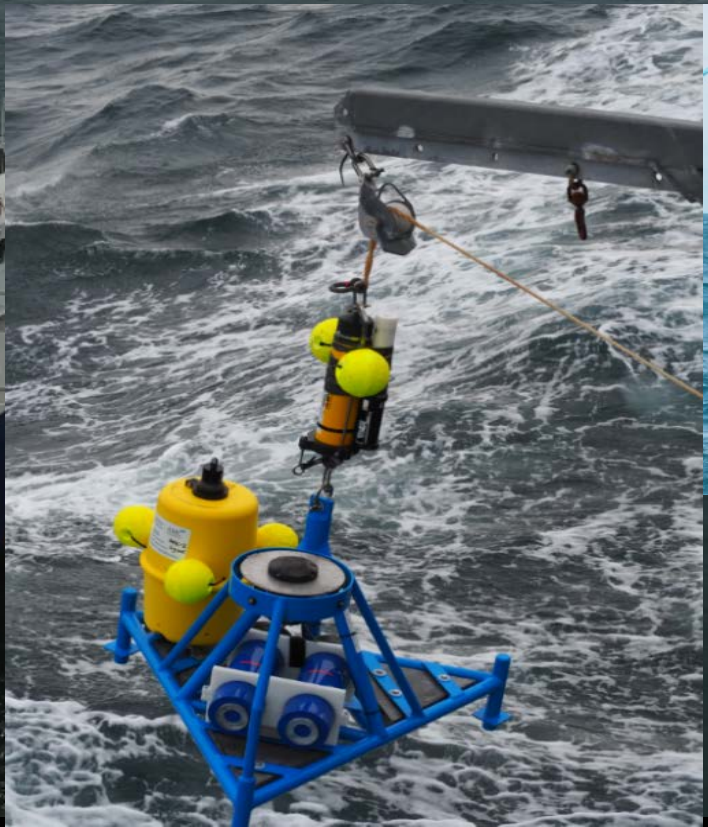
Time-averaged tidal current power, based on the 1/12 degree (~10km) tidal model (CSIRO, 2012).

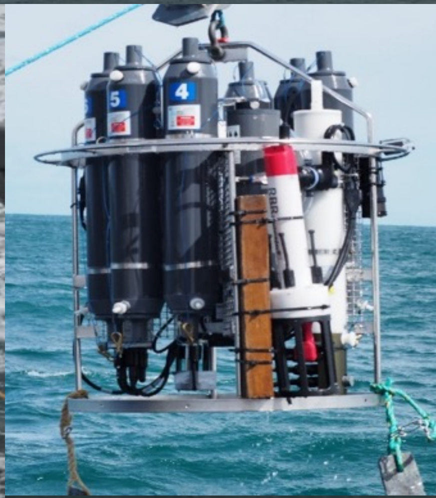
Site 1 location (Google Earth)

Summary of activities

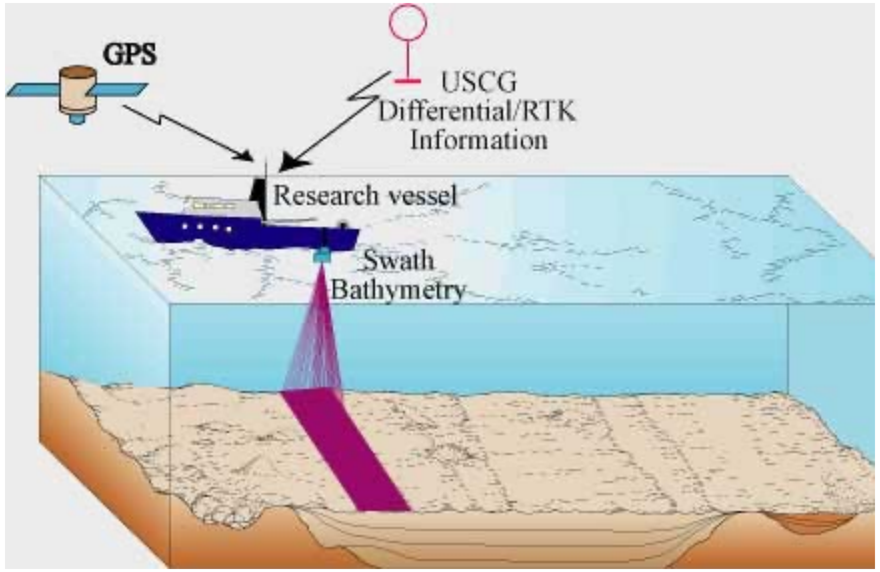
All AUSTEn Campaigns

Instrument type	Activity type	Brand and model	Measures/ Collects
Multi-Beam	Transects	BathySwath 1, 234 kHz	Bathymetry
ADCPs	Moorings	RDI WorkHorse, 300 kHz	Currents
		RDI Sentinel V, 500 kHz	Currents and Waves
		Nortek AWAC, 1 MHz	Currents and Waves
		Nortek Signature, 1 MHz	Currents, Waves, Turbulence, Echo Sounder
		Nortek Signature, 500 kHz	Currents, Waves, Turbulence, Echo Sounder
Temperature	Mooring	RBR Solo T, Generation 2 & 3	Temperature
CTDs	Casts	RBR Concerto Multi Channel Logger, Generation 2	Conductivity, Temperature, Depth, Turbidity
		RBR Maestro, Generation 3	Conductivity, Temperature, Depth
		Seabird SBE 25 plus CTD	Conductivity, Temperature, Depth
Rosette SBE 32	Casts	Seabird SBE 55 ECO Water Sampler	Water sampler controller
		Seabird SBE 63 Optical DO sensor	Optical Dissolved Oxygen
Penetrometer	Casts	blueDrop portable Penetrometer, blue C designs inc.,	Surficial seafloor sediments
LISST	Casts and moorings	Sequoia 100-X	Particle Size distribution
Core sampler	Sampling	Dormer Soil Samplers, Model UWS3515C	Sediment cores
Van Veen Grab sampler	Sampling	Manufactured in a machine shop	Sediment samples
Camera	N/A	GoPro Hero5 and Hero6	Pictures and Videos
Drone	N/A	DJI Phantom 3	Pictures and Videos

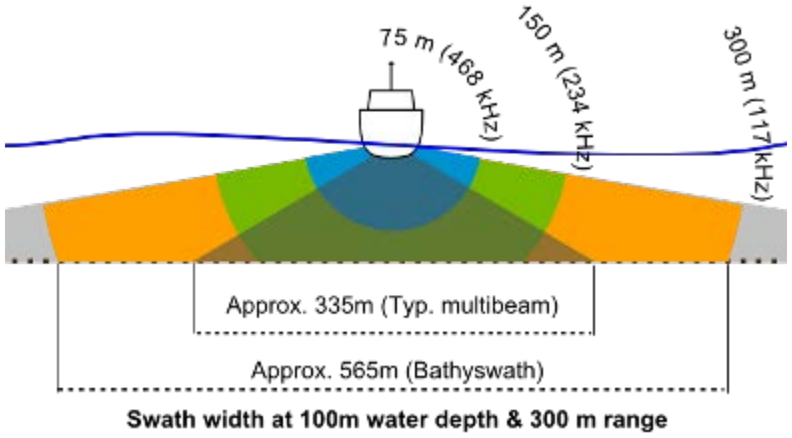




Seafloor survey: Bathymetry mapping

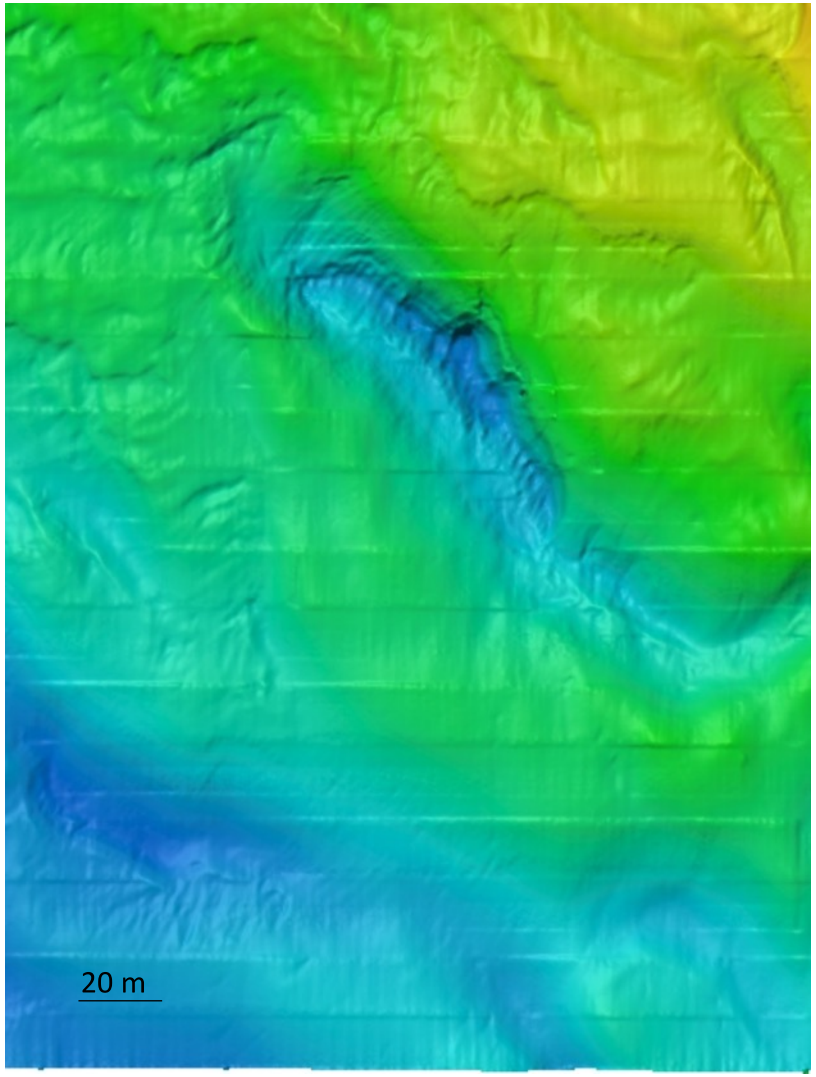


Bathymetry survey schematic (retrieved from Bathyswath.com)



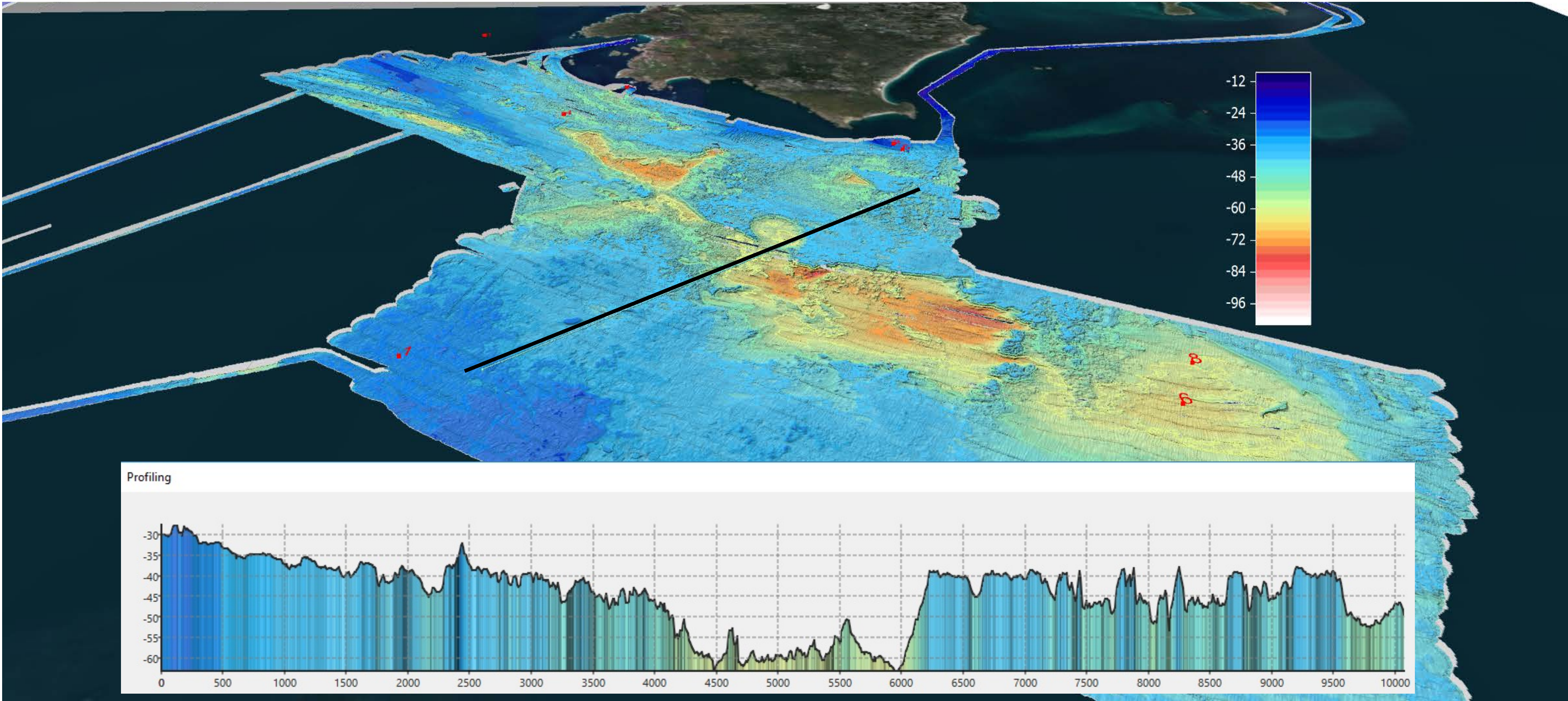
- Bathyswath 234kHz sonar system
- Side-Mounted to the vessel
- Horizontal bin resolution of < 5 m
- Vertical accuracy of approx. 0.1 m

EMEC (IEC) standards :
horizontal < 20 m (stage 2b)
horizontal < 5 m (stage 3)
Met and exceeded

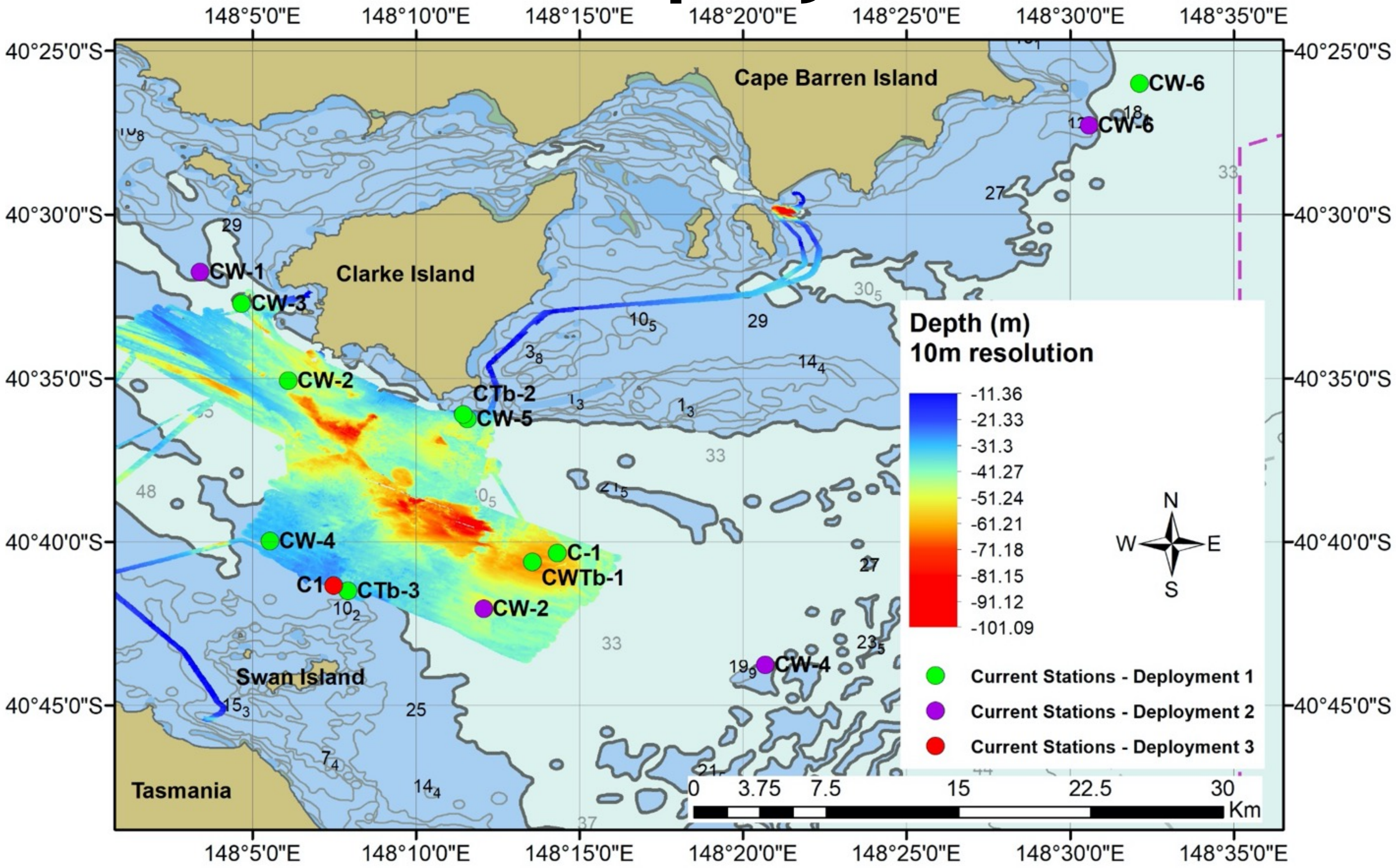


High resolution bathymetry data (Lake Oau)

Bathymetry data collected



All stations deployed in Banks Strait

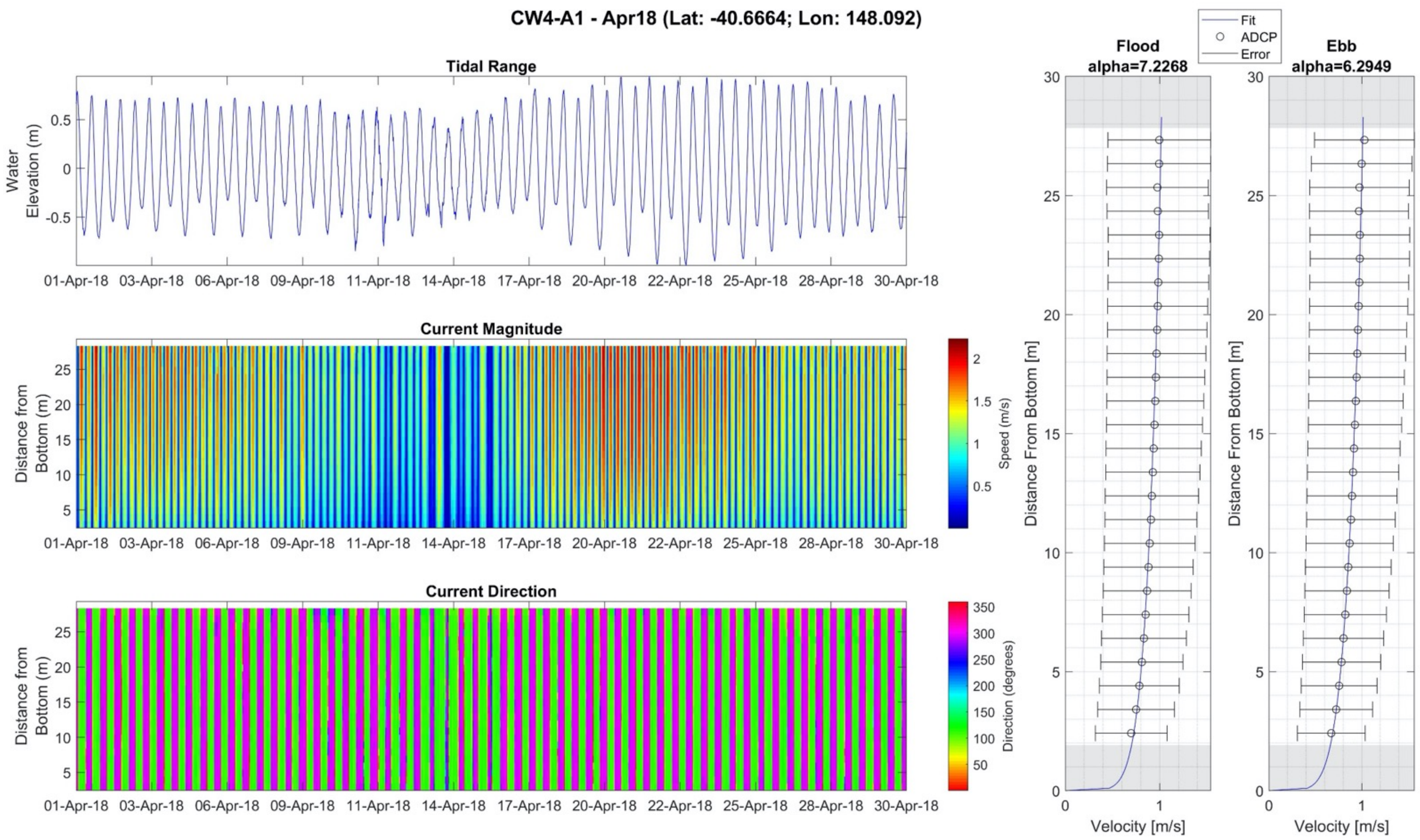


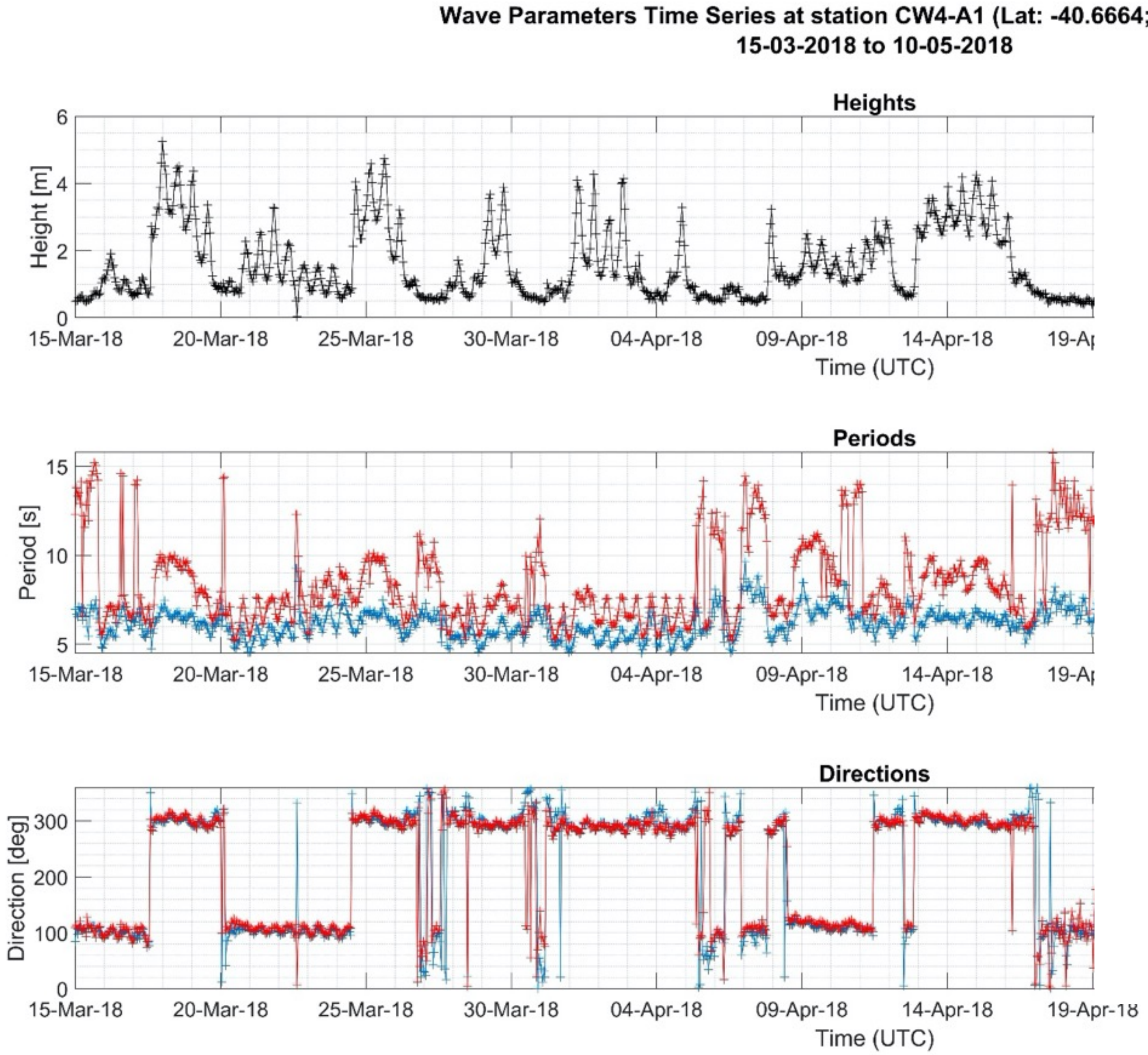
Depl.	Station	Data collected
1	C-1	Currents
	CW-2	Currents
	CW-3	Currents, Waves
	CW-4	Currents, Waves
	CW-5	Currents, Waves
	CW-6	Currents, Waves
	CWTb-1	Currents, Waves, Turbulence
	CTb-2	Currents, Turbulence
	CTb-3	Currents, Turbulence
2	CW-1	Currents, Waves
	CW-2	Currents, Waves
	CW-4	Currents, Waves
	CW-6	Currents, Waves
3	C-1	Currents

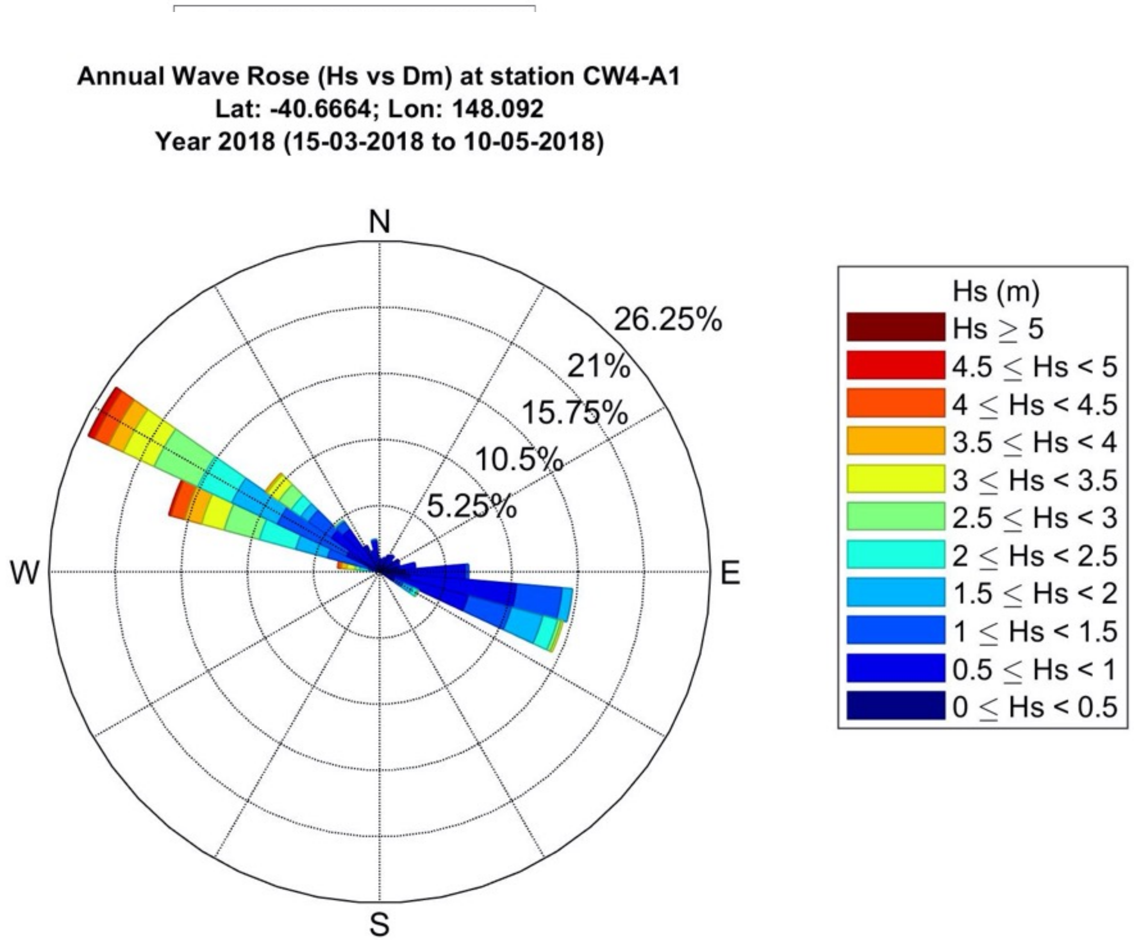
Data processing methodology

- Consistent way to process all Current & Data using the same tool: Ocean Database (AIMS) + IMOS Toolbox
  - Cleaning up data (side lobe, data out of water,…)
  - Correct for any time/compass/tilt errors
- Outputs:
  - Currents: sensor data in time series and current data in matrices (time step * depth cells)
  - Waves: statistical estimates - time series of Hs, Mean direction, Peak direction…
  - Contour plots, vertical plots, time series plots
- IMOS Compliant NC files; Raw & Processed
  - AREMI / AODN/IMOS deposit

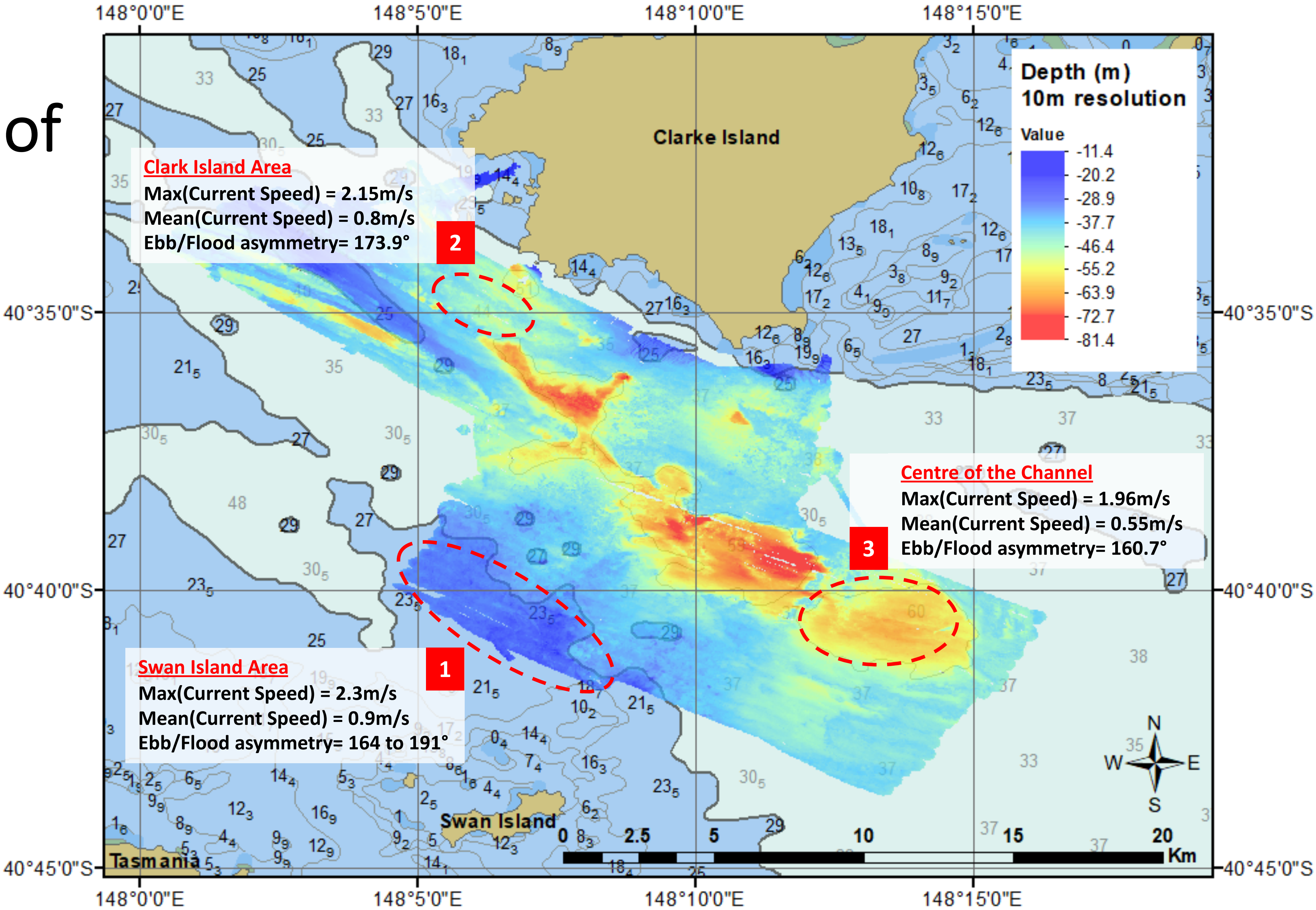
Current & Wave plots



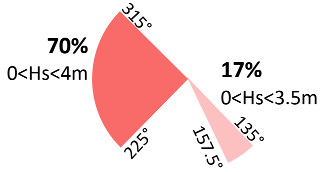

Wave Parameters Time Series at station CW4-A1 (Lat: -40.6664; Lon: 148.092)
15-03-2018 to 10-05-2018
Heights
Height [m]
Time (UTC)
Periods
Period [s]
Time (UTC)
Directions
Direction [deg]
15-Mar-18
20-Mar-18
25-Mar-18
30-Mar-18
04-Apr-18
09-Apr-18
14-Apr-18
19-Apr-18
25-Apr-18
30-Apr-18
05-May-18
10-May-18
Time (UTC)

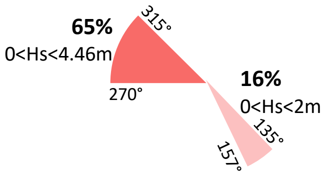

Annual Wave Rose (Hs vs Dm) at station CW4-A1
Lat: -40.6664; Lon: 148.092
Year 2018 (15-03-2018 to 10-05-2018)
N
E
S
W
5.25%
10.5%
15.75%
21%
26.25%
Hs (m)
Hs ≥ 5
4.5 ≤ Hs < 5
4 ≤ Hs < 4.5
3.5 ≤ Hs < 4
3 ≤ Hs < 3.5
2.5 ≤ Hs < 3
2 ≤ Hs < 2.5
1.5 ≤ Hs < 2
1 ≤ Hs < 1.5
0.5 ≤ Hs < 1
0 ≤ Hs < 0.5

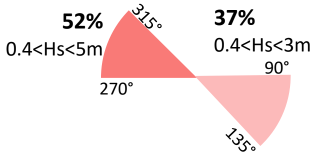
Summary of Results - Currents

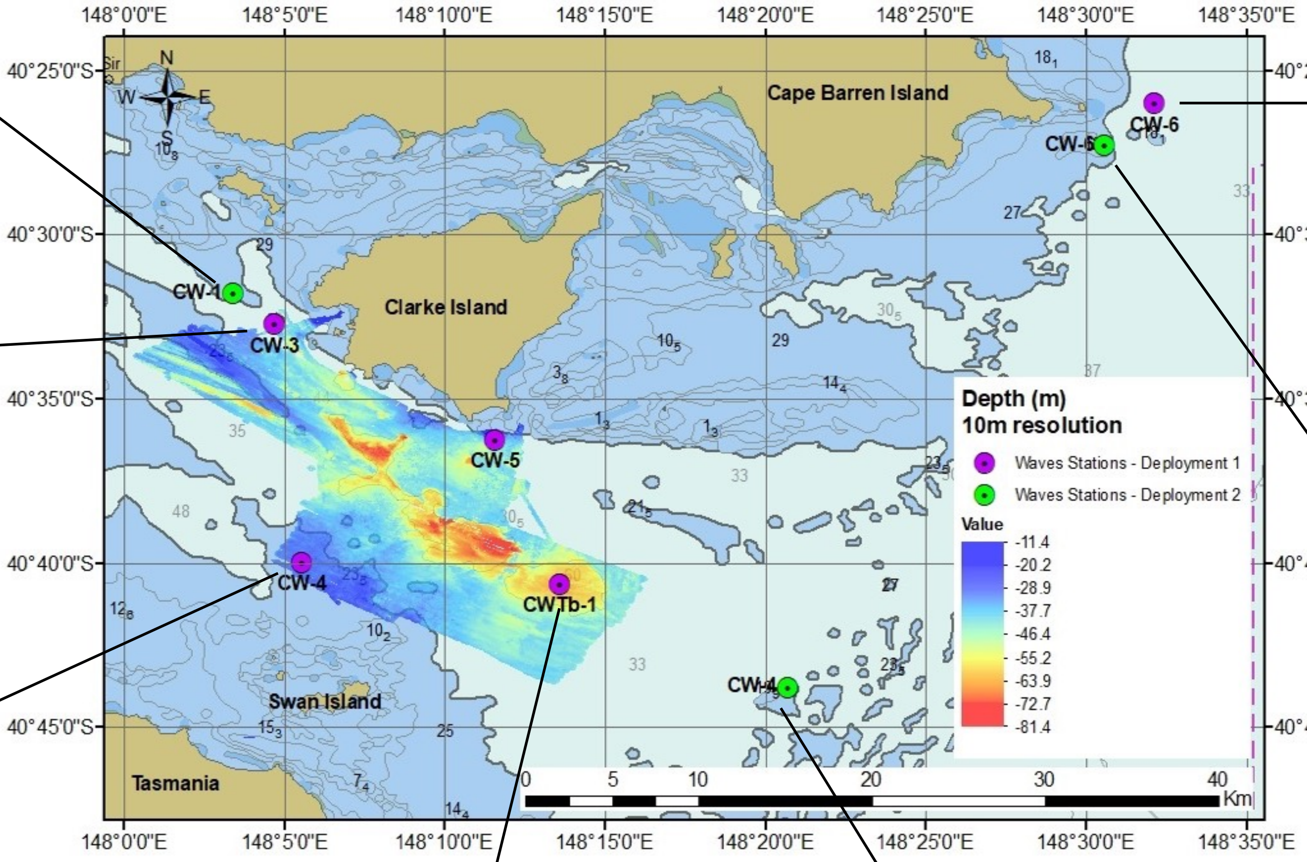


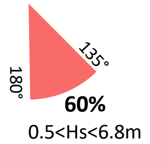
Summary of Results - Waves

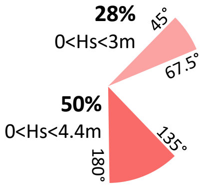
0.18m<Hs<4m	
7s<Tm<13.3s 6s<Tp<16s	

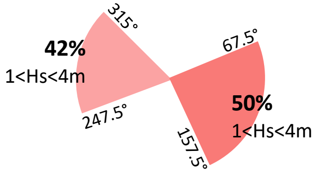
0.2m<Hs<1m Max(Hs)=4.46m	Mean(Power)=15.8kW.m^2 Max(Power)=143kW.m^2
4.8s<Tm<9.6s 6s<Tp<16.5s	
35% of Waves 0m<Hs<0.5m & 5s<Tm<7s	

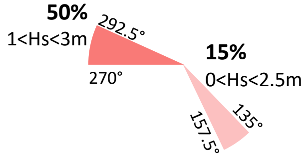
0.4m<Hs<2m Max(Hs)=5.26m	Mean(Power)=19.6kW.m^2 Max(Power)=200kW.m^2
4.5s<Tm<9.6s 5.5s<Tp<15.5s	
12% of Waves 0.25m<Hs<0.5m & 5s<Tm<6s	



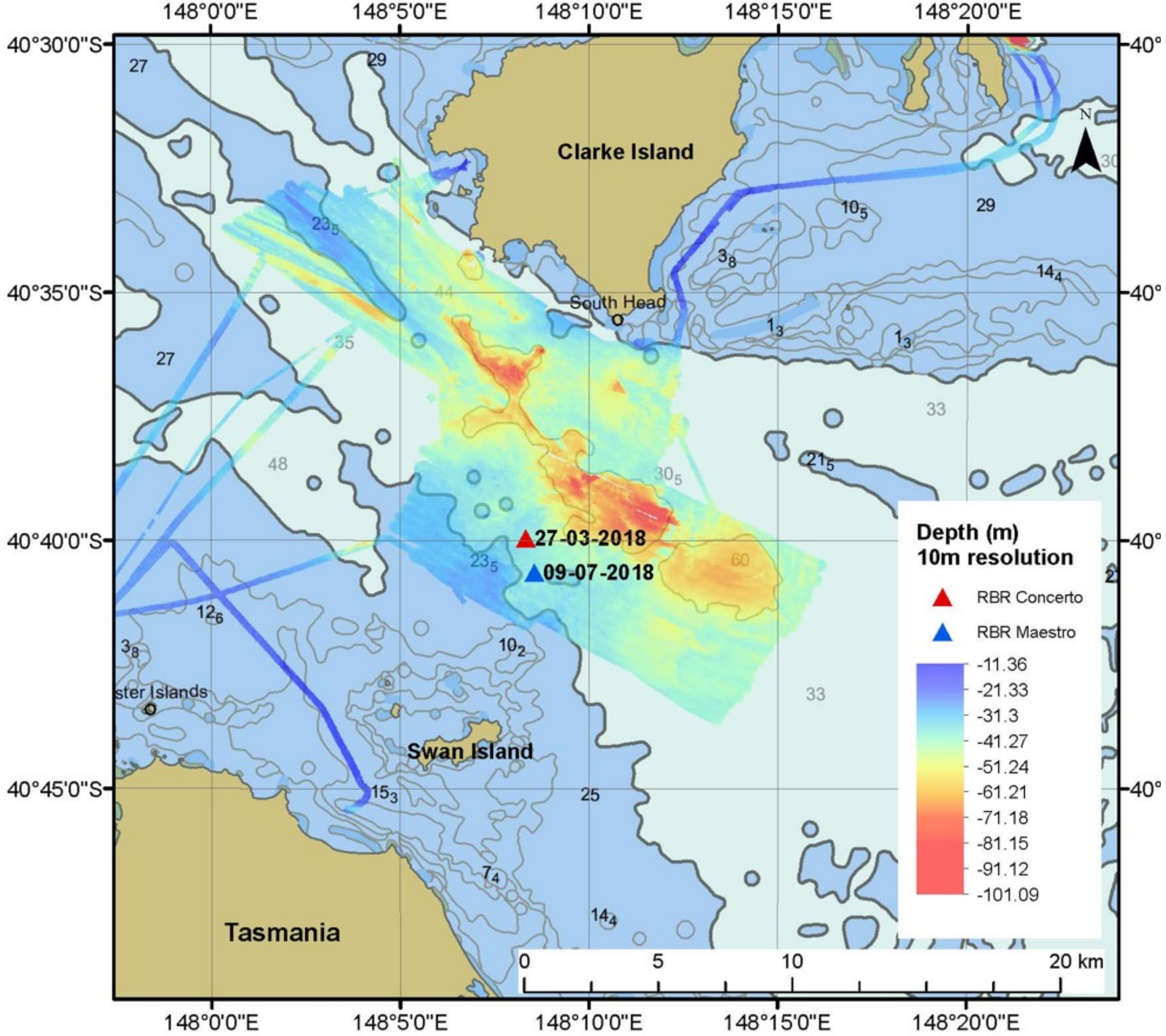
0.5m<Hs<3.5m Max(Hs)=6.8m	Mean(Power)=12.7kW.m^2 Max(Power)=406kW.m^2
3.2s<Tm<9s 5s<Tp<16s	
40% of Waves 0.5m<Hs<1.25m & 2s<Tm<5s	

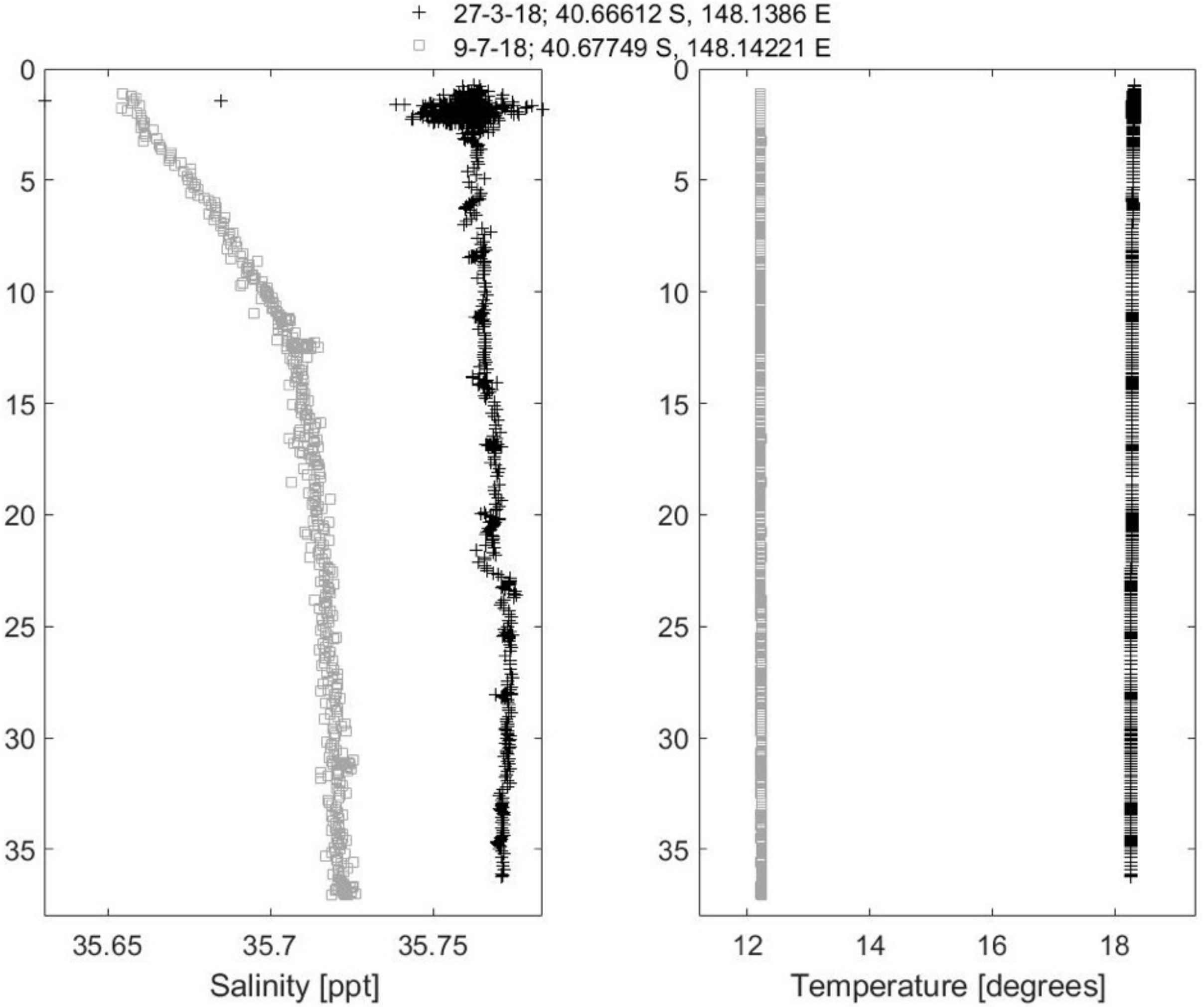
0.5m<Hs<2m Max(Hs)=3.25m	Mean(Power)=6.3kW.m^2 Max(Power)=148kW.m^2
2.7s<Tm<8.2s 3s<Tp<19s	
35% of Waves 0.5m<Hs<1m & 2s<Tm<4s	

0.5m<Hs<4m Max(Hs)=5.17m	Mean(Power)=16.6kW.m^2 Max(Power)=151.5kW.m^2
1.5s<Tm<8s 4s<Tp<14s	
36.5% of Waves 0.5m<Hs<1.75m & 2s<Tm<4s	

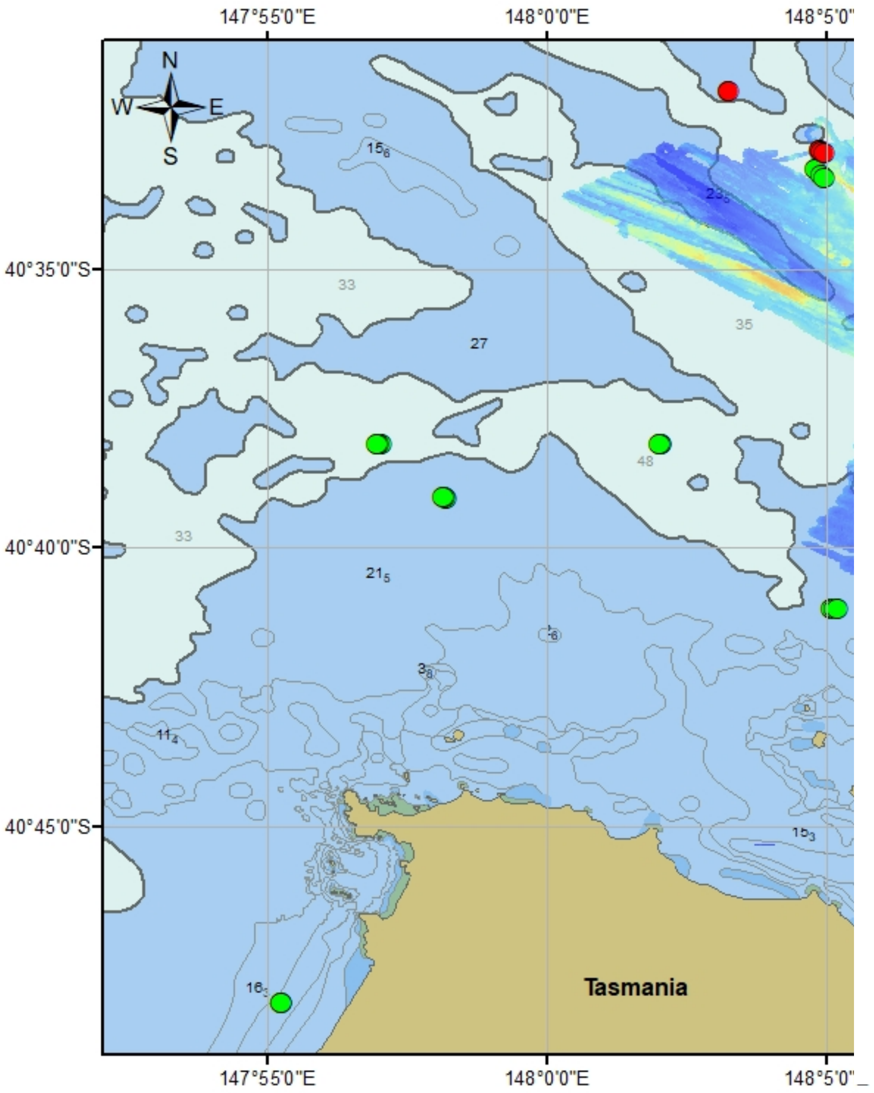
0.4m<Hs<3m Max(Hs)=3.06m	Mean(Power)=14.6kW.m^2 Max(Power)=62.2kW.m^2
5.1s<Tm<9.4s 7s<Tp<14s	
30% of Waves 0.5m<Hs<1.25m & 5s<Tm<6s	

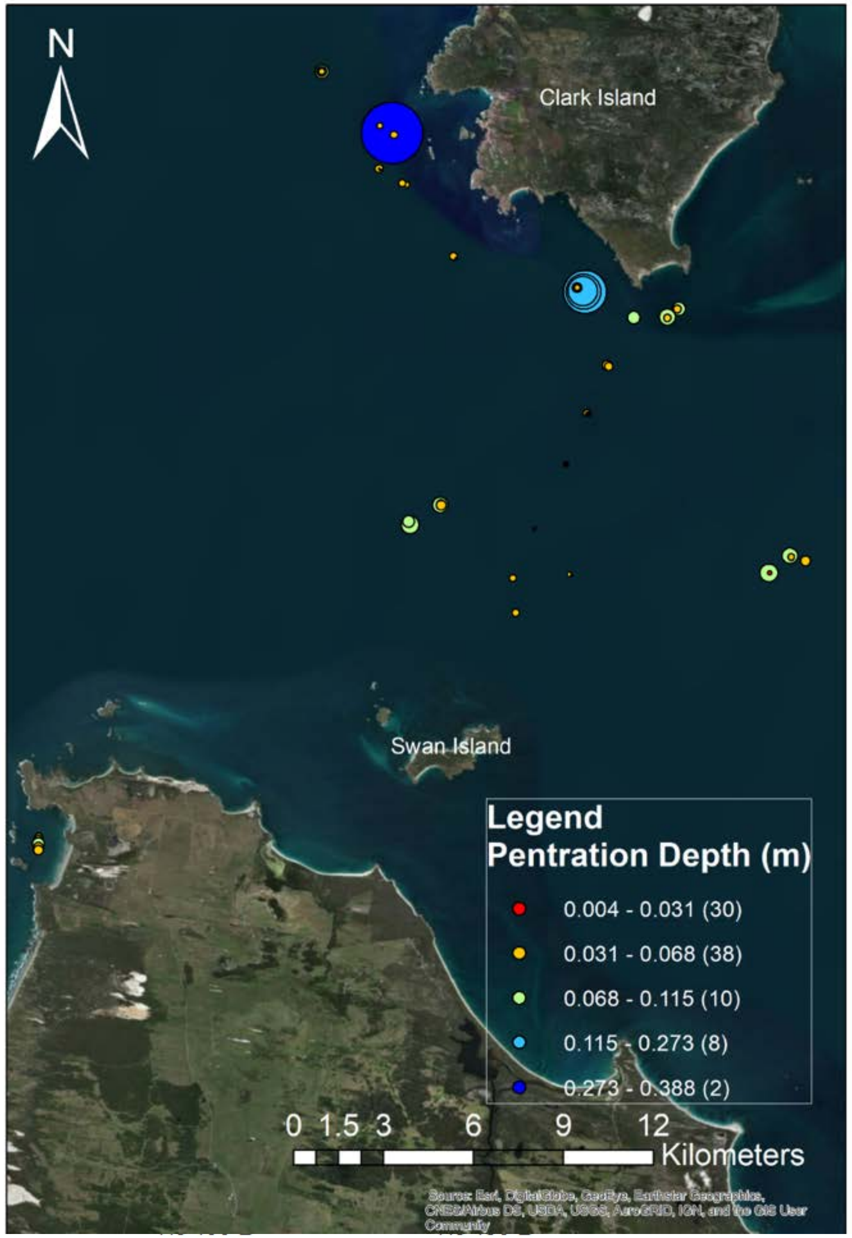
Results - CTD


148°0'0"E
148°5'0"E
148°10'0"E
148°15'0"E
148°20'0"E
40°30'0"S
40°35'0"S
40°40'0"S
40°45'0"S
Clarke Island
South Head
Swan Island
Tasmania
27-03-2018
09-07-2018
Depth (m)
10m resolution
RBR Concerto
RBR Maestro
-11.36
-21.33
-31.3
-41.27
-51.24
-61.21
-71.18
-81.15
-91.12
-101.09
0
5
10
20 km

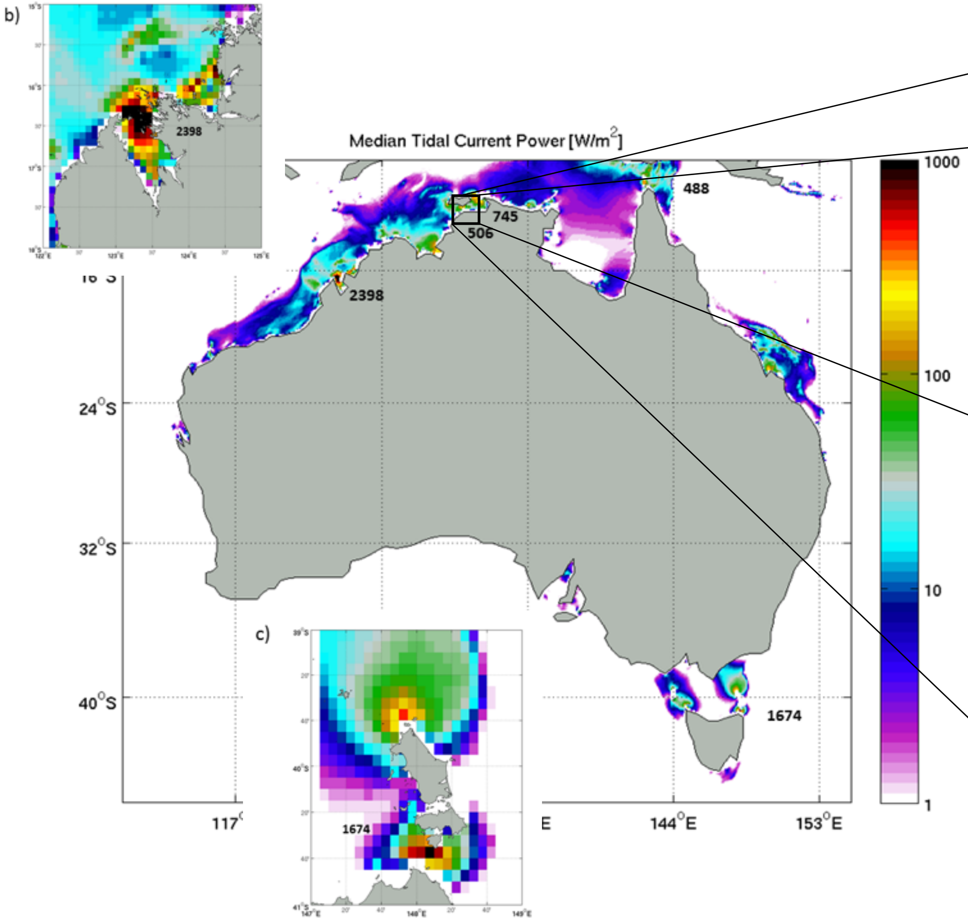

27-3-18; 40.66612 S, 148.1386 E
9-7-18; 40.67749 S, 148.14221 E
0
5
10
15
20
25
30
35
35.65
35.7
35.75
Salinity [ppt]
12
14
16
18
Temperature [degrees]

Results -Penetrometer (March & December 2018 campaigns)

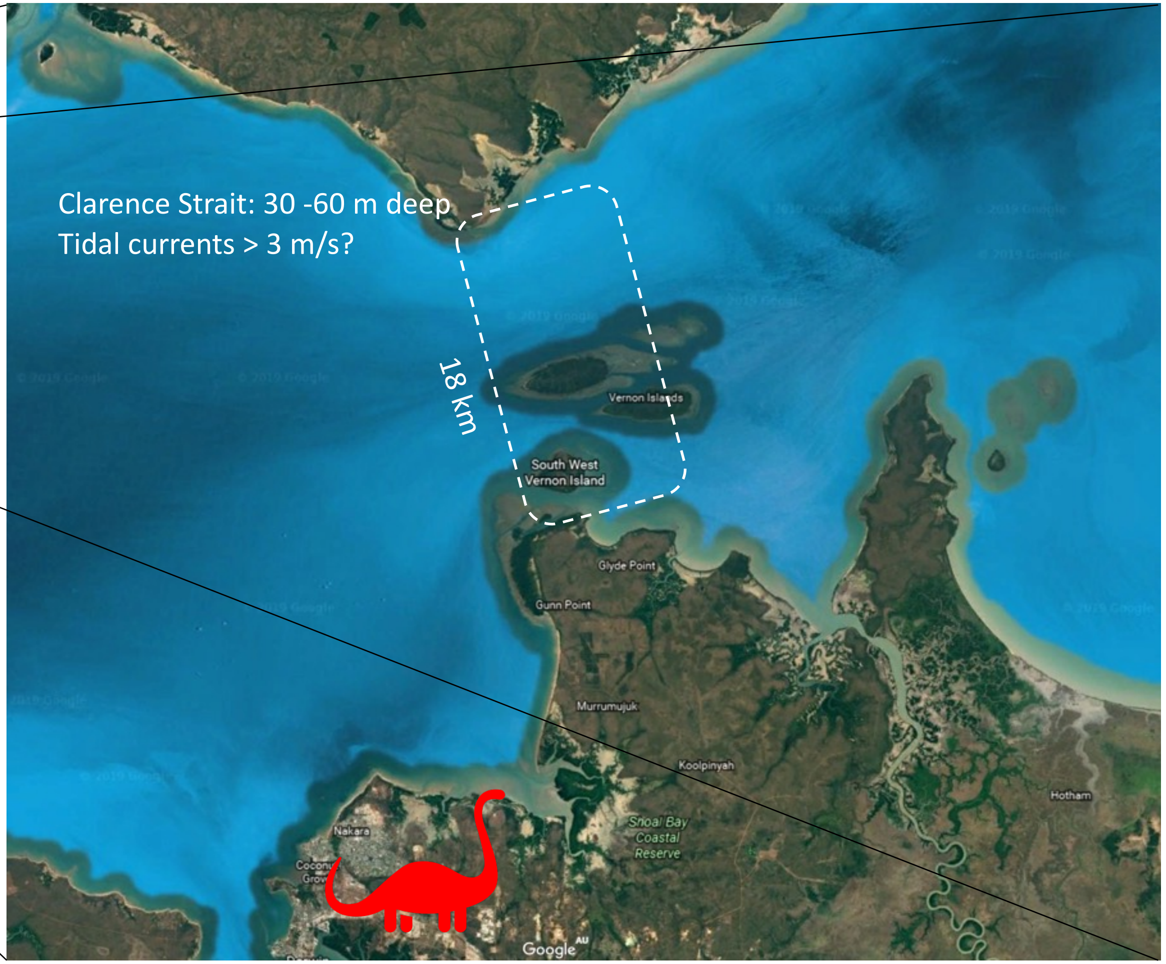




2nd AUSTEn Site: Clarence Strait, Northern Territory

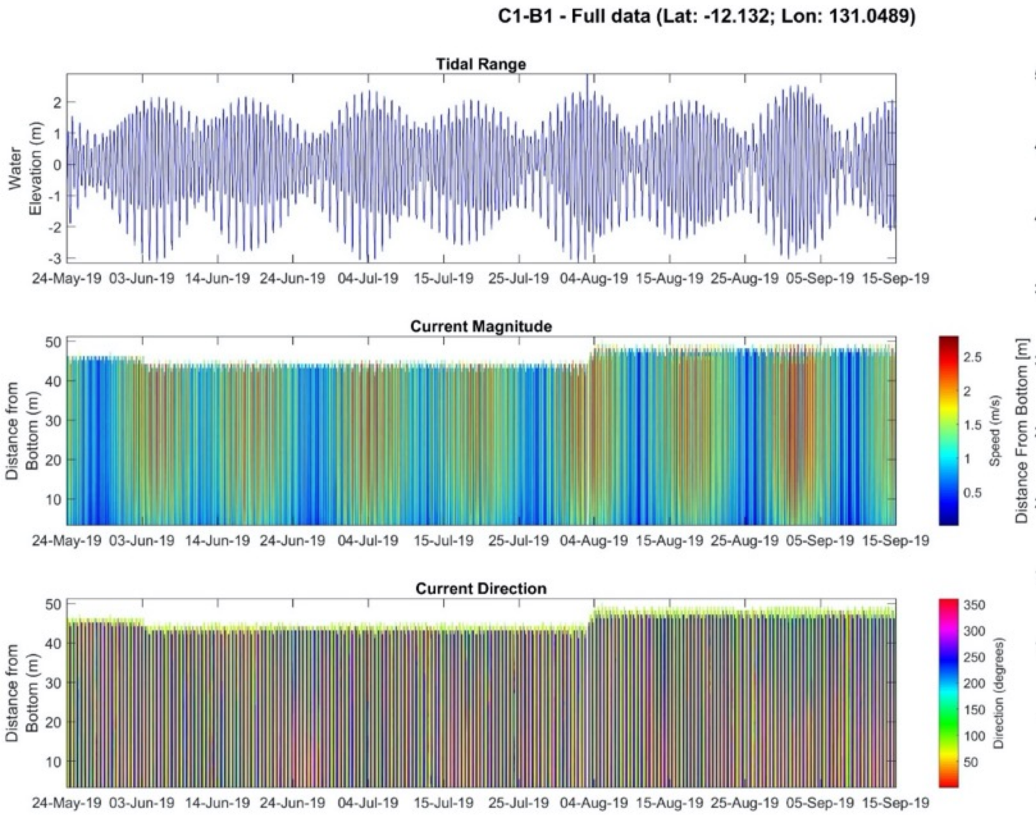


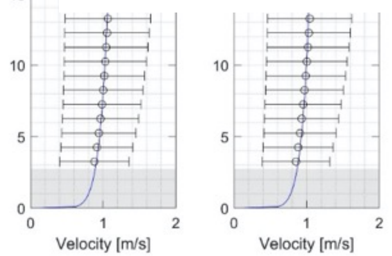
Time-averaged tidal current power, based on the 1/12 degree (~10km) tidal model (CSIRO, 2012).

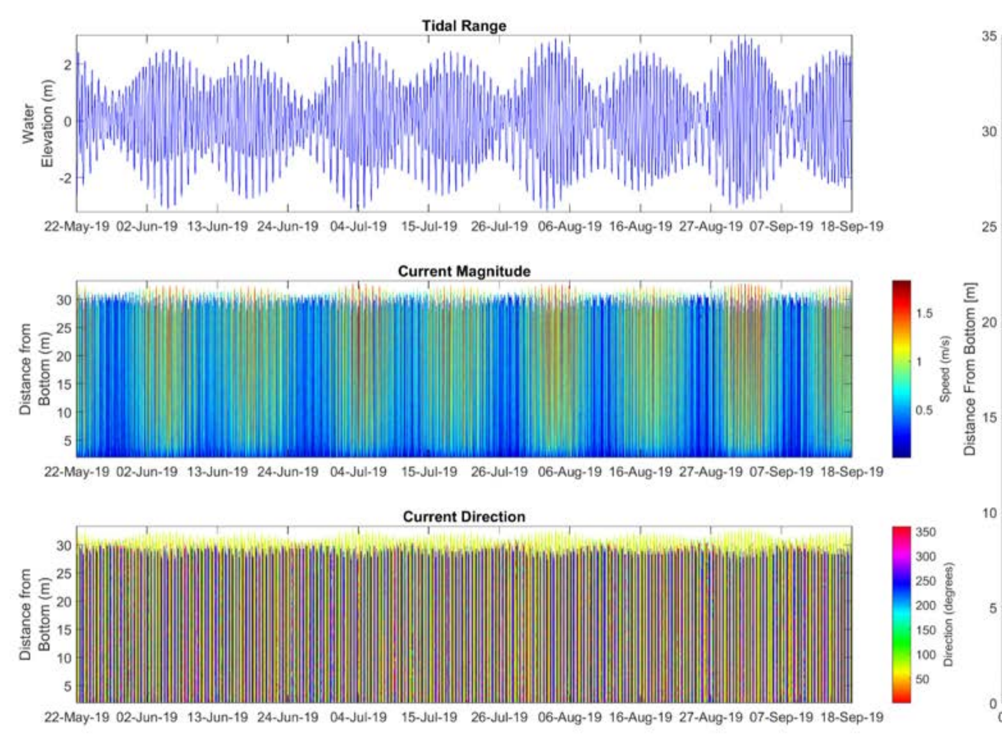


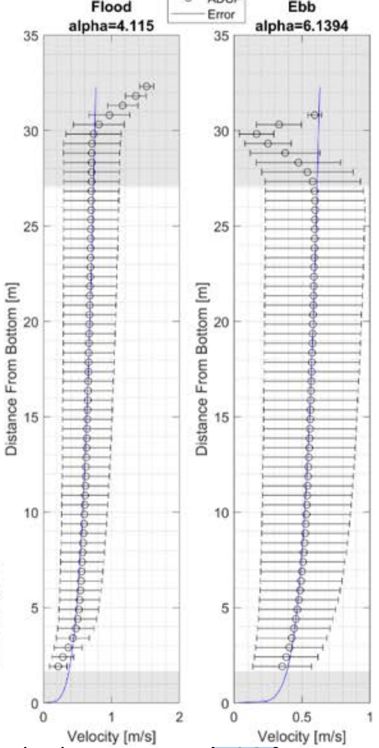
Darwin (pop: 140,000) powered by natural gas!

First deployment in Clarence Strait (May









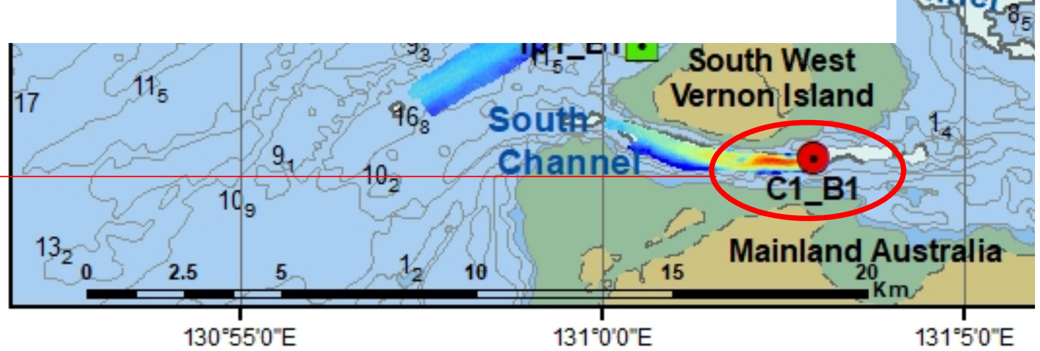
CV **Waves**: *not processed yet*

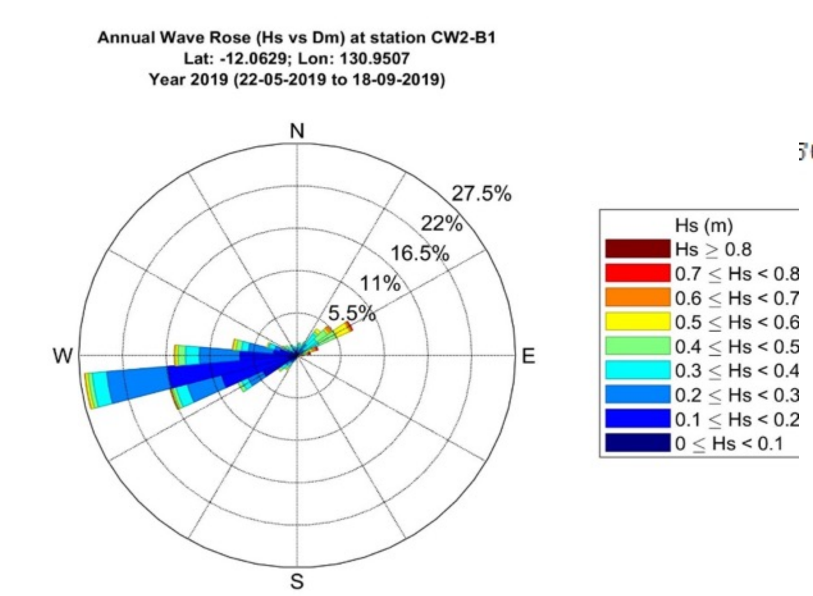
C1_B1 (Sentinel V, 52

12° 7′ 55.29′′ S; 131° 2′ 56.148′′ E

Currents:
Max(Current Speed) = 2.8m/s
Mean(Current Speed)=1.13m/s
Ebb/Flood Asymmetry=174.3°

Waves: *No waves measured*





Numerical Modelling

- Characterise the chosen sites using **fine-scale** numerical models:

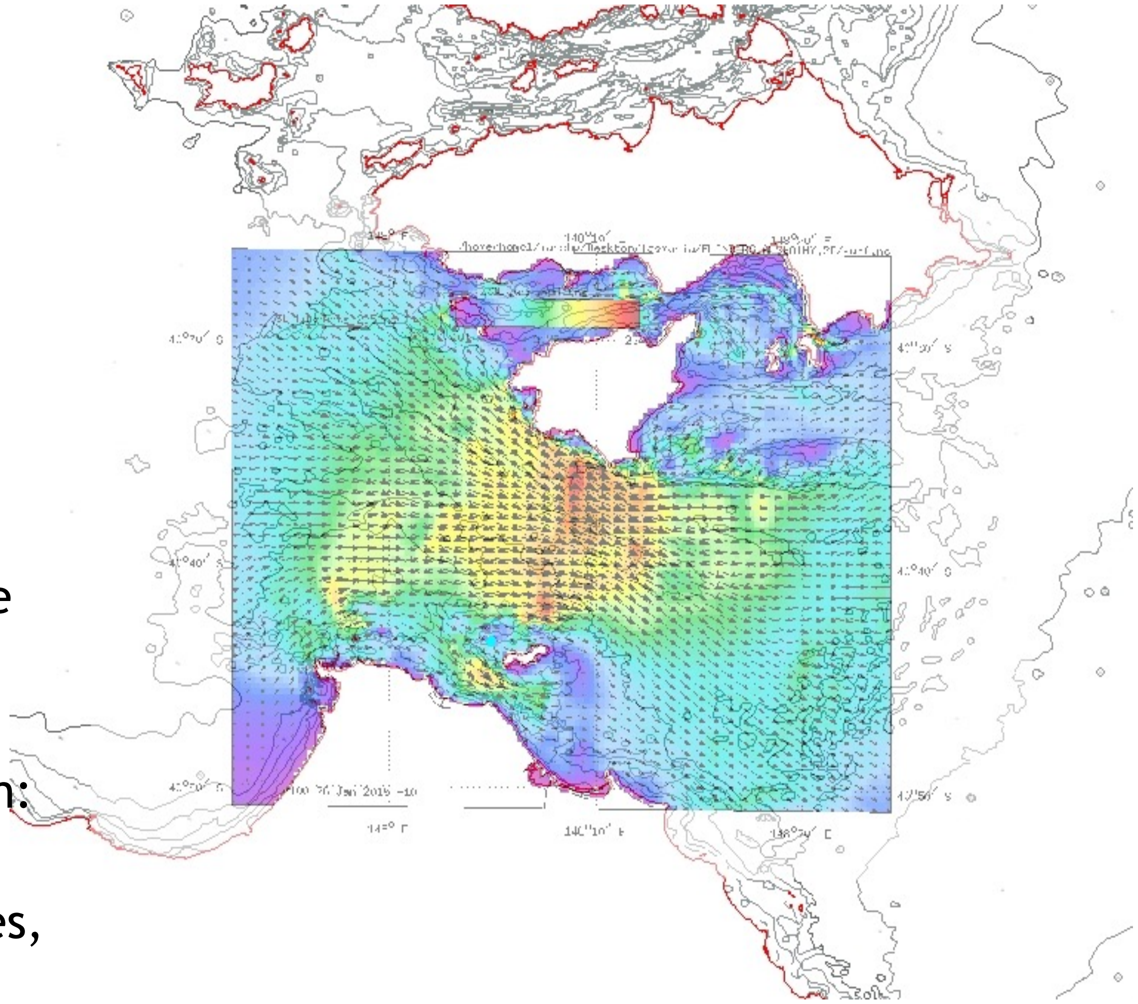
SHOC, 2D and 3D models, more than 3 months, validated according to EMEC / IEC guidelines

- Integrate **tidal turbine arrays** into model:

resource predictions, power density, resource extraction effects for general and/or specific devices in single and **in arrays**

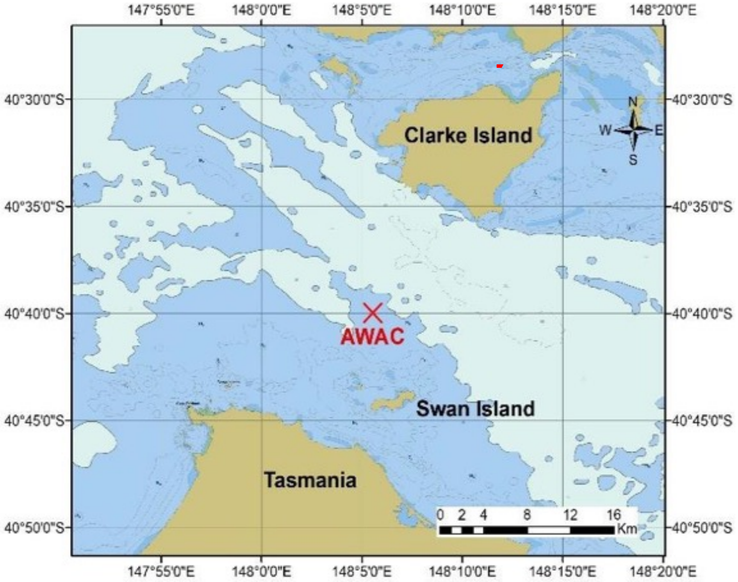
- **Multi-Criteria Evaluation Site Suitability Tool** depending on:

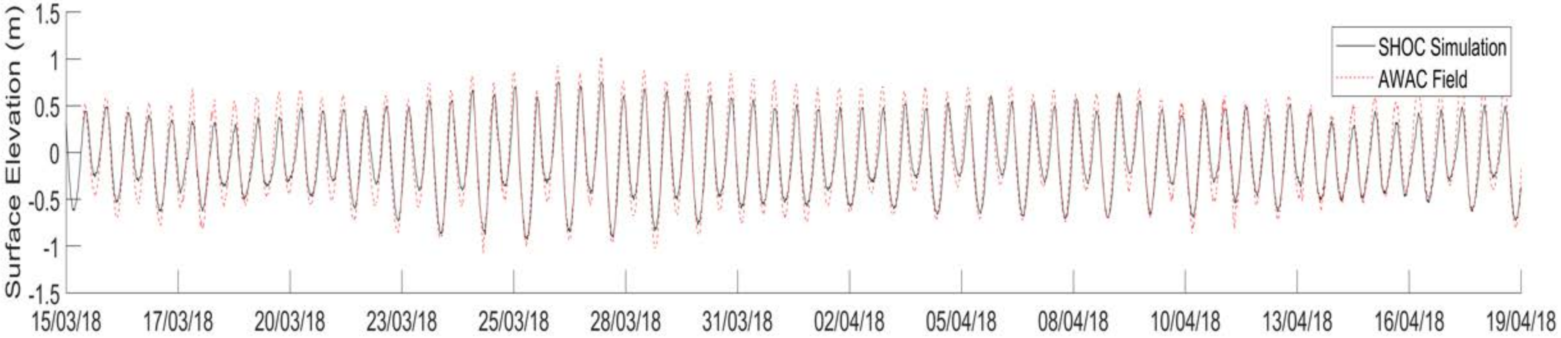
resource size, power output, installation depth, location, electricity demand, proximity to coastline and grid/powerlines, bathymetry limitations, etc…

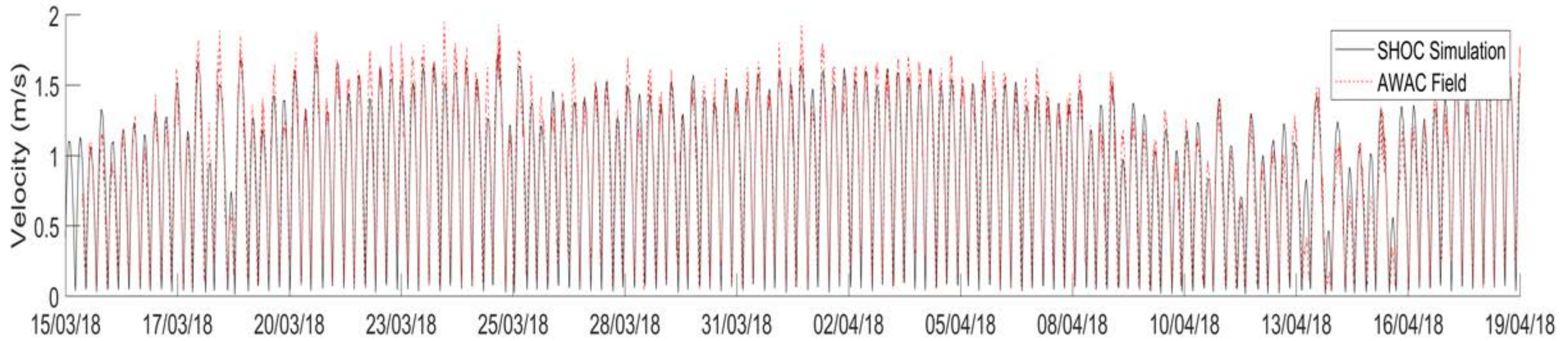


Banks Strait GIS + SHOC Velocity Map

Model Calibration and Validation







	R	RMSE	BIAS
Velocity	0.95	0.15 m/s	0.01 m/s
Elevation	0.97	0.15 m	0.04 m

Next Steps

- Further optimisation of National Model (COMPAS) and integration into open access web-based delivery via the Australian Marine (Wave) Energy Atlas / Australian Renewable Energy Mapping Infrastructure (AREMI).
- Multi-criteria updated based on optimisation of national model
- Processing data from second site and undertaking the next field campaign
- Further development, calibration and validation of fine scale numerical model at the first site and integration of tidal turbine arrays
- Development of technical and economic modelling of integrating tidal turbine arrays at the suitable tidal locations
- Work closely with IMOS & AODN to improve IMOS Toolbox by adding codes to process CTD, Turbulence & echogram data.
- Geoscience Australia – bathy data
- Using grid characteristics, network cost data and earlier assessment of the maximum tidal farm size, determine the optimal tidal farm size.
- Examine competitiveness of tidal with other forms of electricity generation under various scenarios and use this to update tidal farm size in these scenarios.

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Project Lead

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Industry Participants

MAKO Tidal Turbines

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Atlantis Resources

International Collaborators

Arcadia University

Prifysgol Bangor University