Data in Brief 43 (2022) 108336

Contents lists available at ScienceDirect

Data in Brief

journal homepage: www.elsevier.com/locate/dib

Data Article

Datasets for turbulence characterization collected with AD2CPs in potential tidal energy sites in Australia

Larissa Perez[a,*], Remo Cossu[a], Alistair Grinham[a], Irene Penesis[b]

[a] *School of Civil Engineering, University of Queensland, Brisbane, QLD 4072, Australia*
[b] *Australian Maritime College, University of Tasmania, Hobart, TAS 7250, Australia*

ARTICLE INFO

Article history:
Received 11 April 2022
Revised 18 May 2022
Accepted 25 May 2022
Available online 1 June 2022

Keywords:
Ocean turbulence
High-frequency velocity measurements
Tidal currents
Tidal stream energy
Unsteady flows

ABSTRACT

Sites with great potential for electricity generation from tidal stream energy are often characterized by high levels of turbulence and severe wave climates. These characteristics are known to substantially increase turbine blade loadings fluctuations, which may lead to premature device failure and blade fatigue. In order to be commercially competitive, tidal energy devices must function in turbulent environments for approximately 25 years without requiring major maintenance operations. Hence, knowledge of turbulence parameters prior to device deployment is crucial to avoid unnecessary costs with overengineering and maintenance. Aiming to support the development of tidal energy in Australia, the Tidal Energy in Australia (AUSTEn) Project identified two sites with potential for tidal energy: Banks Strait, Tasmania and Clarence Strait, Northern Territory. The datasets presented here reveal high-frequency current velocity measurements taken throughout the water column with Nortek Signature new generation Acoustic Doppler Current Profilers (AD2CPs) at one measurement station in Banks Strait and two in Clarence Strait. Measurement periods are between 2 and 3 months, which are significantly long deployment periods for turbulence characterization in tidal energy sites compared to other

DOI of original article: 10.1016/j.renene.2021.06.116

* Corresponding author.
E-mail address: l.perez@uqconnect.edu.au (L. Perez).

https://doi.org/10.1016/j.dib.2022.108336

datasets available in the literature. Processing steps include the removal of bad quality data points using the manufacturer's software Ocean Contour, considering low correlation, side lobe interference and high amplitude spikes. These data have been used by Perez et al.(2021) to calculate turbulent kinetic energy (TKE), turbulence intensity (TI), Reynolds stresses, integral length scales, TKE dissipation and production rates as well as to discuss wave-turbulence interaction and the application of decomposition methods. In the dataset collected in Banks Strait, velocity fluctuation enhancements caused by wave orbital velocities were mitigated using the Synchrosqueezing Wavelet Transform (SWT) decomposition method. Turbulence estimates were organized by month and are revealed in the post-processed data files. Here we provide raw, processed and post-processed data files, which were made publicly available through the University of Queensland UQ eSpace repository. These datasets may be reused to further advance the understanding of turbulence and its impacts on tidal turbine performance as well as to help establish international guidelines for turbulence measurements in tidal energy site assessments.

Specifications Table

Subject	Oceanography
Specific subject area	Turbulence datasets for tidal energy site assessment
Type of data	AD2CP data MATLAB data
How the data were acquired	The data were acquired with a Nortek Signature 500 kHz and a Nortek Signature 1000 kHz AD2CP
Data format	Raw Processed Post-processed
Description of data collection	The datasets were collected with bottom-mounted Nortek Signature 500 kHz and 1000 kHz AD2CPs which had customized configurations to take high-frequency velocity measurements.
Data source location	Tidal Energy in Australia – AUSTEn Project One measurement station (CTb3) was in Banks Strait, Tasmania and two measurement stations (CTbW and CTbES) were in Clarence Strait, Northern Territory, Australia. GPS coordinates: CTb3: 40.692° S, 148.132° E CTbW: 12.017° S, 130.970° E CTbES: 12.074° S, 131.021° E
Data accessibility	UQ eSpace Data Repository DOI: https://doi.org/10.48610/cdf1c5d Access link: https://espace.library.uq.edu.au/view/UQ:cdf1c5d
Related research article	L. Perez, R. Cossu, A. Grinham and I. Penesis, Seasonality of turbulence characteristics and wave-current interaction in two prospective tidal energy sites, Renewable Energy, 178 (2021) 1322–1336. https://doi.org/10.1016/j.renene.2021.06.116

Value of the Data

- High levels of turbulence are known to induce power coefficient and loadings fluctuations, which may be detrimental to tidal turbines and requires appropriate device designs. These datasets allow for the characterization of turbulence parameters and their variations in two sites with potential for tidal energy in Australia.
- These datasets are valuable to the scientific tidal energy community and turbine developers who are interested in designing devices capable of enduring large unsteady loadings and tidal energy regulators who could establish minimum requirements for turbulence assessment.
- These datasets may be reused by tidal energy researchers in both academia and industry to test and develop hydrodynamic models and data processing techniques as well as to illustrate realistic unsteady conditions which may be reproduced in laboratory experiments.
- Knowledge of turbulence levels throughout the water column in prospective tidal energy sites supports the improvement of hydrodynamic numerical models as well as turbulence parameter estimation and help advance the understanding of loadings acting on turbine blades.
- Establishing international guidelines for turbulence measurements for tidal site assessments is crucial to ensure the collection of high-quality data which provides the tidal energy industry with the necessary information. These datasets are useful to support the development of turbulence measurement and data analysis guidelines for tidal energy site assessments.

1. Data Description

The datasets described here were acquired with Nortek Signature 500 kHz and 1000 kHz AD2CPs at three measurement stations in Australia. Station CTb3 was located in Banks Strait, Tasmania and stations CTbW and CTbES were located in Clarence Strait, Northern Territory (Fig. 1). All the high-frequency velocity measurements are given in beam coordinates and were taken using the burst measurement configuration offered by the Signature series technology. The data from Banks Strait were collected with the AD2CP 4 slanted beams but in Clarence Strait datasets were collected using 5 beams and, therefore, the vertical beam processed data is given separately. A summary of the instrumentation, deployment specifications and number of data files is given in Table 1.

1.1. Raw Data

The raw data originally outputted from the instruments are given in .ad2cp files. These files contain not only the raw velocity data but also a description of the measurement configurations used. These data must undergo initial processing steps in the manufacturer's software Ocean Contour V2.0.5 R1877 [2] to ensure appropriate data quality.

Table 1
Deployment specifications and number of files per category.

Station	Site	GPS coordinates	Instrument	Start date	End date	Number of raw data files	Number of processed data files (4 slanted beams)	Number of processed data (vertical beam)	Number of post-processed data files
CTb3	Banks Strait, TAS	40.692° S, 148.132° E	Signature 1000 kHz	23rd March 2018	9th July 2018	1	186	N/A	1
CTbW	Clarence Strait, NT	12.017° S, 130.970° E	Signature 1000 kHz	24th May 2019	4th August 2019	1	31	9	1
CTbES	Clarence Strait, NT	12.074° S, 131.021° E	Signature 500 kHz	23rd May 2019	26th July 2019	1	57	17	1

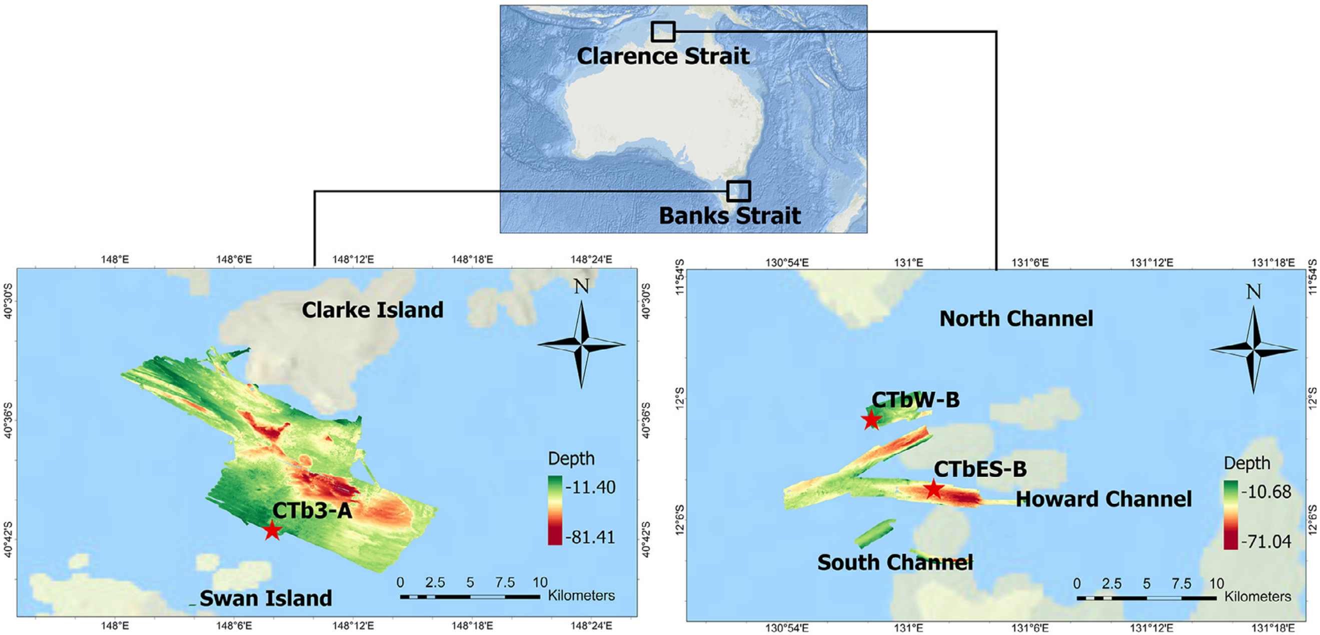

Fig. 1. Map indicating the station locations in Banks Strait, TAS and Clarence Strait, NT.

Table 2
Post-processed data nomenclature.

MATLAB variable	Parameter	Unit
Time	Datapoint time	UTC
um_ensemble	Mean streamwise velocity	m/s
vm_ensemble	Mean cross-stream velocity	m/s
wm_ensemble	Mean vertical velocity	m/s
epsilon(number)	TKE dissipation rate estimated from each beam	m^2/s^3
A(number)	Angular coefficient from second-order structure function regression obtained from dissipation rates estimation from each beam	–
Aerror(number)	A standard error	–
N(number)	Interception of second-order structure function regression from each beam	–
Nerror(number)	N standard error	–
D(number)	Second-order structure function from each beam	–
sigma_eps(number)	TKE dissipation rate uncertainty	m^2/s^3
error_ratio(number)	Ratio between dissipation date uncertainty and dissipation rate	–
epsilon_4beam_mean	Average 4-beams TKE dissipation rate	m^2/s^3
TKE	4-beams TKE	m^2/s^2
TKE5	5-beams TKE	m^2/s^2
TI	Turbulence intensity	%
TI_ref	Turbulence intensity calculated using a reference velocity of 1.5 m/s instead of the mean velocity	%
integral_t	Integral time scale	s
integral_length	Integral length scale	m
uw and vw	4-beams Reynolds stresses in instrument's coordinates	m^2/s^2
uw_ch and vw_ch	4-beams Reynolds stresses in channel coordinates	m^2/s^2
u2_lc, v2_lc, w2_lc, uw_lc, vw_lc	5-beams Reynolds stresses in channel coordinates	m^2/s^2
P_total	Total TKE production rate	m^2/s^3
sigma_RS	Reynolds stress uncertainty	m^2/s^2
sigma_P	TKE production rate uncertainty	m^2/s^3
alpha	Anisotropy ratio ($\frac{w^2}{u^2+v^2}$)	–

1.2. Processed Data

The processed datasets are presented in .mat files. Data were corrected for magnetic declination, low correlation, side lobe interference, minimum amplitude and maximum amplitude spike. Subsequently, datapoints flagged as bad quality were replaced by NaNs in MATLAB and the data file and variable naming was performed following the Integrated Marine Observing System (IMOS) methodology [3], as described in the MATLAB structure field “GlobalAttributes” Time is given in UTC and all variable units and description are shown in the field “Attributes” within each variable.

1.3. Post-Processed Data

The post-processed datasets reveal the turbulence estimates calculated using the methodology described by Perez et al. [1] and are split by measurement month. Methods for 4 and 5 beam Reynolds stresses estimations are detailly described by Guerra et al. [4] and Dewey et al. [5]. The nomenclature and units used are given in Table 2. All parameters were calculated over intervals of 5 min.

Table 3
Instrument's configurations for turbulence measurements (modified from Perez et al. [1]).

	Station		
Configuration	CTb3	CTbW	CTbES
Instrument	Nortek Signature 1000 kHz	Nortek Signature 1000 kHz	Nortek Signature 500 kHz
Average depth	33.0 m	22.4 m	53.0 m
Burst length	900 s	900 s	580 s
Measurement interval	1800 s	3600 s	2320 s
Sampling frequency	8 Hz	4 Hz	4 Hz
Beams	4 slanted	Vertical + 4 slanted	Vertical + 4 slanted
Blanking distance	0.1 m	0.1 m	0.5 m
Cell size	0.5 m	0.5 m	1 m
Standard deviation[1]	H: 0.034 m/s	H: 0.073 m/s	H: 0.073 m/s
	B: 0.021 m/s	V: 0.046 m/s	V: 0.024 m/s

[1] Note: Values obtained from instruments' manufacturer software. H: horizontal; V: vertical; B: beam.

2. Experimental Design, Materials and Methods

2.1. Instruments' Configurations and Data Collection

Following a multi-criteria evaluation, the AUSTEn Project has identified two prospective tidal energy sites to be investigated during multiple field campaigns between 2018 and 2020. Banks Strait is a 16 km wide channel located in Northeast Tasmania, between Swan and Clark Islands and is characterized by current speeds reaching 2.2 m/s and severe wave climates, with maximum significant wave heights reaching 5 m [6]. Clarence Strait is located in a tropical region, in between the Vernon Islands in the Northern Territory. The site reveals current speeds reaching 2.8 m/s and mean significant wave heights remaining below 0.5 m during most of the deployment periods [1]. In order to collect high-frequency velocity measurements for turbulence characterization, one instrument was deployed in Banks Strait and two instruments were deployed in Clarence Strait. The deployment locations are illustrated in Fig. 1. The measurement configuration used in each instrument is described in Table 3.

2.3. Data Processing

The initial processing steps involved correcting the data for magnetic declination and identifying bad quality datapoints in the instruments' manufacturer software Ocean Contour. In order to avoid side lobe interference only the bottom 90% of the water column was included in the processing. As per manufacturer's recommendations, datapoints with correlation below 50% were removed. A minimum amplitude threshold and maximum amplitude spike of 35 dB were also set to avoid weak signal datapoints and outliers. In cases when the water column was shallower than the established number of bins in the configuration, exceeding datapoints were identified as bad, which led to the removal of a large portion of the datasets (e.g. at CTbW the number of bins in the configuration covered 29.6 m of water column above the sensor, but the average depth at the site was only 22.4 m). At CTb3 14%, at CTbW 37% and at CTbES 28% of the datapoints were removed.

Subsequently, the data were exported from Ocean Contour as .mat files and processing was concluded in MATLAB. The datapoints flagged as showing low quality in the previous steps were replaced by NaNs and the data was organized as a MATLAB structure using IMOS parameter nomenclature [3].

2.4. Data Post-Processing

The collection of long high-frequency velocity datasets allowed for the estimation of various turbulence parameters over several months. ADCP measurements are known to include intrinsic Doppler noise which may compromise the accuracy of turbulence parameter estimates. Doppler noise was calculated by averaging the spectral noise floor of beam velocities and integrating it in frequencies between 0.5 $f_{Nyquist}$ and $f_{Nyquist}$ [7]. The equations used to calculate all turbulence parameters reported and uncertainties are given by Perez et al. [1].

The dataset from Banks Strait revealed large peaks in the energy spectra induced by surface waves. The SWT decomposition method [8,9] was applied to avoid overestimation of turbulence parameters.

Ethics Statements

This work did not involve human subjects, animal experiments or data collected from social media platforms.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

AUSTEn Project turbulence datasets (Original data) (University of Queensland eSpace).

CRediT Author Statement

Larissa Perez: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Visualization; **Remo Cossu:** Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration, Funding acquisition; **Alistair Grinham:** Conceptualization, Methodology, Writing – review & editing, Supervision; **Irene Penesis:** Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Acknowledgments

We would like to thank Camille Couzi for her contribution. The AUSTEn Project is co-funded by the Australian Renewable Agency (ARENA) through the Advancing Renewables Programme (grant G00902), the Australian Maritime College (University of Tasmania), the University of Queensland, CSIRO Oceans and Atmosphere, CSIRO Energy, our industry partners, SABELLA, SIMEC Atlantis Energy and MAKO Tidal Turbines.

References

[1] L. Perez, R. Cossu, A. Grinham, I. Penesis, Seasonality of turbulence characteristics and wave-current interaction in two prospective tidal energy sites, Renew. Energy 178 (2021) 1322–1336.
[2] Ocean Illumination, Software Ocean Contour V2.0.5 (2019) R1877.
[3] Integrated Marine Observing System, IMOS Parameters, 2019. https://github.com/aodn/imos-toolbox/blob/master/IMOS/imosParameters.txt. Accessed March 18th, 2022.

[4] M. Guerra, J. Thomson, Turbulence measurements from five-beam acoustic doppler current profilers, J. Atmos. Ocean. Technol. 34 (6) (2017) 1267–1284.
[5] R. Dewey, S. Stringer, Reynolds stresses and turbulent kinetic energy estimates from various ADCP beam configurations: theory, 2007. Unpublished manuscript.
[6] R. Cossu, I. Penesis, J.R. Nader, P. Marsh, L. Perez, C. Couzi, A. Grinham, P. Osman, Tidal energy site characterisation in a large tidal channel in Banks Strait, Tasmania, Australia, Renew. Energy 177 (2021) 859–870.
[7] J. McMillan, A. Hay, R. Lueck, F. Wolk, Rates of dissipation of turbulent kinetic energy in a high Reynolds number tidal channel, J. Atmos. Ocean. Technol. 33 (4) (2016) 817–837.
[8] C. Bian, Z. Liu, Y. Huang, L. Zhao, W. Jiang, On estimating turbulent Reynolds stress in wavy aquatic environment, J. Geophys. Res. Oceans 123 (4) (2018) 3060–3071.
[9] L. Perez, R. Cossu, C. Couzi, I. Penesis, Wave-turbulence decomposition methods applied to tidal energy site assessment, Energies 13 (5) (2020) 1245.