Data Article

A long-term, gridded, subsurface physical oceanography dataset and average annual cycles derived from in situ measurements off the Western Australia coast during 2009–2020

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A B S T R A C T

This article reviewed dataset collected from an array of 12 coastal Integrated Marine Observing System (IMOS) moorings off the southwest coast of Western Australia (WA) during 2009–2020, at depths ranging from 47 m to 500 m. The dataset includes temperatures and salinities collected with Seabird SBE37 and SBE39 sensors and Water Quality Monitor (WQM). Velocities were collected by Teledyne RDI Acoustic Doppler Current Profilers (ADCP) and Nortek ADCPs. Here, a daily gridded in-situ subsurface temperature, salinity and ocean currents, and their average annual cycles are presented. Monthly data are also included. This integrated dataset provides an overview of data availability and allows users to have a quick access to the mooring data, without the need of manipulating over one thousand files individually. This unique dataset offers an invaluable baseline perspective on physical water column properties and temporal variability in WA coastal waters. The data can be used to characterise subsurface features of extreme events such as marine heat waves, marine cold-spells, and to detect long-term change signals along WA coast, influenced by the Leeuwin Current and the wind-driven Capes Current.

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Specifications Table

| Subject | Oceanography |
|---------|--------------|
| Specific subject area | Coastal mooring array off southwest Western Australia coast |
| Type of data | TXT files, and NetCDF files |
| How data were acquired | The data were collected by 12 coastal mooring arrays. It has a mix of Seabird SBE37 sensors, Seabird SBE39 sensors, Wetlabs Water Quality Monitor (WQM), Teledyne RDI Acoustic Doppler Current Profilers (ADCP) and Nortek ADCP. |
| Data format | Processed, quality controlled, analysed, and plots |
| Parameters for data collection | The mooring array is designed to collect physical water column properties (temperature, salinity and current velocity) along WA coast. Each of these moorings has presented unique engineering and design challenges owing to depth, sea conditions (high currents, swell), and operational requirements. |
| Description of data collection | 12 bottom-mounted moorings, with a mix of sensors detailed above were maintained during 2009-2020. WQMs are programmed to sample in bursts, 120 × 1s samples every 15 minutes. SBE39 sensors are generally configured to sample every 10 minutes. SBE37 sensors are typically set to sample every 15 minutes. Teledyne RDI ADCP and Nortek ADCP are typically set to average a number of samples over a 15-minute period. |
| Data source location | Western Australia coastline, mooring stations (on-going stations are in bold): |
| | **Station** | **Latitude(S), Longitude(E)** | **Deployment period** | **Depth (m)** |
| | **NRSROT** | 31°59′3″, 115°23′1″ | 2008.11-present | 60 |
| | **NRSROT** | 32°00′0″, 115°24′9″ | 2011.07-present | 47 |
| | **NRSESP - ADCP** | 33°56′0″, 121°51′0″ | 2008.11-2013.07 | 50 |
| | **NRSESP - ADCP** | 33°55′8″, 121°51′4″ | 2008.11-2013.07 | 52 |
| | **WATR04** | 32.41, 115.24 | 2013.11-2019.06 | 44 |
| | **WATR05** | 31°37′6″, 115°14′7″ | 2009.07-2012.12 | 50 |
| | **WATR10** | 31°38′6″, 115°12′2″ | 2009.07-present | 100 |
| | **WATR15** | 31°41′7″, 115°07′7″ | 2009.07-2013.03 | 150 |
| | **WATR20** | 31°43′4″, 115°02′3″ | 2009.07-present | 200 |
| | **WATR50** | 31°46′1″, 114°57′4″ | 2009.07-present | 500 |
| | **WACA20** | 31°59′0″, 115°13′7″ | 2020.01-present | 200 |
| | **WACA50N** | 31°55′9″, 115°0′6″ | 2010.01-2010.07 | 500 |
| | **WACA50S** | 32°14′5″, 115°15′3″ | 2010.01-2013.03 | 500 |
| Data accessibility | The quality controlled and analysed data are available in public repository at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Data Access Portal (DAP): https://doi.org/10.25919/kjy8-kk77 |
| | | The quality controlled data can also be downloaded at the Australian Ocean Data Network (AODN): https://portal.aodn.org.au |

Value of the Data

- This article provides an overview of data availability of a long-term monitoring program off southwest Australia, and provides a user-friendly, gridded dataset, saving data users’ time of manipulating over one thousand files individually.
- There are the only long-term oceanography monitoring data on the southwest Australian shelf.
- This unique dataset offers an invaluable baseline perspective on physical water column properties and temporal variability in WA coastal waters.
- This dataset can benefit researchers looking to understand the linkage and interaction between physical water column properties and biological variabilities.
- This dataset can be used to identify climate change signals in WA’s two principle boundary currents, the Leeuwin Current [1] and the wind-driven Capes Current [2].

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• This dataset can be used to characterise subsurface features of extreme events such as marine heat waves [3,4,5] and cold-spells [6].
• This dataset can be used for calibration and validation of hydrodynamic models.

1. Data Description

The dataset presented in this article was collected from 12 coastal moorings at depths ranging from 47 m to 500 m, off the southwest coast of Western Australia. The data collection is part of a long-term marine environment monitoring program under IMOS, and is operated by CSIRO, starting from 2009 [3,7]. A total of 168 deployments have been completed until now as shown in Fig. 1. The raw data and quality controlled data is available to download through CSIRO DAP (https://doi.org/10.25919/kjy8-kk77) and AODN Portal (https://portal.aodn.org.au).

In this article, we present the gridded subsurface daily temperature, salinity and velocity data, derived from those deployments, as well as their average annual cycles. Monthly mean was also derived.

Examples of gridded time series and average annual cycles (Figs. 2-12) at selected stations are presented in the main text. These examples include (1) gridded daily temperature (Fig. 1a, Fig. 2a), (2) concatenated salinity data (Fig. 3a-b), (3) gridded current velocity (Fig. 4), (4) daily average annual cycles of temperature (Fig. 1b-e, Fig. 2b-e), salinity (Fig. 3c-d) and current velocity (Figs. 5-10), and (6) monthly temperature (Fig. 11). Zipped txt files (Main_figures_Fig_2-Fig_11.txt.zip) are produced, which can be downloaded from CSIRO DAP (https://doi.org/10.25919/kjy8-kk77).

In addition, the whole gridded time-series and their average annual cycles at each station are provided as supplementary figures (Supplementary_Figures.doc). The supplementary figures include (1) gridded daily temperature time series and their average annual cycles at all on-going stations (Fig. S1), (2) gridded daily temperature at ceased stations (Fig. S2), (3) daily salinity and average annual cycle (Fig. S3), (4) gridded daily U velocity and average annual cycles (Fig. S4), (5) gridded daily V velocity and average annual cycles (Fig. S5), and (6) monthly temperature (Fig. S6). This gridded dataset includes zipped NetCDF files for each station (Station Name.zip).

![Fig. 1. (a) Location of the National Reference station: Rottnest Station (NRSROT) and Esperance Station (NRSESP) at 50 m depth. The red box denotes the location of other coastal mooring stations off the west coast of Australia, and (b) the zoom-in region of the red box shown in (a): the blue dots denote location of other on-going coastal moorings: WATR10 station, WATR20 station, and WATR50 station along the Two Rocks transect at 100 m, 200 m, and 500 m; and WACA20 station at 200 m depth at the head of the Perth Canyon. The red dots denote National Reference Stations. The grey dots denote location of ceased mooring stations: NRSESP station, WATR04 station, WATR05 station, WATR15 station, WACA50N station and WACAS05 station. Bathymetric contours are in metres.](image)
Fig. 2. Temperature (°C) field at NRSROT station: (a) partial time series during April-August 2018, (b) average annual cycles between 28 m and 48 m depth at NRSROT station, and (c-e) average annual cycles at 28 m, 35 m and 42 m depth, respectively.

Fig. 3. Temperature (°C) field at WATR20 station: (a) partial time series during January-May 2011, (b) average annual cycles between 30 m and 170 m depth, and (c-e) average annual cycles at 30 m, 100 m and 170 m depth, respectively.
Fig. 4. Salinity field at NRSROT station: (a,b) partial time series during June-October 2011 at 27 m and 57 m depth, and (c,d) average annual cycles at 27 m and 57 m depth, respectively.

Fig. 5. Time series of gridded ADCP current velocity (a) U velocity (m s$^{-1}$), and (b) V velocity (m s$^{-1}$) at NRSROT station during 2011-2020.

A version of zipped txt files is also produced. Both versions can be downloaded from CSIRO DAP (https://doi.org/10.25919/kjy8-kk77).

A summary of locations, instruments, nominal depth and sampling frequencies of all mooring stations is presented in Table 1 and Fig. 1.
Table 1
Summary of southwest WA coastal mooring stations (ceased & on-going).

| Station   | Instrument | Nominal Depth (m) | Sampling Time Interval (s) | Instrument                      | Mean Depth (m)/Vertical Interval (m) | Time Interval (s) |
|-----------|------------|-------------------|---------------------------|---------------------------------|--------------------------------------|-------------------|
| NRSROT    | WQM\(^a\), SBE39\(^b\) | 22,27,33, 43,55    | 600                       | RDI Workhorse                    | 50/2                                 | 300               |
| WATR04    | —          | —                 | —                         | RDI Workhorse                    | 44/2                                 | 600               |
| WATR05    | SBE39      | 25,30,35, 40, 60   | 300, 600                  | Nortek Aquadopp                  | 100/2                                | 900               |
| WATR10    | SBE39      | 25,30,35,40,50,70,90,95 | 300                      | RDI Workhorse                    | 400 kHz                              | 2-2.5             |
| WATR15    | SBE39      | 25,30,40,50,70,90,100,125,149 | 900                      | Nortek Continental              | 150/5                                | 1200              |
| WATR20    | SBE39      | 25,30,40,50,70,90,100,125,150,175,194 | 600                      | Nortek Continental              | 190 kHz                              | 200/5             |
| WACA20    | SBE37, SBE39 | 25,30,50,70,100,125,150,175,181,193,194 | 300                      | Nortek Signature                | 250 kHz                              | 5-8               |
| WATR50    | SBE39      | 120, 496          | 300, 900                  | RDI Long Ranger                  | 500/16                               | 900               |
| NRSESP    | SBE39, WQM | 30,38, 21,47      | 300, 600, 900             | RDI Workhorse                    | 75 kHz                               | 16                |
|           |            |                   |                           | ADCP 600 kHz                     | 50/2                                 | 900               |

\(^a\) [https://www.seabird.com/moored/wqm-water-quality-monitor/family?productCategoryId=54627473783](https://www.seabird.com/moored/wqm-water-quality-monitor/family?productCategoryId=54627473783)

\(^b\) [https://www.comm-tec.com/prods/mfgs/SBE/manuals_pdf/SBE39_012.pdf](https://www.comm-tec.com/prods/mfgs/SBE/manuals_pdf/SBE39_012.pdf)
Fig. 6. Average annual cycles of $U$ velocity (m s$^{-1}$) at NRSROT station: (a) between 10 m and 35 m depth, and (b-d) at 10 m, 20 m and 35 m depth, respectively.

Fig. 7. Average annual cycles of $V$ velocity (m s$^{-1}$) at NRSROT station: (a) between 10 m and 35 m depth, and (b-d) at 10 m, 20 m and 35 m, respectively.
Fig. 8. Average annual cycles of U velocity (m s\(^{-1}\)) at WATR20 station: (a) between 30 and 170 m depth, and (b-d) at 30 m, 100 m and 170 m, respectively (two deployments are excluded as top 40 m data is not available).

Fig. 9. Average annual cycles of V velocity (m s\(^{-1}\)) at WATR20 station: (a) between 30 m and 170 m depth, and (b-d) at 30 m, 100 m and 170 m, respectively (two deployments are excluded as top 40 m data is not available).

2. Experimental Design Materials and Methods

2.1. Data collection

A long-term program to monitor ocean boundary currents and shelf processes off the WA southwest coast was set in 2009 by IMOS, the shelf mooring array is one of the key components. The moorings at the Rottnest and Esperance National Reference Stations were intended
Fig. 10. Average annual cycles of $U$ velocity (m s$^{-1}$) at WATR50 station: (a) between 55 m and 466 m depth, and (b-d) at 60 m, 180 m and 460 m, respectively.

Fig. 11. Average annual cycles of $V$ velocity (m s$^{-1}$) at WATR50 station: (a) between 55 m and 466 m depth, and (b-d) at 60 m, 180 m and 460 m, respectively.

to provide the physical environment context for the biological measurements at the stations [7]. The shelf moorings off Two Rocks were intended to capture the shelf component of the Leeuwin Current and the wind-driven Capes Current [3,6]. The moorings around the Perth Canyon were intended to capture the canyon induced upwelling processes.

The moorings use a mix of SBE37, SBE39, and WQM sensors as well as RDI Workhorse 300 kHz, RDI Workhorse 600 kHz, RDI Long Ranger 75 kHz, Nortek Continental 190 kHz, Nortek Aquadopp 400 kHz, and Nortek Signature 250 kHz ADCPs.

WQMs are programmed to sample in bursts, 120 × 1 s samples every 15 minutes, to measure temperature, conductivity, and fluorescence.
SBE39 sensors are generally configured to sample every 10 minutes, and some are equipped with a pressure sensor. SBE37 sensors are typically set to sample every 15 minutes.

ADCP instruments, including RDI Workhorse and Nortek Continental, are typically average a number of samples over a 15 minute period. They are mounted upward-looking near the seabed, either in an inline frame or in a separate benthic lander. The depth range and vertical bin size varied with ADCP operating frequency and instrument setup, details are listed in Table 1.

Instrument calibration was conducted at 12 monthly intervals for most of the instruments and 24 monthly intervals for certain instruments/sites due to logistical reasons. Instrument inspection and servicing was carried out as required in line with manufacturer’s recommendations. Before installation into an instrument, each instrument battery was tested under load for 30 seconds and then the load removed to monitor battery recovery for a further 30 seconds. The load size was scaled to the battery under test. The test was carried out with an intelligent battery tester (West Mountain Radio - CBA III) and the voltage curves obtained are compared to known good values.

Instrument clock times were synchronised to UTC referenced to GPS or networked computer time, the time and dates recorded of synching were recorded. On recovery the instrument time was compared to the GPS or networked computer time to ascertain the time drift of the instrument. The instruments on one single mooring were all set to start at the same time after deployment.

On recovery of the instrumentation, the instrument data were downloaded immediately, noting the instrument clock time against a network or GPS time reference so that instrument clock drift can be calculated.

2.2. Data processing

The data were pre-processed using manufacture software and/or IMOS Matlab Toolbox [8]. After pre-processing, standard Quality Assurance and Quality Control (QA/QC) procedures were applied. The QA/QC tests were applied within the frame of IMOS Matlab Toolbox, which were derived from recommendations of international bodies such as the Integrated Ocean Observing System (IOOS) and the Quality Assurance of Real-Time Oceanographic Data (QARTOD). The QC flags used were also derived from international standard. Details of QA/QC procedures can be found in Morello et al., 2014 [9]. Here, only values flagged as 1 (good data) or 2 (probably good data) were used for calculation.

A data processing and quality control report was generated for each mooring deployment, together with the NetCDF file. This report contains information about the parameters applied to QC the data, and manual quality control (if applied).
The data were plotted and visually inspected for obvious problems by personnel who are expert in oceanographic analysis and have a sound understanding of the regional hydrodynamic processes.

Manual QC flags were applied to data as required and any issues that indicated a problem with the sensor was fed back to the instrumentation technicians for follow up.

2.3. Gridded data and average annual cycle

The gridded field was produced in two steps. In the first step, each profile was vertically interpolated to a 1 m grid. Linear interpolation was used to obtain the values at these new standard layer depths. Data gaps of larger than 60 m were not interpolated. In the second step, the daily and monthly means were constructed by data binning. The monthly mean was derived if there was no more than 15 days missing data in any month [10].

Average annual cycles of temperature, salinity and velocity were derived relative to the time of year, using all data within an 11-day window centred on the time of year from which the mean was calculated [11].

Ethics Statement

Not applicable.

CRediT Author Statement

Miaoju Chen: Writing – original draft, Data curtion; Ming Feng: Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

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