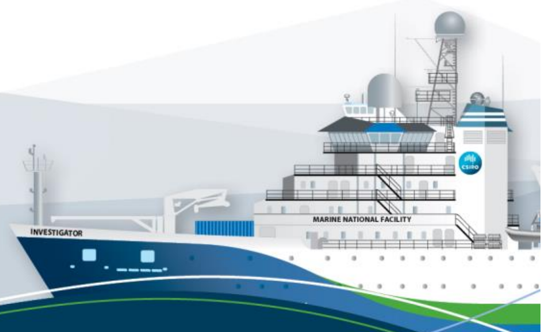
Marine National Facility

RV *Investigator*

Triaxus Processing Report – in2019_v07

Voyage #:	in2019_v07
Voyage title:	RAN Hydrographic and Maritime Heritage Surveys
Depart:	Hobart, 0830 Thursday, 11 April 2019
Return:	Hobart, 0830 Tuesday, 23 April 2019
Report compiled by:	Richard Atkinson
Date:	23 July 2020



Contents

1 Summary

These notes relate to the production of quality controlled Triaxus data from *RV Investigator* voyage in2019_v07, from 11 Apr 2019 to 23 Apr 2019.

Data for 2 Triaxus tows were acquired using Seabird's Seasave acquisition software using the Seabird SBE911+ CTD 24. O&A Calibration lab supplied calibration factors were used to compute the pressure, preliminary conductivity, oxygen and temperature values. The data was subjected to automated QC to remove spikes and out-of-range values.

A Transmissometer and a Cosine Photosynthetically Active Radiation (PAR) sensor were also installed on the auxiliary A/D channels of the CTD. In addition to the auxiliary channels an ECO Triplet and LOPC were mounted on the Triaxus as attached payloads.

The standard data product (1 decibar/10 second binned averaged) was produced using data from the primary sensors to produce an along-track time-series dataset for each data recording file. The data from each tow were recorded as a single file. Vertical casts were created with interpolated values from the along-track time-series binned dataset with a maximum interpolation distance of 1 cast. These generated the along-track and vertical cast section data products for each Triaxus tow.

Due to a cable failure the PAR and transmissometer data were unusable. The flow meter of the LOPC was suspected to be faulty, compromising the recorded data.

2 Voyage Details

2.1 Title

RAN Hydrographic and Maritime Heritage Surveys.

2.2 Principal Investigators

Emily Jateff

2.3 Voyage Objectives

The scientific objectives for in2019_v07 were outlined in the Voyage Plan (Jateff 2019).

For further details, refer to the Voyage Plan and summary which can be viewed on the CSIRO Oceans and Atmosphere web site.

2.4 Area of Operation

Figure 1: Area of operation for in2019_v07. Triaxus tows shown in red.

3 Processing Notes

3.1 Background Information

Three Triaxus tows were conducted. The third tow was to test the altimeter and its data have not been processed. Data for the remaining 2 tows have been recorded in the CTD acquisition software, Seasave, into 2 files, one file per tow. Flight data from the MacArtney Triaxus were logged containing pitch, roll, altimeter, cable length, ship water depth and ship speed.

The data for this voyage were acquired with the CSIRO CTD unit #24, a Seabird SBE911 with dual conductivity and temperature sensors.

The CTD was additionally fitted with two SBE43 dissolved oxygen sensors, a Transmissometer, and a Cosine Photosynthetically Active Radiation (PAR) sensor. An Eco-Triplet and LOPC was attached to the auxiliary serial channels. These sensors are described in Table 1 below. Available data variables are described in Appendix 1: NetCDF Variables.

Unit	Data Channel	SBE9 Connector	Model	Serial Number	Tow Numbers
SBE9			SBE9+ V2	1332	
Primary Temperature		JB1	SBE3T	6302	
Primary Conductivity		JB2	SBE4C	4774	
Primary Pump		JB3	SBE5	9417	
Secondary Temperature		JB4	SBE3T	6258 5932	1 2
Secondary Conductivity		JB5	SBE4C	4773	
Secondary Pump		JB3	SBE5	9404	
Primary Oxygen	A0	JT2	SBE43	3647	
Secondary Oxygen	A1	JT2	SBE43	3646	
PAR	A2	JT3	QCP2300HP	70562	
Transmissometer	A3	JT3	CSTAR	1421	
Eco Triplet	Payload 2		FLBBCD2K	4049	
LOPC	Payload 7		Rolls-Royce LOPC-1xT-3	11480	

Table 1: Triaxus Configuration

The raw CTD data were collected in Seasave version 7.26.7.110, converted to scientific units using SBE Data Processing version 7.26.7.129 and written to netCDF format files with CNV_to_Scan for processing using the Matlab-based CapPro package.

The CapPro software, version 2.11, was used to apply automated QC and preliminary processing to the data. This included spike removal, identification of water entry and exit times, conductivity sensor lag corrections and the determination of the pressure offsets. The automatically determined pressure offsets and in-water points were inspected.

3.2 Pressure calibration

Pressure offsets were not available for the two casts as data recording was started after submersion of the Triaxus and stopped before it was on deck.

3.3 Sensor Correction

3.3.1 Pressure Sensor Location

The location of the pressure sensor relative to the T/C sensors is defined through orthogonal axes XYZ (origin at T/C sensors) with the vehicle travelling along the X axis (if zero pitch), Z vertically up and Y to port. The pressure sensor location is given by a distance to sensor along the X axis (+ve pressure forward of T/C), and Y axis (positive values indicate pressure sensor is to port of T/C) and Z axis (positive value indicates pressure above T/C).

Using pitch (rotation around Y axis, positive nose up) and roll (rotation around X axis, positive clockwise looking forward) from the Triaxus flight data it is possible to correct the pressure at sensor locations.

Note that the pressure sensor location correction was not applied in this instance but for reference, Conductivity and Temperature sensor location for in2019_v07 were as follows (measured in metres):

	Vertical location	Fore / Aft	Starboard Primary
Primary C/T	0.3	-0.45	-1.68
Secondary C/T	0.3	-0.45	-0.05

Table 2: Pressure sensor location relative to the T/C sensors

3.3.2 Thermal Inertia Correction

The temperature of the boundary layer water passing through the conductivity cell lags the temperature of the in-situ water due to the thermal mass of the cell. Since derived salinity is strongly dependent upon temperature, in order to derive correct salinity, the true apparent temperature of the water in the cell is required. To derive the apparent temperature given the in-situ temperature we assume a fraction, beta, of the water (belonging to the boundary layer) is lagged with a time constant, tau. After extensive testing it has been determined that good correction is achieved using two time constants, 7 and 1 seconds with beta factors 0.013 and 0.007 respectively.

3.4 Other Sensors

The Wetlabs C-Star transmissometer was used for all deployments. The transmissometer has been calibrated to give nominal outputs of 0-100 fsd (full scale deflection).

The Biospherical PAR sensor was also used for all deployments.

Due to a data cable failure the PAR and Transmissometer data were unusable.

The Eco Triplet sensor array and LOPC were used for all deployments. Only Eco Triplet data has been merged into the averaged data products. There appeared to be problems with the LOPC flowmeter.

For more information on the cable failure and flowmeter issue refer to the in2019_v07 Instrumentation Report.

3.5 Bad Data Detection

The range limits and maximum second difference for sensors connected to the SBE9+ A/D channels are configured in CAP and are written to the netCDF scan file. Typical limits used for the sensor range and maximum second difference are in Table 3 below.

Eco triplet limits are set in CapPro and were found by examining the data.

Sensor	Range minimum	Range maximum	Max. Second Difference
Pressure	-10	10000	0.8
Temperature	-4	40	0.01
Conductivity	-0.01	10	0.01
Oxygen	-0.1	500	1.5
Transmissometer	80	100	0.5
PAR	0.0	0.2	0.01
CDOM	0	2500	1
Obs	0	0.5e-3	1e-4
Chl	0	1.2	0.1

Table 3: Sensor limits for bad data detection

Observation of the secondary oxygen sensor data revealed a small number of extreme spikes of around 475µM. These were clearly errors and were removed by reducing the maximum limit to 300 µM (see 3.73.7 below).

Data found to be out of range or having a second difference above the maximum second difference were flagged as bad and filtered by CapPro.

3.6 Averaging

Data was filtered and binned into 1 decibar/10 second averaged bins for each deployment along track in netCDF deployment files containing the time-series data.

Data was first binned ‘along the track’ into 1dbar bins, or 10 second bins. Binning is typically done on pressure however in cases where the Triaxus was moving horizontally a bin would be taken every 10 seconds. The binned values were calculated by applying a linear, least-squares fit as a function of pressure to the sensor data for each bin, using this to interpolate the value for the bin mid-point. This method is used to avoid possible biases which would result from averaging with respect to time.

3.6.1 Vertical Cast Creation

‘Vertical casts’ were created from the along track average files. A vertical cast represents a vertical column of data points geographically located at the minimum and maximum pressure points of an undulation. Data for a vertical cast is derived by interpolating between the binned data points on the upcast and downside of either side of the vertical cast.

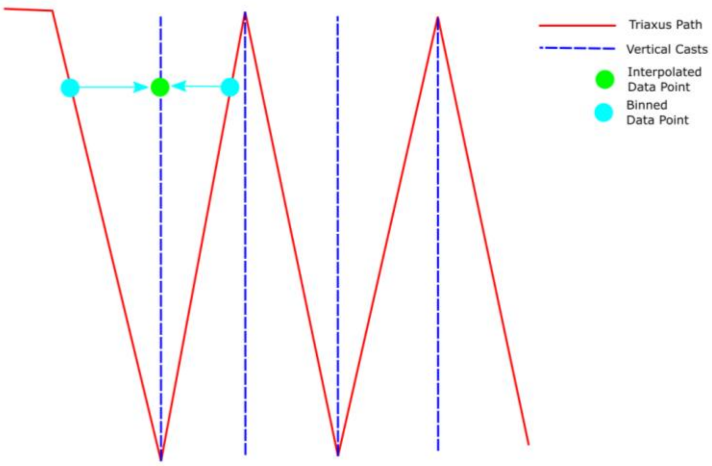


Figure 2: Vertical Cast Creation

3.6.2 Vehicle Position Correction

To provide a better estimate of the Triaxus' actual position, the recorded flight data was used to recalculate a location for the averaged data. This used the wire out, pressure, the ship's current location and a window of the previous locations along which the Triaxus is assumed to have traversed to derive an estimated true location of the Triaxus.

3.6.3 QC flags

Each binned parameter is assigned a QC flag. The quality control flagging scheme is described in Pender (2000). The QC Flag for each bin is estimated from the values for the bin components. The QC Flag for derived quantities, such as Salinity and Dissolved Oxygen are taken to be the worst of the estimates for the parameters from which they are derived.

3.7 Significant Data Issues

Table 4 notes the mean and max absolute difference between the primary and secondary Triaxus CTD sensor average data for each section.

The large value for max(abs(diff)) on Deployment2 was caused by noise on the secondary sensor as can be seen in the plots of the two sensors (Figure 3 and Figure 4). Changing the cutoff threshold to 300 µM removed these values and was used for the published data (Figure 5 and Figure 6).

After the threshold improvement these figures confirm stable statistical variability between the two sensor sets throughout the deployments.

mean(abs(diff))	***Temperature C***	***Salinity PSU***	***Oxygen uM***
deployment1Leg1	0.00246	0.00064	3.98117
Deployment2Leg1	0.00364	0.00070	2.89795
max(abs(diff))			
deployment1Leg1	0.06351	0.01445	56.32630
Deployment2Leg1	0.42043	0.03013	168.41058

Table 4: Comparative difference between primary and secondary CTD sensors

Table 6 details how the different Seasave data recordings have been organised and grouped into Triaxus deployments and legs.

mean(abs(diff))	*Temperature C*	*Salinity PSU*	*Oxygen uM*
deployment1Leg1	0.00246	0.00064	3.98117
Deployment2Leg1	0.00364	0.00070	2.85155
max(abs(diff))			
deployment1Leg1	0.06351	0.01445	56.32630
Deployment2Leg1	0.42043	0.03013	20.54413

Table 5: Comparative difference between primary and secondary CTD sensors with 300µM Oxygen cutoff

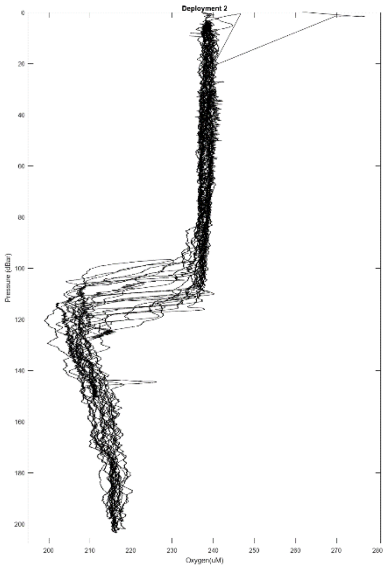


Figure 3: Primary Oxygen Sensor vs Pressure Deployment 2

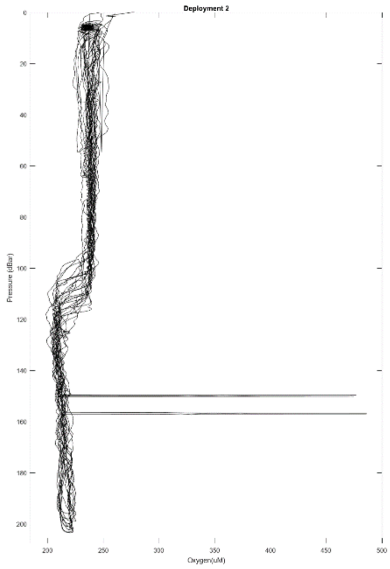


Figure 4: Secondary Oxygen Sensor vs Pressure Deployment 2

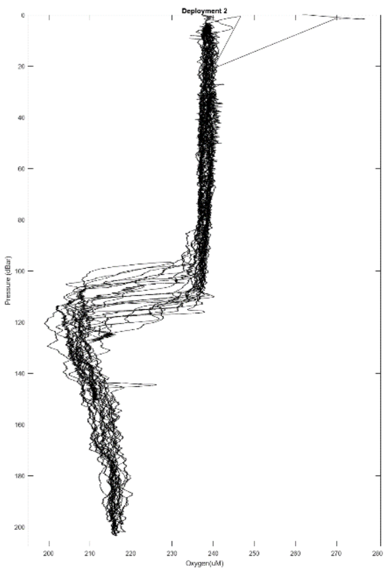


Figure 5: Primary Oxygen Sensor vs Pressure 300µM cutoff Deployment 2

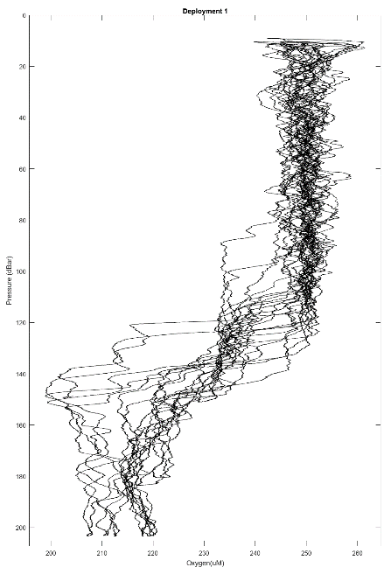


Figure 6: Secondary Oxygen Sensor vs Pressure 300µM cutoff Deployment 2

3.8 Triaxus Deployment Sections

TOW	LEG	START TIME	END TIME	START LATITUDE	START LONGITUDE	END LATITUDE	END LONGITUDE
1		2019-04-11T06:27:27Z	2019-04-11T07:33:31Z	43 11.581S	148 18.810E	43 06.592S	148 28.111E
2		2019-04-12T00:29:10Z	2019-04-12T02:51:24Z	42 47.742S	148 38.418E	42 32.478S	148 35.792E
3		2019-04-12T00:29:10Z	2019-04-12T02:51:24Z	42 47.742S	148 38.418E	42 32.478S	148 35.792E

Table 6: CAP deployment grouping

CAP deployments were grouped for each Triaxus deployment as shown in Table 6 above. (Tow 3 is not included as part of the final dataset as it was for altimeter testing.)

This was followed by the creation of vertical casts at the top and bottom apex along the flight path. See section 3.6.2 for further details on how this was performed.

Sections were then exported as both vertical casts and along-track data products in netCDF format.

4 References

Jateff, E., 2019: The RV Investigator. Voyage Plan IN2019_V07 –
https://www.marine.csiro.au/data/reporting/get_file.cfm?eov_pub_id=143

Pender, L., 2000: Data Quality Control Flags.
http://www.cmar.csiro.au/datacentre/ext_docs/DataQualityControlFlags.pdf

Sea-Bird Electronics Inc., 2012: Application Note No 64.2: SBE 43 Dissolved Oxygen Sensor Calibration and Data Corrections.
https://www.seabird.com/asset-get.download.jsa?id=54627861704

Sea-Bird Electronics Inc., 2014: Application Note No 64.4: SBE 43 Dissolved Oxygen (DO) Sensor – Hysteresis Corrections.
https://www.seabird.com/asset-get.download.jsa?id=54627861705

5 Glossary

Deployment – relates to one instance of the Triaxus entering the water, being towed for a period of time and followed by retrieval from the water.

Leg – relates to a 'section' of the deployment containing a feature of interest, whether it be an eddy, geographic region etc. This can be part of or the whole deployment.

Scan file – a file structure containing data collected from the deployment of the CTD and auxiliary sensors.

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8 Appendix 1: NetCDF Variables

The following variables are available in the provided NetCDF files. Variables marked with a * have a corresponding quality control flag variable. Flags are described in Pender (2000).

Variable Name	Description	Units
latitude	Estimated latitude of the Triaxus	degrees
longitude	Estimated longitude of the Triaxus	degrees
distance	Distance along the tow	km
waterDepth	Depth of water at the estimated position of the Triaxus	m
temperature *	Calibrated reading from the primary temperature sensor	°C
conductivity *	Calibrated reading from the primary conductivity sensor	S/m
salinity *	Calibrated salinity derived from the primary temperature and conductivity sensors	PSU
temperature_2 *	Calibrated reading from the secondary temperature sensor	°C
conductivity_2 *	Calibrated reading from the secondary conductivity sensor	S/m
salinity_2 *	Calibrated salinity derived from the secondary temperature and conductivity sensors	PSU
par *	Calibrated reading from the QCP-2300 Photosynthetically Active Radiation sensor	$\mu E/m^2/sec$
transmissometer *	Calibrated reading from the Wetlabs C-Star transmissometer	%
oxygen_2 *	Calibrated reading from the secondary oxygen sensor	µmole/L
oxygen *	Calibrated reading from the primary oxygen sensor	µmole/L
chlorophyll *	Calibrated reading for chlorophyll from the eco triplet	µg/L
obs *	Calibrated reading for optical backscatter from the eco triplet	m^{-1}
cdom *	Calibrated reading for coloured dissolved organic matter from the eco triplet	ppb
pitch *	Pitch of the Triaxus as recorded by the Triaxus flight data	degrees
roll *	Roll of the Triaxus as recorded by the Triaxus flight data	degrees
altimeter *	Altitude of the Triaxus	m
cableLength *	Cable length between the winch and Triaxus as recorded by the Triaxus flight data	m

Table 7: NetCDF data variables