Marine National Facility

RV *Investigator*

Triaxus Processing Report

Voyage #:	in2022_v03
Voyage title:	Southern Ocean Time Series (SOTS)
Depart:	3rd May 2022
Return:	15th May 2022
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Document History

Date	Version	Author	Comments
16 June 2022	1.0	Steven Van Graas	Initial version

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Contents

1 Summary

These notes relate to the production of quality controlled Triaxus data from RV Investigator voyage in2022_v03, from 03 May 2022 – 15 May 2022.

Data for one Triaxus tow were acquired using Seabird's Seasave acquisition software using the Seabird SBE911+ CTD #25. Sea-Bird and 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 PAR, transmissometer, and SUNA sensors 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. A load cell sensor was also attached to the Triaxus mechanical termination.

The standard data product (1 decibar/10 second binned averaged) was produced using data from the seconday sensors to produce an along-track time-series dataset for each data recording file. These files were grouped into sections containing each Triaxus tow and in each tow, vertical casts were created with interpolated values from the along-track time-series binned dataset with a maximum interpolation distance of 1 cast/undulation. These generated the along-track and vertical cast section data products for each Triaxus tow.

An issue was identified at the start of deployment once the Triaxus was in water and the pumps switched on, where the salinity values were in significant disagreement and both showing unrealistic readings. It was determined that the connectors for the primary and secondary conductivity sensors had been swapped. This was corrected without recovery and redeployment of the Triaxus by swapping the calibration parameters. Further manual manipulation of the data was required during post-processing to match the physically co-located sensors for correct salinity and oxygen value calculations.

2 Voyage Details

2.1 Title

Southern Ocean Time Series

2.2 Principal Investigators

Dr Elizabeth Shadwick

2.3 Voyage Objectives

The scientific objectives for in2022_v03 were outlined in the Voyage Plan (PI YEAR).

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

2.4 Area of Operation

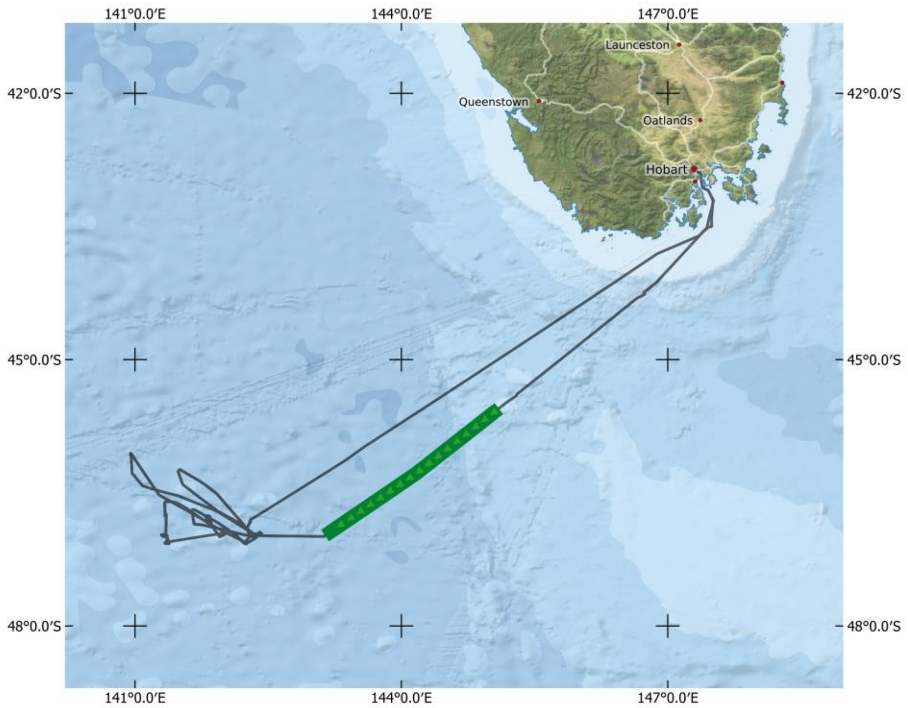

Figure 1: Area of operation for in2022_v03. Triaxus deployment marked in green.

3 Processing Notes

3.1 Background Information

1 Triaxus tow was conducted, divided in the CTD acquisition software Seasave into 1 file. 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 #25, 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	1354	1
Primary Temperature		JB1	SBE3T	4522	1
Primary Conductivity		JB2	SBE4C	3168	1
Secondary Temperature		JB4	SBE3T	6024	1
Secondary Conductivity		JB5	SBE4C	2312	1
Primary Pump		JB3	SBE5	9404	1
Secondary Pump		JB3	SBE5	8344	1
Primary Oxygen	A0	JT2	SBE43	4167	1
Secondary Oxygen	A1	JT2	SBE43	4184	1
PAR	A2	JT3	QCP2300HP	70111	1
Transmissometer	A3	JT3	CSTAR	CST-1735DR	1
Eco Triplet	Payload		FLBBCD2K	4049	1
LOPC	Payload		Rolls-Royce LOPC-1xT-3	11480	1

Table 1: Triaxus Configuration

The raw CTD data were collected in Seasave version 7.26.7.121, converted to scientific units using SBE Data Processing version 7.26.7 and written to NetCDF format files with CNV_to_Scan for processing using the Matlab-based CapPro package.

The CapPro software version 2.12 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

The pressure offsets were not able to be calculated as out of water data was not recorded at the commencement of the deployment.

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 in2022_v03 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. The PAR sensor has been calibrated to give output in uE/m^2/sec. This data channel has been included in the output files for deployments. Clearly, time of day and environmental factors such as sea state and cloud cover impact on these readings. If there are no values for a deployment it is likely because it was night time during the deployment.

The Eco Triplet sensor array and LOPC were used for all deployments. Only Eco Triplet data has been merged into the averaged data products.

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

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.

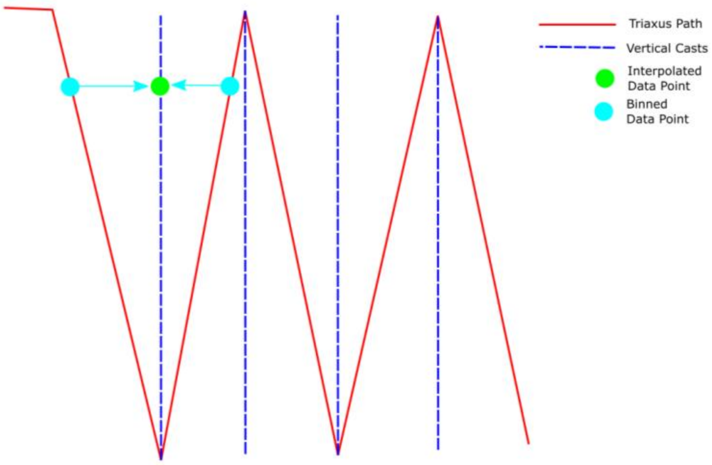

Figure 2: Vertical Cast Creation

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. Our 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

The connectors for the primary and secondary conductivity sensors were swapped on the SBE9+, which required swapping the calibration coefficients in Seasave while acquiring deployment. To ensure that the derived salinity for the primary and secondary channels is correctly generated, the intermediate CNV data file was edited to swap the positions of the conductivity sensor data, thus ensuring that the values for the primary and secondary sensors equated to the same physical water sample measured.

The (effective) primary conductivity sensor, with serial 3168, displayed consistent and significant spiking throughout the entire deployment. Post-processing has filtered the most significant spiking however such errors are indicative of sensor issues and as such it is strongly recommended that the data is not used in analysis, it has been only included in the export as supplemental (designated with '_1' suffix). Additionally, the conductivity spiking has impacted the dissolved oxygen values for the primary channel.

3.8 Triaxus Deployment Sections

Deployment	Leg	File #	Start time	End time	Start latitude	Start longitude	End latitude	End longitude
1	1	1	2022-05-04 22:57:44Z	2022-05-05 13:58:28Z	45 35.924S	145 2.1848E	46 54.656S	143 14.671E

Table 4: CAP deployment grouping

CAP deployments were grouped for each Triaxus deployment as shown in Table 4 above. As this voyage dataset comprised of a single tow, no additional management was required.

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

Shadwick, E., 2022: The RV Investigator. Voyage Plan in2022_v03 - https://www.marine.csiro.au/data/reporting/get_file.cfm?eov_pub_id=1930

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	deg c
conductivity *	Calibrated reading from the primary conductivity sensor	S/m
salinity *	Calibrated salinity derived from the primary temperature and conductivity sensors	PSU
temperature_1 *	Calibrated reading from the secondary temperature sensor	deg c
conductivity_1 *	Calibrated reading from the secondary conductivity sensor	S/m
salinity_1 *	Calibrated salinity derived from the secondary temperature and conductivity sensors	PSU
par *	Calibrated reading from the QCP-2300 Photosynthetically Active Radiation sensor	uE/m^2/sec
transmissometer *	Calibrated reading from the Wetlabs C-Star transmissometer	%
oxygen_1 *	Calibrated reading from the secondary oxygen sensor	umole/L
oxygen *	Calibrated reading from the primary oxygen sensor	umole/L
chlorophyll *	Calibrated reading for chlorophyll from the eco triplet	ug/L
obs *	Calibrated reading for optical backscatter from the eco triplet	m^-1
cdom *	Calibrated reading for coloured dissolved organic matte 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 5: NetCDF data variables