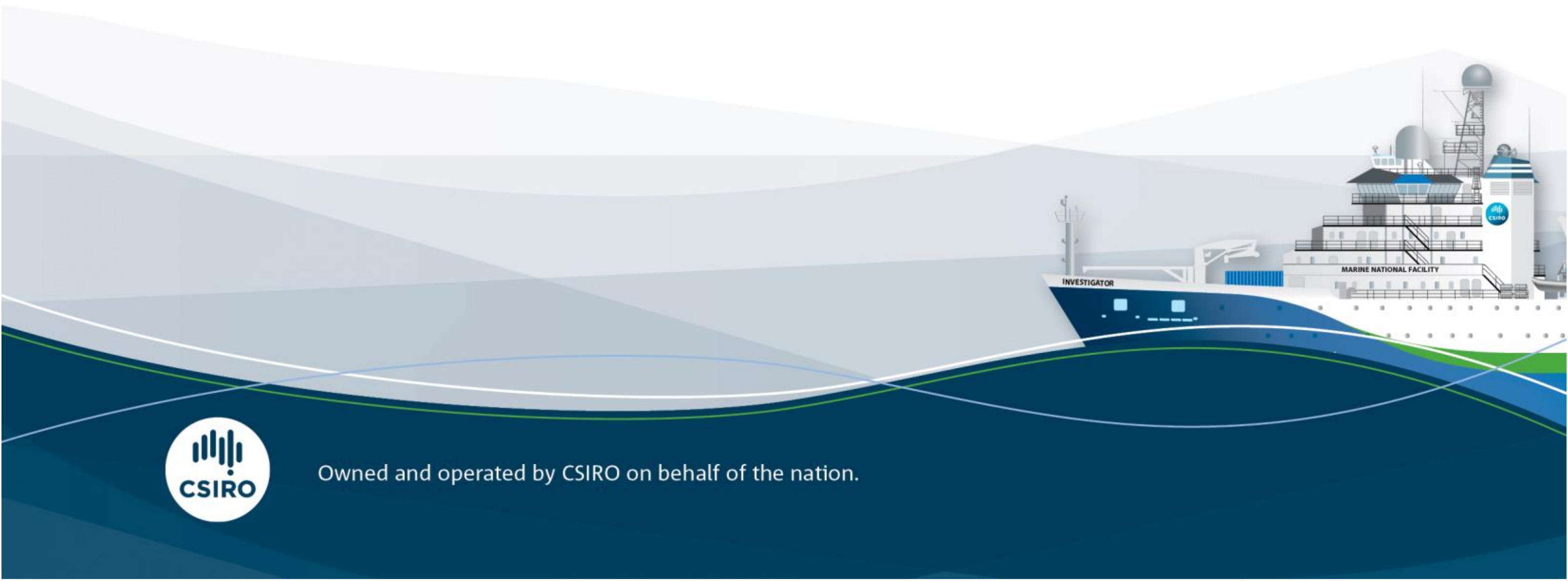
RV *Investigator*

Triaxus Processing Report

Voyage #:	in2019_v05
Voyage title:	Integrated Marine Observing System: monitoring of East Australian Current property transports at 27° S
Depart:	Brisbane, Monday 09 September 2019
Return:	Brisbane, Sunday 29 September 2019
Report compiled by:	Steven Van Graas



Contents

1 Summary

These notes relate to the production of quality controlled Triaxus data from RV Investigator voyage in2019_v05, from 09 Sep 2019 – 29 Sep 2019.

Data for 6 Triaxus deployments were acquired using Seabird's Seasave acquisition software using the Seabird SBE911+ CTD 23. 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 Biospherical QCP2300-HP PAR, and a WetLabs C-STAR Transmissometer 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.

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. These files were grouped into sections containing each Triaxus deployment and in each deployment, 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 deployment.

All deployments except for 3 were along the mooring line transect. Throughout the voyage there were some issues with the Triaxus vehicle. Communication loss with the Triaxus ended Deployment 1 early, requiring re-termination. Deployment 5 also suffered communication loss, ending acquisition early. The Primary SBE43 Oxygen sensor was swapped out after deployment 3 due to increased noise in sensor readings.

2 Voyage Details

2.1 Title

Integrated Marine Observing System: monitoring of East Australian Current property transports at 27° S

2.2 Principal Investigators

Dr Bernadette Sloyan

2.3 Voyage Objectives

The scientific objectives for in2019_v05 were outlined in the Voyage Plan (Sloyan 2019).

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

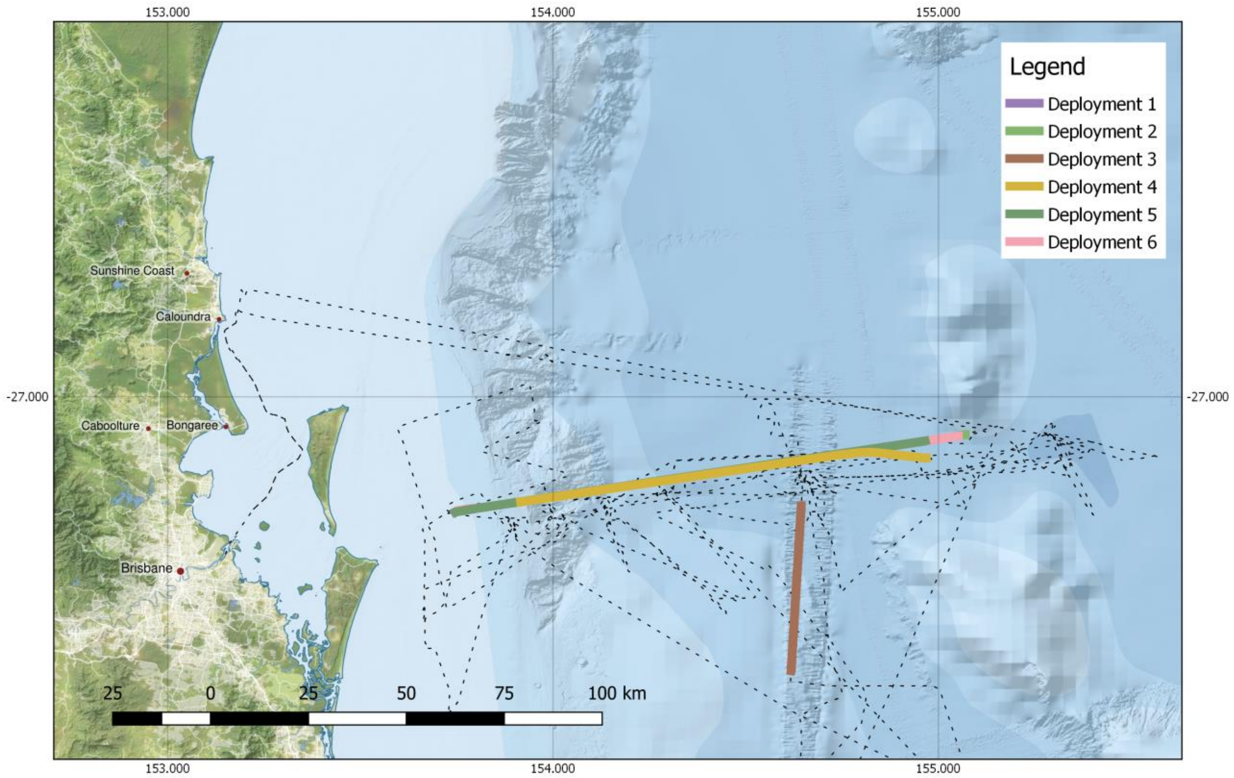


Figure 1: Area of operation for in2019_v05.

3 Processing Notes

3.1 Background Information

6 Triaxus deployments were conducted, divided in the CTD acquisition software Seasave into 15 files. 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 23, 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	Deployment Numbers
SBE9			SBE9+ V2	1312	1-6
Primary Temperature		JB1	SBE3T	6302	1-6
Primary Conductivity		JB2	SBE4C	4774	1-6
Secondary Temperature		JB4	SBE3T	5932	1-6
Secondary Conductivity		JB5	SBE4C	4773	1-6
Primary Pump		JB3	SBE5	9417	1-6
Secondary Pump		JB3	SBE5	9404	1-6
PAR	A0	JT2	QCP2300HP	70677	1-6
Transmissometer	A1	JT2	CSTAR	CST-1735DR	1-6
Primary Oxygen	A2	JT3	SBE43	3199	1-3
Primary Oxygen	A2	JT3	SBE43	1794	4-6
Secondary Oxygen	A3	JT3	SBE43	3646	1-6
Eco Triplet	Payload		FLBBCD2K	5038	1-6
LOPC	Payload		Rolls-Royce LOPC-1xT-3	11480	1-6

Table 1: Triaxus Configuration

The raw CTD data were collected in Seasave version 7.26.6.26, 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 2.11 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

The pressure offsets are plotted in Figure 2 below. The blue circles refer to initial out-of-water values and the red circles the final out-of-water values. Pressure offsets were not available for most casts as data recording was started after submersion of the Triaxus and stopped before it was on deck.

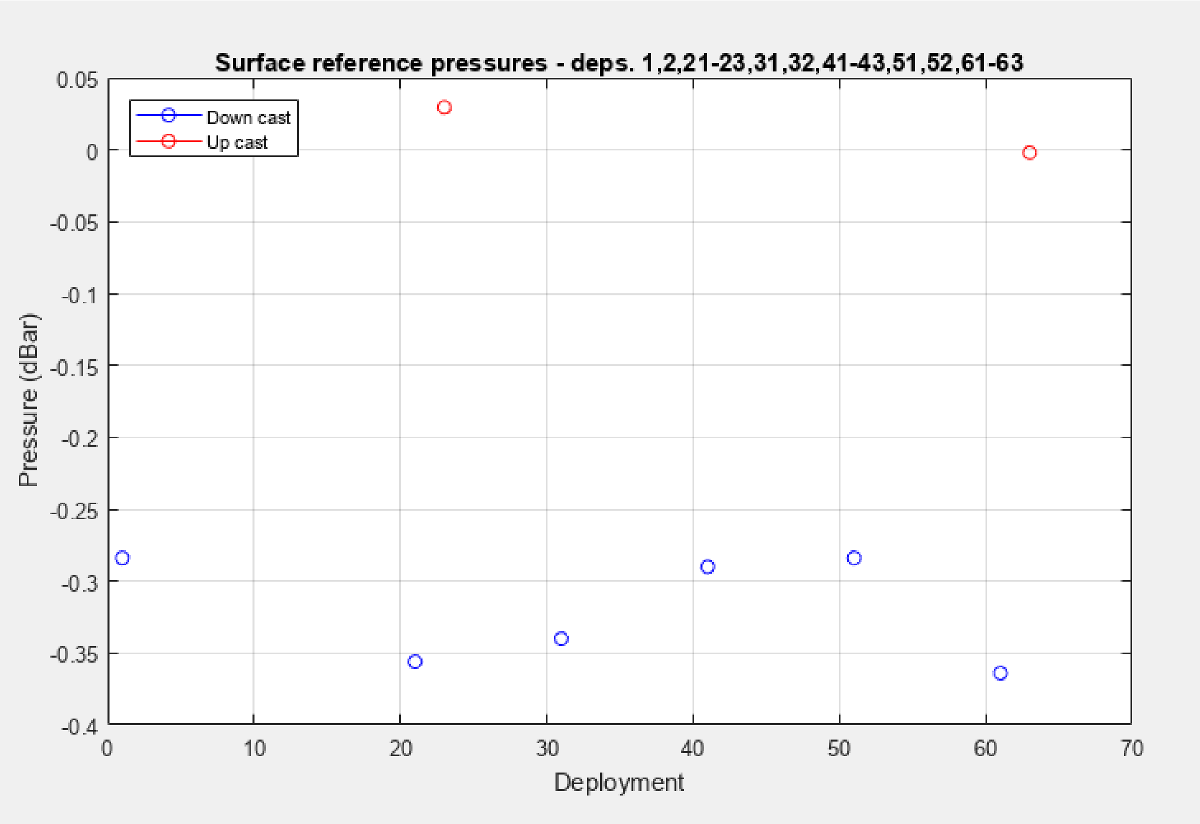


Figure 2: CTD pressure offsets

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_v05 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.

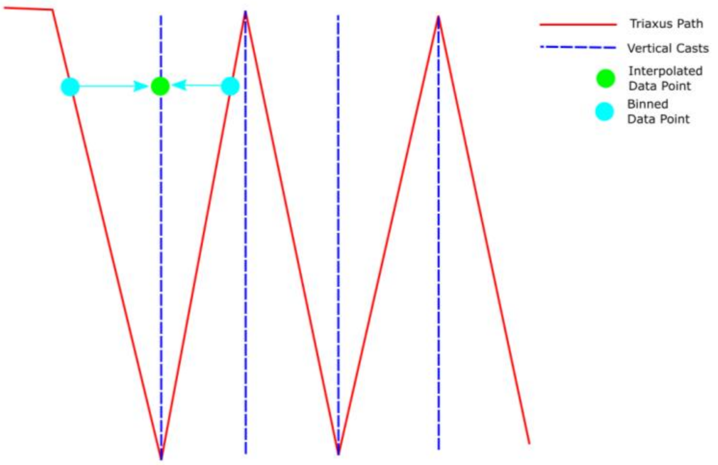


Figure 3: Vertical Cast Creation

3.6.2 Vehicle Position Correction

Due to inconsistencies in the recorded wire-out data during deployments 2,3 and 6 the vehicle position has not been corrected, and no layback has been applied. The wire out data is included in the average file, as supplementary information.

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

Deployment 1 and 5 were ended early due to communication loss. Prior to loss of communication with the Triaxus data quality was good.

The Primary Oxygen sensor was swapped after deployment 3 due to increased noise being observed.

Table 4. notes the mean and max absolute difference between the primary and secondary Triaxus CTD sensor average data for each sectional and confirms stable statistical variability between the two sensor sets throughout the deployments.

mean(abs(diff))	*Temperature C*	*Salinity PSU*	*Oxygen uM*
Deployment 1	0.00353	0.00552	2.90315
Deployment 2	0.00329	0.00661	8.39369
Deployment 3	0.00396	0.00634	8.37994
Deployment 4	0.00371	0.00527	2.00192
Deployment 5	0.00354	0.00564	2.90330
Deployment 6	0.00362	0.00557	3.63047
max(abs(diff))			
Deployment 1	0.132035	0.029877	11.015897
Deployment 2	0.210939	0.072451	24.282837
Deployment 3	0.120690	0.051994	22.045055
Deployment 4	0.116292	0.048037	10.254372
Deployment 5	0.160994	0.047985	11.216742
Deployment 6	0.183216	0.071571	10.387246

Table 4: Comparative difference between primary and secondary CTD sensors

Table 5**Error! Reference source not found.** details how the different Seasave data recordings have been organised and grouped into Triaxus deployments and legs. The sections below detail the data issues per deployment.

3.8 Triaxus Deployment Sections

Deployment	Leg	File #	Start time	End time	Start latitude	Start longitude	End latitude	End longitude
1	0	11	2019-09-24 08:05:05	2019-09-24 08:17:16	-27 17.8324	153 43.8879	-27 17.8324	153 44.6911
	1	12	2019-09-24 08:17:34	2019-09-24 18:38:56	-27 17.9236	153 44.7327	-27 17.9236	154 57.9389
2	0	21	2019-09-17 08:40:04	2019-09-17 09:02:25	-27 6.1854	155 5.2169	-27 6.1854	155 4.2762
	1	22	2019-09-17 09:02:52	2019-09-17 21:34:31	-27 5.8759	155 4.1972	-27 5.8759	153 47.6498
	2	23	2019-09-17 21:35:08	2019-09-17 21:48:51	-27 17.6325	153 46.2744	-27 17.6325	153 45.1885
3	0	31	2019-09-18 17:01:19	2019-09-18 17:24:51	-27 14.2728	154 38.7927	-27 14.2728	154 38.6417
	2	32	2019-09-18 17:25:36	2019-09-18 21:28:05	-27 16.9397	154 38.6320	-27 16.9397	154 37.0603
	3	33	2019-09-21 08:23:39	2019-09-21 08:51:52	-27 9.5800	154 57.6909	-27 9.5800	154 58.1974
4	0	41	2019-09-21 08:52:12	2019-09-21 19:25:22	-27 9.5148	154 58.1279	-27 9.5148	153 54.9424
	1	42	2019-09-21 19:26:07	2019-09-21 19:55:33	-27 16.5413	153 53.7043	-27 16.5413	153 50.4181
	2	43	2019-09-24 08:05:05	2019-09-24 08:17:16	-27 17.8324	153 43.8879	-27 17.8324	153 44.6911
5	0	51	2019-09-24 08:17:34	2019-09-24 18:38:55	-27 17.9235	153 44.7329	-27 17.9235	154 57.9366
	1	52	2019-09-27 16:35:38	2019-09-27 16:52:27	-27 18.2578	153 43.3263	-27 18.2578	153 44.7918
6	0	61	2019-09-27 16:52:57	2019-09-28 03:51:01	-27 17.8262	153 44.8668	-27 17.8262	155 3.1019
	1	62	2019-09-28 03:51:52	2019-09-28 04:18:19	-27 5.8912	155 4.4798	-27 5.8912	155 6.5322
	2	63	2019-09-24 08:05:05	2019-09-24 08:17:16	-27 17.8324	153 43.8879	-27 17.8324	153 44.6911

Table 5: CAP deployment grouping

CAP deployments were grouped for each Triaxus deployment as shown in Table 5 above. Legs marked in green are included as part of the final dataset, whereas the others in blue are not. A light green colour indicates that only part of the leg produced high quality data on one or both sensors. Legs marked as 'leg 0' indicate a file that was used only for deploying or recovering the Triaxus which contains no useful data. Legs which have a number ending in .5 are turns and have also not been included as part of the final data set.

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

Sloyan, B., 2019: The RV Investigator. Voyage Plan IN2019_V05
https://www.marine.csiro.au/data/reporting/get_file.cfm?eov_pub_id=1165

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_2 *	Calibrated reading from the secondary temperature sensor	deg 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	uE/m^2/sec
transmissometer *	Calibrated reading from the Wetlabs C-Star transmissometer	%
oxygen_2 *	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 6: NetCDF data variables