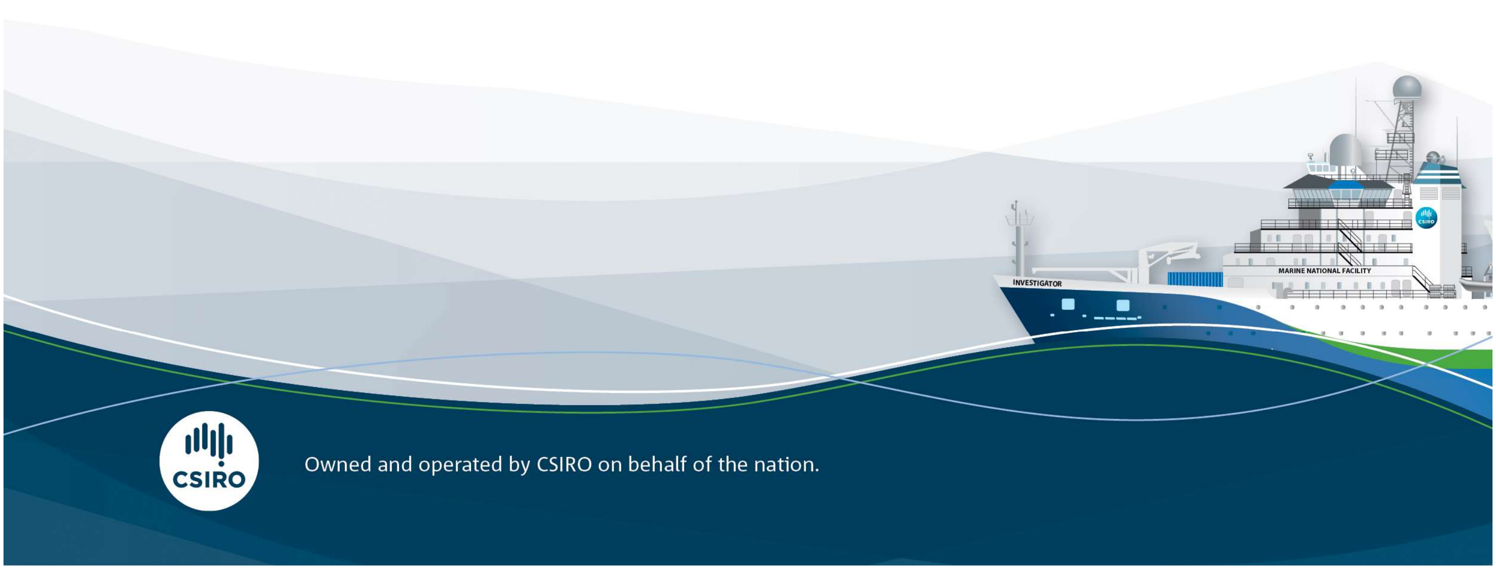
Marine National Facility

RV *Investigator*

Triaxus Processing Report

Voyage #:	IN2018_T02
Voyage title:	Harmful Algal Blooms and their long term sediment record in East Coast Tasmanian waters
Depart:	Brisbane, 0800 Monday, 14th May 2018
Return:	Hobart, 0900 Monday, 21st May 2018
Report compiled by:	Anoosh Sarraf



Contents

1 Summary

These notes relate to the production of quality controlled Triaxus data from RV Investigator voyage in2018_t02, from 14 May 2018 – 21 May 2018.

Data for 3 Triaxus deployments were acquired using seabirds SeaSave acquisition software with Seabird SBE911+ CTD #23.

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.

Dissolved oxygen sensors, Photosynthetically Active Radiation (PAR) and 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 and seconday sensors to produce an along-track time-series dataset for each data scan file. These files were grouped into sections/legs containing the Triaxus deployment. Moreover, for each section, 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.

Throughout the voyage there were some issues with the Triaxus deployments. As a result, the standard data products could not be made for every deployment. See section 2.7 for further details.

Voyage Details

1.1 Title

Harmful Algal Blooms and their long term sediment record in East Coast Tasmanian waters.

1.2 Principal Investigators

Chief Scientist: Prof. Gustaaf Hallegraeff

1.3 Voyage Objectives

The scientific objectives for in2018_t02 were outlined in the Voyage Plan (Hallegraeff G, 2018).

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

1.4 Area of Operation

The voyage track map below, figure 1, illustrates the voyage track and figure 2 highlights the area of operation for the traixus deployments

Figure 1: Area of operation for in2018_t02

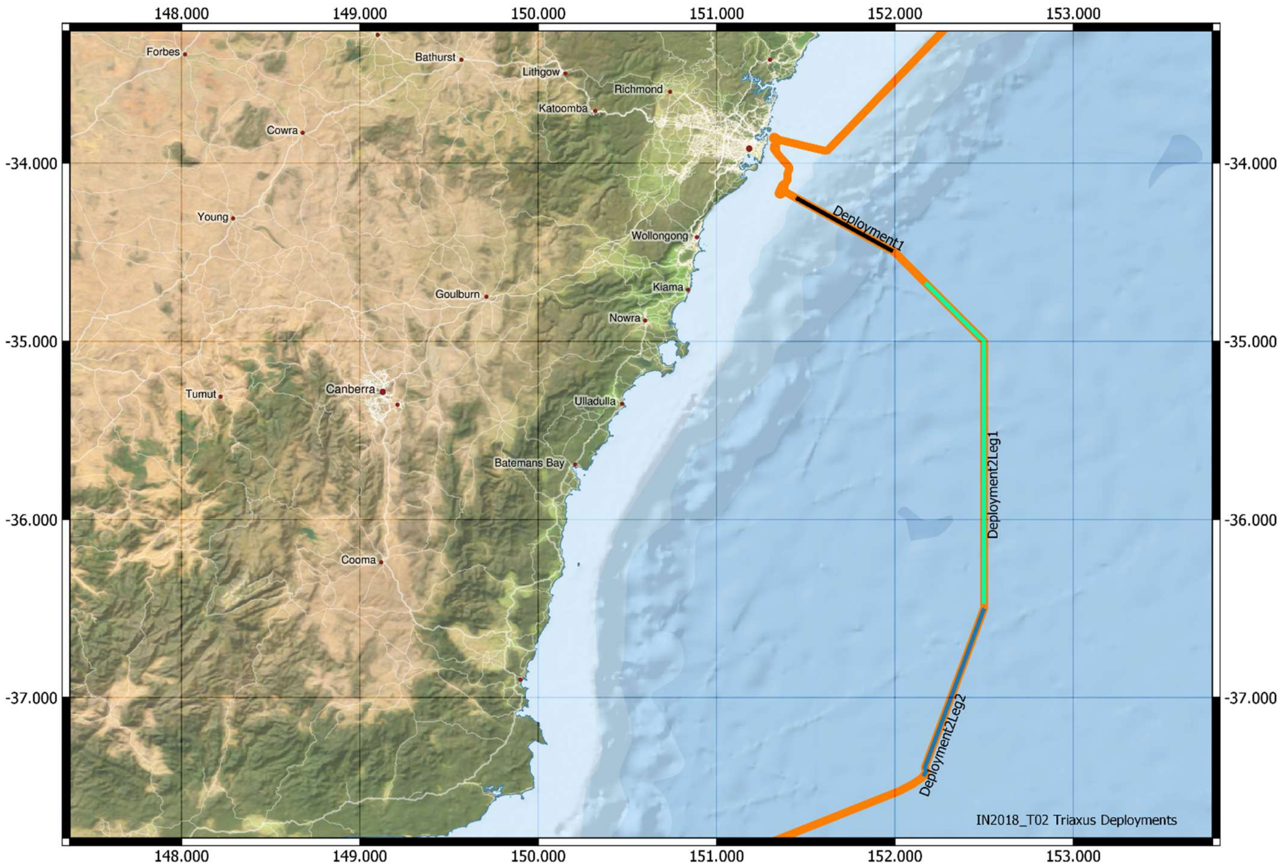


Figure 2: Sub area of operations for Triaxus deployments in2018_t02

2 Processing Notes

2.1 Background Information

Total number of 2 Triaxus deployments were conducted, divided in the CTD acquisition software Seasave into 9 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 and a Cosine Photosynthetically Active Radiation (PAR) sensor. An Eco-Triplet, LOPC Sensor 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.

Sensor	Channel	SBE9 connector	Model	Serial	Cal. Date
CTD			SBE9+ V2	1312	5-Dec-2017
Primary Temperature		JB1	SBE3T	6024	11-Jul-2017
Primary Conductivity		JB2	SBE4C	4426	11-Jul-2017
Primary Pump		JB3	SBE5	5105	
Secondary Temperature		JB4	SBE3T	6022	27-Feb-2018
Secondary Conductivity		JB5	SBE4C	4664	22-Mar-2018
Secondary Pump		JB3	SBE5	4568	
PAR	A2	JT3	QCP2300HP	70111	26-06-2017
Transmissometer	A3	JT1	CSTAR	1735DR	27-Feb-2018
Primary Oxygen	A4	JT5	SBE43	3542	26-02-2018
Secondary Oxygen	A5	JT5	SBE43	1794	01-Aug-2017
Eco Triplet	Payload 2		FLBBCD2K	4049	30-06-2017
LOPC	Payload 7		Rolls Royce LOPC-1xT-3	11480	

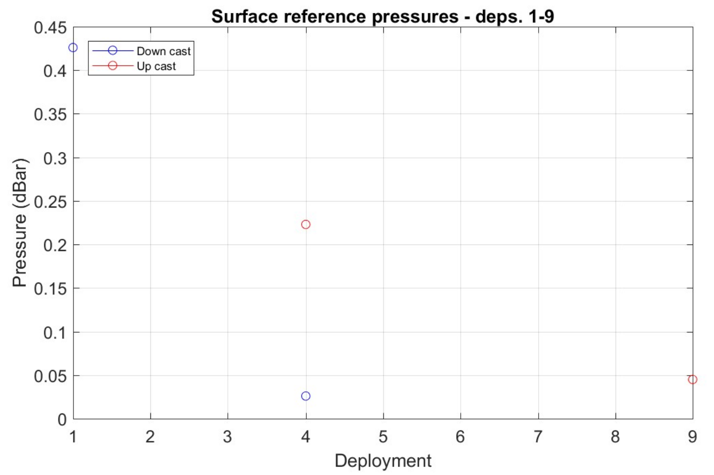
Table 1 Triaxus Configuration

The raw CTD data were collected in SeaSave version 7.26.7.107**,** converted to scientific units using SBE Data Processing version 7.26.6 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.

2.2 Pressure calibration

The pressure offsets are plotted in Figure 3 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.



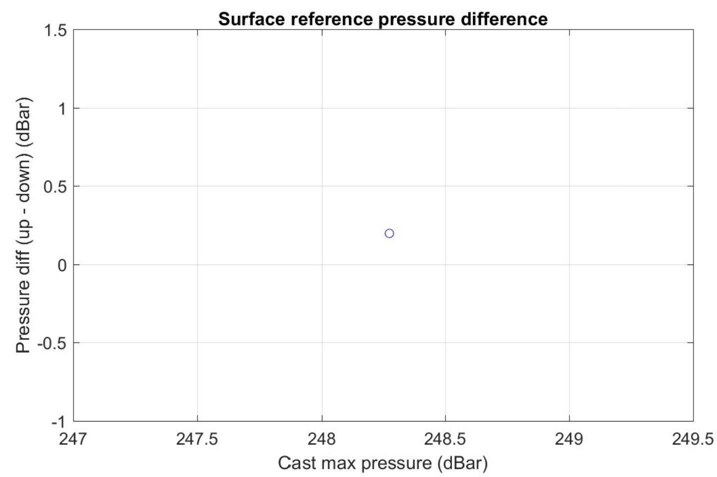


Figure 3: CTD pressure offsets

2.3 Sensor Correction

2.3.1 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 were not applied in this instance but for reference, Conductivity and Temperature sensor location for in2018_t02 were as follows (measured in metres).

	Vertical location	Fore / Aft	Starboard Primary
Primary C/T	0.3	-0333.45	-1.68
Secondary C/T	0.3	-0.45	-0.05

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

2.3.2 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.

2.4 Other Sensors

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.

2.5 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	-7	6500	0.5
Temperature	-10	40	0.05
Conductivity	-0.01	7	0.01
Oxygen	-0.1	500	0.5
Transmissometer	0	100	0.5
PAR	-5	5000	100
CDOM	0	375	0.8
Obs	0	3	1e-4
Chl	0	30	0.5

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.

2.6 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.

2.6.1 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.

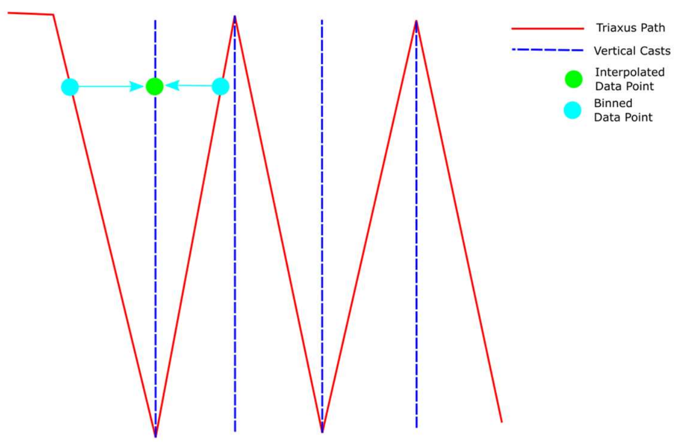


Figure 4: Vertical Cast Creation

2.6.2 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 ships 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.

2.6.3 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.

2.7 Deployment Details

Triaxus deployment was performed in two parts with recovery and redeployment in between to enable routine 12 hourly schedule inspection of the Triaxus vehicle being performed.

2.7.1 Deployment 1

This deployment was cut short due the package flipping probably due to rudder problems.

2.7.2 Deployment 2

The Triaxus deployment and retrievals was not disjointed by the operator in the Seasave data acquisition software therefore necessitating manual QCing as detailed below.

Leg1 : A small portion of data during the initial deployment of the Triaxus prior to undulation was present and this was manually flagged as bad (flag value 165) in the final data product.

Adjustment to the drum caused a tension spike noise that resulted in the pilot program to restart causing a small gap in the data.

Leg2 : A small portion of data during retrieval of the Triaxus was present and this was manually flagged as bad (flag value 165) in the final data product.

2.8 Significant Data Issues

The PAR and Transmissometer data for the Triaxus deployments had invalid ranges and values when processed. The same issue was found in the data for these sensors in voyages before and after in2018_t02, that utilized the same Triaxus platform. An investigation during a subsequent voyage found that a cable had failed during the voyage immediately preceding in2018_t02. Therefore, the values from PAR and Transmissometer are invalid and have been excluded from the final data products for in2018_t02.

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's processed data throughout the deployments.

mean(abs(diff))	***Temperature C***	***Salinity PSU***	***Oxygen uM***
deployment1	0.0032	0.0328	14.6557
deployment2Leg1	0.0043	0.0323	11.4439
deployment2Leg2	0.0042	0.0325	11.4280
max(abs(diff))			
deployment1	0.3711	0.0679	24.6973
deployment2Leg1	0.1689	0.1079	32.4703
deployment2Leg2	0.4006	0.1009	26.3400

Table 4 Details the comparative difference between primary and secondary CTD sensors

Table 5 details how the different Seasave data recordings have been organised and grouped into each Triaxus deployments and legs.

Deployment	Leg	OR OP #	Start time	End time	Start latitude	Start longitude	End latitude	End longitude
1	0	1	16-May-2018 09:51:45	16-May-2018 10:18:41	-34.16343	151.38956	-34.18549	151.42953
	1	2	16-May-2018 10:27:32	16-May-2018 14:30:46	-34.19657	151.44950	-34.48873	151.97950
	0	3	16-May-2018 14:31:46	16-May-2018 15:08:53	-34.49259	151.99244	-34.55737	152.05720

2	1	4	16-May-2018 17:27:32	16-May-2018 20:38:38	-34.67978	152.17933	-34.97951	152.47944
	1	5	16-May-2018 20:44:54	17-May-2018 02:31:58	-34.99372	152.49951	-35.72343	152.49997
	1	6	17-May-2018 02:32:25	17-May-2018 08:12:02	-35.73614	152.49998	-36.47364	152.49997
	0.5	7	17-May-2018 08:13:23	17-May-2018 08:18:59	-36.48966	152.50411	-36.50145	152.49947
	2	8	17-May-2018 08:19:52	17-May-2018 13:57:51	-36.50364	152.49883	-37.15544	152.25641
	2	9	17-May-2018 14:02:34	17-May-2018 16:32:54	-37.17434	152.24924	-37.43074	152.16517

Table 5 CAP deployment grouping

Legs marked in white are not included as part of the final data set whereas legs marked in green are included as part of the final dataset. Legs marked as ‘leg 0’ indicate a file that was used for deploying or recovering the Triaxus. 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 2.6.2 for further details on how this was performed. Sections were then exported as both vertical casts and along-track data products in netCDF format.

Table 6 is the summary Triaxus deployment details for the along track sections final data products.

Section names	Start time	End time	Start latitude	Start longitude	End latitude	End longitude
deployment1	16-May-2018 10:27:32	16-May-2018 14:30:46	-34.19657	151.44950	-34.48873	151.97950
deployment2Leg1	16-May-2018 17:27:32	17-May-2018 08:12:02	-34.67978	152.17933	-36.47364	152.49997
deployment2Leg2	17-May-2018 08:19:52	17-May-2018 16:32:54	-36.50364	152.49883	-37.43074	152.16517

Table 6 Along track section deployment summary

3 References

Hallegraeff G, 2018: The RV Investigator. Voyage Plan IN2018_T02
https://www.cmar.csiro.au/data/trawler/survey_list.cfm?q=&source_id=309&start=21#IN2018_T02

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

Sea-Bird Electronics Inc., 2013: Application Note No 64: SBE 43 Dissolved Oxygen Sensor -- Background Information, Deployment Recommendations, and Cleaning and Storage.
http://www.seabird.com/sites/default/files/documents/appnote64Jun13.pdf

4 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.

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
salinity *	Calibrated salinity derived from the primary temperature and conductivity sensors	PSU
temperature_2 *	Calibrated reading from the secondary temperature sensor	deg c
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	uM
oxygen *	Calibrated reading from the primary oxygen sensor	uM
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 7: NetCDF data variables