RV *Investigator*

Triaxus Processing Report

Voyage #:	IN2016_V04
Voyage title:	Influence of temperature and nutrient supply on the biogeochemical function and diversity of oceans microbes
Depart:	Sydney, 31 August 2016 14:00
Return:	Brisbane, 22 September 2016 16:00
Report compiled by:	Karl Malakoff

Contents

1 Summary

These notes relate to the production of quality controlled Triaxus data from RV Investigator voyage IN2016_v04, from 31 Aug 2016 – 22 Sep 2017.

Data for 11 Triaxus tows were acquired in CAP CTD acquisition software using the Seabird SBE911 CTD 23. Sea-Bird and O&A calibration lab supplied calibration factors were used to compute the pressures and preliminary conductivity values. The data were subjected to automated QC to remove spikes and out-of-range values.

Dissolved oxygen, Transmissometer and Cosine Photosynthetically Active Radiation (PAR) 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 CAP deployment. These deployments 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. These generated the along-track and vertical cast section data products for each Triaxus tow.

2 Voyage Details

2.1 Title

Influence of temperature and nutrient supply on the biogeochemical function and diversity of oceans microbes.

2.2 Principal Investigators

Martina Doblin (CS, University of Technology, Sydney), Mark Brown (PI. Macquarie University), Iain Suthers (PI, UNSW and SIMS).

2.3 Voyage Objectives

The scientific objectives for IN2016_v04 were outlined in the Voyage Plan (Doblin 2016).

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

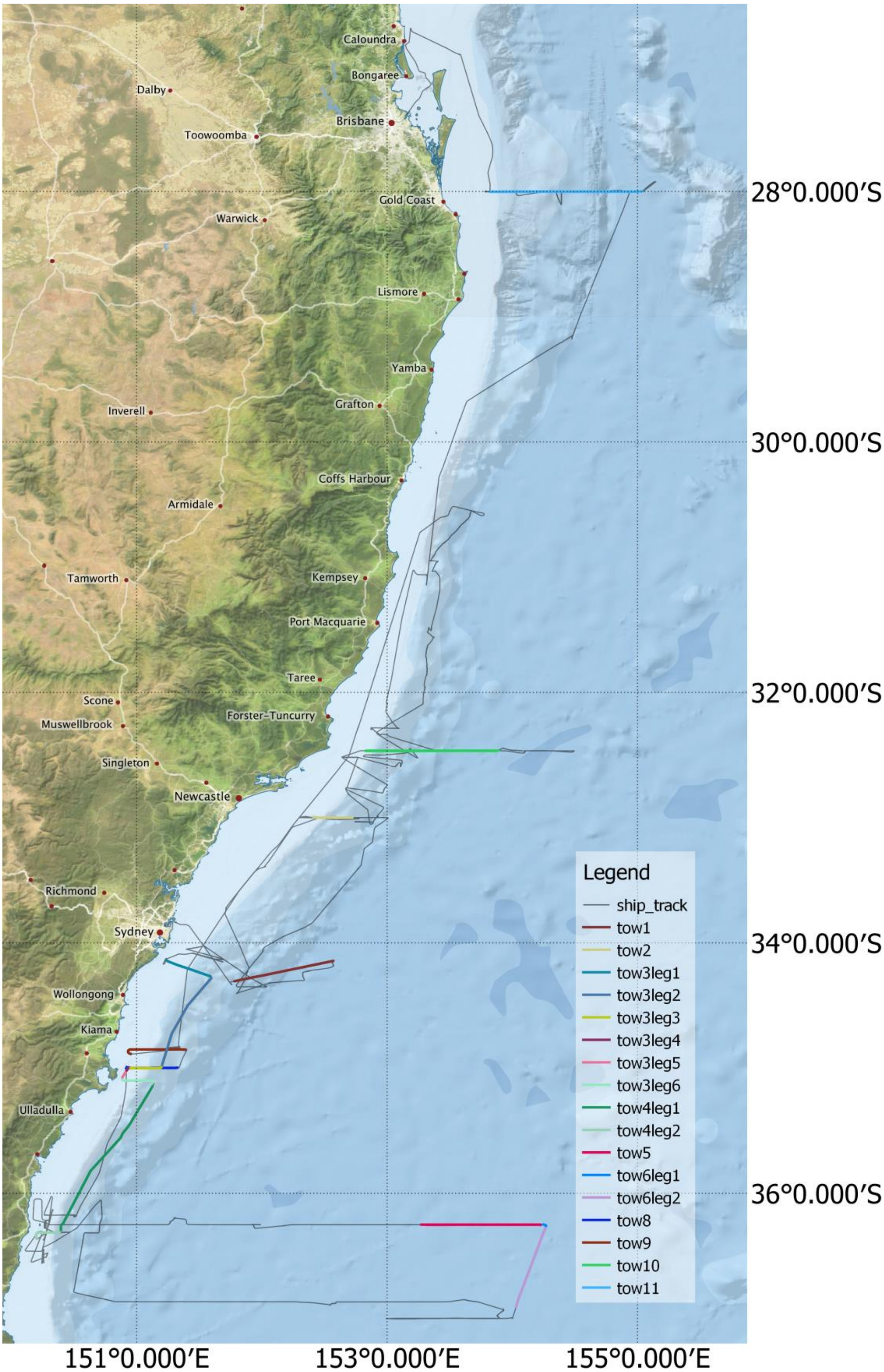

Figure 1 Area of operation for in2016_V04

3 Processing Notes

3.1 Background Information

Eleven Triaxus tows were conducted, divided in the CTD acquisition software CAP into 26 deployments. 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 one.

Unit	Data Channel	SBE9 Connector	Model	Serial Number
SBE9			SBE9+ V2	552
Primary Temperature		JB1	SBE3T	6022
Primary Conductivity		JB2	SBE4C	4425
Secondary Temperature		JB4	SBE3T	6024
Secondary Conductivity		JB5	SBE4C	4426
Primary Pump		JB3	SBE5	8344
Secondary Pump		JB3	SBE5	8345
PAR	A0	JT2	QCP2300HP	70562
Transmissometer	A1	JT2	CSTAR	CST-1735DR
Secondary Oxygen	A2	JT3	SBE43	3199
Primary Oxygen	A3	JT3	SBE43	3198
Eco Triplet	Payload		BBFL2B	754
LOPC	Payload		Rolls-Royce LOPC-1xT-3	11480

Table 1 Triaxus Configuration

The raw CTD data was acquired and converted to scientific units using the CAP data acquisition software. Eco Triplet data and flight data from the Triaxus unit were logged using a Python logging script.

The CapPro software version 2.6 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.

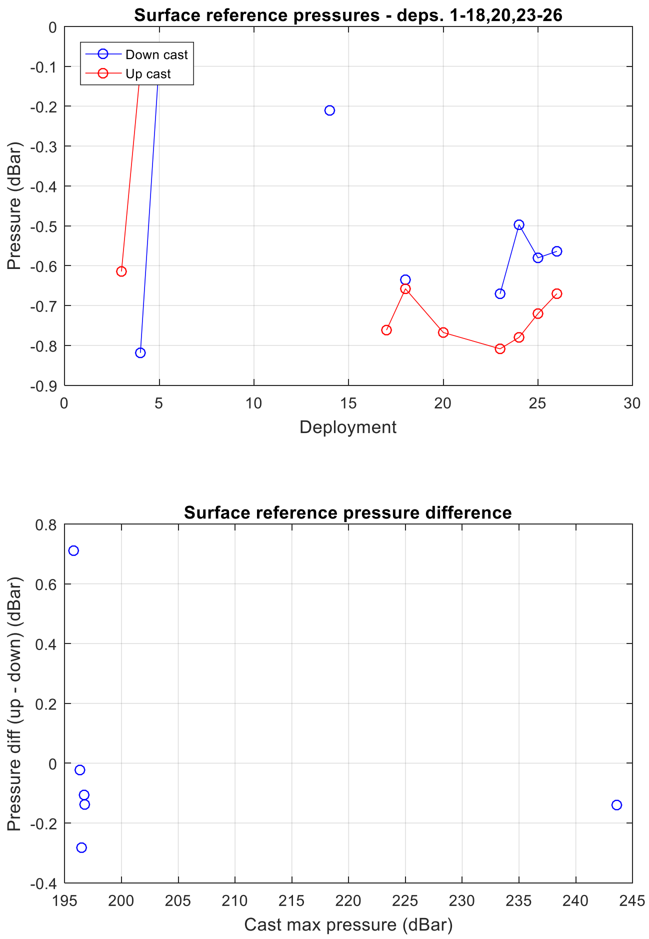

Figure 2: CTD pressure offsets

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 were not applied in this instance but for reference, Conductivity and Temperature sensor location for in2016_v04 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 output is a nominal 0-5 volts. This data channel has been included in the output files for deployments where non-zero values were found. 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.

It was found that PAR sensor data had been acquired with the incorrect calibration values applied, further investigation found that the incorrect calibration sheet was used and secondly that the converted values were mostly out of range. The values were subsequently recalculated from the raw counts and the correct calibration values which can be found in Appendix II: Calibration sheet.

The Eco Triplet sensor array and LOPC were used for all deployments. Only Eco Triplet data has been merged into the averaged data products. Due to an operator error no eco triplet data was recorded for tow 4.

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 4 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	2000
Obs	0	0.5e-3	1.5e-4
Chl	0	1.2	1.3

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.

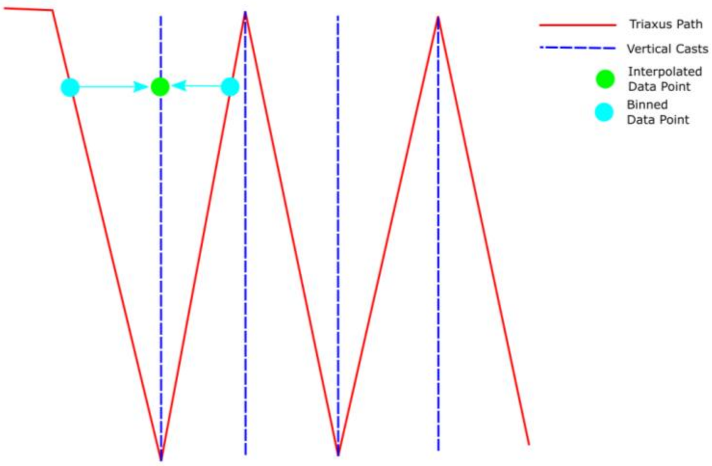

Figure 3: Vertical Cast Creation

3.6.2 Vehicle Position Correction

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.

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

3.7.1 Time Glitch

A glitch in the recoding software caused the time to be incorrectly recorded into the netCDF scan file for CAP deployments 2, 14, 15, 18 and 26. The time was manually corrected by linearly interpolating from the start time by 1/24, the scan rate of an SBE9/11+, for the number of scans contained in the file.

3.7.2 Tow 4

Due to an operator error flight data and eco triplet data was not recorded for this tow. This means that no eco triplet data is available and that no vehicle position correction was performed.

The secondary channel became blocked shortly after the beginning of the tow. Secondary Salinity, conductivity, temperature and oxygen data has all been flagged as bad by the operator.

3.7.3 Tow 6

Tow 6 leg 1, CAP deployment 19 was only a turn and too short to yield useful data and has not been included as part of the final data set.

3.7.4 Tow 7

Tow 7 was aborted and yielded no useful data. It is not included in the final data set.

3.7.5 Tow 11

The transmissometer was not functioning for this tow and all transmission data has been flagged as bad.

There was a blip found in the primary channel data oxygen and salinity that was likely a result of organic matter briefly becoming lodged in the plumbing. The curve of the data was low enough that it could still pass the second difference test. All primary channels were manually marked as bad between average file index 8783 and 8864.

3.8 Triaxus Tow Sections

Deployment	Leg	File	Start time (UTC)	End time (UTC)	Start latitude	End latitude	Start longitude	End longitude
1	1	1	31-Aug-2016 12:04:03	31-Aug-2016 16:05:02	34 18.267S	34 12.360S	151 47.330E	152 16.219E
		2	31-Aug-2016 16:05:15	31-Aug-2016 18:31:40	34 12.354S	34 08.874S	152 16.247E	152 33.149E
		3	31-Aug-2016 18:31:47	31-Aug-2016 19:01:55	34 08.872S	34 08.891S	152 33.161E	152 33.823E
2	1	4	02-Sep-2016 04:08:29	02-Sep-2016 07:02:18	33 00.092S	33 00.023S	152 24.013E	152 43.998E
3	1	5	04-Sep-2016 04:23:28	04-Sep-2016 07:05:05	34 08.067S	34 17.515S	151 14.167E	151 35.182E
	2	6	04-Sep-2016 07:05:13	04-Sep-2016 10:12:46	34 17.530S	34 38.202S	151 35.170E	151 19.780E
		7	04-Sep-2016 10:12:55	04-Sep-2016 12:50:08	34 38.216S	34 59.143S	151 19.773E	151 11.973E
	3	8	04-Sep-2016 12:50:14	04-Sep-2016 12:59:24	34 59.155S	35 00.061S	151 11.969E	151 10.985E
		9	04-Sep-2016 12:59:30	04-Sep-2016 14:25:01	35 00.063S	35 00.003S	151 10.968E	150 56.676E
	4	10	04-Sep-2016 14:25:08	04-Sep-2016 14:39:04	35 00.003S	35 01.351S	150 56.659E	150 55.029E
	5	11	04-Sep-2016 14:39:11	04-Sep-2016 15:02:43	35 01.366S	35 04.595S	150 55.019E	150 53.052E
	6	12	04-Sep-2016 15:02:50	04-Sep-2016 15:22:57	35 04.611S	35 06.001S	150 53.044E	150 55.228E
		13	04-Sep-2016 15:23:14	04-Sep-2016 16:49:43	35 06.000S	35 06.920S	150 55.272E	151 08.469E
4	1	14	04-Sep-2016 17:29:29	04-Sep-2016 20:43:23	35 08.644S	35 40.832S	151 07.605E	150 45.537E
		15	04-Sep-2016 21:33:57	04-Sep-2016 23:36:33	35 40.942S	36 17.762S	150 45.437E	150 23.662E
	2	16	05-Sep-2016 01:52:22	05-Sep-2016 02:48:44	36 17.803S	36 18.795S	150 23.652E	150 15.230E
		17	05-Sep-2016 02:48:50	05-Sep-2016 03:44:42	36 18.795S	36 21.828S	150 15.212E	150 12.078E
5	1	18	06-Sep-2016 20:14:38	06-Sep-2016 21:47:16	36 14.963S	36 15.067S	153 15.903E	154 13.442E
6	1	19	07-Sep-2016 04:12:18	07-Sep-2016 04:31:10	36 14.994S	36 15.620S	154 14.728E	154 16.098E
		20	07-Sep-2016 04:31:21	07-Sep-2016 09:28:57	36 15.635S	36 54.987S	154 16.092E	154 01.621E
7	1	21	10-Sep-2016 21:30:24	10-Sep-2016 21:34:55	35 01.630S	35 01.275S	150 55.062E	150 55.068E
		22	10-Sep-2016 21:44:48	10-Sep-2016 22:06:05	35 00.905S	34 59.372S	150 55.075E	150 55.088E
8	1	23	10-Sep-2016 22:35:22	11-Sep-2016 01:28:44	35 00.150S	34 59.835S	150 54.957E	151 19.529E
9	1	24	11-Sep-2016 02:45:23	11-Sep-2016 05:52:54	34 51.174S	34 53.328S	151 23.518E	150 57.456E
10	1	25	16-Sep-2016 06:33:04	16-Sep-2016 13:51:41	32 27.999S	32 27.556S	152 48.977E	153 53.904E
11	1	26	20-Sep-2016 23:07:39	21-Sep-2016 04:58:23	27 59.866S	28 00.151S	155 02.309E	153 49.299E

Table 4 CAP deployment grouping

CAP deployments were grouped for each Triaxus tow as shown in Table 4 above. Legs marked in red are not 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

Doblin, M., 2016: The RV Investigator. Voyage Plan IN2016_V04 - http://mnf.csiro.au/~/media/Files/Voyage-plans-and-summaries/Investigator/Voyage%20Plans%20summaries/2016/IN2016_V04%20voyage%20plan%2020160829-FINAL.ashx

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

5 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/cm^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	ppb
obs *	Calibrated reading for optical backscatter from the eco triplet	ug/l
cdom *	Calibrated reading for coloured dissolved organic matte from the eco triplet	ug/l
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
shipWaterDepth *	Depth of water at the position of the ship	m
shipSpeed *	Speed of the ship	Kn
shipLatitude *	Latitude of the ship	degrees
shipLongitude *	Longitude of the ship	degrees

Table 5: NetCDF data variables