RV *Investigator*

Triaxus Processing Report

Voyage #:	IN2017_V04
Voyage title:	The whole enchilada: from production to predation in Tasman Sea ecosystems
Depart:	Brisbane, 31 August 2017 14:00
Return:	Sydney, 18 September 2017 14:00
Report compiled by:	Karl Malakoff

Contents

1 Summary

These notes relate to the production of quality controlled Triaxus data from RV Investigator voyage IN2017_v04, from 31 Aug 2017 – 18 Sep 2017.

Data for 8 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.

Though out the voyage there was numerous issues with the Triaxus vehicle. As a result standard data products could not be made for a number of deployments. See section 3.7 for further details.

2 Voyage Details

2.1 Title

The whole enchilada: from production to predation in Tasman Sea ecosystems.

2.2 Principal Investigators

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2.3 Voyage Objectives

The scientific objectives for IN2017_v04 were outlined in the Voyage Plan (Suthers 2017).

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

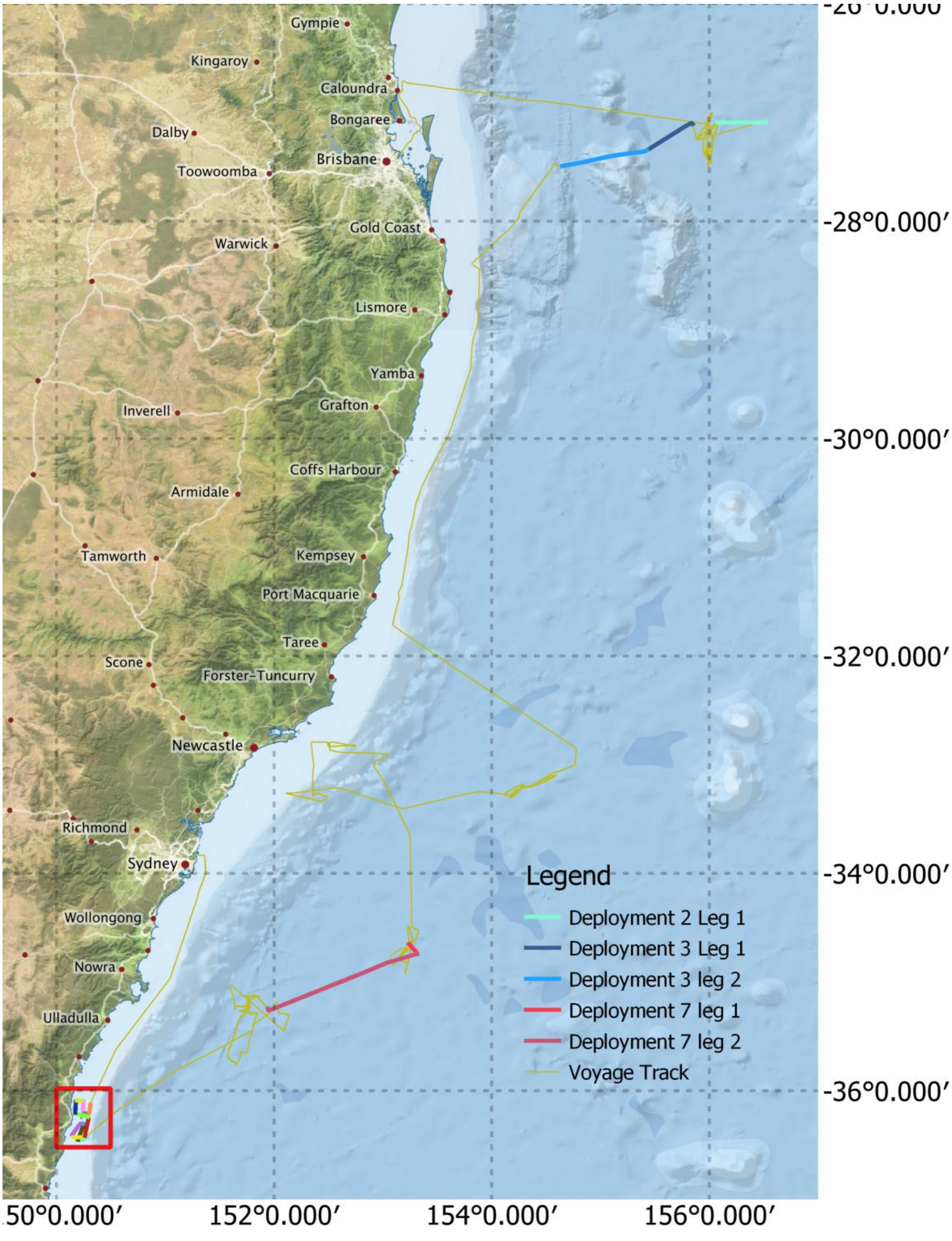

Figure 1 Area of operation for in2017_V04

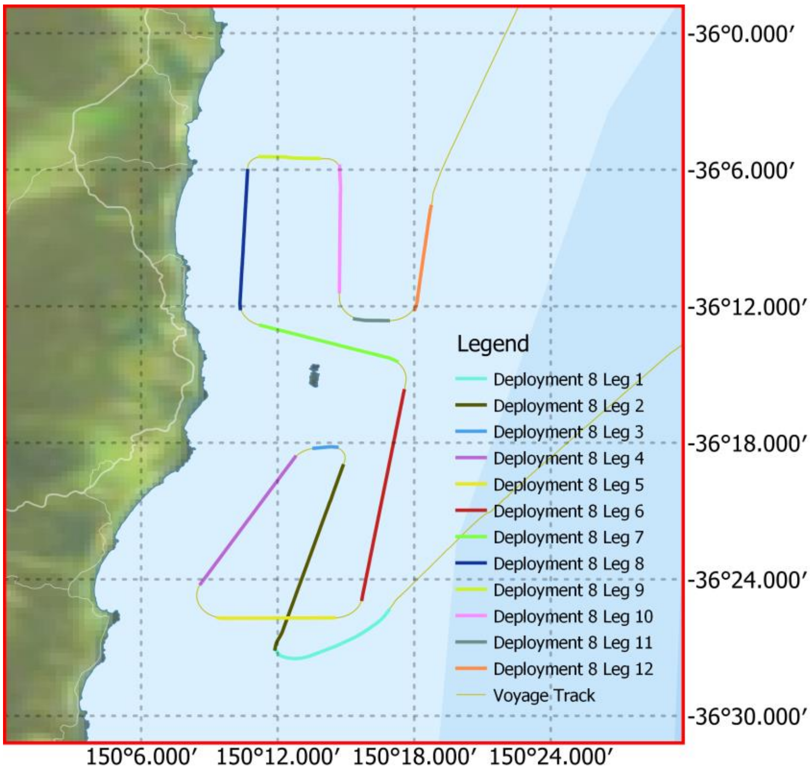

Figure 2: Sub area of operations for in2017_v04

3 Processing Notes

3.1 Background Information

Eight Triaxus tows were conducted, divided in the CTD acquisition software CAP into 39 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	5932
Primary Conductivity		JB2	SBE4C	4683
Secondary Temperature		JB4	SBE3T	6130
Secondary Conductivity		JB5	SBE4C	4662
Primary Pump		JB3	SBE5	054568

Secondary Pump		JB3	SBE5	055105
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		FLBBCD2K	4049
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 2.9 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 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.

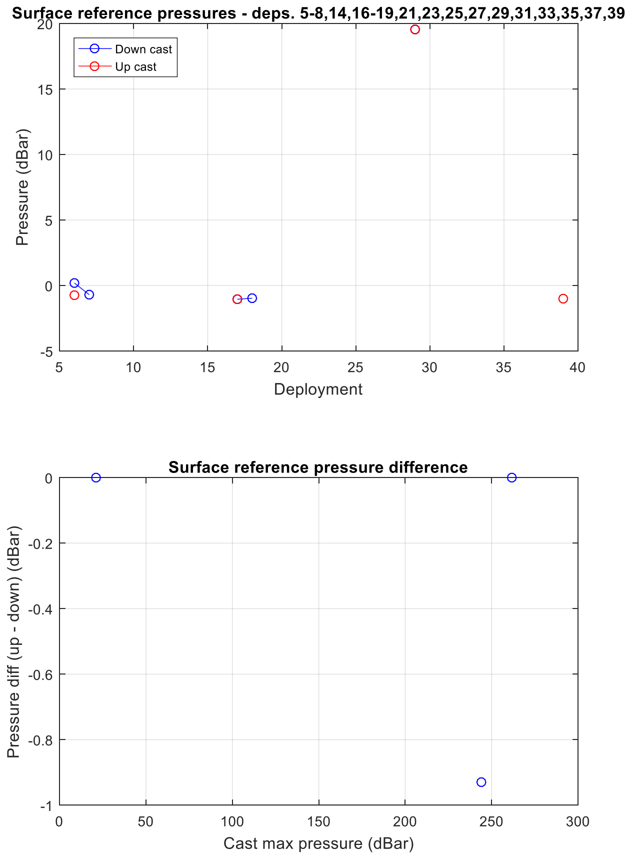

Figure 3: CTD pressure offsets

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 in2017_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. 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.

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	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.

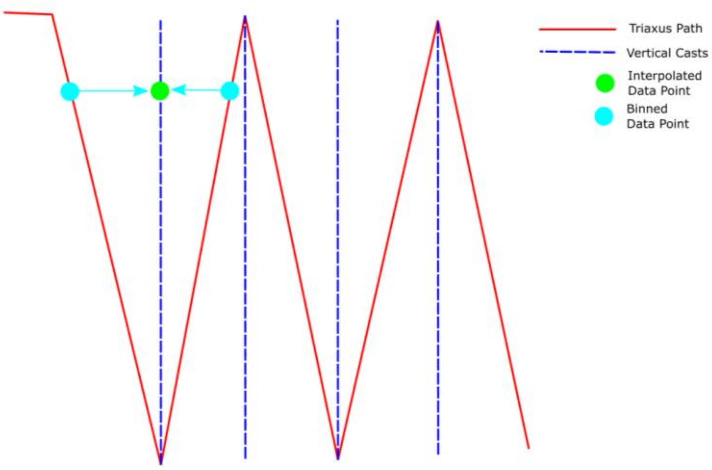

Figure 4: Vertical Cast Creation

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 Tow 1

The Triaxus vehicle was unable to achieve constant depth due to a misalignment of the flaps and the tow was aborted. No useful data was collected for this tow.

3.7.2 Tow 4

The pressure meter malfunctioned and the tow was aborted. No useful data was collected for this tow.

3.7.3 Tow 5

No CTD data was received from the Triaxus on this tow.

3.7.4 Tow 6

The Triaxus was deployed with an SBE37 over the serial channel and no working SBE9. The SBE37 data has not been processed but is available in the raw data set.

3.7.5 Tow 8

The Triaxus was run at constant depth for the first 7 legs of this tow to collect LOPC data. The QC'd and binned data for these legs are included in the final dataset but vertical casts could not be created. Undulations were started from leg 8, vertical casts were created from this point onwards.

3.8 Triaxus Deployment Sections

Deployment	Leg	File #	Start time	End time	Start latitude	Start longitude	End latitude	End longitude
1	0	1	2017-09-01T17:23:16Z	2017-09-01T17:34:18Z	27 27.579S	155 59.573E	27 28.091S	155 59.365E
	1	2	2017-09-01T17:36:34Z	2017-09-01T18:10:02Z	27 28.166S	155 59.340E	27 29.254S	155 59.633E
	2	3	2017-09-01T18:10:12Z	2017-09-01T19:05:17Z	27 29.230S	155 59.634E	27 22.580S	155 59.597E
2	0	4	2017-09-03T16:33:23Z	2017-09-03T16:51:27Z	27 06.274S	156 03.288E	27 05.472S	156 04.735E
	1	5	2017-09-03T16:51:34Z	2017-09-03T17:10:52Z	27 05.472S	156 04.747E	27 05.443S	156 07.488E
		6	2017-09-03T17:11:01Z	2017-09-03T20:03:56Z	27 05.444S	156 07.511E	27 04.857S	156 31.523E
3	1	7	2017-09-04T06:24:03Z	2017-09-04T10:13:50Z	27 06.653S	155 51.163E	27 21.173S	155 25.072E
	2	8	2017-09-04T10:14:12Z	2017-09-04T16:07:02Z	27 21.197S	155 25.029E	27 29.561S	154 38.060E
	0	9	2017-09-04T16:07:14Z	2017-09-04T16:40:07Z	27 29.566S	154 38.035E	27 28.906S	154 35.941E
4	0	10	2017-09-04T23:55:13Z	2017-09-05T00:45:47Z	28 27.566S	153 53.114E	28 34.342S	153 53.176E
5	0	11	2017-09-09T06:23:03Z	2017-09-09T06:36:44Z	32 48.699S	152 29.753E	32 49.869S	152 30.246E
6	0	12	2017-09-09T06:36:55Z	2017-09-09T07:53:05Z	32 49.870S	152 30.271E	32 49.198S	152 42.740E
7	0	13	2017-09-12T13:16:55Z	2017-09-12T13:50:17Z	34 37.684S	153 16.750E	34 39.168S	153 14.559E
	1	14	2017-09-12T13:50:26Z	2017-09-12T14:28:46Z	34 39.177S	153 14.569E	34 43.581S	153 18.696E
	1.5	15	2017-09-12T14:28:53Z	2017-09-12T14:38:44Z	34 43.596S	153 18.709E	34 44.699S	153 18.221E
	2	16	2017-09-12T14:38:50Z	2017-09-12T23:10:20Z	34 44.702S	153 18.209E	35 12.808S	152 04.379E
		17	2017-09-12T23:10:36Z	2017-09-13T00:38:22Z	35 12.820S	152 04.349E	35 14.515S	151 56.519E
8	1	18	2017-09-16T20:15:58Z	2017-09-16T21:12:36Z	36 25.142S	150 17.036E	36 26.954S	150 11.905E
	2	19	2017-09-16T21:12:45Z	2017-09-16T22:14:59Z	36 26.932S	150 11.909E	36 18.879S	150 14.919E
	2.5	20	2017-09-16T22:15:03Z	2017-09-16T22:22:56Z	36 18.868S	150 14.923E	36 18.181S	150 14.451E
	3	21	2017-09-16T22:23:01Z	2017-09-16T22:32:18Z	36 18.180S	150 14.440E	36 18.271S	150 13.423E
	3.5	22	2017-09-16T22:32:23Z	2017-09-16T22:41:12Z	36 18.273S	150 13.414E	36 18.734S	150 12.686E
	4	23	2017-09-16T22:41:16Z	2017-09-16T23:49:07Z	36 18.740S	150 12.681E	36 24.326S	150 08.535E
	4.5	24	2017-09-16T23:49:22Z	2017-09-17T00:06:57Z	36 24.350S	150 08.523E	36 25.704S	150 09.538E
	5	25	2017-09-17T00:07:02Z	2017-09-17T00:40:37Z	36 25.706S	150 09.549E	36 25.679S	150 14.679E
	5.5	26	2017-09-17T00:40:42Z	2017-09-17T00:48:60Z	36 25.677S	150 14.694E	36 24.752S	150 15.724E
	6	27	2017-09-17T00:49:04Z	2017-09-17T01:42:48Z	36 24.738S	150 15.727E	36 15.557S	150 17.586E
	6.5	28	2017-09-17T01:42:53Z	2017-09-17T01:51:16Z	36 15.544S	150 17.589E	36 14.350S	150 17.088E
	7	29	2017-09-17T01:51:20Z	2017-09-17T02:39:06Z	36 14.345S	150 17.077E	36 12.782S	150 11.061E
	7.5	30	2017-09-17T02:39:11Z	2017-09-17T02:47:57Z	36 12.779S	150 11.052E	36 11.962S	150 10.347E
	8	31	2017-09-17T02:48:00Z	2017-09-17T03:41:19Z	36 11.954S	150 10.346E	36 05.857S	150 10.692E
	8.5	32	2017-09-17T03:41:24Z	2017-09-17T03:48:09Z	36 05.848S	150 10.694E	36 05.434S	150 11.415E
	9	33	2017-09-17T03:48:14Z	2017-09-17T04:06:25Z	36 05.434S	150 11.424E	36 05.512S	150 14.119E
	9.5	34	2017-09-17T04:06:35Z	2017-09-17T04:13:05Z	36 05.512S	150 14.140E	36 06.051S	150 14.731E
	10	35	2017-09-17T04:13:22Z	2017-09-17T04:58:01Z	36 06.087S	150 14.732E	36 11.643S	150 14.711E
	10.5	36	2017-09-17T04:58:10Z	2017-09-17T05:08:30Z	36 11.659S	150 14.712E	36 12.603S	150 15.711E
	11	37	2017-09-17T05:08:37Z	2017-09-17T05:16:58Z	36 12.606S	150 15.729E	36 12.596S	150 17.217E
	11.5	38	2017-09-17T05:17:05Z	2017-09-17T05:24:11Z	36 12.593S	150 17.231E	36 11.862S	150 18.110E
	12	39	2017-09-17T05:24:19Z	2017-09-17T05:59:09Z	36 11.845S	150 18.116E	36 07.405S	150 18.789E

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. 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

Suthers, I., 2017: The RV Investigator. Voyage Plan IN2017_V04 - http://mnf.csiro.au/~/media/Files/Voyage-plans-and-summaries/Investigator/Voyage%20Plans%20summaries/2017/IN2017_V04%20Voyage%20Plan-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 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.

6 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