Marine National Facility

RV *Investigator*

Triaxus Processing Report

Voyage ID:	IN2015_V03
Voyage title:	Submesoscale processes - billows and eddies- along the productive shelf by the East Australian Current
Depart:	Brisbane, 0800h Wednesday 3 June, 2015
Return:	Sydney 0800h, Thursday 18 June, 2015
Report compiled by:	Karl Malakoff

Contents

1 Summary

These notes relate to the production of quality controlled Triaxus data from RV Investigator voyage IN2015_v03, from 03 Jun 2015 – 18 Jun 2015.

Data for 8 Triaxus tows were acquired in CAP CTD acquisition software using the Seabird SBE911 CTD 22. 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

Submesoscale processes - billows and eddies- along the productive shelf by the East Australian Current.

2.2 Principal Investigators

Suthers (CS, UNSW and SIMS), Martina Doblin (PI, University of Technology, Sydney)

2.3 Voyage Objectives

The scientific objectives for IN2015_v03 were outlined in the Voyage Plan (Suthers 2015).

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

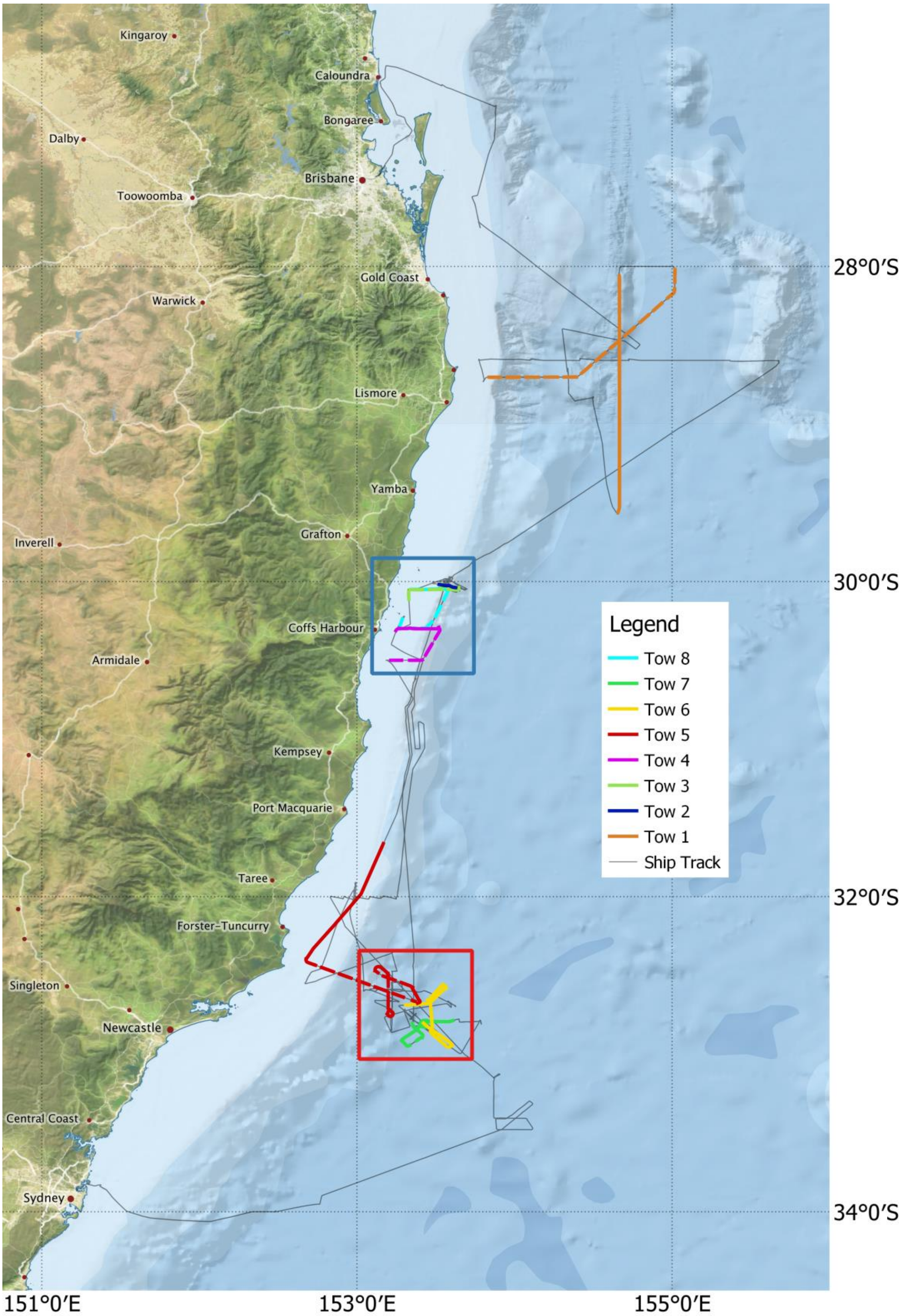

Figure 1 Area of operation for in2015_V03

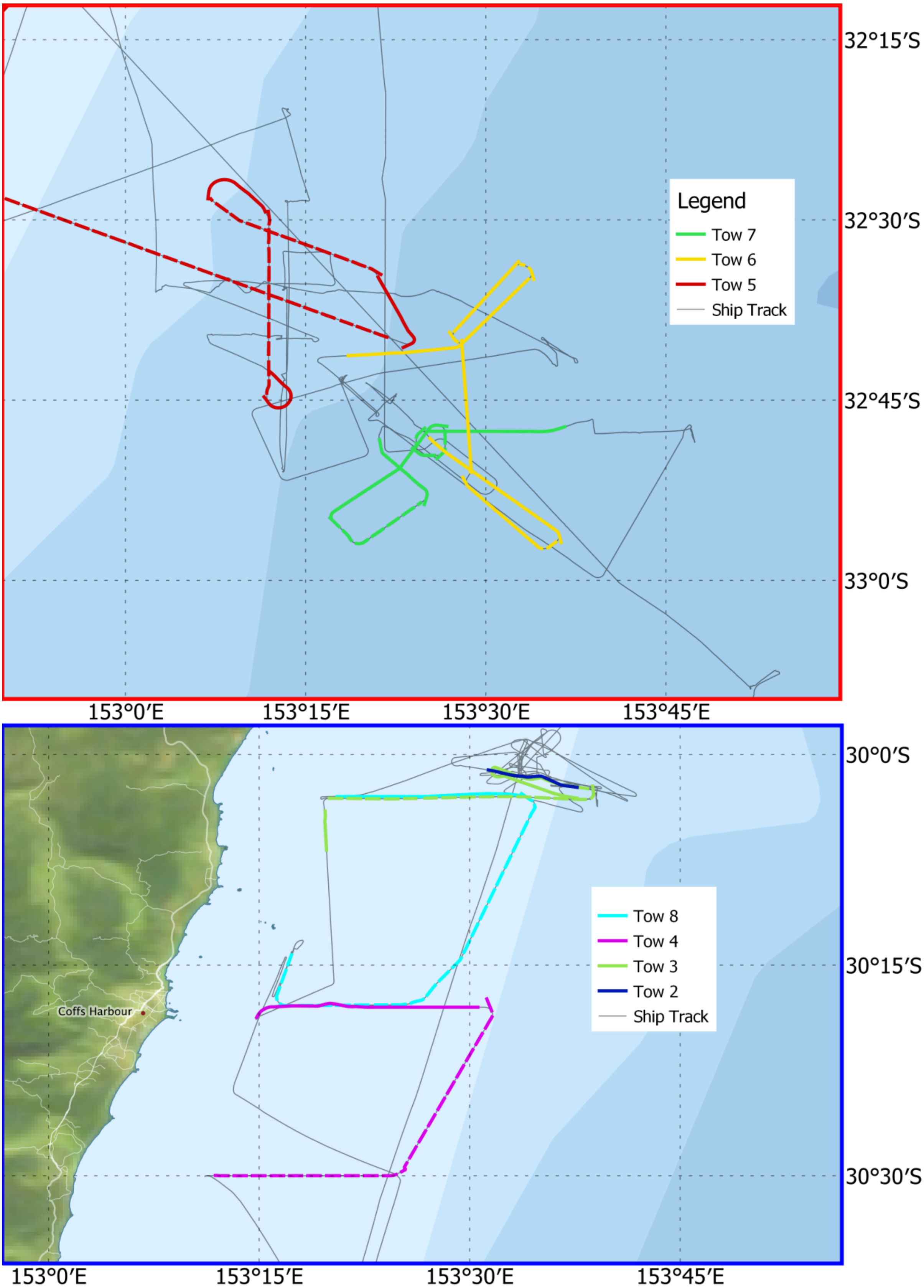

Figure 2: Zoomed in view of area of operations for in2015_v03

3 Processing Notes

3.1 Background Information

Eight Triaxus tows were conducted, divided in the CTD acquisition software CAP into 40 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 22, 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	Model	Serial Number
SBE9	SBE9+ V2	1039
Primary Temperature	SBE3T	2751
Primary Conductivity	SBE4C	3311
Secondary Temperature	SBE3T	4682
Secondary Conductivity	SBE4C	3908
Primary Pump	SBE5	6038
Secondary Pump	SBE5	6041
PAR	QCP2300HP	70371
Transmissometer	CSTAR	CST- 1519DR
Secondary Oxygen	SBE43	2125
Primary Oxygen	SBE43	1794
Eco Triplet	BBFL2B	2916
LOPC	Rolls-Royce LOPC-1xT-3	Unknown

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 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.

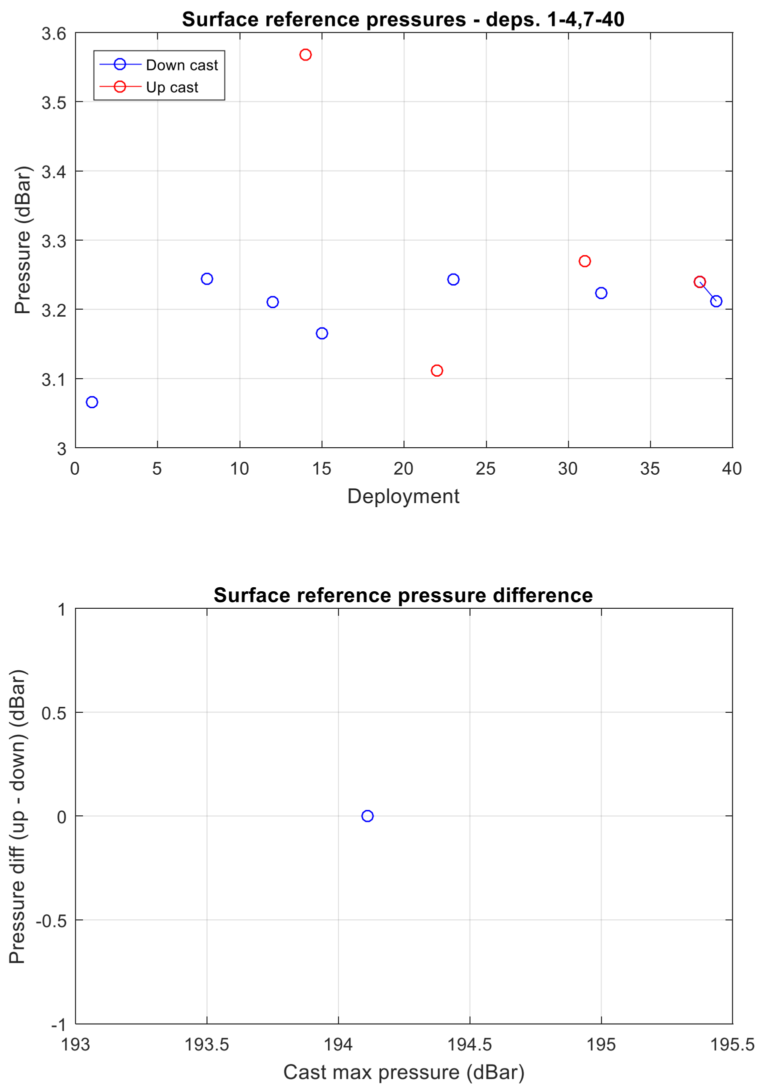

Figure 3: CTD pressure offsets

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.

Due to the loss of the Triaxus during this voyage the pressure sensor location is unknown and no corrections have been applied.

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.

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

Table 2 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.

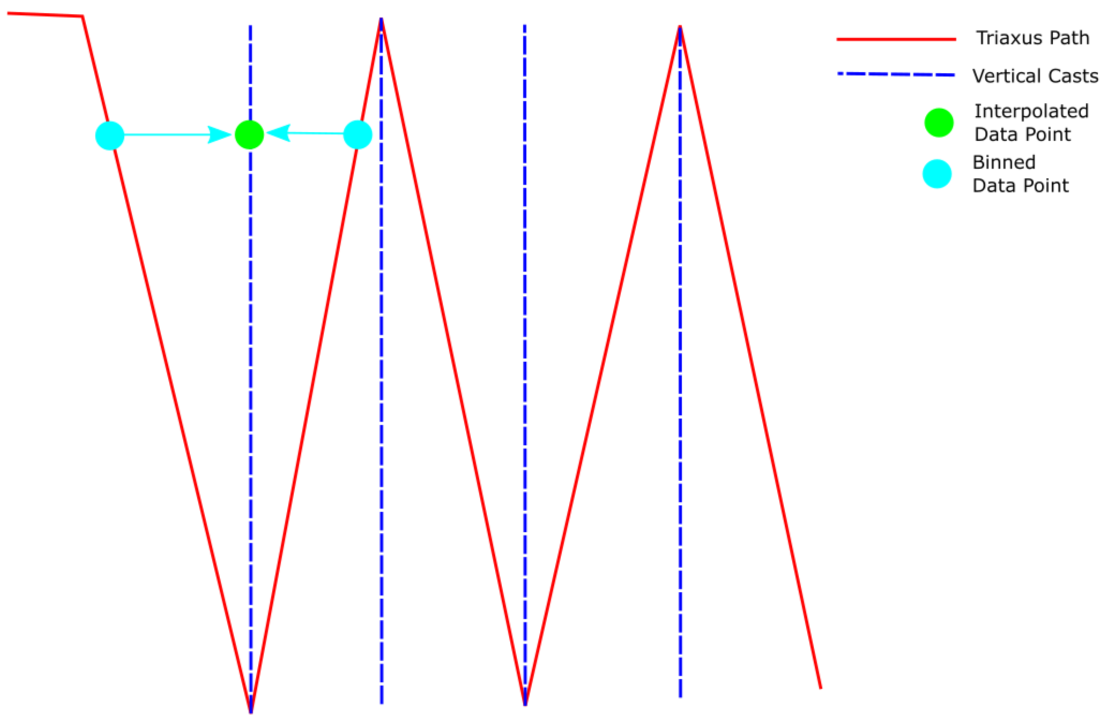

Figure 4: Vertical Cast Creation

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 Cap file 5:

Cap file 5 was recorded only for testing purposes and contains no useful data. It has not been included as part of the final dataset.

3.7.2 Cap file 6:

Cap file 6 only contains data for the initial deployment of tow 2 and has no undulations.

3.7.3 Cap file 26:

Leg 4 of tow 6, cap file 26, only has one undulation meaning that vertical casts could not be generated for this leg.

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	4-Jun-2015 20:22	4-Jun-2015 1:05:49	29 34.366S	29 29.978S	154 39.334E	154 40.016E
		2	4-Jun-2015 21:06	5-Jun-2015 7:12:32	29 29.952S	28 03.159S	154 40.016E	154 39.845E
	2	3	5-Jun-2015 9:46	5-Jun-2015 7:21:22	28 01.845S	28 41.865S	155 01.151E	154 24.247E
		4	5-Jun-2015 17:22	5-Jun-2015 0:55:24	28 41.917S	28 42.191S	154 24.184E	153 49.850E
0	0	5	7-Jun-2015 11:37	7-Jun-2015 3:38:40	30 01.653S	30 02.043S	153 35.630E	153 31.277E
2		6	7-Jun-2015 17:33	7-Jun-2015 8:03:24	30 00.408S	30 01.152S	153 28.740E	153 31.614E
	1	7	7-Jun-2015 18:03	7-Jun-2015 8:50:17	30 01.158S	30 02.353S	153 31.646E	153 37.797E
3	1	8	7-Jun-2015 22:37	7-Jun-2015 3:31:44	30 03.160S	30 01.044S	153 38.488E	153 32.128E
		9	7-Jun-2015 23:39	8-Jun-2015 0:16:29	30 01.498S	30 02.712S	153 33.341E	153 38.827E
	2	10	8-Jun-2015 0:16	8-Jun-2015 2:02:12	30 02.739S	30 03.234S	153 38.832E	153 19.682E
	3	11	8-Jun-2015 2:08	8-Jun-2015 2:26:59	30 04.356S	30 06.885S	153 19.725E	153 19.815E
4	1	12	8-Jun-2015 4:05	8-Jun-2015 6:03:36	30 18.724S	30 18.289S	153 14.836E	153 31.585E
	2	13	8-Jun-2015 6:03	8-Jun-2015 7:29:28	30 18.327S	30 29.817S	153 31.604E	153 24.956E
		14	8-Jun-2015 7:29	8-Jun-2015 9:02:06	30 29.837S	30 30.002S	153 24.923E	153 11.306E
5	1	15	8-Jun-2015 15:05	8-Jun-2015 0:53:56	31 39.168S	32 24.079S	153 10.408E	152 40.628E
	2	16	8-Jun-2015 20:54	8-Jun-2015 3:14:25	32 24.096S	32 32.055S	152 40.626E	153 00.512E
		17	8-Jun-2015 23:17	9-Jun-2015 1:48:28	32 32.205S	32 40.158S	153 00.918E	153 22.858E
	3	18	9-Jun-2015 1:54	9-Jun-2015 2:57:31	32 40.318S	32 34.199S	153 23.761E	153 20.668E
	4	19	9-Jun-2015 2:58	9-Jun-2015 4:55:47	32 34.125S	32 27.642S	153 20.573E	153 06.940E
	5	20	9-Jun-2015 4:56	9-Jun-2015 5:36:46	32 27.593S	32 29.897S	153 06.944E	153 11.978E
	6	21	9-Jun-2015 5:37	9-Jun-2015 7:33:29	32 29.930S	32 45.204S	153 11.985E	153 11.890E
	7	22	9-Jun-2015 7:34	9-Jun-2015 8:27:40	32 45.260S	32 42.555S	153 11.927E	153 11.895E
6	1	23	12-Jun-2015 3:21	12-Jun-2015 5:16:29	32 41.344S	32 34.348S	153 17.670E	153 33.819E
	2	24	12-Jun-2015 5:16	12-Jun-2015 5:29:01	32 34.326S	32 33.974S	153 33.814E	153 32.269E
	3	25	12-Jun-2015 5:29	12-Jun-2015 6:19:11	32 33.990S	32 39.888S	153 32.255E	153 27.339E
	4	26	12-Jun-2015 6:19	12-Jun-2015 6:25:29	32 39.907S	32 40.674S	153 27.351E	153 28.032E
	5	27	12-Jun-2015 6:25	12-Jun-2015 7:30:09	32 40.690S	32 50.568S	153 28.033E	153 28.770E
	6	28	12-Jun-2015 7:30	12-Jun-2015 7:40:09	32 50.586S	32 52.004S	153 28.771E	153 28.392E
	7	29	12-Jun-2015 7:40	12-Jun-2015 8:30:07	32 52.020S	32 57.181S	153 28.399E	153 34.314E
	8	30	12-Jun-2015 8:30	12-Jun-2015 8:47:34	32 57.199S	32 56.238S	153 34.334E	153 36.112E
	6	31	12-Jun-2015 8:47	12-Jun-2015 0:30:08	32 56.226S	32 48.076S	153 36.110E	153 25.267E
7	1	32	13-Jun-2015 1:28	13-Jun-2015 2:51:27	32 46.932S	32 47.767S	153 37.391E	153 24.422E
	2	33	13-Jun-2015 2:51	13-Jun-2015 3:06:21	32 47.779S	32 49.428S	153 24.409E	153 24.424E
	3	34	13-Jun-2015 3:06	13-Jun-2015 3:18:51	32 49.435S	32 49.419S	153 24.433E	153 26.402E
	4	35	13-Jun-2015 3:18	13-Jun-2015 3:34:58	32 49.405S	32 47.092S	153 26.418E	153 26.047E
	5	36	13-Jun-2015 3:35	13-Jun-2015 5:09:20	32 47.089S	32 55.287S	153 26.033E	153 17.523E
	6	37	13-Jun-2015 5:09	13-Jun-2015 6:07:10	32 55.302S	32 53.074S	153 17.538E	153 25.077E
8	1	38	13-Jun-2015 6:07	13-Jun-2015 6:59:36	32 53.056S	32 48.256S	153 25.084E	153 21.134E
	2	39	14-Jun-2015 22:37	15-Jun-2015 0:08:08	30 03.087S	30 03.086S	153 20.075E	153 34.128E

Table 3 CAP deployment grouping

CAP deployments were grouped for each Triaxus tow as shown in Table 3 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

Suthers, Iain., 2015: The RV Investigator. Voyage Plan IN2015_V03 - http://mnf.csiro.au/~/media/Files/Voyage-plans-and-summaries/Investigator/Voyage%20Plans%20summaries/2015/IN2015_V03-Voyage%20Plan%20FINAL.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 4: NetCDF data variables