Marine National Facility

RV *Investigator*

Triaxus Processing Report

Voyage #:	IN2019_V06 Leg 1
Voyage title:	Tropical observations of atmospheric convection, biogenic emissions, ocean mixing, and processes generating intraseasonal SST variability
Depart:	Darwin, 2000 Saturday, 19 October 2019
Return:	Darwin, 0600 Monday, 11 November 2019
Report compiled by:	Stephanie Zeliadt

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Contents

1 Summary

These notes relate to the production of quality controlled Triaxus data from RV Investigator voyage IN2019_V06, from 19 Oct 2019 – 11 Nov 2019.

Data for 3 Triaxus tows were acquired using Seabird's SeaSave acquisition software using the 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, Transmissometer and Cosine Photosynthetically Active Radiation (PAR) sensor were also installed on the auxiliary A/D channels of the CTD. In addition to the auxiliary channels, ECO Triplet and LOPC were mounted on the Triaxus as attached payloads. An RBRconcerto^3 CTD|ODO sensor measuring temperature, conductivity and oxygen was mounted on the Triaxus frame from Deployment 2 Leg 1.

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 recording file. These files 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 2 cast. These generated the along-track and vertical cast section data products for each Triaxus tow.

During some of the deployments, issues occurred with the Triaxus vehicle. As a result, standard data products could not be made for these deployments. See section 3.7 for further details.

2 Voyage Details

2.1 Title

Tropical observations of atmospheric convection, biogenic emissions, ocean mixing, and processes generating intraseasonal SST variability

2.2 Principal Investigators

Dr Alain Protat, Susan Wijffels

2.3 Voyage Objectives

The scientific objectives for IN2019_V06 were outlined in the Voyage Plan (Protat 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

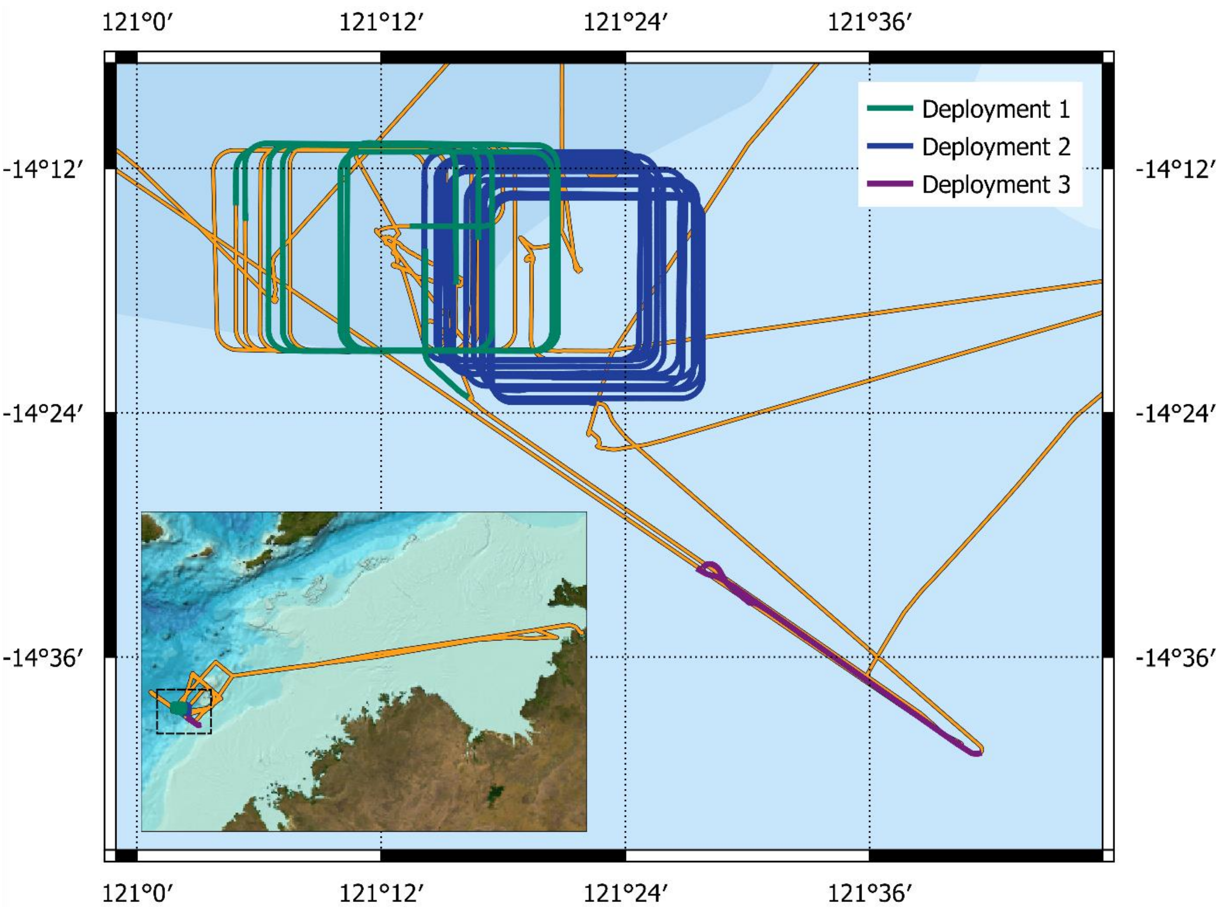

Figure 1: Area of operation for IN2019_V06

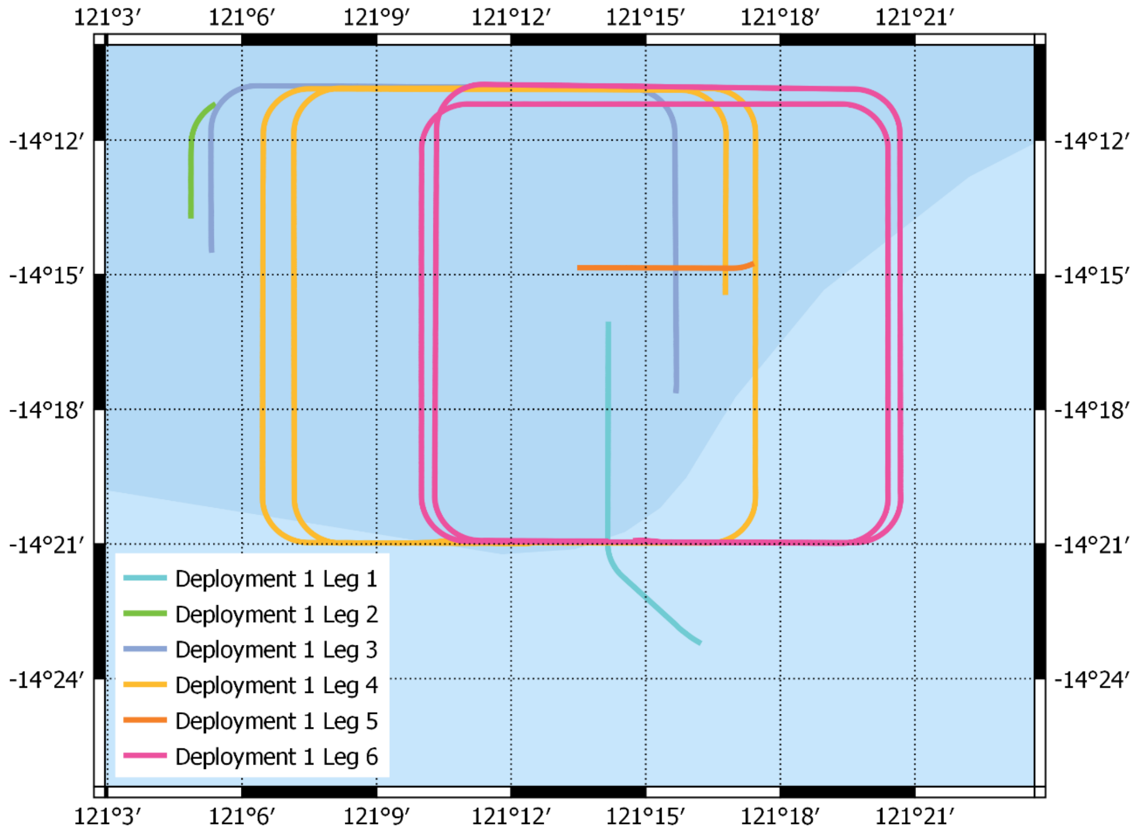

Figure 2: Sub area of operations for IN2019_V06 Deployment 1

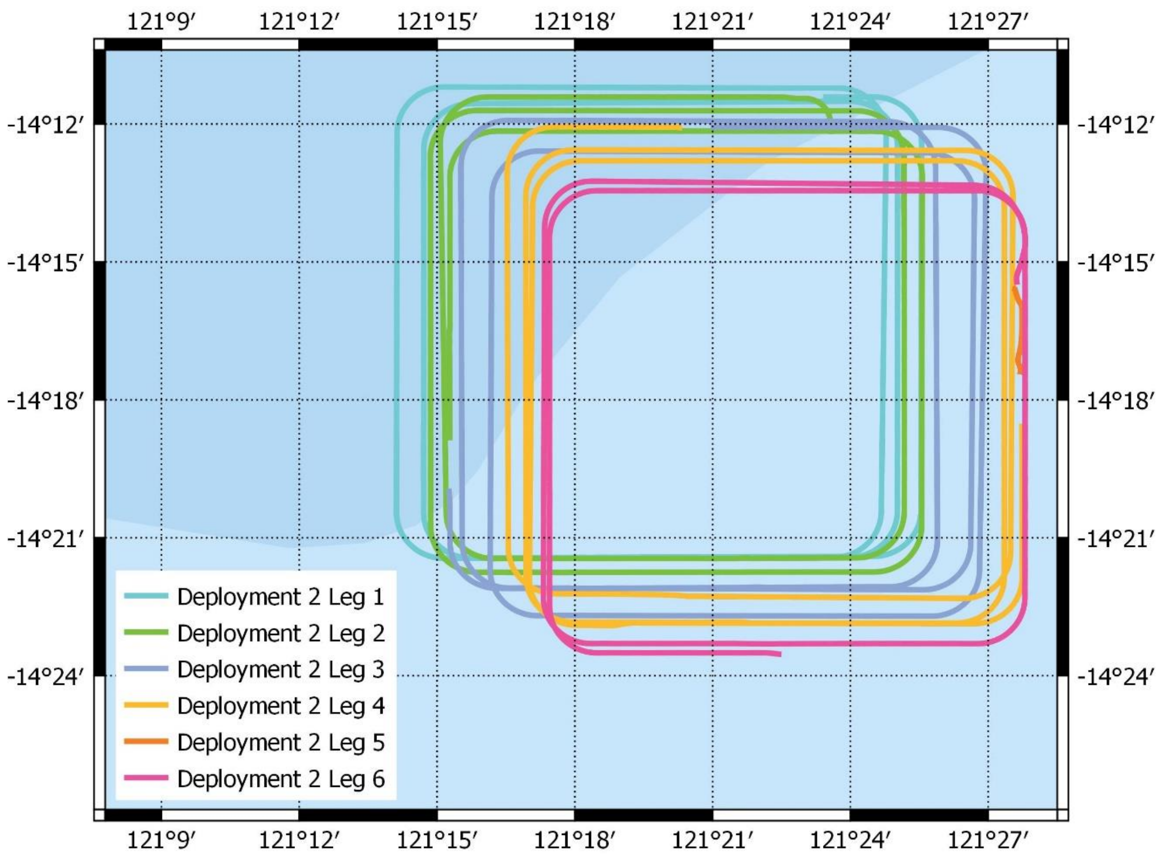

Figure 3: Sub area of operations for IN2019_V06 Deployment 2

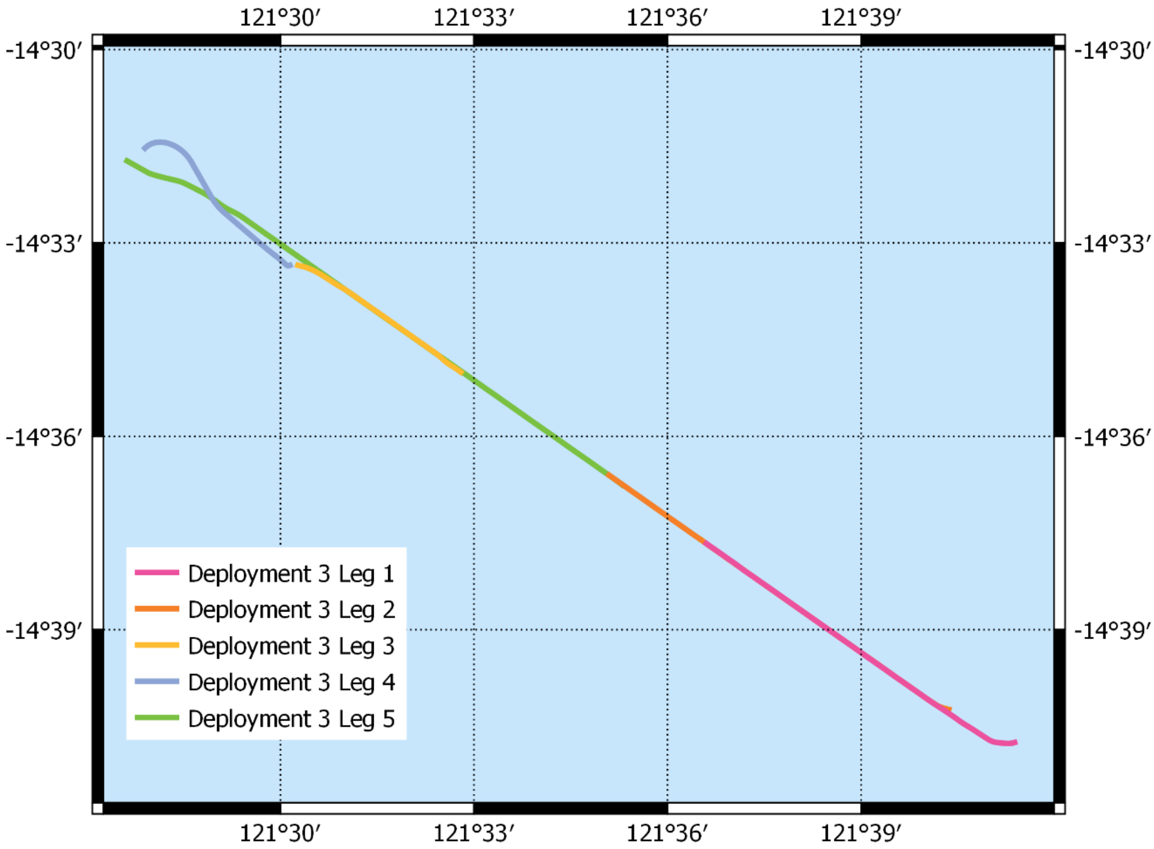

Figure 4: Sub area of operations for IN2019_V06 Deployment 3

3 Processing Notes

3.1 Background Information

3 Triaxus deployments were conducted, divided in the CTD acquisition software Seasave into 18 files, one file for each leg of the 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 1: NetCDF Variables.

Unit	Data Channel	SBE9 Connector	Model	Serial Number	Tow Numbers
CTD23			SBE9+ V2	1312	1-18
Primary Temperature		JB1	SBE3T	4722 5932	1-5 6-18
Primary Conductivity		JB2	SBE4C	3168	1-18
Secondary Temperature		JB4	SBE3T	4522 6024	1-5 6-18
Secondary Conductivity		JB5	SBE4C	2235	1-18
Primary Pump		JB3	SBE5	9417	1-18
Secondary Pump		JB3	SBE5	9404 4567	1-5 6-18
Primary Oxygen	A0	JT3	SBE43	1794	1-18
Secondary Oxygen	A1	JT3	SBE43	3199	1-18
PAR	A2	JT2	QCP2300HP	70677	1-18
Transmissometer	A3	JT2	CSTAR	CST-1735DR	1-18
Eco Triplet	Payload		FLBBCD2K	5038	1-18
LOPC	Payload		Rolls-Royce LOPC-1xT-3	11480	1-18

Table 1: Triaxus Configuration

The raw CTD data were collected in Seasave version 7.26.7.110, converted to scientific units using SBE Data Processing version 7.26.7.129 and written to netCDF format files with CNV_to_Scan for processing using the Matlab-based CapPro package.

The CapPro software version 2.11, dated 23-Aug-2019 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 5 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 some casts as data recording was started after submersion of the Triaxus and stopped before it was on deck.

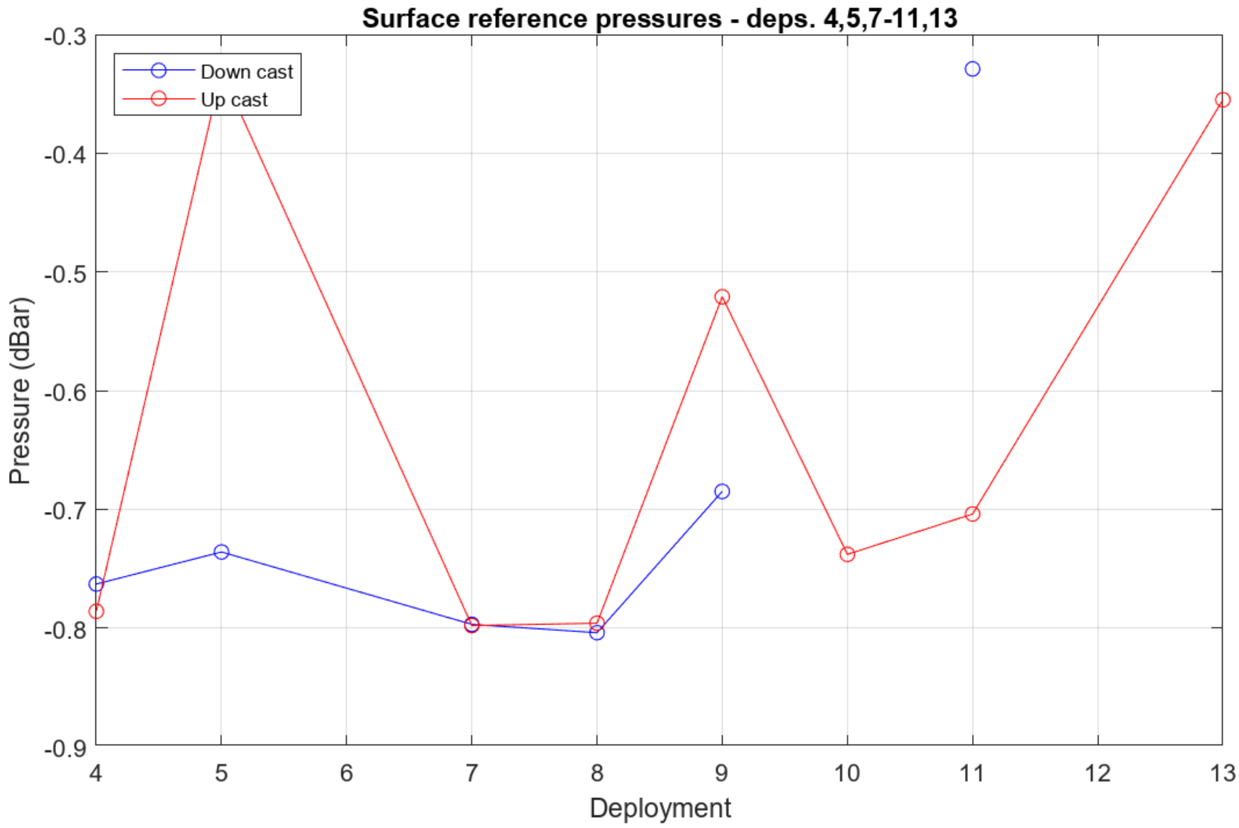

Figure 5: CTD pressure offsets

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_v06 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	-7	6500	0.5
Temperature	-10	40	0.05
Conductivity	-0.01	7	0.01
Oxygen	100	360	0.5
Transmissometer	0	100	0.5
PAR	-3	5000	100
CDOM	0	363	1
Obs	0	0.5e-3	1e-4
Chl	0	3	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.

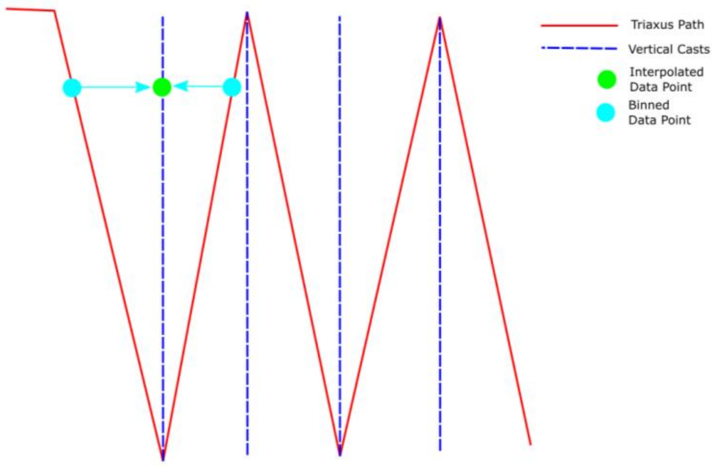

Figure 6: Vertical Cast Creation

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 ship's 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

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. Where the values are not available, the data for one of the sensors was not available or has been flagged as bad.

Table 5 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.

mean(abs(diff))	Temperature C	Salinity PSU	Oxygen uM
deployment1Leg3	0.08172	N/A	N/A
deployment1Leg4	0.09820	N/A	N/A
deployment1Leg6	0.00696	0.00388	5.10171
deployment2Leg1	0.00719	0.00250	7.28988
deployment2Leg2	0.00741	0.00210	6.83265
deployment2Leg3	0.00715	0.00172	5.00638
deployment2Leg4	0.00637	0.00138	5.30251
deployment2Leg6	0.00688	0.01560	12.14750
max(abs(diff))			
deployment1Leg3	0.66255	N/A	N/A
deployment1Leg4	0.80510	N/A	N/A
deployment1Leg6	0.39881	0.04479	11.80243
deployment2Leg1	0.51174	0.04244	17.43421
deployment2Leg2	0.26172	0.05355	17.80465
deployment2Leg3	0.25653	0.07472	12.58763
deployment2Leg4	0.24274	0.03854	13.74287
deployment2Leg6	0.46974	0.14445	28.86442

Table 4: Comparative difference between primary and secondary CTD sensors

3.7.1 Deployment 1

3.7.1.1 Leg 0

The secondary temperature and conductivity values were outside of the expected thresholds when starting this deployment due to the two sensor channels being swapped. Data for this leg was not processed.

3.7.1.2 Leg 1

After 7 undulations, both primary and secondary salinity sensors were reporting values higher than 37 PSU and both oxygen sensors also reported very low oxygen values.

3.7.1.3 Leg 2

Before completing any undulations for this leg, communications were lost with the Triaxus vehicle and it had to be recovered.

3.7.1.4 Leg 3

The primary conductivity, salinity and oxygen values for the leg were still outside the expected thresholds. The secondary sensor data was of high quality for the first half of the deployment, but also outside the thresholds during the second half of the deployment.

3.7.1.5 Leg 4

The primary conductivity, salinity and oxygen values for this leg were still outside the expected range, however, the secondary sensor data was of high quality for the duration of the leg.

3.7.1.6 Leg 5

Both the primary and secondary temperature sensors were replaced before this leg, however, the primary data was still outside the expected range after the undulations started and the secondary also went beyond the range after a few undulations.

3.7.1.7 Leg 6

Both primary and secondary sensors produced high quality data for the duration of this leg.

3.7.2 Deployment 2

3.7.2.1 Leg 1

The first leg of deployment 2 recorded an incorrect NMEA timestamp in the CTD hex file header, resulting in an initial data offset between the Eco Triplet recorded data and the CTD recorded pressure values. This was corrected in the hex file in2019_v06_02_001.hex to remove the offset. Both primary and secondary sensor data was of high quality for the duration of the leg.

3.7.2.2 Leg 2

All data generally of high quality for this leg.

3.7.2.3 Leg 3

All data generally of high quality for this leg.

3.7.2.4 Leg 4

A suspected blockage in the primary sensors occurred around 120km (2019-11-03T17:30-18:00 UTC) most noticeably affecting the oxygen data.

3.7.2.5 Leg 5

Communications with the vehicle were dropping out due to excessive movement in the fibre connection cable. No undulations were performed and the data was not processed.

3.7.2.6 Leg 6

The primary oxygen sensor data was lower than expected for the first 80km, but was of high quality after that. The primary salinity was also noisy for the first 80km. All other sensors produced data of high quality for the duration of the leg.

3.7.3 Deployment 3

The objective of deployment 3 was to perform a linear Triaxus tow with deep undulations, however, errors when attempting to undulate more than 100 metres deep failed and consequently, data for these legs is generally limited and was not processed.

3.8 Triaxus Deployment Sections

Deployment	Leg	File #	Start time	End time	Start latitude	Start longitude	End latitude	End longitude
1	0	1	2019-10-23T00:54:00Z	2019-10-23T02:04:21Z	14 23.644S	121 16.710E	14 19.691S	121 14.172E
	1	2	2019-10-23T02:46:54Z	2019-10-23T03:58:13Z	14 23.212S	121 16.225E	14 15.264S	121 14.170E
	2	3	2019-10-23T11:19:00Z	2019-10-23T11:59:29Z	14 11.227S	121 05.358E	14 13.765S	121 04.861E
	3	4	2019-10-23T14:53:59Z	2019-10-23T17:57:07Z	14 17.573S	121 15.677E	14 14.729S	121 05.311E
	4	5	2019-10-24T00:20:46Z	2019-10-24T09:23:57Z	14 15.670S	121 16.776E	14 20.941S	121 15.886E
	5	6	2019-10-24T12:52:47Z	2019-10-24T13:26:53Z	14 14.845S	121 13.631E	14 14.569S	121 17.664E
	6	7	2019-10-25T17:43:57Z	2019-10-26T03:50:52Z	14 20.923S	121 14.780E	14 20.936S	121 14.807E
2	1	8	2019-11-01T12:38:53Z	2019-11-02T00:59:09Z	14 21.419S	121 21.049E	14 11.430S	121 22.866E
	2	9	2019-11-02T01:26:17Z	2019-11-02T13:10:31Z	14 12.150S	121 23.584E	14 19.494S	121 15.276E
	3	10	2019-11-02T13:39:35Z	2019-11-03T03:14:13Z	14 20.117S	121 15.268E	14 12.076S	121 20.315E
	4	11	2019-11-03T09:17:05Z	2019-11-03T22:47:16Z	14 12.085S	121 20.362E	14 17.933S	121 27.698E
	5	12	2019-11-04T01:07:30Z	2019-11-04T01:47:18Z	14 17.387S	121 27.700E	14 15.572S	121 27.581E
	6	13	2019-11-04T02:15:14Z	2019-11-04T10:49:33Z	14 15.407S	121 27.617E	14 23.778S	121 23.083E
3	1	14	2019-11-04T13:18:07Z	2019-11-04T14:25:55Z	14 40.750S	121 41.378E	14 37.426S	121 36.262E
	2	15	2019-11-04T13:18:07Z	2019-11-04T14:25:55Z	14 40.750S	121 41.378E	14 37.426S	121 36.262E
	3	16	2019-11-04T15:17:44Z	2019-11-04T16:30:32Z	14 40.264S	121 40.446E	14 36.068S	121 34.337E
	4	17	2019-11-04T18:41:55Z	2019-11-04T19:21:45Z	14 35.018S	121 32.816E	14 33.335S	121 30.197E
	5	18	2019-11-04T19:24:55Z	2019-11-04T20:02:14Z	14 33.342S	121 30.163E	14 31.889S	121 27.907E

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.

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

Protat, A., 2019: The RV Investigator. Voyage Plan IN2019_V06
https://www.cmar.csiro.au/data/reporting/get_file.cfm?eov_pub_id=1168

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 a geographic location where the Triaxus was towed, consisting of multiple legs.

Leg – relates to one instance of the Triaxus entering the water, being towed for a period of time and followed by retrieval from the water.

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