RV *Investigator*
Triaxus Processing Report

Voyage Number:	in2020_v08
Voyage Title:	SOLACE - Southern Ocean Large Areal Carbon Export: quantifying carbon sequestration in subpolar and polar waters
Depart:	Hobart, 4 December 2021 08:00 AEDT
Return:	Hobart, 15 January 2021 12:00 AEDT
Report compiled by:	Richard Atkinson

Document History:

Date	Version	Author	Comments
30 August 2021	1	Richard Atkinson	Initial version

Contents

1 Summary

This report describes the production of quality controlled Triaxus data from RV Investigator voyage in2020_v08, from 4 December 2020 to 15 January 2021.

Eight Triaxus tows were undertaken. Tows 1 to 7 were to investigate oceanographic and biological features of interest to the Southern Ocean Large Areal Carbon Export project. The eighth tow was to compare to altimetry satellite data.

Pressure, conductivity, temperature, and dissolved oxygen data were gathered from duplicate sensors using a Seabird SBE9+ CTD. Also carried on the Triaxus hull were a cosine Photosynthetically Active Radiation (PAR) sensor, a transmissometer, an eco-triplet (optical backscatter, CDOM fluorometer and chlorophyll fluorometer), a Laser Optical Plankton Counter (LOPC), and a user-provided Fluorescence Induction and Relaxation (FIRe) system.

On each tow, only data from sections where the Triaxus was undulating regularly were processed. Data from deployment, turns and retrieval were gathered but not further processed.

Pressure, conductivity, temperature, and dissolved oxygen sensor data were converted to calibrated units. Spikes and out-of-range values were removed and primary to secondary sensor data compared. Similarly PAR, transmissometer, and eco-triplet data were combined into the dataset. Both LOPC and FIRe data were gathered but are not processed or published in this report.

Published data have been grouped into 1 decibar bins. Data from the primary sensors were assessed to be more reliable.

On this voyage all tows were made up of sections that were sufficiently short to be recorded in single files.

The published data consists of:

- along-track time-series data for each section
- synthetic interpolated vertical casts data for each undulation peak and trough of each section
- interpolated sectional plots of various taken from along-track time-series data

2 Voyage Details

2.1 Title

SOLACE -Southern Ocean Large Areal Carbon Export: quantifying carbon sequestration in subpolar and polar waters.

2.2 Principal Investigators

Philip Boyd (Chief Scientist), David Antoine, Michael Ellwood, Rudy Kloser, Pere Masque, and Tom Trull.

2.3 Voyage Objectives

The scientific objectives of in2020_v08 are outlined in the Voyage Plan.

For further details, refer to the Voyage Plan which available from the CSIRO Marine National Facility web site.

3 Area of Operation

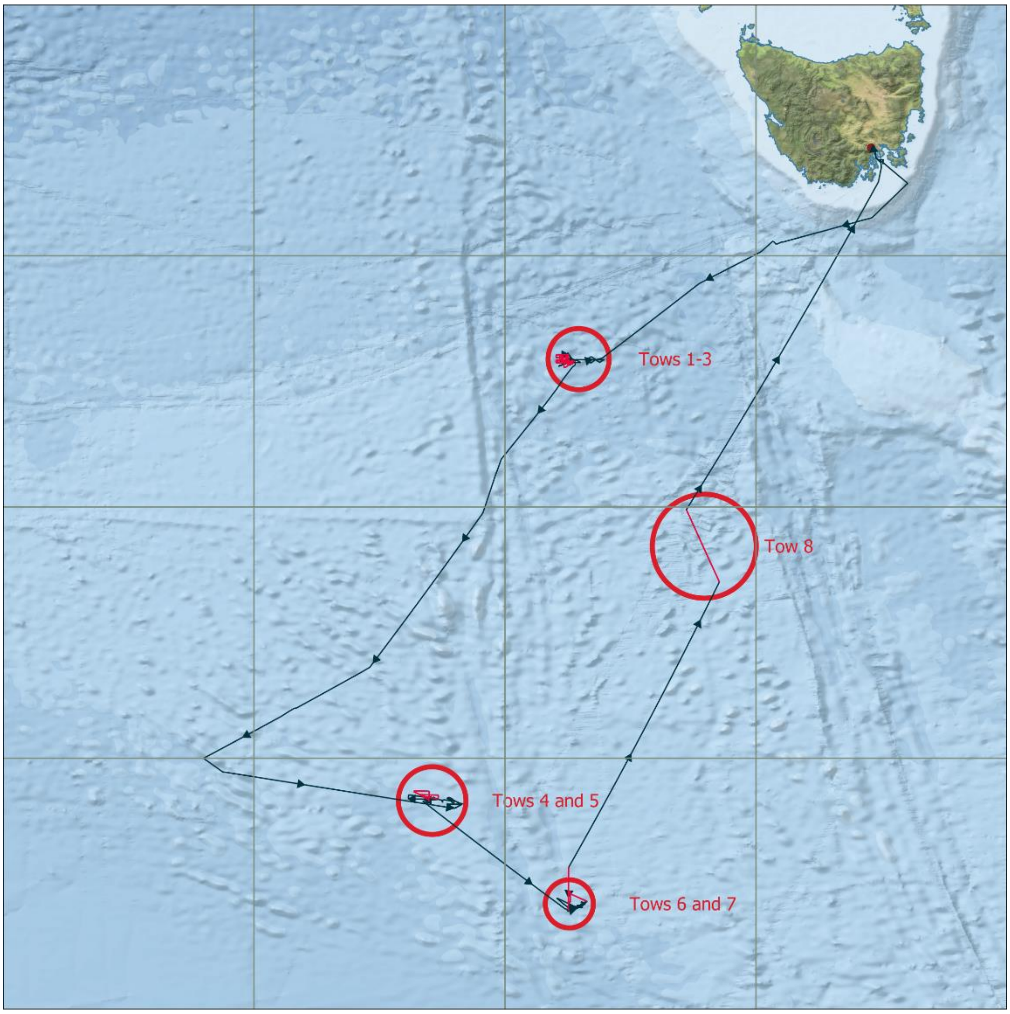

Figure 1: Area of operation for in2020_v08

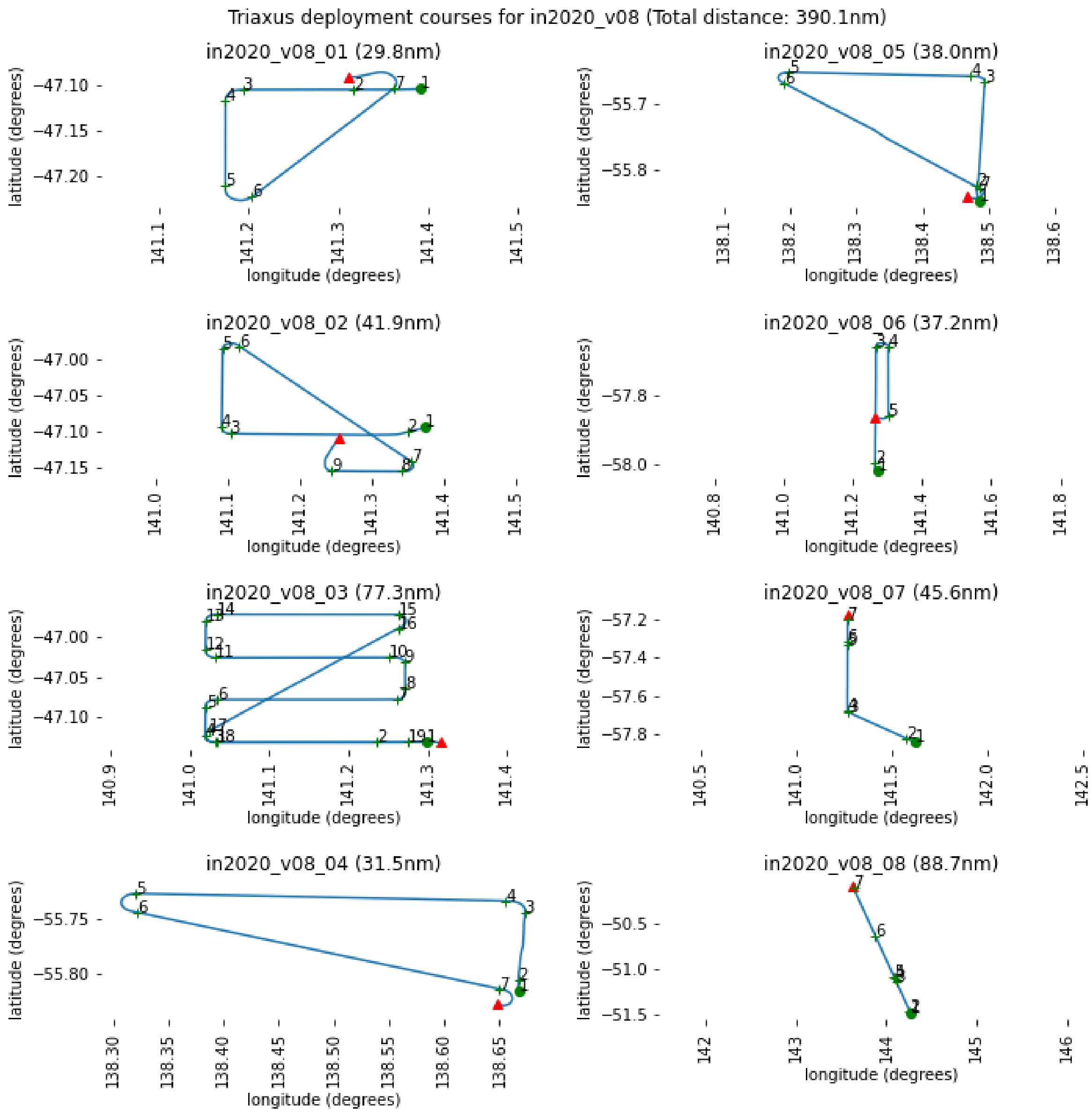

Figure 2: Sub area of operations for in2020_v08

4 Processing Notes

4.1 Background Information

8 Triaxus tows were conducted, divided in the CTD acquisition software, Seasave, into 68 files. Flight data from the MacArtney Triaxus were logged containing pitch, roll, altimeter, cable length.

The data for this voyage were acquired with the CSIRO CTD unit 25, a Seabird SBE911 with dual conductivity and temperature sensors.

Below are descriptions of the tows as provided by the Chief Scientist:

tow1	2020-12-10 07:58	Subpolar site – survey around the station (Eulerian station – fixed way point SW of SOTS)

tow2	2020-12-12 12:15	ditto – further exploration around our way point
tow3	2020-12-16 07:12	ditto – at end of cycle 2 to cross check no change in conditions
tow4	2020-12-29 07:58	Polar site 1 – follow up to CTD survey to better map out site (quasi-Lagrangian following BOM holey sock drogue – drifting way point) as weather have prevented any prior tows at this site
tow5	2020-12-30 07:20	Polar site 1 – further exploration of features such as DCM (deep chlorophyll maximum) at base of seasonal mixed layer
tow6	2021-01-02 07:27	Polar site 2 – exploration to refine location of site (quasi-Lagrangian following BOM holey sock drogue – drifting way point)
tow7	2021-01-10 12:38	Polar site 2 – tow out to look for 'putative' N wall/boundary of the eddy
tow8	2021-01-12 09:15	Long deep (faired cable) tow for Benoit Legresy (CSIRO) to coincide with altimetry satellite overpass

The CTD was also 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.

TRIAXUS HULL NUMBER: 002 (SERIAL NUMBER S1511990)

Sensor	Data Channel	SBE9 Connector	Model	Serial Number
CTD			SBE9+ V2	1354 (#25)
Primary Temperature		JB1	SBE3T	4718
Primary Conductivity		JB2	SBE4C	3868
Primary Pump		JB3	SBE5	9404
Secondary Temperature		JB4	SBE3T	6022
Secondary Conductivity		JB5	SBE4C	4664
Secondary Pump		JB3	SBE5	8344
Primary Oxygen	A0	JT2	SBE43	3534
Secondary Oxygen	A1	JT2	SBE43	3542
PAR	A2	JT3	QCP2300HP	70677
Transmissometer	A3	JT3	CSTAR	1421
Eco Triplet	Payload 2 (12V)		FLBBCD2K	5038
Nitrate Sensor	Payload 3 (12V)		Satlantic SUNA V2	
Active Fluorescence	Payload 4 (12V)		Satlantic FIRe	
LOPC	Payload 7 (12V)		Rolls Royce LOPC-1xT-3	
Iridium Beacon	-	-	Xeos Apollo 3	

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 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.

4.2 Sensor Correction

4.2.1 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.

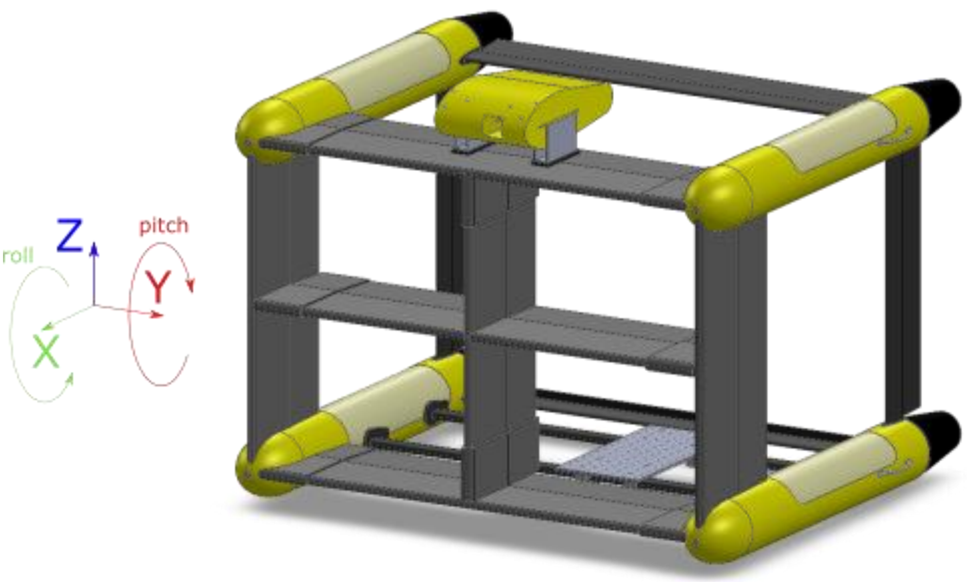

Figure 3: Triaxus General Arrangement

The pressure sensor location correction was not applied in this instance. For reference, Conductivity and Temperature sensor location for in2020_v08 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

4.2.2 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, 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 of the water (belonging to the boundary layer) is lagged by a time constant. After extensive testing it has been determined that good correction is achieved using two water fractions, 0.013 and 0.007, lagged by 7 and 1 seconds respectively.

4.3 Other Sensors

The Wetlabs C-Star transmissometer was used for all tows. The transmissometer has been calibrated to give nominal outputs of 0-100 fsd (full scale deflection).

The Biospherical PAR sensor was used for all tows. The PAR sensor has been calibrated to give output in µE/m²/s. This data has been included in the output files. Time of day and environmental factors, such as sea state and cloud cover, impact these readings. If there are no values for a tow it is likely because it was night time during the tow.

The Eco Triplet sensor array and LOPC were used for all tows. Only Eco Triplet data has been merged into the averaged data products.

4.4 Bad Data Detection

The range limits and maximum second difference for sensors connected to the SBE9+ A/D channels were configured in CapPro and written to the netCDF 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	-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.

4.5 Averaging

Data was filtered and binned into 1 decibar/10 second averaged bins for each section along track in netCDF section 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.

4.5.1 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.

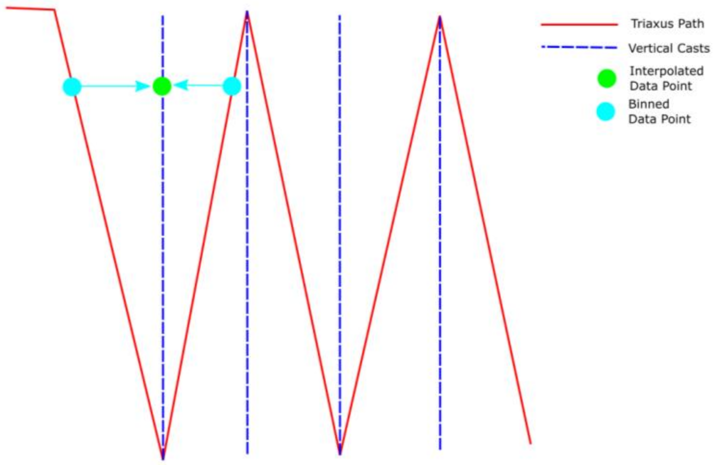

Figure 4: Vertical Cast Creation

4.5.2 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.

4.5.3 QC flags

Each binned parameter is assigned a QC flag. The 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.

4.6 Significant Data Issues

The data was high quality for all tows.

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.

		Mean Absolute Difference Primary to Secondary			Maximum Absolute Difference Primary to Secondary		
Tow	Leg	Temperature (°C)	Salinity (PSU)	Oxygen (µM)	Temperature (°C)	Salinity (PSU)	Oxygen (µM)
1	2	0.00525	0.00158	16.11697	0.18166	0.05100	26.56594
1	4	0.00559	0.02257	17.27471	0.17589	0.56661	92.91298
1	6	0.00476	0.00816	12.18584	0.45104	0.25775	54.75978
2	2	0.00231	0.00221	13.14595	0.12184	0.27839	73.82375
2	4	0.00300	0.00094	11.18993	0.13073	0.04451	23.67469
2	6	0.00330	0.00098	10.87795	0.33953	0.06714	24.87198
2	8	0.00230	0.00062	10.21689	0.09031	0.01912	24.98059
3	2	0.00204	0.00910	16.15565	0.14790	0.57351	82.96969
3	4	0.00678	0.00745	6.80832	0.14936	0.13025	30.08319
3	6	0.00357	0.00439	7.05372	0.09358	0.12634	32.76576
3	8	0.00300	0.00411	7.56805	0.03609	0.02759	27.07442
3	10	0.00325	0.00334	8.14706	0.35630	0.06495	57.11619
3	12	0.00627	0.00408	7.74874	0.19902	0.07481	26.77937
3	14	0.00463	0.00626	12.45841	0.13921	0.15138	79.57804
3	16	0.00490	0.00652	8.16671	0.19763	0.13433	40.89011
3	18	0.01888	0.01388	20.30716	0.31173	0.26221	118.61009
4	2	0.00293	0.00440	9.85337	0.04367	0.02463	18.57217
4	4	0.00365	0.00287	10.76386	0.07359	0.02359	22.48528
4	6	0.00369	0.00328	11.29252	0.07593	0.04596	23.72434
5	2	0.00294	0.00319	12.68427	0.06006	0.00829	21.63889
5	4	0.00287	0.00271	12.35510	0.06774	0.00971	21.63905
5	6	0.00281	0.00182	12.20528	0.11821	0.00719	21.92912
6	2	0.00212	0.00244	12.46050	0.07565	0.00561	24.41439
6	4	0.00260	0.00149	12.14876	0.05129	0.00524	25.12600
7	2	0.00210	0.00270	12.29291	0.04947	0.01825	22.98311
7	4	0.00204	0.00489	11.12582	0.06530	0.03724	25.04685
7	6	0.00123	0.00349	11.70109	0.04311	0.02557	23.43565
8	2	0.00327	0.00223	10.55657	0.23120	0.01943	21.24729
8	5	0.00372	0.00253	9.72789	0.14514	0.03147	19.29095
8	6	0.00320	0.00263	9.22030	0.14909	0.02683	19.04911
8	7	0.00223	0.00253	9.88054	0.06459	0.01285	21.16523

Table 4: Comparative difference between primary and secondary CTD sensors

4.7 Triaxus Deployment Sections

Tow	Leg	Oper-ationn	Start time	End time	Start Latitude	Start Longitude	End Latitude	End Longitude
1	1	1	2020-12-10T07:23:51Z	2020-12-10T07:57:51Z	47°06.193'S	141°23.511'W	47°06.266'S	141°23.511'W
1	2	2	2020-12-10T07:58:13Z	2020-12-10T08:38:56Z	47°06.267'S	141°19.017'W	47°06.275'S	141°19.017'W
1	3	3	2020-12-10T08:39:24Z	2020-12-10T08:48:56Z	47°06.275'S	141°11.623'W	47°06.976'S	141°11.623'W
1	4	4	2020-12-10T08:49:23Z	2020-12-10T09:31:33Z	47°07.042'S	141°10.462'W	47°12.583'S	141°10.462'W
1	5	5	2020-12-10T09:32:05Z	2020-12-10T09:45:42Z	47°12.658'S	141°10.457'W	47°13.477'S	141°10.457'W
1	6	6	2020-12-10T09:46:09Z	2020-12-10T10:58:25Z	47°13.434'S	141°12.237'W	47°06.232'S	141°12.237'W
1	7	7	2020-12-10T10:58:53Z	2020-12-10T11:35:20Z	47°06.178'S	141°21.722'W	47°05.430'S	141°21.722'W
2	1	8	2020-12-12T11:57:52Z	2020-12-12T12:14:31Z	47°05.595'S	141°22.393'W	47°05.963'S	141°22.393'W
2	2	9	2020-12-12T12:15:14Z	2020-12-12T13:34:35Z	47°05.992'S	141°20.953'W	47°06.124'S	141°20.953'W
2	3	10	2020-12-12T13:34:56Z	2020-12-12T13:41:31Z	47°06.123'S	141°06.220'W	47°05.639'S	141°06.220'W
2	4	11	2020-12-12T13:41:55Z	2020-12-12T14:29:02Z	47°05.590'S	141°05.483'W	46°59.084'S	141°05.483'W
2	5	12	2020-12-12T14:29:19Z	2020-12-12T14:37:56Z	46°59.050'S	141°05.568'W	46°58.799'S	141°05.568'W
2	6	13	2020-12-12T14:38:15Z	2020-12-12T16:11:48Z	46°58.843'S	141°06.974'W	47°08.413'S	141°06.974'W
2	7	14	2020-12-12T16:12:27Z	2020-12-12T16:21:08Z	47°08.485'S	141°21.332'W	47°09.270'S	141°21.332'W
2	8	15	2020-12-12T16:21:31Z	2020-12-12T16:49:04Z	47°09.270'S	141°20.434'W	47°09.242'S	141°20.434'W
2	9	16	2020-12-12T16:49:29Z	2020-12-12T17:30:02Z	47°09.229'S	141°14.626'W	47°06.476'S	141°14.626'W
3	1	17	2020-12-16T06:45:34Z	2020-12-16T07:12:03Z	47°07.887'S	141°17.893'W	47°07.954'S	141°17.893'W
3	2	18	2020-12-16T07:12:25Z	2020-12-16T08:17:21Z	47°07.955'S	141°14.117'W	47°07.956'S	141°14.117'W
3	3	19	2020-12-16T08:17:48Z	2020-12-16T08:23:24Z	47°07.955'S	141°01.869'W	47°07.488'S	141°01.869'W
3	4	20	2020-12-16T08:23:56Z	2020-12-16T08:39:12Z	47°07.408'S	141°01.146'W	47°05.337'S	141°01.146'W
3	5	21	2020-12-16T08:39:29Z	2020-12-16T08:46:17Z	47°05.303'S	141°01.166'W	47°04.716'S	141°01.166'W
3	6	22	2020-12-16T08:46:41Z	2020-12-16T10:00:03Z	47°04.717'S	141°02.038'W	47°04.713'S	141°02.038'W
3	7	23	2020-12-16T10:00:22Z	2020-12-16T10:07:19Z	47°04.706'S	141°15.717'W	47°03.980'S	141°15.717'W
3	8	24	2020-12-16T10:07:42Z	2020-12-16T10:22:43Z	47°03.923'S	141°16.296'W	47°01.908'S	141°16.296'W
3	9	25	2020-12-16T10:23:05Z	2020-12-16T10:29:31Z	47°01.853'S	141°16.256'W	47°01.526'S	141°16.256'W
3	10	26	2020-12-16T10:29:52Z	2020-12-16T11:35:39Z	47°01.527'S	141°15.127'W	47°01.544'S	141°15.127'W
3	11	27	2020-12-16T11:36:07Z	2020-12-16T11:42:04Z	47°01.542'S	141°01.870'W	47°01.019'S	141°01.870'W
3	12	28	2020-12-16T11:42:25Z	2020-12-16T11:58:57Z	47°00.963'S	141°01.177'W	46°58.754'S	141°01.177'W
3	13	29	2020-12-16T11:59:14Z	2020-12-16T12:05:22Z	46°58.722'S	141°01.198'W	46°58.258'S	141°01.198'W
3	14	30	2020-12-16T12:05:39Z	2020-12-16T13:16:15Z	46°58.258'S	141°02.051'W	46°58.249'S	141°02.051'W
3	15	31	2020-12-16T13:16:46Z	2020-12-16T13:27:44Z	46°58.256'S	141°15.771'W	46°59.297'S	141°15.771'W
3	16	32	2020-12-16T13:28:02Z	2020-12-16T14:59:20Z	46°59.325'S	141°15.756'W	47°07.039'S	141°15.756'W
3	17	33	2020-12-16T14:59:38Z	2020-12-16T15:09:01Z	47°07.068'S	141°01.420'W	47°07.962'S	141°01.420'W
3	18	34	2020-12-16T15:09:17Z	2020-12-16T16:24:43Z	47°07.962'S	141°02.028'W	47°07.951'S	141°02.028'W
3	19	35	2020-12-16T16:25:12Z	2020-12-16T16:51:43Z	47°07.950'S	141°16.519'W	47°07.943'S	141°16.519'W
4	1	36	2020-12-29T07:52:01Z	2020-12-29T07:57:43Z	55°48.880'S	138°40.032'W	55°48.374'S	138°40.032'W
4	2	37	2020-12-29T07:58:03Z	2020-12-29T08:27:30Z	55°48.337'S	138°40.036'W	55°44.692'S	138°40.036'W
4	3	38	2020-12-29T08:27:52Z	2020-12-29T08:37:13Z	55°44.645'S	138°40.385'W	55°44.012'S	138°40.385'W
4	4	39	2020-12-29T08:37:33Z	2020-12-29T10:06:34Z	55°44.011'S	138°39.321'W	55°43.597'S	138°39.321'W
4	5	40	2020-12-29T10:06:54Z	2020-12-29T10:17:24Z	55°43.601'S	138°19.193'W	55°44.607'S	138°19.193'W
4	6	41	2020-12-29T10:17:42Z	2020-12-29T11:45:14Z	55°44.623'S	138°19.296'W	55°48.767'S	138°19.296'W

Tow	Leg	Oper-ationn	Start time	End time	Start Latitude	Start Longitude	End Latitude	End Longitude
4	7	42	2020-12-29T11:45:37Z	2020-12-29T12:13:29Z	55°48.783'S	138°38.989'W	55°49.579'S	138°38.989'W
5	1	43	2020-12-30T07:04:10Z	2020-12-30T07:19:56Z	55°50.759'S	138°29.138'W	55°49.433'S	138°29.138'W
5	2	44	2020-12-30T07:20:43Z	2020-12-30T08:31:06Z	55°49.344'S	138°28.937'W	55°40.132'S	138°28.937'W
5	3	45	2020-12-30T08:31:27Z	2020-12-30T08:40:23Z	55°40.076'S	138°29.621'W	55°39.520'S	138°29.621'W
5	4	46	2020-12-30T08:40:41Z	2020-12-30T09:52:00Z	55°39.518'S	138°28.335'W	55°39.152'S	138°28.335'W
5	5	47	2020-12-30T09:52:23Z	2020-12-30T10:01:49Z	55°39.150'S	138°11.824'W	55°40.091'S	138°11.824'W
5	6	48	2020-12-30T10:02:06Z	2020-12-30T11:44:57Z	55°40.123'S	138°11.394'W	55°49.665'S	138°11.394'W
5	7	49	2020-12-30T11:45:15Z	2020-12-30T12:15:11Z	55°49.697'S	138°29.171'W	55°50.410'S	138°29.171'W
6	1	50	2021-01-02T07:11:37Z	2021-01-02T07:27:40Z	58°01.198'S	141°16.231'W	57°59.726'S	141°16.231'W
6	2	51	2021-01-02T07:27:59Z	2021-01-02T10:01:55Z	57°59.682'S	141°15.840'W	57°39.611'S	141°15.840'W
6	3	52	2021-01-02T10:02:19Z	2021-01-02T10:16:22Z	57°39.558'S	141°16.002'W	57°39.567'S	141°16.002'W
6	4	53	2021-01-02T10:16:44Z	2021-01-02T11:44:30Z	57°39.622'S	141°18.109'W	57°51.376'S	141°18.109'W
6	5	54	2021-01-02T11:44:53Z	2021-01-02T12:10:25Z	57°51.432'S	141°18.148'W	57°51.808'S	141°18.148'W
7	1	55	2021-01-10T12:15:01Z	2021-01-10T12:38:33Z	57°50.668'S	141°37.453'W	57°49.427'S	141°37.453'W
7	2	56	2021-01-10T12:38:56Z	2021-01-10T14:32:27Z	57°49.396'S	141°34.613'W	57°41.231'S	141°34.613'W
7	3	57	2021-01-10T14:32:47Z	2021-01-10T14:38:14Z	57°41.205'S	141°16.409'W	57°40.690'S	141°16.409'W
7	4	58	2021-01-10T14:38:33Z	2021-01-10T17:46:43Z	57°40.654'S	141°16.003'W	57°20.271'S	141°16.003'W
7	5	59	2021-01-10T17:47:16Z	2021-01-10T18:00:07Z	57°20.208'S	141°16.042'W	57°18.783'S	141°16.042'W
7	6	60	2021-01-10T18:00:33Z	2021-01-10T19:00:17Z	57°18.738'S	141°16.045'W	57°12.199'S	141°16.045'W
7	7	61	2021-01-10T19:00:39Z	2021-01-10T19:30:55Z	57°12.152'S	141°16.058'W	57°10.416'S	141°16.058'W
8	1	62	2021-01-12T09:00:03Z	2021-01-12T09:15:33Z	51°29.332'S	144°16.253'W	51°27.820'S	144°16.253'W
8	2	63	2021-01-12T09:15:55Z	2021-01-12T12:00:37Z	51°27.772'S	144°15.536'W	51°07.999'S	144°15.536'W
8	3	64	2021-01-12T12:02:03Z	2021-01-12T12:15:45Z	51°07.829'S	144°06.321'W	51°06.228'S	144°06.321'W
8	4	65	2021-01-12T12:16:05Z	2021-01-12T12:30:56Z	51°06.188'S	144°05.564'W	51°05.071'S	144°05.564'W
8	5	66	2021-01-12T12:31:18Z	2021-01-12T16:30:56Z	51°05.040'S	144°05.034'W	50°37.985'S	144°05.034'W
8	6	67	2021-01-12T16:31:24Z	2021-01-12T21:04:16Z	50°37.927'S	143°52.628'W	50°06.373'S	143°52.628'W
8	7	68	2021-01-12T21:04:39Z	2021-01-12T21:37:44Z	50°06.336'S	143°38.320'W	50°04.325'S	143°38.320'W

Table 5: CAP deployment grouping

CAP deployments were grouped for each Triaxus deployment as shown in Table 5 above.

Sections in grey have been excluded from the final dataset as they are are deployments, recovery or turns where no useful undulation data are present.

Simulated vertical casts were created at the top and bottom apex along the flight path. See section 4.5.2 details how this was performed.

Sections were then exported as both vertical casts and along-track data products in netCDF format.

5 Glossary

Tow – a contiguous Triaxus operation intended to be treated as one data set.

Section – part of a Tow delineated either by change in operation, such as undulation commencing or terminating or change of course, or to restrict data volume for convenience and disaster recovery.

Deployment – relates to one instance of the Triaxus entering the water, being towed, then retrieved from the water.

Leg – a concatenation of Sections that can be analysed as one data set.

Scan file – a file structure containing data collected from the deployment of the CTD and auxiliary sensors.

For example, a Triaxus Tow might consist of 2 deployments, where the vehicle was removed from the water for inspection during the Tow occasions. During the first Deployment the vehicle was put in the water, towed on one course for 9 hours then the course was changed and it was towed for a further 3 hours. The first 9 hour Leg was broken into 3 Sections of 3 hours each where data acquisition was restarted and a new data file created between each Section. The Section while the course was changing and the vehicle ceased undulating was recorded separately, but not processed as a Leg as its data is of little value.

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 Appendix 2: Data Quality Control Flags.

Variable name	*Description*	*Units*
latitude	Estimated latitude of the Triaxus	Degrees N
longitude	Estimated longitude of the Triaxus	Degrees E
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	°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	°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
oxygen *	Calibrated reading from the primary oxygen sensor	µmole/L
oxygen_2 *	Calibrated reading from the secondary oxygen sensor	µmole/L
par *	Calibrated reading from the QCP-2300 Photosynthetically Active Radiation sensor	$\mu E/m^2/sec$
transmissometer *	Calibrated reading from the Wetlabs C-Star transmissometer	%
chlorophyll *	Calibrated reading for chlorophyll from the eco triplet	µg/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

7 Appendix 2: Data Quality Control Flags

LINDSAY PENDER
29 June 2000

Specification

All quality control flags are to be unsigned integer numbers in the range 0 to 255. Where appropriate, the flags are to be stored as unsigned byte length values. Each byte length QC flag is subdivided into 3 fields. These fields are defined as follows:

Data State (bits 6 & 7)

The data state describes the overall status of the data without concern about the type of error, and the type of correction process performed on the data, if any. If the QC is unknown, the person loading data must determine the data state, i.e. unknown QC does not necessarily imply no QC.

Data State	Numeric value	Description
0	0	Data is good
1	64	Data is suspect
2	128	Data is bad
3	192	No QC

Operation type (bits 4 & 5)

The operation type describes the type of operation performed on the data to enable it to be classified with the given data state.

Operation	Numeric value	Description
0	0	No operation – data used as is.
1	16	Data has been interpolated to replace bad values.
2	32	Data has been averaged or otherwise filtered.
3	48	Data has been manually adjusted.

Error type (bits 0 & 3)

The error type describes the type of data error detected which resulted

in the given data state and subsequent operation on the data.

Error type	Numeric value	Description
0	0	No error – data is good, or if no QC, error is unknown.
1	1	Hardware error.
2	2	Software error.
3	3	Operator error.
4	4	Error flagged by hardware.
5	5	Error flagged by processor.
6	6	Analytical error.
7	7	Recording anomaly, e.g. transcription error.
8	8	Data stream corrupted, e.g. communications fault

9 10	9 10	Data out of range. Anomalous spike, e.g. data spikes.
11	11	Preliminary processing (calibration) only.
12	12	Unprocessed (uncalibrated) or processing error.
13	13	No data – data missing for unknown reason.
14	14	Timing error.
15	15	User defined – user must provide adequate description.

Numeric interpretation

The complete flag for a given data element is the sum of the numeric values of the 3 fields. To unpack a flag, the user can either use a lookup table, or perform the following manipulations:

Arithmetic method	Bit manipulation method
To unpack a flag: state = int(flag / 64) op = int((flag – state * 64) / 16) error = flag – state * 64 – op * 16 To pack a flag: flag = state * 64 + op * 16 + error	To unpack a flag: state = flag >> 6 op = (flag & 0x30) >> 4 error = flag & 0x0f To pack a flag: flag = (state << 6) & (op << 4) & error

On some systems and file formats, eg. netCDF, it is not possible to store unsigned byte values. In this case, flags greater than 127 are stored as negative numbers. To convert them to unsigned integers, add 256.

If a user is only interested in the state flag, the following can be used to interpret flags:

State	Unsigned Byte	Signed Byte
Good	$0 \leq flag \leq 63$	$0 \leq flag \leq 63$
Suspect	$64 \leq flag \leq 127$	$64 \leq flag \leq 127$
Bad	$128 \leq flag \leq 191$	$-128 \leq flag \leq -65$
No QC	$192 \leq flag \leq 255$	$-64 \leq flag \leq -1$