RV *Investigator*

Triaxus Processing Report

Voyage ID:	IN2019_V02
Voyage title:	SOTS: Southern Ocean Time Series automated moorings for climate and carbon cycle studies southwest of Tasmania; Subantarctic Biogeochemistry of Carbon and Iron, Southern Ocean Time Series site
Depart:	Hobart, 0800 Thursday, 14 March 2019
Return:	Hobart, 0900 Thursday, 4 April 2019
Report compiled by:	Francis Chui

Contents

1 Summary

These notes relate to the production of quality controlled Triaxus data from RV Investigator voyage IN2019_V02, from 15 Mar 2019 – 02 Apr 2019.

Data for 3 Triaxus deployments were acquired in CAP CTD acquisition software using the Seabird SBE911 CTD 20. The deployments were conducted with a standard tow speed of between 7 to 9 knots and wire out ranged from 1050 to 1210 m.

During the first two deployments, we encountered issues with the Transmissometer and biofouling of sensors. On the second deployment a communications issue was also addressed.

Sea-Bird-supplied calibration factors and CSIRO supplied calibrations were used to compute the pressures, conductivity and temperature data. The data were 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, Nitrate, FIRe 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 secondary sensors to produce an along-track time-series dataset for each CAP scan files. These scan files were grouped into legs, each containing a section of the Triaxus deployment and in each leg, vertical casts were created with interpolated values from the along-track time-series binned dataset with a maximum interpolation distance of 3 casts. These generated the along-track and vertical cast section data products for each Triaxus deployment.

2 Voyage Details

2.1 Title

SOTS: Southern Ocean Time Series automated moorings for climate and carbon cycle studies southwest of Tasmania; Subantarctic Biogeochemistry of Carbon and Iron, Southern Ocean Time Series site.

2.2 Principal Investigators

Tom Trull (CSIRO).

2.3 Voyage Objectives

The scientific objectives for IN2019_V02 were outlined in the Voyage Plan (Trull 2019).

For further details, refer to the Voyage Plan and/or summary which can be viewed on the Marine National Facility Plans and Summaries web site.

2.4 Area of operation

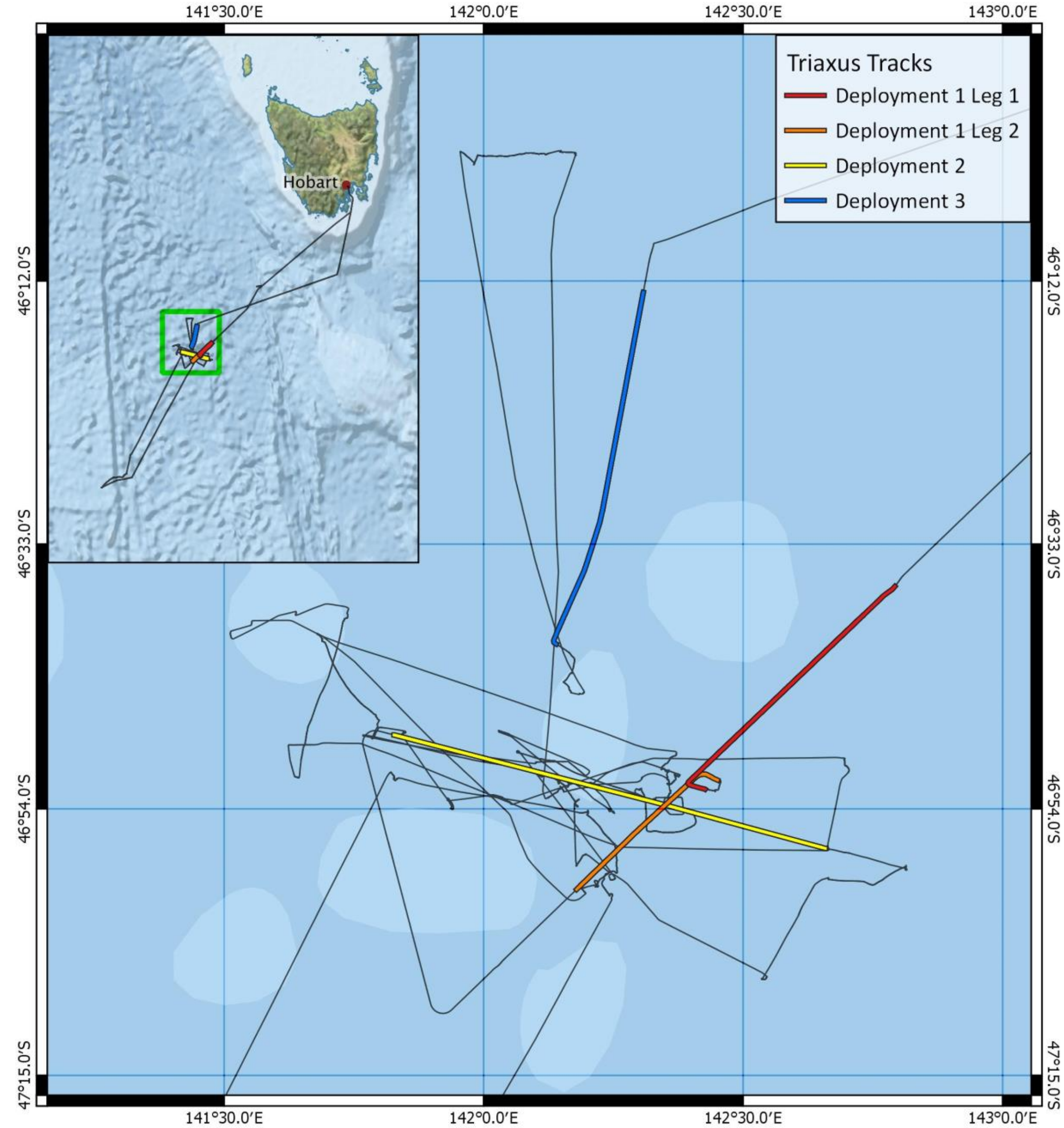


Figure 1. Area of operation for IN2019_V02 with Triaxus deployments highlighted in colour

3 Processing Notes

3.1 Background Information

Two Triaxus deployments were conducted, divided in the CTD acquisition software SeaSave and converted into 4 scan files. Flight data from the MacArtney Triaxus were logged containing pitch, roll, altimeter and cable length.

The data for this voyage were acquired with the CSIRO CTD unit 20, a Seabird SBE911 with dual conductivity and temperature sensors.

The CTD was additionally fitted with SBE43 dissolved oxygen sensors, Transmissometer, Cosine Photosynthetically Active Radiation (PAR) sensor, ECO Triplet, Nitrate and LOPC. These sensors are described in Table 1 with changes for deployment 1 leg 2 onwards described in Table 2.

During deployment 1 leg 1, primary sensors were lost near the beginning which was followed by the secondary sensors during this, the Transmissometer had also dropped to a maximum of 40%. On retrieval, it was found that the primary sensors had come loose and that there was organic matter stuck in the secondary sensors. The Transmissometer was replaced with the sensor mounted with the CTD and the secondary channel set cleaned before redeployment of the Triaxus.

Deployment 1 leg 2 was successful till communications to the instrument were lost requiring a restart of the acquisition machine. This allowed us to regain communications but unfortunately the Triaxus was not able to maintain a set depth so it was retrieved. It was later discovered there was an issue with the termination causing an intermittent communications loss over the fibre which was corrected.

Deployment 2 both primary and secondary sensors had blockages meaning most of the data from this deployment the oxygen and conductivity values could not be relied on.

On deployment 3, a plastic device designed to prevent blockage was attached to the secondary tubing inlet, leaving the primary channel open. This final deployment yielded high quality data from both channels as we crossed a front. While both channels were in good agreeance, further quantitative comparison between these sensors needs to be done to confirm this.

Description	Sensor	Serial No.	A/D	Cal. Date	Cal. Source
Pressure	Digiquartz 410K-134	552	P	06-Dec-2018	CSIRO Cal Lab
Primary Temperature	Seabird SBE3plus	6285	T0	03-Dec-2018	CSIRO Cal Lab
Secondary Temperature	Seabird SBE3plus	6302	T1	03-Dec-2018	CSIRO Cal Lab
Primary Conductivity	Seabird SBE4C	4773	C0	07-Dec-2018	CSIRO Cal Lab
Secondary Conductivity	Seabird SBE4C	4774	C1	03-Dec-2018	CSIRO Cal Lab
Primary Dissolved Oxygen	Seabird SBE43	3646	A4	26-Nov-2018	CSIRO Cal Lab
Secondary Dissolved Oxygen	Seabird SBE43	3647	A5	26-Nov-2018	CSIRO Cal Lab
PAR	Biospherical QCP-2300HP	70562	A0	01-Aug-2018	Biospherical
Transmissometer	Wetlabs C-Star	CST-1841DR	A1	01-Dec-2018	Wetlabs
ECO Triplet	Wetlabs FLBBCD-2K	4049	Payload 2	07-Sep-2018	Wetlabs
Nitrate	Satlantic SUNA V2	449	Payload 3		
Fluorescence	Satlantic FIRe	27	Payload 4		
LOPC	Rolls-Royce LOPC-1xT-3	11480	Payload 7		

Table 1 CTD Sensor configuration on IN2019_V02

Description	Sensor	Serial No.	A/D	Cal. Date	Cal. Source
Transmissometer	Wetlabs C-Star	CST-1421DR	A1	17-Aug-2018	Wetlabs

Table 2 Changes to CTD Sensor configuration on IN2019_V02 for deployment 1 Leg 2, deployment 2 and 3

The raw CTD data were collected in SeaSave version 7.26.4.0, converted to scientific units using SBE Data Processing version 7.23.2 and written to netCDF format files with CNV_to_Scan for processing using the Matlab-based, CapPro package.

The CapPro 2.9 software 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. It also loaded the hydrology data and computed the matching CTD sample burst data. The automatically determined pressure offsets and in-water points were inspected.

Data were binned into 1 decibar/10 second averaged bins for each deployment along track in netCDF format.

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.

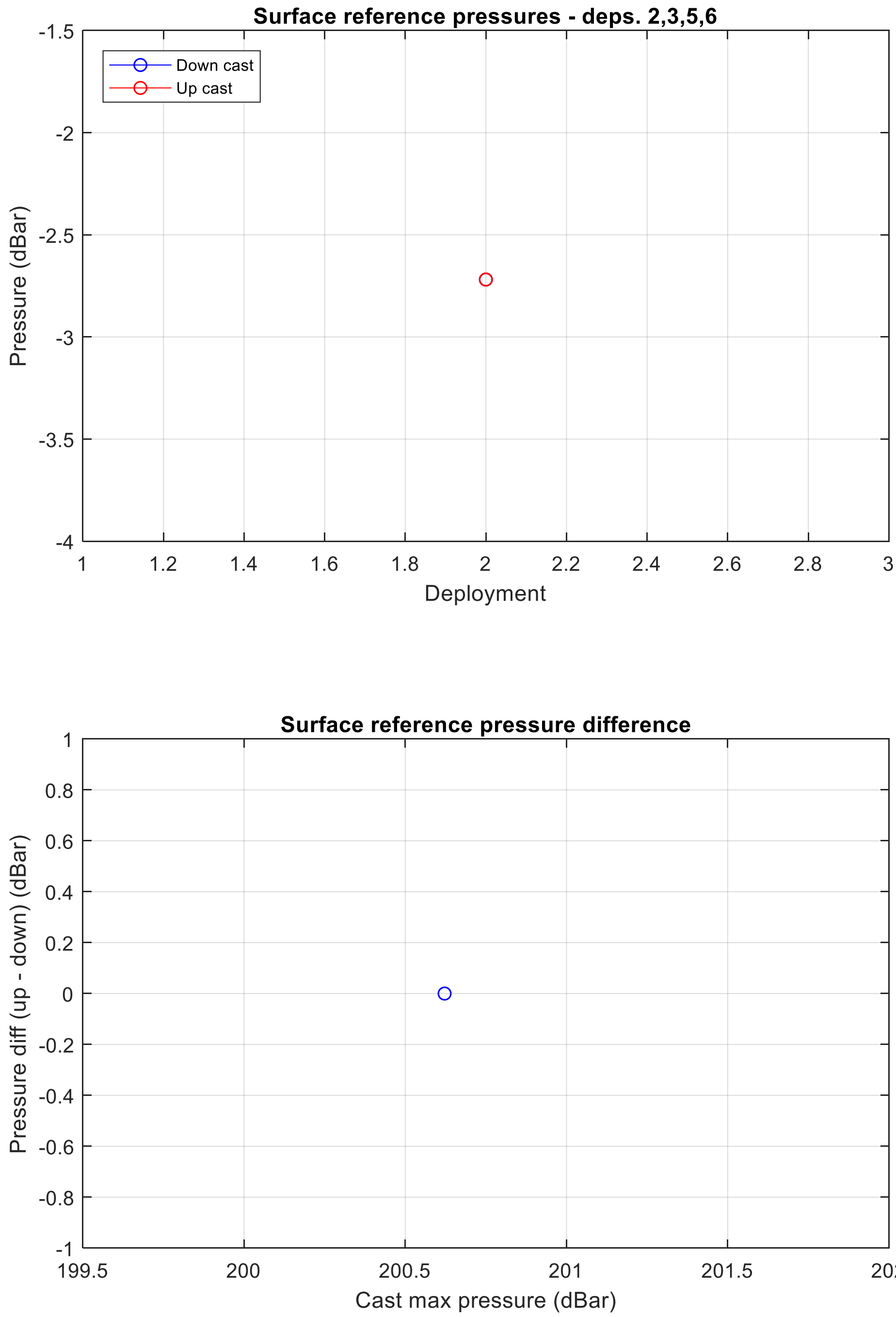


Figure 2. CTD pressure offsets

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 and for reference, Conductivity and Temperature sensor location for IN2019_V02 were as follows (measured in metres):

	Vertical location	Fore / Aft	Port / Starboard
Primary C/T	0.3	-0.45	-1.68
Secondary C/T	0.3	-0.45	-0.05

Table 3 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% transmission.

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 all deployments. Clearly, time of day and environmental factors such as sea state and cloud cover impact on these readings. If most or all of the values for a deployment are near zero it indicates a night-time cast.

The Eco Triplet sensor array, SUNA, FIRe 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.

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	-0.1	500	0.5
Transmissometer	0	100	0.5
PAR	-5	5000	100
CDOM	0	10	0.8
OBS	0	1e-3	6e-4
Chlorophyll	0	3	1

Table 4 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

The data were ‘filtered’ and binned into the standard product of 1 decibar / 10 second averaged netCDF deployment files containing the time-series data. 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 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.

3.6.2 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 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.

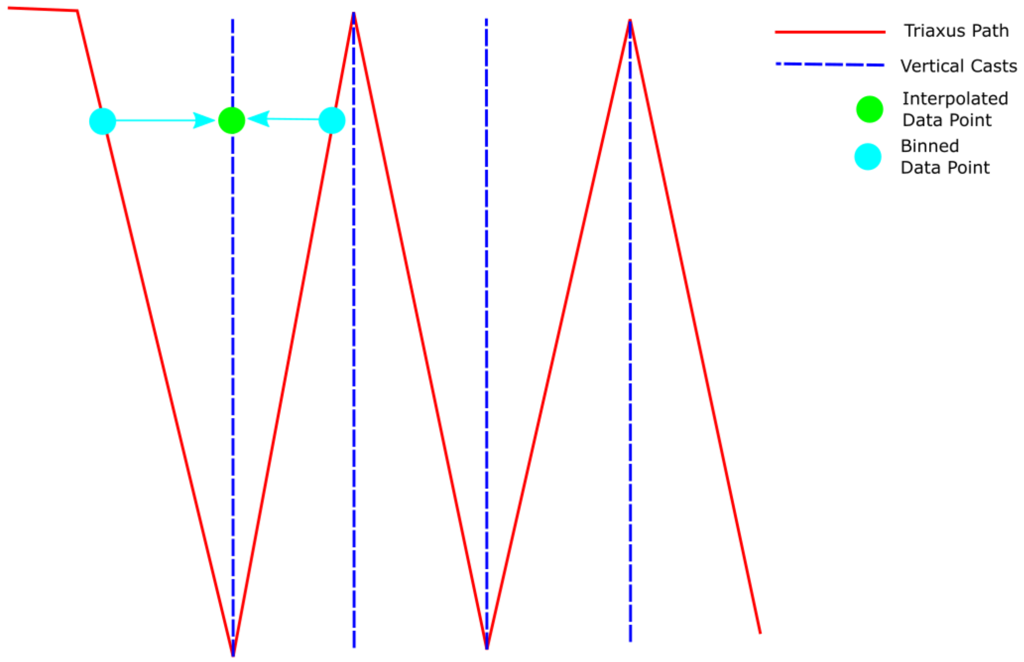


Figure 3. Vertical Cast Creation

3.7 Triaxus Deployments

Dep.	Leg	Scan File	Start time	End time	Start lat.	Start long.	End lat.	End long.
1	1	2	2019-03-15 15:28:35	2019-03-15 19:23:03	-46.60616	142.79279	-46.87417	142.42717
1	2	3	2019-03-15 22:54:43	2019-03-16 01:29:18	-46.86226	142.45107	-47.00623	142.17925
2	-	5	2019-03-16 07:16:32	2019-03-16 11:59:23	-46.80257	141.82730	-46.95220	142.65876
3	-	6	2019-04-02 01:44:58	2019-04-02 05:50:30	-46.68252	142.14011	-46.21494	142.30795

Table 5 CAP deployment grouping

CAP scan files were grouped for each Triaxus deployment/leg as shown in Table 5 above. This was followed by the creation of vertical casts at the top and bottom apex along the flight path. Using the binned time-series data, these vertical casts were filled by interpolation to a maximum of three casts' distance. These were then connected along-track to provide an along-track section profile. Section plots for each deployment/leg can be found in Appendix I: Section Plots, each containing plots for the Primary Temperature, Salinity, Oxygen and PAR. Along with Chlorophyll, CDOM, OBS and Transmission plotted as an along track distance.

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

4 References

Trull, T., 2018: The RV Investigator. Voyage Plan IN2019_V02 - https://www.csiro.au/~/media/MNF/Files/Voyages/Investigator/Voyage-Plans-summaries/2019/IN2019_V02_Voyage-Plan_Final---web.pdf

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

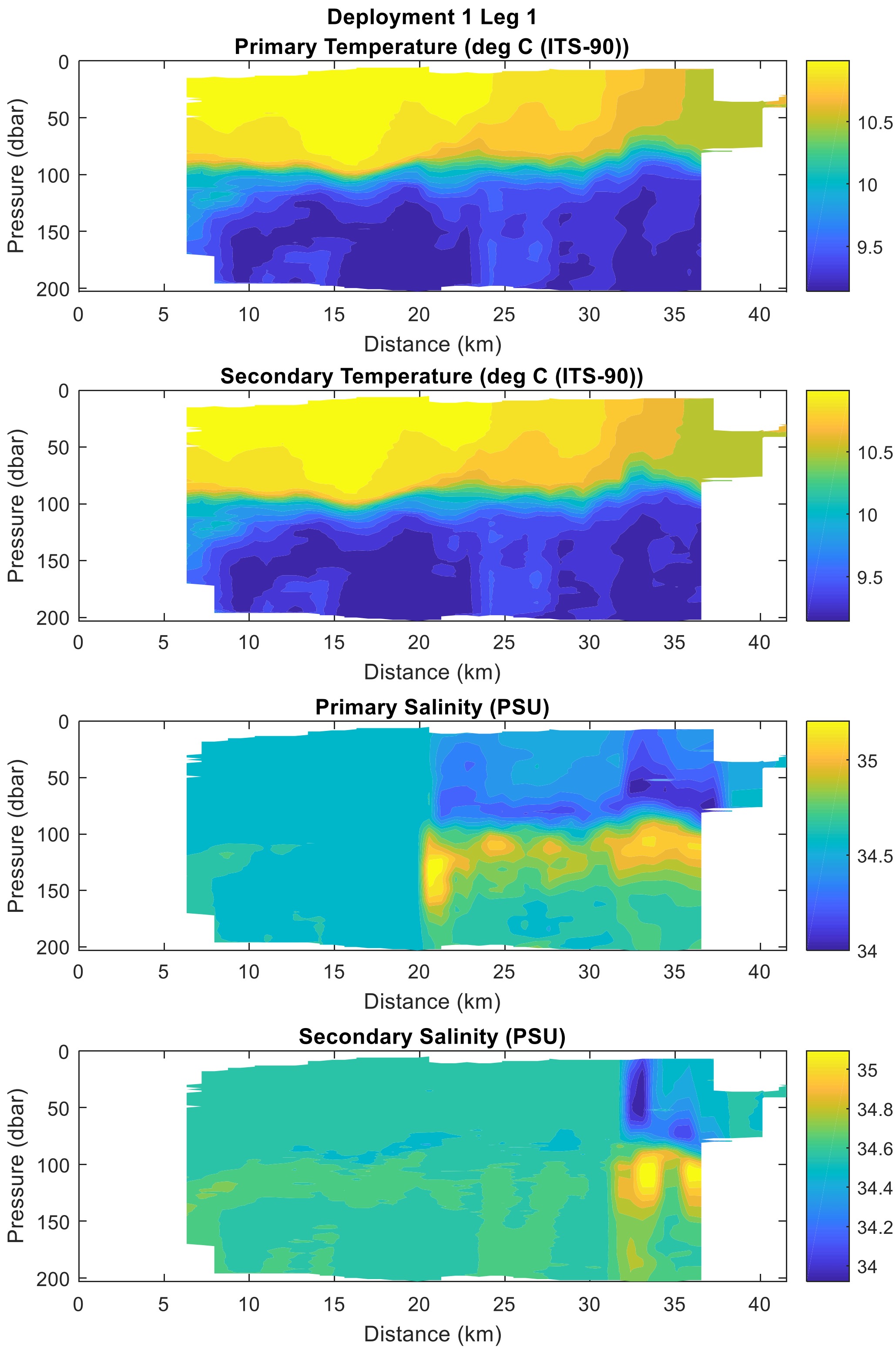
5 Glossary

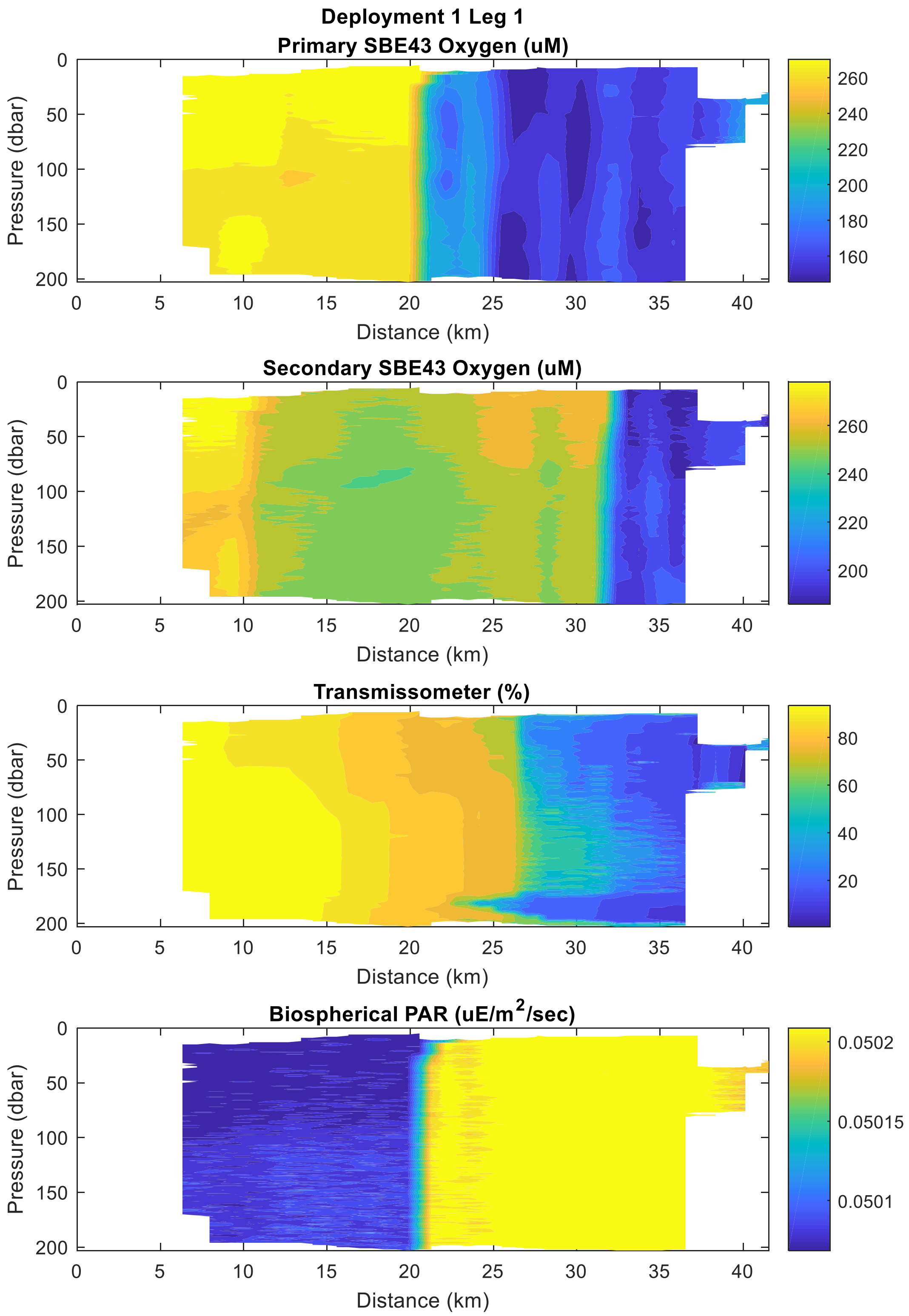
Deployment – relates to one instance of the Triaxus entering the water, being towed for a period of time and followed by retrieval from the water.

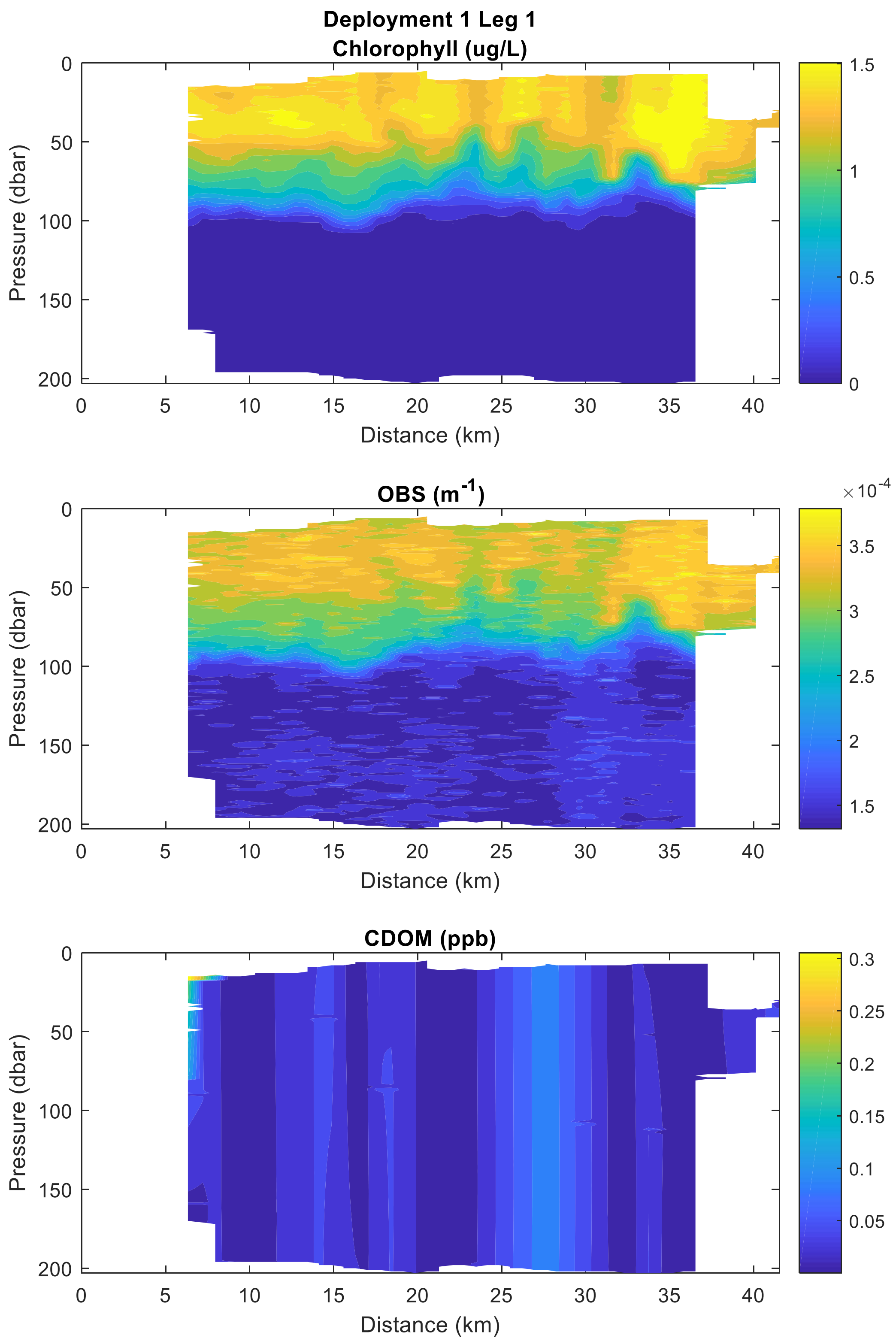
Leg – relates to a 'section' of the deployment containing a feature of interest, whether it be an eddy, geographic region etc. This can be part of or the whole deployment.

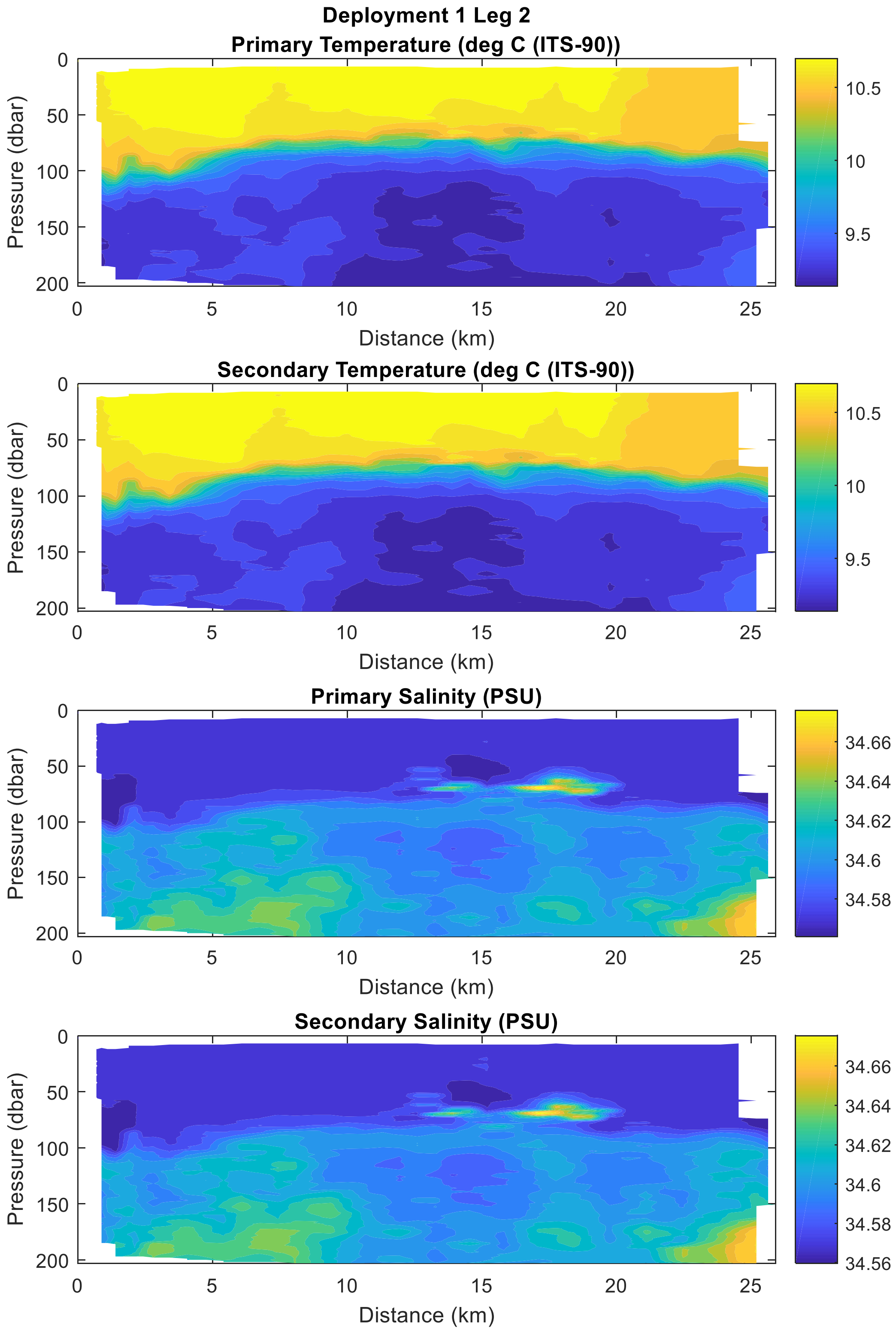
Scan file – a file structure containing data collected from the deployment of the CTD and auxiliary sensors.

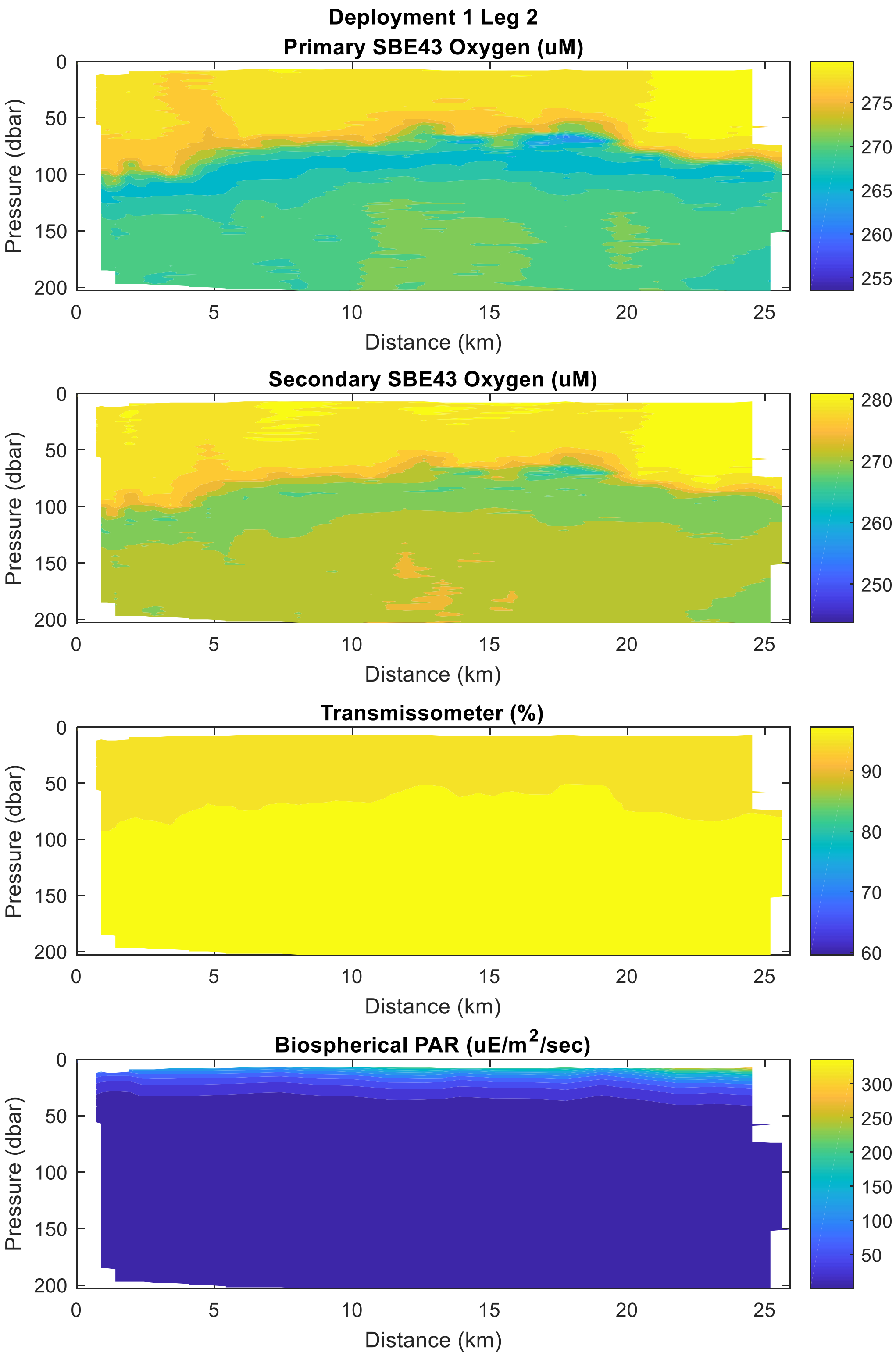
6 Appendix I: Section Plots

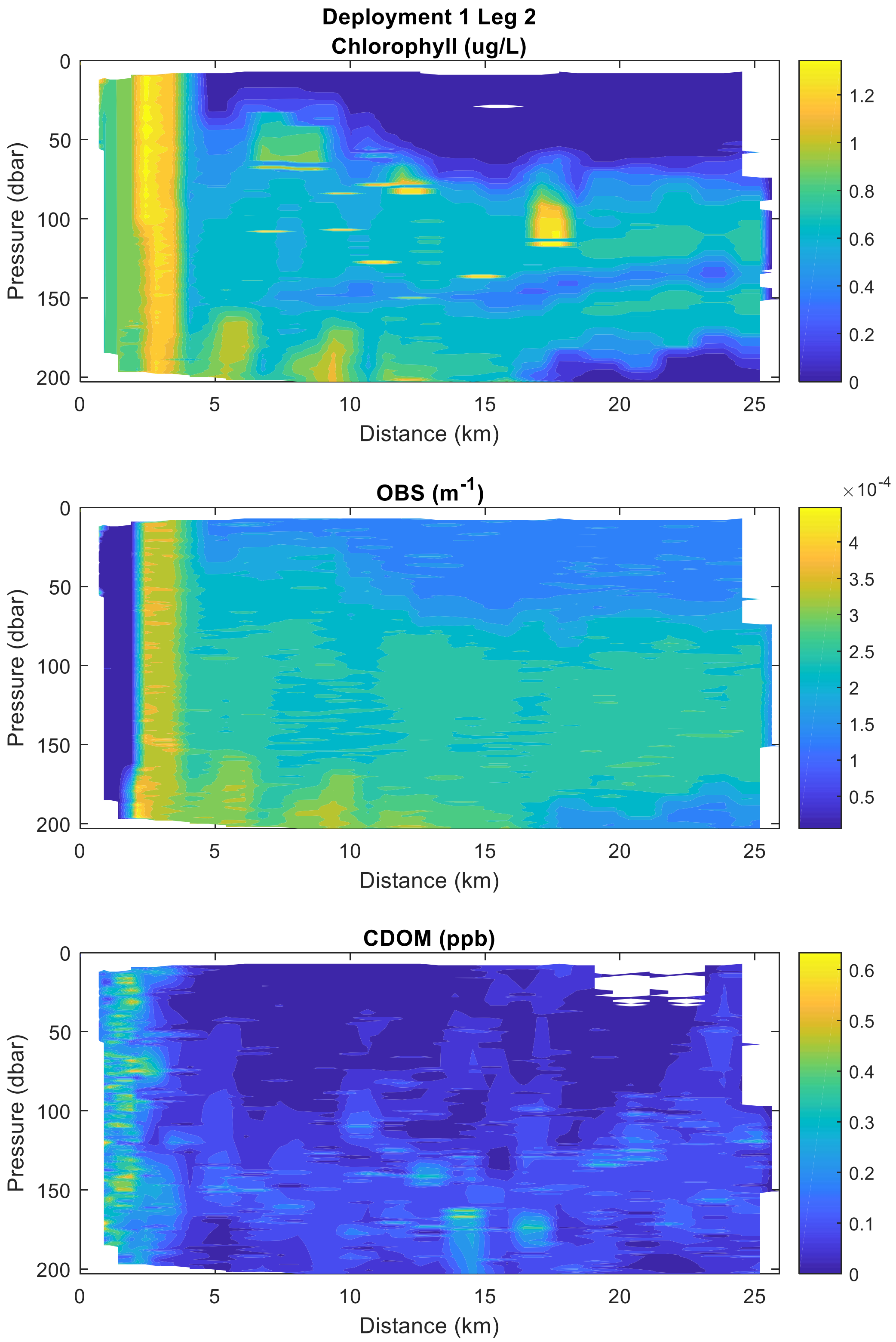


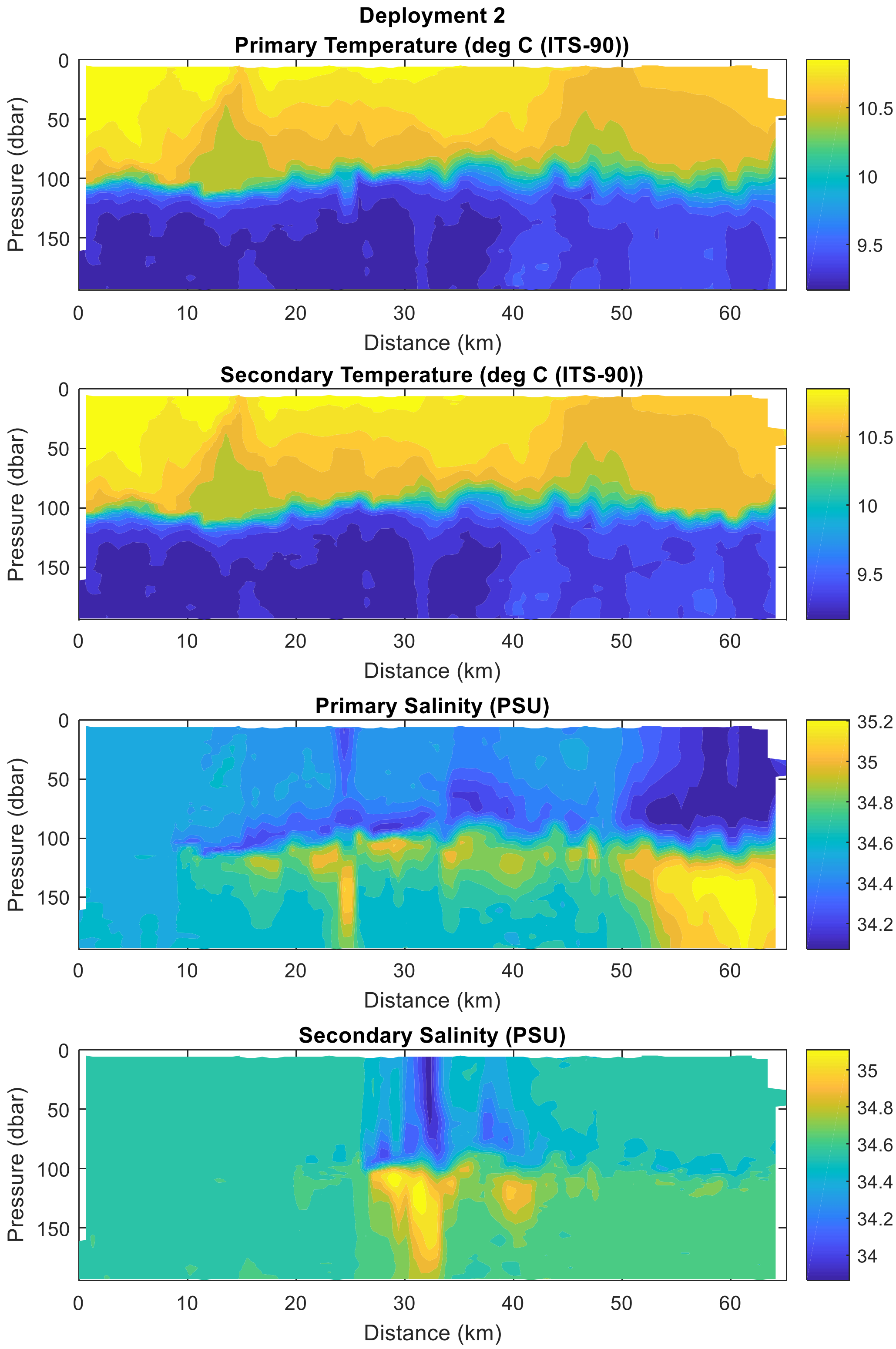

Deployment 1 Leg 1
Primary SBE43 Oxygen (uM)
Pressure (dbar)
Distance (km)
Secondary SBE43 Oxygen (uM)
Pressure (dbar)
Distance (km)
Transmissometer (%)
Pressure (dbar)
Distance (km)
Biospherical PAR (uE/m2/sec)
Pressure (dbar)
Distance (km)

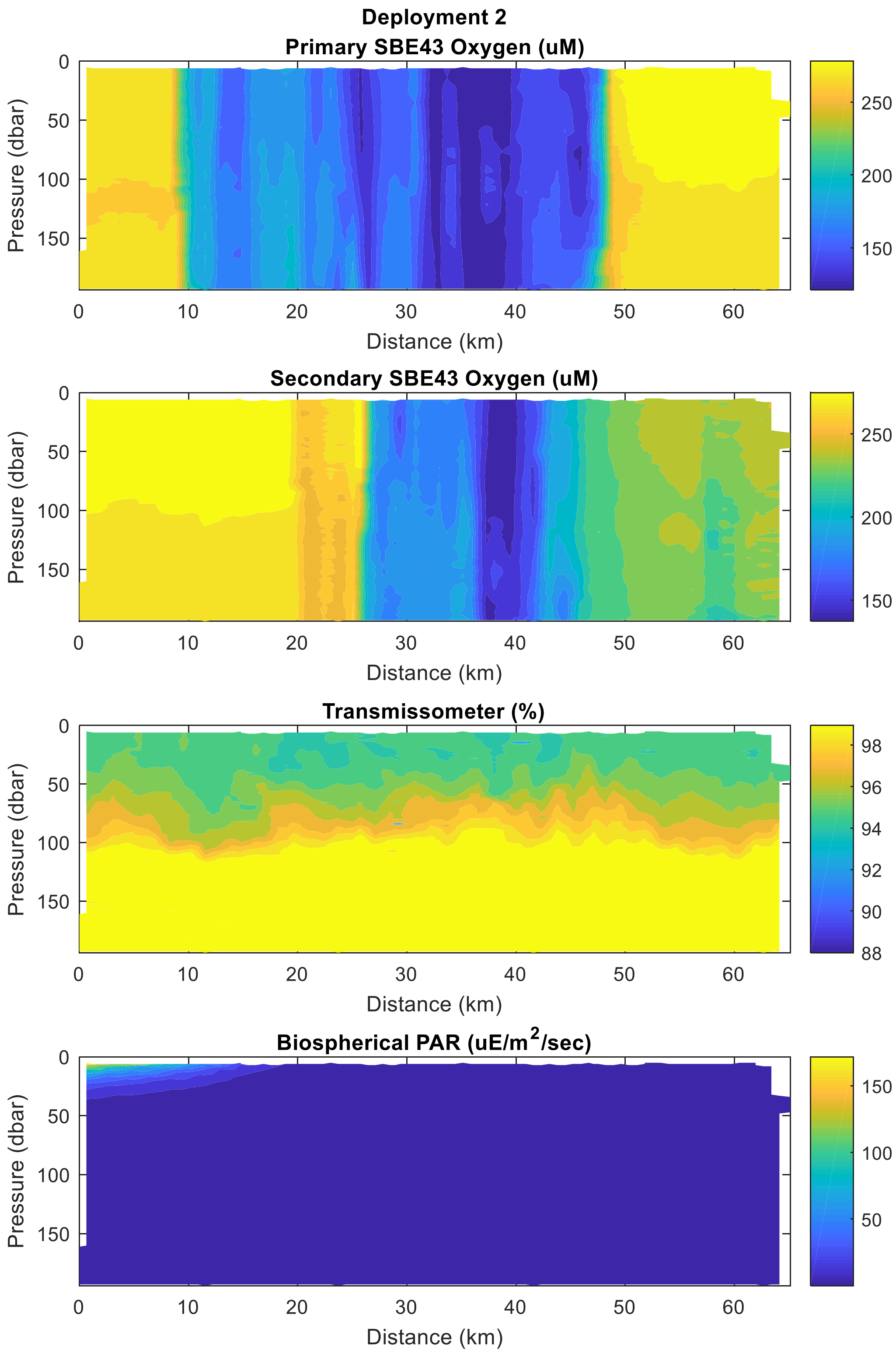

Deployment 1 Leg 1
Chlorophyll (ug/L)
Pressure (dbar)
Distance (km)
OBS (m^{-1})
× 10^{-4}
Pressure (dbar)
Distance (km)
CDOM (ppb)
Pressure (dbar)
Distance (km)


Deployment 1 Leg 2
Primary Temperature (deg C (ITS-90))
Pressure (dbar)
Distance (km)
Secondary Temperature (deg C (ITS-90))
Pressure (dbar)
Distance (km)
Primary Salinity (PSU)
Pressure (dbar)
Distance (km)
Secondary Salinity (PSU)
Pressure (dbar)
Distance (km)

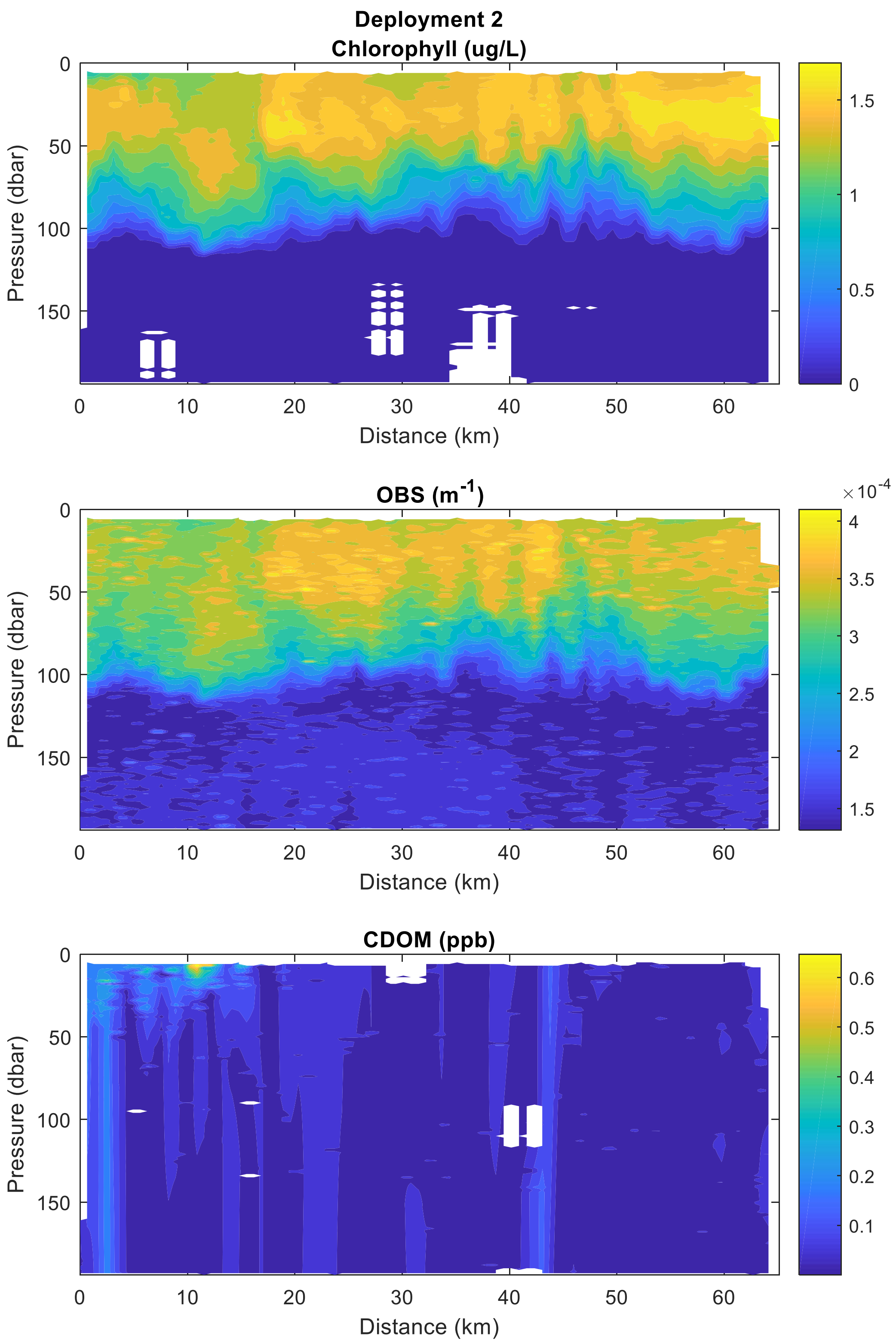

Deployment 1 Leg 2
Primary SBE43 Oxygen (uM)
Pressure (dbar)
0
50
100
150
200
0
5
10
15
20
25
Distance (km)
275
270
265
260
255
Secondary SBE43 Oxygen (uM)
Pressure (dbar)
Distance (km)
280
270
260
250
Transmissometer (%)
Pressure (dbar)
Distance (km)
90
80
70
60
Biospherical PAR (uE/m2/sec)
Pressure (dbar)
Distance (km)
300
250
200
150
100
50

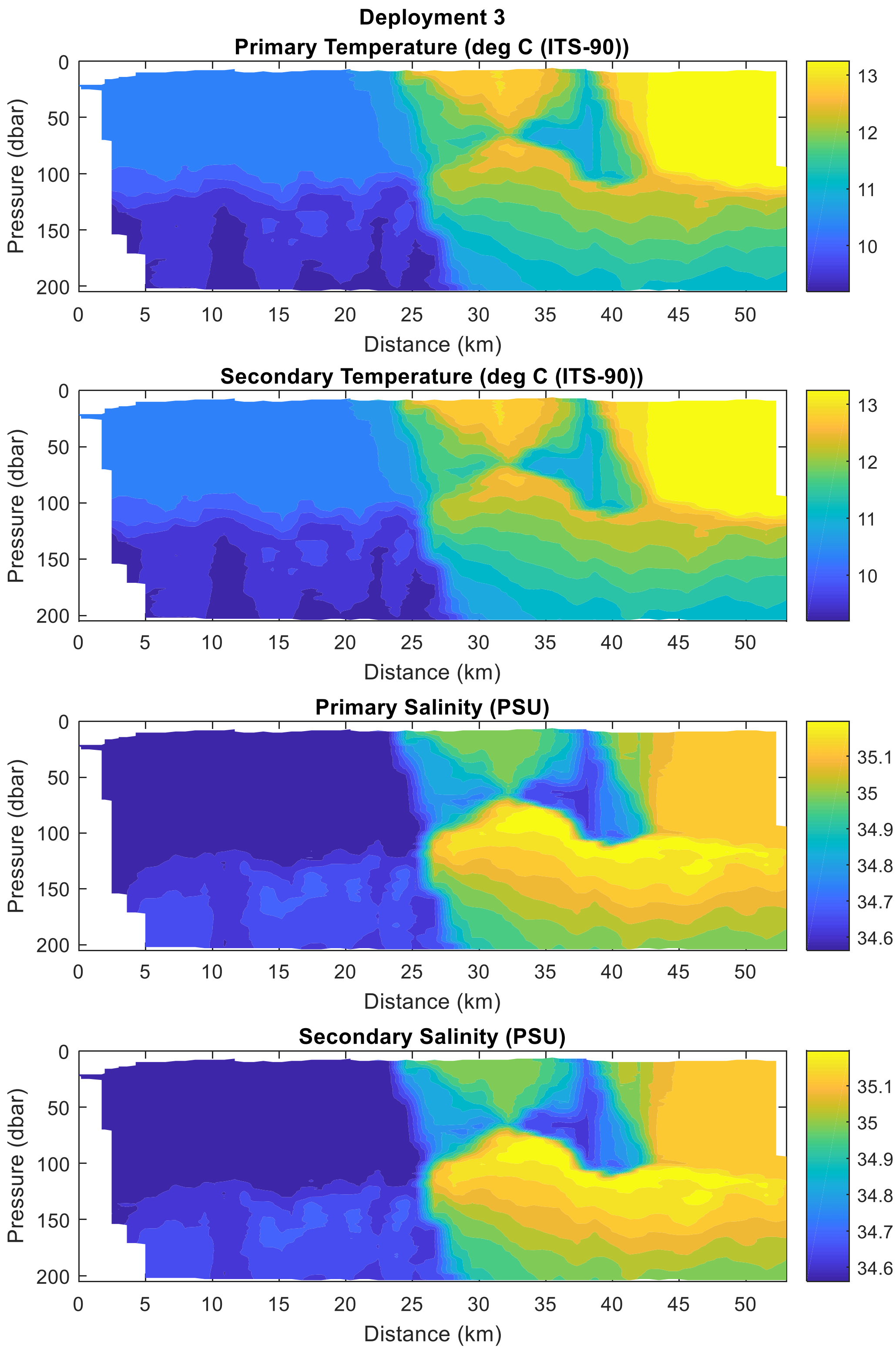

Deployment 1 Leg 2
Chlorophyll (ug/L)
Pressure (dbar)
Distance (km)
OBS (m^{-1})
×10^{-4}
Pressure (dbar)
Distance (km)
CDOM (ppb)
Pressure (dbar)
Distance (km)

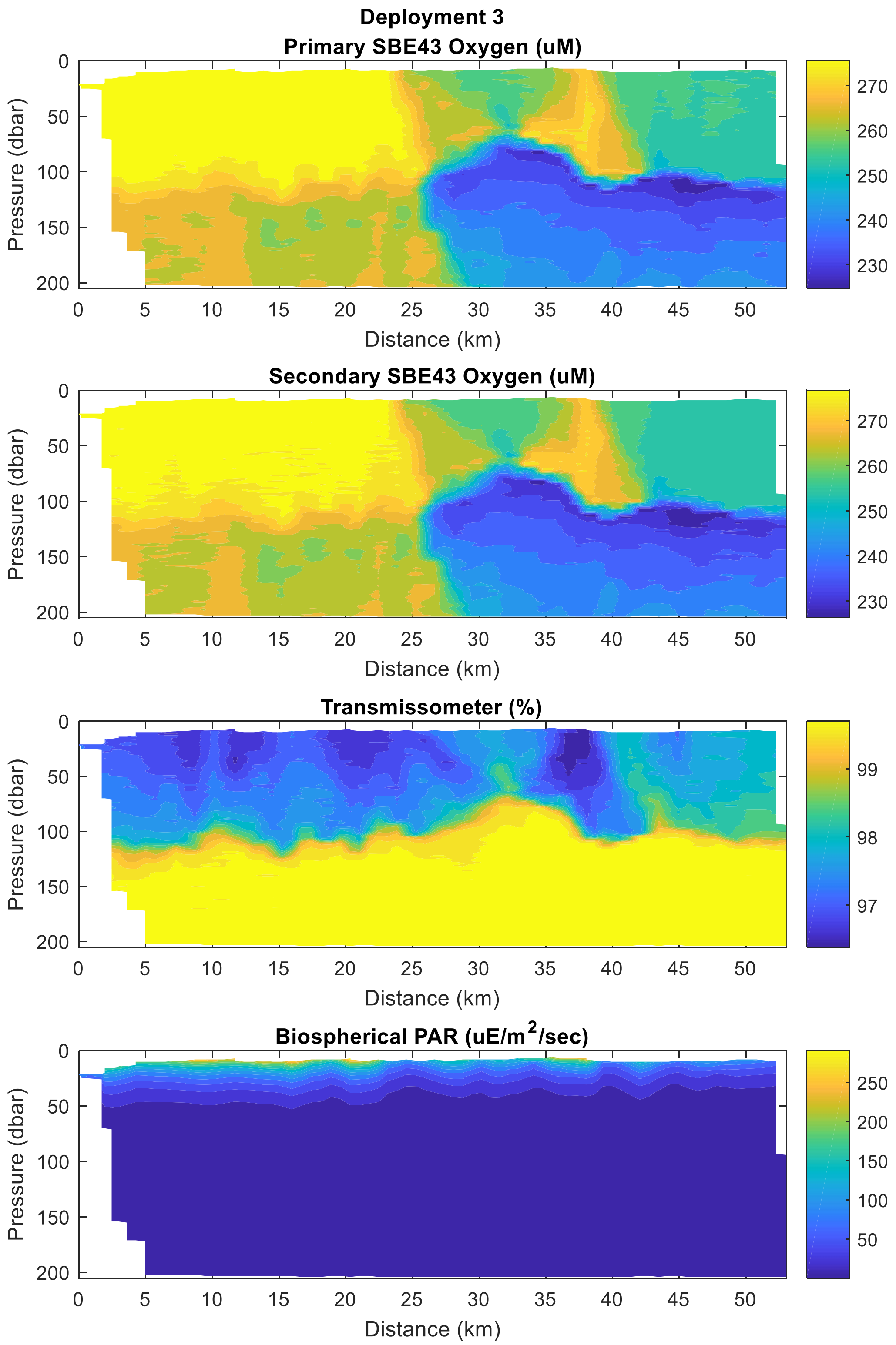

Deployment 2
Primary Temperature (deg C (ITS-90))
Pressure (dbar)
Distance (km)
Secondary Temperature (deg C (ITS-90))
Pressure (dbar)
Distance (km)
Primary Salinity (PSU)
Pressure (dbar)
Distance (km)
Secondary Salinity (PSU)
Pressure (dbar)
Distance (km)

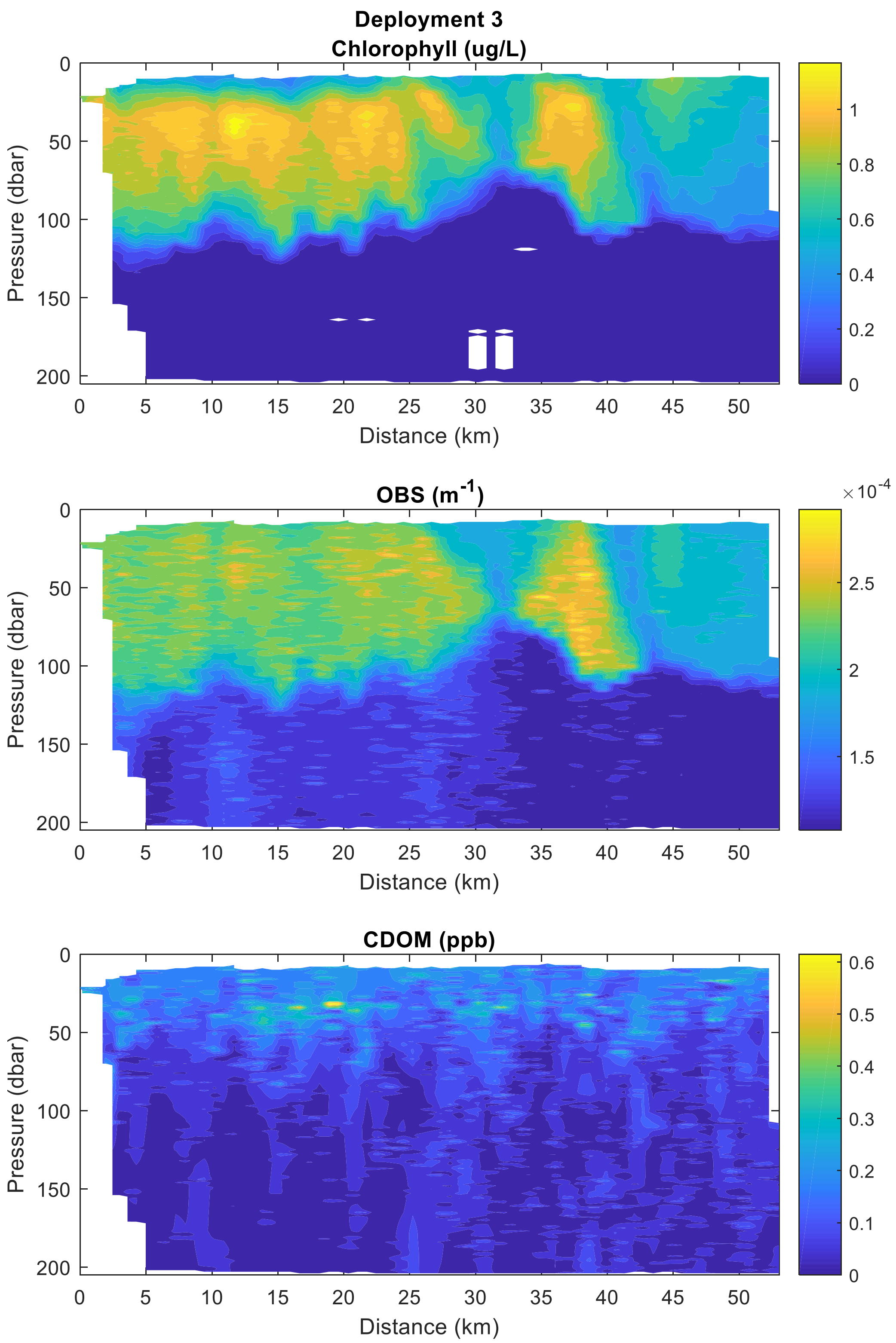


Deployment 2
Primary SBE43 Oxygen (uM)
Pressure (dbar)
Distance (km)
Secondary SBE43 Oxygen (uM)
Pressure (dbar)
Distance (km)
Transmissometer (%)
Pressure (dbar)
Distance (km)
Biospherical PAR (uE/m2/sec)
Pressure (dbar)
Distance (km)


Deployment 2
Chlorophyll (ug/L)
Pressure (dbar)
Distance (km)
0
50
100
150
0
10
20
30
40
50
60
1.5
1
0.5
0
OBS (m^{-1})
$\times 10^{-4}$
4
3.5
3
2.5
2
1.5
CDOM (ppb)
0.6
0.5
0.4
0.3
0.2
0.1


Deployment 3
Primary Temperature (deg C (ITS-90))
Secondary Temperature (deg C (ITS-90))
Primary Salinity (PSU)
Secondary Salinity (PSU)
Pressure (dbar)
Distance (km)
0
50
100
150
200
5
10
15
20
25
30
35
40
45
50
13
12
11
10
35.1
35
34.9
34.8
34.7
34.6


Deployment 3
Primary SBE43 Oxygen (uM)
Secondary SBE43 Oxygen (uM)
Transmissometer (%)
Biospherical PAR (uE/m2/sec)
Pressure (dbar)
Distance (km)
0
50
100
150
200
5
10
15
20
25
30
35
40
45
50
270
260
250
240
230
99
98
97
250
200
150
100
50


Deployment 3
Chlorophyll (ug/L)
Pressure (dbar)
Distance (km)
OBS (m^{-1})
×10^{-4}
Pressure (dbar)
Distance (km)
CDOM (ppb)
Pressure (dbar)
Distance (km)