Cruise Report

R.S. Ellen Khuzwayo – Voyage 188

21 March – 2 April 2019

Oceanographic Survey of the Eastern and Central Agulhas Bank (South Africa)

Chief Scientist

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Nelson Mandela University

2019

Version 2 – 30/07/2021

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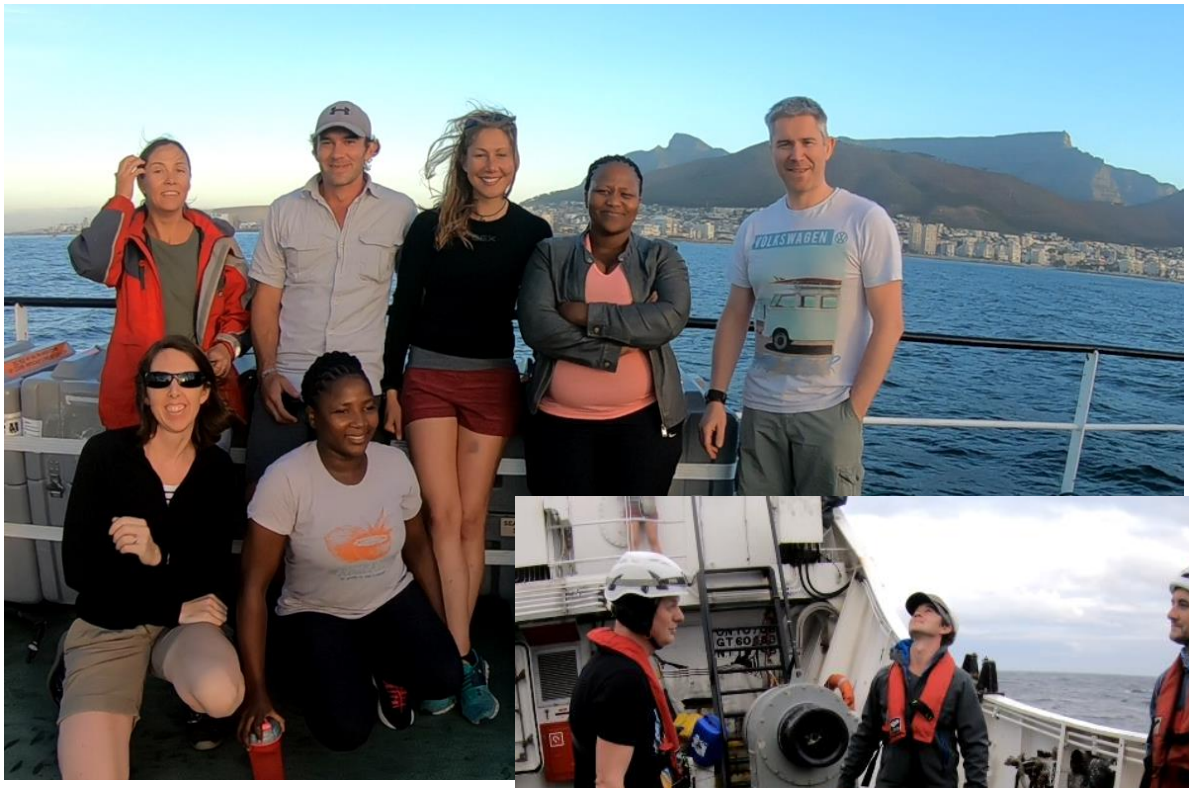
SCIENTIFIC PERSONNEL

Name	Role	Institution
Margaux Noyon	Chief Scientist	Nelson Mandela University
Alex Poulton	Co-PI	Heriot-Watt University
Sari Giering	Scientist	NOC Southampton
Brian Godfrey	Scientific technician	Nelson Mandela University
Riaan Weitz	Intern/Technician	Nelson Mandela University
Sixolile Mazwane	PhD Student	Nelson Mandela University
Lisa Martinengo	PhD Student	Nelson Mandela University
Nwabisa Malongweni	PhD Student	Nelson Mandela University
Stephen Woodward	(Glider) Scientific engineer	MARS, NMF-SS, NOC Southampton
Patrick Hayes-Foley	CTD Operator/Electronics Technician	DAFF



Top picture: *Left to right – Top row*: Lisa Martinengo, Riaan Weitz, Sari Giering, Sixolile Mazwane, Alex Poulton; *Bottom ro* Margaux Noyon, Nwabisa Malongweni

Side picture: *left:* Stephen Woodward, *centre*: Riaan Weitz, *right*: Brian Godfrey

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ABSTRACT

This cruise is part of the large international project named Sustainable Oceans, Livelihoods and food Security Through Increased Capacity in Ecosystem research in the Western Indian Ocean (SOLSTICE-WIO, funded by the Global Challenges Research Fund). One of the three SOLSTICE case studies is to investigate the reasons for the fluctuations of squid catches on the Agulhas Bank. One of these decreases occurred in 2013 and had dramatic consequences on the local, already underprivileged population. The Agulhas Bank is surrounded by a highly productive Benguela Current to the west, and the strong and warm Agulhas Current flowing along its shelf break. It is a highly dynamic region and, despite being well known for its role as a spawning ground for many fish species, including the local "Chokka" squid (*Loligo reynaudii*), very little work has been done on the central and eastern Agulhas Bank. This cruise aimed to better understand the ecosystem functioning and oceanography on the bank, with a focus on upwelling cells and how these may impact productivity. Phytoplankton and zooplankton measurements have been performed at 50 stations, spread out on the eastern and central Agulhas Bank. Vertical fluxes were also investigated at inshore and offshore stations to learn about the mechanisms of benthic nepheloid layer formation, events that are often observed on the coast and may impact squid mating behaviour. During this cruise, 4 moorings and 3 gliders were also recovered. Overall the cruise was successful and managed to achieve a high level of work over a short time.

1. RATIONALE

This cruise is part of a multi-disciplinary project SOLSTICE-WIO (Sustainable Oceans, Livelihoods and food Security Through Increased Capacity in Ecosystem research in the Western Indian Ocean), funded by the Global Challenges Research Fund (GCRF). The South African case study (others in Kenya and Tanzania) focuses on the reasons for the collapse of the squid fishery in 2013 that resulted in dire circumstances for the fishery and fishers. The project results will be assimilated into future management plans through the Squid Working Group forum.

The South African case study has three hypotheses for the collapse of the squid fishery:

1. Abnormally high benthic turbidity events on the squid spawning grounds between Plettenberg Bay and Port Alfred thwarted successful spawning in the summer of 2011-12
2. Abnormally low production on the Central and Eastern Agulhas Bank, linked to the absence of Cold Ridge in the summer of 2011-12, leading to starvation and high mortality of squid paralarvae
3. Abnormal Agulhas Current boundary activity such as Natal pulses and meanders, causing offshore advection of the squid paralarvae, and removal from the ecosystem

Several approaches are being used in the SOLSTICE-WIO project to investigate these hypotheses: modelling (NEMO-Medusa) and remote sensing, as well as field studies where traditional oceanography and gliders are used. This report deals with the oceanographic activities that have been performed on the east and central Agulhas Bank in March 2019 from the R. V. Ellen Khuzwayo, which includes the recovery of three gliders that had been deployed prior to the cruise. Most of the data collected will form a major component of three PhD projects.

2. OBJECTIVES

The cruise aims to study the pelagic ecosystem (*i.e.* physical, chemical and biological oceanography) over the Eastern and Central Agulhas Bank (South Africa) which is a major spawning area for many commercial fisheries including the Chokka squid (*Loligo reynaudii*).

Squid usually mate using a complicated mating behaviour and spawn in the shallow coastal region of the East Agulhas Bank where temperature is optimal for egg development. Despite this, squid have also been seen to spawn in deeper and cooler waters where eggs need two to three times longer to develop. It was hypothesised that the optimal inshore spawning ground were perhaps avoided due to the presence of a dense hyperbenthic layer of particles (Benthic or Bottom Nepheloid Layer, BNL) which might disturb squid mating behaviour. Other observations showed a correlation between the presence of plankton (phytoplankton and zooplankton) and an oceanographic mesoscale feature, named the “Cold Ridge” (CR). The CR is a sub-surface tongue of cold water located in the region expanding from Tsitsikamma towards Mossel Bay and then offshore, following the 100m isobath. It is present only in some years and can also vary in intensity. The processes involved in the formation of the CR are not fully understood. Some authors suggested that it is related to coastal wind-driven upwelling while others attribute it to the divergence of the Agulhas Current offshore. The CR might have an indirect link with the squid fisheries as a result of productivity over the central AB. After hatching, squid paralarvae only have 3 to 5 days to find food before starvation. It is hypothesised that squid paralarvae feed on the abundant zooplankton located in the CR to survive that critical period of their life cycle. In the absence of a CR, the zooplankton drift further west beyond the reach of the squid - leading to low survival rates.

The three overall key questions that this cruise will attempt to address are:

i) What is the composition of the vertical fluxes on the Agulhas Bank and how do they vary spatially?
ii) How is the Cold Ridge formed? What are the physical processes at its origin? What is the circulation on the East and Central Agulhas Bank?
iii) How productive is the Eastern and Central Agulhas Bank? What are the bio-physical interactions and the main drivers of productivity on the Bank?

3. CRUISE NARRATIVE

Chief Scientist Diary:

(all times are in local time here)

Tuesday 19 March

Mobilisation on the R. V. Ellen Khuzwayo. The whole scientific team met up on the ship in the Cape Town harbour to set up the laboratories and check all the winches for deployment of the various instruments brought onboard. All the equipment was loaded on the ship that morning. The laboratories (normally used for fisheries surveys) needed some adjustment to increase the space available for the scientific team to work adequately. A large wooden board was fitted on top of the sorting table for instance. The incubation boxes used for the primary production experiments were set up on the upper deck and the water flowing system fitted. The ship's crew was extremely helpful in facilitating our installation. A full day of work had not been enough to set up and lash everything on the vessel. We planned to come back early the next day to finalise everything before sailing which was scheduled for 18:00 on the 20th of March.

Wednesday 20 March

We all met on the ship early and finalised the preparations. The CTD rosette was delivered late on that day. We also had to top up the dry shipper with liquid nitrogen, which happened to be complicated due to the electrical load shedding that South Africa was experiencing at the time. The Captain of the R. V. Ellen Khuzwayo was changed at the last minute. Finally, at about 18:00, we left the harbour in calm and sunny weather, contouring the Cape Peninsula.

Thursday 21 March

While everybody was getting their sea legs, we planned to do a "test" station to deploy all the instruments: CTD rosette, Marine Snow Catcher (MSC), Vertical and Oblique Bongo nets. All instruments had their own winch to avoid too many gear exchanges and it worked well. The starboard winch wire got stuck into the A-frame block and we lost 1 hour to undo the block and mount a new one. Unfortunately, because the CTD arrived late on the ship the day before, Patrick Hayes-Foley, the DAFF electronic technician, did not have enough time to finish all the connections. We would have to test the CTD the next day. Everything else worked well otherwise. The new Captain was not very used to deploy oceanographic instruments and thus several meetings occurred during that day to describe all the operations (*e.g.* mooring and gliders recovery, nets, MSC…). The -80˚C freezer had been switched on the day before, but the temperature would not drop. Some back-up plans were made to contact people ashore to bring extra liquid nitrogen containers. Eventually after several troubleshooting efforts and cleaning of the heat exchanger and compressor by the ship engineers, the freezer started cooling down and set at -80˚C. During that night, on our way eastwards, 3 satellite-tracked drifters were deployed at

three different locations on the mooring line. One of the gliders had stopped working and was located in proximity to Cape Recife (Port Elizabeth, west of Algoa Bay) but we would be there during night-time. We decided to not pick it up then to not loose time.

Friday 22 March

We are still sailing eastwards in beautiful weather conditions. We are finishing off organising the laboratories, the shifts and station numbering. We stopped to deploy the CTD which worked well. Our estimated time to start the survey was soon after midnight. We decided to start with the shallow inshore station 1.1.

Saturday 23 March

We did the first four stations of transect 1 (off Port Alfred), but the weather conditions deteriorated. Stations 1.4 was partially done with 25 knots wind, gusting 30 knots. We decided to skip the furthest offshore station 1.5., knowing that the conditions would be even worse in the Agulhas Current. We started the second transect with the offshore station 2.3. The night arrived and the weather conditions were not improving. After discussion with the Captain, we decided to stop the operations and went inshore to shelter from the wind. The weather predictions were showing storm-like conditions for the next day or two. The zone being well known for its strong wind, the decision was made to steam to St Francis Bay and skip the whole of Algoa Bay (transects 3 & 4). This allowed us to escape the bad weather and to save days in case of other bad weather events. We decided that a better coverage for the rest of the cruise was a better strategy than waiting for the weather to improve.

Sunday 24 March

The vessel arrived at 3am close to station 5.2, in St Francis Bay. The sea conditions were good, and we decided to go inshore to start sampling transect 5. The wind was very still for the first two stations but increased after that to a steady 20 knots. It was nonetheless workable, and we managed to do 9 stations. Station 6.4 was done in the dark with strong winds, but the scientists and the crew seem to work well despite the far from ideal conditions. We decided to interrupt the survey before moving to transect 7 to recover the first glider that was not working properly as it was located in the vicinity of St Francis Bay.

Monday 25 March

Station 6.1 was finished around 1:00 and the vessel steamed eastwards in St Francis Bay (~4h). We needed to be early in the morning in range of cell phone connection for the pilots to get the latest coordinates of the faulty glider. We headed south towards the glider location and retrieved it easily at about 7:15. We then steamed towards station 7.1. Arrived there at 15:00 and started sampling. The 6 stations of transect 7 were sampled on that day. People were getting into a routine by then and operations were going smoothly.

Tuesday 26 March

The vessel steamed towards station 8.6. (offshore station) at night and arrived there early in the morning. The whole transect was done without any issues. Station 8.1 was finished at about 18:00 and the vessel sailed towards station 9.1. A CTD was deployed just before the wind speed increased to about 30 knots. All operations were interrupted until further notice. Operating in bad weather conditions in the dark were too dangerous for the people working on deck. We decided to stay at this location and wait for the weather to improve.

Wednesday 27 March

At 4am, the wind calmed down to below 20 knots. The conditions were not ideal, but it was daylight and we decided to start sampling. We redeployed the CTD at station 9.1. to have all the parameters collected

at the same time. Transect 9 was finished around 17h30 and we steamed towards transect 10. Stations 10.6 to 10.4 were sampled, making a total of 8 stations sampled on that day.

Thursday 28 March

Once station 10.1 was finished, we steamed to station 11.1 and sampled 8 stations in total on the 28th of March. Station 11.4 had to be cancelled as it was too close to the Mossel Bay oil rig. The wind picked up again on transect 11. The ship was struggling to keep her position which resulted in some deployment being more "oblique" than vertical. One of the scientists got injured deploying the MSC, nothing that required intervention however.

Friday 29 March

Transect 12 was started in the middle of the night and was finished without any issues and under beautiful weather conditions by 19:00. We had been watching the weather forecast and the position of the gliders very carefully all along. We opted to recover the moorings first, and then sail back eastwards to recover the gliders. This was the best strategy at the time considering our location (close to the mooring line), the position of the gliders, the fact that all these operations have to be done during daytime and our need to get closer to the coast to get updates on weather and glider position. We therefore steamed towards CR4, the offshore mooring. We will also do one extra CTD at dawn every morning so we can do more primary production incubations. We are not working on shift anymore.

Saturday 30 March

The CTD at dawn was done to get seawater for the primary production incubations. We successfully recovered the 4 moorings that had been deployed in October 2018. The weather conditions were perfect. The crew and scientists worked very well together, and everything went very smoothly to the point that we were done by 13:00!! Finally, we headed east to retrieve the two gliders that were still operational. The two gliders were far apart by then. The furthest east was about to get into the Agulhas Current offshore St Francis Bay area while the other one was relatively inshore near Tsitsikamma. The weather forecast was predicting very bad weather for the 1st of April. Hence if both gliders could not be recovered on the 31st of March, we would have had to shelter and wait a full day before recovering the last one. We decided to go to the most easterly position first, hoping to get there the next day at first light, recover the Seaglider, steam west towards the last glider and hopefully recover it before sunset before the sea conditions deteriorated.

Sunday 31 March

We deployed a CTD at dawn for the primary production incubations and to obtain nutrient samples to calibrate the Seaglider nutrient data. The CTD wire was also rinsed with freshwater at the same time. We then started to look for the Seaglider which was by then in the Agulhas Current, drifting fast. It took 3 hours and many pairs of eyes to finally find the glider and several attempts to recover it (in less than optimal sea conditions). The vessel went back inshore towards the last glider. The estimated time of arrival was 16:30, leaving only 1 hour of daylight to find and recover the glider. Soon after 17:00, the glider was found and recovered easily since the sea conditions were very good inshore. We were now on route towards Cape Town, with a storm ahead of us. We had started to pack some of the equipment and secure everything.

Monday 1 March

Very few people managed to sleep that night due to the extremely bad weather on the central Agulhas Bank. The average cruising speed had been down to only 3 knots at one stage during the night. On that morning, our estimated time of arrival was delayed to sometimes in the afternoon of the 2nd of March. The sea conditions somehow improved during the day however and we were making progress.

Tuesday 2 March

We finally arrived in Cape Town harbour in the morning of the 2nd of March after 13 days at sea.

Overall, with the exception of the two transects in Algoa Bay that we could not sample due to bad weather, the cruise was successful and allowed a relatively good coverage of the eastern and central Agulhas Bank. With her size, draught and basic equipment, the RV Ellen Khuzwayo is a perfect ship for coastal and shelf oceanography, despite the limited number of berths. The crew was enthusiastic and very helpful in assisting us during the cruise and are thanked again.

4. SCIENTIFIC REPORTS

4.1. Drifter deployment

Lisa Martinengo and Brian Godfrey

Satellite-tracked drifters were deployed at mooring locations CR1, CR2 and CR4 on 21 March 2019. The drifters were supplied by South African Weather Service and forms part of NOAA Surface Velocity Programme. Drifter deployment details are given in Table 1.

Table 1: Drifter Deployment details

Deployment reference	Drifter WMO ID	Date and time (GMT +2)	Latitude	Longitude
CR1	1701560	21/03/2019 23:57	34° 24.484' S	22° 25.729' E
CR2	1701562	22/03/2019 01:13	34° 33.381' S	22° 30.987' E
CR4	1701558	22/03/2019 03:50	34° 52.259' S	22° 42.258' E

Drifter data was downloaded from http://osmc.noaa.gov/erddap/tabledap/OSMC_30day.html. Figure 1 and Figure 2 show the trajectories up to 30 April 2019.

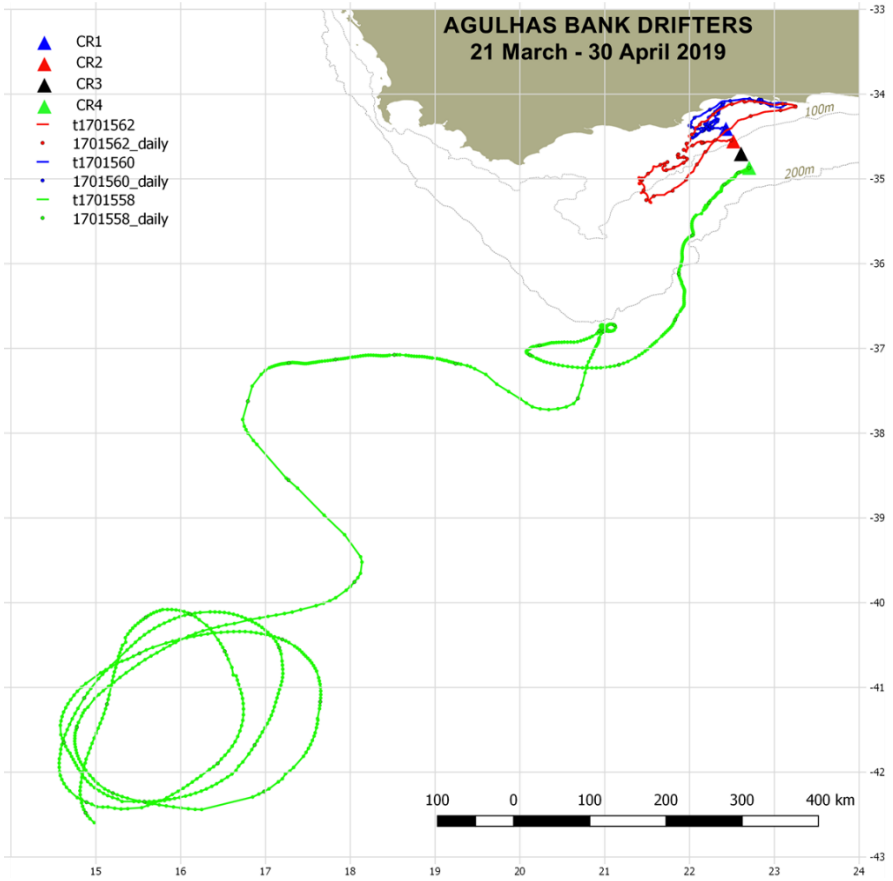


Figure 1: Trajectories of the drifters deployed on the Agulhas Bank in March 2019

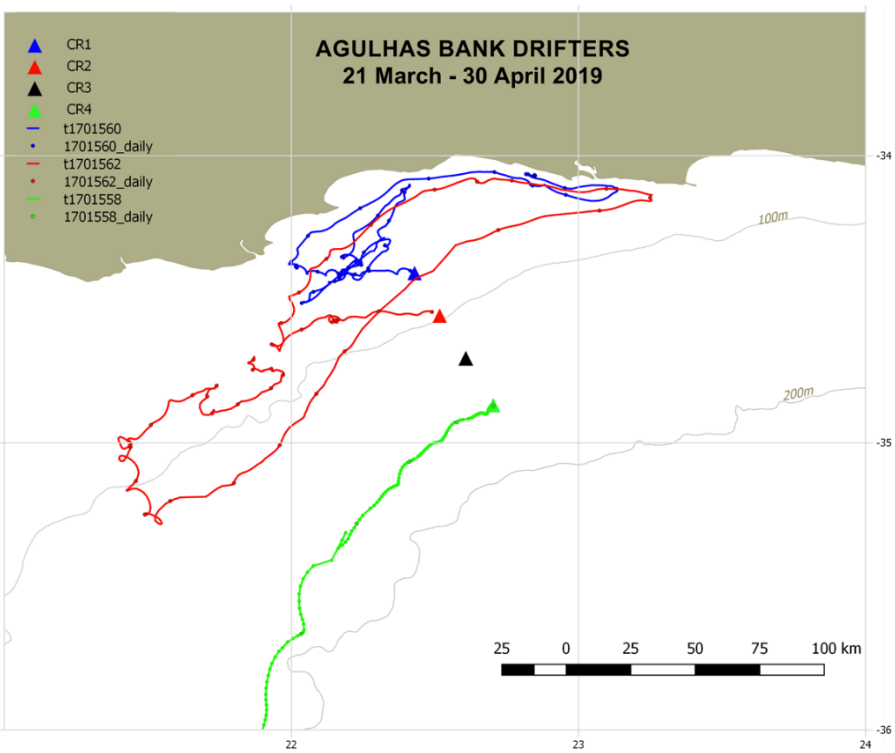


Figure 2: Zoom on the drifters' trajectories deployed on the Agulhas Bank in March 2019

4.2.CTD operations and calibration

Patrick Hayes-Foley and Brian Godfrey

A Seabird 911+ V2 CTD system was used, coupled with a Seabird 32 Carousel/Rosette which had 12 Niskin bottles fitted of 8L capacity each.

Of a total of 63 planned grid sampling stations, a total of 50 CTD profiles and rosette sampling were conducted (Figure 3). One station (9.1) was repeated due to poor weather conditions preventing a full station to be competed. The stations that weren't sampled were largely excluded because of bad weather but one station was inaccessible because it was in an exclusion zone for oil and gas drilling operations. In addition, a CTD profile was conducted at each of the ADCP Mooring sites during recovery of these arrays (four), as well as at each of the recovery sites of the two gliders at the end of the cruise (Gliders 550 and OMG3). This brought the total number of stations to 56. At all stations a full depth profile was conducted to as close to the seafloor as possible.

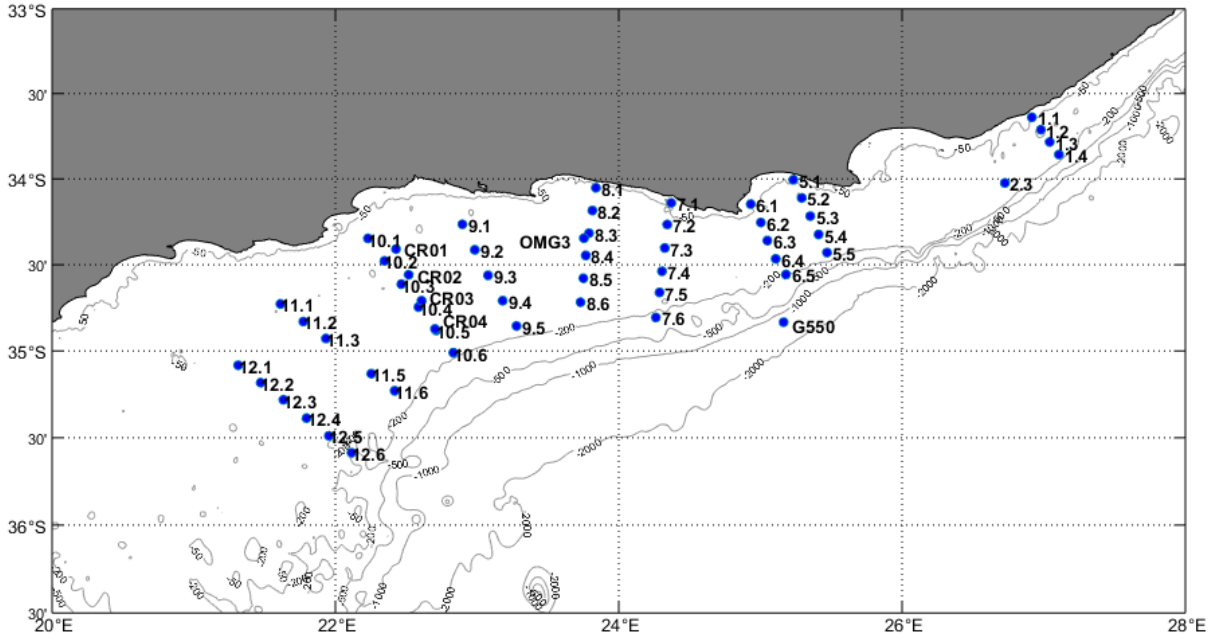


Figure 3: Maps of all the CTD deployed on the Agulhas Bank in March 2019

CTD specification and other instruments

See **Appendix 1** for details of CTD system

The CTD configuration file (*.xmlcon) was derived from the existing file stored on the CTD computer which was transferred from another vessel prior to the cruise. Unbeknownst to the CTD operators on board the ship during this cruise, the acquisition of the 24Hz data from the SBE 9 was averaged to one second. This was only noticed at the end of the cruise, prior to the last two dips at the glider recovery positions.

In addition to the sensor package mounted on the CTD, a sPAR sensor was fitted on the foremast to measure ambient atmospheric light during dips (Biospherical QSR-2200, SN 20473, calibrated 09-Apr-14).

Two additional, independent instruments were mounted on the CTD frame. A Seabird Environmental Characterization Optics (ECO) Triplet Fluorometer and Backscattering sensor measured Chlorophyll-*a*/Fluorescence (excitation/emission 470/695 nm) and backscatter at two wavelengths in the green and red spectrum (532 nm and 700 nm, respectively at 124˚). The instrument was deployed on the horizontally on the rosette, facing outward and acquisition rate was 24Hz. This instrument was calibrated on 15-09-2017. An RBR XR-420 CTD was also mounted on the main CTD frame and this had an acquisition rate of 1 Hz. This instrument was calibrated on 30 November 2018.

The Niskin bottles from the rosette were triggered remotely (Fig. 4). Firing depths were decided for each cast while viewing the live downcast data and were triggered on the upcast (CTD was stopped for approximately 45s before closing a bottle and 30s after closure). Misfires of bottles were rare during the cruise and did not disrupt sampling procedures. Water from the sample bottles was used for the following purposes:

1. CTD Salinity/Conductivity Sensor Calibration
2. CTD Oxygen Sensor Calibration
3. TSG Calibration
4. Nutrient Sampling
5. Phytoplankton and Net Primary Production
6. BNL additional sampling

For CTD calibration purposes, salinity and DO samples were collected by Lisa Martinengo and Steven Woodward; and were analysed by Lisa Martinengo. Salinity measurements were done after the cruise in the laboratory at the University of Cape Town but the results revealed anomalies (due to issues during the analyses) preventing their use for calibration. Oxygen titrations (using the Winkler method) were used to measure bottle oxygen values on board, within 24h of collection.

Discrete Fluorescence measurements were performed on board using a Turner Trilogy instrument (refer to phytoplankton section).

CTD data processing and calibration:

See **appendix 2**

Table 2 shows the list of stations sampled with the CTD with the final coordinates.

Table 2: List of all the CTD stations and their GPS coordinates

Date (DDMM YYYY)	Station # (ship)	Grid #	Event #	ID	Latitude (Decimal) start	Longitude (Decimal) start	Time GMT (HH:MM)
23032019	3977	1.1	4	CTD001	-33.6393	26.91617	03:08
23032019	3978	1.2	8	CTD002	-33.7118	26.9806	05:02
23032019	3979	1.3	11	CTD003	-33.7841	27.04206	06:48
23032019	3980	1.4	13	CTD004	-33.8576	27.10749	08:37
23032019	3981	2.3	16	CTD005	-34.0235	26.7262	14:19
24032019	3982	5.1	18	CTD006	-34.0054	25.23236	02:19
24032019	3983	5.2	24	CTD007	-34.1113	25.29197	04:49
24032019	3984	5.3	27	CTD008	-34.2174	25.35214	06:52
24032019	3985	5.4	30	CTD009	-34.3242	25.41074	09:00
24032019	3986	5.5	33	CTD010	-34.4299	25.47033	11:13
24032019	3987	6.5	38	CTD011	-34.5574	25.18005	15:20
24032019	3988	6.4	41	CTD012	-34.4663	25.10844	17:24
24032019	3989	6.3	44	CTD013	-34.36	25.04927	19:15
24032019	3990	6.2	47	CTD014	-34.2548	25.00343	21:06
25032019	3991	6.1	50	CTD015	-34.147	24.93111	23:03
25032019	3992	7.1	53	CTD016	-34.1403	24.37065	12:40
25032019	3993	7.2	58	CTD017	-34.2662	24.34233	15:03
25032019	3994	7.3	62	CTD018	-34.403	24.3251	17:33
25032019	3995	7.4	65	CTD019	-34.5384	24.30575	19:25
25032019	3996	7.5	68	CTD020	-34.6614	24.28816	21:10
25032019	3997	7.6	71	CTD021	-34.8065	24.26207	23:22
26032019	3998	8.6	74	CTD022	-34.7184	23.73034	04:14
26032019	3999	8.5	79	CTD023	-34.579	23.7504	07:24
26032019	4000	8.4	83	CTD024	-34.4462	23.76745	09:18
26032019	4001	8.3	85	CTD025	-34.3169	23.79012	11:07
26032019	4002	8.2	88	CTD026	-34.1849	23.81442	12:50
26032019	4003	8.1	91	CTD027	-34.0519	23.83897	14:37
26032019	4004	9.1	96	CTD028	-34.2705	22.88987	21:05
27032019	4005	9.1	98	CTD029	-34.2653	22.8965	04:37
27032019	4006	9.2	103	CTD030	-34.4138	22.98389	07:38
27032019	4007	9.3	106	CTD031	-34.5623	23.07762	09:53
27032019	4008	9.4	109	CTD032	-34.7089	23.18063	11:59
27032019	4009	9.5	112	CTD033	-34.8558	23.27848	13:53
27032019	4010	10.6	117	CTD034	-35.0101	22.8322	18:40
27032019	4011	10.5	120	CTD035	-34.8814	22.71065	20:52
27032019	4012	10.4	123	CTD036	-34.7459	22.58647	23:19
28032019	4013	10.3	126	CTD037	-34.6132	22.46574	01:27
28032019	4014	10.2	129	CTD038	-34.478	22.34596	03:42
28032019	4015	10.1	134	CTD039	-34.3474	22.22966	06:16
28032019	4016	11.1	137	CTD040	-34.728	21.61237	11:38

Date (DDMM YYYY)	Station # (ship)	Grid #	Event #	ID	Latitude (Decimal) start	Longitude (Decimal) start	Time GMT (HH:MM)
28032019	4017	11.2	142	CTD041	-34.8299	21.77382	14:03
28032019	4018	11.3	145	CTD042	-34.9278	21.93299	16:21
28032019	4019	11.5	148	CTD043	-35.1312	22.25312	20:08
28032019	4020	11.6	151	CTD044	-35.23	22.41868	22:18
29032019	4021	12.6	156	CTD045	-35.5862	22.11443	04:07
29032019	4022	12.5	161	CTD046	-35.489	21.9539	06:50
29032019	4023	12.4	164	CTD047	-35.3871	21.79626	08:55
29032019	4024	12.3	167	CTD048	-35.2817	21.63318	11:00
29032019	4025	12.2	170	CTD049	-35.1831	21.47272	12:58
29032019	4026	12.1	173	CTD050	-35.0824	21.31328	14:53
30032019	4027	CR4	178	CTD051	-34.873	22.70348	04:06
30032019	4028	CR3	180	CTD052	-34.7089	22.60844	07:18
30032019	4029	CR2	182	CTD053	-34.5587	22.51729	08:56
30032019	4030	CR1	184	CTD054	-34.4095	22.42814	10:28
31032019	4031	glider550	186	CTD055	-34.8341	25.16411	04:32
31032019	4032	gliderOMG3	189	CTD056	-34.3462	23.75433	15:25

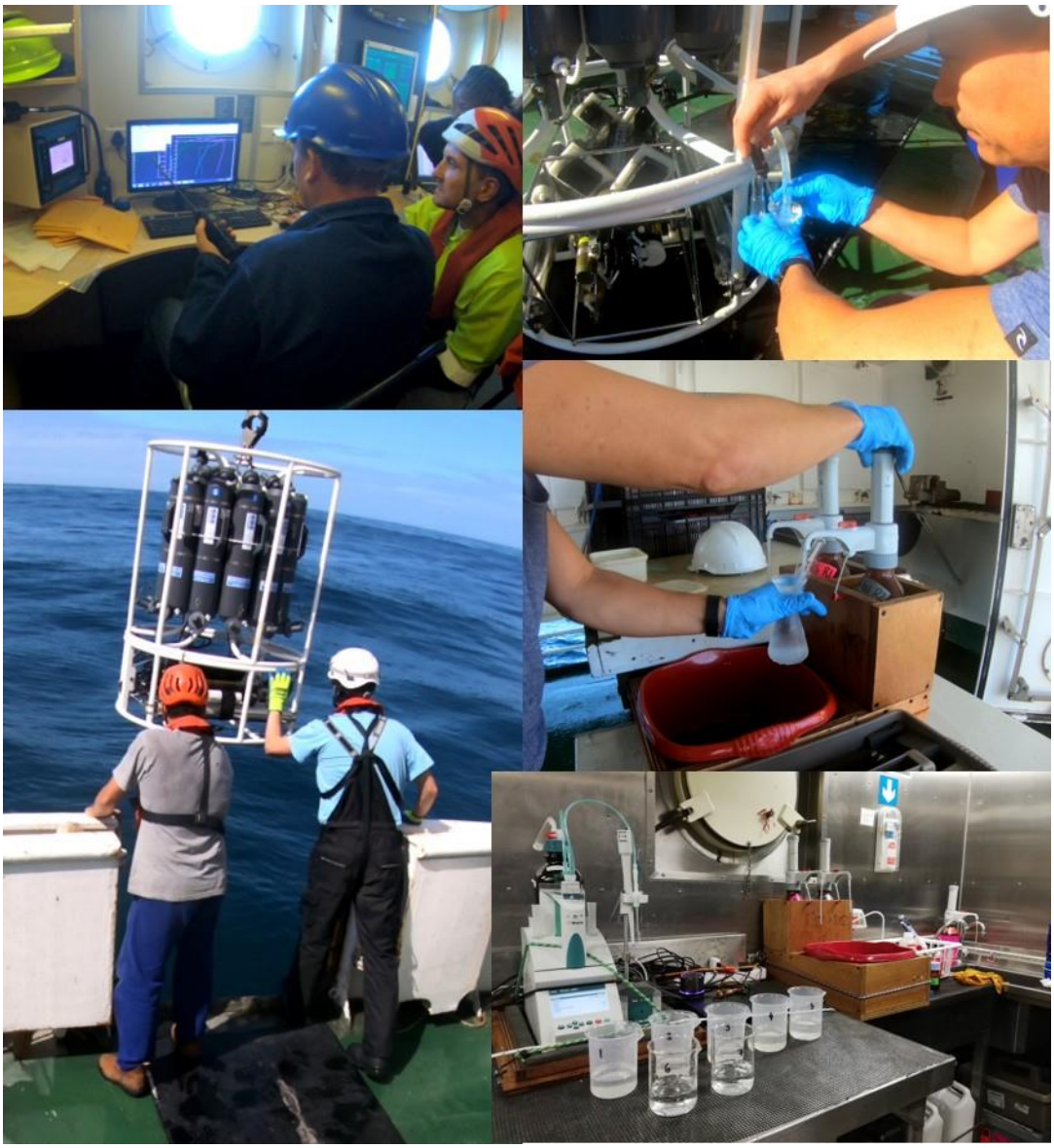


Figure 4: Pictures showing the CTD deployment and collection of dissolved oxygen samples for CTD calibration

4.3. Benthic Nepheloid Layer and Vertical Fluxes

Sarah Giering and Nwabisa Malongweni

The main objectives of the Benthic Nepheloid Layer (BNL) component were as follows:

- Determine the spatial distribution of the BNL on the bank
- Determine the biogeochemical composition of the BNL and the vertical fluxes through the water column
- Determine the microplankton community composition of the sinking and suspended particles
- Measure microbial activity (as bacterial respiration) associated with vertical fluxes

Deployment of the Marine Snow Catcher (MSC)

The MSCs were deployed using a dyneema rope with an A-Frame on the aft deck of the ship (Figure 5 and Figure 6). At each station, two MSCs were deployed at two different depths, apart from 2 stations where only one MSC was used (stn 1.1 and 7.2). The closing depth of the MSC was decided based on the temperature and turbidity profiles of the CTD. One MSC was deployed below the thermocline and the other one close to the seafloor. The depth of the MSC was estimated based on the "wire" out as the MSC did not have a live depth sensor. The device was then closed, using a messenger. Immediately after retrieval, the MSC was tightly secured onto the ship and the first sample was taken at time zero (T_0) from the top section containing suspended particles.

After 2 hours of settling time (T_f), another sample of suspended particles was taken from the top section, after which the MSC was drained and disassembled in order to sample the bottom section which contains the slow sinking and the fast sinking particles (i.e. tray) (Figure 7).

In addition, seawater was also sampled from the CTD rosette at the depth of maximum fluorescence (F-max).

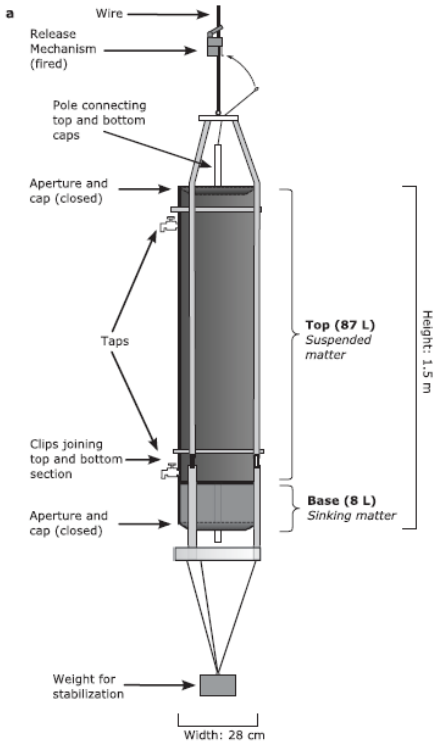


Figure 5: Schematic of a Marine Snow Catcher (from Giering et al. 2016)

Figure 6: Picture of the deployment of a Marine Snow Catcher

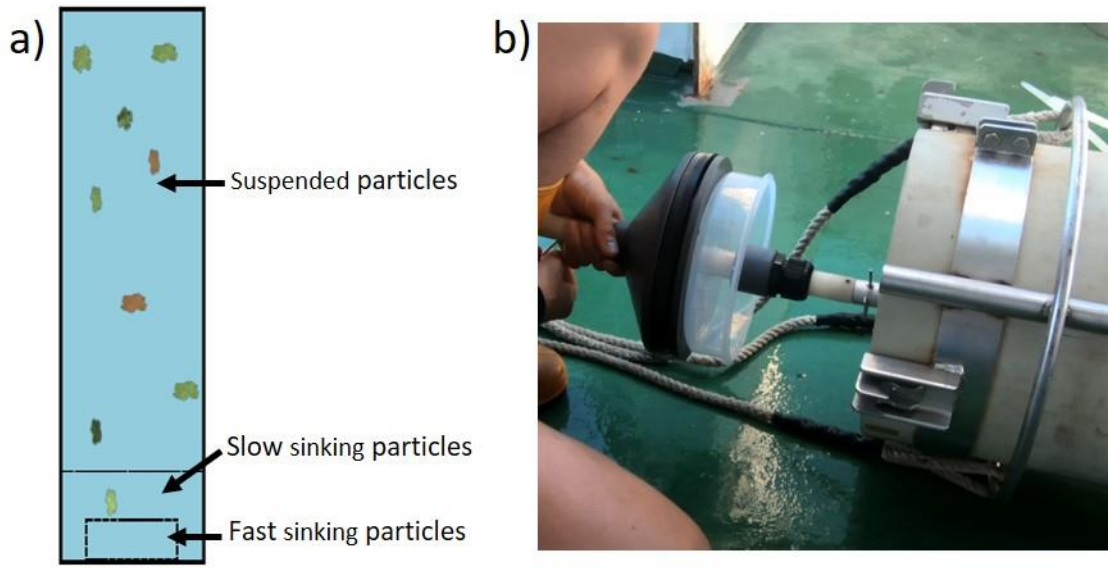


Figure 7: a) Schematic of the Marine snow catcher with the 3 type of particles sampled: suspended, slow-sinking and fast sinking particles. b) Picture of the tray where the fast sinking particles settle in

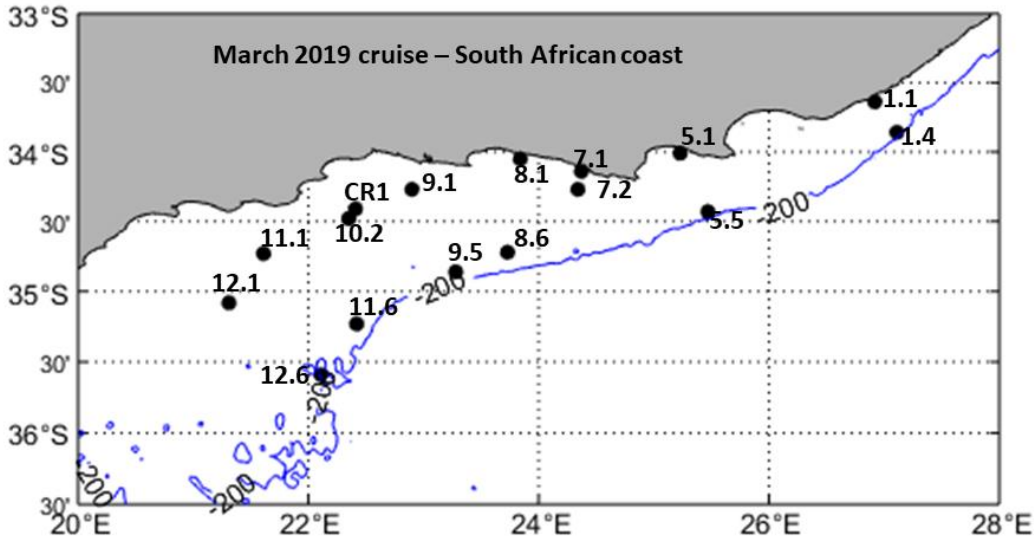


Figure 8: Stations sampled using the Marine Snow Catchers and CTD

<u>Sampling and methods</u>

A total of 15 stations (Figure 8) were sampled. Nine type of measurements were performed on the various fractions of the MSCs and on the seawater collected with the CTD rosette, as described below.

1. *FISH*

A total of 58 samples were collected from the CTDs and both MSCs from the suspended (T_f) and the fast sinking particles (top and tray). Water was prefiltered on a 200 µm mesh and 50 mL was transferred into a falcon tube. The sample was fixed by adding 2 mL of 37% formaldehyde and left in a cool environment for 1 hour. Initially, 25 mL of the sample was filtered through a 25 mm diameter 0.2 µm

polycarbonate filter at low pressure (below 5 mm Hg). The filter was rinsed with PBS (3 mL x 3) to wash the formaldehyde. The filter was transferred into a petri dish with the sample side facing up, labelled and stored at -20°C for later analysis. However half way through, from transect 8 onwards, only 10 mL of the fixed sample was filtered, instead of 25 mL, because the filtration time was too long and a filtration flask broke due to bad weather.

2. ETS

The incubations were prepared by transferring 150 mL of seawater into 4 amber polypropylene bottles (1 control and 3 replicates) from the suspended (T_f) and the fast sinking particles of the bottom MSC and the CTD. The control was fixed immediately by adding 8 mL of formaldehyde to kill all organisms. After 25 minutes all the bottles were inoculated with 3.85 mL of diluted INT solution and left at sea surface temperature for 1 hour. Replicates were then also fixed with formaldehyde similarly to the control. After 15 minutes, the samples were filtered through a 25 mm diameter 0.2 µm pore size polycarbonate filters. Filtration of the samples from the first station took longer than anticipated, which prevented us to sample the second station for ETS. After that, a size fractionated rig of 2 and 0.2 µm 47 mm polycarbonate filters was used for ETS samples to decrease filtering time. Filters were kept in a 2 mL cryotube at -20°C until analysis. A total of 202 filters were collected (101 for each filter size).

3. DNA

Seawater was collected from the suspended (T_f) and the fast sinking particles of the MSC and F-max. One litre of seawater was filtered onto a 47 mm diameter 2 µm and then 0.2 µm pore size for size fractionated DNA sample. After the first station, we rapidly realised that the filtration was taking a very long time and decided to not sample for DNA thereafter. The filters have been kept into a 2 mL cryotube and stored at -80°C; but might not be analysed due to the lack of repeatability.

4. Picoplankton and microbial community for flow cytometry (FC)

Samples were collected from both MSCs at T_f from all 3 fractions *i.e.* suspended, fast and slow sinking particles; as well as from the F-max (CTD). A total of 156 duplicate samples were collected. Seawater was pre-filtered through a 200 µm mesh. All containers and mesh used were pre-washed with diluted HCl to avoid contamination between stations. About 1.6 mL of seawater was then transferred into a cryotube and fixed with 1.6 µL glutaraldehyde (0.25 % glutaraldehyde solution). Samples were left for 10 minutes at room temperature, flashed freeze into liquid nitrogen and kept at -80°C for later analysis.

5. Microplankton community for FLOWCam analyses

Seawater was collected from both MSCs at T_f from the suspended and the fast sinking particles and from the CTD at F-max. For the F-max and the suspended fraction, 200 mL of seawater was transferred into a glass bottle and fixed with buffered formaldehyde (4 % final concentration). For the fast sinking particles, for which the main constrain is its small volume, only 50 mL of seawater was fixed with buffered formaldehyde (4 % final concentration). Samples were kept in a cool dark place until analysis. In total, 65 samples were collected.

6. Particulate Organic Carbon/Nitrogen (POC/N)

Seawater was collected from both MSCs from the suspended particles (T_0 and T_f), the fast and the slow sinking particles as well as from the F-max. About 1100 mL of seawater was filtered, in duplicates, onto pre-combusted and pre-weighed, 25 mm diameter 0.7 µm pore size glass fibre filters (MF300). The volume of seawater filtered from the tray fraction was adjusted for each deployment and ranged from 150 to 300 mL per sample. Filters were rinsed with ammonium buffered distilled water (~3 mL) to remove extra salt and then placed in aluminium foil. Filters were oven dried at 50°C overnight and stored in zip-lock bag for later analysis. A total of 238 samples were collected.

7. Particulate Inorganic Carbon (PIC)

Samples were collected from the F-max and both MSC from the suspended (T_f), the fast and the slow sinking particles. About 600 mL of seawater was filtered through a 25 mm diameter 0.8 µm polycarbonate filter. For the fast sinking particles (i.e. tray), filtered volume was reduced to 100 mL. The filters were rinsed with ammonium adjusted distilled water to remove salt. Filters were then kept in 2 mL labelled cryotubes, dried at 50°C overnight. Samples were stored in a cool dark place for later analysis. The total number of samples collected was 92.

8. Biogenic Silica ($bSiO_2$)

For the $bSiO_2$, 92 samples were collected similarly to PIC. The only difference is that filters were stored in 15 mL falcon tubes instead of 2 mL cryotubes. The filtered volume from the fast sinking particles fraction ranged from 100 to 250 mL.

9. Chlorophyll a (Chl a)

Seawater was collected from both MSCs from the suspended (T_0 and T_f), the slow and fast sinking particles, as well as the CTD. About 200 mL of seawater was filtered through a MF300 0.7µm, 25 mm diameter filter. The volume of seawater filtered from the fast sinking particle fraction was again variable and ranged from 90 to 200 mL per sample. Filters were digested in 6 mL acetone, kept at -20°C for 18 to 24 hours before being read on a fluorometer and expressed in mg Chl *a* m^{-3}. A total of 120 samples have been collected.

The total number of samples collected is summarised in Table 3 and more details on each sample can be found in Table 4.

Table 3: Total number of samples collected from the Marine Snow Catcher

Sample description	Number of samples collected
Particulate organic carbon/nitrogen (**POC/N**) **-** Duplicates	238
Particulate inorganic carbon (**PIC)**	92
Biogenic Silica (**$bSiO_2$**)	92
Chlorophyll *a* (**Chl *a***)	120
Picoplankton & microbial abundance (**FC**) **-** Duplicates	156
Microplankton abundance (**FLOWCam**)	65
Fluorescent in situ hybridization (**FISH**)	58
DNA	4
ETS for bacterial respiration (2 sets of 2 & 0.2 um)	264

Table 4: Detailed list of samples collected using the Marine Snow Catcher and CTD for the study of vertical fluxes and Benthic Nepheloid Layer

Date DD/MM/YYYY	Latitude (Decimal)	Longitude (Decimal)	Grid #	Estimated Depth (m)	ID	ETS	DNA	FISH	FC	Taxonomy	POC	$bSiO_2$	PIC	Chl *a*
23/03/2019	-33.6392	26.9162	1.1	22	CTD001	x		x	x	x	x	x	x	x
23/03/2019	-33.6390	26.9172	1.1	44	MSC001	x		x	x	x	x	x	x	x
23/03/2019	-33.8575	27.1073	1.4	14	CTD004			x	x	x	x	x	x	x
23/03/2019	-33.8673	27.1032	1.4	90	MSC002			x	x	x	x	x	x	x
23/03/2019	-33.8612	27.1070	1.4	20	MSC003			x	x	x	x	x	x	x
24/03/2019	-34.0053	25.2322	5.1	8	CTD006		x	x	x	x	x	x	x	x
24/03/2019	-34.0060	25.2323	5.1	35	MSC004			x	x	x	x	x	x	x
24/03/2019	-34.0065	25.2328	5.1	35	MSC006		x							
24/03/2019	-34.4298	25.4703	5.5	18	CTD010	x		x	x	x	x	x	x	x
24/03/2019	-34.4303	25.4697	5.5	90	MSC007	x		x	x	x	x	x	x	x
24/03/2019	-34.4303	25.4697	5.5	25	MSC008			x	x	x	x	x	x	x
25/03/2019	-34.1402	24.3705	7.1	8	CTD016	x	x	x	x	x	x	x	x	x
25/03/2019	-34.1362	24.3737	7.1	38	MSC009			x	x	x	x	x	x	x
25/03/2019	-34.1362	24.3737	7.1	38	MSC010	x	x	x	x					
25/03/2019	-34.2590	24.3297	7.2	40	MSC011	x	x	x	x	x	x	x	x	x
26/03/2019	-34.7183	23.7303	8.6	15	CTD022	x		x	x	x	x	x	x	x
26/03/2019	-34.7178	23.7400	8.6	125	MSC012			x	x	x	x	x	x	x
26/03/2019	-34.7177	23.7402	8.6	22	MSC013			x	x	x	x	x	x	x
26/03/2019	-34.0518	23.8388	8.1	22	CTD027	x		x	x	x	x	x	x	x
26/03/2019	-34.0492	23.8370	8.1	72	MSC014	x		x	x	x	x	x	x	x
26/03/2019	-34.0492	23.8368	8.1	30	MSC015				x		x	x	x	x
27/03/2019	-34.2652	22.8963	9.1	18	CTD029	x		x	x	x	x	x	x	x
27/03/2019	-34.2717	22.8792	9.1	80	MSC016			x	x	x	x	x	x	x
27/03/2019	-34.2767	22.8640	9.1	30	MSC017			x	x	x	x	x	x	x
27/03/2019	-34.8558	23.2783	9.5	15	CDT033	x		x	x	x	x	x	x	x
27/03/2019	-34.8570	23.2788	9.5	25	MSC018			x	x	x	x	x	x	x
27/03/2019	-34.8570	23.2788	9.5	140	MSC019			x	x	x	x	x	x	x
28/03/2019	-34.4780	22.3458	10.2	18	CTD038	x		x	x	x	x	x	x	x
28/03/2019	-34.4775	22.3515	10.2	84	MSC020	x		x	x	x	x	x	x	x
28/03/2019	-34.4775	22.3515	10.2	23	MSC021			x	x	x	x	x	x	x
28/03/2019	-34.7280	21.6123	11.1	32	CTD040	x		x	x	x	x	x	x	x
28/03/2019	-34.7302	21.6127	11.1	74	MSC022			x	x	x	x	x	x	x
28/03/2019	-34.7302	21.6127	11.1	24	MSC023			x	x	x	x	x	x	x
28/03/2019	-35.2300	22.4187	11.6	10	CTD044	x			x	x	x	x	x	x
28/03/2019	-35.2293	22.4197	11.6	140	MSC024				x	x	x	x	x	x
28/03/2019	-35.2293	22.4197	11.6	20	MSC025				x	x	x	x	x	x
29/03/2019	-35.5862	22.1142	12.6	15	CTD045	x		x	x		x	x	x	x
29/03/2019	-35.5920	22.0940	12.6	140	MSC026	x			x	x	x	x	x	x
29/03/2019	-35.5920	22.0938	12.6	25	MSC027				x	x	x	x	x	x
29/03/2019	-35.0823	21.3132	12.1	28	CTD050	x		x	x	x	x	x	x	x
29/03/2019	-35.0847	21.3053	12.1	84	MSC028	x		x	x	x	x	x	x	x
29/03/2019	-35.0845	21.3053	12.1	40	MSC029			x	x	x	x	x	x	x
30/03/2019	-34.4095	22.4282	CR1	20	CTD054	x		x						

Preliminary results

The concentration of Chl *a* in the suspended particles of the MSC at T_0 is plotted in Figure 9 and show the variability between the deep and the shallow MSC. Note that only 1 deep MSC was deployed at stations 1.1 (44m) and both MSC were deployed at the same depth of 38m (deep) at station 7.1. Both these stations were shallow and did not really have any distinct vertical structures (*i.e*. no thermocline). As expected, the shallow MSCs had overall a higher concentration of Chl *a* compared to the deep ones, ranging from values close to nil up to 5.2 mg m^{-3}.

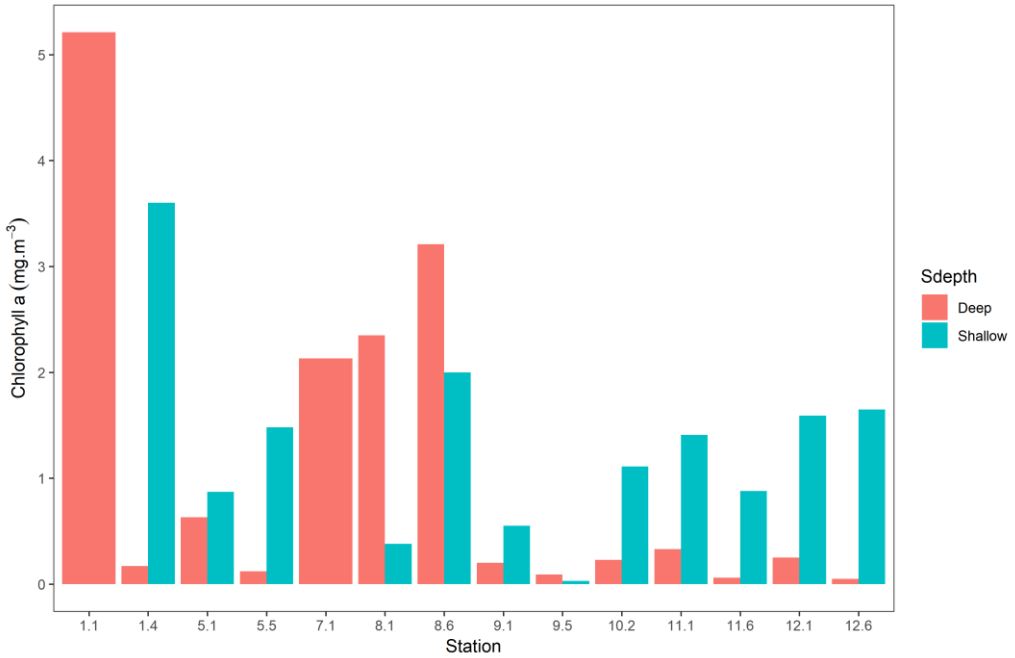


Figure 9: Comparison of Chl a concentrations (mg m^{-3}) in the Marine Snow Catchers at T_0 collected from the deep (red) and the shallow (green) depth

4.4. Nutrients

Alex Poulton and Sixolile Mazwane

Approximately 30 mL of seawater were collected from different depths during the cruise using the CTD rosette (Table 5) and frozen until further laboratory analyses. In total, 427 nutrient samples were collected and will be analysed at NOC, Southampton.

Table 5: Summary of nutrient samples

Station # (ship)	Grid #	ID	Date	Depth (m)	Niskin Bottle	No of samples
3977	1.1	CTD01	23/3/2019	2.2, 5.2, 10.4, 15.3, 21.2, 30.5, 40.4	12, 10, 8, 6, 3, 2, 1	7
3978	1.2	CTD02	23/3/2019	2.8, 5.7, 12.6, 28.3, 39.4, 55, 61.6	9, 7, 6, 4, 3, 2, 1	7
3979	1.3	CTD03	23/3/2019	2.4, 9.6, 19.9, 29.5, 39.3, 49.5, 60.3, 71.8, 85.3	10, 8, 7, 6, 5, 4, 3, 2, 1	9
3980	1.4	CTD04	23/3/2019	3.6, 7.2, 7.3, 10.9, 19.2, 31.7, 49.3, 59.4, 89.8	12, 11, 10, 8, 7, 6, 5, 4, 2	9
3981	2.3	CTD05	23/3/2019	5.2, 8.4, 15.4, 16.5, 23.6, 37.7, 60.6, 72.1, 95.2	12, 11, 9, 7, 5, 4, 3, 2, 1	9
3982	5.1	CTD06	24/3/2019	2.9, 8.3, 16.2, 24.9, 30.1, 42	10, 8, 6, 4, 2, 1	6
3983	5.2	CTD07	24/3/2019	2.6, 5.3, 12.9, 19.7, 29.9, 40.3, 59.9, 72.9	11, 9, 7, 6, 5, 4, 2, 1	8
3984	5.3	CTD08	24/3/2019	7.6, 14.5, 19.9, 29.2, 39.9, 64.4, 81, 89.5, 112.5	11, 9, 8, 7, 6, 5, 4, 3, 1	9
3985	5.4	CTD09	24/3/2019	3.4, 5.2, 9.8, 19.5, 29.2, 39.5, 59.3, 76.1, 118.3	12, 11, 9, 8, 7, 6, 4, 3, 1	9
3986	5.5	CTD10	24/3/2019	6.6, 11.8, 29.1, 40.3, 49.6, 69.7, 89.2, 142.1	12, 10, 8, 7, 6, 4, 3, 1	8
3987	6.5	CTD11	24/3/2019	4.5, 8.5, 15.5, 20.4, 53.4, 75.7, 110.4, 160.5	11, 10, 7, 5, 4, 3, 2, 1	8
3988	6.4	CTD12	24/3/2019	4.8, 9.5, 15.6, 18.8, 40.4, 60.3, 91.1, 117.5	11, 10, 8, 6, 4, 3, 2, 1	8
3989	6.3	CTD13	24/3/2019	10.7, 10.4, 13.2, 19.1, 25.3, 40.2, 54.8, 111.6	10, 9, 8, 7, 6, 4, 3, 1	8
3990	6.2	CTD14	24/3/2019	9.6, 20.3, 24.6, 35.1, 49.8, 70.7, 90, 111.5	12, 10, 8, 6, 4, 3, 2, 1	8
3991	6.1	CTD15	24/3/2019	4.3, 7.9, 12.3, 18.1, 24.5, 28.7	12, 9, 7, 5, 3, 1	6
3992	7.1	CTD16	25/3/2019	3.2, 7.5, 19.3, 30.3, 43.4	10, 7, 5, 3, 1	5
3993	7.2	CTD17	25/3/2019	6.8, 13.9, 18.7, 24.4, 33.5, 60.8, 79.6, 100	12, 10, 9, 7, 5, 3, 2, 1	8
3994	7.3	CTD18	25/3/2019	3.5, 8.3, 11.8, 15.3, 29.7, 69.6, 94.3, 118.2	12, 10, 8, 6, 4, 3, 2, 1	8
3995	7.4	CTD19	25/3/2019	7.9, 15.4, 22.3, 28.4, 40.6, 70.4, 85.8, 111.8	12, 10, 8, 5, 4, 3, 2, 1	8
3996	7.5	CTD20	25/3/2019	4.7, 12.2, 18.9, 22.5, 39.5, 65.7, 90.3, 115	12, 10, 8, 6, 4, 3, 2, 1	8
3997	7.6	CTD21	25/3/2019	5.3, 10.8, 18.2, 30.7, 41.3, 99.5, 129.7, 209.3, 308.1	12, 11, 10, 8, 6, 4, 3, 2, 1	9
3998	8.6	CTD22	26/3/2019	3.5, 5.2, 9.5, 20.4, 30.3, 48.8, 75, 90.9, 127.8	12, 11, 8, 7, 6, 5, 4, 2, 1	9
3999	8.5	CTD23	26/3/2019	7.9, 14.5, 19.7, 30.9, 51.2, 70.1, 94.1, 112.2	10, 9, 8, 7, 6, 4, 2, 1	8
4000	8.4	CTD24	26/3/2019	5.3, 9.9, 20.1, 34.6, 47.8, 58.5, 73.5, 88.8	11, 9, 7, 6, 5, 4, 3, 2	8
4001	8.3	CTD25	26/3/2019	7.1, 16, 26.7, 49.8, 65.1, 80.8, 91.8, 105.5	10, 8, 7, 5, 4, 3, 2, 1	8
4002	8.2	CTD26	26/3/2019	2, 8.3, 16, 28.5, 38.9, 53.7, 67.6, 84.8, 98.4	9, 8, 7, 6, 5, 4, 3, 2, 1	9
4003	8.1	CTD27	26/3/2019	4.4, 10.6, 22.6, 30.5, 37.9, 49, 73.6	12, 10, 8, 6, 4, 2, 1	7

Station # (ship)	Grid #	ID	Date	Depth (m)	Niskin Bottle	No of samples
4004	9.1	CTD28	26/3/2019	6.5, 12.9, 18.3, 20.5, 31, 56.3, 82.4	12, 10, 8, 6, 4, 2, 1	7
4005	9.1b	CTD29	27/3/2019	2.2, 8.2, 17.5, 28.4, 37.3, 49.6, 71, 82.3	11, 9, 7, 6, 5, 4, 2, 1	8
4006	9.2	CTD30	27/3/2019	10.3, 10.8, 25.5, 31.5, 42.4, 71.3, 83.8, 101.4	9, 8, 7, 6, 5, 3, 2, 1	8
4007	9.3	CTD31	27/3/2019	3, 8.8, 19.6, 28.5, 39.1, 50.8, 69.3, 107.4	11, 10, 8, 7, 6, 5, 3, 1	8
4008	9.4	CTD32	27/3/2019	3.4, 11.3, 20.9, 29.7, 45.3, 74, 89.4, 113.3	9, 8, 7, 6, 5, 3, 2, 1	8
4009	9.5	CTD33	27/3/2019	2.1, 4.8, 10.9, 14.3, 24.1, 40.2, 80.2, 121, 142.7	12, 11, 9, 7, 5, 4, 3, 2, 1	9
4010	10.6	CTD34	27/3/2019	3.3, 8.5, 13.6, 18.8, 28.2, 44.9, 75.1, 115.1, 171.1	11, 9, 7, 6, 5, 4, 3, 2, 1	9
4011	10.5	CTD35	27/3/2019	7.8, 13.7, 18, 29.1, 46.5, 59.9, 101.4, 128.3	12, 10, 8, 6, 4, 3, 2, 1	8
4012	10.4	CTD36	27/3/2019	6, 12.5, 20.3, 25, 29.4, 39.8, 60.7, 80.1, 111.4	12, 11, 9, 7, 5, 4, 3, 2, 1	9
4013	10.3	CTD37	28/3/2019	8.5, 18, 22.8, 31.2, 49.1, 60.5, 70.4, 98.3	12, 10, 8, 6, 4, 3, 2, 1	8
4014	10.2	CTD38	28/3/2019	2.2, 4.9, 8.5, 13.8, 22.2, 29.5, 45.2, 66.8, 87.1	12, 10, 8, 6, 5, 4, 3, 2, 1	9
4015	10.1	CTD39	28/3/2019	2.3, 9.6, 16, 27.9, 37.9, 50.4, 60.4, 73.9	12, 10, 8, 6, 4, 3, 2, 1	8
4016	11.1	CTD40	28/3/2019	3.4, 9.7, 18.5, 30.5, 30.7, 39.5, 49.7, 64.3, 79.6	12, 10, 8, 7, 6, 5, 3, 2, 1	9
4017	11.2	CTD41	28/3/2019	9.9, 21.1, 28.4, 32.2, 40.4, 48.4, 66.3, 87.2	12, 10, 8, 6, 4, 3, 2, 1	8
4018	11.3	CTD42	28/3/2019	8.3, 14.9, 22.1, 24.6, 35.5, 49.4, 72.7, 105.2	12, 11, 9, 7, 5, 3, 2, 1	8
4019	11.5	CTD43	28/3/2019	8.7, 15.9, 19, 25.3, 27.1, 36.1, 64.9, 92.3, 112.4	11, 9, 7, 6, 5, 4, 3, 2, 1	9
4020	11.6	CTD44	28/3/2019	5.7, 9.5, 20.5, 36.2, 59.7, 97.2, 144.8	10, 8, 5, 4, 3, 2, 1	7
4021	12.6	CTD45	29/3/2019	2.9, 8.6, 16.3, 21.4, 25.5, 39, 61, 79, 100.5, 172.9	12, 11, 10, 8, 7, 6, 5, 4, 3, 1	10
4022	12.5	CTD46	29/3/2019	3.7, 9.5, 19.7, 30.6, 41, 50.2, 65, 78.8, 99.2, 155.6	12, 11, 10, 9, 8, 6, 5, 4, 3, 1	10
4023	12.4	CTD47	29/3/2019	3.3, 13.2, 21.7, 29.9, 40.1, 50.9, 60.2, 89.2, 133.9	12, 11, 10, 8, 6, 5, 4, 3, 1	9
4024	12.3	CTD48	29/3/2019	2.8, 10.2, 20.7, 27.2, 38.3, 50.3, 59.3, 75.2, 120.6	12, 11, 10, 9, 7, 5, 4, 3, 1	9
4025	12.2	CTD49	29/3/2019	1.8, 10.1, 19.5, 30.7, 38.4, 50.1, 88.6, 113.1	12, 10, 8, 6, 5, 4, 2, 1	8
4026	12.1	CTD50	29/3/2019	4, 11.3, 28.3, 37.9, 45, 55.1, 70.3, 88.9	11, 9, 7, 5, 4, 3, 2, 1	8
4027	CR4	CTD51	30/3/2019	4.6, 10, 15.5, 18.2, 26.1, 37.6, 61.8, 93.6	11, 10, 9, 8, 6, 4, 2, 1	8
4031	Glider 550	CTD55	31/3/2019	7.3, 38.1, 58.2, 73.4, 101.3, 150.8, 200, 250.9, 300, 346.3, 403	12, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1	11

4.5. Phytoplankton and Net Primary Production

Alex Poulton and Sixolile Mazwane

The main objectives for this work were as fellow:

- What is the primary production on the Agulhas Bank?
- Is this primary production available to higher trophic levels (is it diatoms?)?
- What is the depth distribution of this primary production (surface or Deep Chlorophyll Maximum)?
- What factors drive/limit phytoplankton production across the Agulhas Bank?

A total of 34 stations were sampled using the CTD rosette (Figure 10 and Figure 11)

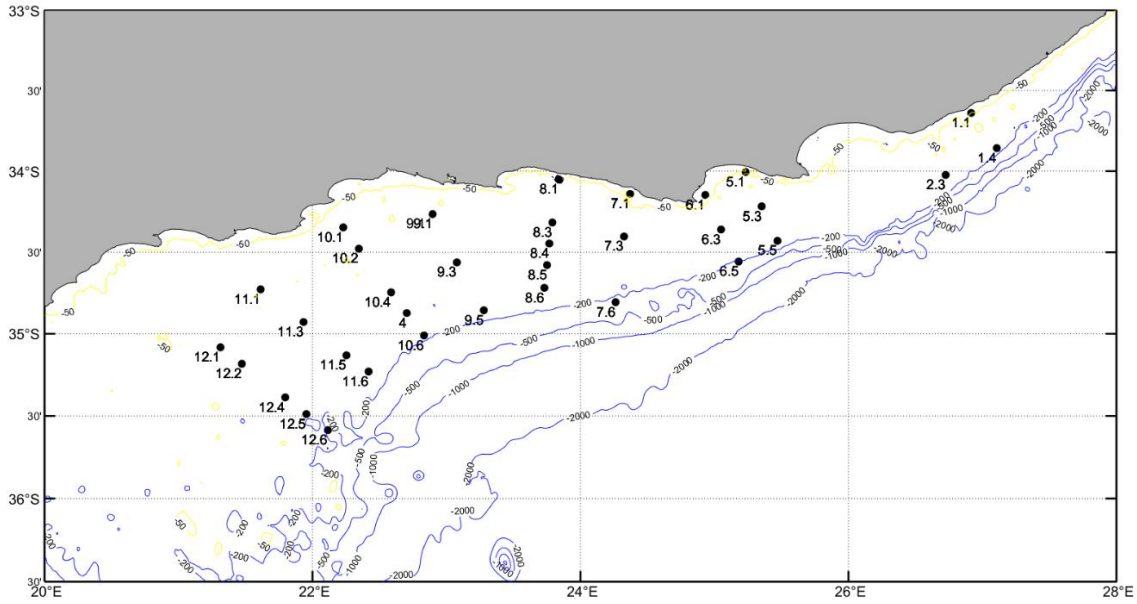


Figure 10: Map of the stations where samples for phytoplankton were collected.

Seawater collected from the Niskin bottles were collected and preserved as fellow:

1. *Particulate Organic Carbon (POC) and Nitrogen (PON)*

For particulate organic carbon (POC) and nitrogen (PON), 1 L of sampled seawater was filtered onto pre-ashed (>450 °C for >4 h) 25 mm MF300 Fisherbrand 0.7 µm filters. After filtration, samples were rinsed with a weak 1 % solution of HCl to remove inorganic carbon residue. Filters were oven dried overnight at 40 °C. After that the samples were kept in cryotubes and will later be pelleted into tin capsules using a laboratory press and analysed for POC and PON content using a CHN Analyzer.

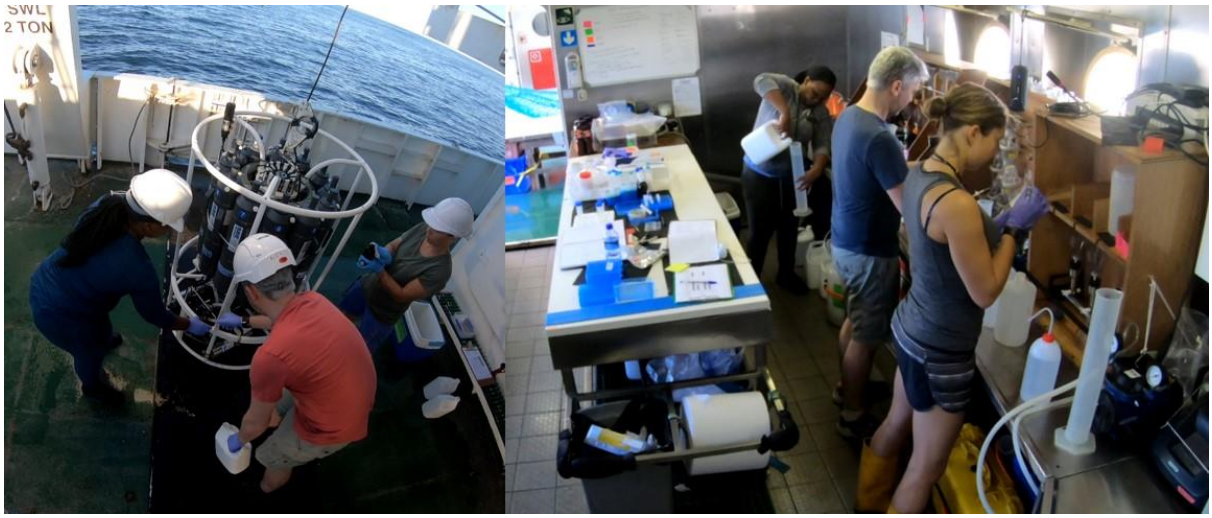


Figure 11: Pictures illustrating the collection of seawater from the CTD and the filtration in the laboratory before preservation

2. *Biogenic Silica ($bSiO_2$)*

The aim is to have a proxy of diatoms in the samples. Six depths were sampled (surface, Fmax depth, upper mixed layer (UML), bottom and two intermediate depths usually within the UML) at each station. About 500 mL of seawater from each depth was filtered through a 25 mm diameter 0.8 µm polycarbonate filter and rinsed with buffered Milli-Q to remove extra salts. Filters were transferred into 15 mL falcon tubes and oven dried at 40°C overnight, then stored in a plastic bag later analysis.

3. *Chlorophyll a (Chl a)*

Seawater samples were collected from the Niskin bottles from different depths for chlorophyll *a* (Chl *a*) concentration measurements. For total Chl *a* concentration, 200 mL of seawater was filtered through Fisherbrand MF300 filters (25 mm diameter 0.7 µm) using a manifold filtration system. For size-fractionated Chl *a*, 200 mL was sequentially gravity filtered through a 20 µm, 2 µm and 0.2 µm 47 mm Nuclepore filters. All Filters were then extracted in 6 mL 90% acetone for 18 to 24 h in the dark and cold (4°C) and then fluorescence was measured using a Turner-Designs Trilogy Laboratory Fluorometer calibrated against a pure Chl *a* standard (Sigma) following Welschmeyer (1994).

4. *Net Primary Production (NPP)*

Phytoplankton productivity in the ocean forms the basis of the marine food chain and the oceanic carbon cycle. To determine net primary production (NPP) of the central and eastern Agulhas Bank, a series of experiments were conducted. A volume of 1.2 L of seawater collected from six different depths, corresponding to 6 different light intensity (55, 20, 14, 7, 4.5 & 1 % light intensity) were inoculated with ~500 µmol L^{-1} of ^{13}C labelled sodium bicarbonate (372382 Sigma-Aldrich), representing 20 % of the ambient dissolved inorganic carbon pool. Samples were incubated in on-deck incubators, chilled with sea surface water, and light depths were replicated using optical filters (misty-blue and neutral density, Lee Filters™, Figure 12). Incubations were terminated after 24 h by filtration onto pre-ashed (>400°C, >4 h) Fisherbrand MF300, 0.7 µm pore size filters. Acid-labile particulate inorganic carbon (PIC) was removed by adding a few drops of 1 % HCl to the filter followed by extensive rinsing with freshly filtered (0.7 µm pore size) unlabelled seawater. Filters were oven dried (40 °C, 8-12 h) and stored in 2 mL cryotubes. Isotopic analysis will be performed on an automated nitrogen and carbon analysis preparation system with a 20– 20 stable isotope analyzer. The ^{13}C-carbon fixation rate will be calculated using the equations described in Legendre and Gosselin, (1996).

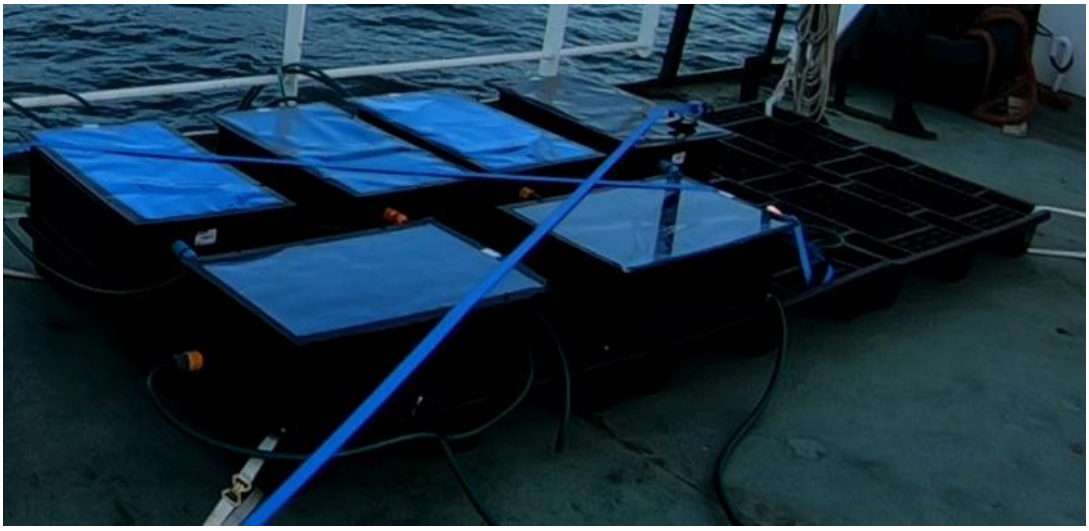


Figure 12: Pictures of the incubation boxes on the deck with the different light intensity level

5. *Phytoplankton growth rates (net changes in Chl a, $bSiO_2$ and diatoms)*

Seawater samples were collected at 3 depths (surface, Deep Chlorophyll Maximum (DCM) and below the DCM). Per depth, 3 samples were analyzed at Tzero and 3 others were incubated for 24h on deck in parallel with the NPP experiments. For each sample, 200 mL was filtered for total Chl *a* (TChl, > 0.7 µm) and another 200 mL was filtered onto a 20 µm filter (SF-Chl) (the difference between 0.7 and 20 µm filters would be the equivalent of the less than 20 µm fraction), 400 ml was filtered for $bSiO_2$ and 400 mL for Scanning Electron Microscopy.

6. *Phytoplankton community composition*

For phytoplankton enumeration, different methods will be used for different size classes:

- Cells larger than 10 µm: 200mL of seawater was preserved with 2% acidic Lugol's Iodine solution in amber glass bottles. According to the Coulon and Alexander (1972) method, the samples will be settled overnight in 50 mL Utermöhl settling chambers (26.5 mm diameter) and all cells will be counted using an inverted microscope to species level when possible.
- Specifically, for diatoms: 1 L of sampled seawater was filtered through 0.8 µm polycarbonate filters, rinsed with buffered Milli-Q, oven dried and stored in dry Petri slides until analysis using a Scanning Electron Microscopy (SEM).
- Cells of 0.2 - 5 µm (*i.e*. pico-phytoplankton) will be analyzed using flow cytometry (FC). Flow cytometry samples were fixed with 0.25 % glutaraldehyde solution, flash-freeze and stored at -80 °C until analysis.

A summary of all the samples collected is shown in Table 6.

Table 6: Sampling log of phytoplankton samples taken and the volume for each sample (The - represents no sample taken)

Date	Time (GMT)	Grid	ID	Niskin #	Sample bottle #	Depth (m)	POC/N (mL)	$bSiO_2$ (mL)	SEM (mL)	TChl (mL)	SFChl (mL)	FC (mL)	Lugols (mL)
23/03/2019	03:11	1-1	CTD01	11	1	1.9	350	420	-	200	200	4	-
23/03/2019	03:11	1-1	CTD01	9	2	5.2	350	430	400	200	200	4	200
23/03/2019	03:11	1-1	CTD01	7	3	10.2	350	500	-	200	200	4	-
23/03/2019	03:11	1-1	CTD01	6	4	15.3	350	500	-	200	200	4	-
23/03/2019	03:11	1-1	CTD01	5	5	21.8	350	500	-	200	200	4	-
23/03/2019	03:11	1-1	CTD01	3	6	21.6	350	500	500	200	200	4	200
23/03/2019	08:38	1-4	CTD04	12	1	3.9	350	500	-	200	200	4	-
23/03/2019	08:38	1-4	CTD04	11	2	7.8	350	500	500	200	200	4	200
23/03/2019	08:38	1-4	CTD04	8	3	10.8	350	500	-	200	200	4	200
23/03/2019	08:38	1-4	CTD04	7	4	19.5	350	500	-	200	200	4	-
23/03/2019	08:38	1-4	CTD04	6	5	31.5	350	500	500	200	200	4	200
23/03/2019	08:38	1-4	CTD04	4	6	59.7	350	500	-	200	200	4	-
23/03/2019	10:00	2.3	CTD05	12	1	5.0	350	500	-	200	N	4	-
23/03/2019	10:00	2.3	CTD05	11	2	8.0	350	500	-	200	N	-	-
23/03/2019	10:00	2.3	CTD05	9	3	12.0	350	500	-	200	N	-	-
23/03/2019	10:00	2.3	CTD05	7	4	15.0	350	500	-	200	N	4	-
23/03/2019	10:00	2.3	CTD05	6	5	20.0	350	500	-	200	N	-	-
24/03/2019	02:21	5-1	CTD06	6	1	4.0	1000	500	500	200	200	4	200
24/03/2019	02:21	5-1	CTD06	8	2	8.0	1000	500	500	200	200	4	200
24/03/2019	02:21	5-1	CTD06	10	3	16.0	1000	500	-	200	200	4	-
24/03/2019	08:50	5-3	CTD08	4	1	81.0	1000	500	-	200	-	4	-
24/03/2019	08:50	5-3	CTD08	5	2	64.4	1000	500	-	200	-	4	-
24/03/2019	08:50	5-3	CTD08	6	3	39.9	1000	500	-	200	-	4	-
24/03/2019	08:50	5-3	CTD08	7	4	29.2	1000	500	-	200	200	4	-
24/03/2019	08:50	5-3	CTD08	9	5	14.5	1000	500	500	200	200	4	200
24/03/2019	08:50	5-3	CTD08	11	6	7.6	1000	500	500	200	200	4	200
24/03/2019	13:16	5-5	CTD10	12	1	6.7	1000	500	500	200	200	4	200
24/03/2019	13:16	5-5	CTD10	10	2	11.9	1000	500	500	200	200	4	200
24/03/2019	13:16	5-5	CTD10	8	3	29.5	1000	500	-	200	200	4	-
24/03/2019	13:16	5-5	CTD10	7	4	40.7	1000	500	-	200	-	4	-
24/03/2019	13:16	5-5	CTD10	6	5	50.2	1000	500	-	200	-	4	-
24/03/2019	17:56	6-5	CTD011	5	1	20	400	500	-	200	-	4	-
24/03/2019	17:56	6-5	CTD011	7	2	15	400	500	300	200	200	4	200
24/03/2019	17:56	6-5	CTD011	9	3	8	400	500	300	200	200	4	200
24/03/2019	17:56	6-5	CTD011	11	4	4	400	N	-	200	200	4	-
24/03/2019	19:18	6-3	CTD013	11	1	5.0	500	500	200	200	200	4	200
24/03/2019	19:18	6-3	CTD013	9	2	10.0	500	500	500	200	200	4	200
24/03/2019	19:18	6-3	CTD013	8	3	15.0	500	500	-	200	200	4	-
24/03/2019	19:18	6-3	CTD013	7	4	20.0	500	500	-	200	-	4	-
24/03/2019	19:18	6-3	CTD013	6	5	25.0	500	500	-	200	-	4	-
25/03/2019	23:03	6-1	CTD015	12	1	4.0	500	500	200	200	200	4	200
25/03/2019	23:03	6-1	CTD015	9	2	8.0	500	500	200	200	200	4	200

Date	Time (GMT)	Grid	ID	Niskin #	Sample bottle #	Depth (m)	POC/N (mL)	$bSiO_2$ (mL)	SEM (mL)	TChl (mL)	SFChl (mL)	FC (mL)	Lugols (mL)
25/03/2019	23:03	6-1	CTD015	7	3	12.0	500	500	-	200	200	4	-
25/03/2019	23:03	6-1	CTD015	5	4	18.0	500	500	-	200	-	4	-
25/03/2019	23:03	6-1	CTD015	3	5	25.0	500	500	-	200	-	4	-
25/03/2019	23:03	6-1	CTD015	1	6	28.0	500	500	-	200	-	4	-
25/03/2019	15:30	7-1	CTD016	11	1	2.9	1000	500	250	200	200	4	200
25/03/2019	15:30	7-1	CTD016	7	2	7.7	1000	500	250	200	200	4	200
25/03/2019	15:30	7-1	CTD016	5	3	19.6	1000	500	-	200	200	4	-
25/03/2019	15:30	7-1	CTD016	3	4	30.5	1000	500	-	200	-	4	-
25/03/2019	15:30	7-1	CTD016	1	5	43.8	1000	500	-	200	-	4	-
25/03/2019	23:00	7-3	CTD018	6	1	15.0	1000	500	-	200	-	4	-
25/03/2019	23:00	7-3	CTD018	8	2	12.0	1000	500	-	200	200	4	-
25/03/2019	23:00	7-3	CTD018	10	3	8.0	1000	500	450	200	200	4	200
25/03/2019	23:00	7-3	CTD018	12	4	4.0	1000	500	450	200	200	4	200
25/03/2019	01:15	7-6	CTD021	12	1	5.0	1000	500	500	200	200	4	200
25/03/2019	01:15	7-6	CTD021	11	2	10.0	1000	500	-	200	200	4	-
25/03/2019	01:15	7-6	CTD021	10	3	18.0	1000	500	500	200	200	4	200
25/03/2019	01:15	7-6	CTD021	8	4	30.0	1000	500	-	200	-	4	-
26/03/2019	06:13	8-6	CTD022	12	1	3.5	1000	500	250	200	200	4	200
26/03/2019	06:13	8-6	CTD022	11	2	5.2	1000	500	250	200	200	4	200
26/03/2019	06:13	8-6	CTD022	8	3	9.8	1000	500	-	200	200	4	-
26/03/2019	06:13	8-6	CTD022	7	4	20.9	1000	500	-	200	-	4	-
26/03/2019	09:55	8-5	CTD023	10	1	7.9	1000	500	-	200	200	-	-
26/03/2019	09:55	8-5	CTD023	9	2	14.6	1000	500	-	200	200	-	-
26/03/2019	09:55	8-5	CTD023	8	3	19.9	1000	500	-	200	200	-	-
26/03/2019	09:55	8-5	CTD023	7	4	31.1	1000	500	-	200	-	-	-
26/03/2019	11:24	8-4	CTD024	11	1	5.2	1000	500	300	200	200	4	200
26/03/2019	11:24	8-4	CTD024	9	2	10.0	1000	500	300	200	200	4	200
26/03/2019	11:24	8-4	CTD024	7	3	20.0	1000	500	-	200	200	4	-
26/03/2019	11:24	8-4	CTD024	6	4	34.8	1000	500	-	200	-	4	-
26/03/2019	11:24	8-4	CTD024	5	5	48.1	1000	500	-	200	-	4	-
26/03/2019	15:00	8-2	CTD025	9	1	2.1	1000	500	300	200	200	4	200
26/03/2019	15:00	8-2	CTD025	8	2	8.3	1000	500	-	200	200	4	-
26/03/2019	15:00	8-2	CTD025	7	3	15.9	1000	500	300	200	200	4	200
26/03/2019	15:00	8-2	CTD025	6	4	28.0	1000	500	-	200	-	4	-
26/03/2019	15:00	8-2	CTD025	5	5	39.5	1000	500	-	200	-	4	-
26/03/2019	15:00	8-2	CTD025	4	6	54.3	1000	500	-	200	-	4	-
26/03/2019	14:37	8-1	CTD027	4	1	38.5	1000	-	-	200	-	-	-
26/03/2019	14:37	8-1	CTD027	6	2	30.0	1000	-	-	200	-	-	-
26/03/2019	14:37	8-1	CTD027	8	3	22.0	1000	-	-	200	-	-	-
26/03/2019	14:37	8-1	CTD027	10	4	10.0	1000	-	-	200	-	-	-
26/03/2019	14:37	8-1	CTD027	12	5	4.0	1000	-	-	200	-	-	-
26/03/2019	01:00	9-1	CTD028	6	1	21.0	1000	500	-	200	200	4	-

Date	Time (GMT)	Grid	ID	Niskin #	Sample bottle #	Depth (m)	POC/N (mL)	$bSiO_2$ (mL)	SEM (mL)	TChl (mL)	SFChl (mL)	FC (mL)	Lugols (mL)
26/03/2019	01:00	9-1	CTD028	8	2	18.0	1000	500	500	200	200	4	200
26/03/2019	01:00	9-1	CTD028	10	3	13.0	1000	500	-	200	200	4	-
26/03/2019	01:00	9-1	CTD028	12	4	6.0	1000	500	500	200	-	4	200
27/03/2019	09:00	9-1B	CTD029	11	1	2.3	1000	500	500	200	200	4	200
27/03/2019	09:00	9-1B	CTD029	9	2	8.5	1000	500	500	200	200	4	200
27/03/2019	09:51	9-3	CTD031	11	1	3.3	1000	500	300	200	200	4	200
27/03/2019	09:51	9-3	CTD031	10	2	8.8	1000	500	300	200	200	4	200
27/03/2019	09:51	9-3	CTD031	8	3	19.8	1000	500	-	200	200	4	-
27/03/2019	09:51	9-3	CTD031	7	4	28.6	1000	500	-	200	-	4	-
27/03/2019	09:51	9-3	CTD031	6	5	39.4	1000	500	-	200	-	4	-
27/03/2019	15:48	9-5	CTD033	5	1	24.3	1000	500	-	200	-	4	-
27/03/2019	15:48	9-5	CTD033	7	2	14.5	1000	500	500	200	-	4	200
27/03/2019	15:48	9-5	CTD033	9	3	9.5	1000	500	-	200	200	4	-
27/03/2019	15:48	9-5	CTD033	11	4	4.9	1000	500	500	200	200	4	200
27/03/2019	15:48	9-5	CTD033	12	5	2.5	1000	500	405	200	200	4	200
27/03/2019	20:40	10-6	CTD034	11	1	3.4	1000	500	-	200	200	4	200
27/03/2019	20:40	10-6	CTD034	9	2	8.5	1000	500	-	200	200	4	200
27/03/2019	20:40	10-6	CTD034	7	3	13.9	1000	500	-	200	200	4	-
27/03/2019	20:40	10-6	CTD034	6	4	18.9	1000	500	-	200	-	4	-
27/03/2019	20:40	10-6	CTD034	5	5	28.4	1000	500	-	200	-	4	-
27/03/2019	01:20	10-4	CTD036	4	1	40.3	1000	500	-	200	-	4	-
27/03/2019	01:20	10-4	CTD036	5	2	29.6	1000	500	??	200	200	4	200
27/03/2019	01:20	10-4	CTD036	7	3	25.0	1000	500	-	200	-	4	-
27/03/2019	01:20	10-4	CTD036	9	4	20.8	1000	500	-	200	200	4	-
27/03/2019	01:20	10-4	CTD036	11	5	12.6	1000	500	-	200	-	4	-
27/03/2019	01:20	10-4	CTD036	12	6	6.0	1000	500	??	200	200	4	200
28/03/2019	05:42	10-2	CTD038	5	1	22.4	1000	500	-	200	-	4	-
28/03/2019	05:42	10-2	CTD038	6	2	13.8	1000	500	500	200	200	4	200
28/03/2019	05:42	10-2	CTD038	8	3	8.5	1000	500	-	200	200	4	-
28/03/2019	05:42	10-2	CTD038	10	4	5.0	1000	500	500	200	200	4	200
28/03/2019	05:42	10-2	CTD038	12	5	2.2	1000	500	-	200	-	4	-
28/03/2019	08:45	10-1	CTD039	6	1	28.4	1000	500	-	200	-	-	-
28/03/2019	08:45	10-1	CTD039	8	2	16.1	1000	500	-	200	200	-	-
28/03/2019	08:45	10-1	CTD039	10	3	9.6	1000	500	-	200	200	-	-
28/03/2019	08:45	10-1	CTD039	12	4	2.5	1000	500	-	200	200	-	-
28/03/2019	14:21	11-1	CTD040	5	1	39.0	1000	500	-	200	-	4	-
28/03/2019	14:21	11-1	CTD040	7	2	31.0	1000	500	-	200	-	4	-
28/03/2019	14:21	11-1	CTD040	8	3	18.7	1000	500	250	200	200	4	200
28/03/2019	14:21	11-1	CTD040	10	4	9.0	1000	500	-	200	200	4	-
28/03/2019	14:21	11-1	CTD040	12	5	3.5	1000	500	500	200	200	4	200
28/03/2019	18:30	11-3	CTD042	3	1	50.0	1000	500	-	200	-	4	-
28/03/2019	18:30	11-3	CTD042	5	2	35.0	1000	500	-	200	-	4	-

Date	Time (GMT)	Grid	ID	Niskin #	Sample bottle #	Depth (m)	POC/N (mL)	$bSiO_2$ (mL)	SEM (mL)	TChl (mL)	SFChl (mL)	FC (mL)	Lugols (mL)
28/03/2019	18:30	11-3	CTD042	7	3	24.8	1000	500	-	200	200	4	-
28/03/2019	18:30	11-3	CTD042	9	4	23.0	1000	500	-	200	200	4	-
28/03/2019	18:30	11-3	CTD042	11	5	15.0	1000	500	-	200	-	4	-
28/03/2019	18:30	11-3	CTD042	12	6	8.0	1000	500	-	200	200	4	-
28/03/2019	23:00	11-5	CTD043	5	1	28.0	1000	500	-	200	-	4	-
28/03/2019	23:00	11-5	CTD043	6	2	28.0	1000	500	500	200	200	4	200
28/03/2019	23:00	11-5	CTD043	7	3	20.0	1000	500	-	200	200	4	-
28/03/2019	23:00	11-5	CTD043	9	4	15.0	1000	500	-	200	-	4	-
28/03/2019	23:00	11-5	CTD043	11	5	8.0	1000	500	500	200	200	4	200
28/03/2019	23:00	11-6	CTD044	4	1	36.0	1000	500	-	200	-	4	-
28/03/2019	23:00	11-6	CTD044	5	2	20.0	1000	500	-	200	200	4	-
28/03/2019	23:00	11-6	CTD044	8	3	10.0	1000	500	500	200	200	4	200
28/03/2019	23:00	11-6	CTD044	10	4	5.0	1000	500	500	200	200	4	200
29/03/2019	06:19	12-6	CTD045	7	1	26.0	1000	500	-	200	-	4	-
29/03/2019	06:19	12-6	CTD045	8	2	21.0	1000	500	-	200	-	4	-
29/03/2019	06:19	12-6	CTD045	10	3	15.4	1000	500	500	200	200	4	200
29/03/2019	06:19	12-6	CTD045	11	4	8.8	1000	500	-	200	200	4	-
29/03/2019	06:19	12-6	CTD045	12	5	3.2	1000	500	500	200	200	4	200
29/03/2019	10:03	12-5	CTD046	12	1	3.5	-	-	-	200	200	-	-
29/03/2019	10:03	12-5	CTD046	11	2	9.8	-	-	-	200	200	-	-
29/03/2019	10:03	12-5	CTD046	10	3	20.0	-	-	-	200	-	-	-
29/03/2019	10:03	12-5	CTD046	9	4	30.7	-	-	-	200	-	-	-
29/03/2019	10:03	12-5	CTD046	8	5	40.2	-	-	-	200	200	-	-
29/03/2019	10:03	12-5	CTD046	6	6	50.6	-	-	-	200	-	-	-
29/03/2019	11:09	12-4	CTD047	12	1	3.2	1000	500	500	200	200	4	200
29/03/2019	11:09	12-4	CTD047	11	2	13.3	1000	500	-	200	200	4	-
29/03/2019	11:09	12-4	CTD047	10	3	21.5	1000	500	-	200	-	4	-
29/03/2019	11:09	12-4	CTD047	8	4	30.3	1000	500	500	200	200	4	200
29/03/2019	11:09	12-4	CTD047	6	5	40.5	1000	500	-	200	-	4	-
29/03/2019	11:09	12-4	CTD047	5	6	51.1	1000	500	-	200	-	4	-
29/03/2019	15:14	12-2	CTD049	12	1	1.7	1000	500	500	200	200	4	200
29/03/2019	15:14	12-2	CTD049	10	2	10.0	1000	500	-	200	200	4	-
29/03/2019	15:14	12-2	CTD049	8	3	19.8	1000	500	-	200	-	4	-
29/03/2019	15:14	12-2	CTD049	6	4	31.0	1000	500	500	200	200	4	200
29/03/2019	15:14	12-2	CTD049	5	5	38.5	1000	500	-	200	-	4	-
29/03/2019	14:53	12-1	CTD050	11	1	4.3	1000	500	454	200	200	4	200
29/03/2019	14:53	12-1	CTD050	9	2	11.4	1000	416	-	200	200	4	-
29/03/2019	14:53	12-1	CTD050	7	3	28.0	1000	500	500	200	200	4	200
29/03/2019	14:53	12-1	CTD050	5	4	38.3	1000	500	-	200	-	4	-
29/03/2019	14:53	12-1	CTD050	4	5	46.4	1000	500	-	200	-	4	-
30/03/2019	06:23	CR4	CTD051	12	1	4.4	1000	500	500	200	200	4	200
30/03/2019	06:23	CR4	CTD051	11	2	4.4	1000	500	-	200	200	4	-

Date	Time (GMT)	Grid	ID	Niskin #	Sample bottle #	Depth (m)	POC/N (mL)	$bSiO_2$ (mL)	SEM (mL)	TChl (mL)	SFChl (mL)	FC (mL)	Lugols (mL)
30/03/2019	06:23	CR4	CTD051	10	3	10.1	1000	500	-	200	-	4	-
30/03/2019	06:23	CR4	CTD051	9	4	15.5	1000	500	-	200	-	4	-
30/03/2019	06:23	CR4	CTD051	8	5	18.2	1000	500	-	200	-	4	-
30/03/2019	06:23	CR4	CTD051	6	6	26.5	1000	500	500	200	200	4	200
						TOTAL	166	160	55	172	104	150	60

Preliminary Results

Preliminary results show that Chl *a* concentration was variable over the central and eastern Agulhas Bank during the cruise. Surface Chl *a* concentrations from *in situ* data shows that patches of high surface Chl *a* concentrations around Port Alfred and the Tsitsikamma coast (Figure 13), which could be as a result of upwelling. No Chl *a* response was visible in the vicinities of the Cold Ridge area. These data correlate relatively well with the composite surface Chl *a* obtained from satellite (VIIRS) from the 23 to the 30 March 2019 (Figure 14) at the exception of St Francis Bay which showed much higher Chl *a* concentration in the remote sensing than in the *in situ* data. Note that Algoa Bay was not sampled during the cruise due to bad weather.

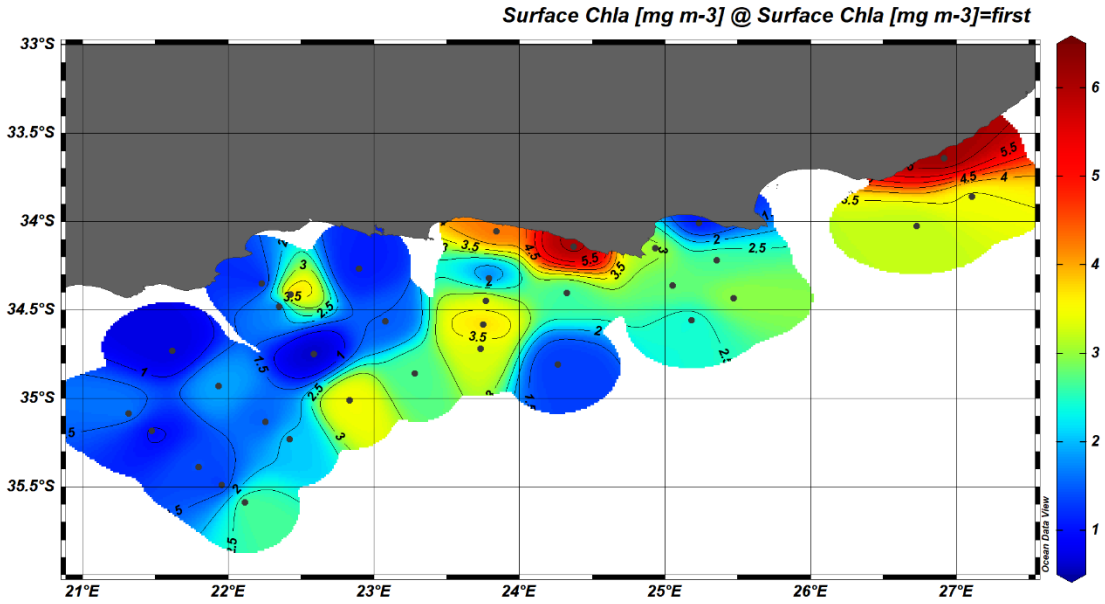


Figure 13: Isosurface map showing surface Chl a concentration along the sampled stations during the EK188 cruise

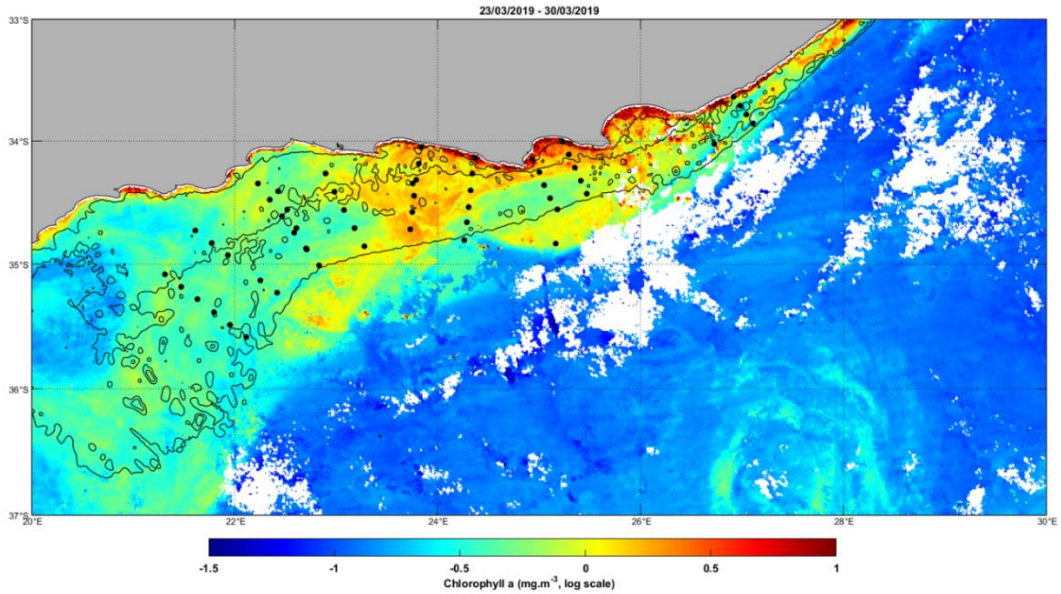


Figure 14: Satellite image obtained from VIIRS, showing Chl a concentration (mg m-3 logged) from 23/03/2019 to 30/03/2019 along the central and eastern Agulhas Bank

Figure 15 shows the contribution of the different sizes of phytoplankton to the total Chl *a* from the *in situ* samples. The picoplankton size fraction (<2 µm) always represented less than 1 mg m^{-3} of the total Chl *a*, representing overall ~20 % of the total Chl *a*. Nanoplankton (2-20 µm) contributed approximately 50 % of the total Chl *a* for total concentration less than 2 mg m^{-3}, and overall contributed to 42 % of the total Chl *a*. Finally, the microplankton fraction (>20 µm) was dominating only when the total Chl *a* concentration was more than 2 mg m^{-3}. The global contribution of microplankton was approximately 38 % to the total concentration. Having phytoplankton cells smaller than 20 µm can have important consequences on the pelagic food web functioning, as these cells are not necessarily available to mesozooplankton organisms. The Chl *a* was distributed above the thermocline with a deep Chl *a* maximum only at some stations while at others Chl *a* was homogeneously distributed in the upper water column.

<u>Encountered issues</u>

One of the issues that we encountered during the cruise was rough weather, as a result of that we had to skip two transects from our planned CTD transects. At two occasions, one Niskin bottle did not close or malfunctioned which resulted in not getting the desired samples.

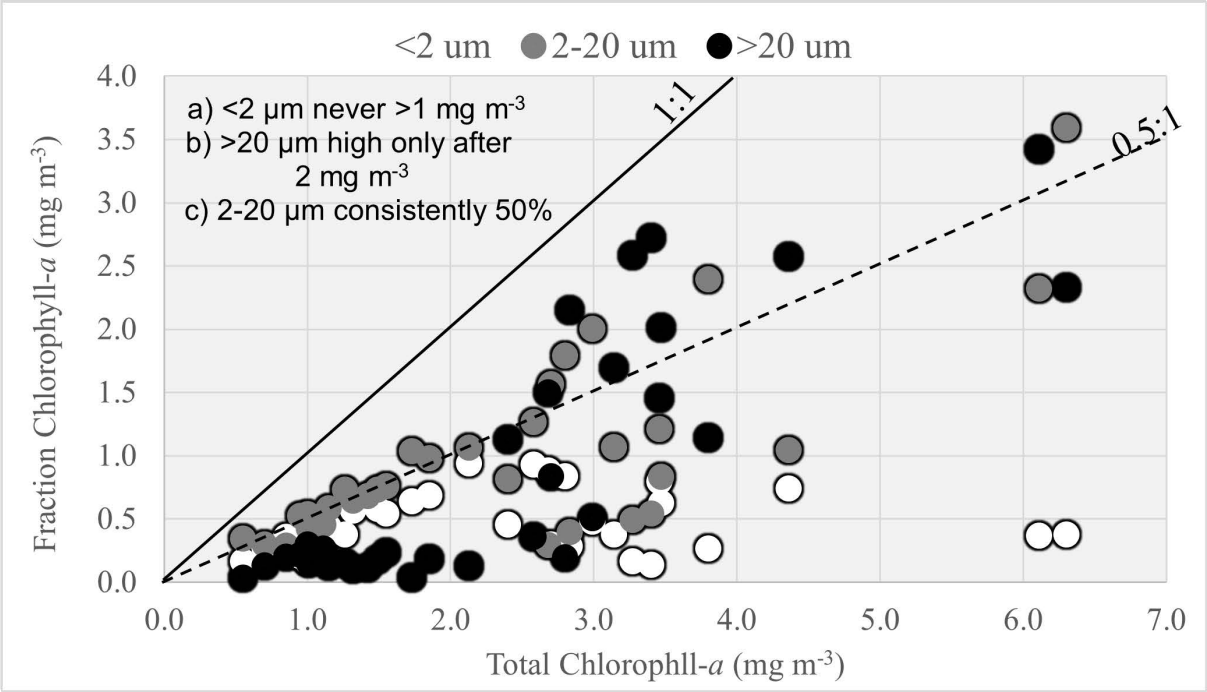


Figure 15: Relationship between total and size fractionated Chl a (mg m^{-3})

4.6. Zooplankton and Secondary Production

Margaux Noyon and Riaan Weitz

The objectives of the zooplankton work were as fellow:

- Determine the spatial distribution of zooplankton abundance and biovolume on the Agulhas Bank and its relationship with environmental parameters
- Determine the size spectrum of the zooplankton on the Agulhas Bank
- Measure secondary production of the zooplankton on the Agulhas Bank and compare it with the parameters of the Normalised Biovolume Size Spectrum (NBSS)
- Collect squid paralarvae for genetic analyses to determine their diet

The map in Figure 16 shows all the stations sampled during the cruise on the Agulhas Bank. Some stations at the start of the cruise (furthest east) were not sampled due to bad weather (wind speed over 25kt) in the region of Port Alfred and Algoa Bay. A summary table can be found Table 7.

At each station, two bongo nets were deployed:

- A 200 µm mesh size net towed vertically from the bottom or 200m depth when deeper
- A 500 µm mesh size net towed obliquely from the bottom or 200m depth when deeper

Both nets were equipped with a flowmeter to determine the volume of seawater filtered. The depth of deployment was determined using the length of the wire out for the vertical net and a live depth sensor (using a conductor cable) for the oblique tow.

Once on deck, both nets were washed with seawater to collect all the biological material into the cod-ends. All cod-ends were rinsed thoroughly with filtered seawater and concentrated onto a mesh of 200 µm (Figure 17).

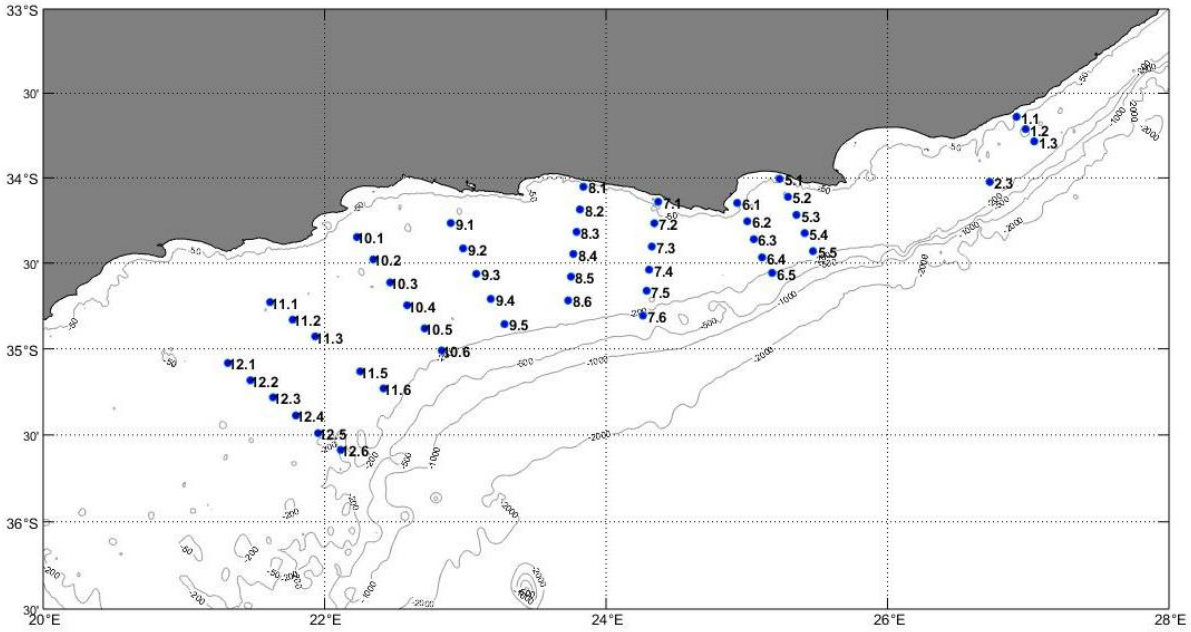


Figure 16: Map of the stations where a 200 µm Bongo net was deployed

Table 7: Sampling log of the zooplankton nets deployed during the March 2019 cruise

Date (YYYYMMDD)	Station	Grid #	Latitude (DD.MMMM)	Longitude (DD.MMMM)	CTD station	Bottom Depth	O. Bongo 200 + 200 (dip #)	O.Bongo 500 + 500 (Dip #)
20190323	3977	1.1	-33.3832	-26.5501	CTD001	43.5	1	1
20190323	3978	1.2	-33.4271	-26.5882	CTD002	66.1	2	2
20190323	3979	1.3	-33.4712	-27.0202	CTD003	92	3	-
20190323	3981	2.3	-34.0168	-26.4375	CTD005	103	4	-
20190324	3982	5.1	-34.0035	-25.1394	CTD006	42	5	3
20190324	3983	5.2	-34.0662	-25.1749	CTD007	73	6	4
20190324	3984	5.3	-34.1296	-25.2188	CTD008	113	7	5
20190324	3985	5.4	-34.194	-25.2525	CTD009	112	8	6
20190324	3986	5.5	-34.2582	-25.2818	CTD010	144.4	9	7
20190324	3987	6.5	-34.3308	-25.1108	CTD011	160	10	8
20190324	3988	6.4	-34.2799	-23.0682	CTD012	118	11	9
20190324	3989	6.3	-34.2161	-25.032	CTD013	117	12	10
20190324	3990	6.2	-34.1516	-25.0063	CTD014	116	13	11
20190325	3991	6.1	-34.0881	-24.5588	CTD015	28	14	12
20190325	3992	7.1	-34.0842	-24.2224	CTD016	43.6	15	13
20190325	3993	7.2	-34.158	-24.202	CTD017	100	16	14
20190325	3994	7.3	-34.2409	-24.1932	CTD018	120	17	15
20190325	3995	7.4	-34.3235	-241828	CTD019	110	18	16
20190325	3996	7.5	-34.3969	-24.1707	CTD020	118	19	17
20190325	3997	7.6	-34.484	-24.1517	CTD021	312	20	18
20190326	3998	8.6	-34.4306	-23.4443	CTD022	129	21	19
20190326	3999	8.5	-34.3463	-23.4511	CTD023	113	22	20

Date (YYYYMMDD)	Station	Grid #	Latitude (DD.MMMM)	Longitude (DD.MMMM)	CTD station	Bottom Depth	O. Bongo 200 + 200 (dip #)	O.Bongo 500 + 500 (Dip #)
20190326	4000	8.4	-34.2692	-23.4612	CTD024	112	23	21
20190326	4001	8.3	-34.1895	-23.4733	CTD025	112	24	22
20190326	4002	8.2	-34.1104	-23.4879	CTD026	97.2	25	23
20190326	4003	8.1	-34.0294	-23.5022	CTD027	72	26	24
20190326	4004	9.1	-34.1645	-22.5271	CTD028	84	27	-
20190327	4005	9.1	-34.1591	-22.538	CTD029	82.5	28	25
20190327	4006	9.2	-34.2512	-22.584	CTD030	105	29	26
20190327	4007	9.3	-34.3396	-23.0422	CTD031	113	30	27
20190327	4008	9.4	-34.4254	-23.1082	CTD032	116.5	31	28
20190327	4009	9.5	-34.5143	-23.1676	CTD033	146	32	29
20190327	4010	10.6	-35.004	-22.5015	CTD034	170	33	30
20190327	4011	10.5	-34.5266	-22.4294	CTD035	128	34	31
20190327	4012	10.4	-34.4486	-223517	CTD036	112	35	32
20190328	4013	10.3	-34.3678	-22.2791	CTD037	99	36	33
20190328	4014	10.2	-34.2866	-22.2076	CTD038	87	37	34
20190328	4015	10.1	-34.206	-22.1398	CTD039	73.9	38	35
20190328	4016	11.1	-34.4379	-21.3677	CTD040	80	39	36
20190328	4017	11.2	-34.4943	-21.4688	CTD041	88	40	37
20190328	4018	11.3	-34.5515	-21.564	CTD042	108	41	38
20190328	4019	11.5	-35.0776	-22.1528	CTD043	114	42	39
20190328	4020	11.6	-35.1381	-22.2507	CTD044	145	43	40
20190329	4021	12.6	-35.358	-22.0492	CTD045	175	44	41
20190329	4022	12.5	-35.29587	-21.5713	CTD046	157	45	42
20190329	4023	12.4	-35.232	-21.4786	CTD047	133	46	43
20190329	4024	12.3	-35.1691	-21.3796	CTD048	121	47	44
20190329	4025	12.2	-35.1099	-21.2832	CTD049	113	48	45
20190329	4026	12.1	-35.0498	-21.1859	CTD050	89	49	46

One of each 200 µm and 500 µm net were preserved in formaldehyde (4% final concentration). These samples are quantitative samples and will be analysed to determine abundance and biovolume of the main taxa using a Zooscan (200 µm net) and to determine the abundance of squid paralarvae and/or fish larvae (500 µm net), respectively. The Normalised Biovolume Size Spectrum (NBSS) will also be calculated based for the 200 µm net.

To measure secondary production, three Eppendorf tubes (2mL) were filled with zooplankton from one of the 200 µm and 500 µm nets. The tubes were flash frozen in liquid nitrogen and then preserved at -80˚C freezer until further analyses. The Aminoacyl-tRNA synthesis (AARS) activity will be measured on these sub-samples, following the protocol of Yebra and Hernandez-Leon (2004), modified by Yebra et al (2011), to assess zooplankton production rates.

Squid paralarvae will be picked out of the second 500 µm net preserved in ethanol (90%) to investigate their diet using a genetic approach.

A summary of the nets, the methods and their aims can be found in Table 8.

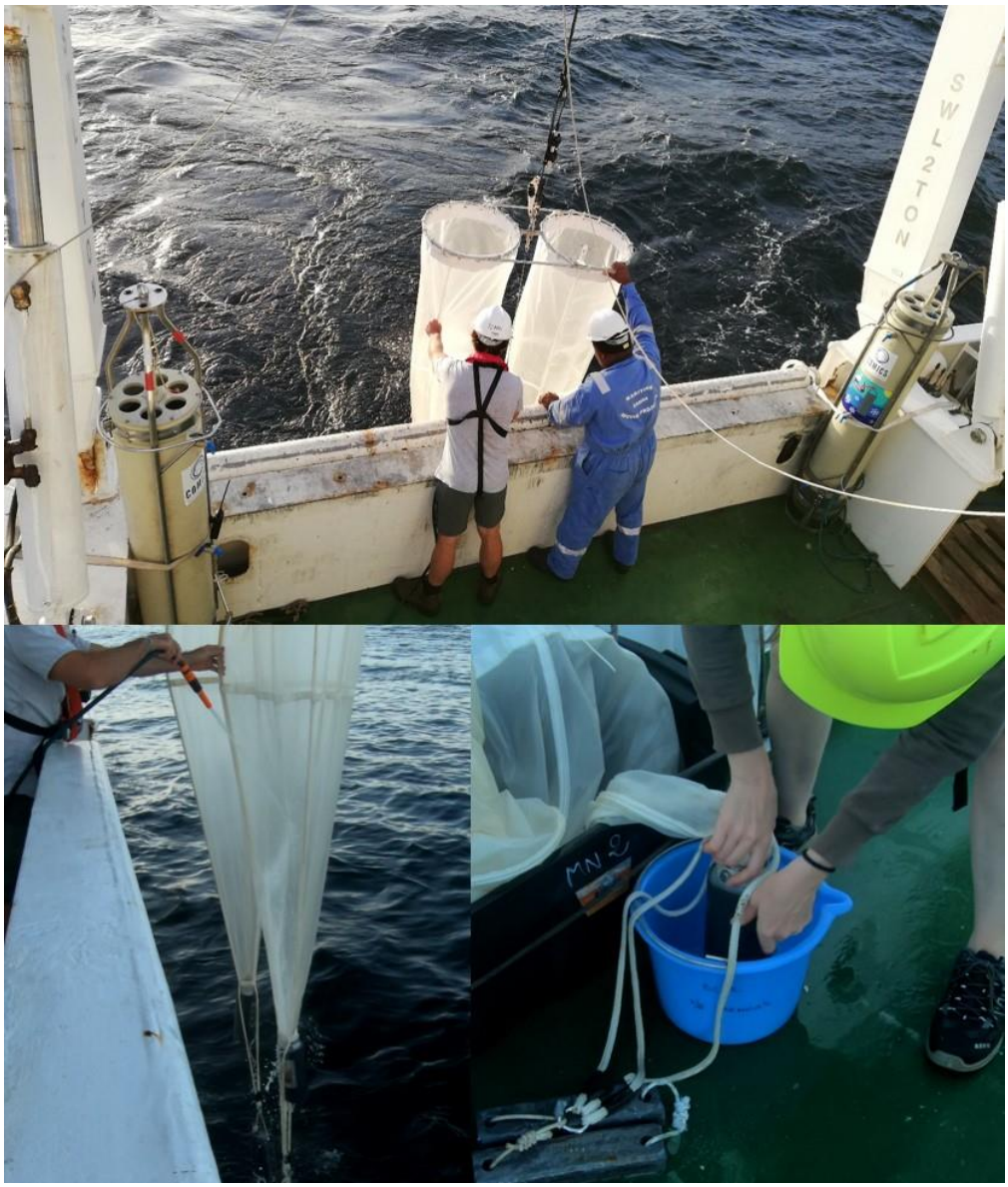


Figure 17: Pictures illustrating the Bongo net deployment

Table 8: Summary of the zooplankton nets deployed, the preservation methods for each sample and the scientific purpose

Net mesh	Preservation method	Purpose
Bongo 200 µm #1	Formaldehyde	Quantitative to measure abundance/biovolume using a Zooscan
Bongo 200 µm #2	Frozen -80˚C	AARS
Bongo 500 µm #1	Formaldehyde	Quantitative to measure abundance of squid paralarvae and maybe other fish larvae
Bongo 500 µm #2	Ethanol & 3 tubes frozen -80˚C	DNA analyses of squid paralarvae & AARS

4.7. Echo-sounder

The EK60 was recording data all along the cruise at 38 and 120 kHz frequencies. Some very preliminary quality checks have been made in France in June 2019 (IRD, Brest) showing that the acquisition of the data was very good and very little noise was present on the echograms. The data will be analysed at a later stage to be determined depending on student.

4.8. Moorings recovery

Brian Godfrey, Riaan Weitz, Lisa Martinengo

The recovery was done on 30 March 2019, under good weather condition. The moorings had been deployed since 17 October 2018.

The main aim of these moorings was to measure the currents as well as the temperature structure throughout the water column on a transect crossing the central Agulhas Bank, and in principle through a feature, when present, called the Cold Ridge (off Mossel Bay, Figure 18).

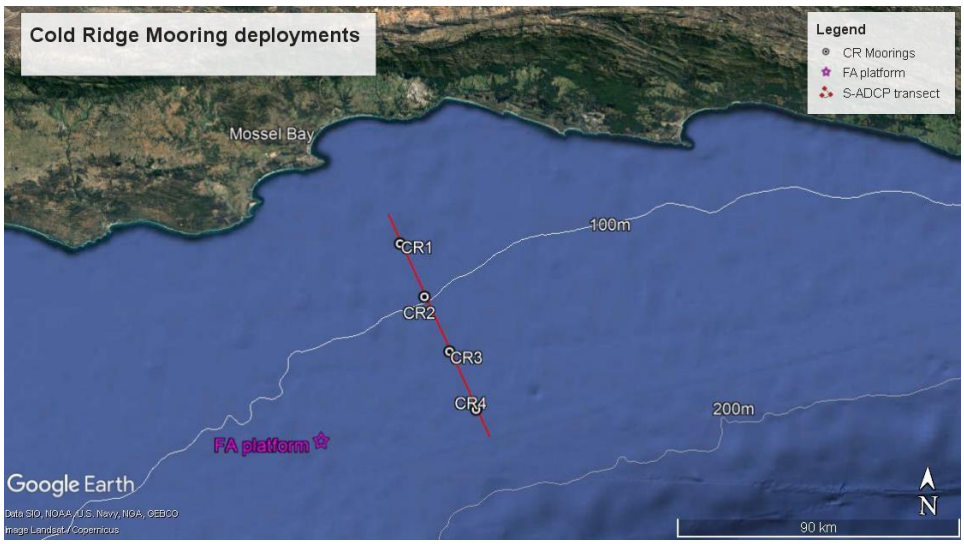


Figure 18: Map of the 4 sub-surface mooring locations

A CTD cast was done at each mooring location prior to recovery. All four moorings were successfully recovered according to the procedures agreed upon at a safety meeting with the captain and the mooring team. The moorings were recovered from the starboard beam. Once released using the acoustic transducer, the ship started its approach towards the buoys after they surfaced. The surface float was brought onboard first with the help of a grapnel hook attached to a rope, and the thermistor line pulled in by hand until the bottom float and acoustic release assembly was alongside. The bottom float was then connected to the crane by using a Seacatch recovery hook attached to a soft sling and lifted on board. The recovery details of the four moorings are given in

Table 9. The dataset is complete (100%), except the Starmon temperature / depth (T/D) recorders on CR1 and CR2. Both these loggers showed signs of water ingress that appeared to have entered through the pressure sensor port. Attempts to connect to the instruments and download the data was unsuccessful. Both loggers have been returned to the manufacturers for further data recovery efforts.

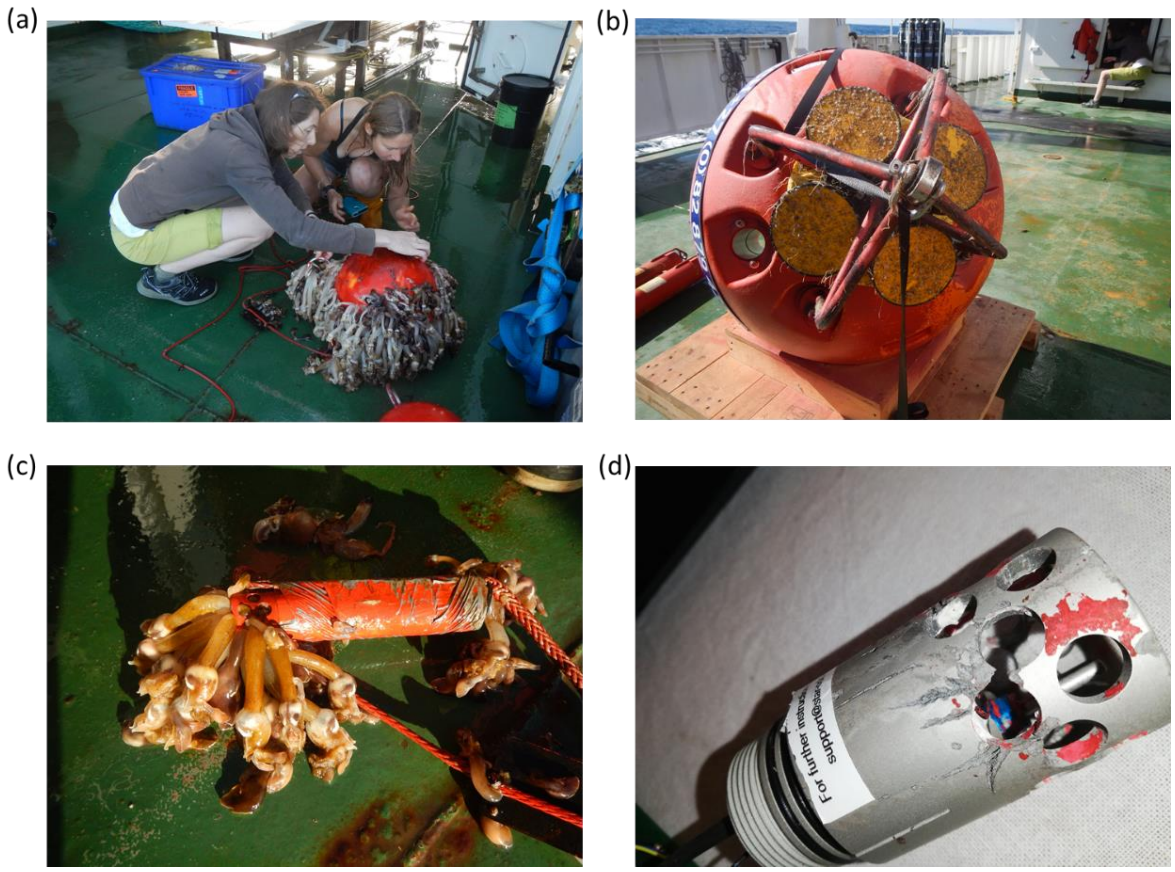


Figure 19: Biofouling on the recovered moorings. a) The top flotation of CR4 covered in goose barnacles. b) Nortek Signature 250 (mounted in buoy) after recovery showing biofouling on the transducer heads. c) Goose barnacles growing on the TD sensor situated just below the surface flotation. d) Corrosion on the housing of the TD sensor could have resulted in flooding of two of the loggers.

Biofouling mostly consisted of goose barnacles and was most pronounced on the top floatation positioned between 15 – 20 m below the surface (Figure 19). It was noted that the offshore mooring (CR4) had more growth than any of the other locations. Biofouling on the ADCP transducers were at an acceptable level and should not have any negative effects on the quality of the current measurements (Figure 19b). The TD sensors situated just below the surface floatation were covered in goose barnacles (Figure 19c). Corrosion of the aluminium housing of the TD loggers was noted once the biofouling was removed (Figure 19d).

The data from the T/D loggers will be examined closely for changes related to the biofouling, for example a gradual increase in depth over time (*i.e*. due to decreased buoyance).The updated diagrams of the moorings can be found in appendix 3.

Table 9: Percentage data return for each instrument deployed

CR1	**Start date**	**End date**	**% data return**
Temp1 / Depth	No data	No data	0
Temp2	17/10/2018	30/03/2019	100
Temp3	17/10/2018	30/03/2019	100
Temp4	17/10/2018	30/03/2019	100
Temp5	17/10/2018	30/03/2019	100
Temp6	17/10/2018	30/03/2019	100
Temp7	17/10/2018	30/03/2019	100
Temp8	17/10/2018	30/03/2019	100
Nortek Current, Temp, Depth	17/10/2018	30/03/2019	100
CR2			
Temp / Depth	No data	No data	0
Temp2	17/10/2018	30/03/2019	100
Temp3	17/10/2018	30/03/2019	100
Temp4	17/10/2018	30/03/2019	100
Temp5	17/10/2018	30/03/2019	100
Temp6	17/10/2018	30/03/2019	100
Temp7	17/10/2018	30/03/2019	100
Temp8	17/10/2018	30/03/2019	100
Temp9	17/10/2018	30/03/2019	100
Nortek Current, Temp, Depth	17/10/2018	30/03/2019	100
CR3	17/10/2018	30/03/2019	100
Temp1 / Depth	17/10/2018	30/03/2019	100
Temp2	17/10/2018	30/03/2019	100
Temp3	17/10/2018	30/03/2019	100
Temp4	17/10/2018	30/03/2019	100
Temp5	17/10/2018	30/03/2019	100
Temp6	17/10/2018	30/03/2019	100
Temp7	17/10/2018	30/03/2019	100
Temp8	17/10/2018	30/03/2019	100
Temp9	17/10/2018	30/03/2019	100
Temp10	17/10/2018	30/03/2019	100
Nortek Current, Temp, Depth	17/10/2018	30/03/2019	100
CR4	17/10/2018	30/03/2019	100
Temp1 / Depth	17/10/2018	30/03/2019	100
Temp2	17/10/2018	30/03/2019	100
Temp3	17/10/2018	30/03/2019	100
Temp4	17/10/2018	30/03/2019	100
Temp5	17/10/2018	30/03/2019	100
Temp6	17/10/2018	30/03/2019	100
Temp7	17/10/2018	30/03/2019	100
Temp8	17/10/2018	30/03/2019	100
Temp9	17/10/2018	30/03/2019	100
Temp10	17/10/2018	30/03/2019	100
Temp11	17/10/2018	30/03/2019	100
Nortek Current, Temp, Depth	17/10/2018	30/03/2019	100

4.9.Gliders recovery

Stephen Woodward

Glider operations on EK188 consisted of the recovery of 3 gliders deployed as part of the Solstice GCRF project.

All 3 gliders were deployed from Port Alfred on 14th March 2019 using the vessel 'Blackfish'. Deployment location for all 3 gliders was close to 33°38.000 S, 26°57.00 E.

All glider recoveries were carried out from the starboard side, using the forward deck crane. Slocum gliders were recovered by jettisoning the nose recovery device (the buoyant nose is detached using a burn wire, and drifts away from the vehicle whilst attached by a buoyant line which can be grappled from the deck) (Figure 20). The Seaglider was recovered using a telescopic carbon fire hoop, lassoing the rudder for recovery.

Calibration CTD casts were performed at recovery of gliders 424 and SG550

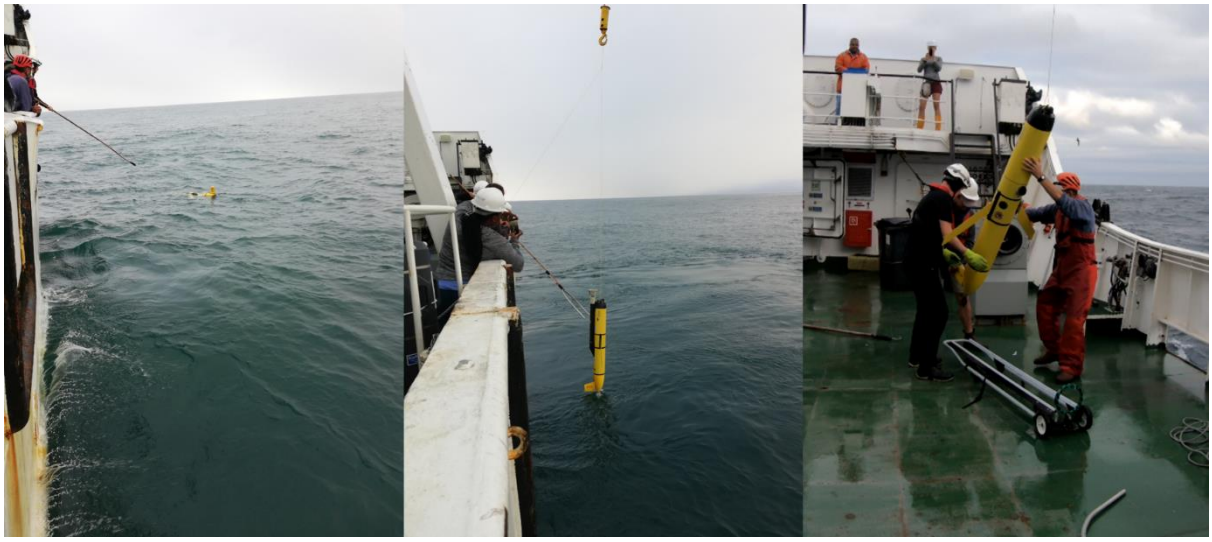


Figure 20: First Slocum recovery onboard the R.V. Ellen Khuzwayo

Dates and position of Recoveries

- Slocum glider 438 ('Frazil'). Recovered 25th March 2019, 04:00 (34°09.303 S, 25°31.874 E)
- Seaglider SG550 ('Eltanin'). Recovered 31st March 2019, 07:30 (34°55.390 S, 24°55.941 E)
- Slocum glider 424 ('OMG3'). Recovered 31st March 2019, 16:20 (34°20.740 S, 23°45.353 E)

Sensor Packages

Slocum glider 438: Seabird CT sensor S/N 9034
Aanderaa Oxygen optode S/N 268
WetLabs Fluorometer S/N 3262
Imagenex Echosounder S/N 6547

Seaglider SG550: Seabird CT sensor S/N 0227
Aanderaa Oxygen optode S/N 122
WetLabs Fluorometer S/N 868
NOC Lab-on-chip Nitrate sensor

Slocum glider 424: Seabird CT sensor S/N 0221
Aanderaa Oxygen optode S/N 332

Rockland Microrider S/N 105:	Shear probe 1 – S/N M1071
	Shear probe 2 – S/N M1074
	Thermistor 1 – S/N T609
	Thermistor 2 – S/N T610

Gliders calibration sheets can be found in appendix 4

Problems encountered

Slocum 438 suffered a critical error early in the mission. The glider lost all communications to the science bay and had to be flown with all sensors off and recovered at the earliest opportunity.

Recovery of SG550 was hampered by the glider being caught in the Agulhas current and drifting very quickly (~3 knots). This made location of the glider very difficult. Recovery to deck took several attempts, the glider initially being pulled under the hull and resurfacing on the port side requiring the vessel to reposition.

Glider tracks

Figure 21 shows the tracks of the Slocum 438 (purple), 424 (orange) and Seaglider 550 (blue). The dashed lines and crosshairs show the final waypoint for each glider at time of recovery. Westward progress was noticeably slower than anticipated at the start of the mission, with the main Agulhas current seemingly situated well beyond the 200m contour and a strong Eastwards counter-current on the shelf. Figure 22 shows the detailed 10m bathymetry used for piloting.

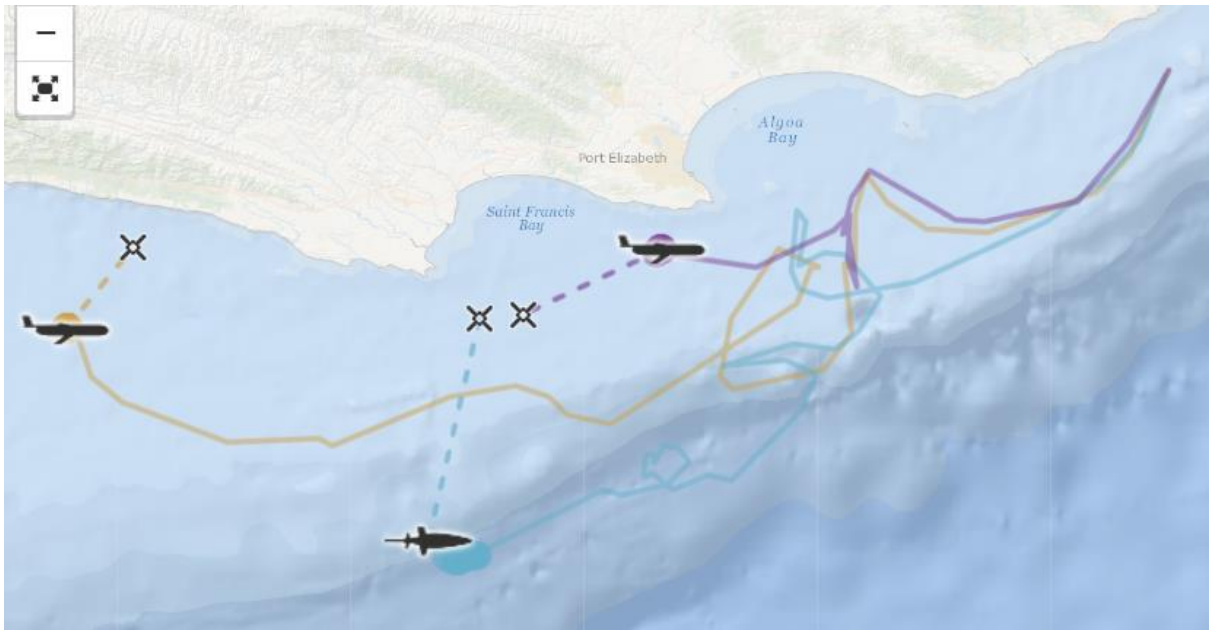


Figure 21: Tracks of the gliders from the 14 March 2019 to their recovery dates (see text for exact dates)

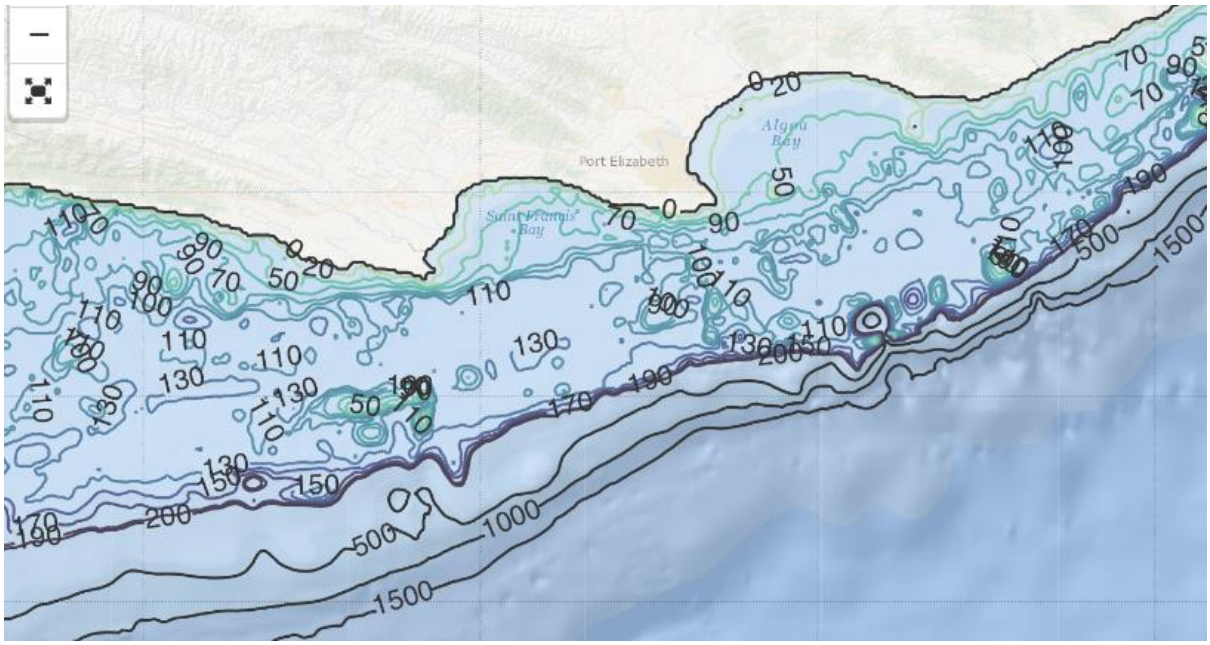


Figure 22: 10 m contour bathymetry used for piloting

4.10. Thermosalinograph (TSG) and SST from remote sensing

A Seabird 45 Thermosalinograph was used during the cruise with the exception of the following occasions:

- From 11:02 to 14:34 on 22/03/2019
- From 7:12 to 7:40 on 23/03/2019
- From 21:55 to 22:51 on 23/03/2019

One salinity bottle per day was taken (9 samples), to measure salinity using a laboratory salinograph as explained in the CTD calibration section above. This data was then used in conjunction with the TSG data to calibrate the TSG using TSG-QC (https://us191.ird.fr/?article63), a Matlab processing tool developed for validating TSG data obtained from research and commercial vessels. The temperature data from the TSG were not validated.

Temperature and salinity plots are illustrated in Figure 24. The temperature data shows cooler waters on the east Agulhas Bank compared to the central part of the bank.

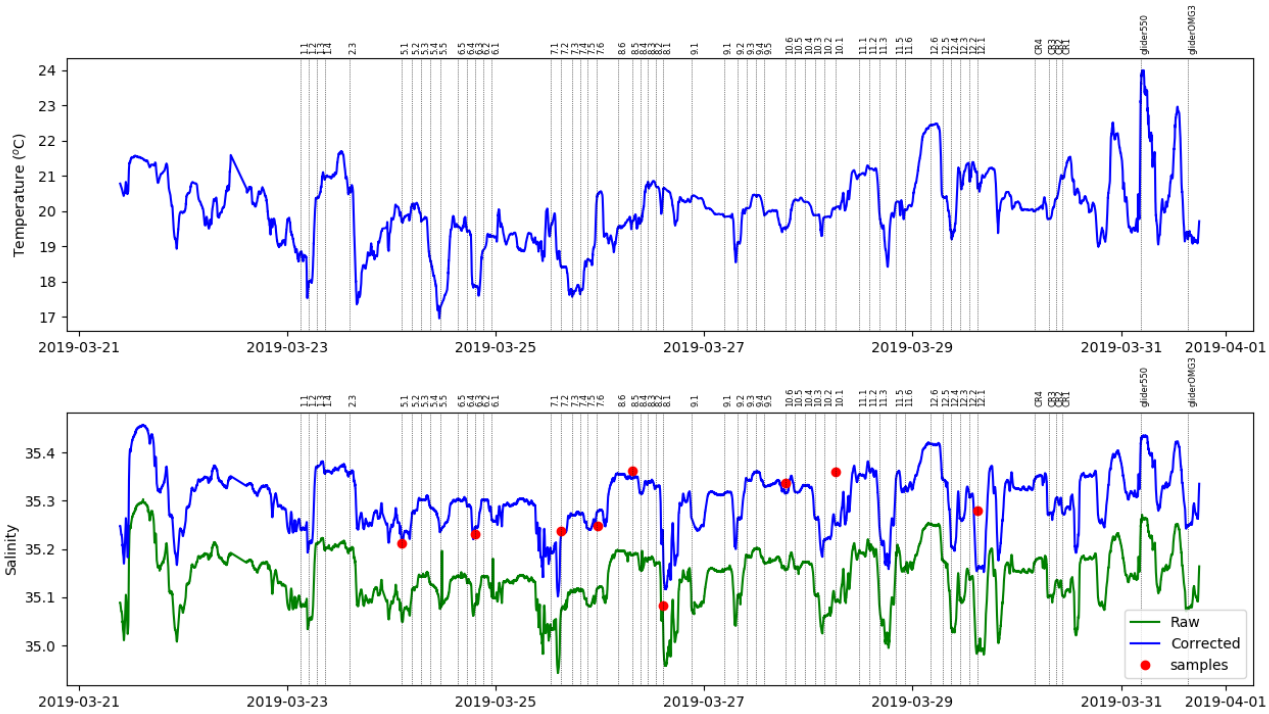


Figure 23: Time series of sea surface temperature (intake) and salinity (raw and corrected) as measured by the TSG during the cruise. Salinity samples used for calibration as well as CTD stations are also indicated.

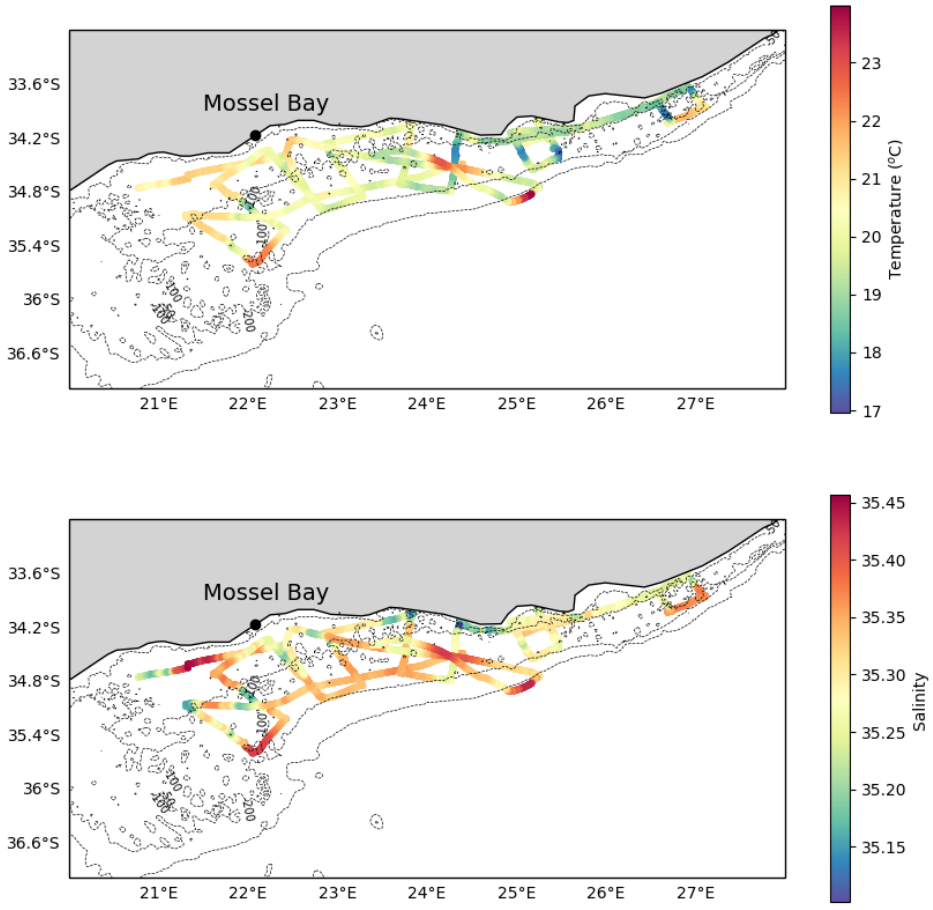


Figure 24: Plots of temperature and salinity as measured by the Thermosalinograph from 21 to 31 March 2019

It is worth noting that the SST from the TSG and MODIS (Figure 25) do not overlap exactly. The strong difference between the east and the west of the bank in the TSG data is not seen as strongly in the satellite data. This discrepancy is not surprising considering the nature and integration time difference between the two measurements.

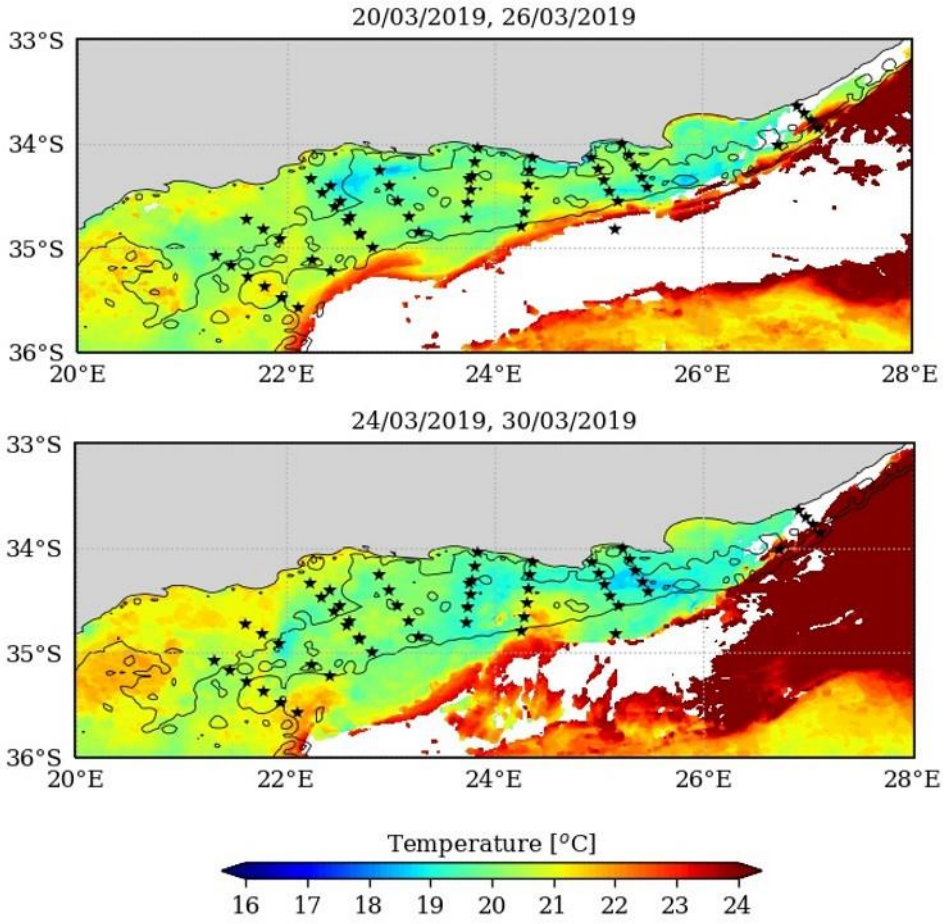


Figure 25: Weekly Sea Surface Temperature from the 20 to 26 March 2019 (top) and from 24 to 30 March 2019 (bottom) from MODIS data

5. Appendix 1: CTD configuration set up & calibration coefficients

911+ Seabird System – Sensor Details:

1. Conductivity, SN 4341, calibrated 19-Jun-14
2. Temperature, SN 5913, calibrated 13-Jun-14
3. Pressure, Digiquartz with TC, SN 1195, calibrated 25-June-14
4. Oxygen, SBE 43, SN 2914, 21-Jun-14
5. Backscattering Meter (650 nm), WET Labs, ECO-BBRTD, SN BBRTD-1203, calibrated 27-May-14
6. Transmissometer, WET Labs C-star, SN CST-1664DR, calibrated 20-Mar-14
7. Transmissometer, WET Labs C-star 2, SN CST-1671DB, calibrated 20-Jun-14
8. Fluorometer, WET Labs FLNTU, SN FLNTURTD-3203, calibrated 10-Jul-14
9. Turbidity Meter, WET Labs, ECO-NTU, SN FLNTURTD-3203, calibrated 10-Jul-14
10. PAR/Irradiance, Biospherical/Licor, SN 70566, calibrated 11-Jun-14
11. Altimeter, SN 51863

Instrument Configuration File: Ellen188_DerivedFrom_afr_ctd_new alti_aug2016.xmlcon

Configuration report for SBE 911plus/917plus CTD

Frequency channels suppressed: 2
Voltage words suppressed: 0
Computer interface: RS-232C
Deck unit: SBE11plus Firmware Version >= 5.0
Scans to average: 24
NMEA position data added: Yes
NMEA depth data added: No
NMEA time added: No
NMEA device connected to: deck unit
Surface PAR voltage added: Yes
Scan time added: No

1) Frequency 0, Temperature
  Serial number: 5913
  Calibrated on: 13-Jun-14
  G: 4.30663214e-003
  H: 6.25593104e-004
  I: 1.92487810e-005
  J: 1.42977558e-006
  F0: 1000.000
  Slope: 1.00000000
  Offset: 0.0000

2) Frequency 1, Conductivity
  Serial number: 4341
  Calibrated on: 19-Jun-14
  G: -9.93703569e+000

H: 1.28075772e+000
I: -2.41792292e-003
J: 2.28828744e-004
CTcor: 3.2500e-006
CPcor: -9.57000000e-008
Slope: 1.00000000
Offset: 0.00000

3) Frequency 2, Pressure, Digiquartz with TC
Serial number: 1195
Calibrated on: 25-Jun-14
C1: -4.042932e+004
C2: -1.162854e+000
C3: 1.224700e-002
D1: 3.406200e-002
D2: 0.000000e+000
T1: 3.030403e+001
T2: -6.701740e-004
T3: 4.024410e-006
T4: 3.016400e-009
T5: 0.000000e+000
Slope: 1.00000000
Offset: 0.00000
AD590M: 1.280500e-002
AD590B: -9.406860e+000

4) A/D voltage 0, Oxygen, SBE 43
Serial number: 2914
Calibrated on: 21-Jun-14
Equation: Sea-Bird
Soc: 5.00430e-001
Offset: -4.88000e-001
A: -3.27850e-003
B: 1.36310e-004
C: -2.88030e-006
E: 3.60000e-002
Tau20: 1.62000e+000
D1: 1.92634e-004
D2: -4.64803e-002
H1: -3.30000e-002
H2: 5.00000e+003
H3: 1.45000e+003

5) A/D voltage 1, Backscattering Meter, WET Labs, ECO-BB
Serial number: BBRTD-1203
Calibrated on: 27-May-14
ScaleFactor: 0.003038
Dark output: 0.057100

6) A/D voltage 2, Transmissometer, WET Labs C-Star

Serial number: CST-1664DR
Calibrated on: 20-Mar-14
M: 21.3650
B: -0.0850
Path length: 0.250

7) A/D voltage 3, Transmissometer, WET Labs C-Star, 2

Serial number: CST-1671DB
Calibrated on: 20-Jun-14
M: 21.0840
B: -0.0420
Path length: 0.250

8) A/D voltage 4, Fluorometer, WET Labs FLNTU

Serial number: FLNTURTD-3203
Calibrated on: 10-Jul-14
Dark output: 0.0700
Scale factor: 1.00000000e+001

9) A/D voltage 5, Turbidity Meter, WET Labs FLNTU

Serial number: FLNTURTD-3203
Calibrated on: 10-Jul-14
Scale Factor: 5.000000
Dark output: 0.058000

10) A/D voltage 6, PAR/Irradiance, Biospherical/Licor

Serial number: 70566
Calibrated on: 11--Jun-14
M: 1.00000000
B: 0.00000000
Calibration constant: 11299000000.00000000
Multiplier: 1.00000000
Offset: -0.09102135

11) A/D voltage 7, Altimeter

Serial number: 51863
Calibrated on: unknown
Scale factor: 15.000
Offset: 0.000

12) SPAR voltage, SPAR, Biospherical/Licor

Serial number: 20473
Calibrated on: 09-Apr-14
Conversion factor: 1629.00000000
Ratio multiplier: 1.00000000
Scan length: 34

Frequency 0, Temperature

Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 5913
CALIBRATION DATE: 13-Jun-14

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

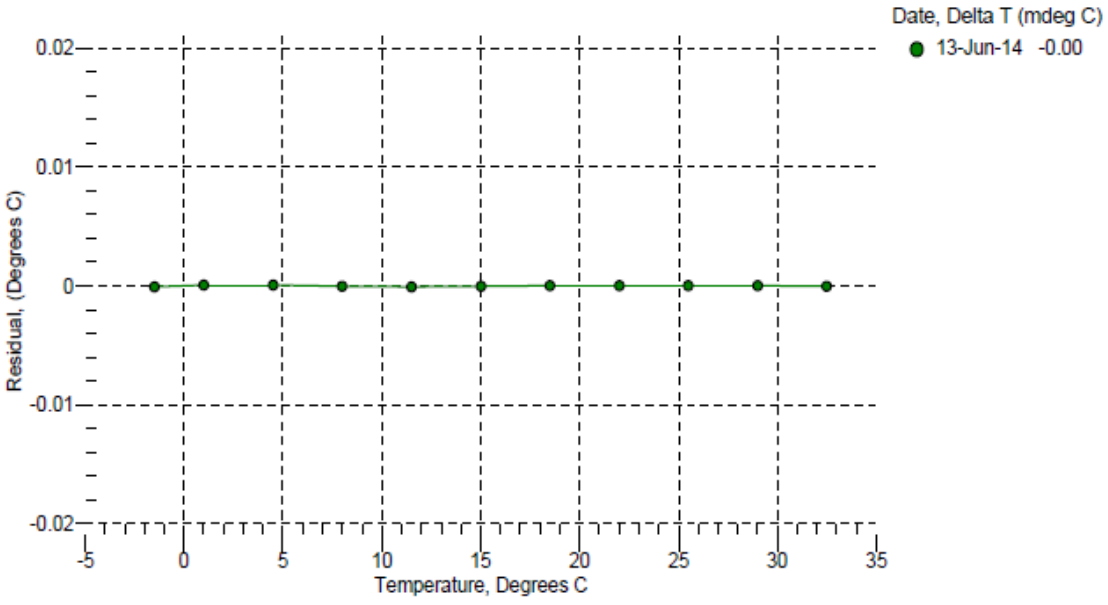
ITS-90 COEFFICIENTS:

g = 4.30663214e-003
h = 6.25593104e-004
i = 1.92487810e-005
j = 1.42977558e-006
f0 = 1000.0

BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5000	2800.693	-1.5001	-0.00008
1.0000	2964.775	1.0001	0.00009
4.5000	3206.058	4.5001	0.00008
8.0000	3461.216	8.0000	-0.00005
11.5001	3730.674	11.5000	-0.00009
15.0000	4014.805	15.0000	-0.00002
18.5000	4314.007	18.5000	0.00002
22.0000	4628.648	22.0000	0.00005
25.5000	4959.089	25.5000	0.00001
29.0000	5305.696	29.0000	0.00001
32.5000	5668.805	32.5000	-0.00003

Temperature ITS-90 = $1/\{ g + h[ln(f_0/f)] + i[ln^2(f_0/f)] + j[ln^3(f_0/f)]\} - 273.15$ (°C)

Residual = instrument temperature - bath temperature



Frequency 1, Conductivity

Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 4341
CALIBRATION DATE: 19-Jun-14

SBE 4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g =  -9.93703569e+000
h =   1.28075772e+000
i =  -2.41792292e-003
j =   2.28828744e-004

CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

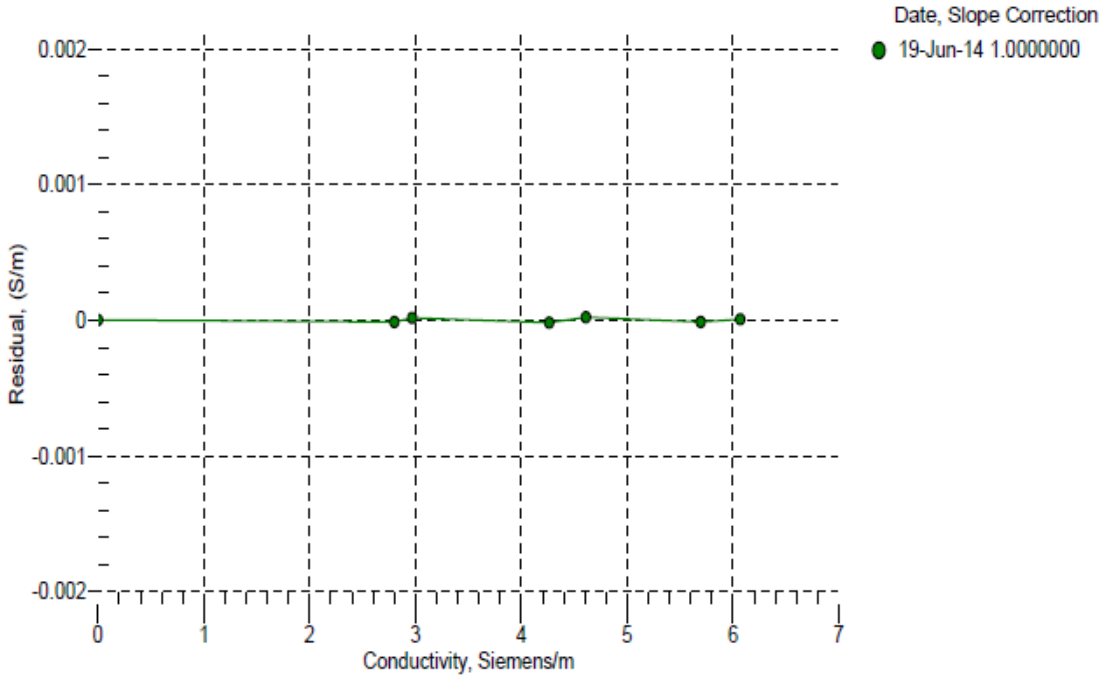
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.79086	0.00000	0.00000
-1.0001	34.7745	2.80151	5.45718	2.80150	-0.00001
0.9999	34.7749	2.97275	5.57894	2.97277	0.00002
14.9999	34.7778	4.26738	6.42461	4.26736	-0.00002
18.4999	34.7781	4.61384	6.63253	4.61386	0.00002
28.9999	34.7785	5.69681	7.24351	5.69680	-0.00001
32.5000	34.7741	6.06946	7.44201	6.06947	0.00001

f = INST FREQ / 1000.0

Conductivity = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$ Siemens / meter

t = temperatur e[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = instrument conductivity - bath conductivity



Frequency 2, Pressure, Digiquartz with TC

Sea-Bird Electronics, Inc.
13431 NE 20th St. Bellevue, Washington 98005 USA
Website: http://www.seabird.com

Phone: (425) 643-9866
FAX: (425) 643-9954
Email: seabird@seabird.com

SBE Pressure Test Certificate

Test Date: **6/19/2014** Description **SBE-9plus CTD**

SBE Sensor Information:

Model Number: **09**
Serial Number: **1195**

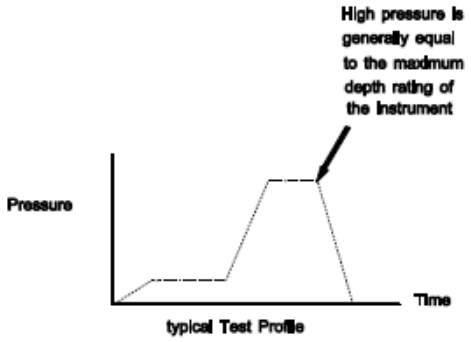
Pressure Test Protocol:

Low Pressure Test: **40** PSI Held For **15** Minutes

High Pressure Test: **10000** PSI Held For **15** Minutes

Passed Test: ☑

Tested By: nd



A/D voltage 0, Oxygen, SBE 43

Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2914
CALIBRATION DATE: 21-Jun-14

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
Soc = 0.5004
Voffset = -0.4880
Tau20 = 1.62

A = -3.2785e-003
B = 1.3631e-004
C = -2.8803e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS
D1 = 1.92634e-4
D2 = -4.64803e-2
H1 = -3.300000e-2
H2 = 5.00000e+3
H3 = 1.45000e+3

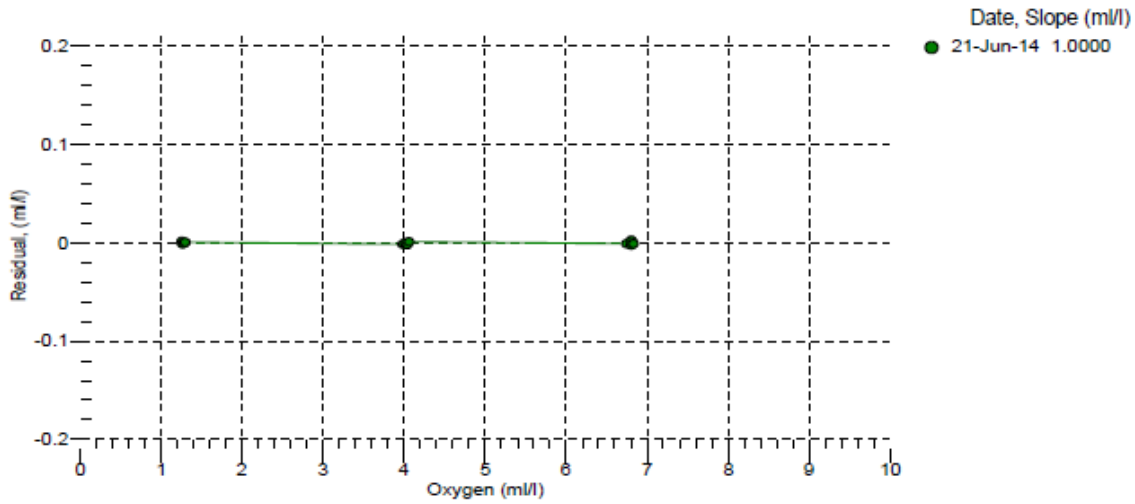
BATH OX (ml/l)	BATH TEMP (ITS-90)	BATH SAL (PSU)	INSTRUMENT OUTPUT (VOLTS)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.26	6.00	0.00	0.781	1.26	0.00
1.26	2.00	0.00	0.750	1.26	-0.00
1.27	12.00	0.00	0.833	1.27	-0.00
1.28	20.00	0.00	0.903	1.28	0.00
1.29	26.00	0.00	0.964	1.29	0.00
1.30	30.00	0.00	1.007	1.30	0.00
3.98	2.00	0.00	1.315	3.98	-0.00
4.01	12.00	0.00	1.578	4.01	-0.00
4.02	5.99	0.00	1.425	4.02	0.00
4.04	20.00	0.00	1.800	4.04	-0.00
4.06	26.00	0.00	1.983	4.06	0.00
4.06	30.00	0.00	2.110	4.06	0.00
6.75	2.00	0.00	1.890	6.75	-0.00
6.80	6.00	0.00	2.073	6.80	0.00
6.80	30.00	0.00	3.203	6.80	-0.00
6.81	26.00	0.00	2.994	6.81	0.00
6.82	12.00	0.00	2.341	6.82	-0.00
6.83	20.00	0.00	2.708	6.83	-0.00

Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * exp(E * P / K)

V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU], K = temperature [deg K]

OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar]

Residual = instrument oxygen - bath oxygen



A/D voltage 1, Backscattering Meter, WET Labs, ECO-BB

PO Box 518
620 Applegate St.
Philomath, OR 97370

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

WET Labs

Scattering Meter Calibration Sheet

5/27/2014
Wavelength: 650 S/N BBRTD-1203

Use the following equation to obtain either digital or analog "scaled" output values:

$$\beta(\theta_c)\ m^{-1}\ sr^{-1} = \text{Scale Factor} \times (\text{Output} - \text{Dark Counts})$$

• Scale Factor for 650 nm	=	3.714E-06	($m^{-1}sr^{-1}$)/counts	3.038E-03 ($m^{-1}sr^{-1}$)/volts
• Output	=	meter output	counts	meter output volts
• Dark Counts	=	38	counts	0.0571 volts
Instrument Resolution	=	1.0	counts	3.71E-06 ($m^{-1}sr^{-1}$)
		0.6992	mV	

Definitions:

- **Scale Factor**: Calibration scale factor, $\beta(\theta_c)$/counts. Refer to User's Guide for derivation.
- **Output**: Measured signal output of the scattering meter.
- **Dark Counts**: Signal obtained by covering detector with black tape and submersing sensor in water.

Instrument Resolution: Standard deviation of 1 minute of collected data.

BBRTD-1203.xls Revision S 10/4/07

A/D voltage 2, Transmissometer, WET Labs C-Star

PO Box 518
620 Applegate St.
Philomath, OR 97370

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

C-Star Calibration

Date March 20, 2014 S/N# CST-1664DR Pathlength 25 cm

	Analog output	Digital output
V_d	0.004 V	0 counts
V_{air}	4.831 V	15867 counts
V_{ref}	4.705 V	15453 counts

Temperature of calibration water	17.6 °C
Ambient temperature during calibration	20.9 °C

Relationship of transmittance (Tr) to beam attenuation coefficient (c), and pathlength (x, in meters): $Tr = e^{-cx}$

To determine beam transmittance: $Tr = (V_{sig} - V_{dark}) / (V_{ref} - V_{dark})$

To determine beam attenuation coefficient: $c = -1/x * \ln(Tr)$

V_d Meter output with the beam blocked. This is the offset.
V_{air} Meter output in air with a clear beam path.
V_{ref} Meter output with clean water in the path.
Temperature of calibration water: temperature of clean water used to obtain V_{ref}.
Ambient temperature: meter temperature in air during the calibration.
V_{sig} Measured signal output of meter.

Revision L 6/9/09

A/D voltage 3, Transmissometer, WET Labs C-Star, 2

PO Box 518
620 Applegate St.
Philomath, OR 97370

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

C-Star Calibration

Date June 20, 2014 S/N# CST-1671DB Pathlength 25 cm

	Analog output	Digital output
V_d	0.005 V	0 counts
V_{air}	4.492 V	14761 counts
V_{ref}	4.750 V	15610 counts

Temperature of calibration water	17.2 °C
Ambient temperature during calibration	20.0 °C

Relationship of transmittance (Tr) to beam attenuation coefficient (c), and pathlength (x, in meters): $Tr = e^{-cx}$

To determine beam transmittance: $Tr = (V_{sig} - V_{dark}) / (V_{ref} - V_{dark})$

To determine beam attenuation coefficient: $c = -1/x * \ln(Tr)$

V_d Meter output with the beam blocked. This is the offset.
V_{air} Meter output in air with a clear beam path.
V_{ref} Meter output with clean water in the path.
Temperature of calibration water: temperature of clean water used to obtain V_{ref}.
Ambient temperature: meter temperature in air during the calibration.
V_{sig} Measured signal output of meter.

Revision L 6/9/09

A/D voltage 4, Fluorometer, WET Labs FLNTU

& A/D voltage 5, Turbidity Meter, WET Labs FLNTU

PO Box 518
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Philomath, OR 97370

WET Labs

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www.wetlabs.com

FLNTU Characterization Sheet

Date: July 10, 2014 S/N: FLNTURTD-3203

Chlorophyll Scale Factor

Chlorophyll concentration expressed in µg/l can be derived using the equation:

CHL (µg/l) = Scale Factor x (Output - Dark Counts)

	Analog		Digital	
Dark Counts	0.070	V	45	counts
Scale Factor (SF)	10	µg/l/V	0.0118	µg/l/count
Maximum Output	4.99	V	4130	counts
Resolution	0.5	mV	1.0	counts
Ambient temperature during calibration	21.0	°C		

Nephelometric Turbidity Unit (NTU) Scale Factor

Turbidity units expressed in NTU can be derived using the equation:

NTU = Scale Factor x (Output - Dark Counts)

	Analog		Digital	
Dark Counts	0.058	V	48	counts
NTU Solution Value	2.36	V	1946	counts
Scale Factor (SF)	5	NTU/V	0.0064	NTU/count
Maximum Output	4.99	V	4130	counts
Resolution	0.7	mV	1.0	counts
Ambient temperature during calibration	21.0	°C		

Definition of terms:

Dark Counts: Signal output of the meter in clean water with black tape over detector.

NTU Solution Value: Signal output of the turbidity sensor when measuring a sample of interest.

SF (CHL): Determined using the following equation: SF = x ÷ (output - dark counts), where x is the concentration of the solution used during instrument characterization. SF is used to derive instrument output concentration from the raw signal output of the fluorometer.

SF (NTU): Scale factor is determined using the following equation: SF = xx ÷ (Output - Dark counts), where xx is the value of a Formazin concentration. For example: 12.2 ÷ (2011 - 50) = 0.0062.

Maximum Output: Maximum signal output the fluorometer is capable of.

Resolution: standard deviation of 1 minute of collected data.

PO Box 518
620 Applegate St.
Philomath, OR 97370

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

Scattering Meter Calibration Sheet

7/10/2014
Wavelength: 700 S/N FLNTURTD-3203

Use the following equation to obtain either digital or analog "scaled" output values:

$$\beta(\theta_c)\ m^{-1}\ sr^{-1} = \text{Scale Factor} \times (\text{Output} - \text{Dark Counts})$$

• Scale Factor for 700 nm	=	1.874E-05 $(m^{-1}sr^{-1})$/counts	1.534E-02 $(m^{-1}sr^{-1})$/volts
• Output	=	meter output counts	meter output volts
• Dark Counts	=	48 counts	0.064 volts
Instrument Resolution	=	1.0 counts 0.6881 mV	1.87E-05 $(m^{-1}sr^{-1})$

Definitions:

- **Scale Factor**: Calibration scale factor, $\beta(\theta_c)$/counts. Refer to User's Guide for derivation.
- **Output**: Measured signal output of the scattering meter.
- **Dark Counts**: Signal obtained by covering detector with black tape and submersing sensor in water.

Instrument Resolution: Standard deviation of 1 minute of collected data.

SPAR voltage, SPAR, Biospherical/Licor

Calibration Date	09/04/2014			
Model Number	QSR-2200			
Serial Number	20473			
Operator	TPC			
Standard Lamp	V-033(3/7/12)			
Probe Excitation Voltage Range:	6	to	18	VDC(+)
Output Polarity:	Positive			

Probe Conditions at Calibration(in air):

Calibration Voltage:	6	VDC(+)
Probe Current:	3.9	mA

Probe Output Voltage:

Probe Illuminated	96.2	mV
Probe Dark	1.0	mV
Probe Net Response	95.2	mV
RG780	1.0	mV

Corrected Lamp Output:

Output In Air (same condition as calibration):

9.342E+15	quanta/cm²sec
0.01551	uE/cm^2sec

Calibration Scale Factor:

(To calculate irradiance, divide the net voltage reading in Volts by this value.)

Dry:	1.0189E-17	V/(quanta/cm²sec)
	6.1357E+00	V/(uE/cm^2sec)

Notes:

1. Annual calibration is recommended.
2. Calibration is performed using a Standard of Spectral Irradiance traceable to the National Institute of Standards and Technology (NIST).
3. The collector should be cleaned frequently with alcohol.
4. Calibration was performed with customer cable, when available.

6. Appendix 2:
EK188 CTD data processing and calibration report

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Table 1: CTD instrumentation and serial numbers.

Instrument/Sensor	**Manufacturer/Model**	**Serial Number**	**Frequency/Channel**
Sea-Bird CTD deck unit	SBE 11plus	11P-1002	
Sea-Bird underwater unit	SBE 9plus	09P-79189-1195	
Sea-Bird temperature sensor	SBE 3plus	03P-5913	0
Sea-Bird conductivity sensor	SBE 4C	04C-4341	1
Digiquartz temperature compensated pressure sensor		1195	2
Sea-Bird dissolved oxygen sensor	SBE 43	43-2914	V0
Light scattering sensor	WET Labs ECO BB(RT)D Scattering Meter	BBRTD-1203	V1
Transmissometer 1	WET Labs C-Star transmissometer	CST-1664DR	V2
Transmissometer 2	WET Labs C-Star transmissometer	CST-1671DB	V3
Fluorometer	WET Labs FLNTU	FLNTURTD-3203	V4
Turbidity meter	WET Labs FLNTU	FLNTURTD-3203	V5
PAR/Irradiance	Biospherical/Licor	70566	V6
Altimeter		51863	V7
SPAR	Biospherical QSR-2200	20473	

Table 2 CTD cast data and locations.

CTD ID	Grid #	Date	Time (UTC)	LAT	LON	Event #	Station #
CTD001	1.1	23/03/2019	03:08	-33.6392	26.9162	4	3977
CTD002	1.2	23/03/2019	05:02	-33.7118	26.9798	8	3978
CTD003	1.3	23/03/2019	06:48	-33.7840	27.0422	11	3979
CTD004	1.4	23/03/2019	08:37	-33.8575	27.1073	13	3980
CTD005	2.3	23/03/2019	14:19	-34.0235	26.7262	16	3981
CTD006	5.1	24/03/2019	02:19	-34.0053	25.2322	18	3982
CTD007	5.2	24/03/2019	04:49	-34.1112	25.2918	24	3983
CTD008	5.3	24/03/2019	06:52	-34.2173	25.3520	27	3984
CTD009	5.4	24/03/2019	09:00	-34.3242	25.4107	30	3985
CTD010	5.5	24/03/2019	11:13	-34.4298	25.4703	33	3986
CTD011	6.5	24/03/2019	15:20	-34.5572	25.1800	38	3987
CTD012	6.4	24/03/2019	17:24	-34.4662	25.1083	41	3988
CTD013	6.3	24/03/2019	19:15	-34.3598	25.0492	44	3989
CTD014	6.2	24/03/2019	21:06	-34.2548	25.0030	47	3990
CTD015	6.1	24/03/2019	23:03	-34.1470	24.9312	50	3991
CTD016	7.1	25/03/2019	12:40	-34.1402	24.3705	53	3992
CTD017	7.2	25/03/2019	15:03	-34.2662	24.3422	58	3993
CTD018	7.3	25/03/2019	17:33	-34.4030	24.3250	62	3994
CTD019	7.4	25/03/2019	19:25	-34.5383	24.3057	65	3995
CTD020	7.5	25/03/2019	21:10	-34.6613	24.2882	68	3996
CTD021	7.6	25/03/2019	23:22	-34.8065	24.2620	71	3997
CTD022	8.6	26/03/2019	04:14	-34.7183	23.7303	74	3998
CTD023	8.5	26/03/2019	07:24	-34.5788	23.7503	79	3999
CTD024	8.4	26/03/2019	09:18	-34.4460	23.7673	83	4000
CTD025	8.3	26/03/2019	11:07	-34.3168	23.7902	85	4001
CTD026	8.2	26/03/2019	12:50	-34.1848	23.8143	88	4002
CTD027	8.1	26/03/2019	14:37	-34.0518	23.8388	91	4003
CTD028	9.1	26/03/2019	21:05	-34.2705	22.8898	96	4004
CTD029	9.1	27/03/2019	04:37	-34.2652	22.8963	98	4005
CTD030	9.2	27/03/2019	07:38	-34.4138	22.9838	103	4006
CTD031	9.3	27/03/2019	09:53	-34.5622	23.0777	106	4007
CTD032	9.4	27/03/2019	11:59	-34.7088	23.1805	109	4008
CTD033	9.5	27/03/2019	13:53	-34.8558	23.2783	112	4009
CTD034	10.6	27/03/2019	18:40	-35.0100	22.8322	117	4010
CTD035	10.5	27/03/2019	20:52	-34.8812	22.7107	120	4011
CTD036	10.4	27/03/2019	23:19	-34.7458	22.5863	123	4012
CTD037	10.3	28/03/2019	01:27	-34.6130	22.4658	126	4013
CTD038	10.2	28/03/2019	03:42	-34.4780	22.3458	129	4014
CTD039	10.1	28/03/2019	06:16	-34.3473	22.2297	134	4015
CTD040	11.1	28/03/2019	11:38	-34.7280	21.6123	137	4016
CTD041	11.2	28/03/2019	14:03	-34.8298	21.7738	142	4017
CTD042	11.3	28/03/2019	16:21	-34.9277	21.9328	145	4018
CTD043	11.5	28/03/2019	20:08	-35.1312	22.2530	148	4019
CTD044	11.6	28/03/2019	22:18	-35.2300	22.4187	151	4020
CTD045	12.6	29/03/2019	04:07	-35.5862	22.1142	156	4021

CTD046	12.5	29/03/2019	06:50	-35.4890	21.9538	161	4022
CTD047	12.4	29/03/2019	08:55	-35.3870	21.7962	164	4023
CTD048	12.3	29/03/2019	11:00	-35.2817	21.6332	167	4024
CTD049	12.2	29/03/2019	12:58	-35.1830	21.4727	170	4025
CTD050	12.1	29/03/2019	14:53	-35.0823	21.3132	173	4026
CTD051	CR04	30/03/2019	04:06	-34.8728	22.7035	178	4027
CTD052	CR03	30/03/2019	07:18	-34.7088	22.6083	180	4028
CTD053	CR02	30/03/2019	08:56	-34.5587	22.5172	182	4029
CTD054	CR01	30/03/2019	10:28	-34.4095	22.4280	184	4030
CTD055	G550	31/03/2019	04:32	-34.8340	25.1640	186	4031
CTD056	G424	31/03/2019	15:25	-34.3462	23.7543	189	4032

1. Data acquisition

Data were acquired through Seasave version 7.23.2. Data from casts CTD001 to CTD054 were acquired at 24Hz but unintentionally averaged to 1Hz by the deck unit and recorded at 1Hz. Raw 24 Hz data were not recorded. Data from casts CTD055 and CTD056 were acquired and recorded at 24Hz.

Raw data files:

The following raw data files were generated for the each CTD cast:

CTD_XXX.bl (a record of bottle firing locations)
CTD_XXX.hdr (header file)
CTD_XXX.hex (hexadecimal raw data file)
CTD_XXX.con (configuration file)

Where _XXX refers to the CTD cast number.

2. SBE data processing steps

The following processing routines were run in the SBEDataProcessing software (Seasave Version 7.26.7):

2.1. DatCnv

Input: CTD_XXX.hex, CTD_XXX.xmlcon, CTD_XXX.bl, CTD_XXX.hdr

Output: CTD_XXX.cnv, CTD_XXX.ros

(where XXX refers to the CTD cast number)

A conversion routine to read in the raw CTD data file (.hex) containing data in engineering units output by the CTD hardware. Calibrations as found in the instrument configuration file (.xmlcon) are applied.

Data Setup options were set to the following:

Process scans to end of file: yes
Scans to skip: 0
Output format: ascii
Convert data from: upcast & downcast
Create file types: both bottle and data
Source of scan range data: bottle log .BL file
Scan range offset: -2 seconds
Scan range duration: 5 seconds
Merge separate header file: No
Source for start time in output .cnv header: NMEA time
Apply oxygen hysteresis correction: yes (2 second window)
Apply oxygen Tau correction: no

The oxygen tau correction was not applied as it appeared to artificially amplify noise in the data (Figure 2). The effect on the oxygen data was greatest near the thermocline where local maxima and minima were introduced.

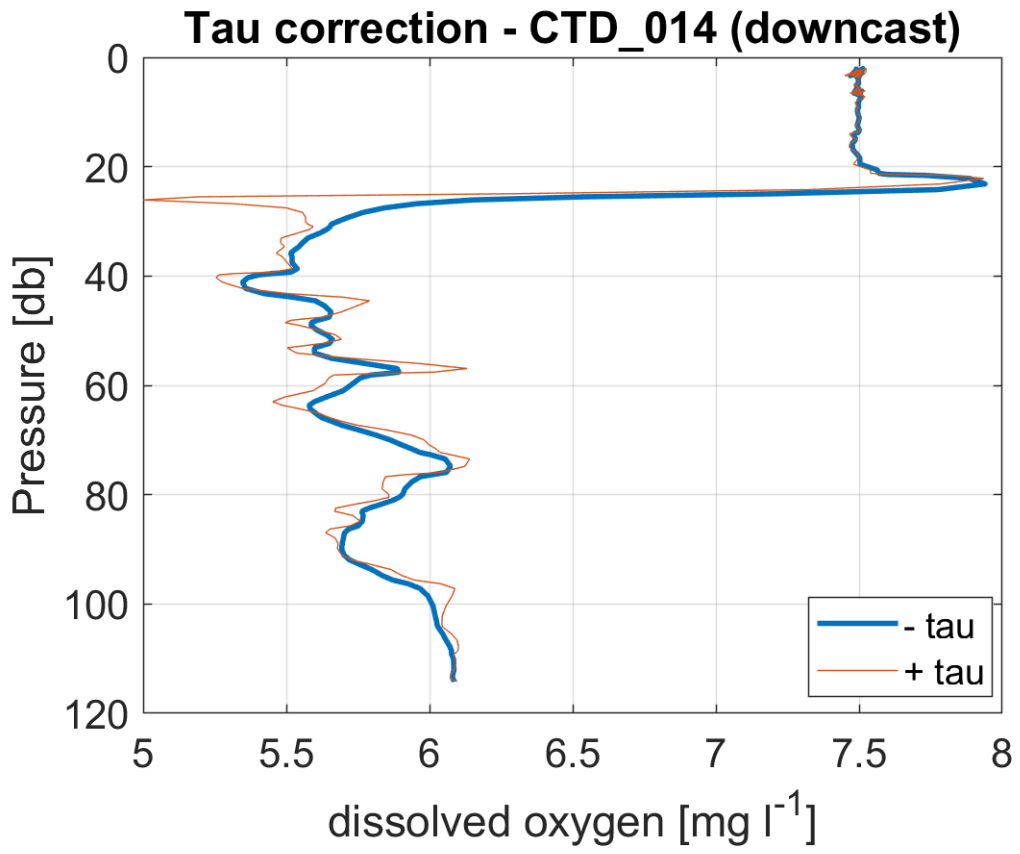


Figure 2 Example of the effect that omitting (blue) or applying (red) the tau correction (using a 2s window) has on the dissolved oxygen data [mg l^{-1}] using CTD014.

Selected output variables:

- Time [seconds]
- Pressure [dbar]
- Temperature [ITS-90, °C]
- Conductivity [S m^{-1}]
- Salinity, practical [PSU]
- Oxygen raw, SBE 43 [V]
- Oxygen, SBE 43 [mg l^{-1}]
- Beam attenuation, WET Labs C-Star 1 [m^{-1}]
- Beam attenuation, WET Labs C-Star 2 [m^{-1}]
- Beam transmission, WET Labs C-Star 1 [%]
- Beam transmission, WET Labs C-Star 2 [%]
- Fluorescence [mg m^{-3}]
- PAR/irradiance, downwelling [µE m^{-2} s^{-1}]
- Turbidity, ECO BB [m^{-1} sr^{-1}]
- Turbidity [NTU]
- Altimeter [m]
- SPAR, Biospherical/Licor [µE m^{-2} s^{-1}]
- CPAR/Corrected Irradiance [%]
- Voltage channel 1: Light scattering Wetlabs BBRTD
- Voltage channel 2: Transmissometer 1
- Voltage channel 3: Transmissometer 2
- Voltage channel 4: Fluorometer
- Voltage channel 5: Turbidity meter
- Voltage channel 6: Downwelling Irradiance sensor (DWIRR)
- Voltage channel 7: Altimeter
- Pump status

2.2.Wild Edit:

Input and output: CTD_XXX.cnv

Removal of pressure spikes.
Standard deviations for pass 1: 2
Standard deviations for pass 2: 20 Scans per black: 100
Keep data within this distance of the mean: 0 Exclude scans marked as bad: yes

2.3.Filter

Input and output: CTD_XXX.cnv

Run on the pressure channel to smooth out high frequency data
Low pass filter time B: 0.15 seconds (as recommended by Sea Bird)

2.4.AlignCTD

Input and output: CTD_XXX.cnv

Here, conductivity and oxygen values (V) are shifted in time to compensate for sensor time lags.

2.4.1. Conductivity

Misalignment between the temperature and the conductivity sensor can lead to salinity spikes, particularly in the vicinity of strong thermal gradients. Salinity spikes are minimized when the best alignment of conductivity with respect to temperature is obtained. The SBE 11plus is factory set to advance conductivity by +1.75 scans (at 24Hz, this is 1.75/24 = 0.073 seconds).

The automatically applied alignment of +1.75 scans led to negative salinity spikes on the down cast (Figure 3, red: +1.75 scans), which is indicative of conductivity leading temperature. Testing of different adjustments (+1, -0.5, -1, -2 and -3 scans) showed that an additional adjustment of -0.5 scans (= -0.021 seconds) resulted in the greatest reduction of noise in the salinity channel (Figure 3). Taking into account the default advance of 1.75 scans, the overall advance was therefore +1.25 scans.

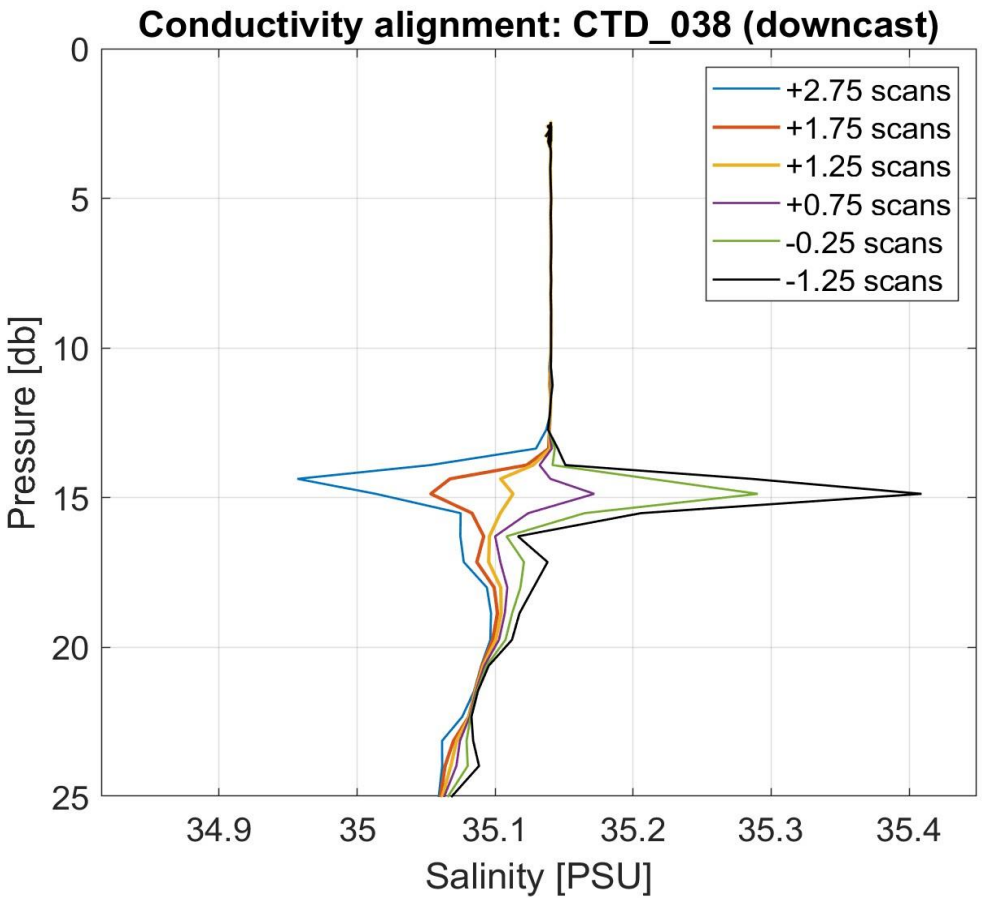


Figure 3 Salinity [PSU] vs pressure [db]. Example of conductivity alignment tests on salinity [PSU] using CTD_038. Alignment adjustments applied were: +2.75 scans (blue), +1.75 scans (red), +1.25 scans (yellow), +0.75 scans (purple), -0.25 scans (green) and -1.25 scans (black). The adjustment times shown here relate to the overall alignment with respect to temperature taking into account the automatically applied advance of +1.75 scans (red).

2.4.2. Oxygen

The typical response time of SBE43 (oxygen) sensors of several seconds leads to oxygen data being systematically delayed with respect to pressure. This alignment is a function of the temperature (longer lag at colder temperatures) and the state of the oxygen sensor membrane. Testing of different adjustments (+0, +2, +3 and +4 seconds, Figure 4) using different casts showed that an adjustment of 3 seconds resulted in the least absolute oxygen difference between corresponding up and down casts profiles. This alignment was chosen as a compromise between results in deep (cold) and shallow (warmer) waters.

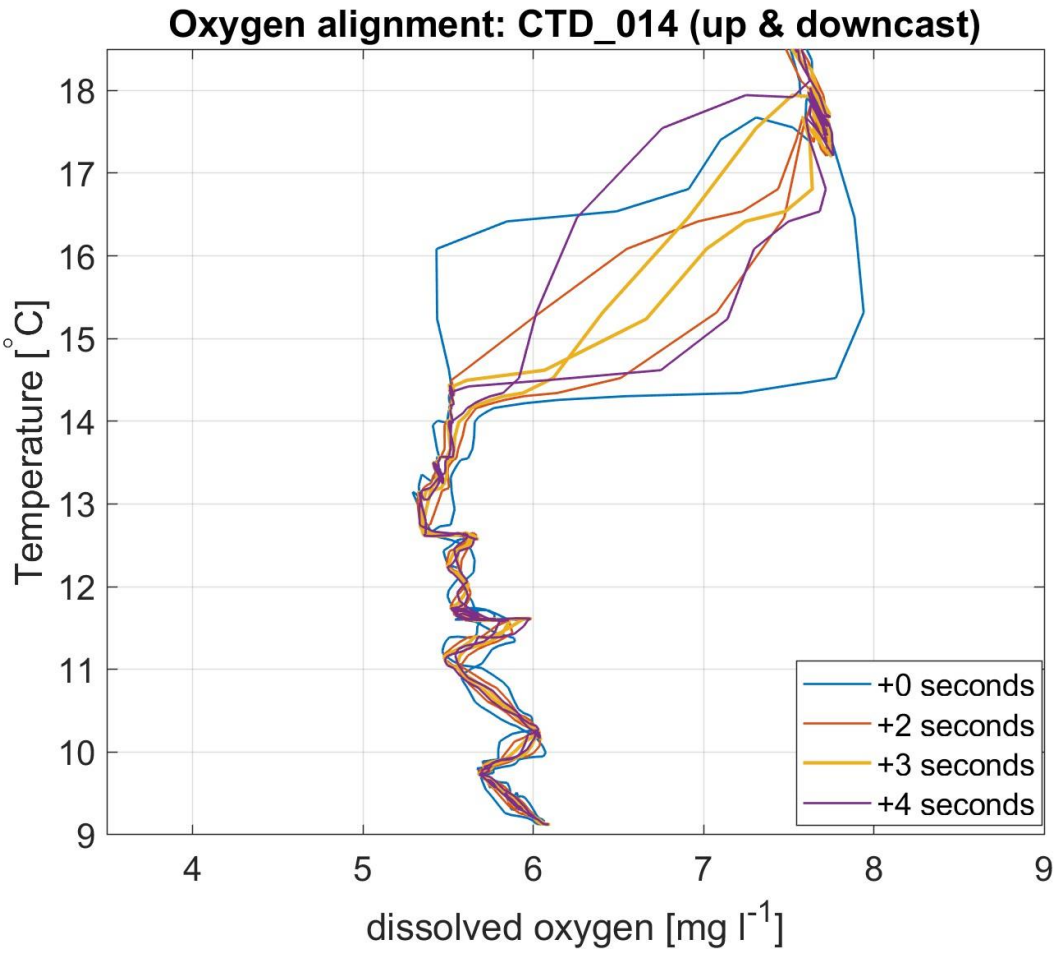


Figure 4 Dissolved oxygen [mg l^{-1}] vs temperature [°C]. Example of oxygen alignment tests using CTD_014. Alignment adjustments applied were: +0 seconds (blue), +2 seconds (red), +3 seconds (yellow) and +4 seconds (purple).

2.5.CellTM

Input and output: CTD_XXX.cnv

Removes the effect of thermal inertia on the conductivity cells. Alpha = 0.03 (thermal anomaly amplitude) and 1/beta = 7 (thermal anomaly time constant).

2.6. Derive

Input and output: CTD_XXX.cnv

After the dynamic corrections have been applied (Filter, Align, thermal inertia correction), oxygen and salinity are derived.

Variables selected are:

Salinity	[PSU, PSS-78]
Oxygen SBE43	[mg l^{-1}] (no tau correction applied)
Oxygen SBE43	[µmol kg^{-1}] (no tau correction applied)

2.7. Bottle Summary

Input: CTD_XXX.cnv CTD_XXX.bl
Output: CTD_XXX.btl

This step created a .btl file containing the average, standard deviation, min and max values at bottle firings. .ROS files were placed in the same directory as the .bl files during this routine to ensure that bottle rosette position was captured in the .btl file.

2.8. BinAverage

Only performed on casts CTD_055 & CTD_056 since casts CTD_001 to CTD_054 had 1Hz averaging applied on collection.

Input: CTD_XXX.cnv
Output: CTD_XXX_2hz.cnv

2Hz (0.5 seconds) averaging of all variables.
Exclude bad scans: yes
Scans to skip over: 0
Casts to process: Up and down

3. Matlab processing steps

The following processing steps were performed in Matlab.

3.1. Create meta data file

The following information was stripped from the cruise master event log and used as header information for each CTD cast file.

CRUISE	EK188
CAST	CTD cast number
ID	CTD ID
GRID	Grid #
DATE	Date at start of cast [dd/mm/yyyy]

TIME	Time at start of cast [UTC]
LAT	Latitude at start of cast [decimal]
LON	Longitude at start of cast [decimal]
DEPTH	Sounding depth at start of cast from echo sounder [m]

File created: CTD_stations_EK188.mat

3.2.Read .cnv files

The 1Hz and 2Hz .cnv files created by the SBE Processing Software were read into a Matlab, combined with the meta data information and saved into a Matlab structure for each cast. Each file (eg. CTD001_1Hz.mat) contains the following un-calibrated channels.

CTDXXX=

CRUISE:	'EK188'	
CAST:	1	
ID:	'CTD001'	
GRID:	' 1.1'	
DATE:	'23/03/2019'	
TIME:	'03:08'	
LAT:	-33.6392	
LON:	26.9162	
DEPTH	43.60	[m]
CTDtime: [1038x1]		[seconds]
CTDpres: [1038x1]		[dbar]
CTDtemp: [1038x1]		[˚C]
CTDcond: [1038x1]		[S m^{-1}]
CTDsal_o: [1038x1]		[PSU]
CTDdoxy_raw: [1038x1]		[V]
CTDdoxy_mgl_o: [1038x1]		[mg l^{-1}]
CTDatt1: [1038x1]		[m^{-1}]
CTDatt2: [1038x1]		[m^{-1}]
CTDtrans1: [1038x1]		[%]
CTDtrans2: [1038x1]		[%]
CTDfluor: [1038x1]		[mg m^{-3}]
CTDpar: [1038x1]		[µE m^{-2} s^{-1}]
CTDturb_obs: [1038x1]		[m^{-1} sr^{-1}]
CTDturb: [1038x1]		[NTU]
CTDalt: [1038x1]		[m]
CTDspar: [1038x1]		[µE m^{-2} s^{-1}]
CTDcpar: [1038x1]		[%]
CTDobs_raw: [1038x1]		[V]
CTDatt1_raw: [1038x1]		[V]
CTDatt2_raw: [1038x1]		[V]
CTDfluor_raw: [1038x1]		[V]
CTDturb_raw: [1038x1]		[V]

CTDpar_dn_raw: [1038x1] [V]
CTDalt_raw: [1038x1] [V]
CTDsal: [1038x1] [PSU]
CTD_doxy_mgl: [1038x1] [mg l^{-1}]
CTD_doxy_umkg: [1038x1] [µmol kg^{-1}]
CTDflag: [1038x1]
CTDpump: [1038x1]

Note that '_o' for the first instances of salinity and oxygen in these files are variables before re-derivation in the SeaBird Processing routines.

3.3.Remove surface soak and out of water data

The 1Hz/2Hz pressure and oxygen data (slowest of all the sensors) were plotted on screen and the start and end of each cast was identified manually. The start was defined as the shallowest pressure after the initial surface soak (at approximately 10 m), just before the CTD package started its decent. The end of each cast was selected as the last good oxygen data point.

The selected start and end times were saved to EK188_castcrop_times.mat

3.4.Split up and downcast

The profile was split into up and down casts (based on the maximum pressure record).

3.5.Manual de-spiking

The downcast temperature, salinity, oxygen, fluorometer, PAR, beam attenuation and transmission were all further quality controlled in a graphical user interface. Spikes in the CT sensors lasting a few seconds, predominantly in regions of strong density gradients were identified. This is a persistent problem in near surface waters with strong property gradients, particularly where a large CTD package carrying large volume Niskin bottles is used. The spikes tend to coincide with a decrease in the decent rate of the CTD package and are therefore likely associated with inefficient flushing of water around the sensors. It is caused by ship heave, so is accentuated during swell. As the decent rate of the CTD package slows on the downcast 'old' water (from above) is pushed back passed the sensors. As the decent rate increases again 'new' water is flushed past the sensors. A similar problem can occur if the veer rate on the CTD winch varies (Figure 5).

Whilst the most significant anomalies were identified and removed it was impossible to eliminate every instance. The impact of smaller scale anomalies that were not removed is mostly minimised during the filtering processes, but care should be taken when interpreting smaller scale features, particularly in the vicinity of large thermal gradients.

Additional vectors of 0's and 1's indicating data that have been replaced with NaN values (=1). Outputs depend on channels loaded and viewed so each column may have variable meaning and is saved for processing archive purposes only.

Pindex: [79x3 double]
Aindex: [79x6 double]

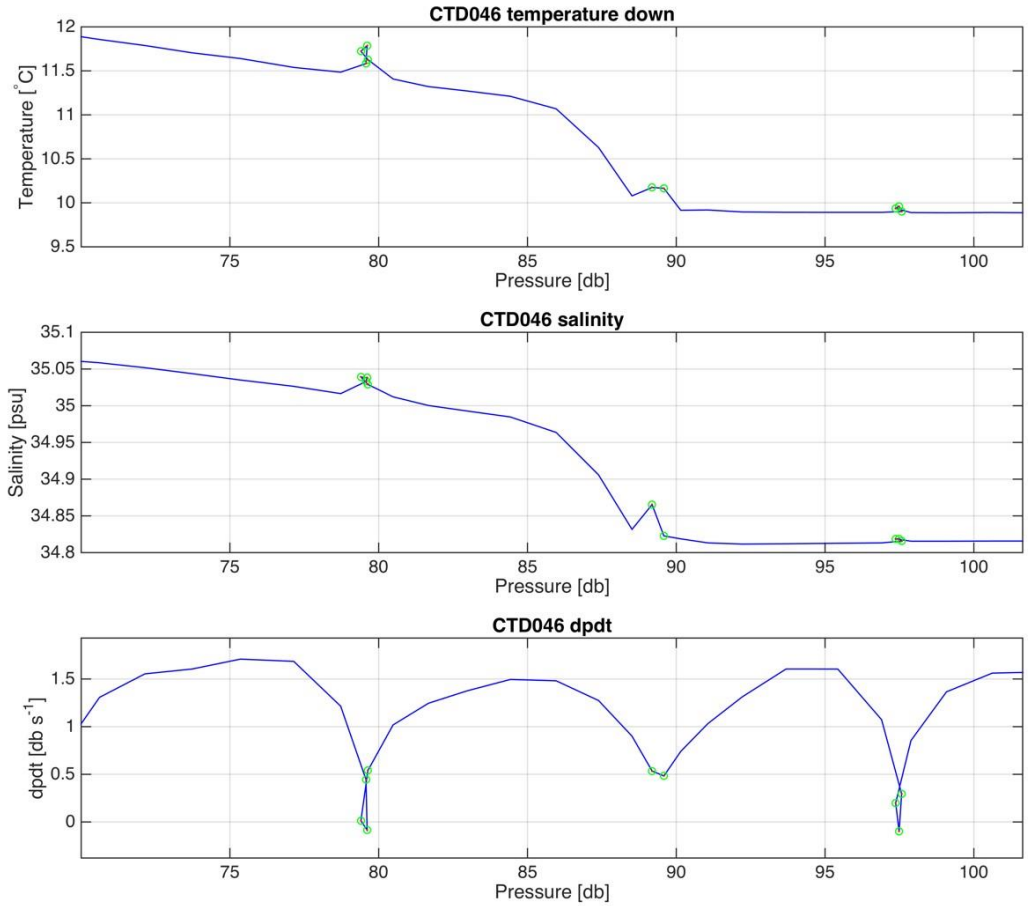


Figure 5 Example of temperature/salinity spikes associated with a decreased descent rate of the CTD package potentially caused by swell. As the CTD package slows warmer (and saltier) water from above is pushed past the sensors. The highlighted dots were identified manually and removed from the profile.

These vectors were saved to CTDXXX_despike_index.mat

These casts data are sufficient to study meso-scale features and anomalies but should not be used for Thorpe scale analysis and interpretation of fine scale structures. To achieve this in a shelf sea environment free fall profiling techniques are more suitable.

3.6.1dbar averaging

Variables were averaged into 1dbar bins. Missing or cropped out data were linearly interpolated for bins between the maximum and minimum pressure. No extrapolation was performed at the surface or bottom.

Output saved to CTDXXX_1db_dn.mat

3.7. Apply oxygen, chlorophyll-a fluorescence and salinity calibrations and derivation of TEOS-10 variables

3.7.1. Oxygen

The oxygen sensor has been calibrated against Winkler titration samples collected from CTD Niskin bottles taken during the cruise. A total of 106 samples were collected during the cruise of which 30 were duplicates from the same bottle. Bottle replicates corresponded well with each other but were treated as separate samples for calibration purposes. Nine outliers were excluded from the slope calculation based on residual values between the Winkler values and the CTD bottle data.

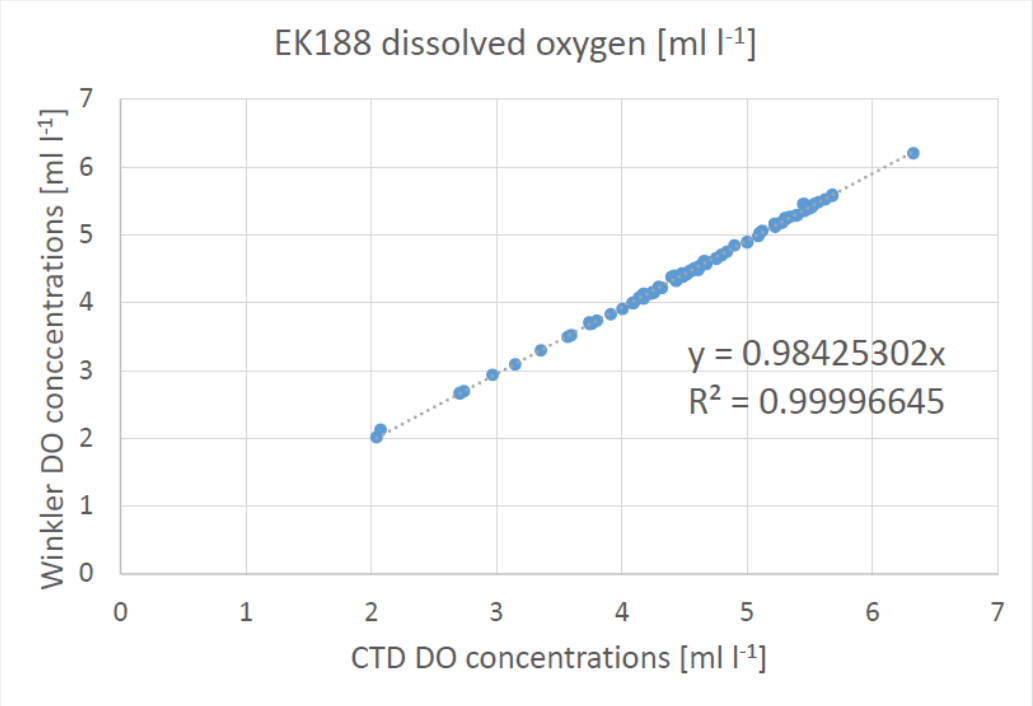


Figure 6 EK188 dissolved oxygen (DO) calibration [ml l^{-1}]

The slope between dissolved oxygen concentrations taken from the CTD sensor and the Winkler samples was calculated as 0.98425302 (R^2 = 0.9999, Figure 6).

3.7.2. Chlorophyll-a fluorescence

After removal of outlier samples, the following calibrations were applied to the fluorometer:

$$\text{Chl } a \text{ fluorescence samples } [\text{mg m}^{-3}] = 14.47046 \times (\text{CTDfluor}_{\text{raw}}[\text{V}] - 0.07393)$$

(R^2 = 0.7393, Figure 7)

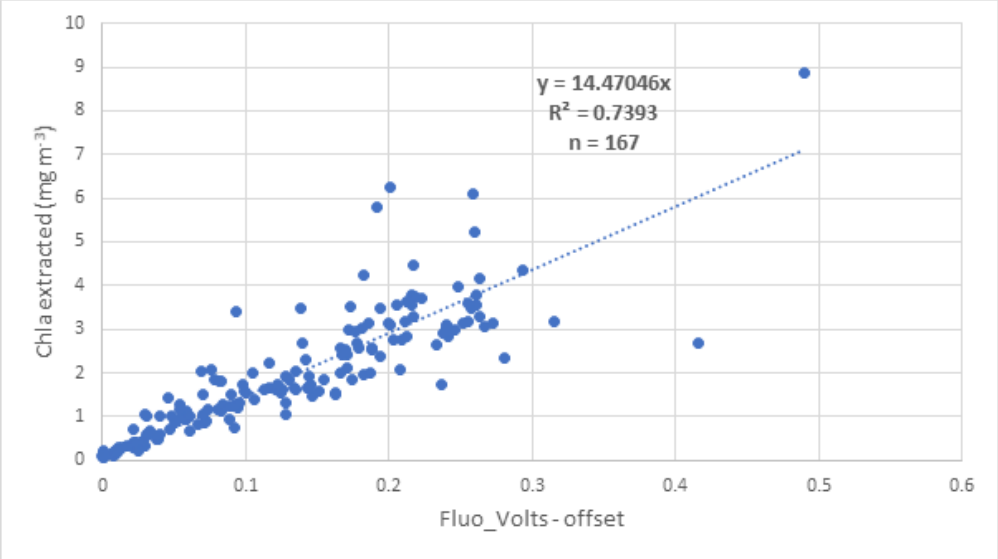


Figure 7 EK188 chlorophyll-a fluorescence calibration

3.7.3. Salinity

A total of 98 salinity samples were taken from Niskin bottles throughout the cruise. The salinities of samples taken ranged from 34.742 psu to 35.528 psu.

For each sample, the bottle (including the cap and plastic insert) was rinsed 3 times with the Niskin bottle sea water and then filled. The bottle neck (inside and outside), plastic insert and cap were all wiped dry and then the insert and bottle top were fitted. Upon arrival back to the labs the crate was then placed in the same temperature-controlled room as the Guildline Portasal salinometer for 24 hours to acclimatise samples to the laboratory temperature. Standard seawater samples were analysed to check for drift of the Portasal but this was only done after the 50th, 75th and 98th samples. Other inconsistencies were also discovered in the analysis using the Portasal including a significant offset of the sampled values after the 70th sample.

The slope between salinity samples taken from the CTD sensor and the discrete bottle samples was calculated as

$$\text{Portasal bottle salinity [PSU} = 1.01300 \times \text{CTDsal [PSU]} - 0.31878$$

(R^2 = 0.90767, Figure 8)

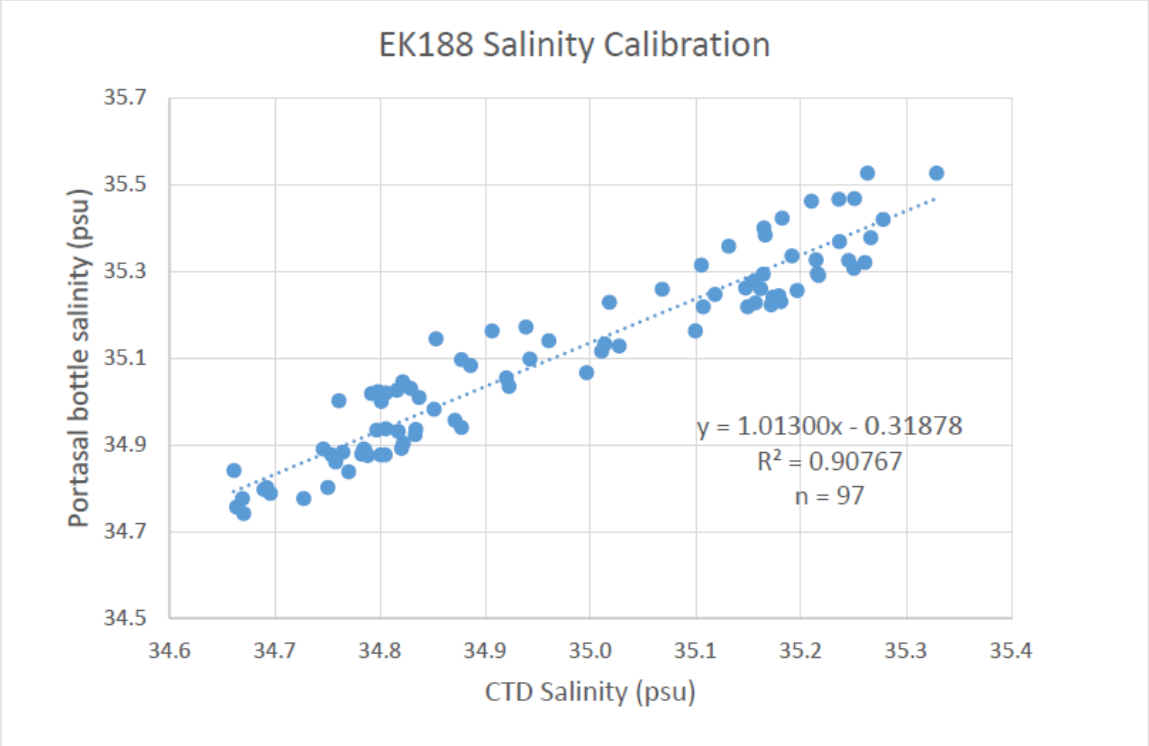


Figure 8 EK188 salinity calibration (PSU)

Further comparison of the calibrated CTD salinity with data collected using three ocean gliders that were in close proximity to the CTD during EK188 however, suggested an offset in the CTD data of approximately 0.1 PSU in temperature- salinity (TS) space (Figure 9). Each of the three CTDs used on the gliders (S/Ns 0221, 9034, 0227, see calibration sheets in Appendix) were recently calibrated and so a systematic error was suspected in the CTD salinity calibration.

Reassessment of the uncalibrated CTD salinity data against data obtained by from the gliders (unit 424, unit 438 and SG550, Figure 9) showed good agreement with the exception of a salinity offset of approximately 0.01 PSU (i.e. CTD too salty), which was an order magnitude better agreement than provided using Portasal calibration. This small offset was however not applied to the final CTD data as it was considered to sit within the likely error margins of the CTD systems and small-scale variability in local waters. Further, the CTD data covered a greater spatial extent than the gliders (Figure 1), potentially experiencing water masses affected by the Benguela Current system that can affect water masses on the western Agulhas Bank (eg Jackson *et al.*, 2012), while the gliders most westerly data point was limited to the eastern Agulhas Bank (see Figure 1 for location of 424 calibration cast CTD056).

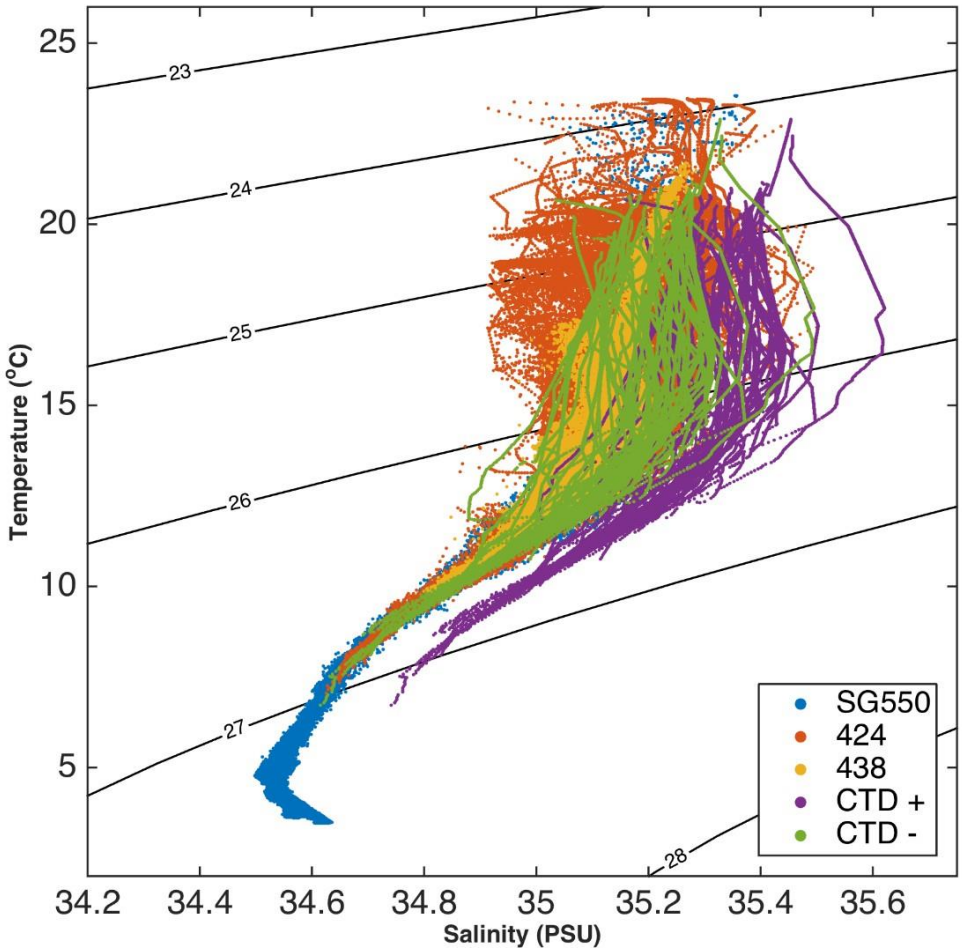


Figure 9 Comparison of glider data SG550 (blue), 424 (red) and 438 (yellow) alongside CTD data with salinity calibration applied (CTD+, purple) and uncalibrated CTD data (CTD-, green) in TS space. A far better agreement between glider data and uncalibrated data is clearly evident than that with the inferred Portasal calibration applied.

3.7.4. Application of calibrations

Application of calibrations to dissolved oxygen chlorophyll-a fluorescence in 1dbar smoothed downcasts and bottle firing data.

3.7.5. Derivation of TEOS-10 variables

Following the application of oxygen and chlorophyll-a calibrations to the 1dbar smoothed down cast profile and the bottle firing data depth, absolute salinity (asal), conservative temperature (ctmp) and potential density anomaly, σ_0 (sig0) were then derived using the Gibbs-SeaWater Oceanographic Toolbox (McDougall & Barker, 2011).

The final calibrated 1dbar smoothed down cast profile data contain the following fields and variables:

CTDXXX=

CRUISE:	'EK188'
CAST:	1
ID:	'CTD001'
GRID:	' 1.1'
DATE:	'23/03/2019'
TIME:	'03:08'
LAT:	-33.6392
LON:	26.9162
DEPTH:	43.60 [m]

pres:	Pressure [dbar]
depth:	Depth [m]
lon:	Longitude [˚E]
lat:	Latitude [˚N]
temp:	Temperature [˚C, ITS-90]
cond:	Conductivity [S m^{-1}]
sal:	Salinity [PSU, PSS-78]
asal:	Absolute salinity [g kg^{-1}]
ctmp:	Conservative temperature [˚C]
sig0:	Potential density anomaly [kg m^{-3}]
doxy_mgl	Dissolved oxygen concentration [mg l^{-1}]
doxy_umkg	Dissolved oxygen concentration [µmol kg^{-1}]
flu	Chl-*a* fluorescence [mg m^{-3}]
turb_obs	Optical backscatter [m^{-1} sr^{-1}]
turb:	Turbidity [NTU]
att1:	Primary attenuation [m^{-1}]
att2:	Secondary attenuation [m^{-1}]
trans1:	Primary transmission [%]
trans2:	Secondary transmission [%]
par	PAR/Irradiance [µE m^{-2} s^{-1}]
spar	SPAR [µE m^{-2} s^{-1}]
cpar	CPAR [%]

Output saved to CTDXXX_1db_calib.mat

The final calibrated CTD bottle firing data contain the following fields and variables:

CTDXXX_b=

CRUISE:	'EK188'
CAST:	1
ID:	'CTD001_b'
GRID:	' 1.1'
DATE:	'23/03/2019'
TIME:	'03:08'
LAT:	-33.6392
LON:	26.9162
DEPTH:	43.60 [m]

dd:	Bottle firing time [UTC, Matlab date convention: hours since 0000-01-01 00:00:00.0]
botl:	Bottle #
pres:	Pressure [dbar]
depth:	Depth [m]
temp:	Temperature [˚C, ITS-90]
sal:	Salinity [PSU, PSS-78]
asal:	Absolute salinity [g kg^{-1}]
ctmp:	Conservative temperature [˚C]
sig0:	Potential density anomaly [kg m^{-3}]
doxy_mgl:	Dissolved oxygen concentration [mg l^{-1}]
doxy_umkg:	Dissolved oxygen concentration [µmol kg^{-1}]
par:	PAR/Irradiance [µE m^{-2} s^{-1}]
flu:	Chl-*a* fluorescence [mg m^{-3}]

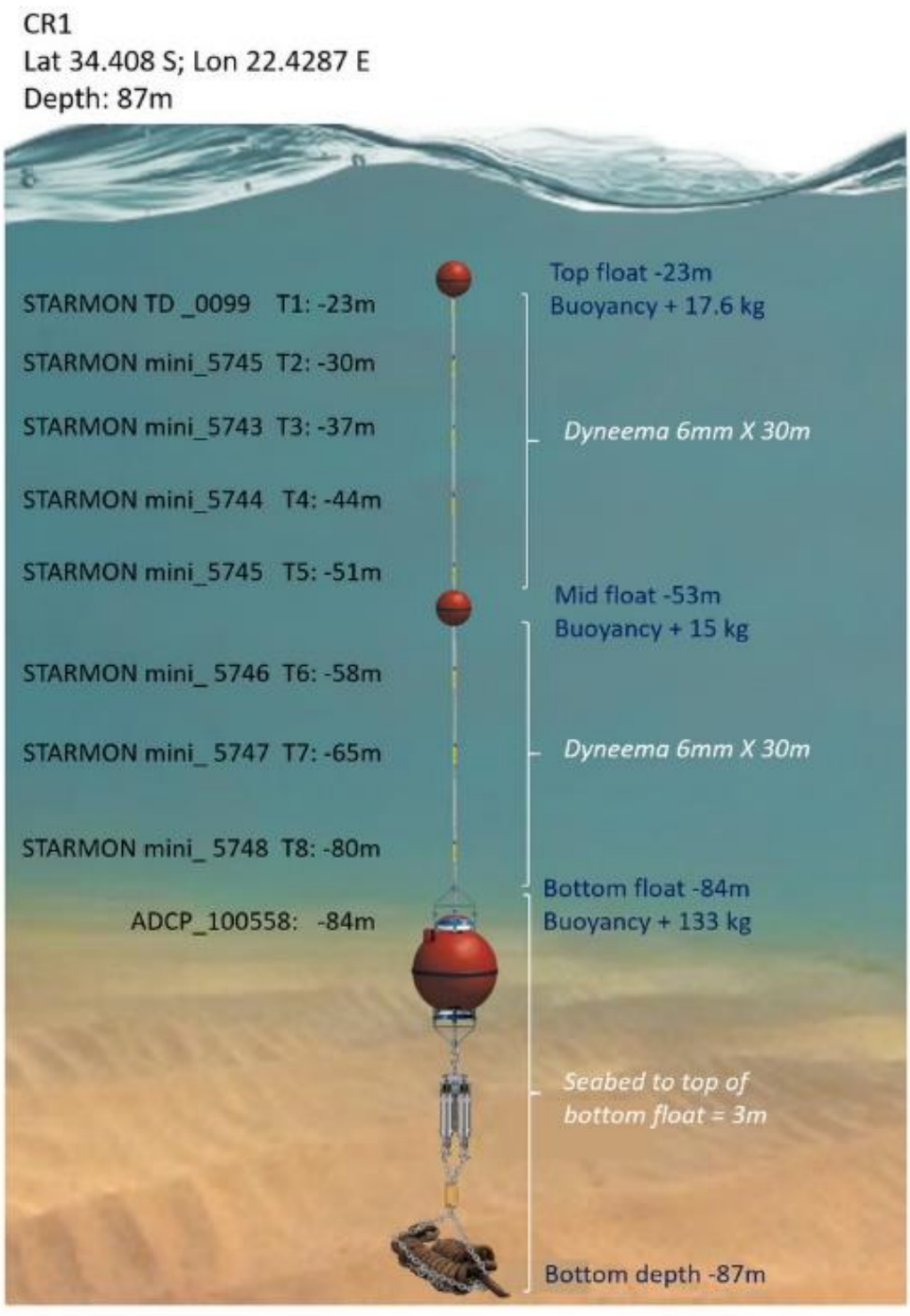
Output saved to EK188_CTDXXX_b_calib.mat

4. References

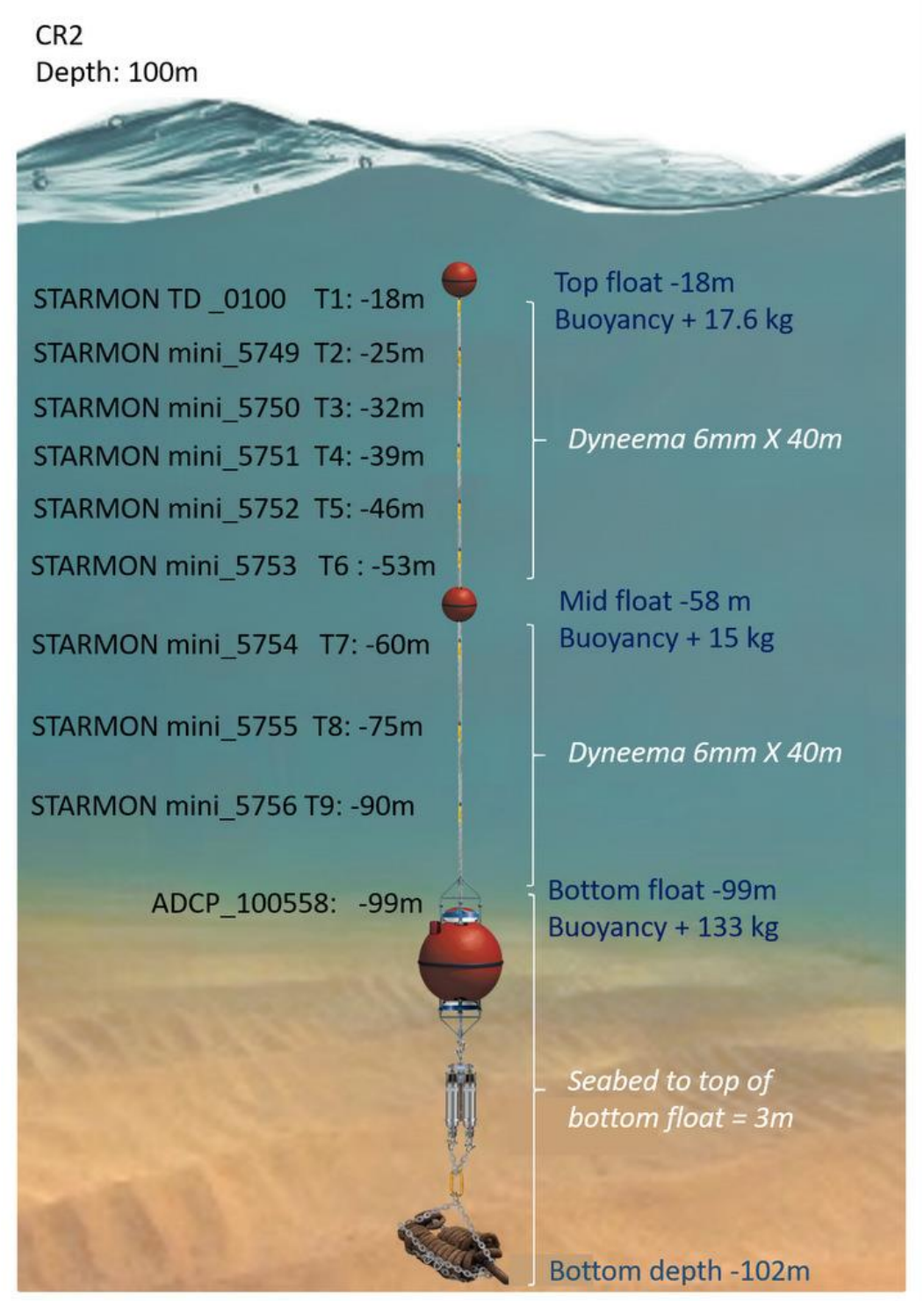
Jackson, J.M., Rainville, L., Roberts, M.J., McQuaid, C.D., & Lutjeharms, J. R. (2012). Mesoscale bio-physical interactions between the Agulhas Current and the Agulhas Bank, South Africa. *Continental Shelf Research*, *49*, 10-24.

McDougall, T. J. and Barker, P. M. (2011). Getting started with TEOS-10 and the Gibbs Seawater (GSW) Oceanographic Toolbox. SCOR/IAPSO WG, 127, 1– 28. ISBN 978-0-646-55621-5.

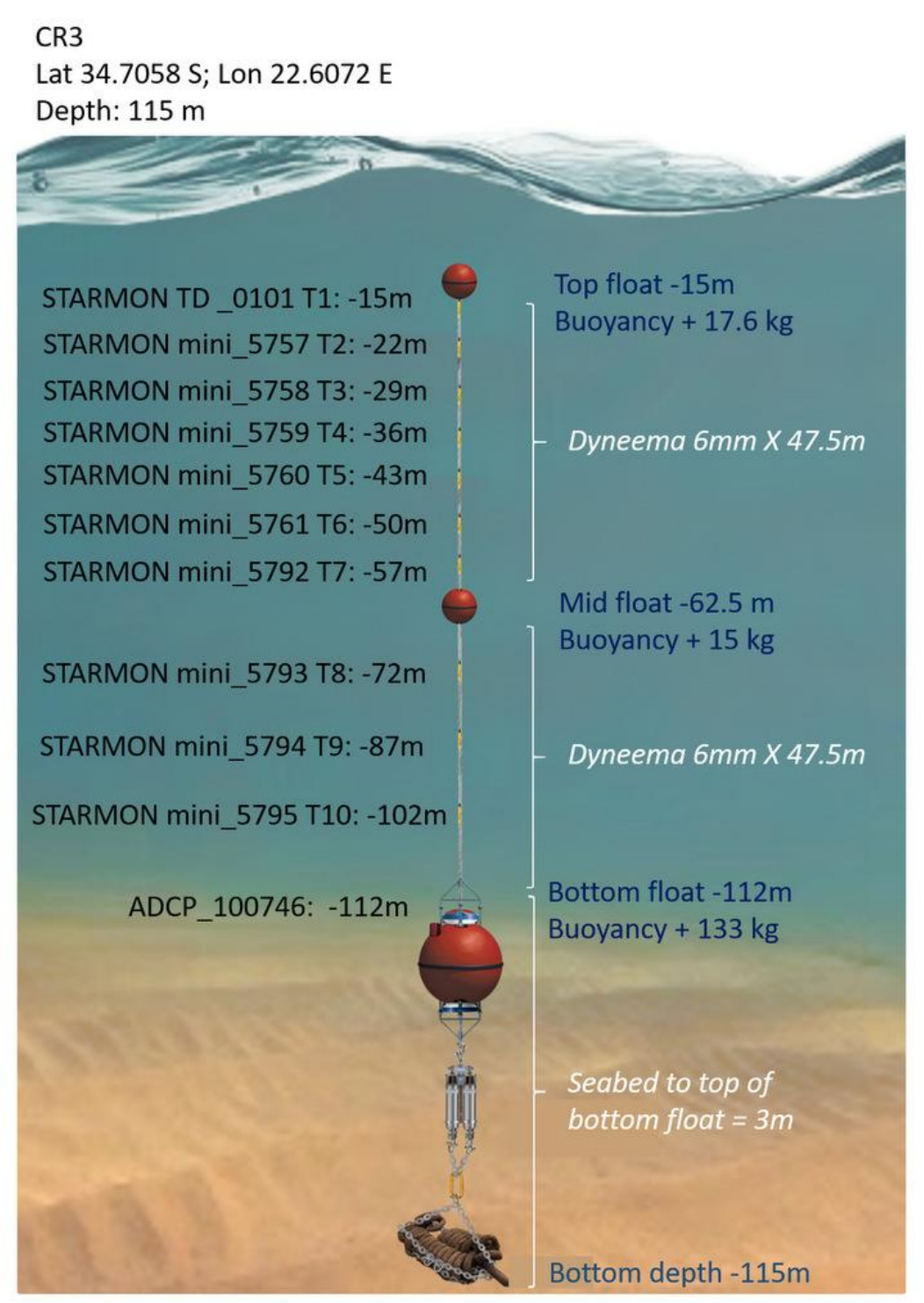
7. Appendix 3: updated mooring diagrams



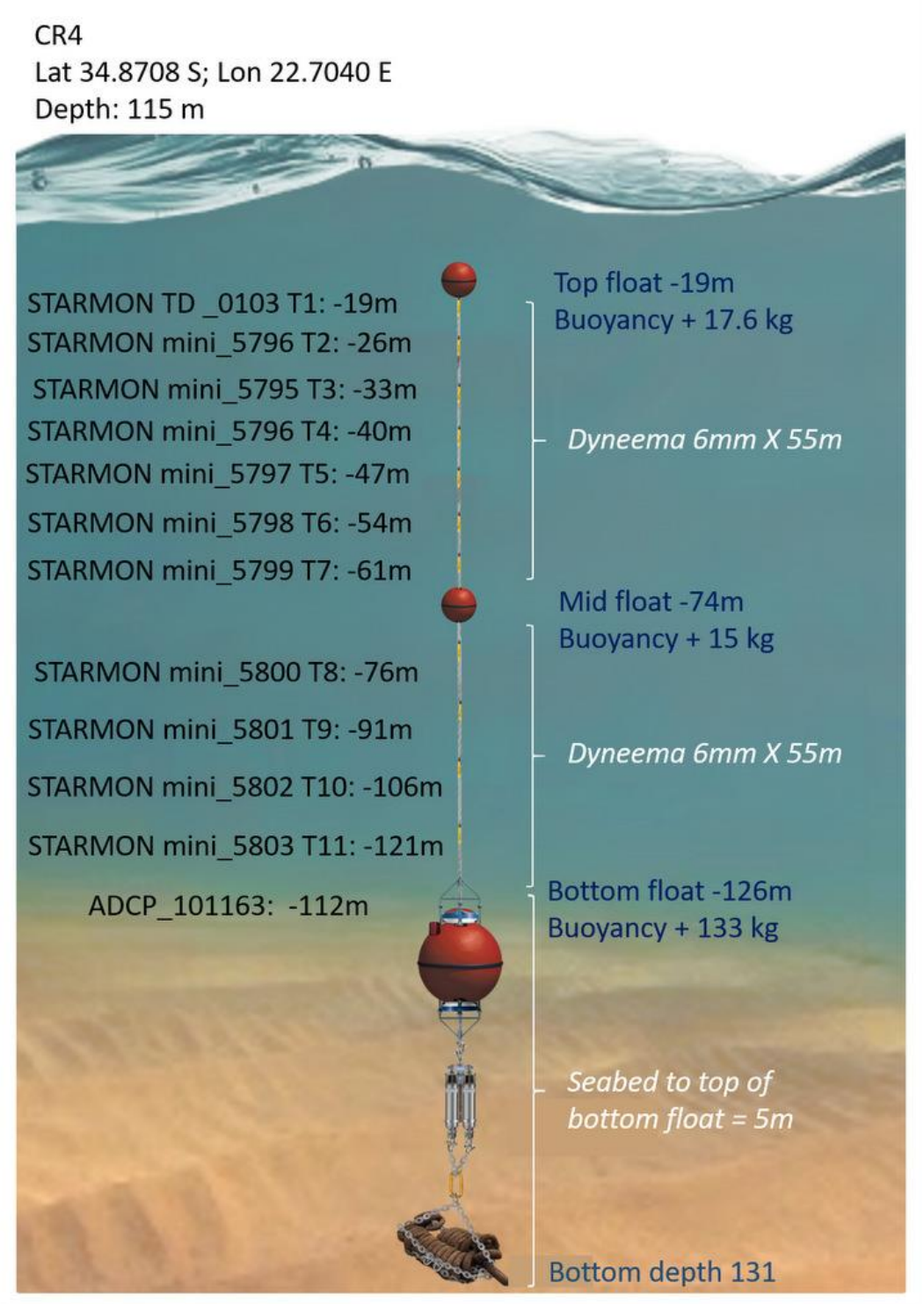
CR1 - Updated mooring diagrams after recovery of the pressure sensor and correction of the instrument real depth of deployment



CR2 - Updated mooring diagrams after recovery of the pressure sensor and correction of the instrument real depth of deployment



CR3 - Updated mooring diagrams after recovery of the pressure sensor and correction of the instrument real depth of deployment



CR4 - Updated mooring diagrams after recovery of the pressure sensor and correction of the instrument real depth of deployment

8. Appendix 4: Gliders Calibration sheets

Calibration data: GPCTD S/N 0221 – fitted on 424

TELEDYNE WEBB RESEARCH
A Teledyne Technologies Company

CUSTOMER SERVICE REPORT

CASE NO. 00004661	**DATE: SEPTEMBER 28, 2018**	
Contact Name: Stephen Woodward		
Organization Address, Email and Phone #: National Oceanography Centre		
NATURE OF PROBLEM		
Equipment: Payload Assembly	**Model:** G2 1000M	**Serial No.** Unit_424
Problem Reported: Fault on CTD pressure sensor, flatlines at 546m		
SERVICE DETAILS		
Analysis: Basic Payload Bay Service (CS-303707) Sea Bird Non-Pumped CTD (CS-303382-FCTD) CTD S/N 0221		
Resolution: Performed CS-303707 Basic Payload Bay Service to Unit 424's Payload bay S/N 1107: • Install re-calibrated CTD sensor 0221 (CS-303382-FCTD) • Replaced all O Rings • Replaced missing CF card retaining clip • Helium Test - passed • Pressure test – passed • Payload bay Functional Test - passed • Cleaning and touch-ups as required • Passed Q/C Inspection		
ENGINEER		
Name: Dan Vient	Title: Service Repair Technician	Phone/Fax: 508.299.6259
Signature:		Date: September 28, 2018

9/28/18

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SERVICE REPORT

Service Request **1005505339**
Date 03-AUG-2018
Sales Order 315188579

PRODUCT INFORMATION

Item: WEBB-GLIDER.LEGACY
Item Description: (LEGACY) WEBB Glider
Serial: 0221

Special Notes
Services Requested:
Evaluate/Repair Instrumentation.
Perform Routine Calibration Service.

Services Performed:
Perform initial diagnostic evaluation. *
Performed pressure calibration.
Performed "POST" cruise calibration.

* The installed anti-foulant appears in good condition.

Item	Item Description	Qty
CAL_SLOCUM	Calibrate SLOCUM conductivity and temperature sensors	1
CNCRTSLOCUM	Confirm & Re-certify Webb SLOCUM Glider CTD	1
PCAL_SLOCUM	Calibrate SLOCUM pressure sensor	1

Unbilled Items

Item	Item Description	Qty

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SENSOR SERIAL NUMBER: 0221
CALIBRATION DATE: 19-Jul-18

WEBB GLIDER TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

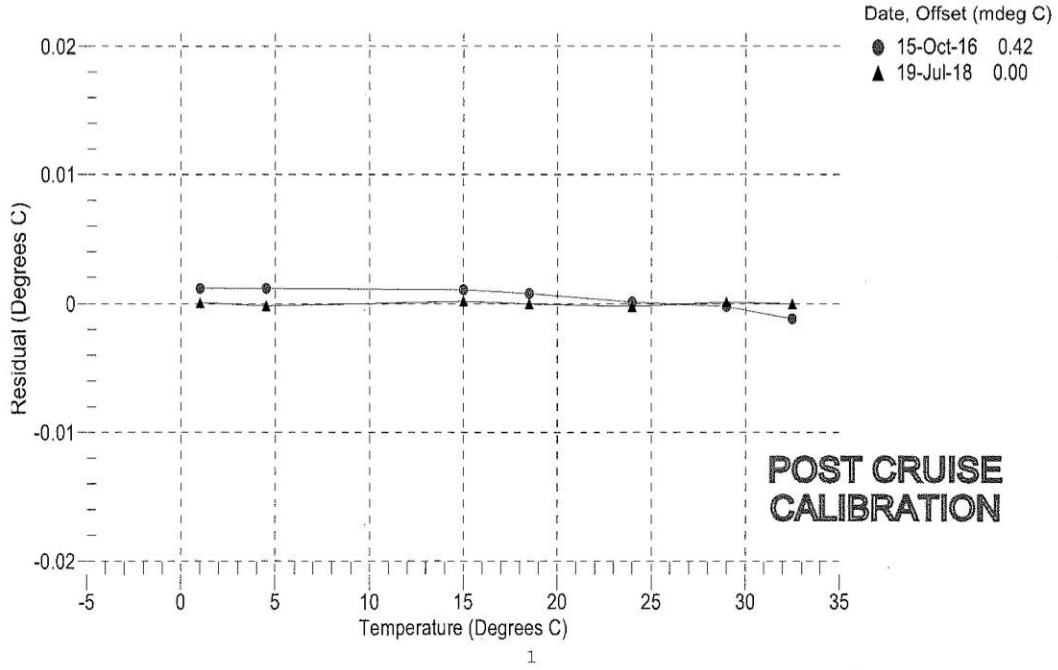
a0 = 7.823640e-005
a1 = 2.706035e-004
a2 = -2.118203e-006
a3 = 1.462281e-007

BATH TEMP (° C)	INSTRUMENT OUTPUT (counts)	INST TEMP (° C)	RESIDUAL (° C)
1.0000	599331.5	1.0001	0.0001
4.5000	511822.3	4.4998	-0.0002
15.0000	325053.0	15.0002	0.0002
18.5000	281148.9	18.5000	-0.0000
24.0000	225159.2	23.9998	-0.0002
28.9999	185114.9	29.0000	0.0001
32.5000	161938.5	32.5000	-0.0000

n = Instrument Output (counts)

Temperature ITS-90 (°C) = $1/\{a0 + a1[ln(n)] + a2[ln^2(n)] + a3[ln^3(n)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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SENSOR SERIAL NUMBER: 0221
CALIBRATION DATE: 19-Jul-18

WEBB GLIDER CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -9.940236e-001
h =  1.434473e-001
i = -3.205037e-004
j =  4.380013e-005

CPcor = -9.5700e-008
CTcor =  3.2500e-006
WBOTC = -3.4753e-007
```

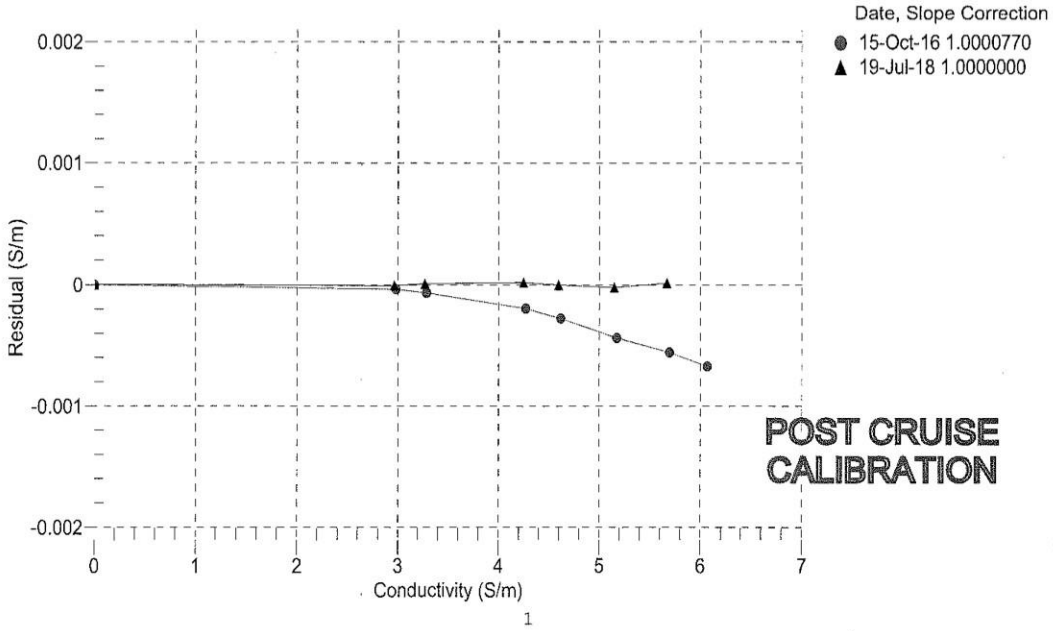
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
22.0000	0.0000	0.00000	2637.39	0.00000	0.00000
1.0000	34.6644	2.96422	5261.67	2.96421	-0.00001
4.5000	34.6449	3.27014	5460.69	3.27015	0.00001
15.0000	34.6030	4.24821	6052.44	4.24822	0.00002
18.5000	34.5942	4.59207	6246.89	4.59207	-0.00000
24.0000	34.5844	5.14793	6548.72	5.14791	-0.00002
28.9999	34.5787	5.66776	6818.59	5.66777	0.00001
32.5000	34.5749	6.03864	7004.55	6.03861	-0.00003

f = Instrument Output(Hz) * sqrt(1.0 + WBOTC * t) / 1000.0

t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



1

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SENSOR SERIAL NUMBER: 0221
CALIBRATION DATE: 18-Jul-18

WEBB GLIDER PRESSURE CALIBRATION DATA
508 psia S/N 3699218

COEFFICIENTS:

PA0 =	-1.010633e-001	PTCA0 =	2.163698e+001
PA1 =	2.439507e-002	PTCA1 =	-3.925721e-002
PA2 =	9.962813e-010	PTCA2 =	-5.489022e-003
PTHA0 =	-7.046803e+001	PTCB0 =	2.508450e+001
PTHA1 =	5.279227e-002	PTCB1 =	-1.000000e-004
PTHA2 =	-7.214323e-007	PTCB2 =	0.000000e+000

PRESSURE SPAN CALIBRATION

PRESSURE (PSIA)	INSTRUMENT OUTPUT (counts)	THERMISTOR OUTPUT (counts)	COMPUTED PRESSURE (PSIA)	RESIDUAL (%FSR)
14.69	624.5	1838.0	14.71	0.00
104.96	4322.4	1838.0	104.95	-0.00
204.97	8419.7	1838.0	204.96	-0.00
304.96	12515.5	1839.0	304.97	0.00
404.97	16609.6	1839.0	404.98	0.00
504.97	20701.2	1839.0	504.95	-0.00
404.97	16609.8	1839.0	404.98	0.00
304.98	12516.0	1839.0	304.99	0.00
204.98	8420.3	1838.0	204.98	-0.00
104.98	4322.9	1839.0	104.96	-0.00
14.69	624.3	1839.0	14.70	0.00

THERMAL CORRECTION

TEMP (°C)	THERMISTOR OUTPUT (counts)	INSTRUMENT OUTPUT (counts)
32.50	2005.40	640.83
29.00	1935.20	642.19
24.00	1835.70	643.76
18.50	1726.00	645.32
15.00	1656.20	646.11
4.50	1448.90	647.60
1.00	1379.70	647.88

TEMPERATURE (°C)	SPAN
-5.00	25.09
35.00	25.08

y = thermistor output (counts)

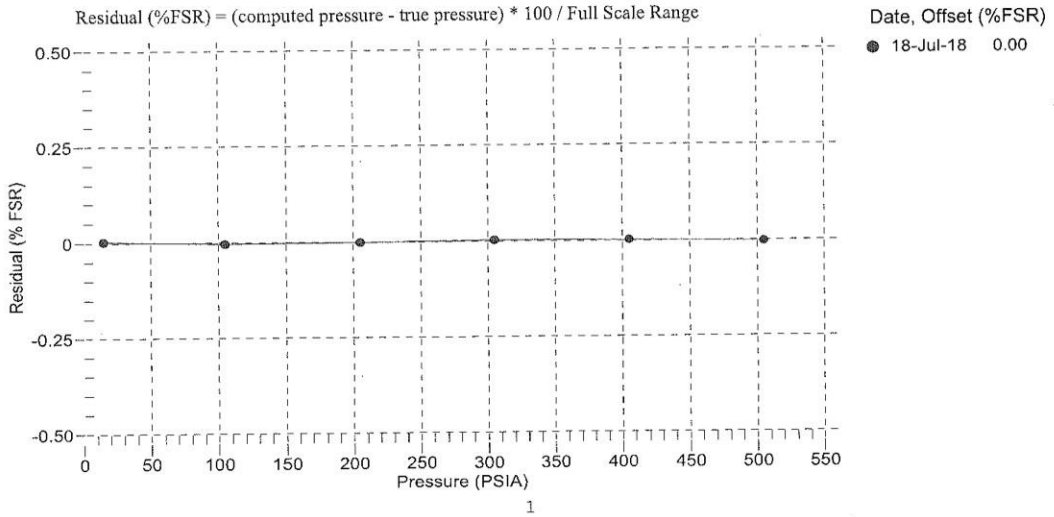
$t = PTHA0 + PTHA1 * y + PTHA2 * y^2$

$x = \text{instrument output} - PTCA0 - PTCA1 * t - PTCA2 * t^2$

$n = x * PTCB0 / (PTCB0 + PTCB1 * t + PTCB2 * t^2)$

$\text{pressure (PSIA)} = PA0 + PA1 * n + PA2 * n^2$

Residual (%FSR) = (computed pressure - true pressure) * 100 / Full Scale Range



1

Calibration data: GPCTD S/N 9034– fitted on 438

TELEDYNE WEBB RESEARCH
A Teledyne Technologies Company

CUSTOMER SERVICE REPORT

CASE NO. 00004366	**DATE: SEPTEMBER 5, 2018**	
Contact Name: Stephen Woodward		
Organization Address, Email and Phone #: National Oceanography Centre		
NATURE OF PROBLEM		
Equipment: Payload Assembly	**Model:**	**Serial No.** Unit_345
Problem Reported: Calibration/Repair		
SERVICE DETAILS		
Analysis: CS-303388 Basic Glider Service – Section Only CS-303382-CTD Sensor calibration Sea Bird CTD CS-303382-WPK Sensor calibration Wet Labs Puck CS-303392 Pressure and Helium ONLY test		
Resolution: CS-303388 Basic Glider Service – Section Only CS-303382-CTD Sensor calibration Sea Bird CTD CS-303382-WPK Sensor calibration Wet Labs Puck Helium test completed and passed Pressure test completed and passed Final functional checkout completed and passed QA/QC check completed and passed		
ENGINEER		
Name : Roger Desmarais	Title: Service Repair Technician	Phone/Fax: (508) 299-6254
~~Signature~~: Roger Desmarais		Date: September 5, 2018

9/5/18

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SERVICE REPORT

Service Request 1005503961
Date 22-MAR-2018
Sales Order 314972677

PRODUCT INFORMATION

Item: SLOCUM.50
Item Description: SLOCUM GLIDER CTD, 1000 dBar, DIRECT GROUND
Serial: 712-9034

Special Notes
Services Requested:
Evaluate/Repair Instrumentation.
Perform Routine Calibration Service.
Replace the instruments "O"-rings.
Perform hydrostatic pressure test.
Replace Antifoulant Device(s).

Services Performed:
Perform initial diagnostic evaluation.
Performed pressure calibration.
Performed "POST" cruise calibration.
Installed NEW AF24173 Anti-foulant cylinder(s).

Item	Item Description	Qty
CAL_SLOCUM	Calibrate SLOCUM conductivity and temperature sensors	1
CNCRTSLOCUM	Confirm & Re-certify Webb SLOCUM Glider CTD	1
REPLACEAF	Extra charge to install one antifoulant device, includes one 801542.1.	1
PCAL_SLOCUM	Calibrate SLOCUM pressure sensor	1

Unbilled Items

Item	Item Description	Qty
801542.1	AF24173 ANTI-FOULANT, SINGLE CYLINDER, V2	1

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SENSOR SERIAL NUMBER: 9034
CALIBRATION DATE: 08-Feb-18

Slocum Payload CTD CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -9.738184e-001
h =  1.348494e-001
i = -1.778810e-004
j =  3.188515e-005

CPcor = -9.5700e-008
CTcor =  3.2500e-006
WBOTC = -2.7882e-007
```

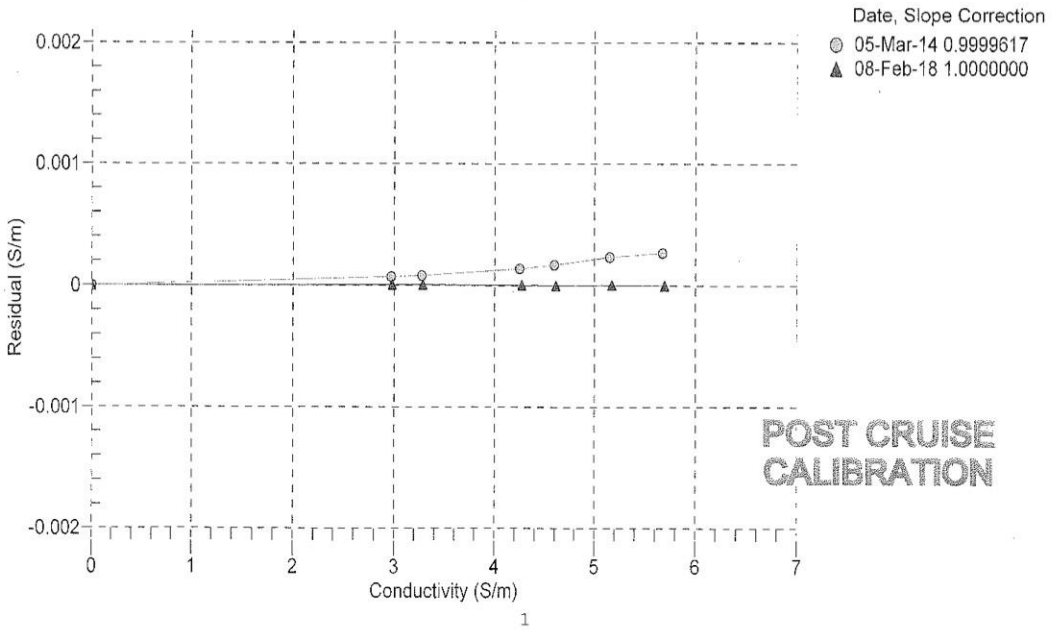
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
22.0000	0.0000	0.00000	2689.77	0.00000	0.00000
1.0000	34.8497	2.97855	5414.40	2.97855	0.00000
4.5000	34.8296	3.28586	5620.23	3.28586	0.00000
15.0000	34.7876	4.26846	6232.13	4.26847	0.00000
18.5000	34.7787	4.61392	6433.14	4.61392	-0.00000
24.0000	34.7687	5.17233	6745.11	5.17233	0.00000
29.0000	34.7622	5.69445	7023.94	5.69445	-0.00000
32.5000	34.7572	6.06685	7215.96	6.06671	-0.00014

f = Instrument Output(Hz) * sqrt(1.0 + WBOTC * t) / 1000.0

t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



1

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SENSOR SERIAL NUMBER: 9034
CALIBRATION DATE: 08-Feb-18

Slocum Payload CTD TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

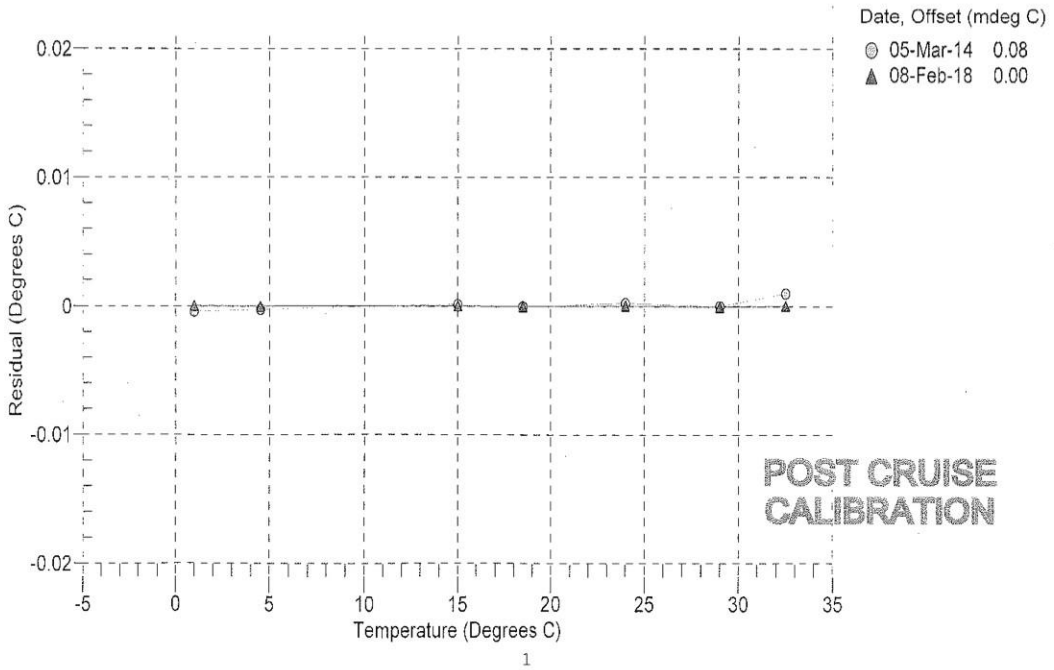
a0 = -1.751961e-004
a1 = 3.183184e-004
a2 = -5.202815e-006
a3 = 2.205537e-007

BATH TEMP (° C)	INSTRUMENT OUTPUT (counts)	INST TEMP (° C)	RESIDUAL (° C)
1.0000	578663.8	1.0000	0.0000
4.5000	495456.4	4.5000	-0.0000
15.0000	317121.8	15.0000	0.0000
18.5000	274999.8	18.5000	-0.0000
24.0000	221134.6	24.0000	0.0000
29.0000	182488.2	28.9999	-0.0001
32.5000	160059.6	32.5000	0.0000

n = Instrument Output (counts)

Temperature ITS-90 (°C) = $1/\{a0 + a1[ln(n)] + a2[ln^2(n)] + a3[ln^3(n)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



1

Calibration data: GPCTD S/N 0227– fitted on SG550

SEA-BIRD

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SERVICE REPORT

Service Request **1005501730**
Date 04-MAY-2017

CUSTOMER INFORMATION
Name: KONGSBERG UNDERWATER TECHNOLOGY INC
Account : 40280537
RICHARD HILE
RICHARD.HILE@KONGSBERG.COM
425 712-1197

PO Number:

Bill To Address
19210 33RD AVE W;SUITE A;
LYNNWOOD,WA,98036,US

Ship To Address
19210 33RD AVE W;SUITE A;
LYNNWOOD,WA,98036,US

PRODUCT INFORMATION

Item: APL-GLIDER.LEGACY
Item Description: (LEGACY) APL Glider
Serial: 227

Special Notes
Services Requested:
Evaluate/Repair Instrumentation.
Perform Routine Calibration Service.

Problems Found:
The temperature probe was found to be shorted.

Services Performed:
Perform initial diagnostic evaluation.
Replaced the temperature probe.
Replaced the O-rings.
Performed a hydrostatic pressure test.
Performed a "Final" Calibration.

Item	Item Description	Qty
CAL_SEAGLIDER	CALIBRATE SEAGLIDER CONDUCTIVITY AND TEMPERATURE SENSORS (FRRF)	1
CNCRTSEAGLDR	CONFIRM & RE-CERTIFY SEAGLIDER CTD (FRRF)	1
REPGLIDERPROB	REPLACE SBE GLIDER THERMISTOR PROBE (FRRF)	1

Unbilled Items

Item	Item Description	Qty
802134	VM GLIDER THERM PROBE ASSY,V3,SHIELDED,FENWAL	1

Page **1** of **2**

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SENSOR SERIAL NUMBER: 0227
CALIBRATION DATE: 02-May-17

Glider APL TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

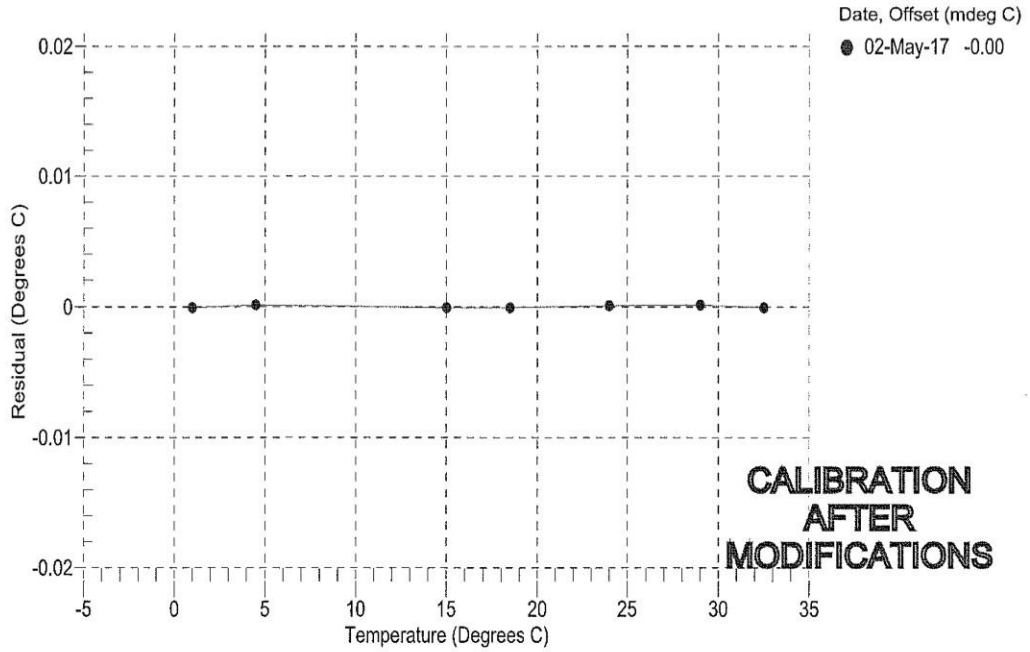
g = 4.41087046e-003
h = 6.44077557e-004
i = 2.52246948e-005
j = 3.06414061e-006
f0 = 1000.0

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
1.0000	3441.249	0.9999	-0.00007
4.5000	3717.886	4.5001	0.00012
15.0000	4642.497	14.9999	-0.00007
18.5000	4983.535	18.4999	-0.00006
24.0000	5553.917	24.0001	0.00005
29.0000	6109.880	29.0001	0.00011
32.5000	6520.713	32.4999	-0.00008

f = Instrument Output (Hz)

Temperature ITS-90 (°C) = $1/\{g + h[ln(f0 / f)] + i[ln^2(f0 / f)] + j[ln^3(f0 / f)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0227
CALIBRATION DATE: 02-May-17

Glider APL CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -9.79118560e+000
h = 1.12890448e+000
i = -3.47731380e-003
j = 3.02279368e-004

CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
22.0000	0.0000	0.00000	2.95504	0.00000	0.00000
1.0000	34.7246	2.96887	5.94004	2.96885	-0.00002
4.5000	34.7049	3.27525	6.16615	3.27527	0.00002
15.0000	34.6630	4.25479	6.83843	4.25480	0.00001
18.5000	34.6543	4.59919	7.05937	4.59920	0.00001
24.0000	34.6451	5.15597	7.40232	5.15595	-0.00001
29.0000	34.6407	5.67679	7.70903	5.67678	-0.00001
32.5000	34.6390	6.04856	7.92052	6.04857	0.00001

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity