National Oceanography Centre

National Oceanography Centre

Cruise Report No. 69

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2/12/19 – 9/1/20

Punta Arenas, Chile – Punta Arenas, Chile

CUSTARD: Carbon Uptake and Seasonal Traits in Antarctic Remineralisation Depth

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ABSTRACT

The CUSTARD project examines how seasonal changes in nutrient availability for phytoplankton, at a key junction of the global ocean circulation, influence how long carbon is trapped in the ocean rather than escaping to the atmosphere as carbon dioxide.

If we want to understand the role of the Southern Ocean in regulating global climate we need to understand both how much carbon is used to make phytoplankton at the ocean surface and how deep this material penetrates into the ocean interior; the 'remineralisation depth'. The objective of CUSTARD is to make new observations of the remineralisation depth and its controls in an important, yet remote, region of the Southern Ocean, using a combination of gliders, a mooring, sophisticated new sensors and a process cruise. The observations will be combined with modelling to determine the key processes regulating carbon uptake in the Southern Ocean.

CUSTARD fieldwork began with DY096 in Nov-Dec 2019. A surface mooring and two gliders were deployed at the OOI site (54.42 S 89 W) to make observations throughout the year. One glider was lost early on and the second had to be recovered in November 2019 after it became trapped at the surface. The mooring was recovered on DY112.

DY111 was a process cruise immediately prior to the mooring recovery cruise (DY112), to allow a more detailed study of the biogeochemistry of the site at the key spring bloom period. Objectives were: to deploy two other gliders (just for the duration of the cruise); to deploy 6 BGC ARGO floats on behalf of the SOCCOM project; to do multiple visits to 3 sites along 89 W (OOI, TN at 57S and TS at 60S); and to carry out a full depth CTD transect between OOI and TS at 1 degree latitude resolution. All objectives were met, though one glider had to be recovered immediately after deployment due to a leak. Additionally, a modest spatial survey was carried out collecting underway data and samples along a grid-pattern extending 90km west of 89W, to assess upstream properties and gradients.

The cruise was exceptionally fortunate both in weather and in coinciding strongly with the spring bloom spanning the area.

CUSTARD (NE/K015613/1) is part of the NERC Role of the Southern Ocean in the Earth System (RoSES) programme. Additional work was funded by the NERC Bridging International Activity and Related Research Into the Twilight Zone (NE/ S00842X/1).

KEYWORDS

carbon, Southern Ocean, biological carbon pump, mode water, phytoplankton, glider, mooring, OOI, lab-on-a-chip, iron, nutrients, diatoms, export, transfer efficiency, SOCCOM, CUSTARD, RoSES, BIARRITZ

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List of Personnel

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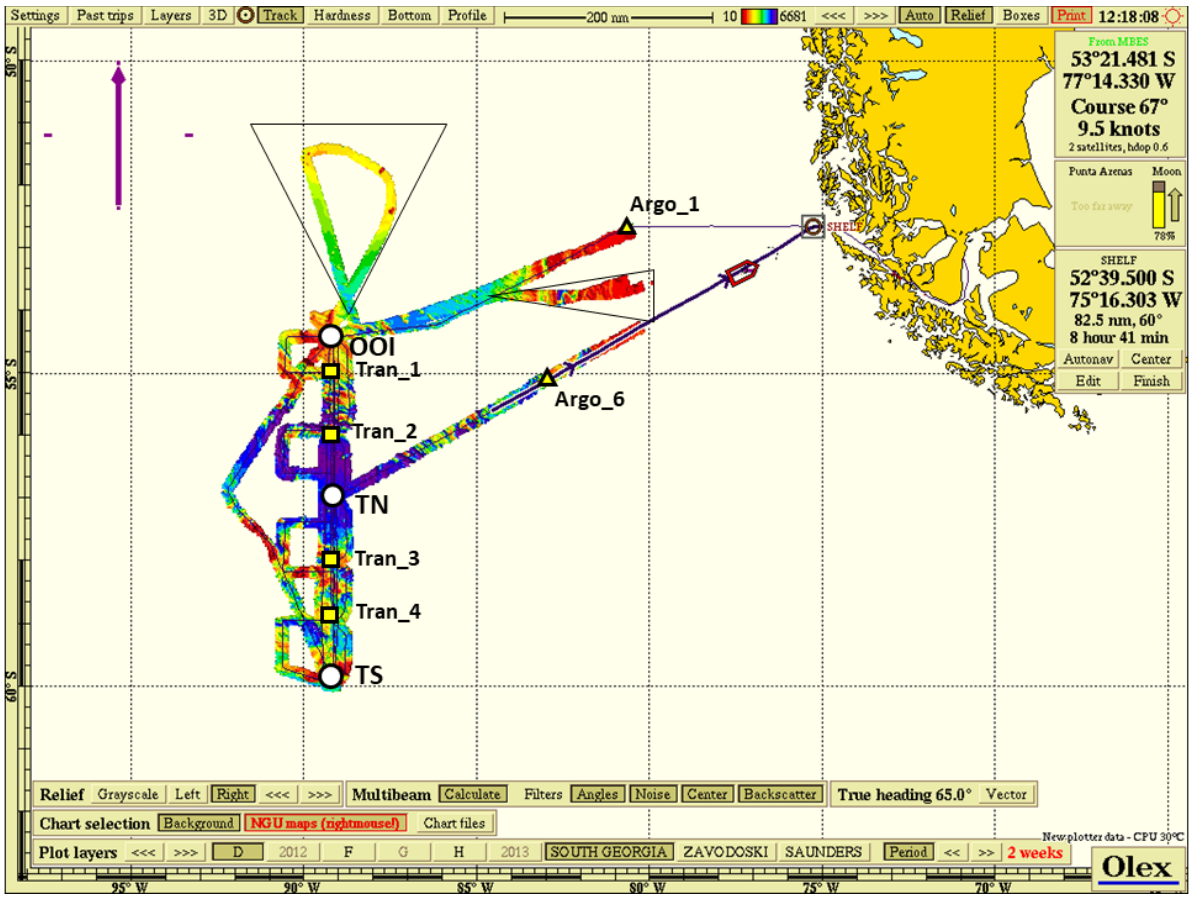
Lynch, Peter	H/Chef
Keighley, Christopher	Chef
Carrilho Mantihna, Clemetina	Stwd
Williams, Denzil	A/Stwd

Itinerary



Map showing site of DY111 activity with additional area covered by DY096 marked in black triangles. The glider was deployed at OOI, with 4 visits to stations OOI, TS and TM along 89W. Also shown are the intermediate stations (Tran_1 to 4) forming part of the full depth CTD transect, and the surface spatial survey running 90km in a grid pattern to the west. BGC ARGO floats were deployed for SOCCOM at OOI, TS, Tran_2, Tran_3, Argo_1 and Argo_6. Colours indicate bathymetry but note that the shallowest depth should be 3500m not 10m.

Objectives

The CUSTARD project examines how seasonal changes in nutrient availability for phytoplankton, at a key junction of the global ocean circulation, influence how long carbon is trapped in the ocean rather than escaping to the atmosphere as carbon dioxide.

If we want to understand the role of the Southern Ocean in regulating global climate we need to understand both how much carbon is used to make phytoplankton at the ocean surface and how deep this material penetrates into the ocean interior; the 'remineralisation depth'. The objective of CUSTARD is to make new observations of the remineralisation depth and its controls in an important, yet remote, region of the Southern Ocean, using a combination of gliders, a mooring, sophisticated new sensors and a process cruise. The observations will be combined with modelling to determine the key processes regulating carbon uptake in the Southern Ocean.

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The cruise was exceptionally fortunate both in weather and in coinciding strongly with the spring bloom spanning the area.

Narrative

Friday 22nd November

Jon Short (Senior Tech) and Alan Wright arrived in order to meet AMT (DY110). AMT delayed by weather though.

Tuesday 26th November

Discovery arrived and alongside.

Thursday 28th November

Calm with a lot of sun during the day. Discovery at anchor so small boat transfer in morning for the science team who have arrived so far. Unpacking containers. Pilot on board just after 1830 and Discovery alongside just after 1900. Science team back to hotel.

Friday 29th November

Pretty calm with a fair bit of sunshine. Setting up. All but one of remaining science team arrived in evening.

Saturday 30th November

Final science team member arrived in morning. Hugh Venables briefed on deploying SOCCOM floats by Greg Brusseau (U.Washington) down for mobilisation. Working on board in morning before transferring personal gear to ship and cabins in afternoon.

Sunday 1st December

A rainy day. Impromptu visit by Prof Charles Eriksen, Seaglider guru, and wife, on holiday in Chile. Tour and presented with Discovery baseball caps and plaque. Safety briefing. Final preparations prior to sailing.

Monday 2nd December

Rain of morning disappeared but a cold, cloudy day with a brisk wind. Sailed at 0510 (0810 GMT) with pilot off at 0522 (0822 GMT). Good progress and through the narrows around 1300. Various wildlife including Killer, Sei and Humpback whales, sealions, albatrosses and Andean Condors. Muster drill at 1600.

Tuesday 3rd December

Grey, with Force 4-5 through the day rising to 7, gusting 8, by end. Good progress overnight, leaving Magellan Strait and crossing the continental shelf into the Pacific. First daily meeting at 0830. Science team briefing at 1030. Talk for crew at 1830. Crossed into international waters and hove to 1032 (0132

GMT). Echosounder started, with Hugh Venables on bridge during wind-up to watch for cetaceans. Logging of eddy covariance system started. First CTD overboard at 1054 (0154 GMT); the titanium to 200m to soak bottles. Back on deck 1120 (0220 GMT).

Wednesday 4th December

Force 7, gusting 8, and rain for CTD and float operations. Steel CTD to 2000m deployed at 0019 (0319 GMT). On deck at 0205 (0505 GMT). SOCCOM BGC Argo float 18242 deployed at 0222 (0522 GMT) at 52 39.22 S 80 32.25 W. Release rope caught in a knot on deployment and float had to be hauled back on deck and redeployed. Brisk wind and choppy all day but with brief blue skies and sunshine part way through. Steaming for OOI site. TM fish deployed 0923 (1223 GMT).

Thursday 5th December

Foggy overnight, then cloudy, Force 5. Underway sampling started at 0900 (1200 GMT). Preparation for arrival at OOI site.

Friday 6th December

Relatively calm, Force 4-5. Arrived on OOI site at 54 25.28 S 89 07.72 W with bridge having visual of mooring on approach due to light on top. Red Camera Frame deployed at 0054 (0354 GMT). Romica winch underestimated cable out by 20%. Factored in to future use of winch. Stainless steel CTD deployed at 0306 (0606 GMT), at 2000m at 0347 (0647 GMT) and back on deck 0513 (0813 GMT). SOCCOM BGC Argo float 18320 deployed at 54 25.24 S 89 07.83 W at 0548 (0848 GMT). Glider 306, with Ecopuck and PAR sensors, deployed 0633 (0933 GMT) at 54 25.21 S 89 07.92 W. Glider 330, with Ecopuck and LISST, deployed 0640 (0940 GMT) at 54 25.19 S 89 07.92 W. Both deployed using new launch trolley which performed very well. Snow Catcher deployed but found to have leaked on recovery. Snowcatching postponed as glider 306 had reported a leak. Glider recovered at 0940 (1240 GMT). Autopsy revealed probable leak associated with front bulkhead connector between nose and body of glider. Any fix likely to carry significant risk of repeated leak prompting another recovery, at best, so decision made not to redeploy. Snow Catcher resumed and 4 Snow Catchers collected, two being a repeated depth due to a suspected leak. Titanium CTD dip to 1000m at 1242 (1542 GMT) for 'standard' metal parameters, plus salts and oxygen for sensor calibrations. First SAPS deployment at 1522 (1822 GMT), with three pairs to allow TM and thorium+fungi to be sampled. Two SAPS didn't pump. Stainless CTD to 1000m at 1910 (2210 GMT) with Ecopuck attached – only rated to 1000m. Second Red Camera Frame dip at 2050 (2350 GMT) followed by first turbulence profiling at 2236 (0136 GMT)

Saturday 7th December

Good weather. Force 4, with weak sea, even some blue sky and sun. Microplastic SAPS deployed at 0019 (0319 GMT) to 4500m. TM fish deployed at 0532 (0832 GMT). Left site, steaming due south for 60S 89W.

Sunday 8th Deccember

Good weather, as yesterday but with even more blue sky. Communication glitch led to fish being brought onboard ahead of station. At station TS_1 59 57.57 S 89 7.73W at 1515 (1815 GMT). Needed to collect water nearer night-time for incubation so started with full depth (5000m) titanium CTD – water depth 5042m. An attempt to sample all hydrographic parameters from the one CTD was successful but demanding in time on users of clean lab. Major anomaly at ~200m depth with high fluorescence, oxygen and backscatter as well as salinity indicative of surface. Likely to be ephemeral subduction event but a few opportunistic attempts to sample it thought possible. Fish deployed and steamed a 2.5 hour loop to allow water to be pumped from TM fish for incubations. TM fish brought up short at 2325 (0225 GMT) having earlier been modified to avoid having to bring it onboard each time.

Monday 9th December

Good weather, with a period of sun afternoon but bitterly cold in wind, Force 4-5. Stainless CTD deployed at 0016 (0316 GMT). Dip to 1000m but time in hand so no bottles sampled and CTD lowered once again to 1000m. Bottles fired on second upcast. Provides material for exploring statistics/reproducibility on UVP data. First use of zooplankton nets at 0254 (0554 GMT). Primary aim to separate out migrators so started with 0-120m haul of 200um net at night. Mesh chosen to match resolution of UVP. Lots of crustaceans and a thick soup of algae. Haul from 300m to surface had very few crustaceans but lots of algae again. Red Camera Frame from 0515 (0815 GMT). Lots of particulate material (in UVP too, including odd doughnut marine aggregates) but no immediate evidence of sinking. Snow Catcher profile at 0704 (1004 GMT) continuing to test patience and detective skills of Chelsey as some leaked in different ways. Turbulence profiling from 0930 (1230 GMT) to 1038, pushing to 250m to try and capture the subducted feature. Titanium CTD at 1131 (1431 GMT) for metals, followed by daytime nets at 1325 (1625 GMT). Very few zooplankton in both 0-120m and 0-300m hauls though a thick soup of algae that blocked sieve on deep haul. Couple of jellies captured too. SAPS at 1542 (1842 GMT). Surface TM SAPS didn't pump again. Stainless CTD dip with full suite including BGC ARGO parameters at 1931 (2231 GMT) followed by deployment of SOCCOM BGC ARGO float, this time decorated with a Fringehead by Sofia. Red Camera Frame at 2156 (0056 GMT) followed by another, very cold, stint of turbulence profiling at 2318 (0218 GMT).

Tuesday 10th December

Calm seas again, some blue sky, Force 4-5. SAPS for microplastics from 0144 (0444 GMT). Glitch with one of three SAPS led to NMF doing a second deployment, with just the deep (4500m) SAPS. TM fish deployed and we steamed towards station TN, at 57N, veering 2-3 miles from line of approach to map more bathymetry in support of Oceans 2030, at suggestion of Jon and Zoltan. Terrible news of loss of Chilean Hercules crossing Drake Passage. On call in case needed for search.

Wednesday 11th December

Decent weather again with blue sky. Deck noticeably warm from sun in afternoon and the sunglasses were out. Arrived at TN site 0254 (0554 GMT), shortening fish after sampling complete on approach. Stainless CTD deployed 0320 (0520 GMT), essentially to get depths for Snow Catcher, but, as we were early, did a double dip, only firing bottles on second ascent. Intention again to provide back-to-back UVP profiles. Snow Catchers from 0531 (0831 GMT), continuing to perplex and surprise. 'Standard' Titanium CTD at 0824 (1124 GMT) followed by single zooplankton net to 120m. Decision to do just one based on need to fir UVP and RCF profiles into short night as well. At last net, Bridge had given a boost with port azimuth (starboard one was off) to clear net when it drifted under. Similarly this time but port azimuth clearly aimed to starboard as water around net smooth from turbulence. Discussed deploying net in future from midships with Jon Short and Steve Smith Sci CPO. Because of damage to one of the 6 SAPS, deployed two pairs on first cast (1136, 1436 GMT), with third pair to be done as part of microplastics cast later. 'Standard' stainless CTD at 1456 (1756 GMT). Had to be recovered to deck soon after deployment as Ecopuck not turned on. Redeployment immediately after. Red camera frame at 1806 (2106 GMT) followed by a more extensive bout of turbulence profiling at 1946 (2246 GMT). Concerned at influence of starboard azimuth, even if port azimuth turned off, Captain came up with plan to position ship with wind behind allowing both azimuths to be turned off. Five profiles like this then Bridge repositioned ship into wind and started starboard azimuth to allow another profile for comparison. SAPS deployed at 2250 (0150 GMT).

Thursday 12th December

Brisker wind and colder, rising to Force 7 before blue calmer weather returned. Impressive sunrise with rising sun on starboard and double rainbow on port reflected in sea. SAPS back on deck 0325 (0625 GMT). One (Jenny) failed to pump again and will need to be used selectively from now on. Time lost to over-running SAPS meant that stainless CTD restricted to 120m to match new depth and to provide water for Chance English's respiration experiments. We already had 1000m UVP data from previous night. First net from midships at 0445 (0745 GMT). Worked OK if slightly trickier to gauge cable speed using tape marks and watch. Red Camera Frame at 0546 (0846 GMT) then left station steaming for 56S 89W. Arrived at Tran_2 at 1442 (1742 GMT) but CTD dips delayed for work on starboard prop.

Titanium CTD deployed at 1633 (1933 GMT) to full depth (4937m). Titanium CTD onboard at 2017 (2317 GMT). Stainless CTD deployed at 2115 (0015 GMT) to full depth of 5030m. Steamed to Tran_1

Friday 13th December

More swell and wind Force 6, with both decreasing over day with blue sky appearing. Force 2 and calm and foggy later. Stainless CTD onboard at 0115 (0415 GMT). Sailed for 55N 89W (Tran_1). On station 0949 (1249 GMT) with titanium CTD deployed at 1009 (1309 GMT), then stainless CTD at 1501 (1801 GMT). Moved north to OOI site, arriving to deploy turbulence profiler just E of glider release site at 2257 (0157 GMT).

Saturday 14th December

Started calm and foggy, freshening, swell increasing but then receding. Stainless CTD at 0108 (0408 GMT) followed by zooplankton net at 0250 (0550 GMT) and red camera frame at 0338 (0638 GMT). Snow Catcher deployed four times from 0529 (0829 GMT) onwards. Titanium CTD at 0815 (1115). Pause while engineers worked on port azimuth. SAPS at 1055 (1355) including rest of repaired one and final chance for "Jenny". Net at 1340 (1640 GMT) followed by an extra Snow Catcher at 1413 (1713 GMT) as Chelsey Baker suspicious that previous one to 400m triggered in mixed layer. In order to get a good calibration of the sensors on board a match-up with the glider was arranged the previous day. The ship was set up 500m NE of the recent glider locations while it had been trying to maintain position. Dave Mackenzie managed to spot it before it had time to report a GPS fix and ship was nudged to ~400m distance. Pilot then triggered a dive at which point we carried out a simultaneous stainless CTD dip at 1539 (1839 GMT). Red Camera Frame straight after at 1800 (2100 GMT). The following turbulence profiling (1950 – 2250 GMT) was curtailed after 3 profiles when it was noticed that screws had come loose and were missing from part of the cable drum. Recovered for inspection and possible repair. SAPS deployed at 2240 (0140 GMT). It was also discovered today that the CPICS sensor from the Red Camera Frame may have a leak; there was condensation visible within two parts. As brand new, it was decided to pack it away for return to manufacturers rather than attempt our own repair as their help line suggested.

Sunday 15th December

A sunny day with blue skies and clouds, Force 5. Full depth Titanium CTD at 0255 (0555 GMT) followed by a full depth stainless CTD at 0712 (1012 GMT). TM fish lowered and headed south sampling from underway every 2 hours for nutrients, salts, metals and carbon, with pigments and particulates every 6 hours.

Monday 16th December

A greyer day if even calmer, Force 4, rain following fog. Continued 2 hourly underway sampling. Science meeting to catch up on results so far and to discuss refinements or additional ideas at 1000 (1300 GMT). On site for TS_2 at 2030 (2330 GMT), with SAPS in water at 2034 (2334 GMT). Apparently substantially weaker current than last visit: ~0.5 kt rather than ~1 kt. Wind direction made easier to deploy without cable passing under vessel so easier to use DP and hold position.

Tuesday 17th December

Fresher start with rain and Force 6, becoming calmer with some sun and blue skies (and occasional showers). Turbulence profiling at 0026 (0326 GMT) to fill time until sufficiently dark for the Stainless CTD at 0151 (0451 GMT). Followed by net at 0316 (0616 GMT) then Red Camera Frame at 04:01 (07:01 GMT). Four Snow Catchers from 0523 (0823 GMT), then Titanium CTD to 1500m with intention of sampling CDW (oxygen minimum) which Hugh Venables had diagnosed at 1200m in previous visit. On basis of this time's oxygen CTD trace, fired bottle at 1100m on both this CTD and later stainless one. SAPS at 1033 (1333 GMT) followed by a more extensive bout of turbulence profiling at 1320 (1620 GMT). 'Standard' stainless CTD, but to 1500m to match titanium, at 1511 (1811 GMT) followed by net at 1651 (1951 GMT) and Red Camera Frame at 1830 (2130 GMT) before leaving station to north.

Wednesday 18th December

Cool, if calm, start, Force 3, then a little rather wet snow, then sun and blue sky with showers scattered throughout. Stopped at 59N (Tran_4) for deep CTD cast double-bill: titanium at 0253 (0553 GMT) and stainless at 0718 (1018 GMT). Then off to Tran_3 for another deep CTD pair at 1908 (2208 GMT) for the titanium and 2335 (0235 GMT) for the stainless. Concern at performance of winch meant that CTD was lowered to ~400m then raised to the surface before the cast, to test control swap over. Performed fine.

Thursday 19th December

A little swell at first, slightly slowing progress to TN but thereafter a calm, sunny day with blue skies and sunglasses in evidence. Titanium CTD on arrival at 1359 (1659 GMT), sent to 1500m by metal team in hope of capturing oxygen minimum again. Spot of turbulence profiling at 1359 (1659 GMT) before the stainless cast to 1000m at 1538 (1838 GMT), with greater priority given to ability to keep Ecopuck attached rather than go the extra 500m given that there was scheduled to be a deep cast later. Member of science party hit head on lug on top frame going through watertight door into deck lab. Attended by second officer and captain and first aid provided. Net at 1650 (1950 GMT) followed by red camera frame at 1732 (2032 GMT) minus PCAM due to broken contact discovered on initial deployment. Deep SAPS at 2003 (2303 GMT)

Friday 20th December

Relatively calm sea and blue sky, Force 4. SAPS onboard at 0225 (0525 GMT) having gone to full depth for microplastics. Night-time trio of stainless CTD (0300; 0600GMT), net (0414; 0715 GMT) and red camera frame (0457; 0757 GMT). Snowcatching from 0609 (0909 GMT) then turbulence profiling at 0809 (1109 GMT). Full depth titanium CTD at 1001 (1301 GMT). Several thousand modulo errors with many spikes including on pressure. Stainless CTD at 1433 (1733 GMT) also to full depth, before leaving station with TM fish lowered at 1743 (2043 GMT). Headed north. Double masted yacht spotted on horizon at 2010 (2310).

Saturday 21st December

A beautiful midsummer sunrise according to those up early enough to see it. Largely quite calm and sunny, Force 1-2, with Force 4 and rain showers occasionally. Arrived at Tran_2 (56S) at 0210 (0510 GMT) and commenced test of titanium CTD following thorough service. Lowered to 1000m then back to surface with no modulo errors – until just one almost before recovery. Decided no basis for further action at this stage. Stainless CTD to 2000m at 0403 (0703 GMT) with full set of samples as calibration for BGC ARGO float (18545) launch which followed straight after at 0556 (0856 GMT). Steamed to OOI arriving 1840 (2140 GMT) and immediately deploying SAPS. Following this, in order to collect water samples from TM fish for incubations, Discovery steered a loop at 5kts, setting up to then run ~1nm in to glider deployment site doing turbulence profiling from 2323 (0223 GMT).

Sunday 22nd December

Fresher than previous day, with a little swell but still a fair bit of blue sky, Force 4-5. Overnight trio of stainless CTD (0108; 0408 GMT), net (0233; 0533 GMT) and red camera frame (0318; 0618 GMT). ADCP scattering layer suggested migration and a number of krill found in net. Snowcatching from 0432 (0732 GMT). Titanium CTD at 0704 (1004 GMT) then the second session of SAPS (0926; 1226 GMT) Followed by another glider rendez-vous. Held at surface by pilot and we positioned within 300m to do a stainless CTD to 500m (1310; 1610 GMT) with no bottles to match depth range of glider (limited due to LISST sensor) followed immediately by a 'standard' as second to 1000m (1355; 1655 GMT). Subsequent red camera frame deployment (1505; 1805 GMT) had to be curtailed when glider surfaced ~20m aft of vessel. Ship relocated and second red camera frame deployment at 1612 (1912 GMT). Zooplankton net at 1709 (2009 GMT) notable for the krill being absent. Turbulence profiling at 1853 (2153 GMT) followed by the last of the three SAPS sessions (1942; 2242 GMT) this time going full depth for microplastics. After deck check that all secure, fish lowered and started spatial survey ~0200 (0500GMT).

Monday 23rd December

Sunny spells, but a little more swell and a fresh breeze, Force 5. Spatial survey continuing with sampling every 6 hours at the turning points.

Tuesday 24th December

Weather and work pattern as yesterday. Science meeting in afternoon. Quiz in bar in evening.

Wednesday 25th December

Grey weather, Force 5, but increasing to 6. Spatial survey continued. Get together in bar prior to lunch, with short speech by Captain and secret Santa. Xmas lunch will all the trimmings.

Thursday 26th December

Increased swell and Force 6 to start but improving a little over the day. Final day of spatial survey. Paused for check on engineering work done earlier in week on line approaching TS. On station at 2040 (2340 GMT) with quick stainless CTD dip to 300m (2043; 2343 GMT) to provide information necessary for following SAPS at 2150 (0050 GMT).

Friday 27th December

A little swell to start but receding to very calm, gently undulating mirrorlike sea, Force 1. Turbulence profiling at 0009 (0309 GMT). Turbulence work restricted at this station to need to use time to address other priorities. Night trio of stainless CTD (0126; 0426 GMT), net (0248; 0548 GMT) and red camera frame (0338; 0638 GMT). Snow Catcher session at 0514 (0814 GMT). Full depth titanium at 0741 (1041 GMT) as yet to collect deep particulates for metals at this site, having tried to do all samples from a single titanium on TS_1. Snow Catcher reprise at 1225 (1525 GMT) as two bottles misfired. Day trio of red camera frame (1347; 1647 GMT), net (1447; 1747 GMT) and stainless CTD (1539; 1839 GMT). Followed by 30m dip of titanium CTD (1712; 2012 GMT) to collect water samples for Jo Ainsworth whose samples couldn't be accommodated on the full depth one. Full depth SAPS at 1825 (2125 GMT) before leaving the site just after midnight.

Saturday 28th December

Generally good but a little fresher and with a little more swell, Force 5-6. Paused at Tran_3 (58S) for stainless CTD to 2000m followed by launch of fifth BGC ARGO float. Reached middle site (TN_3) just before midnight (2318; 0218 GMT).

Sunday 29th December

Weather variable if consistently friskier with some swell. Some warm sunny gaps punctuated by heavy rain and strong gusts, Force 4-7. Turbulence profiling on arrival until dark enough for night-time trio,

tonight in modified order as swell and wind unsuitable to deploy net early on. Red camera frame at 0126 (0426 GMT) followed by double dip stainless CTD to 1000m at 0240 (0540 GMT) and 0328 (0628 GMT), the second CTD on the original assumption that a net might not be possible. Wind dropped a little and net finally deployed at 0450 (0750). Snow Catchers from 0533 (0833 GMT) followed by titanium CTD at 0812 (1112 GMT). More turbulence profiling at 0950 (1250 GMT). The only SAPS at this station at 1144 (1444 GMT) as trace metal team running short of filters and focussing remainder on OOI and TS. Hence could do Thorium and microplastics on a single cast. The 'standard' 1000m stainless CTD cast at 1543 (1843 GMT) with the net finally deployed at 1700 (2000 GMT) once more having been postponed earlier due to wind. Red camera frame last (1726; 2026 GMT) before leaving station, heading south.

Monday 30th December

Swell decreasing and quite a bit of sunshine, but showers too, Force 4-5. Arrived at 60 for TS_4, starting with the red camera frame at 1405 (1705 GMT). 'Standard' stainless CTD at 1525 (1825 GMT) prior to snowcatching (1645; 1945 GMT). Daytime net a little later than usual at 1909 (2209 GMT). SAPS at 2049 (2349 GMT) then turbulence profiling from 2311 (0211 GMT) to carry us through midnight.

Tuesday 31st December

A greyer day, some rain, cold, Force 4-5. Night trio of red camera frame (0110; 0410 GMT), net (0235; 0535 GMT) and stainless CTD (0319; 0619 GMT). More snowcatching to collect samples to test reproducibility at 0442 (0742 GMT). Titanium CTD to 1500m to target oxygen minimum at 0646 (0946 GMT) followed by stainless CTD to full depth of 5000m (0850; 1150 GMT) to address concerns over titanium inorganic carbon samples seeming biased earlier and lacking a deep stainless cast at this location. SAPS at 1616 (1916 GMT) before heading north. Hogmanay quiz in bar followed by the oldest and youngest people on board ringing out the old year and ringing in the new one respectively as the year turned.

Wednesday 1st January 2020

Grey, swell, deteriorating as we caught a weather system passing through when it rose to Force 8. A day in transit taking detour west to try and avoid worst of weather. New Year splash at 1000. Buckets of water liberally applied using bottles fired at 1250m depth yesterday – so water last at surface in 18th Century, or older.

Thursday 2nd January 2020

Blue skies again, with swell and wind reduced. In transit for most of day, with minor detour to go over point, near OOI, marked as 1500m on Admiralty Chart. Scepticism at first, but it shallowed to

1320m. Deep titanium CTD on arrival (1615; 1915 GMT) to try to resolve the deep iron signal spotted in a number of the deep CTDS a little more. Followed by SAPS (2058; 2358 GMT).

Friday 3rd January

Warmer and bluer than yesterday albeit with a few more whitecaps and an edgy breeze, Force 5. Turbulence profiling at 0005 (0305 GMT) followed by the night-time regulars: red camera frame (0119; 0419 GMT), net (0243; 0543 GMT) and stainless CTD (0335; 0635 GMT). Positioned and timed to rendezvous with glider 330 at dawn. On deck at 0659 (0959 GMT). A bit of snowcatching (0717; 1017 GMT) then more turbulence profiling at 0938 (1238 GMT). Titanium CTD cast at 1320 (1620 GMT) ran into trouble when it froze just 750m into a 1500m cast. Eventually diagnosed as a faulty valve controlling the brake and safely recovered to deck. Unanimous agreement of senior tech, Captain and PSO not to re-deploy. Daytime trio: red camera frame at 1343 (1643 GMT), stainless CTD at 1446 (1746 GMT) and net at 1603 (1903 GMT). A couple of extras to round off the station: a Snow Catcher at 1635 (1935 GMT) as an earlier one to 400m suspected to have fired in the surface; a SAPS (1916; 2216 GMT) to 180m as earlier one mistakenly to 280m. Thereafter in transit to TN.

Saturday 4th January

Sun, blue skies and low swell but with bitterly cold wind, Force 5. On station at 1215 (1515 GMT) and straight into double yo-yo of stainless CTD (1215; 1515 GMT) to build up statistics for UVP. Followed by daytime trio of net at 1423 (1723 GMT), stainless CTD at 1500 (1800 GMT) and red camera frame at 1612 (1912 GMT). Snowcatching from 1824 (2124 GMT), followed by SAPS (2105; 0005 GMT) then turbulence profiling (2344; 0244 GMT) into Sunday.

Sunday 5th January

Grey, cold, strong breeze, Force 6. Night-time trio of red camera frame (0115; 0415 GMT), net (0233; 0533 GMT) and stainless CTD (0322; 0622 GMT). Another net straight after as ascent of first one paused at request of bridge. First sample retained by being frozen for a request of a sample from a school. Second net sample preserved in formaldehyde as per usual. Extra snowcatching to complete CUSTARD work then headed Punta-wards.

Monday 6th January

Weather as yesterday with a little more swell. Stopped at 0600 (0900 GMT) for CTD cast and to launch last BGC ARGO float (0810; 1110 GMT) at 55 14.06 S 83 10.31 W. Underway sampling ceased at 1500 (1800 GMT). Crossed into Chilean waters at 2100 with all scientific datastreams stopped and swath turned off.

Tuesday 7th January

A bit of blue back in the sky and wind dropped a little, Force 5. Packing and writing of cruise report. Last science meeting at 1300 (1600 GMT). Entered mouth of Magellan Strait in evening but loitered to allow transit in daylight.

Wednesday 8th January

Blue skies and showers, Force 4. More snow on mountains than when we left. Packing and report writing continued. Discovery alongside around 2130 (0030 GMT).

Thursday 9th January

Demob.

DY111 Event Log

Event	Bridge notes	Activity #	Date	Year day	Dec. date	Time UTC	Time ship	Lat (°S)	Lon (°W)	Notes
	Swath bathymetry recordings started. Marine Mammal Observations started.		4/12/19	338	337.06	0132	2232	52 39.17	80 32.31	Left Chilean waters
001	Ti CTD deployed	CTD001T	4/12/19	338	337.08	0154	2254	52 39.18	80 32.31	To 200m. Only to soak bottles. No samples taken.
001	Ti CTD at max depth	CTD001T	4/12/19	338	337.09	0206	2306	52 39.18	80 32.31	
001	Ti CTD onboard	CTD001T	4/12/19	338	337.10	0220	2320	52 39.18	80 32.31	
002	SS CTD deployed	CTD001SS	4/12/19	338	337.14	0319	0019	52 39.18	80 32.31	To 2000m. For ARGO and glider calibration. Ecopuck removed.
002	SS CTD at max depth	CTD001SS	4/12/19	338	337.17	0401	0101	52 39.18	80 32.31	
002	SS CTD onboard	CTD001SS	4/12/19	338	337.21	0505	0205	52 39.19	80 32.38	
003	BGC ARGO float deployed	ARGO1	4/12/19	338	337.22	0522	0222	52 39.22	80 32.25	SOCCOM float 18242 - FLBB
004	TM fish deployed		4/12/19	338	337.52	1223	0923	52 57.33	81 38.11	
	TM fish recovered		6/12/19	340	339.14	0316	0016	54 25.48	89 6.80	OOI_1 - Arrival OOI site
005	Red Camera Frame deployed	RCF1	6/12/19	340	339.16	0354	0054	54 25.28	89 7.72	

006	SS CTD deployed	CTD002SS	6/12/19	340	339.25	0606	0306	54 25.28	89 7.72	To 2000m. To calibrate gliders and float.
006	SS CTD at max depth	CTD002SS	6/12/19	340	339.28	0647	0347	54 25.28	89 7.71	
006	SS CTD onboard	CTD002SS	6/12/19	340	339.34	0813	0513	54 25.28	89 7.72	
007	BGC ARGO float deployed	ARGO2	6/12/19	340	339.37	0848	0548	54 25.24	89 7.83	SOCCOM float 18320 - FLBB
008	Glider deployed	GLIDER1	6/12/19	340	339.40	0933	0633	54 25.21	89 7.92	Glider 306 – with PAR
009	Glider deployed	GLIDER2	6/12/19	340	339.40	0940	0640	54 25.19	89 8.02	Glider 330 – with LISST
010	Snow Catcher deployed	MSC1	6/12/19	340	339.47	1122	0822	54 25.28	89 7.71	
010	Snow Catcher recovered	MSC1	6/12/19	340	339.48	1130	0830	54 25.28	89 7.71	Leaked
011	Glider recovered	GLIDER2	6/12/19	340	339.53	1240	0940	54 25.08	89 7.65	Glider 306 – leak alarm
012	Snow Catcher deployed	MSC2	6/12/19	340	339.55	1306	1006	54 25.28	89 7.71	
012	Snow Catcher recovered	MSC2	6/12/19	340	339.55	1314	1014	54 25.28	89 7.71	
013	Snow Catcher deployed	MSC3	6/12/19	340	339.56	1324	1024	54 25.28	89 7.72	
013	Snow Catcher recovered	MSC3	6/12/19	340	339.57	1340	1040	54 25.27	89 7.72	
014	Snow Catcher deployed	MSC4	6/12/19	340	339.58	1353	1053	54 25.28	89 7.72	
014	Snow Catcher recovered	MSC4	6/12/19	340	339.60	1422	1122	54 25.28	89 7.72	
015	Snow Catcher deployed	MSC5	6/12/19	340	339.61	1434	1134	54 25.28	89 7.72	
015	Snow Catcher recovered	MSC5	6/12/19	340	339.61	1441	1141	54 25.28	89 7.72	
016	Ti CTD deployed	CTD002T	6/12/19	340	339.65	1542	1242	54 25.28	89 7.72	To 1000m

016	Ti CTD onboard	CTD002T	6/12/19	340	339.71	1704	1404	54 25.28	89.7.72	
017	SAPS deployed	SAPS1	6/12/19	340	339.77	1822	1522	54 25.28	89 7.72	
017	SAPS onboard	SAPS1	6/12/19	340	339.88	2100	1800	54 25.28	89 7.72	
018	SS CTD deployed	CTD003SS	6/12/19	340	339.92	2210	1910	54 25.28	89 7.72	To 1000m – with Ecopuck
018	SS CTD at maximum depth	CTD003SS	6/12/19	340	339.94	2234	1934	54 25.28	89 7.72	
018	SS CTD onboard	CTD003SS	6/12/19	340	339.96	2309	2009	54 25.28	89 7.72	
019	Red Camera Frame deployed	RCF2	6/12/19	340	339.99	2350	2050	54 25.28	89 7.72	
019	Red Camera Frame onboard	RCF2	7/12/19	341	340.05	0107	2207	54 25.28	89 7.72	
020	Turbulence profiler deployed	TURB1	7/12/19	341	340.07	0136	2236	54 25.27	89 7.75	
020	Turbulence profiler onboard	TURB1	7/12/19	341	340.11	0237	2337	54 25.27	89 7.75	
021	SAPS deployed	SAPS2	7/12/19	341	340.14	0319	0019	54 25.15	89 8.11	Microplastics to 4500m
021	SAPS onboard	SAPS2	7/12/19	341	340.33	0755	0455	54 25.15	89 8.10	
022	TM fish deployed		7/12/19	341	340.36	0832	0532	54 25.15	89 8.10	
	TM fish onboard		8/12/19	342	341.76	1815	1515	59 57.57	89 7.73	Station TS_1
023	Ti CTD deployed	CTD004T	8/12/19	342	341.78	1845	1545	59 57.58	89 7.72	To full depth 4880m
023	Ti CTD at maximum depth	CTD004T	8/12/19	342	341.85	2027	1727	59 57.86	89 7.16	
023	Ti CTD onboard	CTD004T	8/12/19	342	341.98	2332	2032	59 58.57	89 5.75	
024	TM fish deployed		8/12/19	342	341.99	2352	2052	59 58.69	89 5.94	

	TM fish brought up short		9/12/19	343	342.10	0225	2325	59 57.56	89 7.54	
025	SS CTD deployed	CTD004SS	9/12/19	343	342.14	0316	0016	59 57.68	89 7.71	To 1000m. No bottles fired.
025	SS CTD back at surface	CTD004SS	9/12/19	343	342.17	0400	0100	59 57.84	89 7.59	
026	SS CTD lowered again	CTD005SS	9/12/19	343	342.17	0405	0105	59 57.85	89 7.59	To 1000m. Bottles fired
026	SS CTD onboard	CTD005SS	9/12/19	343	342.22	0520	0220	59 58.17	89 7.21	
027	Zooplankton net deployed	ZOO1	9/12/19	343	342.25	0554	0254	59 58.07	89 7.31	200µm haul from 120m
027	Zooplankton net onboard	ZOO1	9/12/19	343	342.27	0628	0328	59 58.34	89 7.24	
028	Zooplankton net deployed	ZOO2	9/12/19	343	342.30	0711	0411	59 58.47	89 7.64	200µm haul from 300m
028	Zooplankton net onboard	ZOO2	9/12/19	343	342.33	0754	0454	59 57.86	89 7.14	
029	Red Camera Frame deployed	RCF3	9/12/19	343	342.34	0815	0515	59 57.87	89 7.19	
029	Red Camera Frame onboard	RCF3	9/12/19	343	342.40	0940	0640	59 58.49	89 6.71	
030	Snow Catcher deployed	MSC6	9/12/19	343	342.42	1004	0704	59 57.49	89 7.57	
030	Snow Catcher onboard	MSC6	9/12/19	343	342.43	1014	0714	59 57.57	89 7.51	
031	Snow Catcher deployed	MSC7	9/12/19	343	342.44	1028	0728	59 57.67	89 7.43	
031	Snow Catcher onboard	MSC7	9/12/19	343	342.44	1040	0740	59 57.77	89 7.36	
032	Snow Catcher deployed	MSC8	9/12/19	343	342.46	1059	0759	59 57.87	89 7.29	
032	Snow Catcher onboard	MSC8	9/12/19	343	342.48	1125	0825	59 58.12	89 7.10	
033	Snow Catcher deployed	MSC9	9/12/19	343	342.48	1138	0838	59 58.20	89 7.05	

033	Snow Catcher onboard	MSC9	9/12/19	343	342.50	1159	0859	59 58.42	89 6.89	
034	Turbulence profiler deployed	TURB2	9/12/19	343	342.52	1230	0930	59 58.45	89 6.92	
034	Turbulence profiler onboard	TURB2	9/12/19	343	342.57	1338	1038	59 58.43	89 8.28	
035	Ti CTD deployed	CTD005T	9/12/19	343	342.60	1431	1131	59 57.49	89 7.52	To 1000m
035	Ti CTD recovered	CTD005T	9/12/19	343	342.66	1548	1248	59 58.33	89 7.44	
036	Zooplankton net deployed	ZOO3	9/12/19	343	342.68	1625	1325	59 57.97	89 7.55	
036	Zooplankton net onboard	ZOO3	9/12/19	343	342.70	1649	1349	59 58.32	89 7.56	
037	Zooplankton net deployed	ZOO4	9/12/19	343	342.72	1713	1413	59 57.81	89 7.64	
037	Zooplankton net onboard	ZOO4	9/12/19	343	342.75	1800	1500	59 58.39	89 7.53	
038	SAPS deployed	SAPS3	9/12/19	343	342.78	1842	1542	59 56.88	89 7.66	
038	SAPS onboard	SAPS3	9/12/19	343	342.89	2122	1822	59 57.71	89 7.18	
039	SS CTD deployed	CTD006SS	9/12/19	343	342.94	2231	1931	59 57.58	89 7.72	To 2000m
039	SS CTD onboard	CTD006SS	10/12/19	344	343.01	0008	2108	59 58.36	89 7.72	
040	BGC ARGO float deployed	ARGO3	10/12/19	344	343.03	0037	2137	59 57.57	89 7.31	SOCCOM float 18721 - FLBB
041	Red Camera Frame deployed	RCF4	10/12/19	344	343.04	0056	2156	59 57.39	89 7.52	
041	Red Camera Frame onboard	RCF4	10/12/19	344	343.08	0159	2259	59 58.21	89 7.52	
042	Turbulence profiler deployed	TURB3	10/12/19	344	343.10	0218	2318	59 58.21	89 7.63	
042	Turbulence profiler onboard	TURB3	10/12/19	344	343.14	0325	0025	59 58.02	89 8.67	

043	SAPS deployed	SAPS4	10/12/19	344	343.20	0444	0144	59 56.64	89 7.68	
043	SAPS onboard	SAPS4	10/12/19	344	343.22	0510	0210	59 56.76	89 7.73	
044	SAPS deployed	SAPS5	10/12/19	344	343.23	0527	0227	59 56.78	89 7.73	
044	SAPS onboard	SAPS5	10/12/19	344	343.45	1042	0742	59 58.85	89 7.06	
	Shortened TM fish		11/12/19	345	344.25	0554	0254	56 59.62	89 7.74	Station TN_1
045	SS CTD deployed	CTD007SS	11/12/19	345	344.26	0620	0320	57 0.00	89 7.94	To 1000m. No bottles fired.
045	SS at maximum depth	CTD007SS	11/12/19	345	344.28	0648	0348	57 0.06	89 7.97	
045	SS CTD onboard	CTD007SS	11/12/19	345	344.30	0713	0413	57 0.22	89 8.08	
046	SS CTD lowered	CTD008SS	11/12/19	345	344.30	0713	0413	57 0.22	89 8.08	To 1000m. Bottles fired.
046	SS at maximum depth	CTD008SS	11/12/19	345	344.31	0729	0429	57 0.32	89 8.14	
046	SS CTD onboard	CTD008SS	11/12/19	345	344.33	0801	0501	57 0.51	89 8.28	
047	Snow Catcher deployed	MSC10	11/12/19	345	344.35	0831	0531	56 59.99	89 7.91	
047	Snow Catcher onboard	MSC10	11/12/19	345	344.36	0838	0538	57 0.04	89 7.94	
048	Snow Catcher deployed	MSC11	11/12/19	345	344.37	0852	0552	57 0.13	89 8.01	
048	Snow Catcher onboard	MSC11	11/12/19	345	344.37	0859	0559	57 0.17	89 8.03	
049	Snow Catcher deployed	MSC12	11/12/19	345	344.38	0913	0613	57 0.26	89 8.09	
049	Snow Catcher onboard	MSC12	11/12/19	345	344.39	0924	0624	57 0.33	89 8.14	
050	Snow Catcher deployed	MSC13	11/12/19	345	344.40	0936	0636	57 0.40	89 8.19	

050	Snow Catcher onboard	MSC13	11/12/19	345	344.42	1008	0708	57 0.60	89 8.33	
051	Snow Catcher deployed	MSC14	11/12/19	345	344.43	1020	0720	57 0.67	89 8.38	
051	Snow Catcher onboard	MSC14	11/12/19	345	344.44	1028	0728	57 0.72	89 8.42	
052	Ti CTD deployed	CTD006T	11/12/19	345	344.48	1124	0824	57 0.01	89 7.95	To 1000m
052	Ti CTD recovered	CTD006T	11/12/19	345	344.53	1242	0942	57 0.50	89 8.26	
053	Zooplankton net deployed	ZOO5	11/12/19	345	344.56	1325	1025	57 0.59	89 8.33	
053	Zooplankton net onboard	ZOO5	11/12/19	345	344.57	1343	1043	57 0.76	89 8.44	
054	SAPS deployed	SAPS6	11/12/19	345	344.61	1436	1136	57 0.01	89 7.97	Two pairs
054	SAPS onboard	SAPS6	11/12/19	345	344.71	1701	1401	57 0.75	89 8.93	
055	SS CTD lowered	CTD009SS	11/12/19	345	344.75	1756	1456	57 0.01	89 7.98	To 1000m Had to be recovered to deck just after deployment, as Ecopuck not activated, then redeployed
055	SS CTD onboard	CTD009SS	11/12/19	345	344.80	1912	1612	57 0.27	89 8.33	
056	Red Camera Frame deployed	RCF5	11/12/19	345	344.88	2106	1806	57 0.01	89 8.00	
056	Red Camera Frame onboard	RCF5	11/12/19	345	344.94	2231	1931	57 0.50	89 8.53	
057	Turbulence profiler deployed	TURB4	11/12/19	345	344.95	2246	1946	57 0.58	89 8.50	Both rear azimuths off initially then starboard on from 0017 (GMT) – 1 profile
057	Turbulence profiler onboard	TURB4	12/12/19	346	345.02	0032	2132	57 1.55	89 7.28	

058	SAPS deployed	SAPS7	12/12/19	346	345.08	0150	2250	57 0.03	89 8.04	
058	SAPS onboard	SAPS7	12/12/19	346	345.27	0625	0325	57 0.35	89 9.10	
059	SS CTD lowered	CTD010SS	12/12/19	346	345.30	0713	0413	57 0.04	89 8.03	To 120m – only UVP + resp
059	SS CTD onboard	CTD010SS	12/12/19	346	345.31	0726	0426	57 0.11	89 8.11	
060	Zooplankton net deployed	ZOO6	12/12/19	346	345.32	0745	0445	57 0.12	89 8.12	
060	Zooplankton net onboard	ZOO6	12/12/19	346	345.35	0821	0521	57 0.36	89 8.55	
061	Red Camera Frame deployed	RCF6	12/12/19	346	345.37	0846	0546	57 0.37	89 8.60	
061	Red Camera Frame onboard	RCF6	12/12/19	346	345.40	0943	0643	57 0.53	89 9.41	
	Shortened TM fish		12/12/19	346	345.74	1742	1442	56 0.01	89 7.86	Tran_2
062	Ti CTD deployed	CTD007T	12/12/19	346	345.81	1933	1633	56 0.05	89 8.03	To 4937m
062	Ti CTD at maximum depth	CTD007T	12/12/19	346	345.88	2108	1808	56 0.23	89 7.68	
062	Ti CTD recovered	CTD007T	12/12/19	346	345.97	2317	2017	56 0.48	89 7.14	
063	SS CTD lowered	CTD011SS	13/12/19	347	346.01	0015	2115	56 0.50	89 7.09	To 5030m
063	SS CTD at maximum depth	CTD011SS	13/12/19	347	346.08	0157	2257	56 0.72	89 6.62	
063	SS CTD onboard	CTD011SS	13/12/19	347	346.17	0407	0107	56 1.00	89 6.06	
	Shortened TM fish		13/12/19	347	346.53	1249	0949	55 0.00	89 7.99	Tran_1
064	Ti CTD deployed	CTD008T	13/12/19	347	346.55	1309	1009	55 0.00	89 7.98	To 4652m
064	Ti CTD at maximum depth	CTD008T	13/12/19	347	346.62	1455	1155	55 0.24	89 7.95	

064	Ti CTD recovered	CTD008T	13/12/19	347	346.71	1700	1400	55 0.26	89 7.96	
065	SS CTD lowered	CTD012SS	13/12/19	347	346.75	1801	1501	55 0.26	89 7.96	To 4750m
065	SS CTD at maximum depth	CTD012SS	13/12/19	347	346.81	1931	1631	55 0.26	89 7.96	
065	SS CTD onboard	CTD012SS	13/12/19	347	346.88	2105	1805	55 0.26	89 7.96	
	Shortened TM fish		14/12/19	348	347.08	0155	2255	54 26.03	89 5.94	OOI_2
066	Turbulence profiler deployed	TURB5	14/12/19	348	347.08	0157	2257	54 26.02	89 5.95	Port azimuth off
066	Turbulence profiler onboard	TURB5	14/12/19	348	347.14	0325	0025	54 25.49	89 6.36	
067	SS CTD lowered	CTD013SS	14/12/19	348	347.17	0408	0108	54 25.48	89 6.38	To 1000m
067	SS CTD at maximum depth	CTD013SS	14/12/19	348	347.19	0437	0137	54 25.48	89 6.38	
067	SS CTD onboard	CTD013SS	14/12/19	348	347.22	0519	0219	54 25.48	89 6.38	
068	Zooplankton net deployed	ZOO7	14/12/19	348	347.24	0550	0250	54 25.48	89 6.37	
068	Zooplankton net onboard	ZOO7	14/12/19	348	347.27	0624	0324	54 25.56	89 6.45	
069	Red Camera Frame deployed	RCF7	14/12/19	348	347.28	0638	0338	54 25.64	89 6.37	
069	Red Camera Frame onboard	RCF7	14/12/19	348	347.34	0811	0511	54 25.64	89 6.37	
070	Snow Catcher deployed	MSC15	14/12/19	348	347.35	0829	0529	54 25.64	89 6.37	
070	Snow Catcher onboard	MSC15	14/12/19	348	347.36	0838	0538	54 25.64	89 6.37	
071	Snow Catcher deployed	MSC16	14/12/19	348	347.37	0853	0553	54 25.64	89 6.37	
071	Snow Catcher onboard	MSC16	14/12/19	348	347.38	0905	0605	54 25.64	89 6.37	

072	Snow Catcher deployed	MSC17	14/12/19	348	347.39	0917	0617	54 25.64	89 6.37	
072	Snow Catcher onboard	MSC17	14/12/19	348	347.40	0938	0638	54 25.64	89 6.37	
073	Snow Catcher deployed	MSC18	14/12/19	348	347.41	0947	0647	54 25.64	89 6.37	
073	Snow Catcher onboard	MSC18	14/12/19	348	347.44	1038	0738	54 25.64	89 6.37	
074	Ti CTD deployed	CTD009T	14/12/19	348	347.47	1115	0815	54 25.64	89 6.37	To 1000m
074	Ti CTD at maximum depth	CTD009T	14/12/19	348	347.49	1141	0841	54 25.64	89 6.37	
074	Ti CTD recovered	CTD007T	14/12/19	348	347.53	1239	0939	54 25.64	89 6.37	
075	SAPS deployed	SAPS8	14/12/19	348	347.58	1355	1055	54 25.61	89 6.20	
075	SAPS onboard	SAPS8	14/12/19	348	347.68	1622	1322	54 25.62	89 6.19	
076	Zooplankton net deployed	ZOO8	14/12/19	348	347.69	1640	1340	54 25.62	89 6.20	
076	Zooplankton net onboard	ZOO8	14/12/19	348	347.71	1708	1408	54 25.62	89 6.17	
077	Snow Catcher deployed	MSC19	14/12/19	348	347.72	1713	1413	54 25.62	89 6.17	
077	Snow Catcher onboard	MSC19	14/12/19	348	347.73	1737	1437	54 25.62	89 6.17	
078	SS CTD lowered	CTD014SS	14/12/19	348	347.78	1839	1539	54 25.01	89 8.10	To 1000m
078	SS CTD at maximum depth	CTD014SS	14/12/19	348	347.81	1927	1627	54 25.01	89 8.10	
078	SS CTD onboard	CTD014SS	14/12/19	348	347.83	1953	1653	54 25.01	89 8.10	
079	Red Camera Frame deployed	RCF8	14/12/19	348	347.88	2100	1800	54 25.01	89 8.09	
079	Red Camera Frame onboard	RCF8	14/12/19	348	347.93	2217	1917	54 25.01	89 8.10	

080	Turbulence profiler deployed	TURB6	14/12/19	348	347.95	2250	1950	54 24.65	89 9.19	
080	Turbulence profiler onboard	TURB6	14/12/19	348	347.98	2334	2034	54 24.50	89 9.75	
081	SAPS deployed	SAPS9	15/12/19	349	348.07	0140	2240	54 24.98	89 8.09	
081	SAPS onboard	SAPS9	15/12/19	349	348.20	0444	2341	54 24.98	89 8.09	
082	Ti CTD deployed	CTD010T	15/12/19	349	348.25	0555	0255	54 24.98	89 8.09	To 4500m
082	Ti CTD at maximum depth	CTD010T	15/12/19	349	348.31	0726	0426	54 24.98	89 8.09	
082	Ti CTD recovered	CTD010T	15/12/19	349	348.40	0941	0641	54 24.98	89 8.09	
083	SS CTD lowered	CTD015SS	15/12/19	349	348.43	1012	0712	54 24.98	89 8.09	To 4600m
083	SS CTD at maximum depth	CTD015SS	15/12/19	349	348.48	1136	0836	54 24.98	89 8.09	
083	SS CTD onboard	CTD015SS	15/12/19	349	348.56	1331	1031	54 24.98	89 8.09	
	TM fish lowered		15/12/19	349	348.59	1405	1105	54 25.00	89 8.06	
	Shortened TM fish		16/12/19	350	349.98	2330	2030	59 57.62	89 7.54	TS_2
084	SAPS deployed	SAPS10	16/12/19	350	349.98	2334	2034	59 57.62	89 7.54	
084	SAPS onboard	SAPS10	17/12/19	351	350.12	0251	2351	59 57.62	89 7.54	
085	Turbulence profiler deployed	TURB7	17/12/19	351	350.14	0326	0026	59 57.62	89 7.54	
085	Turbulence profiler onboard	TURB7	17/12/19	351	350.17	0408	0108	59 57.50	89 7.05	
086	SS CTD lowered	CTD016SS	17/12/19	351	350.20	0451	0151	59 57.62	89 7.53	To 1000m
086	SS CTD at maximum depth	CTD016SS	17/12/19	351	350.22	0520	0220	59 57.62	89 7.52	

086	SS CTD onboard	CTD016SS	17/12/19	351	350.25	0557	0257	59 57.63	89 7.41	
087	Zooplankton net deployed	ZOO9	17/12/19	351	350.26	0616	0316	59 57.63	89 7.41	
087	Zooplankton net onboard	ZOO9	17/12/19	351	350.28	0644	0344	59 57.63	89 7.41	
088	Red Camera Frame deployed	RCF9	17/12/19	351	350.29	0701	0401	59 57.63	89 7.41	
088	Red Camera Frame onboard	RCF9	17/12/19	351	350.33	0759	0459	59 57.63	89 7.41	
089	Snow Catcher deployed	MSC20	17/12/19	351	350.35	0823	0523	59 57.63	89 7.41	
089	Snow Catcher onboard	MSC20	17/12/19	351	350.36	0832	0532	59 57.63	89 7.41	
090	Snow Catcher deployed	MSC21	17/12/19	351	350.36	0842	0542	59 57.63	89 7.41	
090	Snow Catcher onboard	MSC21	17/12/19	351	350.37	0854	0554	59 57.64	89 7.41	
091	Snow Catcher deployed	MSC22	17/12/19	351	350.38	0909	0609	59 57.63	89 7.41	
091	Snow Catcher onboard	MSC22	17/12/19	351	350.40	0933	0633	59 57.63	89 7.41	
092	Snow Catcher deployed	MSC23	17/12/19	351	350.40	0941	0641	59 57.63	89 7.41	
092	Snow Catcher onboard	MSC23	17/12/19	351	350.43	1022	0722	59 57.63	89 7.41	
093	Ti CTD deployed	CTD011T	17/12/19	351	350.45	1054	0754	59 57.65	89 7.39	To 1500m
093	Ti CTD at maximum depth	CTD011T	17/12/19	351	350.48	1130	0830	59 57.96	89 6.86	
093	Ti CTD recovered	CTD011T	17/12/19	351	350.52	1230	0930	59 58.34	89 6.21	
094	SAPS deployed	SAPS11	17/12/19	351	350.56	1333	1033	59 57.64	89 7.54	
094	SAPS onboard	SAPS11	17/12/19	351	350.66	1549	1249	59 57.65	89 7.53	

095	Turbulence profiler deployed	TURB8	17/12/19	351	350.68	1620	1320	59 57.65	89 7.53	
095	Turbulence profiler onboard	TURB8	17/12/19	351	350.74	1745	1445	59 57.54	89 7.33	
096	SS CTD lowered	CTD017SS	17/12/19	351	350.76	1811	1511	59 57.62	89 7.53	To 1100m
096	SS CTD at maximum depth	CTD017SS	17/12/19	351	350.78	1849	1549	59 57.63	89 7.51	
096	SS CTD onboard	CTD017SS	17/12/19	351	350.82	1938	1638	59 57.71	89 7.42	
097	Zooplankton net deployed	ZOO10	17/12/19	351	350.83	1951	1651	59 57.72	89 7.42	
097	Zooplankton net onboard	ZOO10	17/12/19	351	350.84	2012	1712	59 57.87	89 7.20	
098	Red Camera Frame deployed	RCF10	17/12/19	351	350.85	2030	1730	59 57.93	89 7.10	
098	Red Camera Frame onboard	RCF10	17/12/19	351	350.90	2130	1830	59 58.31	89 6.47	
			18/12/19	352	351.25	0553	0253	59 0.01	89 8.00	Tran_4
99	Ti CTD deployed	CTD012T	18/12/19	352	351.25	0553	0253	59 0.01	89 8.00	To 4918m
99	Ti CTD at maximum depth	CTD012T	18/12/19	352	351.31	0733	0433	59 0.01	89 8.00	
99	Ti CTD recovered	CTD012T	18/12/19	352	351.41	0951	0651	59 0.01	89 8.00	
100	SS CTD lowered	CTD018SS	18/12/19	352	351.43	1018	0718	59 0.01	89 8.00	To 5020m
100	SS CTD at maximum depth	CTD018SS	18/12/19	352	351.49	1152	0852	59 0.01	89 8.00	
100	SS CTD onboard	CTD018SS	18/12/19	352	351.58	1355	1055	59 0.00	89 7.98	
			18/12/19	352	351.92	2208	1908	58 0.02	89 7.95	Tran_3
101	Ti CTD deployed	CTD013T	18/12/19	352	351.92	2208	1908	58 0.02	89 7.95	To 4820m

101	Ti CTD at maximum depth	CTD013T	19/12/19	353	352.00	0000	2100	58 0.43	89 5.97	
101	Ti CTD recovered	CTD013T	19/12/19	353	352.08	0201	2301	58 0.90	89 4.62	
102	SS CTD lowered	CTD019SS	19/12/19	353	352.11	0235	2335	58 0.91	89 4.53	To 4981m
102	SS CTD at maximum depth	CTD019SS	19/12/19	353	352.17	0408	0108	58 1.10	89 3.62	
102	SS CTD onboard	CTD019SS	19/12/19	353	352.26	0609	0309	58 1.25	89 3.22	
			19/12/19	353	352.63	1500	1200	56 59.98	89 7.96	TN_2
103	Ti CTD deployed	CTD014T	19/12/19	353	352.63	1510	1210	56 59.98	89 7.96	To 1500m
103	Ti CTD at maximum depth	CTD014T	19/12/19	353	352.66	1545	1245	57 0.09	89 8.06	
103	Ti CTD recovered	CTD014T	19/12/19	353	352.69	1634	1334	57 0.29	89 8.29	
104	Turbulence profiler deployed	TURB9	19/12/19	353	352.71	1659	1359	57 0.28	89 8.29	
104	Turbulence profiler onboard	TURB9	19/12/19	353	352.75	1759	1459	57 0.22	89 8.44	
105	SS CTD lowered	CTD020SS	19/12/19	353	352.78	1838	1538	56 59.99	89 7.97	To 1000m
105	SS CTD at maximum depth	CTD020SS	19/12/19	353	352.79	1904	1604	57 0.05	89 8.09	
105	SS CTD onboard	CTD020SS	19/12/19	353	352.82	1937	1637	57 0.10	89 8.19	
106	Zooplankton net deployed	ZOO11	19/12/19	353	352.83	1950	1650	57 0.10	89 8.19	
106	Zooplankton net onboard	ZOO11	19/12/19	353	352.85	2022	1722	57 0.39	89 8.48	
107	Red Camera Frame deployed	RCF11	19/12/19	353	352.86	2032	1732	57 0.40	89 8.49	
107	Red Camera Frame onboard	RCF11	19/12/19	353	352.99	2341	2041	56 59.98	89 7.97	

108	SAPS deployed	SAPS12	19/12/19	353	352.96	2303	2003	56 59.98	89 7.96	
108	SAPS onboard	SAPS12	20/12/19	354	353.23	0525	0225	56 59.98	89 7.96	
109	SS CTD lowered	CTD021SS	20/12/19	354	353.25	0600	0300	56 59.98	89 7.96	To 1000m
109	SS CTD at maximum depth	CTD021SS	20/12/19	354	353.27	0626	0326	57 0.02	89 8.01	
109	SS CTD onboard	CTD021SS	20/12/19	354	353.29	0701	0401	57 0.11	89 8.15	
110	Zooplankton net deployed	ZOO12	20/12/19	354	353.30	0714	0414	57 0.15	89 8.21	
110	Zooplankton net onboard	ZOO12	20/12/19	354	353.32	0740	0440	57 0.33	89 8.41	
111	Red Camera Frame deployed	RCF12	20/12/19	354	353.33	0757	0457	57 0.37	89 8.48	
111	Red Camera Frame onboard	RCF12	20/12/19	354	353.37	0857	0547	57 0.60	89 8.84	
112	Snow Catcher deployed	MSC24	20/12/19	354	353.38	0909	0609	57 0.65	89 8.91	
112	Snow Catcher onboard	MSC24	20/12/19	354	353.39	0915	0615	57 0.67	89 8.94	
113	Snow Catcher deployed	MSC25	20/12/19	354	353.39	0924	0624	57 0.70	89 8.99	
113	Snow Catcher onboard	MSC25	20/12/19	354	353.40	0933	0633	57 0.74	89 9.05	
114	Snow Catcher deployed	MSC26	20/12/19	354	353.40	0942	0642	57 0.77	89 9.10	
114	Snow Catcher onboard	MSC26	20/12/19	354	353.42	1007	0707	57 0.87	89 9.25	
115	Snow Catcher deployed	MSC27	20/12/19	354	353.43	1016	0716	57 0.90	89 9.30	
115	Snow Catcher onboard	MSC27	20/12/19	354	353.45	1054	0754	57 1.05	89 9.52	
116	Turbulence profiler deployed	TURB10	20/12/19	354	353.46	1109	0809	57 1.06	89 9.58	

116	Turbulence profiler onboard	TURB10	20/12/19	354	353.51	1210	0910	57 1.06	89 10.87	
117	Ti CTD lowered	CTD015T	20/12/19	354	353.54	1301	1001	57 0.03	89 8.01	To 5100m
117	Ti CTD at maximum depth	CTD015T	20/12/19	354	353.62	1450	1150	57 0.63	89 8.68	
117	Ti CTD onboard	CTD015T	20/12/19	354	353.71	1658	1358	57 0.97	89 9.12	
118	SS CTD lowered	CTD022SS	20/12/19	354	353.73	1733	1433	57 0.97	89 9.13	To 5220m
118	SS CTD at maximum depth	CTD022SS	20/12/19	354	353.80	1907	1607	57 1.18	89 9.56	
118	SS CTD onboard	CTD022SS	20/12/19	354	353.86	2043	1743	57 1.38	89 9.99	
			21/12/19	355	354.22	0510	0210	56 0.00	89 7.96	Tran_2
119	Ti CTD lowered		21/12/19	355	354.22	0510	0210	56 0.00	89 7.96	Test CTD
119	Ti CTD onboard		21/12/19	355	354.27	0631	0331	56 0.40	89 7.92	
120	SS CTD lowered	CTD023SS	21/12/19	355	354.29	0703	0403	55 59.97	89 7.84	To 2000m
120	SS CTD at maximum depth	CTD023SS	21/12/19	355	354.32	0741	0441	56 0.05	89 7.54	
120	SS CTD onboard	CTD023SS	21/12/19	355	354.36	0839	0539	56 0.17	89 7.07	
121	BGC ARGO float deployed	ARGO4	21/12/19	355	354.37	0856	0556	56 0.17	89 7.10	SOCCOM float 18545 – no FLBB
			21/12/19	355	354.90	2140	1840	54 25.00	89 7.94	OOI_3
122	SAPS deployed	SAPS13	21/12/19	355	354.90	2140	1840	54 25.00	89 7.94	
122	SAPS onboard	SAPS13	21/12/19	355	354.99	2352	2052	54 25.00	89 7.94	

	Fish lengthened		22/12/19	356	355.00	0007	2107	54 25.54	89 8.22	2 hour loop to collect water for incubations.
	Fish recovered to deck		22/12/19	356	355.08	0200	2300	54 26.11	89 3.47	
123	Turbulence profiler deployed	TURB11	22/12/19	356	355.10	0223	2323	54 25.80	89 5.76	
123	Turbulence profiler onboard	TURB11	22/12/19	356	355.15	0334	0034	54 25.48	89 6.62	
124	SS CTD lowered	CTD024SS	22/12/19	356	355.17	0408	0108	54 24.99	89 7.94	To 1000m
124	SS CTD at maximum depth	CTD024SS	22/12/19	356	355.19	0434	0134	54 24.99	89 7.94	
124	SS CTD onboard	CTD024SS	22/12/19	356	355.22	0512	0212	54 24.99	89 7.95	
125	Zooplankton net deployed	ZOO13	22/12/19	356	355.23	0533	0233	54 24.97	89 7.96	
125	Zooplankton net onboard	ZOO13	22/12/19	356	355.26	0618	0318	54 24.97	89 7.96	
126	Red Camera Frame deployed	RCF13	22/12/19	356	355.26	0618	0318	54 24.97	89 7.96	
126	Red Camera Frame onboard	RCF13	22/12/19	356	355.30	0719	0419	54 24.97	89 7.96	
127	Snow Catcher deployed	MSC28	22/12/19	356	355.31	0732	0432	54 24.97	89 7.96	Misfired
127	Snow Catcher onboard	MSC28	22/12/19	356	355.32	0739	0439	54 24.97	89 7.96	
128	Snow Catcher deployed	MSC29	22/12/19	356	355.32	0741	0441	54 24.97	89 7.96	
128	Snow Catcher onboard	MSC29	22/12/19	356	355.33	0750	0450	54 24.97	89 7.96	
129	Snow Catcher deployed	MSC30	22/12/19	356	355.33	0756	0456	54 24.97	89 7.96	
129	Snow Catcher onboard	MSC30	22/12/19	356	355.34	0806	0506	54 24.97	89 7.96	
130	Snow Catcher deployed	MSC31	22/12/19	356	355.34	0816	0516	54 24.97	89 7.96	

130	Snow Catcher onboard	MSC31	22/12/19	356	355.36	0838	0538	54 24.97	89 7.96	
131	Snow Catcher deployed	MSC32	22/12/19	356	355.37	0846	0546	54 24.97	89 7.96	
131	Snow Catcher onboard	MSC32	22/12/19	356	355.39	0926	0626	54 24.97	89 7.97	
132	Ti CTD lowered	CTD016T	22/12/19	356	355.42	1004	0704	54 24.97	89 7.97	To 1500m
132	Ti CTD at maximum depth	CTD016T	22/12/19	356	355.44	1040	0740	54 24.97	89 7.97	
132	Ti CTD onboard	CTD016T	22/12/19	356	355.48	1137	0837	54 24.97	89 7.96	
133	SAPS deployed	SAPS14	22/12/19	356	355.52	1226	0926	54 24.97	89 7.96	
133	SAPS onboard	SAPS14	22/12/19	356	355.61	1433	1133	54 24.97	89 7.96	
134	SS CTD lowered	CTD025SS	22/12/19	356	355.67	1610	1310	54 25.14	89 8.77	To 500m to match glider dive. No bottles fired
134	SS CTD at maximum depth	CTD025SS	22/12/19	356	355.69	1640	1340	54 25.14	89 8.77	
134	SS CTD onboard	CTD025SS	22/12/19	356	355.70	1651	1351	54 25.14	89 8.77	
135	SS CTD lowered	CTD026SS	22/12/19	356	355.70	1655	1355	54 25.14	89 8.77	To 1000m
135	SS CTD at maximum depth	CTD026SS	22/12/19	356	355.72	1718	1418	54 25.14	89 8.77	
135	SS CTD onboard	CTD026SS	22/12/19	356	355.75	1756	1456	54 25.14	89 8.77	
136	Red Camera Frame deployed	RCF14	22/12/19	356	355.75	1805	1505	54 25.14	89 8.76	Recovered early when glider surfaced close to vessel
136	Red Camera Frame onboard	RCF14	22/12/19	356	355.78	1847	1547	54 25.35	89 8.76	
137	Red Camera Frame deployed	RCF15	22/12/19	356	355.80	1912	1612	54 24.98	89 7.95	
137	Red Camera Frame onboard	RCF15	22/12/19	356	355.83	1952	1652	54 24.98	89 7.95	

138	Zooplankton net deployed	ZOO14	22/12/19	356	355.84	2009	1709	54 24.99	89 7.93	
138	Zooplankton net onboard	ZOO14	22/12/19	356	355.85	2031	1731	54 25.00	89 7.86	
139	Turbulence profiler deployed	TURB12	22/12/19	356	355.91	2153	1853	54 24.69	89 7.30	
139	Turbulence profiler onboard	TURB12	22/12/19	356	355.92	2200	1900	54 24.40	89 6.73	
140	SAPS deployed	SAPS15	22/12/19	356	355.95	2242	1942	54 24.97	89 7.91	
140	SAPS onboard	SAPS15	22/12/19	356	355.17	0401	0101	54 24.98	89 7.91	
			26/12/19	360	359.99	2340	2040	59 57.50	89 7.87	TS_3
141	SS CTD lowered	CTD027SS	26/12/19	360	359.99	2343	2043	59 57.50	89 7.87	To 300m, no bottles fired
141	SS CTD at maximum depth	CTD027SS	26/12/19	360	359.99	2352	2052	59 57.53	89 7.84	
141	SS CTD onboard	CTD027SS	27/12/19	361	360.00	0000	2100	59 57.60	89 7.74	
142	SAPS deployed	SAPS16	27/12/19	361	360.03	0050	2150	59 57.57	89 7.76	
142	SAPS onboard	SAPS16	27/12/19	361	360.10	0231	2331	59 58.23	89 6.70	
143	Turbulence profiler deployed	TURB13	27/12/19	361	360.13	0309	0009	59 58.24	89 6.71	
143	Turbulence profiler onboard	TURB13	27/12/19	361	360.16	0352	0052	59 58.22	89 6.84	
144	SS CTD lowered	CTD028SS	27/12/19	361	360.18	0426	0126	59 57.50	89 7.85	To 1000m
144	SS CTD at maximum depth	CTD028SS	27/12/19	361	360.20	0455	0155	59 57.68	89 7.68	
144	SS CTD onboard	CTD028SS	27/12/19	361	360.23	0527	0227	59 57.94	89 7.42	
145	Zooplankton net deployed	ZOO15	27/12/19	361	360.24	0548	0248	59 57.99	89 7.39	

145	Zooplankton net onboard	ZOO15	27/12/19	361	360.26	0617	0317	59 58.38	89 7.16	
146	Red Camera Frame deployed	RCF16	27/12/19	361	360.28	0638	0338	59 58.47	89 7.07	
146	Red Camera Frame onboard	RCF16	27/12/19	361	360.32	0741	0441	59 59.07	89 6.63	
147	Snow Catcher deployed	MSC33	27/12/19	361	360.34	0814	0514	59 57.80	89 7.66	
147	Snow Catcher onboard	MSC33	27/12/19	361	360.35	0820	0520	59 57.86	89 7.62	
148	Snow Catcher deployed	MSC34	27/12/19	361	360.36	0833	0533	59 57.99	89 7.53	
148	Snow Catcher onboard	MSC34	27/12/19	361	360.36	0841	0541	59 58.06	89 7.47	
149	Snow Catcher deployed	MSC35	27/12/19	361	360.37	0851	0551	59 58.15	89 7.41	
149	Snow Catcher onboard	MSC35	27/12/19	361	360.38	0912	0612	59 58.35	89 7.27	
150	Snow Catcher deployed	MSC36	27/12/19	361	360.39	0920	0620	59 58.43	89 7.20	
150	Snow Catcher onboard	MSC36	27/12/19	361	360.42	1000	0700	59 58.80	89 6.95	
151	Ti CTD lowered	CTD017T	27/12/19	361	360.45	1041	0741	59 57.44	89 7.95	To 4889m
151	Ti CTD at maximum depth	CTD017T	27/12/19	361	360.52	1234	0934	59 58.25	89 7.17	
151	Ti CTD onboard	CTD017T	27/12/19	361	360.61	1436	1136	59 58.93	89 6.39	
152	Snow Catcher deployed	MSC37	27/12/19	361	360.64	1525	1225	59 57.47	89 7.87	
152	Snow Catcher onboard	MSC37	27/12/19	361	360.67	1600	1300	59 57.78	89 7.53	
153	Snow Catcher deployed	MSC38	27/12/19	361	360.68	1621	1321	59 57.96	89 7.33	
153	Snow Catcher onboard	MSC38	27/12/19	361	360.69	1628	1328	59 58.02	89 7.26	

154	Red Camera Frame deployed	RCF17	27/12/19	361	360.70	1647	1347	59 58.06	89 7.23	
154	Red Camera Frame onboard	RCF17	27/12/19	361	360.74	1744	1444	59 58.55	89 6.69	
155	Zooplankton net deployed	ZOO16	27/12/19	361	360.74	1747	1447	59 58.55	89 6.69	
155	Zooplankton net onboard	ZOO16	27/12/19	361	360.77	1827	1527	59 58.97	89 6.20	
156	SS CTD lowered	CTD029SS	27/12/19	361	360.78	1839	1539	59 58.98	89 6.19	To 1000m
156	SS CTD at maximum depth	CTD029SS	27/12/19	361	360.79	1901	1601	59 59.17	89 5.89	
156	SS CTD onboard	CTD029SS	27/12/19	361	360.81	1931	1631	59 59.37	89 5.55	
157	Ti CTD lowered	CTD018T	27/12/19	361	360.84	2012	1712	59 57.51	89 7.87	To 150m
157	Ti CTD at maximum depth	CTD018T	27/12/19	361	360.85	2019	1719	59 57.55	89 7.80	
157	Ti CTD onboard	CTD018T	27/12/19	361	360.85	2027	1727	59 57.61	89 7.69	
158	SAPS deployed	SAPS17	27/12/19	361	360.89	2125	1825	59 57.49	89 7.89	Full depth – 4800m
158	SAPS onboard	SAPS17	28/12/19	362	361.13	0313	0013	59 58.84	89 6.08	
			28/12/19	362	361.69	1640	1340	57 59.92	89 7.94	Tran_3
159	SS CTD lowered	CTD030SS	28/12/19	362	361.69	1640	1340	57 59.92	89 7.94	To 2000m
159	SS CTD at maximum depth	CTD030SS	28/12/19	362	361.72	1722	1422	58 0.09	89 7.88	
159	SS CTD onboard	CTD030SS	28/12/19	362	361.76	1820	1520	58 0.37	89 7.81	
	BGC ARGO float deployed	ARGO5	28/12/19	362	361.76	1820	1520	58 0.08	89 7.88	SOCCOM float 18771 – no FLBB
			29/12/19	363	362.10	0218	2318	56 59.99	89 7.97	TN_3

160	Turbulence profiler deployed	TURB14	29/12/19	363	362.10	0226	2326	56 59.99	89 7.98	
160	Turbulence profiler onboard	TURB14	29/12/19	363	362.17	0400	0100	56 59.98	89 7.95	
161	Red Camera Frame deployed	RCF18	29/12/19	363	362.18	0426	0126	57 0.02	89 7.89	
161	Red Camera Frame onboard	RCF18	29/12/19	363	362.22	0516	0216	57 0.33	89 7.66	
162	SS CTD lowered	CTD031SS	29/12/19	363	362.24	0540	0240	57 0.38	89 7.62	To 1000m. No bottles fired
162	SS CTD at maximum depth	CTD031SS	29/12/19	363	362.25	0606	0306	57 0.47	89 7.62	
162	SS CTD onboard	CTD031SS	29/12/19	363	362.27	0627	0327	57 0.57	89 7.68	
163	SS CTD lowered	CTD032SS	29/12/19	363	362.27	0628	0328	57 0.58	89 7.68	To 1000m
163	SS CTD at maximum depth	CTD032SS	29/12/19	363	362.29	0655	0355	57 0.72	89 7.74	
163	SS CTD onboard	CTD032SS	29/12/19	363	362.31	0732	0432	57 0.93	89 7.77	
164	Zooplankton net deployed	ZOO17	29/12/19	363	362.33	0750	0450	57 1.01	89 7.75	
164	Zooplankton net onboard	ZOO17	29/12/19	363	362.34	0812	0512	57 1.27	89 7.64	
165	Snow Catcher deployed	MSC39	29/12/19	363	362.36	0833	0533	57 1.47	89 7.59	
165	Snow Catcher onboard	MSC39	29/12/19	363	362.36	0837	0537	57 1.52	89 7.59	
166	Snow Catcher deployed	MSC40	29/12/19	363	362.36	0845	0545	57 1.59	89 7.58	
166	Snow Catcher onboard	MSC40	29/12/19	363	362.37	0854	0554	57 1.69	89 7.56	
167	Snow Catcher deployed	MSC41	29/12/19	363	362.38	0903	0603	57 1.78	89 7.54	
167	Snow Catcher onboard	MSC41	29/12/19	363	362.39	0927	0627	57 2.01	89 7.51	

168	Snow Catcher deployed	MSC42	29/12/19	363	362.40	0934	0634	57 2.08	89 7.50	
168	Snow Catcher onboard	MSC42	29/12/19	363	362.43	1016	0716	57 2.50	89 7.44	
169	Ti CTD lowered	CTD019T	29/12/19	363	362.47	1112	0812	56 59.98	89 7.97	To 1500m
169	Ti CTD at maximum depth	CTD019T	29/12/19	363	362.49	1145	0845	57 0.26	89 7.92	
169	Ti CTD onboard	CTD019T	29/12/19	363	362.52	1235	0935	57 0.67	89 7.86	
170	Turbulence profiler deployed	TURB15	29/12/19	363	362.53	1250	0950	57 0.68	89 7.90	
170	Turbulence profiler onboard	TURB15	29/12/19	363	362.59	1407	1107	57 0.51	89 8.22	
171	SAPS deployed	SAPS18	29/12/19	363	362.61	1444	1144	57 0.03	89 7.93	
171	SAPS onboard	SAPS18	29/12/19	363	362.73	1735	1435	57 1.18	89 8.55	
172	SS CTD lowered	CTD033SS	29/12/19	363	362.78	1843	1543	57 0.01	89 7.94	To 1000m
172	SS CTD at maximum depth	CTD033SS	29/12/19	363	362.80	1911	1611	57 0.12	89 7.99	
172	SS CTD onboard	CTD033SS	29/12/19	363	362.82	1940	1640	57 0.32	89 7.95	
173	Zooplankton net deployed	ZOO18	29/12/19	363	362.83	2000	1700	57 0.48	89 7.90	
173	Zooplankton net onboard	ZOO18	29/12/19	363	362.85	2017	1717	57 0.76	89 7.79	
174	Red Camera Frame deployed	RCF19	29/12/19	363	362.85	2026	1726	57 0.84	89 7.77	
174	Red Camera Frame onboard	RCF19	29/12/19	363	362.89	2123	1823	57 1.39	89 7.61	
										TS_4
175	Red Camera Frame deployed	RCF20	30/12/19	364	363.71	1705	1405	59 57.52	89 7.92	

175	Red Camera Frame onboard	RCF20	30/12/19	364	363.75	1804	1504	59 58.05	89 8.01	
176	SS CTD lowered	CTD034SS	30/12/19	364	363.77	1825	1525	59 58.07	89 8.01	To 1000m
176	SS CTD at maximum depth	CTD034SS	30/12/19	364	363.78	1846	1546	59 58.20	89 7.90	
176	SS CTD onboard	CTD034SS	30/12/19	364	363.80	1919	1619	59 58.41	89 7.72	
177	Snow Catcher deployed	MSC43	30/12/19	364	363.82	1945	1645	59 58.57	89 7.57	
177	Snow Catcher onboard	MSC43	30/12/19	364	363.83	1954	1654	59 58.66	89 7.49	
178	Snow Catcher deployed	MSC44	30/12/19	364	363.83	2001	1701	59 58.73	89 7.42	
178	Snow Catcher onboard	MSC44	30/12/19	364	363.84	2011	1711	59 58.83	89 7.33	
179	Snow Catcher deployed	MSC45	30/12/19	364	363.85	2019	1719	59 58.92	89 7.25	
179	Snow Catcher onboard	MSC45	30/12/19	364	363.86	2040	1740	59 59.14	89 7.04	
180	Snow Catcher deployed	MSC46	30/12/19	364	363.87	2049	1749	59 59.24	89 6.94	
180	Snow Catcher onboard	MSC46	30/12/19	364	363.90	2132	1832	59 59.67	89 6.46	
181	Zooplankton net deployed	ZOO19	30/12/19	364	363.92	2209	1909	59 57.56	89 7.87	
181	Zooplankton net onboard	ZOO19	30/12/19	364	363.94	2233	1933	59 57.90	89 7.55	
182	SAPS deployed	SAPS19	30/12/19	364	363.99	2349	2049	59 57.53	89 7.97	
182	SAPS onboard	SAPS19	31/12/19	365	364.07	0137	2237	59 57.93	89 7.60	
183	Turbulence profiler deployed	TURB16	31/12/19	365	364.09	0211	2311	59 57.93	89 7.61	
183	Turbulence profiler onboard	TURB16	31/12/19	365	364.17	0400	0100			

184	Red Camera Frame deployed	RCF21	31/12/19	365	364.17	0410	0110	59 57.54	89 7.97	
184	Red Camera Frame onboard	RCF21	31/12/19	365	364.22	0517	0217	59 57.91	89 7.79	
185	Zooplankton net deployed	ZOO20	31/12/19	365	364.23	0535	0235	59 58.00	89 7.73	
185	Zooplankton net onboard	ZOO20	31/12/19	365	364.25	0600	0300	59 58.34	89 7.57	
186	SS CTD lowered	CTD035SS	31/12/19	365	364.26	0619	0319	59 58.36	89 7.55	To 1000m
186	SS CTD at maximum depth	CTD035SS	31/12/19	365	364.28	0644	0344	59 58.52	89 7.55	
186	SS CTD onboard	CTD035SS	31/12/19	365	364.31	0720	0420	59 58.75	89 7.57	
187	Snow Catcher deployed	MSC47	31/12/19	365	364.32	0742	0442	59 58.77	89 7.57	
187	Snow Catcher onboard	MSC47	31/12/19	365	364.33	0752	0452	59 58.88	89 7.58	
188	Snow Catcher deployed	MSC48	31/12/19	365	364.33	0800	0500	59 58.97	89 7.58	
188	Snow Catcher onboard	MSC48	31/12/19	365	364.34	0809	0509	59 59.08	89 7.58	
189	Snow Catcher deployed	MSC49	31/12/19	365	364.34	0816	0516	59 59.16	89 7.58	
189	Snow Catcher onboard	MSC49	31/12/19	365	364.35	0825	0525	59 59.27	89 7.59	
190	Snow Catcher deployed	MSC50	31/12/19	365	364.36	0832	0532	59 59.30	89 7.60	Missing in bridge log
190	Snow Catcher onboard	MSC50	31/12/19	365	364.36	0842	0532	59 59.30	89 7.60	
191	Ti CTD lowered	CTD020T	31/12/19	365	364.41	0946	0646	59 57.53	89 7.97	To 1500m
191	Ti CTD at maximum depth	CTD020T	31/12/19	365	364.43	1021	0721	59 57.85	89 7.81	
191	Ti CTD onboard	CTD020T	31/12/19	365	364.47	1111	0811	59 58.34	89 7.56	

192	SS CTD lowered	CTD036SS	31/12/19	365	364.49	1150	0850	59 58.38	89 7.55	To 4990m
192	SS CTD at maximum depth	CTD036SS	31/12/19	365	364.55	1318	1018	59 58.66	89 7.41	
192	SS CTD onboard	CTD036SS	31/12/19	365	364.63	1508	1208	59 59.18	89 7.16	
193	SAPS deployed	SAPS20	31/12/19	365	364.67	1610	1310	59 57.54	89 8.04	
193	SAPS onboard	SAPS20	31/12/19	365	364.80	1916	1616	59 58.26	89 5.76	
										OOI_4
194	Ti CTD lowered	CTD021T	2/1/20	2	1.80	1915	1615	54 24.92	89 7.56	To 4335m
194	Ti CTD at maximum depth	CTD021T	2/1/20	2	1.86	2032	1732	54 24.92	89 7.56	
194	Ti CTD onboard	CTD021T	2/1/20	2	1.93	2215	1915	54 24.92	89 7.56	
195	SAPS deployed	SAPS21	2/1/20	2	2.00	2358	2058	54 24.91	89 7.60	
195	SAPS onboard	SAPS21	3/1/20	3	2.11	0232	2332	54 24.93	89 7.58	
196	Turbulence profiler deployed	TURB17	3/1/20	3	2.13	0305	0005	54 24.93	89 7.57	
196	Turbulence profiler onboard	TURB17	3/1/20	3	2.17	0405	0105	54 24.93	89 7.57	
197	Red Camera Frame deployed	RCF22	3/1/20	3	2.18	0419	0119	54 24.93	89 7.57	
197	Red Camera Frame onboard	RCF22	3/1/20	3	2.23	0524	0224	54 24.93	89 7.57	
198	Zooplankton net deployed	ZOO21	3/1/20	3	2.24	0543	0243	54 24.93	89 7.57	
198	Zooplankton net onboard	ZOO21	3/1/20	3	2.25	0604	0304	54 24.93	89 7.57	
199	SS CTD lowered	CTD037SS	3/1/20	3	2.27	0635	0335	54 24.68	89 7.69	To 1000m

199	SS CTD at maximum depth	CTD037SS	3/1/20	3	2.29	0700	0400	54 24.68	89 7.69	
199	SS CTD onboard	CTD037SS	3/1/20	3	2.32	0737	0437	54 24.68	89 7.69	
200	Glider recovered	GLIDER1	3/1/20	3	2.42	0959	0659	54 24.87	89 8.16	Glider 330
201	Snow Catcher deployed	MSC51	3/1/20	3	2.43	1017	0717	54 24.91	89 7.58	
201	Snow Catcher onboard	MSC51	3/1/20	3	2.43	1024	0724	54 24.91	89 7.58	
202	Snow Catcher deployed	MSC52	3/1/20	3	2.44	1036	0736	54 24.91	89 7.58	
202	Snow Catcher onboard	MSC52	3/1/20	3	2.45	1049	0749	54 24.91	89 7.58	
203	Snow Catcher deployed	MSC53	3/1/20	3	2.45	1055	0755	54 24.91	89 7.58	
203	Snow Catcher onboard	MSC53	3/1/20	3	2.47	1118	0818	54 24.91	89 7.58	
204	Snow Catcher deployed	MSC54	3/1/20	3	2.48	1125	0825	54 24.91	89 7.58	
204	Snow Catcher onboard	MSC54	3/1/20	3	2.50	1207	0907	54 24.91	89 7.58	
205	Turbulence profiler deployed	TURB18	3/1/20	3	2.00					
205	Turbulence profiler onboard	TURB18	3/1/20	3	2.58	1358	1058	54 24.90	89 7.57	
206	Ti CTD lowered	CTD022T	3/1/20	3	2.59	1416	1116	54 24.90	89 7.57	Brake stuck at 750m. Bottles fired on fly on recovery.
206	Ti CTD at maximum depth	CTD022T	3/1/20	3	2.65	1540	1240	54 24.91	89 7.57	
206	Ti CTD onboard	CTD022T	3/1/20	3	2.68	1619	1319	54 24.91	89 7.57	
207	Red Camera Frame deployed	RCF23	3/1/20	3	2.70	1643	1343	54 24.91	89 7.57	
207	Red Camera Frame onboard	RCF23	3/1/20	3	2.74	1740	1440	54 24.91	89 7.57	

208	SS CTD lowered	CTD038SS	3/1/20	3	2.74	1746	1446	54 24.91	89 7.57	To 1000m
208	SS CTD at maximum depth	CTD038SS	3/1/20	3	2.76	1812	1512	54 24.91	89 7.57	
208	SS CTD onboard	CTD038SS	3/1/20	3	2.78	1846	1546	54 24.91	89 7.57	
209	Zooplankton net deployed	ZOO22	3/1/20	3	2.79	1903	1603	54 24.91	89 7.57	
209	Zooplankton net onboard	ZOO22	3/1/20	3	2.82	1935	1635	54 25.04	89 7.38	
210	Snow Catcher deployed	MSC55	3/1/20	3	2.82	1935	1635	54 25.04	89 7.37	
210	Snow Catcher onboard	MSC55	3/1/20	3	2.83	1958	1658	54 25.13	89 7.25	
211	SAPS deployed	SAPS22	3/1/20	3	2.85	2018	1718	54 24.91	89 7.57	
211	SAPS onboard	SAPS22	3/1/20	3	2.93	2216	1916	54 24.91	89 7.58	
	Fish shortened		4/1/20	4	3.63	1500	1200	56 59.94	89 7.97	TN_4
212	SS CTD lowered	CTD039SS	4/1/20	4	3.64	1515	1215	56 59.98	89 7.97	To 1000m. No bottles fired.
212	SS CTD at maximum depth	CTD039SS	4/1/20	4	3.66	1546	1246	57 0.04	89 8.08	
212	SS CTD onboard	CTD039SS	4/1/20	4	3.67	1606	1306	57 0.09	89 8.12	
213	SS CTD lowered	CTD040SS	4/1/20	4	3.67	1610	1310	57 0.10	89 8.14	To 1000m. Bottles fired but not sampled.
213	SS CTD at maximum depth	CTD040SS	4/1/20	4	3.69	1631	1331	57 0.17	89 8.20	
213	SS CTD onboard	CTD040SS	4/1/20	4	3.70	1651	1351	57 0.23	89 8.25	
214	Zooplankton net deployed	ZOO23	4/1/20	4	3.72	1723	1423	56 59.98	89 7.93	
214	Zooplankton net onboard	ZOO23	4/1/20	4	3.74	1748	1448	57 0.13	89 7.94	

215	SS CTD lowered	CTD041SS	4/1/20	4	3.75	1800	1500	57 0.13	89 7.94	
215	SS CTD at maximum depth	CTD041SS	4/1/20	4	3.00					Details not recorded
215	SS CTD onboard	CTD041SS	4/1/20	4	3.80	1908	1608	57 0.32	89 7.95	
216	Red Camera Frame deployed	RCF24	4/1/20	4	3.80	1912	1612	57 0.34	89 7.95	
216	Red Camera Frame onboard	RCF24	4/1/20	4	3.84	2013	1713	57 0.54	89 7.97	
217	Snow Catcher deployed	MSC56	4/1/20	4	3.89	2124	1824	57 0.00	89 7.96	
217	Snow Catcher onboard	MSC56	4/1/20	4	3.90	2131	1831	57 0.01	89 7.94	
218	Snow Catcher deployed	MSC57	4/1/20	4	3.90	2140	1840	57 0.01	89 7.92	
218	Snow Catcher onboard	MSC57	4/1/20	4	3.91	2151	1851	57 0.01	89 7.90	
219	Snow Catcher deployed	MSC58	4/1/20	4	3.92	2159	1859	57 0.10	89 7.89	
219	Snow Catcher onboard	MSC58	4/1/20	4	3.93	2219	1919	57 0.16	89 7.85	
220	Snow Catcher deployed	MSC59	4/1/20	4	3.94	2227	1927	57 0.19	89 7.83	
220	Snow Catcher onboard	MSC59	4/1/20	4	3.97	2311	2011	57 0.33	89 7.74	
221	SAPS deployed	SAPS22	5/1/20	5	4.00	0005	2105	56 59.98	89 7.97	
221	SAPS onboard	SAPS22	5/1/20	5	4.10	0217	2317	57 0.32	89 7.70	
222	Turbulence profiler deployed	TURB19	5/1/20	5	4.11	0244	2344	57 0.31	89 7.74	
222	Turbulence profiler onboard	TURB19	5/1/20	5	4.16	0349	2449	57 0.18	89 8.09	
223	Red Camera Frame deployed	RCF25	5/1/20	5	4.18	0415	0115	56 59.99	89 7.93	

223	Red Camera Frame onboard	RCF25	5/1/20	5	4.22	0516	0216	57 0.07	89 7.86	
224	Zooplankton net deployed	ZOO24	5/1/20	5	4.23	0533	0233	57 0.08	89 7.85	
224	Zooplankton net onboard	ZOO24	5/1/20	5	4.25	0554	0254	57 0.25	89 7.80	
225	SS CTD lowered	CTD042SS	5/1/20	5	4.27	0622	0322	57 0.27	89 7.80	
225	SS CTD at maximum depth	CTD042SS	5/1/20	5	4.28	0644	0344	57 0.35	89 7.80	
225	SS CTD onboard	CTD042SS	5/1/20	5	4.30	0717	0417	57 0.45	89 7.79	
226	Zooplankton net deployed	ZOO25	5/1/20	5	4.31	0732	0432	57 0.50	89 7.78	
226	Zooplankton net onboard	ZOO25	5/1/20	5	4.33	0753	0453	57 0.68	89 7.67	
227	Snow Catcher deployed	MSC60	5/1/20	5	4.36	0839	0539	57 0.01	89 7.92	
227	Snow Catcher onboard	MSC60	5/1/20	5	4.37	0849	0549	57 0.05	89 7.92	
228	Snow Catcher deployed	MSC61	5/1/20	5	4.37	0858	0558	57 0.10	89 7.93	
228	Snow Catcher onboard	MSC61	5/1/20	5	4.38	0908	0608	57 0.15	89 7.92	
229	Snow Catcher deployed	MSC62	5/1/20	5	4.39	0916	0616	57 0.19	89 7.92	
229	Snow Catcher onboard	MSC62	5/1/20	5	4.40	0929	0629	57 0.26	89 7.92	
230	Snow Catcher deployed	MSC63	5/1/20	5	4.40	0935	0635	57 0.29	89 7.92	
230	Snow Catcher onboard	MSC63	5/1/20	5	4.41	0946	0646	57 0.34	89 7.92	
										ARGO float
231	SS CTD lowered	CTD043SS	6/1/20	6	5.38	0913	0613	55 14.10	89 22.64	

231	SS CTD at maximum depth	CTD043SS	6/1/20	6	5.41	0955	0655	55 14.10	83 22.47	
231	SS CTD onboard	CTD043SS	6/1/20	6	5.45	1054	0754	55 14.10	83 22.43	
	TM fish recovered		6/1/20	6	5.46	1105	0805	55 14.08	83 22.50	
232	BGC ARGO float deployed	ARGO6	6/1/20	6	5.47	1110	0810	55 14.06	83 10.31	SOCCOM float 18098 – no FLBB

Underway Data Processing

Hugh Venables (BAS)

Data Collection:

Throughout the cruise underway data were collected and recorded using the Techsas system. These were logged into mstar, via a synchronisation script. A merged file of navigation, underway and meteorogical variables was made available as a matlab and ascii output. A gap of approximately 30 minutes was due to a failure of the techsas system.

Approximately every six hours, surface water samples were also taken and analysed using a Guildline Autosal 8400B Salinometer in order to calibrate the underway salinity measurements. Data were also extracted at 5m from down and up CTD casts to compare with underway temperature and salinity and the remote SST temperature was compared to the internal thermosalinograph, to assess transit time through the ship.

Underway T,S Calibration:

The underway data were compared to calibrated CTD data from 5m at the start and end of each CTD cast and, for salts, against 120 salinity samples taken from the underway supply. The CTD comparison showed a considerable spread, with the remote SST measurement being 0.3+/- 0.15C too warm. There is significant short-term noise in the SST measurements, such that it is not possible to tell how much of the offset is sensor related and how much is due to warming through the ship. The offset between SST and CTD showed no change with the initial temperature, but the range of temperatures was small and the remote versus internal difference also showed no relationship with temperature.

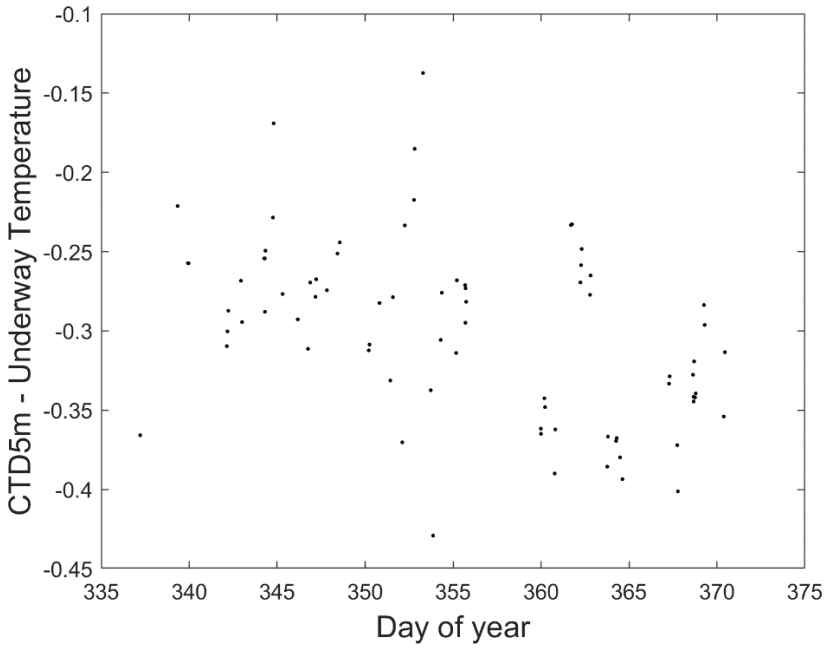

Figure 1: CTD minus underway temperature, showing a large and variable offset. The underway SST was also noisier than expected and the sensor probably needs changing

For salinity, the data shows a close match until jday 349, after which the offset diverges almost linearly until new year and then roughly flattens off, allowing for a reasonable calibration.

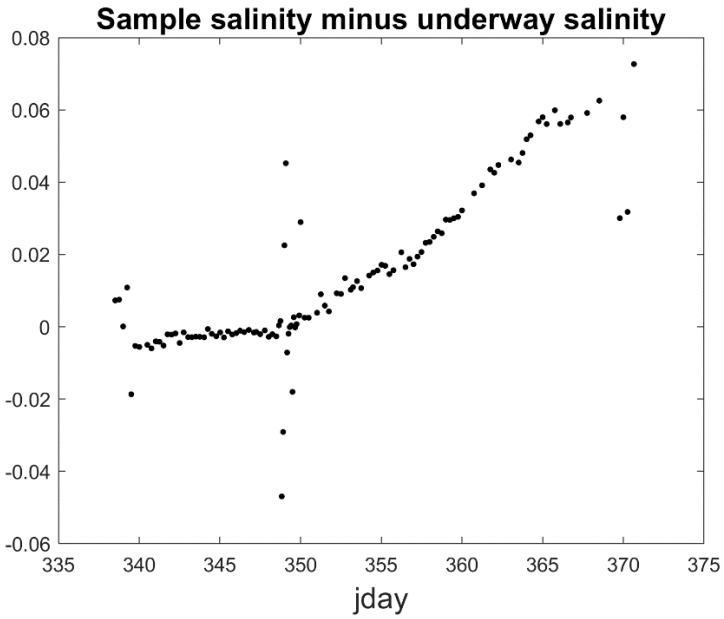

Figure 2: sample salinity versus underway salinity

Comparing the remote SST and the TSG allows an estimate of transit time through the ship to be made. This proved to be about three and a half minutes, shown both by matching the curves of the temperatures

(the internal temperature is also another 0.4C warmer again than the remote temperature). A lagged regression plot also shows a tighter fit for a lag of 210 seconds. A larger flow rate would reduce this offset but also create several tons of grey water each day (getting rid of grey water was a consideration through the cruise).

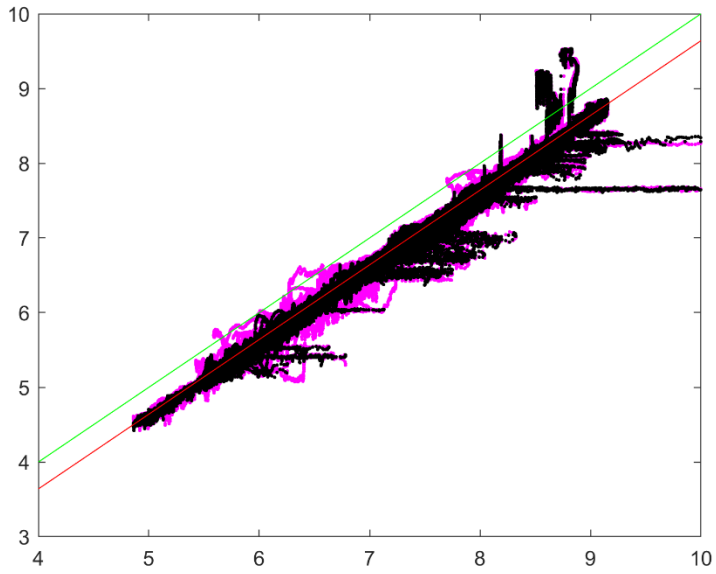

Figure 3: Housing vs remote T, unlagged (magenta) and 210 sec lagged (black). Offsets: horizontal are warming of the internal T due to reduced flow rate, vertical (main line thickness) due to noise in the remote sensor. The red line is 0.36C below the 1:1 line

Profiling Conductivity Temperature Depth (CTD) measurements

Hugh Venables (BAS)

Introduction:

Two Conductivity-Temperature-Depth (CTD) units were used to vertically profile the water column and collect water with 24 Niskin bottles. A stainless rosette had 20l bottles and the Titanium 10l bottles, for trace metal clean sampling. 43 Stainless Steel CTDs were carried out in total, with 22 titanium CTDs. Some Titanium casts suffered from bad spiking. The worst had just over 5000 modulo errors, but all bottles closed so it was considered a successful cast. There were several issues with the secondary conductivity on the Titanium casts so it is ignored in the calibration.

On the stainless package the primary sensors were mounted on the fin, significantly reducing the package effect on the data compared to the secondary sensors under the bottles, which suffer from recording water caught up in the wake of the CTD, especially when the CTD slows or turns round as the ship rolls.

After the initial soak of 15 metres (slightly deeper to be sure the UVP switched on), the CTD was raised to as close to the surface as sea conditions allowed and then lowered to within 10 m of the seabed or the desired depth. Bottles were fired on the upcast, where the procedure was to stop the CTD winch, hold the CTD for a few seconds to allow sensors to equilibrate, and then fire a bottle.

Data acquisition and preliminary processing:

The CTD data were recorded using Seasave version 7.22.3, which created four files:
DY111_[NNN].hex hex data file
DY111_[NNN].XMLCON ascii configuration file containing calibration information
DY111_[NNN].hdr ascii header file containing sensor information
DY111_[NNN].bl ascii file containing bottle fire information where NNN is the CTD number.
The SBE Data Processing module Datcnv was used to convert the hex file to ascii. Align was then used to account for the time lag of the oxygen sensor, with data being advanced by 5 seconds. The cell thermal mass (celltm) module was then used to remove the conductivity cell thermal mass effects from the measured conductivity. This re-derives the pressure and conductivity, taking into account the temperature of the pressure sensor and the action of pressure on the conductivity cell. The output of this process is an ascii file, named as DY111_[NNN]_align_ctm.cnv.

CTD data processing:

Further processing of CTD data was carried out in Matlab using existing programs, predominantly written by Mike Meredith and Karen Heywood, with modifications by numerous others, and further significant changes made on JR177 and JR307. Further significant changes, mostly generalising the code to reduce the number of adjustments needed between cruises were made on JR17003a and covered in more detail in that cruise report. The scripts mentioned are set up to be non-cruise specific. They are summarised in respect to DY111 below, with changes made to allow for using both stainless and titanium CTDs, dealing with temperature spikes, no SBE35 reference thermometer and some CTDs with no bottles:

CTDvarn sets up the cruise-specific details for the processing. These include:

Cruise name. directory paths, file-name conventions, sensors present on the CTD and their position in the SeaBird output described above, which casts to use the secondary sensors.

As this is called in the scripts, the naming must be the same between cruises, but a copy should be kept as CTDvarn_##### as a record and for reprocessing. To deal with two CTDs, there were two CTDvarn.m files, each in separate directories (Steel, Titanium) and processing was done from the relevant place. No filepath was aimed at these directories, so processing failed if it was run from other directories, so it was clear which CTD was being processed. DY111_T was used as the cruise name for titanium, to make sure file names were different.

- *ctdreadGEN* – Reads in DY111_ctd_align_ctm.cnv file. Data are then stored in Matlab arrays. The output file is DY111_ctd_NNN.red. (or DY111_T_ctd_align.cnv for titanium as temperature spikes expected)
- *editctdGEN* - reads in *DY111_ctd_NNN.red* and removes the 10-m soak prior to the CTD cast, through finding the minimum pressure after the soak and asking for user confirmation after displaying the full pressure plot for the cast. Data collected at the end of the upcast when the CTD was out of the water is removed graphically by selecting bad conductivities when the package is out of the water, those going wrong before pumps are switched off and at pressures either side of zero depending on pressure sensor offsets. The selected data points are set to NaN for all scientific sensors. Primary and secondary conductivity are also despiked using the interactive editor at the same time, with the option to edit the temperature profiles and T/S plots (where small conductivity spikes can be more obvious). Selected data points are set to NaN. Output is DY111_ctd_NNN.edt.
- *editctdGEN_spikes, editctdGEN_spikes_ftop* – used for titanium as spikes expected. Removes out of range and sudden jumps and then uses the polygon editor. The _ftop script is not fully generalised, just relying on checking for the existence of a variable before editing it.
- *ctm* was run for titanium casts, as temperature spikes propagate into conductivity, on time scales of a minute if cell thermal mass is run before they are removed.
- *batch_ctdGEN* - Runs a series of scripts in one go,
    - *deriveGEN, onehzctdGEN, splitcastGEN, fallrateGEN* and *gridctdGEN.*
    - *deriveGEN* calculates derived variables – potential temperature, salinity, density and depth
    - *OnehzctdGEN* averages data from a 24hz CTD profile to 1 hz for LADCP processing, creates file DY111_ctd_NNN.1hz (these are offshoots and not used subsequently for CTD processing)

- *SplitcastGEN* splits a CTD file into an upcast and a downcast, DY111_ctd_NNN.var.dn and DY111_ctd_NNN.var.up.
- *FallrateGEN* fallrate is a Matlab version of the Seabird loopedit script. It has to be run after the initial soak is removed as it removes any data point on the downcast where pressure is less than one previously recorded or if the fall rate is <0.25 ms-1. Loopedit flags such points (excluding the initial soak if set to) but these flags are not subsequently used in the processing and often did erroneously include the initial soak. This process results in smoother density profiles with fewer apparent overturns though as the primary sensors are on the fin and so away from the bulk of the package, this effect is reduced relative to the secondary sensors. Input and output is DY111_ctd_NNN.var.dn.
- *GridctdGEN* reads in both *DY111_ctd_NNN.var.dn* and *DY111_ctd_NNN.var.up*, and averages the data into 2-dbar bins. Outputs are *DY111_ctd_NNN.2db.mat* and *DY111_ctd_NNN.2db.up.mat*.

- *makebotGEN* were then run, along with *bot2excel* to quickly provide bottle details to other scientists on board.
- *batch_botGEN* – Once salinity samples have been run, this runs a series of scripts *readsalGEN, addsalGEN, salcalGEN* and *mergebotGEN*. *MakebotGEN* reads in *DY111_NNN.ros* and *DY111_NNN.BL*, and extracts CTD pressure, temperature (1 & 2), conductivity (1 & 2), transmission, fluorescence, oxygen and PAR for each bottle fired. It also calculates the standard deviation for pressure, temperature and conductivity, and writes a warning to the screen if those for temperature and conductivity are greater than 0.001. Salinity and potential temperature are calculated from both primary and secondary temperature and conductivity using *ds_salt* and *ds_ptmp*. Results are saved in *DY111_bot_NNN.1st*.

Once this batch of scripts is has been run for all CTD casts, the offset can be decided, using salcal_decide. These values are then entered into *salcalappGEN* as a cruise specific case. This applies any temperature and conductivity offset and salinity is recalculated. As the conductivity calibration points need to be back-calculated with temperature, the temperature calibration needs to be decided first. The uncalibrated values are then saved with _uncal added to the variable name. All programs following salcalappGEN must then be re-run with versions including the _uncal variables. This is all done via the script *batch_calGEN*. The chosen calibrations were linear pressure-dependent offsets for the two temperature sensors, while two different piecewise linear offsets were chosen for the three conductivity sensors. For specific details on the chosen calibrations see salcalappGEN. The replacement C1 sensor from cast 67 was placed in the C2 position for cast 66. The old C1 was bad for casts 65 and 66.

The offsets are checked to be compatible with the sensor differences and the calibration can then be checked by plotting T1-T2 and C1-C2 for relevant casts through the cruise. These should be centred on zero, showing calibration is correct and applied in the correct direction.

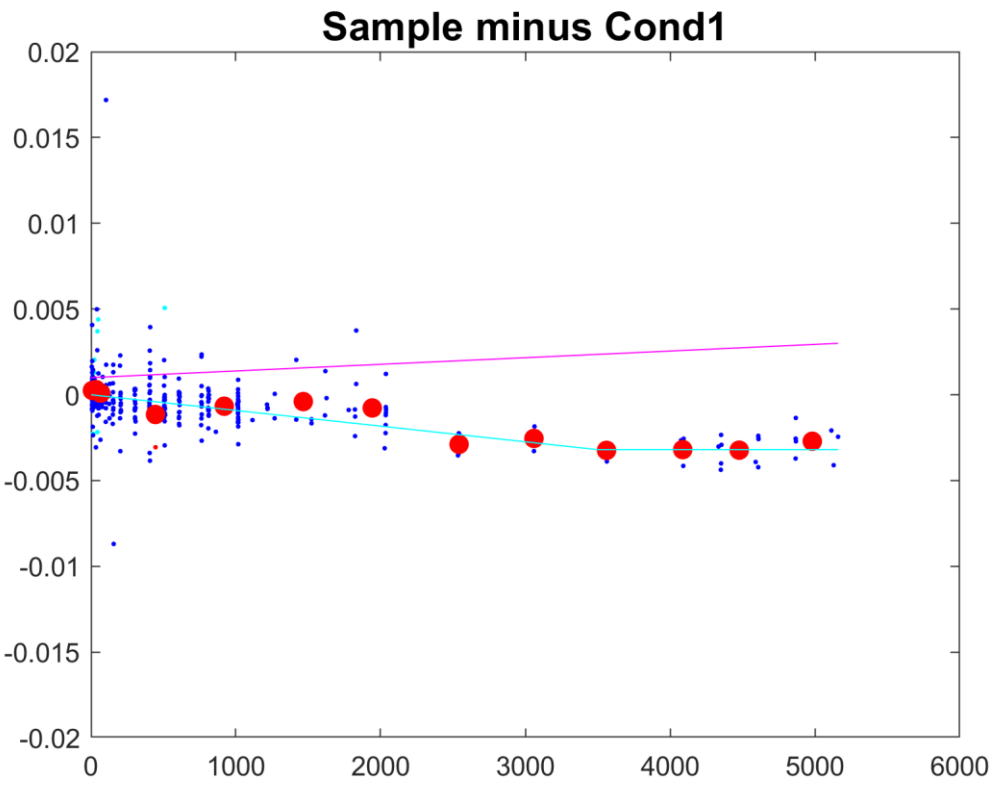

Figure 4 Sample-derived cond. minus CTD Cond1. Dots: depth band averages, outliers removed. Cyan: calibration applied. Magenta: calibration for Ti CTD cond1 (Ti cond2 was blanked). At depth, the difference matches that observed on consecutive deep casts.

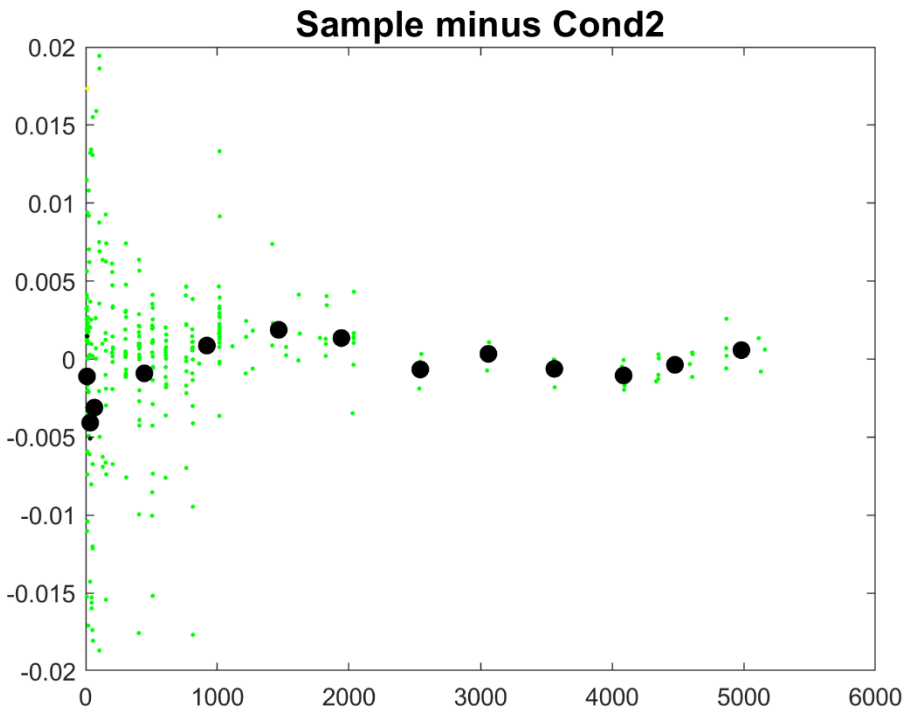

Figure 5 Sample-derived cond. minus CTD Cond2. Black dots: depth band averages (outliers removed). No offset applied. The greater spread of points relative to cond1 is due to the position of the sensors beneath the main CTD package, cond1/temp1 being on the fin.

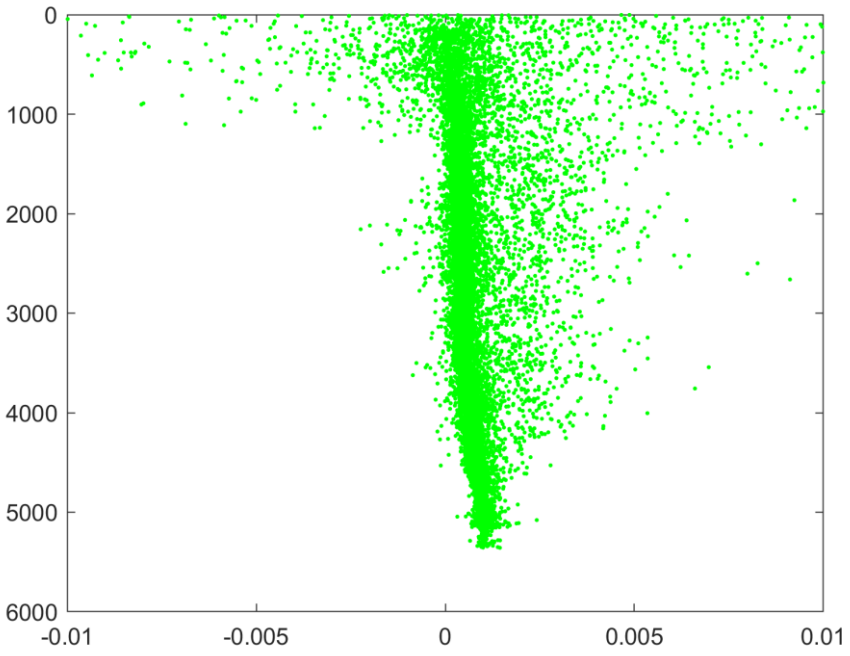

Figure 6 Temp1 minus Temp2 for the stainless CTD, showing minor differences at depth.

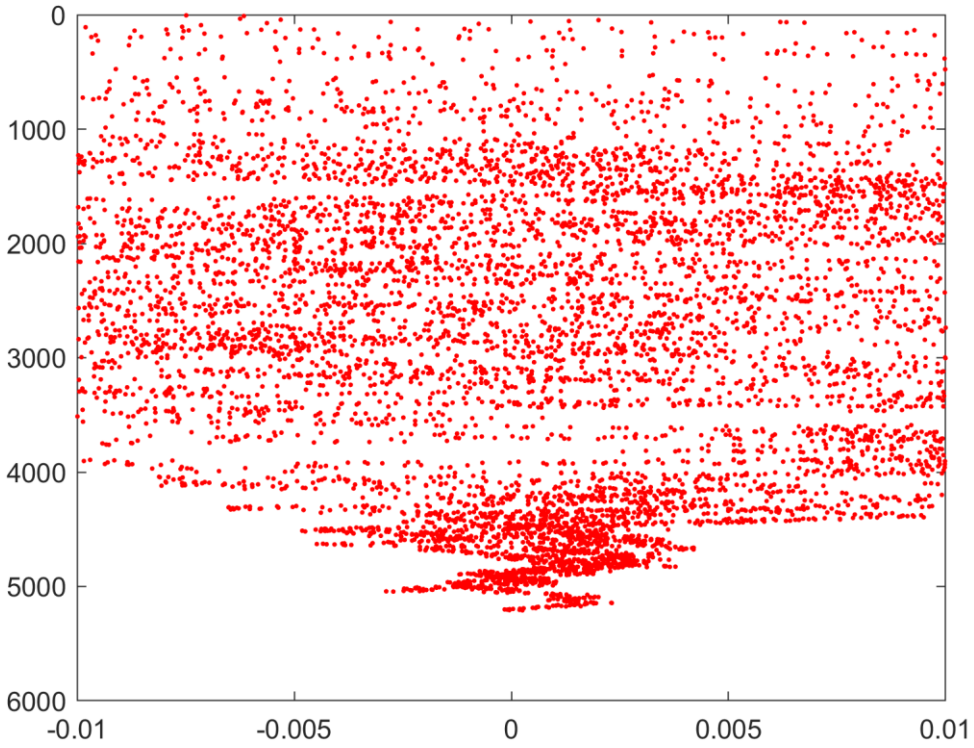

Figure 7 Steel-Titanium temp1, showing little offset at depth. Together with Temp1-Temp2 being small, there can be confidence in the temperatures to approximately 0.002C. No SBE35 was used but no calibration seems good.

Lowered Acoustic Doppler Current Profiler (LADCP) processing

Hugh Venables (BAS)

Instrument Configuration:

One Teledyne RDI 300-kHz Workhorse LADCP was mounted on the CTD in a downlooker configuration. The LADCP was run with a blanking distance of zero and 8 m bins. The data were collected in beam co-ordinates and rotated to earth co-ordinates during processing. Pre-deployment tests were run before each cast using BBtalk to check the internal electronics were working correctly. The deployment script is included below. The file names are of form; CTD0XXSS.000, where XX represents the cast number.

; Master WH300 LADCP for DY111
; removed commands already set by default
;

```
;
WV250                   ; ambiguity velocity [cm/s]
WN25                    ; number of depth cells; NBP0402
WS1000                          ; bin size [cm]; NBP0402: WS1000
WF0                     ; blank after transmit [cm]; NBP0402
WB1                     ; narrow bandwidth mode
EZ0011101               ; Sensor source: (NBP0402: EZ0111111)
EX00100                         ; coordinate transformation: (NBP0402: 11111)
WP1             ; single-ping ensembles; NBP0402: WP3 most of the time
TP 00:00.00             ; time between pings; NBP0402
TE 00:00:01.50          ; time per ensemble
CF11101                         ; Flow control:
SM1             ; set to master
SA011           ; send pulse before ensemble
SW5500          ; master waits .5500 s after sending sync pulse
RNmast_
CK                      ; keep params as user defaults (across power failures)
CS                      ; start pinging
```

Data processing

The data is copied to the sandm drive, from where it is read for processing, with output in the shared cruise drive. Processing was completed using the 2017 version of the Matlab package developed at Lamont-Doherty Earth Observatory (LDEO) by Martin Visbeck and maintained by Andreas Thurnherr. The package uses both inverse and shear methods to calculate velocity profiles. The data should be constrained by the vessel-mounted ADCP (VMADCP), bottom-tracking on the CTD, and GPS from the ship. GPS was always present, most CTDs didn't reach the bottom and the interface between shipboard and lowered ADCP systems was not worked out. The data were therefore processed without using VMADCP data to constrain the surface velocities, as an initial check of quality of the LADCP data.

Linking to CTD data

1Hz CTD data was output from the CTD processing, with file names of form DY111_ctd_XXX.1hz, where XXX represents CTD cast number. The CTD data file is converted to an ascii file using the script convert_CTD_to_ascii.m, with navigation added into the same file as the CTD files on this cruise only had a single position.

Edits to set_cast_params.m

General edits were made to the script to include the cruise details and to link to the correct directories and files for this cruise.

post_process_cast.m was also written to save the signal return data. It is just the line:

```
eval(sprintf('save %sdata.mat d',f.res));
```

Shipboard ADCP processing

Hugh Venables (BAS)

Two underway systems ran through the cruise in international waters, a OS75 and a OS150, both in narrowband mode. Due to ongoing problems, they reached about half the depth that would be expected for the frequencies in good conditions. The reasons for this are being investigated and likely are due to electrical noise somewhere in the system.

The data was logged using the UHDAS system, which gives high quality real-time data that are useful during the cruise for assessing conditions. The data were logged on the LINUX box, but due to a lack of familiarity with the system, nothing more than basic checking and editing was done. More work will be done ashore to finish the processing, but the data quality looks good, within the lowered bounds expected and accounting for sea conditions (which were surprisingly good throughout). In some areas there were insufficient scatterers in the water to give a return below about 200m during the day. The diurnal migration, clearly visible in the signal strength, brought sufficient scatterers to the top 400m during the night.

Turbulence profiling

Adrian Martin (NOC)

The turbulence profiler was deployed on the port quarter as on previous cruises (e.g. JC85), with holes drilled in the bulwark by NMF to secure the power unit and the winch. This was apparently the first time it had been used on this Discovery judging by the need for drilling holes. Two people manned the winch (one with walkie talkie for comms, one for winch) with another on the laptop logging the data inside. As standard practice, cable was spooled out sufficiently quickly to avoid any tension in the cable but not so fast as to leave excessive cable at the surface or to overshoot excessively at the stop depth. Cable was spooled down straight from drum, not over the winch arm (which introduces noise via vibration). The ship was kept moving relative to the water at 0.5-1 kt.

Two profilers were available. For DY111, MSS50 was used throughout. The two shear sensors were 98 and 99, both operated together throughout the cruise.

Issues:

1) *Turbulence due to the ship:* On the new Discovery it is possible to turn of the rear azi nearest the profiling winch, the port one on DY111. However, if the wire starts to veer starboard under the vessel the Bridge will apply a boost from the starboard azi to move the wire aft. This obviously raises the risk of ship-generated turbulence affecting the readings in the mixed layer. To determine the extent of the effect on TN_1, where conditions allowed, the profiler was first run with both rear azis turned off, with the starboard one being turned on for the last profile for comparison (there was insufficient time for more). Unfortunately, the results of the comparison could not be used to inform other deployments in the cruise because of …
2) *Processing software:* The ISS profiler comes with two pieces of software: SSDA which is used to log data; MSSPro which is used to edit and process the data. During DY111 SSDA worked fine, with values on screen for pressure and temperature sensible. On loading into the most up-to-date version of MSSPro available from NMF (the older one crashes every time a plot is tried), the data no longer make sense, with both T and pressure negative and covering a rather different range. By the end of the cruise a solution had still not been found.

Table 1: Turbulence profiles during DY111

Station	Date	Evt	Event	Prof #	Start (GMT)	Bottom (GMT)	Surface (GMT)	Comments
OOI_1	6/12	20	TURB1	1	0138	0144	0148	Wire run over arm
				2	0148	0154	0201	Wire run over arm
				3	0201	0206	0212	Wire run over arm
				4	0213	0218	0222	
				5	0223	0230	0234	
TS_1	9/12	34	TURB2	6	1231	1238	1245	Slow feed initially
				7	1250	1257	1305	
				8	1307	1314	1320	

				9	1322	1329	1335	
	10/12	42	TURB3	10	0219	0227	0235	Only overshot 4m
				11	0237	0244	0251	Only overshot 4m
				12	0255	0302	0308	
				13	0310	0318	0324	
TN_1	11/12	57	TURB4	14	2248	2255	2300	With both azis off
				15	2301	2308	2313	With both azis off
				16	2315	2322	2328	With both azis off
				17	2329	2336	2341	With both azis off
				18	2343	2350	2357	With sbd azi on
	12/12			19	0017	0024	0030	
OOI_2	14/12	66	TURB5	20	0157	0204	0210	
				21	0211	0218	0224	
				22	0225	0232	0238	
				23	0239	0247	0251	
				24	0252	0300	0307	
				25	0308	0315	0323	
		80	TURB6	26	2250	2257	2302	
				27	2303	2311	2315	
				28	2316	2324	2328	Missing screws. Recovered.
TS_2	17/2	85	TURB7	29	0330	0337	0341	Acc_y settled at 25m
				30	0342	0349	0353	
				31	0354	0402	0406	
	17/12	95	TURB8	32	1620	1626	1632	Starboard azi on
				33	1633	1640	1646	
				34	1647	1654	1700	
				35	1701	1708	1713	
				36	1714	1721	1727	
				37	1728	1735	1742	

TN_2	19/12	104	TURB9	38	1659	1706	1712	Cable catch, slowed
				39	1712	1720	1725	
				40	1726	1734	1741	
				41	1741	1749	1755	
	20/12	116	TURB10	42	1112	1119	1125	Started a few m under
				43	1126	1134	1141	
				44	1142	1149	1154	
				45	1155	1202	1207	
OOI_3	22/12	123	TURB11	46	0223	0230	0236	
				47	0237	0244	0248	
				48	0249	0257	0301	At surface ~10 sec
				49	0302	0309	0318	Spurt put on.
								Handset broke and already cast cable took probe to 337m.
				50	0318	0326	0331	
		139	TURB12	51	2100	2107	2113	
				52	2114	2121	2126	
				53	2127	2135	2138	
				54	2139	2147	2151	
TS_3	27/12	143	TURB13	55	0309	0316	0321	
				56	0323	0330	0335	
				57	0327	0344	0350	
TN_3	29/12	160	TURB14	58	0236	0234	0238	Sink speed seemed a little variable though mean about right if low by 0.1m/s
				59	0240	0248	0254	Missed top 4m. Erratic sink speed top 20m. Swell?
				60	0255	0304	0310	~60 sec at surface prior to dive recorded
				61	0310	0318	0323	

				62	0324	0332	0337	
				63	0339	0346	0351	
		170	TURB15	64	1253	1300	1305	Sink speed faster than TURB14 by ~0.4m/s for TURB15
				65	1306	1313	1318	
				66	1319	1327	1332	
				67	1333	1340	1344	
				68	1346	1354	1407	
TS_4	31/12	183	TURB16	69	0210	0218	0223	Sink speed low <20m
				70	0224	0231	0238	Sink speed low <30m
				71	0240	0248	0252	…and variable
				72	0254	0301	0306	
				73	0307	0314	0318	
				74	0320	0327	0333	
				75	0333	0341	0347	At surface ~10sec
				76	0347	0355	0359	
OOI_4	2/1	196	TURB17	77	0307	0314	0318	
				78	0318	0325	0330	
				79	0331	0337	0342	
				80	0342	0349	0354	
	3/1	205	TURB18	81	1238	1246	1251	
				82	1251	1259	1304	
				83	1305	1313	1316	
				84	1317	1325	1330	
				85	1330	1338	1343	
				86	1343	1351	1354	
TN_4	5/1	222	TURB19	87	0244	0251	0257	
				88	0258	0306	0311	

89	0311	0319	0323	
90				Fat finger
91	0323	0331	0336	Few secs at surface
92	0336	0344	0348	

Dissolved oxygen

Pablo Trucco Pignata (U.Southampton)

Instrumentation:

Discrete seawater samples were collected from 35 stainless steel CTD cast and 20 titanium CTD cast for calibrating the CTD oxygen optode sensors and those deployed on gliders and the mooring. Dissolved Oxygen (DO) was determined by automated Winkler titration with potentiometric end-point (Williams and Jenkinson 1982) using a Metrohm 916 Ti-Touch controller and 2 Metrohm Dosino 800 units for dispensing Thiosulphate and Iodate solutions. A Metrohm Pt-Titrode electrode was used for detecting the potentiometric end-point of the titration. The titration sequence and data acquisition were controlled by Metrohm Tiamo software.

Sampling:

Seawater samples for dissolved oxygen concentration were directly collected from the Niskin bottles in the clean laboratory for trace metal sampling for the titanium frame rosette, and on the deck for the stainless steel rosette. Seawater was siphoned into 100 ml borosilicate glass bottles (nominal volume, actual volume was determined gravimetrically prior to the cruise), using silicone tubing and overflowing the bottle volume twice, and samples were immediately fixed. Oxygen in the samples was fixed with Manganese Sulphate and Alkaline Iodide solutions dispensed from calibrated pipettes. The fixing temperature was recorded on a hand-held thermometer. Immediately after fixing, the samples were stored until analysis. Titrations for dissolved oxygen determination were made within the following 24 h. The concentration of thiosulphate was calibrated prior to starting oxygen analyses as well as blank determination. Oxygen saturation was calculated from the equations for solubility in seawater of Benson and Krause (1984).

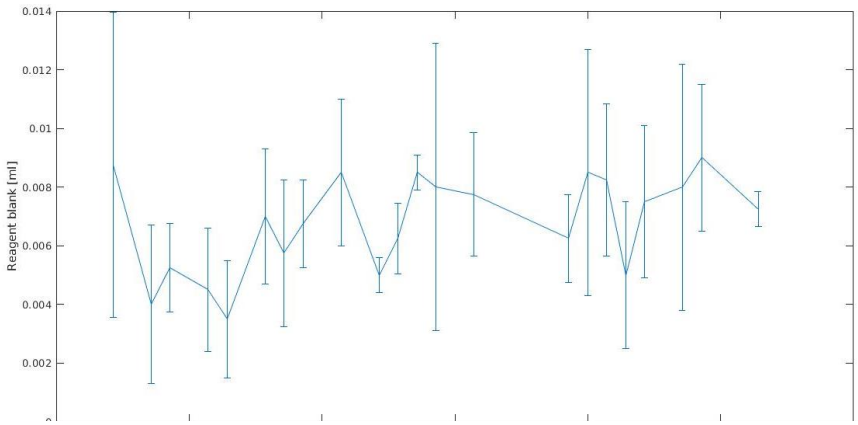

Figure 8 Blank variation versus date of measurement.

Calibration results:

A single Thiosulphate solution was prepared and calibrated against a 0.1667 M KIO3 standard (OSIL). The concentration of the Thiosulphate solution did not vary significantly during the cruise with a mean of 0.1102 ± 0.0003 M. Also the reagent blanks were within standard values for the whole cruise (Figure 1) The mean value calculated for each day of analysis was used for the respective sample calculation. For the oxygen concentrations encountered during DY111, the thiosulphate concentration uncertainty of ±0.0003 M, equates to a 95% confidence interval (2 standard deviation) of approximately 0.9 µmol/L (analytical uncertainty). Replicate samples from the same Niskin bottle varied in difference between 0.07-1.58 µmol/L (average 0.81 µmol/L equivalent to ±0.19 % saturation with respect to atmospheric equilibrium). A depth comparison between CTD oxygen measurement and Winkler determination showed a changing offset with depth for the two different type of frame (Figure 9)

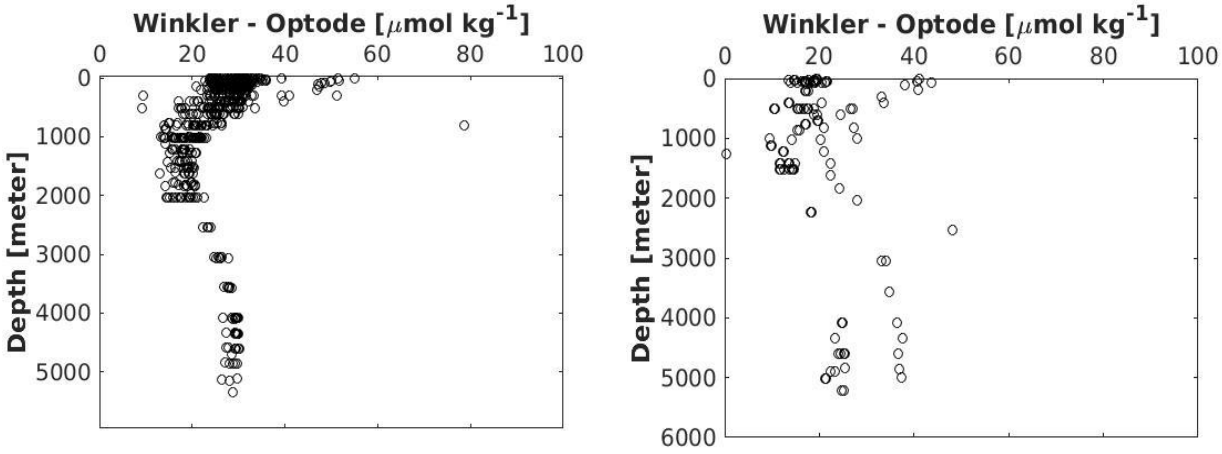

Figure 9 Profile comparison between CTD measurements and Winkler oxygen determination. Right Titanium frame, left stainless steel frame

References:

Benson, BB and Krause DJr. (1984) Limnol. Oceanogr., 29, 630-632.

Williams, PJleB and Jenkinson NW (1982) Limnol. Oceanogr. 27, 576-584.

Inorganic Nutrients Analysis

Katsia Pabortsava (NOC)

Methods and Equipment:

During DY111 water samples were analysed for the determination of inorganic nutrient concentrations. The analyses were for nitrate and nitrite (NO3+NO2), silicate (SiO2), nitrite (NO2) and phosphate (PO4). The water samples were drawn from Niskin bottles from stainless steel and titanium CTDs, underway samples, and experimental water samples from Neil Wayatt and Mark Moore and from Roxana Shafeei.

Sampling protocols used were similar regardless of where the samples were drawn from. From the Niskin bottles for example, pre-labelled 15ml centrifuge tubes were rinsed three times with water from the same Niskin that was being sampled, before being filled to between the 10-15ml marks. All samples were stored in pre-labelled centrifuge tubes that had been rinsed 3 times with the same water as the sample was taken from.

Analysis was within 24 hours of the samples being taken and on a QuAAtro 39 segmented flow autoanalyser linked to a XY-2 Sampler, both by SEAL Analytical UK Ltd, and controlled via a DELL Latitude laptop using the appropriate software package supplied by SEAL, called AACE 7.09. The chemistry methods used were also supplied by SEAL and can be seen in Table 1.

Table 2: Inorganic nutrient method documents used during DY090 for QuAAtro applications as supplied by SEAL Analytical UK Ltd.

Channel number	Method name	Method number	Low range	High range
1	Nitrate and nitrite in water and seawater (with Cd coil)	Q-068-05 Rev. 11	0 – 5µmol/L	0 – 250µmol/L
2	Silicate in water and seawater	Q-066-05 Rev. 5	0 – 5µmol/L	0 – 165µmol/L
3	Nitrite in water and seawater	Q-070-05 Rev. 6	0 – 1µmol/L	0 – 45µmol/L
4	Phosphate in water and seawater	Q-064-05 Rev. 8	0 – 1.3µmol/L	0 – 6µmol/L

During runs ultra-pure water (MilliQ) was used as a wash, to provide the baseline. MilliQ was also the matrix that the stock calibrant solutions were made up in. Artificial seawater solution was used to prepare a range of calibration standard solutions (n=7; Table 2).

Table 3: The standard concentrations used for each chemistry during DY111. These were used for all but the first couple of runs. The concentrations were amended after the first couple of runs to best cover the sample range.

Chemistry	Standard 1 (µmol/L)	Standard 2 (µmol/L)	Standard 3 (µmol/L)	Standard 4 (µmol/L)	Standard 5 (µmol/L)	Standard 6 (µmol/L)	Standard 7 (µmol/L)
NO3+NO2	1.047	5.083	10.166	15.249	20.332	30.699	40.865
SiO2	0.500	5.000	10.003	20.007	50.016	100.033	150.049
NO2	0.0501	0.1003	0.2005	0.3008	0.4011	0.6016	1.0027
PO4	0.05	0.100	0.500	1.001	1.501	2.001	3.002

The correlation coefficient for all chemistries during all runs was higher than 0.9990. In fact, the lowest value seen throughout DY111 was 0.9993 and this low value only occurred once. All other values were 0.9999 or higher.

Throughout DY111 the efficiency of the reduction from NO3 to NO2 by the cadmium coil was calculated by comparing a single NO2 standard against a single NO3 standard (10 µmol/L each). The efficiency should be kept as close to 100% as possible and certainly above 90%. During DY111 the efficiency never dropped below 100%.

Two sets of certified reference materials (CRM Lots CJ and CB, KANSO, Japan) were measured at a start and the end of each sample run. The detection limit was calculated from 10 replicates of the lowest concentration standard for each run.

The baseline (or offset) of the wash solution was always set at 5% of the chart window. The actual absorbance values for the baseline were recorded before starting each run to give an indication of stability of the wash solution and/or cleanliness of the system. The gain was set by running the highest sample through the system and selecting 'set gain' in the software. The chart window was then automatically adjusted so that the top standard peak sits at the 90% point.

The sampling time was 80 seconds per sample and 20 per wash. This ensured a nice stable section reading with no interference from density gradients.

A total of 45 vertical profiles (Table 3) and 129 underway samples (Table 4) were analysed during DY111.

Table 4: DY111 Station and CTD Sampling Summary

Date	Lat °N	Lon° E	CTD#	Site	Type
04/12/2019	-52.65	-80.54	1	Shakedown	Steel
06/12/2019	-54.39	-89.13	2	OOI-1	Steel
06/12/2019	-54.42	-89.13	2	OOI-1	Titanium
06/12/2019	-54.42	-89.13	3	OOI-1	Steel
08/12/2019	-59.96	-89.13	4	TS-1	Titanium
09/12/2019	-59.95	-89.13	5	TS-1	Steel
09/12/2019	-59.96	-89.13	5	TS-1	Titanium
09/12/2019	-59.96	-89.12	6	TS-1	Steel
11/12/2010	-57.00	-89.13	6	TN-1	Titanium

11/12/2010	-57.00	-89.13	9	TN-1	Steel
12/12/2019	-56.00	-89.13	7	Tran-2	Titanium
13/12/2019	-56.01	-89.12	11	TRAN 2	Steel
13/12/2019	-55.00	-89.13	8	TRAN 1	Titanium
13/12/2019	-55.00	-89.13	12	TRAN-1	Steel
14/12/2019	-54.43	-89.11	9	OOI-2	Titanium
14/12/2019	-54.42	-89.13	14	OOI-2	Steel
15/12/2019	-54.42	-89.13	10	OOI-2	Titanium
15/12/2019	-54.42	-89.13	15	OOI-2	Steel
17/12/2019	-59.96	-89.12	11	TS-2	Titanium
17/12/2019	-59.96	-89.13	17	TS-2	Steel
18/12/2019	-59.00	-89.13	12	TRAN-4	Titanium
18/12/2019	-59.00	-89.13	18	TRAN-4	Steel
18/12/2019	-58.00	-89.13	13	TRAN-3	Titanium
19/12/2019	-58.02	-89.07	19	TRAN-3	Steel
19/12/2019	-57.00	-89.13	14	TN-2	Titanium
19/12/2019	-57.00	-89.13	20	TN-2	Steel
20/12/2019	-57.00	-89.13	15	TN-2	Titanium
20/12/2019	-57.02	-89.15	22	TN-2	Steel
22/12/2019	-54.42	-89.13	16	OOI-3	Titanium
21/12/2019	-56.00	-89.13	23	OOI-3	Steel
22/12/2019	-54.42	-89.15	26	OOI-3	Steel
27/12/2019	-59.96	-89.13	17	TS-3	Titanium
27/12/2019	-59.96	-89.13	18	TS-3	Titanium
27/12/2019	-59.65	-89.10	29	TS-3	Steel
28/12/2019	-58.00	-89.13	30	TRAN-3	Steel
29/12/2019	-57.00	-89.13	19	TN-3	Titanium
29/12/2019	-57.00	-89.13	33	TN-3	Steel
30/12/2019	-59.97	-89.13	34	TS-4	Steel
31/12/2019	-59.97	-89.13	36	TS-4	Steel
31/12/2019	-59.96	-89.13	20	TS-4	Titanium
02/01/2020	-54.42	-89.13	21	OOI-4	Titanium
03/01/2019	-54.42	-89.13	22	OOI-4	Titanium
03/01/2020	-54.41	-89.13	37	OOI-4	Steel
03/01/2020	-54.42	-89.13	38	OOI-4	Steel
04/01/2020	-57.00	-89.14	41	TN-4	Steel
06/01/2020	-55.24	-83.38	43	Argo	Steel

Table 5: DY111 Summary of inorganic nutrient analysis of the underway seawater samples

Underway sample ID	Lat (°N)	Lon (°E)
UW1	TBC	TBC
UW2	TBC	TBC
UW3	-54.3962	-88.5745
UW4	-54.4213	-89.1287
UW5	-54.4205	-89.1282
UW6	-54.4213	-89.1286
UW7	-54.4214	-89.1286
UW8	-54.4192	-89.135
UW9	-54.9002	-89.1189
UW10	-55.896	-89.1031
UW11	-56.9626	-89.08
UW12	-58.0309	-89.0513
UW13	-59.0121	-89.0241
UW14	-59.9389	-89.1277
UW15	-59.9855	-89.1151
UW16	-59.968	-89.1216
UW17	-59.9742	-89.1144
UW18	-59.9728	-89.1255
UW19	-59.9716	-89.1287
UW20	-59.9527	-89.1277
UW22	-58.9017	-89.1312
UW23	-57.8881	-89.2111
UW25	-57.0038	-89.1349
UW26	-57.0003	-89.133
UW27	-57.0249	-89.1228
UW28	-57.0059	-89.1518
UW29	-56.7278	-89.2115
UW30	-56.0003	-89.131
UW31	-56.0082	-89.1187
UW32	-55.9197	-89.0263
UW33	-55.0409	-89.0722
UW34	-55.0043	-89.1326
UW35	-54.6472	-89.012
UW36	-54.4253	-89.1075
UW37	-54.4273	-89.1062
UW38	-54.4194	-89.1212
UW39	-54.4071	-89.1672
UW40	-54.4164	-89.1348
UW41	-54.4163	-89.1347
UW42	-54.6937	-89.2639
UW43	-55.0306	-89.2617
UW44	-55.378	-89.2663
UW45	-55.6941	-89.2621
UW46	-56.0346	-89.315
UW47	-56.3605	-89.3564

UW48	-56.7172	-89.3595
UW49	-57.1087	-89.376
UW50	-57.4672	-89.3854
UW51	-57.8191	-89.4008
UW52	-58.1925	-89.4336
UW53	-58.4881	-89.4615
UW54	-58.8139	-89.4666
UW55	-59.1472	-89.4703
UW57	-59.8305	-89.3917
UW58	-59.9604	-89.1257
UW59	-59.9606	-89.1234
UW60	-59.9697	-89.1083
UW61	-59.9604	-89.1255
UW62	-59.6645	-88.8088
UW63	-59.0001	-89.1334
UW64	-59.0001	-89.1333
UW65	-58.4505	-88.7785
UW66	-58.0073	-89.0992
UW67	-58.0209	-89.0537
UW68	-57.2619	-88.767
UW69	-57.0038	-89.1402
UW70	-56.9997	-89.1327
UW71	-56.9997	-89.1327
UW72	-57.0176	-89.1768
UW73	-57.0174	-89.1543
UW74	-56.6301	-88.8121
UW75	-56.0049	-89.1339
UW76	-55.6716	-88.6986
UW77	-54.8186	-88.7413
UW78	-54.4171	-89.1336
UW79	-54.4161	-89.1327
UW80	-54.4162	-89.1326
UW81	-54.4189	-89.1461
UW82	-54.4163	-89.1319
UW83	-54.4164	-89.3619
UW84	-54.4175	-90.4995
UW85	-54.9997	-90.5343
UW86	-55.0076	-89.1334
UW88	-55.9173	-90.5716
UW89	-56.5962	-90.6139
UW90	-56.6001	-89.1385
UW91	-57.3882	-89.1521

UW92	-57.3888	-90.5534
UW93	-58.176	-90.6132
UW94	-58.1844	-89.1169
UW95	-58.9405	-89.1345
UW96	-58.9576	-90.6128
UW97	-59.7298	-90.5874
UW98	-59.9602	-89.1287
UW99	-59.9701	-89.1211
UW100	-59.9685	-89.1223
UW101	-59.9787	-89.1079
UW102	-59.9745	-89.1117
UW103	-59.625	-89.1308
UW104	-58.6489	-89.1334
UW105	-58.0049	-89.1304
UW106	-57.2426	-89.1317
UW107	-57.0076	-89.1272
UW108	-57.0067	-89.1317
UW109	-57.0251	-89.134
UW110	-57.3819	-89.1314
UW111	-58.3311	-89.1307
UW112	-59.1823	-89.1273
UW113	-59.9669	-89.1334
UW114	-59.96	-89.1317
UW115	-59.9725	-89.126
UW116	-59.9739	-89.1253
UW117	-59.9678	-89.1117
UW118	-59.4081	-89.5926
UW121	-57.4162	-91.4945
UW122	-56.8753	-92.2141
UW123	-56.0806	-91.2937
UW124	-55.3086	-90.2832
UW125	-54.5153	-89.2987
UW126	-54.4152	-89.1267
UW127	-54.4155	-89.1262
UW128	-54.4151	-89.1263
UW129	-54.4152	-89.1262
UW130	-54.6112	-89.1375
UW131	-55.5668	-89.1315
UW133	-57.0022	-89.1324
UW134	-56.9996	-89.1328
UW135	-57.0044	-89.13
UW136	-56.8746	-88.7213

Microfluidic Nitrate + Nitrite Analyser

Antony Birchill (U.Plymouth)

A prototype microfluidic analyser for the determination of nitrate + nitrite was deployed on the ship's non-toxic underway supply. Details of the analyser can be found in Nightingale et al. [2019]. The sensor was run for 13 days. The data will inform the future development of the sensor and have been sent back to Adrian Nightingale (U. Southampton) for post processing.

Nightingale, A. M., S.-u. Hassan, B. M. Warren, K. Makris, G. W. Evans, E. Papadopoulou, S. Coleman, and X. Niu (2019), A droplet microfluidic-based sensor for simultaneous in situ monitoring of nitrate and nitrite in natural waters, Environmental science & technology, 53(16), 9677-9685.

Sampling for nitrate and silicate isotopes

Mark Moore (U. Southampton), on behalf of Robyn Tuerena (U. Edinburgh)

Introduction:

Stable isotopes of both silicate and nitrate can be used to investigate the cycling of these nutrients. On cruise DY111 a series of samples were collected for such silicate and nitrate isotope analysis, focusing on the upper 800m of the water column, corresponding to mode and intermediate waters.

Method:

Samples were collected from the stainless steel CTD. Samples were filtered using an online Acropak filter connected direct to the Niskin bottle, the filter being flushed for 30 seconds before sample collection commenced. Bottles were then rinsed 3 times before the final sample was collected. Samples for silicate isotope analysis were then acidified with 230 µl of 20% HCL before being stored at 4°C for return to the UK. Samples for nitrate isotope analysis were placed in a -20°C freezer for storage and return to the UK. All samples will subsequently be analysed by Robyn Tuerena and colleagues.

Samples collected

A total of 66 samples were collected over the top 800m of the water column from a total of 7 stations corresponding to each of the CTD locations occupied along the sampling transect.

Table 6 Samples collected for isotope analysis

Event #	CTD #	JDAY	Location	Niskin #'s sampled	Nominal depths (m) sampled	Samples collected
63	S 011	347	Tran 2	15, 16, 17, 18, 19, 20, 21, 22, 23, 24	800, 600, 500, 400, 300, 200, 100, 75, 40, 10	10 samples for both Si and N isotopes
65	S 012	348	Tran 1	15, 16, 17, 18, 19, 20, 21, 22, 23, 24	800, 600, 500, 400, 300, 200, 100, 60, 30, 20	10 samples for both Si and N isotopes

100	S 018	352	Tran 4	15, 16, 17, 18, 19, 20, 21, 22, 23, 24	800, 600, 500, 400, 300, 200, 100, 50, 30, 20	10 samples for both Si and N isotopes
102	S 019	353	Tran 3	15, 16, 17, 18, 19, 20, 21, 22, 23, 24	800, 600, 500, 400, 300, 200, 100, 80, 40, 20	10 samples for both Si and N isotopes
134	S 025	356	OOI	2, 3, 4, 5, 6, 10, 12, 16, 19	750, 500, 400, 300, 200, 100, 75, 45, 20	9 samples for both Si and N isotopes
156	S 029	361	TS	2, 3, 4, 6, 10, 12, 16, 19	750, 500, 400, 200, 100, 75, 45, 20	8 samples for both Si and N isotopes
172	S 033	363	TN	2, 3, 4, 5, 6, 10, 12, 16, 19	750, 500, 400, 300, 200, 100, 75, 45, 20	9 samples for both Si and N isotopes

In situ Observations of Total Dissolved Inorganic Carbon and Total Alkalinity

Maribel García-Ibáñez, Gareth Lee (UEA)

Assistance with CTD sampling: Sofia Alexiou, Pablo Trucco.

Assistance with underway sampling: Pablo Trucco, Katsia Parbotsava, Adrian Martin, Mark Moore, Chelsey Baker, Angie Milne, and Sofia Alexiou.

Rationale and Objectives:

Understanding how CO_2 behaves in the ocean gives us information about how the ocean uptakes atmospheric CO_2 and how it is the redistributed in the ocean. Human activities have increased atmospheric CO_2 concentrations since the industrial revolution. These anthropogenic CO_2 emissions occur on top of an active natural carbon cycle that circulates carbon between the atmosphere, ocean and land reservoirs. The ocean dominates the storage of CO_2 due to its high solubility in seawater and its sequestration through water sinking away from the surface. In fact, the oceans have absorbed about 30% of the anthropogenic CO_2 emitted to the atmosphere since the industrial revolution. But this

anthropogenic CO_2 is not evenly distributed throughout the oceans. While CO_2 concentration in the surface layers increases as CO_2 increases in the atmosphere, its penetration into the deep ocean depends on the slow vertical mixing and water circulation. In some regions where vertical movements of water are relatively fast, such as the Southern Ocean, the time scale necessary for deep penetration of anthropogenic CO_2 is of the order of decades instead of centuries.

During the CUSTARD cruise, we, the UEA CO_2 team, quantified two variables of the seawater carbonate system in the Southern Ocean to help in answering the question of how deep in the ocean the CO_2 is stored and, therefore, for how long it is kept out of the atmosphere. Two accurate carbonate chemistry measurements are needed for calculation of the other carbonate parameters. During DY111 we made accurate measurements of total dissolved inorganic carbon (DIC) and total alkalinity (TA)

Methods:

Sampling from the CTD Rosette for DIC and TA

Water samples for the determination of DIC and TA were drawn from the 20 L Niskin bottles on the CTD rosette and collected in 250 mL glass bottles with ample rinsing and overflowing to avoid gas exchange with the air. Five replicate 250 mL samples were collected per cast. Most CTD stations and most depths were sampled. Leaking Niskins were not sampled. 26 CTD casts with typically 24 Niskins per cast were sampled and analysed on board, equivalent to about 597 samples. The samples were poisoned with a saturated mercuric chloride solution (50 µL per 250 mL sample) if the analysis was deemed to be undertaken more than 24 hours after sampling.

Surface water sampling for DIC and TA

Six hourly water samples for the determination of DIC and TA were drawn from the non-toxic surface water supply in the underway laboratory. Parallel sampling was undertaken for nutrients, chlorophyll and salinity (4 times per day). The DIC and TA samples were collected in 250 mL glass bottles with ample rinsing and overflowing to avoid gas exchange with the air. Two replicate 250 mL samples were collected every six hours, equivalent to about 280 samples throughout the cruise. The samples were always poisoned with a saturated mercuric chloride solution (50 µL per 250 mL sample).

DIC and TA measurements

Water samples were analysed for DIC and TA on two VINDTA instruments. The VINDTA combined DIC/TA instruments (#4 and #7, version 3C) operate at 25°C (Mintrop, 2004). CTD samples and underway samples were analysed on both instruments (#7) and (#4).

The DIC concentration was determined by coulometry after the method of Johnson et al. (1987). Generally, all samples from stations were run on one coulometer cell and the coulometry cell was changed

every 20-24 hours. Two to three CRMs (Certified Reference Material, batch 182) were used per coulometric cell and station.

The TA measurements were made by potentiometric titration. The acid consumption up to the second endpoint is equivalent to the titration alkalinity. The systems use a Metrohm Titrino 719S for adding acid, an ORION-Ross pH electrode and a Metrohm reference electrode. The burette, the pipette (volume approximately 100 mL), and the analysis cell have a water jacket around them at 25°C. The titrant (0.1 M hydrochloric acid, HCl) was made at UEA.

The VINDTA instruments performed well during the cruise. Problems included a broken Peltier element (#4), a malfunctioning temperature sensor (#4) and rough sea state reducing the accuracy of TA and DIC analyses. The DIC and TA data are undergoing quality control.

Stations sampled

Three stations were visited four times for the duration of the cruise. The stations names, locations, visit dates and depths sampled were as followed:

Table 7 Samples at OOI, TN and TS

Station Name	Location	Visit dates	Depths measured for TA and DIC (m)
OOI_1	54˚S, 89˚W	06/12/19	2000,1800,1600,1400,1200,1000,800,600,500,400, 300,200,125,100,70,50,40,30,20,15,10,5
		06/12/19	1000,800,600,400
OOI_2		14/12/19	1000,750,500,400,300,200,150,125,100,75,50,40, 30,20,15,10,5
		15/12/19	4617,4250,4000,3497,3000,2500,2000,1950,1800, 1600,1500,1400,1200,1000,800,600,500,400,300, 100,75,50,25

OOI_3		22/12/19	1000,750,500,400,300,200,150,125,100,75,50,45, 30,20,15,10,5
OOI_4		03/01/20	1000,750,500,400,300,200,150,125,100,75,60,50, 45,30,20,15,10,5
TN_1	57˚S, 89W	11/12/19	1000,750,500,400,300,200,100,75,60,50,40,30,20, 15,10,5
TN_2		19/12/19	1000,750,500,400,300,200,150,120,100,70,50,40, 30,20,15,10,5
		20/12/19	5000,4750,4500,4250,4000,3500,3000,2500,2000 1800,1600,1400,1200,1000,800,600,500,400,300, 200,100,75,50,25
TN_3		29/12/19	1000,750,500,400,300,200,150,125,100,75,50,40, 30,20,15,10,5
TN_4		04/01/20	1000,750,500,400,300,200,150,125,100,75,60,40, 30,20,15,10,5
TS_1	59˚S, 89˚W	08/12/19	4888,4750,4500,4250,4000,3500,3000,2500,2000, 1800,1600,1400,1200,1000,800,600,500,400,300, 180,100,75,50,20
		09/12/19	2000,1750,1500,1250,1000,750,500,400,300,200, 150,125,100,75,50,40,30,20,15,10,5

TS_2		17/12/19	1100,1000,850,750,500,400,300,200,150,125,100, 75,50,40,30,20,15,10,5
TS_3		27/12/19	1000,750,500,400,200,150,125,100,75,50,40,30,20, 15,10,5
TS_4		30/12/19	1000,750,500,400,300,200,150,125,100,75,60,50, 40,30,20,15,10,5
		31/12/19	5000,4000,3000,2000,1750,1500,1250,1000,900, 600,500,400,300,200,100,50,20,5

In addition, transect stations were sampled between the main study stations. These were as follows:

Table 8 Samples at other locations

Station Name	Location	Visit dates	Depths measured for TA and DIC (m)
'station 1' 'Argo/Shakedown'	52˚39.17S 80˚32.311W	4/12/19	2000,1800,1600,1400,1200,1000,800,600500,400,300,200,150,125,100,75,50,40, 30,20,10,5
Tran_1	55˚0.260S 89˚7.960W	13/12/19	4770,4500,4250,4000,3500,3000,2500, 1750,1500,1250,1000,800,600,500,400, 300,200,100,60,30,20
Tran_2	56˚00.490S 89˚07.117W	13/12/19	5051,4750,4500,4250,4000,3500,3000, 2500,2000,1750,1500,1250,1000,800,600500,400,300,200,100,75,40,10

Tran_3	58˚01.100S 89˚03.620W	19/12/19	4820,4750,4500,4250,4000,3500,3000, 2500,2000,1800,1600,1400,1200,1000, 800,600,500,400,300,200,100,80,40,20
Tran_4	59˚00.00S 89˚08.00W	18/12/19	5020,4750,4500,4250,4000,3500,3000, 2500,2000,1800,1600,1400,1200,1000, 800,600,500,400,300,200,100,50,30,20
'56 ˚S'	56˚ 00.04S 89˚ 07.54W	21/12/19	2005,1800,1600,1400,1200,1000,800,60050 0,400,300,200,150,125,100,70,50,40, 30,20,15,10,5
Tran_3	57˚54.880S 89˚07.890	28/12/19	2000,1800,1600,1400,1200,1000,800,60050 0,400,300,200,150,125,100,70,50,40, 30,20,15,10,5
Tran_2 ARGO	55˚14.102S 83˚22.642W	06/01/20	2000,1750,1500,1250,1000,800,600,500,400 ,300,200,150,125,100,50,40,30,20,15,10,5

Data availability:

The final DIC and TA data will be stored with other cruise data at the British Oceanographic Data Centre (http://www.bodc.ac.uk/). The carbonate parameters will also be submitted to the international, public CO_2 database at the Carbon Dioxide Information Analysis Center (http://cdiac.esd.ornl.gov/oceans/).

Recommendations:

- Stainless steel rosette provided better replication than the titanium rosette.
- Reliable closure of Niskins on the CTD rosette with a reduced failure rate.

References

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^{13}C Sampling

Pablo Trucco Pignata (U. Southampton)

Water samples for stable carbon isotope ($^{13}C/^{12}C$, defined as $\delta^{13}C$) were collected from 20 litre niskin bottles attached to the CTD sampling rosette. A total of 4 deep cast were sampled for $\delta^{13}C$, once at OOI, once at TN and twice at TS. The TS duplicate was done because the previous was taken from the bottles attached to the titanium frame, and in the clean lab. All others were taken from the stainless CTD rosette. Samples were collected using 80 ml borosilicate bottles except for the last cast sampled (TS duplicate) it was made using 30 ml wide-mouth HDPE bottles. The 192 samples were poisoned using 8 µl of saturated mercuric chloride ($HgCl_2$) solution to inhibit biological activity and to reliably preserve the carbon isotope ratios for later analysis. Samples will be shipped back to the National Oceanographic Centre labs in Southampton to determine their $\delta^{13}C$ content.

Air-sea CO2 flux

Pablo Trucco Pignata (U.Southampton)

Air-sea fluxes of CO2, sensible heat, and momentum were continuously measured on the met platform using the eddy covariance method. This requires rapid (>= 10 Hz) sampling of the following:

- 3-dimensional wind velocities and air temperature from two Gill sonic anemometers (one on starboard side, one on port side)
- 3-dimensional acceleration and rotation from two LPMS motion sensors (one on starboard side, one on port side)
- CO2 mixing ratio in the atmosphere (Licor7200)
- pCO2 in the surface ocean – measured using the PML underway system

The data were recorded continuously in international waters for the entire duration of the cruise. In the figure is an example of the data recorded during the 02/01/2020.

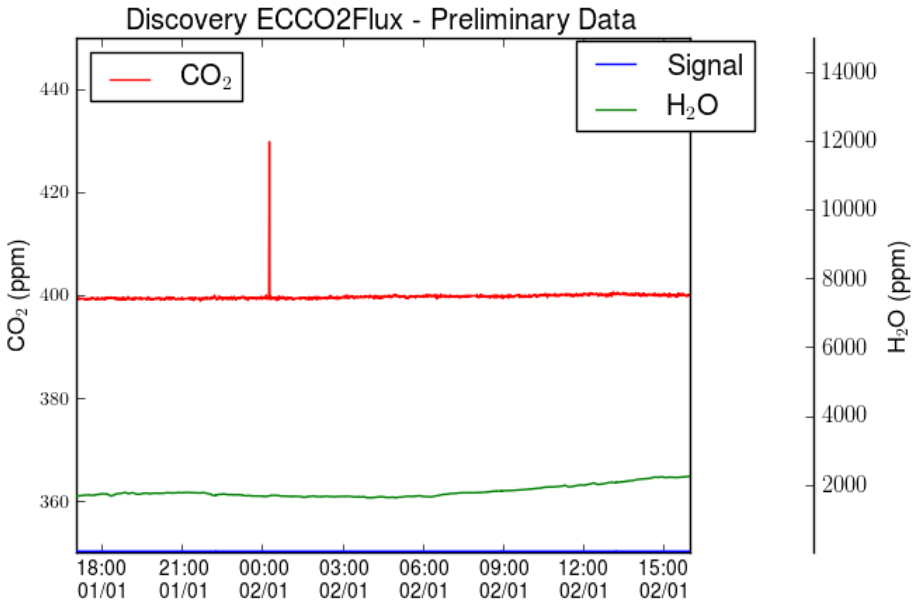


Figure 10 Licor CO2 and H2O Data example data

Trace metal sampling and analysis

Simon Ussher, Angela Milne, Antony Birchill, Isobel Turnbull (University of Plymouth)

Marine primary production drives carbon fixation in the ocean and is the base of the marine food web. It is therefore an important component of the Earth system (Falkowski and Raven, 2007). Iron (Fe) based proteins are required for numerous vital cellular processes (e.g. photosynthesis, respiration, nitrogen fixation), and Fe is therefore an essential nutrient for the growth of marine microbes (Twining and Baines, 2013, Tortell et al., 1996). The low availability of trace metals such as iron, and others such as manganese, can limit the growth of marine microbes (Moore et al., 2013). Therefore, understanding the distribution of trace metals in the ocean is vital in understanding carbon cycling and how this may change under future climate change scenarios. In order to determine the transport mechanisms and distribution of iron in oceanic provinces and determine any kind of meaningful mass balance requires the consideration of all forms of iron from truly soluble molecular species to colloidal and particulate species.

Greater than 99% of all dissolved iron in the oceans is thought to be complexed by organic ligands of unknown origin (Gledhill and Buck, 2012). During iron fertilisation experiments, the concentration of the strongest binding ligands (L1) increased with iron concentrations, leading to the theory that at least a portion of these strong ligands are biologically produced (Rue & Bruland 1997). Marine bacteria release siderophores (iron chelating compounds), which fall in the L1 class of ligands, as a specific iron

uptake strategy to compete for low iron concentrations. In the past 15 years several studies have sought to investigate the significance of bacterial siderophores as part of the iron binding ligand pool by sampling directly from the water column (e.g. Boiteau et al., 2016).

Water and suspended particulate sampling:

To study the iron cycling in the CUSTARD study area (DY111 South East Pacific) seawater and suspended particulate samples were collected for trace metal and ligand analyses to quantify the iron distribution of the region.

Water column samples were collected using OTE-Niskin bottles (10 L OTE bottles with external springs for trace metal work, mounted onto a titanium frame with Kevlar conducting wire). All sample processing was conducted in a trace metal clean laboratory using clean handling techniques. On a typical cast, unfiltered water samples were collected for onboard bacterial iron and carbon addition experiments (see report section on 'Fe and C (co) limitation of bacterial production'), macronutrient analyses (see report section on 'inorganic nutrients analysis'), siderophore filtration (see below), oxygen analyses, salinity calibration and total dissolvable metal analyses (acidified on-board for future analyses). Samples for the determination of dFe, Fe isotopes (to be analysed by Ali Lough at NOCS) and total ligand concentrations were filtered through a 0.2 µm cartridge filter (Sartorius). Approximately half of the 0.2 µm filtered seawater samples were filtered a second time over 0.02 µm Anotop syringe filters (Ussher et al., 2010) to determine the soluble fraction of trace metals. The remainder of the seawater in the OTE-Niskin bottle was passed over 0.45 µm polyethersulfone Supor^{TM} membrane (PES, Pall) filters to collect suspended and sinking particles. The filters were stored frozen for future analyses by acid digestion and ICP-MS analysis (Ohnemus et al. 2014; Milne et al. 2017). Samples for TdFe, dFe, sFe were acidified on board and will be analysed using methods described in Obata et al. (1993) and Klunder et al. (2011).

A total of 21 CTD deployments were carried out with the titanium frame. The first deployment was intended to soak the bottles overnight to ensure that they were 'trace metal clean' for future deployments.

On cast number 2 (CTD 02T Table 1) samples for DIC, C13 and DOC were also taken for each depth from the niskins. Due to difficulty sampling in the clean laboratory this was not continued and so not included in Table 1. DOC was also sampled at 6 depths on cast number 21 (see report section on 'Dissolved organic carbon, total dissolved amino acids').

Throughout the cruise, surface samples (ca. 3-4 m depth) were collected using a towed trace-metal-free fish. Along the sampling transect unfiltered samples were taken every 6 hours when not on station for total dissolvable Fe analyses, and filtered (as above) for dissolved Fe analyses. A total of 90 surface tow-fish samples were taken for TdFe/dFe throughout the cruise focussing along the CUSTARD north-south transect (OOI site to TS site).

Siderophore filtration:

For the collection of samples for siderophore analysis, 2L of unfiltered sea water samples were collected from titanium CTD deployments. Sampling was performed at 3 depths: (i) 20m, (ii) Mixed layer depth + 10m and (iii) 150-500m (one depth targeting the mesopelagic). Each sample was spiked with 50 ng/L (30 uL into 2L) of isotopically labelled riboflavin and filtered through a 0.2 µm PVDF Merck-Millipore Sterivex filter before passing over a 6ml Bond Elut ENV column, in series. The filter was frozen at -80 º C in a chest freezer for future DNA analyses, and the column was stored at -20 º for High Performance Liquid Chromatography Mass Spectrometry (HPLC-MS; see McCormak et al., 2003 for methods). To enable RNA analysis at corresponding depths to the siderophore collection, 3L of water was collected from the stainless CTD cast at the same station. This was filtered over a 0.2µm PVDF Merck-Millipore Sterivex filter within half an hour from water collection and the filter incubated with RNAlater solution for 12 hours at 4 º C. After incubation, the solution was discarded and filters frozen at -80 ºC for nucleic acid extraction back at Plymouth Marine Laboratory.

Remineralisation experiments:

Three remineralisation experiments were undertaken over the course of the cruise, these were initiated at visits to station TS (TS_2, TS_3, and TS_4; named REMIN 1-3). Briefly, SAPS Nitex mesh filters were deployed to a predetermined depth (see Table 2), the particles were rinsed from the mesh using 500 mL of filtered trace metal clean seawater using water from the same depth (from the titanium CTD) as where the particles were collected. This was then split into two equal volumes and used to inoculate duplicate (B1 and B2) polycarbonate incubation bottles containing 2L filtered seawater, again from the same depth as the particles. The bottles were incubated in the dark for a maximum of 10 days and shaken vigorously 3 times a day and just before each subsample. At specified time points, subsamples were taken for pFe and dFe, and POC and DOC. POC will be analysed by Fred Le Moigne and DOC by Chance English. Subsamples for Fe analysis were filtered through a 0.45um PES filter. The filter was frozen at -20 (pFe) and the filtrate acidified (dFe) for later analysis at Plymouth University. Finally bottles were rinsed with 0.02 M HCl to detect any Fe that was adsorbed to the bottle wall.

Remineralisation experiment water was collected from CTD nos. – 11, 17 and 20 (Table 1). Corresponding SAPS see Table 2.

SAPS filtration:

Large volume particle collection was undertaken from deployments of Stand Alone Pumps (SAPS). These were deployed at discrete depths (see Table 2) and the pumps turned on for an hour. The pumped seawater passed firstly over a 52 µm Nytex (Plastok Associates), and secondly through a 0.45 µm filter (293 mm Supor^{TM} PES, Pall). Following recovery, the 52 µm filter was rinsed with UHP water and the re-suspended particles collected on to a 0.45 µm filter (25 mm, Supor^{TM} PES, Pall). The 293 mm, 0.45

µm PES filters was sub-divided and double bagged into zip-lock bags. All collected filters were frozen at -20 ºC for shorebased analysis (Ohnemus et al. 2014; Milne et al. 2017).

Preliminary dissolved iron concentrations were determined onboard by Antony Birchill using flow injection chemiluminescence (Figure 1).

A summary of trace metal sampling is displayed in Table 1.

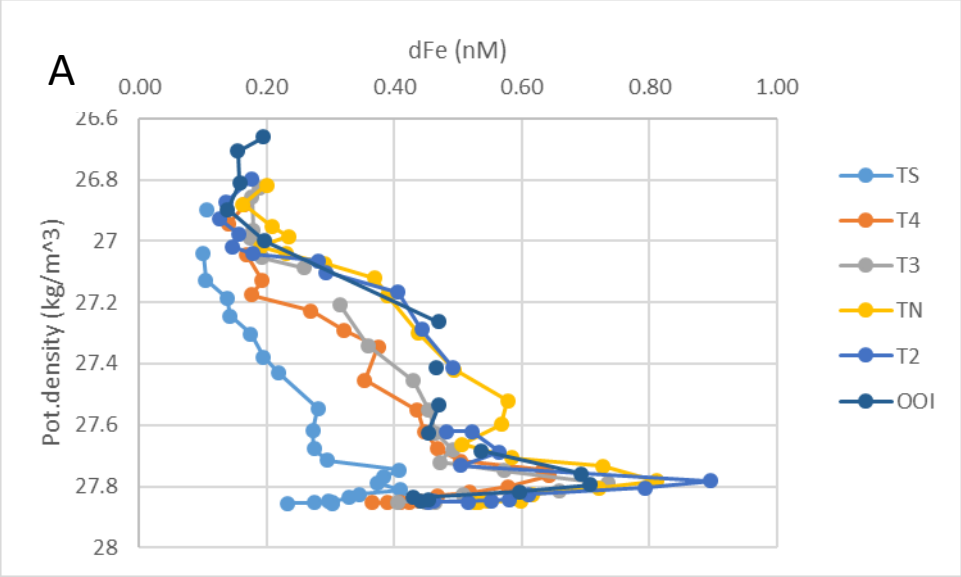
Table 9 Trace metal sampling summary.

Date	Station	CTD	Soluble trace metals	Dissolved trace metals	Total dissolvable trace metals	Particulate Trace Metals	Incubations	Ligands	O_2	Salinity	Siderophores	Macronutrients	Rare earth elements	Isotopes
6/12/19	OOI	2	12	16	16	11	3	3	3	4	3	24	10	11
8/12/19	TS	4	6	24	24	0	0	0	26	4	0	24	0	12
9/12/19	TS	5	12	16	16	11	5	3	3	4	3	24	10	11
11/12/19	TN	6	12	16	16	11	0	3	5	4	3	24	9	0
12/12/19	Tran2	7	12	24	24	0	0	0	3	4	0	24	0	12
13/12/19	Tran1	8	12	24	24	0	0	0	5	4	0	24	0	12
14/12/19	OOI2	9	12	19	19	11	3	3	6	4	3	24	0	0
15/12/19	OOI2	10	6	22	22	8	0	0	6	4	0	24	0	7
17/12/19	TS2	11	12	18	18	13	3	3	6	4	3	24	0	0
18/12/19	Tran4	12	12	24	24	0	0	0	6	4	0	24	0	12
18/12/19	Tran3	13	12	24	24	0	0	0	6	4	0	24	0	12
19/12/19	TN2	14	12	20	20	12	3	3	6	4	3	24	0	3
20/12/19	TN2	15	6	24	24	7	0	0	6	4	0	24	0	7
22/12/19	OOI3	16	12	15	15	10	3	3	6	4	3	24	0	0
27/12/19	TS3	17	12	23	23	15	0	3	6	4	3	24	15	0
27/12/19	TS3	18	0	3	0	0	6	0	0	0	0	6	0	0
29/12/19	TN3	19	12	17	17	11	2	0	6	4	0	24	0	9
31/12/19	TS4	20	12	15	15	10	3	0	6	4	0	24	0	0
02/01/20	OOI4	21	12	13	13	11	0	5	4	4	2	24	13	8
03/01/20	OOI4	22	10	13	13	11	1	0	6	3	0	24	0	8

Table 10 SAPS deployment summary. See Le Moigne cruise report for details on volume filtered and sampling for Th derived and biomineral fluxes.

DATE	STATION	SAPS DEPLOYED	DEPTHS (M)	NOTES
06/12/2019	OOI1	3	80,180,400	80m failed
09/12/2019	TS1	3	80,180,400	80m failed
11/12/2019-12/12/2019	TN1	3	80,180.400	400m failed
14-15/12/2019	OOI2	3	80,180,400	
16-17/12/2019	TS2	4	100, 120, 200, 400	Remin 1 setup (120 m).
21-22/12/2019	OOI3	3	50,150,400	
26-27/12/2019	TS3	3	40, 40, 140, 400	Remin 2 setup (40 m).
30-31/12/2019	TS4	4	50, 150, 150, 400	Remin 3 setup (150 m).

Preliminary data



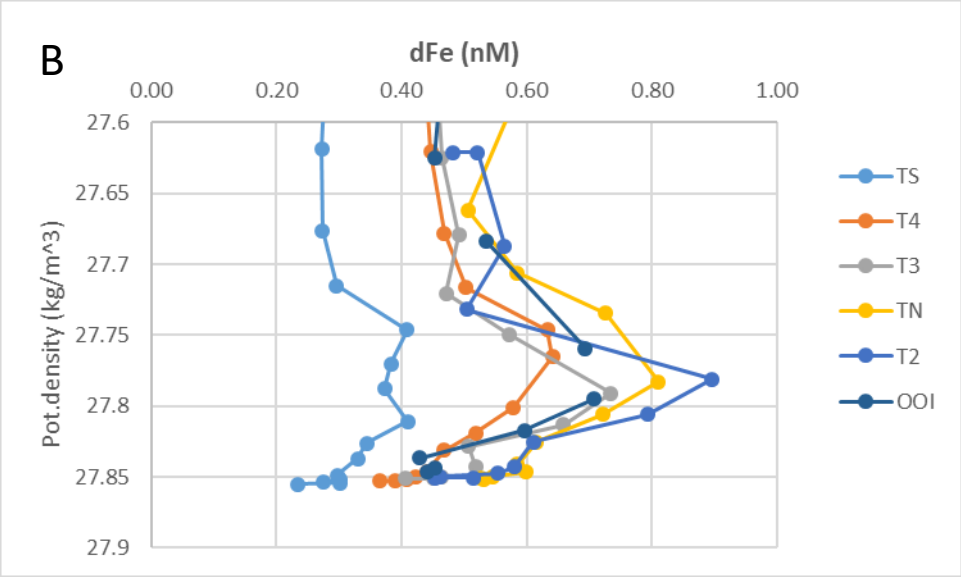


Figure 11 A: Dissolved Fe concentrations vs density for each station. Note the peak in Fe concentrations at density ~27.8 kg/m3. B: Zoomed in at density 27.6 – 27.9 kg/m3 revealing more detail with peak becoming seemingly more pronounced further North.

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^{234}Th and in situ pumps

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^{234}Th derived carbon and biomineral fluxes

Scientific motivation

Thorium-234 (^{234}Th, t1/2=24.1d) can be used to estimate how much POC is exported into the deep ocean (Buesseler et al 1992). ^{234}Th is the daughter isotope of naturally occurring 238-Uranium (^{238}U, t1/2=4.47.10^{9}y) which is conservative in seawater and proportional to salinity in a well oxygenated environment (Ku et al 1977). Unlike ^{238}U, ^{234}Th is particle reactive in the water column. As particles with ^{234}Th sink through the water column, a radioactive disequilibrium is formed between ^{238}U and ^{234}Th, which can be used to quantify the rate of carbon (POC) and biominerals (PIC, BSi) export from the surface ocean. This is possible with the ratios of POC, PIC or BSI to particulate ^{234}Th activity (Tsunogai & Minagawa 1976) obtained from large volume samples (e.g. *in situ* pumps: SAPS).

For DY111, POC, PIC and BSi downward fluxes will be calculated to assess the strength of downward export of particulate matter and interactions between POC and biomineral fluxes (Le Moigne et al 2012, Le Moigne et al 2013b) along contrasting environments in the Southern Ocean as described in (Le Moigne et al 2013a). Additionally, the excess of ^{234}Th below the euphotic zone will be assessed as a potential metric of particle remineralisation in the upper mesopelagic zone.

Sampling methodology and sampling treatment on board

Samples for thorium analysis were collected from a stainless steel CTD rosette at various stations (see Table). 4L water samples were collected at 16 horizons from surface to 750m depth where a significant export of particles is expected and thereby a disequilibrium between ^{234}Th and ^{238}U. ^{238}U concentration is derived from salinity measurement and thus is not directly measured from seawater samples. Total ^{234}Th is obtained by adding $KMnO_6$ (potassium permanganate), $MnCl_2$ (manganese dichloride) and concentrated ammonia (NH_3) to the 4L. Thorium is precipitated with MnO_2 within 8 hours after a spike of ^{230}Th was added as a yield monitor as described in Pike *et al* (2006). The formed precipitate is filtered onto 25mm precombusted QMA filters. Filters were then wrapped in mylar foil and counted in a Riso beta counter as described in (Le Moigne et al 2013b). Corrections are made for ^{234}Th decay and ^{234}Th in growth from ^{238}U decay since sampling. To calibrate ^{234}Th counting efficiency, mid water (2000m) samples were used, away from the surface ocean, coastal areas and seafloor nephleloid layers, where the secular equilibrium between ^{234}Th and ^{238}U is expected. The ratios of POC, PIC or BSI to particulate ^{234}Th activity will be obtained from particles from several depths sampled using SAPS as described in (Le Moigne et al 2013b).

Table 11: Station ID, CTD num, date, depth range.

Date	Station ID	Cast #	Depth	Niskin #	Date	Station ID	Cast #	Depth	Niskin #
06/12/2019	OOI1	002S	500	9	09/12/2019	TS1	005S	500	7
06/12/2019	OOI1	002S	400	10	09/12/2019	TS1	005S	400	8
06/12/2019	OOI1	002S	300	11	09/12/2019	TS1	005S	300	9
06/12/2019	OOI1	002S	200	12	09/12/2019	TS1	005S	200	10
06/12/2019	OOI1	002S	150	13	09/12/2019	TS1	005S	150	11
06/12/2019	OOI1	002S	100	15	09/12/2019	TS1	005S	125	12
06/12/2019	OOI1	002S	70	16	09/12/2019	TS1	005S	100	13
06/12/2019	OOI1	002S	50	17	09/12/2019	TS1	005S	75	15
06/12/2019	OOI1	002S	40	18	09/12/2019	TS1	005S	50	16
06/12/2019	OOI1	002S	125	14	09/12/2019	TS1	005S	40	17
06/12/2019	OOI1	002S	30	19	09/12/2019	TS1	005S	30	18
06/12/2019	OOI1	002S	20	20	09/12/2019	TS1	005S	20	20
06/12/2019	OOI1	002S	15	21	09/12/2019	TS1	005S	15	21
06/12/2019	OOI1	002S	10	22	09/12/2019	TS1	005S	10	22

06/12/2019	OOI1	002S	5	24	09/12/2019	TS1	005S	5	23
11/12/2019	TN1	009S	500	3	14/12/2019	OOI2	014s	500	3
11/12/2019	TN1	009S	400	4	14/12/2019	OOI2	014s	400	4
11/12/2019	TN1	009S	300	5	14/12/2019	OOI2	014s	300	5
11/12/2019	TN1	009S	200	7	14/12/2019	OOI2	014s	200	7
11/12/2019	TN1	009S	150	8	14/12/2019	OOI2	014s	150	8
11/12/2019	TN1	009S	125	9	14/12/2019	OOI2	014s	125	9
11/12/2019	TN1	009S	100	11	14/12/2019	OOI2	014s	100	11
11/12/2019	TN1	009S	75	13	14/12/2019	OOI2	014s	75	13
11/12/2019	TN1	009S	50	15	14/12/2019	OOI2	014s	50	15
11/12/2019	TN1	009S	40	17	14/12/2019	OOI2	014s	40	17
11/12/2019	TN1	009S	30	18	14/12/2019	OOI2	014s	30	18
11/12/2019	TN1	009S	20	20	14/12/2019	OOI2	014s	20	20
11/12/2019	TN1	009S	15	21	14/12/2019	OOI2	014s	15	21
11/12/2019	TN1	009S	10	22	14/12/2019	OOI2	014s	10	22
11/12/2019	TN1	009S	5	23	14/12/2019	OOI2	014s	5	23
17/12/2019	TS2	17s	750	4	19/12/2019	TN2	20s	750	2
17/12/2019	TS2	17s	400	6	19/12/2019	TN2	20s	500	3
17/12/2019	TS2	17s	300	7	19/12/2019	TN2	20s	400	4
17/12/2019	TS2	17s	200	9	19/12/2019	TN2	20s	300	5
17/12/2019	TS2	17s	150	10	19/12/2019	TN2	20s	200	7
17/12/2019	TS2	17s	125	11	19/12/2019	TN2	20s	150	8
17/12/2019	TS2	17s	100	12	19/12/2019	TN2	20s	120	9
17/12/2019	TS2	17s	75	14	19/12/2019	TN2	20s	100	11
17/12/2019	TS2	17s	50	16	19/12/2019	TN2	20s	70	13
17/12/2019	TS2	17s	40	17	19/12/2019	TN2	20s	50	15
17/12/2019	TS2	17s	30	18	19/12/2019	TN2	20s	40	17
17/12/2019	TS2	17s	20	20	19/12/2019	TN2	20s	30	18
17/12/2019	TS2	17s	15	21	19/12/2019	TN2	20s	20	20
17/12/2019	TS2	17s	10	22	19/12/2019	TN2	20s	15	21
17/12/2019	TS2	17s	5	23	19/12/2019	TN2	20s	10	22
22/12/2019	OOI3	24SS	750	2	19/12/2019	TN2	20s	5	23

22/12/2019	OOI3	24SS	500	3	27/12/2019	TS3	29SS	750	2
22/12/2019	OOI3	24SS	400	4	27/12/2019	TS3	29SS	500	3
22/12/2019	OOI3	24SS	300	5	27/12/2019	TS3	29SS	400	4
22/12/2019	OOI3	24SS	200	7	27/12/2019	TS3	29SS	200	7
22/12/2019	OOI3	24SS	150	8	27/12/2019	TS3	29SS	150	8
22/12/2019	OOI3	24SS	125	9	27/12/2019	TS3	29SS	125	9
22/12/2019	OOI3	24SS	100	11	27/12/2019	TS3	29SS	100	11
22/12/2019	OOI3	24SS	75	13	27/12/2019	TS3	29SS	75	13
22/12/2019	OOI3	24SS	50	15	27/12/2019	TS3	29SS	50	15
22/12/2019	OOI3	24SS	45	17	27/12/2019	TS3	29SS	40	17
22/12/2019	OOI3	24SS	30	18	27/12/2019	TS3	29SS	30	18
22/12/2019	OOI3	24SS	20	20	27/12/2019	TS3	29SS	20	20
22/12/2019	OOI3	24SS	15	21	27/12/2019	TS3	29SS	15	21
22/12/2019	OOI3	24SS	10	22	27/12/2019	TS3	29SS	10	22
22/12/2019	OOI3	24SS	5	23	27/12/2019	TS3	29SS	5	23
29/12/2019	TN3	33ss	750	2	30/12/2019	TS4	34SS	750	2
29/12/2019	TN3	33ss	500	3	30/12/2019	TS4	34SS	500	3
29/12/2019	TN3	33ss	400	4	30/12/2019	TS4	34SS	400	4
29/12/2019	TN3	33ss	300	5	30/12/2019	TS4	34SS	300	5
29/12/2019	TN3	33ss	200	7	30/12/2019	TS4	34SS	200	7
29/12/2019	TN3	33ss	150	8	30/12/2019	TS4	34SS	150	8
29/12/2019	TN3	33ss	125	9	30/12/2019	TS4	34SS	125	9
29/12/2019	TN3	33ss	100	11	30/12/2019	TS4	34SS	100	11
29/12/2019	TN3	33ss	75	13	30/12/2019	TS4	34SS	75	13
29/12/2019	TN3	33ss	50	15	30/12/2019	TS4	34SS	50	15
29/12/2019	TN3	33ss	40	17	30/12/2019	TS4	34SS	40	17
29/12/2019	TN3	33ss	30	18	30/12/2019	TS4	34SS	30	18
29/12/2019	TN3	33ss	20	20	30/12/2019	TS4	34SS	20	20
29/12/2019	TN3	33ss	15	21	30/12/2019	TS4	34SS	15	21
29/12/2019	TN3	33ss	10	22	30/12/2019	TS4	34SS	10	22
29/12/2019	TN3	33ss	5	23	30/12/2019	TS4	34SS	5	23
03/01/2020	OOI4	38SS	750	2	04/01/2020	TN4	41SS	750	2

03/01/2020	OOI4	38SS	500	3	04/01/2020	TN4	41SS	500	3
03/01/2020	OOI4	38SS	400	4	04/01/2020	TN4	41SS	400	4
03/01/2020	OOI4	38SS	300	5	04/01/2020	TN4	41SS	300	5
03/01/2020	OOI4	38SS	200	7	04/01/2020	TN4	41SS	200	7
03/01/2020	OOI4	38SS	150	8	04/01/2020	TN4	41SS	150	8
03/01/2020	OOI4	38SS	125	9	04/01/2020	TN4	41SS	125	9
03/01/2020	OOI4	38SS	100	11	04/01/2020	TN4	41SS	100	11
03/01/2020	OOI4	38SS	75	13	04/01/2020	TN4	41SS	75	13
03/01/2020	OOI4	38SS	50	15	04/01/2020	TN4	41SS	50	15
03/01/2020	OOI4	38SS	40	17	04/01/2020	TN4	41SS	40	17
03/01/2020	OOI4	38SS	30	18	04/01/2020	TN4	41SS	30	18
03/01/2020	OOI4	38SS	20	20	04/01/2020	TN4	41SS	20	20
03/01/2020	OOI4	38SS	15	21	04/01/2020	TN4	41SS	15	21
03/01/2020	OOI4	38SS	10	22	04/01/2020	TN4	41SS	10	22
03/01/2020	OOI4	38SS	5	23	04/01/2020	TN4	41SS	5	23
06/01/2020	TranARGO	43SS	2000	1					
06/01/2020	TranARGO	43SS	2000	1					
06/01/2020	TranARGO	43SS	2000	1					
06/01/2020	TranARGO	43SS	2000	1					

Further work and scientific outcomes

These results for ^{234}Th will be corrected for background counting after six months. The ^{238}U results will be calculated from calibrated salinity measurements. Once corrected, the ^{234}Th results will be integrated in order to obtain the ^{234}Th fluxes (dpm m^{-2} d^{-1}) to further extrapolate POC, calcite and opal export (g m^{-2} d^{-1}) with POC/^{234}Th, PIC/^{234}Th and Bsi/^{234}Th ratio obtained from high volume collection of particulate matter (SAPS).

SAPS deployment:

Three stand alone pumping system (SAPS) were devoted to Th derived carbon and biomineral fluxes as summarised in the table below. SAPS pumping time was set as 60 minutes. After recovery, particles were rinsed off the mesh on Th devoted SAPS and split for further Th, POC, PIC and BSi analysis back on land. Additionally, a split for plastics (see report section on 'Microplastics in the Southern Ocean') and DNA was taken (for Kim Bird, MBA, Plymouth). SAPS dedicated to trace metal work were also deployed (see report section on 'Trace metal sampling and analysis').

Table 12 SAPS depths.

Cruise	Station #	Date (dd/mm/yyy)	S/N SAPS	Depth (m)	Pump (min)	V0 (L)	V1 (L)	Volume pumped (L)	type
DY111	OOI1	06/12/2019	Sandie	400	60	99364	99364	0	TH (thorium)
DY111	OOI1	06/12/2019	Minnie	180	60	177242	177263	21	TH
DY111	OOI1	06/12/2019	Polly	80	60	363405	364939	1534	TH
DY111	OOI1	06/12/2019	Sophie	400	60	340693	341655	962	TM (metalS)
DY111	OOI1	06/12/2019	Sally	180	60	3523	4498	975	TM
DY111	OOI1	06/12/2019	Jenny	80	60	5285	5287	2	TM
DY111	TS1	09/12/2019	Polly	80	60	366233	367615	1382	TH
DY111	TS1	09/12/2019	Minnie	180	60	177253	178772	1519	TH
DY111	TS1	09/12/2019	Sandie	400	60	99358	100984	1626	TH
DY111	TS1	09/12/2019	Jenny	80	60	5288	5292	4	TM
DY111	TS1	09/12/2019	Sally	180	60	4500	5383	883	TM
DY111	TS1	09/12/2019	Sophie	400	60	341654	342525	871	TM
DY111	TN1	11/12/2019	POLLY	80	60	368637	370391	1754	TH
DY111	TN1	11/12/2019	MINNIE	180	60	178765	180415	1650	TH
DY111	TN1	11/12/2019	SOPHIE	80	60	344095	344901	806	TM
DY111	TN1	11/12/2019	SANDIE	180	60	102423	103339	916	TM
DY111	TN1	11/12/2019	SOPHIE	400	60	344901	346523	1622	TH
DY111	TN1	11/12/2019	SALLY	400	60	5608	5622	14	TM
DY112	TN1	12/12/2019	POLLY	10	60	370391	371702	1311	PL (plastics)
DY113	TN1	13/12/2019	SANDIE	80	60	103339	104760	1421	PL
DY114	TN1	14/12/2019	MINNIE	3000	60	180415	182081	1666	PL
DY111	OOI2	14/12/2019	POLLY	80	60	371703	373290	1587	TH
DY111	OOI2	14/12/2019	MINNIE	180	60	182092	183786	1694	TH
DY111	OOI2	14/12/2019	SANDIE	80	60	104761	106358	1597	TM
DY111	OOI2	14/12/2019	SOPHIE	180	60	346525	347383	858	TM
DY111	OOI2	14/12/2019	Polly	10	60	373398	374681	1283	PL
DY111	OOI2	14/12/2019	Sophie	80	60	347384	348741	1357	PL
DY111	OOI2	14/12/2019	SALLY	400	60	7524	9383	1859	TH

DY111	OOI2	14/12/2019	Sandie	400	60	106359	107381	1022	TM
DY111	OOI2	14/12/2019	Minnie	1500	60	183786	185468	1682	PL
DY111	TS2	16/11/2019	Polly	10	60	374681	375604	923	PL
DY111	TS2	16/11/2019	Sally	80	60	9383	10383	1000	PL
DY111	TS2	16/11/2019	Sophie	400	60	348042	348858	816	YM
DY111	TS2	16/11/2019	Sandie	400	60	107382	109100	1718	TH
DY111	TS2	16/11/2019	MINI	1200	60	185481	187138	1657	PL
DY111	TS2	17/11/2019	Sophie	100	60	348858	349453	595	TH
DY111	TS2	17/11/2019	MINNIE	100	60	187138	188778	1640	TH
DY111	TS2	17/11/2019	Sally	200	60	10383	11748	1365	TM
DY111	TS2	17/11/2019	Polly	200	60	375604	377316	1712	TM
DY111	TS2	17/11/2019	Sandie	120	60	109100	110807	1707	TM EX
DY111	TN2	19/12/2019	Jenny	10	60	5409	5425	16	PL
DY111	TN2	19/12/2019	SALLY	30	60	11748	13499	1751	TH
DY111	TN2	19/12/2019	SANDIE	130	60	110807	112308	1501	TH
DY111	TN2	19/12/2019	SOPHIE	400	60	349454	351075	1621	TH
DY111	TN2	19/12/2019	Polly	50+sb	60	377317	378952	1635	PL
DY111	TN2	19/12/2019	MINNIE	20+Sb	60	188789	190428	1639	PL
DY111	OOI3	21/12/2019	Minnie	10	60	190428	191818	1390	PL
DY111	OOI3	21/12/2019	Sally	400	60	13499	14550	1051	TM
DY111	OOI3	21/12/2019	Sophie	400	60	351075	352699	1624	TH
DY111	OOI3	22/12/2019	Sally	50	60	14550	15167	617	TM
DY111	OOI3	22/12/2019	Polly	50	60	378952	380626	1674	TH
DY111	OOI3	22/12/2019	Sandie	150	60	112308	113292	984	TM
DY111	OOI3	22/12/2019	Sophie	150	60	352699	354349	1650	TH
DY111	OOI3	22/12/2019	Minnie	50+sb	60	191819	193496	1677	PL
DY111	OOI3	22/12/2019	SANDY	20+Sb	60	113294	114930	1636	PL
DY111	TS3	26/12/2019	SANDIE	40	60	114931	115432	501	TM
DY111	TS3	26/12/2019	Minnie	40	60	193497	195127	1630	TH
DY111	TS3	26/12/2019	Sophie	40	60	354350	355789	1439	tmeX
DY111	TS3	26/12/2019	Sally	140	60	15168	15970	802	TM
DY111	TS3	26/12/2019	Polly	140	60	380627	381952	1325	TH

DY111	TS3	27/12/2019	Polly	10	60	381953	382899	946	PL
DY111	TS3	27/12/2019	SALLY	400	60	15971	16917	946	TM
DY111	TS3	27/12/2019	SOPHIE	400	60	355791	357387	1596	TH
DY111	TS3	27/12/2019	SANDIE	50+SB	60	115439	117083	1644	PL
DY111	TS3	27/12/2019	MINNIE	10+SB	60	195138	196750	1612	PL
DY111	TN3	29/12/2019	Minnie	40	60	196761	198352	1591	TH
DY111	TN3	29/12/2019	SANDIE	140	60	117083	118709	1626	TH
DY111	TN3	29/12/2019	POLLY	400	60	382900	384048	1148	TH
DY111	TN3	29/12/2019	SALLY	1000	60	16918	18754	1836	PL
DY111	TS4	30/12/2019	SOPHIE	50	60	357381	357909	528	TM
DY111	TS4	30/12/2019	Polly	50	60	384050	385083	1033	TH
DY111	TS4	30/12/2019	Sally	150	60	118765	119473	708	TM
DY111	TS4	30/12/2019	Minnie	150	60	198353	200053	1700	TH
DY111	TS4	31/12/2019	Sandie	150	60	118709	121183	2474	TMEX
DY111	TS4	31/12/2019	Sophie	400	60	357909	359428	1519	TM
DY111	TS4	31/12/2019	Minnie	400	60	200053	201739	1686	TH
DY111	TS4	31/12/2019	Polly	1500	60	385083	386007	924	PL
DY111	OOI4	02/01/2020	Polly	80	60	386007	386813	806	TH
DY111	OOI4	02/01/2020	SANDIE	280	60	121184	122858	1674	TH
DY111	OOI4	02/01/2020	MINNIE	400	60	201740	203446	1706	TH
DY111	OOI4	02/01/2020	SOHIE	1000	60	359529	361172	1643	PL
DY111	OOI4	03/01/2020	SANDIE	180	60	122858	124563	1705	TH
DY111	TN4	04/01/2020	SOPHIE	80	60	361173	362728	1555	TH
DY111	TN4	04/01/2020	SANDIE	180	60	124563	126252	1689	TH
DY111	TN4	04/01/2020	MINNIE	400	60	203445	205139	1694	TH

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Dissolved Organic Carbon, Total Dissolved Amino Acids

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Scientific Motivation:

The vertical export of dissolved organic carbon (DOC), a product of net community production, is a significant pathway in the global biological carbon pump. Each year, about 20% of global net community production, or 1.8 Pg C is exported from the euphotic zone as DOC (D. Hansell et al., 2009).While this is significant in the global ocean carbon cycle, DOC export has significant geographic variability and is most pronounced at high latitudes where deep-water formations transport suspended carbon to depth (Carlson et al., 2010; D. A. Hansell & Carlson, 1998). In order to assess the regional magnitude of DOM export it is necessary to quantify and determine the controls of its production and accumulation (i.e export potential). The Southern Ocean is characterized by high nutrient concentrations and several intermediate and deep-water formations that may contribute significantly to the passive

transport of suspended organic matter such as DOC (Takahashi et al., 2012). The goal of sampling DOC during the DY111 cruise is to evaluate its concentrations and fluxes along a meridional transect (54 25.285 – 59 59.170 S & 89 07.166 W) during the spring phytoplankton bloom in order to resolve the temporal and spatial variability of DOC. Additionally, samples for Total Dissolved Amino Acids (TDAA) were taken concurrently with DOC for 6-8 depths in the surface 300m. TDAA normalized to DOC concentrations serves as a proxy for the diagenetic state of DOC in the ocean, with more freshly produced DOC having a higher mol% TDAA than more degraded DOC (Davis et al., 2009). Evaluating the contribution of TDAA to bulk DOC in the surface will indicate recently produced DOC while enhanced TDAA in the upper mesopelagic will indicate recently exported DOC that escaped remineralization in the surface.

Sampling:

DOC profiles were taken 4 times at each main station at (TN, TS, OOI) at 17 depths from 0 to 1000m and at the transect stations at least once at 24 depths from 0-5000m. Approximately 400 samples were collected from profiles. DOC samples were passed through an inline filter holding a combusted GF/F filter attached directly to the Niskin. This was done to eliminate particles larger than 0.7 μm from the sample. All samples were rinsed 3 times with about 5 mL of seawater and collected into combusted 40 mL glass EPA vials. DOC samples were fixed with 75 μL of 4N Hydrochloric acid and stored at 6°C on board. Samples were shipped back to UCSB for analysis via high temperature combustion on Shimadzu TOC-V or TOC L analyzers. Sample vials were prepared for this cruise by soaking in 10% Hydrochloric acid, followed by a 3 times rinse with DI water. The vials were then combusted at 450°C for 4 hours to remove any organic matter. Vial caps were cleaned by soaking in DI water overnight, followed by a 3 times rinse with DI water and left out to dry.

TDAA samples were collected immediately following DOC sampling using the same GF/F filter. All samples were rinsed 3 times with about 5 mL of seawater and collected into 60 ml HDPE bottles. All HDPE's were cleaned by soaking in 10% HCl for 1 day followed by 3x rinse with DI water and dried. TDAA samples were immediately frozen following sampling at -20°C. Approximately 136 samples were taken for TDAA profiles.

Standard Operating Procedure for DOC Analyses- Carlson Lab UCSB

DOC samples will be analyzed via high temperature combustion using a Shimadzu TOC-V or Shimadzu TOC-L at an inshore based laboratory at the University of California, Santa Barbara. The operating conditions of the Shimadzu TOC-V have been slightly modified from the manufacturer's model system. The condensation coil has been removed and the headspace of an internal water trap was reduced to minimize the system's dead space. The combustion tube contains 0.5 cm Pt pillows placed on top of Pt alumina beads to improve peak shape and to reduce alteration of combustion matrix throughout the run.

CO2 free carrier gas is produced with a Whatman® gas generator (Carlson et al., 2010). Samples are drawn into a 5 ml injection syringe and acidified with 2M HCL (1.5%) and sparged for 1.5 minutes with CO2 free gas Three to five replicate 100 µl of sample are injected into a combustion tube heated to 680°C. The resulting gas stream is passed through several water and halide traps, including an added magnesium perchlorate trap. The CO2 in the carrier gas is analyzed with a non-dispersive infrared detector and the resulting peak area is integrated with Shimadzu chromatographic software. Injections continue until at least three injections meet the specified range of a SD of 0.1 area counts, CV ≤ 2% or best 3 of 5 injections. Extensive conditioning of the combustion tube with repeated injections of low carbon water (LCW) and deep seawater is essential to minimize the machine blanks. After conditioning, the system blank is assessed with UV oxidized low carbon water. The system response is standardized daily with a four-point calibration curve of Glucose solution in LCW. All samples are systematically referenced against low carbon water and deep Sargasso Sea (2600 m) or Santa Barbara Channel (400 m) reference waters and surface Sargasso Sea or Santa Barbara Channel sea water every 6 – 8 analyses (D. A. Hansell & Carlson, 1998). The standard deviation of the deep and surface references analyzed throughout a run generally have a coefficient of variation ranging between 1-3% over the 3-7 independent analyses (number of references depends on size of the run). Daily reference waters were calibrated with DOC CRM provided by D. Hansell (University of Miami; (D. Hansell et al., 2009)).

Standard Operating Procedure for TDAA Analyses- Carlson Lab UCSB

TDAA samples will be analyzed via HPLC at an inshore based laboratory at the University of California, Santa Barbara. TDAA, also know as Total Hydrolyzable Amino Acids, includes the total amino acid concentration of seawater including free amino acids as well as proteins and peptides that have been hydrolyzed into their individual amino acids. Concentrations of individual amino acids in samples will be determined against a stock solution of targeted amino acids. Targeted amino acids will include the following: Ammonium Chloride, Alanine, Arginine, Aspartic acid, Glutamic acid, Glycine, Histidine, Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Serine, Threonine, Tyrosine, Valine; γ-ABA and β-ALA can be added.

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Transparent Exopolymer Particles Sampling

Chelsey Baker (NOC)

Transparent exopolymer particles (TEP) were sampled at 4 depths from the CTD at 10 stations between the 6th of December 2019 and the 5th of January 2020.

Sample Collection:

Approximately 1L was sampled from Niskin bottles on the CTD using a tube into a seawater rinsed carboy. Samples were typically stored in the dark at 4 °C until the sample was ready to be filtered.

Sample Preparation:

TEP is measured by filtering seawater under very gentle vacuum (< 110 mmHg) and staining with calibrated diluted Alcian Blue solution which is later digested and the absorption of the sample is measured onshore on a spectrophotometer.

Typically, 30-75 mls of gently mixed seawater were filtered under low vacuum (always < 110 mmHG) through a 0.4 µm 25 mm polycarbonate filter (Whatman). Two 10 % HCL acid-cleaned glass filtration holders were used. Before the filter dried 0.5 mL of calibrated diluted Alcian Blue stain was added, filtered out and rinsed with MilliQ. Filter blanks were made by filtering 0.5 mL of Alcian Blue stain and rinsing with MilliQ. The collected samples were always visibly darker than the 6 blanks. For each depth 3-5 replicates were filtered to quantify the variability arising from filtering and TEP heterogeneity within the seawater. Filters were placed in 15 mL centrifuge tubes and frozen at -20 °C and will be analysed onshore.

Microplastics in Southern Ocean

Katsia Pabortsava (NOC, Southampton)

Rationale:

The extent of pollution of the remote Southern Ocean with small plastic particles of 10-1000 µm in size known as microplastics is unknown. Here we investigate the vertical distribution of these contaminants from surface ocean (10 m) down to bathypelagic depths (> 3000 m), including the nepheloid layer where microplastics could be re-suspended.

For the first time we will attempt to estimate the downward flux of microplastics out of the mixed layer using Thorium-234 as a proxy (see report section on '^{234}Th and in situ pumps' and e.g. Buesseler et al. 1992, Le Moigne et al. 2012).

Methods:

Microplastics in the water column were collected with large-volume stand-alone in situ pumps (SAPs). Cleaning of the filter holders and handling of the filter meshes before and after recovery were always carried out under the laminar flow hood on board of the ship to prevent airborne contamination. The SAPs were set to pump for 60 min. The volumes of seawater filtered by each SAP are shown in the table.

During DY111, two types of SAPs deployments were carried out:

1) Microplastics-dedicated SAPs were deployed to quantify and characterise abundance and distribution of microplastics in the water column. These SAPs were deployed at 3 discrete depths collecting particles including microplastics onto pre-combusted (450°C) 55 µm stainless steel mesh and pre-washed (10%+1%H2O2 HCl) 1 µm NITEX© nylon mesh. Upon recovery, the stainless-steel mesh was carefully folded and packed into a pre-combusted (450°C) glass petri dish, while the nylon mesh was wrapped in pre-combusted aluminium foil. All the samples were stored at -20°C until analysis.
2) Microplastics were also subsampled from SAPs deployed to collect marine particles for determination of the downward export of biogenic particles and microplastics using the Thorium-Uranium disequilibria method (hereafter Thorium-SAPs; see report section on '^{234}Th and in situ pumps'). Thorium-SAPs were deployed at 3 discrete depths below the mixed layer collecting marine particles including microplastics onto pre-washed (10%+1%H2O2 HCl) 53 µm NITEX© nylon mesh. Upon recovery, 1/8 fraction of the filter mesh was carefully cut out with clean stainless-steel scissors, immediately wrapped into pre-combusted (450°C) aluminium foil and stored at -20°C until analysis.

For contamination control, triplicates of all 3 types of meshes were prepared as for sampling with 3 L of MilliQ water washed through. The blanks were also kept at -20°C until analysis.

Samples collected:

The summary of all SAPs deployments is given in the table.

Table 13: Summary of SAPs deployments during DY111. Microplastics-dedicated deployments are highlighted in yellow.

Cruise	Station #	Date (dd/mm/yyyy)	SAPS ID	Depth (m)	V0 (L)	V1 (L)	Volume pumped (L)	Type
DY111	OOI1	06/12/2019	Sandie	400	99364	99364	0	TH (thorium)
DY111	OOI1	06/12/2019	Minnie	180	177242	177263	21	TH
DY111	OOI1	06/12/2019	Polly	80	363405	364939	1534	TH
DY111	OOI1	07/12/2019	Polly	4500	364939	366233	1294	PL (plastics)
DY111	TS1	09/12/2019	Polly	80	366233	367615	1382	TH
DY111	TS1	09/12/2019	Minnie	180	177253	178772	1519	TH
DY111	TS1	09/12/2019	Sandie	400	99358	100984	1626	TH
DY111	TS1	10/12/2019	POLLY	10	367617	368633	1016	PL
DY111	TS1	10/12/2019	SANDY	80	100985	102416	1431	PL
DY111	TS1	10/12/2019	SOPHIE	4400	342528	344087	1559	PL
DY111	TN1	11/12/2019	POLLY	80	368637	370391	1754	TH
DY111	TN1	11/12/2019	MINNIE	180	178765	180415	1650	TH
DY111	TN1	11/12/2019	SOPHIE	400	344901	346523	1622	TH
DY111	TN1	11/12/2019	POLLY	10	370391	371702	1311	PL
DY111	TN1	11/12/2019	SANDIE	80	103339	104760	1421	PL
DY111	TN1	11/12/2019	MINNIE	3000	180415	182081	1666	PL
DY111	OOI2	14/12/2019	POLLY	80	371703	373290	1587	TH
DY111	OOI2	14/12/2019	MINNIE	180	182092	183786	1694	TH
DY111	OOI2	14/12/2019	Polly	10	373398	374681	1283	PL
DY111	OOI2	14/12/2019	Sophie	80	347384	348741	1357	PL
DY111	OOI2	14/12/2019	SALLY	400	7524	9383	1859	TH
DY111	OOI2	14/12/2019	Minnie	1500	183786	185468	1682	PL
DY111	TS2	16/11/2019	Polly	10	374681	375604	923	PL
DY111	TS2	16/11/2019	Sally	80	9383	10383	1000	PL
DY111	TS2	16/11/2019	Sandie	400	107382	109100	1718	TH
DY111	TS2	16/11/2019	MINNIE	1200	185481	187138	1657	PL
DY111	TS2	17/11/2019	Sophie	100	348858	349453	595	TH
DY111	TS2	17/11/2019	MINNIE	100	187138	188778	1640	TH
DY111	TN2	19/12/2019	Jenny	10	5409	5425	16	PL
DY111	TN2	19/12/2019	SALLY	30	11748	13499	1751	TH
DY111	TN2	19/12/2019	SANDIE	130	110807	112308	1501	TH
DY111	TN2	19/12/2019	SOPHIE	400	349454	351075	1621	TH
DY111	TN2	19/12/2019	Polly	50+sb	377317	378952	1635	PL
DY111	TN2	19/12/2019	MINNIE	20+Sb	188789	190428	1639	PL
DY111	OOI3	21/12/2019	Minnie	10	190428	191818	1390	PL
DY111	OOI3	21/12/2019	Sophie	400	351075	352699	1624	TH
DY111	OOI3	22/12/2019	Polly	50	378952	380626	1674	TH
DY111	OOI3	22/12/2019	Sophie	150	352699	354349	1650	TH
DY111	OOI3	22/12/2019	Minnie	50+sb	191819	193496	1677	PL
DY111	OOI3	22/12/2019	SANDY	20+Sb	113294	114930	1636	PL
DY111	TS3	26/12/2019	Minnie	40	193497	195127	1630	TH
DY111	TS3	26/12/2019	Polly	140	380627	381952	1325	TH
DY111	TS3	27/12/2019	Polly	10	381953	382899	946	PL
DY111	TS3	27/12/2019	SOPHIE	400	355791	357387	1596	TH
DY111	TS3	27/12/2019	SANDIE	50+SB	115439	117083	1644	PL
DY111	TS3	27/12/2019	MINNIE	10+SB	195138	196750	1612	PL
DY111	TN3	29/12/2019	Minnie	40	196761	198352	1591	TH
DY111	TN3	29/12/2019	SANDIE	140	117083	118709	1626	TH
DY111	TN3	29/12/2019	POLLY	400	382900	384048	1148	TH
DY111	TN3	29/12/2019	SALLY	1000	16918	18754	1836	PL
DY111	TS4	30/12/2019	Polly	50	384050	385083	1033	TH
DY111	TS4	30/12/2019	Minnie	150	198353	200053	1700	TH
DY111	TS4	31/12/2019	Sophie	400	357909	359428	1519	TM
DY111	TS4	31/12/2019	Minnie	400	200053	201739	1686	TH

DY111	TS4	31/12/2019	Polly	1500	385083	386007	924	PL
DY111	OOI4	02/01/2020	Polly	80	386007	386813	806	TH
DY111	OOI4	02/01/2020	SANDIE	280	121184	122858	1674	TH
DY111	OOI4	02/01/2020	MINNIE	400	201740	203446	1706	TH
DY111	OOI4	02/01/2020	SOPHIE	1000	359529	361172	1643	PL
DY111	OOI4	03/01/2020	SANDIE	180	122858	124563	1705	TH
DY111	TN4	04/01/2020	SOPHIE	80	361173	362728	1555	TH
DY111	TN4	04/01/2020	SANDIE	180	124563	126252	1689	TH
DY111	TN4	04/01/2020	MINNIE	400	203445	205139	1694	TH

Further Analyses:

In the land laboratory, microplastics will be isolated from the biogenic marine particles by chemical digestion. Microplastics will then be detected and their chemical composition (polymer types) and morphology (size and shape) will determined using the Fourier-Transform infrared (FTIR) imaging technique. Concentrations of polymer-specific microplastics at the study region will be estimated.

Export of microplastics out of the mixed layer will be determined for the samples collected with method 2. Assumptions of Thorium-234 affinity to biofouled microplastics and entrained in sinking marine snow will be developed. The fluxes of microplastics will be derived using integrated ^{234}Th fluxes and ratios of microplastics to Thorium-234 on sinking particles using both steady and non-steady state Thorium flux models (Buesseler et al. 1992, Van der Loeff 2006, Le Moigne et al. 2012).

References:

Buesseler KO, Bacon MP, Cochran JK, Livingston HD. 1992. Carbon and nitrogen export during the JGOFS North Atlantic Bloom Experiment estimated from 234Th:238U disequilibria. Deep-Sea Research I 39: 1115-37

Le Moigne FAC, Sanders RJ, Villa-Alfageme M, Martin AP, Pabortsava K, et al. 2012. On the proportion of ballast versus non-ballast associated carbon export in the surface ocean. Geophys. Res. Lett. 39: L15610

Van der Loeff MR, Sarin MM, Baskaran M, Benitez-Nelson C, Buesseler KO, et al. 2006. A review of present techniques and methodological advances in analyzing Th-234 in aquatic systems. Marine Chemistry 100: 190-212

Marine Snow Catcher

Chelsey Baker (NOC) and Emmy McGarry (NOC)

Profiles of suspended, slow-sinking and fast-sinking particles were collected using Marine Snow Catchers (MSC) between the 6th of December 2019 and the 5th of January.

Particle Collection:

MSCs were deployed at three stations (OOI, TN and TS) with a particle profile collected at 3-4 depths which were chosen based on the mixed layer depth (MLD) and were the same as the Stand Alone Pump (SAPs) deployments. Typically, these depths were MLD+10m, MLD+110m, 400m and 750m. The deepest MSC depth of 750 m was chosen as all particles, and associated carbon, which sink below that depth will avoid the deepest winter mixed layers. All MSCs were typically deployed within two hours from shallowest to deepest. On occasions where MSCs were suspected to have misfired (diagnosed by green filters, high chlorophyll concentrations and a noticeable amount of paint and metal from the ship in the tray), a repeat of that depth was undertaken usually within 6 hours of the initial deployment. On occasion, salinity samples were taken for confirmation of whether MSCs had misfired. All MSCs deployed shallower than 600 m were deployed with an RBR mini-CTD which measures temperature, salinity, chlorophyll fluorescence, turbidity and pressure. After the first deployments with the RBR mini-CTD it became apparent that the Romika winch was overestimating the depth to which the MSCs were being deployed (see figure). From deployment 2 onwards all target depths were multiplied by 0.83 to calculate the appropriate depth for the winch. From deployment 1 onwards all depths line up with the SAPS deployment depths.

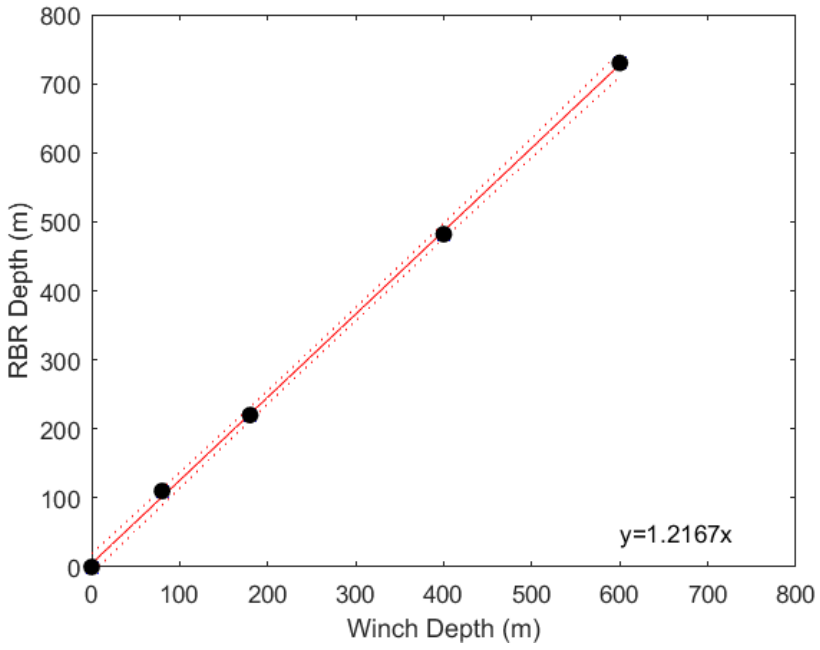


Figure 12 Target depth shown on the winch versus the actual depth recorded by the RBR mini-CTD for deployment 1.

A full description of the MSC and its assumptions are described in Riley et al. (2012), Giering et al. (2017) and Baker et al. (2017). The strategy for sampling fast-sinking particles was altered previously on the COMICS cruises to reduce user bias. Briefly, for T_{zero} and suspended particles 5 L each were collected from the tap in the middle of the top section. T_{zero} was sampled immediately as the MSC was secured on deck and after a 2 hour settling period the suspended particles were sampled from the middle tap. The tap was then left open to drain the suspended water. The lower tap, above the base section, was then opened to allow the remaining suspended water to drain slowly to reduce the re-suspension of any slow-sinking material. Draining the suspended water from the MSCs typically took 30 minutes and then the top section of the Snow Catcher was lifted off using the crane and a strop to allow users to sample from the base section. Before deployment 1 L modified Tupperware trays were placed inside the Snow Catcher to sample the fast-sinking material. The slow-sinking particles are defined as residing above the tray and below the top of the base section (typically 4 L of water) and were siphoned into a carboy from above the lip of the tray. A lid was then placed on the tray and carefully lifted off the MSC central pole. For some Snow Catcher deployments (see table) the remaining water around the tray was siphoned off to provide extra fast-sinking material to allow for O_2 respiration measurements (see report section on 'Dissolved organic carbon, total dissolved amino acids') or intra-MSC variability replicate measurements to be undertaken.

Concentrations of suspended, slow-sinking and fast-sinking particles ($p_{suspended}$, p_{slow} and p_{fast}, respectively) are calculated as follows:

$$p_{suspended} = p_{top} \quad 1)$$

$$p_{slow} = (p_{bottom} - p_{top}) \times V_{base}/V_{MSC} \quad 2)$$

$$p_{fast} = (p_{tray} - p_{bottom}) \times V_{tray}/(A_{tray} \times h_{MSC}) \quad 3)$$

where p is the particle concentration in the top, bottom or tray (p_{top}, p_{bottom} and p_{tray}, respectively), V_{base} is the volume of the base section (8 L), Vtray is the volume of the tray (typically ~ 1 L), V_{MSC} is the volume of the water left in the MSC after Tzero is sampled (95 L), A_{tray} is the area of the tray (0.026 m^2), and h_{MSC} is the height of the MSC (1.58 m).

Sample Preparation:

<u>*Dry weight, particulate organic carbon and nitrogen*</u> – Samples were filtered onto pre-combusted (24 h at 450 °C), pre-weighed glass fibre filters (GF/F; pore-size 0.7 µm, 25 mm diameter, Whatman). To remove any particulate inorganic carbon (PIC) 1-2 drops of 1 % HCl (v/v) were added to the filters, including blanks, and rinsed well with filtered seawater. The filters were then briefly rinsed with pH-adjusted MilliQ water (180 µL 25 % ammonium in 1 L MilliQ), dried in an oven (overnight at 30 °C), and stored in petri slides in a dark place. Blanks were prepared by filtering 1000 mL MilliQ and then following the protocol described above. Typically, for Tzero, suspended and slow-sinking fractions, 1000 mL were filtered in duplicates. For the fast-sinking fraction 250 mL were filtered in duplicates.

Particulate Inorganic Carbon – Samples were filtered onto polycarbonate filters (0.8 µm pore size, 25 mm; Whatman) and briefly rinsed with pH-adjusted MilliQ water (pH 8.5; 180 µL 25 % ammonium in 1 L MilliQ) to remove any salt. For Tzero, suspended and slow-sinking fractions 500 mL were filtered. For the fast-sinking fraction 100 mL were filtered. Blanks were prepared by filtering 500 mL MilliQ through a filter and following the protocol described above. Filters were placed into 50 mL corning tubes, dried (overnight at 30 °C) and stored for analysis back on land.

Biogenic Silica - Samples were filtered onto polycarbonate filters (0.8 µm pore size, 25 mm; Whatman) and briefly rinsed with pH-adjusted MilliQ water (pH 8.5; 180 µL 25 % ammonium in 1 L MilliQ) to remove any salt. For Tzero, suspended and slow-sinking fractions 500 mL were filtered. For the fast-sinking fraction 100 mL were filtered. Blanks were prepared by filtering 500 mL MilliQ through a filter and following the protocol described above. Filters were placed into 15 mL centrifuge tubes, dried (overnight at 30 °C) and stored for analysis on the following cruise DY112.

Chlorophyll a – Samples were filtered onto GF/F filters (nominal pore-size 0.7 µm, 25 mm diameter, Whatman), placed into glass vials filled with 6 mL acetone (90%, HPLC) and pigments extracted for 24 hours at 4 °C. Fluorescence was analysed on board as described in the report on pelagic sampling.

Microplankton Community Composition – 50 mL was transferred into amber glass bottles, fixed with a final concentrations of 3.6 % formaldehyde (buffered with di-sodium tetraborate, 0.25 g per L, 1.8 mL added to sample). Samples were stored at 4 °C in the dark until onshore analysis.

DNA/RNA analysis – Samples of the fast-sinking particle fraction were collected for DNA/RNA analysis on behalf of Dr Kim Bird from the Marine Biological Association. A 1 mL sub-sample of the fast-sinking fraction was transferred via a fresh plastic Pasteur pipette into a 2 mL tube. An equivalent amount of DNA/RNA shield was added. The tube was inverted 3 times to fully mix the sample and stored in a -20 °C freezer.

O_2 Respiration – Respiration profiles were carried once at stations OOI2, OOI4, TN2 and TS2 at three depths for each MSC fraction. At TN4 and TS4 an intra-MSC variability study was carried out on the four fractions with each fraction measured in triplicate. Samples were also taken for Total Carbon (TC). For further detail see the report section ‘Dissolved organic carbon, total dissolved amino acids’.

Variability Study:

An intra- and inter-MSC variability study was carried out at TS4 and TN4 to quantify the expected variability and to improve confidence in MSC concentrations and fluxes at different visits to sampling stations. Four MSCs were deployed at MLD+110m (130m at TS4 and 180m at TN4)

within an 80 minute period. The sampling strategy for the intra- and inter-variability at TS4 is shown below. The variability study was carried out within 12 hours of the MSC profile taken the day before. MSC5 was used in an O_2 respiration variability study outlined further in report section 'Dissolved organic carbon, total dissolved amino acids'.

Table 14

		POC	Bsi	PIC	Chl a	MPC	DNA	O2
MSC 3 @ MLD+110m	Tzero - 10 L	1000	500	500	100	50		
		1000	500	500	100			
		1000	500	500	100			
	Susp - 10 L	1000	500	500	100	50		
		1000	500	500	100			
		1000	500	500	100			
	Slow - All	600	300	300	100	50		
		600	300	300	100			
		600	300	300	100			
	Fast - tray + outside	250	100	100	100	50	1	
		250	100	100	100		1	
		250	100	100	100		1	
MSC 2 @ MLD+110m	Tzero	1000	500	500	100	50		
		1000						
	Susp	1000	500	500	100	50		
		1000						
	Slow	1000	500	500	100	50		
		1000						
	Fast	250	100	100	100	50	1	
		250						
MSC 4 @ MLD+110m	Tzero	1000	500	500	100	50		
		1000						
	Susp	1000	500	500	100	50		
		1000						
	Slow	1000	500	500	100	50		
		1000						
	Fast	250	100	100	100	50	1	
		250						
MSC 5 @ MLD+110m	Tzero	1000	500	500	100	50		125
		1000						125
								125
	Susp	1000	500	500	100	50		125
		1000						125
								125
	Slow	1000	500	500	100	50		125
		1000						125
								125
	Fast - tray + outside	250	100	100	100	50	1	125
		250						125
								125

Table 15 Sample Summary

Date	Ship Station Nr	Event Number	MSC ID	Depth (m)	Latitude	Longitude	Time Fired (GMT)	Time t0 (GMT)	Time Sampling (GMT)	SST	Salinity	Wind Speed (rel)	Heading	Echo Depth	Purpose	Processed	To be analysed	Comments
06.12.2019	OOI1	10	MSC1 blue	80 (110)	-54 25.3	89 7.7	11:28	11:33	-	6.93	34.146	18.6	288.2	4644	Fluxes	No	No	Leaked on retreival. Not processed.
06.12.2019	OOI1	12	MSC1 blue	80 (110)	-54 25.3	89 7.7	13:09	13:15	-	6.91	34.14	13.63	266	4646	Fluxes	No	No	Leaked once on deck and paint entered the base during the separation of the top and the base. Not processed.
06.12.2019	OOI1	13	MSC2 red	180 (220)	-54 25.28	89 7.7	13:32	13:40	15:40	6.9	34.14	18		4645	Fluxes	Yes	Yes	Really hard to detach top and base. Inner tray also stuck on the base pole and started leaking when detached. ~ 2/3 of fast sinking water lost.
06.12.2019	OOI1	14	MSC4 yellow	400 (485)	-54 25.27	89 7.7	11:05	14:23	16:23	6.95	34.14	16.3		4645.9	Fluxes	Yes	Yes	Some paint flakes in the base. Sent down two messengers as we couldn't feel it trigger.
06.12.2019	OOI1	15	MSC5 grey	80 (110)	-54 25.28	89 7.7	14:36	14:41	16:41	6.99	34.133	16.5	289.7	4647	Fluxes	Yes	Yes	For MSCs 10-15 the depths in brackets are the actual depths - the winch was overshooting the target depths - issue will be accounted for with future deployments
09-Dec-19	TS1	30	MSC1 blue	80	-59 57.4	89 7.6	10:10	10:19	12:19	4.81	34.066	18	251.6	5031.1	Fluxes	Yes	Yes	Leaking from bolt at top of MSC. Will still sample. After suspended sampling the top came away from the base therefore suspended water didn't empty very gently
09-Dec-19	TS1	31	MSC2 red	180	-59 57.6	89 7.4	10:35	10:41	12:41	4.79	34.066	17		5037	Fluxes	Yes	Yes	
09-Dec-19	TS1	32	MSC4 yellow	400	-59 57.8	89 7.3	11:11	11:26	-	4.79	34.065	17	248.8	5039.5	Fluxes	No	No	Large leak from base. Not processed. MSC4 should be tightened more than other snowcatchers
09-Dec-19	TS1	33	MSC5 grey	400	-59 58.2	89 7.1	11:49	12:00	14:00	4.79	34.065	16.6	249.7	5041	Fluxes	Yes	Yes	
11.12.2019	TN1	47	MSC1 blue	80	-56 59.9	89 7.9	08:35	08:39	-	6.77	34.15	16	288.9	5248.6	Fluxes	No	No	MSC1 leaked again between the top and the base even after taking extra care to perfectly align the clamps and the seal appeared sound. MSC1 will not be used again on the cruise.
11.12.2019	TN1	48	MSC2 red	80	-57 0.1	89 8.0	08:56	09:01	11:01	6.76	34.15	18	288.2	5244.9	Fluxes	Yes	Yes	
11.12.2019	TN1	49	MSC4 yellow	180	-57 0.3	89 8.1	09:19	09:25	11:25	6.76	34.15	16.8	289.3	5242.1	Fluxes	Yes	No	Chlorophyll concentration indicates it was a misfire
11.12.2019	TN1	50	MSC5-grey	400	-57 0.4	89 8.2	09:45	10:09	12:09	6.77	34.15	17	288.9	5240.8	Fluxes	Yes	Yes	
11.12.2019	TN1	51	MSC3 -green	130	-57 0.67	89 8.4	10:23	10:29	12:29	6.77	34.15	15	288.3	5244.2	Fluxes	Yes	Yes	
14-Dec-19	OOI2	70	MSC2 red	80	-54 25.6	89 6.4	08:35	08:40	10:40	7.63	34.106	5	334.4	4427.7	Fluxes	Yes	Yes	
14-Dec-19	OOI2	71	MSC3 -green	180	-54 25.6	89 6.4	08:59	09:06	11:06	7.56	34.107	3	334.6	4427.7	Fluxes	Yes	Yes	
14-Dec-19	OOI2	72	MSC4 yellow	400	-54 25.6	89 6.4	09:27	09:39	11:39	7.6	34.107	3	335.4	4428.1	Fluxes	Yes	No	Likely a misfire as lots of material in tray and green filters. Processed all apart from MPC and Kim Bird samples. Salnity also tested to check if misfired. Chl indicates also likely a misfire.
14-Dec-19	OOI2	73	MSC5-grey	700	-54 25.6	89 6.4	10:12	10:38	12:38	7.68	34.107	4	334.7	4503.5	Fluxes	Yes	Yes	

Date	Ship Station Nr	Event Number	MSC ID	Depth (m)	Latitude	Longitude	Time Fired (GMT)	Time t0 (GMT)	Time Sampling (GMT)	SST	Salinity	Wind Speed (rel)	Heading	Echo Depth	Purpose	Processed	To be analysed	Comments
14-Dec-19	OOI2	77	MSC5-grey	400	-54 25.6	89 6.2	17:25	17:39	19:39	7.51	34.106	18	290.6	4431.3	Fluxes	Yes	Yes	Completed later as a repeat of event 72 but also appeared to misfire as again lots of paint in the tray and green filters. Salinity also tested. Potentially due to release being dipped in and out of water when held at surface. Swell was quite large when snowcatcher was deployed.
18-Dec-19	TS2	89	MSC2 red	100	-59 57.6	89 7.4	08:28	08:33	10:33	5.84	34.019	17	315.4	5037.5	Fluxes	Yes	Yes	
18-Dec-19	TS2	90	MSC3 -green	200	-59 57.6	89 7.4	08:48	08:55	10:55	5.82	34.021	17	341.7	5054.9	Fluxes	Yes	Yes	
18-Dec-19	TS2	91	MSC4 yellow	400	-59 57.6	89 7.4	09:22	09:34	11:34	5.79	34.021	15	256.5	5037.3	Fluxes	Yes	Yes	
18-Dec-19	TS2	92	MSC5-grey	750	-59 57.6	89 7.4	10:02	10:23	12:23	5.77	34.021	13	122.7	5037.5	Fluxes	Yes	Yes	
20-Dec-19	TN2	112	MSC4-yellow	30	-57 0.6	89 8.9	09:13	09:16	11:16	7.57	34.095	14	308	5252.9	Fluxes	Yes	Yes	tested new release wire with a shorter loop to prevent misfires - worked well
20-Dec-19	TN2	113	MSC2-red	130	-57 0.7	89 8.9	09:29	09:34	11:34	7.57	34.095	14	310.6	5255.2	Fluxes	Yes	Yes	
20-Dec-19	TN2	114	MSC3-green	400	-57 0.8	89 9.1	09:53	10:07	12:07	7.59	34.094	17	309	5258.9	Fluxes	Yes	Yes	
20-Dec-19	TN2	115	MSC5-grey	750	-57 0.9	89 9.3	10:33	10:55	12:55	7.51	34.093	13	311.2	5262	Fluxes	Yes	Yes	
22-Dec-19	OOI3	127	MSC2 red	50	-54 24.9	89 7.9	07:36			8.19	34.001	20	179.1	4650.4	Fluxes	No	No	Messenger fell off (saved by safety wire). Don't use loose messenger again.
22-Dec-19	OOI3	128	MSC2 red	50	-54 24.9	89 7.9	07:44	07:47	09:47	8.19	34.002	18	180.8	4650.9	Fluxes	Yes	Yes	
22-Dec-19	OOI3	129	MSC3 -green	150	-54 24.9	89 7.9	08:01	08:07	10:07	8.17	34.082	20	179.8	4650.5	Fluxes	Yes	Yes	
22-Dec-19	OOI3	130	MSC4 yellow	400	-54 24.9	89 7.9	08:27	08:39	10:39	8.17	34.082	17	180.4	4650.7	Fluxes	Yes	Yes	
22-Dec-19	OOI3	131	MSC5-grey	750	-54 24.9	89 7.9	09:05	09:27	11:27	8.19	34.083	19	180.9	4650.4	Fluxes	Yes	Yes	Tray slightly elevated above the base upon recovery.
27-Dec-19	TS3	147	MSC2 red	40	-59 57.8	89 7.7	08:18	08:21	10:21	5.39	33.989	11	289.9	5034.7	Fluxes	No	No	Likely fired at surface, lots of copepods in tray. Processed Tzero and Susp for POC. Filters very green no further processing.
27-Dec-19	TS3	148	MSC3 -green	140	-59 57.9	89 7.5	08:37	08:42	10:42	5.38	33.988	11	289.3	5043.2	Fluxes	Yes	Yes	
27-Dec-19	TS3	149	MSC4 yellow	400	-59 58.1	89 7.4	09:00	09:13	11:03	5.37	33.99	12	290.6	5044.8	Fluxes	Yes	Yes	Sampled about 10 minutes early
27-Dec-19	TS3	150	MSC5-grey	750	-59 58.4	89 7.2	09:39			5.38	33.989	8	290.2	5044	Fluxes	No	No	Leaking from base seal. After taken apart seen that O-ring had become dislodged.
27-Dec-19	TS3	152	MSC5-grey	50	-59 57.5	89 7.9	15:48	16:09	17:09	5.52	33.986	8	265.6	5031.1	Fluxes	Yes		Sampled for suspended 1 hour early. Drained and dismantled after 2 hours
27-Dec-19	TS3	153	MSC2 red	750	-59 57.9	89 7.3	16:24	16:29	18:29	5.48	33.984	3	271.3	5043.2	Fluxes	Yes	Yes	
29-Dec-19	TN3	165	MSC2-Red	30	-57 1.5	-89 7.6	08:35	08:38	10:38	7.92	34.066	22	309.2	5252.3	Fluxes	Yes	Yes	
29-Dec-19	TN3	166	MSC3-green	130	-57 1.6	-89 7.6	08:50	08:55	10:55	7.88	34.067	23	310.3	5256.6	Fluxes	Yes	Yes	
29-Dec-19	TN3	167	MSC4-yellow	400	-57 1.8	-89 7.5	09:15	09:28	11:28	7.93	34.066	16	308.2	5249.2	Fluxes	Yes	Yes	

Date	Ship Station Nr	Event Number	MSC ID	Depth (m)	Latitude	Longitude	Time Fired (GMT)	Time t0 (GMT)	Time Sampling (GMT)	SST	Salinity	Wind Speed (rel)	Heading	Echo Depth	Purpose	Processed	To be analysed	Comments
30-Dec-19	TS4	177	MSC2-red	50	-59 58.58	-89 7.555	19:49	19:52	21:52	6.22	33.979	13.05	275.3	5043	Fluxes	Yes	Yes	
30-Dec-19	TS4	178	MSC3-green	150	-59 58.74	-89 7.41	20:06	20:13	22:13	6.23	33.977	12.27	275.2	5057.6	Fluxes	Yes	Yes	
30-Dec-19	TS4	179	MSC4-yellow	400	-59 58.92	-89 7.24	20:31	20:43	22:43	6.23	33.97	13.23	274.5	5044.2	Fluxes	Yes	Yes	
30-Dec-19	TS4	180	MSC5-grey	750	-59 59.3	-89 6.9	21:15	21:33	23:33	6.24	33.98	13	273.6	5044.2	Fluxes	Yes	Yes	
31-Dec-19	TS4	187	MSC3-green	130	-59 58.8	-89 7.6	07:47	02:53	09:53	6.19	33.974	9	322.4	5043.7	Variability	Yes	Yes	
31-Dec-19	TS4	188	MSC2-red	130	-59 58.9	-89 7.6	08:04	08:09	10:09	6.18	33.975	6	319.2	5044.2	Variability	Yes	Yes	
31-Dec-19	TS4	189	MSC4-yellow	130	-59 59.2	-89 7.5	08:22	08:26	10:26	6.16	33.975	8	320.8	5044.8	Variability	Yes	Yes	
31-Dec-19	TS4	190	MSC5-grey	130	-59 59.3	-89 7.6	08:37	08:43	10:43	6.15	33.97	6	321.4	5044.2	Respiration Variability	Yes	Yes	
03-Dec-20	OOI4	201 (199)	MSC2-Red	70	-54 24.9	-89 7.6	10:21	10:25	12:25	8.61	34.035	7	270.5	4654.8	Fluxes	Yes	Yes	After suspended was sampled MSC wasn't drained for 10 minutes
03-Dec-20	OOI4	202 (200)	MSC3-green	170	-54 24.9	-89 7.6	10:43	10:48	12:48	8.63	34.034	2.75	270	4654.8	Fluxes	Yes	Yes	
03-Dec-20	OOI4	203 (201)	MSC4-yellow	400	-54 24.9	-89 7.6	11:08	11:18	13:18	8.6	34.036	8	270.1	4654.6	Fluxes	Yes	No	Lots of paint and bits in tray, also filters were greener than expected. Repeated later in the day
03-Dec-20	OOI4	204 (202)	MSC5-grey	750	-54 24.9	-89 7.6	11:49	12:07	14:07	8.64	34.035	8	269.3	4655.1	Fluxes	Yes	Yes	
03-Dec-20	OOI4	210	MSC5-grey	400	-54 24.9	-89 7.6	19:48	19:59	21.59	8.8	34.034	19	293.6	4652.8	Fluxes	Yes	Yes	
04-Jan-20	TN4	217	MSC2-red	80	-56 59.9	-89 7.9	21:28	21:32	23:33	7.82	34.04	20	215.7	5250.5	Fluxes	Yes	Yes	
04-Jan-20	TN4	218	MSC3-green	180	-57 0.04	-89 7.9	21:46	21:52	23:52	7.82	34.041	22	220.7	5248.8	Fluxes	Yes	Yes	
04-Jan-20	TN4	219	MSC4-Yellow	400	-57 0.1	-89 7.9	22:10	22:20	00:20	7.82	34.04	22	220.6	5247.4	Fluxes	Yes	Yes	
04-Jan-20	TN4	220	MSC5-grey	750	-57 0.2	-89 7.8	22:50	23:13	01:13	7.81	34.04	22	211.3	5244.8	Fluxes	Yes	Yes	
05-Jan-20	TN4	227	MSC3-Green	180	-57 0.0	-89 7.9	08:45	08:50	10:50	7.78	34.047	22	300.7	5266.2	Variability	Yes	Yes	
05-Jan-20	TN4	228	MSC2-Red	180	-57 0.1	-89 7.9	09:03	09:09	11:09	7.76	34.047	20	300.6	5264.2	Variability	Yes	Yes	
05-Jan-20	TN4	229	MSC4-Yellow	180	-57 0.2	-89 7.9	09:24	09:30	11:30	7.72	34.046	26	300.1	5245.2	Variability	Yes	Yes	
05-Jan-20	TN4	230	MSC5-Grey	180	-57 0.3	-89 7.9	09:41	09:48	11:48	7.78	34.042	25	300.3	5243.2	Respiration Variability	Yes	Yes	

Red Camera Frame

Nathan Briggs, Emmy McGarry (NOC)

Objective:

The Red Camera Frame (RCF) carried different optical sensors which measure the characteristics of the particle field in the epipelagic and upper mesopelagic zones: LISST HOLO2, P-Cam, CPICS, ECO Triplet and RBR Concerto.

Due to a 600 m depth rating on the LISST HOLO2, profiles were conducted to 600 m, although the first two profiles accidentally went deeper (to 730 m) due to poor calibration of the wire out calculation on the Romica winch. Before each deployment, the frame was lowered to approx. 5 m depth for 30 s in order to remove trapped bubbles and give the LISST Holo2 time to turn on (though it's not clear if this was needed).

In total, 24 RCF deployments were done successfully; 8 at each of the three stations, roughly half at night-time or near night-time.

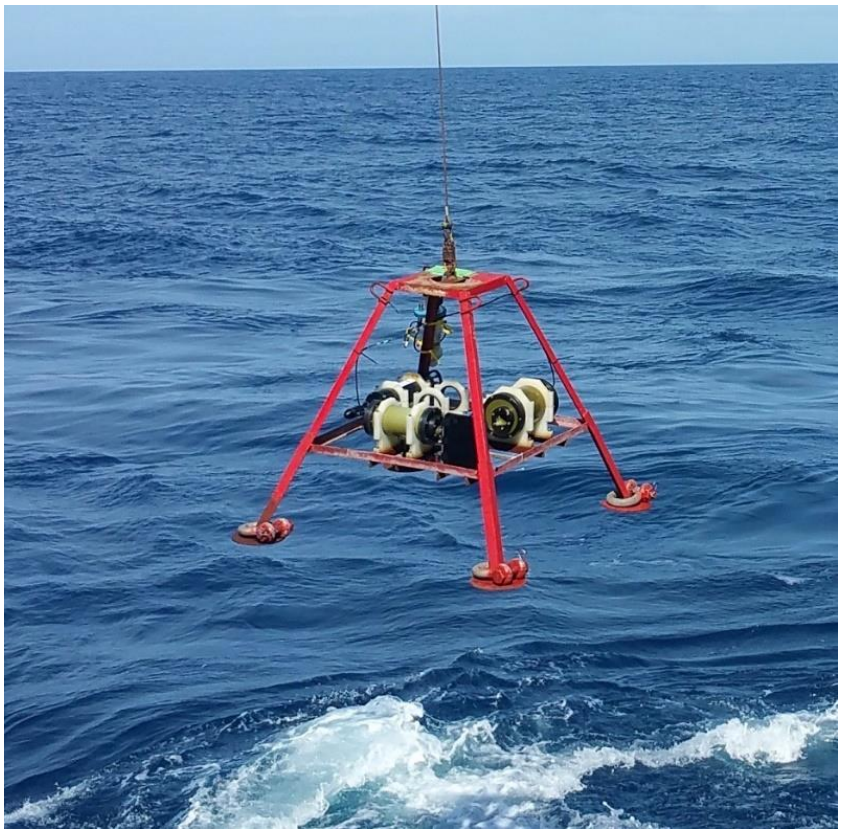


Figure 13 Deployment of Red Camera Frame with LISST HOLO2, P-Cam, Eco Triplet and RBR Concerto. By the time of the photo CPICS had already leaked and was not mounted.

LISST-Holo2:

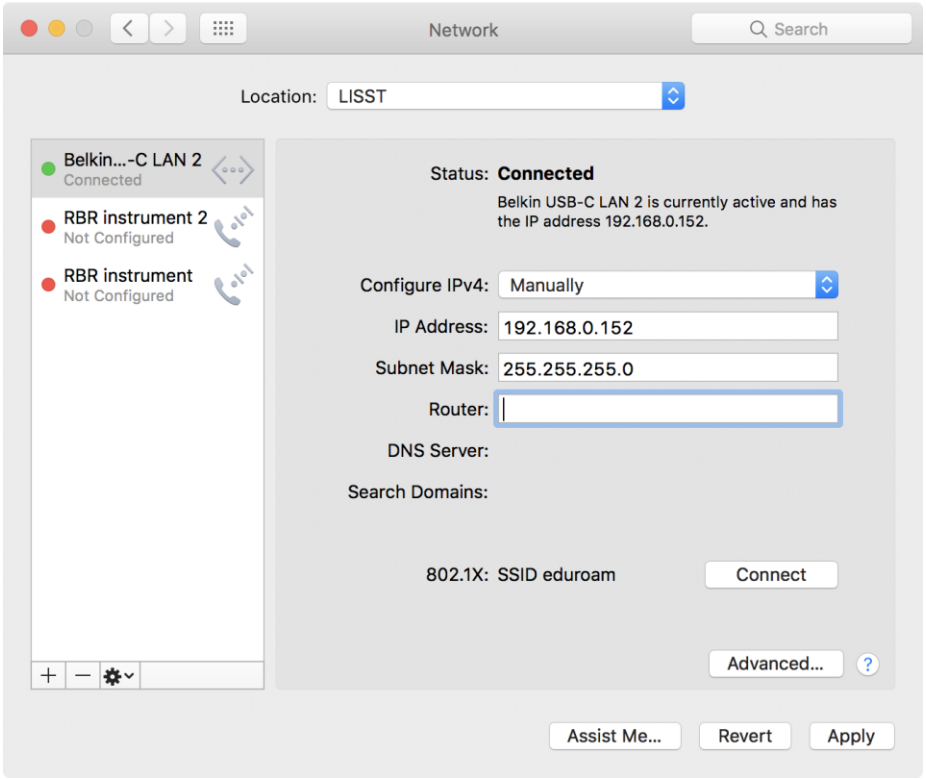
The LISST-HOLO2 is a submersible digital holographic camera. During DY111 it was operated in a self-contained mode powered from its rechargeable internal battery pack. An external battery pack was brought but it was not needed. The LISST-Holo2 internal battery can record for ~40 hours at high resolution according to the manual. We recharged it twice during the cruise. The instrument records in-line holographic images that are stored in internal flash memory or an 'external memory module' (EMM). During this cruise we used internal flash memory only. These PGM (portable grey map) images also code supporting data, date, time, temperature, depth, and instrument details in the file structure (see Sequoia manual section 12, p65 for details). This supporting data can be read in plain text at the end of the file using the 'HEXview' option in Irfanview (convenient software for opening and viewing the .PGM files). This is a useful feature where the file's original timestamp may have been lost on copying of file transfer.

The notional capability of the instrument is the detection and volume measuring of particles in the size range 25-2500µm equivalent spherical diameter, through a path length of 50mm, having a sampled volume of 1.86cm^3. Optical sections of the recorded image are reconstructed mathematically from the interference fringes produced by the interaction of particles with the laser illumination. The LISST Holo2 can sample at up to 25 Hz. However, we did not have sufficient hard disk space to store and back up full-resolution profiles for the entire cruise. In future cruises, we recommend bringing 10 TB or more of storage! We started at 1 Hz and gradually increased sample resolution to 10 Hz over the course of the cruise. At our nominal 0.2 m/s descent rate (actually closer to 0.25 m/s due to the winch calibration), this provided 4-40 images per meter.

LISST-Holo Data Download and Programming

After each profile, data were downloaded to a Macbook Pro directly from the instrument via ftp. The steps to download the data and program the LISST for the next profile were:

1. Connect the LISST Holo2 to external power (not necessary but saves battery)
2. Wake the instrument by switching the magnetic switch from O to I and back to O again.
3. Connect instrument to computer via the supplied ethernet cable.
4. Change the computer's internet settings to a fixed IP address on the same network as the LISST Holo2. The LISST Holo2 IP address was set to 192.168.0.150 so we created a new network profile on the computer, setting the computer to 192.168.0.152 (see image)



5. Open browser (we used Firefox) and navigate to the instrument's IP address (192.168.0.150)
6. If the instrument has finished waking up, this should bring up a webpage for controlling the instrument. Navigate to the "Images" tab to ensure that the instrument has recorded images and note the name of the last image (will be at the top of the list).
7. Navigate to the "tools" tab and click the box labelled "disable sleep" so that the instrument doesn't turn off in the middle of the data download. Then click apply. NOTE: IF YOU FORGET TO UNCHECK THIS BOX AFTER DOWNLOADING, THE LISST WILL NOT SLEEP AND WILL CONTINUE TO DRAIN BATTERY AFTER IT IS UNPLUGGED.
8. We did not have good success using ftp software with a graphical user interface (cyberduck) to download data, because there were too many files and the software couldn't load them. Instead we used ftp via the Mac terminal:
    a. navigate in the terminal to the desired destination folder for the data
    b. enter the command "ftp"
    c. enter "open 102.168.0.150"
    d. for user name, enter "anonymous"
    e. for password, press enter (no password)
    f. enter "cd images" to navigate to the images folder on the instrument
    g. enter "mget *.pgm" to download all .pgm files in the folder
    h. enter "a" to confirm all downloads
    i. The terminal will start showing the names of the files as they are downloaded. The download could take about an hour. When it is done you will see the ftp prompt again.

Check that the name of the last file in the terminal matches the name of the last file in the "images" tab in the browser interface

9. Back up the data on a second hard drive. The fastest way may be to repeat the process above.
10. On the browser interface, navigate to the "tools" tab and select "delete all images". At high resolution, the instrument can't save very many profiles, and it can become unwieldy to download only a portion of the data, so it's easier to delete all files after each profile and then download all to a fresh folder after each profile.
11. In the "tools" tab, uncheck "disable sleep" and click "apply"
12. If necessary, modify instrument settings (such as resolution and on/off criteria) in the "home" tab. We programmed the LISST Holo2 to turn on and off using a depth trigger. We set it to turn on below 4 m and off above 1 m. This ensures that the LISST Holo2 does not waste memory by taking images out of the water.
13. After applying any new settings, the cables can all be disconnected and the computer's network settings should be restored to the "normal" profile to allow connection to the ship's network.

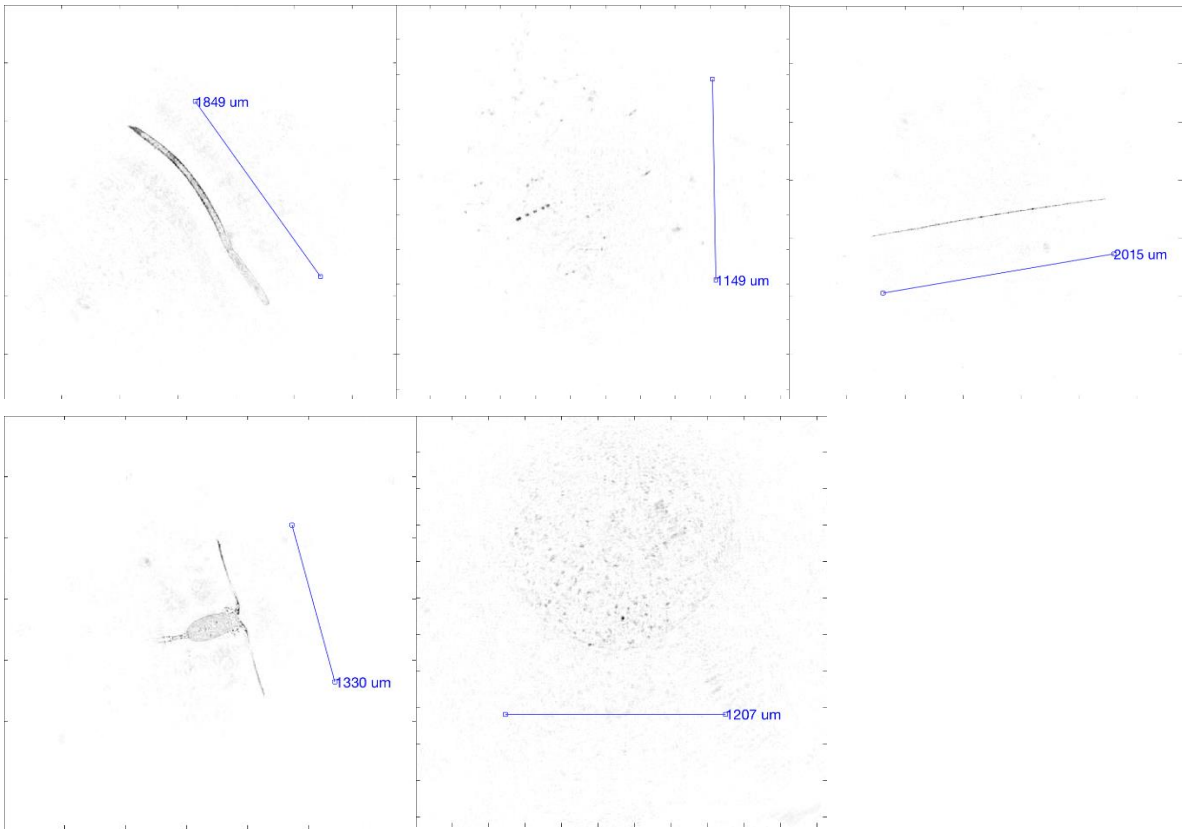
LISST-Holo2 Deployment

Before deployment, if all the desired settings are programmed (see above), all that is needed is to switch the instrument on using the magnetic switch. However, this was more difficult than expected! Sometimes the instrument did not switch on correctly and we lost an entire profile of data. If the instrument is asleep it must be woken up. This can be done by switching the magnetic switch from O to I and back to O again. The LED light at the end with the connectors and the switch will start flashing an orangey colour (looks like a mix of red and green LEDs) to show that it is waking up. Once it is awake it will flash green more slowly (every 5 s or so). Then switch the magnetic switch to I to turn the instrument to sampling mode. It is very important to watch the LED at this stage! The LED will flash several colors. Then, if successful, it will start flashing green, blue, dark, green blue dark every second or so. If unsuccessful, it will go dark again and not flash (at least not frequently). In this case, you have to repeat the process. Sometimes we had to repeat several times before we got it to turn on correctly. Note also that the magnetic switch is held on by a bolt that must be loosened with an allen key in order be switched. Tighten again after switching to avoid the switch falling back to the off position or potentially losing the switch entirely.

Processing

Automated processing can be done using the manufacturer-provided Holo Batch software. This automatically reconstructs particles from each holographic image and allows you to store either particle size distributions, images, or both. With the very high-resolution data from the LISST Holo2, this

software took a very long time and generated very large files if the reconstructed images were stored. Therefore, this was done for only a few profiles. Manual processing can be done using the Holo Detail software. A folder with holograms is loaded into the software (this takes some time) and then the holograms can be sorted by either time, depth, or holographic content. We used the latter to get a quick look at the biggest particles. Then a holographic image can be manually selected and manually "focused" by adjusting the depth of the reconstruction. This manual processing revealed that the automated processing was missing some important features. Most of the time the automated processing correctly focused the particle, but sometimes it did not. More importantly, the raw holograms contained many images of phaeocystis colonies, but the automated software did not detect these, most likely because they are diffuse and low contrast. Furthermore, the automated software split many particles (especially long diatom chains) into smaller particles. We obtained lots of good images of diatom chains, fecal pellets, small zooplankton, and phaeocystis (if manual processing is used) among other things. Below are some examples, including (we think?) a fecal pellet, a loose aggregate with a diatom chain, a free diatom chain, a copepod, and a phaeocystis colony. The aggregate and the colony would not be detected using automated software.



P-Cam:

Description

The P-Cam consisted of a Canon EOS 6D digital SLR camera equipped with a 50 mm macro lens and a Canon Speedlite 600EX RT flash gun. The camera and the flash gun were placed perpendicular to each other to provide illumination from the right side of the captured images. We used a Hahnel Giga T Pro II remote timer to capture an image every 10-20 seconds.

We captured individual particles through the water column in a water volume of 2.15 L for each captured image. The pixel size of the images changed depending on whether the particles were in the front or back of the field of depth. In a previous cruise (DY090), this setup was determined to have a pixel size of 33 µm per pixel in the front of the depth of field (as seen from the camera) and a pixel size of 61 µm per pixel at the back of the depth of field. This suggested an average pixel size of 47 µm per pixel. The field of view for each image was 157 mm width, 101 mm height, and 135 mm depth.

Setup

Once the Camera and flash are set up (see below), turned on, and connected with the supplied cable, the flash should fire automatically each time a picture is taken. This can be tested with the pressure housings open using the camera's shutter button. Initially, we had trouble getting the PCAM to work. We determined that this was due to a bad connection with the cable. After cleaning the connectors and applying silicone spray this problem was fixed. The protocol calls for new flash batteries (four AA) to be used for each profile. We unfortunately ran out part-way through the cruise and needed to re-use batteries. This resulted in partial profiles, as the flash went dead partway through. For setup of the camera in the pressure housing, the sharpie marks must be aligned where the end cap (attached to the camera) meets the rest of the pressure housing. This will ensure that the camera is properly aligned with the window of the pressure housing. When PCAM is mounted on the red camera frame, ensure that the red sharpie line at the end of the pressure housing with the connector is level so that the camera will be level and properly aligned with the dark plate. The flash should be mounted so that it is vertically oriented. For this cruise we angled the flash so that it was not directly hitting the back plate because this caused the black plate to light up, including any faint spots of grease or dust. For the first deployment, the setup should be checked so that the distances match the diagram below and then it is useful to mark the flash and camera housings with a sharpie so that it is not necessary to re-measure for every deployment.

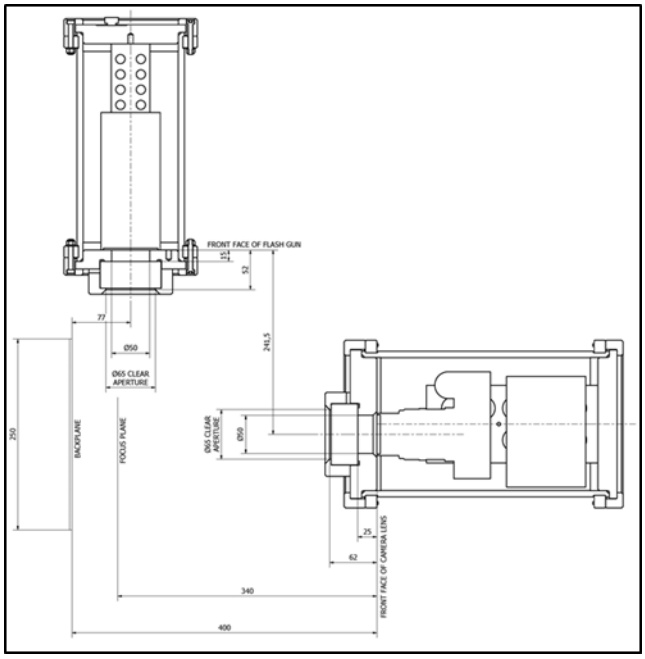


Figure 14 Overview figure of the P-Cam configuration. The pressure housing in the lower right part of the image contained the camera and the upper left pressure housing contained the flash gun.

Camera settings

Image quality:	jpeg highest quality, no raw
Beep:	Disable
Release	shutter without card: OFF
Image review:	OFF
Lens aberration correction:	Enable, Enable
External Speedlite control:	Enable, Evaluate, Auto
Mirror Lockup:	OFF
Expo. Comp./AEB:	0
ISO Speed settings:	blank
Auto lighting optimizer:	off Info selected Disable in M or B modus
White balance:	Flash
Custom White Balance:	blank
WB Shift/Bkt.:	blank 0.0/+/-0
Color space:	sRGB
Picture Style:	Auto
Long exp. Noise reduction:	OFF
High ISO speed NR:	middle (first two bars filled)
Highlight tone priority:	OFF
Dust Delete Data:	Blank

Multiple exposure:	Disable
HDR Mode:	Disable HDR
Live view shot:	Disable
AF Method:	FlexiZoneAF
Grid display:	OFF
Aspect Ratio:	3:2
Expo. Simulation:	Enable
Silent LV shoot:	Mode 1
Metering timer:	16 sec.
Highlight alert:	Disable
AF point disp.	Disable
Playback grid:	Off
Histogram disp.	Brightness
Movie play count:	Rec time
Magnification (apx):	2x
Ctrl over HDMI:	Disable

Manual mode
set time and date to GMT
ISO 2500
shutter 1/160
aperture to f/32
set the lens to manual focus: MF
focus of the lens to 1.5 feet (fixed with yellow tape)

Timer settings
continuous, every 9 sec

Delay: HH:MM:SS
Long: 00 00’ 00”
INTVL1: 00 00’ 00”
N1: 1
INTVL2: 00 00’ 09”

Flash settings

Hold Zm/C.Fn button to enter setup.

m/ft:	0: m
zZZ:	0:ON
Modelling:	0
Auto Cancel:	0
0:	0 → - → +
MODE:	0: ETTL-II/E-TTL
QUICK:	0:OFF
TEST:	0:1/32
AF:	0:ON
0:	ON
zZZ:	1:10min
zZZ:	0:8h
Remote:	0
Flash	+/-: 0
Sound:	OFF
Direction:	1: straight
Light:	1:OFF
Flash:	0

The flash was set in manual mode and put for straight flash direction and a flash output of 1/8.

PCAM deployment

Before each deployment, we opened the pressure housings and chilled the instruments in the 4°C cold room for 30-60 minutes in order to chill the air inside. This was to prevent cooling of the air inside during deployment, which might drop the internal pressure sufficiently so that the pressure housing couldn't be opened on recovery. Before closing the pressure housings, the batteries of the flash were replaced, the flash and camera were turned on (including the camera external battery), and the timer was set. Then the instrument was mounted on the red camera frame and connected. We had significant problems with the flash either overheating or running out of battery and intermittently missing shots and/or stopping entirely partway through a profile, so we set the interval between pictures to 20 s partway through the cruise. There was also quite a bit of motion blur in many of the pictures.

ECO-Triplet and RBR Concerto description:

Each deployment of the Red Camera Frame was equipped with RBR Concerto CTD with Fluorescence and backscatter sensors and the first 17 deployments were equipped with an ECO-Triplet that measured chlorophyll fluorescence and backscatter at two wave-lengths (532 700). Both the ECO-Triplet and the RBR Concerto were timed according to the ship's GMT time. Depth information for both the ECO-Triplet, P-Cam and LISST-Holo was obtained by matching timestamps on those instruments with the RBR Concerto.

A separate report section, 'ECO Triplet Fluorometer and backscattering sensor', highlights the details of the sensor on both the Red Camera Frame deployments and on the CTD.

The table below details each RCF deployment and which sensors were on it.

Table 16: Deployment Events of the Red Camera Frame

Date, Time (GMT)	station	Event	RCF#	Down speed (m/s)	Up speed (m/s)	Cast depth (m)	ECO Triplet Freq. (hz)	LISST frequency (hz)	RBR on	CPICS on	PCAM period (s)	Notes
04:00 6 Dec, 2019	OOI1	5	01	0.2	1	729	1	1	Y	Y	8	PCAM Flash sideways, LISST holo not well cleaned, RBR optics cables reversed (bad optics data)
23:50 6 Dec, 2019	OOI1	19	02	0.2	1	721	1	1	Y	Y	10	
07:11 9 Dec, 2019	TS1	28	03	0.2	1	600	1	X	Y	Y	10	LISST didn't turn on (no data). Changed PCAM shutter to 1/180. Cleaned PCAM plate.
01:00 10 Dec, 2019	TS1	41	04	0.2	1	600	10	2	Y	N	10	No CPICS (leak) ☹
08:46 11 Dec, 2019	TN1	56	05	0.2	1	600	3	1	Y	N	10	Paused on way down to fix winch
21:06 12 Dec, 2019	TN1	61	06	0.2	1	600	3	1	Y	N	10	
07:00 14 Dec, 2019	OOI2	69	07	0.2	1	600	3	10	Y	N	10	Paused on way up at 400 m, 300 m, 300 m, 100 m, and 50 m
21:15 14 Dec, 2019	OOI2	79	08	0.2	1	600	3	5	Y	N	10	Paused on way up at 400 m, 300 m, 300 m, 100 m, and 50 m to check for zooplankton attraction
07:01 17 Dec, 2019	TS2	88	09	0.2	1	600	3	5	Y	N	10	Night
21:30 17 Dec, 2019	TS2	98	10	0.2	1	600	3	5	Y	N	10	Started reusing PCAM flash batteries
20:40 19 Dec, 2019	TN2	107	11	0.2	1	600	3	5	Y	N	X	PCAM connector broke. No data ☹
08:15	TN2	111	12	0.2	1	600	3	5	Y	N	X	PCAM connector broken. No data

20 Dec, 2019												
07:30 22 Dec, 2019	OOI3	126	13	0.2	1	600	3	5	Y	N	10	PCAM rewired and working
19:00 22 Dec, 2019	OOI3	136- 137	14	0.2	1	350 600	3	5	Y	N	10	Double profile. First profile ended early at 350 m due to proximity to glider. 2nd profile fast to 350 m and 0.2 to 600 m.
6:50 27 Dec, 2019	TS3	146	15	0.2	1	600	3	X	Y	N	10	LISST didn't turn on ☹
16:30 27 Dec, 2019	TS3	154	16	0.2	1	600	3	10	Y	N	10	
04:30 29 Dec, 2019	TN3	161	17	0.2	1	600	3	10	Y	N	10	
20:26 29 Dec, 2019	TN3	174	18	0.2	1	600	X	10	Y	N	20	ECO Triplet leaked (no data) ☹
17:15 30 Dec, 2019	TS4	175	19	0.2	1	600	X	10	Y	N	20	
04:30 31 Dec, 2019	TS4	184	20	0.2	1	600	X	X	Y	N	20	LISST didn't start ☹
05:30 3 Jan, 2020	OOI4	197	21	0.2	1	600	X	10	Y	N	20	
13:43 3 Jan, 2020	OOI4	207	22	0.2	1	600	X	10	Y	N	20	
19:12 4 Jan, 2020	TN4	216	23	0.2	1	600	X	10	Y	N	20	
04:15 5 Jan, 2020	TN4	223	24	0.2	1	600	X	10	Y	N	20	

ECO Triplet Fluorometer and Backscattering Sensor

Nathan Briggs (NOC)

Introduction:

A 1000-m rated standalone Wetlabs Environmental Characterization Optics (ECO) Triplet Fluorometer and Backscattering Sensor, measuring backscatter at 2 wavelengths (532nm and 700 nm) and chlorophyll fluorescence was used during DY090.

This ECO triplet was deployed on the Red Camera Frame (RCF) as well as on the CTD rosette on profiles to a maximum of 1000 m. This instrument does not have a pressure sensor, so it relies heavily on the time variable that is then matched to the RBR or SBE39 (on the red camera frame) and the Seabird CTD (on the rosette). On both deployments, the sensor was horizontal, facing the outside. Two brackets were used to secure the instrument to the RCF. These brackets were also used to secure the instrument to the vane on the CTD rosette frame. Bolts size 17mm were used to secure the brackets onto the frames. The ECO triplet was deployed on all stainless steel CTDs up until its malfunction on the afternoon of 29 Dec. Upon opening the pressure housing, a small amount of standing water was found inside, indicating that the sensor had leaked. The inside of the pressure housing was thoroughly rinsed with MiliQ water and it was left to dry for several days. After this, the instrument was reconnected and powered on. Two of the three channels seem to be functioning (red backscatter and chorophyll fluorescence, but a third is not. We decided not to attempt further deployment until we can discover the cause of the leak. The pressure housing had been opened once previously to replace the battery, but there was no clear sign of damage to any of the O-rings.

Calibrations:

S/N: BB2FLWB-1633

Date: 9/15/2017

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

$\beta(\theta_c)$ $m^{-1}sr^{-1}$ = Scale Factor x (Output-Dark counts)

Table 17 Factory supplied parameters used to convert raw data into chlorophyll fluorescence and backscatter concentrations

	ECO Chlorophyll Fluorometer	Scattering meter at 700 nm	Scattering meter at 532 nm
Scale Factor (SF)	0.0305 µg/l/count	3.004E-06 $(m^{-1}sr^{-1})$/counts	6.974E-06 $(m^{-1}sr^{-1})$/counts
Maximum output	4130	N/A	N/A
Dark Counts	53 counts	52 counts	53 counts
Resolution	1.2 counts	1.3 counts 3.94E-06 $(m^{-1}sr^{-1})$	1.3 counts 8.77E-06 $(m^{-1}sr^{-1})$
Ambient temperature during characterization	21.5 °C	N/A	N/A

Standard Operating Procedures:

Prior to the deployment of the RCF and the CTD rosette, the sensor needs to be turned on. A computer with EcoView123 software is required as well as a USB to serial cable (and Windows drivers!).

During this cruise, the computer in the box with the ECO Triplet did not boot up, so we needed to borrow another Windows laptop (intended for the UVP).

Before deployment:

Bring PC, comms cable and blue power plug

1. Launch EcoView123 software
2. Compare PC clock with ship's clock – if necessary, adjust PC clock (see below)
3. Remove dummy plugs from sensor
4. Attach blue power plug and comms cable
5. Attach comms cable to PC using USB to serial connector
6. Select COM port (yellow buttons top right). Check 'Device Manager'
7. Select Device File (BB2FLWB-1633.dev) from the ECO triplet folder
8. Press Stop Data in EcoView123
9. Click Set Date, Set Time and/or Get Date/Time/Setup until correct time appears in top left of window
10. On Meter Setup tab, change settings to:
    a. Avg/Data Rate (depends. 1 for highest frequency). Set to ~3 hz for most of the cruise.

b. Number of Samples 0
c. Number of Cycles N/A
d. Cycle Interval N/A
e. After each change click the relevant button 'Set …..' to update settings. These settings will run the sensor continuously at 1 Hz frequency until switched off again.

11. Press Turn Logging On
12. Press Store To Flash (yellow Setup not stored message in top right should disappear)
13. When ready to deploy, press Start Data
14. Disconnect comms cable and attach dummy plug
15. Take sensor cap off

Items 11 and 12 are sometimes interchangeable. If the order doesn't work, try step 12 before step 11. During COMICS 2, logging was left ON. This allows the sensor to start recording data (and logging) from the time it is powered on – easy to leave it all setup for an early morning CTD! To stop data acquisition just power off the sensor. When plugging the sensor to a PC, all the data should be there.

After deployment:

Bring PC, comms cable, dummy plug, bottle of water to rinse instrument and sensor cap

1. Connect comms cable to PC
2. Select COM port and device file, if necessary
3. Press Stop Data
4. Click Turn Logging Off
5. On Transfer Data tab, click Receive Data and save file
6. Open transferred file with text editor to verify data transfer
7. Press Erase Memory
8. Disconnect comms cable. Disconnect blue power plug.
9. Replace dummy plugs, rinse the instrument and place sensor cap.

Adjust Time

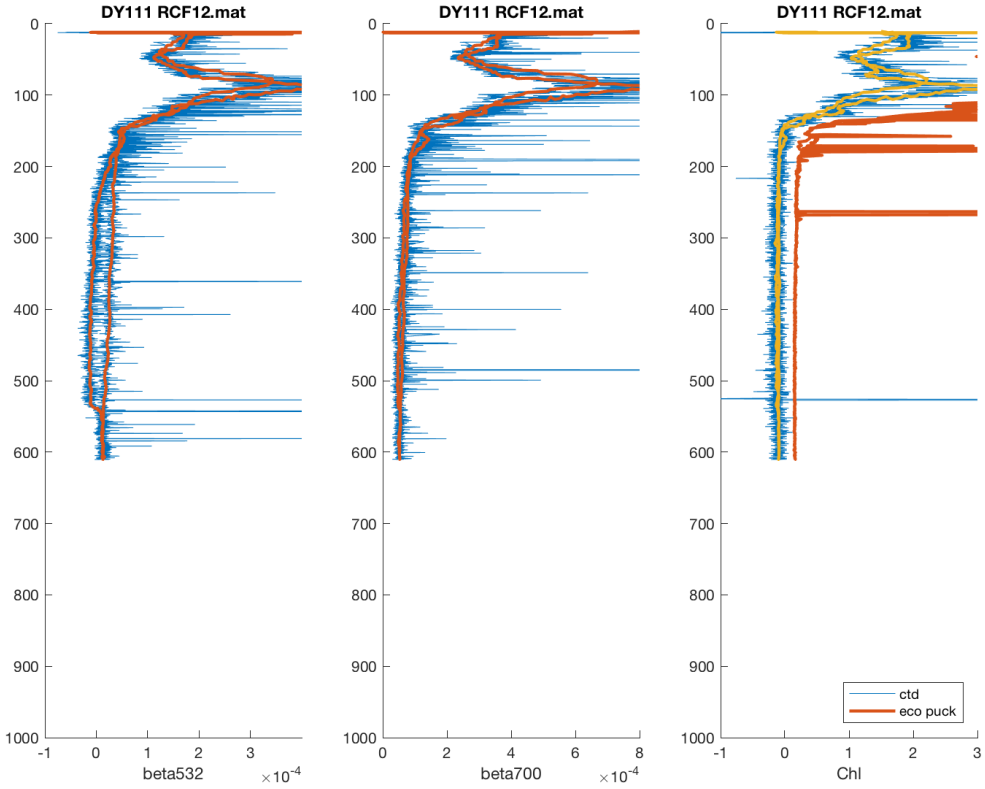
To adjust the time to the ship's time server:

1. Right click on the time on the left right corner of the Windows screen
2. Scroll down to 'Additional date, time and regional settings
3. In the 'Date and Time' menu, select 'Set the time and date'
4. On the 'Internet Time' tab, select 'Change settings'
5. Click 'Synchronize with an 'internet time server'
6. For DY086, the ship's server was 192.168.63.222

Data and operations during DY111

As with the previous cruise (DY090), When the sensor was removed from box, there were signs of corrosion on the face copper plate where the sensors are. Even when rinsed and dried, the copper plate seems to corrode over time.

Like on the last cruise, some data were corrupted. Again, we replaced the batteries and this problem was reduced. We can also see some strange behaviour in the green channel of the ECO triplet (left-most panel in below plot) on some casts, where the signal jumps on the upcast. In retrospect, this may have been early signs of the leak. Therefore, all of the ECO triplet data from this cruise should be used with caution.



UVP

Nathan Briggs (NOC)

Introduction:

The UVP is a commercial in situ camera system made by Hydroptic. Two light sources at the bottom produce a horizontal 2-cm sheet of red light and a camera images particles illuminated by this light sheet from above. The camera internally segments each image into particles and records the size and average brightness of each particle found in each image. For particles larger than a certain threshold, a cropped image is also saved. There is also a mode for saving full images. The UVP was accompanied by a laptop with ImageJ-based "zooprocess" software for controlling the instrument, downloading data, and processing data.

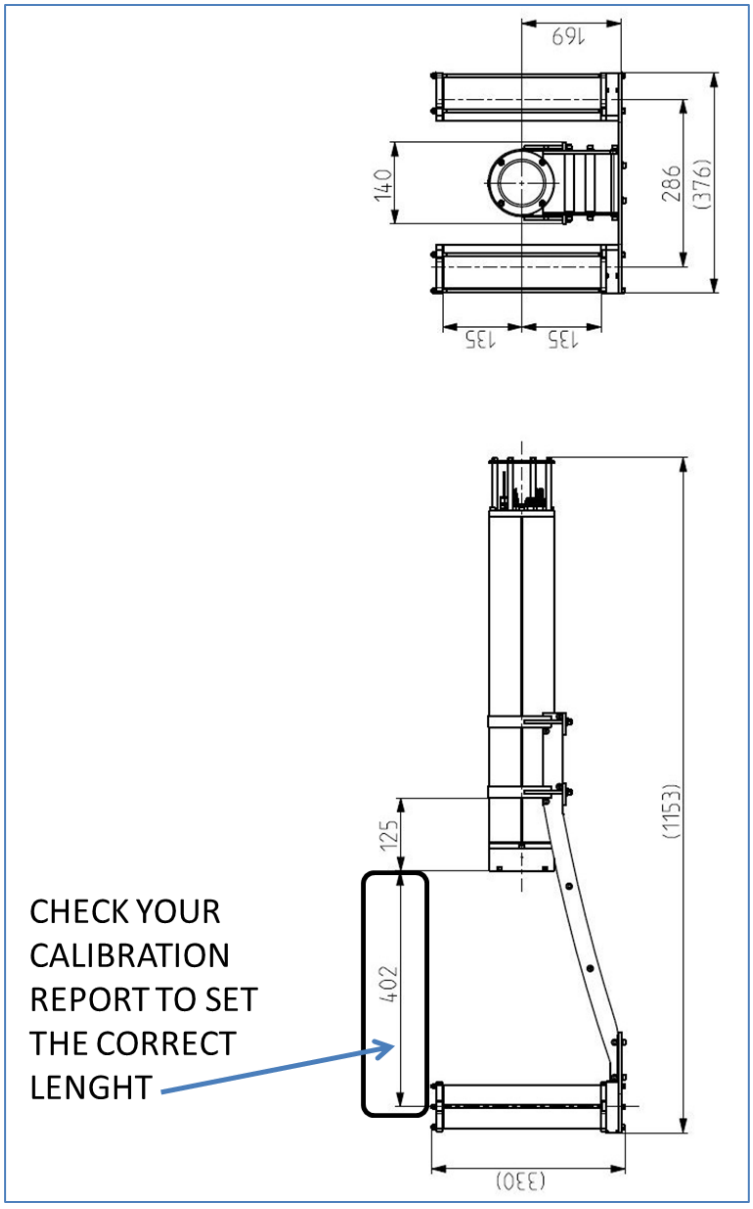


Figure 15 UVP diagram. Bottom and Side view.

Physical Setup

The UVP was attached to the inside of the Stainless Steel CTD frame, with the camera facing down towards undisturbed water (on the downcast) as shown in the picture below. The bottom of the light housings were approximately 117 mm above the deck when mounted on the yellow floor brackets as shown below. The floor brackets hold the CTD frame 53 mm above the deck, so the bottom of the lights were about 64 mm above the bottom of the CTD frame. This means there should be minimal effect of the wake of the frame on the imaged particles when the CTD is moving downwards.

Extension cables for power and data were attached to the top of the UVP and cable tied to the top of the CTD frame to allow access during the cruise. The deck unit (for power and data transfer) was set up at the lab bench nearest the CTD hangar, and the 25 m data and power cables were fed through a conduit and along the ceiling to the lab bench. The deck unit was connected to the UVP laptop via both the supplied serial USB cable (for control) and the supplied ethernet cable (for data).

Software Setup

The software was all set up during the UVP training course on the supplied laptop, along with the initial folders to hold the data. A backup routine was also set up using the supplied backup 1TB hard drive. For all profiles, the UVP was set to maximum resolution of 24 Hz. At 1 m/s descent rate, this equates to one 2-cm-thick slice of water sampled every 4 cm, so the full water column is not quite sampled. However, due to ship heave, the downward speed changed and sometimes reversed, so in practice this meant that many particles were imaged more than once. This means that particle abundance statistics must be interpreted with care. Most profiles were set up in descent mode so that the UVP automatically

turned on when it crossed 6 m at greater than 0.2 m/s. It then takes ~60 s to turn on the UVP camera, so this means that the UVP turns on during the 15 m soak and then returns to the surface for the start of the profile. All profiles except profile c017 (equivalent to ctd017ss) were made to turn on in descent mode. c017 was turned on manually, so there are a lot of bad images out of the water before the beginning of the profile. Most profiles were set to "downcast only" mode, where the UVP turns off when it ascends 30 m shallower than its maximum depth. This worked well, except for profile c014, where the ctd was brought to 50 m, then 15, then 1000 m, due to some miscommunication around a glider calibration cast. This caused the UVP to turn off at 20 m and not restart, losing most of the profile. On profiles c039, c041, and c042, this upturn shutoff was disabled to allow upcast sampling to look for aggregate breakup. This was effective, but means that the UVP collected a lot of data on deck before connecting to switch off manually. c039 was a double profile, corresponding to ctd039ss and ctd040ss, therefore there is no UVP profile c040 in the data. On profile c038, the UVP was programmed to turn off when ascending shallower than 5 m, in an attempt to get a full profile down and up without collecting data out of the water. However, the UVP simply turned off the first time it ascended to the surface after the 15 m soak and didn't turn on again on descent, so the entire profile was lost. Finally, profile c043 did not collect data for unknown reason. Perhaps free disk space was too low? (6%).

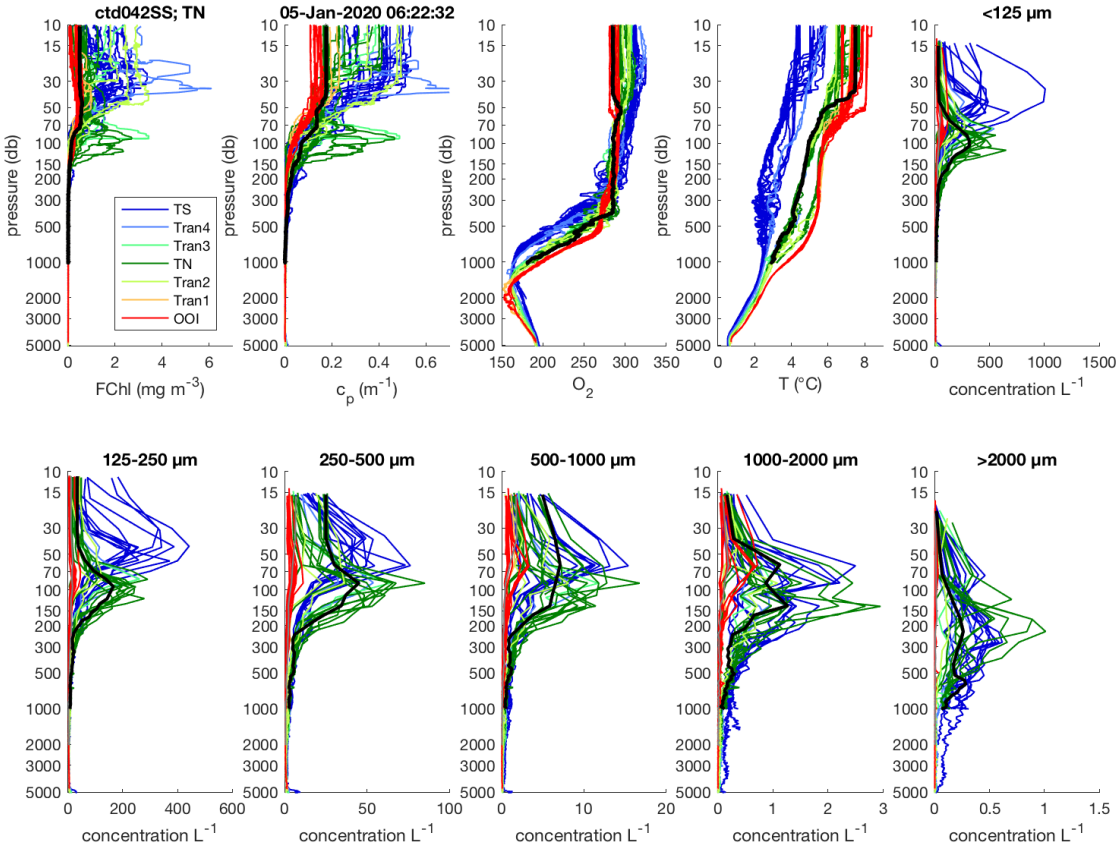
Deployment protocol

While the CTD was on deck, the UVP remained connected to the deck unit via the 25 m power and data cables. This permitted charging, downloading, and programming. If the battery voltage at the end of a cast was below 27 V or if a full-depth cast was planned, the UVP was charged fully. Before deployment, the 25 m power and data cables were unplugged from the short power and data extension cables that were cable-tied to the top of the ctd frame. Then the red power shunt was plugged into the red power extension cable (connected to the UVP) and the green dummy plug was plugged into the green data extension cable (connected to the UVP). The green dummy and red power shunt are always cable-tied to the top of the ctd as well, so they are always "on hand". They each have their own "reverse dummy" plug connected while on deck, so when the 25 m cables are unplugged from the UVP, these "reverse dummies" are removed from the dummy and shunt and plugged straight into the 25 m cables. While this may sound complicated, it is a simple swap before each deployment. When the ctd comes back on deck, it is important to first check if the instrument is flashing. This means it is still on and the red power shunt should not be unplugged, because this could power off the camera computer in the middle of a file transfer and corrupt the disk. In this case, the green data cable should be plugged into the deck unit (via the 25 m cable) and the Zooprocess software should be run to turn off the UVP manually. At that point, the power shunt can be removed and replaced with the 25 m power cable. If the UVP is not flashing, then both the power and data cables can be plugged in once the CTD is secure. Then the data can be downloaded. Note that the data download can take some time, which is variable depending on the number of particles in the water and whether the UVP was on out of the water, in which case many

"particles" may be stored from water droplets or bubbles or other things the UVP sees in the air. While the data are downloading, the UVP should not be disconnected, so if another profile is planned within an hour of the first, it is best not to start a data download. After downloading, metadata must be entered for a profile before it can be processed. Processing cuts out only the downcast (if that option is selected), reverses color on the images to make it easier to see details, and adds depth information and scale bars to the images. This processing uses the same software as the programming of the UVP, so it's best to ensure the UVP is programmed and ready for the next cast before starting processing, which can also take a long time.

Data

Despite the problems stated above, most profiles worked well and required minimal user intervention. A great variety of particles were seen in the images, including lots of aggregates in the southern stations. The UVP software also bin averages the particle size distribution into 6 size bins. A summary of the binned particle concentration profiles from all of the casts is below (upper right and lower panels), along with some CTD data (upper panels excluding the rightmost). Colours show the different stations and black shows the last profile at station TN. We can clearly see that stations TN and TS had many more large particles (mostly aggregates) and that the different-sized particles had different depth distributions.



Upper ocean pelagic sampling for chlorophyll, particulate organic carbon and nitrogen, particulate inorganic carbon, particulate silica and plankton taxonomy

Joanna Ainsworth (U.Southampton), Chelsey Baker (NOC), Heather Bouman (U. Oxford), Emmy McGarry (NOC), Mark Moore (U. Southampton), Alan Wright (U.Southampton), Neil Wyatt (U.Southampton)

CTD Sampling:

For each stainless steel CTD cast (CTDs), seawater was typically collected from 12 depths from the near surface down to ~200 m to filter for pigments (chlorophyll-a via fluorometric analysis, chlorophyll and accessory pigments via High-Performance-Liquid-Chromatography), particulate absorption spectra via spectroscopy (PABS), particulate organic and inorganic carbon (POC, PIC), particulate organic nitrogen (PON) and biogenic silica ($bSiO_2$). Additionally, seawater was collected and processed for evaluation of phytoplankton community structure determined by microscopy from preserved samples (acidic Lugol's solution) or via flow cytometry on Paraformaldehyde and Glutaraldehyde preserved samples (for measurement using a Cytosense flow cytometer), alongside and samples preserved for DNA/gene expression analysis on Sterivex filters. Water samples were also sequentially filtered to determine chlorophyll-a concentrations in different size-fractions (0.2-5 µm, 5-10 µm, >10 µm). Sampling and protocols typically followed those employed previously and described in detail elsewhere (see e.g. Moore et al. 2007a&b; Poulton et al. 2006, 2013).

Underway sampling:

Every 6 hours the underway system was sampled for Chlorophyll-a, HPLC and PABS.

An overall list of CTD samples collected is provided here:

Table 18

Date (JDay)	Site	Event	CTD cast	Niskin Bottle	Nominal Depth (m)	Variables Filtered
338	Argo deploy ment	2	001 S	12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	300, 200, 150, 125, 100, 75, 50, 40, 30, 20, 10, 5	Chl-a, POC/N, HPLC
340	OOI-1	6	002 S	12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24	200, 150, 125, 100, 70, 50, 40, 30, 20, 15, 10, 5	Chl-a, SF Chl-a, POC/N, $bSiO_2$, PIC, HPLC, PABS, Lugols
340	OOI-1	18	003 S	15, 17, 21, 22, 23, 24	150, 110, 70, 50, 20, 5	Chl-a, POC/N
343	TS-1	26	005 S	15, 17, 21, 23, 24	150, 110, 70, 40, 10	Chl-a, SF Chl-a

Date (JDay)	Site	Event	CTD cast	Niskin Bottle	Nominal Depth (m)	Variables Filtered
344	TS-1	39	006 S	10, 11, 12, 13, 14, 16, 17, 18, 19, 21, 22, 24	200, 150, 125, 100, 75, 50, 40, 30, 20, 15, 10, 5	POC/N, $bSiO_2$, PIC, HPLC, PABS, AFC, Lugols, Cytosense, Sterivex
345	TN-1	55	009 S	6, 8, 9, 10, 12, 15, 16, 18, 19, 21, 22, 24	200, 150, 125, 100, 75, 50, 40, 30, 20, 15, 10, 5	Chl-a, SF Chl-a, POC/N, $bSiO_2$, HPLC, PABS, Lugols, AFC, Cytosense
348			014 S	6, 8, 9, 10, 12, 15, 16, 18, 19, 21, 22, 24	200, 150, 125, 100, 75, 50, 40, 30, 20, 15, 10, 5	Chl-a, SF Chl-a, POC/N, $bSiO_2$, PIC, HPLC, PABS, Lugols, AFC, Cytosense, Sterivex
351			017 S	8, 10, 11, 12, 13, 16, 17, 18, 19, 21, 22, 24	200, 150, 125, 100, 75, 50, 40, 30, 20, 15, 10, 5	Chl-a, SF Chl-a, POC/N, $bSiO_2$, PIC, HPLC, PABS, Lugols, AFC, Cytosense, Sterivex
353		105	020 S	6, 8, 9, 10, 12, 15, 16, 18, 19, 21, 22, 24	200, 150, 120, 100, 70, 50, 40, 30, 20, 15, 10, 5	Chl-a, SF Chl-a, POC/N, $bSiO_2$, HPLC, PABS, Lugols, AFC, Cytosense, Sterivex
355			023 S	12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24	200, 150, 125, 100, 70, 50, 40, 30, 20, 15, 10, 5	Chl-a. POC/N, HPLC
356			025 S	6, 8, 9, 10, 12, 15, 16, 18, 19, 21, 22, 24	200, 150, 125, 100 ,75, 50, 45, 30, 20, 15, 10, 5	Chl-a, SF Chl-a, POC/N, $bSiO_2$, PIC, HPLC, PABS, Lugols, AFC, Cytosense, Sterivex
361			029 S	6, 8, 9, 10, 12, 15, 16, 18, 19, 21, 22, 24	200, 150, 125, 100, 75, 50, 40, 30, 20, 15, 10, 5	Chl-a, SF Chl-a, POC/N, $bSiO_2$, PIC, HPLC, PABS, Lugols, AFC, Cytosense, Sterivex
362			030 S	12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24	200, 150, 125, 100, 70, 50, 40, 30, 20, 15, 10, 5	POC/N, HPLC
363			033 S	6, 8, 9, 10, 12, 15, 16, 18, 19, 21, 22, 24	200, 150, 125, 100, 75, 50, 40, 30, 20, 15, 10, 5	Chl-a, SF Chl-a, POC/N, $bSiO_2$, PIC, HPLC, Lugols, AFC, Cytosense, Sterivex
364		176	034 S	6, 8, 9, 10, 12, 15, 16, 18, 19, 21, 22, 24	200, 150, 125, 100, 75, 50, 40, 30, 20, 15, 10, 5	Chl-a, SF Chl-a, POC/N, $bSiO_2$, PIC, HPLC, PABS, Lugols, AFC, Cytosense, Sterivex
003			037 S	6, 8, 9, 10, 12, 15, 17, 18, 19, 21, 22, 24	200, 150, 125, 100, 75, 50, 40, 30, 20, 15, 10, 5	POC/N, HPLC
003			038 S	6, 8, 9, 10, 12, 15, 17, 18, 19, 21, 22, 24	200, 150, 125, 100, 75, 50, 40, 30, 20, 15, 10, 5	Chl-a, SF Chl-a, POC/N, $bSiO_2$, PIC, HPLC, PABS, Lugols, AFC, Cytosense, Sterivex

Date (JDay)	Site	Event	CTD cast	Niskin Bottle	Nominal Depth (m)	Variables Filtered
004			041 S	6, 8, 9, 10, 12, 15, 16, 18, 19, 21, 22, 24	200, 150, 125, 100, 75, 50, 40, 30, 20, 15, 10, 5	Chl-a, SF Chl-a, POC/N, $bSiO_2$, PIC, HPLC, PABS, Lugols, AFC, Cytosense, Sterivex
006			043 S	12, 13, 14, 15, 17, 18, 19, 21, 22, 24	200, 150, 125, 100, 50, 40, 30, 15, 10, 5	POC/N, HPLC, PABS, Lugols, Cytosense

Particulate Organic Carbon and Nitrogen (POC/N):

POC/N samples were collected from the CTD from nominally 6 depths. For POC/N, 0.5 to 1 L of seawater was filtered onto pre-ashed (400^{o}C, 12 h) Whatman GF/F filters. These were then placed in clean Eppendorf tubes, and dried overnight (50°C) for storage prior to analyses back at NOCS / University of Southampton.

Particulate Silica ($bSiO_2$):

Particulate silica ($bSiO_2$) water samples were collected from the CTD from nominally 6 depths. For $bSiO_2$, 500 mL of seawater was filtered onto Whatman 0.8 µm polycarbonate filters. After filtration, the filters were placed into plastic 15 mL centrifuge tubes, dried overnight in an oven prior to digestion and analysis onboard planned to be performed during DY112.

Particulate Inorganic Carbon (PIC):

PIC samples were collected from the CTD from nominally 6 depths. For PIC, 500 mL of seawater was filtered onto Whatman 0.8 µm polycarbonate filters that were then rinsed with pH-adjusted MilliQ (pH ~8.5-9) to remove saltwater residue. The filters were placed in 15 mL centrifuge tubes and oven dried (50^{o}C, overnight) prior to later digestion and analyses at NOC via ICP-OES.

High Performance Liquid Chromatography (HPLC):

For phytoplankton pigment analysis (chlorophylls, carotenoids), 500 to 1000 mL of seawater was filtered onto Whatman GF/F filters for later extraction and analysis of pigments by HPLC. After filtration, HPLC filters were placed into Nunc^{TM} CryoTube^{TM} vials, flash frozen in liquid nitrogen and stored at -80°C prior to later analyses.

Preserved phytoplankton (acidic Lugol's solution):

Water samples of 100 mL were preserved in brown bottles with acidic Lugol's solution (1% final solution) for later enumeration and identification of plankton species by inverted light microscopy.

Particulate Absorption (PABS):

Water samples of between 0.25 and 0.5 L were filtered through Whatman glass fibre GF/F filters using a glass manifold on the filtration rig, then placed in a plastic petri dish and stored in the -80^{o}C freezer. The *in vivo* light absorption spectrum of phytoplankton and non-algal particles will be measured using a UV-VIS spectrophotometer back in Oxford.

AFC:

Water samples of 1.8 mL from the surface were fixed with paraformaldehyde to a final concentration of 1%. The samples were transferred to the -80^{o}C freezer for analysis by flow cytometer at a later date.

Cytosense samples:

Water samples of 45 mL from the surface were fixed with gluteraldehyde to a final concentration of 0.25%. The samples were transferred to the -80^{o}C freezer for analysis by flow cytometer at a later date.

Sterivex:

Water samples of between 0.5 and 4 L from the surface were filtered through a Sterivex filter, flash frozen in liquid nitrogen and transferred to the -80^{o}C freezer for analysis at a later date.

Chlorophyll-*a* analysis:

In order to provide an index of overall phytoplankton biomass, water samples for the determination of chlorophyll-*a* concentrations were collected from:

i) CTD deployments
ii) Marine Snow Catchers (see report section)
iii) Underway samples
iv) Nutrient addition bioasssay experiments (see section)

Further details specific to different sampling types can be found in the corresponding sections of the cruise report, but briefly:

i) CTD samples: The stainless steel CTD was used to collect samples from 200 m to the surface, typically at 10 to 12 different depths (See Table 1). 100 mL of seawater were filtered onto Whatman glass fibre GF/F filters for total chlorophyll-*a* concentration and 100 mL sequentially through polycarbonate 0.2 µm, 5 µm and 10 µm filters for size-fractionated chlorophyll-*a*.
ii) For the MSC samples between 50 and 100 mL were filtered onto Whatman glass fibre GF/F filters for total chlorophyll-*a* concentration from the various fractions of Tzero, suspended, slow and fast sinking particles (see separate report section).
iii) For the underway samples, 100 mL of surface water from the underway system was filtered onto Whatman glass fibre GF/F filters for total chlorophyll-*a* concentration.

iv) For the nutrient addition bioassay experiments between 23 and 100 mL of water from short term and long term nutrient and trace metal addition experiments were filtered onto Whatman glass fibre GF/F filters for total chlorophyll-*a* concentration (see separate report section).

In all cases, chlorophyll-*a* was extracted in 6 mL of 90 % acetone over 20 to 24 hours at 4°C in a fridge in the dark. Measurements of chlorophyll-*a* were subsequently made on board using a Turner Designs Trilogy fluorometer set up with a non-acidification kit (after Welschmeyer, 1994). The fluorometer was calibration against a pure chlorophyll-*a* extract in 2018 (and will be recalibrated on return of the fluorometer to NOC in 2020). A Turner solid standard (Part No. 8000-952) was used at the start and end of each set of readings as well as an 90% acetone blank sample to monitor for instrument drift. Both of these readings are subsequently used in the calculations to determine chlorophyll-*a* concentrations (see Equation 1).

Chlorophyll-*a* concentrations in mg m^{-3} (µg L^{-1}) were calculated as:

$$Chl\ a = Dilution * (R)adj * (F - blank) * (\frac{v}{V}) \quad \text{Equation (1)}$$

Dilution = 1 (unless required for an over-range sample)

(R) adj = response factor adjusted for the shift in the solid standard

F = sample fluorescence

blank = acetone blank reading

v = acetone extracted volume (6 mL)

V = filtered sample volume in mL

References:

Moore et al. 2007a Deep-Sea Research II 54 2045–2065

Moore et al. 2007b Deep-Sea Research II 54 2066–2084

Poulton et al. 2006 Deep-Sea Research II 54 2085–2105

Poulton et al. 2013 Global Biogeochemical Cycles 27, 1-11, doi: 10.1002/2013GB004641.

Welschmeyer 1994 Limnology and Oceanography 39 1985–1992

Active Chlorophyll Fluorescence

Alan Wright, Mark Moore (U.Southampton)

Introduction

The physiology and composition of upper ocean plankton communities has a strong influence on the magnitude and nature of sinking organic and inorganic material. As part of the CUSTARD project, work package 2 is addressing the linkages between surface phytoplankton iron stress and community structure and the subsequent stoichiometric composition and export of material out of the upper ocean. To examine relationships between surface plankton elemental stoichiometry, community structure, community iron status and bio-optical properties, a series of samples and measurements were collected on DY111 to assess levels of phytoplankton biomass (chlorophyll-*a*), community composition (preserved and filtered water samples for microscopy, diagnostic pigments via High-Performance-Liquid-Chromatography), particulate absorption spectra (PABS), biomineral standing stocks (biogenic silica) and total particulate organic carbon and nitrogen standing stocks. The physiological state of near surface phytoplankton communities was assessed using a number of single turnover active chlorophyll techniques applied to water collected from the ship's underway sampling system alongside underway chlorophyll measurements.

Active chlorophyll fluorescence measurements

Chlorophyll fluorescence, using techniques such as Fast Repetition Rate fluorometry (FRRf), can provide a useful non-destructive and rapid index of the physiological status of phytoplankton (e.g. Moore et al. 2007). Instruments such as FRRf's are capable of measuring a suite of parameters pertaining to the photosynthetic physiology of the entire phytoplankton community, most commonly including the photosynthetic energy transfer efficiency (Fv/Fm) which can provide a proxy of the overall photosynthetic 'health' of the community. The FRRf technique measures in real time, in situ and at high sensitivity.

A variety of active chlorophyll fluorometers were employed during DY111.

Underway sampling

Two separate active chlorophyll fluorometers were employed during underway sampling.

Chelsea Technologies Group (CTG) 'Single turnover active fluorescence (STAF)' systems (Kolber et al. 1998), with serial numbers SN002 and SN003 respectively, were connected in series to the ship's non-toxic underway supply within the main lab in order to assess and monitor the physiological state of Photosystem II (PSII) within the surface phytoplankton population of the study area.

Additionally, one Chelsea Technologies Group (CTG) FastOcean™ FRR fluorometer, with serial number 14-9727-004, was connected to the underway system within the general-purpose laboratory.

Additionally, one CTG FRRF II sensor (serial number 07- 6541-001) was available for discrete measurements.

Protocol and set up

SN003 was run in auto FLC mode with DWC inactive. 12 light steps were used, with E ranging from 0-1000, and a pre-E of 20. Each light step was 120 seconds long, with a down step of 120 seconds at the end of the cycle. Auto sample exchange was activated with timings adjusted to evacuate the sample chamber and refill with fresh sample at the end of each FLC. Additional criteria were as follows; push up 80, run time 12 s, on time 600 ms, speed 12, interval 100s.

Between the 2nd of December 2019 and the 22 December 2019 SN002 had exactly the same settings as SN003 when running in 'continuous' mode. On the 22nd December the light step length was changed to 240 seconds, with a 240 second down step. This protocol was maintained for the remainder of the cruise.

Periodically SN002 was used for discrete sampling. Prior to this the sample chamber and sample supply tubes were cleaned with MilliQ. The protocol used for discrete sampling was as above except that the light step was changed to 120 seconds, with a 120 second down step.

A MilliQ blank and a Filtered Sea Water Blank were run every day for SN002 and SN003. For these blanks each light step was adjusted to 5 seconds, with a 5 second down step added. Additionally, prior to running the blanks, the sample chamber was rinsed with MilliQ and wiped. All sample exchange tubes were rinsed in a similar manner.

Duration of sampling

Both STAF instruments (SN002 & SN003) were run semi continuously between the 02nd of December 2019 and the 6th January 2020. (a detailed log book was kept for specifics). All variable fluorescence parameters were recorded (see figures below). CSV files were created by using the CTG 'RunSTAF' software, version 5.5.1.0

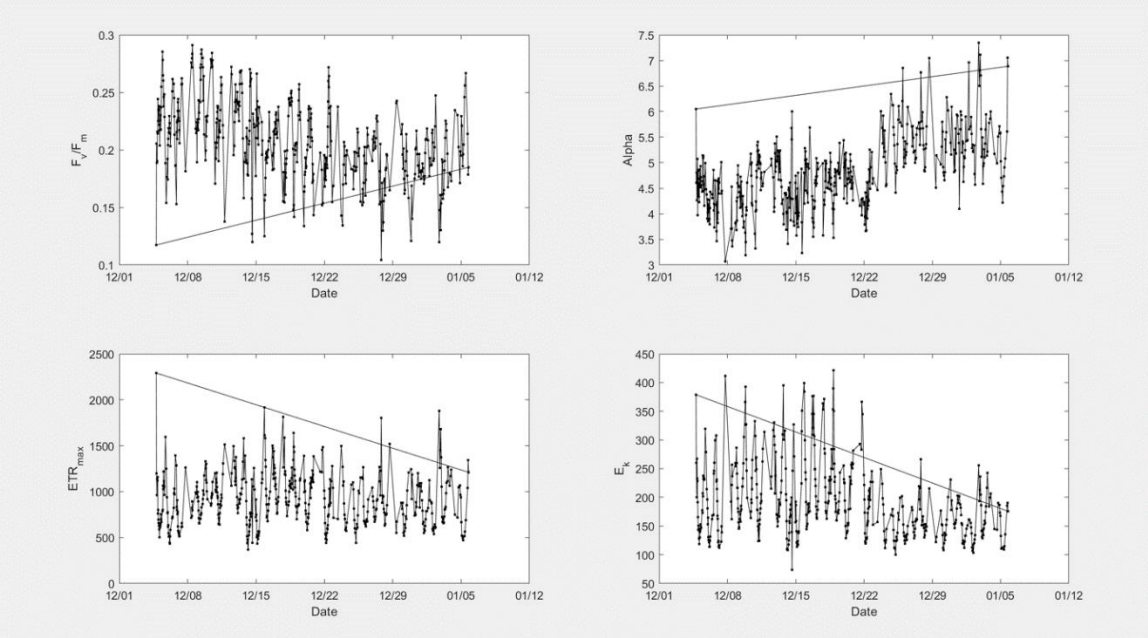


Figure 16 An example of some fluorescence parameters recorded, and the dates of measurement for SN002.

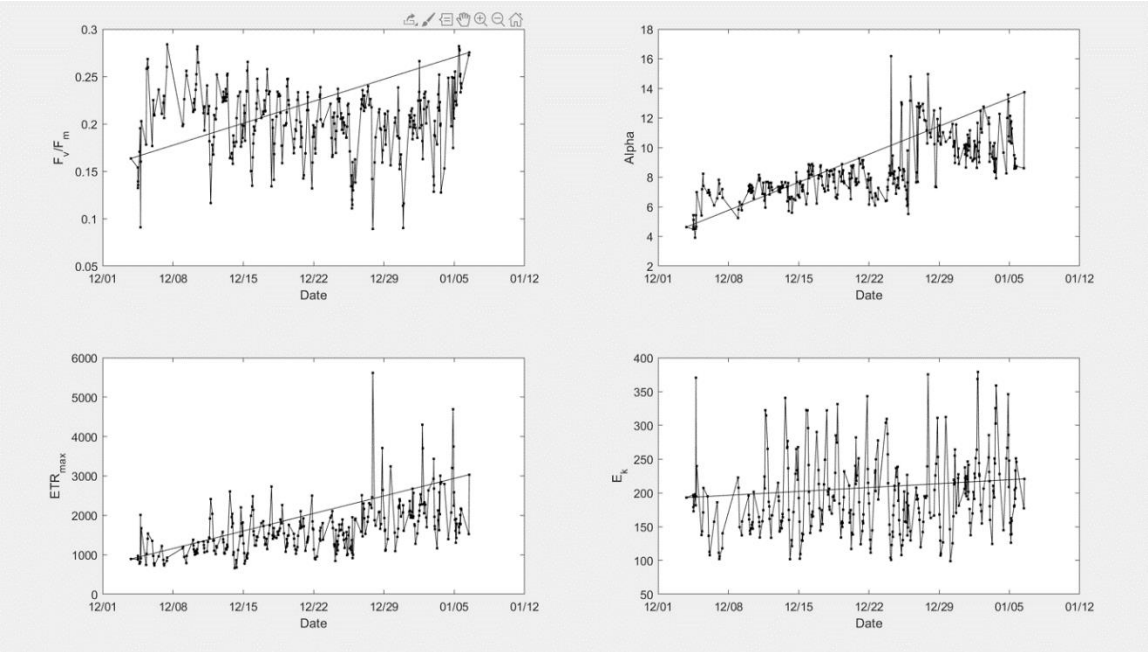


Figure 17 An example of some fluorescence parameters recorded, and the dates of measurement for SN003.

Discrete samples

Discrete sampling was carried out in the following manner. CTD samples were measured on the MkIII CTG instrument (using the DY111 default protocol – see details elsewhere), and duplicated on STAFES SN002 using the discrete protocol. All discrete samples were saved using the syntax in the table below.

Table 19 Discrete sampling carried out on DY111 using various FRRF instruments.

CTD_S_002_N24.csv
CTD_S_009_N24.csv
CTD_S_014_N24.csv
CTD_S_017_N24.csv
CTD_S_020_N24.csv
CTD_S_025_N24.csv
CTD_S_29_N24.csv
CTD_S_33_N24 rPE
CTD_S_34_N24rPE
LTE01_C.csv
LTE01_Fe.csv
LTE02_C.csv
LTE02_Fe.csv
LTE_03_C.csv
LTE_03_Fe.csv
LTE_04_C.csv
LTE_04_Fe.csv
LTE_05_C.csv
LTE_05_Fe.csv
LTE_06_C.csv
LTE_06_Fe.csv
LTE_07_C.csv

The STAFES instruments were controlled by 'RunSTAF' software (version 5.5.1.0) and data were stored on an external data logger and backed up every 1-4 days throughout the cruise. The Instrument optics were cleaned periodically and before the protocol was set to run again blank measurements were performed to calibrate the results. Data will be analysed using custom software in a Matlab™ environment.

Measurements of optical properties.

Objective

To determine surface optical properties throughout the cruise in support of the above STAFES data.

Methods

Particulate optical backscattering coefficient (470, 532, 700 nm), beam-attenuation and absorption coefficients (400–750 nm) were determined quasi-continuously from the ship's underway water following methods detailed in Dall'Olmo et al. 2009 and Dall'Olmo et al. 2017. Highly-accurate estimates of chlorophyll concentration can be obtained from the particulate absorption coefficient which will be calculated post cruise.

References:

Boyd, P.W. *et al.* (1999) *J. Geophys. Res.* **104** 13395-13408

Dall'Olmo et al. (2009) Significant contribution of large particles to optical backscattering in the open ocean. *Biogeosciences*, 6, 947–967.

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Photosynthesis-Irradiance (*PI*) Experiments

Heather Bouman (U. Oxford)

Objectives:

Seawater samples were collected to determine the photosynthetic response of phytoplankton assemblages for CUSTARD stations (OOI, TS, TN), nutrient addition bioassay experiments and the final ARGO deployment station. These data will be used to obtain information on the photosynthetic efficiency of the natural phytoplankton community, which in turn will be used to both estimate primary production for each station alongside chlorophyll profile and irradiance data and to derive parameters used in remotely-sensed models of marine primary production.

Sampling :

For each stainless steel CTD cast (CTDs), seawater was collected from the surface (approximate 5m). Additionally, seawater was collected from the trace-metal fish for Long Term (6 day) Experiments (LTE) to monitor the growth response of natural assemblages to trace metal amendments (see separate section on 'Nutrient addition bioassay experiments'). Seawater was also collected to determine chlorophyll-a concentrations from the same Niskin or experimental bottle in order to normalise carbon uptake rates to pigment biomass (see report section on 'Upper ocean pelagic sampling…') .

PI experiments were conducted in a custom-built incubator holding 15 60ml polycarbonate bottles. Samples were maintained at ambient temperatures (+/- 1˚C) throughout the incubation period in a temperature-controlled container. Each of the 60ml polycarbonate bottles was rinsed three times with sample water then filled to the shoulder in a low-light environment. 100 µl of ^{14}C stock sodium bicarbonate solution is added to each of the 15 bottles (10 µCi added per bottle). The bottles were placed into the incubator and neutral density filters were spaced between bottles to obtain a gradient of light levels. A single dark bottle was also placed in the incubator to measure ^{14}C incorporation in the dark.

The stock containing the ^{14}C sodium bicarbonate solution is stored in the refrigerator until the next experiment is conducted. 100µl of spiked sample was pipetted into a scintillation vial containing 100µl of PEA. 4 ml of scintillation cocktail (Ultima Gold) were added, the cap is replaced and the solution is mixed well. Counts obtained from these vials were provided by the shipboard liquid scintillation counter in disintegrations per minute (DPM).

At the end of the incubation period, samples were filtered through GF/F filters at a vacuum pressure of 200 mm Hg. Filters are removed from the towers and carefully placed in order in a dessicator in the fumehood containing ~ 200 ml of concentrated hydrochloric fuming acid (HCl). After fuming the filters were placed individually into numbered plastic scintillation vials. Scintillation cocktail was added to each vial and were counted in the scintillation counter onboard the ship. The light intensity inside of the incubator was measured using a LI-COR LI-250A light meter.

Samples Collected:

A detailed list of samples collected may be found in the table below.

Sample analysis:

The biomass-normalised primary production, P^B, at each light level will be calculated from the formula:

$$P^B = ((DPM_{light}-DPM_{dark}) \times 12000 \times ALK \times 1.05)/ ((DPM_{add} \times 500) \times N \times Chl),$$

where DPM_{light} is the counts in the light bottle, DPM_{dark} is the counts in the dark bottle, ALK is the carbonate alkalinity (Meq), 12000 converts Meq to µg C, 1.05 is the isotope discrimination factor,

DPM_{add} is the counts from the flask inoculated with 100 µl of ^{14}C stock solution, 500 converts counts to total counts for the DPM_{add} flask, N is the duration of the incubation in hours and Chl is the chlorophyll concentration in µg l^{-1}. The units for P^B is mg C (mg Chl)$^{-1}$ h^{-1}.

Table 20 List of water samples collected for photosynthesis-irradiance incubations.

Date collected	CTD/EXPT	Station	CTD/FISH ID	Depth (m)
06/12/2019	CTD	OOI_1	CTD_002SS	5
09/12/2019	CTD	TS_1	CTD_006SS	5
11/12/2019	CTD	TN_1	CTD_009SS	5
12/12/2019	EXP	EXPT1_C	FISH FROM OO1_1 - DAY 6	3
12/12/2019	EXP	EXPT1_FE+	FISH FROM OO1_1 - DAY 6	3
14/12/2019	CTD	OOI_2	CTD_014SS	5
15/12/2019	EXP	EXPT2_C	FISH FROM TS1 - DAY 6	3
15/12/2019	EXP	EXPT2_FE+	FISHFROM TS1 - DAY 6	3
17/12/2019	CTD	TS_2	CTD_017SS	5
19/12/2019	CTD	TN_2	CTD_020SS	5
20/12/2019	EXP	EXPT3_C	FISH FROM OOI_2 - DAY 6	3
20/12/2019	EXP	EXPT3_FE+	FISH FROM OOI_2 - DAY 6	3
22/12/2019	CTD	OOI_3	CTD_0026SS	5
23/12/2019	EXP	EXPT4_C	FISH FROM TS2 - DAY 6	3
23/12/2019	EXP	EXPT4_FE+	FISH FROM TS2 - DAY 6	3
27/12/2019	CTD	TS_3	CTD_029SS	5
28/12/2019	EXP	EXPT5_C	FISH FROM OOI3 - DAY 6	3
28/12/2019	EXP	EXPT5_FE+	FISH FROM OOI3 - DAY 6	3
29/12/2019	CTD	TN_3	CTD_033SS	5
30/12/2019	CTD	TS_4	CTD_034SS	5
02/01/2020	EXP	EXPT6_C	FISH FROM TS3 - DAY 6	3
02/01/2020	EXP	EXPT6_FE+	FISH FROM TS3 - DAY 6	3
03/01/2020	CTD	OOI_4	CTD_038SS	5
04/01/2020	EXP	EXPT7_C	FISH FROM TN3 - DAY 6	3
04/01/2020	EXP	EXPT7_FE+	FISH FROM TN3 - DAY 6	3
04/01/2020	EXP	EXPT7_Mn	FISH FROM TN3 - DAY 6	3
04/01/2020	EXP	EXPT7_Mn + FE+	FISH FROM TN3 - DAY 6	3
04/01/2020	CTD	TN_4	CTD_041SS	5
06/01/2020	CTD	TRANS_2ARGO	CTD_043SS	5

Nutrient addition bioassay experiments

Neil Wyatt, Mark Moore (U. Southampton)

Factorial nutrient addition experiments were performed during DY111 (see figure) to investigate how spatial and temporal changes in nutrient (Fe, Mn, Zn and Si) availability influenced phytoplankton physiology, growth and nutrient drawdown stoichiometry. Two different experimental designs were run simultaneously, using similar methods to those employed previously in the HNLC Southern Ocean (Moore et al. 2007): 48-hour incubations (n = 8) and 6-day incubations (n = 7). The short-term bioassays (denoted 'STE') were designed to assess the rapid changes in phytoplankton physiology upon Fe addition and to resolve Fe stress development over the duration of the cruise, whilst the long-term experiments (denoted 'LTE') were to assess changes in community physiology, structure and elemental stoichiometry in response to changes in nutrient addition. Further, three of these short-term and two long-term experiments were amended with glacial and non-glacial Patagonian sediment (< 63 µm) additions to investigate the response of atmospheric dust deposition on phytoplankton physiology.

Strict controls were required to avoid the contamination of incubation bottles, sampled seawater water and nutrient spikes. All incubation bottles were passed through a vigorous cleaning process involving a week long soak in 1 M HCl followed by Milli-Q rinsing and storage with 0.024 M HCl prior to sailing. The trace metal spikes were prepared from high purity salts prior to sailing, whilst the Si spike was prepared from high purity NaFSi salt and cleaned for trace metal impurities through a Chelex-100 cation exchange resin prior to sailing. Seawater was collected using a trace metal clean 'tow-fish' through acid-cleaned tubing when the ship was sailing at a minimum of five knots. Bottle filling and all manipulation steps including spiking and sub-sampling were performed in a purpose built, Class-100 clean air container.

Water for the experiments was collected and transferred unfiltered into 2 L polycarbonate bottles (Nalgene) for the 48 h incubation experiments and 4.5 L polycarbonate bottles for the long-term incubation experiments. Incubation bottles were filled in a random order, 50 % at a time, with triplicate samples for initial measurements collected at the beginning, middle and end of the filling process. The average time between the primary initial and final initial sample for the 48 h experiments was 15 minutes while for the 6 d experiments this reached 35 minutes, corresponding to distances of around 2.5 – 5.5 km and 5.5 – 13km for the 48 h and 6 day experiments respectively.

In addition to an unamended control, separate bottles were amended with 2 nM Fe and then further bottles with either 2 nM Mn/Zn and/or 5 µM Si in a series of factorial designed experiments. Patagonian sediment was added to separate incubation bottles by triple rinsing (filtered seawater) of the material from sterile cryovials and was accompanied by replicate controls whereby empty vials were rinsed into separate incubation bottles. All experimental conditions were conducted as biological duplicates or triplicates. Following nutrient amendment, all bottles were parafilm-sealed before transfer into a temperature controlled incubation container set to approximately local sea surface temperature

(5.5 - 6.5 °C). The bottles were incubated on shelves surrounded by light banks with ~200 μE m^2 s^1 flux and set to a local day/night cycle of 6 and 18 h, respectively.

Samples for analysis of chlorophyll, macronutrients and chlorophyll fluorescence (FRRf) were collected from all experiments after 48 h at which point the short-term experiments were terminated. The long-term experiments were sub-sampled after a further four days for the same parameters with additional sub-samples taken for dissolved and particulate trace metals, particulate organic carbon and nitrogen, biogenic silica and HPLC pigment analysis, alongside preservations of samples for later identification of phytoplankton community structure by microscopy and flow cytometry. A series of samples were also collected by filtering through Sterivex filters, flash freezing, then stored at -80°C. No immediate plans for analysis of these samples is in place, but they will be archived for potential future molecular analysis. Preserved samples were collected from a combined sample of the triplicate bottles within a treatment. An additional 2 'gradient' experiments (denoted 'GE') involving incubation of a set of smaller 125ml samples over a gradient of Si availability at both high and low Fe availability were also performed at the northern (OOI) and southern (TS) station locations. A complete list of sampling locations is provided in the table.

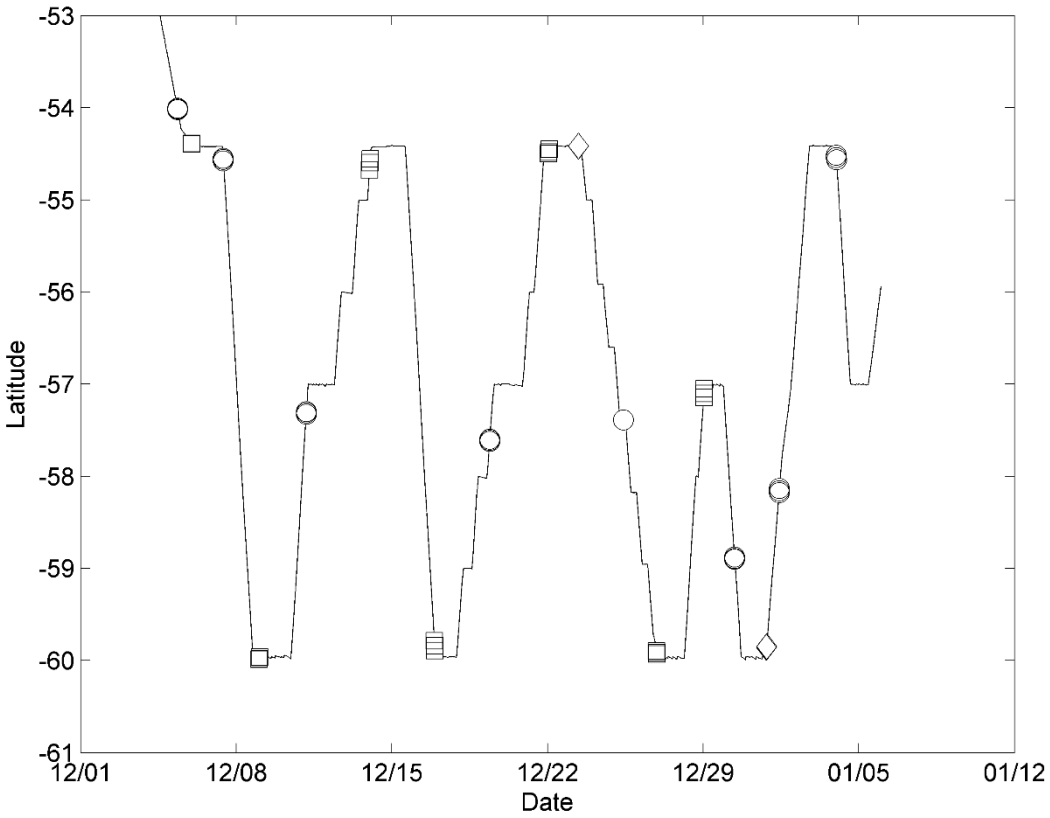

Figure 18 Location/time map of initial samples collected at beginning, middle and end of the short-term (circle) and long-term (square) and gradient (diamond) nutrient addition bioassay experiments during cruise DY111.

Table 21 Sampling locations (mean latitude and longitude of sampling), sampling methods, start and end times for nutrient addition bioassay experiments during DY111.

Experiment id	Latitude	Longitude	Sampling method	Start date	End date
STE-01	-54.0121	-85.3807	Trace clean fish	5/12/19	7/12/19
STE-02	-54.5608	-89.1393	Trace clean fish	7/12/19	9/12/19
STE-03	-57.3123	-89.2222	Trace clean fish	11/12/19	13/12/19
STE-04	-57.6086	-88.7626	Trace clean fish	19/12/19	25/12/19
STE-05	-57.3882	-90.0593	Trace clean fish	25/12/19	30/12/19
STE-06	-58.8904	-89.1363	Trace clean fish	31/12/19	1/1/20
STE-07	-58.1556	-90.6246	Trace clean fish	1/1/20	3/1/20
STE-08	-54.5387	-89.1345	Trace clean fish	3/1/20	6/1/20
LTE-01	-54.3923	-88.5349	Trace clean fish	5/12/19	12/12/19
LTE-02	-59.9784	-89.2614	Trace clean fish	8/12/19	15/12/19
LTE-03	-54.6087	-89.0120	Trace clean fish	15/12/19	20/12/19
LTE-04	-59.8418	-89.3703	Trace clean fish	16/12/19	23/12/19
LTE-05	-54.4761	-89.0326	Trace clean fish	21/12/19	28/12/19
LTE-06	-59.9149	-89.4876	Trace clean fish	26/12/19	2/1/20
LTE-07	-57.0990	-89.1202	Trace clean fish	28/12/19	4/1/20
GE-01	-54.4160	-90.0865	Trace clean fish	23/12/19	29/12/19
GE-02	-59.8545	-89.2093	Trace clean fish	31/12/19	5/1/20

Preliminary results indicated the expected Fe limitation of phytoplankton within the Southern Ocean, with some cases of likely secondary responses to additional nutrients. Some differences in response were also apparent between the geographical locations sampled.

Bacterial Abundance and Diversity

Chance English (UCSB)

BIARRITZ PI: Craig Carlson

Scientific Motivation:

Marine heterotrophic bacteria play a pivotal role in the global carbon cycle as they regulate the turnover of dissolved organic matter, the largest pool of reduced carbon in the ocean (Azam & Malfatti, 2007; Carlson & Hansell, 2015). Despite immense taxonomic and functional diversity, the role of bacterial stocks and diversity in the overturning of DOM remains less clear. The finding that a single bacteria strain is capable of reducing DOM concentrations as much as natural bacterial assemblages questions the role of diversity in the overturning of DOM, however in natural systems bacterial communities show strong temporal and spatial gradients associated with the overturning of DOM (Landa et al., 2016; Pedler et al., 2014). As part of the DY111 field campaign, samples for bacterial abundance and DNA were sampled during the occupation of each major station in order to resolve the temporal and spatial distributions of bacterial communities. Additionally, sampling was targeted to overlap with

measurements for bulk DOC concentrations, total dissolved amino acids and size fractioned respiration rates in order to resolve possible drivers of bacterial diversity.

Sampling:

Bacterial Abundance

Samples for bacterial abundance were taken from 10 depths between 5-1000m during each occupation of the major stations (OOI, TN, TS). Samples were collected into 15 ml sterile falcon tubes and 1 ml sub samples were aliquoted into sterile centrifuge tubes for analysis via flow cytometry. Samples were fixed with 22 μl of 8% paraformaldehyde and frozen at -80°C. Samples will be analyzed using a GUAVA Easy Cyte flow cytometer (Luminex Corp.).

Bacterial Diversity

Samples for bacterial DNA were collected from 5-8 depths between 5-300m during each occupation of the major stations. One litre was collected from each depth into a polycarbonate bottle and subsequently filtered onto a 0.2 μm polycarbonate filter using positive pressure. Filters were stored in sterile cryovials and stored at -80°C until further analysis.

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Microbial Respiration

Chance English (UCSB)

BIARRITZ PI: Prof Craig Carlson (UCSB)

Motivation:

Heterotrophic Respiration is the fundamental process by which organisms obtain energy from organic matter and at the ecosystem level represents the largest sink for organic matter in the ocean. (Del Giorgio & Williams, 2005). Understanding the magnitude and variability of microbial respiration is critical for the understanding the metabolic balance of the ocean and the efficiency at which carbon is stored in the ocean. Measurements for this critical process are rarely performed due to constraints in methodology and feasibility and thus respiration remains one of the least constrained parameters in contemporary oceanography (Robinson, 2019). However, recent advances in methodology including optical optode sensors and the Iodo-nitro-tetrazolium (INT) reduction assay have improved the ability to measure oxygen and respiration in aquatic environments (Bittig et al., 2018; García-Martín et al., 2019). During this cruise, community and size-fractionated respiration rates were determined using a novel automated biological oxygen demand (autoBOD) system as well as the INT reduction method, respectively. Each method is described below. Additionally, the autoBOD was used to measure the respiration rates of the TZero, suspended, slow sinking, and fast sinking fractions collected by the Marine Snow Catchers. These incubations allowed for the determination of respiration rates in the mesopelagic zone as well as the contribution to respiration by sinking and suspended organic matter.

Sampling:

autoBOD

The autoBOD is an automated carousel with an integrated optical optode sensor system (PreSens, Germany) used to measure the oxygen concentration in 12 BOD bottles. The autoBOD was developed by Ben VanMooy's laboratory at the Woods Hole Oceanographic Institute. Each bottle is fixed with an optode sensor spot and the oxygen concentration is measured 25 times every 15 minutes. Incubations of the BOD bottles are performed for approximately 36 hours allowing for 3600 individual measurements of each bottle's oxygen concentration. The repeated measurement over time allows respiration to be determined by the change in oxygen concentration through time in each bottle. Additionally, the high density of oxygen measurements allows for respiration to be statistically resolved via Monte-Carlo approximation. This method involves calculating the change in oxygen over time by randomly pairing data points at least one hour apart. The random pairing is performed one million times and a distribution of the respiration rates is generated. The mean of the respiration rate distribution is determined to be the actual respiration rate for each bottle. Analysis via the Monte-Carlo approximation is performed in R using a program developed by Dan Lowenstein in the VanMooy laboratory at WHOI.

Samples for the autoBOD were collected in triplicate 125 ml BOD bottles from 4 depths directly from the Niskin in the surface 75m. Bottles were rinsed once with sample water and overflowed 3x and sealed with a ground glass stopper. Each main station was sampled during the 1st and 3rd occupation of the cruise with targeted depths of 5, 20, 50 and 75m. Variations from the target depths occurred where no water was available at that depth.

Station	Depth (m)
OOI 1	70
OOI 1	50
OOI 1	20
OOI 1	5
OOI 3	75
OOI 3	50
OOI 3	20
OOI 3	5
TN 1	5
TN 1	20
TN 1	50
TN 1	70
TN 3	5
TN 3	20
TN 3	40
TN 3	75
TS 1	200
TS 1	70
TS 1	20
TS 1	5
TS 3	5
TS 3	20
TS 3	50
TS 3	75

In Vivo Iodo-nitro-tetrazolium (INT) Reduction Assay

This method is based on the reduction of INT (a water soluble, membrane permeable salt which passively penetrates into the cell) by dehydrogenase enzymes in the electron transport system forming insoluble formazan crystals (INT-*f*) (Martínez-García et al., 2009). The *in-vivo* method is based on a variation of the *in-vitro* method described by Packard et al., 1996. Whole seawater was collected from the niskins at 4 depths in the surface 75m in tandem with samples for the autoBOD. Four 250 ml polycarbonate bottles were rinsed 3x with sample water and filled. One sample was immediately killed with 0.2 filtered formalin (2% v/v final concentration) and used as a control. The remaining 3 bottles

were inoculated with 8mM INT solution to a final concentration of 0.2 mM. Samples were incubated within 1 degree of *in situ* temperature for 3 hours and subsequently fixed with formalin. Because the INT-*f* is formed internally, cells can be size-fractionated post-incubation and the INT-reduction rate determined for different size classes. During DY111 samples were filtered sequentially through a 2.0 and 0.2 μm polycarbonate filter which were then stored in 2ml sterile cryovials at -20°C until further analysis. Samples from DY111 were stored on board until being shipped back to an in-shore laboratory at the University of California, Santa Barbara. The method uses the spectrophotometric absorption of the INT-*f* at 485 nm to determine the rate at which the insoluble crystals are formed inside the cell membranes. Absorbance of each sample will be determined by incubating the filters in 1 mL of propanol, followed by sonication and centrifugation. The concentration of the INT-*f* in solution is calculated from its absorbance by applying a standard curve previously determined using twelve different concentrations of stock INT-*f* dissolved in pure propanol. Each main station (TN, TS, OOI) was sampled twice using the INT respiration method, with the exception of OOI-1.

Marine Snow Catcher Respiration Rates:

Using the autoBOD, community respiration rates were measured on the TZero, Suspended, Slow, and Fast sinking fractions of the Marine Snow Catchers (MSC's) at 3 depths during the second occupation of each main station. OOI was sampled twice during the second and fourth occupation and two intra-variability experiments were performed at the fourth TS and TN occupations.

Sampling

MSC's Respiration Profiles

During the second occupation of each main station, 3 MSC's were sampled from the TZero, suspended, slow, and fast factions at 10m below the mixed layer, +100m, and either 450 or 750m. BOD bottles with an optical optode sensor spot were filled with sample water and analyzed using the autoBOD for an incubation period of 36 hours. Respirations rates were determined as described above. Due to constraints of the number of bottles the autoBOD can analyze and sample volume of the slow and fast sinking fractions only one BOD bottle for each fraction at each depth could be analyzed.

Variability Experiments

In order to test the internal variability of the MSC's, variability experiments were performed by measuring respiration rates in each fraction of the MSC's in triplicate at a single depth. Variability experiments were performed at TS4 and TN4 at 130m.

Table 22 MSC Respiration Samples

Station	Depth (m)	Fractions	Replicates
OOI 2	80	T0, Susp, Slow, Fast	no
OOI 2	180	T0, Susp, Slow, Fast	no
OOI 2	700	T0, Susp, Slow, Fast	no
TS 2	100	T0, Susp, Slow, Fast	no
TS 2	200	T0, Susp, Slow, Fast	no
TS 2	400	T0, Susp, Slow, Fast	no
TN 2	30	T0, Susp, Slow, Fast	no
TN 2	130	T0, Susp, Slow, Fast	no
TN 2	400	T0, Susp, Slow, Fast	no
TS 4	130	T0, Susp, Slow, Fast	yes
OOI 4	70	T0, Susp, Slow, Fast	no
OOI 4	170	T0, Susp, Slow, Fast	no
OOI 4	750	T0, Susp, Slow, Fast	no
TN 4	130	T0, Susp, Slow, Fast	yes

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Fe and C (co) limitation of bacterial production

Joanna Ainsworth, Mark Moore, Neil Wyatt (U. Southampton)

The effects of iron (Fe) and organic carbon (C) on bacterial production, abundance and DNA were investigated at 3 stations (OOI, TS and TN) located in the HNLC region of the Southern Ocean/South East Pacific as part of the CUSTARD cruise over the timeframe of 6th December 2019 to 5th January 2020. At all stations water from within the mixed layer and from the upper mesopelagic were taken from the trace metal CTD (see report section 'Trace metal sampling and analysis') and subsampled into acid washed 500 mL polycarbonate bottles, a 1 L sample for Sterivex filtering for DNA analysis was also taken from each depth. The 500 mL samples were transferred into another trace metal clean lab where the following treatments were prepared in triplicate: whole seawater +Fe, whole seawater +C and whole seawater +Fe +C, as well as a control of just whole seawater. The Fe was added as $FeCl_3$ in 0.024M HCL to a final concentration of 2 nM, the C was trace metal clean glucose to a final concentration of 10 µM. The glucose had been passed over a Chelex ion exchange resin to prevent trace metal contamination. The samples were then incubated in the dark to prevent the influence of phytoplankton derived dissolved organic material at in situ temperatures of 6°C for the surface mixed layer and 4°C for the mesopelagic samples, with bacterial production and abundance measurements taken at 2 and 6 days. At each time point the incubation bottles were taken to the trace metal clean lab for subsampling into 30 mL polycarbonate bottles and the following processing.

Bacterial production

For each treatment triplicate, at each depth, 1.8 mL of subsample was placed in each of 3 vials. Either 11 µL or 16 µL of a 3.7kBq/ul 3H Leucine stock 10nM final concentration were added to result in 40.7kBq or 59.2kBq total activity in each sample (Perkin Elmer L-[4,5-3H(N)] 60Ci/mmol). One sample had the addition of paraformaldehyde (PFA) or formaldehyde to a final concentration of 1% as a killed control and the remaining 2 as duplicate live samples. The spiked samples were then incubated in the dark for 4 hours to allow for Leucine uptake. After 4 hours, PFA or formaldehyde to a final concentration of 1% were added to the live samples to terminate the incubation and all samples were filtered on 0.2 µm polycarbonate filters and placed in 6 mL of scintillation cocktail for determination of total incorporated activities within a liquid scintillation counter (Perkin Elmer TriCarb 3180 TR/SL) on board ship.

Bacterial abundance:

For each treatment (including the control), at each depth, 1.8 mL of subsample were fixed with either paraformaldehyde or formaldehyde to a final concentration of 1%. The samples were transferred to the -80°C freezer for analysis by flow cytometer at a later date.

Bacterial DNA:

At the final time point after 6 days, each of the triplicate treatments were combined to allow filtering of 1 L through a Sterivex filter which was then frozen at -80°C for DNA /gene expression analysis at a later date.

Table 23 Bacterial iron and carbon limitation experiments summary

Station	Event	Date	CTD cast	Depths	OTE bottle	Experiment ID	Time step dates	3H Leu activity added
OOI-1	16	06/12/2019	002T	20	22	BP1	T0 – 06/12/19 T1 - 08/12/19 T2 – 12/12/19	T0 - 40kBq T1 – 40kBq T2 – 60kBq
				60	19			
				500	5			
TS-1	35	09/12/2019	005T	20	22	BP2	T0 – 09/12/19 T1 - 11/12/19 T2 – 15/12/19	T0 - 40kBq T1 – 60kBq T2 – 60kBq
				60	19			
				500	5			
OOI-2	74	14/12/2019	009T	20	22	BP3	T0 – 14/12/19 T1 - 16/12/19 T2 – 20/12/19	60kBq
				150	9			
TS-2	93	17/12/2019	011T	20	22	BP4	T0 – 17/12/19 T1 - 19/12/19 T2 – 23/12/19	60kBq
				150	10			
OOI-3	132	22/12/2019	016T	20	22	BP5	T0 – 22/12/19 T1 - 24/12/19 T2 – 28/12/19	60kBq
				150	15			
TS-3	157	27/12/2019	018T	20	6	BP6	T0 – 27/12/19 T1 - 29/12/19 T2 – 02/01/20	60kBq
				150	1			
TN-3	169	29/12/2019	019T	20	23	BP7	T0 – 29/12/19 T1 – 31/12/19 T2 – 04/01/20	60kBq
				150	18			

Results:

A summary of the results can be found in the table below, where a 'Y' indicates the presence of limitation as determined by a one way Anova with a multi comparison test. However, further statistical analysis is required. The results consistently show the presence of iron and carbon co-limitation or secondary iron limitation at both the surface and in the mesopelagic with some experiments showing

single limitation of iron in surface bacteria or carbon in both surface and mesopelagic bacteria. Figure 19 is a subset of the experimental results for TN-3.

Table 24 - Fe and C co limitation results

Expt	Location	Date	Depth (m)	Delta T (days)	+Fe	+C	+Fe+C
BP1	OOI-1	06/12/2019	20	2		Y	
				6			
			60	2			Y
				6			Y
			500	2			
				6			Y
BP3	OOI-2	14/12/2019	20	2			
				6			
			150	2			
				6			Y
BP5	OOI-3	22/12/2019	20	2	Y	Y	Y
				6			Y
			150	2			
				6			Y
BP2	TS-1	09/12/2019	20	2			
				6			Y
			60	2			
				6		Y	Y
			500	2			
				6		Y	Y
BP4	TS-2	17/12/2019	20	2			Y
				6			Y
			150	2			
				6			Y
BP6	TS-3	27/12/2019	20	2		Y	Y
				6			Y
			150	2			
				6			Y
BP7	TN-4	29/12/2019	20	2	Y		Y
				6			Y
			150	2			Y
				6			Y

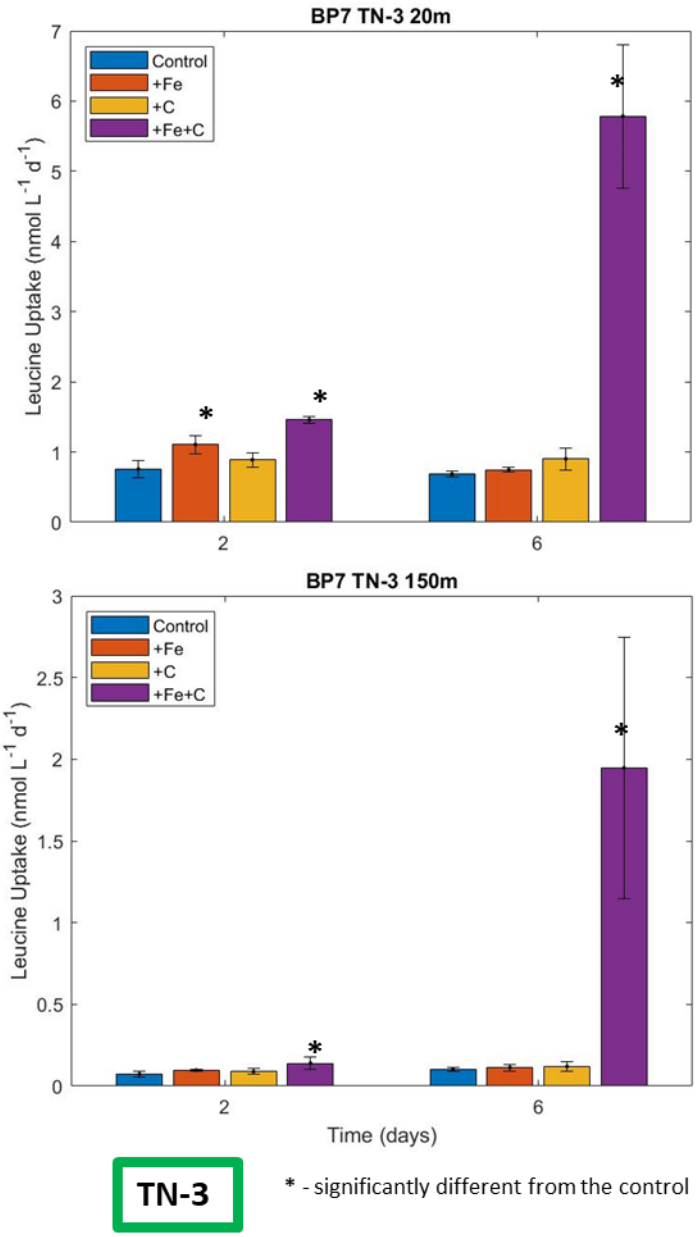

Figure 19 - Results subset for station TN-3 only showing surface bacteria iron limitation and surface and mesopelagic bacteria carbon and iron limitation. Treatments significantly greater than the control (using a one way Anova and multi-comparison test) are indicated by *

Nitrification analysis

Roxana Shafiee (U. Oxford)

Rationale:

Nitrification is the stepwise oxidation of ammonium to nitrite (NO_2^-) and then nitrate (NO_3^-) mediated by two sets of organisms: ammonia oxidising microorganisms and nitrite oxidising organisms respectively. The rate-limiting step of nitrification is ammonia oxidation, carried out by ammonia oxidising archaea (AOA) and bacteria (AOB). Marine nitrification rates are inextricably linked with the global carbon cycle, as higher rates of NO_3^- supply to surface waters promote the growth of larger, faster-sinking microphytoplankton (such as diatoms) which drive two thirds of carbon export to oceanic depth[1-3]. High nitrification rates have been observed in high latitude surface waters and are hypothesised to be linked with light and/or iron limitation of phytoplankton communities[4]. The hypothesis outlines that in the Southern Ocean, light or iron limitation of phytoplankton creates a residual pool of unutilised ammonium normally unavailable to ammonia oxidising microorganisms, providing an explanation for accumulation of nitrite in the water column. The hypothesis assumes that ammonia oxidising microorganisms are themselves limited by iron (or another nutrient), which, considered in light of recent culture work, may not be the case[5], due to the low uptake affinity for iron and significant cellular iron demand of AOA. During the DY111 cruise we tested this hypothesis and examined the potential for nitrification to be limited, seeking to provide explanation as to why NO_2^- concentrations are elevated in Southern Ocean surface waters relative to other regions.

Methodology:

Incubation experiments

Nutrient incubation experiments at sites OOI and Ts were carried out to test for substrate and nutrient limitation of ammonia oxidation. For these experiments, trace metal clean unfiltered seawater was sampled from titanium CTD-niskin bottles at stated depths (see table), 5µm filtered (to remove phytoplankton) and amended with the stated nutrients in the trace metal clean container. Cultures were amended with $KClO_3$, inhibiting the oxidation of nitrite such that the accumulation of nitrite could be used as an indicator of ammonia oxidation rates[6]. After 10 days incubation in the dark at 6°C (4°C for 500m experiment) experiments were sub-sampled for NO_2^-, which was analysed using the AutoAnalyser (see report section 'Inorganic nutrients analysis') and compared with sub-samples taken at the beginning of experiments.

Table 25 Nutrient incubation experiments – no further samples to take back to shore. All analysed on board.

Date	Site	Lat/ Long	CTD #	Depth	Amendments *
6/12/19	OO1 (1)	54 25 280 89 7 719	2	20m	Control + NH_4 + Fe + Fe + NH_4 + Cu
6/12/19	OO1 (1)	54 25 280 89 7 719	2	60m	Control + NH_4 + Fe + Fe + NH_4
6/12/19	OO1 (1)	54 25 280 89 7 719	2	500m	Control + NH_4 + Fe + Fe + NH_4
22/12/19	OO1 (3)	54 24.968 89 07.972	16	20m	Control + NH_4 + Fe + Fe + NH_4 + NH4 + Cu + Cu + Fe
9/12/19	Ts (1)	59 57.377 89 7.319	5	20 m	Control + NH_4 + Fe + Fe + NH_4
9/12/19	Ts (1)	59 57.377 89 7.319	5	120m	Control + NH_4 + Fe + Fe + NH_4

* All NH_4^+ additions were 10mM, Fe additions were 2nM , Cu additions were 1nM

Ammonia-oxidising archaea and bacterial abundance

Recent work has showed that trace metals may play a role in the niche separation between ammonia oxidising bacteria (AOB) and archaea (AOA), with bacteria being better suited to high substrate (NH_4^+), low iron regions characteristic of the Southern Ocean. As of yet, there has been no analysis of the relative abundances of AOA and AOB in the Southern Ocean. We addressed this paucity by collecting 2L seawater samples from the stainless steel CTD-niskin from the all stations with depth (table below). Samples were immediately filtered onto 0.2 μm filters and immersed in DNAlater and stored in the -80°C Freezer number 4. Samples will be analysed for AOA and AOB abundances back on land (Oxford).

Table 26 Filtered samples for further DNA analysis with depth – all stored in labelled box (L300 x W150 x H150) in -80C freezer number 4.

Date	Site	CTD#	Lat/Long	Depths sampled(m)
17/12/19	OOI (2)	CTD #17	54 25.136 89 08.762	10, 20, 30, 50, 75, 100, 150, 300, 1000
19/12/19	TN (2)	CTD #20	56 59.983 89 7.960	5, 20, 40, 70, 100, 120, 300, 400, 1000
22/12/19	TS (2)	CTD #26	59 57.623 89 7.526	1000, 400, 200, 100, 75, 50, 45, 30, 20, 10 5

A further set of nutrient incubations were conducted using surface seawater collected using the towed trace metal free FISH in greater volumes (4L), with the aim examining the effect of changing nutrients on competition between AOA and AOB. Seawater for these experiments was not filtered prior to addition of nutrients and no $KClO_3$ was added. After addition of nutrients (table below) experiments were stored in the dark at 6°C. After 10 days, experiments were vacuum-filtered down onto 0.2 μm filters, immersed in 1 ml of DNAlater and stored in the -80°C freezer number 4 in the same box as previous filtered samples (see above). DNA will be analysed in Oxford upon return of samples to shore.

Table 27 Nutrient incubation experiments at surface. Filtered samples for further DNA analysis all stored in labelled box (L300 x W150 x H150) in -80C freezer number 4.

Date	Site	Lat/Long	Depth	Amendments*
26/12/19	Ts (3)	58 57.35166 90 5.79912	Surface	Control + NH_4 + Fe + Fe + NH_4 + NH4 + Cu + Cu + Fe

* All NH_4^+ additions were 10mM, Fe additions were 2nM , Cu additions were 1nM

References:

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Zooplankton

Adrian Martin (NOC)

Netting zooplankton was a last minute addition to cruise plans and hence kept to a minimum, in no small part due to the inexperienced person doing it. Two bongo nets were available: 200µm and 69µm mesh sizes. As the primary aim was to provide samples to compare to the UVP data, the 200µm mesh net was used as this mesh size corresponds with the minimum size resolved by the UVP. The table shows the details and timing of net deployments. Nets were originally deployed using the Romica winch over the crane on the starboard quarter. It had been found to under-estimate wire out by 20% by analysis of pressure sensors on Snow Catcher deployments so wire out was adjusted accordingly. On ZOO4 the cable veered under the rear of the vessel requiring a boost from the port azimuth (the starboard one was off for the deployment) to move clear. Following this, on ZOO5 there was clear evidence of the port azimuth being directed to starboard to keep distance, raising concerns of how the turbulence was affecting the netting. Therefore, from ZOO6 netting was moved to midships, using a Kevlar rope marked into 10m intervals. The depth ranges chosen for netting were 0-120 m and 0-300 m, both based on study of ADCP returns. The former seemed to capture the range of daily migrators at night with the second being, somewhat arbitrarily (ADCP returns were at best ~300m), chosen to capture some of this population in daytime at depth. After TS_1, only one depth range was sampled (0-120m) due to time constraints. In theory, the difference between day and night nets would be used to infer the migrating population anyway.

Method:

Once the net was on deck the cod end was removed, placed in a bucket and taken to a sink where it was decanted through a 200µm mesh sieve. This sieve was then inverted over a funnel and washed

from above with filtered seawater to displace collected material into a 250ml Nalgene bottle. Contents of the bottle were fixed with 25ml formaldehyde with the bottle topped up using filtered seawater. A paper labelled in pencil with cruise, date, time (GMT), depth range and mesh size was inserted in the bottle prior to closure, with the same information noted on the outside of the bottle. Samples were stored in the Chill Room at 4°C.

Issues:

1) *Damage to net mouth*: At some point during the first 4 deployments the metal ring comprising the mouth of the net got damaged, flattening it slightly into more of a distorted ellipse than a circle. One possibility is that it caught on the roller on deployment but this was deliberately watched and was not observed. A second possibility is that the damage was sustained when the net veered under the starboard quarter on the fourth deployment but the net should have been deeper than the hull when this occurred. A third possibility is that the weight used to keep the net vertical in the water was too heavy, producing too great a pressure on the ring as the support ropes go through guides at the ring perimeter. A heavier shackle was used at one point but no-one noted the shape of the ring before and after deployment. Following the realisation that the ring had been deformed, one of the shackles used to weight the feet of the red camera frame was used consistently. As a rough estimate of how the distortion affects samples, the ring was flattened by ~5% equivalent to a ~10% decrease in area.
2) *Cod-end detachment*: Some sample is inevitably lost when the cod-end is detached from the net, partly because water is held above the level of the top end of the cod-end by the base of the net and partly due to ship movement. This obviously is biased towards material on the surface, such as buoyant organisms. It might be possible to remove the excess water by tilting the cod-end slightly to drain it off through base of net but this would risk leaving the same material on the neck of the net rather than in the cod-end. From ZOO17 onwards the cod-end was placed inside a bucket before being detached to catch any spilled material which was also run through the sieve.

Table 28: Zooplankton netting. Ship times for comparison to day/night. Local dusk was ~0000 and dawn ~0600 at 54S and ~0500 at 60S.

Stn.	Evt.	Sample	Date	Day	Start (ship)	End (ship)	Depth range	Comments
TS_1	27	ZOO1	9/12/19	343	0254	0328	0-120m	
	28	ZOO2	9/12/19	343	0411	0454	0-300m	Ship repositioned before start. Dawn well underway by end. Clumsy decant.
	36	ZOO3	9/12/19	343	1325	1349	0-120m	

	37	ZOO4	9/12/19	343	1413	1500	0-300m	Cable veered under rear starboard of vessel requiring boost on port azimuth to clear. Damage to net mouth noticed.
TN_1	53	ZOO5	11/12/19	345	1025	1043	0-120m	Port azimuth generating turbulence around net.
	60	ZOO6	12/12/19	346	0445	0521	0-120m	Deployed midships. Dawn well underway by end.
OOI_2	68	ZOO7	14/12/19	348	0250	0324	0-120m	
	76	ZOO8	14/12/19	348	1340	1408	0-120m	
TS_2	87	ZOO9	17/12/19	351	0316	0344	0-120m	Wire at angle of ~45^{o} away from ship
	97	ZOO10	17/12/19	351	1651	1712	0-120m	
TN_2	106	ZOO11	19/12/19	353	1650	1722	0-120m	
	110	ZOO12	20/12/19	354	0414	0440	0-120	Aggregate material looked red. Bottle not topped up with seawater until 1200 (1500GMT)
OOI_3	125	ZOO13	22/12/19	356	0223	0318	0-120	Krill
	138	ZOO14	22/12/19	356	1709	1731	0-120	No krill. Difficult to make out depth markings due to sun glint. Possibly +/- 10m.
TS_3	145	ZOO15	27/12/19	361	0248	0317		Sample dominated by jelly ~7-8cm across
	155	ZOO16	27/12/19	361	1447	1527		Overspill when cod-end detached included two ~2cm jellies found on deck – not retained.
TN_3	164	ZOO17	29/12/19	363	0450	0512		Delayed by wind.
	173	ZOO18	29/12/19	363	1700	1717		Delayed by wind
TS_4	181	ZOO19	30/12/19	364	1909	1933		
	185	ZOO20	31/12/19	365	0235	0300		
OOI_4	198	ZOO21	3/1/20	3	0243	0304		
	209	ZOO22	3/1/20	3	1603	1635		
TN_4	214	ZOO23	4/1/20	4	1423	1448		
	224	ZOO24	5/1/20	5	0233	0254		Stalled so not fixed
	226	ZOO25	5/1/20	5	0432	0453		Replacement for ZOO24

Gliders

Mike Smart (MARS)

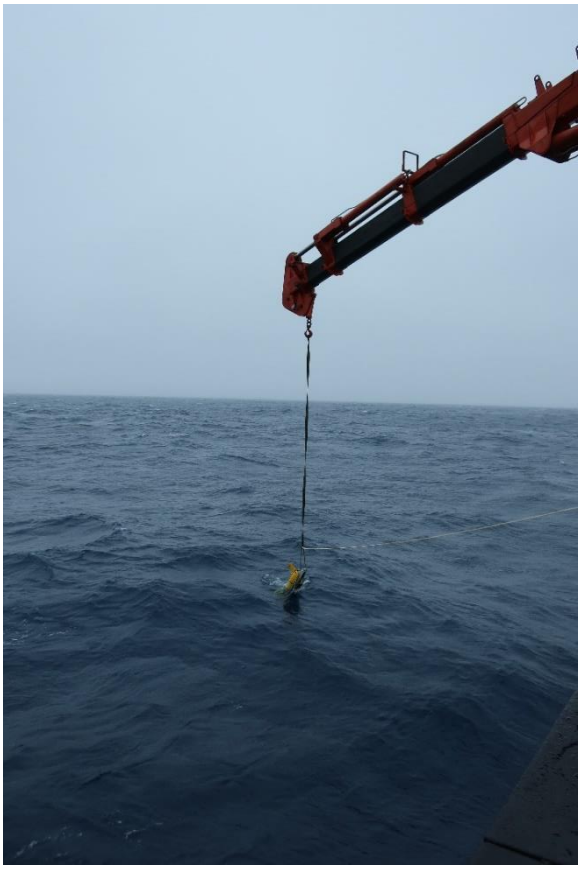
Deployment by Mike, piloting by Alvaro, Ashley, Steve, Racheal and James

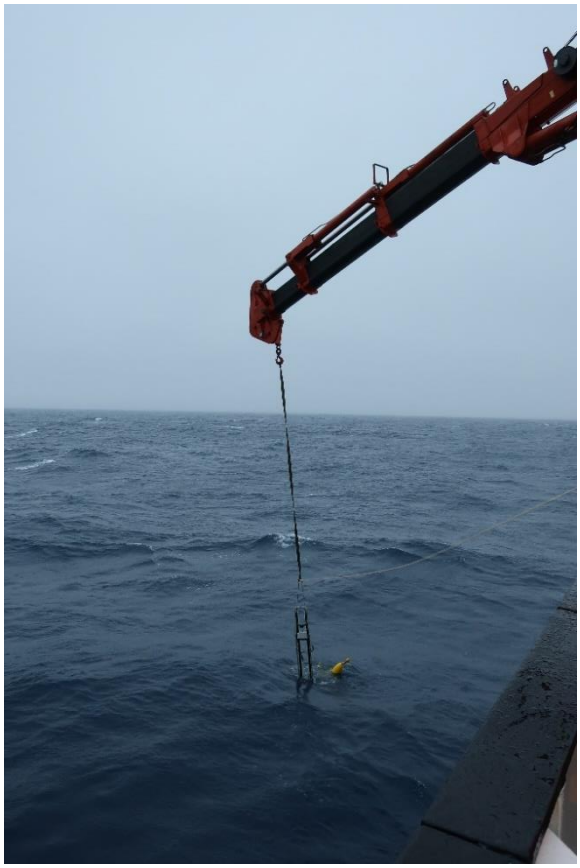
Units 330 and 306 were deployed as part as the CUSTARD project in the Southern Ocean at the OOI mooring site, running a triangle pattern track and, when the Discovery was on station, performing calibration dives at the same time as a CTD profile from the ship. Unit 330 had a payload of Seabird CT, Aanderaa oxygen optode, Wetlabs, Rutgers LISST sensor. Unit 306 had a payload of Seabird CT, Aanderaa oxygen optode, PAR, Wetlabs.

In Punta Arenas the gliders were taken off the ship to an open area of the port to carry out a function and compass check. Both gliders passed the checks and were then stored in the ship's hangar until we reached the deployment site.

Before deployment of the Rutgers LISST sensor on unit 330 it needed calibrating by using sample water and running the sensor to take test readings. These data were used as the base level for the deployment. After this both gliders went through the pre-deployment checks. Unit 330 had an issue with displaying the sensor data on u4stalk but all other aspects passed without issues.

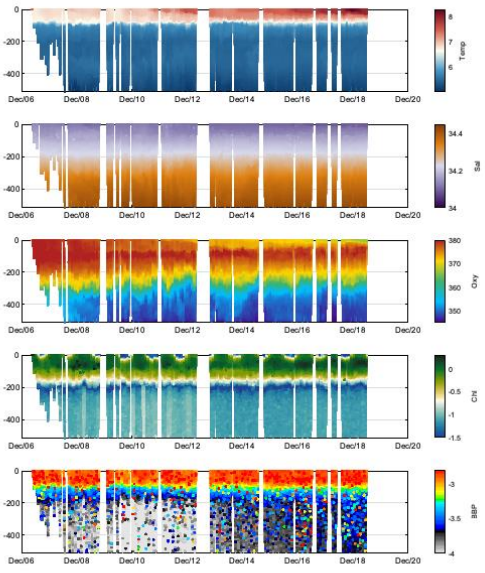
Once we arrived at the OOI site we took the gliders onto the back deck and secured them down until the pilots back at base were ready to deploy. Once we got the OK we rigged the new deployment cradle onto the starboard quarter crane and deployed unit 306 followed, shortly after, by unit 330 (pictures shown below). The new deployment cradle worked smoothly and without issues. There is a full video of the deployment available. A more long-term version of the cradle will be made, following this cruise, as a final version of this and a SOP will be made for future deployments on how to use the new cradle system correctly. Once deployed the piloting was taken care of from NOC.



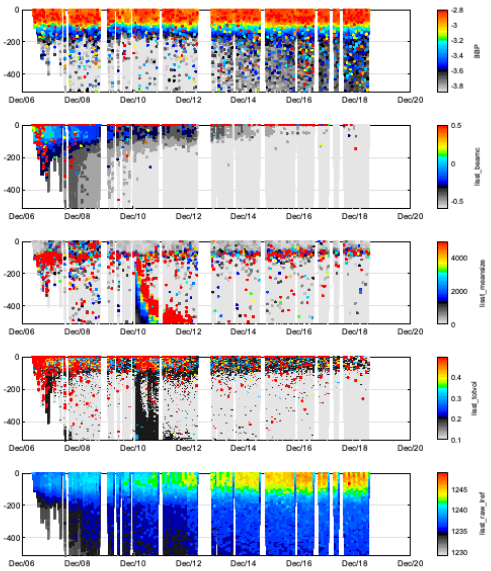


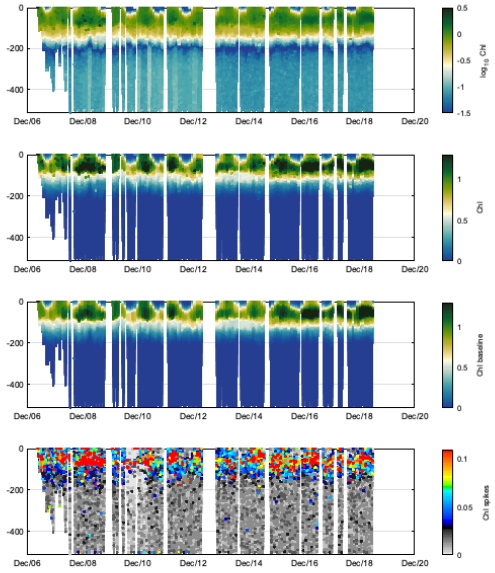
After unit 306 had performed its second initial dive we received information on the Discovery that it had detected a leak so we had to recover the glider. The nose was fired by the pilot and a grapple line thrown from the ship. We recovered on the p-frame winch on the starboard side. After taking the glider apart it appears that the leak was coming from the forward nose bulkhead fitting. Unfortunately it was decided that the glider would not be able to be repaired in the field so it was unable to be re deployed.

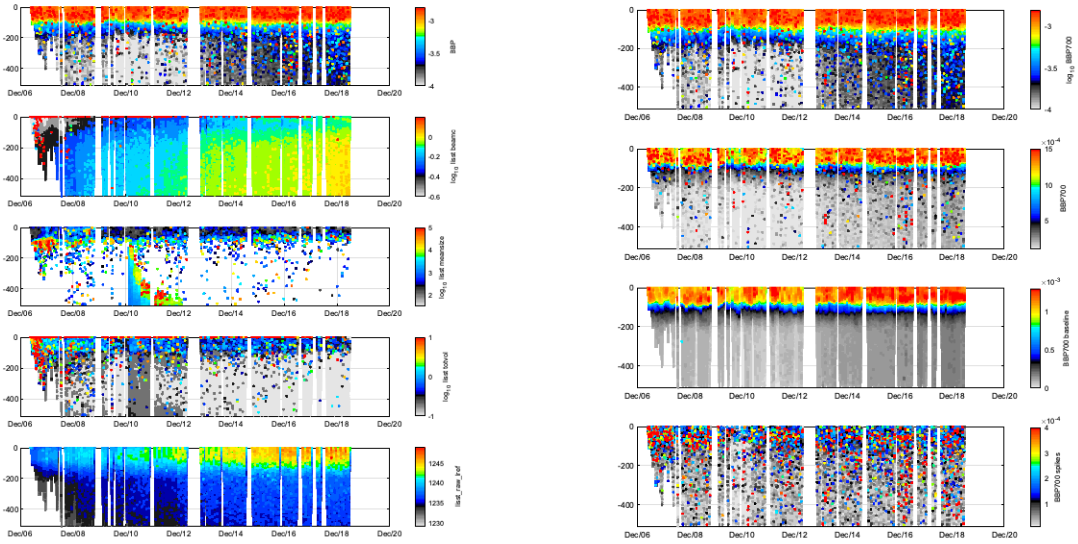
Unit 330 with the LISST sensor was fine to carry on and Discovery left the work site to head to other work sites further south. The glider continued to collect data whilst we were away as shown below. Some examples are shown in the figures below.



When we returned to the OOI site it was required to do a CTD profile from Discovery at the same time the glider dived, to help with the calibration of the sensors. This was done by holding the glider at the surface, bringing the ship a safe distance close to the glider, then letting the glider dive and deploying the CTD from the ship once the glider had disappeared from the surface. The glider was held on the surface by the piloting team at NOC and communication between the ship and land was done via WhatsApp. WhatsApp was used because the email connection was poor. This CTD-glider match-up was done a further two times when returning to the OOI site before the glider was recovered.







For recovery we followed the same procedure as the emergency recovery of unit 306, with the extra step of locating the glider on arrival at the site. Once it was on the surface after finishing a last CTD-matched calibration dive, it was held there with the strobe turned on. Once spotted from the bridge we headed towards the location of the glider. When we had good visibility of the glider the pilot was asked to fire the nose. Once the recovery line streamed out, the glider was recovered by throwing a grapple line and recovering on the p-frame winch. Once back on the ship we ran the LISST sensor with control water again so that these could be used for post calibration of the sensor.

Summary:

The initial look at the science data suggests the deployment seems to have produced some good quality results and the LISST sensor seems to have worked better than expected. We will look into the leak on 306 more closely once back at NOC and see what changes can be made to try and avoid this in the future. The system of carrying out CTD calibration dives near the glider can be further reviewed to see if there are any changes we would want to bring in about having the ship working in close range of the glider.

BGC ARGO deployments

Hugh Venables (BAS) with artistic assistance of Katsia Pabortsava, Sofia Alexiou and Adrian Martin (NOC)

Six bio-Argo SOCCOM floats were deployed during the cruise: two away from the transect line and four along the line, in positions where they should disperse widely. The first three had backscatter sensors. After problems with releasing the deployment rope on the first float, which was lowered by hand from the aft deck, the other five were deployed using the starboard aft crane with a release bar through a rope eye pushed through the hole in the deployment ring. This gives a good grip for a steadying line until the float is in the water, when the bar can then be pulled free as tension is released. This worked smoothly each time.

Before deployment, the nitrate and backscatter (if present) sensors were cleaned. This involved rinsing with milli-Q water and then dabbing with lens cleaning wipes and then lens paper, as supplied by SOCCOM. The orientation of the nitrate sensors is random and several floats had the sensor pointing inwards, meaning that little more than rinsing is possible, though attempts were made.

Before each deployment, a CTD cast was carried out, to 2000m. Sampling was done for oxygen, carbonate parameters (both UEA and SOCCOM samples), nutrients, salts (all bottles) and for HPLC and POC from near-surface depths to match the requirements of SOCCOM deployments.

Table 29: Summary of BGC ARGO float deployments

Float #	Flbb	Lat	Lon	Date	Time (GMT)	CTD #	Adopting School
18242	Y	52 39.22	80 32.25	4/12/19	0522	CTD001SS	N. Monterey County Middle School
18320	Y	54 25.24	89 7.83	6/12/19	0848	CTD002SS	Calif. State College, Monterey Bay
18721	Y	59 57.57	89 7.31	10/12/19	0037	CTD006SS	Twin Oaks High School
18545	N	56 0.17	89 7.10	21/12/19	0856	CTD023SS	James H. Eldredge School
18771	N	58 0.08	89 7.88	28/12/19	1820	CTD030SS	Carmel del Mar School
18098	N	55 14.06	83 10.31	6/1/20	1110	CTD043SS	Lincoln Akerman School

NMF Sensors and Moorings CTD, LADCP & SAPs

Tom Ballinger, Dean Cheeseman, Dave Childs, Jon Short, Mike Smart (NMF)

Stainless Steel and Titanium CTD Operations:

43 CTD casts were undertaken with an NMF 24-way stainless steel CTD frame with 20l Niskin water samplers. An additional 22 casts were undertaken with an NMF 24-way titanium CTD frame with 10l trace metal Niskin water samplers. All instrument serial numbers were checked and all channels of the 9plus underwater unit checked prior to drafting the Sensor Information Sheets for DY111. A SBE 43 Dissolved Oxygen sensor was used to supplement the primary pair of Temperature and Conductivity sensors on both the Stainless Steel and Titanium CTD's.

Between casts, sensors were flushed with MilliQ three times before installation of caps on the TC-duct inlet and pump exhaust of both sensor ducts. After the rosette had been sampled, the whole CTD package was rinsed with fresh water to prevent salt crystals forming in the sensors, associated tubing and particularly the carousel latch assembly. Due to the frequent use of the CTD packages, and low temperatures, the TC-ducts were only cleaned once during the cruise with dilute bleach and Triton-X solutions. No drift or shift was observed in the differences between the Temperature, Conductivity, Salinity or Dissolved Oxygen sensors.

For trace metal work on the Titanium CTD, the science party handed the Niskin water samplers to the technical party to fit to the CTD frame just prior to the cast, protective gloves were fitted to the bottle taps to help keep them clean and the bottles were only cocked into position ready for deployment at the last minute. Upon recovery, the CTD frame was landed on deck and secured whilst the scientific party fitted gloves to the taps. For sampling, the Niskin's were removed from the frame and carried into the clean lab after which the CTD was moved back into the hanger and stowed.

All CTD's were operated out of the hangar using the overhead gantry's to move the CTD frames in and out of position as required. The Stainless Steel CTD was deployed on the 11.43mm conducting CTD wire (CTD1 storage drum) and made use of a swivel. The Titanium CTD was deployed on the Lebus Trace Metal Contingency Winch located on the hanger top. For all CTD operations, the ship's crew drove the winches remotely from the winch cab, with radio contact maintained between the lab and winch cab in order to provide details such as bottom depths and depths to stop the winch for bottle stops.

Usually the normal range of 10m from bottom for maximum wire out was used, the altimeter provided solid returns of the seabed from depths of around 60m for most casts.

The science party sampled the rosette for salinity samples.

Stainless Steel CTD Sensor Information:

The following sensors were installed on the Stainless Steel CTD frame:

Instrument / Sensor	Manufacturer & Model	Serial Number	Channel	Casts Used
Primary CTD deck unit	SBE 11plus	11P-24680-0589	N/A	All Casts
CTD Underwater Unit	SBE 9plus	09P-77801-1182	N/A	All Casts
Carousel	SBE 32	32-31240-0423	N/A	All Casts
Stainless steel 24-way frame	NOCS	SBE CTD 6	N/A	All Casts
Primary Temperature Sensor	SBE 3P	03P-4383	F0	All Casts
Primary Conductivity Sensor	SBE 4C	04C-2580	F1	All Casts
Digiquartz Pressure sensor	Paroscientific	129735	F2	All Casts
Secondary Temperature Sensor	SBE 3P	03P-4381	F3	All Casts
Secondary Conductivity Sensor	SBE 4C	04C-2450	F4	All Casts
Primary Pump	SBE 5T	05T-3086	N/A	All Casts
Secondary Pump	SBE 5T	05T-3090	N/A	All Casts
Primary Dissolved Oxygen Sensor	SBE 43	43-1940	V0	All Casts
Fluorometer	CTG Aquatracka III	88-2615-126	V2	All Casts
Altimeter	Benthos PSA-916T	59494	V3	All Casts
DWIRR PAR	Biospherical QCP-2350-HP	70510	V4	All Casts
UWIRR PAR	Biospherical QCP-2350-HP	70520	V5	All Casts
Transmissometer	WETLabs C-Star	CST-1654DR	V6	All Casts
Backscatter	WETLabs BBRTD	BBRTD-5466	V7	All Casts

Titanium CTD Sensor Information:

The following sensors were installed on the Titanium CTD frame:

Instrument / Sensor	Manufacturer & Model	Serial Number	Channel	Casts Used
Primary CTD deck unit	SBE 11plus	11P-24680-0589	N/A	All Casts
CTD Underwater Unit	SBE 9plus	09P-34173-0758	N/A	All Casts
Tita 24-way frame	NOCS		N/A	All Casts
Primary Temperature Sensor	SBE 3P	03P-2729	F0	All Casts
Primary Conductivity Sensor	SBE 4C	04C-3567	F1	All Casts
Digiquartz Pressure sensor	Paroscientific	90074	F2	All Casts
Secondary Temperature Sensor	SBE 3P	03P-5495	F3	All Casts
Secondary Conductivity Sensor	SBE 4C	04C-2571	F4	All Casts
Primary Pump	SBE 5T	05T-7371	N/A	All Casts
Secondary Pump	SBE 5T	05T-7515	N/A	Casts 1 - 7
Secondary Pump	SBE 5T	05T-6320	N/A	Casts 8 - 22
24-way Carousel	SBE 32	32-24680-0346	N/A	All Casts
Dissolved Oxygen Sensor	SBE 43	43-2831	V0	All Casts
Free	Free	Free	V1	All Casts
Backscatter	WETLabs BBrtd	758R	V2	All Casts
Altimeter	Benthos 916T	112522	V3	All Casts
Transmissometer	WetLabs C-Star	CST-1718TR	V6	All Casts
Fluorimeter	CTG AquaTracka III	88-2050-095	V7	All Casts

Instrument Configuration Files:

The Seasave Instrument Configuration files used for all casts are shown below:

DY111_SS_1.xmlcon

```
<?xml version="1.0" encoding="UTF-8"?>

<SBE_InstrumentConfiguration
SB_ConfigCTD_FileVersion="7.26.4.0" >

 <Instrument Type="8" >

  <Name>SBE 911plus/917plus CTD</Name>


<FrequencyChannelsSuppressed>0</FrequencyChannelsSuppress
ed>

  <VoltageWordsSuppressed>0</VoltageWordsSuppressed>

  <ComputerInterface>0</ComputerInterface>

  <!-- 0 == SBE11plus Firmware Version >= 5.0 -->

  <!-- 1 == SBE11plus Firmware Version < 5.0 -->

  <!-- 2 == SBE 17plus SEARAM -->

  <!-- 3 == None -->

  <DeckUnitVersion>1</DeckUnitVersion>

  <ScansToAverage>1</ScansToAverage>

  <SurfaceParVoltageAdded>0</SurfaceParVoltageAdded>

  <ScanTimeAdded>1</ScanTimeAdded>

  <NmeaPositionDataAdded>1</NmeaPositionDataAdded>

  <NmeaDepthDataAdded>0</NmeaDepthDataAdded>

  <NmeaTimeAdded>0</NmeaTimeAdded>

  <NmeaDeviceConnectedToPC>1</NmeaDeviceConnectedToPC>

  <SensorArray Size="13" >

   <Sensor index="0" SensorID="55" >

    <TemperatureSensor SensorID="55" >

     <SerialNumber>03P-4383</SerialNumber>

     <CalibrationDate>11 July 2018</CalibrationDate>

     <UseG_J>1</UseG_J>

     <A>0.00000000e+000</A>

     <B>0.00000000e+000</B>
```

DY111_Tita.xmlcon

```
<?xml version="1.0" encoding="UTF-8"?>

<SBE_InstrumentConfiguration
SB_ConfigCTD_FileVersion="7.26.4.0" >

 <Instrument Type="8" >

  <Name>SBE 911plus/917plus CTD</Name>


<FrequencyChannelsSuppressed>0</FrequencyChannelsSuppresse
d>

  <VoltageWordsSuppressed>0</VoltageWordsSuppressed>

  <ComputerInterface>0</ComputerInterface>

  <!-- 0 == SBE11plus Firmware Version >= 5.0 -->

  <!-- 1 == SBE11plus Firmware Version < 5.0 -->

  <!-- 2 == SBE 17plus SEARAM -->

  <!-- 3 == None -->

  <DeckUnitVersion>1</DeckUnitVersion>

  <ScansToAverage>1</ScansToAverage>

  <SurfaceParVoltageAdded>0</SurfaceParVoltageAdded>

  <ScanTimeAdded>1</ScanTimeAdded>

  <NmeaPositionDataAdded>1</NmeaPositionDataAdded>

  <NmeaDepthDataAdded>0</NmeaDepthDataAdded>

  <NmeaTimeAdded>0</NmeaTimeAdded>

  <NmeaDeviceConnectedToPC>1</NmeaDeviceConnectedToPC>

  <SensorArray Size="13" >

   <Sensor index="0" SensorID="55" >

    <TemperatureSensor SensorID="55" >

     <SerialNumber>03P-2729</SerialNumber>

     <CalibrationDate>11 July 2019</CalibrationDate>

     <UseG_J>1</UseG_J>

     <A>0.00000000e+000</A>

     <B>0.00000000e+000</B>
```

<C>0.00000000e+000</C>

<D>0.00000000e+000</D>

<F0_Old>0.000</F0_Old>

<G>4.39862417e-003</G>

<H>6.55304958e-004</H>

<I>2.41428164e-005</I>

<J>1.98844984e-006</J>

<F0>1000.000</F0>

<Slope>1.00000000</Slope>

<Offset>0.0000</Offset>

</TemperatureSensor>

</Sensor>

<Sensor index="1" SensorID="3" >

<ConductivitySensor SensorID="3" >

<SerialNumber>04C-2580</SerialNumber>

<CalibrationDate>11 July 2018</CalibrationDate>

<UseG_J>1</UseG_J>

<!-- Cell const and series R are applicable only for wide range sensors. -->

<SeriesR>0.0000</SeriesR>

<CellConst>2000.0000</CellConst>

<ConductivityType>0</ConductivityType>

<Coefficients equation="0" >

<A>0.00000000e+000</A>

<B>0.00000000e+000</B>

<C>0.00000000e+000</C>

<D>0.00000000e+000</D>

<M>0.0</M>

<CPcor>-9.57000000e-008</CPcor>

</Coefficients>

<Coefficients equation="1" >

<G>-1.04804926e+001</G>

<H>1.54201240e+000</H>

<C>0.00000000e+000</C>

<D>0.00000000e+000</D>

<F0_Old>0.000</F0_Old>

<G>4.35519545e-003</G>

<H>6.41791295e-004</H>

<I>2.33034275e-005</I>

<J>2.25073602e-006</J>

<F0>1000.000</F0>

<Slope>1.00000000</Slope>

<Offset>0.0000</Offset>

</TemperatureSensor>

</Sensor>

<Sensor index="1" SensorID="3" >

<ConductivitySensor SensorID="3" >

<SerialNumber>04C-3567</SerialNumber>

<CalibrationDate>27 June 2019</CalibrationDate>

<UseG_J>1</UseG_J>

<!-- Cell const and series R are applicable only for wide range sensors. -->

<SeriesR>0.0000</SeriesR>

<CellConst>2000.0000</CellConst>

<ConductivityType>0</ConductivityType>

<Coefficients equation="0" >

<A>0.00000000e+000</A>

<B>0.00000000e+000</B>

<C>0.00000000e+000</C>

<D>0.00000000e+000</D>

<M>0.0</M>

<CPcor>-9.57000000e-008</CPcor>

</Coefficients>

<Coefficients equation="1" >

<G>-1.04172144e+001</G>

<H>1.25284529e+000</H>

```
    <I>-2.36431999e-004</I>
    <J>1.01511916e-004</J>
    <CPcor>-9.57000000e-008</CPcor>
    <CTcor>3.2500e-006</CTcor>
    <!-- WBOTC not applicable unless ConductivityType = 1. -->
    <WBOTC>0.00000000e+000</WBOTC>
   </Coefficients>
   <Slope>1.00000000</Slope>
   <Offset>0.00000</Offset>
  </ConductivitySensor>
 </Sensor>
 <Sensor index="2" SensorID="45" >
  <PressureSensor SensorID="45" >
   <SerialNumber>129735</SerialNumber>
   <CalibrationDate>3 November 2017</CalibrationDate>
   <C1>-6.064446e+004</C1>
   <C2>6.966022e-002</C2>
   <C3>1.971200e-002</C3>
   <D1>2.882500e-002</D1>
   <D2>0.000000e+000</D2>
   <T1>3.029594e+001</T1>
   <T2>-6.713680e-005</T2>
   <T3>4.165390e-006</T3>
   <T4>0.000000e+000</T4>
   <Slope>0.99982000</Slope>
   <Offset>-1.48930</Offset>
   <T5>0.000000e+000</T5>
   <AD590M>1.279180e-002</AD590M>
   <AD590B>-8.821250e+000</AD590B>
  </PressureSensor>
 </Sensor>
 <Sensor index="3" SensorID="55" >
```

```
    <I>-1.45044812e-003</I>
    <J>1.57017101e-004</J>
    <CPcor>-9.57000000e-008</CPcor>
    <CTcor>3.2500e-006</CTcor>
    <!-- WBOTC not applicable unless ConductivityType = 1. -->
    <WBOTC>0.00000000e+000</WBOTC>
   </Coefficients>
   <Slope>1.00000000</Slope>
   <Offset>0.00000</Offset>
  </ConductivitySensor>
 </Sensor>
 <Sensor index="2" SensorID="45" >
  <PressureSensor SensorID="45" >
   <SerialNumber>90074</SerialNumber>
   <CalibrationDate>19 Jul 2019</CalibrationDate>
   <C1>-6.571123e+004</C1>
   <C2>2.050504e-001</C2>
   <C3>1.612220e-002</C3>
   <D1>2.883800e-002</D1>
   <D2>0.000000e+000</D2>
   <T1>2.986693e+001</T1>
   <T2>-2.678465e-004</T2>
   <T3>3.986390e-006</T3>
   <T4>7.472100e-010</T4>
   <Slope>0.99996000</Slope>
   <Offset>0.31620</Offset>
   <T5>0.000000e+000</T5>
   <AD590M>1.283700e-002</AD590M>
   <AD590B>-8.642460e+000</AD590B>
  </PressureSensor>
 </Sensor>
 <Sensor index="3" SensorID="55" >
```

<TemperatureSensor SensorID="55" >
<SerialNumber>03P-4381</SerialNumber>
<CalibrationDate>25 July 2018</CalibrationDate>
<UseG_J>1</UseG_J>
<A>0.00000000e+000</A>
<B>0.00000000e+000</B>
<C>0.00000000e+000</C>
<D>0.00000000e+000</D>
<F0_Old>0.000</F0_Old>
<G>4.42359439e-003</G>
<H>6.44950441e-004</H>
<I>2.26922968e-005</I>
<J>1.98186505e-006</J>
<F0>1000.000</F0>
<Slope>1.00000000</Slope>
<Offset>0.0000</Offset>
</TemperatureSensor>
</Sensor>
<Sensor index="4" SensorID="3" >
<ConductivitySensor SensorID="3" >
<SerialNumber>04C-2450</SerialNumber>
<CalibrationDate>14 June 2018</CalibrationDate>
<UseG_J>1</UseG_J>
<!-- Cell const and series R are applicable only for wide range sensors. -->
<SeriesR>0.0000</SeriesR>
<CellConst>2000.0000</CellConst>
<ConductivityType>0</ConductivityType>
<Coefficients equation="0" >
<A>0.00000000e+000</A>
<B>0.00000000e+000</B>
<C>0.00000000e+000</C>
<D>0.00000000e+000</D>

<TemperatureSensor SensorID="55" >
<SerialNumber>5495</SerialNumber>
<CalibrationDate>11 July 2019</CalibrationDate>
<UseG_J>1</UseG_J>
<A>0.00000000e+000</A>
<B>0.00000000e+000</B>
<C>0.00000000e+000</C>
<D>0.00000000e+000</D>
<F0_Old>0.000</F0_Old>
<G>4.38204912e-003</G>
<H>6.30680571e-004</H>
<I>2.00793666e-005</I>
<J>1.53789483e-006</J>
<F0>1000.000</F0>
<Slope>1.00000000</Slope>
<Offset>0.0000</Offset>
</TemperatureSensor>
</Sensor>
<Sensor index="4" SensorID="3" >
<ConductivitySensor SensorID="3" >
<SerialNumber>04C-3768</SerialNumber>
<CalibrationDate>25 July 2018</CalibrationDate>
<UseG_J>1</UseG_J>
<!-- Cell const and series R are applicable only for wide range sensors. -->
<SeriesR>0.0000</SeriesR>
<CellConst>2000.0000</CellConst>
<ConductivityType>0</ConductivityType>
<Coefficients equation="0" >
<A>0.00000000e+000</A>
<B>0.00000000e+000</B>
<C>0.00000000e+000</C>
<D>0.00000000e+000</D>

```
    <M>0.0</M>
    <CPcor>-9.57000000e-008</CPcor>
   </Coefficients>
   <Coefficients equation="1" >
    <G>-1.04375764e+001</G>
    <H>1.66338115e+000</H>
    <I>-1.95407131e-003</I>
    <J>2.78452913e-004</J>
    <CPcor>-9.57000000e-008</CPcor>
    <CTcor>3.2500e-006</CTcor>
    <!-- WBOTC not applicable unless ConductivityType = 1. -->
    <WBOTC>0.00000000e+000</WBOTC>
   </Coefficients>
   <Slope>1.00000000</Slope>
   <Offset>0.00000</Offset>
  </ConductivitySensor>
 </Sensor>
 <Sensor index="5" SensorID="38" >
  <OxygenSensor SensorID="38" >
   <SerialNumber>43-1940</SerialNumber>
   <CalibrationDate>21 July 2018</CalibrationDate>
   <Use2007Equation>1</Use2007Equation>
   <CalibrationCoefficients equation="0" >
    <!-- Coefficients for Owens-Millard equation. -->
    <Boc>0.0000</Boc>
    <Soc>0.0000e+000</Soc>
    <offset>0.0000</offset>
    <Pcor>0.00e+000</Pcor>
    <Tcor>0.0000</Tcor>
    <Tau>0.0</Tau>
   </CalibrationCoefficients>
   <CalibrationCoefficients equation="1" >
    <M>0.0</M>
    <CPcor>-9.57000000e-008</CPcor>
   </Coefficients>
   <Coefficients equation="1" >
    <G>-1.02284081e+001</G>
    <H>1.49861592e+000</H>
    <I>-1.33719830e-003</I>
    <J>1.94341809e-004</J>
    <CPcor>-9.57000000e-008</CPcor>
    <CTcor>3.2500e-006</CTcor>
    <!-- WBOTC not applicable unless ConductivityType = 1. -->
    <WBOTC>0.00000000e+000</WBOTC>
   </Coefficients>
   <Slope>1.00000000</Slope>
   <Offset>0.00000</Offset>
  </ConductivitySensor>
 </Sensor>
 <Sensor index="5" SensorID="38" >
  <OxygenSensor SensorID="38" >
   <SerialNumber>43-2831</SerialNumber>
   <CalibrationDate>20 August 2019</CalibrationDate>
   <Use2007Equation>1</Use2007Equation>
   <CalibrationCoefficients equation="0" >
    <!-- Coefficients for Owens-Millard equation. -->
    <Boc>0.0000</Boc>
    <Soc>0.0000e+000</Soc>
    <offset>0.0000</offset>
    <Pcor>0.00e+000</Pcor>
    <Tcor>0.0000</Tcor>
    <Tau>0.0</Tau>
   </CalibrationCoefficients>
   <CalibrationCoefficients equation="1" >
```

```
        <!-- Coefficients for Sea-Bird equation - SBE calibration in 2007 and later. -->
        <Soc>5.3030e-001</Soc>
        <offset>-0.4970</offset>
        <A>-3.4650e-003</A>
        <B> 1.9513e-004</B>
        <C>-3.3354e-006</C>
        <D0> 2.5826e+000</D0>
        <D1> 1.92634e-004</D1>
        <D2>-4.64803e-002</D2>
        <E> 3.6000e-002</E>
        <Tau20> 1.3300</Tau20>
        <H1>-3.3000e-002</H1>
        <H2> 5.0000e+003</H2>
        <H3> 1.4500e+003</H3>
      </CalibrationCoefficients>
    </OxygenSensor>
  </Sensor>
  <Sensor index="6" SensorID="27" >
    <NotInUse SensorID="27" >
      <SerialNumber></SerialNumber>
      <CalibrationDate></CalibrationDate>
      <OutputType>2</OutputType>
      <Free>1</Free>
    </NotInUse>
  </Sensor>
  <Sensor index="7" SensorID="5" >
    <FluoroChelseaAqua3Sensor SensorID="5" >
      <SerialNumber>88-2615-126</SerialNumber>
      <CalibrationDate>16 August 2018</CalibrationDate>
      <VB>0.593340</VB>
      <V1>2.105980</V1>
      <Vacetone>0.756140</Vacetone>
        <!-- Coefficients for Sea-Bird equation - SBE calibration in 2007 and later. -->
        <Soc>4.8910e-001</Soc>
        <offset>-0.4826</offset>
        <A>-4.7359e-003</A>
        <B> 2.0655e-004</B>
        <C>-3.0062e-006</C>
        <D0> 2.5826e+000</D0>
        <D1> 1.92634e-004</D1>
        <D2>-4.64803e-002</D2>
        <E> 3.6000e-002</E>
        <Tau20> 1.3200</Tau20>
        <H1>-3.3000e-002</H1>
        <H2> 5.0000e+003</H2>
        <H3> 1.4500e+003</H3>
      </CalibrationCoefficients>
    </OxygenSensor>
  </Sensor>
  <Sensor index="6" SensorID="27" >
    <NotInUse SensorID="27" >
      <SerialNumber></SerialNumber>
      <CalibrationDate></CalibrationDate>
      <OutputType>2</OutputType>
      <Free>1</Free>
    </NotInUse>
  </Sensor>
  <Sensor index="7" SensorID="70" >
    <TurbidityMeter SensorID="70" >
      <SerialNumber>758R</SerialNumber>
      <CalibrationDate>30 August 2019</CalibrationDate>
      <ScaleFactor>4.284e-003</ScaleFactor>
      <!-- Dark output -->
      <DarkVoltage>5.440e-002</DarkVoltage>
```

<ScaleFactor>1.000000</ScaleFactor>

<Slope>1.000000</Slope>

<Offset>0.000000</Offset>

</FluoroChelseaAqua3Sensor>

</Sensor>

<Sensor index="8" SensorID="0" >

<AltimeterSensor SensorID="0" >

<SerialNumber>59494</SerialNumber>

<CalibrationDate>25 March 2013</CalibrationDate>

<ScaleFactor>15.000</ScaleFactor>

<Offset>0.000</Offset>

</AltimeterSensor>

</Sensor>

<Sensor index="9" SensorID="42" >

<PAR_BiosphericalLicorChelseaSensor SensorID="42" >

<SerialNumber>70510</SerialNumber>

<CalibrationDate>27 June 2019</CalibrationDate>

<M>1.00000000</M>

<B>0.00000000</B>

<CalibrationConstant>20300000000.00000000</CalibrationConstant>

<Multiplier>1.00000000</Multiplier>

<Offset>-0.05009162</Offset>

</PAR_BiosphericalLicorChelseaSensor>

</Sensor>

<Sensor index="10" SensorID="42" >

<PAR_BiosphericalLicorChelseaSensor SensorID="42" >

<SerialNumber>70520</SerialNumber>

<CalibrationDate>27 June 2019</CalibrationDate>

<M>1.00000000</M>

<B>0.00000000</B>

</TurbidityMeter>

</Sensor>

<Sensor index="8" SensorID="0" >

<AltimeterSensor SensorID="0" >

<SerialNumber>112522</SerialNumber>

<CalibrationDate>15 July 2013</CalibrationDate>

<ScaleFactor>15.000</ScaleFactor>

<Offset>0.000</Offset>

</AltimeterSensor>

</Sensor>

<Sensor index="9" SensorID="42" >

<PAR_BiosphericalLicorChelseaSensor SensorID="42" >

<SerialNumber>01</SerialNumber>

<CalibrationDate>22 September 2017</CalibrationDate>

<M>0.43879900</M>

<B>1.59570900</B>

<CalibrationConstant>217400000000.00000000</CalibrationConstant>

<Multiplier>1.00000000</Multiplier>

<Offset>0.00000000</Offset>

</PAR_BiosphericalLicorChelseaSensor>

</Sensor>

<Sensor index="10" SensorID="42" >

<PAR_BiosphericalLicorChelseaSensor SensorID="42" >

<SerialNumber>03</SerialNumber>

<CalibrationDate>22 September 2017</CalibrationDate>

<M>0.43119000</M>

<B>1.78533800</B>

<CalibrationConstant>217400000000.00000000</CalibrationConstant>

<Multiplier>1.00000000</Multiplier>

<Offset>0.00000000</Offset>

<CalibrationConstant>19900000000.00000000</CalibrationConstant>
<Multiplier>1.00000000</Multiplier>
<Offset>-0.05148773</Offset>
</PAR_BiosphericalLicorChelseaSensor>
</Sensor>
<Sensor index="11" SensorID="71" >
<WET_LabsCStar SensorID="71" >
<SerialNumber>CST-1654DR</SerialNumber>
<CalibrationDate>7 April 2017</CalibrationDate>
<M>21.1627</M>
<B>-0.1550</B>
<PathLength>0.250</PathLength>
</WET_LabsCStar>
</Sensor>
<Sensor index="12" SensorID="70" >
<TurbidityMeter SensorID="70" >
<SerialNumber>BBRTD-5466</SerialNumber>
<CalibrationDate>4 February 2019</CalibrationDate>
<ScaleFactor>3.307e-003</ScaleFactor>
<!-- Dark output -->
<DarkVoltage>5.100e-002</DarkVoltage>
</TurbidityMeter>
</Sensor>
</SensorArray>
</Instrument>
</SBE_InstrumentConfiguration>

</PAR_BiosphericalLicorChelseaSensor>
</Sensor>
<Sensor index="11" SensorID="71" >
<WET_LabsCStar SensorID="71" >
<SerialNumber>CST-1718TR</SerialNumber>
<CalibrationDate></CalibrationDate>
<M>21.2862</M>
<B>-0.1040</B>
<PathLength>0.250</PathLength>
</WET_LabsCStar>
</Sensor>
<Sensor index="12" SensorID="5" >
<FluoroChelseaAqua3Sensor SensorID="5" >
<SerialNumber>88-2050-095</SerialNumber>
<CalibrationDate>4 June 2018</CalibrationDate>
<VB>0.369380</VB>
<V1>1.839090</V1>
<Vacetone>0.443120</Vacetone>
<ScaleFactor>1.000000</ScaleFactor>
<Slope>1.000000</Slope>
<Offset>0.000000</Offset>
</FluoroChelseaAqua3Sensor>
</Sensor>
</SensorArray>
</Instrument>
</SBE_InstrumentConfiguration>

CTD Suite Technical Issues & Instrument Changes:

There were no major technical issues with the Stainless CTD suite during the cruise and no instruments required changing for spares. 2 full sets of spare instruments were available for use and a spare CTD frame was also available on board.

There were some occasional issues with the bottom end-cap of bottles leaking. Several taps needed replacing throughout the cruise, along with two bottles that required new bottom seal o-rings. At the end of the cruise all bottles were leak tested again and all sealed well.

Spot checks of the termination took place throughout the cruise to make sure the bolts and locking nuts on the clamps were tight and at the correct torque.

With the Titanium CTD we encountered several issues during the cruise. On cast 15 a very high number of modular errors were received causing lots of data spikes. It was decided to continue with the cast and to try to fix the problem once the CTD was back on deck. A thorough inspection of the CTD found no obvious faults, so every connection and cable was cleaned, checked and remade. This solved the problem with only a couple of modular errors received during the remaining casts of the cruise. During the final cast the Lebus winch suffered a mechanical issue with its brake system. This resulted in the cast being terminated at a shallower depth than planned. After approximately 40 minutes the decision was made to try and recover the CTD, but without bottle stops, instead the bottles were fired on the fly as close to the required depths as possible. Once back at the surface the CTD was recovered to deck in the normal way and the decision was made that the winch would remain out of service for the remainder of the cruise, cancelling one planned cast. During casts 6 and 7 a jump in salinity was observed and traced to a faulty pump, serial number 05T-7515 was replaced with pump serial number 05T-6320. This removed the salinity jump and remained in place for the remaining casts.

Cast Summary:

Stainless Steel

Cast	Julian Day	Max Wire Out (m)
001	338	2008
002	340	2009
003	340	1000
004	343	1000
005	343	1000
006	343	2000
007	345	1000
008	345	1000
009	345	1000
010	346	70
011	347	5051
012	347	4770
013	348	1000
014	348	1000
015	349	4617
016	351	1000
017	351	1100
018	352	5020
019	353	4981
020	353	1000
021	354	1000
022	354	5220
023	355	2005
024	356	1000
025	356	1000
026	356	1000
027	360	300
028	361	1000
029	361	1000
030	362	2000
031	363	1000
032	363	1000
033	363	1000
034	364	1000
035	365	1000
036	365	5000
037	003	1000
038	003	1000
039	004	1000
040	004	1000
041	004	1000
042	005	1000
043	006	2000

Titanium

Cast	Julian Day	Max Wire Out (m)
001	338	200
002	340	1000
003		
004	342	4880
005	343	1000
006	345	1000
007	346	4937
008	347	4652
009	348	1000
010	349	4500
011	351	1500
012	352	4910
013	352	4820
014	353	1500
015	354	5100
016	356	1500
017	361	4900
018	361	150
019	363	1500
020	365	1500
021	002	4250
022	003	7500

Data Processing:

Standard Sea-Bird processing of the raw data was completed using Sea-Bird Data Processing software. The BODC "Recommended steps for basic processing of SBE-911 CTD data." Version 1.0 October 2010 instructions were followed for all casts. However the scientific party only required three processing steps to be completed by the NMF team, these being:

- Data Conversion and Bottle Summary to create .btl file -2.5 to +2.5 seconds around bottle closure event.
- CellTM
- AlignCTD 6s on oxygen channels only

All processed and raw data files were saved to the network drive for access by the scientific party.

LADCP:

Instrument Configuration

One self-logging Teledyne RDI Workhorse 300kHz ADCP was installed on the Stainless Steel CTD frame and was used for all Stainless Steel CTD casts. The down-looking unit (S/N: 23444) was sited off centre of the frame to allow fitting of a third party optical instrument, with its transducers just above the bottom tube of the CTD frame. The instrument was powered with NMF Workhorse Battery Pack serial number WH007.

Deployment Command Scripts

Downlooking LADCP

```
; Master WH300 LADCP for DY111
; removed commands already set by default
;
;
WV250                   ; ambiguity velocity [cm/s]
WN25                    ; number of depth cells; NBP0402
WS1000                  ; bin size [cm]; NBP0402: WS1000
WF0                     ; blank after transmit [cm]; NBP0402
WB1                     ; narrow bandwidth mode
EZ0011101               ; Sensor source: (NBP0402: EZ0111111)
EX00100                 ; coordinate transformation: (NBP0402: 11111)
WP1                     ; single-ping ensembles; NBP0402: WP3 most of the time
TP 00:00.00             ; time between pings; NBP0402
TE 00:00:01.50          ; time per ensemble
CF11101                 ; Flow control:
SM1                     ; set to master
SA011                   ; send pulse before ensemble
SW5500                  ; master waits .5500 s after sending sync pulse
RNmast_
CK                      ; keep params as user defaults (across power failures)
CS                      ; start pinging
```

Deployment & Recovery Procedure

Prior to each deployment a standard checklist was followed:

Pre-deployment

- Create a deployment terminal capture log file named in the form castxxxSS.txt
- Change baud rate to 9600 baud (CB411) to ensure correct parsing of command file.
- Check instrument time (TS?) by comparing to GPS time. Reset time if offset > 5s.
- Check free data storage available (RS?), reformatting the card if required.
- Record number of deployments on instrument storage card (RA?)
- Run pre-deployment tests (PA, PT200 and PC2)

Note that a lot of these tests are intended to be run with the instrument submerged in still water and can be expected to fail in air.

The command script file is then sent to the instrument to deploy it, once started the battery is then taken off charge and the deck-cables disconnected and blanking plugs fitted for deployment.

Post-deployment

- Reconnect deck-cables. Start charging battery pack.
- Upon recovery at the end of the cast, the instruments are stopped by sending a break in BBTalk.
- The baud rate is changed to 115200 baud (CB811) to reduce the data download time.
- Record number of deployments on instrument storage card (RA?)
- Start download of data using BBTalk 'Recover Recorder' command, selecting appropriate file(s) and noting their number in the default filename sequence RDI_xxx.000.
- Rename the downloaded files using the form DY111_WHM_CTDxxx.000.
- Backup the files to the network archive.
- Check data files in WinADCP:
- Select a region of data with high echo intensity and check for consistent levels for all four beams for echo intensity and beam correlation.
- Check that the start and stop times of the data files corresponds with the deployment and recovery times.
- Record the number of pings (ensembles) in each data file.

Salinometry:

Salinity samples were taken from the CTD rosette by the science party using crates of sample bottles (24 bottles per crate). After collection, all samples were stored in the Salinometer lab for a period of at least 24 hours prior to sampling; this is to allow the samples to stabilise at the lab's temperature.

All samples were analysed on Guildline Autosal 8400B S/N 68426. A standard was run as a sample before and after each crate of samples as a control.

The Autosal was standardised using IAPSO Standard Seawater batch P162 (K15=0.99983, 2xK15=1.99966, 34.993 PSU). The machine was standardised at the beginning of the cruise and left throughout the cruise.

A software fault developed just before the processing of the final crate of samples, requiring the reinstallation of the Autosal application, due to this a standardisation was required, after which the final 24 samples were processed in the same way as the previous samples.

A data file from the analysis software was supplied for each crate as an Excel spreadsheet. All measurements were also logged manually on paper log-sheets.

In-Situ Pumps (SAPs):

Six Challenger Oceanic Stand Alone Pumps were used on the cruise:

- S/N 04-14 (Sally)
- S/N 02-004 (Sandie)
- S/N 02-003 (Polly)
- S/N 03-02 (Minnie)
- S/N 03-05 (Sophie)
- S/N 04-15 (Jenni)

All pumps were dismantled for inspection, all flow-meters checked for accuracy and all SAPs tested circulating water on a bench for 1.5hrs prior to shipping.

Configuration

293mm double chamber pancake filter housings were used with a 90 degree elbow on the inlet and the outlet plumbed directly into the flow-meter. The scientific party supplied filters and fitted them into the housings as required for each deployment.

Sea-Bird SBE 39 Temperature & Pressure Loggers

Four Sea-Bird SBE 39 Temperature and Pressure Loggers were available during the cruise to provide deployed depth measurements where possible.

A new 9V Lithium battery was installed in each SBE 39, the sample interval was set to 60 seconds to provide enough data points to average for each deployment whilst now draining the battery too much. The serial sync mode was disabled as this was not used. The real-time output was enabled to confirm logging pre and post deployment. The instruments were configured to record temperature and pressure.

After configuration, terminal captures were obtained of each instruments response to the DS (Display Settings) and DC (Display Calibrations) and saved as files in each instrument folder for reference. For each cast a capture file was created for each of the SBE 39's, a ***samplenum=0*** command was issued followed by a ***DS*** and then a ***DC*** command. Once happy a ***startnow*** command was entered, once a sample had been taken and displayed the capture file was stopped and the instrument disconnected.

After the deployment, the SBE 39's were stopped by issuing the ***stop*** command and then the data uploaded by scan count using SBE SeaTerm.

Deployment Summary

A total of 22 deployments were completed throughout the cruise, some deployments used SAPs in pairs at certain depths whilst others were deployed singularly.

Deployment	SOPHIE	SANDIE	MINNIE	SALLY	POLLY	JENNI
1	400m – 962l	400m – 1l	180m – 11l	180m – 976l	80m – 1534l	80m – 3l
2	N/A	N/A	N/A	N/A	4500m – 1294l	N/A
3	400m – 871l	400m – 1627l	180m – 1519l	180m – 885l	80m – 1382l	80m – 4l
4	N/A	N/A	N/A	N/A	N/A	N/A
5	80m – 806l	180m – 916l	180m – 1650l	N/A	80m – 1754l	50m – 97l
6	400m – 1622l	80m – 1421l	3000m – 1666l	400m – 18l	10m – 1311l	N/A
7	180m – 860l	80m – 1598l	180m – 1704l	50m – 1902l	80m – 1688l	50m – 16l
8	80m – 657l	400m – 1022l	1500m – 1640l	400m – 1859l	10m – 1283l	N/A
9	400m – 817l	400m – 1720l	1200m – 1667l	80m – 1557l	10m – 924l	N/A
10	100m – 595l	120m – 707l	100m – 1640l	200m – 1365l	200m - 1712l	N/A
11	400m – 1621l	130m – 1502l	5180m – 1651l	30m – 1748l	5150m – 1636l	10m – 16l
12	400m – 1624l	N/A	10m – 1390l	400m – 1051l	N/A	N/A
13	150m – 648l	150m – 983l	N/A	50m – 616l	50m – 1673l	N/A
14	N/A	4550m – 1640l	10m – 1667l	N/A	N/A	N/A
15	40m – 1441l	40m – 502l	40m – 1641l	140 – 803l	140m 1326l	N/A
16	400m – 1596l	4800m – 1643l	4840m – 1653l	N/A	10m – 946l	N/A
17	N/A	140m – 1627l	40m – 1612l	1000m – 1847l	400m – 1151l	N/A
18	50m – 528l	150m – 708l	150m – 1700l	N/A	50m – 1033l	N/A
19	400m – 1518l	150m – 1709l	400m – 1695l	N/A	1250m – 806l	N/A
20	1000m – 1643l	180m – 1674l	400m – 1706l	N/A	80m – 806l	N/A
21	80m – 1516l	180m – 1690l	400m – 1706l	N/A	N/A	N/A
22	N/A	180m – 1704l	N/A	N/A	N/A	N/A

All SAP units were configured to pump for 1.0 hours (60 minutes). The delay was set as appropriate to give 15-30 minutes of contingency for deployment. Start of recovery was begun 10 minutes after estimated completion of pumping. The pancake filter housings were not primed prior to deployment. The inlet elbows were protected by Parafilm or foil until moving the unit away from the rail. When conditions were appropriate, SAPs were held just below the surface until air bubbles ceased from the 90 degree inlet elbow before descending.

For all of the deployments a 500kg clump weight was used as ballast, this was attached wire, then deployed down to a depth of between 10m and 20m before zeroing the wire out count.

Technical Issues

A total of 22 deployments were carried out with 3 – 6 SAPS deployed each time. On the first deployment all six SAPS were deployed, three failed to pump a suitable volume; Sophie: 962 L, Sandie: 1 L, Minnie: 11 L, Sally: 976 L, Polly: 1534 L, Jenni: 3 L. Post deployment information showed that all the SAPs ran their full cycles and didn't reach their low voltage cut out.

Initial thought was the failure to pump was due to twists and kinks in the hose connection the filter housing to the flowmeter. To prevent this happening again each SAP was fitted with its filter housing and the hose was adjusted to ensure the length was correct to prevent twists or kinks in future deployments. One of the new style unions on a filter housing was replaced with an old union as it was noticed that the new style was slightly bigger and prevented the face seal engaging on the coupler.

Following these adjustments each SAP pumped sensible volumes of water 1500 L – 600 L. There was a big variation in amount pumped but it was noticed that the lower volumes were seen when a much finer filter was used.

During cast 4 the venting plug had been left open on Sally, this wasn't realised until the SAP had reached ~100m depth. Once this had been realised the SAP was immediately recovered to deck. A small volume of water was noticed within the housing, the board and batteries showed signs of corrosion. The motor was removed and soaked in Milli-Q for approximately 4 hours with a number of water changes made to remove any salt and prevent corrosion. The motor was then left to dry for approximately 36 hours. Once dry the motor was bench tested and it worked as expected. Both battery packs were replaced and a new board was fitted. Once rebuilt Sally was bench tested and it became apparent that the motor would intermittently cut out. This was tracked down to an issue with the connection of the Arduino on the board, applying pressure to the nano would start the motor running. A replacement board was fitted and this issue wasn't seen again.

Throughout the cruise Jenni consistently failed to pump adequate volumes, and so was not used for science but deployed a number of times for testing. Both battery packs were replaced and alternative

impeller tested. The board was inspected for a similar fault to the one seen in Sally, no issues were found. During bench testing the system worked as it should, a test run was conducted in the sink and again all worked as it should. As it was not critical to get 6 SAPs deployed every time and due to a busy science schedule no more testing was conducted and further inspection will take place back at Southampton.

Software Used

Sea-Bird SeaTerm 1.59
Sea-Bird Seasave 7.26.6.26
Sea-Bird SBE Data Processing 7.26.6.28
TRDI BBTalk
TRDI WinADCP 1.14

Scientific Ship Systems

Zoltan Nemeth (NMF)

Ship Scientific Systems (SSS) is responsible for operating and managing the Ship's scientific information technology infrastructure, data acquisition, compilation and delivery, and the suite of ship-fitted instruments and sensors in support of the Marine Facilities Programme (MFP)
All times in report are UTC unless otherwise stated

Scientific Computer Systems:

Acquisition

Network drives were set up on the on-board file server; firstly a read-only drive of the ship's instruments data ('current_cruise') and a second drive ('Public') for the scientific party. Both were combined at the end of the cruise and copied to a disk for the PSO. A disk is also produced of the 'current_cruise' for BODC.

Data were logged by the Techsas 5.11 data acquisition system. The system creates NetCDF and ASCII output data files located in the below 'TechSAS' directory. The format of the data files is given per instrument in the "Data Description" directory:

Cruise Disk Location:

DY111/Cruise_Documentation/Data_Description_Documents
/
DY111/Ship_Fitted_Scientific_Systems/TechSAS

The logged ship-fitted instruments are listed in the file in the below location (includes BODC/Level-C notes):

Cruise Disk Location:

DY111/Cruise_Documentation/Data_Description_Documents
/

Events

Cruise events may be recorded by cruise participants accessing the NMF Discovery Event Logger webpage. This produces a selection of EventLog files that may be located in the below cruise directory. These files are csv.

Cruise Disk Location:

DY111/Cruise_Documentation/EventLogs/current_csv_logs
/

Main Acquisition Period

Techsas logging for 'DY111' commenced **01/12/2019 (J335)** whilst alongside in the port (Punta Arenas, CL). Legacy 'Level-C' logging was also started on 01/12/2019 (J335) 15:11:11.
All logging was stopped 20:00:00 **J008 (08/01/2020)** during final transit to Punta Arenas, Chile.

Data Gaps

The event log 'general.csv' and 'Underway (Non-toxic).csv' includes information for any lost data. This includes periods where underway instrumentation was cleaned.

RAW NMEA

The NMF 'RVDAS/ingester' raw data logger also records raw data streams as a backup/QC option to the primary Techsas logger. These raw ASCII files are located in the below cruise directory:

Cruise Disk Location:

`DY111/Ship_Fitted_Scientific_Systems/Raw_NMEA/`

Legacy Data Format

Data was additionally logged into the legacy RVS Level-C format.

There are ASCII dumps of all the Level-C streams included on the data disk in the directory:

Cruise Disk Location:

`DY111/Ship_Fitted_Scientific_Systems/Level-C/Enterprise/pro_data/ascii/`

Communications

On board for the cruise were 22 marine staff, 6 NMF technicians, and 23 members of the science party.

Internet provision:

Satellite Communications was provided with the Vsat system. The Vsat had a guaranteed speed of 1.5Mbps unlimited data (and provides 3 on board phone lines to cabins/work areas).

Inbound data rates of around 5 mega-bits per second (mbps) were achieved at times, with an average cruise throughput of approximately 3.0 mbps

On Friday 27th of December, 2019 the remote Speedcast support reconfigured the X7 modem (belongs to VSAT) and afterwards the VSAT network was intermittent until Sunday 5th of January, 2020. The block Upconverter was replaced but didn't solve the problem.The original one was swapped back but we had no connection if the ship heading was in the NW quadrant. The network re-joining was not automatic until 5th of January. The system set back to network mostly manually when I asked the support to do it.

The vessel also has a FBB backup available with a maximum un-guaranteed speed of 256kbps and a 20GB monthly plan. This FBB was used when we lost the VSAT.

Email Provision:

Email communications were provided primarily through user email clients, web-browser clients. There is no longer an onboard email system – this is the second cruise where the legacy AMS system has not been available.

Instrumentation:

Position and Attitude

GPS and attitude measurement systems were run throughout the cruise.

Applanix POSMV

The ***Applanix POSMV*** system is the vessel's primary scientific GPS system, outputting the position of the ship's common reference point in the gravity meter room (Refer to Parker Report, 2013 – Enclosure 3/Coordinate System 2). The POSMV is available to be sent to all scientific systems and is repeated around the vessel. The position fixes attitude and gyro data are logged to the Techsas system. Position fixes and attitude data are logged to the Techsas system.

Kongsberg Seapath 330

The ***Kongsberg Seapath 300*** system is the vessel's secondary GPS system. It provides an input to the Gravity meter due to the POSMV not having vessel course available in its RMC NMEA message. Position fixes and attitude data are logged to the Techsas system.

C-Nav 3050

The ***CNav 3050*** GPS system is a differential correction service. It provides the Applanix POSMV system with RTCM DGPS corrections (greater than 1m accuracy). The position fixes data are logged to the Techsas system.

Fugro Seastar 9205

The **Fugro Seastar 9205** GPS system is a differential correction service. It provides the Seapath system with RTCM DGPS corrections. Fugro NMEA output messages are logged to the Techsas system.

Meteorology and sea surface monitoring package

The NMF Surfmet system was run throughout the cruise, excepting times for cleaning, entering and leaving port and whilst alongside. Please see the separate information sheet for details of the sensors used and whether calibrations values have been applied:

Cruise Disk Location:

DY111/Ship_Fitted_Scientific_Systems/Surfmet/DY110_Surfmet_sensor_calibrations.doc

Instrument calibration sheets are also included within this directory.

Underway TSG Data

Events, including cleaning and any observed issues/flow adjustments (e.g. occasions when the transmissometer was noisy), were recorded using the NMF EventLog. Underway TSG samples were collected daily by scientific party. The instrument flow rate (approx. 1.6L/min.) is also logged by the ship's acquisition systems.

- Underway System data collection started after we left Chilean waters on 4th of December 01:20UTC
- Underway system cleaned at 01/12/2019 JD335 16:56
- Transmissometer CST open air voltages before cleaning: 4.640, close: 0.009, after cleaning: 4.073
- Underway system cleaned at 06/01/2020 JD006 18:00
- Transmissometer CST open air voltage before cleaning: 3.888, close: 0.009, afer cleaning: 4.872
- Uderway System switched OFF at 06/01/2020 JD006 18:00

The TSG samples were processed using the Autosal system and the data included on the cruise directory:

Cruise Disk Location:

…/Ship_Fitted_Scientific_Systems/Surfmet/tsg_salinities

Kongsberg EA640 10 & 12 KHz Single-Beam

The EA640 single-beam echo-sounder was run throughout the cruise. The 10kHz active mode/12kHz passive mode transducers were both used. This depth was used as the input for the CLAM (Cable Logging and Measurement) during deployment activities.

The instrument was generally set to free-run at its maximum ping rate. This relates to approximately every 10 seconds in a water depth of 5000m. During shallow depths the maximum ping interval used was 2 seconds. Changes to power levels and pulse duration were included in the event log for this system.

The system used a constant sound velocity of 1500 ms^{-1} throughout the water column to allow it to be corrected for sound velocity in post processing if required.

Salinity (35 PSU) and Temperature (10degreeC) and Conditions (salt water) were also left as constant values for the cruise duration.

Kongsberg *.raw files (100MB maximum file size) and *.xyz files are logged and depths were logged to Techsas and Level-C.

Raw Files Data Gap

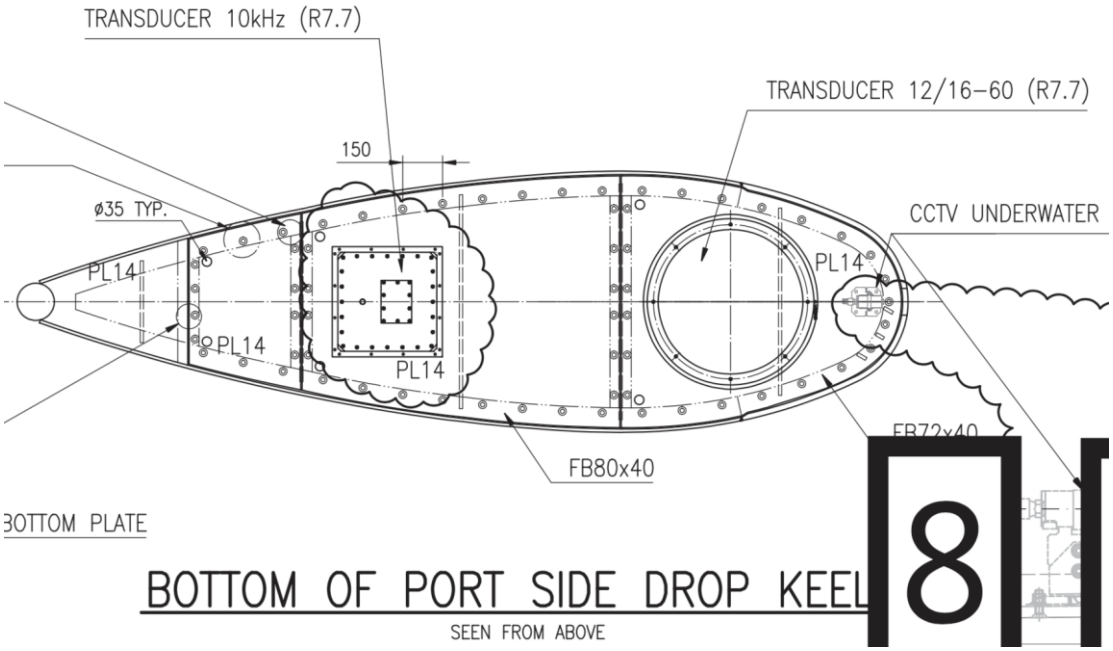
Raw data logged gaps was recorded in the eventlog. The depth data for this missing period is available in both Techsas and the vessel's raw data logger.

EventLogs:

`'EA640_Includes_Depth.csv;  'General.csv'`

Cruise Disk Location:

`…/Ship_Fitted_Scientific_Systems/Acoustics/EA640/raw/`



Port Drop Keel: 10 & 12KHz Transducer location

EM122 Multibeam Echosounder

The EM122 s/n:123 Multibeam echo-sounder was run throughout the cruise.

Pinging and Logging started in International Water at 04/12/2019 02:18 JD338

Surveys:

Name	Start Datetime	End Datetime	Lines	Cellsize / Grid	Depth	GPS	MRU	SVP applied in line number
DY111-001	2019-12-04 02:18:10	2019-12-10 10:28:39	307	100m / 256x256	Deep	PosMV	PosMV	176; 236
dy111-002	2019-12-10 11:14:04	2019-12-23 01:23:49	609	100m / 256x256	Deep	PosMV	PosMV	249, 433, 507
dy111-003-Christmas-Survey	2019-12-23 01:45:52	2019-12-30 16:52:35	371	90m 256x256	Deep	PosMV	PosMV	232
dy111-004	2019-12-30 17:02:33	2020-01-06 23:26:27	352	90m 256x256	Deep	PosMV	PosMV	51, 326

EventLogs:

`'EM122 Multibeam Echosounders Events.csv;  'General.csv'`

Cruise Disk Location:

`…/Ship_Fitted_Scientific_Systems/Acoustics/EM122/`

ADCP; OS75KHz & OS150KHz (RDI Teledyne)

The RDI Teledyne Ocean Surveyor 75KHz and 150KHz ADCPs were used throughout the cruise. The UHDAS suite of programs and processes was used to perform data acquisition, processing and monitoring.

"**UHDAS**" (University of Hawaii Data Acquisition System) acquires data from RDI ADCPs and ancillary sensors (eg. gps, gyrocompass, gps and inertial attitude sensors…) and uses CODAS processing to incrementally build a dataset of averaged, edited ocean velocities for each ADCP and ping type specified. Processed data and plots are served on the shipboard network, and daily status summaries are emailed.

Configuration

The ADCP was configured to run in Narrow Band (NB) and Bottom-Tracking (BT) mode during the departure from Southampton for DY110. NB it was turned off once the water depth reached approximately 1000m.

Saved Data

There are two directories of saved data; 'DY111'.

EventLogs:

'ADCP_UHDAS.csv; 'General.csv'

Cruise Disk Location:

…/Ship_Fitted_Scientific_Systems/Acoustics/ADCP-UHDAS/

WAMOS Wave Radar

The Ocean Waves/Rutter WAMOS wave radar was used during the cruise. The data was logged in ASCII and NetCDF by the Techsas acquisition system. The system is not calibrated, so is for indication only.

Cruise Disk Location:

…/Ship_Fitted_Scientific_Systems/TechSAS/NMEA/WAMOS

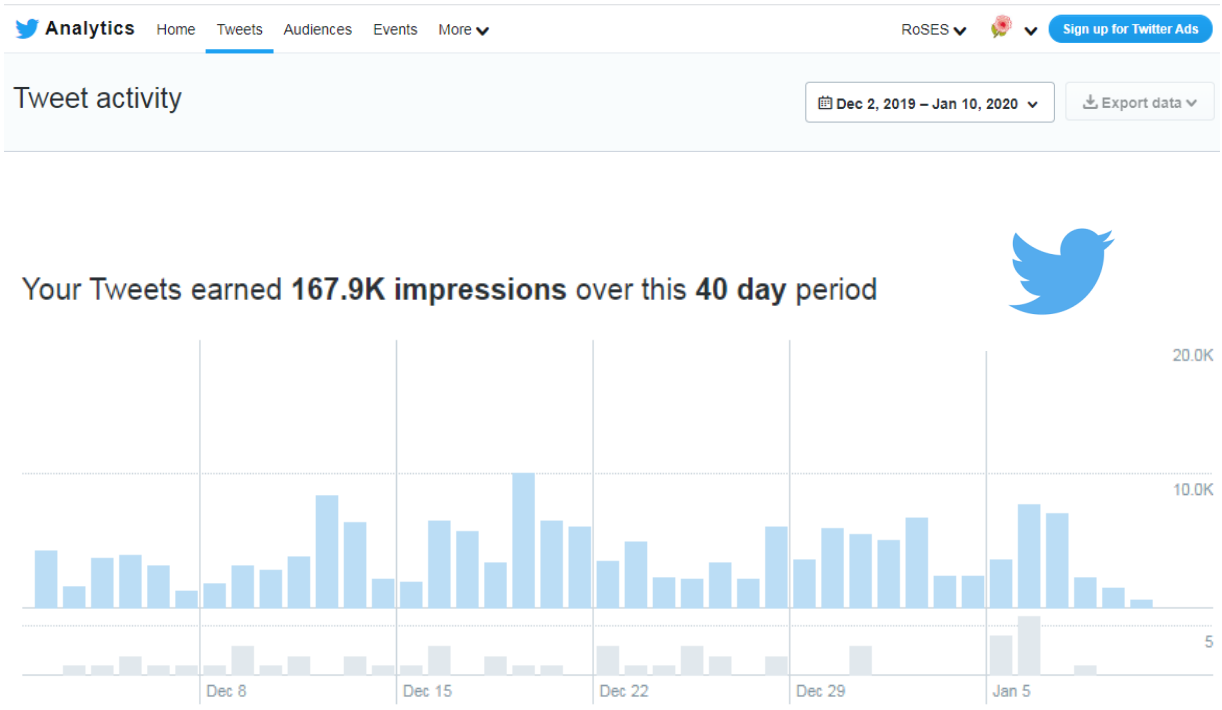
…/Ship_Fitted_Scientific_Systems/TechSAS/NetCDF/NC

Outreach

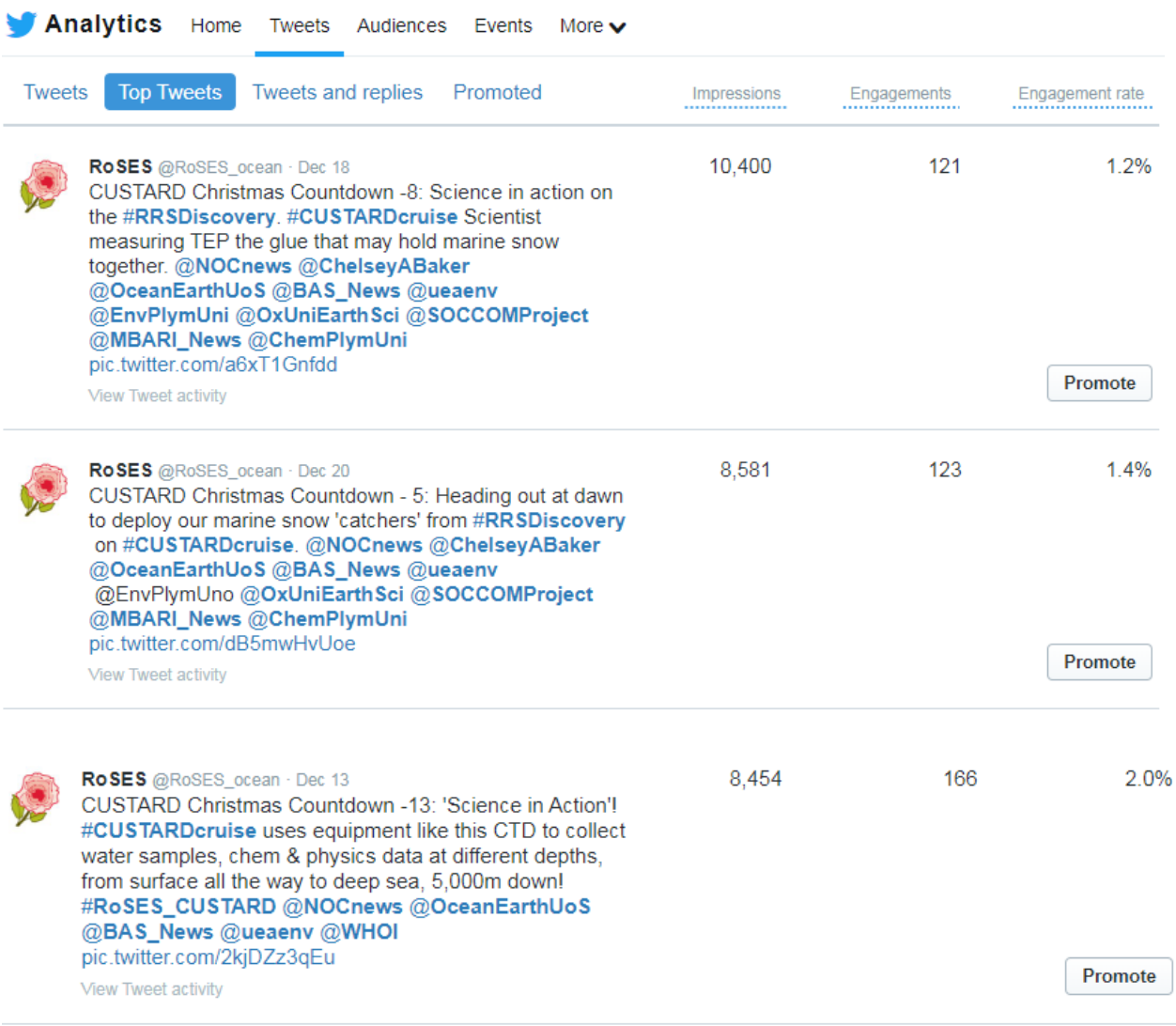
Sofia Alexiou (NOC)

Twitter:

During DY111, CUSTARD ran daily tweets for 40 days, from the 2nd of December 2019 until 10th January 2020. This included a 25-day 'Countdown to Christmas' with a daily Advent Calendar hosting pictures and videos of different research and ship activities, as well as wildlife that was encountered during that time. After Christmas, CUSTARD hosted '12 Days of Christmas' style campaign featuring research equipment used during the expedition. Additional tweets included announcements of blog posts, Argo float deployments, wildlife sightings and retweets of posts by scientists on-board. During the 40 days, CUSTARD posted 50 tweets, which analytics show earned over 167 thousand impressions (times tweets are viewed on Twitter) in that time period (and growing).

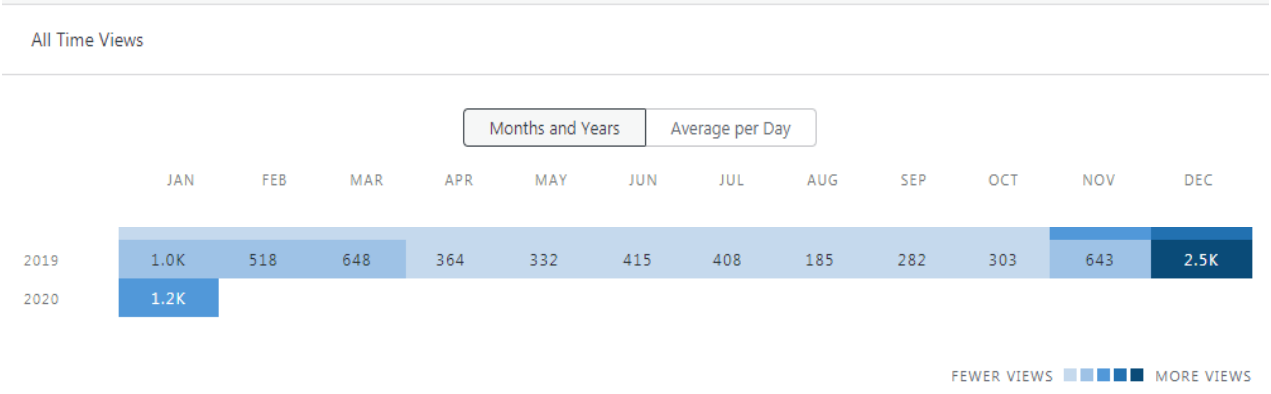


Top three tweets from the research expedition all garnered more than 8K views, with the top tweet over 10K views as of 10th January 2020, (see below). Furthermore, these higher viewed posts were all videos, suggesting that video content is of most interest to followers.


Analytics
Home
Tweets
Audiences
Events
More
Tweets
Top Tweets
Tweets and replies
Promoted
Impressions
Engagements
Engagement rate
RoSES @RoSES_ocean · Dec 18
CUSTARD Christmas Countdown -8: Science in action on the #RRSDiscovery. #CUSTARDcruise Scientist measuring TEP the glue that may hold marine snow together. @NOCnews @ChelseyABaker @OceanEarthUoS @BAS_News @ueaenv @EnvPlymUni @OxUniEarthSci @SOCCOMProject @MBARI_News @ChemPlymUni
pic.twitter.com/a6xT1Gnfdd
View Tweet activity
10,400
121
1.2%
Promote
RoSES @RoSES_ocean · Dec 20
CUSTARD Christmas Countdown - 5: Heading out at dawn to deploy our marine snow 'catchers' from #RRSDiscovery on #CUSTARDcruise. @NOCnews @ChelseyABaker @OceanEarthUoS @BAS_News @ueaenv @EnvPlymUno @OxUniEarthSci @SOCCOMProject @MBARI_News @ChemPlymUni
pic.twitter.com/dB5mwHvUoe
View Tweet activity
8,581
123
1.4%
Promote
RoSES @RoSES_ocean · Dec 13
CUSTARD Christmas Countdown -13: 'Science in Action'! #CUSTARDcruise uses equipment like this CTD to collect water samples, chem & physics data at different depths, from surface all the way to deep sea, 5,000m down! #RoSES_CUSTARD @NOCnews @OceanEarthUoS @BAS_News @ueaenv @WHOI
pic.twitter.com/2kjDZz3qEu
View Tweet activity
8,454
166
2.0%
Promote

Blog:

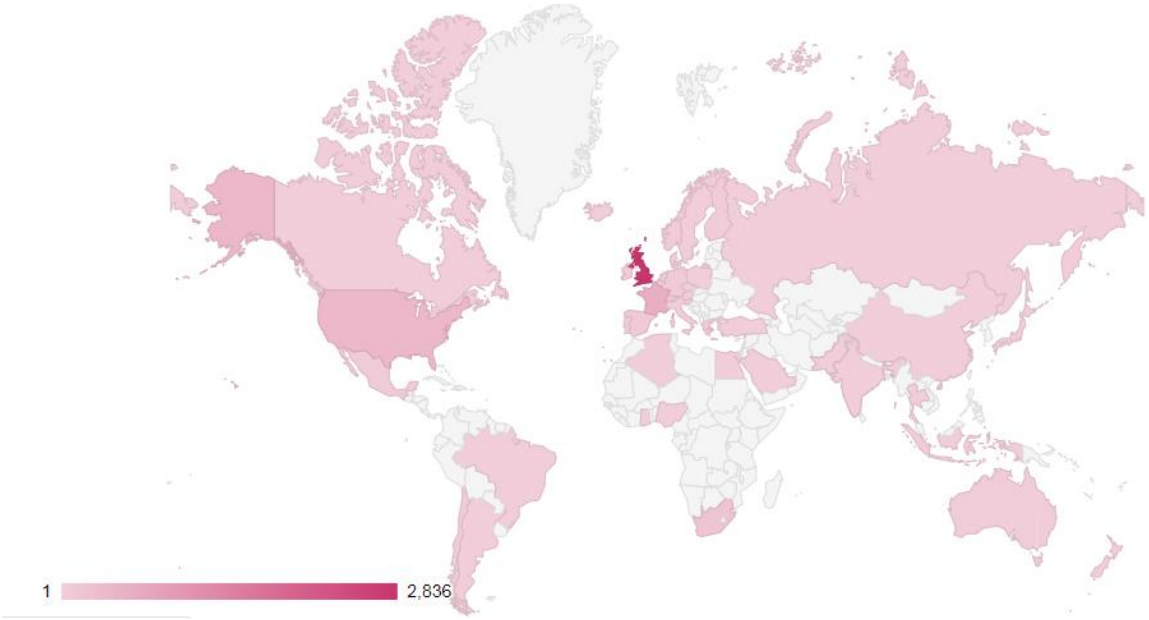
During the DY111 research expedition, CUSTARD hosted 12 blogs, an average of 2 per week, which can be found on https://roses.ac.uk/category/custard/2019-expedition/. Contributions came from scientific teams from NOC, UEA, BAS and Plymouth University giving followers insight of research activities and day to day operations of the cruise, as well as accounts of wildlife encountered. Website analytics shows a spike of over 3.5K views from November 2019 to January 2020, illustrating that regular blogs and their advertisement on social media can increase traffic to the blog pages and to the RoSES website in general.



Demographic data for the 90 day period of Nov 2019 to Jan 2020 shows the breakdown of viewers by location, with the UK being the highest, details listed below from Wordpress analytics.

Day Summary | 7 days | 30 days | Quarter | Year | All Time

Stats for 90 days ending January 17, 2020 (Summarized)



Country	Views
United Kingdom	2,836
France	567
United States	414
South Africa	192
Spain	92
Mexico	54
Germany	44
Netherlands	43
Australia	39
Greece	35
Austria	29
Finland	26

Chile	18
Belgium	16
Norway	15
Portugal	15
China	11
Ireland	11
Brazil	11
Italy	6
Switzerland	6
Sweden	5
Poland	5
Hong Kong SAR China	5
Japan	4
India	4
Bermuda	3
Saudi Arabia	3
Canada	3
New Zealand	3
Argentina	2
Turkey	2
St. Lucia	2
Russia	1
Indonesia	1
Guernsey	1
Iceland	1
Algeria	1
Pakistan	1
Thailand	1
Egypt	1
Qatar	1
Denmark	1
Czech Republic	1
Ghana	1
Nigeria	1
Slovenia	1

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Appendix A:

Table 30 Stainless steel CTD summary

Event	Station	CTD (steel)	Year	Month	Day	Time	Latitude	Longitude	Max depth	Type	Comments
			2019	12	4	03:20:01	-52 39.18	-80 32.31			
2		1	2019	12	4	04:01:42	-52 39.18	-80 32.31	2012	Argo	
			2019	12	4	05:05:04	-52 39.19	-80 32.28			
			2019	12	6	06:01:02	-54 25.28	-89 07.72			
6	OOI_1	2	2019	12	6	06:45:47	-54 25.28	-89 07.72	2012	Argo	
			2019	12	6	08:11:42	-54 25.28	-89 07.72			
			2019	12	6	22:06:02	-54 25.28	-89 07.72			
18	OOI_1	3	2019	12	6	22:35:09	-54 25.28	-89 07.72	1008	O2/S	
			2019	12	6	23:07:07	-54 25.28	-89 07.72			
			2019	12	9	03:18:05	-59 57.68	-89 07.71			
25	TS_1	4	2019	12	9	03:41:30	-59 57.76	-89 07.66	1004	UVP dip1	
			2019	12	9	04:03:37	-59 57.86	-89 07.58			
			2019	12	9	04:05:02	-59 57.87	-89 07.58			
26	TS_1	5	2019	12	9	04:30:08	-59 57.98	-89 07.49	1004	O2/S	
			2019	12	9	05:18:14	-59 58.17	-89 07.21			
			2019	12	9	22:29:01	-59 57.58	-89 07.72			
39	TS_1	6	2019	12	9	23:11:42	-59 57.89	-89 07.72	2008	Argo	
			2019	12	10	00:08:32	-59 58.36	-89 07.72			
			2019	12	11	06:22:03	-57 00.00	-89 07.94			
45	TN_1	7	2019	12	11	06:47:58	-57 00.06	-89 07.96	1005	UVP dip1	
			2019	12	11	07:06:40	-57 00.17	-89 08.04			
			2019	12	11	07:09:01	-57 00.19	-89 08.05			
46	TN_1	8	2019	12	11	07:30:17	-57 00.32	-89 08.15	1005	O2/S	
			2019	12	11	08:00:15	-57 00.51	-89 08.27			
			2019	12	11	18:07:02	-57 00.02	-89 07.98			
55	TN_1	9	2019	12	11	18:30:25	-57 00.11	-89 08.10	1005	Full	
			2019	12	11	19:10:47	-57 00.27	-89 08.33			
			2019	12	12	07:11:04	-57 00.03	-89 08.02			
59	TN_1	10	2019	12	12	07:20:28	-57 00.08	-89 08.08	123	Chance	
			2019	12	12	07:25:46	-57 00.11	-89 08.11		water	
			2019	12	13	00:07:01	-56 00.49	-89 07.12			
63	Tran2	11	2019	12	13	01:56:26	-56 00.72	-89 06.63	5055	Deep	

			2019	12	13	04:05:26	-56 01.00	-89 06.06			
			2019	12	13	17:56:03	-55 00.26	-89 07.96			
65	Tran1	12	2019	12	13	19:30:29	-55 00.26	-89 07.96	4772	Deep	
			2019	12	13	21:03:16	-55 00.26	-89 07.96			
			2019	12	14	04:08:01	-54 25.48	-89 06.38			
67	OOI_2	13	2019	12	14	04:39:25	-54 25.48	-89 06.38	1005	O2/S	
			2019	12	14	05:17:26	-54 25.48	-89 06.37			
			2019	12	14	18:32:03	-54 25.01	-89 08.10			
78	OOI_2	14	2019	12	14	19:25:42	-54 25.01	-89 08.10	1004	Full	
			2019	12	14	19:54:20	-54 25.01	-89 08.10			
			2019	12	15	10:08:01	-54 24.98	-89 08.08			
83	OOI_2	15	2019	12	15	11:36:09	-54 24.98	-89 08.09	4619	Deep	
			2019	12	15	13:29:59	-54 24.98	-89 08.08			
			2019	12	17	04:47:05	-59 57.62	-89 07.53			
86	TS_2	16	2019	12	17	05:19:56	-59 57.62	-89 07.52	1002	O2/S	
			2019	12	17	05:55:57	-59 57.63	-89 07.41			
			2019	12	17	18:10:01	-59 57.62	-89 07.53			
96	TS_2	17	2019	12	17	18:49:13	-59 57.63	-89 07.51	1504	Full	
			2019	12	17	19:36:55	-59 57.70	-89 07.43			
			2019	12	18	10:17:01	-59 00.01	-89 08.00			
100	Tran4	18	2019	12	18	11:52:35	-59 00.01	-89 08.00	5023	Deep	
			2019	12	18	13:54:24	-58 59.99	-89 07.98			
			2019	12	19	02:31:04	-58 00.90	-89 04.59			
102	Tran3	19	2019	12	19	04:08:13	-58 01.10	-89 03.63	4983	Deep	
			2019	12	19	06:06:54	-58 01.25	-89 03.23			
			2019	12	19	18:35:03	-56 59.99	-89 07.97			
105	TN_2	20	2019	12	19	19:04:13	-57 00.05	-89 08.09	1006	Full	
			2019	12	19	19:35:59	-57 00.10	-89 08.19			
			2019	12	20	05:59:04	-56 59.98	-89 07.96			
109	TN_2	21	2019	12	20	06:26:16	-57 00.02	-89 08.02	1006	O2/S	
			2019	12	20	06:59:37	-57 00.10	-89 08.14			
			2019	12	20	17:30:01	-57 00.97	-89 09.13			
118	TN_2	22	2019	12	20	19:06:55	-57 01.17	-89 09.55	5243	Deep	
			2019	12	20	20:42:01	-57 01.38	-89 09.99			
			2019	12	21	07:03:04	-55 59.96	-89 07.84			

120	Tran2	23	2019	12	21	07:40:16	-56 00.05	-89 07.55	2009	Argo	
	Argo		2019	12	21	08:38:30	-56 00.17	-89 07.08			
			2019	12	22	04:09:03	-54 24.99	-89 07.94			
124	OOI_3	24	2019	12	22	04:34:53	-54 24.99	-89 07.95	1006	O2/S	
			2019	12	22	05:10:25	-54 24.99	-89 07.95			
			2019	12	22	15:56:01	-54 25.10	-89 08.72			
134	OOI_3	25	2019	12	22	16:41:14	-54 25.14	-89 08.76	506	Glider	
			2019	12	22	16:51:47	-54 25.14	-89 08.76		dip 1	
			2019	12	22	16:53:03	-54 25.14	-89 08.76			
135	OOI_3	26	2019	12	22	17:18:17	-54 25.14	-89 08.76	1006	Full	
			2019	12	22	17:55:21	-54 25.14	-89 08.77			
			2019	12	26	23:33:04	-59 57.46	-89 07.87			
141	TS_3	27	2019	12	26	23:51:05	-59 57.53	-89 07.85	302	MLD check	
			2019	12	26	23:58:18	-59 57.58	-89 07.76			
			2019	12	27	04:21:04	-59 57.50	-89 07.85			
144	TS_3	28	2019	12	27	04:55:42	-59 57.68	-89 07.68	1005	O2/S	
			2019	12	27	05:25:46	-59 57.93	-89 07.44			
			2019	12	27	18:35:02	-59 58.97	-89 06.20			
156	TS_3	29	2019	12	27	19:02:17	-59 59.17	-89 05.88	1005	Full	
			2019	12	27	19:30:21	-59 59.36	-89 05.56			
			2019	12	28	16:33:02	-59 58.47	-89 06.70			
159	Tran3	30	2019	12	28	0.7243056	-59 58.47	-89 06.70	2009	Argo	
	Argo		2019	12	28	18:20:03	-59 58.47	-89 06.70			
			2019	12	29	05:38:01	-57 00.38	-89 07.62			
162	TN_3	31	2019	12	29	06:06:20	-57 00.48	-89 07.64	1006	UVP dip1	
			2019	12	29	06:28:35	-57 00.58	-89 07.69			
			2019	12	29	06:29:03	-57 00.59	-89 07.69			
163	TN_3	32	2019	12	29	06:56:04	-57 00.72	-89 07.74	1006	O2/S	
			2019	12	29	07:31:20	-57 00.93	-89 07.77			
			2019	12	29	18:41:03	-57 00.01	-89 07.94			
172	TN_3	33	2019	12	29	19:09:12	-57 00.11	-89 07.99	1007	Full	
			2019	12	29	19:39:25	-57 00.31	-89 07.96			
			2019	12	30	18:22:01	-59 58.07	-89 08.02			
176	TS_4	34	2019	12	30	18:46:57	-59 58.21	-89 07.90	1005	Full	
			2019	12	30	19:19:20	-59 58.40	-89 07.72			

			2019	12	31	06:17:05	-59 58.36	-89 07.55			
186	TS_4	35	2019	12	31	06:43:32	-59 58.51	-89 07.56	1005	O2/S	
			2019	12	31	07:18:07	-59 58.74	-89 07.58			
			2019	12	31	11:46:01	-59 58.36	-89 07.55			
191	TS_4	36	2019	12	31	13:18:35	-59 58.66	-89 07.41	5008	Deep	
			2019	12	31	15:05:46	-59 59.17	-89 07.17			
			2020	1	3	06:30:05	-54 24.68	-89 07.69			
199	OOI_4	37	2020	1	3	07:00:36	-54 24.68	-89 07.69	1006	Glider recovery	
			2020	1	3	07:35:01	-54 24.68	-89 07.69			
			2020	1	3	17:44:02	-54 24.91	-89 07.57			
208	OOI_4	38	2020	1	3	18:12:27	-54 24.91	-89 07.57	1005	Full	
			2020	1	3	18:44:46	-54 24.91	-89 07.57			
			2020	1	4	15:12:03	-56 59.98	-89 07.97			
212	TN_4	39	2020	1	4	15:46:40	-57 00.04	-89 08.07	1006	UVP first dip	
			2020	1	4	16:05:45	-57 00.09	-89 08.13			
			2020	1	4	16:09:01	-57 00.10	-89 08.14			
213	TN_4	40	2020	1	4	16:32:19	-57 00.18	-89 08.20	1006	UVP	
			2020	1	4	16:51:04	-57 00.23	-89 08.25			
			2020	1	4	17:57:01	-57 00.13	-89 07.94			
215	TN_4	41	2020	1	4	18:28:51	-57 00.20	-89 07.94	1006	Full	
			2020	1	4	19:06:21	-57 00.32	-89 07.95			
			2020	1	5	06:17:02	-57 00.26	-89 07.80			
226	TN_4	42	2020	1	5	06:46:20	-57 00.35	-89 07.79	1005	O2/S	
			2020	1	5	07:16:37	-57 00.45	-89 07.79			
			2020	1	6	09:11:01	-55 14.10	-83 22.67			
232		43	2020	1	6	09:56:17	-55 14.10	-83 22.46	2008	Argo	
			2020	1	6	10:54:15	-55 14.10	-83 22.43			

Table 31Titanium CTD summary

Event	Station	CTD (Ti)	Year	Month	Day	Time	Latitude	Longitude	Max depth	Type	Comments
			2019	12	4	01:49:01	-52 39.18	-80 32.31			
1	Argo/	1	2019	12	4	02:06:46	-52 39.18	-80 32.31	203	Bottle	
	test		2019	12	4	02:19:49	-52 39.18	-80 32.31		soak	
			2019	12	6	15:30:04	-54 25.28	-89 07.72			
16	OOI_1	2	2019	12	6	16:09:38	-54 25.28	-89 07.72	1105		
			2019	12	6	17:02:23	-54 25.28	-89 07.72			
Deck test		3									
			2019	12	8	18:41:04	-59 57.58	-89 07.72			
23	TS_1	4	2019	12	8	20:26:51	-59 57.86	-89 07.16	4888		
			2019	12	8	23:30:29	-59 58.56	-89 05.76			
			2019	12	9	14:21:02	-59 57.43	-89 07.52			
35	TS_1	5	2019	12	9	14:59:50	-59 57.79	-89 07.47	1001		
			2019	12	9	15:43:43	-59 58.30	-89 07.38			
			2019	12	11	11:15:04	-56 59.98	-89 07.93			
52	TN_1	6	2019	12	11	11:49:50	-57 00.17	-89 08.05	1003		
			2019	12	11	12:41:49	-57 00.49	-89 08.26			
			2019	12	12	19:29:04	-56 00.05	-89 08.04			
62	Tran2	7	2019	12	12	21:09:23	-56 00.23	-89 07.68	4941		
			2019	12	12	23:15:07	-56 00.47	-89 07.15			
			2019	12	13	13:03:05	-54 59.99	-89 07.99			
64	Tran1	8	2019	12	13	14:57:04	-55 00.25	-89 07.96	4653		
			2019	12	13	16:57:47	-55 00.26	-89 07.96			
			2019	12	14	11:16:03	-54 25.64	-89 06.37			
74	OOI_2	9	2019	12	14	11:41:43	-54 25.64	-89 06.37	1002		
			2019	12	14	12:37:28	-54 25.64	-89 06.37			
			2019	12	15	05:52:01	-54 24.98	-89 08.09			
82	OOI_2	10	2019	12	15	07:23:25	-54 24.98	-89 08.08	4511		
			2019	12	15	09:36:48	-54 24.98	-89 08.08			
			2019	12	17	10:50:01	-59 57.63	-89 07.41			
93	TS_2	11	2019	12	17	11:28:41	-59 57.90	-89 06.97	1503		
			2019	12	17	12:28:50	-59 58.33	-89 06.22			

			2019	12	18	05:51:03	-59 00.01	-89 08.00			
99	Tran4	12	2019	12	18	07:32:10	-59 00.01	-89 08.00	4920		
			2019	12	18	09:49:23	-59 00.01	-89 08.00			
			2019	12	18	22:02:02	-58 00.02	-89 07.97			
101	Tran3	13	2019	12	18	23:59:23	-58 00.42	-89 05.98	4801		
			2019	12	19	01:59:06	-58 00.89	-89 04.65			
			2019	12	19	15:02:01	-56 59.98	-89 07.96			
103	TN_2	14	2019	12	19	15:43:51	-57 00.09	-89 08.05	1504		
			2019	12	19	16:33:14	-57 00.29	-89 08.29			
			2019	12	20	12:58:04	-57 00.01	-89 08.00			
117	TN_2	15	2019	12	20	14:42:58	-57 00.60	-89 08.64	5104		
			2019	12	20	16:35:09	-57 00.91	-89 09.05			
			2019	12	22	10:01:04	-54 24.97	-89 07.97			
132	OOI_3	16	2019	12	22	10:41:20	-54 24.97	-89 07.97	1501		
			2019	12	22	11:35:40	-54 24.97	-89 07.96			
			2019	12	27	10:38:03	-59 57.43	-89 07.95			
151	TS_3	17	2019	12	27	12:32:58	-59 58.24	-89 07.18	4891		
			2019	12	27	14:34:59	-59 58.92	-89 06.41			
			2019	12	27	20:09:04	-59 57.51	-89 07.87			
157	TS_3	18	2019	12	27	20:19:35	-59 57.55	-89 07.80	157		
			2019	12	27	20:26:16	-59 57.60	-89 07.71			
			2019	12	29	11:10:01	-56 59.96	-89 07.97			
169	TN_3	19	2019	12	29	11:45:52	-57 00.26	-89 07.92	1505		
			2019	12	29	12:33:21	-57 00.65	-89 07.86			
			2019	12	31	09:45:01	-59 57.52	-89 07.98			
191	TS_4	20	2019	12	31	10:21:31	-59 57.85	-89 07.81	1503		
			2019	12	31	11:10:16	-59 58.33	-89 07.56			
			2020	1	2	19:08:01	-54 24.92	-89 07.56			
194	OOI_4	21	2020	1	2	20:33:00	-54 24.92	-89 07.56	4336		
			2020	1	2	22:14:13	-54 24.92	-89 07.56			
			2020	1	3	14:14:05	-54 24.90	-89 07.57			
206	OOI_4	22	2020	1	3	15:17:27	-54 24.90	-89 07.57	745		
			2020	1	3	16:18:48	-54 24.91	-89 07.57			

Appendix B: DY112 summary cruise report

Objectives

The primary objective of this cruise (DY112, OOI Southern Ocean 6 Cruise) was recovery of the Ocean Observatories Initiative (OOI) Southern Ocean Array Surface Mooring (GS01SUMO-00004), which was deployed in December 2018 on DY096. This mooring included lab-on-a-chip sensors which were part of the CUSTARD (Carbon Uptake and Seasonal Traits of Antarctic Remineralisation Depth) project. During the previous CUSTARD cruise, DY111, water sampling was conducted in the vicinity of the OOI Surface Mooring for data validation. The mooring was successfully recovered on 20 Jan 2020 with no issues. Additionally, CUSTARD project personnel onboard conducted sampling from the underway system, and Go-flo water sampling in the vicinity of the recovered mooring.

Figure 20 Cruise track of DY112.

Personnel

The OOI team from the Woods Hole Oceanographic Institution (WHOI) were led by Sheri White (PSO): James Ryder, Kris Newhall, Nico Llanos, and Jennifer Batryn. Three of the scientific team from DY111 stayed onboard for DY112: Adrian Martin, Chelsey Baker and Katsia Pabortsava, all from NOC. The NMF team included Andy Leadbeater (STO), Steve Whittle, Andrew Cottmore and Jennifer Ward-Neale. The only crew change from DY111 was that ERPO Brian Conteh was replaced by Neil Glyndor.

Narrative

Thursday 16th January

Wind picked up rising to Force 8. Sailed at 0600 (0900 GMT) with pilot off soon after. A day of setting up with emergency muster drill at 1030 shiptime (1330 GMT). In Narrows (~1530) of Magellan Strait visibility dropped sufficiently to require the foghorn.

Friday 17th January

Grey and windy, force 7. Slow going against the swell and wind.

Saturday 18th January

Grey, windy (Force 7) and swell making it heavy going all day once more. Briefing by OOI Team on mooring recovery at 0900. Underway turned on as we entered international waters ~1530 (1830 GMT). Adrian Martin on bridge during ramp-up of swath to monitor for marine mammals but none seen.

Sunday 19th January

Hint of a sunrise but bumpy overnight. Swell diminished towards end of day allowing speed to increase.

Monday 20th January

Some blue sky, lower wind (Force 4) and reduced swell. At 0655 (0955 GMT) stopped at 54° 23.69' S 89° 13.38' W 0.95 nm NW of mooring anchor position. Mooring released acoustically at 0701 (1001 GMT). The details of the mooring recovery are described below. The recovery was completed at 1605 (1905 GMT). Early evidence of a lot of lost and damaged and sensors from inductive line. NOC LOCs removed from NSIF and cleaned down.

Tuesday 21st January

Wind freshened but a blue and warm day despite squalls roaming the horizon. Two profiles using single Go-flo bottles on Kevlar rope fired by messenger. Depths sampled: 150m, 100m, 50m, 10m. RBR Concerto attached to bottle to collect data on pressure, T, fluorescence, turbidity. After first profile, a download of RBR Concerto data suggested turbidity was awry, with a flat line punctuated by noise. Connection was purged with silica spray prior to redeployment. Same issue persisted on second profile. On recovery, science all done and soon heading back to Punta.

Wednesday 22nd January

Grey with sunny spells, Force 5-6. Packing up

Thursday 23rd January

Underway turned off when entering Chilean waters ~0030 (1330 GMT). Continued packing up. Grey with sunny spells, with the wind picking up in the evening. Entered the Strait around 2030.

Friday 24th January

Transited through the Straight. Overcast with bits of sun. Calm sea and winds, Force 4 and lower. Finishing packing up. Ship starboard lifeboat test and crew fire drill.

Saturday 25th January

Docked at Mardones Pier at 0735 (1035 GMT). All OOI gear offloaded by 1110.

Mooring recovery

Sheri White (WHOI)

20 Jan had an appropriate weather window with decreasing seas and light winds for mooring recovery operations. Despite a slow transit into headwinds, the ship was able to increase speed in the afternoon of 19 Jan and arrived at the mooring site on 20 Jan at approximately 0600 shiptime (0900 GMT). The surface buoy was SE of the anchor position and winds were ~20 kts out of the NW. The ship took up position 1 nm NW of the anchor position (upwind). The acoustic release was fired at 0701 (1001 GMT). The glass balls were expected to surface in 45-50 minutes, but visibility was limited due to fog. The ship closed to 0.5 nm from the anchor position and the glass balls were spotted on the surface at 0809. Due to the position of the glass balls, buoyant Colmega line streaming from the balls, and the buoy, the ship drove to the SE (with the wind), bringing the glass balls along the starboard side of the ship. The balls were held along the starboard side with a grapnel and hooked with a 5-ton lifting hook connected to the TSE winch leader. The ship then steamed ahead to the SE-E stringing out the mooring astern. The majority of the mooring rise is synthetic wire rope which was reeled in onto the TSE winch. Hauling in was stopped twice and the mooring line was stopped off and cut, such that the synthetic rope on TSE could be off-spooled into Ropak containers on the deck.

Figure 21 Glass balls on deck and Colmega line being hauled in (left), and the TSE winch being off-spooled (right).

At 1314 the wire rope section began coming aboard along with instrumentation clamped onto the line. Instrumentation was removed and the wire rope was hauled in on the TSE winch. The wire rope was stopped off at 500 m for the ADCP cage to be removed. Wire rope and instrumentation recovery continued to the 180 m depth mark. The wire rope was cut at the 180 m depth mark, and the buoy and upper riser section were set free (due to the top-heaviness of the buoy, having a portion of the mooring riser hanging below the buoy ensures it remains upright and stable).

Figure 22 ADCP and instrumentation clamped onto the wire rope being hauled aboard.

The ship then turned into the wind and brought the buoy along the starboard side of the ship. The buoy was hooked with a 5-ton hook on a 12 m pennant shackled to the TSE winch leader. The ship steamed slowly ahead allowing the buoy to come astern. The TSE hauled the buoy in close to the ship's stern, then the 12 m pennant was transferred to the ship's core wire reeved through the A-frame centre block. As the buoy was lifted out of the water it rotated, bringing the masthead forward. Tag lines were put on to control the motion of the buoy and it was lowered gently to the deck using the A-frame and core wire. The buoy was shifted forward and starboard on the deck and secured with aircraft straps. The Near Surface Instrument Frame (NSIF) was then lifted on to the deck and the remaining instrumentation and wire rope were recovered. The mooring recovery was completed at 1605 (1905 GMT). A more detailed cruise report (3201-00603) will be posted on the OOI Document Management System (alfresco.oceanobservatories.org), and all OOI data are available at ooinet.oceanobservatories.org.

Figure 23 Buoy hooked and coming astern (left) and being hauled on board (right).

Lab-on-a-chip sensors

Adrian Martin, Katsia Pabortsava (NOC)

Following recovery of the mooring on 20 Jan, the two NOC Lab-on-a-chip sensors were detached from the Near Surface Instrument Frame (NSIF) that hung 12 m below the buoy. Biofouling was apparently light given the 14 months they had been in the water. They were cleaned with fresh water and left to dry for 36 hours. After this the casing was removed. Remaining reagents and waste products were decanted into a carboy. Standards and blanks were split, with one set being run on board and the other stored (nitrate in -20C freezer and silicate in chill room). The analysed set demonstrated that the standards remained very stable throughout the deployment, giving values apparently identical to the original concentrations. The inside was carefully cleaned and then left to dry for another 24 hours. Following this the data cable was attached and data were downloaded. Raw files were numbered sequentially, starting in Dec 2018 and finishing on the day before the mooring's recovery, suggesting that all files were recovered, though as there are over 400 for each sensor they weren't opened individually to check. The data will be analysed back in NOC.

Figure 24 Lab-on-a-chip sensors within the NSIF on recovery of the buoy.

Underway sampling

Adrian Martin, Chelsey Baker, Katsia Pabortsava (NOC)

Water samples were taken from the non-toxic supply every 6 hours at 0300, 0900, 1500 and 2100 shiptime (0000, 0600, 1200 and 1800 GMT) to be consistent with DY111. Sampling started on 18 Jan at 1500 (1800 GMT) and continued until 0600 (0300GMT) on 22 Jan. Samples were taken for salinity, nutrients, Chl a, HPLC and DIC/TA. Some lugols were also taken for later analysis of phytoplankton community. At 1500 shiptime each day samples were also taken for size-fractionated Chl a (>0.2, >5, >10/20 µm – the 10 µm ran out on UW208 so a second sample was run for UW208 using 20µm and all subsequent samples, including all Go-flo samples, used 20µm). All protocols were as DY111.

There were considerable problems with bubbles in the non-toxic supply. Jennifer Ward-Neale, the NMF SS tech, adjusted the system but problems persisted. The only time sampling for DIC/TA was possible was when stationary at the OOI site. While the journey out to the site was bumpy, at other times it was no different to DY111 when sampling had been possible.

UW#	Date	JDAY	Lat (S)	Lon (W)	Time (GMT)	S bottle	Time (GMT)	Nuts	Time (GMT)	Inorg C	Time (GMT)	Chl, HPLC	Size-frac Chl	Lugols
200	18/01/2020	18	53 18.29	80 55.07	18:35	200	18:34	UW200	-	Bubbles	18:34	UW200	UW200	-
201	19/01/2020	19	53 32.00	81 49.14	00:01	201	00:00	UW201	-	Bubbles	00:04	UW201	-	-
202	19/01/2020	19	53 45.43	82 57.11	06:00	202	06:03	UW202	-	Bubbles	06:05	UW202	-	-
203	19/01/2020	19	53 56.92	83 57.26	12:04	203	12:06	UW203	-	Bubbles	12:09	UW203	-	-
204	19/01/2020	19	54 1.35	85 2.44	18:03	204	18:06	UW204	-	Bubbles	18:07	UW204	UW204	-
205	20/01/2020	20	54 10.11	86 37.74	00:00	205	00:00	UW205	-	Bubbles	00:04	UW205	-	-
206	20/01/2020	20	54 20.92	88 23.46	05:56	206	05:58	UW206	-	Bubbles	06:00	UW206		
207	20/01/2020	20	54 29.59	89 11.57	12:02	207	12:04	UW207	12:08	96,116	12:06	UW207	-	-
208	20/01/2020	20	54 29.80	89 2.87	18:00	208	18:02	UW208	18:03	45,117	18:08	UW208	UW208	-
209	21/01/2020	21	54 25.29	89 2.32	00:01	209	00:03	UW209	-	Bubbles	00:11	UW209	-	-
210	21/01/2020	21	54 25.11	89 8.35	05:59	210	06:01	UW210	06:05	88,97	06:03	UW210	-	-
211	21/01/2020	21	54 25.11	89 8.31	11:44	211	11:46	UW211	11:50	113,114	11:48	UW211	-	yes
212	21/01/2020	21	54 25.11	89 8.31	-	-	17:37	UW212	-	-	-	-	-	-
213	21/01/2020	21	54 24.22	89 0.53	18:10	220	18:01	UW213	-	Bubbles	18:06	UW213	UW213	yes
214	22/01/2020	22	54 11.92	87 20.32	00:00	221	00:01	UW214	-	Bubbles	00:02	UW214	-	yes
215	22/01/2020	22	53 59.63	85 39.84	05:58	222	05:59	UW215	-	Bubbles	06:01	UW215	-	yes

Figure 25 DY112 underway sampling

Go-flo sampling

Adrian Martin, Chelsey Baker, Katsia Pabortsava (NOC)

The primary aim of DY112 was to recover the mooring so any sampling had to be done on an opportunistic basis. In particular the CTD frame was not available as there was not a CTD technician onboard. Two sampling profiles were nevertheless collected using single Go-flo bottles on a Kevlar rope fired using a messenger. Four depths were sampled: 150 m, 100 m, 50 m, 10 m. Each depth was sampled using a single bottle, with water taken before the bottle was sent back down, to the next depth. Sampling was as for underway but plus oxygen, POC, PIC and BSi. Once again protocols were as DY111. To obtain depth and higher frequency data, an RBR Concerto was attached to the bottle with sensors for pressure, T, fluorescence, and turbidity.

GoFlo#	Date	JDAY	Lat (fired)	Lon (fired)	Depth (m)	Time (GMT; fired)	Oxygen	S bottle	Nuts	Inorg C	HPLC	Lugols	POC	Bsi	PIC	Chl a	Chl a Size Frac (>20, >5, >0.2)
GF1	21/01/2020	21	-54 25.132	-89 8.274	150	12:22	120	212	GF1	85 & 30	GF1 DY112	GF1 DY112	DY112 POC GF1 150m	DY112 BSi GF1 150m	DY112 BSi GF1 150m	x	x
GF2	21/01/2020	21	-54 25.21	-89 8.19	100	13:05	61 & 90	213	GF2	34 & 60	GF2 DY112	GF2 DY112	DY112 POC GF2 100m	DY112 BSi GF2 100m	DY112 BSi GF2 100m	x	x
GF3	21/01/2020	21	-54 25.22	-89 8.18	50	13:26	106	214	GF3	93 & 31	GF3 DY112	GF3 DY112	DY112 POC GF3 50m	DY112 BSi GF3 50m	DY112 BSi GF3 50m	x	x
GF4	21/01/2020	21	-54 25.24	-89 8.168	10	13:42	80 & 67	215	GF4	57 & 35	GF4 DY112	GF4 DY112	DY112 POC GF4 10m	DY112 BSi GF4 10m	DY112 BSi GF4 10m	x	x
GF5	21/01/2020	21	-54 25.28	-89 8.14	150	16:21	92	216	GF5	94 & 32	DY112 HPLC GF5 150m	GF5 DY112	DY112 POC GF5 150m	DY112 BSi GF5 150m	DY112 BSi GF5 150m	x	x
GF6	21/01/2020	21	-54 25.35	-89 8.096	100	16:43	111 & 45	217	GF6	37 & 40	DY112 HPLC GF6 100m	GF6 DY112	DY112 POC GF6 100m	DY112 BSi GF6 100m	DY112 BSi GF6 100m	x	x
GF7	21/01/2020	21	-54 25.41	-89 8.056	50	17:03	94	218	GF7	33 & 41	DY112 HPLC GF7 50m	GF7 DY112	DY112 POC GF7 50m	DY112 BSi GF7 50m	DY112 BSi GF7 50m	x	x
GF8	21/01/2020	21	-54 25.46	-89 8.016	10	17:20	79 & 99	219	GF8	86 & 95	DY112 HPLC GF8 10m	GF8 DY112	DY112 POC GF8 10m	DY112 BSi GF8 10m	DY112 BSi GF8 10m	x	x

Figure 26 DY112 Go-flo sampling