NBP1503 Cruise Report

24.03.2015
03.05.2015

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with contributions by the participants

Cover: Aerial view of NB Palmer, credit Guy Williams, Alex Fraser, Eva Cougnon

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1. Introduction and Background

(Frank Nitsche)

1.1 Background

Understanding the reaction of large ice sheets to climate change is critical for predicting future sea levels. However, many details of past and future ice sheet behavior are still uncertain. Significant progress has been made with recent studies of the West Antarctic Ice Sheet (WAIS) that revealed the intrusion of warm ocean water onto the continental shelf as the main cause for present thinning of major ice streams.

Although the East Antarctic Ice Sheet (EAIS) is generally considered more stable than the WAIS, recent satellite data indicate that some East Antarctic ice streams are thinning. Hence, parts of the EAIS might be more vulnerable to future ice loss than previously thought. Similar to the WAIS the main mechanism for EAIS thinning is probably warm water intrusions onto the continental shelf.

Few data exists from the East Antarctic continental shelf that can identify potential pathways for warm ocean water towards major ice streams. Identifying such pathways is particular important for ice streams located along the section of the continental margin where the Aurora and Wilkes Basins might have a deep connection with the continental shelf.

The lack of data also limits our understanding of past ice stream behavior in this area. It is still unclear if some ice streams had reached the shelf break in the past, or if they only extended to the mid-shelf area. There is also an ongoing debate about the contribution of EAIS to past sea-level maxima, which are difficult to explain by contributions from West Antarctica and Greenland alone. Better understanding of past EAIS behavior would add constraints for these questions.

1.2 Original objectives

The overarching goal of the cruise NBP1503 is to acquire data that will allow determining if parts of the EAIS are potentially vulnerable to warm water incursions and therefore less stable than previously thought. Therefore the plan was to investigate

(1) if several East Antarctic ice streams between 160°E and 90°E are linked to deep cross-shelf troughs (especially those that experience thinning today) and thus are vulnerable to melting by warm ocean water;

(2) if relative warm ocean water (above local freezing point) is currently reaching some glaciers along these troughs and thus could be potentially be the reason for the observed thinning of these systems;

(3) if these ice streams have been grounded in the past near the shelf break and thus have been more dynamic than previously thought.

Originally, we selected three to four ice streams as primary targets for our investigations including the Frost Glacier, the Totten Glacier and the Scott and Denman Glacier. If the cruise had started in McMurdo, we would have also included the Ninnis Glacier Fig. 1.1).

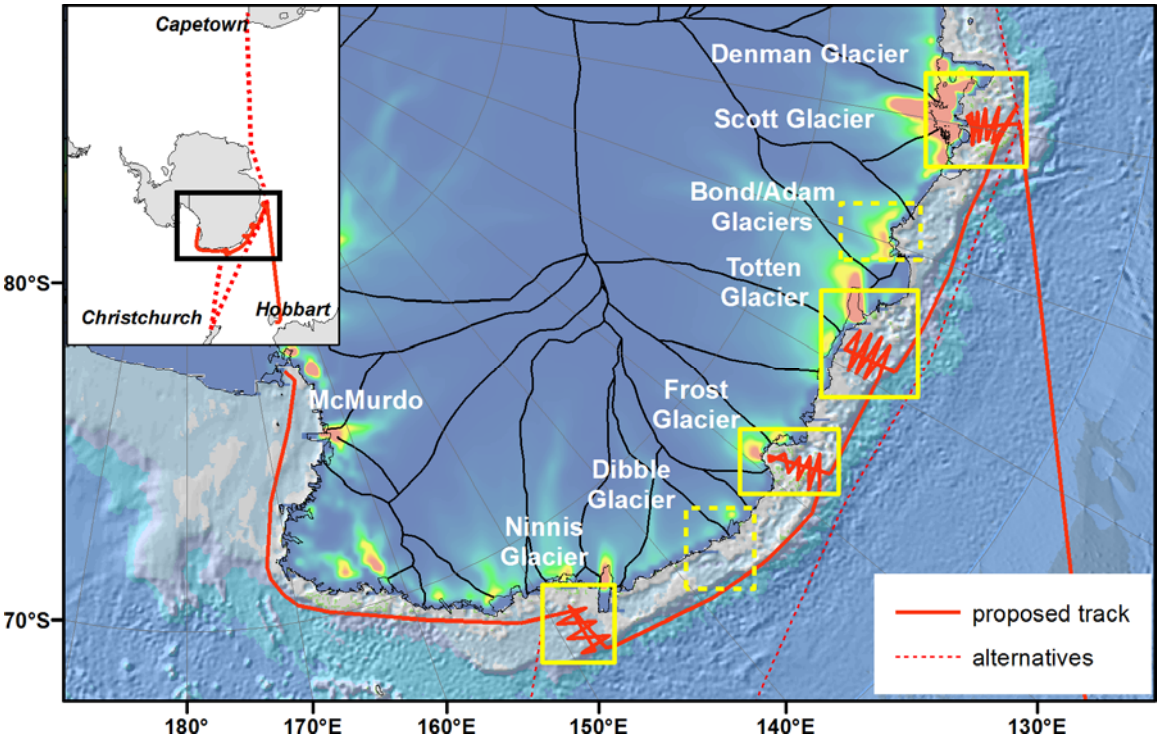

Figure 1.1- Original cruise plan with primary (yellow boxes) and secondary (dashed yellow boxes) target areas.

The general goal was to use **multibeam swath bathymetry system** to map the continental shelf in front of these glaciers and determine if cross-shelf troughs exist in front of these glaciers and how deep the troughs are. Then we would conduct **water column measurements (CTD)** of temperature and salinity along and across these troughs as well as on the continental slope nearby to examine the general structure of water masses on the shelf and identify any intrusions of warm modified circumpolar deep water. Detailed analysis of multibeam and **subbottom data** would reveal glacial features on the seafloor that could provide insights into the past (Pleistocene) dynamic of these glaciers.

1.3 Sea Ice Conditions

Access to the continental shelf in front of these glacial systems is strongly dependent on the sea ice cover. Historically the sea ice cover in this area is a minimum between mid-February to mid or end of March. However, exactly which areas of the continental shelf become ice free varies from year to year. Figure 1.2 shows the conditions from March 13 2015. Areas in front of the Frost Glacier, parts of the Totten and the Scott and Denmark Glaciers were still covered with ice. Since it was unlikely that we would be able to access areas with such thick multi-year ice cover, the original plan was revised to target the more open areas and concentrate on the potential shelf break access of warm water across the continental slope and onto the outer continental shelf (Fig 1.3).

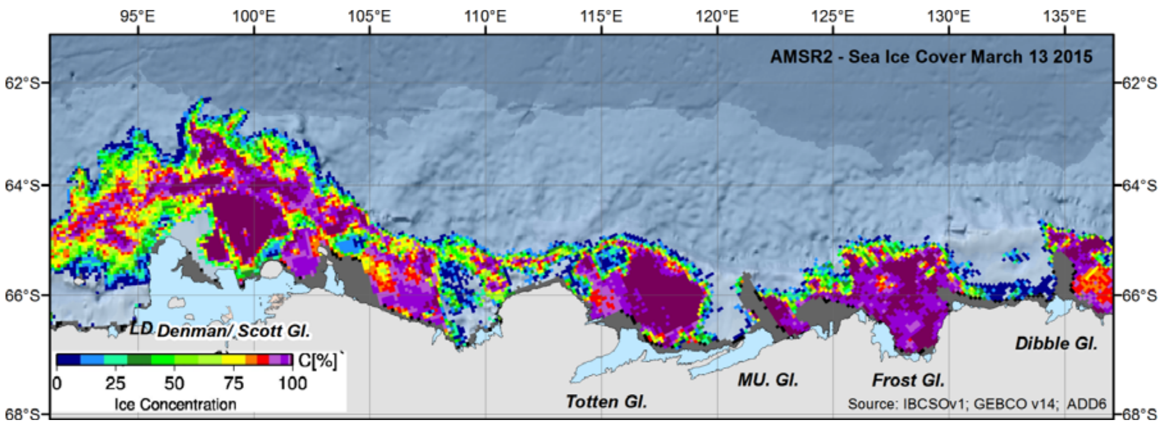

Figure 1.2 - Sea ice cover March 13 2015. Source AMSR2, University Bremen (http://www.iup.uni-bremen.de:8084/amsr2/).

Our cruise started, after a 2-day delay in Hobart for unforeseen vessel repairs, on March 26 and ended on May 3. We reached the study area on the April 4th, by which time some areas had started forming new sea ice and the access to the shelf regions became more difficult. Therefore we concentrated our efforts on the continental slope, shelf break and outer shelf areas. Sea ice was continuously increasing in extent and concentration and most of the continental shelf and slope areas were completely covered by the end of the cruise (Fig. 1.3).

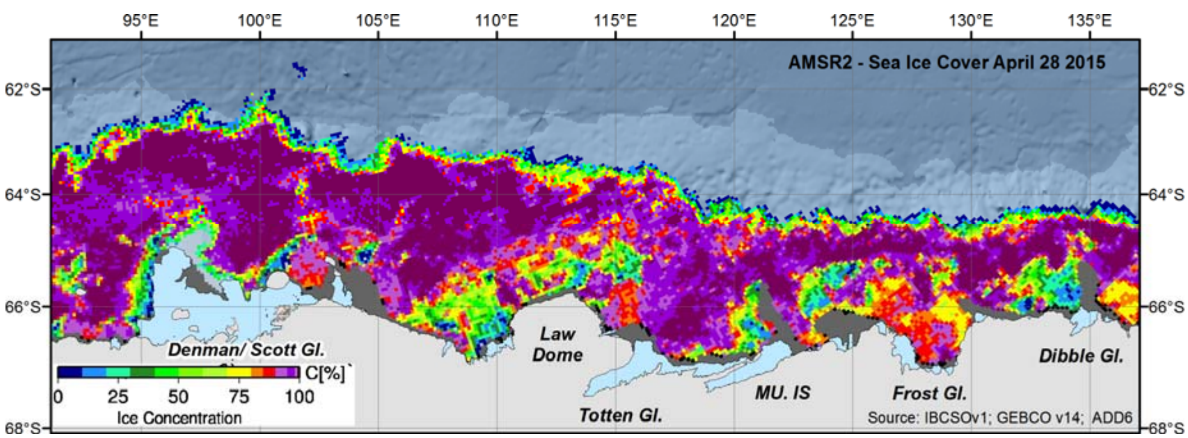

Figure 1.3: Sea ice cover April 28 2015. Source AMSR2, University Bremen (http://www.iup.uni-bremen.de:8084/amsr2/).

Throughout the cruise we received weather data from the US Navy and Scott Carpentier provided updates from the Australian Bureau of Meteorology - Tasmania/Antarctic Region every 12 hours. We also received frequent (often daily) sea ice updates from the AMSR2 service of the University of Bremen, OSSI sea concentration data from the Drift and Noise Polar Services, additional high resolution imagery from Andy Archer (ACS, Boulder, CO) and detailed sea ice analysis from Jan Liesser (ACE CRC, University of Tasmania). All these information were essential for our operational planning throughout the cruise, especially in this late season.

1.4 Itinerary and Cruise Track

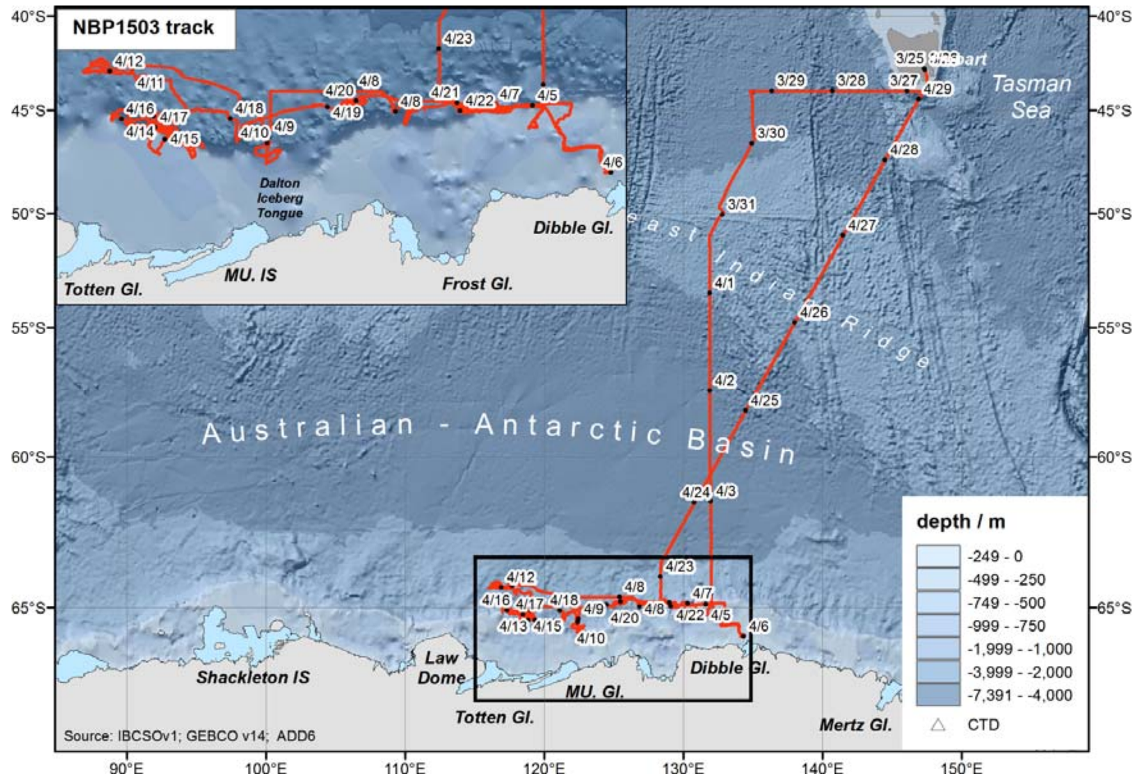

Figure 1.4: Track and itinerary of entire cruise NBP103. Each label marks the position of 00:00 GMT of this date. MU IS-Moscow University Ice Shelf.

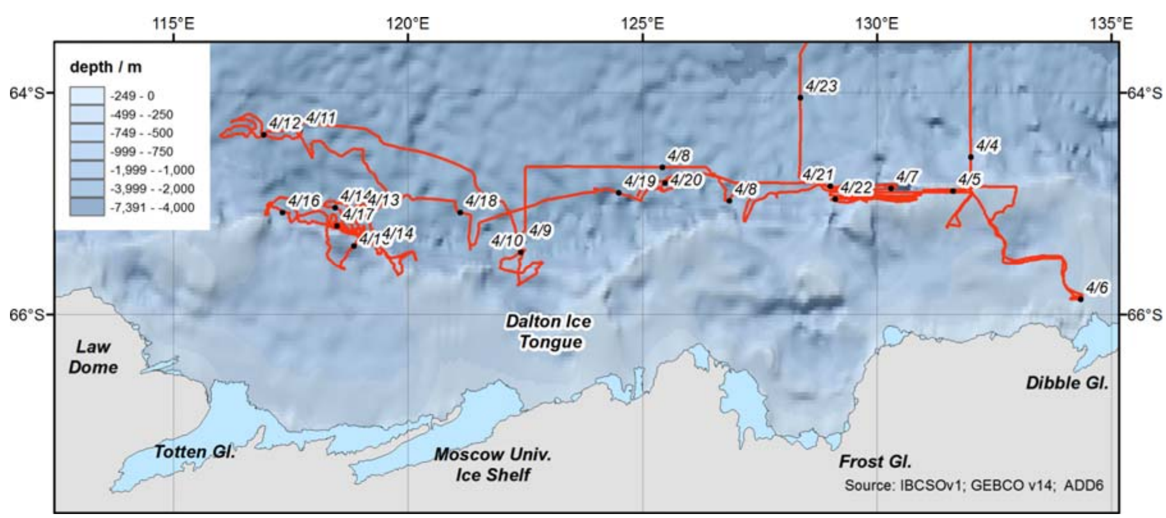

Figure 1.5: Detailed map of the main working areas along the East Antarctic Margin.

We left Hobart in the evening (20:00) of March 26 2015 after being delayed for two days due to some ship maintenance issues. A serious storm system in our path made us head west first, before heading south, to get between two storm systems. After the crossing we reached our first work area on the Antarctic continental margin north of the Dibble

Glacier and Ice Tongue on April 4th. We worked briefly in the polynya west of the Dibble Ice Tongue on April 5 and 6. On April 7 we continue west. We unsuccessfully tried to get onto the continental shelf north of the Frost Glacier on April 8th, but succeeded to reach the shelf break northeast of the Dalton Iceberg Tongue (~123°E) on April 9th. We continued west and on April 11/12 we tried to get through the outer ice barrier to a polynya north of Law Dome, but the ice conditions did not permit this. From April 13 to April 17 we worked along the shelf break north of the Totten Glacier and the Moscow University Ice Shelf, where we successfully entered the shelf break and outer shelf areas. Meanwhile ice conditions farther west, including Scott and Denman Glaciers and Shackleton Ice Shelf, had worsened and we did not expect to get close to the continental shelf in these areas. Therefore we decided on April 17 to go back east and increase the density of our data there. We worked our way east and then focused sampling between 128°E and 130°E until April 21. After waiting out a major storm on April 21 and 22 throughout which we acquired multibeam bathymetry data, we repeated several CTD stations along a northern transect along 128 22'E on April 22 and 23. After finishing these stations we started the transit back to Hobart in the night from April 23 to 24. After crossing the Southern Ocean with favorable weather conditions we arrived in Hobart on April 30.

Of the total 41 days we spent 7 days in Hobart, 20 days in the work area and 14 days in transit to and from the main study area.

2. Oceanography

(Raul Guerrero, Guy Williams, David Porter, Eva Cougnon, Alex Fraser)

2.1 Background

The goal of the oceanographic measurements was to establish a better understanding of the different water masses along the East Antarctic continental margin and determine if modified Circumpolar Deep Water with temperature above the pressure melting point of ice can be found near or on the continental shelf, which might enhance melting of nearby glaciers and ice shelves. In addition, measurements and water samples taken at the late season of this cruise could be compared to historical data and to sea ice formation processes.

2.2 CTD operations

Operation and Maintenance

During NBP1503, 42 temperature, salinity, and dissolved oxygen profiles were obtained with a SeaBird Electronics SBE 911plus CTD (Fig. 2.1). Table 2.1 presents the list of CTD stations, positions, bottom depth and max depth reached (in db).

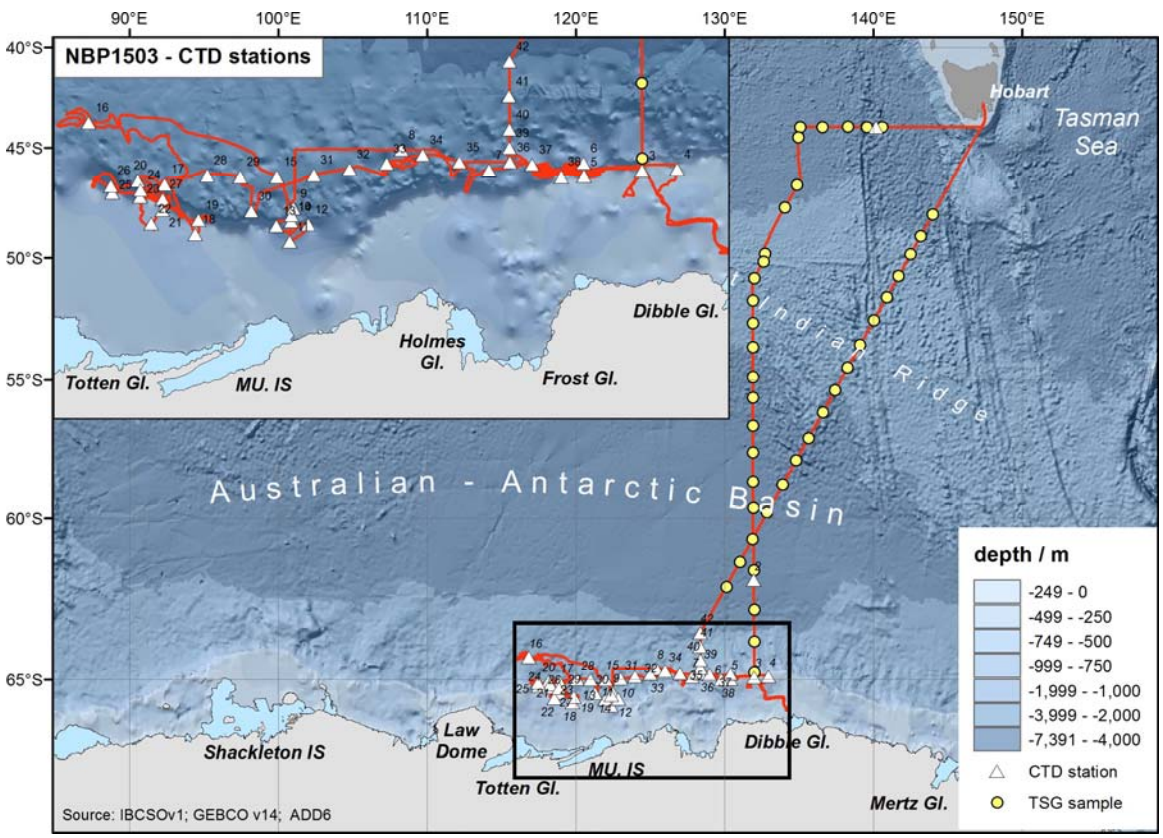

Figure 2.1: Locations of CTD stations (white triangles) and locations of TSG salinity samples (yellow circles) on NBP1503.

Table 2.1: CTD locations with date, max depth reached (db) and distance to the bottom.

Station ID	Latitude	Longitude	Date (GMT)	MaxPr (db)	Distance from bottom (m)
001	-44.002	140.189	Mar 28 2015 02:59:33	505.435	
002	-62.014	131.966	Apr 03 2015 03:20:30	4485.74	100
003	-64.933	131.997	Apr 04 2015 02:18:00	310.232	8
004	-64.9128	132.962	Apr 05 2015 03:44:37	367.72	10
005	-64.9925	130.405	Apr 06 2015 20:24:02	507.832	10
006	-64.8447	130.399	Apr 07 2015 00:39:23	1917.02	27
007	-64.925	127.81	Apr 07 2015 13:02:56	2015.942	25
008	-64.6898	125.42	Apr 08 2015 08:05:49	2780.38	34
009	-65.362	122.465	Apr 08 2015 23:47:23	2164.374	20
010	-65.5087	122.404	Apr 09 2015 04:23:04	424.339	60
011	-65.7425	122.362	Apr 09 2015 07:44:47	420.238	10
012	-65.547	122.865	Apr 09 2015 12:20:51	713.597	25
013	-65.5653	121.987	Apr 09 2015 18:28:42	445.05	10
014	-65.4435	122.406	Apr 09 2015 22:22:00	1643.321	20
015	-65.0008	122.007	Apr 10 2015 03:51:56	2540.881	27
016	-64.3665	116.863	Apr 11 2015 22:28:28	2197.126	80
017	-65.0863	118.936	Apr 12 2015 21:39:41	2672.852	30
018	-65.6588	119.781	Apr 13 2015 07:13:29	488.622	9
019	-65.4973	119.87	Apr 13 2015 14:23:09	458.894	8
020	-65.042	118.203	Apr 14 2015 09:05:57	2796.623	31
021	-65.3863	118.875	Apr 14 2015 23:06:09	486.361	8
022	-65.5365	118.572	Apr 15 2015 02:12:27	544.003	9
023	-65.2322	118.266	Apr 15 2015 09:33:47	489.561	8
024	-65.149	118.283	Apr 15 2015 11:32:09	2113.952	34
025	-65.1817	117.503	Apr 15 2015 18:50:48	507.802	8
026	-65.1023	117.463	Apr 15 2015 21:36:04	1943.474	28

Station ID	Latitude	Longitude	Date (GMT)	MaxPr (db)	Distance from bottom (m)
027	-65.2587	118.883	Apr 16 2015 18:47:54	1558.38	11
028	-64.9853	120.104	Apr 17 2015 15:33:45	2745.432	97
029	-65	121	Apr 17 2015 20:53:18	2744.493	100
030	-65.3958	121.314	Apr 18 2015 03:53:46	2662.659	26
031	-64.9772	123.016	Apr 18 2015 13:02:43	2711.368	75
032	-64.913	123.999	Apr 18 2015 18:51:45	2748.905	19
033	-64.8492	125.007	Apr 19 2015 18:13:03	3046.013	27
034	-64.7497	126	Apr 20 2015 02:46:29	3276.652	30
035	-64.8345	127.001	Apr 20 2015 10:34:04	2541.181	35
036	-64.8332	128.382	Apr 20 2015 18:45:01	1900.538	10
037	-64.8612	128.995	Apr 20 2015 23:22:43	1774.995	13
038	-65.0007	129.784	Apr 21 2015 04:06:36	303.243	18
039	-64.6658	128.366	Apr 22 2015 14:58:40	2498.237	19
040	-64.4502	128.366	Apr 22 2015 18:36:31	2713.333	18
041	-64.0483	128.359	Apr 22 2015 23:22:02	3598.755	24
042	-63.6338	128.365	Apr 23 2015 05:12:06	4017.127	44

The CTD system was fitted with 2 sets of ducted conductivity-temperature sensors, dual pumps, and two SBE 43 dissolved oxygen sensors (table 2.2). The sensor suite was mounted horizontally on a flat surface just inboard of the lower CTD/rosette frame supports. A transmissometer and fluorometer were also installed (table 2.2), both with 6000 m-depth capability. Table 2.2 present instrument and sensors serial numbers and calibration dates.

Table 2.2: NBP1503 CTD Instruments Installed. Serial numbers, calibration date and date installed into the CTD system are also presented.

Instrument	***Serial Number***	***Last Calib Date***	***Install Date***	***Comments***
CTD Fish	09P78915-1190	6/9/2014	10/19/14	
CTD Fish Pressure	130016	6/9/2014	10/19/14	
CTD Deck Unit	11P19858-0490	N/A	11/8/2007	
Slip-Ring Assembly	1.406	N/A		
Carousel Water Sampler	3270675-0925	N/A	12/11/14	
Pump (primary)	055641 3.0K	3/31/2014	12/27/2014	
Pump (secondary)	051646 3.0K	8/10/2014	12/27/2014	
Temperature (primary)	03P2438	1/7/2014	12/27/2014	
Temperature (secondary)	03P5185	8/8/2014	03/08/2014	
Conductivity (primary)	044151	3/7/2014	12/27/2014	
Conductivity (secondary)	042513	7/16/2014	12/27/2014	
Dissolved Oxygen (prim.)	0152	1/5/2014	03/08/2014	Unreliable at sfc
Dissolved Oxygen (sec.)	2267		3-Apr-15	
Dissolved Oxygen (old second)	0080	7/11/2014	12/27/2014	Removed 3-Apr
SPAR	6356	2/3/2014	8/14/2014	
PAR	4469	2/3/2014	03/08/2014	
Fluorometer, WetLabs	AFLD-011	6/11/2014	03/08/2014	
Transmissometer	CST-889DR	09/05/2013	11/30/2014	
Altimeter	49432	n/a	10/20/2014	
Bottom Contact Switch	#3	n/a	10/20/2014	

1-Hz GPS data from the vessel's SEAPATH 330 GPS was merged with the CTD data stream and recorded at every CTD scan (24 Hz). Data were acquired using a PC running SeaBird's SeasaveV7.22.5 (2013) software was run on the CTD Windows 7 Virtual Machine (VM). The CTD VM existed on the “Instrument01” physical machine. Data collected by the SeaSave software was saved to the local drive in real time and then immediately processed into cnv, btl, asc files and plotted as graphs. Both raw and processed data were then backed up to the “ctd_data” drive located on a separate server, accessible to the science group. The contents of this drive were synchronized to the ship’s data repository on another server containing fully mirrored drives. This data was backed up again on multiple redundant storage arrays, as well as a tape.

Prior to the CTD02 cast, several problems were reported with the CTD system. Firstly, a number of bottles were not firing reliably (see water samples paragraph below). Secondly, there was a communications problem with the sensor package. After a short delay to address these problems, the CTD02 cast commenced. However, while troubleshooting the communications problem, the CTD cast was initialized in “Acquiring data” mode, rather than “Archiving data” mode. Unfortunately, CTD02 was cast while still in “Acquiring” mode, meaning that despite the CTD appearing to proceed as normal, no data were being saved. This problem was identified after the package was secured back on deck. The CTD control and data acquisition software was still running at this stage, but it became evident that no data file had been generated. Because the software was still running, it was possible to generate plots of temperature, salinity and oxygen as a function of depth. ASC contractor and ET Dr. Gabrielle Inglis used the operating system’s screenshot functionality to save these plots. NSF grantee Dr. Alex Fraser then reconstructed the temperature, salinity and oxygen profiles from these screenshots using the IDL programming language. The output of this procedure was an ASCII file with four columns: Depth (m), temperature, salinity and oxygen (code written by Alex Fraser is enclose in appendix C). Using the ASCII file, Raul Guerrero and Eva Cougnon reconverted the ASCII file using SeaBird DataProcessing V7. The software generated a CNV file with SBE ASCIII module and the addition of pressure in decibars. The latter was done by applying a fitting between depth (m) and pressure (db) using values from the associated CTD log sheet, handwritten during the cast. Salinities were retrieved from the reconstructed CNV file in order to compare with the rosette salinity samples and the retrieved information from the bottle firing log sheet. The reconstructed CTD cast shows a good match to the CTD log sheet values and the difference between the reconstructed salinity from the primary sensor and the salinity measured with the salinometer is -0.0011 psu with a standard deviation of 0.0027 psu, confirming the good quality of the reconstruction.

The CTD was typically raised and lowered at 50m/min, but slower during the initial ‘soak’ at the start of the station (first 100/150 m), as well as when approaching the bottom. Station setup took in general between 10 to 15 minutes. The CTD package was sent to 10 m for soaking sensor until pairing values were stable, then the CTD was raised to the surface (between 3 to 5 m). Thereafter the archiving of data was initiated and the CTD package was sent down to maximum planned depth. On deck reading of pressure was recorded on the CTD log sheet before entering the water. The reading of this value was between -.7 to -.9 db. This value should be used latter in the final processing of the data. For safety reasons some stations were kept between 100 to 50 m of the bottom (deep stations and/or stations under rough weather conditions). The approach to the bottom on each station was monitored using a Benthos Altimeter and SBE bottom contact switch fitted with 8 m lanyard and a weight.

Water samples were taken with a brand new 24-position SBE 32 Carousel sampler with 12 liter 'Bullister' bottles. Water was collected for onboard analyses of salinity (see “salinity report”) and neodymium isotopes (see “water sampling” report). Many bottles leaked at the spigot when sampling during the first stations.

What follows is a transcript of the MTs work report of the CTD assembly **in bold**:

- ***Maintenance on the CTD assembly on this cruise included shortening of internal lanyards on bottles 3,4,5,8,10,17,19 and 24. Bottom end-cap O-rings were replaced on bottles #3, 5, and 19. Spigot O-rings were replaced on bottles #3, 5, 19, and 24 to arrest previous leaking***.

Despite this work, bottles 5 and 17 kept leaking while sampling throughout the cruise. These bottles were not used for salinity or isotope sampling.

- ***An extra shackle was added to the bottom contact weight to help mitigate the effect of drift and current on bottom contact operation.***

- ***We only had one issue with sticky trigger mechanisms in the Pylon, which we believe was due to salt build-up. Increasing vigilance on FW rinsing the Pylon post-sampling helped this issue.***

-

All 24 bottles were tripped on each station, usually two or three were closed at each chosen depth, as no more detailed sampling of the water column was needed. Sample depths emphasized water masses and column extremes in T and S and also included regions with homogeneous layers for salt and near the sea surface and sea floor.

Redundant sensor comparison

The CTD instrument was equipped with redundant sensors for temperature, conductivity (salinity) and oxygen. Differences between pairs vs. station number are shown Fig 2.2. Table 2.3 presents the statistic of the difference. Temperature pairs show no shift with time. Salinity pairs presented a weak drift on primary sensor 1 (see salinity analysis) and oxygen pairs show two large jump. Large offset (~0.12 ml/l) was observed between oxygen sensors in the first (test) station CTD001. After station 2, secondary oxygen sensor S/N 080 was replaced by S/N 2267. Immediately prior to station 16, the Baltic room temperature was significantly warm; despite an extended soaking reading of oxygen sensors showed at that station an offset of 0.12 ml/l that stayed constant throughout the rest of the cruise (Fig. 2.2c).

As the salinity reading from the conductivity sensor pairs gave slightly different values and drifted slightly with time (see "salinity analysis"), post-cruise calibration and further intercomparisons with bottle data will be required during data reduction.

Table 2.3: Statistics of sensor comparison (T-Temperature, S-Conductivity/salinity, OC-oxygen sensors).

	T0 – T1	S00 – S11	OX0 – OX1 (sta 2 & 3)	OX0 – OX1 (sta 16-42)
Mean	0.00011	-0.00401	TBC by RG	0.123
Standard Dev.	0.00092	0.0018		0.023
N obs	977	946		664
N discarded (>mean±2StdDev)	30	74		9

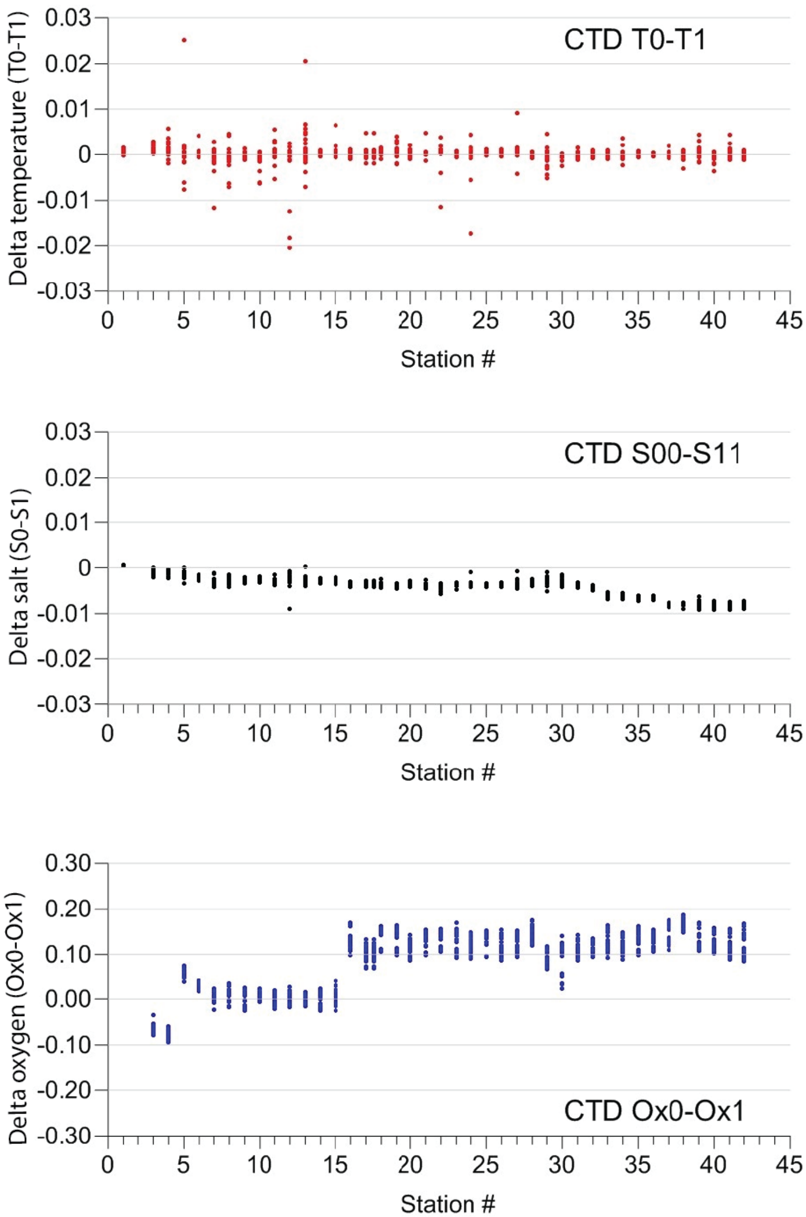

Figure 2.2: Sensor comparison. For detailed statistics see table 2.3.

On board CTD post processing (preliminary)

Preliminary post-processing of the CTD profiles was conducted using SBEDataProcessing V7.22.5 (2013). The SBE processing sequence and parameter applied for each module are enclosed in the header of each profile. The processing modules applied to the CTD data were:

- DATA CONVERSION:
  Convert raw data from CTD (.hex or .dat file) to engineering units, storing the converted data in .cnv file (all data) and/or .ros file (water bottle data).
- WILD EDIT:
  Marks wild individual points in the data by replacing the data value with *badflag*.

- FILTER:
  Low-pass filter columns of data.
- ALIGN CTD:
  Align oxygen data relative to pressure.
- CELL THERMAL MASS:
  Perform conductivity thermal mass correction.
- LOOP EDIT:
  Mark scan with *badflag* if scan fails pressure reversal or minimum velocity test (Wave filtering).
- DERIVE VARIABLES:
  Calculate derive variables (oxygen, fluorescence, density, transmisivity, potential temperature, and salinity)
- BIN AVERAGE:
  Average data on 1m pressure intervals.

Preliminary results

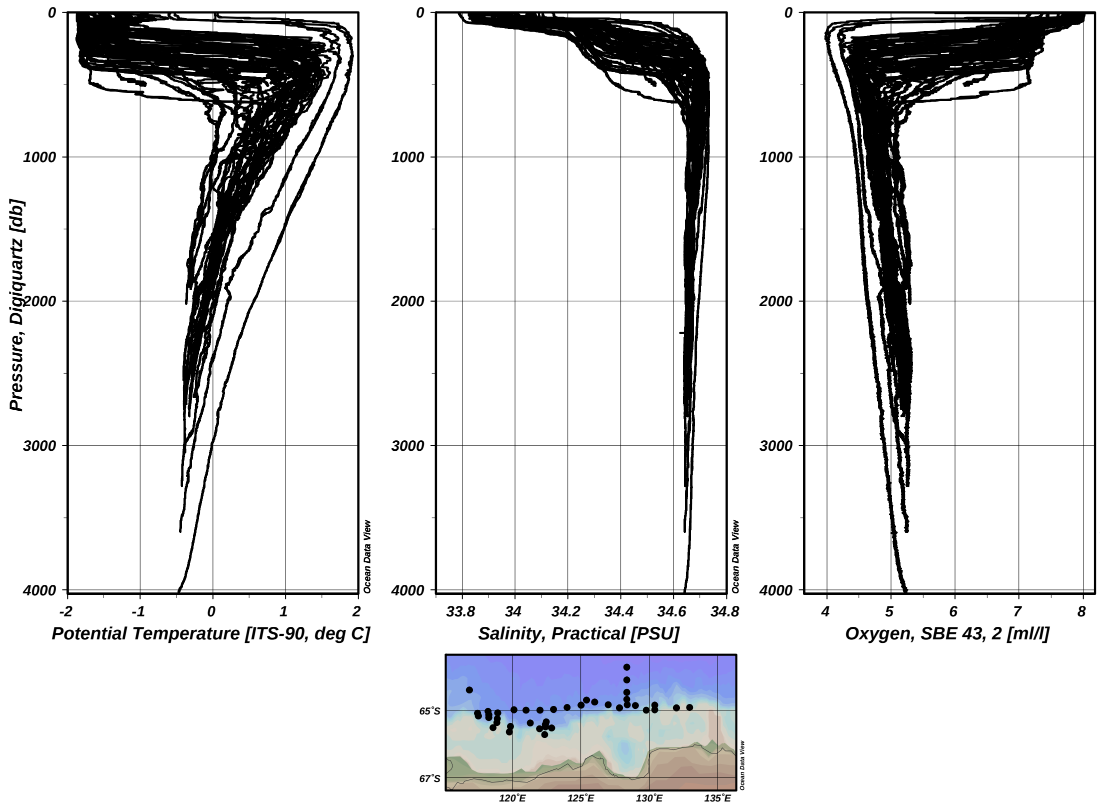

Figure 2.3: Profile plots from 40 out of the 42 total CTD casts. Both up and down traces are shown in the potential temperature (left), salinity (center) and Oxygen (right) profiles.

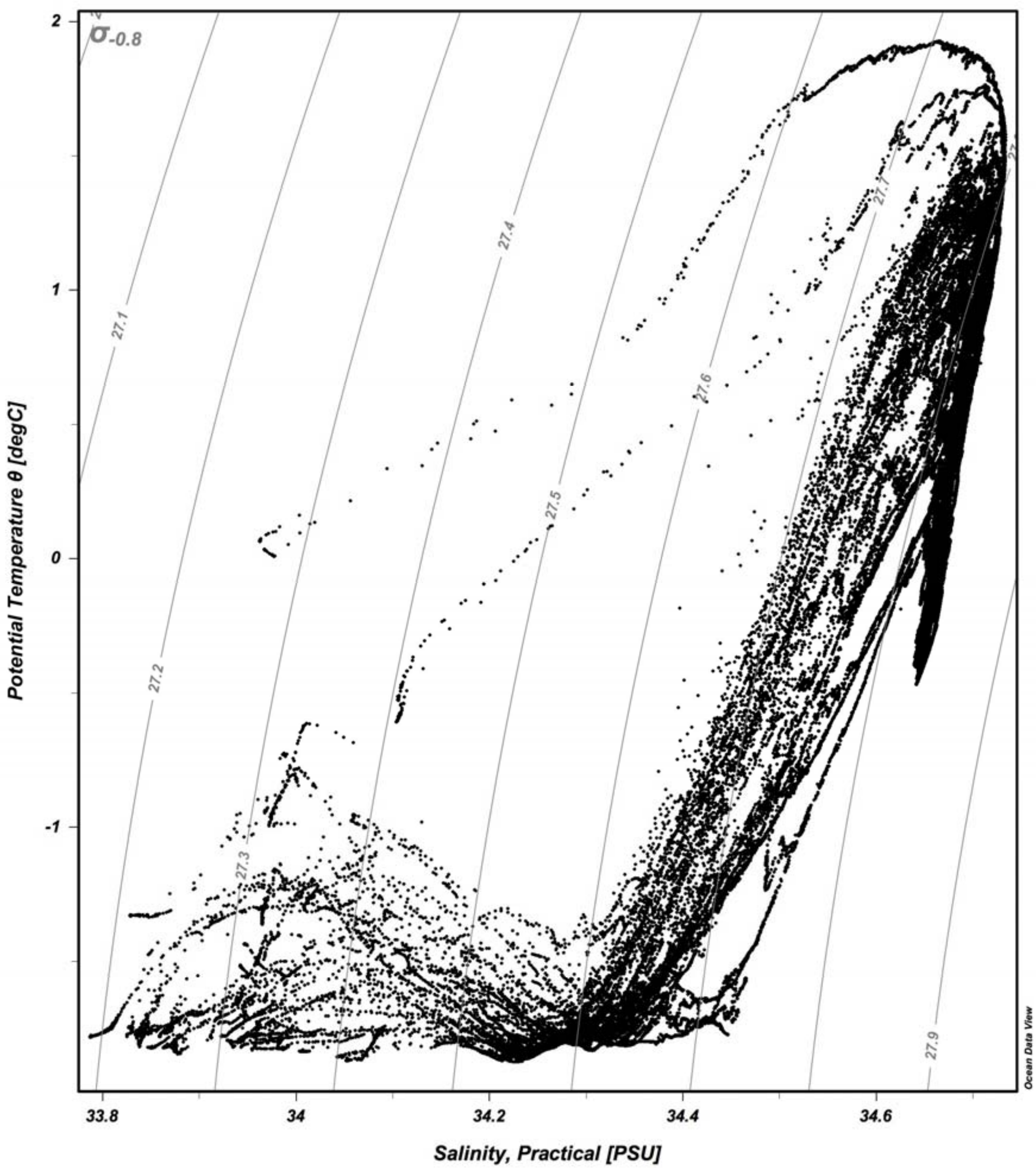

Figure 2.4: Temperature-salinity plot of 40 of the total 42 CTD casts. Both up and down traces are shown. Sigma-theta lines, with a deck pressure of -0.8 dbar, are overlain.

2.2 Salinity analysis

Salinometer proccedure

306 salinity samples were analyzed onboard to monitor the performance of the CTD conductivity sensors. Two salinometers were available on the ship, Portasal #69942 and Autosal #61670. Portasal was used during the whole cruise. However, samples from 2 stations (CTD015 and CTD016) and one station duplicate (CTD017) were run on Autosal for comparison with Portasal. The salinometers bath temperature was set to 24˚C and the room temperature was kept between 0.5 and 3˚C below the setting temperature. A fan was used to regulate the temperature variations and homogenize the temperature through the whole room. Once we started to use the fan (at run number SAL06) the room temperature was kept between 0.5 and 1.5˚C below the bath temperature. Raul Guerrero and Eva Cougnon ran the samples and the calibration for each of the 10 runs. At the start of each run, the standardization was performed using new IAPSO standard seawater bottle from batch P156 (from July 2013)**,** except for run 4 where no calibration was performed, as the run was performed less than 24 hours after run SAL03. As the manual suggested, no calibration is needed if the different runs are performed within 24 hours.

Portasal calibration was performed following the manual of the instrument, starting with a bath temperature control check, and then followed by the reference calibration as well as the zero calibration. Before starting the standardization, we flushed the cell about 6 times with used (opened bottle) IAPSO standard seawater to clean the cell from DI water standing in the system since the previous run. Once the cell was rinsed with salty water, a new standard seawater bottle was introduced. The cell was then flushed 3 times before each of at least 3 readings. Once the readings were stable, we standardized the Portasal, entering the value of the conductivity ratio and the batch number of the standard seawater. At the end of the standardization, a **standard number** is given (values around 4.20000). Following the **standard number** and the **standby ratio** (values around 1.270000) shown after calibration allowed a check of the stability of Portasal throughout the runs (see Table 2.4). Depending on the circumstances between standardizations, the changes in **standard number** were typically up to ±0.0005.

In order to check the functioning of the CTD, testing the water tightness of bottles and the overall functioning of the salinometer, twenty samples were drawn from 500 m depth on a test station performed early on the cruise (CTD001) and 4 samples at 10 m depth on the same station. The salinity measured from these samples was consistent, with only one sample discarded from the mean calculation. The salinity measured at 500m was 34.641 psu with a standard deviation of 0.0024. The comparison between both sensors found good agreement with a mean difference between sensor S00 (S11) and the salinity sample of -0.0003 (0.0001) with a standard deviation of 0.0024 (0.0024).

Salinometer results

Table 2.4 gives the **standby ratio** and the **standard number** at calibration for each run. The Portasal data were recorded using the Salinometer data logger software, from Ocean Scientific International, while data from Autosal could not be recorded directly on the

computer, as there were some issues to install the Autosal software (ACI2000) on the laptop at the time we completed the samples. The Autosal data (CTD014, CTD015 and duplicates from CTD017) had to be recorded by hand. The salinity was later calculated as a function of the conductivity ratio and bath temperature for a salinity reference of 35 psu. The Autosal software was later installed and satisfactorily tested, using the Autosal Computer interfaces (SN 70032 and 70017) with the 50 pin ribbon cable.
In order to test the functioning of the Portasal, we took 12 duplicates from the bottom bottle (2197 db) on station CTD016. These duplicates were used as standards for the Autosal calibration, as well as sub-standards for the Portasal. From run SAL05 onwards, one sub-standard was used at the opening of the run (after calibration), and sometimes at mid-run and at the end when no IAPSO standard seawater was used to close the run. This procedure allowed us to follow the stability of Portasal and choose a correction when the readings of the sub-standards or the standards differed from one run to another. Also, we ran duplicates from station CTD019 at run SAL09 in order to adjust run SAL06. During run SAL09, we used new standard seawater at the beginning of the run (after calibration) and another standard seawater at the end of the run to correct run SAL06.

Table 2.4: Details of each salinometer run for the CTD bottle and the Thermo-Salinograph (TSG) samples (ran on Autosal).*

Run	**SAL01**	**SAL02**	**SAL03**	**SAL04**	**SAL05**	**SAL05***
Standard number	4.21934	4.21924	4.21914	“	4.21864	
Standby conductivity ratio	1.27075	1.27078	1.27081	“	1.27094	
CTD Stations	1	2-4	5-11	12-13	16-18	14-15+17
# of CTD bottles	24	20	45	10	21	23
# TSG	9	15				

Run	**SAL06**	**SAL07**	**SAL08**	**SAL09**	**SAL10**
Standard number	4.21958	4.21937	4.21984	4.21953	
Standby conductivity ratio	1.27067	1.27074	1.27059	1.27070	
CTD Stations	19-26	27-34	35-42	19 (duplicates)	TSG
# of CTD bottles	44	60	54	5	
# TSG					20

Examining the changes in the **standby conductivity ratio** between each run shows that the calibration was not very stable between runs (Table 2.4). For instance, between run SAL05 and SAL06 the standby conductivity ratio changed of -0.00027 units. In order to correct the jumps in salinity between the runs we used the **standby conductivity ratio** as well as the **standard seawater** and the **substandard** values to apply a correction. During run SAL08, 4 vials were opened to follow the accuracy of Portasal calibration. The first vial was opened for the standardization. Then, after the calibration and before reading the water samples, a new bottle of standard seawater was measured, as well as at mid-run and at the end of run SAL08. All the readings from the standard seawater after calibration showed that the Portasal was constantly measuring a fresher salinity value by 0.0055 psu (0.00014 conductivity ratio units). We decided to apply this correction to the salinity calculated from run SAL08.

Run SAL07 also shows that the vial measured in the middle of the run was showing weaker/lower conductivity ratio readings, resulting in a fresher salinity calculation of -0.003 psu. Subsequently an adjustment of +0.003 psu was applied to all samples from run SAL07.

At run SAL06, we did not pass standard seawater mid-run, but we had a sub-standard that we could compare with corrected run from SAL07. Also, we ran another salinity run (SAL09) with duplicates from station CTD019. This station was first measured at run SAL06. For an accurate correction, we ran the duplicated station CTD019, opening a new standard seawater after calibration, and another standard at the end of the run. Analyzing runs SAL06 and SAL09, we decided to apply a correction on run SAL06 of +0.00015 units in conductivity ratio, which correspond to a correction +0.0055 psu in salinity.

Finally, comparing SAL05 and with the corrected SAL06 and SAL03 (SAL04 has the same calibration value than SAL03), we applied an adjustment of -0.003 psu to the entire run for SAL05.

CTD sensor performance

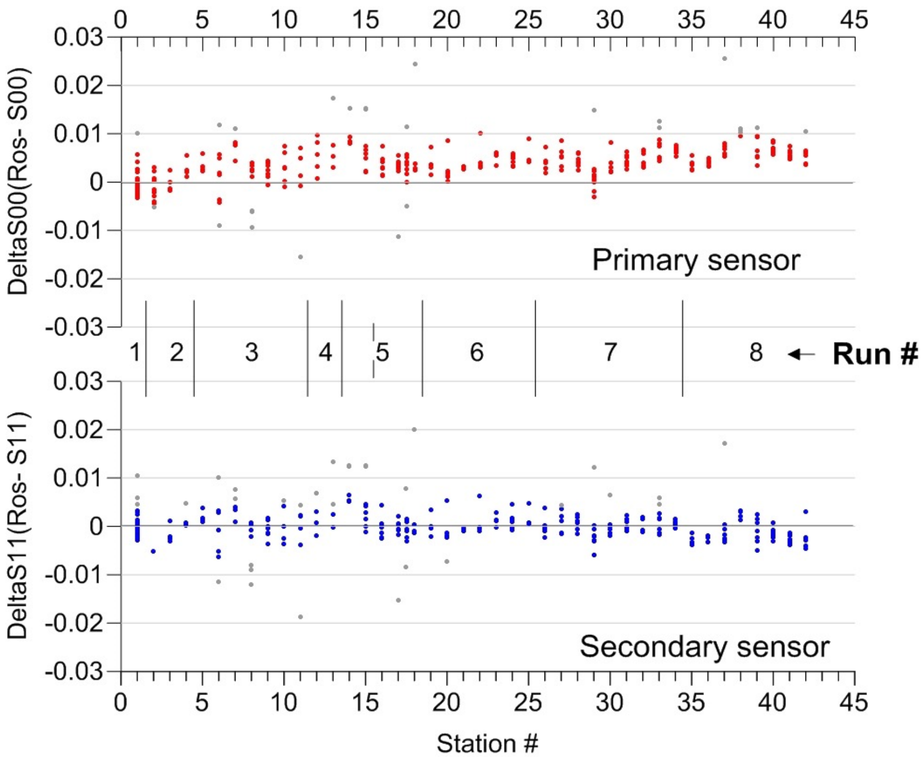

Figure 2.5: Difference of salinity measured by CTD sensor S00 (top) and sensor S11 (bottom) compared to salinometer analysis.

After adjusting the runs with the salinometer calibration errors, and in order to compare the water samples to the salinity measured by the CTD, we plotted the delta salinity between the salinity measured on Portasal and each of the CTD sensors (Fig. 2.5). For better accuracy, we applied a fit to identify and flag outliers that were two standard deviations away from the average (grey points on Figure 2.5). Both sensors gave good error estimations between the water samples and the primary (secondary) sensor, with an average of 0.0037 psu (-0.0003 psu) and a standard deviation of 0.0029 (0.0023). Also, only 9% of the water samples were outliers for the primary sensor and 11% for the secondary sensor. In this preliminary analysis we have not yet considered the drift in time that both conductivity sensor had, as shown in figure 2.2a and 2.2b. The primary sensor showed a positive drift and the secondary sensor had a negative drift relative to the adjusted readings from the Portosal (although weaker than the primary). The drift difference between pairs is also shown in Fig. 2.2b.

TSG sensor performance

On this cruise only the TSG1 error was evaluated, corresponding to instrument SBE45 SN 0389. Using the TSG1 readings when a sample bottle was taken, the comparison of TSG1 salinity values to 41 bottle salinity measurements was performed. To follow the error on the TSG1 salinity calculation, DeltaS values of Bot-TSG1 was plotted in Fig. 2.6. A linear regression was calculated as the differences were observed to increase with.

DeltaS values that were larger than 2 standard deviations from the line of best fit were not considered for the final residual analysis. 34 samples were finally used for calibration with a standard deviation for the residual of +- 0.0017 PSU.

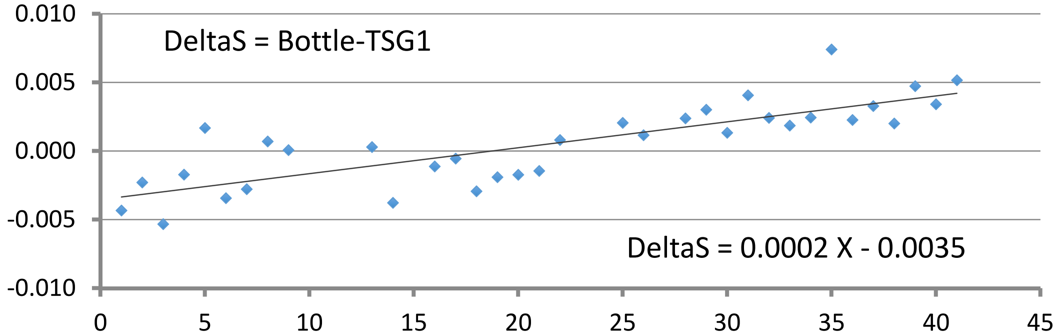

Figure 2.6: Difference of salinity measured by TSG1 sensor and salinometer analysis.

Associated bottle data file:

Bottle_Salt_NBP1503.xls:

- Bottle information from the CTD instruments for each Niskin bottle firing levels
- Integrated bottle information with the adjustment calculation on each salinity run
  - Integrated information for the Autosal run
  - Portasal calibration references used to apply the adjustments

Note that the CTD salinity for the primary sensor on station CTD002 were taken from the CTD reconstruction. Data was not archived for this station (see CTD report) but salinity bottles were taken and measured.

2.3 Water Sampling

Water samples were collected at various depths for post-cruise analysis of the radioisotope ratios of Neodymium (Nd), a possible tracer for water mass origin and transport. Seawater samples were taken from the rosette bottles on 8 of the 42 CTD stations (Table 2.5). These comprised of 2 deep offshore stations (>3000 m depth), 3 along the continental slope (3000-1000 m depth), and 3 on the shelf (<1000 m depth). At each station, samples were taken at depths ranging from near the seafloor to the surface. The sampling strategy for the intermediate bottles was to capture the water masses present at each particular station. For the deep stations, this resulted in sampling water from 12 depths. We collected between 6 and 8 samples for the slope stations (depending on water depth and water masses present) and 4 samples for each of the shelf stations.

Table 2.5: CTD stations at which water samples for Nd were taken.

Station ID	Latitude	Longitude	date	MaxPr dB	Bottom Distance m	# Depths	*Notes
002	-62.014	131.966	Apr 03 2015 03:20:30	4485.74	100	12	
005	-64.9925	130.405	Apr 06 2015 20:24:02	507.832	10	4	"CTD005#4" filled with #3 due to leaking
006	-64.8447	130.399	Apr 07 2015 00:39:23	1917.02	27	8	#10 finished with water from #9
010	-65.5087	122.404	Apr 09 2015 04:23:04	424.339	60	4	
015	-65.0008	122.007	Apr 10 2015 03:51:56	2540.881	27	8	
018	-65.6588	119.781	Apr 13 2015 07:13:29	488.622	9	4	
024	-65.149	118.283	Apr 15 2015 11:32:09	2113.952	34	8	#8 completed with #9, #18 completed with #16, #21 completed with #20, #23 completed with #24
040	-64.4502	128.366	Apr 22 2015 18:36:31	2713.333	18	2	Only 2 for bottom water
041	-64.0483	128.359	Apr 22 2015 23:22:02	3598.755	24	11	1L from #7 added to #6, 0.5L of #23 added to #24
					Total Samples	**61**	

After each cast, a pre-cleaned tube and 0.2 micrometer AcroPak filter was attached to the spigot of the Niskin bottle for each sampling depth. The particular bottle was chosen based on any observed leaks or other anomalies. Rarely, there was not enough water in the bottle to complete sampling from just a single bottle (10 L samples from ~12 L Niskin bottles). This likely resulted from leaky spigots or end caps, and possibly the over-rinsing of each filter with seawater. When this occurred, a note was added to the bottle log and the remaining water was taken from another bottle at the same depth. When only a few distinct water masses were identified during the downcast, seawater samples were taken from equally spaced depths (e.g. every 500 m) in order to provide a representative “profile” of isotopic ratios.

After allowing 0.5 to 1 L of seawater to rinse through the filter, it was placed over the opening of each cubitainer until a 10 L volume of seawater was collected. The filter/tubing combinations were stored in individual containers in a 4C refrigerator that was reused for similar depths on subsequent stations. Following filtration, each sample was acidified using 12 ml of 12 M HCL to prevent biological growth. Due to uncertainty of the concentration of acid provided, a 20 ml dose of HCL was added to seawater samples taken from CTD002 (per instructions) and only 10 ml added to CTD005. After confirmation, all other samples were acidified using the correct 12 ml dosage. All operations involving the HCL followed stringent safety protocols for both handling and storage of corrosive and acidic chemicals on board. To protect the integrity of the samples, the caps were sealed with parafilm tape. Each cubitainer was then double bagged and zip-tied. Two cubitainers each were placed into a rigid plastic container that was also zip-tied and labeled for shipping from Hobart after the cruise. In total, 31 containers (containing 61 cubitainers and foam packing material) were filled and stored in the Aft Dry Lab. Extra plastic containers were filled with sampling equipment (e.g. used and spare filters, extra cubitainers, etc) and also prepared for shipping.

2.4 ADCP

The Shipboard Acoustic Doppler Current Profiler (SADCP) provides data on water speed and direction below the vessel, both while underway as well as while on station (for CTD, coring, UAV ops, etc.). The NBP is equipped with two RDI phased-array sonar systems: both a 38 kHz and a 150 kHz unit. The 38 kHz Ocean Surveyor ADCP operates in both broadband and narrowband modes (manually switched) and is capable of getting quality returns from up to 1 km deep. To recover the highest vertical resolution data possible, the 38 kHz system was operated in narrowband mode for the entire cruise. The range can be severely reduced if weather is poor, ice passes under the hull, in the presence of air bubbles from cavitation during dynamic positioning, or there are too few scatterers in the water column. The 150 kHz RDI system should provide higher resolution information, albeit to a shallower depth, than the lower frequency system, however a transformer malfunction during the previous cruise meant it was not operational for NBP15-03.

Data from the SADCP was acquired during the entire length of the cruise. On board distribution of the processed SADCP data is through an intranet site maintained by E. Firing and J. Hummon of the University of Hawaii. The provided velocity data follows a QA/QC procedure that corrects for ship gyro heading and also retains only "good" data. The final version of the SADCP data will not be completed until after the cruise when the full suite of corrections for adverse sampling conditions (e.g., heavy seas, clear water, and shallow depths) can be applied. For our onboard analysis, we have chosen to use data from the higher resolution "narrowband" system, which is available in 12 m depth bins, averaged over 15 minute intervals. Although fully automated plotting is done every half hour, our interest is in analyzing the velocity data during each CTD station. For each station, all quality 15-minute SADCP velocities concurrent with the CTD cast were averaged to create a mean zonal (U) and meridional (V) current profile.

Post-cruise analysis of SADCP data will be used to identify ship drift and water mass change during CTD stations, evidence for on and off-slope flow, sea ice-atmosphere-ocean interactions, and identification of eddies and mesoscale processes.

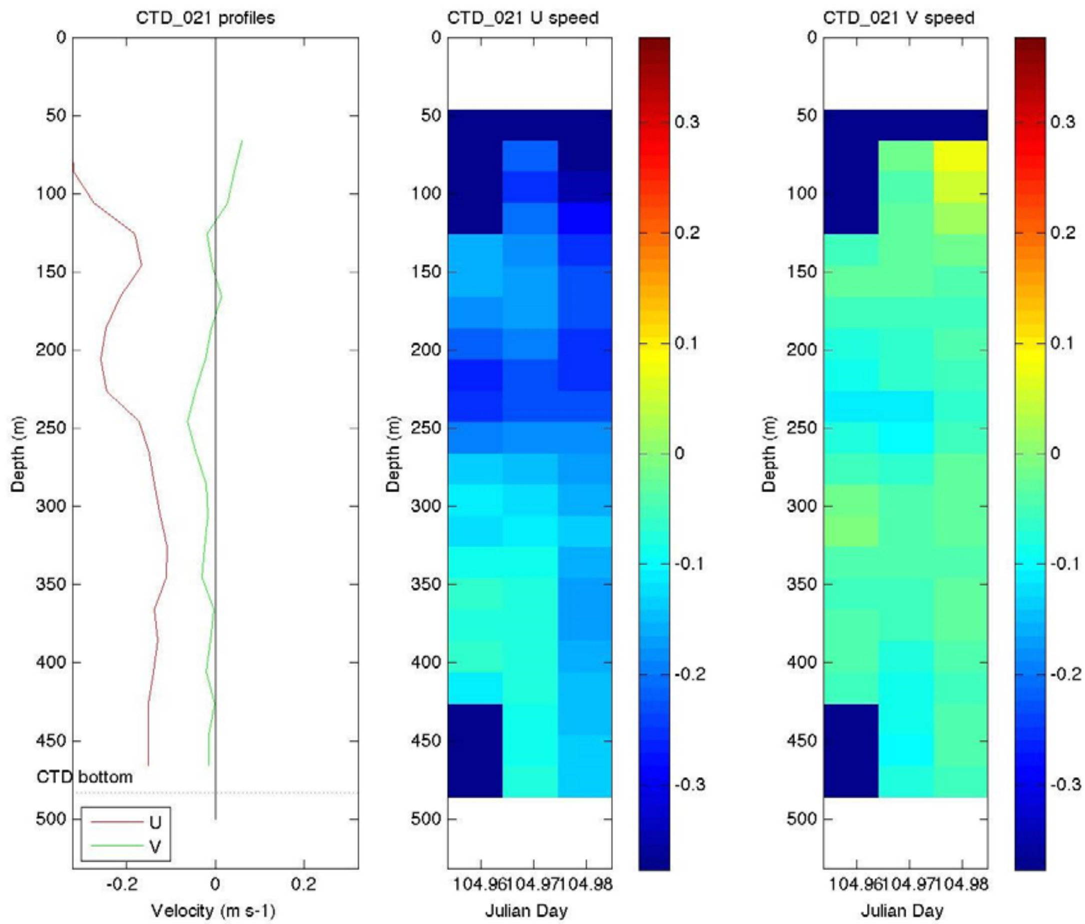

Figure 2.7: ADCP northward (positive V) and eastward (positive U) velocities concurrent with CTD station 021. Averaged U and V profiles (left) along with time series of U (center) and V (right) speeds. All ADCP data below sea floor omitted. Bad data colored dark blue.

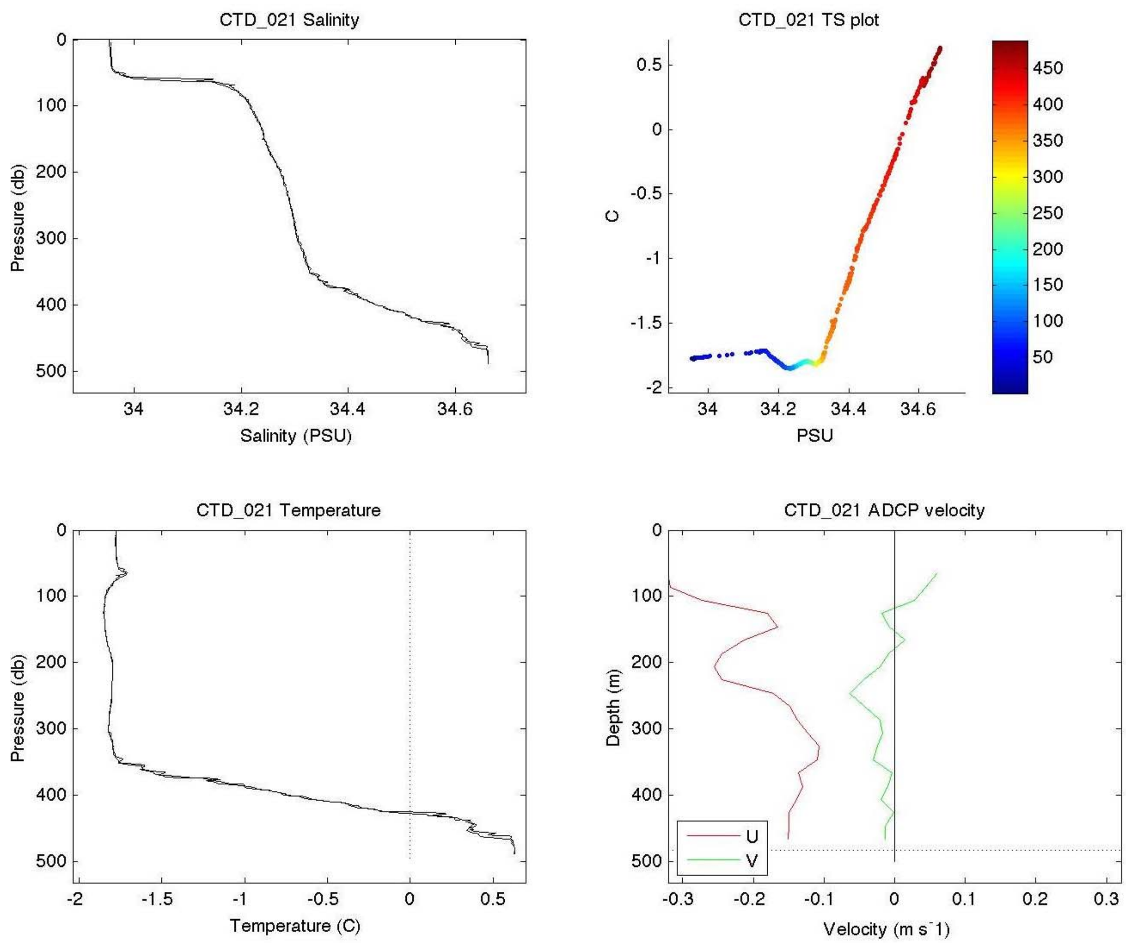

Figure 2.8 Example CTD data from station 021 including salinity (top left), T-S diagram (top right), and temperature (bottom left). Included is concurrent ADCP velocities averaged during the cast (bottom right, positive U eastward, positive V northward).

3. Multibeam mapping

(Kathleen Gavahan, Ricardo Correia, Dominique Richardson, and Frank Nitsche)

3.1 Background and Objective

One of the main objectives of this project is to identify potential pathways of "warmer" Circumpolar Deep Water onto the self and towards ice shelves and the base of grounded glaciers in the study area. The depths of continental shelf right in front of the glaciers would determine how much of these glaciers are exposed to those warmer water, if it would get onto the continental shelf.
Multibeam bathymetry provides detailed depth information needed to answer these questions. In addition, the high-resolution bathymetry data reveal detailed seafloor morphology that can be used to reconstruct past ice flow and retreat histories.

3.2 System Description and Operation

The NB Palmer has a Simrad EM122 multibeam system with a 1°x 2° degree resolution including the capability of logging the acoustic properties of the water column. The transceiver unit was upgraded in June, 2014 from an EM120 to an EM122. The EM122 multibeam can perform seabed mapping to full ocean depth (11,000 m). The nominal sonar frequency is 12 kHz with an angular coverage sector of up to 150 degrees and 432 beams per ping. Due to the ice protection of the transceivers, the useable angular coverage is reduced down to less than 2 × 60°. In deep water and noisy conditions with the current transceivers, the coverage can be reduced to 2 x 30°. In the present configuration, width of the useable mapping data is typically one to three times the water depth. The transmit fan is split in several individual sectors with independent active steering according to vessel roll, pitch and yaw.
A Seatex Seapath 200 motion sensor is used for roll, pitch and heave compensation of the Multibeam echo sounder. The Seapath 200 is also use to provide heading and position information. The acquisition is controlled by Kongsberg SIS software.

The multibeam system was operated starting April 3 and ended on April 23 2015. Due to the current state of transducer (see comments below) the system was not operated in the deeper (>4000m) during the transits from and to Hobart, Tasmania.

The raw data are recorded digitally and displayed in real-time using the SIS acquisition system. From there the raw data were copied to a separate workstation, where additional processing was applied and the ping files were edited manually for outliers and false bottom returns using the Caris HIPS and SIPS software package version 8. Figure 3.1 shows the general work flow used during the cruise.
The final data are exported as gsf and ascii data as well as grids in various formats. The data will be archived at the Antarctic Multibeam Synthesis Database (http://www.marine-geo.org/antarctic/).

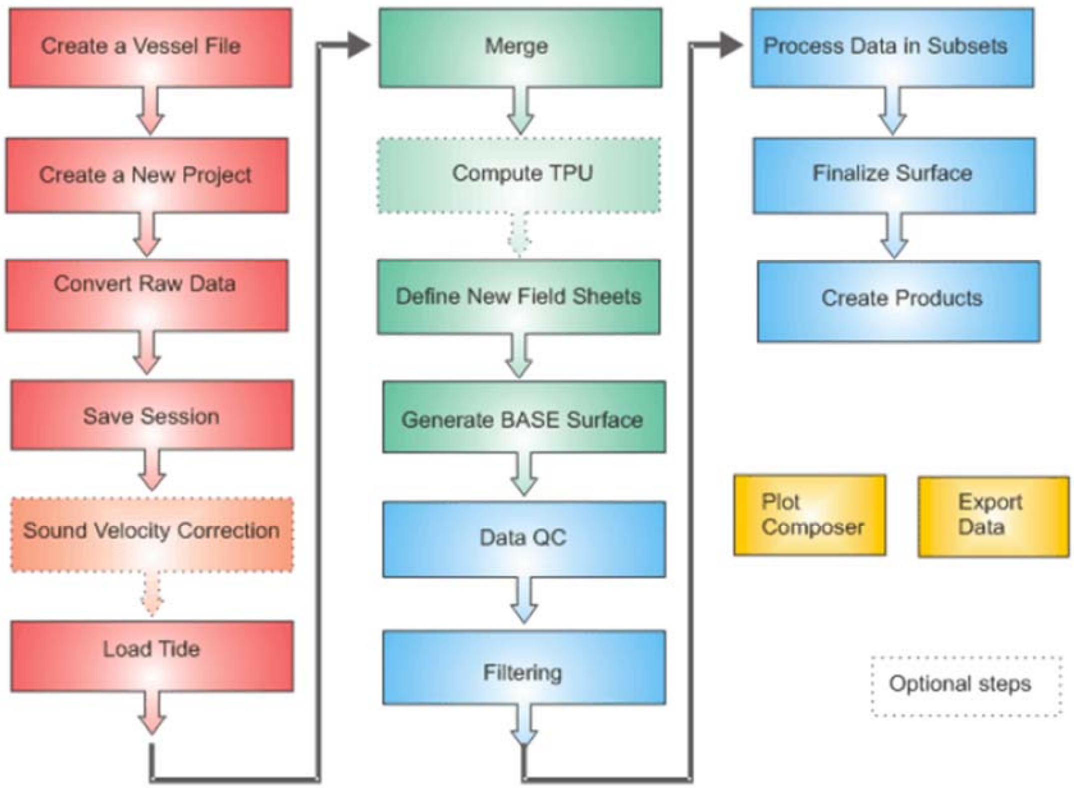

Figure 3.1. Overview of workflow states (from CARIS HIPS and SIPS User Guide).

Sound Velocity correction

The correct depth depends on the speed of sound in water. During this cruise we used CTD and XBT (eXpendable Bathy Thermograph) data to derive sound velocity profiles. In total 15 CTD stations and one XBT station were used to adjust for changes in sound velocity. The conditions directly near the transducers under ship were continuously monitored using a thermosalinograph connected to seawater intake under the ship and directly integrated into the system.

The multibeam and subbottom data acquisition was monitored around the clock by Kathleen Gavahan, Ricardo Correia, and Dominique Richardson. Post-processing of the multibeam and was done during the watches.

System Performance and Problems

The multibeam bathymetry system was operated with a limited number of transducers. Since several aging and possibly damaged transducers failed in the fall of 2014, software updates were implemented to exclude failing transducers from the systems operations. The software updates allowed "normal" operations but with reduced power output, which diminishes bottom detection in deeper waters (>3000m). In shallower (<1000m) depth this is less of a problem. During our cruise much of the areas of interested are less than 2000 m so that this was only a minor issue.

However, to avoid further straining of the transducers we decided not to run the system in dual swath mode.

Two times during the cruise the system needed to be rebooted for issues of unclear origin. Kathleen Gavahan documented the errors and contacted Kongsberg. Otherwise the system operated normally under most conditions, but had problems with receiving good data in some sea ice conditions. The EM-122 multibeam had problems with heavy pack ice and certain types of newly formed ice such as grease ice and nilas. The ice gets under the ship, blocking signals coming to and from the transducers, producing bad data even in easy and calm conditions. We rarely encountered such ice conditions during NBP1503. Certain types of pencake ice and other, loose and moderately thick (0.2 – 1m) sea ice cover was often less of a problem, if the ship drove at ~3-6kn. However, a larger issue was the drastic drop in data quality in rough seas. Due to the location of the transducers it is likely that they are effected by air bubbles generated by the waves and ship-sea interactions.
We also had problems loading existing data from previous cruise into the system, which might have been useful for avoiding data duplication in some areas. However, we had existing ship track information and probably avoided mapping again existing areas this way.

3.3 Preliminary Results

Throughout the cruise we recorded 5112km of multibeam data corresponding to a total size of ~80 GigaBytes. Most of the newly acquired bathymetry data cover previously uncharted areas, adding significantly to our understanding of the regional bathymetry. As result of heavy ice concentration on most of the continental shelf areas, we concentrated operation on the shelf break and outer shelf areas. Despite the fact that the majority of the data were collected in areas with sea ice in one form or the other, we were able to image relatively well with reasonable quality. Figure 3.2 shows the acquired multibeam data in the main study area:

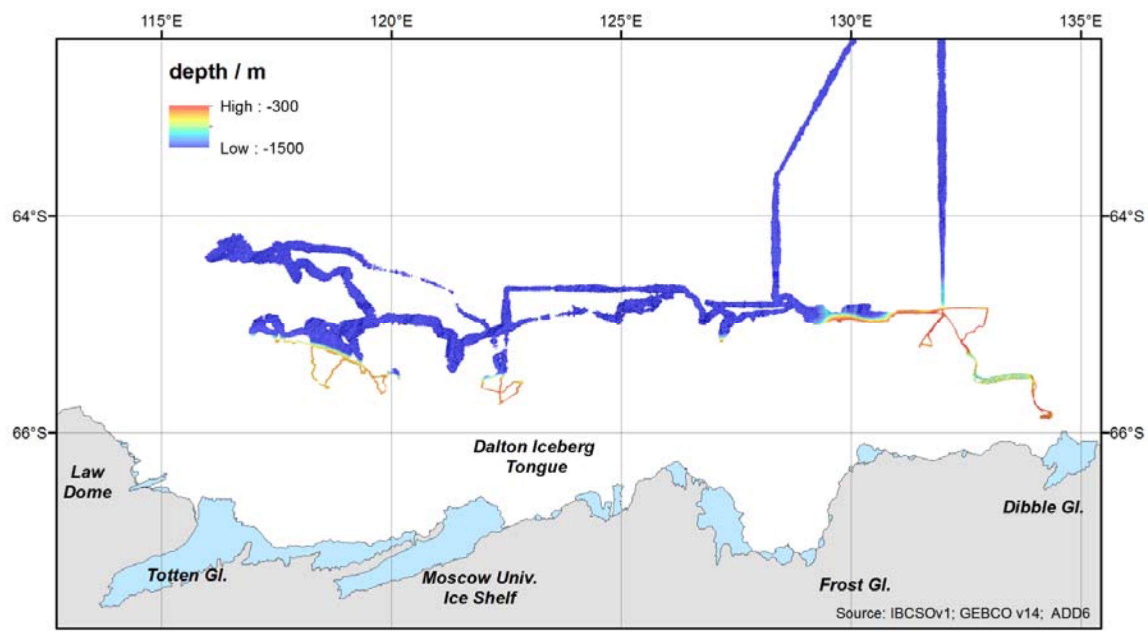

Figure 3.2 Coverage of multibeam bathymetry data acquired during NBP1503.

Most data were acquired on the outer continental shelf, the shelf break and the continental slope and rise. We also managed to collect data during a quick excursion into a polynya covering the mid and inner shelf area west of the Dibble Ice Tongue.

Figures 3.3 to 3.5 show a few examples of features that we observed in the multibeam data.

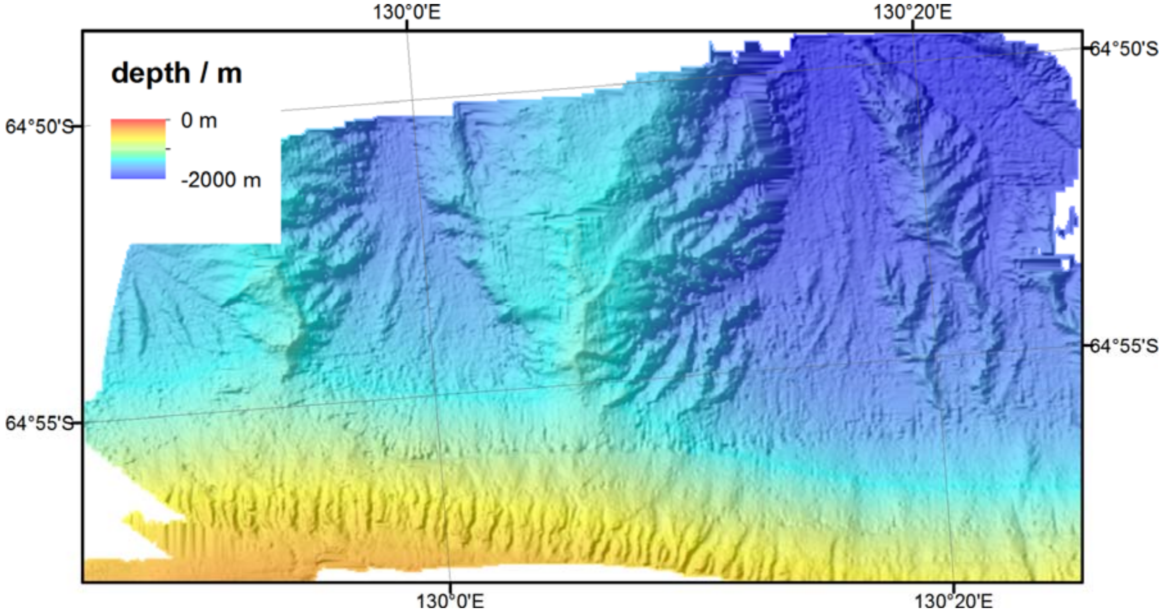

Figure 3.3 Gullies north of the shelf break and a series of sediment mounds on the continental slope and rise.

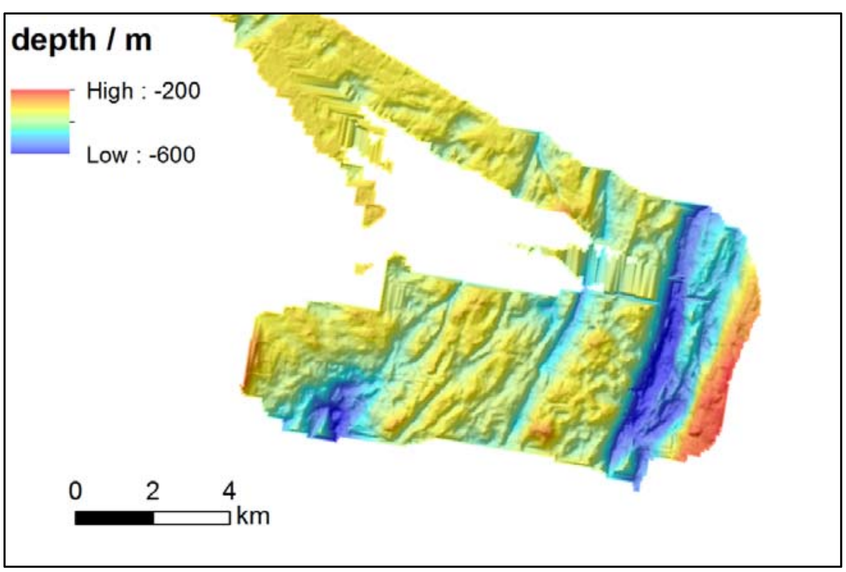

Figure 3.4: Example of a series of channels on the continental shelf near the Dibble Ice Tongue.

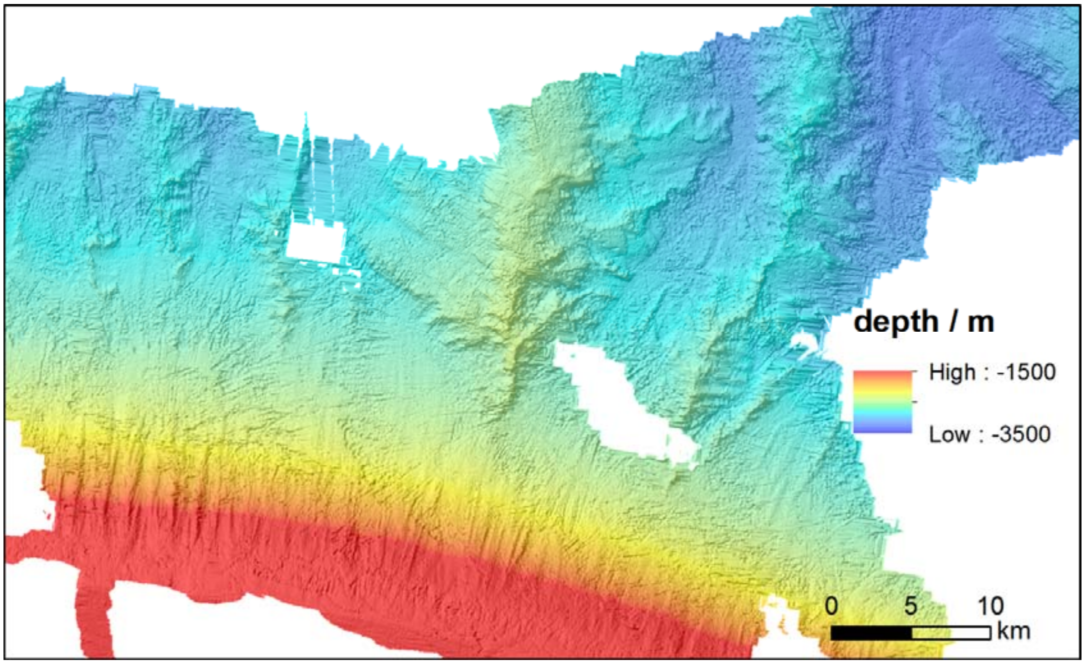

Figure 3.5: Details of the continental slope north of Totten and Moscow University Ice Shelves showing again several gullies near the shelf break as well as sediment mounds on the continental slope and rise.

4. Subbottom Profiling

(Ricardo Correia, Frank Nitsche)

4.1 Background/Objective

In addition to the multibeam system we used a subbottom profiler throughout the cruise.
The subbottom system provides alternative depth information, but is also capable to identify and characterize sediment layers beneath the seafloor. The signal penetration and resulting image depends type of substrate and resolvable acoustic impedance contrasts. The data can be used as guidance for identification of locations for the acquisition of sediment cores. Since we were planning to obtain some sediment cores, we monitored the system closely.
The saved data will also help in interpreting the nature of features observed in the multibeam including the distinction between facies as well as erosional or depositional environments.

4.2 System Description and Operation

During NBP1503 we used the Knudson Chirp 3260 subbottom system. The system allows 3.5 kHz and 12kHz center frequency operations and sends out sweeps around that frequency to provide better bottom penetration. Sweep length can be adjusted. The vertical resolution depends on the frequency used and the water depth. Practical resolution of the 3.5 kHz frequency used on this cruise is between 0.5m and 1m.

During the cruise we used the 3.5kHz mode with sweep length between 1ms (shallow) and 32ms (>4000m depth) and various amplitude correction settings.

The system is controlled through a client software terminal and contains all the necessary controls for standard operation of the echosounder, data acquisition and archiving. The application gives access to the operational controls to define the acquisition parameters and displays a graphical representation of real-time received data (Figure 4.1).

Data are stored in Knudson *.keb and in SEGY format. SEGY can be stored as raw data without chirp correlation, just with chirp signal correlation (filtered –FLT), or with chirp signal correlation and envelop detection (detected - DET). Most the data we collected have been stored as FLT or DET. Filtered allows more post-processing to be applied since the whole waveform is included in the data. Whereas the data with envelop detection provide good images without additional processing. The profiles are named by default through acquisition software, starting with a consecutive line number, followed by Julian day, month, day, and time of the start of the line. While there is only one file for each *.keb formatted line, there can be several SEGY files for the same line. They are automatically truncated if there are over 25Mbytes in size or when the length, i.e. number of samples, are changed.

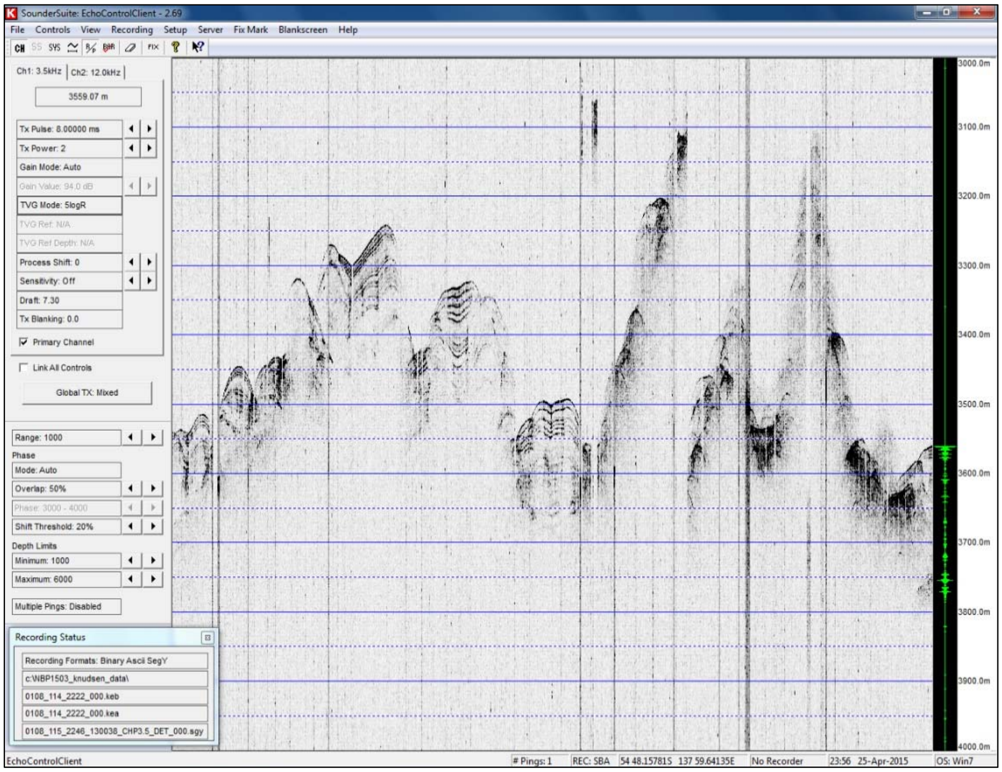

Figure 4.1: Knudsen subbottom control interface.

Most of time the acquisition was used a mode TVG (time varied gain) between 5logR-30logR (with R being the radius of the wave) generally with start and stop frequencies of 2.3 kHz and 5.3 kHz respectively, providing a vertical nominal resolution of 0.1-0.5m. The most commonly applied settings are listed in table 4.1.

Table 4.1: Settings of major acquisition parameters on the Knudson Chirp system.

Signal Setting	
Start frequency	2.3 kHz
Stop frequency	5.3 kHz
Bandwidth	3 kHz
Recording window range	200m,500,1000m
Sample rate	60 µs
Gain Mode	Auto
TVG Mode	5logR-30logR
Channel Setting	
Eco strength	-125 dB
Pulse length	8-15ms

We started acquiring subbottom data after crossing the Australian EEZ and archived data starting at March 30th 2015. The archiving was stopped during science stations, which led to the start of a new line.

4.3 System Performance and Problems

Overall the system performed reliably and continuously. The only interruptions in data acquisition were due to manual stopping archiving. We observed good penetration (>50m) in soft sediments on the continental rise (e.g., Figs. 4.2, 4.6), which makes this system a useful tool for determining locations for sediment sampling.
Similar to the multibeam bathymetry system the subbottom system lost the bottom/signal in heavy ice or wind conditions.

The software worked well. The only complaint is with the depth range window setting, which has strange limits for allowable windows and led occasionally to brief intervals of data loss when the auto range setting would not move to shallower depth.

4.4 Data Examples

In total we acquired over 5300 km of subbottom data. They show a wide range of subbottom facies. Figures 4.2 to 4.6 show several examples of chirp sonar data from various parts of the survey.

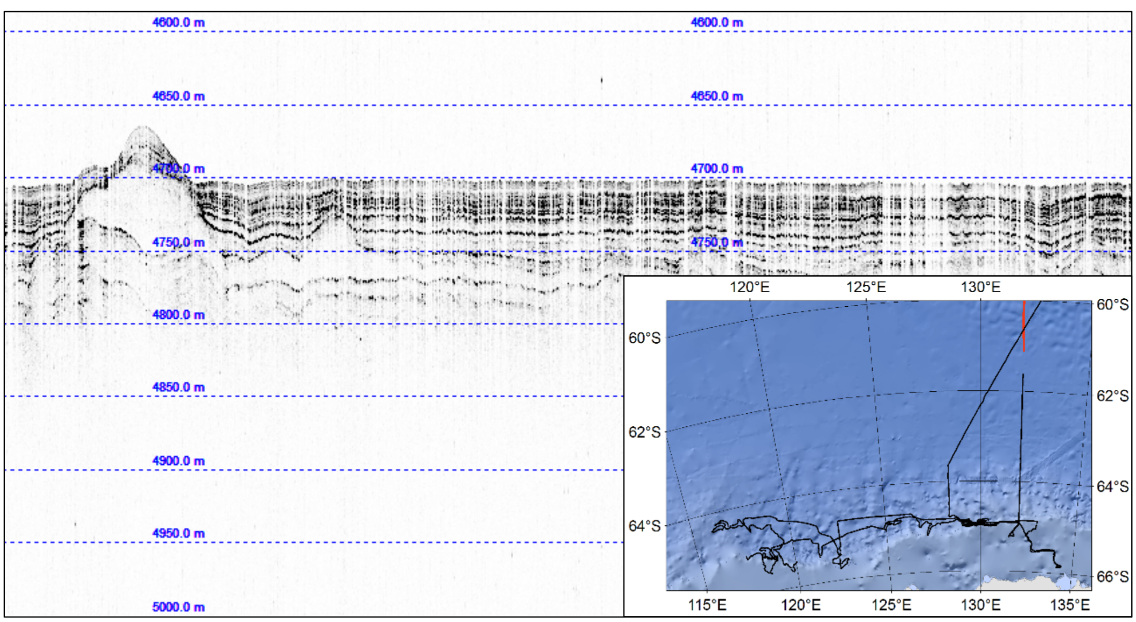

Figure 4.2. Subbottom example showing 50m of acoustical stratified facies. Most likely soft hemipelagic muds in the Australian-Antarctic Basin. Subbottom profile section of acquisition Line 0009. The bold red line show the location of the subbottom profile illustrated.

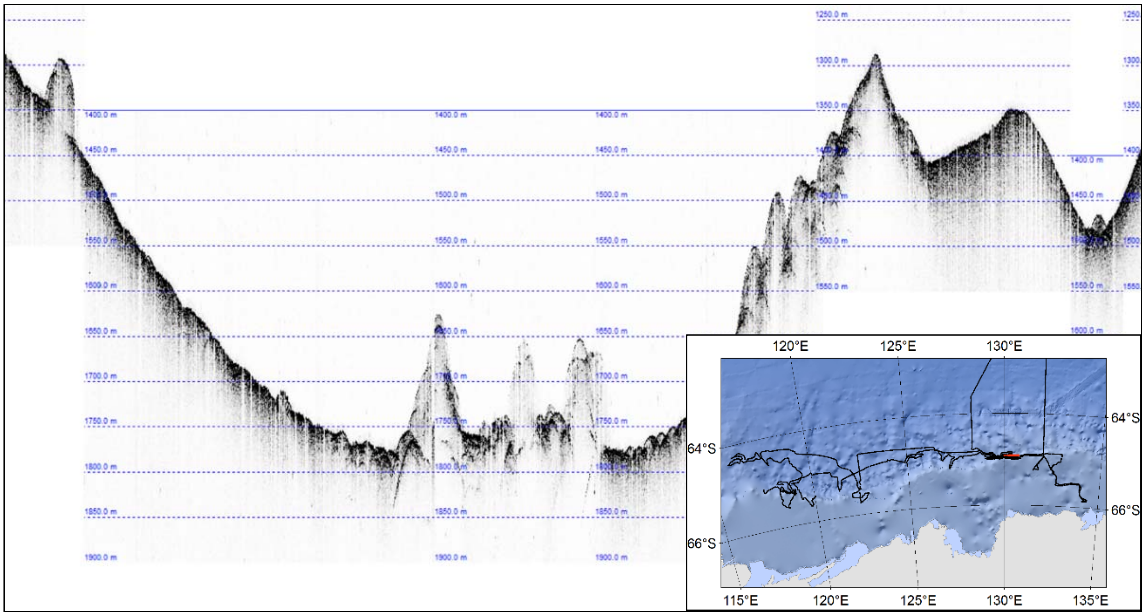

Figure 4.3. Subbottom profile of Line 0023 showing a channel with smaller ridges on the continental slope north of the Dibble Polynya. The bold red line show the location of the subbottom profile illustrated.

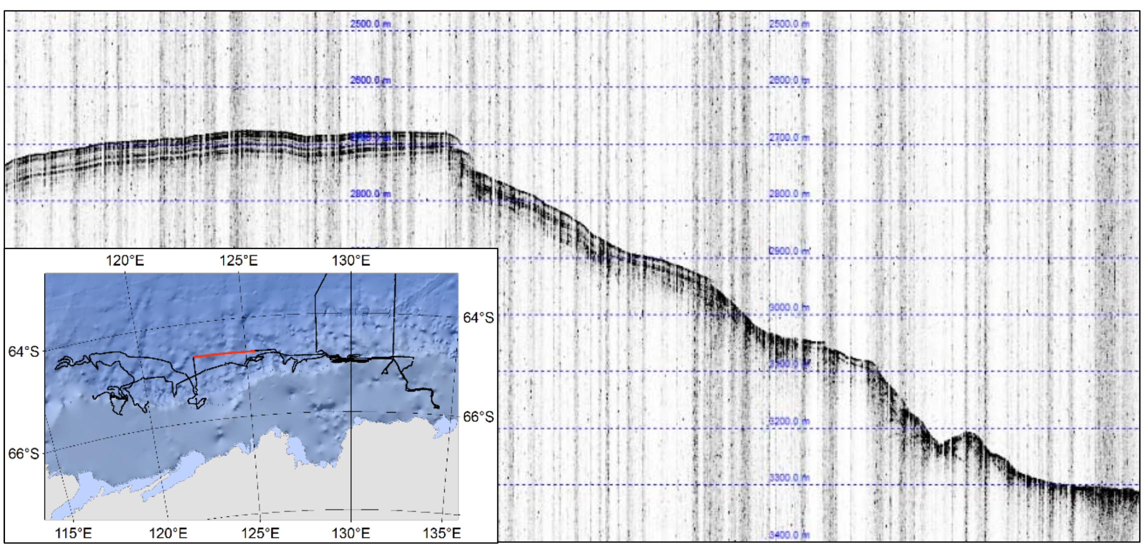

Figure 4.4. Subbottom data example of a sediment mount along the continental slope with better penetration on the top indicating softer sediments and less penetration on the bottom part, which indicates coarser sediments. Subbottom profile section of acquisition Line 0047. The bold red line show the location of the subbottom profile illustrated.

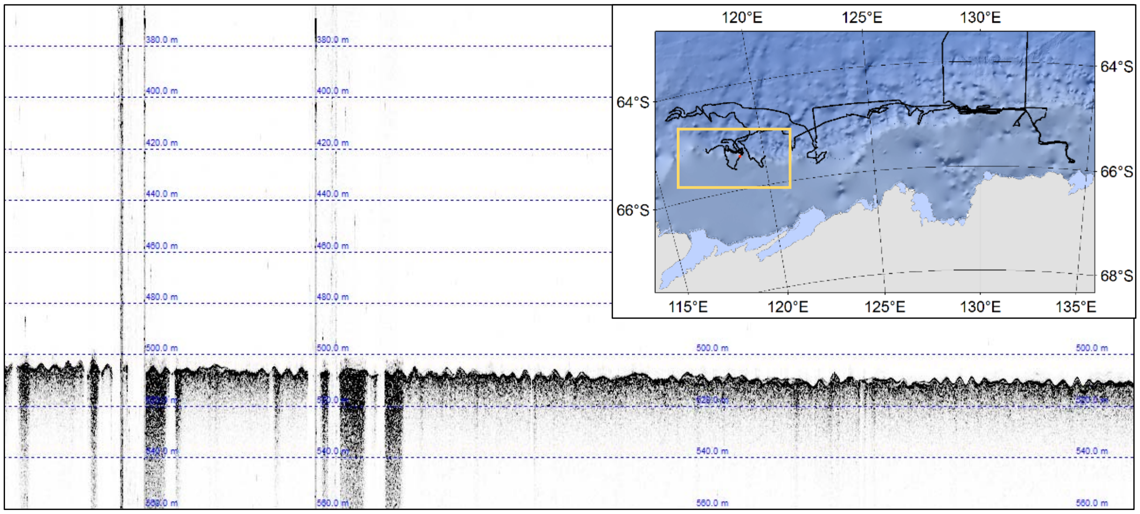

Figure 4.5: Subbottom profile showing hard bottom with irregular reflectors potentially indicating iceberg scours near the continental shelf break north of the Totten/Moscow University Ice Shelves. Line 0075. The bold red line show the location of the subbottom profile illustrated.

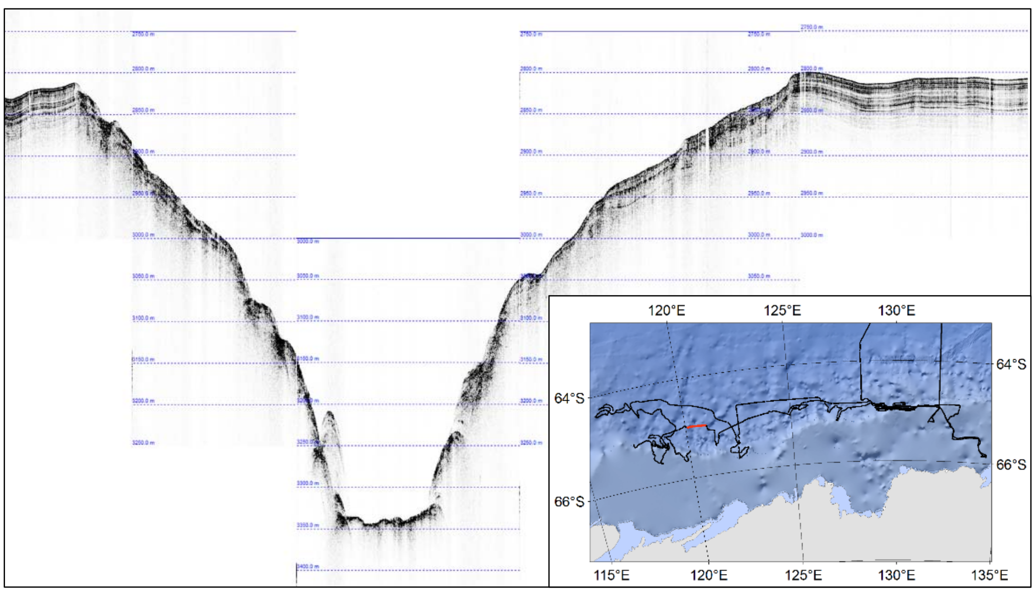

Figure 4.6. Subbottom profile of Line 0086 showing a deep channel section and acoustically stratified facies with continuous, parallel internal reflectors indicating softer sediments on either side of the channel. The bold red line show the location of the subbottom profile illustrated.

5. UAS operations and tests

(Guy Williams, Alex Fraser, Eva Cougnon)

5.1 Background

PI Williams was invited to co-lead the physical oceanographic component of NBP15-03 in 2013, as the result of an existing collaboration with Lamont-Doherty Earth Observatory after his previous participation on NBP00-08 Dec 2000-Jan 2001. In line with his new funding to research ocean/sea-ice interaction using autonomous observation platforms, Dr Williams requested the opportunity to bring multicopter UAVs for opportunistic testing and acquisition of aerial sea ice imagery. The flights were specifically testing the aerial mapping of Antarctic sea ice to determine floe-size distribution. This will be important for future integrated observation programs investigating wave/ice interactions in marginal ice zones.

Overall, as USAP is in the process of developing a policy on the safe -and environmentally sound - use of Unmanned Aerial Vehicles (UAVs), the use of the pilotless aircraft by program personnel currently is prohibited without specific authorization. Per a Sept. 15, 2014 agency memorandum, the prohibition includes "the operation of commercially available or custom designed "quad copters", remote controlled camera systems, and any other unmanned airborne systems." A special review was performed in order to permit the flights from the Palmer.

5.2 The UAV Systems

Table 5.1: Technical specifications of the UAV/UAS systems used on NBP1503.

DJI Phantom 2 Vision+	**DJI S1000**	**DJI S1000+**
	 credit: Kathleen Gavahan	 credit: 'Bug' Turner
IceFloe – NTG	BlackFrost-TIB-1	BlackFrost-TIB-2
In-built camera and gimbal	Zenmuse Z15 gimbal with Panasonic Lumix GH4	Zenmuse Z15 gimbal with Panasonic Lumix GH4
DJI Controller	Futaba 14SG	Futaba 14SG
IPhone DJI Ground Station	IPad DJI Ground Station	IPad DJI Ground Station
DJI 11.1 V, 'smart' batteries	2 x Turnigy Nanotech 22.2 V, 6S, 25-50C, 5500 mah	2 x Turnigy Nanotech 22.2 V, 6S, 25-50C, 5500 mah

5.3 Pre-Cruise and Pre-Flight Preparations

Pilot Training

In preparation for NBP15-03, Guy Williams logged over 30+ hours of UAV flight training. At least 5 hours were conducted in 'ATTITUDE' mode and the equivalent time completing autonomous mapping missions under 'GPS' mode. Many aspects of the training were conducted under the supervision of Mr Darren Turner, chief pilot for TerraLuma UAV facility at the University of Tasmania. Limited area take-offs and landings in strong wind conditions were a focus of final training. This was to prove invaluable during ship operations. 10 hours of flying was also completed in high wind scenarios using a flight simulator RC Phoenix.

Operational Certification

The regulatory environment in Australia surrounding UAV operations and pilot certification was playing 'catch-up' with the rapid development of ready-to-fly UAV products entering the market during the period leading up to NBP1503. In March 2015 Guy Williams completed his 'Remote Pilot Certificate' through a private company (RPAS Training) endorsed by the Civil Aviation Safety Authority at a cost of ~$4500. This 5-day course covered aerodynamics, meteorology, navigation, laws and regulations, maintenance, LiPo batteries and provided basic certification for UAV classed below 7kg. It was a requirement of the course to pass a written exam and 15-minute flight assessment in 'Attitude' mode. In order to gain certification for the larger S1000 UAV, he also obtained a separate 'Manufacturer's assessment' for the 7-20 kg class UAV by building a second DJI S1000 UAV and completing a competency assessment through another company (Australian RPAS Consultants). Additionally he received a Radio Operator's Certificate. All components of this certification were lodged with the Civil Aviation Safety Authority prior to NBP15-03.

NSF approval

In the 3 months leading up to NBP1503, the UAV team leader consulted with NSF and participated in an **AFSRB Flight Safety Review process** to gain approval for the UAV operations and to set out the guidelines defining this approval. This began with the submission of a draft Concept of Operations (CONOPS) document, based on an earlier CONOPS document for UAV operations at McMurdo by PI J. Cassano et al., in 2012-2013. At this point it was requested that PI Williams begin developing a Standard Operating Procedure (SOP) document to be used on the NB Palmer and to supply more detailed information about the UAV operations through completion of a questionnaire in Appendix G of the AOS Chapter 4 (UAS Ops Policy). PI Williams supplied information regarding his certification, together with a letter of reference from his UAV trainer. The AFSRB considered the information supplied, requested additional details and then approved the operations with the following conditions (note these have been generically re-written).

1 The PIC is a certified UAV pilot for the weight-class of UAVs to be used. Please provide the AFSRB with a copy of your certification.
2 The UAV team follow manufacturer's guidance re the recharging of the LiPO battery inherent in your UAS systems. LiPO batteries as a class have a reputation for catching fire during the recharging phase. At a minimum, the batteries should be placed in a fire resistant container while being charged. Recharging of the batteries must also be conducted in accordance with vessel policies.
3 The air vehicles will be maintained and operated in accordance with all manufacturer-provided guidelines, manuals, latest firmware updates, etc.
4 The UAV team conduct all UAS operations in accordance with NBP's standard flight operations procedures and Vessel SOP.
5 The UAV team will not conduct simultaneous flight operations with the S1000 and Phantom 2. Only one UAS will be in flight in the airspace at a time, per NBP's Master's requirement.
6 The UAV team will employ their UAS in the support of science only.
7 If the UAV team plan to release any aerial footage obtained via UAS during this cruise to the public, they and Chief Scientist must review your plans for such outreach or broader impacts activities with the NSF Polar Outreach Program Manager (Peter West, pwest@nsf.gov <mailto:pwest@nsf.gov>; 703-292-7530) and the NSF Antarctic Science Program Manager (Dr. Mark Kurz, mkurz@nsf.gov <mailto:mkurz@nsf.gov>; 703-292-7431).
8 Prop guards are installed on the Phantom 2, and you exercise additional caution in the operation of the S1000, given its lack of available blade guards. Both the S1000 and the Phantom 2 shall be recovered by landing on the NBP's Helo deck and neither will be "plucked" manually from the air while in flight.
9 PIC will not overfly concentrations of wildlife and will maintain a minimum distance of 61 m (200 feet) from individual animals, so that animals do not react to the UAS.
10 In the event either UAS crashes into the sea or onto the ice, you and the NBP Captain shall carefully weigh the risk of attempting a recovery with that of abandoning the UAS.

Pre-departure in Hobart

The UAV team met with the ASC Marine Projects Coordinator and ECO Captains (previous and current voyage) on board the NBP to examine the workspaces allocated to the UAV project: the helo workshop, hangar and deck. An early priority was a discussion regarding LiPo battery recharging. It was determined that the helo workshop was the optimal location for recharging and that a specific SOP for battery recharging be written, together with an ECO specific JHA. Furthermore,

- An additional metal storage container was purchased, thereby allowing one to be dedicated to recharging and another to the storage of batteries.
- A 20L bucket of sand installed in recharging area.
- Extra documentation was acquired for necessary fire extinguishers (A-C, not D)
- Extra documentation was acquired concerning safe disposal of LiPo batteries.
- A screen connected to the ship's RVDAS channels was requested and subsequently installed for the heli-workshop.

Recommendation: It would be optimal if components of the RVDAS, in particular true wind speed, and the ship's course and speed over ground could be wirelessly transmitted to a tablet for the UAV team to monitor during operations.

The UAV team also conducted a walk-through of planned UAV operations with ASC staff and Chief Scientist, in particular examining the available space on the helideck. It was determined that the Zodiacs needed to remain on the helideck and that the UAV team would preferentially like to take off and land at the aft region. There was also a discussion regarding the 'fencing' around the helideck. It was determined that although they could be lowered, they would remain upright. There were other miscellaneous items that also required storage on the helideck and ultimately the clear operational area for take-off and landing was approximately 30ft x 30ft, with a 4 ft vertical fence. It is also worth noting that the NBP has a large aft A-frame on its lower deck and this limits the area available for take-off and approach to the rear of the ship.

There was a short-delay in our departure and this afforded the UAV team an opportunity to conduct some final testing on the S1000+ UAV away from the ship. However, this did present a problem in the sense that it was not legal to simply walk the UAV box off the ship, given that it had been loaded as cargo. Australian Customs officials reacted quickly, and the situation was quickly solved, with the appropriate paperwork for the removal and subsequent re-loading of the UAV box facilitated by personnel from TasPorts in conjunction with the MPC and bridge

Transit

There was a nine day transit, affording sufficient time to complete SOPs for both UAV operations and LiPo battery recharging, with accompanying JHA's completed with ECO officers. The UAV also spent time testing cameras and GPS loggers, which were used with the S1000 UAV to allow post-flight geotagging of imagery. *Note: One of the key limitations of the DJI UAV is that a time-stamped output of telemetry is not readily available from the basic units.* The Panasonic GH4 cameras were placed in the -30ºC refrigerator and successfully operated under time-lapse settings for 30 minutes.

Static testing of the UAVs was conducted to examine satellite acquisition. The dynamic re-positioning of the Phantom 2 Vision+ home location was also tested while underway at 10 knots, as an extreme case study of what could potentially happen if the ship is drifting during a 10-15 minute flight. It worked the first time, but not on the second time and the UAV was shutdown as it began to initiate its 'return to home' failsafe.

5.4 UAV Flights

During the cruise we conducted 9 individual flights at 3 different stations. Table 5.2 summarises the test flights, which are described in detail below.

Table 5.2: Summary of UAV Flights.

Flight No.	**Date**	**Location**	**UAV**	**Mission**	**Flight time**
1.1	8th April	-64.493ºS, 126.4ºE	Phantom	Hover testing	7:36 m
1.2	8th April	-64.493ºS, 126.4ºE	S1000+	Hover testing	6:52 m
1.3	8th April	-64.493ºS, 126.4ºE	S1000	Hover testing	7:44 m
2.1	9th April	-65.261ºS, 122.29ºE	S1000	Imaging	2:16 m
2.2	9th April	-65.261ºS, 122.29ºE	S1000+	Imaging	5:36 m
2.3	9th April	-65.261ºS, 122.29ºE	S1000+	Imaging	6:21 m
2.4	9th April	-65.261ºS, 122.29ºE	S1000	Imaging	0:49 m
3.1	13th April	-65.274ºS, 119.95ºE	Phantom	Imaging	12:46 m
3.2	13th April	-65.274ºS, 119.95ºE	S1000+	Imaging	5:48 m

UAV Operations 1 – 8th April – Helideck Hover Testing

Summary: Basic hover testing over the helideck at maximum altitude of 5m. This was an important first step in running through all deployment operations with ECO crew, ASC staff and the UAV team. It was also desirable to investigate that controlled flight was possible in ‘Attitude’ mode. The ships was placed in ‘dynamic positioning’ mode, nose into the wind and therefore providing some shelter in the lee of the heli hangar.

Flight 1.1 PHANTOM 2 VISION+

Time	2:16:00 -> 2:23:36 am GMT– 7:36 mins
Location	-64.493ºS, 126.4ºE
Data	Phantom 2 images and video, GoPro, Remote Time Lapse [DSC_0206.JPG ->DSC_0319.JPG]
Flight	Basic hovering and simple ‘yaw’ manoeuvres. Attempted ‘GPS’ mode resulted in rapid response of UAV towards the heli-hanger and the UAV was returned to ‘Atti’ mode. DJI smart battery performance was fine.

Flight 1.2 S1000-1

Time	2:40:36 -> 2:47:28 am GMT– 6:52 mins
Location	-64.493ºS, 126.4ºE
Data	GH4 video, GoPro, Remote Time Lapse [DSC_0575.JPG -> DSC_0677.JPG]
Flight	As above.
Batteries	25.1 V -> 22.77 V, 25.1V -> 22.78 V

Flight 1.3 S1000-2

Time	3:01:12 -> 3:08:56 am GMT - 7:44 mins
Location	*-64.493ºS, 126.4ºE*
Data	GH4 images, GoPro, Remote Time Lapse [DSC_0883.JPG -> DSC_001_2.JPG]
Flight	As above.
Batteries	25.1 V -> 22.63 V, 25.1V -> 22.60 V

UAV Operations 2 – 9th April – Flights over Sea Ice

Summary: These were the first flights away from the ship, building on the success of the initial hover testing. Planned missions were essentially limited range tests, 100m in both vertical and horizontal. Wind speeds were between 10-15 knots as the ship drifted, near orthogonal to the wind, which was slightly forward of the port side. Both the S1000 and S1000+ were flown twice each.

Flight 2.1 S1000-1

Time	2:52:28 -> 2:54:44 am GMT – 2:16 mins
Location	-65.261ºS, 122.29ºE
Data	GH4 Video, GoPro, Remote Time Lapse [DSC_0321.JPG -> DSC_0365.JPG]
Flight	UAV brought to a hover at 5m, then turned to port and proceeded ~50m into the wind. It appeared to be behaving well, so an anti-clockwise circuit was initiated, turning first to face parallel with the ship. When the UAV turned clockwise into the wind, it began to behave abnormally, and it accelerated and descended towards the rear of the ship. There appeared to be a lagged response to the controls, of up to 2 seconds, before control was restored and the UAV ascended and was brought to a hover aft of starboard side of the ship. The UAV was returned to the helideck shortly after.
Batteries	Not logged.

Flight 2.2 S1000+

Time	3:09:12 -> 3:14:48 am GMT – 5:36 mins
Location	-65.261ºS, 122.29ºE
Data	Remote Time Lapse [DSC0658.JPG -> DSC0766.JPG], GoPro (GH4 did not operate correctly)
Flight	Basic hovering at 20m, some turns to nose-in and back, ascent to 60-70 m for aerial imaging. GPS hold did not appear stable.
Batteries	25.1 V -> 23.25 V, 25.1 V -> 23.20 V

Flight 2.3 S1000+

Time	3:19:52 -> 3:26:13 AM GMT– 6:21 mins
Location	-65.261ºS, 122.29ºE
Data	Remote Time Lapse [DSC0872.JPG->DSC0999.JPG], GoPro GH4 Aerial images of sea ice - GH4 image 688 – approximate height - GH4 images 698-702 – approximate height - GH4 images 714,715, 719, 720, 721, 722 – approximate height from USB GPS logger [start count 862]
Flight	Repeat of previous flight. Ascent to 100m, strong winds encountered and unintentional ascent continued to 150m. Horizontal and vertical camera positions tested. Return to deck.
Batteries	25.1 V -> 22.93 V, 25.1 V -> 23.04 V

Flight 2.4 S1000-1

Time	3:37:48 am -> 3:38:37 am GMT– 0:49 mins
Location	-65.261ºS, 122.29ºE
Data	GoPro, GH4 Movie (stopped), Remote Time Lapse [DSC0032_2.JPG -> DSC0080_2.JPG]
Flight	Short flight, erratic behaviour in strong wind gusts meant the flight was aborted early
Batteries	25.1 V -> 24.78 V, 25.1 V -> 24.76 V

UAV Operations 3 – 13th April – Evening flights over Sea Ice

Summary

Flight 3.1 PHANTOM 2 VISION+

Time	8:28:48 am -> 8:41:34 am GMT – 12:46 mins
Location	-65.274ºS, 119.95ºE
Data	Phantom 2 images and video, GoPro, Remote Time Lapse *[DSC_0261.JPG -> DSC_0644.JPG]*

Flight	Soon after take-off, the Phantom successfully engaged 'GPS' mode and maintained a very stable hover and essentially flew perfectly. The UAV ascended to 120m, and then the failsafe kicked in and it began to return to home. Manual control was re-established and the vehicle was brought down to ~30m altitude. Thereafter a series of circuits and figure-of-eights were executed over the helideck, before another ascent for aerial imagery and video. At an altitude of 20-50m, the UAV attracted the attention of snow petrels, but there appeared to be no danger to either the birds or the vehicle.
Batteries	25% charge remaining

Flight 3.2 S1000+

Time	8:49:58 am -> 8:54:56 am GMT – 4:58 mins
Location	-65.274ºS, 119.95ºE
Data	GH4 images, GoPro, Remote Time Lapse *[DSC_0924.JPG -> DSC_0224.JPG]*
Flight	The S1000 took off and was hovered at ~20m before testing the GPS mode. It did not appear to work immediately, or at least as well as the previous flight with the Phantom. One contributing factor is likely to be the winds, which suddenly doubled to 20 knots, after being relatively stable at just under 10 knots for the hour beforehand. The UAV ascended and a second attempt at GPS hold was made, but once again, the UAV behaviour was not stable and it was returned to ATTITUDE mode. There is an element of doubt as to whether the correct mode was chosen, given the switch direction for GPS mode is reversed between the DJI and Futaba controller. However post-flight analysis of the time lapse and GoPro video suggests it was in GPS mode during these tests. The UAV ascended to 50-60m but ultimately the decision was made to land, given the decreasing light.
Batteries	25.1 V -> 23.39 V, 25.1 V -> 23.39 V

Figure 5.1: Example of UAV test flight over sea ice.

5.5 Conclusions

This was in many ways a very successful project and a critical first step in the development of ship-based UAV operations in Antarctica. Icebreaker deployed UAV operations were safely conducted on three days resulting in 9 take-offs and landings and the proof-of-concept for the acquisition of aerial sea ice imagery for determining sea ice concentration and floe-size distribution. While wind speed and temperature remain ongoing concerns for Antarctic UAV operations, together with outstanding questions relating to compass performance specific to multi-rotors, this project demonstrated that current off-the-shelf UAVs can operate safely with advanced pilot training, competent ground support and the right environmental conditions. There have been invaluable lessons learned from this project that promise to set the foundation for future UAV operations that will inevitably expand into the future to meet the observational needs of polar scientists seeking to understand this extreme and important environment.

5.6 Acknowledgements

This work was funded by the Australian Research Council's 'Future Fellowship' program, with additional support from the Institute of Marine and Antarctic Studies and Antarctic Climate and Ecosystems Cooperative Research Centre at the University of Tasmania. Alex Fraser was supported by Grant-in-Aids for Scientific Research 25.03748 of the Ministry of Education, Culture, Sports, Science and Technology in Japan. The UAV team would like to express its gratitude to the National Science Foundation for supporting this blue-sky work, in particular the considerable efforts of Mike

Scheuermann and the AFSRB Flight Safety Committee to review and approve this project, as well as Peter West and the NSF communications team. Special thanks to the Chief Scientist Frank Nitsche and Marine Projects Coordinator Al Hickey for handling the logistics of UAV operations during NBP15-03, together with all ASC technicians and ECO crew for their enthusiasm and support during the voyage. Thanks also to Arko Lucieer and Darren Turner at TerraLuma UAV facility at the University of Tasmania for overseeing the development of this work.

Figure 5.2: UAV flight team with other cruise participants.

6. Argo float deployment

(Frank Nitsche, Al Hickey, MTs)

Background

Argo floats are autonomous drifters that take salinity and temperature profiles and relay those via satellite to the shore station. The floats deployed on NBP1503 are operated by the University of Washington, Seattle, WA, USA.

Figure 6.1: Argo float ready for deployment.

Deployment procedures

During this cruise the MTs deployed 10 Argo floats (Fig. 6.2). Seven floats were deployed on the leg southward and three on the northward leg of this cruise. Table 6.1 shows the details of the deployment locations:

The floats do not need to be 'started' as they are in pressure activation mode. This means that once the float is lowered into the water it will sink (not right away but about 3-5 minutes after deployment) where it will then feel the pressure on the sensor and begin its mission. For each deployment the ship slowed down to between .5 and 1 knot over water. The individual floats were deployed using a slip line from the stern of the boat.

Table 6.1: Argo deployment details.

Date & Time GMT		Tag #	Depth	Latitude	Longitude
southbound					
31-Mar-15	08:10:29 GMT	6854	3323	051 00.056 S	131 54.008 E
31-Mar-15	20:19:28 GMT	9311	3847	052 59.948 S	131 52.952 E
01-Apr-15	08:39:38 GMT	5314	4391	055 00.040 S	131 52.999 E
01-Apr-15	20:49:53 GMT	9257	4560	057 00.022 S	131 53.331 E
02-Apr-15	08:36:43 GMT	9318	4740	058 59.943 S	131 53.204 E
02-Apr-15	20:25:15 GMT	9266	4614	061 00.003 S	131 57.177 E
03-Apr-15	13:15:28 GMT	9300	4301	063 00.043 S	131 58.725 E
northbound					
23-Apr-15	21:11:39 GMT	9264	4498	061 59.931 S	130 20.899 E
24-Apr-15	11:53:45 GMT	9319	4715	059 59.920 S	132 38.229 E
25-Apr-15	02:21:43 GMT	9284	4998	057 59.443 S	134 48.089 E

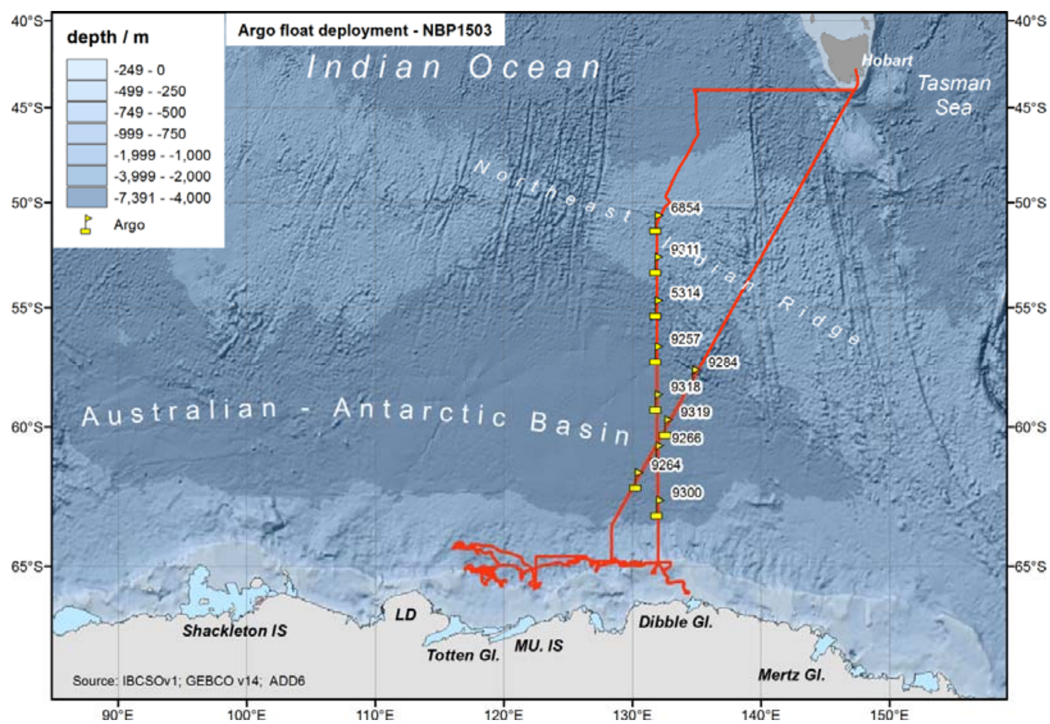

Figure 6.2: Argo Deployment locations. See table for details.

7. Thermosalinograph observations for Aquarius validation

(Raul Guerrero)

Background

To better understand the regional and global processes that link variations in ocean salinity to changes in the global water cycle - and how these variations influence ocean circulation and climate - NASA (USA) built and launched Aquarius, the primary instrument aboard is the USA/ARGENTINA Aquarius/*Satelite de Aplicaciones Científicas (SAC)-D* observatory (http://aquarius.umaine.edu/cgi/index.htm).
This Earth System Science Pathfinder mission is mapping global changes in ocean surface salinity with a resolution of 150 kilometers (93 miles), showing how salinity changes in time. Scientists are combining Aquarius data with in-water measurements to generate operational maps of ocean salinity distribution.
One of the target on this cruise was to measure *in-situ* sea surface salinity (SSS) in the south/northbound transit from/to Hobart/Antarctica using the underway thermosalinograph observations on board (Project 08 CONAE-INIDEP (Argentina), Raul Guerrero PI). This information will afterward be used for validation and eventual of Aquarius SSS observations in cool region areas.

UW TSG sampling

The underway sampling was carried out during the transit, taking Termosalinograph (TSG) information from the on-board TSG system. The TSG system collects surface temperature and salinity and ancillary information, such as position (Latitude, Longitude), date and time. In order to calibrate the underway salinity values (measured with the TSG), 41 salinity samples were taken at an interval of roughly 6 hours (Fig. 2.1). Salinity samples were then analyzed on-board to monitor the performance of the CTD conductivity sensors using Portasal #69942 (Table 2.4). TSG1 error estimation in salinity is reported in section 2.2 Salinity analyses.

8. Education and Public Outreach

(Dominique Richardson)

Engaging students and the public through outreach is an effective way to increase scientific literacy and awareness for current Antarctic research. The NBP1503 cruise included an educator from PolarTREC, Dominique Richardson, to focus on outreach and science communication for research being conducted on the ship. PolarTREC (Polar Teachers and Researchers Exploring and Collaborating) is a program that works to advance polar science education by engaging students and educators in current research. To foster an integration of research and education, PolarTREC pairs educators with researchers, allowing the educators to participate in polar field research in order to improve their knowledge of polar science and to interpret current scientific research, beyond the scientific community, to students, other teachers and the public. In addition to the PolarTREC teacher's outreach projects, several of the scientists on the cruise also participated in independent outreach projects of their own.

8.1 Blogs

During the cruise three blogs were run to keep an international audience of varying ages appraised of the research and life aboard the ship.

Dominique Richardson ran a blog through the PolarTREC website (www.polartrec.com/expeditions/antarctic-ice-stream-dynamics) that was updated daily, receiving more than 6,000 hits. It introduced the science behind the cruise and research techniques used in terms accessible to a diverse audience of all ages. It also explained life on the ship, answered questions submitted by students and the public, introduced members of the science team and science support contracts, and offered at home activities and contests. The blog allowed students and teachers to comment and ask questions directly on the work being done.

Frank Nitsche posted weekly entries to a blog run through Columbia University (http://blogs.ei.columbia.edu/tag/west-antarctica/) providing regular updates on the trip, research activities, and conditions.

Ricardo Correia also posted weekly blogs in Portuguese through ProPolar (www.propolar.org), detailing life on the ship, research and research equipment on board.

8.2 Media and Social Media

Before departing for the expedition, Dr. Guy Williams gave TV and newspaper interviews for media in Hobart, Tasmania, which were also posted to the Institute for Marine and Antarctic Studies (IMAS) Facebook page and YouTube. During the expedition Guy gave a radio interview to ABC Radio National in Australia.

Regular cruise updates were also posted to social media. Dominique ran a Facebook Page (Dominique in East Antarctica) with a post reach of about 1,300 people, where photos, updates, blog links and giveaways were posted. IMAS also posted interviews with Guy regarding the cruise to Facebook. Frank (@FrankAtSea) posted cruise updates to Twitter. Dominique (@EastAntarctica) posted cruise photos to Instagram and Twitter (Fig. 8.1).

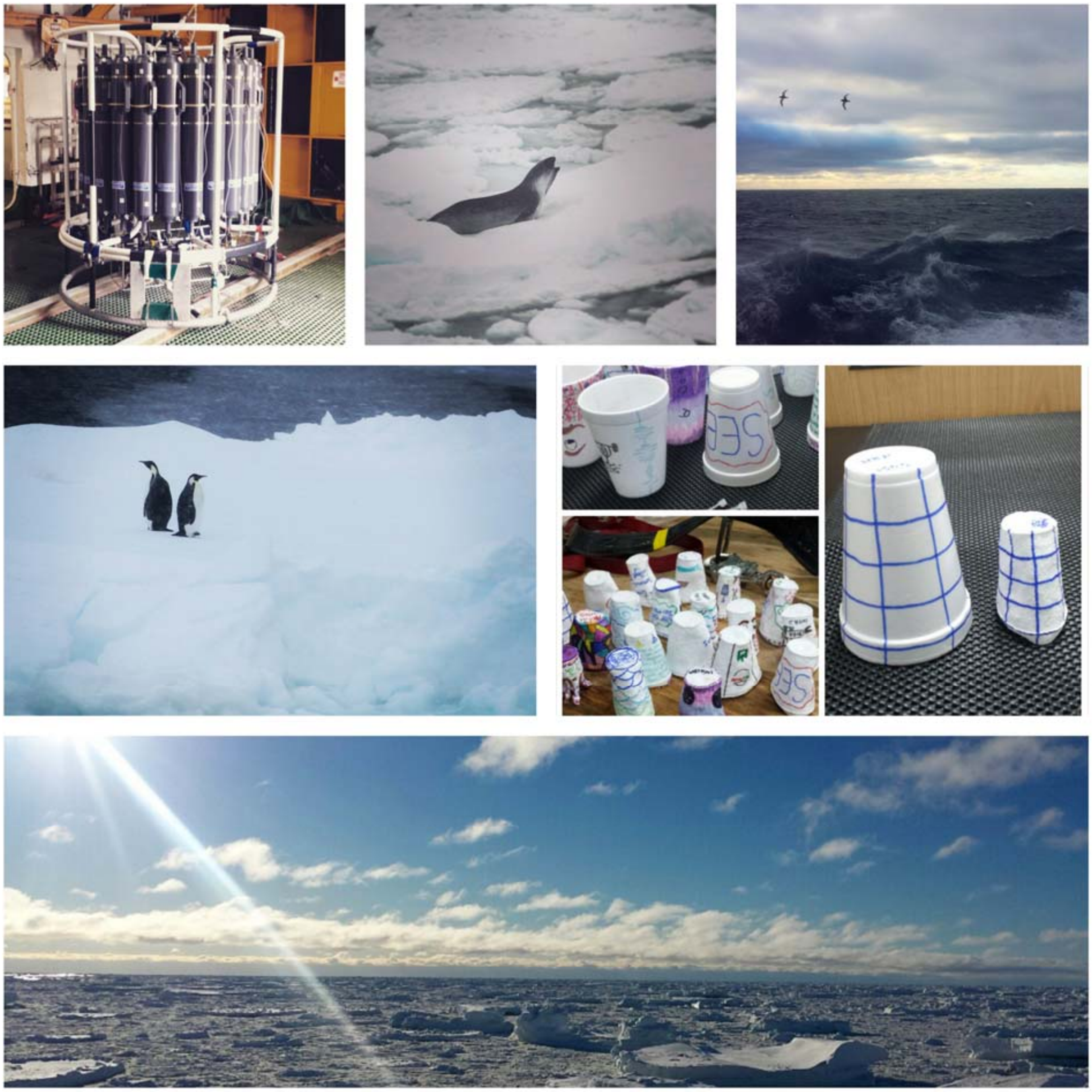

Figure 8.1: Examples of photos posted to social media by PolarTREC teacher, Dominique Richardson during the NBP1503 cruise.

8.3 PolarConnect

During the cruise, Frank and Dominique, participated in a PolarTREC PolarConnect event — an hour-long, live webinar from the ship. Frank and Dominique talked about the research on NBP1503 and life on the ship before opening the webinar up to answer questions from participants. Over 70 people, K-Adult, participated in the event, including Earth Day Festival attendees from Cabrillo Marine Aquarium in San Pedro and people from Los Angeles, Australia, New York, Japan, Germany and other parts of the world.

8.4 Student and Teacher Outreach

Before the cruise, Dominique, visited five schools (K-12), two homeschool events (K-12) and two public aquariums (all ages) to generate interest in following the expedition. Outreach visits included lectures on proposed NBP1503 research, an information table, hands-on activities, and ECW gear. Over the course of eight public events, 1,588 people of diverse backgrounds were reached, and from five schools (including inner city schools) 172 students were reached (Fig. 8.2).

Figure 8.2: Students at a school in Los Angeles try on ECW gear during NBP1503 outreach done before the cruise.

In the pre-expedition outreach students were offered the opportunity to submit questions for the scientists to be answered during the cruise (101 question received) (Fig. 8.3).

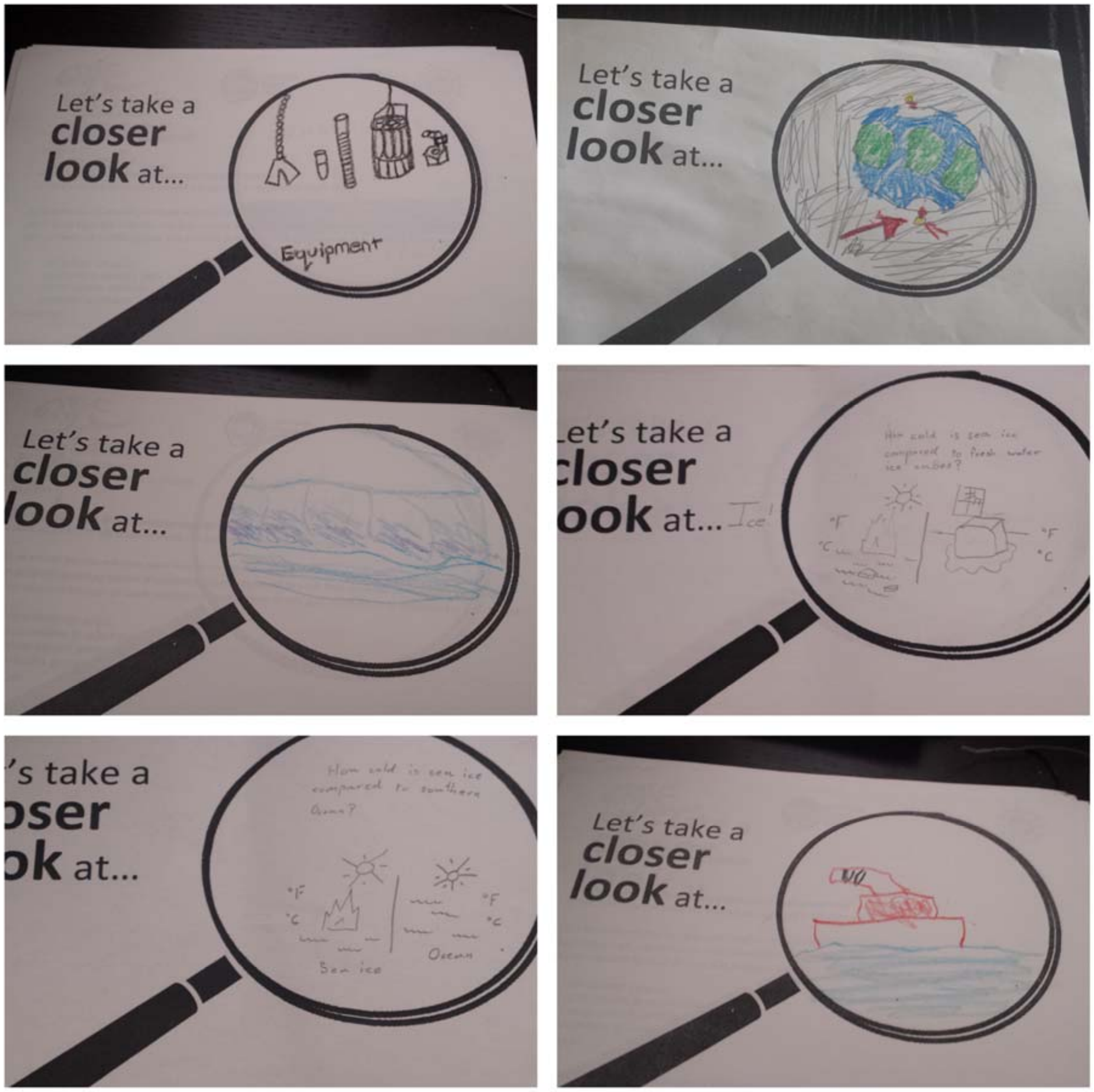

Figure 8.3: A selection of questions submitted by students (K-12) to be answered on the NBP1503 cruise.

An art contest was also made available to all ages, where participants designed a flag to represent the NBP1503 cruise or Antarctic science. Winners had their flag flown from the ship (92 entries received) and returned to them after the expedition (Fig. 8.4).

Throughout the cruise, Guy kept in contact with 12 different classes, grades 4 and 7, from four schools in Hobart, Tasmania. He regularly emailed with the schools, answering questions submitted to him by the students and sending them pictures and updates from the cruise.

As part of the follow- up after the cruise, Dominique will develop two lesson plans based on research done during the NBP1503 trip. These lesson plans will be presented to teachers in a professional development workshop in Los Angeles and will also be made available to teachers and educators, worldwide, for free on the PolarTREC website.

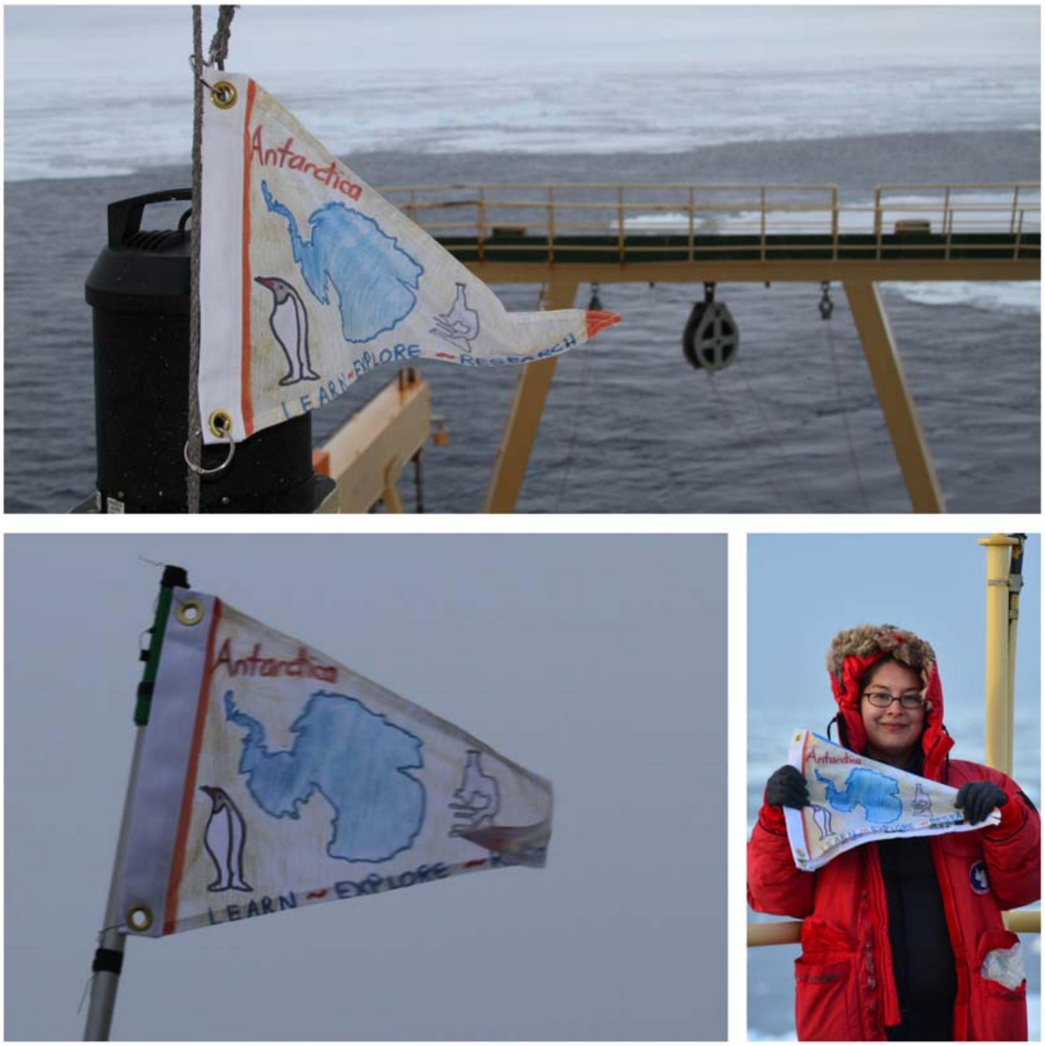

Figure 8.4: An example of an art contest winner (grades 6-8th) from pre-expedition outreach. Participants submitted flag designs to represent the NBP1503 cruise, winners had their designs flown from the ship.

9. Acknowledgements

We are grateful for the excellent technical and logistic support provided during the cruise by the 11-person ASC crew under the direction of Marine Project Coordinator Al Hickey, and the 19-person ECO contingent led by Captain John Souza.
The primary financial support for this work has come from the US National Science Foundation, Office of Polar Programs to Columbia University (Award ANT-1245879) and to Antarctic Support Contractors/Edison Chouest Offshore.

The Australian science component was funded by the Australian Research Council and supported by the Australian Cooperative Research Centre program and by Grant-in-Aids for Scientific Research 25.03748 of the Ministry of Education, Culture, Sports, Science and Technology in Japan.

Raul Guerrero is supported INIDEP and Project 08 MinCyT/CONAE-(*Ministerio de Ciencia y Tecnologia – Comision Nacional de Actividades Espaciales),* Argentina. Ricardo Correia received support from ProPolar (Programa Polar Portugues) and the University of Aveiro, Portugal. Dominique Richardson was supported by NSF through PolarTREC and the Arctic Research Consortium of the United States.

We also thank the many other agencies, institutions and individuals that helped in planning, organizing, and preparing for this cruise and supported us from the shore sites during the cruise by providing critical information including on weather and sea ice. Last, but not least we are thankful for the moral support of more than a few friends and families who managed the home fronts while we went south.

Figure 9.1: NBP1503 Science Team.

Figure 9.2: NBP1503 Science Team including people not in Fig. 9.1.

A – Participants List

Scientists and Science Support

Name	Position	Affiliation
Frank Nitsche	Chief Scientist	Lamont-Doherty/Columbia University
Al Hickey	MPC	Antarctic Support Contractors/LM
George Aukon	ET	Antarctic Support Contractors /GHG
David Branson	IT	Antarctic Support Contractors /LM
Ricardo Correia	Scientist	University of Aveiro, Portugal
Eva Cougnon	Scientist	ACE CRC, University of Tasmania
Alexander Fraser	Scientist	ACE CRC, University of Tasmania
Kathleen Gavahan	IT/Multibeam	Antarctic Support Contractors /GHG
Raul Guerrero	Scientist	Instituto Nacional de Investigacion y Desarollo Pesquero
Mackenzie Haberman	MT	Antarctic Support Contractors /PAE
Meredith Helfrich	MT	Antarctic Support Contractors /PAE
Gabrielle Inglis	ET	Antarctic Support Contractors /GHG
David Porter	Scientist	Lamont-Doherty/Columbia University
Dominique Richardson	PolarTREC Teacher	Cabrillo Marine Aquarium, California
Krista Tyburski	MT	Antarctic Support Contractors /PAE
Valerie Warner	IT	Antarctic Support Contractors /GHG
Amy Westman	MLT	Antarctic Support Contractors C/GHG
Guy Willams	Scientist	ACE CRC, University of Tasmania

Ship Crew

Name	Position	Affiliation
Souza, John	Master	Edison Chouest Offshore
Wiemken, Richard	Chief Mate	Edison Chouest Offshore
Talbot, Gary	2nd Mate	Edison Chouest Offshore
Tweedy, Brian	3rd Mate	Edison Chouest Offshore
Repin, Vladimir	Ice Pilot	Edison Chouest Offshore
Pierce, Johnny	Chief	Edison Chouest Offshore
Morris, Rob	1st Asst Eng	Edison Chouest Offshore
Rafferty, Trevor	2nd Asst Eng	Edison Chouest Offshore
Smith, Kaleb	3rd Asst Eng	Edison Chouest Offshore
Plaza, Danilo	Oiler	Edison Chouest Offshore
Rogando, Rolly	Oiler	Edison Chouest Offshore
Pagdanganan, Rogelio	Oiler	Edison Chouest Offshore
Garde, Lauro	AB	Edison Chouest Offshore
Dela Cruz, Jermaine	AB	Edison Chouest Offshore
Aaron, Bienvenido	AB	Edison Chouest Offshore
Naraga, Fernando	AB	Edison Chouest Offshore
Trombatore, Michael	OS-Cook	Edison Chouest Offshore
Bowen, Michael	OS-Cook	Edison Chouest Offshore
Sandoval, Lorenzo	OS-Cook	Edison Chouest Offshore

B – Station list

Station	Name	Type	Latitude	Longitude	Date	JD	Time GMT	Comments
1	CTD-001	CTD	-44.002	140.189	Mar 28 2015	87	02:59	500m deep test CTD
2	CTD-002	CTD	-62.014	131.966	Apr 03 2015	93	03:20	deep CTD; water samples
3	CTD-003	CTD	-62.014	131.966	Apr 04 2015	94	02:18	on cont. slope
4	CTD-004	CTD	-64.913	132.962	Apr 05 2015	95	03:44	Dibble cont. shelf
5	CTD-005	CTD	-64.993	130.406	Apr 06 2015	96	20:24	Dibble cont. shelf
6	CTD-006	CTD	-64.845	130.400	Apr 07 2015	97	00:39	Dibble slope
7	CTD-007	CTD	-64.925	127.810	Apr 07 2015	97	13:02	cont. slope transit
8	CTD-008	CTD	-64.690	125.420	Apr 08 2015	98	08:05	cont. slope transit
9	UAS-001	UAS	-64.493	126.400	Apr 08 2015	98	02:40	test flights (hoover over deck)
10	UAS-002	UAS	-65.261	122.290	Apr 09 2015	99	02:52	test flight (hoover over deck)
11	CTD-009	CTD	-65.362	122.465	Apr 08 2015	98	23:47	slope Dalton
12	CTD-010	CTD	-65.509	122.404	Apr 09 2015	99	04:23	shelf Dalton
13	CTD-011	CTD	-65.743	122.362	Apr 09 2015	99	07:44	shelf Dalton
14	CTD-012	CTD	-65.547	122.865	Apr 09 2015	99	12:20	shelf Dalton
15	CTD-013	CTD	-65.565	121.987	Apr 09 2015	99	18:28	shelf Dalton
16	CTD-014	CTD	-65.444	122.406	Apr 09 2015	99	22:22	slope Dalton
17	CTD-015	CTD	-65.001	122.007	Apr 10 2015	100	03:52	slope Dalton
18	CTD-016	CTD	-64.367	116.863	Apr 11 2015	101	22:28	cont. rise north of Low Dome
19	CTD-017	CTD	-65.086	118.936	Apr 12 2015	102	21:39	cont. ise slope north of Moscow
20	CTD-018	CTD	-65.659	119.781	Apr 13 2015	103	07:13	shelf Totten/Moscow
21	UAS-003	UAS	-65.274	119.950	Apr 13 2015	103	08:28	test flight shelf Totten/Moscow
22	CTD-019	CTD	-65.497	119.870	Apr 13 2015	103	14:23	shelf break Totten/Moscow
23	CTD-020	CTD	-65.042	118.203	Apr 14 2015	104	09:05	slope Totten/Moscow
24	CTD-021	CTD	-65.386	118.875	Apr 14 2015	104	23:06	shelf break Totten/Moscow
25	CTD-022	CTD	-65.537	118.572	Apr 15 2015	105	02:12	shelf break Totten/Moscow

Station	Name	Type	Latitude	Longitude	Date	JD	Time GMT	Comments
26	CTD-023	CTD	-65.232	118.266	Apr 15 2015	105	09:33	shelf break Totten/Moscow
27	CTD-024	CTD	-65.149	118.283	Apr 15 2015	105	11:32	slope Totten/Moscow
28	CTD-025	CTD	-65.182	117.503	Apr 15 2015	105	18:50	slope Totten/Moscow
29	CTD-026	CTD	-65.102	117.463	Apr 15 2015	105	21:36	slope Totten/Moscow
30	CTD-027	CTD	-65.259	118.883	Apr 16 2015	106	18:47	slope Totten/Moscow
31	CTD-028	CTD	-64.985	120.104	Apr 17 2015	107	15:33	cont. slope transit
32	CTD-029	CTD	-65.000	121.000	Apr 17 2015	107	20:53	cont. slope transit
33	CTD-030	CTD	-65.396	121.314	Apr 18 2015	108	03:53	cont. slope transit
34	CTD-031	CTD	-64.977	123.016	Apr 18 2015	108	13:02	cont. slope transit
35	CTD-032	CTD	-64.913	123.999	Apr 18 2015	108	18:51	cont. slope transit
36	CTD-033	CTD	-64.849	125.007	Apr 19 2015	109	18:13	cont. slope transit
37	CTD-034	CTD	-64.750	126.000	Apr 20 2015	110	02:46	cont. slope transit
38	CTD-035	CTD	-64.835	127.001	Apr 20 2015	110	10:34	cont. slope transit
39	CTD-036	CTD	-64.833	128.382	Apr 20 2015	110	18:45	cont. slope transit
40	CTD-037	CTD	-64.861	128.995	Apr 20 2015	110	23:22	cont. slope transit
41	CTD-038	CTD	-65.001	129.784	Apr 21 2015	111	04:06	outer shelf north of Dibble Polynya
42	CTD-039	CTD	-64.666	128.366	Apr 22 2015	112	14:58	repeat BURKE station
43	CTD-040	CTD	-64.450	128.366	Apr 22 2015	112	18:36	repeat BURKE station
44	CTD-041	CTD	-64.048	128.359	Apr 22 2015	112	23:22	repeat BURKE station
45	CTD-042	CTD	-63.634	128.365	Apr 23 2015	113	05:12	repeat BURKE station

C – IDL code for reconstruction of CTD02

IDL code for reconstruction of CTD02 from screenshots (see section 2 for details on this cast):

```
=========================================

pro reconstruct_ctd

  oxy_dir='../oxy'
  sal_dir='../sal'
  temp_dir='../temp'

  ;get filename lists
  spawn, 'find ../oxy -name "*.png" | sort', oxylist
  spawn, 'find ../sal -name "*.png" | sort', sallist
  spawn, 'find ../temp -name "*.png" | sort', temlist
  ;should be 14 in each.

  ;constants....
  ;tem: 845 px = 1.96
  tem1pxupper=1.96D/845.D
  tem1pxlower=1.96D/837.D
  temmin=0.D - (tem1pxupper*86.D)
  temmax=1.96D + (tem1pxupper*126.D)
  ;sal: 951 px = 0.918 PSU
  sal1pxupper=0.918D/951.D
  sal1pxlower=0.918D/942.D
  salmin=33.762D - (sal1pxupper*33.D)
  salmax=34.680D + (sal1pxupper*73.D)
  ;oxy: 845 px = 3.304
  oxy1pxupper=3.304D / 845.D
  oxy1pxlower=3.304D / 837.D
  oxymin=4.13D - (oxy1pxupper*79.D)
  oxymax=7.434D + (oxy1pxupper*133.D)

  ;make some crop limits
  x1upper=47
  x1lower=58
  x2upper=1103
  y1upper=88
  y2upper=822
  numy=y2upper-y1upper
  numxupper=x2upper-x1upper
  numxlower=x2upper-x1lower

  ;y conversions
  ;upper: 100 m in 735 px
  ;lower: 500 m in 735 px
  ytodepthupper=735.D/100.D
  ytodepthlower=735.D/500.D



  ;make space
  oxypngs=bytarr(3, 1135,933,14)
  salpngs=bytarr(3, 1135,933,14)
  tempngs=bytarr(3, 1135,933,14)

  ;read pngs
  for i=0, 13 do begin
    read_png, oxylist[i], tempoxy
    read_png, sallist[i], tempsal
```

```
    read_png, temlist[i], temptem

    ;store for safe keeping
    oxypngs[*,*,*,i]=tempoxy
    salpngs[*,*,*,i]=tempsal
    tempngs[*,*,*,i]=temptem
  endfor

  ;now process...
  ;need mean arrays.
  meanoxyupper=fltarr(numy*5)
  meansalupper=fltarr(numy*5)
  meantemupper=fltarr(numy*5)
  ;do the upper 500m.... indices 0 to 4
  for i=0, 4 do begin
    ;crop
    thisoxy=reform(oxypngs[*,x1upper:x2upper, y1upper:y2upper, i])
    thissal=reform(salpngs[*,x1upper:x2upper, y1upper:y2upper, i])
    thistem=reform(tempngs[*,x1upper:x2upper, y1upper:y2upper, i])

    ;make binary array...
    ;salinity is yellow ffff00
    ;temp is red ff0000
    ;oxy is cyan 00ffff
    bintem=reform(thistem[0,*,*] eq 255 and thistem[1,*,*] eq 0 and$
thistem[2,*,*] eq 0)
    binsal=reform(thissal[0,*,*] eq 255 and thissal[1,*,*] eq 255 and$
thissal[2,*,*] eq 0)
    binoxy=reform(thisoxy[0,*,*] eq 0 and thisoxy[1,*,*] eq 255 and$
thisoxy[2,*,*] eq 255)

    ;now horizontally mean it
    horizvect=indgen(1057)

    for j=0, 733 do begin

      meantemupper[(i)*734+(733-
j)]=(total(bintem[*,j]*horizvect)/$(n_elements(where(bintem[*,j] ne
0))))*tem1pxupper+temmin
      meanoxyupper[(i)*734+(733-
j)]=(total(binoxy[*,j]*horizvect)/$(n_elements(where(binoxy[*,j] ne
0))))*oxy1pxupper+oxymin
      meansalupper[(i)*734+(733-
j)]=(total(binsal[*,j]*horizvect)/$(n_elements(where(binsal[*,j] ne
0))))*sal1pxupper+salmin

    endfor

  endfor
  ;now make a median array... 5 point should work
  medtemupper7=median(meantemupper,7)
  medoxyupper7=median(meanoxyupper,7)
  medsalupper7=median(meansalupper,7)
  medtemupper19=median(meantemupper,19)
  medoxyupper19=median(meanoxyupper,19)
  medsalupper19=median(meansalupper,19)

  ;fill in the gaps
  temzeros=where(meantemupper eq float(temmin))
  salzeros=where(meansalupper eq float(salmin))
  oxyzeros=where(meanoxyupper eq float(oxymin))

  firstdisjoint=temzeros[0:2]
  meantemupper[firstdisjoint]=medtemupper7[firstdisjoint]
```

```
  meanoxyupper[firstdisjoint]=medoxyupper7[firstdisjoint]
  meansalupper[firstdisjoint]=medsalupper7[firstdisjoint]

  otherdisjoints=temzeros[3:26]
  meantemupper[otherdisjoints]=medtemupper19[otherdisjoints]
  meanoxyupper[otherdisjoints]=medoxyupper19[otherdisjoints]
  meansalupper[otherdisjoints]=medsalupper19[otherdisjoints]

  ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
  ;now let's go deeper... 500 to 4500.
  ;make space....
  ;735 per 100m.... we have 4500,.... so...
  meantemall=fltarr(735L*45)
  meansalall=fltarr(735L*45)
  meanoxyall=fltarr(735L*45)
  meantemall[0:3669]=meantemupper
  meansalall[0:3669]=meansalupper
  meanoxyall[0:3669]=meanoxyupper


  meanoxylower=fltarr(numy*8)
  meansallower=fltarr(numy*8)
  meantemlower=fltarr(numy*8)
  for i=0, 7 do begin
    ;crop
    thisoxy=reform(oxypngs[*,x1lower:x2upper, y1upper:y2upper, i+6])
    thissal=reform(salpngs[*,x1lower:x2upper, y1upper:y2upper, i+6])
    thistem=reform(tempngs[*,x1lower:x2upper, y1upper:y2upper, i+6])

    ;make binary array...
    ;salinity is yellow ffff00
    ;temp is red ff0000
    ;oxy is cyan 00ffff
    bintem=reform(thistem[0,*,*] eq 255 and thistem[1,*,*] eq 0 and$
thistem[2,*,*] eq 0)
    binsal=reform(thissal[0,*,*] eq 255 and thissal[1,*,*] eq 255 and$
thissal[2,*,*] eq 0)
    binoxy=reform(thisoxy[0,*,*] eq 0 and thisoxy[1,*,*] eq 255 and$
thisoxy[2,*,*] eq 255)
    ;now horizontally mean it
    horizvect=indgen(1046)

    for j=0, 733 do begin

      meantemlower[(i)*734+(733-
j)]=(total(bintem[*,j]*horizvect)/$(n_elements(where(bintem[*,j] ne
0))))*tem1pxlower+temmin
      meanoxylower[(i)*734+(733-
j)]=(total(binoxy[*,j]*horizvect)/$(n_elements(where(binoxy[*,j] ne
0))))*oxy1pxlower+oxymin
      meansallower[(i)*734+(733-
j)]=(total(binsal[*,j]*horizvect)/$(n_elements(where(binsal[*,j] ne
0))))*sal1pxlower+salmin

    endfor


  endfor

  ;work up some medians again... 5 points should be fine now.
  medtemlower5=median(meantemlower,5)
  medoxylower5=median(meanoxylower,5)
  medsallower5=median(meansallower,5)
```

```
  ;fill in the gaps
  temzeros=where(meantemlower eq float(temmin))
  salzeros=where(meansallower eq float(salmin))
  oxyzeros=where(meanoxylower eq float(oxymin))

  numtem0s=3
  numoxy0s=3
  numsalzeros=6

  temzeros=temzeros[0:2]
  salzeros=salzeros[0:5]
  oxyzeros=oxyzeros[0:2]

  meantemlower[temzeros]=medtemlower5[temzeros]
  meansallower[salzeros]=medsallower5[salzeros]
  meanoxylower[oxyzeros]=medoxylower5[oxyzeros]

  ;now put lower into all.
  for i=0, 5871 do begin
    meantemall[3670L+(i*5L):3674L+(i*5L)]=meantemlower[i]
    meanoxyall[3670L+(i*5L):3674L+(i*5L)]=meanoxylower[i]
    meansalall[3670L+(i*5L):3674L+(i*5L)]=meansallower[i]
  endfor

  ;plug that last gap
  meantemall[3666:3668]=meantemall[3669]
  meansalall[3666:3668]=meansalall[3669]
  meanoxyall[3666:3668]=meanoxyall[3669]

  ;and truncate
  meantemall=meantemall[0:32318]
  meansalall=meansalall[0:32318]
  meanoxyall=meanoxyall[0:32318]

  ;convert y to depth now...
  y=lindgen(32319)
  depth=y/double(ytodepthupper)

  ;write it all out.
  openw, lun, 'CTD002_reconstructed.txt', /get_lun
  printf, lun, "Depth(m) Temperature Salinity Oxygen"
  for i=0L, 32318L do begin
      printf, lun, strtrim(depth[i],2)+" ``+strtrim(meantemall[i],2)+$"
"+strtrim(meansalall[i],2)+" "+strtrim(meanoxyall[i],2)
  endfor
  free_lun, lun

  stop

end
```