CRUISE REPORT: MSM42

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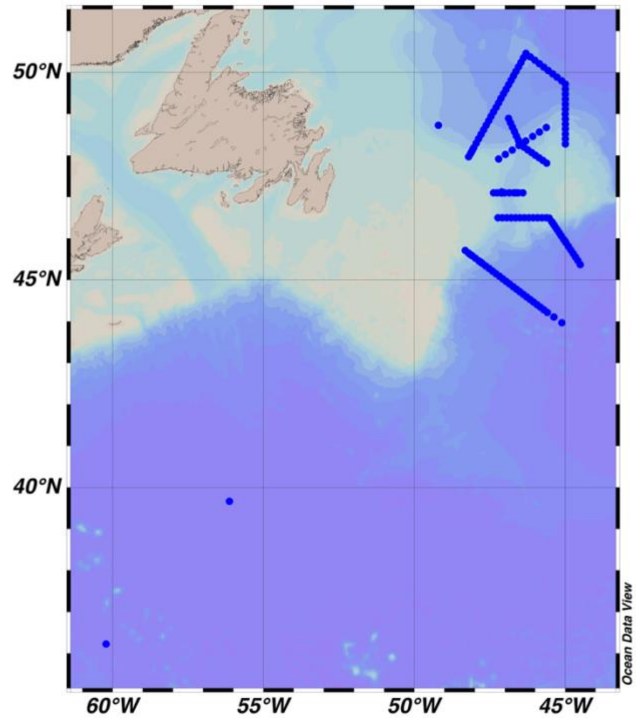

Highlights

Cruise Summary Information

Section Designation	N/A
Expedition Designation (ExpoCode)	06M220150502
Chief Scientists	**Dagmar Kieke, IUPHB/MARUM**
Dates	5 May – 22 May 2015
Ship	R/V *MARIA S. MERIAN*
Ports of Call	Ireland Island, Bermuda – St. Johns, Canada
Geographic Boundaries	50.46°N 60.22°W 44.5°W 36.23°N
Stations	146 [Bottle]
Floats and Drifters Deployed	0
Moorings Deployed and Recovered	1 deployed

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Maria S. Merian-Berichte

FLEPVAR 2015 (Variability in Flemish Pass)

Cruise No. MSM42

May 2 – May 22, 2015,
Bermuda – St. John’s (Canada)

D. Kieke, R. Barbosa Primon, K. Bulsiewicz, C. Gjerdrum, K. Jochumsen, J. Meyerjürgens, M. Moritz, V. Müller, C. Rieper, A. Rochner, P. Sültenfuß, L. Tiemann, E. Varotsou, A. Welsch, S. Wett, K. Wiegand, J. Winkel, F. Wischnewski

Editorial Assistance:

DFG-Senatskommission für Ozeanographie
MARUM – Zentrum für Marine Umweltwissenschaften der Universität Bremen

2016

The MARIA S. MERIAN-Berichte are published at irregular intervals. They are working papers for people who are occupied with the respective expedition and are intended as reports for the funding institutions. The opinions expressed in the MARIA S. MERIAN-Berichte are only those of the authors.

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Table of Contents

1 Summary

Cruise MSM42 with RV MARIA S. MERIAN dealt with investigating the recent changes in the water mass structure and the oceanic circulation system in a narrow region focusing on the vicinity of Flemish Pass and Flemish Cap located at the western edge of the subpolar North Atlantic. Several densely spaced hydrographic sections were carried out across major pathways associated with the southward export of Labrador Sea Water (LSW), one of the important water masses that contribute to the cold and deep limb of the Atlantic Meridional Overturning Circulation (AMOC). Particular focus was on the LSW export through Flemish Pass, a meridional underwater passage located at about 47°W having a sill depth of about 1200 m. There, a deep-sea mooring (*BM-25/3*) carrying an Acoustic Doppler Current Profiler (ADCP) of type *Long Ranger*, capable to record the current velocity over a vertical distance of about 600 m, was successfully deployed. Work at hydrographic stations included conductivity-temperature-depth/oxygen (CTD/O) profiling and analysis of water samples to calibrate the corresponding conductivity and oxygen sensors. Furthermore, water samples were taken at selected stations and measured on board with respect to analyzing the oceanic content of anthropogenic tracers such as sulphurhexafluoride (SF_6) and chlorofluorocarbon (component CFC-12) throughout the water column. Continuous and station-based data of the oceanic velocity field was obtained from lowered and vessel-mounted ADCP devices. Weather conditions were most of the time quite fair, sea ice or any icebergs were absent. Including two test-stations, 160 CTD/O- and ADCP-stations have been carried out in total, delivering a valuable high-quality set of physical oceanographic data.

Zusammenfassung

Die Reise MSM42 mit FS MARIA S. MERIAN befasste sich mit der Untersuchung der jüngsten Änderungen in der Wassermassenstruktur und der ozeanischen Zirkulation in einer enggefassten Region rundum die Flämische Passage und die Flämische Kappe, die sich beide am Westrand des subpolaren Nordatlantiks befinden. Es wurden mehrere hoch aufgelöste hydrographische Schnitte über die Hauptpfade ausgeführt, die mit dem südwärtigen Export von Labradorseewasser (LSW) assoziiert werden, eine der wichtigen Wassermassen, die zum tiefen kalten Zweig der Atlantischen Meridionalen Umwälzzelle (AMOC) beiträgt. Ein Schwerpunkt lag auf dem LSW-Export durch die Flämische Passage, einer meridionalen Unterwasserpassage mit einer Schwellentiefe von ca. 1200 m, die sich bei ca. 47°W befindet. Dort wurde eine Tiefsee-Verankerung (*BM-25/3*), die mit einem akustischen Doppler-Profilstrommesser (ADCP) vom Typ *Long Ranger* ausgestattet ist, erfolgreich ausgelegt. Dieser ist in der Lage, die Strömungsgeschwindigkeit über eine vertikale Distanz von ca. 600 m zu messen. Arbeiten auf den hydrographischen Stationen beinhalteten Leitfähigkeit-Temperatur-Druck/Sauerstoff-Profil-Arbeiten (CTD/O) und die Analyse von Wasserproben, um die Leitfähigkeits- und Sauerstoff-Sensoren zu kalibrieren. Des Weiteren wurden auf ausgewählten Stationen Wasserproben für die Anbordmessung und Analyse des ozeanischen Gehaltes an anthropogenen Spurenstoffen genommen (Sulphurhexafluorid, SF_6, und Fluorchlorkohlenstoff, Komponente CFC-12). Kontinuierliche und stationsbezogenen Daten des ozeanischen Geschwindigkeitsfeldes wurden mit gefierten und schiffsgebundenen ADCPs ermittelt. Die Wetterbedingungen waren die meiste Zeit über recht gutartig. Meereis oder Eisberge wurden nicht gesichtet. Inklusive von zwei Test-

Stationen wurden insgesamt 160 CTD/O- und ADCP-Stationen durchgeführt, die einen wertvollen hochqualitativen Satz an physikalisch-ozeanographischen Daten erbracht haben.

2 Participants

Name	Discipline	Institution
Kieke, Dagmar, Dr.	chief scientist	IUPHB/MARUM
Barbosa Primon, Rafael	CTDO/LADCP watch, data analysis	IFMHH
Bulsiewicz, Klaus	tracer sampling & analysis	IUPHB
Jochumsen, Kerstin, Dr.	CTDO data processing, calibration, analysis	IFMHH
Meyerjürgens, Jens	tracer sampling	IUPHB
Moritz, Martin	oxygen titration and analysis	IFMHH
Müller, Vasco	LADCP data processing & analysis	MARUM
Rieper, Christoph	CTDO/LADCP watch & oxygen titration	IFMHH
Rochner, Andrea	CTDO/LADCP watch	IFMHH
Sültenfuß, Pia	tracer sampling	IUPHB
Tiemann, Louisa	CTDO/LADCP watch	IFMHH
Varotsou, Eirini	salinometry, data analysis	IFMHH
Welsch, Andreas	technics & salinometry	IFMHH
Wett, Simon	CTDO/LADCP watch	IFMHH
Wiegand, Kevin	CTDO/LADCP watch	IFMHH
Winkel, Jeannine	bird observations	CWS
Wischnewski, Fanny	CTDO/LADCP watch	IUPHB

CWS	Canadian Wildlife Service, Dartmouth, Canada
IFMHH	University of Hamburg, Institute of Oceanography, Dep. Experimental Oceanography, Hamburg, Germany
IUPHB	University of Bremen, Institute of Environmental Physics, Dep. Oceanography, Bremen, Germany
MARUM	University of Bremen, Center for Marine Environmental Sciences, Bremen, Germany

3 Research Program

Physical oceanographic measurements conducted during cruise MSM42 contributed to the scientific project "FLEPVAR", funded by the *German Science Foundation* (DFG). Tracer measurements were carried out as part of the cooperative research project "RACE", sub-project 1.2, funded by the *Federal Ministry of Education and Research* (BMBF). Focus was on investigating the pathways of North Atlantic Deep Water (NADW) in the vicinity of Flemish Cap, a topographic obstacle centered at 48°N, 45°W at the western rim of the subpolar North Atlantic. This obstacle divides the Deep Western Boundary Current (DWBC) into two branches. The shallow branch enters Flemish Pass (sill depth of 1200 m) located to the west of the cap and limits any southward NADW export to its lightest component, the Labrador Sea Water (LSW).

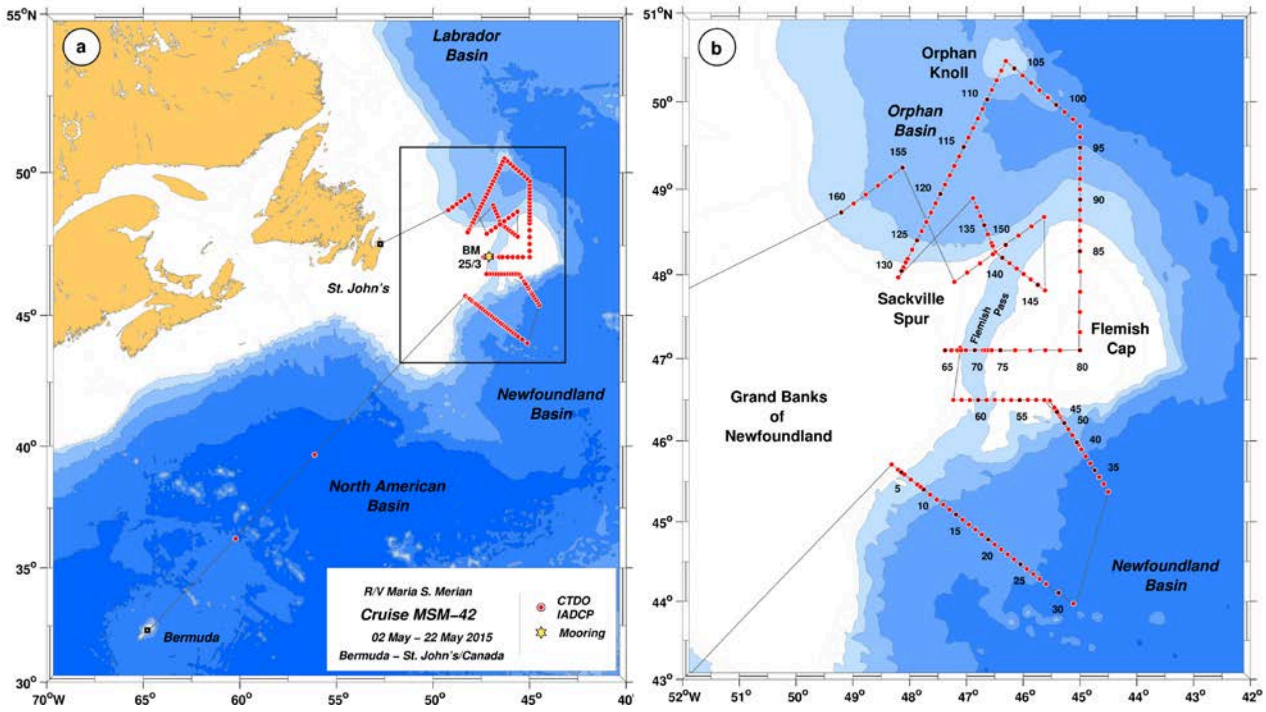

Fig. 3.1 Track chart of R/V MARIA S. MERIAN cruise MSM42. Numbers indicate hydrographic profiles.

The second but deeper branch detours to the east around Flemish Cap and carries all NADW components including LSW and the denser overflow waters towards the south. The primary objectives of cruise MSM42 were:

1. to assess the strength of the southward deepwater transport in the boundary current system near Flemish Cap and to compare it to the export observed in Flemish Pass as well as to estimates from previous surveys. Particular focus was on the LSW, one of the major NADW components;

2. to investigate the physical mechanisms that govern the inflow of LSW into Flemish Pass near Sackville Spur, a topographic protrusion located at the northern entrance of Flemish Pass. The pass constitutes a shortcut allowing parts of LSW to be exported southwards on a more direct and undisturbed pathway compared to the detour around Flemish Cap, where the DWBC may interact with the northbound and saline North Atlantic Current (NAC);

3. to analyze the spatial and temporal variability of the exported deep water components and to put this into relation to either local or to remote forcing mechanisms;

4. to infer the persistency of so far observed trends regarding warming and salinification of the LSW.

Scientific tools comprised profiling of the entire water column using a Conductivity-Temperature-Depth/Oxygen (CTD/O) unit and two lowered Acoustic Doppler Current Profilers (LADCP) attached to the carousel water sampler. Tracer measurements consisted of analyzing oceanic concentrations of chlorofluorocarbon-12 (CFC-12) and sulphur hexafluoride (SF_6), with high concentrations marking young or newly formed NADW in the deep ocean. Vessel-mounted ADCP measurements delivered velocity data of the upper water column while transiting across the working area.

4 Narrative of the Cruise

RV MARIA S. MERIAN left the pier at Dockyard, Ireland Island, Bermuda on May 02nd, 2015, at 11:24 UTC. The scientific mission of cruise MSM42 started at 13:00 UTC the same day after having passed the pilot station. Continuous logging of underway data (thermosalinograph, vessel-mounted Acoustic Doppler Current Profilers (ADCP) operated at 38 kHz and 75 kHz, and multibeam echo-sounding) was switched on at 03:00 UTC on May 03rd, when the border of the Exclusive Economic Zone (EEZ) of Bermuda was crossed. Course was set to northeast towards the southern flank of the Grand Banks of Newfoundland.

While on the way towards the Grand Banks two test stations were carried out on May 03rd (#050/001) and May 04th (#051/002), with the purpose to check the performance of the CTDO unit and the two LADCP devices attached to the carousel water sampler. First water samples were drawn for the gas-chromatographic analytical tracer system and for sensor calibration regarding dissolved oxygen and conductivity.

Scientific station work began on May 06th, 2015, 09:53 UTC, when the first hydrographic section crossing the boundary current system in the Newfoundland Basin was carried out (station distances of 6 nm[1], stations #052/003 to #080/031). Station work included profiling of the entire water column with the CTD/O and LADCP units attached to the carousel water sampler as well as water sampling and subsequent analysis in the laboratories. Having finished this section on May 09th, RV MARIA S. MERIAN was in transit for about 88 nm towards 45°22'N/44°30'W. From there she approached the southern flank of Flemish Cap to perform a second hydrographic section at similar high-resolution across the boundary current system southeast of Flemish Cap (stations #081/032-#100/051, finished on May 11th). This was followed by a hydrographic section directed towards west that crossed the southern exit of Flemish Pass at the latitude of 46°30'N (stations #101/052 to #112/063, finished on May 12th).

After a short transit of about 40 nm towards north, mooring *BM-25/3* was installed at 47°07.11'N, 47°06.38'W at the western side of Flemish Pass on May 12th. Afterwards, RV MARIA S. MERIAN headed eastwards along 47°06'N and crossed Flemish Pass and Flemish Cap, thereby performing hydrographic stations that were carried out without any water sampling while on the shallow top of the cap (stations #114/065 to #130/080, finished on May 13th).

Having reached the longitude of 45°W on top of Flemish Cap, another high-resolution section was conducted towards north along 45°W, which was later on shifted towards northwest to end on top of Orphan Knoll (stations #131/081 to #156/106, finished on May 16th). RV MARIA S. MERIAN subsequently crossed the Orphan Basin towards the southeast and reached the shelf break at 47°58'N, 48°12'W on May 18th (stations #157/107 to #181/131). Between May 18th and May 20th a number of short hydrographic sections were run across the northern Flemish Pass and across as well as along Sackville Spur at the northern entrance of Flemish Pass (stations

1 nm = nautical mile

#182/131 to #204/154). On May 20th, RV MARIA S. MERIAN headed northwest towards 49°15'N, 48°07'W in the central Orphan Basin to carry out a final hydrographic section that led in southwestern direction towards the shelf break (station distances of 11 nm, stations #205/155 to #210/160). Scientific station work was finished at 48°43.9'N, 49°12.2°W on May 21st, 16:50 UTC, and RV MARIA S. MERIAN started her westward transit towards St. John's, Canada. Continuous logging of underway data was stopped on May 22nd, 01:00 UTC. The same day at 09:30 UTC, the scientific mission MSM42 of RV MARIA S. MERIAN ended. The vessel arrived at the pilot station of St. John's at 09:58 UTC and was finally towed at pier 17 at 11:30 UTC. In total, 160 hydrographic stations were carried out during cruise MSM42. Weather conditions during the cruise were surprisingly comfortable for most of the time. Station work in the Newfoundland Basin proper was affected by higher sea states and swell from different directions. Dense fog prevailed over the period May 18th to May 21st.

5 Preliminary Results

5.1 CTD/O Measurements and Sensor Calibration

5.1.1 CTD/O System and Performance

(K. Jochumsen, M. Moritz, E. Varotsou, A. Welsch)

Conductivity-temperature-depth-oxygen (CTD/O) profiles were obtained with a *Sea-Bird Electronics* (SBE) 9plus, integrating a pressure sensor with a digiquarz unit. For temperature and conductivity/salinity measurements, a double sensor pack was used. Additionally, a dissolved oxygen sensor was attached to the CTD. The instrument distance above the sea floor was derived from a *Benthos* altimeter working at a frequency of 200 kHz, which was lowered with the CTD. An alarm was furthermore active from a mechanical alert system using a weight when the distance from the bottom was below 10 m. All operating devices of the CTD/O-system are listed in Table 5.1.

Instrument	**Serial Number**	**Property of**
SBE 9plus	09p26816-0657	University of Bremen
pressure sensor	0657	University of Bremen
SBE3 (primary temperature sensor)	4145	University of Bremen
SBE3 (secondary temperature sensor)	4022	University of Hamburg
SBE43 (primary oxygen sensor)	0267	University of Bremen
SBE4 (primary conductivity)	2643	University of Bremen
SBE4 (secondary conductivity)	2433	University of Hamburg
SBE5 (primary pump)	0532	University of Bremen
SBE5 (secondary pump)	3275	University of Hamburg
Altimeter (*Benthos* PSA-916, 200 kHz)	44189	University of Bremen
Altimeter (*Benthos* PSA-916, 200 kHz)	1187	RV Maria S. Merian
Mechanical bottom alert	-	University of Bremen

Tab. 5.1 CTD/O devices used during cruise MSM42.

The CTD/O instrument was attached to a metal rosette frame, holding a 24-bottle-carousel water sampling system with 10l *Niskin* bottles and stainless steel springs. A configuration with 22 bottles was used to obtain water samples from selected depth levels, as two bottles were removed to attach a lowered ADCP system. In the laboratory, the data from the CTD cast was converted by an *SBE 11 plus deckunit* (V5.1c, s/n 11p26816-0598), and recorded with a standard "*MS Windows 7*" PC, using the *Seasave* software (V 7.23.2). The conductivity signal of both sensor packs was automatically advanced in time by the deckunit with a setting of 0.073 s, therefore only a minor misalignment of the sensors remained (except for oxygen). The processing and conversion of the raw data was done with the *SBE Data Processing* program package (V 7.23.2). For calibration the MATLAB program package *GEOMAR CTD Processing V0.29* was applied.

The altimeter was found to malfunction at station #092/042. After removal of the instrument, a service check revealed water intrusions into the body of the device. The instrument was dried, cleaned, and the leakage was fixed. However, a test at station #129/079 was unsuccessful; the instrument still did not work properly. The altimeter was thus exchanged before station #130/080 by an altimeter of the same type supplied by the ship's staff. This device worked well for the remaining stations of the cruise.

The CTD-water sampler system was used for 160 casts, which were generally conducted from the surface to 10 m above the bottom of the ocean (see station list). The downcast of the primary sensor pack was chosen as the final dataset as 1) sensor hysteresis starts from a well-defined point; 2) the incoming flow is not perturbed by turbulence generated by the CTD-water sampler package and 3) the primary sensor pack corresponds better to the oxygen measurements, which were obtained from the pump system. Only for station #200/150 the secondary sensor pack was used in the final data set, as the conductivity record of the primary sensor contained a prominent spike in the downcast data, probably caused by biological particles pumped through the system.

5.1.2 CTD/O Sensor Calibration

Conductivity/Salinity

Date	Batch	K15 value	Samples from Profiles
08 May 2015	P155	0.99981	004-016 / MSM-053 – 065
10 May 2015	P155	0.99981	017-030 / MSM-066 – 079
12 May 2015	P155	0.99981	030-049 / MSM-079 – 098
13 May 2015	P155	0.99981	050-058 / MSM-099 – 107
14 May 2015	P155	0.99981	060-072 / MSM-109 – 122
16 May 2015	P155	0.99981	073-095 / MSM-123 – 145
17 May 2015	P155	0.99981	095-108 / MSM-145 – 158
18 May 2015	P155	0.99981	108-128 / MSM-158 – 178
20 May 2015	P155	0.99981	128-141 / MSM-178 – 191
21 May 2015	P155	0.99981	142-150 / MSM-192 – 200

Tab. 5.2 Standard seawater specifications and salinometer sessions for cruise MSM42.

For the calibration of the conductivity cells the CTD data was compared with salinity measurements from the bottle samples, which were obtained by a *Guildline* salinometer of type *Autosal 8400A* (s/n 59.083), provided by the University of Hamburg. Calibration during operation was done using IAPSO standard seawater, which was measured at the beginning and end of the salinometer use each day. The salinometer sessions and specifications of the standard seawater used are summarized in Table 5.2.

The salinometer data showed trends below 0.001 in salinity for half a day in operation, which were removed from the measured salinity samples. The two sensors showed a persistent offset from each other (Fig. 5.1), which was removed during the calibration process. The conductivity calibration of the downcast data was performed using a linear fit with respect to conductivity, temperature, and pressure:

C_corrected_primary = C_observed - 0.015385 + 2.9273e-07*P + 0.00057843*T - 0.0054682*C
C_corrected_secondary = C_observed - 0.013528 + 1.7059e-07*P + 0.0004081*T - 0.004571*C

Using 67% of the 407 samples for calibration an r.m.s. of 7.7e-005 S/m was found for the downcast of the primary sensor and of 7.4e-05 S/m for the secondary sensor. The resulting accuracy for salinity is ±0.001 psu, giving a density uncertainty of ±0.001 kgm^{-3}.

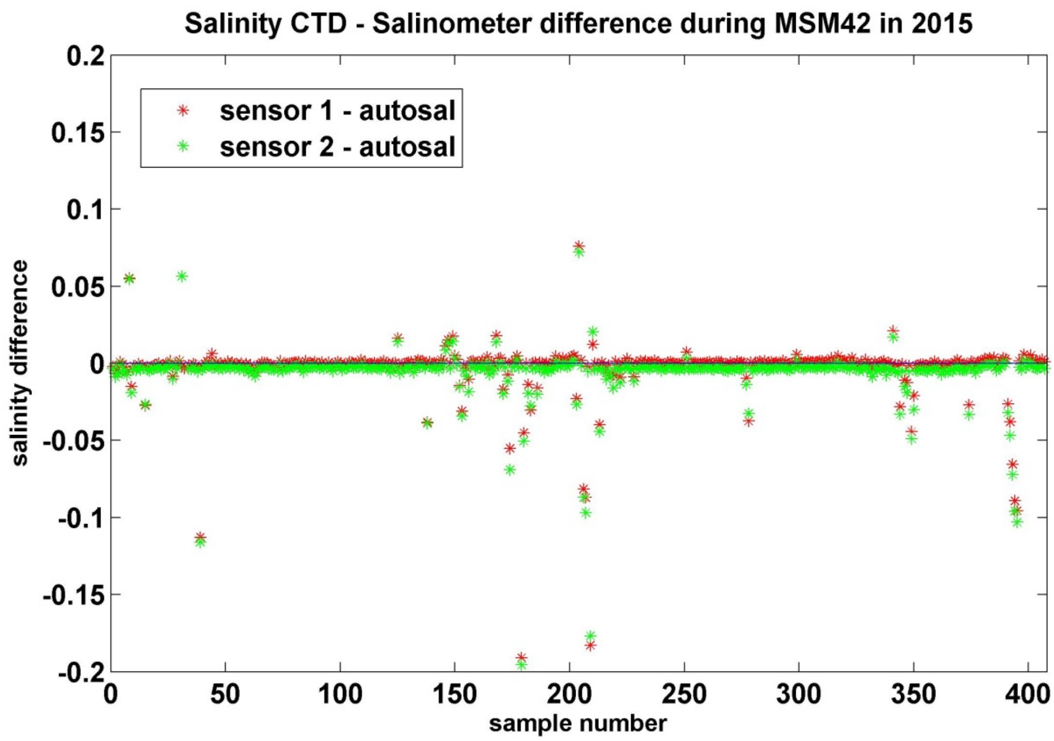

Fig. 5.1 Difference in salinity between each sensor and the salinometer results. Large differences result from sampling at shallow depth levels; these outliers were removed prior to the calibration process.

<u>Oxygen</u>

To calibrate the SBE dissolved oxygen sensor bottle samples were collected and oxygen concentration was measured in the laboratory using the Winkler titration method. Generally four samples per station deeper than 1000 m and three samples at shallower stations were taken. In total 545 samples were titrated in the period from 5th of May to 20th of Mayy 2015, including 121 double samples that were used for a quality and stability estimates of the sampling and titration procedure.

During sampling the flasks were filled carefully from the bottom using a silicone tube and letting the water overflow approx. three times the flask volume. Directly after sampling the oxygen was fixed by adding 0.5 ml of Manganese(II)Chloride ($MnCl_2$) and 0.5 ml of alkaline solution (NaOH+KI). The sample bottles were then shaken and stored at a dark location. After adding 1 ml of 50% sulfuric acid (H_2SO_3) the samples were titrated using the automated *Metrohm 848 Titrino Plus* system (s/n 10304277) equipped with a *Metrohm Pt Titrode* (s/n 01290932) and set to a *Dynamic Equivalence* Method. The titration was done within 12 hours from when the samples were taken. The concentration of oxygen was calculated from the volume of thiosulfate that was needed to reach the endpoint.

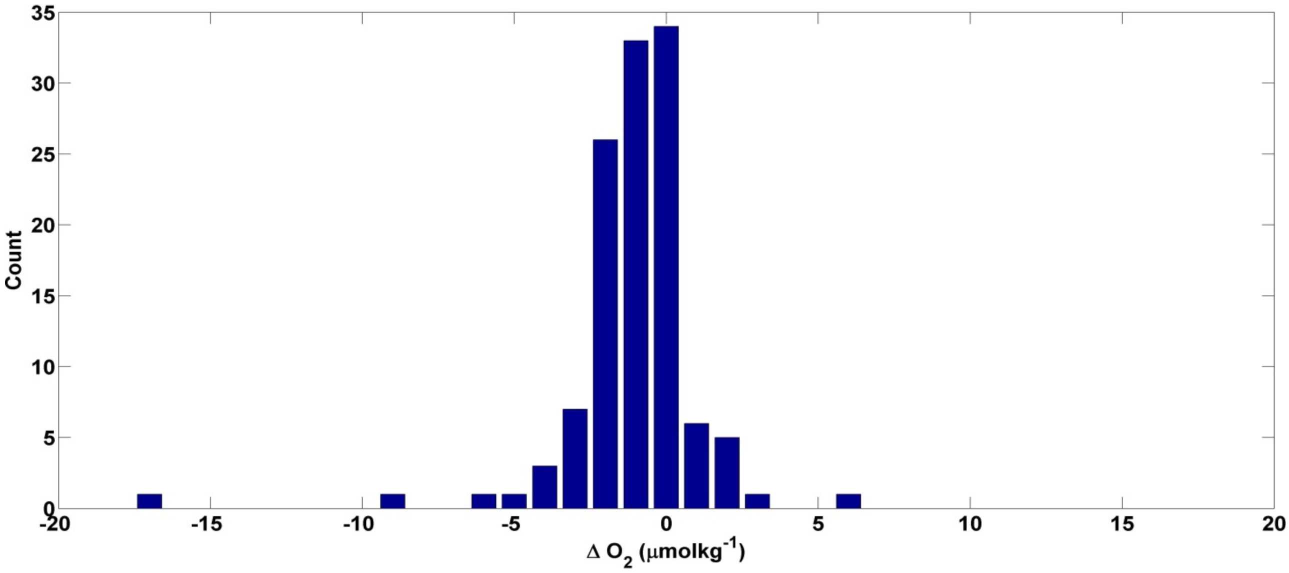

Fig. 5.2 Histogram of oxygen concentration differences between double samples. The mean difference from 121 double samples is -0.55±2.3 μmol kg^{-1}.

The sodium thiosulfate solution ($Na_2S_2O_3$) with a concentration of 0.01 N was prepared from ready-made *Merck Titrisol* ampoules (Ref. Num. 1.09950.0001). The concentration of thiosulfate solutions was checked on a daily basis and whenever a new thiosulfate solution was prepared. For the standard 1 ml of potassium iodad solution (KIO_3) with a concentration of 0.1 N was added to 100 ml of pure water. This solution was prepared from ready-made *Merck Titrisol* ampoules (Ref. Num 1.09917.0001). Then 1 ml of 50% sulfuric acid and 5 ml of 10% potassium iodid (KI) solution were added. The titration was run and the volume of consumed thiosulfate noted. This procedure was repeated three times and the final titer factor was calculated by dividing 10 ml, which would be theoretically needed to titrate 1 ml of KIO_3 (0.1 N), by the mean volume of consumed thiosulfate. The concentration of the thiosulfate solution was 8 out of 16 times (50%) different from the nominal concentration (0.01 N). The average relative difference from the nominal concentration amounts 1 %. The relative error of the oxygen analysis obtained from the double samples (*Fig. 5.2*) was 0.51 %.

The calibration of the oxygen sensor attached to the CTD/O system was performed for the downcast data, using a fit with respect to pressure, temperature, and oxygen content:

$$O\_corrected = O\_observed - 31.0685 + 0.0021262*P + 0.083664*T + 0.30339*O - 0.00049379*O^2$$

The method is similar to the conductivity calibration described above. Using 67% of the 424 samples for calibration an r.m.s. of 1.3 µmol/kg was found for the sensor after the correction had been applied.

The following figures exemplarily show salinity and oxygen distributions derived from CTD/O measurements for the section crossing Flemish Pass at 47°N (Fig. 5.3) and for the section running from the shelf break in the Orphan Basin towards the top of Orphan Knoll (Fig. 5.4). Upper Labrador Sea Water (ULSW) is found at intermediate depths (σ_θ = [27.68-27.74] kg/m^3), and the most undiluted variety is tagged by the freshest salinities coinciding with the highest oxygen contents.

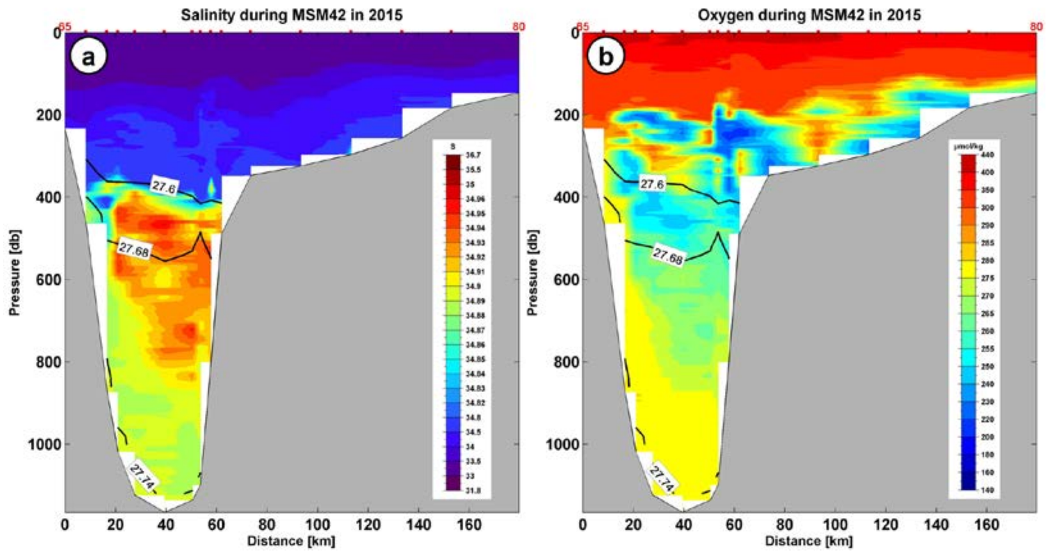

Fig. 5.3 Salinity and dissolved oxygen [µmol/kg] as observed in Flemish Pass at 47°N during cruise MSM42.

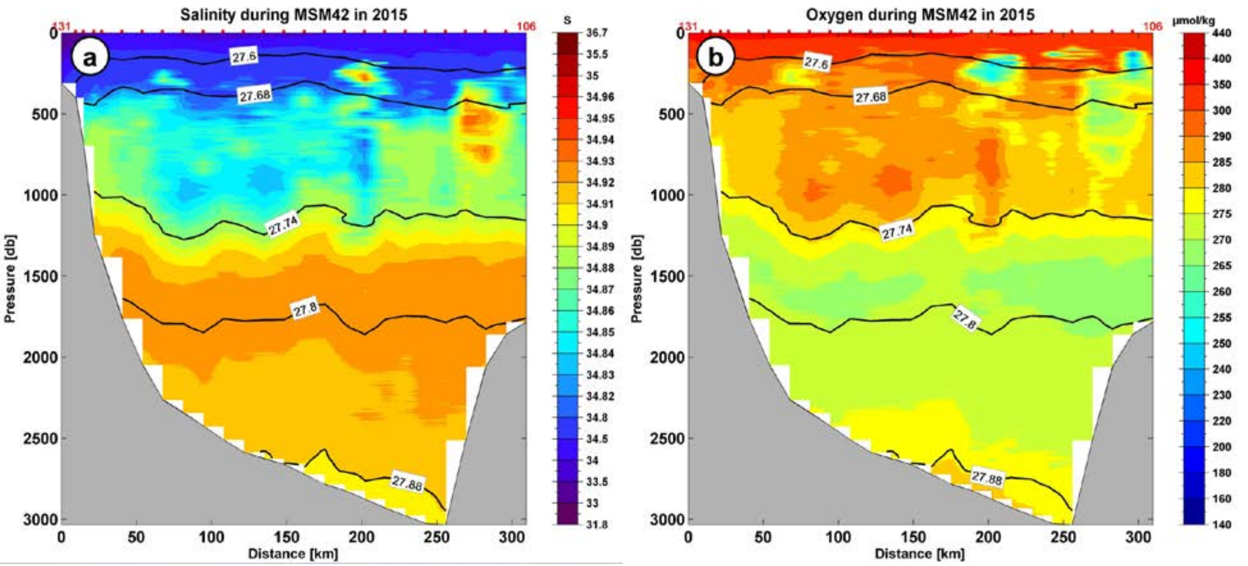

Fig. 5.4 Salinity and dissolved oxygen [µmol/kg] as observed along the section connecting the shelf break in the Orphan Basin with the top of Orphan Knoll, see Figure 3.1 for location of the sections.

5.2 Sampling and Analysis of Transient Tracers

(K. Bulsiewicz, D. Kieke)

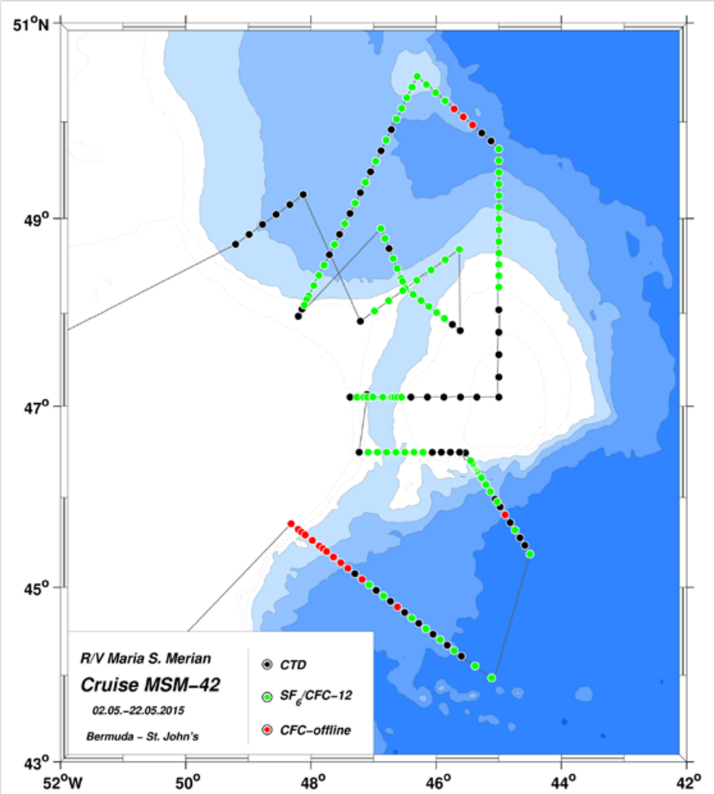

Fig. 5.5 Location of hydrographic stations with SF_6/CFC12-sampling (green dots) as well as CFC-offline sampling and subsequent sample storage (red dots), cruise MSM42. Black dots denote CTD/O stations without any tracer sampling.

During cruise MSM42 an analytical technique for simultaneous measurements of the trace gases sulphur hexafluoride (SF_6) and the chlorofluorocarbon component CFC-12 in water and air was used. The determination of the two compounds was performed by analysis through gas-chromatography with micro electron capture detection (µECD).

Throughout the cruise water-samples were tapped from 10 l Niskin bottles and collected in 200 ml glass ampoules. 140 ml of this water were transferred to a water purge chamber. After purging of the water, the compounds were trapped in a 1/8" large ID *Porapak-Q* trap. After thermal desorption sample gases held in the trap were flushed onto a *MS5A* pre-column, where SF_6 and CFC-12 were separated from nitrous oxide and any other late eluting gases. The compounds were refocused then on a 1/16" trap packed with *Porapak-Q* to narrow their chromatographic peaks and enhance their detection. After thermal desorption the released gases were separated on a pre-column of type *Alumina Bond/CFC, 0.54mm ID x 3m* and a main column of type *Alumina BOND/CFC, 0.54 mm ID x 30 m*. SF_6 and CFC-12 were then detected on a µECD.

Altogether 701 water-samples were taken on 96 stations (Fig. 5.5), and sampling levels were chosen to cover the entire water column from top to bottom (Fig. 5.6). Based on the analysis of replicate water samples, we estimate precisions ~0.7% for measurements of SF_6 and ~ 0.4 % for CFC-12. The overall accuracy for tracer measurements during cruise MSM42 is ~3% for SF_6 and

~1.6% for CFC-12. The detection limit is 0.01 fmol/kg for SF_6 and 0.002 pmol/kg for CFC-12. Concentrations of SF_6 and CFC-12 in air, seawater samples, and gas standards are reported on the *SIO-98* scale. Gas standards were prepared and calibrated by B. Hall at CMDL, Boulder, Colorado.

At the beginning of the cruise, there were some problems with the electronics of the machine and an unidentified peak, which interfered with the SF_6 signal. Several parts of the machine had to be changed after station #097/048. After that, the data of the SF_6 and CFC-12 measurements looked well.

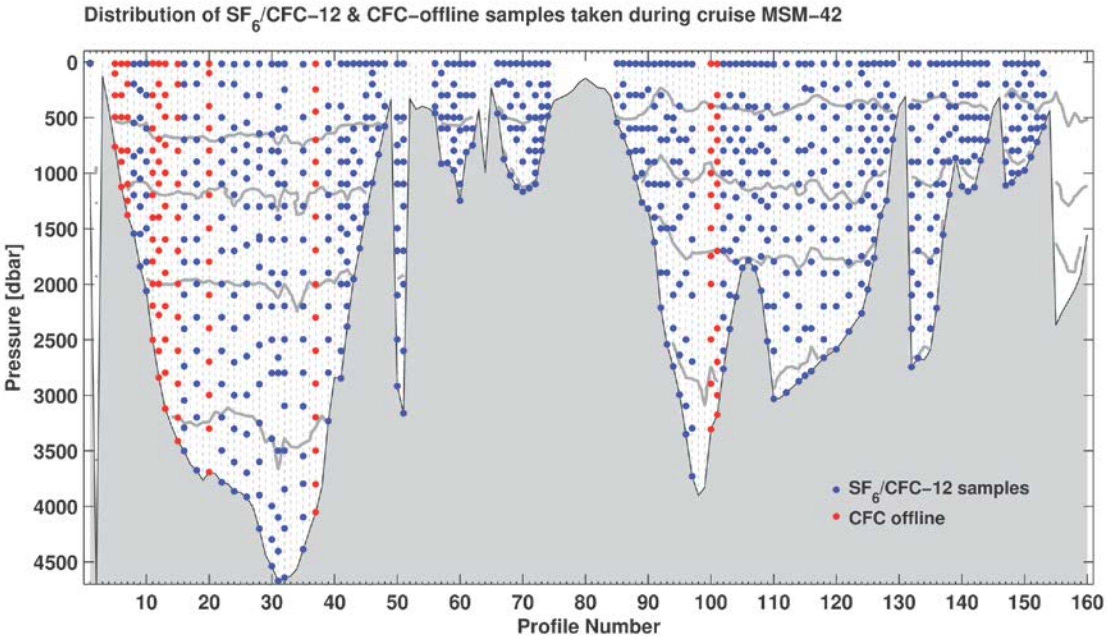

Fig. 5.6 Depths chosen for tracer sampling with respect to SF_6 and CFC components. Grey contours denote the isopycnals σ_θ = [27.68, 27.74, 27.80, 27.88] kg/m^3, from top to bottom.

At selected stations, especially in the beginning of the cruise, when the gas-chromatographic analytical system showed a decreased performance, so-called offline tracer samples were taken from the Niskin bottles, with the intention to analyze the content of the chlorofluorocarbon components CFC-12 and CFC-11 in seawater at the home laboratory in Bremen.

Tracer sampling comprises a volume of ~90 ml of seawater that is collected in so-called flow-through containers. These consist of a glass ampoule connected to a head which carries a movable central and a fixed side tubing. CFCs behave similar to inert gases and have a low solubility. Any contact to the atmosphere must therefore be avoided to prevent any contamination of the water sample and input of air as the containers are detached from the *Niskin* bottles. Preparing the samples for storage requires the insertion of CFC-free purified nitrogen into the glass ampoule. Consequently, a head space is created which is required to accommodate the thermal expansion of the included seawater sample. Afterwards, the glass ampoule is flame-sealed by closing the open end of the ampoule with a burner fueled with propane gas. After finishing the flame-sealing process and allowing time for cooling of the sealed glass, the remaining glass piece is stuck on the labeled glass ampoule. Together with the precise dead weight of the glass ampoule which was carefully determined earlier in the Bremen laboratory, knowledge of the total weight of the flame-sealed glass ampoule is necessary for determining CFC concentrations later on.

The data set collected during cruise MSM42 will be used to further extend in time existing tracer time series that deliver insight into to variations in the formation of different types of Labrador Sea Water and changes in the storage of anthropogenic carbon. They will be furthermore combined with respective measurements from the subsequent cruise *MSM-43* to form one large-scale tracer data set. This will allow to highlight the large-scale spreading pathways of various components of North Atlantic Deep Water (NADW) in the subpolar North Atlantic in spring 2015. The data of cruise MSM42 serves to analyze the particular spreading in the vicinity of Flemish Pass and Flemish Cap.

5.3 Performance of Lowered Acoustic Doppler Current Profilers

(V. Müller)

Two Lowered Acoustic Doppler Current Profilers (LADCP) of type *Teledyne-RD Instruments (T-RDI) Workhorse Monitor*, operating at 300 kHz, were attached to the carousel water sampler. They were operated in a synchronized master-slave configuration in which the downward looking master device triggers the upward looking slave device. Both instruments were used with a ping rate of 1 Hz and a 10 m depth cell size. The power for both instruments was supplied by 35 commercial quality 1.5V batteries, externally assembled in a modified *Aanderaa* pressure housing. Additional weights of about 300 kg in total were mounted to the water sampler, ensuring a stable movement of the instruments with little tilt and generally steady vertical velocity. As the LADCPs lack an internal pressure gauge, CTD pressure profiles were incorporated during the LADCP data processing to obtain the exact depth information of the LADCP instruments during the cast.

During the cruise three different LADCP instruments were used. A compass calibration of the instruments was carried out prior to the cruise in Bremen, Germany on Feb. 15th, 2015. Two of the instruments were calibrated as master devices (s/n 7915 and s/n 2161) and one as a slave device (s/n 1973). Two device (s/n 7915 and 1973) had the firmware version 50.40, the master device with s/n 2161 had the newer firmware version 51.40. The command files used to program the instruments before deployment are shown in Table 5.3.

LADCP data were recorded on all CTD casts. Including the test stations, 160 LADCP casts were made in total. During the two test stations (profile #050/001 and profile #051/002), the instruments were configured with wrong command files, so that no data is available for these test stations. For profile #059/008 and profile #088/039 a problem with the cable connection inside the battery case occurred that resulted in corrupted data for these two stations. This problem was subsequently fixed. During station #076/027, sensors in the slave instrument (s/n 1973) malfunctioned. Unfortunately, this problem was not immediately recognized. After profile #094/045, the slave (s/n 1973) was therefore replaced with instrument s/n 7915 (calibrated as master but now used in upward looking slave modus). A recalibration of instrument s/n 7915 to slave mode was not possible on board of the ship.

Master instrument	Slave instrument
WM15	WM15
ED0000	ED0000
ES35	ES35
EX11111	EX11111
SM1	SM2
SB0	SB0
SA001	SA001
SI0	
SW75	ST3600
TE00:00:01.00	TE00:00:00.00
TP00:01.00	TP00:00.00
WD111100000	WD111100000
WP00001	WP00001
WN020	WN020
WS1000	WS1000
WF0000	WF0000
WV170	WV170
WB1	WB1
WW1	WW1
EZ0111111	EZ0111111
EA00000	EA00000
EB00000	EB00000
CF11101	CF11101
CK	CK
CS	CS

Tab. 5.3 Sequence of *Teledyne-RD Instruments* commands used to program the master and slave LADCP instruments after profile #051/002.

The overall performance of the two instruments in use, apart from the sensor failure, was good. The range of each instrument was typically 150 m (and up to 200 m) in the upper parts of the water column and less close to the bottom depending on the abundance of scatterers. As a consequence, there were about 100-200 current shear estimates per depth cell in the deep water, and much more towards the sea surface. Due to large errors in the bin close to the instrument, the first bin was discarded for the estimation of all profiles.

All data processing and quality evaluation were accomplished using the MATLAB toolbox *ladcp-1.2.2* developed at the Department for Oceanography of the Institute of Environmental Physics in Bremen. For the post-processing of the raw data an inverse method incorporating the bottom track velocities was used for most profiles. The shear method was used for the profiles #056/007, #075/016, #076/017, #077/018, #078/021, #138/068, #145/095, #149/099 and for those stations with sensor malfunction. For all other profiles, the inverse method was used.

Sensor error affecting profiles #076/027 to #094/045

During the post-processing an error in the compass data of the slave instrument (s/n 1973) was found. Opening the instrument and further analysis showed that all internal sensors of the instrument (compass, both temperature sensors, tilt sensor and the moisture sensor) had failed.

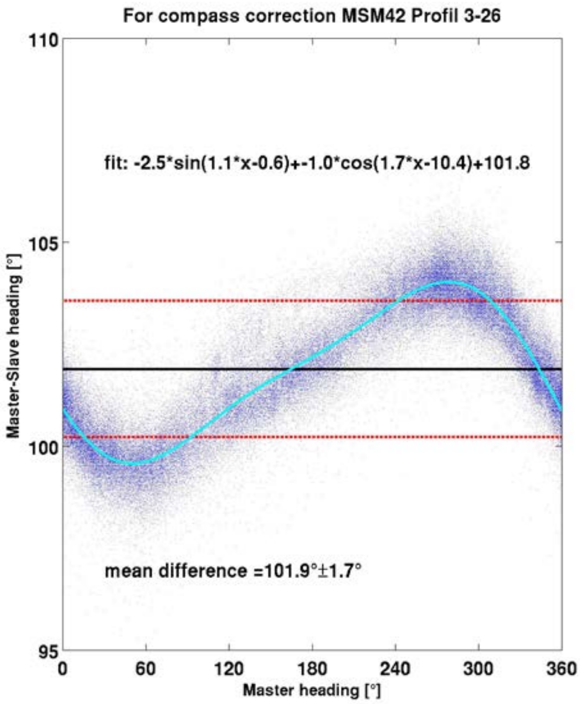

Fig. 5.7 Transfer function derived from LADCP data of profiles #052/003 to #075/026 used for correcting compass errors observed during profiles #076/27 to #094/45, see text for details.

A correction for the compass error was applied to the velocities of all profiles between station #076/027 (where the problem first occurred) and station #094/045. The underlying idea is to fit a transfer function to the relation between master and slave sensor values for the stations before the sensor failure and then replace the erroneous slave sensors of the corrupted profiles using the master data of the same profiles and the respective transfer functions. The velocities of the slave then need to be rotated so that they match the corrected sensor data.

For the correction of the defect compass, a harmonic function was fitted to the difference between master and slave heading with respect to the master instrument's heading, using only the data from the stations before the compass problem occurred (Fig 5.7). The erroneous headings of the slave instrument were then replaced with values calculated from the transfer function (Fig. 5.8) using the master's heading of the respective stations. The u/v velocities of the slave instrument were then rotated to match the corrected heading. As the inverse approach does not lead to a stable solution for the corrected profiles, the shear method was applied to these profiles.

Even though pitch and roll also have an influence on the measured velocities, these were not corrected as the influence on the velocities is small and very likely within the range of uncertainty caused by the compass uncertainty.

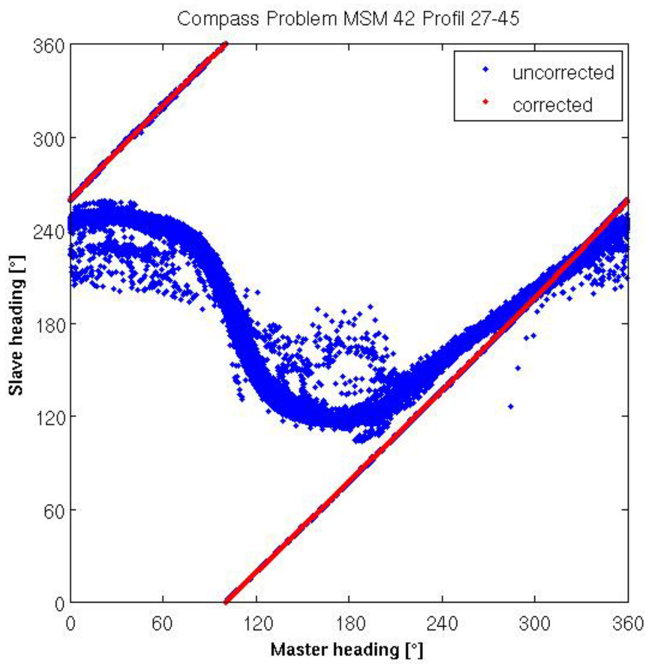

Fig. 5.8 Comparison between data of profiles #076/27 to #094/45 affected by compass errors (uncorrected, blue) and the same data that were corrected by applying a transfer function (red), see text for details.

Correction of data spikes

Due to the ship movements, the vertical instrument velocities oscillated usually by more than ±0.5 m/s (depending on weather conditions) around the nominal heave and veering velocities. These oscillations induced spikes in some of the profiles and needed to be removed. An automated algorithm using a 3-d phase space method that allows for spike detection and subsequent removal (*Mori et al., 2007*) showed promising results and was applied to the processed LADCP data to remove features that were identified as spikes.

5.4 Performance of Vessel-Mounted Acoustic Doppler Current Profilers

(D. Kieke, K. Jochumsen)

During cruise MSM42, oceanic velocity data of the upper water column were recorded by means of two different vessel-mounted Acoustic Doppler Current Profilers (vmADCP) of type *Teledyne-RD Instruments* (T-RDI) *Ocean Surveyor* (OS). The OS75 device operating at 75 kHz is permanently installed in the ship's hull, while the OS38 device operating at 38 kHz has been installed in the ship's sea chest during the cruise. Both instruments were continuously and simultaneously in use and set to narrowband mode. Particular instrument settings partly deviated. Since the OS38 operates at a lower frequency it achieves a larger vertical depth range of up to 1200 m if not higher. Bin length was set to 32 m in order to achieve maximum range. Measurements of the OS75 working at a higher frequency do extend to about 800 m depth. Its bin length was set to 8 m to provide a higher vertical resolution in the upper water column. The actual maximum range is, however, strongly depending on the strength of the ship's motion.

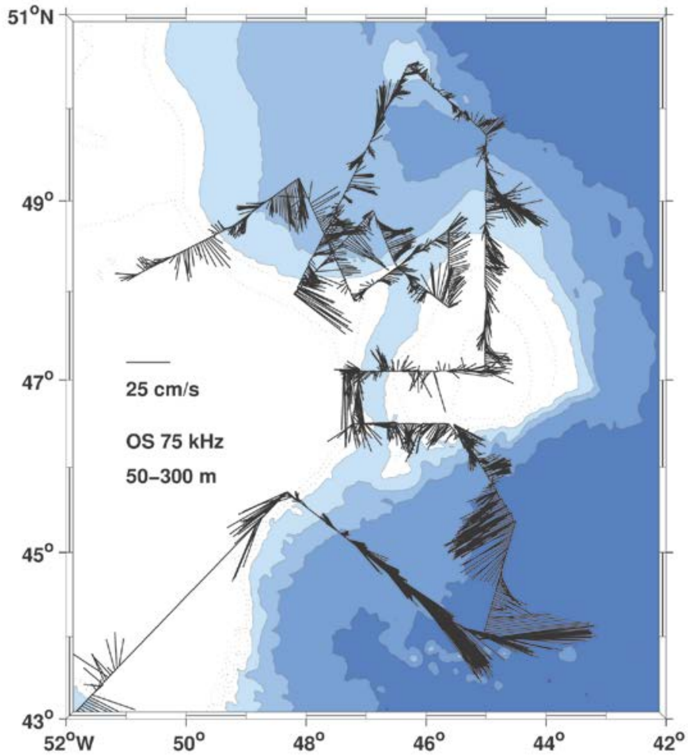

Fig. 5.9 Upper ocean velocity field observed during cruise MSM42. Velocity data from the OS75 vessel-mounted ADCP are averaged over the depth range 50-300 m and binned in 10 min intervals.

Throughout the cruise recording of the raw data of both instruments was performed with *T-RDI VmDas* software, version 1.46. Information on GPS position, heading, and tilt were provided through the ship's *Seapath* database and *Trimble* system and internally linked to the OS data through the *VmDas* software. Post-processing of the data and water track calibration was done using the vmADCP-toolbox *OSSI* for MATLAB, version 1.9, which was provided by the *Geomar Helmholtz Centre for Ocean Research* Kiel. This processing served to determine the phase and amplitude of the transducer misalignment of both devices and to convert recorded raw data in to MATLAB-readable files. For the OS75, a misalignment angle of -3.19°±0.86° and an amplitude factor of 0.999±0.010 was obtained, while processing of the OS38 data yielded a misalignment angle of -0.80°±0.66° and an amplitude factor of 0.999±0.010. These values are comparable to estimates of transducer misalignments obtained during the cruises *MSM-38* and *MSM-39* carried out in summer 2014.

Continuous recording of data logging was started on May 03rd, 03:00 UTC, after leaving the EEZ of Bermuda. While transiting towards the Grand Banks, instrument settings were tested. Continuous data logging was switched off on May 22nd, 01:00 UTC, when on transit towards St. John's. Noticeable interruptions occurred on May 04th/05th when the navigational information of one of the three GPS channels could not be passed on to the system for about 10 hours. Post-processing of data recorded during this time is therefore not straightforward and requires manual adjustment of the processing routines to close this gap. As GPS information is redundant, only those parts of the program dealing with the standard data conversion the water-track calibration are affected.

The upper ocean velocity field derived from the OS75 vessel-mounted ADCP is shown in Figure 5.9. Data are averaged over a depth range from 50 to 300 m and binned in 10-min intervals. From Orphan Basin in the north to Flemish Pass and the Grand Banks in the south, the velocity field reveals strong boundary currents that follow the shelf break. These are associated with the presence of the southward Labrador Current. The southernmost section across the deep part of the boundary current reveals a strong along-section flow, which is not seen to a similar extent in a similar section located further to the north. Inflow into Flemish Pass is observed at Sackville Spur, a topographic extension located at the western side of the northern entrance to Flemish Pass, as well as near the northern flank of Flemish Cap.

5.5 Mooring Activities

(D. Kieke, A. Welsch, K. Jochumsen)

Mooring ID	Latitude	Longitude	Depth [m]	Deployment Date/Time	CTD Profile
BM-25/3	47°07.11'N	47°06.38'W	1003	12 May 2015 21:16-21:58	#114/064

Tab. 5.4 *Summary of deployment information related to mooring BM-25/3. All times given in UTC.*

Due to limited resources, instrument losses of both participating groups in previous years, and no mooring deployment in Flemish Pass in 2014, only one mooring could be deployed, and none were recovered during the cruise. Preparation for mooring activities began on May 03rd when an acoustic single release of type *IXBLUE Oceano 2500 S-Universal* (s/n 1874) was attached to the carousel water sampler (test station #050/001). The device was brought to a water depth of 1000 m with the purpose to check its performance when exposed to deep-sea conditions. Active acoustic communication with the device was established with a deckunit of type *iXSEA Oceano TT301B*. The release was furthermore passively acoustically tracked with the ship's hydrophone attached to a deckunit of type *Benthos DS7000*. At depth the device responded immediately to all commands (ranging and release). The test was thus rated as being successful.

On May 12th, mooring BM-25/3 was deployed on the western side of Flemish Pass at a water depth of 1003 m (Fig. 5.10). The aim of the mooring is to capture the variability of the flow structure in the lower 600 m range of the water column. The mooring has a total length of about 42 m and was installed at a water depth of 1003 m. It consists of an Acoustic Doppler Current Profiler (ADCP) of type *Teledyne-RDI Longranger* (s/n 16975) operated at 75 kHz and supplied with an external battery pack that are both installed in a 45" top buoy. Additional floatation and the acoustic single release mentioned above (s/n 1874) are installed below the top element. Major connecting shackles and rings are made of titanium; ropes are of type *Dyneema* having 12 mm diameter. The top buoy is equipped with two radio beacons of type *Novatech RF-700A1* (s/n

V01-025 and V09-44, operating at 159.480 MHz and 160.725 MHz). Self-tests of the *Longranger* ADCP performance were run prior to the cruise at the home lab and repeated prior to the deployment, with the device successfully passing all tests at both occasions.

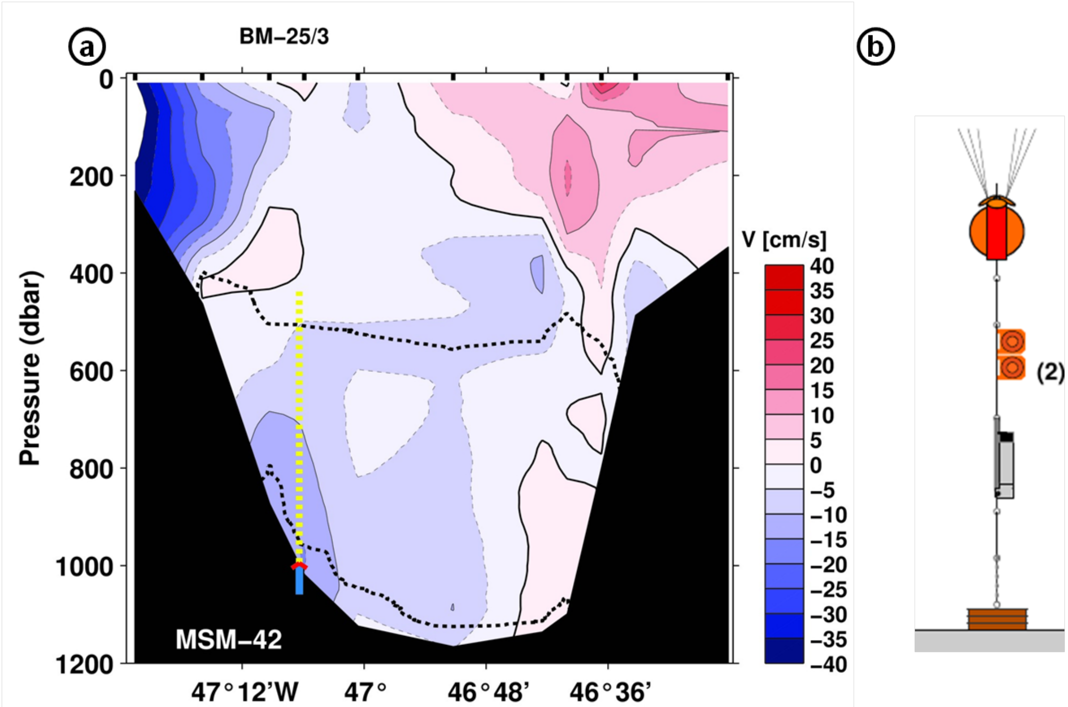

Fig. 5.10 Left: Detided meridional current velocity (cm/s) in Flemish Pass along 47°N from lowered ADCP data, recorded during cruise MSM42. The location of mooring BM-25/3 and the vertical range of the Longranger ADCP are schematically indicated. Bold dashed lines highlight the isopycnals σ_θ = [27.68, 27.74] kg/m³. Right: Design of mooring BM-25/3 carrying a Longranger ADCP installed in the top element, two additional floatation bodies, and an acoustic release attached to a bottom weight.

Mooring deployment activities started at good visibility conditions at 21:16 UTC, when the top buoy carrying the *Longranger* ADCP was put into the water (Table 5.4). The anchor weight was slipped at 21:39 UTC, and the mooring descended immediately to the bottom. Afterwards, the acoustic release was contacted via a hydrophone connected to a deck unit of type *iXSEA OCEANO TT301B*. The acoustic release repeatedly responded valid range values confirming that the mooring was properly installed at the sea bottom. Mooring activities were finished at 22:00 UTC.

5.6 Bird Observations

(C. Gjerdrum, J. Winkel)

<u>Background</u>

The east coast of Canada supports millions of breeding marine birds as well as migrants from the southern hemisphere and northeastern Atlantic. In 1969, PIROP (*Programme intégré de recherches sur les oiseaux pélagiques*) was initiated based on a systematic survey technique and computer database (*Brown et al. 1975; Brown 1986*) to document the abundance and distribution of marine birds in Atlantic Canada and elsewhere. The program was operated by the Canadian Wildlife Service (CWS) of Environment Canada and supported by the large DFO (Department of Fisheries and Oceans) oceanographic fleet based in eastern Canada. Much of the data collected under PIROP are limited beyond the mid-1980s, therefore, CWS reinvigorated the pelagic seabird monitoring program in 2005 with the goal of identifying and minimizing the impacts of human activities on birds in the marine environment. Since 2005, a protocol for collecting data at sea (*Gjerdrum et al. 2012*) and a sophisticated geodatabase have been developed, relationships with industry and others to support offshore seabird observers have been established, and over 160,000 km of ocean track have been surveyed by CWS-trained observers. These data are now being used to identify and address threats to birds in their marine environment (*Gjerdrum et al. 2008; Fifield et al. 2009; Lieske et al. 2014; Wong et al. 2014*).

Objective

The objective of our seabird survey on board the RV MARIA S. MERIAN in May, 2015 (MSM42) was to collect data on the distribution and abundance of seabirds from Bermuda to St. John's, NL as part of our long term monitoring program for seabirds at sea in eastern Canada.

Methods

Seabird and marine mammal surveys were conducted from the port side of the bridge of the RV MARIA S. MERIAN during oceanographic surveys from Bermuda to St. John's, NL from 2-22 May, 2015. Surveys were conducted while the ship was moving at speeds greater than 4 knots, looking forward and scanning a 90° arc to one side of the ship. All birds observed on the water within a 300 m-wide transect were recorded, and we used the snapshot approach for flying birds (intermittent sampling based on the speed of the ship) to avoid overestimating abundance of birds flying in and out of transect. Distance sampling methods were incorporated to address the variation in bird detectability (*Buckland et al. 2001*). Marine mammal observations were also recorded, although surveys were not specifically designed to detect marine mammals. Details of the methods used can be found in the CWS standardized protocol for pelagic seabird surveys from moving platforms (*Gjerdrum et al. 2012*).

Results and discussion

a. Seabird sightings

We surveyed 6789 km of ocean track from 2-22 May, 2015 (Figure 5.11). A total of 5321 birds from 8 families were observed during the surveys; 4570 of the birds sighted were counted in transect (Table 5.5). With the exception of 1 white-throated sparrow (*Zonotrichia albicollis)* and 3 Manx shearwater (*Puffinus puffinus*), all sightings occurred north of 42 degrees latitude, in and around the Grand Banks of Newfoundland (Figure 5.11). Overall, bird densities averaged 12.0 birds/km^2 (ranging from 0 – 4452.0 birds/km^2). The highest densities of birds (> 200 birds/km^2; Figure 5.11) were observed on the northeastern Grand Bank, Flemish Cap, and near the Orphan Knoll; all of these were large flocks of northern fulmar (*Fulmaris glacialis*).

Northern fulmar was the most commonly observed species, accounting for 67 % of the observations (Table 5.5). They were not observed until the ship reached the slope of the southern Grand Bank, but were sighted in large numbers throughout the northern survey area (Figure 5.10a). Northern fulmar breed in Arctic and sub-Arctic colonies of eastern Canada, as well as Greenland, Iceland and the United Kingdom (*Mallory et al., 20*12). Although birds often arrive on their breeding grounds in April or May, they may leave for short periods of time to forage offshore as eggs are not typically laid until late May or early June *(Mallory et al.,* 2012). Individuals observed during these surveys could therefore have been breeders from North America, or perhaps non-breeding individuals not yet tied to any particular breeding location. Other members of the family Procellariidae were sighted in far fewer numbers, and included great shearwater (*Puffinus gravis*), sooty shearwater (*P. griseus*), and Manx shearwater (Table 5.5, Figure 5.12b). Both the great and sooty shearwaters breed in the southern hemisphere and spend their non-breeding season in the north Atlantic. They typically arrive off the coast of Newfoundland and Labrador in April and remain through October or November (CWS unpublished data).

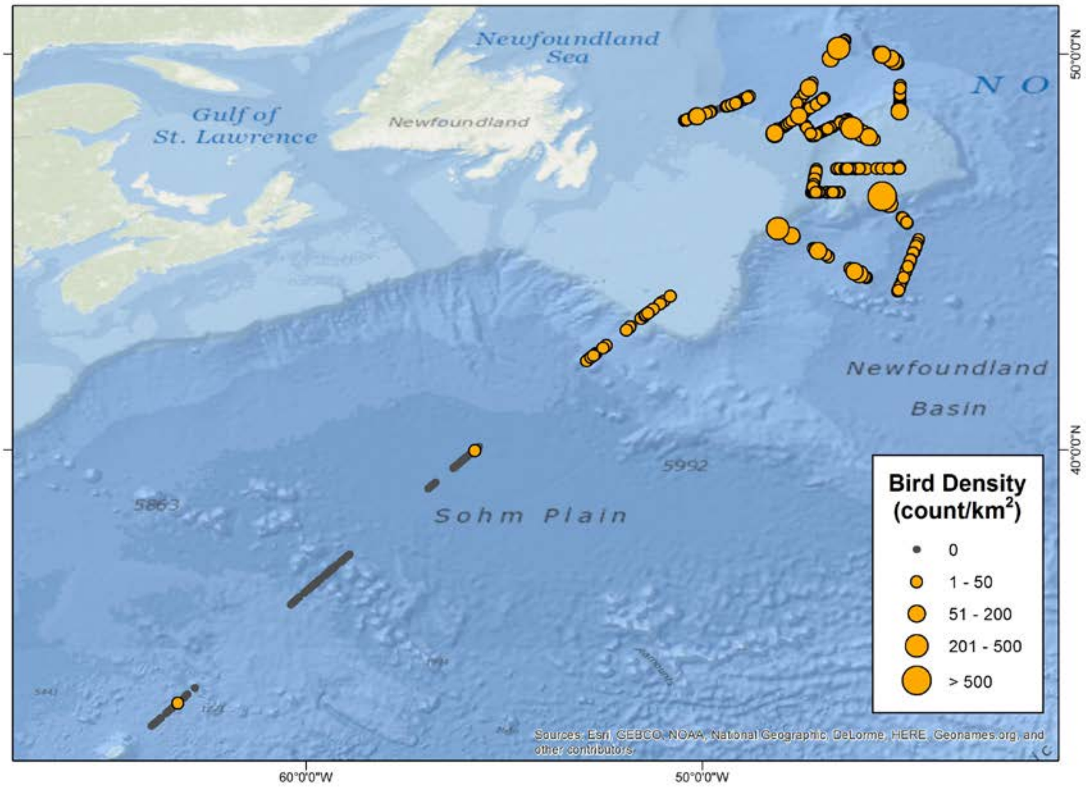

Fig. 5.11 Density of birds (all species combined) sighted during the seabird survey on board the RV MARIA S. MERIAN, cruise MSM42 from 2-22 May, 2015.

Storm-petrels (Leach's *Oceanodroma leucorhoa* and those that were unidentified to species) made up 6% of the observations. The largest flocks were observed in the Orphan Basin, although individuals were sighted throughout the northern survey area (Figure 5.12c). The Leach's storm-petrel breeds in the millions in Newfoundland and Labrador and Nova Scotia. They begin arriving in Atlantic breeding colonies in April and May, and are known to wander widely prior to egg-laying, which typically begins in late May (*Huntington et al., 1996*). Individuals observed during these surveys could have been breeders from western Atlantic colonies or perhaps nonbreeders as Leach's storm-petrels don't commonly start breeding until 5 years of age (*Huntington et al., 1996*).

Family	**English**	**Latin**	**Number observed in transect**	**Total number observed**
Procellariidae	Northern Fulmar	*Fulmarus glacialis*	3059	3072
	Great Shearwater	*Puffinus gravis*	154	370
	Sooty Shearwater	*Puffinus griseus*	16	20
	Manx Shearwater	*Puffinus puffinus*	3	7
Hydrobatidae	Leach's Storm-Petrel	*Oceanodroma leucorhoa*	270	420
	Unidentified Storm-Petrels	Hydrobatidae	19	49
Fregatidae	White-tailed Tropicbird	*Phaethon lepturus*	0	1
Sulidae	Northern Gannet	*Morus bassanus*	6	7
Scolopacidae	Ruddy Turnstone	*Arenaria interpres*	13	13
	Least Sandpiper	*Calidris minutilla*	0	1
	Unidentified Shorebird	Scolopacidae	0	3
Laridae	Herring Gull	*Larus argentatus*	332	349
	Black-legged Kittiwake	*Rissa tridactyla*	208	216
	Glaucous Gull	*Larus hyperboreus*	13	13
	Parasitic Jaeger	*Stercorarius parasiticus*	9	12
	Pomarine Jaeger	*Stercorarius pomarinus*	6	10
	Long-tailed Jaeger	*Stercorarius longicaudus*	5	9
	Lesser Black-backed Gull	*Larus fuscus*	5	6
	Unidetified Tern	Sternidae	5	6
	Great Black-backed Gull	*Larus marinus*	3	4
	Iceland Gull	*Larus glaucoides*	3	4
	UnidentifiedJaegers	*Stercorarius Jaegers*	1	3
	Sabine's Gull	*Xema sabini*	1	1
	Great Skua	*Stercorarius skua*	0	1
	Black-headed Gull	*Larus ridibundus*	0	1
	Laughing Gull	*Larus atricilla*	0	1
Alcidae	Dovekie	*Alle alle*	221	412
	Unidentified Murres	*Uria*	75	130
	Common Murre	*Uria aalge*	85	92
	Unidentified Alcids	Alcidae	28	44
	Thick-billed Murre	*Uria lomvia*	11	12
	Murre or Razorbill	*Uria* or *Alca*	6	10
	Atlantic Puffin	*Fratercula arctica*	6	9
	Razorbill	*Alca torda*	6	9
Emberizidae	White-throated Sparrow	*Zonotrichia albicollis*	1	2
	Unknown Bird	Aves	0	2
Totals			**4570**	**5321**

Tab. 5.5 List of bird species sighted during the seabird survey on board the RV MARIA S. MERIAN, cruise MSM42 from 2-22 May, 2015.

Sightings of the family Laridae made up a total of 13% of the observations, the majority of which were herring gulls (*Larus argentatus*) and black-legged kittiwakes (*Rissa trydactyla*) (Table 5.5). Although both these species are typically around breeding colonies on the Newfoundland and Labrador coast at this time of year, significant numbers were observed on and around the Flemish Cap and Orphan Basin (Figure 5.12d and 5.13a). All three Arctic-nesting species of jaeger were also observed during the survey (Table 5.5), most likely on their way towards breeding colonies further north (Figure 5.13b).

Members of the family Alcidae made up a total of 10% of the observations (Table 5.5), the majority of which were Dovekie (*Alle alle*). Dovekie were observed around the Flemish Cap and Grand Banks (Figure 5.13c) and were presumably moving to more northerly breeding grounds in Greenland where the bulk of their population breeds (*Montevecchi and Stenhouse, 2002*). Murre (common murre *Uria aalge*, thick-billed murre *U. lomvia*, and those unidentified to species) were sighted in the same areas with the highest densities observed on the Flemish Cap (Figure 3d). Both species of murre breed in large numbers in Newfoundland and Labrador, with the thick-billed murre breeding distribution also reaching up into the eastern Arctic (*Gaston and Hipfner, 2000; Ainley et al., 2002*). Only a few Atlantic puffin (*Fratercula arctica*) and razorbill (*Alca torda*) were sighted during the survey (Table 5.5); both of these species breed in significant numbers in Atlantic Canada (*Lowther et al., 2002; Lavers et al., 2009*).

b. Marine Mammal sightings

Although the survey protocol (*Gjerdrum et al., 2012*) used for the seabird surveys was not designed for marine mammals, all marine mammals observed were also recorded. A total of just 55 marine mammals were sighted (Table 5.6). These included 40 Long-finned pilot whales (*Globicephala melas*), which were observed south of the Flemish Cap and the in Orphan Basin; 14 dolphin, 4 of which were identified as bottle-nosed dolphin (*Tursiops truncatus*); and 1 humpback whale (*Megaptera novaeangliae*) (Figure 5.14).

English	**Latin**	**Total number observed**
Long-finned Pilot Whale	*Globicephala melas*	40
Unidentified Dolphins	Delphinidae	10
Bottle-nosed Dolphin	*Tursiops truncatus*	4
Humpback Whale	*Megaptera novaeangliae*	1
Totals		**55**

Tab. 5.6 List of marine mammals sighted during the seabird survey on board the RV MARIA S. MERIAN, cruise MSM42 from 2-22 May, 2015.

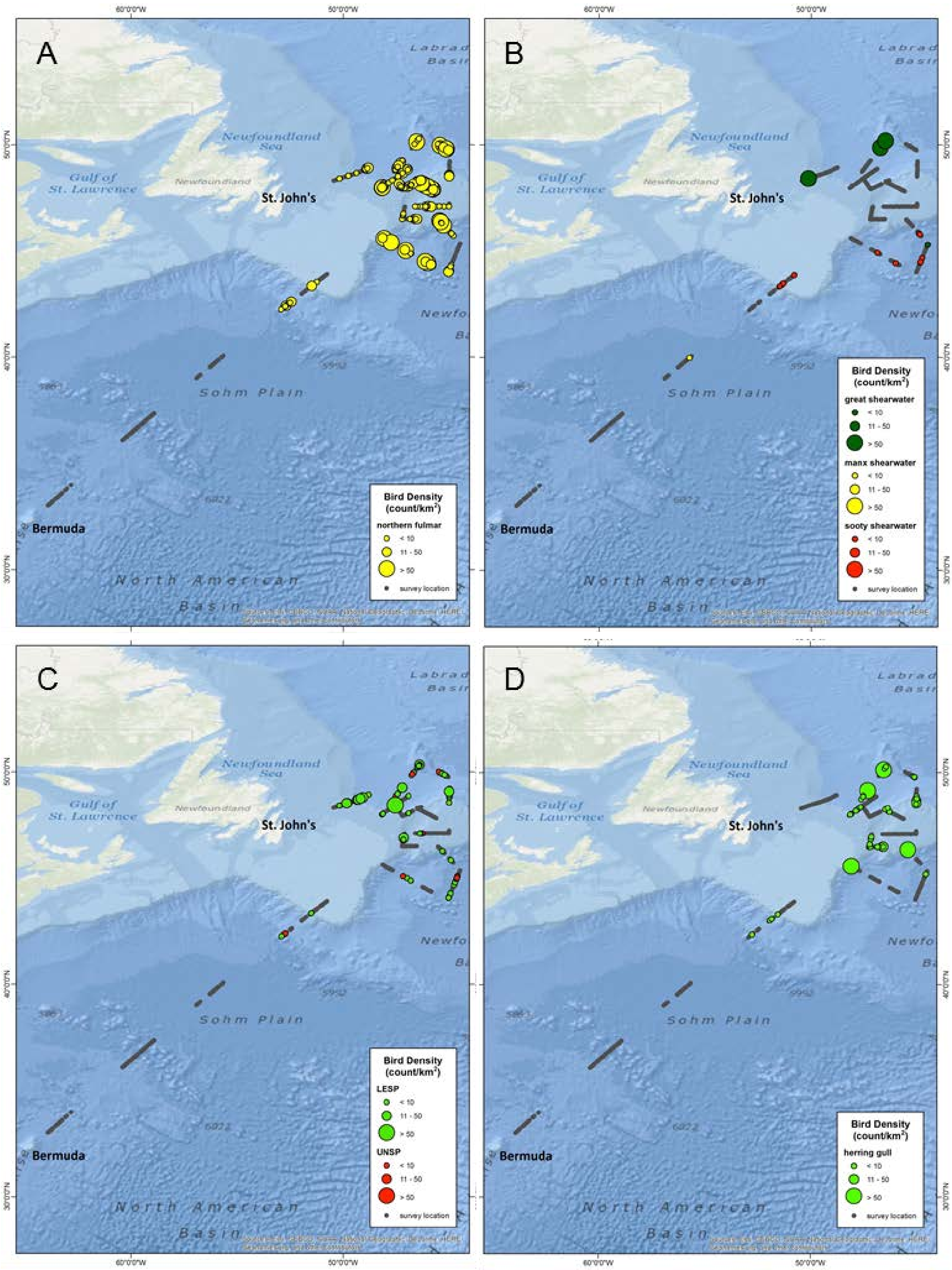

Fig. 5.12 Density of A. northern fulmar; B. great shearwater, sooty shearwater, and Manx shearwater; C. Hydrobatidae (LESP = Leach's storm-petrel; UNSP = unidentified storm-petrel); and D. herring gull during seabird surveys on board the RV MARIA S. MERIAN, cruise MSM42 from 2-22 May, 2015.

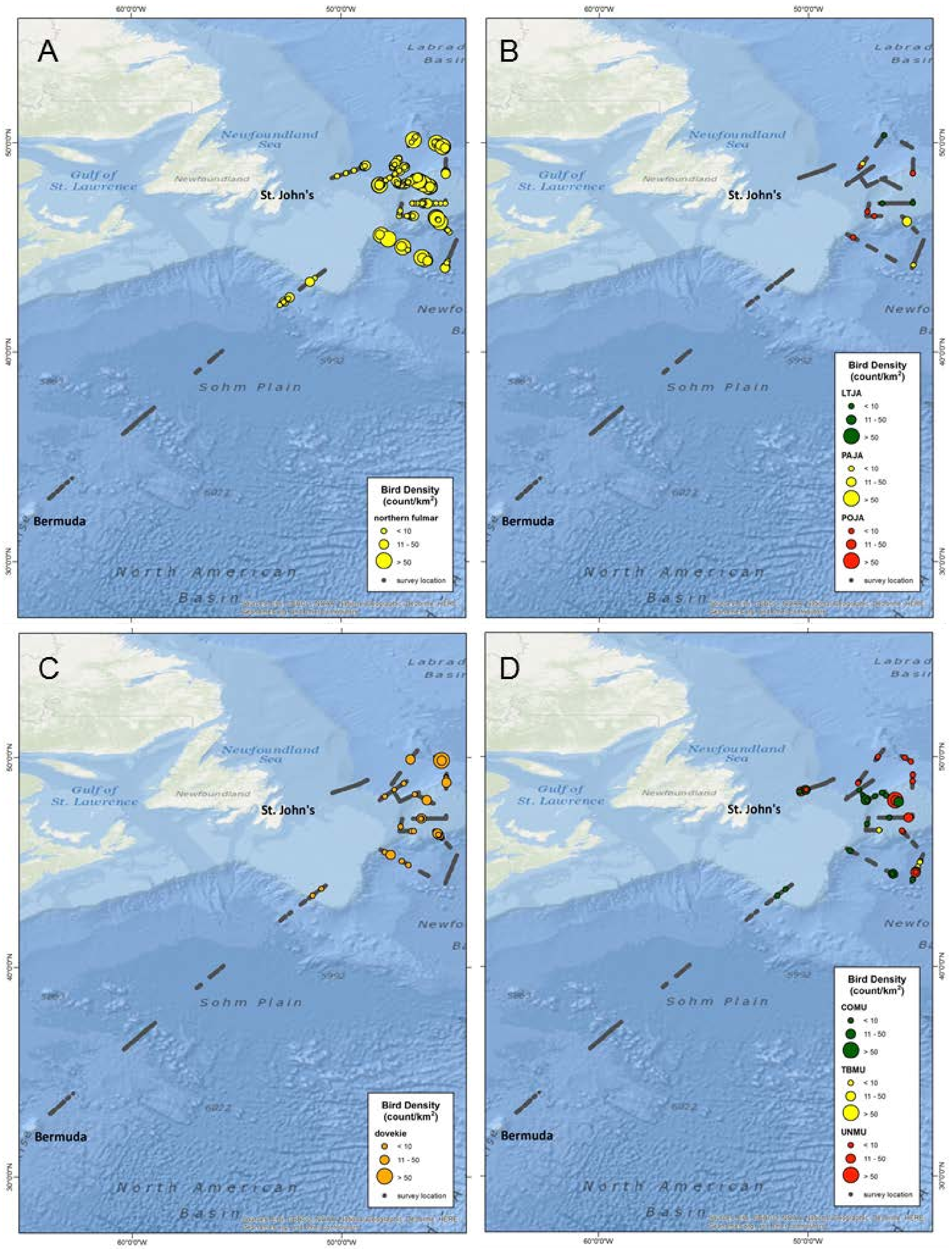

Fig. 5.13 Density of A. black-legged kittiwake; B. jaeger species (LTJA = long-tailed jaeger; PAJA = parasitic jaeger; POJA = pomarine jaeger); C dovekie; and D. murre (COMU = common murre, TBMU = thick-billed murre, UNMU = unidentified murre) during seabird surveys on board the RV MARIA S. MERIAN, cruise MSM42 from 2-22 May, 2015.

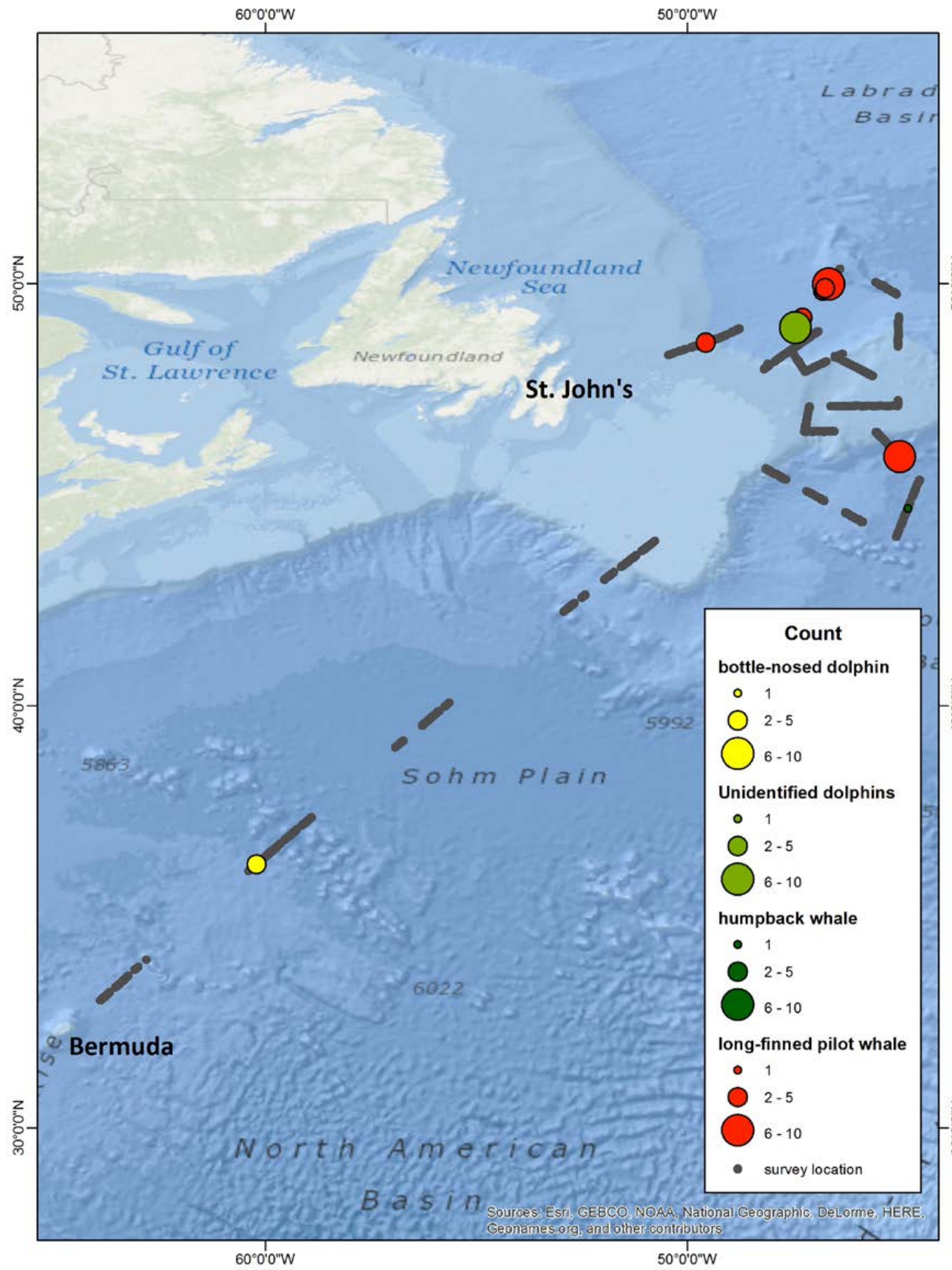

Fig. 5.14 Counts of marine mammals during surveys on board the RV MARIA S. MERIAN, cruise MSM42 from 2-22 May, 2015.

6 Underway measurements

(D. Kieke)

During cruise MSM42 a large variety of underway measurements were carried out. Acquired data of interest included navigational information, near surface hydrography (temperature, conductivity, and thus salinity) measured by the vessel's thermosalinograph (TSG) or the automatic weather station operated by the *German Weather Service* (DWD) (water temperature only), water sounding data recorded by the echo-sounder system as well as further meteorological parameters recorded by the weather station. Respective data was logged in time steps of 1 second by the vessel's *Davis-Ship* system (DSHIP). All underway data relevant to this cruise were exported from the database on a daily basis and converted into MATLAB-readable netCDF-files.

6.1 Meteorological data

(D. Kieke)

Aboard RV MARIA S. MERIAN the *German Weather Service* (DWD) operates an autonomous weather station. It automatically records all meteorological standard parameters like wind speed and direction, air temperature and respective pressure and others.

Throughout the cruise large-scale weather maps indicated variable conditions of atmospheric pressure with cells of low and high pressure moving across the investigation region. Atmospheric pressures recorded by the autonomous weather stations throughout cruise MSM42 reveal this evolution (Figure 6.1). Pressure ranged from < 995 hPa observed on May 12th to 1035 hPa observed on May 17th. Atmospheric temperatures were high (>20°C) when in the vicinity of Bermuda. While heading towards north and leaving the subtropical regime, temperatures started to drop, with the greatest change noticed between May 3rd and May 6th when temperatures decreased from > 20°C to about 2°C. Depending on the actual position of the ship, air temperatures between May 6th and May 16th were between 1°C and 7°C, while afterwards they were most of the time between 4°C and 5°C. Water temperatures basically showed the same trend. However, during May 07th/08th and May 10th water temperatures were up to 5°C warmer than air temperatures. At those times, RV MARIA S. MERIAN was heading offshore towards the deep Newfoundland Basin to carry out the first hydrographic section or was heading back onshore from the deep Newfoundland Basin towards the boundary current regime to carry out the second sections. Only the observations from May 10th could be associated with crossing of the warm and saline North Atlantic Current as also salinity increased to S > 35. Periods of absolute wind speeds of 7 Bf and higher lasting for several hours were observed three times during the cruise: May 13th, May 15th, and May 21st.

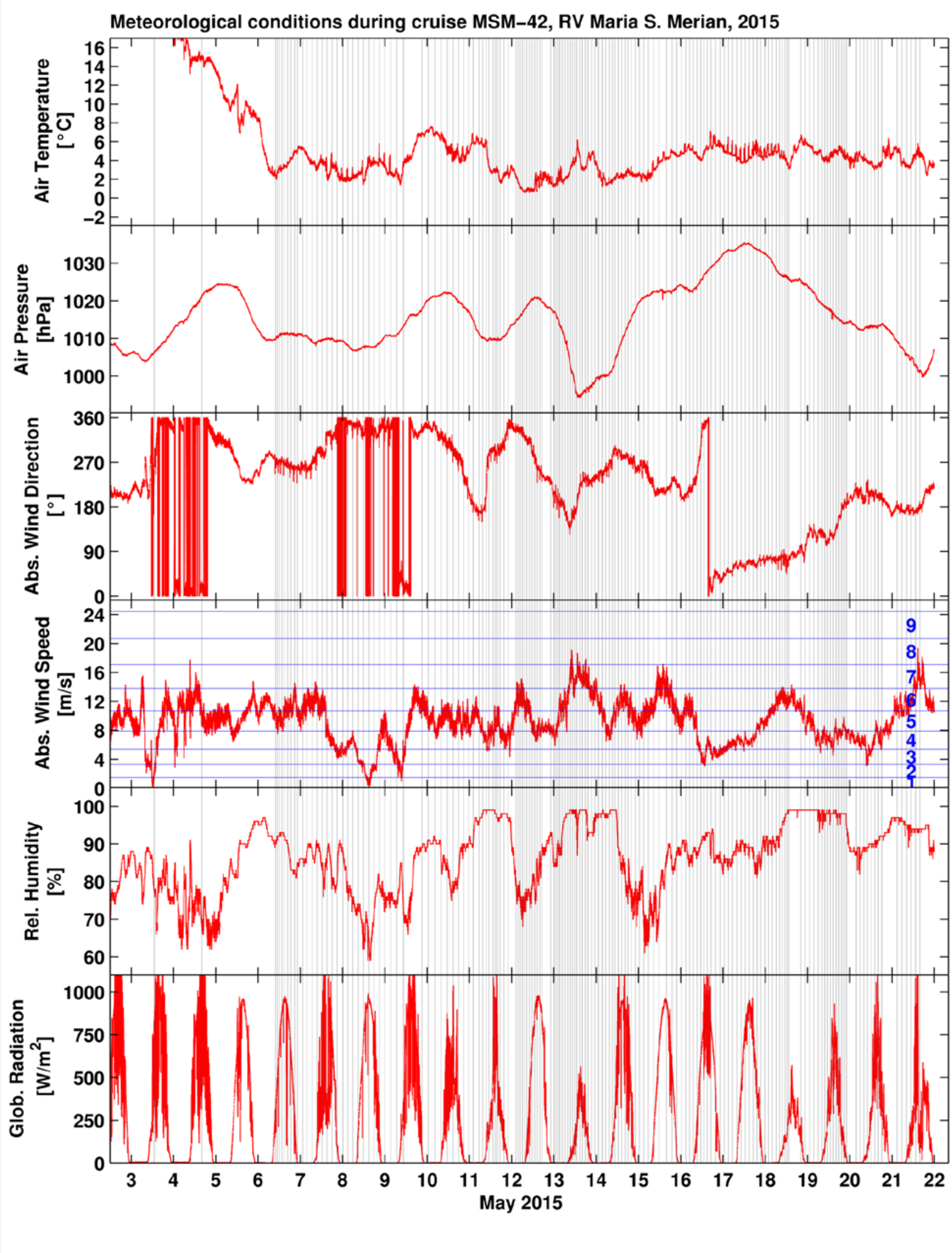

Fig 6.1 Meteorological conditions observed during May 02nd to May 22nd, 2015, cruise MSM42. Gray thin lines denote the beginning of CTD station activities, blue horizontal lines and scale on the right side of the figure indicate absolute wind speeds reported on the Beaufort scale.

Maps charting sea ice coverage and icebergs (1°x1° boxes) were received on a daily basis from the Canadian Ice Service (*www.ec.gc.ca/glaces-ice*) throughout the cruise and did not indicate any sea ice cover in the investigation region. However, iceberg charts pointed to a higher abundance of icebergs on the Canadian shelf (Grand Banks) and in the vicinity of Flemish Cap with iceberg count numbers on the shelf continuously decreasing from > 100 to > 30, while sightings at Flemish Cap were on the order of > 30 throughout the cruise. Any ice or iceberg was neither encountered nor sighted during the cruise.

6.2 Thermosalinograph data

(D. Kieke, K. Jochumsen, A. Rochner, S. Wett, K. Wiegand)

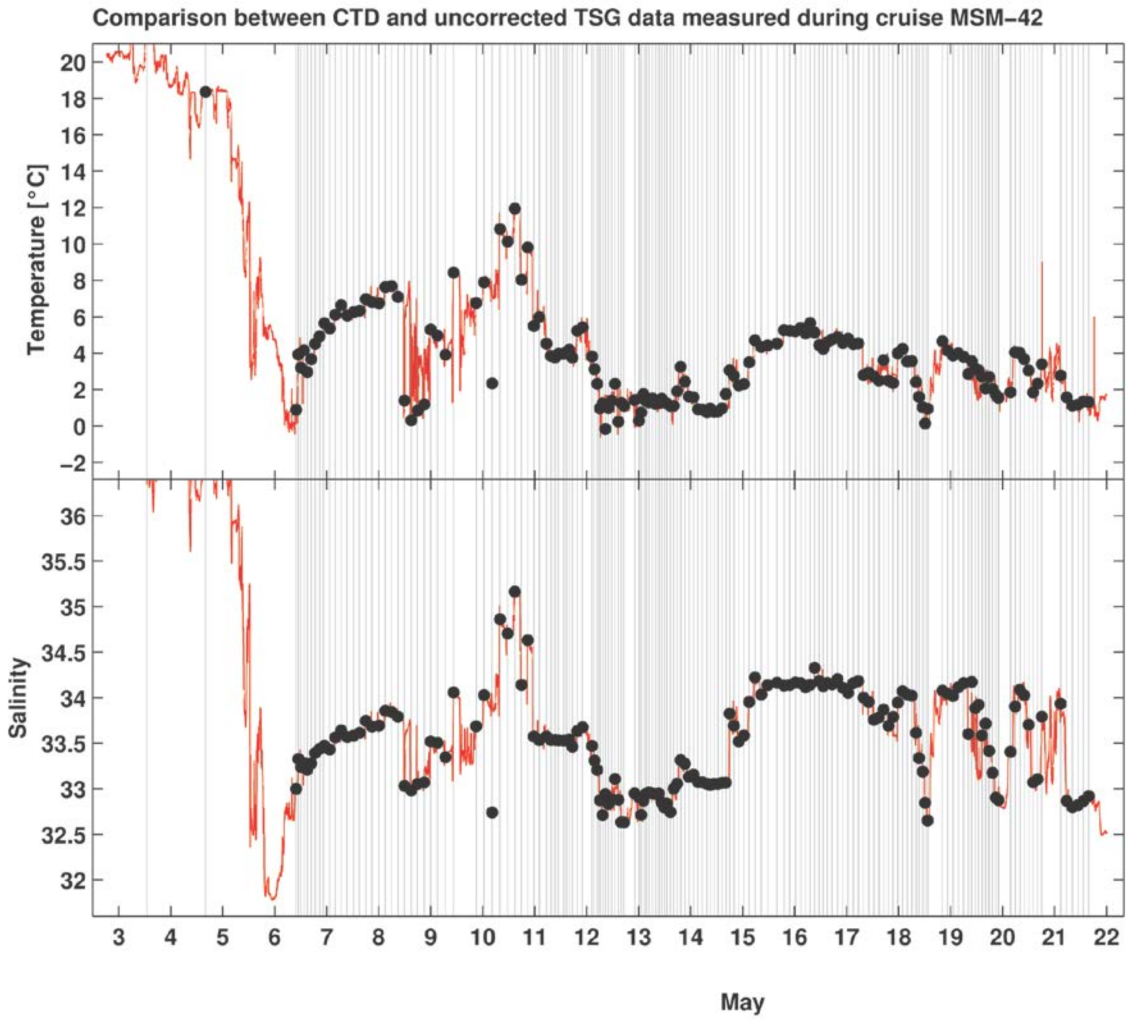

Fig. 6.2 Comparison of raw TSG data (red lines) recorded during cruise MSM42 by RV MARIA S. MERIAN and calibrated CTD values recorded at 6 dbar (black dots). Gray thin lines denote the beginning of CTD station activities.

Aboard RV MARIA S. MERIAN a thermosalinograph (TSG) system is integrated into the vessel's clean seawater system, which is installed in the vessel's echo-sounder room. Two water suction points exist at a water depth of about 6.2 to 6.8 m, where respective sensors continuously pump up seawater. The flow rate measurement system consists of two seawater measurement containers, with one being active at a time and the second one being on stand-by. Use of containers typically switches after 12 hours.

Throughout the cruise, twice a day seawater samples were drawn by the ship's staff from the two different seawater containers. These samples were measured onboard using a salinometer of type *Guildline Autosal*, model 8400A. At the end of the cruise respective salinometer and TSG data was sent by the ship's officers to the *Leitstelle Deutsche Forschungsschiffe* (Control Station German Research Vessels) affiliated to the University of Hamburg. There, the quality of the TSG data of RV MARIA S. MERIAN is checked on a routine basis. A first and preliminary comparison of raw TSG data and calibrated CTD values recorded at 6 dbar, which matches about the depth of the water inlet point, is shown in Figure 6.2. Both data sets are generally in very good agreement, with the only exception noted on May 10th, when a large difference between TSG data and CTD data of profile #083/034 was observed for unknown reason, with CTD data being much fresher and colder than TSG data. The large drop in temperature and salinity observed in the beginning of the cruise is associated with leaving the subtropical gyre and entering the subpolar ocean when approaching the Grand Banks. RV MARIA S. MERIAN thereby crossed the extensive thermal and haline fronts between the Gulf Stream and extensions of the Labrador Current located to the north of the Gulf Stream.

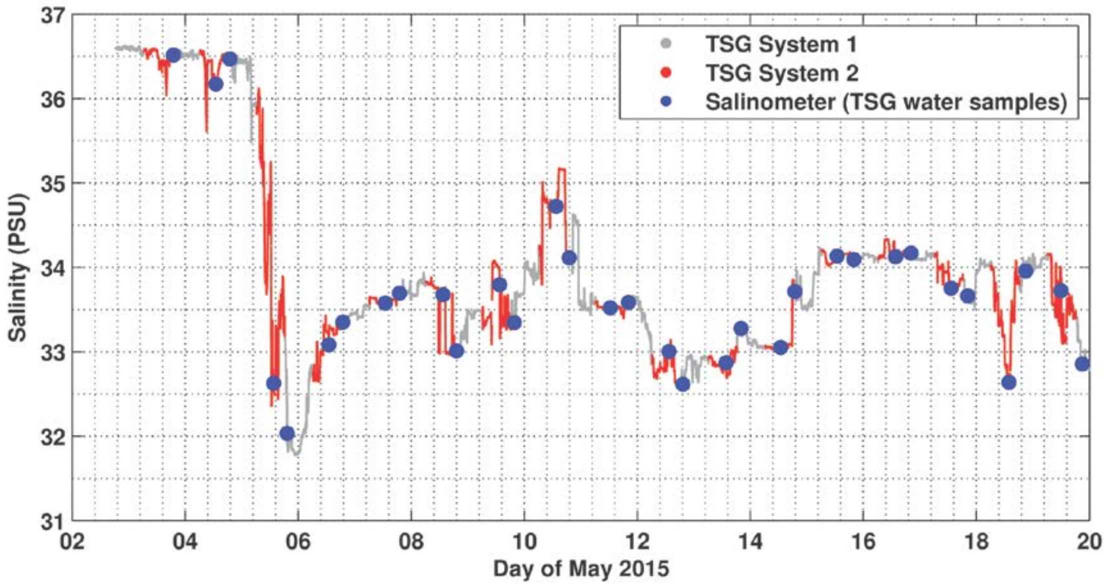

Fig. 6.3 Comparison of raw TSG data (red and grey) recorded during cruise MSM42 by RV MARIA S. MERIAN and waters samples (blue dots) taken twice a day from the two TSG systems and analyzed with a salinometer of type *Guildline Autosal 8400A.*

Also the comparison between water samples taken from the two TSG systems twice a day and the continuously recorded TSG showed a very good agreement (Figure 6.3). Closer analysis of the data revealed a larger offset between TSG water samples and TSG data derived from system 1 (internal ship's number 2) than for TSG samples and continuous TSG data taken from system 2 (internal ship's number 3). The mean salinity offsets and standard deviations were ΔS = 0.020± 0.014 (system 1) and ΔS = 0.014±0.032. If only those differences were taken into account that did not exceed the standard deviation, the mean offset reduced to were ΔS = 0.017 (system 1) and ΔS = 0.007 (system 2), see Figure 6.4.

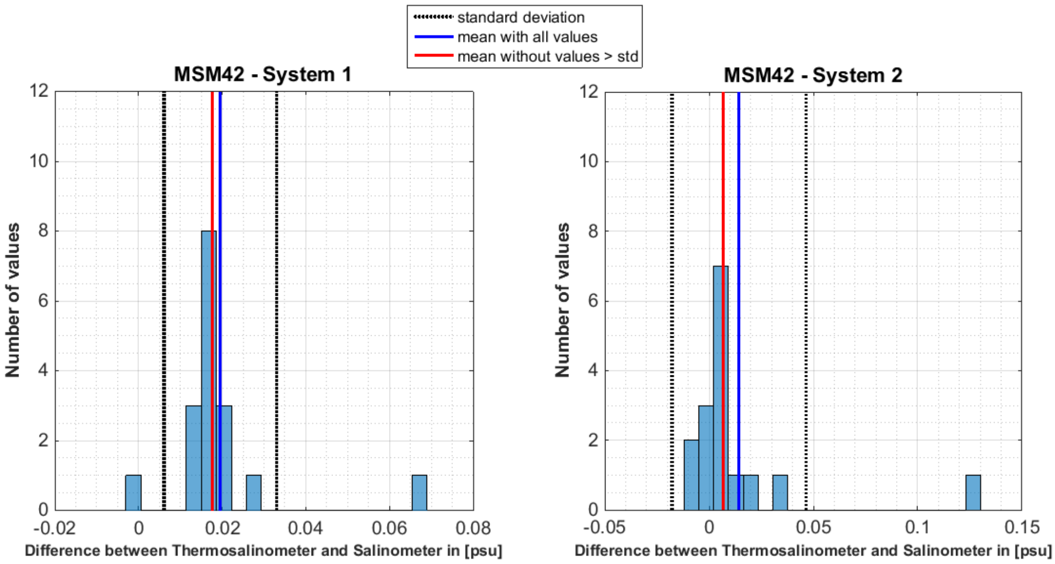

Fig. 6.4 Difference between salinity data of TSG system 1 and respective bottle samples (left) as well as for TSG 2 and corresponding bottle samples (right).

7 Station List MSM42

Station	Profile	Date	Time [UTC]	Latitude	Longitude	Water Depth [m]	CFC offline	SF6/ CFC	Bottle Oxygen	Bottle Salinity	LADCP	Comments
MSM42_050	001	2015/05/03	12:58	36°13.67'N	60°13.20'W	5064			x	x	x	test station, test of acoustic release s/n 1874
MSM42_051	002	2015/05/04	16:06	39°39.96'N	56°07.80'W	5263		x	x		x	test station
MSM42_052	003	2015/05/06	09:51	45°42.64'N	48°19.13'W	141			x		x	
MSM42_053	004	2015/05/06	10:55	45°38.89'N	48°12.31'W	432			x	x	x	
MSM42_054	005	2015/05/06	12:06	45°36.98'N	48°08.93'W	757	x		x	x	x	
MSM42_055	006	2015/05/06	13:30	45°35.20'N	48°05.50'W	1113	x		x	x	x	
MSM42_056	007	2015/05/06	15:02	45°31.50'N	47°58.72'W	1363	x		x	x	x	
MSM42_057	008	2015/05/06	16:54	45°27.77'N	47°51.92'W	1528		x	x	x		LADCP low battery, malfunction
MSM42_058	009	2015/05/06	18:44	45°26.01'N	47°48.44'W	1820		x	x	x	x	
MSM42_059	010	2015/05/06	20:45	45°24.06'N	47°45.05'W	2037		x	x	x	x	
MSM42_060	011	2015/05/06	22:59	45°20.31'N	47°38.33'W	2469	x		x	x	x	
MSM42_061	012	2015/05/07	01:25	45°16.56'N	47°31.46'W	2800	x		x	x	x	
MSM42_062	013	2015/05/07	04:01	45°12.75'N	47°24.54'W	3074	x		x	x	x	
MSM42_063	014	2015/05/07	06:42	45°09.17'N	47°17.95'W	3226			x	x	x	
MSM42_064	015	2015/05/07	09:30	45°05.36'N	47°11.07'W	3359	x		x	x	x	
MSM42_065	016	2015/05/07	12:24	45°01.61'N	47°04.21'W	3446		x	x	x	x	
MSM42_066	017	2015/05/07	15:11	44°57.88'N	46°57.51'W	3564			x	x	x	
MSM42_067	018	2015/05/07	18:03	44°54.19'N	46°50.67'W	3614		x	x	x	x	
MSM42_068	019	2015/05/07	20:53	44°50.44'N	46°43.88'W	3702			x	x	x	
MSM42_069	020	2015/05/08	00:11	44°46.71'N	46°37.03'W	3633	x		x	x	x	
MSM42_070	021	2015/05/08	03:06	44°42.98'N	46°30.25'W	3643			x	x	x	
MSM42_071	022	2015/05/08	05:56	44°39.20'N	46°23.44'W	3722		x	x	x	x	
MSM42_072	023	2015/05/08	08:53	44°35.56'N	46°16.68'W	3735			x	x	x	
MSM42_073	024	2015/05/08	11:57	44°31.83'N	46°09.93'W	3800		x	x	x	x	
MSM42_074	025	2015/05/08	15:04	44°28.08'N	46°03.06'W	3811			x	x	x	
MSM42_075	026	2015/05/08	18:02	44°24.41'N	45°56.29'W	3849		x	x	x	x	
MSM42_076	027	2015/05/08	21:05	44°20.59'N	45°49.46'W	3942			x	x	x	
MSM42_077	028	2015/05/09	00:00	44°16.97'N	45°42.78'W	4128		x	x	x	x	
MSM42_078	029	2015/05/09	03:10	44°13.15'N	45°35.89'W	4362			x	x	x	
MSM42_079	030	2015/05/09	06:50	44°06.48'N	45°22.66'W	4456		x	x	x	x	

Station	Profile	Date	Time [UTC]	Latitude	Longitude	Water Depth [m]	CFC offline	SF6/ CFC	Bottle Oxygen	Bottle Salinity	LADCP	Comments
MSM42_080	031	2015/05/09	10:36	43°58.21'N	45°06.91'W	4586		x	x	x	x	
MSM42_081	032	2015/05/09	21:02	45°22.39'N	44°30.25'W	4557		x	x	x	x	
MSM42_082	033	2015/05/10	00:37	45°28.16'N	44°34.98'W	4541			x	x	x	
MSM42_083	034	2015/05/10	04:24	45°33.31'N	44°39.71'W	4477			x	x	x	
MSM42_084	035	2015/05/10	07:58	45°38.42'N	44°44.36'W	4308		x	x	x	x	
MSM42_085	036	2015/05/10	11:32	45°43.46'N	44°49.11'W	4142			x	x	x	
MSM42_086	037	2015/05/10	14:51	45°48.63'N	44°53.94'W	3983	x		x	x	x	
MSM42_087	038	2015/05/10	17:58	45°53.80'N	44°58.70'W	3758			x	x	x	
MSM42_088	039	2015/05/10	20:48	45°57.25'N	45°01.68'W	3183		x	x	x		LADCP low battery, malfunction
MSM42_089	040	2015/05/10	23:40	45°58.90'N	45°03.47'W	2798			x	x	x	
MSM42_090	041	2015/05/11	02:08	46°04.04'N	45°08.17'W	2805		x	x	x	x	
MSM42_091	042	2015/05/11	05:25	46°17.75'N	45°20.98'W	2349		x	x	x	x	
MSM42_092	043	2015/05/11	07:31	46°19.26'N	45°22.27'W	1931		x	x	x	x	
MSM42_093	044	2015/05/11	09:24	46°20.20'N	45°23.18'W	1658		x	x	x	x	
MSM42_094	045	2015/05/11	11:02	46°21.21'N	45°24.17'W	1339		x	x	x	x	
MSM42_095	046	2015/05/11	13:23	46°21.90'N	45°24.73'W	1078		x	x	x	x	LADCP s/n 1973 replaced with s/n 7915
MSM42_096	047	2015/05/11	14:43	46°22.77'N	45°25.45'W	824		x	x	x	x	
MSM42_097	048	2015/05/11	16:02	46°24.41'N	45°27.13'W	574		x	x	x	x	
MSM42_098	049	2015/05/11	17:24	46°29.54'N	45°31.94'W	349			x	x	x	
MSM42_099	050	2015/05/11	19:38	46°13.13'N	45°16.62'W	2874		x	x	x	x	
MSM42_100	051	2015/05/11	22:07	46°08.59'N	45°12.44'W	3112		x	x	x	x	
MSM42_101	052	2015/05/12	02:31	46°29.94'N	45°37.63'W	328			x	x	x	
MSM42_102	053	2015/05/12	03:37	46°30.00'N	45°46.34'W	422			x	x	x	
MSM42_103	054	2015/05/12	04:56	46°29.97'N	45°55.12'W	395			x	x	x	
MSM42_104	055	2015/05/12	06:08	46°29.93'N	46°03.83'W	415			x	x	x	
MSM42_105	056	2015/05/12	07:25	46°29.93'N	46°12.61'W	456		x	x	x	x	
MSM42_106	057	2015/05/12	08:38	46°29.96'N	46°21.32'W	908		x	x	x	x	
MSM42_107	058	2015/05/12	10:04	46°29.96'N	46°30.13'W	899		x	x	x	x	
MSM42_108	059	2015/05/12	11:33	46°29.95'N	46°38.78'W	972		x	x		x	
MSM42_109	060	2015/05/12	13:04	46°29.97'N	46°47.59'W	1235		x	x	x	x	
MSM42_110	061	2015/05/12	14:41	46°29.97'N	46°56.39'W	804		x	x	x	x	

Station	Profile	Date	Time [UTC]	Latitude	Longitude	Water Depth [m]	CFC offline	SF6/ CFC	Bottle Oxygen	Bottle Salinity	LADCP	Comments
MSM42_111	062	2015/05/12	15:59	46°29.98'N	47°05.10'W	741		x	x	x	x	
MSM42_112	063	2015/05/12	17:15	46°30.00'N	47°13.84'W	421			x	x	x	
MSM42_113	-	2015/05/12	21:10	47°07.60'N	47°06.42'W	1001						deployment, mooring BM-25/3
MSM42_114	064	2015/05/12	22:10	47°07.60'N	47°06.42'W	981			x	x	x	
MSM42_115	065	2015/05/13	00:09	47°05.97'N	47°22.55'W	231				x	x	
MSM42_116	066	2015/05/13	01:10	47°05.97'N	47°15.93'W	460		x		x	x	
MSM42_117	067	2015/05/13	02:12	47°05.98'N	47°09.34'W	865		x	x	x	x	
MSM42_118	068	2015/05/13	03:24	47°05.96'N	47°05.90'W	1008		x	x	x	x	
MSM42_119	069	2015/05/13	04:45	47°06.04'N	47°00.61'W	1113		x	x	x	x	
MSM42_120	070	2015/05/13	06:24	47°06.02'N	46°51.24'W	1154		x	x	x	x	
MSM42_121	071	2015/05/13	07:56	47°06.02'N	46°42.49'W	1124		x	x	x	x	
MSM42_122	072	2015/05/13	09:19	47°06.02'N	46°40.04'W	1088		x	x	x	x	
MSM42_123	073	2015/05/13	10:39	47°06.02'N	46°36.66'W	793		x	x	x	x	
MSM42_124	074	2015/05/13	11:47	47°06.03'N	46°33.29'W	483		x	x	x	x	
MSM42_125	075	2015/05/13	12:57	47°06.03'N	46°24.21'W	345			x	x	x	
MSM42_126	076	2015/05/13	14:40	47°06.03'N	46°08.41'W	322					x	
MSM42_127	077	2015/05/13	16:10	47°05.99'N	45°52.65'W	294					x	
MSM42_128	078	2015/05/13	17:47	47°06.01'N	45°36.73'W	254					x	
MSM42_129	079	2015/05/13	19:23	47°05.98'N	45°21.09'W	181					x	
MSM42_130	080	2015/05/13	21:18	47°06.01'N	45°00.05'W	146					x	
MSM42_131	081	2015/05/13	23:13	47°19.03'N	45°00.03'W	186					x	
MSM42_132	082	2015/05/14	01:17	47°33.48'N	45°00.08'W	231					x	
MSM42_133	083	2015/05/14	03:24	47°47.90'N	44°59.99'W	235					x	
MSM42_134	084	2015/05/14	05:24	48°02.29'N	44°59.99'W	304					x	
MSM42_135	085	2015/05/14	07:33	48°16.70'N	45°00.03'W	539		x	x	x	x	
MSM42_136	086	2015/05/14	09:06	48°23.94'N	45°00.03'W	660		x	x	x	x	
MSM42_137	087	2015/05/14	10:47	48°31.13'N	44°59.98'W	806		x	x	x	x	
MSM42_138	088	2015/05/14	12:30	48°38.35'N	45°00.01'W	1031		x	x	x	x	
MSM42_139	089	2015/05/14	14:29	48°45.53'N	44°59.97'W	1254		x	x	x	x	
MSM42_140	090	2015/05/14	16:18	48°52.78'N	44°59.86'W	1307		x	x	x	x	
MSM42_141	091	2015/05/14	18:04	48°59.97'N	45°00.11'W	1605		x	x	x	x	
MSM42_142	092	2015/05/14	19:59	49°07.16'N	44°59.97'W	2184		x	x	x	x	

Station	Profile	Date	Time [UTC]	Latitude	Longitude	Water Depth [m]	CFC offline	SF6/ CFC	Bottle Oxygen	Bottle Salinity	LADCP	Comments
MSM42_143	093	2015/05/14	22:13	49°14.35'N	44°59.97'W	2507		x	x	x	x	
MSM42_144	094	2015/05/15	00:35	49°21.56'N	44°59.97'W	2701		x	x	x	x	
MSM42_145	095	2015/05/15	03:02	49°28.81'N	44°59.92'W	2948		x	x	x	x	
MSM42_146	096	2015/05/15	05:38	49°36.00'N	44°59.96'W	3299		x	x	x	x	
MSM42_147	097	2015/05/15	08:36	49°43.26'N	45°00.01'W	3666		x	x	x	x	
MSM42_148	098	2015/05/15	11:32	49°48.22'N	45°07.42'W	3833			x	x	x	
MSM42_149	099	2015/05/15	15:53	49°53.14'N	45°16.29'W	3765			x	x	x	
MSM42_150	100	2015/05/15	19:04	49°58.03'N	45°25.15'W	3253	x		x	x	x	
MSM42_151	101	2015/05/15	21:44	50°03.02'N	45°33.95'W	3125	x		x	x	x	
MSM42_152	102	2015/05/16	00:23	50°07.97'N	45°42.85'W	2725	x		x	x	x	
MSM42_153	103	2015/05/16	02:46	50°12.92'N	45°51.69'W	2368		x	x	x	x	
MSM42_154	104	2015/05/16	05:01	50°17.88'N	46°00.56'W	2086		x	x	x	x	
MSM42_155	105	2015/05/16	07:13	50°22.80'N	46°09.41'W	1830		x	x	x	x	
MSM42_156	106	2015/05/16	09:14	50°27.73'N	46°18.21'W	1761		x	x	x	x	
MSM42_157	107	2015/05/16	11:20	50°21.24'N	46°23.21'W	1834		x	x	x	x	
MSM42_158	108	2015/05/16	13:12	50°14.74'N	46°28.17'W	2031		x	x	x	x	
MSM42_159	109	2015/05/16	15:06	50°08.21'N	46°33.14'W	2476		x	x	x	x	
MSM42_160	110	2015/05/16	17:17	50°01.70'N	46°38.09'W	2984		x	x	x	x	
MSM42_161	111	2015/05/16	19:48	49°55.24'N	46°43.05'W	2979			x	x	x	
MSM42_162	112	2015/05/16	22:17	49°48.72'N	46°47.98'W	2931		x	x	x	x	
MSM42_163	113	2015/05/17	00:42	49°42.23'N	46°52.91'W	2885			x	x	x	
MSM42_164	114	2015/05/17	03:03	49°35.71'N	46°57.89'W	2831		x	x	x	x	
MSM42_165	115	2015/05/17	05:25	49°29.22'N	47°02.82'W	2780			x	x	x	
MSM42_166	116	2015/05/17	07:48	49°22.70'N	47°07.78'W	2741		x	x	x	x	
MSM42_167	117	2015/05/17	10:14	49°16.20'N	47°12.70'W	2683			x	x	x	
MSM42_168	118	2015/05/17	12:35	49°09.69'N	47°17.65'W	2623		x	x	x	x	
MSM42_169	119	2015/05/17	14:52	49°03.23'N	47°22.61'W	2587			x	x	x	
MSM42_170	120	2015/05/17	17:05	48°56.71'N	47°27.57'W	2549		x	x	x	x	
MSM42_171	121	2015/05/17	19:20	48°50.18'N	47°32.57'W	2474			x	x	x	
MSM42_172	122	2015/05/17	21:29	48°43.71'N	47°37.46'W	2392		x	x	x	x	
MSM42_173	123	2015/05/17	23:39	48°37.22'N	47°42.39'W	2310			x	x	x	
MSM42_174	124	2015/05/18	01:49	48°30.71'N	47°47.36'W	2232		x	x	x	x	

Station	Profile	Date	Time [UTC]	Latitude	Longitude	Water Depth [m]	CFC offline	SF6/ CFC	Bottle Oxygen	Bottle Salinity	LADCP	Comments
MSM42_175	125	2015/05/18	03:58	48°24.22'N	47°52.31'W	2021		x	x	x	x	
MSM42_176	126	2015/05/18	06:08	48°17.69'N	47°57.32'W	1741		x	x	x	x	
MSM42_177	127	2015/05/18	08:04	48°11.17'N	48°02.27'W	1368		x	x	x	x	
MSM42_178	128	2015/05/18	09:24	48°08.69'N	48°04.11'W	1233		x	x	x	x	
MSM42_179	129	2015/05/18	11:09	48°05.28'N	48°06.43'W	691		x	x	x	x	
MSM42_180	130	2015/05/18	12:15	48°02.71'N	48°08.48'W	397			x	x	x	
MSM42_181	131	2015/05/18	13:22	47°58.16'N	48°12.12'W	309			x	x	x	
MSM42_182	132	2015/05/18	20:16	48°53.75'N	46°52.97'W	2704		x	x	x	x	
MSM42_183	133	2015/05/18	22:35	48°47.43'N	46°49.06'W	2626		x	x	x	x	
MSM42_184	134	2015/05/19	01:08	48°41.17'N	46°45.20'W	2643			x	x	x	
MSM42_185	135	2015/05/19	03:33	48°34.87'N	46°41.22'W	2556		x	x	x	x	
MSM42_186	136	2015/05/19	05:59	48°28.55'N	46°37.39'W	2184		x	x	x	x	
MSM42_187	137	2015/05/19	08:12	48°22.24'N	46°33.50'W	1537		x	x	x	x	
MSM42_188	138	2015/05/19	09:45	48°20.36'N	46°32.28'W	1180		x	x	x	x	
MSM42_189	139	2015/05/19	11:20	48°15.91'N	46°29.55'W	858		x	x	x	x	
MSM42_190	140	2015/05/19	12:56	48°12.04'N	46°22.02'W	1106		x	x	x	x	
MSM42_191	141	2015/05/19	14:30	48°08.21'N	46°14.52'W	1152		x	x	x	x	
MSM42_192	142	2015/05/19	16:10	48°04.37'N	46°07.05'W	1116		x	x	x	x	
MSM42_193	143	2015/05/19	17:46	48°00.51'N	45°59.55'W	879		x	x	x	x	
MSM42_194	144	2015/05/19	19:22	47°56.70'N	45°52.02'W	699		x	x	x	x	
MSM42_195	145	2015/05/19	20:51	47°52.84'N	45°44.50'W	412				x	x	
MSM42_196	146	2015/05/19	22:05	47°49.00'N	45°37.06'W	314				x	x	
MSM42_197	147	2015/05/20	03:40	48°40.60'N	45°37.90'W	1097		x	x	x	x	
MSM42_198	148	2015/05/20	05:51	48°34.11'N	45°51.42'W	1073		x	x	x	x	
MSM42_199	149	2015/05/20	07:59	48°27.62'N	46°04.91'W	990		x	x	x	x	
MSM42_200	150	2015/05/20	09:59	48°21.09'N	46°18.49'W	965		x	x	x	x	
MSM42_201	151	2015/05/20	12:02	48°14.54'N	46°32.00'W	847		x			x	
MSM42_202	152	2015/05/20	14:08	48°08.02'N	46°45.57'W	714		x	x		x	
MSM42_203	153	2015/05/20	16:10	48°01.51'N	46°59.12'W	579		x			x	
MSM42_204	154	2015/05/20	18:04	47°54.98'N	47°12.66'W	429					x	
MSM42_205	155	2015/05/21	02:50	49°14.97'N	48°07.41'W	2333					x	
MSM42_206	156	2015/05/21	05:31	49°08.73'N	48°20.28'W	2219					X	

Station	Profile	Date	Time [UTC]	Latitude	Longitude	Water Depth [m]	CFC offline	SF6/ CFC	Bottle Oxygen	Bottle Salinity	LADCP	Comments
MSM42_207	157	2015/05/21	08:15	49°02.54'N	48°33.32'W	2122					x	
MSM42_208	158	2015/05/21	10:45	48°56.30'N	48°46.36'W	2021					x	
MSM42_209	159	2015/05/21	13:17	48°50.08'N	48°59.22'W	1887					x	
MSM42_210	160	2015/05/21	15:49	48°43.89'N	49°12.19'W	1536					x	

8 Data and Sample Storage and Availability

After the end of the cruise all meta information, underway, and bathymetric data was sent to the *German Oceanographic Data Centre* (DOD), which inventoried the respective cruise summary report under reference number 20150254. Already aboard, raw and processed scientific oceanic data was merged into the data collections of the Universities of Bremen and Hamburg, which facilitates any exchange of data products and results among project partners. All scientific data is immediately available to project partners and can be obtained on request by interested cooperating scientists.

Measurements of the vessel's thermosalinograph system (TSG) and respective salinometer data obtained during the cruise were sent to the *Control Station German Research Vessels*. Respective staff members will forward it to those in charge of taking care of the quality control of the vessel's TSG system. Calibrated CTD data (temperature and salinity) of the upper water column (0-2000 dbar) in a 10 dbar resolution were sent to the CORIOLIS data center at *Ifremer*, France (codata@ifremer.fr). There, respective data will be used in the quality-control of *Argo* data and integrated into operational models.

Scientific data of cruise MSM42 will be made public and submitted to international data centers like the CLIVAR & Carbon Hydrographic Data Office (cchdo.ucsd.edu) and PANGAEA (www.pangaea.de) in quarter 2 of year 2018. Both serve as open access long-term archives providing free access to the scientific data. Contact person is D. Kieke (dkieke@physik.uni-bremen.de).

All data collected on marine bird and mammal sightings from cruise MSM42 have been imported into the main pelagic seabird survey database (MS Access), which is managed by the Canadian Wildlife Service, Environment Canada in Dartmouth, Nova Scotia, Canada. The data are made publically available on *OBIS* (Ocean Biogeographic Information System), which is updated on a semi-annual basis. Contact person for bird observations is C. Gjerdrum (carina.gjerdrum@ec,gc.ca).

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