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Short Cruise Report
Maria S. Merian cruise MSM59/2
Cape Town (South Africa) – Port Louis (Mauritius)
28.11.2016 – 22.12.2016
Chief Scientist: Dr. Ulrich Schwarz-Schampera
Captain: Björn Maaß

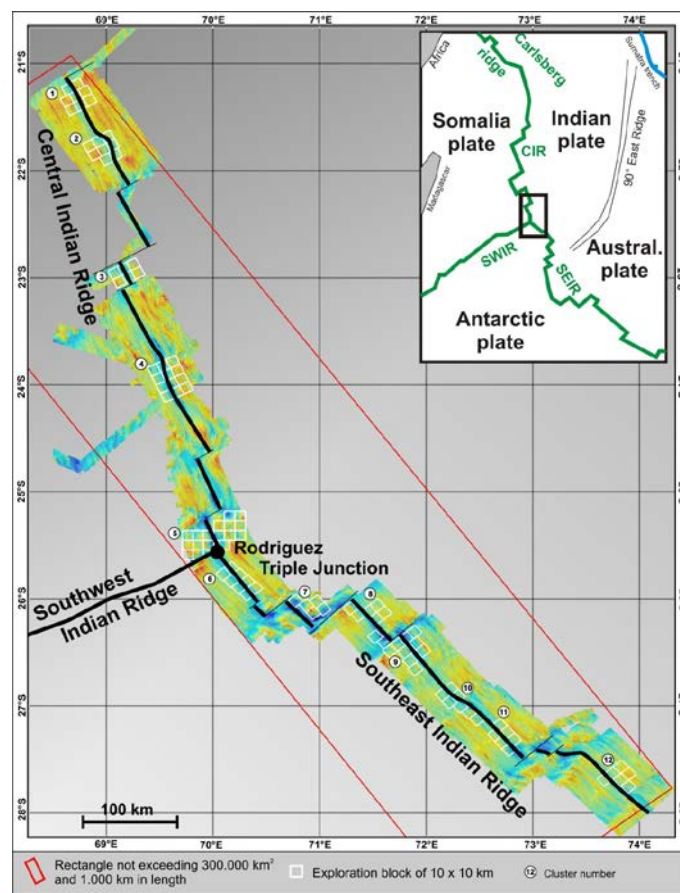


Fig. 1: The German exploration license area along the southernmost Central Indian Ridge and the northernmost Southeast Indian Ridge. Cruise MSM59/1-2 (INDEX 2016_2) with FS MARIA S. MERIAN addressed the North of the Rodriguez Triple Junction along the southern Central Indian Ridge (working area see locations of the license clusters 1-2-3-4).

ABSTRACT

The MSM59/2 expedition (INDEX 2016_2) of BGR with R/V Maria S. Merian targeted the German license area for polymetallic sulphides in the Indian Ocean. The cruise focused on the detailed bathymetric and geological exploration for active vents and inactive sulphide fields in the clusters #1, #2 and #3. The wider license area and the individual clusters were sampled for environmental, i.e., (paleo) oceanographic, sedimentary and faunal base line studies by gravity coring, water sampling, and sediment trap moorings. Very few studies were carried out in this part of the Indian Ocean so far. Our work will contribute to the understanding of regional and wider oceanographic and sedimentation processes and to the faunal census.

The program during MSM59/2 could be carried out completely without any limitations despite the limited time of only 21 working days. Three license clusters were studied for an overview and to some detail for the occurrence of sulphide ores. The results are very promising. In total 70 different stations were carried out including 15 AUV ABYSS-dives, 14 deep-towed bathymetric and sensor-based HOMESIDE surveys, 10 tow-yo sensor sled stations for the identification of hydrothermal discharge and sources, 12 vertical CTD-rosette stations for oceanographic, sedimentological and biological surveys and sampling, 8 heat flow measurements for the evaluation of the temperature regime up to 200 km distance from the Central Indian Ridge, 7 gravity core stations for paleo oceanographic and geochemical studies and 3 moorings of sediment traps, combined with current meters in three different license clusters. One mooring, positioned in 2015, was recovered.

The detailed bathymetric measurements cover a total of 988 km (AUV) and 245 km (HOMESIDE) and 257 hours on the seafloor. Hydrothermal activity could not be detected in the three clusters. However, prospective morphological, structural and volcanic features and edifices possibly indicating sulphide structures and enrichments and former hydrothermal venting on the seafloor were identified in all three clusters, both on the so far more prospective eastern graben side as well as on the western flank of the Central Indian Ridge. The prospective potential increase from cluster #3 (with 2 features) to the cluster #2 (3-4 locations) and to the cluster #1 (5 prospective ridges).

The concomitant environmental base line studies were followed up by three new sediment trap moorings, studies of the biodiversity and sediment sampling. The moorings were synchronized to detect the particle flux and sedimentation rates in the license area in a 20-days interval. At the same time current meters detect the deep water current conditions in various depths of the northern part of the license area. The environmental conditions in the regional part of the license area is continuously studied by gravity core sediment stations. Core lengths up to 9.77 m may cover up to 2 million years. A new sensor and passive sampling devices allow for measurements of dissolved nutrients and metals in the actual water column. Base line studies for the biodiversity from CTD water stations and sediment cores retrieved a total of 279 samples with 5085 individuals. Base line information about the temperature regime and the regional cooling of the oceanic crust along the southern Central Indian Ridge were obtained by heat flow measurements. Over a distance of 200 km towards the spreading axis the measurements indicated notable differences between 0 und 360 mW/m².

Information and thematic contributions of the expedition can be followed at <http://planeterde.de/planeterde-tv/logbuecher/fs-m.s.-merian-indischer-ozean>.



Fig. 2: The scientific participants of cruise MSM59/2 (INDEX2016_2/2) (from left to right): Ralf Freitag, Henning Wedemeyer, Oliver Kefel, Malte Junge, Ingo Heyde, Christian Wöhl, Dennis Hagedorn, Ulrich Schwarz-Schampera, Simone Sturm (alle BGR), Meike Klischies (GEOMAR), Andreas Lückge (BGR), Terue Kihara, Klaas Gerdes (DZMB Senckenberg), Natalie Harms (IFBM Uni Hamburg), Marcel Rothenbeck (GEOMAR), Conny Kriete (BGR), Lars Triebe (GEOMAR), Niko Lahajnar (IFBM Uni Hamburg), Willi Weinrebe (Kiel), Manu Wenzlaff (GEOMAR), Gary Massoth (MassEx), Sergei Zorin (GEOMAR).

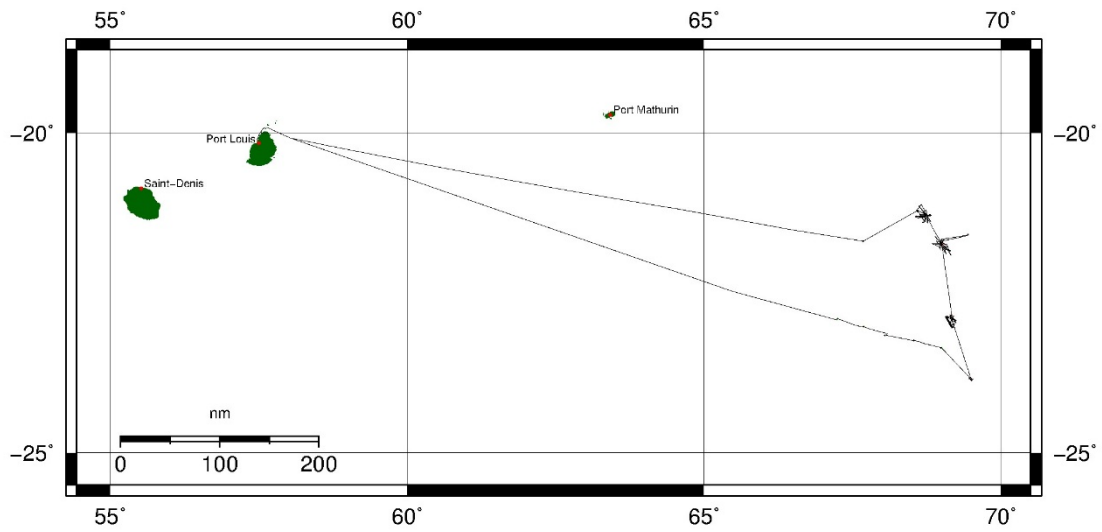


Fig. 3: Overview of the MSM59/2 (INDEX 2016_2) working area and courses along the southern Central Indian Ridge, Central Indian Ocean. The cruise started and ended in Port Louis, Mauritius.

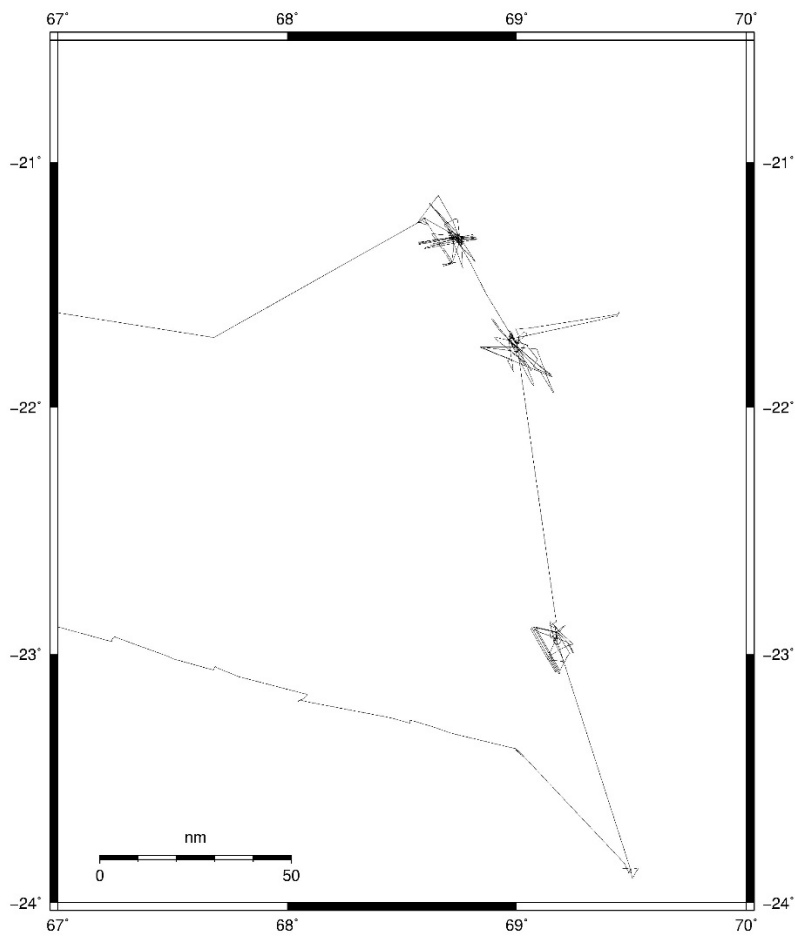


Fig. 4: Overview of the MSM59/2 (INDEX 2016_2) working areas (from North to South cluster #1, cluster #2, cluster #3 and cluster #4) and courses along the southern Central Indian Ridge, Central Indian Ocean (refer to Figure 1 for cluster distribution in the German license area).

CRUISE NARRATIVE

The Shipboard Scientific Party for cruise MSM59/2 (INDEX2016_2) boarded the R/V MARIA S. MERIAN in Port Louis, Mauritius in the morning of November 27th. The containers and the lab equipment were delivered in the morning hours and were taken aboard. Heavy weight equipment including AUV and its launch and recovery system (LARS), plume sled SOPHI, gravity corer and its weight, HOMESIDE, the video sled STROMER and the dredges (DR) as well as various laboratory equipment were installed and unpacked. R/V MARIA S. MERIAN left port of Port Louis on November 28th at 08:50 and started bathymetric mapping during the transit to the working area after leaving the EEZ of Mauritius.

On Wednesday, November 30th we arrived at 08:00 (UTC+4hrs; 04:00 UTC) at the first gravity core station ~250 km west of the CIR spreading axis. A number of five gravity core stations each 50 km apart and followed by heat flow measurements and water column measuring and sampling was carried out while approaching the spreading axis. Core lengths between 468 and 971 cm were achieved. Sediment trap recovery (cluster 4 west 01) followed by CTD stations for sedimentation studies and water column biodiversity. Then deployment of a new sediment trap mooring (Cluster #4-02; same position as 2015 #4-01) at a water depth of 3559m.

Start of working in license cluster #3. After the transponder positioning we left for AUV deployment position east of ridge axis and subsequent deployment of the deep-towed HOMESIDE bathymetry system. Potential sulphide-bearing area to the end of line 1 with a more irregular shape and hummocky structure. No physical or chemical anomalies measured. After its recovery and the recovery of AUV ABYSS we noticed a hit of a redox anomaly on third track line close to a shallow mound-shaped structure on bathymetric map; no temperature or particle anomaly recorded. The next AUV and HOMESIDE stations were deployed for parallel bathymetry lines. After their recovery leaving for CTD stations in preparation of the sediment trap in cluster #3. We obtained 24 water samples for the study of the particle flux in the water column for comparison with the sediment trap samples (biology, biochemistry, nutrient supply, nitrate fixation). AUV and HOMESIDE deployment for detailed bathymetric mapping on the eastern and western graben flanks. A check of the redox anomaly by our plume sled SOPHI could not identify the anomaly. AUV and HOMESIDE stations finished the survey of promising prospective targets along the western and eastern graben flanks. Afterwards deployment of another sediment trap at the northern central end of cluster #3. Then heading to exploration cluster #2 (day 1) with a ~60nm transit to the central area of cluster #2 for deployment of AUV transponders. Deployment of the AUV for detailed mapping of the northern end of a promising interridge section (upper right corner of cluster #2). Deployment of the plume sled for surveying the southern axial ridge section of cluster #2. Indication for a distal signal of particle anomalies at 2400m water depth indicating a possible distal source at water depths of 2500-2700m. CTD stations were performed full water column analysis and gravity core station for the sedimentation record. The AUV and HOMESIDE program continued in cluster #2 with a number of 12-hours profiles. We studied prominent structures and normal fault zones, some with young volcanic edifices. The cluster is clearly in the tectonic stage of ridge evolution and some indications for morphology filling mounds aligned along prominent normal faults exist. Well-developed secondary graben systems are probably too small for hydrothermal systems. There are no clear indications for hydrothermal activity or sulphide fields but good potential for inactive sites. The plume sled did not track any plume anomaly. Another plume sled survey along the southeastern part of cluster #2 identified a weak and distal plume signal. An AUV and a HOMESIDE station surveyed along the eastern slope of the eastern ridge axis graben. The south-eastern corner of cluster #2 was surveyed over 8 km by another plume sled track. A weak particle anomaly is associated with a volcanic edifice sitting on a rather shallow volcanic ridge at ~2530m

along the remaining profile; no Eh anomaly was present. AUV and HOMESIDE stations finished up the detailed mapping program in cluster #2.

The central ridge axis of cluster #1 did not show any indications for hydrothermal venting neither during AUV dives nor from the plume hunting. However, the high resolution bathymetric surveys along the strike of a lower volcanic ridge identified a number of positive morphologically infilling structures. The complete survey highlighted ~4-5 promising targets for inactive sulphide sites – all off-axis between 2 and 4 km apart from the graben axis. The targets feature unusual orientation and shapes when compared to the surrounding mounds and ridges. This includes unusual surfaces (flat or structured) and fractured to various degrees, in part at the rims or the top: Ridge-type graben filling on the western shoulder (target A), flat-topped ridge(s) at the western slope (target B), two smaller ridges at the base of the eastern slope (targets C, D) and mound-shaped feature on a very flat-topped, normal faulted block (type E). The sizes compare well with typical ~300mx200 m sizes of vent sites. The last sediment trap deployment in the northernmost part of cluster #1 was prepared by CTD stations. The CTD covered the entire water column and identified and sampled the different water masses as well as the productive zone. The mooring was set in the north-western most corner of cluster #1 on a plateau-type location, about 1 km in diameter.

The last sediment core position occurred about 63.7 nm away from the sediment trap position (~120km towards Port Louis). The site study started with two CTD stations and water sampling for biological and sedimentological purposes. Subsequent heat flow measurements were successful and so was the coring of the area distal to the exploration claim for establishing the regional sedimentary and paleo oceanographic framework. The end of the scientific program was followed by the transit back to Port Louis (576 nm). After two days of transit (December 20th and 21st) we arrived on December 22nd in Port Louis, Mauritius followed up by complete demobilization of our containers and the departure of Mauritius the same day. Table 3.1 summarizes the time and station plan during cruise MSM59/2 (INDEX2016_2).

Table 3.1. Time and station plan during cruise MSM59/2 (INDEX 2016/2)

Date	Activities	Working days/at sea
Thu 24.11.2016	Travel Hannover – Paris – Port Louis/Mauritius	1
Fri 25.11.2016	Arrival. Hotel	2
Sat 26.11.2016	Hotel. Ship's visit	3
Sun 27.11.2016	Hotel. Vessel occupation.	4
Mon 28.11.2016	Leaving Port Louis. Transit.	5 / 1
Tue 29.11.2016	Transit.	6 / 2
Wed 30.11.2016	INDEX2016_2 - 01GC INDEX2016_2 - 02HF INDEX2016_2 - 03CTD INDEX2016_2 - 04GC	7 / 3
Thu 01.12.2016	INDEX2016_2 - 05GC INDEX2016_2 - 06HF INDEX2016_2 - 07HF INDEX2016_2 - 08GC INDEX2016_2 - 09HF	8 / 4
Fri 02.12.2016	INDEX2016_2 - 10HF INDEX2016_2 - 11HF INDEX2016_2 - 12GC INDEX2016_2 - 13ST INDEX2016_2 - 14CTD INDEX2016_2 - 15CTD INDEX2016_2 - 16ST	9 / 5
Sat 03.12.2016	Cluster #3/1. INDEX2016_2 - 17AUV	10 / 6

	INDEX2016_2 – 18HMS INDEX2016_2 – 19HMS	
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Table 3.1. (continued) Time and station plan during cruise MSM59/2 (INDEX 2016/2)

Sun 04.12.2016	Cluster #3/2. INDEX2016_2 – 20AUV INDEX2016_2 - 21HMS	11 / 7
Mon 05.12.2016	Cluster #3/3 INDEX2016_2 – 22CTD INDEX2016_2 - 23CTD INDEX2016_2 – 24AUV INDEX2016_2 – 25HMS	12 / 8
Tue 06.12.2016	Cluster #3/4. INDEX2016_2 – 26AUV INDEX2016_2 – 27 PS INDEX2016_2 – 28HMS INDEX2016_2 – 29ST	13 / 9
Wed 07.12.2016	Cluster #3/5. INDEX2016_2 – 30AUV INDEX2016_2 - 31PS	14 / 10
Thu 08.12.2016	Cluster #2/1. INDEX2016_2 – 32CTD INDEX2016_2 – 33CTD INDEX2016_2 – 34AUV INDEX2016_2 – 35CTD INDEX2016_2 – 36GC	15 / 11
Fri 09.12.2016	Cluster #2/2. INDEX2016_2 - 37PS INDEX2016_2 – 38AUV	16 / 12
Sat 10.12.2016	Cluster #2/3. INDEX2016_2 – 39HMS INDEX2016_2 - 40PS INDEX2016_2 – 41AUV INDEX2016_2 – 42HMS	17 / 13
Sun 11.12.2016	Cluster #2/4. INDEX2016_2 – 43PS INDEX2016_2 – 44 AUV INDEX2016_2 – 45HMS	18 / 14
Mon 12.12.2016	Cluster #2/5. INDEX2016_2 – 46HMS INDEX2016_2 – 47AUV INDEX2016_2 – 48PS	19 / 15
Tue 13.12.2016	Cluster #1/1. INDEX2016_2 – 49PS INDEX2016_2 – 50AUV INDEX2016_2 – 51HMS	20 / 16
Wed 14.12.2016	Cluster #1/2. INDEX2016_2 – 52CTD INDEX2016_2 – 53CTD INDEX2016_2 – 54AUV INDEX2016_2 – 55HMS	21 / 17
Thu 15.12.2016	Cluster #1/3. INDEX2016_2 – 56PS INDEX2016_2 – 57AUV INDEX2016_2 – 58HMS	22 / 18
Fri 16.12.2016	Cluster #1/4. INDEX2016_2 – 59HF INDEX2016_2 – 60AUV INDEX2016_2 – 61HMS	23 / 19

Table 3.1. (continued) Time and station plan during cruise MSM59/2 (INDEX 2016/2)

Sat 17.12.2016	Cluster #1/5. INDEX2016_2 – 62PS INDEX2016_2 – 63AUV INDEX2016_2 – 64HMS	24 / 20
Sun 18.12.2016	Cluster #1/6. INDEX2016_2 – 65PS INDEX2016_2 – 66ST	25 / 21
Mon 19.12.2016	Cluster #1/7. INDEX2016_2 – 67CTD INDEX2016_2 – 68CTD INDEX2016_2 – 69HF INDEX2016_2 – 70GC	26 / 22
Tue 20.12.2016	Transit to Port Louis	27 / 23
Wed 21.12.2016	Transit to Port Louis	28 / 24
Thu 22.12.2016	Arrival Port Louis, Mauritius. Departure Mauritius	29
Fri 23.12.2016	Arrival Hannover from Paris Charles de Gaulle	30

Acknowledgements

The cruise was carried out based on an intergovernmental agreement between the Federal Ministry for Science and Education and the Ministry of Economy and Energy. For the first time BGR was provided a German research vessel to carry out exploration activities in the German license area for polymetallic sulfides under this agreement. We thank the Ship Coordination Office (Leitstelle) at the Institute of Marine Science, Hamburg University and BRIESE research for their comprehensive support in logistic preparation of the cruise. On behalf of the scientific crew I would like to thank Captain Björn Maaß and the ship's crew for their outstanding assistance and support during all survey operations.

Participants

	Participants	Discipline	Institution
1.	Dr. Ulrich Schwarz-Schampera	Economic Geologist/Chief Scientist	BGR
2.	Dr. Ralf Freitag	Geologist/Bathymetry	BGR
3.	Dr. Andreas Lückge	Geologist/Sedimentology	BGR
4.	Malte Junge	Geologist/Water Column Analysis	BGR
5.	Dr. Ingo Heyde	Geophysicist/Magnetics, Heat Flow	BGR
6.	Conny Kriete	Chemist/Water Column Analysis	BGR
7.	Hennig Wedemeyer	Technician/Electronics	BGR
8.	Oliver Kefel	Technician/Mechanics	BGR
9.	Dennis Hagedorn	Technician/Electronics	BGR
10.	Christian Wöhr	Technician/Sedimentology	BGR
11.	Simone Sturm	Technician/Logistics	BGR
12.	Gary Massoth	Chemist/Water Column Analysis	Mass-Ex ³
13.	Dr. Terue Kihara	Biologist/Biodiversity	Senck
14.	Klaas Gerdes	Biologist/Biodiversity	Senck
15.	Dr. Niko Lahajnar	Geologist/Sedimentology	U. HH
16.	Natalie Harms	Geologist/Sedimentology	U. HH
17.	Dr. Willi Weinrebe	Geologist/Water Column Analysis	Wein_Kiel
18.	Meike Klischies	Geologist/AUV Bathymetry	GEOMAR
19.	Marcel Rothenbeck	Technician/AUV Bathymetry	GEOMAR
20.	Lars Triebe	Technician/AUV Bathymetry	GEOMAR
21.	Emanuel Wenzlaff	Technician/AUV Bathymetry	GEOMAR
22.	Sergei Zorin	Technician/AUV Bathymetry	GEOMAR

Station List

MSM59 St. No.	Date	BGR St. No.	Latitude	Longitude	Location
		INDEX2016_2	Lat	Lon	[m]
729-1	30.11.2016	01GC	22° 55,88' S	67° 14,73' E	Transit
729-2	30.11.2016	02HF	22° 55,88' S	67° 14,73' E	Transit
729-3	30.11.2016	03CTD	22° 55,86' S	67° 14,87' E	Transit
730-1	30.11.2016	04GC	23° 3,17' S	67° 41,06' E	Transit
730-2	30.11.2016	Test	23° 3,17' S	67° 41,06' E	AUV Test
731-1	30.11.2016	05GC	23° 11,55' S	68° 2,77' E	Transit
731-2	01.12.2016	06HF	23° 11,55' S	68° 2,75' E	Transit
731-3	01.12.2016	07HF	23° 11,55' S	68° 2,75' E	Transit
732-1	01.12.2016	08GC	23° 16,04' S	68° 31,92' E	Transit
732-2	01.12.2016	09HF	23° 16,04' S	68° 31,92' E	Transit
733-1	01.12.2016	10HF	23° 23,18' S	68° 59,75' E	Transit
733-2	01.12.2016	11HF	23° 23,18' S	68° 59,75' E	Transit
733-3	02.12.2016	12GC	23° 23,16' S	68° 59,73' E	Transit
734-1	02.12.2016	13ST	23° 52,39' S	69° 29,49' E	Cluster#4
734-2	02.12.2016	14CTD	23° 52,50' S	69° 29,72' E	Cluster#4
734-3	02.12.2016	15CTD	23° 52,50' S	69° 29,72' E	Cluster#4
734-4	02.12.2016	16ST	23° 52,76' S	69° 29,17' E	Cluster#4
735-1	02.12.2016	17AUV	22° 56,83' S	69° 10,48' E	Cluster#3
735-4	03.12.2016	18HMS	22° 53,76' S	69° 5,01' E	Cluster#3
736-1	03.12.2016	19HMS	22° 59,63' S	69° 8,55' E	Cluster#3
737-1	04.12.2016	20AUV	22° 54,74' S	69° 10,50' E	Cluster#3
738-1	04.12.2016	21HMS	22° 53,53' S	69° 4,53' E	Cluster#3
739-1	04.12.2016	22CTD	22° 53,15' S	69° 9,81' E	Cluster#3
739-2	05.12.2016	23CTD	22° 53,15' S	69° 9,81' E	Cluster#3
740-1	05.12.2016	24AUV	22° 54,75' S	69° 10,51' E	Cluster#3
741-1	05.12.2016	25HMS	22° 53,78' S	69° 4,01' E	Cluster#3
742-1	05.12.2016	26AUV	22° 54,73' S	69° 10,50' E	Cluster#3
743-1	06.12.2016	27PS	22° 57,83' S	69° 13,76' E	Cluster#3
744-1	06.12.2016	28HMS	22° 53,97' S	69° 3,63' E	Cluster#3
745-1	06.12.2016	29ST	22° 52,29' S	69° 8,78' E	Cluster#3
747-1	07.12.2016	30AUV	21° 43,39' S	68° 57,83' E	Cluster#3
748-1	07.12.2016	31PS	21° 54,47' S	69° 4,50' E	Cluster#3
749-1	08.12.2016	32CTD	21° 46,55' S	69° 1,03' E	Cluster#2
749-2	08.12.2016	33CTD	21° 46,55' S	69° 1,03' E	Cluster#2
750-1	08.12.2016	34AUV	21° 43,39' S	68° 57,82' E	Cluster#2
751-1	08.12.2016	35CTD	21° 36,86' S	69° 26,64' E	Cluster#2
751-2	08.12.2016	36GC	21° 36,85' S	69° 26,64' E	Cluster#2
752-1	08.12.2016	37PS	21° 46,56' S	69° 1,04' E	Cluster#2
753-1	09.12.2016	38AUV	21° 43,37' S	68° 57,78' E	Cluster#2

Station List (continued)

754-1	09.12.2016	39HMS	21° 48,40' S	69° 1,26' E	Cluster#2
755-1	10.12.2016	40PS	21° 50,30' S	69° 4,33' E	Cluster#2
756-1	10.12.2016	41AUV	21° 43,39' S	68° 57,78' E	Cluster#2
757-1	10.12.2016	42HMS	21° 52,53' S	69° 9,10' E	Cluster#2
758-1	11.12.2016	43PS	21° 56,36' S	69° 9,41' E	Cluster#2
759-1	11.12.2016	44AUV	21° 43,41' S	68° 57,77' E	Cluster#2
760-1	11.12.2016	45HMS	21° 51,30' S	68° 59,12' E	Cluster#2
761-1	11.12.2016	46HMS	21° 45,39' S	68° 51,45' E	Cluster#2
764-1	12.12.2016	47AUV	21° 18,38' S	68° 45,35' E	Cluster#2
765-1	12.12.2016	48PS	21° 25,96' S	68° 45,85' E	Cluster#2
766-1	13.12.2016	49PS	21° 16,37' S	68° 42,15' E	Cluster#1
767-1	13.12.2016	50AUV	21° 18,43' S	68° 45,32' E	Cluster#1
768-1	13.12.2016	51HMS	21° 24,64' S	68° 43,28' E	Cluster#1
769-1	14.12.2016	52CTD	21° 10,14' S	68° 37,32' E	Cluster#1
769-2	14.12.2016	53CTD	21° 10,14' S	68° 37,31' E	Cluster#1
770-1	14.12.2016	54AUV	21° 18,38' S	68° 45,37' E	Cluster#1
771-1	14.12.2016	55HMS	21° 17,66' S	68° 37,79' E	Cluster#1
772-1	15.12.2016	56PS	21° 15,33' S	68° 41,01' E	Cluster#1
773-1	15.12.2016	57AUV	21° 18,38' S	68° 45,38' E	Cluster#1
774-1	15.12.2016	58HMS	21° 21,20' S	68° 35,81' E	Cluster#1
775-1	16.12.2016	59HF	21° 19,66' S	68° 34,15' E	Cluster#1
776-1	16.12.2016	60AUV	21° 18,41' S	68° 45,30' E	Cluster#1
777-1	16.12.2016	61HMS	21° 18,59' S	68° 49,08' E	Cluster#1
778-1	17.12.2016	62PS	21° 24,33' S	68° 49,07' E	Cluster#1
779-1	17.12.2016	63AUV	21° 18,38' S	68° 45,32' E	Cluster#1
780-1	17.12.2016	64HMS	21° 18,99' S	68° 44,11' E	Cluster#1
781-1	18.12.2016	65PS	21° 14,23' S	68° 43,10' E	Cluster#1
782-1	18.12.2016	66ST	21° 14,93' S	68° 33,96' E	Cluster#1
783-1	19.12.2016	67CTD	21° 43,08' S	67° 40,44' E	Transit
783-2	19.12.2016	68CTD	21° 43,08' S	67° 40,44' E	Transit
783-3	19.12.2016	69HF	21° 43,07' S	67° 40,67' E	Transit
783-4	19.12.2016	70GC	21° 43,07' S	67° 40,67' E	Transit