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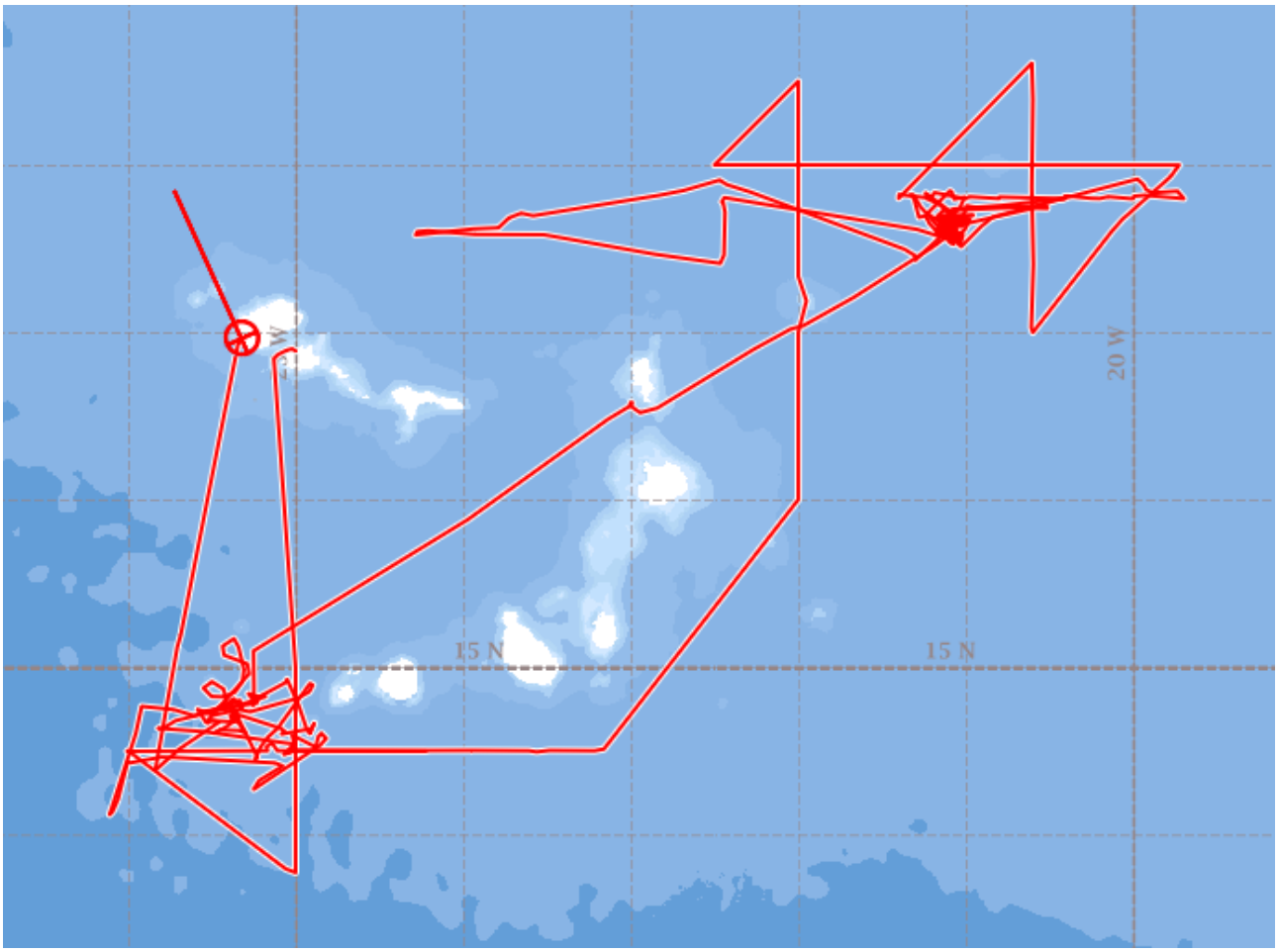
Short Cruise Report

Meteor M160

Mindelo/Cabo Verde – Mindelo/Cabo Verde

23rd November – 20th December 2019 Chief Scientist: Prof. Dr. Arne Körtzinger

Captain: Rainer Hammacher



Objectives

The ultimate goal of cruise M160 (MOSES Eddy Study II) was to contribute significantly to our understanding of how ocean eddies generated in one of the major eastern boundary upwelling systems, i.e. the Canary Current system, shape and mediate ocean productivity and vertical carbon export via the biological carbon pump.

For this purpose, we aimed to carry out a detailed high-resolution, interdisciplinary, multi-parameter study of two individual eddies in Cabo Verdean waters. Eddies are an omnipresent feature of the tropical northeast Atlantic Ocean. They are generated off West Africa throughout the year with a peak in frequency during summer. At an average propagation speed of 3.0 ± 2.5 km d^{-1} along their typical westward trajectories this peak in eddy abundance has reached the region to the northeast of the Cabo Verdean archipelago by November/December. The timing of cruise M160 therefore provided the highest likelihood of encountering strong eddies in the working area, the extension of which was to some extent constrained by the safe operation range of the Stemme S10 VTX motorglider (Aachen University of Applied Sciences) used for parallel airborne observations of sub-mesoscale eddy features.

This ambitious eddy study built on an approach demonstrated successfully during the 2014 “Eddy Hunt Project” (GEOMAR & Kiel University) combined with the successful approaches of the sub-mesoscale studies SubEx I & II and the “Expedition Clockwork Ocean” (HZG). Using refined automated detection methods employing remote sensing products (sea level anomaly, sea surface temperature, ocean color) early detection of eddies was possible during the months preceding the cruise. For groundtruthing of potential candidate eddies, ocean gliders were deployed from the ‘Ocean Science Centre Mindelo’ (www.oscm.cv, São Vincente island, Cabo Verde) prior to the cruise.

The main goal was to carry out both detailed mesoscale and sub-mesoscale studies of two individual eddies selected through the early detection and verification scheme described above. The general concept of the eddy study started with a detailed survey of mesoscale properties of an eddy. This included the current field in the upper 1200 m as well as physical and a whole suite of biogeochemical and biological properties at the surface and in the upper 1200 m of the water column. On the basis of this survey and with the aid of remote sensing information of temperature, currents and ocean color information – both from satellites and the glider plane – the exact locations of the sub-mesoscale studies were determined. Both mesoscale and sub-mesoscale studies featured a large range of observational techniques that were deployed in a concerted way. Special attention was given to the frontal region at boundary of the eddies where strong vertical and horizontal sub-mesoscale motion is concentrated in sharp fronts at the surface connecting matter exchange with the surface layer and across the eddy boundary. Elucidating these contrasting roles by connecting the large range of relevant scales was a major and novel aim of the study.

Narrative

The scientific party of RV Meteor cruise M160 arrived to Mindelo/Cabo Verde between Nov. 19 and 21 and immediately started unpacking and installing the large amount of equipment such that everything had been installed in a seaworthy manner at departure on Nov. 23. Prior to that, a brief meeting was held on Meteor with the chief pilot and principal investigator of the joint research airplane mission and representatives of the Coast Guard of Cabo Verde to discuss aircraft operations, communications and safety issues.

After departure, we headed to the southwest of the islands of Fogo and Brava where satellite imagery suggested the presence of a strong cyclonic eddy. This eddy was surveyed in its entirety along a cross-like pattern with underway current (ADCP) and underway CTD hydrographic measurements. In addition, one wave glider, two gliders, two Argo floats (1 BGC-Argo float) and a surface drifter were deployed around and within the eddy. Furthermore we carried out a zonal section across the eddy with the towed instrument array (TIA) of the HZG and deployed a short-term mooring near the eastern flank of the eddy. Finally, a full station program with CTD-rosette, multi opening/closing net and marine snow catcher was performed in the eddy center where also the first 24 h drift experiment with the sediment traps took place. The duration of the 24 h station allowed us to also quickly survey a strong but shallow anticyclonic eddy on the leeward side of the island of Santiago where two more gliders, a float and a surface drifter were deployed before return to the cyclone. By this, we aimed at capturing the eddy in its current state as a reference to the state it would have when we returned to it for detailed study towards the end of the cruise.

After completion of this eddy pre-survey, we departed on Nov. 26 for a new study area to the northeast of the Cabo Verdean archipelago, where interesting eddy features had shown up in the satellite images. On the way, we performed a CTD/ADCP section to 1200 m depth along 22°W reaching to 18.5°N (Nov. 28) where we carried out a search for a possible anticyclonic mode water eddy (ACME) which express themselves only very weakly in satellite data. In situ data from the gliders and wave glider, however, had given us – already prior to the start of the M160 cruise – some hints of the presence of such a feature in that region. The survey revealed indeed shallow filaments of strongly oxygen-depleted water, which could be remnants of an ACME, but no coherent eddy.

We therefore decided to head east towards a large and dynamic cyclonic eddy centered around 18°N/22°36’W where we spent the next 12 days (Nov. 29 to Dec. 10) and executed the first complete eddy study program starting with a detailed ADCP and CTD/RO survey along a cross-like pattern spanning the entire eddy into surrounding waters. During the course of this, 5 more gliders, 3 floats (2 BGC-Argo floats) and surface drifters were deployed. One of our wave gliders was recovered, refurbished and re-deployed. Also, three 24 h sediment trap drifters with biogeochemical sensor package in the mixed layer were deployed in different locations of the eddy (centre, rim).

This eddy was also chosen for the first detailed study of sub-mesoscale eddy dynamics. After a larger ADCP, X-band radar and thermosalinograph survey in the southwestern frontal region, a target area was identified where a clear thermal front was located. In a distance of about 1 nm on the cold eddy-side of the front, the first of two dye release

experiments was carried out. For this experiment, about 70 kg of the non-toxic, environmentally harmless water tracer rhodamine WT were prepared in about 900 L of a water-isopropanol solution, the density of which was carefully adjusted to the target density at planned deployment depth. For deployment, a reinforced hose was lowered attached to a modified CTD with rhodamine sensor to the target depth of about 65 m. By means of a pump the dye solution was then pumped at constant rate down to the end of the hose where it was dispersed through a 1 m long holey pipe into the waters. We adjusted the ship speed through water to about 1 knot while a pump rate of approx. 1000 L/h was maintained. This way, the dye was laid out as narrow and thin streak with a length of nearly 1 nm. Right after deployment, the TIA was towed across the dye streak in a zigzag pattern allowing us to map the depth-density-temperature range and the geographical location to which the streak had actually been placed. In the following 3 days we repeatedly returned to the dye streak to map its changing location and shape. After the initial spreading we changed from the TIA to the Moving Vessel Profiler (MVP), a free falling CTD sensor package with rhodamine sensor and its own winch that allows CTD profiles to be taken of the upper 100 m at about 4-5 min separation from the moving vessel. While this method gave less horizontal resolution, it provided beautifully resolved peaks of the vertical dye distribution.

As complementary observational component of the sub-mesoscale eddy study, the research motorglider Stemme of the University of Applied Sciences in Aachen was used for aerial observations of temperature (infrared camera) and ocean color/chlorophyll (hyperspectral camera) by the HZG Institute for Coastal Research. Initial technical problems with the aircraft and the scientific payload delayed the start of the aircraft operations. Strongly overcast cloud conditions and the long distance between study area and the plane’s base at Sal airport further reduced the time window for aerial observations. Nevertheless, a few successful flights with nice IR images of the frontal situation in the sub-mesoscale study area could be performed from a flight altitude of about 5000 m.

Towards the end of the work program at this cyclonic eddy, unfavorable weather conditions with wind force around 7 Beaufort prevented the safe recovery of 6 gliders and 1 wave glider. In order to save ship time while waiting for somewhat calmer conditions, we preponed the visit to the long-term time series station “Cape Verde Ocean Observatory” (CVOO). Station work there included among standard instruments a further float and surface drifter deployment. After completion of the CVOO station (Dec. 8-10), we returned to the eddy where conditions had only slightly improved but still prevented deployment of the zodiac for glider recoveries. We therefore decided to use the “Rescue Star” for recoveries, an instrument developed specifically for the rescue of shipwrecked people during bad weather conditions and heavy sea state. Using this device, we were able to safely recover all 6 gliders, 5 of which had previously been aligned into a straight formation with close distances of 0.5-1 nm at the sea surface so that they could all be recovered in record-breaking 2 hours in total.

After the work at this eddy was finished, we returned to the cyclone southwest of Fogo island which had remained very intense throughout this. Due to time constraints, we repeated the full eddy study program of the first eddy here but for large parts in parallel (Dec. 11-18). Again, underway ADCP, X-band radar and thermosalinograph survey were

combined with the full station work including 3 additional 24 h drift stations, glider, wave glider, float and surface drifter deployments etc. Operations went very smoothly although the parallel execution of the mesoscale and sub-mesoscale surveys and the synchronization with the flight operations placed several additional time constraints on the work plan and made planning rather complex. For the sub-mesoscale component, the dye release experiments was repeated successfully in a very similar way, this time near the eddy center at about 45 m depth. There, very cold water (up to 5°C temperature contrast to surrounding non-eddy waters) with clear upwelling signatures and drastically elevated primary and secondary production had been encountered.

The aircraft team had decided to move operations from the international airport of Sal to the small domestic airport of Fogo. The resulting proximity to the Fogo eddy allowed longer observation flights at lower altitude (about 3000 m) yielding more and better data. During the sub-mesoscale studies, some beautiful infrared and hyperspectral image maps of staggered thermal fronts around the eddy core were obtained and allowed the Meteor to perform its TIA and X-band radar observations as well as its hyperspectral light measurements to be guided by and synchronized with the aircraft. These studies again show highly dynamic features even near the eddy center pointing at rapid adjustment processes possibly triggered by a drop in the prevailing wind forcing. The final flight finished with a close overflight of RV Meteor on Dec. 15. The aircraft and the entire team then flew back to Sal to dismantle the plane and stow it into a 40’-container for shipment back to Aachen.

The Meteor continued the Fogo eddy study until Nov. 19. During the time was started the recovery of the manifold instruments that we had placed in the eddy. The short-term mooring as well as the 2 wave gliders were successfully recovered on Dec. 16 while the gliders stayed active until Dec. 18. The final CTD cast was performed late on Dec. 17 allowing groups to wind down operations already on Dec. 18. The short transit to Mindelo prevented all groups from relaxing after the end of the work program as all equipment had to be dismantled, cleaned, packed and prepared for shipment prior until the evening of Dec. 20. On Dec. 19, RV Meteor and RV Maria S. Merian had a brief rendezvous at sea in the sheltered bay of Tarrafal on the Cabo Verdean island of Santo Antão. The cruise ended after 3845 nautical miles in the morning of Dec. 20 in Mindelo.

Throughout the cruise, meetings with the captain and the heads of the ship departments were held every day at 8:00 board time. Also we had a full science meeting with discussion of work progress, first results, following work plan as well status of instruments and everyday at 10:00 board time. Finally, a brief teleconference was held nearly every day at 19:30 board time with the airplane team for discussion of previous and upcoming flight missions and their synchronization with the ship operations.

Given the complexity and density of the work program, the parallel execution of different yet connected studies (mesoscale, sub-mesoscale, aerial) and the large number of instruments operated both on board and autonomously in the ocean it is amazing how smooth, cooperative and successful it could be carried through to the end. All cruise objectives were met and all groups received very much all their requested station time and sample material.

Group photo of M160 scientific party (Photo: Andreas Raeke, DWD)

Research motorglider of the University for Applied Sciences in Aachen during overflight of RV Meteor as seen from the vessel (left, photo: Arne Körtzinger, GEOMAR) and the plane (right, photo: Burkard Baschek, HZG)

Acknowledgements

We greatly appreciate the wonderful working atmosphere as well as the professionalism and seamanship of crew, officers and Captain of R/V METEOR, which made this ambitious and complex work a great success.

The Chief Scientist further acknowledges the skillfulness, great working spirit and cooperativeness of the scientific party of M160, which can be proud of its achievements.

List of Participants

1.	Körtzinger, Arne	Fahrtleiter / *Chief Scientist*	GEOMAR
2.	Dengler, Marcus	Physical Oceanography	GEOMAR
3.	Fischer, Tim	Physical Oceanography	GEOMAR
4.	Müller, Mario	Physical Oceanography	GEOMAR
5.	Pinck, Andreas	Physical Oceanography	GEOMAR
6.	Chouksey, Manita	Physical Oceanography	UNI HH
7.	Andrae, Alexandra	Physical Oceanography	GEOMAR
8.	Knudsen, Juri	Physical Oceanography	GEOMAR
9.	Fiedler, Björn	Chemical Oceanography	GEOMAR
10.	Paulsen, Melf	Chemical Oceanography	GEOMAR
11.	Bogner, Boie	Chemical Oceanography	GEOMAR
12.	Hahn, Tobias	Chemical Oceanography	GEOMAR
13.	Leibold, Patrick	Data Science	GEOMAR
14.	Golde, Sandra	Biological Oceanography	GEOMAR
15.	Hepach, Helmke	Biological Oceanography	GEOMAR
16.	Devresse, Quentin	Biological Oceanography	GEOMAR
17.	Becker, Kevin	Biological Oceanography	GEOMAR
18.	Nothof, Maren	Biological Oceanography	UNI KL
19.	Katzenmeier, Sven	Biological Oceanography	UNI KL
20.	Flintrop, Clara	Biological Oceanography	MARUM
21.	Hufnagel, Lili	Biological Oceanography	MARUM
22.	Moradi, Nasrollah	Biological Oceanography	MARUM
23.	Rezende Calil, Paulo	Physical Oceanography	HZG
24.	Merckelbach, Lucas	Physical Oceanography	HZG
25.	Alvarez Carrasco, Ruben	Physical Oceanography	HZG
26.	Blandfort, Daniel	Physical Oceanography	HZG
27.	Hieronymi, Martin	Physical Oceanography	HZG
28.	Kock, Thomas	Physical Oceanography	HZG
29.	Schultze, Larissa	Physical Oceanography	HZG
30.	Raeke, Andreas	Meteorology	DWD

Institutions

DWD	Deutscher Wetterdienst
GEOMAR	GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel
HZG	Institut für Küstenforschung, Helmholtz-Zentrum Geesthacht
MARUM	Zentrum für Marine Umweltwissenschaften, Universität Bremen
UNI HH	Institut für Meereskunde, Universität Hamburg
UNI HH	Fachbereich Biologie, Universität Kaiserslautern

Station list

Stations

Station times refer to time the instrument goes into water (FLOAT, GLD/D, MDRIFT, MSS, SVP, WGLD/D, WRIDE/D), the instrument reaches depth (CTD/RO, MSC, MSN), the anchor weight is released (DST/D, MOOR/D), or the instrument is fully taken on board (GLD/R, MOOR/R, WGLD/R, WRIDE/R) unless otherwise stated in the “comments” column.

Station	Date in 2019	Time [UTC]	Device	Latitude	Longitude	Water Depth (m)	Profile depth (m)	Comment
M160_1-1	24.11.	09:56	GLD/D	14° 30,028' N	026° 00,029' W	4581		
M160_2-1	24.11.	10:49	WGLD/D	14° 30,025' N	026° 00,030' W	4580		
M160_3-1	24.11.	11:34	GLD/D	14° 30,049' N	026° 00,044' W	4580		
M160_4-1	24.11.	19:56	DST/D	14° 30,014' N	025° 10,108' W	4344		
M160_5-1	24.11.	20:54	CTD/RO	14° 30,204' N	025° 10,169' W	4346	2000	
M160_6-1	24.11.	23:25	MSS	14° 31,914' N	025° 10,410' W	4360		
M160_7-1	24.11.	23:32	FLOAT	14° 32,119' N	025° 10,384' W	4354		Argo Float
M160_8-1	24.11.	23:37	FLOAT	14° 32,306' N	025° 10,358' W	4348		BGC-Argo Float
M160_9-1	24.11.	23:40	SVP	14° 32,390' N	025° 10,355' W	4344		SVP drifter
M160_10-1	25.11.	12:25	CTD/RO	14° 30,059' N	024° 59,923' W	4196	4231	
M160_11-1	25.11.	18:43	MOOR/D	14° 32,786' N	025° 00,166' W	4017		KPO 1217
M160_12-1	25.11.	20:03	DST/R	14° 28,999' N	025° 02,985' W	4294		
M160_13-1	25.11.	20:25	MSC	14° 28,999' N	025° 02,986' W	4297	20	
M160_14-1	25.11.	20:36	MSC	14° 29,000' N	025° 02,984' W	4292	17	
M160_15-1	25.11.	21:23	CTD/RO	14° 28,999' N	025° 02,985' W	4297	1000	
M160_16-1	25.11.	22:48	MSN	14° 28,998' N	025° 02,985' W	4295	1000	
M160_17-1	26.11.	15:40	CTD/RO	14° 29,962' N	023° 33,029' W	3939	2000	
M160_18-1	26.11.	17:06	GLD/D	14° 29,960' N	023° 33,029' W	3941		
M160_19-1	26.11.	17:23	GLD/D	14° 29,957' N	023° 33,030' W	3943		
M160_20-1	26.11.	19:08	MSS	14° 29,673' N	023° 32,092' W	3940		
M160_21-1	26.11.	19:32	CTD/RO	14° 29,664' N	023° 32,081' W	3939	500	
M160_22-1	26.11.	19:57	FLOAT	14° 29,641' N	023° 32,018' W	3937		Argo Float
M160_23-1	26.11.	19:58	SVP	14° 29,640' N	023° 31,991' W	3937		SVP drifter
M160_24-1	27.11.	12:16	CTD/RO	16° 00,065' N	021° 59,966' W	3432	1200	
M160_25-1	27.11.	15:33	CTD/RO	16° 20,122' N	022° 00,019' W	3619	1200	
M160_26-1	27.11.	18:53	CTD/RO	16° 39,994' N	021° 59,984' W	3525	1200	
M160_27-1	27.11.	22:11	CTD/RO	17° 00,093' N	021° 59,962' W	3384	1200	
M160_28-1	28.11.	00:26	CTD/RO	17° 11,263' N	021° 57,116' W	110	100	
M160_29-1	28.11.	02:16	CTD/RO	17° 20,028' N	021° 59,974' W	3029	1200	
M160_30-1	28.11.	05:36	CTD/RO	17° 41,542' N	021° 59,983' W	3340	1200	
M160_31-1	28.11.	07:50	CTD/RO	17° 50,007' N	021° 59,995' W	3322	1200	
M160_32-1	28.11.	10:09	CTD/RO	18° 00,059' N	022° 00,026' W	3305	1200	
M160_33-1	28.11.	12:30	CTD/RO	18° 10,085' N	022° 00,012' W	3308	1200	
M160_34-1	28.11.	14:47	CTD/RO	18° 20,031' N	022° 00,027' W	3321	1200	
M160_35-1	28.11.	17:10	CTD/RO	18° 30,017' N	021° 59,998' W	3333	1200	
M160_36-1	28.11.	22:48	CTD/RO	18° 00,049' N	022° 29,997' W	3338	1200	
M160_37-1	29.11.	01:34	CTD/RO	17° 59,954' N	022° 14,920' W	3322	1200	
M160_38-1	29.11.	22:46	CTD/RO	17° 00,001' N	020° 36,002' W	3438	1200	
M160_39-1	30.11.	00:22	MSS	17° 00,330' N	020° 36,475' W	3440		
M160_40-1	30.11.	02:08	CTD/RO	17° 12,006' N	020° 35,955' W	3396	1200	
M160_41-1	30.11.	03:50	MSS	17° 12,682' N	020° 36,269' W	3394		
M160_42-1	30.11.	04:18	CTD/RO	17° 12,711' N	020° 36,279' W	3393	500	
M160_43-1	30.11.	06:37	CTD/RO	17° 23,990' N	020° 35,956' W	3327	1200	
M160_44-1	30.11.	08:20	MSS	17° 24,399' N	020° 35,799' W	3327		
M160_45-1	30.11.	10:04	CTD/RO	17° 36,005' N	020° 35,997' W	3226	1200	
M160_46-1	30.11.	11:48	MSS	17° 36,746' N	020° 36,055' W	3216		
M160_47-1	30.11.	12:16	CTD/RO	17° 36,766' N	020° 36,052' W	3220	500	

M160_48-1	30.11.	14:19	MSN	17° 47,963' N	020° 36,023' W	3140	1000	
M160_49-1	30.11.	15:39	CTD/RO	17° 47,964' N	020° 36,026' W	3139	800	
M160_50-1	30.11.	16:35	GLD/D	17° 47,960' N	020° 36,020' W	3139		
M160_51-1	30.11.	17:08	GLD/D	17° 47,959' N	020° 36,020' W	3140		
M160_52-1	30.11.	17:52	GLD/D	17° 47,960' N	020° 36,021' W	3141		
M160_53-1	30.11.	18:55	MSC	17° 47,962' N	020° 36,022' W	3139	34	
M160_54-1	30.11.	19:07	MSC	17° 47,963' N	020° 36,024' W	3139	40	
M160_55-1	30.11.	20:10	CTD/RO	17° 47,961' N	020° 36,022' W	3140	1200	
M160_56-1	30.11.	22:38	MSC	17° 49,075' N	020° 36,044' W	3138		
M160_57-1	30.11.	23:21	CTD/RO	17° 49,084' N	020° 36,051' W	3136	1000	
M160_58-1	01.12.	00:26	MSN	17° 49,086' N	020° 36,049' W	3136	1000	
M160_59-1	01.12.	01:16	FLOAT	17° 49,162' N	020° 36,155' W	3135		BGC-Argo Float
M160_60-1	01.12.	01:22	FLOAT	17° 49,365' N	020° 36,269' W	3135		BGC-Argo Float
M160_61-1	01.12.	01:26	FLOAT	17° 49,462' N	020° 36,327' W	3132		Argo Float
M160_62-1	01.12.	01:27	SVP	17° 49,505' N	020° 36,353' W	3133		
M160_63-1	01.12.	03:08	CTD/RO	18° 00,030' N	020° 36,011' W	3091	1200	
M160_64-1	01.12.	04:56	MSS	18° 00,785' N	020° 36,262' W	3086		
M160_65-1	01.12.	06:38	CTD/RO	18° 11,977' N	020° 36,036' W	3125	1200	
M160_66-1	01.12.	08:23	MSS	18° 12,342' N	020° 36,628' W	3126		
M160_67-1	01.12.	10:08	CTD/RO	18° 24,021' N	020° 36,021' W	3175	1200	
M160_68-1	01.12.	11:21	MSS	18° 24,042' N	020° 36,035' W	3177		
M160_69-1	01.12.	13:43	CTD/RO	18° 35,999' N	020° 36,026' W	3212	1200	
M160_70-1	01.12.	15:39	MSS	18° 36,576' N	020° 36,390' W	3212		
M160_71-1	01.12.	15:51	MSC	18° 36,579' N	020° 36,399' W	3212	40	
M160_72-1	01.12.	16:05	MSC	18° 36,579' N	020° 36,400' W	3212	40	
M160_73-1	02.12.	02:26	CTD/RO	17° 48,053' N	021° 24,026' W	3239	1200	
M160_74-1	02.12.	04:07	MSS	17° 48,698' N	021° 24,382' W	3236		
M160_75-1	02.12.	06:15	CTD/RO	17° 48,071' N	021° 12,081' W	3205	1200	
M160_76-1	02.12.	08:07	MSS	17° 48,710' N	021° 12,488' W	3203		
M160_77-1	02.12.	08:37	CTD/RO	17° 48,728' N	021° 12,494' W	3203	500	
M160_78-1	02.12.	09:38	WGLD/R	17° 49,227' N	021° 11,463' W	3197		
M160_79-1	02.12.	10:12	GLD/D	17° 49,195' N	021° 11,437' W	3195		
M160_80-1	02.12.	10:42	GLD/D	17° 49,170' N	021° 11,419' W	3197		
M160_81-1	02.12.	13:28	CTD/RO	17° 47,934' N	021° 00,062' W	3162	1200	
M160_82-1	02.12.	15:29	MSS	17° 48,353' N	021° 00,324' W	3157		
M160_83-1	02.12.	15:42	WGLD/D	17° 48,287' N	021° 00,394' W	3158		
M160_84-1	02.12.	17:50	CTD/RO	17° 47,992' N	020° 48,075' W	3134	800	
M160_85-1	02.12.	19:24	MSS	17° 48,538' N	020° 48,010' W	3130		
M160_86-1	02.12.	19:58	CTD/RO	17° 48,542' N	020° 48,012' W	3131	500	
M160_87-1	02.12.	23:28	DST/D	17° 47,957' N	020° 24,467' W	3168		Combined with BGC drifter
M160_88-1	03.12.	00:30	CTD/RO	17° 48,382' N	020° 24,456' W	3160	1200	
M160_89-1	03.12.	02:12	MSS	17° 48,881' N	020° 24,541' W	3154		
M160_90-1	03.12.	02:44	CTD/RO	17° 48,881' N	020° 24,542' W	3155	500	
M160_91-1	03.12.	03:17	MSC	17° 48,880' N	020° 24,541' W	3154	60	
M160_92-1	03.12.	03:29	MSC	17° 48,880' N	020° 24,542' W	3155	60	
M160_93-1	03.12.	04:26	MSN	17° 48,881' N	020° 24,542' W	3155	1000	
M160_94-1	03.12.	06:59	CTD/RO	17° 48,000' N	020° 12,022' W	3199	1200	
M160_95-1	03.12.	08:33	MSC	17° 48,729' N	020° 11,961' W	3198		
M160_96-1	03.12.	10:16	CTD/RO	17° 48,007' N	019° 59,997' W	3239	1200	
M160_97-1	03.12.	12:06	MSC	17° 48,384' N	019° 59,890' W	3236		
M160_98-1	03.12.	14:35	CTD/RO	17° 47,941' N	019° 42,022' W	3262	1200	
M160_99-1	03.12.	16:48	MSC	17° 48,140' N	019° 41,746' W	3264		
M160_87-1	04.12.	17:46	DST/R	17° 44,549' N	020° 30,826' W	3174		
M160_100-1	04.12.	18:32	CTD/RO	17° 44,973' N	020° 30,889' W	3169	600	
M160_102-1	05.12.	13:36	DCTD	17° 39,969' N	021° 04,885' W	3243		Start of dye release
M160_103-1	05.12.	14:22	DCTD	17° 39,703' N	021° 05,867' W	3245		End of dye release
M160_101-1	05.12.	14:23	DCTD	17° 39,701' N	021° 05,878' W	3244		CTD profile for release
M160_104-1	05.12.	23:40	CTD/RO	17° 40,918' N	021° 05,550' W	3234	500	
M160_105-1	06.12.	00:40	CTD/RO	17° 43,465' N	021° 05,399' W	3223	500	

M160_106-1	06.12.	04:57	CTD/RO	17° 48,003' N	020° 24,234' W	3170	100	
M160_107-1	06.12.	10:01	GLD/R	17° 37,195' N	021° 03,960' W	3263		
M160_108-1	06.12.	16:31	MSN	17° 47,450' N	021° 13,177' W	3223	1000	
M160_109-1	06.12.	17:52	CTD/RO	17° 47,973' N	021° 14,002' W	3216	1200	
M160_110-1	06.12.	19:25	DST/D	17° 48,500' N	021° 14,334' W	3213		Combined with BGC drifter
M160_111-1	06.12.	20:22	MSS	17° 49,281' N	021° 14,117' W	3205		
M160_112-1	06.12.	20:41	MSC	17° 49,327' N	021° 14,191' W	3204	60	
M160_113-1	06.12.	20:57	MSC	17° 49,413' N	021° 14,380' W	3204	60	
M160_114-1	06.12.	21:41	MSN	17° 49,834' N	021° 14,414' W	3201	1000	
M160_115-1	06.12.	23:06	CTD/RO	17° 49,982' N	021° 14,370' W	3199	1200	
M160_116-1	07.12.	18:14	DST/R	17° 48,289' N	021° 18,604' W	3225		
M160_117-1	07.12.	19:47	CTD/RO	17° 49,183' N	021° 19,723' W	3227	1200	
M160_118-1	09.12.	05:55	MSN	17° 34,963' N	024° 16,978' W	3611	1000	
M160_119-1	09.12.	08:02	CTD/RO	17° 35,001' N	024° 17,012' W	3611	3630	
M160_120-1	09.12.	10:40	MSS	17° 35,417' N	024° 16,948' W	3613		
M160_121-1	09.12.	11:35	CTD/RO	17° 35,432' N	024° 16,957' W	3615	500	
M160_122-1	09.12.	12:18	MSN	17° 35,431' N	024° 16,955' W	3614	600	
M160_123-1	09.12.	12:50	FLOAT	17° 35,500' N	024° 16,983' W	3614		Argo Float
M160_124-1	09.12.	12:52	SVP	17° 35,580' N	024° 16,885' W	3615		SVP drifter
M160_125-1	10.12.	08:13	GLD/R	17° 48,235' N	022° 27,815' W	3339		
M160_126-1	10.12.	16:05	GLD/R	17° 34,188' N	021° 08,498' W	3304		
M160_127-1	10.12.	16:28	GLD/R	17° 34,368' N	021° 08,450' W	3300		
M160_128-1	10.12.	16:50	GLD/R	17° 34,883' N	021° 08,267' W	3292		
M160_129-1	10.12.	17:24	GLD/R	17° 35,927' N	021° 07,857' W	3281		
M160_130-1	10.12.	18:00	GLD/R	17° 34,748' N	021° 08,454' W	3294		
M160_131-1	10.12.	19:07	WGLD/R	17° 37,253' N	021° 05,360' W	3264		
M160_132-1	12.12.	00:33	CTD/RO	15° 05,996' N	025° 15,107' W	4305	1200	
M160_133-1	12.12.	01:52	MSS	15° 06,182' N	025° 15,438' W	4284		
M160_134-1	12.12.	03:29	CTD/RO	14° 55,860' N	025° 15,025' W	4291	1200	
M160_135-1	12.12.	05:08	MSS	14° 55,856' N	025° 14,944' W	4288		
M160_136-1	12.12.	06:44	CTD/RO	14° 46,059' N	025° 15,083' W	4315	1200	
M160_137-1	12.12.	08:25	MSS	14° 47,111' N	025° 14,787' W	4309		
M160_138-1	12.12.	08:38	WGLD/D	14° 47,134' N	025° 14,877' W	4307		
M160_139-1	12.12.	11:30	GLD/R	14° 55,859' N	025° 03,125' W	4171		
M160_140-1	12.12.	14:41	MSN	14° 36,295' N	024° 54,896' W	2900	1000	
M160_141-1	12.12.	16:01	CTD/RO	14° 36,881' N	024° 54,594' W	2560	1200	
M160_142-1	12.12.	16:58	MSS	14° 37,382' N	024° 54,655' W	2435		
M160_143-1	12.12.	19:01	CTD/RO	14° 36,511' N	024° 54,783' W	2701	500	
M160_144-1	12.12.	19:42	MSC	14° 37,313' N	024° 54,459' W	2516	42	
M160_145-1	12.12.	19:55	MSC	14° 37,576' N	024° 54,364' W	2501	57	
M160_146-1	12.12.	20:14	DST/D	14° 38,062' N	024° 54,193' W	2395		Combined with BGC drifter
M160_147-1	12.12.	21:59	MSN	14° 36,643' N	024° 54,846' W	2662	1000	
M160_148-1	12.12.	23:21	CTD/RO	14° 37,653' N	024° 54,309' W	2510	1200	
M160_149-1	13.12.	01:37	CTD/RO	14° 35,978' N	025° 05,009' W	4229	1200	
M160_150-1	13.12.	02:39	MSS	14° 36,081' N	025° 04,863' W	4229		
M160_151-1	13.12.	04:12	CTD/RO	14° 36,967' N	025° 03,888' W	4161	500	
M160_152-1	13.12.	04:33	WRIDE/D	14° 36,969' N	025° 03,868' W	4164		
M160_153-1	13.12.	12:12	GLD/D	14° 39,579' N	025° 22,802' W	4399		
M160_154-1	13.12.	12:19	GLD/D	14° 39,855' N	025° 22,610' W	4396		
M160_155-1	13.12.	14:02	MDRIFT	14° 41,824' N	025° 20,233' W	4390		
M160_156-1	13.12.	14:02	MDRIFT	14° 41,817' N	025° 20,229' W	4390		
M160_157-1	13.12.	14:03	MDRIFT	14° 41,810' N	025° 20,225' W	4390		
M160_158-1	13.12.	15:05	MDRIFT	14° 45,003' N	025° 21,681' W	4357		
M160_159-1	13.12.	15:05	MDRIFT	14° 45,020' N	025° 21,692' W	4362		
M160_160-1	13.12.	15:06	MDRIFT	14° 45,032' N	025° 21,699' W	4359		
M160_161-1	13.12.	15:54	MDRIFT	14° 48,268' N	025° 23,718' W	4367		
M160_162-1	13.12.	15:54	MDRIFT	14° 48,278' N	025° 23,724' W	4367		
M160_163-1	13.12.	15:54	MDRIFT	14° 48,287' N	025° 23,731' W	4367		
M160_164-1	13.12.	21:26	DST/R	14° 53,113' N	024° 53,325' W	3647		
M160_165-1	13.12.	22:34	CTD/RO	14° 54,011' N	024° 54,311' W	3731	1000	

M160_166-1	14.12.	02:58	CTD/RO	14° 26,134' N	025° 14,933' W	4414	500	
M160_167-1	14.12.	03:24	MSS	14° 26,250' N	025° 14,807' W	4412		
M160_168-1	14.12.	04:59	CTD/RO	14° 27,504' N	025° 13,716' W	4394	1200	
M160_169-1	14.12.	09:02	CTD/RO	14° 45,008' N	025° 27,062' W	4404	1000	
M160_170-1	14.12.	09:35	DST/D	14° 45,022' N	025° 27,091' W	4408		Combined with BGC drifter
M160_171-1	14.12.	14:59	DCTD	14° 42,029' N	025° 22,610' W	4391	47	CTD profile for release
M160_171-1	14.12.	15:06	DCTD	14° 42,059' N	025° 22,663' W	4390	47	Start dye release
M160_172-1	14.12.	15:30	GLD/D	14° 42,181' N	025° 22,872' W	4393		
M160_173-1	14.12.	15:38	GLD/D	14° 42,200' N	025° 22,963' W	4388	52	
M160_171-1	14.12.	16:01	DCTD	14° 42,344' N	025° 23,199' W	4392	52	End dye release
M160_174-1	15.12.	00:05	MSN	14° 42,701' N	025° 29,487' W	4423	1000	
M160_175-1	15.12.	01:16	CTD/RO	14° 42,701' N	025° 29,487' W	4420	1200	
M160_176-1	15.12.	03:08	MSS	14° 43,241' N	025° 29,337' W	4420	0	
M160_177-1	15.12.	03:17	MSC	14° 43,252' N	025° 29,341' W	4417	40	
M160_178-1	15.12.	03:29	MSC	14° 43,251' N	025° 29,341' W	4418	40	
M160_179-1	15.12.	03:58	CTD/RO	14° 43,270' N	025° 29,374' W	4414	500	
M160_180-1	15.12.	05:54	CTD/RO	14° 44,846' N	025° 35,111' W	4474	1200	
M160_181-1	15.12.	07:34	MSS	14° 44,650' N	025° 35,135' W	4479		
M160_182-1	15.12.	08:48	DST/R	14° 40,136' N	025° 31,882' W	4443		
M160_183-1	16.12.	04:22	MSN	14° 39,538' N	025° 45,445' W	4496	1000	
M160_184-1	16.12.	05:39	CTD/RO	14° 39,208' N	025° 45,734' W	4497	1200	
M160_185-1	16.12.	07:14	MSS	14° 38,711' N	025° 46,535' W	4502		
M160_186-1	16.12.	07:28	MSC	14° 38,486' N	025° 46,799' W	4507	60	
M160_187-1	16.12.	07:40	MSC	14° 38,226' N	025° 47,071' W	4509	60	
M160_188-1	16.12.	08:18	CTD/RO	14° 37,874' N	025° 47,625' W	4514	1000	
M160_189-1	16.12.	09:29	DST/D	14° 37,512' N	025° 48,536' W	4521		Combined with BGC drifter
M160_190-1	16.12.	10:16	MSN	14° 37,960' N	025° 49,039' W	4522	1000	
M160_191-1	16.12.	21:13	MOOR/R	14° 34,997' N	025° 01,476' W	3976		KPO 1217
M160_192-1	16.12.	23:35	WGLD/R	14° 36,969' N	024° 51,295' W	3339		
M160_193-1	17.12.	00:33	WGLD/R	14° 34,624' N	024° 48,991' W	3921		
M160_194-1	17.12.	04:23	CTD/RO	14° 16,186' N	025° 15,008' W	4463	1200	
M160_195-1	17.12.	06:02	MSS	14° 18,165' N	025° 14,243' W	4455		
M160_196-1	17.12.	06:33	CTD/RO	14° 18,382' N	025° 14,384' W	4455	500	
M160_197-1	17.12.	13:53	DST/R	14° 25,541' N	025° 59,068' W	4591		
M160_198-1	17.12.	15:02	CTD/RO	14° 25,887' N	025° 59,867' W	4588	1000	
M160_199-1	17.12.	17:49	WRIDE/R	14° 06,474' N	026° 07,013' W	4738		
M160_200-1	17.12.	23:24	CTD/RO	14° 45,056' N	025° 55,085' W	4562	1200	
M160_202-1	18.12.	16:16	Glider	14° 39,703' N	025° 31,446' W	4445		
M160_203-1	18.12.	16:53	Glider	14° 39,764' N	025° 31,321' W	4447		
M160_204-1	18.12.	17:15	Glider	14° 40,054' N	025° 30,834' W	4442		
M160_205-1	18.12.	17:30	Glider	14° 40,830' N	025° 30,674' W	4430		
M160_206-1	18.12.	18:15	Glider	14° 40,365' N	025° 27,688' W	4425		
M160_207-1	18.12.	20:55	Glider	14° 22,603' N	025° 50,608' W	4612		
M160_208-1	18.12.	21:06	Floater	14° 22,782' N	025° 50,654' W	4609		
M160_209-1	18.12.	21:06	SV Drifter	14° 22,800' N	025° 50,657' W	4608		
M160_210-1	19.12.	02:16	SV Drifter	15° 07,874' N	025° 42,128' W	4438		
M160_211-1	19.12.	08:18	SV Drifter	16° 05,284' N	025° 30,532' W	4262		
M160_212-1	19.12.	12:12	SV Drifter	16° 44,300' N	025° 22,843' W	2952		

Instrument abbreviations

CTD/RO = CTD Rosette
DCTD = Dye Release CTD
DST/D = Drifting Sediment Traps Deployment
DST/R = Drifting Sediment Traps Recovery
FLOAT = Argo Float
GLIDER/D = Glider Deployment

GLIDER/R = Glider Recovery
MDRIFT = Mini Surface Drifter
MOOR/D = Mooring Deployment
MOOR/R = Mooring Recovery
MSC = Marine Snow Catcher
MSN = Multiple Opening/Closing Net (Multi Net)
MSS = Micro Structure Sonde
MVP = Moving Vessel Profiler
uCTD = underway CTD
SVP = Surface Velocity Program Drifter
TIA = Towed Instrument Array
WVGL/D = Wave Glider Deployment
WVGL/R = Wave Glider Recovery
WRIDE/D = Wave Rider Deployment
WRIDE/R = Wave Rider Recovery