FRS Algoa Cruise Report:
Cruise Alg-179
East Madagascar,
28 September - 8 October 2010

Jenny Ullgren

8 December 2010

Figure 1: The mooring team on FRS Algoa cruise Alg-179.

The research reported here was funded by the Netherlands Organisation for Scientific Research (NWO), the Agulhas and Somali Current Large Marine Ecosystems (ASCLME) program and the Royal Netherlands Institute for Sea Research (NIOZ).

Contents

1 Cruise summary

1.1 Highlights

a: FRS Algoa cruise Alg-179 to eastern Madagascar

b: Expedition Designation (EXPOCODE): 91AL20100928

c: Chief Scientist: Dr. Jenny Ullgren
Royal Netherlands Institute for Sea Research (NIOZ)
P.O. Box 59
1790 AB Den Burg/Texel
The Netherlands
Telephone: 31(0)222-369437
Telefax: 31(0)222-319674
e-mail: jenny.ullgren@nioz.nl

d: Ship: FRS Algoa Call Sign: ZR4311
Length 52 m
Beam 10.8 m
Draft 4.85 m
Cruising speed 10.0 knots

e: Ports of Call: Port Elizabeth (South Africa) to Toamasina (Madagascar)

f: Cruise dates: September 28, 2010 to October 8, 2010

1.2 Background and motivation

The South Equatorial Current (SEC) separates when it reaches Madagascar at about 17°S into a northward part and a southward part, the East Madagascar Current (EMC). Interannual variability in the strength of the SEC, and thus of the EMC, is associated with the Indian Ocean Dipole (IOD; Palastanga et al., 2006). Where the EMC separates from the coast south of Madagascar, eddies and bipoles are often formed (de Ruijter et al., 2004). Many of these continue southwestward and eventually feed into the Agulhas Current (e.g. Schouten et al., 2002). The flow from the EMC can also take an alternative path upon leaving Madagascar, retroflecting to join with the Subtropical Indian Ocean Countercurrent (Palastanga et al., 2007; Siedler et al., 2009). The mean and variability of the flow in the region are not well known, much less the relative importance of different pathways or what mechanisms determine the routes taken (Quartly et al., 2006).

A new mooring array will continue and accompany the mooring observations in the Mozambique Channel in the Long-term Ocean Climate Observations (LOCO) programme. By direct measurement of the transport

and variability in the EMC, the mooring array will help fill the gaps in our understanding of the western boundary current of the Indian Ocean.

1.3 Scientific programme and methods

The main objective of this cruise leg was to deploy five current meter moorings in the EMC. This is the first deployment in this area as part of the project Indian-Atlantic exchange in present and past climate (INATEX), part A. The location of the East Madagascar mooring array is close to the northern mooring in an array of three deployed by Schott and co-workers in 1984-1985 (Schott et al., 1988).

Five moorings were deployed along the section, at various water depths. All moorings carry an upward-looking ADCP mounted in the top buoy, intended to sit at 500 m below the surface, to give a current velocity profile of the whole upper layer. Two of the moorings on the shoremost side of the array are also equipped with an upward-looking ADCP (with a higher pressure rating) in a frame positioned at about 13 m above the seabed. At intermediate depths, RCMs placed inline along the mooring cable will supply point measurements of current velocity. All moorings are equipped with double acoustic releases and satellite beacons to help locating the moorings during recovery. For a complete list of the mooring positions and instrumentation, see table 1.

1.4 Cruise narrative

The FRS Algoa left the port of Port Elizabeth in the early afternoon on Tuesday the 28 September 2010, and followed the South African coast northeastward. The coastal waters were teeming with life - many humpback whales, common dolphins, and various seabirds were sighted during the following days. On Wednesday 29th the weather was sunny, with a northeasterly wind of about 6 Bft and swell of 1-2.5 m. While in transit, preparations for the forthcoming mooring deployments were done; ADCP fastened in frame, cable spooled up, etc. Thursday 30 September was still rather windy with swell up to 3 m. At about 16.30 on Thursday afternoon the FRS Algoa diverted to Richards Bay for refuelling, on request from the ship's operators because of stability concerns. About 8.5 hours later the planned course could be resumed.

The ship left the South African coast at about the latitude of Vidal on Friday 1 October and started crossing the southern entrance of the Mozambique Channel, steaming east-northeast. The wind was weaker and there was less swell, while the sunny weather persisted. On Saturday 2 October a surface drifter was deployed for NOAA's "Adopt a Drifter Program". Another surface drifter was deployed on Sunday morning 3 October. In preparation for the deployment of the first mooring (EMC5), four current

meters were checked and started up. On Monday 4 October, the remaining current meters were prepared for deployment. Head-on wind of 6-7 Bft and waves of ca 4 m slowed the progress towards the study area, which was eventually reached in the early morning of Tuesday 5 October.

The first CTD station of the hydrographic section was carried out at 6 am on Tuesday 5th. It turned out that the bathymetry differed strongly from the expected; the depth at the site of the first CTD profile was about 1500 m rather than 500 m as per the cruise plan. Since it was necessary to find a location with 500 m depth for the shortest mooring, and such a location could not be far away (the 1500 m deep site was only ca 14 nm from shore), the ship first steamed inshore until the echosounder reading showed a depth of 500 m. There, a second CTD cast was carried out including water sampling for $d^{18}O$ measurements. Then the original course was resumed, eastward along the transect. While steaming, echo sounder depth readings were recorded manually at a time interval of five minutes. A third CTD station was completed at midday. The maximum depth of any CTD station was about 1000 m, because of limited wire length.

Because the time window in which the weather would permit mooring work was limited - harder winds and large swell in the area being forecast for Thursday - it was decided to break the hydrographic transect for an early mooring deployment. Mooring EMC5 was successfully deployed in the afternoon of Tuesday 5 October. The cable was shortened by 50 m as the water depth was ca 40 m shallower than planned. As there was not enough current to keep the mooring stretched out, the ship moved slowly southeastward along an extension of the section, and the mooring was deployed ca 2 nm offshore of the originally planned location but on the same line. In the evening, another two CTD stations were completed at the eastern part of the transect, before the ship headed westwards towards the site of mooring EMC4. Water samples for $d^{18}O$ were taken at CTD station 4.

The following day the mooring deployment work began with mooring EMC4 at first light, 5 am. The weather was good, with about 2 Bft of north-northeasterly wind and a long swell of ca 2 m. Because the bathymetry used in the cruise planning deviated from the observed bottom depths, the planned mooring locations and the design cable lengths had to be adjusted. The biggest difference in cable length was at EMC4, which was lengthened by 300 m at the bottom, just above the acoustic releases. The deployment operation went smoothly and mooring EMC4 was deployed before breakfast on Wednesday 6 October.

While steaming towards the next mooring site, the cable for mooring EMC3 was spooled onto the main winch drum. Deployment of EMC3 started took place at around midday on Wednesday. For this mooring, 150 m cable was added above the deepest ADCP. In the early afternoon, the next mooring (EMC2) was deployed, with an additional 100 m of cable above the deep ADCP. Mooring sites 2, 3, and 4 were all approached from the south,

and the bottom weights were released exactly on the planned mooring positions, according to the revised plan that took into account the observed bathymetry. The final and shortest mooring, EMC1, had been moved almost 6 nm inshore of the original plan, but there was no change to the cable length, a mere 4 m. The mooring was deployed on location (no steaming necessary) in the late afternoon on 6 October. All the four deployments this day went smoothly, without a hiccup.

After the last deployment on Wednesday 6 October, the Algoa set course northward to avoid the bad weather which was to hit the area southeast of Madagascar on the Thursday. During Thursday 7 October, the ship continued steaming northward following the Madagascan coast. Further north the weather was very calm and sunny with a gentle swell. In the evening, two CTD profiles were carried out, about 6.5 nm apart on a track perpendicular to the coast of Madagascar. After the second CTD profile, course was set towards Toamasina. The Algoa entered the port of Toamasina in the morning of Friday 8 October.

1.5 Cruise track

The cruise took place from Port Elizabeth, South Africa to Toamasina, Madagascar. From Port Elizabeth to Vidal, the FRS Algoa sailed close to the South African coast, in order to avoid sailing against the strong Agulhas Current by passing inshore of it. At about 28° S an east-northeasterly course was set, towards the southern tip of Madagascar (see full cruise track in figure 2). The main work was carried out along a section roughly perpendicular to the southeast coast of Madagascar at about 23° S. This section was first surveyed from west to east with hydrographic and bathymetric measurements, with a break for one mooring deployment. Then the same line was followed from east to west (offshore to inshore) while deploying the remaining moorings. During transit northwards from the study area to port in Toamasina, the ship sailed close to the coast of Madagascar. A short detour to the east for CTD stations was done at about 19° S.

1.6 Hydrographic transect

Hydrographic measurements were done using the ship's SBE-9 CTD with auxiliary sensors: a WETlabs ECO-AFL/FL fluorescence sensor and SBE-43 dissolved oxygen sensor. A total of seven CTD casts were completed during the cruise; five on the mooring transect and two at a more northerly location (see figure 3). All profiles were done to the maximum cable length of ∼1000 m, or shallower depending on water depth. At two CTD stations, water samples for $d^{18}O$ analysis were taken.

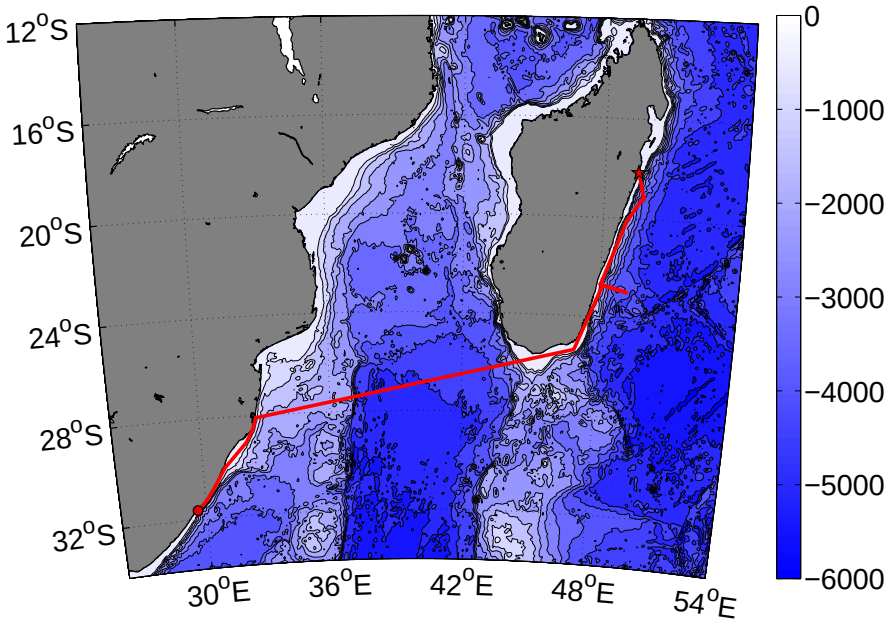

Figure 2: Cruise tracked followed on FRS Algoa cruise Alg-179.

1.7 Moorings

1.7.1 Mooring deployments

Five current meter moorings were successfully deployed across the continental slope of southeast Madagascar. The times and positions of the mooring deployments are listed in table 5. The instruments for the moorings had been previously serviced at the institute. Thus, only a minimum of handling onboard was required, in principle only to switch some instruments (RCMs and satellite beacons) on prior to deployment. Because the real bottom topography differed from the expected, the lengths of several moorings had to be adjusted by adding spare lengths of cable (see table 2).

1.7.2 Mooring instrumentation

The design of the mooring array (see figure 4) was largely based on the LOCO mooring array in the Mozambique Channel, operational since 2003. For details of the instrumentation on each mooring, see table 1.

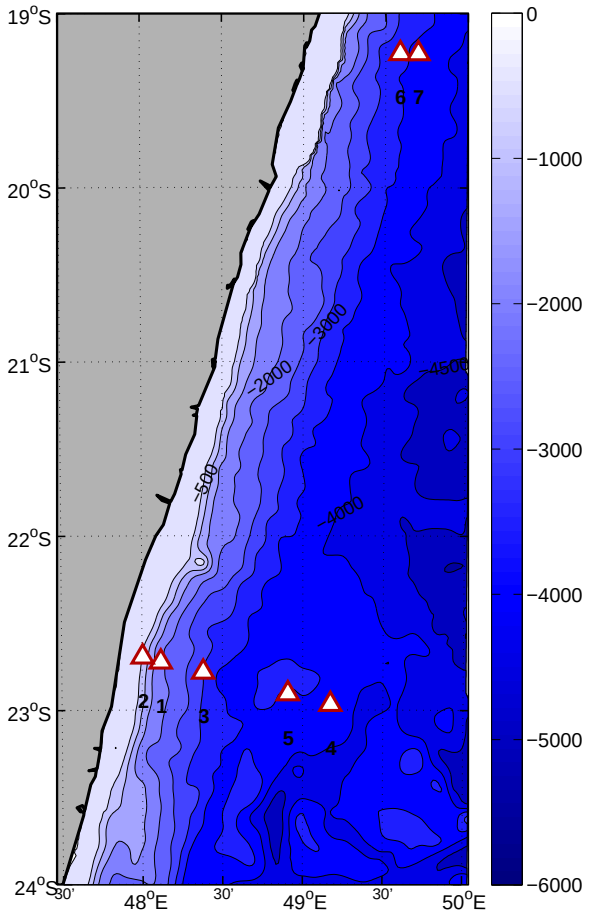

Figure 3: Positions of CTD deployments during Alg-179. Numbers in bold show the order of completion.

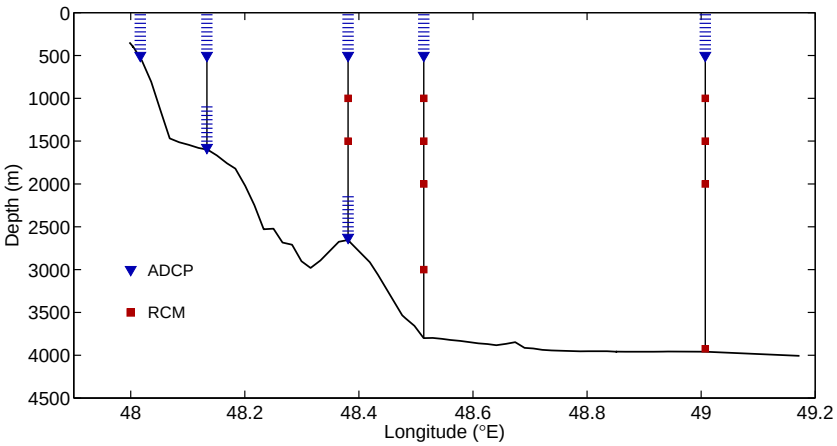

Figure 4: Instrumentation on the INATEX East Madagascar Current array, with the observed bottom topography.

1.8 Other activities

Two NOAA surface drifters were deployed during the cruise. The positions where the drifters were released can be found in table 3. Current velocity data from the upper layer were recorded underway by the hull-mounted ADCP. Shipboard ADCP data collection was done during the crossing of the southern Mozambique Channel, on the mooring/CTD section, and also in part while steaming northward along the east coast of Madagascar.

1.9 Major problems encountered

No major problems were encountered during the cruise. All the gear worked well, the weather was good and all the operations went flawlessly. The only inconvenience was associated with the very heavy load the ship was carrying, of equipment for a later cruise leg. The heavy load on the foredeck meant some lack of stability of the ship, giving us a narrower weather window to work in. This did not impact on our operations, as we were lucky with the weather for the mooring deployments, but it influenced the planning and added pressure in scheduling activities.

2 Preliminary results

2.1 Hydrography

The T-S profiles showed interleaving in the upper layer between fresh Tropical Surface Water (TSW) and more saline Subtropical Surface Water (STSW). This was particularly marked at the two northern stations, and at station

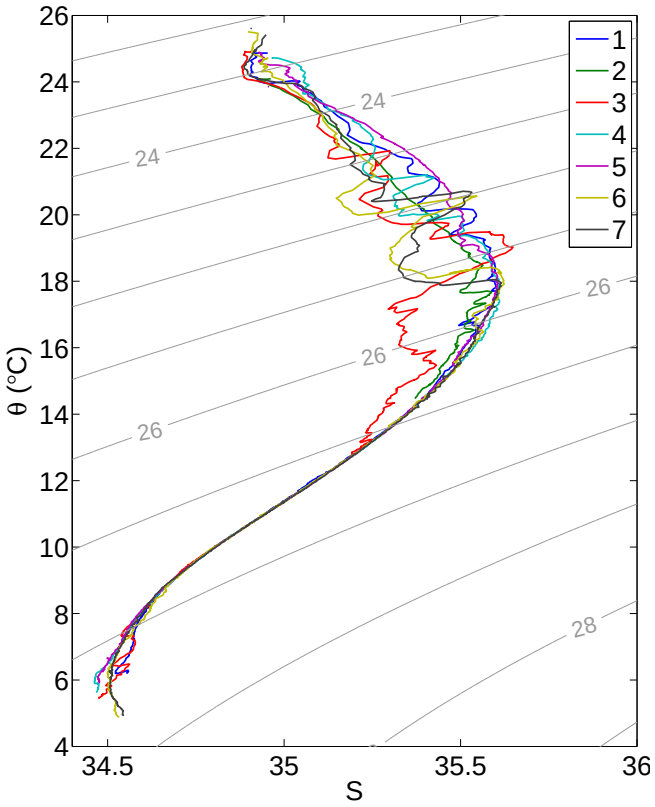

Figure 5: θ-S diagram with data from all CTD stations during the cruise. For station positions, see figure 3.

3 in the middle of the southern transect (figure 5). During the CTD cast on station 3, which is at the same position as mooring EMC3, there was a southward current of ca 2 kn. The strong current at this location might explain the difference in the T-S profile from this station compared to the neighbouring stations, notably the stronger influence of low-salinity TSW in the upper layer. Coincidently there was also a thin lense of relatively high salinity - about 0.1 higher than the surrounding water - stretching between station 3 and 1 (figure 6).

While the salinity maximum in this lense was about 0.1 more saline than in neighbouring profiles, the upper layer salinity overall was low compared to the Intrathermocline Eddies (ITEs) observed in the southern EMC in 2001 (Nauw et al., 2006). The T-S properties across the section were typical of the EMC.

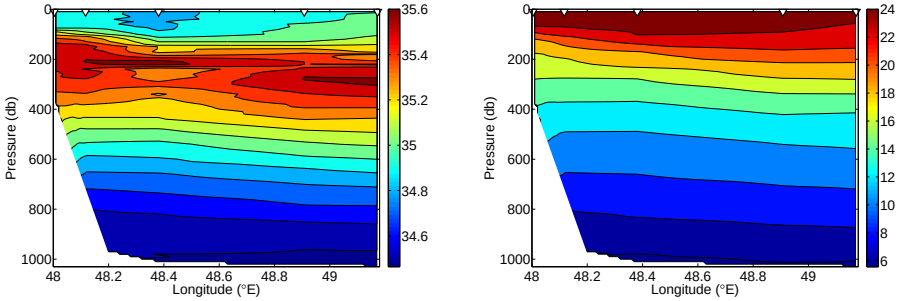

Figure 6: Preliminary results from hydrographic section, (*left*) salinity (*right*) temperature

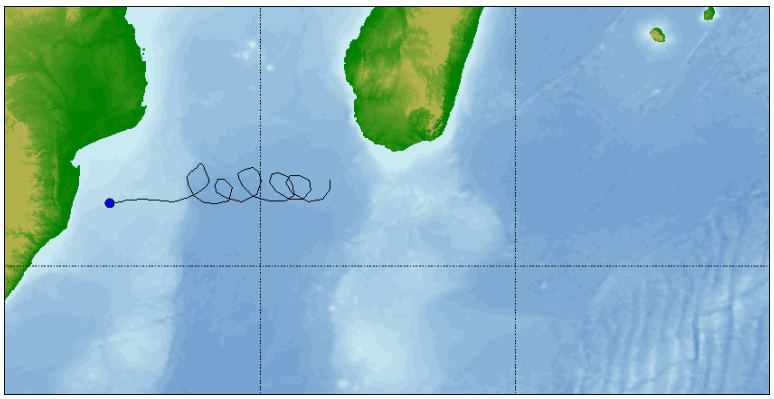

Figure 7: Trajectory of surface drifter number 70972, from deployment on 3 October 2010 until the beginning of December 2010.

2.2 Drifters

The surface drifting buoys deployed during the cruise as part of NOAA's "Adopt a Drifter Program" (ADP; http://www.adp.noaa.gov/index.html) can be followed online via the Observing System Monitoring Center (OSMC) website as soon as the drifters have been assigned a WMO ID number. At the time of writing, only one of the drifters deployed during the cruise had been given a WMO ID; the other one possibly failed. Float 70972, deployed in transit across the southern mouth of the Mozambique Channel, was caught in a westward moving eddy and followed a swirling path towards the African continent (figure 7). Surface temperature data from the drifter's temperature sensor can also be accessed via the OSMC website.

Acknowledgements

The research reported here was funded by the Netherlands Organisation for Scientific Research (NWO), the Agulhas and Somali Current Large Marine Ecosystems (ASCLME) program and the Royal Netherlands Institute for Sea Research (NIOZ). We thank the officers and crew of the FRS Algoa for their excellent workmanship, professionalism and helpfulness during the cruise. The technical and logistical help and support before, during and after the cruise from members of the NIOZ marine technology department (MTM, MTE), marine research facilities and other groups (DMG, SML, FYS) is gratefully acknowledged. Particular thanks are owed to Herman Ridderinkhof who was on stand-by as scientific advisor throughout the cruise and provided invaluable support. The helpful advice of Will de Ruijter at the IMAU and Hendrik van Aken at the NIOZ is also appreciated.

References

de Ruijter, W. P. M., H. M. van Aken, et al. (2004), Eddies and dipoles around South Madagascar: formation, pathways and large-scale impact. Deep-Sea Research I 51: 383-400.

Nauw, J. J., H. M. van Aken, J. R. E. Lutjeharms, and W. P. M. de Ruijter (2006), Intrathermocline eddies in the Southern Indian Ocean, J. Geophys. Res., 111, C03006.

Palastanga, V., P. J. van Leeuwen, and W. P. M. de Ruijter (2006), A link between low-frequency mesoscale eddy variability around Madagascar and the large-scale Indian Ocean variability, J. Geophys. Res., 111, C09029.

Palastanga, V., P. J. van Leeuwen, M. W. Schouten, and W. P. M. de Ruijter (2007), Flow structure and variability in the subtropical Indian Ocean: Instability of the South Indian Ocean Countercurrent, J. Geophys. Res., 112, C01001.

Schott, F., M. Fieux, et al. (1988), The boundary currents east and north of Madagascar 2. Direct measurements and model comparisons. Journal of Geophysical Research 93(C5): 4963-4974.

Schouten, M.W., W. P. M. de Ruijter, P. J. van Leeuwen, and H. A. Dijkstra (2002), An oceanic teleconnection between the equatorial and southern Indian Ocean, Geophys. Res. Letters, 29 (16), 1812.

Siedler, G., M. Rouault, A. Biastoch, B. Backeberg, C. J. C. Reason, and J. R. E. Lutjeharms (2009), Modes of the southern extension of the East Madagascar Current, J. Geophys. Res., 114, C01005.

NOAA's Adopt a Drifter Program (ADP) http://www.adp.noaa.gov/index.html

OSMC In-Situ Metadata http://osmc.noaa.gov/Monitor/OSMC/OSMC.html

Tables

Moor. ID	Lat (S) Long (E) Water depth (m)	Instrument				Time interval (s)	DSU/ ARM-code	Instrument start time (GMT)	Deployment date, time (GMT)
		function	type	SN	depth (m)				
EMC1	22°41.879	Beacon	Iridium	2100	500				06/10/2010 14:17
	48°1.006	Curr. profile	ADCP LR	1431	500	1800		03/10/2010 06:00	06/10/2010 14:17
	504	Release	Oceano	170			04DA		
		Release	Oceano	179			04E4		
EMC2	22°43.484	Beacon	Iridium	8960	500				06/10/2010 11:55
	48°8.013	Current profile	ADCP LR	3641	500	1800		03/10/2010 06:00	06/10/2010 11:55
	1603	Curr. profile	ADCP LR	3700	1600	1800		03/10/2010 06:00	06/10/2010 12:55
		Release	Oceano	172			04DC		
		Release	Oceano	171			04DB		
EMC3	22°46.950	Beacon	Iridium	9290	500				06/10/2010 07:50
	48°22.860	Current profile	ADCP LR	3549	500	1800		03/10/2010 06:00	06/10/2010 07:50
	2654	Curr. meter	RCM-11	237	1000	1200	10887	04/10/2010 14:00	06/10/2010 08:06
		Curr. meter	RCM-11	238	1500	1200	2783	04/10/2010 14:00	06/10/2010 08:35
		Curr. profile	ADCP LR	3701	2600	1800		03/10/2010 06:00	06/10/2010 09:45
		Release	Oceano	158			04CD		
		Release	Oceano	352			032C		
EMC4	22°48.689	Beacon	Iridium	5980	500				06/10/2010 02:16
	48°30.827	Curr. profile	ADCP LR	7082	500	1800		03/10/2010 06:00	06/10/2010 02:16
	3799	Curr. meter	RCM-11	49	1000	1200	3384	04/10/2010 13:20	06/10/2010 02:37
		Curr. meter	RCM-11	244	1500	1200	2110	04/10/2010 13:45	06/10/2010 03:06
		Curr. meter	RCM-11	403	2000	1200	12645	04/10/2010 13:45	06/10/2010 03:30
		Curr. meter	RCM-11	236	3000	1200	11327	04/10/2010 14:00	06/10/2010 04:14
		Release	Oceano	153			04C8		
		Release	Oceano	176			04E1		
EMC5	22°55.483	Beacon	Iridium	4980	500				05/10/2010 11:35
	49°0.435	Curr. profile	ADCP LR	3439	500	1800		03/10/2010 06:00	05/10/2010 11:35
	3959	Curr. meter	RCM-11	45	1000	1200	12638	03/10/2010 08:08	05/10/2010 12:05
		Curr. meter	RCM-11	201	1500	1200	11365	03/10/2010 08:20	05/10/2010 12:40
		Curr. meter	RCM-11	204	2000	1200	12607	03/10/2010 09:40	05/10/2010 13:00
		Curr. meter	RCM-11	241	4000	1200	12713	03/10/2010 10:00	05/10/2010 14:23
		Release	Oceano	159			04CE		
		Release	Oceano	164			04D4		

Table 1: Mooring instrumentation

Table 2: Mooring cable length adjustments

Mooring ID	Lat. (°S)	Lon.(°E)	Planned depth (m)	Actual depl. depth (m)	Changed cable length (m)
EMC2	22°43.484	48°08.013	1500	1603	+100
EMC3	22°46.950	48°22.860	2500	2654	+155
EMC4	22°48.689	48°30.827	3500	3799	+300
EMC5	22°55.483	49°00.435	4000	3959	-50

Table 3: Drifters deployed

ID	WMO ID	Date, time (UTC)	Lat. (°S)	Lon.(°E)	Depth (m)
70902	not assigned	2010-10-02, 07:44	27° 13.6	37° 43.4	4425
70972	17681	2010-10-03, 06:09	26° 26.4	42° 11.8	4073

Table 4: List of participants

Name	Institute	Nationality	Function
Jenny Ullgren	NIOZ	SE	Chief scientist
Jack Schilling	NIOZ	NL	Senior mooring tech.
Yvo Witte	NIOZ	NL	Mooring technician
Sander Asjes	NIOZ	NL	Electronics technician
Dewi Le Bars	IMAU	FR	PhD student
Jean Rabary	IHSM	MG	Observer
Paubert Mahatante	IHSM	MG	Observer
Gildas Todinanahary	IHSM	MG	Observer
Dani Ramanantsoa	IHSM	MG	Observer

Table 5: Cruise summary

Cruise	Stn	Date	Time (GMT)	Lat (°S)	Lon (°E)	Depth (m)	Gear	Action	Comment
AL179	1	5-10-2010	03:05	22°43.4630	48°06.9880	1582	CTD	CTD station started	CTD 1. Profile to 940 m depth.
AL179	1	5-10-2010	03:50				CTD	CTD station finished	
AL179	2	5-10-2010	04:43	22°41.7000	48°0.2100	395	CTD	CTD station started	CTD 2. Profile to 346 m depth. Samples for G.-J. B.
AL179	2	5-10-2010	05:00				CTD	CTD station finished	
AL179	3	5-10-2010	07:30	22°46.9870	48°22.8420	2655	CTD	CTD station started	CTD 3. Profile to ca 1000 m. Ca 2 kn current.
AL179	3	5-10-2010	08:30	22°47.6100	48°22.3900		CTD	CTD station finished	
AL179	4	5-10-2010	11:35	22°54.6160	48°56.4730	3956	MOR	Top buoy in water	Start deployment of mooring INA-EMC 5
AL179	4	5-10-2010	14:40	22°55.4830	49°00.4351	3959	MOR	Anchor released	End deployment of mooring INA-EMC 5
AL179	5	5-10-2010	15:50	22°58.0850	49°10.3500	4008	CTD	CTD station started	CTD 4. Profile to 1015 m. Samples for G.-J. B.
AL179	5	5-10-2010	16:30				CTD	CTD station finished	
AL179	6	5-10-2010	18:00	22°54.4490	48°54.4480	3957	CTD	CTD station started	CTD 5
AL179	6	5-10-2010					CTD	CTD station finished	
AL179	7	5-10-2010	02:16				MOR	Top buoy in water	Start deployment of mooring INA-EMC 4
AL179	7	5-10-2010	05:18	22°48.6894	48°30.8272	3799	MOR	Anchor released	End deployment of mooring INA-EMC 4
AL179	8	6-10-2010	07:50	22°48.7970	48°21.6919	3012	MOR	Top buoy in water	Start deployment of mooring INA-EMC 3
AL179	8	6-10-2010	09:53	22°46.9545	48°22.8581	2654	MOR	Anchor released	End deployment of mooring INA-EMC 3
AL179	9	6-10-2010	11:55	22°44.3040	48°07.5211	1602	MOR	Top buoy in water	Start deployment of mooring INA-EMC 2
AL179	9	6-10-2010	13:05	22°43.4840	48°08.0129	1603	MOR	Anchor released	End deployment of mooring INA-EMC 2
AL179	10	6-10-2010	14:17				MOR	Top buoy in water	Start deployment of mooring INA-EMC 1
AL179	10	6-10-2010	14:21	22°41.8786	48°01.0006	504	MOR	Anchor released	End deployment of mooring INA-EMC 1
AL179	11	7-10-2010	18:19	19°13.8000	49°35.3000	3309	CTD	CTD station started	CTD 6
AL179	11	7-10-2010	18:50				CTD	CTD station finished	
AL179	12	7-10-2010	19:55	19°13.8000	49°41.9000	3658	CTD	CTD station started	CTD 7
AL179	12	7-10-2010	20:24				CTD	CTD station finished	