Cruise report 64PE431

Netherlands Initiative Changing Oceans (NICO) leg 4

Dr. M. Femke de Jong

Chief-scientist

4 – 11 February 2018

Oranjestad, Aruba – Phillipsburg, Sint Maarten

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Acknowledgements

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1. Cruise narrative

1.1 Cruise highlights

A. Cruise goals: To survey the hydrographic and velocity structure of a Caribbean anti-cyclone and to investigate gradients in marine fauna associated with this anti-cyclone.

B. Expedition designation (EXPOCODE): 64PE431

C. Chief scientist: Dr. M. Femke de Jong

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D. Ship: RV Pelagia   Call sign: PGRQ   Captain: M. John Ellen

Length: 66 m
Beam: 12.8 m
Draft: 4 m

E. Ports of call: Oranjestad, Aruba, to Phillipsburg, Sint Maarten

F. Cruise dates: 4 to 11 February 2018

1.2 Cruise goals

The Caribbean Sea is rich in eddy activity. Large eddies are formed in the east, strengthen while travelling westward, and leave through Yucatan Channel. They have a large impact on currents and sea level variability in the Caribbean. It is unclear what processes govern the lifecycle of these eddies. Model studies suggest they are affected by winds, the background flow, river run-off, and/or the presence of North Brazil Current Eddies.

However, dedicated surveys of eddies in the Caribbean have not yet been performed. We aimed to observed one to three eddies in the eastern Caribbean Sea (typical radius 200km). Optimal targets were determined based on the altimetry signature of the eddies (~35cm). The survey consisted of a CTD/ADCP section across an eddy, with minimal stations distance in order to resolve fronts. Hydrography and velocities can provide the structure of the eddy; information that cannot be obtained from altimetry. In addition, our aim was to deploy four Argo floats (funded by KNMI) to survey the eddy for a longer time period, while it travels westward. This cruise goal ties in with an ongoing PhD project at TU Delft, Netherlands, in which the dominant physical processes affecting the life cycle of these eddies will be identified from model simulations.

Acoustic and visual surveys were performed in order to quantify spatial gradients in the occurrence of marine fauna related to this anticyclone. In particular, an enriched zone was expected at the anticyclone perimeter.

1.3 Cruise summary

RV Pelagia left Aruba at 17:00 on 4 February 2018 to start a survey across the Caribbean Sea. Hydrographic stations were performed between the 1200 m isobath north of Aruba to the 800 m isobaths just south of the Dominican Republic. A soundtrap was deployed on hydrographic stations visited during daylight. Four Argo floats provided by the European Argo program were deployed at hydrographic stations. A visual survey of birds and other marine fauna was performed during daylight on transects between stations. The RV Pelagia arrived in the port of Phillipsburg on 11 February.

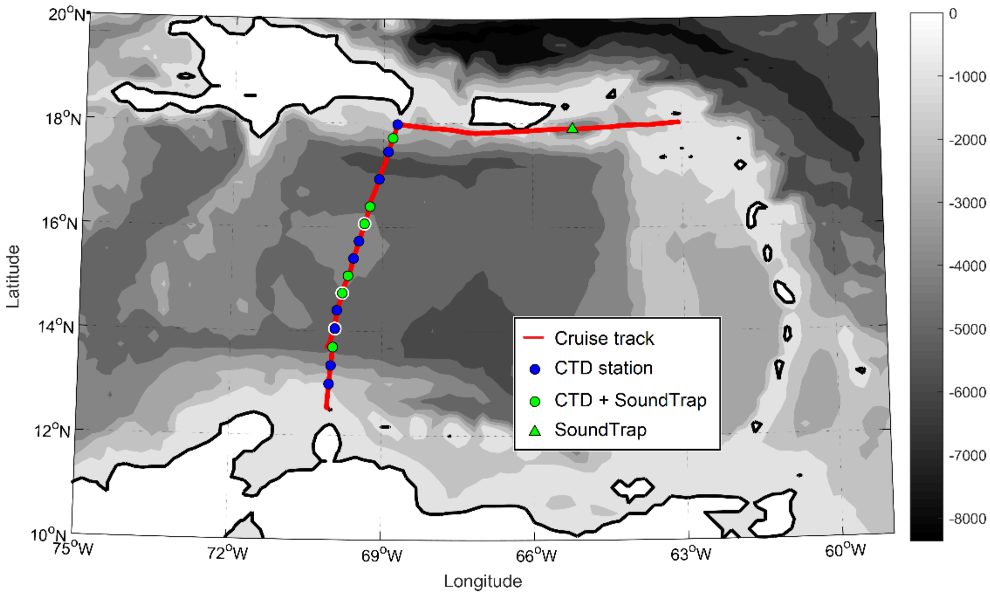

Figure 1. Cruise track from Aruba to Sint Maarten with station locations indicated. White circles indicate Argo float deployments. Grey scale indicates bathymetry in m.

Table 1. Station list.

Station [#]	Date time UTC [d-m hh:mm]	Latitude [deg min N]	Longitude [deg min W]	Bottom depth [m]	Max CTD depth [m]	Sound trap	Argo deployed
1	5-2 01:45	12° 59.02’	70° 02.60’	1300	1290	-	-
2	5-2 08:20	13° 20.31’	70° 00.49’	2948	2936	-	-
3	5-2 14:40	13° 20.30’	70° 00.50’	4939	4927	Yes	-
4	6-2 00:30	14° 02.81’	69° 56.17’	4133	2000	-	Yes (2x)
5	6-2 06:20	14° 24.03’	69° 54.01’	4202	2000	-	-
6	6-2 12:00	14° 44.00’	69° 47.59’	3967	2000	Yes	Yes
7	6-2 18:00	15° 03.98’	69° 41.20’	3863	2000	Yes	-
8	6-2 23:20	15° 24.00’	69° 34.80’	3839	3801	-	-
9	7-2 05:58	15° 43.99’	69° 28.43’	3790	2000	-	-
10	7-2 11:50	16° 04.00’	69° 22.00’	4434	2000	Yes	Yes
11	7-2 18:24	16° 23.99’	69° 15.63’	4113	2000	Yes	-
12	8-2 01:48	16° 55.61’	69° 04.78’	4803	4793	-	-
13	8-2 10:50	17° 27.20’	68° 53.99’	4112	4100	-	-
14	8-2 17:20	17° 42.92’	68° 48.57’	2069	2058	Yes	-
15	8-2 22:39	17° 58.81’	68° 43.20’	780	770	-	-
16	10-2 14:51	17° 53.59’	65° 11.83’	4439	-	Yes	-

1.4 List of cruise participants

Scientific crew	***Responsibility***	***Institution***
M. F. de Jong	Chief scientist, hydrowatch	NIOZ
M. Scheidat	Co-chief, fauna observations	WUR
S. Asjes	Electronic engineering, hydrowatch	NIOZ
K. Bakker	Nutrient analysis, hydrowatch	NIOZ
K. Schulz	Hydrowatch	NIOZ
C. van der Boog	Hydrowatch	TU Delft
T. Cömert	Hydrowatch	TU Delft
O. Meuriot	Hydrowatch	TU Delft
A. Vries	Biological sampling	UU
M. Leopold	Fauna observations	WUR
S. Geelhoed	Fauna observations	WUR
D. de Haan	Soundtrap	WUR
R. Buiter	Science journalist	Freelance

NIOZ: Royal Netherlands Institute for Sea Research
WUR: Wageningen Marine Research
TU Delft: Delft Technical University
UU: Utrecht University

Ship's crew	***Function***
J. C. Ellen	Master
L. Bliemer	First officer
E. Loonen	Second officer
B. Hogewerf	Chief engineer
F. Hiemstra	Second engineer
C. Stevens	Bosun
P. van Maurik	AB
N. Dos Santos	AB
M. de Vries	AB
I. den Breejen	Cook
V. Maksimovs	Steward

2 Underway measurements

2.1 Navigation

A differential GPS receiver was used for logging the positions. The data from the Sercel GPS receiver and the gyro compass were recorded every ten seconds in the underway data logging system. An additional Seapath dual antenna GPS receiver also determined the ship's heading.

2.2 Echo Sounding

The 3.5 kHz echo sounder was used on board to determine the water depth. The uncorrected depths from this echo sounder were recorded in the underway data logging system.

2.3 Thermo-Salinograph Measurements

The sea surface temperature and salinity were measured continuously with the SBE Seacat thermo-salinograph system with the water intake at a depth of about 3 m. These sensors were calibrated by comparison with the CTD-cast after CTD calibration. An offset of 0.102°C was found between the temperature recorded by the thermos-salinograph system and the CTD, likely due to warming after intake. The salinity was found to have an offset of -0.0025.

2.4 Meteorological data

Air temperature, relative wind velocity and direction and air pressure were measured and recorded by the underway logging system. These data will be further processed on shore.

2.5 Vessel Mounted ADCP measurements

The 75 kHz Acoustic Doppler Current Profiler (VMADCP) mounted under the Pelagia has been used to collect velocity data on transects between the hydrographic stations. The final processing of the data will take place back at Texel. The VMADCP data were collected with a dedicated service computer, together with the appropriate navigational data. These data were transferred daily to the appropriate directory of the ships computer network. The first phase of the VMADCP data processing took place on board.

2.6 Multibeam

During the final steaming from the last CTD station, south of the Dominican Republic, to Sint Maarten bathymetry data was collected using the multibeam, a Kongsberg EM302 Swath Multibeam with ping and chirp mode with Seapath GPS and motion sensors, 1° x 2°, 30kHz, swath 4200m at 5km water depth.

3. Hydrographic measurements

3.1 Aim

The aim of these measurements was to document the background hydrography of the Caribbean Sea as well as the hydrographic and velocity structure of a Caribbean anticyclone. Therefore 15 CTD stations were taken on a south-north transect through the Caribbean, from Aruba to the Dominican Republic. Special focus was on the southern part of the transect, where an anticyclone was visible in satellite sea surface height data.

3.2 CTD data collection and processing

A recently (November 2017) calibrated SBE 9/11+ CTD has been used to measure temperature, salinity, and chlorophyll/turbidity profiles. The sensors mounted on the CTD were an SBE3 temperature sensor SN-032118, SBE4 conductivity sensor SN-1204, a Digiquatz pressure sensor SN-127486. Also mounted were a Wetlabs CStar beam transmission meter SN-CST-1406DR (calibrated September 2017) with a path length of 25 cm and a SBE43 Oxygen sensor SN-043-0350 (calibrated July 2016). Chlorophyll was recorded by a Chelsea Aqua 3 Fluorometer SN-092 (calibrated October 2017) and a Wetlabs ECO-FLNT NS-4787 (calibrated July 2017) that additionally measured turbidity. PAR/Irradiance was measured by a Chelsea licor sensor SN-118 (calibrated July 2014). The CTD was mounted in a rack containing water samplers. Samples were taken for nutrient analysis and salinity calibration.

For the data collection the Seasave software for Windows (version V 7.26.7), produced by SBE, was used. The CTD data were recorded with a frequency of 24 data cycles per second. After each CTD cast the data were copied to the appropriate directory on the hard disk of the ship's computer network, where a daily back-up copy was made.

The CTD data were processed with the recently obtained calibration data, using the Seasoft software, also produced by SBE, and reduced to 1 dbar average ASCII files. These were used for the preliminary analysis of the data. The final data processing will be completed at Royal NIOZ, Texel.

3.3 Reference salinity measurements

Four salinity samples were taken from the up-cast of each of the CTD stations. Depths with minimum salinity gradients were selected for these samples. The sample bottles were taken to the labcontainer in the ship’s hold where they rested for at least 24 hour to equilibrate to container temperature.

The samples were analysed on the Guildline Autosal SN-66179. Each measurement started and ended with a standard seawater calibration, OSIL batch P161. Additional standard calibration was done every 15 samples. Results from these reference salinity measurements were used to calibrate the CTD conductivity sensor.

Due to the large range of sampled salinities, between 34.7 and 37.2, the signal suppression dial on the Guildline had to be adjusted frequently. This led to some initial difficulties in the final determination of the sample salinities. A mean salinity offset of -0.00504 was found, with no apparent relation to salinity (amplification), depth or station number (time). The mean conductivity offset was -0.00044 S/m, which has been input as a correction factor in the CTD's configuration files before final processing.

3.4 Data Management

All raw data were copied to a cruise directory on the ship's network computer. Subsequent processed data, final products, documents and figures were copied to separate sub-directories within the cruise directory. Back-ups of the network disks were made on a daily basis. At the end of the cruise copies of the whole cruise directory have been made on portable hard-disk. By help of paper measurement forms and computerized data inventory files all data are tracked. A final inventory of the mooring activities, hydrographic stations, and the available raw data files was made in a cruise summary file.

3.5 Preliminary results

Temperature and salinity profiles were obtained on 15 stations along a south-north section through the Caribbean Sea (Figure 1). The Caribbean Sea hydrography is characterized by a strong thermocline (Figure 2), typical for tropical regions. North-south differences are mainly found in the upper ocean, with waters around 200 to 800 m getting progressively warmer and more saline towards the north (Figure 2).

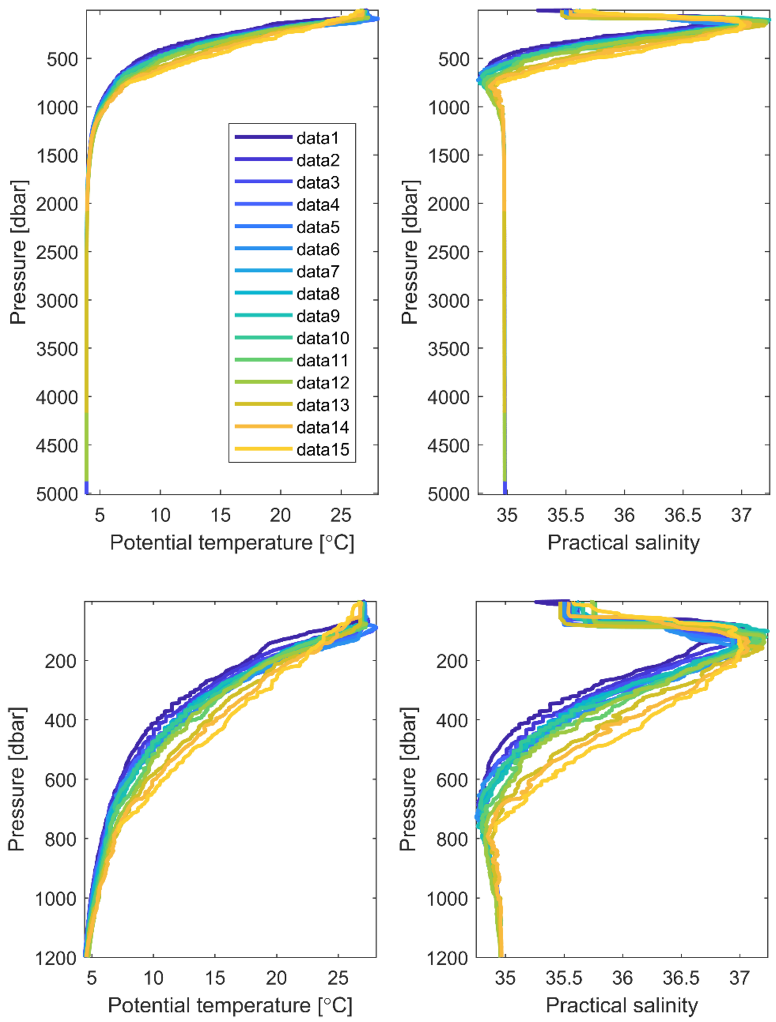

Figure 2. Vertical profiles of potential temperature (left column), salinity (right column). The upper panels show the entire vertical profile. The lower panels show a zoom in on the upper 1200 m of the water column. CTD stations numbers indicated as data #.

Relatively fresh mixed layers, down to 50 to 130 m, were found at all stations (Figure 2). The lower salinities are likely a result of the through flow of the Caribbean Current, which transports part of the fresher Amazon and Orinoco River Plume. The salinity maximum is found between the bottom of the mixed layer and 200 m depth (Figure 2 and 3).

Mixed layer temperatures were nearly uniform across stations, but underneath the mixed layer a temperature inversion stands out in stations 4 and 5 (~150 km from station 1 in Figure 3). Here, a warmer subsurface core, with temperatures above 28°C, characterizes the core of an anticyclonic eddy. This anticyclone is also visible by the depression of the isopycnals.

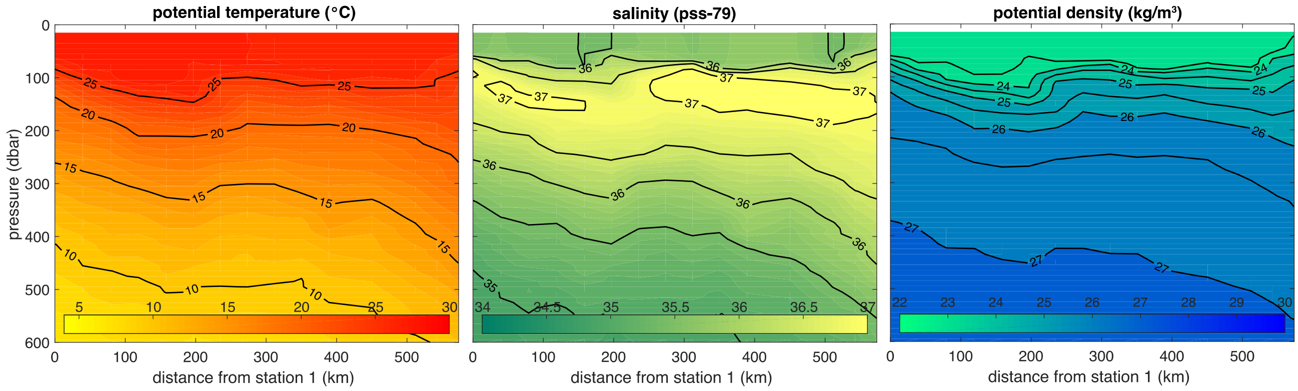

Figure 3. Zoom in on the upper 600 dbar of the potential temperature (left), salinity (middle) and potential density (right) fields.

The observed anticyclone stands out in both the altimetry of February 6th 2018, obtained from the Copernicus Marine Environment Monitoring Service (CMEMS, http://marine.copernicus.eu) as well as the VMADCP data (Figure 4). The VMADCP measured flow velocities up to 600m depth. The main direction of the zonal velocity is westward (Figure 4). The meridional velocity is predominantly northward. The signature of the anticyclonic eddy is visible as the surface counterflow at 15°N. We estimate the radius to be 100 km.

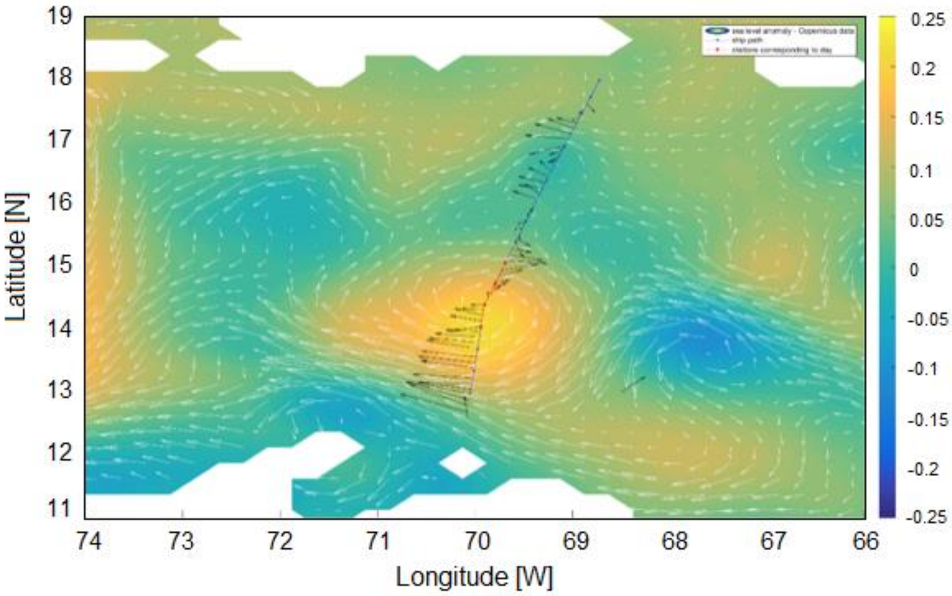

Figure 4. VMADCP velocities (black vectors) on top of velocities (white) and CMEMS sea surface height anomalies (colors) of 6 February 2018.

The surface temperature and salinity of the mixed layer were measured continuously from the ship's intake at 3 m depth. Figure 5 shows small lateral gradients within the mixed layer, with temperatures of 27.3°C in the southern part of the basin decreasing towards 26.8°C in the north. At 16.5°N, the surface temperature increases slightly. At the same location, the salinity measurements indicate a positive anomaly (Figure 5) with a yet unclear origin. In combination with the CTD profiles and ADCP data, this anomaly is located outside the anticyclonic eddy. Along the continental slope of the Dominican Republic and Puerto Rico, a similar salty anomaly is found. Further analysis is necessary to identify the origin of these anomalies.

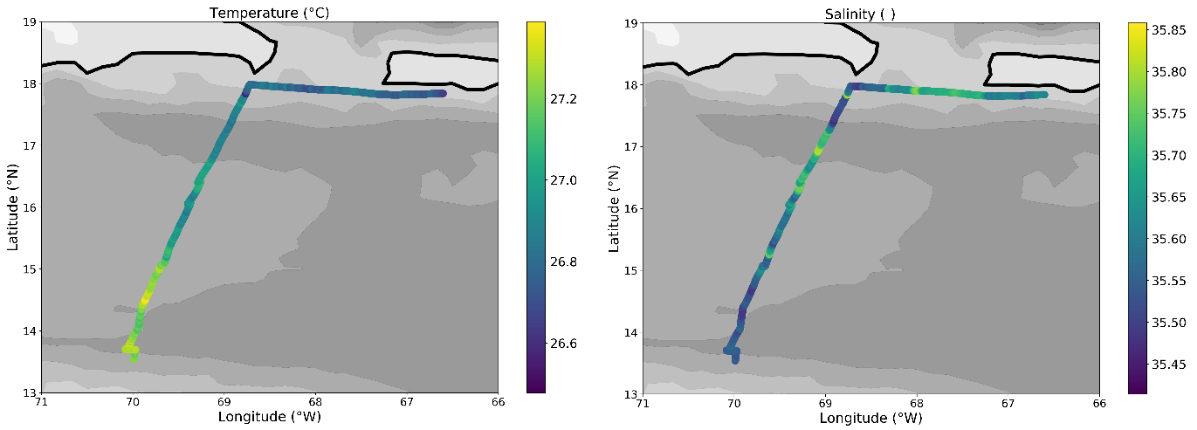

Figure 5. Temperature and salinity along the ship track as recorded by the thermo-salinograph.

3.6 Nutrient analysis

A. Summary

Nutrients were analysed in a temperature controlled lab-container equipped with a QuAAtro Gas Segmented Continuous Flow Analyser, measuring approximately 220 samples for different parameters. Samples were collected from all 15 stations with the CTD-rosette. Measurements were made simultaneously on four channels for phosphate, silicate, nitrate with nitrite together and Nitrite separate. All measurements were calibrated with stock-standards diluted in low nutrient seawater (LNSW) in the same salinity range as the samples.

B. Equipment and Methods

The samples were collected in 125 ml high-density polyethylene bottles from Niskin bottles of the rosette. The sample bottles were first rinsed three times with a small amount of sample before being completely filled up.

After sampling on deck the samples were stored in a refrigerator at 4°C. PO4, Si and NO3 plus NO2 samples were simultaneously measured in the lab container within 12 hours after sampling. All sampler vials ("Pony vials HDPE 6ml) including caps were pre-rinsed three times with sample before filled up.

Calibration standards were freshly prepared every day by pipetting stock standards of the different nutrients into calibration flasks and diluted with 0.2µm filtered LNSW to the mark. The LNSW was also used as baseline water for the analysis in-between the samples. Each run of the system had a correlation coefficient of at least 0.9999 for 10 calibration points, but typical 1.0000 with linear chemistry. The samples were measured from the lowest to the highest concentration in order to keep carry-over in the flow system as small as possible, so from surface to deep waters.

Before analysis started, standards and samples were acclimatised at lab temperature of 23°C. Concentrations were recorded in 'µmol per liter' (µM/L). During the cruise each run, a freshly diluted mixed nutrient standard (nutrient cocktail), containing, phosphate, silicate and nitrate was diluted 100 times in LNSW. Independently of the standards the cocktail standard was used to monitor the performance of the system.

A second control sample (LNSW from OSIL batch LNS 21) close to the method detection limits was measured direct after the baseline.

C. Analytical Methods

The colorimetric methods used are as follows:

Ortho-Phosphate (PO4) reacts with ammonium molybdate at pH 1.0, and potassium antimonyltartrate is used as a catalyst. The yellow phosphate-molybdenum complex is reduced by ascorbic acid and forms a blue reduced molybdophosphate-complex which is measured at 880nm (Murphy & Riley, 1962).

Silicate (Si) reacts with ammonium molybdate to a yellow complex and after reduction with ascorbic acid, the obtained blue silica-molybdenum complex is measured at 820nm. Oxalic acid is added to prevent formation of the blue phosphate-molybdenum complex (Strickland & Parsons, 1968).

Nitrate plus Nitrite (NO3+NO2) is mixed with an imidazol buffer at pH 7.5 and reduced by a copperized cadmium column to nitrite. The nitrite is diazotized with sulphanyl-amide and naphtyl-ethylene-diamine to a pink coloured complex and measured at 550nm. nitrate is calculated by subtracting the nitrite value of the nitrite channel from the 'NO3+NO2' value. (Grasshoff et al, 1983).

Nitrite (NO2) is diazotized with sulphanyl-amide and naphtyl-ethylene-diamine to form a pink colored complex and measured at 550nm. (Grasshoff et al, 1983).

D.Calibration and Standards

Nutrient primary stock standards were prepared in deionised water (18.2MΩ) at the NIOZ as follows;

Phosphate: by weighing potassium dihydrogen phosphate in a calibrated volumetric PP flask to make 1mM PO4 stock solution.

Silicate: by weighing Na2SiF6 in a calibrated volumetric PP flask to make 19.84mM Si stock solution.

Nitrate: by weighing potassium nitrate in a calibrated volumetric PP flask set to make a 10mM NO3 stock solution.

Nitrite: by weighing sodium nitrite in a calibrated volumetric PP flask set to make a 0.5mM NO2 stock solution.

The cocktail standard, a mixture of phosphate, silicate and nitrate preserved with addition of 1ml saturated HgCl2

All stock-standards were stored at room temperature in a 100% humidified box. The calibration standards were prepared daily by diluting the separate stock standards, using three electronic pipettes, into four 100ml PP volumetric flasks (pre-calibrated at NIOZ) filled up with LNSW. The background values of the diluted LNSW were measured before the cruise in the NIOZ lab and added up to the standard values to compute the final calibration-point values.

E. Quality Control

Our standards have already been proven by inter-calibration exercises from ICES and Quasimeme, and since 2006 by the Inter Comparison exercises organised by MRI, Japan. Our cocktail standard was measured every run for all nutrients during the cruise. To obtain international comparable results, two KANSO CRM's produced by The General Environmental Technos Co., Ltd. Japan in triplicates were analysed in three consecutive run.

F. Method Detection Limits

The method detection limit M.D.L was calculated during the cruise using the standard deviation of ten samples containing 2% of the highest standard used for the calibration curve and multiplied with the student's value for n=10, thus being 2.82. (M.D.L = std. dev. of 10 samples x 2.82 E.P.A. procedure). Only a few near-surface samples for PO4, NO3 and NO2 were just below or close to the detection limit.

M.D.L.	µM/l	At applied measuring range µM/l:
PO4	0.004	3.0
Si	0.007	40
NO3	0.008	40
NO2	0.004	0.5

<u>Control sample close to the M.D.L.</u>

As an independent control on near baseline values from in-between analytical runs, LNSW from OSIL batch LNS 21 was measured every day n=7:

	µM/l	st. dev. µM/l
PO4	0.011	0.003
Si	0.31	0.03
NO3	0.04	0.03
NO2	0.031	0.013

From day to day variation no trends over time were observed concluding that the baseline water used LNSW stayed stable during the cruise.

<u>Precision at calibration levels.</u>

Used concentration level µM/l and c.v. % (triplicate analysis):

	µM/l	c.v. %	µM/l	c.v. %	µM/l	c.v. %
PO4	0.6	0.4	1.2	0.4	2.0	0.8
Si	8	0.7	16	0.5	28	0.9
NO3	8	0.9	16	0.6	30	0.7
NO2	0.1	1.5	0.2	0.8	0.35	0.5

<u>Cocktail statistics.</u>

The average value of 7 triplicates was 2.26uM for PO4, 34.98 uM Si and 34.60 uM for NO3 with a coefficient of variation being respectively 0.8% for PO4, 0.58 for Si and 0.54% for NO3 as an indication of in-between analytical runs precision. From the cocktail measurements no trends were observed concluding that the calibration standards were stable during the cruise.

<u>Obtained CRM values KANSO lots BU and CA</u>

The average value of 3 triplicate measurements of **CRM "BU"** are:

	µM/l **23°C**	converted to **µM/kg**:	assigned KANSO in **µM/kg**:
PO4	0.366	**0.357**	**0.345**
Si	20.85	**20.37**	**20.92**
NO3	3.98	**3.914**	**3.937**
NO2	0.095	**0.092**	**0.072**

The average value of 3 triplicate measurements of **CRM "CA"** are:

	µM/l **23°C**	converted to **µM/kg**:	assigned KANSO in **µM/kg**:
PO4	1.454	**1.421**	**1.407**
Si	36.43	**35.59**	**36.58**
NO3	20.01	**19.55**	**19.66**
NO2	0.079	**0.077**	**0.063**

The CRM values obtained are in good agreement with the assigned values for PO4 and NO3. However for silicate the reported value is with a factor 0.97 deviating from the assigned value recognised as an international problem in lack of availability to get a 100% pure absolute stock standard for calibration. No post cruise adjustments are suggested.

3.7 Preliminary results nutrient analysis

Preliminary nutrient data show depleted values in the near surface layer (Figure 6) of all measured nutrients. Concentrations increase beneath the mixed layer, with higher values in the south of the basin and lower values in the north. This north-south gradient is likely connected to the north south temperature gradient observed at the same depths (Figure 2), where colder temperatures were seen in the south and warmer temperatures in the north. The origin of these nutrient gradients will be subject of further study.

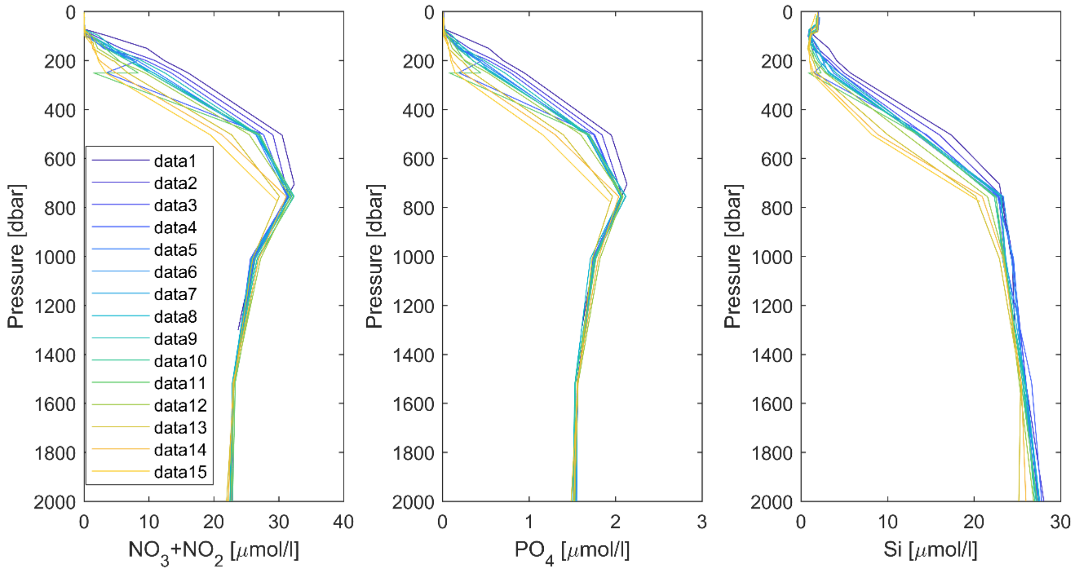

Figure 6. Vertical profiles of nitrate + nitrite (left), phosphate (middle) and silica (right).

4. Acoustic measurements

4.1 Aim

The aim of the acoustic measurements was to record cetacean vocalisations for species identification and quantification. Acoustic passive monitoring was carried out at the CTD stations during daytime.

4.2 Methods and station positions

To monitor whale vocalisations an autonomous recording device SoundTrap (type ST300HF, Ocean Instruments, New Zealand) was attached to a line that was hanging from a buoy at a depth of 100 m from the surface. The sampling rate of the SoundTrap recorder was set to 96 kHz enabling a frequency range of 10 Hz to 48 kHz, wide enough to capture low frequency (LF) and mid frequency (MF) whales and dolphin species.

A radio beacon and a GPS transponder were attached on top of the buoy to retrieve the buoy position (Figure 7). Radio beacon updates were transmitted every 20 s and monitored on the ship's wheelhouse. The GPS transponder was set to transmit GPS positions every 20 minutes and send these by email. However, after three hours the beacon's programming automatically overrides this setting and returns to its default setting, which halts the 20 minute updates. No workaround was found for this issue.

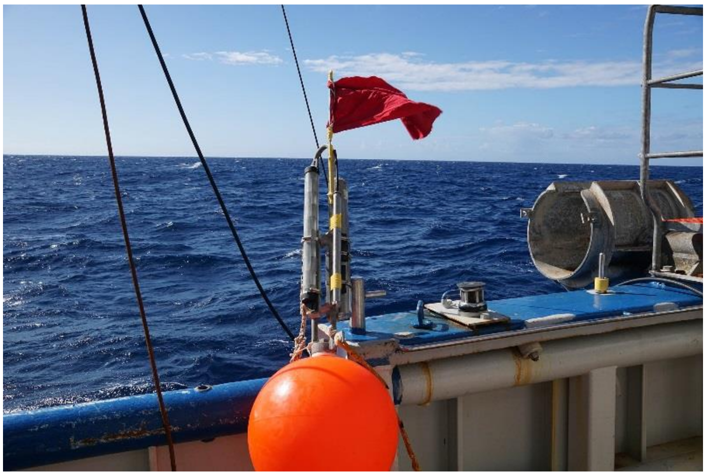

Figure 7. Main buoy with radio and GPS beacon attached.

The buoy system was deployed nearby CTD stations and recovered when the CTD sampling was completed and the equipment recovered on deck. In this set-up an acoustic monitored period mainly depended on the sampling depth of the CTD, which ranged between 1000 and 5000 m. This corresponds to a recording time between 2 to 5 ½ hours. During the CTD manoeuvres the ship was kept in position by the bow and stern thrusters and main propeller at low propulsion power. All echo-sounders and ADCP were switched off during the acoustic sampling.

Of the 15 stations defined in the cruise programme six were acoustically observed for the presence of vocalising marine mammals (Figures 1 and 8). An additional station was monitored southeast of Puerto Rico (station 16).

Table 2. Overview of dates, times and positions of recorded tracks with first impression of marine mammal detection.

Date	Station (nr)	Track record		Observed track		Marine mammal sounds (preliminary analyses)
		Start	stop	Start (latN/lonW)	Stop (latN/lonW)	
05-02	3	14:35	19:54	13°41.50 & 69°58.30	13°42.23 & 70°04.86	
06-02	6	11:34	13:45	14°43.94 & 69°47.30	14°43.89 & 69°47.41	
06-02	7	17:24	19:47	15°03.93 & 69°41.09	15°03.92 & 69°39.81	y
07-02	10	11:37	14:00	16°03.89 & 69°22.11	16°03.33 & 69°23.86	
07-02	11	18:11	20:29	16°23.95 & 69°15.74	16°23.84 & 69°17.21	y
08-02	14	16:50	19:35	17°42.66 & 68°48.37	17°40.95 & 68°48.97	
10-02	16	14:51	17:00	17°53.59 & 65°11.83	17°53.17 & 65°13.12	y

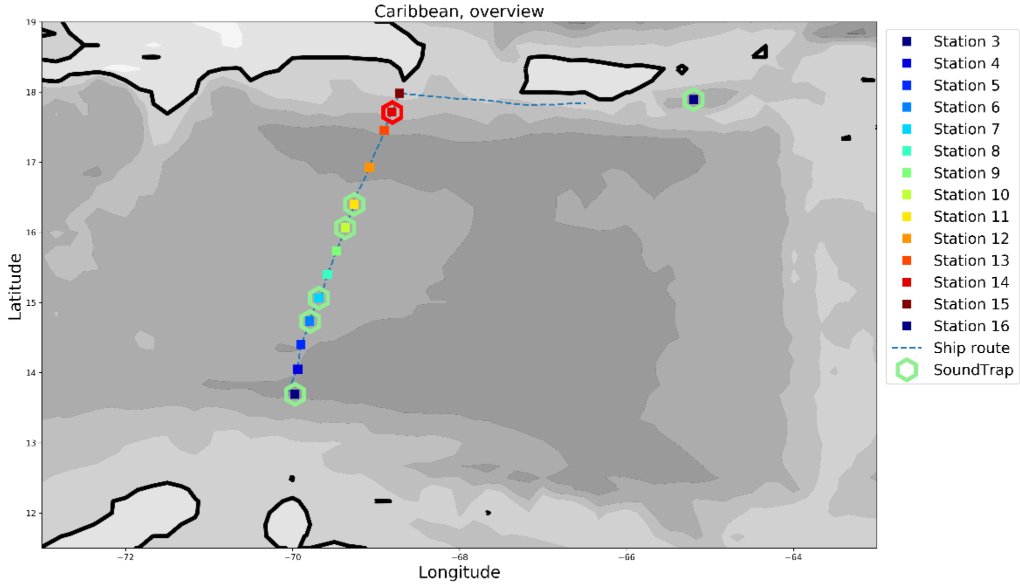

Figure 8. Overview of acoustically monitored stations, marked SoundTrap. No data were recorded on Station 14 (high-lighted in red). Note that the first two CTD stations are not plotted here.

4.3 Preliminary Results

Weather conditions were moderate in most cases with winds mainly from east-northeast to east, force 5 to 6 Bft. Given the surface deployment the background noise levels under these conditions were rather significant. On approaching the northern Caribbean island Puerto Rico the conditions shortly improved, but the acoustic data mainly were collected in sea state 5 conditions with a wave height of 2.5 m as an average level. Vessel propulsion noise was a second source determining background noise levels. These levels were highest on deployment and recovery, but were also detected when the buoy drifted in the air-filled propeller wake. The direction of the drifting buoy depended on the tidal current, which was mainly east or west. Conditions with the buoy drifting against the wind in eastern directions did also occur. This indicates strong currents, possibly associated with the targeted eddy. Lowest noise level contribution was found when the buoy drifted away in the direction of the ship’s stationary heading.

Figure 9. Buoy system initial deployment.

The preliminary results show that at least on three of the six SoundTrap deployments whale vocalisations were detected. On station 7 numerous vocalisations of humpback whale (*Megaptera novaeangliae*) were detected. For these detections and the pre-conditioning of adding 20 dB gain, these calls are likely to have been received at 5-10 km form the source.

On station 11 sperm whale (*Physeter macrocephalus*) type echolocations (clicks) were detected. Sperm whale clicks are produced in a 10 Hz–30 kHz frequency band, with an inter-click interval (ICI) that varies from 0.5 to 2.0 seconds during descents. Clicks produced during foraging dives are directional, with a high level, forward-directed beam with levels as high as 230 dB re 1 µPa2m2. The off-axis low frequency components can be detected up to a distance of 15 km in 3 Bft winds (Mohl et al., 2003). With the hydrophone at a relatively shallow depth, the surface noise contribution was significant and secondly the wave height variations were coupled to the vertical variations of the deployed depth adding self-noise of the buoy. In addition the sound was likely to be produced during descents the calls in the received position were reflected by the bottom and/or temperature layers.

5. Visual surveys

5.1 Aim

The aim of the visual surveys was to quantify the occurrence of marine megafauna, such as seabirds and cetaceans, in relation to oceanographic data. Biota were expected to react numerically to hydrography. In particular, an enriched zone was expected at the eddy's perimeter.

5.2 Methods

Data collection took place whenever RV Pelagia was steaming during daylight hours. The observation platform was on top of the bridge ("monkey island").

All birds, cetaceans, flying fish, and particular floating matter (balloons, seaweed) were logged at one side of the ship with the best observation conditions, along the transect lines sailed. To this end, one survey team of two to four observers detected, identified and counted these object within a strip of 300 m wide. A wider 180 degrees forward watch was maintained simultaneously for birds and other fauna beyond the strip boundaries. Standardized counting methods from the European Seabirds At Sea (Tasker et al. 1984) were used. All birds seen were logged per 10-min counts. The behaviour of observed birds and marine mammals was noted according to Camphuysen & Garthe (2004). GPS positions and environmental conditions were recorded, for each 10-minute count the central position and time were calculated and these are to be correlated to the hydrographical data collected synoptically.

5.3 Preliminary results

The surveys were conducted from 4-11 February 2018 in moderate to poor conditions, due to strong winds of at least 4 Bft, with a maximum of 7 Bft. Marine mammal surveys are normally conducted up to 4 Bft, but bird counts can carry on longer. We have no previous data on detectability of flying fish in different seastates.

In total 541.8 km could be surveyed. All observed birds, marine mammals, flying fish and other objects seen during the survey are presented in Table 3. In total 15 birds species were recorded, of which Brown Booby (*Sula leucogaster*) was the most abundant (n = 276). It was seen throughout the whole survey area, but numbers were low during the northbound transects from Aruba to Hispanola. On the transects east to Sint Maarten numbers were higher, and several areas with flocks of feeding boobies were encountered. Feeding boobies were mostly hunting for flying fishes.

The survey shows a general pattern of a high species diversity and low densities further offshore, and higher species diversity and numbers relatively close to the islands.

Table 3. Observations of seabirds, marine mammals, flying fish and other objects, 4-11 February 2018.

English	Dutch	Scientific	Total
Counts without observations	Tellingen zonder waarnemingen	Zero-counts	96
Black-capped Petrel	Zwartkapstormvogel	*Pterodroma hasitata*	12
Great Shearwater	Grote Pijlstormvogel	*Puffinus gravis*	3
unidentified shearwater	ongedeterm. pijlstormvogel	*Puffinus* spec.	12
Audubon's Shearwater	Audubons Pijlstormvogel	*Puffinus lherminieri*	1
Leach's Storm-petrel	Vaal Stormvogeltje	*Oceanodroma leucorhoa*	1
Red-billed Tropicbird	Roodsnavelkeerkringvogel	*Phaethon aethereus*	5
Red-footed Booby	Roodpootgent	*Sula sula*	20
Masked Booby	Maskergent	*Sula dactylatra*	7
Brown Booby	Bruine Gent	*Sula leucogaster*	276
Booby spec.	gent spec.	*Sula* spec.	3
Brown Pelican	Bruine Pelikaan	*Pelecanus occidentalis*	1
Magnificent Frigatebird	Amerikaanse Fregatvogel	*Fregata magnificens*	22
Pomarine Skua	Middelste Jager	*Stercorarius pomarinus*	1
Caspian Tern	Reuzenstern	*Sterna caspia*	1
Royal Tern	Koningsstern	*Sterna maxima*	25
Bridled Tern	Brilstern	*Sterna anaethetus*	3
Sooty Tern	Bonte Stern	*Sterna fuscata*	40
Tern	ongedeterm. stern	*Sterna* spec.	15
Pantropical Spotted Dolphin	Slanke Dolfijn	*Stenella attenuata*	26
Atlantic Spotted Dolphin	Atlantische Gevlekte Dolfijn	*Stenella frontalis*	23
unidentified flying fish ("adult")	onged. vliegende vis (volwassen)	Exocoetidae	1441
unidentified flying fish ("smurf")	onged. vliegende vis (smurf)	Exocoetidae	1032
Dolphin Fish	Dorado	*Coryphaena hyppurus*	3
Portugese Man of War	Portugees oorlogschip	*Physalia physalis*	1
set net (flag)	staand of drijfnet (joontje)		1
Butterfly	Vlinder		39

The first impression is that flyingfishes were most abundant at the eddy's perimeter (note: n = 1 crossing!). Biota higher in the food chain were too scarce to be correlated to eddy hydrography. Remarkably, flying fish were seen in good numbers along all transects and birds specialized in feeding on flying fish (e.g., boobies) appeared to have little difficulty catching flying fish. It appears that in the offshore realm of the Caribbean Sea, a large ecological niche (food: flyingfish). The piscivore birds and marine mammals we investigated occurred in such low numbers that these are unsuitable as indicators for changes in productivity here, but flyingfish may be (data need to be processed).

6. Biochemical sampling

6.1 Aim

This sampling was conducted to understand more about micro-organisms and algae in the ocean's photic zone. Algae can produce DMSP, which might reach the surface in form of DMS, which is an important source for aerosols over the ocean. Aerosols have a wide range of effects, one of them being reflecting light which is a negative forcing in the global energy budget. Moreover, aerosols have various effects on clouds that also influence the global climate and weather. Samples are done in order to study abundance, health and DMSP production of algae, bacteria and viruses.

6.2 Method

CTD samples were taken at two stations per week for 6 different heights (see Table 4). The depth of the DCM was determined by the fluorescence sensor in the CTD profile when going down. Water samples collected were analysed for two projects; samples for flow cytometry (FCM) and molecular analysis for Prof Corina Brussaard (NIOZ), and samples for DMSP content, high pressure liquid chromatography (HPLC) pigment composition, particulate organic carbon (POC), and photosynthetic ability (PAM fluorometry) for Dr Maria van Leeuwe (RUG). Samples for dissolved inorganic macronutrients were taken for both projects. In Table 4 the type of analysis conducted for both projects, as well as the water volumes required from the CTD, are summarized. Water samples for fluorometry (PAM) were subsampled from the HPLC samples prior to analysis.

Table 4: Overview of samples taken for biochemical analysis.

Depth	DMSP	Abundance (Phytoplank-ton, bacteria, viruses)	PAM	Nutrients	Molecular analysis (viruses)	POC (Carbon)	HPLC
3 3 m (surface)	70 ml	50 ml	6 ml	50 ml		2 l	4 l
15 m (mixed layer)	70 ml	50 ml	6 ml	50 ml	4 l	2 l	4 l
DCM start		50 ml					
DCM top	70 ml	50 ml	6 ml	50 ml	4 l	2 l	4 l
DCM bottom		50 ml					
200 m		50 ml					

The order of sampling was first DMSP (since this contains a volatile compound). Then the molecular filtering would be started (this takes at least five hours). A PAM analysis and after that the abundance and nutrients were processed in order to finish with the filtering of the POC and HPLC samples. The second depth (DCM top) of the molecular sampling was processed the following day.

For the DSMP samples two 10 ml bottles of water were collected, one with the original sample and one with a filtered sample (to filter the algae cells out). Water samples for molecular work were kept cool on ice until analysis, and were per depth first filtered over a 0.22 µm Sterivex filter to collect the larger planktonic organisms, flash frozen in liquid nitrogen and stored at -80˚C in a labelled plastic bag. The filtrate collected from this first filtration was then filtered over a 0.02 µm Anotop filter to collect the viruses also present in the water column, after which it was stored under the same conditions as the Sterivex filter. To determine abundance of plankton as well as bacteria and viruses samples from all depths were fixed for flowcytometry, i.e. with formaldehyde/hexamine for phytoplankton and glutaraldehyde for bacteria and viruses (duplicate samples). Samples were fixed for 30 min in the fridge, followed by flash freezing in liquid nitrogen and storage at -80˚C in labelled plastic bag. Water for nutrient analysis, i.e. dissolved inorganic silicate (Si), nitrogen (N) and phosphate (P) was taken from 3m, 15m and DCM peak if present (otherwise 50m) and filtered over 0.2 µm pore-size Acrodisc syringe filter. Samples for silicate were stored at 4 ˚C, and for N+P upright in the -20 ˚C freezer, for N and P analysis. Pony-vials were numbered consecutively, starting from 1, independent of station and depth; the same number was used for duplicate vials originating from the same CTD water sample. HPLC samples, used to determine algal pigments, were vacuum filtered over 4.7cm GF/F filters while 2.5 cm GF/F filters were used for POC samples. For both filtrations the volume of water filtered over each filter (3 in total for each depth) was noted. The filters where then stored in prepared aluminium foil marked with leg and station number, as well as depth and filter number, snap frozen in liquid nitrogen and stored in labelled plastic bags.. For PAM measurements water was subsampled from the HPLC water samples into the PAM vials, 2 vials per depth, and dark acclimated for 10 minutes before measuring. For all measurements Ft values were ensured to be above 100 before proceeding. In such instances where this was not the case the PM-Gain and Out-Gain were increased up to 12. Samples for which the gain setting needed to be above 12 in order to have high enough Ft values were discarded. Further processing and analysis of these samples will be performed at NIOZ.

7. Argo float deployments

Four Argo (Arvor) floats were provided via the European Union's MOCCA project (Monitoring the Oceans and Climate Change with Argo, http://www.euro-argo.eu/EU-Projects/MOCCA-2015-2020; contact person in the Netherlands; Andreas Sterl, KNMI, sterl@knmi.nl).

The Caribbean Sea is typically poorly sampled by Argo floats due to the shallow entrances between the windward islands. Four floats were deployed during this cruise to amend this situation. Two floats were deployed near the core of the observed anticyclone, with the expectation that these would travel with the surveyed eddy. Two other floats were deployed outside the anticyclone to observe the ambient hydrography. The sampling frequency and parking depths of these floats was adjusted, 3-day cycling rather than the standard 10-day cycle and 500 m instead of the usual 1000 m. In this way, we hope to avoid that these floats get stranded on the shallow ridges in the area. The fate of these four floats will continue to be monitored from shore.

Table 5. Argo deployment information.

IMEI	300234064800200	300234064703820	300234064806020	300234064801050
	IRIDIUM	IRIDIUM	IRIDIUM	IRIDIUM
Comment after visual inspection	OK	OK	OK	OK
Magnet removal in UTC	6-2-2018 02:03	7-2-2018 13:13	6-2-2018 02:00	6-2-2018 13:15
Comment on float internal checks (valve and pump actions)	OK	Initially failed starts on 02/06/2018. OK after update.	OK	OK
Deployment time (dd/mm/yyyy hh:mm) in UTC	6-2-2018 02:15	7-2-2018 13:32	6-2-2018 02:18	6-2-2018 13:39
Deployment latitude (dd°mm,mm N/S)	14° 2.98 N	16° 4.02 N	14° 3.04 N	14° 44.00 N
Deployment longitude (ddd°mm,mm E/W)	069° 56.18 W	069° 22.01 W	069° 56.19 W	069° 47.60 W
Deployment method	By hand	By hand	By hand	By hand
Deployment height (m)	1,5	1,5	1,5	1,5
Ship speed (kts)	0.3	0.6	0.3	0.5
Wind speed (Beaufort)	4	5	4	5
Sea state	slight	moderate	slight	slight
Bathymetry (m)	4180	3908	4180	4066
CTD	CTD station# 4	CTD station# 10	CTD station# 4	CTD station# 6

References

Camphuysen C.J. and S. Garthe, 2004. Recording foraging seabirds at sea: standardised recording and coding of foraging behaviour and multi-species foraging associations. Atlantic Seabirds 5: 1-23.

Grasshoff, K. et al, 1983. Methods of seawater analysis. Verlag Chemie GmbH, Weinheim, 419 pp.

Helder, W., and R. de Vries, 1979. An automatic phenol-hypochlorite method for the determination of ammonia in sea- and brackish waters. Neth. J. Sea Research 13: 154-160.

Møhl, B., M. Wahlberg, P. T. Madsen, A. Heerfordt, and A. Lund. 2003. The monopulsed nature of sperm whale clicks. The Journal of the Acoustical Society of America 114: 1143.Murphy, J. and J.P. Riley, 1962. A modified single solution method for the determination of phosphate in natural waters. Analytica chim. Acta, 27, p31-36.

Strickland, J.D.H. and T.R. Parsons, 1968. A practical handbook of seawater analysis. first edition, Fisheries Research Board of Canada, Bulletin. No 167, p.65.

Tasker M.L., Jones P.H., Dixon T.J. and B.F. Blake, 1984. Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. Auk 101: 567-577.