Cruise Report

RRS James Cook JC149

VOILA - Volatile recycling in the Lesser Antilles arc

16 April – 19 June 2017

Freeport, Bahamas (BSFPO) –to- Pointe a Pitre, Guadeloupe (GPPTP)

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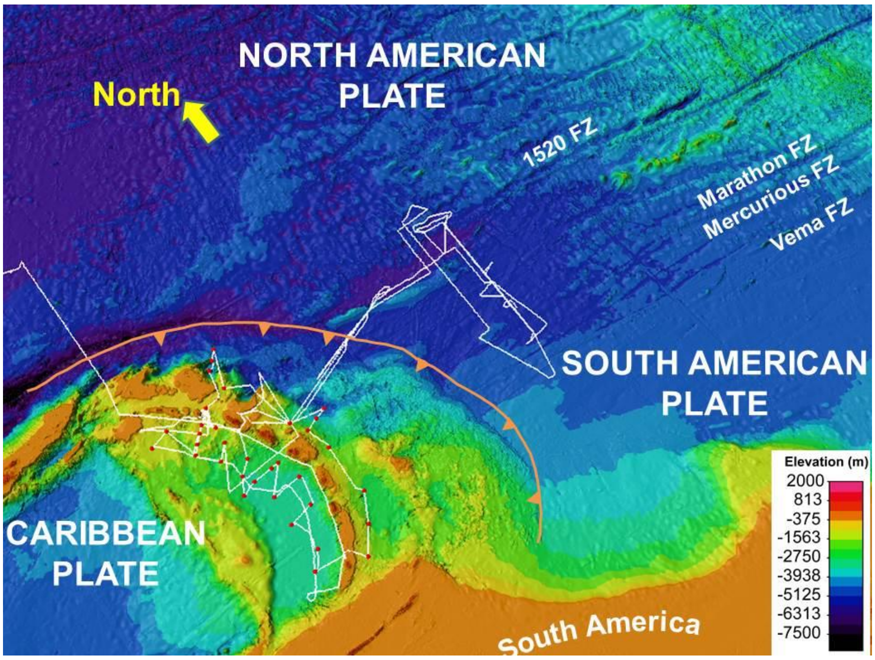

JC149 tracks (white line) and BBOBS locations (red spheres) on a perspective view of the Lesser Antilles subduction zone

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1 Executive Summary

The VOILA (Volatile cycling in the Lesser Antilles arc: Processes and consequences) research programme takes a holistic approach to understanding the cycling of volatiles (principally water) into the deep Earth at the Lesser Antilles subduction zone (Figure 1). Here the North and South American Plates, soaked with water from the Atlantic Ocean, subduct beneath the Caribbean Plate. The project combines a range of Earth scientists with skills in petrology, geochemistry, numerical modelling as well as marine geophysics. The UK-based team will combine with Caribbean-based researchers to track the passage of the water as it goes into and out of the subduction zone system. The project will also lead to a better understanding of natural hazards (earthquakes and volcanic eruptions) in the region.

The VOILA research programme consisted of two cruises onboard *RRS James Cook*, JC133 and JC149. The main aim of the cruise JC149 (SME 697) was to (i) shoot into 34 broad-band ocean bottom seismometers (BBOBS) deployed in March 2016 during JC133 (SME 698) around the arc (ii) recover these instruments and then (iii) conduct an active source short-period ocean bottom seismometer (SPOBS) experiment with 50 instruments on the incoming plate. Due to the size and scope of the

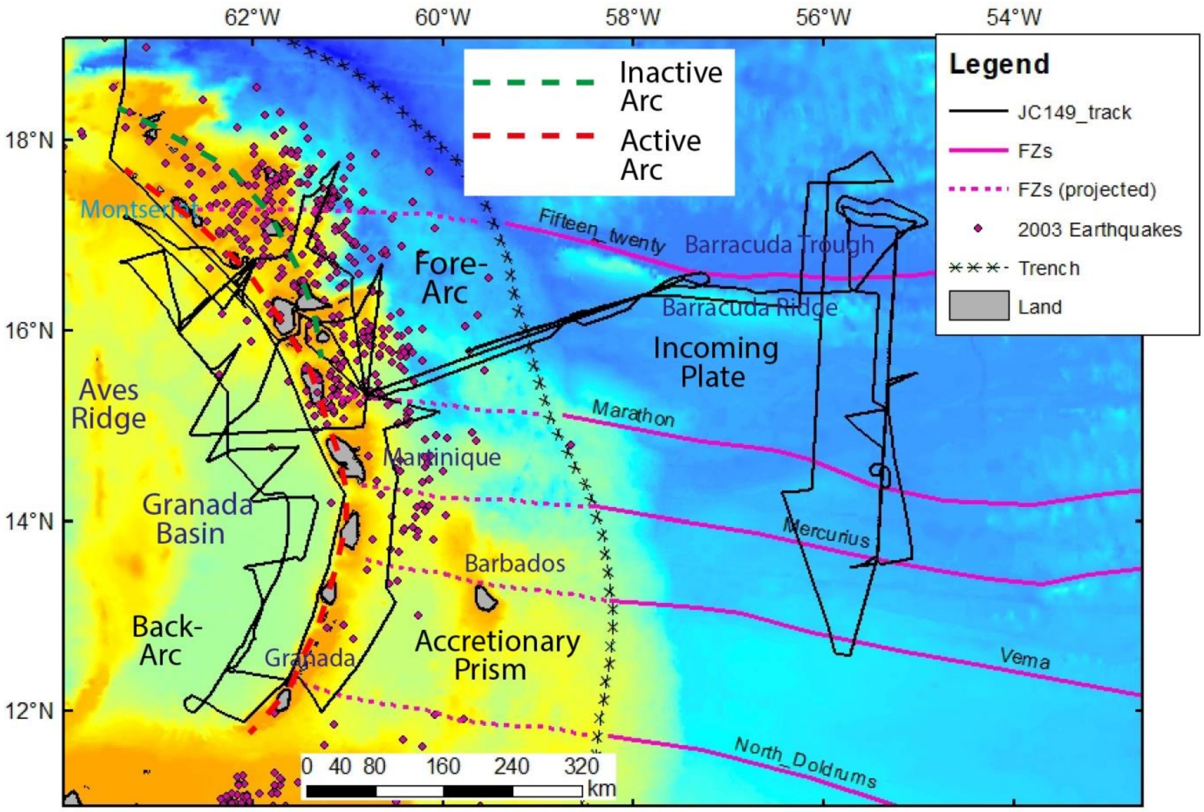


Figure 1 Map showing the JC149 ship track together with some named tectonic (black text) and physiographic (blue text) features mentioned in the text labelled.

experiment OBS from three groups were used (DEPAS/Germany, SIO/USA and OBIF/UK). The cruise was divided into 3 legs to allow personnel and equipment changes. Legs 1 and 2 took place around the Lesser Antilles islands and Leg 3 east of the trench on the incoming plate.

Vessel operations at sea were generally excellent and all planned scientific work was successfully completed. All BBOBS instruments were recovered with 32 out of the 34 DEPAS and SIO instruments having successfully recorded data (94%). During Leg 3 a total of 136 stations were occupied during three deployment/recovery cycles of DEPAS and OBIF instruments. Two SPOBS were lost and two further instruments were found damaged on recovery. The overall success rate (i.e. instruments with useable data recorded) of the entire OBS programme was 96% (Table 1).

OBS Success Rates

Phase	Pool Success/Deploy		Total			Succss rate
			Deploy	Recover	Success	
BB	SIO 8/10	DEPAS 24/24	(JC133)	34	32	94%
SP-line1	OBIF 23/25	DEPAS 23/23	48	46	46	96%
SP-line2	OBIF 18/18	DEPAS 24/26	44	44	42	95%
SP-line3	OBIF 23/23	DEPAS 21/21	44	44	44	100%
		SP Subtotal	136	134	132	97%
		GRAND TOTAL	136	168	164	96%

Failures

Station	Deploment/Recovery date yr/JD	yr/JD	WD m	Line	Pool	Recovered	Comment
20	JC133 16/073	JC149 17/125	2566	BB	SIO	yes (Leg2)	Logger reset
29	JC133 16/074	JC149 17/133	1389	BB	SIO	yes (Leg2)	Seismometer non-deployment + Logger reset
101	JC149 17/138	JC149 17/147	5262	1	OBIC	no (Leg3)	No response - flotation sphere failure?
125	JC149 17/139	JC149 17/144	5744	1	OBIC	no (Leg3)	No response - flotation sphere failure?
219	JC149 17/148	JC149 17/156	5789	2	DEPAS	yes (Leg3)	Trillium seismometer case implosion
249	JC149 17/149	JC149 17/161	5528	2	DEPAS	yes (Leg3)	Trillium seismometer case failure

Table 1 JC149 ocean-bottom seismometer (OBS) deployment and recovery overview

In total 9,286 airgun array shots were made during Leg 1 and 18,254 during Leg 3. Underway geophysical data (PES, EM120 MBES, SBP, magnetic and gravity) were collected along all shot lines and most transits. A detailed EM710 swath bathymetry survey of *Kick'em Jenny* volcano was also conducted. This active underwater volcano is the only known in the region and so presents a unique opportunity for study. It presents a potential hazard to local populations due to its proximity to the island of Grenada.

2 Scientific Background

Cruise JC149 forms part of NERC NE/K010743/1 grant, project VOILA (Volatile recycling in the Lesser Antilles arc: Processes and consequences). The project will study a key element of the solid Earth water cycle and in particular the effect on natural hazards and melting at subduction zones. We target the Lesser Antilles Arc as:

(1) it is one of only two subduction zones that consume lithosphere formed at the slow-spreading Mid-Atlantic Ridge. It therefore represents an end member particularly suitable to study the role of the mantle lithosphere in transporting water into the deep Earth;

(2) the Antilles are a prime candidate for studying the impact of several key variables, because of large along-strike variations in sediment input and structure of the incoming plate, while thermal subduction parameters are almost constant along the arc;

(3) large high-quality data sets (especially geochemical and petrological) are already available from the volcanic arc itself, and

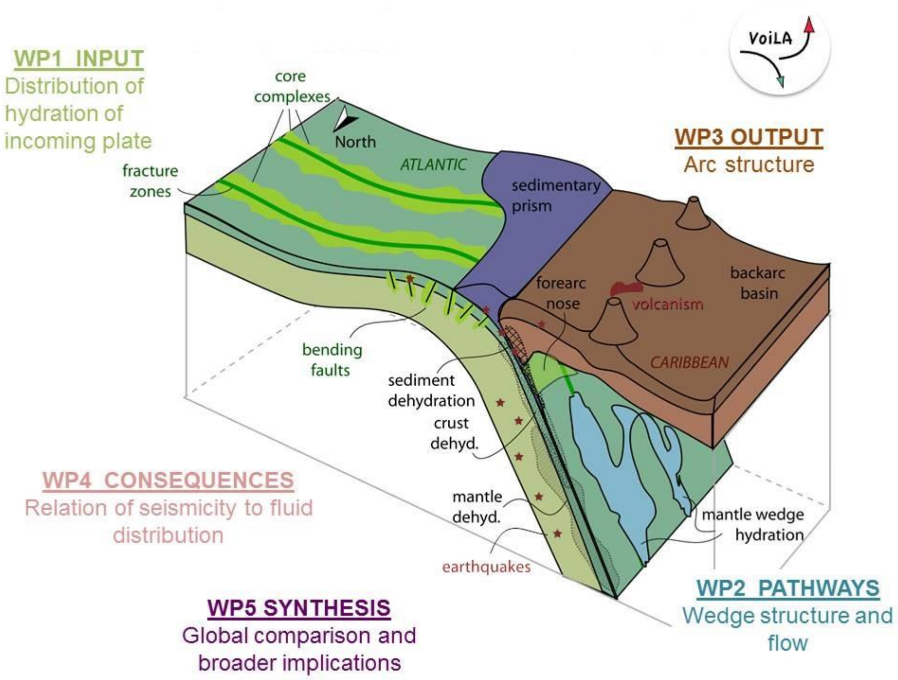
(4) the PIs have a good history of positive collaboration with scientists in the region.

We will determine the distribution of water in the downgoing plate, how slab dehydration is distributed with depth and along strike, how dehydration affects flow in the subduction mantle wedge, and what controls the characteristics of the volcanic arc.

2.1 VOILA Programme

The VOILA programme is divided into 5 work-packages; the overall objectives of each are summarised below and illustrated in Figure 2.

Figure 2 Overview of the VOILA research programme. The possible passage of water through the Lesser Antilles subduction zone from incoming plate with fracture zones, across the mantle wedge and into the arc is illustrated.



WP1. The distribution of hydration on the incoming plate, in particular the role of fracture zones and oceanic core complexes, which have been proposed to be key bearers of water in mantle serpentinite. (Leg3)

WP2. The distribution of water release below the arc (specifically the role of serpentinite dehydration) and the effect of the dehydration distribution on the style of wedge flow (Leg 1 and 2)

WP3. The along strike variations in arc structure and its relation to that of the incoming plate and mantle wedge (Leg 1)

WP4. The relation of water pathways to the distribution of seismicity, volcanism and mineralization

WP5. Compare the hydration and dehydration processes in the end member Antilles subduction zone and its effect on the arc and tectonic hazards with other subduction zones (especially those around the Pacific) to improve our overall understanding of the subduction water cycle.

2.2 Geophysical Field Programme

The geophysical fieldwork components of project VOILA can be summarised as follows:

1) 2016 JC133 Deploy 34 SIO/DEPAS BBOBS around the islands
2) 2016 Deploy temporary DEPAS seismic landstations provided by GFZ on the islands
3) 2017 JC149 Shoot into stations and recover BBOBS. Conduct an active shoot wide-angle experiment into DEPAS BBOBS/OBIF SPOBS
4) 2018 Recover temporary landstations from the islands

This field programme was designed together with collaborators from the region, and in particular the Seismic Research Centre (SRC) of the University of West Indies based in Trinidad and the IPGP Volcanic and Seismic Observatories based in Martinique and Guadeloupe.

2.3 JC149 Cruise Objectives

Cruise JC149 Leg 1 and 2 forms part of *WP2: Pathways* and *WP4: Consequences*. The 15-month passive broad-band ocean-bottom seismometer deployment recorded global teleseismic earthquakes, regional and local events for seismic tomography analysis to determine wedge structure. Regional and local earthquake recordings will contribute to the seismicity catalogue of the region. Cruise JC149 Leg3 forms part of *WP1: Input.* An active source seismic experiment was conducted on the incoming plate across the Fifteen Twenty, Marathon and Mercurious Fracture zones and across the plate bending zone. We expect the plate around the fracture zones to contain more water than between fracture zones (green shading, Figure 2). By determining the seismic velocity of the oceanic plate we will be able to determine the pattern of hydration. This hydration may also change as the plate bends on its way down into the subduction zone.

The aims of the cruise were as follows. All tasks were successfully completed.

1. Shoot over Broad-band OBS deployed in the back-arc basin and into landstations deployed on the islands.

2. Recover 34 Broad-band ocean bottom seismometers in the Lesser Antilles arc.

   These instruments recorded local and global earthquakes for the past 15 months. The data will be used to

   a) Improve the seismicity catalogue of the region (in collaboration with international partners at the University of West Indies and Seismological Observatories of Martinique and Guadaloupe).
   b) Determine the seismic structure of the mantle wedge beneath the Lesser Antilles arc.
   c) Determine the crustal structure in the back-arc basin.

3. Collect underway geophysical data (magnetics gravity, swath bathymetry and sub-bottom profiler data)

   This data will be combined with earlier surveys sourced from international databases and the published literature to

   d) aid the interpretation of the geological evolution of the back-arc, arc, fore-arc and incoming plate regions

4. Conduct an EM710 swath bathymetry survey of *Kick'em Jenny* volcano offshore Grenada

   This data will be combined with the JC133 survey and earlier MBES surveys and monitoring/sampling work from international partners at the University of West Indies to

   e) determine the history of underwater volcanic processes (constructive and collapse)
   f) contribute to hazard assessment

5. Conduct an active source seismic experiment around the flexural bulge and along strike of the incoming plate.

   This data will be used to

   g) determine the pattern of along strike hydration
   h) determine how the incoming plate hydration is affected by bending.

3 Personnel

3.1 Ship's Officers and Crew

John Leask (Captain)
Stewart MacKay (Chief Officer)
Malcolm Graves (2nd Officer)
Sean Hoxby (3rd Officer)

Robert Doyle (Chief Engineer)
Lawrie Porrelli (2nd Engineer)
Derek Hay (3rd Engineer)
Gavin Nicholson (3rd Engineer)
Chris Howard (ETO)
Paula McDougall (Purser)

Martin Harrison (Chief PO, Scientific)
Greg Lewis (Chief PO, Deck)
Dave Price (PO, Deck)

Brian Conteh (Engine Room PO)

Barry Edwards (Seaman)
Steve Day (Seaman)
Brian Burton (Seaman)
Kevin Riley (Seaman)

Darren Caines (Head Chef)
David Noble (Chef)
Peter Robinson (Steward)
Carl Piper (Steward)

Andrea Dodd (Cadet)
Jack Bush (Cadet)

3.2 Science Party

3.2.1 Leg1

Jenny Collier (IC London, PSO)
Tim Henstock (Soton)
Andreas Rietbrock (Liverpool)

Robert Allen (IC London, student)
Ben Chichester (Soton, student)
Chris Ogden (IC London, student)
Mel Grey (IC London, student)

Sian Evans (IC London, student)
Tatiana Kalinicheva (IC London, student)
Mark Maltby (NMF, IT and Sea Systems)
Jason Scott (NMF)
Andy Henson (NMF)
Andy Leadbeater (NMF)
Stephan Paterson (EEL Contractor)
James Wells (EEL Contractor)

3.2.2 Leg2

Jenny Collier (IC London, PSO)
Tim Henstock (Soton)
Andreas Rietbrock (Liverpool)
Nick Harmon (Soton)
Lidong Bie (Liverpool, post-doc)
Steve Hicks (Soton, post-doc)
Robert Allen (IC London, student)
Ben Chichester (Soton, student)
Dan Possee (Soton, student)
Mark Maltby (NMF, IT and Sea Systems)

Jason Scott (NMF, Scientific engineering)
Andy Leadbeater (NMF, Scientific engineering)
Matt Thalio (NMF, Cruise manager)
James Wells (EEL Contractor)
Anna Bird (OBIF)
Andy Clegg (OBIF)
Henning Kirk (DEPAS)
Maria Tsekhmistrentko(DEPAS)
Mark Gibaud (SIO)
Sean McPeak (SIO)

3.2.3 Leg3

Jenny Collier (IC London, PSO)
Tim Henstock (Soton)
Gabriella Castiello (Durham, post-doc)
Robert Allen (IC London, student)
Dan Possee (Soton, student)
Chen Chen (Soton, student)
Sophie Butcher (IC London, student)
Caroline Harkin (Liverpool, student)
Ben Roche (Soton, student)
Andy Moore (NMF, IT and Sea Systems)
Will Richardson (NMF, Scientific engineering)
Ian Murdoch (NMF, Scientific engineering)
Ben Poole (NMF, Scientific engineering)
Stephan Paterson (EEL Contractor)
James Wells (EEL Contractor)
Anna Bird (OBIF)
Andy Clegg (OBIF)
Ben Pitcairn (OBIF)
Martin Weeks (OBIF)
Henning Kirk (DEPAS)
Erik Labahn (KUM)

3.3 Vessel Specification

An overview of particulars of the vessel used are given below.

Name:	*RRS James Cook*
Type/Class:	Lloyds +100 A1 Ice Class C1 + LMC, UMS, DP(AM), "Research Vessel"
Nationality (Flag State):	British
Identification Number (IMO/Lloyds No.):	9338242
Owner:	Natural Environmental Research Council
Operator:	National Marine Facilities Sea Systems
Overall length (meters):	89.20 Metres
Maximum draft:	6.315 Metres
Displacement/Gross Tonnage:	Net Tonnage: 1620 Gross Tonnage: 5401
Propulsion:	Wartsila Diesel Electric
Cruising & maximum speed:	10 Knots
Call sign:	MLRM6
INMARSAT number and method and capability of communication (including emergency frequencies):	773238783 – Voice 783255430 – Fax 423501712=jame x - Telex

Table 2 *RRS James Cook* vessel specification.

4 Pre-cruise Planning

4.1 Diplomatic Clearances

The work was conducted within the Exclusive Economic Zones of the following countries. The experiment was designed to honour all known exclusion zones and protected areas. Diplomatic clearances were granted through the usual channels.

1) Bahamas - port call (gravity base-station); transit (grav,mag,MBES)
2) Anguilla - transit (grav,mag,MBES)
3) France (Guadeoupe & Martinique) - port call (gravity base-station); transit (grav,mag)
4) Saba - MCS,grav,mag,MBES
5) St Eustasius - MCS,grav,mag,MBES
6) St Kitts & Nevis - MCS,grav,mag,MBES
7) Antigua & Barbuda - MCS,grav,mag,MBES
8) UK (Monsterrat) - MCS,grav,mag,MBES
9) Dominica - MCS,grav,mag,MBES
10) St Lucia - MCS,grav,mag,MBES
11) St Vincent & Grenadines - MCS,grav,mag,MBES
12) Grenada - MCS,grav,mag,MBES

There were no requests to carry observers onboard. No work restrictions were requested apart from the clearance from France to “Limit intensity of noise emissions to 224 decibels”. For this reason no airgun or swath work was conducted in their territorial waters. Permission to work in Barbados waters required a port-call prior to undertaking any scientific work. Due to logistical reasons this was not possible and so no data were collected in their territorial waters.

4.2 Environmental Considerations

The cruise was scheduled to minimise environmental impact by avoiding the marine mammal winter breeding season (November to early April). The second scheduling consideration was to avoid the region’s hurricane season (July to October). Also no seismic activity was planned within known marine reserves. Following recommendations of the Environmental Impact Assessment a monitoring and mitigation program designed to minimize impact of the proposed activities was implemented. Although only a medium-sized array was employed (<5000 cu in), given the levels of sound emitted by airguns and sonar systems in general, a precautionary approach was nevertheless adopted. As there are no known policies for marine noise in any of the host countries where data was collected, the guidelines installed by the JNCC for UK waters were followed. Mitigation measures were:

- shooting started only during the daylight hours between dawn and dusk;
- a pre-start observation period of 60 min by a trained Marine Mammal Observer (MMO) with a 0.5 km exclusion zone for any marine animal and
- a soft-start over a period of around 30 min with a dedicated MMO maintaining a visual watch.

In practice the soft start consisted of bring in one gun at a time, starting with the smallest gun every 2 minutes. As there were 13 guns total the total length of the soft start was 26 mins duration. During surveying all observations of marine life were recorded. As an extra precaution a constant MMO was maintained during daylight hours while surveying in non-international waters (Figure 5). During a total active seismic period of 314 hours a total of 7 observations of marine mammals were recorded. These sightings are given in table 3 and plotted on a map in Figure 3. There were no recorded interactions with the seismic equipment nor reported alterations of behaviour.

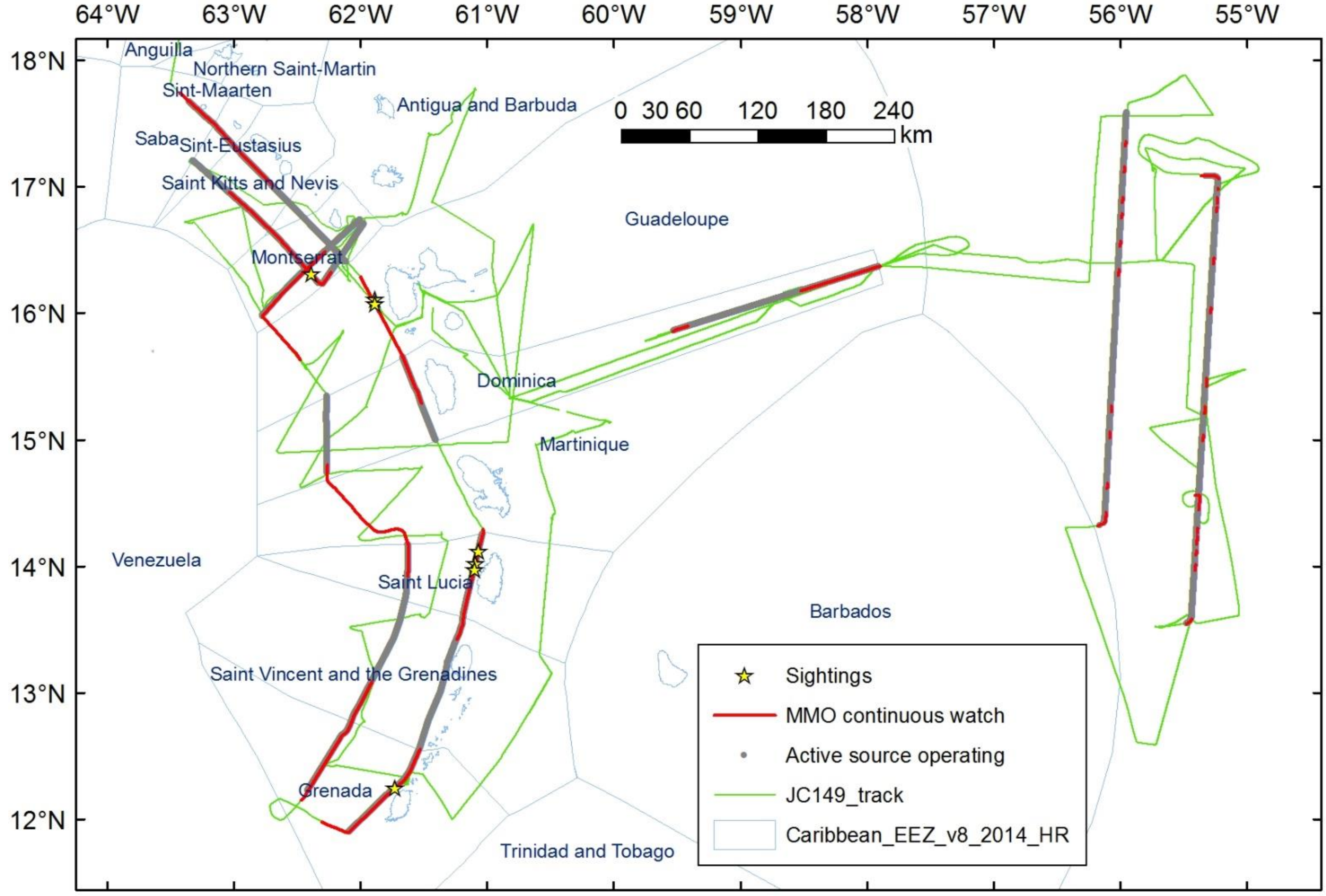


Figure 3 Map showing MMO watch keeping and mammal sightings throughout JC149. See Table 3 for details.

Date	Time (UTC)	Latitude (deg and min)	Longitude (deg and min)	Species Sighted
25-Apr	12:15	16 06.60 N	61 53.12 W	School of dolphins
25-Apr	12:30	16 04.60 N	61 53.12 W	Pod of short-finned pilot whales
26-Apr	13:20	14 07.14 N	61 03.82 W	School of common bottlenose dolphins
26-Apr	14:30	14 01.20 N	61 05.26 W	Pilot whale
26-Apr	15:10	13 58.51 N	61 05.91 W	Pilot whale
27-Apr	13:40	12 14.95 N	61 43.44 W	School of dolphins
01-May	12:44	16 18.58 N	62 23.25 W	Green Ridley turtle

Table 3 JC149 MMO sightings. Note that there were no sightings during the Leg 1 seismic trials or Leg 3. The locations are plotted on the map shown in Figure 3.

5 Cruise Narrative

5.1 Mobilisation (10-16 April, JD100-106) All times are local (=UTC-4 hrs)

The JC145 *RAPID* experiment/JC149 *VOILA* experiment change-over was managed in Freeport (BSFPO) by Jon Short from NMF. The previous cruise was successfully demobilised by midday on Saturday 9 April. The OBIF OBS instruments were sent from the UK to Freeport, Bahamas in 2x20' containers. These were loaded onto the vessel without incident. The major part of the mobilisation involved unpacking the NMF seismic equipment from the 4x20' containers and starting to build the system on the ship. All went well and according to plan despite the rough condition of the quayside. A diagram of the arrangement of the geophysical equipment on the back deck is shown in Figure 4. Once the seismic streamer winch had been built the 3000 m, 20-section (240 channel) Sercel Sentinel - solid hydrophone streamer was successfully wound onto it. This was followed by the installation of the cherry pickers and air-supply umbilical winches. Finally,the building of the airgun beams started and the commissioning of the gun controller (Big Shot) and seismic recording (Seal 428) system in the main lab. The OBIF container was opened and a GPS clock was setup in the Deck Lab to enable accurate timing of all the airgun shots. All work was completed to schedule with the ship ready for sailing on Monday 17 April as planned.

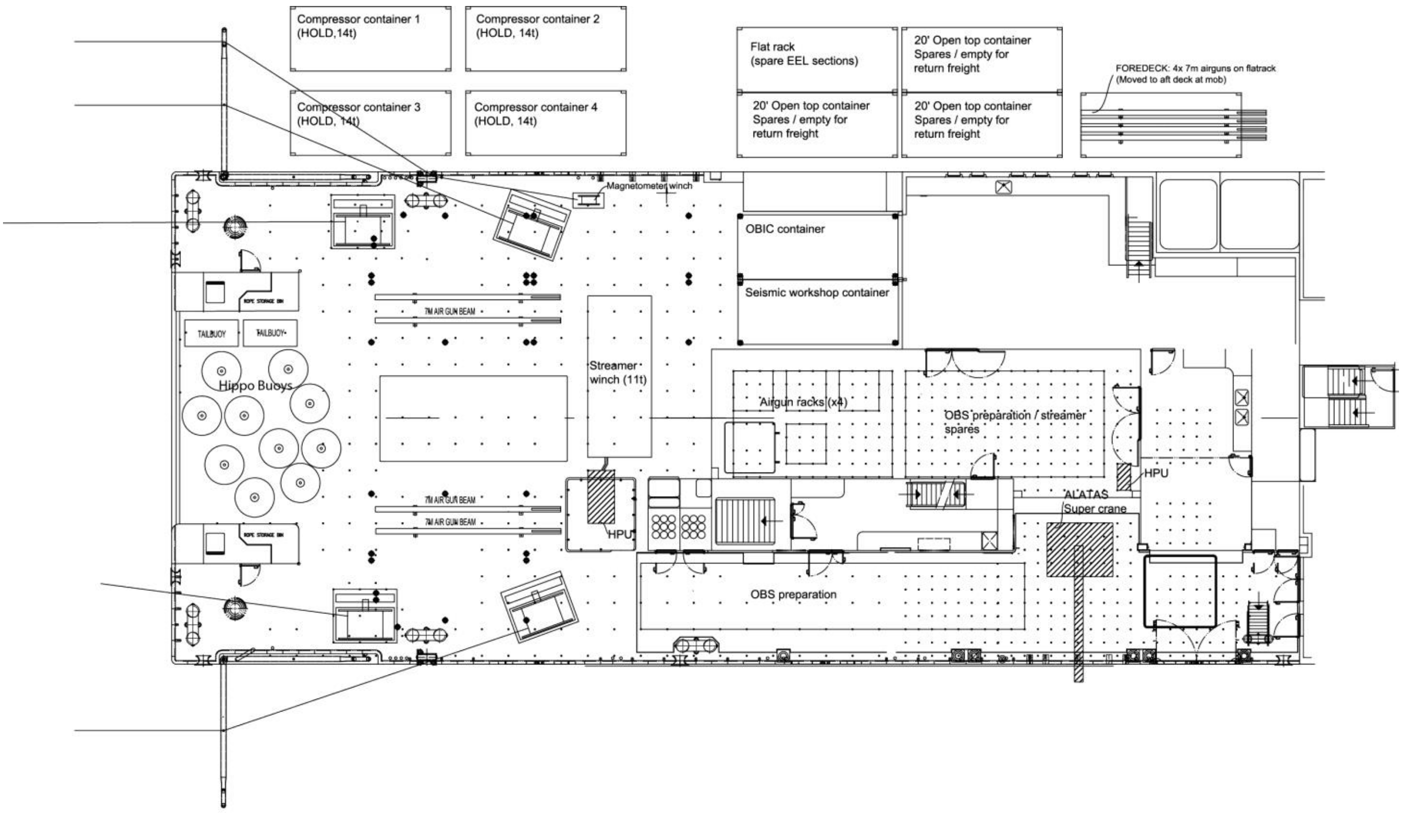


Figure 4 ***RRS James Cook*** **Upper back deck plan for JC149.**

5.2 Science Work At Sea. All times are local

5.2.1 Leg 1 (17 April-3 May, JD107-123)

5.2.1.1 Transit and seismic trials

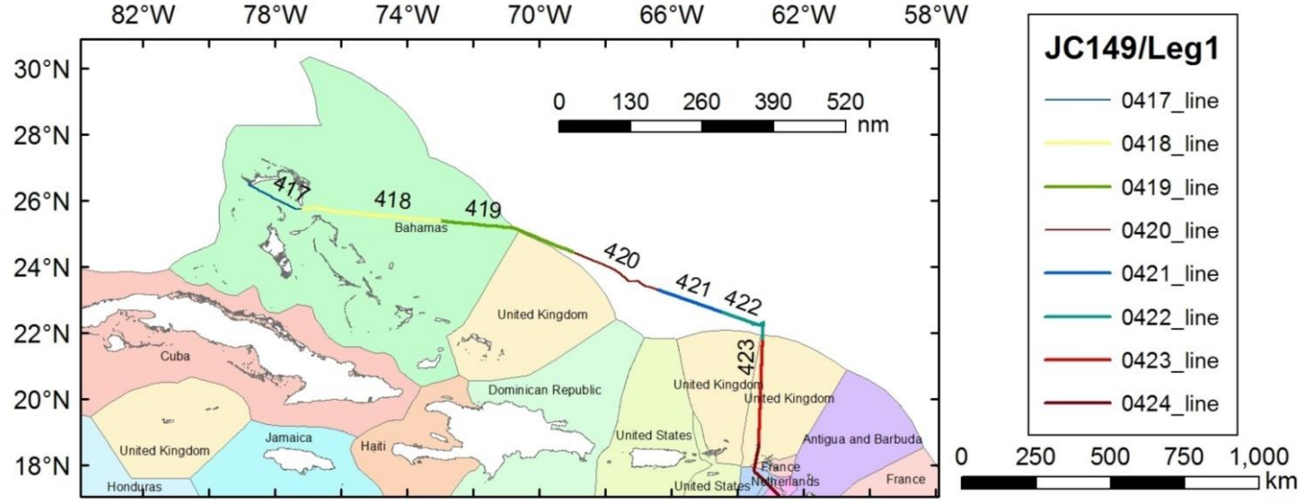


Figure 5 Map showing Leg 1 seismic trials ship tracks by day (written as monthday) together with EEZ boundaries.

Mon 17/4 JD 107

The ship left Freeport at 09:20, with the MBES systems started around 40 minutes later. Scientific watches started at 12:00. Sea conditions were calm and good progress through Bahaman waters was made. A Muster Drill was held at 16:15, after which Marine Mammal Observations started to familiarise the team.

Tue 18/4 JD 108

During the morning it was noticed that the Seapath GPS navigation had lost both its heading (from Receiver 2) and position (from Receiver 1). As a result the primary navigation was changed to the Applanix POS MV 320.

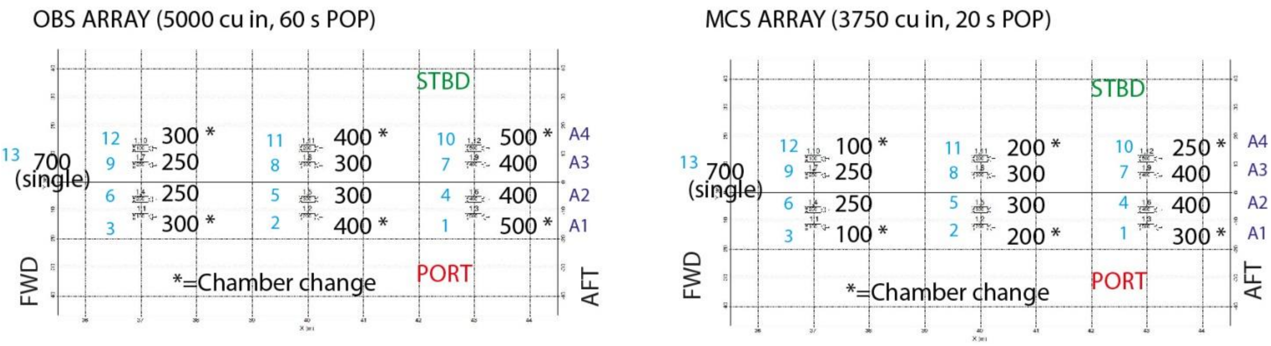


Figure 6 Airgun array specifications, showing chamber volumes and element numbers (1-13). The individual guns marked with a * required changing when swapping between the two arrays. During Leg 1 a 500 cu in rather than a 700 cu in chamber was used for the single (element 13) making the total volume 4800 cu in.

During the day the science party continued to set up the computers and software. The NMF team were mainly concerned with the ongoing construction of the Bolt airgun array components on the back deck. For JC149 it was planned to use two airgun arrays, the details of which are shown in Figure 6. The arrays were designed to maximise power and resolution (frequency content) within the operational constraints (number of guns, expected failure rates for large guns, compressor power and shot interval). The guns are towed from 4 metal beams together with a freely hung single from a midships wire. For Leg 1 the "OBS array" was used throughout.

Wed 19/4 Day 109

At 09:00 the first deployment of the SeaSpy2 magnetometer was made from the port side of the Upper Deck. As this was a brand new instrument careful measuring out and marking of the cable was done. Green electrical tape was applied at intervals from the winch to the boom eyelet (a cable distance of 15.2 m). In full deployment this left 10m of cable on the drum winch. See Figure 7 for details. The total offset from the magnetometer sensor to the ship's central reference point was estimated to be 304 m astern.

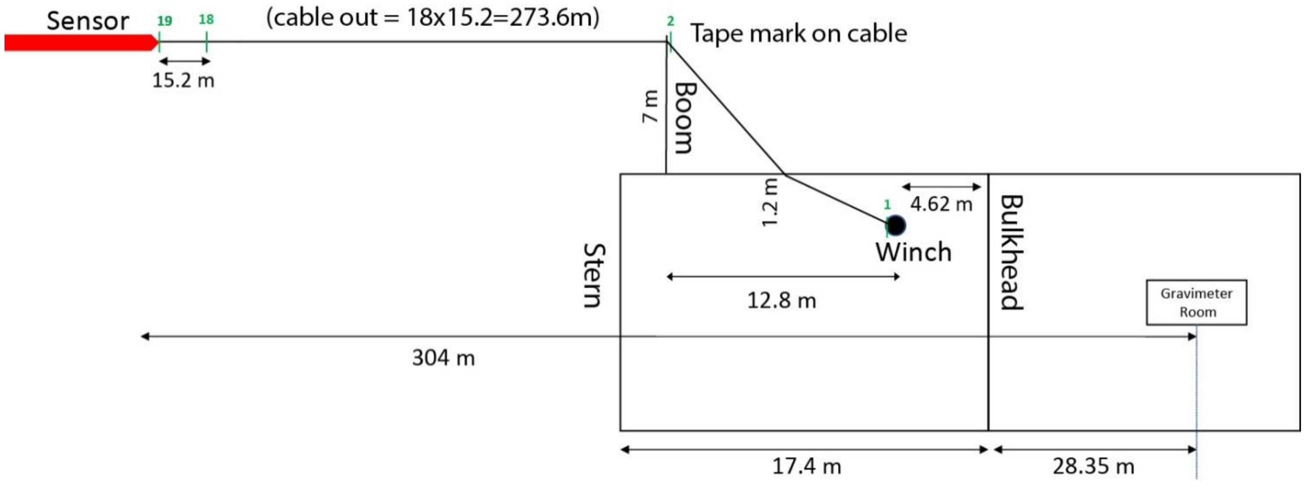


Figure 7 Magnetometer configuration relative to the ship's central reference point (the Applanix POSMV MRU situated in the gravity room). See also the deck plan shown in Figure 4.

The magnetometer system performed well until it was recovered around 19:00. The ship arrived in international waters around 10:00. At 10:30 pressure testing of the guns on the back deck started.

Thu 20/4 Day 110

At 06:20 we started to deploy the 3 km streamer. Whilst there were some initial problems with bird communications, these were readily resolved. By 09:40 the streamer and 21 birds was fully deployed and starting to dive. By 10:00 it was concluded that the streamer was correctly weighted and was towing evenly at the required 8 m depth. However, the tailbuoy was not communicating. The streamer was therefore recovered and it was discovered that there had been a human error in connecting the tailbuoy (due to confusion whilst threading the streamer through the "caterpillar" block hung from the A-frame). By 13:30 the tailbuoy

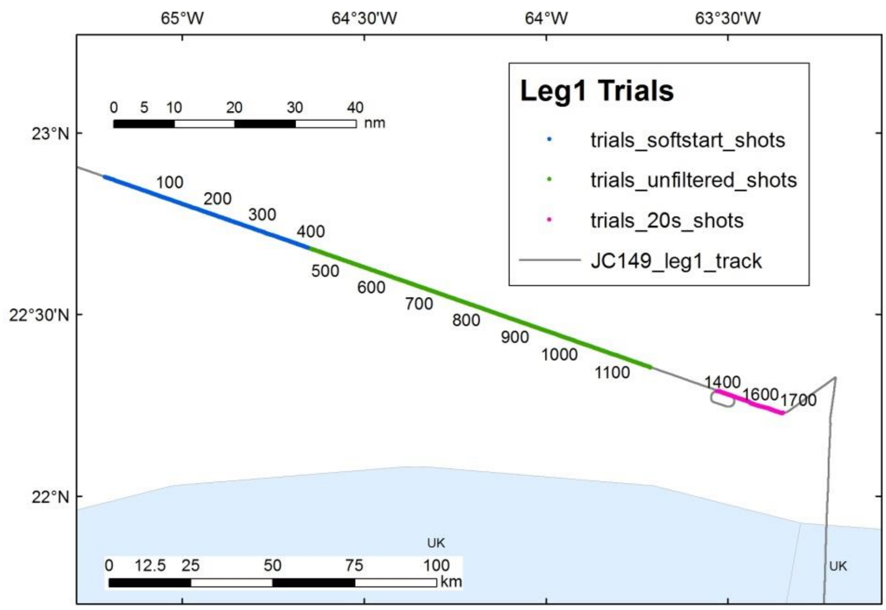


Figure 8 Map showing Leg 1 seismic trials profiles. The numbered dots refer to FFID #. All are within International waters.

connection was secured and the redeployment of the 3 km streamer started. This was completed by 16:30 by which time all three of the NMF technicians were out of working hours and so it was not possible to deploy the airguns. The streamer was therefore left out and towed at 5 knots overnight.

Fri 21/4 Day 111

At 06:10 we started to deploy the starboard side airgun beams. Both were in the water by 07:20 with two hippo buoys per beam – one tied to the front and one to the back, all with 8 m long ropes. As the system was pressurised one of the compressors tripped which resulted in one gun flooding on the outer beam. The beam was therefore recovered, the gun drained and redeployed by 10:40. The starboard side beams were then deployed with just 1 hippo buoy per beam at the back in to conduct a tow test with the new depth sensors installed on the four 7m beams. Marine mammal watching started at 10:56 with the soft start commencing at 11:50 (profile Trials-1). First of all individual gun tests were made (twice) before the full array was brought in with a 60s POP. The full array was then left firing overnight. The data were recorded under two headers ("Softstart" and "Unfiltered", Figure 8, Table 4).

Line name	Shoot direction	#shots	Duration (hours)	FFID	yr	jd	hr	min	sec	Lat (dec deg)	Lon (dec deg)	Airgun volume (cu in)	Guns lost	Pop (s)	Streamer (m)
Trials-1 ("Softstart")	E->W	427	7.1	1	2017	111	14	56	48.53	22.88	-65.21	4800	n/a	60	3000
				428	2017	111	22	4	21.00	22.68	-64.65				
Trials-1 ("Unfiltered")	E->W	707	11.8	429	2017	111	22	5	21.08	22.68	-64.65	4800	n/a	60	3000
				1136	2017	112	9	53	14.77	22.35	-63.71				
Trials-2 ("20s")	E->W	632	2.2	1	2017	112	14	40	42.73	22.29	-63.53	4300	n/a	20/40	300
				633	2017	112	16	54	16.20	22.23	-63.35				
Arc_north - Line 1	N->S	1283	21.4	1	2017	114	11	5	34.52	17.67	-63.35	4800	n/a	60	300
				1284	2017	115	8	30	11.99	16.40	-62.11				
Arc_centre - Line 2	N->S	510	8.5	1	2017	115	18	17	14.27	15.65	-61.66	4800	n/a	60	300
				511	2017	116	2	48	57.09	15.00	-61.40				
Arc_south - Line 3	N->S	1885	31.5	1	2017	116	12	6	42.57	14.26	-61.03	4800	n/a	60	300
				1886	2017	117	19	34	5.86	11.90	-62.09				
Back_arc_south - Line 4	S->N	1608	25.7	1	2017	118	10	37	33.76	12.23	-62.41	4800/4300/3900/3400	10 (500),2 (400),1 (500)	60	3000
				1609	2017	119	12	18	30.77	14.17	-61.62				
Back_arc_centre - Line 5	S->N	442	7.4	37	2017	119	22	8	45.93	14.74	-62.26	4400	2 (400)	60	3000
				479	2017	120	5	31	19.51	15.34	-62.26				
Montserrat-cross - Line 6	E->W	727	12.1	56	2017	120	14	58	34.78	15.98	-62.77	4800	n/a	60	300
				783	2017	121	3	6	29.98	16.74	-62.00				
Montserrat-cross - Line 7	W->E	441	7.4	829	2017	121	3	53	24.53	16.71	-61.97	4800/4300	10 (500)	60	300
				1270	2017	121	11	14	58.00	16.23	-62.30				
Back_arc_north - Line 8	S->N	937	15.7	21	2017	121	11	38	59.82	16.24	-62.32	3800	10(500),13(500)	60	300
				958	2017	122	3	17	11.02	17.21	-63.32				
	TOTAL	**9599**	**150.8**												

Table 4 Leg 1 seismic line summary. The record length was 19 s and sample rate 2 ms on all lines. The locations of the lines can be seen in Figure 8. Further details about the gun failures are provided in Table 5.

Sat 22/4 Day 112

The airgun saturation test was completed at 05:50 when the array was stopped and recovery started. First the single airgun was recovered, followed by the 3 km streamer. At 07:45 the streamer was clamped off and a 100 m stretch section inserted, converting it to a 300 m (24 channel) streamer (with 3 birds to control depth). Firing (4 x beams, no single) at a 20 s POP started again at 09:00. Unfortunately, this resulted in a compressor failure (electricity tripped) and another compressor reducing to half power (Table 5). Firing was therefore reduced to 40 s interval (profile Trials-2, recorded under header "20s"). During this period the Captain made a 360 degree turn to check the vessel manoeuvrability whilst towing the airgun array and 300 m streamer. Good physical clearance between the streamer and inner airgun beams was maintained at 10 degree/minute.

Firing stopped at 13:00, and by 15:00 all the seismic gear was recovered. Based on the recorded bird depths some extra weight was added to the front of the short streamer. At 15:30 the ship speed was increased to 10 knots to start the transit to scientific work area.

Sun 23/4 Day 113

Throughout the day the transit to the science work area continued. During this time the NMF team set about making the necessary repairs to the 4th compressor. The NMF technicians at this point removed the new compressor pressure sensors (5 sensors in total – one on each compressor and one on the main (joined) supply. The science party then installed the manufacturers software on a PC in the computer room but unfortunately it was discovered that the sensors had not been set to "run" and so no data during the trials had been logged.

5.2.1.2 Scientific work

Mon 24/4 Day 114

At 04:00 the seismic equipment deployment started – consisting of the full "OBS ARRAY" airgun array, 300 m streamer and magnetometer. The short streamer was taken in and out twice to add more weight (to get the front end down at the required 8m). At 07:05 the soft start began, just north of start-of-line 1 (south of the island of Saba). This marked the start of the scientific work programme with the collection of Line 1 (Table 4 and Figure 10). The sea-state was 2/3. At 10:00 a small deviation at WP 2 was made to avoid shallow water and oil tanker refuelling hold point

Tue 25/4 Day 115

Shooting was stopped as we entered French waters. All equipment was left in the water. The sea-state had calmed to just 1/2. At 08:00 while offshore Guadeloupe 6 Pilot Whales and small shoal of Dolphins observed (Table 3, Figure 3). MCS Line 2 was shot as we crossed Dominican waters.

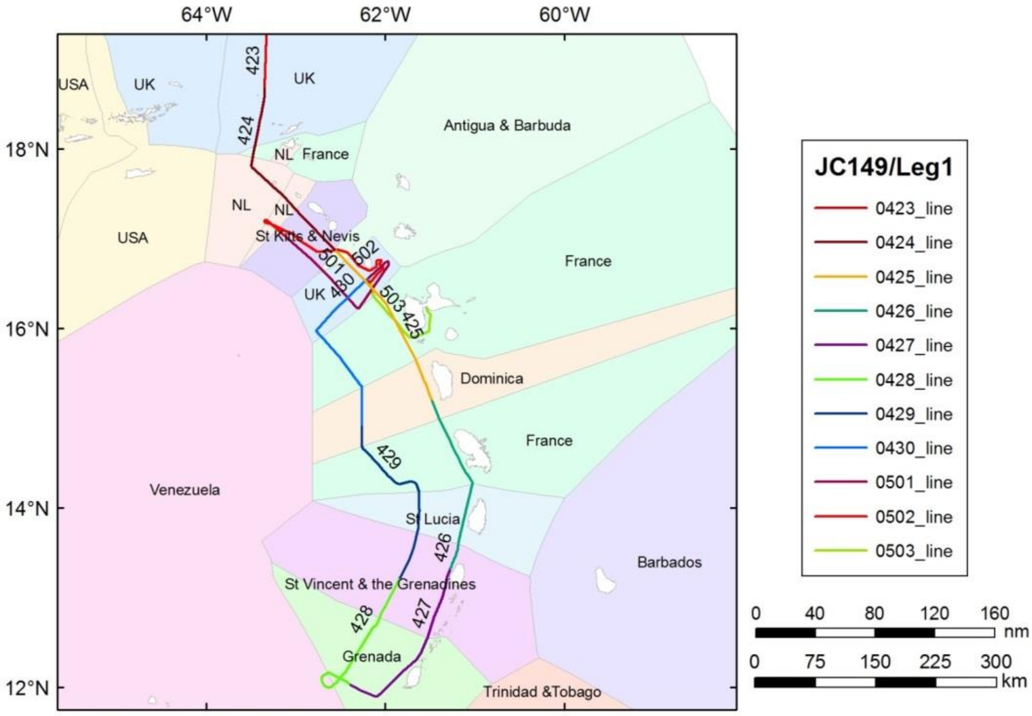


Figure 9 Map showing Leg 1 ship tracks by day (written as monthday) together with EEZ boundaries.

Line#	Gun#	Volume (cu in)	JD	Time (UTC)	FFID	Cause of failure	Comments
Trials-2	-	-	112	14:00	121	Compressor	Firing interval changes from 20 s to 40 s
Line 4	10	500	119	04:39	1150	Air supply	New design supply valve sheared off
	2	400	119	08:56	1406	Air supply	New design supply valve sheared off
	1	500	119	11:36	1567	Air supply	New design supply valve sheared off
Line 5	2	400	119	22:20	112	Trigger	Human error in assembly
Line 7	10	500	121	08:33	379	Trigger	Solenoid sheared off at beam end - mechanical damage
Line 8	13	500	121	11:39	100	Air supply	Hole in supply hose - mechanical damage

Table 5 Leg 1 seismic equipment failures.

Wed 26/4 Day 116

At 08:00 the soft start for MCS Line 3 commenced. The line was shot without incident apart from some minor course alterations due to the sightings of some possible fishing buoys off the island of St Vincent.

Thu 27/4 Day 117

The shooting of MCS Line 3 continued until 15:30. At 17:00 the port gun array was recovered (the starboard array was left in the water). At 18:00 the short streamer was also recovered. At 18:10 the first XBT-T5 (which was good to a water depth of 1000m) was collected (Table 6; Figure 25). At 20:00 the full 3 km streamer was deployed and dived to 8 m.

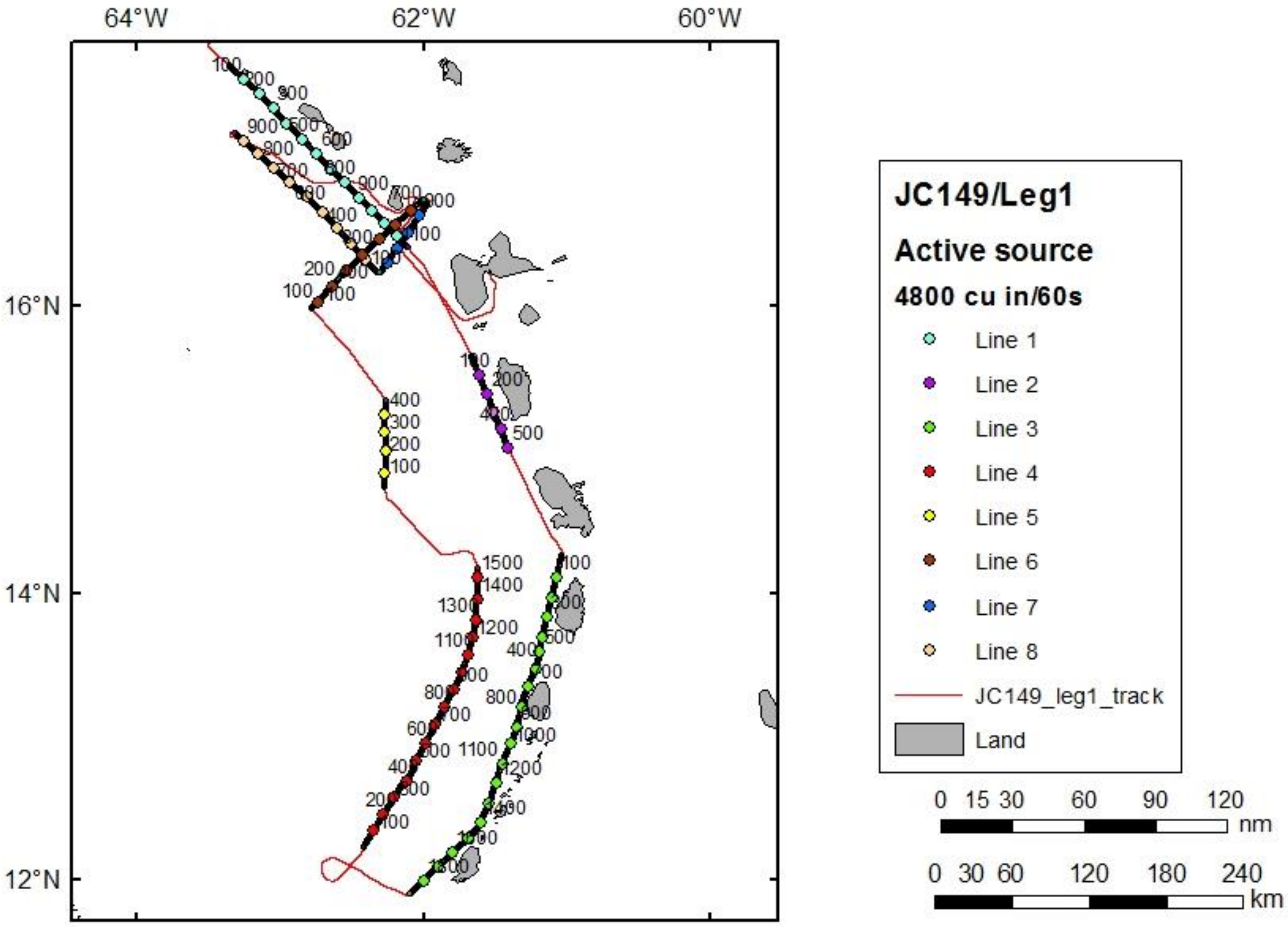


Figure 10 Map showing Leg 1 multi-channel seismic profiles. The numbered dots refer to FFID #.

Fri 28/4 Day 118

At 06:35 the soft start for MCS Line 4 commenced. Winds continued as easterlies 4/5 knots. Around 12:00 we altered course to avoid a fishing vessel. Whilst it was feared there may been a snag of a fishing line, no evidence of this was seen later when the towed equipment was recovered. The rest of the day continued without incident.

Sat 28/4 Day 119

Around midnight, Gun 10 (500 cu in; Starboard outer) failed. At 04:00 Gun 2 (400 cu in; Port outer) also failed. By 06:30 Gun 1 (500 cu in; Port outer) started to loose pressure and was switched off at 07:30, prior to the line ending at approximately 08:00.

The outer gun beams were then recovered. All three guns had failed due to a break in the supply of air caused by the shear of the bolt between the large hose and the small hose going into each gun solenoid. As this was a new design, and all had mechanically failure around the same time (after ~6400 shots), it was concluded that future failures could be prevented by replacing the bolts as part of routine maintenance of the airgun system after similar periods of use. By 11:00 the repairs were finished and the transit to the next waypoint started. During this transit the pressure gauges on the recovered outer beams were removed and their data downloaded.

At 12:30 the two outer airgun beams were re-deployed together with the magnetometer. A soft start commenced at 18:00 for the start of MCS line 5. Unfortunately Gun 2 failed to seal, but due to the lack of daylight to resume a MMO pre-shooting watch the line was shot without it.

Sun 30/4 Day 120

At 04:00 the line ended and the 3 km streamer was recovered and reconfigured for 300 m. At 07:00 the Port outer beam was recovered to investigate the Gun 2 failure. It was discovered that it was due to Human error. This was corrected and beam redeployed. By 10:30 we had exited French waters and the soft start for MCS Line 6 started. The line was shot without incident until around 23:00.

Mon 1/5 Day 121

The vessel continued shooting during the night (Line 7 which forms a back loop to the originally planned back-arc north profile). At 04:00, approximately in the middle of the line, we lost Gun 10 (500 cu in). At the start of Line 8 around 08:30 we also lost the single Gun 13 (500 cu in). At 23:00 we reached the end of the line which marked the end of the survey.

Tue 2/5 Day 122

The recovery of the seismic equipment started at 08:00. By 11:00 everything was back on board. The transit into port commenced.

5.2.2 Port call 1

Wed 3/5 Day 123

The Pilot boarded the vessel at 07:00 and proceeded to guide us into the “Cruise terminal” at Pointe a Pitre (GPPTP).

In the afternoon members of the science party met up with colleagues from the l’Université des Antilles et de la Guyane, who accompanied them to the gravity basestation at Universite Laboratoire de Biologie Marine in Pointe-a-Pitre to carry out a tie (Table 10)

Thu 4/5 Day 124

Around 09:00 the OBS teams from the US, Germany and UK joined the vessel. At 10:00 the DEPAS container was unpacked and the contents (12 pallets of anchors and battery packs) loaded onto the ship. In an effort to maximise deck space for OBS recoveries all possible MCS spares were packed away into the top container. The 10 Hippo Buoys were also moved from the back to the front of the ship. During the rest of the day the OBS teams set up their recovery equipment and erected their antennas etc.

The onboard gravity meter was reset to see if it solved some irregular reading patterns seen during Leg 1 and a second basestation tie at the l'Université des Antilles et de la Guyane site was made.

5.2.3 Leg 2 (5 May-15 May, JD125-135)

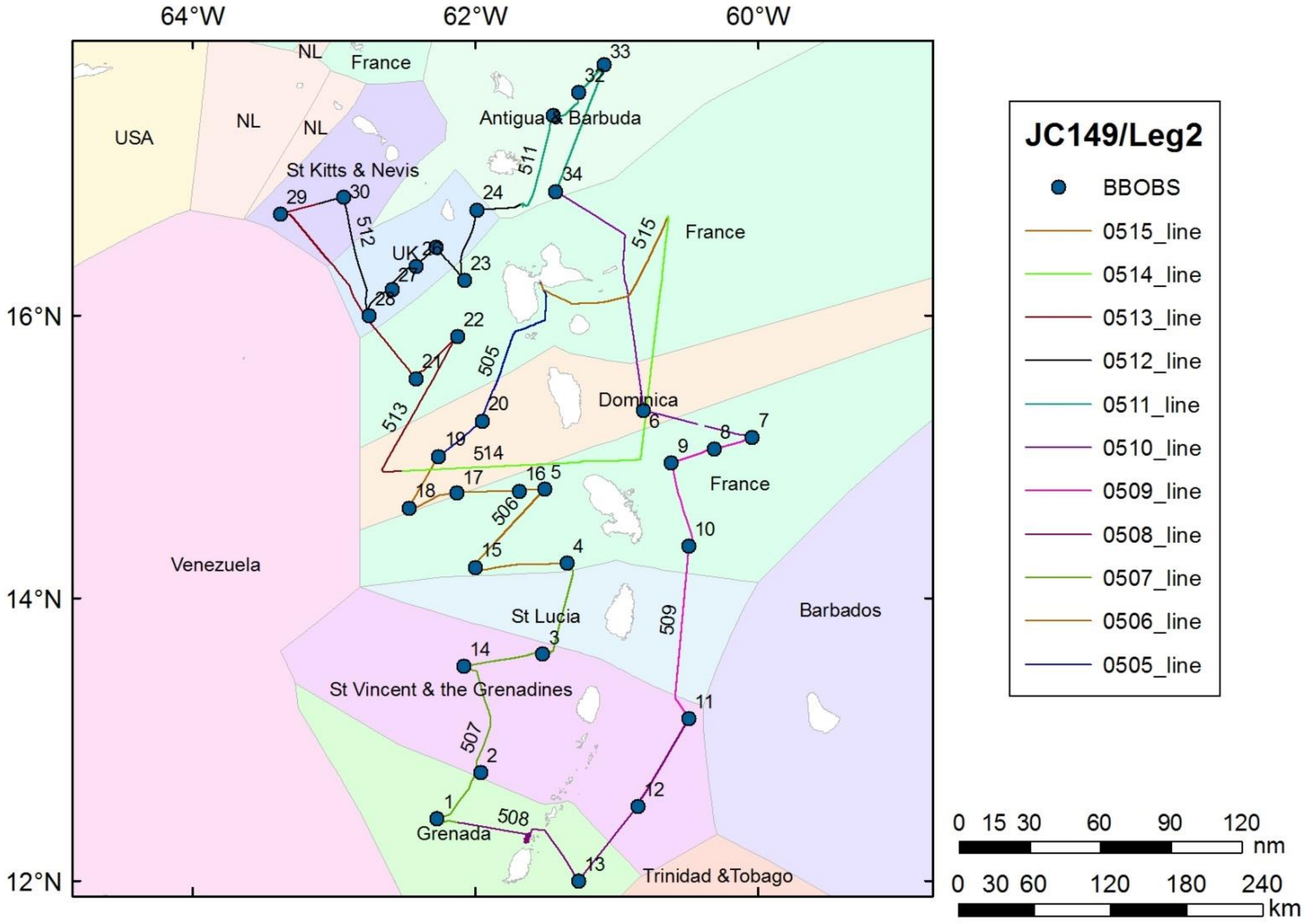


Figure 11 Map showing Leg 2 ship tracks by day (written as monthday) together with EEZ boundaries. The numbered circles are the BBOBS stations. Also see Table 6.

Fri 5/5 Day 125

The ship left port at around 09:00. At 10:00 the new members of the Science Party underwent a safety induction (Muster station and lifeboats). This was followed at 11:00 by a meeting with the crew to review BBOBS recovery protocols. At 14:00 the first OBS, SIO 20, was released and was physically onboard by 17:00. The ship then travelled to DEPAS 19 and 18, both of which were successfully onboard by midnight. During these recoveries the rise times were set to be 1.1 m/s for the DEPAS instruments and 0.67 m/s for the SIO instruments. Given the range of water depths between 807 and 5048 m this corresponds to a range of rise times between 12 and 126 minutes

Sat 6/5 Day 126

Overnight and morning a successful string of BBOBS recoveries were made, totalling 5 DEPAS instruments. The sea-state was calm at 1/2.

After SIO15 recovery at 15:00 it was hoped to do a SVP. However, while threading the wire through the P-frame a serious oil leak on the starboard gantry was discovered (the one being used for OBS recoveries). This was a known problem with a distribution block, but was significantly worse than previously thought. Inspections concluded the gantry was no longer safe to use – due to the potential of catastrophic failure of the block and release of large volumes of pressurised oil. To repair the problem a new part was needed – this had already been on order from Rolls Royce for past 3 months.

Due to this discovery the planned SVP was abandoned (also due to the risk of not being able to bring in the SVP when out). An XBT was done at station 15 at 15:15 instead. Discussions were had about using the yellow "super crane" for recoveries – which was thought relatively straight forward for the DEPAS design, not so simple for SIO due to the height of their instruments.

At 21:00 DEPAS 4 was recovered with the yellow super crane. This was not considered satisfactory as there was too much swinging with the instrument hitting the side of vessel too often. The angle of lift over the balustrade also needed adjustment

Leg 2 BBOBS Recoveries												
Station		Date		Time (UTC)			Hooked position				Water	Total Clock
				On			Latitude		Longitude		depth	drift
ID	Pool	dd/mm/yr	JD	surface	Hooked	On deck	(dd°mmm)	(dd.dddd °)	(dd°mmm)	(dd.dddd °)	(m)	(s)
20	SIO	05/05/2017	125	20:40:00	21:09:00	21:11:30	15 15.287 N	15.2548	61 57.520 W	-61.9587	2566	0.559133
19	DEPAS	06/05/2017	126	00:06:00	00:15:00	00:19:00	15 0.273 N	15.0046	62 15.634 W	-62.2606	2754	1.419906
18	DEPAS	06/05/2017	126	03:31:00	04:01:40	04:03:58	14 37.610 N	14.6268	62 28.379 W	-62.4730	2842	1.407093
17	DEPAS	06/05/2017	126	07:04:00	07:14:40	07:16:50	14 44.931 N	14.7488	62 7.793 W	-62.1299	2858	1.885000
16	DEPAS	06/05/2017	126	10:37:00	10:59:00	11:00:30	14 46.080 N	14.7680	61 41.306 W	-61.6884	2752	2.117375
5	DEPAS	06/05/2017	126	12:48:41	13:00:52	13:02:18	14 47.011 N	14.7835	61 30.742 W	-61.5124	2707	11.901406
15	SIO	06/05/2017	126	19:05:00	19:16:37	19:18:36	14 12.652 N	14.2109	62 0.285 W	-62.0047	2941	1.442257
4	DEPAS	07/05/2017	127	00:52:30	01:08:48	01:10:38	14 15.635 N	14.2606	61 21.255 W	-61.3542	2887	2.315281
3	DEPAS	07/05/2017	127	07:20:10	07:36:02	07:42:56	13 36.904 N	13.6151	61 31.378 W	-61.5230	2871	1.323875
14	DEPAS	07/05/2017	127	11:21:00	12:16:00	12:18:13	13 30.643 N	13.5107	62 4.647 W	-62.0775	2947	1.229156
2	SIO	07/05/2017	127	18:34:33	18:40:21	18:44:20	12 46.275 N	12.7712	61 57.692 W	-61.9615	2973	-0.583257
1	DEPAS	07/05/2017	127	22:30:45	22:53:30	22:57:25	12 25.921 N	12.4320	62 16.119 W	-62.2687	2948	3.057343
13	SIO	07/05/2017	127	13:22:11	13:41:11	13:45:06	11 59.874 N	11.9979	61 16.569 W	-61.2761	1323	-0.010879
12	DEPAS	08/05/2017	128	18:25:24	18:33:00	18:42:00	12 31.974 N	12.5329	60 51.176 W	-60.8529	1931	1.962781
11	SIO	09/05/2017	129	00:19:07	00:49:50	00:53:19	13 10.238 N	13.1706	60 30.262 W	-60.5044	2315	-0.049830
10	DEPAS	09/05/2017	129	08:57:00	09:40:00	09:47:00	14 24.195 N	14.4033	60 28.969 W	-60.4828	2039	2.015062
9	DEPAS	09/05/2017	129	14:05:58	n/r	14:30:33	14 57.409 N	14.9568	60 36.610 W	-60.6102	1405	1.049031
8	DEPAS	09/05/2017	129	17:34:22	17:47:26	17:51:06	15 3.156 N	15.0526	60 18.274 W	-60.3046	3107	2.521875
7	SIO	09/05/2017	129	21:22:00	21:43:30	21:47:20	15 8.300 N	15.1383	60 1.045 W	-60.0174	4680	-1.253154
6	DEPAS	10/05/2017	130	10:20:00	10:50:00	10:56:00	15 19.382 N	15.3230	60 48.408 W	-60.8068	1530	1.679218
34	DEPAS	10/05/2017	130	22:49:53	23:19:30	23:24:30	16 52.483 N	16.8747	61 25.909 W	-61.4318	1113	0.932250
33	SIO	11/05/2017	131	07:13:00	07:33:00	07:36:00	17 45.936 N	17.7656	61 5.266 W	-61.0878	5049	-1.053262
32	DEPAS	11/05/2017	131	14:17:59	14:48:34	14:52:28	17 34.254 N	17.5709	61 16.028 W	-61.2671	4015	3.212037
31	DEPAS	11/05/2017	131	17:39:47	17:46:14	17:48:30	17 25.143 N	17.4191	61 27.132 W	-61.4522	3822	2.262468
24	DEPAS	12/05/2017	132	02:13:14	02:40:12	02:43:46	16 44.910 N	16.7485	61 59.189 W	-61.9865	807	2.181031
23	SIO	12/05/2017	132	06:30:30	06:42:00	06:46:00	16 15.080 N	16.2513	62 4.570 W	-62.0762	1396	-1.327000
25	DEPAS	12/05/2017	132	09:08:07	09:33:00	09:38:00	16 29.338 N	16.4890	62 16.853 W	-62.2809	1108	2.482906
26	SIO	12/05/2017	132	11:22:00	11:49:00	11:52:00	16 21.513 N	16.3586	62 25.651 W	-62.4275	1071	0.477942
27	DEPAS	12/05/2017	132	13:59:30	14:10:41	14:15:49	16 11.073 N	16.1845	62 35.573 W	-62.5929	1831	2.535437
28	DEPAS	12/05/2017	132	16:23:17	16:34:11	16:36:30	16 0.133 N	16.0022	62 45.267 W	-62.7544	1799	1.659812
30	DEPAS	12/05/2017	132	22:26:00	22:44:50	22:47:20	16 50.236 N	16.8373	62 55.859 W	-62.9310	1196	5.340718
29	SIO	13/05/2017	133	02:07:30	02:32:16	02:35:06	16 43.106 N	16.7184	63 22.817 W	-63.3803	1389	n/a
21	DEPAS	13/05/2017	133	12:44:32	13:00:00	13:07:38	15 33.231 N	15.5538	62 25.409 W	-62.4235	2031	5.742812
22	DEPAS	13/05/2017	133	16:20:37	16:24:14	16:27:52	15 51.243 N	15.8541	62 7.816 W	-62.1303	1793	1.135187

Table 6 Leg 2 BBOBS recoveries

Sun 7/5 Day 127

The cruise proceeded with OBS recoveries, with a total of 5 (3 DEPAS and 2 SIO) being made during the day. The recovery method with the yellow super-crane slowly improved and at 13:00 the first SIO recovery since failure of the starboard gantry was successfully made.

At 23:00 we started the EM710 MBES survey of the Kick 'em Jenny volcano.

Mon 8/5 Day 128

The MBES survey continued and at 03:30 an XBT was released in the crater. For the final part of the survey the sonar head SVP recording was lost (presumably due to seaweed). It was hoped that this could be corrected during processing. At 05:00 the KeJ survey ended and the vessel transited to station 13 for the next BBOBS recovery, which was onboard around 21:00. On the eastern side of the arc the sea-state was significantly rougher, but fortunately the recovery methods had now been sufficiently tuned for this not to be a problem.

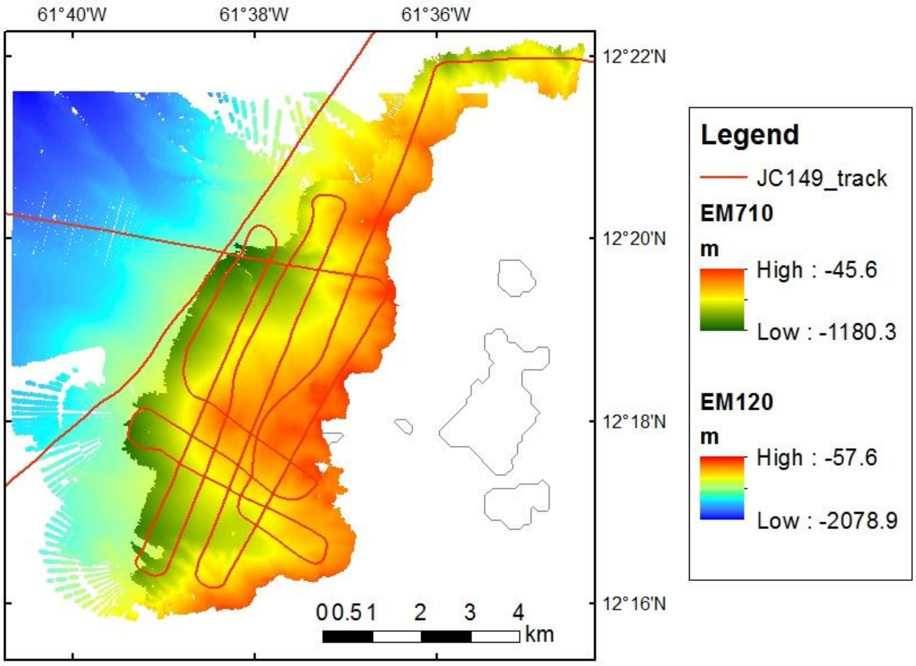


Figure 12 Map showing ship tracks used for the EM710 Kick'em Jenny swath survey

Tue 9/5 Day 129

Overnight and during the day five more BBOBS recoveries, 3 DEPAS and 2 SIO (Stations 11-7), were completed without incident. At 18:00 we started the OBIF releaser tests (after SIO recovery BBOBS7). This was done off the A-frame as the Starboard Gantry was out-of-action. Unfortunately there were some initial problems getting enough weight onto the wire, and what was expected to be a 1 hour per dip + 1 hour spare – overran by 2 hours.

Wed 10/5 Day 130

At 06:30 during recovery of DEPAS 6, the radio antenna and light broke off (presumably it hit the side of the vessel as it was being lifted out of the water) leaving rough, stubby ends. This was noticed as the instrument was lifted over the balustrade, but as instrument was being lowered onto the deck it swung around quickly and Maria was cut (about 2 cm long, quite deep, side of right knee). The cut was treated by the ship's Medical Officer and needed 2 stitches.

By 07:10 the magnetometer was deployed and the ship was underway to the next OBS site (station34). This instrument was safely onboard by 20:30. Around 11:10 the computer network router failed, and so there was no ship's data logged for a period of about 20 minutes (07:10:53.329-07:30:55.338).

Thu 11/5 Day 131

At 02:25 SIO 33 was recovered which was followed at 04:40 by a DEPAS full water-column acoustic releaser test from the A-frame. A SVP was taken at the same time. Later two further DEPAS BBOBS (Stations 32 and 31) were recovered and the transit back across the arc started. Around 17:00, when the vessel was south of the island of Antigua the weather deteriorated with thunder and lightning and winds reaching force 8. Luckily as the vessel was in transit this did not affect the work programme significantly. While crossing the shallow water the opportunity to make an EM710 Patch Test was taken at 18:00. This work finished at 20:00 and the next OBS recovery in the back-arc (station 24) was completed by 23:00.

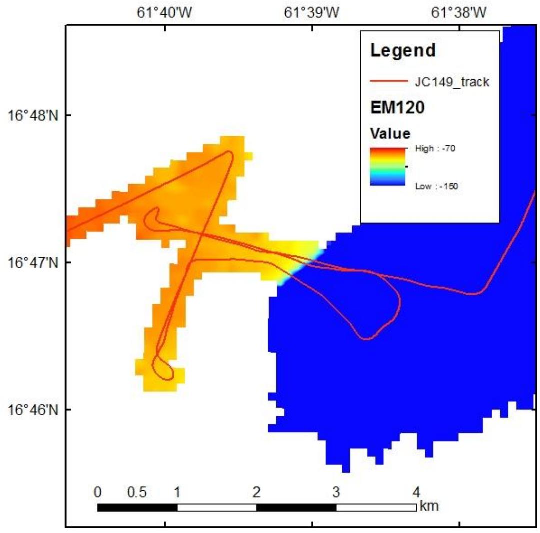


Figure 13 Map showing ship tracks used for the EM710 Patch Test

Fri 12/5 Day 132

The day consisted of an especially intense period of BBOBS recoveries, with a total of 7 (3 SIO, 4 DEPAS), all without incident.

Sat 13/5 Day 133

The final two DEPAS instruments (21 and 22) were recovered by mid-day. At 13:00 the magnetometer was deployed and a survey started to fill the unused contingency day (not needed as all 34 instruments had acoustically released without any delays) and to position the ship east of the arc in deep water for an OBS releaser test. The OBS teams continued to work on the instruments on deck, replaying/archiving data, disassembling (SIO) and starting to prepare for deployment in short-period mode during Leg 3 (DEPAS).

Sun 14/5 Day 134

The magnetometer survey continued until 15:00 when it was recovered ready for a DEPAS acoustic release test and SVP to the east of Guadeloupe. This was completed by 20:00 which marked the end of the science programme for JC149 Leg 2.

5.2.4 Port call 2

Mon 15/5 Day 135

The Pilot was onboard by 07:00 and by 09:00 the ship was tied up at the adjacent berth in the "Cruise terminal" that was used during the Leg1/2 port call in Pointe a Pitre (GPPTP). During the morning the ten SIO instruments were lifted ashore and packed into a 40' container. In the afternoon a 700 cu in airgun chamber shipment was received together with the spare part for the Gantry from Rolls Royce. The engineers proceeded to work on fitting the new distributer.

Tue 16/5 Day 134

Repairs to the gantry continued and the OBS teams prepared for the active source experiment.

Members of the Science Party participated in approximately 4 hours of filming about the VOILA project with a two-person crew from the Discovery Channel's *Daily Planet* science programme. The resulting 6-minute news item was broadcast on Tues 17 October 2017 (https://review.bellmedia.ca/view/45793672).

5.2.5 Leg 3 (17 May-19 June, JD137-170)

Wed 17/5 Day 137

At 09:00 the vessel was pushed away from the mooring, and at 09:30 a scheduled lifeboat lowering test was conducted. By 10:00 the Pilot disembarked, and the ship was underway. At 18:15 an OBIF prototype BBOBS was deployed at 15^0 19.6’N 60^0 48.5’W. At 18:45 the magnetometer was deployed and the transit to the start of the next line started. Overnight the swell increased with the winds reaching Force-6 before subduing to Force-4.

Thu 18/5 Day 138

The transit continued until about 13:30 when the magnetometer was recovered. At 13:40 OBS deployments started in Dominican waters with station 101, and averaged 1 deployment per 30 mins with the two teams (DEPAS and OBIF) alternating most of the time. A map of the station positions is given in Figure 13 and details of all deployments and recoveries are given in Appendix A. A few of the deployments were done by turning the vessel head-to-wind but the majority did not require this.

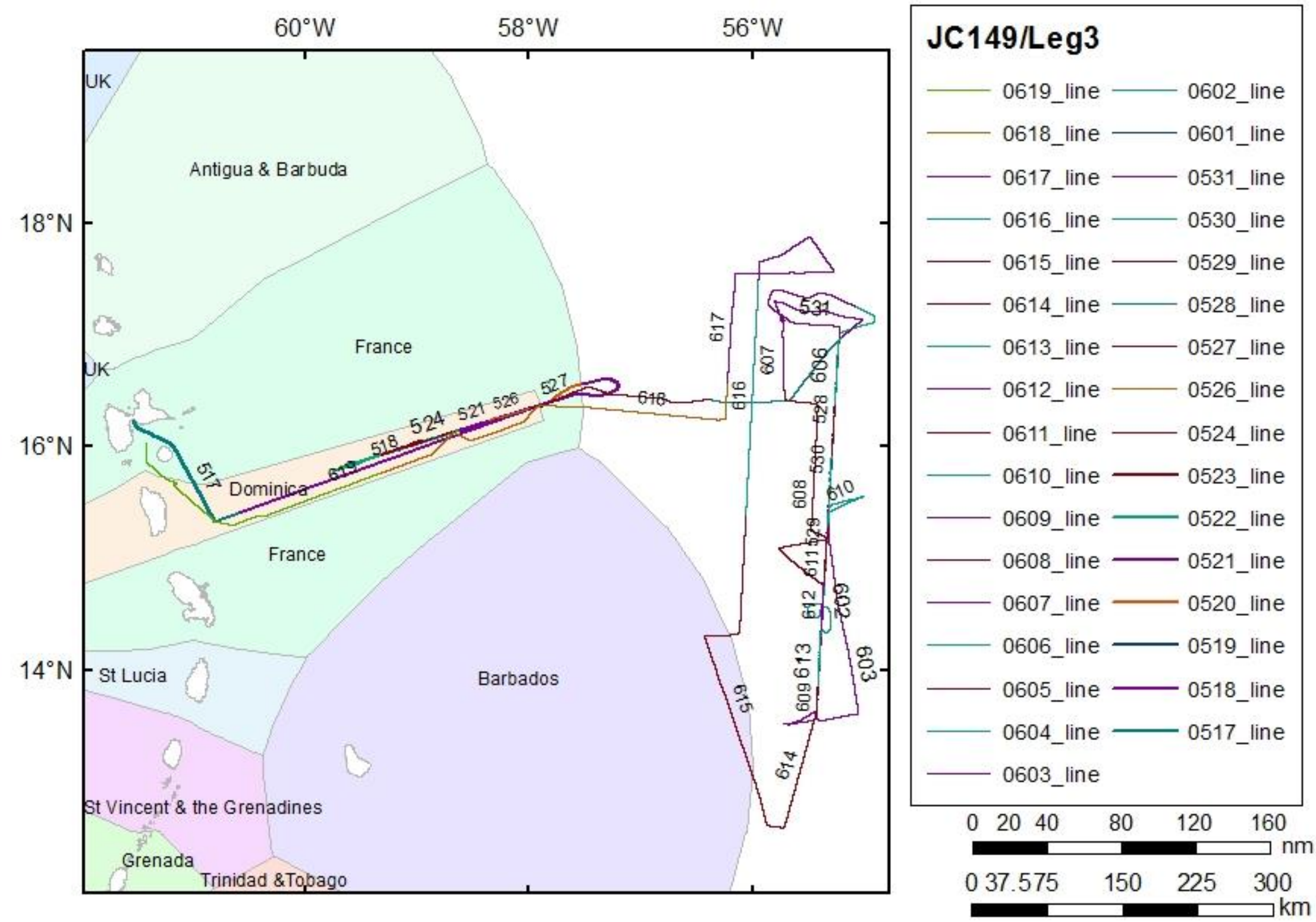


Figure 14 Map showing Leg 3 ship tracks by day (written as monthday) together with EEZ boundaries. Much of the work took place within International waters (unshaded).

Fri 19/5 Day 139

OBS deployments continued until 06:00 when the OBIF vertical array (mooring) was deployed between station 133 and 134. OBS deployments continued as planned until around 10:00 two new KUM instruments (known as NAMUs) were deployed (at stations 140 and 142). This is the first time they will record active shots. By 13:20 the last OBS was deployed giving a total of 48 instruments on this line. The "OBS" airgun array was then deployed (totalling 5000 cu in volume, see Figure 6). There was insufficient daylight to deploy the hydrophone streamer so it was decided to shoot the line without one. At 16:00 the MMO pre-shooting watch started, with the soft start commencing at 17:30. Full power was achieved by 18:00 and the 60 s shoot started as the vessel travelled eastward.

Sat 20/5 Day 140

The shooting of 60 s pop OBS Line 1 continued overnight without incident. At 12:30 we reached the end-of-line and entered French waters. In total, 1235 shots were made (Table 7). By 15:00 all the airguns were onboard for maintenance and array change. This required swapping 6 gun chambers (as indicated in Figure 6). At 19:00 the 3 km streamer deployment started whilst the guns were still being changed. Unfortunately a point was reached when the 3 NMF technicians were out of working hours which meant there was a delay in gun deployment until morning.

Sun 21/5 Day 141

Since the first day of this leg the seas had noticeably calmed, and the sea-state was now just Force-2, with little swell and few white caps. There were also increasingly large drifts of surface-floating sargassum seaweed. The deployment of the MCS airgun array started at 08:00. The middle gun on the Port outer beam failed to seal (Gun 2, one of the guns chambers that had been swapped over) so the beam was bought back onboard. The gun was corrected while deployment of starboard beams continued. MMO observation started at 09:30.

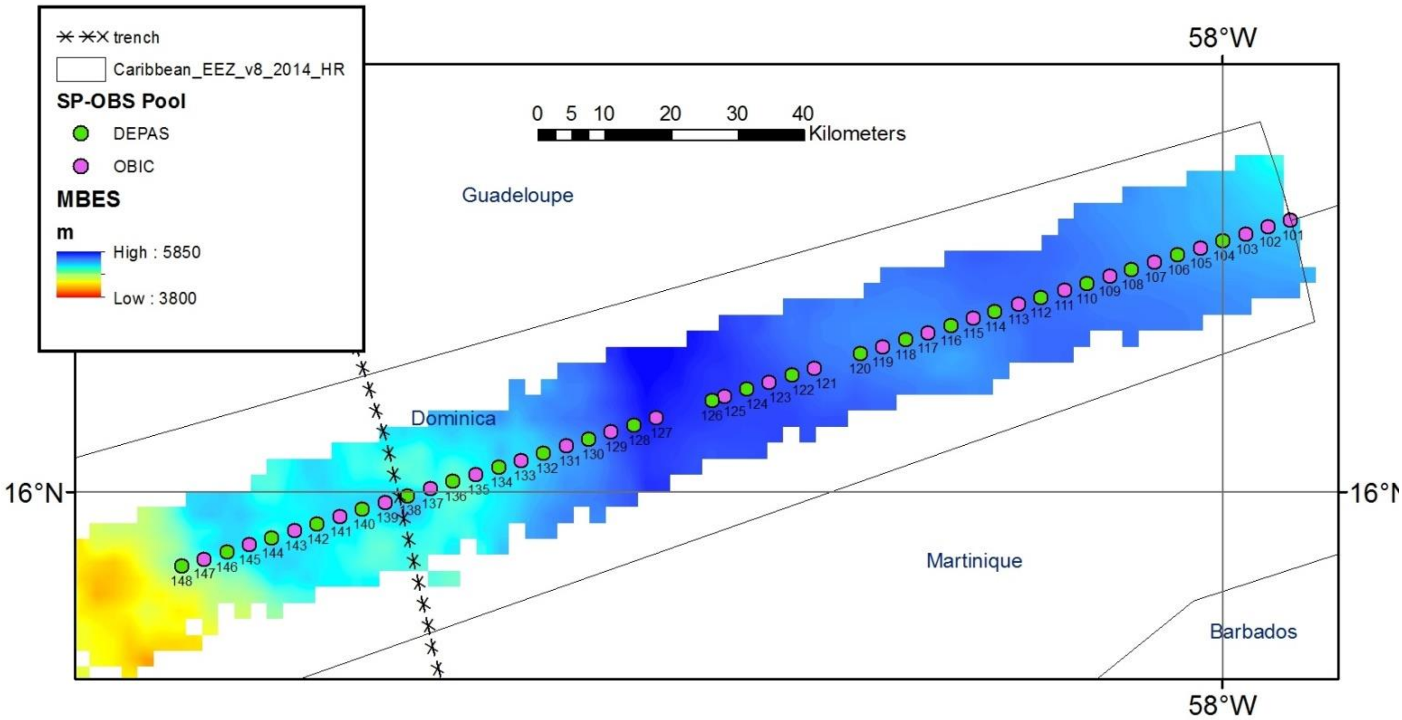


Figure 15 Map showing OBS deployment locations along Line 1 together with EEZ boundaries. The approximate position of the trench (North American Plate to the east; Caribbean Plate to the west) is shown. Note that stations 140 and 142 were occupied by KUM NAMU instruments.

The Way Point (entry into French waters) was scheduled to be 11:30 by the Bridge, and prior to this a test was made to improve the horizontal tow of the airguns. The Port outer beam was still towing deeper at the front so first 2 m and then 1 m of umbilical was bought in. From the vantage of the Bridge this resulted in the outer buoy being about 1 m closer to the ship. It was estimated that this means an equivalent amount of buoyant umbilical was in the water (as the outers are fed out through the Davits). This configuration was used for the rest of the survey. Unfortunately the gun depths are not logged until the guns are shooting so these tests are not recorded.

At 11:30 the ship was positioned over OBIF OBS 101 marking the Start-of-Line - OBS Line 1/20s – 3750 cu in array, 20s POP, 3 km streamer. The line was shot from station 101 to 148 (i.e. east to west).

Gun 2 started with double triggers. Whilst it was firing at correct time it was also firing in between. As this was a small gun (200 cu in) it was thought that it was simply filling to 2000 psi too quickly. This behaviour stopped after about 30 mins (just before the end of the soft start) and so it was left in. However, by 16:20 Noise bursts were seen on the single trace monitor. These were attributed to Gun 2 double firing again and so it was switched out. However by 17:00 it was realised this noise was not from Gun 2 (as the random nose bursts on unknown origin were still visible on the monitor record) and so the gun was switched back in. Later, analysis of the recorded data suggested the noise to be on streamer channel 1 only (the one that unfortunately was being used as a single trace monitor display to determine gun quality). The noise bursts were not detected on the other channels.

At 22:00, when the vessel was passing over station 128, Gun 4 (inner port, 400 cu in) started leaking air. It was assumed this was the result of another failure of the air-supply bolt. Shooting was paused for approx. 3 mins (by this point we were losing so much pressure there was a risk of other guns flooding). Gun 4 was shut out and firing restarted.

Mon 22/5 Day 142

There were no further gun losses overnight and the line ended at 16:30 (approx. 18 hours of shooting) when the tailbuoy was estimated to have passed station 148. The recovery of the airguns and magnetometer started. This work was finished by 08:00 and the streamer recovery started. During this process the winch overheated and there was a delay of 20 mins to allow it to cool down. There was also noted to be a problem with transmission down one of two of the streamer high voltage cables. Although the system only needs one of these to operate, it was decided to check its continuity across streamer sections during the next deployment. By 09:30 the streamer was fully recovered and the ship started to turn back onto line. OBS recoveries started at noon with the instrument at station 148. See Appendix A for details.

Line name	Shoot direction	#shots	SOL/EOL	Duration (hours)	FFID	yr	jd	hr	min	Lat (deg min)	Lon (deg min)	Airgun Array	Airgun volume (cu in)	Guns lost	Pop (s)	Streamer
OBS Line1/60s	W->E	1235	SOL	18.9	1	2017	139	21	32	15 51.771	59 31.304	OBS	5000	none	60	none
			EOL		1235	2017	140	16	26	16 22.068	57 54.305					
OBS Line1/20s	E->W	3281	SOL	18.3	101	2017	141	15	22	16 22.093	57 54.341	MCS	3750/3350	4 (400)	20	3km
			EOL		3381	2017	142	9	38	15 53.326	59 26.372					
OBS Line2	S->N	1207	SOL	21.9	100	2017	149	18	53	15 09.738	55 23.477	OBS	5000	none	60	3km
			EOL		1306	2017	150	16	49	16 59.230	55 13.850					
OBS Line 2_3	N-S	7914	SOL	33.9	292	2017	151	18	50	17 05.245	55 19.238	MCS	3750	none	20	3km
			EOL		5932	2017	153	4	44	14 27.936	55 22.880					
			SOL-C	12.7	10001	2017	153	15	37	14 30.197	55 22.744	MCS	3750	none	20	3km
			EOL-C		12274	2017	154	4	18	13 35.838	55 26.030					
OBS Line3	S->N	1210	SOL	21.0	101	2017	160	12	24	13 34.815	55 26.409	OBS	5000	none	60	3km
			EOL		1310	2017	161	9	21	15 25.996	55 19.509					
Line4	S->N	3306	SOL	37.2	101	2017	166	11	52	14 20.688	56 7.57	OBS	5000/4500/ 3800	10 (500), 13 (700)	40	3km
			EOL		3406	2017	168	1	4	17 34.975	55 56.862					
Gun Trigger Test	S->N	101	SOL	0.6	100	2017	168	1	9	17 35.373	55 56.807	OBS	3800	none	~20	3km
			EOL		200	2017	168	1	44	17 38.316	55 56.671					
	TOTAL	**18254**		**164.4**												

Table 7 Leg 3 seismic line summary. The record length was 19 s and sample rate 2 ms on all lines. The locations of the lines can be seen in Figures 16 and 17. Further details about the gun failures are provided in Table 8.

Tue 23/5 Day 143

Overnight OBS recoveries continued, including the 2 new DEPAS frames (NAMU). These new frames were difficult to see as they float low and spin in the water. Also the flag seemed to block the light at night. The only other minor incident was that some of the OBIF stray lines failed to release making recovery more difficult. By 09:30, after OBIF

139 was recovered the sequence was broken to recover the vertical array. This was released by NMF at 11:10 and was sighted at the surface at 11:45. It then proved difficult to grapple, but after several failed attempts was achieved at about 12:30. The ship was then repositioned to stream the array in an attempt to untangle it slightly. By 13:30 the system was fully onboard and the ship returned to OBS recovery 138.

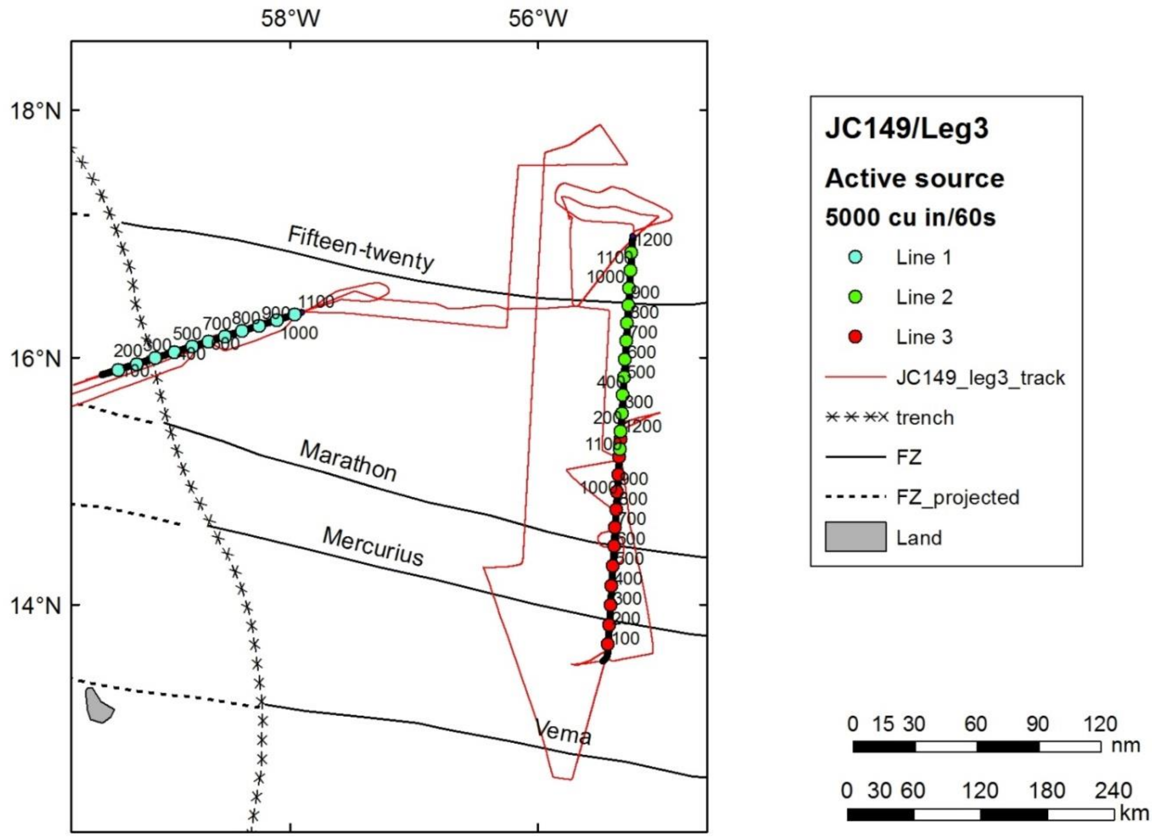


Figure 16 Map showing Leg 3 shots (60s firing intervals). The numbered dots are FFID #.

Wed 24/5 Day 144

OBS recoveries continued without incident. At 09:00 we lost the POS-MV GPS feed. This results in a 3 hour gap in the logged position (from UTC 13:01:55.914 to 16:59:46.591). As a result the Seapath was set to be the primary navigation (the ship doesn't have any alternative, third system). Investigations suggested that the Seapath had not shown further random spikes since leaving Bahamas (see entry for JD 108).

At 19:00 a problem with communication with OBIF 125 (water depth 5262 m) via the hull transducer or hand held over-the-side transducer was identified. We waited until 22:00 (to give time for the instrument to surface following the sending of the last release command) before the attempt to recover it was aborted.

Thu 25/5 Day 145

At 08:00 the Captain reported picking up faint channel 62 signals on the Bridge. Initial indications with the OBIF directional radio suggested it was coming from a direction compatible with instrument 125 at the sea surface. By 10:00 DEPAS station 120 was onboard and the ship was turned to steam to the likely drift position of OBIF 125. Unfortunately by 11:30 it was discovered that the signal was coming from a faulty radio on one of the OBIF instruments on the back deck. The search was therefore aborted and we returned to recover DEPAS 119. Recoveries continued without incident, until around 23:50 the DEPAS 114 instrument surfaced without a working light or radio. Luckily it was spotted with the ship's search light and was recovered without further problems.

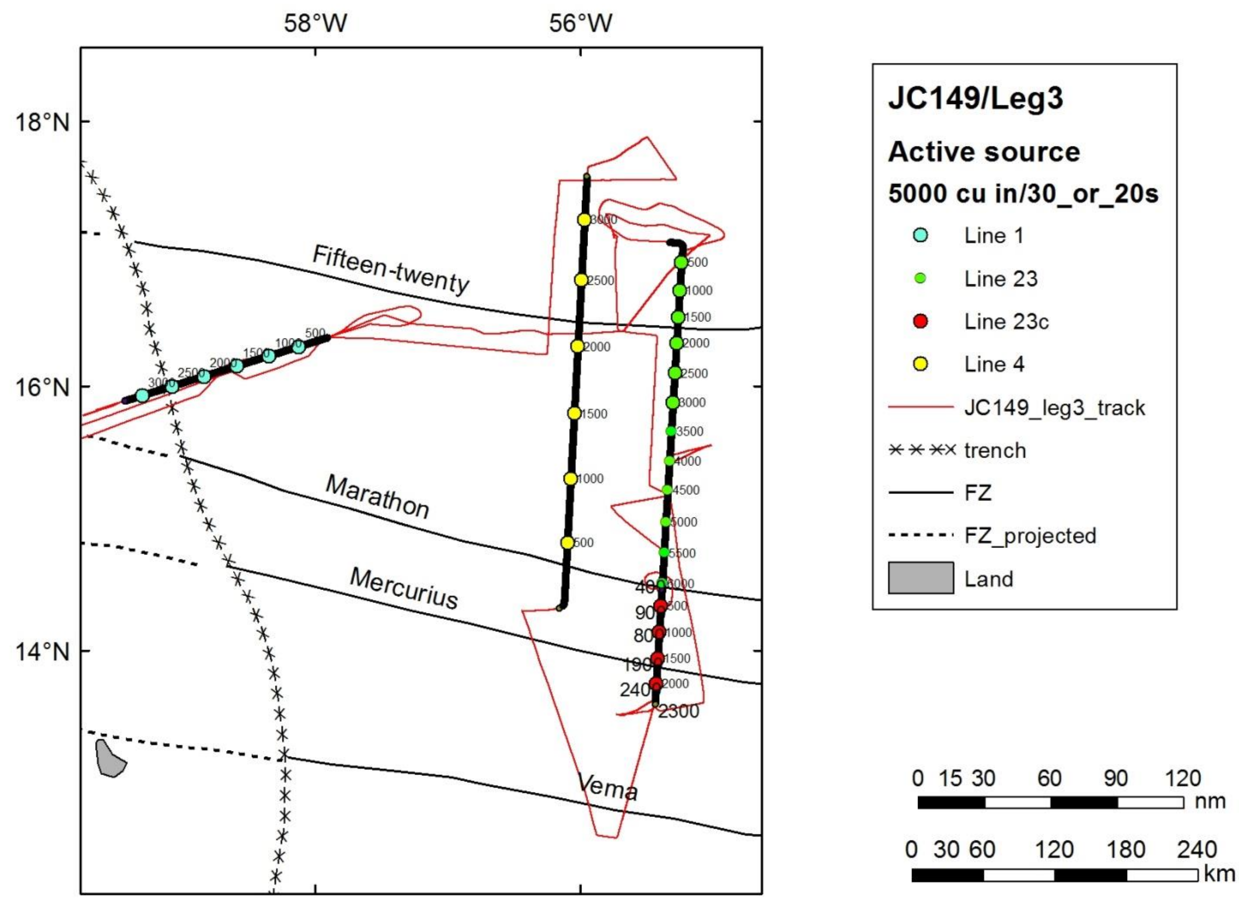


Figure 17 Map showing Leg 3 shots (20 and 30 s firing intervals). The numbered dots are FFID.

Fri 26/5 Day 146

OBS recoveries continued overnight. At approximately 08:00 we lost VSAT, and so all internet and telephone communication. At 16:15 a safety drill was conducted, consisting of a simulated bomb search. OBS recoveries continued without incident.

Sat 27/5 Day 147

At 05:00 no communication was possible with the final OBS to be recovered - OBIF 101 and the search was abandoned. At 06:00 a DEPAS releaser test + SVP was conducted at site 101. This equipment was back onboard by 08:30 when the magnetometer was deployed and a swath survey along the northern margin of Barracuda Ridge looking for potential dredge targets was started. At 18:00 a BBQ was held on the back deck to celebrate the successful completion of OBS Line 1 (albeit with the 2 unrecovered instruments).

Sun 28/5 Day 148

Overnight the weather had picked up a little, with Force-5 winds, more swell and sea-state 4/5. At 06:00 we started OBS deployments along Line 2. Several of the planned OBIF sites at the northern end of the line were taken out (stations 201, 204, 206, 208, 210 and 212) due to water depth concerns following the two lost instruments on Line 1. The most likely cause was thought to be failure of some of the new glass flotation spheres. The solid flotation system of the DEPAS instruments meant that this was not an immediate concern for that pool. Note that because the protocol sheets had already been completed the stations were not renumbered). Instead the six un-deployed instruments were put down in their planned SOL 3 positions (stations 302, 304, 306, 308, 310 and 312) once the Line

2 deployments had finished. The deployments started with the first two DEPAS instruments (both NAMUs, stations 202 and 203) being deployed off the stern from the cherry pickers due to the sea state.

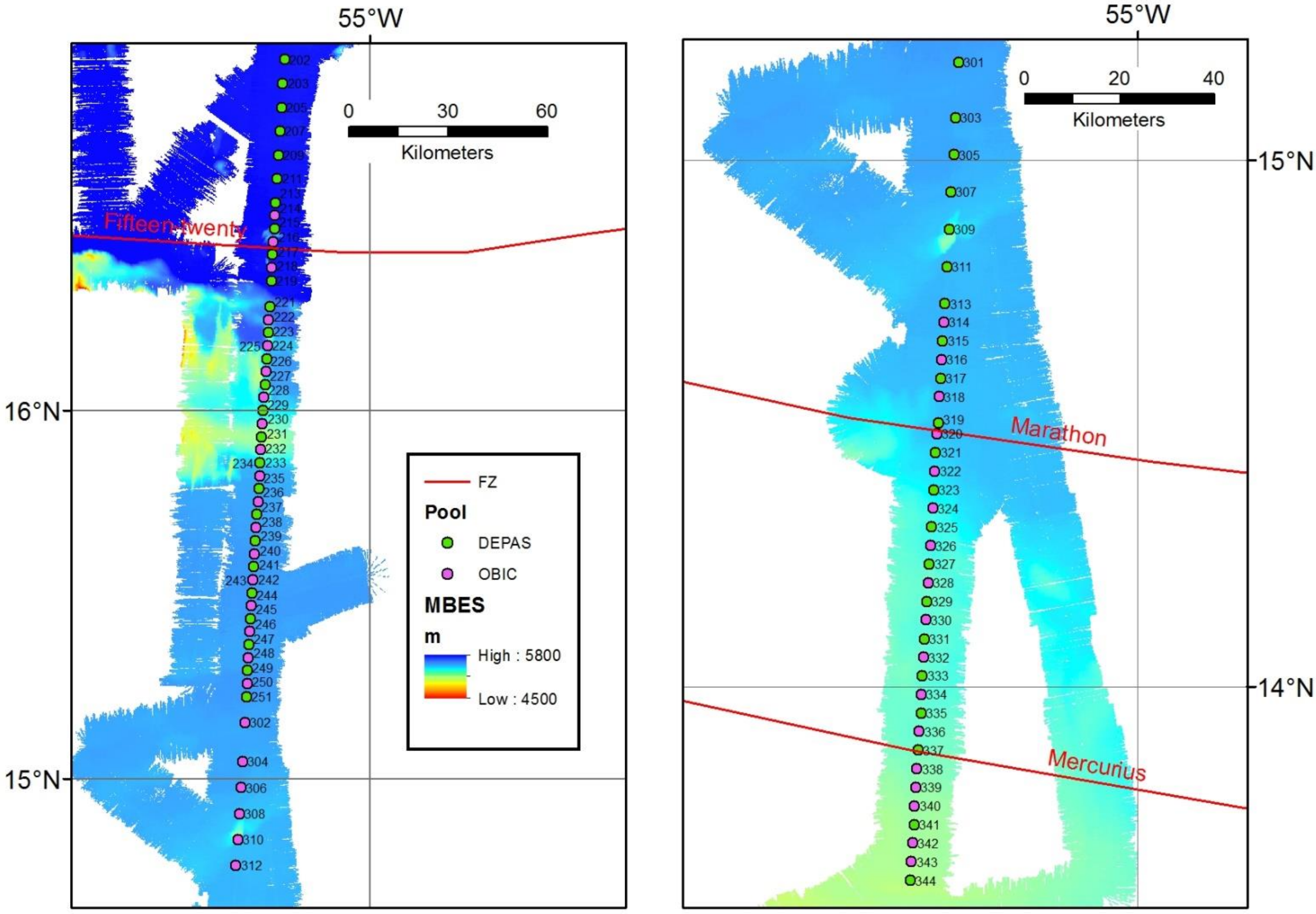


Figure 18 Map showing OBS deployment locations along Lines 2 and 3. The red lines show approximate positions of oceanic fracture zones.

Mon 29/5 Day 149

OBS deployments continued in a southerly direction without incident. The final Line 2 OBS (OBIF 250) was deployed around midnight. This was then followed with the six OBIF instruments at the start of Line 3, with the last instrument (station 312) being deployed at 05:00. The ship was then turned to get into position for streamer deployment (head to wind). At 08:00 the streamer deployment started. During deployment tests for electrical connectivity were made, with all streamer junctions taken apart and sprayed with compressed air and cleaner. This action appeared to correct the problem with the second high voltage. At 13:00 the OBS (5000 cu in) airgun array and magnetometer deployment started. By 15:30 we were ready to start to turn on to the line. The airgun soft start commenced at 15:50 with a 60 s firing interval. The full array firing roughly coincided with station 250, and continued as the ship travelled northwards at 5 knots throughout the evening and night.

At 16:00 it was announced that the VSAT internet and telephone communication system had been repaired! In total we were without internet and email for about 88 hours.

Tue 30/5 Day 150

As the day continued the weather increased a little, with Force 3 winds, more swell and a sea-state of 2/3. The airguns however continued to fire without any issues. At 12:30 the end-of-line was reached and the shooting stopped. By 15:00 all the towed equipment had been recovered. At 16:30 an XBT-T5 was taken (see Table 8). At the same time the magnetometer was deployed and a magnetic survey conducted overnight.

Wed 31/5 Day 151

At the 12:30 the magnetometer was bought in, which was followed at 12:45 by the start of the airgun deployment. By 15:00 all guns (The MCS array 3750 cu in total volume, see Figure 6) and magnetometer were deployed. At 16:00 the ship turned onto the start of MCS Line2+3 20 s pop. The line commenced as the vessel travelled southwards at 5 knots.

Line #	Gun#	Volume (cu in)	JD	Time (UTC)	FFID	Cause of failure	Comments
OBS Line1/20s	2	200	141	15:47	101-176	Mis-trigger	Double firing (see narrative text for more details)
	4	400	142	01:46	1971	Air supply	
OBS Line 2_3	All	n/a	153	04:44	Line break	All compressors	Loss of ship's cooling water system. Line divided into Line2_3 (north) and Line 2_3C (south)
Line 4	10	500	166	20:53	868	Air supply	
	13	700	167	18:55	2855	Air supply	

Table 8 Leg 3 seismic equipment failures.

Thu 1/6 Day 152

Overnight we continued collecting the profile, with no gun failures. The sea-state was moderate at 3/4. At 10:30 an XBT was attempted but was unsuccessful (possibly it got caught in the guns). At approximately 21:00 the vessel passed over the most southerly deployed OBS (station 312) and continued southwards to collect and unbroken line along both Line 2/3 wide-angle profiles.

Fri 2/6 Day 153

At 01:30 there was a catastrophic loss of the compressors. The pipe in the ship’s salt water cooling system had failed causing all compressors to overheat and shut down. The Engineers were called and they managed to repair the leaking supply by patch welding within the hour. During this time the vessel started to make a 360 degree turn to Port to re-join the line. As a precautionary measure the magnetometer was bought in closer to ship, the block lead on streamer was raised and the front end birds were shallowed to place the water entry point of the streamer beyond the airgun buoys

At 5:00 the MMO observations started, ready to resume shooting at 06:00, unfortunately due to wind on the beam of the ship did not manage to make turn back onto the line where the last shot was made. By 6:15 it was decided that the ship’s course would result in an unacceptable gap in the seismic line so the decision was taken to make a second (larger and to Starboard) turn. By 10:00 we were ready to restart line. The towed equipment was re-set. As the green-light was given to restart the line (10:30) the Seal acquisition software crashed twice due to a problem with the GPS connection. The two aborted lines were named Line 2_3A and Line 2_3B. This resulted in 11 minutes of lead in data to be lost as the system was rebooted, but luckily there was enough contingency built in to the turn. Finally, all systems were back working (Line 2_3C) with about 10 minutes steam time to spare! Later as the data was processed, no loss of fold at the line splice was confirmed. Collection of the MCS profile continued throughout the day without further incident.

Sat 3/6 Day 154

At 00:30 we reached the end-of-line. In total we had achieved 8207 shots without any gun failures compared to just ~6400 shots before gun failures occurred during Leg 1. NMF had used a new washer on the high pressure inlet (where the shearing was happening) and it seems to have worked. On recovery we had lost 1 pressure shock buffer from the chains between the beam and individual guns, but otherwise the system was in a good condition.

By 08:00 all towed equipment in and the 11 knot transit to the first OBS recovery station (245) started. The steam took around 8 hours, with the ship arriving about 16:00 when the first response from the instrument was heard. OBS recoveries then started in earnest, with a new instrument on deck typically every two hours. See Appendix A for details.

Sun 4/6 Day 155

OBS recoveries proceeded all day without incident. Whilst there had been some swell overnight, sea conditions had quietened down by sunrise.

Mon 5/6 Day 156

OBS recoveries continued without incident until around 19:00 DEPAS station 219 was discovered to have an imploded titanium seismometer housing. Later assessment concluded this happened before the shooting had started and so no data was recorded.

Tues 6/6 Day 157

OBS recoveries continued without incident. Around 11:00 whilst streaming the core wire the hydraulic oil supply hose failed causing some oil leakage on the back deck. Once this had been cleaned up the streaming of the wire continued in readiness for the planned dredge the next day.

The final OBS recovery occurred at 19:30 (DEPAS 202). Unfortunately this NAMU instrument lost its releaser during the recovery (the second securement had accidentally been forgotten during preparation.) The releaser was traced falling to the seabed! At this point we started an EM120 swath survey in order to fill in one of the dredge target locations (a possible geological core complex) in the Fifteen-twenty Fracture Zone area.

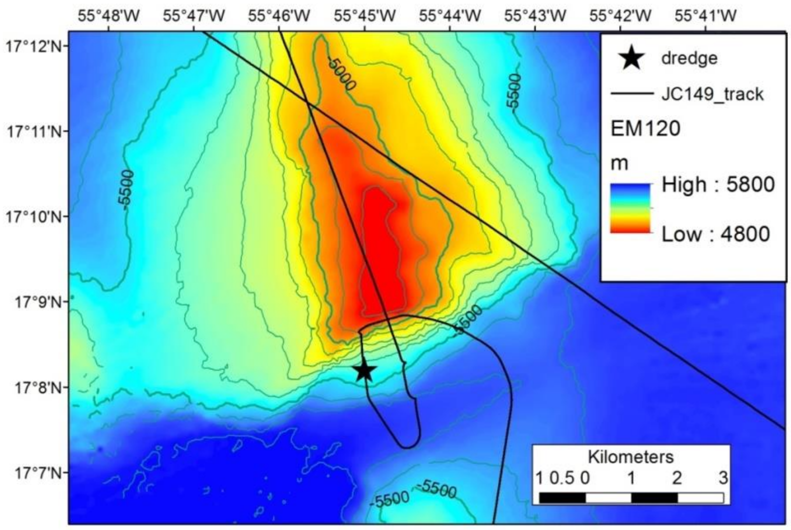


Figure 19 Map showing the ship track during the dredge target – a 1000m steep scarp. The star marks the point the budget hit the seabed towards the base of the scarp.

Wed 7/6 Day 158

At 08:00 we arrived at the dredge location, and conduced a short survey of the area to select the best location to deploy the wire. At 9:30 the dredge was over side in a water depth of 5250m. At 11:15 the bucket hit bottom (wire out 5121m) and we continued to pay out 20 m/min of cable while moving the ship forward 0.5 knots due north. We stopped this procedure at 11:24 (water depth 4969 m) and started to haul in at 10 m/min. During this period the tension on the cable ranged between 3-6.5 Te (the weak link being good to 8 Te). By 12:25 the wire out was 4467 m, and given the water depth was 4967m we were confident it was off the bottom. There were problems in the winch room getting the wire back on spool evenly (the only remedy being to keep paying in and out), however by 16:30 the dredge was onboard and it was full of rocks!

The magnetometer was then deployed and we started the transit to start of OBS Line 3.

Thu 8/6 Day 159 (UK General Election)

We arrived at the site for the first OBS deployment (station 301) and recovered the magnetometer at 08:00. OBS deployments followed for the rest of the day without incident. The activity was extremely efficient, with instruments going over the side every 40 minutes or so. In the evening the Science Party gathered in the Main Lab for the online Election Results.

Fri 9/6 Day **160**

The final instrument (station 344) was deployed around 1:30 and the seismic equipment was in the water such that the soft start commenced around 8:20. Line 3, with the 5000 cu in “OBS” array and 60s shot interval, was then collected from south to north.

Sat 10/6 Day 161

The line ended without any incident at around 05:30, and all the seismic equipment was recovered by 11:00. The vessel then returned to the OBS line and the final set of recoveries started at 12:30 (station 246). At about 18:30, DEPAS instrument 249 was recovered and found to have an imploded trillium seismometer case (like the instrument at station 219). Again this malfunction happened before any shots were fired so no data was collected at this station.

Sun 11/6 Day 162

OBS recoveries continued throughout the day without incident.

Mon 12/6 Day 163

OBS recoveries continued throughout the day without incident. At 19:30 we passed an unidentified flashing buoy (but the light was red unlike our OBS).

Tue 13/6 Day 164

OBS recoveries continued throughout the day without incident. Overnight the sea state reached its highest so-far experienced during the cruise, with winds up to 4 knots and 2 m of swell. Fortunately this didn’t hinder OBS recoveries significantly.

Wed 14/6 Day 165

The last OBS (station 344 DEPAS-NAMU) was on deck 09:00. All instruments had been recovered without incident. At 09:15 the magnetometer was deployed and a survey started. An XBT was released at 09:30. At approximately 18:00 we entered Barbadian waters and so stopped all data collection.

Thu 15/6 Day 166

The final deployment of the seismic equipment started 03:00. There had been another communication failure down one of the two high-voltage cables and two of the connectors between sections were unscrewed and cleaned during the hydrophone deployment. This did not fix the problem, so we again relied on the redundancy of the system. At 08:00 we started to collect Line 4 with the 5000 cu in "OBS" airgun array, 3 km hydrophone and a 40 s POP. This line was extra to the original plan and was made possible by the lack of technical problems and efficiency of OBS deployment and recovery.

At 16:50 we noticed we were losing pressure (down to 1800 psi) and the Bridge reported gas bubbling from the Starboard outer beam. Gun 10 (500 cu in) was therefore shut off.

Fri 16/6 Day 167

Overnight the seas and wind had calmed relative to the previous few days, with a sea-state of 2 and wind direction 070, 10 knots. We continued to shoot the line northward, passing over Barracuda Ridge at about 09:00. At 15:00 we lost a second gun due to a leak in the air supply, this time the 700 cu in single. The line ended at 22:00 and was followed by a short "Apparation test", with a flutter of 20 ms added to alternate gun triggers; 20 s firing, 100 shots. The seismic gear was then recovered and the magnetometer re-deployed to undertake a swath and SBP survey across the Barracuda Trough.

Sat 17/6 Day 168

The survey continued without incident as the Science Party started to process the final datasets and pack away equipment. In the evening a BBQ was held and the ship started its transit back into port.

Sun 18/6 Day 169

During the day the NMF technicians started the disassembly of the seismic system. On the way back into port we made further attempts to communicate with the missing OBIF OBS lost at stations 101 and 125. No response was obtained. We then continued back through Dominican waters by collecting a further MBES line parallel to OBS Line 1.

Mon 19/6 Day 170

At 06:00 we recovered the OBIF BBOBS prototype and arrived at the "Commercial port" in Pointe a Pitre (GPPTP) at 16:00.

5.3 Demobilisation (JD171) All times are local

The Science Party spent much of the day processing the underway geophysical data and packing up the equipment. At 10:00 the first gravity readings were made at the quayside next to the ship, and at 13:20 the measurements at the gravity basestation at the University campus were made. The final set of gravity measurements were taken alongside the vessel at 13:50. Ship's logging was then closed and a final backup to portable disk drives was completed by 16:00.

6 Data Acquisition & Equipment Performance

6.1 Ship's fitted equipment

6.1.1 Navigation and data logging

Both of the available navigation systems were used during JC149 (1) an Applanix POSMV 320 which integrates two GPS receivers with a motion reference unit; and (2) a Seapath 330+. Both systems are interfaced with a Cnav 3050 which provides the required DGPS corrections from a Kongsberg Seatex DPS 116 receiver on the bridge. The positional accuracy is expected to be 0.5-2 m depending on the quality of the differential corrections. Both produce a location of the ship's central reference point in the gravity metre room every second. The navigation was fed into an Olex 3D chart system and displayed in real-time. The navigation data, together with other ship systems, were logged by the TechSAS version 5.11 in "NetCDF" and ascii "NMEA" time-series format. Further details of logged items are given in Appendix C.

There were three periods when no navigation was logged on one or other of the systems:

Seapath:

17/04/18 00:14:17.212 – 00:54:59.221 (approx. 41 mins; GPS system bought down the TechSAS)
17/04/18 05:35:30.143 – 11:57:13.216 (approx. 382 mins; GPS system bought down the TechSAS)
17/05/10 07:10:53.147 – 07:30:55.236 (approx. 20 mins; network failure)

POSMV:

17/05/10 07:10:53.329 – 07:30:55.338 (approx. 20 mins; network failure)
17/05/24 13:01:55.914 – 16:59:46.591 (approx. 180 mins; GPS failure)
17/05/24 19:16:07.618 – 19:24:36.674 (approx. 8 mins; GPS failure)

The primary navigation source was as follows:

Start of Leg 1 -to- 18/4/17 (JD 108) 07:00	Seapath (EM120 line 13)
18/4/17 (JD 108) 07:00 -to- 24/5/17 (JD 155) 17:40	POSMV
24/5/17 (JD 155) 17:40 -to- end of cruise	Seapath

6.1.2 Internet

Satellite Communications were provided with both the Vsat and FBB systems. The Vsat had a guaranteed speed of 512 kbps with unlimited data and the FBB had a maximum un-guaranteed speed of 256kbps with a fair use policy that equates to 15 GB of data a month.

There was a hardware failure of the Servo Drive Unit which resulted in the loss of the Vsat system (and so removal of email and external internet connection) 26/05/2017 from 02:30 UTC for around 88 hours until the issue was rectified.

6.1.3 Meteorology and sea-surface monitoring

The weather and sea-state during JC149 was fair to good. The significant wave height was typically between 2 and 5 m. Meteorological data acquired throughout the cruise include sea-surface temperature (around 28^{o}C), air pressure, wind direction and humidity and logged by the NMFSS Surfmet system. Some problems with sea-surface seaweed required frequent cleaning of these systems, especially in Leg 3. Details of the sensors used and calibrations needed are included in Appendix C.

6.1.4 EM Speed logs

The single axis bridge Skipper Log and the dual axis Chernikeef science log were recorded throughout the cruise. The Chernikeef log was calibrated in September 2016, in the English Channel.

It was observed that the Chernikeef reading has drifted considerably undermining confidence in the data. This is probably due both to a build-up of marine fouling on the sensor and the change of temperature and salinity of the water away from the conditions in which the sensor was calibrated.

6.1.5 Single-beam echo sounding (EA600)

Throughout the cruise, we acquired 12 kHz single-beam echo soundings with a hull-mounted Kongsberg EA600. The system was switched off during OBS acoustic operations (releaser tests and recoveries). The system was run mostly in passive mode triggered via K-sync to receive the EM120 systems pulse. During Leg 3 the system was in free-running mode.

The system was run with a constant sound velocity of 1500 m/s for the water column to allow it to be corrected for the measured water column sound speed in post-processing. The system performed well. The bathymetric data are archived as ASCII xyz files and bmp images.

6.1.6 Sub-bottom profiling (SBP120)

Throughout the cruise while not in French or Barbadian waters, we acquired sub-bottom profiling data which yielded useful high resolution images of various tectonic features (such as faulting and folding in the Grenada back-arc and Barracuda Trough) and seabed processes (such as landslides from the volcanic islands). Again, the system was switched off during OBS acoustic operations (releaser tests and recoveries). Although this shallow profiling technique was not central to the success of the cruise, it provides very useful ancillary data which will enhance our geological and geophysical interpretations.

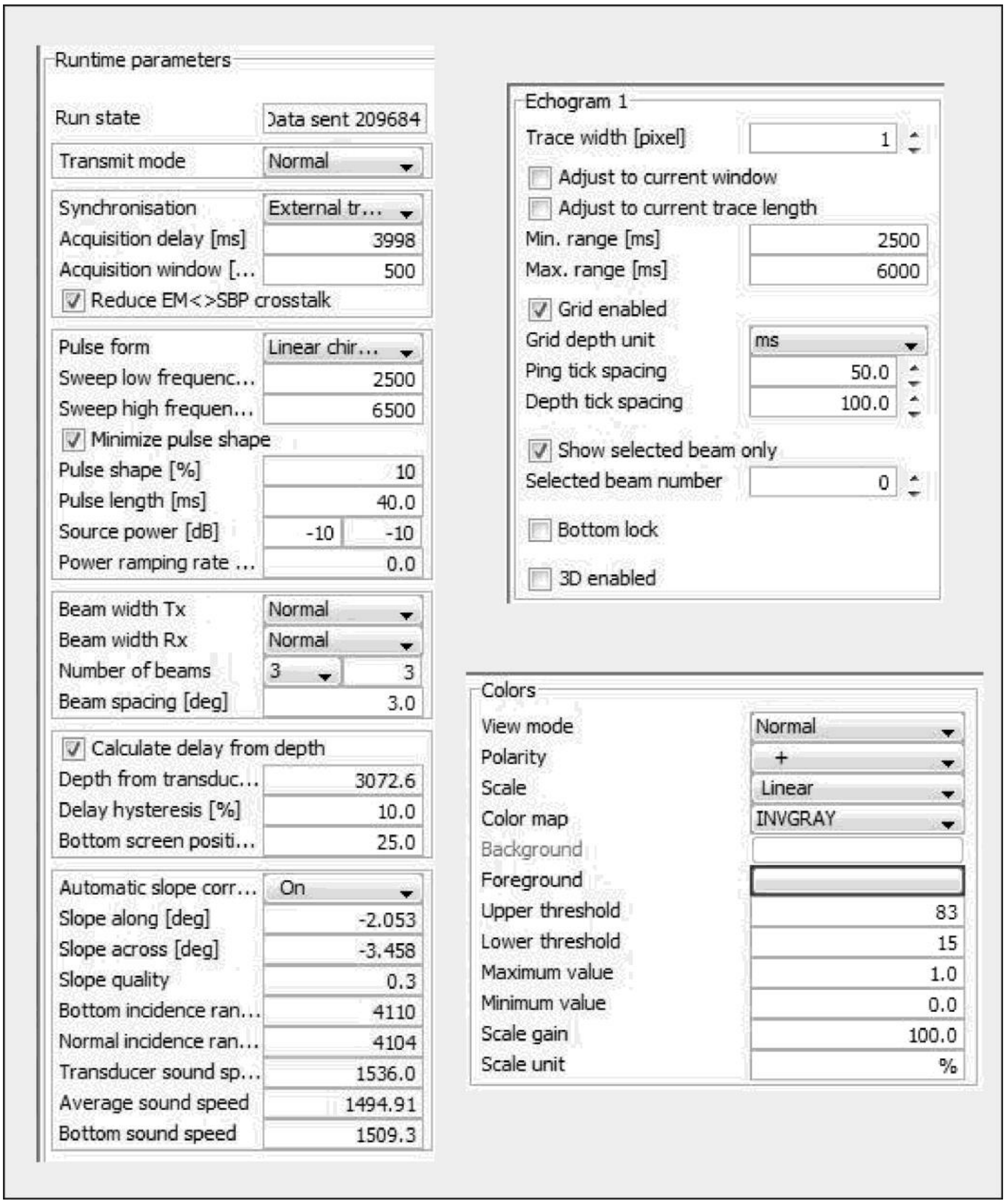


Figure 20 SBP acquisition settings.

The SBP120 runtime parameters initially used and the echogram display settings are shown in figure 20. The only processing options enabled were in the following order below. These were the suggested settings from the Kongsberg training notes. After the initial setup the scientific party took control of the setup. The SBP120 software is included with the data for replay and reprocessing.

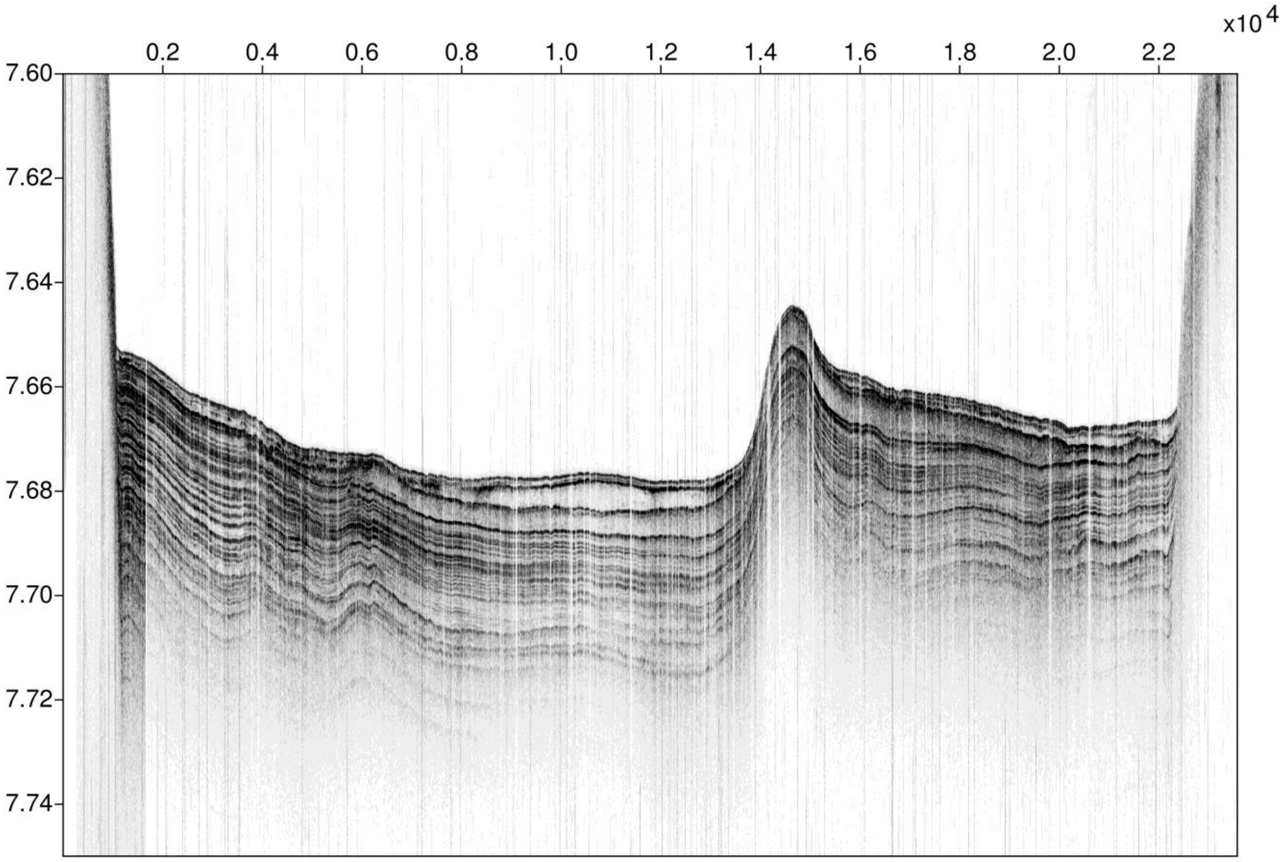


Figure 21 Example Sub-Bottom Profiler segy file plotted in sunix from the Barracuda Trough. The vertical axis is TWT in s and the horizontal axis trace number (800 traces is equivalent to about 30 minutes along track).

During Leg 3 the maximum Source Power used was -15dB. There were several periods where the SBP was unable to find the seabed, and required to be power cycled for several minutes. This is possibly a Tx power issue, which will be investigated, but this did not inhibit the collection of data on most occasions and was able to be rapidly rectified.

The source was a linear chirp sweep with frequencies 2.5 - 6.5 kHz delivered in a 40 ms pulse and a ping interval of 2175 ms.

The system was run with a deep water delay that was entered manually by the watchkeeper and a typical record length of 300 ms and 48 micro-s sample rate. Penetration was typically 50-100 ms. The system kept hanging for an unknown reason and was also severely affected by sea-state, even slight degeneration and/or increased ship speed or use of the thrusters resulted in losing the bottom image. We estimate that usable data was collected about 30% of the time.

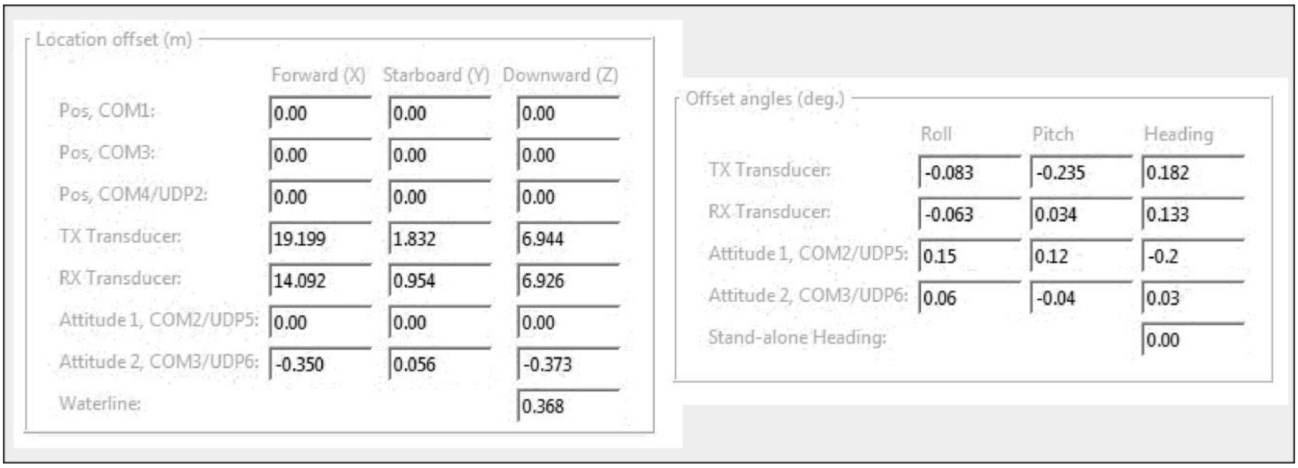
The data are archived as both .raw and processed .seg (conventional segy format, deconvolved from the source sweep) with files named by time-stamp. An example of the processed data collected (filtered and AGC applied) across the Barracuda Trough plotted with sunix software is shown in Figure 21.

6.1.7 Swath bathymetry

6.1.7.1 EM120

The swath data were primarily acquired using a Kongsberg EM120 multibeam echosounder (MBES), which operates at a frequency of 12 kHz with angular coverage sector of up to 150 degrees and 191 beams per ping. This geometry yields a swath width of six times water depth. Beams are automatically adjusted to be equidistant horizontally No swath bathymetry data was collected within French or Barbadian waters.

Figure 22 shows the system installation configuration. The attitude angular corrections for use with the Seapath 300 system were derived from a post refit trial calibration on JC108 Sept 2014. The attitude angular corrections for use with the Applanix POSMV system are from calibration during JC103 May 2014.



Location offset (m)

	Forward (X)	Starboard (Y)	Downward (Z)
Pos, COM1:	0.00	0.00	0.00
Pos, COM3:	0.00	0.00	0.00
Pos, COM4/UDP2:	0.00	0.00	0.00
TX Transducer:	19.199	1.832	6.944
RX Transducer:	14.092	0.954	6.926
Attitude 1, COM2/UDP5:	0.00	0.00	0.00
Attitude 2, COM3/UDP6:	-0.350	0.056	-0.373
Waterline:			0.368

Offset angles (deg.)

	Roll	Pitch	Heading
TX Transducer:	-0.083	-0.235	0.182
RX Transducer:	-0.063	0.034	0.133
Attitude 1, COM2/UDP5:	0.15	0.12	-0.2
Attitude 2, COM3/UDP6:	0.06	-0.04	0.03
Stand-alone Heading:			0.00

Figure 22 EM120 Transducer offsets

The Surface Sound Velocity sensor (AML SmartSV) mounted on the drop keel experienced occasions where it would only output zero values to the EM120 SIS multibeam system, suggesting it was either out of the water, or blocked. On 1/6 it was established that the likely cause was seaweed and from then on when sustained zero values were obtained the drop keel was raised approx. 1m whilst underway in suitable sea states and then returned to the flush position. This process seemed to resolve the issue and reinstated regular surface SV data to the EM120

During Leg 3, 'manual' Surface Sound Velocity was used in SIS for the EM120 on the occasions below:

- 20:54 J151 31/05/2017 Manual value of 1540 was used from XBT deployment
- 13:42 J152 01/06/2017 Manual value updated to 1539.55 from XBT (and applied salinity from SBE45)
- 21:06 J152 01/06/2017 Partial raise of drop keel – cleared blockage. EM120 set to 'sensor'.

The data collected suffered from motion artefacts, limited swath coverage, along track artefacts and substantial noise caused by keel aeration. During transits and rougher weather the maximum angle had to be reduced to 60-70^0. In general all transits when travelling west in Leg 3 were significantly better than transects travelling east (with the swell behind the ship). Some tangling of weed was also experienced intermittently. Significant effort was required by the Science Party to clean the data within CARIS software to a useable state, and even at low speeds this meant that in moderate sea states up to 70% of the data was rejected.

6.1.7.2 EM710

For water depths less than about 600 m the EM710 system was also used which operates in the 70-100 kHz range and 200 beams per ping. The system was run with the drop keel flush to the hull. This was due to time constraints to make the necessary patch test at the time of the survey and also doubt as to its likely data quality improvement given the calm sea-state conditions.

During the processing of the Kick-em Jenny survey it was discovered that the EM710 transducers have been installed the wrong way around! This was realised when trying to apply a new SVP to a CARIS project used by the Science Party at Imperial College London to process EM710 collected during JC133. This was confirmed by Mark Maltby by looking into the original Kongsberg commissioning report. It is not helpful that there are many versions of the vessel config file on the ship system – all of which we believe are wrong. We solved the problem with a clean install of the CARIS software on a new laptop.

A calibration patch test was performed for the EM710 on 12/5/17 using the geometry shown in Figure 13. The ship was sailed in reverse directions up a slope and across an area of relatively flat seabed. Results obtained were insignificant from those obtained during the patch test made on JC133

The system was operated without the drop keel throughout. The calibration results were:

Roll error = -0.14; Pitch error = -1.14; Navigation timing = -0.87

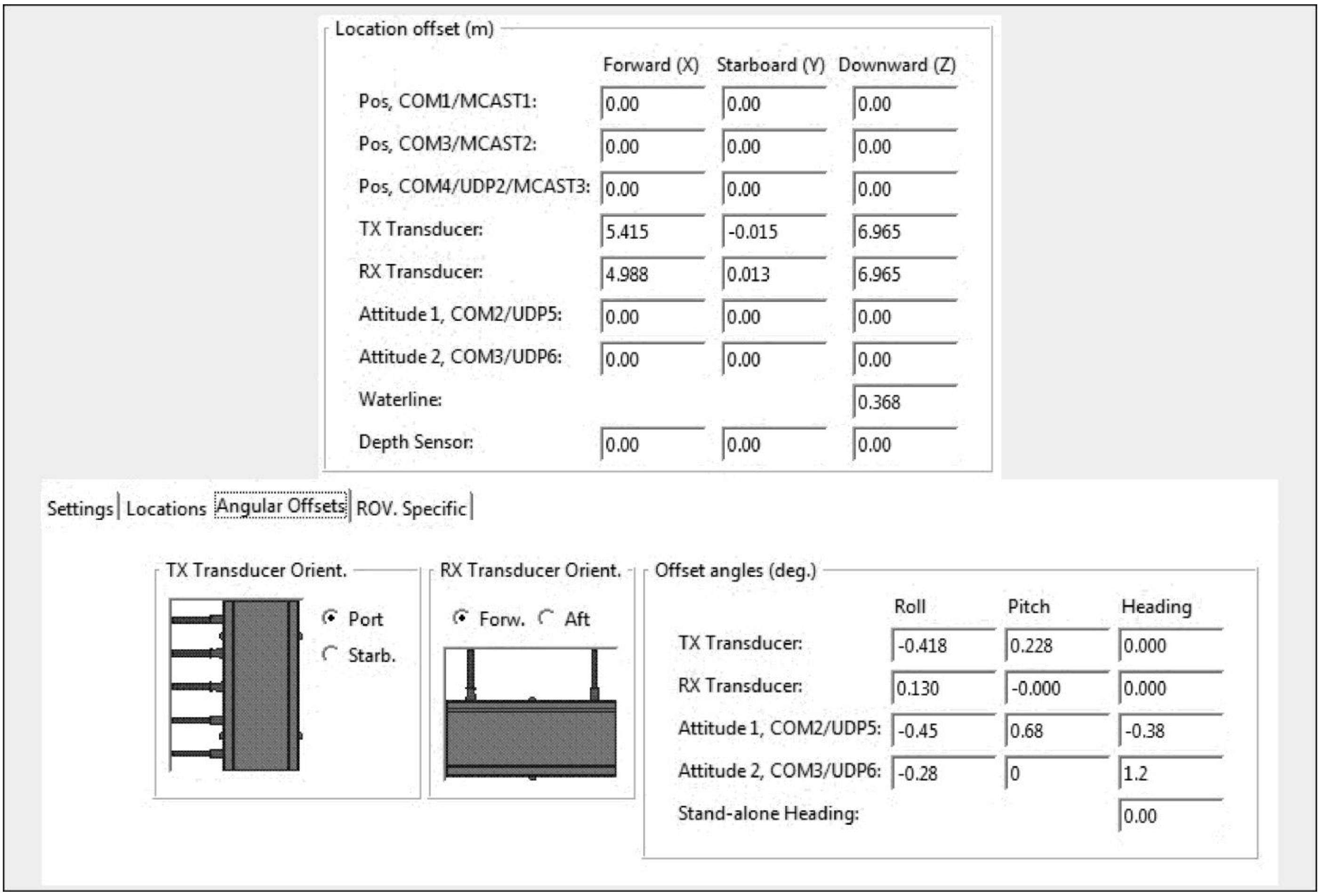


Figure 23 EM710 Transducer offsets

6.1.7.3 Processing

Profiles were recorded in 30 minute segments on the SIS v 4.1.5 interface and archived in .all binary format (water depth and backscatter). The EM120 data collected during JC149 were combined with the JC133 CARIS project (Figure 24).

Bathymetry data processing was carried out using Caris HIPS software version 9.1 in UTM zone 20N. Firstly, sound velocity corrections were calculated using the recorded velocity profiles nearest in distance to the swath. Next, spurious points were removed by eye from the attitude, navigation and bathymetric data. Next, total propagated uncertainty (TPU) was derived from the combination of all individual error sources and a final manual edit of data points completed. Tidal corrections were not applied as the range in the area surveyed is less than 0.5m. No changes to the configuration files for the EM120 processing were made, so the .hvf vessel file established during JC109 (October 2014) was used. Surfaces gridded at 100-30m and 5-3m were produced for the EM120 and EM710 respectively, and exported as ASCII xyz files for import into IVS Fledermaus, arcgis and gmt software.

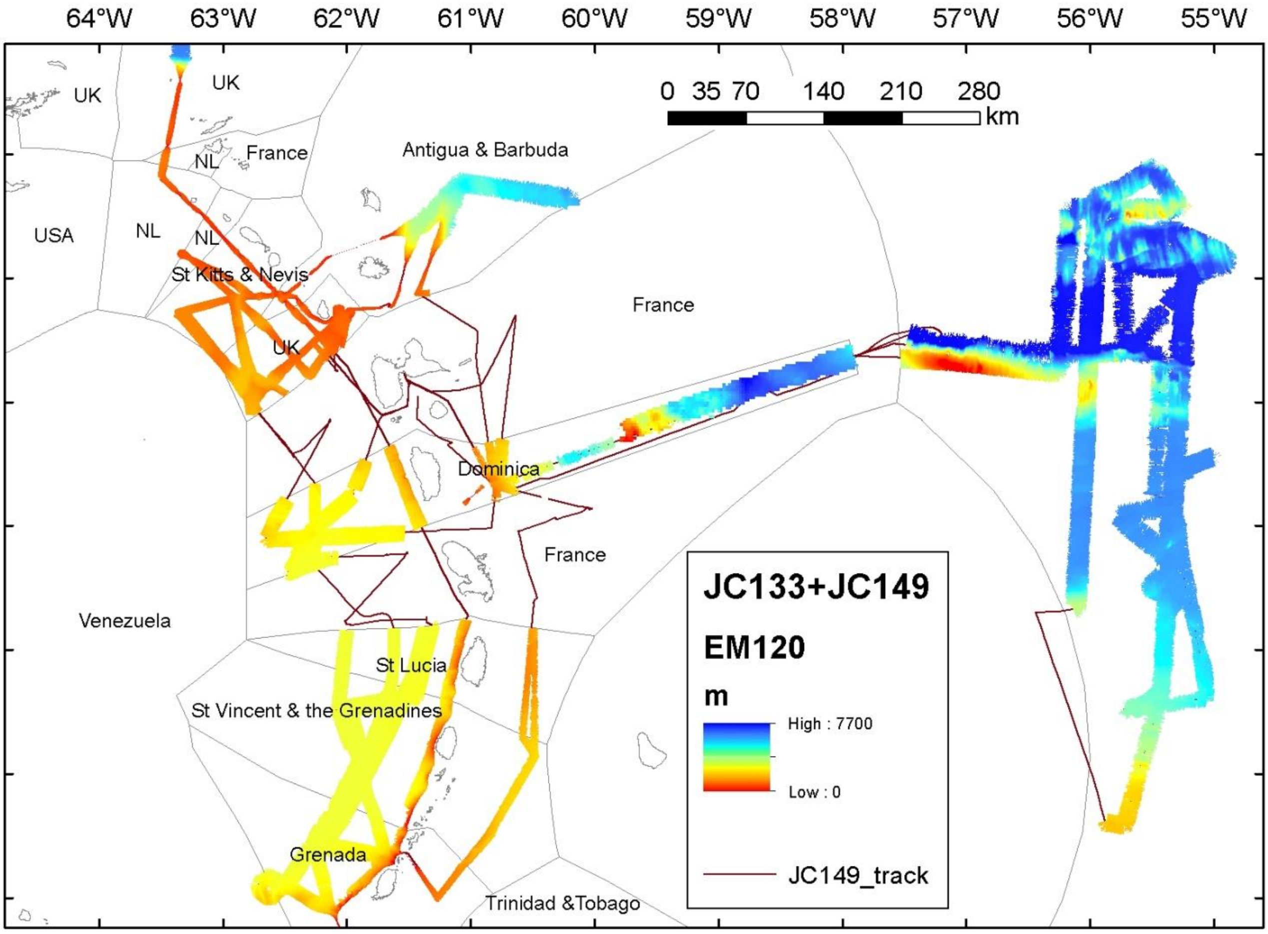


Figure 24 Final EM120 MBES grid collected during the two VOILA cruises (JC133 and JC149). No MBES data were collected within French or Barbados territorial waters.

6.1.8 EK60

This system was used during the survey of Kick 'em Jenny to record the water column at a range of frequencies. The data were imported into IVS Fledermaus to combine with the EM710 data. Unfortunately there was found to be a time stamp mis-match with ship navigation – shown by the KeJ plume being in the wrong place. Further investigation showed that the time stamp was from the acquisition pc clock rather than the primary GPS clock (hence approx. 4

mins difference). Also whilst it was recording attitude it was also not recording GPS position. This makes the data unusable at sea, and will require careful post-processing to correct.

6.2 Water sound velocity profiles (SVP & XBT)

A total of 3 water column sound velocity profiles using a retrievable Valeport Midas SN 22355 SVP sensor and 5 expendable bathythermographs XBT-T5 casts were made (Table 9). The onboard XBT hardware had been repaired since its failure on JC133 and performed without incident.

Ref	Type	Date	JD	Start time (UTC)	Water depth (m)	Longitude			Latitude			ID	Comment
						Deg	Min	DD	Deg	Min	DD		
XBT1	XBT-T5	27/04/2017	117	21:23:00	2957	62	12.38	-62.206	11	56.22	11.937	JC149_T5_0001	
XBT2	XBT-T5	06/05/2017	126	20:11:00	2466	61	59.34	-61.989	14	12.30	14.205	JC149_T5_0002	
XBT3	XBT-T5	08/05/2017	128	07:07:00	278	61	38.27	-61.638	12	18.04	12.301	JC149_T5_0003	KeJ crater
SVP1	SVP	10/05/2017	129	21:59:01	969	60	1.54	-60.026	15	8.44	15.141	JC149_129_23	DEPAS Releaser test
SVP2	SVP	14/05/2017	134	20:06:31	3535	60	38.05	-60.634	16	42.02	16.700	JC149_134_21	DEPAS Releaser test
SVP3	SVP	27/05/2017	147	09:37:35	3891	57	54.384	-57.906	16	22.08	16.368	JC149_147_11	DEPAS Releaser test
XBT4	XBT-T5	30/05/2017	150	20:29:00	5200	54	58.13	-54.969	17	4.30	17.072	JC149_T5_0004	
XBT5	XBT-T5	14/06/2017	165	13:40:00	5111	55	26.154	-55.4359	13	37.082	13.61803	JC149_T5_0005	

Table 9 Location and time of sound velocity dips made. The positions are shown on a map in Figure 23

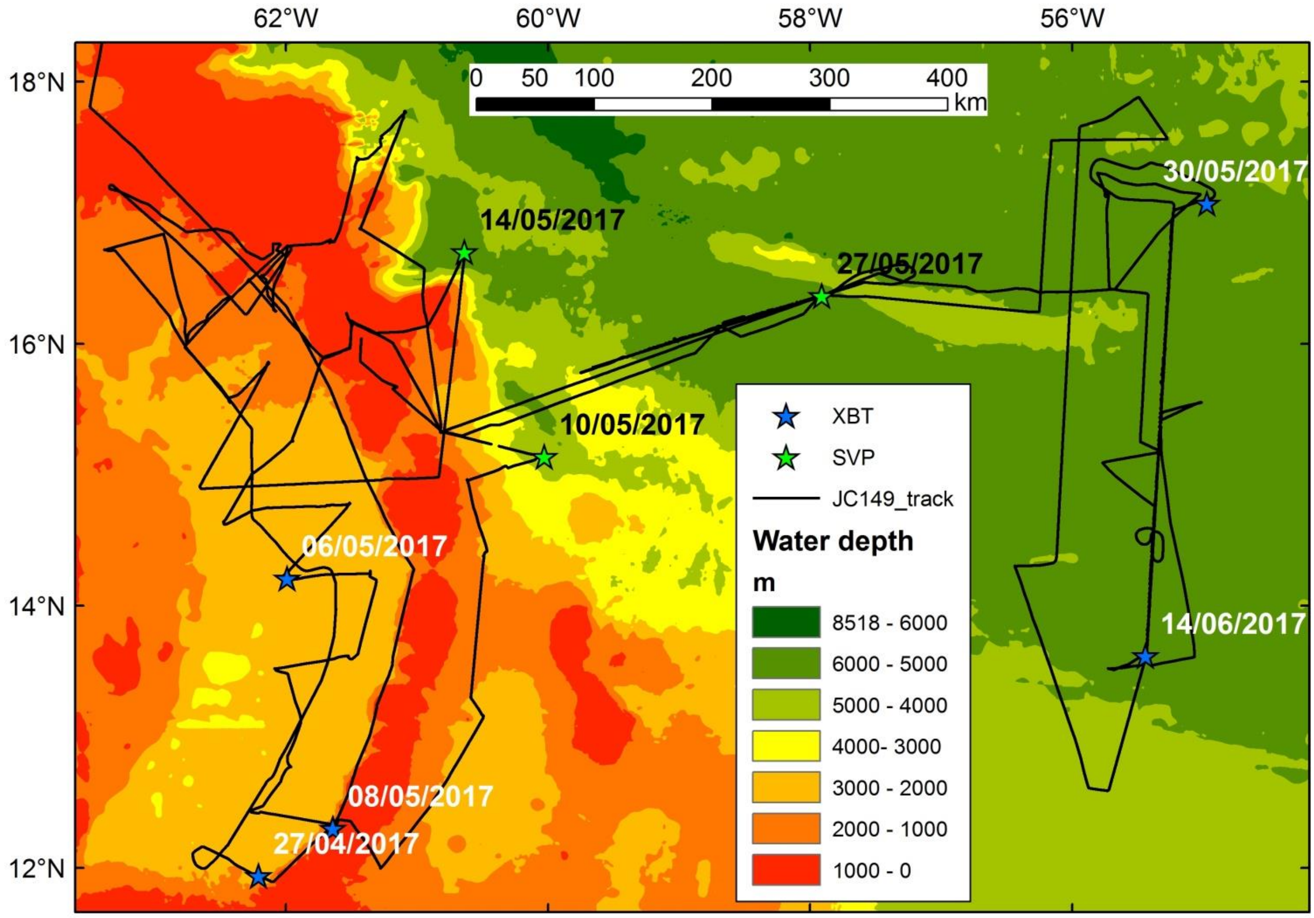


Figure 25 Location of water column sound velocity probe (SVP) dips and XBT casts. The profiles are referenced by their calendar date in dy/mn/yr.

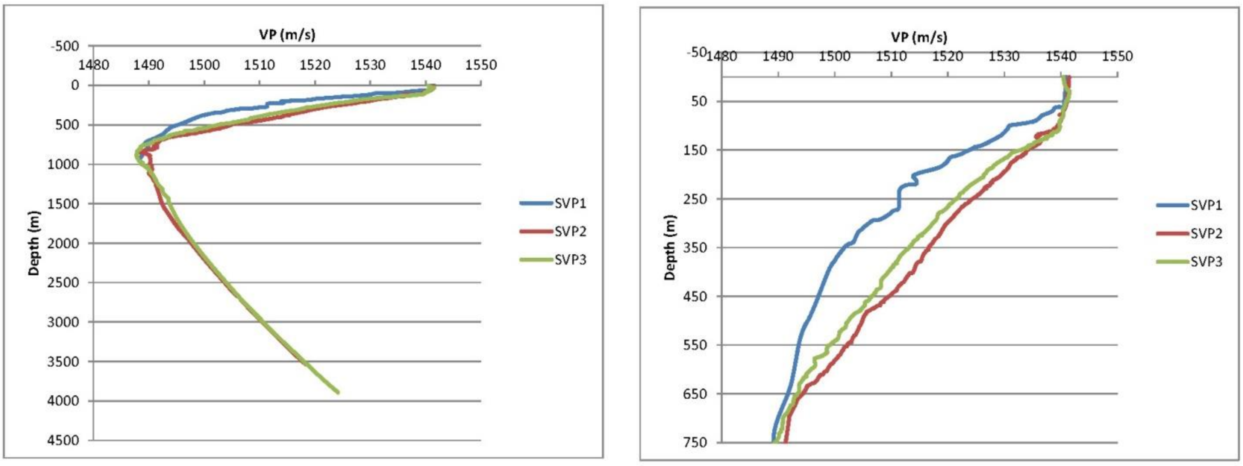


Figure 26 Sound Velocity Probe results. The dips are referenced by their calendar date in dymn.

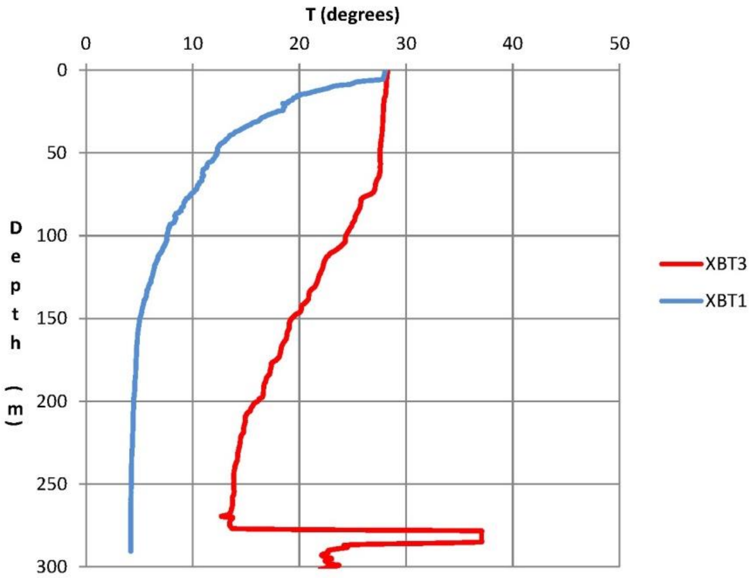


Figure 27 Comparison of the water column sound-velocity-depth profiles from open water within the Grenada Basin (XBT1) and within the KeJ crater (XBT3)

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6.3 Magnetometer (Seaspy 2)

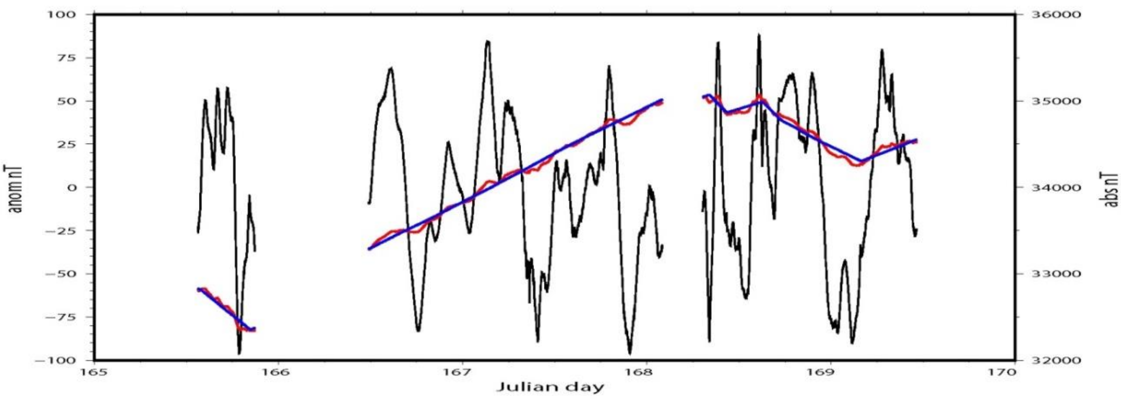


Figure 28 Example of processed ship track magnetics. The black line is the magnetic anomaly (LHS y-axis) and the red line is the observed total magnetic field and the blue line the IGRF12 (RHS y-axis).

Total magnetic field strength was measured with a SeaSPY2 sensor (Marine Magnetics S/N:14043). The sensor was deployed during all MCS profile collection, on some of the longer (> 3 hour) transits between BBOBS and in some dedicated surveys. In total there were 27 deployments/file exports (between JD109 to JD168).The sensor was towed 273 m behind the ship from the port side. The total layback from the ship's navigation reference point was 304 m (Figure 7). The instrument contains a pressure sensor which showed it typically towed at 5-7 m depth. Deployment and recovery used a small electronic winch and typically took 30 mins to wind out/in. The data were recorded on Marine Magnetics BOB software (Version 2.15.3.11). New survey databases were created for each survey/line.

At the end of each profile "BOB" was shut down before sensor recovery and the ASCII files containing the measured total field, instrument depth, quality index, time, position (with layback applied) at a 1 Hz sample interval archived. These files were then processed by the science party to compute the magnetic anomaly every 10 s. Processing included filtering and subtracting the 12th generation IGRF (2014 version). An example of the output for five days is shown in Figure 28. A visual comparison of these new data with a grid computed from the historical database is shown in Figure 29. A good general match between the two can be seen. A detailed cross-over error analysis is underway but is beyond the scope of this cruise report.

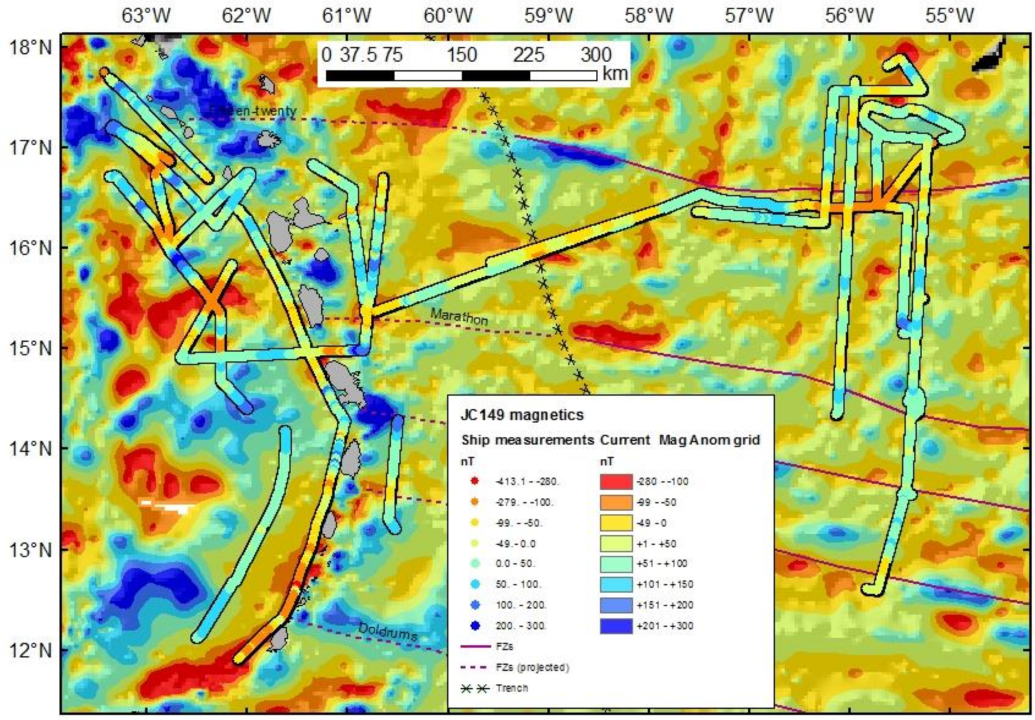


Figure 29 Map showing magnetic anomaly data collected during JC149 plotted on top of a grid of magnetics produced from legacy marine surveys sourced from the US NGDC and European SeaNetData databases. Note that the two datasets have the same plot scale and neither is reduced to the pole.

6.4 Gravimeter

Gravity data were acquired using a Micro-g-Lacoste AirSea-2 gravimeter (Serial number S40), which was mounted on a gyro-stabilised platform. The sensor is comprised of a highly damped invar beam and changes in g were obtained by time-averaging the beam motions to eliminate accelerations caused by ship motion. Basestation measurements were made using a portable Lacoste & Romberg Model G (Serial number G-484). It was not ideal that the mobilisation island did not have a gravity basestation and so this had to be made on a neighbouring island during the previous cruise. We were fortunate that this was possible; however it does not make Freeport and ideal location to start any geophysics cruise.

Stage of JC149	Tie	Lat/Lon	IGSN-71 #	JD	Date/UTC time of S40 reading	S40 Reading (cu)	g at s40 (mGal)
End of JC145	Nassau, Prince George Wharf1	25 04.77'N, 77 20.60'W	101.01	86	27/03/2017 22:44:00	16419.9	979014.5712
End of JC145	Nassau, Prince George Wharf2	22 04.75'N, 77 20.44'W	101.02	86	27/03/2017 22:44:00	16419.9	979014.3675
	Mean						979014.4693
End of Leg1	Point-a-Pitre, l'Université des Antilles et de la Guyane	16.223401N 61.530155W	9712002	123	03/05/2017 19:46:00	15951	978548.0571
Start of Leg 2 (post instrument reset)	Point-a-Pitre, l'Université des Antilles et de la Guyane	16.223401N 61.530155W	9712002	124	04/05/2017 18:08:00	7122.3	978547.8794
End of Leg3	Point-a-Pitre, l'Université des Antilles et de la Guyane	16.223401N 61.530155W	9712002	171	20/06/2017 18:04:00	7120.4	978545.4572

DRIFT during Leg1

g(Nassau) – g(P-a-P)	466.412	mGal		
According to meter:				
g(Nassau) – g(P-a-P)	468.900	cu		
	465.008	mGal		
Apparent meter drift	-1.404	mGal in	36.9	days
	-0.038	**mGal/day**		

S40 meter constant 0.9917

NB Metre reset between 03/04 May 2017

Previous tie:
Santa Cruz de Tenerife, TENE-CHIP, 26/02/2017

DRIFT during Leg2 and 3

g(P-a-P) – g(P-a-P)	2.422	mGal		
According to meter:				
g(P-a-P) – g(P-a-P)	1.900	cu		
	1.884	mGal		
Apparent meter drift	-0.538	mGal in	47.0	days
	-0.011	**mGal/day**		

Table 10 Gravimeter ties and calculated drift

On arrival at Freeport it was found that the Spring Tension (ST) mechanical reading did not match the software ST. After some investigation it was decided that this only caused an offset. Therefore so as not to lose the basestation tie in the software ST wasn't changed and the difference was monitored to check for drift. The difference remained constant at 8828cu throughout Leg 1.

Following the first leg the meter was tied in at Pointe-a-Pitre, Guadeloupe IGSN71 (3/5/2017) then the software ST and mechanical ST were synchronised and full port checks were undertaken (4/5/2017) due to concerns with the meter's data quality. The port checks found the following:

Initial Beam Zero = 6.93, Clamped -0.055v
Initial Beam Gain = 18.03, top stop 4.852v
Revised Beam Zero = 6.76, Clamped 0.000v
Revised Beam Gain 18.95, top stop 4.999v

Then the beam scale factor was checked:

SR = 7122.0
ST_0=7121 TC_0 =1.4
ST_{+50}=7170.9 TC_1=-47.9
ST_{-50}=7071.1 TC_2=52

The meter was then re tied in at Pointe-a-Pitre, Guadeloupe IGSN71

At the conclusion of Leg 3 a tie in was performed on20/6/2017 (JD 171). This was completed at the same basestation in as before: at the Universite Laboratoire de Biologie Marine in Pointe-a-Pitre (IGSN71 – 9712002). Details of the basestations and ties are given in Appendix D.

No further changes to the Beam Gain/Zero were made during the transitional Leg2-3 port call (15^{th}-17^{th} May) or at any point during Leg3.

The quality of the recorded gravity data remains a concern. As an example, figure 30 shows a comparison of the flutter obtained when the ship was moving to when it was stationary.

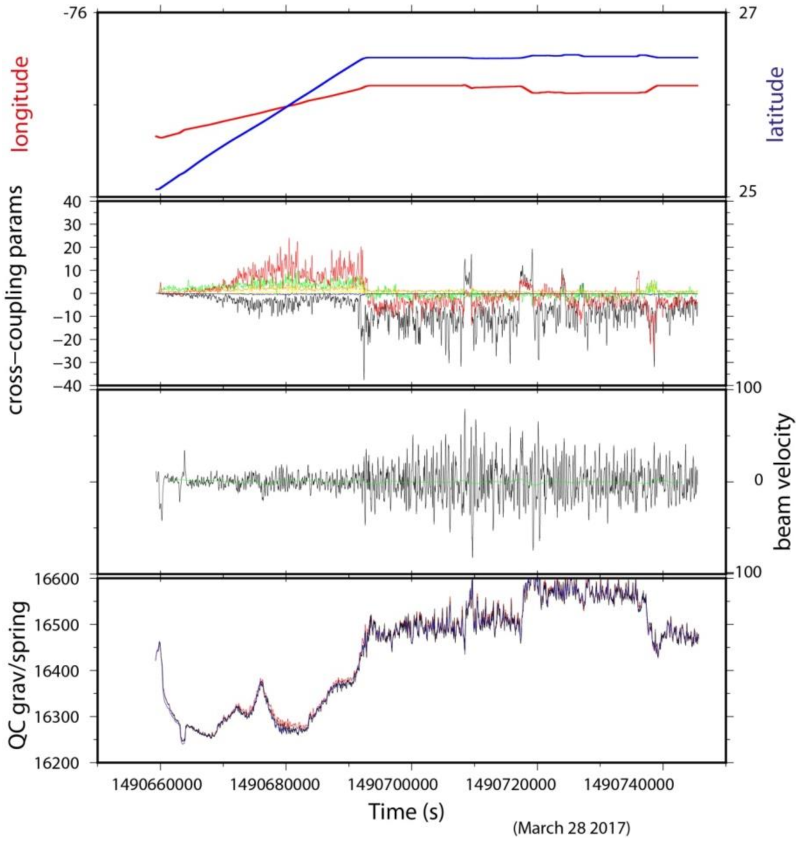


Figure 30 Gravity time series showing noise ("flutter") recorded during March 28.

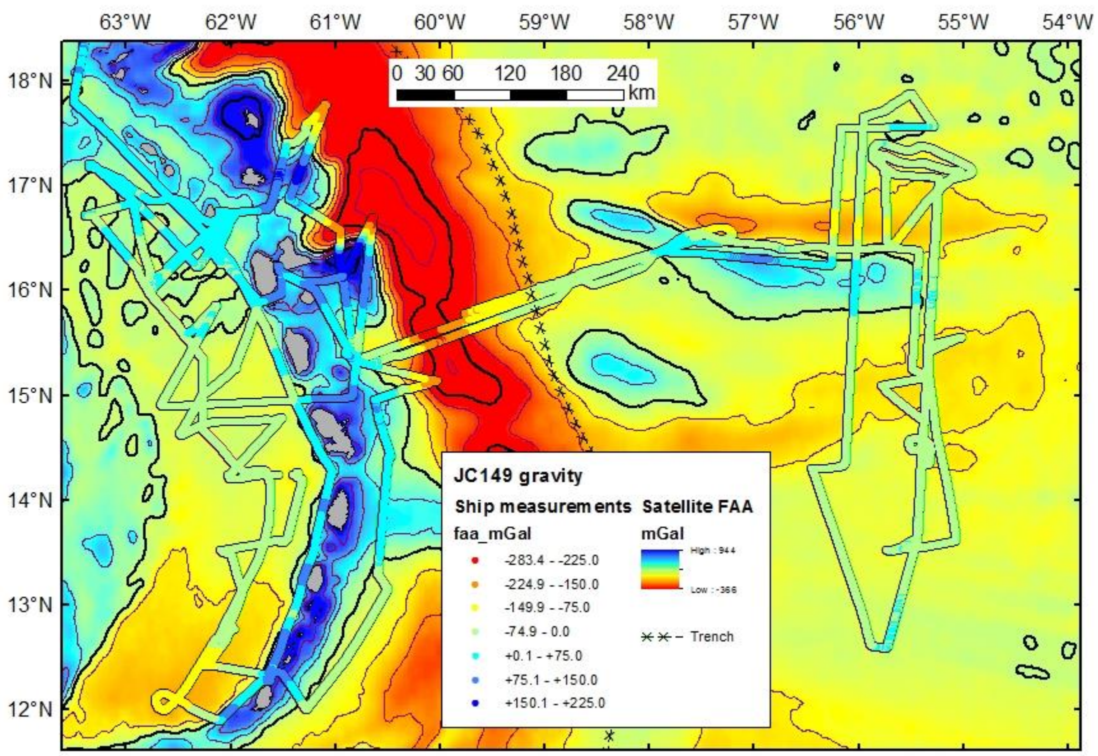


Figure 31 Comparison of preliminarily processed gravity data from JC149 against the v23.1 satellite altimetry grid from Dave Sandwell.

6.5 BBOBS

All 24 of the DEPAS BBOBS deployed in March 2016 during JC133 were recovered without incident. All were shown to have recorded excellent data. At the time of deployment there was uncertainty as to whether the data logger batteries would last for 15 months (only experience for 12 month deployments were available) but on recovery all data loggers were still running and the instruments did record the active shots from Leg 1. This was therefore a great bonus to the project.

All 10 SIO BBOBS deployed in March 2016 during JC133 were recovered without incident. However only 8 instruments recorded useable data, again including the Leg 1 active shots. The following problems occurred:

- SIO 20 FPGA (card between the digitiser and the data logger) reset on deck before deployment. Instrument therefore did not record any data. According to SIO this event had not be seen before, and it was thought to be possibly due to a battery power surge due to a poor connector within the instrument.

- SIO 29 Sensor ball did not deploy onto the seabed. This was due to a problem discovered during JC133 and the R/V Langseth (PiLab) deployment cruises – new batch of Mg releases failed during assembly on deck – causing sensor ball to (dangerously) release before deployment. This first happened during deployment of OBS 26, and so for the last 3 OBS deployments (OBS26, OBS29 and OBS33) added additional securing wires (to corrode after deployment and so release ball). The other 2 worked (OBS26 and OBS33) and the ball was deployed. However for this OBS 2 of the 3 wires did not corrode or break. The FPGA also seems to have reset and the battery was very low (probably due to heavy power use as the sensor ball swung and was corrected for). No data was recovered.

In addition failure of the seismometer on instrument DEPAS21 during the final 3 deployment months means that only useable hydrophone data from the shots of leg1 was collected from this location. DEPAS21 worked well during the first year and recorded high quality earthquake data. Overall the 94% data recovery (99% DEPAS, 80% SIO) is excellent given the length of the deployment and battery life of the instruments. The final distribution of BBOBS data is shown in Figure 32.

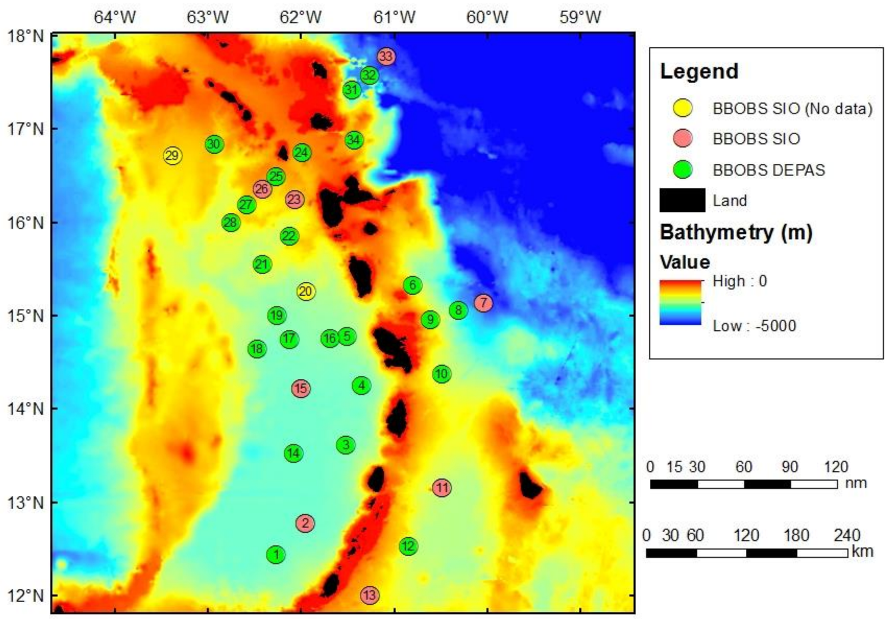


Figure 32 Broad-band OBS locations by instrument type and station number. All instruments were recovered; two did not record any data (coloured yellow).

The data recorded are being used for four types of analysis: (1) active source shots to determine local crustal structure (2) recordings of distant earthquakes to determine crustal and mantle structure (3) recording of the ambient noise to infer crustal and mantle structure and (4) recordings of local earthquakes to infer crustal and mantle structure and importantly to improve the understanding of hazards. Examples of the data collected for these aims are shown in Figures 33-35.

6.5.1 BBOBS recording of active shots

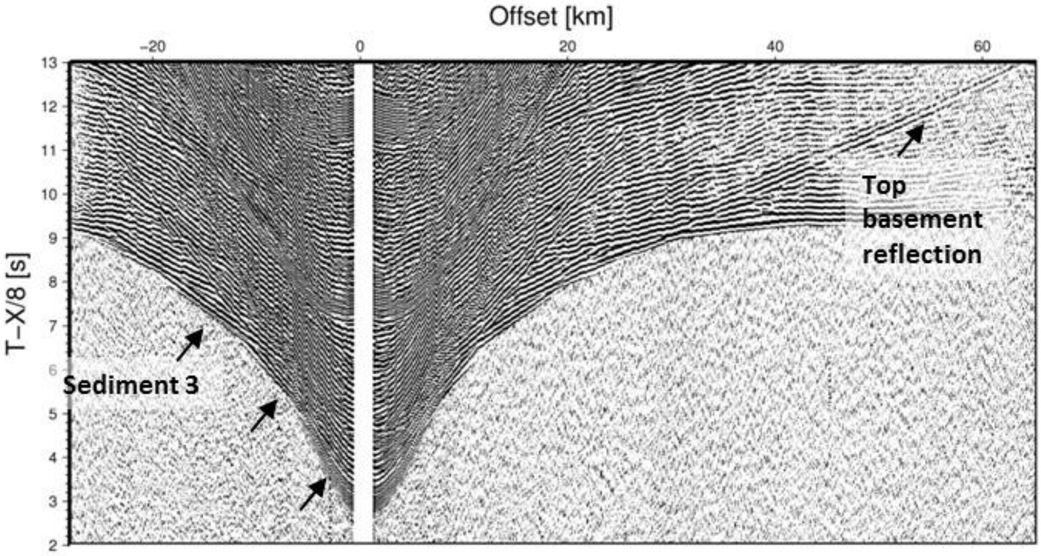


Figure 33 Example of BBOBS data recording of active shots made during Leg 1. The section is reduced at 8 km/s.

The data quality on the instruments recovered was generally high. This is particularly true in the south of the arc, where the flat seafloor and lack of major crustal structures appears to have been ideal for the recording of these data. On the southern instruments in the back-arc (e.g. DEPAS01 and SI02) compressional arrivals are clearly visible from multiple different sedimentary packages, crust and mantle (generally up to offsets of 60-70 km). Further offsets would likely have been pickable on a number of the instruments; however these were often limited by the length of the active lines. The inability to continue shooting through the waters of Martinique and Guadeloupe was particularly damaging in this regard.

In the north of the back-arc there is a deterioration in the quality of the data recorded, particularly over line 8. By this point in the shoot the failure of several of the airguns coupled with a much more uneven seabed and a thicker, more variable crustal structure, means that only the sediment and upper crustal arrivals are easily picked, with arrivals from the lower crust and mantle rarely recorded.

6.5.2 BBOBS recording of earthquakes

The BBOBS passive recording data quality was checked by looking for earthquakes with known locations (at regional and teleseismic distances) that occurred during the deployment period. Figure 34 shows examples of waveform recordings from regional earthquakes occurring within the Lesser Antilles region and Figure 35 shows recordings from a magnitude 6.7 earthquake in Chile. These examples demonstrate the excellent performance of the BBOBS during the deployment period, both at relatively low and high frequencies.

Noise performance of the BBOBS was analysed by assessing the probability density functions (PDF) of power spectral density estimates (PSD) from continuous seismic waveform data. For SIO instruments the analysis was carried out on board as preliminary sensor instrument response metadata files were only available for these sensors. A complete noise performance analysis has now been carried out for the whole data set using finalised instrument response files. Examples of the resulting PDF plots are shown in Appendix E. Overall, the noise performance of the OBS stations is excellent, with the vertical components of most instruments lying between the USGS New Low Noise

Model and New High Noise Model reference curves. The noise performance of both instrument types is comparable with permanent land station installations. While water depth seems to play a role a more complicated distribution of noise level is emerging and will be investigated. The noise level on the horizontal components is higher than that of the vertical; this is to be expected since the horizontal components are more susceptible to currents, infra-gravity and tilt-inducing noise in the ocean. The excellent performance of both instrument types will enable us to use high resolution seismic analysis tools that have been thought not applicable for OBS recording setting due to poor recording conditions.

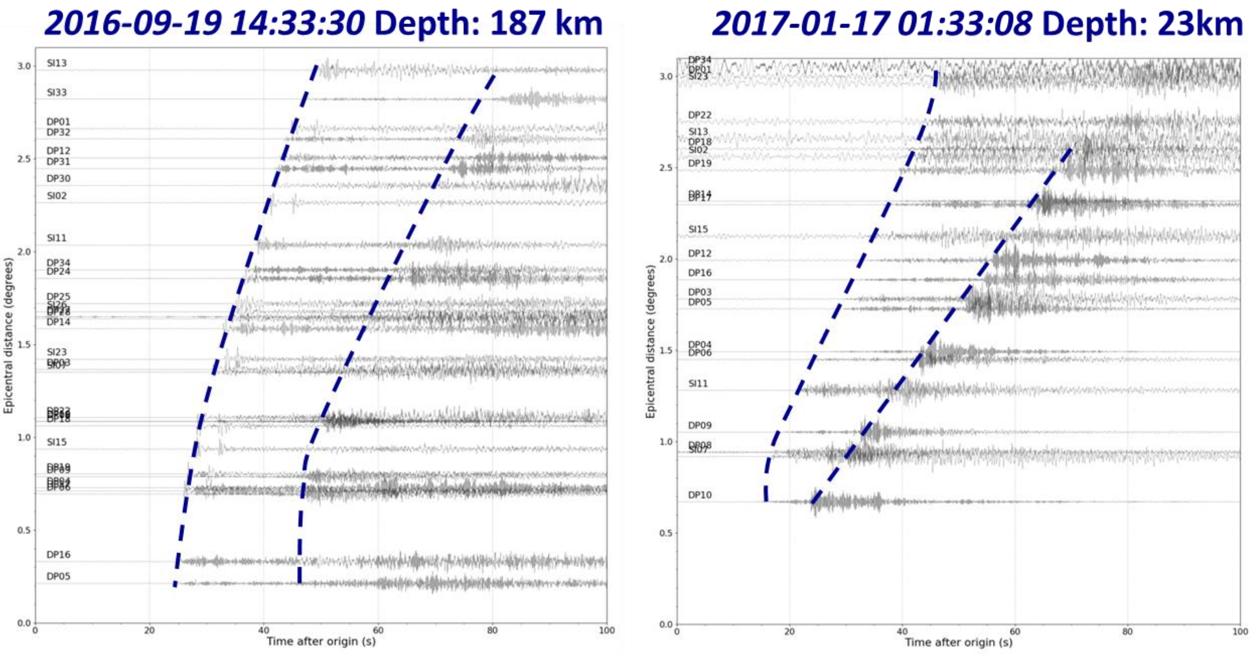


Figure 34 Record sections of two examples of local earthquakes recorded by the BBOBS. The approximate arrivals of P- and S-waves are given by the blue dashed lines.

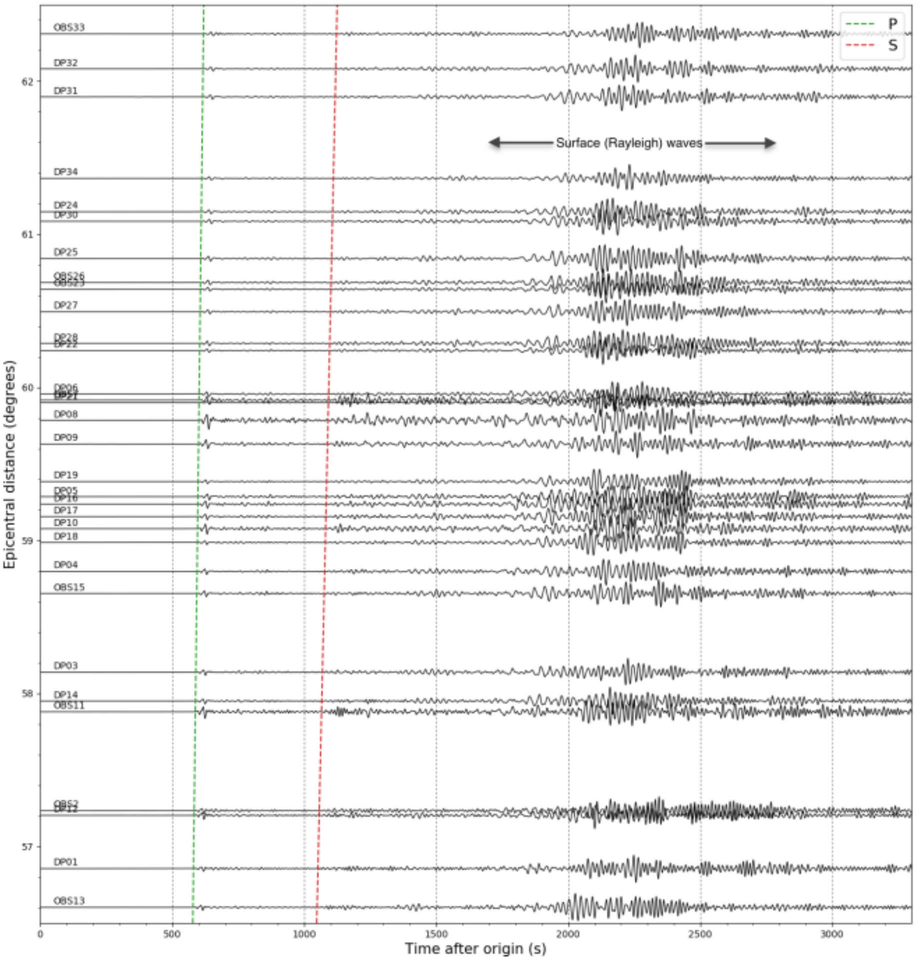


Figure 35 Record sections of a teleseismic earthquake (Apr. 2017 M6.7 Valparaiso earthquake, Chile) recorded by the BBOBS. The approximate arrivals of P- and S-waves are given by the green and red dashed lines, respectively.

Further advanced seismological analysis is ongoing at the time of writing this report. Receiver functions are being calculated from teleseismic earthquakes to try and determine the geometry of the main crust and mantle domains of the Lesser Antilles region. In addition, a new local catalogue of earthquakes is being assembled. So far, 400+ earthquakes occurring within the Lesser Antilles subduction zone have been accurately located and small events are being detected in regions previously thought to be aseismic. A more detailed noise analysis is underway to also investigate the reason for spurious transient high and low frequency signals being recorded mainly in the northern part of the deployment area.

6.6 SPOBS and BBOBS (active acquisition)

Of the 136 SPOBS deployed during Leg 3 of JC149, only OBIC instruments 101 and 125 were not successfully recovered from the seafloor, giving an instrument recovery rate of 99%. Three of the recovered instruments yielded no, or limited, data due to the following reasons:

- DEPAS instruments 219 and 249 failed before shooting began due to pressure implosions of the seismometer housing.
- OBIC instrument 224 returned only hydrophone data, due to a failure of the instruments geophone.

Overall, data was obtained from 97% of the OBS, which is an excellent recovery rate for such a deployment. The recorded seismic receiver gather data (e.g. Figure 36) are generally of a very high quality. Compressional waves from the upper mantle (Pn) are detectable on both the vertical geophone and the hydrophone to around 80-100 km of offset on most instruments, while some instruments show excellent signal to offsets of 120-160 km or more. Shear wave energy (from the crust and mantle, Sg and Sn) can be identified on all instrument components, particularly on instruments deployed over areas of uniform oceanic crust (line 3). Typically, these shear arrivals are weaker and more limited in their identifiable offsets, when compared to the compressional arrivals. The horizontal geophone components of the SPOBS are generally much noisier than that of the hydrophone and vertical geophone, but still exhibit identifiable signal out to 80-120 km. Tidal noise is observed on several of the instruments, particularly those deployed along line 3, which diminishes the offsets to which seismic arrivals can be confidently identified.

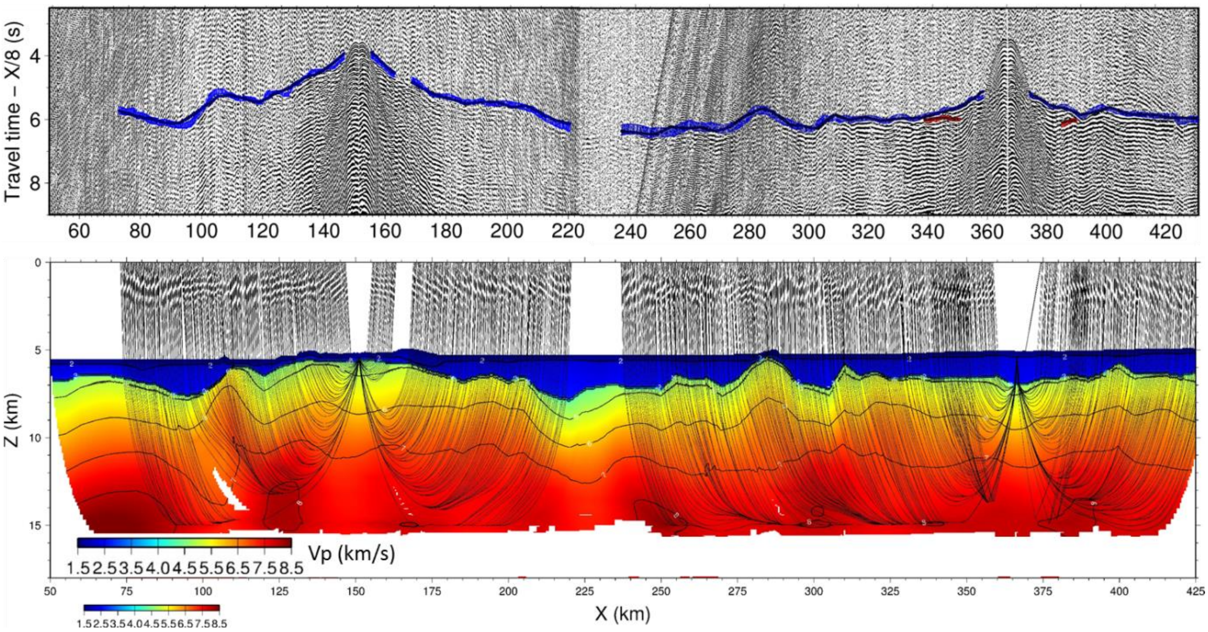


Figure 36 Example of two vertical-component OBS recordings from Leg 3 Line 2/3 together with a preliminary ray-traced velocity model. First arrivals out to ~120 km range can clearly been seen on both record sections.

A full analysis of the data quality of the 136 OBS recordings made is given in Appendix B.

6.7 MCS

For JC149 a new set of pressure and depth sensors had been bought by NMF to monitor the Bolt airgun performance. Data from these sensors could be downloaded after the airgun system was recovered and de-pressurised.

An example of the output from the airgun beam sensors is given in Table 11. As can be seen there were 8 sensors in total, with one at the front and back of each metal beam. These data were analysed by the science party by putting all recorded values in 0.2 m bins and plotting as histograms (Figure 37).

11:35:23	04/24/17	100	7.8	7.1	7.3	6.8	6.9	6.6	7.8	6.9
11:36:23	04/24/17	101	8.0	7.1	7.4	6.8	7.4	7.1	8.3	7.4
11:37:23	04/24/17	102	7.6	6.9	7.1	6.4	6.8	6.6	7.9	7.1
11:38:23	04/24/17	103	8.0	7.0	7.3	6.5	7.0	6.8	8.0	7.1
11:39:23	04/24/17	104	7.9	6.9	7.4	6.5	7.1	6.8	8.0	7.2
11:40:24	04/24/17	105	8.2	7.3	7.8	7.2	7.4	7.1	8.2	7.5
11:41:24	04/24/17	106	7.5	6.6	7.3	6.5	7.1	6.9	8.2	7.4
11:42:24	04/24/17	107	8.0	7.3	7.7	7.0	7.2	6.9	8.0	7.2
11:43:24	04/24/17	108	8.0	7.3	7.3	6.8	7.3	7.0	8.0	7.3
11:44:24	04/24/17	109	8.2	7.1	7.7	7.0	7.3	6.9	8.1	7.3
11:45:24	04/24/17	110	7.9	7.1	7.5	7.0	7.3	7.0	8.3	7.5
11:46:24	04/24/17	111	8.0	6.9	7.7	6.8	7.1	6.9	8.1	7.3
11:47:24	04/24/17	112	7.9	7.1	7.5	6.6	7.3	7.1	7.8	7.1
11:48:24	04/24/17	113	7.9	7.0	7.5	7.0	7.6	7.5	8.3	7.5
11:49:24	04/24/17	114	7.9	6.9	7.3	6.6	7.3	7.0	8.0	7.3

Table 11 Example airgun beam depth sensor ascii output.

In this example the difference in tow characteristics between having a single buoy at the back (Starboard beams) or one at the front and one at the back (Port beams) can be seen. These data were extremely valuable in making the decision to use a single buoy tow for the rest of the cruise.

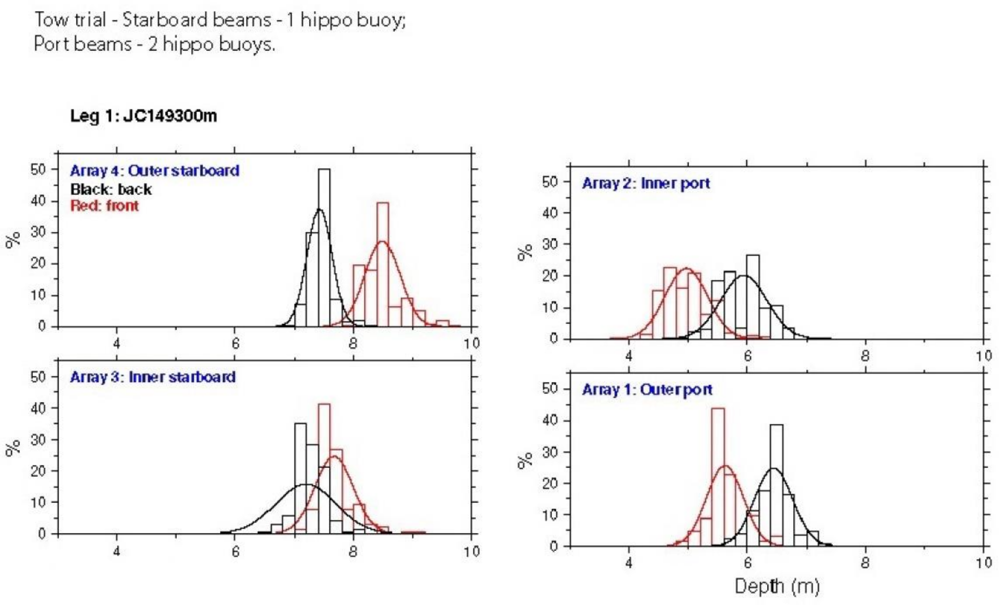


Figure 37 Gun tow depth trials (JD 111). Individual depth values are binned into 0.2 m intervals. Note how the tow of the two starboard beams is more even and closer to the specified 8 m depth.

In terms of monitoring the positions of the beams, in an ideal world it would also be possible to track their lateral locations. A stable source wavelet that is produced by every shot being generated by guns in identical positions is a founding principal of the seismic reflection method. Currently there is thought to be excessive motions in the beams laterally – partially caused by them towing through the wake generated by the dual propellers of the *Cook* - as well as vertical motion of individual guns, but this cannot be quantified at present. Similarly there is no control or monitoring of the position of the single gun towed from the wire amidships.

An example of the air supply pressure QC plot generated during the cruise is shown in Figure 38. In this case there was a 60 s pressure gauge sample rate and a 60 s firing interval. Note that the apparent gradual drop-off in gun pressure from the desired 2000 psi to ~1750 psi on a ~10 hour cycle is an aliasing effect due to clock drift. However it demonstrates that for significant periods of time there is <2000 psi within the system. Runs with 1 s or 5 s pressure gauge sampling showed the pressure is only reaching this target just before the shot. It was thought that the pressure in the air system should rise to the target pressure within ~5-10 s after the previous shot if the air handling is working effectively. This probable deficiency should be investigated further.

In terms of overall performance, the 4 containerised Hamworthy compressors performed well, with no significant failures apart from when the seawater cooling was lost.

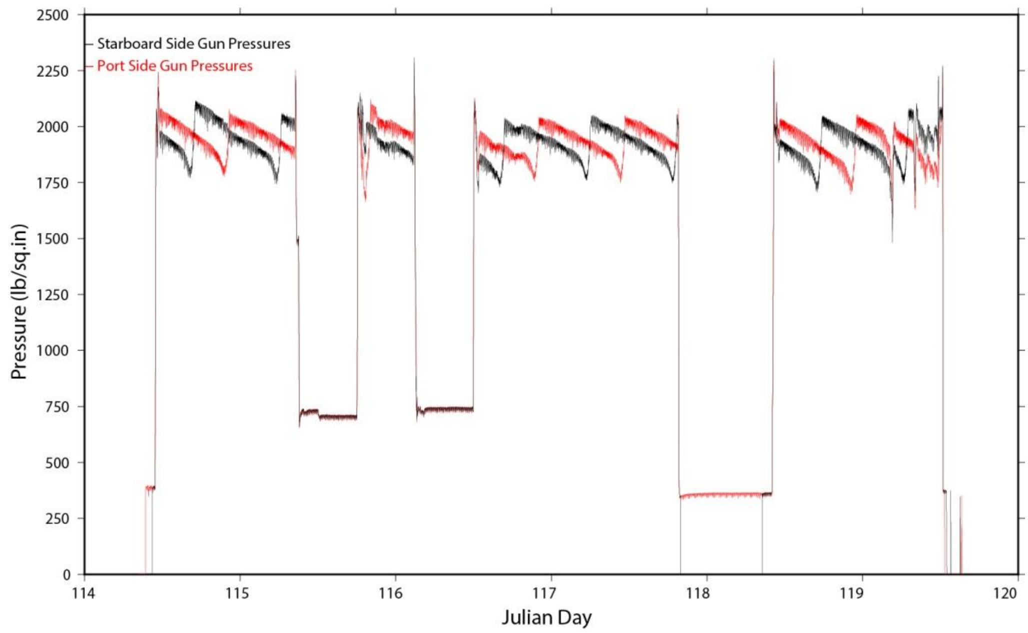
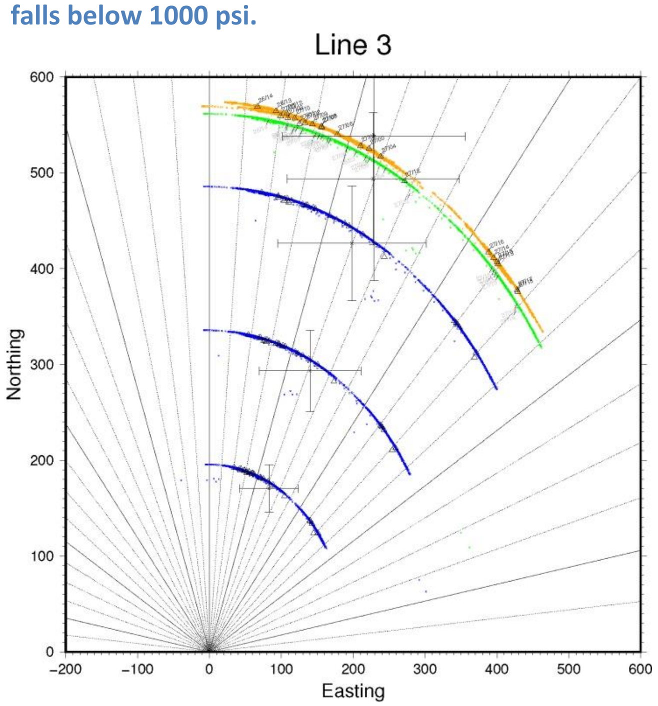


Figure 38 Measured gun pressures during Leg 1 lines 1-4 (60 s shot intervals, 60 s pressure gauge sampling). The system is designed to operate at 2000 psi. During periods between lines when there was no shooting the pressure falls below 1000 psi.



A final example of QC at sea is shown in Figure 39 where the compass and tailbuoy GPS logging was compared. As can be seen there is a sensible relationship between the two, suggesting good performance of these systems.

Future work will investigate more fully the characteristics of the recorded wavefield from the streamer, vertical array and OBS.

Figure 39 Positions of the three birds (blue) and tailbuoy (green and orange) relative to the ship's GPS position during the collection of Leg1-Line 3 (300 m streamer).

6.8 Seismic shot timing and positions

Seismic shots were both triggered from, and logged by, GPS clocks provided by OBIF. An initial trigger on exact seconds was sent from the GPS clock to the Bigshot gun controller. The gun controller was configured to fire the guns in the array synchronously at 50 ms after the trigger. The shot aim point pulse was then used to trigger the Seal recording system, and also linked back to the GPS clock, with that time logged in a text file. The position of the GPS clock antenna (rail above the rear starboard quarter of the hangar) was also recorded at each shot, and the shooting in Leg 1 reports these positions. Shot positions for the OBS records during Leg 3 were determined by interpolating the ship primary navigation system at these shot times. Shot times for the MCS are output into the Seal logs; however for part of the cruise these show an offset of 18 s from the GPS times; this may be that the system was logging time of the end of record, or alternatively that one system configuration was set to ignore leap seconds on the GPS clock.

7 Recommendations

7.1 Scheduling and manning

Scheduling of our cruise was a major concern. We waited 3 years from funding to sailing which caused significant tensions within our NERC Large grant project. This delay was due to a backlog of active source seismic cruises and the desire by NMF to only conduct one per year and the reliance on the *Cook* to mount a full seismic campaign such as this one (the *Discovery* is ruled out due to deck space considerations as the compressors cannot be placed in the hold). These factors combined with a limited time window imposed by the marine mammal breeding and hurricane seasons. The scheduling process was also made difficult as the project had two cruises that had temporal dependencies. It would have been reassuring to have received more recognition of this during the planning stage. In the end we took a gamble by swapping elements of our programme around, and we are fortunate that due to outstanding BBOBS performance this has not compromised our science.

Denial of the **French authorities** to allow us permission to conduct any acoustic work in their territorial waters (Guadeloupe and Martinique) has seriously compromised our science programme. This is especially disappointing as our French colleagues on R/V L'Atalante were given permission during the approximate same time window.

Whilst **deck space** was tight, with help from NMF between legs and co-operation from all onboard we managed to physically manage the 60 OBS units (and in Leg 3, three sets of bottom weights for 50 instruments) around the full MCS equipment installation.

In terms of **equipment provision**, the main item that was requested on the SME and not delivered was a 4.5 km streamer under the CSIC barter scheme. Whilst the new Sentinel 3 km streamer is of high quality and has performed well, not having the 3-4.5 km source-receiver offset range has restricted our ability to image deep crustal structure which was part of the programme.

The **mobilisation** was difficult due to the extremely rough quayside (rough carbonate rock) at Freeport, Bahamas. The island also does not have a gravity basestation. This makes it less than ideal for any geophysical cruise.

The support provided was very good. The approach of hiring contractors from EEL to provide support for the electronics and data recording side is working well. However, there was a **bottleneck in manning** between seismic lines when switching between the two desired airgun arrays. This was because the current design requires the recovery of the entire seismic system to do this which effectively consumed all available working hours in a day. For seismic intensive cruises in the future it would be preferable to allocate 4 people to this team to prevent down-time.

At multiple points in the data stream it is apparent that there is a lack of **standardised approaches**. Different technicians on board approach the same problem in different ways. This makes ongoing QC by visiting scientists more difficult than needed.

7.2 Equipment

Two **ship's infrastructure failures** occurred that were efficiently repaired by the ship's engineering staff:

1) P-frame. The loss of this facility early in Leg 2 which meant that majority of the 34 OBS recoveries had to be made with the less efficient starboard deck crane. However, thanks to the efforts of the engineers to repair the P-frame it was available for the 136 OBS recoveries in Leg 3.

2) Cooling water supply to the compressors. There was a catastrophic failure of the supply of cooling water due to a burst pipe. This was efficiently repaired by the ship's engineers and NMF technicians with a loss of just ~4 hrs of ship time.

The performance of **the EM120 swath bathymetry** is a major concern. Even at slow speeds (5 kn) and under calm sea-states the outer beams are badly affected by interference under the hull. As a result we only achieved an aperture of 60 degrees on a few lines which reduced seabed coverage significantly. The **SV probe** at the sonar was also persistently unreliable even though it is critical for EM120 integrity. Large amounts of time were needed to clean the data within CARIS to produce semi-reasonable grids. On average, the single dongle workstation was in use about 80% of the time by the scientific watchkeeping team. For the worst lines, up to 50% of the individual pings needed to be rejected.

Problems with the data string to the **EK60** were experienced. It turned out that it was only receiving the local PC time and not central GPS time. As a result we were not able to use the data collected as we were unable to change the time-stamping with the software we had in order to co-locate it with the EM710 swath data. Possibly this can be corrected onshore – but will require some effort. Of course, this may limit our ability to analyse the frequency spectra characteristics of the water column bubbles being released from Kick 'em Jenny volcano.

The **SBP-120** hangs often and is unexpectedly affected by a range of ship operations. Negative behaviour did not always correlate with that of other acoustic systems and so was not directly attributable to sea-state.

Both the scientific **GPS navigation systems** running (POS-MV and Seapath) displayed intermittent problems (data spikes) and were switched as the primary source used for various pieces of geophysical equipment. It was not possible to repair or properly investigate the causes of this at sea.

The **S40 gravimeter** is still displaying significant cross-coupling/stabilisation errors under certain sea states. This problem (DC shift and high-frequency flutter w.r.t. the satellite gravity benchmark) was documented in the JC133 cruise report, and despite efforts by NMF staff to have the unit serviced, still appears to be present. Considerable effort was put into trying to trace the problem, but no conclusive results were achieved. We suspect the issue is mechanical and given the unpredictability is possibly two problems interacting. We estimate that just 40% of the gravity data collected will be usable without heavy filtering.

The **airgun system** proved to be more reliable than expected (based on reports from previous seismic experiments). Part of this improvement in performance was achieved by conservative array design (removal of the larger, >500 cu in guns) and part due to the efforts of the NMF team to adapt the air supply configuration. The improvements made to the air supply system between the hoses and guns implemented between Leg 1 and 3 increased the average shots before failure from ~6000 to ~8000 before the air hoses sheared off. In practice on any line up to 2 guns failed due to air supply problems. Because of the current complex airgun deployment system it is not possible to bring in individual strings during acquisition to repair them. This is common practice on all other seismic vessels. Therefore there was no choice but to continue shooting the lines with degraded input source signatures. However we were fortunate not to have major airgun failure which would have required around 24 hours of ship time to rectify. This coupled with excellent BBOBS recoveries that did not require backup clocks resulted in us being able to use the 4-days of contingency we had to collect an additional multi-channel seismic line (Leg 3 –line 4).

It was great to see the acquisition of new gun hydrophones, beam depth sensors and pressure gauges to provide improved QC facilities. After each seismic collection period the science party analysed all these data. These items should be a routine fitment for all seismic cruises, NMF staff should be trained in how to analyse the recorded data and the performance results should be made publically available in **cruise trials reports**. The results from the beam depth sensors were especially helpful and allowed improvements to the towing configuration as a step towards achieving level beams (and hence constructive interference of the ghosts) to be made. In an ideal world it would also be possible to track their lateral locations. A stable source wavelet that is produced by every shot being generated by guns in identical positions is a founding principal of the seismic reflection method. Currently there is thought to be excessive lateral motions in the beams (not helped by the wake generated from the dual propellers of the *Cook*) as well as vertical motion of individual guns, but this cannot be quantified at present.

The status of the **air pressure** within the airgun system was potentially a concern – with long recharge periods between shots detected by the new monitoring system. With short firing intervals there is a danger that pressure would not be reached. This should be further investigated. To do this it would help to invest in a Bluetooth enabled pressure sensor so that the results could be continuously monitored rather than spot recording over 30 minute intervals which can only be checked after shooting.

It should be noted that the equipment to do the GPS **shot logging** needed for OBS recordings was provided by OBIC. NMF should look to replicate this capability. A dedicated Passive Acoustic Monitoring (PAM) system should also be part of the NMEP seismic acquisition system to provide more flexibility by allowing shooting to start at night.

The short (300 m) and long (3000 m) **hydrophone streamer** with 2400 m provided by NMF and 600 m plus spare sections hired from EEL, birds, tailbuoy, gun trigger (Bigshot) and MCS recoding system (SEAL) all performed well. The system towed predictably and no issues were encountered when reconfiguring between the 3000 and 300 m lengths. There were no loss of channels and the bird depth and compasses in general performed without fault. The new **magnetometer** also performed without fault.

Whilst we have no criticisms of the staff operating the current system, **looking forward** the seismic capability of the *Cook* falls far behind that of equivalent multi-purpose (academic) research vessels. The **seismic source array** volume is smaller, the number of guns that can be towed is fewer and the reliability (gun failure and repeatability) is much less than other vessels. The current method of deploying the airguns also severely limits flexibility to gun servicing, which would be an issue in a seismic cruise with greater MCS content than JC149. A reasonable benchmark with the current hardware would be to fire a 14-gun 6000 cu in array at 30 s for 7-10 days continuously. This was achievable on the single-propeller *Darwin* 15 years ago. However, similar academic seismic-enabled vessels in other countries typically have airgun arrays of 8000 cu in made up of ~36 individual chambers. This is clearly desirable to keep the UK competitive going forward.

In the future it would clearly also be desirable to adapt the tow of the guns such they are displaced sideways beyond the wake. This would also give more clearance for the streamer. A change in deployment design to allow single string recovery whilst shooting would also bring the system into the 21st century. A redesign of the airgun recovery and deployment system (which has been implemented on at least 2 vessel cycles) is long overdue. The ability to recover a single string at a time would be essential for larger element arrays. This would not only save sea-time (it typically takes 6 hours to bring just one side of the beams in and the turning of the vessel if the 3000 m streamer is out adds another 4-6 hours) but also relieve pressure-points on NMF manning. Similarly taking the metal beams out of the system (which are thought to be the cause of much of the mechanical damage as the larger guns bounce up and hit them between shots) would not only improve data quality but also reduce ship time allocated for potential gun repairs when planning seismic cruises. Aspiration should also be to operate a 6000 m streamer, as currently done so by the US, French and Spanish academic fleet.

8 Acknowledgements

The cruise was highly successful which was greatly aided by the professionalism of the entire ship's complement. We thank the Captain, John Leask for his direct contribution to the execution of the science. The deck crew are especially acknowledged for their hard work in deploying and recovering the OBS and the Purser, Paula MacDougall and catering staff for looking after us so well. Back onshore, we also thank Colin Day and Matt Tailho for their overall assistance and Jane Thompson for her work on the complex diplomatic clearances (and good humour at all times!).

9 Appendix A: Leg 3 OBS deployment and recovery details

Three tables showing Leg3-Line1, 2 and 3 OBS deployment positions and times (when released over-board) and recovery times (when instrument on deck). DEPAS* means the new KUM NAMU instrument.

10 Appendix B: Leg 3 OBS data QC

11 Appendix C: Ships logging and data formats

12 Appendix D: Gravity basestation ties

13 Appendix E: BBOBS data QC

Probability density functions of power spectral density estimates for each sensor component (BH1, BH2, BHZ) of the SIO BBOBS instruments. Noise reference models of the USGS New Low Noise Model (NLNM) and New High Noise Model (NHNM) are given by the black lines.

Appendix A: Leg 3 OBS deployment and recovery details

Three tables showing Leg3-Line1, 2 and 3 OBS deployment positions and times (when released over-board) and recovery times (when instrument on deck). DEPAS* means the new KUM NAMU instrument.

Station		Latitude			Longitude			Water depth	Deployment		Recovery	
No.	Pool	Deg	Min	Dig Deg	Deg	Min	Dig Deg	m	UTC	JD	UTC	JD
101	OBIC	16	22.059	16.3677	57	54.407	-57.9068	5262	18:05	138	Not recovered	
102	OBIC	16	21.491	16.3582	57	56.195	-57.9366	5309	18:41	138	04:36	147
103	OBIC	16	20.937	16.3490	57	58.042	-57.9674	5334	19:07	138	02:09	147
104	DEPAS	16	20.360	16.3393	57	59.875	-57.9979	5364	19:35	138	23:52	146
105	OBIC	16	19.786	16.3298	58	1.728	-58.0288	5391	19:59	138	22:23	146
106	DEPAS	16	19.209	16.3202	58	3.575	-58.0596	5413	20:27	138	20:11	146
107	OBIC	16	18.631	16.3105	58	5.441	-58.0907	5458	20:55	138	18:35	146
108	DEPAS	16	18.052	16.3009	58	7.286	-58.1214	5474	21:23	138	16:03	146
109	OBIC	16	17.494	16.2916	58	9.044	-58.1507	5493	21:54	138	14:12	146
110	DEPAS	16	16.897	16.2816	58	10.935	-58.1823	5516	22:22	138	11:57	146
111	OBIC	16	16.339	16.2723	58	12.751	-58.2125	5530	22:46	138	10:23	146
112	DEPAS	16	15.748	16.2625	58	14.640	-58.2440	5549	23:15	138	08:02	146
113	OBIC	16	15.213	16.2536	58	16.456	-58.2743	5551	23:39	138	06:21	146
114	DEPAS	16	14.640	16.2440	58	18.417	-58.3070	5506	00:03	139	03:59	146
115	OBIC	16	14.080	16.2347	58	20.128	-58.3355	5504	00:22	139	01:54	146
116	DEPAS	16	13.467	16.2245	58	21.957	-58.3660	5474	00:43	139	23:38	145
117	OBIC	16	12.907	16.2151	58	23.807	-58.3968	5474	01:02	139	21:47	145
118	DEPAS	16	12.324	16.2054	58	25.644	-58.4274	5463	01:24	139	19:43	145
119	OBIC	16	11.745	16.1958	58	27.492	-58.4582	5486	01:43	139	18:08	145
120	DEPAS	16	11.196	16.1866	58	29.330	-58.4888	5488	02:07	139	13:47	145
121	OBIC	16	10.008	16.1668	58	33.039	-58.5507	5544	02:44	139	11:31	145
122	DEPAS	16	9.459	16.1577	58	34.856	-58.5809	5604	03:03	139	09:04	145
123	OBIC	16	8.875	16.1479	58	36.710	-58.6118	5659	03:21	139	07:11	145
124	DEPAS	16	8.323	16.1387	58	38.559	-58.6427	5673	03:41	139	04:50	145
125	OBIC	16	7.736	16.1289	58	40.366	-58.6728	5744	04:27	139	Not recovered	
126	DEPAS	16	7.414	16.1236	58	41.364	-58.6894	5720	05:26	139	22:06	144
127	OBIC	16	6.013	16.1002	58	45.882	-58.7647	5782	06:31	139	20:21	144
128	DEPAS	16	5.424	16.0904	58	47.691	-58.7949	5736	07:05	139	17:42	144
129	OBIC	16	4.866	16.0811	58	49.553	-58.8259	5683	07:34	139	15:37	144
130	DEPAS	16	4.283	16.0714	58	51.359	-58.8560	5473	08:02	139	13:16	144
131	OBIC	16	3.718	16.0620	58	53.212	-58.8869	5447	08:33	139	11:38	144
132	DEPAS	16	3.121	16.0520	58	55.033	-58.9172	5328	09:04	139	09:19	144
133	OBIC	16	2.538	16.0423	58	56.895	-58.9483	5229	09:34	139	07:22	144
134	DEPAS	16	1.980	16.0330	58	58.702	-58.9784	5271	11:32	139	04:45	144
135	OBIC	16	1.401	16.0234	59	0.548	-59.0091	5145	12:01	139	02:45	144
136	DEPAS	16	0.840	16.0140	59	2.397	-59.0400	5059	12:28	139	00:52	144
137	OBIC	16	0.269	16.0045	59	4.222	-59.0704	5243	12:49	139	22:58	143
138	DEPAS	15	59.680	15.9947	59	6.070	-59.1012	5239	13:12	139	20:44	143
139	OBIC	15	59.119	15.9853	59	7.927	-59.1321	5261	13:32	139	13:44	143
140	DEPAS*	15	58.567	15.9761	59	9.752	-59.1625	5235	13:56	139	11:25	143
141	OBIC	15	57.976	15.9663	59	11.573	-59.1929	5220	14:19	139	09:10	143
142	DEPAS*	15	57.397	15.9566	59	13.446	-59.2241	5220	14:45	139	06:47	143
143	OBIC	15	56.843	15.9474	59	15.256	-59.2543	5202	15:07	139	05:07	143
144	DEPAS	15	56.235	15.9373	59	17.107	-59.2851	5225	15:28	139	02:37	143
145	OBIC	15	55.703	15.9284	59	18.958	-59.3160	5168	15:48	139	01:05	143
146	DEPAS	15	55.096	15.9183	59	20.753	-59.3459	5247	16:23	139	22:59	142
147	OBIC	15	54.531	15.9089	59	22.615	-59.3769	5094	16:55	139	21:19	142
148	DEPAS	15	53.949	15.8992	59	24.440	-59.4073	4962	17:23	139	19:02	142

Station		Latitude			Longitude			Water depth	Deployment		Recovery	
No.	Pool	Deg	Min	Dig Deg	Deg	Min	Dig Deg	m	UTC	JD	UTC	JD
202	DEPAS*	16	57.175	16.95292	55	13.943	-55.23238	5779	10:13	148	23:36	157
203	DEPAS*	16	53.312	16.88853	55	14.214	-55.2369	5778	11:00	148	21:24	157
205	DEPAS	16	49.354	16.82257	55	14.442	-55.2407	5777	11:42	148	19:07	157
207	DEPAS	16	45.516	16.7586	55	14.682	-55.2447	5773	12:22	148	16:33	157
209	DEPAS	16	41.624	16.69373	55	14.896	-55.24827	5795	12:56	148	13:34	157
211	DEPAS	16	37.733	16.62888	55	15.135	-55.25225	5787	13:32	148	11:55	157
213	DEPAS	16	33.853	16.56422	55	15.375	-55.25625	5791	14:07	148	10:31	157
214	OBIC	16	31.716	16.5286	55	15.472	-55.25787	5793	14:29	148	08:57	157
215	DEPAS	16	29.584	16.49307	55	15.59	-55.25983	5790	14:49	148	06:51	157
216	OBIC	16	27.504	16.4584	55	15.737	-55.26228	5712	15:11	148	05:19	157
217	DEPAS	16	25.388	16.42313	55	15.862	-55.26437	5787	15:32	148	02:40	157
218	OBIC	16	23.255	16.38758	55	15.982	-55.26637	5794	15:53	148	01:08	157
219	DEPAS	16	21.133	16.35222	55	16.075	-55.26792	5789	16:27	148	22:48	156
221	DEPAS	16	16.893	16.28155	55	16.361	-55.27268	5555	17:16	148	20:19	156
222	OBIC	16	14.757	16.24595	55	16.492	-55.27487	5390	17:43	148	18:50	156
223	DEPAS	16	12.635	16.21058	55	16.614	-55.2769	5261	18:09	148	16:32	156
224	OBIC	16	10.524	16.1754	55	16.741	-55.27902	5345	18:34	148	14:55	156
225	DEPAS	16	8.392	16.13987	55	16.863	-55.28105	5447	18:59	148	12:48	156
226	OBIC	16	6.268	16.10447	55	16.985	-55.28308	5432	19:22	148	11:07	156
227	DEPAS	16	4.173	16.06955	55	17.115	-55.28525	5400	19:46	148	08:58	156
228	OBIC	16	2.077	16.03462	55	17.28	-55.288	5405	20:12	148	07:18	156
229	DEPAS	15	59.914	15.99857	55	17.401	-55.29002	5387	20:39	148	05:01	156
230	OBIC	15	58.793	15.97988	55	17.47	-55.29117	5292	21:04	148	03:19	156
231	DEPAS	15	55.693	15.92822	55	17.646	-55.2941	5156	21:28	148	01:07	156
232	OBIC	15	53.557	15.89262	55	17.788	-55.29647	5244	21:58	148	23:38	155
233	DEPAS	15	51.445	15.85742	55	17.892	-55.2982	5404	22:22	148	21:31	155
234	OBIC	15	49.333	15.82222	55	18.014	-55.30023	5506	22:47	148	20:07	155
235	DEPAS	15	47.221	15.78702	55	18.122	-55.30203	5507	23:10	148	17:49	155
236	OBIC	15	45.115	15.75192	55	18.243	-55.30405	5512	23:33	148	16:04	155
237	DEPAS	15	42.99	15.7165	55	18.426	-55.3071	5516	23:58	148	13:52	155
238	OBIC	15	40.874	15.68123	55	18.527	-55.30878	5517	00:18	149	12:05	155
239	DEPAS	15	38.748	15.6458	55	18.668	-55.31113	5506	00:38	149	09:56	155
240	OBIC	15	36.604	15.61007	55	18.796	-55.31327	5522	00:57	149	08:27	155
241	DEPAS	15	34.489	15.57482	55	18.914	-55.31523	5527	01:16	149	06:09	155
242	OBIC	15	32.376	15.5396	55	19.051	-55.31752	5528	01:34	149	04:18	155
243	DEPAS	15	30.235	15.50392	55	19.185	-55.31975	5528	01:54	149	01:52	155
244	OBIC	15	28.125	15.46875	55	19.3	-55.32167	5529	02:13	149	00:13	155
245	DEPAS	15	26.034	15.4339	55	19.418	-55.32363	5528	02:32	149	21:37	154
246	OBIC	15	23.892	15.3982	55	19.553	-55.32588	5518	02:50	149	18:35	161
247	DEPAS	15	21.782	15.36303	55	19.702	-55.32837	5518	03:08	149	19:50	161
248	OBIC	15	19.652	15.32753	55	19.814	-55.33023	5508	03:27	149	22:05	161
249	DEPAS	15	17.531	15.29218	55	19.953	-55.33255	5528	03:48	149	23:37	161
250	OBIC	15	15.43	15.25717	55	20.027	-55.33378	5527	04:14	149	01:53	162
251	DEPAS	15	13.292	15.22153	55	20.168	-55.33613	5532	04:40	149	03:22	162

Station		Latitude			Longitude			Water depth	Deployment		Recovery	
No.	Pool	Deg	Min	Dig Deg	Deg	Min	Dig Deg	m	UTC	JD	UTC	JD
301	DEPAS	15	11.15	15.186	55	20.357	-55.339	5524	12:17	159	05:27	162
302	OBIC	15	9.064	15.151	55	20.42	-55.34	5508	05:24	149	07:39	162
303	DEPAS	15	4.843	15.081	55	20.727	-55.345	5509	13:20	159	08:23	162
304	OBIC	15	2.702	15.045	55	20.813	-55.347	5500	06:24	149	11:30	162
305	DEPAS	15	0.592	15.01	55	20.942	-55.349	5509	13:59	159	13:11	162
306	OBIC	14	58.45	14.974	55	21.064	-55.351	5510	07:06	149	15:20	162
307	DEPAS	14	56.368	14.939	55	56.368	-55.939	5494	14:38	159	17:16	162
308	OBIC	14	54.21	14.904	55	21.317	-55.355	5475	07:46	149	19:36	162
309	DEPAS	14	52.121	14.869	55	21.483	-55.358	5308	15:17	159	20:34	162
310	OBIC	14	49.965	14.833	55	21.558	-55.359	5485	08:22	149	22:54	162
311	DEPAS	14	47.863	14.798	55	21.733	-55.362	5477	15:54	159	00:17	163
312	OBIC	14	45.763	14.763	55	21.838	-55.364	5483	09:01	149	02:30	163
313	DEPAS	14	43.625	14.727	55	21.942	-55.366	5486	16:42	159	03:53	163
314	OBIC	14	41.505	14.692	55	22.078	-55.368	5488	17:15	159	06:21	163
315	DEPAS	14	39.397	14.657	55	22.206	-55.37	5476	17:44	159	07:40	163
316	OBIC	14	37.27	14.621	55	22.33	-55.372	5456	18:10	159	09:42	163
317	DEPAS	14	35.148	14.586	55	22.462	-55.374	5470	18:37	159	11:31	163
318	OBIC	14	33.025	14.55	55	22.589	-55.376	5468	19:03	159	13:36	163
319	DEPAS	14	30.016	14.5	55	22.732	-55.379	5468	19:31	159	15:04	163
320	OBIC	14	28.795	14.48	55	22.843	-55.381	5466	19:57	159	17:25	163
321	DEPAS	14	26.678	14.445	55	23.005	-55.383	5429	20:24	159	18:42	163
322	OBIC	14	24.557	14.409	55	23.096	-55.385	5419	20:51	159	20:47	163
323	DEPAS	14	22.411	14.374	55	23.209	-55.387	5375	21:13	159	22:13	163
324	OBIC	14	20.324	14.339	55	23.356	-55.389	5338	21:45	159	00:39	164
325	DEPAS	14	18.186	14.303	55	23.457	-55.391	5332	22:12	159	01:58	164
326	OBIC	14	16.061	14.268	55	23.594	-55.393	5304	22:36	159	04:17	164
327	DEPAS	14	13.957	14.233	55	23.721	-55.395	5307	21:00	159	05:37	164
328	OBIC	14	11.822	14.197	55	23.848	-55.397	5280	23:24	159	07:34	164
329	DEPAS	14	9.72	14.162	55	23.996	-55.4	5289	23:49	159	08:49	164
330	OBIC	14	7.608	14.127	55	24.15	-55.403	5304	00:13	160	10:52	164
331	DEPAS	14	5.444	14.091	55	24.311	-55.405	5302	00:36	160	12:27	164
332	OBIC	14	3.351	14.056	55	24.404	-55.407	5282	00:58	160	14:28	164
333	DEPAS	14	1.223	14.02	55	24.517	-55.409	5294	01:20	160	15:47	164
334	OBIC	13	59.106	13.985	55	24.634	-55.411	5298	01:41	160	18:26	164
335	DEPAS	13	57.002	13.95	55	24.634	-55.411	5274	02:02	160	19:44	164
336	OBIC	13	54.886	13.915	55	24.88	-55.415	5279	02:23	160	21:44	164
337	DEPAS	13	52.766	13.879	55	24.992	-55.417	5250	02:44	160	23:09	164
338	OBIC	13	50.63	13.844	55	25.138	-55.419	5240	03:04	160	01:13	165
339	OBIC	13	48.516	13.809	55	25.29	-55.422	5210	03:25	160	03:20	165
340	OBIC	13	46.406	13.773	55	25.417	-55.424	5209	03:45	160	05:49	165
341	DEPAS	13	44.279	13.738	55	25.486	-55.425	5182	04:09	160	07:11	165
342	OBIC	13	42.174	13.703	55	25.639	-55.427	5177	04:38	160	09:05	165
343	OBIC	13	40.039	13.667	55	25.762	-55.429	5167	05:06	160	11:11	165
344	DEPAS*	13	37.908	13.632	55	25.884	-55.431	5143	05:36	160	13:02	165

Appendix B: Leg 3 OBS data QC

Station	Pool	Logger no	Size of raw file MB	Start	Stop	Runtime	Data H	Data Z	Data X	Data Y	Comments
148	DEPAS	"050914"	386	19.05.2017 09:34:13	22.05.2017 19:22:55	294500	clear to 90km	reverberations at station, some noisy intervals, pickable to 160km	nice arrivals to 90km	close range only	
147							good pick to 85km	good pick to 85km	v. noisy, no pick possible beyond 45km	little data, no real pick possible	
146	DEPAS	"050915"	426	19.05.2017 08:30:28	22.05.2017 23:23:31	312761	very good, pickable to 160km	near surface reverb at station, pegleg extremely clear	weak, pickable to 90km	close range only	
145							noisy, little beyond 40km	pick to 50km	amplitude jumping again as 137, little data	noisy, no real pick possible	
144	DEPAS	"050910"	398	19.05.2017 14:53:45	23.05.2017 03:04:33	303026	very good, pickable to at least 90km	v good, pickable to 160km	v good but lots of p wave	lots of p waves, ok to 50km	
143							excellent v. clear to 150km	excellent, v. clear to 150km	good to 75km	good to 80km	
142	DEPAS	"61607017"	1525				01? possible conversion artefacts, or hydrophone mismatch	04? good at short ranges usable to 50km	02? poor	03? usable to 50km?	Namu with geophone Electronics noise burst every 65s
141							excellent, pick to 140km	clear to 65km	excellent, pickable to 80km	Pick to 65km	
140	DEPAS	"61607012"	1532				01? nice reflections but refractions weak, pickable to 70km	04? OK, pickable to 80km	02? OK for S waves, P waves very emergent	03 OK water wave and short range reflections, not much more	Namu with trillium
139							clear to 70km	clear to 60km	noisy pickable to 60km	noisy pickable to 60km	
138	DEPAS	"120202"	529	19.05.2017 03:55:43	23.05.2017 21:02:22	407178	low f, pickable to 130km	excellent, pickable to 130km	clear signals, but lots of p wave	weak	
137							clear to 60km	clear to 65km	strange jump in amplitude at 40km, pick may be possible to 65km	noisy, pick to 70km	
136	DEPAS	"050901"	765	19.05.2017 02:31:38	24.05.2017 00:50:25	425905	very noisy at low f but pickable with high pass filter to 130km	very noisy	very noisy	v noisy	
135							clear to 55km	clear to 75km	pickable to 50km	pickable to 60km	
134	DEPAS	"060752"	652	18.05.2017 21:01:34	24.05.2017 05:13:05	461468	OK, pickable to 90km	constant clip	close to clipping, some signal of water wave when filter	constant clip	seismometer levelling failure?
133							pickable to 75km	clear to 60km	noisy pickable to 50km	pickable to 55km	
132	DEPAS	"060739"	628	18.05.2017 22:02:01	24.05.2017 09:36:05	473621	OK, pickable to 90km	very good, pickable to 90km	excellent, pickable >90km	OK to 60km	
131							excellent to 75km	excellent to 75km	noisy, pickable to 50km	noisy, pickable to 50km	
130	DEPAS	"060715"	623	18.05.2017 22:58:43	24.05.2017 13:32:15	484390	good, pickable to 100km	very good, pickable to 90km	ok	ok, quite reverberant	
129							pickable to 80km	clear to 70km	pickable to 85km	worked, but almost no data	

128	DEPAS	“060754”	616	18.05.2017 23:52:18	24.05.2017 18:01:43	497343	good, pickable to 70km	OK, first arrivals not v strong	noisy, reverberations	ok once filtered	
127							noisy but pickable to 100km	excellent, clear to 100km	pick to 60km	pick to 60km	
126	DEPAS	“060747”	627	18.05.2017 20:11:37	24.05.2017 22:22:22	526223	ok, quite noisy	ok, pickable to 65km	excellent to W, OK to E	noisy, reverberations	
125							Lost				
124	DEPAS	“091106”	731	18.05.2017 18:47:08	25.05.2017 05:05:10	555460	very good	very good, pickable to 90km	good	noisy, reverberations	
123							noisy, pickable to 75km	good to 55km, perhaps 65km	excllent clear to 120km	good to 70km	
122	DEPAS	“060708”	735	18.05.2017 18:28:49	25.05.2017 09:21:23	571932	very good, pickable to 90km	noisy, pickable to ~55km	excellent to W, good to E	noisy, reverberations	
121							pickable to 50km	noisy, but pickable to 65km	good to 80km, may be possible to pick further	pickable to 90km	
120	DEPAS	“060707”	754	18.05.2017 18:15:25	25.05.2017 14:04:27	589720	very good	good, pickable to 90km	very good to W, OK to E	noisy, reverberations	
119							v. noisy, pickable to 50km	pickable to 50km	pickable to 70km	noisy, pickable to 50km	
118	DEPAS	“050919”	716	18.05.2017 16:54:44	25.05.2017 19:56:36	615690	OK to 60km	good, pickable to 70km	OK to 60km	very good	
117							pickable to 75km	good, pickable to 85km	noisy, may be possible to pick to 85km	noisy, pick possible to 90km	
116	DEPAS	“091111”	804	18.05.2017 17:06:36	25.05.2017 23:48:48	628904	good, pickable to 100km	very good, pickable to 110km	ok, strong P waves	weak. Reverberations	
115							good, pickable to 80km	good, pickable to 90km	messy, ok to 40km	good to 70km	
114	DEPAS	“060711”	832	18.05.2017 17:41:43	26.05.2017 04:26:49	643484	good, pickable to 90km	good, pickable to 90km	good to W, OK to E	weak. Reverberations	
113		114					70km	pickable to 140km	ok to 40km	ringy weak	
112	DEPAS	“120201”	754	18.05.2017 17:56:09	26.05.2017 08:17:07	656438	good, pickable to 90km	very good, pickable to 90km	good, possible splitting to W	reverberations	
111		119					80km	very good, clear to 80km, some pn to 140km	ok to n weak to s	ok to n weak to s	
110	DEPAS	“080105”	748	18.05.2017 18:04:58	26.05.2017 12:10:45	669925	noisy, pickable to 50km	excellent, pickable to 160km	weak, not much S wave energy	weak. Reverberations	
109							OK, pickable to 50km	excellent, pickable to 160km	some energy, not very clear	good to E, maybe ok to W	
108	DEPAS	“060753”	884	18.05.2017 16:38:07	26.05.2017 16:10:18	689509	very good	excellent, pickable to 160km	excellent, clear to 160km	reverberations	
107							good, pickable to 80km, on multiple to 160km	very good, pickable to 150km	weak, not much S wave energy	weak. Reverberations	
106	DEPAS	“060743”	926	18.05.2017 15:28:58	26.05.2017 20:24:41	708924	excellent, pickable to 160km	very good, pickable on multiple to 130km	very good, clear to 90km	weak. Reverberations	
105							good, pickable to 70km	excellent, pickable to 160km	ok to 70km	reverberations	
104	DEPAS	“050923”	936	18.05.2017 15:10:47	27.05.2017 00:29:24	724695	good, pickable to 90km	good, pickable to 90km	very good, clear to 90km	weak. Reverberations	
103							very good, pickable to 160km	v good, pickable to 160km	excellent, clear to 160km	reverberations	
102							OK, pickable to 60km	good,pickable to 80km	OK to 60km	weak, 40km	
101							Lost				

Station	Pool	Logger no	Size of raw file MB	Start	Stop	Runtime	Data H	Data Z	Data X	Data Y	Comments
312							tide noise but 200km	Primary pickable to 200km multiple to 240km	pickable to 220km	weak energy to 200km	
310							tide noise but 50km	water wave, no refractions	water wave, no refractions	water wave, no refractions	
308							weak 40km, crustal only	weak, 60km	weak arrivals	weak 60km	
306							220km	very clear 220km	clean, 90km	weak, but arrivals to 220km	
304							tide noise but 90km	very good, pickable to 120km	exceptional, ringy but arrivals to 220km	ringy, pickable to 150km	
302							ok to 65km, hints of energy at longer offset	exceptional, pickable to 200km	very good, arrivals to 160km	weak but some pickable energy at longoffsets	strong tide noise on hydrophone
251	DEPAS	“050919”	1473	27/05/2017 07:29:39	06/11/2017 03:45:36	1282535	weak, 40km	good, primary 50km but multiple pickable to 160km	OK, 50km	weak, reverberation s	
250							weak, 30km	clean but crustal only	poor, very weak arrivals	weak arrivals only	strong tide noise
249	DEPAS	“091111”	244	27/05/2017 07:43:58	29/05/2017 06:41:12	168818	failed before shooting				seismometer housing implosion; instrument stopped normally due to low battery
248							ok 45km	ok 45km	reverberations	weak arrivals	
247	DEPAS	“060711”	1627	27/05/2017 07:52:21	06/10/2017 20:05:19	1253550	good, clear to 50km then weak energy around 150km	excellent, pickable to 170km	some energy to 170km	reverberations	
246							excellent, pickable to 160km	excellent	good, arrivals to 80km	ok, arrivals to 80km but weak	tide noise shots 1-187, 750-1000; strong noise around shot 886
245	DEPAS	“050901”	875	27/05/2017 07:16:16	06/03/2017 22:02:39	657955	excellent	excellent			
243	DEPAS	“060715”	888	27/05/2017 08:11:42	06/04/2017 02:08:26	669382	excellent	excellent	excellent	excellent, splitting?	
242							excellent, pickable to 160km	excellent	very good, pickable to 90km	weak arrivals	tide noise, strong noise around shot 886
241	DEPAS	“060707”	946	27/05/2017 10:16:37	06/04/2017 06:25:46	677327	good, noisy at times	OK, complicated multiples	strong pSMS	very reverberant	
240							tide noise but 60km	very good, 140km	OK, 60km	Good, energy at 140km	
239	DEPAS	“060708”	904	27/05/2017 10:25:14	06/04/2017 10:09:03	690207	good, fairly noisy	very good			
238							N ok to 60km, noisy to S	very good, 140km	noisy, not much s wave	ok to S only, reverberations	
237	DEPAS	“060716”	919	27/05/2017 21:34:11	06/04/2017 14:04:18	664185	very good	noisy, good when bp filter			
236							ok to 50km, strong multiple	weak to N, S ok to 50km	clean but reverberations	arrivals ok to 50km	
235	DEPAS	“050928”	941	28/05/2017 03:11:01	06/04/2017 18:00:57	658174	ok to 55km	very noisy	very noisy	very noisy+reverberations	
234							Ok to 45km	Ok, some noise bursts	good, N to 90km, S to 45km	arrivals better to N	
233	DEPAS	“050923”	962	27/05/2017 21:21:50	06/04/2017 21:42:00	692388	Good-very good	very good	reverberations	very good	
232							Ok to 50km, slightly noisy	Ok to N, weak arrivals to S	ok, reverberations		
231	DEPAS	“050910”	980	27/05/2017 19:44:51	06/05/2017 01:19:17	711243	Good-very good	good	OK	reverberations	
230							good	ok, 60km to S, 30km to n	weak arrivals	noisy	

229	DEPAS	“060747”	963	27/05/2017 19:52:57	06/05/2017 05:22:28	725349	ok to 60km	ok	weak, reverberations	weak, reverberation s	
228							ok to 70km, fairly noisy	ok, 60km to N, 30km to S	Ok to S, reverberations to N	weak arrivals	
227	DEPAS	“060739”	1069	27/05/2017 20:07:24	06/05/2017 09:09:41	738114	excellent	ok, quite noisy	weak arrivals	OK	
226							Ok to 70km, some noise	ok to 45km	ok to S with reverberations, poor to N	ok to S only, reverberations	
225	DEPAS	“120202”	1037	27/05/2017 20:30:47	05/06/2017 12:59:03	750476	noisy, OK to 50 km	noisy, OK to 50 km	noisy, OK to 50km	noisy	
224							very noisy to N, less noisy to S	Geophone failed, no data			
223	DEPAS	“050914”	1076	27/05/2017 20:14:20	05/06/2017 16:40:32	764749	very good	ok	ok, reverberations	good to S OK to N	
222							ok, 80km	poor, ringy weak arrivals	weak arrivals to 40km	weak arrivals to 40km	check components, maybe mislabelled
221	DEPAS	“050915”	1057	27/05/2017 20:19:43	05/06/2017 20:30:26	778221	very good, pickable to 90km	weak arrivals only	weak arrivals only	weak arrivals only	
219	DEPAS	“060731”	157	27/05/2017 19:34:09	none	82716	failed before shooting				seismometer housing implosion; rescue mode in the conversion software; instrument stopped at 2017/05/28 18:33:12
218							Ok to 50km, slightly noisy	ok to 50km	ok, reverberations	weak arrivals, reverberations	
217	DEPAS	“091106”	1116	27/05/2017 10:36:07	06/06/2017 02:51:42	836113	excellent, pickable to 110km	excellent, pickable to 120km	very good	very reverberant	
216							very good, pickable to 130km	noisy intervals, high background noise prob pickable to 140km though	Ok, S pickable to 100km	weak arrivals	
215	DEPAS	“060754”	1045	27/05/2017 10:45:07	06/06/2017 07:02:07	850598	weak, noisy	noisy, background and individual intervals	noisy, but pickable to 50km	weak, reverberation s	
214							ringy, primary OK to 60km, multiple to 130km	good, 100km, noise bursts	weak arrivals	reverberations	
213	DEPAS	“060743”	1175	27/05/2017 10:05:57	06/06/2017 10:57:27	867071	excellent, pickable to 110km	OK, noisy intervals	noisy, some arrivals visible	reverberations	
211	DEPAS	“060753”	1177	27/05/2017 09:54:50	06/06/2017 12:16:46	872493	good, pickable to 50km	OK, noisy intervals	very good, pickable to 90km	reverberations	?diurnal noise
209	DEPAS	“080105”	1110	27/05/2017 08:33:35	06/06/2017 14:06:34	883957	weak, noisy	noisy intervals, OK to 50km	noisy, weak arrivals only	reverberations	?diurnal noise
207	DEPAS	“120201”	1132	27/05/2017 08:24:30	06/06/2017 16:41:54	893824	noisy intervals, pickable to 50km	noisy intervals, pickable to 50km	weak arrivals only	weak arrivals only	?diurnal noise
205	DEPAS	“050921”	1388	28/05/2017 06:16:34	06/06/2017 19:16:28	817444	excellent, pickable to 160km	OK, noisy intervals	noisy intervals, probably pickable to 50km	reverberations	logger crashed during recovery, several restarts after 2017/06/06 19:15:29
203	DEPAS	“61607017”	3521				01 – noisy, 45km	04 – weak pn to 50km	02 – reverberant	03 – reverberant, 35km	NAMU – geophone; instrument noise spikes at 65s on ch 2-4, random intervals on ch 1
202	DEPAS	“61607012”					01 – pn to 50km	04 – pn prob pickable to 150km, not a great record though	02 – reverberant; shear waves to 45km, p waves to 150km	03 – reverberant, p waves to 150km, shear waves only 40km	NAMU – seismometer; no instrument noise. Poor coupling for shear wave motions

Station	Pool	Logger no	Size of raw file MB	Start	Stop	Runtime	Data H	Data Z	Data X	Data Y	Comments
344	DEPAS	“61607012”	1859				01 noisy, visible to 60km	04 primary to 70km, arrivals on multiple to 170km, but weak	02 strong p wave not much s wave	03 reverberations, not much s wave energy	NAMU with Trillium
342							ok 60km	very good 90km			
341	DEPAS	“060752”	762	09/06/2017 03:01:27	14/06/2017 08:02:33	441530	very good, 100km	excellent, clear to 140km	some reverberations but mostly clean to 100km	reverberations but clear onset to 100km	several instrument resets during recovery
340		127					ok to 90km, some noise bands	very good , 140km	very good, arrivals at 180km	good to 140km	
339		123					ok to 65km, fairly noisy	ok to 70km	good to 80km	ok to 80km	
338		135					Many noise bursts, arrivals ok to 45km	good to 130km	ok to 70km	reverberations but good to 80km	
337	DEPAS	“060716”	697	07/06/2017 18:49:39	13/06/2017 23:20:49	534648	good, 80km	very good record to 85km	reverberations but arrivals to 80km	reverberations but clear onset to 80km	
336		136					ok to 75km, slighly noisy	noisy, pickable to 50km though	good 90km, some reverberations	good to 100km, some reverberations	
335	DEPAS	“060707”	706	07/06/2017 18:36:27	13/06/2017 19:52:12	522922	excellent, clear to 130km	excellent, 150km	weak, reverberations	weak, reverberations	
334		130					60km	very good 120km maybe 160km	ok 60km	very good 140km	
333	DEPAS	“060743”	678	07/06/2017 18:42:20	13/06/2017 15:53:57	508278	very good, 120km	excellent, 160km	good, 70km	reverberations but clear to 70km	
332		113					tide noise but OK to 60-70km	very good 120km	60km, strong noise shots 1050-1100	90km? Noise 1050-1100	
331	DEPAS	“050918”	651	07/06/2017 18:23:38	13/06/2017 12:38:30	497668	OK to 60km, maybe only crustal	good, maybe hard to pick	very good, clear to 100km, strong P waves	reverberations	
330		119					very good 100km	excellent 140km	OK to 60km	excellent 140km	
329	DEPAS	“120201”	602	07/06/2017 17:54:51	13/06/2017 08:58:50	486218	very good to s, good to n	very good	OK to 60km	reverberations, may be better than X if can suppress them	hydrophone tide noise after shot 750
328		128					tide noise, ok to 60km	excellent 120km	energy but hard to make sense of	ringy, arrivals but hard to see	
327	DEPAS	“060753”	618	07/06/2017 18:31:02	13/06/2017 05:49:09	472664	very good, pickable to 90km	good range but reverberations	OK, maybe crustal only	reverberations but clear onset to 70km	hydrophone tide noise after shot 750; very noisy on Z 900-1100
326		129					good 80km	very good 100km	ringy but OK to S, weak to N	ringy but clear to 120km	
325	DEPAS	“080105”	555	07/06/2017 18:04:11	13/06/2017 02:07:34	460981	very good to s, ok to n	excellent to s, very good to n	good tos ok to n	reverberations but clear onset to 90km	some discrete noise all channels shots 770-800
324		126					excellent, 100km N and S	excellent	very good to S, weak to N	very good to S, weak to N	
323	DEPAS	“091106”	645	07/06/2017 10:12:26	12/06/2017 22:21:28	475720	some tide noise, but clear to 80km	some tide noise, but clear to 80km	good	reverberations	
322							pn on multiple to 100km	tide noise but 70km	OK, weak arrivals but pickable	ringy, not much s wave	
321	DEPAS	“060754”	575	07/06/2017 10:01:10	12/06/2017 18:54:15	463963	very noisy shots 900-1100, otherwise good	very noisy shots 900-1100, otherwise very good, poss pn beyond noise	excellent record, clear sn to 100km	very noisy shots 900-1100, otherwise reverberations but clear onsets	very noisy on h,z,y shots 900-1100

320							good, 80km	very good to 80km	ringy but clear onset to 100km	very clean 100km	
319	DEPAS	“060715”	610	07/06/2017 09:51:21	12/06/2017 15:16:22	451479	some tide noise, 50km to s 80km to n	very good, 80km	Ok-good	reverberations but clear onset to 100km	tide noise after shot 750
318							good to 60km, some energy around 100km	very good 100km	very good to S, OK to N	weak	
317	DEPAS	“050901”	591	07/06/2017 09:41:38	12/06/2017 11:40:02	439076	excellent to s, 120km, noisy to n	excellent, 120km to s, 75km to n	excellent to S, Ok to N	very good but reverberations	tide noise after shot 750
316							ok to 60km	very good 110km	excellent 120km	excellent 120km	
315	DEPAS	“050910”	591	07/06/2017 09:31:20	12/06/2017 07:52:07	426025	ok quality, maybe no pn	weak pn to N 70km, maybe no pn to S	good to n weak to s	weak, reverberations	
314							clean, pn weak ~50km	very good			
313	DEPAS	“060747”	513	07/06/2017 08:53:19	06/12/2017 04:03:44	414603	ok to 60km	very good, clear to 80km	excellent, clear to 120km	reverberations but clear onset to 90km	
312							clear to 60km	primary clear to 80km	ringy ok to 70km	weak	
311	DEPAS	“060739”	573	07/06/2017 08:41:21	12/06/2017 00:28:10	402387	ok to 60km	very good, pickable to 120km	OK to 60km	reverberations but clear onset to 100km	
310							60km	OK, 60km, maybe pickable on mulitple to longer	weak	some energy to 60km	
309	DEPAS	“120202”	574	07/06/2017 08:29:00	11/06/2017 20:43:00	389620	very good, pickable to 60km	very good, pickable to 60km	OK to 60km	weak, reverberations	
308							ok to 70km	45km	weak 35km	ringy but clear to 100km	
307	DEPAS	“050914”	486	07/06/2017 08:18:56	11/06/2017 17:24:16	378298	exceptional	exceptional	excellent, clear to 120km	reverberations but clear onset to 120km	
306							tide noise but clear to 90km	excellent 120km	excellent to 80km	clear to 80km	
305	DEPAS	“050915”	489	07/06/2017 08:09:49	11/06/2017 13:21:16	364265	excellent, clear to 120km	excellent, clear to 120km	excellent, clear to 120km	reverberations but clear onset to 120km	
304							very good 100km	very good, 120km	ringy some energy to 120km	ringy weak	
303	DEPAS	“060708”	446	07/06/2017 08:00:21	11/06/2017 10:14:29	353626	very good, primary nice pn at 25km, multiple pickable to 120km	very good	Limited crust but good mantle to 100km	reverberations	
302							tide noise, ok to 50km	Weak pn maybe pickable to 140km	ringy weak	ringy but clear to 100km	
301	DEPAS	“050923”	447	07/06/2017 07:49:46	11/06/2017 06:27:07	340619	OK, 50km	OK, 60km, maybe pickable on mulitple to longer	excellent, pickable to 160km	excellent record, very clear split	
251	DEPAS	“050919”	1473	27/05/2017 07:29:39	11/06/2017 03:45:36	1282535	clear to 50km, some energy > 100km	excellent, clear to 150km	very good, clear to 100km	reverberations	
250							tide noise pn to 35km	pn to 40km	some energy to 200km	ringy but some energy to 100km	
249	DEPAS	“091111”	244	27/05/2017 07:43:58	29/05/2017 06:41:12	168818	failed before shooting				seismometer housing implosion; instrument stopped normally due to low battery
248							noisy, 40km	clean but only crustal	some energy to 200km	ringy but some energy to 100km	
247	DEPAS	“060711”	1627	27/05/2017 07:52:21	10/06/2017 20:05:19	1253550	weak, 35km	ok to 35km, may have some energy >100km	weak 35km	weak, reverberations	
246							noisy, only crustal	clean but only crustal	some energy to 200km	ringy but some energy to 100km	

Appendix C: Ships logging and data formats

Cruise	JC149
Technician	Andrew Moore, Mark Matlby
Date	17th April - 20th June 2017

BODC Ship-fitted Systems Information Sheet (James Cook)

Ship-fitted instruments:

The following table lists the logging status of ship-fitted instrumentation and suites.

Manufacturer	Model	Function/data types	Logged? (Y/N)	Comments
Steatite	MM3S	GPS network time server (NTP)	N	Not logged
Applanix	POS MV	DGPS and attitude	Y	Scientific GPS
C-Nav	3050	DGPS and DGNSS	Y	
Kongsberg Seatex	DPS116	Ship's DGPS	Y	Bridge GPS
Kongsberg Seatex	Seapath 330+	DGPS and attitude	Y	Scientific GPS
Sonardyne	Fusion USBL	USBL	N	
Sperry Marine		Ship gyrocompasses x 2	Y	
Chernikeef Instruments	Aquaprobe Mk5	Electromagnetic speed log	Y	Use with caution – Last cal 09/2016
Kongsberg Maritime	Simrad EA600	Single beam echo sounder (hull)	Y	
Kongsberg Maritime	Simrad EM120	Multibeam echo sounder (deep)	Y	GPS/ATT/HDG inputs changed (ref cruise report)
Kongsberg Maritime	Simrad EM710	Multibeam echo sounder (shallow)	Y	Leg1/2 only
Kongsberg Maritime	Simrad SBP120	Sub bottom profiler	Y	
Kongsberg Maritime	Simrad EK60	Scientific echo sounder (fisheries)	Y	Logged times are 3min 43secs ahead of Sci GPS
NMFSS	CLAM	CLAM system winch log	Y	
NMFSS	Surfmet	Meteorology suite	Y	
NMFSS	Surfmet	Surface hydrography suite	Y	
		Skipper log (ship's velocity)	Y	
OceanWaveS GmbH	WaMoS II	Wave Radar	Y	Summary data logged only
Teledyne RD Instruments	Ocean Observer 75 kHz	VM-ADCP	N	
Teledyne RD Instruments	Ocean Observer 150 kHz	VM-ADCP	N	
Microg Lacoste	Air-Sea System II	Gravity	Y	

***bestnav* hierarchal ordering:**

The following table lists the order of navigational systems in the *bestnav* process for positional fix.

Rank	**Order of positional fixes**	**Comment**
1	posmvpos	(Primary input file) Gap before change = 0030S, Least status = 9
2	gps_cnav	(Second input file) Gap before change = 0030S, Least status = 9
3	dps116	(Third input file) Gap before change = 0030S, Least status = 9

```
Known Drift Velocity: magnitude 00000 knots: direction 000 degrees
Maximum acceptable drift magnitude 05.0_knots
Units of dist_run: nautical miles
```

***Relmov* source:**

The following table lists the navigational systems that are used in the *relmov* process for ship's motion.

Navigational source of ship's motion	**Comment**
Input file: gyro (gyro_s)	Data rate 01S
Input file: log (log_chf)	(Chernikeef speed log)

RVS data processing:

The following table lists the RVS Level-C processing programs that were run.

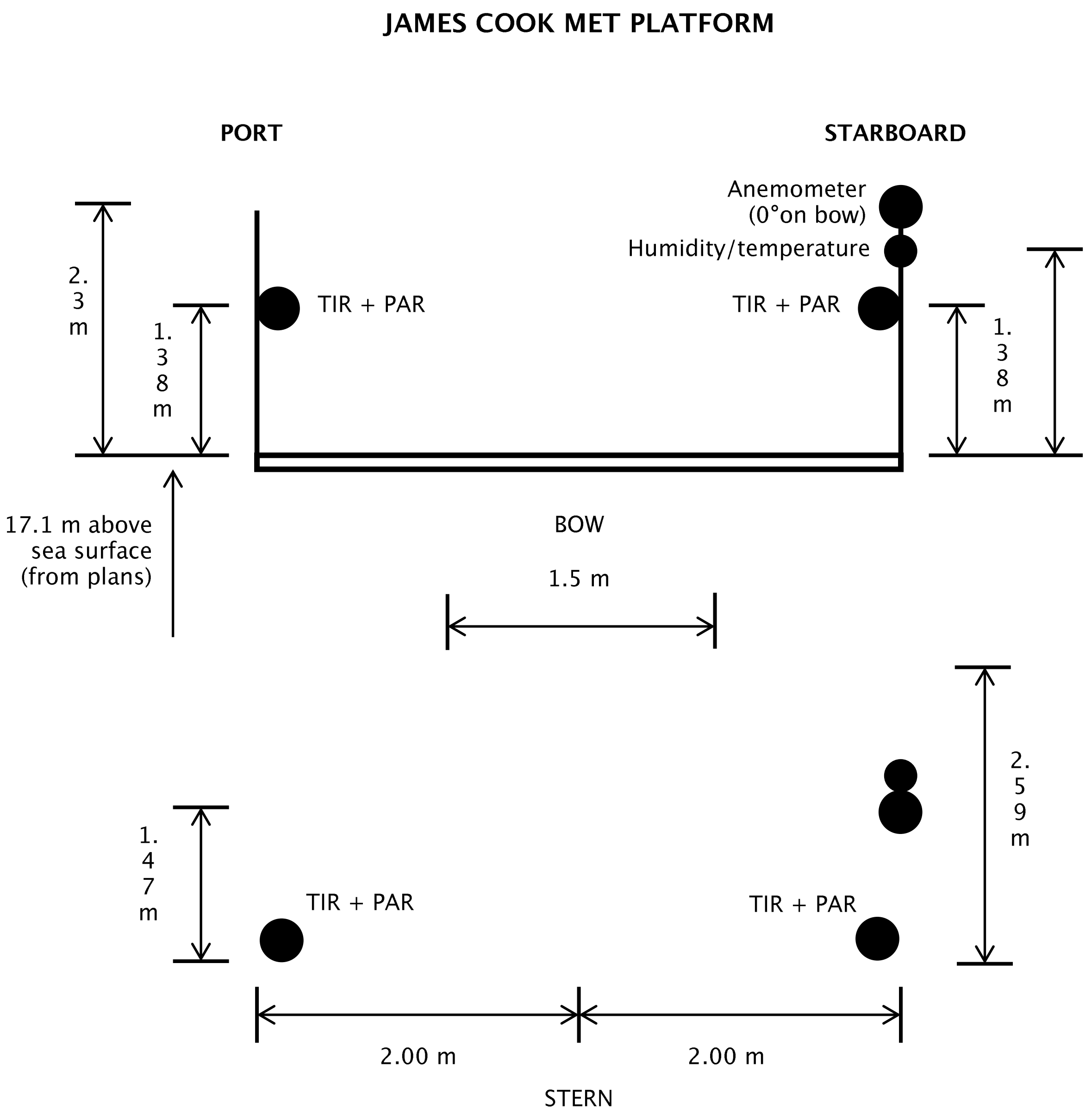
Program	**Was it run?**	**Comments**
bestnav	Y	
*prodep***	Y	
protsg	N	
relmov	Y	
satnav	N	
windcalc	N	

**Please state if sound velocity probes used for depth correction instead of *prodep*.

Surfmet Sensor Information Sheet (James Cook)

Cruise	JC149
Technician	Leg 1&2 Mark Maltby Leg 3 Andrew Moore
Date	16th April – 20th June 2017

Meteorology platform (Foremast)



Pumped seawater flow rates (ml/min):	1500
Anemometer orientation on bow (deg):	0
Seawater intake depth (m):	5.5

Fitted Sensors:

Manufacturer	**Sensor**	**Serial No.**	**Comments (eg. Port)**	**Calibration applied?**	**Last calibration date**
AML	Smart SV	5444	-	-	03/10/2016
Skye	PAR	28560	Starboard	No	15/09/2015
Skye	PAR	28559	Port	No	11/09/2015
Kipp & Zonen	TIR	047463	Starboard	No	15/06/2015
Kipp & Zonen	TIR	994132	Port	No	15/07/2016
Gill	Windsonic	064537	Tested 09/09/2016	No	No cal
Vaisala	HMP45 Temp./Hum.	E105502		No	18/07/2016
Vaisala	PTB110 Air Pres.	J0710002		No	27/12/2016
Wet Labs	WS3S Fluorimeter	WS3S-246		No	12/12/2016
Wet Labs	CST Transmissometer	CST-114PR		No	19/12/2016
Sea-Bird	SBE38 Temperature	3853440-0476		No	28/07/2016
Sea-Bird	SBE45 TSG	4548881-0232	Up to 1yr of operation from install date (within 2yrs of calibration date)	No – Install date 20/09/2016	13/10/2015
Valeport	MIDAS SVP	22355			23/09/2015
Valeport	MIDAS SVP	22241			14/09/2016

Spare Sensors on-board not fitted:

-	**Sensor**	**Serial No.**	**Comments (eg. Port)**	**Calibration applied?**	**Last calibration date**
AML	Smart SV	5124	-	-	09/08/2016
Skye	PAR	28563	-	-	13/05/2016
Kipp & Zonen	TIR	047462	-	-	01/06/2015
Kipp & Zonen	TIR	994133	-	-	03/11/2016
Gill	Windsonic	064538	Tested 09/09/2016	-	No cal
*					
Vaisala	HMP45A Temp./Hum.	D1440038	-	-	17/01/2017
Vaisala	HMP45 Temp./Hum.	C1320001	-	-	27/12/2016
Vaisala	PTB110 Air Pres.	J0710001	-	-	12/04/2016
Vaisala	PTB110 Air Pres.	L2240581	-	-	11/07/2016
Wet Labs	WS3S Fluorimeter	WS3S-117	-	-	20/12/2016
Wet Labs	CST Transmissometer	CST-112	-	-	11/07/2016
Sea-Bird	SBE38 Temperature	3868285-0689	-	-	28/07/2016
Sea-Bird	SBE38 Temperature	3854115-0487	-	-	15/02/2017
Sea-Bird	SBE38 Temperature	3853440-0416	-	-	15/02/2017
Sea-Bird	SBE45 TSG	0485	Up to 1yr of operation from install date (within 2yrs of calibration date)	-	28/07/2016

National Marine Facilities – RRS James Cook NetCDF Description Version 2.10 – March 2016

This document describes how the variables logged by the National Marine Facilities Sea System's Techsas version 5.9 data logging system are recorded and processed on RRS James Cook. There is a similar set-up on RRS Discovery, but the NetCDF filenames are different; a similar document is available for RRS Discovery. If you have any questions then please contact the Scientific Ship Systems Group via email at: nocs_nmfss_shipsys@noc.ac.uk or via the head of the group, Gareth Knight on 023 8059 6281.

The following list of variables is arranged by the NetCDF files in which each variable occurs, with the RVS Level-C stream name afterwards in round brackets. The NetCDF files are arranged into sub-directories and the directory name is given before the filename, separated by a forward slash. The variable name in round brackets is the variable name from the RVS Level-C data file. The units are given in square brackets.

The **time** variable in the NetCDF files is a floating point number giving the number of days since 30th December 1899 00:00:00 UTC. The decimal part gives the time of day. The **Time** variable in the RVS Level-C files when they are presented in an ASCII format varies depending upon the program used to generate the ASCII file, but is commonly YY DDD HH:MM:SS where YY is the last two digits of the year, DDD is the Julian day of the year and the remainder is the UTC time.

Variables in the Level-C files have a status flag associated with them. The value of these status flags indicates the following:

Flag	Meaning
60	Accept
55	Correct
50	Good (default)
45	Uncorrected
40	Interpolated
35	Restart
30	Suspect
20	Reject
10	Test
0	Not written

Changes

Version 1.10: an error was found in YYYYMMDD-hhmmss-MET-JC-SM_JC1.SURFMETv2 (surfmet). In version 1.00 the anemometer was described as having an RS232 output, when in fact it had an analogue output. This has been corrected in this version. The error was solely in this document; no changes have been made to the hardware.
Version 1.11: added the post-processed Level-C data streams relmov, bestnav, bestdrf, pro_wind and prodep. Added the RVS Level-C statuses and a complete description of the USBL data for the first time.

Version 1.12: a bug was discovered in the CNAV NetCDF data. All NetCDF data logged since the GPS was fitted to the vessel on cruise JC052 in September 2010 was logged in the format described in version 1.12 of this document.
Version 1.13: added in details about the CLAM cable types and a bug that occurred in the CLAM cable type prior to cruise JC68.
Version 1.14: improved the description of the USBL accuracy.
Version 1.15: updated after changes were made to Techsas and Level-C. A bug was found in the Level-C winch data recorded prior to 25th July 2012. Details are on the winch page. The CNAV module was fixed to remove the bug in position. The CNAV page has been updated to describe when this bug was present in the data. The POSMV and DPS116 modules prior to 25th July 2012 did not record data in the gndcourse or gndspeed variables. The Seapath 200 still does not record data in gndcourse or gndspeed.
Version 1.16: fixed three errors in this document. The unit for dist_run in the Level-C had been given as degree when it should have been nautical miles. In the satellite info files for the POSMV, Seapath 200 and DPS116 GPSs the descriptions for VDOP and PDOP had been swapped over. The page for the CNAV satellite info file had been omitted from previous versions.
Version 1.17: included a numerical example of how to apply the calibration to TIR data as the units of light intensity are given in an unusual format.

Version 2.0: a new version for Techsas 5.9, which began to be used on the James Cook on cruise JC108 on 23rd September 2014. Details of bugs that occurred in the older Techsas 2.35 have been removed from this document. If you are working with data prior to JC108 then you should consult version 1.17 of this document.

Version 2.1: 'SURFMETv2/YYYYMMDD-hhmmss-Light-JC-SM_JC1.SURFMETv2 (surfmet)' page 9 – Added second pressure equation for converting PTB110 voltage to hPa. This only applies to PTB110 S/N:L2240581, L2240582 (as of 03/2016).

Table of Contents

AIRSEAII/YYYYMMDD-hhmmss-AirSeaII-S84_JC1.AirSeaII (gravity)

This file contains data from the Micro-g Lacoste gravity meter.

grav_av (grav_av) [counter units] is the filtered gravity value.

springt (springt) [counter units] is the spring tension.

beam (beam) [volt × 750000] is the beam position.

vc (vc) [see manual] VCC data field.

al (al) [see manual] AL data field.

ax (ax) [see manual] AX data field.

ve (ve) [see manual] VE data field.

ax2 (ax2) [see manual] AX2 data field.

xac2 (xac2) [see manual] XACC2 data field.

lac2 (lac2) [see manual] LACC2 data field.

xac (xac) [Gal] Cross acceleration.

lac (lac) [Gal] Longitudinal acceleration.

eotcor (eotcor) [milliGal] EOTVOS correction.

lat (lat) [degree] is the latitude that the gravity value was taken at.

lon (lon) [degree] is the longitude that the gravity value was taken at.

heading (heading) [degree] is the course made good from the GPS data.

velocity (vel) [knot] is the vessel's velocity from the GPS data.

not logged (xcup) [] a constant value of zero.

time (Time) []

CLAM/YYYYMMDD-hhmmss-CLAM-CLAM_JC1.CLAM (winch)

The CLAM system records data from the ship's permanently fitted winches.

cabltype (cabltype) [] is the type of cable in operation.

The cable types are shown below:

Numeric Value	Cable Type
0	No winch selected
1	CTD1
2	CTD2
3	Core Warp
4	Trawl
5	Fibre Optic Deep Tow
6	Plasma

cablout (cablout) [metre] is the length of cable deployed.

rate (rate) [metre per minute] is the rate of cable deployment. A positive rate indicates that the cable is being paid out (veered) and a negative rate indicates that the cable is being hauled in.

tension (tension) [tonne] is the cable tension.

btension (btension) [tonne] is the cable back tension.

angle (angle) [degree] is no longer be measured by the winch system, but was probably the vessel heel (roll) angle.

time (Time) []

EA600/YYYYMMDD-hhmmss-EA600-EA600_JC1.EA600 (ea600m)

The EA600 echo sounder outputs the depth that it measures from the sea bed to the ship's waterline, (i.e. compensating for the depth of the sensor below the waterline). The compensation factor is set in the software. The sensor is mounted on the drop keel. The sonar user should modify the compensation factor when the drop keel is moved. The depth is output in various units, all of which are logged to the NetCDF file. Only the depth in metres is recorded in the RVS data files. No compensation is made for the current tidal height. No information about the sound velocity correction applied is contained in the file and the cruise report should be consulted for further information.

depthft (not logged) [feet]

depthm (depth) [metre]

depthF (not logged) [fathom]

time (Time) []

LOG/YYYYMMDD-hhmmss-vmvbw-log_chf_JC1.log (log_chf)

The Chernikeef Electromagnetic dual-axis log measures the ship's velocity through the water.

speedfa (speedfa) [knot] is the speed of the vessel through the water in a fore and aft direction. Forward motion results in a positive speed.

speedps (speedps) [knot] is the speed of the vessel through the water sideways. Starboard motion results in a positive speed.

time (Time) []

ATT/YYYYMMDD-hhmmss-gppat-GPPAT_JC1.att (adu5pat)

This data file contains data from the Ashtech ADU5 GPS-based attitude-measuring system.

measureTS (measureT) [days] is the time stamp applied to the data by the GPS unit.

lat (lat) [degree] is the latitude.

long (lon) [degree] is the longitude.

alt (alt) [metre] is the measured altitude.

heading (heading) [degree] is the true heading of the ship.

pitch (pitch) [degree] is the pitch of the ship. A bow up rotation gives a positive pitch value.

roll (roll) [degree] is the roll of the ship. A rotation of the ship's superstructure to starboard gives a positive roll value.

mrms (mrms) [metre] attitude phase measurement RMS error.

brms (brms) [metre] attitude baseline length RMS error.

time (Time) []

SURFMETv2/YYYYMMDD-hhmmss-Light-JC-SM_JC1.SURFMETv2 (surfmet)

This NetCDF file gives the voltages recorded by the four light sensors and also the air pressure (it is unknown why air pressure is included in this file rather than the met file). The voltages recorded by the light sensors must be converted to an intensity using the calibration factor given on each sensor's latest data sheet. The units for the voltage do not use a standard SI prefix and care must be taken when converting them to light intensity. The following example shows how the conversion should be performed:

A typical maximum value for a TIR in a Techsas or Level-C file is 1108.7. This is 1108.7×10^{-5} V. From the data sheet for this TIR the calibration to be applied is 11.94 µVolts/W/m^2. So the actual TIR light intensity is 0.011087 / 0.00001194 = 928.5 W/m^2.

pres (press) [hectopascal] is the atmospheric pressure. The voltage measured by the Nudam ADC is converted to hPa in the Surfmet program by the equation:

$pres = 800 + (52\times voltage)$

where *voltage* is the measured voltage in volts.

[Version 2.1 Change] For fitted PTB110 sensors S/N: L2240581, L2240582 the voltage measured by the Nudam is converted to hPa in the Surfmet program by the equation:

$pres = 500 + (120*voltage)$

ppar (ppar) [volt × 10^{-5}] is the voltage measured by the Nudam ADC in millivolts multiplied in the Surfmet software by 100, from the Photosynthetically Active Radiation (PAR) sensor on the port side of the ship's meteorological platform. To convert this value to a light intensity, it should be divided by the calibration factor specified on each sensor's data sheet, paying attention to the fact that the calibration factor typically has units of microvolt per watt per metre squared and this value has units of $\times10^{-5}$ volts.

spar (spar) [volt × 10^{-5}] is the voltage measured by the Nudam ADC in millivolts multiplied in the Surfmet software by 100, from the PAR sensor on the starboard side of the ship's meteorological platform. To convert this value to a light intensity, it should be divided by the calibration factor specified on each sensor's data sheet.

ptir (ptir) [volt × 10^{-5}] is the voltage measured by the Nudam ADC in millivolts multiplied in the Surfmet software by 100, from the Total Irradiance (TIR) sensor on the port side of the ship's meteorological platform. To convert this value to a light intensity, it should be divided by the calibration factor specified on each sensor's data sheet.

stir (stir) [volt × 10^{-5}] is the voltage measured by the Nudam ADC in millivolts multiplied in the Surfmet software by 100, from the TIR sensor on the starboard side of the ship's meteorological platform. To convert this value to a light intensity, it should be divided by the calibration factor specified on each sensor's data sheet.

time (Time) []

SURFMETV2/YYYYMMDD-hhmmss-MET-JC-SM_JC1.SURFMETv2 (surfmet)

speed (speed) [metre per second] is the relative wind velocity. The wind speed and direction are at the height of the anemometer on the met platform, approximately 18.7 metres above the sea surface depending upon the trim of the ship. The sensor outputs a voltage between 0 and 5 volts corresponding to 0 and 50 ms^{-1}. These voltages are measured by a Nudam ADC. The Surfmet software converts this voltage to a speed using the equation:

$$speed = (50/5) \times voltage$$

The units attribute of the speed variable in the NetCDF file say that the units are knot, but this is incorrect and the units are meter per second.

direct (direct) [degree] is the wind direction relative to the vessel that the wind is blowing from. 0° is at the bow. The sensor outputs a voltage between 0 and 5 volts corresponding to 0 and 360°. The Surfmet software converts this voltage to a direction using the equation:

$$direct = (360/5) \times voltage$$

airtemp (airtemp) [degree Celsius] is the air temperature. The sensor outputs a voltage between 0 and 1 volt, corresponding to -40°C to +60°C. This voltage is measured by a Nudam ADC and is converted to a temperature in the Surfmet software using the equation:

$$airtemp = (100 \times voltage) - 40$$

where *voltage* is the measured voltage in volts.

humid (humidity) [percent] is the relative humidity of the air. The sensor outputs a voltage between 0 and 1 volt, corresponding to 0% and 100% relative humidity respectively. The voltage is measured by a Nudam ADC and is converted to relative humidity in the Surfmet software using the equation:

$$humid = 100 \times voltage$$

where *voltage* is the measured voltage in volts.

time (Time) []

GPS/YYYYMMDD-hhmmss-ADUPOS-ADUPOS_JC1.gps (adu5pos)

This data file contains position data from the Ashtech ADU5 GPS-based attitude-measuring system.

type (type) [] specifies the position type. 0 indicates a raw position and 2 specifies a differentially corrected position.

svc (svc) [] is number of satellites used to compute the position.

measureTS (measureT) [] is the time stamp applied to the data by the ADU5 GPS.

lat (lat) [degree] is the latitude.

long (lon) [degree] is the longitude.

alt (alt) [metre] is the altitude.

cmg (cmg) [degree true] is the course made good, or course over the ground.

smg (smg) [knot] is the speed over the ground, or speed made good.

vvel (vvel) [metre per second] is the vertical velocity with a positive value indicating motion upwards.

pdop (pdop) [] is the GPS positional dilution of precision.

hdop (hdop) [] is the GPS horizontal dilution of precision.

vdop (vdop) [] is the GPS vertical dilution of precision.

tdop (tdop) [] is the GPS time dilution of precision.

time (Time) []

TSG/YYYYMMDD-hhmmss-SBE45-SBE45_JC1.TSG (sbe45)

The Sea-Bird Electronics SBE45 Thermosalinograph's (TSG) data is logged directly by the Techsas data acquisition system. Techsas rebroadcasts the data and it is logged for a second time in the Surfmet data files.

temp_h (temp_h) [degree Celsius] is the water temperature measured in the SBE45 housing. The SBE45 contains its own calibration coefficients and outputs over RS232 the calibrated temperature.

cond (cond) [siemen per metre] is the conductivity measured by the SBE45. It is the calibrated conductivity output via RS232.

salin (salin) [] is the water salinity calculated by SBE45. It is measured using the Practical Salinity Scale and hence is unit less.

sndspeed (sndspeed) [metre per second] is the velocity of sound in the sampled water calculated by the SBE45 using the Chen-Millero equation.

temp_r (temp_r) [degree Celsius] is the water temperature measured by the SBE38 remote thermometer at the raw water inlet to the ship. The SBE38 contains its own calibration coefficients and outputs over RS232 the calibrated temperature.

time (Time) []

SURFMETV2/YYYYMMDD-hhmmss-Surf-JC-SM_JC1.SURFMETv2 (surfmet)

This file contains the underway water sampling data. The transmissometer and fluorimeter data has been recorded directly by Techsas. The SBE45 data is first logged by the Techsas, which then broadcasts the data across the network. The Surfmet software then logs these broadcasted values. Occasionally Surfmet can be delayed in logging values and data will be buffered in the software. Comparing salinity or temperature data from the SBE45 file with the delayed data in this file will allow the length of the delay to be found.

temp_h (temp_h) [degree Celsius] is the SBE45 housing water temperature.

temp_m (temp_r) [degree Celsius] is the SBE38 remote temperature at the ship's raw water inlet.

cond (cond) [siemen per metre] is the conductivity measured by the SBE45.

fluo (fluo) [volt] is the voltage measured by the Nudam Analogue to Digital Converter (ADC) from the Wet Labs WS3S Fluorimeter. Each fluorimeter's data sheet should be consulted for the equation and calibration factors to convert from voltage to chlorophyll concentration.

trans (trans) [volt] is the raw voltage measured by the Nudam ADC from the Wet Labs C-Star Transmissometer. Each transmissometer's data sheet should be consulted for the equation and calibration factors to convert from voltage to transmittance.

time (Time) []

LOG/YYYYMMDD-hhmmss-vdvhw-log_skip_JC1.Log (log_skip)

The Skipper single-axis log measures the vessel's speed through the water. It is primarily intended for bridge navigation purposes but is also logged by Techsas and Level-C.

heading (heading) [degree true] is the true heading of the vessel. This field may not contain any data.

headMag (headMag) [degree magnetic] is the magnetic heading of the vessel. This field may not contain any data.

speed (speed) [knot] is the speed of the vessel through the water.

speedKPH (speedKPH) [kilometre per hour] is the speed of the vessel through the water.

time (Time) []

GPS/YYYYMMDD-hhmmss-cnav-CNAV.GPS (gps_cnav)

This data file contains data from the CNAV GPS unit. The CNAV GPS data is not motion compensated and so the positions are the position of the antenna at the top of the mast.

measureTS (measureT) [] is the time stamp applied to the data by the GPS unit.

lat (lat) [degree] is the latitude of the CNAV GPS antenna in the format described above.

long (lon) [degree] is the longitude of the CNAV GPS antenna in the format described above.

alt (not logged) [metre] is the height of the CNAV GPS antenna above the reference ellipsoid.

prec (not logged) [] is the horizontal position precision code. It is defined by the following table:

prec	HDOP
0	HDOP < 0.3
1	0.3≤HDOP<1.0
2	1.0≤HDOP<3.0
3	3.0≤HDOP<10.0
4	10.0≤HDOP<30.0
5	30.0≤HDOP<100
6	100≤HDOP<300
7	300≤HDOP<1000
8	1000≤HDOP<3000
9	3000≤HDOP

mode (prec) [] is the mode that the GPS was operating in. 0 indicates an invalid fix, 1 a GPS fix and 2 a DGPS fix.

not logged (pdop) [] this is a null value that is only logged in the RVS data file.

gndcourse (cmg) [degree true] is the course made good, or course over the ground.

gndspeed (smg) [knot] is the speed over the ground, or speed made good.

time (Time) []

GYR/YYYYMMDD-hhmmss-gyro-GYRO1_JC1.gyr (gyropmv)

heading (heading) [degree true] is the true heading of the ship in degrees from the POSMV gyro.

time (Time) []

GYR/YYYYMMDD-hhmmss-gyro-SGYRO_JC1.gyr (gyro_s)

heading (heading) [degree true] is the true heading of the ship in degrees from the ship's gyro compass.

time (Time) []

GPS/YYYYMMDD-hhmmss-position-Applanix_GPS_JC1.gps (posmvpos)

This data file contains data from the POSMV GPS unit. The POSMV outputs the position of the vessel's common reference point, the cross on top of the POSMV Motion Reference Unit (MRU) in the gyro and gravity meter room.

measureTS (measureT) [] is the time stamp applied to the data by the GPS unit.

lat (lat) [degree] is the latitude of the vessel's common reference.

long (lon) [degree] is the longitude of the vessel's common reference point.

alt (alt) [metre] is the height of the surveyed reference point above the reference ellipsoid.

prec (prec) [] is the horizontal position precision code. It is defined by the following table:

prec	HDOP
0	HDOP < 0.3
1	0.3≤HDOP<1.0
2	1.0≤HDOP<3.0
3	3.0≤HDOP<10.0
4	10.0≤HDOP<30.0
5	30.0≤HDOP<100
6	100≤HDOP<300
7	300≤HDOP<1000
8	1000≤HDOP<3000
9	3000≤HDOP

mode (mode) [] is the mode that the GPS was operating in. 0 indicates an invalid fix, 1 a GPS fix and 2 a DGPS fix.

gndcourse (cmg) [degree true] is the course made good, or course over the ground.

gndspeed (smg) [knot] is the speed over the ground, or speed made good.

heading (not logged) [degree true] is the direction that the vessel's bow is pointing towards calculated from the POSMV's motion reference unit.

time (Time) []

GPS/YYYYMMDD-hhmmss-position-DPS-116_JC1.gps (dps116)

This data file contains data from the DPS116 GPS unit. The DPS116 outputs the position of the DPS116 antenna at the top of the main mast.

measureTS (not logged) [] is the time stamp applied to the data by the GPS unit.

lat (lat) [degree] is the latitude of the DPS116 antenna.

long (lon) [degree] is the longitude of the DPS116 antenna.

alt (alt) [not logged] is the height of the DPS116 antenna above the reference ellipsoid.

prec (not logged) [] is the horizontal position precision code. It is defined by the following table:

prec	HDOP
0	HDOP < 0.3
1	0.3≤HDOP<1.0
2	1.0≤HDOP<3.0
3	3.0≤HDOP<10.0
4	10.0≤HDOP<30.0
5	30.0≤HDOP<100
6	100≤HDOP<300
7	300≤HDOP<1000
8	1000≤HDOP<3000
9	3000≤HDOP

mode (not logged) [] is the mode that the GPS was operating in. 0 indicates an invalid fix, 1 a GPS fix and 2 a DGPS fix.

gndcourse (not logged) [degree true] is the course made good, or course over the ground, which is not available for the DPS116.

gndspeed (not logged) [knot] is the speed over the ground, or speed made good, which is not available for the DPS116.

heading (not logged) [degree true] is the direction that the vessel's bow is pointing towards but is not available for the DPS116.

time (Time) []

GPS/YYYYMMDD-hhmmss-position-Seapath200_JC1.gps (sb-pos)

This data file contains data from the Seapath 200 GPS unit. The Seapath 200 outputs positions at the vessel's common reference point.

measureTS (measureT) [] is the time stamp applied to the data by the GPS unit.

lat (lat) [degree] is the latitude of the common reference point (the cross on the top of the POSMV MRU).

long (lon) [degree] is the longitude of the common reference point.

alt (not logged) [metre] is the height of the surveyed reference point above the reference ellipsoid.

prec (not logged) [] is the horizontal position precision code. It is defined by the following table:

prec	HDOP
0	HDOP < 0.3
1	0.3≤HDOP<1.0
2	1.0≤HDOP<3.0
3	3.0≤HDOP<10.0
4	10.0≤HDOP<30.0
5	30.0≤HDOP<100
6	100≤HDOP<300
7	300≤HDOP<1000
8	1000≤HDOP<3000
9	3000≤HDOP

mode (not logged) [] is the mode that the GPS was operating in. 0 indicates an invalid fix, 1 a GPS fix and 2 a DGPS fix.

gndcourse (not logged) [degree true] is the course made good, or course over the ground, which is not available for the Seapath 200.

gndspeed (not logged) [knot] is the speed over the ground, or speed made good, which is not available for the Seapath 200.

heading (not logged) [degree true] is the direction that the vessel's bow is pointing towards but is not available for the Seapath 200.

time (Time) []

GPS/YYYYMMDD-hhmmss-position-usbl_JC1.gps (usblpos)

This data file contains the positions of beacons being tracked by the USBL system. It is generated from the NMEA GGA stream output by the Sonardyne USBL software and uses a GPS data logging module to record the data and so there are additional fields logged that do not contain any meaningful data. The name of the beacon being tracked is not logged and so if multiple beacons are being tracked, the data from all of the beacons will be logged with no way of telling which beacon the position logged refers to.

measureTS (measureT) [] is the time stamp applied to the data by the GPS unit.

lat (lat) [degree] is the latitude of the object being tracked.

long (lon) [degree] is the longitude of the object being tracked.

alt (alt) [metre] is the depth relative to the water surface of the object being tracked. A negative value is depth below the water and a positive value is a depth above the water and so is not valid.

prec (prec) [] contains no meaningful data.

mode (mode) [] contains no meaningful data and is always 2.

gndcourse (cmg) [degree true] contains no meaningful data.

gndspeed (smg) [knot] contains no meaningful data.

heading (not logged) [degree true] contains no meaningful data.

time (Time) []

GPS/YYYYMMDD-hhmmss-satelliteinfo-Applanix_GPS_JC1.gps (not logged)

Additional information from the Applanix POSMV regarding the GPS position fix quality.

nbseen (not logged) [] is the number of satellites that can theoretically be seen from the current position.

nbused (not logged) [] is the number of satellites actually used to compute the position.

HDOP (not logged) [] is the GPS horizontal dilution of precision.

VDOP (not logged) [] is the GPS vertical dilution of precision.

PDOP (not logged) [] is the GPS positional dilution of precision.

time (not logged) []

GPS/YYYYMMDD-hhmmss-satelliteinfo-DPS-116_JC1.gps (not logged by Level-C)

Additional information from the DPS116 regarding the GPS position fix quality.

nbseen (not logged) [] is the number of satellites that can theoretically be seen from the current position.

nbused (not logged) [] is the number of satellites actually used to compute the position.

HDOP (not logged) [] is the GPS horizontal dilution of precision.

VDOP (not logged) [] is the GPS vertical dilution of precision.

PDOP (not logged) [] is the GPS positional dilution of precision.

time (not logged) []

GPS/YYYYMMDD-hhmmss-satelliteinfo-Seapath200_JC1.gps (not logged by Level-C)

Additional information from the Seapath 200 regarding the GPS position fix quality.

nbseen (not logged) [] is the number of satellites that can theoretically be seen from the current position.

nbused (not logged) [] is the number of satellites actually used to compute the position.

HDOP (not logged) [] is the GPS horizontal dilution of precision.

VDOP (not logged) [] is the GPS vertical dilution of precision.

PDOP (not logged) [] is the GPS positional dilution of precision.

time (not logged) []

GPS/YYYYMMDD-hhmmss-satelliteinfo-CNAV.gps (not logged by Level-C)

Additional information from the CNAV regarding the GPS position fix quality.

nbseen (not logged) [] is the number of satellites that can theoretically be seen from the current position.

nbused (not logged) [] is the number of satellites actually used to compute the position.

HDOP (not logged) [] is the GPS horizontal dilution of precision.

VDOP (not logged) [] is the GPS vertical dilution of precision.

PDOP (not logged) [] is the GPS positional dilution of precision.

time (not logged) []

GPS/YYYYMMDD-hhmmss-satelliteinfo-usbl_JC1.gps (not logged by Level-C)

Additional information from the Fusion USBL system regarding the GPS position fix quality. None of this data does not contain meaningful information and is generated because the default GPS logging module is used to log the USBL NMEA GGA output.

nbseen (not logged) [] contains no meaningful data.

nbused (not logged) [] contains no meaningful data and is always 12.

HDOP (not logged) [] is the semi-major axis value for the fix of the beacon’s position in metres.

VDOP (not logged) [] contains no meaningful data.

PDOP (not logged) [] contains no meaningful data.

time (not logged) []

DEPTH/YYYYMMDD-hhmmss-sb_depth-EM120_JC1.depth (em120cb)

This data file contains the depths logged by the centre beam of the EM120 multi-beam echo sounder. The data has been corrected for sound velocity and the cruise report should be consulted for details of the corrections applied. The depths have not been corrected for tidal height.

snd (depth) [metre] is the depth measured by the EM120 multi-beam sonar from the sea bed to the sea surface. No compensation is made for the current tidal height.

freq (not logged) [kilohertz] is the sound frequency used to make the depth measurement. -1 indicates that the frequency was not included in the telegram from the echo sounder.

time (not logged) []

ATT/YYYYMMDD-hhmmss-shipattitude-Aplanix_TSS_JC1.att (posmvtss)

This data file contains data from the Applanix POSMV system's Motion Reference Unit (MRU).

measureTS (not logged) [] is the time stamp applied to the data by the POSMV.

head (heading) [degree] is the true bearing that the bow of the vessel is pointing at.

roll (roll) [degree] is the roll angle of the vessel. A positive angle indicates that the port side of the vessel is above the starboard side.

pitch (pitch) [degree] is the pitch of the ship. A bow up rotation gives a positive pitch value.

heave (heave) [metre] is the vertical variation in height of the reference point on top of the POSMV MRU. Positive values indicate the reference point has risen above its stationary position. Please see the POSMV documentation for details of the filtering applied to the MRU data to calculate this value.

mode (not logged) [] is a quality indicator of the heading data. 0 indicates that the calculation of the heading was performed without any GPS aid, 1 indicates the heading calculation was aided by the GPS and 2 that it was aided by GPS and GAMS.

time (Time) []

ATT/YYYYMMDD-hhmmss-shipattitude-Seapath200AT_JC1.att (sb-att)

This data file contains data from the Seapath 200 system's Motion Reference Unit (MRU).

measureTS (not logged) [] is the time stamp applied to the data by the Seapath 200.

head (heading) [degree] is the true bearing that the bow of the vessel is pointing at.

roll (roll) [degree] is the roll angle of the vessel. A positive angle indicates that the port side of the vessel is above the starboard side.

pitch (pitch) [degree] is the pitch of the ship. A bow up rotation gives a positive pitch value.

heave (heave) [metre] is the vertical variation in height of the reference point on top of the POSMV MRU (the Seapath's data is referenced to the POSMV MRU). Positive values indicate the reference point has risen above its stationary position. Please see the Seapath 200 documentation for details of the filtering applied to the MRU data to calculate this value. This variable in the RVS data stream may have every value as 0.

mode (not logged) [] is a quality indicator of the heading data. 0 indicates that the calculation of the heading was performed without any GPS aid, 1 indicates the heading calculation was aided by the GPS and 2 that it was aided by GPS and GAMS.

time (Time) []

ATT/YYYYMMDD-hhmmss-shipattitude_aux-Aplanix_TSS_JC1.att (posmvtss)

This data file contains data from the Applanix POSMV system's Motion Reference Unit (MRU).

acX (not logged) [] is not valid data.

acY (not logged) [] is not valid data.

acZ (not logged) [] is not valid data.

hunc (acc_hdg) [degree] is the heading uncertainty determined by the POSMV MRU.

runc (acc_roll) [degree] is the roll uncertainty determined by the POSMV MRU.

punc (acc_ptch) [degree] is the pitch uncertainty determined by the POSMV MRU.

time (Time) []

ATT/YYYYMMDD-hhmmss-shipattitude_aux-Seapath200AT_JC1.att (sb-att)

The logging module for the Seapath 200 system is based upon the POSMV's data logging module. This file is generated automatically but does not contain any valid data. The **accroll**, **accpitch** and **acchdg** variables do exist in the RVS Level-C stream, but every value is set to 0.0.

Not logged by Techsas (relmov)

This RVS Level-C post processed file contains details of the motion of the vessel and is used by other Level-C post-processing streams. This file is generated from a gyro and log. The cruise documentation should be consulted to find which log and gyro source were used.

not logged (vn) [knot] is the north component of the vessel's velocity.

not logged (ve) [knot] is the east component of the vessel's velocity.

not logged (pfa) [knot] is the vessel's speed in the fore direction.

not logged (pps) [knot] is the vessel's speed in the port direction.

not logged (pgyro) [degree true] is the vessel's average heading.

time (Time) []

Not logged by Techsas (bestnav)

This RVS Level-C post processed file was written when satellite positioning was in its infancy and there could be long periods of time between fixes. The program bestnav reads position fixes from up to three RVS data files along with the ship's motion as calculated by relmov and generates a series of positions at time intervals of the navigation window. The cruise report should be consulted to find the source of the three position fixes used.

The basis for the program's calculations is a series of position fixes. The input fix files are given in order and a timeout given for each file. Fixes will be taken from the first file until a data gap longer than that file's timeout is encountered. Fixes will then be taken from the second file until either the first file resumes or the second file also times out. In the latter case the third file will be used.

The gaps in the series of fixes are next filled using dead-reckoning based on the ship's motion relative to the water. When the end of each gap is reached the position obtained by dead-reckoning is compared with the fix position and the difference between the positions attributed to drift, caused either by wind or water currents. The drift in position is used to calculate an average drift velocity during the fix gap whose magnitude is compared with the known drift and maximum allowable drift entered on the menu. If the drift is greater than the limit then the fix is assumed to be in error and processing is halted. If this occurs the user should either correct (or delete) the fix or increase the allowed drift and re-run the program.

If an acceptable drift velocity is found this is added to the dead reckoned positions. This completes the calculation of the ship's track. For each navigation window a position is interpolated from the calculated track and a record written to the output fixes file. Each record also contains the calculated velocity represented as north and east components and as speed made good and course made good. The average heading of the ship is calculated along with a cumulative distance since the start of the file. If the output file contains a variable stream this will be set to 1, 2 or 3 to indicate which of the fix files the current fix was taken from. The status of the calculated values will either be good, if there was a fix at the time of the output record, or interp otherwise.

not logged (lat) [degree] is the vessel’s calculated latitude.

not logged (lon) [degree] is the vessel’s calculated longitude.

not logged (vn) [knot] is the north component of the vessel’s velocity.

not logged (ve) [knot] is the east component of the vessel’s velocity.

not logged (cmg) [degree] is the vessel’s course made good.

not logged (smg) [knot] is the vessel’s speed made good.

not logged (dist_run) [nautical miles] is the distance that the vessel has run since the start of this bestnav file. Bestnav can also output this value in km. The BODC documentation produced for each cruise should be consulted for the units for cruises after December 2012.

not logged (heading) [degree] is the vessel's heading.

time (Time) []

Not logged by Techsas (bestdrf)

The drift velocities calculated by the bestnav program are also written to the bestdrf file. This contains either one record per navigation window (if there is more than one fix in the window) or one record per fix. The file contains the north and east calculated drift velocities as well as the known and limit drift speeds entered on the menu.

not logged (vn) [knot] is the north component of the vessel's drift.

not logged (ve) [knot] is the east component of the vessel's drift.

not logged (kvn) [knot] is the known north velocity entered in the relmov menu.

not logged (kve) [knot] is the known east velocity entered in the relmov menu.

time (Time) []

Not logged by Techsas (prodep)

The prodep post-processing file takes echo sounder depths that have been logged with a fixed sound velocity of 1500 ms-1 and corrects them for typical sound velocities for that geographical area using Carter's tables by the Hydrographic Office.

not logged (uncdepth) [metre] is the uncorrected depth.

not logged (cordepth) [metre] is the corrected depth.

not logged (cartarea) [] is the number of the Carter area used for the correction.

time (Time) []

Not logged by Techsas (pro_wind)

The Level-C windcalc post-processing program takes the bestnav and surfmet Level-C files and calculates the absolute wind speed and direction.

not logged (abswpsd) [knot] is the absolute wind speed at the height of the anemometer.

not logged (abswdir) [degree true] is the absolute wind direction.

time (Time) []

Appendix D: Gravity basestation ties

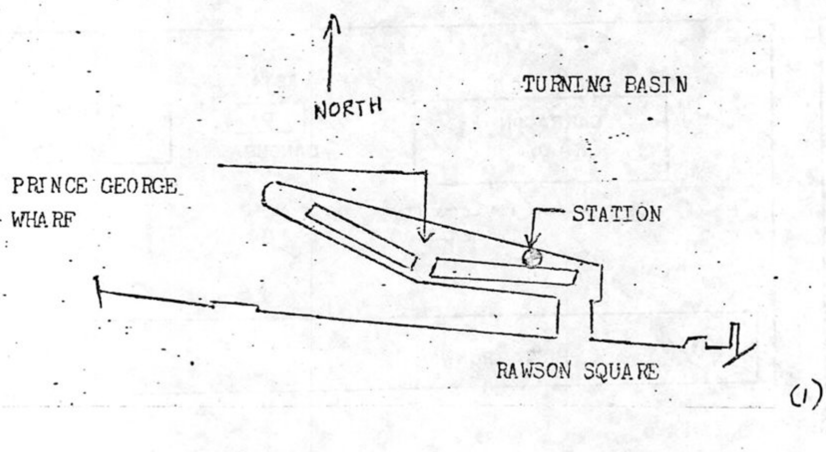
GRAVITY BASE STATION

LATITUDE 25° 04.75'N (1)	STATION DESIGNATION NASSAU
LONGITUDE 77° 20.44'W (1)	
ELEVATION 0.0 METERS (1)	COUNTRY/STATE Bahamas

REFERENCE CODE NUMBERS		ADOPTED GRAVITY VALUE	
ACIC 2088-1		g= 979 027.1 mgals	
NHO 83.02			
		ESTIMATED ACCURACY	DATE
		± 1.0 mgals	MONTH/YEAR 10/70

DESCRIPTION AND/OR SKETCH

Station is located on north side of Prince George Wharf, about 2 meters west of the fourth bollard from the northeast corner and 1 foot from the edge. (1)



REFERENCE SOURCE

(1) 02632

GRAVITY BASE STATION

101.01

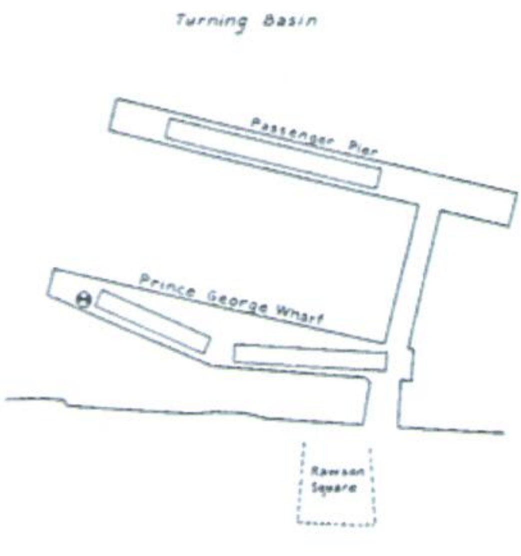
LAT.	25°04'.77N	COUNTRY/STATE	BAHAMAS - NEW PROVIDENCE IS
LONG.	77°20'.60W	TOWN/CITY	NASSAU
CHART REF.	1452	STATION NAME	PRINCE GEORGE WHARF (1)
OTHER REF.	NAVO 0083.03	IGSN 71 g=	979 013.16 mgals

STATION DESCRIPTION

The station is situated on the south side of Prince George Wharf, about 4.0 metres east of the second bollard from the south-west corner and 0.3 metres from the edge.

Elevation 2.7 m

LOCATION DIAGRAM



OBSERVATIONS/CONNECTIONS

Date	Observed by	Instrument	Ref. Station	Value	Δg	
Jan 1965	GID AND RNN	W642	101.02	979 013.36	- 0.2	
Jan 1965	GID AND RNN	W642	NASSAU AIRPORT	979 029.2	- 16.04	

GRAVITY BASE STATION

101.02

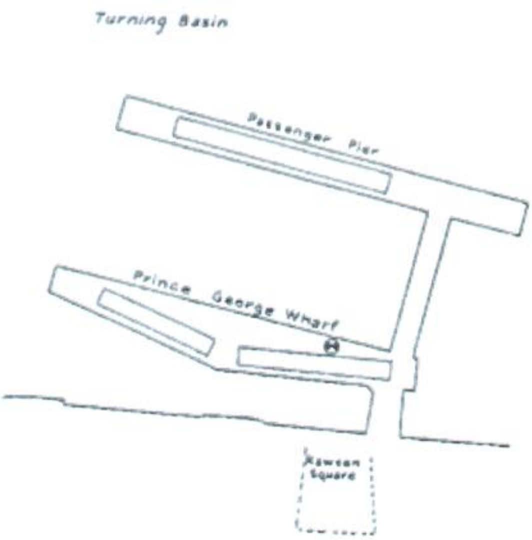
LAT. 25°04'.75N
LONG. 77°20'.44W
CHART REF. 1452
OTHER REF. NAVO 0083.02

COUNTRY/STATE BAHAMAS - NEW PROVIDENCE IS
TOWN/CITY NASSAU
STATION NAME PRINCE GEORGE WHARF (2)
IGSN 71 g= 979 013.36 mgals

STATION DESCRIPTION

The station is located on the north side of Prince George Wharf, about 2 metres west of the fourth bollard from the north-east corner and 0.3 metres from the edge.

LOCATION DIAGRAM



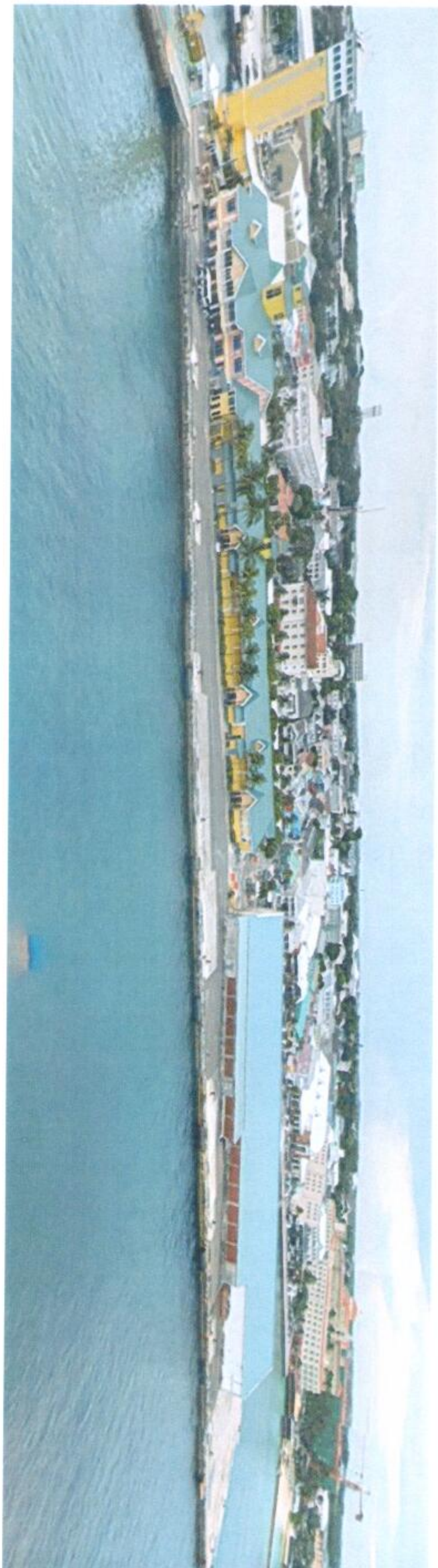
OBSERVATIONS/CONNECTIONS

Date	Observed by	Instrument	Ref. Station	Value	Δg	
Jan 1965	GID AND RNN	W642	101.01	979 013.16	+ 0.2	
Jan 1965	GID AND RNN	W642	NASSAU AIRPORT	979 029.0	- 15.64	

Prepared by Geophysics Section MS6 2/1982

MP608

Imagery ©2017 CNES / Astrium, DigitalGlobe, Map data ©2017 Google 50 m



FICHE DE STATION GRAVIMETRIQUE	DIFFUSION

DESCRIPTION

NOM DU POINT: GUADELOUPE – POINTE-A-PITRE – UNIVERSITE – LABORATOIRE DE BIOLOGIE MARINE

PAYS: FRANCE MISSION: IGN DATE: 01/01/2014

SYSTEME DE REFERENCE

RESEAU GRAVIMETRIQUE: IGSN71

SYSTEME GEODESIQUE: WGS84 PROJECTION: /

REFERENCE D'ALTITUDE: IGN 1988 MODELE DE POTENTIEL: GRS 80

DESIGNATION DU POINT

1) Mesure	Latitude :	16,223401° N	X :	
	Longitude :	-61,530155° W	Y :	
	Altitude :	2,97 m	Hauteur au-dessus du sol :	0 m

VALEURS DE LA PESANTEUR

1)	Pesanteur absolue:	**978 548,185 mGal**	+/–	**0,020**	**mGal**
	Gravimètre:	CG-5			
2)	Gradient vertical:		+/–		
	Gravimètre:				

REDUCTIONS

Néant.

COMMENTAIRES

Valeur de pesanteur issue de la fiche géodésique de l'IGN n° 9712002 (Pointe-à-Pitre II). Il s'agit probablement d'un point rattaché avec un gravimètre CG-5 à partir d'une mesure absolue réalisée par le gravimètre A10-014 lors de la campagne de mesures sur l'île en 2011 (11 sites absolus).

La station de référence gravimétrique se trouve à Pointe-à-Pitre, sur le site de l'Université des Antilles et de la Guyane, entre le laboratoire de biologie marine et la faculté des sports. Le point de mesure se situe au niveau de la dalle en béton du captage d'eau de mer (point h de la fiche IGN).

RESERVE AU SHOM

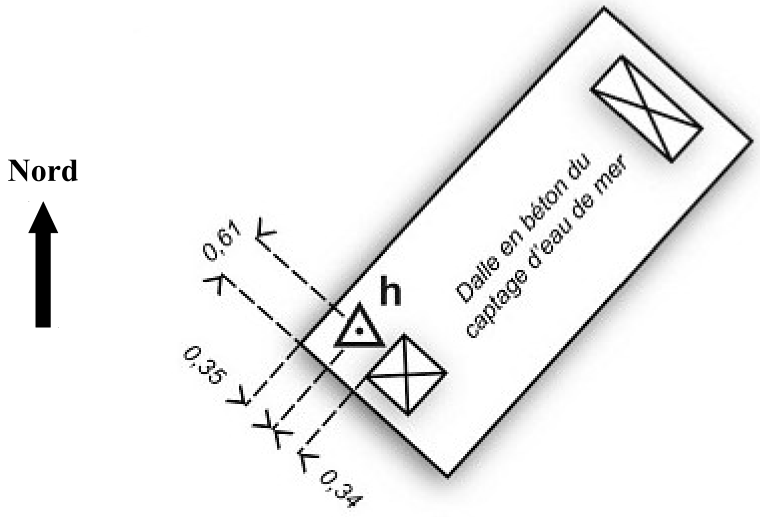
Néant.

N°: **1238-A**

SILHOUETTE ET CROQUIS DE REPEREMENT

Description :
matérialisée par un repère en laiton de 25 mm 2008.

Environnement :
dalle en béton.

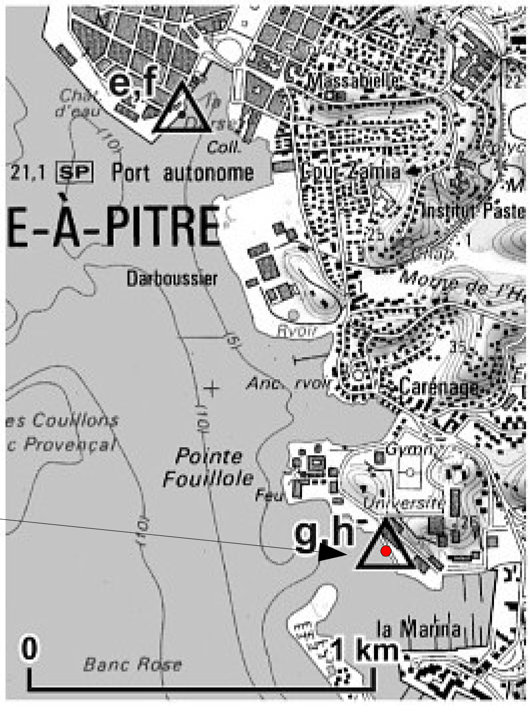


Source : IGN

PLAN DE SITUATION

Source : IGN

Station gravimétrique



DOCUMENTS

Néant.

Cachet et signature			
A :	Brest	Le :	20 avril 2016

IEF Sylvain Lucas

Nom du point : GUADELOUPE – POINTE-A-PITRE – UNIVERSITE – LABORATOIRE DE BIOLOGIE MARINE

Pays : FRANCE

Case réservée au SHOM

Numéro du point : **1238-A**

Mission : IGN

Année : 2014

FEUILLET DE PRISES DE VUES PHOTOGRAPHIQUES

Figure 1 : vue aérienne de Pointe-à-Pitre et localisation du laboratoire de biologie marine.

Nom du point :	GUADELOUPE – POINTE-A-PITRE – UNIVERSITE – LABORATOIRE DE BIOLOGIE MARINE	Pays :	FRANCE
Case réservée au SHOM	Mission : IGN	Année :	2014
Numéro du point : **1238-A**			

FEUILLET DE PRISES DE VUES PHOTOGRAPHIQUES

Figure 2 : vue aérienne de l'université et localisation de la station.

Nom du point :	GUADELOUPE – POINTE-A-PITRE – UNIVERSITE – LABORATOIRE DE BIOLOGIE MARINE	Pays :	FRANCE

Case réservée au SHOM	Mission :	IGN	Année :	2014
Numéro du point : **1238-A**				

FEUILLET DE PRISES DE VUES PHOTOGRAPHIQUES

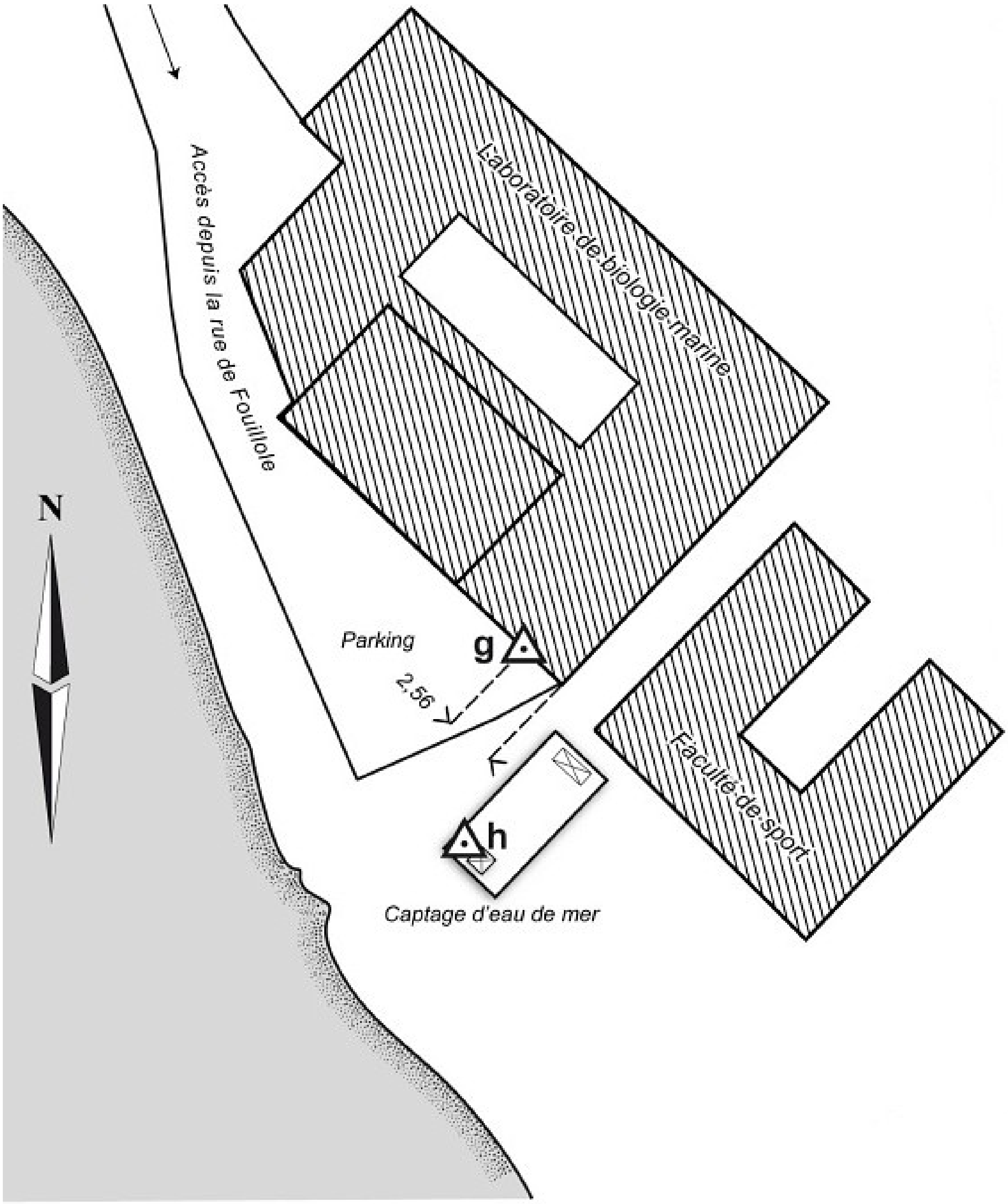


Figure 3 : plan de situation de la station gravimétrique (point h). Source : IGN.

Nom du point :	GUADELOUPE – POINTE-A-PITRE – UNIVERSITE – LABORATOIRE DE BIOLOGIE MARINE	Pays :	FRANCE
Case réservée au SHOM Numéro du point : **1238-A**	Mission : IGN	Année :	2014

FEUILLET DE PRISES DE VUES PHOTOGRAPHIQUES

Figure 4 : photographie de la dalle en béton, avec en arrière plan la faculté des sports. Le repère en laiton est au centre de la photographie. Source : IGN.

		Completed by:	Date:	Checked by:	Date:
Cruise Information:					
Vessel	RRS James Cook	JW			
Cruise No.	JC145 (Pre JC149)				
Last tie In Information (if applicable):	Santa Cruz de Tenerife, TENE-CHIP, 26/02/2017	JW	26/02/2017		
Ship-Fitted Gravity Meter Information:		**Completed by:**	**Date:**	**Checked by:**	**Date:**
Meter Serial No.	S-040	JW			
Fitted Control Module (CM):	CM2	JW			
Fitted Power Module (PM):	PM2	JW			
Meter Factor (‘Coef1’)*	0.9917	JW			

* ‘**Coef1’ may be found in ‘Meter_Table’ in the ASII_Hw.ini file on control module** - Also refer to Air Sea II Manual v2_Oct_2010 - page 6-5 ‘’Scaling Data To MilliiGals. ALL data is recorded by the meter in CU (Counter Units). NMF Gravity Meters S-040 and S-084 both have a single coefficient only. Apply this ‘meter factor/coef1’ to scale from CU to mGals. eotvos corrections may be shown on AirSea display (for daily QC monitoring) but are not saved.

Verify Pre-Tie In Checks have been Completed:		Completed by:	Date:	Checked by:	Date:
Period ship-fitted meter has been continuously on heat	> 40 days	JW			
Confirm gimbal is unclamped	Yes	JW			
Confirm Torque Motors Operational	Yes	JW			
Confirm Air Mounts pressure (28-32psi)					
AirSea Software running	Yes	JW			
Is there an active GPS input?	Yes	JW			
What is the GPS Source? **					

Position Input present/updating?	Yes	JW			
Course present/updating? **	Yes	JW			
Speed present/updating? **	Yes	JW			
Verify the input source is NOT providing a **Heading** value **					
Ambient temperature (from meter display)	27.5				
Meter Temperature (from meter display)	49.3				
Meter/software is stable and in still position (i.e. TC <2)					

** AirSea Software requires an NMEA GPRMC message for the navigation information. Course and speed data is required for eotvos calculations. **Heading must not be used**.

Base Station Information:		**Completed by:**	**Date:**	**Checked by:**	**Date:**
Location of Base Station	Nassau, Bahamas	JW	27/03/2017		
ISGN-71 Station Number*	101.01 (?)				
Coordinates (Lat/Long)	25 04.77'N, 77 20.60'W				
Other Notes	Prince George Wharf, 1				
Absolute Gravity	979013.16				

*IGSN-71 is the worldwide official gravity datum (International Gravity Standardisation Net 1971)

Obtain Tide information:	**Completed by:**	**Date:**	**Checked by:**	**Date:**
^ JC/DY both have Admiralty TotalTide Available to identify Height of last Low Water (**a**) and Height of next High Water (**b**) *[Refer to Readings/Calculations pages]*	JW	23/02/2017		

Checklist Page Completed By:		**Date:**	
Checked By:		**Date:**	

Gravity Tie-In Readings

Cruise Name	JC145 (Pre JC149)			
Date:	27-Mar-17			
Julian Day No.	87			
Time Zone:	GMT-0400			

* If at any station stable/consistent values are achieved from the initial **3 readings** then no further readings are required. Fields 'Counter Reading 4/5' (below) are to be used at operator discretion if the first three readings are not consistent.

First Set of Readings on *quay wall adjacent to vessel* *(counter units* :			**Time Local**	**Time UTC**
Counter Reading 1	2448.74	***st1*** ***(**** start time of readings)***	17:26	21:26
Counter Reading 2	2448.76		17:28	21:28
Counter Reading 3	2448.75		17:31	21:31
Counter Reading 4*				
Counter Reading 5*				
Height above water level of Land Gravity Mete ***(h1)***			1.7	meters
GPS Position of quay wall meter location if available:			Photographed/Sketched Area (if required)	Y/N

Example for reading Land Gravity Meter S/N:167 —> The meter's Dials display is '16517'. The '7' is not exactly aligned with the other dials. The '7' is tenths, so the reading may be interpreted as 1651.7 (counter units). However the meters Nulling Dial allows a further degree of accuracy to be read (hundredths) which should be used to determine the correct value for tenths (i.e.1651.69).

Base Station Readings:			**Time Local**	**Time UTC**
Counter Reading 1	2448.46	***st3***	17:47	21:47
Counter Reading 2	2448.51		17:48	21:48
CounterReading 3	2448.43		17:50	21:50
Counter Reading 4*	2448.42		17:52	21:52
Counter Reading 5*	2448.4		17:53	21:53

Second Set of Readings on *quay wall adjacent to vessel:*			**Time Local**	**Time UTC**
Counter Reading 1	2448.66	***st2***	18:28	22:28

Gravity tie 27_03_2017

Counter Reading 2	2448.65		18:30	22:30
Counter Reading 3	2448.63		18:32	22:32
Counter Reading 4*				
Counter Reading 5*		*****End Time of Readings*		
Height above water level of Land Gravity Mete ***(h2)***			1.5	meters
Height of ships Gravity Meter above static Water Line ***(h3)***			0.76	meters
Value of '**GRAVITY (cu)**' on ships gravity meter (Air-Sea software display) **			Time Local	Time UTC
	16419.9	Counter Units (CU)	18:44	22:44
** Note: confirm 'GRAVITY(cu)' is used and not 'QC GRAV (mGal)'				
Land Gravity Meter Information:		Meter Type/Description		Lacoste & Romberg
Serial No.	G-484	Factor For Interval +		1.02275
+ Factor For Interval can be found from individual meter's documentation (value relates to observed Counter Reading range thus allowing conversion to mGals. This is used on 'Calculations' page.				
Notes on related Tie-in(s) (if applicable):				
Readings Page Completed By:	JW		**Date:**	27/03/2017
Checked By:			**Date:**	

Gravity Tie-In Calculations

Variable	Variable Description	Input/Formula	Units:	Notes:
a	Height of last Low Water (LW)	0.3	meters	
-	Approx. Time of (a)	11:00	UTC Time	
b	Height of next High Water (HW)	1.3	meters	
-	Approx. Time of (b)	23:24	UTC Time	
d	Height of Tide above LW at ***average time*** of readings	1.18	meters	
Completed By:		JW	**Date Completed:**	27/03/2017

Note: Heights and Times of LLW and NHW (a, b) are to be obtained from the **Admiralty TotalTide tables** and graphs obtained from the Bridge on DY/JC.

Note: ***Average time*** of readings is calculated as the mid-point between the time of the first counter reading from set one taken from the quay wall, and the final quay wall reading from the second set. Once the average time is obtained, operator will need to cross-reference this time against the Admiralty Total Tide graph to obtain the ***Height of the Tide (d)***

Calculations to Obtain Absolute Gravity Values (all automatically calculated - no user input required):

Variable	Variable Description	Input/Formula	Units:	Notes:
c	Tidal Range	1	meters	**b-a** (calculated automatically)
e	Height of tide above mean sea level '(d-c/2)=e'	0.68	meters	**d-0.5c=e** (calculated automatically
f	Average height of land GM above ***waterline*** '(h1+h2)/2=f'	1.6	meters	**(h1+h2)/2=f** (calculated automatically)
g	Average height of land GM above ***mean sea level*** 'e+f=g'	2.28	meters	**e+f=g** (calculated automatically)
-	Height difference between land and ship GM **'f-h3'**	2.36	meters	h3 from Readings Page (automatic calculation)
-	***Free Air corrected*** value for height difference '0.3086(f-h3)'	0.728296		**0.3086(f-h3)**. Note: using 0.3086mGal/m
s1	Average (mean) counter reading of ***First Set*** of quay wall readings (s1)	18:00	counter units	Automatically calculated (no. of readings detected)

s2	Average (mean) counter reading of ***Second Set*** of quay wall readings (s1)	15:31	counter units	Automatically calculated (no. of readings detected)
s3	Average (mean) counter reading from Base Station set of readings (s3)	10:39	counter units	Automatically calculated (no. of readings detected)
-	Time difference (mins) between first and second sets of quay wall readings (st2-st1)	-0.08	mins	**st2-st1** (Automatically calculated - uses time of first reading in each set)
k	Drift of Land GM 's1-s2/st2-st1=k'	-1.291666667	counter units/min	**s1-s2/st2-st1=k** (calculated automatically)
-	Time difference (mins) between first quay wall readings and base station (st3-st1)	-0.28	mins	**st3-st1** (Automatically calculated - uses time of first reading in each set)
m	Corrected quay wall reading at the time of Base station reading 's1+k(st3-st1)=m'	2449.111667	counter units	**s1+k(st3-st1)=m**
N	Difference between quay wall reading and base station 'm-s3=N'	0.667666667	counter units	m-s3=N
	'**Converted Value**' (in mGals) of the variation between quay wall and base station readings (land gravity '**factor for interval'*N**)	0.682856083	mGals	**Factor for interval** is recorded on Readings Page.
	Absolute Value at quay wall	979013.8429	mGals	Known Absolute (from Checklist Page) + 'Converted Value'
	Absolute value at ship's GM	979014.5712	mGals	Absolute Value at quay wall + **Free Air Corrected Value**
Completed By:		JW	**Date Completed:**	27/03/2017

GRAVITY Checklist

		Completed by:	Date:	Checked by:	Date:
Cruise Information:					
Vessel	RRS James Cook	JW			
Cruise No.	JC145 (Pre JC149)				
Last tie In Information (if applicable):	Santa Cruz de Tenerife, TENE-CHIP, 26/02/2017	JW	26/02/2017		
Ship-Fitted Gravity Meter Information:		**Completed by:**	**Date:**	**Checked by:**	**Date:**
Meter Serial No.	S-040	JW			
Fitted Control Module (CM):	CM2	JW			
Fitted Power Module (PM):	PM2	JW			
Meter Factor ('Coef1')*	0.9917	JW			
* '**Coef1' may be found in 'Meter_Table' in the ASII_Hw.ini file on control module** - Also refer to Air Sea II Manual v2_Oct_2010 - page 6-5 ''Scaling Data To MilliiGals. ALL data is recorded by the meter in CU (Counter Units). NMF Gravity Meters S-040 and S-084 both have a single coefficient only. Apply this 'meter factor/coef1' to scale from CU to mGals. eotvos corrections may be shown on AirSea display (for daily QC monitoring) but are not saved.					
Verify Pre-Tie In Checks have been Completed:		**Completed by:**	**Date:**	**Checked by:**	**Date:**
Period ship-fitted meter has been continuously on heat	> 40 days	JW			
Confirm gimbal is unclamped	Yes	JW			
Confirm Torque Motors Operational	Yes	JW			
Confirm Air Mounts pressure (28-32psi)					

AirSea Software running	Yes	JW			
Is there an active GPS input?	Yes	JW			
What is the GPS Source? **					
Position Input present/updating?	Yes	JW			
Course present/updating? **	Yes	JW			
Speed present/updating? **	Yes	JW			
Verify the input source is NOT providing a **Heading** value **					
Ambient temperature (from meter display)	27.5				
Meter Temperature (from meter display)	49.3				
Meter/software is stable and in still position (i.e. TC <2)					

** AirSea Software requires an NMEA GPRMC message for the navigation information. Course and speed data is required for eotvos calculations. **Heading must not be used**.

Base Station Information:		**Completed by:**	**Date:**	**Checked by:**	**Date:**
Location of Base Station	Nassau, Bahamas	JW	27/03/2017		
ISGN-71 Station Number*	101.02 (?)				
Coordinates (Lat/Long)	22 04.75'N, 77 20.44'W				
Other Notes	Prince George Wharf, 2				
Absolute Gravity (mgals)	979013.36				

*IGSN-71 is the worldwide official gravity datum (International Gravity Standardisation Net 1971)

Obtain Tide information:		Completed by:	Date:	Checked by:	Date:
^ JC/DY both have Admiralty TotalTide Available to identify Height of last Low Water (**a**) and Height of next High Water (**b**) *[Refer to Readings/Calculations pages]*		JW	27/03/2017		
Checklist Page Completed By:		**Date:**			
Checked By:		**Date:**			

Gravity Tie-In Readings

Cruise Name	JC145 (Pre JC149)		
Date:	27-Mar-17		
Julian Day No.	87		
Time Zone:	GMT-0400		

* If at any station stable/consistent values are achieved from the initial **3 readings** then no further readings are required. Fields ‘Counter Reading 4/5’ (below) are to be used at operator discretion if the first three readings are not consistent.

First Set of Readings on *quay wall adjacent to vessel (counter units* :			**Time Local**	**Time UTC**
Counter Reading 1	2448.74	***st1*** ***(**** start time of readings)***	17:26	21:26
Counter Reading 2	2448.76		17:28	21:28
Counter Reading 3	2448.75		17:31	21:31
Counter Reading 4*				
Counter Reading 5*				
Height above water level of Land Gravity Mete ***(h1)***			1.7	meters
GPS Position of quay wall meter location if available:			Photographed/Sketched Area (if required)	Y/N

Example for reading Land Gravity Meter S/N:167 —> The meter’s Dials display is ‘16517’. The ‘7’ is not exactly aligned with the other dials. The ‘7’ is tenths, so the reading may be interpreted as 1651.7 (counter units). However the meters Nulling Dial allows a further degree of accuracy to be read (hundredths) which should be used to determine the correct value for tenths (i.e.1651.69).

Base Station Readings:			**Time Local**	**Time UTC**
Counter Reading 1	2448.62	***st3***	18:07	22:07
Counter Reading 2	2448.67		18:10	22:10
CounterReading 3	2448.63		18:11	22:11
Counter Reading 4*	2448.61		18:12	22:12
Counter Reading 5*	2448.63		18:16	22:16

Second Set of Readings on *quay wall adjacent to vessel:*			**Time Local**	**Time UTC**
Counter Reading 1	2448.66	***st2***	18:28	22:28

Counter Reading 2	2448.65		18:30	22:30
Counter Reading 3	2448.63		18:32	22:32
Counter Reading 4*				
Counter Reading 5*		****End Time of Readings		
Height above water level of Land Gravity Mete ***(h2)***			1.5	meters
Height of ships Gravity Meter above static Water Line ***(h3)***			0.76	meters
Value of '**GRAVITY (cu)**' on ships gravity meter (Air-Sea software display) **			Time Local	Time UTC
	16419.9	Counter Units (CU)	18:44	22:44
** Note: confirm 'GRAVITY(cu)' is used and not 'QC GRAV (mGal)'				
Land Gravity Meter Information:		Meter Type/Description		Lacoste & Romberg
Serial No.	G-484	Factor For Interval +		1.02275
+ Factor For Interval can be found from individual meter's documentation (value relates to observed Counter Reading range thus allowing conversion to mGals. This is used on 'Calculations' page.				
Notes on related Tie-in(s) (if applicable):				
Readings Page Completed By:	JW		**Date:**	27/03/2017
Checked By:			**Date:**	

Gravity Tie-In Calculations

Variable	Variable Description	Input/Formula	Units:	Notes:
a	Height of last Low Water (LW)	0.3	meters	
-	Approx. Time of (a)	11:00	UTC Time	
b	Height of next High Water (HW)	1.3	meters	
-	Approx. Time of (b)	23:24	UTC Time	
d	Height of Tide above LW at ***average time*** of readings	1.18	meters	
Completed By:		JW	**Date Completed:**	27/03/2017

Note: Heights and Times of LLW and NHW (a, b) are to be obtained from the **Admiralty TotalTide tables** and graphs obtained from the Bridge on DY/JC.

Note: ***Average time*** of readings is calculated as the mid-point between the time of the first counter reading from set one taken from the quay wall, and the final quay wall reading from the second set. Once the average time is obtained, operator will need to cross-reference this time against the Admiralty Total Tide graph to obtain the ***Height of the Tide (d)***

Calculations to Obtain Absolute Gravity Values (all automatically calculated - no user input required):

Variable	Variable Description	Input/Formula	Units:	Notes:
c	Tidal Range	1	meters	**b-a** (calculated automatically)
e	Height of tide above mean sea level ‘(d-c/2)=e’	0.68	meters	**d-0.5c=e** (calculated automatically
f	Average height of land GM above ***waterline*** ‘(h1+h2)/2=f’	1.6	meters	**(h1+h2)/2=f** (calculated automatically)
g	Average height of land GM above ***mean sea level*** ‘e+f=g’	2.28	meters	**e+f=g** (calculated automatically)
-	Height difference between land and ship GM **‘f-h3’**	2.36	meters	h3 from Readings Page (automatic calculation)
-	***Free Air corrected*** value for height difference ‘0.3086(f-h3)’	0.728296		**0.3086(f-h3)**. Note: using 0.3086mGal/m
s1	Average (mean) counter reading of ***First Set*** of quay wall readings (s1)	18:00	counter units	Automatically calculated (no. of readings detected)

s2	Average (mean) counter reading of ***Second Set*** of quay wall readings (s1)	15:31	counter units	Automatically calculated (no. of readings detected)
s3	Average (mean) counter reading from Base Station set of readings (s3)	15:10	counter units	Automatically calculated (no. of readings detected)
-	Time difference (mins) between first and second sets of quay wall readings (st2-st1)	-0.08	mins	**st2-st1** (Automatically calculated - uses time of first reading in each set)
k	Drift of Land GM 's1-s2/st2-st1=k'	-1.291666667	counter units/min	**s1-s2/st2-st1=k** (calculated automatically)
-	Time difference (mins) between first quay wall readings and base station (st3-st1)	-0.12	mins	**st3-st1** (Automatically calculated - uses time of first reading in each set)
m	Corrected quay wall reading at the time of Base station reading 's1+k(st3-st1)=m'	2448.905	counter units	**s1+k(st3-st1)=m**
N	Difference between quay wall reading and base station 'm-s3=N'	0.273	counter units	m-s3=N
	'**Converted Value**' (in mGals) of the variation between quay wall and base station readings (land gravity '**factor for interval'*N**)	0.27921075	mGals	**Factor for interval** is recorded on Readings Page.
	Absolute Value at quay wall	979013.6392	mGals	Known Absolute (from Checklist Page) + 'Converted Value'
	Absolute value at ship's GM	979014.3675	mGals	Absolute Value at quay wall + **Free Air Corrected Value**
Completed By:		JW	**Date Completed:**	27/03/2017

GRAVITY Checklist

		Completed by:	Date:	Checked by:	Date:
Cruise Information:					
Vessel	James Cook				
Cruise No.	JC149				
Last tie In Information (if applicable):	Nassau	JW	37/03/17		
Ship-Fitted Gravity Meter Information:		**Completed by:**	**Date:**	**Checked by:**	**Date:**
Meter Serial No.	S-040	MM	03/05/2017	AM	19/06/2017
Fitted Control Module (CM):	CM2	MM	03/05/2017	AM	19/06/2017
Fitted Power Module (PM):	PM2	MM	03/05/2017	AM	19/06/2017
Meter Factor ('Coef1')*	0.9917	MM	03/05/2017	AM	19/06/2017
* '**Coef1' may be found in 'Meter_Table' in the ASII_Hw.ini file on control module** - Also refer to Air Sea II Manual v2_Oct_2010 - page 6-5 ''Scaling Data To MilliiGals. ALL data is recorded by the meter in CU (Counter Units). NMF Gravity Meters S-040 and S-084 both have a single coefficient only. Apply this 'meter factor/coef1' to scale from CU to mGals. eotvos corrections may be shown on AirSea display (for daily QC monitoring) but are not saved.					
Verify Pre-Tie In Checks have been Completed:		**Completed by:**	**Date:**	**Checked by:**	**Date:**
Period ship-fitted meter has been continuously on heat	>80Days	MM	03/05/2017		
Confirm gimbal is unclamped	y	MM	03/05/2017		
Confirm Torque Motors Operational	y	MM	03/05/2017		
Confirm Air Mounts pressure (28-32psi)	y	MM	03/05/2017		
AirSea Software running	y	MM	03/05/2017		

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Is there an active GPS input?	y	MM	03/05/2017		
What is the GPS Source? **	Seapath	MM	03/05/2017		
Position Input present/updating?	y	MM	03/05/2017		
Course present/updating? **	y	MM	03/05/2017		
Speed present/updating? **	y	MM	03/05/2017		
Verify the input source is NOT providing a **Heading** value **	y	MM	03/05/2017		
Ambient temperature (from meter display)	27.9	MM	03/05/2017		
Meter Temperature (from meter display)	49.3	MM	03/05/2017		
Meter/software is stable and in still position (i.e. TC <2)	y TC=0.2	MM	03/05/2017		

** AirSea Software requires an NMEA GPRMC message for the navigation information. Course and speed data is required for eotvos calculations. **Heading must not be used**.

Base Station Information:		**Completed by:**	**Date:**	**Checked by:**	**Date:**
Location of Base Station	Guadeloupe Pointe-a-Pitre	MM	03/05/2017	AM	19/06/2017
ISGN-71 Station Number*	IGSN71	MM	03/05/2017		
Coordinates (Lat/Long)	16.223401N 61.530155W	MM	03/05/2017	AM	19/06/2017
Other Notes	Station No. 1238-A			AM	19/06/2017
Absolute Gravity	978548.185	MM	03/05/2017	AM	19/06/2017

*IGSN-71 is the worldwide official gravity datum (International Gravity Standardisation Net 1971)

Obtain Tide information:		**Completed by:**	**Date:**	**Checked by:**	**Date:**

Gravity tie 03_05_2017

^ JC/DY both have Admiralty TotalTide Available to identify Height of last Low Water (**a**) and Height of next High Water (**b**) *[Refer to Readings/Calculations pages]*		MM	03/05/2017		
Checklist Page Completed By:	MM	**Date: 03/05/17**			
Checked By:	AM (where indicated)	**Date:**		**19/06/2017**	

Gravity Tie-In Readings

Cruise Name	JC149			
Date:	03/05/2017			
Julian Day No.	123			
Time Zone:	-4			

* If at any station stable/consistent values are achieved from the initial **3 readings** then no further readings are required. Fields 'Counter Reading 4/5' (below) are to be used at operator discretion if the first three readings are not consistent.

First Set of Readings on *quay wall adjacent to vessel (counter units* :			**Time Local**	**Time UTC**
Counter Reading 1	1991.17	***st1*** ***(**** start time of readings)***	10:56	14:56
Counter Reading 2	1991.17		10:58	14:58
Counter Reading 3	1991.15		10:59	14:59
Counter Reading 4*	1991.18		11:00	15:00
Counter Reading 5*	1991.18		11:02	15:02
Height above water level of Land Gravity Mete ***(h1)***			2.11	meters
GPS Position of quay wall meter location if available:	16 14.0706N 061 32.2193W		Photographed/Sketched Area (if required)	Y

Example for reading Land Gravity Meter S/N:167 —> The meter's Dials display is '16517'. The '7' is not exactly aligned with the other dials. The '7' is tenths, so the reading may be interpreted as 1651.7 (counter units). However the meters Nulling Dial allows a further degree of accuracy to be read (hundredths) which should be used to determine the correct value for tenths (i.e.1651.69).

Base Station Readings:			**Time Local**	**Time UTC**
Counter Reading 1	1992.39	***st3***	14:29	18:29
Counter Reading 2	1992.37		14:32	18:32
CounterReading 3	1992.42		14:34	18:34
Counter Reading 4*	1992.41		14:36	18:36
Counter Reading 5*	1992.41		14:37	18:37

Second Set of Readings on *quay wall adjacent to vessel:*			**Time Local**	**Time UTC**
Counter Reading 1	1991.19	***st2***	15:35	19:35

Counter Reading 2	1991.18		15:37	19:37
Counter Reading 3	1991.18		15:37	19:37
Counter Reading 4*	1991.19		15:39	19:39
Counter Reading 5*	1991.18	****End Time of Readings***	15:40	19:40
Height above water level of Land Gravity Mete ***(h2)***			2.1	meters
Height of ships Gravity Meter above static Water Line ***(h3)***			1.59	meters
Value of '**GRAVITY (cu)**' on ships gravity meter (Air-Sea software display) **			Time Local	Time UTC
	15951	Counter Units (CU)	15:46	19:46
** Note: confirm 'GRAVITY(cu)' is used and not 'QC GRAV (mGal)'				
Land Gravity Meter Information:		Meter Type/Description		Lacoste & Romberg
Serial No.	G-484	Factor For Interval +		1.02212
+ Factor For Interval can be found from individual meter's documentation (value relates to observed Counter Reading range thus allowing conversion to mGals. This is used on 'Calculations' page.				
Notes on related Tie-in(s) (if applicable):				
Readings Page Completed By:	MM		**Date:03/05/17**	
Checked By:			**Date:**	

Gravity Tie-In Calculations

Variable	Variable Description	Input/Formula	Units:	Notes:
a	Height of last Low Water (LW)	0.514814815	meters	
-	Approx. Time of (a)	04:06	UTC Time	
b	Height of next High Water (HW)	0.6	meters	
-	Approx. Time of (b)	23:48	UTC Time	
d	Height of Tide above LW at ***average time*** of readings	-0.12	meters	
Completed By:		MM	**Date Completed:**	03/05/2017

Note: Heights and Times of LLW and NHW (a, b) are to be obtained from the **Admiralty TotalTide tables** and graphs obtained from the Bridge on DY/JC.

Note: ***Average time*** of readings is calculated as the mid-point between the time of the first counter reading from set one taken from the quay wall, and the final quay wall reading from the second set. Once the average time is obtained, operator will need to cross-reference this time against the Admiralty Total Tide graph to obtain the ***Height of the Tide (d)***

Calculations to Obtain Absolute Gravity Values (all automatically calculated - no user input required):

Variable	Variable Description	Input/Formula	Units:	Notes:
c	Tidal Range	0.09	meters	**b-a** (calculated automatically)
e	Height of tide above mean sea level ‘(d-c/2)=e’	-0.16	meters	**d-0.5c=e** (calculated automatically
f	Average height of land GM above ***waterline*** ‘(h1+h2)/2=f’	2.105	meters	**(h1+h2)/2=f** (calculated automatically)
g	Average height of land GM above ***mean sea level*** ‘e+f=g’	1.94	meters	**e+f=g** (calculated automatically)
-	Height difference between land and ship GM **‘f-h3’**	3.70	meters	h3 from Readings Page (automatic calculation)
-	***Free Air corrected*** value for height difference ‘0.3086(f-h3)’	1.140277		**0.3086(f-h3)**. Note: using 0.3086mGal/m
s1	Average (mean) counter reading of ***First Set*** of quay wall readings (s1)	1991.17	counter units	Automatically calculated (no. of readings detected)

s2	Average (mean) counter reading of ***Second Set*** of quay wall readings (s1)	1991.18	counter units	Automatically calculated (no. of readings detected)
s3	Average (mean) counter reading from Base Station set of readings (s3)	1992.40	counter units	Automatically calculated (no. of readings detected)
-	Time difference (mins) between first and second sets of quay wall readings (st2-st1)	04:39:00	mins	**st2-st1** (Automatically calculated - uses time of first reading in each set)
k	Drift of Land GM 's1-s2/st2-st1=k'	-0.072258065	counter units/min	**s1-s2/st2-st1=k** (calculated automatically)
-	Time difference (mins) between first quay wall readings and base station (st3-st1)	03:33:00	mins	**st3-st1** (Automatically calculated - uses time of first reading in each set)
m	Corrected quay wall reading at the time of Base station reading 's1+k(st3-st1)=m'	1991.159312	counter units	**s1+k(st3-st1)=m**
N	Difference between quay wall reading and base station 'm-s3=N'	-1.240688172	counter units	m-s3=N
	'**Converted Value**' (in mGals) of the variation between quay wall and base station readings (land gravity '**factor for interval'*N**)	-1.268132194	mGals	**Factor for interval** is recorded on Readings Page.
	Absolute Value at quay wall	978546.9169	mGals	Known Absolute (from Checklist Page) + 'Converted Value'
	Absolute value at ship's GM	978548.0571	mGals	Absolute Value at quay wall + **Free Air Corrected Value**
Completed By:		MM	**Date Completed:**	03/05/2017

GRAVITY Checklist

		Completed by:	Date:	Checked by:	Date:
Cruise Information:					
Vessel	James Cook				
Cruise No.	JC149				
Last tie In Information (if applicable):	Ponte-a-Pitre	MM	03/05/2017	AM	19/06/2017
Ship-Fitted Gravity Meter Information:		**Completed by:**	**Date:**	**Checked by:**	**Date:**
Meter Serial No.	S-040	MM	04/05/2017	AM	19/06/2017
Fitted Control Module (CM):	CM2	MM	04/05/2017	AM	19/06/2017
Fitted Power Module (PM):	PM2	MM	04/05/2017	AM	19/06/2017
Meter Factor (‘Coef1’)*	0.9917	MM	04/05/2017	AM	19/06/2017
* **‘Coef1’ may be found in ‘Meter_Table’ in the ASII_Hw.ini file on control module** - Also refer to Air Sea II Manual v2_Oct_2010 - page 6-5 ‘’Scaling Data To MilliiGals. ALL data is recorded by the meter in CU (Counter Units). NMF Gravity Meters S-040 and S-084 both have a single coefficient only. Apply this ‘meter factor/coef1’ to scale from CU to mGals. eotvos corrections may be shown on AirSea display (for daily QC monitoring) but are not saved.					
Verify Pre-Tie In Checks have been Completed:		**Completed by:**	**Date:**	**Checked by:**	**Date:**
Period ship-fitted meter has been continuously on heat	>80Days	MM	04/05/2017		
Confirm gimbal is unclamped	y	MM	04/05/2017		
Confirm Torque Motors Operational	y	MM	04/05/2017		
Confirm Air Mounts pressure (28-32psi)	y	MM	04/05/2017		

AirSea Software running	y	MM	04/05/2017		
Is there an active GPS input?	y	MM	04/05/2017		
What is the GPS Source? **	Seapath	MM	04/05/2017		
Position Input present/updating?	y	MM	04/05/2017		
Course present/updating? **	y	MM	04/05/2017		
Speed present/updating? **	y	MM	04/05/2017		
Verify the input source is NOT providing a **Heading** value **	y	MM	04/05/2017		
Ambient temperature (from meter display)	27.9	MM	04/05/2017		
Meter Temperature (from meter display)	49.3	MM	04/05/2017		
Meter/software is stable and in still position (i.e. TC <2)	y TC=0.1	MM	04/05/2017		

** AirSea Software requires an NMEA GPRMC message for the navigation information. Course and speed data is required for eotvos calculations. **Heading must not be used**.

Base Station Information:		**Completed by:**	**Date:**	**Checked by:**	**Date:**
Location of Base Station	Guadeloupe Pointe-a-Pitre	MM	04/05/2017	AM	19/06/2017
ISGN-71 Station Number*	IGSN71	MM	04/05/2017		
Coordinates (Lat/Long)	16.223401N 61.530155W	MM	04/05/2017	AM	19/06/2017
Other Notes	Station No. 1238-A			AM	19/06/2017
Absolute Gravity	978548.185	MM	04/05/2017	AM	19/06/2017

*IGSN-71 is the worldwide official gravity datum (International Gravity Standardisation Net 1971)

Obtain Tide information:		**Completed by:**	**Date:**	**Checked by:**	**Date:**

^ JC/DY both have Admiralty TotalTide Available to identify Height of last Low Water (**a**) and Height of next High Water (**b**) *[Refer to Readings/Calculations pages]*		MM	04/05/2017		
Checklist Page Completed By:	MM	**Date: 04/05/2017**			
Checked By:	AM (where indicated)	**Date:**		**19/06/2017**	

Gravity Tie-In Readings

Cruise Name	JC149			
Date:	04/05/2017			
Julian Day No.	124			
Time Zone:	-4			

* If at any station stable/consistent values are achieved from the initial **3 readings** then no further readings are required. Fields 'Counter Reading 4/5' (below) are to be used at operator discretion if the first three readings are not consistent.

First Set of Readings on *quay wall adjacent to vessel* *(counter units* :			**Time Local**	**Time UTC**
Counter Reading 1	1991.19	***st1*** ***(**** start time of readings)***	12:30	16:30
Counter Reading 2	1991.16		12:31	16:31
Counter Reading 3	1991.16		12:32	16:32
Counter Reading 4*	1991.18		12:33	16:33
Counter Reading 5*	1991.16		12:35	16:35
Height above water level of Land Gravity Mete ***(h1)***			1.92	meters
GPS Position of quay wall meter location if available:	16 14.0706N 061 32.2193W		Photographed/Sketched Area (if required)	Y

Example for reading Land Gravity Meter S/N:167 —> The meter's Dials display is '16517'. The '7' is not exactly aligned with the other dials. The '7' is tenths, so the reading may be interpreted as 1651.7 (counter units). However the meters Nulling Dial allows a further degree of accuracy to be read (hundredths) which should be used to determine the correct value for tenths (i.e.1651.69).

Base Station Readings:			**Time Local**	**Time UTC**
Counter Reading 1	1992.48	***st3***	13:27	17:27
Counter Reading 2	1992.52		13:28	17:28
CounterReading 3	1992.51		13:28	17:28
Counter Reading 4*	1992.51		13:29	17:29
Counter Reading 5*	1992.52		13:29	17:29

Second Set of Readings on *quay wall adjacent to vessel:*			**Time Local**	**Time UTC**
Counter Reading 1	1991.25	***st2***	13:57	17:57

Counter Reading 2	1991.26		13:58	17:58
Counter Reading 3	1991.24		13:58	17:58
Counter Reading 4*	1991.26		13:59	17:59
Counter Reading 5*	1991.24	****End Time of Readings	13:59	17:59
Height above water level of Land Gravity Mete ***(h2)***			1.97	meters
Height of ships Gravity Meter above static Water Line ***(h3)***			1.67	meters
Value of ‘**GRAVITY (cu)**’ on ships gravity meter (Air-Sea software display) **			Time Local	Time UTC
	7122.3	Counter Units (CU)	14:08	18:08
** Note: confirm ‘GRAVITY(cu)’ is used and not ‘QC GRAV (mGal)’				
Land Gravity Meter Information:		Meter Type/Description		Lacoste & Romberg
Serial No.	G-484	Factor For Interval +		1.02212
+ Factor For Interval can be found from individual meter’s documentation (value relates to observed Counter Reading range thus allowing conversion to mGals. This is used on ‘Calculations’ page.				
Notes on related Tie-in(s) (if applicable):				
Readings Page Completed By:	MM		**Date:**	04/05/2017
Checked By:			**Date:**	

Gravity Tie-In Calculations

Variable	Variable Description	Input/Formula	Units:	Notes:
a	Height of last Low Water (LW)	0.49	meters	
-	Approx. Time of (a)	05:35	UTC Time	
b	Height of next High Water (HW)	0.61	meters	
-	Approx. Time of (b)	00:33	UTC Time	
d	Height of Tide above LW at ***average time*** of readings	0.56	meters	
Completed By:		MM	**Date Completed:**	04/05/2017

Note: Heights and Times of LLW and NHW (a, b) are to be obtained from the **Admiralty TotalTide tables** and graphs obtained from the Bridge on DY/JC.

Note: ***Average time*** of readings is calculated as the mid-point between the time of the first counter reading from set one taken from the quay wall, and the final quay wall reading from the second set. Once the average time is obtained, operator will need to cross-reference this time against the Admiralty Total Tide graph to obtain the ***Height of the Tide (d)***

Calculations to Obtain Absolute Gravity Values (all automatically calculated - no user input required):

Variable	Variable Description	Input/Formula	Units:	Notes:
c	Tidal Range	0.13	meters	**b-a** (calculated automatically)
e	Height of tide above mean sea level '(d-c/2)=e'	0.5	meters	**d-0.5c=e** (calculated automatically
f	Average height of land GM above ***waterline*** '(h1+h2)/2=f'	1.945	meters	**(h1+h2)/2=f** (calculated automatically)
g	Average height of land GM above ***mean sea level*** 'e+f=g'	2.445	meters	**e+f=g** (calculated automatically)
-	Height difference between land and ship GM **'f-h3'**	3.615	meters	h3 from Readings Page (automatic calculation)
-	***Free Air corrected*** value for height difference '0.3086(f-h3)'	1.115589		**0.3086(f-h3)**. Note: using 0.3086mGal/m
s1	Average (mean) counter reading of ***First Set*** of quay wall readings (s1)	1991.17	counter units	Automatically calculated (no. of readings detected)

s2	Average (mean) counter reading of ***Second Set*** of quay wall readings (s1)	1991.25	counter units	Automatically calculated (no. of readings detected)
s3	Average (mean) counter reading from Base Station set of readings (s3)	1992.51	counter units	Automatically calculated (no. of readings detected)
-	Time difference (mins) between first and second sets of quay wall readings (st2-st1)	01:27:00	mins	**st2-st1** (Automatically calculated - uses time of first reading in each set)
k	Drift of Land GM 's1-s2/st2-st1=k'	-1.324137931	counter units/min	**s1-s2/st2-st1=k** (calculated automatically)
-	Time difference (mins) between first quay wall readings and base station (st3-st1)	00:57:00	mins	**st3-st1** (Automatically calculated - uses time of first reading in each set)
m	Corrected quay wall reading at the time of Base station reading 's1+k(st3-st1)=m'	1991.117586	counter units	**s1+k(st3-st1)=m**
N	Difference between quay wall reading and base station 'm-s3=N'	-1.390413793	counter units	m-s3=N
	'**Converted Value**' (in mGals) of the variation between quay wall and base station readings (land gravity '**factor for interval'*N**)	-1.421169746	mGals	**Factor for interval** is recorded on Readings Page.
	Absolute Value at quay wall	978546.7638	mGals	Known Absolute (from Checklist Page) + 'Converted Value'
	Absolute value at ship's GM	978547.8794	mGals	Absolute Value at quay wall + **Free Air Corrected Value**
Completed By:		MM	**Date Completed:**	04/05/2017

GRAVITY Checklist

		Completed by:	Date:	Checked by:	Date:
Cruise Information:					
Vessel	James Cook				
Cruise No.	JC149				
Last tie In Information (if applicable):	Ponte-a-Pitre Universite (04/05/017)	MM	04/05/2017		
Ship-Fitted Gravity Meter Information:		**Completed by:**	**Date:**	**Checked by:**	**Date:**
Meter Serial No.	S-040	AM	20/06/2017		
Fitted Control Module (CM):	CM2	AM	20/06/2017		
Fitted Power Module (PM):	PM2	AM	20/06/2017		
Meter Factor ('Coef1')*	0.9917	AM	20/06/2017		

* '**Coef1' may be found in 'Meter_Table' in the ASII_Hw.ini file on control module** - Also refer to Air Sea II Manual v2_Oct_2010 - page 6-5 ''Scaling Data To MilliiGals. ALL data is recorded by the meter in CU (Counter Units). NMF Gravity Meters S-040 and S-084 both have a single coefficient only. Apply this 'meter factor/coef1' to scale from CU to mGals. eotvos corrections may be shown on AirSea display (for daily QC monitoring) but are not saved.

Verify Pre-Tie In Checks have been Completed:		**Completed by:**	**Date:**	**Checked by:**	**Date:**
Period ship-fitted meter has been continuously on heat	>80Days	AM	20/06/2017		
Confirm gimbal is unclamped	y	AM	20/06/2017		
Confirm Torque Motors Operational	y	AM	20/06/2017		
Confirm Air Mounts pressure (28-32psi)	y	AM	20/06/2017		

AirSea Software running	y	AM	20/06/2017		
Is there an active GPS input?	y	AM	20/06/2017		
What is the GPS Source? **	Seapath	AM	20/06/2017		
Position Input present/updating?	y	AM	20/06/2017		
Course present/updating? **	y	AM	20/06/2017		
Speed present/updating? **	y	AM	20/06/2017		
Verify the input source is NOT providing a **Heading** value **	y	AM	20/06/2017		
Ambient temperature (from meter display)	27.8	AM	20/06/2017		
Meter Temperature (from meter display)	49.2	AM	20/06/2017		
Meter/software is stable and in still position (i.e. TC <2)					

** AirSea Software requires an NMEA GPRMC message for the navigation information. Course and speed data is required for eotvos calculations. **Heading must not be used**.

Base Station Information:		Completed by:	Date:	Checked by:	Date:
Location of Base Station	Guadeloupe Pointe-a-Pitre	AM	20/06/2017		
ISGN-71 Station Number*	IGSN71 No. 1238-A	AM	20/06/2017		
Coordinates (Lat/Long)	16.223401N 61.530155W	AM	20/06/2017		
Other Notes	Altitude 2.97m	AM	20/06/2017		
Absolute Gravity	978548.185	AM	20/06/2017		

*IGSN-71 is the worldwide official gravity datum (International Gravity Standardisation Net 1971)

Obtain Tide information:	Completed by:	Date:	Checked by:	Date:
^ JC/DY both have Admiralty TotalTide Available to identify Height of last Low Water (**a**) and Height of next High Water (**b**) *[Refer to Readings/Calculations pages]*				

Checklist Page Completed By:	AM	**Date:**	
Checked By:		**Date:**	**20/06/2017**

Gravity Tie-In Readings

Cruise Name	JC149			
Date:	20/06/2017			
Julian Day No.	171			
Time Zone:	-4			
* If at any station stable/consistent values are achieved from the initial **3 readings** then no further readings are required. Fields 'Counter Reading 4/5' (below) are to be used at operator discretion if the first three readings are not consistent.				
First Set of Readings on *quay wall adjacent to vessel (counter units* :			**Time Local**	**Time UTC**
Counter Reading 1	1986.6	***st1*** ***(**** start time of readings)***	09:52	13:52
Counter Reading 2	1986.57		09:56	13:56
Counter Reading 3	1986.55		09:58	13:58
Counter Reading 4*				
Counter Reading 5*				
Height above water level of Land Gravity Mete ***(h1)***			1.58	meters
GPS Position of quay wall meter location if available:	Ship Position: 16deg 13.99'N 61deg 32.68'W	Phone time used for tie in - checked against GPS prior to collecting first set of readings	Photographed/Sketched Area (if required)	Y - photographed ships draft for set 1 & 3
Example for reading Land Gravity Meter S/N:167 —> The meter's Dials display is '16517'. The '7' is not exactly aligned with the other dials. The '7' is tenths, so the reading may be interpreted as 1651.7 (counter units). However the meters Nulling Dial allows a further degree of accuracy to be read (hundredths) which should be used to determine the correct value for tenths (i.e.1651.69).				
Base Station Readings:			**Time Local**	**Time UTC**
Counter Reading 1	1990.08	***st3***	13:20	17:20
Counter Reading 2	1990.06		13:22	17:22
CounterReading 3	1990.11		13:23	17:23
Counter Reading 4*				
Counter Reading 5*				
Second Set of Readings on *quay wall adjacent to vessel:*			**Time Local**	**Time UTC**
Counter Reading 1	1986.8	***st2***	13:47	17:47

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Counter Reading 2	1986.8		13:48	17:48
Counter Reading 3	1986.84		13:49	17:49
Counter Reading 4*				
Counter Reading 5*		****End Time of Readings***		
Height above water level of Land Gravity Mete ***(h2)***			1.4	meters
Height of ships Gravity Meter above static Water Line ***(h3)***			2	meters
Value of '**GRAVITY (cu)**' on ships gravity meter (Air-Sea software display) **			Time Local	Time UTC
	7120.4	Counter Units (CU)	14:04	18:04
** Note: confirm 'GRAVITY(cu)' is used and not 'QC GRAV (mGal)'				CU confirmed
Land Gravity Meter Information:		Meter Type/Description		Lacoste & Romberg
Serial No.	G-484	Factor For Interval +		1.02212
+ Factor For Interval can be found from individual meter's documentation (value relates to observed Counter Reading range thus allowing conversion to mGals. This is used on 'Calculations' page.				
Notes on related Tie-in(s) (if applicable):	Tie in location photographed, base station photographed. Ship drafts photographed for each set of readings.			
Readings Page Completed By:	AM		**Date:**	20/06/2017
Checked By:			**Date:**	

Gravity Tie-In Calculations

Variable	Variable Description	Input/Formula	Units:	Notes:
a	Height of last Low Water (LW)	0.42	meters	
-	Approx. Time of (a)	11:30	UTC Time	
b	Height of next High Water (HW)	0.77	meters	
-	Approx. Time of (b)	05:00	UTC Time	
d	Height of Tide above LW at ***average time*** of readings	0.22	meters	
Completed By:		AM	**Date Completed:**	20/06/2017

Note: Heights and Times of LLW and NHW (a, b) are to be obtained from the **Admiralty TotalTide tables** and graphs obtained from the Bridge on DY/JC.

Note: ***Average time*** of readings is calculated as the mid-point between the time of the first counter reading from set one taken from the quay wall, and the final quay wall reading from the second set. Once the average time is obtained, operator will need to cross-reference this time against the Admiralty Total Tide graph to obtain the ***Height of the Tide (d)***

Calculations to Obtain Absolute Gravity Values (all automatically calculated - no user input required):

Variable	Variable Description	Input/Formula	Units:	Notes:
c	Tidal Range	0.35	meters	**b-a** (calculated automatically)
e	Height of tide above mean sea level '(d-c/2)=e'	0.045	meters	**d-0.5c=e** (calculated automatically
f	Average height of land GM above ***waterline*** '(h1+h2)/2=f'	1.49	meters	**(h1+h2)/2=f** (calculated automatically)
g	Average height of land GM above ***mean sea level*** 'e+f=g'	1.535	meters	**e+f=g** (calculated automatically)
-	Height difference between land and ship GM **'f-h3'**	3.49	meters	h3 from Readings Page (automatic calculation)
-	***Free Air corrected*** value for height difference '0.3086(f-h3)'	1.077014		**0.3086(f-h3)**. Note: using 0.3086mGal/m
s1	Average (mean) counter reading of ***First Set*** of quay wall readings (s1)	1986.57	counter units	Automatically calculated (no. of readings detected)

s2	Average (mean) counter reading of ***Second Set*** of quay wall readings (s1)	1986.81	counter units	Automatically calculated (no. of readings detected)
s3	Average (mean) counter reading from Base Station set of readings (s3)	1990.08	counter units	Automatically calculated (no. of readings detected)
-	Time difference (mins) between first and second sets of quay wall readings (st2-st1)	03:55:00	mins	**st2-st1** (Automatically calculated - uses time of first reading in each set)
k	Drift of Land GM 's1-s2/st2-st1=k'	-1.470638298	counter units/min	**s1-s2/st2-st1=k** (calculated automatically)
-	Time difference (mins) between first quay wall readings and base station (st3-st1)	03:28:00	mins	**st3-st1** (Automatically calculated - uses time of first reading in each set)
m	Corrected quay wall reading at the time of Base station reading 's1+k(st3-st1)=m'	1986.360908	counter units	**s1+k(st3-st1)=m**
N	Difference between quay wall reading and base station 'm-s3=N'	-3.722425532	counter units	m-s3=N
	'**Converted Value**' (in mGals) of the variation between quay wall and base station readings (land gravity '**factor for interval'*N**)	-3.804765585	mGals	**Factor for interval** is recorded on Readings Page.
	Absolute Value at quay wall	978544.3802	mGals	Known Absolute (from Checklist Page) + 'Converted Value'
	Absolute value at ship's GM	978545.4572	mGals	Absolute Value at quay wall + **Free Air Corrected Value**
Completed By:		AM	**Date Completed:**	20/06/2017

Appendix E: BBOBS data QC

Probability density functions of power spectral density estimates for each sensor component (BH1, BH2, BHZ) of the SIO BBOBS instruments. Noise reference models of the USGS New Low Noise Model (NLNM) and New High Noise Model (NHNM) are given by the black lines.

JC149 Leg 2
Ocean-bottom Seismometer noise performance - preliminary analysis