Cruise Report

RRS James Clark Ross 269B

Reykjavik to Reykjavik
7th to 24th July 2012

Arctic hydrate dissociation as a consequence of climate change: determining the vulnerable methane reservoir and gas escape mechanisms

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Reykjavik - Reykjavik

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Contents **Page Number**

1. Summary

Cruise JR269B was the second part of a two-leg geophysical programme led by a science party from the School of Ocean and Earth Science, University of Southampton, and carried out on the western margin of the Svalbard archipelago. The overall objective was to investigate gas transport and escape mechanisms and quantify gas and hydrate saturation values, in shallow sediments along the margin in areas where both significant accumulations of methane hydrate and active methane venting through the sea floor are known to occur. During the first leg, JR269A, which was completed in August-September 2011, the main objective had been to acquire high resolution seismic reflection and wide-angle survey data, working in collaboration with IFREMER's 'SYSIF' team. In contrast, the primary objective of this second (2012) leg, JR269B, was the acquisition of controlled source electromagnetic (CSEM) survey data, to complement the pre-existing seismic data and to provide better constraints on the gas and hydrate saturation values within pore spaces. Secondary objectives during both legs included acquiring additional sub-bottom profiler, water column physical properties, and swath bathymetry data. A key objective of the analysis of data from both legs will be the joint inversion of co-located seismic and CSEM data, in order to optimise *in situ* estimates of concentrations of methane in free gas and hydrate forms within the subsurface.

Work was focused on two separate geographical areas (Figure 2). The first of these was west of Prins Karls Forland, in water depths of between 150 and 1200 m, and between latitudes 78^o 30' and 78^o 45' N. Towards its landward end, this survey area crosses a region at water depths up to 400 m where a dense concentration of methane escape bubble plumes occur, and where the MASOX / AOEM observatory lander was deployed from October 2010 to September 2012.

The second survey area straddles the summit of the Vestnesa Ridge, in water depths of 1180 to 1400 m, and is also the site of methane escape bubble plumes within the water column and of fluid escape chimneys and pockmarks previously imaged at and beneath the sea bed. This area lies approximately 100 km west of the mouth of Kongsfjorden, at latitudes 78^o 55' to 79^o 05' N.

CSEM data were successfully acquired by arrays of 14 seafloor electric field recorders (LEMURs) at the Prins Karls Forland site and 11 receivers at the Vestnesa Ridge site. A total of 60 km of CSEM transmitter tow lines were completed across both sites. In addition the Vulcan receiver was towed 300m behind the transmitting antenna, providing higher resolution, shallow CSEM profiles along all tow lines.

Supplementary data sets acquired during the cruise included 115 km of multi-channel seismic data, 130 km of swath bathymetry survey (including water column acoustic measurements for detecting bubble plumes), 4 CTD casts, 3 XBT casts, continual monitoring and daily sampling of air chemistry, deep-towed CTD data from both CSEM transmitter deployments, and a small amount of ADCP data.

2. **Scientific party**

Martin Sinha	**PSO**	University of Southampton
Amelia Astley		University of Southampton
Joan Campanya i LLovet		University of Barcelona
Johnnie Edmonston		British Antarctic Survey
Bedanta Goswami		University of Southampton
Carolyn Graves		University of Southampton
Timothy Henstock		University of Southampton
Veit Hühnerbach		National Oceanography Centre
Robert Kirk		University of Southampton
Hector Marin Moreno		University of Southampton
Helen Miller		University of Southampton
Laurence North		University of Southampton
Ben Pitcairn		Durham University
Anupama Rajan		University of Tromsø
Thomas Roberts		National Oceanography Centre
Jason Scott		National Oceanography Centre
Neil Sloan		National Oceanography Centre
Yee Yuan Tan		University of Southampton
Seth Thomas		British Antarctic Survey
Karen Weitemeyer		University of Southampton
Michael Myers		Sonardyne **

** Reykjavik to Longyearbyen Only

3. Ship's company

Graham Chapman	Master
Robert Paterson	Chief Officer
Piers Alvarez-Munoz	2nd Officer
Benjamin Thompson	3rd Officer
Charles Waddicor	ETO Comms
David Cutting	Chief Engineer
Glyn Collard	2nd Engineer
Andrew Smith	3rd Engineer
Steven Eadie	4th Engineer
Simon Wright	Deck Engineer
Nicholas Dunbar	ETO Eng
James Gibson	Purser
George Stewart	Bosun
Derek Jenkins	Bosun's Mate
Clifford Mullaney	SG1
Colin Leggett	SG1
John O'Duffy	SG1
David Triggs	SG1
David Harkes	SG1
Stewart Barrett	SG1
Mark Robinshaw	MG1
Ian Herbert	MG1
Keith Walker	Cook
Padraig Molloy	2nd Cook
Kenneth Weston	Senior Steward
James Newall	Steward
Derek Lee	Steward
Thomas Patterson	Steward

Figure 1. *The ship's company and scientific party of JR269B in Reykjavik*

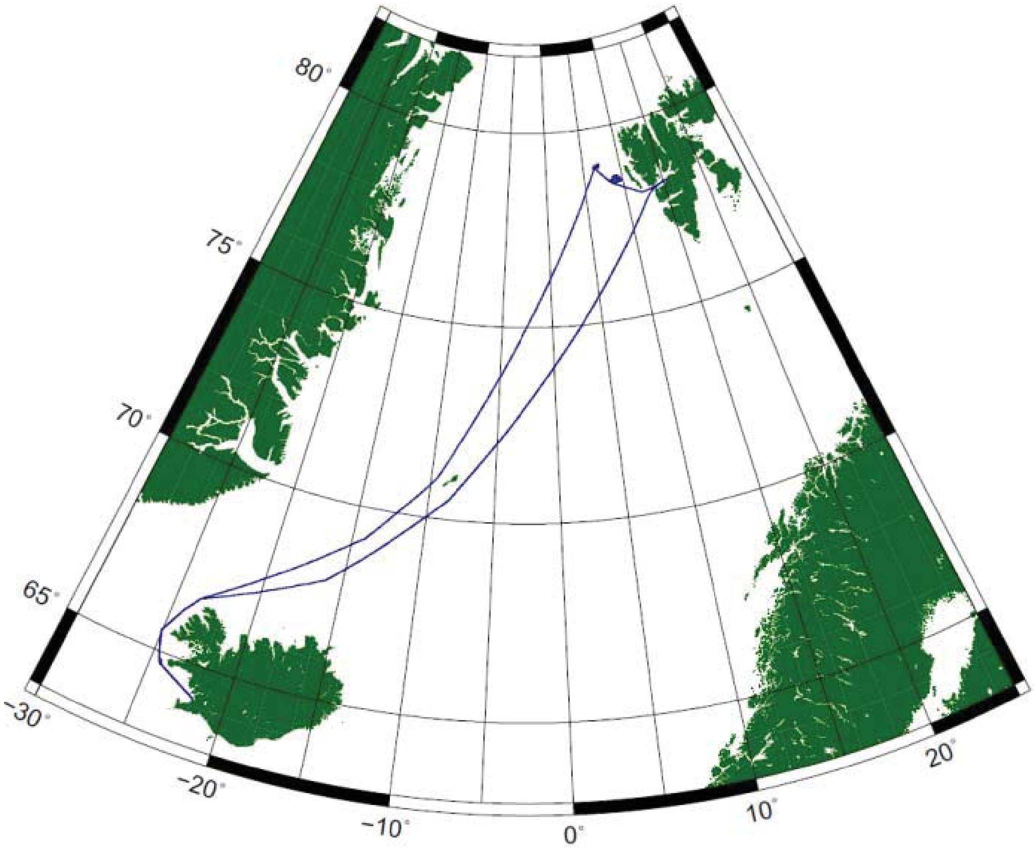

Figure 2. *General location map and complete ship track for JR269B*

4. Background and objectives

The formation and release of methane is a normal consequence of the deposition and burial of sediments, and contributes a significant proportion of global carbon fluxes into the ocean and atmosphere. Under certain low temperature and high pressure conditions, some of this methane can be trapped within the sediment column in the form of methane hydrate. Methane in both free gas and hydrate forms is known to be present in shallow marine sediments on the continental shelf and margin west of Svalbard, and these accumulations are also known to be releasing methane into the water column – with the evidence for this coming from observations both of bubble plumes emerging from the sea bed, and pock marks, chimneys and other fluid escape features at and beneath the sea bed.

In 2008 an International Polar Year research cruise aboard RRS *James Clark Ross* (JR 211, Westbrook *et al*. 2008) detected a dense concentration of more than 250 methane bubble plumes emerging from the sea bed west of Prins Karls Forland, in water depths down to about 400 m. A number of authors have hypothesised that increased rates of methane release from marine sediments as a result of destabilisation of gas hydrate reservoirs by increasing sea bed temperatures could be an agent of past and future rapid climate change (e.g. Nisbet , 2003). Sea floor temperature in the area where the west Svalbard plumes occur is governed by the northward flowing West Spitzbergen Current, which has warmed by about 1°C since 1975. This conjunction of local observations and general hypothesis led Westbrook *et al.* (2009) to note that the greatest concentration of bubble plumes occurs close to the current landward limit of the gas hydrate stability zone (GHSZ); and to conclude that rapid warming of the sea bed west of Svalbard, and consequent downslope retreat of this limit of the GHSZ, was both contributing to and influencing the distribution of methane fluxes into the water column (Figure 3).

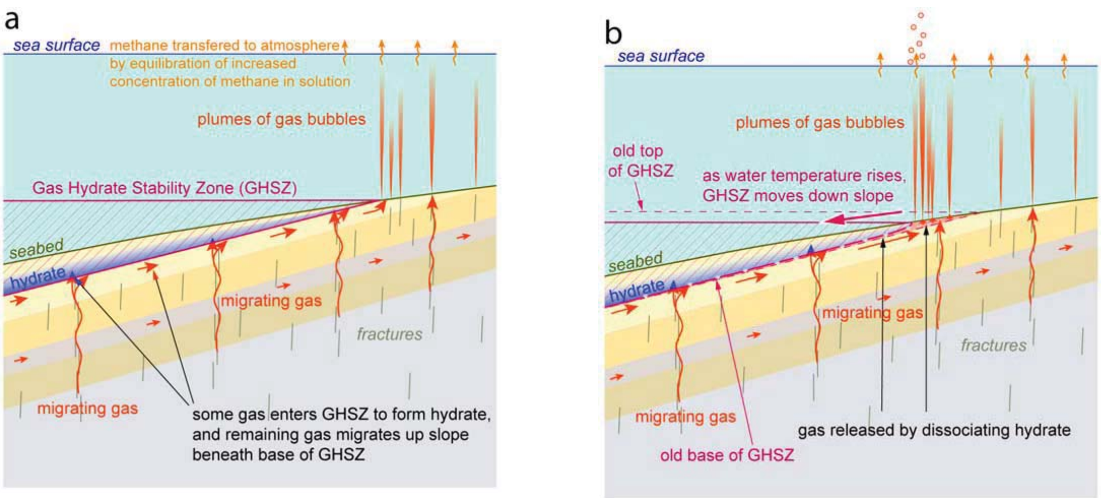

Figure 3 *(a)Schematic diagram showing upper and lower surfaces (controlled by temperature and pressure) of the gas Hydrate Stability Zone (GHSZ) on the west Svalbard continental margin, and likely gas migration routes within the sediments and into the water column. (b) Schematic diagram showing the deepening of the upper surface of the GHSZ caused by warming of the West Spitzbergen Current, and consequent seaward (downslope) retreat of the landward edge of the GHSZ. The dense concentrations of methane escape bubble plumes at water depths of approximately 400 m on the margin west of Prins Karls Forland are likely to result from a combination of hydrate dissociation in the subsurface and associated changes in hydrate controls on gas migration pathways within the sediments. From Westbrook* et al.*, 2009.*

The continental margin west of Svalbard is currently the site of an intensive and multi-national series of studies of methane hydrate accumulation and possible destabilisation by rapid climate change, and associated fluxes of methane into the water column from the sea bed. RRS *James Clark Ross* contributed three science cruises to this effort, all led by science teams from Southampton, during Arctic summers 2011 and 2012. These were JR 253 (Wright *et al.,* 2012), JR 269A (Minshull *et al.*, 2012) and the subject of this report, JR 269B.

Cruise JR 269B was the second part of an integrated, two-leg geophysical programme. The overall objectives are: to determine the spatial distribution of gas and hydrate accumulations beneath the sea bed; to investigate and understand gas transport and escape mechanisms, their spatial distribution, and the controls on these; and to quantify gas and hydrate saturation values *in situ* within the pore spaces of the shallow sediment reservoirs. The research is focused on specific areas where significant accumulations of methane hydrate and active methane venting through the sea floor were observed and documented during the earlier JR 211 cruise in 2008.

During the first leg, JR 269A, which was completed in August-September 2011, the principal objective had been to acquire high resolution seismic reflection and wide-angle survey data. JR 269A included a major element of deep-towed high resolution chirp profiling using IFREMER's SYSIF system. During the second (2012) leg - JR 269B - reported on here, the principal objective was instead the acquisition of controlled source electromagnetic (CSEM) survey data. Secondary objectives during both legs included acquiring additional sub-bottom profiler, water column physical properties, and swath bathymetry data. A key aim of the analysis of data from both legs will be the joint inversion of co-located seismic and CSEM data, in order to provide greatly improved *in situ* estimates of concentrations of methane in free gas and hydrate forms within the subsurface.

Work during both JR 269A and JR 269B was focused on two separate geographical areas. The first of these was west of Prins Karls Forland, in water depths of between 150 and 1200 m, and between latitudes 78^{o} 30' and 78^{o} 45' N. Towards its landward end, this survey area crosses a region at water depths up to 400 m where a dense concentration of methane escape bubble plumes occur. This is also where the MASOX / AOEM European observatory lander was deployed in October 2010 by R/V *Jan Mayen* (Mienert *et al*., 2010), subsequently serviced during JR 253 in 2011 (Wright *et al*. 2012), and recovered in August 2012 by RV *Maria S Merian* (Berndt *et al.* 2012).

The second survey area straddles the summit of the Vestnesa Ridge, in water depths of 1180 to 1400 m, and is also the site of methane escape bubble plumes within the water column and of fluid escape chimneys and pockmarks previously imaged at and beneath the sea bed. This area lies approximately 100 km west of the mouth of Kongsfjorden, at latitudes 78^{o} 55' to 79^{o} 05' N.

Objective 1

Our first specific objective for JR 269B was to collect CSEM data along an approximately WSW-ENE profile across the margin in the Prins Karls Forland area. The profile is coincident with an existing seismic profile, and extends at its landward end to water depths shallower than the upper limit of the Gas Hydrate Stability Zone (GHSZ); and at its seaward end to where a bottom-simulating reflector (BSR) coincident with the base of the GHSZ can be traced on pre-existing MCS profiles from JR 211. This survey locality is referred to in this document either as 'west of Prins Karls Forland' or 'the Plumes area'.

The NERC Ocean-Bottom Instrument Facility (OBIF) can deploy up to 14 seafloor geophysical receivers equipped as LEMURs – Low frequency, ElectroMagnetic Underwater Recorders. In this mode the instruments are fitted with an orthogonal pair of 12 m horizontal electric dipole receiver antennas, and high gain electric field pre-amplifiers. All fourteen were to be deployed for this CSEM profile. In order to accurately position the LEMUR instruments on the sea bed, the NOC's HYBIS mini-ROV system was modified by adding a lifting frame and release pin specifically designed for the LEMUR instruments.

CSEM signals were to be generated by the University of Southampton's DASI (Deep-Towed Active Source Instrument) system, consisting of a towed vehicle which is designed to operate at a constant altitude of approximately 50 m above the sea bed, and a 120 m long neutrally buoyant streamer which incorporates the horizontal electric dipole transmitting element.

The first objective was fully achieved (Figure 4). All 14 LEMUR instruments were deployed using HYBIS, and all were recovered safely at the end of the survey, with useable data records. In addition to the fixed LEMURs, a towed Vulcan receiver was acquired by the University of Southampton shortly prior to the commencement of JR 269B. This was streamed behind DASI's transmitting antenna, and provided additional high resolution, multi-frequency, fixed-offset CSEM profile data. DASI transmissions were successfully made both along the main profile D1, providing in-line geometry CSEM data; along a secondary DASI-plus-Vulcan profile D2; and also along a set of six supplementary profiles D3 to D8, orthogonal to the main line D1, which provide broadside geometry CSEM observations at a series of locations along D1.

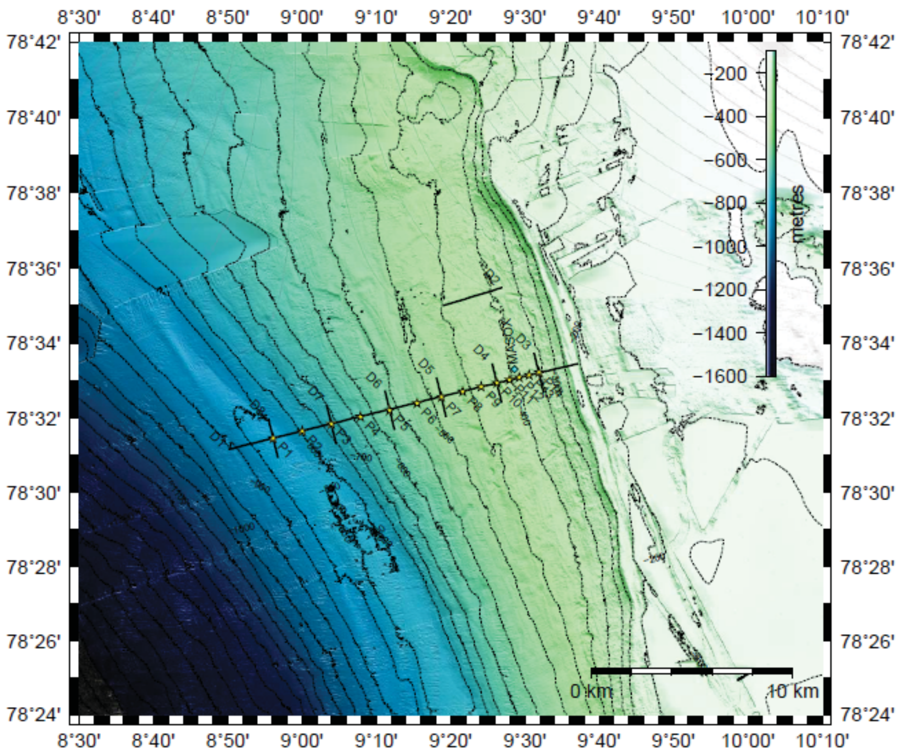

Figure 4. *Location map for the CSEM survey completed west of Prins Karls Forland. D1 to D8 are the DASI transmitter plus Vulcan receiver tow lines. P1 to P14 are the locations of the fixed LEMUR electric field recorders. Also shown is the location of the MASOX observatory*

Objective 2
Our next objective for JR269B was to acquire a second CSEM survey data set in the Vestnesa Ridge work area. The target site for this survey is centred on a gas escape structure at the summit of the ridge near 79° N, which was imaged on JR 211 multi-channel seismic data. The site is characterised by a bright BSR, multiple bright reflectors identified as free gas, fluid escape chimneys within the sediments, a pock mark at the sea floor and a plume of gas escape bubbles detected by sonar within the water column. Our specific plan was to deploy all 14 LEMURs at this survey site, and to tow DASI along a series of 4 profiles – three across the ridge and one along its crest – to provide a 3-D CSEM data set with both inline and broadside geometry data. In the event, shortage of time meant that this survey plan was slightly truncated (Figure 5). Eleven of the 14 receivers were deployed, again using HYBIS; and three of the four planned transmitter tow lines, D9, D10 and D11, were completed using the DASI system accompanied by the Vulcan towed receiver. All eleven receivers were recovered safely, all with useable data.

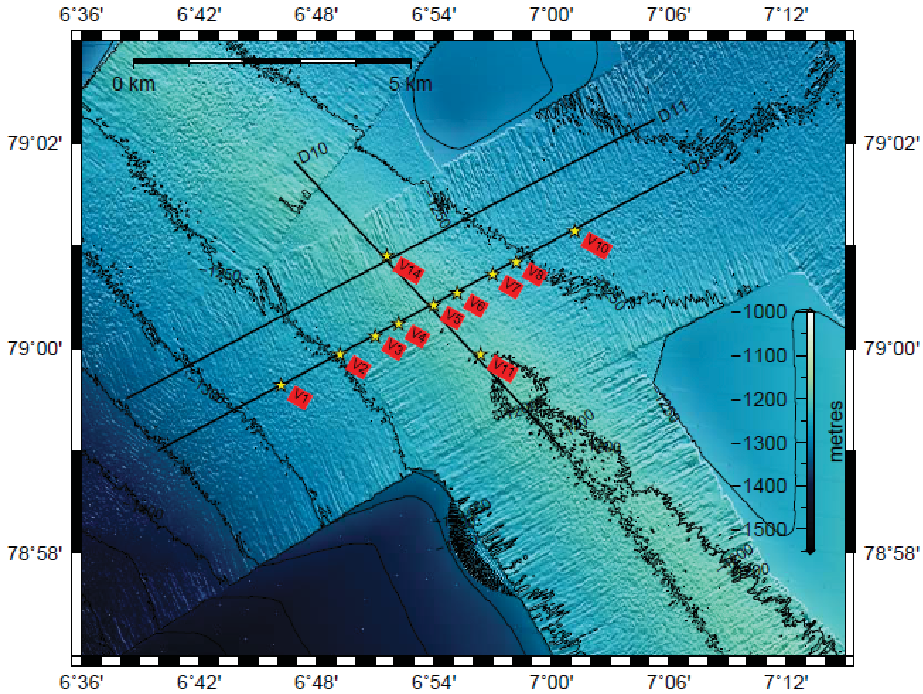

Figure 5. *Location map for the CSEM survey completed at Vestnesa Ridge. D9 to D11 are the DASI transmitter plus Vulcan receiver tow lines. V1 to V8, V10, V11 and V14 are the locations of the fixed LEMUR electric field recorders*

Objective 3
The necessity for adequate rest periods for the OBIF LEMUR team, the DASI team and the HYBIS operator (all requiring overlapping sets of people) meant that it was essential to interlace CSEM survey operations with other uses of the ship that could be carried out by different members of the scientific party. The first objective for such operations was the acquisition of additional multi-channel seismic reflection profiles using a short, high-resolution streamer and GI gun source. A number of profiles were planned for both the Vestnesa Ridge work area and the Prins Karls Forland work area, with lines positioned so as to fill gaps between existing 2-D profiles collected during JR 211 and JR 269A. This objective was achieved, with 7 profiles, lines 2012-1 to 2012-7, acquired across the margin west of Prins Karls Forland (Figure 6); and six profiles (2012-8 to

2012-13) acquired along and across the Vestnesa Ridge site (Figure 7). The total length of profile acquired is approximately 115 km.

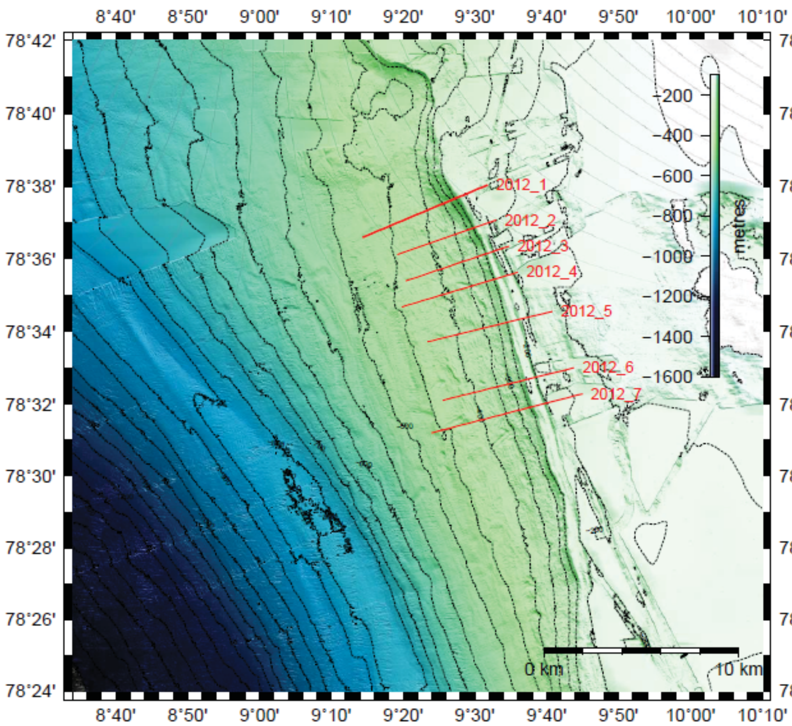

Figure 6. *Location map of seismic reflection profiles 2012-1 to 2012-7 acquired west of Prins Karls Forland*

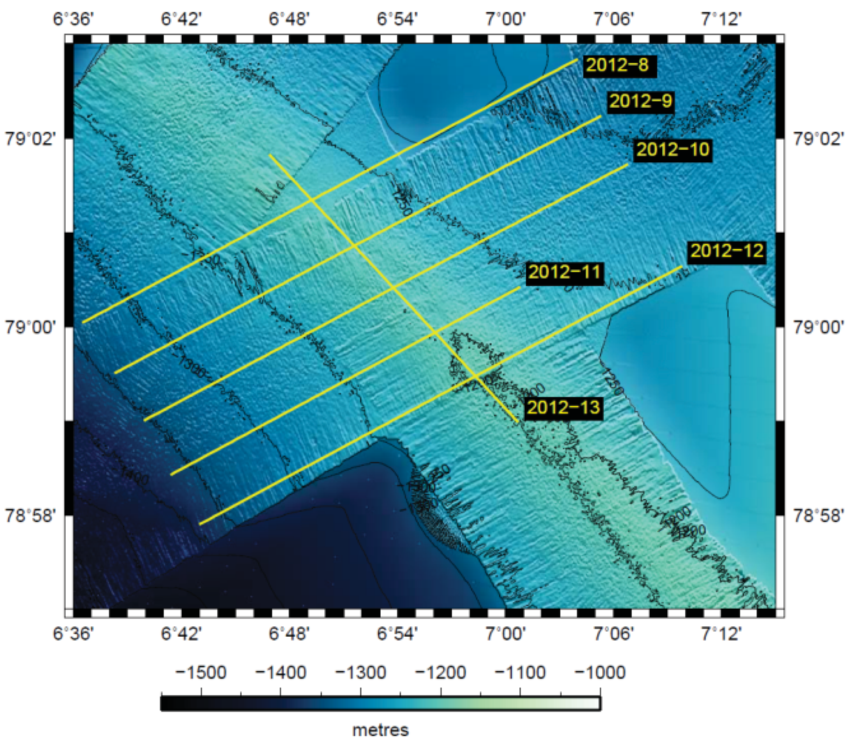

Figure 7. *Location map of seismic reflection profiles 2012-8 to 2012-13 acquired at Vestnesa Ridge*

Objective 4
A fourth objective was to acquire further sonar images of the water column and sea bed, using the fixed sonar equipment fitted to RRS *James Clark Ross*. These devices consisted of the EM122 multi-beam swath bathymetry, including logging of water column returns; the Kongsberg TOPAS PS18/15 sub bottom profiler; and the SIMRAD EK60 multi-frequency (38, 120 and 200 kHz) 'fishfinder' sonar. Due to the need for precise and reliable USBL navigation of equipment at and close to the sea floor during HYBIS and DASI operations, all the ship's sonar devices were switched off (to minimise acoustic interference) for prolonged periods during CSEM acquisition and LEMUR deployments and recoveries. However the sonars were operated during the seismic reflection profiling periods, and in addition a small grid of multibeam and other sonar lines was acquired west of Prins Karls Forland, consisting of seven profiles across the margin designed to fill gaps and improve data redundancy in existingswath bathymetry coverage; and one profile parallel to the coast at approximately 400 m water depth, designed to re-image the large number of gas escape plumes that had been previously documented in 2008 and 2011 (Figure 8). The total length of these profiles is approximately 130 km.

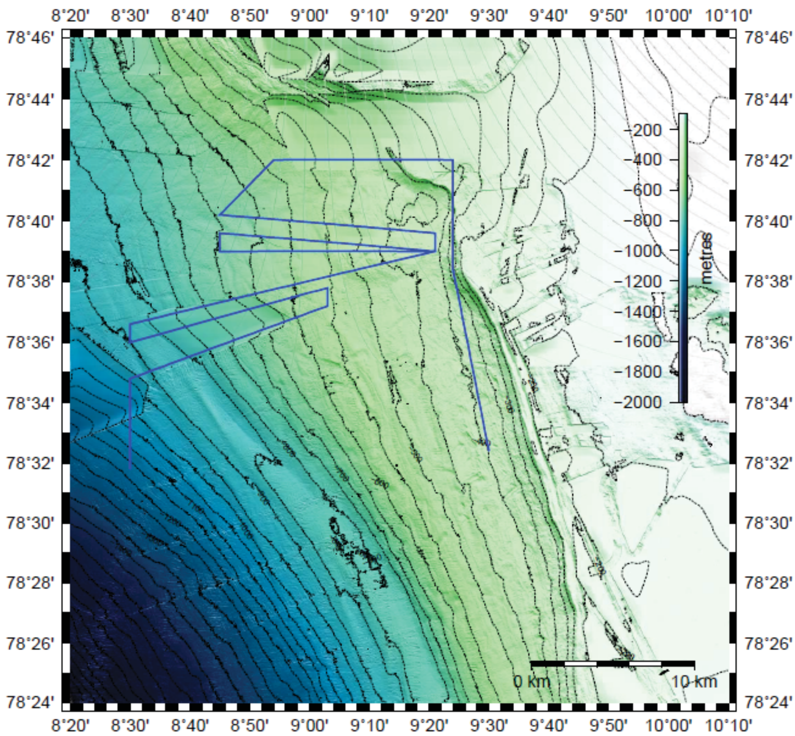

Figure 8. *Location map of swath bathymetry, sub-bottom profiler and other sonar system profiles acquired west of Prins Karls Forland*

Objective 5
Water column physical properties measurements were required in order to calibrate the sound velocity structure used by the swath bathymetry and USBL acoustic navigation processing; and to determine the electrical resistivity structure of the water column, for subsequent processing, analysis and inversion of the CSEM data. To achieve this, four CTD casts (two each at the Prins Karls Forland and Vestnesa Ridge work areas) and three XBT casts were taken. In addition, the DASI deep tow vehicle is fitted with a CTD instrument, and continuous measurements were recorded from this throughout the DASI dives in

both work areas. Lastly, the ship's ADCP system was operated for a short period of time, collecting approximately 8 km of ADCP profile.

Objective 6

A PICARRO continuous air chemistry monitoring device has been installed on RRS *James Clark Ross* by Professor Euan Nisbet's research team at Royal Holloway, University of London. A supplementary objective was therefore to maintain continuous measurement and logging by this instrument, and to take regular air samples for calibration purposes. This was done.

Objective 7

The ship had been tasked to deploy a number of ARGO floats while on passage to and from the work area as part of the British Antarctic Survey's Arctic Research Programme. Six floats were successfully deployed – one northbound and five southbound – in water depths greater than 3,000 m over the Greenland Abyssal Plain, at latitudes between 74^{o} 04' N and 75^{o} 32' N.

5. Cruise Narrative

Date	Time	Activity
Julian Day	UTC	
Wednesday 4 July 186		RRS *James Clark Ross* arrived in Reykjavik at the end of the previous cruise. Disembarkation of the previous scientific party and demobilization.
Thursday 5 July 187		Embarkation and mobilization of heavy scientific equipment. Main science party flew from UK to Reykjavik. Evening: science party embarked aboard RRS *James Clark Ross.* Initial safety briefing.
Friday 6 July 188		Audit of, and advice on, high voltage electrical safety systems, procedures, documentation and training by external consultant. Other scientists and NMF mobilization team preparing and setting up instruments, equipment and laboratories. Vessel bunkered.
Saturday 7 July 189	08:30	Sailed from Reykjavik. Followed by detailed safety briefing then emergency and lifeboat drill. PM continued scientific preparations on passage to work area.
Sunday 8 July 190	09:50	High voltage insulation test of container/winch/deeptow cable/terminations and interconnecting cables.
	10:30 to 11:00	Vessel stopped briefly for acoustic test deployment of Sonardyne transponder (the device to be used later for recalibration of the USBL acoustic positioning system). Remainder of the day continued on passage and continued scientific and technical preparations.
Monday 9 July 191		On passage. Continuing preparations including additional training for Marine Mammal Observers. AM Jan Mayen Land in sight to port.
Tuesday 10 July 192	12:30	Deployed Sonardyne acoustic transponder on sea bed for calibration of USBL underwater positioning system. During USBL recalibration calculations, successfully wire-tested all acoustic release units for LEMUR instruments in mid-water-column for correct operation of release units and shipboard telecommand sonar unit and transducers.
	23:20	Wire tests of LEMUR acoustics and USBL recalibration successfully completed. Released Sonardyne transponder from the sea bed and recovered it.
Wednesday 11 July 193	00:05	Deployed ARGO float
	00:12	Launched XBT #1 - system test and operator / scientific watch keeper familiarisation. On completion resumed passage to Longyearbyen.
	00:15 to 01:30	Ran EK60, EM122 and TOPAS sonar systems for operator / scientific watch keeper training and familiarization. All instruments switched off at 01:30 prior to entering Svalbard EEZ.
	20:30	Arrived off Longyearbyen. Landed Sonardyne engineer Michael Myers by boat transfer.
	21:40	Departed Longyearbyen. On passage to work area west of Prins Karls Forland.

Thursday 12 July 194	04:45	Vessel entered work area covered by Diplomatic Clearance / License.
	05:50	Scientific watch keeping commenced. EK60, EM122 and TOPAS sonar/echo sounder systems switched on and data logging commenced.
	06:59	On station for CTD Cast #1 at western edge of Prins karls Forland (southern) survey area. Start of seismic, CSEM and swath bathymetry operations in this survey area.
	07:49	CTD station Cast #1 complete and CTD recovered. CTD data transferred as sound velocity structure to EM122 and USBL underwater positioning systems.
	07:55	On transit to seaward end of CSEM line D1, to commence deployment of LEMUR CSEM receivers using HYBIS mini-ROV system.
	09:35	LEMUR 1 deployed at position P1
	11:32	LEMUR 2 deployed at position P2
	13:32	LEMUR 3 deployed at position P3
	15:14	LEMUR 4 deployed at position P4
	16:49	LEMUR 5 deployed at position P5
	18:48	LEMUR 6 deployed at position P6. Atmospheric methane anomaly recorded.
	20:18	LEMUR 7 deployed at position P7
	21:39	LEMUR 8 deployed at position P8. Air sample taken during another apparent atmospheric methane anomaly. On completion recovered HYBIS then transited to start position for first seismic line. LEMUR deployments and HYBIS operations suspended to allow a rest period for the OBIF team and HYBIS operator.
	22:08	commenced Marine Mammal watch
	23:20	Started deployment of seismic reflection profiling equipment near W end of seismic line 2012_1.
Friday 13 July 195	01:01	Started Seismic Line 2102_1 from W to E.
	02:38	Started Seismic Line 2102_2 from E to W
	03:48	Started Seismic Line 2102_3 from W to E.
	05:36	Started Seismic Line 2102_4 from E to W
	06:59	Started Seismic Line 2102_5 from W to E.
	08:29	Started Seismic Line 2102_6 from E to W
	09:31	Launched XBT #2
	10:01	Started Seismic Line 2102_7 from W to E.
	11:05	Seismic line 2012_7 completed. Recovered seismic profiling equipment. Marine mammal observations ended.
	12:25	Passed over LEMUR P6 location (where apparent atmospheric methane anomaly was observed), heading into the wind - took additional air sample but no anomaly seen this time.
	13:00	On station to deploy next LEMUR receiver at position P9
	14:36	LEMUR 9 deployed at position P9
	15:53	LEMUR 10 deployed at position P10

	17:10	LEMUR 11 deployed at position P11
	18:17	LEMUR 12 deployed at position P12
	19:41	LEMUR 13 deployed at position P13
	20:55	LEMUR 14 deployed at position P14. This instrument initially failed to disengage from the HYBIS frame when the hydraulic release pin was operated; but was successfully released onto the seabed after a couple of minutes, when the winch was used to jiggle HYBIS up and down a little with the pin out.
	21:51	On station above MASOX lander site, preparing HYBIS for a reconnaissance dive
	22:15	Hybis at sea bed at MASOX lander site. The lander was seen exactly where expected and in good order so after a few minutes to record some HYBIS video of it in position, HYBIS was recovered.
	22:45	Hybis back on deck. Switched on all swath/echo-sounder/water column sonar systems.
	22:57	Vessel got underway to commence overnight swath bathymetry survey
Saturday 14 July 196	00:26	Started multi-beam survey at point Swath 1
	00:46	Passed point Swath 2
	01:32	Passed point Swath 3
	01:43	Passed point Swath 4
	02:28	Passed point Swath 5
	02:44	Passed point Swath 6
	03:53	Passed point Swath 7
	04:03	Passed point Swath 8
	04:57	Passed point Swath 9
	05:08	Passed point Swath 10
	05:56	Passed point Swath 11
	06:03	Passed point Swath 12
	06:50	Passed point Swath 13
	07:12	Passed point Swath 14
	07:50	Passed point Swath 15
	08:12	Passed point Swath 16
	08:53	Passed point Swath 17. End of multi-beam survey tracks. Headed for DASI deployment position.
	12:22	Started deployment of Vulcan towed receiver followed by DASI transmitter system.
	14:12	DASI system deployed and towing just below sea surface.
	14:20	Began lowering DASI to operational depth.
	15:33	DASI bottom tracking
	16:15	DASI passed start position (western end) of tow line D1
	17:00	It became apparent that DASI was being operated at approximately 150 to 160 m above the sea bed, rather than the target 50 m. This was due to the altimeter readout being out of phase by one transmit ping interval.

	17:10	Started adjusting DASI tow height to resolve the altimeter phase / cycle issue.
	17:30	DASI now tracking steadily at correct altitude of 50 m above the sea bed.
	22:29	DASI passed end point (eastern end) of tow line D1
	22:38	Vulcan passed end of tow line. End of line D1.
Sunday 15 July 197	00:46	DASI passed start position (eastern end) of tow line D2
	01:54	DASI and Vulcan passed end point (western end) of tow line D2. End of line.
	04:25	Start (northern end) of DASI tow line D3
	04:58	End (southern end) of DASI tow line D3
	06:25	Start (southern end) of DASI tow line D4
	07:08	End (northern end) of DASI tow line D4
	08:46	Start (northern end) of DASI tow line D5
	08:50	Problem with one electric-hydraulic motor on deep tow winch - switched to back-up motor
	09:20	End (southern end) of DASI tow line D5
	11:01	Start (southern end) of DASI tow line D6
	11:35	End (northern end) of DASI tow line D6
	13:13	Start (northern end) of DASI tow line D7
	13:50	End (southern end) of DASI tow line D7
	15:39	Start (southern end) of DASI tow line D8
	16:46	End (northern end) of DASI tow line D8. End of DASI operations for this survey. Commenced recovery of DASI and Vulcan.
	17:40	Deployed XBT #3
	18:15	Recovery of DASI and Vulcan completed - starting recovery of LEMUR receivers
	20:27	LEMUR #1 recovered on deck
	21:32	LEMUR #2 recovered on deck
	22:39	LEMUR #3 recovered on deck
	23:42	LEMUR #4 recovered on deck
Monday 16 July 198	00:41	LEMUR #5 recovered on deck
	01:38	LEMUR #6 recovered on deck
	02:32	LEMUR #7 recovered on deck
	04:10	LEMUR #8 recovered on deck
	05:05	LEMUR #9 recovered on deck
	05:55	LEMUR #10 recovered on deck
	06:43	LEMUR #11 recovered on deck
	07:33	LEMUR #12 recovered on deck. Wind and sea state had deteriorated at this point so recovery operations were suspended to await an improvement.
	09:47	Weather conditions considered workable for further recoveries so release signal sent to LEMUR #13
	10:25	LEMUR #13 recovered on deck - weather conditions marginal

	12:32	Release signal sent to last LEMUR, #14
	13:15	LEMUR #14 recovered on deck
	15:10	Commenced CTD cast #2
	16:00	CTD cast #2 completed. Scientific operations in Prins Karls Forland (southern) survey area completed. Started transit to Vestnesa Ridge (northern) survey area.
	19:50	Commenced CTD cast #3 at western edge of Vestnesa Ridge survey area
	20:42	CTD cast #3 completed
	22:20	LEMUR # 1 deployed using HYBIS at position V1
Tuesday 17 July 199	00:17	LEMUR #2 deployed at position V2
	02:17	LEMUR #3 deployed at position V3
	04:17	LEMUR #4 deployed at position V4
	06:13	LEMUR #5 deployed at position V5
	08:02	LEMUR #6 deployed at position V6
	09:45	LEMUR #7 deployed at position V7. End of HYBIS operations for now, to allow HYBIS and LEMUR receivers teams a rest period. Started preparations for seismic reflection profiling.
	10:10	Commenced Marine Mammal watch
	11:15	Started deploying seismic streamer and GI gun
	11:45	Soft started GI gun firing
	12:31	Start of seismic line 2012_8 at SW end
	13:53	End of seismic line 2012_8 at NE end
	14:22	Start of seismic line 2012_10 at NE end
	15:28	End of seismic line 2012_10 at SW end
	16:05	Deployed XBT #4
	16:11	Start of seismic line 2012_12 at SW end
	17:22	Deployed XBT #5
	17:44	End of seismic line 2012_12 at NE end
	18:20	Start of seismic line 2012_9 at NE end
	18:23	Deployed XBT #6
	19:27	End of seismic line 2012_9 at SW end
	20:06	Start of seismic line 2012_11 at SW end
	21:10	End of seismic line 2012_11 at NE end. Line ended short of original, planned end point due to time constraints.
	22:05	Start of seismic line 2012_13 at SE end
	22:57	End of seismic line 2012_13 at NW end
	22:58	Stopped GI gun firing. Started recovery of seismic profiling equipment.
Wednesday 18 July 200	00:00	On station at site V8 to start deployment of next LEMUR receiver
	01:01	LEMUR #8 deployed at position V8 using HYBIS
	02:50	LEMUR #9 deployed at position V10

	04:49	Attempted to release LEMUR #10 at position V11. The HYBIS release mechanism failed to operate because the LEMUR flag was jamming the release pin. We were forced to recover the LEMUR back onto the ship, still attached to HYBIS, and resolve the problem.
	06:21	LEMUR # 10 deployed successfully on the second attempt at position V11.
	08:12	LEMUR # 11 deployed at position V14.
	08:56	HYBIS recovered and back on deck. Set off to DASI deployment position, while changing over the deep tow umbilical cable from HYBIS to DASI.
	11:21	Started deployment of DASI and Vulcan
	12:46	DASI vehicle deployed. Began manoeuvring onto start of first DASI tow line.
	14:54	DASI at start point (SW end) of CSEM transmitter tow line D9
	18:49	Vulcan at end point (NE end) of tow line D9. End of line D9.
Thursday 19 July 201	00:15	DASI at start point (SE end) of CSEM transmitter tow line D10
	02:06	Vulcan at end point (NW end) of tow line D10. End of line D10.
	06:19	DASI at start point (SW end) of CSEM transmitter tow line D11
	10:20	Vulcan at end point (NE end) of tow line D11. End of line D11. Started recovery of DASI and Vulcan systems.
	12:29	DASI and Vulcan systems recovered. Set off to start LEMUR instrument recoveries.
	13:43	Released LEMUR at V10
	14:10	Released LEMUR at V8
	15:37	LEMUR recovered on deck at site V10
	16:09	LEMUR recovered on deck at site V8
	16:19	Released LEMUR at V7
	17:25	Released LEMUR at V5
	18:00	LEMUR recovered on deck at site V7
	18:15	Released LEMUR at V6
	19:08	LEMUR recovered on deck at site V5
	19:40	Released LEMUR at V11
	19:57	LEMUR recovered on deck at site V6
	20:31	Released LEMUR at V4
	21:14	LEMUR recovered on deck at site V11
	21:40	Released LEMUR at V14
	22:16	LEMUR recovered on deck at site V4
	22:20	Released LEMUR at V3
	23:23	LEMUR recovered on deck at site V14
	23:30	Released LEMUR at V2
	23:51	LEMUR recovered on deck at site V3
	23:54	Unsuccessful attempt to release LEMUR at V1
Friday 20 July 202	00:23	Second unsuccessful attempt to release LEMUR at V1

	01:07	LEMUR recovered on deck at site V2
	01:28	Third unsuccessful attempt to release LEMUR at V1
	01:46	Fourth attempt to release LEMUR at V1
	02:12	Fifth attempt to release LEMUR at V1. Started preparations to deploy HYBIS to go down and fetch it if that should prove necessary.
	02:45	Sixth attempt to release LEMUR at V1
	03:08	Seventh attempt to release LEMUR at V1 - partial response heard
	03:18	LEMUR surfaced at V1
	03:32	LEMUR recovered on deck at site V1. All LEMURs now safely back on board. Set off to CTD location on W edge of Vestnesa Ridge work area
	04:14	Commenced CTD cast #4 at western edge of Vestnesa Ridge survey area
	05:07	CTD cast #4 completed
	05:16	Ship departed CTD station. End of science programme.
	06:38	Ship exited Diplomatic Clearance/License area. On passage to Reykjavik.
	PM	Science party started to dismantle laboratories, pack up equipment, and down load and archive cruise data.
Tuesday 24 July 206	08:00	Ship picked up pilot for entry to Reykjavik
	08:45	Ship arrived alongside, Reykjavik. Commenced demobilization after clearing Iceland customs and immigration.
	15:15	Demobilization completed
Wednesday 25 July 207	AM	Majority of science party flew back to UK

6. Navigation

Vessel navigation used GPS in non-differential mode. Several GPS receivers were installed and logged, and of these the Seatex unit was used as the primary device for scientific navigation. In the absence of differential signal corrections, the expected uncertainty in ship position for the Seatex system using the GPS C/A code is of the order of ±5 m horizontally.

Acoustic navigation of the HyBIS and DASI deep submergence systems used a Sonardyne Fusion Ultra-Short-Baseline (USBL) acoustic positioning system. This consists of a Fusion Data Engine, the USBL transceiver device fitted to the vessel, transponders attached to each submerged vehicle, and inputs from other systems including GPS and attitude (motion reference unit) sensors. The transponder attached to the remote vehicle can be interrogated acoustically (transponder mode) or electrically (responder mode), and then replies acoustically. The USBL system then provides a range, inclination and horizontal bearing estimate of the transponder position relative to the ship's position. The resulting data are logged as latitude, longitude and depth coordinates for the remote vehicle. The transceiver fitted to the ship was a Sonardyne 'Big-Head' Type 8023, with an acoustic cone of ±50° from vertical. The transponders fitted to DASI and HYBIS were Sonardyne WideBand Sub-Mini Type 8070.

The 8023 transponder fitted to the ship had been changed prior to the start of this cruise, with the result that a recalibration of the USBL system was necessary before our scientific operations. The recalibration process uses a remote transponder which is placed on the sea bed in a water depth of between 2500 and 3000 m. The vessel manoeuvres in a predetermined pattern for several hours while calibration measurements are made. A recalibration inversion algorithm can then be run, and the results installed in the Fusion system. For this purpose a Sonardyne engineer, Michael Myers, was embarked in Reykjavik. He successfully carried out the recalibration during passage to the work area, and disembarked in Longyearbyen.

During DASI operations, the USBL navigation system was operated using electrical interrogation (responder mode). During HYBIS operations, acoustic interrogation (transponder mode) was used. Both modes worked well. Post cruise analysis of DASI positions during transmitter tow lines shows an apparent short period scatter in the logged positions of the order of ±2 m. During post processing, this scatter has been largely removed by filtering. Post processing also involved editing out bad USBL fixes, which are logged from time to time. While this processing approach can provide an indication of random errors in the logged position, there may be other systematic errors that exceed ±2 m.

The USBL recalibration carried out on passage resulted in rms errors at the end of the inversion run of the order of 2 to 3 m. Since this was carried out in a water depth of just under 3000 m, this would imply position errors of the order of 0.1% of slant range. Previous experience with USBL navigation suggests that errors of up to 1% of slant range are not uncommon, so this may be overoptimistic. The maximum slant range from ship to remote vehicle during DASI and HYBIS operations was approximately 1850 m. In shallower water depths the slant ranges were substantially less than this. Taking account of all these factors including GPS uncertainties for the ship's position, we can estimate that uncertainties in HYBIS and DASI positions during underwater operations are likely to be of the order of ± 6 m at best, and possibly somewhat worse than this in deeper water.

7. CSEM Operations

The CSEM survey work made use of three types of equipment. The DASI (Deep-towed Active Source Instrument) transmitter provided frequency domain signals which were recorded by fixed sea-bottom receivers (LEMURs – Low-frequency ElectroMagnetic Underwater Recorders) and also by the deep-towed Vulcan instrument.

The University of Southampton's DASI system uses a high voltage power supply which transmits electrical energy (up to approximately 10 kW) through the coaxial conductors in the umbilical tow cable. The energy is converted in the DASI vehicle to a high current, low voltage pseudo-square wave and transmitted through a grounded horizontal dipole antenna. The antenna is in the form of a neutrally buoyant streamer, towed behind the DASI system. An acoustic altimeter and other sensors (including CTD) are fitted to the DASI vehicle. Data from these are telemetered to operators at the surface ship through an optical fibre system embedded within the umbilical tow cable. This allows the winch operator to maintain the towed vehicle at a constant altitude above the sea floor.

The fixed seabed LEMUR receivers record horizontal electric field data from two orthogonal channels. The sensor for each channel consists of a 12 m grounded electric dipole. The sampling rate was 125 Hz. The LEMURs were provided and operated by the UK Ocean Bottom Instrument Consortium (OBIC), through the NERC Ocean Bottom Instrument Facility OBIF. Since it was necessary to place the instruments on the sea floor in locations within 50 m or less of their target locations, and to then determine their final positions to within 10 m or better, they were deployed using NOC's HYBIS mini-ROV vehicle, equipped with Sonardyne near-real-time USBL navigation. By a combination of ship manoeuvring using Dynamic Positioning (DP) and to a minor extent by using the HYBIS vehicle's thrusters, it was possible to place the instruments within 5 m or better of their target locations in most cases, and within 10 m in all cases. Achieving this despite the length of cable, the water depth and the considerable (typically 1 knot) West Spitzbergen current encountered here required a very high level of skill on the part of the Bridge watch keeping officers, which deserves a special mention here. In all cases, the receivers were lowered attached to HYBIS until the sea bed came into view on HYBIS's camera systems. The sea bed was then checked for obstacles; HYBIS was raised a few metres clear of the sea floor; and the instrument was then released, free-falling the last few metres until it settled. In all cases, HYBIS video was recorded of the instrument after it had landed on the seafloor before HYBIS was recovered ready for the next deployment.

The third type of CSEM instrument used was the Vulcan towed receiver. Vulcan is approximately neutrally buoyant in seawater (1 kg positive buoyancy) and is equipped with compass and inclinometer, three channels of accelerometer, and three orthogonal channels of electric field sensor (in-line, cross-line and vertical). For this survey Vulcan was towed 300 m behind the tail end of the DASI transmitting antenna.

The Vulcan receiver recorded the DASI frequency domain signal throughout DASI operations. The resulting multi-frequency data will provide a set of 2-D, shallow, high-resolution profiles of electrical resistivity to depths of 100 to 150 m beneath the sea floor along these tracks.

7.1 DASI transmitter performance

(B. Goswami & M. Sinha)

During the JR 269B surveys DASI operated at an altitude of approximately 50 m above the sea bed, and at a speed over the ground of approximately 1.5 knots (2.7 km/hr; 0.75 m/s). For both surveys, the signal used throughout was a 1.00 Hz pseudo-square wave of approximately 100 A amplitude, and the transmitting dipole length was 100 m, giving a source dipole moment of approximately 10^4 Am at 1.0 Hz. Other transmitted frequencies consist of all odd harmonics of this (3, 5, 7, 9, 11, ... Hz) at progressively smaller amplitudes. The DASI transmitter system was substantially refurbished and modernised over the period 2010 to 2012; and this was the third seagoing expedition with the new system. DASI functioned well and broadly to specification throughout both CSEM surveys during JR269B.

The outgoing antenna current and voltage waveforms were both digitised at 4,096 Hz sampling rate and continuously recorded at the ship, to provide precise transmitter signal characteristics for subsequent processing and normalising of the receiver data. Good records of the transmitted current and waveform were logged for 6 tow lines. Due to technical problems, only a good voltage record was obtained for 2 tow lines; and neither current nor voltage information were logged for 3 of the lines.

Tow Line	Current	Voltage
D1	Not reliable	Good
D2	Not reliable	Good
D3	Good	Good
D4	Good	Good
D5	Good	Good
D6	Good	Good
D7	No	No
D8	No	No
D9	Good	Good
D10	Good	Good
D11	No	No

7.2 LEMUR receiver performance and data quality

(K. Weitemeyer)

The fourteen ocean bottom electric field receivers (LEMUR's - low frequency electromagnetic underwater receivers) - were configured to measure two horizontal and orthogonal components of the electric field (Ex, Ey) using Ag-AgCl electrodes along a 12 m dipole. Prior to the first deployment all connectors on the electrodes were cleaned and a small amount of silver grease was applied to improve electrical contact. A best attempt was made at pairing electrodes with a similar resting potential, based on measurements provided by OBIC, however due to a lack of time this pairing was not always ideal. In future, electrodes that share a channel should have less than 0.5 mV potential difference, and electrode pairs deployed on the same instrument should be no more than 1 mV different from each other.

To ensure we indeed measured two orthogonal components of the electric field we used the same wiring that was used during the Meteor M87-2 cruise in May. We checked that the internal wiring was consistent on the electric field amplifier board and then relabelled the outside of the instrument frame such that white and blue are one pair and yellow and red are the other pair. We also kept the orientation consistent on all instruments such that the white/blue pair is along the axis of the logger (white on digital face, blue on analogue face) and red and yellow are across the axis of the logger (red to the right of the white face and yellow to the left of the white face).

All data were run through initial quality control by generating spectrograms after the first deployment. This allowed us to spot a bad channel at p06 which was likely a result of a poor electrode pairing. A more suitable pair was used for the second deployment and significantly improved data quality. Appendix 1(a) provides a table of summary comments on data quality and all spectrograms from LEMUR deployments in the first survey, west of Prins Karls Forland. Appendix 1(b) provides the same for the Vestnesa Ridge survey LEMUR deployments. Appendix 1(c) provides a comparison of data quality for each instrument between the two sites, and Appendix 1(d) provides information about how the initial data processing was done. All seafloor ocean bottom electric field sensors require calibration files before definitive processing, and at the time of processing these are being finalised. In addition the data needs to be merged with the DASI transmission data and navigation data before it can be interpreted or the data quality further assessed.

Figure 9 shows a spectrogram for the overall best data collected on instrument 1 during the western margin and Vestnesa surveys. At the location west of Prins Karls Forland this receiver is in 400 m of water and is fairly close to the coastline of Svalbard (30 to 40 km). This is considered to be fairly shallow water for marine electromagnetic measurements and so naturally susceptible to underwater currents which may induce motion on the electric field sensors. In addition, the earth's natural magnetotelluric signal is not filtered as much as at the deeper Vestnesa (1200 m) location causing all receivers west of Prins Karls Forland to naturally have more power at low MT frequencies. This does not affect the CSEM frequencies above 1 Hz.

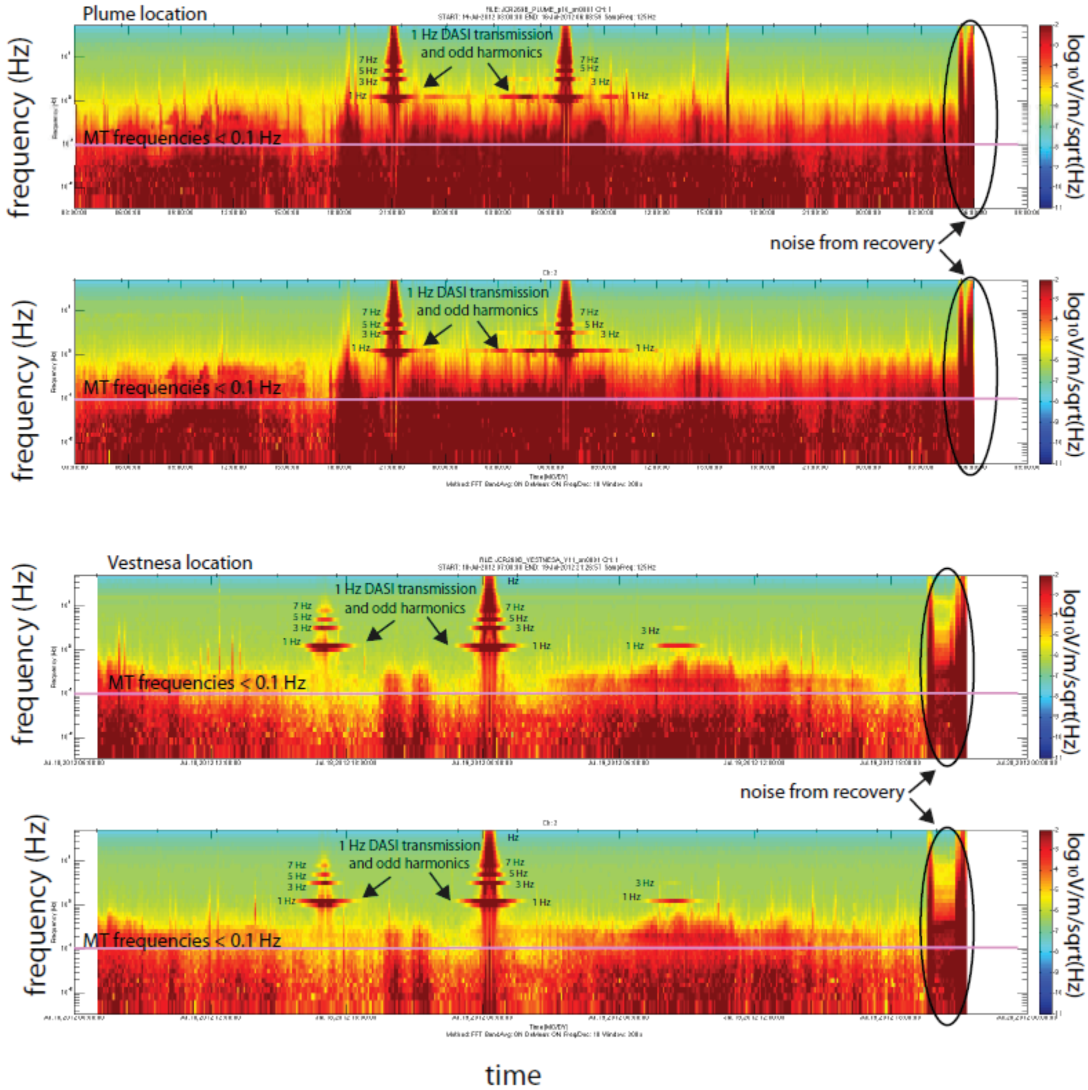

Figure 9. *Spectrogram (time versus frequency) of instrument 1 during the first deployment, p10 (top 2 (CH1,CH2)) and the Vestnesa deployment, v11 (bottom 2 (CH1, CH2)). The colour scale is in units of Volts - no electric field amplifier correction has been made. The ocean has a filtering effect on the natural telluric fields as is observed by the quieter signal in the Vestnesa site which is in deeper water (1200 m versus 426 m). In addition, at the plume location in 400 m water there are more bottom currents which may cause motion on the electric field sensors causing this location to be electrically noisier (almost to the transmission frequency of 1 Hz). One can observe a diurnal variation at the Vestnesa area at the start of data recording 09:00 July 18, 2012 repeating again at about 09:00 July 19, 2012. The CSEM transmission frequency of 1 Hz is clearly observed as well as the odd harmonics of the square wave. Upon instrument recovery the instruments rises at a rate of 14 m/min which causes motion of the electric field sensors putting noise at all frequencies. There are some stripping patterns observed which may be due to disk write noise or some other unknown effect. This instrument had the best data quality consistently for both deployments when compared to the other instruments with repeat deployment.*

Figure 10 shows a 15 minute times series chosen just before instrument saturation and therefore providing a good signal to noise ratio, used to compute the power spectra for both the western margin and Vestnesa surveys as recorded by instrument 1. A gain correction was applied based on circuit diagrams for the amplifier board. However, no amplifier response correction has been applied since that is currently awaiting final calibration. Again one can see the Vestnesa area is naturally electrically quieter then the Plume location. One can observe the fundamental transmission frequency and odd harmonics for both locations. However, at the location west of Prins Karls Forland the even harmonics can also be observed.

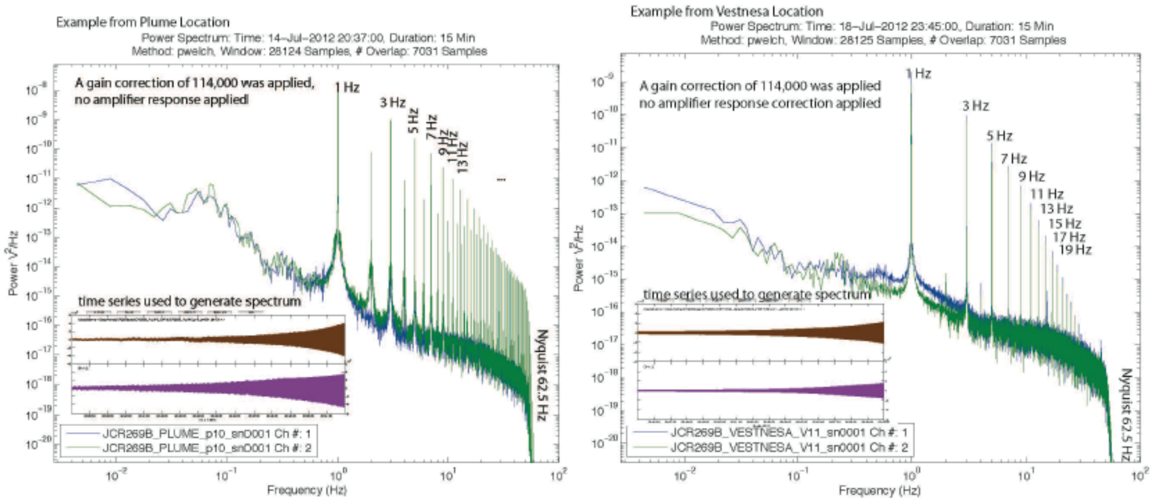

Figure 10. *Example of a power spectrum for site p11 and v11 with the 15 minute time series used to generate it in the inset. The y-axis is not the same as in Figure 3. The transmission frequency of 1 Hz and harmonics are clearly shown. The v11 location has roughly an order of magnitude less power then the Plume location due to the filtering effect of the deeper water column above this site. The transmission frequency of 1 Hz and odd harmonics are clearly shown.*

During the second deployment (the Vestnesa survey) there is a much more common occurrence of spikes on the time series which is also reflected by the long red lines in the spectrograms. This greatly effected sites v5,v6,v10 and v14. Careful examination of the time series during CSEM transmission will be required to ensure that these spikes are not included in the final analysis of the data, as it will cause a jump in amplitude that is not reflective of the geologic environment. Caution is also advised for places with fewer spikes but may overlap during the CSEM transmission.

7.3 Vulcan receiver performance and data quality

(K. Weitemeyer)

Vulcan is a 3-axis electric field receiver (Ex, Ey, Ez) that is towed 300 m behind the transmitter's (DASI) antenna. This instrument was deployed at both survey sites – west of Prins Karls Forland and Vestnesa - marking its second and third dives. Vulcan is fitted with a 3-axis accelerometer, a pressure sensor, and a compass which measures heading, pitch and roll. These record the orientation of Vulcan as it is deep-towed about 50 m above the seafloor, and give a sense of its depth and geometry relative to DASI. Figures 11 and 12 show the heading, pitch, roll and depth as recorded by Vulcan during the two dives.

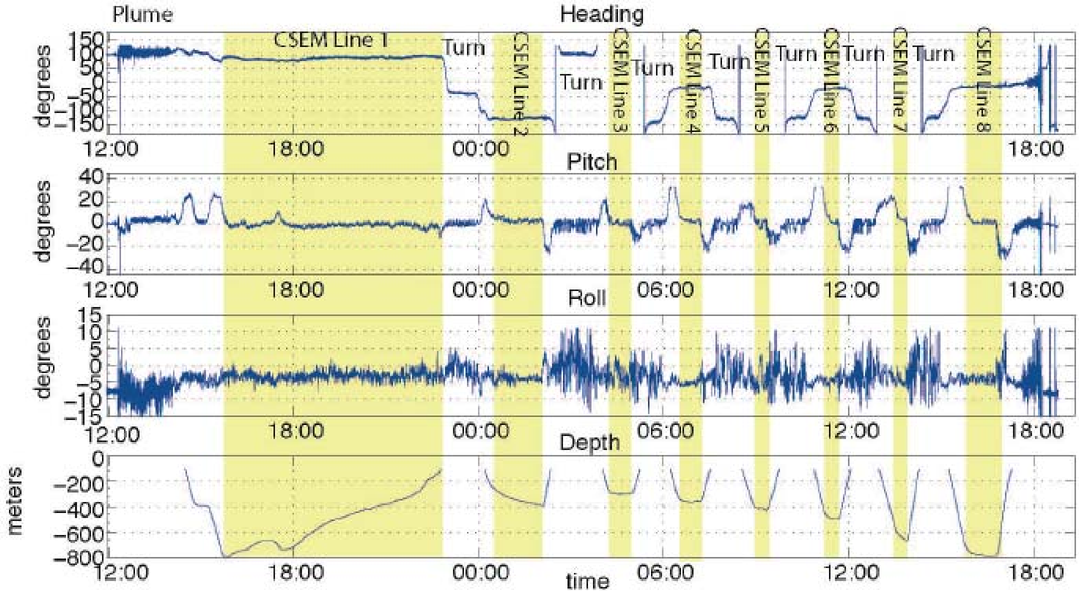

Figure 11. *Heading, pitch, roll and depth of Vulcan during Dive 2 west of Prins Karls Forland. Yellow regions highlight the CSEM lines when Vulcan and DASI were approximately 50 m above the seafloor. During regions when the deep-tow wire is hauled in our out the pitch of Vulcan varies. Similarly during turns the roll of Vulcan varies considerably*

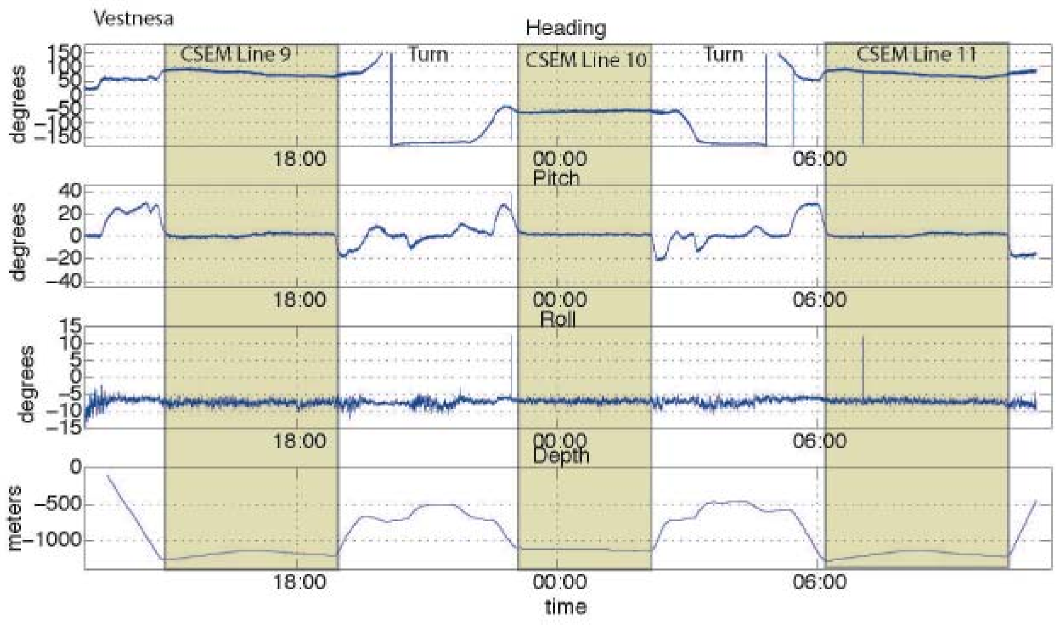

Figure 12. *Heading, pitch, roll and depth of Vulcan during Dive 3 at the Plume region. Yellow regions highlight the CSEM lines when Vulcan and DASI were approximately 50 m above the seafloor. During regions when the deep-tow wire is hauled in our out the pitch of Vulcan varies. Similarly during turns the roll of Vulcan varies considerably more*

Dive 2 shows considerably more roll than Dive 3. This may be caused by stronger currents at the shallower Dive 2 location.

A quick look at the recorded time series shows a good signal to noise ratio for the inline electric field components (Ey - CH2, Ez - CH3) and some small signal on Ex – the CH1 component. Ideally Ex would be zero in a pure inline regime. Figure 13 shows a 2 minute time series for both dives as well as the power spectra for that time segment. In both locations there is good signal from the fundamental transmission frequency of 1 Hz and we also see many odd harmonics that will be usable, with reasonably good signal to noise ratios up to at least 45 Hz. It is worth noting that at times the Ez component has overshoots at the up and down points of the square wave whose cause should be determined.

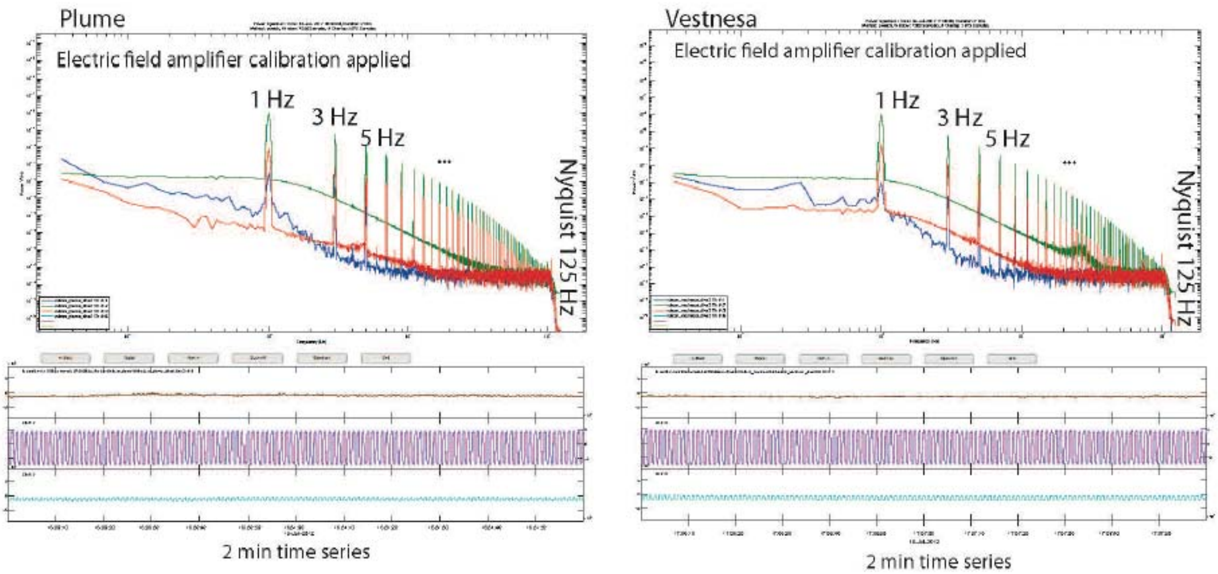

Figure 13. *Power spectra and time series during Dive 2 west of Prins Karls Forland (left) and Dive 3 at Vestnesa Ridge (right). The power spectra colours are: green - CH 2 Ey, red - CH 3 Ez, blue - CH 1 Ex. The time series plot colours are: brown - CH1 Ex, magenta CH 2 Ey, cyan CH3 Ez.*

In Appendix 2 are spectrograms from both dives which generally show the electric noise environment as observed by Vulcan as well as the DASI transmission. During times of heaving in the wire, paying out the wire or during turns one can see the signal transferred to the cross-line component (Ex) as the geometry of Vulcan varies relative to the transmitting antenna.

8. HYBIS Operations

(Veit Hühnerbach, Marine Geosciences Group, National Oceanography Centre, Southampton, UK)

8.1 The HyBIS vehicle

HyBIS is a simple, low-cost, multi-purpose, survey and sampling robotic underwater vehicle (RUV) with a depth capability of 6000m (Figure 14(a)). It was designed and built in the UK by Hydro-Lek Ltd. in collaboration with the National Oceanography Centre, Southampton (NOC) in 2008. Since then, the vehicle has had 3 successful trials cruises and completed 7 scientific expeditions, from the Arctic to the Tropics.

The vehicle has a modular design that make its very versatile, with the top module being a command and power system that comprises power management, cameras, lights, hydraulics, thrusters and telemetry. Telemetry is via a single-mode fibre optic link and provides 3 channels of real-time standard-definition colour video plus vehicle attitude data. Power is supplied through a single-phase 1500V ac, 8kVA umbilical. Power is converted on the vehicle to provide 3-phase 120V for the thrusters (by two silicon motor controllers), 240V ac for the lights, and 24 to 12 V dc for onboard instruments.

The easily changeable lower modules available at the moment include a clam-shell sampling grab, a 5-function manipulator-arm and tool sled, a winch with 600m rope for instrument recovery and an ocean bottom seismometer deployment module. The lower module used during JR269B was the Ocean Bottom Electro-Magnetic (OBEM) deployment module, which worked perfectly (Figure 14(b)).

Unlike a conventional ROV, HyBIS does not have any floatation or buoyancy, it is rather suspended by its umbilical cable directly from the ship which makes it slightly susceptible to ship roll and heave motion. On the positive side, the advantage of direct suspension is that HyBIS can recover or deploy a payload of up to 750kg.

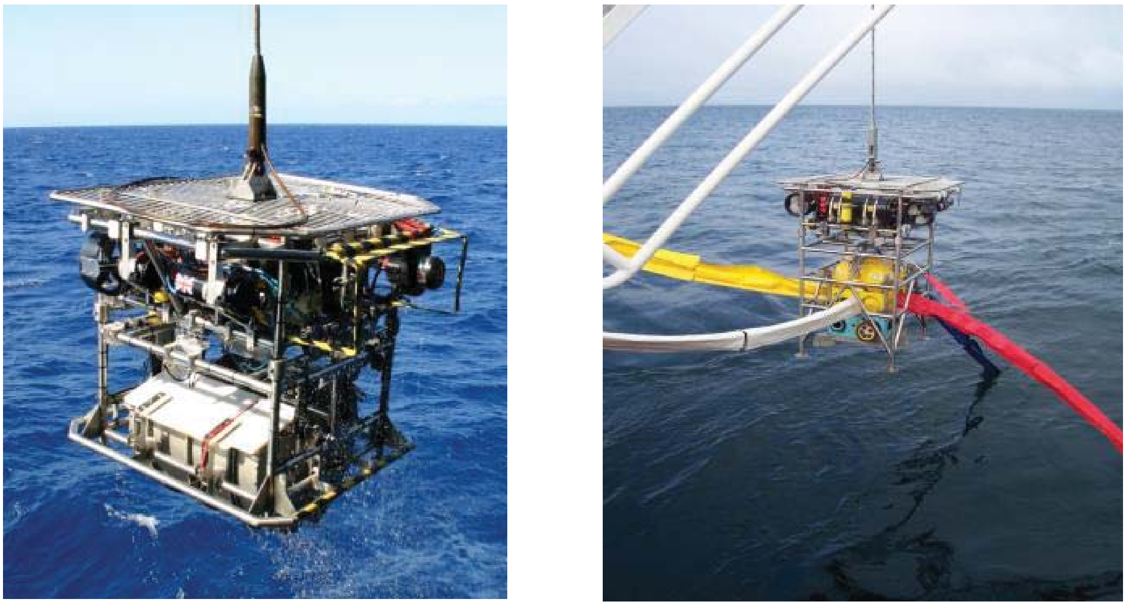

Figure 14. The *HyBIS vehicle, with the grab (left) and OBEM deployment (right) modules*

8.2 Laboratory control unit setup

The ship-board control centre (Figure 15) was established in the UIC Lab, starboard side, near the winch control stand, in line with the MacArtney deep-tow winch. This minimised the length of fibre optic lead across the deck. The DASI HV container provided access to the high-voltage junction box. For details about the setup inside the DASI container, please see Section 14 of this report. The vehicle's primary control box was supplemented with additional monitors and a relay display of the USBL navigation screen. A dedicated GPS aerial was mounted on an out-rigger above the winch control stand and provided a continuously recorded GPS string to the Garmin GPS navigation system in the control box. Winch controls were established adjacent to the vehicle pilot's position, allowing synchronisation between winch operator and pilot.

Video was recorded digitally as DV and AVI formats on 2Tb hard-discs. Two cameras (forward and downward SD) were recorded continuously in standard definition. The forward looking camera also had vehicle attitude data overlain. Full HD video (1080i, PAL, 30fps, AVCHD format) was not used. Back-ups of all dive data and videos were then made at regular intervals. All GPS navigation data were recorded on the top-side command unit and copied to a USB portable drive. Time codes were all set and synchronised to UTC.

Acoustic navigation was provided by the 'Sonardyne' USBL system using the Fusion software suite on the RRS James Clark Ross and a mini transponder on the HyBIS vehicle. Tracking was very good although transponder battery conditions provide a limited maximum dive time of about 6-8 hours until recharge becomes necessary. All available USBL navigation data were recorded by the BAS computing representative onboard.

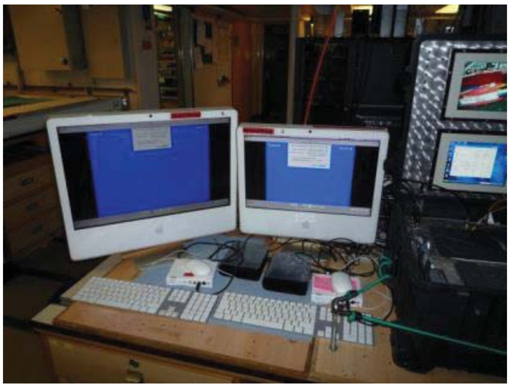

Figure 15. *UIC Lab HYBIS control console setup, showing video screen arrangements (left) and the HyBIS video logging system and main control box (right)*

8.3 High-voltage power setup

The HyBIS HV transformer was installed inside the DASI system High Voltage container in order to comply with high-voltage health and safety requirements. HV safe working procedures were put in place which meant that neither HyBIS nor DASI were to be switched on prior to deployment and recovery. All procedures were communicated to and agreed with the crew. HV working permits were issued and signed off for each deployment. In addition, an area of the back deck, from the DASI container onward, as well as next to the MacArtney winch and its slipring was closed off after power up of the HV equipment to prevent access to the area.

8.4 Dive narrative and vehicle performance summary

12th July 2012, HyBIS Dive #97

West of Prins Karls Forland: (78° 31.45N, 08° 56.11E), water depth ~850m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur P1).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

12th July 2012, HyBIS Dive #98

West of Prins Karls Forland: (78° 31.64N, 09° 00.01E), water depth ~805m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur P2).

HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

12th July 2012, HyBIS Dive #99
West of Prins Karls Forland: (78° 31.83N, 09° 03.97E), water depth ~730m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur P3).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

12th July 2012, HyBIS Dive #100
West of Prins Karls Forland: (78° 32.02N, 09° 07.90E), water depth ~635m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur P4).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

12th July 2012, HyBIS Dive #101
West of Prins Karls Forland: (78° 32.20N, 09° 11.83E), water depth ~565m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur P5).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

12th July 2012, HyBIS Dive #102
West of Prins Karls Forland: (78° 32.39N, 09° 15.48E), water depth ~530m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur P6).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.
The light bulb of the downward light blew upon switch on, and vehicle attitude data was not recorded completely during this dive.

12th July 2012, HyBIS Dive #103
West of Prins Karls Forland: (78° 35.54N, 09° 18.77E), water depth ~490m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur P7).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

12th July 2012, HyBIS Dive #104
West of Prins Karls Forland: (78° 32.70N, 09° 21.66E), water depth ~470m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur P8).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.
Compass heading data shows wrong values.

13th July 2012, HyBIS Dive #105
West of Prins Karls Forland: (78° 32.82N, 09° 24.17E), water depth ~440m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur P9).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

13th July 2012, HyBIS Dive #106
West of Prins Karls Forland: (78° 32.92N, 09° 26.24E), water depth ~425m

Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur P10).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

13th July 2012, HyBIS Dive #107
West of Prins Karls Forland: (78° 33.02N, 09° 27.95E), water depth ~400m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur P11).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.
Vehicle attitude data was not recorded completely during this dive.

13th July 2012, HyBIS Dive #108
West of Prins Karls Forland: (78° 33.09N, 09° 29.27E), water depth ~395m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur P12).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

13th July 2012, HyBIS Dive #109
West of Prins Karls Forland: (78° 33.16N, 09° 30.58E), water depth ~375m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur P13).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

13th July 2012, HyBIS Dive #110
West of Prins Karls Forland: (78° 33.22N, 09° 31.89E), water depth ~350m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur P14).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

13th July 2012, HyBIS Dive #111
West of Prins Karls Forland: (78° 33.30N, 09° 28.62E), water depth ~395m
Aim: Video survey of the MASOX seabed observatory.

16th July 2012, HyBIS Dive #112
Vestnesa Ridge area (78° 59.65N, 06° 46.33E), water depth ~1290m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur V1).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

16th July 2012, HyBIS Dive #113
Vestnesa Ridge area (78° 59.95N, 06° 49.32E), water depth ~1260m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur V2).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

17th July 2012, HyBIS Dive #114
Vestnesa Ridge area (79° 00.10N, 06° 50.78E), water depth ~1245m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur V3).

HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

17th July 2012, HyBIS Dive #115
Vestnesa Ridge area (79° 00.25N, 06° 52.29E), water depth ~1230m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur V4).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

17th July 2012, HyBIS Dive #116
Vestnesa Ridge area (79° 00.41N, 06° 53.80E), water depth ~1225m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur V5).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

17th July 2012, HyBIS Dive #117
Vestnesa Ridge area (79° 00.55N, 06° 55.30E), water depth ~1235m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur V6).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

17th July 2012, HyBIS Dive #118
Vestnesa Ridge area (79° 00.71N, 06° 56.81E), water depth ~1250m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur V7).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

18th July 2012, HyBIS Dive #119
Vestnesa Ridge area (79° 00.85N, 06° 58.26E), water depth ~1270m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur V8).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

18th July 2012, HyBIS Dive #120
Vestnesa Ridge area (79° 01.16N, 07° 01.28E), water depth ~1280m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur V10).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

18th July 2012, HyBIS Dive #121
Vestnesa Ridge area (78° 59.93N, 06° 56.10E), water depth ~1220m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur V11).
Dive abandoned at the seabed because the OBEM instrument flag pole disconnected a hydraulic cable from the system, resulting in HyBIS not being able to release the OBEM instrument.

18th July 2012, HyBIS Dive #122
Vestnesa Ridge area (78° 59.93N, 06° 56.10E), water depth ~1220m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur V11).

HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

18th July 2012, HyBIS Dive #123
Vestnesa Ridge area (79° 00.87N, 06° 51.50E), water depth ~1230m
Aim: Place an Ocean Bottom Electro-Magnetic receiver on the seabed (Lemur V14).
HyBIS deployed the OBEM instrument successfully and its position and orientation on the seabed was recorded by a short video survey.

Vehicle summary
With over 31 hours of total dive time, HyBIS played an important part of the science activity during the cruise although the available time window for HyBIS operations was limited.

There were no technical problems with the high-voltage system or any other part of the vehicle, apart from a single blown light bulb of the downward light. Its replacement did not cause any delay in the operations. The only other problem that occurred was a vehicle compass freeze which meant that the deployment directions of the OBEM are not fully accurate.

One dive (No 121) had to be abandoned at the seabed without releasing the payload because a hydraulic hose of the instrument release system had been disconnected by the OBEM flag pole during descent.

9. Seismic reflection profiling operations

(T. Henstock, University of Southampton)

9.1 Acquisition

Seismic data were collected at each of the two main survey sites. The source was a GI gun operating in true mode with 45 cu.in. generator and 105cu.in. injector, at a nominal pressure of 140 bar. The gun was towed by its umbilical 25m behind the stern of the ship 1m to starboard of the A frame centre (Figure 16), with a 2m rope between the float and gun-frame and 1m chains to the gun.

An Avalon RSS2 source controller linked to a GPS clock was configured with the Generator as Gun 1, and the Injector as Gun 2. Gun 1 was allowed to vary its trigger characteristics based on the shot hydrophone to match the required shot instant, and Gun 2 was fired 37ms later than Gun 1 to match the specifications of the Sercel GI-gun manual, giving good suppression of the bubble pulse on the shot hydrophone. The hydrophone output display was monitored visually throughout the acquisition, and the time and amplitude of the peak of each shot were automatically logged by the controller to a spreadsheet file, and the gun hydrophone waveform recorded in a SEGY file.

Figure 16. *View of JCR's after deck during seismic operations, with the air from the most recent shot reaching the surface immediately behind the float.*

The shots were recorded on the University of Southampton hydrophone streamer. This has 60 channels at 1m group interval, configured with channel 1 at the rear and channel 60 at the front. There are 10m stretch sections to either side of the active section, with a small float an additional 20m behind the streamer, and approximately 35m of lead-in used. The streamer was deployed through a fairlead in the bulkhead and towed using the standard aluminium hoop suspended from the port-side hydraulic arm, arranged to ensure that the effective tow point was close to the sea surface. The streamer was taped to the towing hoop, and fed underneath the shackle of the tow rope to ensure it was secure. In practice the streamer tows much closer to the vessel than the outer point of the arm (Figure 17), and the relative positioning of the source and streamer depends strongly on sea conditions. The analogue streamer was digitised on a Geometrics Strataview R60 recorder positioned on the afterdeck, operated together with Geometrics CNT1 Marine Controller software running on a Dell workstation in the UIC lab. Data were recorded using a 0.5ms sample interval and 3s records throughout in SEGD3058 format. The Dell workstation was connected to a GPS clock, and the clock on the Strataview which generates the timestamps for the shots is automatically synchronised to the workstation at line changes; drift rates while the clock is free-running were up to 1-2s per hour.

Figure 17. *Tow arrangements for the 60 channel high resolution seismic streamer.*

Shots were triggered by the RSS2 source controller with a firing aim point 50ms after the GPS second. Visual observation from the bridge for marine mammals was undertaken for 1 hour before deployment of the seismic gear, during which time no mammals were present within 500m of the ship. A soft-start procedure then used a shot interval decreasing from 60s to 6s over a 30 minute period. Shooting thereafter was maintained continuously at 6s interval, corresponding to 10-15m shot spacing, including during turns. Continuous shooting meant that no additional soft-start procedure was required. A continuous watch for marine mammals was maintained from the bridge during the survey period; no mammals were observed during either seismic survey at distances of less than 500m.

A nominal speed through the water of 4.5knots was maintained to ensure towing loads on the streamer and gun umbilical remained reasonable. Turns were typically made at rates of 5-15 degrees per minute depending on sea conditions, with visual observation to ensure adequate separation between the airgun and streamer was maintained.

Following the survey shotpoint locations (Figures 18 and 20) were generated using the shot times from the Geometrics logfile and the vessel navigation from the Seapath 320 system. Clarification of which point on the vessel is returned by the Seapath is still awaited from BAS. The lat-long positions were converted into UTM zone 32N using mapproject from version 4.5.8 of the GMT software. Initial geometry assignment on board the ship was carried out using ProMAX version 5000.0.3.0, assuming that the positions reported are those of the Seapath 320 GPS antenna; the gun was treated as fixed 25m behind the stern, and the best average streamer geometry for each line was generated using the times of the direct wave at channels 1 and 60. CDPs were assigned at 1m spacing along the straight-line data sections. Further processing to generate brute stacks used a 10-20-500-1000Hz bandpass filter, true amplitude recovery with a gain function of $t^{2.2}$-$t^{2.5}$, normal moveout correction following velocity analysis at 1km intervals, and a median stack.

9.2 Survey area west of Prins Karls Forland

The vessel approached the seismic deployment location at 194/2300, heading into the weather. The streamer was deployed first starting at approximately 2320, with the airgun following. Shooting of the airgun at 60s interval started at 195/0001 and full acquisition started at 195/0031, starting with FFID 1. Seven lines were acquired (2012_1-2012_7), which fill in gaps remaining from the survey conducted during JR269A in 2011 (Figure 6). Shooting continued until 195/1106, when the ship turned to weather and the gear was recovered to deck. Weather and sea conditions were good throughout; turns could be maintained at 6degrees/minute to starboard and up to 15 degrees/minute to port.

Initial processing shows good quality data with high-resolution and little noise in the shallow sections, although penetration is relatively limited with clear reflections seen only to 300-500ms beneath the seabed (Figure 19). The best penetration is beneath the shelf, although imaging is then disrupted by the water column multiple.

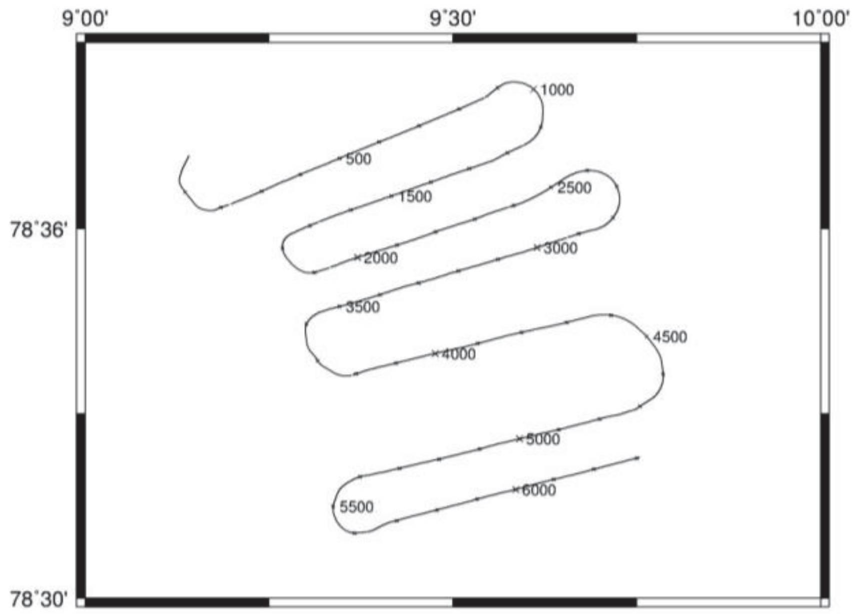

Figure 18. *Shot point map for the survey west of Prins Karls Forland. FFIDs are indicated every 100, and annotated every 500.*

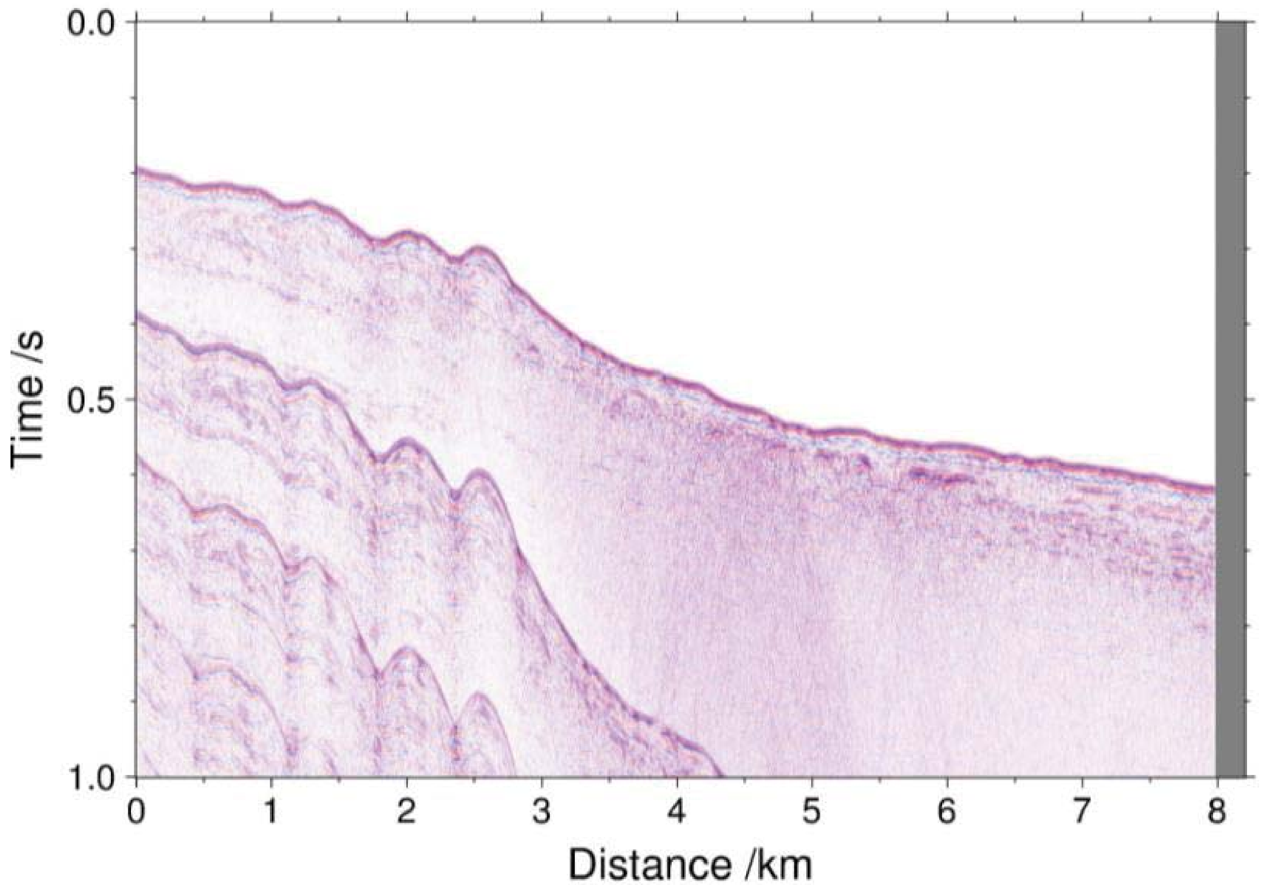

Figure 19. *Brute stack for seismic line 2012_4, across the margin west of Prins Karls Forland.*

9.3 Vestenesa Ridge survey area

The vessel approached the deployment waypoint at 199/1114 heading into the weather. The gear was deployed by 1130, and shooting at 60s interval commenced. Shooting at 6s shot interval and seismic recording started at 1200, with the first FFID 10000. Five lines (2012_8-2012_12) were collected perpendicular to the ridge, and one (2012_13) along the crest (Figure 20). The two perpendicular lines 2012_10 and 2012_13 correspond to the profiles along which EM instruments were deployed. Lines were shot in an alternating pattern because the spacing is too close to easily turn onto adjacent lines. The last of the cross-ridge lines to be shot, 2012_11, was terminated approximately 3 km short of its originally planned end point, due to time constraints. Shooting continued until 199/2258, and the vessel turned to wind for recovery of the gear. Recovery started at 2303, the gun was fully recovered at 2309 and the streamer was on board at approximately 2315. Weather conditions during shooting were generally less favourable for this survey with wind reaching 20kts from the N, and 1-2m swell with some whitecaps. On the NE legs the ship was typically steering 15degrees to port of the line, and the speed over the ground is asymmetric between the two shooting directions. Turns could be maintained at 10 degrees/minute in either direction.

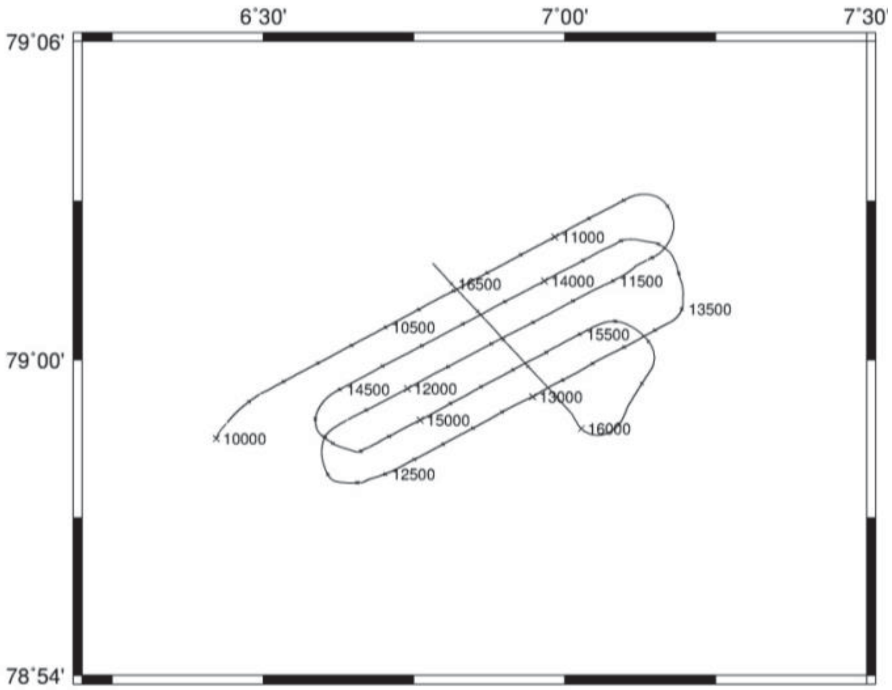

Figure 20. *Shot point map for the Vestnesa Ridge seismic survey. FFIDs are indicated every 100, and annotated every 500.*

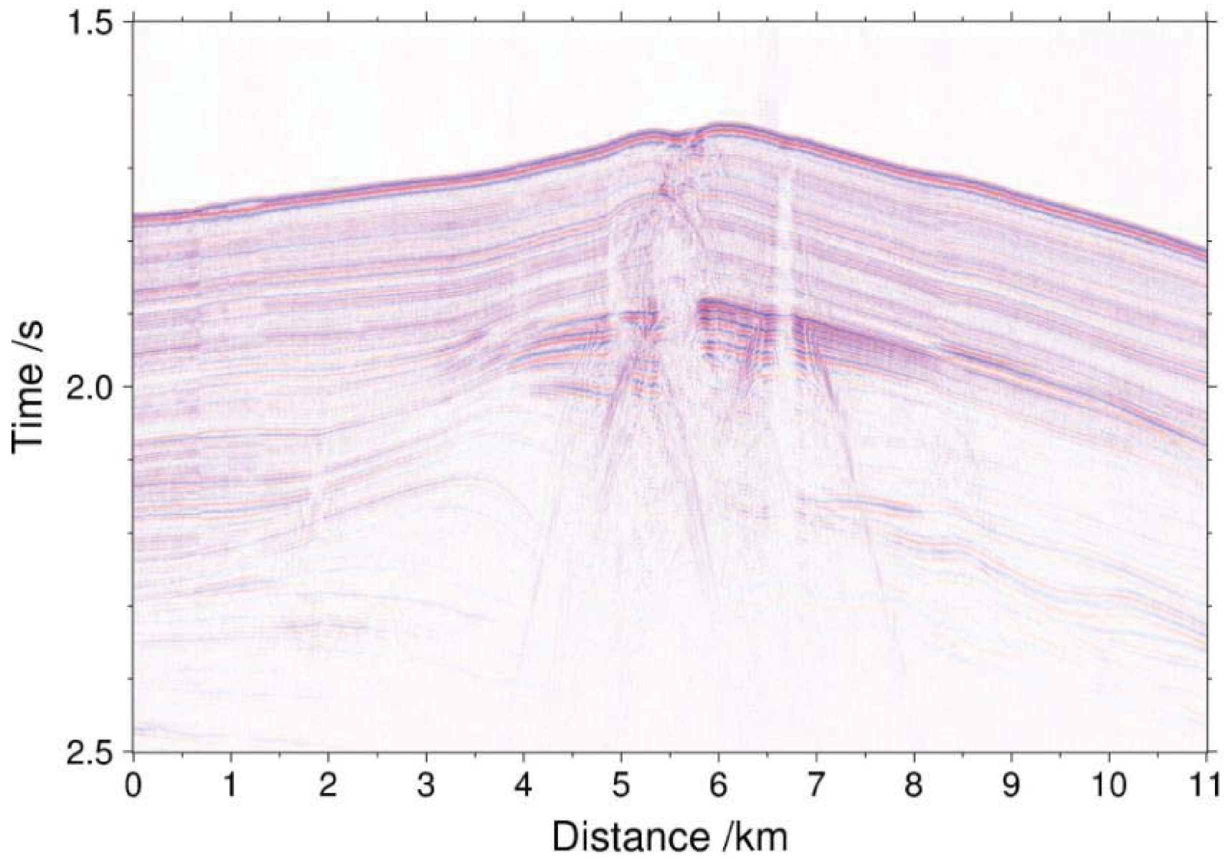

Figure 21. *Brute stack for seismic line 2012_10, across the Vestnesa Ridge.*

The shipboard processing again shows generally good data quality (Figure 21), and although at times there is significant swell noise this is generally at frequencies lower than the seismic source and was removed by the bandpass filter. Reflections can be clearly identified up to 1s beneath the seabed. At this location the high seabed travel time compared with the shot interval means that some previous shot noise can be seen on the records, however the increased fold makes this a worthwhile compromise, and it doesn't affect the main part of the section.

9.4 Review of seismic equipment performance and recommendations

The equipment performed well throughout, with no downtime and good quality data. Improved penetration without affecting the resolution might be possible by using a pair of GI guns instead of the single gun. An alternative source which would further improve the resolution, although may risk lower penetration, would be a high energy (~5kJ) sparker. The streamer is clearly too short to have significant velocity sensitivity in these water depths, and is unable to provide any level of multiple suppression; we also approached the edge of the streamer's weather window, when a streamer with longer lead-in, stretch section, and active birds would still have been usable, however a short group interval is clearly important with a high-resolution source. The benefit of using a short streamer and single gun is the efficient setup to make use of gaps within the cruise programme – the simple seismic system can be consistently deployed and operational within 20 minutes, and recovered in 10-15 minutes. The biggest constraint on start up time is actually the marine mammal observation.

10. Swath Bathymetry and Echo Sounder Operations

10.1 Kongsberg EM122 Multibeam Echosounder

The Kongsberg EM122 multibeam echosounder was operated during the cruise in water column mode at all times within the licensed research area, except when other operations (principally the USBL acoustic navigation requirements for DASI and HYBIS) prevented its use. A written log of water column features was maintained by the scientific watch keeping team. Data from the EM122 were logged for the following times:

Start: day number	Start: time (UTC)	End: day number	End time (UTC)
194	0552	194	0649
194	2234	195	1246
195	2249	196	0907
196	1617	197	1821
199	1145	200	0005

10.2 Kongsberg TOPAS PS18/15 sub-bottom profiler

The Kongsberg TOPAS sub-bottom profiler was operated during the cruise at all times within the licensed research area, except when other operations (principally the USBL acoustic navigation requirements for DASI and HYBIS) prevented its use. A written log of the trigger delay applied to the display was maintained by the scientific watch keeping team. TOPAS data were logged for the following times:

Start: day number	Start: time (UTC)	End: day number	End time (UTC)
194	0602	194	0649
194	2225	195	1245
195	2249	196	0907
198	1628	198	2010
199	1043	200	0005

10.3 Simrad EK60 multi-frequency echo sounder

The Simrad EK60 ‘fishfinder’ sonar was operated at 38, 120 and 200 kHz to detect and image bubble plumes during the cruise at all times within the licensed research area, except when other operations (principally the USBL acoustic navigation requirements for DASI and HYBIS) prevented its use. A written log of water column events was maintained by the scientific watch keeping team. EK60 data were logged for the following times:

Start: day number	Start: time (UTC)	End: day number	End time (UTC)
194	0602	194	0649
194	2216	195	1247
195	2249	196	0907
198	1607	198	2010
199	1049	200	0005

10.4 Simrad EA600

The Simrad EA600 display system was operated in passive mode at times, with the source being provided by the EM122. This provided a useful visual reference within the after part of the UIC laboratory close to the DASI and HYBIS operator stations, but was not logged as a primary depth indication.

11. Water column measurements and ARGO float deployments

11.1 Vertical CTD profiles

CTD casts were carried out in both survey areas (west of Prins Karls Forland and at the Vestnesa Ridge) to provide sound velocity structures for the swath and USBL systems. A Sea-Bird 911*plus* CTD system was used. This consists of an underwater unit with built in pressure sensor, to which a suite of modular sensors can be connected, and a SBE11*plus* Deck Unit. Sea-Bird's standard modular temperature and conductivity sensors (SBE 3*plus* and SBE 4*plus*) are mounted to the underwater unit within the guard cage. Two pairs of sensors are used to provide *primary* and *secondary* temperature and conductivity data sets for error comparison and redundancy. The CTD also had a fluorometer, transmissometer, altimeter and dissolved oxygen meter. Data were collected from the sea surface to just above the sea bed on the western edge of each survey area (*i.e.* in the deepest water) at the start and end of operations in each location.

11.2 XBT casts

Sippican XBT probes types T5 (maximum depth 1870m) and T7 (maximum 780m) were used to complement the CTD casts. Six XBTs were launched in total. The first three produced useful data, but the last three (all launched during seismic profiling at Vestnesa Ridge) all failed shortly after entering the water. This was almost certainly due to the XBT wire being broken by contact with the streamed seismic equipment.

11.3 DASI CTD data

The DASI deep-tow vehicle is fitted with a Seabird 911*plus* V2 CTD device. Data from this are telemetered to the ship by means of the fibre optic within the umbilical cable. Continuous measurements of electrical conductivity and temperature were logged throughout both DASI dives.

11.4 ARGO floats

(Simon Wright, BAS)

The *James Clark Ross* (JCR) had been asked to deploy up to thirteen Argo floats on an opportunistic basis during the 2012 Arctic cruises. These deployments are referred to by the cruise number JR285.

The floats are funded by the Department of Energy and Climate Change (DECC) via the Arctic Research Programme (ARP) which is run from the British Antarctic Survey's (BAS) headquarters in Cambridge.

The initial aim was to deploy the floats in three basins; the Norwegian, Lofoten and Greenland. However due to routing changes floats were only deployed in the Lofoten and Greenland basins by JCR. During JR269B the passages to and from Reykjavik presented the opportunity to deploy six floats: one on the northbound leg and five southbound. This was due to ice conditions pushing the northbound leg further east and hence reducing the length of passage over the target deep (>3000m) basin areas.

Details of the floats are given in Appendix 3.

12 Atmospheric Methane Measurement and Sampling

(C. Graves, University of Southampton)

12.1 Continuous Monitoring of Methane Concentrations in Air

A Picarro Cavity Ring-Down Spectrometer (CRDS) was installed in the underway instrumentation and control room of the RRS *James Clark Ross* before the previous cruise (JR271). Ambient external air is collected in front of the ship's navigation bridge and pumped into the analytical cavity of the Picarro, where both methane and carbon dioxide concentrations are determined at 5 second intervals by means of their absorption of an internal laser. The instrument was calibrated by measurement of a tank of known gas composition before departure from and upon return to Reykjavik. Data from the Picarro were downloaded regularly by researchers at Royal Holloway University of London (Drs Rebecca Fisher, Dave Lowry, and James France) for analysis in conjunction with the ship's track and atmospheric weather patterns.

12.2 – Air Sampling for Methane Isotopic Analysis

A total of 18 air samples were collected from the wings of the ship's navigation bridge during JR269b, both during transit to and from Reykjavik and during scientific operations in the vicinity of observed methane flares from the seafloor offshore western Svalbard (see table in Appendix 4). Daily sample collection was undertaken in the morning to coincide with sampling at the Zeppelin research station, Ny-Ålesund, Svalbard. During scientific work additional samples were collected when the Picarro indicated peaks in methane concentration, especially coincident with seafloor gas escape detected by the EK60 echo-sounder. All air samples will be analysed for methane concentration and carbon isotopic ratio ($\delta^{13}C$-CH_4) by Rebecca Fisher, Dave Lowry and James France at Royal Holloway, University of London using a gas chromatograph isotope ratio mass spectrometer (GC-IRMS) which is capable of high precision measurements of the low methane concentrations of ambient air.

The concentration and isotopic signatures of atmospheric methane during JR269b, in conjunction with weather data and on-shore measurements, will indicate if any of the methane escaping the seafloor in the study area is reaching the atmosphere. Data will build upon samples collected in 2008 aboard JR211 and in 2011 during JR253 and JR269A.

13 Overall ship operations and logistics

Mobilization and demobilization of this research cruise both proceeded smoothly and to plan in Reykjavik. The use of Reykjavik for the port calls was a great improvement on the use of Longyearbyen in 2011 (JR253 and JR269B), which had led to difficulties in providing sufficient working space on deck (especially for JR269A) due to the lack of sufficient time alongside in Longyearbyen. This was however at the cost of additional passage time. In the event, passage time to the work area was used constructively for setting up and preparing labs and instrumentation; while the transit back to Reykjavik allowed ample time for dismantling and packing up ready for demobilization.

The layout of major items of equipment on the after deck of RRS *James Clark Ross* is shown in Figure 22.

Figure 22. *Layout of major items of equipment on the after deck of RRS* James Clark Ross.

Both during passage and at all times during scientific work, both the ship and her officers and crew proved themselves admirably capable of supporting and delivering all aspects of this complex scientific mission.

During JR269B there was NO ship downtime. There were 3.4 hours of weather downtime during LEMUR recoveries after the first CSEM survey; and 3 hours of equipment downtime due to a break in the fibre optic connection at the outboard end of the deep-tow cable, when changing from HYBIS to DASI operations during the second CSEM survey. This is an excellent outcome for such a complex and instrumentally demanding scientific programme at high latitudes.

14. High Voltage Electrical Systems

(Y.Y. Tan & M. Sinha, University of Southampton)

The HYBIS and DASI instrument systems both require a high voltage electrical supply through their umbilical/tow cable in order to operate. In the case of the

HYBIS system the operating voltage is approximately 1,600 V rms ac. In the case of the DASI system, the operating voltage varies under user control between 1,000 and 2,000 Vrms ac. In order to provide a safe high voltage compartment at sea for the power supplies that generate these voltages, one end of a 20 foot shipping container was suitably fitted out as a high voltage container space prior to the summer 2012 CSEM survey campaigns.

The container was divided using a steel partition mid way along its length. This enables one half to continue to be used for shipping or storing equipment while the other end is used for the high voltages. For JR269B, both the HYBIS and DASI high voltage power supply cabinets were bolted down to steel mounting plates attached to the deck of the high voltage space. Three pairs of electrical sockets, arranged back-to-back on the inside and outside of the container wall, provide a 32 A, 380 V, 3-phase supply from the ship for the DASI system; a 220 V 16A single phase supply for the HYBIS system; and a 220 V 16A single phase supply for general utilities (lighting and domestic type electric sockets) through a distribution board and breaker system installed in the container.

The container was securely earthed to the ship's structure at a single point consisting of an earthing bolt on the outside of the container. All other earths within the container were connected to this point by suitably specified copper conductors.

The high voltage outputs from the DASI and HYBIS power supply units are fed to the conductors in the umbilical/tow cable through a single lockable steel junction box, rated to 2,000 V ac, mounted on an interior bulkhead of the container. Only one device can be connected at a time. Both power supply units can be instantly shut down by pressing a prominent and clearly labelled Emergency Stop button mounted next to the door of the container on the outside. There is one emergency stop button each for DASI and HYBIS. Additional switches and breakers inside the container allow the input supply to either of the power supply units to be shut off safely, and physically locked off, at any time. Both high voltage power supply units can in addition be shut down instantly by a further Emergency Stop button each, located respectively at the DASI and HYBIS control consoles in the UIC laboratory. The door of the high voltage container space is lockable.

Operation of the High Voltage power supply systems for both HYBIS and DASI were controlled by means of written procedures, which included the designation of specific individuals as responsible and/or Competent Persons, and the issuing of Isolation Certificates and Permits to Work, augmented by physical locks.

In view of the Norwegian maritime regulations on high voltage (1kV and above) operation and safety, an external expert consultant was engaged to visit the ship and audit / advise on the high voltage installations and procedures for this Cruise. Mr Brian Simmonds MIEE, of Power & Generation Sevices Ltd (a registered training provider for IMCA) therefore visited the ship during the mobilization port call in Reykjavik. Mr Simmonds had previously worked with NOCS and the University of Southampton to provide training in high voltage operations at sea to relevant engineering, technical and scientific staff.

The assessment was performed onboard the JCR on 6 July 2012. Those attending were Ian Tan for DASI; Veit Huehnerbach for HYBIS; and Nicholas Dunbar (ETO Eng) for the ship. After some adjustments the Consultant approved the installation and procedures for JR269B; however he made a number of recommendations for further improvements to installations and suggestions for additional training for future operations, which will have to be implemented.

15. The MacArtney winch system and cable termination

(J. Scott, National Marine Facilities)

For this cruise the purpose built, containerised MacArtney winch system was used for DASI and HYBIS deep submergence operations. It consists of a standard 20' container carrying the winch drum and local operator stand. The winch and stand are removed from the container and bolted to the ship's deck during use. The cable was a Tyco/Rochester 17.3mm double-armoured steel cable with a conductor, a return and a fibre-optic in its centre.

The local controls were used during DASI and HYBIS launches and recoveries. Control was switched to a remote control unit in the UIC laboratory when the instruments were at depths greater than 50 m. The length of wire out was logged continuously during all dives.

The optical termination was carried out using a Corning termination kit, however part of the fibre coating had to be cut off because the total diameter exceeded the maximum allowed by about 70 micrometres. This resulted in the fibre being very fragile when being transferred from one vehicle to another. The optical values were around -10 to -13 dB, sufficient for both DASI and HyBIS. Re-termination was necessary after the first switch-over from HyBIS to DASI and it was found that the plastic ST-connectors supplied by Corning do not always provide a sufficiently good optical connection.

The winch could be operated very smoothly allowing the winch drivers to keep the vehicles at the required depth

16. Summary of data collected

60 km of CSEM profile consisting of 11 transmitter tow lines and 25 receiver deployments across two survey areas

115 km of 2-D multi-channel seismic reflection profile consisting of 13 lines across the 2 survey areas

130 km of swath bathymetry, sub-bottom profiler and multi-frequency echo sounder data

27 HYBIS dives

8 km of ADCP data

4 CTD casts

3 successful XBT casts

Continuous measurement plus daily sampling of atmospheric methane content

Continuous standard suite of meteorological and sea surface properties data

17 Tables of Line, Instrument and Station Locations

JR269B - instrument deployment positions - First work area - west of Prins Karls Forland						
Site for CTD Casts				CTDs 1 & 2		
	Lat N Deg	**Minutes**		**Long E Deg**	**Minutes**	
	78	30.650		8	34	
For reference only: MASOX lander location -						
	Lat N Deg	**Minutes**		**Long E Deg**	**Minutes**	
	78	33.304		9	28.61	
LEMUR Locations Plumes Site						
LEMUR Location	**Lat N Deg**	**Minutes**		**Long E Deg**	**Minutes**	
P1	78	31.457		8	56.13	
P2	78	31.640		9	0.05	
P3	78	31.828		9	3.98	
P4	78	32.028		9	7.90	
P5	78	32.202		9	11.83	
P6	78	32.389		9	15.50	
P7	78	32.556		9	18.77	
P8	78	32.702		9	21.66	
P9	78	32.827		9	24.15	
P10	78	32.933		9	26.25	
P11	78	33.019		9	27.95	
P12	78	33.084		9	29.27	
P13	78	33.150		9	30.58	
P14	78	33.216		9	31.89	
(NOTE: LEMUR = Low-frequency ElectroMagnetic Underwater Recorder:						
autonomous ocean bottom instruments used for the CSEM survey.						
Each LEMUR was deployed using the HYBIS underwater remotely operated vehicle)						

JR269B - instrument deployment positions – first work area - west of Prins Karls Forland					
DASI Transmitting Lines					
Line End Locations	**Lat N Deg**	**Minutes**		**Long E Deg**	**Minutes**
1 Start	78	31.155		8	50.13
1 End	78	33.455		9	37.20
2 Start	78	35.483		9	27.00
2 End	78	35.000		9	19.00
3 start	78	33.748		9	31.24
3 end	78	32.684		9	32.54
4 start	78	32.401		9	26.90
4 end	78	33.465		9	25.60
5 start	78	33.088		9	18.12
5 end	78	32.024		9	19.42
6 start	78	31.670		9	12.48
6 end	78	32.734		9	11.18
7 start	78	32.360		9	3.33
7 end	78	31.296		9	4.63
8 start	78	30.925		8	56.78
8 end	78	31.989		8	55.48
(NOTE: DASI = Deep-towed Active Source Instrument: the electromagnetic					
transmitter system used for the CSEM survey.					
The neutrally buoyant Vulcan receiver was towed just above the sea floor behind					
DASI throughout the survey. DASI transmissions were also recorded by all LEMURs					

JR269B - survey lines - First work area – west of Prins Karls Forland					
Seismic Lines					
Line End Locations	**Lat N Deg**	**Minutes**		**Long E Deg**	**Minutes**
2012-1 Start	78	36.60		9	14.4
2012-1 End	78	38.04		9	31.8
2012-2 Start	78	37.08		9	33.0
2012-2 End	78	36.12		9	19.2
2012-3 start	78	35.40		9	20.4
2012-3 end	78	36.36		9	34.8
2012-4 start	78	35.64		9	36.0
2012-4 end	78	34.68		9	19.8
2012-5 start	78	33.72		9	23.4
2012-5 end	78	34.56		9	40.8
2012-6 start	78	33.00		9	43.8
2012-6 end	78	32.10		9	25.5
2012-7 start	78	31.20		9	24.0
2012-7 end	78	32.28		9	45.0

JR269B - survey lines - First work area – west of Prins Karls Forland					
Swath Survey					
Point	**Lat N Deg**	**Minutes**		**Long E Deg**	**Minutes**
1	78	32.000		8	30.00
2	78	35.000		8	30.00
3	78	37.150		9	3.00
4	78	37.500		9	3.00
5	78	35.800		8	30.00
6	78	36.300		8	30.00
7	78	38.700		9	21.00
8	78	38.850		9	21.00
9	78	39.200		8	45.00
10	78	39.500		8	45.00
11	78	39.200		9	21.00
12	78	39.400		9	21.00
13	78	39.900		8	45.00
14	78	41.850		8	54.00
15	78	41.850		9	24.00
16	78	38.500		9	23.85
17	78	32.250		9	30.10

JR269B - instrument positions - Second work area Vestnesa Ridge					
Site for CTD Casts		**CTD 3 & 4**			
	Lat N Deg	**Minutes**		**Long E Deg**	**Minutes**
	78	58.500		6	36.00
LEMUR Locations - Vestnesa Ridge					
LEMUR Location	**Lat N Deg**	**Minutes**		**Long E Deg**	**Minutes**
V1	78	59.646		6	46.34
V2	78	59.952		6	49.33
V3	79	0.102		6	50.82
V4	79	0.252		6	52.31
V5	79	0.408		6	53.81
V6	79	0.558		6	55.30
V7	79	0.708		6	56.80
V8	79	0.858		6	58.29
V10	79	1.158		7	1.28
V11	78	59.934		6	56.11
V14	79	0.876		6	51.50
(NOTE: LEMUR = Low-frequency ElectroMagnetic Underwater Recorder:					
autonomous ocean bottom instruments used for the CSEM survey					
Each LEMUR was deployed using the HYBIS underwater remotely operated vehicle)					

DASI Transmitting Lines Vestnesa Ridge					
Line End Locations	**Lat N Deg**	**Minutes**		**Long E Deg**	**Minutes**
D9 start	78	59.004		6	39.91
D9 end	79	1.724		7	6.80
D10 start	78	58.987		7	0.70
D10 end	79	1.821		6	46.88
D11 start	78	59.510		6	38.30
D11 end	79	2.230		7	5.30
(NOTE: DASI = Deep-towed Active Source Instrument: the electromagnetic					
transmitter system used for the CSEM survey.					
The neutrally buoyant Vulcan receiver was towed just above the sea floor behind					
DASI throughout the survey. DASI transmissions were also recorded by all LEMURs					

JR269B Seismic Survey Lines Vestnesa Ridge						
Line End Locations	**Lat N Deg**	**Minutes**		**Long E Deg**	**Minutes**	Comments
2012-8 start	79	0.04		6	36.5	
2012-8 end	79	2.83		7	4.0	
2012-9 start	79	2.23		7	5.3	same as D11 end
2012-9 end	78	59.51		6	38.3	same as D11 start
2012-10 start	79	1.72		7	6.8	same as D9 end
2012-10 end	78	59.00		6	39.9	same as D9 start
2012-11 start	78	58.43		6	41.4	same as D12 end
2012-11 end	79	0.42		7	0.8	
2012-12 start	78	57.90		6	43.0	
2012-12 end	79	0.64		7	9.8	
2012-13 start	78	58.99		7	0.7	same as D10 start
2012-13 end	79	1.82		6	46.9	same as D10 end

18 Acknowledgements

We thank NERC for funding this research project, and for providing ship time and National Marine Facilities resources. We thank the British Antarctic Survey and NERC National Marine Facilities for logistical and technical support during the cruise, and during mobilisation and demobilisation. We are indebted to the master, officers and crew of RRS *James Clark Ross* for their skills and professionalism throughout, and for making us welcome on board.

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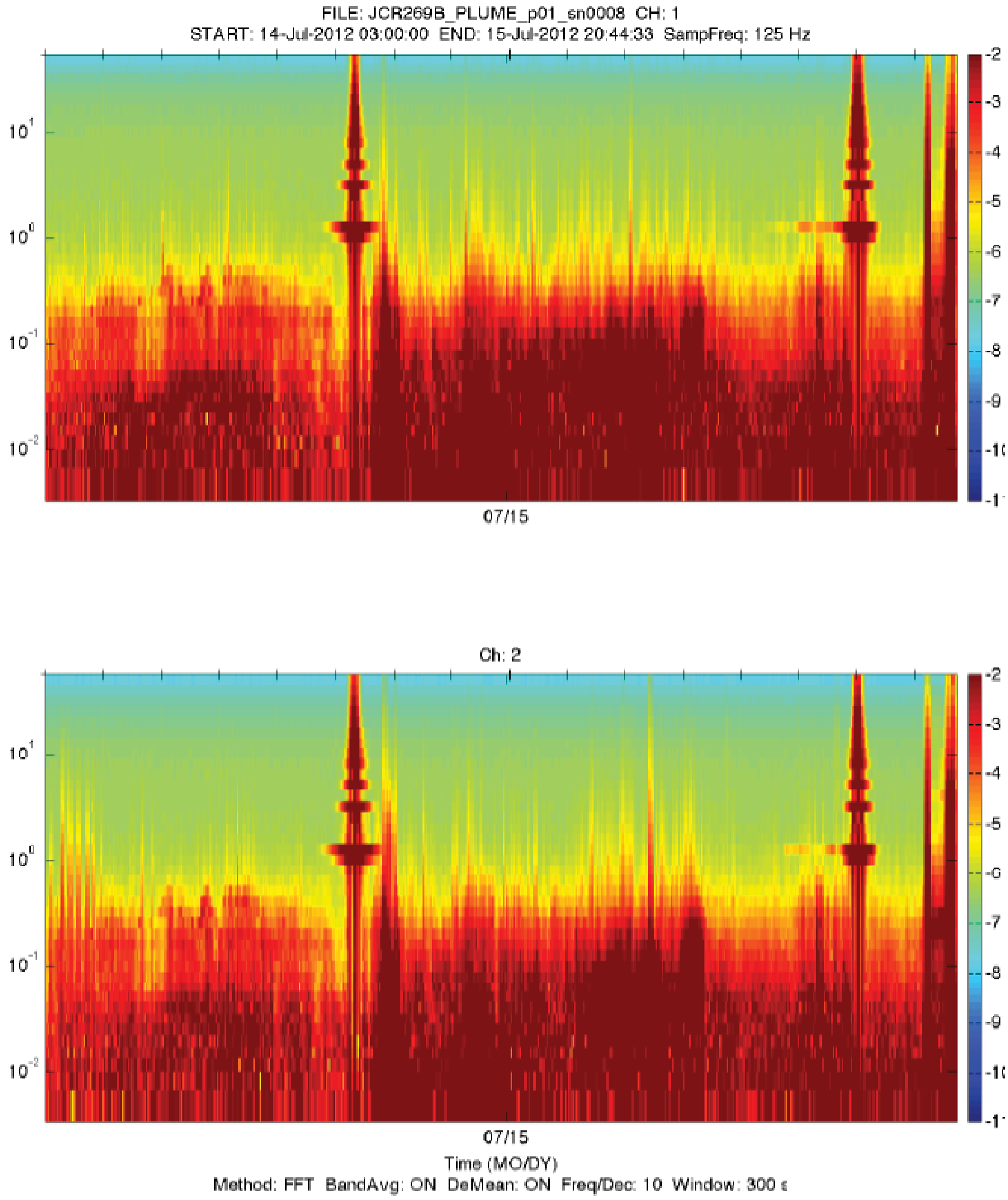
Appendix 1 : LEMUR Spectrograms from the First Survey Area west of Prins Karls Forland

General data quality is good. Site p06 had a bad channel as a result of bad electrode pairing. This was improved in the Vestnesa deployment of the same receiver by finding a better pairing of electrodes. Site p14 had a larger number of spikes that occurred less frequently near the end of the deployment. The spike characteristic was more common at the Vestnesa area and is attributed to the instrument.

instrument	site	CH1	CH2
8	p01	good	good
6	p02	good	good
4	p03	good	good
13	p04	good	good
14	p05	good/ odd spikes	good
10	p06	good/ odd spikes	**bad channel**
5	p07	**good / spikes**	good/ odd spikes
2	p08	**good / spikes**	**good / spikes**
17	p09	good	good
1	p10	good/ odd spikes	good/ odd spikes
12	p11	good/ odd spikes	good
11	p12	good/ odd spikes	good/ odd spikes
18	p13	good	good/ odd spikes
16	p14	**spikes**	**spikes**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07/15
Ch: 2
07/15
Time (MO/DY)
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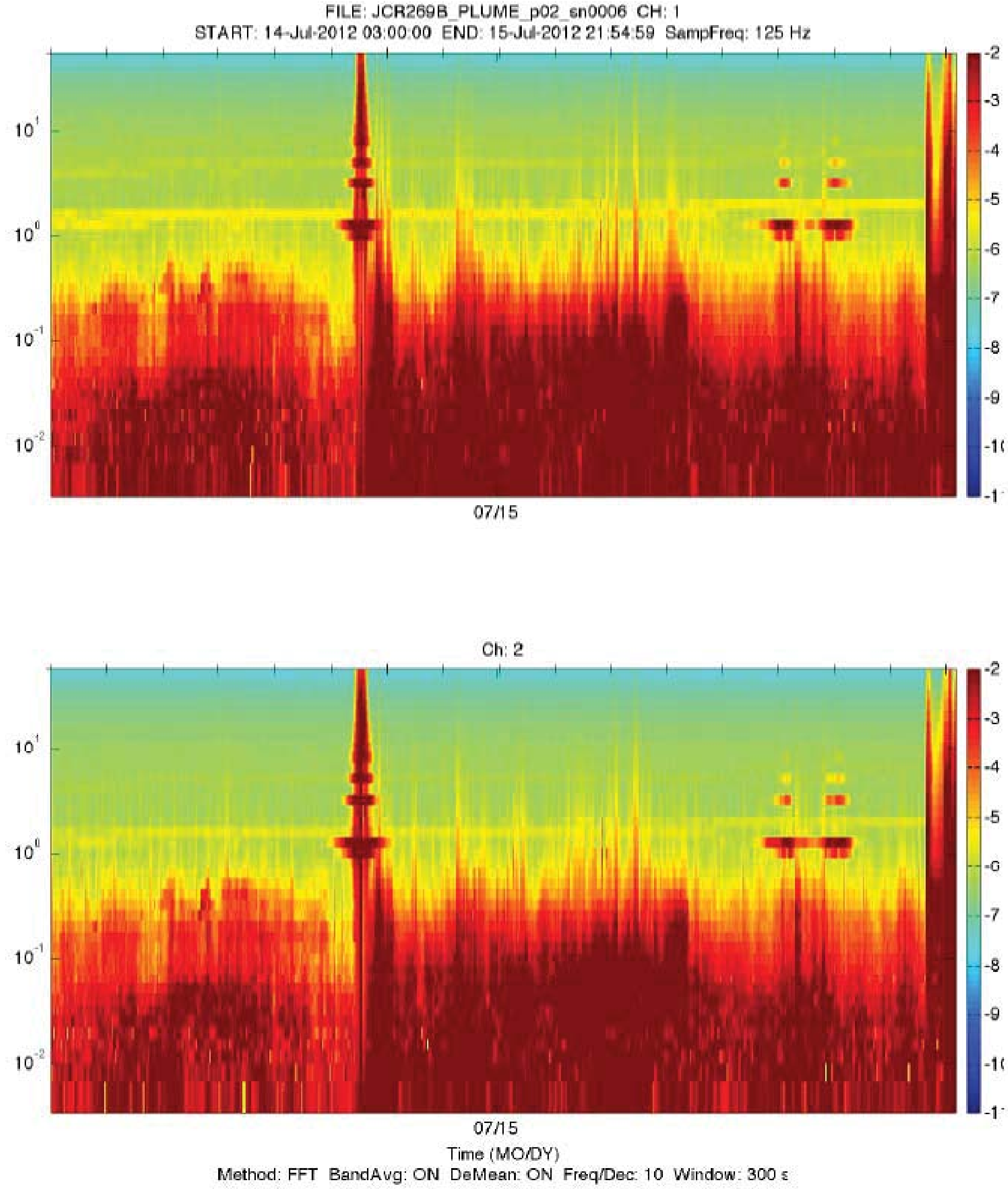
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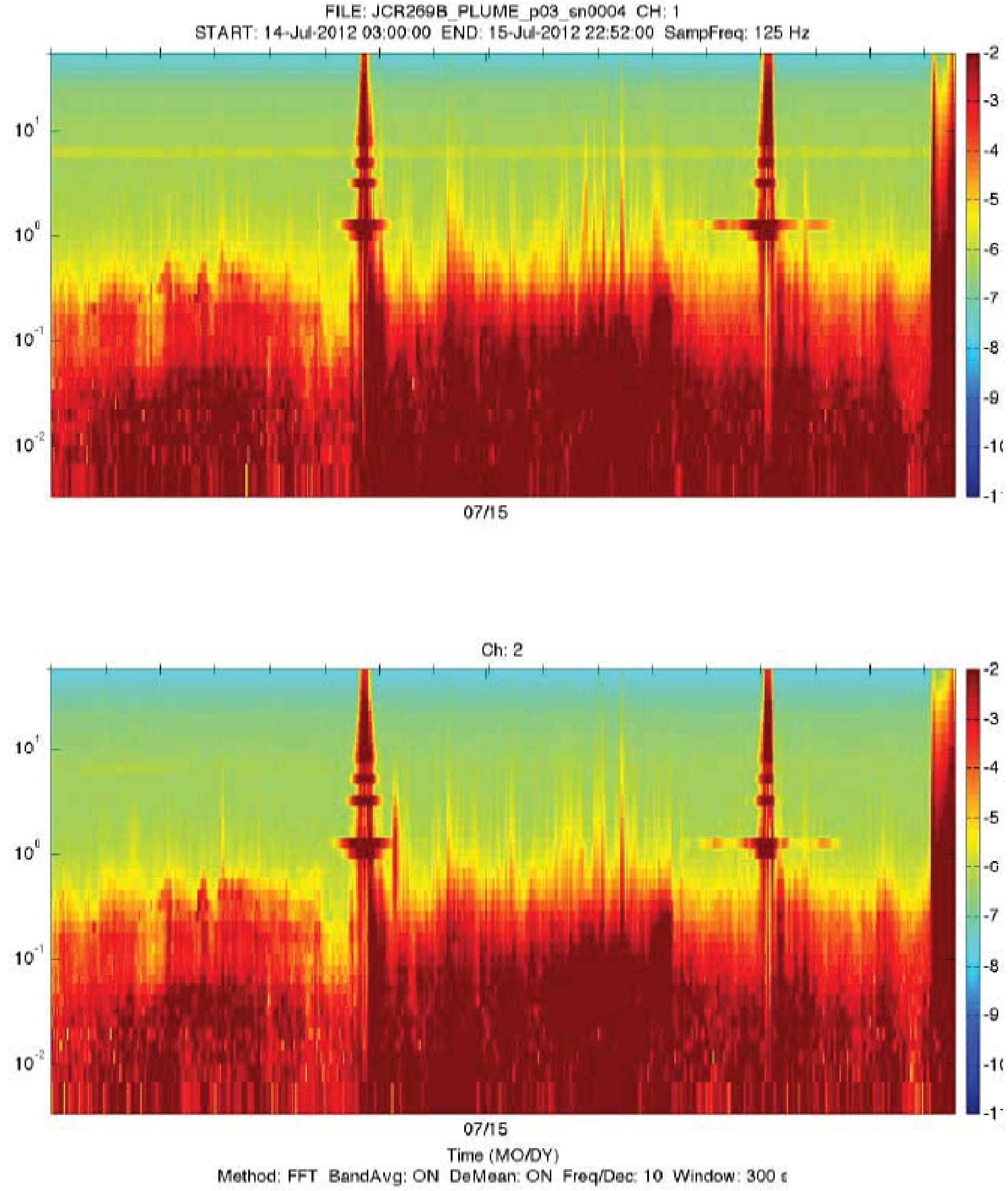
07/15
Ch: 2
07/15
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s



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07/15
Ch: 2
07/15
Time (MO/DY)
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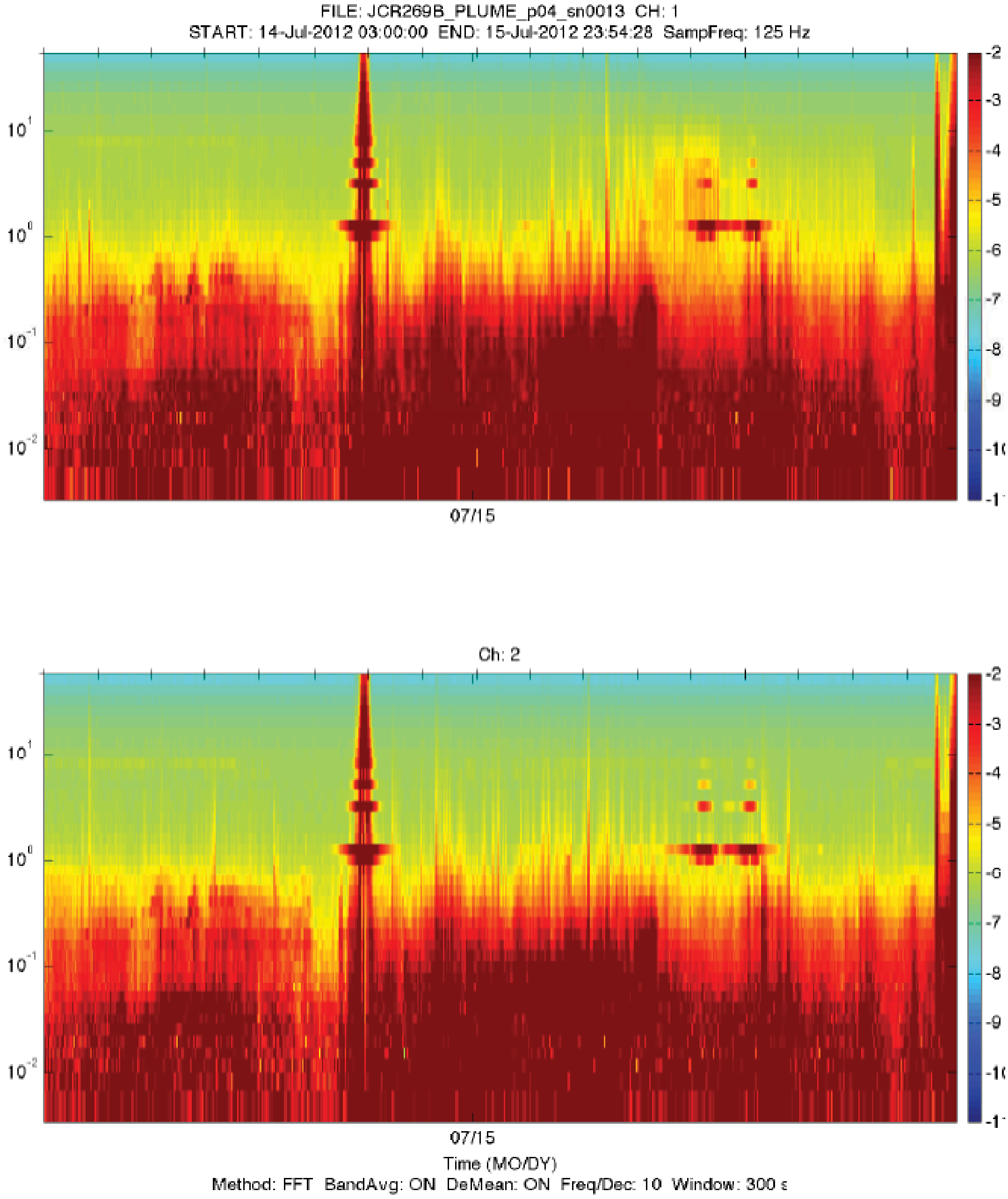
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07/15
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07/15
Time (MO/DY)
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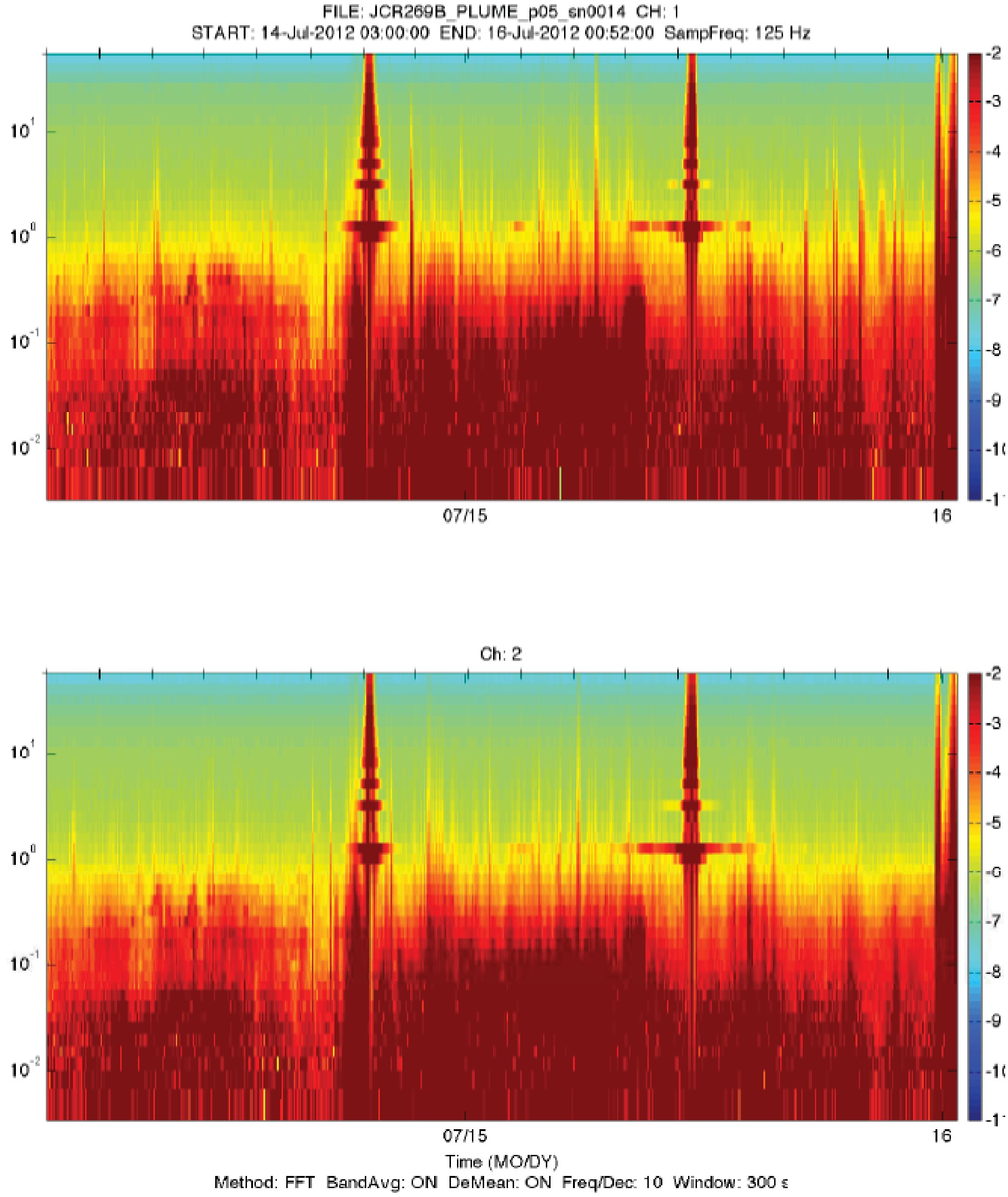
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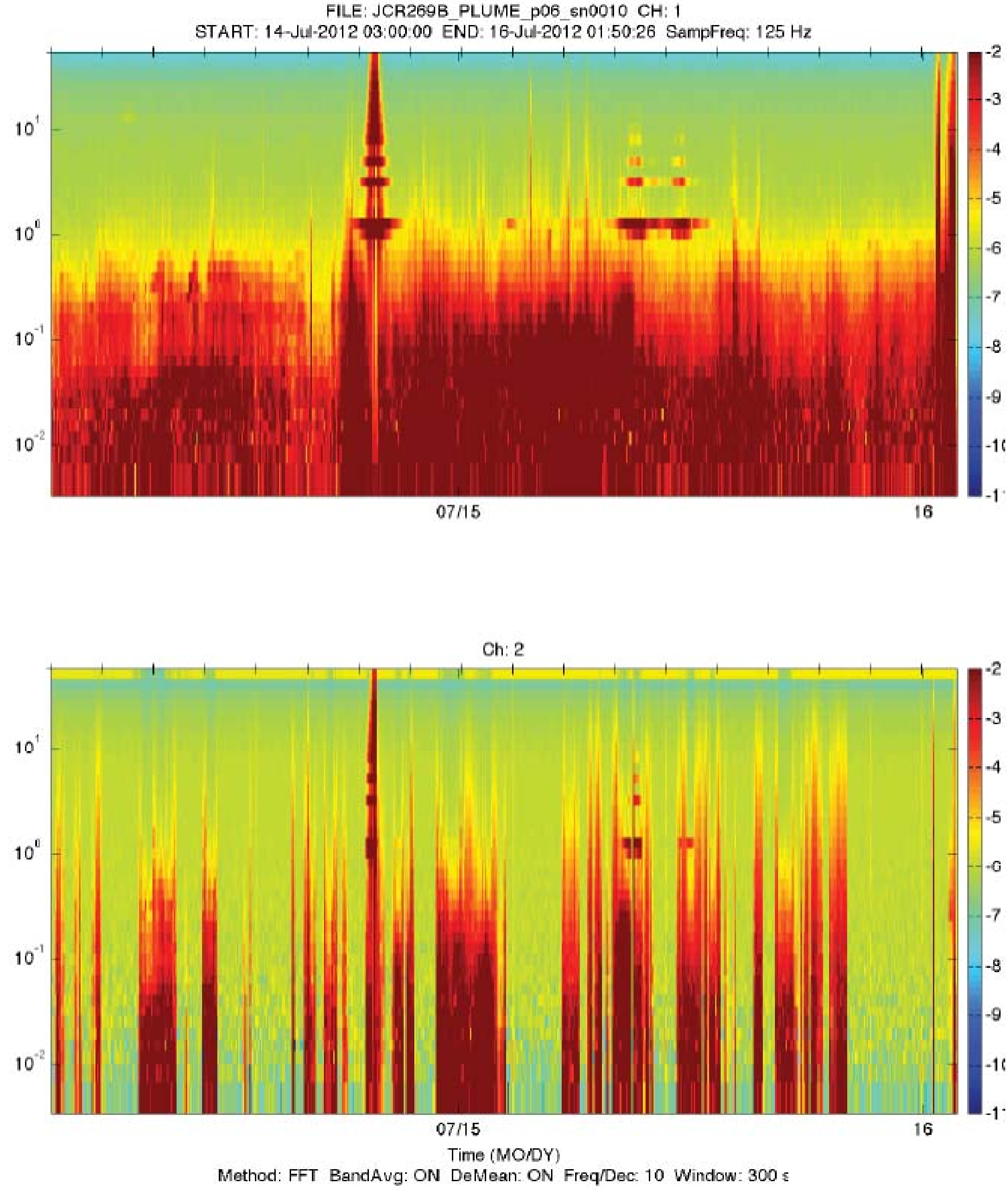
Ch: 2
07/15
16
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s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Ch: 2
07/15
16
Time (MO/DY)
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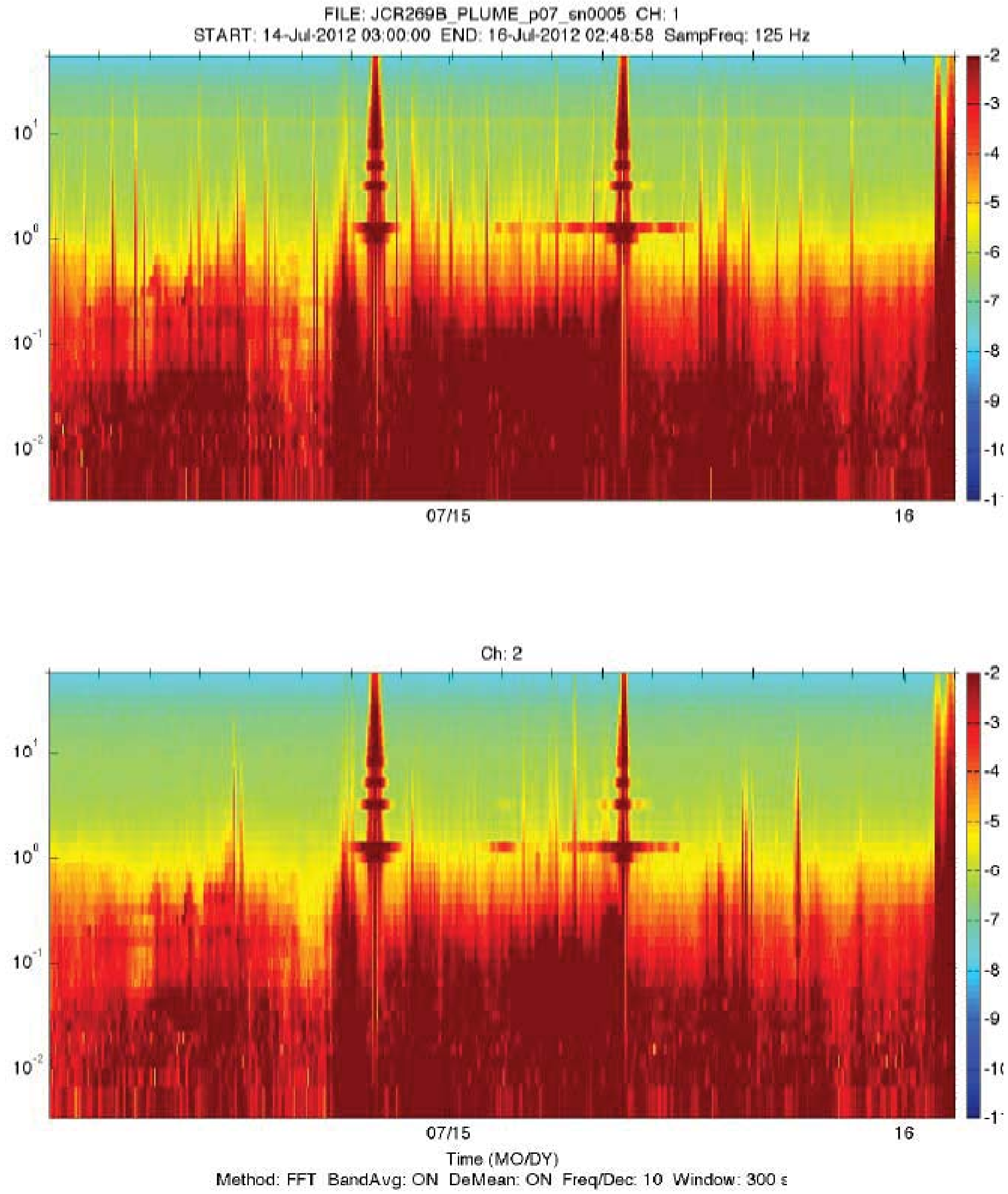

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07/15
16
Ch: 2
07/15
16
Time (MO/DY)
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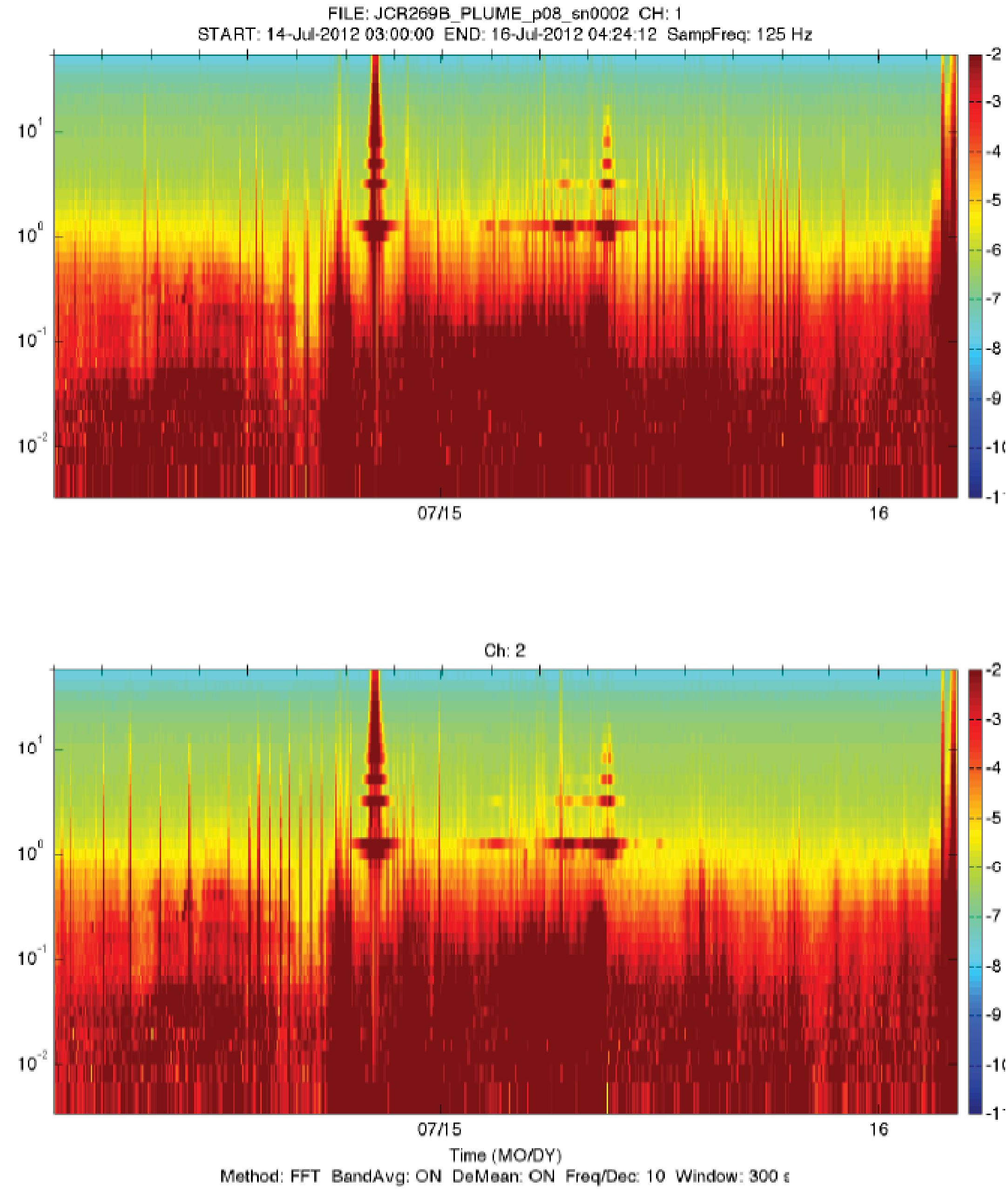
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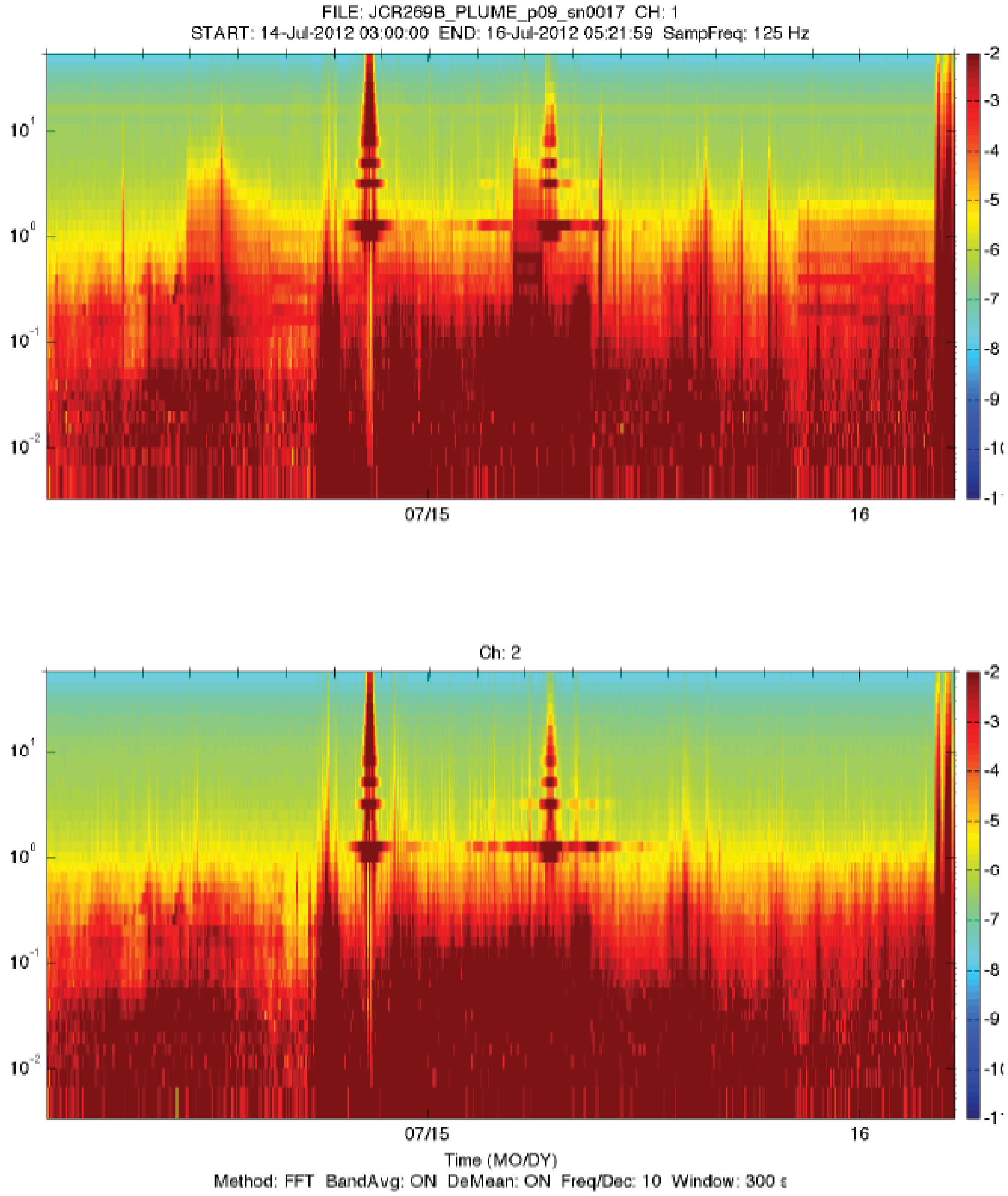
Ch: 2
07/15
16
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s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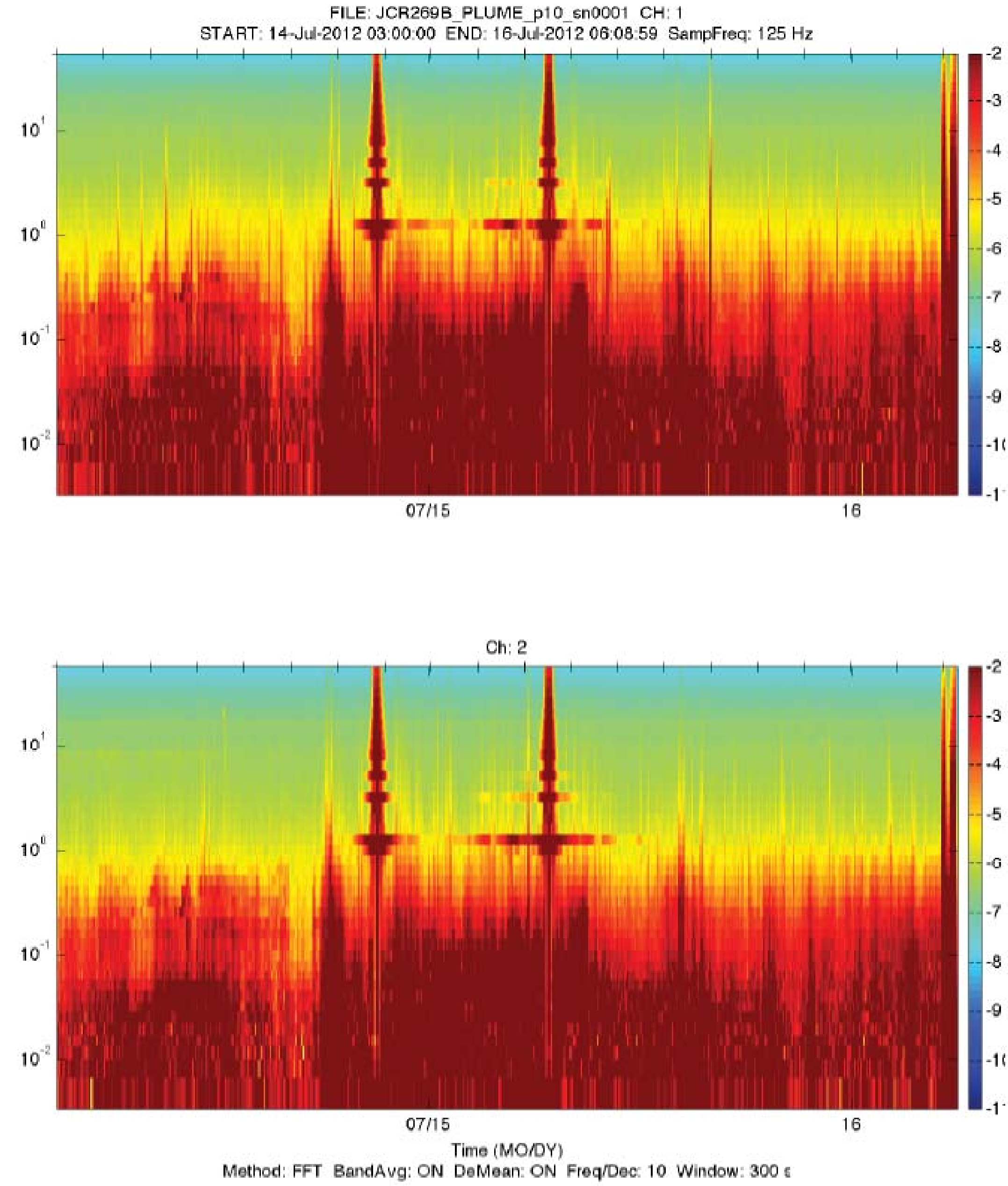
07/15
16
Ch: 2
07/15
16
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s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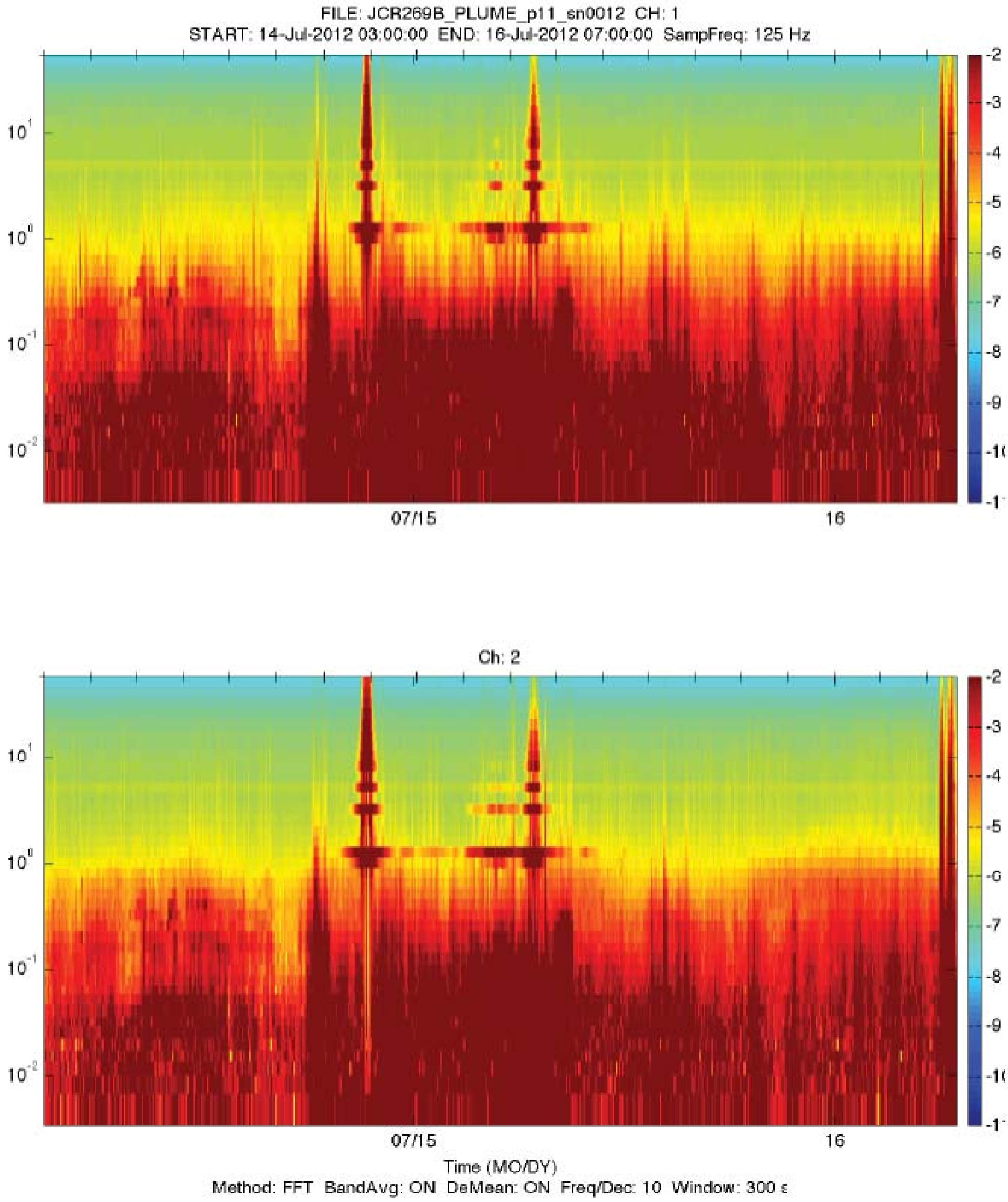
10^{1}
10^{0}
10^{-1}
10^{-2}
07/15
16
Ch: 2
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s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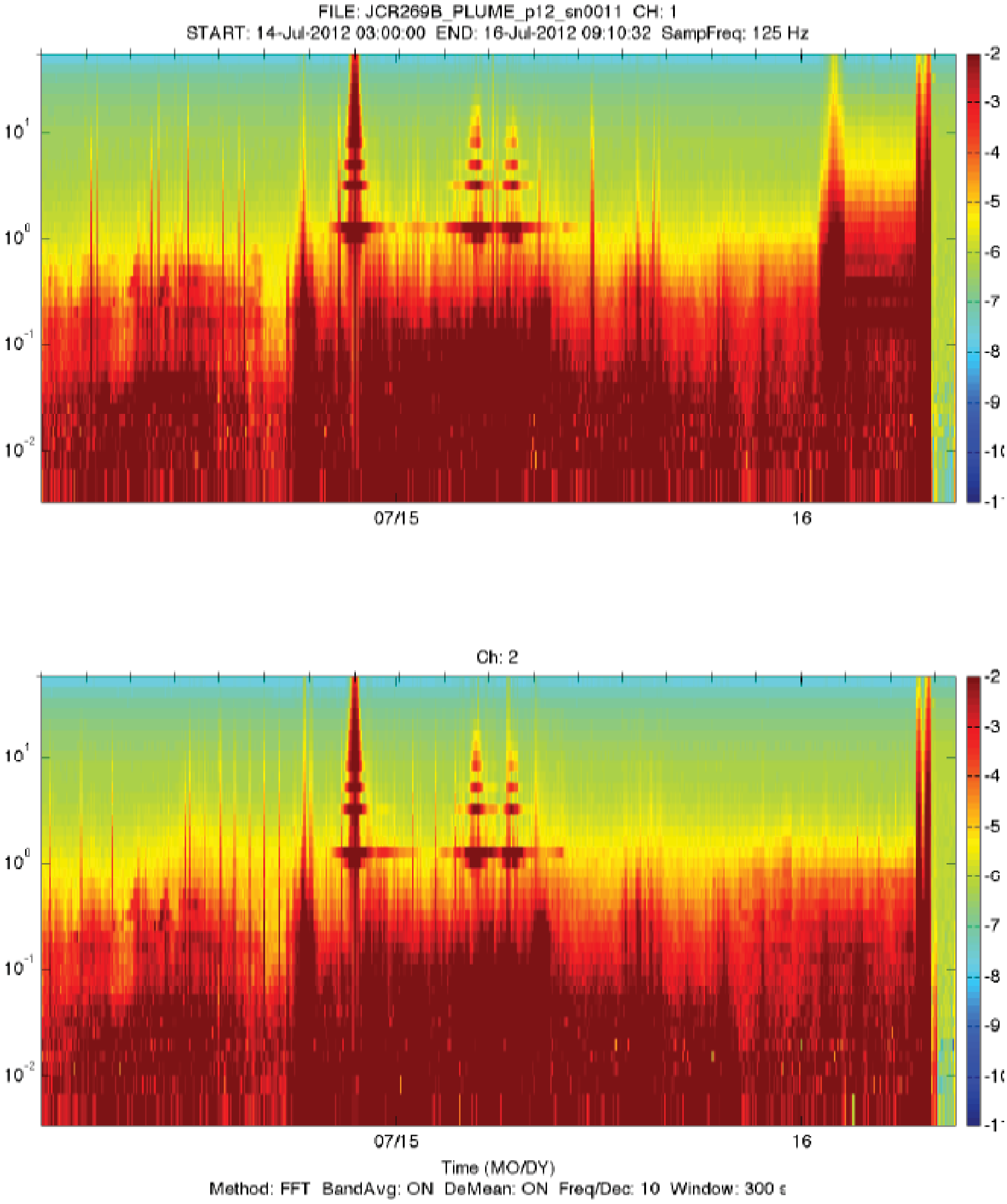
07/15
16
Ch: 2
07/15
16
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s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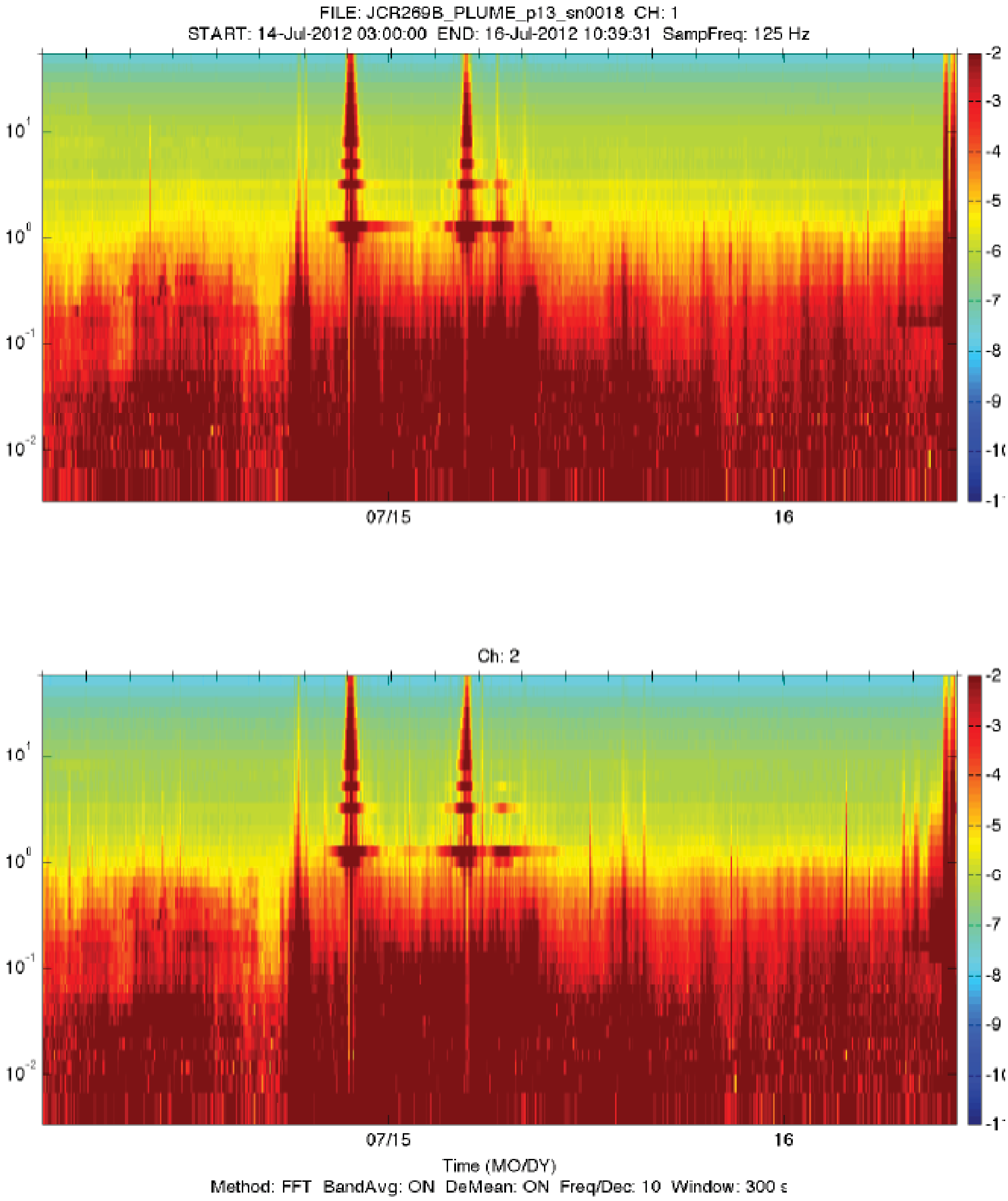
Ch: 2
07/15
16
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s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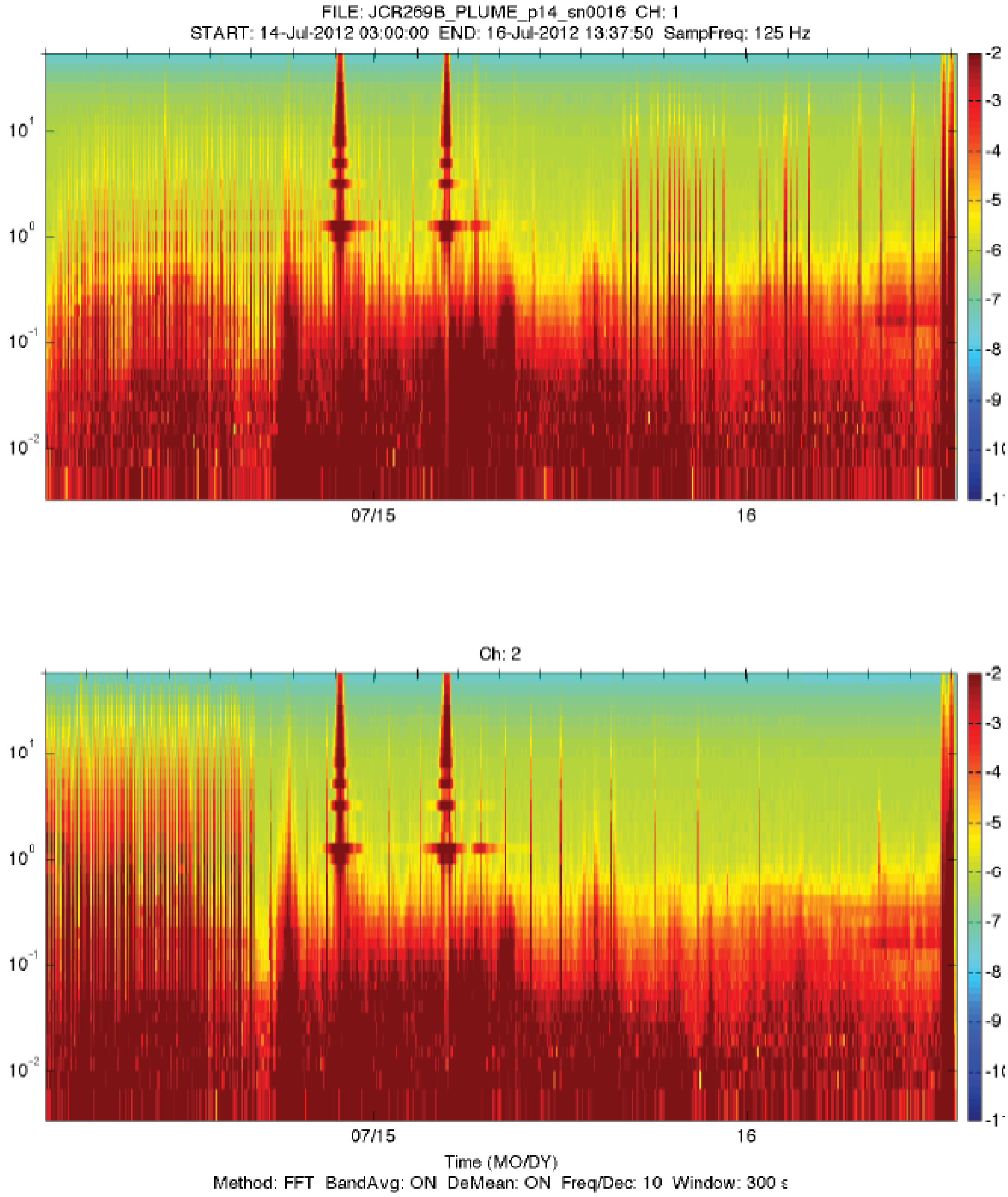
07/15
16
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s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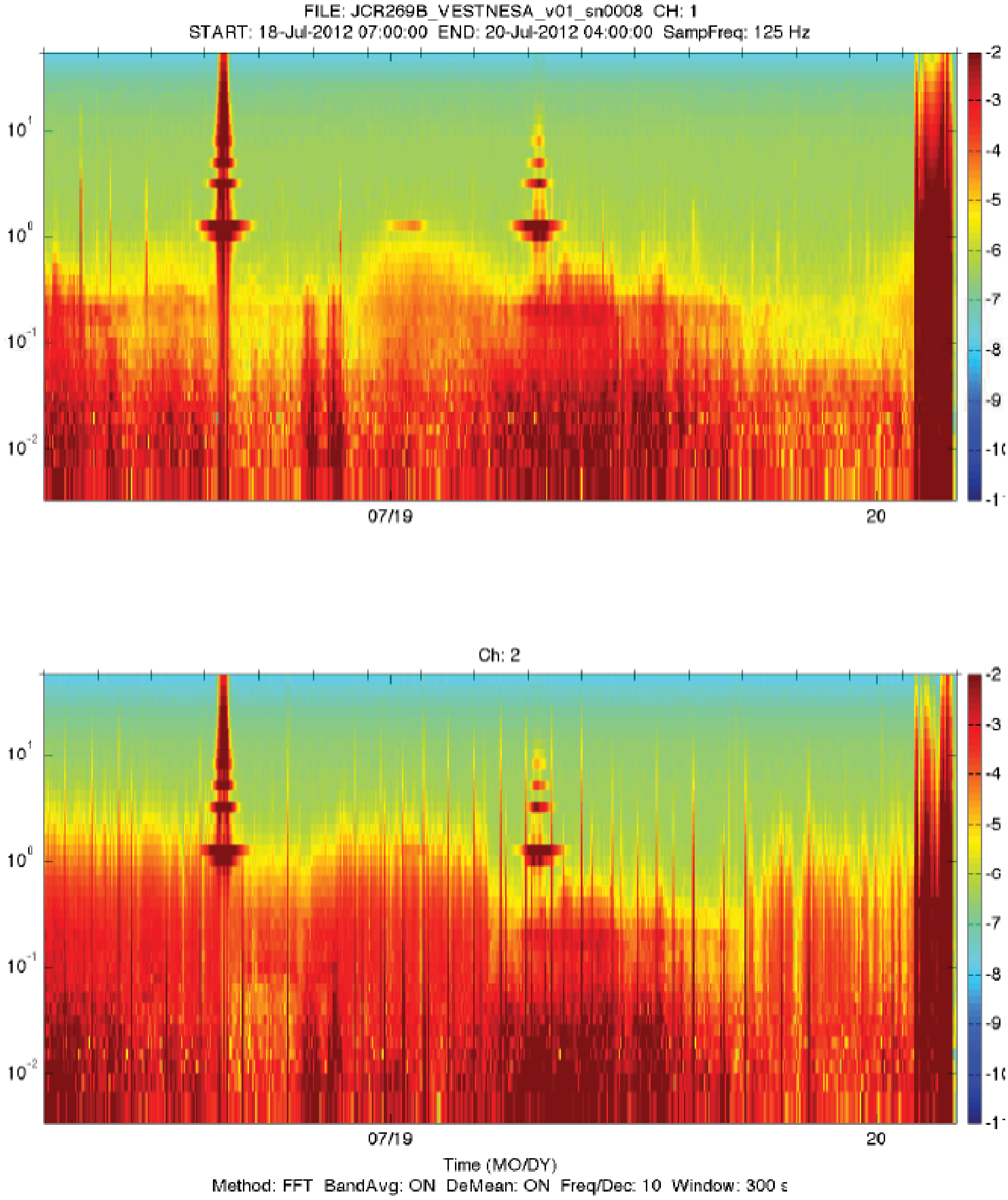
07/15
16
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s

Appendix 1(b): LEMUR Spectrograms from the Vestnesa Ridge Survey Area

Overall the data quality degraded for the second deployment (v05, v10, v14) as marked by the much more common occurrence of spikes in the time series as well as shown in the spectrograms. There are a number of factors that could contribute to this. (1) The quick turn around of the instruments meant that the electrodes were moved from ambient seawater conditions to the seawater within the electrode jar and back into ambient seawater conditions. This may have resulted in some chemical instability of the Ag-AgCl electrodes. (2) It was observed that at times during this deployment the cable ties securing the electrodes where not cut short allowing the end of the cable tie to flap in the currents which may cause spikes. (3) For the first deployment the electrode connectors where carefully cleaned and silver greased, perhaps more care is required in cleaning electrodes for a second deployment, since the cables and covers used to make the connection with the electrode and the electrode breakout cable are dirty or worn.

	site	CH1	CH2
8	v01	good	some spikes
6	v02	good	good/ odd spikes
4	v03	noisy	good
13	v04	noisy	good
14	v05	**spikes**	**spikes**
10	v06	**some spikes**	**some spikes**
5	v07	good	good/odd spikes
2	v08	good/ odd spikes	good/ odd spikes
17	v10	**spikes**	good
1	v11	good	good
12	v14	**spikes**	**spikes**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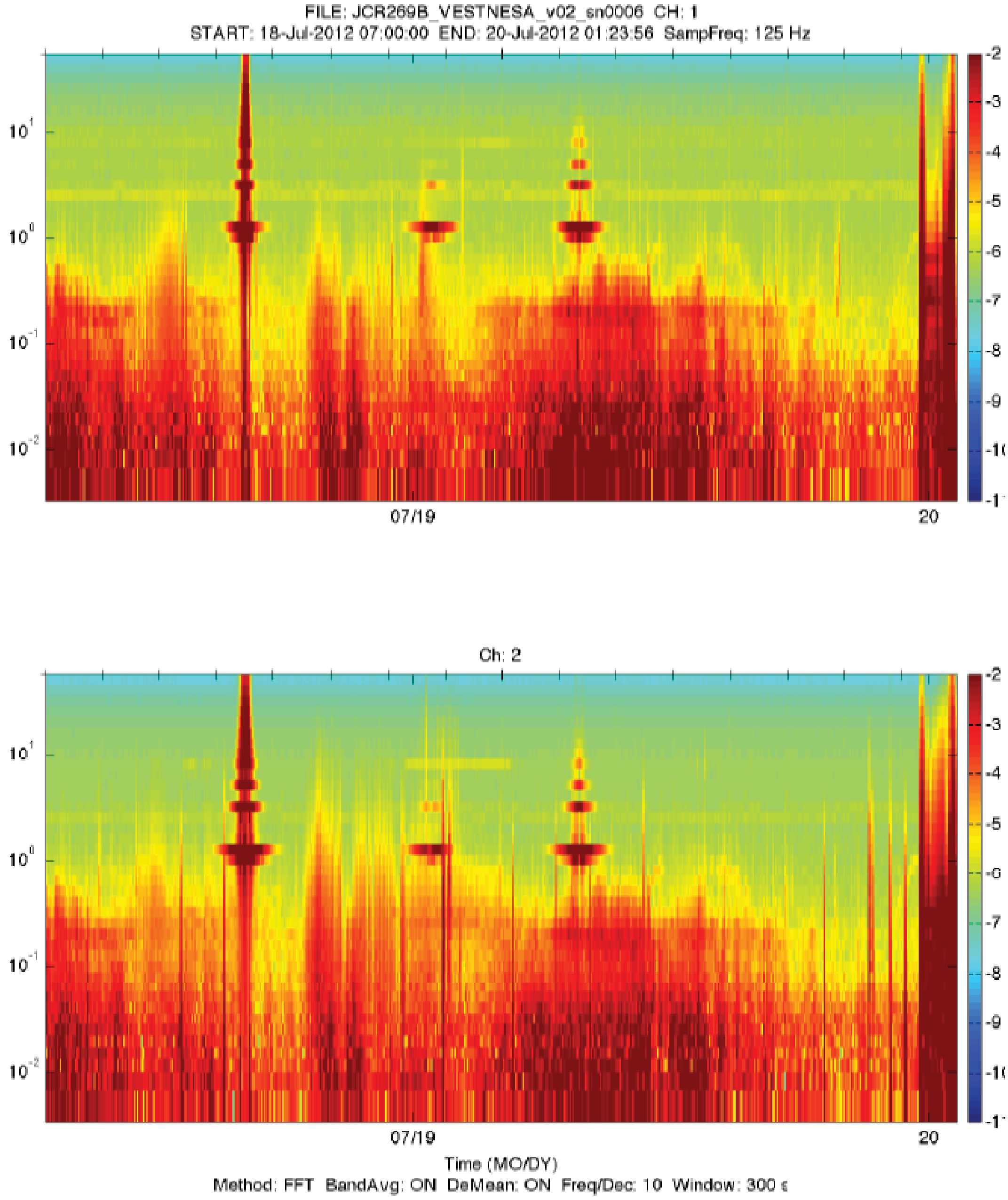
Ch: 2
07/19
20
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s



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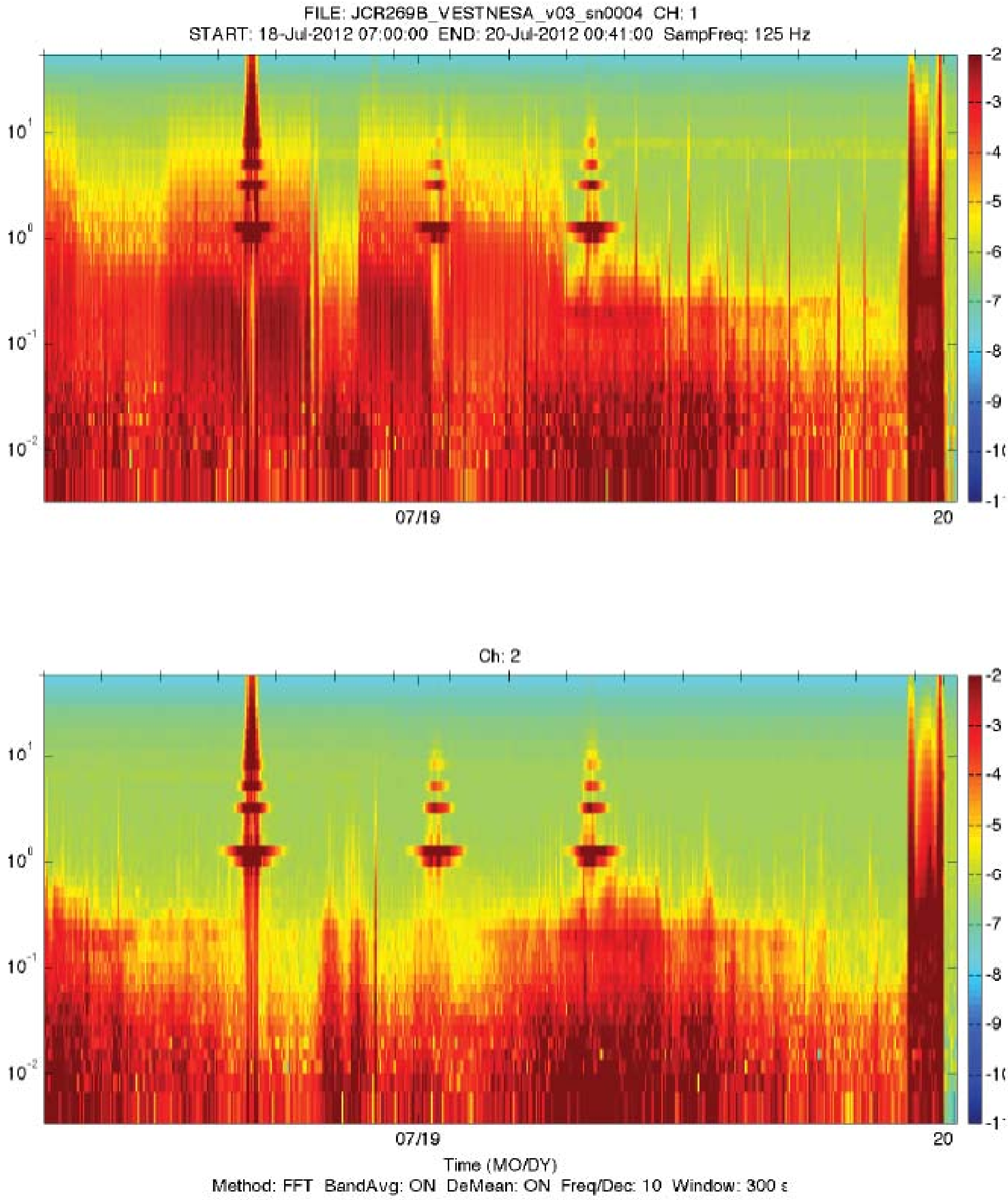
07/19
20
Ch: 2
07/19
20
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s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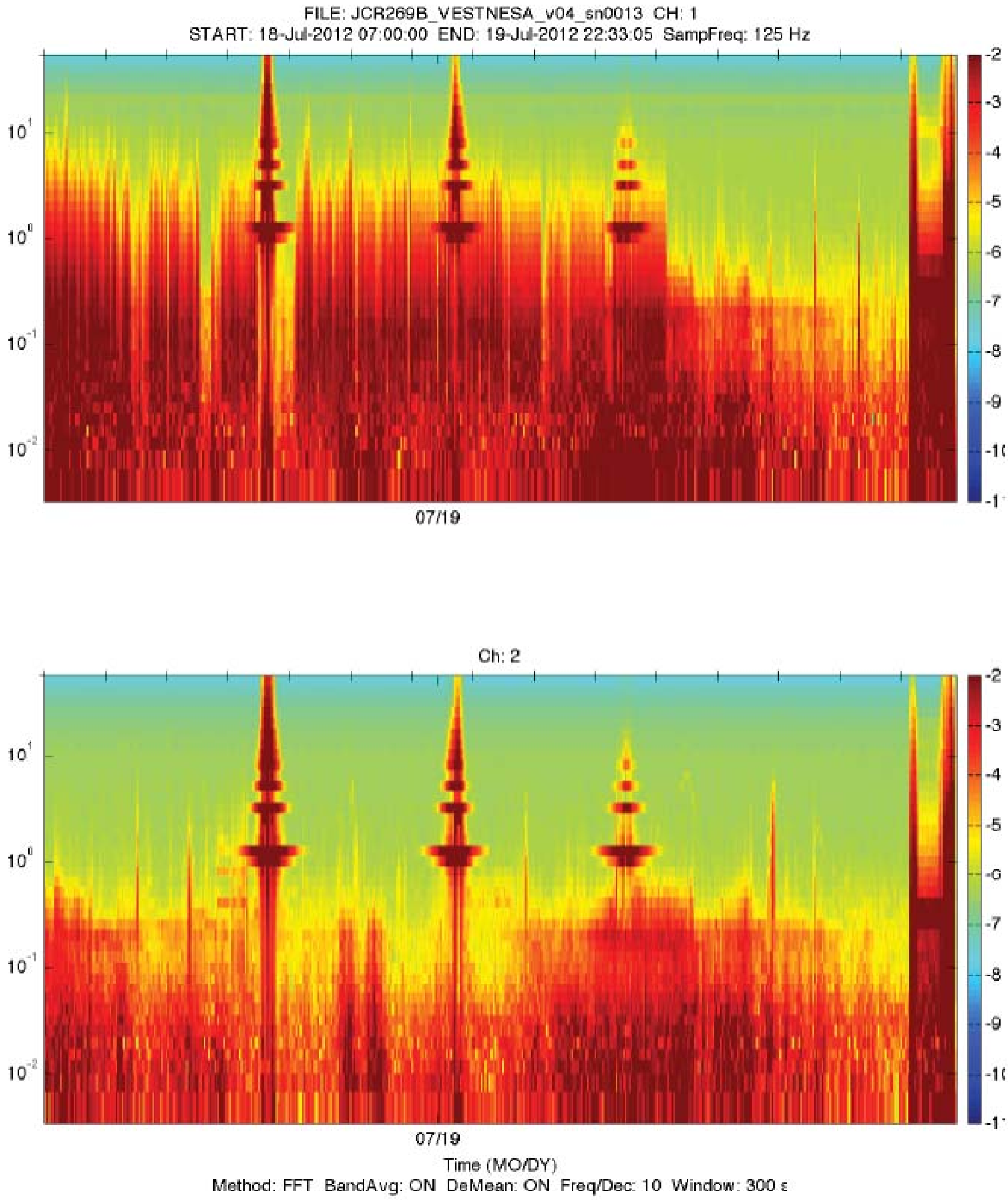
07/19
20
Ch: 2
07/19
20
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s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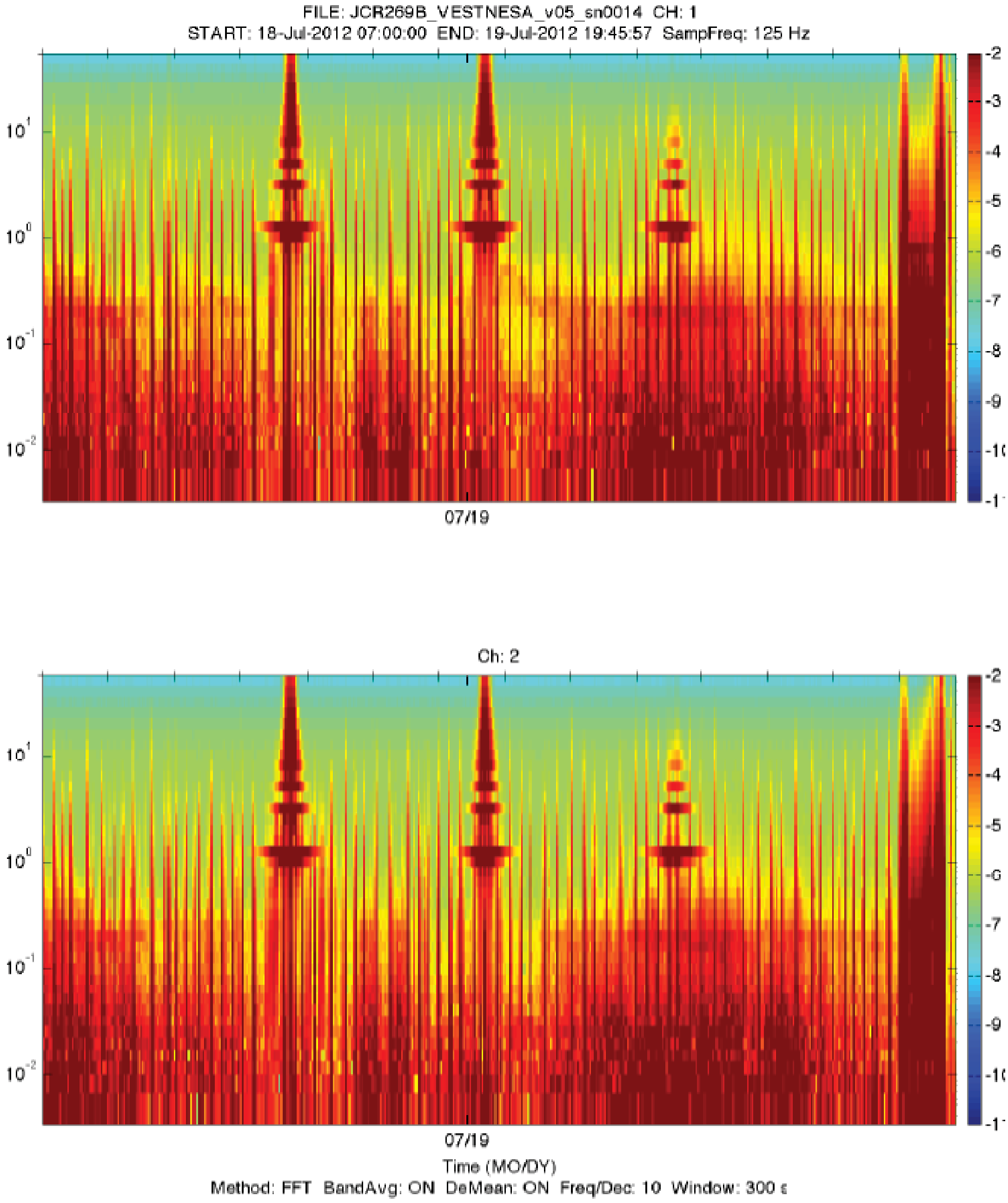
07/19
Ch: 2
07/19
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s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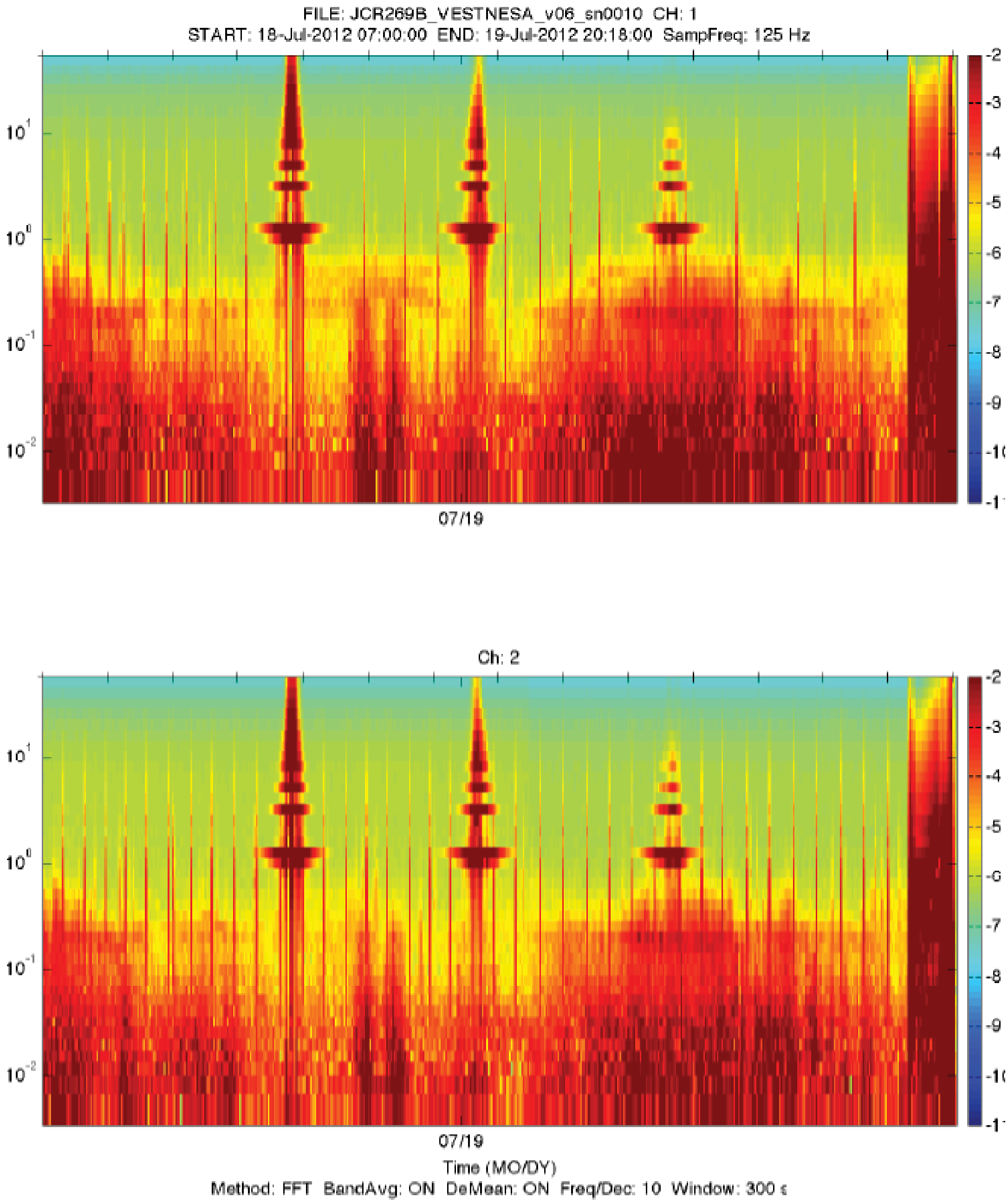
07/19
Ch: 2
07/19
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s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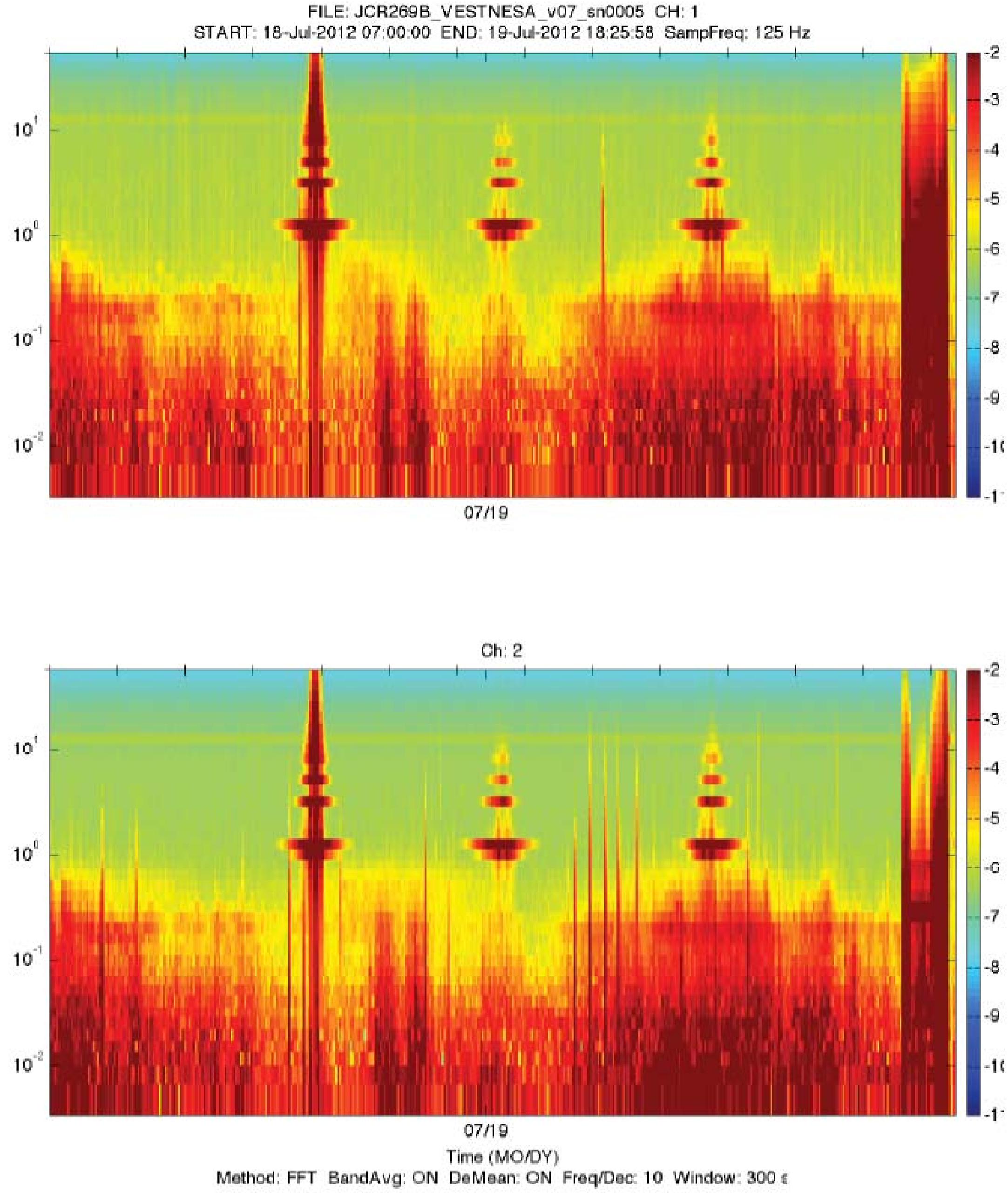
10^1
10^0
10^-1
10^-2
07/19
-2
-3
-4
-5
-6
-7
-8
-9
Ch: 2
07/19
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s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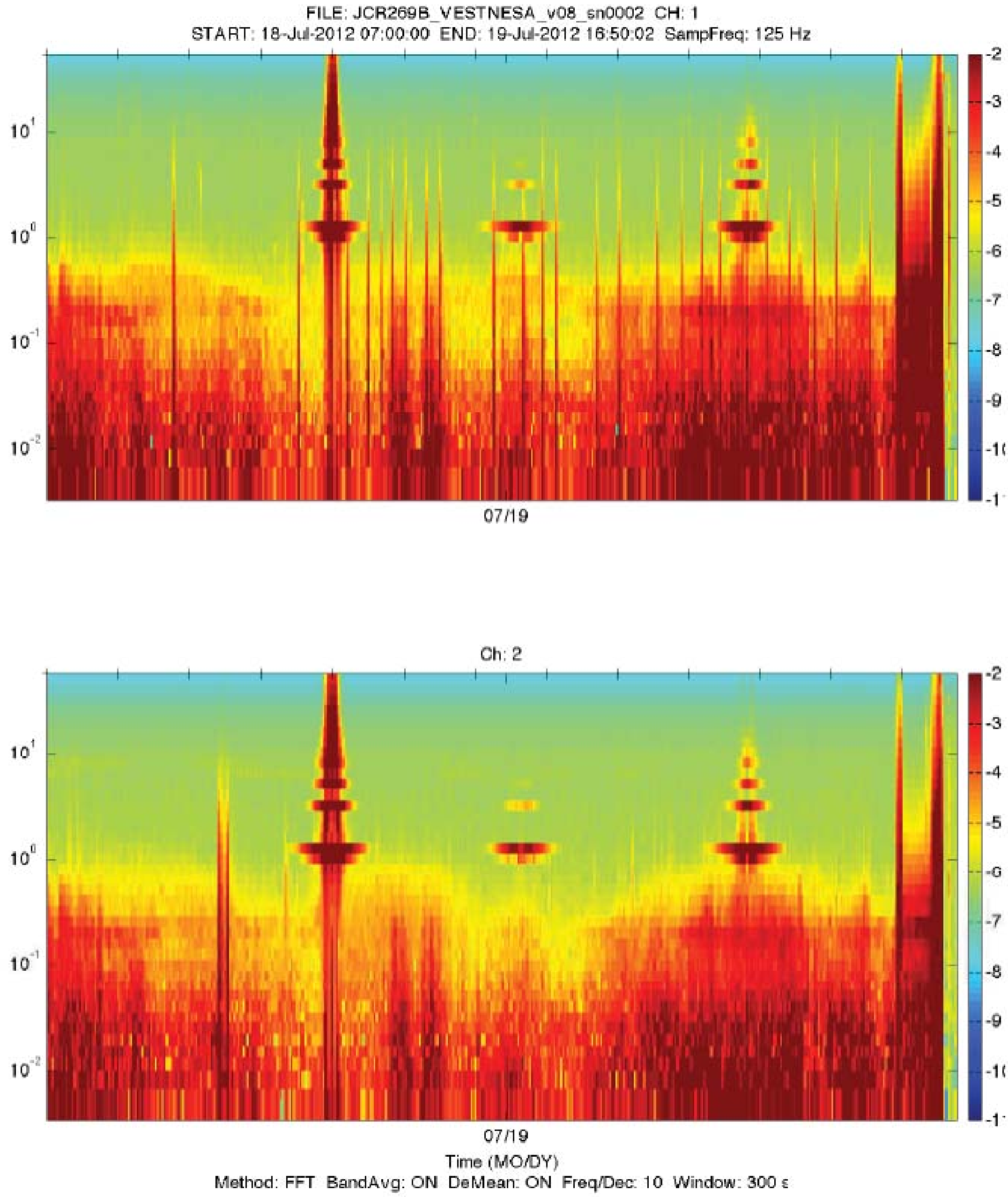
07/19
Ch: 2
07/19
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s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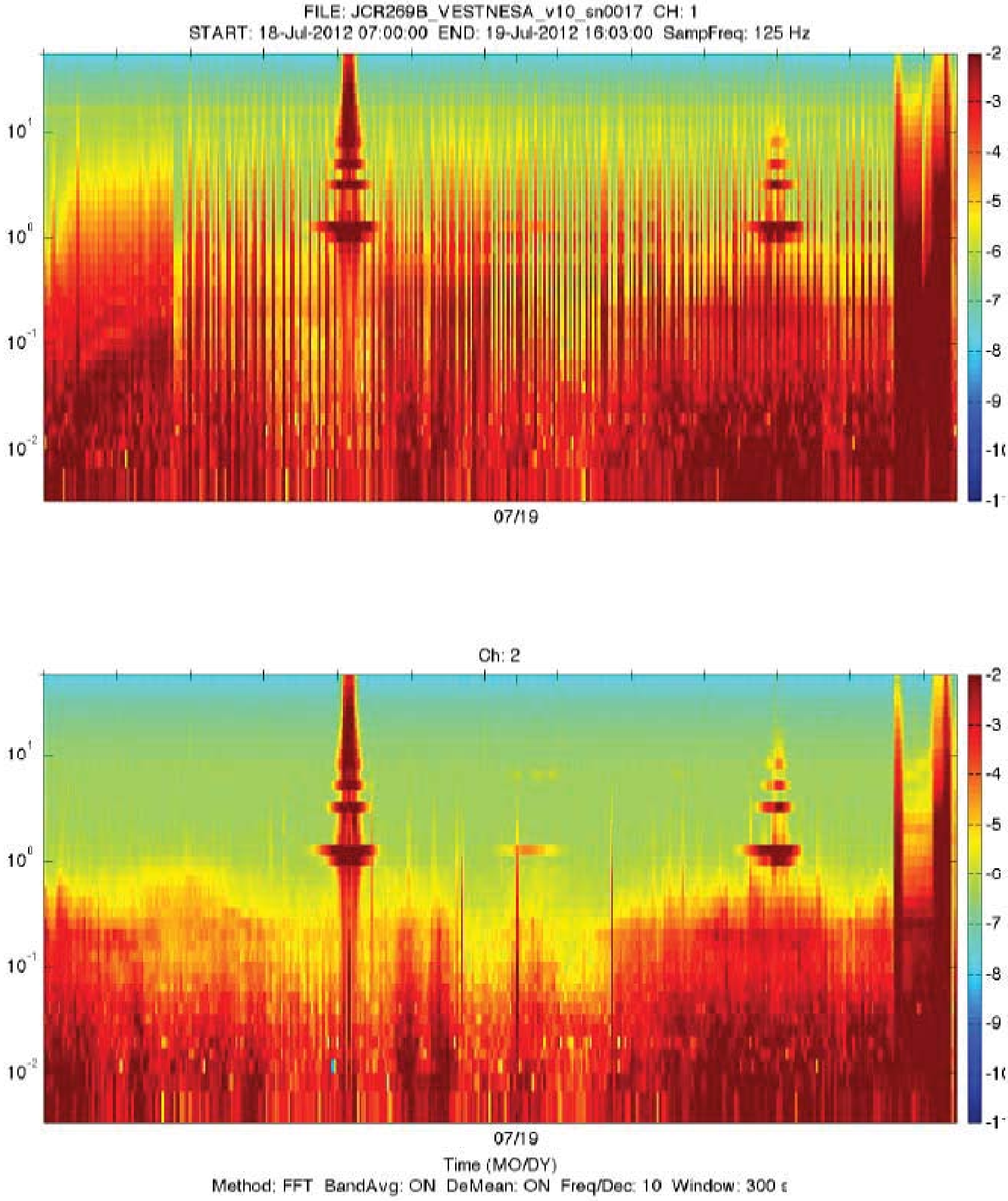
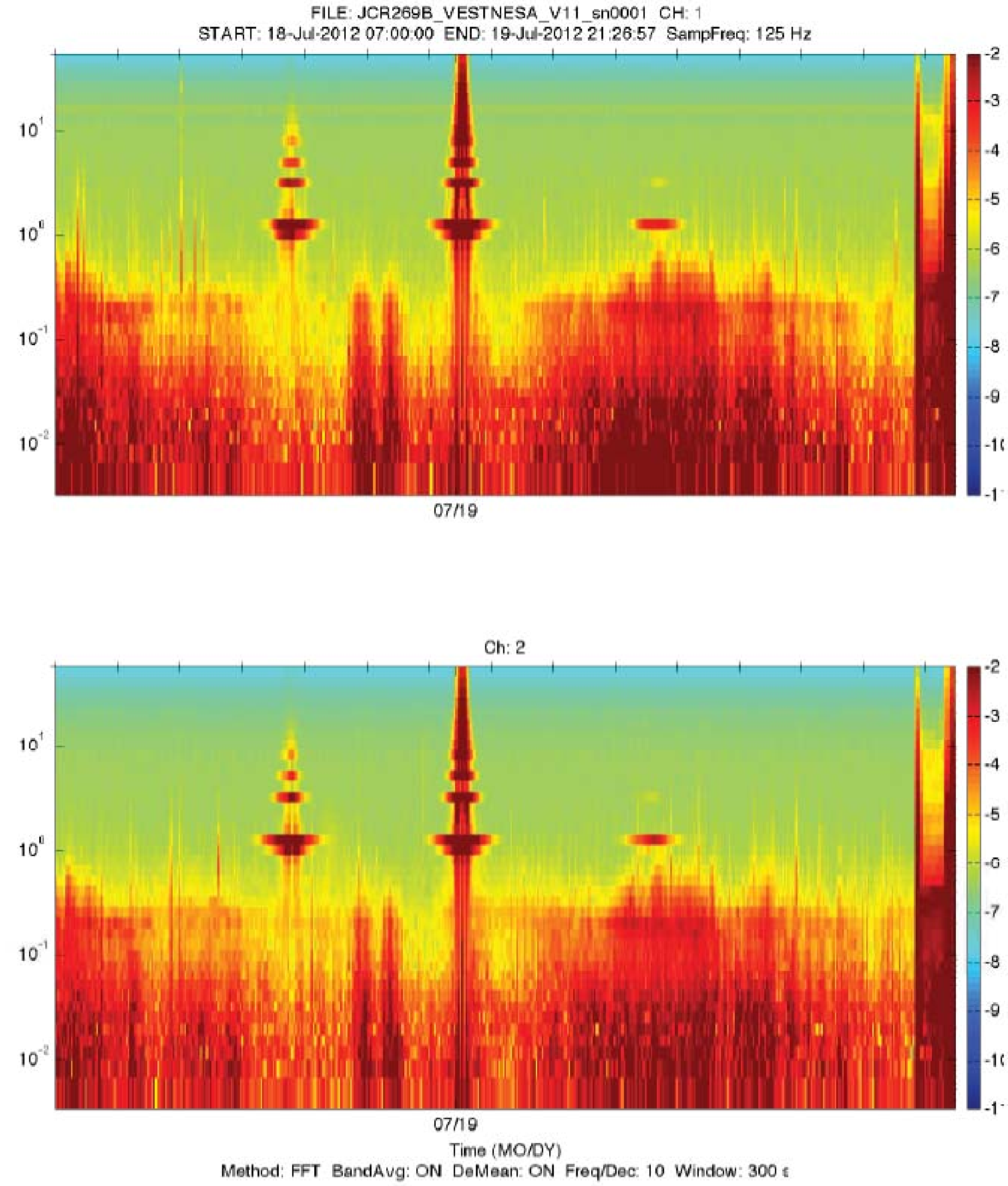
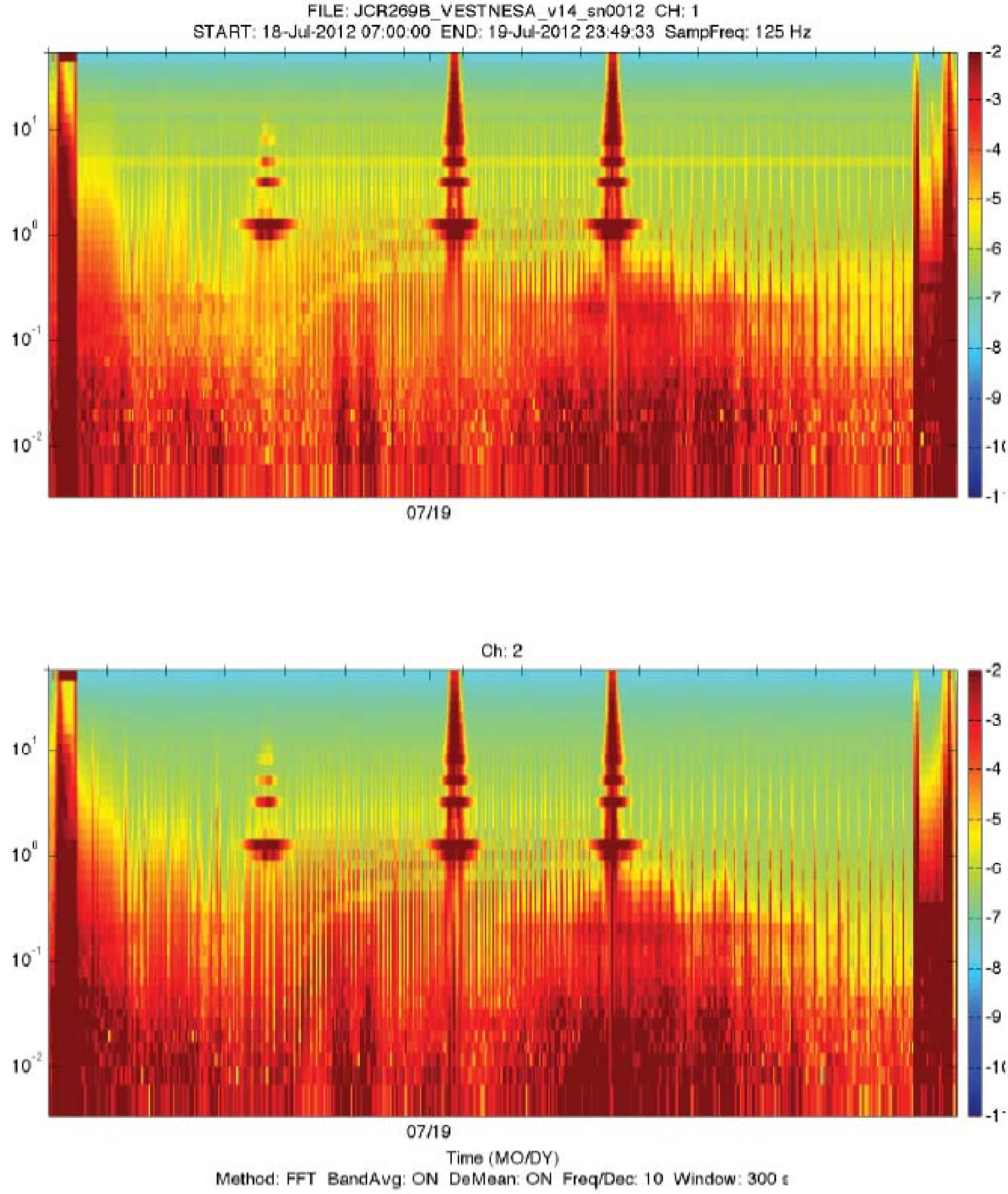
07/19
Ch: 2
07/19
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s


FILE: JCR269B_VESTNESA_v10_sn0017 CH: 1
START: 18-Jul-2012 07:00:00 END: 19-Jul-2012 16:03:00 SampFreq: 125 Hz
07/19
Ch: 2
07/19
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s


FILE: JCR269B_VESTNESA_V11_sn0001 CH: 1
START: 18-Jul-2012 07:00:00 END: 19-Jul-2012 21:26:57 SampFreq: 125 Hz
07/19
Ch: 2
07/19
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s


FILE: JCR269B_VESTNESA_v14_sn0012 CH: 1
START: 18-Jul-2012 07:00:00 END: 19-Jul-2012 23:49:33 SampFreq: 125 Hz
07/19
Ch: 2
07/19
Time (MO/DY)
Method: FFT BandAvg: ON DeMean: ON Freq/Dec: 10 Window: 300 s

Appendix 1(c) Comparison of western margin and Vestnesa area repeat instrument deployment

instrument	sites	comments
8	p01 and v01	plume more noise at < 0.1 Hz because in shallower water
6	p02 and v02	plume more noise at < 0.1 Hz because in shallower water
4	p03 and v03	plume more noise at < 0.1 Hz because in shallower water, CH1 during v03 noisier at start also observed at v04 - environmental?
13	p04 and v04	plume more noise at < 0.1 Hz because in shallower water CH1 during v04 noisier at start also observed at v03 - environmental?
14	p05 and v05	plume more noise at < 0.1 Hz because in shallower water. **Many spikes are present for the entire duration at v05**
10	p06 and v06	plume more noise at < 0.1 Hz because in shallower water. CH2 is bad during p06 deployment, electrode was changed for the deployment at v06 which improve the data quality. There are some spikes during v06 deployment in both channels more frequent in CH2.
5	p07 and v07	plume more noise at < 0.1 Hz because in shallower water. Fewer spikes in second deployment at v07 then the first deployment p07 in CH1.
2	p08 and v08	plume more noise at < 0.1 Hz because in shallower water. Fewer spikes in second deployment at v08 then the first at p08 in CH 2
17	p09 and v10	plume more noise at < 0.1 Hz because in shallower water. **CH1 large number of spikes not seen before in the previous deployment (p09) below about 10 Hz.**
1	p10 and v11	plume more noise at < 0.1 Hz because in shallower water. **This instrument has the best data quality overall.**
12	p11 and v14	plume more noise at < 0.1 Hz because in shallower water. **This instrument has a number of spikes below about 2 Hz during the second deployment (v14). This instrument also started recording prior to being deployed.**

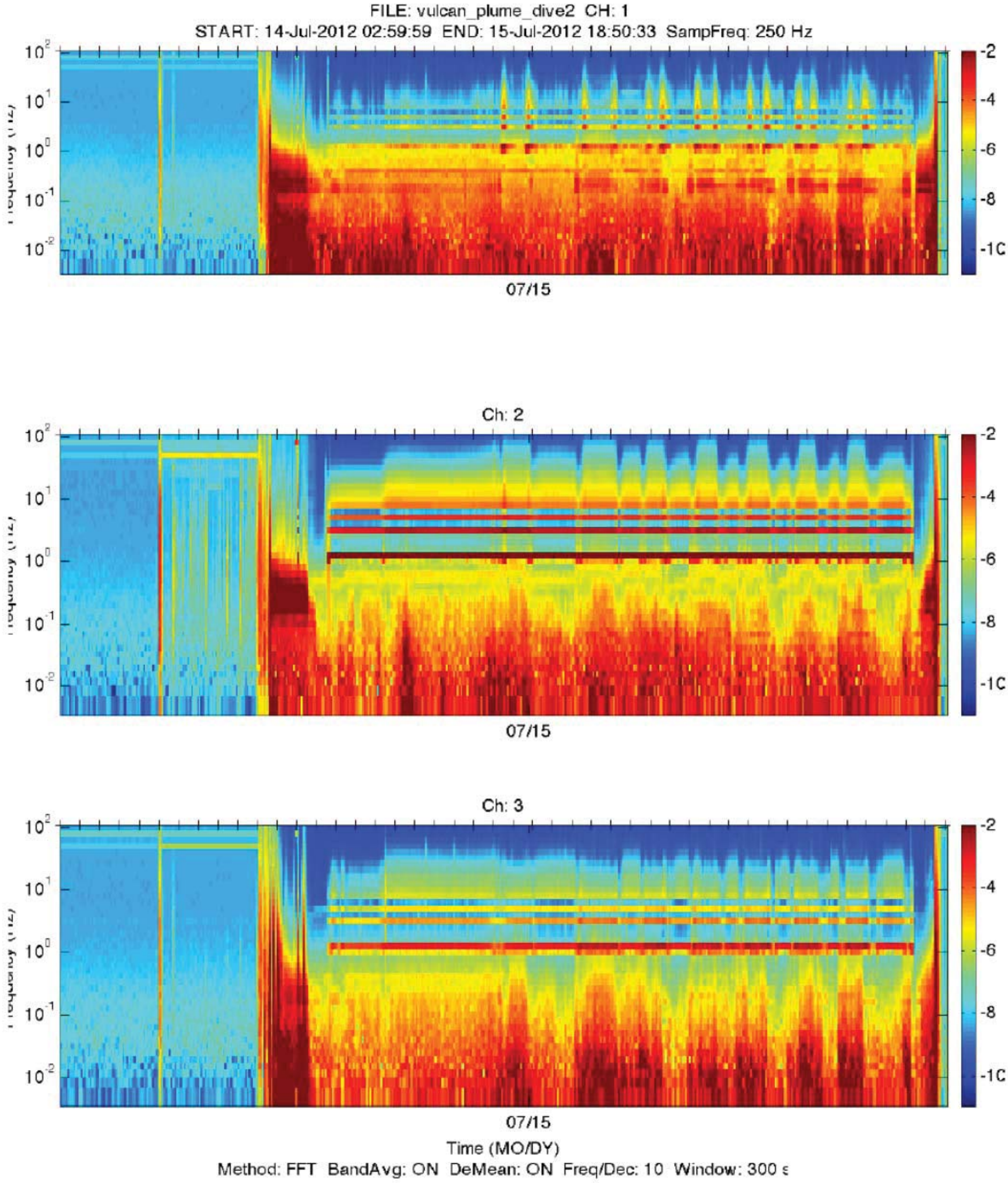
Appendix 1(d) Notes on LEMUR data preliminary processing

'The full-scale input range of the A-to-D converters is ±4.5 volts which corresponds to a range of +5,242,879 to –5,242,880 counts at their outputs' - LC2000 Users Manual.

Hence the count conversion of the ADC is 9 V/(5,242,879+ 5,242,880 counts) - the same ADC used in Mk II instruments.

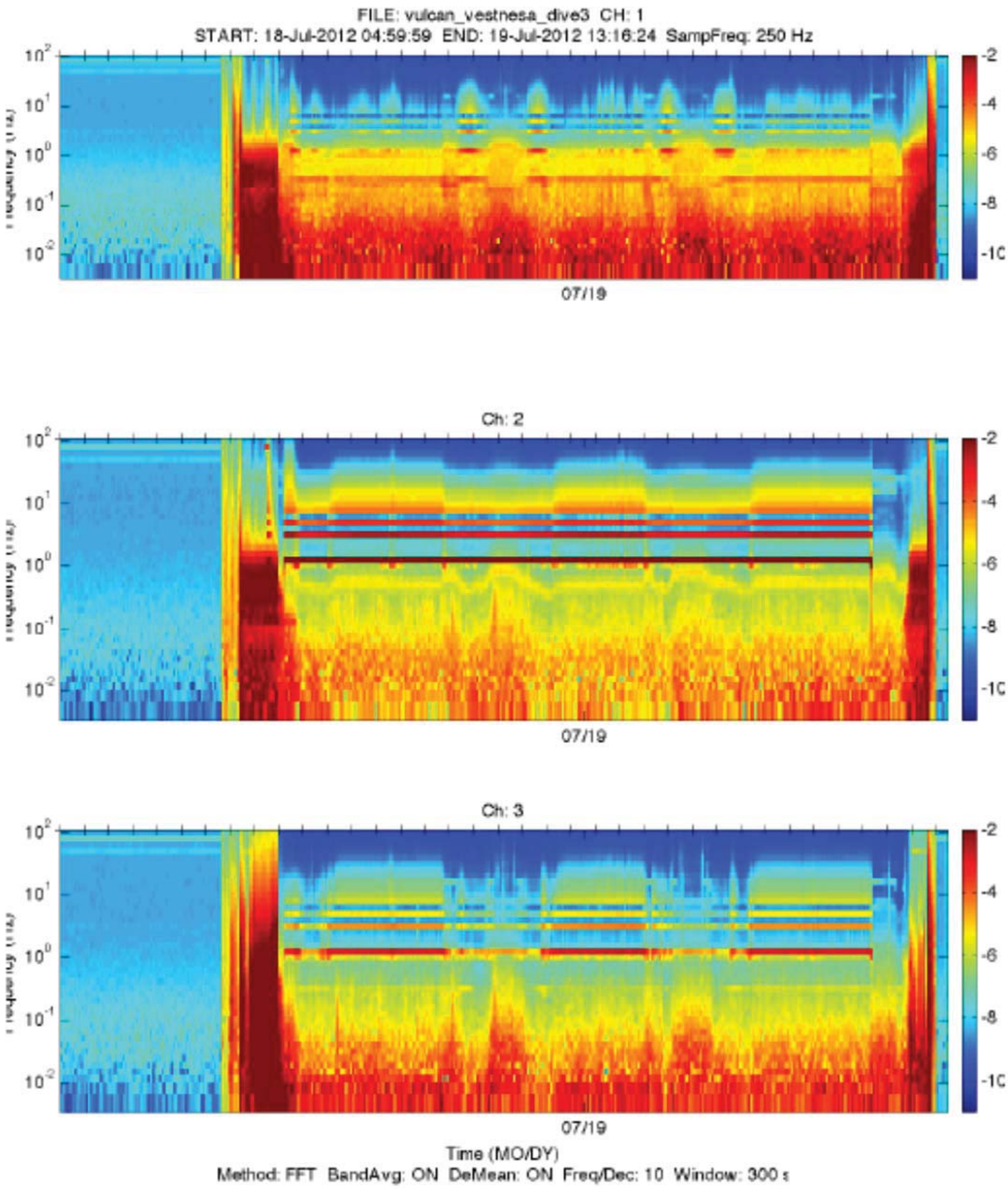
The gain of the Seamap electric field amplifier is 114,000 based on the circuit schematics.

Appendix 2(a) Spectrogram from Vulcan dive 2, west of Prins Karls Forland



CH 1 = Ex crossline; CH 2 = Ey inline, CH3 = Ez inline

Appendix 2(b) Spectrogram from Vulcan dive 3, Vestnesa Ridge



CH 1 = Ex crossline; CH 2 = Ey inline, CH3 = Ez inline

Appendix 3: Argo Float Deployments

1. *Argo Float No. 6231*
   Started @ 20:15 hrs. GMT (10/07/12)
   Deployed @ 00:04 hrs GMT (11/07/12)
   Latitude - 75° 00.0'N
   Longitude - 002° 53.0'W

2. *Argo Float No. 6232*
   Started @ 22:05hrs GMT 20/07/12
   Deployed @ 23:59hrs GMT
   Latitude - 75° 32.1' N
   Longitude - 001° 28.8' W

3. *Argo Float No. 6229*
   Started @ 00:03hrs GMT 21/07/12
   Deployed @ 02:10hrs GMT
   Latitude - 75° 10' N
   Longitude - 002° 13.65' W

4. *Argo Float No. 6230*
   Started @ 02:32hrs GMT 21/07/12
   Deployed @ 04:18hrs GMT
   Latitude - 74° 47.8' N
   Longitude - 002° 57.7' W

5. *Argo Float No. 6235*
   Started @ 04:20hrs GMT 21/07/12
   Deployed @ 06:24hrs GMT
   Latitude - 74° 25.7' N
   Longitude - 003° 40.2' W

6. *Argo Float No. 6236*
   Started @ 06:29hrs GMT 21/07/12
   Deployed @ 08:32hrs GMT
   Latitude - 74° 3.54' N
   Longitude - 004° 21.6' W

Appendix 4: Air samples

Time	Sample ID	Collection Site	Latitude (degrees)	Longitude (degrees)	Wind Speed (knots)	Wind Direction (degrees)	Air Temperature (C)	Pressure (hPa)	Comment
08/07/2012 9:11	AS-01	In transit from Reykjavik to Svalbard	67.34122	-19.59315	5	160	8.87	1018.46	several other ships around visible on radar.
09/07/2012 9:00	AS-02	In transit from Reykjavik to Svalbard	70.18919	-9.48076	23.6	337	3.25	1021.29	-
10/07/2012 8:39	AS-03	In transit from Reykjavik to Svalbard	74.20947	0.61152	25.7	330	3.38	1011.88	-
11/07/2012 9:56	AS-04	In transit from Reykjavik to Svalbard	76.65975	8.07557	20.7	334	3.35	1010.58	-
12/07/2012 8:07	AS-05	At first study area offshore Svalbard in the vicinity of JR211 flares along GHSZ boundary (approaching deep end of LEMUR transect approximately 1000 m water depth)	78.5135	8.68057	15.5	55	4.18	1012.38	about 1000 m water depth
12/07/2012 21:10	AS-06	At first study area offshore Svalbard in the vicinity of JR211 flares along GHSZ boundary (steaming between LEMURs 7 and 8)	78.54491	9.36113	14.7	16	5.12	1010.7	about 460 m water depth
12/07/2012 23:47	AS-07	At first study area offshore Svalbard in the vicinity of JR211 flares along GHSZ boundary	78.65008	9.1602	14.6	8	5.08	1010.09	sample taken just after a peak in atmospheric [CH_4] was seen on PICARRO which corresponded to a flare-like signal on the EK60 200
13/07/2012 12:29	AS-08	At first study area offshore Svalbard in the vicinity of JR211 flares along GHSZ boundary (above LEMUR position 6)	78.53442	9.26774	19.4	355	5.15	1009.68	revisiting site of large PICARRO [CH_4] peak observed yesterday, this time with echo-sounding
14/07/2012 8:39	AS-09	At first study area offshore Svalbard in the vicinity of JR211 flares along GHSZ boundary (during transect along 400 m depth	78.57456	9.46516	10.4	1	3.83	1011.53	some flares observed on EK60 echo sounder during sampling
15/07/2012 8:28	AS-10	At first study area offshore Svalbard in the vicinity of JR211 flares along GHSZ boundary (start of DASI tow line 5, about 460 m water depth)	78.55507	9.29735	14.2	209	5.89	1007.39	recent increase in PICARRO baseline [CH_4] up from about 1.84 ppm to 1.85 ppm
16/07/2012 8:54	AS-11	At first study area offshore Svalbard in the vicinity of JR211 flares along GHSZ boundary	78.55371	9.50949	22.9	349	3.43	1004.06	winds just coming down from being up to 39 knots earlier in
17/07/2012 10:37	AS-12	At second study area: Vestnesa Ridge	79.01113	6.93397	24.5	103	2.31	1008.6	-
17/07/2012 19:39	AS-13	At second study area: Vestnesa Ridge	78.98218	6.58734	10.4	195	4.03	1010.37	sample taken during a broad peak in [CH_4] seen on the
18/07/2012 11:49	AS-14	At second study area: Vestnesa Ridge	78.93698	6.54917	14.9	347	3.55	1010.66	
19/07/2012 8:49	AS-15	At second study area: Vestnesa Ridge	79.02666	6.97837	7.3	26	5.22	1013.53	a few hours after sampling all air was gone from sample bag - must have been a small hole.
20/07/2012 7:59	AS-16	Transit back from Svalbard to Iceland	78.4977	5.32737	11.6	27	5.01	1015.71	-
22/07/2016 8:47	AS-17	Transit back from Svalbard to Iceland	74.02884	-4.41529	8.9	83	3.12	1010.37	-
23/07/2016 10:00	AS-18	Transit back from Svalbard to Iceland	69.53893	-13.32904	13.3	275	6.23	1000.73	-

Appendix 5: HYBIS dives

Station/Event No.	HyBIS Dive No.	Date & Time Deployed	Date & Time Recovered	Notes
JR269B (Lemur P1)	97	12 July – 0856	12 July – 1013	Deployment of an OBEM instrument. Video inspection on the seabed. Blue arm forward on deployment.
JR269B (Lemur P2)	98	12 July – 1058	12 July – 1204	Deployment of an OBEM instrument. Video inspection on the seabed. Blue arm forward on deployment.
JR269B (Lemur P3)	99	12 July – 1258	12 July – 1401	Deployment of an OBEM instrument. Video inspection on the seabed. Blue arm forward on deployment.
JR269B (Lemur P4)	100	12 July – 1442	12 July – 1540	Deployment of an OBEM instrument. Video inspection on the seabed. Blue arm forward on deployment.
JR269B (Lemur P5)	101	12 July – 1621	12 July – 1714	Deployment of an OBEM instrument. Video inspection on the seabed. Blue arm forward on deployment.
JR269B (Lemur P6)	102	12 July – 1822	12 July – 1912	Deployment of an OBEM instrument. Video inspection on the seabed. Blue arm forward on deployment. Downward light bulb blown. Vehicle attitude data accidentally not recorded.
JR269B (Lemur P7)	103	12 July – 1954	12 July – 2043	Deployment of an OBEM instrument. Video inspection on the seabed. Blue arm forward on deployment.
JR269B (Lemur P8)	104	12 July – 2117	12 July – 2208	Deployment of an OBEM instrument. Video inspection on the seabed. Blue arm forward on deployment.
JR269B (Lemur P9)	105	13 July – 1356	13 July – 1457	Deployment of an OBEM instrument. Video inspection on the seabed. Blue arm forward on deployment.
JR269B (Lemur P10)	106	13 July – 1530	13 July – 1616	Deployment of an OBEM instrument. Video inspection on the seabed. Blue arm forward on deployment.
JR269B (Lemur P11)	107	13 July – 1647	13 July – 1732	Deployment of an OBEM instrument. Video inspection on the seabed. Blue arm forward on deployment. Vehicle attitude data accidentally not recorded.
JR269B (Lemur P12)	108	13 July – 1757	13 July – 1836	Deployment of an OBEM instrument. Video inspection on the seabed. Blue arm forward on deployment.
JR269B (Lemur P13)	109	13 July – 1922	13 July – 2000	Deployment of an OBEM instrument. Video inspection on the seabed. Blue arm forward on deployment.
JR269B (Lemur P14)	110	13 July – 2034	13 July – 2113	Deployment of an OBEM instrument. Video inspection on the seabed. Blue arm forward on deployment.
JR269B (MASOX)	111	13 July - 2158	13 July – 2244	Video inspection of the MASOX seabed observatory. Deployment module used with second forward camera and extra light.
JR269B (Lemur V1)	112	16 July – 2133	16 July – 2301	Deployment of an OBEM instrument. Video inspection on the seabed. Red arm forward on deployment.
JR269B (Lemur V2)	113	16 July – 2331	17 July – 0059	Deployment of an OBEM instrument. Video inspection on the seabed. Red arm forward on deployment.
JR269B (Lemur V3)	114	17 July – 0128	17 July – 0253	Deployment of an OBEM instrument. Video inspection on the seabed. Red arm forward on deployment.
JR269B (Lemur V4)	115	17 July – 0325	17 July – 0457	Deployment of an OBEM instrument. Video inspection on the seabed. Red arm forward on deployment.

JR269B (Lemur V5)	116	17 July – 0526	17 July – 0649	Deployment of an OBEM instrument. Video inspection on the seabed. Red arm forward on deployment.
JR269B (Lemur V6)	117	17 July – 0715	17 July – 0840	Deployment of an OBEM instrument. Video inspection on the seabed. Red arm forward on deployment.
JR269B (Lemur V7)	118	17 July – 0904	17 July – 1026	Deployment of an OBEM instrument. Video inspection on the seabed. Red arm forward on deployment.
JR269B (Lemur V8)	119	18 July – 0013	18 July – 0137	Deployment of an OBEM instrument. Video inspection on the seabed. Red arm forward on deployment.
JR269B (Lemur V10)	120	18 July – 0203	18 July – 0326	Deployment of an OBEM instrument. Video inspection on the seabed. Red arm forward on deployment.
JR269B (Lemur V11)	121	18 July – 0359	18 July – 0531	Dive abandoned at seabed due to hydraulic release malfunction caused by the OBEM instrument.
JR269B (Lemur V11)	122	18 July – 0540	18 July – 0656	Deployment of an OBEM instrument. Video inspection on the seabed. Red arm forward on deployment.
JR269B (Lemur V14)	123	18 July – 0725	18 July – 0852	Deployment of an OBEM instrument. Video inspection on the seabed. Red arm forward on deployment.