R/V TANGAROA VOYAGE REPORT

TAN1806-QUOI

QUANTITATIVE OCEAN-COLUMN IMAGING (QUOI) USING HYDROACOUSTIC

3 - 22 July 2018

Photo credit front cover: Tom Weber, deploying the bubble maker

i. Science Party

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3	Vanessa Lucieer	IMAS	Co-leader
4	Yoann Ladroit	NIWA	Acoustic
5	Arne Pallentin	NIWA	GIS, Processing
6	Sally Watson	NIWA	Geosciences
7	Arnaud Gaillot	IFREMER	Data processing
8	Cyrille Poncelet	IFREMER	Scientist
9	Tom Weber	UNH	Scientist
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Name	**Role**
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Dave Rankin	
Ian Smith	
Kendal Ravengoss	
Peter Wall	
Yvonne O'Neill	Stewart
Lindsay Battersby	Chief Engineer
Alex Miller	3rd Engineer
Mark Hansen	2nd Mate
Ian Pepenhagen	1st Mate
Peter Morrison	AB
Bruce Mcintyre	AB
Share Harvey	Bosun
Godfrey Hagedorn	2nd Cook
Peter Wall	AB
Ian Smith	Leading Hand
Grant Wilkinson	Cook
Bryce Bennett	AB

1 SYNOPSIS

The aim of the voyage was to enhance our capability to acoustically detect and characterise liquid and gaseous targets in the water column. The mapping of fluids and bubbles in our oceans is a challenge at the forefront of acoustic science, because of the potentially high economic value and environmental significance of gas seepages. The 20-day voyage (2-22 July) concentrated on the Calypso Hydrothermal Vent Field (CHVF), ca. 15 km SW of Whakaari-White Island volcano where numerous hydrothermal vents occur. The voyage collected ca. 4.6 Tb of acoustic data and video recording of gas bubble and liquid seepages at the seafloor. Pioneering deployments of multiple synchronous echosounders, including 30 kHz and 200 kHz multibeam, 6 single-beam two of which were deployed on the seafloor to ensonify bubble streams horizontally enabled us to generate implausible and contrasting images of gas bubble streams on echograms. Other innovative experiments included high echosounder swath overlap to enable the study of angular backscatter response in both seafloor and water-column data; a multi-angle, multi-frequency coverage over both artificially generated bubbles and natural vents in steps of 5° thanks to the use of a swivelling pan&tilt device. Thirty-one sediment samples and 43 water samples were collected for ground truthing. The research was undertaken by experts from NIWA, France (CNRS/Uni Rennes, IFREMER), Australia (IMAS), and the USA (CCOM-UNH). The research undertaken during voyage TAN1806-QUOI (Quantitative Ocean-Column Imaging using hydroacoustic sources) was a milestone of the Royal Society of New Zealand's Catalyst:Seeding project "*Building Capability for in situ quantitative characterisation of the ocean water column using acoustic multibeam backscatter data*".

The 21-day voyage TAN1806-QUOI () of R.V. Tangaroa aimed at studying the fate of gas bubbles in the water column using hydroacoustics. acquire multifrequency and multiresolution acoustic data and ground truthing data (video, samples) over the Calypso hydrothermal vent field in the Bay of Plenty, ca. 15 km SW of Whakaari-White Island volcano where numerous hydrothermal vents occur. Twenty participants from 8 organisations contributed by bringing specific expertise and equipment onboard.

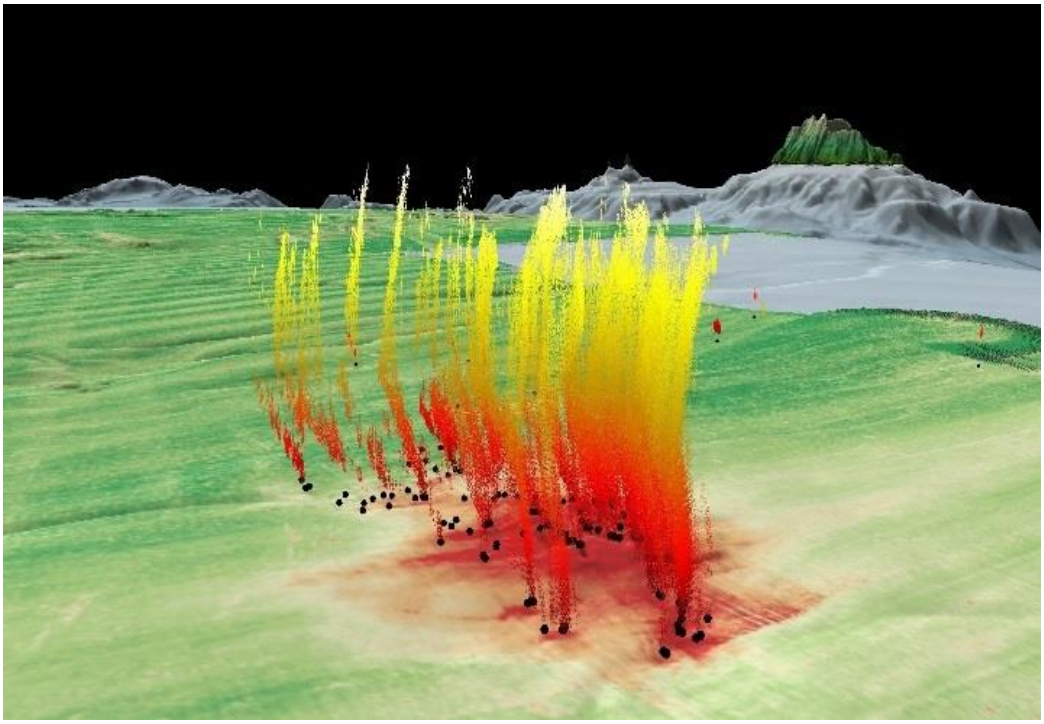


Figure 1-1 - Perspective view of the Calypso Hydrothermal Vent Field with acoustic flares generated by gas bubbles backscattered acoustic echos

The voyage collected ca. 4.6 Tb of acoustic data and video recording of gas bubble and liquid seepages at the seafloor. Pioneering deployments of multiple synchronous echosounders, including 30 kHz and 200 kHz multibeam, 6 single-beam two of which were deployed on the seafloor to ensonify bubble streams horizontally enabled us to generate implausible and contrasting images of gas bubble streams on echograms. Other innovative experiments included high echosounder swath overlap to enable the study of angular backscatter response in both seafloor and water-column data; a multi-angle, multi-frequency coverage over both artificially generated bubbles and natural vents in steps of 5° thanks to the use of a swivelling pan&tilt device.

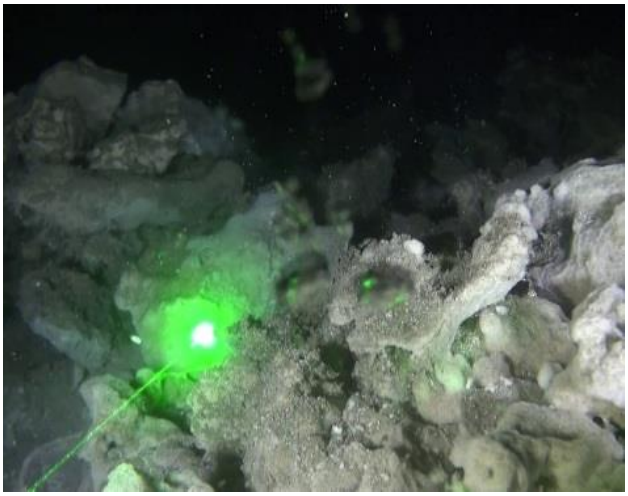


Figure 1-2 - bubble escaping from the seafloor in the Calypso Hydrothermal vent field

Thirty-one sediment samples and 43 water samples were collected for ground truthing. The voyage resulted in the collection of an outstanding marine acoustic dataset over intensive methane and CO2 active vents. Our survey proved exceptionally successful and demonstrated the potential to differentiate methane and CO2 bubbles in the water column. A result thought impossible up until now.

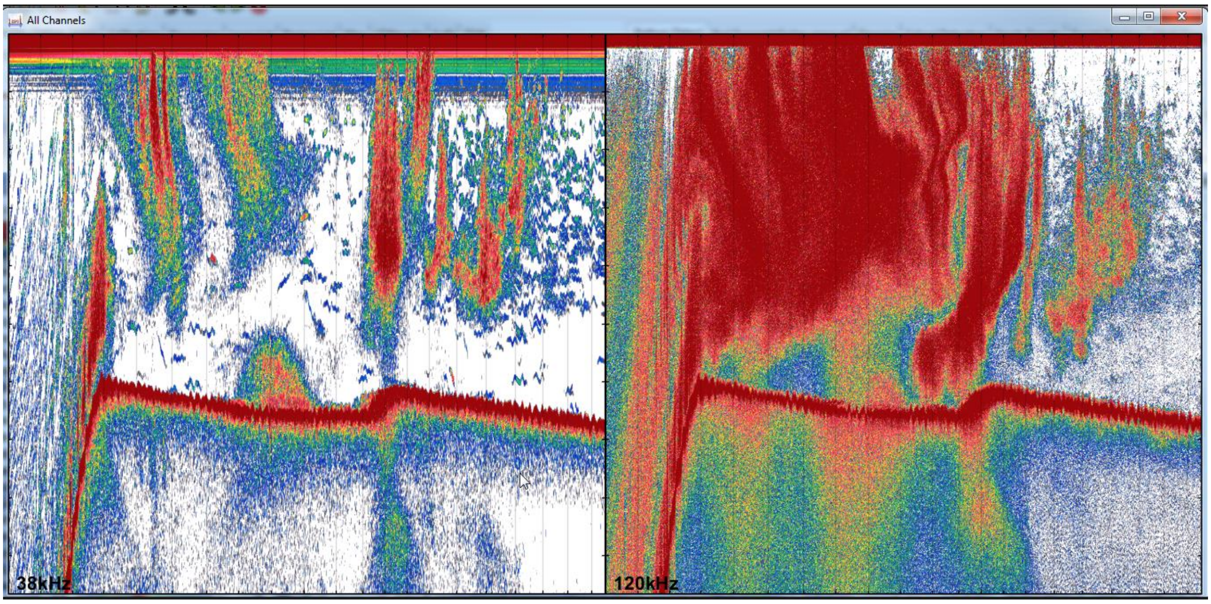
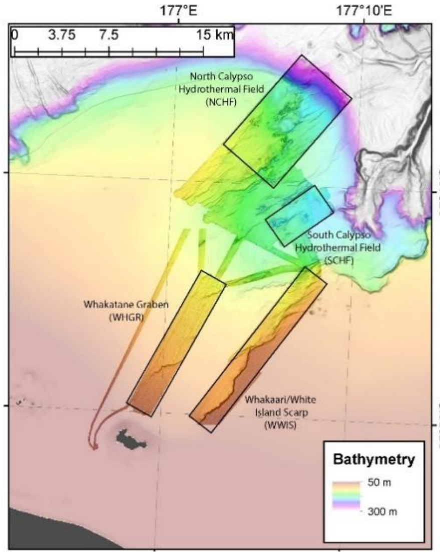
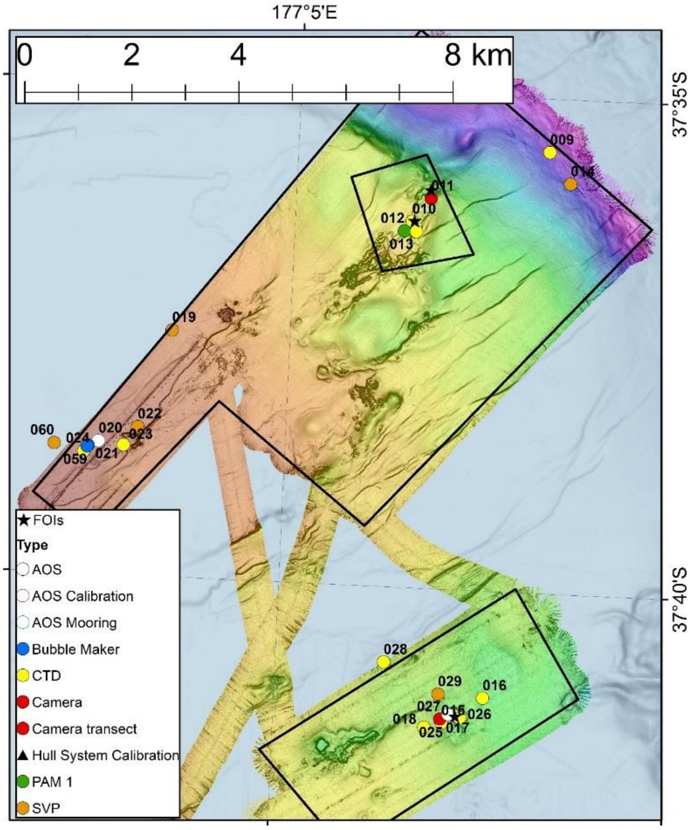


Figure 1-3 - Echograms over a flare at 38kHz (left) and 120kHz(right), showing very different responses


177°E
177°10'E
0 3.75 7.5 15 km
North Calypso Hydrothermal Field (NCHF)
South Calypso Hydrothermal Field (SCHF)
Whakatane Graben (WHGR)
Whakaari/White Island Scarp (WWIS)
37°40'S
37°50'S
Bathymetry
50 m
300 m


177°5'E
0 2 4 8 km
37°35'S
37°40'S
FOIs
Type
AOS
AOS Calibration
AOS Mooring
Bubble Maker
CTD
Camera
Camera transect
Hull System Calibration
PAM 1
SVP

ACKNOWLEDGEMENT

Our first and warmest thank you goes to Captain and Crew of R.V. *Tangaroa*. Their work, dedication and commitment were truly excellent. Some deployments were complex and new, and some were repeated over and over again. Their patience and good-hearted attitude was all the more appreciated.

This survey would not have happened without the hard work and dedication of NIWA Marine Technology group, and in particular Steve Wilcox and Nic Eaton who along with Mike Brewer, Kim Goetz, Andrew Marriner, and Giacomo Giorli who contributed to the preparation and mobilisation of some of the equipment.

We wish to thank the Whakatane Coast Guard for their help in delivering spares electronics part to the Vessel in the lee side of Motouhora on Saturday 14 July. This enabled us to continue our experiment with minimal disruption and their help was critical in that. White Island Tours were also very helpful in receiving the goods and offering alternative help.

Our warmest gratitude goes to Xavier Lurton who contributed in planning this voyage and provided support and ideas continuously. Larry Marry from CCOM-UNH also supported this initiative from its inception and provided support to some of his student to board the vessel. Although not onboard both Larry and Xavier presence was felt in the air!

NIWA staff were funded NIWA programme Marine Geological Processes and resources funded by the Strategic Science Investment Fund (SSIF) of the Ministry of Business, Innovation and Employment (MBIERV Tangaroa ship time for the voyage was awarded by the Tangaroa Reference Group (TRG) and funded by the Ministry of Business Innovation and Employment (MBIE).

This work was partly funded and certainly initiated thanks to the Royal Society of New Zealand Catalyst:Seeding fund for a project entitled "*Building capability for in situ quantitative characterisation of the ocean water column using acoustic multibeam backscatter data.*"

Vanessa Lucieer was supported by the Marine Biodiversity Hub through funding from the Australian Government's National Environmental Science Programme and the University of Tasmania. Amy Nau is supported by the University of Tasmania and CSIRO Quantitative Marine Science Program. Erica Spain is supported by the Australian Research Council's Special Research Initiative for Antarctic Gateway Partnership (Project ID SR140300001).

Support for the University of New Hampshire's participation was provided by the US National Science Foundation grant #1352301 and by the UNH Center for Coastal and Ocean Mapping.

Ifremer's contribution was conducted within the framework of the Underwater Acoustics R&D program R703-06. We wish to acknowledge Dr Xavier Lurton who was the director of R703-06 at the time of the voyage, and who greatly supported this project.

The Legend of Whakaari and Motouhora

Maori mythology says that back in the times when mountains walked, talked, loved and fought, two sister mountains, Whakaari and Motuhora lived on the Huiarau Range. One night they broke away and pushed down to the sea they had always wanted to visit. As they went Whakaari gouged the bed of the Whakatane River, and Motouhora, being tall and slim, formed the narrow gorges of the Waimana River. Feeling hungry, the plump Whakaari sent her sister to find food while she kindled a fire. Suddenly Whakaari saw the first flush of dawn and, knowing that when the sun's rays touched her they would transfix her to the spot forever, she fled out to sea. Motouhora returned to find her sister gone. Furious, she picked up a blazing log and chased after her. The sun's rays caught the pair before Motouhora could reach her sister, and with all her remaining strength she hurled the blazing log at Whakaari. So it was that fire came to the volcano and so it is that Motouhora (Whale Island) is much closer to shore [from http://www.nzterritory.com/geographic/white.html].

Top: Whaharaki/White Island, photo A. Pallentin; Bottom: Motouhora/Whale Island, Photo G. Lamarche

2 INTRODUCTION

Detecting liquid or gaseous features in the ocean is generating considerable interest in the geoscience community because of their potentially high economic values (oil & gas, mining, freshwater), their significance for environmental management (oil/gas leakage, biodiversity mapping, greenhouse gas monitoring) and, in New Zealand, cultural and traditional values. Analysis of the acoustic energy backscattered by such features in the water column is still the most reliable, accessible and technologically advanced way to develop quantitative methods of analysis of such features. Identifying and characterising flares and plumes from the backscatter ("Backscatter" refers to marine acoustic backscatter signal throughout this voyage plan) is difficult however, due to (1) the often very weak contrast of acoustic impedance between scatterers and sea-water (e.g. freshwater); (2) the transient and dynamic behaviour of the scatterers; and (3) the complexity of the physics involved in marine acoustic signal analysis in this dynamic environment.

The research undertaken during this voyage is part of NIWA's *Marine Geological Processes and Resources* programme, and a milestone of the Royal Society of New Zealand's Catalyst:Seeding project "*Building Capability for in situ quantitative characterisation of the ocean water column using acoustic multibeam backscatter data*". The research is undertaken by a consortium of internationally recognised experts established for the Catalyst project to gather all expertise required in the field of marine acoustics and geophysics, spatial analysis and ocean environment, from New Zealand (NIWA, University of Auckland), France (CNRS/Uni Rennes, IFREMER), Australia (IMAS), the USA (CCOM-UNH) and Germany (GEOMAR).

The aim of the TAN1806-QUOI (Quantitative Ocean-Column Imaging using hydroacoustic sources) voyage of RV *Tangaroa* was to enhance our capability to acoustically detect and characterise liquid and gaseous targets in the ocean water column. The voyage place between 3 and 22 July 2018. The science party consisted of 20 scientists and students from the consortium organisations as well as students from the University of Auckland, the University of Tasmania, the University of New Hampshire and the *Ecole Nationale Supérieure des Technologies Avancées*. The vessel crew consisted of 18 staff led by Master Evan Solly.

The 20-day voyage covered ca. 3640 km (1970 NM) from Wellington to the Bay of Plenty and back to Wellington. The large part of the voyage took place in the Bay of Plenty with 13 days spent over the Calypso Hydrothermal Vent Field (CHVF), ca. 15 km SW of Whakaari-White Island volcano. Numerous hydrothermal vents have been identified in the past over the region through acoustic flares and visual observation and the location therefore provided an excellent opportunity to develop our experiments.

The voyage collected ca. 4.6 Tb of acoustic data and video recording. The acoustic data were recorded using two Multibeam Echosounders (MBES), namely a 30 kHz EM 302 and a 200 kHz EM 2040, , and 6 single-beam echosounder including EK60 and EK80 providing 38, 70, 120 and 200 kHz. We also collected 31 sediment samples and 43 water samples that required 111 gear deployments using a van Veen Grab; towed video camera, CTD and an Acoustic Optical System (AOS).

Several experiments were developed during the voyage to achieve our objectives:

- **i. Echosounders calibration.** Both SBES and MBES were either calibrated of cross calibrated at the beginning of the voyage. This was critical for quantitative use of acoustic signals.
- ii. **High swath overlap MBES coverage** over the CHVF using both 30 kHz (EM302) and 200 kHz (EM 2040) MBES. A large overlap of the swath footprint was generated to enable us to study angular backscatter response in seafloor and water-column data, and sidelobe interference.

iii. **Multi-sensor data acquisition.** Over specific flares and a synthetic Seep generator (a.k.a. Bubble Maker). This included a multi-angle (5° increment) and multi-frequency backscatter, high swath overlap coverage and the use of a 200 kHz SBES mounted on a pan&tilt device beneath the vessel's hull. The SSG enabled to control the bubble size and rate.

iv. Passive acoustic monitoring of the northern CHNVF was attempted using a hydrophone deployed for XX days.

v. **Ground truthing** samples and video footage was undertaken using a towed video camera.

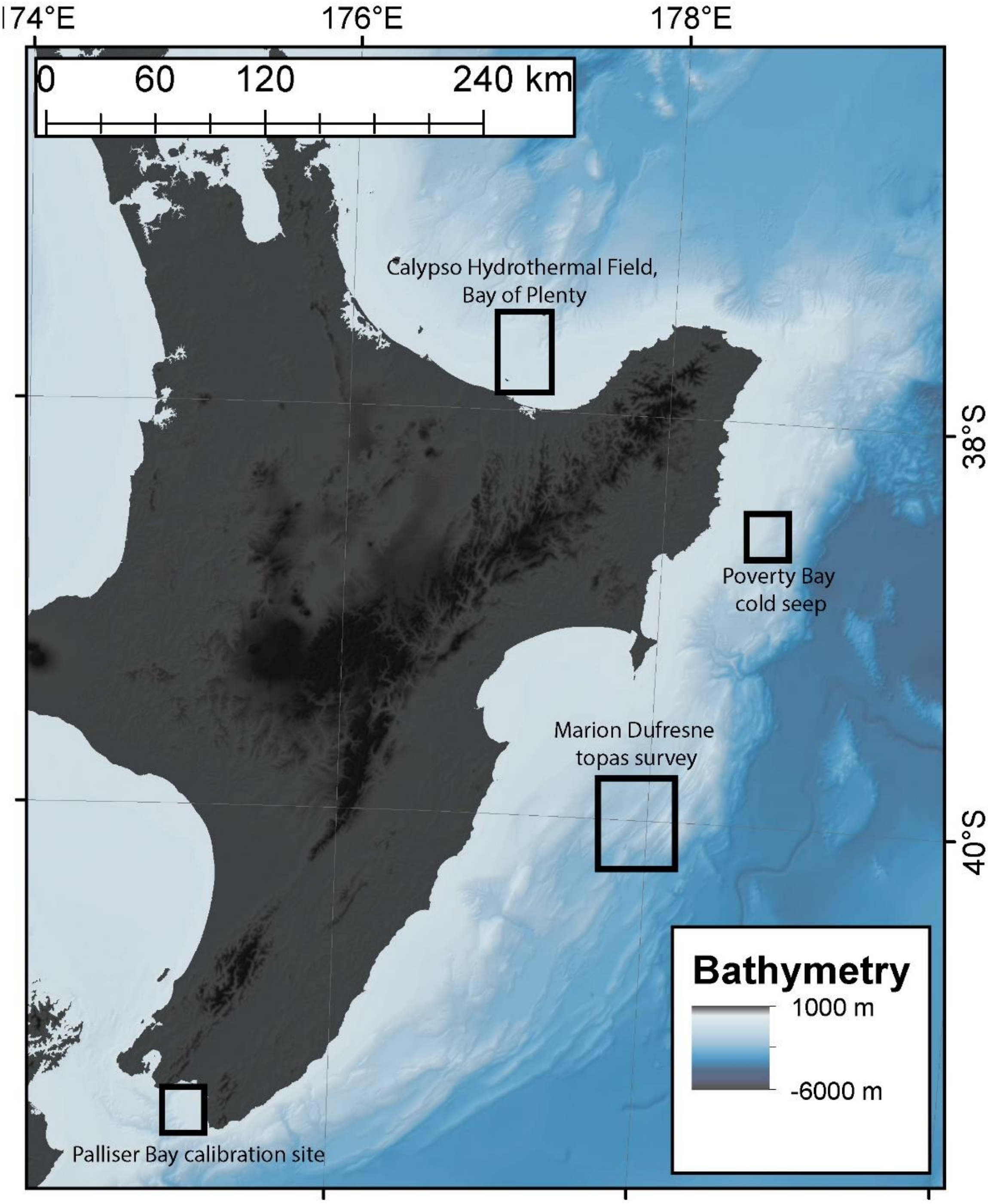


Figure 2-1 - the four areas of surveying during TAN1806-QUOI

3 BACKGROUND GEOLOGY & GEOPHYSICS

New Zealand sits astride the active convergent Pacific-Australia Plate Boundary (Figure 3-1). The Pacific Plate enters subduction under the Australian Plate along the Hikurangi Margin, east of Te Aka A Maui/North Island of New Zealand, at a rate of ca. 48 mm/yr at 38°S (Barnes et al., 2010). In response to the subduction process, an arc-back volcanic system has developed as the Taupo Volcanic Zone (TVZ) in central North Island which extends northward into the Kermadec Arc-back-arc system (Cole, 1990; Wright, 1990). Crustal extension across the TVZ occurs at a rate of up to 15 mm/yr (Wallace et al., 2004).

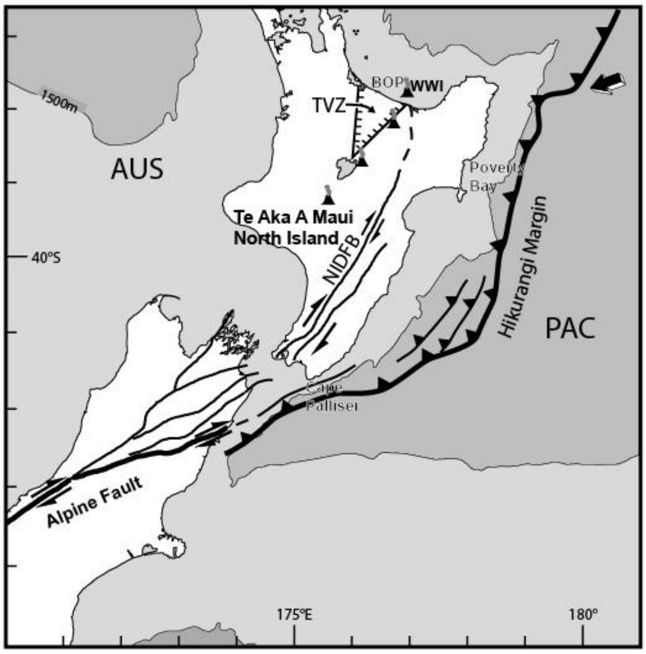


Figure 3-1 - The Pacific-Australia Plate Boundary in New Zealand. BOP: Bay of Plenty; WWI: Whakaari White Island; NIDFB: North Island Dextral Fault Belt; PAC: Pacific Plate; AUS: Australian Plate; TVZ: Taupo Volcanic Zone. The arrow indicates the relative PAC-AUS plate motion of ca. 48 mm/yr at ca. 38°S.

1.1 The Calypso Hydrothermal Vent Field

The TVZ is a region of Quaternary calc-alkaline volcanism, geothermal activity, intense shallow (<10 km) seismicity, and continental extensional faulting within the back-arc environment of the Hikurangi subduction system. Geothermal activity is widespread within the TVZ. The TVZ extends

40-km wide zone of NE-trending faulted basement blocks, bathymetric ridges and troughs and volcanic centres that extend to the toe of the continental slope (Lamarche et al., 2006; Taylor et al., 2004; Wright, 1990). The active rift of the TVZ is represented by a dense series of SW-NE trending active normal faults forming the Taupo Fault Belt. Offshore the Taupo Fault Belt extends into the Whakatane Graben.

The Whakatane Graben lies at a depth of ~ 60-150 mbsl between Motouhora/Whale Island located at about 5 km from the North Island coast, and Whakaari/White Island, an active calc-alkaline volcano located at about 40 km from the coast.(Wright 1990; Lamarche et al. 2006). The graben is bounded to the east by the up to 80 m high Motouhora Scarp that is the morphological expression of the White Island Fault. A very dense network of faults has been mapped using 3.5 kHz and multichannel seismic data (Lamarche et al., 2006, Figure 3-3). The graben is filled by up to 2.5 km of volcaniclastic material derived from post-65 ka caldera-forming rhyolitic eruptions on the subaerial portion of the TVZ (Davey et al., 1995). Volcaniclastic deposits in the immediate vicinity of the Calypso vents are thought to be related to post-18 ka eruptions including on nearby White Island.

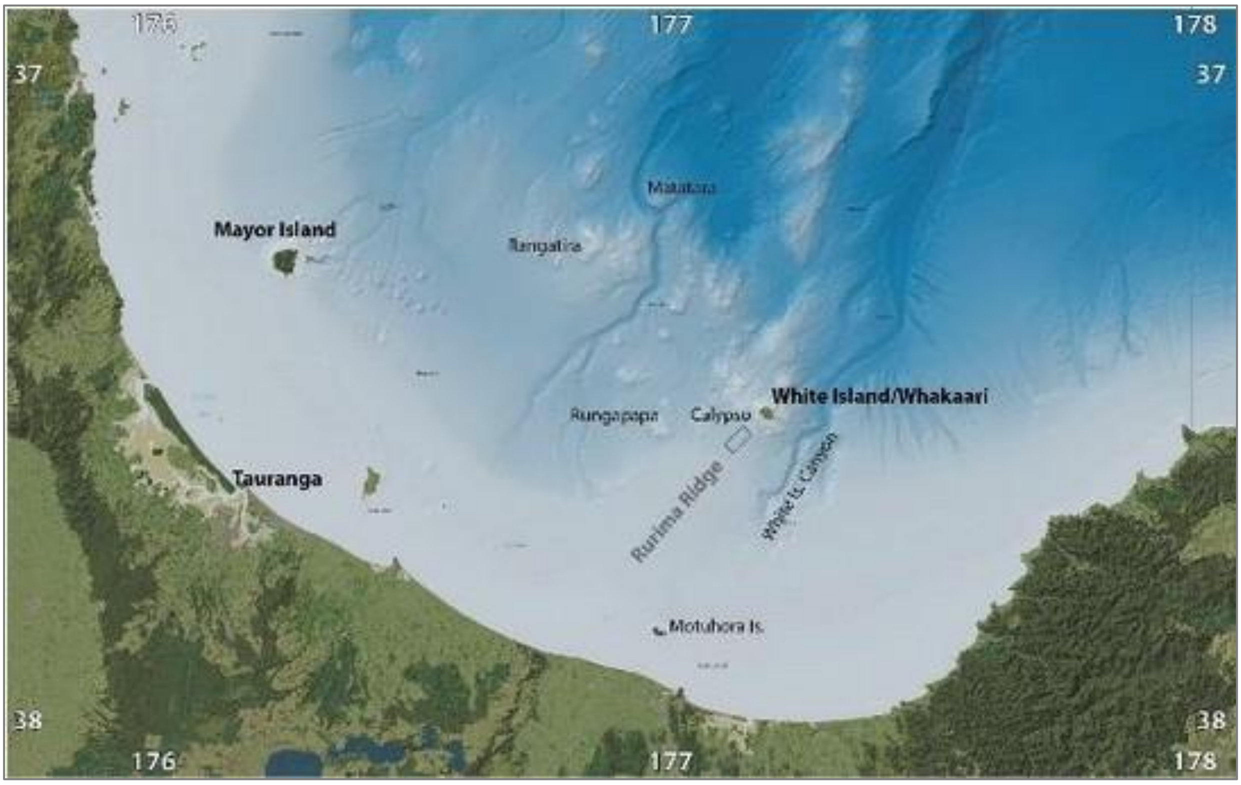


Figure 3-2 - The Bay of Plenty (BOP) – Black box indicates approx. location of the northern Calypso Hydrothermal Vent Field (CHVF)

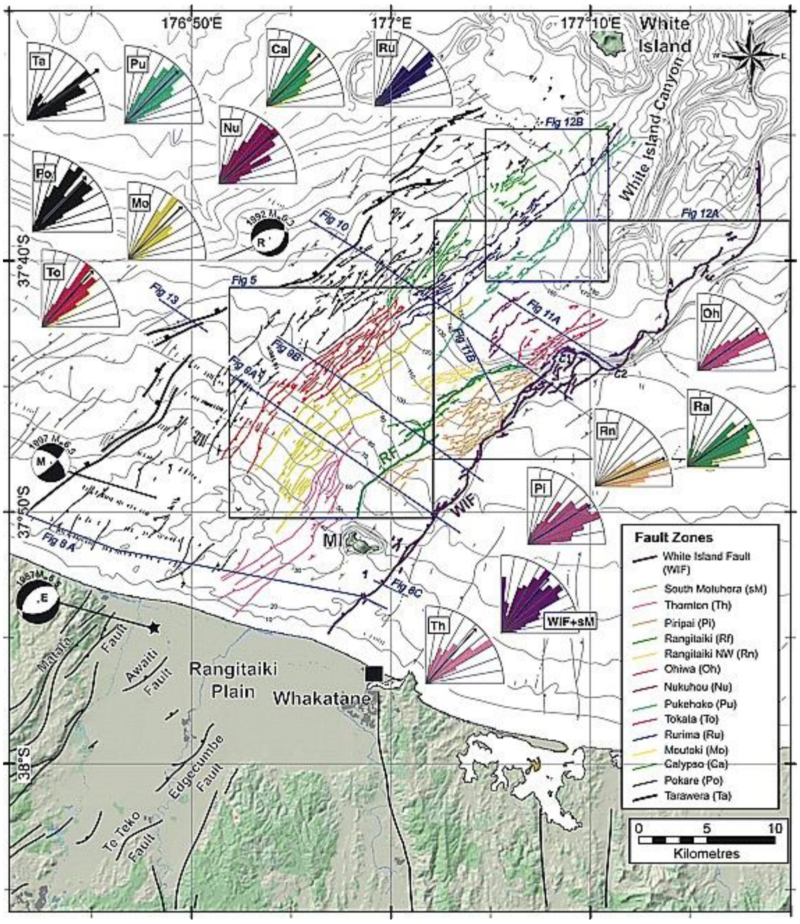


Figure 3-3 - Fault map of the Whakatane Graben from Lamarche et al. (2006)

The Calypso Hydrothermal Vent Field (CHVF) is located on the north part of the Whakatane Graben, ~15 km southwest of the Whakaari/White Island volcano. The CHVF consists of four localized regions recognized by Hocking et al. (2010) as the northern, central, southeast and southwest fields (

Figure 3-4).

The first observations of submarine hydrothermal activity in the BOP were made by Duncan and Pantin (1969) during the Ngatoro voyage of the New Zealand Oceanographic Institute. The vents were located based on visual sighting of bubbles rising to the sea surface, and imaged with the single beam echosounder depth recorder. Glasby (1971) discovered other evidences of geothermal activity in shallow depths (c. 50 m bsl) around Motouhora/Whale Island using a 12-38.5 kHz echosounder. In 1987, Sarano et al. (1989) extended similar works to the northern part of the Bay of Plenty, around Whakaari/White Island in water depths around 170 m, using a 200 kHz echosounder and direct observations (samples, photographs and videos) by submersible from research vessel Calypso. Additional vents were mapped during RV Sonne SO 135 voyage (Stoffers et al. 1999a; Stoffers et al. 1999b).

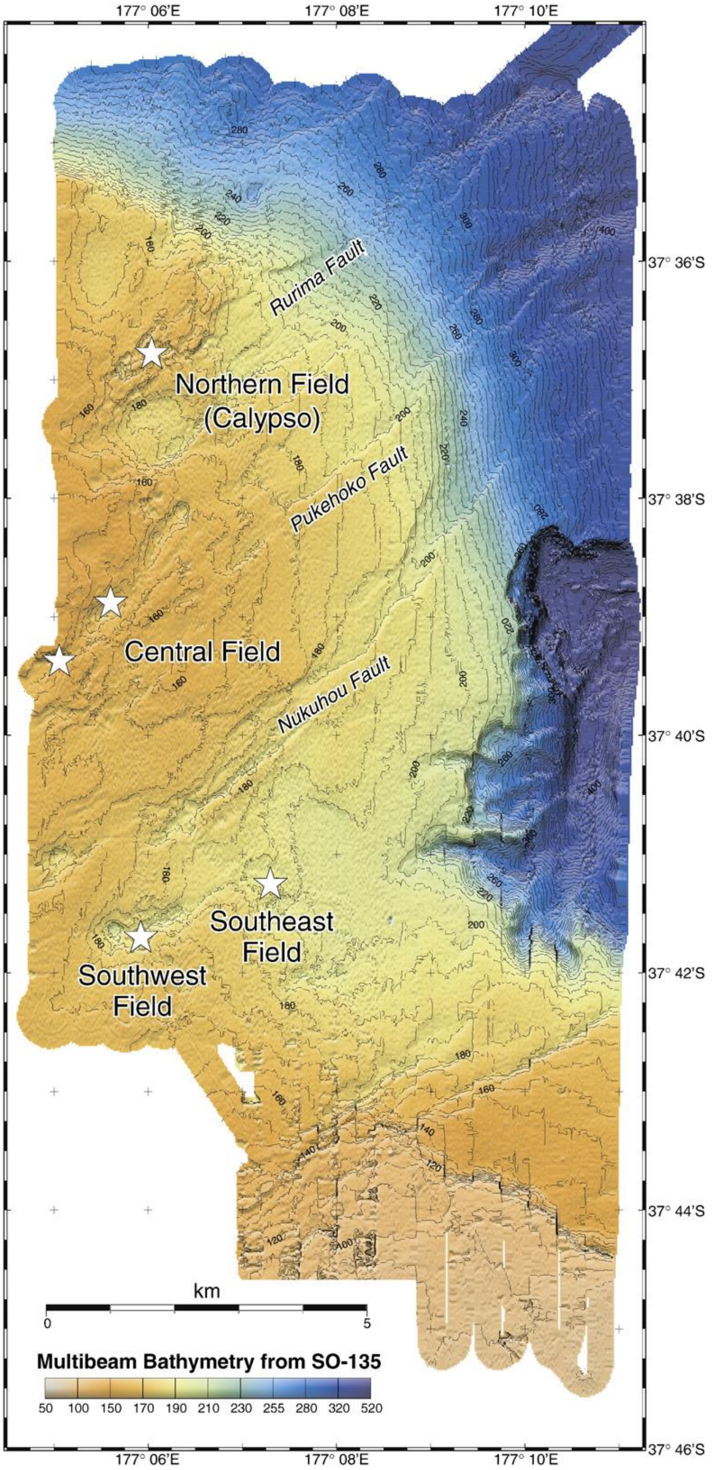


Figure 3-4 - Bathymetry of the Calypso Hydrothermal Vent Field from Hocking et al. (2010)

These observations suggested the perennial occurrence of submarine geothermal activity in the BOP. The hydrothermal vents occur along circular depressions which locations are structurally controlled by the SW-NE trending fault system. Venting of clear hydrothermal fluids, which are characterized by both gas and liquid discharge, occurs where rocky outcrops are exposed in the sandy bottom along the fault scarps (Hocking et al., 2010). Botz et al. (2002) report that carbon dioxide is the dominant gas, accounting for between 45 and 84% of the total gas discharge by volume, and hydrogen sulfide accounting for 0.83 to 1.9 vol%. Observations indicates that fluids discharge from small centimeter-size holes in the sandy sediment and along fractures in the exposed bedded volcaniclastic rocks. The vents are typically surrounded by halos of native sulfur and white filamentous bacteria covering areas up to ∼10 m×10 m, and the seafloor in the vicinity of vents is pockmarked by fluid and/or gas escape structures. Although anhydrite mounds were observed in the North Vent Field, no chimneys or other significant mineral deposits have been reported in the vicinity.

Extensive seafloor mapping, geochemical and geological sampling were undertaken onboard RV Tangaroa (Table 3-1) and RV Sonne in 1998 (SO135 Stoffers et al., 1999a; Stoffers et al., 1999b), and 2007 (SO-192Schwarz-Schampera et al., 2007) over the CHVF. The surveys provided detailed information on the region bathymetry and tectonic environment which provided means to precisely localise the vents. Over 20 vents were identified in the four hydrothermal fields. The 2007 Sonne voyage focused on the geochemistry of the vents using towed camera, dredges and the manned submersible JAGO, and collected water, gas and biological samples. Temperature measurements at the vents was reported as high as 201°C. The Canadian remotely-operated vehicle ROPOS was used during SO-192 to locate additional vents and significantly extend the area of mapping.

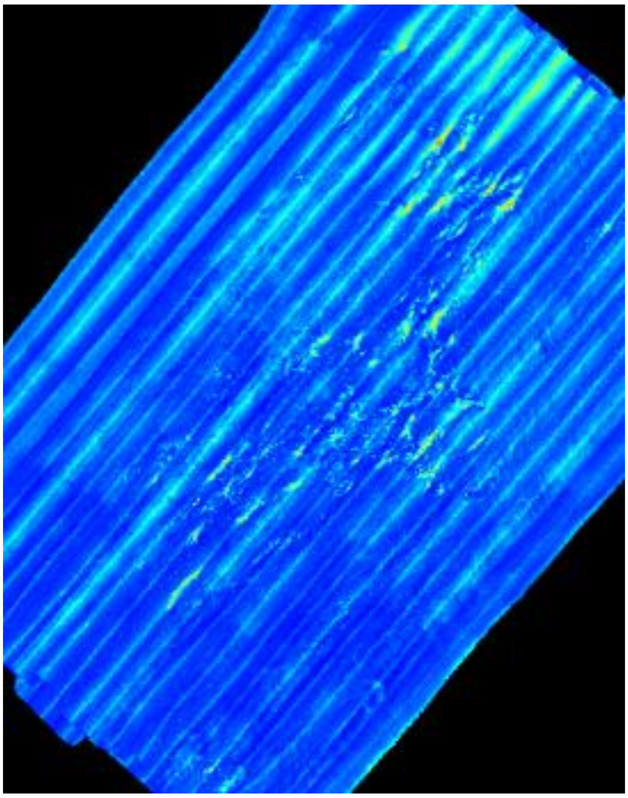


Figure 3-5 - Echo-integration of water column backscatter, CHVF, using SonarScope; SAMSARA voyage (Wysoczanski et al., 2015)

Subsequent surveys with an interest in benthic ecosystem, seafloor geology and active hydrothermal activity have been undertaken in the BOP by NIWA and other national and international research organizations (Table 3-1). Data accessible include geophysical data (Seismic, bottom profiler, multibeam echosounder), geological and biological samples, photo and video, etc.

The Bay of Plenty was also mapped in details using low fold multichannel seismic reflection data in 1999 (Lamarche and Barnes, 2005; Lamarche et al., 2006; Lamarche et al., 2000), and mapped using an EM300 during the October 2004 voyage TAN0412 of R.V. Tangaroa (Mitchell et al., 2004), and an EM302 in 2015 (voyage TAN153 Wysoczanski et al. 2015). The later included high swath overlaps and water column data.

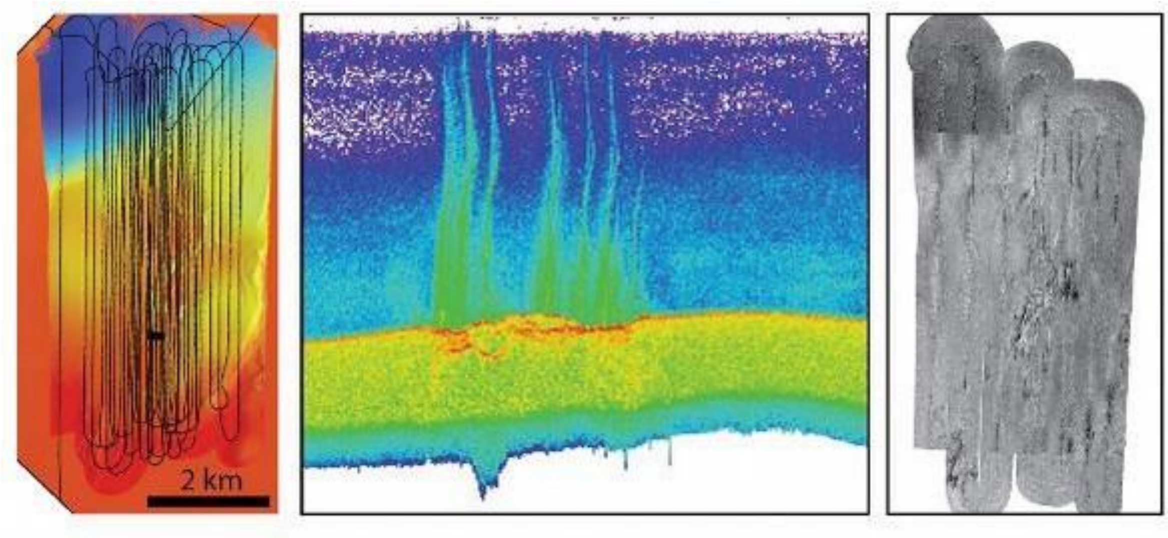


Figure 3-6 – MBES data acquisition over the northern CHVF - Closely parallel lines (left) resulted in high definition backscatter without specular (right). Many flares were imaged in the water column (centre) – Voyage SAMSARA-TAN1513 (Wysoczanski et al., 2015).

Table 3-1 -Selected geophysical, geological and biological surveys in Calypso region

Voyage	Vessel	Name	Tool	year	report
TAN1513	Tangaroa	SAMSARA	EM302, 3.5 kHz	2015	yes
KAH1004	Kaharoa	BOP Seeps		2010	no
TAN0810	Tangaroa	BOP Faults	EM302 - MCS - 3.5kHz	2008	yes
SO192-2	Sonne	MANGO	Hydrosweep	2007	yes
TAN0411	Tangaroa	NZPLUME III	EM300	2004	yes
TAN0412	Tangaroa	BOP Swath	EM300	2004	yes
TAN0413	Tangaroa	BOP Seamounts	biology-EM300	2004	yes
TAN0206	Tangaroa	NZ PLUMEII	Geochemistry	2002	no
SO135	Sonne	Havre Trough- Kermadec Arc	Hydrosweep	1998	no
TAN9603-CR3028	Tangaroa	Kermadec Volcanoes	low fold seismic	1996	yes
CR2023	Rapuhia	BOP Geology 3	low Fold MCS	1989	no
CR2017	Rapuhia	BOP Geology 1	low Fold MCS	1988	yes
DR8803	Ch. Darwin	GLORIA Surveys BOP and Tonga	GLORIA MR1 side scan	1988	no
TAN9914	Tangaroa	BOP Active seabed	Low Fold MCS, 3.5 kHz	1999	yes

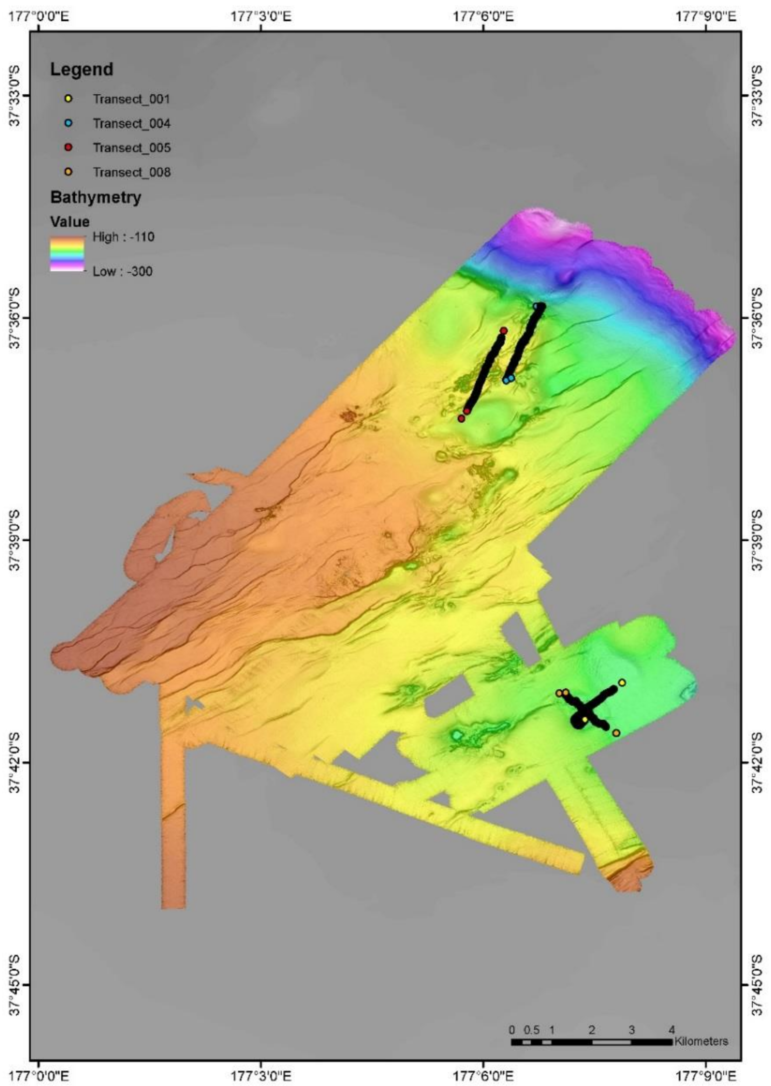


Figure 3-7- Video transects from 2014 Kaharoa KAH1405 voyage superimposed on the fully processed bathymetric data

1.2 Poverty Bay

The continental shelf east of Poverty Bay is located on the northern part of the Hikurangi Margin. The margin is the deformation zone associated with the subduction of the Pacific Plate beneath the Australian plate, i.e offshore to the east and beneath the North Island / Te Aka a Maui. Numerous gas hydrates and cold seeps have been identified and mapped along the margins. They reflect the migration of fluids and gas towards the seabed as a result of tectonic deformation, compaction, porosity reduction, and dewatering of the sedimentary sequence (Barnes et al. 2010). These seafloor sites of methane rich fluid expulsion have been characterized by the presence of chemosynthetic biological communities, the development of carbonate hard grounds, pockmark depressions, mud volcanism, and hydroacoustic flares. Of particular interest is the great extent of the gas reserve beneath the continental shelf, which is characterized by the extensive and ubiquitous presence of a gas hydrate layer that shows in seismic reflection data as a Bottom Simulating Reflector (BSR Henrys et al. 2008).

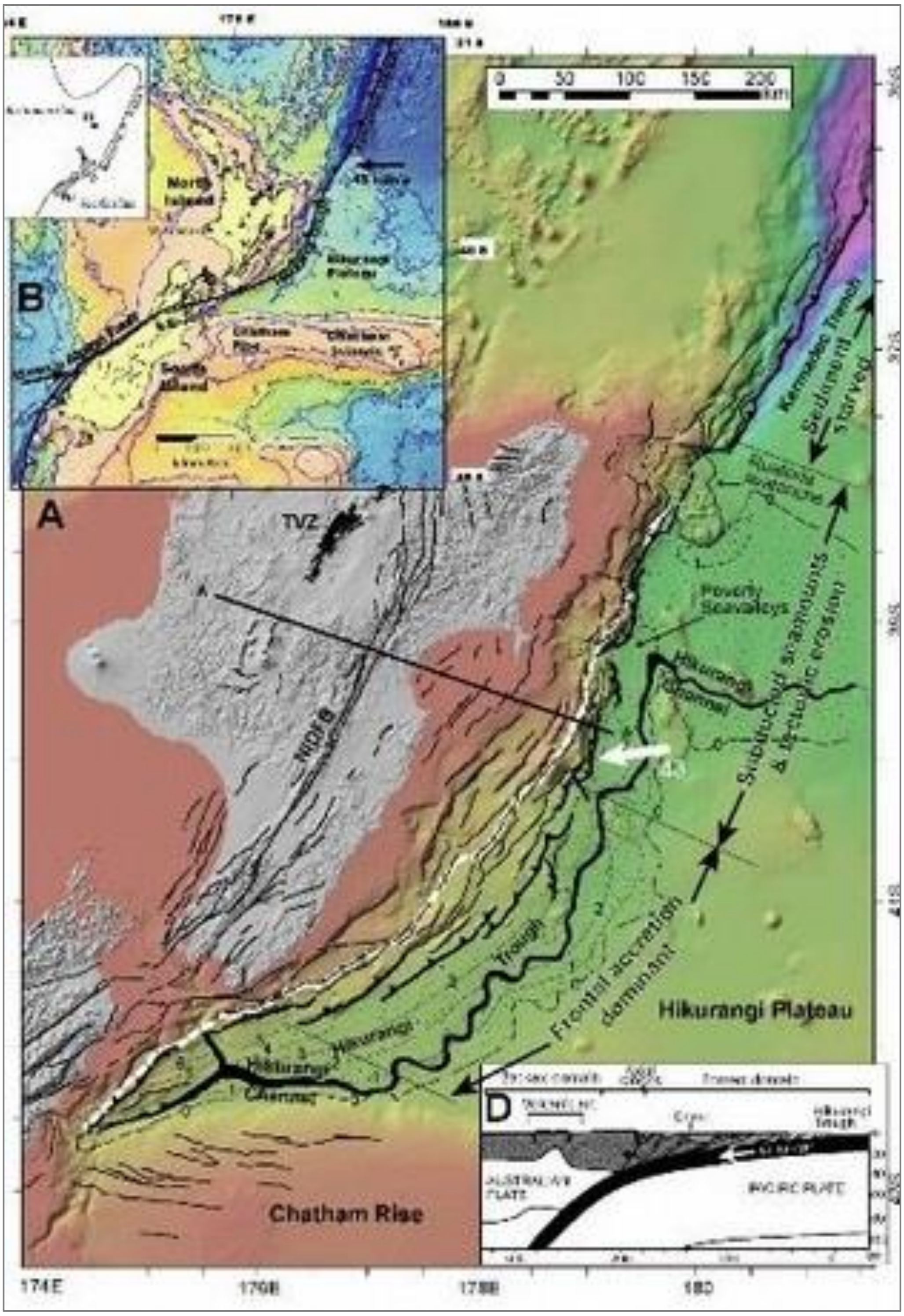


Figure 3-8 – Map of the Hikurangi Margin along the Te Aka a Maui/North Island of New Zealand. Plate boundary in white (from Barnes et al., 2010).

The Hikurangi Margin has been the focus of extensive geophysical research which has led to the near-complete multibeam mapping of the continental shelf and slope, and a large number of seismic reflection data of various type, origin and quality. An encompassing multibeam dataset acquired using 12 and 30 kHz echosounders have been processed to variable grids of 10 to 30 m resolution (CANZ, 2008).

4 Voyage Narrative

This section provides a short factual narrative of daily events, accompanied by key figures.

Mobilisation on Monday 2 July proceeded smoothly with multiple equipment loaded on time. All non-NIWA personal were onboard on Monday night. Port and vessel inductions were conducted on that morning and the previous Friday morning.

08:00 Mobilisation starts at Burham Wharf. Container already loaded. All equipment from the US (bubble maker), France (pan&tilt; multiple split-beam echo sounders), Australia (small ROV and deep water camera), as well as NIWA equipment (AOS, scuba tanks, AMARS passive acoustics, CTD, grab,...) but nothing requiring the large crane.

08:00 port induction for non-NIWA science crew (some done the week before)

c. 10:30 and 13:30 Vessel inductions for non-NIWA science crew.

Most non-New Zealand science staff stayed onboard on Monday night.

4.1 Tuesday 3 July

08:00 Mobilisation was completed with Bubble Maker onboard early in the morning.

08:30 Vessel crew and science party meeting in mess room; Master Evans Solly and Voyage Leader addressed the staff and crew.

c. 13:00 Departure from Burham Wharf; departure delayed from ETD of 008:00 due to the Chief Engineer being unwell and having to be replaced.

17:00 SVP (Station 01); Some problems with importing SVP in SIS software had us fiddling with software for a solid 3 hours until a temporary solution was found by reducing the number of samples in the input file. Kongsberg has been advised.

17:00 Multibeam calibration started in Palliser Bay and continued all night. Run the procedure for all modes for EM302 and EM2040.

21:30 Pitch, roll, heave EM302 (30kHz); EM2040 (200kHz)1 line, fore and aft

23:00 CTD (Station 02) issues with two boxes

4.2 Wednesday 4 July

Calibrating the AOS over the side of the vessel was run in daylight, followed by calibration of the hull mounted fisheries sounders (EKs), and the EK80 on the pan&tilt, under Yoann Ladroit's responsibility. This went well, despite the usual entanglement of the lines under the vessel!

00:00 - 06:30 Backscatter calibration; EM302 30 kHz medium/shallow; EM2040 200 kHz long/medium CW; EK80 Pan&Tilt 200 kHz; EK80 Gondola 18(FM)/38/70/120 kHz CW; 2 lines, fore and aft for each configuration: EM302 medium + EM2040 long CW; EM302 shallow + EM2040 medium CW; + EK80 continuous acquisition (1ms)

08:06 CTD (Station 03);

10:20 EK80 AOS sphere calibration 38, 120 and 200 kHz; Station 04

13:20 EK60 Gondola ; 18, 38, 70, 120 and 200 kHz Station 05

18:00 EK80 pan & tilt calibration; 200 kHz

19:30 CTD (Station 06)

Picth/Roll test; EM2040 200 kHz (FM) deep part of Tuesday3 line, return OK

21:00 start transit to Poverty Bay;10 knots; EM2040 in <350m, EM302.

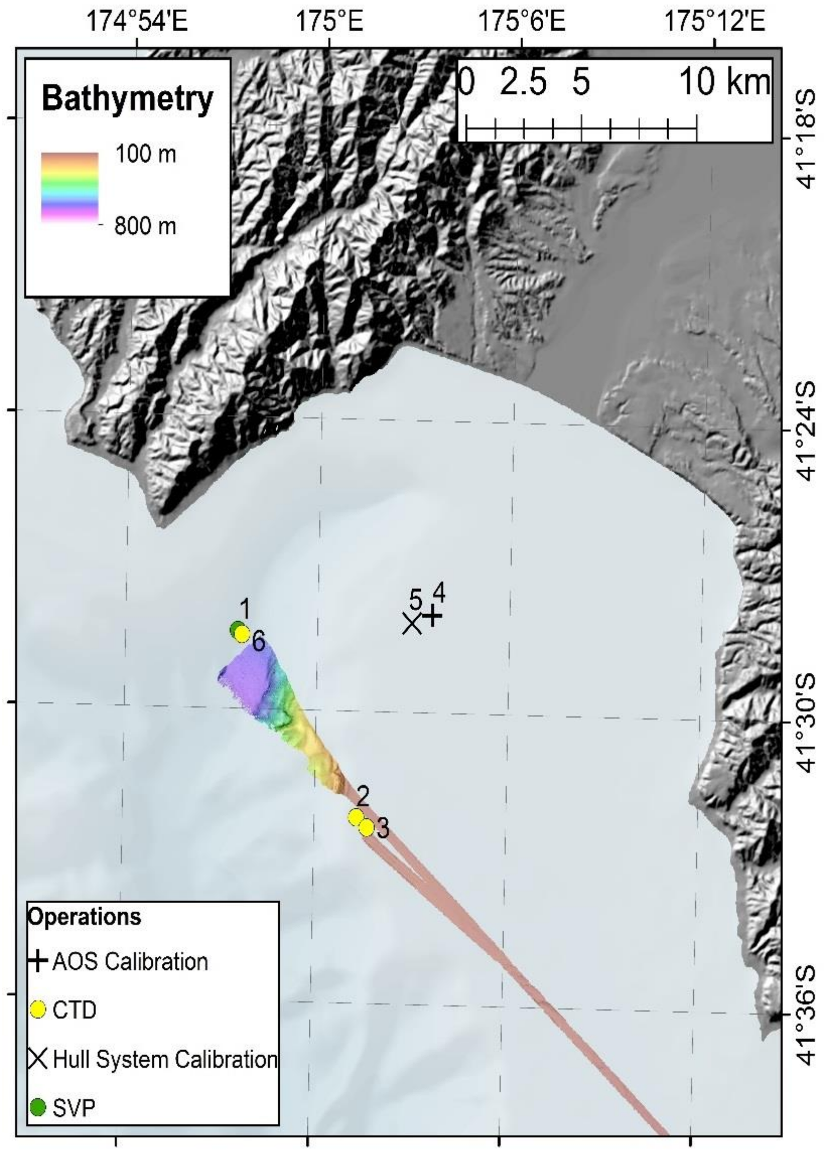


Figure 4-1 - -Location of calibration experiment in Palliser Bay and making a cradle for the calibration sphere

Figure 4-2 - making a sphere cradle for the calibration sphere

4.3 Thursday 5 July

Transit to Poverty Bay site at 10 knots.

14:30 TOPAS lines; 8 profiles run off Cape Turnagain over the location of ponded basin where previous sediment cores had been collected during the Nov. 2016 TAN1613 voyage of RV Tangaora {Barnes, 2016 #1437}. These will be used to reinforce a future Marion Dufresne proposal; Lines numbered HB1 to HB8.

10:15 Science party meeting (See minutes in Appendix 1).

21:00 Topas line completed; transit to Poverty Bay resumed Figure 4-4.

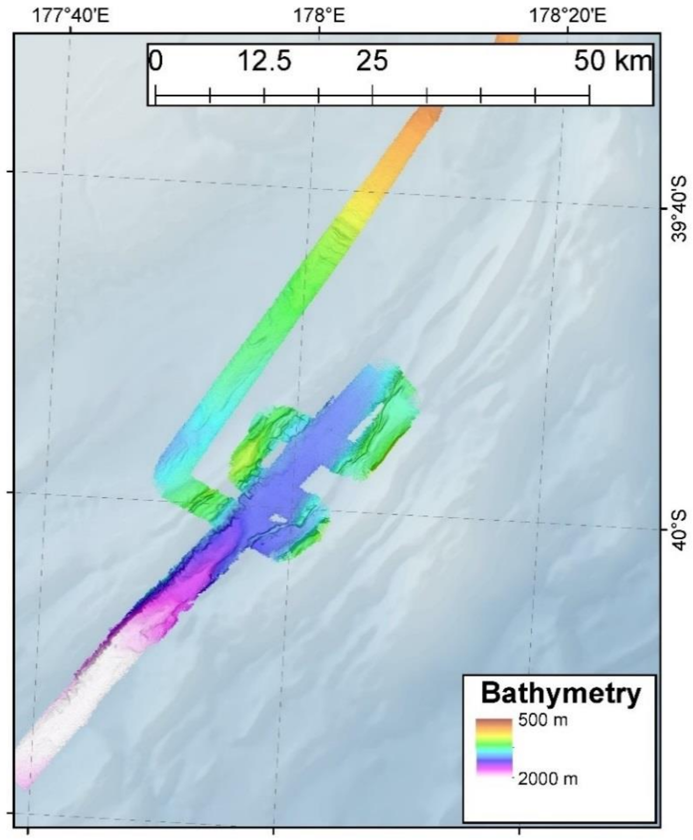


Figure 4-3 - Location of the Topas lines over of TAN1613 cores HB5 and HB6

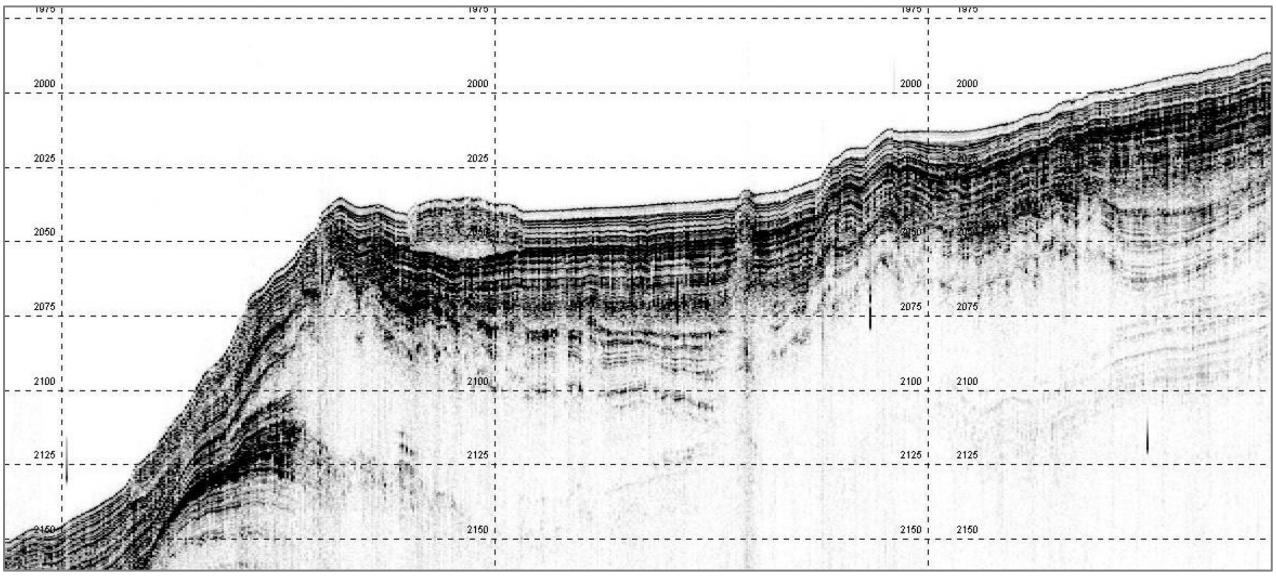


Figure 4-4 - Topas lines over the location of TAN1613 cores HB5

4.4 Friday 6 July - Poverty Bay

Day spent acquiring seafloor and water column backscatter over the flares using 18, 38, 70, 120, 200 (pan&tilt), and 300 kHz.

04:00 Arriving in Poverty Bay

04:25 CTD (Station 07); 38°37.21'S 178°35.63'E Wire:230/Depth:243

05:00 Acquisition on EM302 + EK80-200 kHz over cold seeps; 7 km-long NE-SW profiles at the continental slope break. Some good flares over methane seeps were imaged. Swath overlap 75% - EM302, EK80: 70, 120, 200 - same cycle. Issues with EM2040 in CW mode and the Pan&Tilt both very noisy. EM2040 data not usable, and system turned off. Likely due to too deep-water depth. Technician trying various options.

08:00 MBES mapping on cold seep field; swath 75%; EM302, Pan&Tilt 45° starboard 200 kHz, EK80 18/38/70 and 120 kHz (200 kHz in passive) over intense plumes on the North-East; EK80-200kHz on pan&tilt very noisy but some workaround using different electrical source have mitigated the problem. Not ideal but workable.

15:00 CTD (Station 08); 80m. 38°37.36'S 178°33.59'E Wire:176/Depth:180. HIPAP pole down - M47 Beacon.

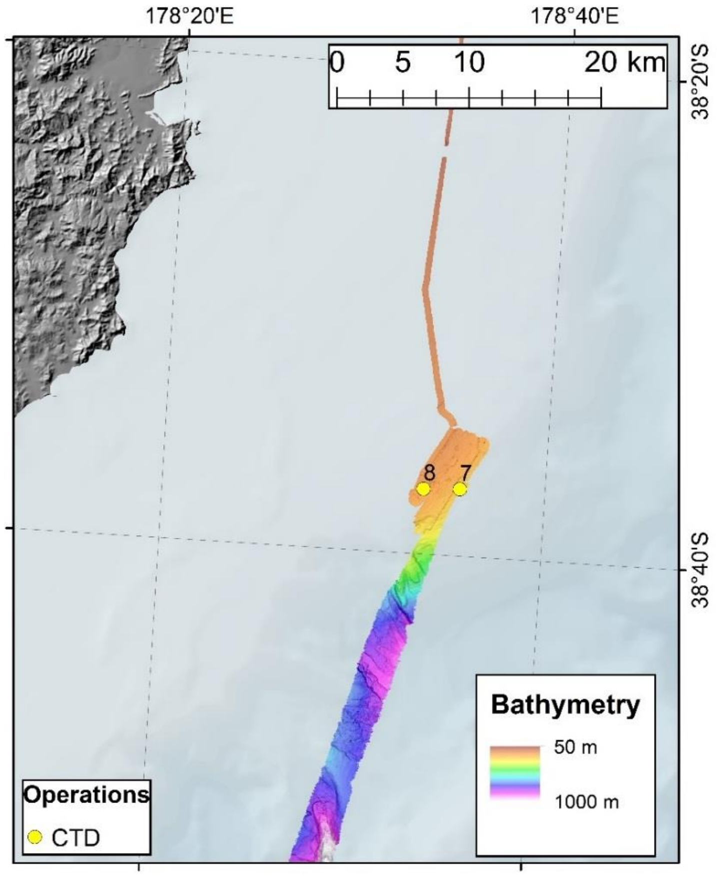


Figure 4-5 - Location of Poverty Bay box, with 2 CTD cast positions indicated.

16:00 continue MBES mapping on cold seep fields swath 75%; EM302, EK80, Pan&TiltIntense plumes on the North-East: return there with EM302 and Pan&Tilt 45° starboard; 200 kHz only, EK80 18/38/70 and 120 kHz (200 kHz in passive).;

17:30 Three TOPAS lines over the flares to test the potential to use the low frequency of the system for bubble detection; (FM and Ricker); EM2040, EM302 and EK80

20:00 Operations stopped; transit to Bay of Plenty resumed; EM2040 and Topas left running, EM302 from N East Cape due to water depth. EM2040 even with EM302 to 200m WD

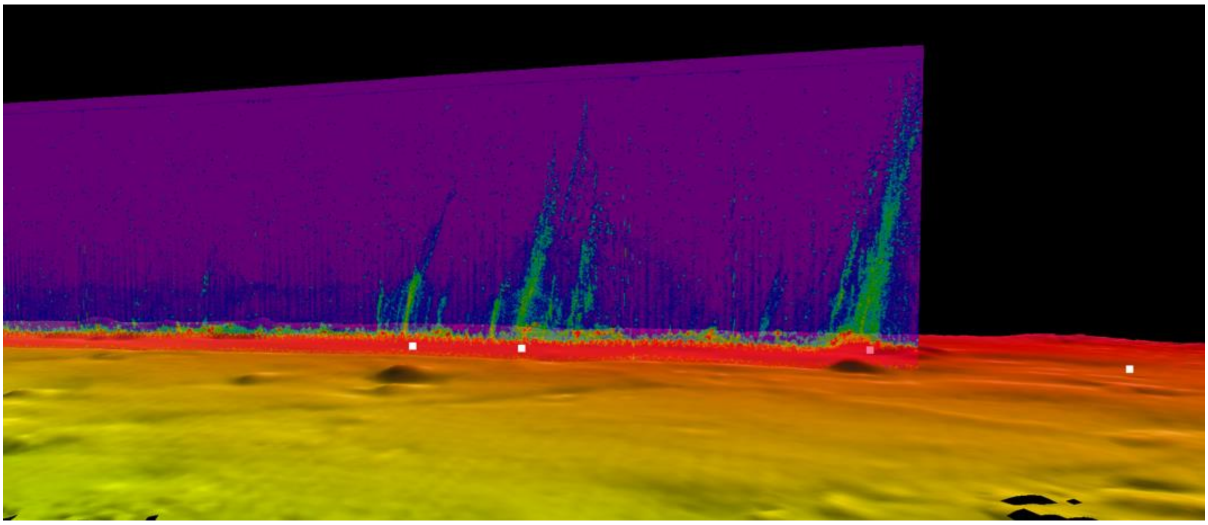


Figure 4-6 - Curtain projection over the central path in Poverty

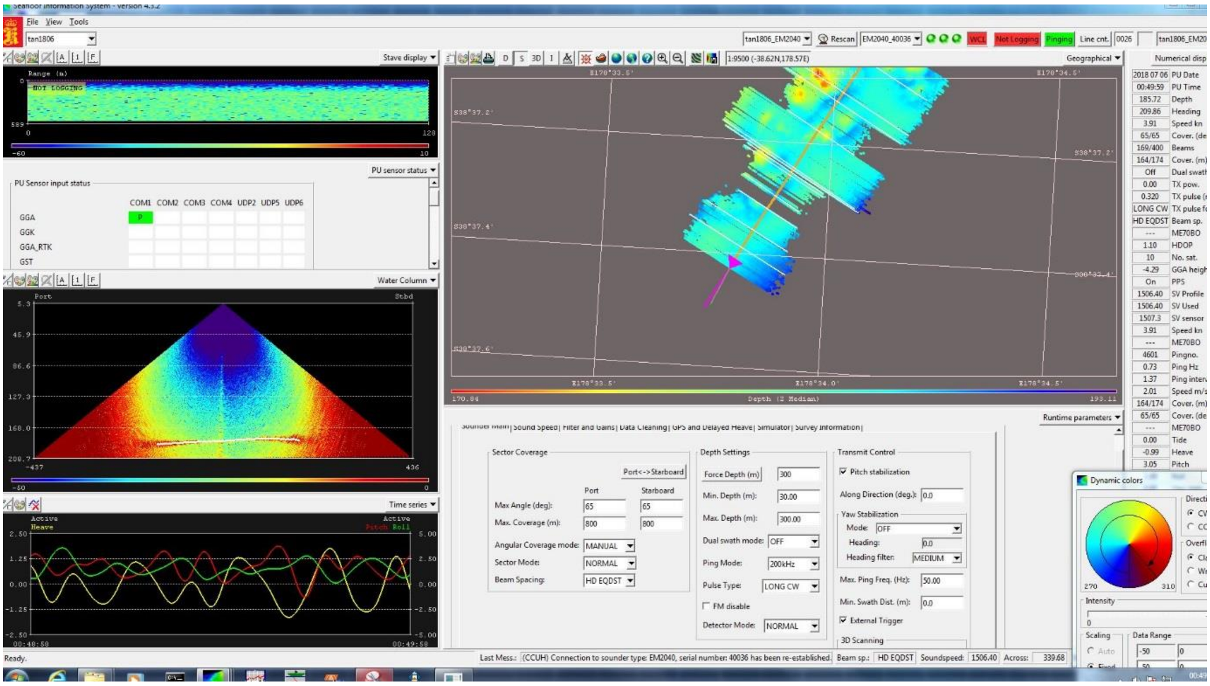


Figure 4-7- Screen dump of acquisition at Poverty bay - EM2040 FM Mode, 6 Jul 00:46:09 GMT

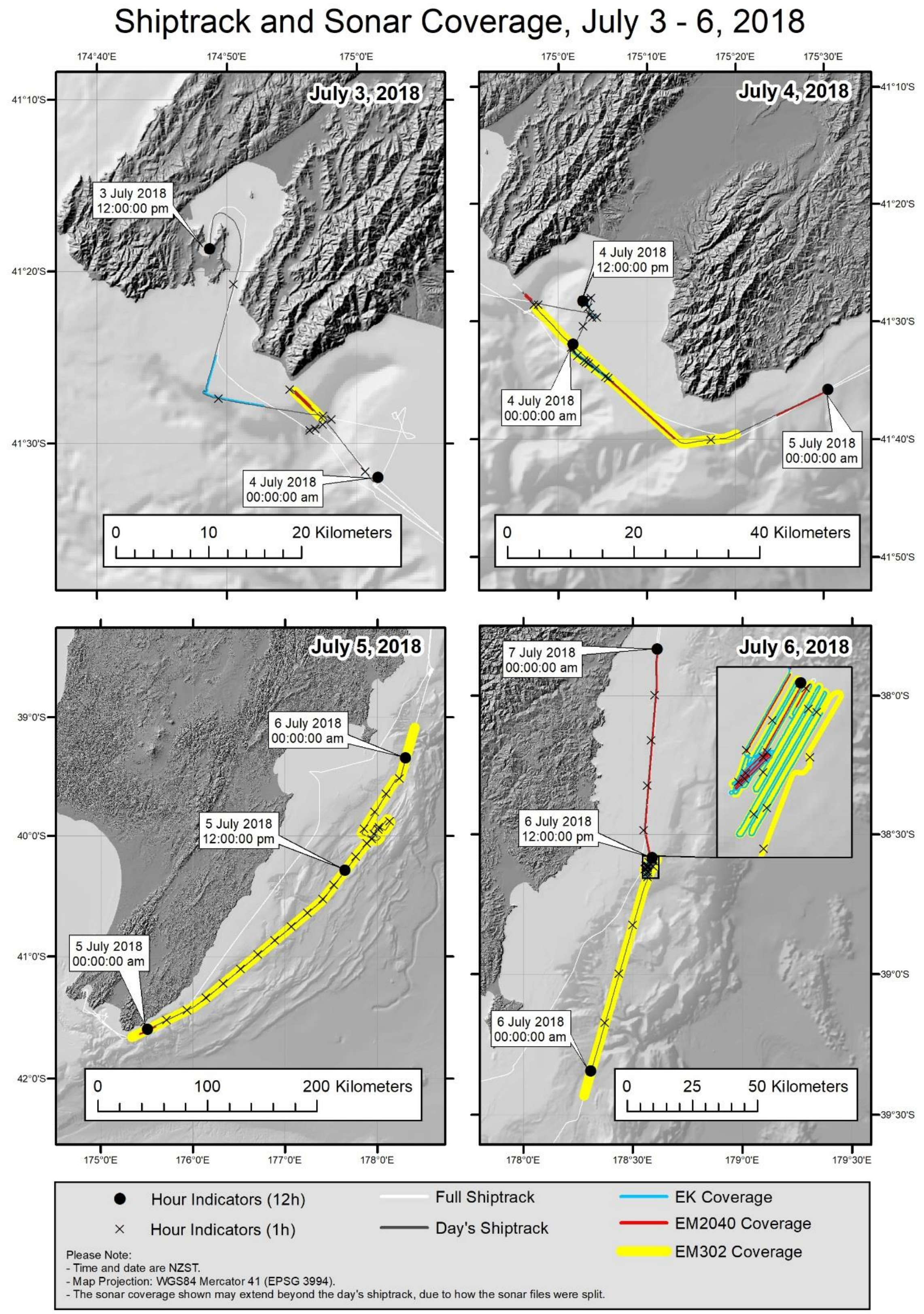


Figure 4-8 - Shiptrack and sonar coverage 3 - 6 July 2018

4.5 Saturday 7 July

09:00 Arrived in Bay of Plenty - Calypso Hydrothermal vent field, south of Whakaari White Island

09:29 CTD (Station 09); 37°35.56'S 177°08.24'E Depth 256m.

10:00 MBES mapping NCVF 65% overlap; Many flares, including a conspicuous oblique flare and multiple interference of dolphins with sonars (Figure 4-9)!

10:15 Science party meeting to discuss the bubble maker operations (See minutes in Appendix 1)

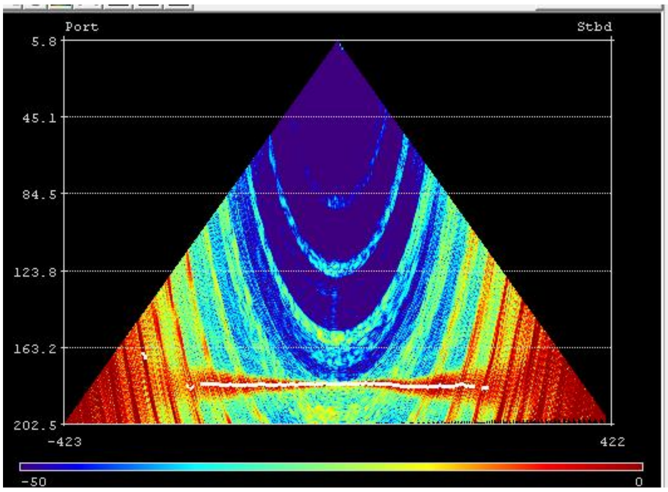


Figure 4-9 - Typical interference from dolphins with the MBES

16:34 CTD (Station 10); 37°36.314'S 177°06.507'E Wire:165/Depth:16

18:10 Station 11: Short test of camera system on the oblique flare with Ifremer hydrophone (Station 011); 37°36.06'S 177°06.71

Short transit with the IMAS drop camera system over the centre of the Northern Calypso Vent Field; lasted ~40mn. This was essentially to test the system. The profile was short and no bubbles could be imaged. The Ifremer hydrophone was attached to the camera frame. Completed ca. 19:00.

19:00 MBES mapping over NHVF 65% overlap Night spent on mapping the Hydrothermal field at 75% overlap.

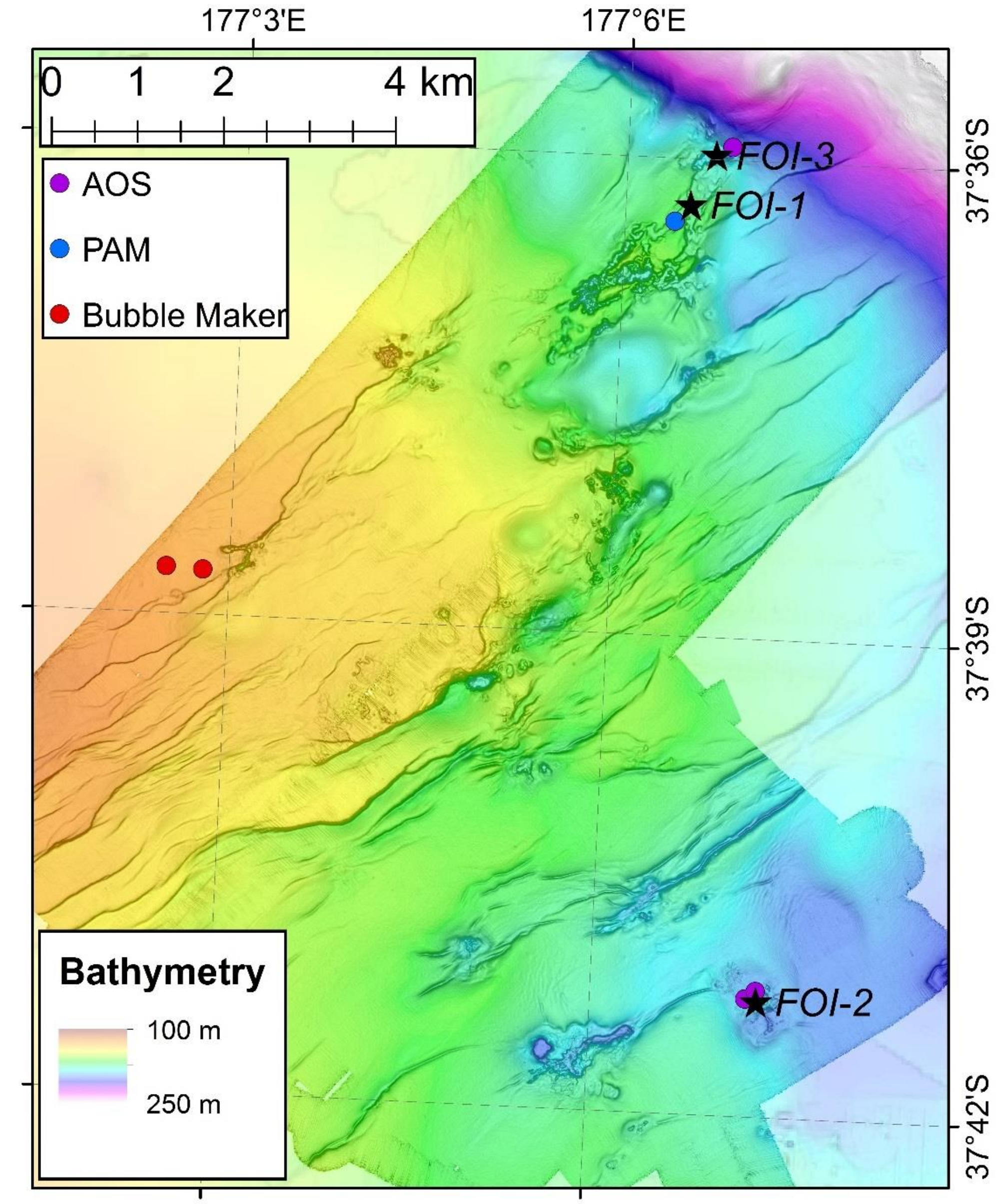


Figure 4-10 - The Calypso Hydrothermal Vent Field map. Flares of Interest (FOI) which were the focus of further studies are indicated.

Worthy of note is the imaging of an oblique flare within a field of sub-vertical flares imaged only on 70 and 120 kHz (CHECK). This intrigued the science crew and may warrant more investigation.

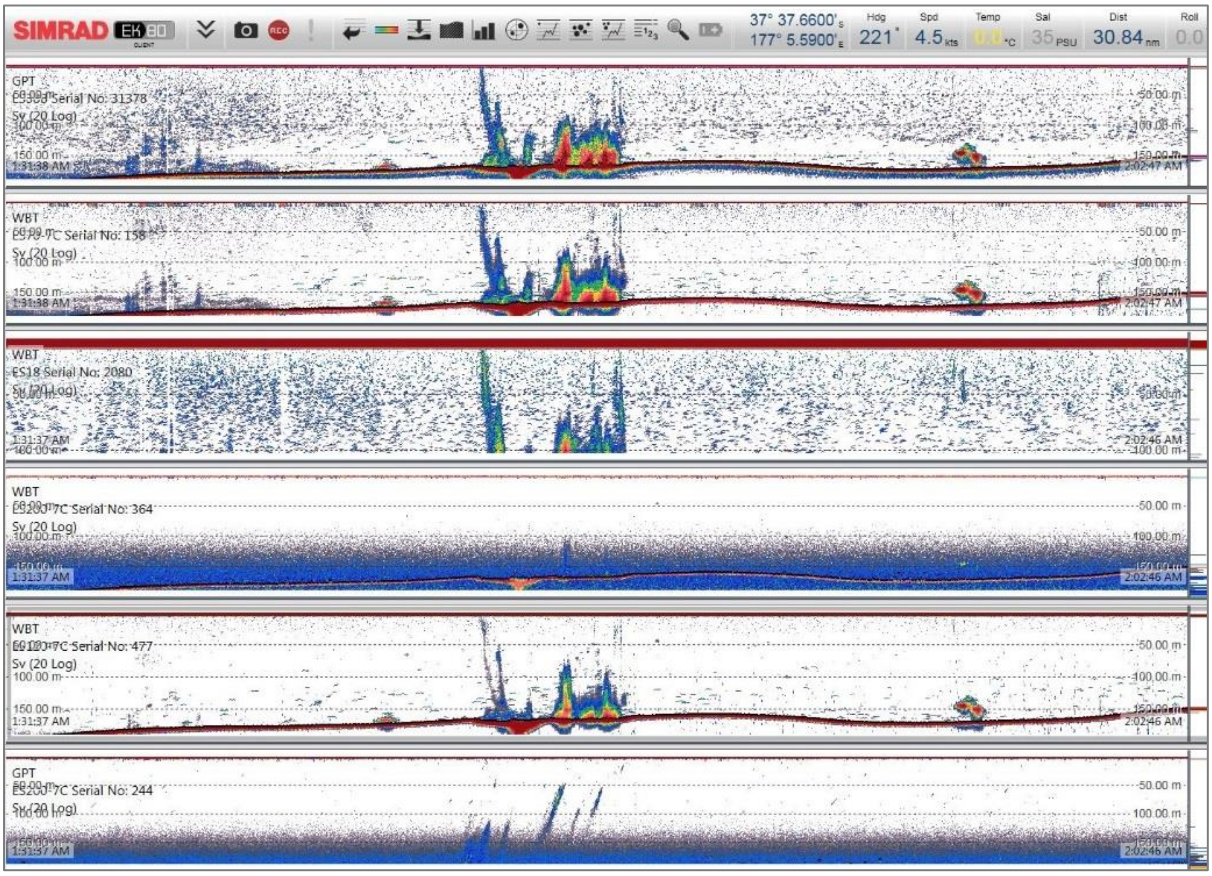


Figure 4-11 - ESP3 display of EK records along the Calypso Hydrothermal Vent Field - 8 July 2018 02:02.

4.6 Sunday 8 July

Survey at 75% completed overnight; added 2 lines to the NW to provide time to select position for Passive Acoustic Monitoring (PAM) and prepare equipment.

09:30 Wind 23 knots, cloudy, sea slightly agitated. Wind up to 60 knots, noisy data acquired during the night: ‘bad’ data on the EM302, ‘marginal’ data on the EM2040.

11:22 PAM1 (Station 12 -37°36'41''S 177°06'21"E 174m). Proceeded to deploy the PAM system in center of Flare Of Interest 1 (FOI-1). FOI-1 is an oblique flare relative to most other flares in the vicinity. Interestingly it is only identified on the *** and *** kHz records. This provides a good feature for further investigation.

13:26 CDT (station 13) with M47 & M19 transponder. 37°36'40"S 177°06'54"E Wire:164/Depth :173; objective was to sample water above the flare, water samples collected at 5 depths (166 m, 150 m, 130 m, 100 m, 10 m). This CTD needs to be redone; probes are unreliable

14:00 MBES survey NCVF; swath overlap 95%; EM302 and EM2040, EK80line spacing ~35m, speed 5knots; 2 lines not done because of Autonomous Multichannel Acoustic Recorder (AMAR) mooring; Sea conditions: getting rough, windy (→ noise because of bubbles); Last lines performed southeastward only (less noisy data)

22h pan&tilt brought up (steering difficulties); Then travel 7 knots, changed mode from dual swath fixed to off.

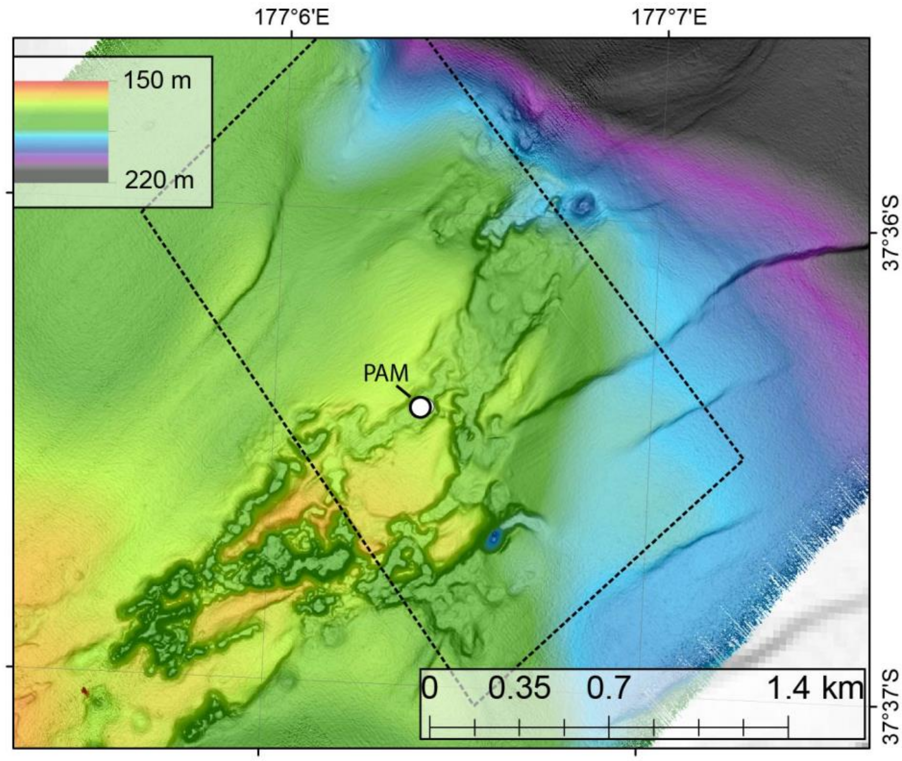


Figure 4-12 - Location of the PAM-AMAR device

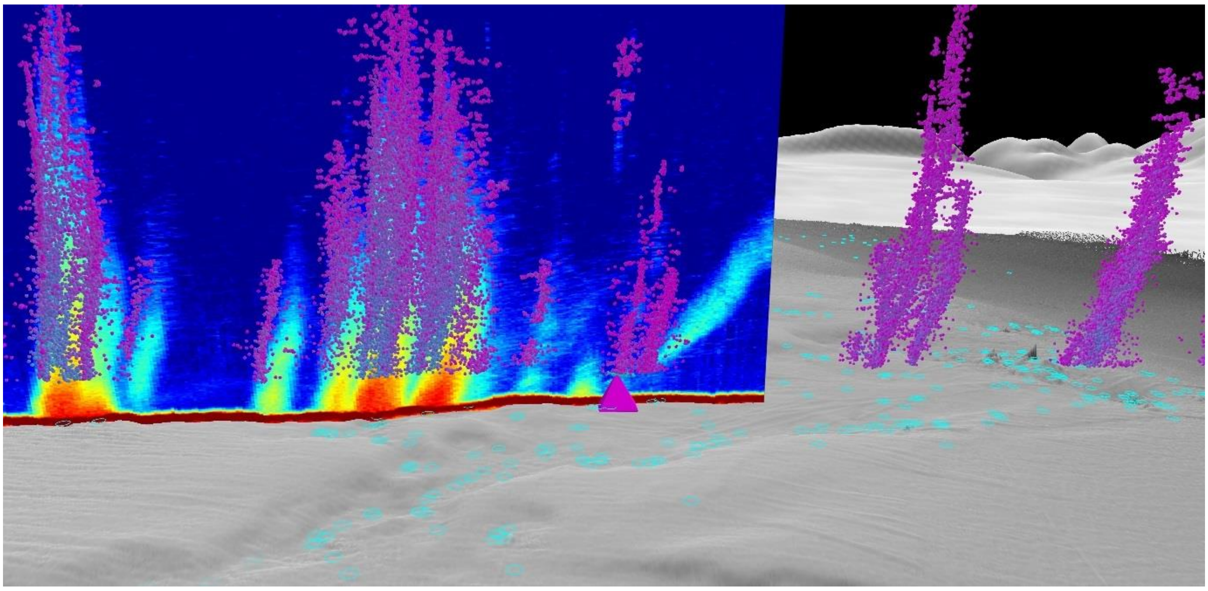


Figure 4-13 - 38 kHz vs 70 kHz over FOI-1

4.7 Monday 9 July

05:00	Transit to Motouhora; 60 knots wind; Mapping in Whakatane Graben 65% swath overlap; EM2040, EM302 and Topas
08:00	EK80 is no longer communicating with software. EK80 rebooted and fixed
10:15	Science party meeting to discuss data processing, figures and products, etc. (See minutes in Appendix XX).

Waiting few hours for the wind to drop, then transit shallow water (120m), lines ~12km long @ 4knots; very few flares

17:00 one flare observed in central Whakatane Graben, possibly corresponding to that reported in literature (Figure 4-15).

20:35 MBES mapping of Motouhora Scarp (Whakaari White Island Fault - WWIS) For flare detection only, does not require very good quality data; swath overlap 25%; 7knots, Wind up to 41 knots; Data of better quality from north to south; No flare detected along the scar; Moving on.

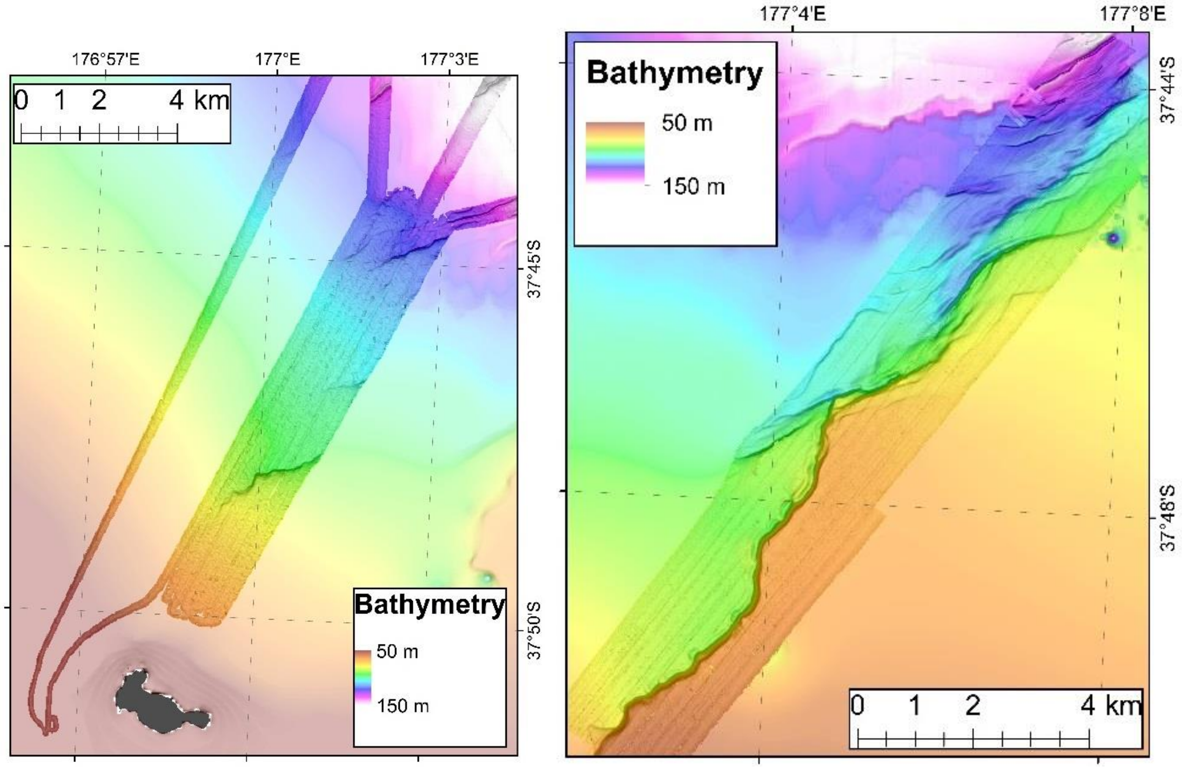


Figure 4-14 - The Whakatane Graben (left) and Whakaari-White Island Scarp (right) boxes

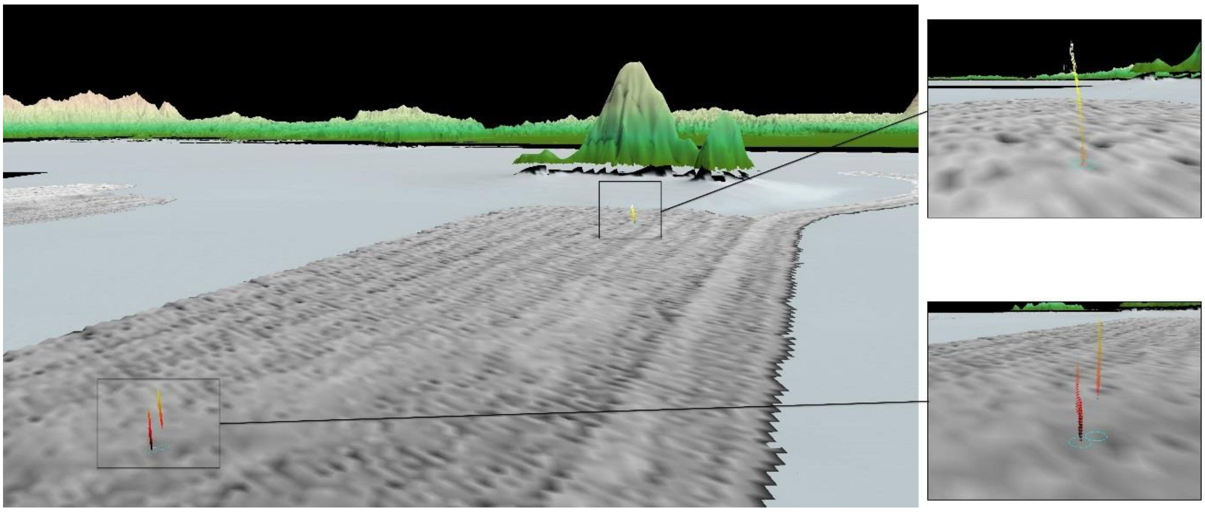
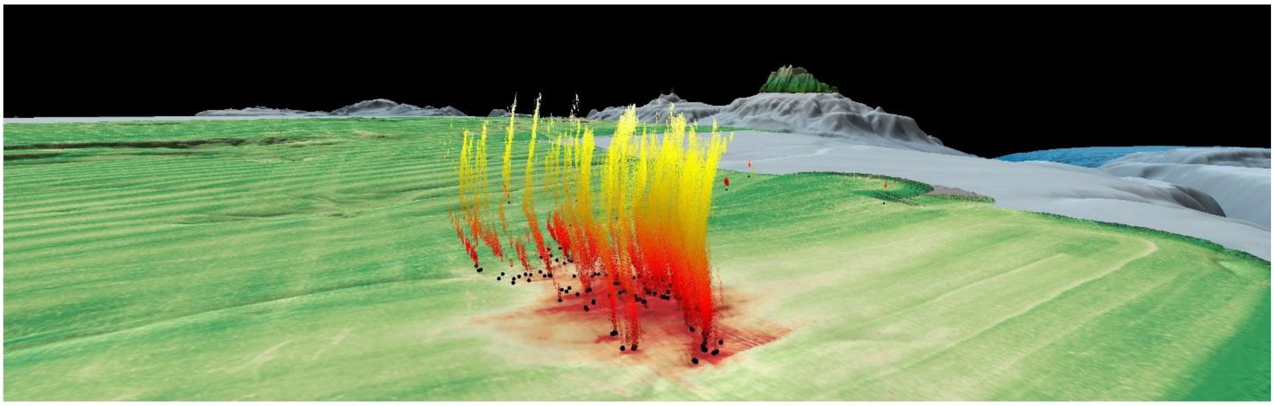


Figure 4-15 - perspective view of Whakatane Graben looking south, with Motouhora Island in the background and the two images flares.

4.8 Tuesday 10 July

Day mostly spent extending the MBES mapping of the NCVF box to the South-East; Flares observed on transit from 95% overlap area to Whakatane Graben box; Objective is flare mapping so line spacing of 1xW.D. is used. Vessel Speed c 5knt (sea state). Wind c 30 knt; W.

05:30	SVP Station 14
12:30	Survey of Southern Calypso Vent Field (SCVF) in SW-NE transects; 65% overlap (ca. 180 m line spacing). Mapping southern CHVF swath overlap 65%; 180 m line spacing; 5 knts, wind 28 knots;
16:50	Line SCVF 7: FOI2 flare identification; Line7 continues in the opposite direction, with Topas
17:48	CTD (Station 15 - 37.692S; 177.104E) over FOI2; no water sample; Three CTD casts. One in the centre of FOI-2, the other on either sides. These CTD are unreliable - probes defective.
17:55	Continue mapping SCVF; Pan&tilt @ 45deg. Wind speed decreases <24knts
	Line8 to the North: starts at 18:30
	Line9: Other intense flare, “Line8 repeat” with Topas
20:35	Station 16 CTD used as a reference (37°41.08'S; 177°07.66'E), North FOI2
21:13	CTD (Station 17 37°41.09'S; 177°07.67'E) centre FOI-2; CTD unreliable - probes defective.
21:36	CTD (Station 18 37°41.40'S; 177°06.93'E) South FOI2; CTD unreliable - probes defective.
00:15	Mapping SCVF with Pan&tilt @ 45deg.



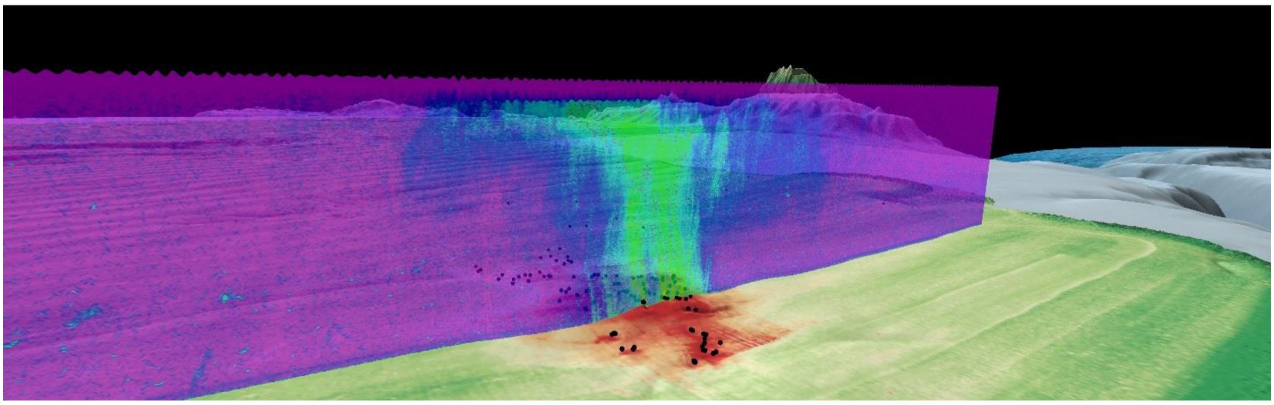


Figure 4-16 - the very impressive FOI-2

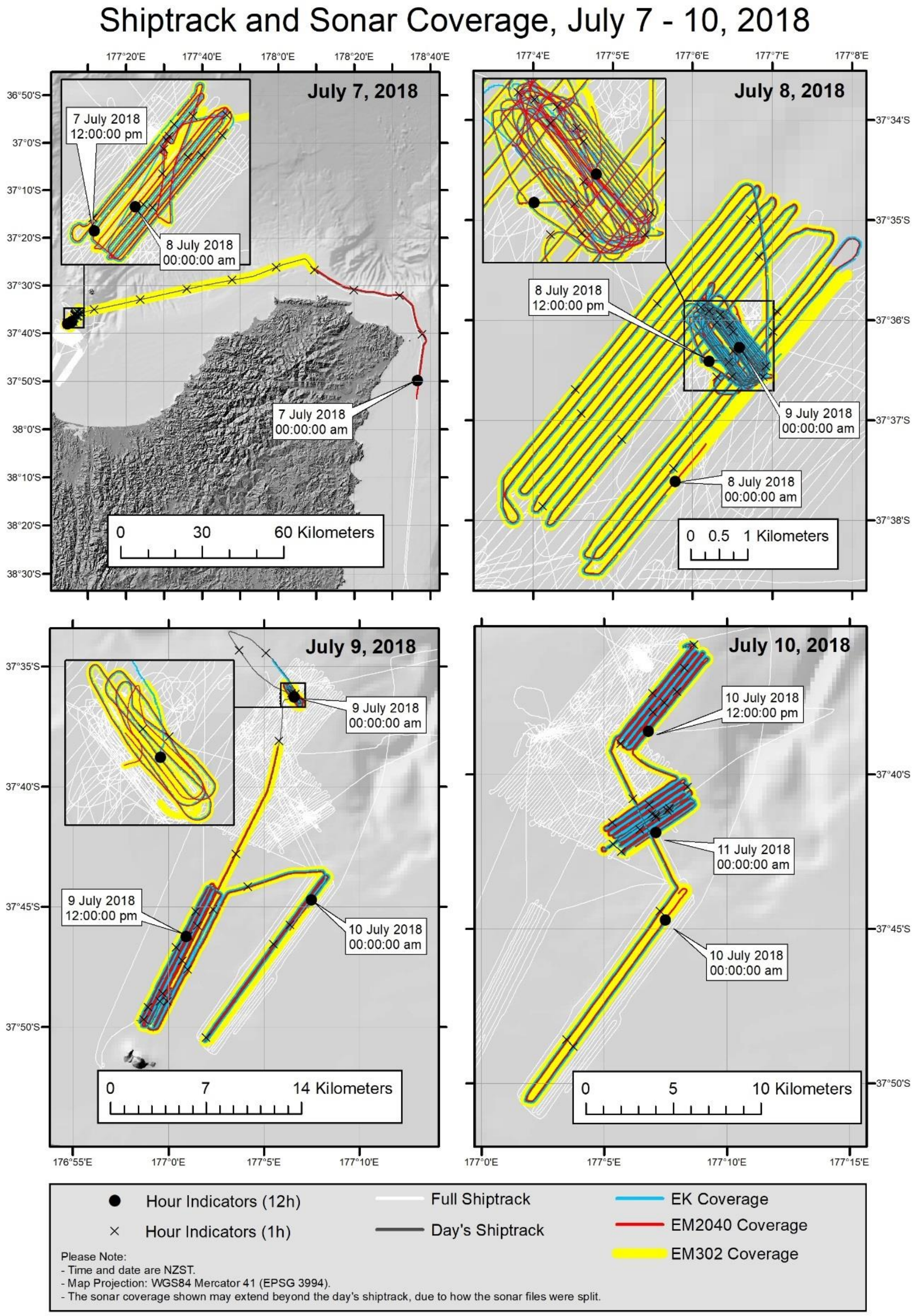


Figure 4-17 - Shiptrack and sonar coverage 7 -10 July 2018

4.9 Wednesday 11 July

Transit on site for bubble maker deployment in the early hours of the morning. Short survey over the site to ascertain absence of natural seeps in the region. A site identified and the vessel moved in position to deploy the AOS at around 7 am. This deployment is very complex and required long preparation, specific SOPs and JHAs. The rigging was mostly organised during the previous days. The deployment proceeded according to the SOP and the AOS entered the water at ca. 11.50am. Finalisation of the deployment with the second weight positioning so the AOS was directed south-westward ensued, and the deployment was completed around 2 pm.

01:51 SVP - Station 19

10:20 AOS Mooring Station 20

15:20 Bubble Maker Station 21. The position of the Bubble Maker was calculated using the 2 transponders installed on the AOS from which a position was calculated for the Bubble Maker in it enter the water at 3 pm. Deployment of the bubble maker was much easier. A buoy was attached to the bubble maker frame.

At the bubble maker location, the water depth is about 130 m and a multi-angle survey has been planned to ensonify the bubbles located at 80 mbsl at different angles, i.e. at different distances from the bubble maker (angle=atan(distance/80)).

Distance (m)	0	10	20	30	40	50	60	70	80	90
Angle (°)	0	7	14	21	27	32	37	41	45	65

Because of the current and the close vicinity of the buoy to the bubble maker, the survey was difficult and did not allow turning around the target: 8 successful lines for only 3 different angles could be acquired.

15:30 Science party meeting (See minutes in Appendix 1)

4.10 Thursday 12 July

Survey resumed with daylight but the vessel hooked the buoy tie dragging the bubble maker on the seafloor several 10s of metres. The bubble maker was retrieved immediately and very little damaged was done, with only the arm of the GoPro mount slightly bent.

AOS retrieved but unfortunately failed to record any data. The hydrophone recorded data, with saturated signals mainly related to the solenoid of the bubble maker.

00:00 SVP Station 22

12:00 CTD Station 23

09:40 CTD Station 24

Transit to FOI-2

13:20 Camera Transect - Station 25 using :

(1) camera transect across vent field: many gas bubbles of different sizes and fluid releases clearly observed, highlighting the strong activity of the site; also observed biology, with garden of red anemones;

(2) CTD measurements (16:45 - Station 26) temperature, salinity, oxygen, etc.), fluctuations along FOI-2;

(3) AOS transect 60m below vessel (water depth ~190; 18:15 Station 27); backscatter data with the EK80;
(4) Topas profiles, one on transect and one to the NW: gas observed in superficial sediments, but quality marginal; EKs recording in passive mode;
(5) 20:45 - Station 28; CTD outside FOI-2 as a reference;
(6) 21:31 Station 30 - SVP profile to control the CDT measurements;
(7) transect covered 20 times with EM302, EM 2040 and EKs (10 reciprocal lines), with 10 angles of the Pan&Tilt (0, 5, 10, 15, 20, 25, 30, 40, 50 and 60°).

4.11 Friday 13 July

Measurements with hull mounted EK80 120 kHz in the FM mode. Transit to FOI-3

11:00 AOS deployment over FOI-3 - Station 30

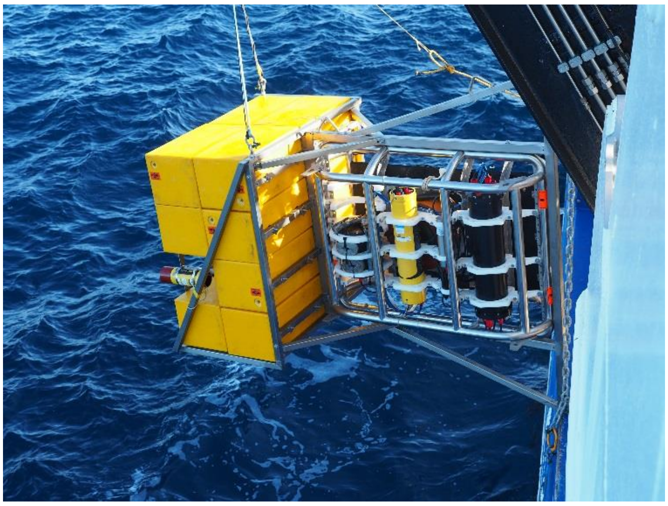


Figure 4-18 - deployment of the AOS

Retrieval of PAM system AMAR. Buoys not at surface on location. After two hours of visual search (MBES turned off), the AMAR is found and retrieved. Downloading the data took several days.

Twenty seven van Veen Grab sampling (Station 32 to 58) at different sites in accordance to specific seafloor backscatter strength patches showing different contrast with the EM302 and EM2040: the samples have been described (carbonate and biology contents, smell, sand, wood, etc.), photographed and put in bags (in a fridge) for future laboratory analyses. The operation failed few times because the tool didn't trigger when reaching the seafloor. Poor recovery rate (XX sediment samples recovered out of 27 deployments) due to numerous fail to trigger; Engineer working on it.

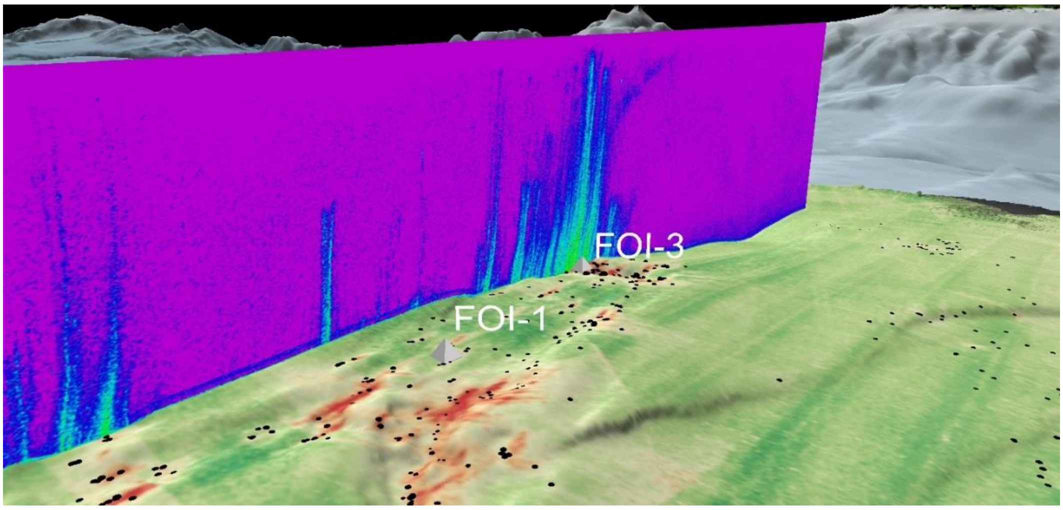


Figure 4-19 - FOI-1 and FOI-3

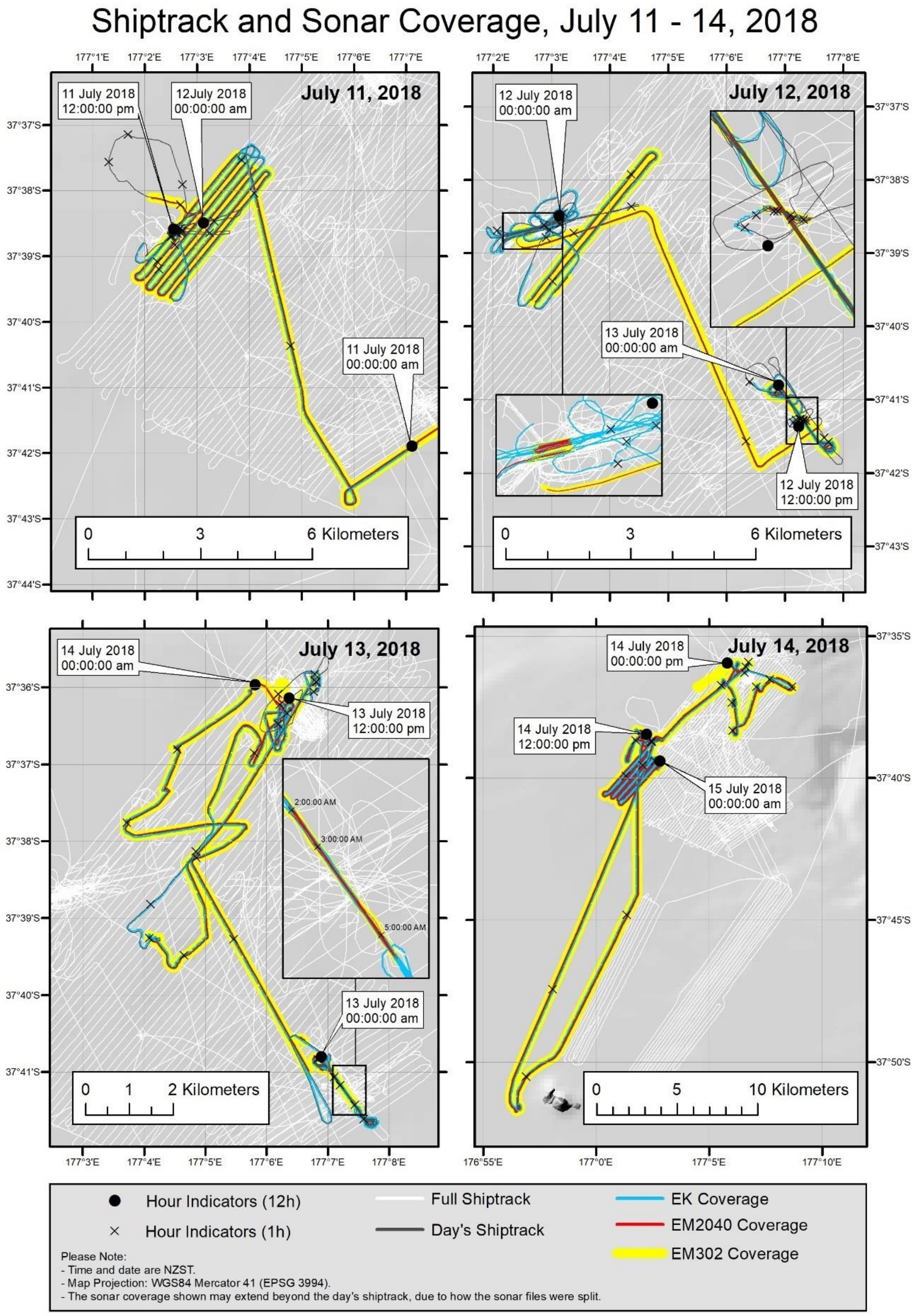


Figure 4-20 - Shiptrack and sonar coverage 11 - 14 July 2018

4.12 Saturday 14 July

06:08 Last van Vee Grab deployment (Station 58); next is second attempt to deploy the bubble maker, equipped with a light and a camera. A hydrophone has also been fixed on the frame (512 kHz sampling frequency).

11:10 Deployment of Bubble Maker (Station 59)

13:15 Seminar Peter Urban

15:30 CTD bottles; batteries and two SBE37 probes delivered by the Whakatane Coast Guard to Tangaroa on the lee side of Motouhora/Whale Island.

17:46 SVP (Station 61)

Because of fish abundancy and wind to come, the pan&tilt had been up and the bubble recovered, on board at about 20:00. The following operations have been dedicated to complete the area mapping (NCVF).

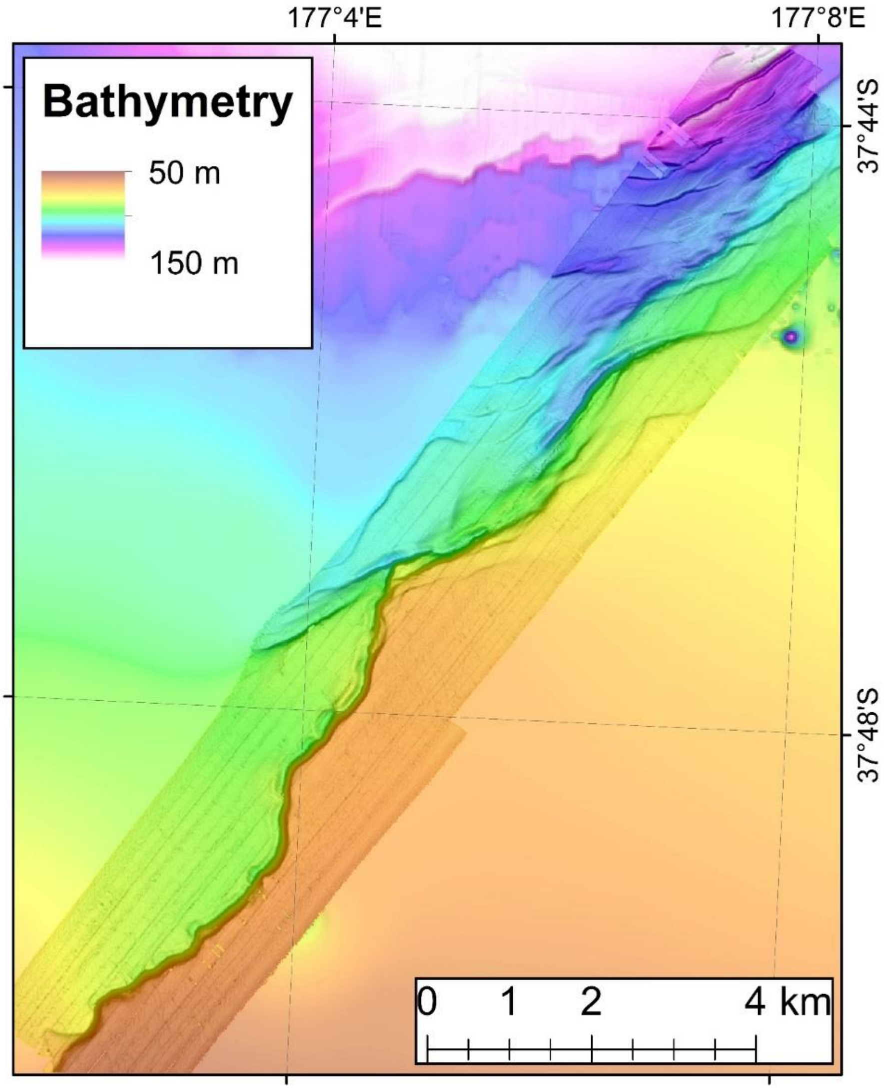


Figure 4-21 -Mapping of the Motouhora Scarp (box referred as Whakaari-White Island Scarp)

4.1 Sunday 15 July

Strong wind and swells persisting all day. Mapping continues on the NCVF and subsequently over the Whakaari-White Island Fault Scarp to complete previous transects.

13:00 Drill

14:00 Yoann Ladroit seminar on the ESP processing tools

18:00 Wind persisting above 30 knots. Mapping continues to the west side of the scarp. EM302 backscatter data noisy.

19:30 Wind abating to 20knots, last line up north of the scarp before transiting to CTD cast to test SBE37. Arriving on site, the wind started to increase (not possible to grab samples) and we continue MBES mapping to fill gaps.

4.2 Monday 16 July

Day spent on sediment grabs; testing and running the temperature and salinity probes from the CTD and camera and running one camera transect. Low wind but residual swell. Few grab samplings were done during the night when the wind calmed down, but operations were not completed (system did not always triggered). In the morning, CDT casts were resumed. The first one was located out of FOI-2, along with ADCP measurements to define the current direction, the second was performed twice to confirm the measurements. Many spikes were observed on the temperature profiles, suggesting bad quality data. The spare probe had a very low acquisition sampling rate.

01:50 CTD calibration (Station 62)

02:20 CTD calibration (Station 63)

03:30 Resume van Veen grabs; 6 stations (63 to 68); however repetitive failed; despite attempts from crew to fix the issue. Out of 6 deployments, only two were successful.

06:30 CTD testing (Stations 69 to 73) . First one located out of FOI-2, with ADCP to define current direction and two next CTDs locations.

11:25 CTD transect across FOI-2 at 0.1 knt (Station 74)

03:30 Resume van Veen grabs; 6 stations (63 to 68); however repetitive failed; despite attempts from crew to fix the issue. Out of 6 deployments, only two were successful.

06:30 CTD testing (Stations 69 to 73) . First one located out of FOI-2, with ADCP to define current direction and two next CTDs locations.

11:25 CTD transect across FOI-2 at 0.1 knt (Station 74)

13:15 Seminar Amy Nau

14:00 Re-casting of upstream and downstream CTDs completed (Station 75)

15:00 Transect camera across FOI-2 (Station 76), with both two CTD probes (SBE37 and RBR), one GoPro and Ifremer's hydrophone. RPR probe later removed as too heavy to work ballast properly. Swell a problem to keep camera on seafloor. Recording started at 15:57 in c. 190m water depth. Numerous bubble seeps observed various sizes, rates and density.

18:15 Resume the van Veen grab sampling (Stations 77 to 93), started with stations on FOI-2. Different sediment types could be identified, from muddy sand to clayish-sandy mud.

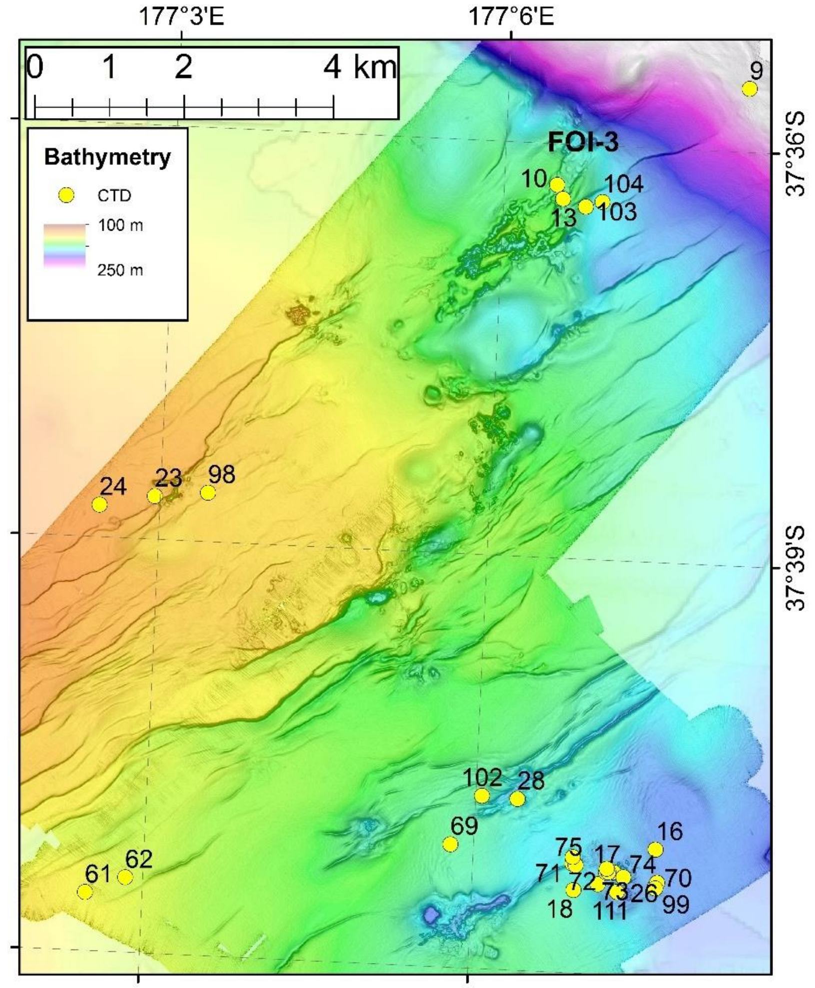


Figure 4-22 - All CTD Stations

4.3 Tuesday 17 July

Mapping at 65% overlap resumed with two more lines acquired. Calibration of the 120 kHz EK, both on the Pan&Tilt and Hull, by using a calibrated sphere. Two spheres lost during operation, but calibration successful. Camera transect over FOI-2.

Morning - calibration of 120 kHz EK sounders, both on the Pan&Tilt and Hull, by using a calibrated sphere. During the operation, two spheres have been lost.

03:30	Last Grab sampling completed (Station 93 - Figure 4-23)
14:00	CTD in FOI-2 and then a camera transect perpendicular to the one performed on the day before. Many strong bubbly sites have been observed during the 3h recording.
20:30	AOS with CTD transect across FOI-2. Strong temperature and salinity contrasts have been observed.
22:00	extension of the MBES mapping with a 65% over swath overlap to complete the study area.

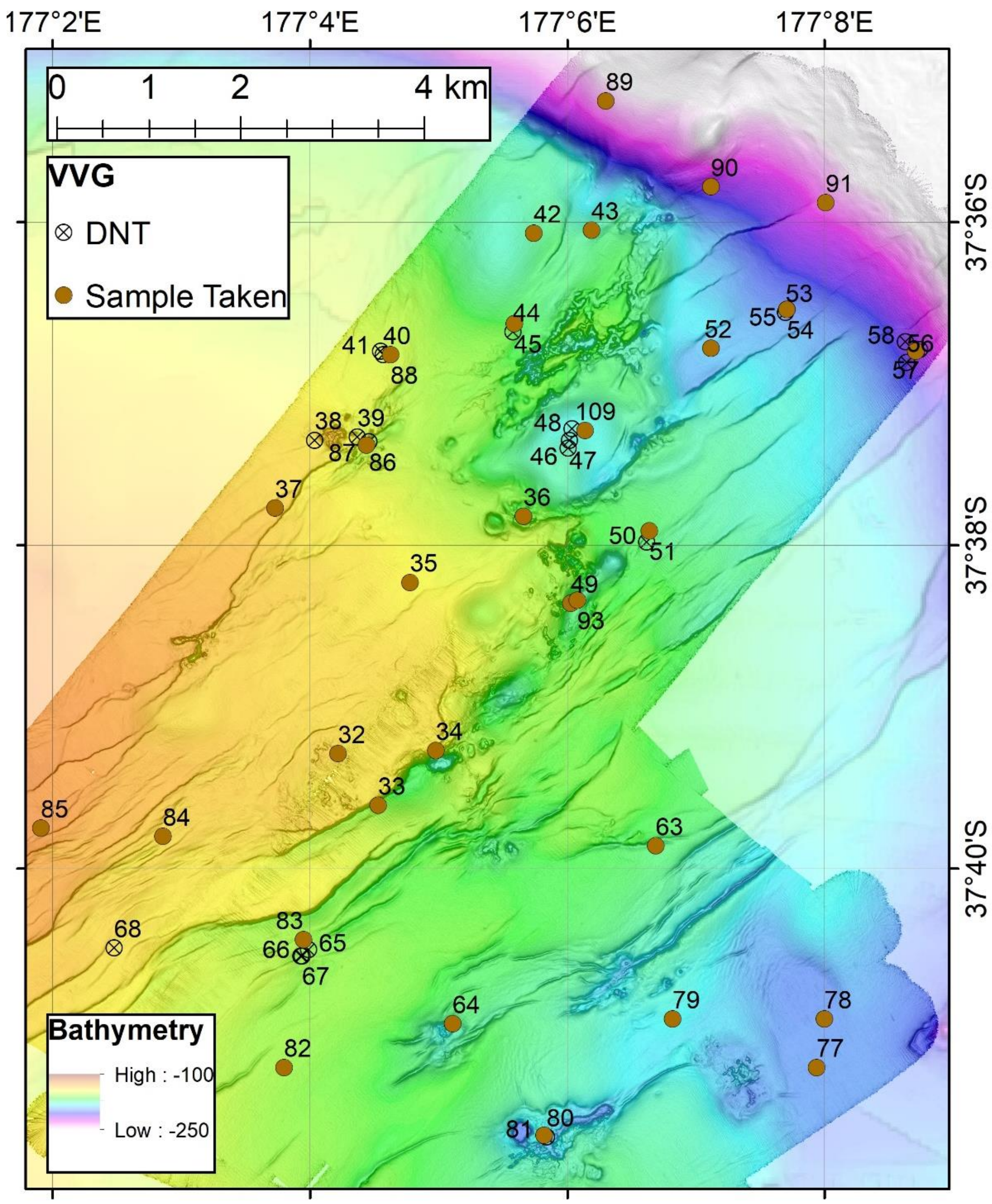


Figure 4-23 - All van Veen Grab van Veen Grab sample stations

4.4 Wednesday 18 July

07:00 DP to deploy bubble maker. Transects acquired over the bubble maker. At that time, fishes were not numerous. Multi-angle measurements started at different distances from the bubble maker. 0°, 7°, 14°, 21°, 27°, 32°, 37°, 41°, 45° and 65° for associated distances 0, 10, 20, 30, 40, 50, 60, 70, 80 and 90m. The lines were reciprocal.

10:15 Science Party meeting (See minutes in Appendix XX)

10:50 CTD (Station XX) at the bubble maker location

13:40 Resume multi-angle measurement (14°). During the measurements, the bubbles were observed on both EKs and EMs. At the end, the number of angles was increased by fixing the distance: operation took 2mn per line and about 20mn per turn. Last line done twice to study the bubble detection in the side lobe zone.

22:00 Retrieval of the bubble maker. Pan&Tilt pull up before transiting to FOI2 at 10 knots.

23:00 Four CTDs on FOI2: ADCP to determine the stream flow, one CTD located up stream out of FOI2, one in the middle of FOI2, one in the downstream direction. Since the structure of FOI2 extended to the NW, another CDT has been done at a further distance.

00:00 After the retrieval of the last CDT transit to FOI1.

Figure 4-24 - deployment of the Bubble Maker (photo G. Lamarche)

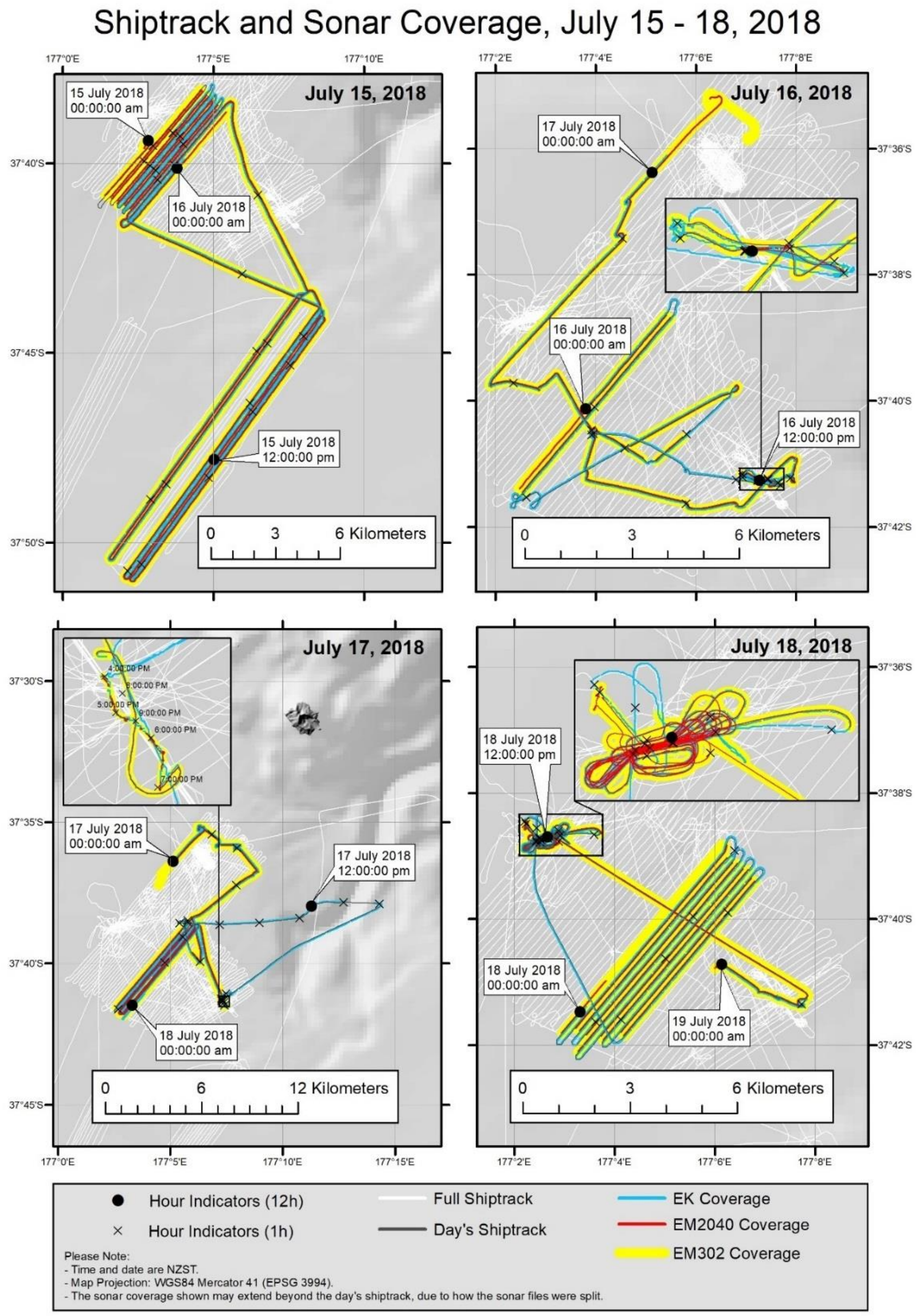


Figure 4-25 - Shiptrack and sonar coverage 15 -18 July 2018

4.5 Thursday 19 July

From 00:00 to 07:00 high swath overlap mapping with 95% of coverage. A total of 19 lines, 35m apart and 800m in length have been acquired with both the EM302 and the ME2040.

07:30 after the preparation of the camera trawler, the GoPro and the hydrophone, the system has been deployed at about 9:00 on FOI1. The sea conditions were good, with no wind.

11:20 the camera was on board and prepared for a second transit, perpendicular to the previous one.

13:15 seminar: Arne Pallentin on “Comparison seafloor backscatter from an EM302 MBES and a 45 tilted EK60 split-beam SBES; is cross calibration a valid method?

13:45 Camera in the water for transect.

16:05 2h20 of recording already acquired

16:35 stop for 1mn over a strong bubbly vent, listened by the hydrophone. A stop has also been performed in a calm area to measure the ambient noise as a reference.

18:00 Transit for a new camera transect on FOI3. At 19:00, the cable was not well deployed but recording continued, with the observation of bubbles and bacteria.

20:00 Stop of the camera transect for a grab sampling at station 47 where the sampling did not trigger: 177 06.031’E/37 37.328’S.

21:20 Topas transect across geological features around FOI1. The preliminary analysis of the data did not highlight particular observation/conclusion.

22:00 After a SVP, the next operations consist in extended mapping in order to fill MBES gaps at 5knots.

4.6 Friday 20 July

Last operations in Bay of Plenty; two transects along the west and east sides of the Motouhora scarp.

14:00 Group picture on the bow with White Island in the background

14:30 Science Party meeting to discuss about data backup (see minutes in appendix).

Transit back to Wellington, 10knots, MBES et EKs are running, not the Topas.

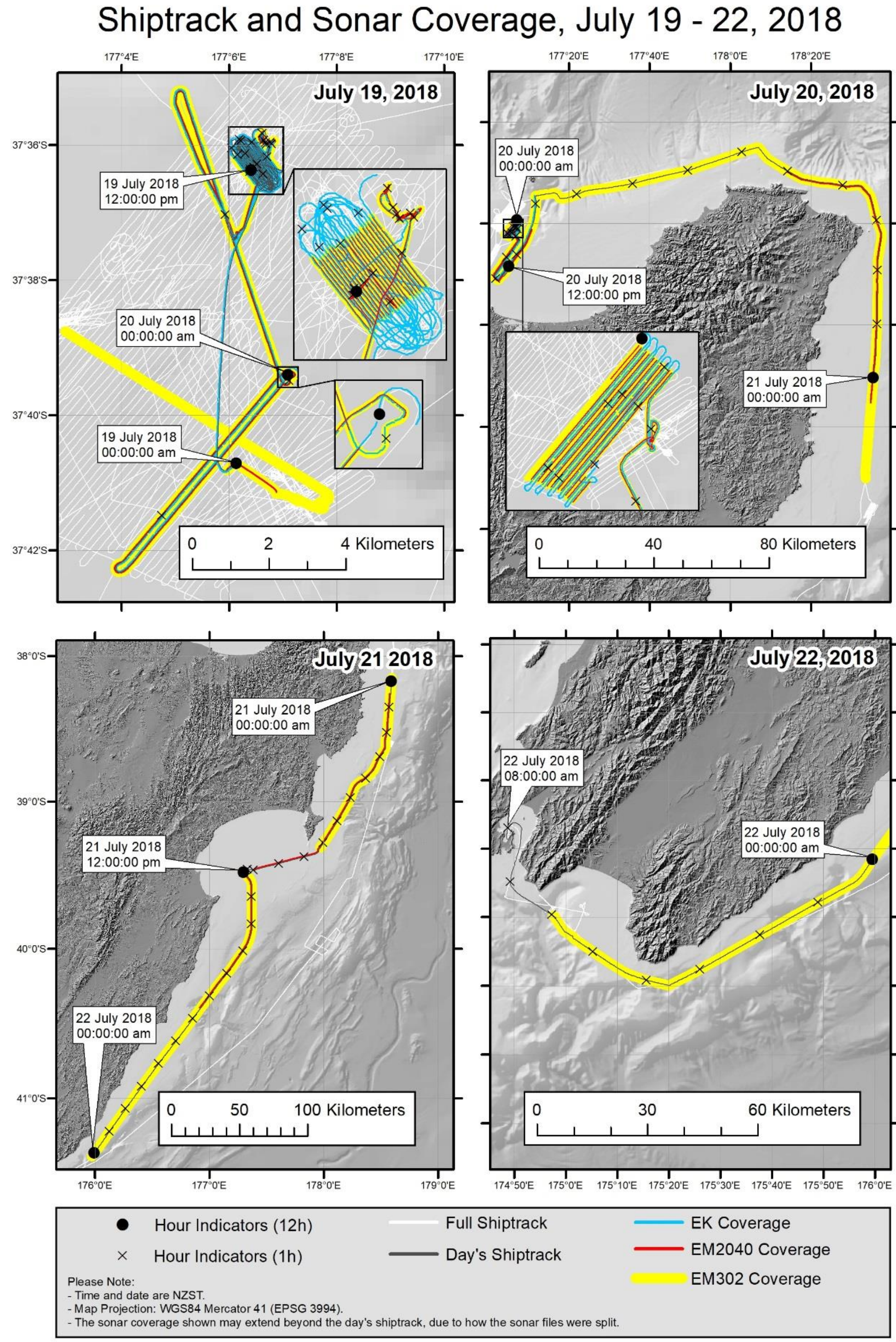


Figure 4-26 - Shiptrack and sonar coverage 9 -22 July 2018

5 EQUIPMENT

5.1 Dynamic Positioning System

In 2010 the Tangaroa was upgraded to a DP2 (Dynamic Positioning) class vessel. Stern and Bow thrusters were installed along with a retractable azimuth propeller. In addition, all electronic devices and positioning systems supplying the DP system with data have corresponding redundancies that are automatically activated when a fault occurs. When in DP operations the R.V. Tangaroa can hold a given geographical position within 2.5m in up to 35 knots of wind. DP can also provide controlled maneuverability when travelling at low speeds.

During the QUOI voyage DP was used during mooring deployments, tow camera runs, and Van Veen grab operations.

5.2 High Precision Acoustic Positioning (HiPAP) System

The Tangaroa is equipped with a HiPAP 500 system. This Ultra Short Base Line (USBL) acoustic positioning system provides the capability to calculate a geographical position for submerged objects equipment with a HiPAP transponder.

NIWA supplied 5 transponders for the QUOI voyage. 2 cNode MiniS 34-40V transponders with the corresponding ID codes of M19 and M47 along with 3 older MST transponders using the ID codes of B12 and B14.

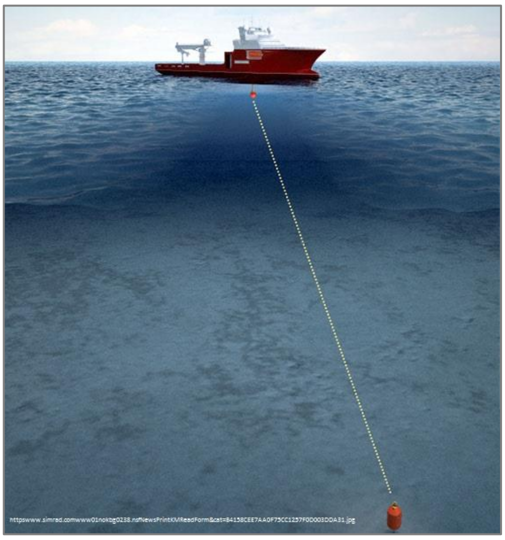


Figure 5-1 -HiPAP system in operation (left) cNode transponder (right)

All HiPAP positioning was recorded during deployments. It is important to note that there is an offset in the position recorded by the NaviPac software and therefore should not be used. For correct, un-offset, positions it is advised that either the NetCDF files or converted .csv files are used.

5.3 AOS Mooring

The frame for the AOS mooring was designed and built in-house at NIWA. The upper end of the frame housed 14 syntactic foam floats each with a buoyancy of about 21kg in water and a weight of about 40kg in air. The frame was constructed of 30mm stainless steel square tube with a wall thickness of about 1.5mm. All holes through the frame were strengthened by welded tube. Two 16mm eyes were fixed diagonally to the top of the frame and a 10mm Dyneema bridle was shackled between the eyes to facilitate lifting (Figure 5-2).

The AOS was bolted into the deployment frame which was lying on its side in the cutaway. Two HPR beacons were secured to the flotation to allow accurate positioning of the mooring (Figure 5-2).

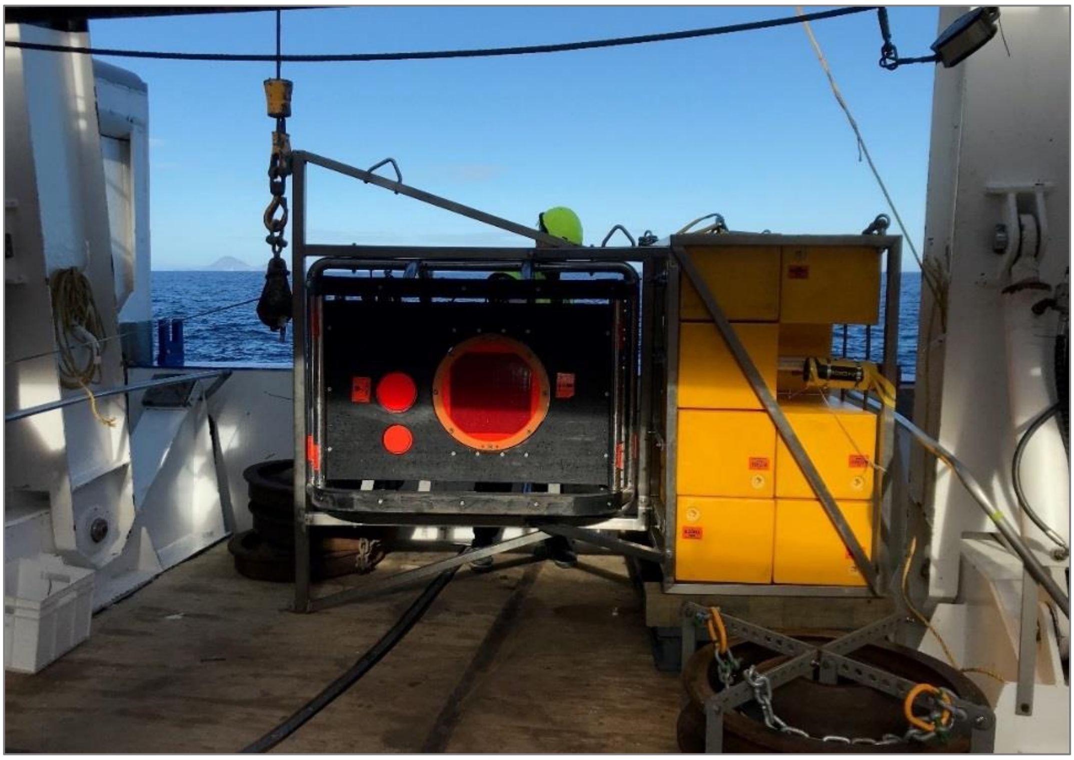


Figure 5-2 AOS fitted to the frame on deck ready for deployment. The two sets of bottom weights are also visible.

Figure 5-3 - The two HiPAP beacons secured to the frame.

The first bottom weight (approximately 375 kg) with a HiPAP beacon secured to the chain above the weights was attached to the first 42m rope length and lowered into the water. The upper end of the rope was then shackled to the bottom end of the frame while the bridle on top of the floats was attached to the A-frame winch wire with a quick-release. The next 42m rope section was then attached to the upper end of the frame which was lifted using the crane and the A-frame winch and lowered into the water until the floats were just at the surface. The quick release was then triggered.

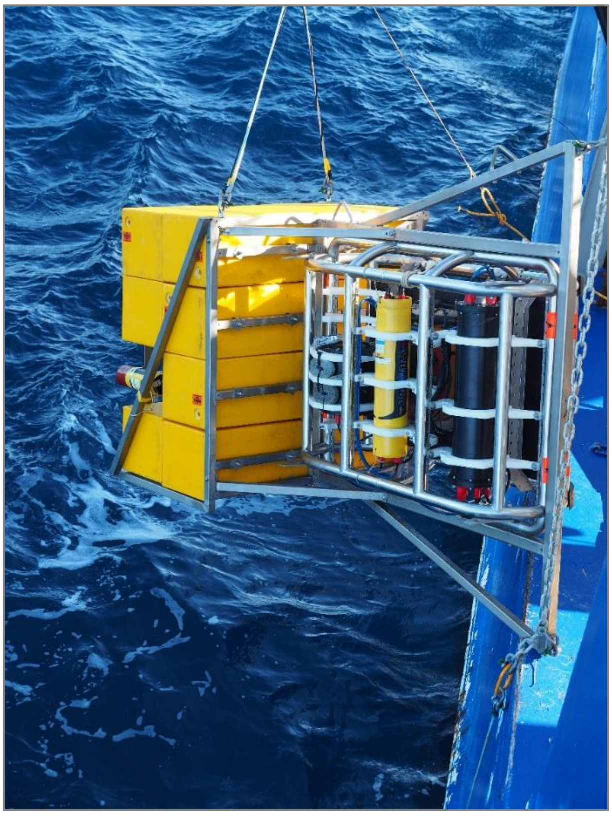


Figure 5-4 - AOS being lowered into the water.

This left the full weight of the mooring on the Dyneema rope supported by the block on the crane hook. The second 42m length of Dyneema was then paid out and the second bottom weight was attached to the line. At this point the weight of the mooring in water was approximately 1400kg. The third section of Dyneema (100m) was then paid out until a 3m section of 13mm chain was reached. Three Viny 12B-3 floats were shackled to this chain and the following 150m length of Dyneema was paid out until the second bottom weight was on the seabed. The ship was then maneuvered using DP so that the AOS was about 30m off the bottom and floating above the midpoint of the two weights. The Dyneema continued to be paid out and a recovery float was attached to another short length of chain at the end of this section. This was followed by a 25m section of rope with a single Viny float attached completing the mooring.

Recovery of the mooring was essentially the reverse of the deployment. The recovery floats were brought aboard and the mooring rope was wound onto the sweep winch, removing the floats as required, until the first bottom weight was at the wave gate. The crane was swung inboard and the weight was unshackled from the chain and dragged out of the way. The crane was swung outboard again and the recovery continued until the AOS frame was at the surface. A boathook was used to hold the lifting bridle while a hook attached to the A-frame winch was secured to the eye in the bridle. The frame was then lifted aboard using both the crane and the A-frame winch working in unison. The mooring line was unshackled from the chain on the base of the AOS frame and the crane was used to lift the frame out of the cutaway onto the deck. The crane was then swung outboard to recover the final weight.

Two deployments were successfully completed during the trip with some minor changes made before the second which improved the procedure. Placing the crane outside the A-frame greatly simplified things as the crane was better able to move without being limited by the A-frame. Positioning the AOS in the correct orientation on the seabed proved to be relatively simple with the two HiPAP beacons showing position, orientation, and depth. The ship was maneuvered using DP to place the second bottom weight so the frame was at the correct depth and facing the right way.

Recommendations

Weight-first mooring deployments are inherently dangerous as if there is a breakage there is no time for people involved to get out of harm’s way. There are many problems with this mooring design, its deployment and retrieval some of which are outlined below. Some of the problems are due to the design and construction of the mooring, others are due to limitations of the vessel layout.

1. Although 10mm Dyneema as used here has a breaking strain of about 8 T, it does not have much chafe resistance. At several points during deployment it can run over sharp steel edges, especially the outer edge of the wave gate. This was partially alleviated in the second deployment by adding extra lengths of chain at the point where the AOS is attached to the

mooring line, and where the Viny floats are attached. The extra lengths of chain could be run over the wave gate edge with the Dyneema being kept clear of any edges.

2. The wave gate needs to have the original roller reinstated for this type of work, preferably without copious amounts of rust on its surface which would cause Dyneema to chafe. Alternatively, thought should be given to designing and building a removeable roller guide system which can be put in place when required.
3. Another area of concern is the steel pipe attached to the underside of the riser deck. This is too small a radius to be useful and is not long enough. During the first retrieval the mooring rope ran off the forward end of the pipe and was fortunate not to be cut.
4. The size of the AOS frame is such that there is very little space left in the cutaway to work until it is over the side. It is difficult to see how this could be improved without a complete redesign. A two-piece design with the AOS separated from the floats is a possibility. This would result in both smaller sizes and weights to deal with as the floats and AOS could be launched and retrieved separately.

Figure 5-5 - Shackle with a badly deformed thimble.

5. The weight of the frame with the AOS installed is about 950 kg and with the first bottom weight attached is about 1320 kg. With the second bottom weight attached and the frame submerged, the weight in water (taking the flotation buoyancy into account) is about 1400 kg. If a mooring rope broke or one of the splices failed the chance of injury to one or both people in the cutaway is very high. Again, it is difficult to see how to reduce this risk with the current setup. The use of glass instead of the syntactic foam floats would be one way to reduce the weight but it is difficult to see how to reduce the size unless the mooring is in two pieces as outlined above.
6. The stainless-steel thimbles used to terminate the various rope lengths are not strong enough with several being badly deformed. Stronger thimbles must be used (Figure 4).
7. The construction of the frame is too light. When lifting the frame with the Dyneema bridle the frame distorts markedly. The two lifting eyes aren't rated and this needs to be rectified before future use. The use of a bridle as a lifting point is not adequate. A much more robust frame which encloses all sides of the floats is required. A solid, rated, large diameter eye could be securely bolted or welded to the centre of the side to replace the bridle. Much heavier square tube should be used instead of the 1.5mm WT tubing currently used.
8. Severe chaffing occurred on several rope sections during the two deployments. Larger diameter or perhaps jacketed Dyneema is recommended for all the ropes.
9. Although it has been standard practise for many years, I feel it is dangerous to have to use the sweep winches for mooring deployment and recovery. The winch driver can't see what is happening and the use of a block to turn the right angle from the cutaway to the sweep winch introduces another level of complexity. A moveable winch like that used for the disturber on Tan1805 could be placed on top of the galleries. This would provide a straight path to the cutaway and would enable a direct view of what is happening in the cutaway for the winch operator.

5.4 Passive Acoustic Device

The EM302, EM2040, EK60, and TOPAS PS18 are provided by NIWA.

During the QUOI voyage, passive acoustic measurements have been performed by using two different sensors: the hydrophone icListen, deployed for few hours at different sites (on the bubble maker and on the towed camera during video transects), and the AMAR, deployed for several days in the area of FOI1.

- **AMAR**

Two Autonomous Multichannel Acoustic Recorder (AMAR) hydrophones from JASCO Applied Ltd were provided by NIWA. These instruments allow the measurement of quiet or distant acoustic events, such as noise emitted by gas bubbles in the water column: when rising to the sea surface, gas bubbles oscillate and emit characteristic acoustic signals that may be recorded by the hydrophones. The 24-bit data sampling of the AMAR gives accurate measurements of acoustic events up to 128 ksps: the memory capacity is about 1.8 TB, allowing long term measurements. Option to deploy such receivers is being discussed.

One AMAR was used to record ambient acoustic signals in FOI1, simultaneously at 128kHz/24 bits in one channel and at 440kHz/16bits in the other.

Figure 5-6 - the AMAR recorder and mooring system

- **icListen – 3500m Smart Hydrophone**

The icListen – 3500m Hydrophone is a hydrophone provided by Ifremer and allow to measure quiet or distant acoustic events, such as the noise emitted by gas bubbles in the water column: when detaching from sea floor, gas bubbles oscillate and emit characteristic acoustic signals that might be recorded by the hydrophone.

The 24-bit data sampling of the hydrophone gives accurate measurements of acoustic events up to 512 ksps. Its bandwidth start from 10 Hz to 200 kHz, it has a sensitivity of -170 dBV re.µPa (Curve detailed in Annexe Hydrophone calibration certificate C3986_U1597-reissued). One should note that a constant offset of 3db to the data recorded must be added to the recorded levels.

Its battery once charged allow a recording at full of approximately 9 hours, allowing it to be deployed with the Synthetic Seep Generator and the Camera Trawler experiments.

All data from the Hydrophone are encoded as .wav audio file (encoded between -1 and +1 volt) of one minute each. File names reflect the date and time in UTC time. Time synchronization is done before each dive with a laptop computer itself synchronized with the ship network.

In order to retrieve absolute values from the recorded data, a factor of -168 dB (V/µPa) at 10kHz should be added to data, and an inherent 20log(3) scaling factor. Thus for 10kHz, -177.5 dB shall be take into account.

Figure 5-7 the IcListen Hydrophone of Ifremer

5.5 Synthetic Seep Generator (a.k.a. Bubble Maker)

The synthetic seep generator was constructed at CCOM-UNH by Tom Weber's graduate student Kevin Rychert. The seep generator (Figure 5-8) employs a differential pressure sensor combined with a fast-response-time solenoid valve to generate individual bubbles. The size of an individual bubble can be selected to be between approximately 1-5 mm in radius by controlling the differential pressure between the solenoid input and the ambient water. The rate of bubble release is defined by the rate at which the solenoid valve is fired. A standard scuba tank is used for gas (air in the present case) storage.

Bubble generation is controlled using an Arduino microcontroller, which is mounted inside of a pressure housing along with the gas regulation system. The differential pressure threshold and solenoid fire rate are defined in the Arduino script prior to survey operations. A GoPro HERO4 camera, in a full ocean depth pressure housing, monitors the bubble generation *in-situ*. The bubble maker pressure housing and scuba tank are then mounted on a tripod so that it can be lowered to the seabed (Figure 5-9). A mooring system that has been designed so that the pick-up line is removed from the seep is used to facilitate easy recovery of the system. The mooring line is separated from the tripod via a mooring weight to avoid contamination of the water column above the bubble maker.

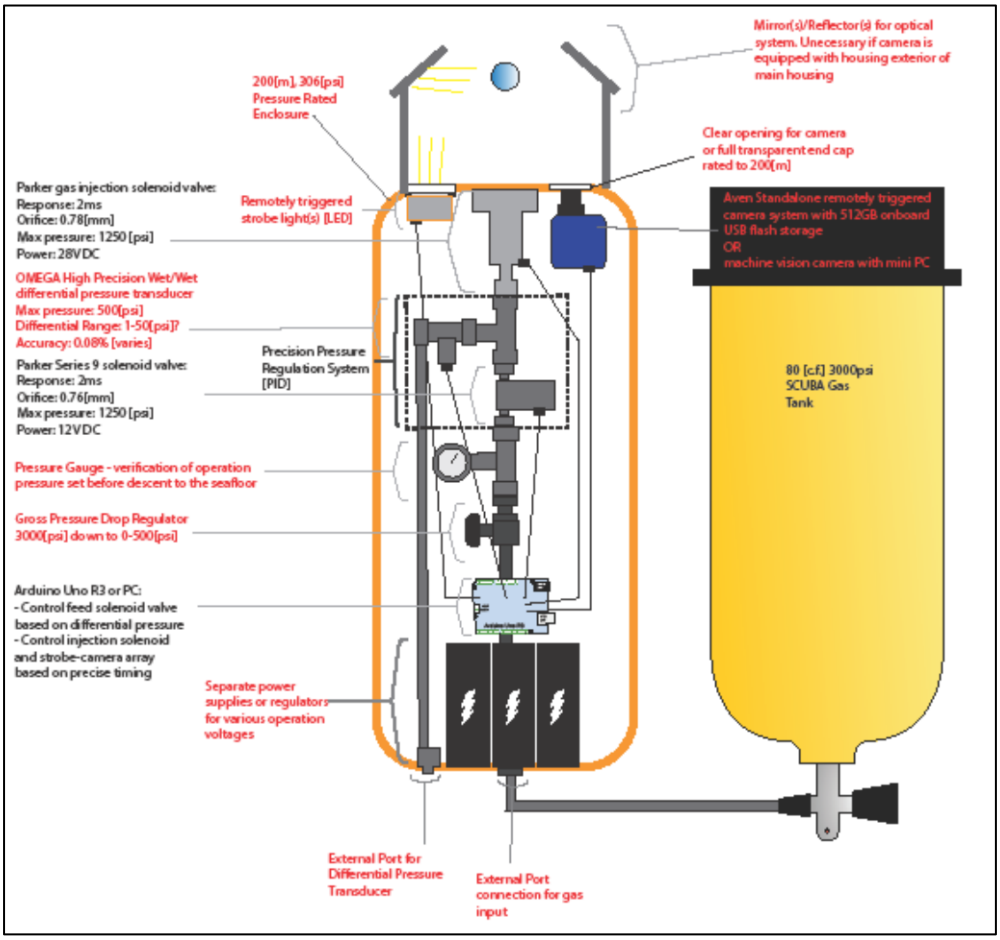


Figure 5-8 - The Synthetic Seep Generator (a.k.a. Bubble Maker) from CCOM-UNH

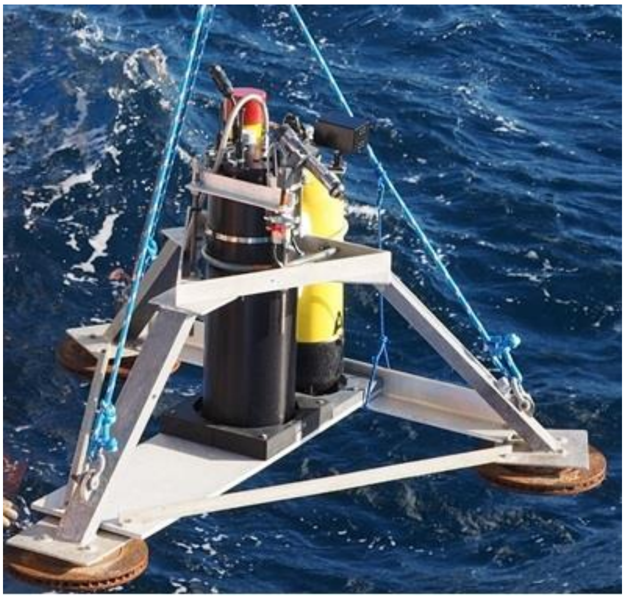


Figure 5-9. The bubble maker recovery during TAN1806 operations.

During TAN1806 operations several auxiliary systems were deployed with the bubble maker including *in-situ* video monitoring and passive acoustic monitoring (Figure 5-10, Table 5-1). The video monitoring system is made up of a GroPro and scuba dive light and was used to verify bubble generation as well as monitor bubble shape and nature during operations. A [type] hydrophone was also attached to the bubble maker tripod to acoustically monitor bubble release at the source.

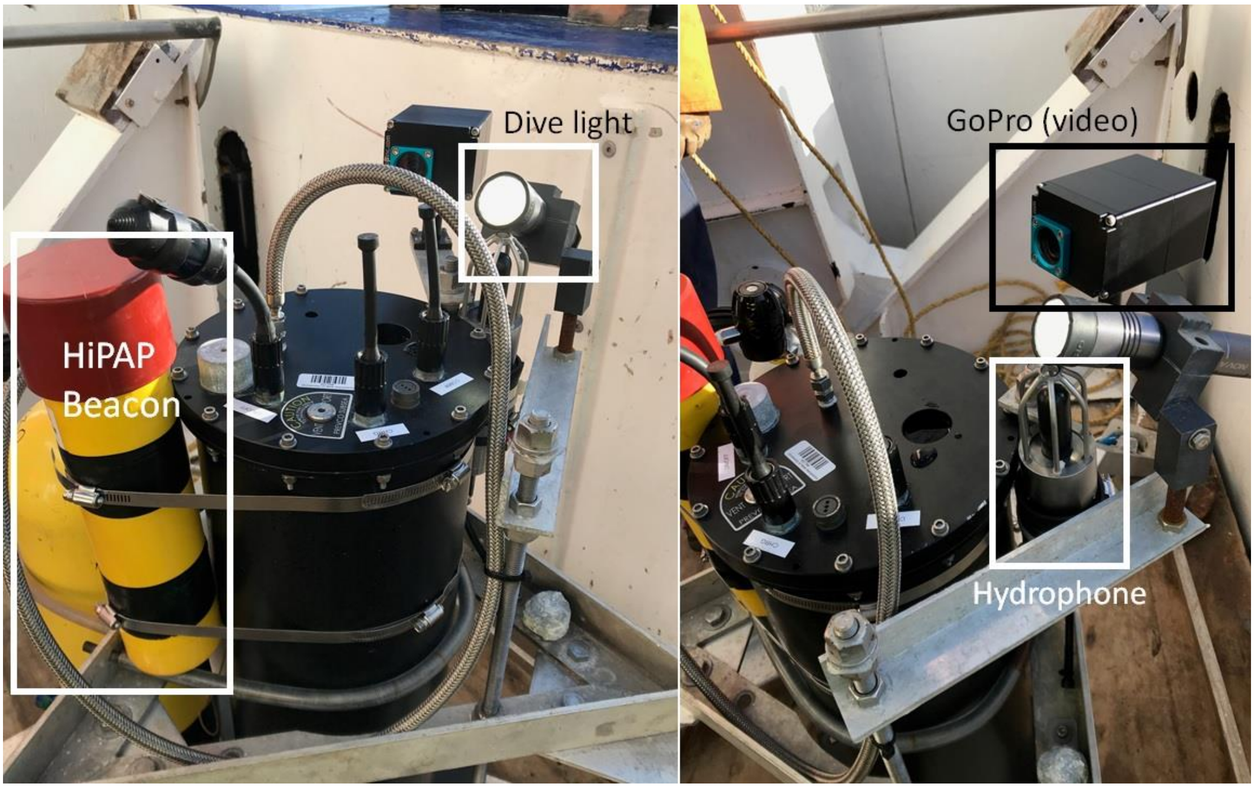


Figure 5-10. Auxiliary equipment employed during bubble maker operations: positioning beacon, video camera/dive light, and hydrophone.

Table 5-1. Description of the auxiliary equipment deployed with the bubble maker during one or more deployment operations.

Equipment	Description	Organization	D1	D2	D3
GoPro HERO4	Video camera for *in-situ* monitoring of bubble release, placed in a housing rated to full ocean depth	UNH/CCOM	X	X	X
Dive light	Diffuse light source for video collect	UNH/CCOM	X	X	X
HiPAP beacon	High precision acoustic positioning (HiPAP) beacon to monitor deployment location of the bubble maker and serve as back-up position identification is mooring floats fail	NIWA	X	X	X
[type] hydrophone		Ifermer	X	X	

5.6 CTD

An SBE 911-Plus CTD was used to collect water column data and to take water samples for methane analyses. NMEA position from the Tangaroa DAS was added to the files during acquisition. Instrumentation was as follows:

- SBE 3-plus Temperature probe
- SBE 4C Conductivity cell
- SBE 43 Oxygen sensor
- Digiquartz with TC pressure

- Seapoint fluorometer
- WETLabs SeaStar transmissometer
- Tritech altimeter

The package was lowered in a 24-bottle frame with bottle closure controlled by an SBE carousel. A HiPAP transponder was usually attached to the winch wire immediately above the CTD to allow accurate positioning of the package.

Several problems with the CTD were encountered during the trip, starting with the failure of the temperature sensor on the first cast. On recovery it was noticed that the TC duct tubing connecting the sensor to the conductivity cell was missing and the plastic tube enclosing the temperature probe had been dislodged and had broken the probe. The unit was replaced with another identical unit and the appropriate calibration coefficients were added to the con file.

The following six casts all appeared to be good with nothing obviously wrong but cast u9067 showed very spikey data with density and salinity minima at about 65m. Both the salinity and temperature data showed considerable fluctuations at this point. Once down to 100m both traces again looked normal and the up-cast seemed to be good. There was a marked hysteresis in the down- and up-casts around the 60m mark (see Figure 1).

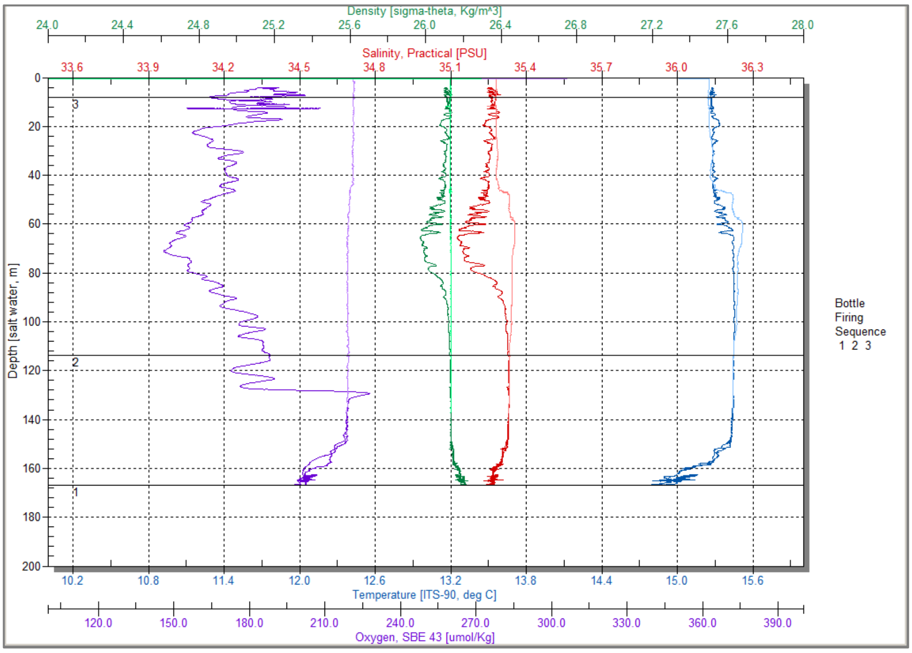


Figure 5-11 - Cast u9067 showing temperature and salinity anomalies and strong hysteresis between the up and down casts on all sensors. Note that this and the following figures show unprocessed data.

Cast u9073 was started when the CTD was at 12m depth and was immediately lowered without waiting for the sensors to equilibrate. This and the following three casts were all suspect with spikey data and marked hysteresis (example shown in Figure 2). Note also that the data appears to be unstable rather than exhibiting the usually much sharper electrical spikes associated with poor cable connections. The peaks in the salinity and temperature data also occur at the same depth.

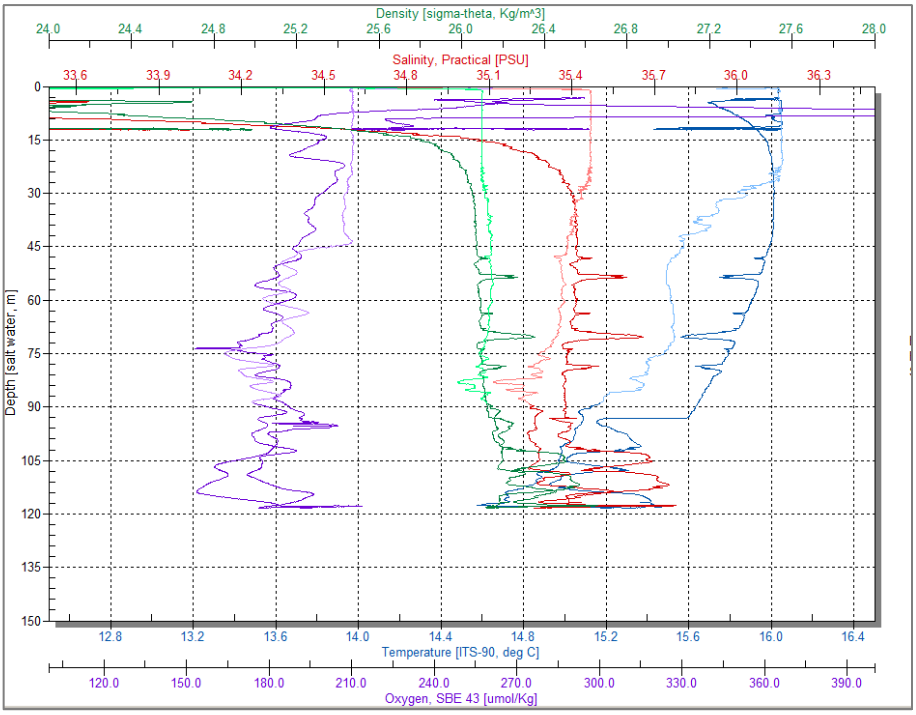


Figure 5-12 - Example of the data obtained from this (u9073) and the subsequent three casts.

The following two casts appeared ok but the down-cast on u9079 again showed highly variable temperature, salinity and density data. The up-cast was markedly different and appeared to be good (see Figure 3).

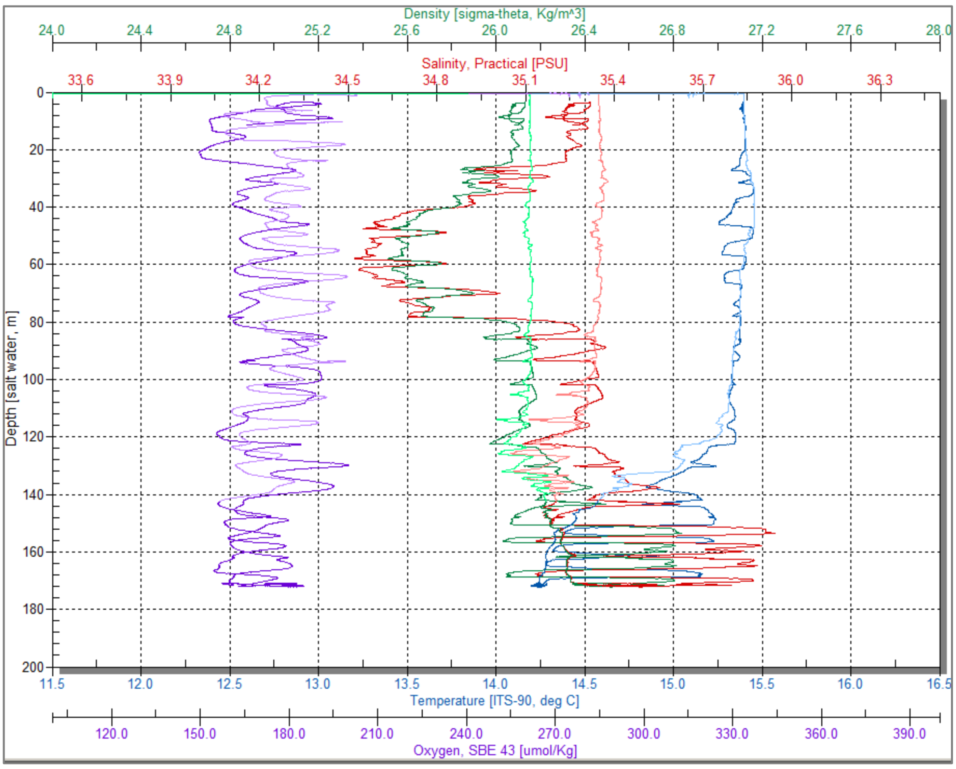


Figure 5-13 - *Data from cast u9079.*

Given the uncertainty about the CTD data, especially the temperature, it was decided to replace the temperature sensor with another SBE 3-plus and to add a SBE-37 to the package as a check. Two further casts were done with this configuration and then another SBE-37 was added along with two RBR temperature loggers as a further check. There was no improvement in the temperature data after changing to the spare sensor.

On most of the suspect casts including u9079 above, it was noted that there was a marked increase in salinity and temperature variability at about 160m. Also, in most of the casts, the up-cast looked much more stable than the down-cast.

After reviewing the data, it was decided to swap to the spare CTD after cast u9085. The altimeter and 12 bottles were taken off the original CTD and added to the spare one and the .con file was edited to reflect the changes. The first cast with the new unit showed an immediate improvement in the data with the oxygen, temperature and salinity all showing improved stability with none of the spikiness experienced with the original unit. No further problems were noted even after bottom contact was made on cast u9089, apart from bottle 11 failing to fire on cast u9093.

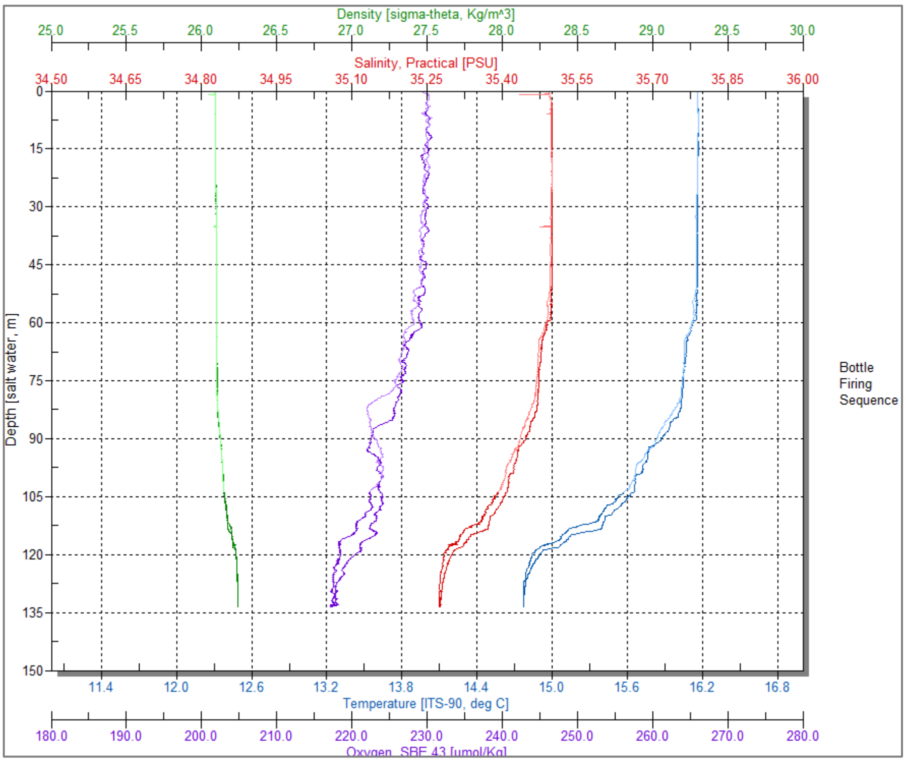


Figure 5-14 - First cast with the spare CTD (u9086).

Thirty-two CTD casts were performed; two in Palliser Bay, two at the Poverty Bay site and 28 across the Calypso site in the Bay of Plenty. Water samples were collected at nine sites for shore-based analysis of dissolved gases (methane and CO_2). Water sampling from CTD casts targeted locations where acoustic flares of interest (FOI) were detected, with a total of forty-three water samples collected (all with duplicates; Table 5-2). We collected water samples across two CTD transects ~80 m long at FOI#2. Five water column profiles were sampled for methane analysis across the Calypso Field and one at the Poverty Bay site. Water samples to test for CO_2 concentrations were collected at FOI#2 within an anomalous acoustic signal at 160 m water depth.

Table 5-2 - Locations, stations and water sampling from CTDs throughout the duration of TAN1806

Longitude	Latitude	CTD ID	Samples taken (yes/no)	Station	Depth (m)	Comments	Date time (NZST) UCT+12hrs
175.022	-41.537	U9061	no	2	121	Good cast	20180703 23:17
175.027	-41.540	U9061a2	no	3	121	Same location as U9061, recast. AKA U9062	20180704 08:02
174.986	-41.478	U9063	no	6	560	Good cast	20180704 19:49
178.593	-38.621	U9064	no	7	240	Good cast	20180706 04:25
178.562	-38.623	U9065	yes	8	186	Good cast. 5 water samples at Poverty Bay (178, 124, 74, 41, 10 m)	20170706 14:47
177.136	-37.592	U9066	yes	9	252	Good cast. 5 water samples north of Calypso Vent Field (250, 200, 155, 100, 10 m)	20170707 09:26
177.108	-37.605	U9067	yes	10	168	Suspicous sensor data on CTD. 3 water samples at FOI#1 (167, 114, 8 m)	20170707 16:10
177.109	-37.607	U9068	yes	13	173	5 water samples east of FOI#1 (166, 149, 129, 99, 9 m)	20180708 13:26
177.128	-37.687	U9069	no	15	175	Suspicious sensor data	20180710 17:27
177.134	-37.682	U9070	no	16	198	Suspicious sensor data	20180710 20:35
177.122	-37.688	U9071	no	17	197	Suspicious sensor data	20180710 21:13
177.115	-37.692	U9072	no	18	180	Suspicious sensor data	20180710 02:13
177.050	-37.645	U9073	no	23	120	Suspicious sensor data	20180712 03:00
177.042	-37.646	U9074	no	24	126	Suspicious sensor data	20180712 09:30
177.123	-37.688	U9075	yes	26	192	Suspicious sensor data. CTD transect at FOI#2, 5 water samples (186, 189, 138, 84, 38 m)	20180712 16:16
177.106	-37.680	U9076	no	28	190	Suspicious sensor data	20180712 20:41
177.041	-37.693	U9077	no	61	144	Test CTD with SBE37	20180716 01:47
177.047	-37.691	U9078	no	62	144	Suspicious sensor data	20180716 02:16
177.097	-37.685	U9079	no	69	144	Suspicious sensor data on downcast, upcast ok.	20480716 06:20
177.128	-37.690	U9080	yes	70	197	Suspicious sensor data. Upstream of FOI#2, 5 water samples (191, 170, 131, 90, 50 m)	20180716 07:30
177.115	-37.686	U9081	yes	71	188	Suspicious sensor data. Downstream of FOI#2, 5 water samples (188, 160, 122, 79, 40 m)	20180716 08:30
177.121	-37.688	U9082	no	72	188	Test CTD with 4 extra sensors (2xSBE37 & 2xRBR)	20180716 10:00
177.121	-37.688	U9083	yes	73	188	CTD transect on FOI#2, 9 water samples (185, 184, 186, 186, 182, 185, 128, 91, 39 m)	20180716 11:19
177.128	-37.689	U9084	no	74	188	Upstream of FOI#2 repeat with extra sensors	20180716 13:06
177.117	-37.686	U9085	no	75	188	Downstream of FOI#2 repeat with extra sensors	20180716 13:40
177.057	-37.644	U9086	no	98	135	New CTD test cast	20180718 10:50
177.128	-37.689	U9087	no	99	197	Good cast	20180718 22:50
177.120	-37.687	U9088	no	100	188	Good cast	20180718 23:12
177.115	-37.686	U9089	no	101	188	Good cast	20180718 23:35
177.101	-37.679	U9090	no	102	179	Good cast	20180719 00:05
177.113	-37.608	U9091	no	103	183	Good cast	20180719 01:06
177.115	-37.607	U9092	no	104	188	Good cast	20180719 07:30
177.122	-37.690	U9093	yes	111	196	Good cast. All water samples taken at 160 m (location of anomalous acoustic signal)	20180720 08:20

6 Data Acquisition Methods and Operations

6.1 Navigation

Positioning data will be the same for every sounder, including attitude compensation and transducer hull position.

RV *Tangaroa* operates three separate navigation systems:

- two of these are on the Fugro Wide Area Differential GPS (WADGPS) system, with the SeaStar 9200 unit being on the HP network and the SeaStar 8200 unit on the VBS network. Both these units receive differential corrections directly via the Pacific Ocean Region (POR) satellite or alternatively the AUSAT satellite;
- the third system is the POS/MV which is the prime navigation system for the EM302: the primary positioning system used on the RV *Tangaroa* for the EM302 is the position derived from the forward Applanix POS/MV GPS Antenna, differentially corrected by the Fugro SeaStar HP WADGPS service, transmitted from the SeaStar 9200 receiver.

The differential corrections consist of pseudo-range corrections generated by the Fugro SeaStar HP WADGPS system. These corrections are uplinked through a Fugro monitoring station and received on board the vessel via the POR satellite.

Heave and attitude are provided by an Applanix POS/MV 320 motion sensor on RV *Tangaroa*. The POS/MV generates attitude data in three axes. Measurements of roll, pitch and heading are accurate to 0.02º or better (manufacturer's specifications) regardless of the vessel latitude. Heave measurements supplied by the POS/MV maintain an accuracy of 5 % of the measured vertical displacement or ±5 cm (whichever is the larger) for movements that have a period of up to 20 seconds (manufacturer's specifications).

➢ **Software and onboard processing**

MBES data will be acquired using Kongsberg Seafloor Information System (SIS) software (currently v.4.2.1) and stored in the raw formats (*.all/*.wcd). SIS will provide planning and navigation facilities as well as data acquisition, realtime display the sounding coverage imagery, and water-column data. Through SIS Helm, we supply the bridge personnel with navigation information and survey coverage.

NIWA MBES workstations on board have available IFREMER SonarScope & GLOBE, QPS Fledermaus and QIMERA, and CARIS HIPS/SIPS. Licenses for at least one of each of these will be on board. The different packages are kept up to date, so latest versions will be available.

SonarScope & GLOBE, developed by IFREMER, are dedicated to processing of seafloor and water-column backscatter data. IFREMER staff on board will provide support and expertise in this domain (Augustin 2016); moreover they will operate the Movies 3D software suite dedicated to quantitative processing of EK80 water-column data, especially its capacities for multi-frequency analysis.

Table 6-1 - Software

Software	Organisation
CARIS HIPS/SIPS (v. 10.4 or later)	NIWA
ArcGIS Desktop (v. 10.4.1 or later	NIWA
QPS Fledermaus (v. 7.7.9 or later)	NIWA
QPS QIMERA (v. 1.6 or later)	NIWA
ESP3 (v. 0.9.3 or later)	NIWA
SonarScope, GLOBE, Movies 3D	IFREMER

CARIS HIPS/SIPS, QPS Fledermaus GeoCoder Toolbox (FMGT) and Fledermaus Midwater will also be available for processing bathymetry, seafloor and water-column backscatter data in standard workflows.

An example of flare imaging over the backscatter draped over the bathymetry is displayed in where the data have been processed both with FMGT and SonarScope software.

The acoustic data are georeferenced both in the water column and at the seafloor, providing Sound Velocity Profile (SVP) of the water column is acquired. During MBES operations, regular SVP and CTD dips will be undertaken to insure the quality of sounding data (both depth and backscatter). This will happen at the start of any mapping and either periodically or whenever the operator deems this necessary due to artefacts showing in the realtime data. Continues surface Sound Speed data is available through a tank mounted SVP and an underway seawater system including a CTD probe. The sound speed at the surface of the seawater is continuously measured and used by the MBES system to calculate departure angles at the transducer face and is also used as an indicator of sound speed changes throughout the water column.

Figure 6-1 – The Sound Velocity Profile (SVP) probe

6.2 PAM-AMAR

The AMAR was deployed on 7 July at 11:22 NZST (station PAM1) at 177.1065E/37.6067S. At the end of the acquisition period, 3790 data files have been acquired for each channel: the data format is the wav format (161 Go at 128kHz) and the duration of each file is 2mn.

In a first approach, the preliminary analysis is based on the energy content of the 128kHz recording, divided in 7s time windows in the frequency range 10-1000 Hz. The Figure 6-3 display the result of the acoustic energy recorded by the system over its deployment. The matching tides are represented on the red curve.

Long period variations of 12h are observed, related to the tide and high frequency variations may be attributed to perturbations inside the water column (fishes for instance). Note that these high frequency variations regularly appear just before and up to high tide.

We also observe a "denoisy" tide feature at the end of the experiment: this may be due to a displacement of the AMAR (see the shock at about time 100h) which has been recovered at a different location than the initial one. The aim of the experiment is identifying the acoustic signature of gas bubble released by active vents, and potential temporal variations of the activity. To better identify such a complex signature, a solution was to place an hydrophone in the close vicinity of the active vent as described in the following section.

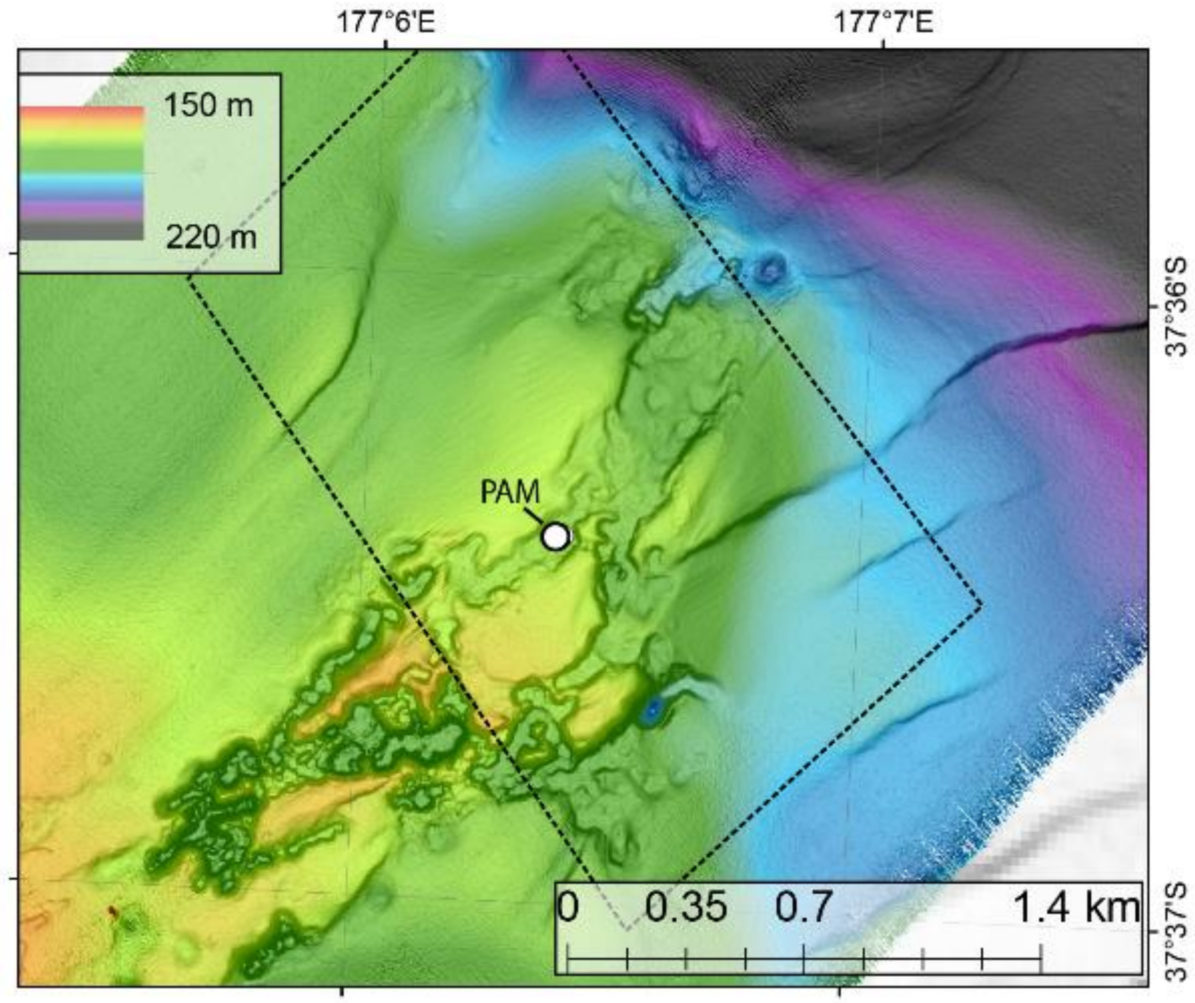


Figure 6-2 AMAR location

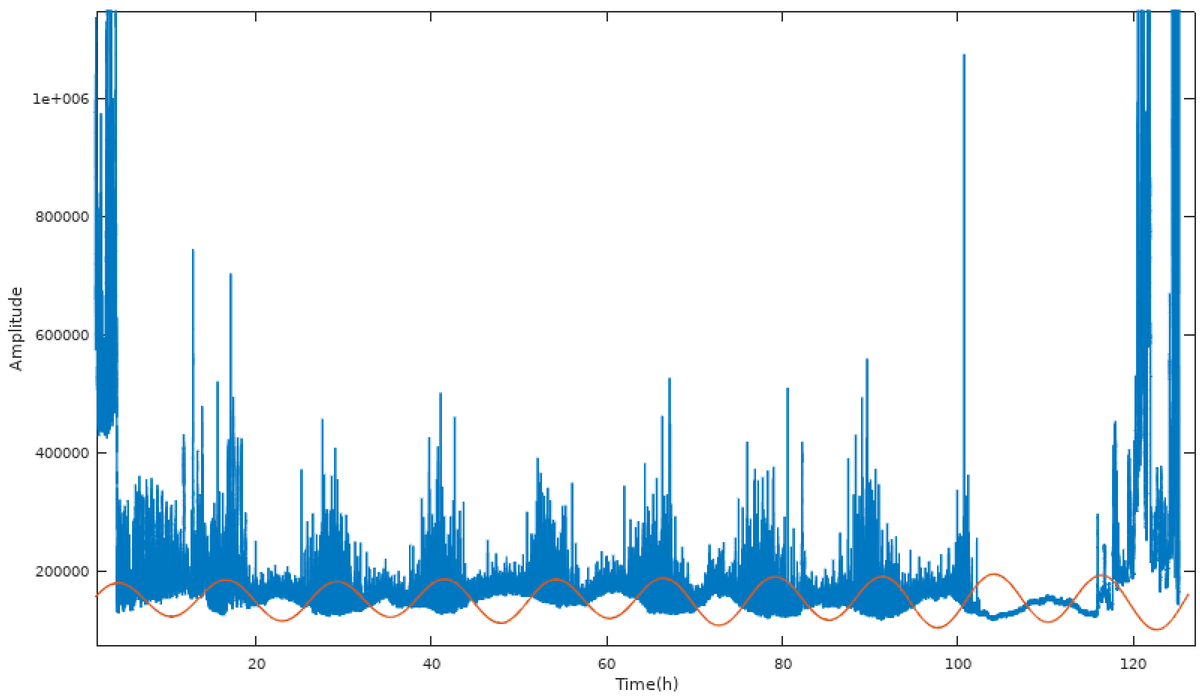


Figure 6-3 AMAR acoustics energy recorded

6.3 Echosounder calibration

Echosounder calibration is critical to enhance quantitative analysis of the acoustic data. For hull mounted echosounders, such as EM302 and EM2040 MBES, the calibration will be undertaken at the start of the voyage on shallow and medium NIWA's calibration patches in Palliser Bay and Palliser Bank, respectively (the deep seafloor calibration patch outside of Cook Strait will not be used), chosen for their depth, flat seafloor topography and known sedimentology (NIWA holds a good concentration of sediment data for the Cook Strait region). These factors allow beam pattern compensation for the used multibeam systems. Calibration of the fixed SBES on RV *Tangaroa* has been routinely done on sites in Cook Strait taking advantage of close by sheltered area in nearly all weather.

➢ **Calibration EM302**

The Kongsberg EM302 operates in several 'modes' depending on water depth. These modes are selected either manually by the operator or automatically by the software (SIS).

Table 6-2 - EM302 modes

mode	CW pulse		FM pulse	
	Single swath	Dual swath	Single swath	Dual swath
Very Shallow	Not run as backscatter is affected by near field effects of the sounder			
Shallow	✓	x	NA	NA
Medium	✓	x	NA	NA
Deep	x	x	x	x
Very Deep	x	NA	x	NA
Extra Deep	x	NA	x	NA

The TAN1806-QUOI voyage will operate in shallow and medium water depths, i.e. only four mode-settings will be run: shallow-CW-single, shallow-CW-dual, medium-CW-single and medium-CW-dual.

To generate a complete set of backscatter compensation curves for the EM302, some lines will have to be run multiple times on the two calibration patches: shallow and medium mode lines (4 times) in Palliser Bay and medium mode lines (6 times) in Palliser Bank. Each line will consist of one 'there-and-back' pair with a minimum of 300 pings each way to allow for robust statistical analysis. This number of pings will be acquired on the shallow and medium sites within ca. 15 and 30 min, respectively, according to the following runtime settings:

Sounder main tab:	Filter and gain tab:
• Wide swath • Angular coverage mode: Auto • Beam spacing: High density Equidistant • Normal coverage sector (single sector is not supported) • Dual swath mode: Off and/or dynamic, depends on user needs • Yaw stabilization: off • Pitch stab: on	• Beam intensity: Use Lamberts law • Absorption coeff. source: CTD profile • **Sector tracking= off (important!!)**

One SVP cast per site and every ca. 3h thereafter will be required.

Note: It is not clear here if the cross-calibration is conducted with a 38 kHz SBES deployed from the moonpool using P&T (for multi-angle analysis).

- **Calibration EM2040**

Calibration of the EM2040 will be undertaken in the Palliser Bay patch in c 115 mbsl. The procedure includes reciprocal lines in all settings and frequencies used on the subsequent voyage: CW mode only, medium and long pulse lengths will be selected as this is deemed sufficient for the experiment, and SVP/CTD casts (the runtime settings are similar to the EM302 described above).

As the EM2040 at this stage does not allow for beampattern files to be loaded into the PU, the acquired data will be utilized in post-processing.

- **Calibration of Split-beam echosounders (EK60, EK80, WBT Tube)**

Calibration of all split beam echosounder will be done following procedures described in the ICES document on calibration of acoustic instrument (Demer et al., 2015). All instruments will be calibrated using a 38.1mm WC (tungsten carbide) sphere in CW mode, and completed with a Copper sphere of 32mm in FM mode, in order to get a calibration value over the whole band.

For the hull systems (EK60 at 18, 38,70, 120 and 200kHz) and the transducers mounted on the pan and tilt, the sphere will be lowered on 3 spectra lines with a weight 3 meters below it, at a distance of at least 15 meters, to ensure that we are well into the far-field of all transducers. The boat will be allowed to drift and declutched to minimize the noise and to make the sphere positioning easier.

Once the sphere has been located within the beam of a sounder, it will be moved within it to obtain full coverage of the beam pattern, to control the transducer aperture. We'll then be aiming at getting a minimum of 100 pings on-axis to have a good on-axis gain estimation as well, as this is the critical parameter in the calibration. The operation will be repeated for each system, in CW and FM mode where available, using survey parameters. For each mode, calibration results and beam pattern estimation will be checked in real-time to ensure that proper results are obtained before getting the sphere back.

For the deployed system (AOS), a surface calibration will first be done, by lowering the AOS over the side, keeping communication with the instrument with a RJ45 cable. The sphere will be attached directly to the AOS frame that will be deployed facing down. As for the hull sounder, we will be trying to cover as much of the beam and get enough on-axis measurement for each of the frequencies.

For the AOS, the operation will have to be repeated at each working depth. For those calibration, the AOS will be operating in autonomous mode, lower facing down in a similar configuration than at surface, and left recording autonomously for one hour at each target depth (i.e. 50m, 100m, 150m). The operation will be done both in CW and FM mode for the 120kHz and 200kHz. Note that when calibrating in CW, all different frequencies can ping simultaneously, whereas in FM, we will be setting the echo sounders to ping sequentially.

The calibration data will analysed with NIWA's software ESP3, as well as with the build-in calibration module of the EK80 software, in order to get the best possible results and exclude any processing issue.

6.4 Split-beam Echosounders Calibration

All calibrations were done following procedure described in (Demer et al., 2015). For all frequencies we used a 38.1mm tungsten carbide sphere.

➢ AOS

All frequencies/frequency bands of the AOS was calibrated at 20 meters depth on 4 July. Those were:

- 38kHz in CW mode
- 120kHz in CW mode
- 200 kHz in CW mode
- 120 kHz in FM mode,

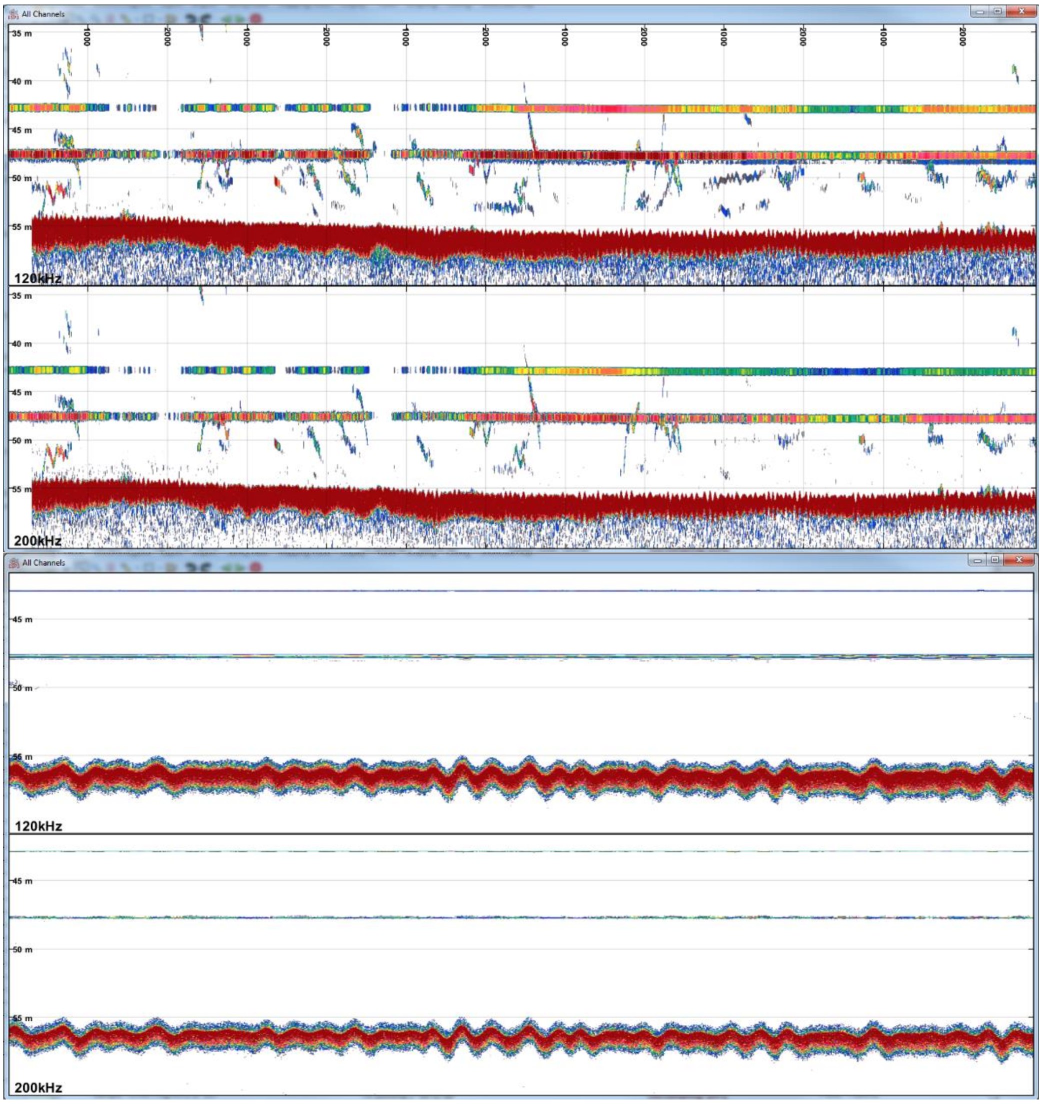


Figure 6-4. AOS calibration data collected in CW (top) and FM for the 120 kHz and 200 kHz data.

➢ Hull systems

Calibrations of the hull systems took place during the trip, on 4 and 16 July 2018. All sets of setting used for experiments data collection were calibrated. The second calibration was done, as there had been some swap done between GPT and WBT on the hull systems, meaning that not all configurations used during the survey were properly calibrated.

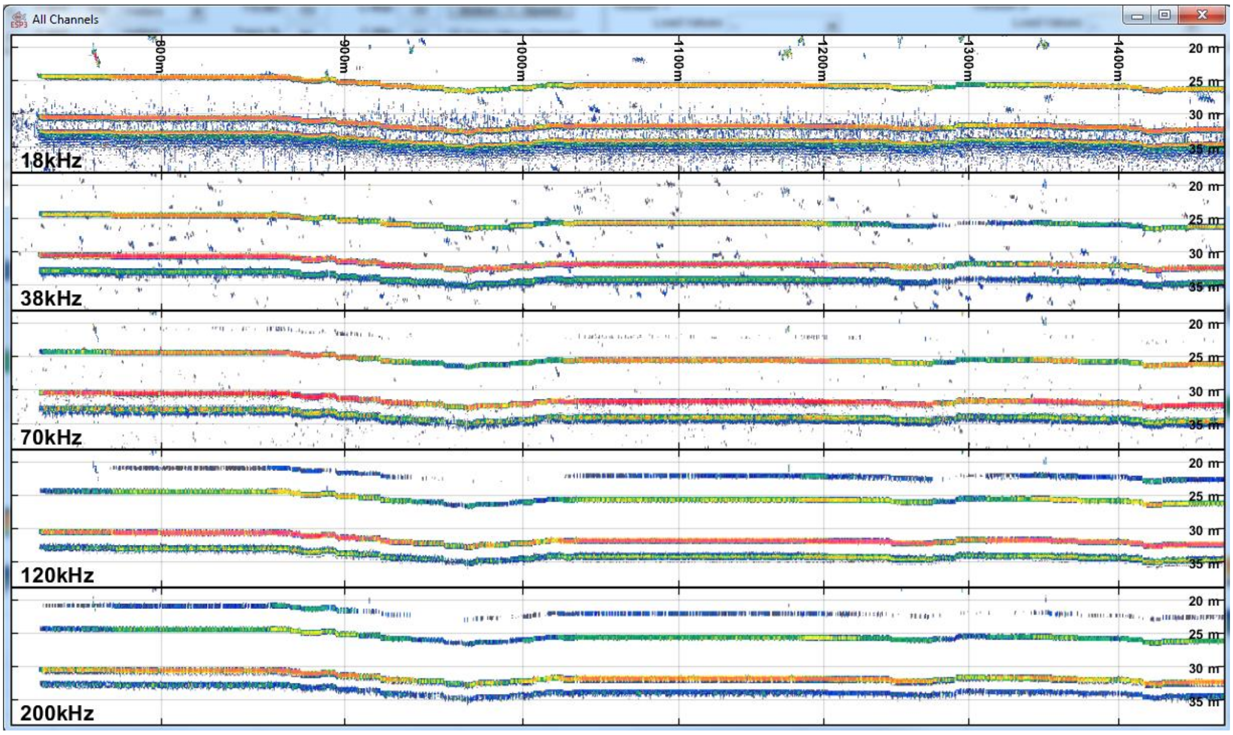


Figure 6-5. Hull calibration data collected in CW on all Frequencies.

- **Pan and Tilt**

Calibrations of the pan and tilt took place on 4 July for the 200kHz and 16 July for the 120kHz, both in CW and FM mode in both cases. Calibration was made somewhat easy using the pan and tilt to change the position of the sphere within the beam instead of moving the sphere itself.

6.5 Split-beam echo sounders acquisition

- **Acquisition settings/setups**

A summary of the various acquisition settings and transceivers/transducer configurations used during the survey is shown in Table 6-3. Figure 6-4 shows the database structure generated at the end of the survey. This database links configurations with file names and show how files can be linked to different setup (combination of transceiver/transducer) and calibration. The database is created in an SQLite format to ensure ease of access to any platform (PC, Mac, Unix…).

- **Data format and external sensors**

All data have been recorded using the software Simrad EK80 version 1.12.2 and its associated *.raw format. For WBTs, full complex signals were recorded in the standard RAW3 datagram in all cases to capture as much information as possible. For GPTs, standard power and phase data were recorded in RAW0 datagrams.

For hull and pan and tilt mounted transducer, position data were embedded in those *.raw files from the POS/MV output containing NMEA GGA, RMC for position and PASHR for motion (pitch, roll, heave).

For the AOS data, position was not embedded in the files, but depth and motion were. Motion was added using a NIWA-made motion sensor providing pitch and roll, and depth from an RBR duo sensor with its output converted to NMEA DBS sentences

Table 6-3 Setups used and calibration dates. Hull systems are in blue, Pan and tilt mounted systems in pink.

Manufacturer	Transceiver	S/N	Transducer	S/N2	Pulse	Length (ms)	Start Freq. (Hz)	End Freq.(Hz)	Power (W)	Calibration Date (UTC)
Simrad	WBT	545599	ES18	2080	FM	8.192	14000	27000	1000	04 and 16/07/2018
Simrad	WBT	545599	ES18	2080	FM	1.024	14000	27000	1000	--
Simrad	WBT	545599	ES18	2080	FM	8.192	14000	27000	2000	--
Simrad	WBT	545599	ES18	2080	CW	1.024	18000	18000	1000	--
Simrad	WBT	545599	ES18	2080	CW	1.024	18000	18000	2000	04/07/2018
Simrad	WBT	545599	ES18	2080	CW	8.192	18000	18000	2000	--
Simrad	GPT	652	ES38B	31378	CW	1.024	38000	38000	2000	04/07/2018
Simrad	WBT	720834	ES70-7C	158	FM	1.024	45000	80000	750	04/07/2018
Simrad	WBT	720834	ES70-7C	158	FM	4.096	45000	80000	750	--
Simrad	WBT	720834	ES70-7C	158	FM	1.024	45000	90000	750	--
Simrad	WBT	720834	ES70-7C	158	CW	1.024	70000	70000	750	04/07/2018
Simrad	WBT	720834	ES70-7C	158	FM	4.096	80000	45000	750	--
Simrad	WBT	720834	ES70-7C	158	FM	1.024	80000	45000	750	--
Simrad	GPT	668	ES120-7CD	999	CW	1.024	120000	120000	400	16/07/2018
Simrad	GPT	668	ES120-7CD	999	CW	0.256	120000	120000	400	--
Simrad	GPT	668	ES120-7C	477	CW	1.024	120000	120000	250	--
Simrad	WBT	549760	ES120-7C	477	FM	1.024	90000	135000	250	16/07/2018
Simrad	WBT	549760	ES120-7C	477	CW	0.256	120000	120000	250	--
Simrad	WBT	549760	ES120-7C	477	CW	1.024	120000	120000	250	--
Simrad	WBT	549760	ES120-7C	477	FM	2.048	135000	90000	250	--
Simrad	WBT	549760	ES120-7C	477	FM	4.096	135000	90000	250	--
Simrad	WBT	549760	ES120-7C	477	FM	1.024	135000	90000	250	16/07/2018
Simrad	WBT	549760	ES120-7C	477	FM	1.024	156000	90000	250	--
Simrad	WBT	737970	ES200-7C	244	FM	1.024	160000	260000	150	16/07/2018
Simrad	WBT	737970	ES200-7C	364	CW	1.024	200000	200000	150	16/07/2018
Simrad	WBT	737970	ES200-7C	244	CW	1.024	200000	200000	150	04/07/2018
Simrad	GPT	692	ES200-7C	364	CW	1.024	200000	200000	150	04/07/2018
Simrad	GPT	692	ES200-7C	244	CW	1.024	200000	200000	150	16/07/2018

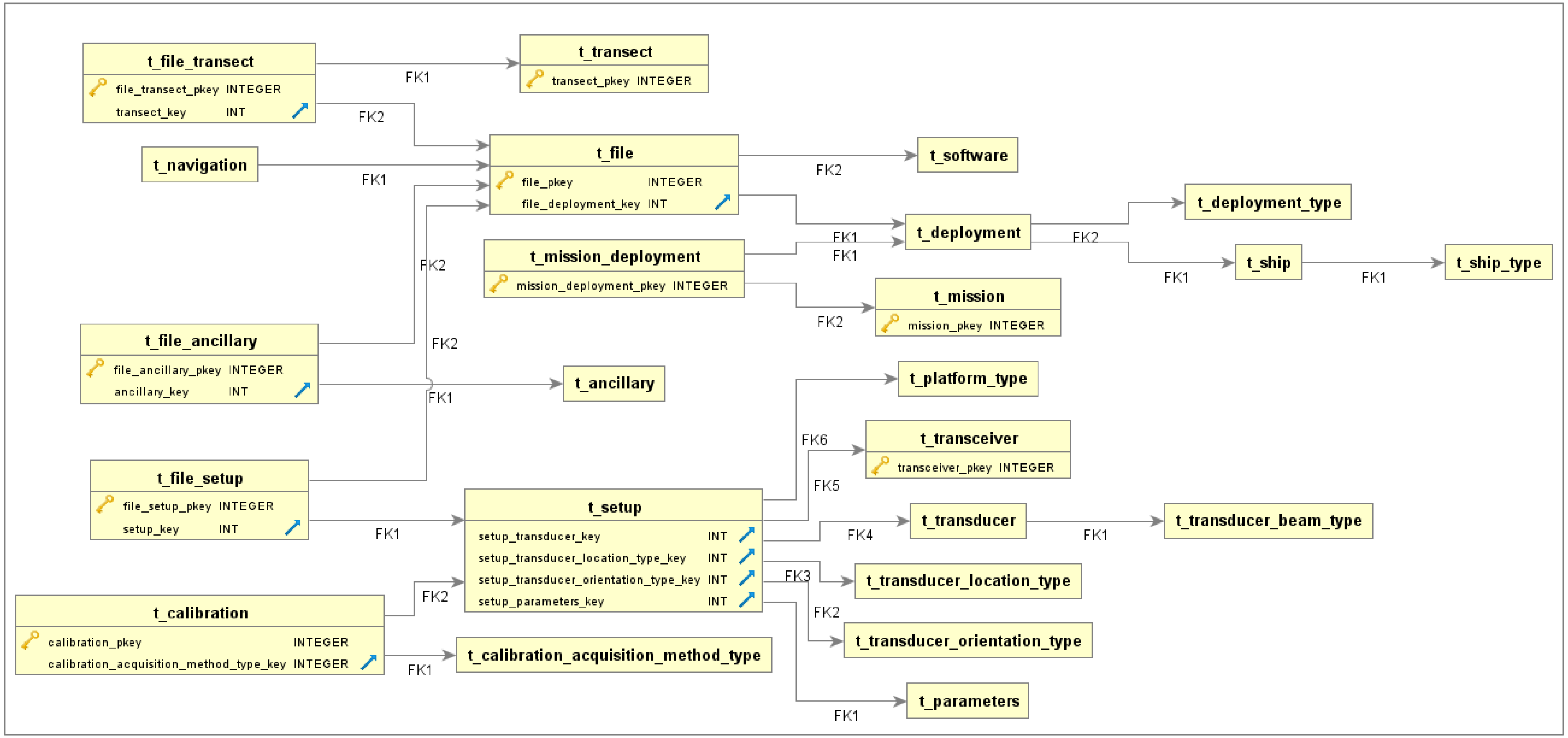


Figure 6-6 Split Beam Echo sounder metadata database structure

➢ **Total data volume and file structure**

A total of 1.46 TB of split beam acoustic data was recorded during the trip. Data were put in a simple folder structure, TAN1806/AOS/EK80 for AOS files, and TAN1806/hull/EK80 for the hull mounted and pan and tilt data.

6.6 Swath overlap MBES protocol

Both MBES mapping and survey operations aim at generating a swath overlap, defined by the ratio:

$$overlap = 100\frac{W-\delta}{W}$$

where W is the swath width at the seafloor, related to the water depth H by $W = 3.5 \times H$ (aperture 120°) and δ the distance between two consecutive lines ($\delta = W/2$ means a 50 % overlap, $\delta > W$ means no overlap). The line spacing δ is constant but to optimize the acquisition duration, the lines can be performed in a specific order (see Figure 6-8a).

The number of lines N and the associated duration D to perform a swath overlap of a rectangular seafloor area of dimensions $l \times L$ at a vessel speed v (in knots) are expressed by:

$$\mathrm{N} = \frac{\mathrm{l+W}}{\delta} \qquad \mathrm{D} = \mathrm{N}\frac{\mathrm{L}}{1.8\mathrm{v}}$$

A target at the seafloor is ensonified at different incident angles A_i ($i = -n, n$) with an increment α_i which are expressed by:

$$\mathrm{A_i} = \mathrm{atan}\frac{\mathrm{i}\delta}{\mathrm{H}} \qquad \alpha_\mathrm{i} = \mathrm{atan}\frac{\delta\mathrm{H}}{\mathrm{H}^2 + \mathrm{i(i\text{-}1)}\delta^2}$$

Note that α_i is not linear with the line number.

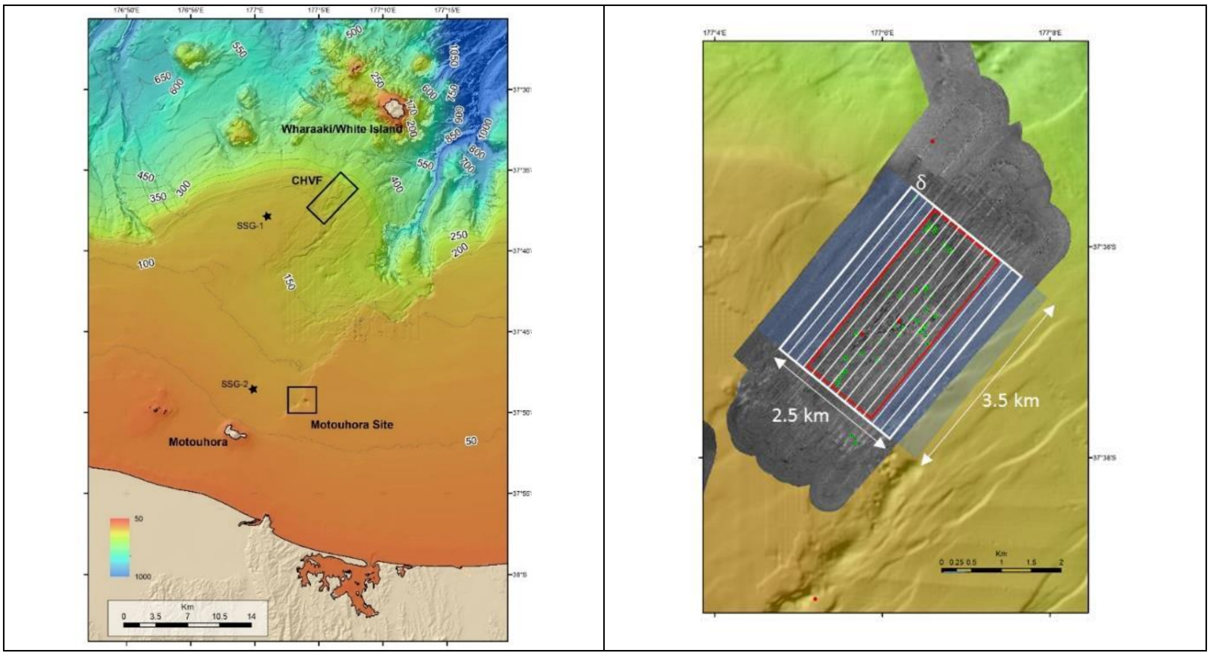


Figure 6-7 – MBES swath overlap over CHVF, Bay of Plenty

<u>Example 1</u>: for the EM302, the number of beams is 288 in a 120° fan (swath width $W = 3.5 \times H$). To perform a 50 % swath overlap of a 3x7 km area located in a 180 m water depth, $N = 12$ lines (7 km

long) are required ($D = 12$ h) but corresponds to only 3 different angles between -60° and +60° when a 95 % swath overlap allows 21 different angles.

Example 2: to perform a EM302 swath overlap of a 2x3 km area located in a 50 m water depth, $N = 25$ lines (7 km long) are required ($D = 11$ h) but corresponds to only 3 different angles between -60° and +60° when a 95 % swath overlap allows 21 different angles.

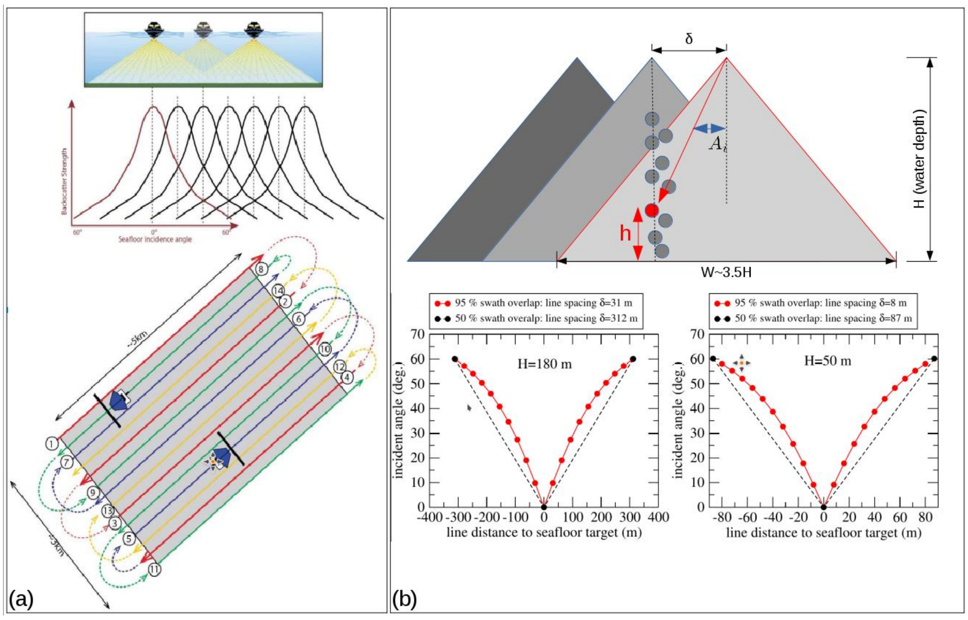


Figure 6-8 – Schematic of the MBES swath overlap principle

6.7 Multi-angle MBES protocol used in the multi-sensor experiments

To measure the backscatter strength of a target located at the seafloor with different incident beam angles and a regular angle increment α, a series of lines needs to be run with different distances between two consecutive lines. For a fan aperture of 120°, the number of lines N and the associated duration D to perform a multi-angle measurement (0.1 km long centred on the target) of at a vessel speed v (in knots) are expressed by:

$$\mathrm{N} = \frac{120}{\alpha} + 1 \qquad \qquad \mathrm{D} = \mathrm{N}\frac{0.1}{1.8\mathrm{v}}$$

A target at the seafloor is ensonified at different incident angles A_i ($i = -n, n$) with an increment α corresponding to different line distances d_i and increments δ_i which are expressed by:

$$\mathrm{A_i} = \mathrm{i}\alpha \qquad \qquad \mathrm{d_i} = \mathrm{H}\tan(\mathrm{i}\alpha) \qquad \qquad \delta_\mathrm{i} = \frac{\mathrm{H}\sin(\alpha)}{\cos(\mathrm{i}\alpha)\cos((\mathrm{i}\text{-}1)\alpha)}$$

Example3: to measure the MBES backscatter strength of a single water column target, located 20 m above the seafloor, every 5° at 4 knots in a water depth of 200 m (aperture of 120°), N=25 lines will be recorded and require 30min of measurements, the line spacing ranging between 15 and 75 m.

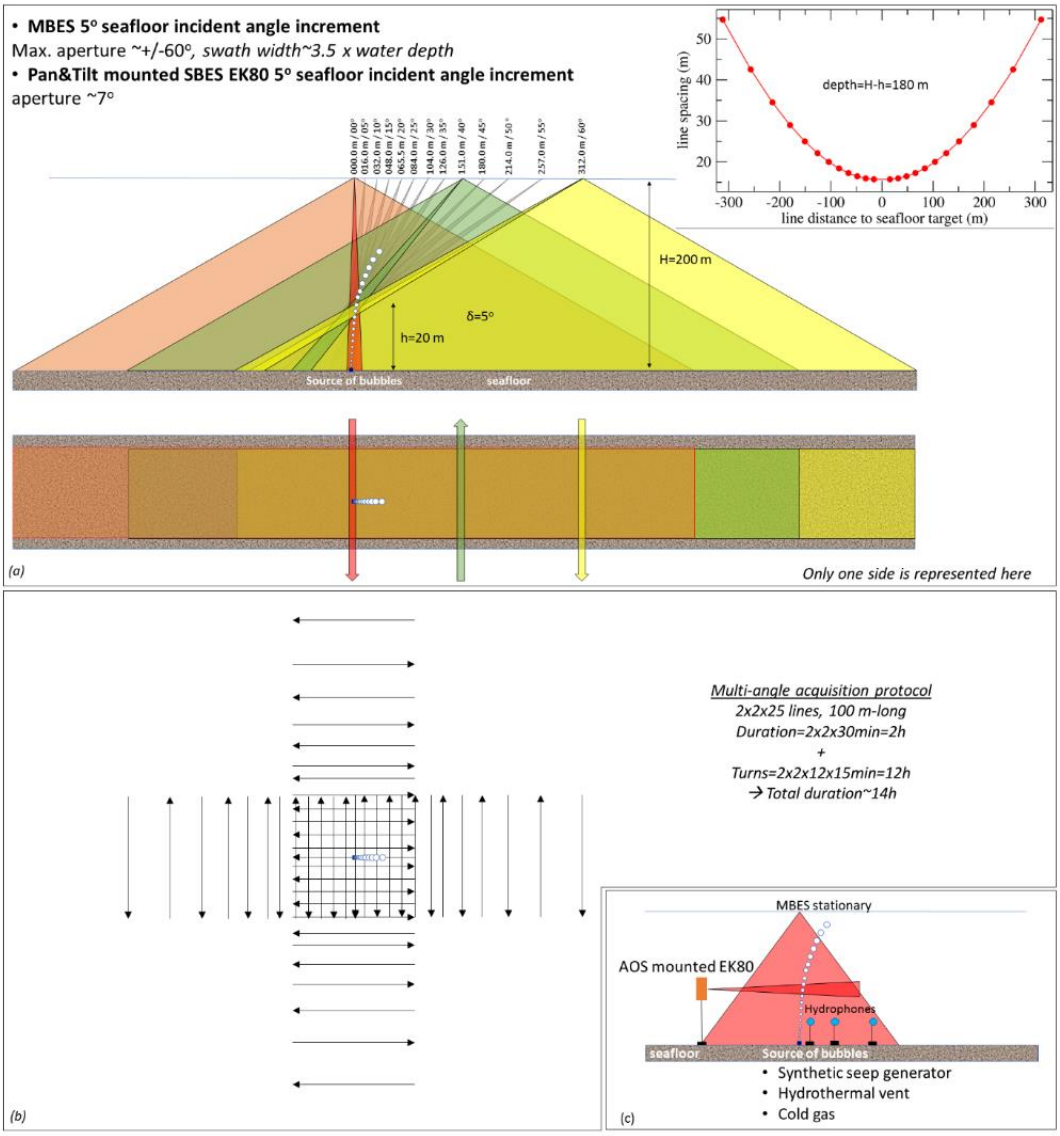


Figure 6-9 – Principles of a multi-sensor experiment on a single seep (5° incident angle increment)

6.8 Water column optimal acquisition protocol

- Synchronization: SBP, ADCP and not synchronized acoustic equipment should be turned OFF. EM2040 used as master and EM302/SBES as slaves. In case of acoustic pollution, it would be interesting to double the coverage by turning OFF the acoustic equipment generating interference;
- EM2040: central mode (single sector in the across distance ±60°), single swath and manual selection of the CW pulse duration;
- EM302: 120° aperture, single swath, CW and manual selection of the mode (shallow or medium, be careful with the automatic selection which can provide unstable acoustic levels when the depths are in the limit condition of the mode);
- Use an inter-profile distance by taking into account the water column useful swath.

6.9 Passive acoustic experiments using hydrophones

➢ **Hydrophone deployment on towed camera**

Figure 6-10 the IMAS towed camera frame

The hydrophone was mounted on the towed camera frame (Figure 6-10). This experiment identified as 20190707 (Station 11) was a short test of the towed camera in situ, it lasted ca. 30 minutes with one single line towards one of the FOI-1. No bubbles were observed on the camera which was in movement during the whole transect.

The hydrophone was deployed on 07/07/2018 05:47:00 UTC (05:47 NZT), in water at 06:09 UTC (18:09 NZT) and recorded during 32 minutes (3.5 Gbits). The hydrophone was configured at full sample rate (up to 200kHz/512 Ksps). An example of the data recorded by the hydrophone is illustrated by Figure 6-11

Two conclusions are drawn from this experiment:

1. The hydrophone is very sensitive when the trawler is moving; it generated a strong low frequency response that prevented us from having a chance to listen to bubble sounds (Bubbles being supposed to vibrate at frequencies between 1kHz to 10kHz). The source of those low frequencies can be the natural sound of the ocean, the camera movements, the currents in the ocean. Thus, for subsequent experiments a standby position on the seabed and as close as possible of bubble sources was be required to minimize the effects of the movements of the camera. We also noted that at some points, the camera movements can induce saturation of the signal preventing to hear anything at those times.
2. The hydrophone is very sensitive to the ship noise (Figure 6-11), in particular that of the Dynamic Positioning system, and of course that of hull mounted sounders. For the latest their respective frequencies being high enough (18, 38, 70,120, 200 kHz) they do not prevent from analysing the data on lower frequencies.

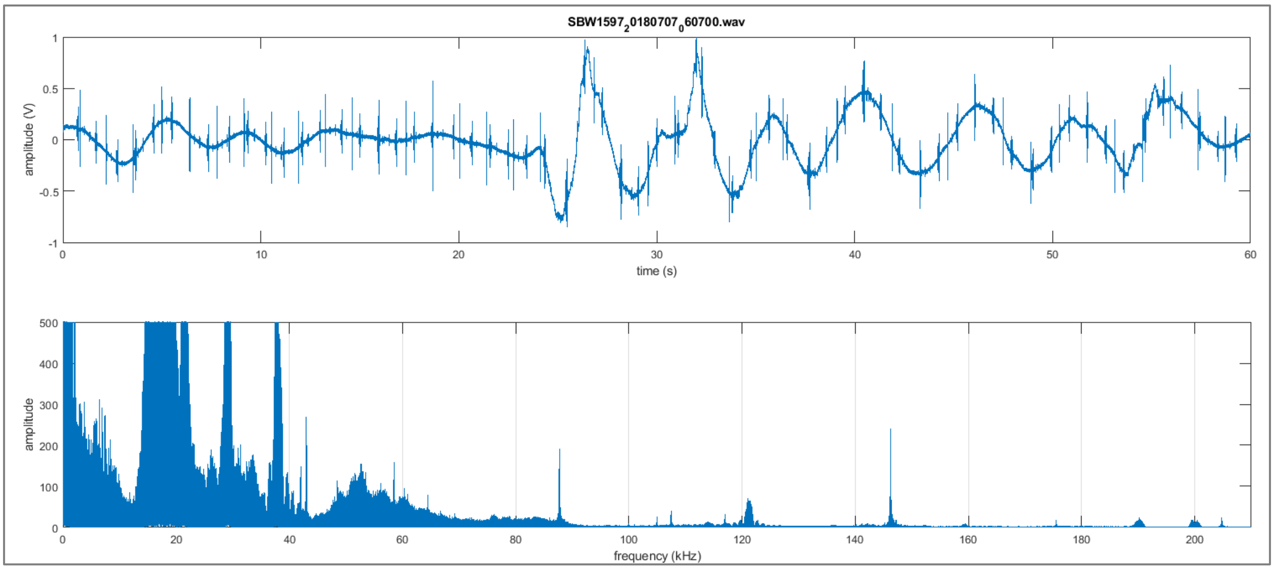


Figure 6-11: 1mn signal recorded by the hydrophone during the first camera survey

➤ **Hydrophone deployment on Bubble Maker**

The Hydrophone was mounted on the bubble maker and deployed at a depth of ~125m (Station 21) on 11 July. The purpose of the experiment for the hydrophone was to check if we was able to detect bubbles, and if so evaluate their sizes, frequencies and other characteristics. The hydrophone was deployed at 03:19 UTC (15:19 NZST), in water at 03:52 UTC (15:52 NZST) and recorded for 9 hours (47.9 Gbits). The hydrophone was configured at full sample rate (up to 200kHz/512 Ksps).

Figure 6-12 Hydrophone on Synthetic Seep Generator

On 13 July, Station 30, the hydrophone was deployed on the AOS at 13/07/2018), considered on bottom at 23:12 UTC (11:12 NZT) and recorded for 9 hours (41.9 Gbits). The hydrophone was configured at full sample rate (up to 200kHz/512 Ksps).

The main purpose of the experiment for the hydrophone was to check if we were able to identify gas bubbles from ambient noise recording performed in the very close vicinity of a synthetic bubble release, and potentially to quantify size and flux.

The principle of the bubble maker is based on solenoids that control the pressure into the system. As a result, each emission of an artificial air bubble corresponds to three characteristic noises. In particular, the last one dominates and can be used as a time trigger to adjust each individual bubble emission (Figure 6-13, top). After trigger of the solenoid, two relaxation schemes are detected around 2 kHz (Figure 6-13, middle). The filtered signal a 2-3 kHz is displayed on Figure 6-13, lower part. The relaxations appear at 62 ms and 66 ms. No conclusion can be drawn from these data since the signal recorded can be due to either the bubble maker system, or only a part due to the bubble maker, another due to the bubble itself.

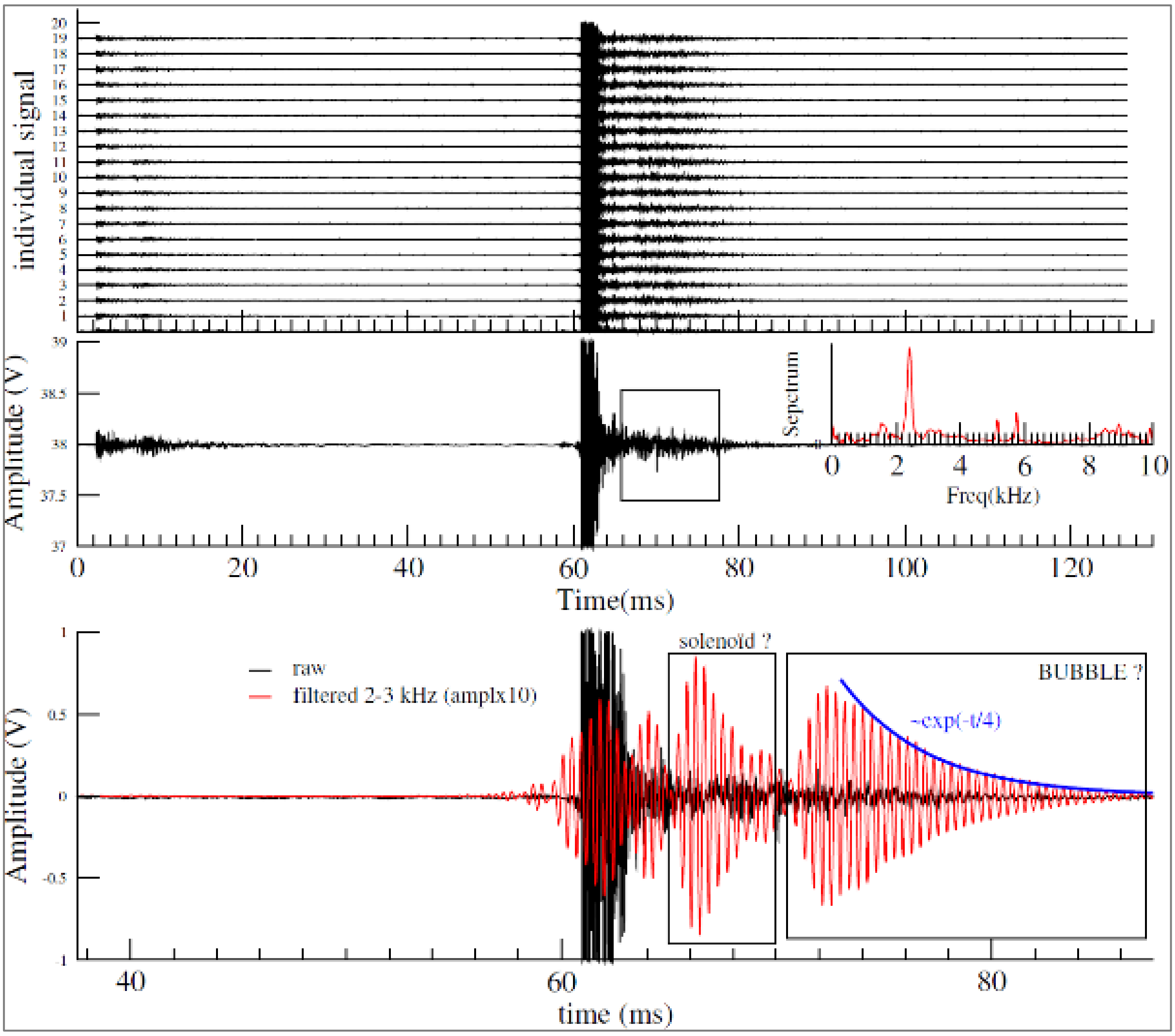


Figure 6-13 Hydrophone analysis on Synthetic Seep Generator deployement

➢ Hydrophone deployment on CTD

The hydrophone was deployed on four CTD casts and recorded during each cast (11 Gbs of data). Those are identified as Experiments 20180715/Exp1, 20180715/Exp2, 20180715/Exp3, 20180715/Exp4. These CTD casts made with the hydrophone are described on Table 6-4 :

Table 6-4 - Hydrophone on CTD cast

Station Number	Start/Finish	Time (NZST)	Water depth (m)	Comments
	Start	16/07/2018 08:25	188	
071	Finish	16/07/2018 08:39	188	Bottom 08:33 37°41.22'S 177°06.93'E 178m
	Start	16/07/2018 10:19	193	
072	Finish	16/07/2018 10:38	193	Bottom 10:29 37°41.271'S 177°07.233'E 193m
	Start	16/07/2018 11:23	193	
073	Finish	16/07/2018 12:36	192	11:34 start Tow Yo 37°41.265'S 177°07.24'E
	Start	16/07/2018 13:01	195	
074	Finish	16/07/2018 13:23	195	Bottom 13:15 37°41.32'S 177°07.69'E 190m

Given the movement of the CTD, the fact that the CTD was not on the ground and bubbles emitting noise mainly where disconnecting from the seabed, data were not analyzed on board. Figure 6-14 shows an example of the signal recorded during one CTD, with saturations of the signal due to the CTD movements.

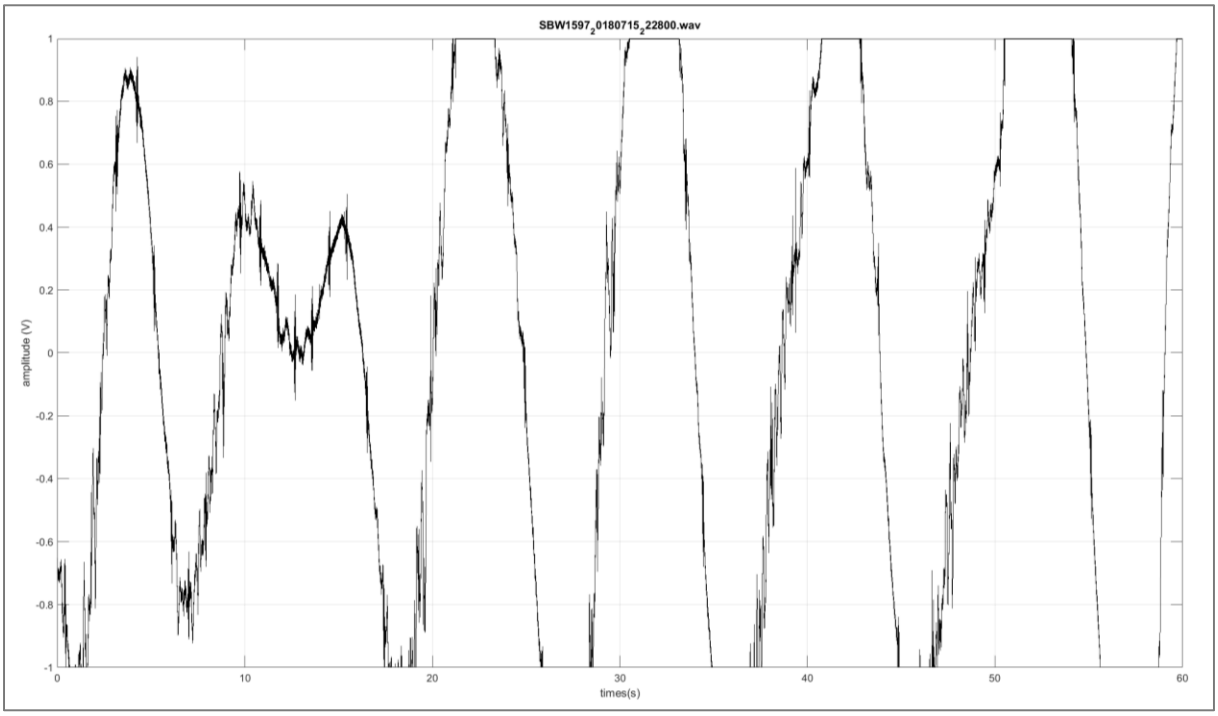


Figure 6-14 - Signal recorded during a CTD cast

➢ **Hydrophone deployment on natural gas seep**

The hydrophone was deployed on the camera frame during several transects. The aim of those experiments is to record audio data when the camera was observing natural seeps of gas and fluids. The hydrophone made two dives corresponding to several transect detailed here.

- *Experiment 20180716-*

During this experiment, the hydrophone was mounted on the camera frame as shown on Figure 6-16. Recording started at 15/07/2018 02:36:00 and ended at 05:07:00. The matching camera transect are identified by TOWCAM003, TOWCAM004, (both aborted) and TOWCAM005. The hydrophone is situated on the left side of the videos. The hydrophone was configured at full sample rate (up to 200kHz/512 Ksps).

During the camera transects, two main sites were identified where the camera sat on the seabed in front or even on source of bubbles.

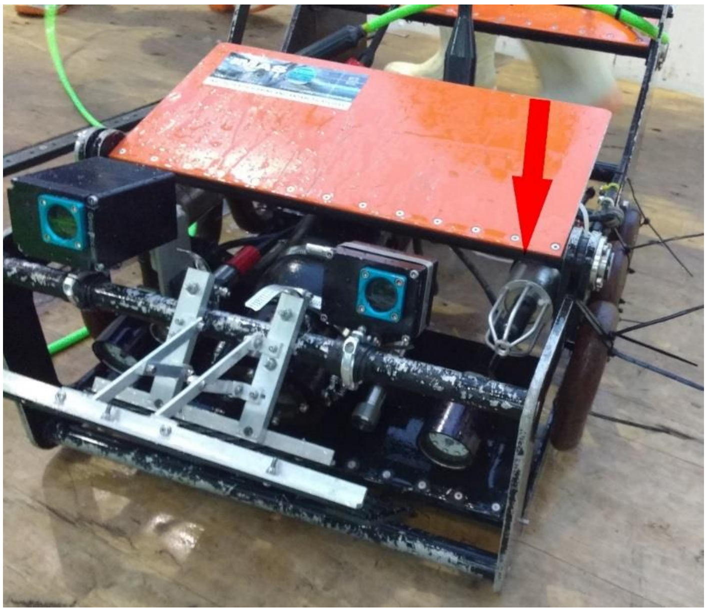


Figure 6-15 Hydrophone on Towed Camera for TOWCAM005

Event 1 - The camera hit the ground at 04:29:33 UTC and stays on site up to 04:33:50. One can see a constant raise of bubbles on the right of the camera at a rate of approximately 1Hz. On the same site, periodic fast release of bubbles but farthest on the left of the camera are seen from 04:30:59 UTC to 04:31:06 UTC, 04:31:50 UTC to 04:31:59 and 04:33:12 UTC to 04:33:23 UTC. Hydrophone is mounted on the right side of the trawler.

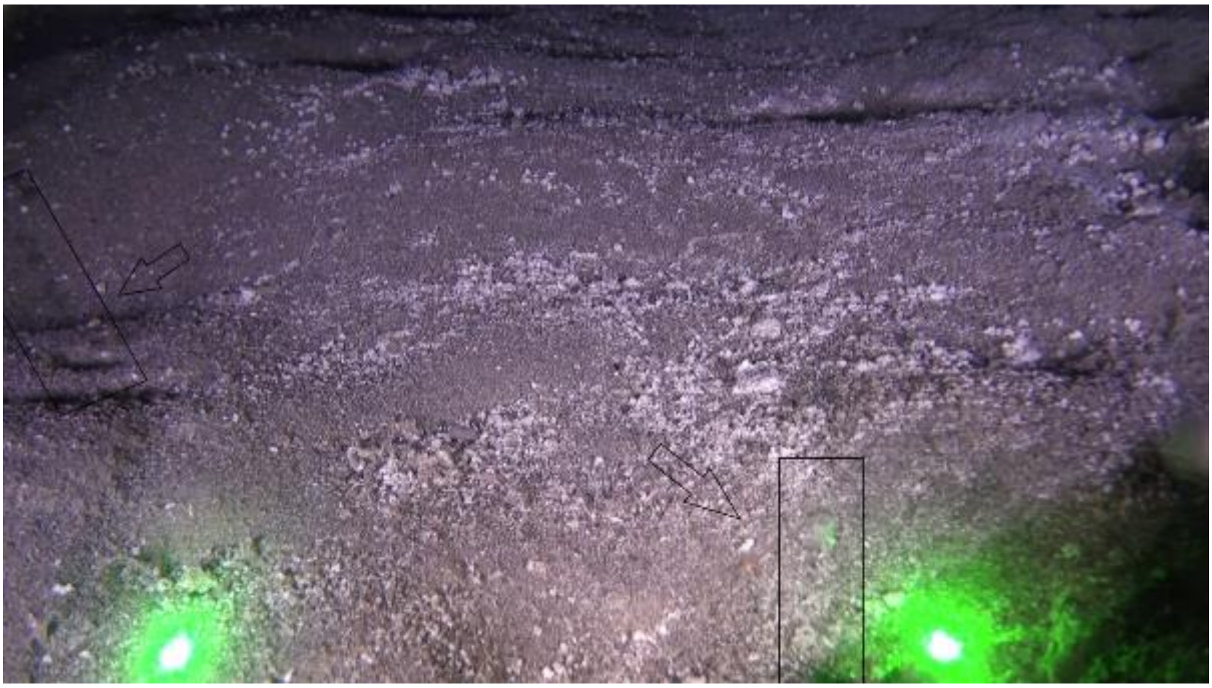


Figure 6-16 Hydrophone Event 1 during Camera Transit

Event 2 - During the same transit, another site of interest with the camera on stand-by is identified as Event 2. The camera hit the ground from 04:52:30 UTC to 04:52:49 UTC, moved a little bit at 04:56:00 UTC and took off at 04:56:25 UTC. During that time a huge amount of bubbles was released.

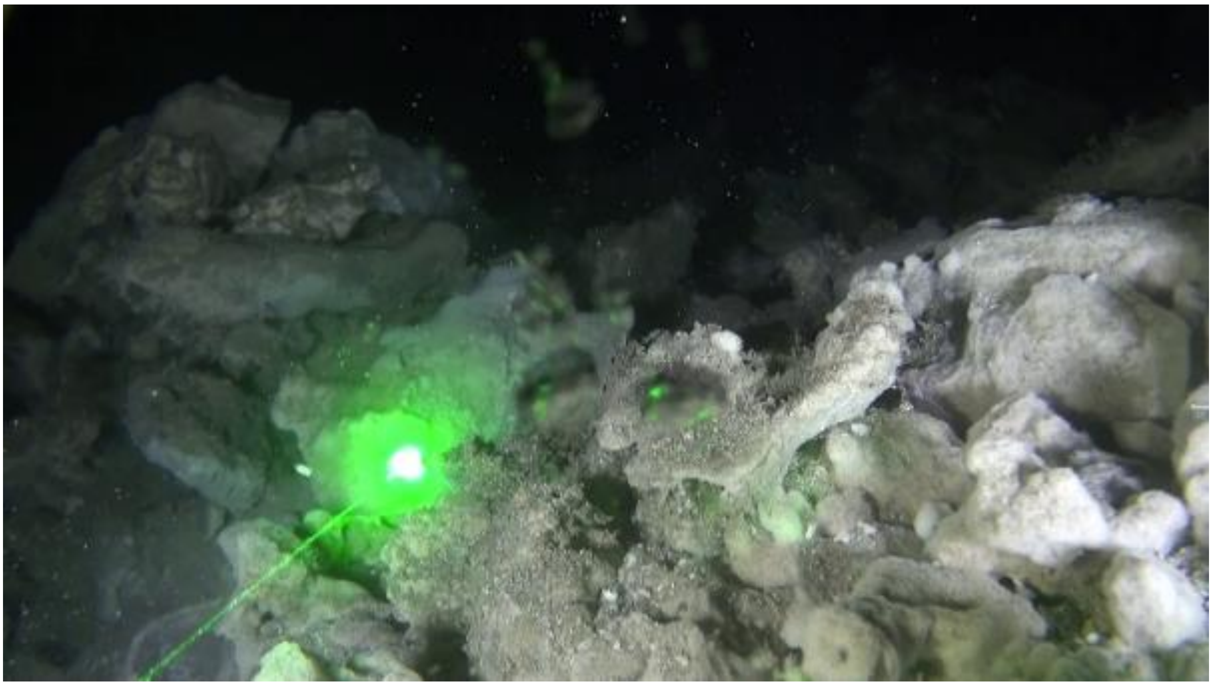


Figure 6-17 Figure 7 Hydrophone Event 2 during Camera Transit

- *Experiment 20180718*

During this experiment, the hydrophone was mounted on the camera frame as shown on Figure 6-18 and Figure 6-16. Recording started at 18/07/2018 21:00:00 UTC and ended at 05:44:00, with a short stop between 23:27:00 and 23:45:00 due to a transect from FOI-2 to FOI-3.

The matching camera transect are identified by TOWCAM007, TOWCAM008, TOWCAM009 and TAWCAM010. The hydrophone is situated on the left side of the videos. The hydrophone was not stopped during transects TOWCAM008, TOWCAM009 and TAWCAM010 and stopped recording during TOWCAM009 du to a lack of battery.

Figure 6-18 Hydrophone on camera frame exp. 20180718 (left) and hydrophone and RBR on camera frame exp. 20180718(right)

A noticeable point of the mounting is that the hydrophone was attached to an RBP Temperature Probe System.

To be able to compare the audio data recorded on natural seeps with the background noise, two points away from any seeps were recorded for approximately one minute:

- Reference 1: stop on seabed for reference during transect TOWCAM007 at 22:10 UTC
- Reference 2: stop on seabed for reference during transect TOWCAM009 at 04:02 UTC

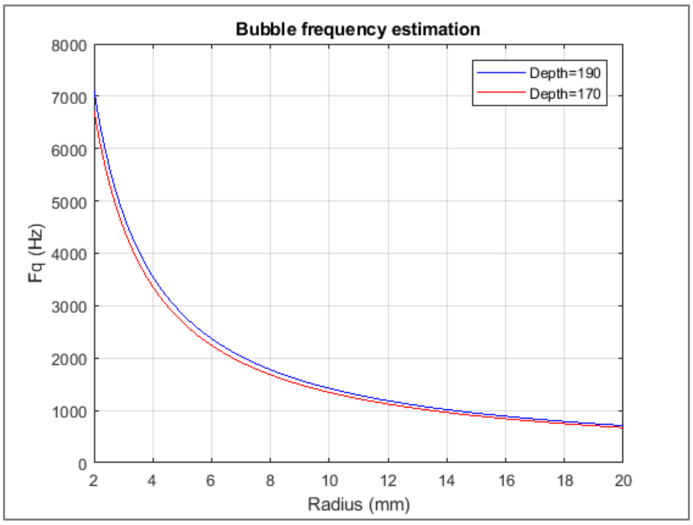
The events and times of bubbles analyzed during TOWCAM009 are identified in Table 6-5

Table 6-5 - Hydrophone events on TOWCAM009

Event	Category	Time (UTC)
Event 3	Bubble	02:51
Event 4	Bubble	02:54
Event 5	Bubble	02:56
Event 6	Bubble	03:31
Event 7	Bubble	03:46
Event 8	Bubble	03:48
Event 9	Bubble	03:51
Event 10	Bubble	04:33
Event 11	Fluides	04:35

- *Comments*

The resonance frequency of bubbles emerging from the sea floor if given by the Minneart formula (Minnaert, 1933).



$$F = \frac{1}{2\pi r} * \sqrt{\frac{3\gamma P}{\rho}}$$

Where F is the frequency in Hertz; P is the pressure in Pa; r is the bubble radius in meters; γ is the specific heat ratio (1.4 for air); ρ is the density (1000)

Figure 6-19 Bubble Frequency estimation

As a first approach this gives an estimate of the frequency expected for several bubble sizes for depth of 170m and 190m (approximate camera spot depths). Given those figures, the data where analyzed with a frequency window of 1 kHz up to 10 kHz.

Reference points - The two reference points “Reference 1” and “Reference 2” have each been recorded for 1 minute.

The power spectral density (PSD) is computed using Welch's overlapped segment averaging estimator. Each record of one minute was split into segments of 5 seconds each, PSD is computed, and a mean and standard deviation are computed for the segments.

Power spectral density and standard deviation are displayed on Figure 6-20 for reference point 2. Standard deviation can vary up to 2dB depending on the frequency considered

The mean values for Reference 1 and Reference 2 are displayed on Figure 6-21, those are taken on two different sites (FOI-1 and FOI-2), at different time of the same day. The natural variation of the background noise appears as a very versatile, difference in power level going up to 10 dB. Remarkable pikes are noticed at 2kHz, 1.4 kHz, 1.313 kHz, 1.181 kHz, they seem to be constant and are probably linked to onboard instruments or ship noise.

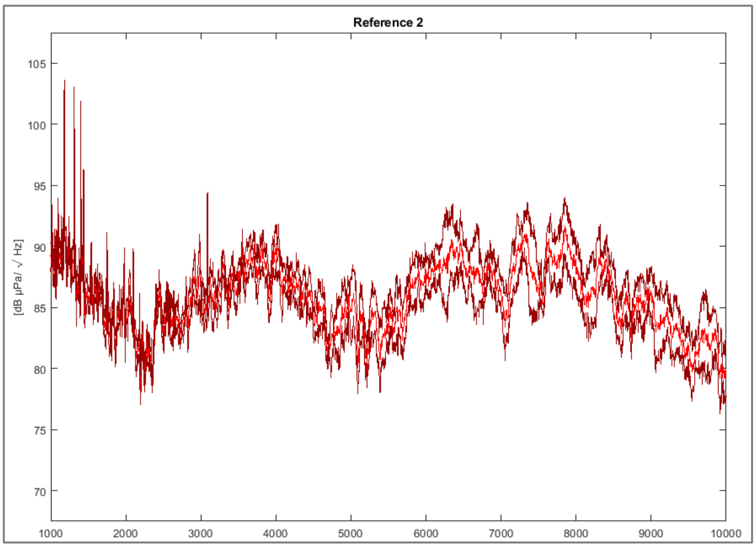


Figure 6-20 Reference 2 PSD and standard deviation

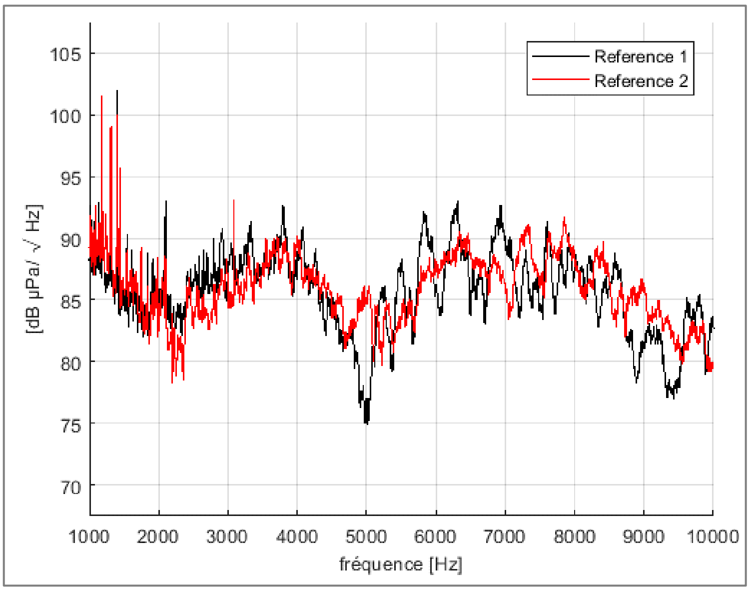


Figure 6-21 PSD for Reference 2 and Reference 1

- **Natural Seeps**

On experiment 20180716, during event 1 two kinds of bubbles were identified. The first one identified as “Low”, is a constant release at approximately 1Hz. The second identified as “High” is a high rate release of bubbles appearing sporadically for a short amount of time.

Those events were analyzed, and their power spectral density computed with segment of 5 seconds displayed on Figure 6-22. The PSD for each event Low and High is displayed. The reference 2 curve is given as an indication. The two curves are similar. High rate event having a new source of bubbles of different or equal size should generate a higher spike on the bubble resonance frequency. Such signal, fitting into the standard deviation of the Low rate event cannot be distinguish at any frequency. No such event can be seen on the different curves, especially taking into account for standard deviation of the signal.

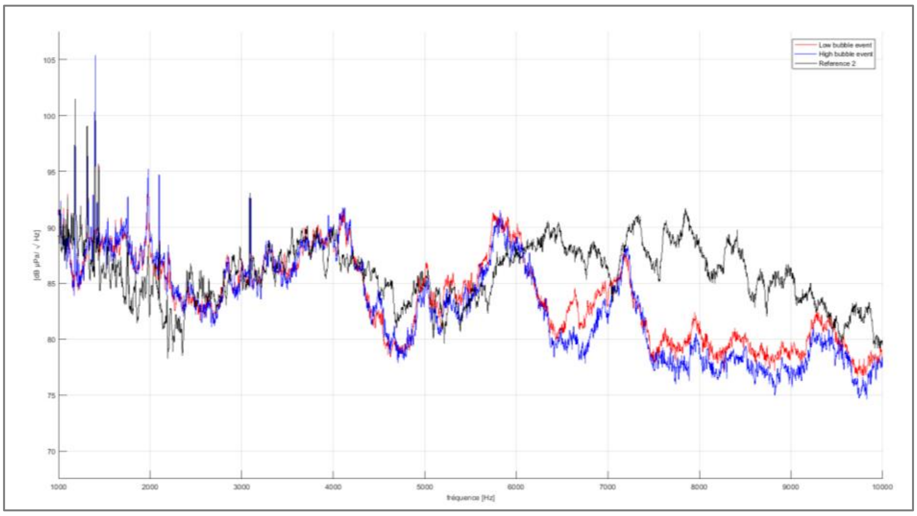


Figure 6-22 Low, High bubble event and Reference 2

An overview of the different bubble event of experiment 20180719 show a big variation in the PSD of the various sites, the closest reference "Reference 2" point if given in black (Figure 6-23). The variation of the PSD hides any possible spike matching a bubble frequency response.

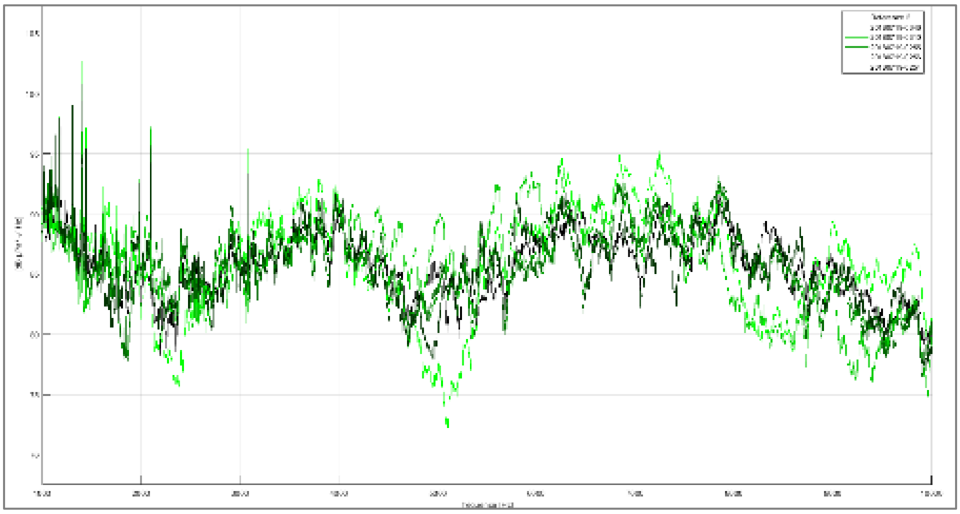


Figure 6-23 Bubbles event for 20180718 and Reference 2

Data were computed and analyzed on the Low 1Hz bubble event with tighter windows of 0.1s to detect smaller spikes on the power frequency, ambient noise being assumed constant for such an amount of time. No conclusive frequency or wave form of bubble emerged from this study. More precisely nothing was found being high enough and occurring at the expected rate in spatial time and having a typical bubble relaxation scheme as described in Leifer and Tang (2007).

- **Comments**

No obvious evidence of bubbles was detected on the hydrophone records, further work includes:

- Leifer and Tang (2007) note that FFT was quite limited for analysis such data with low signal to noise ratio.
- The windows used for analysis were set by default, but it probably can be tuned to be adapted to the signal
- Splitting of the files was arbitrary (5s, 0.1s) and a more precise split could be evaluated.

6.10 The Synthetic Seep Generator (a.k.a. Bubble Maker)

➢ **Deployment**

The deployment of the Synthetic Seep Generator was performed according to the document provided by Tom Weber (Appendix).

➢ **Objectives**

The bubble maker (aka Synthetic Seep Generator) provided an objective test for seep-detection sonar and was provided by CCOM-UNH. A multi-sensor experiment was performed over the bubble maker in medium water depths (120 m), using EM302, EM2040, EK80 WBTs, EK60 GPTs, the Pan&Tilt mounted EK60 GOT and direct visual observations. The objectives of the bubble maker operations were to:

1) to calibrate the water column MBES and assess cross-calibration approaches between SBES and MBES;
2) to develop quantitative analyses of bubbles flares (bubble size distribution, flux and shape) from frequency and angular dependencies; and
3) to define the limits and resolutions of gas bubble detection in acoustic systems

➢ **Deployment and mooring**

For all deployment activities the bubble maker tripod was connected to the mooring weight and float buoys by a Dyneema (spectra) mooring line (Figure 6-24). The bubble maker was deployed with the crane from the cut-away deck. The bubble maker tripod was lowered on the mooring line to the seafloor. Once the tripod was on the seafloor, the position was noted, and the ship was maneuvered approximately 600 meters away from the initial deployment site with the DP system while the mooring line continued to pay out. Connected to the mooring line, the weight was also lowered to the seafloor, providing a line-free water column above the bubble maker. The rest of the mooring line is paid out and connected to a set of floats at the surface.

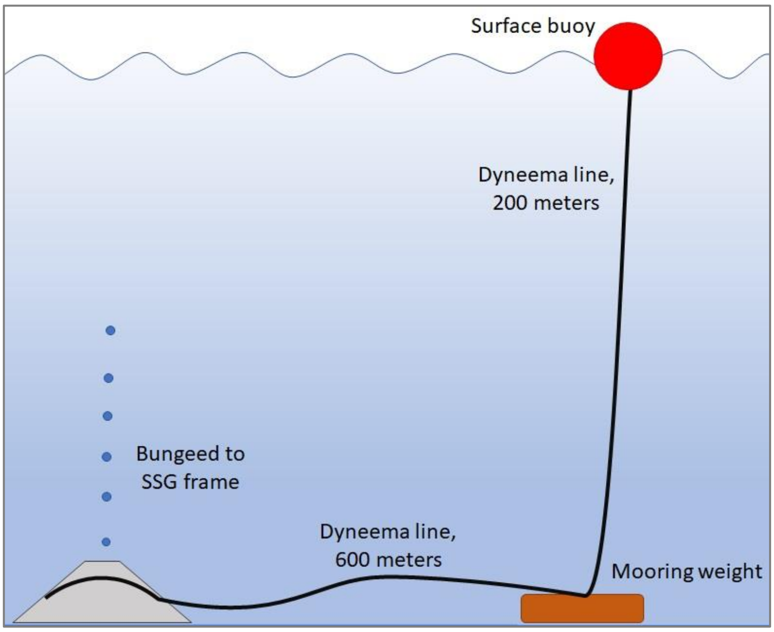


Figure 6-24. A notional schematic showing the bubble maker tripod, weight, buoy, and mooring lines that are used to facilitate deployment and recovery.

Initially the bubble maker tripod and mooring weight were placed with 100 meters(?) of each other, causing the excess mooring line to float free in the water column. During the first deployment the Tangaroa drove over the deployment location and caught the line in the water column. As a result, the bubble maker and mooring equipment were drug along the seafloor. All subsequent deployments placed the bubble maker tripod and mooring weight at a greater distance apart to reduce the amount of free line floating in the water column.

- **Survey planning**

After successful deployment of the bubble maker, survey lines were created based on the bubble maker position noted during deployment operations. An initial survey line was drawn directly over top of the bubble maker positions, running in a perpendicular direction to the line between the bubble maker tripod and the mooring weight/surface buoy position to avoid potential snags between the ship and line. From the initial line, a series of nine offset lines were also created at an interval of 10 meters across-track range to be run with the Pan&Tilt EK60 system (Figure 6-25).

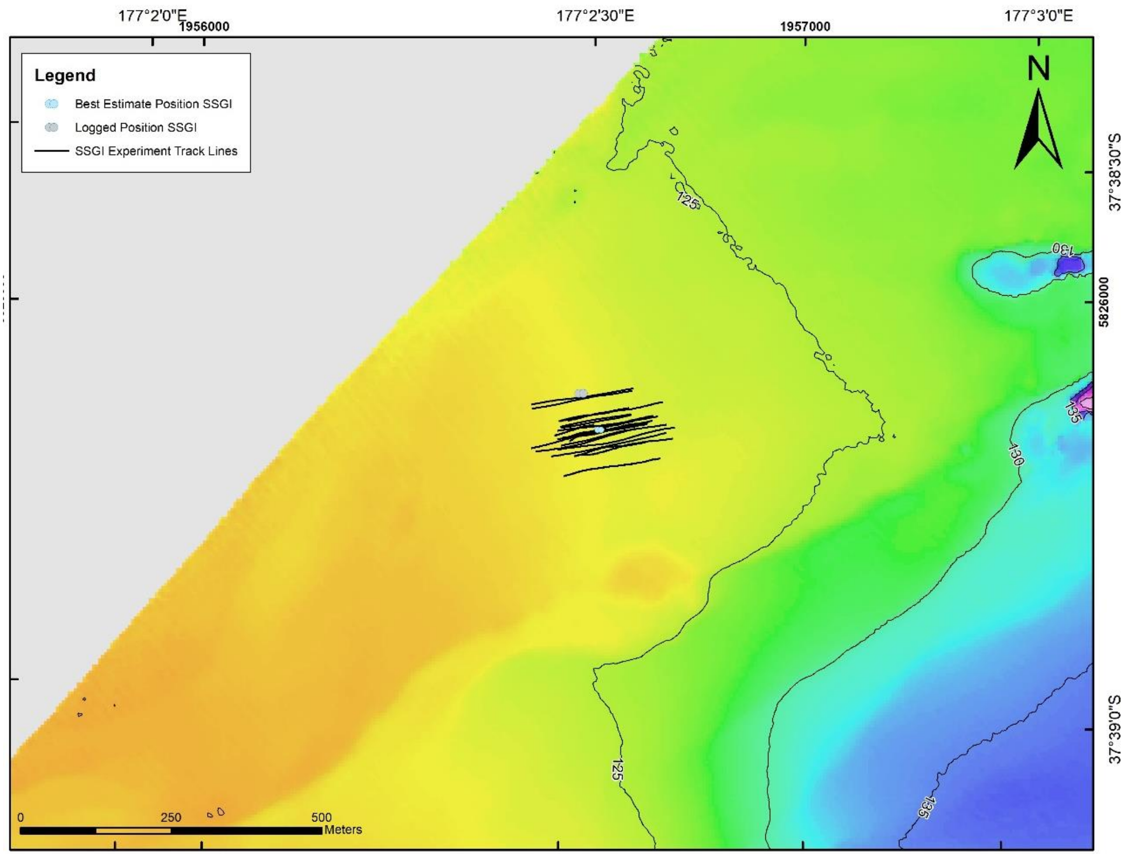


Figure 6-25. Survey tracks from the third bubble maker deployment showing the location of the bubble maker (logged position and best estimate from HIPAP) and the survey lines.

- **Survey Operations**

During TAN1806 the bubble maker was deployed on three separate occasions, at approximately the same location (177.05, -37.644) in water depths between 110 and 115 meters (Table 2). The deployment location was chosen after a preliminary survey of the area to verify no natural seeping would interfere with acoustic data collection. During survey operations both MBES systems and all EK systems, including the pan&tilt, were run.

The first deployment occurred on 11 July. The bubble maker threshold was set to a differential value of 10 and release rate of approximately one bubble every 5 seconds. The bubble maker was deployed after the deployment of the AOS in order to place the bubble stream in the view of the AOS acoustic systems. Once the AOS experiment was completed and the AOS mooring was recovered the acoustic survey with the onboard acoustic systems began at approximately 02:00 NZST (16:00 UTC). During the night survey operations there was high density of fish in the water column, especially near the seafloor. This interfered with the identification of single bubbles in the acoustic data (Figure 5). At approximately 18:30 UTC the mooring line between the bubble maker and the mooring weight was snagged by the Tangaroa and the bubble maker was dragged across the seafloor 200 meters from its original mooring location. The equipment was recovered and was found to have no major damage; however, the first deployment was terminated at this point.

The second deployment occurred on 14 July with the differential pressure threshold lowered to 5 but the rate of release unchanged. Acoustic survey operations were run during daylight hours to reduce fish density in the water column. The survey was terminated before completion for the pickup of replacement CTD equipment from the coast guard.

The third deployment occurred on 18 July. The differential pressure threshold was set at 10 and the release rate of bubbles was unchanged from deployment one and two. Acoustic survey operations were run during daylight hours. During the first two survey lines only the hull-mounted EK echosounder systems were run, the pan&tilt was put into passive mode. The ES18, ES70, ES120, and ES200 were all run in FM mode, while the ES38 was run in CW mode. The bubble stream origination from the bubble maker was identifiable in all five echograms (Figure 6).

Following the initial passes over the bubble maker the pan&tilt multi-angle survey was completed. The survey plan, illustrated in Figure 4, consists of a series of increasingly offset parallel lines with separation of 10 meters between. The incident angle of the pan&tilt was correspondingly increased with increasing offset from the initial survey line (see Table 3). Line were run from east to west, as the tilt of the pan&tilt system could only be increased on starboard side. Lines were run as planned from 0 m offset to 60 m offset. At this point the signal attenuation of the ES120 on the pan&tilt made identification of individual bubbles difficult and the remaining lines were run at a 30-meter offset (see Table 3).

Table 6-6. General information and operational parameters for the three bubble maker deployments.

Deploym't ID	**Date (NZST)**	**Time of operations (UTC)**	**Latitude**	**Longitude**	**Seafloor depth (m)**	**BM threshold**
BBM1	11/07/2018	16:00-19:00	-37.644	177.047	110	10
BBM2	14/07/2018	23:00-02:00	-37.645	177.043	110	5
BBM3	18/07/2018	22:00-08:00	-37.646	177.034	115	10

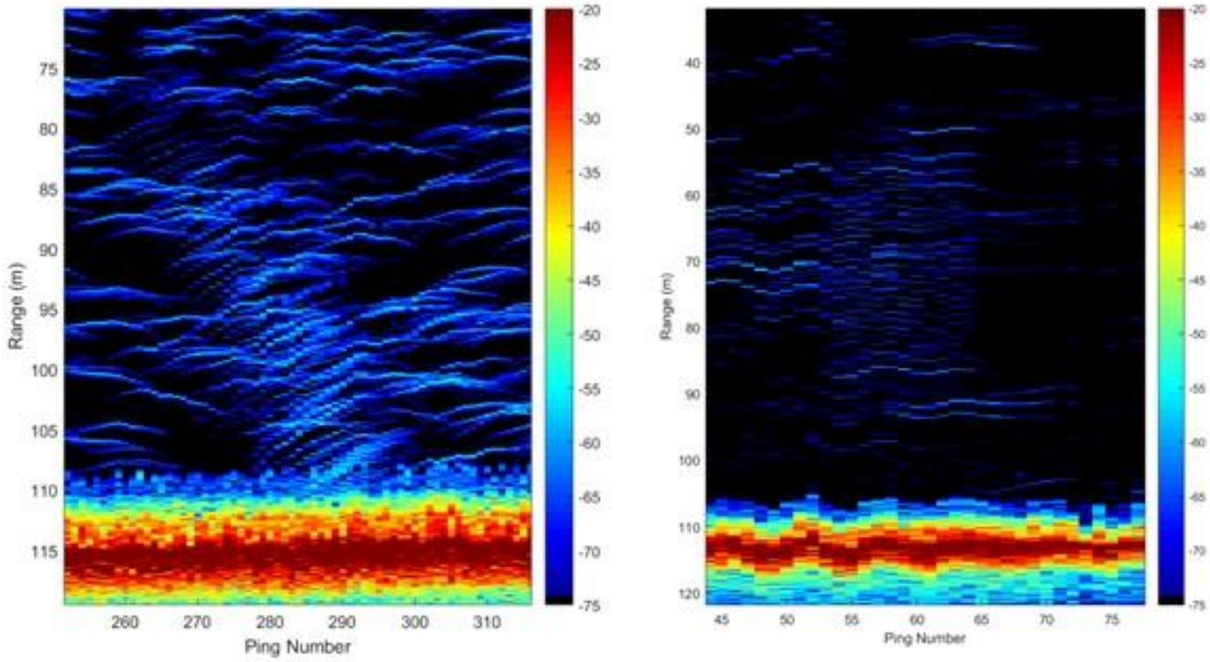


Figure 6-26. Example echogram of ES18 WBT data from the first deployment (left) and second deployment (right). The density of fish in the water column is higher during the night survey (first deployment).

Table 6-7 Information on EK files with successful acoustic identification of single bubble stream.

Deploym't ID	EK filename (minutes only)	Line offset (m)	P&T angle (°)	Line direction	Additional Information
BM1	T181929	0	0	SE-NW	ES70 & ES120 (hull) in passive
BM1	T184351	10	7	NW-SE	ES70 & ES120 (hull) in passive
BM2	T013535	0	0	SW-NE	
BM3	T233454	0	N/A	E-W	No p&t
BM3	T235442	0	N/A	W-E	No p&t
BM3	T002733	0	0	E-W	ES120 (hull) in passive
BM3	T011850	10	7	E-W	ES120 (hull) in passive
BM3	T015308 & T015728	20	14	E-W	ES120 (hull) in passive
BM3	T022633	30	21	E-W	ES120 (hull) in passive
BM3	T025712	40	27	E-W	ES120 (hull) in passive
BM3	T032511	50	32	E-W	ES120 (hull) in passive
BM3	T040424	60	37	E-W	ES120 (hull) in passive
BM3	T043152	30	42	E-W	ES120 (hull) in passive
BM3	T045844	30	47	E-W	ES120 (hull) in passive
BM3	T052007	30	52	E-W	ES120 (hull) in passive

➢ **<u>Bubble Streams in Echosounder Data</u>**

The SBES acoustic data were parsed in both ESP3 and CCOM internal MATLAB scripts. MBES water column data was viewed in FM Midwater and CCOM internal MATLAB scripts.

- *Hull-mounted EK echograms*

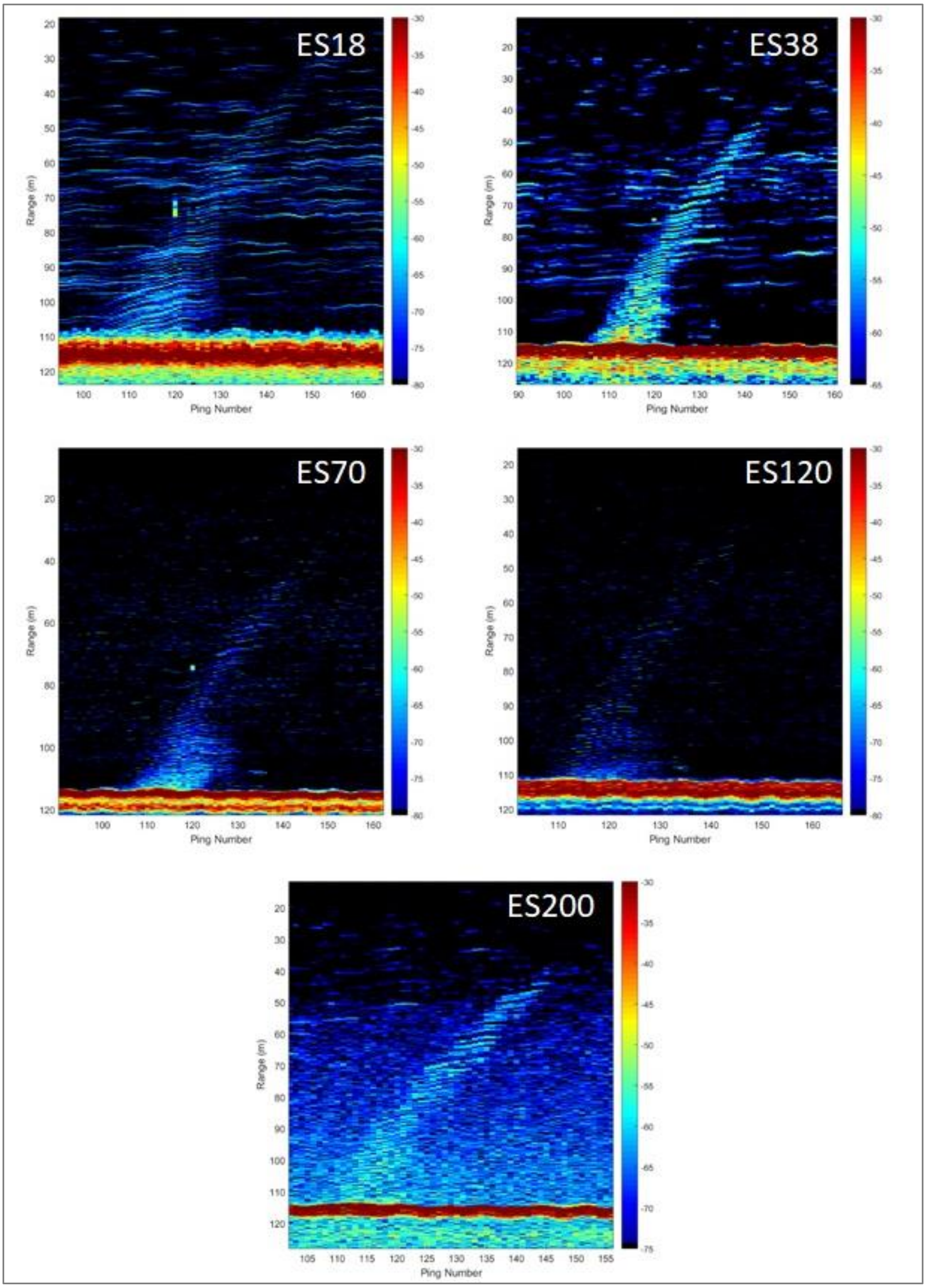


Figure 6-27. Bubble stream from the bubble maker in the four broadband (ES18, ES70, ES120, ES200) and one narrowband (ES38) echograms. Individual bubbles are distinguishable in all echograms.

- *Pan&Tilt echograms*

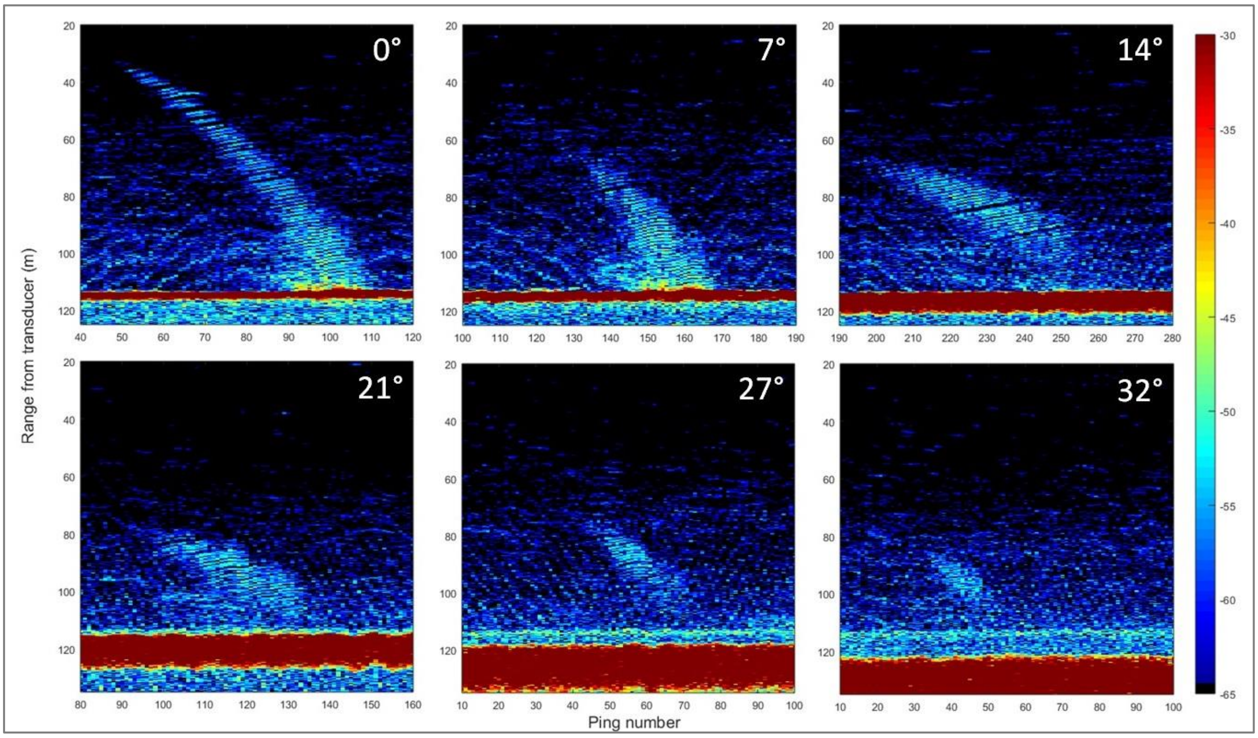


Figure 6-28. Pan&tilt ES120 echograms of the bubble maker bubble stream in a series of different incident angles.

- *Multibeam*

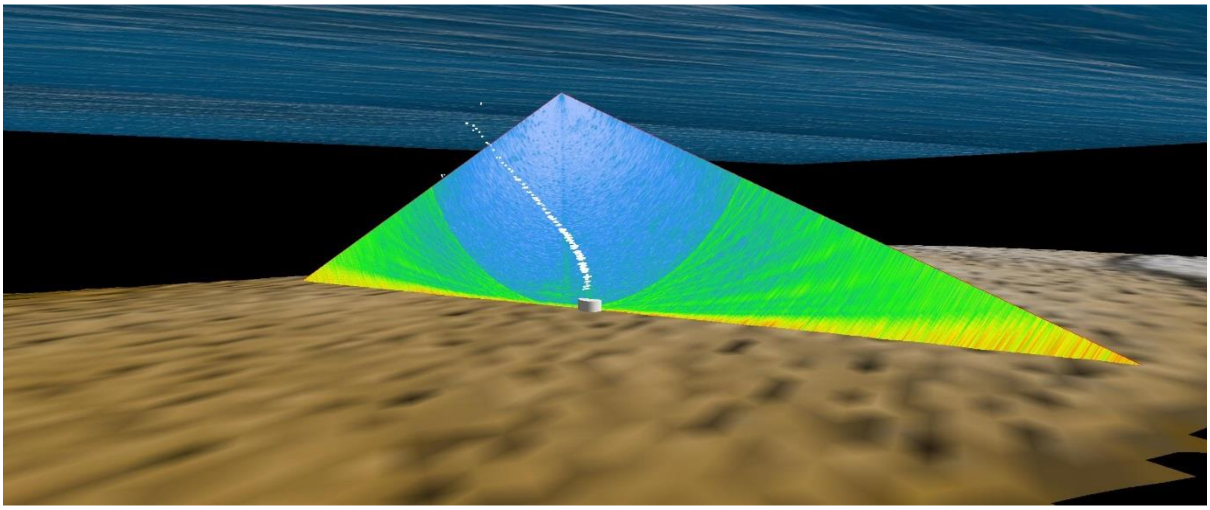


Figure 6-29. MBES swath over the bubble maker. The white points are the bubbles extracted from the MBES swath from FMMidwater.

6.11 Towed video camera

A towed video camera system from IMAS was deployed on a cable and winch from the *RV Tangaroa.* The tow frame has no propulsion mechanism but was slowly towed along by the vessel at 0.1 knots. This speed permitted the consistent flying altitude of the tow camera to be at 1 m above the seafloor. The video camera was pointed at a 45° angle to the seafloor and recorded data in high definition. The data were recorded and stored on a SD card on the camera and was downloaded back at the surface. The towed video camera is able to provide an important non-invasive sampling alternative to sediment sampling where extractive methods were either unnecessary or unsuitable, such as on carbonate terraces or when looking for bubble seeps on the seafloor. The towed platform also has the added advantage of providing cost-effective permanent data capture along transects that can be up to several kilometers in length and can be used to traverse highly heterogeneous seafloor topography. The quality of imagery acquired by the towed camera depended largely on the sea conditions and water clarity. Sea states in < 15 knots of wind and < 2 m of swell were determined as suitable for video data collection at this site. In the depths sampled on this voyage, commonly > 150 m depth lighting was vital. The towed video camera frame was also mounted with two green laser lights- set at 15 cm apart that could be used to scale objects in the video data. A hydrophone (see section 6.9) was also mounted on the camera frame for transect lines 1 and 3. On transect lines 2 and 3 a 'Go Pro' camera and 'bubble validation matrix grid' were also tested to collect imagery of bubbles released from the seafloor. On one transect, a temperature and salinity probe was mounted onto the camera frame and was successful in sampling temperature records along the track.

Survey operation:

1. Towed video transect locations were planned in Fledermaus (v7.8.4) based on the location of the flares FOI#1, FOI#2 and FOI#3. The planned transects were further refined using an echo integration overlay created in ESPRESSO using the EM302 water column data as well as the locations of potential flares bases, which were generated using the EM302 water column data and automated feature detection and clustering tools in Fledermaus and MATLAB.
2. The transect location was provided to the bridge for navigation using the Direct Positioning (DP) system.
3. An alternate television system with live feed from the camera was set up for the winch operator on the level above to assist in manoeuvring the vertical movement of the camera above the seabed (insert Figure 6-30).
4. The camera system was prepared (Figure 6-30) by a) ensuring that the SD card on the camera was empty; b) the O-rings were greased and sealed correctly; c) that the 'Go Pro' camera was turned on and housing sealed correctly, and d) that the shackles were all connected properly by 'snubbing the shackle'.
5. Once deployed over the side of the vessel, a transponder was attached to the cable at 30 m above the towed video on the line.
6. The video camera system was set to record, and the time stamp was synchronised to the navigational string from the transponder.
7. In addition to the live video feed, a laptop was set up for the science team displaying real-time EK data (using the EK80 software Client) as well as the real-time TOWCAM position overlaid on bathymetry, integrated echo strength, FOI location, and potential flare base locations (using the Fledermaus software running Vessel Manager).
8. Upon completion of the video survey, the vessel was put into DP maintain position and the camera was raised to the surface. The HD camera was stopped via laptop which completed the recording of the SD feed via the Video Control Unit.

See Carroll et al. (2018) and Przeslawski et al. (2018) for more info.

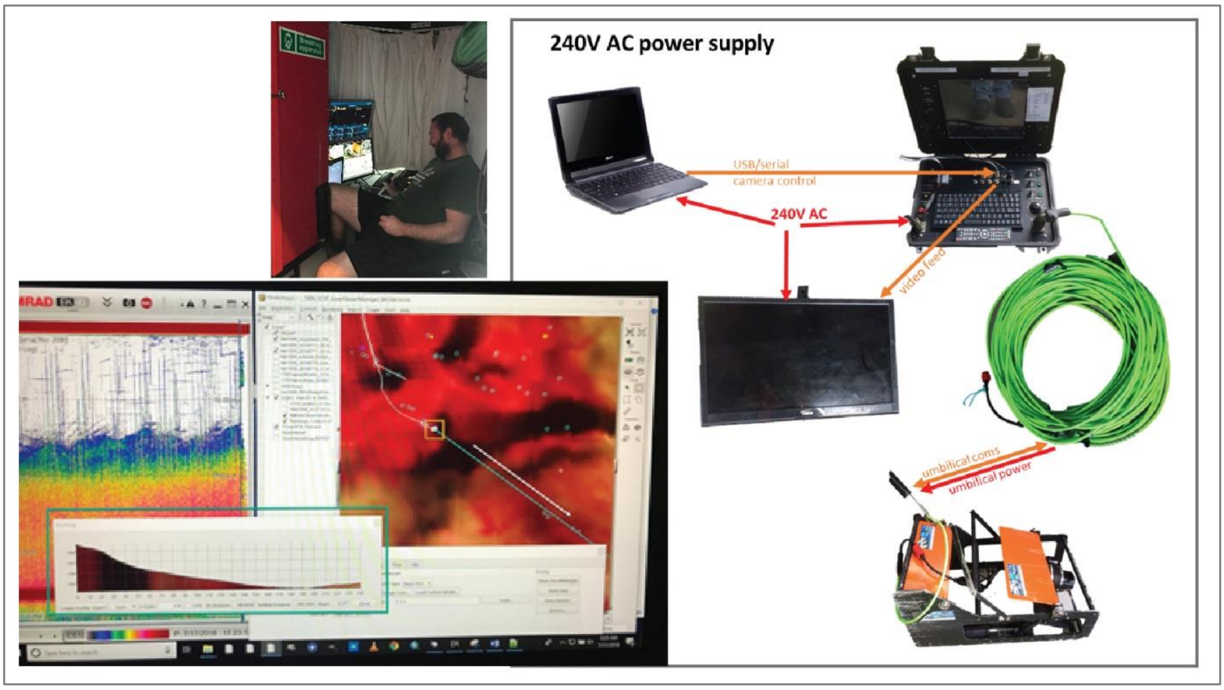


Figure 6-30 - Towed video camera set up; Bottom left: Photo of laptop set-up for real-time monitoring of TOWCAM position. On the left, the EK*) software was run in client mode to show surrounding water column real time. On the right, Fledermaus Vessel Manager was used to mornitor the position of the HIPAP attached to the TOWCAM in real time. The yellow box indicates the position of the TOWCAM, the white arrow the direction the vessel and TOWCAM were moving. The profile tool (inset window, indicated with green box, and blue-green line on main screen) was used to monitor upcoming bathymetric changes. The white line shows the TOWCAM track and open circles show the location of possible seep bases; Top left camera for winch operator.

Data processing

1. The video data was converted to a .mov format and the was saved on the server in folder organised by Transect number in V:\VIDEO\TOWCAM\TOWCAM001 [001-???] \ within this folder will be two other folders- one with Images (screen shots taken during the survey) or RAW-VIDEO which is the entire transect from deployment to recovery. In some instances, we have made a highlights edited video [TOWCAM00x_showcase.mp4].
2. The video data will be processed once back at site using Quantitative Video Analysis software and will be completed by E. Spain as part of her PhD analysis.

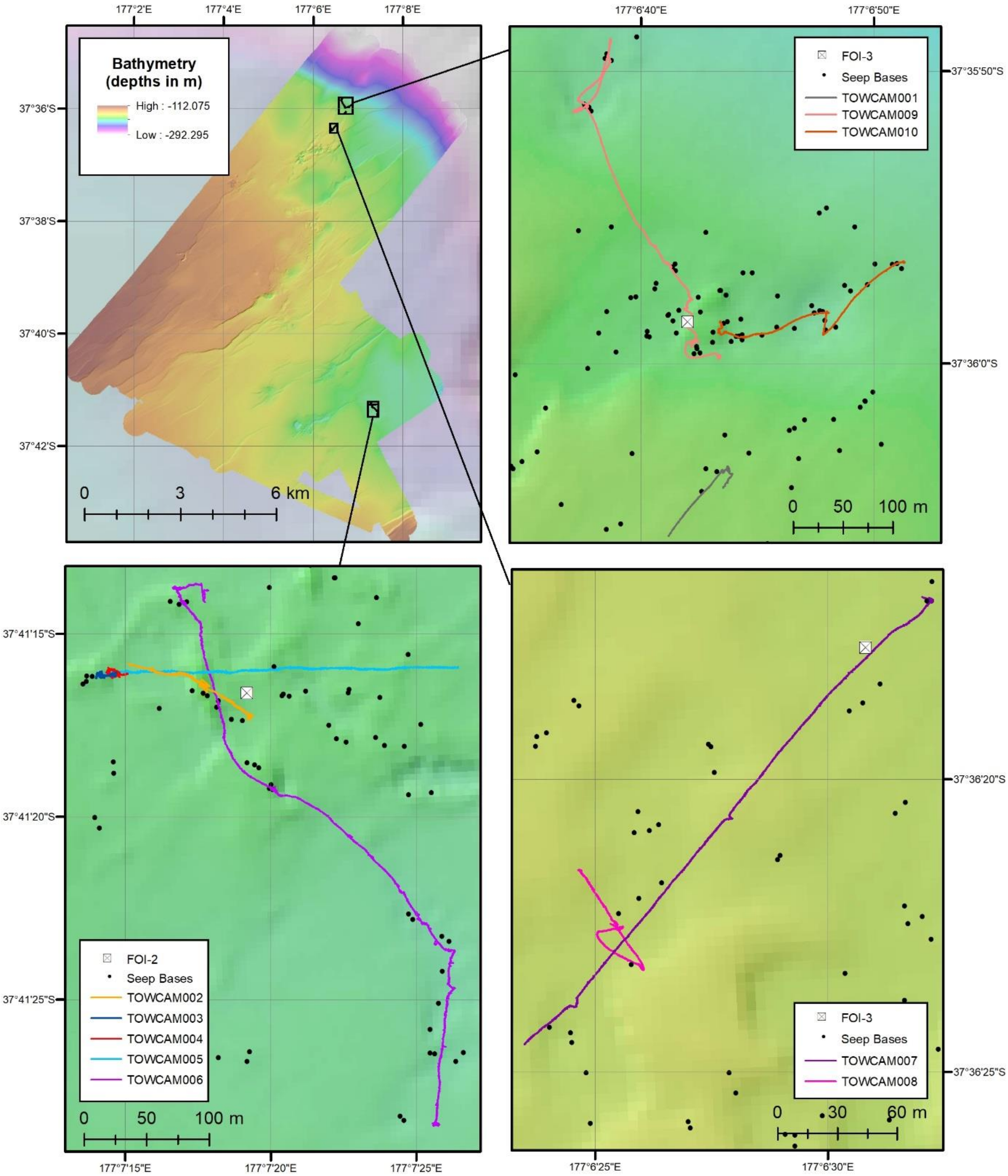


Figure 6-31 - Towcam transects and location of seeps

6.12 T-S Transects

➢ **Objectives**

Several near-bottom temperature-depth (TD) and conductivity-temperature-depth (CTD) transects were conducted over areas of gas-bubble and fluid seepage observed with shipboard acoustic and towed video camera systems. These transects were conducted in order to examine the hypothesis that anomalies observed over isolated regions of the study area were related to the expulsion of fluid with different temperature and/or salinity.

- **Equipment**

Transects were made using internally logging temperature-depth (TD) and conductivity-temperature-depth (CTD) probes during the voyage. These transects used one or more of the two RBR TD probes and two SBE 37 CTD probes available for this work. These probes were attached to three different deployment platforms: the CTD (*Figure 6-32*), the IMAS Tow Camera (*Figure 6-33*), and the NIWA AOS. Multiple sensors were used on each deployment with the exception of the 12 July CTD transect and the 16 July tow camera deployment, multiple sensors were used on each deployment. The details of each deployment are provided in *Table 6-8*. With the exception of the AOS, the locations of the platforms were recorded using the ship's HiPAP system. The HiPAP system was not used during the AOS due to concern about the interference between the AOS acoustic systems and the transponders.

Figure 6-32 Two SBE 37 CTD probes and two RBR TD probes mounted on the CTD rosette.

Figure 6-33 The IMAS Tow Camera with RBR sensor (left) and SBE 37 (right).

Table 6-8. Temperature-depth and Conductivity-Temperature-Depth transects conducted during the voyage.

Deployment Date	Deployment Time (NZST)	Deployment Platform	Sensor	Sensor Sampling Rate (Hz)	Notes
12/07/2018		CTD	CTD sensors only	23.8	CTD sensor data
16/07/2018	08:27	CTD	SBE 37 Ser. No. 5675 SBE 37 Ser. No. 5839 RBR Ser. No. 50747 RBR Ser. No. 50936	1/30 1/5 1 1	Engineering QA/QC test cast
16/07/2018	11:25	CTD	SBE 37 Ser. No. 5675 SBE 37 Ser. No. 5839 RBR Ser. No. 50747 RBR Ser. No. 50936	1/30 1/5 1 1	CTD Transect
16/07/2018	15:57	Tow Cam	RBR Ser. No. 50936	1	Initial try with both SBE 37 and RBR, but SBE 37 mounted in poor location for ballast and subsequently removed
17/07/2018	14:51	Tow Cam	SBE37 Ser. No. 5675 RBR Ser. No. 50936	1/6 1	
17/07/2018	20:30	AOS	SBE37 Ser. No. 5675 RBR	1/6 1	Need RBR data
19/07/2018	8:55	Tow Cam	SBE37 Ser. No. 5675 RBR Ser. No. 50936	1/6 1	One data file for all of 19th
19/07/2018	11:48	Tow Cam	SBE37 Ser. No. 5675 RBR Ser. No. 50936	1/6 1	One data file for all of 19th
19/07/2018	13:44	Tow Cam	SBE37 Ser. No. 5675 RBR Ser. No. 50936	1/6 1	One data file for all of 19th
19/07/2018	18:09	Tow Cam	SBE37 Ser. No. 5675 RBR Ser. No. 50936	1/6 1	One data file for all of 19th

➤ **Preliminary Results**

The first transect was conducted on 12 July with the CTD. The downcast and upcast for this transect showed odd behavior including outliers (short duration spikes of data) and several 2° 2 PSU temperature swings in the lower 50 m of the water column. These observations, and similar casts that showed several outliers, caused some doubt in the performance of the CTD. Two SBE 37 CTD probes were subsequently delivered to the vessel and strapped to the CTD, along with two RBR TD probes, for a side-by-side comparison (engineering cast) on 16 July. During this cast, the SBE 37 and RBR probes showed nearly identical temperature profiles, while the CTD temperature sensor showed anomalous data excursions (*Figure 6-32*). None of the three conductivity cells (CTD plus both SBE probes) agreed, but the SBE 37 Ser. No 5675 showed the most consistent measurements with depth (but with only one sample every 30 seconds). Due to the uncertainty in the quality of many of these measurements, subsequent transect data utilized only the SBE 37 (serial number 5675) with a sample interval updated to 6 seconds and one of the RBR probes.

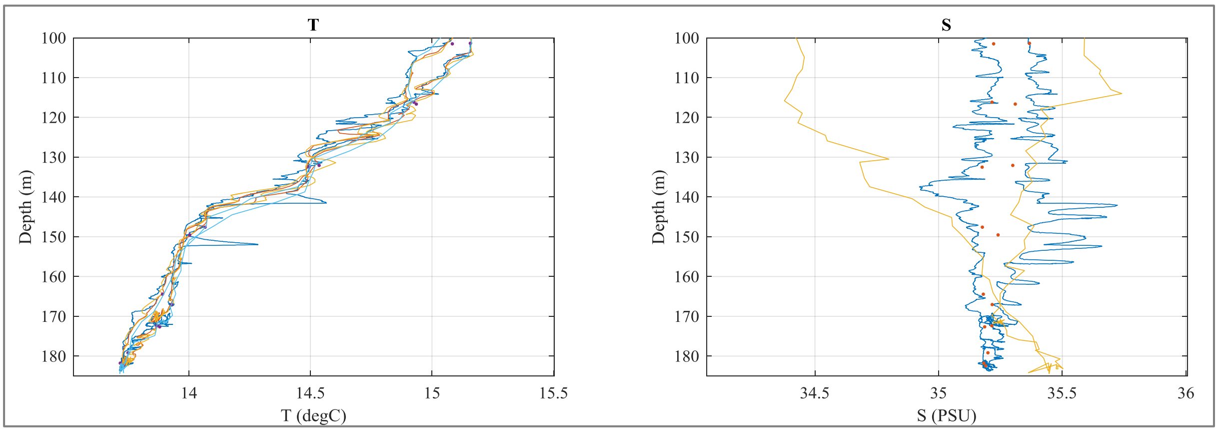


Figure 6-34 Overlay of temperature (left) and salinity (right) measurements from the 16 July 2018 engineering cast on the CTD rosette. The ship's CTD is shown in blue, and has evidence of both temperature and salinity excursions. Temperature measurements made with both RBR sensors and both SBE 37 sensors agree. Salinity measurements made with both the ship's CTD conductivity cell (blue) and SBE 37 serial number 5839 show anomalous excursions and the down-cast and up-cast vary by a significant amount. SBE 37 serial number 5675 salinity measurements, sampled every 30 seconds, are shown as red dots.

Several near-bottom CT and CTD transects were conducted over areas of gas-bubble and fluid seepage observed with the shipboard acoustic and towed video camera (*Figure 6-35*). Anomalous temperature readings – increases in bottom temperature by up to ~ 2˚C – were observed on these transects, with at least some anomalies being co-located with tow camera observations of fluid seepage. Conductivity measurements suggest the presence of small variations in salinity in areas associated with temperature fluctuations, although it is possible that sediment disturbances from the tow camera caused erroneous conductivity measurements. One large excursion, co-located with a 2˚C increase in temperature, showed a 1 PSU drop in salinity, suggesting that escaping fluid was slightly warmer and less saline than the surrounding ocean waters. The CTD transect on 16 July was conducted at approximately 10 m off the seabed, much higher than the tow camera transects, and showed a weak temperature anomaly of ~0.1˚C over a short region of the transect. Temperature anomalies were present in all tow camera transects.

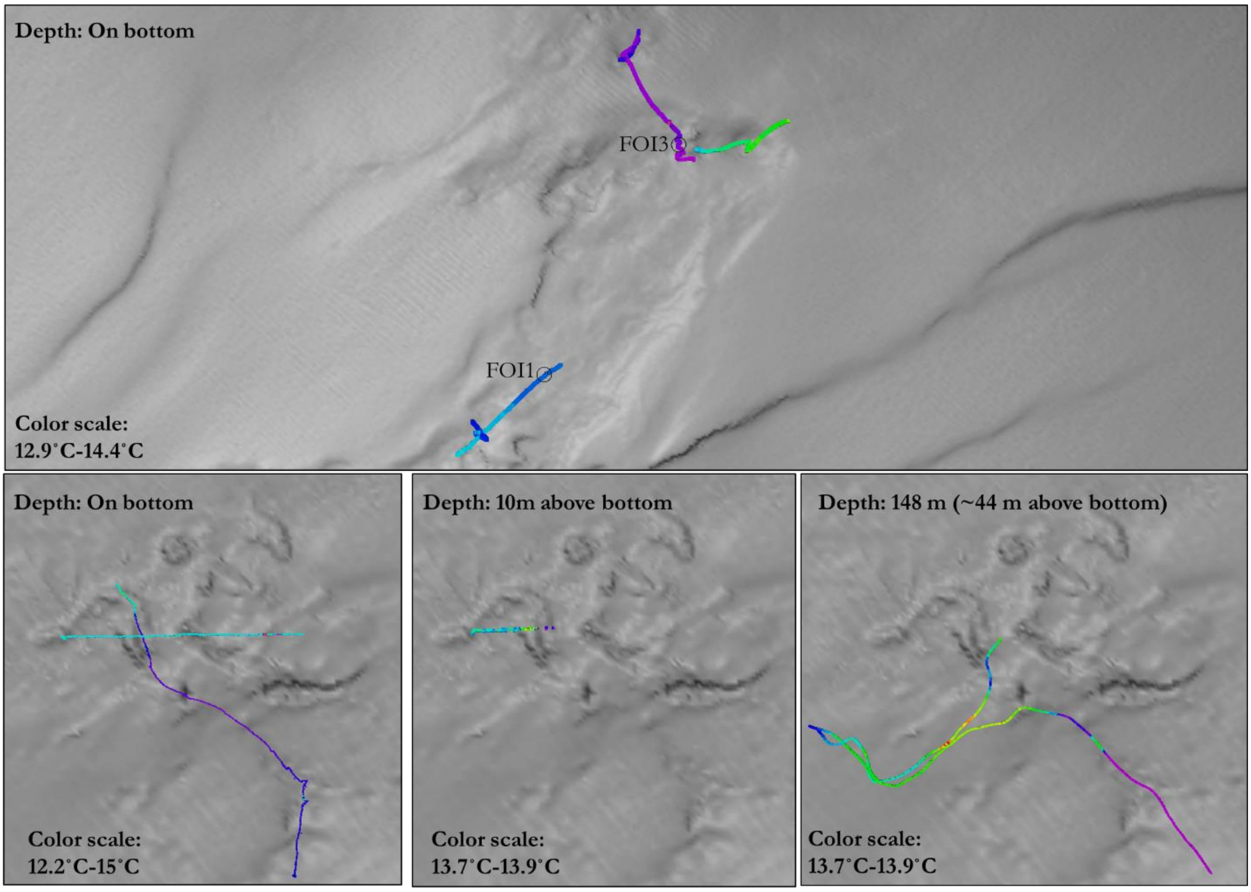


Figure 6-35 Transect results for temperature. Top panel: measurements made in the vicinity of FOI1 and FOI3. Bottom panel: measurements made at different depths in the vicinity of FOI2. Each track is positioned using the HIPAP system except for the bottom right AOS transect, which is positioned using the ship's position.

7 PROCESSING

7.1 Seafloor backscatter processing

The seafloor MBES backscatter data acquired during TAN1806-QUOI were processed onboard daily using the SonarScope software of IFREMER (Augustin, 2016). The resulting products consist of daily seafloor backscatter mosaics for each survey area, for both EM2040 and EM302 MBES. MBES bathymetry data were first processed with CARIS HIPS/SIPS, and sounding validity was introduced into SonarScope backscatter processing sequence, so that signal samples corresponding to invalid soundings were not taken into account for the BS mosaic. The backscatter data were mosaicked after compensation for transmit sector beam pattern and angular backscatter variation.

➢ **EM302 Tx beam pattern modelling**

EM302 calibration lines were run on Palliser Bay using the main acquisition parameters set for the voyage: shallow mode, CW pulse, single swath. Fore and aft lines were used to model a transmit sector beam pattern following the standard Sonarscope three steps workflow:

1. Remove all Kongsberg introduced backscatter correction (BSN-BSO, absorption, insonified area),
2. Model the local backscatter angular variation using a Lurton model,
3. Model the Tx beam pattern (steered sync).

This provides the possibility to generate a BScorr curve that could be subsequently introduced into the EM302 PU; this step was not undertaken during this voyage and can be implemented at a later stage.

The result for the EM302 shallow mode, CW, single swath is shown on Figure 7-1

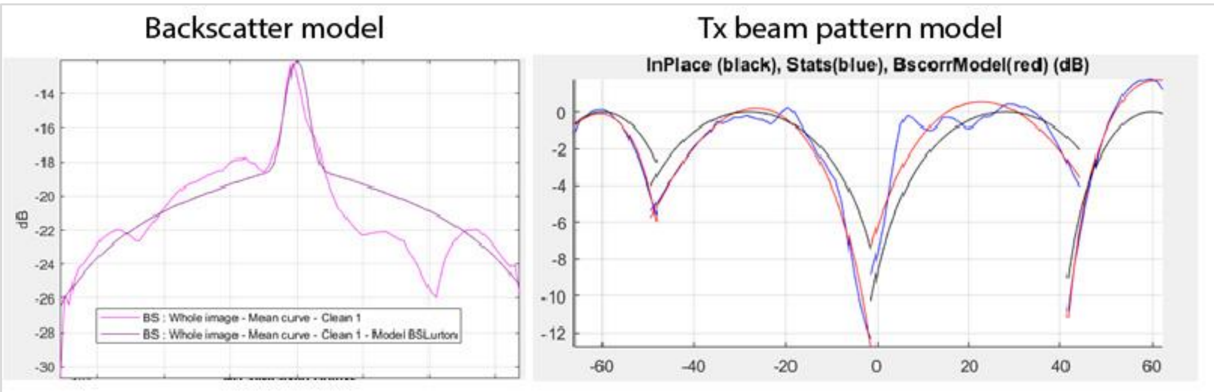


Figure 7-1 : BS model for EM302 calibration lines, mode shallow, CW, single swath, and resulting Tx beam pattern model

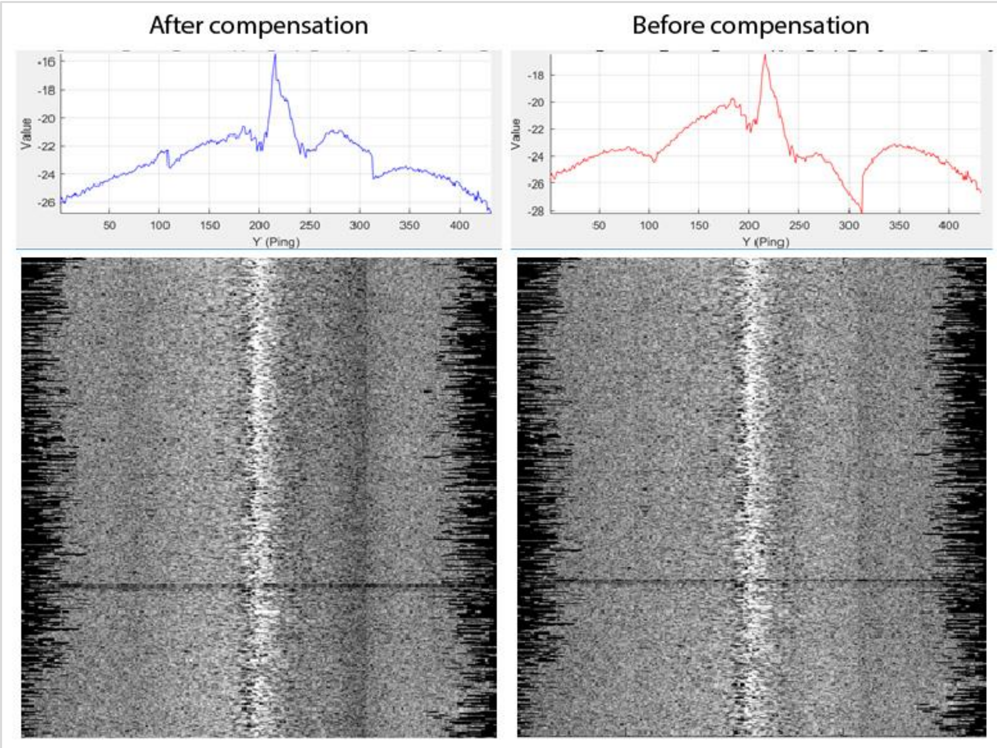


Figure 7-2 - Tx beam pattern compensated BS images, EM302, shallow mode, CW, single swath

The same processing sequence is not applicable to EM2040 data, as its PU does not taken into account such curves.

- **Backscatter mosaics**

The backscatter mosaics computed onboard took advantage of the very high seafloor coverage overlap generated during the voyage. This acquisition geometry enabled us to only consider beams outside the nadir sector [-20°/20°], and compute an average backscatter value on each grid point from each overlapping survey lines samples, after having been compensated from transmit sector beam pattern and angular backscatter variation.

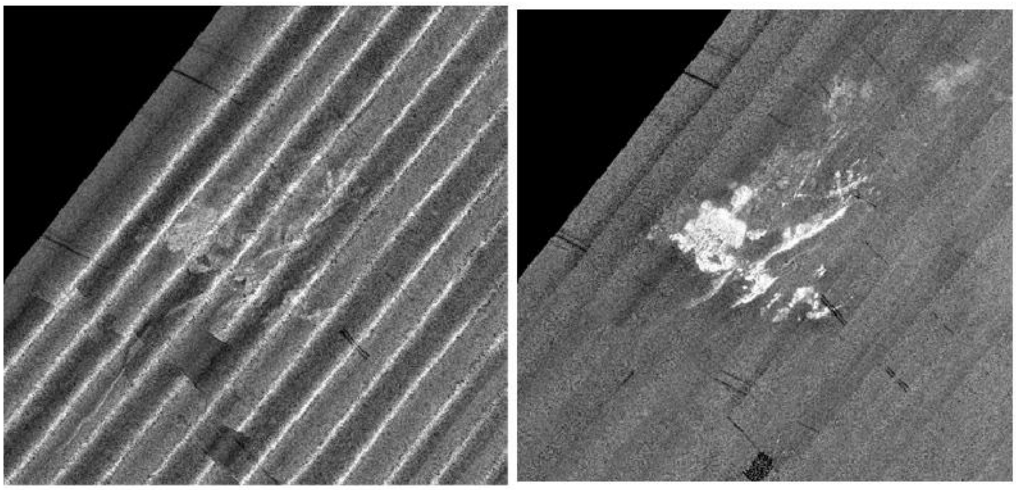


Figure 7-3 - classical raw backscatter mosaic (left), backscatter mosaic produced during the QUOI voyage taking advantage of the high overlap (right)

➢ **Bad weather**

Poor weather conditions - particularly on 9 and 14 July - affected the quality of the backscatter and the resulting mosaics. Bubble sheeting - aeration of the array - from strong heaving and pitching, resulted in very poor backscatter data quality (Figure 7-4). Some of the data are not usable. The EM302 is more strongly affected by poor weather than the EM2040. Affected lines should be removed from the final backscatter mosaic.

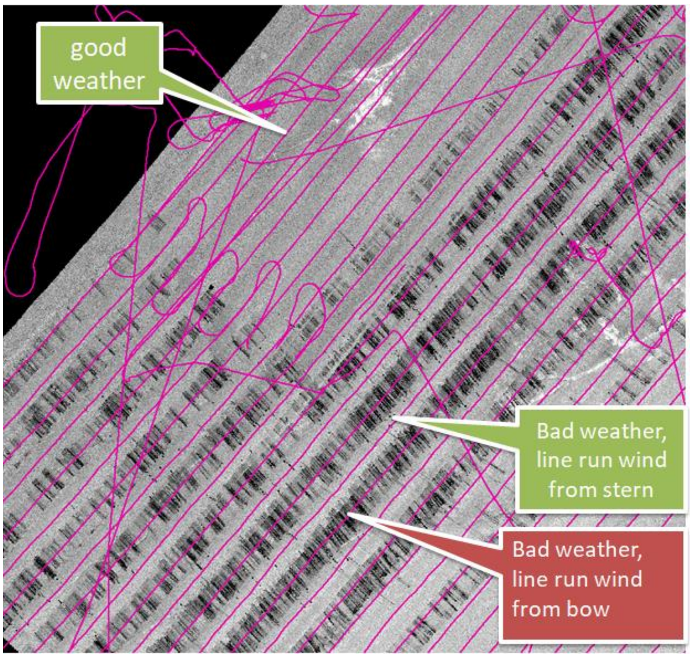


Figure 7-4: Influence of weather conditions on backscatter quality, EM302 mosaic over NCVF pictured here. Survey lisnes are drawn in purple.

- *Frequency dependent backscatter response*

Comparison of the EM2040 (200 kHz) and EM300 (30 kHz) datasets provides excellent means to discuss the frequency response of the seafloor backscatter. While most of the backscatter mosaics from the EM2040 and EM302 are similar, two in discrete locations in the NW and in the middle of the NCVF (Figure 7-4) show contrasting BS responses from both systems. These areas have a strong BS at 30kHz and weak BS at 200kHz.

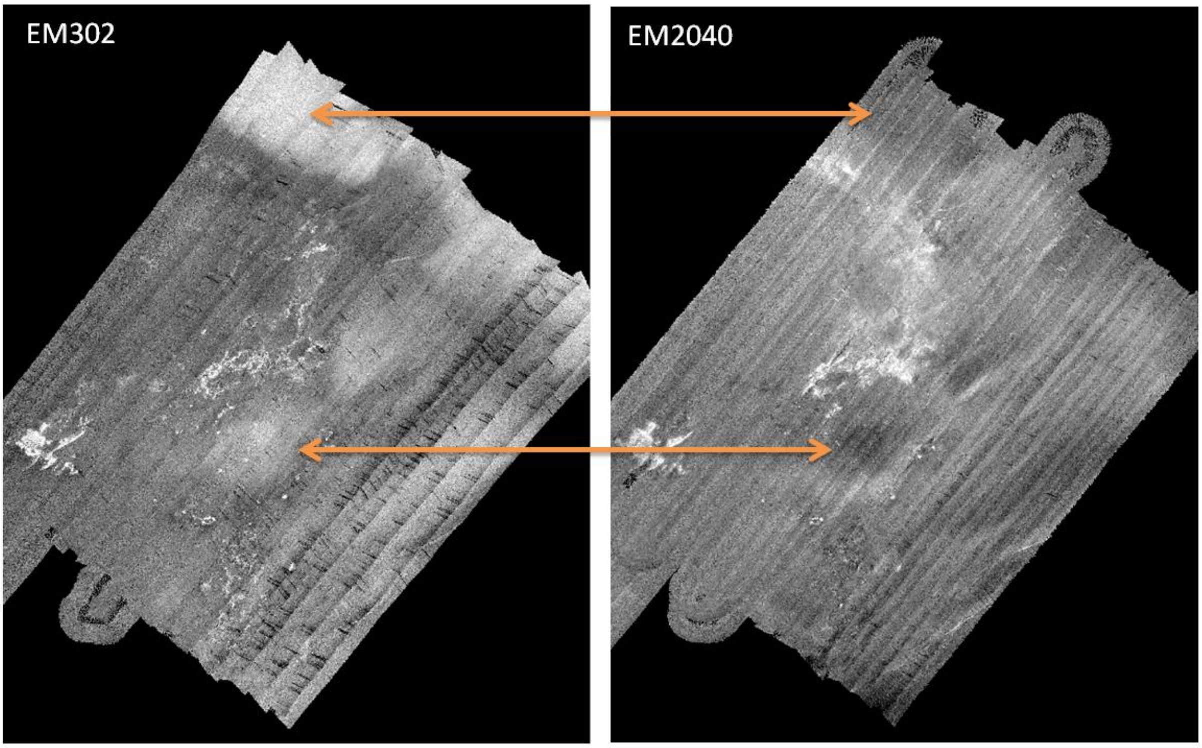


Figure 7-5 : spatial variation of backscatter on MBES frequency.

This spatial variation is illustrated by the backscatter profile on Figure 7-6 made over the two backscatter mosaics, and shows a decrease at higher frequency for northern tip, while it is the opposite at lower frequency.

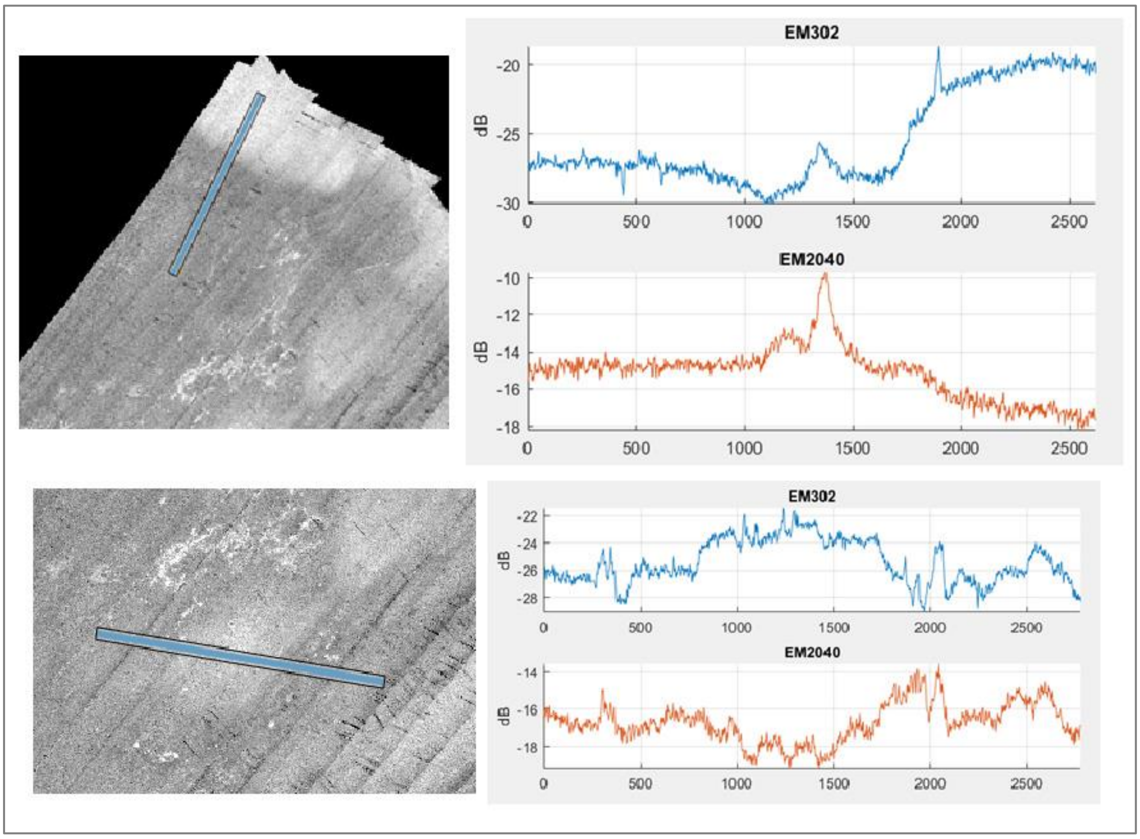


Figure 7-6 : Spatial backscatter variation as a function of the frequency along the profile

➢ **Discussion and Recommendations**

▪ *EM2040 cross calibration*

Cross-calibration of the pan-tilted mounted EK @200kHz and EM2040, as already done for the EM302.

▪ *Frequency dependent backscatter response*

We should investigate this backscatter opposite trend according the frequency. Maybe signal penetration involved here

▪ *Seafloor classification*

Very high overlap survey gives access on every point on the seafloor to angular backscatter variation with a fine angular sampling. We could then try to classify the seafloor based on a set of backscatter angular curves robustly computed over the very high overlap surveyed areas, and extrapolate this method to the whole bay of plenty (cf. Ridah's paper). As the whole area was surveyed with both MBES, we could even try to include the backscatter frequency dependence into our classifier.

7.2 Split-beam echosounder

Data were scrutinized during acquisition to ensure that important observation were not impacted by weather condition, or interferences from other equipment. On a regular basis, and when having observed interesting features, data was then opened using the open-source software ESP3. broadband/multifrequency analysis was then performed, to characterize and identify the observed features.

In most cases, a bottom detection algorithm the applied to remove the bottom echo from any further analysis. Some of the most interesting flares were then detected, using a school detection algorithm with tweaked parameters to fit this application (see Figure 7-7), and then exported to an *.xyz format, to visualize them in Fledermauss.

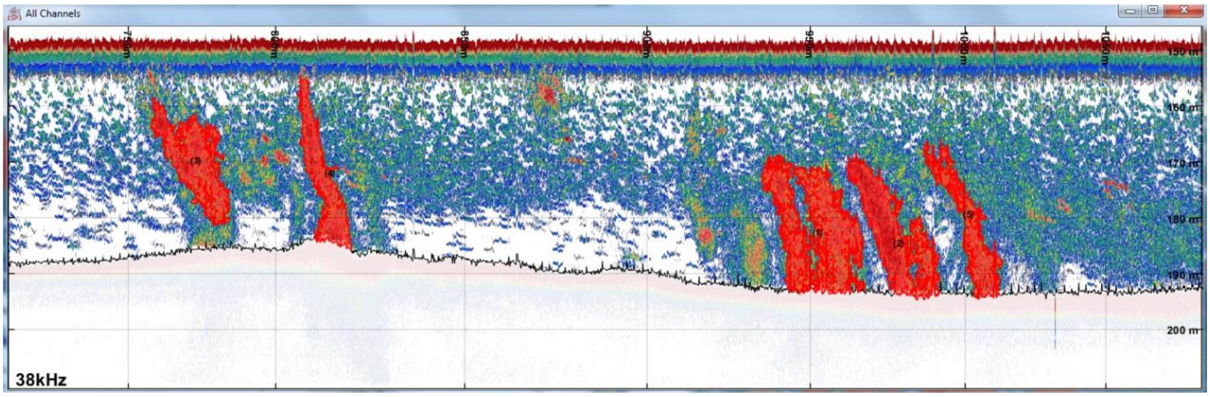


Figure 7-7. Echogram with bottom echo excluded, and flares detected automatically.

8 SUMMARY AND CONCLUSIVE STATEMENTS

R.V Tangaroa TAN1806-QUOI voyage aim was to enhance our capability to acoustically detect and characterise liquid and gaseous targets in the water column. The mapping of fluids and bubbles in our oceans is a challenge at the forefront of acoustic science, because of the potentially high economic value and environmental significance of gas seepages. The 20-day voyage (2-22 July) concentrated on the Calypso Hydrothermal Vent Field (CHVF), ca. 15 km SW of Whakaari-White Island volcano where numerous hydrothermal vents occur. A short survey offshore Poverty bay was started on the way north.

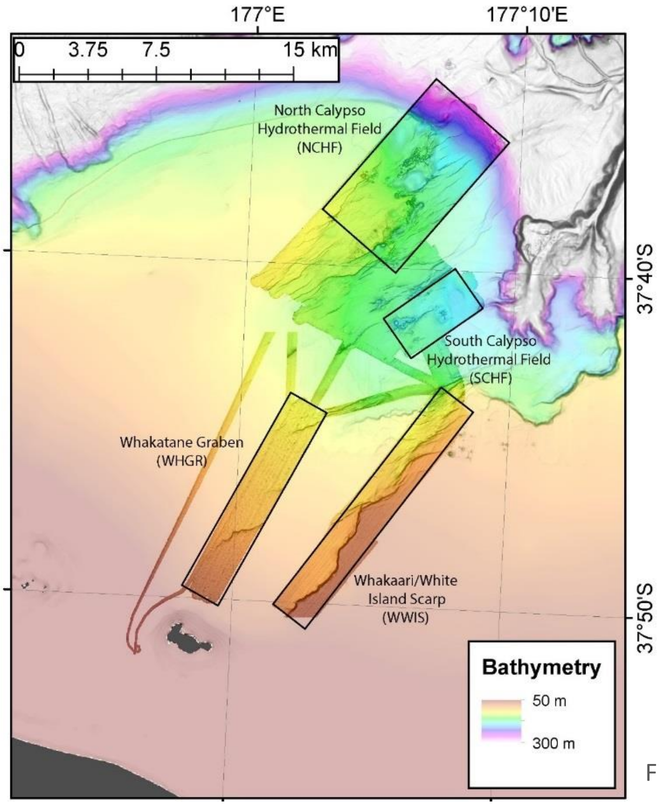


Figure 8-1 Overview of TAN1806-QUOI

The voyage collected ca. 4.6 Tb of acoustic data and video recording of gas bubbles and liquid seepages at the seafloor. Pioneering deployments of multiple synchronous echosounders, including 30 kHz and 200 kHz multibeam, six split-beam echosounders, two of which were deployed on the seafloor to ensonify bubble streams horizontally enabled us to generate implausible and contrasting images of gas bubble streams on echograms.

Other innovative experiments included high echosounder swath overlap to enable the study of angular backscatter response in both seafloor and water-column data; a multi-angle, multi-frequency coverage over both artificially generated bubbles and natural vents in steps of 5° thanks to the use of a swivelling pan&tilt device.

Thirty-one sediment samples and 43 water samples were collected for ground truthing.

Heavy weather (i.e. with wind greater than 30 knots - See Figure 8-2) impacted the deployment of equipment over two periods of 48 and 24 hours. During these times, data was acquired but quality was compromised.

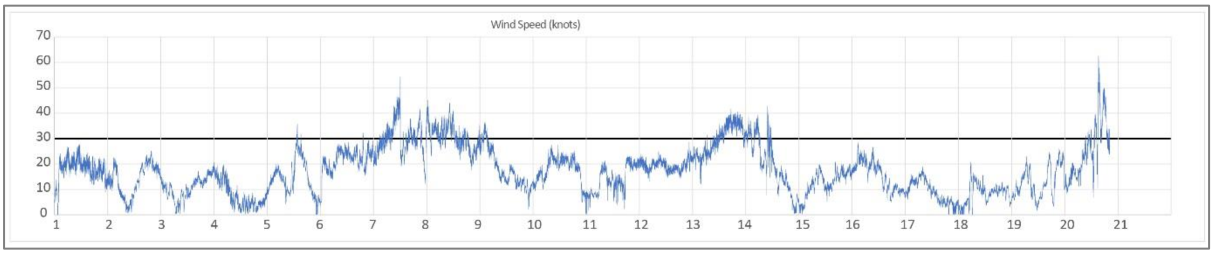
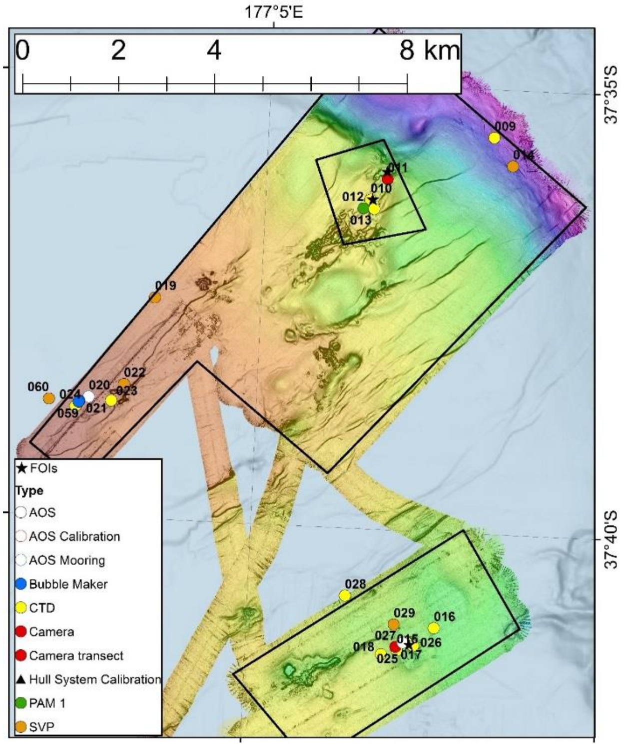


Figure 8-2 - Winds during TAN1806

The research was undertaken by experts from NIWA, France (CNRS/Uni Rennes, IFREMER), Australia (IMAS), and the USA (CCOM-UNH). The research undertaken during voyage TAN1806-QUOI (Quantitative Ocean-Column Imaging using hydroacoustic sources) was a milestone of the Royal

Society of New Zealand's Catalyst:Seeding project "*Building Capability for in situ quantitative characterisation of the ocean water column using acoustic multibeam backscatter data*".



- *Preliminary analysis generated by the split-beam echosounders*

These should be treated with care as the dataset needs a lot more work before anything can be concluded.

One of the most interesting observations from split-beam data, have been the very different frequency responses on flares, both using the AOS and the hull system.

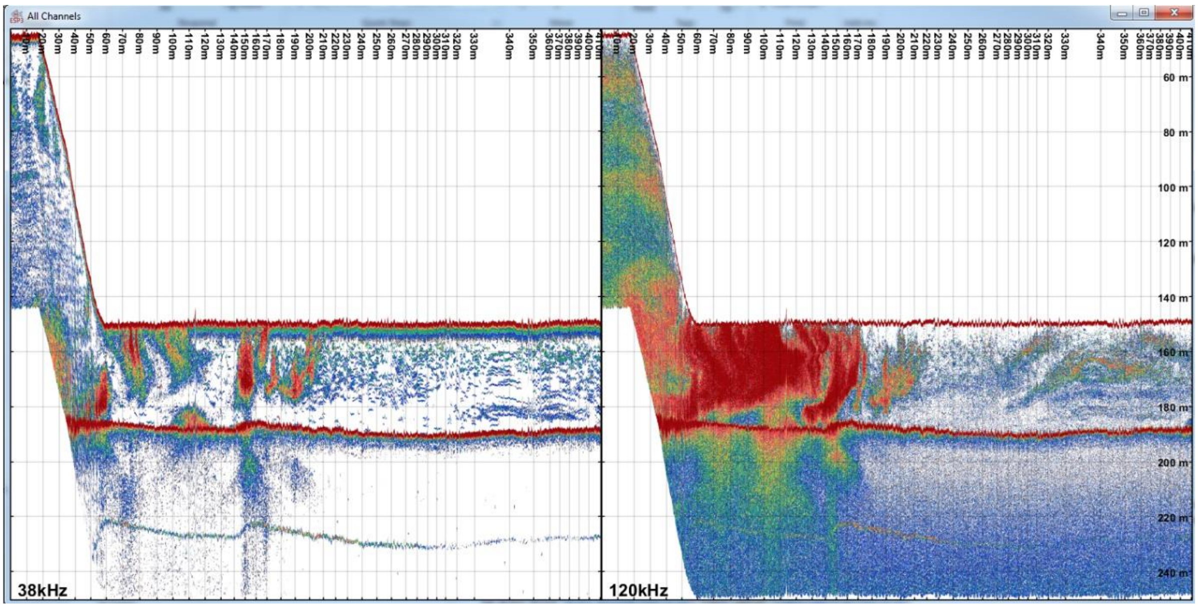


Figure 8-3 AOS Data collected on FOI-2. Flares observed at 38kHz (left). Flares observed at 90-150kHz (right).

AOS deployment on *FOI-2* has given good measurements, showing good potential for the use of acoustic for characterization of bubble size and bubble density estimation. Figure 8-3 shows a flare seen by a single frequency (38kHz) and a frequency band (90-150kHz). On the first part of the echogram, you can see the AOS being lowered down to a 150m to get closer to the flare and get better spatial resolution of the structures.

Observations on this transect proved to be very interesting. Figure 8-4 shows a smaller version of the flare, where two regions have been isolated. Those two regions have a very different frequency response, likely indicating a very different size distribution of bubbles (as they are a at a similar depth), and probably a difference in composition.

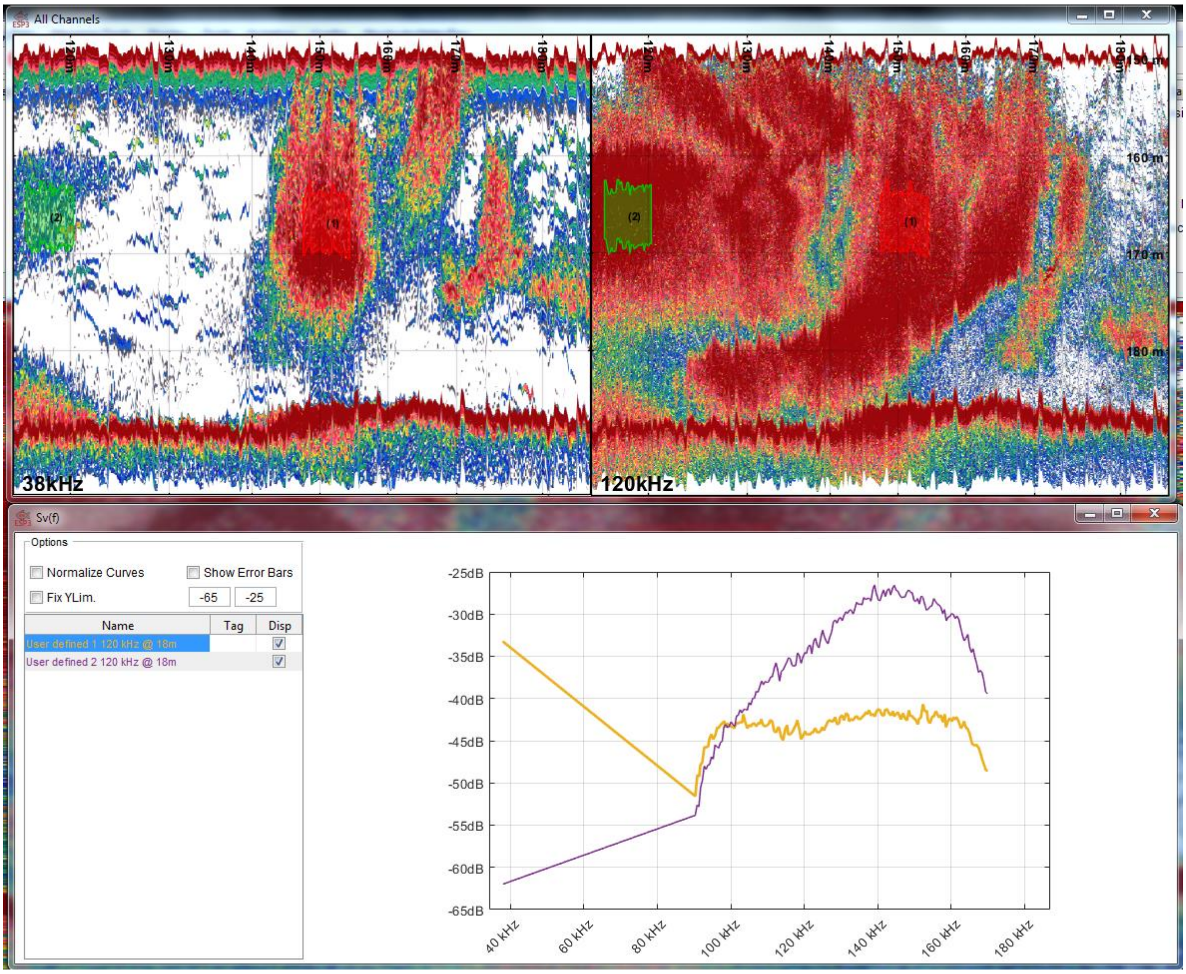


Figure 8-4. Volume backscatter frequency response $S_v(f)$of two regions taken in two different places in the FOI-2 flare(s). $S_v(f)$from region 1 (red) is shown in purple, $S_v(f)$ from region 2 in yellow.

Preliminary analysis shows promising results, with frequency responses on flares behaving as expected, telling us that there is potential here to use those data for qualitative analysis and potentially flux estimations of various gases.

- *Bubble Maker - Frequency response of individual bubbles*

Individual bubbles are identifiable in all the EK echograms. The frequency-modulated acoustic response of single targets can be extracted from these data and with the application of calibration offsets target strength can be calculated (Figure 8-5). The mean target strength of bubbles from both deployment data appears to be approximately -55 dB (bubbles between 80-85 m). In comparison of these target strength data to acoustic scattering models places the radii of these bubbles between 1.5 and 2.0 mm (Figure 8-6).

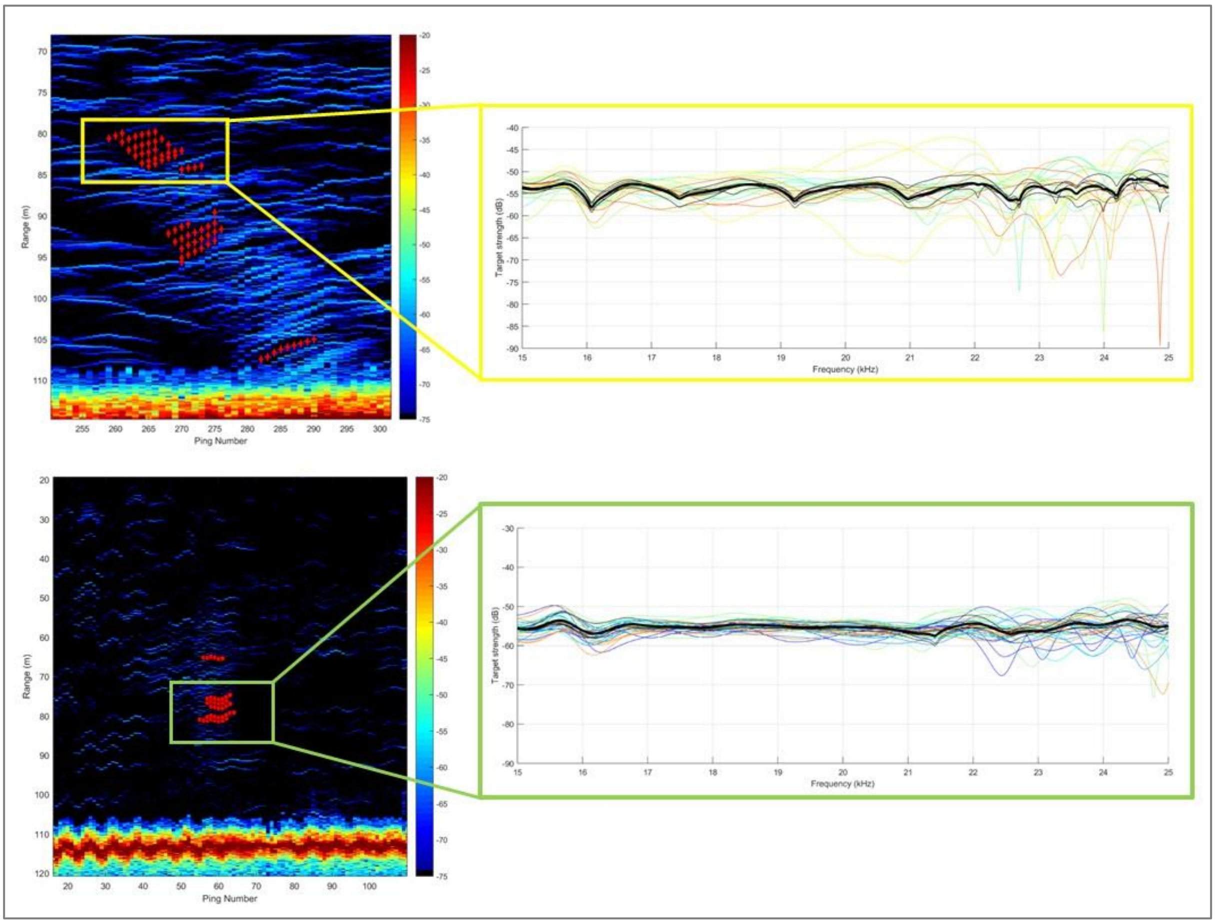


Figure 8-5. Frequency-modulated target strength curves (right side) from individual bubbles from the first and second deployment (right) of the bubble maker.

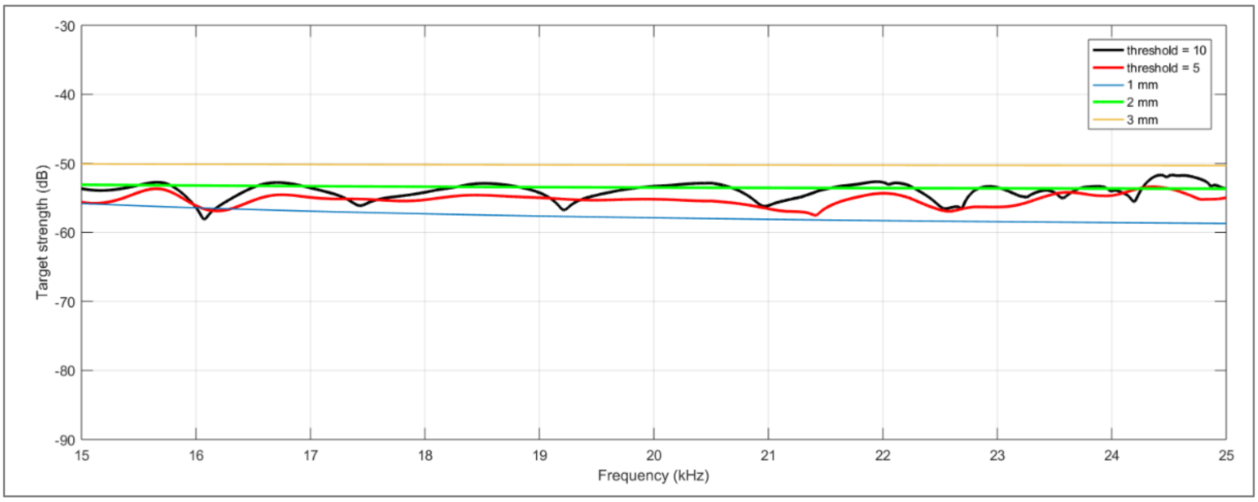


Figure 8-6. Comparison of the mean frequency-modulated target strength curves from the first (black) and second (red) deployment data to an acoustic scattering model for single bubbles (blue, green, and yellow).

9 RECOMMENDATIONS

Glossary of Acronymes

NCVF	Northern Calypso Vent Field survey box
SCVF	Southern Calypso Vent Field survey box
WHGR	Whakatane Graben survey box
WWIS	WHakaari-White Island Scarp survey box
MBES	Multibeam echosounder
BOP	Bay of Plenty
CTD	Conductivity Temperature Depth sensor
FOI	Flare of Interest
SBES	Single beam echosounder
PSD	Power Spectral Density
PAM	Passive Acoustic Monitoring
AMAR	Autonomous Multichannel Acoustic Recorder

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APPENDIX -1

ONBOARD MEETING MINUTES

Science Meeting 1 - Thursday 5 July

Chair: GL Note: VL
Attendance- Erica (ES), Camille (CL), Arnaud (AG), Tom (TW), Yves (YLG), Erin (EH), Vanessa (VL), Sally (SW), Cyrille (CP), Pete (PG); Peter (PU), Yoann (YL), Geoffroy (GL), Arne (AP), Liz (LW), Katie (KW), Will (WQ)

- **What we have done:**

a) Calibration:
- YL: went quite well and very helpful to have everyone involved.
- GL, PPE important on the back deck. Some people have been allocated a life jacket if you think you will need one please see GL.
- Comparison with the 2040 will be compromised if the noise from the pan and tilt is not addressed.

b) Topas
- Arne has run a brief training course on the TOPAS.

- **What we are doing**

1. Transiting.
2. Now acquiring the Hawkes Bay Line for future research proposal.
3. TOPAZ and MBES.
4. Transit will resume to the Poverty Bay site- we hope to find cold seeps in the region. We will do a lot of mapping with overlap.
5. EK60 is not turned on presently but we will acquire it in Poverty Bay.
6. One water depth spacing which in Poverty Bay translates as 200m on the deeper site.
7. Time allocation to sampling in Poverty Bay 15 hours.
8. CTD at beginning of mapping Poverty Bay-.
9. Run TOPAS water column over previously mapped and identified seep locations.

- **Issues Discussion**

10. Topas- do we want to record water column?

- **Life Jackets**

11. PG wished to talk about the order of moorings- they will be deployed and recovered in identical order each time.
12. Bubble maker discussion- 1pm in the hydro dry lab.
13. On the shared drive Yves has developed a form to update what has been done.

Science meeting 2 - Friday 6 July

Chair: GL Note: VL

Attendance: AP, GL, AG, PU, TW, CR, YL, YLG, VL

1. Top of the line stop the 200m vertical and drop the pan and tilt and fill in some of the lines.
2. Decision – 2 more north western lines-
3. 18 and 38Khz and 200P&T then second separate line with the Topaz.
4. Top of the transect then we need to stop and deploy the pan and tilt.
5. No EK s on the first few lines and no 2040.
6. Single beam has been recording top 50 m of water since midnight, since the calibration.
7. Pan and tilt 200kHz at 45degrees only over targeted mounds.
8. 1015am to 1030 am we have been collecting very strong target data.
9. MBES 2040 problem
10. BIS test came back clean.
11. All other units were turned off.
12. Noisy from 130 m onwards.
13. Could not see a lobe in the water column.
14. From 130 m onwards the data looks saturated.

Science meeting 3 - Saturday 7 July

Chair YLG; Note GL
Attendance : GL; VL; YLG; AP; TW; YL; CP; PU; EW; WQ

what's happening over the next few days as weather is about to change?

1. Survey centre of CHVF
2. Identify location for Drop camera and AMAR
3. CTD then drop camera on afternoon
4. Deploy AMAR either late pm is bridge ok or in the morning'
5. If weather turned bad - finish survey of CHVF
6. Parameters for SSG not too critical.
7. Transponders on cable from weight and boys; these are quiet and only respond to request; need to check that they wont respond to EKs
8. Can we deploy the AOS then SSG and retrieve the other way - Check with PG

- **Plan for Saturday night and Sunday 8 July**

1. Resume and complete 75% overlap (c. one water depth line interval) over the CHVF
2. In morning deploy AMAR incentre of CHVF next to oblique plume identified today
3. Weather permitting undertake one video survey - modalities to be discussed but better comms between bridge-video-survey labs is required.
4. Alternative is to start very high detailed survey of oblique plume with very closely spaced and various headings profiles. Amy to Start design survey with what is in voyage plan as guide.

Other notes not discussed in meeting from Voyage Leader

Several files and directories have been created on the Voyage drive to make life easier to the science crew:

1. V:\Jpg-tiff\ is a directory for images and screendumps; please give meaningful name to your images and screendump.

2. .\ Readme_Jpg_descriptions.docx , A description file for all jpg and tiff etc. please fill it appropriately
3. OperationInProgress.xlsx files. Include narrative and next operation to come. Read; Yves to fill.

Update Sunday 8 July 9 am

- Deployment of Passive Acoustic Monitoring system
  Position 37 36.41S 177 06.40E
  Name of station is PAM-1 (on top of sequential TAN station)
- Proposition for file naming Site_Offset_Tool (ABCD_XXX_XXXkHz)

Site= 4 letter site description

Offset= Direction and number of lines from center (E,W, N,S)

Tool= Sounder frequency

e.g FOI1_W001__200kHz

To discuss and validate by 10:30 Monday

Science meeting 4 - Monday 9 July 10.15 - EK lab

Chair: GL Note: VL
Attendance - GL; YL, YLG; KW; CR; WQ; CP; AG; TW; PU; PG; ES; AP; EH; SW

1. Update:
   - 75% overlap mapping is completed over the CHVF
   - 95% overlap over FOI#1 (Flare of interest, oblique flare) in central CHVF started but many lines too noisy will have to be redone
   - Buoys for PAM-AMAR in the way of NE-SW lines so these were not done
   - acquisition was stopped for a few hours
   - EK80 dropped out for a while circuit board failed; repaired at 8 am;
   - now doing southern lines toward Motouhora Island; seep hunting in Whakatane Graben along NNW-SSE lines; not many seep seen;
2. Reminders
   - watch time, be on time; be in lab earlier for watch transfer;
   - watch duty check with watch leader; make sure not always the same person in charge
   - Log books now includes a **diary of event** time in NZST in 24 hours format please!;
   - Clean the sandwich press please!
   - Log book for EK need a bit of attention; add line name; EK log to be filled MB room
3. File naming
   - Line names in logs should follow same pattern LOCA-OFFS-SYSTEM with
     LOCA = four letter for location
     OFF= 4 digit for offset from central line
     SYSTEM = text for system used.
4. Processing:
   - Seafloor backscatter : ES; AG; AP; AN; note that AN has started processing with FMGT; but full processing should be done with Sonarscope; please keep a log/diary of backscatter processing

- MBES - AP in charge
- EK single beams- YL; TW; LW cleaning; visualisation, picking; 3D view
- Water Column - Erin; FMMD; point cloud and layers; 3D grids; run feature detection; seep detection preliminary detection; integrated layer; height; bottom; 3D grids; visualisation of FOI.
- ARC project on voyage project need a revamp of a good base layer. Use Mercator 41; geotiff + SHP

5. Figures - every one to think of nice figures; need coherency; use meaningful filenames and add shot description/caption in readme document
6. What next
   - seep hunting in southern region
   - If weather improves by Tuesday pm do a video
   - more mapping at night
   - Deploy bubble maker on Wednesday
   - **To be reviewed at 5 pm on Monday to allow changes with weather**
7. Erin to think for

Science meeting 5 - Wednesday 11 July - 3.30 pm

Chair: GL Note: VL

AOS and Bubble Maker in the water; Thank you to the crew and Pete for safe operation. High five!

The position of the SSG is known and we can now see bubbles. Following a short EM200 transect with the pan&tilt it was decided to change the sounder on the pan&tilt to install the 120 kHz.

The next actions/operations until WE and subject to weather are

1. Swap 200 kHz for 120 kHz on the pan&tilt
2. Retrieve the AOS
3. Multiangle and multifrequency survey over the bubble maker with a nominal line spacing of 10 m to obtain a ca. 7° transmission angle.
4. Retrieve the bubble maker
5. CTD at location of bubble maker
6. Transit to FOI-2 (Flare of Interest)
7. Camera transit at FOI-2
8. AOS transect (drifting over flare with AOS ~60 m (TBC) below vessel over FOI-2
9. CTD with water sampling
10. Transit to FOI-3
11. Full AOS deployment
12. Transit to FOI-1
13. Retrieve PAM
14. Drop camera transect
15. Redo full survey over FOI-1
16. Sediment sampling using grab (x30 samples)
17. Multiangle survey over FOI-2
18. Shallow Bubble maker deployment north of Motouhora
19. ROV over shallow water seep

Indeed, all this subject to weather and new opportunity arising from data being processed and interpreted.

Science meeting 6 - Thursday 11 *(? Date unsure as no date on original notes)*

Present: GL, VL, Cyrille, Erica, Sally, Peter, Yoann, Arnaud, Erin, Arne, Camille, Yves, Liz, Tom.

- Yesterday we deployed the AOS and bubble maker- deployments were successful.
- Started to record late in the night, AOS recording on its own in silence for 3 hours. The survey over the bubble maker with the slack on the 1st weight made the 1st mate nervous and he would not survey over. 8 attempts of lines with three that were successful. On the other 5 the lines were not complete, and the bubble maker would not have been detected. Cannot be counted as successful lines. Lines only 200 m long- and the pan and tilt was facing in the wrong direction.
- Wind was turning from SE to NW.
- This morning Evan hooked one of the lines and dragged the bubble maker. No damage to bubble maker.
- The AOS was deployed successful but failed to start recording data. We are currently doing test runs and it has failed 4 out of 77 times.
- We are transiting back to FOI #2 in South Calypso vent field.
- Video transect, water sample CTD, and dragging the AOS in the water column will take up till 10pm.
- 2 hour transit back to FOI#3. Drop the AOS. Pick up the AMAR.
- 75% overlap of map of FOI#3.
- Action Item- J and T to select site of FOI#3.
- Bubble make will be redeployed on Friday the 13th.
- Saturday the 14th. AOS will be on FOI#3.
- Compromise- dangling AOS over the side and map the bubble maker next week.
- How can we stop the AOS spinning on deployment- would an additional line help?
- 95% overlap of at least 1 flare. What was completed over FOI#1 was poor quality.
- If we can put a transponder on the drop weight will this help with deployment of the bubble maker? The weight can be a long way from the buoy so that we can map over the top of the bubble maker- it will require a transponder on the weight.
- The bubble maker was not visible in the MBES data (although there was some uncertainty about this) it was clear in the EK data.
- Bubbles from the SSG were visible in the pan and tilt.
- Perhaps we turn the 38 and 200 kHz turned off when we run one line over the SSG.
- FOI #2 multi angled experiment- perhaps this could be completed this evening?

PLAN

- 95% overlap of FOI#2.
- Transect 2 of Towed Video Camera
- CTD
- 120kHZ was put on the pan and tilt on the evening of 11 July.
- The 120kHz pan and tilt and the hull 120 will also require calibration.

Science meeting 6 - Saturday 14 July 16.15 - Library

Chair: GL Note: VL
Attendance: CP; PG; YL; TW;AN; KW; EH; VL, GL, SW; GM; WQ; YLG

- **Update**

Just back from Motouhora/Whales Island to collect SBE37 and CTD water sampling bottles, Mapping one line NW of Whakatane Graben box on the way back.

A great dataset has been acquired over FOI-2 but a complete dataset over a natural vent would need to add (1) 95% coverage box; (2) validated salinity-temperature casts; (3) CTD water samples; (4). FOI-2 obviously the closest and best target for this.

Sediment sampling went ok- recovery rate of 50% - 14 recovery out of 28 stations.

The Ifremer hydrophone is currently on the bubble maker which was deployed Sat at 1pm.

- **Voyage Report Writing Responsibilities:**

- Background GL
- Methodologies- Sediments VL, Video tows VL, EK acoustics TW, YL, MBES- AN, GM; Hydrophone CP; YLG, PAM YL; AOS- YL.
- Brief (factual) description of the results with some screen dumps and summary.
- Data output for each section.
- Deployment operations to be described with good and bad! PG to write on the AOS deployment.
- EH, SW Figures.

Science outputs needs to be discussed next week for scientific hypothesis; papers etc. please start thinking about it.

- **House keeping**

Please fill out the voyage daily log. This helps with writing the narrative.

- **Options for next 24-36 hours**

Predicted high wind so no deployment no Bubble maker.

CTD: we can deploy SBE37, need to wait on calibration files for new sensors (subsequently found on email)

Bubble Maker: priority 1 for GL. SW vs DW, issues with fish/scattering layer.

TW priorities: 1. Calibration, so that we can use/publish with all this data 2. Temp/salinity measurements over FOI2

TW: Good story with fluid flow, we need T/S and can we get SBD37 on camera

Priorities still overruled by weather, need to work around weather. In rough weather we can do sediment sampling, CTDs, recover bubble maker.

Bubble maker should come up tomorrow morning at latest (back on deck since), CP would also like hydrophone back to recharge. Maybe opportunity to put it in shallow water (50-60m). Have to have different mapping plan – circle it, drift over, etc.

TW notes that PU would be interested in a high flux rate experiment with bubble maker, requires recovery and redeployment of bubble maker.

PG will check weather on bridge and make call on when to get bubble maker. Tomorrow morning?

CTD is high priority. TW start with offsite cast for check on CTD where not much is happening, then re-do FOI-2. Where PAM was deployed. FOI-1. FOI-3. Possibly a few casts at FOI-2, maybe not sampling, and ADCP so we can get upstream, downstream.

Sediment sampling tonight, move **CTD sampling to tomorrow morning**. One outside, just north of CCVF, then into FOI-2?

Sediment sampling needs someone to mark position on hipap, not necessarily need someone in MB room. Minimum of three, better four in cutaway to run sampling. Every site is a station, untriggered is a station, every deployment is a station.

SBE36 needs to be programmed and put on CTD. YL, Will will take a look at it

Action	Priority	Comment
Hull Calibration	1	
Temperature-Salinity over FOI-2	2	
Bubble maker	3	
95% over FOI-2	4	
Water sampling CTD	5	Redo out of flares; water sampling based on cast; Working CTD; ADCP;
Complete sediment grabs	6	
95% over FOI-1	7	
Camera over FOI-1	8	
Shallow Water Bubble Maker	9	
Bubble maker high flux rate	10	

Science meeting 7 - Wednesday 18 - Library

Chair: GL Note: VL
Attendance : GL; VL; TW; CL; AG' ES; EH; PU; EW; CP; YLG

1 - Update:

- Overnight filling in between the two survey sites of North and South HTVF at 65% overlap. -
- Profiles of temperature gradients- 1.5 degrees were recorded on yesterday's video transect from temperature probe on the sled.
- No background temperature record when sitting in an area with no bubbles.
- AOS transect on 17th night- bubbles and fluids on the echogram- very good data.

No health and safety records to report.

On Friday we need to leave site at the latest 1pm.

- **2 - Next**

- On Bubble Maker site - check CTD probes and redo cast that had erroneous data.
- Bubble maker is being deployed. Repeat transect above bubble maker and then start the 12 profiles with varying pan&tilt inclinations.
- One or 2 camera transects on FOI-1
- CTD, temp probe RBR, hydrophone, 2 go pros on FOI#1 + other that need being redone (Check repair first).
- Finish mapping at 65%
- Tomorrow (19/07)
- video transect FOI#3
- AOS transect onFOI-3 (drift).
- 95% survey over FOI-1 or FOI-3 (or both if possible)

We are aiming at leaving BoP at midnight on Thursday to enable completing map at Poverty Bay

Noted that DP noise has been impacting the same watch for the last 2 days. Unfortunately, not possible to plan otherwise at this late stage in the voyage.

Possibly redo a patch at Palliser Bay (Arne's request).

- **3 - Figures- Report**

Everyone being given report duties.

Figure list in V:\QUOI-Voyage\VoyageReport\Figures please fill appropriately

Offset between the HYPAP and the position sent in real time from the bridge. Offset is 6m. EH to check with WQ

Need to inquire about possibility of spending Sunday night onboard.

Science meeting 8 - 20 July 2018

Chair: GL Note: VL
Attendance: GL; VL; AY; YLG; CP; PU; TW; EH; EW; AP; YL; ES; SW;

- We are now on transit to Wellington.
- 5 Hours of DP calibration and Pallister Bay calibration.
- ETA Wellington 10 am. Weather will not be good on arrival.

- **Update on work done**

- FOI#2 CTD
- Mapped the link between the Northern and Southern Calypso.
- Added a couple of profiles on the scarp.
- Topas profiles taken on the depression on the side of FOI#1.
- Two litres of water were taken on FOI#1- Oxygen, flurosence etc – taken mainly for CO2 analysis.

- **Housekeeping**

- Labs cleaning is the researcher's responsibility
- Acoustics lab- 2 wet labs etc.
- Please also leave your cabin clean on departure

Data: GL proposes that NIWA will send out copies of the data to each of the four research groups. Yoann will compile a data record and list.

NAVIPAC- data has ~15 m offset; folders need to be used with caution as this is not the best data. WQ is going to write a method for the positional information with the offset for the HYPAP. A list will be made of what folder contains what- and the coordinates for each one.

- **Report**

- Voyage report is coming together- everyone has been assigned a duty- please ensure that you write your section and complete it.
- Please list your reference or save in Endnote.
- Please use English spell corrections.
- Figures should be numbered by section and numbered. Please save the figures onto the server.
- Options for the report- unpublished report. Second option- to format to a full NIWA technical report.

- **Demobilisation**

- Please make sure all the bags are on the back deck and that all gear is packed by Sunday morning.

Academic output meeting will be held on 21 July.