Sounding the sparkling depths

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It's a calm winter's evening on the Bay of Plenty, on the New Zealand's North Island shores. Under the watchful peak of Whakaari/ White Island, the country's only presently active, emerged marine volcano on the New Zealand continental shelf, a group of international scientists are huddled around a computer monitor visually displaying pings and clicks as they 'listen' to sound echoes from a water column below the vessel.

They're aboard the RV *Tangaroa*, New Zealand's deep water research vessel, listening to the returning echo from an array of echosounders, as they fire in the ocean water at their target: air bubbles, produced by a specially-developed machine deposited within the hydrothermal vent field below, around 200 metres beneath the calm surface upon which RV *Tangaroa* rests.

If this all sounds a bit strange, it is. Echosounders are the primary tool for submarine surveying, using acoustic waves to map at depths that optical technology on the surface, or in the atmosphere or can't penetrate.

But what about the bubble machine, and why here? The team of 20 scientists, technicians and students, from seven different international institutions, are seeking to capture a chimera of sounding techniques — quantifying the volume of gas emanating from the seafloor — or accurately measuring the size of bubbles escaping from the seafloor.

The team is comprised of experts in marine acoustics, geophysics and spatial analytics from New Zealand (NIWA, University of Auckland), France (Géosciences Rennes, IFREMER), Australia (IMAS), USA (University of New Hampshire) and Germany (GEOMAR) who are combining their expertise and state-of-the art equipment to carry out the objectives of this voyage.

Moving targets

From her office in the IMAS headquarters in Hobart, co-voyage leader Dr. Vanessa Lucieer lays out some of the diverse applications for the techniques the team is studying that underpin the significance of this voyage.

Her IMAS team is interested in precise quantification of submarine gases and liquid seepage from the sea floor for geoscientific industry-related applications, for which quantifying these emissions has a huge economic value, and environmental management such as biodiversity mapping.

The New Zealand team led by Associate Professor Geoffroy Lamarche, is also looking to quantify methane and CO2 emissions for a different purpose.

"The current global models that we have for CO2 emissions to the atmosphere are terrestrial. We don't actually have part of that algorithm to account for CO2 emissions from the ocean," Dr. Lucieer said.

"They do account for the chemical transformation in the water mass through water chemistry analysis, but not from the seafloor. So how much CO2 is actually being emitted from the seafloor is currently not part of the model because there is no direct and accurate way of measuring flux — the size and rate of the bubbles."

I allow the implications of these statements to wash over me while Dr. Lucieer describes the team's technique.

Method in the methane field

Building on laboratory-based experiments carried out by French institution IFREMER and at the University of New Hampshire, this voyage aimed to test those results with a plethora of different echosounding configurations.

"So we were extending some of that laboratory-based work and wanted to see how well the models fit to looking at bubbles in natural environments. We looked at optimisation: with which acoustic frequency, at which angle could we best detect bubbles coming out from the seafloor, to calibrate those systems," she said.

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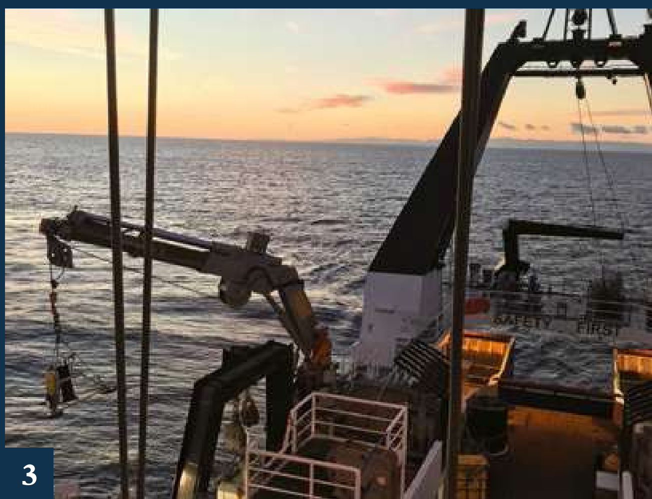

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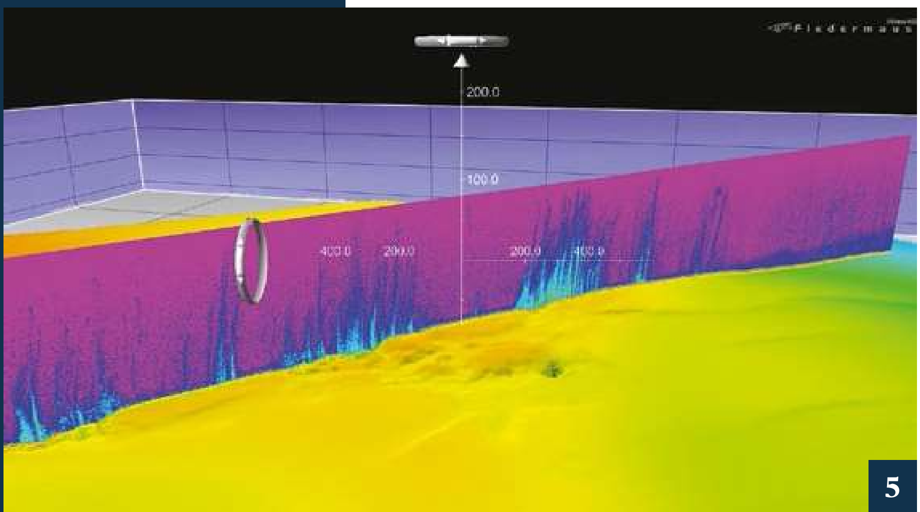
4/ Acoustic equipment and floats securely stored on the stern of R.V. Tangaroa for deployment on the Calypso Hydrothermal Vent Field. The mighty Whakaari – White Island watching over us. Image by Geoffroy Lamarche.

5/ Acoustic curtain showing the gas plumes imaged as acoustic flares rising from the seabed. Image by Erin Heffron.



1/ Associate Professor Tom Webber and PhD candidate Liz Weidner (Center for Coastal & Ocean Mapping/Joint Hydrographic Center, University of New Hampshire) prepare the 'bubble maker' for deployment from RV Tangaroa. Image by Erin Heffron.

2/ The bow of R.V. Tangaroa with the mighty Whakaari White Island volcano in the background. The vessel is just above the Calypso hydrothermal vent field. Image by Geoffroy Lamarche.

3/ Deploying the bubble maker in the early hours of the morning in the Bay of Plenty. Sun rising over the Raukumara Peninsula, NE New Zealand from R.V. Tangaroa. Image by Erin Heffron.

Using a purpose-built machine that released a one-millimetre diameter bubble every five seconds, the team was able to compare acoustic properties of the artificial bubbles with those being produced by the neighbouring hydrothermal methane vents.

"By counting how fast the bubbles moved through a known space, and since we have a good idea of their size, we can get an idea of flux," Dr. Lucieer said.

"This is all done coincidently over where the acoustics are run, and then we're taking temperature, salinity, conductivity measurements in those areas too, so you can accurately understand the water mass, which is going to affect how the acoustic sounds look at those bubbles as well."

The IMAS team built a specially designed grid extension for their towed camera that facilitated visual validation of the bubbles that the sounders were measuring.

A perfect matrix of results

Describing the overall outcomes of the voyage, Dr. Lucieer is buoyant over the perfect environmental conditions, and smooth operation of the tests the team was running.

"If you've ever been to sea on a survey – you will realise how hard it is for all of the 'constellations to align'," she laughs. "The environment will sometimes get in the way of the perfect survey."

"Having the opportunity to have all those instruments coincidentally collecting data, all looking at the same thing was novel, and then through having the bubble maker we were able to calibrate them all — that was really what this project set out to achieve. Had we have got poor weather, or had some of the systems not worked then we wouldn't have achieved that objective."

Dr. Lucieer said that the team managed to achieve almost textbook-perfect results in terms of attaining their objectives, and that the results of their experiments bode extremely well for securing future support to extend the scope of the research.

"The exciting news is that we've been able to resolve a really nice matrix of accuracies versus water depth versus feature size, and that we've also been able to detect fluids coming up from the sea floor, and acoustically separate those," she said.

"Now independently, work's been done on acoustics and bubbles in the past. That's not completely novel. Marine acoustic study has also been done on fluids and freshwater or hot water seepage emanating from the seafloor. But doing that coincidentally, and knowing from having eight different frequencies and systems to be able to determine the best one for a different ranges throughout the water column — that's completely novel," Associate Professor Lamarche said.

"We were able to set optimisation parameters for a range of water depths for the detection of targets at one-millimetre resolution, which in 200 metres of water is far from insignificant."

Funding from the Royal Society of New Zealand was awarded for the two year project, which began with a voyage planning meeting in Rennes France in May 2017, and a University of Tasmania Research Enhancement Program (REP) grant funded the development of the bubble validation methods. ■