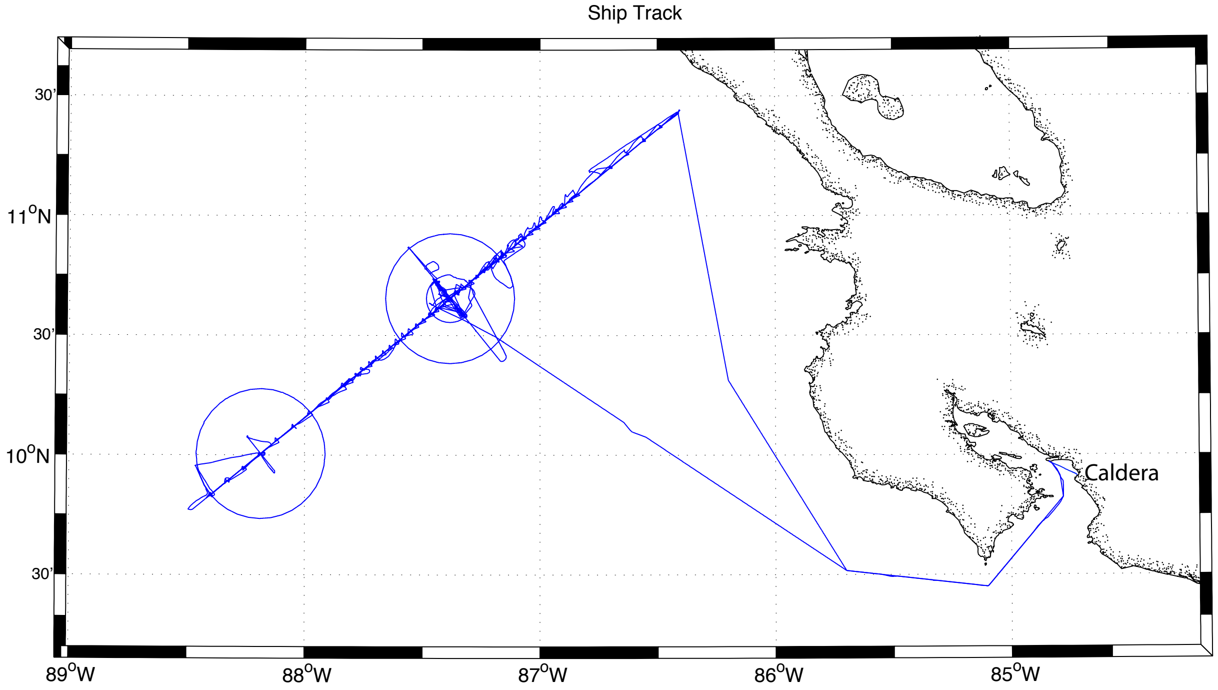
SERPENT: Serpentinite, Extension and Regional Porosity Experiment across the Nicaraguan Trench

Preliminary Cruise Report



Ship Track

Prepared by Kerry Key

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Contents

1 Summary

In April/May 2010 we carried out a 28 day research cruise aboard the R/V Melville in order to image electrical conductivity variations in the deep ocean seafloor offshore Nicaragua. Our project, the Serpentinite, Extension and Regional Porosity Experiment across the Nicaraguan Trench (SERPENT), aims to provide unique constraints on porosity across an active subduction zone through measurements of seafloor electrical conductivity. During the research cruise we collected 54 stations of marine magnetotelluric (MT) data and deep-towed nearly 800 km of controlled-source electromagnetic (CSEM) data. This is a huge milestone for marine EM, as our project's size far exceeds previous MT surveys of subduction zones, and furthermore represents the first CSEM survey of a subduction zone. We did lose two EM receivers, likely due to accidental release by the ship's multi-beam system, whose frequency overlaps our acoustic release systems. However, we consider the 96% data recovery rate very successful. We now have a huge volume of marine EM data, from which we will be able to learn a great deal about the nature of cracking, extension, porosity and serpentinization of the oceanic lithosphere at a subduction zone.

2 Motivation

Water plays an important role in the volcanic processes occurring at convergent margins, as the release of water from the downgoing slab affects the rheology of the mantle, impacts seismicity, allows melting to occur more readily by lowering the solidus temperature, and alters the chemistry of arc-lavas. Yet, the amount of water entering the subduction system remains poorly constrained. One of the major uncertainties in terms of fluid inputs into the subduction factory, and a primary goal of the MARGINS program, concerns the extent of serpentinization of the oceanic upper mantle and the volumes of water than can be carried into the subduction system. We proposed this large-scale electromagnetic experiment along a 300 km profile off Nicaragua that was also the recent focus of a seismic reflection/refraction experiment. Our survey combines controlled-source electromagnetics (CSEM) with broadband and long period magnetotellurics (MT) to provide a comprehensive picture of the conductivity structure of the oceanic crust and upper mantle that represents the input into the Nicaraguan subduction factory. Since conductivity is highly dependent on thermal structure, crack porosity and the presence of serpentinite, our experiment will provide constrains on:

1. The fluid content and alteration state of the incoming plate.
2. The depth of active circulation with the oceanic crust and mantle.
3. The variation of fluid circulation with distance from the trench, and hence with the degree of plate bending.
4. The porosity structure of the Nicaraguan accretionary prism.
5. The extent of dewatering of the subducting slab in the shallow portion of the mantle wedge.

These constraints will be strengthened through combined analysis with seismic data recently collected along the proposed EM profile.

3 Survey Area

The survey area is located in the Middle American Trench offshore Nicaragua, as shown in Figure 1. The regional seafloor topography of the trench region is shown in Figure 2 and the relief along the survey profile is shown in Figure 3.

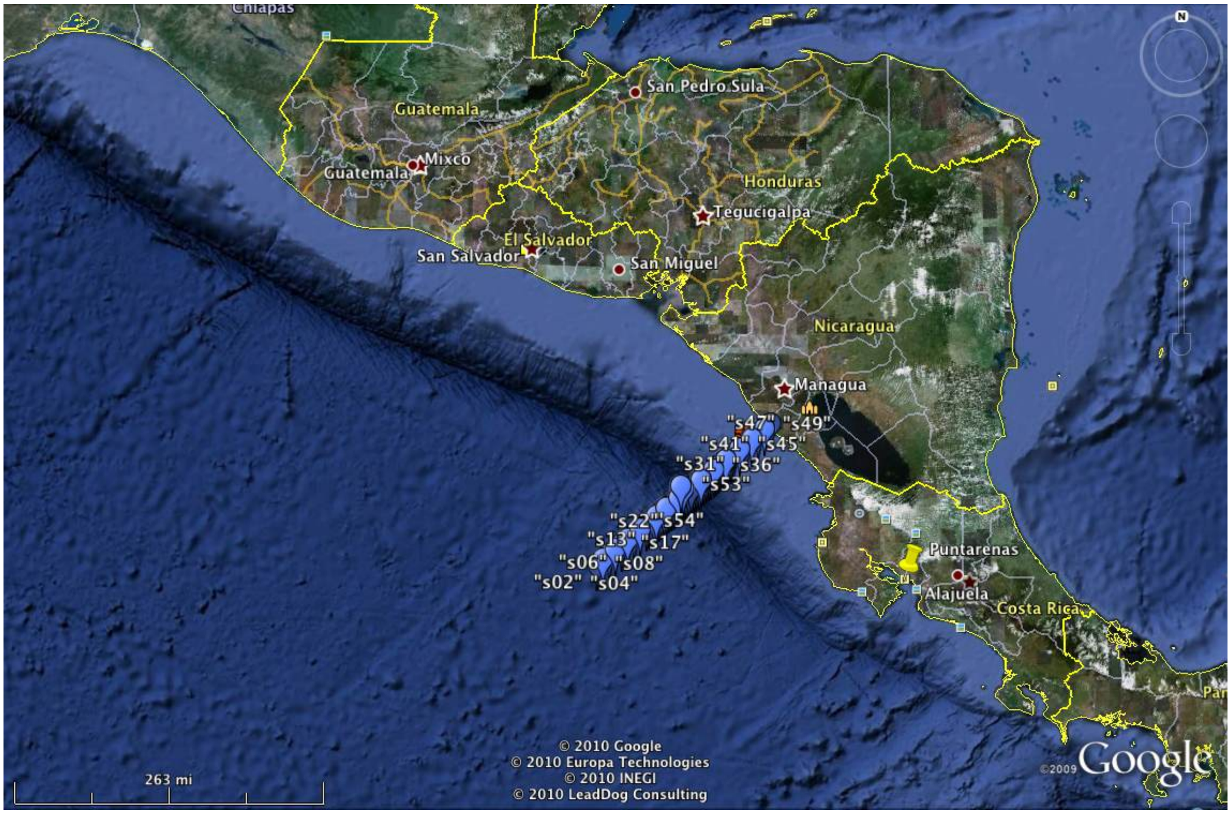


Figure 1: Location of the SERPENT cruise offshore the west coast of Nicaragua.

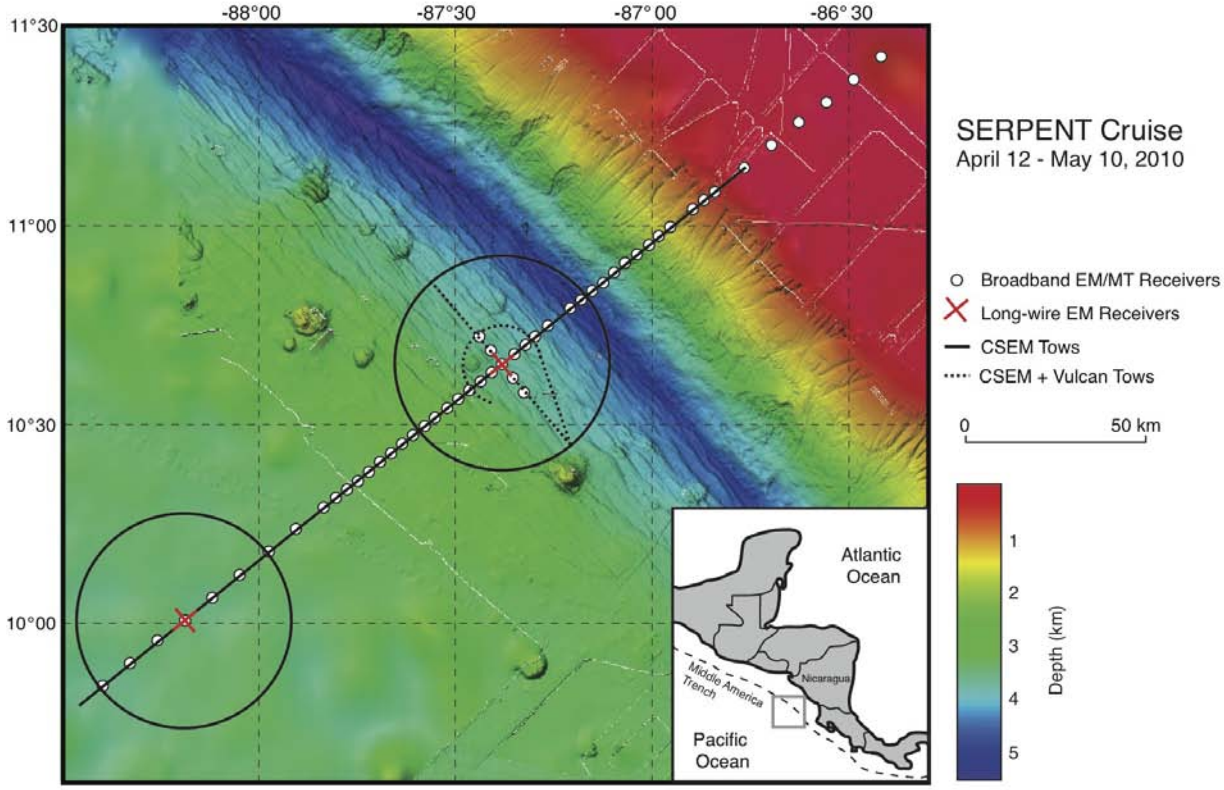


Figure 2: Survey Region. EM receivers waypoints are spaced at 10 and 4 km intervals. LEM circles have 30 km radius. Site s01 is the westernmost site and site s50 is the easternmost site. Sits 51-54 are along the trench outerslope from southeast to northwest.

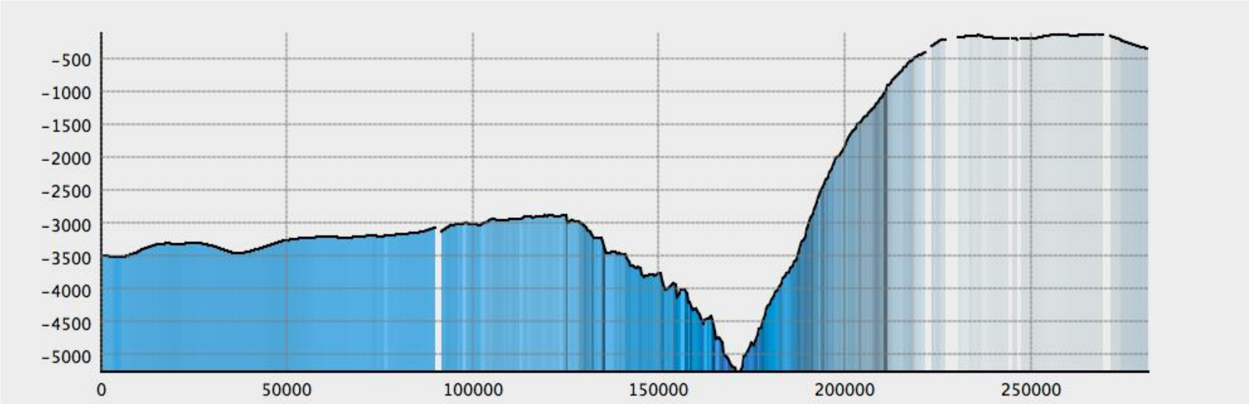


Figure 3: Topographic relief along the survey profile. Positions and depths are shown in units of meters.

4 Methods

The SERPENT project uses a variety of electromagnetic methods in order to capture electrical conductivity variations in the near surface, the crust and the upper mantle. A cartoon depicting these methods is shown in Figure 4. EM receivers deployed to the seafloor record electric and magnetic field variations (Figure 5). Natural variations at low frequencies of 0.0001 to 1 Hz arise from the interaction of the solar wind with Earth's magnetosphere, and are used in the marine magnetotelluric (MT) method to probe the structure of the crust and upper mantle. Shallower conductivity in the crust is probed using the controlled-source electromagnetic (CSEM) method, where a dipole transmitter is towed above the seabed and injects energy into the seabed at higher frequencies than used for the MT method. Figure 6 shows our CSEM transmitter SUESI (Scripps Undersea EM Source Instrument) being deployed during the SERPENT cruise. In order to navigate the EM transmitter's position in real-time, an inverted long-baseline (iLBL) acoustic navigation system (Barracuda) was towed along the ocean surface behind the Melville during the deep-tow operations. Figure 9 shows the Barracuda paravanes, which contain GPS beacons and acoustic transponders that are used to constrain the inverted long-baseline navigation. At two locations we deployed specialized long-wire EM receivers (LEMs) by deep-towing them to the seafloor. Figure 7 depicts the process for deploying a LEM by deep-towing it to the seafloor. The LEMS offer about a factor of 10 increase in signal-to-noise ratio for CSEM data, assuming environmental noise is minimal, and therefore can be used to sense much deeper than possible with conventional CSEM data. Finally, we also towed a 3-component EM receiver named Vulcan about 500 m behind SUESI to collect high-frequency constant offset CSEM data that is sensitive to conductivity variations in the upper 100 m of crustal rocks and sediments.

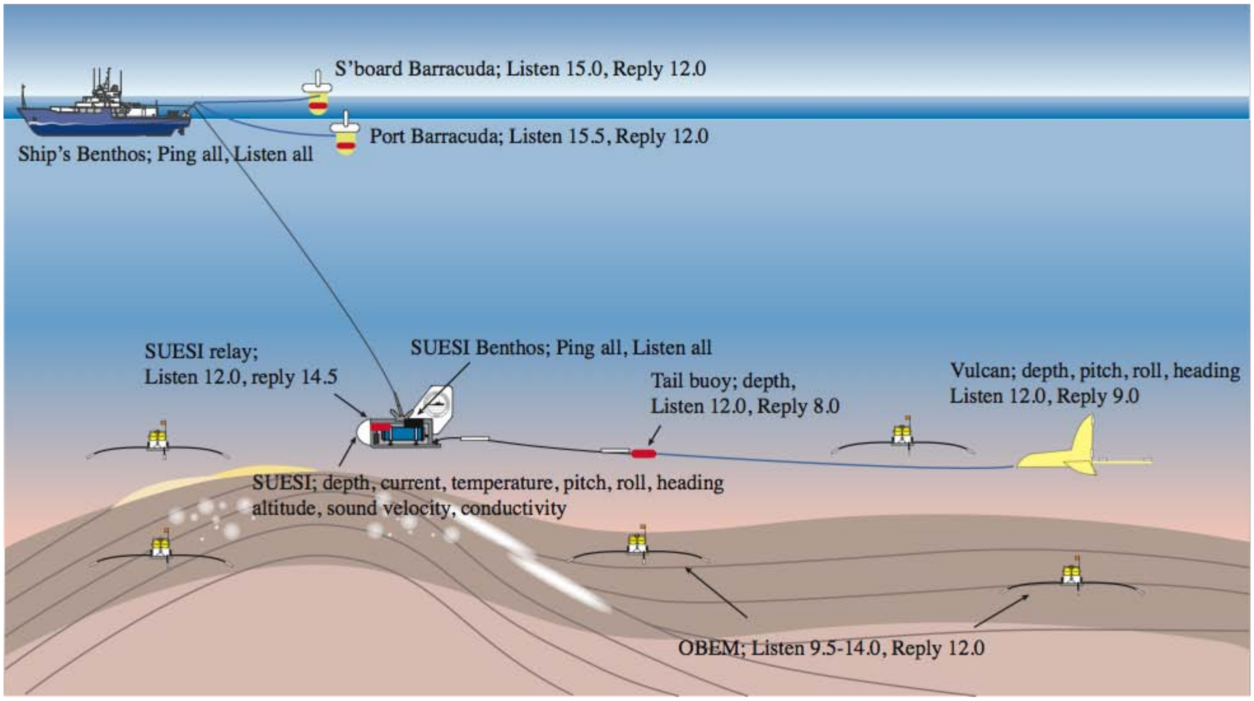


Figure 4: Marine EM survey operations. EM receivers (OBEM) are deployed from the ship and record electric and magnetic fields on the seafloor. A deep-towed transmitter (SUESI) is towed behind the ship and transmits EM energy through the seabed to the receivers. Paravanes (Barracudas) are towed behind the ship and used to collect inverted long-baseline (iLBL) acoustic navigation data for triangulating the transmitter's position. The towed receiver Vulcan collects constant offset 3-axis electric field data.

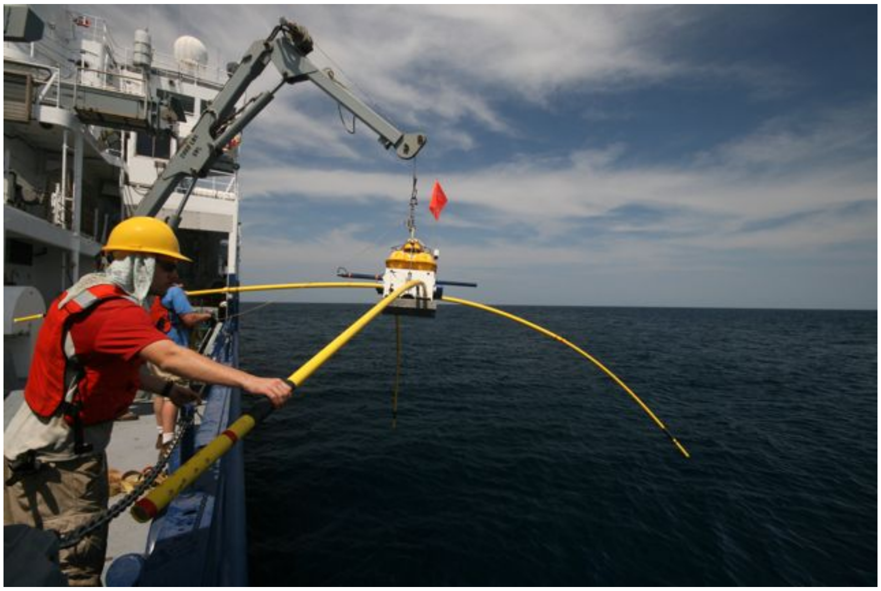


Figure 5: EM receiver being deployed during the SERPENT cruise.

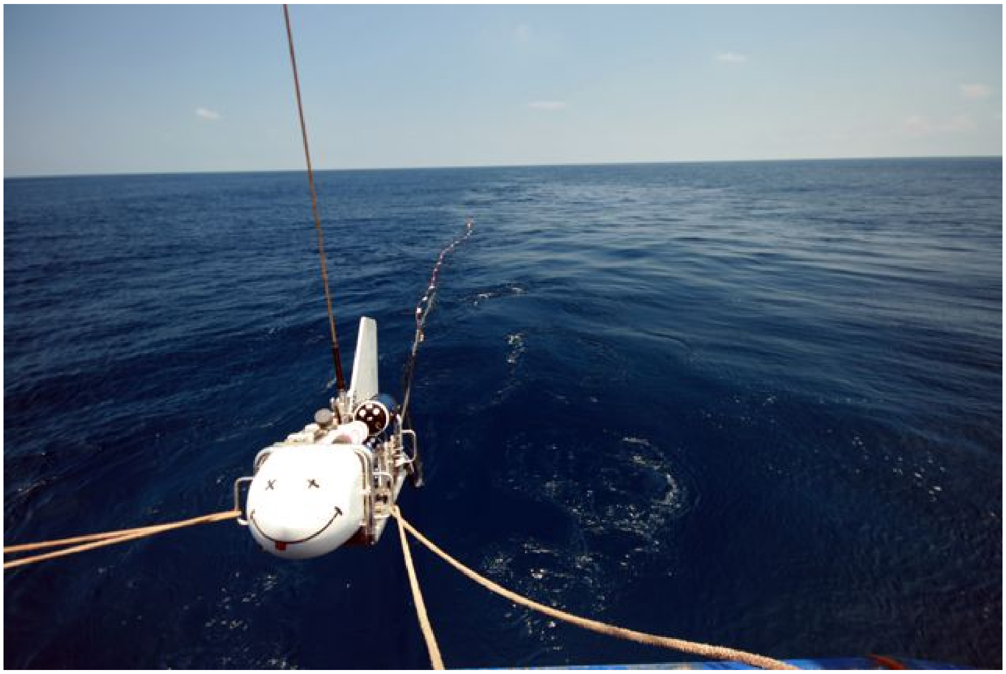


Figure 6: SUESI: Scripps Undersea EM Source Instrument during deployment on the SERPENT cruise.

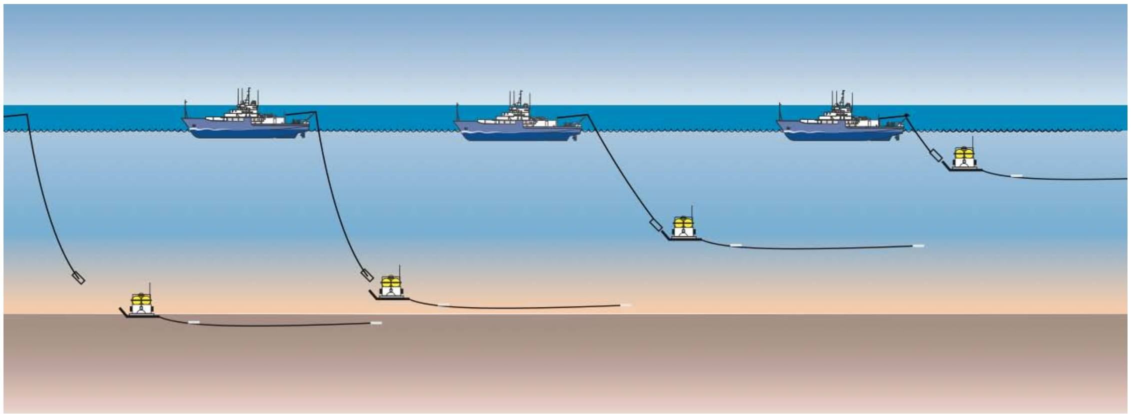


Figure 7: Deploying a long-wire EM receiver (LEM). The LEM is lowered the seafloor while the ship maintains a slow speed and constant heading. The LEM is released from the deep-tow cable when it is a few meters above the seafloor.

Figure 8: Vulcan, the towed 3-axis electric field receiver, on deck during the SERPENT cruise.

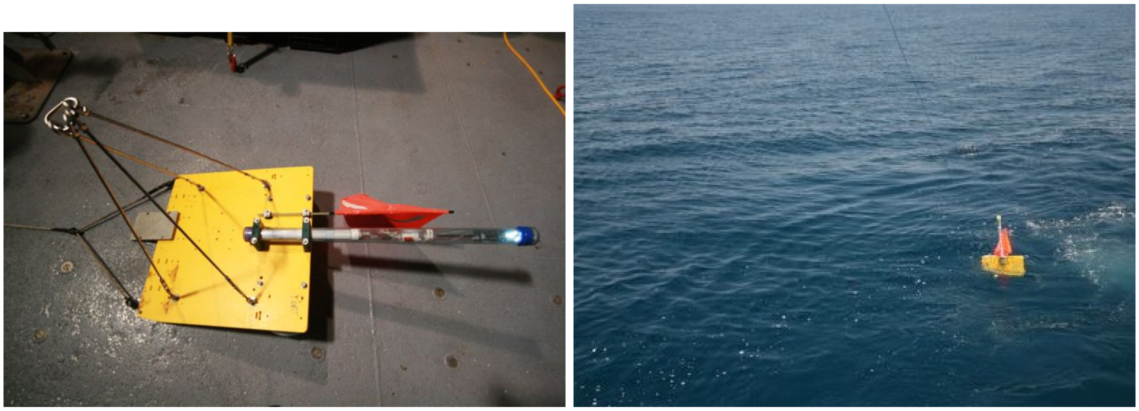


Figure 9: Barracuda paravane on deck (left) and being towed behind the ship (right).

5 Data Collected

We collected a variety of data sets during the SERPENT cruise as the Melville drove around the tracklines shown in Figure 10. The primary data consists of the 58 EM receiver time series that will be used for CSEM, LEM and MT interpretations. Ancillary data required for the CSEM analysis include long-baseline navigation data for accurate positions of the seafloor EM receivers, inverted long-baseline navigation data for SUESI's antenna position and a host of other data related to the transmitter's performance and output during the survey. Additional data sets collected include EM122 multibeam bathymetry and gravity measured with the Melville's gravimeter. A brief overview of these data sets is given in the sections below. Appendix D contains an event log showing the planned and actual durations for the various operations required during the survey.

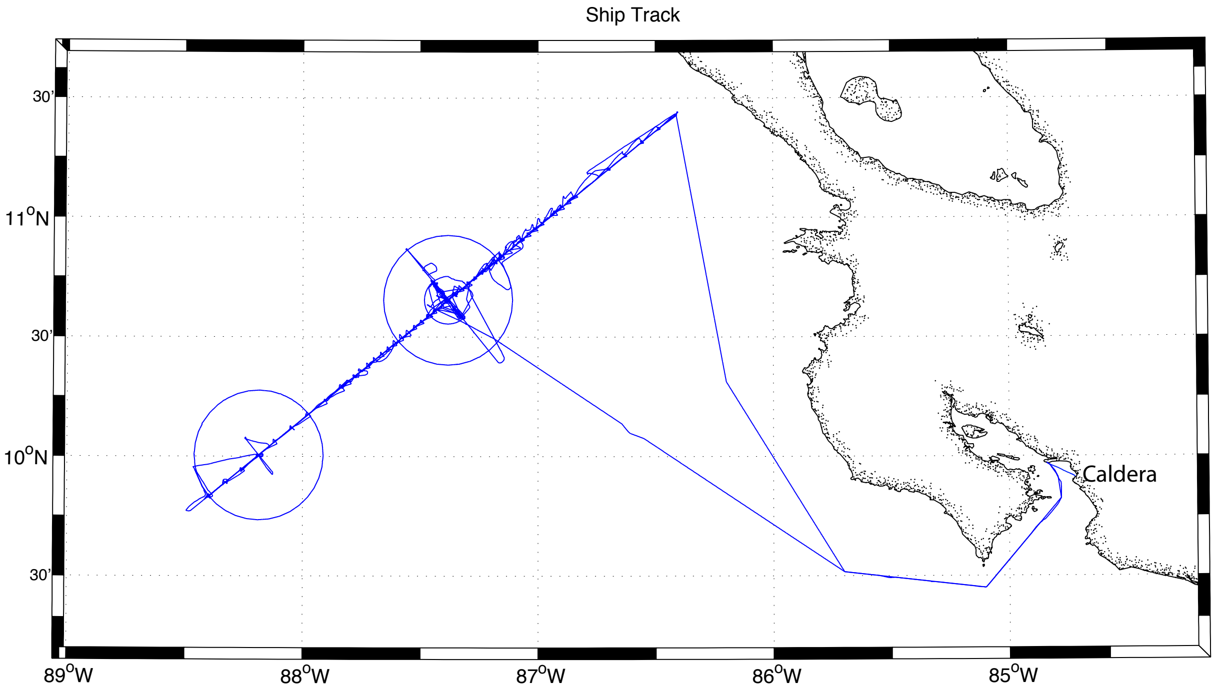


Figure 10: Trackline plot of the R/V Melville's position from April 12 - May 11, 2010.

5.1 Seafloor Magnetotelluric Data

Seafloor magnetotelluric (MT) data were collected with 56 EM receiver deployments. Figure 11 shows the layout of the electric and magnetic field sensors on the EM receiver, as well as the location and bearing of the electronic compass used to determine orientation of the receiver on the seafloor. **Note the local magnetic declination is 1.5° east.** Appendix C gives a qualitative assessment of each data channel, as determined by inspection of time series spectrograms. We made 56 deployments and were able to recover all receivers except two, as noted in Appendix C. Out of all the instruments recovered, only two channels were noisy due to equipment failure (Ch 3 on s2, and Ch 3 on s30), both are attributed to breaks in electrode cables, presumably due to mis-handling on deck. Overall the data quality is good to acceptable, but there are some noisy data sets. Some instruments show a tidally modulated noise in the magnetic channels, presumably from water currents shaking the receivers. However, in most cases this noise is relatively weak and occurs at higher frequencies than the expected MT signal for these water depths. s27 recorded good electric fields but had very noisy magnetic field data over a wide range of frequencies, suggestive that this instrument landed on a rocky region in the trench and was wobbling erratically. Instruments deployed near the top of the continental slope and on the shallow continental shelf are generally marginal to noisy, presumably due to increased shaking from strong water currents. The shallowest station, s50, is in 61 m of water and appears to be dominated by motional induction noise. Figure 12 shows a representative spectrogram, obtained from the data at site s06.

At the end of the experiment we were extremely fortunate to have a magnetic storm occur, which generated strong MT signals that will surely improve the overall quality of the MT responses we derive from the time series data. Figure 13 shows 12 hours of time series during the storm, as recorded on two receivers. While storms are not necessary for the collection of broadband MT data, they can enhance the signal quality.

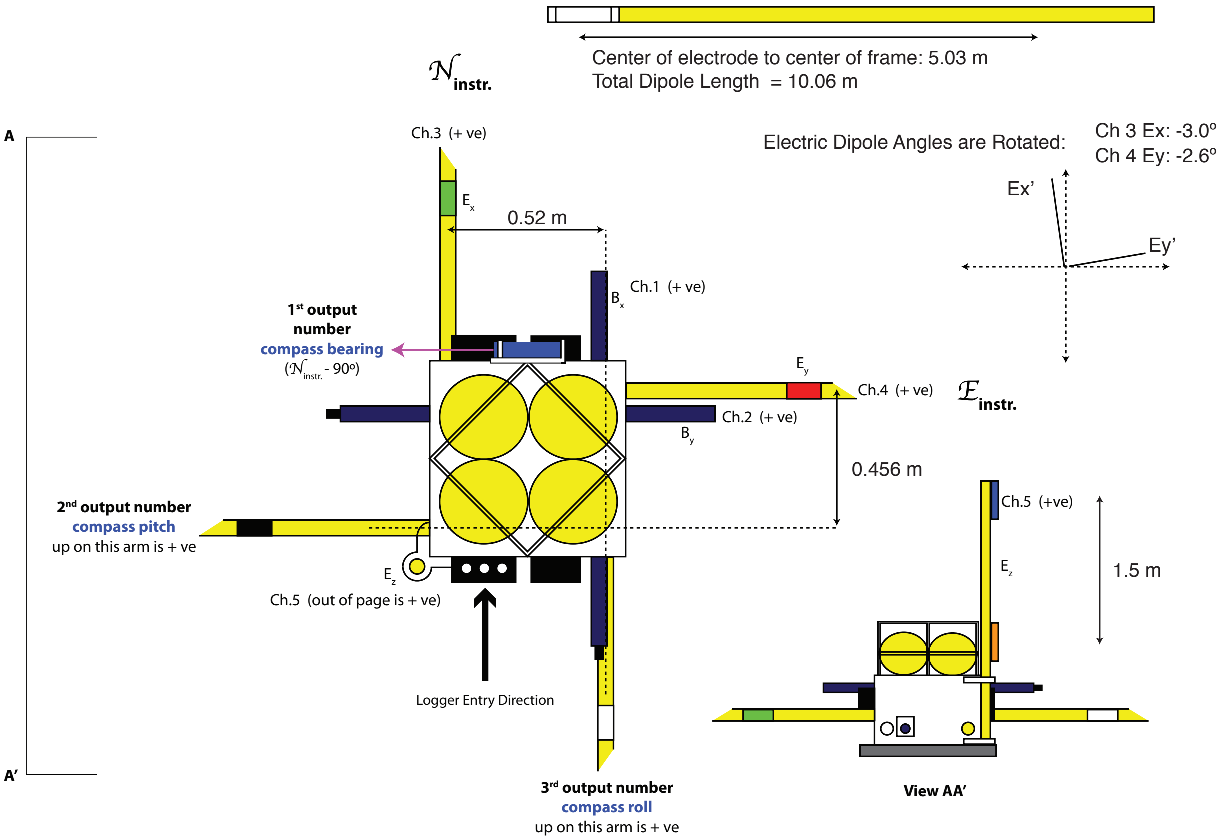


Figure 11: Diagram showing the positions, lengths and orientations of various components on the Scripps EM receiver. Channels 1 and 2 are Bx and By, and Channels 3 and 4 are Ex and Ey. Note the relative orientations of the electric field arms and their lengths and the compass orientation.

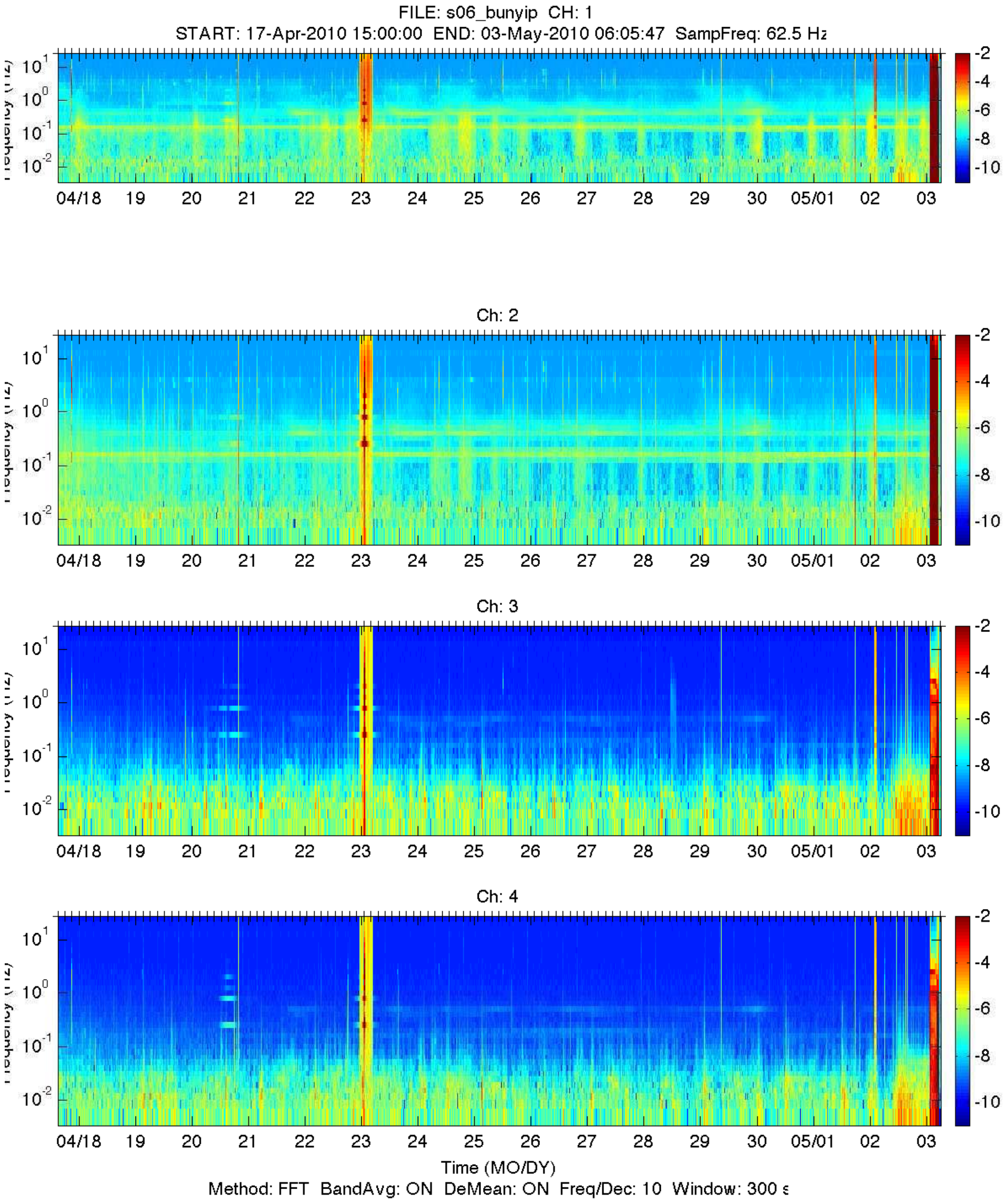


Figure 12: Spectrograms of the Bx,By,Ex and Ey channels for receiver Bunyip deployed at s06 showing generally nice looking MT data, particularly for the electric channels. Note the magnetic storm seen at low frequencies on 05/02 to 03.The vertical band of strong energy on 04/23 and the weaker band near the end of 04/21 show CSEM energy from when the SUESI was towed nearby this location for the Main Line tow (04/23) and the easter side of Circle#1 (04/21).

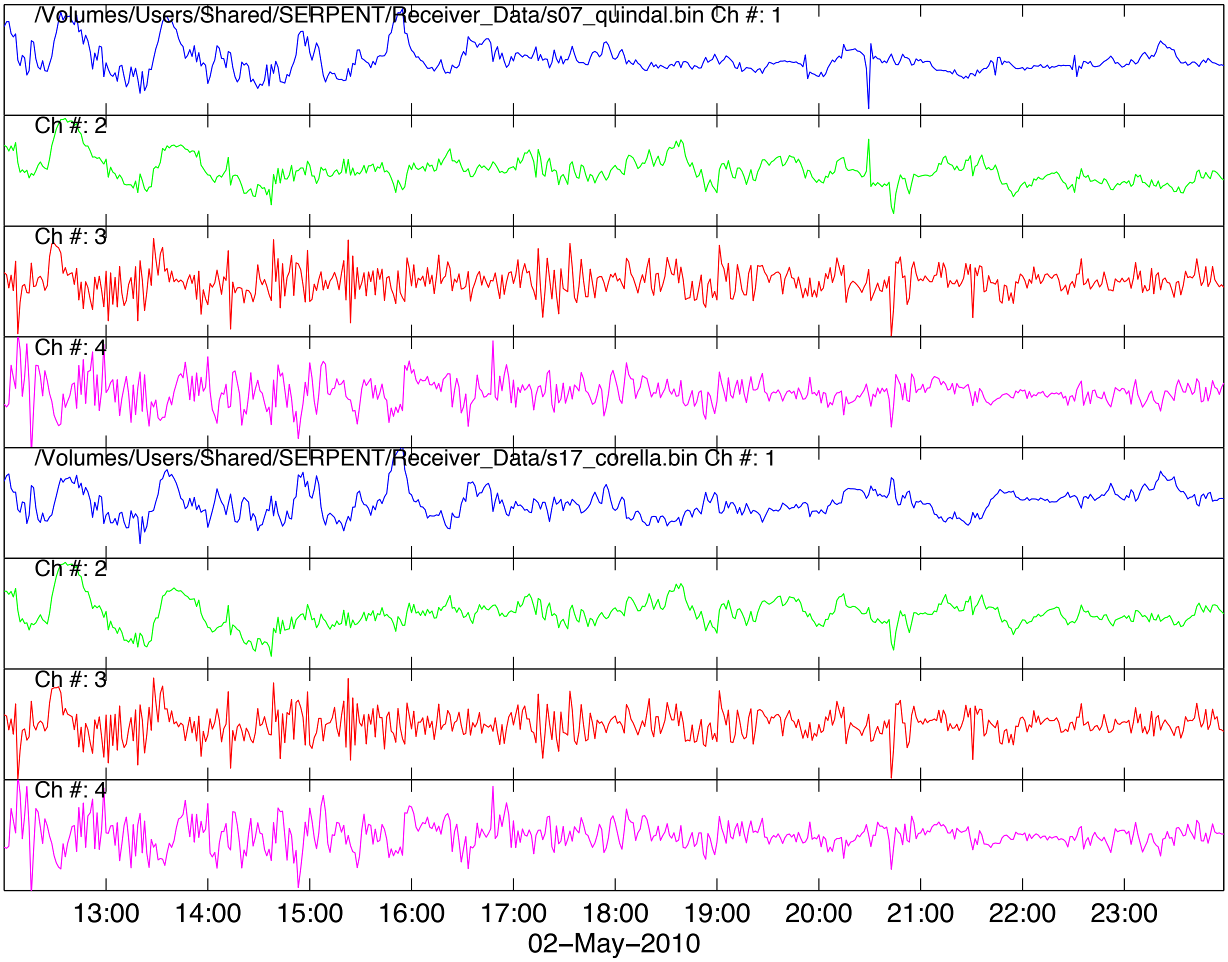


Figure 13: Twelve hours of data recorded at stations s07 and s17 during the magnetic storm on May 2, 2010. Note the high correlation in the MT signal. The data have been decimated to an effective 0.0125 Hz sampling rate.

5.2 Seafloor Controlled-source Electromagnetic Data

Controlled source EM data were collected by towing SUESI along the paths shown in Figure 14. Our primary objectives were to transmit CSEM signals along the Main Line and Circles 1 and 2. After completing these objectives without any major problems, we were able to use our contingency time to collect the Strike Line and Mini-Circle 2 tows. Table 1 lists each CSEM tow and whether or not iLBL navigation data and Vulcan data were also collected. Figure 15 shows the configuration of SUESI's antenna, which was slightly modified for the Strike-Line and Mini-Circle 2 tows. Figure 16 shows the depth and dip of SEUSI's antenna for Circles 1 and 2 and the Main Line tows, illustrating the dramatic seafloor bathymetry SUESI was towed over. The dip of the antenna is fairly uniform, but there are some notable exceptions where the dip deviates by up to 10-20 degrees as the transmitter was either raised or lowered as it passed over some steep features such as the fault scarps along the trench outer rise.

For the CSEM transmissions we used a specialize compact, doubly symmetric waveform with a base frequency of 0.25 Hz. Figure 17 shows a snap-shot of the waveform transmitted by SUESI and Figure 18 shows the corresponding broadly peaked amplitude spectrum. This waveform is useful for distributing the peak energy over a broad bandwidth, which is desirable for frontier exploration purposes where the seafloor conductivity is largely unknown. The broadband width helps ensure that we will be able to constrain multiple depth scales and conductivity magnitudes. An example of the recorded CSEM time series in Figure 19. The CSEM response of the Earth can be found by deconvolution with the source waveform shown in Figure 17.

Figure 20 shows the tracklines of the Barracuda paravanes systems that were used for inverted long-baseline navigation of SUESI. We had successfully used the Barracuda systems in 1 km water depths during the 2009 survey at Scarborough gas field and we anticipated good performance on this cruise. However, once SUESI was lowered to depths below about 2 km we were unable to range from SUESI to the Barracuda surface transponders. After some careful testing, we concluded that the acoustic transponders on the paravanes were too close to the sea-surface and were probably unable to hear SUESI's relatively weak acoustic pings over the water splashing and other sea surface noises. We then modified the paravanes so that the transponders were suspended a few meters below the paravanes and to our delight this lower noise environment enabled the transponders to hear SUESI's pings again. The Barracuda system worked great for the Main Line, Circle 2 and Strike Line tows. However, for Mini-Circle 2 we discovered a limitation of this system when strong water currents began to push the towed-paravanes into the ship and the system could no longer be safely deployed. Overall we were able to collect good navigation data where it mattered the most—on the Main Line, where the short-source receiver offsets demand accurate navigation data in order to reduce uncertainty in the data. Since the source-receiver distances are 30 km for the Circle tows, accurate navigation data from the Barracuda system is not necessary for this data.

Table 1: Summary of CSEM towlines, iLBL navigation and Vulcan data collection.

Towline	iLBL Nav?	Vulcan Deployed?
Circle 1	No	No
Main Line	Yes	No
Circle 2	Yes	No
Strike Line	Yes	Yes
Mini Circle 2	No	Yes

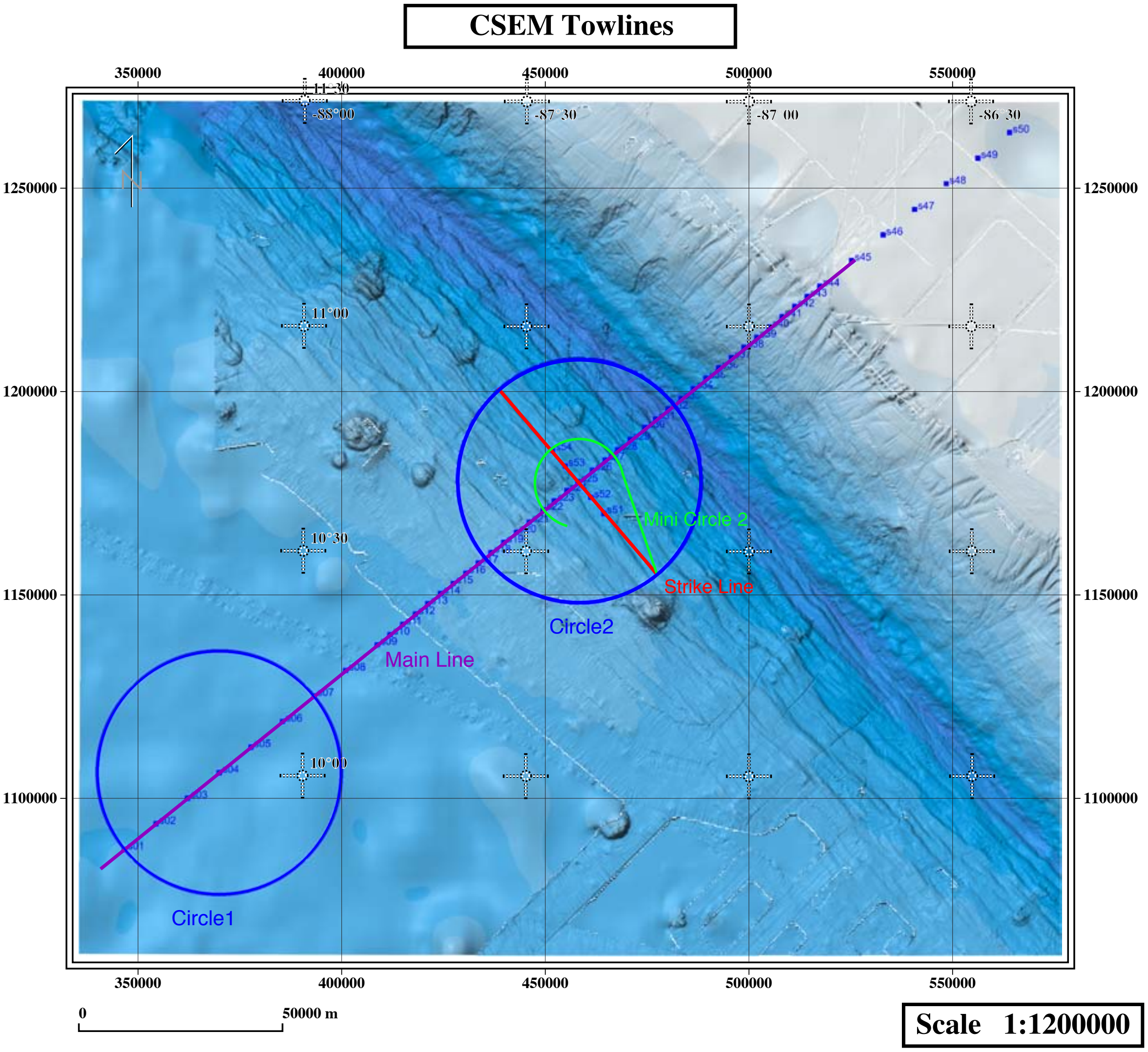
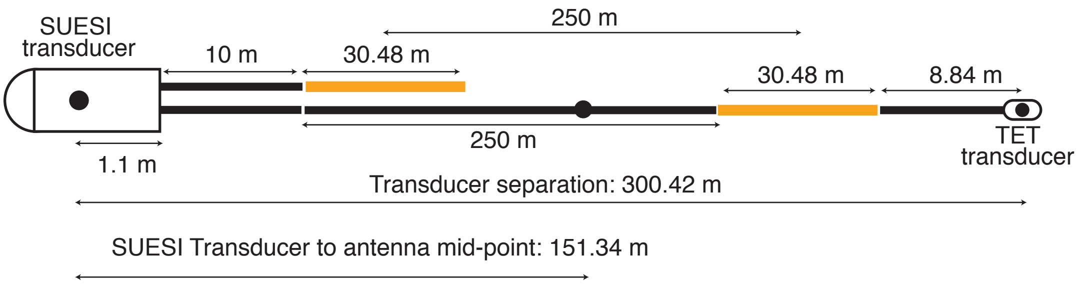


Figure 14: CSEM tow lines completed.

Phase 1: Circle 1, Main Line, Circle 2



Phase 2: Strike-Trench , Mini-Circle 2, used Vulcan

* Note polarity switch (short and long antennas reversed, means 180° phase shift)

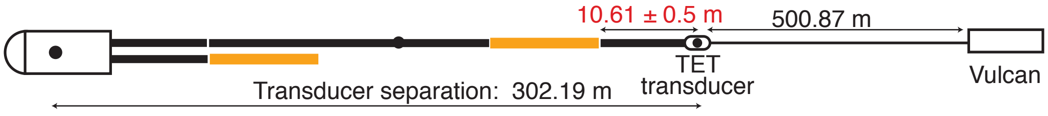


Figure 15: Configuration of the SUESI antenna system for Phase 1 and Phase 2 deep-tows.

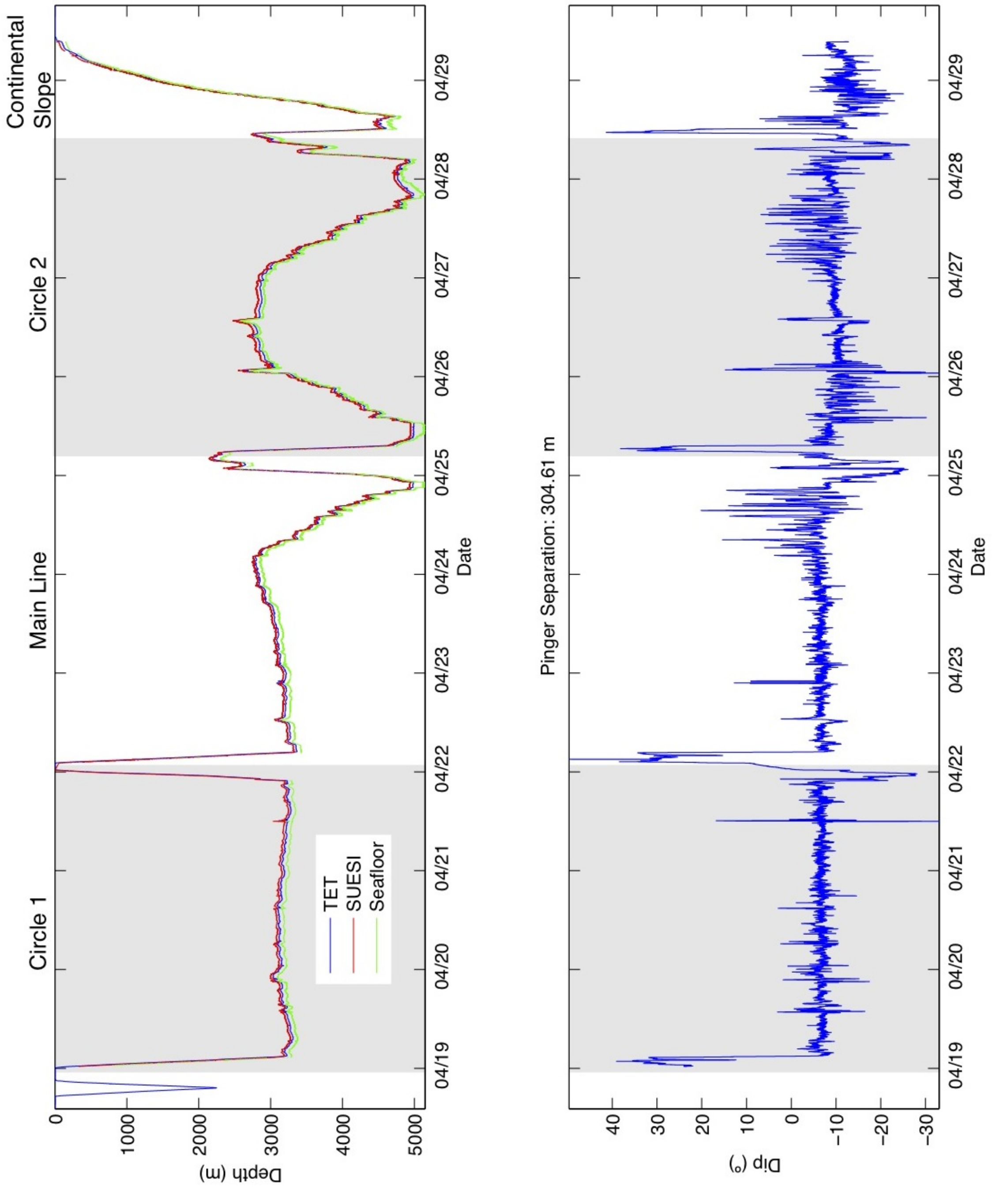


Figure 16: Depth of SUESI and the tail-end transponder recorded by pressure gauges during the Circle 1, Main Line and Circle 2 tows. The seafloor depth is found by adding SUESI's acoustic echosounder height measurements to the pressure gauge data. Right panel shows the dip of the antenna as determined from the depth measurements of the head and tail of SUESI's antenna.

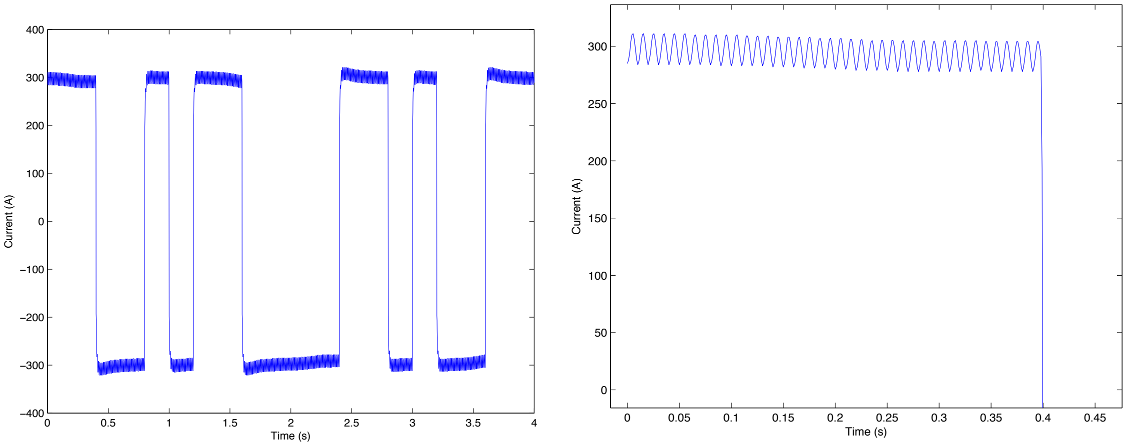


Figure 17: Snapshot of the CSEM transmitter's 4 s waveform (left) and a close-up of the first positive cycle (right). Due to software bug, negative amplitude data was not recorded and here is just a copy of the positive amplitude waveform.

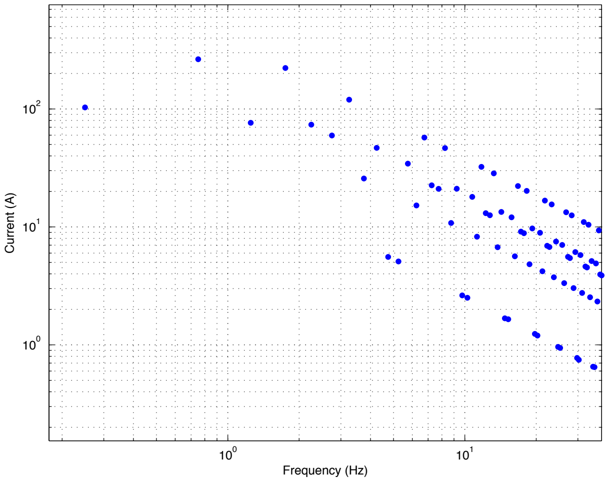


Figure 18: Amplitude spectrum of the transmitter waveform snapshot shown in Figure 17.

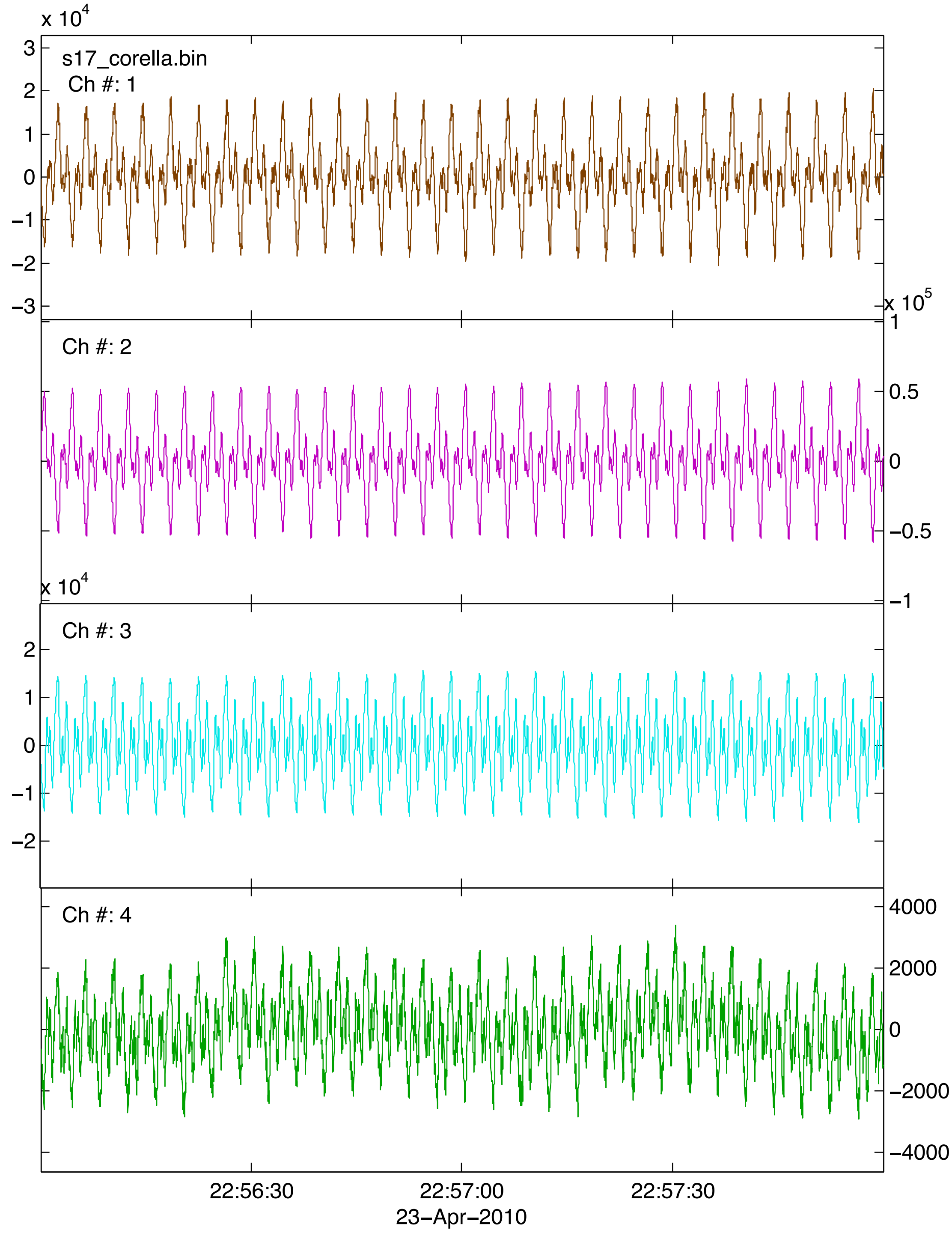


Figure 19: Example of 5 minutes of CSEM data recorded on receiver Corella at site s17.

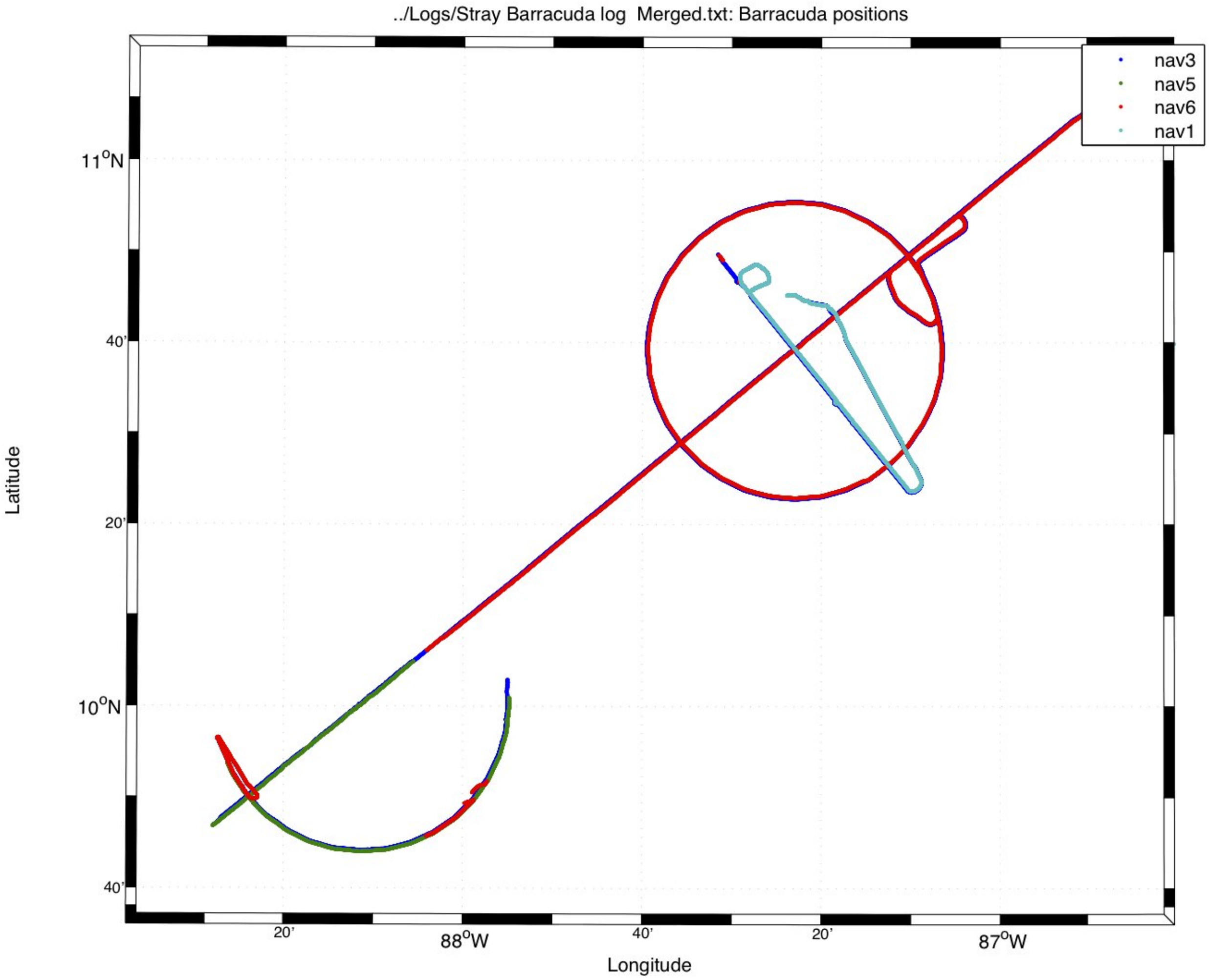


Figure 20: Trackline plot of the Barracuda sea-surface towed transponders positions. Barracuda tows on Circle 1 were abandoned after the circle was halfway completed since the Benthos system was inoperable due to water noise overwhelming the surface transponders. After fixing the transponders, successful Barracuda tows and ranging were accomplished for the Main Line, Circle 2 and the Strike Line tows. During the attempt at Mini-Circle 2, the Barracudas were recovered due to strong water currents. The legend refers to the GPS-radio units mounted on the Barracudas.

5.3 Long-wire Electromagnetic (LEM) Data

Long-wire electromagnetic (LEM) receivers were deployed at the center of each circle to collect CSEM data that will be sensitive to the presence of anisotropic conductivity in the uppermost mantle, as well as to collect very long-offset CSEM data during the Main Line tow. LEM's require careful deployment so that their 200 m long antennas land on the seabed fully stretched-out, as shown in Figure 7. Two LEMs were deployed at the center of each circle, one along the main line tow path and the other perpendicular, as shown in Figure 21. The locations of the LEM receivers are given at the bottom of Appendix B. Figure 22 shows the antenna configurations. We report that all four LEM's were successfully recovered and all contain high quality data.

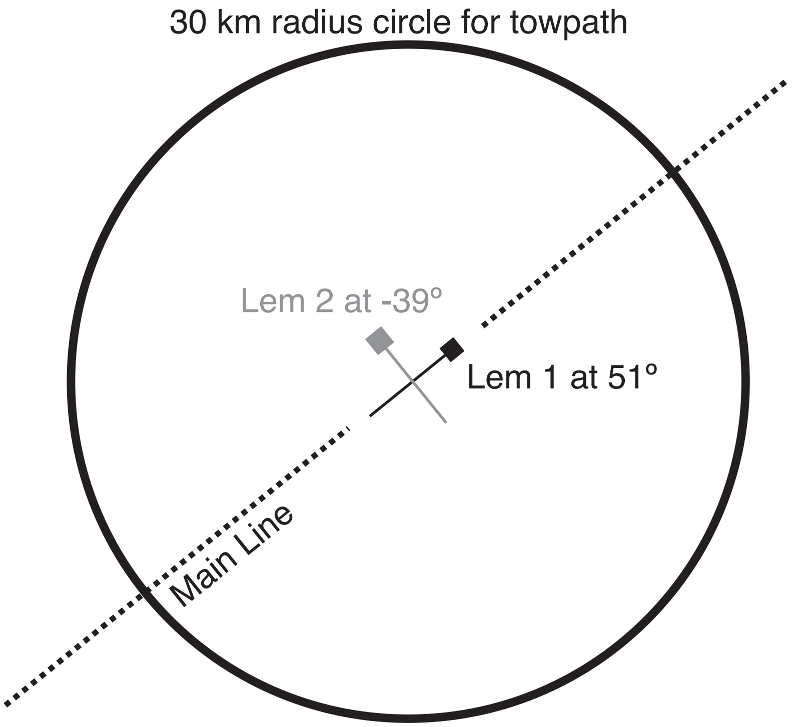


Figure 21: Long-wire EM receivers (LEMs) are aligned in cross so that their 200 m antennas cross in the middle of the 30 km radius LEM circle towpath. One LEM's antenna is aligned at a geographic bearing of 51° and the other at -39°.

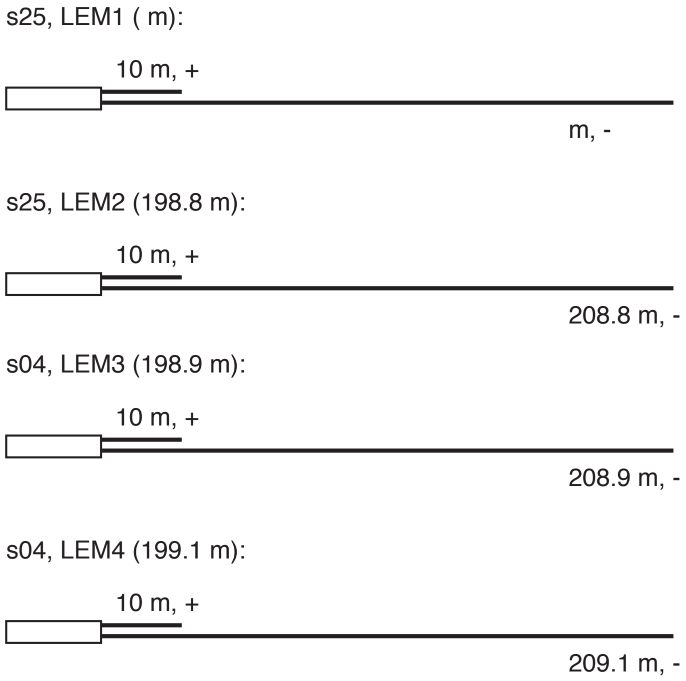


Figure 22: Antenna configurations for the 4 LEM receivers.

5.4 Vulcan Data

Vulcan, a 3-axis electric field receiver that is towed at some distance behind SUESI, was deployed for the Strike and Mini-Circle 2 deep-tows. A schematic of Vulcan's configuration is shown in Figure 23. Figure 15 shows that Vulcan was towed about 500 m behind the end of SUESI's antenna. Vulcan's data logger recorded during the entire deployment, as did its electronic compass/tiltmeter and Parosci pressure gauge. Both the inline and vertical electric field channels worked, but the crossline channel suffered from a broken electrode (discovered on recovery). Fortunately, the primary useful components are the inline and vertical fields, whereas the crossline component is non-zero only in the presence of 3D effects, so this is a relatively insignificant loss.

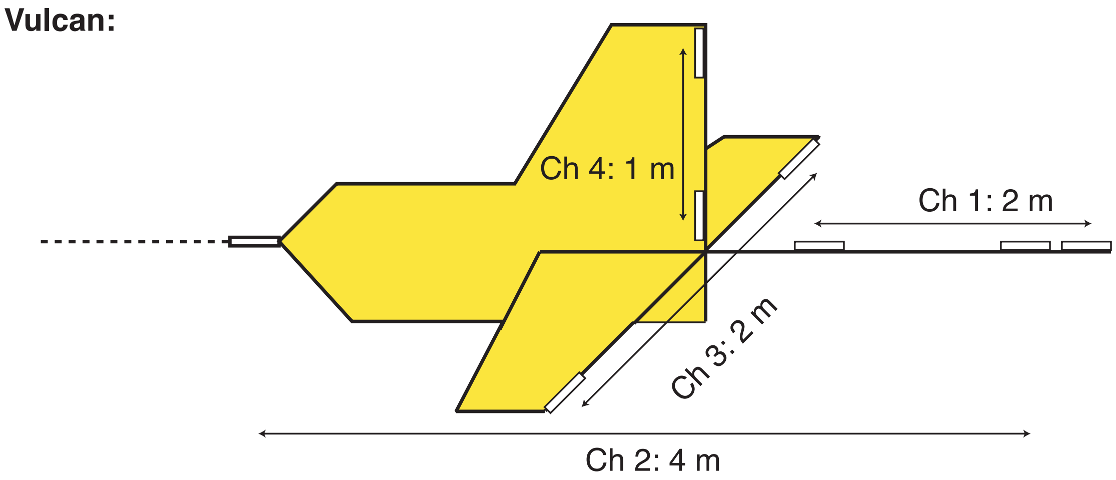


Figure 23: Configuration of the Vulcan towed 3-component EM receiver used for Phase 2.

5.5 Long Baseline Navigation Data for Seafloor EM Receiver Locations

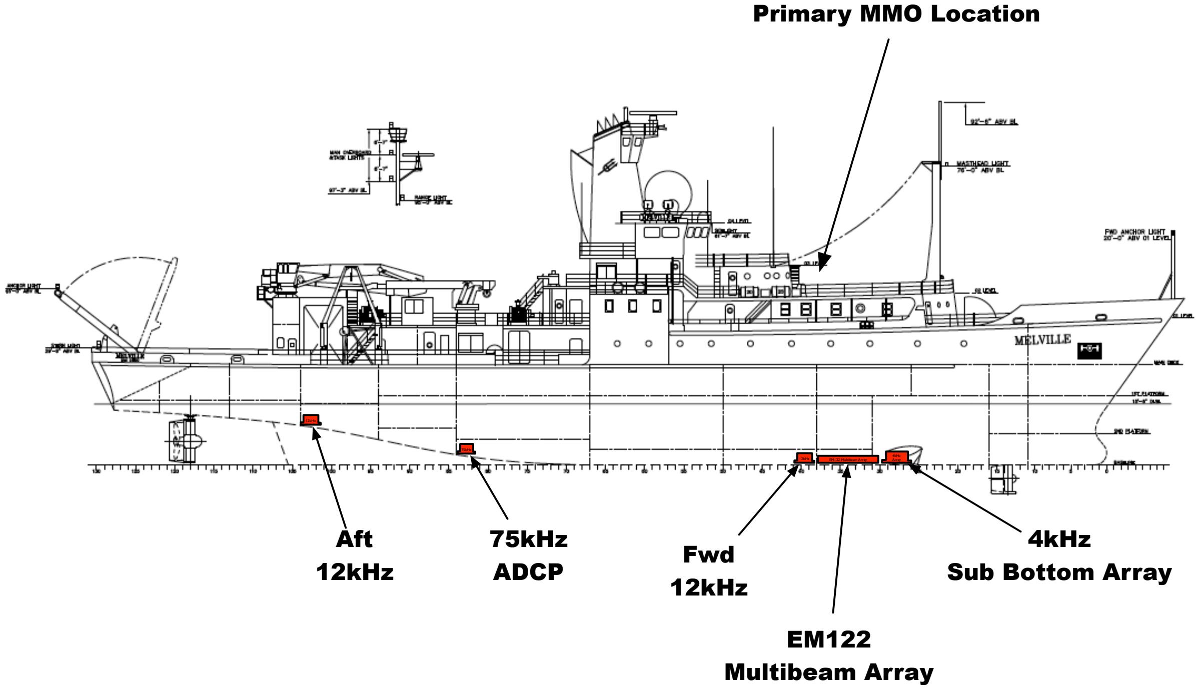


Figure 24: Location of acoustic transducers on the R/V Melville.

Long baseline (LBL) navigation data were collected for nearly all EM receiver and LEM deployments. This system uses a Benthos DS-7000 acoustic ranging system to collect acoustic travel times from the ship's transducer to each receiver. This data is combined with the ship's position data from the GPS log files and is used to triangulate the receiver's position using a non-linear minimization technique that includes ray-tracing in the seawater to account for bending of the acoustic rays through ocean's sound velocity profile. Expendable Bathy-thermograph (XBT) data collected daily is used to find the sound velocity. In addition, SUESI's Valeport sensor directly records sound velocity, giving a velocity profile during as it is lowered and raised at the start and end of each deep-tow. Figure 24 shows the location of the various transducers on the R/V Melville.

The LEM deployments require additional navigation in order to determine their antenna headings. The Benthos navigation data yields the location of the LEM receiver, and the ship's GPS log files will be used to estimate the antenna's heading as it was deployed.

We found out that our Benthos DS-7000 digital system is not optimized for the Melville's transducer and therefore was unable to range on a few of the deepest instruments. For these instruments, we instead used the more powerful Scripps analog acoustic system to collect closest-point-of-arrival (CPA) measurements to each receiver as the ship drove along perpendicular lines crossing over the receiver. These can be used with the ship's log to find the receiver positions, but in a far less accurate manner than with the Benthos digital system. Table 2 list the receiver CPA times for the few receivers without Benthos data.

Table 2: CPA data for receivers that could not be navigated with the Benthos system

Site	CPA 1	CPA 2
s51b	126 08:05:30	126 08:40:00
s54b	126 11:43:00	126 12:25:00
s33	125 14:01:00	125 13:19:00
s32	125 14:48:00	125 15:26:30
s30	125 20:07:48	125 21:41:18
s29	125 07:06:00	125 06:41:00

5.6 Seafloor Geophone Seismic Data

One receiver (Bunyip) was outfitted with a three-component geophone in addition to the standard magnetic and electric field sensors, in order to test joint seismic and EM data collection performance and noise issues. This instrument had just begun recording when a magnitude 5.4 earthquake occurred at 62 km depth just off the Nicaraguan coast to the north of the survey line (Figure 25). A comparison of data from three receivers scattered across the profile shows the arrival of the seismic phases from this event (Figure 26).

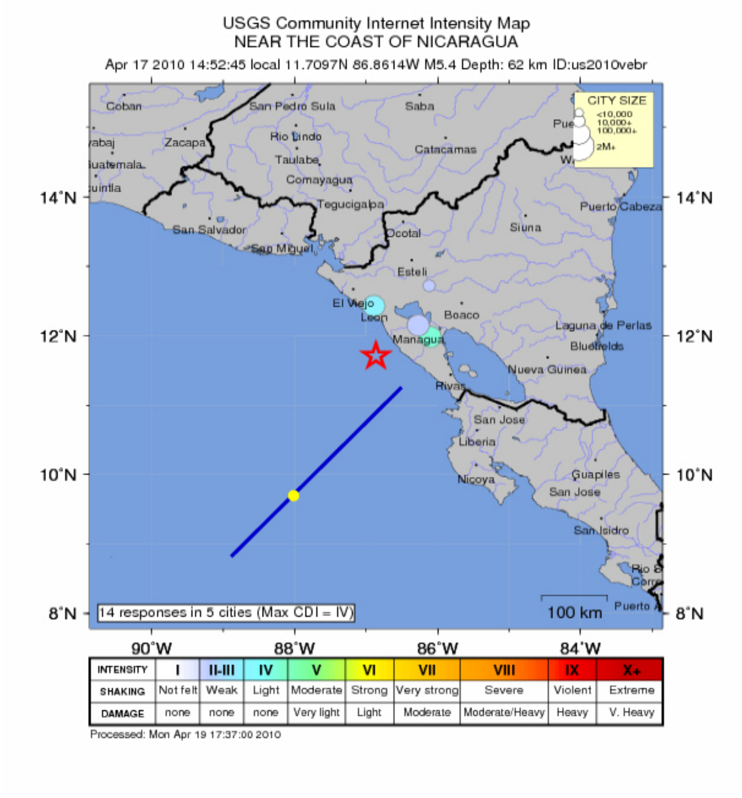


Figure 25: USGS map of the 5.4 earthquake on April 17, 2010 20:52:45 UTC. The blue line shows the location of the marine EM receiver array. The yellow dot shows the location of site s06, where receiver Bunyip was deployed with a 3 component geophone in addition to the standard magnetic- and electric-field sensors.

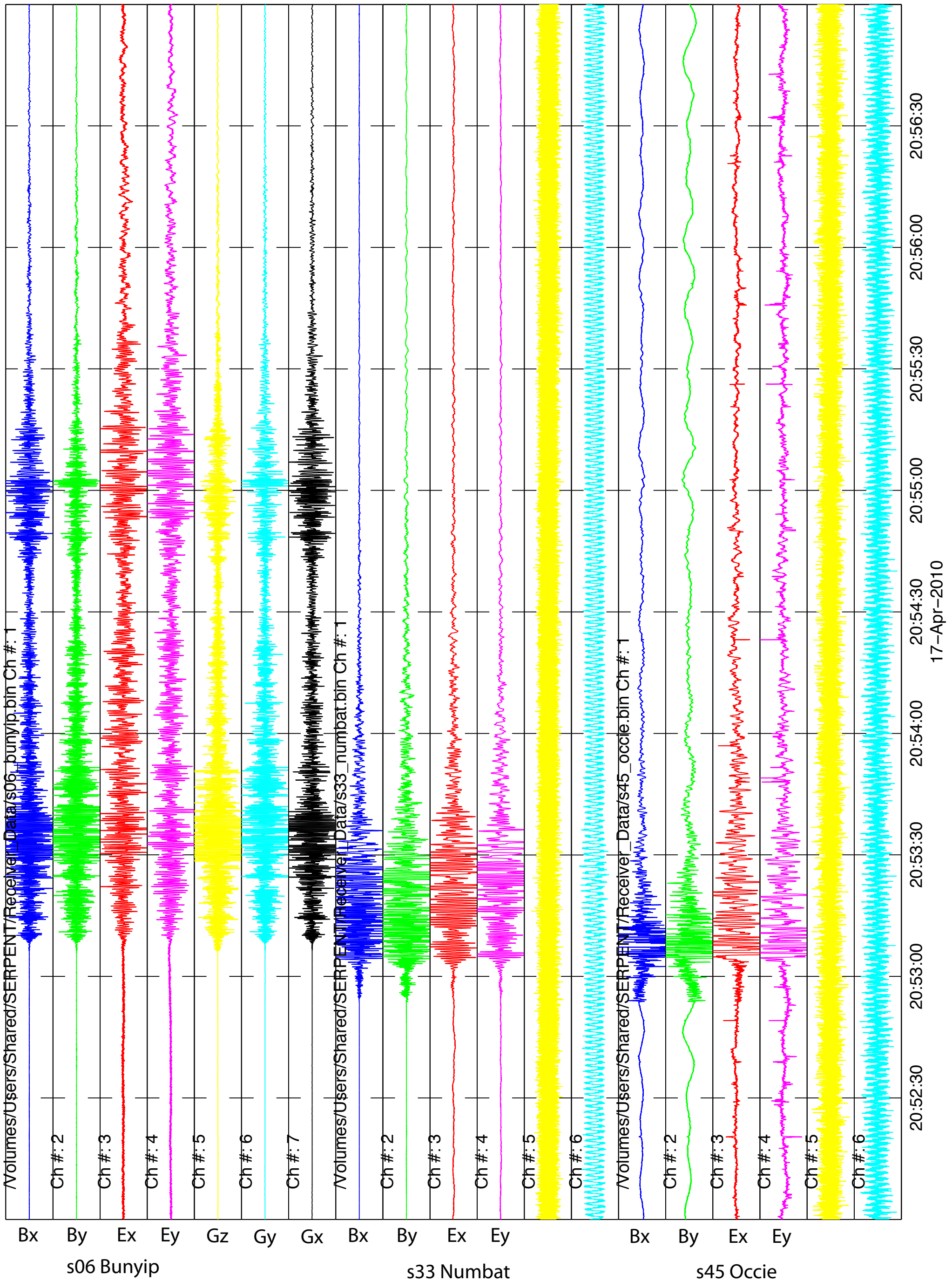


Figure 26: Five minutes of raw data showing the arrival of the 5.4 earthquake seismic waves on three receivers EM receivers. s06 Bunyip had a 3-component geophone (Gx,Gy,Gz) in addition to the standard magnetic (Bx,By) and electric field (Ex,Ey) sensors. Note that since the electric and magnetic field sensors are very sensitive to tilting and shaking, they also detect the arrival of the various seismic phases.

5.7 Gravity and Multibeam Data

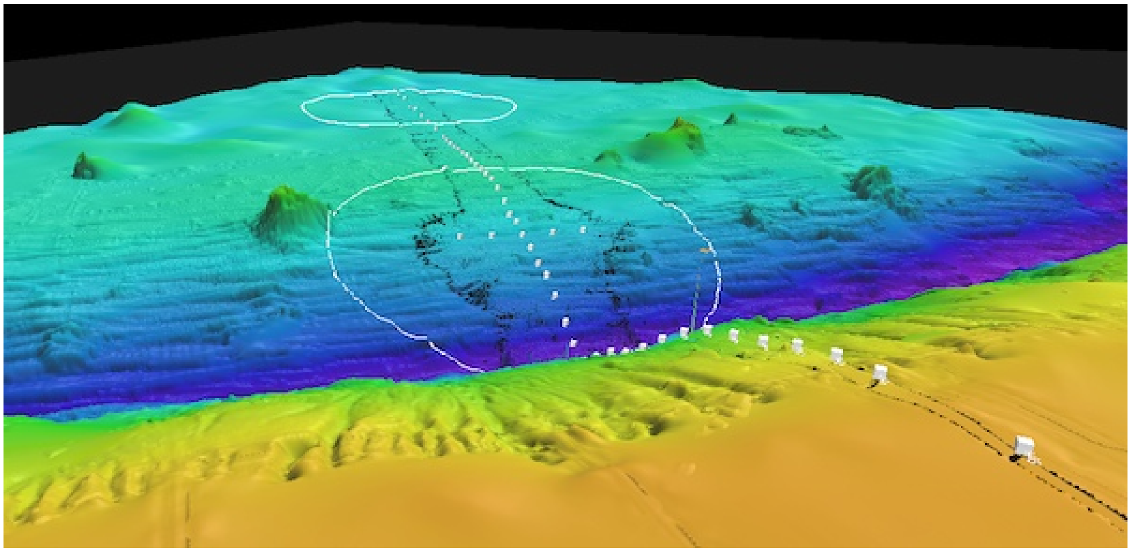


Figure 27: 3D view showing existing seafloor bathymetry data and the strip of higher resolution EM122 bathymetry collected along the survey line.

Gravity data was recorded by the ship's gravimeter during the entire cruise track, as shown in the trackline plot of Figure 10. Tie-points were collected at the Puerto Caldera dock and a nearby monument both before and after the cruise.

Multibeam bathymetry soundings were collected using the Melville's EM122 system, providing some spectacular high-resolution images of the heavily faulted seafloor around the trench, a mud-volcano on the continental shelf and some small sea-mounts in the deep-ocean. This system was operating during the transit to and from Puerto Caldera, during the EM receiver deployments and during the deep-tow operations. The deep-tow operations were done at 1.5 kts speed and therefore this portion of the multibeam data contains a very high density of soundings. However, once we began to deep-tow in the shallow water on the continental shelf (<200 m depth) we discovered that the adaptive high-repetition rate of the EM122 system can release our seafloor EM receivers since its sounding frequencies overlap with our acoustic releases. The EM122 system was stopped when receiver s45 prematurely released in front of the ship during the final stage of the Main Line deep-tow. The multibeam system was turned back on once all the remaining EM receivers were recovered.

6 Sneak Peak at Some Preliminary Data Results

The data analysis for this project is currently underway, but here we provide two sneak peaks at some very preliminary results.

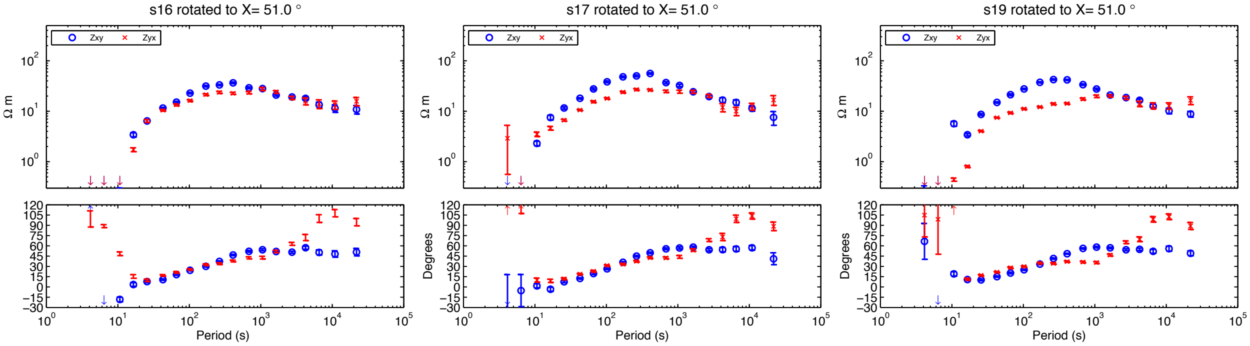
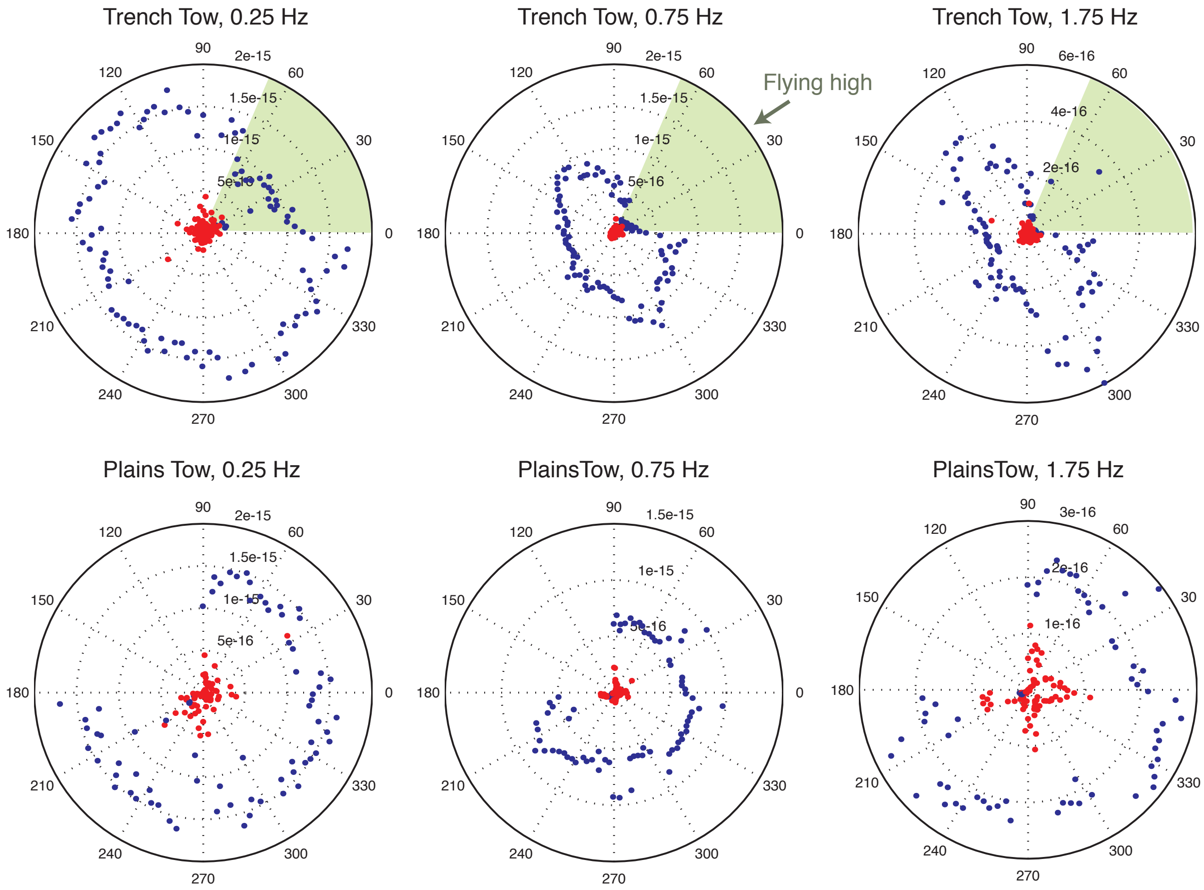


Figure 28: Preliminary MT responses from SERPENT sites s16, s17 and s19. The trench-parallel mode (in red) shows resistivities decreasing towards the trench (higher numbered sites), but, pending modeling, we do not yet know whether this is anisotropy, bathymetry, or 2-dimensional structure.



Trench Tow, 0.25 Hz

Trench Tow, 0.75 Hz

Trench Tow, 1.75 Hz

Plains Tow, 0.25 Hz

PlainsTow, 0.75 Hz

PlainsTow, 1.75 Hz

Flying high

Figure 29: Preliminary LEM data for the two circular tows (40 minute stacks). The green segment of the trench tow was when we were flying SUESI at maximum depth of 5,000 m even though the seafloor was over 5,200 m deep in places, resulting in depressed amplitudes, and the 90-180 degree data dropout for the plains tow is from a processing code bug which will be fixed very soon. The noise floor at the higher frequencies is about 1e-17 V/Am^2, similar to the APPLE data, but the signal is about an order of magnitude smaller than for APPLE, presumably due to the larger degree of sedimentation in the SERPENT area. A signal from trench-parallel anisotropy clearly develops above 0.25 Hz in both tows, but mostly in the major polarization ellipse axis (blue dots) for the trench and the minor axis (red dots) for the plains, suggesting some kind of evolution with depth or type of anisotropy as the plate bends.

7 Summary of Lessons Learned and Considerations for Future Projects

The list below summarizes some of the valuable lessons we learned and solutions we implemented during the cruise, and suggestions for future improvements.

Problem	Solution
EM122 multi-beam system overlaps frequencies with our acoustic releases, triggering them to ping and sometimes also to accidentally release on the secondary code.	The accidental pings add noise to the EM data, so don't use the EM122 during CSEM deep-tow operations. To stop accidental releases, we can change the secondary release code to something other than all time bits on.
Towed Barracuda paravanes can become wrapped around the ship if strong following currents and wind.	We need to develop a remotely-controlled Barracuda power-boat system.
Acoustic transponders on the Barracuda Paravanes had trouble hearing SUESI Benthos pings when transmitter went below about 1 km water depth.	We figured this was due to water sloshing noise on the acoustic transponders so we rigged up harnesses that suspended the transponders a few meters below the paravane and they began hearing the SUESI Benthos unit without any difficulty.
Not enough portable hard drive space to save all the raw HD video camera footage.	Bring at least 1TB instead of 500GB. A wide angle lens adapter would be useful as well.
Styrofoam cups don't shrink uniformly :)	Stuff the cups with paper towels before deploying them to the deep.

8 Outreach and Media Coverage

As part of our outreach effort, we have been maintaining a project website at http://marineemlab.ucsd.edu/Projects/SERPENT. During the cruise we populated this page with near daily updates in the form of a cruise blog containing text describing the days' activities along with photographs, movie clips and music videos. The cruise movies, made by graduate student Brent Wheelock, have also been made available at YouTube.com. The movies are a mix of MTV styled music videos documenting life and events aboard the ship to more ribald Monty Python-esque sketches and mock-horror movies; all are intended to promote interest in marine geophysics, shipboard research and the marine life wonders seen during a month offshore. As a measure of the website's impact, Figure 30 shows a Google Analytics plot of daily visits to the entire Marine EM Lab website since December 2008. As can be readily seen, the traffic to our site significantly increased during the SERPENT cruise time period, surpassing the high traffic during the Scarborough cruise one year earlier.

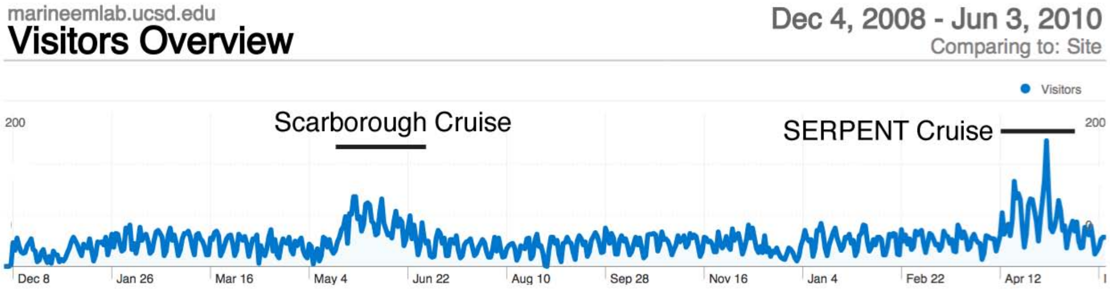
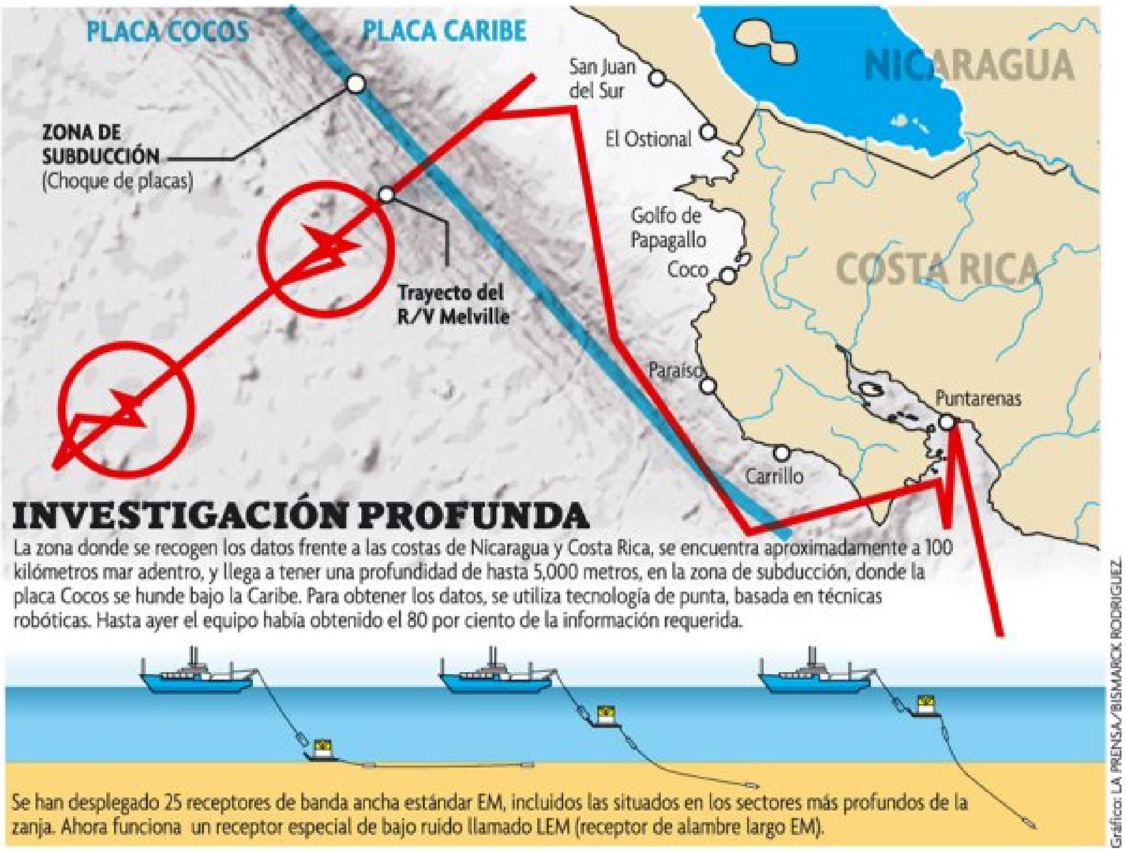


Figure 30: Google Analytics showing daily site traffic for the Scripps Marine EM Lab website since tracking began in December, 2008. The SERPENT cruise set a new record, with a peak of just under 200 visitors for the busiest day, beating our previous record set during the industry funded Scarborough cruise.

Another measure of the website's visibility and impact is the unsolicited cruise coverage by several news-media organizations. On May 2 the San Diego Union-Tribune posted an entry about the ongoing cruise in its online Science Blog. On May 5 the local San Diego television station Fox5 conducted a Skype video chat with Kerry Key onboard the R/V Melville during their morning news show. The Nicaraguan press covered the cruise with articles in *El Nueva Diario* on May 5 and *La Prensa* on May 6 and May 12. Figure 31 shows a graphic accompanying the May 6 story.



INVESTIGACIÓN PROFUNDA

La zona donde se recogen los datos frente a las costas de Nicaragua y Costa Rica, se encuentra aproximadamente a 100 kilómetros mar adentro, y llega a tener una profundidad de hasta 5,000 metros, en la zona de subducción, donde la placa Cocos se hunde bajo la Caribe. Para obtener los datos, se utiliza tecnología de punta, basada en técnicas robóticas. Hasta ayer el equipo había obtenido el 80 por ciento de la información requerida.

Se han desplegado 25 receptores de banda ancha estándar EM, incluidos las situados en los sectores más profundos de la zanja. Ahora funciona un receptor especial de bajo ruido llamado LEM (receptor de alambre largo EM).

Gráfico: LA PRENSA/BISMARCK RODRIGUEZ

Figure 31: Graphic accompanying an article about the research cruise that was published in the Nicaraguan paper La Prensa pon May 6, 2010.

9 Data Distribution

Raw data from this cruise will be made available to the governments of Nicaragua and Costa Rica no later than May 10, 2011 (one year after the cruise). Data from this project will be submitted in a timely manner to Margins data portal at the Marine Geosciences Data System (http://www.marine-geo.org). After publication, modeling results and processed data will also be made available through our web site at http://marineemlab.ucsd.edu/Projects/SERPENT.

10 Conclusions

This was a tremendously successful cruise. Using 54 seafloor EM receivers, 4 long-wire EM receivers, three Barracudas, two SUESIs, one Vulcan and a great team on the R/V Melville we were able to conduct the world's largest marine EM survey of a subduction zone. We deployed the EM receivers a total of 56 times, collecting 54 data sets but losing two instruments. Of the 54 recoveries, all receivers recorded data and we only lost two main data channels out of 216 total (a 99% success rate, or 96% if you count the two missing receivers). We deployed each LEM once and all four LEMs came back with good data on all channels. We towed SUESI #1 around Circle #1, along the Main Line, around Circle #2 and then up the continental slope; after switching to SUESI #2, we towed along the trench outer-rise for 50 km and then about 1/2 of a mini-Circle#2, for a combined distance of nearly 800 km of CSEM tows. Our tail-end transponder (TET) worked beautifully for all the SUESI tows, returning depth recordings for the end of SUESI's antenna. After debugging the Barracuda/Benthos navigation system, we collected good SUESI navigation data for the Main Line, Circle #2, the continental slope and the outer-rise tows. Our towed 3-axis electric field receiver Vulcan recorded data during the outer-rise and mini-Circle #2 tows. In summary, we have collected a huge volume of marine EM exploration data, from which we will be able to learn a great deal about the nature of cracking, extension, porosity and serpentinization of the oceanic lithosphere at a subduction zone.

Acknowledgments

This work was made possible by National Science Foundation Grants OCE-0841114 and OCE-0840894. We thank the governments of Nicaragua and Costa Rica for permission to work in their exclusive economic zones. We thank Marine Geology and Geophysics Program Director Richard Carlson for his efforts nurturing our proposal through the system. A big thank-you to Captain Murray Stein and the crew of the R/V Melville for making sure we had a safe and successful research cruise. Without the hard-work and devotion of the students, technicians and research assistants of the Scripps Marine EM Lab, we would not have been able to carry out this project. In particular, we acknowledge Jacques Lemire and Arlene Jacobs for their shoreside support efforts. Finally, we extend a huge thanks to our guests from Woods Hole Oceanographic Institution, who were great shipmates and the hardest working group of marine EM newbies we've ever sailed with.

A Cruise Personnel

Science Party:

Kerry Key	Researcher, Chief Scientist
Steven Constable	Professor, Co-Chief Scientist
Arnold Orange	Research Associate
Karen Weitemeyer	Postdoctoral Researcher
David Myer	SIO Ph.D. Student
Brent Wheelock	SIO Ph.D. Student
John Souders	SIO Engineer
Chris Armerding	SIO Technician
Cambria Colt	SIO Technician
Jake Perez	SIO Technician
Tetsuo Matsuno	WHOI Postdoctoral Researcher
Emily Carruthers	WHOI Ph.D. Student
James Elsenback	WHOI Technician
Sam Zipper	WHOI Technician
Ben Cohen	Computer Technician
Keith Shadle	Resident Technician

R/V Melville:

Murray Stein	Captain
Paul Bueren	Chief Engineer
Rene Buck	1st Mate
Melissa Turner	2nd Mate
Jeff Kirby	3rd Mate
Edward Keenan	Boatswain
Cletus Finnel	AB
David Gilmartin	AB
John Ryan	AB
Paul Shute	OS
Richard Buck	Sr. Cook
Leoncio Nartires	Cook
Pat Fitzgerald	1st A/E
Elizabeth Mack	2nd A/E
Luis Navarrete	3rd A/E
Joe Sill	Electrician
Manuel Ramos	Oiler
John Baon	Oiler
Bob Juhasz	Oiler
Philip Hogan	Oiler
William Bouvier	Wiper

B Receiver Deployments

* Note that listed positions are drop locations and not the navigated positions (pending).

Site	Instrument	Config.	Startup Times	Water Depth (m)	Longitude	Latitude
1	27 Bogong	MT	17-Apr-2010 15:00	3357	88° 23.8800’W	9° 50.0334N
2	99 Vulcan	MT	17-Apr-2010 15:00	3348	88° 19.6450’W	9° 53.4680’N
3	31 Skink	ACDC MT	17-Apr-2010 15:00	3282	88° 15.4086’W	9° 56.9019’N
4	63 Bower	MkIV	18-Apr-2010 15:00	3311	88° 11.1706’W	10° 0.3351’N
5	14 Magpie	MT	17-Apr-2010 15:00	3255	88° 6.9311’W	10° 3.7675’N
6	10 Bunyip	GEO	17-Apr-2010 15:00	3254	88° 2.6901’W	10° 7.1992’N
7	11 Quindal	MT	17-Apr-2010 15:00	3169	87° 58.4476’W	10° 10.6301’N
8	98 Vulcan 2	MT	17-Apr-2010 15:00	3191	87° 54.2035’W	10° 14.0603’N
9	55 Brolga	ACDC MT	17-Apr-2010 15:00	3140	87° 49.9578’W	10° 17.4896’N
10	26 Dugite	MT	17-Apr-2010 15:00	3128	87° 48.2591’W	10° 18.8611’N
11	57 Potoroo	MT	17-Apr-2010 15:00	3119	87° 46.5602’W	10° 20.2324’N
12	54 Cuscus	ACDC MT	17-Apr-2010 15:00	3072	87° 44.8610’W	10° 21.6037’N
13	43 Mozzie	MT	17-Apr-2010 15:00	3003	87° 43.1615’W	10° 22.9748’N
14	42 Currawong	MT	17-Apr-2010 15:00	3010	87° 41.4619’W	10° 24.3457’N
15	53 Marron	ACDC MT	17-Apr-2010 15:00	2939	87° 39.7619’W	10° 25.7165’N
16	40 Rabbit	MT	17-Apr-2010 15:00	2934	87° 38.0617’W	10° 27.0872’N
17	37 Corella	MT	17-Apr-2010 15:00	2924	87° 36.3613’W	10° 28.4578’N
18	52 Bilby	ACDC MT	17-Apr-2010 15:00	2891	87° 34.6606’W	10° 29.8282’N
19	39 Taipan	MT	17-Apr-2010 15:00	2866	87° 32.9596’W	10° 31.1985’N
20	32 Shark	MT	17-Apr-2010 15:00	2867	87° 31.2584’W	10° 32.5686’N
21	51 Yabby	ACDC MT	17-Apr-2010 15:00	2972	87° 29.5570’W	10° 33.9386’N
22	36 Camel	MT	17-Apr-2010 15:00	3201	87° 27.6425’W	10° 35.4797’N
23	9 Fruitbat	MT	16-Apr-2010 15:00	3450	87° 26.1533’W	10° 36.6781’N
24	18 Devil	ACDC MT	16-Apr-2010 15:00	3457	87° 24.4511’W	10° 38.0477’N
25	50 Koala	MkIV	17-Apr-2010 15:00	3662	87° 22.9615’W	10° 39.2459’N
26	25 Echidna	MT	16-Apr-2010 15:00	3766	87° 21.0459’W	10° 40.7864’N
27	47 Budgie	ACDC MT	16-Apr-2010 15:00	3986	87° 19.3429’W	10° 42.1555’N
28	7 Dingo	MT	16-Apr-2010 15:00	4048	87° 17.6397’W	10° 43.5244’N
29	1 Bandi	MT	16-Apr-2010 15:00	4358	87° 15.9362’W	10° 44.8933’N
30	49 Ibis	ACDC MT	15-Apr-2010 15:00	4746	87° 13.9342’W	10° 46.5014’N
31	22 Joey	MT	15-Apr-2010 15:00	5073	87° 12.5284’W	10° 47.6304’N
32	6 Wombat	MT	15-Apr-2010 15:00	5154	87° 10.8242’W	10° 48.9988’N
33	44 Numbat	ACDC MT	15-Apr-2010 15:00	4647	87° 9.1196’W	10° 50.3669’N
34	5 Cass	MT	15-Apr-2010 15:00	4118	87° 7.4148’W	10° 51.7350’N
35	21 Bullant	MT	15-Apr-2010 15:00	3738	87° 5.7098’W	10° 53.1029’N
36	41 Cocky	ACDC MT	15-Apr-2010 15:00	3222	87° 4.0045’W	10° 54.4706’N
37	45 Redback	MT	15-Apr-2010 15:00	2636	87° 2.2989’W	10° 55.8382’N
38	8 Glider	MT	15-Apr-2010 15:00	2110	87° 0.5931’W	10° 57.2056’N
39	35 Rosella	ACDC MT	15-Apr-2010 15:00	1685	86° 58.8870’W	10° 58.5728’N
40	3 Quokka	MT	15-Apr-2010 15:00	1403	86° 57.1807’W	10° 59.9399’N
41	17 Wallaby	MT	15-Apr-2010 15:00	1133	86° 55.4741’W	11° 1.3069’N
42	46 Penguin	ACDC MT	15-Apr-2010 15:00	806	86° 53.7672’W	11° 2.6736’N
43	48 Brumby	MT	15-Apr-2010 15:00	554	86° 52.0601’W	11° 4.0402’N
44	16 Possum	MT	15-Apr-2010 15:00	395	86° 50.3527’W	11° 5.4067’N
45	33 Occie	ACDC MT	15-Apr-2010 15:00	154	86° 46.0830’W	11° 8.8219’N
46	28 Spit	MT	15-Apr-2010 15:00	168	86° 41.8117’W	11° 12.2363’N
47	38 Stingray	MkIV	15-Apr-2010 15:00	172	86° 37.5388’W	11° 15.6495’N
48	30 Mantis	ACDC MT	15-Apr-2010 15:00	138	86° 33.2641’W	11° 19.0616’N

Continued on the next page

Site	Instrument	Config.	Startup Times	Water Depth (m)	Longitude	Latitude
49	24 Galah	MT	15-Apr-2010 15:00	109	86° 28.9878'W	11° 22.4726'N
50	56 Quoll	MT	15-Apr-2010 15:00	61	86° 24.7099'W	11° 25.8825'N
51	2 Goanna	ACDC MT	16-Apr-2010 15:00	3570	87° 19.5013'W	10° 35.0353'N
52	34 Lorrie	MT	16-Apr-2010 15:00	3617	87° 21.2312'W	10° 37.1407'N
53	23 Roo	MT	16-Apr-2010 15:00	3648	87° 24.6921'W	10° 41.3510'N
54	29 Kooka	ACDC MT	16-Apr-2010 15:00	3662	87° 26.4232'W	10° 43.4558'N
51b	37 Corella	MT	6-May-2010 6:00	3570	87° 19.5013'W	10° 35.0353'N
54b	38 Stingray	MkIV	6-May-2010 6:00	3662	87° 26.4232'W	10° 43.4558'N
25 LEM1	58 Shrike	LEM	16-Apr-2010 15:00	3656	87° 17.6397'W	10° 43.5244'N
25 LEM2	60 Jabiru	LEM	16-Apr-2010 15:00	3656	87° 15.9362'W	10° 44.8933'N
4 LEM3	59 Pelican	LEM	18-Apr-2010 15:00	3282	88° 6.9311'W	10° 3.7675'N
4 LEM4	61 Lyre	LEM	18-Apr-2010 15:00	3296	88° 2.6901'W	10° 7.1992'N

C Receiver Data Quality

Site	Instrument	Config.	Water Depth (m)	Ch 1 Bx	Ch 2 By	Ch 3 Ex	Ch 4 Ey	Remarks		
1	27 Bogong	MT	3357	🟩	🟩	🟩	🟩		Good	🟩
2	99 Vulcan	MT	3348	🟩	🟩	🟥	🟩		Acceptable	▧
3	31 Skink	ACDC MT	3282	▧	▧	🟩	🟩	Chs1-4 noisy first day	Marginal	🟨
4	63 Bower	MkIV	3311	🟩	🟩	🟩	▧	Ch 4 noisy first two days	Very noisy	🟧
5	14 Magpie	MT	3255	🟩	🟩	🟩	🟩	Chs 1-4 noisy first four days	Bad Sensor	🟥
6	10 Bunyip	GEO	3254	🟩	🟩	🟩	🟩	Ch 5-7 geophone are good	Not Recovered	⬛
7	11 Quindal	MT	3169	🟩	🟩	🟩	🟩			
8	98 Vulcan 2	MT	3191	▧	▧	🟩	🟩	Some spikes on mags		
9	55 Brolga	ACDC MT	3140	▧	▧	▧	▧	Some spikes, wobble noise in 2nd half		
10	26 Dugite	MT	3128	▧	▧	🟩	▧	Ch 4 noisy first 4 days; Tidal wobble noise in 2nd half		
11	57 Potoroo	MT	3119	▧	▧	🟩	🟩	Tidal wobble noise in 2nd half		
12	54 Cuscus	ACDC MT	3072	🟧	🟧	🟨	🟩	Strong wobble noise in chs 1-3		
13	43 Mozzie	MT	3003	🟨	🟨	▧	▧	Tidal wobble noise in 2nd half		
14	42 Currawong	MT	3010	▧	▧	🟩	🟩	Tidal wobble noise in 2nd half		
15	53 Marron	ACDC MT	2939	▧	▧	🟩	🟩	Tidal wobble noise in 2nd half		
16	40 Rabbit	MT	2934	▧	▧	🟩	🟩	Tidal wobble noise in 2nd half		
17	37 Corella	MT	2924	🟩	🟩	🟩	🟩	Tidal wobble noise in 2nd half		
18	52 Bilby	ACDC MT	2891	🟨	🟨	▧	🟩	Moderate wobble noise in chs 1-3 during 2nd half		
19	39 Taipan	MT	2866	🟩	🟩	🟩	🟩			
20	32 Shark	MT	2867	▧	▧	🟩	▧	Ch 4 noisy first 6 days; occasional spikes		
21	51 Yabby	ACDC MT	2972	▧	▧	▧	▧	Chs 1-4 noisy first 5 days		
22	36 Camel	MT	3201	🟨	🟨	▧	🟩	strong wobble noise in chs 1-3 during 1st 6 days		
23	9 Fruitbat	MT	3450	▧	▧	▧	🟩			
24	18 Devil	ACDC MT	3457	▧	▧	🟩	🟩			
25	50 Koala	MkIV	3662	▧	▧	🟩	🟩			
26	25 Echidna	MT	3766	▧	▧	▧	🟩	Chs 1,2 have wobble noisy April 24 - May 04		
27	47 Budgie	ACDC MT	3986	🟧	🟧	🟩	🟩	Mags amp problem		
28	7 Dingo	MT	4048	▧	▧	🟩	🟩	Some wobble noise on Ch2 at start		
29	1 Bandi	MT	4358	⬛	⬛	⬛	⬛	Missing in action		
30	49 Ibis	ACDC MT	4746	▧	▧	🟧	🟩	Ch 3 noisy but quiet in some places		
31	22 Joey	MT	5073	🟩	🟩	▧	🟩	Some low freq spikes on ch3		
32	6 Wombat	MT	5154	🟨	🟨	▧	▧	Strong wobble noise in chs 1-2; Chs 3-4 noisy first 2 days		
33	44 Numbat	ACDC MT	4647	🟩	🟩	🟩	🟩	Stopped recording April 30 (5 days early)		
34	5 Cass	MT	4118	▧	▧	▧	🟩	Ch 3 noisy first 5 days		
35	21 Bullant	MT	3738	▧	▧	🟩	🟩	Some wobble noise on chs 1-2		
36	41 Cocky	ACDC MT	3222	🟩	🟩	🟩	🟩	Very clean data		
37	45 Redback	MT	2636	🟩	🟩	🟩	🟩			
38	8 Glider	MT	2110	🟨	🟨	▧	▧	Strong wobble noise in chs 1-2		
39	35 Rosella	ACDC MT	1685	▧	▧	🟩	🟩			
40	3 Quokka	MT	1403	⬛	⬛	⬛	⬛	Missing in action		
41	17 Wallaby	MT	1133	▧	▧	▧	▧			
42	46 Penguin	ACDC MT	806	▧	▧	▧	▧	Low freq good, but acoustic spikes in high freq		
43	48 Brumby	MT	554	🟧	🟧	🟨	🟨	Mags very noisy, e’s better		
44	16 Possum	MT	395	🟧	🟧	🟨	🟨	Mags very noisy, e’s better		
45	33 Occie	ACDC MT	154	▧	▧	▧	▧	Chs 1,2,4 have 0.1 Hz waveband, occasional acoustic spikes, otherwise good		
46	28 Spit	MT	168	🟨	🟨	▧	▧	Chs 1-4 have 0.1 Hz waveband, occasional acoustic spikes, otherwise good		
47	38 Stingray	MkIV	172	🟨	🟨	▧	▧	Chs 1-4 have 0.1 Hz waveband, occasional acoustic spikes, otherwise good		
48	30 Mantis	ACDC MT	138	🟧	🟧	▧	🟨	0.1 Hz waveband, mags have broadband noise (water motion?)		
49	24 Galah	MT	109	🟧	🟧	▧	▧	0.1 Hz waveband, mags have broadband noise (water motion?)		
50	56 Quoll	MT	61	🟧	🟧	🟧	🟧	Looks like strong motional noise all around (chs and freqs)		
51	2 Goanna	ACDC MT	3570	🟩	🟩	🟩	🟩			
52	34 Lorrie	MT	3617	🟩	🟩	🟩	🟩			
53	23 Roo	MT	3648	▧	▧	▧	🟩	Ch 3 noisy first 5 days, some wobble noise on chs 1-2		
54	29 Kooka	ACDC MT	3662	▧	▧	🟩	🟩			
51b	37 Corella	MT	3570	🟩	🟩	▧	🟩	some spikes on ch 3		
54b	38 Stingray	MkIV	3662	🟩	🟩	▧	▧			

D Event Log

Action	Planned	Actual	Start (Local)	End (Local)	Remarks
Loading	63:00	63:00	11-Apr 0:00	13-Apr 15:00	
Transit to site	18:00	18:00	13-Apr 15:00	14-Apr 9:00	
Deploy s50	2:00	0:20	14-Apr 9:00	14-Apr 9:20	
Deploy s49	2:00	0:40	14-Apr 9:20	14-Apr 10:00	
Deploy s48	2:00	0:42	14-Apr 10:00	14-Apr 10:42	
Deploy s47	2:00	0:43	14-Apr 10:42	14-Apr 11:25	
Deploy s46	2:00	0:50	14-Apr 11:25	14-Apr 12:15	
Deploy s45	2:00	0:45	14-Apr 12:15	14-Apr 13:00	
Deploy s44	2:00	0:51	14-Apr 13:00	14-Apr 13:51	
Deploy s43	2:00	0:34	14-Apr 13:51	14-Apr 14:25	
Deploy s42	2:00	0:30	14-Apr 14:25	14-Apr 14:55	
Deploy s41	2:00	0:50	14-Apr 14:55	14-Apr 15:45	
Deploy s40	2:00	1:00	14-Apr 15:45	14-Apr 16:45	
Deploy s39	2:00	0:55	14-Apr 16:45	14-Apr 17:40	
Deploy s38	2:00	1:08	14-Apr 17:40	14-Apr 18:48	
Deploy s37	2:00	1:12	14-Apr 18:48	14-Apr 20:00	
Deploy s36	2:00	1:25	14-Apr 20:00	14-Apr 21:25	
Deploy s35	2:00	1:35	14-Apr 21:25	14-Apr 23:00	
Deploy s34	2:00	1:30	14-Apr 23:00	15-Apr 0:30	
Deploy s33	2:00	1:45	15-Apr 0:30	15-Apr 2:15	
Deploy s32	2:00	1:55	15-Apr 2:15	15-Apr 4:10	
Deploy s31	2:00	2:00	15-Apr 4:10	15-Apr 6:10	
Deploy s30	2:00	1:55	15-Apr 6:10	15-Apr 8:05	
Deploy s29	2:00	1:46	15-Apr 8:05	15-Apr 9:51	
Deploy s28	2:00	1:54	15-Apr 9:51	15-Apr 11:45	
Deploy s27	2:00	1:20	15-Apr 11:10	15-Apr 12:30	
Deploy s26	2:00	1:15	15-Apr 12:20	15-Apr 13:35	
Deploy LEM1 at s25	8:00	8:44	15-Apr 14:46	15-Apr 23:30	
Deploy s51	2:00	1:21	16-Apr 0:26	16-Apr 1:47	
Deploy s52	2:00	1:12	16-Apr 1:12	16-Apr 2:24	
Deploy s53	2:00	1:18	16-Apr 3:17	16-Apr 4:35	
Deploy s54	2:00	1:15	16-Apr 3:47	16-Apr 5:02	
Deploy s24	2:00	1:09	16-Apr 5:49	16-Apr 6:58	
Deploy s23	2:00	1:04	16-Apr 6:25	16-Apr 7:29	
Deploy LEM2 at s25	8:00	9:05	16-Apr 8:00	16-Apr 17:05	
Deploy s25	2:00	2:05	16-Apr 17:05	16-Apr 19:10	
Deploy s22	2:00	1:45	16-Apr 19:10	16-Apr 20:55	
Deploy s21	2:00	0:56	16-Apr 20:26	16-Apr 21:22	
Deploy s20	2:00	1:15	16-Apr 21:22	16-Apr 22:37	
Deploy s19	2:00	0:55	16-Apr 22:12	16-Apr 23:07	
Deploy s18	2:00	2:00	16-Apr 23:27	17-Apr 1:27	Not watching to seabed anymore
Deploy s17	2:00	0:23	16-Apr 23:51	17-Apr 0:14	
Deploy s16	2:00	0:27	17-Apr 0:14	17-Apr 0:41	
Deploy s15	2:00	0:26	17-Apr 0:41	17-Apr 1:07	
Deploy s14	2:00	0:27	17-Apr 1:07	17-Apr 1:34	
Deploy s13	2:00	0:26	17-Apr 1:34	17-Apr 2:00	
Deploy s12	2:00	0:30	17-Apr 2:00	17-Apr 2:30	
Deploy s11	2:00	0:28	17-Apr 2:30	17-Apr 2:58	
Deploy s10	2:00	0:30	17-Apr 2:58	17-Apr 3:28	

Continued on the next page

Action	Planned	Actual	Start (Local)	End (Local)	Remarks
Deploy s09	2:00	0:50	17-Apr 3:28	17-Apr 4:18	
Deploy s08	2:00	0:42	17-Apr 4:18	17-Apr 5:00	
Deploy s07	2:00	0:44	17-Apr 5:00	17-Apr 5:44	
Deploy s06	2:00	0:41	17-Apr 5:44	17-Apr 6:25	
Deploy s05	2:00	1:12	17-Apr 6:25	17-Apr 7:37	
Deploy s03	2:00	0:44	17-Apr 7:37	17-Apr 8:21	
Deploy s02	2:00	0:45	17-Apr 8:21	17-Apr 9:06	
Deploy s01	2:00	0:30	17-Apr 9:06	17-Apr 9:36	
Deploy LEM3 at s04	8:00	7:30	17-Apr 10:00	17-Apr 17:30	
Deploy LEM4 at s04	8:00	8:30	17-Apr 17:30	18-Apr 2:00	
Deploy s04	2:00	2:00	18-Apr 2:00	18-Apr 4:00	
Deploy SUESI	4:00	13:00	18-Apr 8:00	18-Apr 21:00	Recovered to fix benthos#1
Deep-tow Circle 1	68:00	68:00	18-Apr 21:00	21-Apr 17:00	
Recovery SUESI, fix, redeploy	7:00	7:00	21-Apr 17:00	22-Apr 0:00	
Deep-tow Main Line Part 1	68:00	68:00	22-Apr 0:00	24-Apr 20:00	
Deep-tow Circle 2	68:00	76:00	24-Apr 20:00	28-Apr 0:00	
Deep-tow Main Line Part 2	44:00	30:30	28-Apr 0:00	29-Apr 6:30	Aborted at s45
Nav s50-s25	24:00	29:30	29-Apr 6:30	30-Apr 12:00	
Nav s54, s53, recover s54,s25	6:00	7:00	30-Apr 12:00	30-Apr 19:00	
Nav s51,s52, recover s51	6:00	5:30	30-Apr 19:00	1-May 0:30	
Nav s1-s23	24:00	28:30	1-May 0:30	2-May 5:00	
Recover 47 Rx + 2 LEMs	120:00	91:00	2-May 5:00	6-May 0:00	Bandicoot, Quokka missing
Deploy s51b, s54b	12:00	6:00	6-May 0:00	6-May 6:00	
Deep-tow along strike	29:00	30:30	6-May 6:00	7-May 12:30	
Deep-tow Mini-Circle 2	34:30	33:30	7-May 12:30	8-May 22:00	
Recover 9 Rx in center	36:00	21:30	8-May 22:00	9-May 19:30	
Transit to Caldera	18:00	18:00	9-May 19:30	10-May 13:30	
Total Days at Sea:	**27**				