Marine Electromagnetic Survey, Offshore Uruguay

R.V. Ocean Stalwart, January 9th – February 5th, 2014

Final Project Report

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SUMMARY

From January 9th to February 5th, 2014, we carried out a 28-day cruise on the R.V. Ocean Stalwart offshore Uruguay to collect magnetotelluric (MT) data on the continental margin. The objective of this experiment was to characterize the background geology and electrical conductivity structure prior to continued exploration in the area. A total of 165 MT sites were deployed with only two failures to record usable data (one instrument lost and one premature release). Data were collected along 5 lines spanning three blocks, with one 233 km-long line co-located with a low-frequency seismic line and extending onto what should be oceanic crust in deep water.

Bottom currents were measured during the entire project at three locations using a deployed current meter. Currents were up to ten times larger than would be expected in these water depths, often changing abruptly. In spite of this, all but a couple of sites could be processed into MT response functions, with data quality ranging from very good (about a third of the sites) to poor but usable. Deployment times varied from 4 to 9 days, and good sites have data ranging from 10 second period to at least 5,000 seconds.

Four battery-powered, deployed EM transmitters were built for this project and deployed twice each. One failed to release on the second deployment but probably functioned up to that point. Because the Ocean Stalwart had a suitable winch and cable, we were able to collect conventional deep-towed CSEM data on three lines spanning the blocks, although problems with the ship's short baseline acoustic system meant that the necessary navigation data was lacking for the first CSEM tow. On the later two tows we supplemented the ship's acoustics with a novel long baseline navigation approach using the deployed seafloor receiver instruments as a long baseline navigation net.

Inversions of the MT data show that the upper few kilometers of sediment are quite conductive, with horizontal resistivities between 0.5 and 1 Ωm. If the 10 Ωm contour is used to pick depth to basement, then sediment thicknesses are between about 4 and 6 km. The MT inversions are sensitive to basement resistivity to depths of about 50 km, at which point the models show resistivities of about 1,000 Ωm.

Vertical resistivities of the sediment obtained from CSEM inversions are slightly higher than from the MT data, between 1 and 2 Ωm, suggesting moderate levels of anisotropy. On line 5, where the CSEM data are sensitive to basement, depths to basement of 3–4 km are consistent with those estimated from the MT inversions. Joint inversion of CSEM and MT data on line 1 show a similar slight increase in vertical resistivity, with an indication that resistivity in the uppermost 500 m is higher than that of the deeper sediments.

INTRODUCTION

This aim of this project is to provide sediment conductivity estimates for use in planning future CSEM surveys offshore Uruguay, and to characterize basin geometry and develop better geological models of the eastern South American margin. The original plan was to collect between 150 and 250 marine MT sites in order to accomplish this, supplementing the marine MT data with shallow controlled source EM (CSEM) data collected using novel, battery-powered deployed transmitters developed by Scripps for this project. It transpired that the vessel chartered for the MT work also had a winch and A-frame suitable for use with the Scripps deep-towed transmitter, so we were able to expand to scope of work and collect several CSEM lines along the MT profiles, while still collecting more than the planned minimum number of MT sites. The quality of the CSEM data was somewhat compromised by the poor performance of the vessel's short baseline acoustic system, but we were able to supplement this with long baseline acoustic data collected using deployed seafloor instruments as a navigation net.

OPERATIONS

VESSEL

The vessel used for this operation was the R/V Ocean Stalwart, chartered by Scripps from Stabbert Maritime. This vessel started life in 1984 as the USNS Stalwart, the first of the Stalwart-class T-AGOS series, and was used for submarine detection. She left military service in 2002 and was donated to the State University of New York Maritime College as a training vessel. In 2011 she was acquired by Stabbert and given a major refit, which included improved laboratory space, dynamic positioning, and multibeam. The Stalwart is 68 meters long with a beam of 13 metes, and has a diesel electric propulsion system.

Although our choice of vessel was limited, and we would probably have chartered the Stalwart for the MT work anyway, one aspect that made her attractive was a winch, cable, and A-frame that was compatible with SUESI, our deep-towed EM transmitter, which allowed us to add a few lines of CSEM data collection to the MT program. The vessel was also equipped with a HiPap USBL transducer head which we planned to use for navigation of SUESI. The ship also had a new 12 kHz acoustic hull transducer, essential for the navigation and release of our seafloor instruments, and a LaCoste gravity meter. We attempted to collect multibeam data during our EM operations, but the ship's computers were not fully equipped with the software to process and display the results, and the raw data files that were generated were too large to keep the system running for more than a few hours. We did run the gravimeter, and although there is no tie to a land station, we are hopeful that the relative data will prove useful.

Although there were some hiccups getting a deep-water transponder for the HiPap USBL system, all the ship's systems worked well during our operations. The crew were competent and extremely helpful.

INSTRUMENTATION

The following instrumentation was used for this project:

i) A total of 51 seafloor electromagnetic recorders, each measuring horizontal electric and magnetic fields with 24 bit resolution. Electric fields are measured using silver-chloride electrodes on orthogonal 10 antenna and magnetic fields are measured on orthogonal induction coils. Depth rating is 6,000 m. Deployment and recovery is by means of long-baseline acoustic navigation and release systems.
For more information see `http://marineemlab.ucsd.edu/instruments/receiver.html`, Constable *et al.* (1998), and Constable (2013).

ii) 4 deployed battery-powered electromagnetic transmitters (DUESI instruments). These instruments transmit 25–30 A on two orthogonal 10 m antenna for a period of 6 hours, providing controlled-source EM data to ranges of about 2 km.

iii) One Valeport model 802 electromagnetic current meter, configured in a custom package for seafloor deployment with continuous recording for up to 7 days, depth rating 3,000 m.

iv) 2 deep-towed electromagnetic transmitters (one plus one spare), with a typical output current of 400 A on a 300 m neutrally buoyant antenna, providing a dipole moment of 120 kAm. Depth rating is 6,000 m. For more information see `http://marineemlab.ucsd.edu/instruments/suesi.html` and Constable (2013).

v) A 3-axis electromagnetic recorder ("Vulcan") that was towed at a fixed offset of 400 m behind the SUESI transmission antenna.

DESCRIPTION OF OPERATIONS

We mobilized in Montevideo on the 8th and 9th of January, unpacking and loading equipment from two 40' and one 20' containers and loading two 20' containers of receiver anchors. Since the ship had no bolt-down pattern, the two anchor containers, our antenna winch, receiver arm rack, receiver magnetometer rack, and instrument launch plate had to be welded to the deck. We had supplied deck plates with threaded bolt-holes for this, which greatly facilitated the unload at the end of the cruise, since the equipment could be unbolted before the welders arrived to move the plates. We sailed at 18:15 on the 9th.

The MT instruments were deployed on 5 lines (see Figure 1), moving them between lines in batches of 8–16 instruments. Deployment times varied from 4 to 9 days (see Appendix C), which is normally more than sufficient to collect good MT data. The four DUESI instruments were deployed between sites 65 and 69 on line 3, and then two each between sites 191 and 193 and 177 and 180 on line 5. We deployed our seafloor current meter near sites 83, 29, and 171.

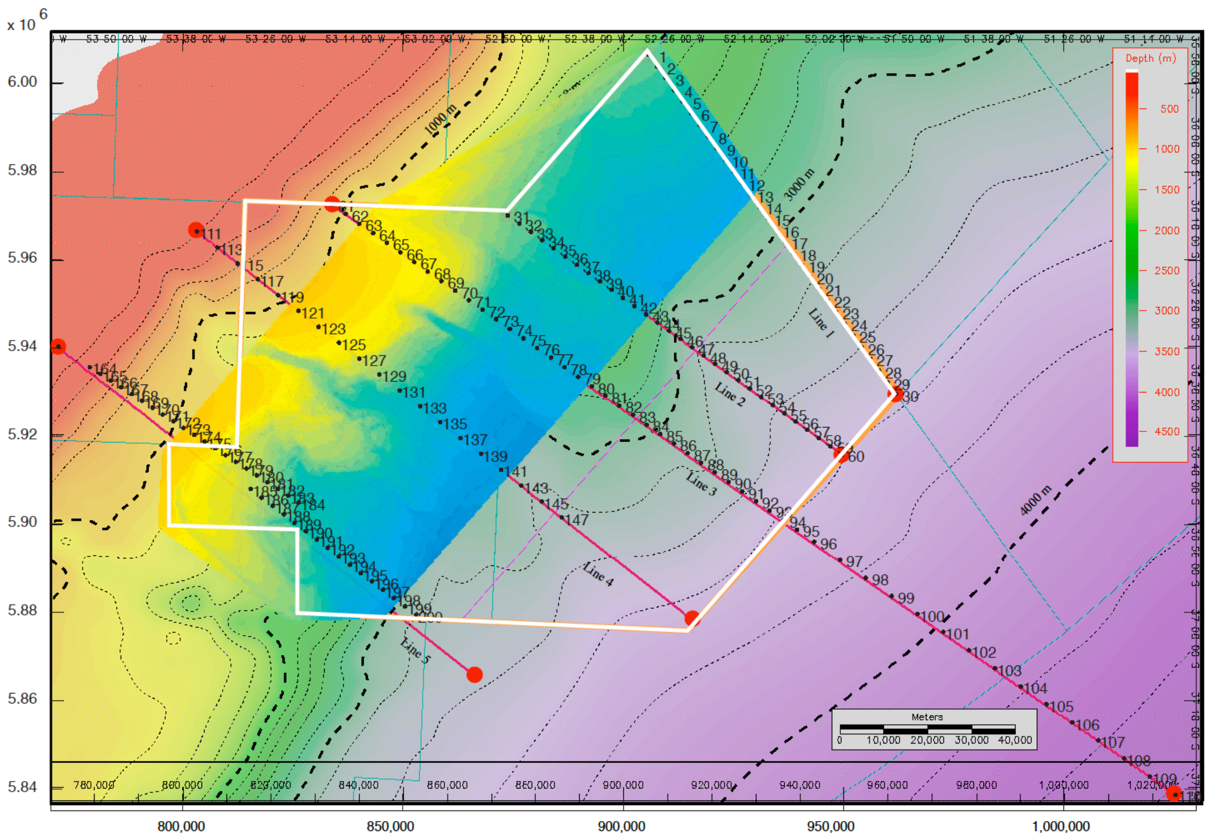


Figure 1. Map of sites as deployed.

SUESI tows were carried out on the shallow ends of lines 1, 3, and most of line 5. On lines 1 and 3, SUESI tows were terminated after we had to deviate off line to avoid seismic operations being carried out on the blocks. Seismic lines were being colleccted perpendicular to our lines, with tow speeds of around 6 knots and an exclusion zone 10 nautical miles wide. Our tow speed was about 1.5 knots, so it was almost inevitable that our paths would cross. Fortunately, by the time we towed line 5 towards the end of the operations, the seismic operations had moved to the southeast edge of the blocks and away from this shorter survey line.

We demobilized in Montevideo on the 5th February. Table 1 presents a summary of operations.

Table 1: Summary of operations:

8–9 January	Load and mobilization, Montevideo
10–12 January	Deploy 50 MT instruments, 4 DUESIs, and current meter on line 3
13–14 January	Towed SUESI from site 65 to site 72, but HF USBL transponder failed and navigation poor
15–16 January	Tow SUESI from site 66 to site 82 using external battery pack for HF USBL
16–19 January	Recover and deploy instruments
20 January	Tow SUESI from site 1 to site 13 on line 1 using LF USBL
21–29 January	Recover and deploy instruments
29–30 January	Tow SUESI from site 200 to site 185 on line 5a using LF USBL
30–31 January	Recover and deploy instruments
31 Jan – 1 Feb	Tow SUESI from site 184 to site 164 on line 5b using LF USBL
1–4 February	Recover instruments
5 February	Tie up Montevideo and offload equipment

INSTRUMENT PERFORMANCE

MT Receivers. Technically, the MT receiver fleet worked better than it ever has, notwithstanding the severe bottom currents (see next section). One instrument released shortly after deployment and was retrieved several days later floating on the surface in what has to be admitted was an extreme stroke of good luck. It faithfully collected data, but these were of course useless. In hindsight we could have avoided this debacle if we had been more conservative about a glitch that we observed when the acoustics were checked out on deck, but they re-checked OK and the glitch as observed on deck should not have caused the release, so we went ahead with deployment. A second instrument failed to respond to acoustics on recovery. Since this was a second deployment this was likely a failure of the glass floatation balls, which do implode occasionally (once in every several thousand ball-deployments). Our long term loss rate is about 1%, so one instrument out of 165 MT deployments is better than average. Otherwise we had 100% data recovery rate, which is a first for us on a project of this size (we usually lose another few percent of data to component failure or operator error). Although the bottom currents were nothing short of severe, the MT instrument systems were mostly able to handle them.

DUESI Instruments. The new DUESI instruments appeared to work quite well, although a software glitch did cut transmission short on the first deployment. On the second recoveries, DUESI 2 responded to acoustics but did not release. Various things can cause this, but we suspect a leak in a glass ball (rather than implosion, which destroys the instrument). The glass balls being used in the DUESI instruments have been in use for about 40 years, and probably should be retired. Adding this loss, and the 11 DUESI and current meter deployments to our statistics, our loss rate for this project is 2 instruments in 176 deployments, or 1.14%, which is still not too bad and is close to what was factored into the budget.

Seafloor Current Meter. Our Valelport current meter was deployed 3 times and worked well every time, for a total of about 18 days data (see next section). Since bottom currents were clearly an issue with the MT data quality, it has been really very helpful to be able to quantify bottom conditions.

SUESI. Our EM transmitter, the Scripps Undersea Electromagnetic Source Instrument, worked well until the end. We had a minor problem with one of the three power modules in our topside power supply which limited us to 250 amps for a while, but we were able to swap out a module from the spare power supply and get back to 300 amps, which is the capacity of the antenna system we were using. The major problem we had was after we had finished towing line 5, we had about half a day of spare time and so decided to transit to the center of the line and make a short cross-line tow. One of the terminations on our antenna failed mechanically shortly after we started transmitting. We suspect that the combination of high speeds during maneuvers to avoid the seismic vessel in the area, coupled with the surface transit, put too much load on the termination. We will re-design our termination system, but since this problem occurred after all the scheduled data collection, it did not compromise the project, although a flooded antenna is a significant loss to the laboratory.

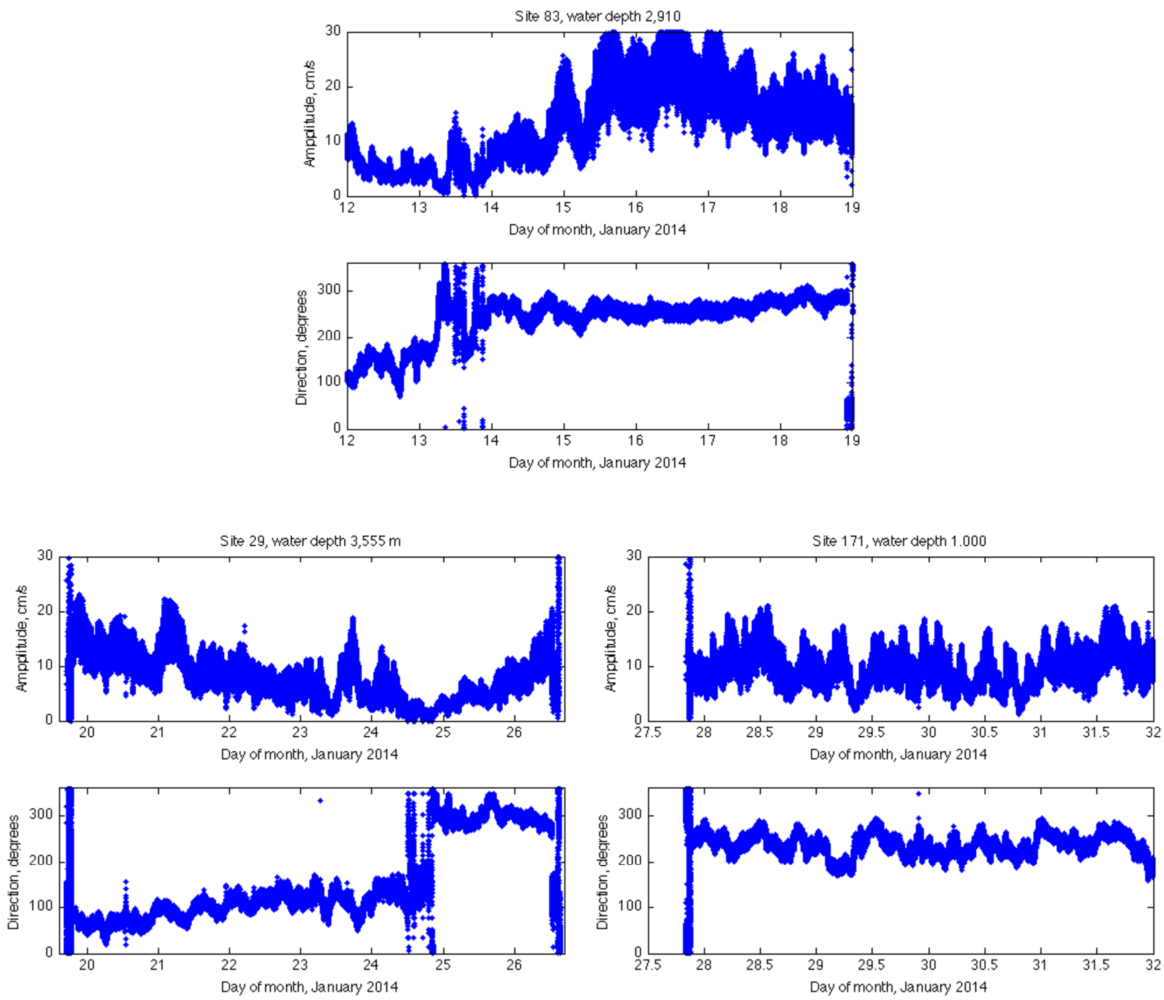


Figure 2. Bottom current data from the three deployments of our current meter.

The biggest problem we had with the SUESI operations was with the ship's USBL system, which suffered various operational problems and in the end proved to be badly out of calibration. In order to supplement the USBL system, we used the long base line (LBL) acoustic system on SUESI to range on the seafloor instruments during the CSEM tows, to provide auxiliary navigation data.

SEAFLOOR OCEAN CURRENTS

Although we were warned that ocean currents in this area off Uruguay were quite strong, we were not expecting just how bad things would be. First, many people confuse surface currents with bottom currents. Everyone has experience of surface currents, but rarely do people have bottom current data from areas without seafloor infrastructure (which is why we developed our deployed current meter instrument). Bottom currents are largely decoupled from surface currents. Second, we very rarely see large bottom currents in deep water away from the shelf break. Almost all of our planned sites were deeper than 1,000 m, and half of them were in water deeper than 2,500 m on relatively flat seafloor.

Figure 2 shows the bottom current data that we collected. Peak currents of over 30 cm/s are ten times what we would normally expect to see in water at depths of a third of those here. There does appear to be a 12-hour tidal modulation, but shorter period variations are of similar magnitude and there is a long-term variation in speed that may also be tidally modulated. However, as is seen in the magnetometer spectrograms, one characteristic of the bottom currents is the very rapid increase in magnitude over a very short time scale.

The bottom currents had a big impact on MT data quality. However, it is not clear how we could have mitigated this problem. Deployment times were fairly generous, and the instrument has been optimized in terms of stability. Our only thoughts at this time is to stiffen up the recovery flag mount, which can rock back and forth a little bit.

TRANSMITTER AND RECEIVER NAVIGATION

RECEIVER NAVIGATION

Receiver navigation was carried out using long baseline (LBL) acoustic ranging from the vessel's 12 kHz transponder to the navigation/release acoustics on the seafloor receivers. Because we had not anticipated the ability to carry out CSEM tows on this project, we had not built in dedicated time to navigate all the receivers into the MT field program, and so only receivers in range of controlled-source EM (CSEM) transmissions were navigated. For magnetotelluric (MT) sounding, the locations of instrument release points from the vessel are sufficiently accurate for the analysis. We carried out LBL navigation with minimal impact on the schedule by ranging on instruments from the vessel during CSEM tows, collecting closest point of approach (CPA) data in the along-line direction, and then ranging on the instruments immediately prior to release by approaching the instruments in the cross-line direction. We used a Benthos DS-8000 ranging unit connected to the vessel's hull transducer, under control of a laptop computer which also collected ship positions from the CSEM transmitter's GPS clock.

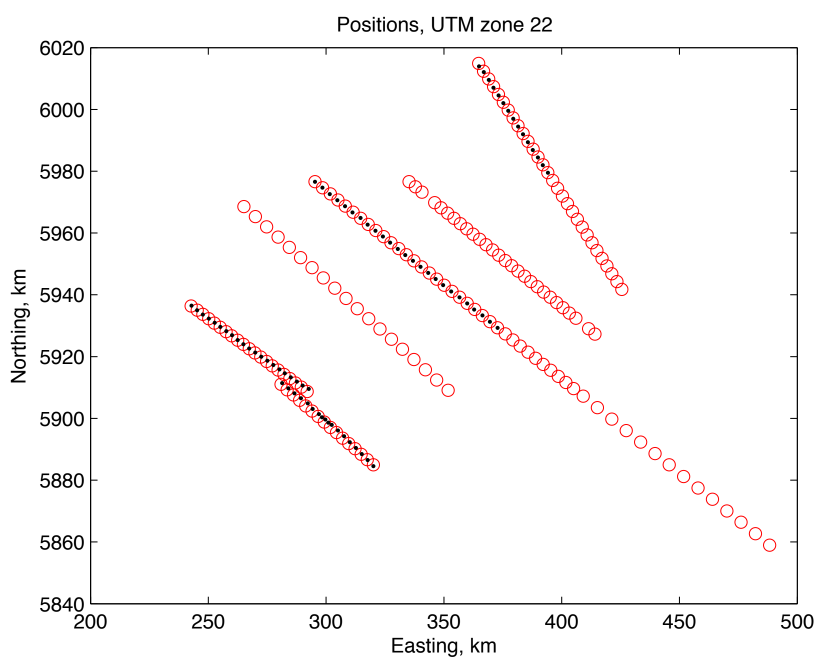


Figure 3. Nominal site locations (red circles - essentially identical to the actual release positions) and navigated positions (black dots).

Sound velocity profiles were collected by the Valeport CTD-V unit mounted on the CSEM transmitter, and instrument locations were obtained by carrying out a Marquardt iterative non-linear parameter inversion, using the drop locations as a starting value. Ray-tracing was used to account for ray-bending in the stratified water column. Figure 3 shows navigated positions as well as nominal drop locations. Figure 4 shows the navigated depths along with depths obtained from the paper acoustic recordings collected during deployment and recovery of the seafloor instruments. Errors on inverted positions are mostly less than 3 m in horizontal axes and 1 m in depth.

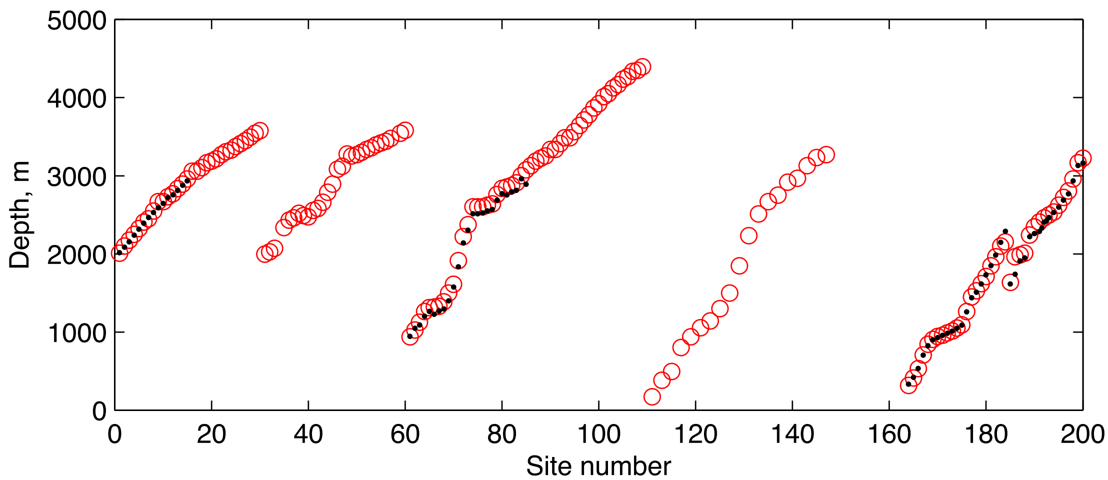


Figure 4. Nominal site depths obtained from paper acoustic records during release and recovery (red circles) and navigated depths (black dots).

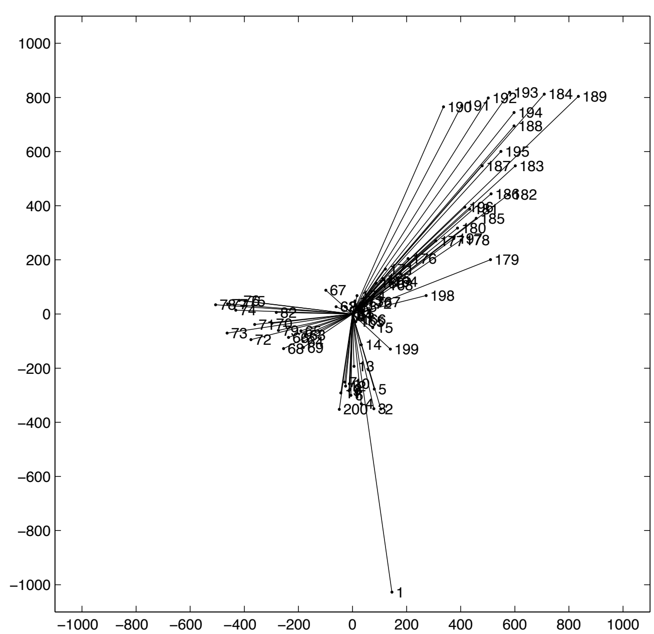
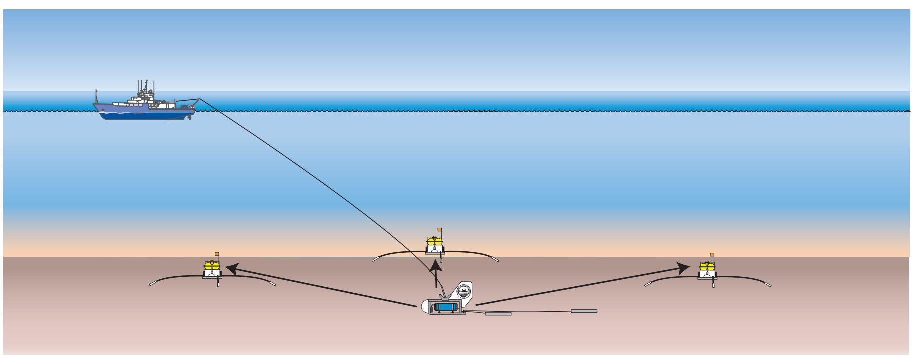


Figure 5. Drift of instruments (in meters) from release position (always [0,0]). Site 1 is probably a bad survey location. Drifts towards the west are mostly associated with line 3 in 1,500–3,000 m water depths. Drifts towards the northeast are mostly associated with line 5, again in 1,500–3,000 m water depths.

Figure 5 shows the drift of the instruments from the drop locations. For operations in 1,000 m water one would typically observe 50 m drifts from the deployment locations. On project Scarborough, which had moderate currents, drifts were around 100 m. Here drifts were as much as 800 m, particularly on lines 5a and 5b. The large drift on site 1 is probably a result of poor LBL navigation at the end of the line, and it may be desirable to use the drop point rather than the navigated position for this site. From this plot, one can conclude that the error in the locations of the un-navigated MT sites is about 300 m.

TRANSMITTER NAVIGATION

The vessel was advertised as having a Kongsberg-Simrad HiPap ultra-short baseline (USBL) navigation system installed, and during the vessel charter we requested use of this system in order to navigate the SUESI transmitter system during CSEM deeptow operations. Unfortunately this request was not passed on to the vessel operators, and when we arrived in Montevideo we discovered that there was nobody on board who could operate this system. However, Stabbert were quick to locate a suitable technician and bring them onto the survey team. During the first use of SUESI (line 3) we discovered that the smaller USBL transponder on board the vessel had a very poor battery endurance and quit working after only 7 hours of operations. We were able to rig spare seafloor logger pressure case as an external battery, but then discovered that the range on this unit was limited to a 2,000 m slant range. There was a larger, lower frequency transponder on board the vessel, but when we went to use this we discovered that it had been flooded with water during previous use.



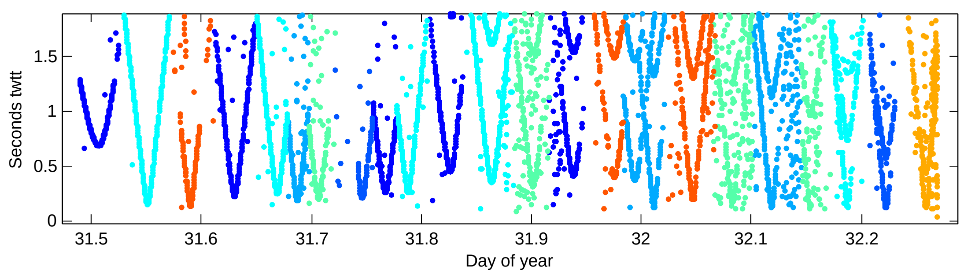


Figure 6. Top: During deeptowing we were able to range on the adjacent seafloor receiver instruments using the LBL navigation system installed in SUESI. This provides ranges to the nearest instruments on the in-tow and out-tow, and a lateral range to the nearest instrument at the closest point of approach. When combined with depth and altimeter data this provides a complete navigation solution with an ambiguity associated with which side of the instrument line we are towing. Bottom: Acoustic LBL ranges to instruments along line 5 – each seafloor instrument is represented by a different color.

We arranged for spare USBL transponders to be delivered to the ship by a support vessel, and were able to get positions on lines 1 and 5 using the USBL system. However, there was no processing software on board, and so all we could do was collect raw data. When we processed up the data onshore during the CSEM data processing we discovered that the calibration of the USBL system was so far off that the data were essentially useless for CSEM navigation purposes.

Fortunately, during the initial tow on line 3 we decided to try and range on the seafloor receiver instruments using the long baseline (LBL) acoustic system that is a standard part of SUESI. We had tried this method some years ago without success, but it worked well in this case. We could record acoustic ranges to the nearest seafloor instruments on the in-tow and out-tow, and also obtain a lateral range to the nearest instrument at the closest point of approach (Figure 6). When combined with depth and altimeter data this provides a complete navigation solution with an ambiguity associated with which side of the instrument line we are towing, which could usually be worked out .

MT DATA PROCESSING

MT data were processed using the multi-station transfer function estimation code of Egbert (1997). We have found that this code provides good results for seafloor data, where noise can be quite high but largely uncorrelated between instruments. Figures 7–11 show examples of processed MT data and raw data spectrograms to provide some idea of the range of quality we obtained and how the bottom currents factor into final data quality. We use the figure captions for commentary, but in all cases the top two spectrogram panels are the magnetic fields and the bottom two the electric fields.

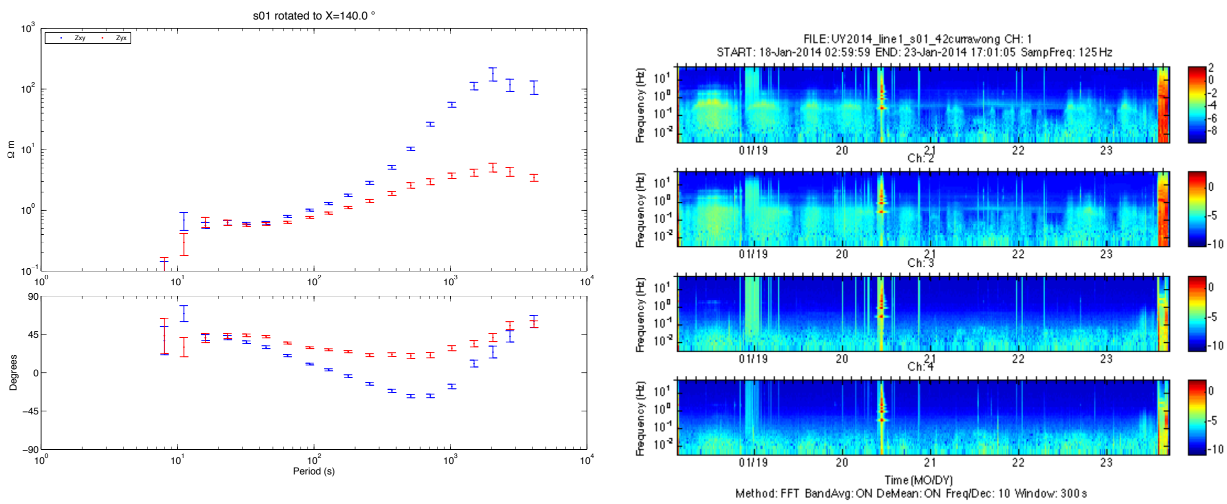


Figure 7. Example of good quality data, similar to what would be collected under normal conditions. Although there is a significant amount of noise in the spectrograms (green/yellow areas), there are many periods where noise is low or absent, and the noise is not particularly strong at the longest periods. Note the CSEM signal at day 20.5.

In order to get an overview of MT data quality, Figures 12–14 present polar plots for all sites that have been processed to date (there are about 5 sites on line 3 that we are having obscure technical problems with). These plots contain a lot of information and require some explanation for those unfamiliar with the MT method, but the main point to make here is that site to site and frequency to frequency consistency in the shape of the polar diagrams is some indication of data quality. Thus we see that for Line 1 data look good across the entire line at periods greater than 16 seconds except for a couple of data points. The high frequency cutoff is normal for these water depths, and one can see a loss of 16 second data in the deeper part of the line. Line 2 is nearly as good, with some remarkably high frequency data at a few sites.

Line 3 is the long line that extends into the deepest water and hopefully onto oceanic crust. There are around 3 clearly bad sites, and a general degradation at the highest frequencies around site 89. Line 4 had 3 or 4 bad sites but otherwise looks good.

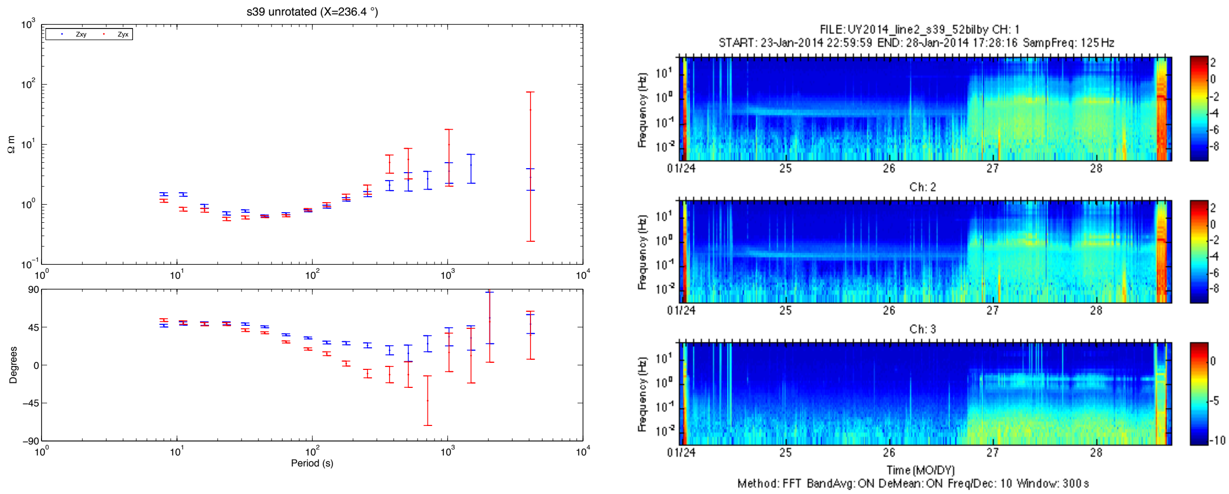


Figure 8. An example of the sudden onset of severe currents, here at day 26.5. This shortens the length of useful data to about 2.5 days, which impacts the long period response.

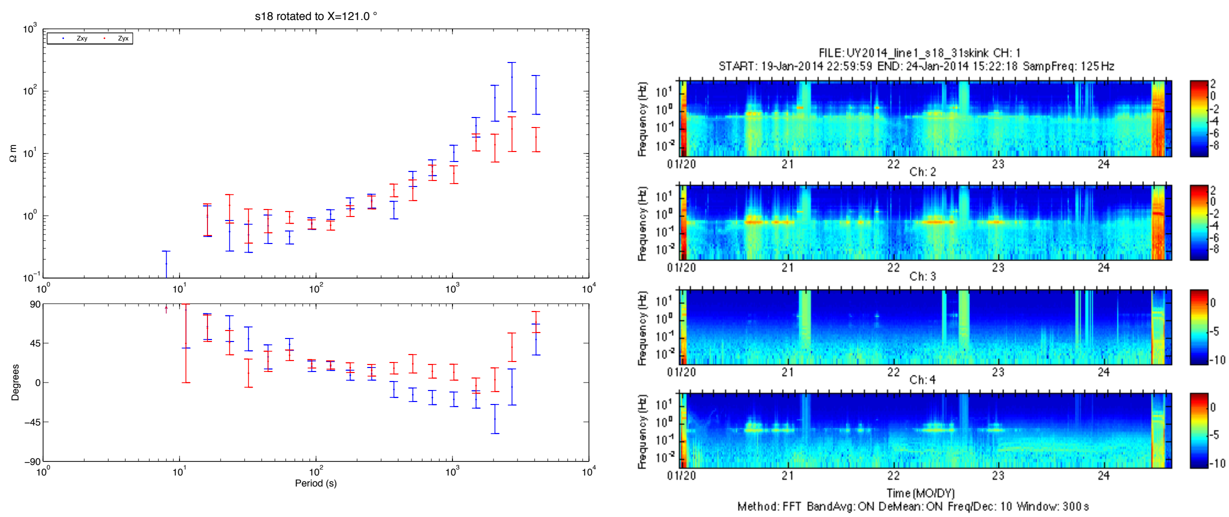


Figure 9. Poor, but usable, data. There is noise throughout the deployment period, but it is moderately narrow-band (probably an instrument vibration mode). The error bars are large, but the data scatter within the error bars suggests that the data are not biased and the error bars are realistic, so these data could be included in a 2D or 3D inversion and contribute to the model.

Line 5a, the deeper section of line 5, is the worst of the data sets, with about half the data appearing noisy. Line 5b, the shallower section, is not too bad, with about 3 bad sites. Compare sites 182–184 with sites 185–187. These sites are on parallel lines, in similar water depths, deployed for between 5.5 and 5.8 days at the same time, yet the data quality is very different. Clearly, the noise regime varies significantly over very small distances.

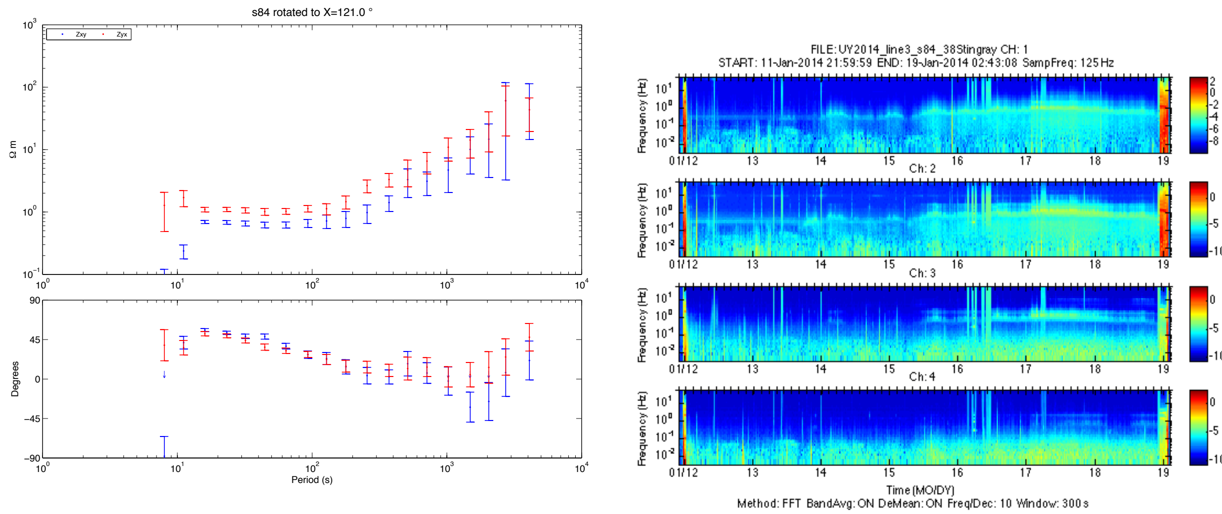


Figure 10. Usable looking data, but the data do not scatter within the error bars, suggesting that there may be bias or that the error bars have been overestimated.

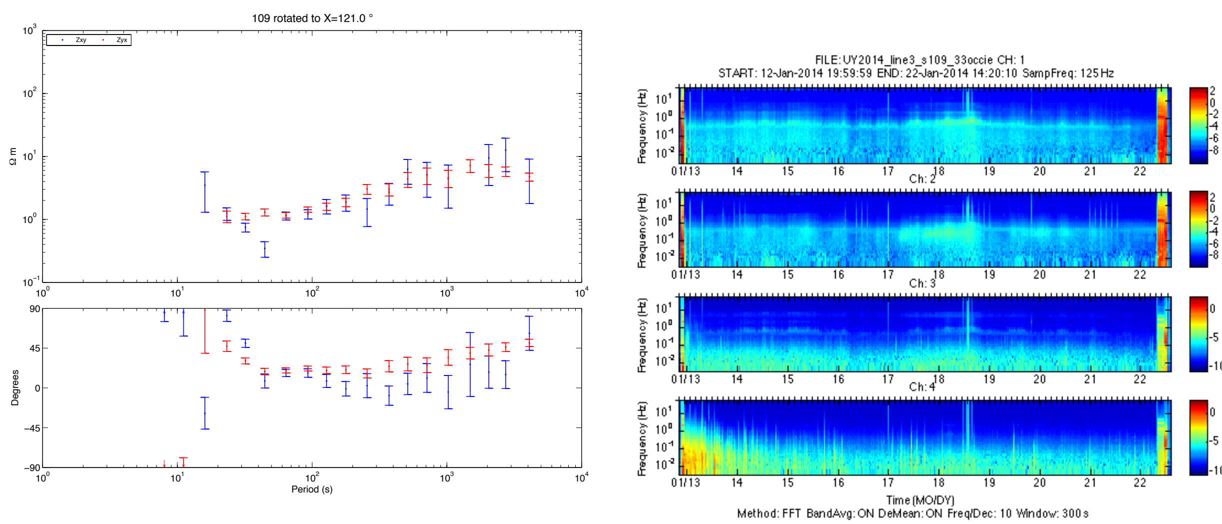


Figure 11. Very poor data. The spectrogram does not look overwhelmingly noisy, but the electric field data are corrupted at long periods. As noisy as these data are, they are still scattered around sensible values and may be amenable to improved processing.

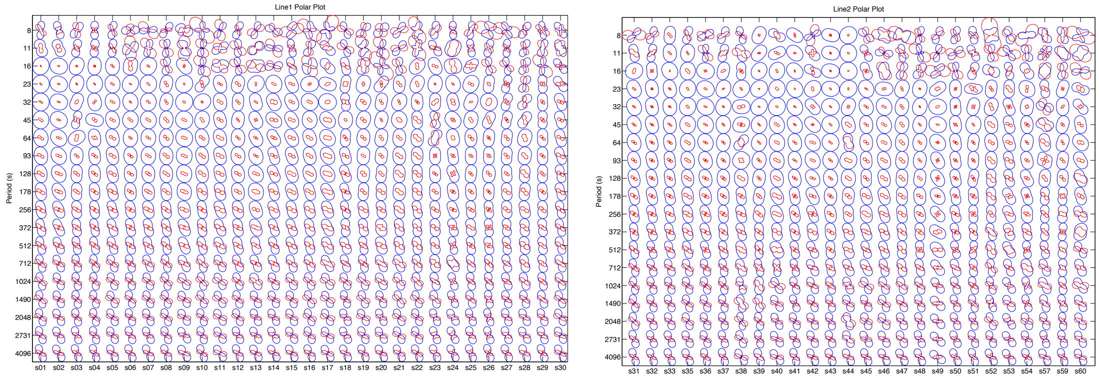


Figure 12. Polar plots for lines 1 and 2.

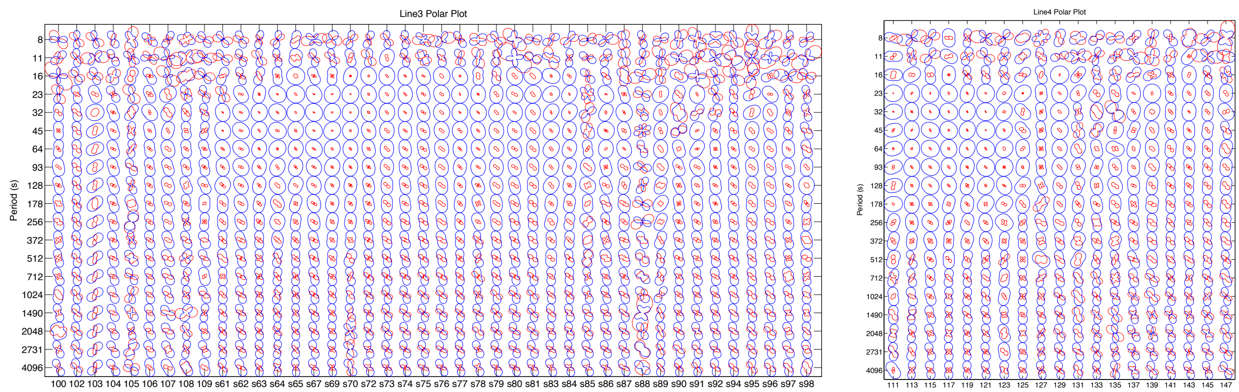


Figure 13. Polar plots for lines 3 and 4. Note the plotting routine has placed sites 100–109 on the right side of the plot.

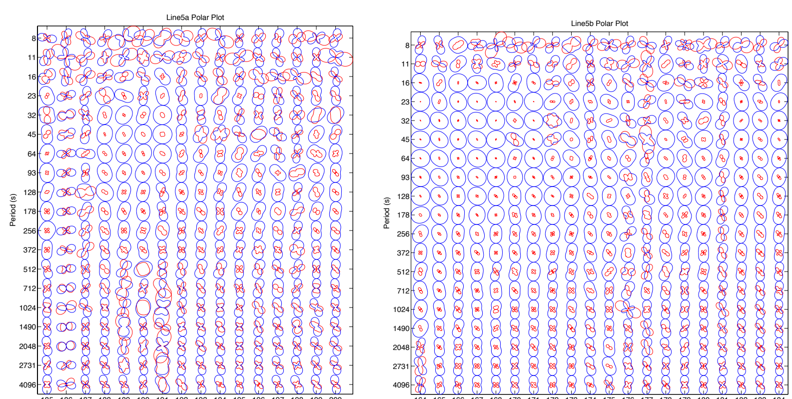


Figure 14. Polar plots for lines 5a and 5b.

CSEM DATA PROCESSING

We transmitted approximately 300 A on a 250 m antenna using the Waveform-D of Myer *et al.* (2011), and processed the raw time series data using the algorithm described in that same paper. This algorithm provides error estimates for the CSEM amplitudes and phases. The fundamental transmission frequency was 0.25 Hz and we processed 0.75 and 1.75 Hz harmonics. The processed CSEM data are then assembled with the transmitter and receiver navigation with the receiver data.

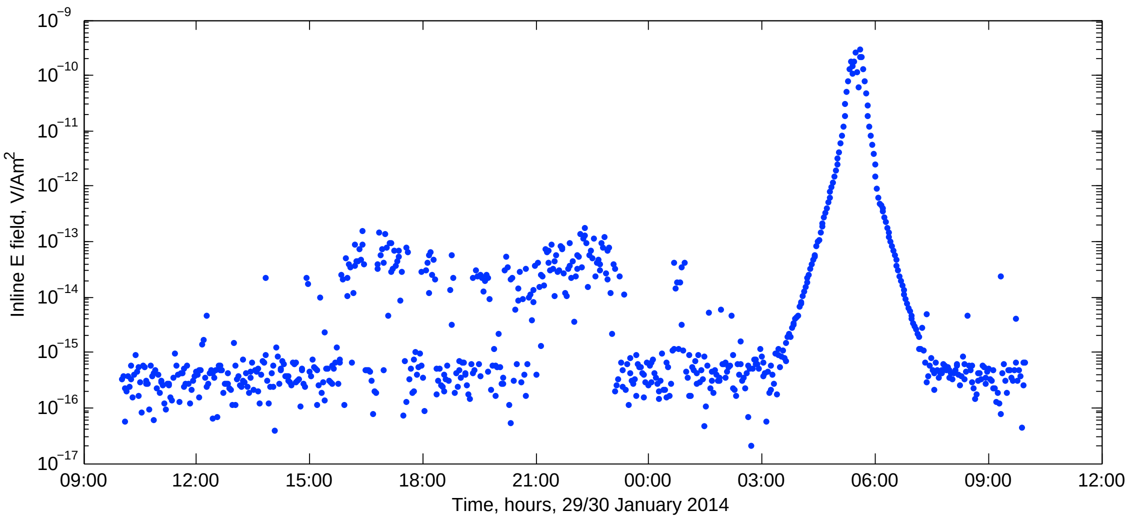


Figure 15. Polarization ellipse maxima for site 187 on line 5a. Frequency is 0.75 Hz and the data are 120 s stacks. The tent shape at 03:00 to 09:00 is real data, while the earlier bursts of high amplitudes are from water current noise.

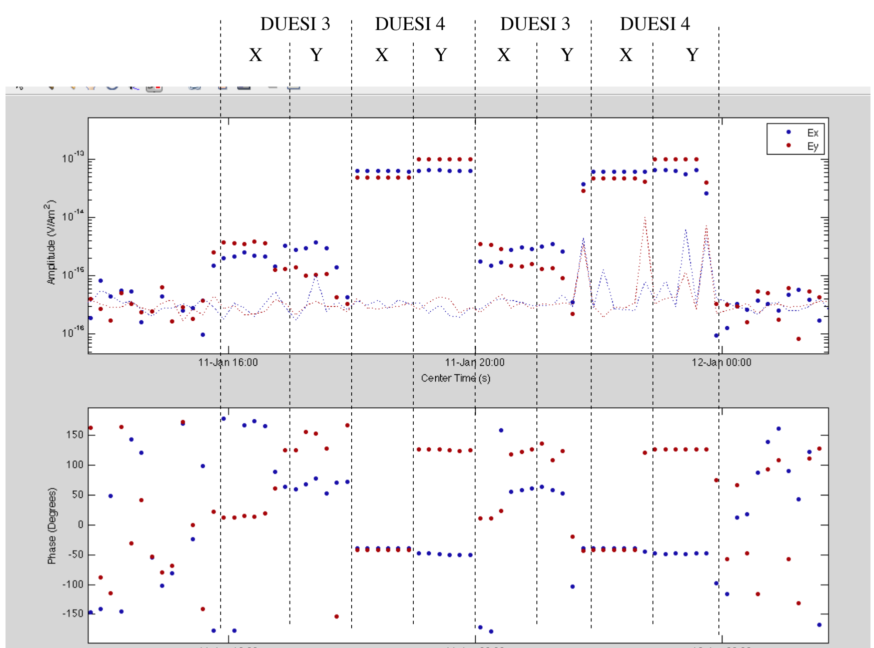


Figure 16. Sample of 10-minute stacks from one receiver instrument and two DUESI instruments. Frequency is 0.75 Hz, and X and Y transmissions are from the two different polarizations on the transmitter antennae.

The CSEM data are generally of good quality, with noise floors around 5×10^{-16} V/Am^2, but were affected by the water bottom currents. Figure 15 shows a sample of data from one line 5 site which exhibits bursts of noise from water currents. Since the noise was not during the CSEM reception window, it has not compromised the data in this case.

Figure 16 shows 10 minute stacks from one receiver that was in range of several DUESI instruments. For final analysis, the stacking was extended to the full one hour transmission windows to obtain slightly better signal to noise ratios.

INVERSIONS

INTRODUCTION

All the inversions were done with MARE2DEM, an open-source 2D finite element inversion code developed at Scripps (http://mare2dem.ucsd.edu/). The code will handle joint CSEM and MT data, with or without anisotropy. It is based on the Occam regularized inversion algorithm (Constable *et al.*, 1987), and has been optimized to run on parallel architecture.

All the MT lines were successfully inverted, but because of navigation issues with the USBL system, only CSEM data from lines 1, 5a and 5b have been inverted.

MT INVERSIONS

As discussed in the previous section, the quality of MT data varied significantly and not all sites were worth including in the inversion. Line 1 had some of the best data and 28 out of 30 sites were useable. The deep sites on Line 2 were especially noisy, 22 out of 30 sites were kept for inversion. Line 3 had bad sites spread throughout the line, and s110 bounced and never recorded data, resulting in 34 out of 50 sites being useable. Line 4 only had a few noisy sites and 16 out of 19 were used. Line 5a was very noisy throughout the line, 11 out of 16 were kept. Line 5b was much better and 16 out of 21 were kept. Combined Line 5a/b retained 27 out of 37 sites, but most of these had larger error bars than the average site from Line 1.

Inversions were done using Kerry Key's MARE2DEM code, a goal oriented finite element code that uses unstructured grids and adaptive mesh refinement. It employs the Occam inversion algorithm, which produces the smoothest model that fits the data to a specified misfit. The smoothing constraint helps avoid overfitting and the appearance of spurious structure, but it also does not allow for resistivity jumps. Due to its smoothness EM data alone cannot give a precise depth to basement. Instead we chose to arbitrarily assign the "basement" to be the 10 ohm-m contour, which is reasonable because we expect sediments around 1 ohm-m and basement around a couple hundred ohm-m and given the sensitivity of EM and the smoothness of the inversion once the resistivity reaches 10 ohm-m it is unlikely it is sampling many sediments. MT only inversion results for all 5 lines are shown here and a depth to basement is reported, but this is simply the depth to the 10 ohm-m contour for the reasons just described. Vertical profiles of resistivity were also extracted from inversion results and are plotted in Fig. 27. Figure captions will be used for further commentary.

Model fits to the input MT data are plotted along with psuedosections and their residuals. In general, the models fit the data to within the error bars and it is clear from the psuedosections that the model is fitting the smooth background trends in the MT data, even if it misses some of the small scale details. Residuals look speckled, which is good and shows no systematic discrepancies.

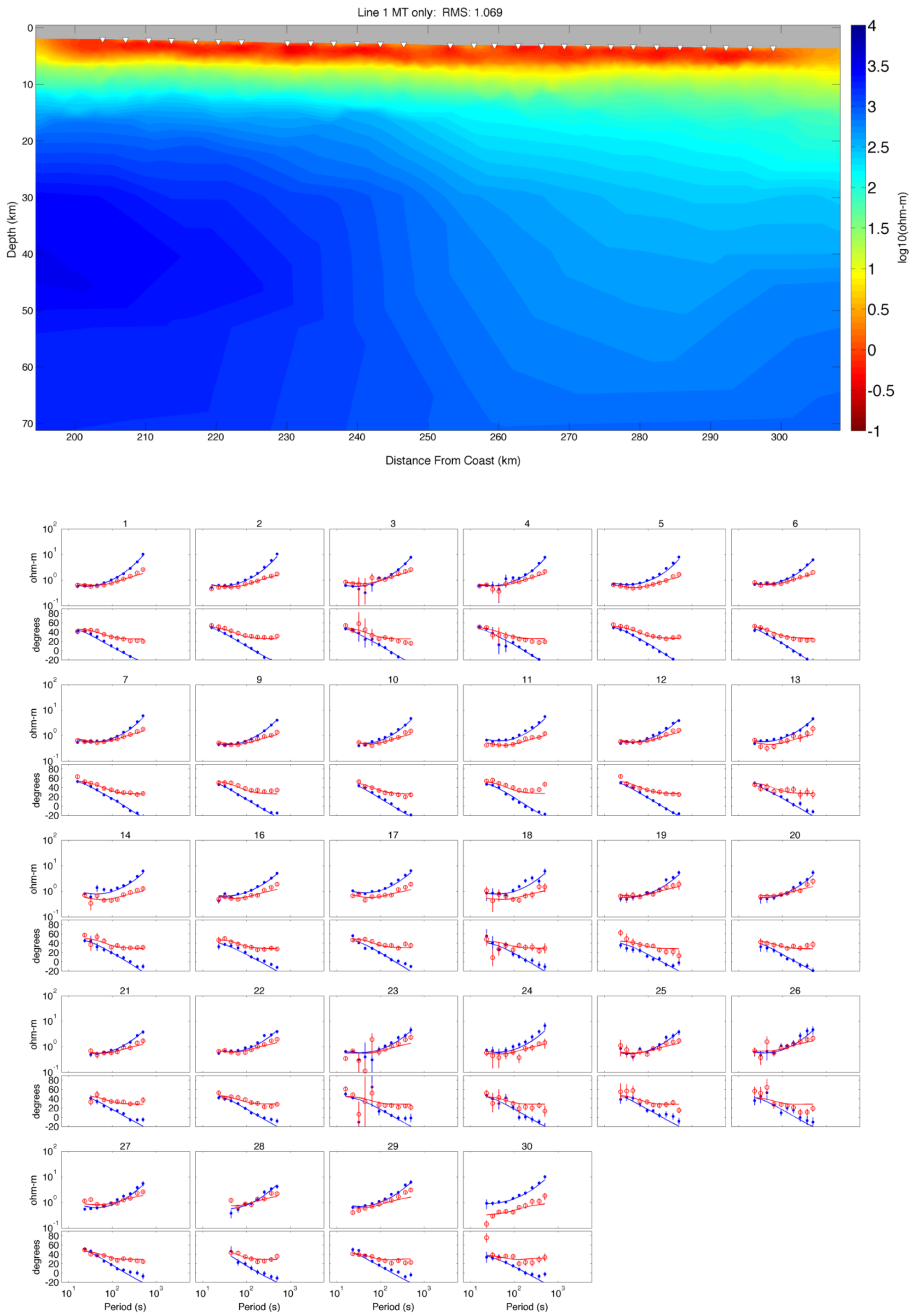


Figure 17: Top: Line 1 MT-only inversion, showing a depth to basement of about 4.4 km. Bottom: MT responses for Line 1 inversion. Line 1 had some very nice data with small error bars and smooth curves. A few sites (i.e. 3 and 23) have increased scatter and uncertainty between 10s and 100s periods, this a result of induced current noise affecting only select frequencies.

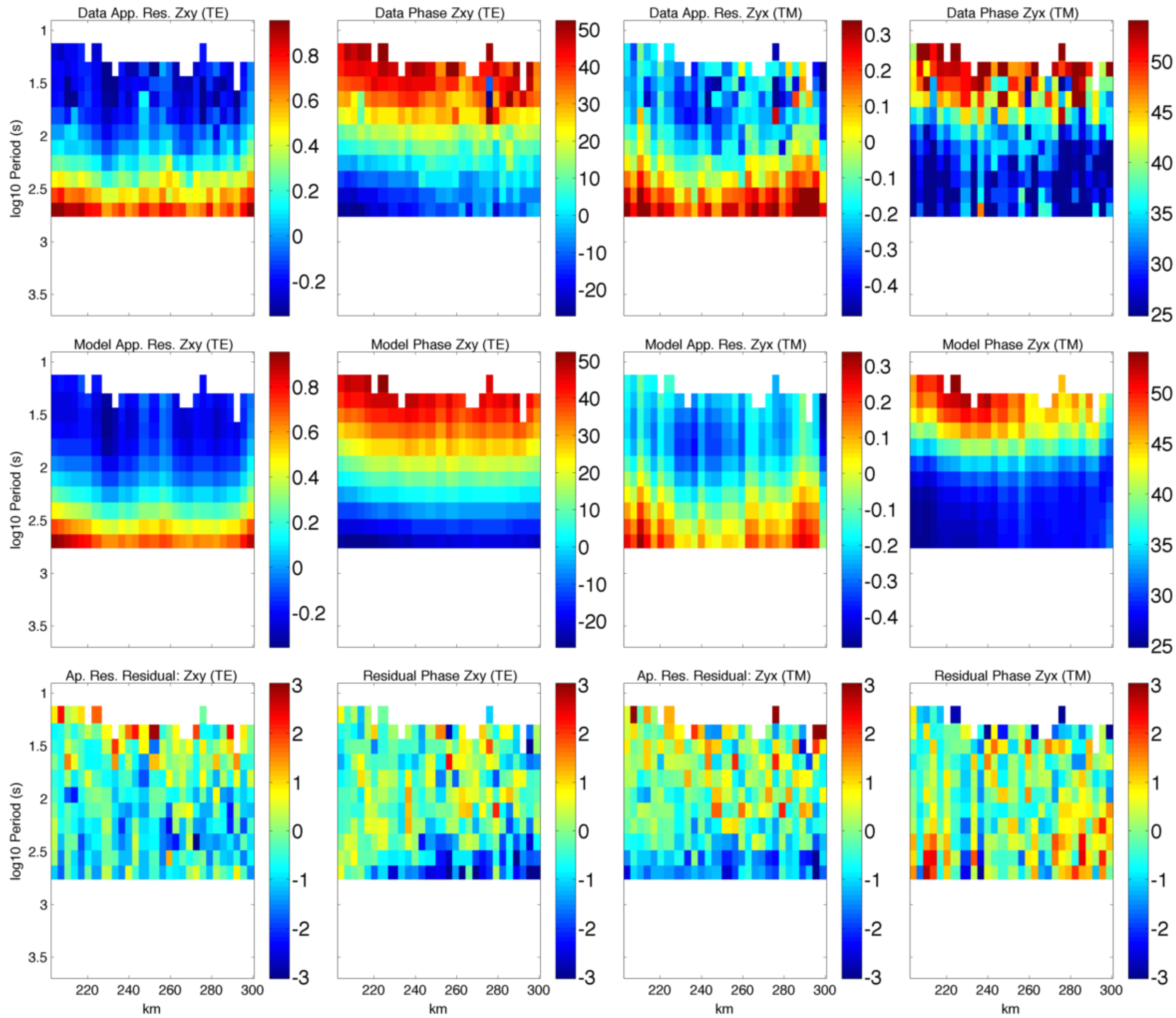


Figure 18: MT psuedosections for Line 1 MT inversion. Residuals mostly scattered, but show that data at long periods is consistently fit less well.

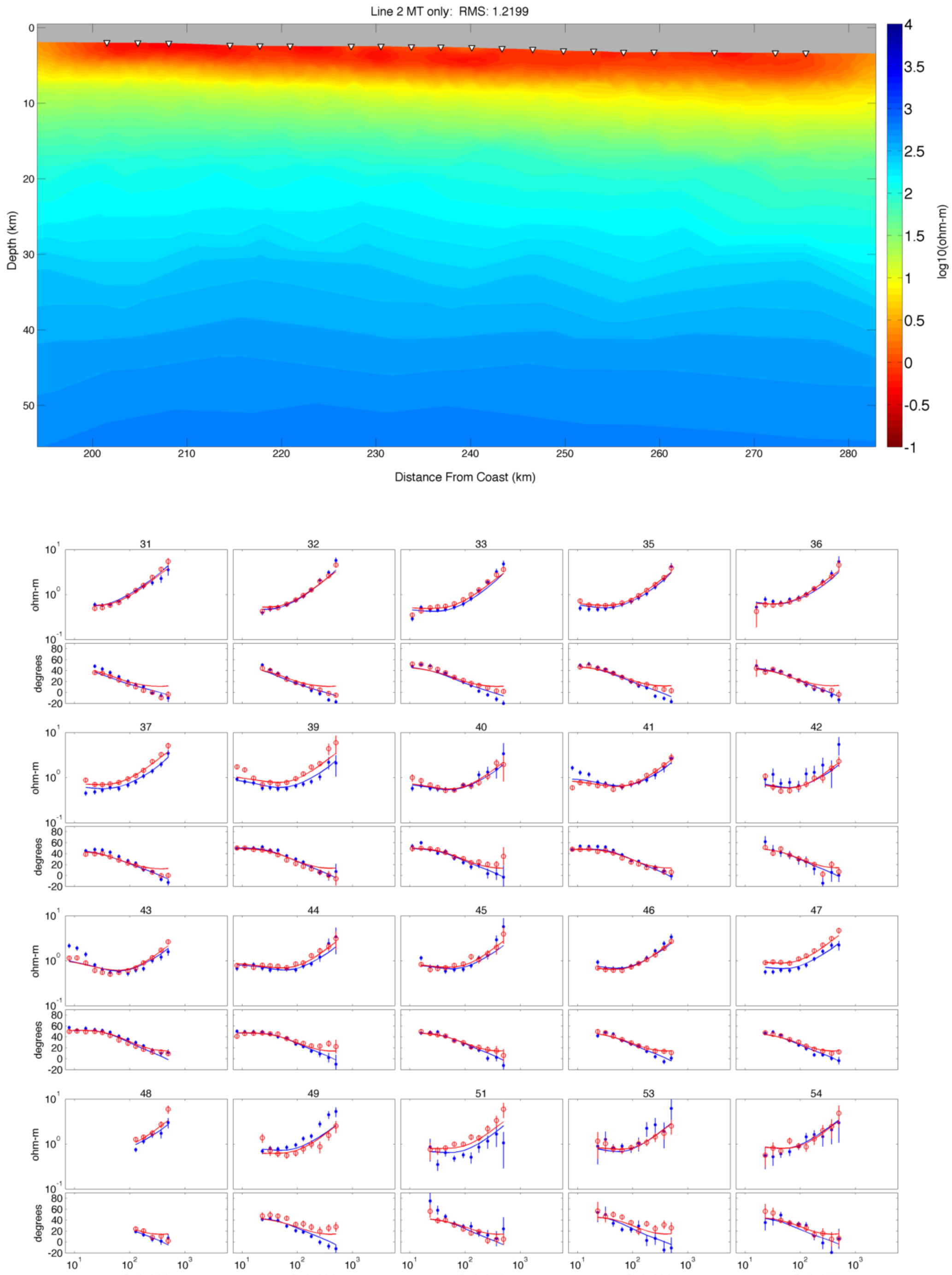


Figure 19: Top: Line 2 MT-only inversions, showing depth to basement of about 6.3 km. Bottom: MT responses for Line 2 inversion. Line 2 has has a mix of very high quality data and data contaminated with current noise, especially the deep water sites.

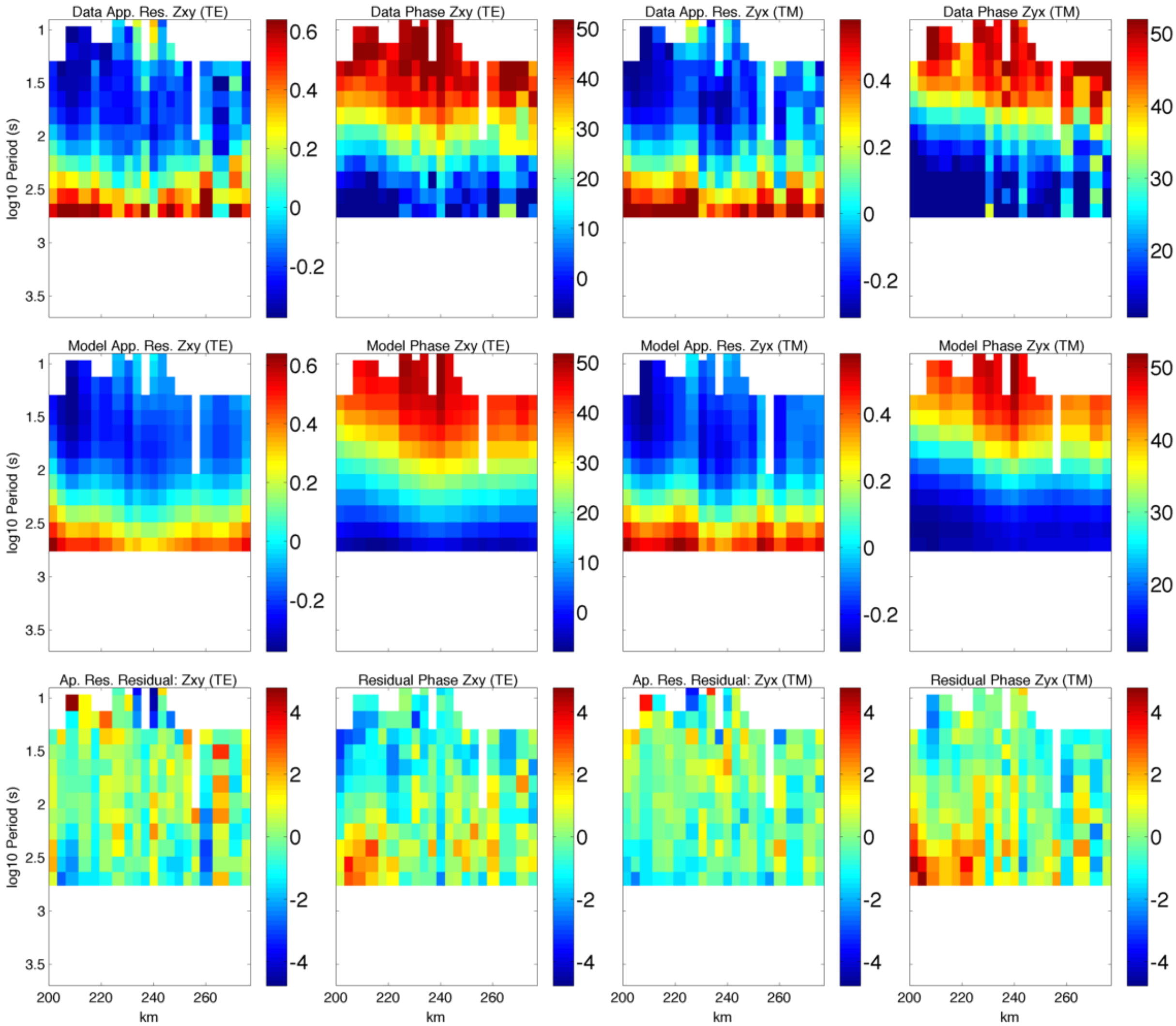


Figure 20: MT psuedosections for Line 2 MT only inversion. Phase from sites in shallow water at long periods, especially in the TM mode, have consistently higher residuals. The responses show that the model predicts higher phases than the data for sites 31-39 at long periods.

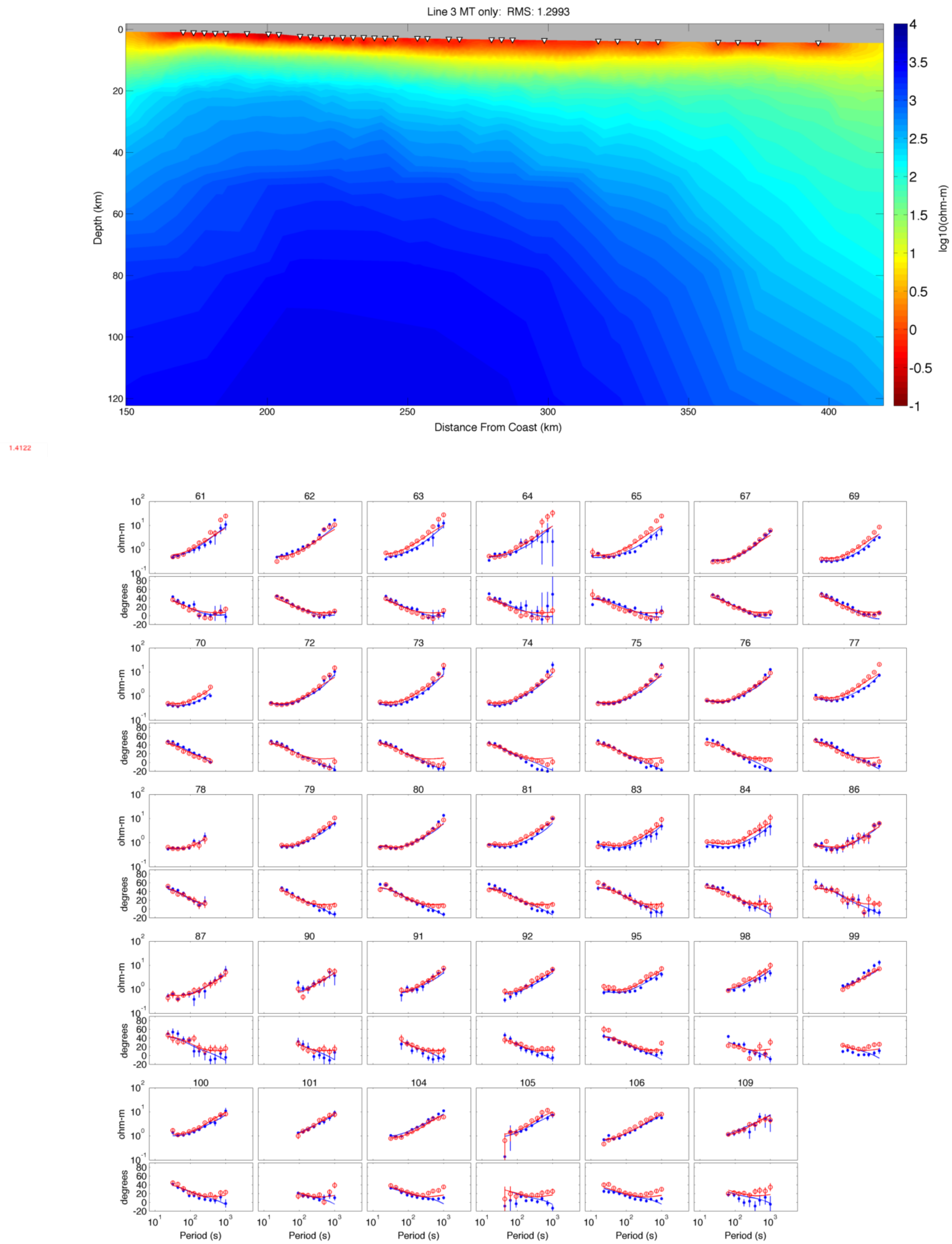


Figure 21: Top: Line 3 MT only inversion, showing depth to basement about 6.2 km. Bottom: MT responses for Line 3 inversion. Line 3 is the longest line that was deployed and has variable data quality.

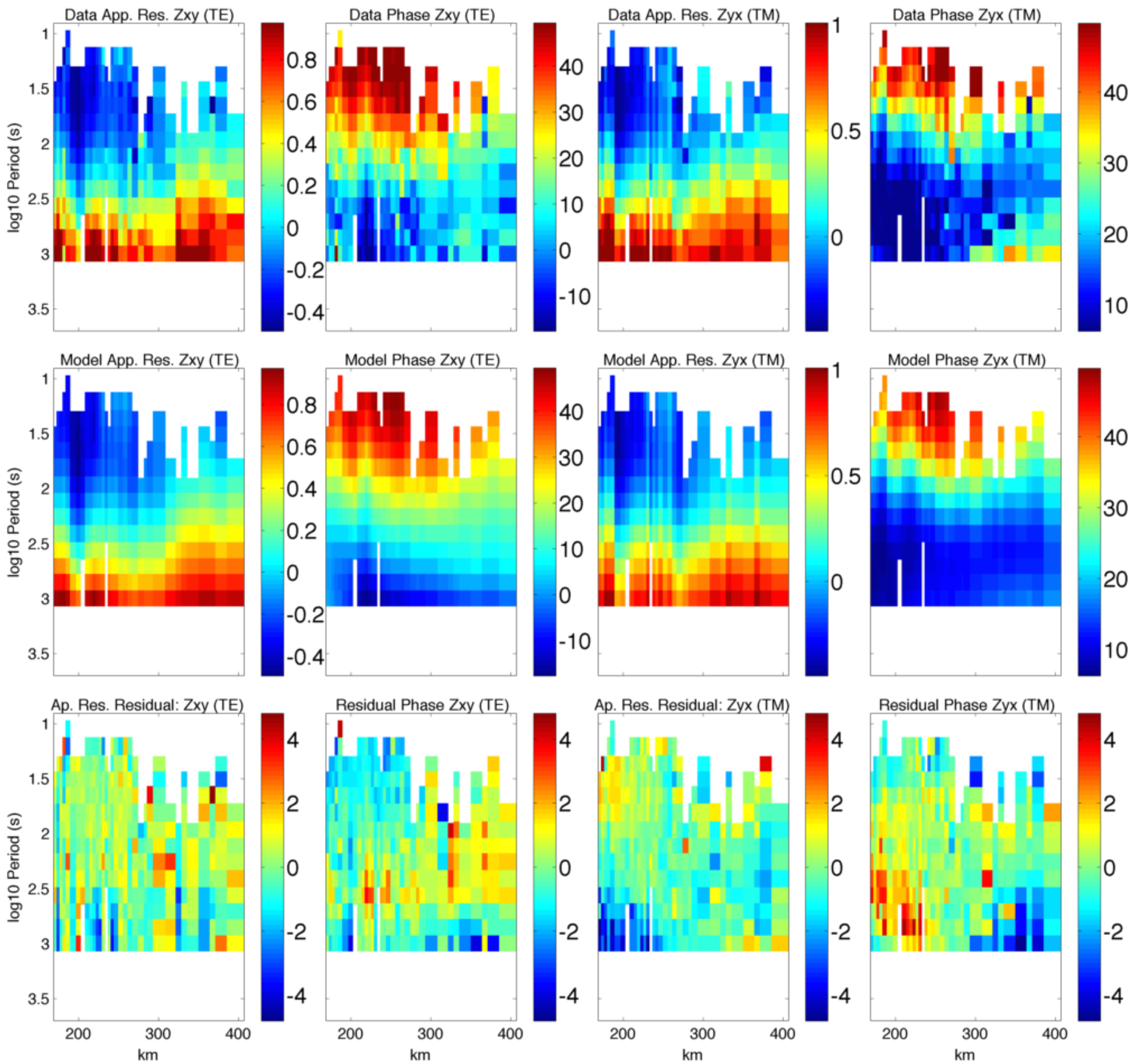


Figure 22: MT psuedosections for Line 3 inversion. Similar to other lines, residual plots show long period TM mode data is less well described by the model.

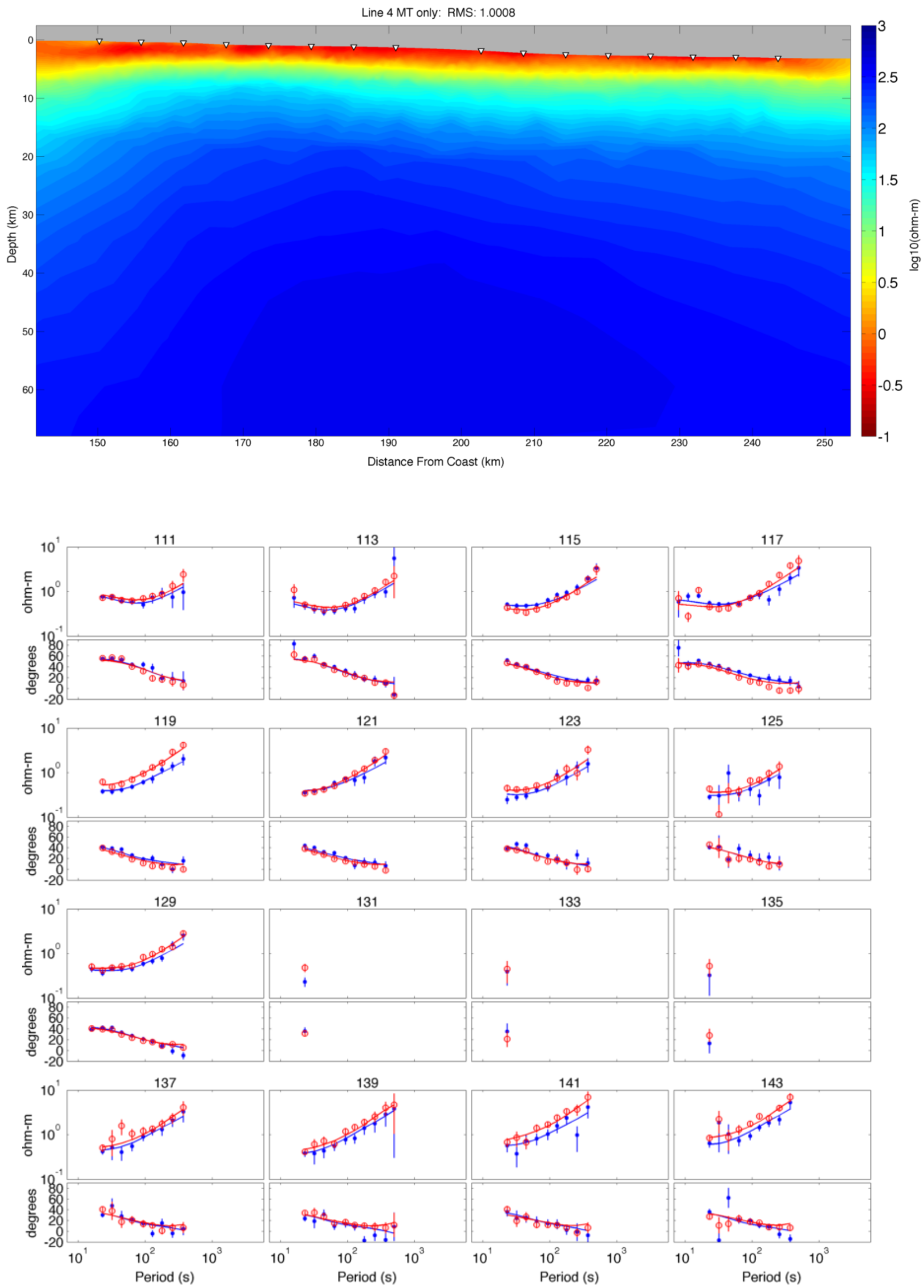


Figure 23: Top: Line 4 MT only inversion, showing depth to basement at about 2.9 km. Bottom: MT response for Line 4 inversion. No psuedosection is available for Line 4 because there are a few sites with only one frequency and more are needed to make the psuedosections.

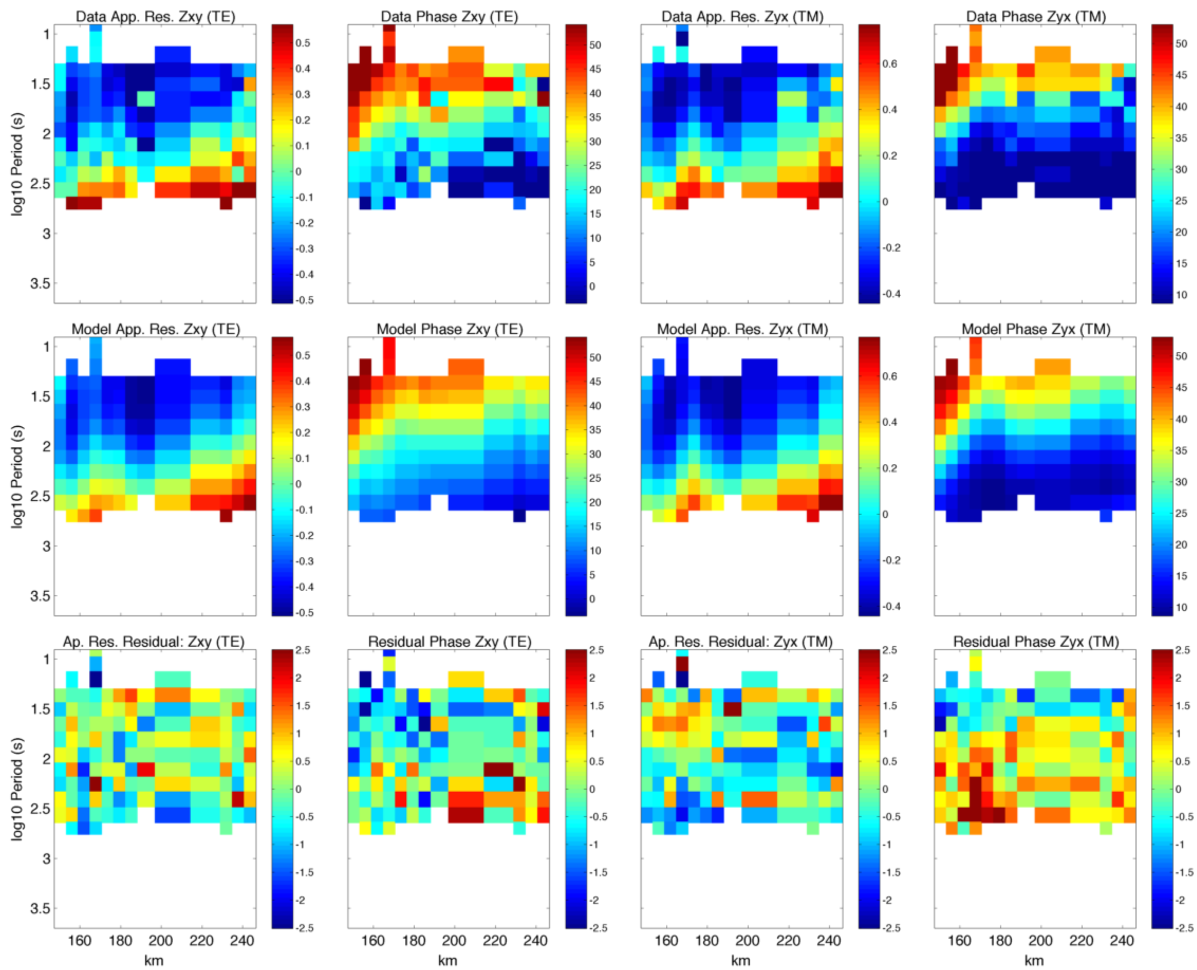


Figure 24: MT psuedosections for Line 4 inversion.

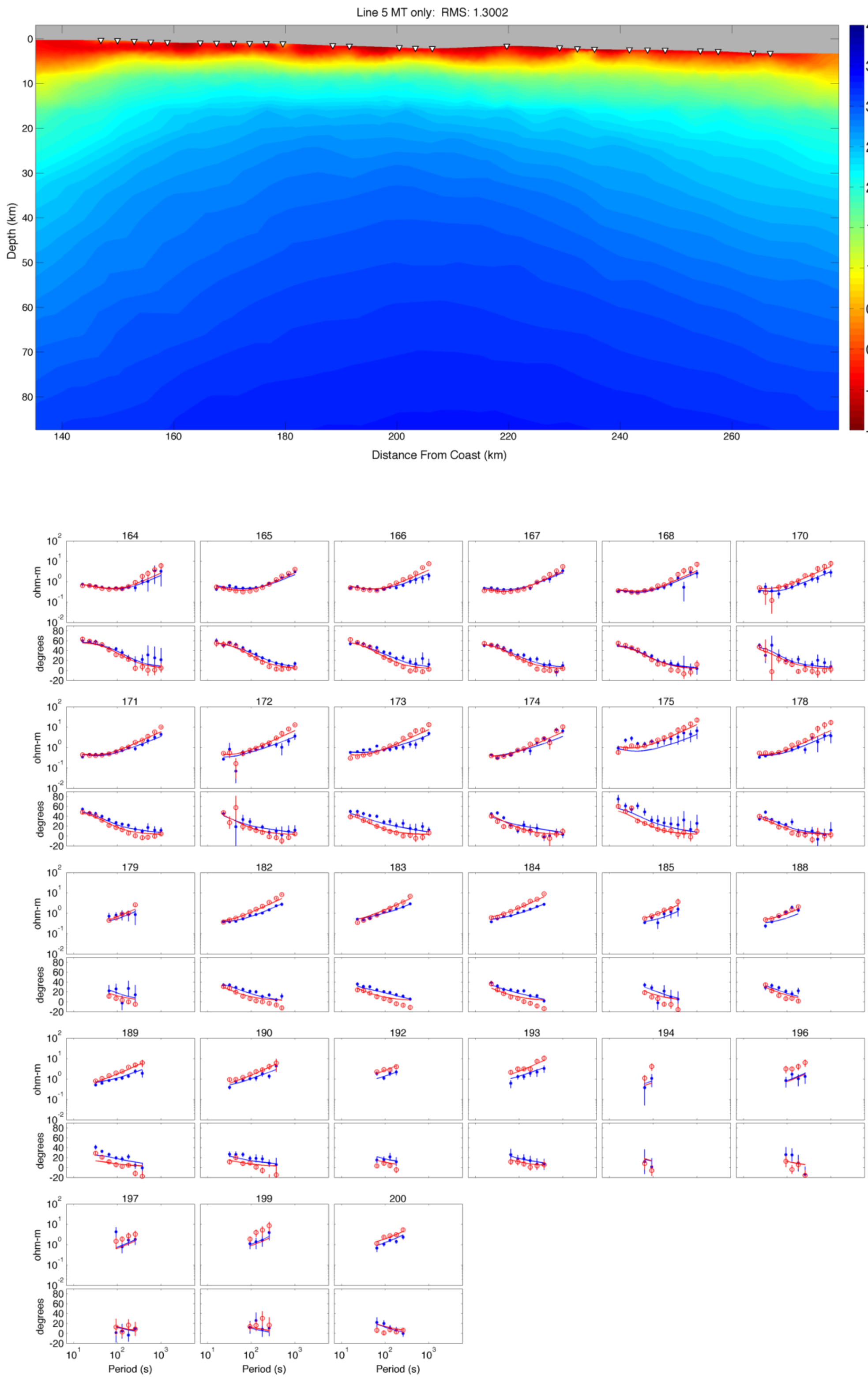


Figure 25: Top: Line 5 MT only inversion, showing depth to basement about 4.4 km Bottom: MT response for Line 5 inversion). Line 5 was noisier than most of the other lines, which can be seen in the size of error bars on the data. Also, many sites from Line 5 had limited useful frequency bands – these were used in the inversion, but only for the

50s – 800s period range, outside of this range the data was too noisy to be useful.

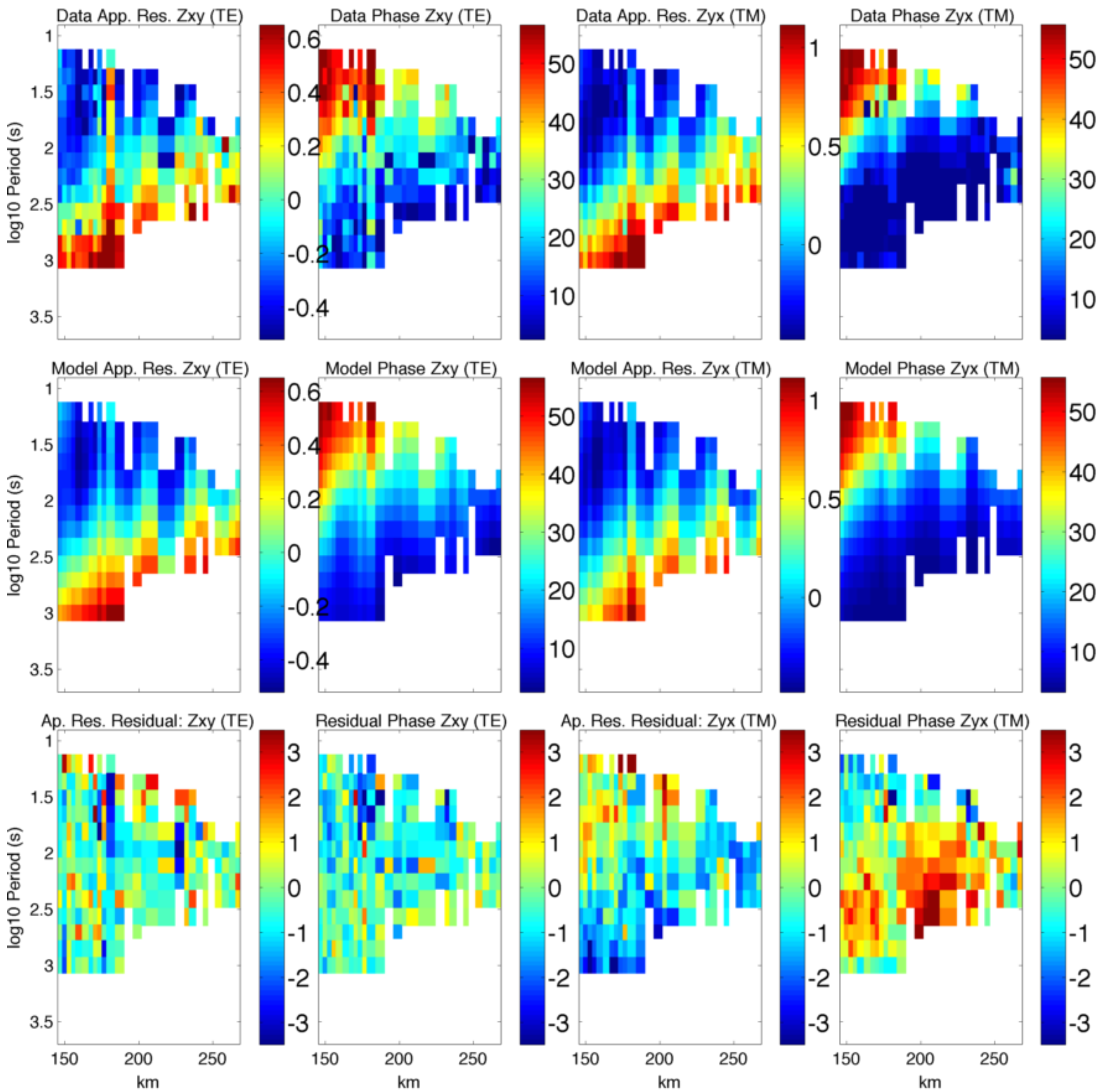


Figure 26: MT psuedosections for Line 5 inversion. Line 5a (the deeper sites) were much noisier than Line 5b, which can easily be seen in the psuedosection plot because deep sites have fewer useable frequencies.

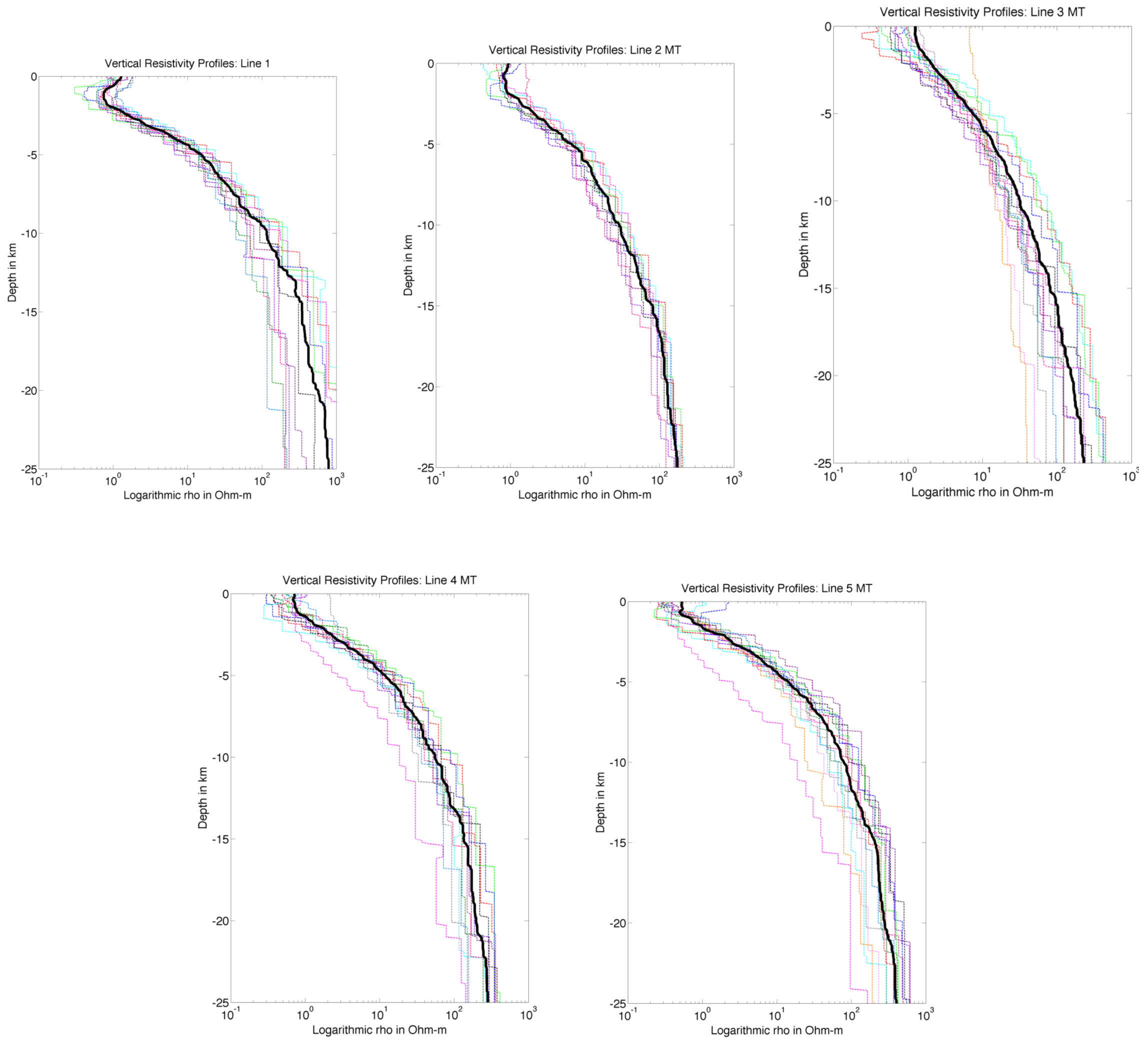


Figure 27: Vertical resistivity profiles extracted from MT inversions. Depth has been corrected for bathymetry, depth = 0 is the seafloor. Colored dotted lines are profiles taken every 5km across the line and the thick black line is the average profile. VertProf

CSEM INVERSIONS

Towed CSEM data were collected over the shallow end of Line 1 and Line 3 and all of Line 5. Lines 1 and 3 were not towed deeper in large part because the M.V. Polarcus Amani was still towing its streamers in that area of the block and it was not feasible to maneuver around her with SUESI in the water. Line 5 was collected later and we were not in the way of the seismic vessel, making it possible to tow the entire length of the line. Data from all lines have noise floors near 10^{-15} V/Am^2 and 10^{-17} T/Am for E and B channels respectively. The currents that had such a large impact on MT data were less of a problem for CSEM, but they did cause occasional bursts of noise that raised the noise floor a couple orders of magnitude. This is easy to cut out of the CSEM data and only results in a loss of data if the burst happens to occur when the transmitter is near a receiver.

The ship was equipped with a USBL, which we intended to use to navigate SUESI's position. We collected USBL data, but after returning to San Diego we realized that the data was not calibrated and have so far been unsuccessful in getting reasonable SUESI positions. During the Line 1 and Line 5 tows we employed a back-up LBL navigation scheme using the acoustic unit on SUESI. SUESI pinged on the instrument she was approaching at one frequency and the instrument behind her at a different frequency. Because we know the positions of the seafloor instruments we can use them to triangulate SUESI's position based on the travel time of the acoustic pulse. Though this method is not very precise, it worked well enough and its results were much more reasonable than the USBL.

All CSEM inversions shown here are preliminary, but show reasonable results. They were also done with MARE2DEM and a 10% error floor, the higher noise floor was chosen because of errors in navigation. Both isotropic and traversely isotropic models (horizontal and vertical resisitivites can differ) were used, but a minimal amount of anisotropy was found. Fits are presented at 0.75 Hz, but this is representative of the other frequencies. See captions for further discussion.

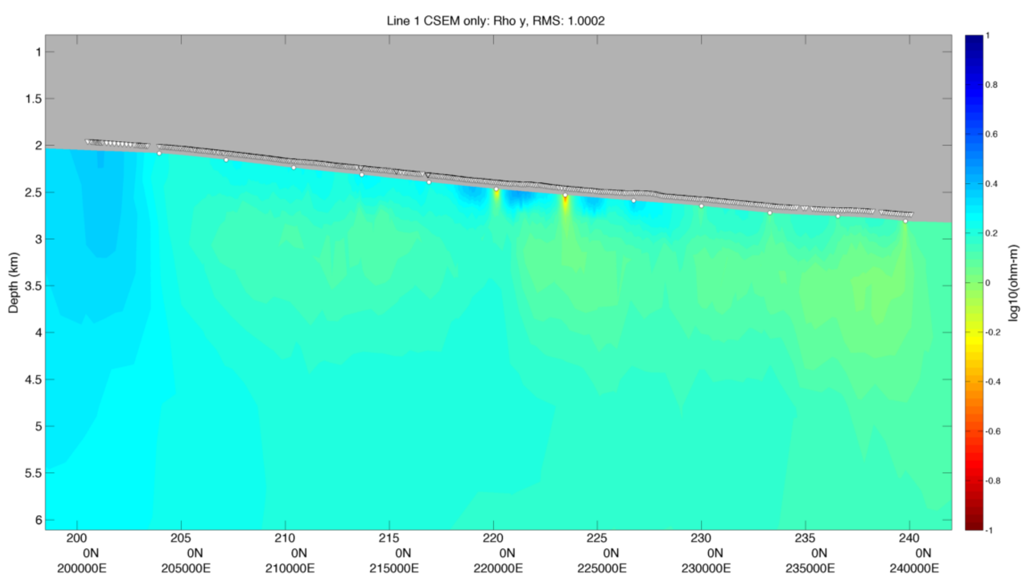


Figure 28: Preliminary CSEM only inversion for Line 1, horizontal resistivity. Basement is too deep to be detected by the CSEM alone, so the inversion shows conductive sediments in a 1 ohm-m half space with some shallow resistors near the surface. Some of these resistors are strongest between sites and are therefore fairly unconstrained. Jointly inverting with Vulcan data will help this issue.

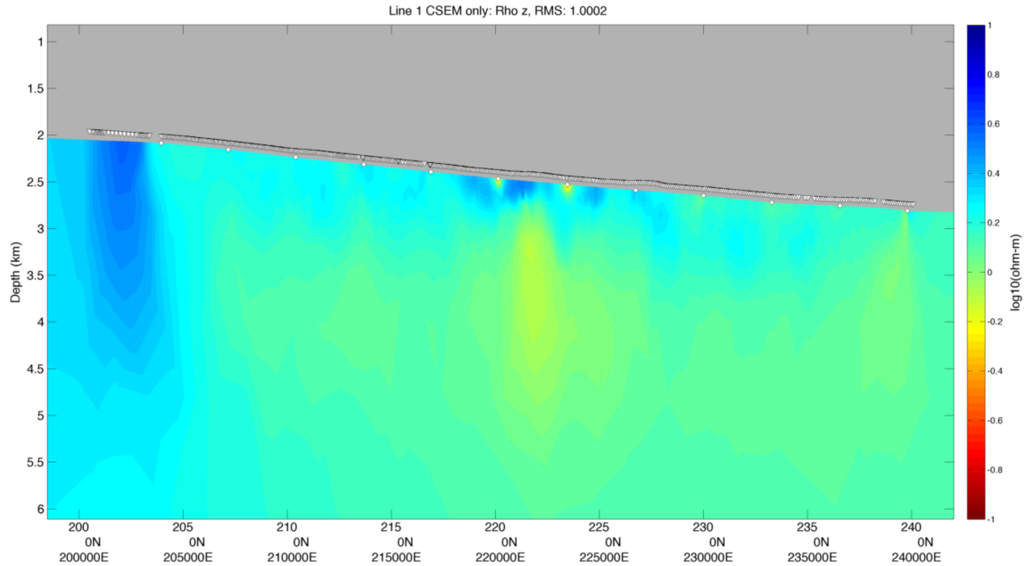


Figure 29: Preliminary CSEM only inversion for Line 1, vertical resistivity. Very similar to horizontal resistivity, but the shallow resistors are more resistive in the vertical direction. The large resistor on the far left is only due to the in-tow of the first site and is probably an artifact of noise.

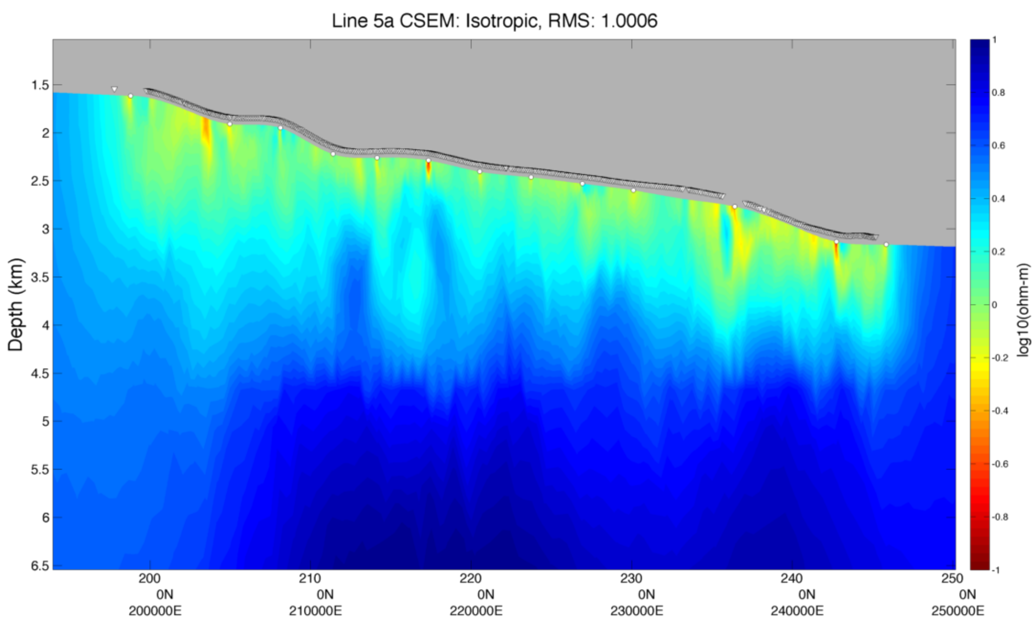


Figure 30: CSEM only inversion for Line 5a, isotropic. Unlike Line 1, the basement is coming in on the Line 5a inversion implying that the depth to basement must be shallower. The anisotropic inversions showed minimal differences.

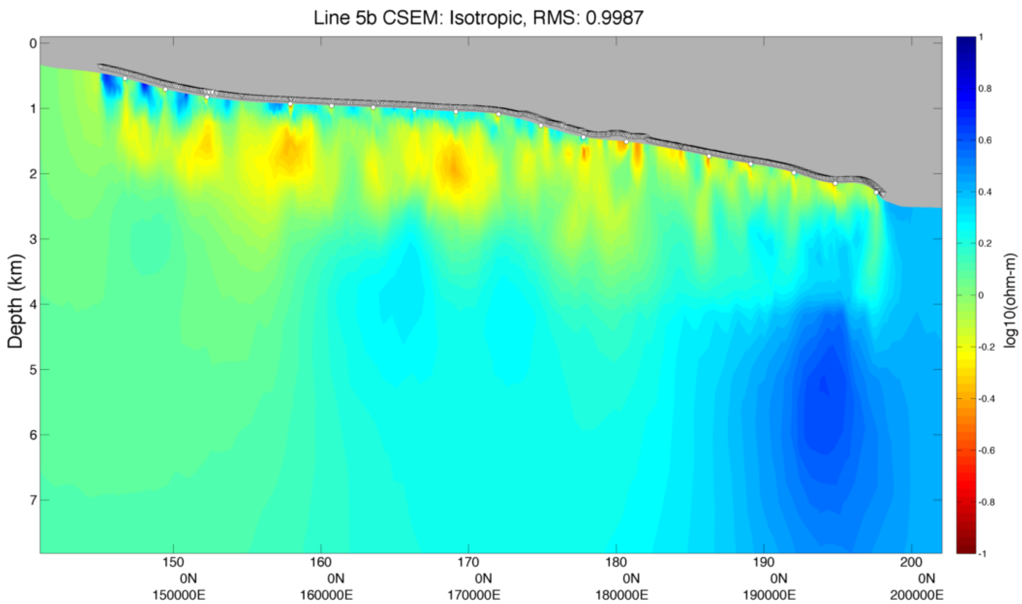


Figure 31: Preliminary CSEM only inversion for Line 5b, isotropic. Conductive sediments very prevalent in this image with some basement bleeding up near the deep end of the line, but the shallow end fades out to a 1 ohm-m half space and does not sense the basement.

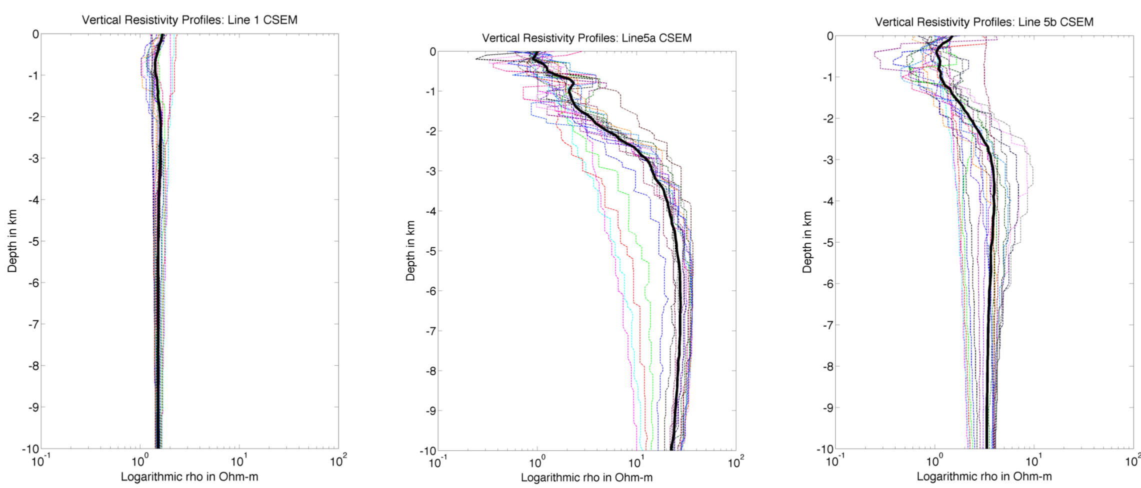


Figure 32: Vertical resistivity profiles extracted from CSEM inversions for Line 1, 5a and 5b. . Depth has been corrected for bathymetry, depth = 0 is the seafloor. Colored dotted lines are profiles taken every 2-5 km down the line and the thick black line is the average profile. All profiles are plotted on the same axes for easy comparison across lines. Line 1 has the least variation in resistivity and is not sensitive to the resistive basement.

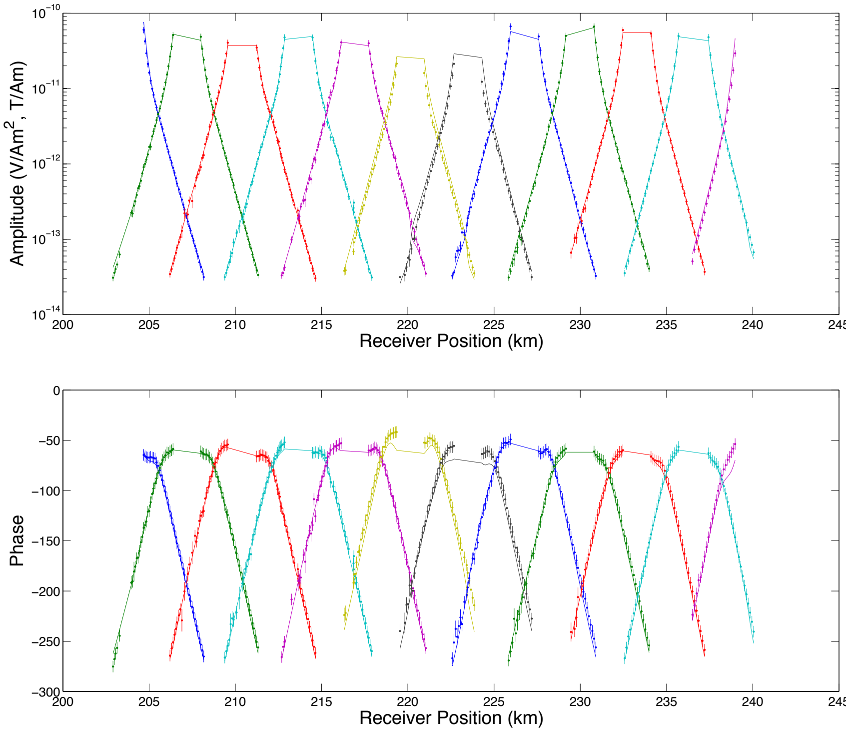


Figure 33. Line 1 CSEM fits at 0.75 Hz.

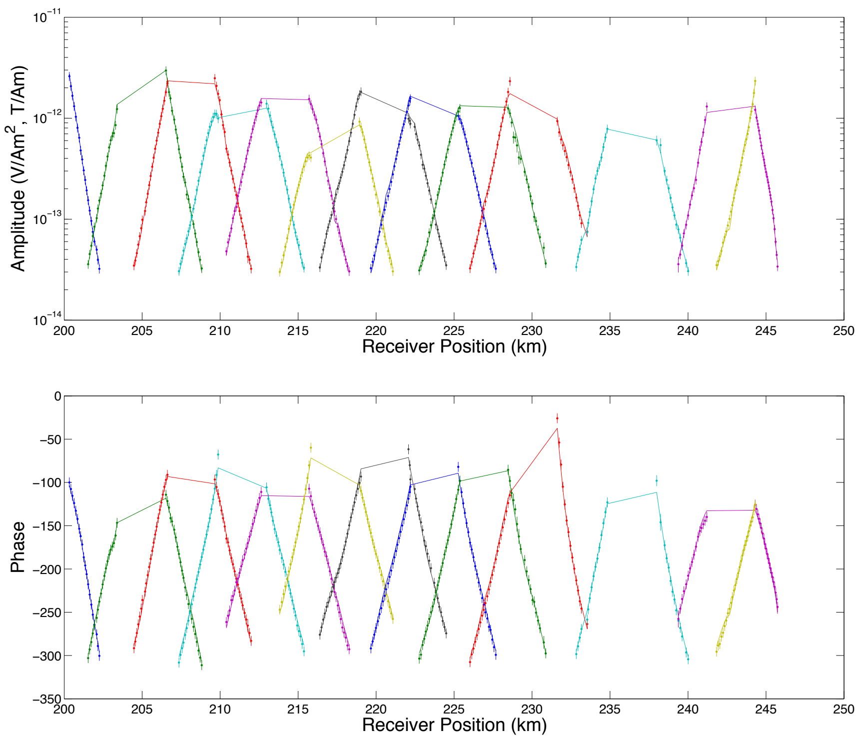


Figure 34. Line 5a CSEM fits at 0.75 Hz.

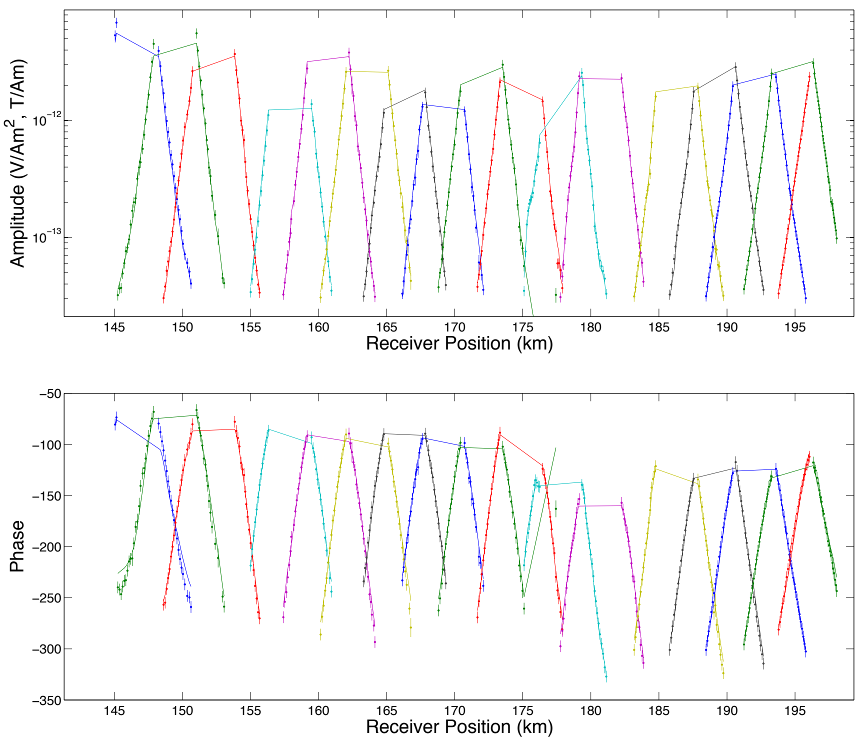


Figure 35. Line 5b CSEM fits at 0.75 Hz.

JOINT MT AND CSEM INVERSION

Joint Inversion of MT and CSEM data has only been completed for Line 1, though we plan on completing one for each towed line. In the CSEM only inversion the basement was too deep to be detected, and so adding MT data increases sensitivity at depth and creates a more complete picture. The images presented here are from an anisotropic inversion where ρ_y and ρ_z are allowed to differ. There is a minimal amount of anisotropy, but the vertical resistivity tends to be larger, as one would expect. There are still a couple features that are likely artifacts of issues in the navigation and we likely will need to remove more of the short range data.

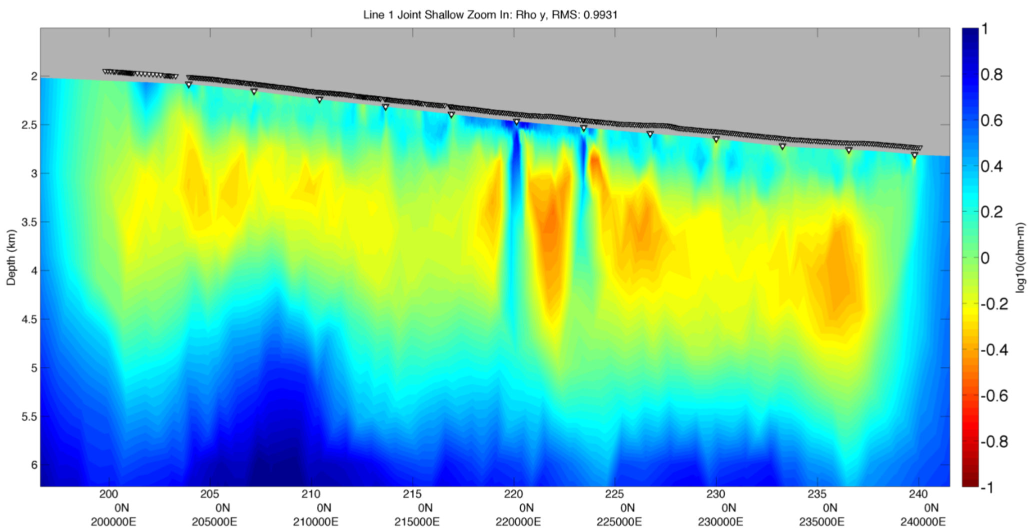


Figure 36: Joint inversion for Line 1, horizontal resistivity, zoomed in to the shallow area

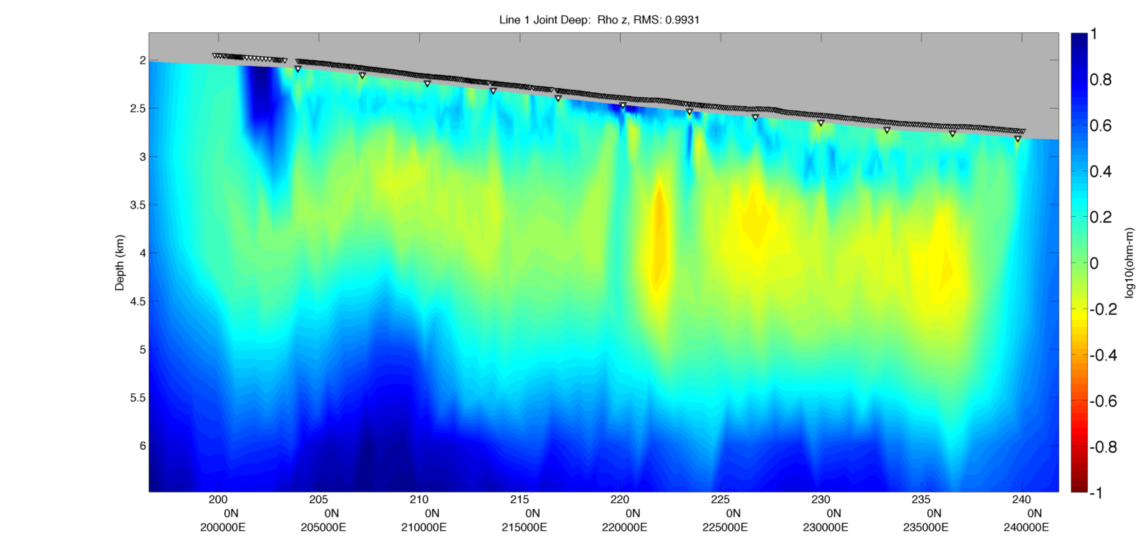
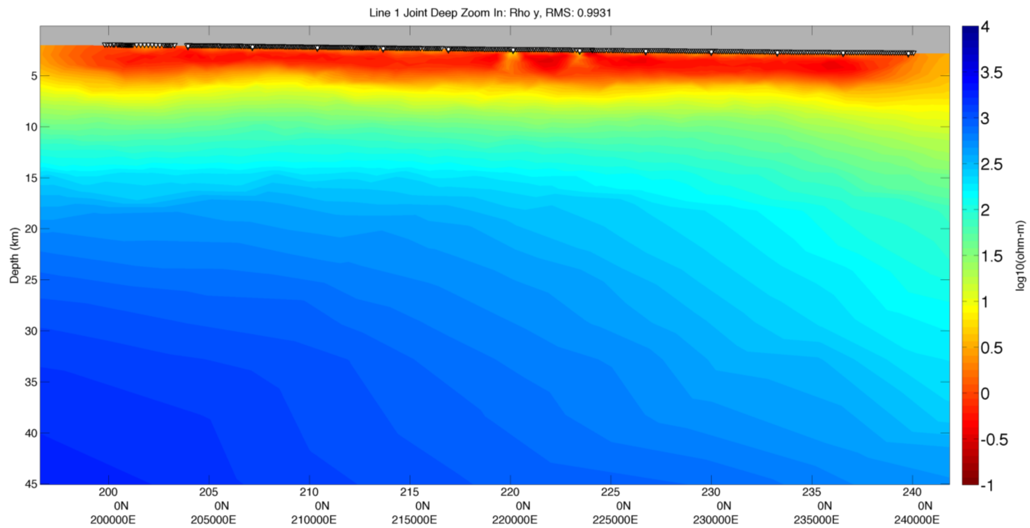


Figure 37: Joint inversion for Line 1, vertical resistivity, zoomed in to the shallow area



0.7234

Figure 38: Joint inversion for Line 1, zoomed out to show deeper structure, on a different color scale than shallow section. Actual plot is horizontal resistivity, but looks no different from the vertical resistivity. Most anisotropy is in the shallow region.

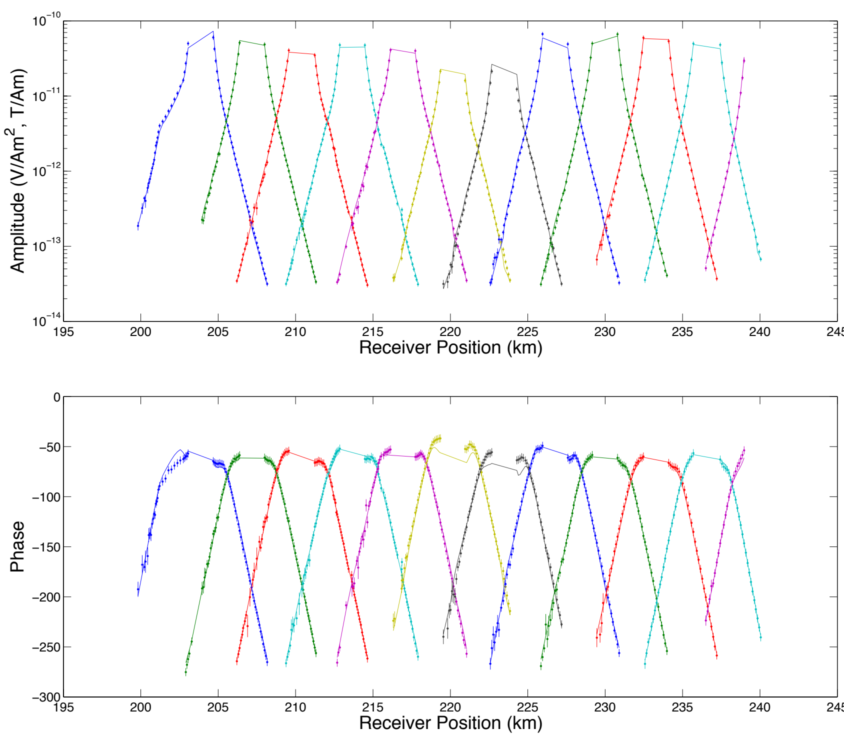


Figure 39. Top: Line 1 CSEM fits at 0.75 Hz for joint CSEM/MT inversion.

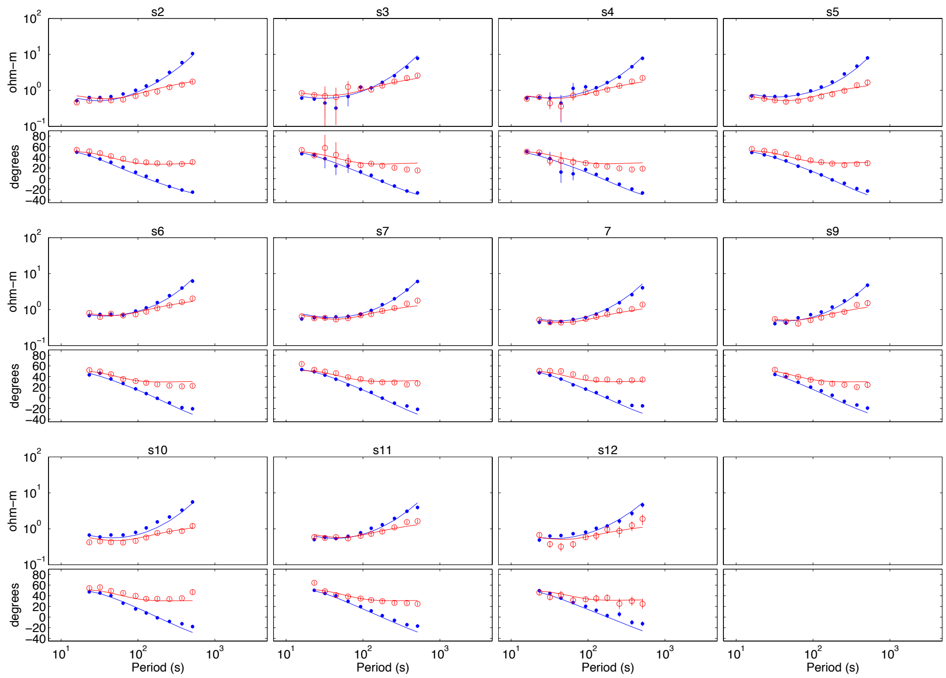


Figure 40. Line 1 MT fits for joint CSEM/MT inversion.

DUESI DATA

Although to some extent the role of the DUESI instruments was usurped by our ability to carry out deep-towed CSEM transmission using SUESI, we did deploy these instruments as a test of their capabilities. Figure 41 shows an inversion of the line 5b DUESI data compared with the section of the line 5b SUESI inversion over the same region. Although there were only two transmitters and three receivers in the DUESI deployment, by transmitting a broadband waveform we had four frequencies to process (0.25, 0.75, 1.75, and 3.25 Hz), two transmission polarizations, two electric field channels and two magnetic field channels collecting both amplitude and phase data. As a result, even after eliminating all data with a poor signal to noise ratio, we had 165 data to invert. The average seafloor resistivity down to a depth of about 1,000 m below mudline is recovered by the DUESI data, and even some of the details, such as the near-seafloor resistor in the center of the profile and the deeper conductor near the deeper end of the line have been recovered.

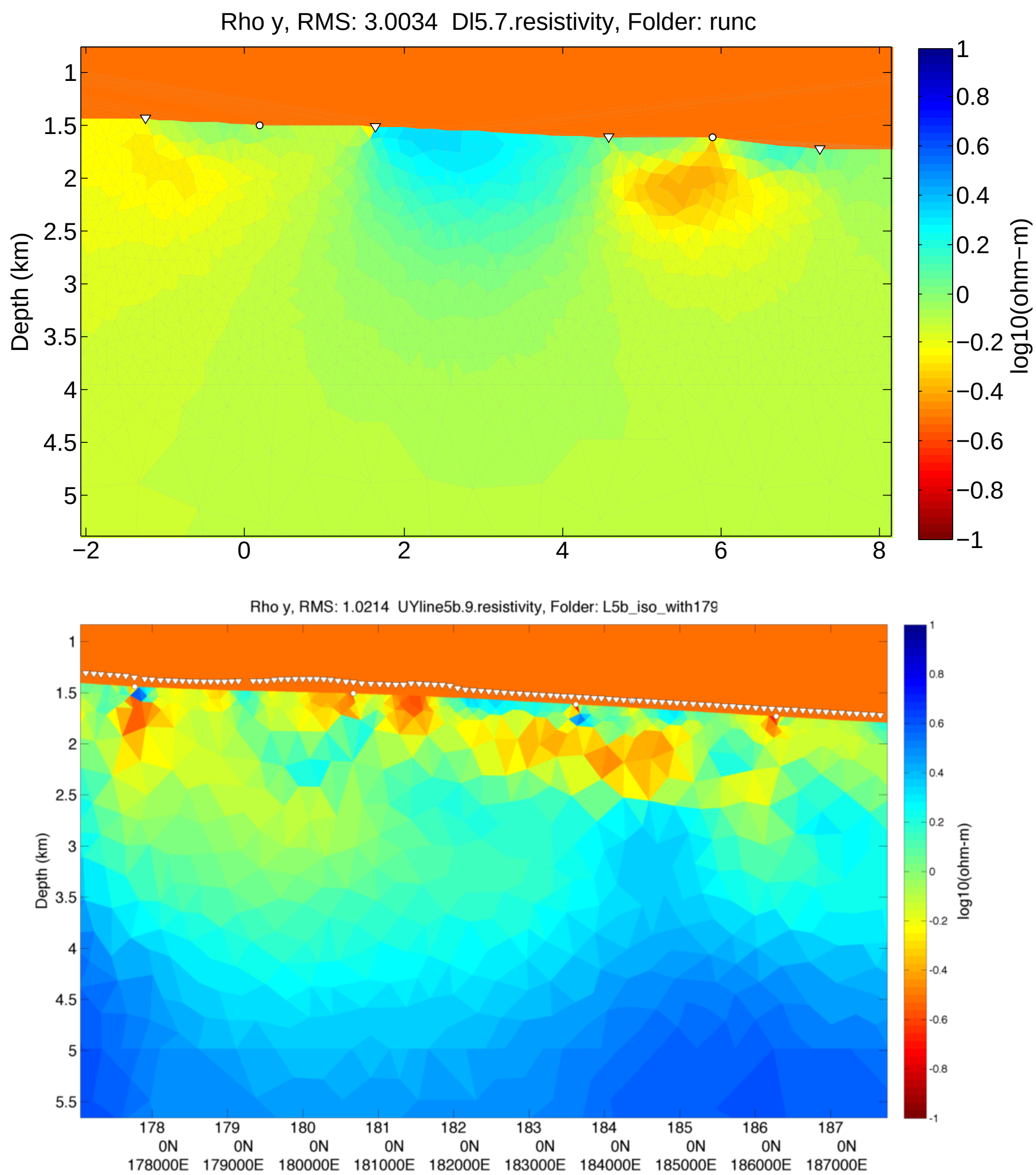


Figure 41. Top: Inversion of DUESI data on line 5b. Four seafloor receivers are located at the triangles, and the DUESI transmitters are located at the two circles. Bottom: Section of the line 5b CSEM inversion plotted on a similar scale.

VULCAN DATA

Vulcan data has been processed and looks good, but with minimal structure. The vulcan data will be instrumental in constraining the shallow regions of the CSEM inversions - both for determining the presence of hydrate and constraining the area between sites where SUESI is too far to reach any seafloor receivers (will confirm or reject the shallow resistors between sites in Line 5b). Inversion of the Vulcan data is ongoing.

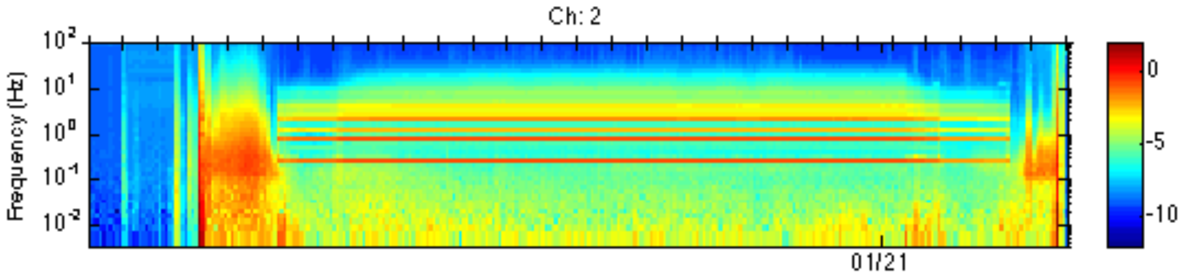


Figure 42: Spectrogram of Vulcan data from tow over Line 1, strips of red are the frequencies transmitted. Data quality looks excellent.

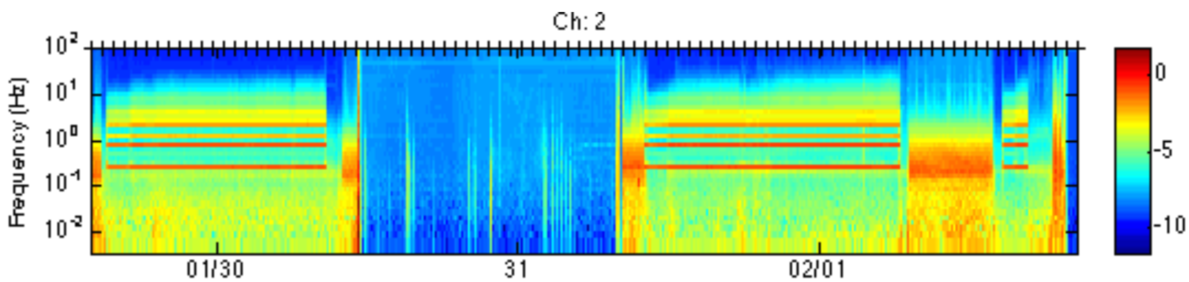


Figure 43: Spectrogram of Vulcan data from tow over Line 5a (first section) and Line 5b (second section). We chose not to stop recording between segments of line 5, the section of white noise is easily cut out before processing. The last bit at the end is when we started to do a cross line tow at the intersection of Lines 5a and 5b, but then the antenna termination failed and we had to stop before completing the cross line tow.

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Constable, S., A. Orange, G.M. Hoversten, and H.F. Morrison, 1998. Marine magnetotellurics for petroleum exploration Part 1. A seafloor instrument system. *Geophysics*, **63**, 816–825.

Constable, S.C., Parker, R.L., and Constable, C.G., 1987. Occam's Inversion: a practical algorithm for generating smooth models from EM sounding data. *Geophysics*, **52**, 289–300.

Egbert, G. D., 1997. Robust multiple-station magnetotelluric data processing. *Geophysical Journal International*, **130**, 475—496.

Myer, D., S. Constable, and K. Key, 2011. Broad-band waveforms and robust processing for marine CSEM surveys. *Geophysical Journal International*, **184**, 689–698.

Appendix A
Daily Log

All times local (UT - 2h).

5th January:

The core of our team is now in Montevideo. Steve met with the agent's rep and the ship's rep this afternoon. We are cautiously optimistic that we'll have port access on the morning of the 7th to load our gear. The plan will be to load on the 7th, finish the tie down on the morning of the 8th and entertain a visit from ANCAP, and sail to station in the afternoon/evening of the 8th.

We have established contact with the seismic operations going on in the area.

6th January:

As predicted, nothing happened on the 6th (holiday).

7th January:

A very large electrical storm blew through today, and seemed to slow down all the port operations. The vessel finally tied up at 19:30 local time and we were promptly bought to the port and admitted aboard. We were met by the medic, who immediately gave us a safety briefing and a walk-through of the vessel. She's been well-used, clearly, but clean and tidy and looks very much fit for purpose. Accommodation is spacious by our standards. The owners have clearly gone out of their way to prepare things for us, and seem very much on board both from a science/operations point of view and from a safety awareness point of view. I have touched base with the Captain and discussed the self-certification process and a general overview of our safety requirements, operations, shift changes, etc. We plan to meet first thing after breakfast to review the OVID and go through the HSE requirements of the contract. We hope to get the certification letter to BG by mid-morning tomorrow our time.

We were discouraged from working at night and so the plan is to start loading tomorrow morning. We are told the containers will show at 7am and we can start loading at 8am. We should have everything aboard by the end of the day, but there may be some tie-down, set-up, and welding to do tomorrow night, which can be done at nearby anchorage if needs be.

Initial impressions of the vessel are good. There's going to be a learning process on both sides, clearly, but there is a clear willingness to communicate, which in my experience is what it is all about.

8th January:

Sat around until about 10:30 am for the containers to show up, but then the loading went fast, and we had all the gear on board by mid-afternoon. The rest of the day was spent tying down, welding down, moving things around, setting up instrument systems. The biggest job for us was getting the SUESI power conditioners through a door that was one inch too small to do things the easy way. The biggest job for the ship was spotting and welding down the two 20' containers of concrete anchors. Welding continues and is expected to be done by 2am. The ship's engineers have been mighty helpful - they really know their stuff.

We discovered half way through the day that nobody knows how to operate the USBL system that they have on board and that I had requested for the SUESI navigation, but Stabbert are sending out a technician tomorrow to sail with us.

Late morning we hosted a visit by Pablo Gristo from ANCAP, Marcelo Figuero from BG Uruguay, and two others. Seemed to go well. We had only just started bringing stuff aboard but there was enough equipment for a reasonable show and tell.

9th January:

Continued setting up the laboratories and deck spaces while tied up in port. Started charging instrument batteries. Hung a block on the A-frame and pulled the 17 mm cable through ready for termination.

14:30 the technician who has been enlisted to help us operate the multibeam bathymetry system and the USBL system arrived.

18:15 pushed off the dock and set sail in calm seas.

Carried out the mechanical termination of the 17 mm cable after dinner.

10th January:

Continued transit to station in the morning and starting up instruments. Light seas and good weather all day. A couple of people are queasy but no bad seasickness.

09:00 load tested the 17 mm cable termination. Tested OK.

12:30 fire and boat drill.

13:00 arrived on station. Carried out tests of USBL system. Tested OK.

Start deploying instruments on Line 3:

15:34 Deployed MT instrument Rosella at site 61
16:45 Deployed MT instrument Rabbit at site 62
17:52 Deployed MT instrument Corella at site 63
19:14 Deployed MT instrument Wallaby at site 64
19:50 Deployed MT instrument Cassowary at site 65
21:22 Deployed DUESI 1 (battery powered deployed transmitter) at site D1
21:57 Deployed MT instrument Goanna at site 66
22:55 Deployed DUESI 2 (battery powered deployed transmitter) at site D2
23:36 Deployed MT instrument Shark at site 67

We also carried out tests of the multi-beam system (working, but lacks some software), and continued to set up the SUESI topside systems. The 12 kHz LBL hull transducer (used to navigate and release instruments) is working very nicely. The ship is acoustically quiet (should be, of course, since it was built as a submarine hunter). Things seem to be going slowly, as we train new people, build instruments up from scratch, train up the bridge and deck crews, etc., but in fact we are not far off our nominal rate of one instrument per hour.

11th January:

Continued deploying instruments on Line 3:

00:33 Deployed DUESI 3 (battery powered deployed transmitter) at site D3
01:28 Deployed MT instrument Bilby at site 68
02:24 Deployed DUESI 4 (battery powered deployed transmitter) at site D4
03:25 Deployed MT instrument Bogong at site 69
03:57 Deployed MT instrument Quindall at site 70
04:40 Deployed MT instrument Cocky at site 71
06:00 Deployed MT instrument Fruitbat at site 72
06:37 Deployed MT instrument Kooka at site 73

07:40 Deployed MT instrument Yabby at site 74
08:20 Deployed MT instrument Marron at site 75
09:01 Deployed MT instrument Currawong at site 76
10:31 Deployed MT instrument Koala at site 77
11:20 Deployed MT instrument Bunyip at site 78
11:52 Deployed MT instrument Joey at site 79
12:58 Deployed MT instrument Skink at site 80

13:15 stood down while Polarcus passed our line

17:03 Deployed MT instrument Camel at site 81
18:32 Deployed MT instrument Ibis at site 82
20:39 Deployed MT instrument Valeport current meter at site 83
21:15 Deployed MT instrument Wombat at site 83
21:52 Deployed MT instrument Stingray at site 84
22:24 Deployed MT instrument Magpie at site 85
23:07 Deployed MT instrument Lerp at site 86
23:57 Deployed MT instrument Quoll at site 87

We also made the electrical termination on the 17 mm deep-tow cable and tested our EM transmitter, SUESI #1. Tested OK. We tested the Benthos LBL acoustic navigation system (used for locating the seafloor receivers). Tested OK. Some time was lost due to problems with a GPS clock and the acoustic hull transducer, but these were resolved. Weather fair but seas are picking up a bit.

Weather fair. No incidents to report.

12th January:

Continued deploying instruments on Line 3:

00:38 Deployed MT instrument Lorikeet at site 88
01:37 Deployed MT instrument Taipan at site 89
02:15 Deployed MT instrument Possum at site 90
02:52 Deployed MT instrument Bower at site 91
03:25 Deployed MT instrument Potoroo at site 92
04:02 Deployed MT instrument Cuscus at site 93
04:55 Deployed MT instrument Lyrebird at site 94
05:41 Deployed MT instrument Echidna at site 95
06:27 Deployed MT instrument Shrike at site 96
08:25 Deployed MT instrument Pelican at site 97
09:15 Deployed MT instrument Glider at site 98
10:36 Deployed MT instrument Devil at site 99
11:30 Deployed MT instrument Jabiru at site 100
12:09 Deployed MT instrument Brolga at site 101
13:02 Deployed MT instrument Mozzie at site 102
13:47 Deployed MT instrument Penguin at site 103
14:34 Deployed MT instrument Spitfire at site 104
15:39 Deployed MT instrument Bullant at site 105
16:30 Deployed MT instrument Quokka at site 106
17:22 Deployed MT instrument Redback at site 107
18:38 Deployed MT instrument Budgie at site 108
19:27 Deployed MT instrument Occie at site 109
20:23 Deployed MT instrument Roo at site 110

These instruments will remain deployed until about the 16th January.

20:40 Transit to site 80 on 3 engines (about 11+ knots with a following current).

There is some uncertainty about how long and how deep the USBL transponder will go, so we plan to start our CSEM tow from the shallow end of this line (line 3). We will carry out some acoustic navigation on sites 61 – 80 as we transit up the line.

Today we also set up the computer systems to be used for the SUESI tow and carried out a second test of SUESI.

Weather remains on the bumpy side of fair. No incidents to report.

13th January:

05:00 Started navigation run for sites 79 - 61 at 5 knots. Prepped SUESI for deployment.

12:00 Finished navigation. Transit to CSEM start position 5 nm beyond site 61.

13:50 Start antenna deployment. Vulcan (towed 3-axis electric field receiver) in water.

14:25 Antenna far-end depth sensor (TET) in water.

15:35 Main antenna made fast to SUESI. Test depth telemetry from Vulcan and TET. Tests OK.

16:07 Near antenna in water. Test transmission at 100 A. Tests OK.

16:30 SUESI in water.

17:22 Start transmission with 0.25 Hz waveformD, 260 A on a 250 m antenna (dipole moment 65 kAm).

17:38 At target flying height of 75 m.

22:45 Passing over site 65.

Weather fair. No incidents to report.

14th January:

Continued CSEM deep-tow of line 3. The USBL transponder's batteries went flat after only 7 hours of operation. The other transponder on the vessel turned out to have been flooded, and we are in the process of getting a rental transponder flown out from Houston. However, we found a compatible underwater pigtail in the lab which allowed us to rig up an external power pack using a spare data logger pressure case and logger batteries. We continued our deep-tow by hanging two of our LBL transponders from the stern of the ship in order to get layback ranges, giving us a modicum of navigation, but aborted the tow when we realized we could rig up the extra batteries for the USBL unit.

We also had some problems with our depth telemetry to the towed electric field receiver, which is not a show-stopper but a nice thing to have. Fortunately, we were able to isolate the part which had failed and we had a spare.

Not a great day, but we were up and running again before midnight.

00:00 Passing over site 66.

00:30 USBL battery went flat. Hung some LBL transponders from the stern quarters to get layback ranges using

SUESI's Benthos LBL ranging system.

01:22 Passing over site 67.
02:45 Passing over site 68.
04:12 Passing over site 69.
05:38 Passing over site 70.
06:56 Passing over site 71.
08:25 Passing over site 72.

08:38 SUESI at 2,000 m depth. LBL navigation weak. Recovering SUESI.

10:08 Stopped transmission as a routine matter, which immediately caused the depth telemetry from the towed receiver to be corrupted.

11:30 SUESI aboard. Diagnosed depth telemetry problem to a malfunctioning RS422/232 converter on SUESI. Swapped in the unit from SUESI #2. Rigged an external power pack for the USBL transponder, using a spare logger pressure case and 45 AH worth of NiMH logger batteries. Recovered SUESI's antenna/towed receiver array in order to adjust buoyancy and allow faster transit to re-start this line.

15:30 At site 77, turned to go back up the line to site 63 for re-deployment.

22:15 Turning back onto line heading south to re-start tow.

23:45 SUESI back in water at 36° 23.76 53° 09.65 (between sites 64 and 65). All systems working OK.

15th January:

Continuing CSEM deep-tow of line 3. The external battery bottle worked really well for the USBL transponder, but we lost good fixes at a slant range of about 2,000 m, or around site 70. We relied on our LBL transponders hung over the stern for layback estimates, but these ranges started to get sparse at about 3,750 m. At site 79 we tried something new: ranging on the seafloor receivers from SUESI. I had tried this some years ago but it didn't work. However, it is working superbly this time. During the in-tow and out-tow we are getting the layback of SUESI (equivalently, inline position), and during the CPA (closest point of approach) of the receiver we are getting the crossline set. Along with the depth sensor, this provides a complete navigation solution that is independent of water depth. Our plan is to continue this line until we run out of cable (the Chief and I have agreed to leave 1.5 wraps on the drum). We have about 5,000 m cable, so this will be at a water depth of about 3,000 m, or site 85.

01:25 SUESI at 75 m flying altitude.

02:40 Passing over site 66.
03:42 Passing over site 67.
05:13 Passing over site 68.
06:45 Passing over site 69.
08:07 Passing over site 70.
09:16 Passing over site 71.
10:35 Passing over site 72.
12:05 Passing over site 73.
13:28 Passing over site 74.
14:50 Passing over site 75.
16:15 Passing over site 76.
17:28 Passing over site 77.
18:52 Passing over site 78.
20:15 Passing over site 79.

21:40 Passing over site 80.
23:10 Passing over site 81.

Weather excellent. No incidents to report.

16th January:

Continuing CSEM deep-tow of line 3. Had to turn off the line to avoid the seismic vessel Polarcus, and then when we were back on line we discovered a floating instrument. This instrument (Roo) had been deployed at site 110 and at the time a glitch in the acoustic test was noted, although the instrument appeared OK after repeated tests and we decided to deploy it. Clearly a mistake, but we got lucky with its drift direction. We were very low on wire anyway, so we finished the CSEM line at that point.

When we went to bring in the SUESI antenna our spooling winch refused to operate. We hauled the antenna in by hand with the assistance of a crane, while the Chief Engineer worked on our winch. We chased down Roo and released it, by which time the Chief had our winch working again. We started routine releases of line 3 instruments in order to move them to line 1, hopefully getting a CSEM run in on it before the Polarcus returns for its trip to port.

Vulcan (towed fixed-offset receiver) data look excellent. Seafloor instrument data show some evidence of motional noise but should easily be processable for MT, and the CSEM signal is clear.

01:34 Passing over site 82.
02:55 Hauling in on winch and turning to avoid Polarcus
05:00 Begin turning back onto line.
06:03 Back on line, SUESI at 2,500 m depth.
06:37 Strayline system announces instrument Roo is on the surface
07:11 SUESI being hauled in for release
10:00 SUESI landed on deck. Antenna winch does not work! Pull antenna in by hand.
12:30 Antenna and Vulcan released. Hunting for roo.
14:00 Recovered Roo. Transit to site 61 for routine releases.

18:38 Rosella site 61 released
19:10 Rabbit site 62 released
20:51 Corella site 63 released
21:25 Wallaby site 64 released
23:34 Cassowary site 65 released

Weather fair. Incidents only as above (premature instrument release, temporary failure of spooling winch).

17th January:

Continued releasing instruments from line 3 in order to re-deploy on line 1.

00:22 DUESI 1 at site D1 released
00:32 Goanna site 66 released
03:29 DUESI 2 at site D2 released
04:06 Shark at site 67 released
06:16 DUESI 3 at site D3 released
06:25 Bilby at site 68 released
06:56 DUESI 4 at site D4 released
09:14 Bogong at site 69 released
09:46 Quindal at site 70 released
12:15 Cocky at site 71 released

12:53 Fruitbat at site 72 released
13:28 Kookaburra at site 73 released
16:28 Yabby at site 74 released
17:01 Marron at site 75 released
17:34 Currawong at site 76 released

20:20 Currawong on deck, transit to site 1 for deployments.

Weather excellent. No incidents to report.

18th January:

Deploying instruments on line 1:

01:10 deploy Currawong on site 1
01:58 deploy Marron on site 2
02:29 deploy Yabby on site 3
03:04 deploy Kookaburra on site 4
03:38 deploy Fruitbat on site 5
04:12 deploy Cocky on site 6
04:43 deploy Quindal on site 7
05:13 deploy Bogong on site 8
05: 38 deploy Bilby on site 9
06:00 deploy Shark on site 10
06:25 deploy Goanna on site 11
07:19 deploy Cassowary on site 12
07:43 deploy Wallaby on site 13
08:12 deploy Corella on site 14
08:43 deploy Rabbit on site 15
09:13 deploy Rosella on site 16
09:39 deploy Roo on site 17

Continued release of instruments on line 3:

13:54 released Koala site 77
14:27 released Bunyip site 78
15:13 released Joey site 79
15:42 released Skink site 80
19:03 released Camel site 81
19:42 released Ibis site 82
20:18 released current meter at site 83
20:43 released Stingray site 84
21:11 released Wombat site 83

Weather excellent. Incidents to report: vessel lost power for about 30 minutes at 22:00 because watch over-loaded the generators (the vessel has diesel-electric propulsion). Only two engines were running at the time – requested that we run three engines at all time from now on to prevent reoccurrence.

19th January:

00:40 released Magpie site 85
01:02 released Lerp site 86
01:25 released Quoll site 87

01:52 released Lorikeet site 88
07:30 released Taipan site 89
08:03 released Possum site 90
08:28 released Bowerbird site 91
09:01 released Potoroo site 92

12:30 Fire and boat drill. CPR instruction from medic.

15:12 deploy Potoroo site 30
15:34 deploy current meter at site 29.5
16:03 deploy Bowerbird site 29
16:32 deploy Possum site 28
16:59 deploy Taipan site 27
17:43 deploy Lorikeet site 26
18:34 deploy Quoll site 25
19:04 deploy Lerp site 24
19:32 deploy Magpie site 23
20:03 deploy Stingray site 22
20:31 deploy Wombat site 21
20:58 deploy Ibis site 20
21:21 deploy Camel site 19
21:46 deploy Skink site 18

Transit to site 1 to meet with the supply vessel that is bringing new USBL transponders.

Seas choppy with 15–20 knot winds. No incidents to report.

20th January:

02:00 Pick up transponders and stores from supply vessel. Prepare to deploy SUESI on line 1.

04:30 Ready to deploy SUESI.

05:50 Antennas in - transmission test of SUESI OK.

06:20 SUESI in water, paying out to depth

07:55 Ship passes site 1

08:12 SUESI at 75 m altitude, transmitting.

09:13 Ship passes site 2
10:25 Ship passes site 3
11:37 Ship passes site 4
12:56 Ship passes site 5
14:13 Ship passes site 6
15:17 Ship passes site 7
16:25 Ship passes site 8
17:28 Ship passes site 9
18:32 Ship passes site 10
19:33 Ship passes site 11
20:28 Ship passes site 12
21:25 Ship passes site 13

22:00 Polarcus requests that we turn to the NW. This is impossible, but we did it anyway. Recovering SUESI.

Seas choppy with 15–20 knot winds. No incidents to report.

21th January:

00:00 Continue to release SUESI. Transit to site 93 for last line 3 releases.

06:57 release Cuscus at site 93
07:32 release Lyrebird at site 94
08:07 release Echidna at site 95
08:50 release Shrike at site 96
13:27 release Pelican at site 97
14:05 release Glider at site 98
14:45 release Devil at site 99
15:24 release Jabiru at site 100
20:05 release Brolga at site 101
20:42 release Mozzie at site 102
21:18 release Penguin at site 103
22:11 release Spitfire at site 104

These releases are in approximately 4,000 m water, and so are taking a little longer than average. Moderately rough weather is not helping, and we stood down for an hour because of lighting in the vicinity.

Seas moderately rough with variable 18–30 knot winds. No incidents to report.

22nd January:

03:25 release Bullant at site 105
04:04 release Quokka at site 106
04:30 release Redback at site 107
05:13 release Budgie at site 108
05:52 release Occie at site 109

10:10 transit to site 60 for deployments on line 2

16:41 deploy Koala on site 60
17:05 deploy Bunyip on site 59
17:27 deploy Joey on site 58
17:52 deploy Occie on site 57
18:31 deploy Budgie on site 56
18:52 deploy Redback on site 55
19:18 deploy Quokka on site 54
19:41 deploy Bullant on site 53
20:09 deploy Spitfire on site 52
20:30 deploy Penguin on site 51
21:02 deploy Mozzie on site 50
21:23 deploy Brolga on site 49
21:44 deploy Jabiru on site 48
22:15 deploy Devil on site 47
22:38 deploy Glider on site 46
23:21 deploy Brumby on site 45
23:42 deploy Shrike on site 44

Transit to site 10 for line 1 releases.

Seas relatively calm with variable 10–20 knot winds. No incidents to report.

23rd January:

00:07 deploy Lyrebird on site 43
00:29 deploy Cuscus on site 42

00:30 transit to site 10 for releases

03:13 release Shark at site 10
03:46 release Bilby at site 9
04:15 release Bogong at site 8
04:45 release Quindal at site 7
05:12 release Cocky at site 6

stand down for lightning

10:10 release Fruitbat at site 5
10:40 release Kookaburra at site 4
11:10 release Yabby at site 3
11:38 release Marron at site 2
12:04 release Currawong at site 1.

transit to site 31 for deployments

18:17 deploy Currawong on site 31
18:45 deploy Marron on site 32
19:10 deploy Yabby on site 33
skipping site 34 because Kookaburra's clock has gone bad
19:42 deploy Fruitbat on site 35
20:54 deploy Cocky on site 36
21:19 deploy Quindal on site 37
21:45 deploy Bogong on site 38
22:07 deploy Bilbly on site 39
22:29 deploy Shark on site 40
22:57 deploy Pelican on site 41

Transit to site 11 for releases.

Seas relatively calm with variable 10–20 knot winds. No incidents to report.

24th January:

Releasing instruments from line 1:

01:27 release Goanna from site 11
02:00 release Cassowary from site 12
02:30 release Wallaby from site 13
03:17 release Corella from site 14

stand down for lightning and (then) repair of deck crane

07:52 release Rabbit from site 15
08:16 release Rosella from site 16
08:37 release Roo from site 17
08:55 release Skinks from site 18
12:29 release Camel from site 19
12:48 release Ibis from site 20
13:07 release Wombat from site 21
13:27 release Stingray from site 22

17:00 standing down for bad weather.

Seas relatively calm with variable 10–18 knot winds building to 4–5 m seas with 30 knot winds. No incidents to report.

25th January:

00:00 continue standing down for weather.

16:00 seas and wind have died down. Resume deployments on line 5

16:13 deploy Stingray on site 200
16:35 deploy Wombat on site 199
16:53 deploy Ibis on site 198
17:39 deploy Camel on site 197
18:14 deploy Skink on site 196
18:37 deploy Roo on site 195
18:53 deploy Rosella on site 194
19:20 deploy Rabbit on site 193
19:42 deploy Corella on site 192
20:05 deploy Wallaby on site 191
20:30 deploy Cassowary on site 190
20:53 deploy Goanna on site 189

Transit to lines 1 and 2 for releases.

Seas 4–5 m with 30 knot winds, dying down to relatively calm seas and 10-15 knot winds. No incidents to report.

26th January:

Recoveries from lines 1 and 2:

02:52 release Penguin from site 51
03:27 release Spitfire from site 52
03:43 release Bullant from site 53
04:06 release Quokka from site 54
04:30 release Redback from site 55
09:54 release Potoroo from site 30
10:17 release Bowerbird from site 29
10:35 release current meter from site 29.5
11:02 release Possum from site 28
11:25 release Taipan from site 27
15:17 release Lorikeet from site 26
15:38 release Quoll from site 25
16:01 release Lerp from site 24

16:24 release Magpie from site 23
20:53 release Budgie from site 56
21:14 release Occie from site 57
21:45 no response from Joey at site 58
21:57 release Bunyip from site 59
22:15 release Koala from site 60

Transit to line 1 for deployments

Seas relatively calm with 5-20 knot winds. No incidents to report.

27th January:

Deployments on line 1:

08:47 deploy DUESI 1 on site 192.5
09:28 deploy DUESI 2 on site 191.5
10:15 deploy Bunyip on site 188
11:43 deploy Occie on site 184
11:07 deploy Koala on site 183
11:34 deploy Budgie on site 187
12:00 deploy Magpie on site 182
12:30 deploy Lerp on site 186
13:05 deploy Quoll on site 181
13:45 deploy Lorikeet on site 185
14:12 deploy Taipan on site 180
14:40 deploy DUESI 3 on site 179.5
15:03 deploy Possum on site 179
15:27 deploy Bower on site 178
15:50 deploy DUESI 1 on site 177.5
16:08 deploy Potoroo on site 177
16:31 deploy Quokka on site 176
16:53 deploy Redback on site 175
17:15 deploy Bullant on site 174
17:38 deploy Spitfire on site 173
18:22 deploy Penguin on site 172
18:43 deploy current meter on site 171.5

Seas relatively calm with 5-20 knot winds. No incidents to report.

28th January:

Recoveries on line 2:

01:48 release Mozzie site 50
02:10 release Brolga site 49
02:34 release Jabiru site 48
02:57 release Devil site 47
03:21 release Glider site 46
03:45 release Brumby site 45
07:30 release Shrike site 44
07:49 release Lyrebird site 43
08:09 release Cuscus site 42

08:35 release Pelican site 41
09:01 release Shark site 40
11:56 release Bilby site 39
12:16 release Bogong site 38
12:32 release Quindal site 37
12:52 release Cocky site 36
15:43 release Fruitbat site 35
16:11 release Yabby site 33
16:28 release Marron site 32
16:44 release Currawong site 31

Transit to line 4 for deployments

23:26 deploy Currawong site 111

Seas relatively calm with 5-20 knot winds. No incidents to report.

29th January:

Deployments on line 4:

00:00 deploy Marron site 113
00:28 deploy Yabby site 115
00:58 deploy Fruitbat site 117
01:28 deploy Cocky site 119
01:59 deploy Quindal site 121
02:32 deploy Bogong site 213
03:01 deploy Bilbly site 125
03:32 deploy Shark site 127
04:05 deploy Pelican site 129
04:35 deploy Cuscus site 131
05:03 deploy Lyrebird site 133
05:31 deploy Shrike site 135
05:58 deploy Brumby site 137
06:25 deploy Glider site 139
06:53 deploy Devil site 141
07:31 deploy Jabiru site 143
07:48 deploy Brolga site 145
08:27 deploy Mozzie site 147

Transit to start of SUESI line 5a

12:35 SUESI in the water
14:20 ship CPA site 200
15:00 SUESI at 75 m flying height.15:25
15:25 ship CPA site 199
16:19 ship CPA site 198
17:10 ship CPA site 197
18:01 ship CPA site 196
18:56 ship CPA site 195
19:55 ship CPA site 194
20:54 ship CPA site 193
21:23 ship CPA DUESI site 192.5

21:53 ship CPA site 192
22:23 ship CPA DUESI site 191.5
22:52 ship CPA site 191
23:47 ship CPA site 190

Seas relatively calm with 5-20 knot winds. No incidents to report.

30th January:

Continue SUESI tow on line 5a:

00:47 ship CPA site 189
01:48 ship CPA site 188
02:57 ship CPA site 187
04:00 ship CPA site 186
05:01 ship CPA site 185
05:34 SUESI CAP site 185
06:35 start hauling SUESI in
09:20 SUESI and antenna aboard, transit to site 193 for recoveries

Recoveries on line 5:

10:58 release Rabbit site 193
11:26 release Rosella site 194
12:02 release Roo site 195
12:25 release Skink site 196
15:28 release Camel site 197
15:56 release Ibis site 198
16:20 release Wombat site 199
16:42 release Stingray site 200

Transit to site 171 for deployments.

Seas relatively calm with 5-15 knot winds. No incidents to report.

31st January:

Deployments on line 5:

00:06 deploy Stingray on site 171
00:28 deploy Wombat on site 170
00:48 deploy Ibis on site 169
01:07 deploy Camel on site 168
01:27 deploy Skink on site 167
01:47 deploy Roo on site 166
02:05 deploy Rosella on site 165
02:24 deploy Rabbit on site 164

Transit to site 185 for SUESI tow on line 5b.

07:50 SUESI in the water
09:36 ship CPA site 184
10:33 ship CPA site 183

11:33 ship CPA site 182
12:34 ship CPA site 181
13:30 ship CPA site 180
14:26 ship CPA site 179
15:26 ship CPA site 178
16:26 ship CPA site 177
17:26 ship CPA site 176
18:25 ship CPA site 175
19:25 ship CPA site 174
20:14 ship CPA site 173
21:07 ship CPA site 172
21:56 ship CPA site 171
22:50 ship CPA site 170
23:43 ship CPA site 169

Seas relatively calm with 5-20 knot winds. No incidents to report.

1st February:

Continue to tow line 5b:

00:35 ship CPA site 168
01:28 ship CPA site 167
02:22 ship CPA site 166
03:17 ship CPA site 165
04:10 ship CPA site 164
end of line, hauling in.
05:00 SUESI on deck

Transit with antenna in water at 4 knots to carry out a crossline tow through sites 181 and 186.

11:34 SUESI in water
15:32 SUESI at 75 m altitude
14:30 lost current on SUESI, hauling in.
16:30 SUESI on deck, 17:30 antenna aboard.
Antenna termination broken.

Start recoveries:

19:15 release DUESI-4 from site 192.5
19:40 release Corella from site 192
20:16 could not release DUESI-2 from site 191.5
20:31 release Wallaby from site 191
21:01 release Cassowary from site 190

Seas relatively calm with 5-20 knot winds. No incidents to report.

2nd February:

Continue line 5 recoveries:

00:11 release Goanna site 189
00:43 release Bunyip site 188

01:20 release Budgie site 187
01:48 release Lerp site 186
02:20 release Lorikeet site 185
06:05 release Occie site 184
06:28 release Koala site 183
07:01 release Magpie site 182
07:36 release Quoll site 181
08:06 release Taipan site 180
10:49 release DUESI-3 site 179.5
11:15 release Possum site 179
11:45 release Bower site 178
12:08 release DUESI-1 site 177.5
14:12 release Potaroo site 177
14:48 release Quokka site 176
15:14 release Redback site 175
17:02 release Bullant site 174
17:24 release Spitfire site 173
17:45 release Penguin site 172

Transit to line 4 for recoveries:

21:25 release Currawong site 111
22:10 release Marron site 113
23:02 release Yabby site 115

Seas calm with 5-15 knot winds. No incidents to report.

3rd February:

Continue recoveries on line 4:

00:18 release Fruitbat site 117
00:45 release Cocky site 119
02:20 release Quindal site 121
02:48 release Bogong site 123
04:31 release Bilby site 125
04:57 release Shark site 127
05:21 release Pelican site 129
07:22 release Cuscus site 131
07:55 release Lyrebird site 133
08:24 release Shrike site 135
08:50 release Brumby site 137
11:45 release Glider site 139
12:11 release Devil site 141
12:38 release Jabiru site 143
13:05 release Brolga site 145
13:31 release Mozzie site 147

18:00 begin re-spooling 17 mm deeptow cable.

Seas calm with 5-15 knot winds. No incidents to report.

4th February:

00:00 Finish level wind on winch. Transit to site 191.5 to check on DUESI-2. Still on seafloor.

Transit to site 164 for final releases

05:40 release Rabbit site 164
06:28 release Rosella site 165
06:56 release Roo site 166
08:23 release Skink site 167
08:58 release Camel site 168
10:26 release Ibis site 169
11:65 release Wombat site 170
12:34 release Stingray site 171
12:49 release Current Meter site 171.5

14:00 all done, transit to Montevideo. ETA pilot station 09:00 on the 5th.

Seas calm with 5-15 knot winds. No incidents to report.

4th February:

10:00 Tie up in Montevideo. Stage equipment for offloading.

13:00 Containers arrive, start unloading

17:00 All equipment offloaded.

Appendix B
Personnel

Steven Constable	Chief Scientist	Scripps Institution of Oceanography
Arnold Orange	Scientist	Scripps Institution of Oceanography
Joanna Sherman	PhD Student	Scripps Institution of Oceanography
Peter Kannberg	PhD Student	Scripps Institution of Oceanography
Christopher Armerding	Technician	Scripps Institution of Oceanography
Jacob Perez	Technician	Scripps Institution of Oceanography
Joel White	Technician	Scripps Institution of Oceanography
Keith Shadle	Safety Officer	Scripps Institution of Oceanography
Stephanie Senderowitz	Geologist	Strataimage Consultoria, Brazil
Fabricio Loureiro	Geophysicist	Strataimage Consultoria, Brazil

John Childress	Master
Stanley Langaker	Chief Officer
Julio Bonilla	Chief Engineer
Lorenso Crisantos	First Engineer
Elvin Suazo	OS
Ramon Javier	OS
Crystal Nailor	Cook
Derek Marcel	Wiper
Aaron Lanet	QM
Tony Zelaya	Second Mate
Francisco Sanchez	Messman
Samson Madeja	AB
Jason Benton	AB
William Young	Medic
James Woodford	Qmed

Appendix C
Seafloor Instrument Positions

Positions and times of deployment for all MT and CSEM sites. UTM positions are zone 22. If the navigation flag (NF) is set to 1, the UTM positions (only) are from LBL acoustic navigation, otherwise nominal release points. Line numbers are designated LN.

Site no.	Latitude	Longitude	UTM N	UTM E	Depth	NF	LN	deployed d/m/y h:m					released d/m/y h:m					days down
1	-36.00069	-52.50023	364784	6014934	2017	0	1	18	1	2014	1	10	23	1	2014	12	4	5.4
2	-36.02375	-52.47744	366982	6012058	2085	1	1	18	1	2014	1	58	23	1	2014	11	38	5.4
3	-36.04680	-52.45463	369050	6009532	2155	1	1	18	1	2014	2	29	23	1	2014	11	10	5.3
4	-36.06985	-52.43182	371096	6007024	2240	1	1	18	1	2014	3	4	23	1	2014	10	40	5.3
5	-36.09289	-52.40898	373238	6004553	2315	1	1	18	1	2014	3	38	23	1	2014	10	10	5.2
6	-36.11592	-52.38615	375243	6002004	2393	1	1	18	1	2014	4	12	23	1	2014	5	12	5.0
7	-36.13895	-52.36329	377314	5999528	2466	1	1	18	1	2014	4	43	23	1	2014	4	45	5.0
8	-36.16197	-52.34042	379426	5996976	2530	1	1	18	1	2014	5	13	23	1	2014	4	15	4.9
9	-36.18499	-52.31753	381516	5994446	2592	1	1	18	1	2014	5	38	23	1	2014	3	46	4.9
10	-36.20801	-52.29463	383611	5991945	2648	1	1	18	1	2014	6	0	23	1	2014	3	13	4.8
11	-36.23102	-52.27172	385672	5989386	2721	1	1	18	1	2014	6	25	24	1	2014	1	27	5.7
12	-36.25402	-52.24879	387784	5986887	2758	1	1	18	1	2014	7	19	24	1	2014	2	0	5.7
13	-36.27702	-52.22585	389908	5984436	2810	1	1	18	1	2014	7	43	24	1	2014	3	17	5.8
14	-36.30001	-52.20289	392028	5981990	2876	1	1	18	1	2014	8	12	24	1	2014	7	52	5.9
15	-36.32299	-52.17992	394164	5979530	2935	1	1	18	1	2014	8	43	24	1	2014	8	16	5.9
16	-36.34598	-52.15695	396182	5977055	3060	0	1	18	1	2014	9	13	24	1	2014	8	37	5.9
17	-36.36895	-52.13396	398276	5974531	3060	0	1	18	1	2014	9	39	24	1	2014	8	55	5.9
18	-36.39192	-52.11095	400369	5972007	3105	0	1	19	1	2014	21	46	24	1	2014	12	29	4.6
19	-36.41488	-52.08792	402463	5969483	3165	0	1	19	1	2014	21	21	24	1	2014	12	48	4.6
20	-36.43784	-52.06488	404556	5966960	3187	0	1	19	1	2014	20	58	24	1	2014	13	7	4.6
21	-36.46079	-52.04183	406650	5964436	3217	0	1	19	1	2014	20	31	24	1	2014	13	27	4.7
22	-36.48375	-52.01876	408744	5961912	3270	0	1	19	1	2014	20	3	24	1	2014	17	0	4.8
23	-36.50669	-51.99568	410838	5959389	3307	0	1	19	1	2014	19	32	26	1	2014	16	24	6.8
24	-36.52962	-51.97259	412931	5956866	3330	0	1	19	1	2014	19	4	26	1	2014	16	1	6.8
25	-36.55255	-51.94948	415025	5954343	3375	0	1	19	1	2014	18	34	26	1	2014	15	38	6.8
26	-36.57548	-51.92637	417118	5951820	3412	0	1	19	1	2014	17	43	26	1	2014	15	17	6.8
27	-36.59839	-51.90324	419212	5949298	3450	0	1	19	1	2014	16	59	26	1	2014	11	25	6.7
28	-36.62132	-51.88008	421306	5946775	3495	0	1	19	1	2014	16	32	26	1	2014	11	2	6.7
29	-36.64422	-51.85692	423400	5944252	3547	0	1	19	1	2014	16	3	26	1	2014	10	17	6.7
30	-36.66712	-51.83374	425494	5941730	3577	0	1	19	1	2014	15	12	26	1	2014	9	54	6.7
31	-36.34121	-52.83635	335201	5976640	1995	0	2	23	1	2014	18	17	28	1	2014	16	44	4.9
32	-36.35702	-52.80638	337924	5974936	2025	0	2	23	1	2014	18	45	28	1	2014	16	28	4.9
33	-36.37283	-52.77639	340648	5973233	2070	0	2	23	1	2014	19	10	28	1	2014	16	11	4.8
35	-36.40441	-52.71637	346094	5969826	2340	0	2	23	1	2014	19	42	28	1	2014	15	43	4.8
36	-36.42019	-52.68635	348817	5968123	2430	0	2	23	1	2014	20	54	28	1	2014	12	52	4.6
37	-36.43596	-52.65631	351541	5966420	2460	0	2	23	1	2014	21	19	28	1	2014	12	32	4.6
38	-36.45173	-52.62626	354264	5964718	2520	0	2	23	1	2014	21	45	28	1	2014	12	16	4.6
39	-36.46749	-52.59620	356987	5963014	2490	0	2	23	1	2014	22	7	28	1	2014	11	56	4.9
40	-36.48324	-52.56613	359709	5961311	2475	0	2	23	1	2014	22	29	28	1	2014	9	1	4.4
41	-36.49897	-52.53605	362432	5959609	2557	0	2	23	1	2014	22	57	28	1	2014	8	35	4.4
42	-36.51470	-52.50595	365155	5957907	2580	0	2	23	1	2014	0	29	28	1	2014	8	9	5.3
43	-36.53042	-52.47584	367878	5956204	2662	0	2	23	1	2014	0	7	28	1	2014	7	49	5.3
44	-36.54613	-52.44573	370601	5954502	2790	0	2	22	1	2014	23	42	28	1	2014	7	30	5.3
45	-36.56184	-52.41559	373323	5952800	2895	0	2	22	1	2014	23	21	28	1	2014	3	45	5.1

Site no.	Latitude	Longitude	UTM N	UTM E	Depth	N F	L N	|– |–	deployed d/m/y h:m			–| –|	|– |–	released d/m/y h:m			–| –|	days down
46	-36.57753	-52.38544	376047	5951098	3082	0	2	22	1	2014	22	38	28	1	2014	3	21	5.1
47	-36.59322	-52.35529	378769	5949397	3120	0	2	22	1	2014	22	15	28	1	2014	2	57	5.1
48	-36.60890	-52.32512	381492	5947695	3277	0	2	22	1	2014	21	44	28	1	2014	2	34	5.2
49	-36.62457	-52.29494	384214	5945994	3255	0	2	22	1	2014	21	23	28	1	2014	2	10	5.1
50	-36.64023	-52.26475	386937	5944292	3270	0	2	22	1	2014	21	2	28	1	2014	1	48	5.1
51	-36.65588	-52.23455	389659	5942591	3300	0	2	22	1	2014	20	30	26	1	2014	2	52	3.2
52	-36.67152	-52.20434	392381	5940890	3337	0	2	22	1	2014	20	9	26	1	2014	3	27	3.3
53	-36.68717	-52.17411	395103	5939188	3360	0	2	22	1	2014	19	41	26	1	2014	3	43	3.3
54	-36.70279	-52.14388	397826	5937487	3397	0	2	22	1	2014	19	18	26	1	2014	4	6	3.3
55	-36.71841	-52.11363	400548	5935787	3420	0	2	22	1	2014	18	52	26	1	2014	4	30	3.4
56	-36.73402	-52.08337	403270	5934086	3442	0	2	22	1	2014	18	31	26	1	2014	20	53	4.0
57	-36.74962	-52.05310	405992	5932386	3480	0	2	22	1	2014	17	52	26	1	2014	21	14	4.1
59	-36.78079	-51.99252	411436	5928985	3547	0	2	22	1	2014	17	5	26	1	2014	21	57	4.2
60	-36.79637	-51.96221	414157	5927285	3585	0	2	22	1	2014	16	42	26	1	2014	22	15	4.2
61	-36.33381	-53.28052	295316	5976614	943	1	3	10	1	2014	15	34	16	1	2014	18	38	6.1
62	-36.35225	-53.24508	298484	5974667	1049	1	3	10	1	2014	16	45	16	1	2014	19	10	6.1
63	-36.37069	-53.20962	301599	5972590	1092	1	3	10	1	2014	17	52	16	1	2014	20	51	6.1
64	-36.38911	-53.17414	304820	5970596	1202	1	3	10	1	2014	19	14	16	1	2014	21	25	6.0
65	-36.40751	-53.13865	308041	5968664	1265	1	3	10	1	2014	19	50	16	1	2014	23	34	6.1
66	-36.42592	-53.10315	311224	5966668	1226	1	3	10	1	2014	21	57	17	1	2014	0	32	6.1
67	-36.44430	-53.06762	314590	5964872	1270	1	3	10	1	2014	23	36	17	1	2014	4	6	6.1
68	-36.46268	-53.03208	317663	5962684	1295	1	3	11	1	2014	1	28	17	1	2014	6	25	6.2
69	-36.48104	-52.99652	320964	5960719	1398	1	3	11	1	2014	3	25	17	1	2014	9	14	6.2
70	-36.49939	-52.96095	324077	5958837	1576	1	3	11	1	2014	3	57	17	1	2014	9	46	6.2
71	-36.51773	-52.92537	327241	5956862	1833	1	3	11	1	2014	4	40	17	1	2014	12	15	6.3
72	-36.53606	-52.88976	330456	5954836	2140	1	3	11	1	2014	6	0	17	1	2014	12	53	6.2
73	-36.55437	-52.85414	333596	5952891	2304	1	3	11	1	2014	6	37	17	1	2014	13	28	6.2
74	-36.57268	-52.81850	336856	5951005	2514	1	3	11	1	2014	7	40	17	1	2014	16	28	6.3
75	-36.59097	-52.78285	340119	5949070	2514	1	3	11	1	2014	8	20	17	1	2014	17	1	6.3
76	-36.60926	-52.74718	343325	5947102	2522	1	3	11	1	2014	9	1	17	1	2014	17	34	6.3
77	-36.62752	-52.71150	346509	5945120	2551	1	3	11	1	2014	10	31	18	1	2014	13	54	7.1
78	-36.64578	-52.67579	349694	5943148	2569	1	3	11	1	2014	11	20	18	1	2014	14	27	7.1
79	-36.66403	-52.64007	353154	5941084	2686	1	3	11	1	2014	11	52	18	1	2014	15	13	7.1
80	-36.68225	-52.60434	356629	5939203	2770	1	3	11	1	2014	12	58	18	1	2014	15	42	7.1
81	-36.70047	-52.56859	359884	5937201	2754	1	3	11	1	2014	17	3	18	1	2014	19	3	7.0
82	-36.71869	-52.53282	362829	5935245	2790	1	3	11	1	2014	18	32	18	1	2014	19	42	7.0
83	-36.73688	-52.49703	366353	5933299	2813	1	3	11	1	2014	21	15	18	1	2014	20	43	6.9
84	-36.75507	-52.46124	369566	5931300	2960	1	3	11	1	2014	21	52	18	1	2014	21	11	6.9
85	-36.77324	-52.42542	372797	5929336	2891	1	3	11	1	2014	22	24	19	1	2014	0	40	7.0
86	-36.79140	-52.38959	376019	5927367	3127	0	3	11	1	2014	23	7	19	1	2014	1	2	7.0
87	-36.80956	-52.35374	379247	5925399	3190	0	3	11	1	2014	23	57	19	1	2014	1	25	7.0
88	-36.82769	-52.31788	382474	5923432	3227	0	3	12	1	2014	0	38	19	1	2014	1	52	7.0
89	-36.84581	-52.28200	385700	5921465	3255	0	3	12	1	2014	1	37	19	1	2014	7	30	7.2
90	-36.86393	-52.24610	388927	5919497	3337	0	3	12	1	2014	2	15	19	1	2014	8	3	7.2
91	-36.88203	-52.21018	392155	5917531	3337	0	3	12	1	2014	2	52	19	1	2014	8	28	7.2
92	-36.90012	-52.17425	395381	5915564	3412	0	3	12	1	2014	3	25	19	1	2014	9	1	7.2
93	-36.91819	-52.13831	398608	5913598	3487	0	3	12	1	2014	4	2	21	1	2014	6	57	9.1
94	-36.93626	-52.10235	401834	5911632	3487	0	3	12	1	2014	4	55	21	1	2014	7	32	9.1
95	-36.95431	-52.06637	405060	5909665	3562	0	3	12	1	2014	5	41	21	1	2014	8	7	9.1
96	-36.97703	-52.02104	409123	5907189	3645	0	3	12	1	2014	6	27	21	1	2014	8	50	9.0
97	-37.01106	-51.95299	415218	5903477	3712	0	3	12	1	2014	8	25	21	1	2014	13	27	9.2

Site no.	Latitude	Longitude	UTM N	UTM E	Depth	N F	L N	|– |–	deployed d/m/y h:m			–| –|	|– |–	released d/m/y h:m			–| –|	days down
98	-37.04505	-51.88490	421311	5899764	3780	0	3	12	1	2014	9	15	21	1	2014	14	5	9.2
99	-37.07899	-51.81673	427405	5896053	3870	0	3	12	1	2014	10	36	21	1	2014	14	45	9.1
100	-37.11290	-51.74851	433499	5892341	3922	0	3	12	1	2014	11	30	21	1	2014	15	24	9.1
101	-37.14676	-51.68024	439591	5888630	4012	0	3	12	1	2014	12	9	21	1	2014	20	5	9.3
102	-37.18057	-51.61190	445684	5884921	4050	0	3	12	1	2014	13	2	21	1	2014	20	42	9.3
103	-37.21435	-51.54351	451777	5881211	4125	0	3	12	1	2014	13	47	21	1	2014	21	18	9.3
104	-37.24806	-51.47506	457868	5877503	4170	0	3	12	1	2014	14	34	21	1	2014	22	11	9.3
105	-37.28175	-51.40655	463961	5873794	4237	0	3	12	1	2014	15	39	22	1	2014	3	25	9.4
106	-37.31539	-51.33799	470052	5870086	4272	0	3	12	1	2014	16	30	22	1	2014	4	4	9.4
107	-37.34897	-51.26936	476144	5866380	4335	0	3	12	1	2014	17	22	22	1	2014	4	30	9.4
108	-37.38252	-51.20067	482235	5862673	4350	0	3	12	1	2014	18	38	22	1	2014	5	13	9.4
109	-37.41602	-51.13193	488325	5858968	4395	0	3	12	1	2014	19	27	22	1	2014	5	52	9.4
111	-36.39929	-53.61889	265137	5968577	172	0	4	28	1	2014	23	26	2	2	2014	21	25	4.9
113	-36.43023	-53.56626	269949	5965270	382	0	4	29	1	2014	0	0	2	2	2014	22	10	4.9
115	-36.46115	-53.51358	274762	5961964	495	0	4	29	1	2014	0	28	2	2	2014	23	2	4.9
117	-36.49204	-53.46087	279574	5958659	802	0	4	29	1	2014	0	58	3	2	2014	0	18	4.9
119	-36.52290	-53.40811	284386	5955354	937	0	4	29	1	2014	1	28	3	2	2014	0	45	4.9
121	-36.55374	-53.35531	289198	5952049	1057	0	4	29	1	2014	1	59	3	2	2014	2	20	5.0
123	-36.58456	-53.30247	294010	5948745	1140	0	4	29	1	2014	2	32	3	2	2014	2	48	5.0
125	-36.61534	-53.24959	298822	5945441	1297	0	4	29	1	2014	3	1	3	2	2014	4	31	5.0
127	-36.64611	-53.19667	303633	5942138	1500	0	4	29	1	2014	3	32	3	2	2014	4	57	5.0
129	-36.67683	-53.14370	308445	5938836	1845	0	4	29	1	2014	4	5	3	2	2014	5	21	5.0
131	-36.70754	-53.09070	313256	5935533	2235	0	4	29	1	2014	4	35	3	2	2014	7	22	5.1
133	-36.73823	-53.03765	318067	5932231	2512	0	4	29	1	2014	5	3	3	2	2014	7	55	5.1
135	-36.76888	-52.98456	322878	5928929	2670	0	4	29	1	2014	5	31	3	2	2014	8	24	5.1
137	-36.79952	-52.93144	327689	5925627	2752	0	4	29	1	2014	5	58	3	2	2014	8	50	5.1
139	-36.83011	-52.87826	332500	5922328	2917	0	4	29	1	2014	6	25	3	2	2014	11	45	5.2
141	-36.86069	-52.82505	337310	5919027	2970	0	4	29	1	2014	6	53	3	2	2014	12	11	5.2
143	-36.89124	-52.77180	342121	5915727	3127	0	4	29	1	2014	7	31	3	2	2014	12	28	5.2
145	-36.92176	-52.71851	346931	5912427	3232	0	4	29	1	2014	7	48	3	2	2014	13	5	5.2
147	-36.95226	-52.66517	351741	5909128	3270	0	4	29	1	2014	8	27	3	2	2014	13	31	5.2
164	-36.68320	-53.87877	242904	5936528	333	1	5	31	1	2014	2	24	4	2	2014	5	40	4.1
165	-36.69633	-53.85174	245240	5934995	420	1	5	31	1	2014	2	5	4	2	2014	6	28	4.1
166	-36.70945	-53.82470	247705	5933619	535	1	5	31	1	2014	1	47	4	2	2014	6	56	4.2
167	-36.72257	-53.79765	250218	5932298	705	1	5	31	1	2014	1	27	4	2	2014	8	23	4.2
168	-36.73569	-53.77060	252724	5930977	827	1	5	31	1	2014	1	7	4	2	2014	8	58	4.3
169	-36.74879	-53.74353	255151	5929598	898	1	5	31	1	2014	0	48	4	2	2014	10	26	4.4
170	-36.76190	-53.71647	257627	5928220	928	1	5	31	1	2014	0	28	4	2	2014	11	5	4.4
171	-36.77499	-53.68939	260102	5926881	958	1	5	31	1	2014	0	6	4	2	2014	12	34	4.5
172	-36.78807	-53.66230	262478	5925369	984	1	5	27	1	2014	18	22	2	2	2014	17	45	5.9
173	-36.80115	-53.63520	264907	5923994	1010	1	5	27	1	2014	17	38	2	2	2014	17	24	5.9
174	-36.81423	-53.60809	267373	5922629	1048	1	5	27	1	2014	17	15	2	2	2014	17	2	5.9
175	-36.82729	-53.58097	269927	5921309	1089	1	5	27	1	2014	16	53	2	2	2014	15	14	5.9
176	-36.84036	-53.55385	272478	5919998	1259	1	5	27	1	2014	16	31	2	2	2014	14	48	5.9
177	-36.85341	-53.52672	275039	5918680	1440	1	5	27	1	2014	16	8	2	2	2014	14	12	5.9
178	-36.86646	-53.49957	277591	5917299	1508	1	5	27	1	2014	15	27	2	2	2014	11	45	5.8
179	-36.87949	-53.47242	280158	5915842	1614	1	5	27	1	2014	15	3	2	2	2014	11	15	5.8
180	-36.89253	-53.44526	282495	5914575	1731	1	5	27	1	2014	14	12	2	2	2014	8	6	5.7
181	-36.90555	-53.41808	284998	5913262	1849	1	5	27	1	2014	13	5	2	2	2014	7	36	5.7
182	-36.91857	-53.39091	287598	5911931	1985	1	5	27	1	2014	12	0	2	2	2014	7	1	5.7
183	-36.93158	-53.36373	290082	5910655	2150	1	5	27	1	2014	11	7	2	2	2014	6	28	5.8

Site						N	L	|–	deployed			–|	|–	released			–|	days
no.	Latitude	Longitude	UTM N	UTM E	Depth	F	N	|–	d/m/y h:m			–|	|–	d/m/y h:m			–|	down
184	-36.94459	-53.33653	292647	5909536	2289	1	5	27	1	2014	11	43	2	2	2014	6	5	5.7
185	-36.92130	-53.45960	281368	5911385	1616	1	5	27	1	2014	13	45	2	2	2014	2	20	5.5
186	-36.93758	-53.43077	284037	5909735	1739	1	5	27	1	2014	12	30	2	2	2014	1	48	5.5
187	-36.95387	-53.40194	286617	5908097	1910	1	5	27	1	2014	11	34	2	2	2014	1	20	5.5
188	-36.97013	-53.37309	289349	5906504	1949	1	5	27	1	2014	10	15	2	2	2014	0	43	5.6
189	-36.98639	-53.34425	292200	5904873	2220	1	5	25	1	2014	20	53	2	2	2014	0	11	7.1
190	-37.00265	-53.31537	294315	5903093	2261	1	5	25	1	2014	20	30	1	2	2014	21	1	7.0
191	-37.01890	-53.28650	296995	5901358	2288	1	5	25	1	2014	20	5	1	2	2014	20	31	7.0
192	-37.03513	-53.25760	299708	5899645	2405	1	5	25	1	2014	19	42	1	2	2014	19	40	6.9
193	-37.05137	-53.22870	302400	5897926	2464	1	5	25	1	2014	19	20	30	1	2014	10	58	4.6
194	-37.06759	-53.19978	305030	5896111	2530	1	5	25	1	2014	18	53	30	1	2014	11	26	4.6
195	-37.08380	-53.17086	307594	5894228	2598	1	5	25	1	2014	18	37	30	1	2014	12	2	4.7
196	-37.10001	-53.14192	310074	5892281	2689	1	5	25	1	2014	18	14	30	1	2014	12	25	4.7
197	-37.11621	-53.11297	312645	5890426	2767	1	5	25	1	2014	17	39	30	1	2014	15	28	4.9
198	-37.13240	-53.08400	315156	5888476	2936	1	5	25	1	2014	16	53	30	1	2014	15	56	4.9
199	-37.14859	-53.05503	317637	5886538	3132	1	5	25	1	2014	16	35	30	1	2014	16	20	4.9
200	-37.16476	-53.02604	320062	5884576	3164	1	5	25	1	2014	16	13	30	1	2014	16	42	5.0