Seismic Hazards from Earthquakes in the Locked Zone Offshore Wellington

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Executive Summary

The Earthquakes and Locking inVEstigation of Subduction (ELVES) project is investigating the subduction interface below and offshore the Wellington region. This area is currently "locked", building up stress that will be released in a large, destructive subduction thrust earthquake. The onshore GeoNet network is effectively blind to small earthquakes offshore, and even large earthquakes are not well located, hindering understanding of the hazard posed by the offshore subduction zone. We deployed 20 ocean bottom seismometers (OBS) from November 2023 through early January 2025 in the locked region to detect earthquakes. Except for two stations that could not be retrieved, the data are excellent; we have been able to use recordings of distant earthquakes to determine the orientation of the seismometers, to relocate some earthquakes recorded by GeoNet and to find smaller earthquakes that were unable to be located by GeoNet. When the earthquakes are fully analysed, we expect them to feed into improved seismic and tsunami hazard estimates.

Abstract

The subduction interface below and offshore the Wellington region is currently “locked”, building up stress that will be released in a large, destructive subduction thrust earthquake. The onshore GeoNet network is effectively blind to small earthquakes offshore, and even large earthquakes are not well located, hindering understanding of the hazard posed by the offshore subduction zone. In the Earthquakes and Locking inVEstigation of Subduction (ELVES) project, we deployed 20 ocean bottom seismometers (OBS) from November 2023 through early January 2025 in the locked region to detect earthquakes there. Eighteen seismometers were recovered; the data on those seismometers are excellent. We have been able to use recordings of distant earthquakes to determine the orientation of the seismometers, to relocate some earthquakes recorded by GeoNet, and to locate smaller earthquakes that were previously undetected by GeoNet. When the earthquakes are fully analysed, we expect them to feed into improved seismic and tsunami hazard estimates.

Keywords

Earthquake, Tsunami, Quantifying hazards and risk, ELVES, Ocean Bottom Seismometers, TAN237b, TAN2501

Introduction

The Earthquakes and Locking inVEstigation of Subduction (ELVES) project is a multi-institutional, international, seafloor seismological investigation of seismicity near the locked section of the Hikurangi subduction thrust offshore the North Island's east coast (Wairarapa/Wellington region). Previous Ocean Bottom Seismometer (OBS) deployments on the east coast (e.g., HOBITSS: Hikurangi Ocean Bottom Instrument for Tremor and Slow Slip, PULSE: Physical processes UnderLying Slow Earthquakes) have taken place further north and were designed to study the vertical movement in Slow Slip Events, which involve slip on the order of 100's of mm taking place over weeks to months. The ELVES deployment is designed to study the "locked" section, where stress is building up without being relieved by slow slip or creep offshore. There are very few small earthquakes reported by GeoNet in this region, but the region has high seismic and tsunami hazards.

Data collected from these deployment (ELVES-1, TAN2317b; 25 Nov – 1 Dec 2023 and TAN2501; 3-8 Jan 2025) (Figure 1) will be used to investigate the offshore occurrence of earthquakes in the locked zone on and near the megathrust, and its relationship to subduction interface characteristics from passive and active source seismic imaging (Barker et al., 2018; Henrys et al., 2013; Wallace et al., 2016). The OBS will be used to investigate a range of seismological phenomena and will contribute to testing hypotheses regarding the structure and the state of stress in and above the subducting slab and plate interface. Neither time nor funding for the analysis was available for this project; we are actively pursuing other sources to complete the analysis. Therefore any results in this report should be considered preliminary.

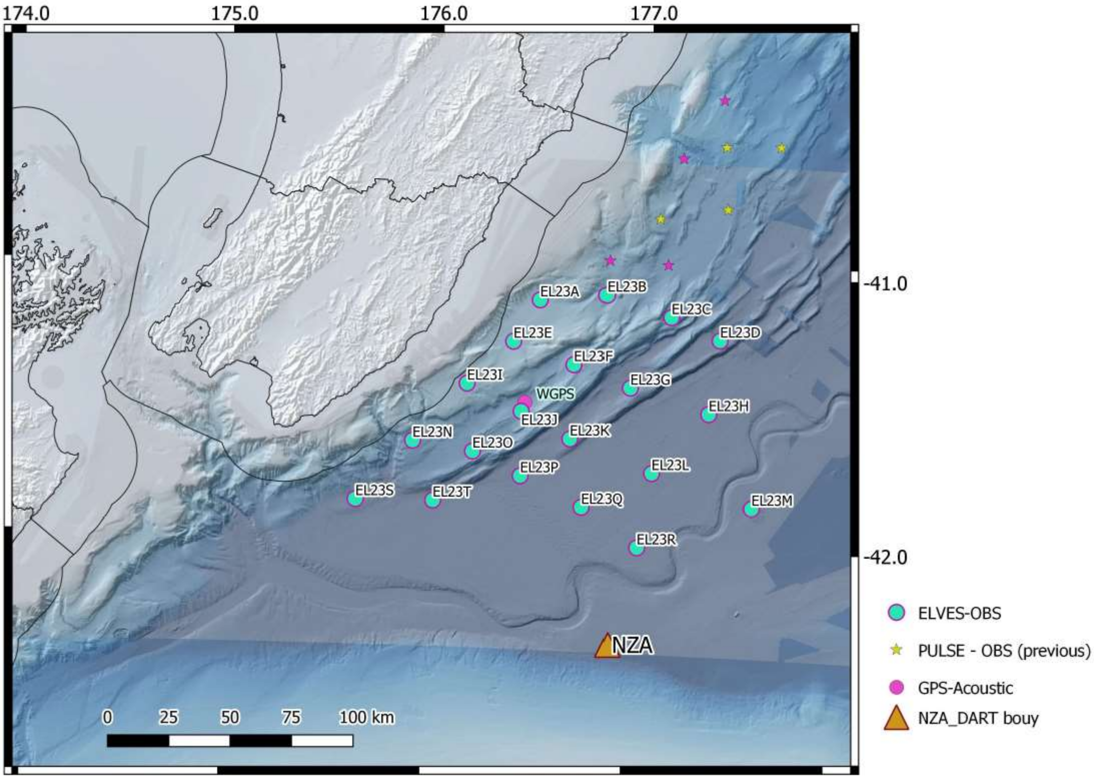

Figure 1. Instruments deployed as part of ELVES-1 experiment on TAN2317b. Previous deployments of OBS as part of the PULSE project are shown with pink and yellow stars. The NZA-DART buoy, which is used for tsunami studies, is also shown. EL23F and EL23R could not be retrieved.

Scientific and Societal Context

Understanding the earthquake and tsunami potential posed by the Hikurangi subduction zone, our largest tectonic plate boundary fault, has fundamental implications for life, safety and New Zealand's economic security. The data we have acquired fills a major observational gap in the most hazardous portion of the subduction zone and will greatly improve our understanding of these hazards. The plate interface below the Wellington region is currently "locked", building up stress that will be released in a large, probably destructive undersea subduction thrust earthquake (Wallace et al., 2009). Because of its onshore location, the GeoNet network is largely suited to detecting earthquakes occurring beneath the land. Without offshore seismometers, we are unable to accurately locate offshore earthquakes, nor can we record the many low-magnitude (< 2 to 3) earthquakes that provide much-needed information about the seismic slip behaviour of the offshore subduction zone and insights into other offshore active faults. Several previous Ocean Bottom Seismometer (OBS) deployments further north, offshore Gisborne, have revealed thousands of earthquakes that were not detectable by the onshore GeoNet network (Yarce et al., 2019; Yarce et al., 2023). However, except for short-term (days to weeks) deployments for "active source" subsurface imaging, there have been no OBS deployments above the locked region offshore the Wairarapa coast. Therefore, we know very little about the seismicity rates and the distribution of earthquakes in this area.

Determining the distribution of earthquakes offshore Wellington will enable us to estimate the recurrence intervals of earthquakes of various sizes. Knowledge of the locations of small earthquakes will also help us to determine whether mapped faults are active and whether there could be unmapped, active faults. The resulting earthquake catalogue will reveal the rates of earthquake occurrence, give new insights into the up-dip limit of the seismogenic zone (with implications for tsunamigenic rupture), and help constrain offshore fault geometries. Our results will be incorporated into the National Seismic Hazard model through our partners at GNS Science and the new Natural Hazards Platform to enhance our understanding of the hazards and risks posed to the Wellington region.

This work will build upon a wealth of existing Hikurangi subduction zone research farther north(e.g., Wallace et al., 2016; Yarce et al., 2019; Yarce et al., 2023), undertaken in part through an Endeavour Fund project that concluded in March 2022, and a Marsden-funded deployment offshore Pōrangahau. Understanding the range of seismic behaviours in this region is necessary to identify the underlying processes at work and to build a more holistic picture of the hazard posed to central New Zealand. Since there was neither time nor budget to analyse the data in this project, we are currently preparing a full proposal to Marsden to fully analyse the data we have collected, in connection with the previous data collection.

Methodology

We deployed 20 seismometers from the Tangaroa on the first voyage (TAN2317b) in November of 2023. We located the seismometers using standard triangulation with acoustic signals sent to the seismometers once they arrived on the ocean floor. To retrieve the seismometers with the Tangaroa in January 2025, we sent acoustic signals to release the seismometers and followed their signals when they reached the surface. Final retrieval occurred after they were sighted. Before retrieval of the instruments, preparatory work on re-locating earthquakes that GeoNet had recorded in the general vicinity of the locked region was carried out, using GeoNet data and data from a community project that installed RaspberryShake seismometers.

The seismometers were returned to the NFSI in Canada, after which the data were retrieved and time corrections were applied. Spectrograms were calculated for each station, channel and each month. The NFSI team provided the digitized (primary and auxiliary) data and metadata in the form of mini-SEED and station XML files, respectively.

Primary channels include the three-component seismic waveforms sampled at 250 Hz. The auxiliary channels record the internal and external environment of the station. Metadata information describes each primary and auxiliary data channel, including location, instrumentation, and operational parameters. The orientation of seismic stations on the seafloor is generally unknown and must be established before standard seismological analyses can be performed. A necessary first step is thus to determine the orientation of each station and realign the components of motion along the North-East-Vertical coordinate system.

The Aquarius seismometer instrument employs the naming scheme H1 and H2 for the horizontal components, with H2 oriented orthogonally clockwise from H1, and H3 for the near-vertical, upward-positive component. This results in a left-handed coordinate system, with components 123 in the yxz directions, respectively (see Figure 2 below). The station's orientation is fully characterized by the dip (inclination) and azimuth (measured clockwise from North) of each of the three components of motion (i.e., six angles). In practice, determining the station orientation requires only three key pieces of information: the dip and azimuth of the tilt axis, and the azimuth of the H1 component.

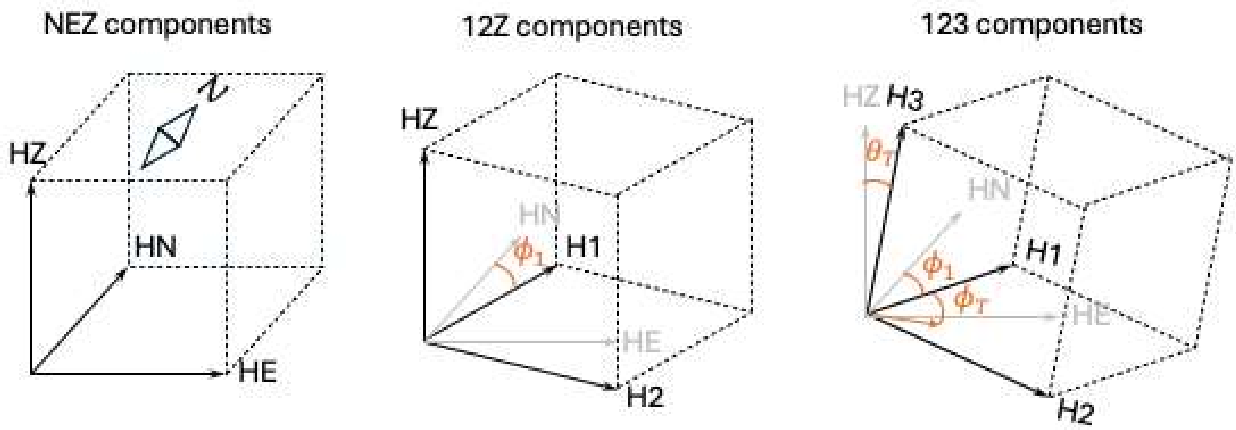

Figure 2. Definition of the orientation of the three components of ground motion recorded by the seismometer. On the seafloor, the seismometer is rotated and tilted, leading to the nomenclature 123. After determining the azimuth of the H1 component (ϕ_1), the tilt angle (θ_T) and the tilt direction (ϕ_T), we can rotate the instrument back to the North-East-Vertical (NEZ) coordinate system.

Tilt effects are caused by the station resting on a non-horizontal (i.e., tilted) surface. The tilt axis is defined by the orientation of the pole (or unit vector) to this plane; by definition, it coincides with H3. We characterize the orientation of H3 using two angles: the angle between H3 and the vertical axis HZ (i.e., the *tilt angle*, θ_T), and the angle between the H1 axis and the tilt azimuth (i.e., the *tilt direction*, ϕ_T) (see Figure 2). For NFSI data, the tilt angle is determined upon recovery using recordings from the accelerometer aboard the seismograph. The tilt direction can be found by analyzing seismic noise data to determine the rotation angle (clockwise from H1) that maximizes the coherence between H3 and the rotated H1 components. This analysis is performed daily.

Finding the orientation of the horizontal components on the seafloor requires the analysis of polarized signals with known particle motion. This can be done in several ways: 1) longitudinal polarization caused by incoming P waves from earthquakes with known locations, 2) radial-vertical polarization from Rayleigh waves caused either by known earthquakes or ambient seismic noise, and 3) other known polarizations (e.g., seismic noise or acoustic pings from known ship locations, etc.). For broadband OBS data, the most reliable estimate of station orientation is from the Doran-Laske (DL) method (Doran and Laske, 2017), which relies on the expected correlation between the (Hilbert transformed) horizontal-radial HR and vertical HZ or H3 components. The rotation angle ϕ_R from HN to HR is known from the earthquake-to-station great circle path. The problem thus involves determining the rotation angle ϕ_1 to maximize the correlation coefficient between H1 and HZ or H3. The difference between ϕ_R and ϕ_1 provides an estimate of the azimuth of H1. Thanks to the dispersive property of surface waves, this calculation can be done for several wavelengths (or periods), as well as for the short and long orbits of propagation around the globe, thus providing multiple estimates for a single earthquake. A quality control parameter, the correlation coefficient, is used as a filter to yield a final robust estimate.

Alternatively, the Braunmiller-Nabelek-Ghods (BNG) method (Braunmiller et al., 2020) is based on the longitudinal polarization of P waves from earthquakes. When a P wave arrives from below at some non-zero incidence angle, its longitudinal polarization yields linear radial-transverse particle motion pointing in the direction of back-azimuth (i.e., azimuth from the station to the earthquake). This method thus seeks to find the azimuth of H1 for which the particle motion aligns with the back-azimuth angle. This is done automatically for all available earthquakes recorded, and several filters are used to yield a reliable and robust estimate.

These methods were used to determine the orientation of the seismometers during a training workshop held from April 14 to 16 as part of a Catalyst: Leaders fund project that brought AI Pascal Audet to New Zealand. In addition to seismometer orientation, the workshop enabled users to perform initial receiver function calculations and modelling, as well as initial testing to detect small earthquakes using AI methods. The results from those efforts are too preliminary to report herein.

Results and discussion

Instrument Locations, Data Quality and Station Orientations

Following deployment of the instruments overboard, the site locations on the seafloor were determined by a survey procedure. Table 1 gives the surveyed instrument positions and the start and end times for all 20 OBS instruments deployed on TAN2317b.

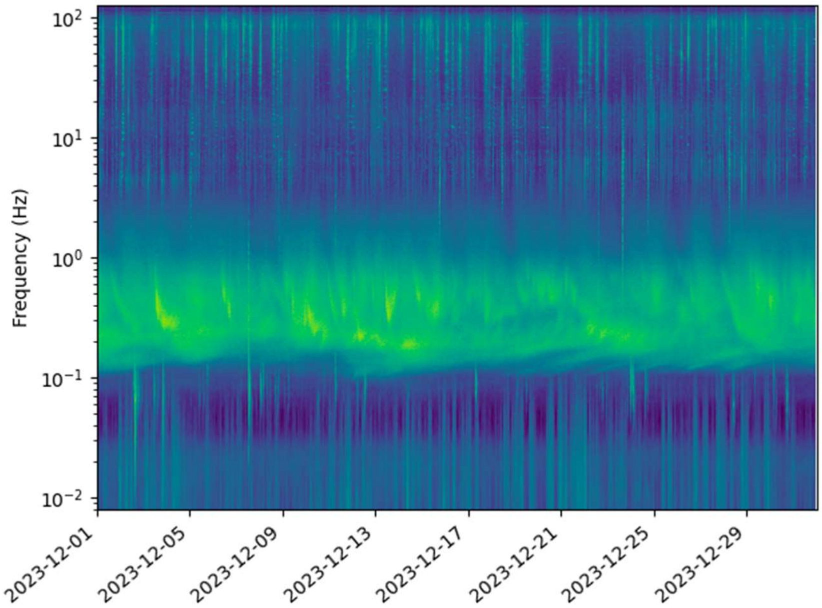

Figure 3. Spectrogram of ground motion acceleration for channel CH3 (near-vertical component) for December 2023 measured at station EL23A.

Figure 3 shows an example of a spectrogram in December 2023 for one of the seismometers, highlighting the high data quality of the ELVES deployment. The strong energy at frequencies between 0.1 and 1 Hz corresponds to fluctuations in the primary and secondary micro-seismic peaks. Vertical spectral lines may correspond to seismic events at various distances, including global, regional, and local earthquakes. These data also contain noise from infragravity waves, passing ships, seafloor mass wasting events, ocean-bottom currents, and other weather/climate-related effects.

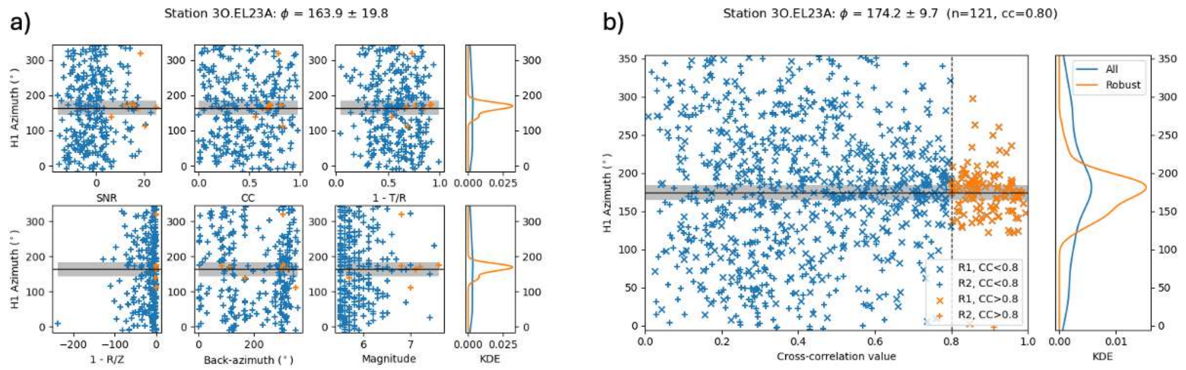

Figure 4. Azimuth of component H1 for station EL23A determined using the BNG method (a) and the DL method (b). In a) the H1 azimuth is shown for all teleseismic P waves recorded at the station. Blue and orange symbols represent poor and good results, respectively, based on predetermined filters for signal-to-noise ratio (SNR), cross-correlation value (CC), and amplitude ratios. The panels on the right indicate the distribution of good estimates, and the final value is displayed at the top with its associated uncertainty. In b) the H1 azimuth is shown for all surface waves at various periods and for both the short (R1) and long (R2) orbits. Blue and orange symbols show the poor and good results, respectively, based on the cross-correlation value (CC). The panels on the right indicate the distribution of good estimates, and the final value is displayed at the top with its associated uncertainty.

Figure 4 shows an example of determining the seismometer orientation in terms of the azimuth of component H1. Both the BNG and DL methods yield consistent and reliable estimates. The final value is taken as the mean of the two methods.

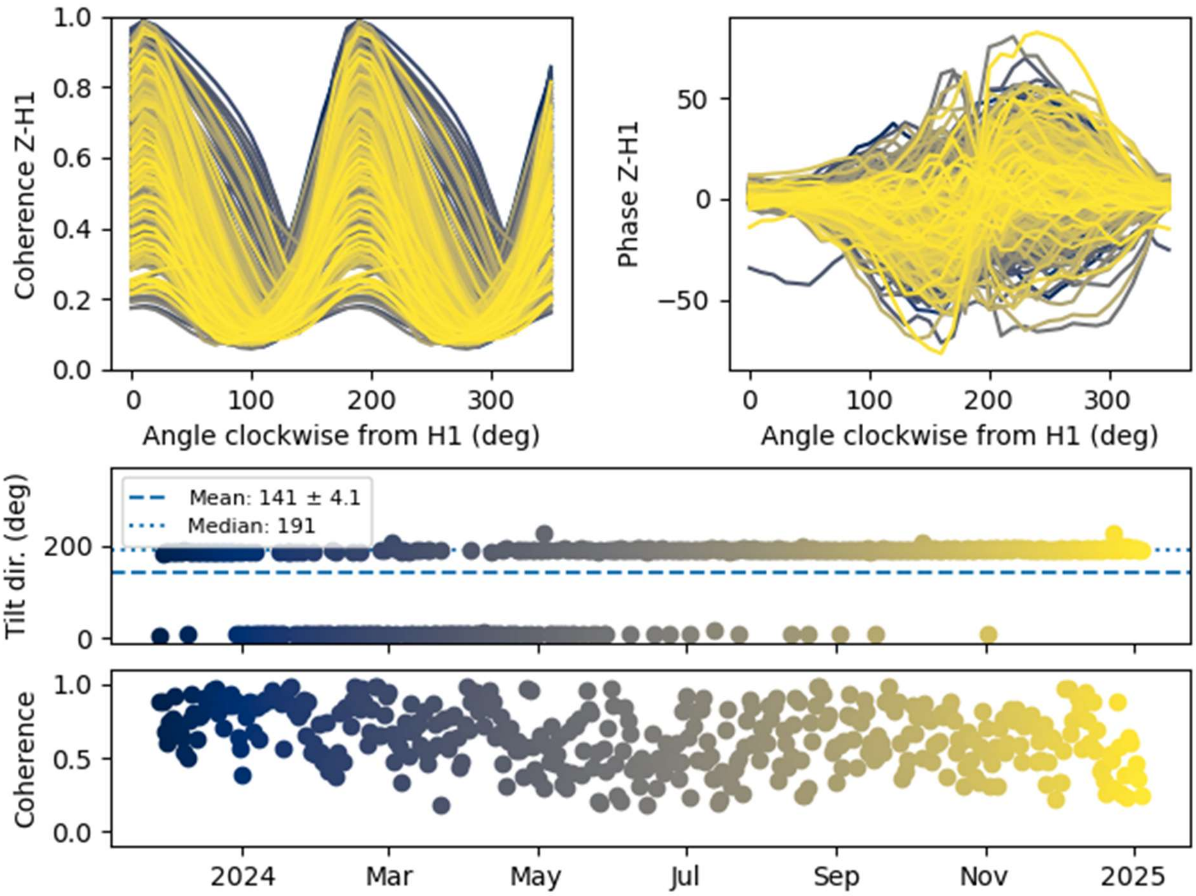

Figure 5. Daily measurements of the tilt direction from the analysis of ambient noise for station EL23A. The tilt direction has a 180-degree ambiguity, shown here as a double-peaked coherence, and the two possible directions are plotted as colored circles as a function of time. The median is taken as the robust measure of tilt direction.

The tilt direction can be found by analyzing seismic noise data to determine the rotation angle (clockwise from H1) that maximizes the coherence between H3 and the rotated H1 components. This analysis is performed daily, and the results are shown in Figure 5.

Table 2 presents the final orientations of the 18 seismometers that were retrieved in terms of the three angles.

Earthquake locations

Edinburgh University student Daniel Murray is participating in a study abroad programme at Victoria University of Wellington. As part of a Directed Individual Study course, he determined arrival times at the OBS stations for 15 earthquakes previously located by GeoNet. He used the NonLinLoc nonlinear location code (Lomax et al., 2009) with the NZAtom three-dimensional velocity model (Chow et al., 2022) to relocate the earthquakes. Figure 6 shows an example of waveforms of some of the picked arrivals, and Figures 7 and 8 show the locations of the 16 earthquakes relative to the GeoNet locations.

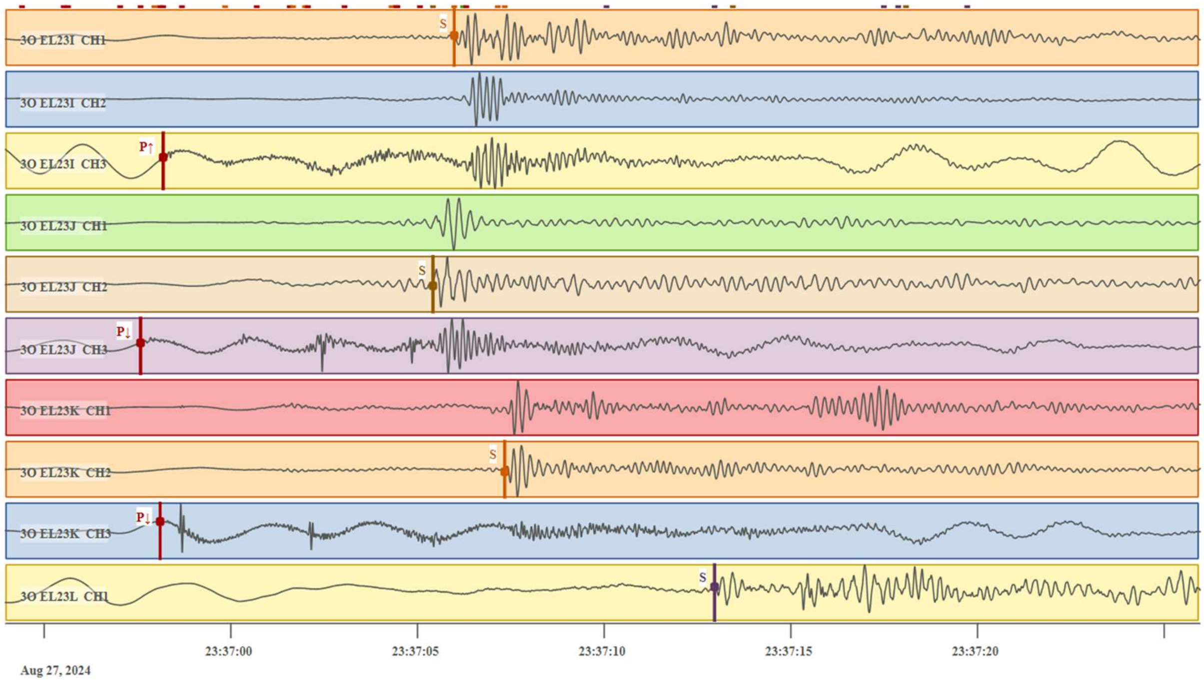

Figure 6. Waveforms of an offshore magnitude 2.18 earthquake located by GeoNet on August 27, 2014. 10 channels from 4 stations (EL23I, EL23J, EL23K, EL23L) are shown. P phases are picked on the vertical (H3) channel, whereas S waves are picked on one of the two horizontal channels (H1 or H2).

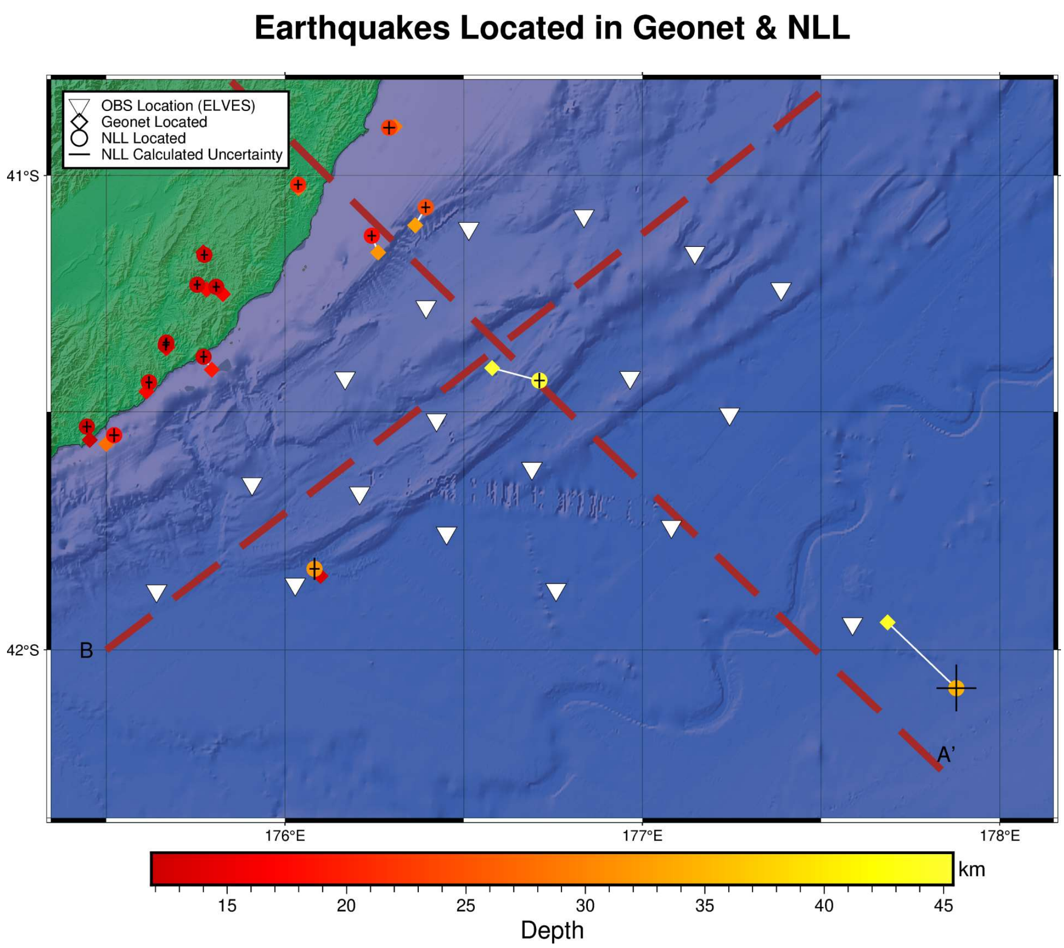

Figure 7. Map view of the earthquakes determined by GeoNet (diamonds) and their relocations (circles) using the nonlinear location code NONLINLOC (Lomax et al., 2009) and the arrival times determined by both GeoNet and by Daniel Murray on the ELVES OBS. Grey lines connect the same earthquakes located by the two methods. Line A-A' is the cross section shown in Figure 8. Note that the on-land locations are close, while some of the offshore earthquakes have larger variations.

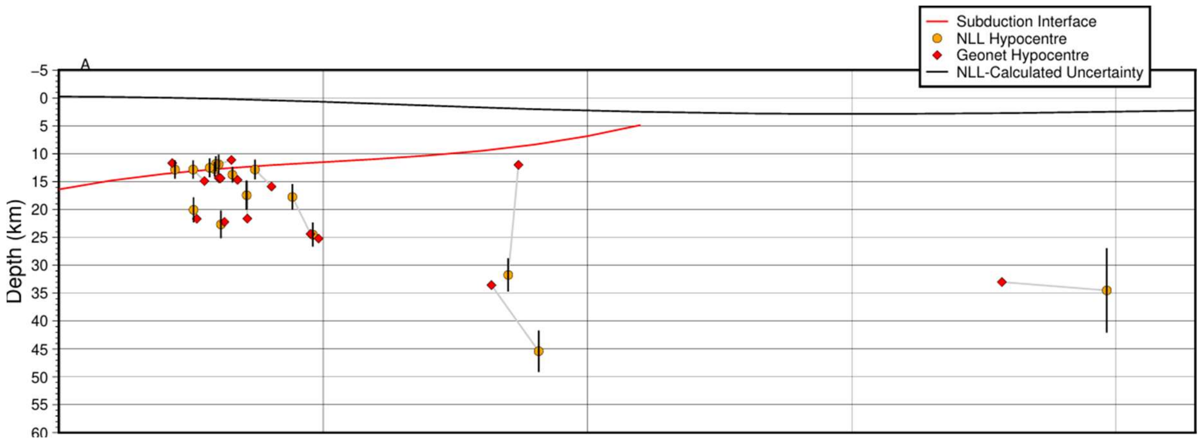

Figure 8. Cross section of earthquake locations along line A-A' in Figure 7, with the same symbols used. The red line is the subduction interface determined by Williams et al. (2013). Depth variations are apparent for offshore earthquakes.

Issues and Notes

Seismometer failures in 2022 and 2025: We had planned to deploy seismometers in January 2023. However, the seismometers came from a new pool of equipment. A test deployment of the equipment in deep water revealed some teething problems with the instrumentation and retrieval, including timing issues, difficulty communicating with the seismometers on the ocean floor and rusting of parts. The issues needed to be resolved before our deployment to ensure we could retrieve the instruments and obtain usable data recovery. The timeline for addressing these issues made it very difficult to ship the equipment in time for the planned voyage. We therefore requested a variation of the contract to delay the deployment by one year. Delaying the project allowed us to resolve the instrument issues. However, during the shipping of ancillary equipment used to locate the instrument on the seafloor during deployment, the NFSI team learned about the dual commercial and military use of the equipment and the additional permits required. This would have significantly delayed the deployment, jeopardizing the entire project. Thankfully, a plan B was quickly put in place to bypass the need for this ancillary equipment and use alternative, non-dual-use gear to locate the instrument on the seafloor during the deployment.

During the recovery trip, we were able to retrieve 18 out of the 20 seismometers deployed, due to circumstances that are not yet fully understood. Station EL23F did not respond to any commands sent. EL23R received three burn commands to release the station's anchor, but they did not appear to be effective. An automatic release signal was set for March 2025, but there is still no sign of the instrument. Two more stations would have been lost due to a lack of communication with the instrument once they were released from the seafloor; thankfully, the issue was that the stations were floating upside-down, which disabled all communication devices. The stations were located visually and pulled on board thanks to the expertise of the crew members.

Health of crew: On both voyages, several of the people who were meant to stand on the watches were seasick to the extent that they could not leave their cabins. On the deployment voyage, one watch-stander tested positive for COVID-19 just before the first watch started and remained in isolation for several days in their cabin. That meant that the schedules of the watch-standers had to be changed, leading to fatigue and strain on remaining watchstand.

Table 1. ELVES-1 instrument locations. The position was obtained by post-deployment acoustic transponder surveys, once the instrument had settled on the seafloor.

Station Name	Serial Number	Date Deployed (mmddyy) local	Time Deployed (NZDT)	Latitude	Longitude	Date Retrieved (mmddyy) local	Time Retrieved (NZDT)
EL23A	AQU-4261	28/11/2023	18:26	-41.11711	176.51380	1/05/2025	10:38
EL23B	AQU-B163	28/11/2023	21:27	-41.09093	176.83309	1/05/2025	6:56
EL23C	AQU-8163	29/11/2023	0:52	-41.166389	177.14712	1/04/2025	10:29
EL23D	AQU-B263	29/11/2023	5:13	-41.23887	177.38945	1/04/2025	8:25
EL23E	AQU-C85A	28/11/2023	5:22	-41.27135	176.39005	1/07/2025	0:21
EL23F	AQU-8063	28/11/2023	8:34	-41.34854	176.69172		
EL23G	AQU-0964	28/11/2023	12:20	-41.42783	176.96377	1/05/2025	16:48
EL23H	AQU-835E	29/11/2023	10:59	-41.514928	177.35561	1/06/2025	19:05
EL23I	AQU-8263	28/11/2023	2:24	-41.43423	176.16460	1/07/2025	6:32
EL23J	AQU-F961	27/11/2023	23:25	-41.52596	176.43651	1/07/2025	8:13

EL23K	AQU-0A64	27/11/2023	19:58	-41.620701	176.69035	1/06/2025	15:31
EL23L	AQU-B063	27/11/2023	15:40	-41.74200	177.08832	1/06/2025	5:17
EL23M	AQU-1762	27/11/2023	8:30	-41.946751	177.58094	1/06/2025	1:38
EL23N	AQU-945F	26/11/2023	10:17	-41.65302	175.91105	1/07/2025	15:00
EL23O	AQU-035F	26/11/2023	14:05	-41.674674	176.20917	1/07/2025	12:57
EL23P	AQU-555A	26/11/2023	17:46	-41.75789	176.451	1/07/2025	10:59
EL23Q	AQU-B15A	26/11/2023	23:09	-41.87578	176.75326	1/06/2025	12:53
EL23R	AQU-FE61	27/11/2023	3:13	-42.016455	177.03012		
EL23S	AQU-105D	26/11/2023	1:47	-41.872598	175.64865	1/07/2025	19:55
EL23T	AQU-DF5B	26/11/2023	5:54	-41.866146	176.03068	1/07/2025	17:21

Table 2. ELVES station orientations and surveyed depth. Note that these are preliminary determinations and may be changed with further analysis.

Station Name	H1 Azimuth (deg)	Standard Deviation	Tilt Direction (deg)	Tilt Angle (deg)	Surveyed Depth (m)
EL23A	170	1.5	191	1.8	1198.7
EL23B	15	1.4	58	4.3	1579.6
EL23C	304	1.1	270	6.6	1817.6
EL23D	153	4.8	358	3.4	2508
EL23E	83	0.6	320	0.4	1192.9
EL23F					1757.6
EL23G	27	0.6	87	2.0	2551.2
EL23H	248	2.3	307	5.3	2885.1
EL23I	305	2.3	215	3.6	1139
EL23J	37	3.0	209	0.6	1919.9
EL23K	245	4.2	304	4.4	2628.2
EL23L	235	0.8	353	1.1	2870.3
EL23M	218	2.7	304	3.7	2828
EL23N	256	6.3	316	3.8	1754.8
EL23O	151	12.5	302	1.0	2097
EL23P	258	2.7	251	6.9	2767.5
EL23Q	334	3.5	246	2.2	2798.2
EL23R					2804.5
EL23S	161	1.3	337	1.1	2484.1
EL23T	356	3.7	295	0.6	2687.3

Conclusions

We have deployed 20 and retrieved 18 seismometers from the ocean floor in the locked region of the Hikurangi margin, offshore the Wellington/Wairarapa region. The data are high quality in the sense that we were able to use teleseismic events recorded during the deployment to determine their orientation, and we were able to determine arrival times from earthquakes previously located by GeoNet. The orientations will allow us to carry out structural studies such as shear-wave splitting to determine azimuthally anisotropic properties, receiver function analysis to determine the shear-wave velocity structure and noise cross-correlation analysis to determine Love and Rayleigh wave velocity structure, which will allow a determination of the radial and azimuthal anisotropic fabric of the subducting plate.

Several earthquakes located by GeoNet have been detected on the seismometers. The waveforms show clear earthquake phases, and we have successfully used them to relocate the earthquakes using a three-dimensional velocity model. Most relocated earthquakes align more closely with the plate interface, indicating the thrust fault is active despite being dominantly locked. Preliminary AI analysis on a few stations has detected numerous possible small earthquakes that have been undetected by GeoNet.

Several key learnings from the deployment were that one should be cautious when using instruments that may have potential military applications, particularly if they are imported from other countries. Furthermore, there should be enough people on board designated to watch stands and other duties so that there can be substitutes in the case of sickness of the scientific crew.

Once the earthquakes are located and analyzed compared to nearby earthquake and slow slip catalogues, we expect that we will be able to better understand the earthquake and tsunami potential posed by the Hikurangi subduction zone, our largest plate boundary. This area has fundamental implications for public safety and NZ's economic security. The new data fills a critical observational gap on the most hazardous portion of the zone and will significantly improve understanding of these hazards, leading to disaster risk reduction. If the locked and creeping portions of the subduction zone rupture together, a magnitude 9 or above earthquake may occur. Estimates from the National Emergency Management Agency suggest that a magnitude 9 earthquake and resultant tsunami on the East Coast could kill over 22,000 people and injure 26,000. Up to 400,000 people are projected to be displaced, with 30,000 homes suffering damage or complete destruction, leading to an estimated $144 billion in damage (https://www.dpmc.govt.nz/sites/default/files/2024-02/bim-2023-nema.pdf). If a smaller magnitude event is more likely, less damage would occur. By yielding a greater understanding of the hazards, our work will lead to better models and more informed decision-making through our outreach to communities and hazard planning groups.

Outputs and dissemination

For training outputs, we took two Canadian PhD students, Taylor Tracey Kyrulik and Quan Zhang, and two New Zealand undergraduate students, Sam Clouston and Zhiuian Zhang, on the deployment trip on TAN2317b in November 2023. In January 2025, we sent Quan Zhang and Sam Clouston again, as well as New Zealand undergraduate students David Hobbis and Daniel Murray (who is on an exchange programme from Edinburgh University), on the recovery trip on TAN2501.

As part of a related Catalyst grant, AI Pascal Audet led a workshop to train 16 people in the New Zealand Geoscience community how to analyse OBS data (https://sites.google.com/view/2025obsworkshop/home).

The software packages used to orient the sensors used during workshop training are publicly available on the NFSI GitHub page (https://github.com/nfsi-canada) and were all updated prior to the workshop.

The NFSI currently holds all the data at their facilities in Canada, and has made the data available to all the investigators on the project. One full copy is currently on the VUW computer servers. NFSI is developing a data policy, with a likely three-year embargo period once the dataset has been delivered to the PIs, after which time the data will be available to the public. They are in the process of setting up a public-facing server to distribute the data through FDSN web services. We are also discussing with GeoNet how best to ensure the data can be kept intact and available for other researchers after a similar embargo period.

Publications, communications and engagement

Outreach Activities

With Toka tū Ake EQC we prepared a press release in January of 2022, soon after the funding was announced, which led to several articles in New Zealand newspapers.

With the help of Georgia McCombe of East Coast Lab, we put a description of the experiment on the "Science Projects" section of the East Coast Lab website in October of 2023 https://www.eastcoastlab.org.nz/projects/science-projects/.

We also worked with Toka tū Ake EQC to develop media content about the preparation of the deployment and loading the ship. TVNZ used that content and their own, to broadcast a story on the first deployment day (Saturday 25 November at 6 PM)

https://www.1news.co.nz/2023/11/25/experts-study-earthquake-tsunami-risk-from-nzs-most-active-fault/

https://www.stuff.co.nz/science/133266336/hikurangi-subduction-zone-how-dangerous-is-locked-part-of-our-biggest-earthquake-fault

Video footage was recorded on board, and was used to produce a social media post by GNS Science. Several blogs were also written by students on board, which was uploaded to a series of posts by East Coast Lab in the weeks following the voyage:

https://www.eastcoastlab.org.nz/news/article/227/rv-tangaroa-blog-day-1-off-to-a-rocky-start

https://www.eastcoastlab.org.nz/news/article/228/rv-tangaroa-blog-day-2-getting-our-sea-legs

https://www.eastcoastlab.org.nz/news/article/229/rv-tangaroa-blog-day-3-overcoming-obstacles

https://www.eastcoastlab.org.nz/news/article/230/rv-tangaroa-blog-days-4-and-5-re-route-to-re-survey

The East Coast Lab was no longer operating by the time of the retrieval in 2025. Instead, GNS Science hosted a discussion of the deployment on their web page: : https://www.gns.cri.nz/news/elves-helping-understand-the-hikurangi-subduction-zone/

Presentations to scientists and Stakeholders

We presented results from recent OBS deployments, and the state of the ELVES deployment at community workshops and meetings at the: Marine Geophysics Workshop in Wellington on August 29 2023; Wellington Earthquake Resilience Collaboratory meetings on 18 June 2024 and on 13 November 2024, and we have agreed to give another presentation on 18 June 2025.

We have presented results from recent OBS deployments, and the state of the ELVES deployment at scientific meetings at the Geological Society of New Zealand meeting in Dunedin in 2024, and the American Geophysical Union in Washington DC in 2024. AI Audet delivered a series of seminars at various New Zealand institutions, including GNS Science, VUW, U. Canterbury, U. Otago, and U. Auckland, to showcase the NFSI infrastructure using ELVES as a case study.

Stephen Kwong has submitted his PhD thesis as part of the Marsden grant on PULSE.

Publication citations

3499/3050 Seismic Hazards from Earthquakes in the Locked Zone Offshore

Kwong, S., Microseismicity, Stress, and Slow Slip near Pōrongagau, Hikurangi Subduction Zone, New Zealand, 261 pp., PhD thesis, Victoria University of Wellington, submitted May 2025. Under review.

Savage, M.K., Kwong, S., Warren-Smith, E., James, L., Mochizuki, K., and Wallace, L.M., 2024, Seismicity and moment tensors from a dense deployment spanning slow slip earthquakes in the central Hikurangi margin, New Zealand, Abstract S31D-3261, presented at AGU24, 9-13 Dec. 2024. (https://agu.confex.com/agu/agu24/meetingapp.cgi/Paper/1653230)

Savage, M.K., Kwong, S., James, L., Warren-Smith, E., Jacobs, K., Mochizuki, K., and Wallace, L.M., 2024, Seismicity and moment tensors from a dense deployment spanning slow slip events near Pōrongahau, central Hikurangi margin, in GSNZ Abstract Volume, Annual Conference 2024 25-29 Nov. University of Otago, Ōtepoti Dunedin, GSNZ Miscellaneous Publication 167A, ISBN (PDF): 978-1-0670512-0-4, p. 223. https://gsnz.org.nz/assets/Uploads/Shop/Products/GSNZ_annual_conference/MP167_2024_Dunedin/MP167A_2024_GSNZ_conference_Dunedin_abstracts.pdf

Kwong, S., Savage, M.K., Warren-Smith, E., and Jacobs, K., 2023, Using Deep Learning Algorithms to Create a Microseismicity Catalogue of the Central Hikurangi Margin to Understand SSE Episodicity, Abstract (T31H-0301), presented at AGU23, 11-15 Dec (https://ui.adsabs.harvard.edu/abs/2023AGUFM.T31H0301K/abstract)

Kwong, S., Savage, M.K., Warren-Smith, E., and Jacobs, K., 2023. Using deep learning algorithms to create a microseismicity catalogue of the Pōrangahau region to understand SSE episodicity, Abstract in: Frontin-Rollet, GE and Nodder, SD (eds), Geoscience Society of New Zealand Annual Conference 2023: Abstracts Volume, GSNZ Miscellaneous Publication 164A: 280pp. (This won the prize for the best Geophysics poster of the conference) (https://gsnz.org.nz/assets/Uploads/Shop/Products/GSNZ_annual_conference/MP164_2023_Wellington/MP164A_2023_GSNZ_conference_Wellington_Abstract_Volume.pdf)

Kwong, S., Savage, M.K., Jacobs, K., Warren-Smith, E., and, Wallace, L., Mochizuki, K. Constructing an Earthquake Catalogue to Understand SSE Propagation Mechanisms and Their Interaction with Earthquakes on the Hikurangi Subduction Zone. Workshop Abstracts, 11th ACES International Workshop, Blenheim, 28-February- 3 March, 2023, p. 88 (https://www.gns.cri.nz/assets/News-files/N-files/ACES-files/ACES-Abstracts.pdf)

Kwong, S., Savage, M.K., Warren-Smith, E., Jacobs, K., Wallace, L.M., and Mochizuki, K., 2022, The PULSE Network: Building an Earthquake Catalogue to Understand SSE-Earthquake interaction on the Hikurangi Subduction Zone, in: Zernack A.V., Palmer, J. eds. Geoscience Society of New Zealand Annual Conference 2022: Programme & Abstracts Volume. Geoscience Society of New Zealand Miscellaneous Publication 161A. Geoscience Society of New Zealand, Wellington, B14, p 141. (https://gsnz.org.nz/assets/Uploads/Shop/Products/GSNZ_annual_conference/MP161_2022_Palmerston_North/MP161A_2022_GSNZ_conference_Palmerston_North_Abstract_Volume.pdf

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