Defining “good” in pursuit of “better”: a collective effort to define "good" seismic data quality using New Zealand ambient noise models

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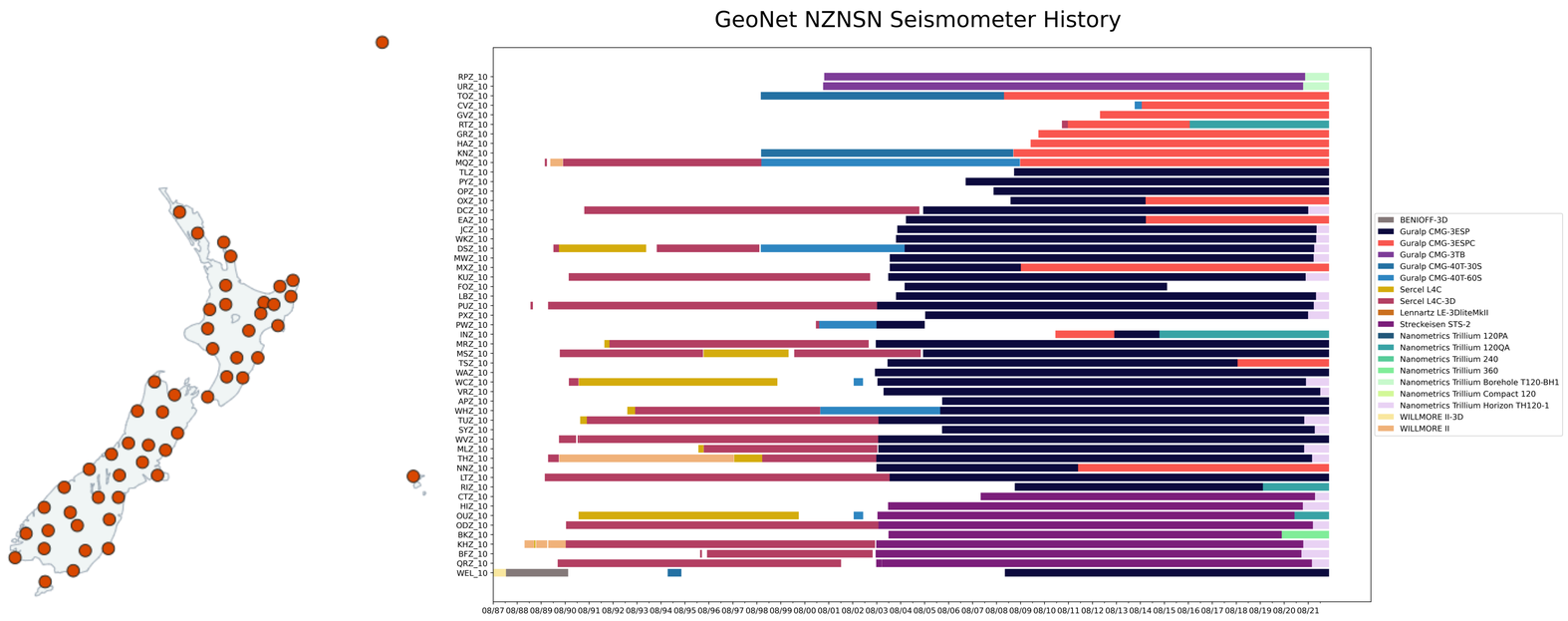
Introduction

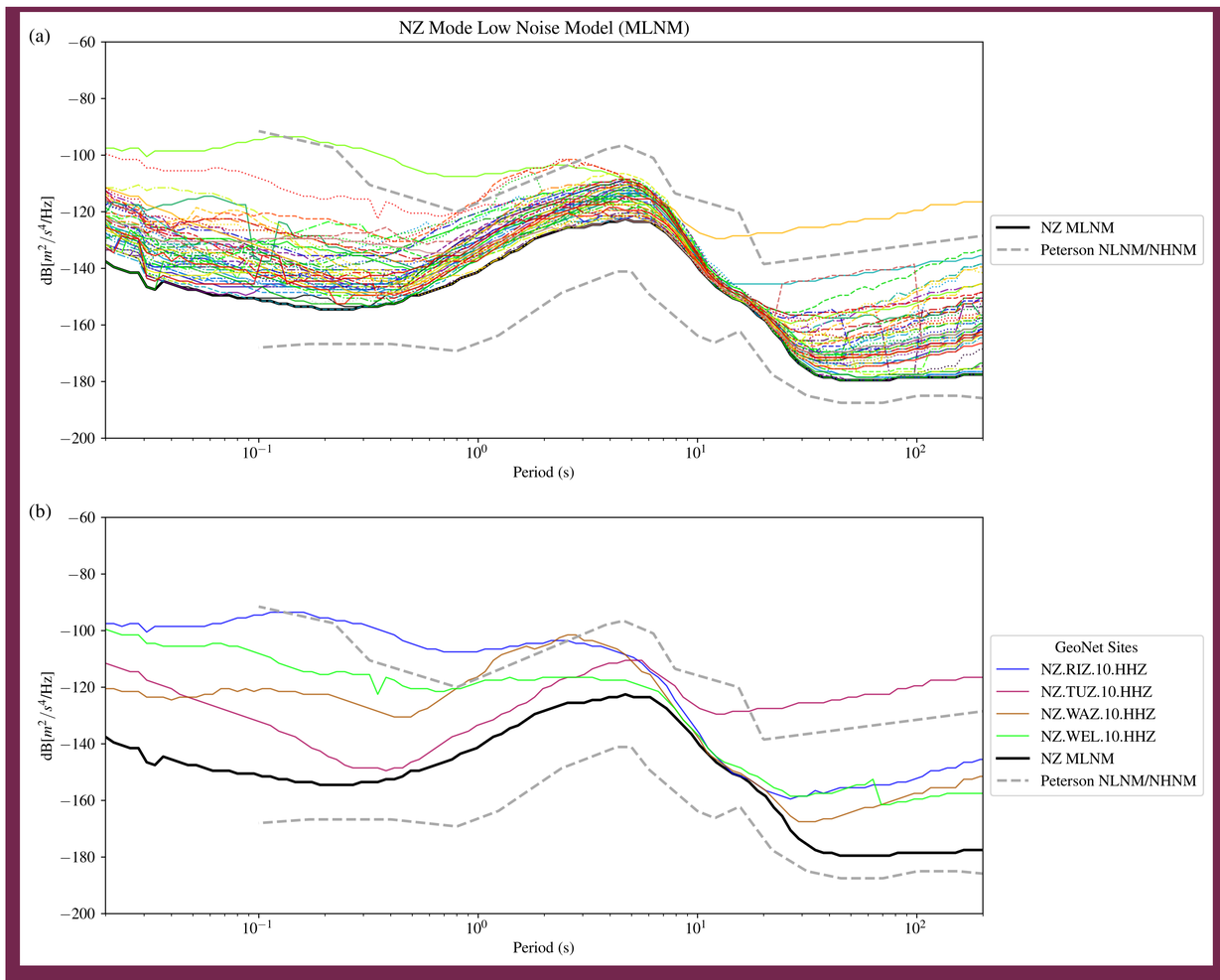
The New Zealand National Seismic Network (NZNSN) totalling some 53 stations forms the core GeoNet seismic network and underpins earthquake, volcano, and tsunami monitoring. In the age of “Big Data”, readily-accessible measures of data quality are critical. To quantify data quality, both a definition of “good” and a way to measure against this are needed. To explore what these could be, we ran a consultation with the expert seismic data user community. Here we focus on one particular output of the consultation: how Probabilistic Power Spectral Densities (PPSDs) of ambient seismic noise could be used to measure seismic data quality. Our definition of “good” took the form of PPSD reference models reflecting the character of seismic noise in the absence of issues at sites, in data collection, or at any other stage in the life history of seismic data. To

Reference Model Parameters

The consultation informed us that using data over a large temporal period with consistent data acquisition systems (DAS — seismometer and digitiser) and a broad frequency range was crucial to a measure of “good”. Therefore the epoch of our analysis was chose to range from 01/01/2010 until 31/12/2020 (11 years) as this encompasses consistent broadband DAS with a corner period greater than or equal to 60s and sampling rates of 100Hz (i.e. we can be confident in our results within a frequency range of 50-0.016Hz or 60-0.02s). To ensure greater spatial coverage we supplemented our 53 NZNSN stations with 5 broadband stations completing the NZNSN as sparse network spread across the country in all seismic environments (broadly speaking). In total 58 stations were used incorporating 53 NZNSN stations and the 5 additional stations (COVZ, KHEZ, MKAZ, OPRZ, RATZ).

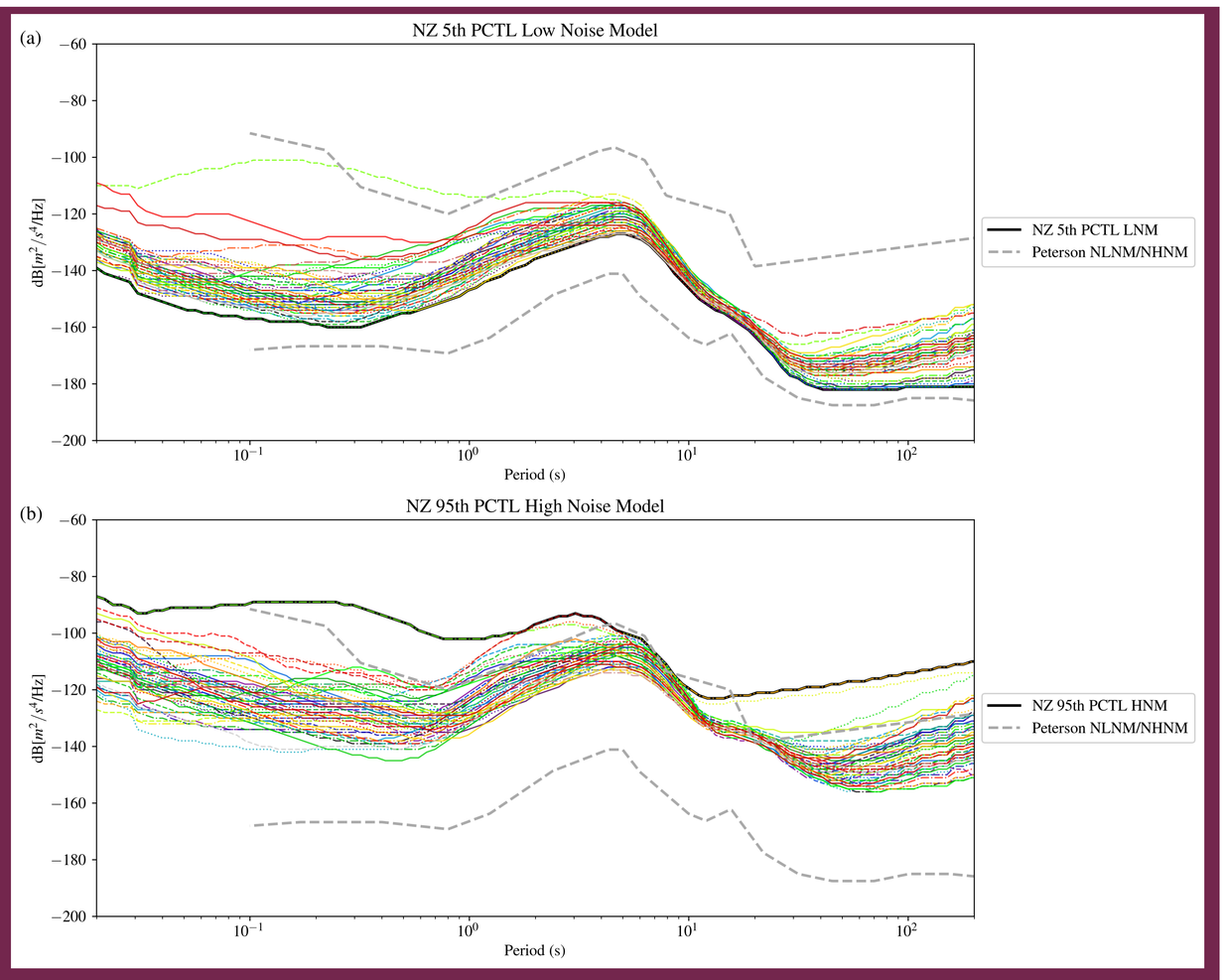


Map of the current operational New Zealand National Seismic Network (NZNSN) as of November 2022 (left) and a Gantt chart representation of location code 10 seismometers at NZNSN stations from 1987 until present day (right).



Network Models — The New Zealand Mode Low Noise Model (NZ MLNM)

(a) The NZ Mode Low Noise Model (MLNM) produced from taking the minimum mode noise power per frequency (or period as displayed) interval across all 58 input stations. The mode is the value which occurs most often in a dataset and for a PPSD represents the most likely seismic energy level across frequencies at a station. The NZ MLNM is represented by the solid black line forming the lower bound of all the individual station modes. The Peterson NLNM and NHNM are provided for comparison as the dashed grey lines . (b) GeoNet sites of interest RIZ, TUZ, WAZ, WEL which show strong variations from the NZ MLNM at both short and long periods as well as in the secondary microseism band.

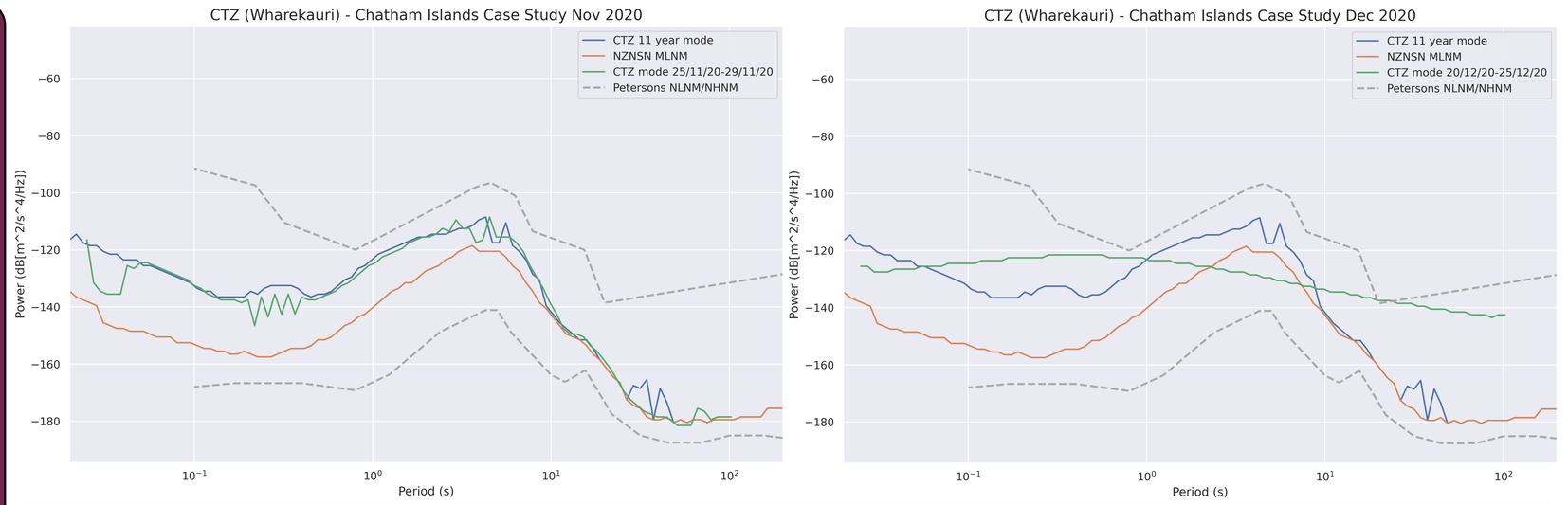


Network Models — The New Zealand Low and High Noise Models (NZ LNM/HNM)

(a) The NZ 5th Percentile Low Noise Model (LNM) and (b) the NZ 95th Percentile High Noise Model (HNM) produced from taking the minimum 5th percentile and maximum 95th percentile noise power per frequency (or period as displayed) respectively across all 58 input stations. The NZ LNM is represented by the solid black line forming the lower bound of all stations 5th percentiles and the NZ HNM is represented by the solid black line forming the upper bound of all the stations 95th percentiles. The Peterson NLNM and NHNM are provided for comparison. Both models were primarily produced to explore the more extreme low and high noise levels of the representative network.

Single Site Models

The single station models are implicitly calculated through our derivation of the network models above. Comparing a short duration (days) station PPSD statistics with that of one of the station’s long term (years) PPSD reference model can provide insight into potential station issues. NZNSN station CTZ (Wharekauri) on the Chatham Islands over November/ December 2020 provides a great example. Here the DAS of the station refers to the combination of the broadband seismometer, cabling/ breakout box, and digitiser/datalogger. Analysing 4 days of vertical component seismic data at the station in November 2020 shows the DAS functioning as expected. An issue with the seismometer mass positions was noticed and work was carried out in early December to swap the seismometer cable/breakout box. Following this, the PPSD mode of 5 days (20-25 December 2020) shows a major disagreement between this short-term mode and both the 11-year CTZ mode and our NZ MLNM. Given the recent works, the problem was very likely related to them, although the effects were not obvious in the regular analysis performed by GeoNet and the issue was not noticed until mid-January 2021. Automating a process of measuring, recording, and visualising the daily difference between a station’s daily PPSD mode and the station’s long-term reference (11-year mode) at distinct frequency/period intervals would be a simple yet powerful way to identify these types of issues easily and readily.



The PPSD short-term mode of NZNSN station CTZ produced from vertical component broadband data (green) from 4 days in November 2020 (left) and 5 days in December 2020 (right). The 11-year PPSD single station mode for CTZ (blue), NZ MLNM (orange), and Peterson NLNM/NHNM (dashed grey) are provided for comparison.

References

Rastin SJ, Unsworth CP, Gledhill KR, McNamara DE; A Detailed Noise Characterization and Sensor Evaluation of the North Island of New Zealand Using the PQLX Data Quality Control System. Bulletin of the Seismological Society of America 2012;; 102 (1): 98–113. doi: https://doi.org/10.1785/0120110064.

McNamara DE., Buland RP; Ambient Noise Levels in the Continental United States. Bulletin of the Seismological Society of America 2004;; 94 (4): 1517–1527. doi: https://doi.org/10.1785/012003001

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