Using nodal seismic sensors to estimate seismic moment tensors
Part A: Effects of signal processing on amplitudes

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This is Part A of the collection; see also Part B, which focuses on the application of nodal stations to seismic moment tensors.

Overview: This document shows the amplitude effects when removing the instrument response of nodal seismic sensors for various water levels and frequency ranges. The nodal sensor examined in this study is a Geo Space GS-30CT/FairfieldNodal ZLAND 3C sensor.

Event selection

During the 400 node deployment along the intersection of the Denali Fault and Parks Highway (2019-02-10 to 2019-03-27) the largest event was:
Mw 7.49 2019-02-22 10:17:28.000 lon -77.09 lat -2.26 dep 121.10 km.
We use this event for comparison purposes since it generated high signal-to-noise levels across a wide frequency range.

Data proccesing

We use the open-source software repository `pysep` (`https://github.com/uafgeotools/pysep`) to fetch and process seismic waveforms from the IRIS DMC. `pysep` employs ObsPy (*Beyreuther et al.*, 2010; *Krischer et al.*, 2015). The three sensors used for comparing waveforms are nodal station ZE.1304 and two broadband sensors XV.FAPT and DE.UAF01. These sensors are within several meters of each other and thus we expect any site effects on the waveforms to be nearly the same. The sample rate of ZE.1304, XV.FAPT, and DE.UAF01 are 500, 100, and 200 Hz, respectively. We filter the waveforms in sac using a four-pole Butterworth filter with corners of 0.05 (20 s) and 0.1 Hz (10 s) for the long period comparison and 0.5 (2 s) and 1.5 Hz (0.67 s) for the short period comparison.
For all waveforms, the instrument response is removed with pre-filter frequencies:

$$
\begin{aligned}
f_1 &= 0.5\, f_2 \\
f_2 &= 4/(endtime - starttime) \\
f_3 &= (sample\ rate)/4 \\
f_4 &= 2\, f_3
\end{aligned}
$$

These recommendations are found from `https://ds.iris.edu/files/sac-manual/commands/transfer.html`. Table A2 lists each stations prefilter values.

Comparison of waveform amplitudes

The water level effects are displayed by making comparisons between waveforms from nodal sensor ZE.1304 and the two neighboring broadband sensors XV.FAPT and DE.UAF01 for various water levels and frequency ranges.

In general, at long periods (10–20 s) the water level must be high in order for the node and broadband waveforms to match. Figure A2 shows that nodal amplitudes are too low at long periods when using a low water level.

This discrepancy does not persist when examining shorter periods (0.67–2 s). Figure A3 shows that waveforms for the node and broadband sensors have the same amplitude and shape for both the high at low water levels at shorter periods.

The instrument response function of the node is not flat for either of the frequency ranges examined here. The nodal response function is shown in Figure A4.

References

Beyreuther, M., R. Barsch, L. Krischer, T. Megies, Y. Behr, and J. Wassermann (2010), ObsPy: A Python toolbox for seismology, *Seismol. Res. Lett.*, *81*(3), 530–533, doi:10.1785/gssrl.81.3.530.

Krischer, L., T. Mengies, R. Barsch, M. Beyreuther, T. Lecocq, C. Caudron, and J. Wassermann (2015), ObsPy: a bridge for seismology into the scientific Python ecosystem, *Computational Science & Discovery*, *8*(1), 014003, doi:10.1088/1749-4699/8/1/014003.

Table A1: A subset of permanent stations and the closest node to each station. The closet node to any permanent station is ZE.1304. It is within several meters of XV.FAPT and DE.UAF01.

network	station	lat	lon	closest node	lat	lon
XV	FAPT	64.549797	-149.083099	ZE.1304	64.549804	-149.083236
DE	UAF01	64.549797	-149.083099	ZE.1304	64.549804	-149.083236
AK	BWN	64.173203	-149.299103	ZE.1254	64.174613	-149.29314
AK	MCK	63.7318	-148.937302	ZE.1197	63.72594	-148.890259
AK	RND	63.405602	-148.860199	ZE.1156	63.409151	-148.884498
AK	CUT	62.4058	-150.262497	ZE.1011	62.402898	-150.259042

Table A2: Prefilter values used when removing the instrument response for each station.

network.station	sample rate	f_1	f_2	f_3	f_4
XV.FAPT	100 Hz	0.0005405	0.0010810	50.0	100.0
DE.UAF01	200 Hz	0.0005405	0.0010810	50.0	100.0
ZE.1304	500 Hz	0.0005405	0.0010810	124.9	249.9

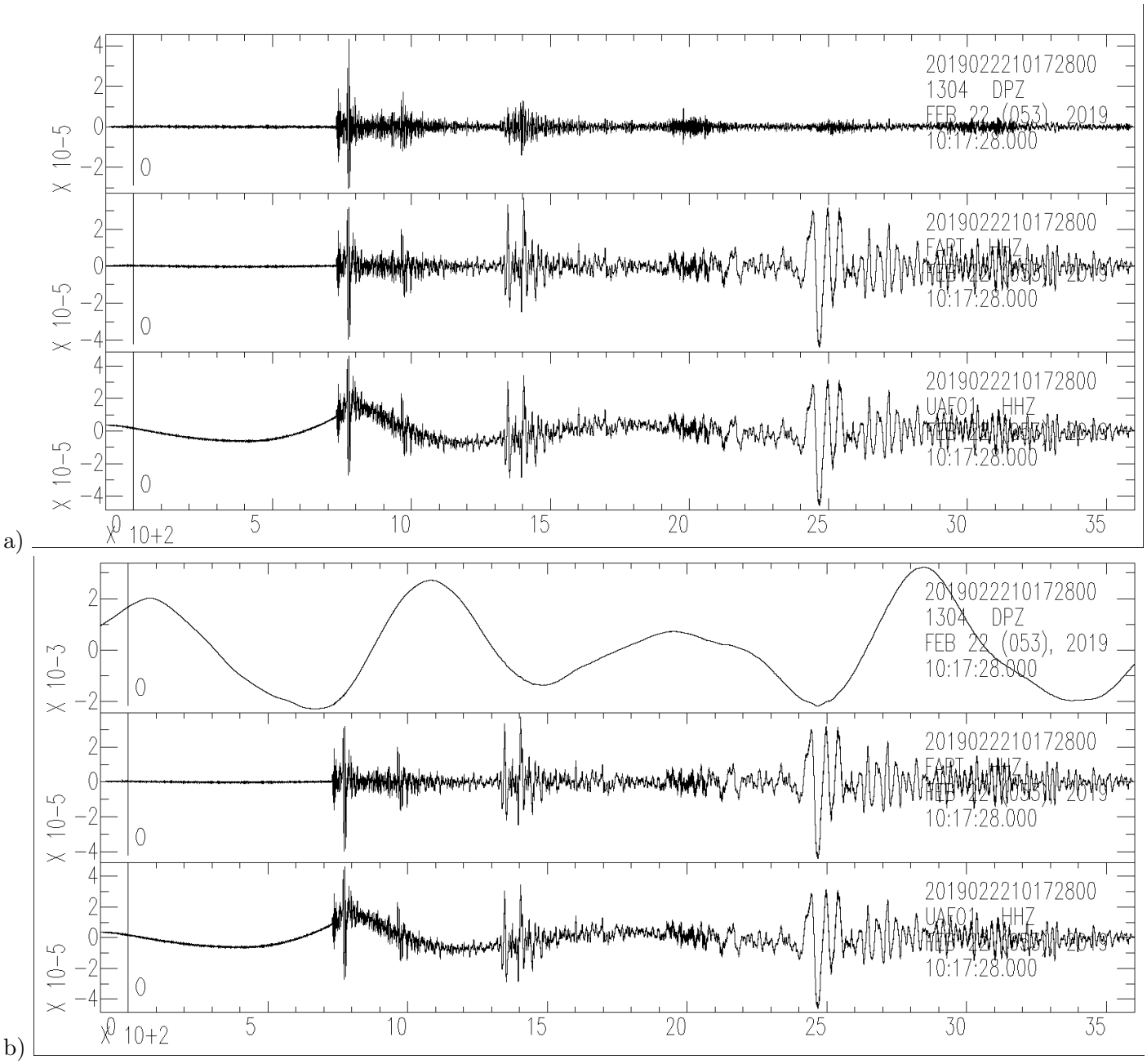

Figure A1: Waveforms for nodal station 1304 and broadband sensors FAPT and UAF01 (instrument response removed). All three sensors are located within a few meters of each other. (a) water level 60. (b) water level 600000. For both water levels the node's waveform differs from the collocated broadband stations. The different water levels also cause the waveforms of the node itself to differ.

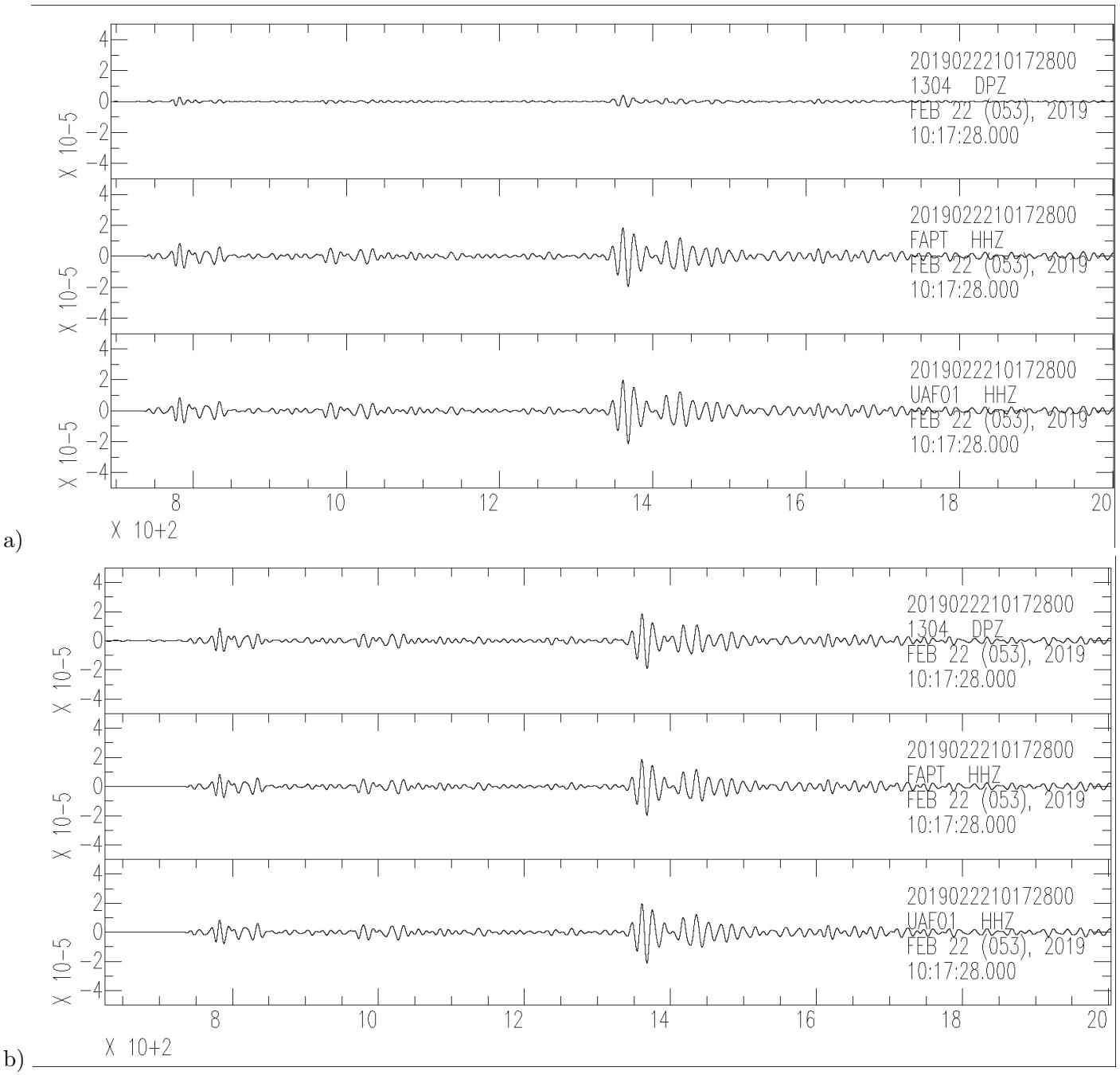

Figure A2: Waveforms filtered (10–20 s) for nodal station 1304 and broadband sensors FAPT and UAF01. All three sensors are located within a few meters of each other. (a) water level 60. (b) water level 600000. The high water level (b) causes the node's waveform to match those of the broadband stations for this bandpass. For the lower water level (a) the amplitude of the node is too low.

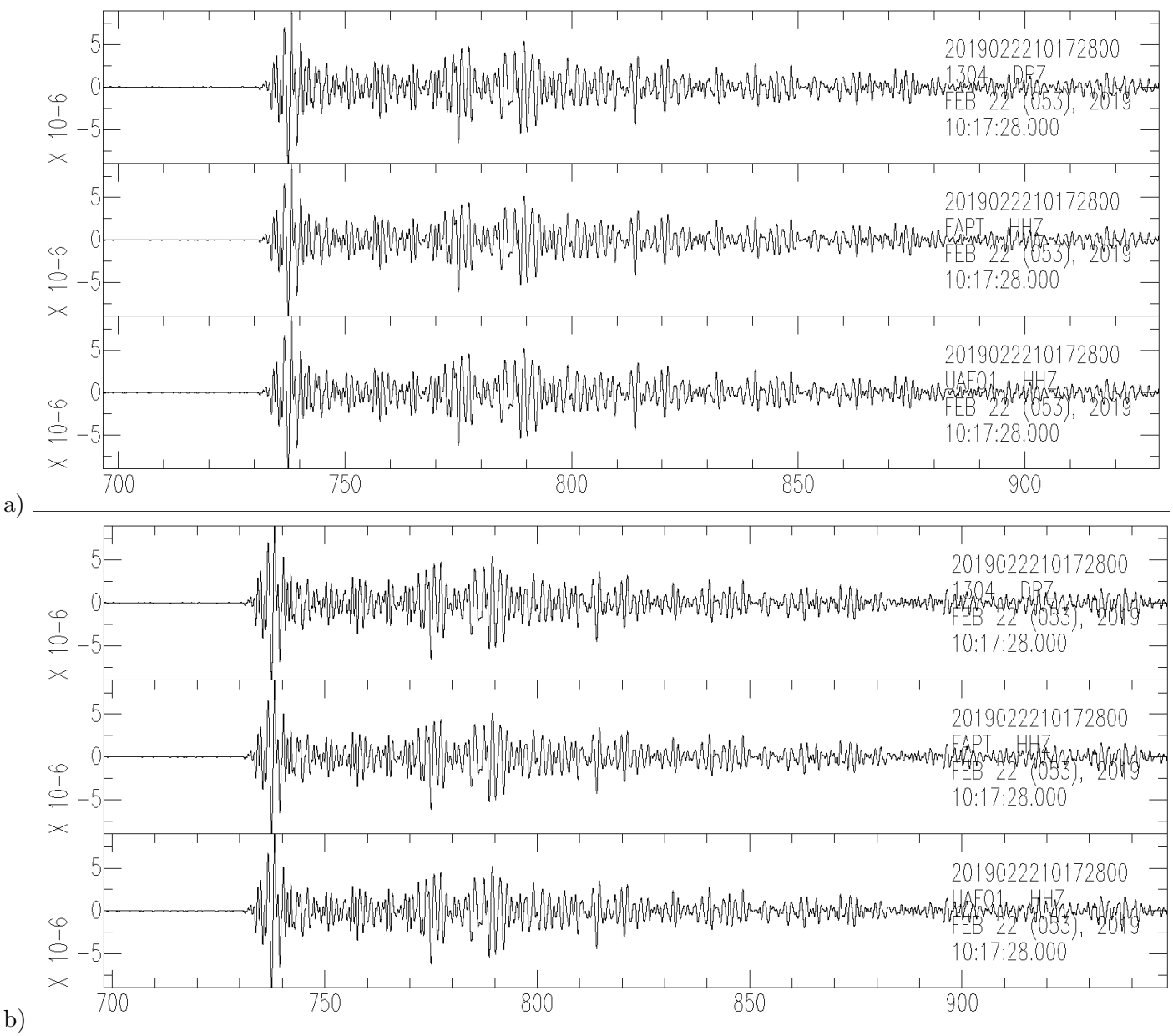

Figure A3: Waveforms filtered (0.67–2 s) for nodal station 1304 and broadband sensors FAPT and UAF01. All 3 sensors are located within a few meters of each other. (a) water level 60. (b) water level 600000. At both the high water level (b) and low water level the node's waveforms match those of the broadband stations for this bandpass. This is not the case for the longer period band (10–20 s) as seen in Figure A2.

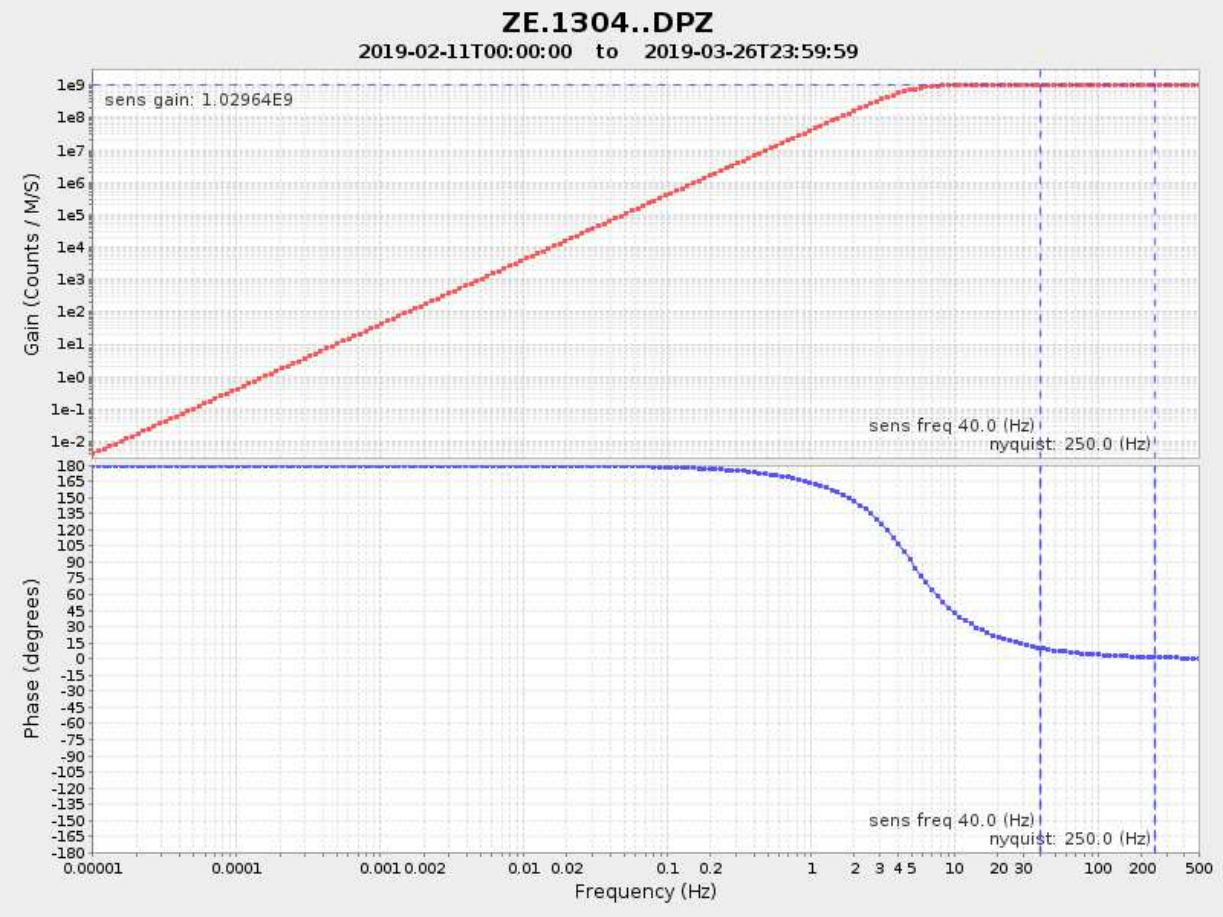

Figure A4: Instrument response function of Geo Space GS-30CT/FairfieldNodal ZLAND 3C nodal stations. Note: this study examines 0.5 to 1.5 Hz (0.67–2 s) and 0.05 to 0.1 Hz (10–20 s). The response function is not flat for either of these bands.