



An Assessment of Seismic Noise Levels for the Advanced National Seismic System Backbone Network and Selected Regional Broadband Stations

By D. E. McNamara, R.P. Buland, H. M. Benz and W.R. Leith

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
yard (yd)	0.9144	meter (m)
Area		
acre	4,047	square meter (m ²)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm ²)
acre	0.004047	square kilometer (km ²)
square foot (ft ²)	929.0	square centimeter (cm ²)
square foot (ft ²)	0.09290	square meter (m ²)

square inch (in ²)	6.452	square centimeter (cm ²)
section (640 acres or 1 square mile)	259.0	square hectometer (hm ²)
square mile (mi ²)	259.0	hectare (ha)
square mile (mi ²)	2.590	square kilometer (km ²)
Volume		
barrel (bbl), (petroleum, 1 barrel=42 gal)	0.1590	cubic meter (m ³)
ounce, fluid (fl. oz)	0.02957	liter (L)
pint (pt)	0.4732	liter (L)
quart (qt)	0.9464	liter (L)
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m ³)
gallon (gal)	3.785	cubic decimeter (dm ³)
million gallons (Mgal)	3,785	cubic meter (m ³)
cubic inch (in ³)	16.39	cubic centimeter (cm ³)
cubic inch (in ³)	0.01639	cubic decimeter (dm ³)
cubic inch (in ³)	0.01639	liter (L)
cubic foot (ft ³)	28.32	cubic decimeter (dm ³)
cubic foot (ft ³)	0.02832	cubic meter (m ³)
cubic yard (yd ³)	0.7646	cubic meter (m ³)
cubic mile (mi ³)	4.168	cubic kilometer (km ³)
acre-foot (acre-ft)	1,233	cubic meter (m ³)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm ³)
Flow rate		
acre-foot per day (acre-ft/d)	0.01427	cubic meter per second (m ³ /s)
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m ³ /yr)
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year (hm ³ /yr)
foot per second (ft/s)	0.3048	meter per second (m/s)
foot per minute (ft/min)	0.3048	meter per minute (m/min)
foot per hour (ft/hr)	0.3048	meter per hour (m/hr)
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per year (ft/yr)	0.3048	meter per year (m/yr)
cubic foot per second (ft ³ /s)	0.02832	cubic meter per second (m ³ /s)
cubic foot per second per square mile [(ft ³ /s)/mi ²]	0.01093	cubic meter per second per square kilometer [(m ³ /s)/km ²]
cubic foot per day (ft ³ /d)	0.02832	cubic meter per day (m ³ /d)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m ³ /d)

gallon per day per square mile [(gal/d)/mi ²]	0.001461	cubic meter per day per square kilometer [(m ³ /d)/km ²]
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m ³ /s)
million gallons per day per square mile [(Mgal/d)/mi ²]	1,461	cubic meter per day per square kilometer [(m ³ /d)/km ²]
inch per hour (in/h)	0.0254	meter per hour (m/h)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
mile per hour (mi/h)	1.609	kilometer per hour (km/h)
Mass		
ounce, avoirdupois (oz)	28.35	gram (g)
pound, avoirdupois (lb)	0.4536	kilogram (kg)
ton, short (2,000 lb)	0.9072	megagram (Mg)
ton, long (2,240 lb)	1.016	megagram (Mg)
ton per day (ton/d)	0.9072	metric ton per day
ton per day (ton/d)	0.9072	megagram per day (Mg/d)
ton per day per square mile [(ton/d)/mi ²]	0.3503	megagram per day per square kilometer [(Mg/d)/km ²]
ton per year (ton/yr)	0.9072	megagram per year (Mg/yr)
ton per year (ton/yr)	0.9072	metric ton per year
Pressure		
atmosphere, standard (atm)	101.3	kilopascal (kPa)
bar	100	kilopascal (kPa)
inch of mercury at 60°F (in Hg)	3.377	kilopascal (kPa)
pound-force per square inch (lbf/in ²)	6.895	kilopascal (kPa)
pound per square foot (lb/ft ²)	0.04788	kilopascal (kPa)
pound per square inch (lb/in ²)	6.895	kilopascal (kPa)
Density		
pound per cubic foot (lb/ft ³)	16.02	kilogram per cubic meter (kg/m ³)
pound per cubic foot (lb/ft ³)	0.01602	gram per cubic centimeter (g/cm ³)
Energy		
kilowatthour (kWh)	3,600,000	joule (J)
Radioactivity		
picocurie per liter (pCi/L)	0.037	becquerel per liter (Bq/L)
Specific capacity		
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter [(L/s)/m]
Hydraulic conductivity		

foot per day (ft/d)	0.3048	meter per day (m/d)
Hydraulic gradient		
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
Transmissivity*		
foot squared per day (ft ² /d)	0.09290	meter squared per day (m ² /d)
Application rate		
pounds per acre per year [(lb/acre)/yr]	1.121	kilograms per hectare per year [(kg/ha)/yr]
Leakance		
foot per day per foot [(ft/d)/ft]	1	meter per day per meter
inch per year per foot [(in/yr)/ft]	83.33	millimeter per year per meter [(mm/yr)/m]

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F}=(1.8\times^{\circ}\text{C})+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$^{\circ}\text{C}=(^{\circ}\text{F}-32)/1.8$$

Vertical coordinate information is referenced to the insert datum name (and abbreviation) here for instance, “North American Vertical Datum of 1988 (NAVD 88).”

Horizontal coordinate information is referenced to the insert datum name (and abbreviation) here for instance, “North American Datum of 1983 (NAD 83).”

Altitude, as used in this report, refers to distance above the vertical datum.

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft³/d)/ft²]/ft. In this report, the mathematically reduced form, foot squared per day (ft²/d), is used for convenience.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (μS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (μg/L).

NOTE TO USGS USERS: Use of hectare (ha) as an alternative name for square hectometer (hm²) is restricted to the measurement of small land or water areas. Use of liter (L) as a special name for cubic decimeter (dm³) is restricted to the measurement of liquids and gases. No prefix other than milli should be used with liter. Metric ton (t) as a name for megagram (Mg) should be restricted to commercial usage, and no prefixes should be used with it.

SI to Inch/Pound

Multiply	By	To obtain
Length		
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)
Area		
square meter (m ²)	0.0002471	acre
hectare (ha)	2.471	acre
square hectometer (hm ²)	2.471	acre
square kilometer (km ²)	247.1	acre
square centimeter (cm ²)	0.001076	square foot (ft ²)
square meter (m ²)	10.76	square foot (ft ²)
square centimeter (cm ²)	0.1550	square inch (in ²)
square hectometer (hm ²)	0.003861	section (640 acres or 1 square mile)
hectare (ha)	0.003861	square mile (mi ²)
square kilometer (km ²)	0.3861	square mile (mi ²)
Volume		
cubic meter (m ³)	6.290	barrel (petroleum, 1 barrel = 42 gal)
liter (L)	33.82	ounce, fluid (fl. oz)
liter (L)	2.113	pint (pt)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)
cubic meter (m ³)	264.2	gallon (gal)
cubic decimeter (dm ³)	0.2642	gallon (gal)
cubic meter (m ³)	0.0002642	million gallons (Mgal)
cubic centimeter (cm ³)	0.06102	cubic inch (in ³)
cubic decimeter (dm ³)	61.02	cubic inch (in ³)
liter (L)	61.02	cubic inch (in ³)
cubic decimeter (dm ³)	0.03531	cubic foot (ft ³)
cubic meter (m ³)	35.31	cubic foot (ft ³)
cubic meter (m ³)	1.308	cubic yard (yd ³)
cubic kilometer (km ³)	0.2399	cubic mile (mi ³)

cubic meter (m ³)	0.0008107	acre-foot (acre-ft)
cubic hectometer (hm ³)	810.7	acre-foot (acre-ft)
Flow rate		
cubic meter per second (m ³ /s)	70.07	acre-foot per day (acre-ft/d)
cubic meter per year (m ³ /yr)	0.000811	acre-foot per year (acre-ft/yr)
cubic hectometer per year (hm ³ /yr)	811.03	acre-foot per year (acre-ft/yr)
meter per second (m/s)	3.281	foot per second (ft/s)
meter per minute (m/min)	3.281	foot per minute (ft/min)
meter per hour (m/hr)	3.281	foot per hour (ft/hr)
meter per day (m/d)	3.281	foot per day (ft/d)
meter per year (m/yr)	3.281	foot per year ft/yr)
cubic meter per second (m ³ /s)	35.31	cubic foot per second (ft ³ /s)
cubic meter per second per square kilometer [(m ³ /s)/km ²]	91.49	cubic foot per second per square mile [(ft ³ /s)/mi ²]
cubic meter per day (m ³ /d)	35.31	cubic foot per day (ft ³ /d)
liter per second (L/s)	15.85	gallon per minute (gal/min)
cubic meter per day (m ³ /d)	264.2	gallon per day (gal/d)
cubic meter per day per square kilometer [(m ³ /d)/km ²]	684.28	gallon per day per square mile [(gal/d)/mi ²]
cubic meter per second (m ³ /s)	22.83	million gallons per day (Mgal/d)
cubic meter per day per square kilometer [(m ³ /d)/km ²]	0.0006844	million gallons per day per square mile [(Mgal/d)/mi ²]
cubic meter per hour (m ³ /h)	39.37	inch per hour (in/h)
millimeter per year (mm/yr)	0.03937	inch per year (in/yr)
kilometer per hour (km/h)	0.6214	mile per hour (mi/h)
Mass		
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)
megagram (Mg)	1.102	ton, short (2,000 lb)
megagram (Mg)	0.9842	ton, long (2,240 lb)
metric ton per day	1.102	ton per day (ton/d)
megagram per day (Mg/d)	1.102	ton per day (ton/d)
megagram per day per square kilometer [(Mg/d)/km ²]	2.8547	ton per day per square mile [(ton/d)/mi ²]
megagram per year (Mg/yr)	1.102	ton per year (ton/yr)
metric ton per year	1.102	ton per year (ton/yr)
Pressure		
kilopascal (kPa)	0.009869	atmosphere, standard (atm)
kilopascal (kPa)	0.01	bar

kilopascal (kPa)	0.2961	inch of mercury at 60°F (in Hg)
kilopascal (kPa)	0.1450	pound-force per inch (lbf/in)
kilopascal (kPa)	20.88	pound per square foot (lb/ft ²)
kilopascal (kPa)	0.1450	pound per square inch (lb/ft ²)
Density		
kilogram per cubic meter (kg/m ³)	0.06242	pound per cubic foot (lb/ft ³)
gram per cubic centimeter (g/cm ³)	62.4220	pound per cubic foot (lb/ft ³)
Energy		
joule (J)	0.0000002	kilowatthour (kWh)
Radioactivity		
becquerel per liter (Bq/L)	27.027	picocurie per liter (pCi/L)
Specific capacity		
liter per second per meter [(L/s)/m]	4.831	gallon per minute per foot [(gal/min)/ft]
Hydraulic conductivity		
meter per day (m/d)	3.281	foot per day (ft/d)
Hydraulic gradient		
meter per kilometer (m/km)	5.27983	foot per mile (ft/mi)
Transmissivity*		
meter squared per day (m ² /d)	10.76	foot squared per day (ft ² /d)
Application rate		
kilograms per hectare per year [(kg/ha)/yr]	0.8921	pounds per acre per year [(lb/acre)/yr]
Leakance		
meter per day per meter [(m/d)/m]	1	foot per day per foot [(ft/d)/ft]
millimeter per year per meter [(mm/yr)/m]	0.012	inch per year per foot [(in/yr)/ft]

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F}=(1.8\times^{\circ}\text{C})+32$$

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An Assessment of Seismic Noise Levels for the Advanced National Seismic System Backbone Network and Selected Regional Broadband Stations

By D. E. McNamara, R.P. Buland, H. M. Benz and W.R. Leith¹

Abstract

In this paper we assess the relative noise levels of 113 broadband seismic stations within the United States Geological Survey's (USGS) Advanced National Seismic System (ANSS) (netcode US), the Global Seismic Network (GSN) (netcodes II, IU) and several United States regional networks (netcodes CI, LB, UO, UW, NM). This assessment makes use of seismic power spectral data collected by a continuous noise monitoring system developed by the USGS-ANSS and the Incorporated Research Institutions in Seismology (IRIS) Data Management Center (DMC). We rank the stations relative to the Peterson Low noise model (LNM) (Peterson, 1993) for 11 different period bands. Results are listed in Appendix A. Results show that most regional stations rank low in all period bands. In general, stations in the US network have lower noise levels at short periods (0.0625-8.0 seconds), high frequencies (8.0-0.125Hz) while stations in the GSN network are quieter at long periods (16.0-128.0 seconds), low frequencies (0.03125-0.01563Hz). This result reflects the overall mission and objectives of each network.

Introduction

In this analysis, we apply rankings to the vertical component (BHZ) of 113 broadband stations within the US, IU, II, CI, LB, UO, UW and NM networks. Stations with US, IU, and II network codes will comprise much of the ANSS backbone network and are operated by the USGS and IRIS. Stations with CI, LB, UW, UO, and NM network codes are part of various regional earthquake monitoring networks within the United States. The rankings are based on ambient seismic noise levels relative to the Peterson Low Noise Model (LNM) and are listed as a function of period in Appendix A. The stations analyzed in this document are not complete for any network but are intended to show the relative quality of most potential ANSS backbone stations versus various regional and international stations of interest.

Waveform Data and Ambient Noise

The noise processing software used in this analysis computes a probability density function (PDF) to examine the distribution of seismic power spectral density (PSD) as a function of period

¹ USGS Geological Hazards Team, Golden, CO.

(PSD method after Peterson, 1993) (see Appendix B). The noise processing software has been implemented against the entire continuous data stream available within the Incorporated research Institutions in Seismology (IRIS) Data Management Center's (DMC) Buffer of Uniform Data (BUD) utilizing the QUACK framework. Resultant PDF plots corresponding to this analysis can be viewed at <http://www.iris.washington.edu/servlet/quackquery>. We determine the mode of the PDFs to represent the ambient seismic noise levels for each station since the statistical mode represents the highest probability powers to occur for a given period (fig. 1). See Appendix B for a more detailed discussion on the seismic noise PDF processing methods.

Station Ranking Method and Results

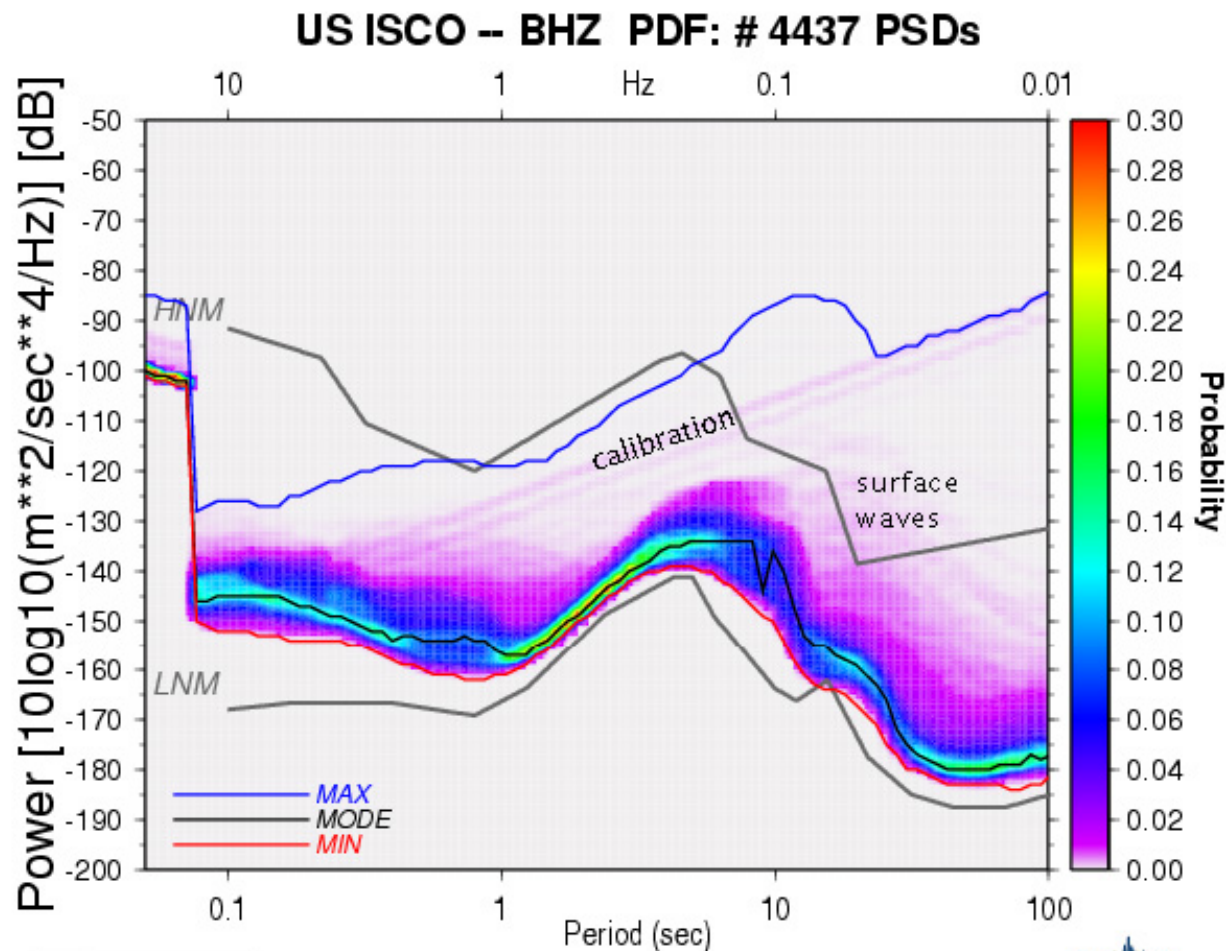
Appendix A lists relative broadband station rankings for 11 different period bands (0.0625-0.125 sec, 0.125-0.25 sec, 0.25-0.5 sec, 0.5-1.0 sec, 1.0-2.0 sec, 2.0-4.0 sec, 4.0-8.0 sec, 8.0-16.0 sec, 16.0-32.0 sec, 32.0-64.0 sec, 64.0-128.0 sec). Rankings for each period band are determined by computing the difference between the band average of the highest probability powers (mode) and the band average of the Peterson LNM (McNamara and Buland, 2004). For each period band, Appendix A lists from left to right: Station name, network code, location code, and dB of mode above LNM. Each period band is sorted on the 4th column (mode-LNM in dB) resulting in the quietest stations for that period on top and the noisiest on the bottom.

As expected, the relative rank of a particular station changes as a function of period. In general, borehole stations within the Global Seismic Network (GSN) (netcodes II, IU) are ranked higher at longer periods, where surface wave research and global tomography have been emphasized. In contrast, at shorter periods, United States National Seismograph Network stations (netcode US) rank higher, where earthquake monitoring has been emphasized. Noise at short periods generally is due to human activity "cultural noise" while longer period noise tends to be related to vault construction quality, seismometer self noise (STS2, KS54000) and microseisms due to oceanic storm activity. See Appendix B for a more complete discussion of noise sources.

The shortest period, highest frequency band in this analysis must be viewed with some caution since it includes frequencies higher than the Nyquist frequency for II and IU stations recorded at 20 samples/sec. This lack of high frequencies, rather than ambient noise conditions, is the reason most IU and II stations are not included in the 0.0625-0.125 second band. US stations, on the other hand, record at 40 samples/sec and are sensitive to ambient noise conditions in the 0.0625-0.125 second band.

References Cited

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- Peterson, J.R., 1993, Observation and modeling of seismic background noise, United States Geological Survey, Open-File Report, No.OF 93-0322, 94p.



PDF analysis code by Daniel E. McNamara (USGS-NEIC), Ray Buland (USGS-NEIC) & Richard Boaz (private contractor).

Figure 1. This figure is a PDF example for US ISCO BHZ, with some artifacts and signals identified. The highest probability power levels (mode, black line) generally are higher than the minimum powers (red line). The minimum will approach the Peterson LNM less than 2% of the time indicating that the station minimum does not reflect actual ambient noise conditions across the whole spectrum. Instead, ambient noise conditions are better represented by the highest probability mode (black line). Body waves occur as low probability signal in the 1 sec range while surface waves generally are higher power at longer periods. The mode will not be smooth when significant power variations occur (note microseism variations near 10 sec).

Appendix A

BHZ 0.0625-0.125sec (8.0-16.0Hz)	BHZ 0.125-0.25sec (4.0-8.0Hz)	BHZ 0.25-0.5sec (2.0-4.0Hz)
SAO US -- 13.7443	QSPA IU 10 -1.13747	QSPA IU 10 -0.795853
DBO UO -- 17.2443	DUG US -- 9.98753	QSPA IU 00 5.82915
WDC US -- 18.2443	TPNV US -- 11.6125	SDCO US -- 8.32915
CMB US -- 25.9943	BW06 US -- 12.2375	TPNV US -- 8.82915
DUG US -- 27.4943	SDCO US -- 13.9875	ANMO IU 00 9.32915
TPNV US -- 29.2443	ANMO IU 10 14.6125	BOZ US -- 9.32915
BW06 US -- 29.8693	DBO UO -- 14.8625	DUG US -- 9.82915
BMN LB -- 30.4943	ELK US -- 15.8625	HLID US -- 10.2041
HWUT US -- 31.8693	HWUT US -- 16.4875	TUC IU 00 11.4541
GNW UW -- 32.6193	WMOK US -- 16.8625	ANMO IU 10 11.8291
MIAR US -- 32.6193	WVOR US -- 18.1125	BW06 US -- 11.8291
WMOK US -- 32.6193	BOZ US -- 18.4875	ELK US -- 13.2041
ISCO US -- 33.2443	GNW UW -- 19.1125	WMOK US -- 13.2041
SDCO US -- 33.2443	LBNH US -- 19.3625	DBO UO -- 13.4541
NCB US -- 33.3693	HLID US -- 19.6125	SSPA IU 00 13.8291
LTY UW -- 33.9943	NCB US -- 19.6125	MSO US -- 14.0791
NEW US -- 34.4943	MSO US -- 19.8625	ISCO US -- 14.3291
WUAZ US -- 34.8693	NEW US -- 19.9875	HKT IU 00 14.5791
HAWA US -- 34.9943	ISCO US -- 20.2375	HWUT US -- 15.7041
BOZ US -- 35.2443	SAO US -- 20.4875	WVOR US -- 15.7041
MSO US -- 36.1193	MNV US -- 20.7375	RSSD IU 00 16.2041
LON UW -- 36.4943	KDAK II 00 21.2375	KDAK II 00 16.3291
WVOR US -- 37.2443	MIAR US -- 21.6125	CHF CI -- 16.5791
JFWS US -- 37.8693	PFO II 10 21.6125	MIAR US -- 16.5791
DAC LB -- 39.3693	BMN LB -- 22.2375	WVT IU -- 16.5791
LBNH US -- 39.3693	WUAZ US -- 23.6125	WVT US -- 16.5791
TPH LB -- 39.8693	LTY UW -- 24.2375	NEW US -- 16.7041
ELK US -- 41.4943	LON UW -- 25.3625	PFO II 00 16.7041
HLID US -- 41.8693	HAWA US -- 25.6125	LON UW -- 16.8291
LTX US -- 41.9943	ANMO IU 00 26.1125	LBNH US -- 17.0791
AHID US -- 42.4943	BINY US -- 26.4875	OCWA US -- 17.2041
BINY US -- 43.4943	CMB US -- 26.4875	NCB US -- 17.4541
PAL LD -- 43.6193	TUC IU 00 26.6125	PFO II 10 17.5791
DGMT US -- 43.9943	LTX US -- 27.7375	PLM CI -- 18.2041
LAO US -- 44.3693	TPH LB -- 28.6125	CCM IU 00 19.0791
EYMN US -- 44.4943	PAL LD -- 29.2375	MNV US -- 19.0791
OXF US -- 44.6193	CCM IU 00 29.3625	CMB US -- 19.3291
MNV US -- 44.8693	OCWA US -- 29.3625	LRAL US -- 19.3291
MCWV US -- 45.3693	JFWS US -- 29.7375	DGR CI -- 19.7041
CBKS US -- 45.4943	LRAL US -- 29.9875	BMN LB -- 20.7041
EUO UO -- 47.1193	DGR CI -- 30.6125	WDC US -- 20.8291
BLA US -- 47.3693	WVT IU -- 30.7375	HEBO UW -- 21.0791
OCWA US -- 47.6193	WVT US -- 30.8625	LTX US -- 21.7041
PIN UO -- 52.7443	HKT IU 00 31.4875	WUAZ US -- 21.8291
LRAL US -- 52.9943	MVL LD -- 31.6125	DWPF IU 00 22.2041

HEBO UW -- 53.2443	CHF CI -- 31.8625	LTY UW -- 22.2041
TTW UW -- 53.3693	PIN UO -- 31.9875	JCS CI -- 22.8291
ERPA US -- 53.6193	RSSD IU 00 31.9875	PIN UO -- 22.9541
OPC UW -- 53.8693	LAO US -- 32.3625	SAO US -- 23.2041
NATX US -- 54.2443	QSPA IU 00 32.3625	ACCN LD -- 24.2041
SQM UW -- 54.7443	HEBO UW -- 32.8625	HAWA US -- 24.2041
OFR UW -- 55.7443	PLM CI -- 32.8625	HRV IU -- 24.2041
HOOD UW -- 55.9943	ACCN LD -- 32.9875	MVL LD -- 24.3291
CBN US -- 56.1193	DGMT US -- 33.6125	BAR CI -- 24.4541
ACCN LD -- 56.9943	SSPA IU 00 33.7375	TPH LB -- 26.0791
JCT US -- 57.4943	COLA IU 00 33.8625	BINY US -- 26.7041
MVL LD -- 57.8693	DAC LB -- 33.9875	ADK IU 00 27.3291
KSU1 US -- 59.4943	JCS CI -- 34.6125	WCI IU 00 27.7041
UALR NM -- 59.7443	DWPF IU 00 34.7375	PAL LD -- 27.8291
AAM US -- 59.8693	AHID US -- 36.1125	COLA IU 00 27.9541
ACSO US -- 59.9943	WCI IU 00 36.7375	GNW UW -- 27.9541
TAKO UW -- 60.2443	BAR CI -- 36.9875	MWC CI -- 28.9541
USIN NM -- 60.4109	MCWV US -- 36.9875	UALR NM -- 30.8291
BLO NM -- 60.7443	EYMN US -- 37.4875	OXF US -- 31.8291
WVT US -- 61.0776	HRV IU -- 37.4875	JFWS US -- 32.2041
CPNY LD -- 61.1193	OPC UW -- 37.9875	SIUC NM -- 32.9541
BRNJ LD -- 63.1193	KSU1 US -- 38.2375	DAC LB -- 33.0791
CONY LD -- 63.8693	UALR NM -- 38.6125	DGMT US -- 33.2041
PVMO NM -- 64.4109	SIUC NM -- 39.3625	MCWV US -- 33.5791
SLM NM -- 64.4109	CBKS US -- 39.6125	TTW UW -- 34.2041
UTMT NM -- 65.0776	OXF US -- 40.3625	EYMN US -- 34.3291
NHSC US -- 65.9943	COR IU 00 40.8625	HOOD UW -- 34.3291
FOR LD -- 67.3693	PFO II 00 41.3625	DJJ CI -- 34.9541
ALLY LD -- 69.7443	EUO UO -- 41.6125	LAO US -- 35.5791
MPH NM -- 70.7443	WDC US -- 41.7375	AHID US -- 36.3291
TOLO UW -- 72.7443	DJJ CI -- 42.7375	COR IU 00 38.0791
MEGW UW -- 82.9943	ADK IU 00 42.8625	OPC UW -- 38.0791
GENY LD -- 92.4943	ERPA US -- 43.1125	ACSO US -- 38.2041
	NATX US -- 43.6125	FOR LD -- 38.8291
	MWC CI -- 44.3625	CBKS US -- 38.9541
	SQM UW -- 44.4875	KSU1 US -- 39.5791
	HOOD UW -- 45.6125	CPNY LD -- 39.7041
	OFR UW -- 45.6125	PAS CI -- 40.7041
	BLO NM -- 45.7375	EUO UO -- 40.8291
	CONY LD -- 45.8625	TAKO UW -- 40.9541
	CPNY LD -- 45.9875	TOV CI -- 41.4541
	BRNJ LD -- 46.2375	CONY LD -- 41.7041
	PAS CI -- 46.3625	NATX US -- 42.0791
	BLA US -- 47.1125	BRNJ LD -- 42.4541
	CBN US -- 47.2375	ERPA US -- 43.4541
	ACSO US -- 47.4875	BLA US -- 43.7041
	FOR LD -- 48.3625	RPV CI -- 43.8291
	TOV CI -- 48.8625	BLO NM -- 44.2041
	MLAC CI -- 49.7375	AAM US -- 44.4541
	TTW UW -- 50.2375	OFR UW -- 44.5791
	ALLY LD -- 51.8625	GENY LD -- 45.5791
	AAM US -- 52.2375	ALLY LD -- 46.0791
	USIN NM -- 52.2375	MLAC CI -- 46.0791
	COLA IU 10 53.7375	CBN US -- 46.5791

NHSC US -- 55.9875	COLA IU 10 46.8291
RPV CI -- 56.3625	USIN NM -- 46.8291
JCT US -- 58.4875	SQM UW -- 47.4541
GENY LD -- 58.9875	NHSC US -- 48.2041
TAKO UW -- 59.3625	MEGW UW -- 48.9541
VTV CI -- 61.4875	SLM NM -- 49.8291
SLM NM -- 62.7375	VTV CI -- 50.2041
TOLO UW -- 63.2375	TOLO UW -- 51.2041
MEGW UW -- 63.6125	UTMT NM -- 51.3291
UTMT NM -- 63.8625	JCT US -- 55.5791
MPH NM -- 65.6125	MPH NM -- 64.5791
PVMO NM -- 69.1125	BAK CI -- 66.0791
USC CI -- 69.7375	USC CI -- 68.0791
BAK CI -- 72.2375	PVMO NM -- 73.3291

BHZ
0.5-1.0sec
(1.0-2.0Hz)

BHZ
1.0-2.0sec
(0.5-1.0Hz)

BHZ
2.0-4.0sec
(0.25-0.5Hz)

HLID US -- 4.17801	ANMO IU 00 3.55612	EYMN US -- 1.62506
SDCO US -- 5.80301	ANMO IU 10 4.43112	MSO US -- 3.37506
QSPA IU 10 6.92801	HLID US -- 5.18112	ANMO IU 00 3.87506
BOZ US -- 7.17801	TUC IU 00 5.80612	TUC IU 00 4.25006
ANMO IU 00 7.42801	ELK US -- 5.93112	ANMO IU 10 4.87506
BW06 US -- 7.55301	MSO US -- 6.30612	BMN LB -- 5.12506
QSPA IU 00 7.80301	BW06 US -- 6.43112	ISCO US -- 5.50006
ANMO IU 10 8.30301	BOZ US -- 6.55612	HLID US -- 5.62506
ELK US -- 8.42801	ISCO US -- 6.80612	BW06 US -- 5.87506
TUC IU 00 8.42801	SDCO US -- 7.05612	SDCO US -- 6.00006
TPNV US -- 8.92801	MNV US -- 7.68112	DUG US -- 6.12506
WMOK US -- 10.178	DUG US -- 7.80612	BOZ US -- 6.50006
ISCO US -- 10.428	TPH LB -- 8.18112	RSSD IU 00 6.62506
DUG US -- 11.303	HWUT US -- 8.43112	TPH LB -- 6.62506
MNV US -- 11.928	RSSD IU 00 8.43112	DAC LB -- 6.75006
MSO US -- 12.428	WMOK US -- 8.68112	HWUT US -- 6.87506
HWUT US -- 13.553	TPNV US -- 10.1811	WMOK US -- 7.00006
WVOR US -- 13.553	WVOR US -- 10.3061	WUAZ US -- 7.00006
MIAR US -- 13.678	NEW US -- 10.4311	AHID US -- 7.37506
LTY UW -- 14.678	WUAZ US -- 10.4311	ELK US -- 7.37506
LON UW -- 14.803	LTX US -- 10.6811	COLA IU 00 7.50006
TPH LB -- 14.803	BMN LB -- 11.1811	NEW US -- 7.50006
RSSD IU 00 14.928	CMB US -- 11.3061	MNV US -- 7.62506
WVT US -- 14.928	AHID US -- 11.9311	VTV CI -- 7.87506
LRAL US -- 15.178	LON UW -- 12.0561	DGR CI -- 8.37506
NEW US -- 15.178	COLA IU 00 12.3061	CMB US -- 8.50006
WVT IU -- 15.178	CCM IU 00 12.9311	COLA IU 10 8.50006
WUAZ US -- 15.803	HAWA US -- 13.3061	LTX US -- 8.50006
CMB US -- 16.178	QSPA IU 00 13.4311	WVOR US -- 8.75006
PIN UO -- 16.553	WVT US -- 13.4311	PFO II 10 9.00006
PFO II 10 16.803	LTY UW -- 13.6811	LON UW -- 9.12506
PFO II 00 16.928	COLA IU 10 13.8061	PFO II 00 9.25006
SSPA IU 00 17.053	QSPA IU 10 13.9311	CBKS US -- 9.50006
HKT IU 00 17.428	MIAR US -- 14.0561	CHF CI -- 9.50006
CHF CI -- 17.678	TTW UW -- 14.1811	HKT IU 00 9.50006
LTX US -- 17.678	PFO II 10 14.4311	TPNV US -- 9.87506
CCM IU 00 17.928	PFO II 00 14.5561	MIAR US -- 10.1251
DBO UO -- 17.928	DGR CI -- 14.6811	TTW UW -- 10.1251
NCB US -- 18.928	HKT IU 00 14.9311	JCS CI -- 10.2501
DGR CI -- 19.178	WVT IU -- 15.0561	LTY UW -- 10.6251
WDC US -- 19.303	PIN UO -- 15.1811	HAWA US -- 10.7501
JCS CI -- 19.678	GNW UW -- 15.3061	PLM CI -- 10.7501
BMN LB -- 20.678	VTV CI -- 15.3061	SLM NM -- 10.7501
MVL LD -- 21.428	WDC US -- 15.4311	GNW UW -- 10.8751
PLM CI -- 21.553	LRAL US -- 15.6811	CCM IU 00 11.0001
GNW UW -- 22.178	SLM NM -- 16.0561	WVT US -- 11.1251
LBNH US -- 22.553	LAO US -- 16.3061	USIN NM -- 11.2501
BINY US -- 22.928	CHF CI -- 16.5561	MLAC CI -- 11.5001
TTW UW -- 22.928	BLO NM -- 17.4311	BAR CI -- 11.6251
ACCN LD -- 23.178	UALR NM -- 17.4311	WVT IU -- 11.6251

HAWA US -- 23.303	JCS CI -- 17.8061	SIUC NM -- 11.7501
BAR CI -- 23.678	WCI IU 00 17.8061	AAM US -- 12.0001
WCI IU 00 24.178	CBKS US -- 18.0561	UALR NM -- 12.0001
MWC CI -- 24.303	DGMT US -- 18.3061	OXF US -- 12.3751
JFWS US -- 25.303	KSU1 US -- 18.8061	BLO NM -- 12.6251
KDAK II 00 25.428	PLM CI -- 18.9311	MWC CI -- 12.7501
OCWA US -- 26.053	BAR CI -- 19.3061	NATX US -- 12.8751
COLA IU 00 26.553	DAC LB -- 19.8061	JFWS US -- 13.1251
HRV IU -- 27.053	HOOD UW -- 19.8061	LRAL US -- 13.1251
SAO US -- 27.178	SSPA IU 00 19.8061	HOOD UW -- 13.2501
ACSO US -- 27.428	NCB US -- 19.9311	WDC US -- 13.3751
UALR NM -- 27.428	AAM US -- 20.1811	PIN UO -- 13.6251
MCWV US -- 28.053	SIUC NM -- 20.1811	CBN US -- 13.8751
HOOD UW -- 29.178	USIN NM -- 20.4311	WCI IU 00 13.8751
VTV CI -- 30.178	ACCN LD -- 20.5561	PAS CI -- 14.5001
DGMT US -- 30.303	MWC CI -- 20.6811	PVMO NM -- 14.6251
DWPF IU 00 31.053	MVL LD -- 20.8061	KSU1 US -- 14.7501
AHID US -- 31.303	JFWS US -- 21.0561	ACSO US -- 15.0001
SIUC NM -- 31.553	NATX US -- 21.4311	DJJ CI -- 15.1251
AAM US -- 31.928	ACSO US -- 21.9311	MVL LD -- 15.1251
PAL LD -- 31.928	BINY US -- 22.0561	SSPA IU 00 15.5001
DAC LB -- 32.178	MLAC CI -- 22.3061	UTMT NM -- 16.0001
ALLY LD -- 32.303	MCWV US -- 22.4311	SAO US -- 16.1251
LAO US -- 32.303	LBNH US -- 23.3061	ERPA US -- 16.3751
PAS CI -- 32.553	SAO US -- 23.5561	QSPA IU 00 16.5001
FOR LD -- 32.803	DBO UO -- 24.3061	LAO US -- 16.7501
COLA IU 10 32.928	CBN US -- 25.0561	QSPA IU 10 16.8751
KSU1 US -- 32.928	OXF US -- 25.5561	ALLY LD -- 17.1251
HEBO UW -- 33.553	PAS CI -- 25.6811	ACCN LD -- 17.2501
BLO NM -- 33.678	HRV IU -- 26.0561	DGMT US -- 17.3751
OXF US -- 33.928	PAL LD -- 26.0561	NCB US -- 17.3751
DJJ CI -- 34.803	ALLY LD -- 26.4311	MPH NM -- 17.5001
EUO UO -- 34.928	CPNY LD -- 26.9311	PAL LD -- 17.6251
USIN NM -- 35.053	FOR LD -- 27.5561	MCWV US -- 17.8751
TAKO UW -- 35.178	ERPA US -- 27.6811	TOV CI -- 18.1251
CPNY LD -- 35.303	BAK CI -- 28.4311	CPNY LD -- 18.8751
COR IU 00 35.553	DJJ CI -- 28.4311	HRV IU -- 19.0001
ERPA US -- 36.428	EUO UO -- 29.3061	FOR LD -- 19.2501
NHSC US -- 36.428	BRNJ LD -- 30.0561	LBNH US -- 19.8751
ADK IU 00 36.928	KDAK II 00 30.1811	BAK CI -- 20.0001
CBKS US -- 36.928	OCWA US -- 30.3061	RPV CI -- 20.5001
MLAC CI -- 36.928	EYMN US -- 31.1811	BINY US -- 20.6251
SLM NM -- 36.928	UTMT NM -- 31.1811	BRNJ LD -- 21.8751
OFR UW -- 37.553	PVMO NM -- 31.3061	DBO UO -- 22.1251
NATX US -- 38.053	COR IU 00 33.1811	MEGW UW -- 24.6251
TOV CI -- 38.678	TOV CI -- 33.1811	NHSC US -- 24.6251
BRNJ LD -- 38.928	JCT US -- 34.0561	OCWA US -- 25.3751
BLA US -- 40.678	DWPF IU 00 35.9311	DWPF IU 00 25.7501
CONY LD -- 41.678	MEGW UW -- 35.9311	EUO UO -- 25.8751
EYMN US -- 42.428	MPH NM -- 35.9311	KDAK II 00 26.0001
GENY LD -- 42.428	NHSC US -- 36.6811	COR IU 00 26.6251
CBN US -- 43.303	CONY LD -- 37.3061	OPC UW -- 29.2501
JCT US -- 44.178	TAKO UW -- 37.3061	SQM UW -- 29.3751
OPC UW -- 44.553	BLA US -- 38.5561	JCT US -- 29.7501

UTMT NM -- 45.678	RPV CI -- 38.8061	USC CI -- 30.2501
SQM UW -- 45.803	ADK IU 00 39.5561	TAKO UW -- 30.3751
RPV CI -- 46.178	GENY LD -- 40.0561	ADK IU 00 32.2501
TOLO UW -- 46.928	OFR UW -- 41.6811	BLA US -- 32.5001
MEGW UW -- 47.803	OPC UW -- 41.9311	HEBO UW -- 33.5001
BAK CI -- 51.803	HEBO UW -- 42.0561	GENY LD -- 34.2501
MPH NM -- 60.303	TOLO UW -- 42.5561	TOLO UW -- 34.6251
USC CI -- 60.303	SQM UW -- 43.0561	CONY LD -- 35.1251
PVMO NM -- 60.928	USC CI -- 44.1811	OFR UW -- 36.5001

BHZ 4.0-8.0sec (0.125-0.25Hz)	BHZ 8.0-16.0sec (0.0625-0.125Hz)	BHZ 16.0-32.0sec (0.03125-0.0625Hz)
EYMN US -- -0.4467	AAM US -- 11.206	MSO US -- 7.68666
MSO US -- 6.67889	PAL LD -- 11.456	ERPA US -- 9.43666
LON UW -- 8.67889	MIAR US -- 11.831	MIAR US -- 9.68666
BMN LB -- 10.1789	DWPF IU 00 11.956	ANMO IU 00 9.81166
COLA IU 00 10.1789	FOR LD -- 12.081	PAL LD -- 9.93666
MIAR US -- 10.1789	NHSC US -- 12.081	DWPF IU 00 10.0617
AAM US -- 10.4289	ACCN LD -- 12.206	SSPA IU 00 10.3117
NEW US -- 10.4289	ERPA US -- 12.331	AAM US -- 10.4367
SIUC NM -- 10.4289	OXF US -- 12.581	CCM IU 00 10.4367
DUG US -- 10.6789	USIN NM -- 12.581	TUC IU 00 10.4367
LTY UW -- 10.6789	MSO US -- 12.831	WCI IU 00 10.5617
PVMO NM -- 10.6789	DUG US -- 12.956	HRV IU -- 10.6867
DWPF IU 00 10.8039	LRAL US -- 12.956	ACCN LD -- 10.8117
OXF US -- 11.0539	SIUC NM -- 12.956	ANMO IU 10 11.0617
TTW UW -- 11.0539	LON UW -- 13.081	LRAL US -- 11.0617
COLA IU 10 11.1789	COLA IU 00 13.331	COLA IU 00 11.1867
GNW UW -- 11.1789	EYMN US -- 13.331	WDC US -- 11.1867
HLID US -- 11.3039	BLO NM -- 13.456	RSSD IU 00 11.3117
USIN NM -- 11.3039	HRV IU -- 13.456	NATX US -- 11.4367
TPH LB -- 11.4289	PIN UO -- 13.581	NEW US -- 11.4367
BOZ US -- 11.5539	SLM NM -- 13.581	MCWV US -- 11.5617
DAC LB -- 11.5539	WDC US -- 13.581	TTW UW -- 11.5617
HOOD UW -- 11.5539	CBKS US -- 13.706	WVT US -- 11.5617
HWUT US -- 11.6789	UALR NM -- 13.831	CBKS US -- 11.6867
SDCO US -- 11.6789	PVMO NM -- 14.081	DUG US -- 11.6867
BLO NM -- 11.8039	CCM IU 00 14.206	HKT IU 00 11.6867
ANMO IU 00 11.9289	NATX US -- 14.206	USIN NM -- 11.6867
ANMO IU 10 11.9289	SSPA IU 00 14.206	FOR LD -- 11.8117
MLAC CI -- 12.0539	ANMO IU 00 14.331	SIUC NM -- 11.8117
WVOR US -- 12.0539	HWUT US -- 14.331	WVT IU -- 11.8117
ISCO US -- 12.1789	MCWV US -- 14.456	BLO NM -- 11.9367
HKT IU 00 12.3039	CBN US -- 14.706	BW06 US -- 11.9367
SLM NM -- 12.3039	WVT US -- 14.706	MNV US -- 11.9367
UALR NM -- 12.3039	WUAZ US -- 14.956	LON UW -- 12.0617
BW06 US -- 12.4289	ALLY LD -- 15.206	DGR CI -- 12.1867
WUAZ US -- 12.4289	COLA IU 10 15.331	HWUT US -- 12.3117
AHID US -- 12.5539	MVL LD -- 15.331	LTY UW -- 12.3117
PAL LD -- 12.5539	UTMT NM -- 15.331	NHSC US -- 12.3117
RSSD IU 00 12.5539	WVT IU -- 15.331	BMN LB -- 12.4367
MNV US -- 12.6789	BMN LB -- 15.456	BOZ US -- 12.4367
CBKS US -- 12.8039	JFWS US -- 15.456	HLID US -- 12.4367
UTMT NM -- 12.8039	WCI IU 00 15.581	ISCO US -- 12.5617
MPH NM -- 12.9289	DBO UO -- 15.706	PVMO NM -- 12.5617
NHSC US -- 12.9289	TTW UW -- 15.831	UALR NM -- 12.5617
WMOK US -- 12.9289	SDCO US -- 16.081	WUAZ US -- 12.6867
CHF CI -- 13.0539	DGMT US -- 16.206	GNW UW -- 12.8117
LRAL US -- 13.1789	BOZ US -- 16.331	HAWA US -- 12.8117
FOR LD -- 13.3039	GNW UW -- 16.331	LBNH US -- 12.8117
TUC IU 00 13.4289	LAO US -- 16.331	PLM CI -- 12.8117
KDAK II 00 13.5539	LBNH US -- 16.331	TPH LB -- 12.8117

LTX US -- 13.5539	TUC IU 00 16.331	CMB US -- 13.3117
PIN UO -- 13.5539	ANMO IU 10 16.456	AHID US -- 13.5617
ALLY LD -- 13.9289	RSSD IU 00 16.456	LTX US -- 13.5617
HAWA US -- 14.0539	LTX US -- 16.581	COLA IU 10 13.6867
CBN US -- 14.1789	KDAK II 00 16.706	COR IU 00 13.6867
NATX US -- 14.3039	MNV US -- 16.706	PIN UO -- 13.6867
WVT US -- 14.3039	WMOK US -- 16.706	PFO II 00 13.8117
ACCN LD -- 14.5539	BW06 US -- 16.831	PFO II 10 13.8117
WDC US -- 14.5539	HLID US -- 16.831	SAO US -- 13.8117
MVL LD -- 14.8039	NCB US -- 16.831	SDCO US -- 13.8117
SSPA IU 00 14.8039	LTY UW -- 16.956	WMOK US -- 13.9367
CCM IU 00 14.9289	AHID US -- 17.081	LAO US -- 14.1867
JFWS US -- 14.9289	HKT IU 00 17.081	JFWS US -- 14.3117
NCB US -- 14.9289	MPH NM -- 17.206	KDAK II 00 14.3117
CPNY LD -- 15.8039	NEW US -- 17.206	MWC CI -- 14.3117
ERPA US -- 15.9289	TPH LB -- 17.206	PAS CI -- 14.4367
WVT IU -- 15.9289	ISCO US -- 17.456	BAR CI -- 14.5617
ACSO US -- 16.1789	SQM UW -- 17.581	CBN US -- 14.5617
CMB US -- 16.4289	CHF CI -- 17.831	ADK IU 00 14.9367
ELK US -- 16.4289	ACSO US -- 17.956	ALLY LD -- 14.9367
MEGW UW -- 16.6789	CPNY LD -- 18.081	RPV CI -- 15.3117
WCI IU 00 16.6789	WVOR US -- 18.206	WVOR US -- 15.3117
DGMT US -- 16.9289	DAC LB -- 18.706	DBO UO -- 15.4367
DBO UO -- 17.1789	BAK CI -- 18.956	DAC LB -- 15.6867
HRV IU -- 17.1789	HAWA US -- 19.206	QSPA IU 00 15.6867
BRNJ LD -- 17.5539	TOLO UW -- 19.331	SLM NM -- 15.9367
LAO US -- 17.6789	KSU1 US -- 19.581	BAK CI -- 16.1867
MCWV US -- 18.0539	HEBO UW -- 19.706	CHF CI -- 16.6867
DGR CI -- 18.1789	PLM CI -- 20.206	ELK US -- 16.6867
EUO UO -- 18.3039	TPNV US -- 20.206	JCS CI -- 16.6867
KSU1 US -- 18.3039	PFO II 10 20.331	QSPA IU 10 16.8117
TPNV US -- 18.6789	DGR CI -- 20.456	TPNV US -- 16.8117
LBNH US -- 19.4289	PFO II 00 20.456	DGMT US -- 17.3117
PLM CI -- 19.9289	CMB US -- 20.581	USC CI -- 17.6867
BINY US -- 20.1789	ELK US -- 20.581	TOV CI -- 17.9367
DJJ CI -- 20.9289	COR IU 00 20.706	DJJ CI -- 18.6867
VTV CI -- 20.9289	HOOD UW -- 21.206	OCWA US -- 18.6867
MWC CI -- 21.0539	TAKO UW -- 21.331	VTV CI -- 18.6867
HEBO UW -- 21.1789	TOV CI -- 21.331	OXF US -- 20.5617
OCWA US -- 21.3039	JCS CI -- 21.456	KSU1 US -- 20.9367
PFO II 00 21.4289	MLAC CI -- 21.456	UTMT NM -- 20.9367
JCS CI -- 21.6789	MWC CI -- 21.456	MVL LD -- 21.4367
PFO II 10 21.8039	BAR CI -- 21.581	MPH NM -- 23.3117
OPC UW -- 21.9289	PAS CI -- 21.706	EYMN US -- 25.4367
SAO US -- 21.9289	VTV CI -- 21.706	TOLO UW -- 27.1867
COR IU 00 22.1789	OPC UW -- 21.956	BLA US -- 27.3117
QSPA IU 00 22.3039	BINY US -- 22.081	SQM UW -- 27.8117
SQM UW -- 22.5539	MEGW UW -- 22.456	HEBO UW -- 29.6867
BAR CI -- 22.9289	SAO US -- 22.581	ACSO US -- 30.5617
TOV CI -- 22.9289	DJJ CI -- 22.706	TAKO UW -- 30.6867
QSPA IU 10 23.0539	OCWA US -- 23.081	CPNY LD -- 31.1867
BAK CI -- 23.5539	EUO UO -- 23.706	NCB US -- 31.5617
PAS CI -- 23.8039	RPV CI -- 23.706	JCT US -- 32.5617
TAKO UW -- 23.8039	QSPA IU 00 24.081	HOOD UW -- 32.8117

RPV CI -- 24.8039	USC CI -- 24.456	OPC UW -- 33.4367
TOLO UW -- 25.9289	QSPA IU 10 24.706	CONY LD -- 35.0617
USC CI -- 28.1789	ADK IU 00 25.831	MEGW UW -- 35.0617
BLA US -- 30.6789	BRNJ LD -- 26.081	MLAC CI -- 35.4367
OFR UW -- 31.6789	BLA US -- 29.081	EUO UO -- 38.5617
ADK IU 00 32.8039	OFR UW -- 32.456	BRNJ LD -- 39.1867
JCT US -- 33.4289	GENY LD -- 32.956	BINY US -- 39.5617
GENY LD -- 34.1789	JCT US -- 35.331	GENY LD -- 43.3117
CONY LD -- 34.6789	CONY LD -- 48.706	OFR UW -- 44.1867

BHZ	BHZ
32.0-64.0sec	64.0-128.0sec
(0.015625-0.03125Hz)	(0.0078125-0.015625Hz)

HRV IU -- 2.90118	WCI IU 00 1.24872
MSO US -- 3.15118	HRV IU -- 2.49872
TUC IU 00 4.15118	MSO US -- 2.62372
WCI IU 00 4.65118	CCM IU 00 2.99872
HKT IU 00 4.77618	TUC IU 00 3.37372
CCM IU 00 4.90118	HWUT US -- 3.87372
HWUT US -- 5.02618	HKT IU 00 4.12372
ANMO IU 00 5.40118	WVT IU -- 4.12372
DGR CI -- 5.65118	BW06 US -- 4.24872
DWPF IU 00 5.65118	CMB US -- 4.24872
PFO II 00 5.65118	WVT US -- 4.37372
WVT US -- 5.77618	ERPA US -- 4.49872
BW06 US -- 5.90118	WDC US -- 4.62372
WVT IU -- 6.02618	PFO II 00 4.74872
CMB US -- 6.27618	DGR CI -- 4.87372
ERPA US -- 6.27618	CBKS US -- 4.99872
PAS CI -- 6.40118	COR IU 00 5.24872
WDC US -- 6.40118	DWPF IU 00 5.62372
KDAK II 00 6.52618	PAS CI -- 5.87372
PFO II 10 6.52618	ADK IU 00 5.99872
ANMO IU 10 6.65118	NATX US -- 5.99872
PLM CI -- 7.15118	PLM CI -- 6.12372
RSSD IU 00 7.15118	ANMO IU 00 6.24872
AAM US -- 7.27618	KDAK II 00 6.24872
MWC CI -- 7.27618	MWC CI -- 6.37372
COLA IU 00 7.40118	ANMO IU 10 6.62372
COR IU 00 7.40118	LAO US -- 6.62372
SSPA IU 00 7.77618	PFO II 10 6.87372
CBKS US -- 7.90118	RSSD IU 00 7.12372
ISCO US -- 7.90118	OCWA US -- 7.37372
ADK IU 00 8.02618	SDCO US -- 7.62372
OCWA US -- 8.15118	AAM US -- 7.99872
MIAR US -- 8.27618	COLA IU 10 7.99872
SDCO US -- 8.52618	SSPA IU 00 8.62372
NEW US -- 8.65118	ISCO US -- 8.99872
PAL LD -- 8.77618	COLA IU 00 9.12372
ACCN LD -- 9.02618	ACCN LD -- 9.74872
HAWA US -- 9.02618	NEW US -- 9.74872
LAO US -- 9.52618	HAWA US -- 10.1237
LTX US -- 10.4012	TOV CI -- 10.1237
COLA IU 10 10.6512	PAL LD -- 11.1237
WVOR US -- 11.0262	LTX US -- 11.4987
LRAL US -- 11.1512	LBNH US -- 12.9987
LBNH US -- 11.4012	LRAL US -- 13.2487
BOZ US -- 11.5262	USC CI -- 13.2487
GNW UW -- 11.9012	TPNV US -- 13.6237
CBN US -- 12.5262	QSPA IU 10 13.9987
TTW UW -- 13.0262	RPV CI -- 13.9987
QSPA IU 00 13.1512	QSPA IU 00 14.2487
TPNV US -- 13.1512	DGMT US -- 14.6237

HLID US -- 13.2762	CBN US -- 14.8737
NATX US -- 13.4012	WVOR US -- 14.8737
QSPA IU 10 13.6512	HLID US -- 15.1237
RPV CI -- 13.6512	UALR NM -- 15.2487
WMOK US -- 13.9012	BOZ US -- 15.3737
MCWV US -- 14.0262	MIAR US -- 15.6237
UALR NM -- 14.0262	BLO NM -- 16.2487
DUG US -- 14.1512	DUG US -- 16.6237
BLO NM -- 14.2762	BAR CI -- 16.7487
SIUC NM -- 14.2762	TTW UW -- 16.8737
PIN UO -- 14.5262	SAO US -- 17.1237
WUAZ US -- 15.2762	NHSC US -- 17.6237
BMN LB -- 15.4012	MVL LD -- 17.8737
NHSC US -- 15.5262	GNW UW -- 18.6237
MNV US -- 15.6512	VTV CI -- 18.6237
BAR CI -- 16.2762	MPH NM -- 18.9987
SAO US -- 16.6512	MCWV US -- 19.4987
TOV CI -- 17.9012	SIUC NM -- 19.8737
TPH LB -- 18.5262	WMOK US -- 19.9987
USIN NM -- 18.6512	BMN LB -- 20.3737
VTV CI -- 18.7762	AHID US -- 20.6237
ELK US -- 19.0262	ELK US -- 21.1237
AHID US -- 19.4012	PVMO NM -- 21.7487
USC CI -- 19.5262	TPH LB -- 22.4987
PVMO NM -- 19.9012	USIN NM -- 22.6237
DAC LB -- 21.4012	BAK CI -- 23.1237
LON UW -- 21.5262	MNV US -- 23.6237
LTY UW -- 21.9012	JCT US -- 24.9987
JFWS US -- 22.1512	DAC LB -- 25.2487
BAK CI -- 22.4012	PIN UO -- 26.4987
CHF CI -- 23.2762	JFWS US -- 27.2487
FOR LD -- 24.1512	DBO UO -- 28.3737
DBO UO -- 24.4012	LON UW -- 28.7487
MVL LD -- 24.9012	WUAZ US -- 28.8737
DGMT US -- 26.0262	BLA US -- 29.2487
ALLY LD -- 26.2762	ALLY LD -- 29.4987
BLA US -- 26.4012	JCS CI -- 32.8737
MPH NM -- 26.5262	LTY UW -- 33.3737
JCT US -- 27.5262	DJJ CI -- 33.7487
SLM NM -- 28.2762	SLM NM -- 33.8737
JCS CI -- 28.5262	CHF CI -- 34.3737
DJJ CI -- 28.7762	FOR LD -- 35.2487
KSU1 US -- 30.6512	UTMT NM -- 36.2487
UTMT NM -- 33.2762	KSU1 US -- 36.6237
EYMN US -- 35.9012	EYMN US -- 36.9987
OXF US -- 37.6512	TOLO UW -- 43.1237
TOLO UW -- 40.5262	SQM UW -- 43.3737
SQM UW -- 41.0262	ACSO US -- 45.9987
HEBO UW -- 43.5262	HEBO UW -- 46.3737
ACSO US -- 43.9012	TAKO UW -- 46.3737
TAKO UW -- 44.0262	OXF US -- 47.8737
CPNY LD -- 44.6512	CPNY LD -- 48.6237
CONY LD -- 44.7762	OPC UW -- 50.2487
OPC UW -- 46.9012	HOOD UW -- 50.6237

HOOD UW -- 47.1512	CONY LD -- 52.1237
NCB US -- 48.9012	MEGW UW -- 52.3737
MLAC CI -- 49.0262	MLAC CI -- 52.4987
MEGW UW -- 49.4012	NCB US -- 52.4987
EUO UO -- 53.0262	EUO UO -- 53.3737
BRNJ LD -- 53.2762	GENY LD -- 54.8737
GENY LD -- 55.5262	BRNJ LD -- 58.8737
BINY US -- 55.7762	BINY US -- 60.3737
OFR UW -- 63.4012	OFR UW -- 70.1237

Appendix B

Ambient Noise Probability Density Functions

A new system for analyzing data quality is now available to the seismology community allowing users to evaluate the long-term seismic noise levels for any broadband seismic data channel streaming into the buffer of uniform data (BUD) within the Incorporated Research Institutions for Seismology (IRIS) data management system (DMS). BUD is the IRIS DMS's acronym for the online data cache from which the DMC distributes near-real time miniSEED data holdings prior to formal archiving.

The new noise processing software uses a probability density function (PDF) to display the distribution of seismic power spectral density (PSD) (PSD method after Peterson, 1993) and has been implemented against the entire continuous data-stream available within the BUD utilizing the QUACK framework. QUACK is the software package at the IRIS DMC responsible for managing the quality control (QC) of the real-time seismic data flowing into the BUD (see <http://www.iris.washington.edu/servlet/quackquery/>).

This noise processing system is unique in that there is no need to screen the data for earthquakes, system glitches, or general data artifacts, as is commonly done in seismic noise analysis. Instead with this new analysis, system transients map into a low-level background probability while ambient noise conditions reveal themselves as high-probability occurrences. In fact, examination of artifacts related to station operation and episodic cultural noise allows us to estimate the overall station quality and a baseline level of earth noise at each site.

PDF noise plots are useful for characterizing the current and past performance of existing broadband sensors, for detecting operational problems within the recording system, and for evaluating the overall quality of data for a particular station. The advantages of this new approach include:

- (1) Provides an analytical view representing the true ambient noise levels rather than a simple absolute minimum,

- (2) provides an assessment of the overall health of the instrument/station and
- (3) provides an assessment of the health of recording and telemetry systems.

Processing Methods: Power Spectral Density

Employing the algorithm used to develop the USGS Albuquerque Seismological Laboratory (ASL) low noise model (LNM; Peterson, 1993), we compute the power spectral density (PSD) for broadband stations streaming into the IRIS DMC BUD system.

In this algorithm, hour-long, continuous, and over-lapping (50%) time-series segments are processed. (There is no removal of earthquakes, system transients and(or) data glitches.) The instrument transfer function is removed from each segment, yielding ground acceleration (for easy comparison to the LNM). Each hour-long time series is divided into 13 segments, each about 15 minutes long and overlapping by 75%, with each segment processed by:

- (1) Removing the mean
- (2) removing the long period trend
- (3) tapering using a 10% sine function and
- (4) transforming by using an FFT algorithm (Bendat and Piersol, 1971).

Segments then are averaged to provide a PSD for each 1-hour time series segment.

Processing Methods: Probability Density Functions

For each channel, raw frequency distributions are constructed by gathering individual PSDs in the following manner:

- (1) Binning periods in 1/8 octave intervals and
- (2) binning power in 1 dB intervals.

Each raw frequency distribution bin then is normalized by the total number of PSDs to construct a Probability Density Function (PDF). The probability of occurrence of a given power at a particular period is plotted for direct comparison to the Peterson high and low noise models (HNM, LNM) (see fig. 1, LTX BHZ). We also compute and plot the minimum (red line), mode (black line), and maximum (blue line) powers for each period bin. A wealth of seismic noise information can be obtained from this statistical view of broadband seismic noise. For a more detailed discussion of the methods and interpretation of the PDFs, see McNamara and Buland (2004).

Figure 1

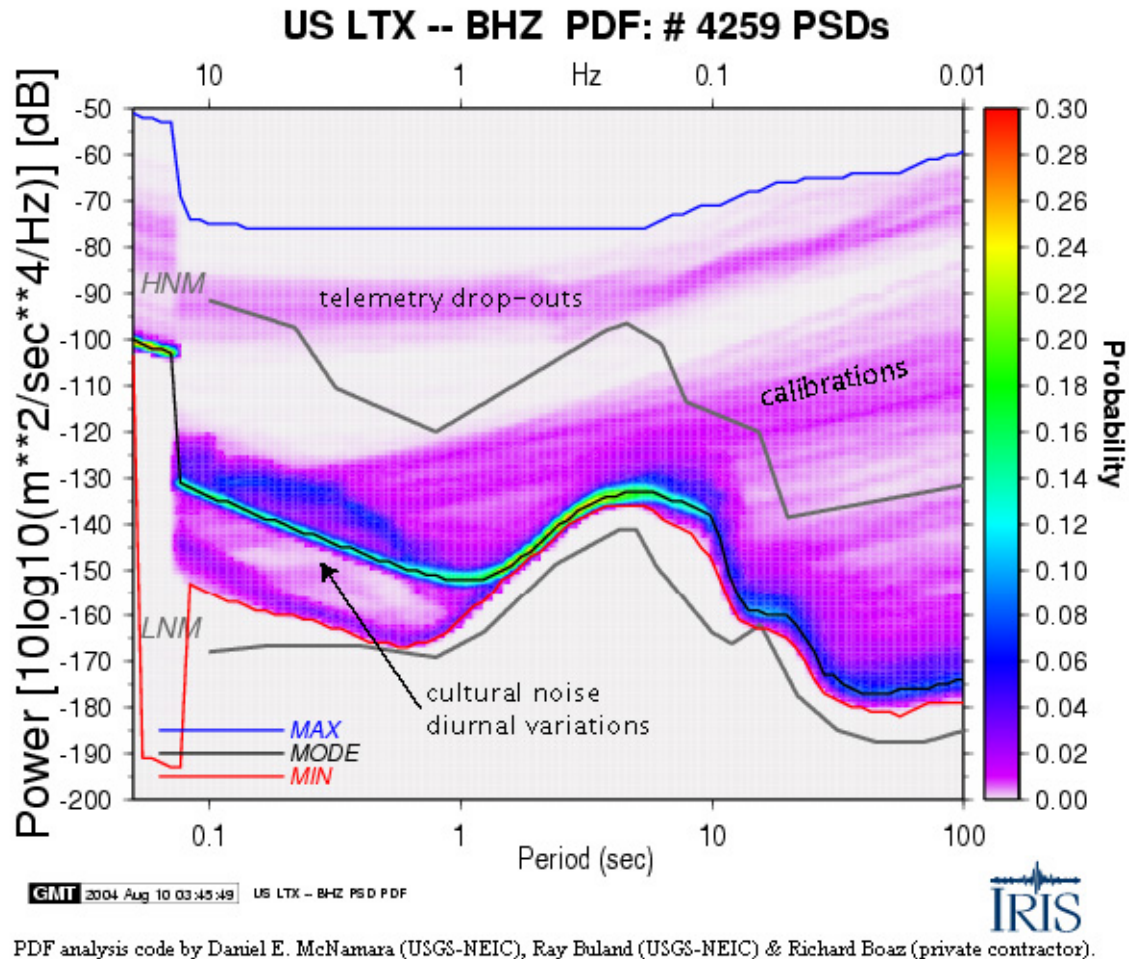


Figure 1 is a PDF example for LTX BHZ, with some artifacts and signals identified. Station LTX - Lajitas TX, was instrumental in the original Peterson Low Noise Model (Peterson, 1993), however, due to increased cultural noise (0.1-1s, 1-10Hz) the highest probability power levels (mode, black line) now are significantly higher than the Peterson low noise model (LNM). The minimum (red line) will approach the LNM <2% of the time indicating that the station minimum does not reflect actual ambient noise conditions across the whole spectrum. Instead, ambient noise conditions are better represented by the highest probability mode (black line).

Characterizing Sources of Noise and Signal in the PDFs

Cultural noise

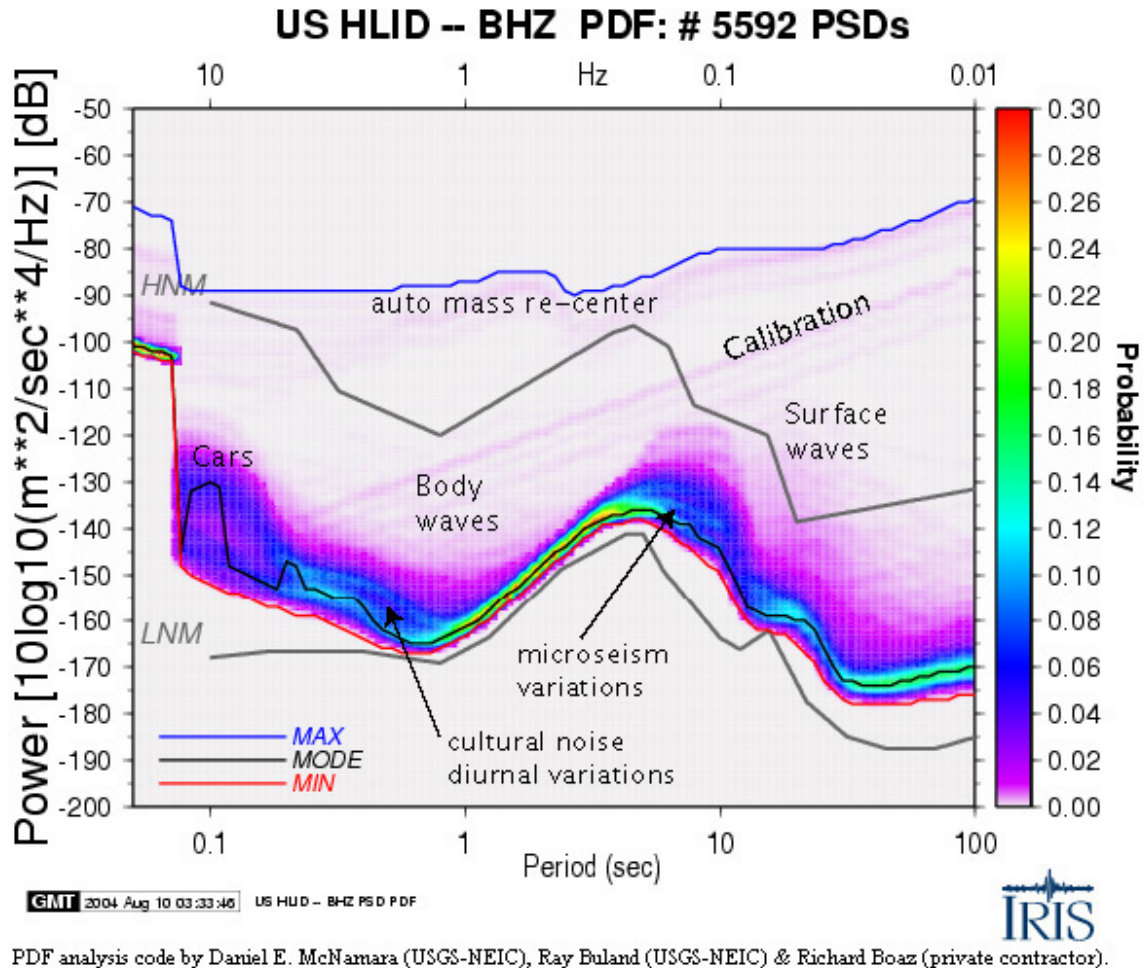
The most common source of seismic noise is from the actions of human beings at or near the surface of the Earth. This is often referred to as “cultural noise” and primarily originates from the coupling of traffic and machinery energy into the earth. Cultural noise propagates mainly as high-frequency surface waves ($>1\text{-}10\text{Hz}$, $1\text{-}0.1\text{s}$) that attenuate within several kilometers in distance and depth. For this reason cultural noise generally will be significantly reduced in boreholes, deep caves and tunnels. Cultural noise shows very strong diurnal variations and has characteristic frequencies depending on the source of the disturbance (fig. 1).

Earthquakes

Our approach differs from many previous noise studies in that we make no attempt to screen the continuous waveforms to eliminate body and surface waves from naturally occurring earthquakes. Earthquake signals are included in our processing because they generally are low probability occurrences even at low power levels (small magnitude events). We are interested in the true noise that a given station will experience, thus we include all signals. For example, including earthquakes tells us something about the probability of teleseismic signals being obscured by small local events as well as various noise sources. Large teleseismic earthquakes can produce powers above ambient noise levels across the entire spectrum and are dominated by surface waves $>10\text{s}$, while small events dominate the short period, $<1\text{s}$. Earthquakes are observed in the PDFs as low-probability smeared signal at short and long periods (fig. 2).

System Artifacts

Since we make no attempt to screen waveforms for system transients such as data gaps and sensor glitches, the PDF plots contain numerous system generated artifacts that can be very useful for network quality-control purposes. We have attempted to determine the source of several coherent, high power, low-probability noise artifacts in the PDF plots. Several artifacts in the PDFs are explained easily and may be useful to the network operator. For example, data gaps (due to telemetry drop-outs) and automatic mass recenters (necessitated by “drift” in sensor mass position) are easily identifiable in the PDFs. Should the probability of mass recentering and telemetry drop outs drastically increase, a remote network operator could readily diagnose the problem (figs. 1 and 2). Additional features and artifacts observed in the PDFs are described online at: http://geohazards.cr.usgs.gov/mcnamara/PDFweb/Noise_PDFs.html and in McNamara and Buland (2004).



PDF analysis code by Daniel E. McNamara (USGS-NEIC), Ray Buland (USGS-NEIC) & Richard Boaz (private contractor).

Figure 2: HLID - Typical ANSS station ~10km from Hailey Idaho. Automobile traffic along a dirt road only 20 meters from station HLID creates a 20-30dB increase in power at about 0.1 sec period (10Hz). This type of cultural noise is observable in the PDFs as a region of low probability at high frequencies (1-10 Hz, 0.1-1 seconds). Body waves occur as low probability signal in the 1sec range while surface waves generally are higher power at longer periods. Automatic mass recentering and calibration pulses show up as low probability occurrences in the PDF.

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