Improvements in Very Long-Period Observations

A. T. Ringler[1], J. Steim[2], R.Widmer-Schnidrig[3], David Jones[4], R. E. Anthony[1], T. Forbriger[3], C. R. Hutt[1], and D. C. Wilson[1]

[1]U.S. Geological Survey, Albuq. Seis. Lab., [2]Qaunterra, Inc., [3]Black Forest Observatory, [4]KBRwyle, Albuq. Seis. Lab.

Abstract

Our ability to unambiguously record long period (greater than 200 s) seismic signals (e.g. normal modes) is limited as a result of a combination of sensor noise, site noise, and the sensitivity of our recording equipment to non-seismic noise sources (e.g. pressure and temperature). With the recent development of the STS-6 very broadband seismometer the Global Seismographic Network (GSN) is reducing noise levels at many stations. These improvements come from two fundamentally different changes at the station. The first is a direct result from installing a borehole seismometer with low self-noise so that the true local site noise becomes the limitation instead of the sensor noise, as was the case with the KS-54000. The second improvement comes from replacing a vault installation with a borehole sensor at shallow depth. This can be achieved by drilling through the pier in a standard seismic vault. This reduces a large amount of local tilt noise as well as increase the thermal capacity around the sensor over a vault type installation. Several surface vaults are being transitioned into shallow boreholes which results in a further reduction of noise. We look at initial improvements at a few GSN sites as well as what are some of the potential limitations in long-period resolution at these sites. Such improvements will have implications for the fidelity and observability of very long-period signals like earth hum and observing torsional normal modes.

Questions

1) What improvements can we expect with replacing the borehole sensors in the GSN with STS-6?

2) Can the STS-6 compete with the best STS-1s in the GSN?

3) What new observations might we see?

4) What previous observations could be revisited?

Improvement over the KS-54000

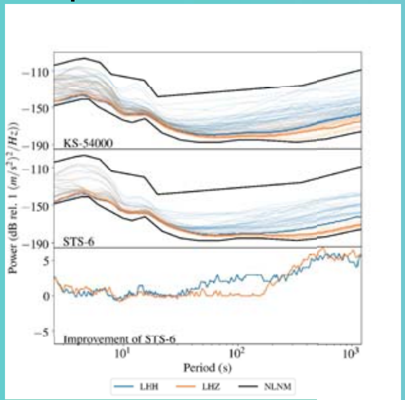

Figure 1: 10th percentile Power Spectral Density (PSD) estimates for 365 days of data for all Global Seismographic Network (GSN) station operatoring GeoTech KS-54000 (top) or a Streckeisen STS-6 (middle) starting September 7, 2018. The horizontals components are denoted in blue (LHH) and the vertical components in orange (LHZ). The 10th percentile differences between the 10th percentile for the KS-54000 and the STS-6 are also shown (bottom). For reference we include the Peterson (1993) NLNM.

1) We can easily get 5 dB improvement at 100+ s period

STS-6 at Black Forest Observatory

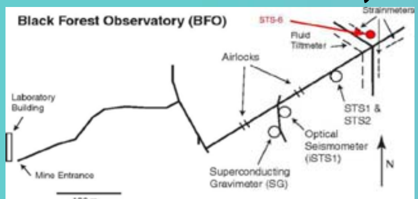

Figure 2: Layout of the Black Forest Observatory vault (reproduced from Berger et al., 2014). Three 1.5 m cased boreholes were drilled next to the strainmeter (red circle) on a cement pad. This location is behind the airlocks.

Figure 3: Field engineer David Jones and Rudolf Widmer-Schindrig drilling the second of three holes in the east strainmeter tunnel. The middle cased hole can be see n at the very bottom.

Figure 4: Bird-eye view of hole with casing and sensor inside of it.

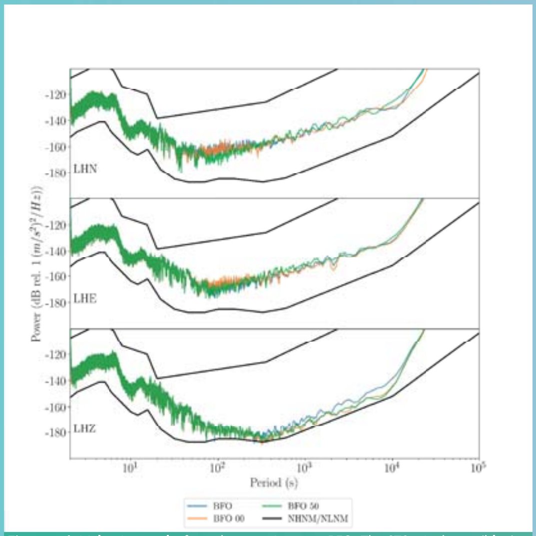

Figure 5: Initial noise results from the experiment at BFO. The STS-2 is shown (blue) for a time range of September 23, 2018 to September 24, 2018. The STS-1 is shown in orange and the STS-6 is shown in green. For reference we include the Peterson (1993) NHNM/NLNM

1) Initial installation results look promising. However, we are still investigating the differences in horizontals at 100 to 200 s period. Initial time dependence will need to be further investigated.

Revisiting Very Long-Period Observations

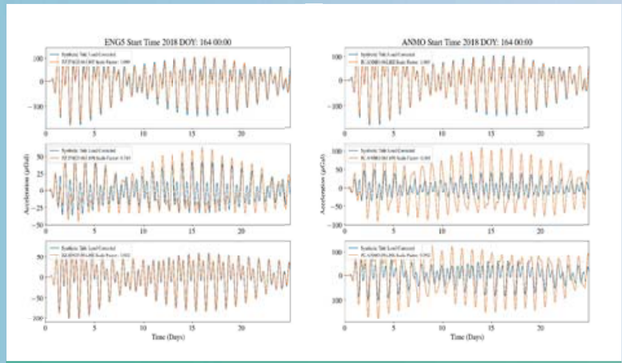

Figure 6: (Left) Semi-diurnal and diurnal synthetic Earth tides (blue) after load correction overlaid by the STS-6 that replaced ANMO (station name ENG5 at the time of testing, orange) for the vertical (top), the North-South (middle) and the East-West (bottom). (Right) same as Left, but for the ANMO KS-54000.

3 and 4) LOTS! With just one new sensor we get a NEW NLNM and horizontal hum

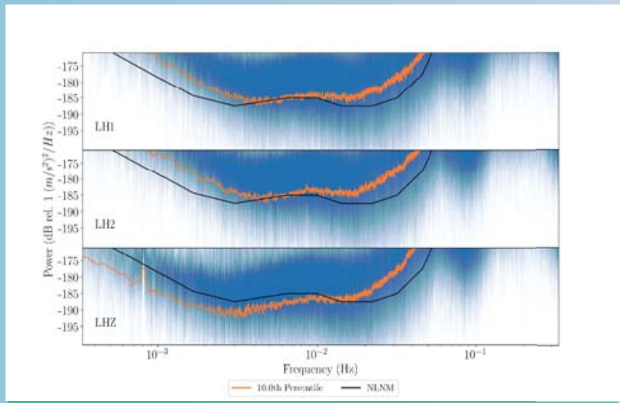

Figure 8: (Top) Stacked PSD estimates for the LH1 component of ANMO from August 18, 2018 to September 27, 2018. The background PSD estimates are shown (blue) along with the 10th percentile (orange). (Middle) Same as top, but for the LH2 component. (Bottom) Same as top, but for the LHZ component. We have included the Peterson (1993) NLNM for reference.

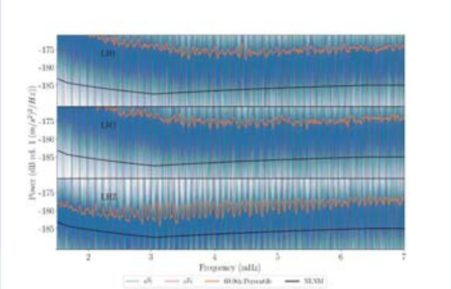

Figure 7: (Top) Stacked PSD estimates for ANMO from July 11, 2018 to September 27, 2018. The background PSD estimates are shown (blue) along with the 60th percentile (orange). We show fundamental mode spherical (green) and torodial (red) modes using PREM (Dziewonski and Anderson, 1981).

Conclusion

- We should expect 5 dB or greater improvements in horizontal noise levels across the GSN. Stations with KS-54000 should also see improvement in the verticals.

- The STS-6 appears to be able to produce data as good as some of the very best operating STS-1.

- Locally induced tilt signals as well as better resolution of very long-period normal modes should become more frequent because of more relaible and higher resolution borehole sensors.

- Previous observations like the NLNM (Peterson (1993) or horizontal Earth hum (Kurrle and Widmer-Schnidrig, 2008) should be revisited with the improved data set that the GSN is producing.

Acknowledgments

We thank Dan Auerbach, Pete Davis, Peter Duffner, Carl Ebeling, Robi Freudenmann, and Walter Zuern for help with the tests conducted at BFO as well as other discussions that that motivated this work. We thank Duncan Agnew for help with ocean loading corrections

References

Berger, J., Davis, P., Widmer-Schnidrig, R., and Zumberge, M. (2014). Performances of an optical seismomemter from 1μHz to 10 Hz, Bulletin of the Seismological Society of America, 104, 2422-2429.

Dziewonski, A. M., and Anderson, D. L. (1981). Preliminary reference Earth mode, Physics of the Earth and Planetary Interiors, 25, 297-356.

Kurrle, D., and Widmer-Schnidrig, R. (2008). The horizontal hum of the Earth: A global background of spheroidal and toroidal modes, Geophysical Research Letters, 35, L06304.

Peterson, J. (1993). Observations and modeling of seismic background noise, U.S. Geol. Surv. Open-File Rept. 93-322, 94 pp.