Long-period Noise Analysis of Power Spectral Density (PSD) PDFs in Sweetwater, TX, USA

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I. The Sweetwater Mixed Phase Array Experiment

In March 2014, as a result of a collaborative effort between Nodal Seismic, Nanometrics, and IRIS/PASSCAL, a temporary network of 20 Trillium Compact Post Hole sensors (20 sec) and 5 Trillium 120 Post Hole sensors were deployed ~ 20 km north of Sweetwater, Texas. Data were recorded and digitized with Centaur datalogger systems at 20 and 200 sps. The broadband stations were operative until the end of April 2014. One of the main objectives of the project was to characterize noise fields in order to optimize station locations, instrument performances, and to improve imaging applications. The area is characterized by a plethora of noise sources including wind, injection wells, oil pump jacks, electric pump, fracking wells, wind farms, roads, trains, windmill water pumps, and farm related machinery. This experiment generated an active-passive, multi-mode dataset, that is now publicly available at the DMC (XB.2014-2014) for use in a wide variety of studies.

II. Array Installation Procedure

25 broadband sensors were directly buried in shallow auger holes (20-24 inches in depth, 6-8 inches in diameter), compacted at the base. Five stations were telemetered via cell modems. The geometry of the array features a small aperture array contained within a greater circular array.

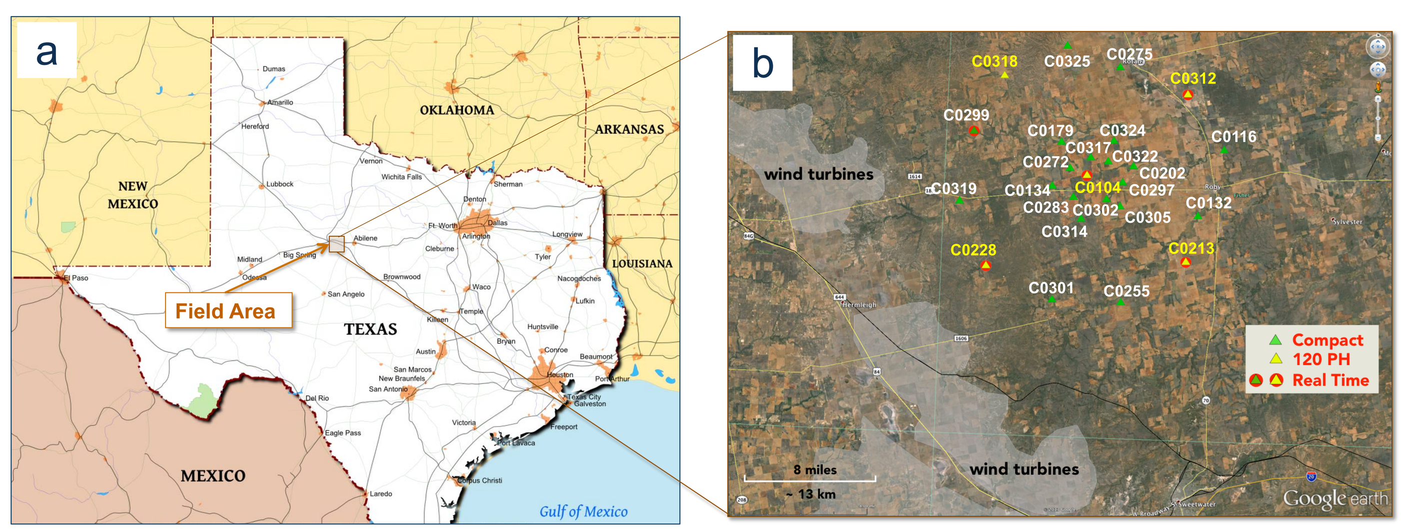


Figure 1. a) Location map of Sweetwater, Texas. b) Location and geometry of the array of 25 broadband stations used within this study.

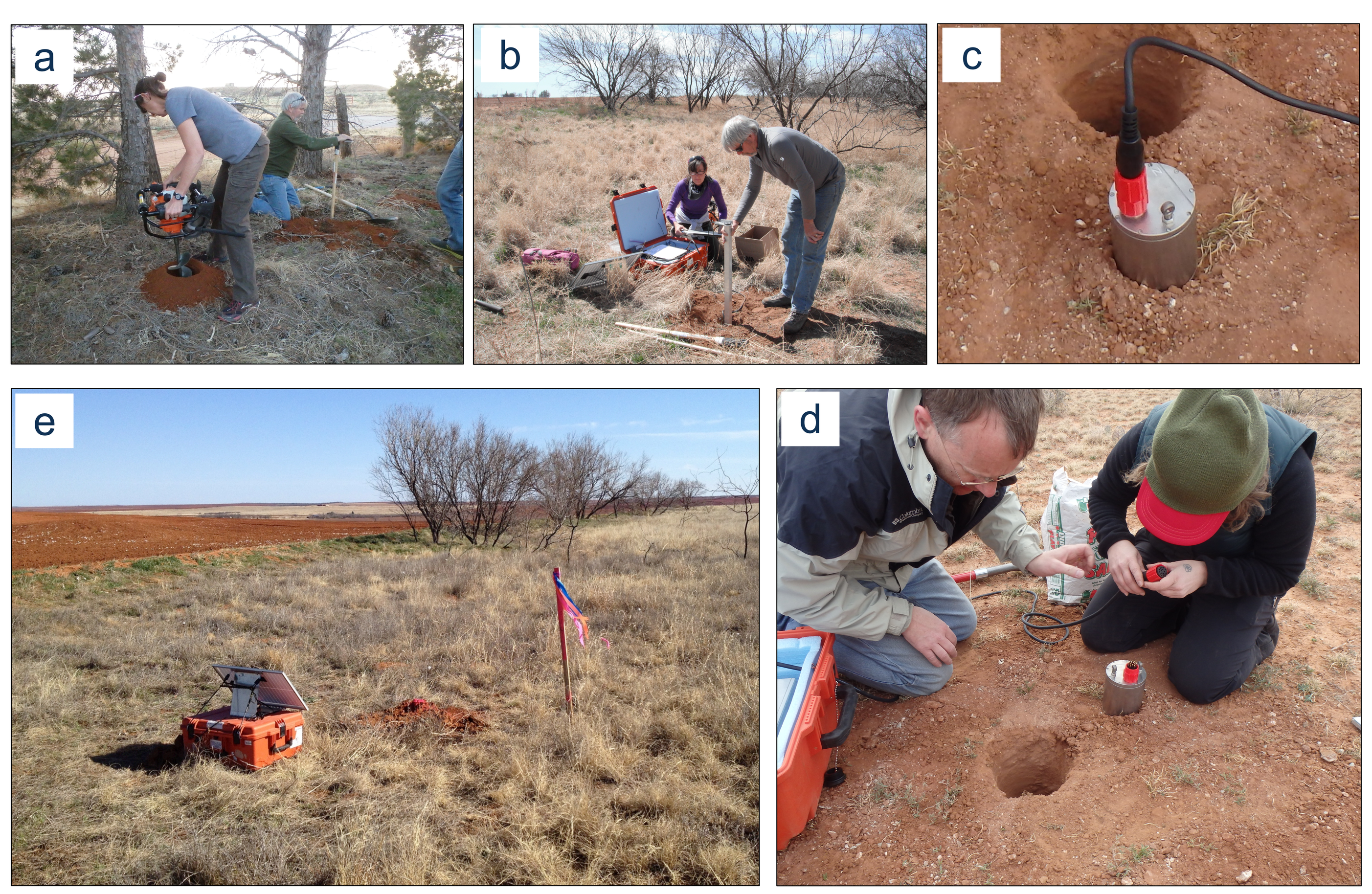
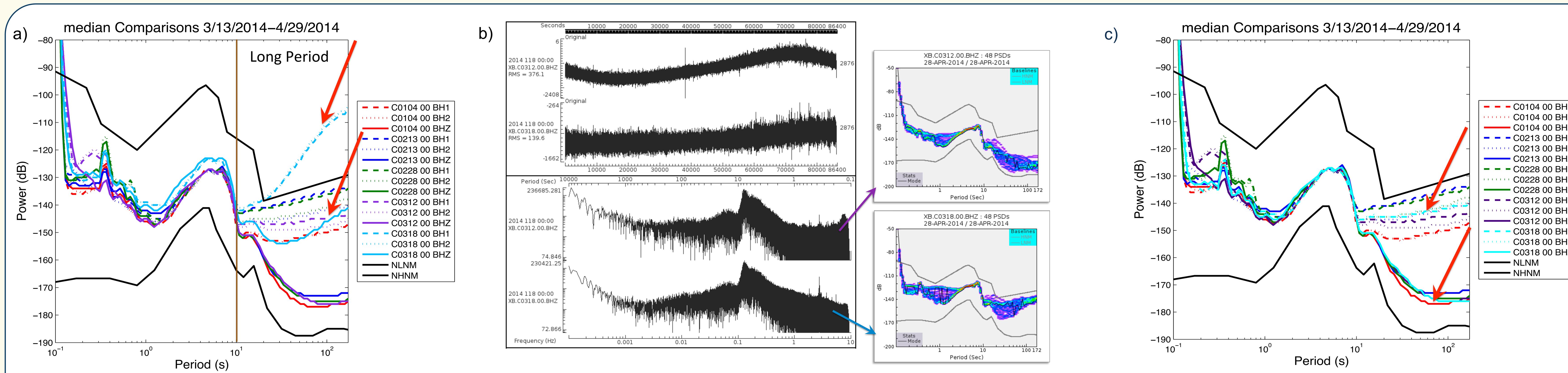


Figure 2. Direct burial installation procedure: a) Augering a hole for the sensors. b) Orienting the sensor with orienting tool: position orienting tool within the groove on the top of the sensor and place compass on top. Make sure bubble level flat. c) Trillium Compact PH sensor. d) Trillium Compact PH sensor ready to be connected and placed in the hole. e) Station installed and powered with solar panel.

III. Power Spectral Density (PSD) PDFs

Channel specific median Power Spectral Density Probability Distribution Functions (median PSD PDFs) were generated from continuous, overlapping (50 %) 1-hour segments using SQLX software system (McNamara and Buland, 2004). All available data are included (i.e., earthquakes, system transients, sensor calibrations and data glitches). We analyze PSD PDFs in order to identify station quality issues and to estimate the variation of noise at a given station. Seismic noise can be the result of the instrument itself (self-noise) or it can be produced from ambient Earth vibrations. In this study, we focus on long-period noise (> 10 sec) over the entire installation period, first for the 5 Trillium 120 Post Holes, then for the 20 Trillium Compacts, and thereafter for the entire dataset.



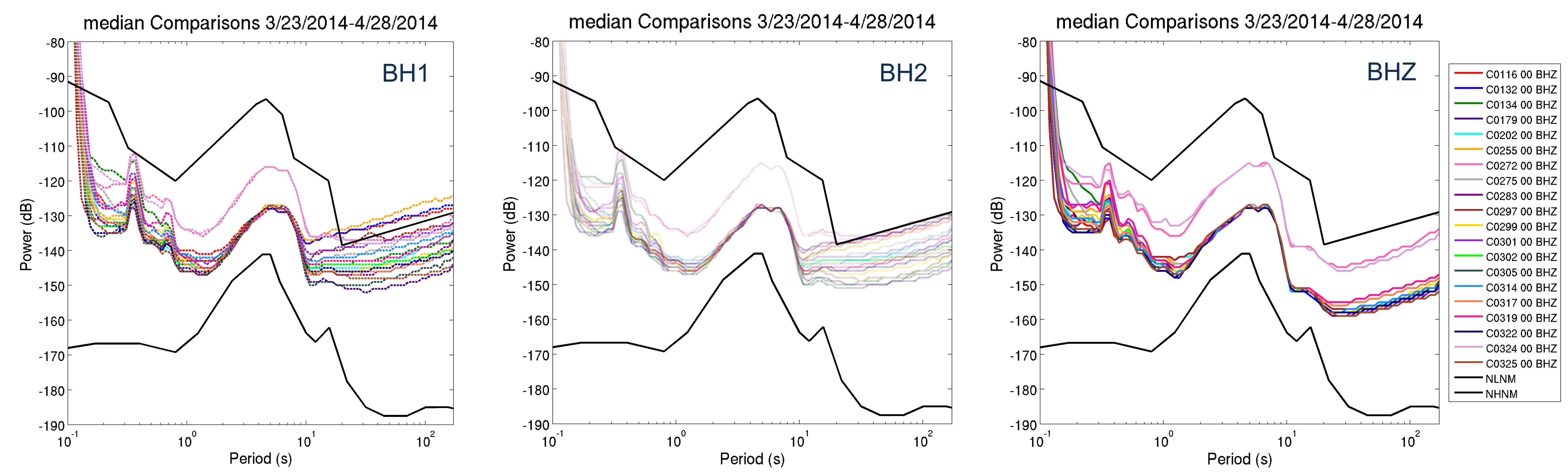


Figure 4. Median PSD PDF comparisons from 3/23-4/28/2014 for the 20 Trillium Compact PH (20 sec) stations. Each channel is shown separately for clarity. Notice the higher noise levels C0272 (pink line) and C0324 (light pink line) observed at all frequencies, even in the microseism band, which should be the same for all stations. All of the stations were programmed to have a gain of 4. A factor of ~4 difference was observed in the RMS values of C0272 and C0324 as compared to the other stations, suggesting that the gain for these two stations may actually be 16. A malfunctioning datalogger, which could switch the gain to higher setting may be a potential cause for this problem. Nanometrics has been notified and PASSCAL personnel will work with them in order to resolve the issue.

Figure 3. a) Median PSD PDF comparisons from 3/13-4/29/2014 for the 5 Trillium 120 PH stations (all components). Station C0318 shows anomalous high noise levels on both vertical and horizontal components, raising above the New High Noise Model (NHNM – Peterson, 1993) for the latter (red arrows). b) The raw data and spectra for C0318 and a reference station (C0312) were examined further in order to determine whether the station was truly a noisy site, had a problematic sensor, or had an incorrect meta-data description that was affecting the deconvolution. Notice how the raw data and spectra do not show the anomalous behavior that is observed in the PDF. If, for example, C0318 was actually using a Trillium Compact response (20 sec), it would raise the long period noise levels higher in order to correct for a lack of long period response after 20 sec (observed in the horizontal components, figure 3a). Also note the strong corner after 20 sec on the Z component, then the upturn of the response, which is not observed in the other station's Z components, suggesting that C0318 is experiencing (falsely) instrument self-noise beyond 20 sec. c) Corrected PSD PDFs. Although the dataless suggested C0318 was by label a Trillium 120 PH sensor, the actual response was mistakenly associated with a Trillium Compact (20 sec) response. After associating the correct response with C0318, notice how the PSD PDF noise levels are more reasonable in comparison to the other stations.

Data and Resources

The instruments used in the field were provided by Nanometrics, with the fieldwork supported jointly by the PASSCAL staff and Nanometrics field technicians. Data collected during the experiment are available through the Incorporated Research Institutions for Seismology (IRIS) Data Management Center under the network code XB.2014-2014. The facilities of the IRIS Consortium are supported by the National Science Foundation under Cooperative Agreement EAR-0552316 and by the Department of Energy National Nuclear Security Administration.

References

McNamara, D. E., and Buland, R. P. (2004). Ambient Noise Levels in the Continental United States, *Bull. Seismol. Soc. Am.* 94: 1517-1527.

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Summary Observations

1. Generally, at long periods, for both the Trillium Compact (TC) and Trillium 120 PH (T120PH) horizontal components have higher noise levels than their corresponding vertical components (~15 dB higher for TC, and ~35 dB for T120PH). These high noise levels can be possibly attributed to tilt (i.e., wind-induced tilt). Tilt is, indeed, usually two orders of magnitude greater in amplitude on the horizontal components than on the vertical channel.
2. Horizontal components show a wider range of noise power (~20 dB), whereas the vertical channels are restricted to a narrower band (< ~5 dB). The spread, for both horizontal and Z components, becomes larger as it reaches periods of 100s.
3. Instrument self-noise of the Trillium Compact is clearly visible beyond 20 sec, whereas the Trillium 120 PHs exhibit lower noise levels beyond 20 sec.

Conclusions

This study validates the importance of utilizing PSD PDFs as quality control tools as they can allow for simple evaluations of sensor performances and instrument response issues. They also provide guidance on the optimization of network design, by individuating locations that show minimum levels of seismic noise and discarding those with high noise levels.