Geologic Hazards Science Center
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Global Seismographic Network Data Quality from Signal to Noise Measurements at Tidal Frequencies

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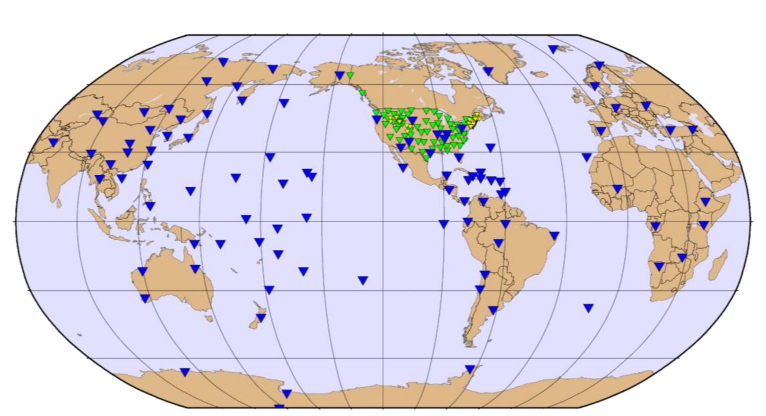
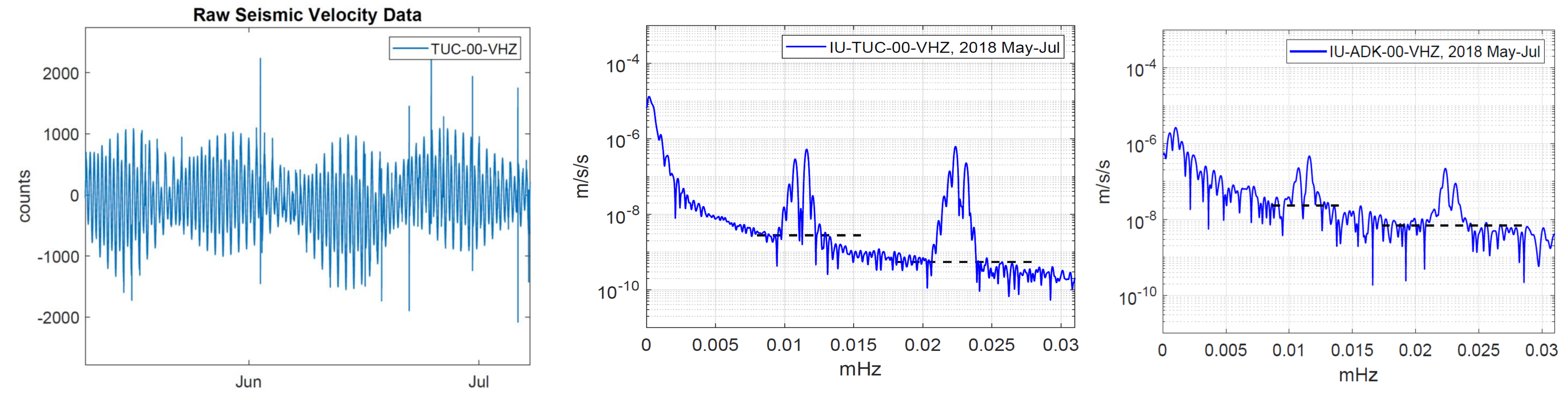
Introduction

We assess data quality at the IRIS/USGS Global Seismographic Network (GSN) sites using seismic amplitudes measured at diurnal and semidiurnal Earth tide frequencies (0.011 and 0.022 mHz) relative to the noise floor at each site measured between the diurnal and semidiurnal tides. Earth tide amplitudes have been previously used for verification of the long period response of GSN stations (Davis and Berger, 2007). In this study we examine our ability to resolve Earth tides and the dependence of this resolution on installation site characteristics (vault vs. borehole, installation depth, etc.) as well as sensor type. We find that Earth tide resolution is improved by changing from a vault installation to a posthole (in bedrock) or borehole installation. This may be in part due to the better thermal isolation of a sensor at depth. We also look at sites where possible cavity effects could produce anomalous horizontal tides. Finally, we also find that the latest generation of very broadband borehole sensors that are being installed in the GSN are leading to a lowered noise floor at very long periods. These improvements will ultimately help to reach the GSN design goals by improved (lower) noise levels over a wide range of frequencies.

Map of GSN stations



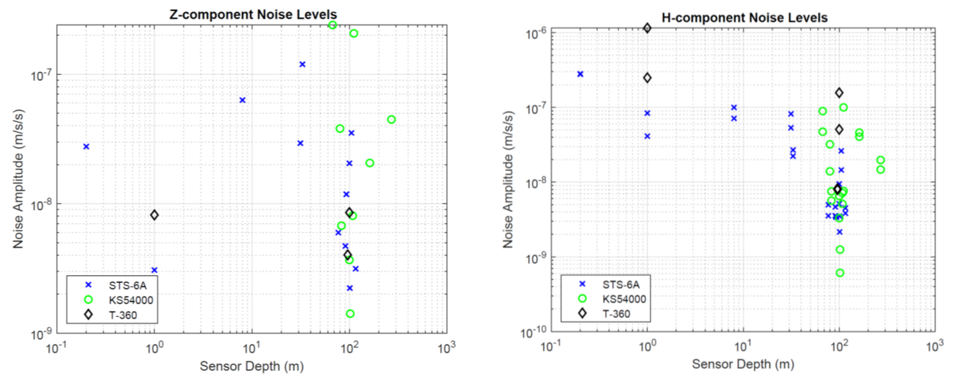
Global map of IU, IC, and CU Global Seismographic Network (GSN) stations (blue triangles) used in this study. GSN stations range from mid-continent to oceanic island stations. Sensor installations range from 100+ meter borehole installations to shallow surface vault installations.



The primary sensors of the GSN are predominantly STS-1's (surface vault sensor) or KS54000's (borehole sensors). In recent years the GSN has been replacing primary sensors with Streckeisen STS-6A and Trillium-360 Borehole sensors. The example above shows 1.5 months of data from an STS-6A installed at shallow depth (2m) at IU-TUC (Tucson, Arizona). The 24hr and 12hr Earth tide oscillations are evident in the raw data along with several large earthquakes.

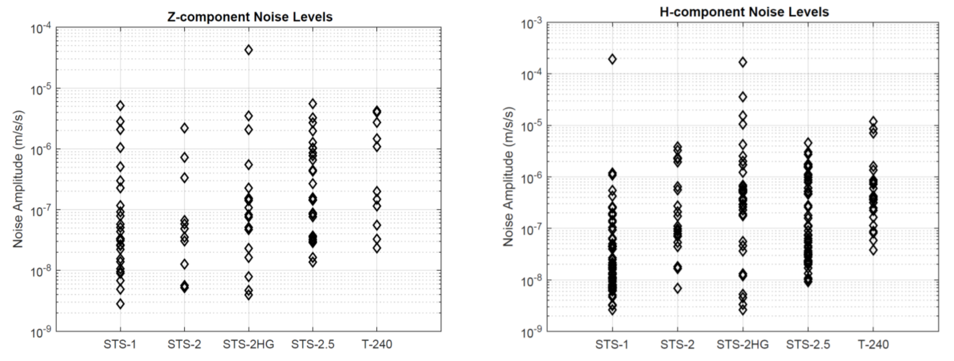
Tidal noise measurements in this study are made by computing the amplitude spectra for seismic data recorded at GSN sites (network codes IU, IC, and CU) between May, 2018 – July 2018. Each noise measurement is done by taking the median amplitude over a half-octave width centered at a given frequency (i.e. from 0.75f to 1.25f). The noise measurement is shown as a black dashed line in the examples above. The left panel shows the noise measurement for the STS-6A at IU-TUC and the data in the right panel is from station IU-ADK which for this time period was a STS-1 in a surface vault.

Tidal Noise by Sensor Type: Borehole Sensors

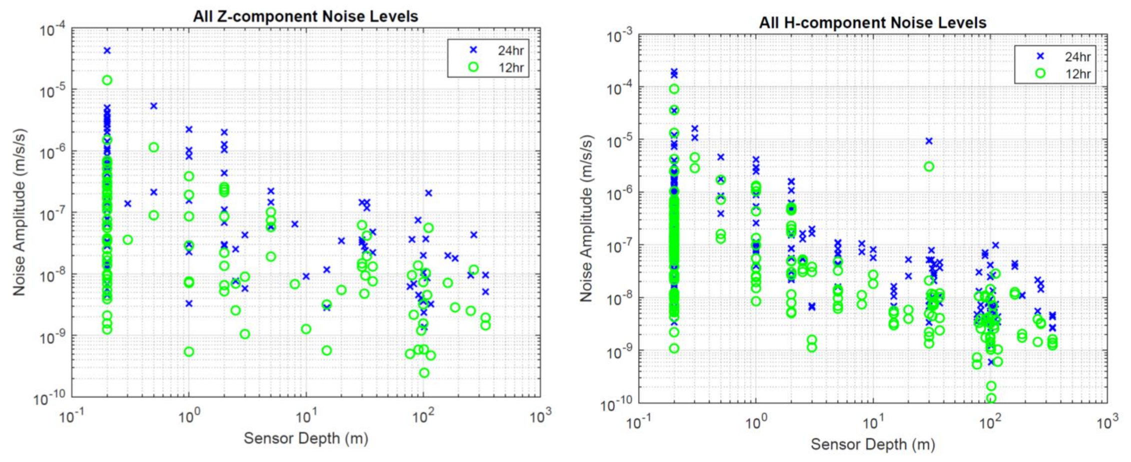


There is no clear pattern of one borehole sensor having lower noise than the others. Even at 100 meters depth sensors can have a wide range of noise levels at tidal frequencies.

24hr Tidal Noise by Sensor Type: Surface Vault Sensors



All surface vault sensors show a wide range of 24hr noise levels. STS-1's appear to have slightly lower average noise than other sensors, however, STS-1's are typically installed in the primary (quietest) vault while the other sensors may be located on a lower quality pier.

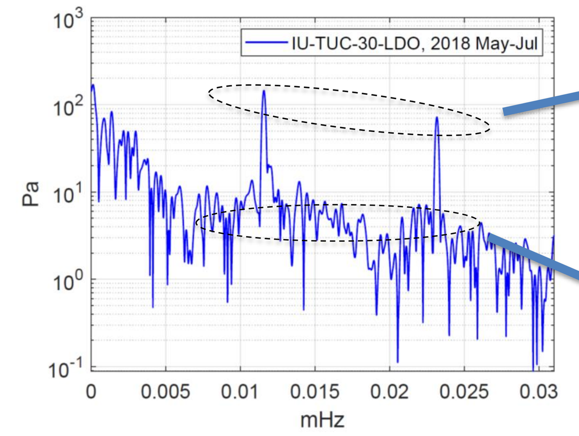


24hr and 12hr Tidal Noise Vs. Sensor Depth

At tidal frequencies there should not be significant attenuation with depth in terms of a surface deformation propagating downwards (e.g. Sorrells, 1971) because the wavelengths at tidal frequencies would be orders of magnitude greater than the sensor burial depth. Perhaps the decreased noise with depth is an indicator of a higher quality installation (in caves, tunnels, and boreholes), not an attenuation phenomenon.

What is the influence of 24hr and 12hr pressure fluctuations on seismic background noise at these same frequencies?

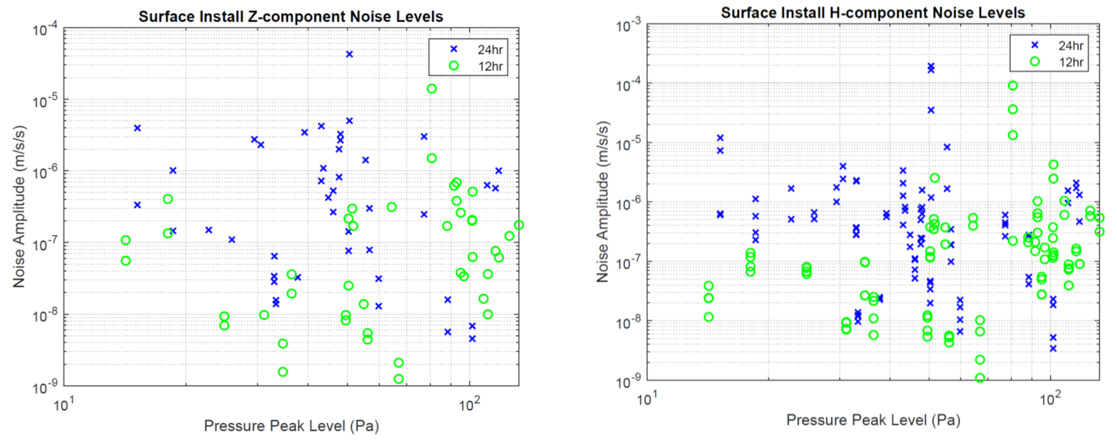
The majority of GSN stations have pressure sensors that can be used to identify the effect of pressure fluctuations on seismic data. Amplitude spectra for the pressure channel at station IU-TUC is shown below. Pressure noise levels were calculated using the same method as for the seismic data.



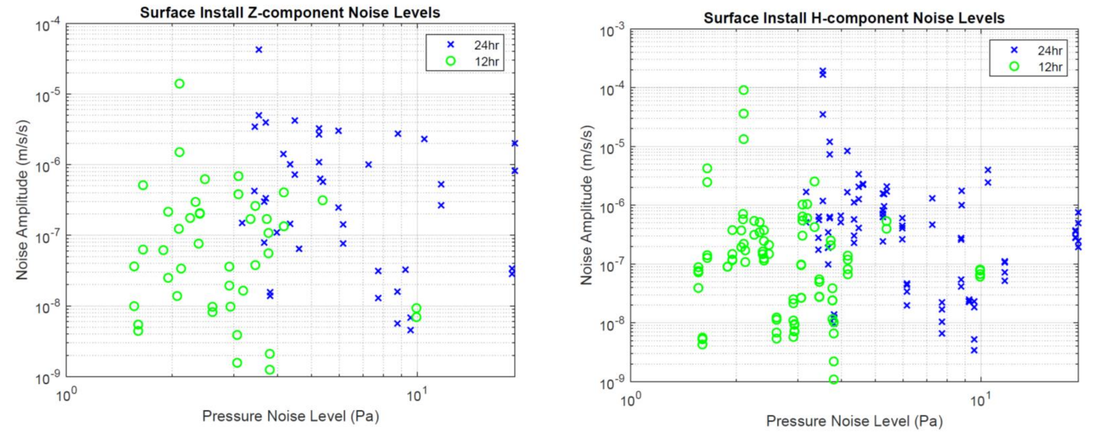
Two possible pressure effects could be 1) noise due to ground surface/vault deformation in response to pressure changes, or 2) pressure fluctuations acting directly on the sensor's mass causing excess noise.

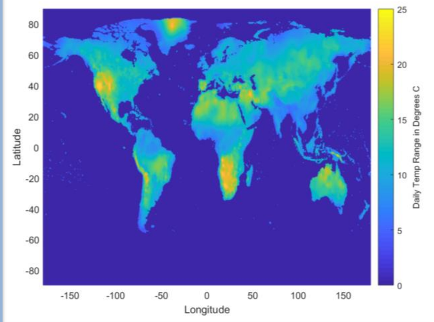
The plots to the right indicate that there is no apparent correlation between pressure fluctuations at tidal frequencies to seismic background noise at these frequencies.

Surface Vault Noise Vs. Pressure Peak Measurement



Surface Vault Noise Vs. Pressure Noise Level

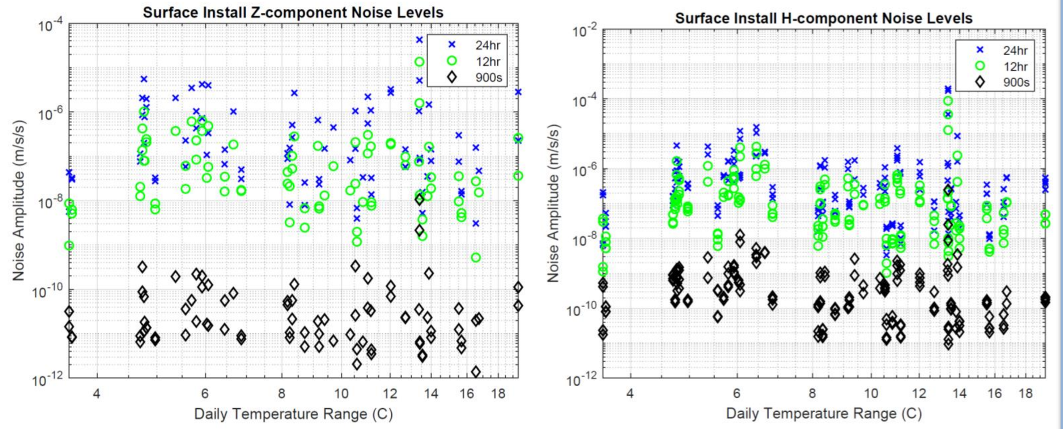




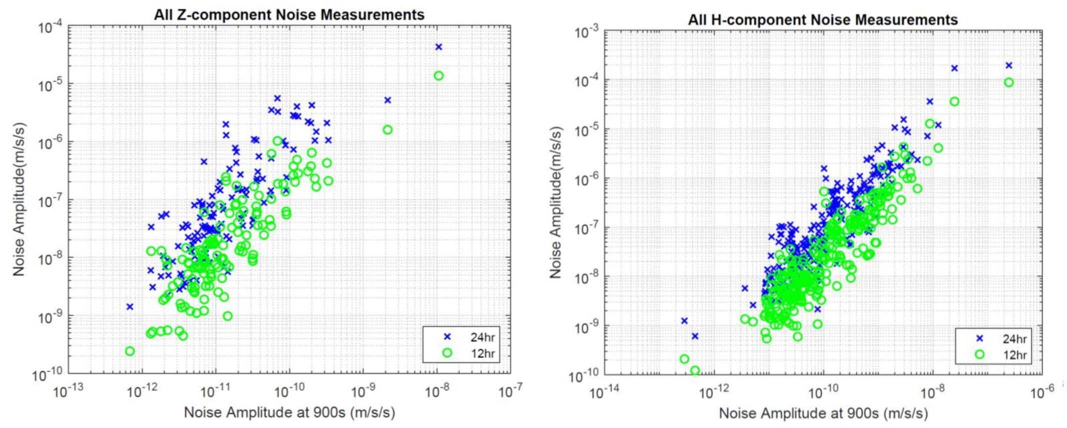
Daily temperature range average for the month of July for years 2011-2016 (Harris et al, 2014)

What is the influence of daily temperature fluctuations on seismic background noise at tidal frequencies? The plots to the right indicate there is no apparent correlation.

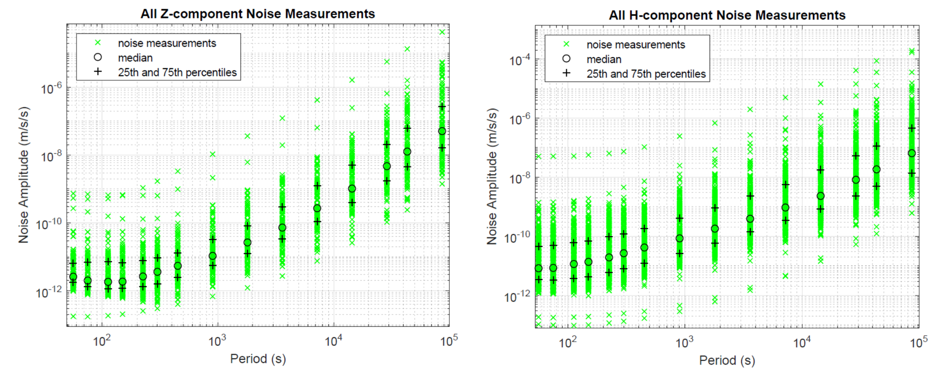
Two possible temperature effects could be 1) noise due to ground surface/vault deformation in response to temperature changes, or 2) the noise output of the sensor may change as a function of temperature due to poor thermal compensation of the springs (Doody et al., 2017). Neither seems to be a factor at tidal frequencies nor at higher (900s) frequencies.



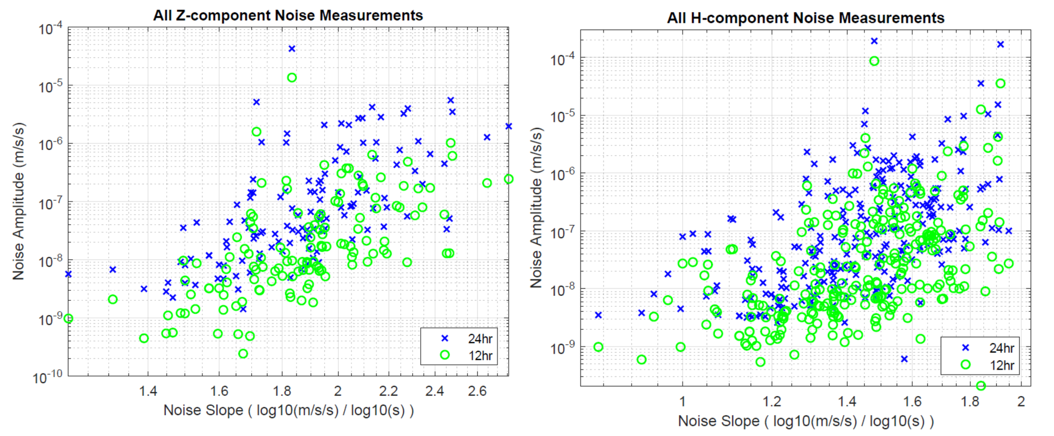
Surface Vault Noise Vs. Temperature Variation

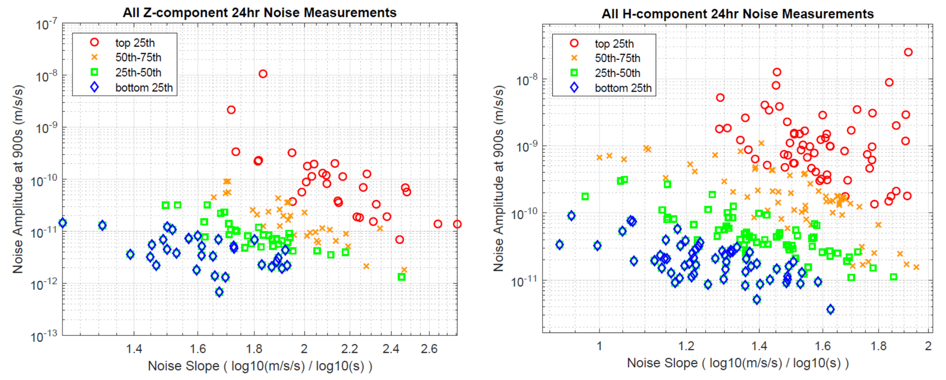


Background noise measurements typically show a change in slope as shown below. This slope change is most evident in the vertical components and happens around 900s period. This may represent the point which separates the region where 1/f noise (e.g., Melton, 1976) dominates (at lower frequencies) from other site noise at higher frequencies. 1/f noise extends to higher frequencies for the horizontal components likely due to the greater effect of tilt on the seismic background noise on the horizontals.



If environmental drivers at tidal frequencies do not correlate with seismic background noise levels at tidal frequencies, is background noise controlled by 1/f noise from sources at higher frequency? The plots above show that there is a strong correlation between noise at higher frequencies (900s in this case) and noise at tidal frequencies.

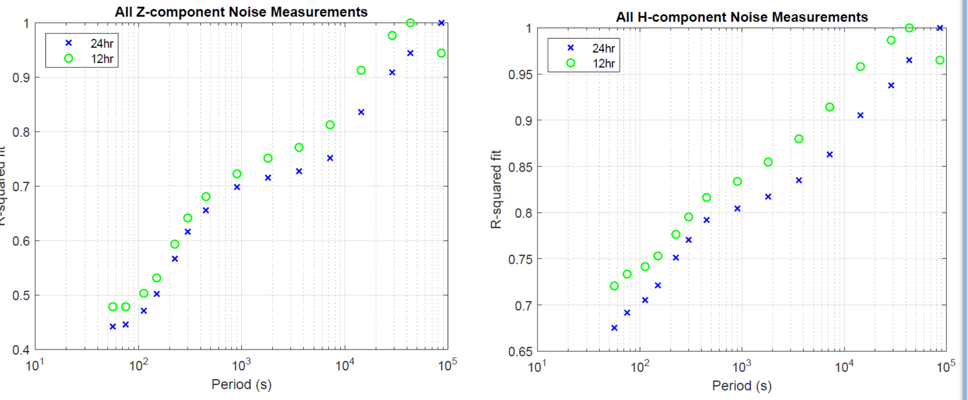




Given the strong correlation between noise at 900s and noise at tidal frequencies, is the slope of the background noise (in amplitude/frequency space) between 900s and 24 hours relatively constant? No, instead there is a correlation between steeper slopes (noise increasing more rapidly at longer periods) and higher background noise levels at tidal frequencies as shown above.

High noise levels at tidal frequencies are strongly correlated both with noise levels at higher frequencies (900s) and with steeper amplitude/frequency slopes.

The plots to the right show the coefficient of determination (R-squared) for linear fits to noise levels at periods along the X-axis vs the noise levels at 24 and 12 hours. Horizontal components have a better fit to higher frequencies than the verticals, likely due to the greater effect of tilt on the seismic background noise on the horizontals.



Conclusions

- Background seismic noise levels at tidal frequencies are not correlated with sensor type, daily pressure variations, or the magnitude of diurnal temperature swings.
- Sensors installed at greater depths tend to have lower noise levels at tidal frequencies, however some surface installations can achieve low noise levels as well. This, along with the point above, indicates the quality and stability of an individual installation is more critical for determining noise levels than environmental drivers or sensor depth alone.
- Background noise at tidal frequencies correlates with noise levels at higher frequencies indicating a major control on noise levels may be 1/f noise from sources at higher frequency. 1/f noise extends to higher frequencies for the horizontal components likely due to the greater effect of tilt on the seismic background noise on the horizontals.

References

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