Schumann Resonance Coherence Across Multiple Kilometer Distances

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Introduction

In order to study if a magnetometer placed at a location a dozen kilometers from an interferometer could be used for future exclusion of Schumann resonances from interferometer data, measurements were made of the magnetic coherence between the remote site Villa Cristina (43°32'22.3"N 10°24'36.2"E) and EGO VIRGO (43°39'24.9"N 10°30'58.4"E). Villa Cristina was chosen for its very low background magnetic noise due to its location on a mountainside.

Method

A magnetometer and seismometer were left attached to a datalogger inside the Villa Cristina house from June 23rd to June 27th and from June 29th to July 1st. During the first period a magnetometer and datalogger were also placed at 600 meters down the west arm of the VIRGO detector from June 24th to June 27th. During the second period the magnetometer was moved to the western edge of the fence around the north end building, and connected by a long cable directly to the VIRGO DAQ system from June 29th to July 1st. In all cases the magnetometers were oriented North-South. The datalogger was set to a sampling rate of 250 Hz and a 10V input range. The magnetometer directly connected to the DAQ was sampled at 20000 Hz and then decimated to 250 Hz to match the other data sets.

Analysis

Data was converted from the datalogger .miniseed files or from frame files into MATLAB vectors for ease of use[1]. A calibration factor was applied to data from the dataloggers. PSDs and CPSDs were then calculated using a ten second hanning window across June 25-26 (Villa Cristina 1 - 600 west) and June 30 (Villa Cristina 2 - North End Building). A percentile "cleaning" scheme was used to select data which we thought would lead to the highest coherence. Data acquired at the VIRGO site was very noisy due to the density of electrical systems there. A set of "good" time bins were determined by calculating the RMS of each CPSD and then selecting ones between the 1st and 10th percentile of lowest RMS values. As the Schumann resonances are very low in amplitude, almost all unwanted noise has a higher amplitude and can be eliminated. Very low RMS CPSDs were generally due to zero values from missing data in the DAQ system, and were therefore also eliminated. Then, using a similar process a set of "good" frequency bins was determined taking the 98th percentile of lowest RMS values, in order to eliminate an 8Hz line and its harmonics, which was so constant in frequency we believed it must come from our own datalogger or the power supply to the magnetometer. From these selected bins, the coherence was calculated using the formula $\gamma_{xy}^2(f) = \frac{|S_{xy}(f)|^2}{S_{xx}(f)S_{yy}(f)}$, where S_{xy} is the cross spectral density and S_{xx} and S_{yy} are the respective power spectral densities. Comparing coherence plots, The Villa Cristina 2 - North End Building data set shows the best coherences over the most Schumann resonances, although it has lower coherence below 12 Hz. That data set is the source of all the figures in this document.

[1] The MATLAB scripts used for analysis and plotting can be found at `https://github.com/TristanShoemaker/Schumann/`

In Time

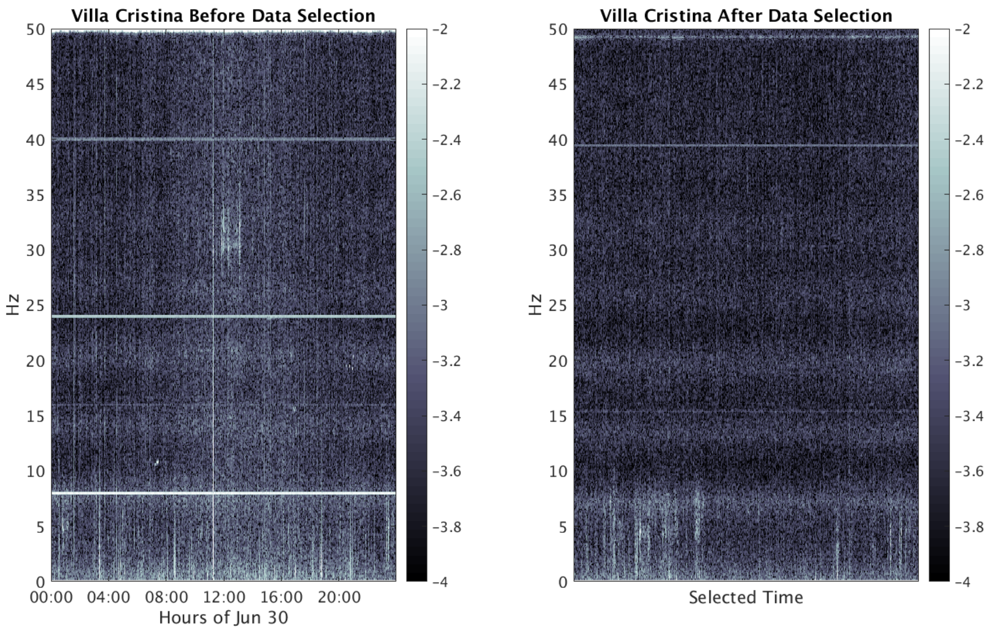

Figure 1: *The Villa Cristina spectrogram shows how quiet it is, five Schumann resonances are visible in the cleaned data.*

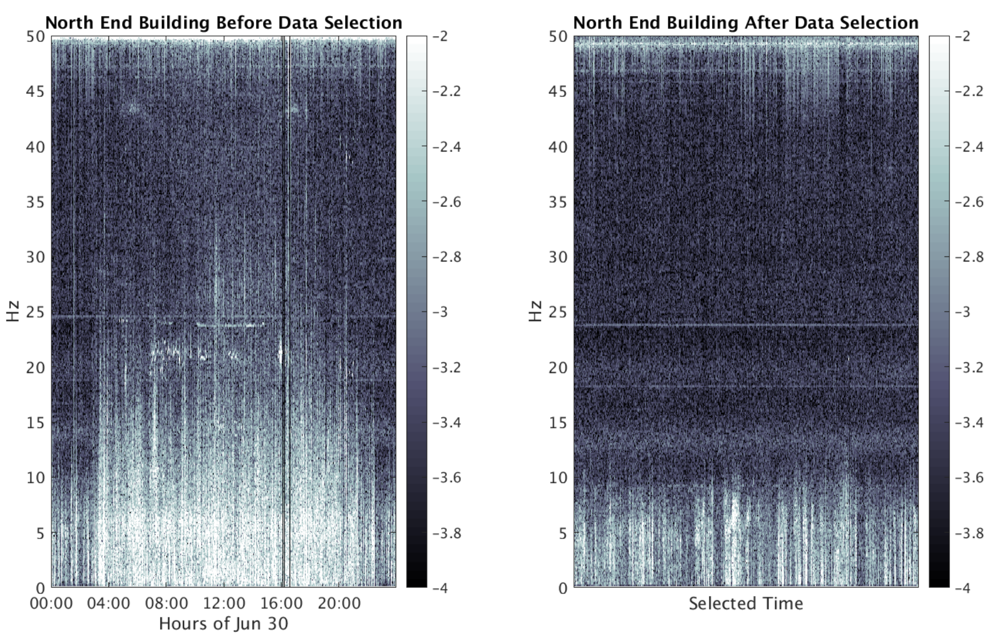

Figure 2: *The magnetometer could only be placed so far away from the North End Building, and so there is significant noise from the nearby mains and electronics, especially during the day. Almost all of the day data is removed in cleaning.*

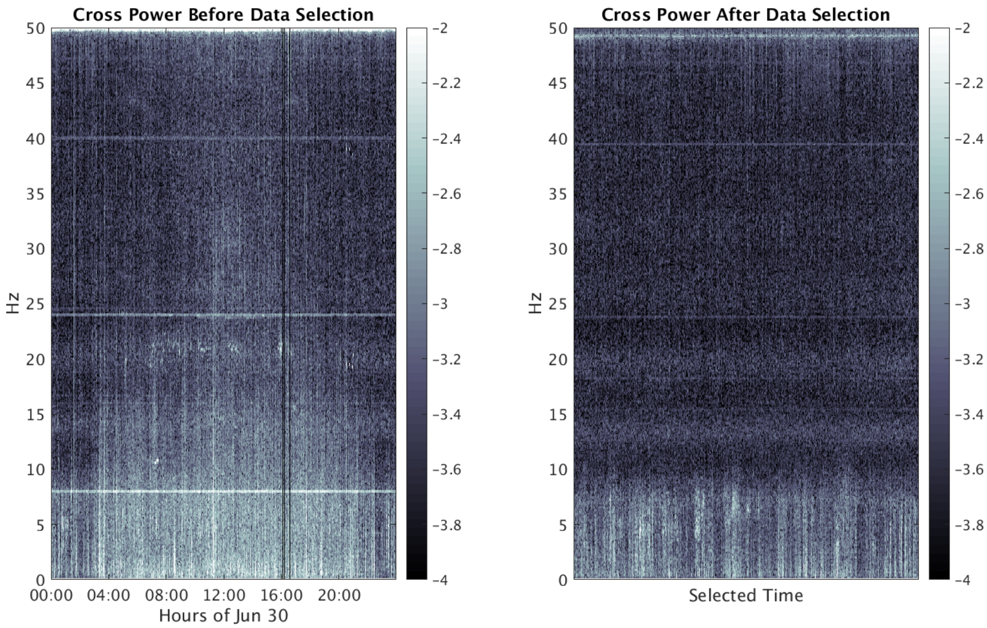

Figure 3: *The noise in the cross power spectrogram matches most with the noise from the north end building, as it is much higher amplitude.*

In Frequency

Figure 4: *The three spectras used in the coherence formula. The 14Hz peak in the north end is not due to Schumann resonances as the coherence is low, and the amplitude is much higher than in Villa Cristina. This is a well known noise source around VIRGO buildings.*[2]

[1]See `https://tds.ego-gw.it/itf/osl_virgo/index.php?callRep=30827` for more information about this noise.

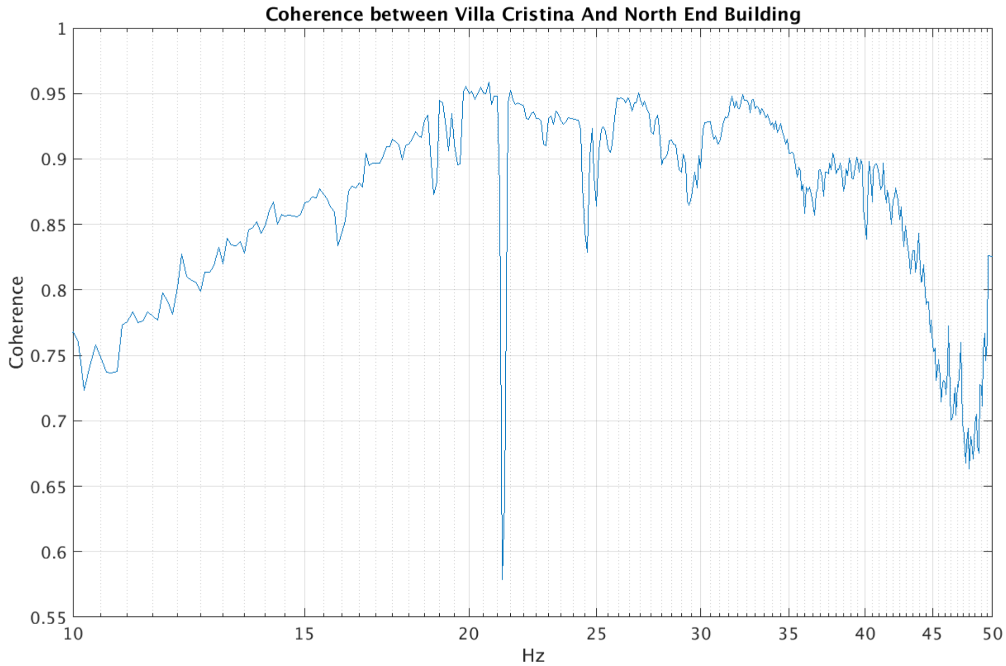

Figure 5: *Coherence across frequency band of interest. Four, possibly five Schumann resonances are visible here with greater than 0.85 coherence.*

Conclusions

The biggest obstacle to acquiring good coherence for Schumann resonances in different locations is local noise. Villa Cristina is exceptionally quiet, and this allows an excellent view of the resonances. However, the boundaries of the VIRGO site make it difficult to place a magnetometer far enough away from major electronics to acquire clean data. Very stringent data selection has to be applied in order to get any visible coherence. The two locations were chosen based on a previous survey of probable low noise environments. In the weeks following these measurements other possible locations and orientations are being explored in order to find the lowest noise possible on the VIRGO site. If a better site is found it would be used to perform further coherence measurements with another new site near Villa Cristina.