TIME FREQUENCY ANALYSIS OF THE LSSB'S GREEN'S FUNCTION FOR i-DUST 2010, Apt, France

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ABSTRACT

By cross correlating fully diffuse wave fields between two stations with random amplitude and phases, and propagating in all directions, the Green's function between the pair of stations considered emerges. Several authors in the past decade have published results where they show the validity of this technique when cross correlating seismic noise. Using the continuously recorded noise in the LSBB laboratory, we recover the Green's function between several pairs of stations and perform a time frequency analysis to determine the velocity and polarization of the emerging waves. This approach is commonly referred to as passive tomography because field parameters are extracted without any controlled sources or earthquakes. Furthermore, polarization filtering techniques are applied to gain deeper knowledge of the cross correlations. We show the results obtained for a synthetic example, an earthquake seismogram and for the LSBB Green function recovered.

The techniques applied here are useful seismic signal analysis tools, and the wavefield filtering method is useful for wave type characterization, surface wave filtering, separation of converted waves, or removal of out of plane energy.

INTRODUCTION

Traditionally, seismic imaging has been done with coherent seismic waves emitted by explosions or earthquakes. These waves are used to measure travel times of the body waves and dispersion curves of the surface waves with the use of ray theory. Through these measurements, it is possible to gain information about the Earth's interior and structure. One setback of this technique is that it requires energetic sources such as large explosions or earthquakes, in order to accurately locate the source. Therefore, this procedure has been used only in highly seismic areas.

In the past two decades, methods to study low seismic regions have been proposed. Using fully diffuse wave fields with random amplitude and phases, and propagating in all directions, information about the earth has been extracted by computing the cross correlation between two stations. The emergence of the Green's function by wave field cross correlation has had a substantial impact several branches of physical disciplines such as ultrasonics, acoustics, ocean acoustics, medical diagnostics and seismology. Therefore, a considerable amount of theoretical work has been done to support this procedure of retrieving the Green's function. In the past decades, results [1, 2, 3, 6, 7, 12, 14] have shown the numerical validity of this approach in seismology.

The Green's function can provide information about the earth's interior. With this idea in mind, we use the noise recorded in the LSBB's stations to retrieve the Green's. This represents a challenge because the stations are close to each other (approximately 1.5 km) and are underground (approximately 500m). Once the Green's function is reconstructed, we seek to determine the wave speed to find dispersion curves. The analysis is complemented by following the method proposed in [17], in which we perform a covariance matrix analysis with wavelets that estimates the polarization parameters in the time-frequency domain. We test first with a synthetic signal and with an earthquake seismogram, and find the expected polarization attributes. Finally we apply these techniques to the LSBB Green function and analyze the results obtained.

CROSS CORRELATIONS

The seismic noise recorded by the stations is in the diffusive regime, and has a random distribution. However, to guarantee an adequate result for the cross correlations between two time series, the noise time series to be correlated have to be properly prepared. For one hour segments, we synchronize the signals, detrend the series and remove the mean. The signal is whitened by making the amplitude of each frequency component equal. The magnitude of the seismic noise varies by several orders of magnitude, depending on the distance the wave has traveled. Doing a cross correlation between two stations would overweight the part of the noise with greater amplitudes. However, to find the Green function there is only interest in the phase of the waves being correlated, therefore the amplitude is disregarded by considering only one bit signals. Binarization gives equal weight to the longest paths, which have had more diffraction and scattering, helping to improve the conditions needed to retrieve successfully the Green's function. There are other less aggressive methods to perform the time domain normalization, but as shown in [8] results with one bit normalization have good results The cross-correlations are calculated for all the windows within an hour, and finally they are stacked per day.

For two stations of LSBB the noise recorded in 2008 is cross correlated, Figure 1. The cross correlations are not symmetric, which is because of the non homogeneous distribution of sources all around the stations.

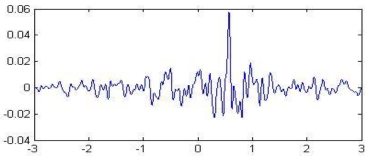

Figure 1

FREQUENCY TIME ANALYSIS

Once the reconstruction of the approximate Green function is complete, it is possible to use this waveform to estimate the wave velocities using traditional phase picking and frequency time analysis (FTAN) [11, 13] and then to study the polarization attributes.

The time frequency analysis consists in applying several narrow bandpass gaussian filters to the signal, with central frequency w_0. Thus, the main steps consist in computing the Fourier transform of the input signal, and multiplying the complex spectrum by the gaussian filter. Following, the inverse Fourier transform of the filtered spectrum is calculated which gives a frequency time dependent function. The time at which the amplitude of this function is maximum is $t(\omega_0)$. For a distance between stations d, the group velocity is approximated by $U(\omega_0) = d / t(\omega_0)$.

The polarization analysis of a three component signal $S_x(t), S_y(t), S_z(t)$ is done through the eigen analysis of the cross-energy matrix, [15]. The polarization ellipse is computed within a sliding time window of length T by solving the eigen problem for the covariance matrix. With this, the quantities that allow characterizing the polarization are calculated such as major and minor half axis, dip angle, azimuth angle and ellipticity. An important and difficult step to determine the success of the covariance analysis consists in finding an appropriate length of the time window. Recently, several polarization analysis techniques were extended to the time frequency domain [16, 17, 18] through wavelet analysis. In particular, the covariance method was extended by [16]. We apply this method to a synthetic signal, and earthquake seismogram and the LSBB's Green's function .

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