SPECTRAL ANALYSIS OF PORE PRESSURE DATA RECORDED FROM THE 2010 SIERRA EL MAYOR (BAJA CALIFORNIA) EARTHQUAKE AT THE NEES@UCSB WILDLIFE FIELD SITE

Daniel Lavallee and Sandra W. H. Seale

1-Earth Research Institute, University of California, Santa Barbara (daniel.lavallee@eri.ucsb.edu)

website: http://nees.ucsb.edu/

ABSTRACT

On 4 April 2010, the M7.2 Sierra el Mayor event occurred in Baja California, Mexico. The NEES@UCSB Wildlife Liquefaction Array (WLA) in the Imperial Basin is located 110 km NNW of the hypocenter. The event was recorded on all channels at WLA: by three-component strong-motion accelerometers at the surface and in boreholes at various depths and by pore pressure transducers located in a saturated, liquefiable layer.

We have computed the spectra of the pore pressure response in the frequency domain for signals recorded at different depths. At each depth, the spectrum is attenuated as a power law with a sharp discontinuity at a frequency close to 1 Hz. We report the value of the exponents that characterize the power-law behavior of these spectra. We also computed cross-spectral analysis of the pore pressure records from different depths. The functional behaviors of the curves of the cross-spectra are similar to that of the original spectra. For comparison, we present the spectrum of each component of the ground motion recorded at a nearby accelerometer.

Partially due to the late arrival of the surface waves, the frequency content of the recorded pore pressure signal is also a function of time. To gain a better understanding of the time-dependence of the frequency content, we performed a spectral analysis of the signal in a moving window. The spectral analysis suggests that, except for high frequencies, the curves exhibit a complex behavior as a function of the window position.

We interpret and discuss the consequences of the estimated spectra and cross-spectra.

1. THE 4 APRIL 2010 M7.2 SIERRA EL MAYOR EVENT RECORDED AT THE NEES@UCSB WILDLIFE STATION

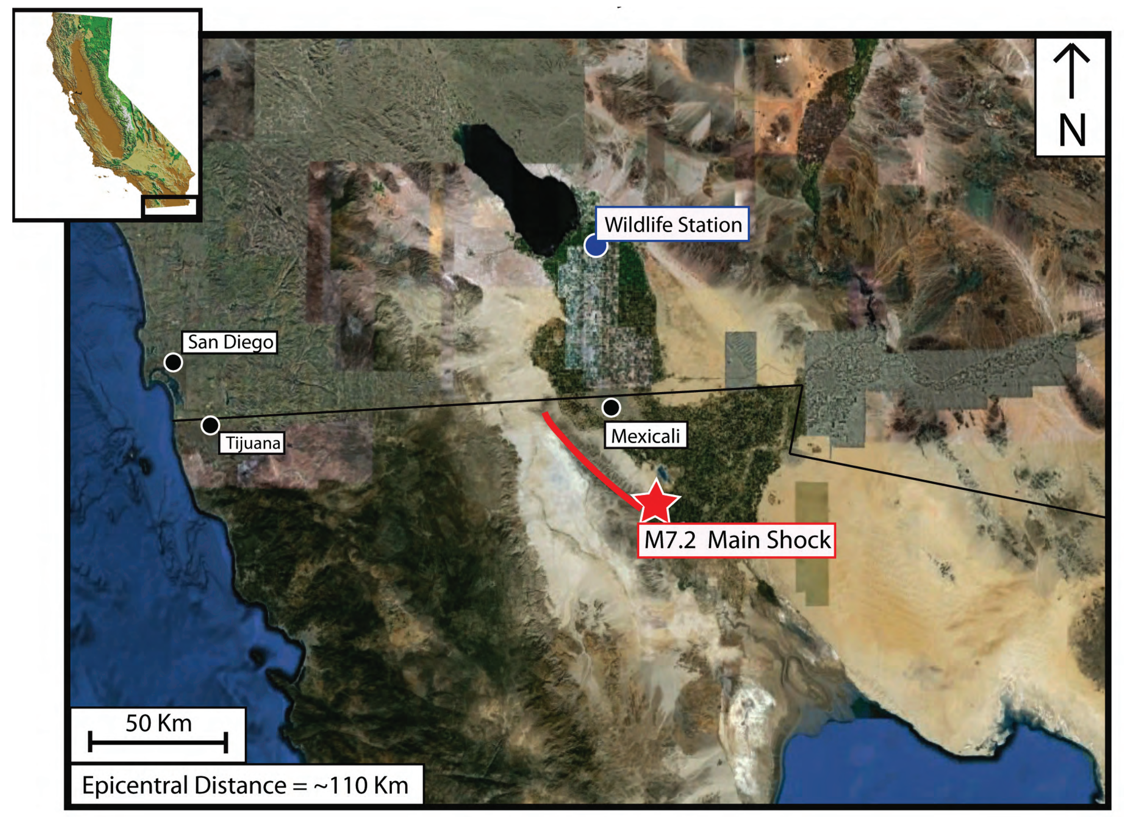

Figure 1: The 4 April 2010 M7.2 Sierra el Mayor event with the NEES@UCSB Wildlife Station 110 km away.

USGS Wildlife Station (5210)

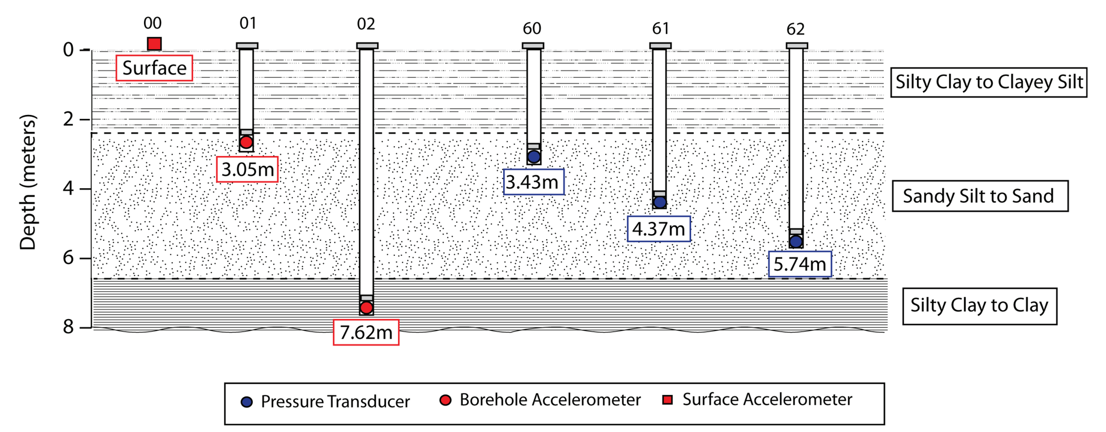

Figure 2: A cross section showing instrumentation at the NEES@UCSB Wildlife Station (Holzer and Youd, 2007, Youd *et al.*, 2007).

2. RECORDED DATA

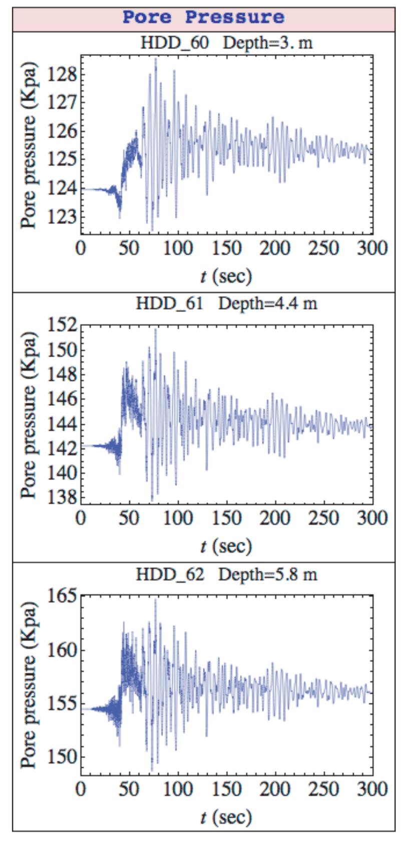

Figure 3: Pore pressure recorded at all depths at Wildlife Station (Figure 1). Pore pressure is recorded at 200 Hz. In the plots above, the data are sampled at 20 Hz.

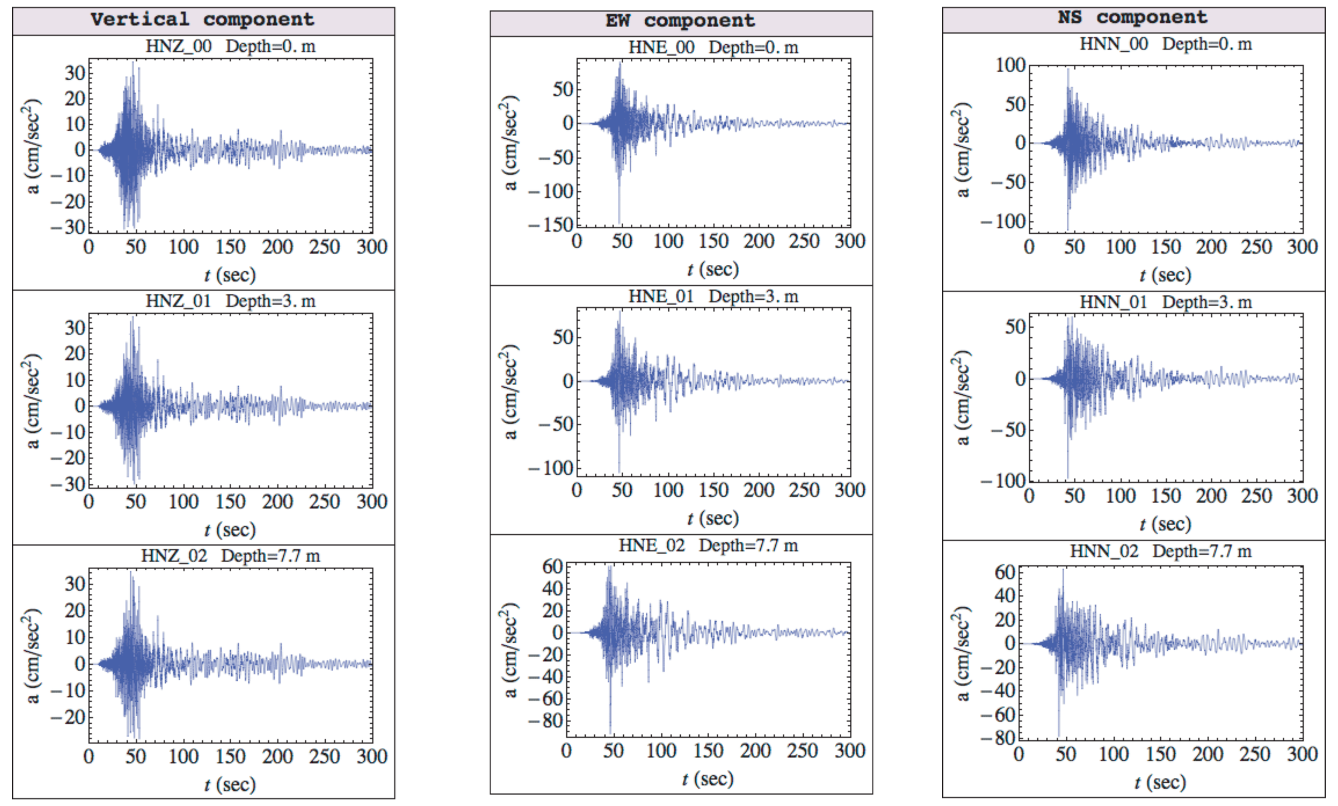

Figure 4: The three components of ground motion recorded at all depths at Wildlife Station. The data are recorded at 200 Hz. In the plots above, the data are sampled at 20 Hz.

3. SPECTRA OF PORE PRESSURE & GROUND MOTION DATA

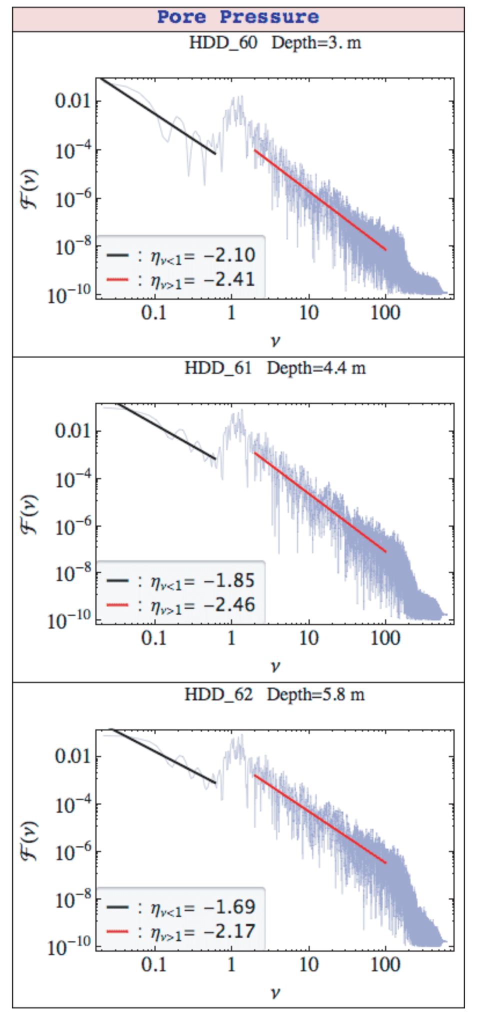

Figure 5: Frequency spectra of the recorded pore pressure for a time window of 300 sec (Figure 3). Note the sharp discontinuity at 1 Hz that occurs at every depth. For frequencies < 1Hz, the spectra attenuate according to a power law. The same functional dependency is observed for frequencies ranging from 2 Hz - 100 Hz.

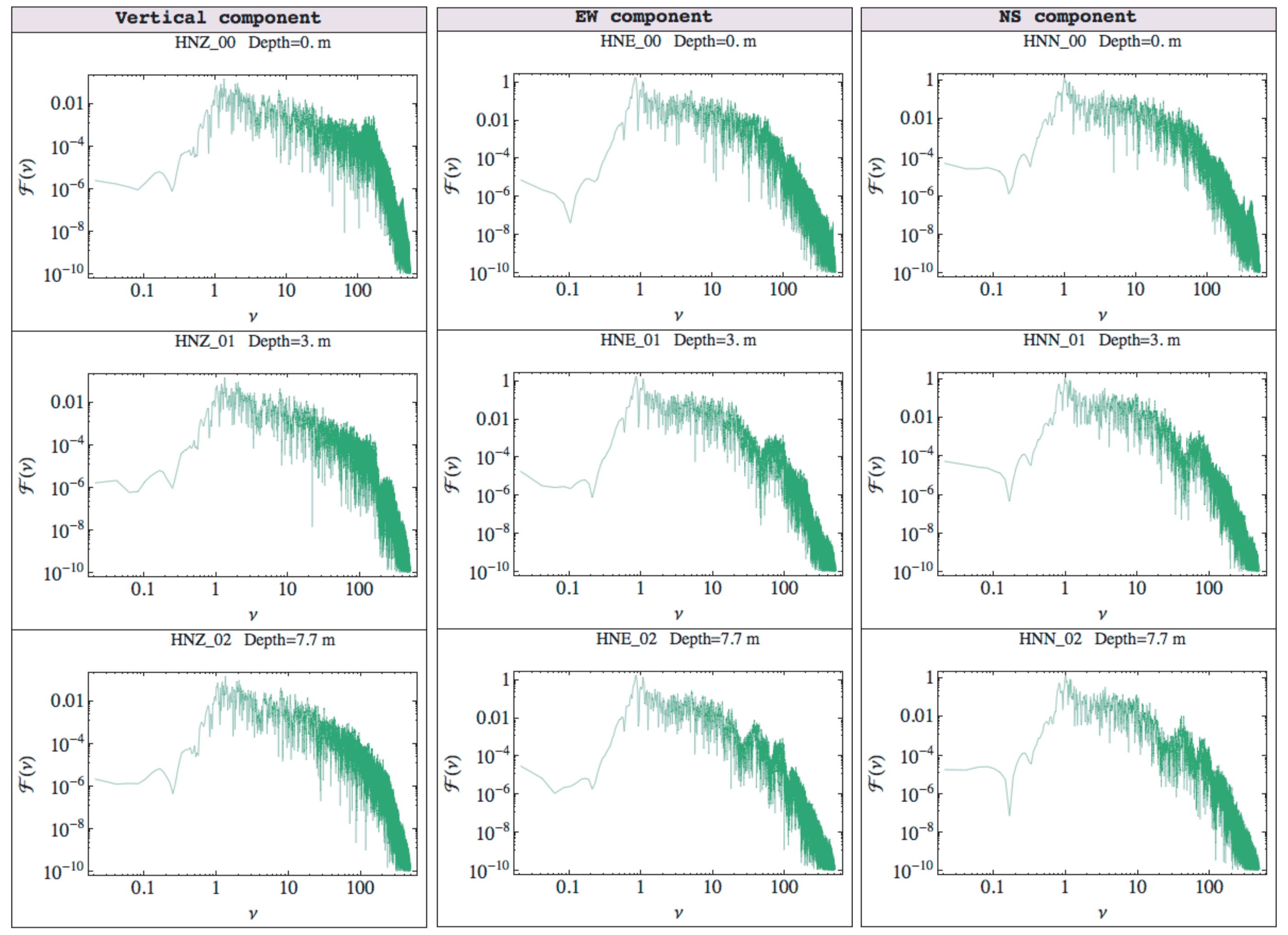

Figure 6: Frequency spectra of the three components of ground motion computed for a time window of 300 sec (Figure 4). The shapes of the curves are complicated, especially for the EW and NS components, and there is no simple functional representation. Note that for the EW and NS components at 3 m and 7.7 m depths, there are depletions of the spectral curves at several frequencies in the range 10 to 100 Hz.

4. CROSS-SPECTRA OF PORE PRESSURE DATA

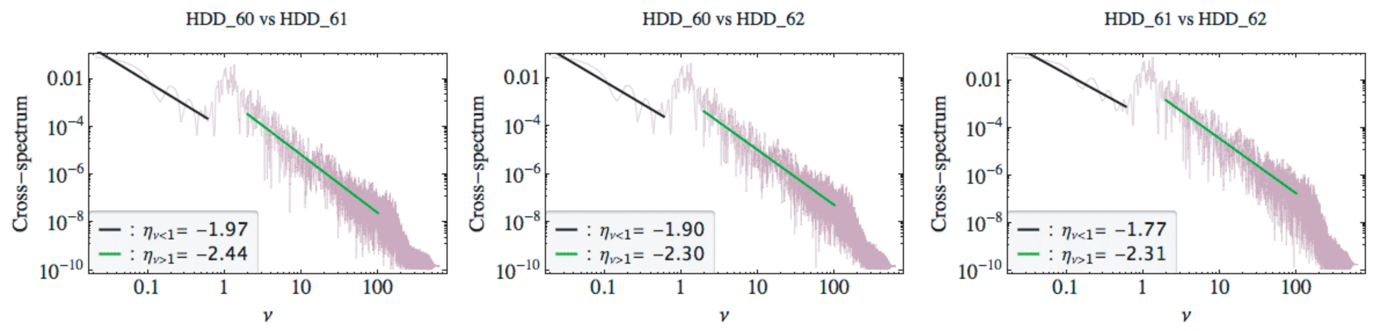

Figure 7: Cross-spectra computed between the pore pressure signals recorded at different depths (Figure 3). The curves exhibit the same behavior illustrated in Figure 5, where a sharp discontinuity is observed at 1Hz and attenuation follows a power law for frequencies < 1Hz and from 2 Hz - 100 Hz. The exponents characterizing the power law attenuation of the spectral curves have the same order of magnitude than those reported in Figure 5.

5. SPECTRAL ANALYSIS IN THE TIME-FREQUENCY DOMAIN

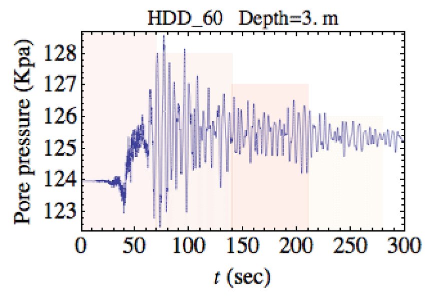

Figure 8: Fourier transforms of a time signal only provide an "average" measure of the amplitude of the signal at a given frequency. Wavelet analysis (Seale *et al.*, 2010) is a proper method for understanding the variation of the frequency contained in the signal as a function of time. An alternative to wavelet analysis is to compute the spectra over a moving time window (Mallat, 1998). For the pore pressure records shown in Figure 3, we applied time windows of 70 sec duration, which are indicated by the shaded rectangles in the figure to the left.

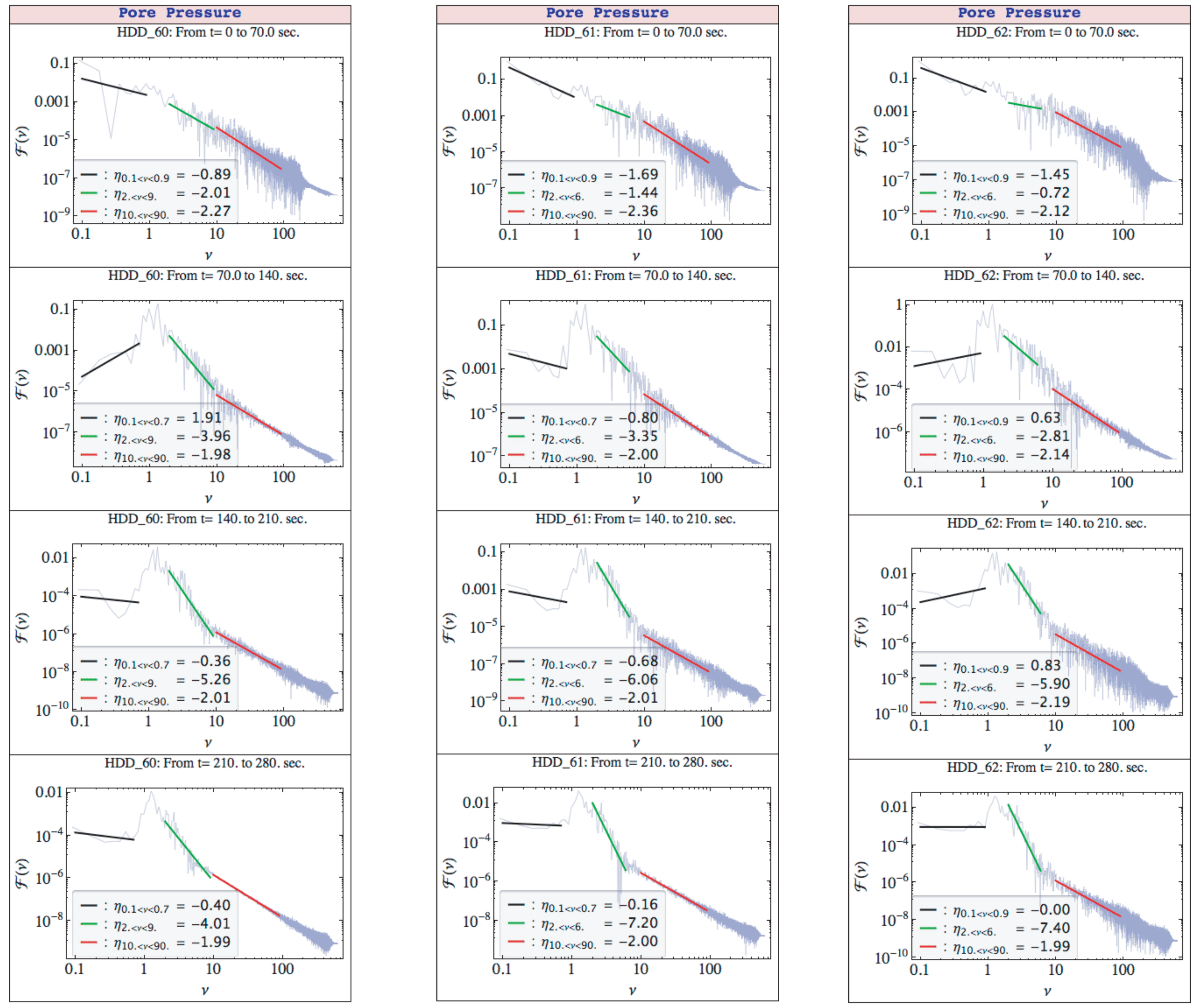

Figure 9: The frequency spectra of the pore pressure records are illustrated above for each time window (top to bottom) and each depth (left to right). Each spectrum is divided into low-, mid- and high-frequency intervals. Within each interval, the spectral curves are fitted with a power law. The spectral fit in the low frequency range (black line) dramatically changes when going from the first to the second time window. The attenuation in the mid-frequency range (green line) increases as the time window moves from the beginning of the recorded signal to the end. This suggests an increase in the amount of correlation of the parts of the signal characterized by this frequency range as time increases. The attenuation of the curves corresponding to the high-frequency range (red line) is almost identical for all the time windows.

References

Mallat, S. A Wavelet Tour of Signal Processing. Academic Press, 1999.

Seale, Sandra H., Daniel Lavallee, Jamison H. Steidl, Hank Ratzesberger, and Paul Hegarty. Spectral Analysis of Pore Pressure Data Recorded from the 2010 Sierra el Mayor (Baja California) Earthquake at the NEES@UCSB Wildlife Field Site [abstract]. 2010 AGU Fall Meeting, 13 - 17 December, San Francisco, ID 967823.

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SCEC Meeting 2010