Earthquakes, Aftershocks, and Total Energy

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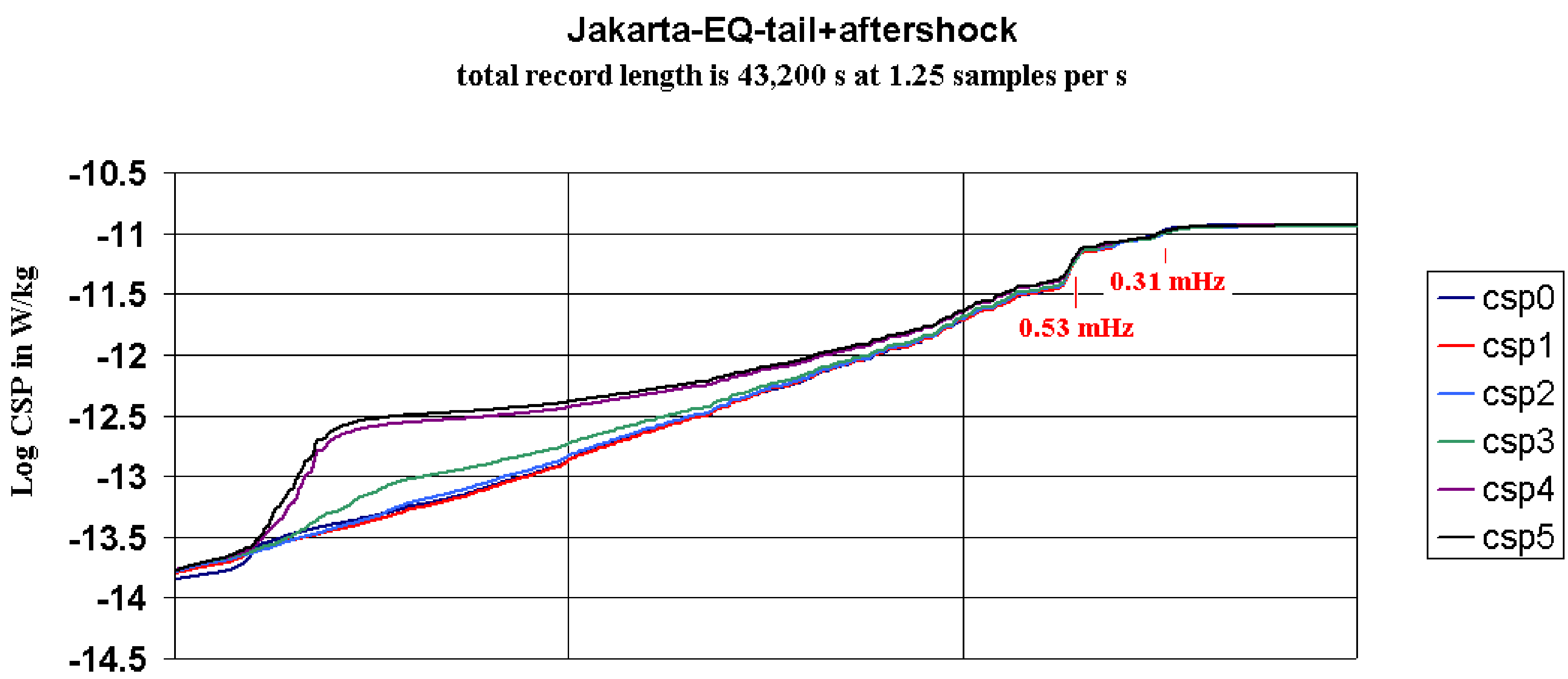
Abstract

The evolutionary spectral characteristics of a large earthquake/aftershock pair have been studied using a tool that is new to seismology, called the Cumulative Spectral Power. Invariance of the total energy, during the time period that was analyzed, supports a recent theory that aftershocks are triggered by dynamic seismic waves rather than changes in stress of nearby faults [1].

1 Background

History demonstrates the great value of frequency domain data for understanding the physics of complex processes. The Cumulative Spectral Power (CSP) opens a new window into the study of earthquake evolution [2]. For this purpose, the CSP has a significant advantage over the Power Spectral Density (PSD) from which it is derived by integration. The FFT spectrum used to generate the PSD is inherently very noisy. An overlay of time-differing PSD curves on the same graph results in so much clutter that interpretation is very difficult. Because integration reduces the random noise of real world data, clutter is dramatically reduced when one does the same overlay using CSP data. As illustrated in Fig. 1 below, it is now possible to observe in a meaningful manner the evolutionary character of earthquakes and their aftershocks.



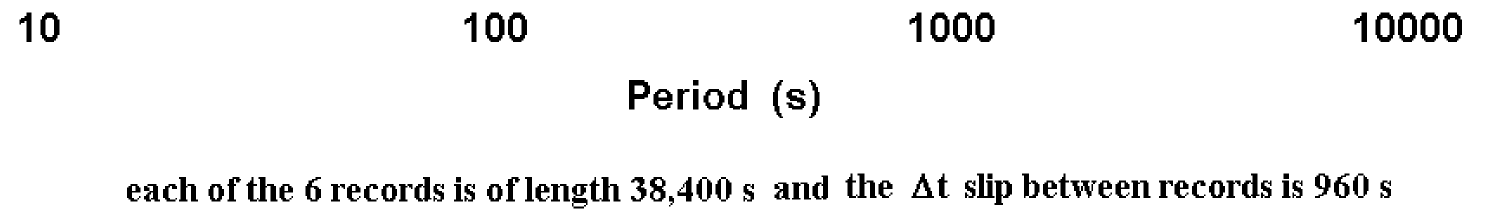


Figure 1. Six overlaid CSP curves differing in time from one another by 960 s, to demonstrate the evolutionary spectral character of Earth vibrations following the large earthquake near Jakarta on 12 September 2007.

Each of the curves in Fig. 1 derives from a time record whose duration was 38,400 s. The delay in start time (Δt) from a given curve to the following one was 960 s. Figure 2 illustrates the start/stop times for only the first and last of the six records that were used to generate Fig. 1. The data were recorded by the north-south pendulum of the VolksMeter located in Redwood City, CA [3]. The start of curve 0 (13:40 UTC, 12 September) was chosen to capture the very last portion of the obvious surface waves from the M 8.2 earthquake. The end of curve 5 was chosen to capture P and S waves from the aftershock and also the largest portion of its surface waves.

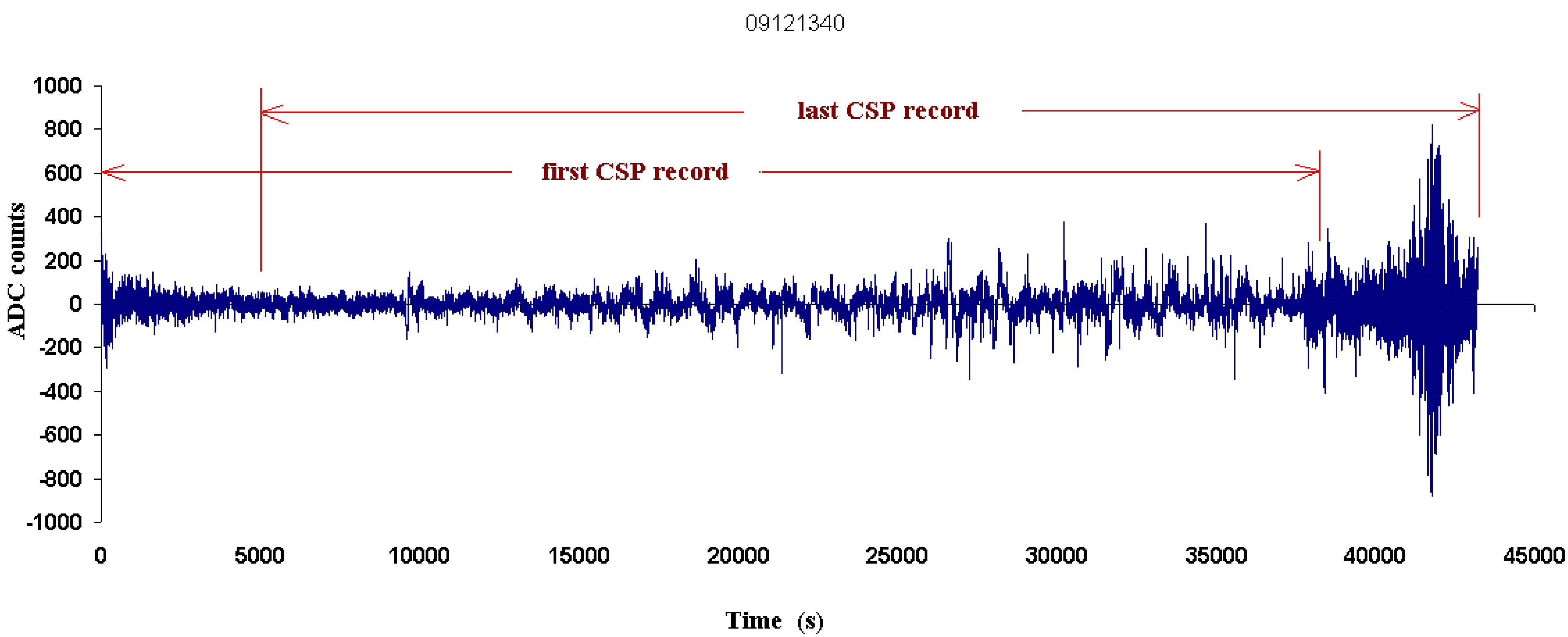


Figure 2. Temporal-record from which each of the six overlaid curves of Fig. 1 were generated one at a time.

A 32,768 point FFT was used to generate the spectral data. The FFT magnitude was corrected for the transfer function of the instrument in calculating the PSD of each of the six records. The integration over frequency of a given PSD to obtain its associated CSP was performed numerically using Excel.

To the surprise of most, there is no significant variation in the CSP values for period greater than 3000 s. The increase of power occurs for periods less than 1900 s, with the overwhelming majority of this increase taking place in the range from 15 s to 25 s.

Two eigenmode oscillations that contribute to the redistribution of power among modes is clearly visible. The lowest frequency oscillation is the spherioidal mode at 0.32 mHz and the strongest oscillation is the mode at 0.53 mHz.

According to the properties of the CSP, these curves show that there is no change in the total kinetic energy during the time period of Fig. 2. The M 8.2 earthquake was an event in which a great deal of potential energy was converted to kinetic energy in the form of seismic waves and eigenmode oscillations following the earth's rupture. Although a similar, few-fold smaller potential- to kinetic-energy conversion due to the aftershock might be expected, because of its large size (estimated at M 7.8)- the data of Fig. 1 imply something different. Invariance of the total kinetic energy is in support of the claim provided in reference [1]. The author of [4] paraphrases that claim as follows: ``Received wisdom relates that static stress change associated with an earthquake mainshock is the prime mover of its aftershocks. But a fresh look at the data points the finger at wave surfing dynamic stress".

Bibliography

[1] Felzer, K. R. & Brodsky, E.E: ``Decay of aftershock density with distance indicates triggering by dynamic stress", Nature 441, 735-738 (8 June 2006).
[2] Peters, R., ``A new tool for seismology, the Cumulative Spectral Power", online at http://arxiv.org/pdf/0705.1100
[3] Peters, R., ``State of the art digital seismograph", AGU presentation Fall Meeting 2006, abstract #S14B-01. Online at http://psn.quake.net/volksmeter/State-of-the-art_Digital_Seismograph.pdf
[4] Main, I, ``Earthquakes: A hand on the aftershock trigger", Nature 441, 704-705 (8 June 2006)

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