Coupling of Microseisms and Eigenmodes

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Abstract

Using unconventional frequency-domain information, it is shown that microseisms are seasonally coupled to the Earth's eigenmode oscillations.

Theory

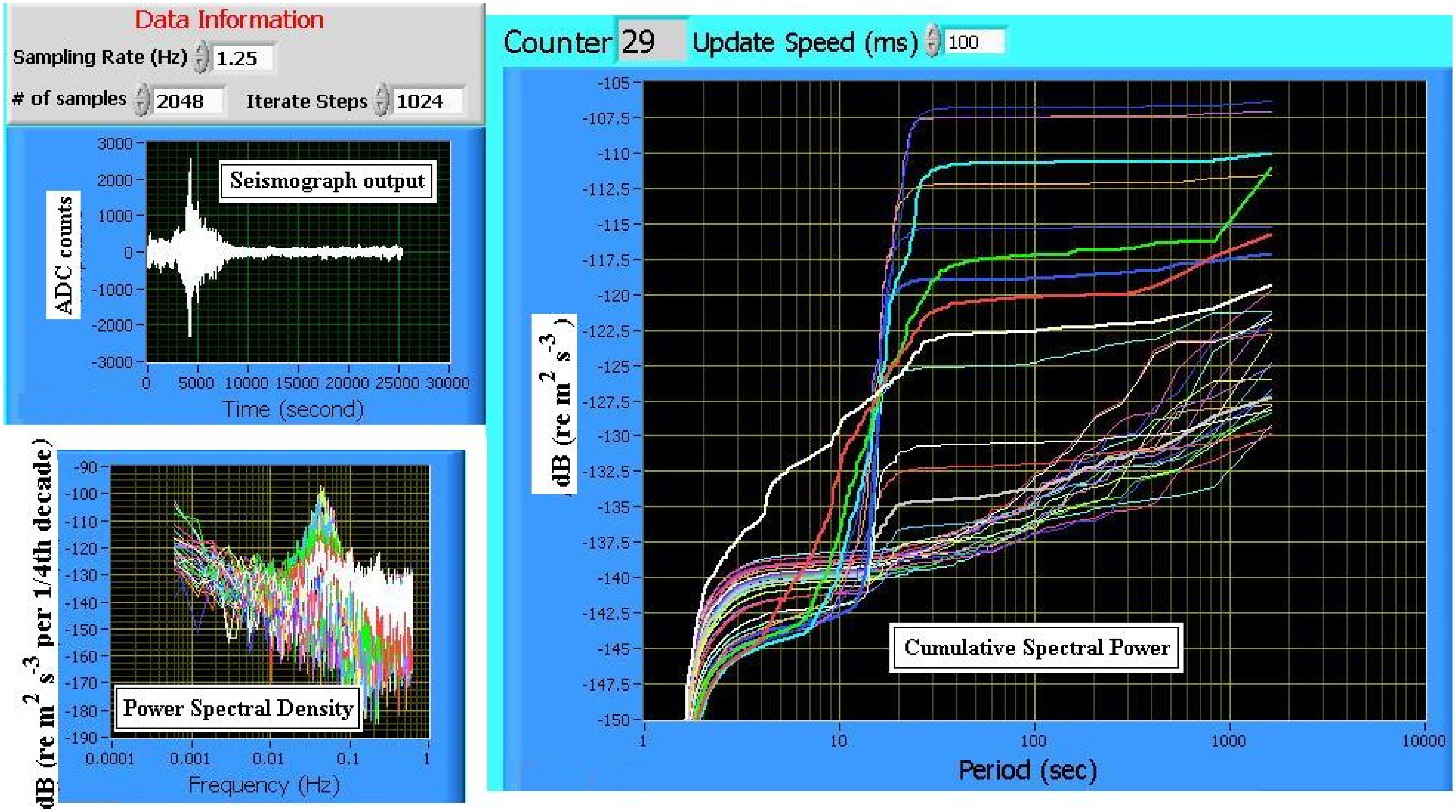
Recent publications have demonstrated a connection between ocean storms and the earth's incessant `hum'[1]. The present study goes further by providing evidence that microseisms are in general coupled to the earth's eigenmode oscillations. Moreover, the earth's total vibrational power appears to be fairly constant with time.

Tools

The present study was made possible by the author's invention of two key tools, one being of hardware type, the other software. The hardware component is the VolksMeter fully-digital seismograph [2]. The software tool is referred to as the Cumulative Spectral Power (CSP) [3].

The CSP is obtained from the well-known Power Spectral Density (PSD) by means of integration. For the present work the negative derivative of the CSP with respect to frequency is equal to the PSD; however, the CSP is here plotted versus period rather than frequency. Because integration is a noise-reducing process, many time-differing CSP curves can be overlaid on a single graph to show the evolution of spectral characteristics. A similar overlay of PSD curves is too cluttered to be useful.

For reason of the novelty of the CSP, Figures 1 and 2 are provided below, to illustrate its advantages over PSD plots.



Data Information

Sampling Rate (Hz) 1.25

# of samples 2048

Iterate Steps 1024

Counter 29

Update Speed (ms) 100

Figure 1. Output from a LabView-generated program illustrating the differences between an overlay of time-differing CSP curves and PSD curves (lower left). The earthquake raw-data record from which the curves were generated is shown in the upper left.

The earthquake of Fig. 1 was the Southern Sumatra, Indonesia event (M 8.4) that occurred on 12 Sep 2007. As with all other seismograph data presented in this article, the record is from a VolksMeter located in Redwood City, CA. The single pendulum of this instrument is oriented N-S. A comparison of the two overlays shows the dramatic noise advantage of the CSP over the PSD.

The generation of Fig. 1 involved a sequential scan from start to finish of the output record whose length was 25,200 s, accumulated at a sample rate of 1.25 per s. Each FFT for generating the PSD from which the CSP was calculated- used 2048 points (time duration of 1,638 s). The time step (iteration interval of 1024) between curves was 819 s, resulting in 30 individual curves. All 30 curves have been plotted on each of the CSP and PSD graphs. As is obvious from Fig. 1, the CSP graph provides information about teleseismic earthquake evolution that would be very difficult to glean from PSD data.

A final comparison of CSP and PSD is provided in Fig. 2, which has extracted from Fig. 1 only two cases - curve numbers 6 and 10.

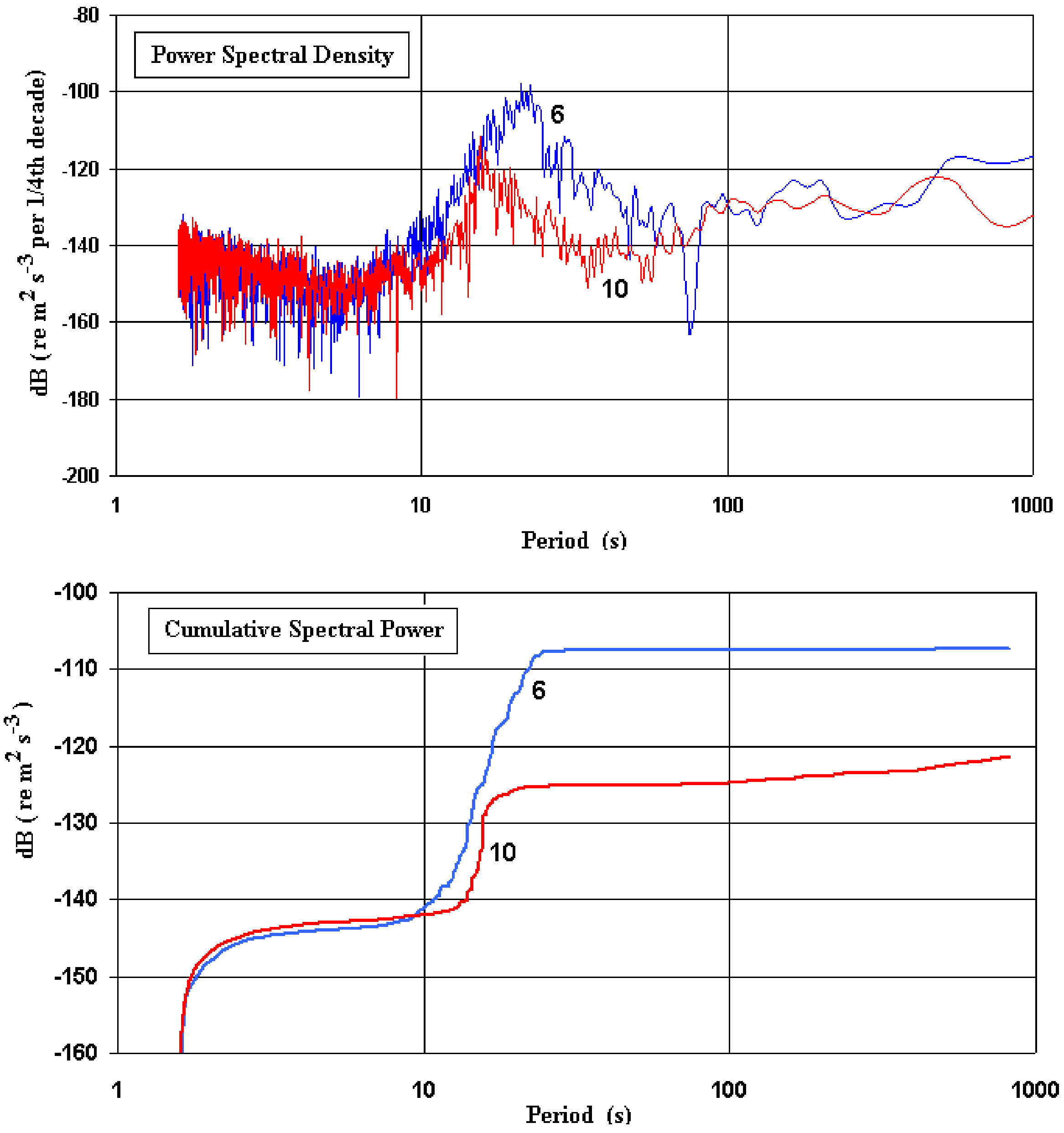


Figure 2. Comparison of a pair of PSD (top graph) and CSP (lower graph) curves taken from Fig. 1. The well-known dispersion of the surface waves is evident in both graphs.

The peak of the larger amplitude component (case 6) occurs at a period of 19.2 s, compared to the later (smaller) component peak at 15.6 s.

Seasonal Dependence of the Cumulative Spectral Power

For the results that follow, monthly averages were calculated from daily-sequential records. Each record was of length 720 minutes, collected at a sample rate of 1.25 per s, and starting in every case at 01:10

UTC. The start-time was selected to coincide with the minimum of seismic locally-generated noises in the Redwood City, CA area. The FFT-size per curve was in all cases 4096 points, with an iteration step size of 2048, yielding 25 individual CSP curves per LabView-generated record. The mean value of each 25-curve daily set was computed, and for the number of days considered in a given month; the average of those mean-values was calculated for plotting in Fig. 3.

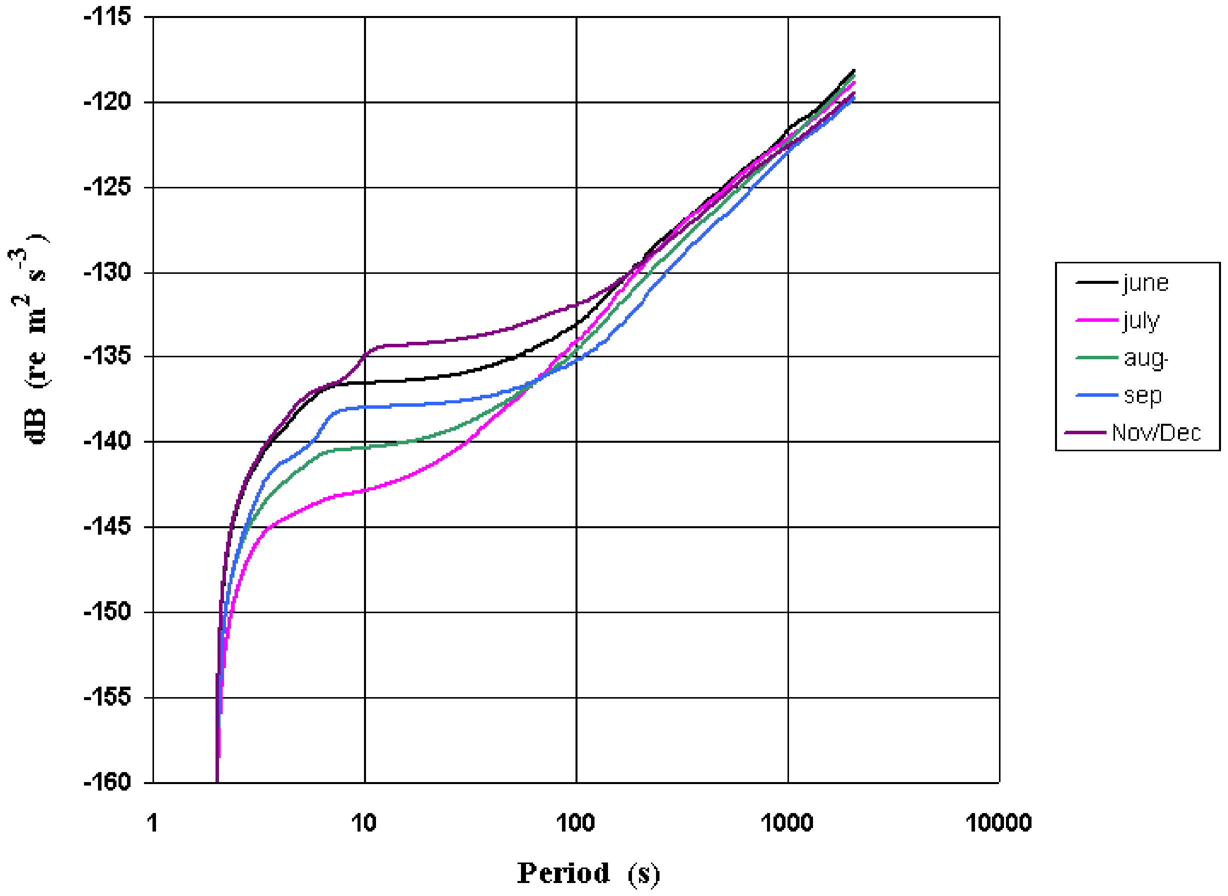


Figure 3. CSP curves corresponding to each of the five monthly intervals indicated in the legend.

Two conclusions are to be drawn from the set of curves shown in Fig. 3. First, the well-known seasonal variation of microseism intensity is clearly evident. Also evident and not well-known is the manner in which all five curves converge to virtually the same level at a period of 2000 s. What this means is that the total vibrational power of the Earth is virtually constant during these five months of 2007, for the period range considered (2 s to 2000 s).

One must conclude from Fig. 3 that there is mode-coupling among the short- and long-period oscillations of the earth. More specifically, microseisms and eigenmodes must be coupled. When microseism intensities increase (as is happening with the approach toward winter in the northern hemisphere), the energy for exciting these short-wavelength modes comes at the expense of long-wavelength (including standing wave) modes of the earth.

Acknowledgment

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Bibliography

[1] J. Rhie & B. Romanowicz, ``Excitation of Earth's continuous free oscillations by atmosphere-ocean-seafloor coupling", Nature **431**, 552-556 (2004), and ``A study of the relation between ocean storms and the Earth's hum", Geochem. Geophy. Geosys., Vol. 7, Issue 10).

[2] ``State of the art digital seismograph", AGU presentation Fall Meeting 2006, abstract #S14B-01.

[3] R. Peters, ``A new tool for seismology, the Cumulative Spectral Power", online at http://physics.mercer.edu/hpage/CSP/cumulative.html

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