The time dependence of ambient noise beneath the deep sea floor

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Between February and May 1998, the Ocean Seismic Network Pilot Experiment (OSNPE) acquired over 115 days of broadband borehole seismic data at ODP Site 843B in 4407m water depth off Oahu (Collins et al., 2001; Stephen, 1998; Stephen et al., 1999a; Stephen et al., 1998; Stephen et al., 1999b). The borehole seismometer was clamped in casing within the upper 6m of igneous basement beneath 242m of sediment. In addition to over fifty earthquake events that were observed, ranging from a 4.5Mb event at 44° epicentral distance to the 7.9Mw Balleny Islands earthquake at 91° epicentral distance, this data set provides an opportunity to study the time dependence of ambient noise in a borehole in the deep sea over a four month duration. During the OSNPE we acquired seafloor current measurements near the site and sea state and wind data were obtained from near-by NOAA weather buoys. Estimates of the tides at the site are obtained directly from the borehole sensor itself at very long periods.

Figures 1 and 2 show true amplitude spectrograms of the vertical and horizontal (X) components, respectively, in the band 0.6mHz to 7.5Hz for over 110days of the broadband borehole seismometer deployment at OSN-1. The diagonal events around 100mHz, with lower frequencies arriving earlier, correspond to dispersed surface gravity waves from distant storms. The steady bands between 350mHz and 2.0Hz correspond to Scholte modes (or shear wave resonances) within the sediment column.

The arithmetic and geometric means of all of the spectra in Figure 1 are shown in Figure 3. Also shown are the largest and least spectral values at each frequency. The very high levels in bands B through F correspond to the large (Mw=7.9) Balleny Islands earthquake on Julian Day 84. The USGS high and low noise models (land models) are based on a synthesis of data from land and island stations. In general seafloor noise levels are comparable to land noise levels. The ambient noise behavior can be divided into ten frequency bands as shown: 0.6 to 3mHz (A), 3 to 8mHz (B), 8 to 55mHz (C), 55 to 70mHz (D), 70 to 90mHz (E), 90 to 120mHz (F), 120 to 350mHz (G), 350mHz to 2Hz (H), 2 to 4.5Hz (I), and 4.5 to 7.5Hz (J).

The mean noise level in the infra-gravity band (0.6-3mHz, band A) correlates extremely well with tides (Figure 4). The 'tidal' curve in this figure is just the time series of the KS54000 vertical component. In the infra-gravity band the borehole sensor exhibited much higher noise levels than a co-located buried sensor (Collins et al., 2001), suggesting that the sensor is suffering from instrument or installation noise. The correlation with tides indicates that the noise may be related to fluid-flow in the well or that it may be caused by non-linearities in the sensor.

The largest amplitude changes occur in the noise notch (C, 8-55mHz), where vertical component noise varies from the quietest levels observed world-wide [less than -190dB re: 1(m/s^2)^2/Hz] to levels above –90dB re: 1(m/s^2)^2/Hz after the Balleny Islands earthquake (Figure 3). The noise notch minimum rises dramatically after most earthquakes observed on the IRIS DMC catalog (Figure 5). All of the events above -160dB can be associated with quakes in the IRIS DMC catalog. The smaller peaks that do not occur at a known earthquake event may be caused by smaller local and regional earthquakes that are not observed on the global network. If we use -175dB as the threshold for an 'event' there are about 34 of these local and regional events in the 30 day interval shown.

The micro-seism band (D, E, F, and G), 55-350mHz, is characterized by three peaks. Levels of the single frequency micro-seism peak (D) at 60mHz can increase 80dB after a large earthquake. The levels of the two double frequency micro-seism peaks (G), one each from distant and local sources, are much less variable (about 20dB). The highest levels of the microseism peak (120-350mHz, band G) correlate very well with sea state in the band 60-175mHz as predicted by the wave-wave interaction mechanism (Figure 6).

The short period band (or HOLU spectrum, H), 350mHz to 2.0Hz, consists of a set of peaks that correspond to Scholte modes in the seafloor which are excited by local sea state. Mean noise levels in the HOLU spectrum also correlate with sea state at half the frequency (0.175-1.0Hz) (Figure 7).

Above 4.5Hz (J) there is a weak tidal dependent effect, primarily on the vertical component, which could be related to bottom currents washing against the re-entry cone (Figure 8). (Also see http://msg.whoi.edu.)

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References

Collins, J.A., Vernon, F.L., Orcutt, J.A., Stephen, R.A., Peal, K.R., Wooding, F.B., Spiess, F.N., and Hildebrand, J.A. (2001). "Broadband seismology in the oceans: Lessons from the Ocean Seismic Network Pilot Experiment," Geophys. Res. Lett. 28, 49-52.

Stephen, R.A. (1998). "Ocean Seismic Network Seafloor Observatories," Oceanus 41, 33-37.

Stephen, R.A., Austin, G.L., Babcock, J., Bolmer, S.T., Collins, J.A., Gieskes, J.M., Gould, M.R., Hildebrand, J.A., Hollinshead, C.B., Jabson, D.M., Jonke, P., Orcutt, J.A., Peal, K.R., Price, D.V., Spiess, F.N., and Vernon, F.L., (1999a). *The Ocean Seismic Network Pilot Experiment Recovery Cruise* (WHOI-03-99), WHOI Technical Memorandum, Woods Hole, MA.

Stephen, R.A., Austin, G.L., Bolmer, S.T., Chadwell, C.D., Collins, J.A., Jabson, D.M., Jonke, P., Goldsborough, R.G., Gould, M.R., Hildebrand, J.A., Hollinshead, C.B., Offield, D.G., Orcutt, J.A., Peal, K.R., Price, D.V., Rosenblad, S.G., Spiess, F.N., Vernon, F.L., Willoughby, D.F., and Wooding, F.B., (1998). *The Ocean Seismic Network Pilot Experiment Deployment Cruise* (WHOI-02-98), WHOI Technical Memorandum, Woods Hole Oceanographic Institution.

Stephen, R.A., Collins, J.A., Peal, K.R., Hildebrand, J.A., Orcutt, J.A., Spiess, F.N., and Vernon, F.L. (1999b). "Seafloor Seismic Stations Perform Well in Study," Eos, Transactions, AGU 80, 592.

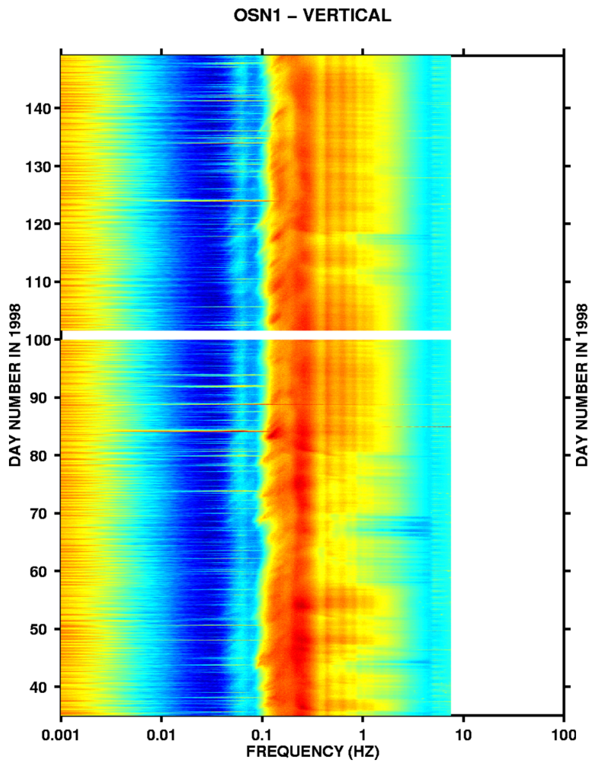

Figure 1: OSN Vertical Spectrogram

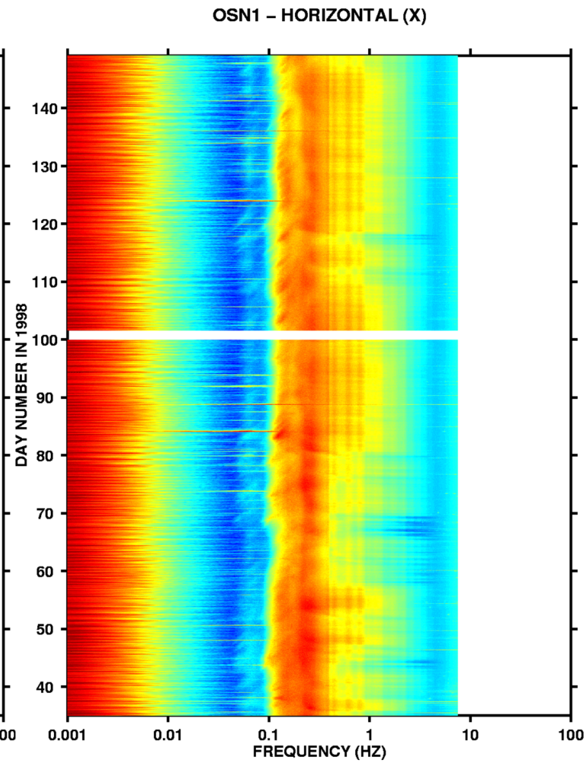

Figure 2: OSN Horizontal Spectrogram

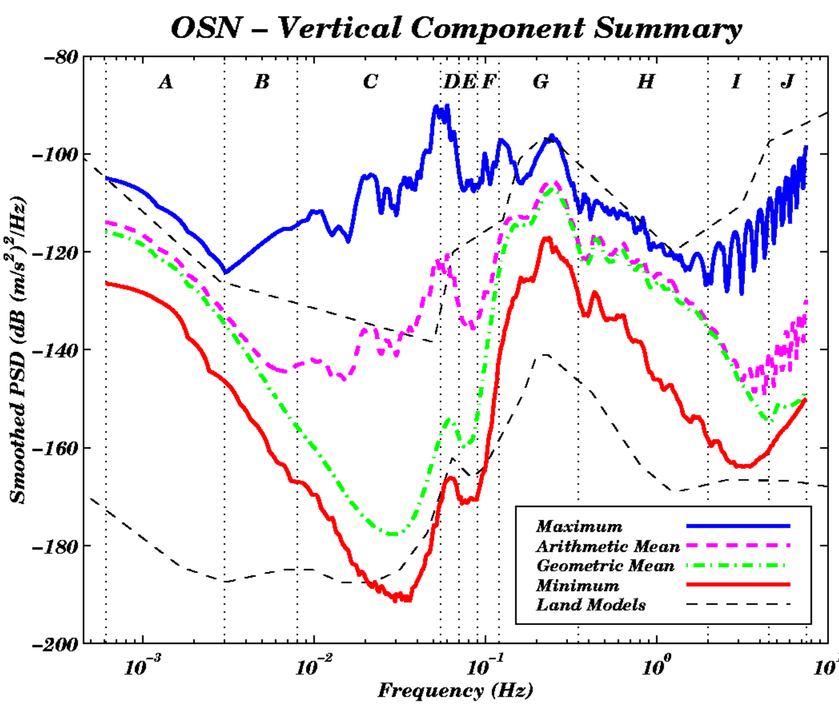

Figure 3: Summary of OSN power spectral densities which were computed every 1.82hrs for the whole data set.

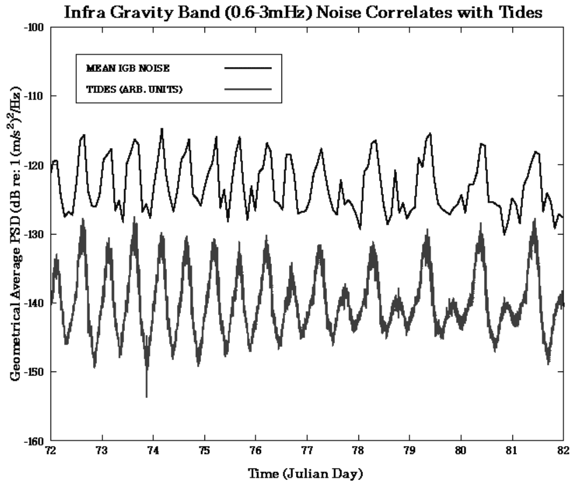

Figure 4: The top line is the geometric mean of band A. The bottom line is tides.

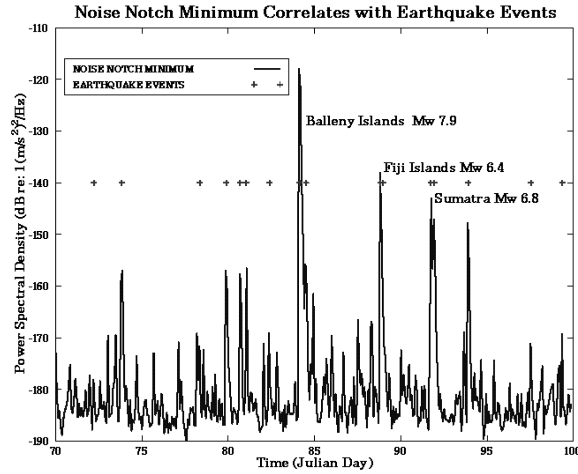

Figure 5: The bottom line is the minimum level in band C. +'s mark earthquake events.

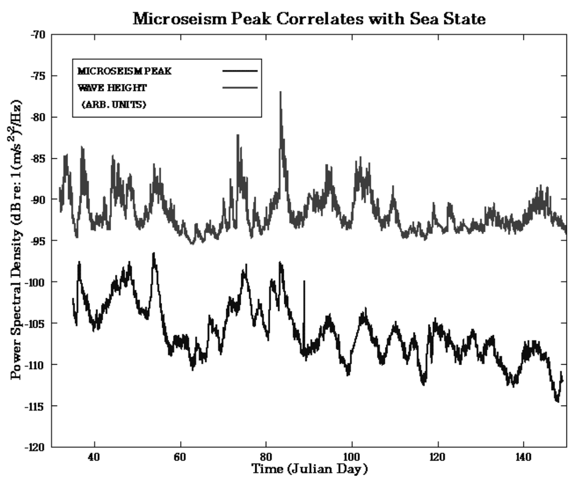

Figure 6: The top line is wave height (60-175) mHz). The bottom line is the maximum in. in band G.

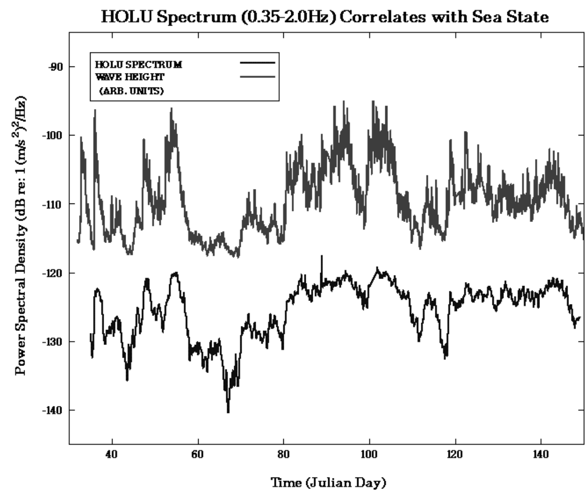

Figure 7: The top line is wave height (0.175-1.0 Hz). The bottom line is the geometric mean of band H.

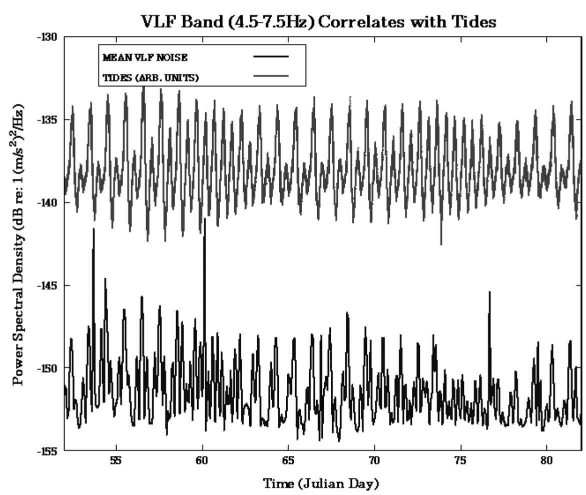

Figure 8: The top line is tides. The bottom line is the geometric mean of band J.