Ocean Bottom Seismometer Augmentation of the NPAL 2010-2011 Philippine Sea Experiment

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LONG-TERM GOALS

This project, OBSAPS, addresses the coherence and depth dependence of deep-water ambient noise and signals. Seafloor signals are studied in the band from 50-400Hz and seafloor ambient noise is studied in the band from 0.03 - 80Hz. On NPAL04 we observed a new class of arrivals in long-range ocean acoustic propagation that we call Deep Seafloor Arrivals (DSFAs) because they are the dominant arrivals on ocean bottom seismometers (Mercer *et al.*, 2009; Stephen *et al.*, 2009; Stephen *et al.*, 2008). They either were undetected or very weak on the deepest DVLA hydrophone located near the conjugate depth about 750m above the seafloor. It appears that at least part of the path for DSFAs is through or on the seafloor perhaps as an interface wave. One goal is to see if DSFAs will be observed in the Philippine Sea at relatively short ranges of 50km or less and, if so, to study their characteristics and physical mechanism.

OBJECTIVES

The objective here is to understand the relationship between seafloor pressure and seafloor particle motion for both ambient noise and short- and long-range signals. What is the relationship between the seismic (ground motion) noise on the seafloor and the acoustic noise in the water column? What governs the trade-offs in contributions from local and distant storms and in contributions from local and distant shipping? How effective is seafloor bathymetry at stripping distant shipping noise from the ambient noise field?

APPROACH

Originally the OBSAPS DVLA (O-DVLA) was to be deployed at the location of the PhilSea10 DVLA, following its recovery. Because of fouling problems at this site, the OBSAPS site was moved about 8.7km to the southwest: Lat: 21deg 19.559'N Lon: 125deg 56.325'E. The goal was to use the existing DVLA acoustic transponder net, which would not be recovered until after the OBS experiment. The O-DVLA consisted of one 1000-m DVLA section, with a D-STAR at the top. The O-DVLA consisted of 15 hydrophone modules from 12m above the seafloor to near the conjugate depth (852m above the seafloor). A current meter was deployed at the bottom of the DVLA.

Each OBS had a three-component seismometer and hydrophone or differential pressure gauge. Four OBSs were L-CHEAPOS sampling at 1000sps suitable for the frequency band from 1-400Hz, and two OBSs were broadband instruments sampling at 200sps and suitable for the frequency band from 0.03 to 80Hz. The L-CHEAPO short period OBSs are pretty much the same units we had in 2004. Some critical differences are that the 2011 OBSs acquired three components of particle motion plus acoustic pressure and they sampled at 1000sps. (The 2004 OBSs had only a vertical geophone and hydrophone and sampled at 500sps.) We do not expect that the system noise levels for the geophone or hydrophone channels will be significantly different from the 2004 experiment which was system noise limited (Stephen *et al.*, 2008). We did attach autonomously recording hydrophone modules (identical to the ones in the O-DVLA, to three of the short-period OBSs. The broadband OBSs will provide seafloor ambient noise data for comparison with other deep-water, broadband data sets in the Pacific such as the Hawaii-2 Observatory (H2O) (Duennebier *et al.*, 2002; Stephen *et al.*, 2006) and the Ocean Seismic Network Pilot Experiment (OSNPE) (Stephen *et al.*, 2003).

The source program was carried out using a J15-3 with a bandwidth from 50 to 400Hz, depths down to 100m, ranges to 250km and a variety of azimuths based on the known bathymetry. The main format of the transmission program was binary maximal-length sequences (m-sequences). The receptions can be time compressed using matched field processing to yield impulsive arrivals, that can be studied for multi-path effects and signal-to-noise ratios. For at least one azimuth we had no bathymetric blockage along a line out to 250km, similar to NPAL04, where we can look for DSFA's in a clean wave guide. At least one other path will had bathymetric blockage for comparison. Many radial lines and a "Star of David" at one CZ range were shot to study the range and azimuth dependence of the bottom interaction within one CZ. We also stayed at fixed locations for durations up to four hours to study the temporal variability of the arrival structure and to permit stacking to improve signal-to-noise ratios.

WORK COMPLETED

This project had a start date of September 1, 2010 and our work is just beginning. The cruise was carried out from April 29 to May 16, 2011. We prepared a cruise report with some quick look results (Stephen *et al.*, in press) which was submitted as a WHOI Technical Report on September 1, 2011.

RESULTS

A cruise report with some quick look results (Stephen *et al.*, in press) was submitted as a WHOI Technical Report on September 1, 2011. Figures 1, 2 and 3 show some sample results.

Figure 1 compares signal-to-noise ratios, between the hydrophone module on the North short-period OBS and the shallowest hydrophone module on the O-DVLA - 852m above the seafloor, as a function of range for a single line from 50km SW of the O-DVLA to 50km NE of the O-DVLA. Good SNR's were acquired on both sensors at center frequencies of 77.5, 155, and 310Hz. At all three frequencies there are ranges where the signal is undetectable in the background noise (either ambient or system generated). There are also instances when the deep hydrophone has better SNR than the shallow hydrophone.

Figure 2 shows one example of a potential DSFA arrival. Potential DSFA arrivals are identified by two characteristics: a) they arrive much later than the PE predicted arrival (by 2-7sec) and b) their SNR is highest on the seafloor receivers and decreases with increasing height above the seafloor. The relative amplitude of the three arrivals at the North OBS is quite different between the vertical component geophone and the co-located (within 1m) hydrophone module.

Samples of power spectral density of the vertical component channels on the three short-period OBSs (one flooded) and the two long period OBSs are compared in Figure 3. The long-period instruments resolve the noise notch between 0.01 and 0.2Hz.

IMPACT/APPLICATIONS

Clearly the ability of Navy systems to detect and identify ships and submarines by acoustic techniques will depend on at least the following factors: i) the system noise of sensors used to detect the acoustic field, ii) the true field noise for a given sensor type and location, and iii) accurate knowledge of how sound travels in the ocean including bottom interaction if necessary. The observation of deep seafloor arrivals on NPAL04 showed that there is a significant bottom path for coherent sound propagation that was previously unrecognized and is still poorly understood. If this path is as ubiquitous as we expect it will have significant consequences for the performance of any ASW system that uses seafloor receivers, for predictions of long- and short-range propagation to seafloor receivers, and for models of near seafloor ambient noise in the deep ocean.

TRANSITIONS

None yet

RELATED PROJECTS

LOAPEX - ONR Award Number N00014-1403-1-0181

SPICEX - ONR Award Number N00014-03-1-0182

PhilSea09 and PhilSea10 - ONR Award Number N00014-08-1-0840

Bottom Interaction in Ocean Acoustic Propagation - ONR Award Number: N00014-10-1-0510

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PUBLICATIONS

None

HONORS/AWARDS/PRIZES

Ralph Stephen, WHOI, Edward W. and Betty J. Scripps Chair for Excellence in Oceanography, WHOI.

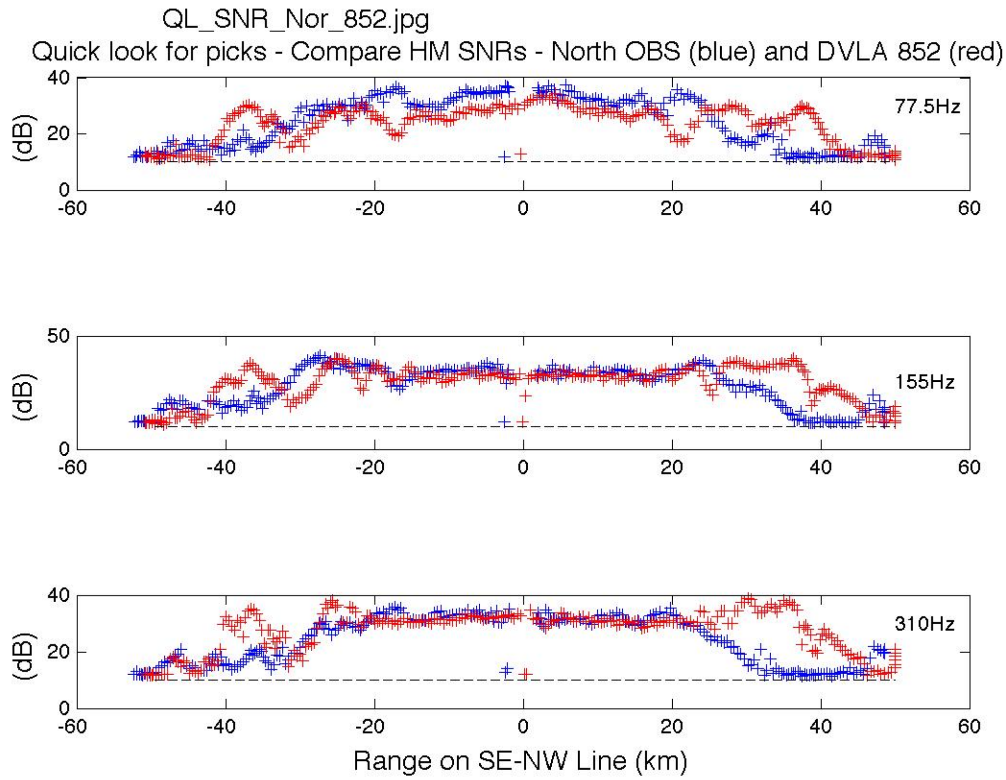

Figure 1: SNRs as a function of range are compared between the seafloor hydrophone module (on the North OBS) and the shallowest element on the O-DVLA (at 852m above the seafloor). Figure from Stephen et al (in press).

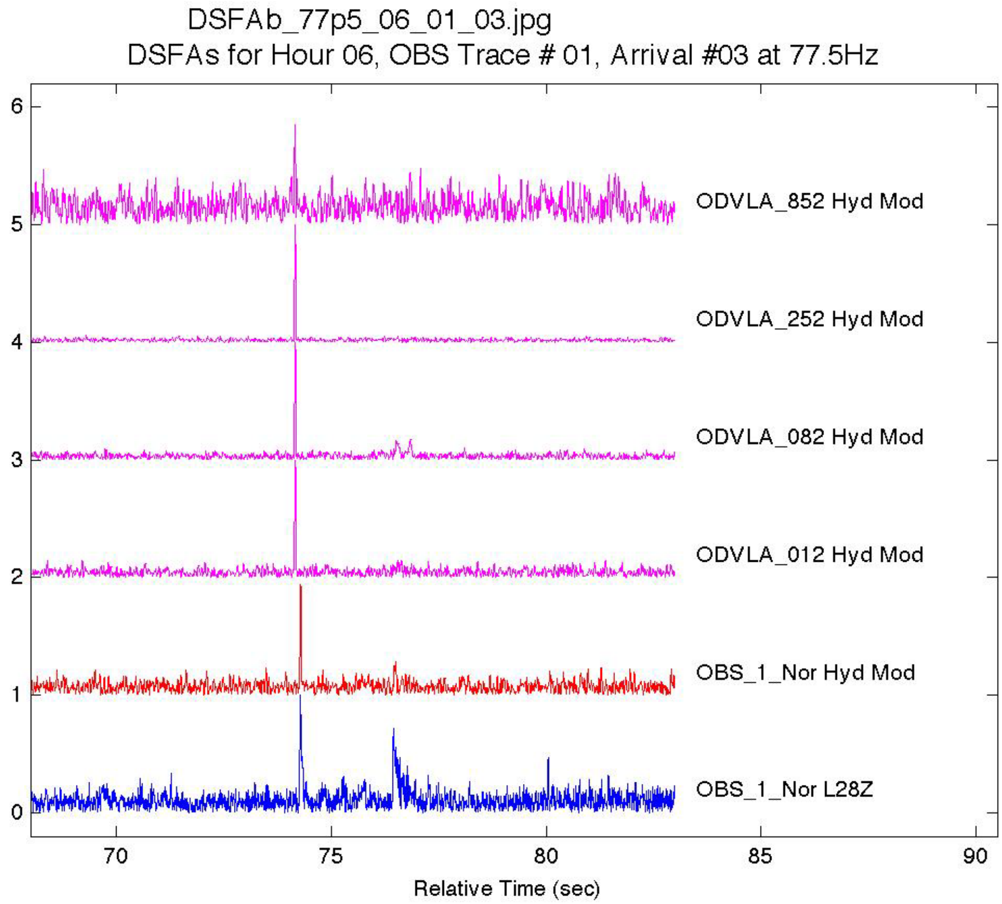

Figure 2 - DSFA Example #1: Here we compare receptions for a single 77.5Hz M-sequence on six OBSAPS receivers: (from bottom to top) the vertical geophone on the North OBS (blue), the hydrophone module on the North OBS (red), and the hydrophone modules on the O-DVLA at 12, 82, 252 and 852m above the seafloor (magenta). The range to the North OBS (bottom two traces) was 31.4km and the range to the O-DVLA (top four traces) was 30.3km. We call the large peak near 74sec the "PE predicted" arrival because it is consistently a large arrival across all of the receivers. The strong arrival about 3sec later on the vertical geophone on the OBS is a classic DSFA, although it is strange that this arrival is so weak on the co-located hydrophone module. There is a weak indication of this arrival on the O-DVLA up to at least 82m above the seafloor. There is also a weak indication of second DSFA on the geophone channel near 80sec. Figure from Stephen et al (in press).

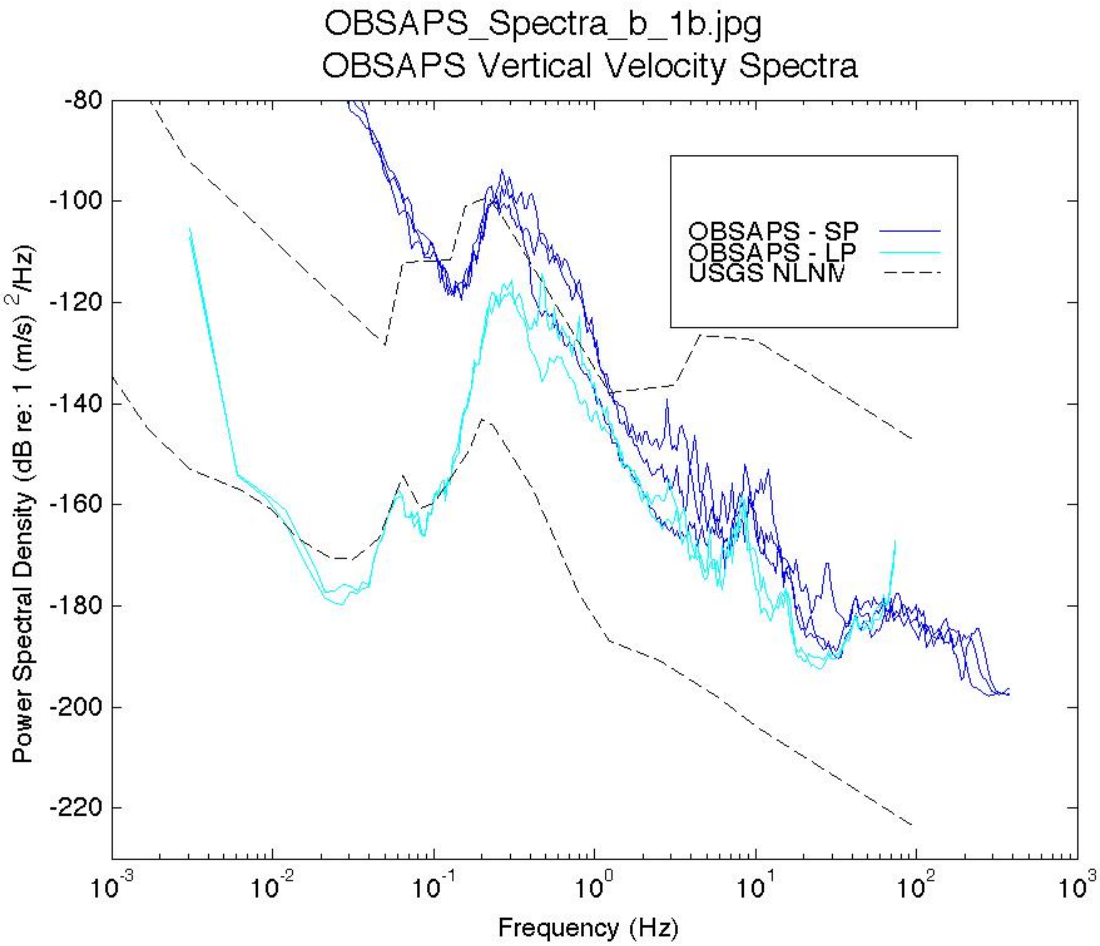

Figure 3: Samples of vertical particle velocity spectra for the three short-period and two long-period OBSs on OBSAPS. The discrepancy at the microseism peak needs to be fixed. Figure from Stephen et al (in press).