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Instrument Testing and First Results from the MOBB Observatory

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Introduction

The Monterey ocean bottom broadband station (MOBB) was installed on the sea floor in Monterey Bay, 40km offshore, and at a depth of 1000m from the sea surface, in April 2002. It is a collaborative effort between MBARI (Monterey Bay Aquarium Research Institute) and BSL (Berkeley Seismological Laboratory).

The Ocean-bottom MOBB station currently comprises a three-component seismometer package, a current-meter, and a recording and battery package. A differential pressure gauge (DPG) with autonomous recording (e.g. Cox et al., 1984) was deployed in the vicinity of the seismometer package during the data recovery dive in September 2002. The seismic package contains a low-power (2.2W), three-component CMG-1T broadband seismometer system, built by Guralp Systems, Ltd., with a three-component 24-bit digitizer, a leveling system, and a precision clock. The seismometer package is mounted in a cylindrical titanium pressure vessel 54 cm in height and 41 cm in diameter, custom built by the MBARI team and outfitted for underwater connection.

Because of the extreme sensitivity of the seismometer, air movement within the pressure vessel must be minimized. We describe extensive testing and insulation procedures performed at BSL. Among others, the top of the pressure vessel was thermally insulated with two inches of insulating foam and reflective Mylar. The sides were then insulated with multiple layers of reflective Mylar space blanket, and the vessel was filled with argon gas to inhibit convection.

The installation was completed during three dives (9-11 April, 2002), with the help of the MBARI ROV (Remote Operated Vehicle) Ventana and ship Point Lobos. The site was revisited on 22 April, to check the functioning of the system and 3 Mb of data were then retrieved. The ship and ROV returned to the site two months later, on 27 June, and the data recording and battery modules were replaced, in the first of a series of such dives planned over the next three years.

Many regional and teleseismic earthquakes have been well recorded and the mass position signals indicate that the instruments are progressively settling. Preliminary analysis of the data retrieved during the 2002 dives are presented.

Testing

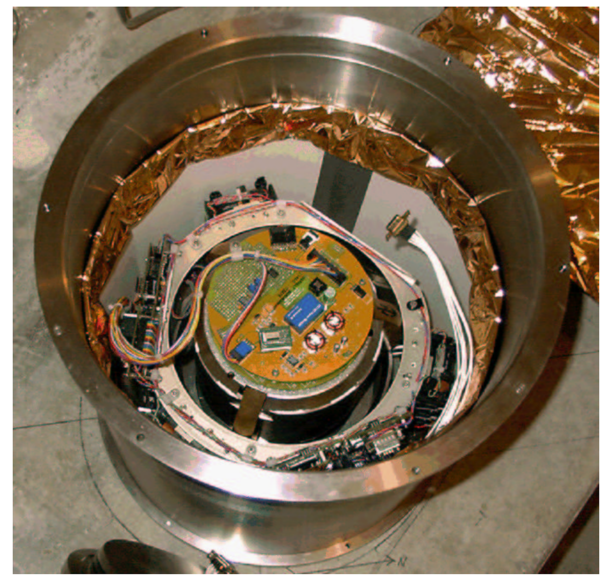

Figure 1. The CMG-1T OBS installed in the titanium pressure vessel. The space between the inside cylindrical surface of the pressure vessel and the seismometer is insulated with multiple layers of Mylar (space blanket) insulation supported by a cardboard form. Partly visible on the upper right is the Mylar covered urethane foam plug which fills the void between the top of the seismometer and the bottom of the top end cap of the pressure vessel (to provide insulation as well as to reduce the free air volume within the vessel).

Figure 2. Titanium pressure vessel being purged with dry argon gas. Visible are the hose used to purge the air from the pressure vessel and top part of the Mylar insulation which, along with a 2 inch thick urethane foam disk, is used to insulate the top of the seismometer. By insulating the top and side of the cylindrical pressure vessel, but not the bottom, the ~2.2 Watt power dissipation of the sensor produces a stable stratification of the argon gas in the pressure vessel and inhibits the convective air currents which were generating a high background noise PSD on the CMG-1T vertical component as shown in Figure 3.

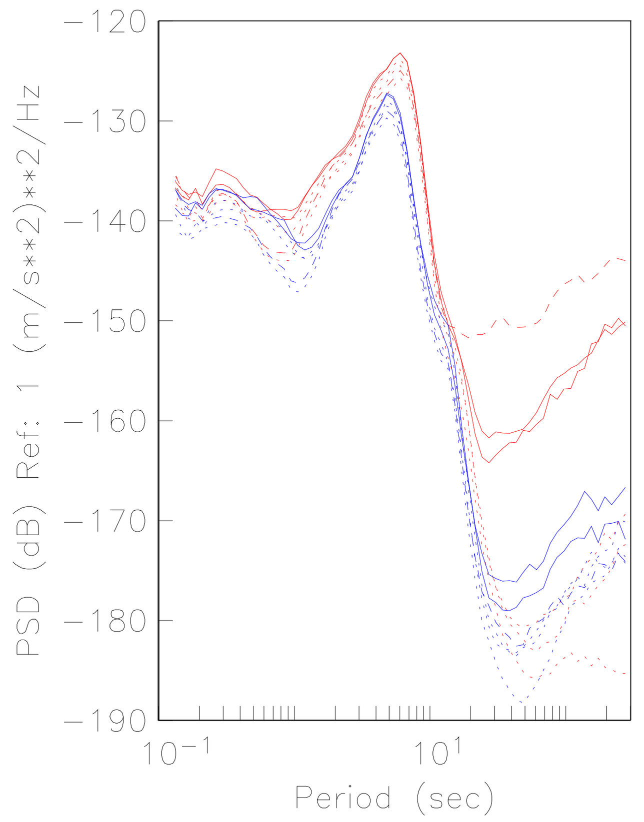

Figure 3. Comparison of the background noise PSD from the CMG-1T OBS, installed in the titanium pressure vessel, and from the co-sited STS-1 sensors housed in the BKS Vault. Shown are the PSD's for the CMG-1T vertical (large dashed), the CMG-1T horizontals (solid), and the STS-1's (small dashed). The colored PSD's are for data collected prior (red) and after (blue) installing the insulation and purging with dry argon gas. The CMG-1T and STS-1 PSD's are within ~6 dB of each other after insulating and purging with argon. That the CMG-1T and STS-1 PSD track each other over a wide range of periods is also indicates that the CMG-1T calibration and transfer functions are correct.

Deployment

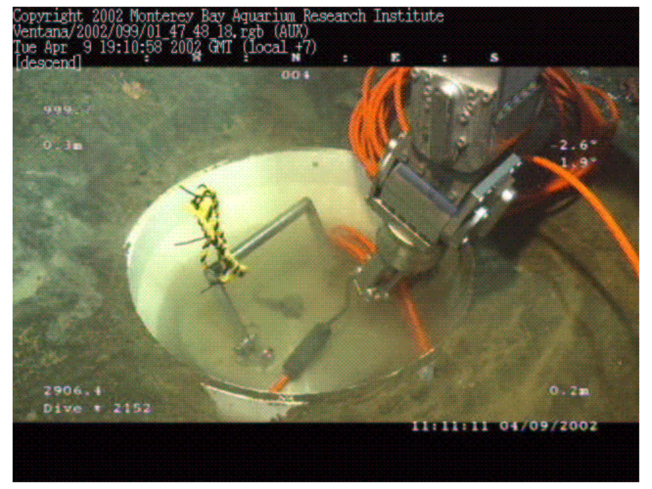

Figure 4. Installation of the seismometer package inside the PVC caisson. The top of the package is buried at least 10 cm below the the seafloor level. Burial of the seismometer package in the seafloor sediments is crucial to reducing the tilt noise induced by ocean currents. The package was later completely covered with tiny (0.8 mm) glass beads to further isolate it from the effects of water circulation.

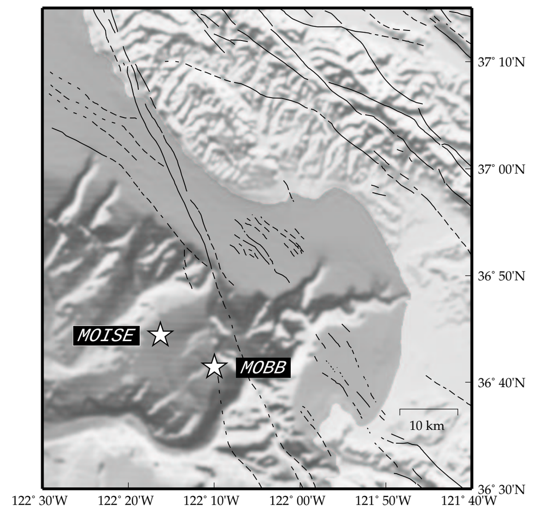

Figure 5. Location of MOBB and its predecessor MOISE in Monterey Bay, California (Stakes et al., 1998), against seafloor and land topography. Fault lines are from the California Geological Survey database. MOBB is located at 1000 m below sea-level.

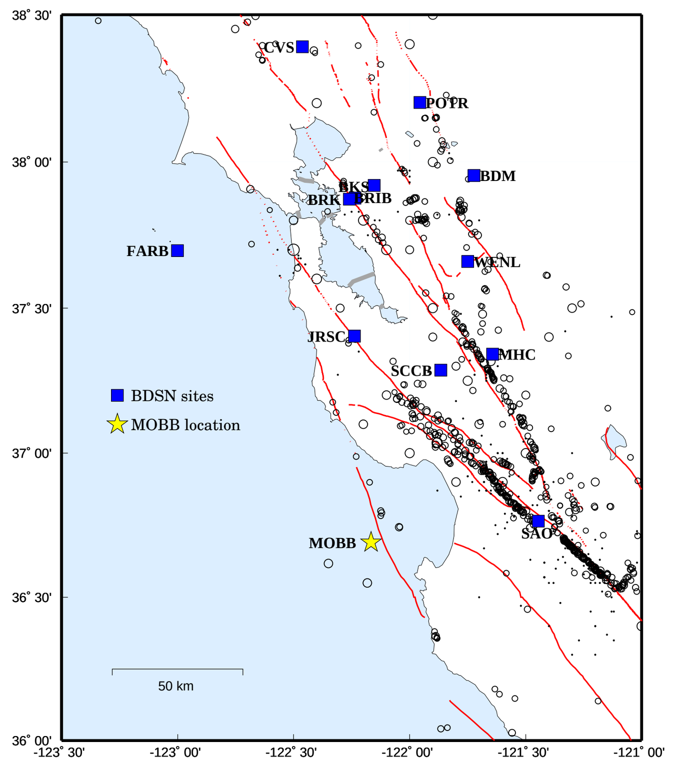

Figure 6. Location of MOBB in relation to nearby Berkeley Digital Seismic Network (BDSN) stations in the Central Coast Ranges. Also shown are the Holocene faults and the background seismicity. FARB is located on the Farallon Islands. MOBB is just west of the Holocene trace of the offshore Palo Colorado-San Gregorio fault.

First Results

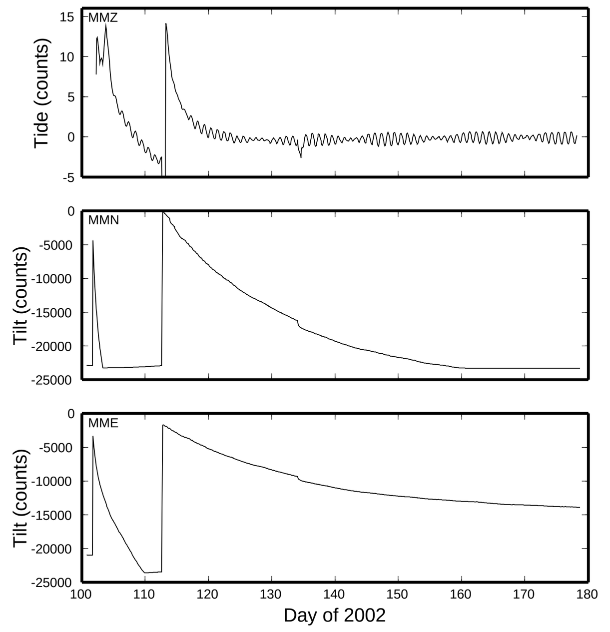

Figure 7. Guralp CMG-1T OBS mass position data for the time period 04/11/02-06/27/02. The large steps are associated with: 1) installation (day 100); 2) recentering (day 112), and a smaller step with a local Mw 4.95 earthquake on day 134. The tide signal is clearly visible on the vertical component. The data indicate that the seismometer package has been experiencing an exponentially decaying tilt in a south-southwesterly direction, which is also the down slope direction (e.g. Figure 5).

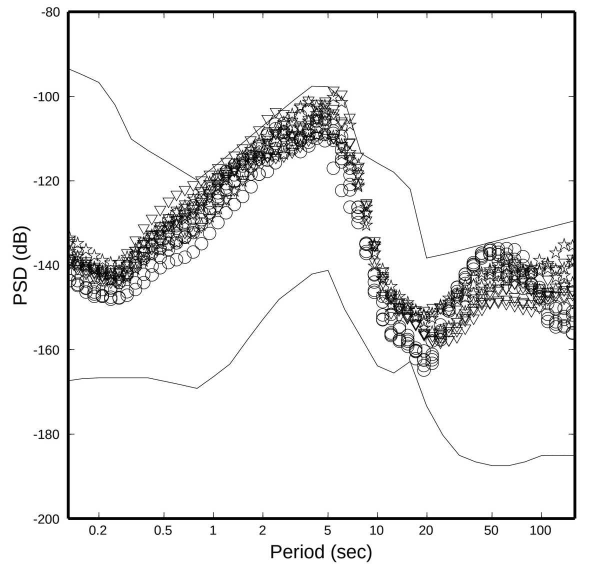

Figure 8. Observed background noise PSD at MOBB. Shown are the Z-component (circles), N-component (stars) and E-component (triangles). The USGS high- and low-noise models (solid lines) are shown for comparison. The increase in the noise level at periods longer than ~20 seconds is probably due to the ocean currents interacting with the highly compliant seafloor sediments.

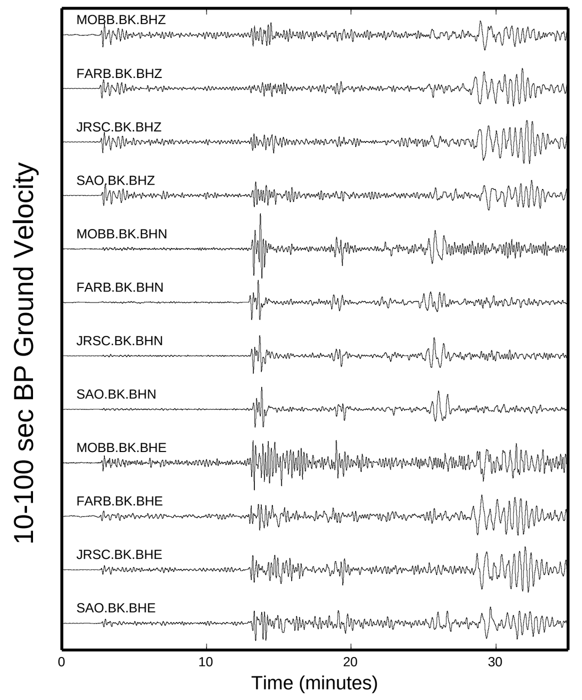

Figure 9. Comparison of 10-100 second band pass filtered absolute ground velocities recorded at MOBB and nearby BDSN stations FARB, JRSC and SAO (see Figure 6) from a Mw 7.1 teleseism which occured 84.8° N78°W of MOBB on 26 April 2002 in the Mariana Islands. The scale for the N-components has been reduced by half. The comparison shows consistency between the recording at MOBB and nearby stations. On the horizontal components there appears to be some signal-generated noise following the S-waves and the Love wave, which is likely associated with ringing in the shallow mud layers.

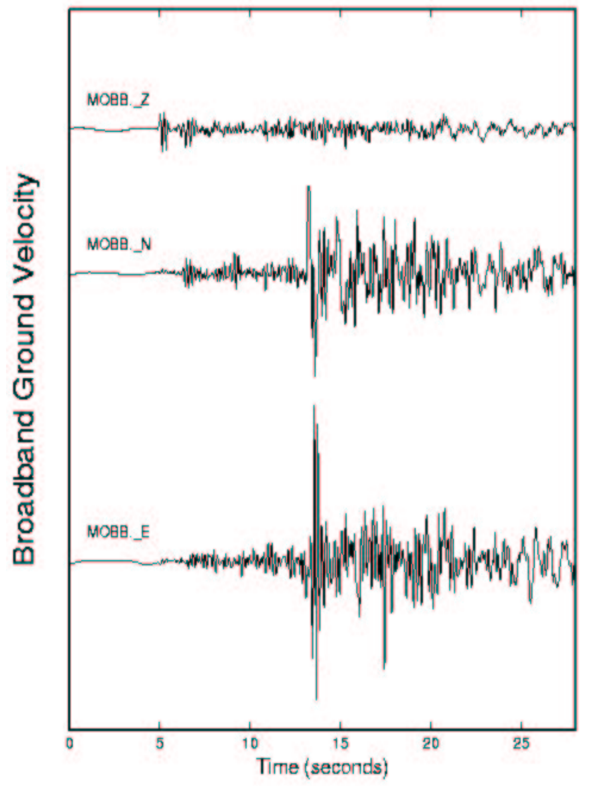

Figure 10. Deconvolved ground velocity records at MOBB of the 04/23/02 M 3.63 San Andreas fault event (53.4 km N68°E of MOBB). The very large S wave pulse on the horizontal components as well as the subsequent ringing are likely due to site response and need to be investigated further. On the vertical component, the water reflection of the P wave is clearly seen 1.5 seconds after the P wave. In spite of these strong site effects, these data can be used in moment tensor studies as illustrated in Figure 11.

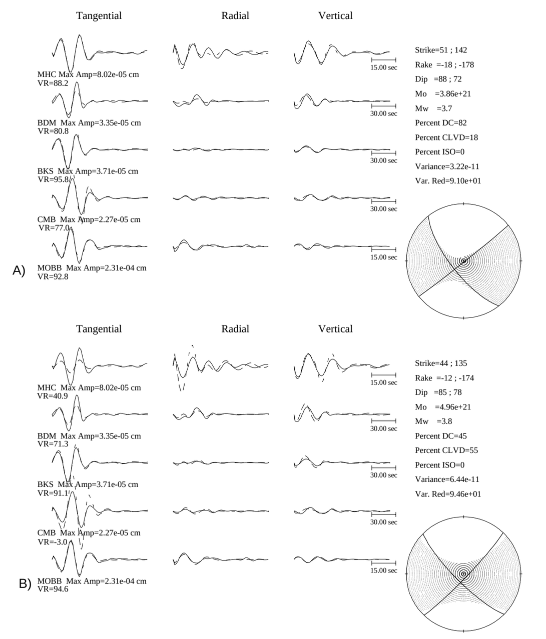

Figure 11. Results of moment tensor inversions for the M 3.63 regional event shown in Figure 10. Top: inversion using 4 stations of the BDSN and MOBB (BDM, BKS, CMB are band passed between 0.02 and 0.05 Hz; MHC and MOBB, between 0.05 and 0.1 Hz). Bottom: results of inversion using only MOBB, showning the good fits of the single station solution to the other BDSN data.

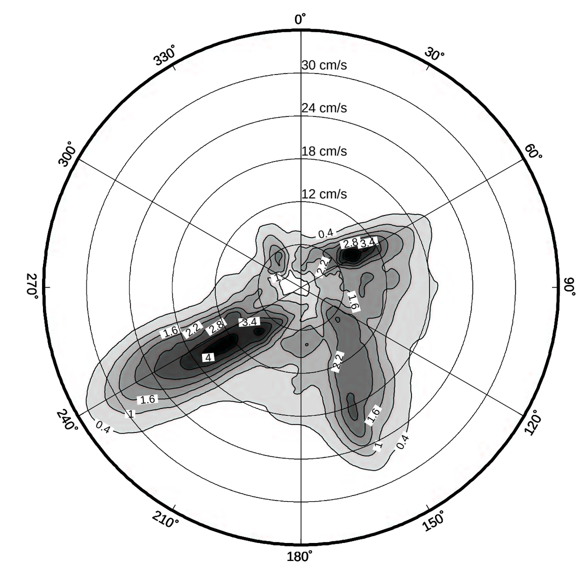

Figure 12. Distribution of current velocity data as a function of azimuth. The contour label units are fractions of the average density distribution of the current. The two dominant maxima (centered at 60 and 240 degrees, i.e. orthogonal to the continental shelf) are associated with the semi-diurnal tidal currents. The third directional peak is roughly parallel to the coastline and appears to be associated with the dominant ocean circulation.

Future Plans etc.

Our first goal is to access the data quality and possible improvements, through post-processing and/or installation adjustments. We plan to evaluate the long term time evolution of background noise, as the system continues to settle and stabilize, and the shorter term noise fluctuations in relation to tides and currents as recorded by the current-meter as well as the Digital Pressure Gauge (DPG).

Our second goal is to systematically analyze body wave and surface wave data for regional earthquakes to obtain constraints on the moment tensor solutions and 3D crustal structure at the western edge of the plate boundary.

MOBB is the first step towards extending the land-based broadband network in northern California off-shore to better characterize the seismicity, tectonics and structure of this region.

Ultimately the experience gained through MOBB can help design better future near-off-shore ocean floor broadband seismic station deployments to complement the land based networks in the western US, either permanently, or in the intermediate time scale (1-2 years), for example in complement to such programs as the USArray of Earthscope. Already, the MOBB instrument preparation and deployment experience acquired over the last two years will benefit similar experiments planned in the context of preparation for the Keck program.

A significant contribution to this project is provided by MBARI through the continuing support of the operation and maintenance of the MOBB site (at the minimum: exchange of data loggers, checking and recentering the seismometers and timing adjustments, every three months for the next three years), and by BSL, through the systematic archival of the data at the NCEDC, at no cost to the project.