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MOBB: Data Analysis From an Ocean Floor Seismic Observatory in Monterey Bay, California

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Introduction

MOBB (Monterey bay Ocean floor Broad Band project) is a collaborative project between the Monterey Bay Aquarium Research Institute (MBARI) and the Berkeley Seismological Laboratory (BSL). Its goal is to install and operate a permanent seafloor broadband station as a first step towards extending the on-shore broadband seismic network in northern California, to the seaside of the North America/Pacific plate boundary, providing improved azimuthal coverage for regional earthquake and structure studies. The MOBB station was installed on the seafloor in Monterey Bay, 40 km offshore, and at a depth of 1000 m from the sea surface, in April 2002, and is completely buried under the seafloor level. The installation made use of MBARI's Point Lobos ship and ROV Ventana and the station currently records data autonomously. Dives are scheduled regularly (about every three months) to recover and replace the recording and battery packages. Some data were lost in the first half of 2003 due to hardware and software problems in the recording system.

The ocean-bottom MOBB station currently comprises a three-component seismometer package (Guralp CMG-1T), a current-meter, a digital pressure gauge (DPG) and recording and battery packages. 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.

Since the background noise in the near-shore ocean environment is high in the band pass of interest, for the study of regional and teleseismic signals, an important focus of this project is to develop methods to a posteriori increase the signal to noise ratios, by deconvolving contributions from various sources of noise. We present results involving analysis of correlation of background noise with tide, ocean current and pressure records, combining data from MOBB and regional land based stations of the Berkeley Digital Seismic Network (BDSN). We also present preliminary results of modeling of the signal generated noise in the near surface sedimentary pile.

The experience gained in MOBB will be valuable, in particular, for future long term or temporary deployments of buried broad-band seismometers such as are envisaged in the context of the Ocean Mantle Dynamics Initiative.

Testing

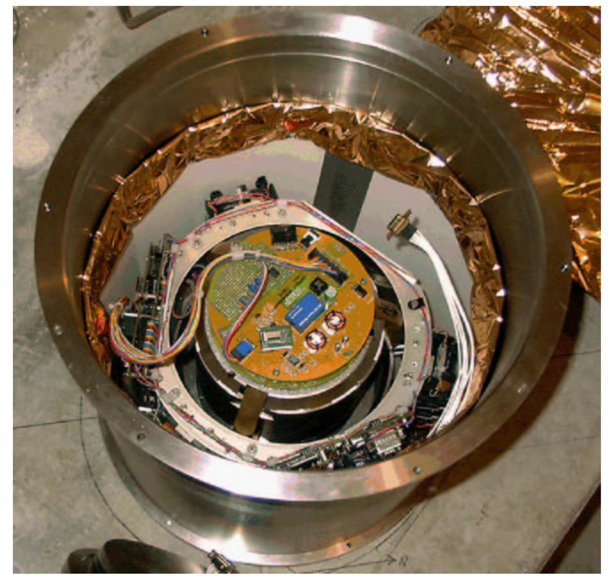

Figure 1. The CMG-1T OBS installed in the titanium pressure vessel. The space between the inside cylindrical surface of the pressure vessel and the seismometer is insulated with multiple layers of Mylar (space blanket) insulation supported by a cardboard form. Partly visible on the upper right is the 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.

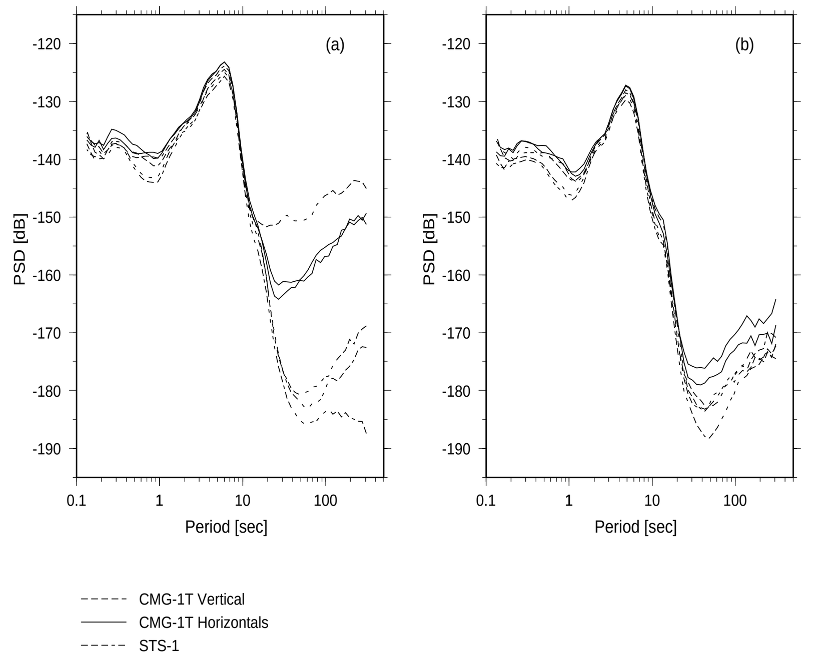

Figure 3. Comparison of the background noise PSD from the CMG-1T OBS, installed in the titanium pressure vessel, and from the co-sited STS-1 sensors housed in the BKS Vault. Shown are the PSD's for the CMG-1T vertical (large dashed), the CMG-1T horizontals (solid), and the STS-1's (small dashed). The PSD's are for data collected prior to (a) and after (b) 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

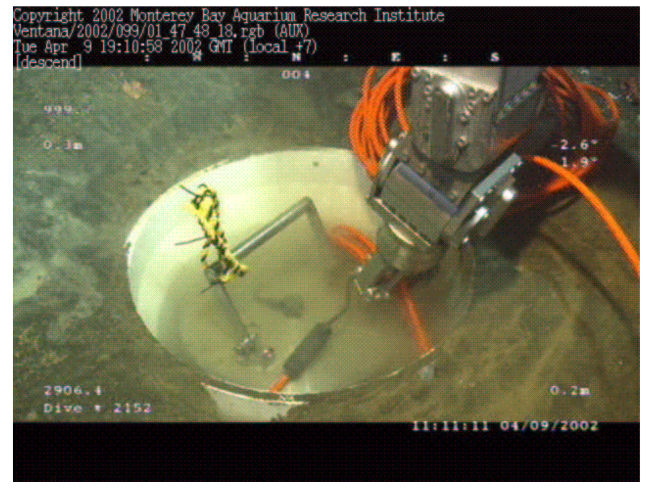

Figure 4. Installation of the seismometer package inside the PVC caisson. The top of the package is buried at least 10 cm below the the seafloor level. Burial of the seismometer package in the seafloor sediments is crucial to reducing the tilt noise induced by ocean currents. The package was later completely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

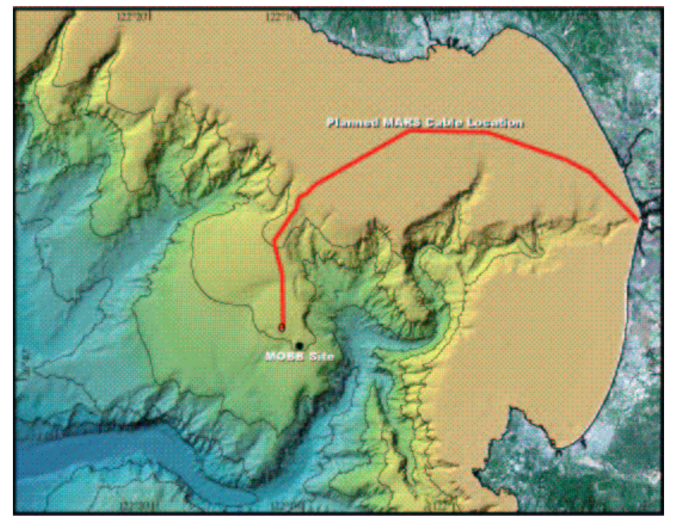

Figure 5. Location of MOBB in Monterey Bay, California, against seafloor and land topography. The planned route of the Monterey Accelerated Research System (MARS) cable is shown in red. MOBB is located at 1000 m below sea-level.

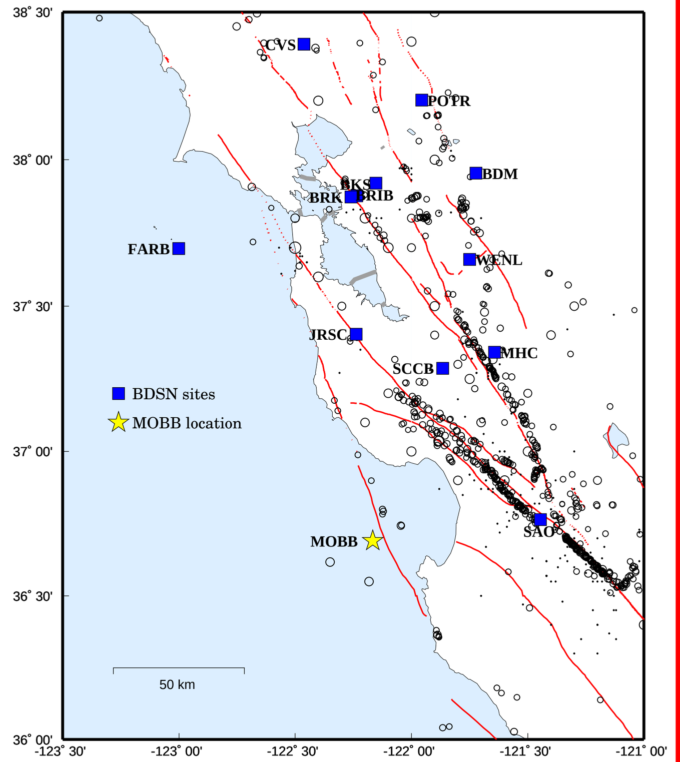

Figure 6. Location of MOBB in relation to nearby Berkeley Digital Seismic Network (BDSN) stations in the Central Coast Ranges. Also shown are the Holocene faults and the background seismicity. FARB is located on the Farallon Islands. MOBB is just west of the Holocene trace of the offshore Hosgrei fault.

Data Analysis

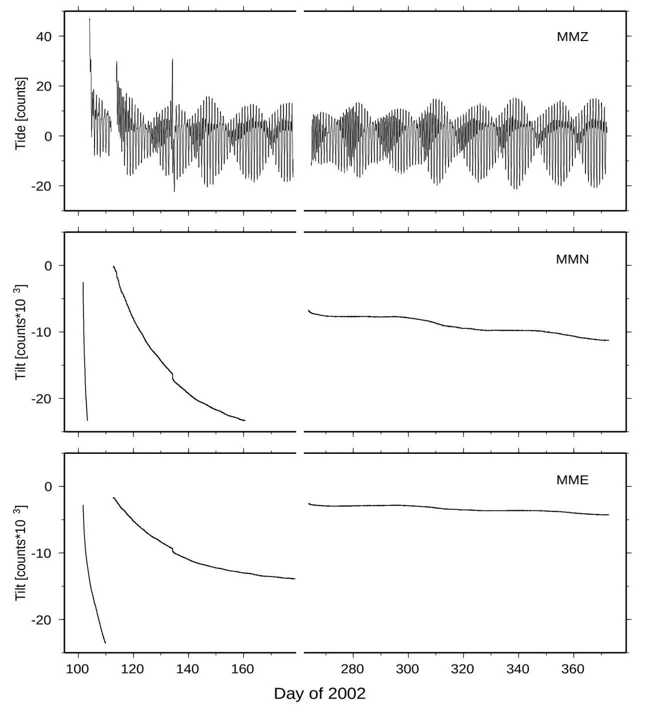

Figure 7. Guralp CMG-1T OBS mass position data for the time period 04/11/02-06/27/02. The large steps are associated with: 1) installation (day 100); 2) recentering (day 112), and a smaller step with a local Mw 4.95 earthquake on day 134. The tide signal is clearly visible on the vertical component (with a 36 hour running mean removed). 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).

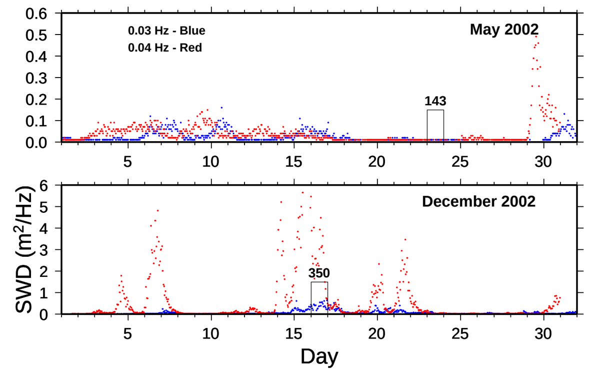

Figure 8. Spectral wave density of the ocean waves recorded on a NOAA weather buoy in Monterey Bay. Energy in 0.03 Hz and 0.04 Hz bin is shown for May and December 2002. Day 143 was selected as a "quiet" data and day 350 was selected as a "stormy" day for further analysis (see Figure 9). Note different scales on y-axis.

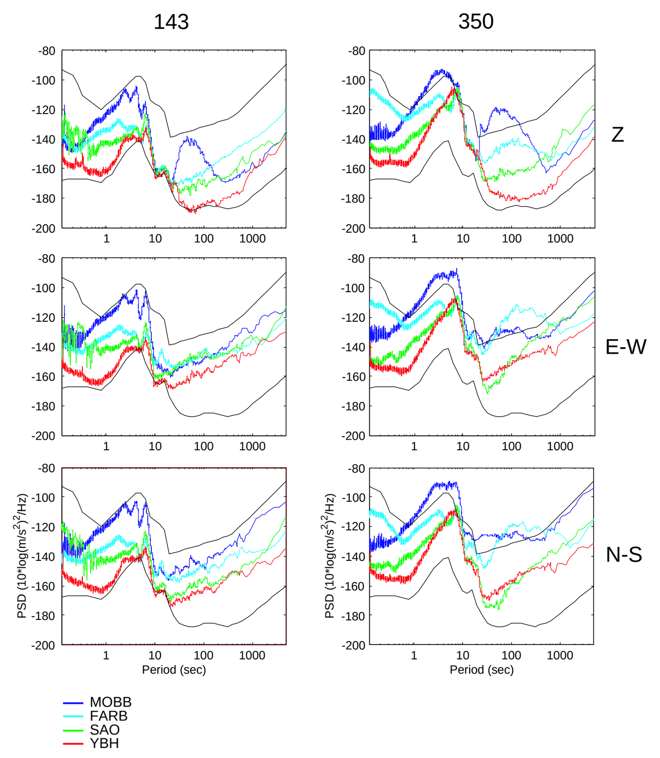

Figure 9. Observed background noise PSD at MOBB. Shown are the Z-component (circles), N-component (stars) and E-component (triangles). The USGS high- and low-noise models (solid lines) are shown for comparison. The increase in the noise level at periods longer than ~20 seconds is probably due to the ocean currents interacting with the highly compliant the seafloor sediments.

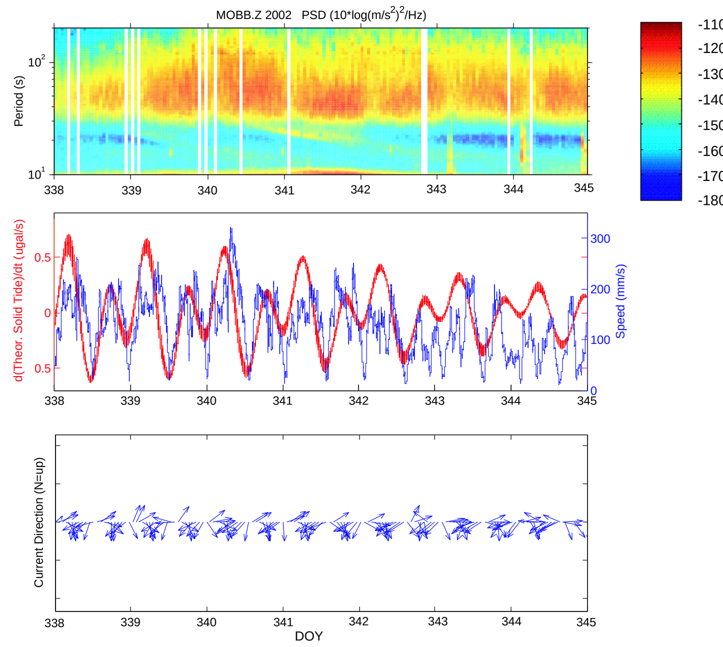

Figure 10. Noise analysis and comparison of MOBB signals. (a) PSD calculated for a vertical seismic channel during a seven day period (Dec. 4-10, 2002). Period range of the infragravity wave band is shown. (b) Time derivative of the theoretical solid earth tides (red, left axis) and the measured ocean speed (blue, right axis). (c) Direction of ocean current (N is up).

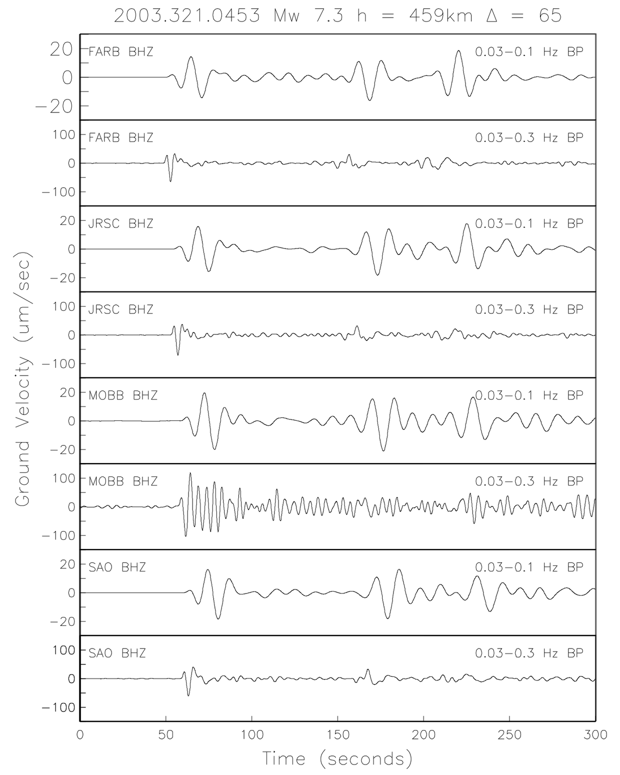

Figure 11. Comparison of vertical component records at stations FARB, JRSC, MOBB and SAO for the deep Kurile Islands earthquake of 11/17/2002 (Mw 7.3; 459 km depth; 65 degrees NW of MOBB). The data are shown in two pass-bands: 0.03-0.1 Hz and 0.03-0.3 Hz to emphasize the narrow-band character of the ringing in the MOBB P wave data. Clearly visible;e lower frequency band are the P, pP, and sP arrivals.

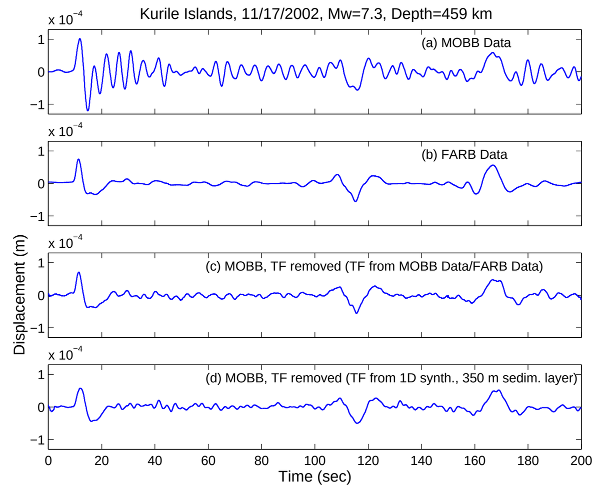

Figure 12. Two examples of deconvolution of signal generated noise in the P-wave part of the recording of a deep focus teleseism at MOBB: a) original MOBB data; b) original FARB data; c) processed MOBB data after removing the empirical transfer function constructed using only the P-wave MOBB and FARB data; d) processed MOBB data after removing a synthetic transfer function obtained by 1-D modeling of the shallow structure. Result is obtained with transfer function of a 350 m thick layer with vp = 0.324 km/s, vs = 0.196 km/s and density = 1.3 gm/cc is shown.

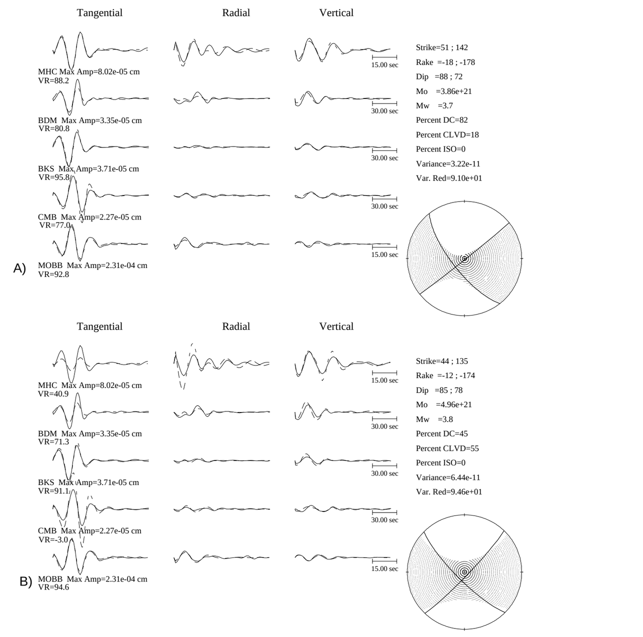

Figure 13. Results of moment tensor inversions for the M 3.63 regional event. Top: inversion using 4 stations of the BDSN and MOBB (BDM,BKS, CMB are band passed between 0.02 and 0.05 Hz; MHC and MOBB, between 0.05 and 0.1 Hz). Bottom: results of inversion using only MOBB, showing the good fits of the single station solution to the other BDSN data.

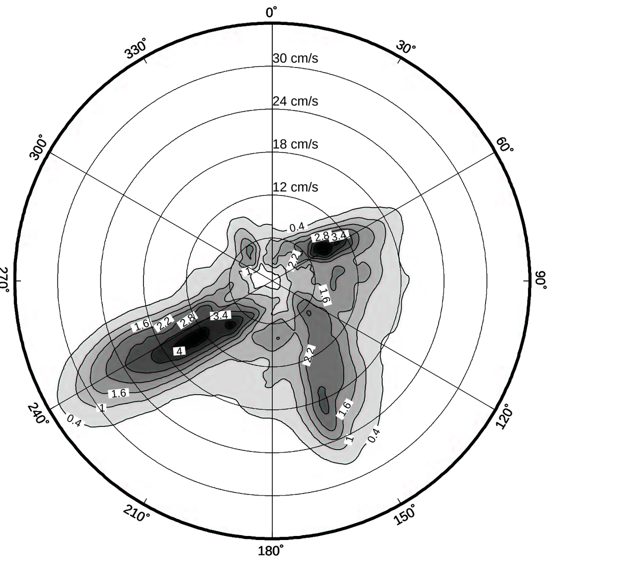

Figure 14. Distribution of current velocity data as a function of azimuth. The contour label units are fractions of the average density distribution of the current. The two dominant maxima (centered at 60 and 240 degrees, i.e. orthogonal to the continental shelf) are associated with the semi-diurnal tidal currents. The third directional peak is roughly parallel to the coastline and appears to be associated with the dominant ocean circulation.