Hydroacoustic resonance in the 2003 Tokachi-oki tsunami source

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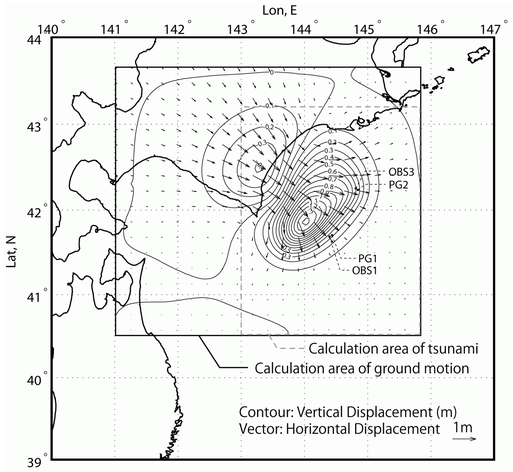
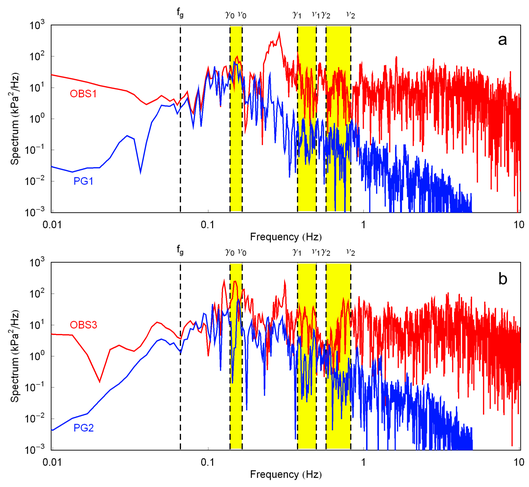
In recent years, when JAMSTEC (Japan Agency for Marine-Earth Science and Technology) deployed a real-time observatory at the continental slope close to the islands of Japan, it became possible to investigate a tsunami formation, including hydroacoustic phenomena, just at its source. The Tokachi-oki earthquake of 2003 turned out to be the first strong tsunamigenic seismic event, the epicentre of which was located in the immediate vicinity of the JAMSTEC sensors. Spectral analysis of variations of bottom pressure recorded during the earthquake provided a unique opportunity to reveal the hydroacoustic resonance – manifestations of compressibility of water in tsunami source. In present study, we provide a joint analysis of 10 Hz bottom pressure dataset and 100 Hz ocean-bottom seismometers dataset recorded during the 2003 Tokachi-oki earthquake. In particular, it is shown that the hydroacoustic resonance is clearly manifested in both datasets: bottom pressure and up-down (UD) bottom acceleration. Moreover, we reveal the frequency band ("Forced oscillations") within which a nearly ideal coincidence of spectra of bottom pressure and UD bottom acceleration is observed. Numerical experiments aimed at reproducing bottom pressure variations in the Tokachi-oki 2003 tsunami source by means of 3D numerical simulation technique taking into account dynamic bottom deformations and water compressibility are also described. A reasonable agreement between amplitudes and dominating frequencies of numerically simulated and in-situ recorded bottom pressure variations is achieved. Special attention is paid to the influence of the rise time on the amplitude of bottom pressure variations.

In-situ measurements

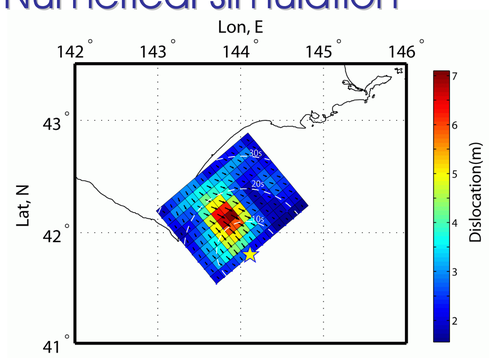


Location map and calculation areas. Location of ocean-bottom seismometers (OBSs) and ocean-bottom pressure gauges (PGs). The vertical co-seismic bottom deformation is shown by black contours at 0.1-m intervals. The horizontal co-seismic bottom deformation is shown by black arrows.

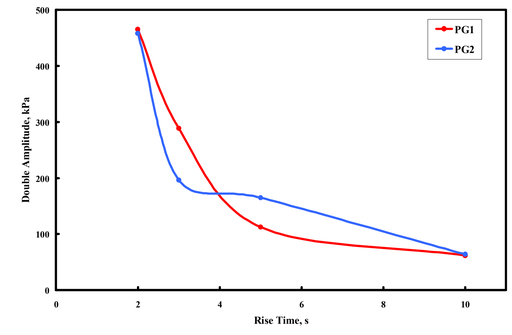


Frequency spectra of bottom pressure variations and UD acceleration of bottom recorded during the 2003 Tokachi-oki earthquake: (a) PG1 and OBS1, (b) PG2 and OBS3. Red and blue curves stand for OBSs and PGs, respectively. The UD acceleration is shown in pressure units ($p = \rho\, H\, a_{UD}$, where a_{UD} — UD component of bottom acceleration).
Vertical dashed lines stand for the positions of characteristic frequencies: gravitational wave frequency f_g , discrete set of normal frequencies of elastic oscillations of compressible water column ν_n, discrete set of normal frequencies of coupling elastic oscillations of compressible water column and sediments layer γ_n.

Numerical simulation

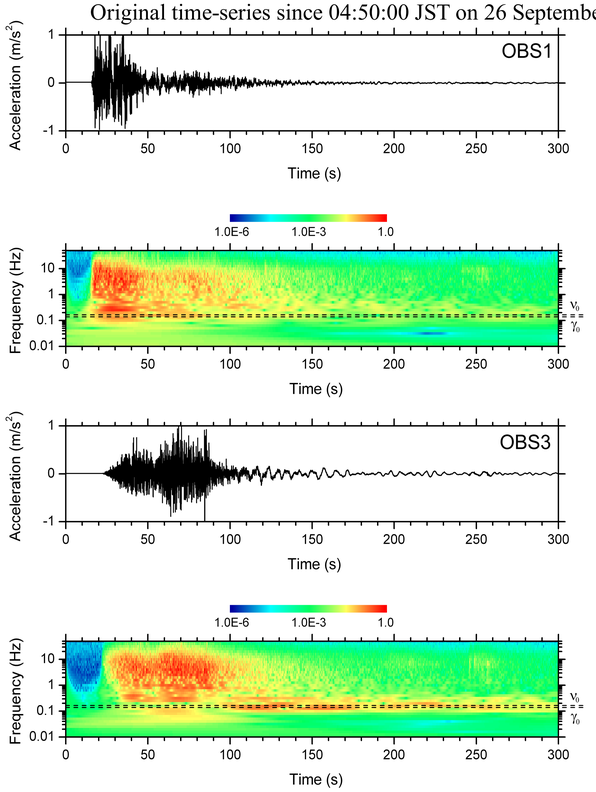


The fault projection and slip distribution estimated by strong-motion waveforms and GPS data. Yellow star shows the mainshock epicentre. White dashed lines stand for the positions of rupture front at 10-s intervals.

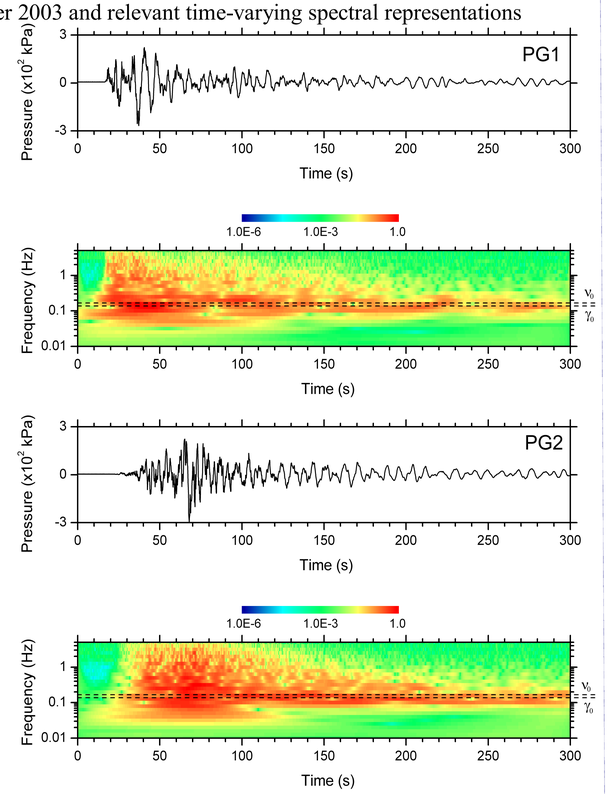


Double amplitude of synthetic bottom pressure variations versus rise time

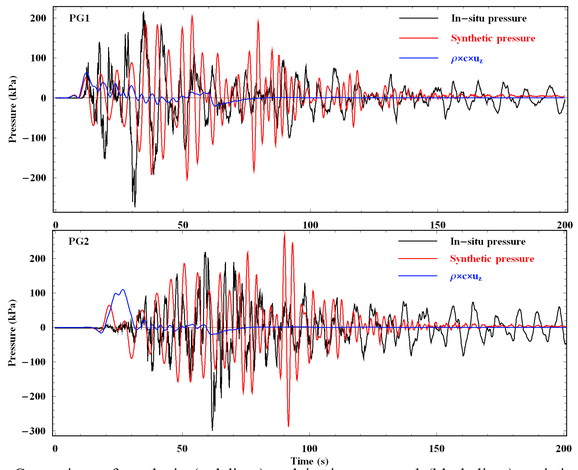
Original time-series since 04:50:00 JST on 26 September 2003 and relevant time-varying spectral representations



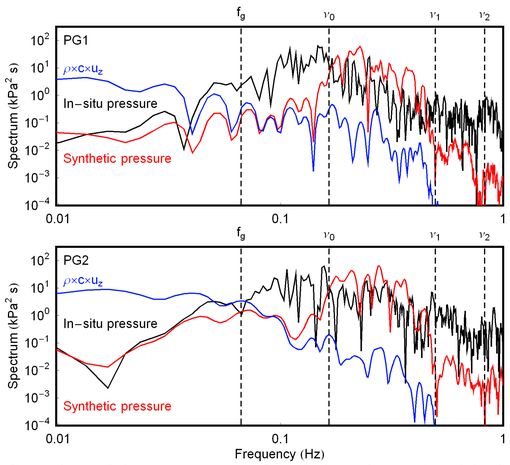
The UD acceleration of bottom recorded during the 2003 Tokachi-oki earthquake by OBS sensors.



The bottom pressure recorded during the 2003 Tokachi-oki earthquake by PG sensors.



Comparison of synthetic (red lines) and in-situ measured (black lines) variations of bottom pressure. Blue lines stand for the synthetic UD bottom velocity represented in pressure units ($p = \rho\, c\, u_{UD}$, where u_{UD} — bottom velocity). Zero time corresponds to the moment of 04:50:06 JST on September 26, 2003.



Comparison of frequency spectra of synthetic (red curves) and in-situ measured (black curves) variations of bottom pressure. Blue curves stand for the frequency spectra of synthetic UD bottom velocity represented in pressure units ($p = \rho\, c\, u_{UD}$). Vertical dashed lines stand for the positions of characteristic frequencies of compressible water column.

Publications

Kolesov, S., Bolshakova, A., Inoue, S., Matsumoto, H., Nosov, M., and Ohmachi, T.: Numerical simulation of hydroacoustic effects in tsunami source, Joint Conference Proceedings, 7th International Conference on Urban Earthquake Engineering (7CUEE) & 5th International Conference on Earthquake Engineering (5ICEE), March 3-5, 2010, Tokyo Institute of Technology, Tokyo, Japan, 1687-1692, 2010.

Nosov, M. A., Kolesov, S. V., Denisova, A.V., Alekseev, A.B., and Levin, B. W.: On the near-bottom pressure variations in the region of the 2003 Tokachi-Oki tsunami source, Oceanology, 47(1), 26-32, 2007.

Nosov, M. A., Kolesov, S. V., Ostroukhova, A. V., Alekseev, A. B., and Levin, B. W.: Elastic oscillations of the water layer in a tsunami source, Doklady Earth Sciences, 404 (7), 1097-1100, 2005.

Nosov, M.A. and Kolesov, S.V.: Elastic oscillations of water column in the 2003 Tokachi-oki tsunami source: in-situ measurements and 3-D numerical modeling, NHESS, 7, 243-249, 2007.

Ohmachi, T. and Inoue, S.: Dynamic tsunami generation process observed in the 2003 Tokachi-oki, Japan, earthquake, Advances in Geosciences - Ocean Science, 18, 159-168, 2010.

Ohmachi, T., Tsukiyama, H., and Matsumoto, H.: Simulation of tsunami induced by dynamic displacement of seabed due to seismic faulting, BSSA, 91 (6), 1898-1909, 2001.