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Cross-correlation of the sea level changes off Muroto Cape and off Hatsushima Island, Japan

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Recently, seismic interferometry has drawn attention in seismology and exploration geophysics. It estimates the seismic Green's function between two points, one of which is a source and the other is a receiver, by calculating the cross-correlation functions (CCF) of ambient seismic noises recorded at these points. Equivalent approaches have been also applied and validated in other fields, such as oceanic acoustics and helioseismology. However, there seems to be no report of applying such an approach to observed ocean surface waves. In this study, we calculate the CCF of sea level changes recorded at two points off the Pacific coast of Japan, and we examine the possibility of retrieval of Green's function of ocean waves from the CCF. We actually treat long-wavelength ocean waves (or tsunami) with the periods of 10 min or more.

We treat records of two water pressure gauges (tsunami sensors) deployed on the deep-sea floor by JAMSTEC, Japan. One gauge is PG1 of Long-Term Deep Sea Floor Observatory off Muroto Cape (about 100 km offshore and 2,308 m depth; hereinafter MPG1), and the other is a component of Long-Term Deep Sea Floor Observatory off Hatsushima Island in Sagami Bay (about 6 km offshore and 1,175 m depth; hereinafter HPG1). The records are 1 s sampled water heights, calculated based on measured water pressures. We select good-quality records for 1,130 days in the period from May 19, 2004 to May 31, 2008, which are then resampled at 30 s intervals.

We process the data for each day at the both stations in the following manner. (1) Remove the mean water height from the data for each day. Thereby obtain sea level changes. (2) Apply a harmonic analysis to the sea level changes for each day. Thereby remove the tidal constituents. (3) Bandpass-filter the tide-removed data with the passband from 10 to 60 min, which may be typical periods of tsunami. (4) Apply one-bit normalization to the bandpassed data, in which only the signs of the data are retained by replacing all positive amplitudes with 1 and all negative amplitudes with -1. (5) Calculate the CCF between the processed data at MPG1 and those at HPG1 for each day. Finally, we stack the CCF for all the days to obtain the time-averaged CCF.

It is shown that the obtained CCF denotes roughly harmonic and symmetrical features with respect to time lag. It has large amplitudes at around the absolute time lag from 1 to 6 h. For comparison, we synthesize the tsunami observed at HPG1 due to a source located at MPG1. This is achieved by a finite difference simulation with the linear long-wave approximation, in which we give a Gaussian-type initial disturbance of sea levels in the area around MPG1 with the radius of 50 km. Note that Saito and Kawahara (2011, this meeting) theoretically suggests that tsunami Green's function would be given by the derivative of CCF with respect to time lag. Additionally, a representation theorem denotes that a wave generated by delta function-like initial displacement results in the time-derivative of Green's function. Therefore, we calculate the second derivative of the present CCF with respect to time lag. We then lowpass-filter it with the cutoff of 60 min, in order to match the dominant periods of the synthetic tsunami. Although the function thus obtained and the synthetic tsunami do not agree in the arrival times of first motion, they show good similarity in the overall waveforms. This indicates that the present CCF can partly reflect the tsunami Green's function between the two stations.

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Keywords: Sea level change, Cross-correlation, Tsunami, Green's function