Application of ocean bottom tsunami gauge data for real-time tsunami forecasting

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Tsunami forecasting is one of the most effective methods to mitigate tsunami hazards. Now, in Japan, tsunami warning is announced within three minutes after the occurrence of an earthquake. This warning is based only on the seismic data and therefore has some problems; no one can assess the validity of the forecasting until tsunami reaches coasts and, in principle, tsunami amplitudes may be underestimated when “tsunami earthquakes”, which generate tsunamis much larger than those expected from its magnitude estimated by seismic data, occur. To avoid these problems, tsunami data observed at offshore should be effectively used for the forecasting because the offshore stations can detect tsunami earlier than it reaches to the coastal area. In this study, we develop an algorithm for real-time tsunami forecasting system using offshore Ocean Bottom Tsunami Gauge (OBTG) data.

To forecast coastal tsunami in real-time, we plan to use pressure data measured by cabled OBTGs. The offshore tsunami waveforms are inverted for a coseismic sea-floor vertical displacement distribution, which is used to calculate coastal tsunami waveforms before actual tsunami arrives. Owing to calculate Green’s functions in advance, we can accomplish the successive calculation about one minute. Due to use more OBTG data in inversion as time lapses after a tsunami occurs, the reliability of forecasting is expected to improve.

In order to check whether our method is practical before tsunamis reach the coasts, we performed numerical test assuming the case of the 1896 Sanriku tsunami earthquake (Ms=7.2, Mt=8.6). We use only four OBTGs, presently operating in the Tohoku-Hokkaido region. Tsunami waveforms were calculated using the source parameters by Tanioka and Satake (1996), and regarded as the observed waveforms. Then, we compare the “observed” tsunami waveforms with those calculated by our forecasting scheme for coastal tide stations. The sea-floor displacements, used for the waveform synthesis, were inverted from the “observations” at four offshore stations. This test shows that our method can provide more reliable forecasting results, as time lapses. Five minutes before the earliest arrival time to the coast, our method can provide very good estimation of arrival time and amplitude of first and maximum wave at most stations along the Pacific coast of the Tohoku-Hokkaido region. This indicates that our method is enough practical for tsunami forecasting.

We also applied our method to the actual tsunami observations in the 2003 Off-Fukushima earthquake (M6.8); the tsunami was recorded by both two OBTGs and coastal stations. In the result, the calculated tsunami waveforms match to the observations within five minutes in arrival times and within 70 % of the first waves in amplitudes at three coastal stations.

On the other hand, we found that the accuracy of the tsunami wave height forecasting is subject to effects of azimuthal dependence of tsunami radiation, which is significant for large interplate underthrusting earthquakes. This effect can be reduced by increasing the density of OBTG systems along the trench. The result of our numerical experiment shows that the accuracy of the wave height forecasting will considerably improve if we build additional four OBTG stations between the two existing cabled system.