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Generation and propagation of the 2011 Tohoku earthquake tsunami inferred from the OBEM array in the North-West Pacific

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The 2011 Tohoku earthquake tsunami caused a destructive damage along the shoreline from the Tohoku to Kanto districts. Because many of the tide gauge stations along the Tohoku coast were damaged by the tsunami, source process of the tsunami has not been well determined yet. After the Tohoku earthquake, several cruises of JAMSTEC research vessels recovered Ocean Bottom ElectroMagnetometers (OBEMs) from the seafloor sites in the North-West Pacific area, where the OBEMs had been installed before the earthquake. These sites are BM14 (39.058N, 144.808E, 5830m; recovered by NT11-08), NWP (41.103N, 159.952E, 5816m; recovered by KR11-07), and NM04 (38.211N, 154.190E, 5940m; recovered by KR11-10). OBEMs from these sites clearly recorded the ElectroMagnetic(EM) tsunami signals.

Seafloor measurement of the EM signals due to tsunamis had not been attained until very recently (Toh et al., 2011) because of their low signal levels. However, recent advances in technology enabled the seafloor measurements of the tsunami EM signals by using OBEMs. First simultaneous measurements of EM signals and bottom pressure during the passage of 2010 Chile earthquake tsunami in the French-Polynesia region (Hamano et al.,2011), proved that seafloor observation of EM signals is powerful tool to investigate the generation and propagation of tsunamis in the open sea, in which temporal variations of the vertical magnetic field, Bz, reproduce the variations of the sea level change due to the passage of tsunami wave, and two horizontal magnetic fields, Bx and By, indicate the propagation direction of tsunamis. As for the Tohoku earthquake, combination of the three OBEM stations with the tsunami monitoring stations ST2418 (38.718N, 148.698E, 5500m), ST21413 (30.528N, 152.123E, 5874m), and ST21419 (44.455N, 155.735E, 5285m) operated by NOAA, comprises an observational network for the tsunami located in the east of the fault plane of the Tohoku earthquake, which provides valuable information on the generation and propagation of the 2011 Tohoku earthquake tsunami. Among the network stations, the OBEM at site BM14 recorded the tsunami arrival after 4 minutes of the origin time of the Tohoku earthquake. This early observation at the closest place to the tsunami source enable reliable estimate of the source process of the tsunami (Ichihara et al., 2011). Here, we report the propagation process of the tsunami inferred from this tsunami observational network. By taking cross-spectra of the 24 hours signals of sea level change from each station correspond to the signals from BM14 (closest site to the tsunami source) , dispersion relations of the tsunami wave across the network were calculated. The result indicates that the tsunami generated just west to site BM14 propagates across the line from BM14 through ST21418 to NM14. This west to east propagated tsunami wave shows a dispersion relation consistent with the theoretical estimate of gravity waves corresponding to the water depth of 5500 m. The dispersion shows that the decrease of phase velocity by about 15 % from the period of 20 minutes to 3 minutes. Cross-spectra of the records from ST21413 and ST21418 to that from BM14 indicate that the tsunami arrived at these sites propagate along west-east direction, suggesting the sources for the tsunami passing through these two stations are different from the source responsible for the tsunami propagated along the BM14-ST21418-NM14 line.

Keywords: tsunami, electromagnetic observation, sea floor observation, ocean dynamo effect, 2011 Tohoku earthquake