

Generation Processes of Large Later Phases Caused by the 2011 Tohoku Earthquake and Observed along the Pacific Coast of Hokkaido

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The 2011 Tohoku tsunami caused the significant damages along the Pacific coast in Japan, including the coasts of Sanriku in Tohoku and Hokkaido. The local largest tsunamis were observed during the first wave at many sites on the Sanriku coast, where the source area was close. However, at large cities on the coast of Hokkaido, such as Hakodate and Kushiro, the local largest tsunami arrived at 9 hours after the earthquake (the large later phase), inundated in the cities, and caused severe damages. It is, therefore, important to investigate the generation mechanism of such large later phase observed in the 2011 Tohoku tsunami.

In this research, we numerically computed the tsunami propagation from the source model of the 2011 Tohoku-oki earthquake estimated by Fujii et al. (2011) to investigate the generation mechanism. First, the tsunami was computed by solving the linear long wave equations. The observed tsunami waveforms at five tide gauge stations, Hakodate, Muroran, Tomakomai, Tomakomai-Nishi and Urakawa, were compared with the computed ones. The result showed that the observed large later phases were clearly overestimated by the computed ones although the observed initial phases are well explained by the computed ones. Next, the tsunami was computed by solving the nonlinear shallow water equations with a moving boundary condition to account for the tsunami runup. The comparison of the observed and computed later phases at the above five stations showed that the observed large later phases were well reproduced by the computed ones for this simulation. This result indicates that the energy dissipation of tsunami by the nonlinear effects and the runup along the Pacific coast of Tohoku region largely affects the generation of the large later phases along the coast of Hokkaido. Because those large later phases caused damages at Hakodate in Hokkaido, we further investigated the generation mechanism of those large later phases observed at this city from the computed tsunami waveforms and propagation patterns.

At Hakodate, the observed tsunami waveform shows that a dominant period of the tsunami is about 50 minutes. That is also reproduced by the computed tsunami waveform. The map view of the computed tsunami propagation clearly shows that those tsunamis of about 50 minutes are generated by the oscillation of sea water in the Hakodate bay which has a size of about 7km X 8 km. The bathymetry of the Hakodate bay shows that the average water depth of the bay is about 10.5 m. At the mouth of the Hakodate bay, the depth is about 25 m. The water depth suddenly increases from the mouth to the deep ocean. A simple calculation of the fundamental mode of the free oscillation for the Bay using the above parameters is about 46-53 minutes. This result indicated that the large later phases at Hakodate are caused by the free oscillation of the Bay with the energy supplied by the tsunamis propagated through the shallow sea along the coast as edge waves.

Keywords: 2011 Tohoku-oki earthquake, Tsunami along the coast of Hokkaido, Hakodate

