Generation Mechanism of Large Later Tsunami Phases,
: A case study of the 2011 Tohoku-oki tsunami in Hokkaido

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The 2011 Tohoku earthquake generated a large tsunami causing a significant disaster along the Pacific coast in Japan. The Pacific coast of Hokkaido was also severely damaged. Along the Sanriku coast, the most hazardous tsunami was the first wave because the coast was close to the source area. However, at large cities in the Pacific coast in Hokkaido, such as Hakodate or Kushiro, the largest tsunami wave arrived at 9 hours after the origin time of the earthquake. It is very important to understand generation mechanism of those large later phases for tsunami warning, evacuation, and disaster mitigation.

In this research, we numerically computed tsunami using both the linear shallow water theory and the non-linear shallow water theory with a moving boundary condition. The tsunami initial condition was computed from the source model estimated by Satake et al., (2013). The comparison of the observed later phases of the tsunami waveforms along the Pacific coast of Hokkaido with the computed ones shows that the later phases computed from the non-linear shallow water theory could explain the observed waveforms although those computed from the linear
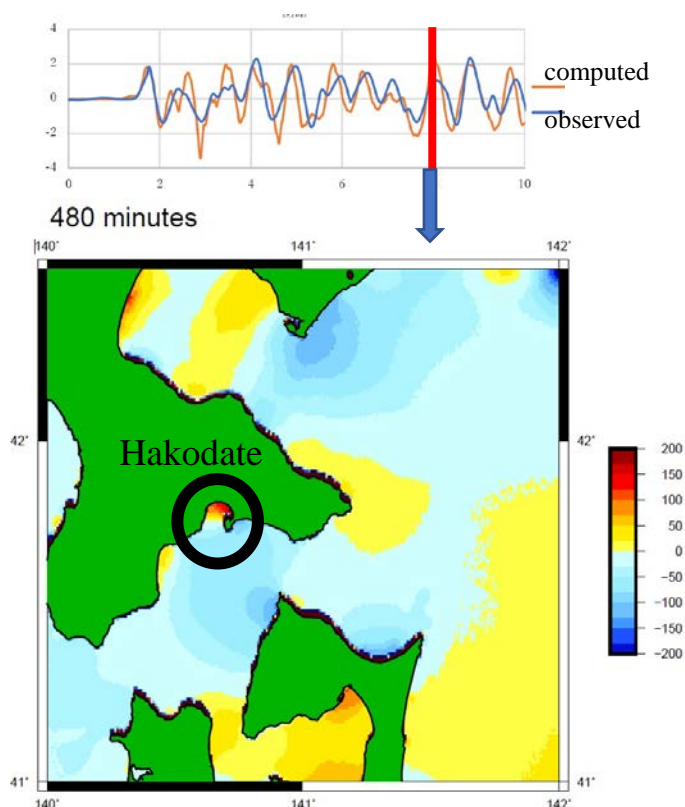

Figure 1. top) computed and observed tsunami waveforms at Hakodate, bottom) A snap shot of tsunami propagation at 480 minutes

long-wave theory mostly overestimated the observed ones. This indicates that the energy dissipation of tsunami along the Pacific coast largely affects the tsunami later phases along the coast of Hokkaido.

At Hakodate, large later phase has a period of about 50 minutes (Figure 1). Snap shots of tsunami propagations at 460, 480 (Figure 1), 505, and 534 minutes indicates that a resonance of Hakodate bay generated those large later phases. Then, the resonance of Hakodate bay was computed using the normal mode theory of harbour oscillation (Loomis, 1975) from the actual bathymetry. The period of the first mode was calculated to be 49 minutes which is the same as the observed and computed period of tsunami waveforms at Hakodate. We also found that the eigenfunction of the first mode has large values near the most populated area in Hakodate city. Our results clearly show that large later tsunamis at the populated area in Hakodate city were caused by a resonance of Hakodate bay.