# Development of Automatic Tsunami Inversion System, Marlin

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NIED has constructed and maintained a large-scale seafloor observation network, S-net, in the offshore of the Pacific coast of east Japan along the Japan Trench. With ocean bottom pressure gauges or tsunamimeters, S-net can observe tsunamis much earlier and more accurately than before. Tsunami forecast will be much more improved using S-net taking these advantages. Tsushima et al. (2009) proposed an effective approach for forecasting near-field tsunamis using ocean bottom pressure data based on the estimation of the heterogeneous tsunami source model or initial tsunami height distribution. This approach could overcome a problem originated from a heterogeneous source process of actual large earthquakes, which might make tsunami phenomena very complex but cannot be modeled by pre-calculated simple tsunami patterns. This has become feasible as the dense and real-time observation data are available as well as computer performance increases. Inspired by the preceding researches, an automatic tsunami source inversion system named “Marlin” has been developed and in operation using the S-net data. Marlin includes a forward tsunami simulation based on the tsunami source derived from the inversion analysis.

In Marlin, an analysis is triggered by receiving a CMT solution estimated within the S-net deployed regions by NIED AQUA system. The CMT information is used not only for triggering the system but for determining spatial range of inversion; that is, element tsunami sources to be inverted are distributed over the areas in which some crustal deformation is expected based on the fault models assumed by the CMT solution. The uplift or subsidence at each element tsunami source is estimated by solving linear observation equation connecting the tsunami source and the offshore tsunami data via Green’s functions. In addition to the ordinary tsunami source inversion, the two new techniques are incorporated in Marlin for the purpose of obtaining results stably and rapidly. One is an inversion method using the derivative of the offshore pressure waveforms, which could reduce the effect of non-tsunami components involved in the pressure data (Kubota et al., 2018). The other is like a two-step inversion in which the initial tsunami source model (crustal deformation) is estimated from observed data other than tsunami data, and then the source model is improved by inverting an observation equation comprising the difference between the observed pressure data and simulated ones based on the initial model (Tsushima et al, 2014). We use the AQUA CMT solution to initially constrain the extent of the tsunami source rapidly after the earthquake.

Based on the estimated initial tsunami height distribution, Marlin performs a forward tsunami simulation on GPU device. Use of GPU accelerates the tsunami calculation and enables to derive a rough image of coastal tsunami distribution within a few minutes with a 810-m grid topography model. On the other hand, it takes forty minutes to derive a rough image of inundation along the Pacific coast of east Japan using a 90-m grid topography model.

Marlin shows a good performance based on a test using a simulated data for an $M_W$8.2 interplate earthquake. A performance test using the observed data during the 2016 $M_W$7.0 Off Fukushima earthquake suggests that a size of an element source is large for earthquakes with such a relatively small magnitude. Based on this result, we have been updating the system to incorporate with a smaller element source.

Keywords: Real-time tsunami forecast, Automatic inversion system, Tsunami source, S-net, Seafloor pressure data

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