Tsunami simulation method initiated from waveforms observed by ocean bottom pressure sensors for real-time tsunami forecast; Applied for 2011 Tohoku-oki Tsunami

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After tsunami disaster due to the 2011 Tohoku-oki great earthquake, improvement of the tsunami forecast has been an urgent issue in Japan. National Institute of Disaster Prevention is installing a cable network system of earthquake and tsunami observation (S-NET) at the ocean bottom along the Japan and Kurile trench. This cable system includes 125 pressure sensors (tsunami meters) which are separated by 30 km. This system is the most dense observation network system on top of source areas of great underthrust earthquakes in the world.
Real-time tsunami forecast has depended on estimation of earthquake parameters, such as epicenter, depth, and magnitude of earthquakes. Recently, tsunami forecast method has been developed using the estimation of tsunami source from tsunami waveforms observed at the ocean bottom pressure sensors. However, when we have many pressure sensors separated by 30km on top of the source area, we do not need to estimate the tsunami source or earthquake source to compute tsunami. Instead, we can initiate a tsunami simulation from those dense tsunami observed data. We have already presented a method at the 2015 SSJ meeting. Observed tsunami height differences with a time interval at the ocean bottom pressure sensors separated by 30 km were used to estimate tsunami height distribution at a particular time. Tsunami numerical simulation was initiated from tsunami height distribution. We demonstrated that the method worked well for case studies.
In this paper, the above method is improved and applied for the tsunami generated by the 2011 Tohoku-oki great earthquake. Tsunami source model of the 2011 Tohoku-oki great earthquake estimated using observed tsunami waveforms, coseimic deformation observed by GPS and ocean bottom sensors by Gusman et al. (2012) is used in this study. The ocean surface deformation is computed from the source model and used as an initial condition of tsunami simulation. Linear long wave equations are solved by finite difference scheme. A grid size is 1 min. (about 1.8 km). Figure (left) shows the computed tsunami height distribution at 10 minutes after the earthquake. By assuming that this computed tsunami is a real tsunami and observed at ocean bottom sensors, new tsunami simulation is carried out using the above method. The station distribution (each station is separated by 15 min., about 30 km) observed tsunami waveforms which were actually computed from the source model as an experiment is shown in Figure (right) as red dots. Tsunami height distributions are estimated from the above method at 40, 80, and 120 seconds after the origin time of the earthquake. After interpolation of these tsunami height distribution into a 1 minute grid system, the tsunami numerical simulation is carried out using those tsunami height distribution. Tsunami height distribution computed from the source model includes large short wavelength waves which are originally generated near the trench (see Figure). This is one of important characteristics of the 2011 Tohoku-oki tsunami. However, observed points separated by 30 km are too coarse to describe such a short wavelength wave. Therefore, that causes some error in the overall tsunami height distribution. Also, because this method uses the observed height differences with a time interval as data, a resolution of very long wavelength is low. In this paper, we improve the method by applying a special filter to the estimated tsunami height distribution from the observed tsunami waveforms separated by 30km in order to obtain a stable solution. The tsunami height distribution at 10 minutes after the earthquake estimated from the new method is shown in Figure (right). Comparison between Figure (left) and Figure (right) shows that generally the method works well. The

method developed in this paper is effective as a real-time tsunami forecast.

Keywords: Real time tsunami forecast, Tsunami simulation method, The 2011 Tohoku-oki Tsunami