Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SEM37-09 Room:201B Time:May 22 16:45-17:00

2-D tsunami dynamo simulations in the northwest Pacific using the finite element method

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Conductive seawater moving in the geomagnetic main field can cause dynamo effects in the ocean. This effect is well-known as "Oceanic Dynamo Effects (e.g., Sanford, 1971)". In recent years, it has been reported that tsunamis also cause Oceanic Dynamo Effects. Hereafter, we call it as tsunami dynamo effects, and tsunami-induced electromagnetic (EM) field variations were observed mainly by seafloor observations so far (Toh et al., 2011; Suetsugu et al., 2011; Manoj, 2011). In the late 1900s, Oceanic Dynamo Effects were mainly attributed to low frequency oceanic current such as tidal currents. This is the reason why most of the preceding studies on Oceanic Dynamo Effects neglected self-induction effects. Tyler (2005) first derived a useful formulation that can be applied to short-period tsunami dynamo studies, considering the self-induction effects. However, Tyler assumed a completely flat seafloor and an insulator beneath the ocean layer. Now that many tsunami-induced EM field variations can be observed on the seafloor as well as on land, it is important to appreciate the effects of bathymetry and conductivity structures beneath the seafloor on EM variations observed on the seafloor.

In this study, we developed a two-dimensional (2-D) tsunami-dynamo simulation code, using the finite element method (FEM). Our code can include actual bathymetry and arbitrary conductivity structures beneath the seafloor with the help of FEM. Our simulation consists of two steps. In the first step, oceanic flows associated with tsunami propagations are calculated. In the second step, using obtained oceanic flows, the induction equation in terms of the vertical magnetic component is first solved to obtain the remaining EM components.

Our research group succeeded in observing tsunami-induced magnetic fields at our seafloor EM observatory in the North-West Pacific (NWP), at the time of the 2011 off the Tohoku earthquake. In this study, we first reproduced the oceanic flows associated with the tsunami by fitting calculated sea surface elevations to seawater column variation data observed at DART21401 and 21419 operated by NOAA. Second, we calculated tsunami-induced magnetic field variations and compared them with the data observed at NWP. As a result, it was found that magnetic field variations observed at NWP were well reproduced by our simulation, and the 3 nT peak of the magnetic downward component is surely due to the effect of the 2011 tsunami, especially for the first wave. In addition, the 2011 tsunami can be regarded as an almost 2-D phenomenon around NWP. In our recent simulation, a homogeneous conductor of 100 Ohm.m is allocated beneath the seafloor. In the presentation, we will also report simulation results with a 1-D conductivity structure inferred at NWP using long EM time-series accumulated so far as well.

Keywords: tsunami, finite element, conductivity structure, The Tohoku earthquake, time domain, self-induction