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On the tsunami-generated electromagnetic fields: its physical properties and potential for tsunami forecast

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It has been shown, first by seafloor electromagnetic observation (Toh et al., 2011), that tsunamis are associated with weak but significant electromagnetic fields. This is due to the electromotive force (v x F) generated by coupling between particle motions (v) of the conductive seawater and the geomagnetic main field (F). Namely, the particle motions forced by tsunamis generate electric currents in the ocean mostly tangential to tsunami wave fronts as a result of interaction with the weak but ubiquitous Earth's magnetic field. This means that curtain-like electric currents propagate all through the ocean along with tsunamis, which can create secondary magnetic fields observable both on land and at the seafloor.

Recently, we have succeeded in deriving an analytical solution of the tsunami-generated electromagnetic fields for two-dimensional linear dispersive waves. It turned out that the tsunami-generated electromagnetic fields consist of two parts: one resulting from interaction of horizontal particle motions with the downward component of the ambient magnetic field, i.e. the geomagnetic main field and the other from coupling between vertical particle motions of the conductive seawater with the horizontal magnetic component parallel to the direction of tsunami propagation. Furthermore, the latter was found to have larger phase leads (>90deg) with respect to the maximum wave height than the former, although its amplitudes are smaller ($\sim$20% of the former). The relation between the latter and former electromagnetic fields is quite similar to that of P-wave and S-wave in seismology. This also implies that the latter electromagnetic field can also be used for tsunami forecast because it tells us arrival of tsunamis before their actual arrival, and because the latter coupling does not vanish even in the equatorial region where the downward component of the geomagnetic main field is asymptotic to nil.

However, in order to make use of those newly found properties of tsunami-generated electromagnetic fields properly, they should be isolated from other geomagnetic variations such as those of external origin. In addition, our analytical solution is two-dimensional, while the real world is always three-dimensional. It, therefore, needs to be examined/verified by three-dimensional numerical simulation so as to apply the tsunami-generated electromagnetic fields to actual tsunami forecast.

In this paper, we will make a further report on how to achieve sufficient protection against external noises for the tsunami-generated electromagnetic fields as well as a three-dimensional simulation result of the tsunami-generated electromagnetic fields in time domain for the hazardous gigantic tsunami at the time of the M9 Tohoku earthquake in March, 2011.