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Tsunami-induced magnetic fields observed at Chichijima magnetic station of Kakioka magnetic observatory

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Magnetic fields generated by the tsunami from 2011 Tohoku earthquake were observed at the magnetic station on Chichijima (Hamano et al. 2011). The tsunami signal was evident in vertical component of the magnetic field as quasi-periodic signals with periods of about 20 minutes lasting more than several hours. Comparison with the sea level change recorded at Chichijima tide station indicates that the waveforms are very similar in each other and the amplitude of the first wave of about 1.5 nT in magnetic field corresponds to the tsunami height of about 1 m. It is to be noted that the starting time of the magnetic variation is at 6:55 UTC, whereas the arrival time of the sea level change is at 7:15 UTC. This 20 minutes difference can be attributed to the delay of the tsunami signals at the tide station due to the shallow water area surrounding the tide station, whereas the magnetic field sense the electric current system outside the Chichijima, which is induced in the sea water by the motional induction effects due to tsunami flows. Distribution of the induced electric currents calculated from the numerical simulation of the tsunami propagation suggests that the electric currents flowing in the surrounding area extending about 100 km from Chichijima are responsible for the magnetic fields observed at Chichijima (Tatehata and Hamano, 2011).

At Chichijima, many tsunami arrivals have been reported, in which 18 tsunamis are recorded since 2000 by the tide gauge. We examined the tsunami-induced magnetic fields for these tsunami events by comparing 1-second interval geomagnetic field data sets and the tide gauge data sets with 15-seconds interval. The comparison shows that tsunami-induced magnetic fields are evident corresponding to the tsunamis from 7 earthquakes besides the 2011 Tohoku earthquake. These are 2010 Chichijima-kinkai, 2010 Chile, 2009 Iryan-jaya, 2007 and 2006 Kuril islands, 2004 Tokai-oki, and 2003 Tokachi-oki earthquakes. The result suggests that tsunamis with the maximum amplitudes greater than 30 cm in Chichijima tide gauge accompany observable magnetic field variations unless external magnetic field disturbances are too large. The conversion factor from the sea level change to the magnetic field is roughly ˜1 nT/m at Chichijima. Close comparison of the waveforms of the sea level change and the magnetic fields indicates that arrival direction of the tsunamis affect the waveforms of the magnetic field variations. In case the tsunamis arrives from north-east or north-west direction, the waveforms of the first several hours of magnetic field variation resemble with the sea level change and the magnetic field variation starts earlier than the tsunami arrival time recorded at the tide gauge by about a few tens of minutes. On the other hand, waveforms of the magnetic field variations of tsunamis arriving from south or south-east direction, are different from that of the sea level change. This difference may suggests that the electric current system induced by tsunami flows, which is responsible for the magnetic field observed on Chichijima, depends on the arrival direction of the tsunamis.

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Keywords: tsunami, geomagnetic field, motional induction, magnetic observatory, chichijima, Kakioka