

## Investigation of ULF seismo-magnetic phenomena in Kanto, Japan during 2000-2010

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In this study we have conducted an investigation of ULF seismo-magnetic phenomena in Izu and Boso Peninsulas, Japan, based on the data observed from 2000-2010.

First, case studies of major events have been applied. Energy of ULF geomagnetic signals at the frequency around 0.01 Hz has been investigated by wavelet transform analysis. In order to minimize the influences of artificial noises, only the midnight time data (LT 1:00 ~ 4:00) have been utilized. To identify anomalous changes from ionospheric disturbances, the standard station Memabutsu has been chosen as a reference station. (1) Case studies of the 2000 Izu Islands earthquake swarm have indicated that there are unusual geomagnetic energy enhancements in vertical component before and during the earthquake swarm. (2) Case studies of the 2005 Boso M 6.1 earthquake have also shown clear geomagnetic energy enhancements in vertical component before the earthquake. (3) Case studies of the 2002 and 2007 slow slip events have demonstrated that there are geomagnetic energy enhancements in both vertical and horizontal components during the slip events.

Then, to verify and clarify the relation between ULF geomagnetic anomalies and seismicity, statistical studies by superposed epoch analysis (SEA) have been carried out. The results have indicated that before a sizeable earthquake there are clearly higher probabilities of ULF anomalies than after the earthquake: for Seikoshi (SKS) station in Izu, about 20~30 days before, one week and few days before, and one day after the event statistical results of daily counts are significant; for Kiyosumi (KYS) station in Boso around two weeks before, few days before, and one day after the event.

Finally, to find out the detailed waveform of anomalous magnetic signals, waveform analysis has been performed. The results show that there are mainly two kinds of seismo-magnetic signature. (1) Noise-like signals: Compared with the background, the signals exhibit small increases of amplitudes at a wide frequency range. (2) Transient/quasi-rectangular signals: the signals have transient/quasi-rectangular waveforms with amplitudes of several nT ( $\sim$  nT). The noise-like signals usually persist for several days or even a few weeks, and are mainly associated with large earthquakes; the transient/quasi-rectangular signals have durations of few seconds to few ten seconds, and are registered mainly during slow slip events.

Based on the results obtained above, we conclude that: (1) there is a correlation between ULF geomagnetic anomalies and local sizeable earthquakes in Izu and Boso Peninsulas, Japan, and the common period of significant results is few days before and one day after a sizeable earthquake; (2) there are mainly two kinds of seismo-magnetic signature registered in Izu and Boso Peninsulas: noise-like signals and transient/quasi-rectangular signals. The mechanisms of the anomalous geomagnetic signals are still unclear and need further studies.

Keywords: ULF seismo-magnetic phenomena, earthquake, wavelet transform analysis, statistical study, geomagnetic field, superposed epoch analysis (SEA)