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Signal discrimination of ULF geomagnetic field variations with use of interstation method

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1. Introduction

Electromagnetic phenomena preceding large earthquakes have been reported in various frequency range. Ground-based observation of ULF geomagnetic field changes is one of the most promising methods to monitor the seismic and volcanic activities due to the sufficient skin depth. In order to detect earthquake-related ULF magnetic phenomena and clarify the possible physical mechanism(s), network observation using sensitive (geo) magnetic sensors is in operation in Japan.

The observed ULF signals are considered to be superposition of following inputs:

[1] Global change (a several hundreds to thousands km) ; natural global signals such as daily variation of geomagnetic field and magnetic pulsations which are related to solar activities and most intense.

[2] Regional change (a several km to some ten km) ; artificial noises such as those generated by direct current driven trains and factories. Signals associated with seismic or volcanic activity.

[3] Local change (within a few km) ; local signals nearby the magnetometer such as the ground motion, movement of magnetized objects, and inner circuit noises.

In general, the signal associated with such a crustal activity is very weak. Therefore, the problem is how to discriminate earthquake/volcano-related signals from other noises. At first step, we try to eliminate the global geomagnetic changes from observed time series data. In this aim, we adopt the interstation transfer function (ISTF) approach with the wavelet transform.

2. Interstation Transfer Function

ISTF is defined as the response function between two sets of three components of magnetic field data observed at a certain ULF magnetic station and reference station. At the remote reference station, the data must satisfy the following conditions: (1) artificial noise is sufficiently small, (2) global change is highly coherent for the reference and other stations. ISTF has information on the underground electrical structure, which is considered to be constant within the time duration of our concern. So, once we can determine adequate ISTF, we can construct the normal magnetic field variation at the ULF station. The residual between actual and estimated normal variations includes only regional and local signals around the ULF magnetic station.

3. Wavelet Transform

Usually, ISTF is interpreted in Fourier domain. In this study, we adopt wavelet transform in stead of Fourier transform because the former method is superior in case of the data with many transient signals.

The wavelet transform of a discrete sequence is defined as the convolution of the data with a scaled and translated version of the mother wavelet. The Morlet wavelet is used in this study, since it contents with the following conditions: (1) relation between Fourier frequency and wavelet scale is quite simple, (2) reconstruction of original sequence is possible by inverse wavelet transform.

4. Application to Data and Conclusions

The proposed method has been applied to the data observed by the ULF magnetic sensor array at Boso Peninsula, Japan. The intersensor distance is bout 5 km. As a remote reference, the data at Kakioka Geomagnetic Observatory, Japan Meteorological Agency are used. The results shows that the global change has been removed as a whole and signals around the ULF magnetic station are appeared clearly.

In the next step, we try to determine artificial noises and earthquake/volcano-related signals. On the other hand, we must pay attention to the long and short term variations of ISTF. Because the accuracy of the estimated ISTF have influence upon the signal discrimination, the application of the robust estimation should be taken in account in the future.