ULF emissions associated with earthquakes in Kyushu

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Abstract

Spectral analyses have been performed for ULF magnetic data associated with 1997 Kagoshima earthquakes observed at Tarumizu Station. The variations of magnetic field intensity and polarization during the period of local midnight time (00:00-04:00 L.T.) have been investigated and the results suggest that there are anomalies preceding two moderate earthquake (Mj=6.5 and Mj=6.3) in comparison with the results of remote reference data observed at the geomagnetic conjugate point of Darwin. The apparent increase of the vertical component Z has been observed a few weeks before the first earthquake on March 26, 1997. And the earthquake occurred and this situation lasted one week before the second earthquake. Polarization analysis also seems to be powerful to distinguish between signals associated with earthquakes and other signals such as magnetic pulsations. The value of polarization is found to increase about one month before the first earthquake. The intensity of signals associated with the earthquakes seems to be between the mean value and mean + σ value. These observational facts suggest that these activities around two Kagoshima earthquakes seem to be local phenomena, which may suggest seismogenic ULF magnetic anomalies. Also, the causative currents for ULF emissions were estimated.

1. Introduction

Electromagnetic phenomena are recently considered as a promising candidate for the short-term prediction of large earthquakes (e.g. Hayakawa and Fujinawa, 1994; Hayakawa, 1999) and there have been accumulated observational reports in a very wide frequency range. In this paper, we will present results of ULF emissions for big earthquakes occurred at Kagoshima region, Japan, 1997. Two moderate earthquakes occurred at 17h31m L.T. on March 26, 1997, and 14h38m (L.T.) on May 13, 1997, respectively. The Japan Meteorology Agency (JMA) reported that the magnitude of former earthquake was 6.5 and latter one was 6.3 and their depth were less than 20km. Their epicenters were located at the geographic coordinates (32.0N, 130.3E) and (31.9N, 130.3E), respectively. A fluxgate type magnetometer measuring 3 components of geomagnetic fields with 1Hz sampling rate, is in operation at Tarumizu Station (31.48N, 130.72E). The distances between the observatory and epicenters are about 60km. The geographical relationship between the ULF magnetic station and epicenters of earthquakes is shown in Fig.1. The ULF instrument is composed of three ring -core type fluxgate magnetometers (H (NS), D (EW), and Z (vertical) component) and the wave-form data are recorded. In this paper we will report on ULF magnetic phenomena associated with Kagoshima earthquakes.

2. Procedure of Data Analysis

We analyzed data from August 19,1996 to September 30, 1997. The seismic activity is also shown in Fig.1. The active seismic zones are divided into 3 regions, which are Kagoshima, Hyuganada, and Tanegashima regions, respectively. The epicentral distance to Hyuganada and Tanegashima regions are about 100km and the strongest earthquake

in both Hyuganada and Tanegashima regions was Mj=6~7. It is very important to extract subterranean effects from the geomagnetic field data in order to clarify the relationship between earthquakes and ULF magnetic activity. The observed data have been analyzed in a similar manner as reported in Hayakawa et al.(1996).
(1) The data observed in the midnight (L.T. = 0h - 4h) have been used because the artificial disturbance is considered to be much smaller than in the daytime. **(2)** Spectral analysis based on FFT method with 30 minutes interval has been applied to waveforms of three magnetic field components. There are 8 units for one day. **(3)** The mean value and standard deviation σ for obtained frequency spectrum have been calculated over the whole period to estimate the dominant frequency range as seismogeneic ULF emissions. **(4)** In order to distinguish subterranean effects from the phenomena of geomagnetic pulsation more clearly (Hayakawa et al., 1996), variation of spectral density ratio of vertical and horizontal components such as Z/H has been investigated. We call this procedure "polarization" analysis. The average over 8 FFT units in a certain frequency band has been taken as a daily value. **(5)** The data observed at the place far from the epicenter region and at the geomagnetic conjugate point have been analyzed in the same way to discriminate between local and global phenomena.

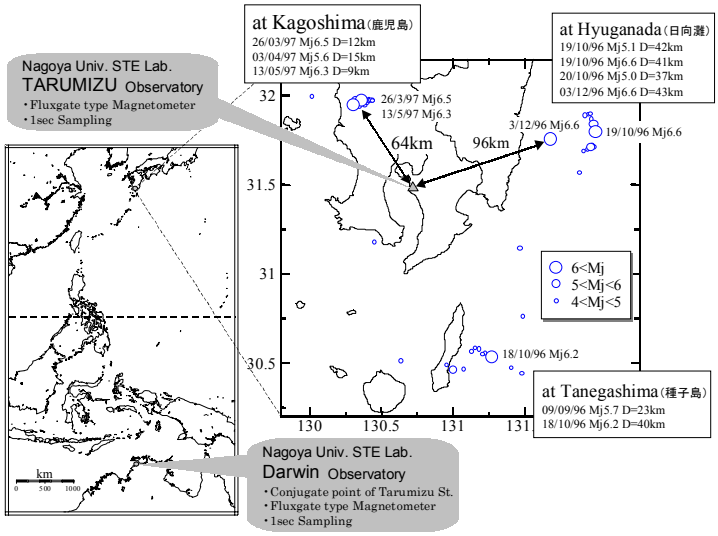

Fig.1 Observations and Earthquakes

3. Observational Results

Fig.2 show the variation of spectral density of vertical component Z. The upper panel indicates the variation at Tarumizu st., the lower panel indicates, that at Darwin. The intensity at frequency between 0.005Hz and 0.03Hz is found to increase in Fig.2. The thin and thick lines in Fig.2 indicate the variation of average values during midnight and their 11 days running mean (5 days before, 5 days after and the day of a quake). The days of two big earthquakes and other earthquakes are indicated by the broken vertical lines with triangle symbols. These are corresponding to hypocenter regions of Kagoshima, Hyuganada, and Tanegashima, respectively. The most important fact of this figure is an obvious enhancement of vertical component around two moderate earthquakes for the running mean variation. Another enhancement around December, 1996 is also recognized, however it is found to be accompanied by the horizontal enhancement. Fig.3 shows the daily variation of polarization at the frequency of 0.01Hz(0.007-0.013Hz). The solid and broken lines correspond to the daily value variation and 11 days running mean as in Fig.2. At first, since we will concentrate our talk on earthquakes on March 26 and May 13. During this period there is found to be no significant earthquakes (Mj>4.5) except Kagoshima region. The polarization is found to be increased at the end of February; that

is, about one month before the first earthquake (Mj=6.5). It then decreased gradually after the earthquake occurred. As for the second earthquake, there is no apparent enhancement such as the first earthquake, however it occurred the decreasing phase of the ratio. At the end of June, the value of ratio seemed to recover to the ordinary values. The similar tendency can be seen in the different frequencies such as 0.02Hz and 0.03Hz. Of course, different detailed aspects are recognized as an activation against the background level. A careful attention should be paid to long-term analyses. Fig.3 shows the data with the duration of nearly one year. Fig. 1 presents the relationship between epicenters (M>4) and the observation site during the analyzed period. The distances between the observation site and Hyuganada region or Tanegashima region are about 100km. Earthquakes with Mj=6.6 and M=6.0 occurred in Hyuganada region on October 19 and December 3, 1996. There were several moderate earthquakes (4<Mj<6) in the Tanegashima region during this period. We notice no significant signals connected with both Hyuganada and Tanegashima earthqukaes. In order to investigate whether the obtained ULF magnetic phenomena is global or local activity, the data observed at Darwin station, Australia which corresponds to the geomagnetic conjugate point (12.40S, 130.90E), have been analyzed as a remote reference data. The same magnetometer system has been installed and operated at the station. Fig. 1 indicates the coordinate system between Kagoshima region and Darwin station. There is no earthquake around the Darwin station during the analyzed period within 500km. It is found that the horizontal variations are quite similar for the stations of Tarumizu and Darwin. On the other hand, the variation of the vertical component around the first earthquake is quite different from each other. At the conjugate point, the similar variation is expected for the global activities because the geomagnetic field line is same. Except this period, the variation between Tarumizu and Darwin looks like similar. We cannot say in detail because of data missing, however it seems that the variation of Darwin station around March 10 and differences of the shape and the slope of onset in the end of February might be informative about this.

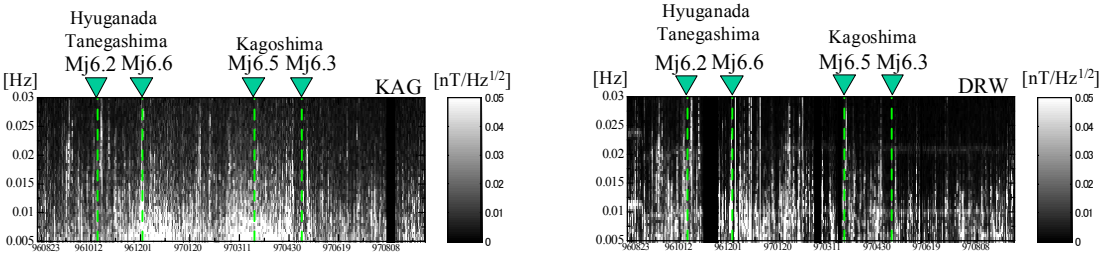

Fig.2 Intensity of Vertical component (Left panel : Tarumizu st., Right panel : Darwin st.)

Now we investigate what intensity of signals contribute to the enhancement of the polarization around the earthquakes in the statistical sense. Fig. 3 plots polarization values Z/G versus time with the use of lower threshold values of mean - σ, mean, and mean + σ versus for each component, where mean and σ indicate the mean value and the standard deviation over one month. The top panel is with the use of mean + σ, middle panel is with use of mean, and the bottom panel with use of mean - σ. It is found from this figure that signals with intensities between mean and mean + σ are significant for seismogenic ULF magnetic phenomena. Also we analyzed narrow frequency band case and wide frequency band with a certain statistical threshold; that is, we use the spectrum beyond mean or mean + σ over the whole data set to calculate polarization. Results with the use of narrow band seem to indicate the frequency dependence of penetration or propagation of seismogenic ULF magnetic phenomena. Tarumizu station seems to be sensitive for earthquakes occurred in Tanegashima region at the lower frequency

(0.01Hz). For wide band case, spectra at activated frequencies are used to make computations and as a result the polarization data is found to become very sparse and obtained results seem to be highly correlated with Kagoshima earthquakes.

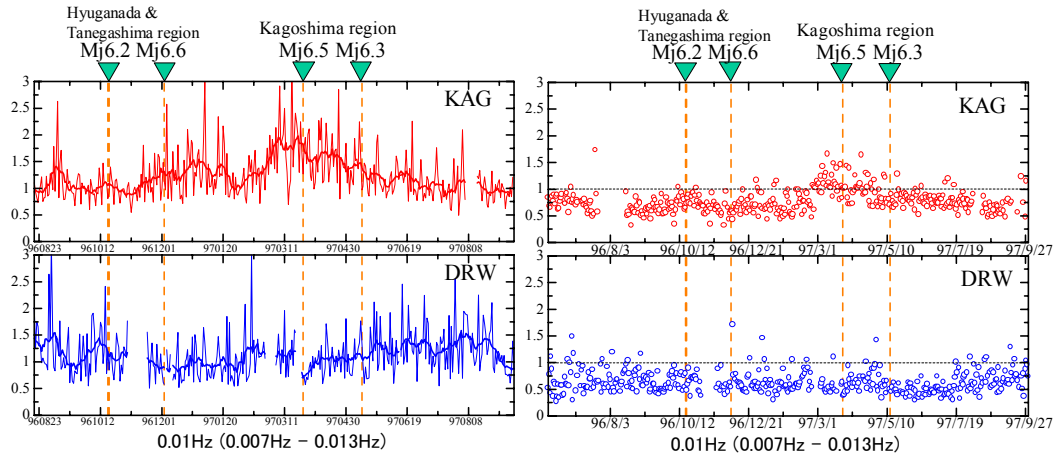

Fig.3. Variation of polarization (Z/G)
(Upper panel : Tarumizu st., Lower panel : Darwin st; Left : Daily Value, Right : using threshold)

4. Concluding Remarks

Spectral analysis has been performed for ULF magnetic data observed at Tarumizu station. The variations of spectral density and polarization ratio have been investigated during local midnight time (00:00-04:00L.T.) and it is suggested that there are the anomalies preceding two Kagoshima earthquakes. The use of the remote reference data observed at the geomagnetic conjugate point of Darwin is found to be very effective to eliminate the global effects. The apparent increase of the vertical component Z has been observed a few weeks before the first earthquake on March 26, 1997. The increase is found to be about 1pT. And the earthquake occurred and this situation lasted for one week before the second earthquake. Polarization analysis also seems to be powerful in distinguishing between signals associated with earthquakes and other signals such as magnetic pulsation. The values of polarization is found to increase about one month before the first earthquake. The earthquake occurred at the stage of decreasing of polarization values. The intensity of signals associated with the earthquakes seems to be between mean value and mean + σ value. It is very important in order to eliminate global effects from observed ULF data when monitoring the earth crust activity. The usage of data from multiple stations, especially the remote reference site and the magnetic conjugate sites are very intrinsic. But the data observed at stations distributed near the epicenter are also informative on spatial correlation of ULF anomaly associated with earthquakes. Furthermore they might also provide us a key for propagation effects, which seem to be strongly connected with the underground structure; that is conductivity. Of course, it is very significant to remove artificial effects in Japan. These are our future problems.

Reference

[1] Hayakawa, M. and Y. Fujinawa, Editors, “Electromagnetic Phenomena Related to Earthquake Prediction”, Terra Scientific Pub. Comp., Tokyo, 1994.

[2] Hayakawa, M., Editor, “Atomospheric and Ionospheric Electromagnetic Phenomena Associated with Earthquakes”, Terra Scientific pub. Comp., Tokyo, 1999.