Statistical analysis of the ULF magnetic field data during earthquake swarm

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Abstract

In this paper, we intend to extract the statistical properties of seismo-ULF signatures and to address their physical mechanism. The statistical properties (i.e. cumulative probability distribution function) are calculated by using each half-hour period in a number of frequency bands ranging from 1mHz to 2Hz for the time period of about three years around Izu Island earthquake swarm. The statistical analysis has been performed during the year of the swarm, one year before and after the swarm. As a result, the remarkable change in the shape of cumulative probability distribution starts about one month before the swarm particularly at the frequency band of 6.7mHz to 0.01Hz. After the swarm, the statistical distribution returns to the original distribution. For other two years (before and after the swarm), the cumulative probability distribution does not show systematic dependence as is seen for the year of the swarm, which indicates that the observed changes of the distribution is due to the swarm.

1. Introduction

The ULF magnetic anomalies in relation with seismic activities are one of the most promising methods which one can observe near the epicenter because of its large wave length in the ULF frequency range. There have been many reports on ULF magnetic anomalies in relation with local large seismic activities. Most previous works are based on the physical principle such as fractal and polarization analyses [1-2], whilst there are only few works based on the statistical principle [3]. In this paper we pay attention on the statistical distribution of the ULF magnetic field observed near the epicenters of the earthquake swarm (<100km) and intend to derive the anomalous changes in relation with the seismic activities.

2. Observations

The magnetic time series of three orthogonal components consisting of two horizontal and one vertical magnetic fields were continuously recorded by induction magnetometers with a sampling rate of 10Hz around the year of the Isu Island earthquake swarm in Seikoshi field station in Izu peninsula Japan. We have used this magnetic field data for three consecutive years starting from one year before the swarm.
Figure 1 illustrates the relative locations of Seiskoshi field site and major three seismic activities (M>6.0) during Izu Island earthquake swarm in 2001. All three earthquakes occurred within 90km from the field site and had seismic centers shallower than 15 km (see Table 1).

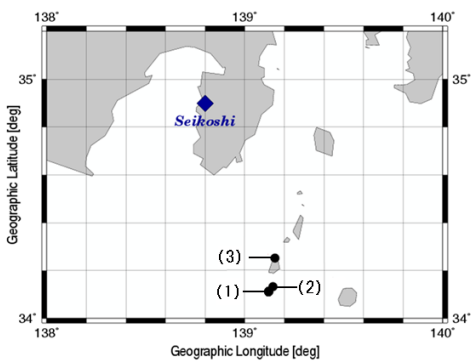

Figure 1. Locations of epicenters and observation site.

Table 1. List of major earthquakes during Izu Island earthquake swarm.

	Date	Magnitude	Dist.	Depth
(1)	2000/07/01	6.4	80km	15km
(2)	2000/07/09	6.1	81km	14km
(3)	2000/07/15	6.3	59km	5km

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3. Method of analysis

We perform the statistical analysis for three years including the swarm as follows. We compute the power spectral density (PSD) by conventional Fast Fourier Transformation for each 30-minute time series. The calculated PSD are divided into 10 frequency bands ranging from 1.7mHz to 2Hz. These 10 frequency bands starting from the lowest frequency band contains the average intensity of PSD within the band are so-called MP1 to MP10. In this paper we focus on MP4 (6.7mHz to 0.01Hz) because the magnetic anomaly has been found to be most significant in this frequency band. Moreover the data from the night time period (0LT to 4LT) have been used in the analysis to minimize local industrial noise.

The cumulative probability distribution (CPD) function based on the temporal dependence of MP4 is calculated for four different representative time periods relative to the earthquake swarm, namely before the swarm, just before the swarm, during the swarm and after the swarm. For the years before and after the swarm, same time period of the year are used to compute the CPD to compare the statistical characteristics between different years and to suppress the effect of the seasonal dependence if any. Each the period contains the data around 30days.

4. Results

Figures 2 to 4 show the CPDs for one of the magnetic field components (north-south component) for 1999, 2000 (year of the swarm) and 2001 respectively. Each figure contains four different curves corresponding to four different time period of the year relative to the swarm occurrence defined in the section 3. As is seen from figure3, curves above 80% of the probability have been found to increase significantly by about 3.4 dB for the time periods from before the swarm to during the swarm. On the contrary other two years do not show similar tendencies as is seen in the year of the swarm.

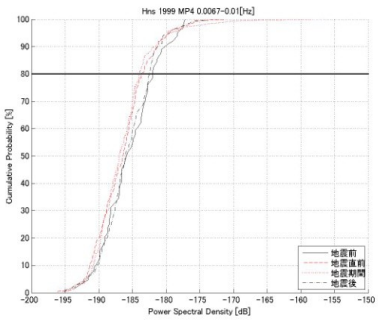

Figure 2. Cumulative probability distribution of the north-south magnetic field at Seikoshi for 1999.

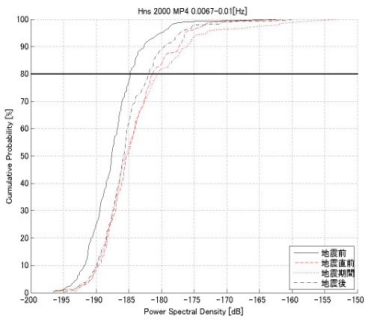

Figure 3. Cumulative probability distribution of the north-south magnetic field at Seikoshi for 2000.

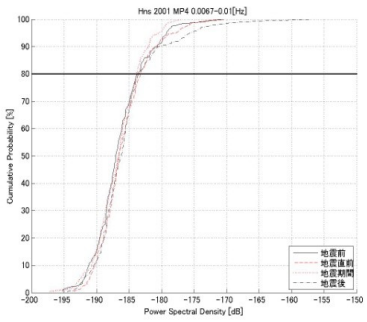

Figure 4. Cumulative probability distribution of the north-south magnetic field at Seikoshi for 2001.

5. Conclusion

The cumulative probability distributions for the ULF magnetic field have been calculated for three years around the earthquake swarm in Japan. The cumulative probability only for the year of swarm has a particular tendency such as significant increase of the magnetic intensity above 80% probability level starting before the swarm indicative of the statistical nature of the ULF magnetic anomaly.

References

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