Waveform characteristics of deep low-frequency earthquake and tremor base on the Average Dissipation Spectrum

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To construct a source model of deep low-frequency earthquakes, deep low-frequency tremor, and volcanic tremors, it is important that we obtain as much information from the waveforms as possible. Takeo et al. (2006) developed a new method to represent the characteristics of the coda parts of deep low-frequency earthquakes employing the theory of KM2O-Langevin equations, and proposed a new algorithm to estimate an averaged KM2O-Langevin matrix function for multiple local time series excited by the same source dynamics. They also proposed a new concept of Average Dissipation Spectrum, which is very useful for revealing characteristics of waveforms under noisy environment. Here, we summarize the waveform characteristics of deep low-frequency earthquakes (DLF) and tremors (LFT) based on the Average Dissipation Spectrum.

The new averaging algorithm for the KM2O-Langevin matrix function was applied in the analysis of DLF (M=1.0), which occurred in Akita prefecture on 11 July 2001. We estimate the common characteristics of this DLF successfully by using the Average Dissipation Spectrum, which is made up of typical frequencies and attenuation factors. The elements of (1.5Hz, -0.3) and (3.25Hz, -0.45) are common factors indicating the characteristics of the source dynamics of the Akita DLF. We also succeeded in separating the characteristics of the source vibration system and the source excitation process into the averaged dissipation term and the fluctuation term, respectively. The time series of the excitation process indicates the necessity of second source, lying about 1.5 km, N56E of the hypocenter.

On 2002 March 11, we recognized swarm activity of DLF in Ashio region, central Japan. More than 140 DLF events were observed within only 4 hours. We obtain high-resolution relative hypocenters of similar earthquakes (22 events) by cross-spectral analysis method and double-difference earthquake location algorithm. Relocated DLF hypocenters did not show remarkable migration. The distribution of DLF hypocenters looks like a horizontal disk (with radius 700 m and thickness 500 m). The elements of (5.7Hz, -2.6) are common factors indicating the characteristics of the source dynamics of the Nikko DLF. The two sources of the Akita DLF separates about 1.5 km, whose span is about double-wide the distribution of relocated hypocenters of the Nikko DLF. On the other hand, the typical frequency of the Nikko DLF is about two and four times higher than those of the Akita DLF. This suggests that the special extent of source region is related with the typical frequency and attenuation factor of DLF.

Using the Average Dissipation Spectrum, we could obtain the characteristic frequency structure of LFT which occurred at western part of Shikoku in 2002 and 2003. Several Discrete peaks existed in the frequency range 1-5Hz of the LFT, at intervals of about 0.5Hz with the attenuation factors between -0.15 and -0.20.

The major parts of the coda waves of DLF satisfy the stationary property, and the causality values for the linear and odd-degree non-linear transformations are relatively higher than those for the even-degree non-linear transformations. This quantitative property is common among all DLF, but is quite different from those of LFT. The major parts of LFT satisfy the stationary property, and the causality values for the odd-degree non-linear transformations are almost same as those for the even-degree non-linear transformations. A mathematical structure producing the difference in causality values has been partially revealed, but its physical interpretation has not been made now. To make this clear, we need to investigate the nonlinear property of the DLF and LFT waveforms.