Analysis of the vibration structure of a hypocenter using a singular value decomposition method

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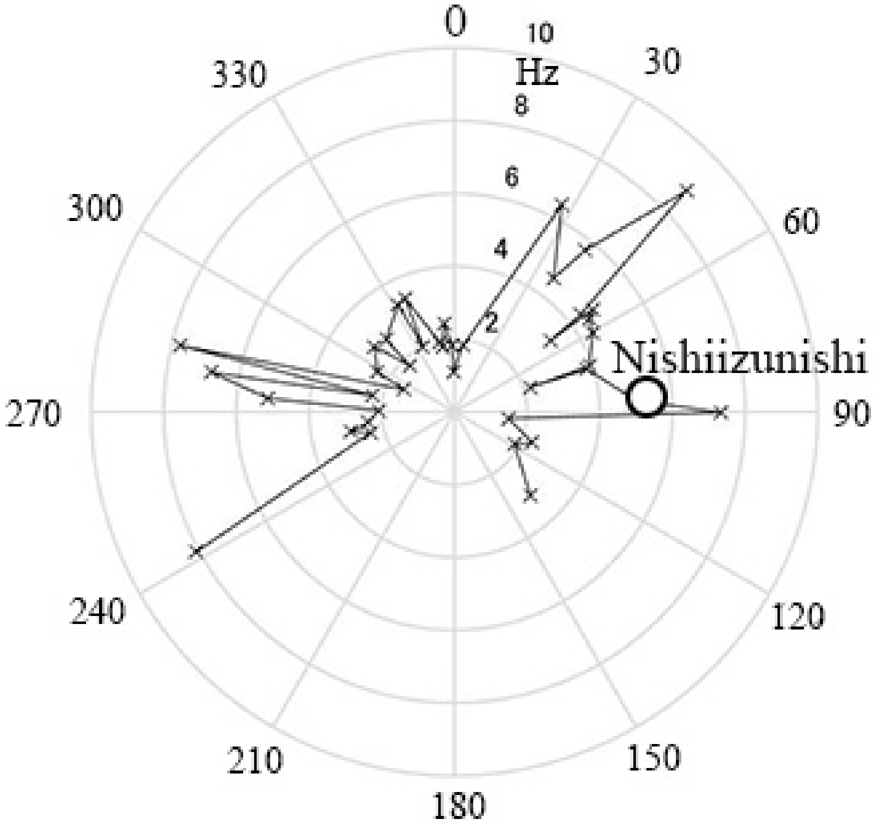
The vibration structure of a hypocenter are analyzed using a singular spectrum analysis. Specific radiation characteristics related to a hypocenter structure from the results become apparent. The specific radiation characteristics are confirmed for five earthquakes including Kumamoto earthquake. The analysis process is carried out in two stages of the acquisition of equivalent hypocenter vibrations using a time reversal method and the singular spectrum analysis of acquired hypocenter vibration. First, a P wave is cut out from a seismic wave received at an observation station surrounding a hypocenter, and the signal obtained by inverting the time axis of the signal is radiated on a propagation simulation to obtain a pulse formed at the hypocenter position.
At this time, a propagation environment is changed to obtain the condition that the amplitude of a pulse becomes maximum, and the condition is set as the optimum propagation environment. Next, a time reversal pulse (TRP) that is, equivalent hypocenter vibration obtained on the best propagation environment, is analyzed. Since the TRP is a complex oscillating nonlinear signal consisting of multiple frequencies, it is analyzed using a singular value decomposition method. The matrix of time interval dt that consists of n points that consists of the TRP corresponding to an observation station is created. Next, the second matrix that delayed the entire matrix by dt is created. In addition, the third matrix that delayed second matrix by dt is created. This process is repeated m times to obtain a matrix of m×n. The final matrix is an orbital matrix **X**. Singular value W is obtained solving the following expression, $\mathbf{X}=\mathbf{UWV}^T$. Here, **U** and **V** are orthonormal matrices satisfying the equation, $\mathbf{U}^T\mathbf{U} = \mathbf{V}^T\mathbf{V} = \mathbf{E}$ (**E**: unit matrix). The largest singular value in the W is assumed to be a main component. Here, the earthquake of M6.5 that occurred in the southern part of Suruga Bay on August 11, 2009 was analyzed. First, a P wave is cut out from a signal received at the observation station located around Suruga Bay, and the time axis of the signal is reversed. The reversed signal are radiated from the observation station on the propagation simulation and the pulse (TRP) at the hypocenter location is formed. The singular value decomposition method is applied to the TRP to calculate the components constituting the pulse, and the component with the largest amplitude among them is obtained. The determined main component is a gently fluctuating pulse consisting of almost a single frequency. Likewise, the singular value decomposition method is applied to the TRP corresponding to each observation station, and the component with the largest amplitude is extracted. The frequencies of these components are shown in the figure as a distribution to the azimuth of observation stations centered on the hypocenter. Obviously, the radiation frequency from the hypocenter shows a directivity greatly different depending on the azimuth. That is, the frequency from Susono with the azimuth of 27.4° to Kawadu with the azimuth of 97.0° is high.
These radiation patterns are considered to be related to the vibration mode of active faults.

Keywords: Hypocenter vibration, Time reversal method, Singular value decomposision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