The Coherency Estimate Method of Short Span Array Wave Data which uses Complex Wavelet Transform

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Introduction

Seismic observation with a short-span array has been carried out in volcano areas and earthquake swarm areas, in order to detect scattered bodies and sources of volcanic earthquakes. The semblance technique is one of the coherency estimate methods, and has been conveniently used in those observation's data analysis. Briefly, it determines the propagation directions and apparent propagation speeds of spatially coherent components in the array wave data. Calculation in this technique is easy to be performed and to be understood. But the relation of time window width versus frequency is not still determined, in this technique. Moreover, recognition of each signal element from wave train, composed of many signals, is generally hard to work out (Kuwahara et al.,1990). Standardization of the time window versus frequency relation and separation of the compound signals are helpful for stability and to get high resolution of the analytical result.

Recently, a wavelet transform has been used in a time series analysis. It decomposes time series into time-frequency domains. In the scope of the time series, the transform is able to be understood as a technique to dissolve the wave data into a group of wavelets and to interpret it. Briefly, wavelet transform has possibility to standardize the time-frequency relation and to decompose the compound signals.

In this study, we adopt these features of wavelet transform to develop a new analysis method, which enables us to evaluate wave's coherency, conveniently. That is to say, the method leads us to high-resolution determination of propagation directions of apparent propagation speeds of spatially coherent components, involved in the array wave data.

Method

A value that represents coherency of array wave is calculated from the distribution of the phase angles which are calculated from complex wavelet transform. The calculation procedure is in the followings:.

1. Transform the time series of array waves into the time-frequency domain
2. Extract the phase angle data from the time-frequency domain data.
3. Calculate the Akaike information criterion(AIC) from the phase angle distribution.
4. Forwardly calculate each of the imaginable propagation directions and apparent propagation speeds.
5. Choose a set of the propagation direction and apparent propagation speeds which looks most reasonable in reference to the AIC result.

The phase angle in the time-frequency domain can be obtained from the complex wavelet transform of time series. If array waves cohere, the phase angles of array waves are expected to gather about a value consequently suggesting that their distribution resembles the Gauss distribution. In other case, the phase angle distribution is expected to be uniform over a wide range. Now, let us assume the coherent wave's phase angle distribution that follows the Gauss distribution, and calculate the AIC of this. Then, the result of the AIC calculation will indicate the model's adequacy. This value, representing the coherency (AIC value), will be helpful to choose a reasonable set of propagation direction and apparent propagation speeds.

Property of this method

This method has following properties

(1) Ability of setting up a time-frequency window by a wavelet function

You can easily set up the time-frequency window, by choosing a wavelet function and by determining its parameters.

(2) Extraction of coherent signals from the wave data

In a calculation of the AIC value representing the coherency, it is used the phase angle of individual time-frequency domain that is divided into by the wave data. Accordingly, the coherent time-frequency domain can be definite.