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Focal Mechanisms estimation of Earthquakes Occurred on October 19, 2022, Kyoto Nishiyama Fault Zone, with Distributed Acoustic Sensing

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Distributed-Acoustic-Sensing (DAS) is a new technology of seismology, which observes the axial strain or strain-rate of optic-fiber cable by analyzing the phase of backscattered light passing through it. However, obtaining the seismic information from DAS records is challenging, because DAS measures only the component in the direction along the cable.

For example, when we determine the focal mechanism with three-component seismograms, we see the polarity of the far-field term of the P-wave, denoted as u^P.

The partial derivative of u^P with respect to the axial direction is represented as

$$\varepsilon_i^P = \frac{\partial u_i^P}{\partial x_i} = \frac{\partial u^P}{\partial x}\cos\theta,$$

where θ is the angle between the direction of the P-wave and cable. The polarity of ε highly depends on θ, so we must consider how to deal with θ.

Here, to estimate the focal mechanism, we utilized cross-correlation and deconvolution techniques between neighboring earthquakes. If we assume that neighboring events occurred at the same location, then the path will be same and θ will also be same. From this assumption, we can remove the sign of $\cos\theta$ by utilizing cross-correlation as follows,

$$\varepsilon_i^{P1}\cdot\varepsilon_i^{P2} = \frac{\partial u^{P1}}{\partial x}\frac{\partial u^{P2}}{\partial x}\cos^2\theta,$$

and we obtain the polarity of P-wave from DAS records.

However, waveforms recorded along the cable are likely to be deformed by path and site effect due to its unknown coupling conditions. To remove these effects, we utilized deconvolution between neighboring events.

The Seismic waveform is represented as

$$\hat{u}(\omega) = \hat{M}\cdot\hat{P}\cdot\hat{S}$$

in frequency domain, where $\hat{M}$, $\hat{P}$, and $\hat{S}$ represent source, path, and site, respectively. Waveforms from earthquakes occurred in same location should have the same properties of path and site, so that we obtain the difference of source between two neighboring events just by deconvoluting between them. We can also remove the effect of θ since deconvolution is a dividing process, while it is computationally unstable compared to cross-correlation due to this nature.

Four earthquakes of M2.2, M2.3, M3.2 and M3.4 in Kyoto Nishiyama Fault Zone on October 19, 2022, were recorded by the DAS along Route 9. We utilized cross-correlation and deconvolution on each event pairs. Figure 1 shows one example of such an event pair. We can see the polarity-flip around Channel No. 4000.

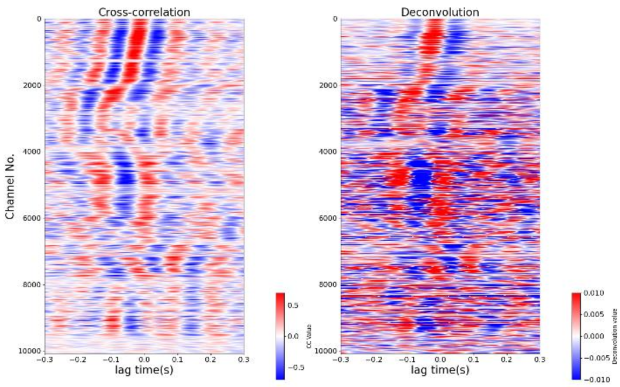

Figure 1. Cross-correlation (left) and deconvolution (right) by M3.2 and M3.4

We will show the results of cross-correlation and deconvolution on each event pair and discuss these results.