An attempt of using Green functions based on a three-dimensional structure in waveform inversion of the seismic source process

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In waveform inversion of the seismic source processes by using the seismograms of local stations, the Green functions for synthetic waveforms are often calculated assuming a one-dimensional structure. And it is often difficult to obtain reasonable results in the case of using far stations seismograms such as inversion for earthquakes off shore by using seismic records in land, because the waveforms are greatly affected by the structure inhomogeneity in the long propagation.
So I attempt to obtain reasonable focal area with Green functions calculated from a three-dimensional structure at far stations.

1. Method
(1) Green function
The fault plane was set as a plane which passed the hypocenter and had the equivalent dip with the CMT. The source grids were evenly placed on that. Then, Green function between each grid and station used in inversion was calculated. To caluculate the Green functions I used OpenSWPC(Maeda *et al.*, 2017) with the reciprocity mode. They were obtained as the convolution of the spatial derivatives of Green tensor with the source time function, so I used a source time functiuon with enough short duration compared to the period band used in inversion. The Japan Integrated Velocity Structure Model (JIVSM) (Koketsu *et al.*, 2012) was used in that caluculation.
For comparison, I also caluculated Green functions from one-dimensional structure. They were calculated by the discrete wavenumber method (Bouchon, 1981) using reflection-transmission matrices (Kennett and Kerry, 1979). The anelasticity effect was included by the use of complex velocity (Takeo, 1985). The one-dimensional structure did not include seawater and topography.

(2) Inversion
Waveform inversion was carried out under the conditions that source rupture propagated from the hypocenter within a rupture velocity and the slip direction at each grid was within ±45 degree range from the equivalent slip angle with the CMT. I used the linear multiple time window inversion method with constraints on the smoothness of the spatiotemporal slip distribution (e.g., Ide *et al.*, 1996). The smoothness parameter was selected to minimize ABIC (Fukahata *et al.*, 2003). The time of initial motion of each Green function from the hypocenter grid were read and the initial motion time was adjusted to first arrival time at each station.

2. Analysis
I applied the method to the earthquake off Miyagi prefecture(M_J6.8) on May 1, 2021. It was evaluated that this event was occurred at the boundary between the Pacific and the continental plates (Earthquake Research Committee, 2021). I carried out inversion in two cases . The "Case 1" was in the use of 13 stations of K-NET and KiK-net which were relatively close to the epicenter (within about 100 km). The "Case 2" was in the use of 10 stations of JMA seismic network (accelerometers or broadband strong-motion seismometers) which were relatively far from the epicenter (main range: 100-200 km). I used waveform converted to velocity and filterd between 0.05 and 0.2 Hz.
When using one-dimensional structure, I tested two different strucutures. One was made from JIVSM data

near the epicenter. Another was the structure which Muto *et al.*(2014) used by reference to Matsubara and Obara(2011).

3. Result
In "Case 1", the rupture area propagates to the upper part toward the north of the hypocenter in both results using the one-dimensional structure and using the three-dimensional structure, then all results were similar.
In "Case 2", the rupture area in the result using the one-dimensional structure was dispersed, so it was not reasonable. But in the result using the three-dimensional structure, the rupture area was similar to ones in "Case 1".
For this event, it was able to obtain the reasonable source process from far station records by reflecting the three-dimensional structure to waveform inversion.

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