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Effect of various factors on the estimation of source process by the waveform inversion of teleseismic body waves

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In this study, we perform a test for investigating effect of various factors on the estimation of source process by the waveform inversion of teleseismic body waves. The test is constructed from four steps. First, we assume a slip distribution model. Second, synthetic waveforms at assumed stations are calculated based on the assumed model. Third, using the calculated waveforms as observed waveforms, we conduct waveform inversions in various analysis conditions. Fourth, we compare the obtained slip distribution with the assumed model in each condition.

We assume 24 stations with an equal azimuth interval of 15 deg and a common epicentral distance of 90 deg. P-wave part with a time length of 85s of the up-down component at each station is used for the waveform inversion.

Assuming a down-dip extension type earthquake in the upper plane of the double seismic zone in the Pacific slab beneath Northeastern Japan, we adopt two types of the fault planes: low-angle thrust fault plane and high-angle thrust fault plane. Mechanism of the former is (strike, dip, rake) = (0deg, 20deg, 90deg) and that of the latter is (strike, dip, rake) = (180deg, 70deg, 90deg). The hypocenter depth is assumed to be 70km.

The assumed fault plane is 36km x 24km, divided into 4km x 4km subfaults. The assumed slip distribution is composed of two large-slip areas. One large-slip area has a slip amount of 2.5m over an area of 12km x 8km near the hypocenter. Another has a slip amount of 2.5m over an area of 12km x 12km at about 20km southwest of the hypocenter. A Slip amount in the back ground area is assumed to be zero.

The waveform inversion is done using multiple time window analysis. By using a nonnegative constraint, the rake angle of the slip vector of each subfault is allowed to vary within the central angle +/- 45 deg. A spatial and temporal smoothing constraint is used. The value of smoothing strength parameter is fixed in all the inversions. The values of other source parameters (e.g. first time window velocity) are also fixed.

First, effect of using depth phase is checked by comparing the two cases; one case where only direct waves are used for the inversion, and the other where both of direct waves and depth phases are used.

The assumed model is recovered fairly well in the latter case. In contrast, it is not recovered well in the former case. This result is seen for both of the two types of the fault plane. Since travel times of depth phases are sensitive to source depth, use of depth phases is interpreted to improve the resolution in depth direction. Additionally, recovery of the slip distribution in the case of the high-angle fault plane is better than in the case of the low-angle fault plane. Since the depth difference between adjacent subfaults along a dip direction in the case of the low-angle fault plane is smaller than in the case of the high-angle fault plane, it becomes difficult to distinguish depth phases from adjacent subfaults on the time axis in the case of the low-angle fault plane.

Next, effect of station distribution related to the directivity on the estimation of the source model is checked. The 24 stations are divided into four groups according to the azimuth; 45deg-135deg (group A), 135deg-225deg (group B), 225deg-315deg (group C) and 315deg-45deg (group D). And we conduct a waveform inversion for each station group. Group B is in the direction of forward directivity and group D is in the direction of backward directivity.

Recovery of slip distribution in the case of using group B is not as good as for the case of using other groups. This result is seen for both of the two types of the fault plane. Since the difference between travel times from adjacent subfaults is small at the stations in the direction of forward directivity, it becomes difficult to distinguish the waves from the adjacent subfaults.

Acknowledgments: We used the program of Kikuchi and Kanamori (1982) for calculating the Green functions of telesesimic body waves.

Keywords: waveform inversion, teleseismic body wave, depth phase, directivity