Potency Backprojection

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The backprojection (BP) method has been used as a tool to image the rupture propagations of the M8–9 megathrust earthquakes since its successful application to the Mw 9.1 2004 Sumatra-Andaman earthquake. The BP method back-projects waveforms onto a point of a source area by stacking them with theoretical travel time shifts between the point and the stations. The hybrid backprojection (HBP) method, an alternative BP technique, resolves a spatiotemporal distribution of waveform-radiation sources by stacking cross-correlation functions of the observed waveforms and theoretically calculated Green’s functions. As the Green’s function contains information of the direct P-phase as well as the later phases (pP and sP phases), the HBP method enhances the depth-resolution of the image and mitigates the dummy-imaging of the later phases, which had been the shortcomings of the conventional BP method. Both methods are able to track high-frequency (HF) radiation sources, which are hard to be resolved with the waveform inversion method. The HF waves are radiated when rupture velocity and/or slip rate abruptly change, and contain rich information of a heterogeneous rupture evolution. Thus, an integrated analysis with the BP/HBP method and the waveform inversion provides us fruitful information to understand the rupture process of a megathrust/large earthquake.

The intensity at a point of the BP/HBP image represents how much wave radiated from the point accounts for the observed waveforms. Since the amplitude of the Green’s function associated with unit slip-rate increases with depth as the rigidity increases with depth, the intensity of the BP/HBP image inherently has a depth dependence. To make a direct comparison of the BP/HBP image with a slip distribution inferred from the waveform inversion, and discuss the rupture properties of the fault, it should be required the BP/HBP image to represent the slip-rate distribution that corresponds to the potency rate density distribution.

Here we propose new formulations of the BP/HBP methods, which image the potency rate density distribution by refining the normalizing factors in the conventional formulations. For the BP method, the observed waveform, that is shifted with the relative travel time, is normalized with the maximum amplitude of P-phase of the theoretically calculated Green’s function. For the HBP method, we normalize the cross-correlation function of the observed waveform and the Green’s function with the squared-sum of the Green’s function. The normalized waveforms and the cross-correlation functions are then stacked for all the stations to enhance the signal to noise ratio, and the back-projected image now represents the potency rate density distribution.

We tested the new formulations against synthetic waveforms and the real data of the Mw 8.3 2015 Illapel Chile earthquake. We back-projected the synthetic waveforms originated from randomly distributed synthetic source points possessing a uniform potency. The resulting image intensity at the shallow parts of the fault was increased compared to that from the conventional formulations, reproducing the potency distribution of the input model. The intensity, however, were still weak at the very shallow parts, where the relative travel time between the P-phase and the later phases are very close. We also applied the new formulations to the real data, and found that the intensity of the image at shallower than 25 km depth was also slightly increased, compared to that from the conventional formulations.

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