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Introduction of uncertainty of Green's function into waveform inversion for seismic source processes

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In principle, we can never know the true Green's function, which is a major error source in seismic waveform inversion. So far, many studies have devoted their efforts to obtain a Green's function as precise as possible. In the present study, we propose a new strategy to cope with this problem. That is to say, we introduced uncertainty of Green's function into waveform inversion analyses. Due to the propagation law of errors, the uncertainty of Green's function results in a data covariance matrix with significant off-diagonal components, which naturally reduce the weight of observed data in later phases. Because the data covariance matrix depends on the model parameters that express slip distribution, the inverse problem to be solved becomes non-linear. Applying the developed inverse method to the teleseismic P-wave data of the 2006 Java, Indonesia tsunami earthquake, we obtained a reasonable slip distribution and moment rate function without the non-negative slip constraint. The solution was independent of the initial condition of the model parameters. If we neglect the modeling errors due to Green's function as in the conventional formulation, the total slip distribution is much rougher with significant opposite slip components, whereas the moment rate function is much smoother. If we use a stronger smoothing constraint, more plausible slip distribution can be obtained, but then the moment rate function becomes even smoother. By comparing the observed waveforms with the synthetic waveforms, we found that high frequency components were well reproduced only by the new formulation. The modeling error is essentially important in waveform inversion analyses, although they have been commonly neglected.

Keywords: Seismic Source Process, Waveform Inversion, Uncertainty of Green's function, Modeling error, Tsunami Earthquake