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Proper selection of least squares parameters in tsunami waveform inversion through computational intelligence

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Nature-inspired computational methodologies have been successfully applied to many geophysical optimization problems. One of the advantages of such methods is the ability to avoid local optimum solutions, which is something classical methods fail to do. This is because the methods require no derivative information and thus the search is not restricted by the local gradient of the objective function. This feature is of importance in real world applications, where the optimization problems are often characterized by irregular error surfaces that are sometimes non-differentiable. In the standard tsunami waveform inversion based on the Green's function superposition, the linear assumption allows model parameters to be determined straightforwardly using least squares. Therefore, the use of a more advanced method is unnecessary, unless a different design parameter is introduced leading towards a better solution. To that end, we proposed a utilization of computational intelligence in the tsunami waveform inversion using distinct design parameters.

In this study, a tsunami waveform inversion without the fault model assumption is used to test our proposed method. We develop an optimization method based on a genetic algorithm that further enhanced by a pattern search method to find optimal model parameters for the least squares inversion, which mainly dependent on the spatial distribution. Here, we do not use the method for directly estimating the unknown parameters formulated in the least squares inversion. In addition, we apply the same algorithm to determine the water movement initiation time at specified locations inside the inverse region or tsunami source-influenced area. This is applicable to cases where the transient deformation is not negligible. The results suggest that the method not only leads to better accuracy, but also increases the ability to reveal the underlying physics associated with the tsunami generation process. The method has been applied to both artificial and real event of the 2011 Tohoku-Oki tsunami.

Keywords: Tsunami waveform inversion, Computational intelligence, 2011 Tohoku-Oki tsunami