An improvement of a time dependent inversion method based on GPS displacement time series to analyze the aseismic slip evolutions

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1. Introduction

The displacement time series that is estimated from Global Positioning System (GPS) continuous observation data have been taking important role to reveal the slip and the slip deficit distributions on some faults and plate interfaces. Especially, many studies applied the time dependent inversion methods to the time series data in order to survey the spatio-temporal evolutions of postseismic slip distribution and to accumulate the knowledge about frictional properties and partitioning of asperities and non-asperities.

Time dependent inversion methods are generally categorized into two methods. First one is typified by the Network Inversion Filter (NIF) developed by Segall and Matthews (1997). NIF is based on state space model and utilizes Kalman filter to solve the model. The flagship of the other method is devised by Yagi and Kikuchi (2004). In their method, temporal evolution of slip or slip deficit is expressed by the summation of the basis functions whose shape with respect to the temporal domain need to be predetermined. We improved the time dependent inversion method of the latter one.

2. Procedure

As described above, the original method requires prior determination of the length of the time step and shape of the temporal basis function. Because of this inflexibility, it is difficult to estimate accurate slip distribution when the slip rate abruptly changes. We may overcome this difficulty by shortening of the time step, however, it must require tremendous calculation cost, and the optimality of the solution is not guaranteed when we configure too short interval of the time steps.

Thus, we introduced a function I(t) to control the division of temporal domain that is able to be optimized by Akaike's Bayesian Criterion (ABIC). I(t) is defined as follows: I(t_j)=1 when t_j and t_{j+1} belong same time interval for that one slip rate or slip deficit is estimated for one grid point on the fault or plate boundary, and I(t_j)=0 otherwise, where displacements are observed at t_1, t_2, ..., t_j,...,t_J. Finally, We can estimate the spatio-temporal evolution by optimizing the form of the function I(t) and weight of the prior constraint with respect to spatial domain based on ABIC.

In order to determine the form of the function I(t), we adopted Genetic Algorithm (GA). It drastically reduces the calculation cost. We performed analysis based on simple GA as follows:

1) Initial individuals are generated by using pseudo random numbers.
2) Single point crossover is adopted in the child generation process.
3) The mutation inverts the value of a point on the time axis.
4) Roulette wheel selection based on ABIC is performed to survive the individuals of good model.
5) Pick up the model that the largest number of individuals corresponds to as a final solution.

3. Application

We applied the improved inversion method to two postseismic slip events, which occurred after the largest aftershock of 2005 Miyagi-oki Earthquake (M6.6 on 2 December 2005) and the Niigataken Chuetsu-Oki Earthquake in 2007 (M6.8 on 16 July 2007). We will demonstrate the results of our inversion analyses with the results based on the traditional method.