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Spatio-temporal distribution of afterslip due to the 2011 Tohoku-Oki earthquake from MCMC inversion

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INTRODUCTION

The 2011 off the Pacific coast of Tohoku Earthquake (Mw9.0) occurred at 5:46 a.m. on March 11, 2011 (UTC). In northeast Japan, an earthquake of magnitude 9 has first recorded in history. Moreover, the information of the huge earthquake is poor in the world. On the other hand, national GPS observation network (GEONET) observes detail of crustal deformation. GEONET observes eastward post-seismic displacements due to the Tohoku-Oki earthquake on the plate interface. We asuume that the post-seismic displacement is due to an afterslip. In order to understand earthquake, it is important to infer stress state and frictional behavior on the plate boundary from spatio-temporal distribution of afterslip (Hsu *et al.*,2006). Hence, we estimate spatio-temporal distribution of afterslip due to the 2011 Tohoku-Oki earthquake.

GPS DATA

In this study, we used daily coordinates of GPS station (F3 solution), which is observed by GEONET and analyzed by Geospatial Information Authority of Japan (GSI). The period of observation is from 1996 to now. In this period, the time series of crustal deformation include a liner trend, annual variations, and co- and post-seismic deformations. They can be modeled by a linear, trigonometric, Heaviside-step and logarithmic functions, respectively. We estimate these model parameters using least square method for linear part and the interior-reflective newton method for non-linear part (Coleman *et al.*, 1996). We extract the post-seismic displacements due to the Tohoku-Oki earthquake through a modeling of time series of crustal deformation.

INVERSION METHOD

We use a method based on a Markov chain Monte Carlo (MCMC) Method to estimate the spatiotemporal distribution of afterslip. The conventional inversion method, such as least squares method, estimates one solution for each unknown parameter. On the other hand, MCMC method estimates probability density functions (PDFs) of each unknown parameter. Especially, MCMC method represents an under-determined problem as the correlation between each solution. To estimate afterslip distribution, the observation equation, representing a relation between observed data and the afterslip distribution, is written as $\mathbf{d} = \mathbf{G}\,\mathbf{m}$. Here, $\mathbf{d}$ is an observation data, $\mathbf{m}$ is afterslip of every sub-fault in strike and dip directions, and $\mathbf{G}$ is a Green function that is the coefficient matrix which defines a relation between $\mathbf{d}$ and $\mathbf{m}$, and including the coefficient of Laplacian smoothing parameter. In this study, we use a Green function considered a 3-dimensional heterogeneous structure in northeast Japan, which is produced by 3D Finite Elements Method. In the smoothing parameter, we employ weighted Laplacian smoothing regularized by scale of the Green function. The sampling method of MCMC is Metropolis-Hastings algorithm. In order to enhance computational speed, we use GPU (Graphics Processing Unit), because MCMC method needs large amounts of calculations.

RESULTS

Mainly afterslip locates in depth range between 25 and 35 km, and in width range of 400km, which is below the co-seismic slip distribution (Simons *et al.*, 2011). The peak of afterslip is about 3m in Fukushima-Oki after 7 months from the Tohoku-Oki earthquake. This area agrees with the area of the 1983 Fukushima-Prefecture-Oki earthquake. For the temporal change of afterslip, the large afterslip started at off the Fukushima prefecture. After then, afterslip move to off the Iwate prefecture. Furthermore, the spatial distribution of residual is similar pattern of interseismic strain concentration area.

Keywords: Tohoku-Oki earthquake, afterslip, Malcov chain Monte Carlo method, Green function using FEM