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Bayesian inversion with sparsity constraint for spatial distribution of afterslip

NAKATA, Ryoko[1*] ; KUWATANI, Tatsu[2] ; OKADA, Masato[3] ; HORI, Takane[1]

[1]JAMSTEC, [2]Tohoku University, [3]University of Tokyo

Heterogeneous distribution on the plate interface is considered to be the manifestation of heterogeneity in plate coupling, which may slip as earthquake sources in the future. However, it seems to be difficult to resolve clearly such heterogeneous distribution for M7 class earthquakes in offshore region because of stations only on land and narrow expected heterogeneous area.

We demonstrated the reproducibility of spatial distribution of afterslip following a M˜7 earthquake through numerical experiments, which estimate slip distribution on the plate interface from displacements observed on the free surface (Nakata et al., 2014). We calculated synthetic displacement data from the result of numerical simulation conducted for the afterslip following a M 6.8 earthquake, for existing global navigation satellite system stations on land (GEONET) and planned ocean floor pressure gauge network stations (DONET). The spatial distribution of fault slip is estimated using a Kalman filter-based inversion. The slip distribution estimated by using ocean floor stations demonstrated the heterogeneity of plate coupling within the coseismic area of the M 6.8 earthquake with a radius of 10 km. The estimated slip amount in the coseismic area is nearly half of the peak one around it, although no slip is the true answer. This discrepancy is caused by the smoothness constraint in the inversion.

To improve the reproducibility of the slip distribution, it is necessary to introduce different type of constraints. We have incorporated three constraints into the evaluation function as follows: First is continuous and smooth constraint in non-zero slip area. Second is the sparsity constraint that the number of subfaults with non-zero afterslip is significantly smaller than that of residual area. Third constraint is discontinuity between locked area (slip = 0) area and afterslip area.

By developing a method of Kuwatani et al. (2014), we proposed an evaluation function combined with Markov random field (e.g., Kindermann & Snell, 1980; Geman & Geman, 1984) model and sparse modeling (e.g., Tibshirani, 1996). Obtained afterslip distribution that minimizes the evaluation function could be resolved heterogeneity due to the M˜7 seismic source sharper than that using previous methods.