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Spatio-temporal renewal model for repeating earthquakes and analysis of slip rate on plate boundaries

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We propose a new spatio-temporal stochastic model based on a renewal process to estimate quasi-static slip rate from repeating earthquakes on plate boundaries.

A renewal process is a point process that assumes intervals of events are independently and identically distributed. It is applied to long-term forecast of large earthquakes in active faults or on plate boundaries. But when we apply it to small repeating earthquakes, the assumption of stationarity in renewal processes often fails because their intervals are influenced largely by the change in slip rate near their hypocenters.

Thus, we consider a non-stationary renewal process that the repeating intervals are inversely proportional to their neighbourhood slip rate. We introduce the space-time structure into this model by smooth cubic B-spline functions allocated to partitioned grids. On estimating the coefficients of spline bases, we use a penalty function for unsmooth change into the model to avoid over-fitting for the dataset. Optimal hyper-parameters are selected by Akaike's Bayesian Infromation Criteria (ABIC). We use relations between magnitudes and slip lengths of repeating earthquakes derived by Nadeau and Johnson (1998) to estimate the absolute slip rate.

We apply this model to the set of repeating earthquake sequences in Parkfield segment of San Andreas Fault, California. From the result of analysis, we see the accelaration of slip from 1993 and afterslip of larger earthquakes at M4.6. We also analyze the aftershocks in repeating sequences after 9/28/2004 Parkfield earthquake at M6.0.

Proposal model can estimate slip rate at depth where GPS system can not measure directly. Although it is difficult to estimate coseismic slip of large earthquakes from repeating earthquakes, this model can monitor the characteristic change in slip rate.

Keywords: repeating earthquake, slip rate, spatio-temporal analysis, renewal process