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Incorporating uncertainty into the estimation of slip during pre-instrumental earthquakes

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Slow plate motion (e.g. 45mm/yr) is continuously loading faults causing them to catastrophically release this stored energy during earthquakes. Resolving the location and the amount of slip occurring during a sequence of earthquakes constrains the size and location of future events along the fault. In particular, detecting areas where the fault has accumulated large amounts of slip deficit (i.e. the amount of slip required for the fault to 'catch up' with the plate motion) allows us to define areas which could potentially produce large earthquakes in the future. GPS and seismic networks are successfully used to resolve the slip distribution of modern earthquakes. However, to explore size and distribution of slip for pre-instrumental events dating back hundreds of years we need to exploit proxy sources of data.

Coral microatolls growing in the intertidal zone of the outer island arc of the Sunda trench act as long term geodetic recorders; their growth influenced by the tectonic flexing of the continental plate beneath them. Spread over large areas of an active subduction zone, they offer the possibility of high resolution reconstructions of slip for a number of pre-instrumental earthquakes.

The sparse, distributed nature of the corals and the fact that all observation points are located some distance from the event (i.e. on the earth's surface) means that the inversion is an under-determined system which produces non-unique slip distributions. To overcome this difficulty a Monte Carlo Slip Estimation (MCSE) technique is used, whereby many models are produced and tested to identify those best replicating the observed displacement data. A Genetic Algorithm (GA) is employed to accelerate the identification of suitable models and a catalog of slip distributions can be constructed.

The displacement measurements for each coral location have an associated range of uncertainty. Successive iterations of the GA each sample a different set of displacement values from within this range. As a result, the GA produces a collection of possible models based on the full range of measured uncertainties. These models can be stacked and a weighted average calculated to give a high resolution estimate of the distribution of slip for each event. Furthermore, areas of high confidence in the weighted average model can identified where the standard deviation of values is low. Similarly, where the standard deviation is high confidence in the weighted average model will be low. These high resolution models can be used to construct a history of slip along the fault, both identifying and quantifying of slip deficits and constraining confidence in the accuracy of the modelled information.