Cross-Correlation-Based Relocation for Early Rupture Process of Earthquakes

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Location is one of the primary information one requires after any earthquake. To better determine the location of earthquakes, there are generally two approaches: to use picking information to determine the hypocenters, or to utilize much longer waveform to infer the centroids of earthquakes. Among which, cross-correlation-based methods, e.g. implemented in the popular HypoDD method (Waldhauser and Ellsworth, 2000), are commonly used for the relocation of earthquake centroids for they could yield high resolution locations. However, there currently lack a method to relocate event hypocenters, or early parts of the ruptures, from which can enjoy the high resolution from cross-correlation-based methods that allows us to escape from ambiguity in phase picking in traditional approaches.

Inspired by a recent study by Ide (2019) that widely identifies earthquakes re-rupturing same patches of location while only some cascading up into larger events, we developed a new approach to relocate the very initial part of the rupture of earthquakes. By adding a term to optimize the window of waveforms to cross-correlate with, we could utilize cross-correlation to determine high-resolution locations of earthquakes with essentially the same P-wave first motions. We have tested our relocation method on the collocating event pairs listed in Ide (2019) that have highest cross-correlation coefficient, showing that except for events too far off-shore which the effect of attenuation is too strong, our method succeeds in determining most event within 400 m relative to each other horizontally and vertically for their initial rupturing location. We then further apply the method to relocating hypocenters of events that are similar in focal mechanism, hence similar waveform, with high resolution offered by the cross-correlation. We believe that this new method may be beneficial to future studies that require high resolution hypocenter information.

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