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Analysis of the 2011 Tohoku-oki earthquake sequence using the back-projection technique and the data from North America

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There are a variety of slip models of the Mw 9.0 Tohoku earthquake available, but the slip distribution differ significantly from one model to another. This type of difference between models produced by different groups has been observed in the past, and one of the main reasons is the type of assumptions made to constrain the slip inversion. We use a back-projection method that requires very little a priori input to image the rupture process and area of the mainshock, foreshock, and a sequence of events that followed the mainshock.

At the time of this earthquake, the transportable component of the USArray project in the United States was, fortunately, still at a teleseismic distance that allowed good P-waveform recordings. We take advantage of this dense, broadband array in the back-projection analysis, and combine it with other stations in North America (including Canada) to expand the distance and azimuthal coverage of our data set.

The results of the back-projection analysis show that the area that ruptured during the foreshock sequence on March 9th does not overlap significantly with the rupture area of the mainshock. In addition, there is a discrepancy between the region defined by the aftershocks and the mainshock rupture area. The aftershock distribution is better reconciled when rupture areas of events subsequent to the mainshock are included, i.e., these events are occurring on plate interface that did not rupture during the mainshock. The cascading failure of the plate interface suggests that the earthquake magnitude could have been larger if the entire area slipped during a single event.

This approach of running back-projection on continuous data also demonstrates that some early aftershocks following large earthquakes are missed by conventional source-location algorithms. In the case of 2011 Japanese earthquakes, many events are missing from the JMA catalogue immediately following a large earthquake. The back-projection analysis using high-quality data can, therefore, contribute to improving the catalogue completeness following giant earthquakes.