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Bayesian multiple rupture plane inversion to assess rupture complexity: application to the 2018 Mw 7.9 Alaska earthquake

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When the earthquake rupture is complex and ruptures of multiple fault segments contribute to the total energy release, the produced wavefield is the superposition of individual signals produced by single subevents. Resolving source complexity for large, shallow earthquakes can be used to improve ground shaking and surface slip estimations, and thus tsunami models. The 2018 Mw 7.9 Alaska earthquake showed such complexity: according to previous studies, the rupture initiated as a right-lateral strike-slip fault on a N-S oriented fault plane, but then jumped onto a left-lateral strike-slip fault oriented westward. Rupture complexity and presence of multiple subevents may characterize a number of other earthquakes. However, even when individual subevents are spatially and/or temporally separated, it is very difficult to identify them from far field recordings. In order to model complex earthquakes we have implemented a multiple double couple inversion scheme within Grond, a tool devoted to the robust characterization of earthquake source parameters included in the Pyrocko software. Given the large magnitude of the target earthquake, we perform our source inversions using broadband body waves data (P and S phases) at teleseismic distances. Our approach starts with a standard moment tensor inversion, which allows to get more insights about the centroid location and overall moment release. These values can then be used to constrain the double source inversion. We discuss the performance of the inversion for the Alaska earthquake, using synthetic and real data. First, we generated realistic synthetic waveforms for a two-subevents source, assuming double couple sources with the strike-slip mechanisms proposed for the Alaska earthquake. We model the synthetic dataset both using a moment tensor and a double double couple source, and demonstrate the stability of the double double couple inversion, which is able to reconstruct the two focal mechanisms, the moment ratio and the relative centroid locations of the two subevents. Synthetic tests show that the inversion accuracy can be in some cases reduced, in presence of noisy data and when the interevent time between subevents is short. A larger noise addition affects the retrieval of the focal mechanism orientations only in some cases, but in general all the parameters were well retrieved. Then, we test our tool using real data for the earthquake. The single source inversion shows that the centroid is shifted 27 s in time and 40 km towards NE with respect to the original assumed location retrieved from the gCMT catalogue. The following double double couple source inversion resolves two subevents with right-lateral and left-lateral strike-slip focal mechanisms and Mw 7.6 and 7.8 respectively. The subevent centroids are separated by less than 40 km in space and less than 20 s in time.