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Joint seismic and geodetic transdimensional earthquake source optimization guided by multi-array teleseismic backprojection

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Earthquakes have been observed to initiate and terminate near geometrical irregularities (bends, step-overs, branching of secondary faults). Rupture segmentation influences the seismic radiation and therefore, the related seismic hazard. Good imaging of rupture segmentation helps to characterize fault geometries at depth for follow-up tectonic, stress-field or other analyses. From reported earthquake source models it appears that large earthquakes with magnitudes above 7 are most often segmented, while earthquakes with magnitudes below 6.5 most often are not. If this observation reflects nature or if it is rather an artifact of our abilities to well observe and infer earthquake sources can not be answered without an objective strategy to constrain rupture complexity. However, data-driven analyses of rupture segmentation are not often conducted in source modeling as it is mostly pre-defined through a given and fixed number of sources.

We, here, propose a segmentation-sensitive source analysis by combining a model-independent teleseismic back-projection and image segmentation methods with a kinematic fault inversion. Our approach is twofold. We first develop a time-domain multi-array back-projection of teleseismic data with robust estimations of uncertainties based on bootstrapping of the travel-time models and array weights (Palantiri software, <https://braunfuss.github.io/Palantiri/>). Backprojection has proven to be a powerful tool to infer rupture propagation from teleseismic data and identify irregularities of the rupture process over time.

We then model the earthquake sources with the results obtained from the backprojection and additional information obtained from the application of image segmentation methods to the InSAR displacement maps. For this second step, we use a combination of different observations (teleseismic waveforms and surface displacement maps based on InSAR) to increase the resolution on the spatio-temporal evolution of fault slip. We develop a novel Informational criterion based transdimensional optimization scheme to model an adequate representation of the source complexity. We present our method on two cases study: the 2016 Muji Mw 6.7 earthquake (Pamir) and the 2008-2009 Qaidam (Tibet) sequence of earthquakes. We find that the 2008 Qaidam earthquake ruptures one segment, the 2016 Muji earthquake on two segments and

the Qaidam 2009 earthquake on two or three segments.

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