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Multi-Array Back-Projection as a High-Resolution approach: Application to the 2007 Mw 7.7 Tocopilla and 2018 Mw 7.5 Palu earthquakes

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Since the 2004 Mw 9.1 Sumatra-Andaman earthquake, back-projection imaging of earthquakes based on high-frequency emissions has become a complementary method to Finite Source Inversions, providing information related to the rupture area, rupture velocity, and energy distribution in time and space without any prior fault geometry knowledge requirements. Further developments have allowed its extension from a time-domain approach to frequency-domain methods while multiple applications have, for example, characterized complex ruptures and intermediate-depth earthquakes. However, its dependency on large arrays has severely limited azimuthal coverage of many events, exacerbating artifacts such as the so-called "swimming artifact" and others related to source effects. Here we extended the traditional time-domain back-projection with a multi-array approach, which harnesses regionally distributed seismic stations in addition to the large-scale arrays usually employed to widen azimuthal coverage. The method involves a reference array and multiple groups of stations acting as complementary arrays, whose contribution to the solution depends on their azimuthal distribution. Additionally, we included the analysis of multiple seismic phases in the back-projection algorithm to reduce source effects, specifically those caused by pP phases for interface events and events in the shallow slab ($d < 70$ km). Our analysis is suitable to be standardized and automated for near-real-time applications. We tested the procedure with two major earthquakes. The first is the 2007 Mw 7.7 Tocopilla earthquake. We have calibrated the travel time corrections with some of the large aftershocks of this event in order to be able to interpret the rupture history within their context. We found the high-frequency rupture emissions (0.5-2.0 Hz) have encircled the dominant asperities along the fault area with the cumulative energy being emitted updip of the coseismic slip area, which can be associated to the well-described dip segmentation acting as a barrier in this region. Our second analysis involved the strike-slip rupture of the 2018 Mw 7.5 Palu earthquake where we identified a prominent super-shear rupture (4.1 kms^{-1}) from the epicenter to the south which is exceptionally well correlated with the trace of the active fault identified from the Advanced Land Observation Satellite-2 (ALOS-2) interferograms. The method revealed important high-frequency peaks centered at Palu city and far away from the epicenter ($\sim$140 km) providing a clue to link back-projected energy emissions with potential damages areas.