Resolving the geometrical complexity of dynamic ruptures using slowness-enhanced back-projections.

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Over the last decade, the development of large-scale dense seismic networks has promoted rapid progress in a broad spectrum of seismological sciences. High-frequency seismic waveforms from these large arrays have enabled back-projections (BP), an emerging tool to probe earthquake dynamics. BP is widely used to study large earthquakes, but its derived images are array-dependent. For the same earthquake, different arrays often produce different images, and it is difficult to judge which result should be trusted more. In this talk, I will present a new approach to effectively mitigate the BP uncertainties of large earthquakes based on their aftershocks. We introduced a slowness (ray parameter) error term calibrated by aftershocks to achieve consistency between BPs of different seismic networks. This correction accounts for the P-wave travel time errors in each receiver array, due to approximating 3D earth structure with 1D reference velocity model.

Such technological improvement in earthquake source observations allows us to address the open questions of earthquake source dynamics. For instance, we perform a joint seismic and geodetic investigation of the 2016 Mw 7.8 Kaikoura earthquake in New Zealand. We find that the Kaikoura earthquake is one of the most geometrically complex earthquakes on record, involving a series of cascade failures and wide stepovers in the Malborough Fault system. The high-frequency radiations occur mainly on three shallow thrust faults located in the dilatational quadrants of rupture on the Hope-Kekerengu fault, consistent with the unclamping effect predicted by both the static and dynamic Coulomb stress in our dynamic rupture models.　The complexity of dynamic rupture can be also appreciated in the 2015 M8.3 Illapel earthquake in central Chile. This earthquake is featured by splitting of rupture fronts around the rim of a large asperity or barrier. This encircling pattern is analogous to the double-pincer movement in military tactics. Such degree of complexity is previously only seen in simulations and it is observed for the first time in real earthquakes enabled by enhanced high-resolution BP. These studies demonstrate the capability of the BP method, enhanced by aftershock calibrations, to describe earthquake rupture kinematics in regions of complex fault systems.