Static inversion of SAR and optical data for the Balochistan Earthquake (2013, Mw 7.7)

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Résumé

The 2013 Mw7.7 Balochistan earthquake occurred in the complex tectonic setting of the triple junction between Arabia, Eurasia and India tectonic plates. The earthquake ruptured a 200-km-long curved section of the Hoshab fault. Coseismic motion was dominated by left-lateral slip with a minor reverse component. Since the Hoshab Fault is mainly a thrust fault on which the rupture would have been expected to be mainly dip-slip, the strike-slip motion induced by the 2013 earthquake raises important questions on the mechanics of earthquake faulting.

We process TerraSAR-X ScanSAR and RADARSAT-2 data using interferometry and amplitude correlation. We also apply optical image correlation using two pairs of Landsat-8 images and five pairs of SPOT-5 images. By combining all datasets, we derive the full 3D coseismic displacement field at the surface, covering the whole rupture. Retrieval of the

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fault-parallel and fault-normal components of slip along the fault enables us to show that surface slip exceeds 6-7m over more than 100km, with a maximum of 12m in the central part of the rupture. The vertical component reaches up to 3m towards the southern extremity of the fault. Our analysis shows evidence for a north dipping fault, as already suggested in previous studies.

We carry out an elastic inversion of the geodetic dataset to determine the slip distribution at depth. To explore the first-order features of the slip distribution, we use a simple geometry for the fault. The northern part is modeled as a $70\circ$N dipping fault down to 18 km, consistent with linkage with the strike-slip Chaman Fault. The fault dip is gradually flattened towards the south to comply with the thrust fault morphology in the Makran accretionary wedge. At depth, the fault is modeled with a listric geometry that flattens at 10km, consistent with a previously inferred décollement level. We use Okada's equations to invert for the strike-slip and dip-slip components of the earthquake. The proposed model explains 90% of our dataset. The strike-slip component is segmented in two parts, with a slip of 10m on a 75km-long section to the north, and a slip of 5-6m on a 75km-long section to the south. The dip-slip component is mostly restricted to the southern section, with an average 1.5m slip. Transition between the two segments occurs around a major geometric complexity visible along the fault trace. This suggests that the fault geometry exerts a control on the coseismic slip distribution.
Synthetics are however systematically lower than the original data close to the fault ($<$ 2km). This suggests that the inversion cannot reconstruct inelastic deformation or apparent slip overshoot due to shallow flattening of the fault. Furthermore, the predicted asymmetry of displacements in the mid-field (4 to 10 km) is underestimated by the model. The fault dip at depth could be steeper than previously proposed from the analysis of on-fault relative displacements. This would be consistent with a steepening of the fault dip with depth, again suggesting that complexities within the geometry of the Hoshab Fault strongly influenced the coseismic slip distribution of this large earthquake.