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Facilitating open global data use in earthquake source modelling to improve geodetic and seismological approaches

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In the last few years impressive achievements have been made in improving inferences about earthquake sources by using InSAR (Interferometric Synthetic Aperture Radar) data. Several factors aided these developments. The open data basis of earthquake observations has expanded vastly with the two powerful Sentinel-1 SAR sensors up in space. Increasing computer power allows processing of large data sets for more detailed source models. Moreover, data inversion approaches for earthquake source inferences are becoming more advanced. By now data error propagation is widely implemented and the estimation of model uncertainties is a regular feature of reported optimum earthquake source models. Also, more regularly InSAR-derived surface displacements and seismological waveforms are combined, which requires finite rupture models instead of point-source approximations and layered medium models instead of homogeneous half-spaces. In other words the disciplinary differences in geodetic and seismological earthquake source modelling shrink towards common source-medium descriptions and a source near-field/far-field data point of view. We explore and facilitate the combination of InSAR-derived near-field static surface displacement maps and dynamic far-field seismological waveform data for global earthquake source inferences.

We join in the community efforts with the particular goal to improve crustal earthquake source inferences in generally not well instrumented areas, where often only the global backbone observations of earthquakes are available provided by seismological broadband sensor networks and, since recently, by Sentinel-1 SAR acquisitions. We present our work on modelling standards for the combination of static and dynamic surface displacements in the source's near-field and far-field, e.g. on data and prediction error estimations as well as model uncertainty estimation. Rectangular dislocations and moment-tensor point sources are exchanged by simple planar finite rupture models. 1d-layered medium models are implemented for both near- and far-field data predictions. A highlight of our approach is a weak dependence on earthquake bulletin information: hypocenter locations and source origin times are relatively free source model parameters.

We present this harmonized source modelling environment based on example earthquake studies, e.g. the 2010 Haiti earthquake, the 2009 L'Aquila earthquake and others. We discuss the benefit of combined-data non-linear modelling on the resolution of first-order rupture parameters, e.g. location, size, orientation, mechanism, moment/slip and rupture propagation.

The presented studies apply our newly developed software tools which build up on the open-source seismological software toolbox pyrocko (www.pyrocko.org) in the form of modules. We aim to facilitate a better exploitation of open global data sets for a wide community studying tectonics, but the tools are applicable also for a large range of regional to local earthquake studies. Our developments therefore ensure a large flexibility in the parametrization of medium models (e.g. 1d to 3d medium models), source models (e.g. explosion sources, full moment tensor sources, heterogeneous slip models, etc) and of the predicted data (e.g. (high-rate) GPS, strong motion, tilt).

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