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Joint earthquake source inversions of InSAR and seismic data using 3D Earth models

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Progress in seismology led to numerous earthquake catalogues, which routinely report source models. However, evaluating the quality of reported source parameters is difficult, due to the general lack of benchmark solutions. Ongoing efforts in satellite geodesy can help us tackle these issues, as they provide an independent way of characterizing earthquakes. For example, advances in Interferometric Synthetic Aperture Radar (InSAR) have enabled the investigation of over 60 global earthquakes, which were compiled into an archive of InSAR centroid moment tensor (ICMT) models (Weston et al., 2011). Such an archive gives us a unique opportunity to examine errors in both seismic and InSAR earthquake models and thus to devise new schemes for robust joint inversions of these data types.

Recent systematic comparisons between InSAR and seismic source models allowed us to identify errors of up to 40 km in seismically-determined centroid locations, as well as inaccuracies in earthquake slip distributions retrieved using InSAR. Moreover, we found that differences between moment magnitude and fault strike determined using InSAR and seismic data are substantially reduced when using some recent 3D Earth models (Ferreira et al., 2011).

We investigate these issues further by testing how well ICMT parameters explain long-period seismic data (body and surface waves), compared to the Global Centroid Moment Tensor (GCMT) method. We calculate theoretical seismograms using the spectral element method for two 3D Earth models and for the ICMT and GCMT source models. The synthetic seismograms are compared with real seismic data for six global earthquakes – 1992, Mw 7.3, Landers; 1993, Mw 6.1, Eureka Valley; 1994, Mw 5.9, Nevada; 1996, Mw 6.7, N Chile; 1999, Mw 7.5, Izmit; 2007, Mw 8.1, Pisco – for which there are substantial discrepancies between ICMT and GCMT solutions.

We find that for moderate magnitude events the ICMT location leads to the best data fit, but for the largest earthquakes, GCMT locations produce lower data misfits, suggesting limitations in the Earth models used. In some cases a solution that is a combination of ICMT and GCMT parameters leads to the best data fit. These comparisons highlight the complementary nature of InSAR and seismic data and the sensitivity of the solutions to Earth structure, guiding us in the development of joint inversions for more robust point source models, using for the first time 3D Earth models.

We jointly invert long-period seismic data and unwrapped interferograms using a hybrid downhill simplex Monte Carlo algorithm. While the InSAR data are modelled using classical elastic dislocation theory, 3D Earth effects are taken into account when modelling the seismic data. Initial results for the 1993, Mw 6.1, Eureka Valley earthquake show that the uncertainties in the joint model are reduced compared to those when the data are inverted individually; while the InSAR data for this particular event provide a strong constraint on the location and strike of the fault, the seismic data are useful in constraining the moment magnitude. Further joint inversions for events in different tectonic settings are explored and discussed.