Reconciling earthquake source parameters from InSAR and long-period seismic waveform data

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Comparisons between earthquake source parameters as determined by InSAR and the global centroid moment tensor (GCMT) catalogue show widespread discrepancies between locations derived using these independent methods (Ferreira et al., 2011; Weston et al., 2011, 2012). Earthquake centroid location determination using InSAR data (named the 'InSAR Centroid Moment Tensor', or 'ICMT' location) is more robust, since it is independent of Earth velocity structure errors that impact on long-period surface wave inversions used in the GCMT method. Ferreira et al (2011) showed that these discrepancies cannot be resolved at present by applying more detailed 3D Earth velocity structures from mantle tomography models. Earthquake location determination is extremely dependent on the assumed velocity structure, not only in the GCMT method, but also in all of the seismic based earthquake source parameter inversions. Velocity structures are typically produced by seismic tomography, which itself depends on seismic phase travel times. These travel times are a function of source location and origin time, plus the path between the source and receivers (i.e. the Earth's velocity structure). Errors in source location can therefore be compounded as errors in the velocity structure.

In a preliminary study we analyze long-period seismic data for four shallow continental earthquakes studied with InSAR – Zarand M_w 6.5 (Iran, 2005), Eureka Valley M_w 6.1 (California, 1993), Aiquile M_w 6.5 (Bolivia, 1998) and Wells M_w 6.0 (Nevada, 2008). We use the spectral element wave propagation package, SPECFEM3D GLOBE, and Earth model S40RTS (Ritsema et al., 2010) to calculate Green's functions and synthetic seismograms for these events using their ICMT source locations. Using a cross-correlation method we were able to estimate phase shifts for each source-receiver pair between synthetic and observed long period waveforms. We believe these phase shifts may correspond to unmodeled heterogeneity in the S40RTS model, and if systematically documented could provide additional constraints on seismic tomographic models in future. GCMT-style source inversions that account for these phase shifts show much better agreement with the ICMT mechanisms than inversions where they are not accounted for. Several published studies relate GCMT location errors to unknown and/or unmodeled heterogeneities within the Earth's crust and upper mantle. However, here we show that source mechanism and moment can also be sensitive to these unknown heterogeneities in some cases.

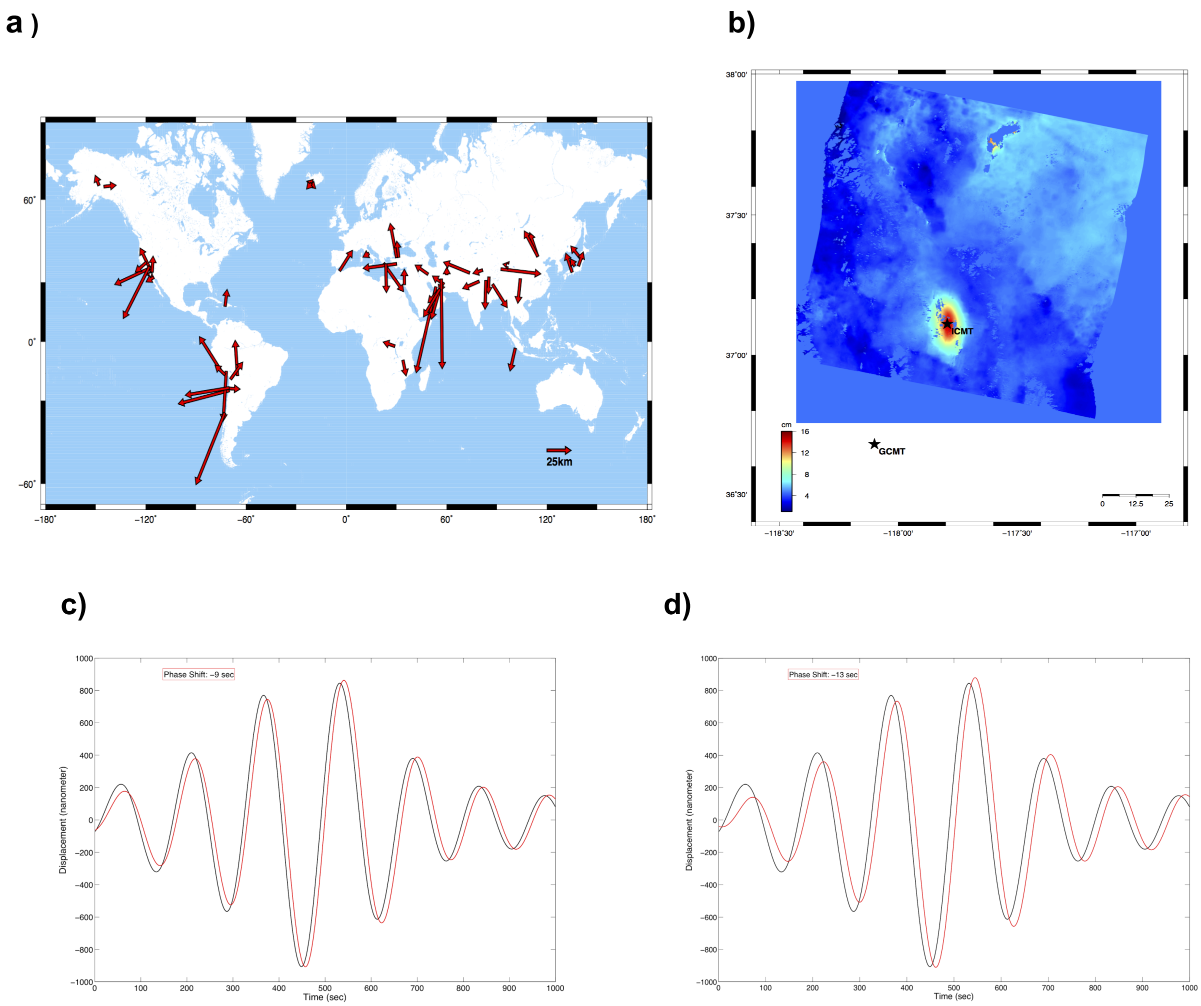

Figure 1. (a) Mislocation vectors for 58 earthquakes, showing differences between centroid epicentral locations derived from the ICMT and GCMT methods. [Tail of each vector is the InSAR centroid.] (b) Comparison of epicentral centroid locations in the GCMT and ICMT catalogs for the 1993 Eureka Valley, CA earthquake, superposed on the ERS-1 interferogram for the event. Note that the ICMT location is consistent with the maximum line-of-sight deformation in the InSAR data, but the GCMT location is 54 km away, at an azimuth of 210° (c) One example of comparison between real data (black) and synthetics (red) in the Z component of station TLY in Russia for the Mw 6.5 Zarand, Iran earthquake. The synthetic seismogram is calculated using the ICMT location and a source mechanism derived from inversion of long period surface waves (284.2°/24.2°/136.2°/8.52 for strike/dip/rake/moment respectively; Weston et al., 2014). (d) The same comparison with the same assumed location in (c) but using the ICMT source mechanism (266.1°/63.7°/104.1°/6.37 from Weston et al., 2014). Note that the waveforms are very similar in shape, but the synthetic is shifted in time, indicating a bias in travel time (here of 13 seconds) that we attribute to inaccuracies in the Earth model used to calculate it. [Centroid depth: 12 km, centroid time fixed to GCMT catalog value, S40RTS/CRUST2.0 Earth model (Ritsema et al., 2010; Bassin et al., 2000).]