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Afterslip on the L'Aquila earthquake (M6.3) surface rupture captured in 4D using a Terrestrial laser scanner (TLS)

Maxwell Wilkinson (1), Ken McCaffrey (1), Gerald Roberts (2), Patience Cowie (3), Richard Phillips (4), and Alessandro Michetti (5)

(1) Department of Earth Sciences, South Road, Durham University, Durham, UK DH1 3LE, (2) School of Earth Sciences, Birkbeck College, University of London, Malet St, London, UK WC1E 7HX, (3) School of Geosciences, University of Edinburgh, Drummond Street, Edinburgh, UK EH8 9XP, (4) Institute of Geophysics and Tectonics, University of Leeds, Leeds, UK LS2 9JT, (5) Dipartmento Di Scienze Chimiche E Ambientale, Via Valleggio 11, 22100, Como, Italy

Normal faulting earthquakes produce coseismic vertical motions that are expected to amplify during the days and weeks after the mainshock. The amplitude, wavelength and timescales associated with such postseismic deformation can help constrain the seismic cycle and reveal whether the isostatic response to an earthquake is driven by fluid and poro-elastic effects, visco-elastic creep in the mantle or afterslip within a velocity strengthening zone in the shallow crust, or a combination of the above.
Here, we report the results of an innovative survey of the surface rupture formed during the 6th April L'Aquila earthquake (M6.3) using precise 3D terrestrial laser scan (TLS) technology. Our measurements began 8 days after the mainshock, with repeated measurements 11, 35, 39, 43, 48 and 124 days after the mainshock. Using surface modelling techniques, we have produced a 4D afterslip survey across a 3 x 65 m area that has detected millimetre-scale movements on and adjacent to the rupture at exceptionally high horizontal spatial resolution (4 cm). We identify and present surface motion observations of two distinct styles. After 124 days, we recorded a total of 14.6 mm slip across the rupture, accompanied by a further 11.6 mm of continuous vertical subsidence in the form of a 30 m wide hangingwall syncline developing 7 m from the surface rupture. The localised proximity of these observations to the surface rupture suggests that shallow afterslip dominates the deformation we have measured. The total vertical offset recorded between 8 and 124 days after the earthquake is 26.2 mm (rupture slip and syncline subsidence combined). However, 44.3 % of the measured postseismic deformation within tens of metres of the surface rupture occurred via syncline growth, which would have been difficult to identify without the precision and spatial resolution provided by LiDAR. In an attempt to calculate the magnitude of afterslip that occurred prior to initiation of our measurements, on days 0-8 after the earthquake, and how this was partitioned between the rupture and the syncline, we back extrapolated the surface motions measured between days 8 - 124 using a variety of published creep functions. We conclude that centimetric to decimetric scale post-seismic deformation occurred on days 0-8, an appreciable portion of which we estimate occurred via syncline growth that would be difficult to observe without LiDAR. This raises the question as to how much slip has gone unobserved for other historical earthquakes that were not measured with LiDAR. Both surface rupture afterslip and hangingwall synclines on normal faults have been observed in palaeoseismic studies of other earthquakes, but this is the first time the incremental growth of both features has been observed in 4D.