The 2016 earthquake sequence and associated coseismic deformation in Central Apennines in Italy

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The Central Apennines in Italy were struck by multiple moderate-size but damaging shallow earthquakes in 2016. In this study, we optimize the fault geometry and invert for fault slip based on coseismic GPS and Interferometric Synthetic Aperture Radar (InSAR) analysis of Copernicus Sentinel-1A and -1B, JAXA ALOS-2 data, and ASI COSMO-SkyMed for the 2016 M_w6.2 Amatrice, M_w6.1 Visso, and the M_w6.4 Norcia earthquakes in Italy. For the Amatrice event, there was less than 4 cm static surface displacement at the town Amatrice where the most devastating damage occurred. Landslides triggered by earthquake ground shaking are not uncommon, but triggered landslides with sub-meter movement are challenging to be observed in the field. We find evidence of coseismically triggered deep-seated landslides northwest and northeast of the epicenter where coseismic peak ground acceleration was estimated > 0.5 g. By combining ascending and descending InSAR data, we are able to estimate the landslide thickness as at least 100 and 80 m near Mt. Vettore and west of Castelluccio, respectively. The landslide near Mt. Vettore terminates on the pre-existing fault Mt. Vettore Fault (MVEF) scarp. Our results imply that the long-term fault slip rate of MVEF estimated based on paleoseismic studies could potentially have errors due to triggered landslides from nearby earthquake events. Two months after the Amatrice earthquake, the M_w6.1 Visso and M_w6.4 Norcia earthquakes stroke Central Apennines in late October. Both events occurred ~30 km north of the Amatrice earthquake. We combine ascending/descending InSAR and GPS measurements to constrain the fault geometry as well as the slip distribution. The geodetic data infer that the majority of slip is on a west-dipping moderately dipping normal fault. However, the InSAR result suggests antithetic normal faults above a shallow detachment with normal sense of motion also slipped. The antithetic faults and the detachment all slipped during or right after the Norcia earthquake. Although the complicated slip on multiple faults cannot be well constrained by strong motion seismic data, the aftershocks recorded three months following the earthquake illuminate the antithetic fault as well as the detachment. Our results demonstrate how earthquakes can illuminate geological structures and the significant advantage of using space geodesy to obtain detail of surface deformation during earthquakes.