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The Mw 5.9 February 2014 Cephalonia earthquake (Greece): 3D deformation field and source modeling from multiple SAR techniques

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On Jan. 26, 2014 at 13:55 UTC an Mw 6.0 earthquake struck the island of Cephalonia, Greece, followed five hours later by an Mw 5.3 aftershock, and by an Mw 5.9 event on Feb. 3, 2014 (National Observatory of Athens, Institute of Geodynamics), causing extensive structural damages and inducing widespread environmental effects.

We measured the 3D coseismic deformation field of the Feb. 3, 2014 event, by applying Differential Synthetic Aperture Radar Interferometry (DInSAR), Intensity cross-correlation and Spectral Diversity (also known as Multi Aperture Interferometry) to descending passes of the Italian Space Agency (ASI) COSMO-SkyMed satellites and ascending passes of the German Space Agency (DLR) TanDEM-X satellite. These techniques allowed the observation of four independent displacement components (descending and ascending radar line-of-sight and azimuth), each of which was measured with two different techniques, resulting in an increased spatial coverage, robustness and sensitivity to all Cartesian displacement components.

Our SAR measurements were found to be in very good agreement with those from available continuous Global Positioning System (cGPS) stations.

We modeled the seismic source of the Feb. 3, 2014 earthquake with a joint inversion of the eight SAR displacement maps, using the analytical solutions for dislocation in an elastic half-space. Firstly, we considered a model based on a single-fault plane and carried out a non-linear inversion to estimate its geometric and kinematic source parameters, assuming a uniform slip. Subsequently, we performed a linear inversion to retrieve the slip distribution, adopting a damped and Non-Negative Least Squares approach. Slip values were computed on a variable-size mesh, which maximizes the model resolution matrix.

We find the majority of the observed surface deformation to be explained by a 20 km long $\sim$N-S oriented and west-dipping fault running parallel to the east coast of the Paliki peninsula, with a main right-lateral strike-slip mechanism and a lesser reverse component (rake=147°). The slip on this structure is mostly confined to depths shallower than 5 km. However a comparison of observed and modelled displacements, suggests a non-negligible slip to occur also along a second structure, $\sim$10 km in length, located in the south of Paliki and striking NE-SW. We therefore performed a second inversion of the SAR displacement maps, finding a dominant right-lateral strike-slip mechanism (rake=164°) and a high dip angle (76°) for the NE-SW striking fault. Most of the slip on this latter structure is found to occur at depths between 2 km and 5 km, although our model is poorly constrained at greater depths. Inclusion of the NE-SW fault in the source model is found to significantly improve the fit to all observed displacements in the south-east of the Paliki peninsula.

Finally, we compare the full moment-tensor derived from our models to those obtained by several global and regional seismic networks. We also compare the slip distributions resulting from our inversions to hypocenter relocations based on a 2D velocity model, which accounts for a non-horizontal Moho structure. A remarkable agreement is found, which also allows several considerations to be made on the rupture mechanism.