Geophysical Research Abstracts
Vol. 21, EGU2019-15843, 2019
EGU General Assembly 2019

Structural complexities controlling the 2012 Emilia seismic sequence: new insights from 3D fault modelling and FEM-based inversion of DInSAR data

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The 2012 Emilia sequence (Northern Apennines, Italy) represents one of the largest Italian seismic sequences occurring in a continental active compressional tectonic setting and strikes the Ferrara Arc, at the Padan buried front of the northern Apennines Outer Thrust System. The sequence begins on 20 May 2012 with a Mw 6.1 earthquake; before this event, the local seismometric network records five foreshocks that reached a maximum magnitude of 4.1. On 29 May, a Mw 6.0 event occurs about 15 km southwest of the first shock on an adjacent fault segment. After this second mainshock, seismicity further propagates westward, in a portion of the fault system close to the lateral termination of the Ferrara arc, where three more ML $\geq$ 5.0 aftershocks occur between May 29 and June. The existing literature substantially agrees in associating the 20 May Mw 6.1 mainshock to the middle segment of the Ferrara Thrust System (FTS), whereas the debate is mostly focused on attributing the 29 May Mw 6.0 earthquake to the inner segment of the Ferrara Thrust System or, rather, to the outer segment of the Mirandola Thrust System (MTS). Note that the FTS and MTS represent two near parallel, well distinct, fold-and-thrust systems of the north-verging Ferrara Arc. In this work, we propose a new 3D reconstruction of the main faults involved during the 2012 Emilia multi-events seismic sequence. We show that the 20 May and the 29 May events nucleate along the Middle and the Inner S-dipping splays of the Ferrara Thrust system, respectively. These two thrust segments are along-strike connected by an up to now unnoticed left-lateral transfer fault. This linkage may have controlled the location and the timing of the two subsequent major ruptures throughout the sequence. In order to verify our findings and to constrain the best possible earthquake/fault association, we start our analysis by developing a 3D fault model of the investigated area. In particular, in order to create this 3D FE model and to consider the heterogeneities present in the seismogenic volume, we take into account the collected geological information of the selected area, the relocated seismicity and the Vp/Vs tomographic models. Subsequently, we further extend our analysis by applying a 3D numerical modelling approach based on the finite elements method (FEM), implemented in a structural-mechanic framework; this allows us to simulate the ground deformation patterns retrieved through the DInSAR measurements obtained from the radar data acquired by the RADARSAT-2 sensor. Finally, we retrieve the volumetric distribution of the coseismic strain and stress variation, responsible for the observed ground deformation pattern.