MAPPING AND MODELLING OF 27 SEPT 2021 CRETE EARTHQUAKE DEFORMATION

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Abstract: **The main focus of the present study is to create a sound model of the surface displacements occurred after an earthquake with magnitude Mw 5.9 or Mw 6.0 according to different authors that struck the Crete Island on September 27, 2021. The prime source of information for the produced ground motions maps are the SAR data from Sentinel-1 mission processed by DInSAR method that delivers interferometric images. Our calculations revealed that the largest displacements based on single interferograms, show the predominant negative movements in the Line-of-Sight (LoS) of the satellite, indicating subsidence. The results are supplemented with information on the well-known faults in the region. The maps generated from SAR data were compared with the results obtained using the Okada method, revealing a good compatibility between them.**

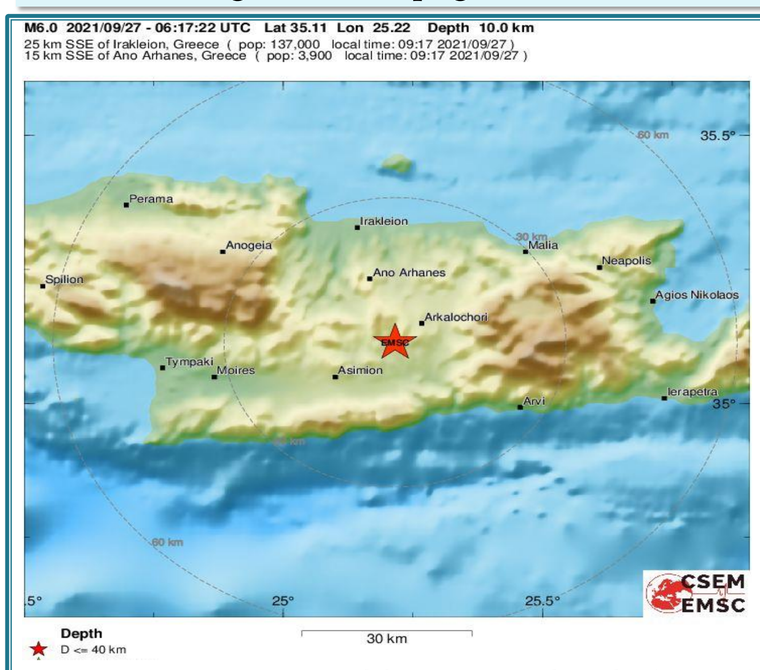

Figure 1. Location map of the strong earthquake (Mw 5.9) on Crete Island, September 27, 2021 (EMSC).

Data and methods: **InSAR is a remote sensing technique used in geodesy for mapping the ground deformation by analyzing radar images of the Earth`s surface collected from orbiting satellites. In this study, SAR data from Sentinel-1A were utilized to analyze the deformation of co-seismic events. The data were selected to primarily reflect the co-seismic effects of the main event, excluding consideration of foreshocks and aftershocks as much as possible. To enhance the quality of the results, SAR data from both ascending and descending orbits of the satellite were processed using freely provided software by ESA specifically developed for SAR data analysis. The Okada elastic dislocation model was employed to invert the geometric parameters of the fault and the distribution co-seismic slip.**

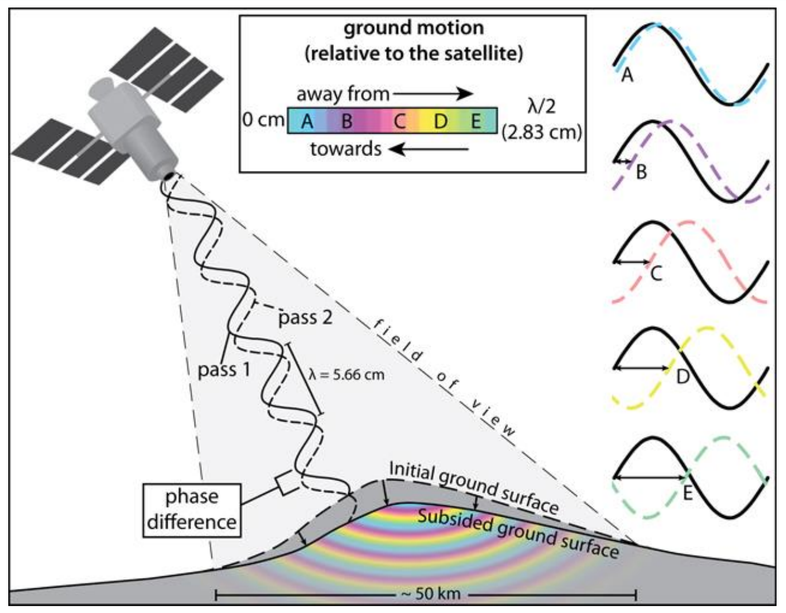

Figure 2. Schematic diagram of Principle of radar interferometry.

Results

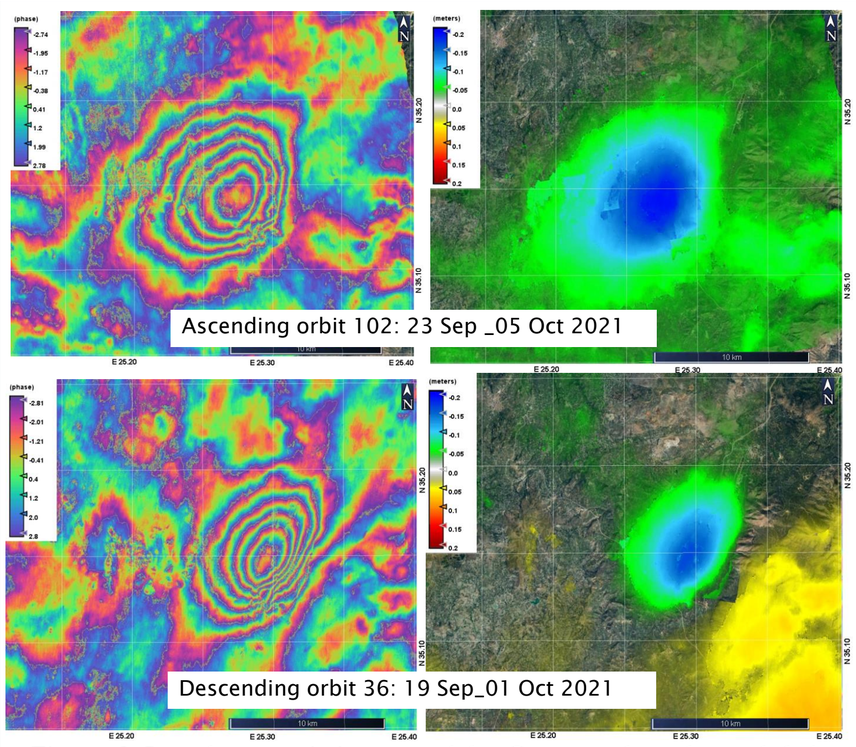

Figure 3. Interferometric images of the Crete earthquake and deformation maps along the LoS direction determined by the two types of orbits.

In the process of DInSAR processing an important and critical step is to transform the data in modulo 2π to metric values (also known as unwrapping), which in SNAP is realized by means of Snaphu plugin. In our workflow the MCF algorithm was used. The interferometric images and the produced displacement maps are shown in Figure 3. Our calculations revealed that the largest displacements based on single interferograms, show the predominant negative movements in Line-of-Sight (LoS) of the satellite, indicating subsidence. Their magnitudes for the most affected region are -16 cm as indicated by the information from the ascending orbit and -13 cm from the descending orbit.

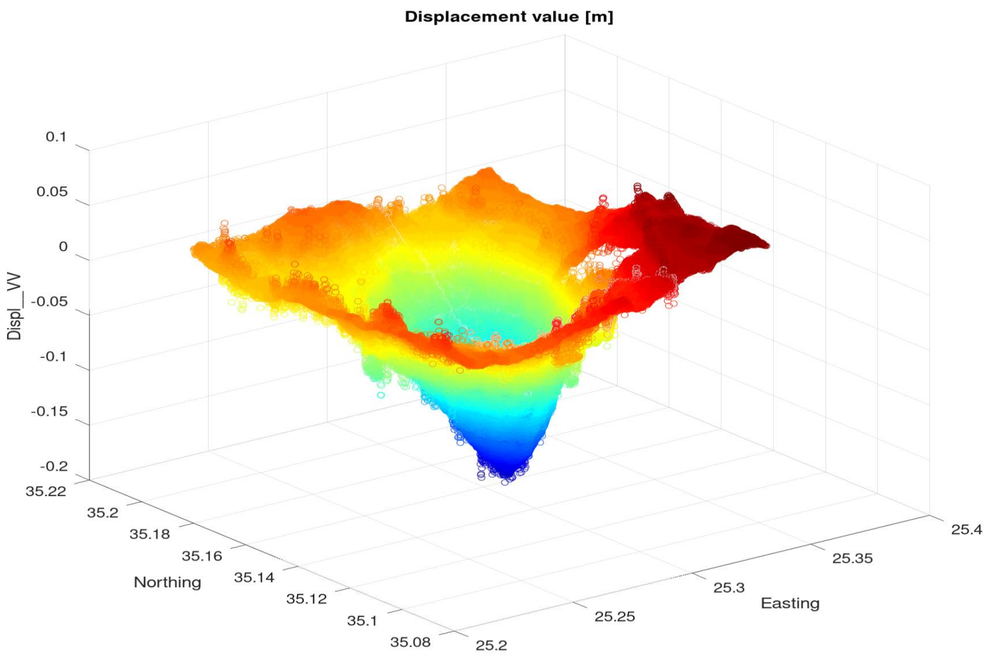

Figure 4. 3D visualization of the registered displacements in the area around the largest subsidence.

In Figure 4, a reconstruction of the subsidence in 3D, that resulted from the both mentioned earthquake events as registered in ascending orbit is shown. To produce the 3D visualization, the value from each pixel corresponding to the area of the largest ground motions was extracted and afterwards was plotted. Since the volume of data was too large it was not possible to prepare figure that can be directly compared with the results from Okada modelling (see Figure 5). Nevertheless, it is seen that even the small uplift in southeast direction depicted at the upper right part of Figure 3 is noticeable in Figure 4 as well. In addition to the maps produced by SAR, modelling of the event was carried out using the Okada method with different geometries. In the modelling of Crete earthquake, we have tested several types of geometries, varying the length, the width and the tangential slip. We tested also several focal mechanisms, since some of them are quite different. Table 1 presents the focal mechanisms provided in ISC. The best coincidence with the InSAR images is for geometry with length L=14 km and width W=9 km. The best fit for focal mechanism for this event is taken from GFZ data center (strike 218.66, dip 57.47, rake -85.61). Figure 5 shows the results for two values of the displacement over the fault: 0.25 m and 0.35 m. The results are supplemented with information on the well-known faults in the region (Basili et al., 2013). The maps generated from SAR data were compared with the results obtained using the Okada method, revealing a good compatibility between the two. The negative values of subsidence are well seen in both InSAR images and Okada`s modelling results.

Table 1. Focal mechanisms parameters for the main event (data from ISC).

Author	NEIC	IPGP	MED_RCMT	GFZ	GCMT
Strike1	54.72	24.00	34.00	30.53	40.00
Dip1	56.65	38.00	57.00	32.79	43.00
Rake1	-79.07	-111.00	-95.00	-96.84	-85.00
Strike2	215.37	229.00	223.00	218.66	214.00
Dip2	34.90	55.00	33.00	57.47	47.00
Rake2	-106.07	-75.00	-82.00	-85.61	-94.00
Focal mechanism					
M_W	6.0	6.0	6.0	5.9	5.9

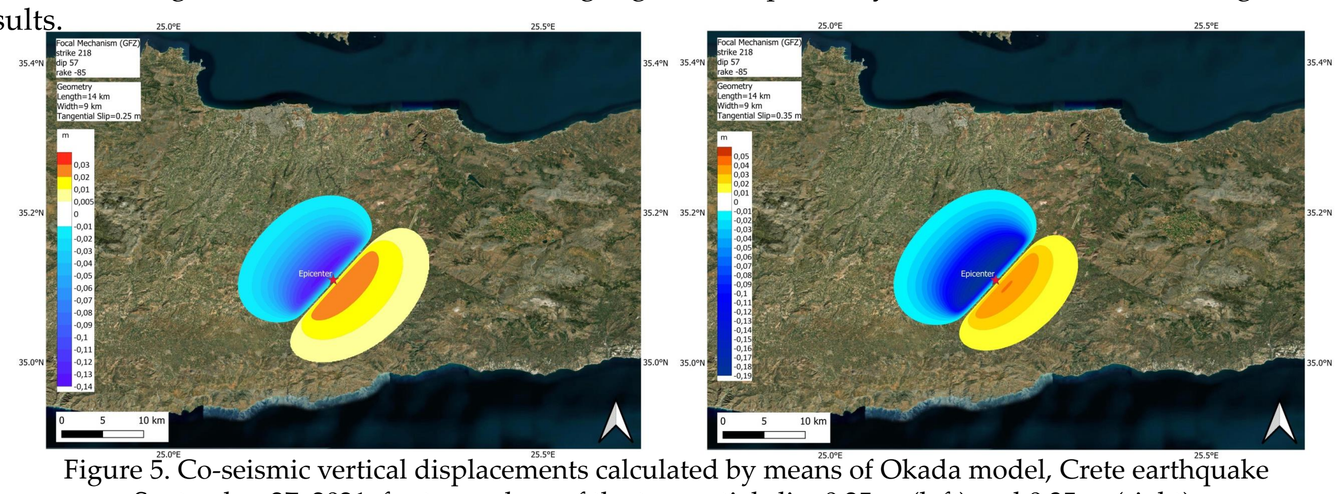

Figure 5. Co-seismic vertical displacements calculated by means of Okada model, Crete earthquake September 27, 2021, for two values of the tangential slip: 0.25 m (left) and 0.35 m (right).

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Conclusions: **The results presented from SAR data processing reveal the co-seismic deformations in the region, which are in good agreement with data from other studies and from the modelling using the Okada method. The main task is to demonstrate operational readiness to determine the degree of deformation of the Earth's surface, and to prepare displacement maps that could be used by large number of experts. The applied processing methodology, employed by the authors, has successfully generated Interferometric Images that visually depict the displacements around the epicenters. The presented example demonstrate the application of space technologies such as InSAR for researching and monitoring seismogenic zones, highlighting their importance and advantages in establishing patterns in the movements within these zones. The interpretation of space distribution and co-seismic deformation of major earthquakes also provide insights into the geodynamic and tectonic processes.**