Study of co-seismic deformations of the earth's crust for the territory of the Balkan Peninsula

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The Balkan Peninsula is located in the Alpine-Himalayan seismic zone - the second most active in the world, making it prone to earthquakes. At the beginning of the twentieth century several destructive earthquakes with a magnitude above 7.0 have occurred in Bulgaria, which is located on the northern side of the region. Resent stronger shocks have been recorded around the Hellenic arc and less frequently in the continental part of the region. Earthquakes are a natural disaster that causes damage measured in terms of human lives and infrastructure destruction. In recent decades, satellite SAR technologies have made it possible to track surface deformations caused by earthquakes, volcanoes, landslides

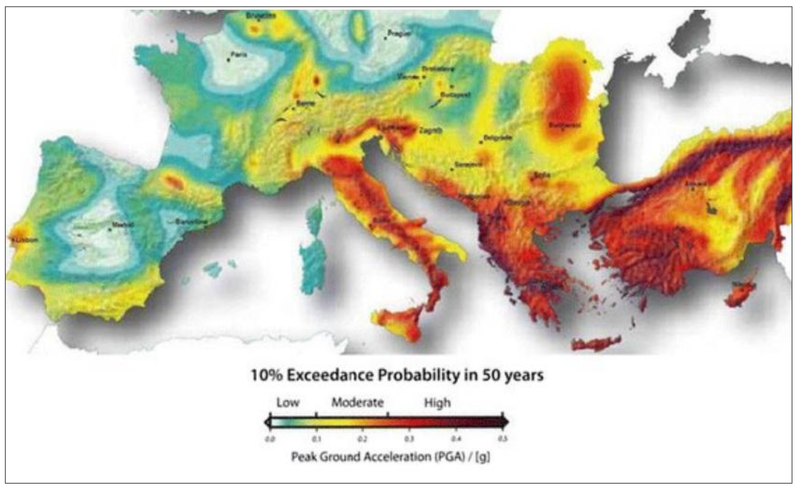


Fig. 1. Seismic hazard map of Europe

The new research technologies could help in a preparation plan to overcome the consequences of future events. In this study, we focused our research on determining the surface deformations after several earthquakes of magnitude gather than 6.5 in the last 5 years along the Hellenic Arch. The presented results from SAR data processing reveal the co-seismic deformations in the region, which are compared and well agree with GNSS data from other studies. The main task is to demonstrate operational readiness, to determine the degree of deformation of the earth's surface, and to prepare displacement maps.

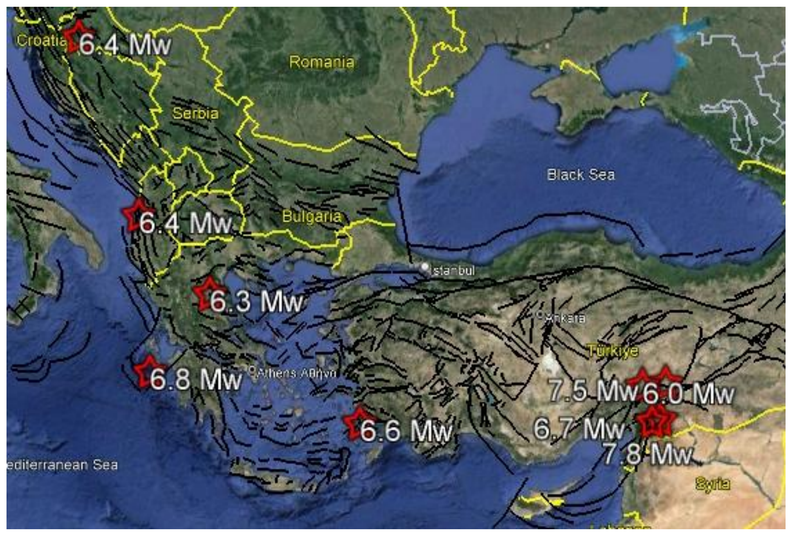


Fig. 2.. Locations of the epicentres of the studied earthquakes, their magnitudes and the main faults.

Table 1. Seismic events with a magnitude greater than 6.0 studied for the region of the Mediterranean Seismic Zone

N	Name	Latitude Longitude	Mw	Dates, time/UTC
1	Kos-Bodrum Greece-Turkey	36.96 N 27.45 E	6.6	July 20, 2017
2	Zakynthos Ionian Sea	37.53 N 20.62 E	6.8	October 25, 2018 22:54
3	Durast - Albania	41.38 N 19.47 E	6.4	November 26, 2019
4	Petrinya -Croatia	45.42 N 16.12 E	6,4	December 29, 2020
5	Larissa - Greece	39.76 N 22.21 E	6.3	March 03, 2021
6	Larissa - Greece	39.80 N 22.20 E	6.1	March 04, 2021
7	Turkey-Syria	38.07 N 36.47 E	6.0	February 6, 2023 12:02
8	Turkey-Syria	38.11 N 37.24 E	7.5	February 6, 2023 10:24
9	Turkey-Syria	37.13 N 36.81 E	6.7	February 6, 2023 01:28
10	Turkey-Syria	37.17 N 37.08 E	7.8	February 6, 2023 01:17

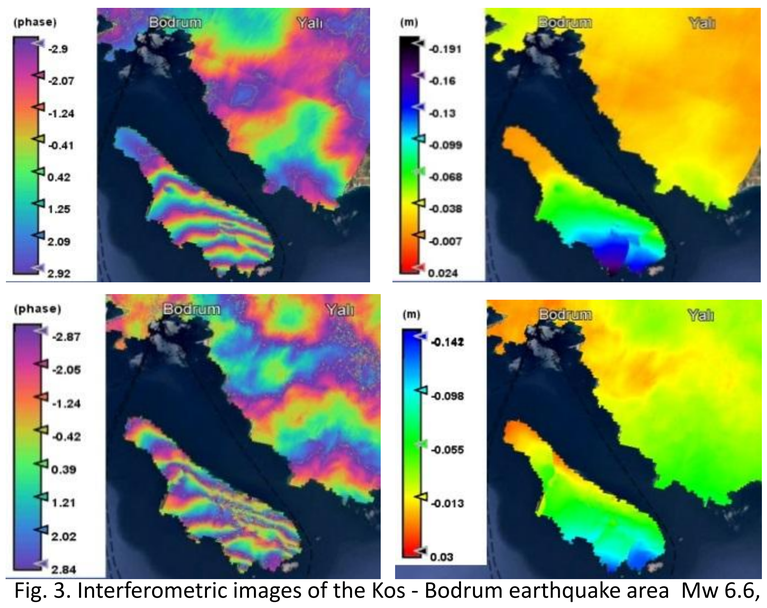
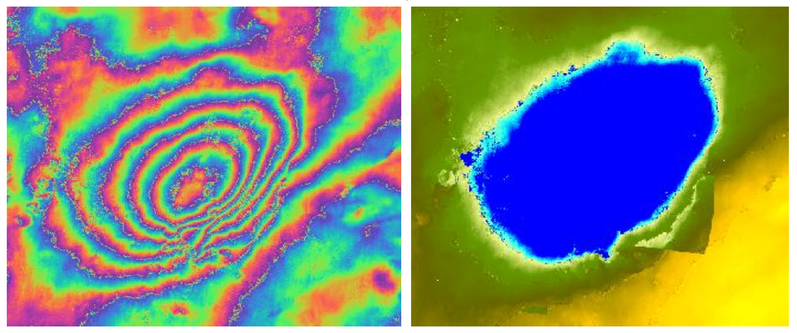


Fig. 3. Interferometric images of the Kos - Bodrum earthquake area Mw 6.6, ascending orbit 131, 12.07-24.07. 2017 and descending orbit 36, 18.07-30.07.2017 deformation map LOS direction



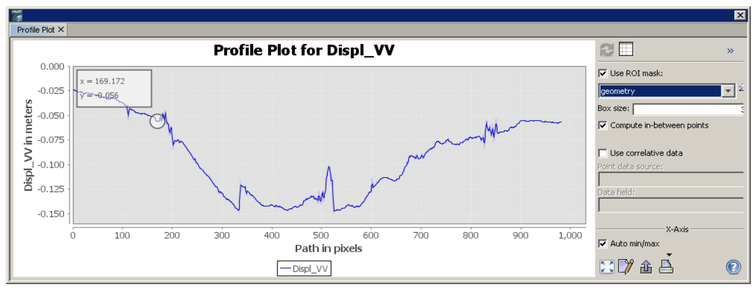


Fig. 4. Interferometric images of the Crete descending orbit 19Sep2021_01Oct2021, deformation map LOS direction and profile displacement

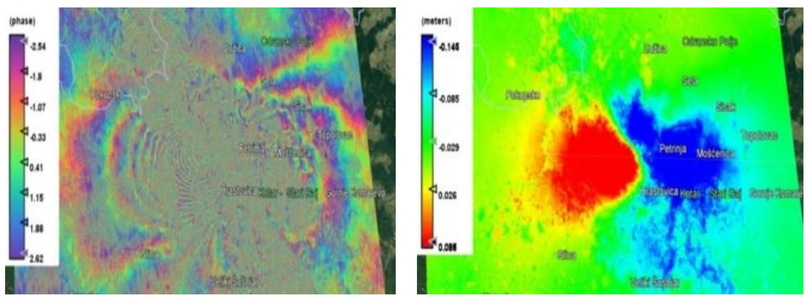


Fig. 5. Interferometric image of the Petrinja - Croatia earthquake area on 29 Dec., 2020 ascend. orbit and deformation map along the LOS direction

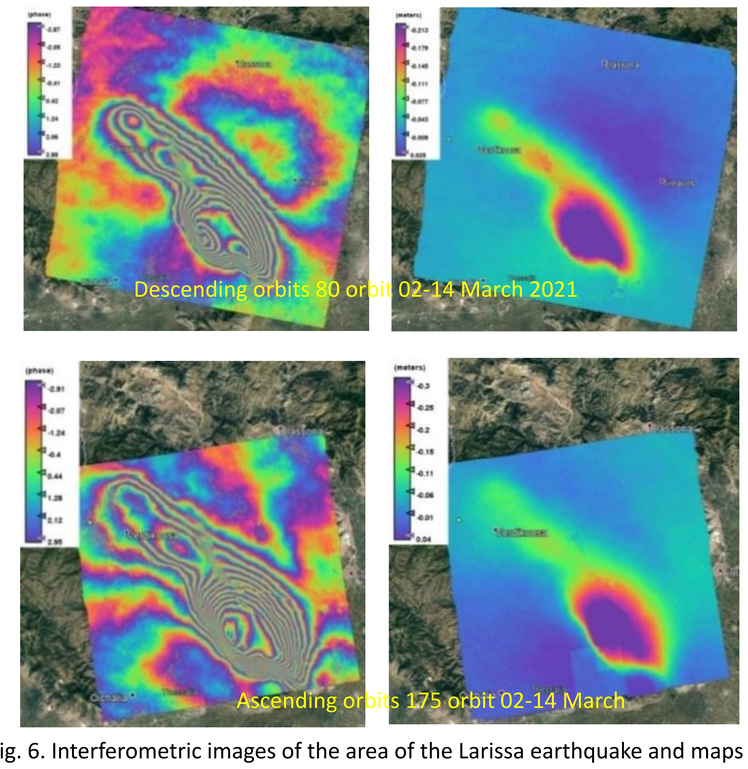


Fig. 6. Interferometric images of the area of the Larissa earthquake and maps of the deformations along the LOS direction determined by the two types of orbits

The main data sources used are SAR products from the Sentinel-1 mission satellites. By processing data using the DInSAR method, greater spatial coverage is provided. Their large territorial coverage has allowed the production of maps that reveal the extent of disturbances on the Earth's surface.

The latest presented results obtained as a result of the processing of SAR data, based on which movements of the earth's surface caused by the series of earthquakes that occurred in the border region between Turkey and Syria were detected. The latest challenge is to record the deformations of the vast areas, following the two devastating earthquakes of magnitude M 7.8 and M 7.5 on February 6, 2023 (see Fig. 8 and Fig. 9). The earthquake was followed by intense aftershocks, the effect of which was proven after interferometric processing of SAR data from the European Space Agency's Sentinel-1 mission and revealed the size of the affected area and the magnitude of the deformations that occurred after the earthquakes. The created maps are combined data from several sources, with event epicenters from EMSC and active faults from EDAF both considered to be the driving forces of these SAR data ground motions , used to obtain information indicating the actual surface displacements. It should be emphasized that the mentioned information does not reflect the consequences of a single seismic event, but the effect of all earthquakes that occurred in the studied region between the dates of registration by the SAR instrument.

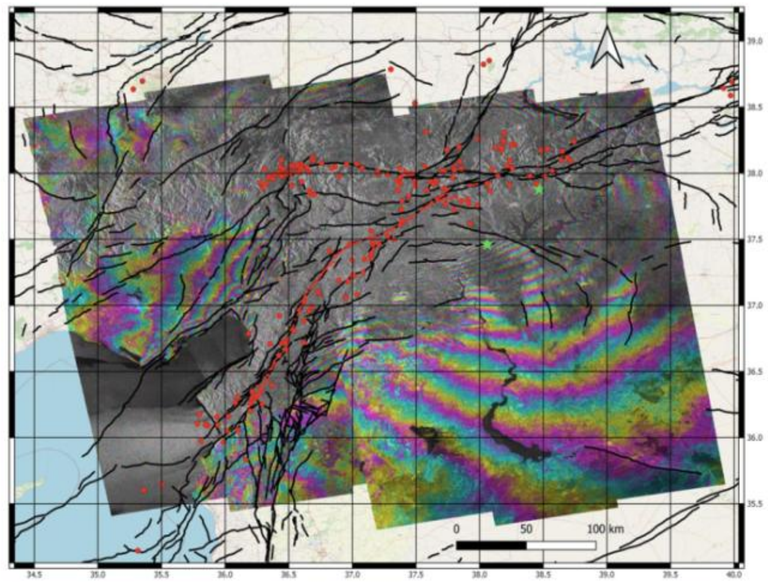


Fig. 7 Interferometric images of the area of the Turkey earthquake - ascending orbit, event epicenters from EMSC

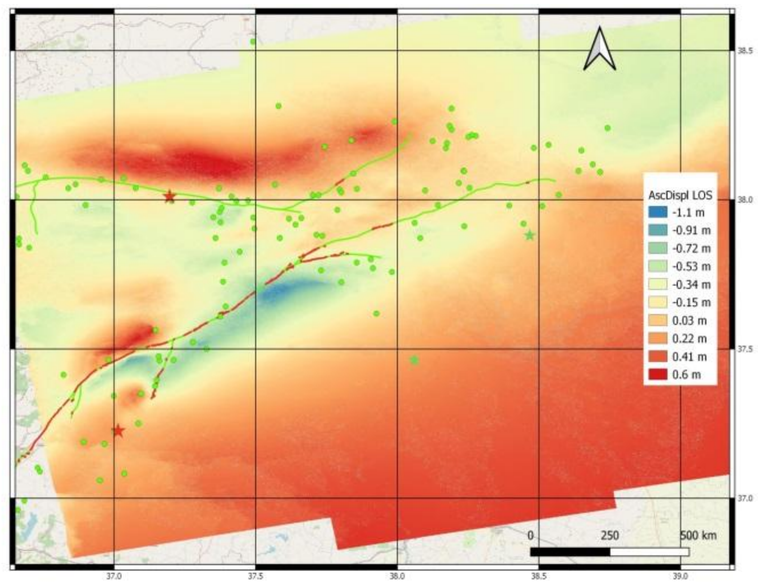


Fig. 8 Registered deformations by SAR data from an ascending orbit, earthquake area and epicenters February 6, 2023,
Lines - active faults from EDAF

Conclusions

From the presented results after processing the SAR data using the InSAR method, it can be concluded that they are an additional source of information about the deformations of the earth's crust that have occurred due to earthquakes. The good compliance between InSAR maps, FPS and regional tectonics shows that the SAR method is reliable and very useful source of information. Their advantage is that this information is obtained for large areas and in a relatively short time after the event, which supports the preparation of maps to overcome it's consequences and update the preparation plans in future strong events in same area. The processing methodology applied by the authors made it possible to obtain IFIs that visually represent the displacements around the epicentres.

Acknowledgments:

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