ON THE RELATIONSHIP BETWEEN GROUND MOTION BASED ON InSAR DATA, THE 2021 EARTHQUAKES IN GREECE AND THE COSSEISMIC PHENOMENON

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The aim of the study was to find a connection between slow movements and earthquakes in a seismically active region. The connection between fast (earthquakes) and slow (tectonic creep) motions is important in terms of searching for earthquake precursors. The study of such a connection based on an integrated approach that combines high-density geodetic observations (GNSS or SAR) and seismological information [1].

The initial information for assessing slow motions was data from the Copernicus Earth observation service, part of the *European Union's Space Programe*. The Ortho 2019-2023 vector product for ascending and descending orbits of the *European Ground Motion Service* used. Ground motion parameters (velocities and displacements) in the vertical direction and in the horizontal direction (east west) for different azimuths from the earthquake epicenter obtained using the InSAR (*Interferometric Synthetic Aperture Radar*) method.

The research object is located in Greece. The territory of Greece is a seismically active region where strong earthquakes occur. The main shock with a magnitude of M_w 6.3 (20210303-101609) and subsequent aftershocks occurred in northern Thessaly (central Greece). The seismotectonic setting in the research area characterized by the predominance of extension in the north-south direction. In the central part of the research area, the faults have a normal faulting mechanism and form a graben-like structure [2].

Among 19 aftershocks with magnitudes greater than 3.7, the first aftershock (20210304-183820) with a magnitude of M_w 6.0 occurred one day after the main shock. The main shock and the first aftershock were the strongest earthquakes in this area since 1941. The mechanism of the analyzed earthquakes is predominantly of a normal faulting. However, among 19 aftershocks there are earthquake focal mechanisms with a strike-slip component: *Normal Right-Lateral Oblique, Normal Left-Lateral Oblique*.

Because of the main shock impact and possibly also under the influence of the first aftershock, a depression zone (Fig. 1) of about 123 km^2 (16 x 10 km) in size was formed as result of coseismic and/or early post-seismic subsidence phenomenon. The zone extends in the northwest-southeast direction and surrounded by the *Larisa* and *Tyrnavos* faults in the northeast and the *Pineias* fault in the south - southeast. The planes of the first two faults dip to the northeast, and the third fault dips to the southeast [2]. In the central part of the depression zone, the maximum vertical subsidence velocity reached 128 mm/year, and the sharp displacement after the main shock reached 131 mm (as of 20210303). Subsequent subsidence occurred due to aftershock activity and subsequent aseismic creep, and reached 425 mm in October 2023 (2023-1007). The maximum horizontal velocity in the east-west direction reached 56 mm/year. The amplitude of a sharp change in the direction of displacement from west to east occurred on March 3, 2021 and reached 285 mm.

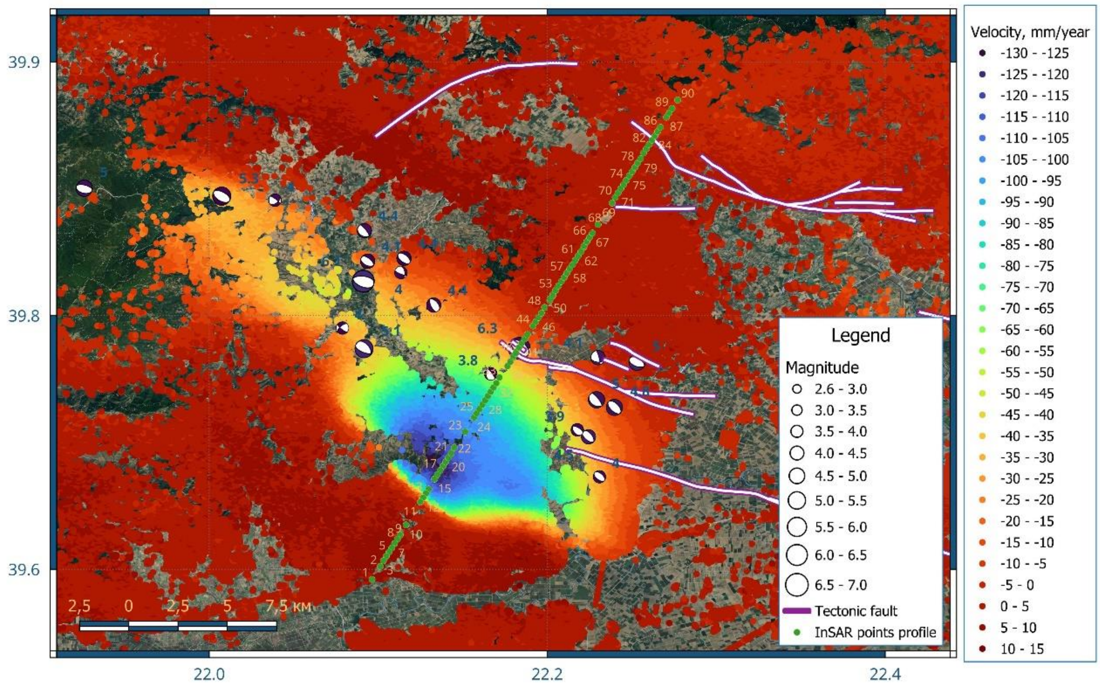

Fig. 1. Seismotectonic setting and vertical motion velocities after the earthquake of 03.03.2021 (10:16:09 GMT) with magnitude of M_w 6.3 in Greece

The gradient zone of ground displacement velocities well revealed based on vertical velocities and much weaker based on horizontal velocities. The gradient zone can be an indicator of a fault zone oriented from northwest to southeast with an azimuth of about 140º.

The orientation of maximum horizontal stresses is important for understanding the dynamics of the earth's crust. The orientation of the P-axes of the earthquake focal mechanisms allowed us to estimate of indirectly the directions of horizontal stresses. The parameters of the P-axes (azimuth and angle of incidence) obtained based on the solution of the focal mechanisms of the main shock and the 19 subsequent aftershocks. The orientation of horizontal stresses supplemented by an estimate of their conditional value. This parameter gives an idea of the stress-strain state of the geological environment and shows the influence (contribution) of earthquakes on the process of depression zone formation.

The *Coulomb* stress variation on adjacent receiving faults estimated. The main shock stress release at its source contributed to the occurrence of increased stress at both ends of the *Tyrnavos* fault. The proposed *Coulomb* stress variation model showed an increase in stress at the northwestern end of the *Tyrnavos* fault, where the first strongest foreshock with a magnitude of M_w 6.0 occurred.

Conclusions

1. The main shock 2021/03/03 (10:16:09 GMT) led to the formation of a depression zone, in which the subsidence process continued until October 2023 probably due to foreshock seismic activity and tectonic creep.
2. The depression zone identified using the InSAR synthetic aperture interferometric method based on vertical velocity of ground motion data.

3. The band with a high gradient of change in the velocity of vertical ground motions according to InSAR data in the southwestern part of the depression zone may be an indicator of an active tectonic fault extending for a distance of about 10 km from northwest to southeast at an azimuth of approximately 140º.

References:

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