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Ground Deformation Study of the Ionian Islands (W. Greece) Based on Continuous GNSS Measurements

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Abstract

Seismicity accompanied with intense ground deformation in the Ionian Sea (W. Greece) is mainly generated along the Cephalonia-Lefkada Transform Fault Zone (CLTFZ), in the central Ionian, and on the northwestern termination of the Hellenic subduction margin in the south. Pre- co- and post-seismic ground deformation analysis is performed at the broad Ionian area, aiming to homogeneously study the spatiotemporal evolution of the ground deformation prior to and after the occurrence of strong (M > 6) earthquakes during the last decade. The 2014 Cephalonia earthquakes (Mw6.1 and Mw5.9) were generated on a faulting system adjacent to CLTFZ, causing local ground deformation. Co-seismic displacement was recorded in the broader area after the 2015 Lefkada earthquake. The 2018 Zakynthos earthquake (Mw6.7) caused regional deformation and, alterations on the near- velocity field. In the northern Ionians, con-vergence between the Apulian platform and the Hellenic foreland occurs, exhibiting increased velocity vectors on the local GNSS sites, with respect to the southern Ionian stations.

Introduction

The area of the Ionian Islands in western Greece plays an important role in the kinematic processes of the eastern Mediterranean. This tectonically complex area is by far the most seismically active region in Greece and among the most seismogenic regions in Europe. It is characterized by the frequent occurrence of destructive large earthquakes. The area undergoes intense ground deformation. The central Ionian Islands constitute part of the Eastern Mediterranean lithosphere that is subducted beneath the Aegean lithosphere along the Hellenic Arc.

Three major tectonic features in the Ionian Islands define the regional kinematic field and control the seismic activity: the convergence of the Apulian Platform and the Hellenic foreland in the north; the long NNE–SSW Cephalonia–Lefkada Transform Fault Zone (CLTFZ) offshore and west of the respective islands in the central part; and the northwestern tip of the Hellenic Arc in the southern Ionian Sea. These major structures, together with smaller local faults, create a complex tectonic environment generating intense seismic activity and strong ground deformation. During the last decade, and mainly during the period between 2014 and 2018, increased seismicity was observed, and strong events (M > 6.0) shocked the central Ionian Islands, in 2014 in Cephalonia, in 2015 in Lefkada and in 2018 in Zakynthos Islands. The regional crustal motion along the entire Ionian Sea and western Greece, as well as the local deformation on the central Ionian Islands, have been studied and monitored with local dense Global Positioning System (GPS) networks and continuous Global Navigation Satellite System (GNSS) stations (e.g. Sakkas et al., 2022).

The present work presents an overview of the ground deformation in the broad area of Ionian Sea, extending from Corfu Island to the north to Strofades Islet in the south. The time span of the data covers the period before, during and after the occurrence of the strong 2014 to 2018 earthquakes. Pre-, co- and post-seismic deformation is quantitatively described, aiming to understand the pattern of the ground motion associated with the recorded seismicity. The geodetic data from the commercial and institutional continuous GNSS networks in the area were used on the framework of this study.

GNSS Data

Daily GNSS data from stations located in the Ionian Islands and the western mainland Greece and the Peloponnese were processed for the period from 2009 to 2022. The analysis intended to determine the crustal velocity field of the broad area, detect possible pre-seismic displacements and study co- and post-seismic deformation. The continuous GNSS stations belong to National Observatory of Athens (Ganas et al., 2008; Chousiantitis et al., 2021), to National and Kapodistrian University of Athens (Sakkas and Lagios, 2017), to PPGNET (Czech GEO/EPOS) and to commercial network of METRICA SA (HexagonSmartNet). The raw GNSS data were processed using the Bernese v5.2 software. The processing resulted in the estimation of high-precision station coordinates. Time series were formed, annual velocities were calculated (Figure 1) and co-seismic displacements were determined.

Together with the continuous GNSS stations in the Ionian Islands, stations located to in western mainland Greece and western and northwestern Peloponnese were also processed. The goal was to study the velocity field, ground deformation

and differential motions in the broad region of the Ionian Sea, focusing to on the area close to the highly activated central Ionian Islands.

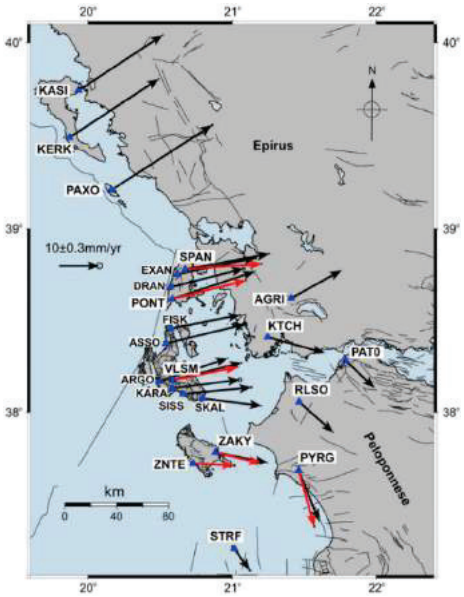

Figure 1. Horizontal velocity vectors (black arrows) for the continuous GNSS sites (blue triangles) of the broad Ionian Islands area. Red arrows indicate the horizontal velocity component estimated for the period after the strong (M>6) earthquakes in the area (ITRF 2014)..

GNSS Results

In the north Ionian Sea, where the collision between the Apulian platform and the Hellenic foreland is taking place, the velocity field of the area, deduced by GNSS stations on Corfu and Paxoi Islands, shows horizontal NW motion, transverse to the collision front. The vertical component reveals a subsiding pattern, compatible with the convergence process in the area.

The CLTFZ feature offshore of the central Ionian Islands of Cephalonia and Lefkada is the prevailing structure, generating the strong and intense seismic activity observed in the region. The 2014 Mw6.1 and Mw5.9 Cephalonia earthquakes occurred on an adjacent local faulting zone, causing strong ground displacement on the island but not in the broader area. Few months later, on 17 November 2015, another strong earthquake (Mw6.4) occurred on or parallel to the Lefkada segment of the CLTFZ. Co-seismic displacement was recorded in almost all the southern Ionian Islands, highlighting the regional character of the seismogenic source. The temporal evolution of the post-seismic ground deformation shows a long relaxation period.

The October 2018 Mw6.7 Zakynthos earthquake occurred close to the northwestern tip of the Hellenic Arc. Strong ground displacement took place on the near-field GNSS stations, as well as on Cephalonia Island and the Peloponnese. The motion field of the stations in Zakynthos and the western Peloponnese showed significant alterations with respect to the pre-seismic period, on both north and east motional components, which regained its anticipated pattern about eight months after the mainshock.

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