The Aitolo-Akarnania (Western Greece) GNSS network PPGNet – first results

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ABSTRACT

At the Aitolo-Akarnania prefecture, western Greece, strong earthquakes have occurred, and large active faults have been mapped. The most significant faults include the Katouna sinistral strike slip fault and the Trichonis Lake normal fault system. Proximity of these faults to large cities, as well as lack of information related to their seismogenic potential calls for detailed monitoring. Since 2013 crustal deformation in the area, is monitored by a dense GPS network. The GNSS Network PPGNet consists of five stations in Aitolo-Akarnania, equipped with Leica and Septentrio receivers. Data are recorded using two sampling frequencies, 1 Hz and 10Hz and hourly and daily files are produced. Daily data are processed using the Bernese GNSS Processing Software using final orbits of the International GNSS Service. The double-difference solution is computed using data from the PPGNet network data complemented by four stations from the GNSS network of National Observatory of Athens and six stations from METRICA network.

The first results show a NNE movement of PVOG station at 12 mm/y and a similar movement of RETS station at about 9 mm/y. This means that the Trichonis Lake normal fault system, that is located between these two stations, depicts a slip rate of 3 mm/y. The KTCH and RGNI stations move eastwards at a velocity of about 5 mm/y.

It is expected that data from PPGNet will provide valuable information on the Aitolo-Akarnania area internal deformation and eventually will help us understand how this deformation is linked to the major active structures in the broader area.

Introduction

Greece is an earthquake prone country located at the convergence boundary between Nubian and Eurasian plate (Fig. 1). The fast convergence rate, ~30mm/y at southern Greece and Aegean Sea, is transformed to crustal collision in northwestern Greece and Adriatic Sea. This transition is accomplished through the Cephalonia dextral strike slip fault located in the Ionian Sea (Louvari et al., 1999; Pearce et al., 2012).

To the east of the Ionian islands and in the central Greece area, crustal extension in a NS direction dominates. A major tectonic element in this area, is the Corinth Gulf rift, which is a fast-extending continental rift (~15mm/y) (Avallone et al., 2004, Bernard et al.,2006) (Fig.1).

The area west of Corinth Gulf rift appears to be a “triple junction” with the E-W normal faults of Corinth Rift to the east, the NW-SE striking, Katouna-Stamna fault system (KSF) (Haslinger et al., 1999), and the Trichonis Graben to the north, at the Aitolo-Akarnania area (Kiratzi et al, 2008), and the Achaia-Elia (AE) strike-slip fault, of NE-SW direction to the south (Serpetsidaki et al., 2014). These fault systems are connected to the Kefalonia-Lefkada fault system, and the subduction at the southwest, bounding a crustal block that seems internally undeformed.

Recently, Pérouse et al., 2017 proposed the existence of a microplate in the area i.e. the Ionian Islands-Akarnania Block (IAB), based on GPS and tectonic data. Based on the above it is clear that Aitolo-Akarnania is a key area for understanding the deformation pattern in Western Greece. Chousianitis et al, 2015 using a high-quality dataset of ~100 continuous GPS stations in Greece, identified a shear zone in Aitolo-Akarnania in a NW-SE direction, compatible with the KSF fault system. Moreover, they compared the geodetic and seismic moment rates and found a large deficit of the seismic moment rate. This can be attributed either in lack of events from the seismic catalog or to aseismic behavior of the fault zone. These results are compatible with the findings of Perouse et al., 2012.

Although the rough characteristics and the main tectonic elements in the area have been recognized, there is a lack of continuous and dense monitoring of the crustal deformation in the area.

Since 2013 this is monitored by a network of five GNSS stations (PPGNet), complementary to permanent seismic network. The main purpose of PPGNet is to densify the regional GPS network and monitor the crustal deformation, in order to investigate further the existence of the IAB microplate and elucidate the role of the active faults in the area.

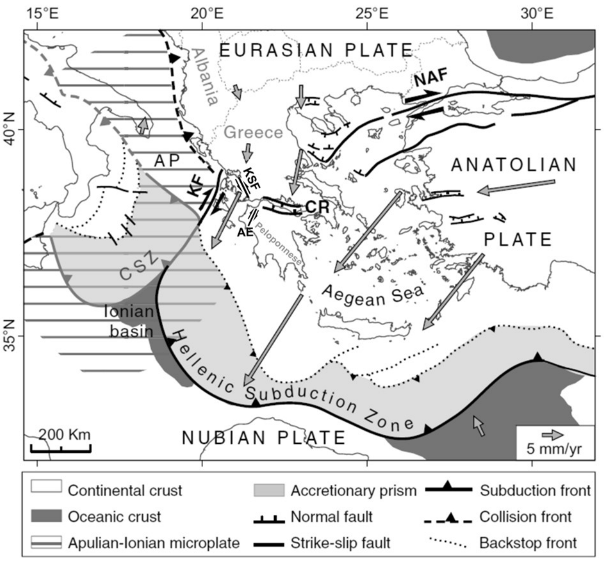

Figure 1: Geodynamic setting of Greece AP: Apulian Platform; CR: Corinth Rift; CSZ: Calabrian Subduction Zone; KF: Kefalonia Fault; NAF: North Anatolian Fault, KSF: Katouna-Stamna fault, AE: Achaia-Elia fault, modified from Pérouse et al., 2017.

PPGNet – Station Status

The main active tectonic elements in Aitolo-Akarnania are the Katouna sinistral strike slip fault and the Trichonis Lake normal fault system. In Fig.2 a simplified tectonic map of the area is presented. Major events, for the time period 1900-2010, with M>5.5 are taken from Papazachos et al, 2010. Seismicity is of course, denser in the Ionian islands (Lefkada and Cephalonia), where catastrophic events have occurred in the past.

Nevertheless, strong events have occurred in Aitolo-Akarnania also. These events are clearly connected with the Trichonis Lake faults or with the northern part of the Katouna - Stamna fault. Their magnitude is close to 6Mw or slightly larger, thus oppose a significant treat for the major cities in the area (Fig.2).

What is surprising and important for the seismic hazard of the region, is the absence of strong events in the central – south part of the Katouna - Stamna fault. This could be attributed to the large return period of events in this part of the fault system or in the creeping behavior of the fault as suggested by Pérouse et al., 2017.

Since 2013 crustal deformation in the area, is monitored by a network of five GNSS stations, complementary to permanent seismic network. The GNSS Network PPGNet consists of five stations in Aitolo-Akarnania (Fig. 3), i.e. Katochi, (KTCH), Lepenou (LEPE), Paravola (PVOG), Rigani (RGNI) and Kato Retsina (RETS) and one station in south-west Peloponnese peninsula i.e. Valyra (VALY).

The instruments are owned by the Charles University of Prague and the Research Institute of Geodesy, Topography and Cartography, Czech Republic. Station operation is managed by the Seismological Laboratory of University of Patras, Greece.

Stations are equipped by Leica, Septentrio and Trimble instruments. The Septentrio and Trimble receivers produce GPS NAVSTAR data only. Data are stored in RINEX format using two sampling frequencies, 1 Hz for stations RETS, RGNI, VALY and 10Hz for KTCH, LEPE and PVOG. Hourly and daily files are produced, and the daily files with 30 seconds sampling interval are freely available. Data with 10Hz sampling are available upon request in the frame of CzechGeo/EPOS project.

Data quality plots are produced automatically, in a daily basis, using TEQC software https://www.unavco.org/software/data-processing/teqc/teqc.html (Fig. 4). These plots provide a first indication of the data characteristics and assist in data quality management.

Basic network information is listed in Table 1. It describes the state of the PPGNet network up to December 2017.

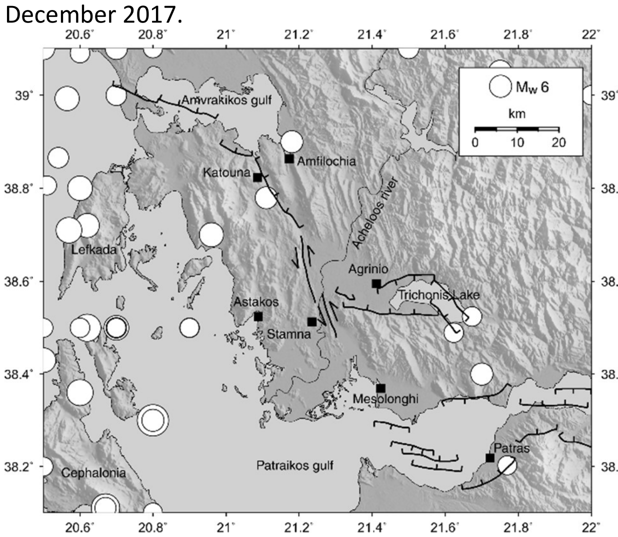

Figure 2: Tectonic map of Aitolo-Akarnania. The Katouna – Stamna sinistral fault and the Trichonis lake normal faults are shown. Seismicity is taken from Papazachos et al, 2010, (time period 1900-2010, events with M>5.5 are presented). Major cities are also shown. The simplified fault traces have been taken from Pérouse et al., 2017.

Table 1: Station code, approximate location and equipment details for PPGNet stations

Code	Latitude	Longitude	Height (m)	Receiver / Antenna type
KTCH	38 24'42"	21 14'49"	64	Leica GR10 Leica AR10
LEPE	38 42'35"	21 17'24"	222	Leica GR10 Leica AR10
PVOG	38 36'50"	21 31'24"	114	Leica GR10 Leica AR10
RETS	38 25'44"	21 25'46"	374	Septentrio PolaRx2 Trimble Zephyr Geodetic
RGNI	38 34'54"	21 14'19"	112	Septentrio PolaRx2 Trimble Zephyr Geodetic
VALY	37 09'50"	21 59'01"	56	Trimble 4700 Trimble Choke Ring

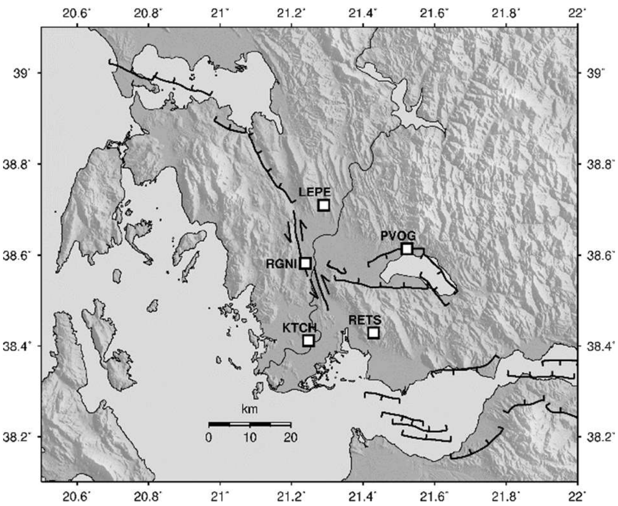

Figure 3: Station location of the GNSS Network PPGNet in Aitolo-Akarnania, in relation to active fault systems in the area. The simplified fault traces have been taken from Pérouse et al., 2017.

Processing of the Network

Daily data are processed using the Bernese GNSS Processing Software version 5.0 (Dach et al., 2007).
For the processing automation, the Bernese Processing Engine was used with complementary scripts from EPN (EUREF Permanent Network www.epncb.oma.be) local analytic center Geodetic Observatory Pecny (GOP).
The processing strategy is based at good practice defined during long term processing of EPN subnetworks. Processed network consists of all six stations of PPGNet, complemented by four stations, namely PLAT, PYLO, RLSO and SPAN from the GNSS network of the National Observatory of Athens (http://www.gein.noa.gr/services/GPS/noa_gps.html) and six stations AGRI, KALM, KARP, KOPA, PATR and PYRG from METRICA network (https://www.metrica.gr/).

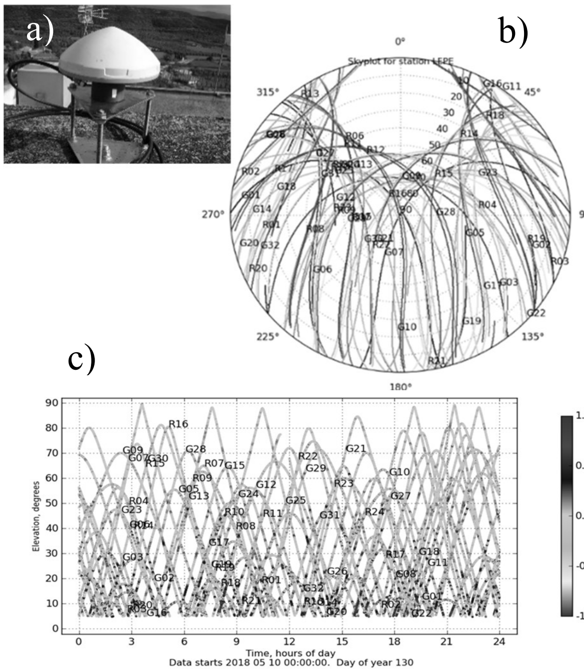

Figure 4: a) Antenna installation in station LEPE, b) skyplot example and c) time-elevation plot example of multipath, for station LEPE

As fiducial sites, we used 9 Class A stations of EUREF Permanent Network (AUT1, COST, DUB2, DUTH, GOPE, MATE, ORID, SRJV, USAL). Data from the GPS NAVSTAR system only at elevation above 3 degrees were used because we do not have GLONASS data from all processed stations. Input data in RINEX format with sampling interval of 30s in time period from 2013-11-20 till 2017-10-01 were processed. From all stations we obtained data from more than two years. The IGS05 system with minimum constraint (only translations) to fiducial sites was used for refence system definition, final coordinates are in IGS05 system in epoch of measurement. Final orbits of the International GNSS Service in the ITRS coordinate system were used for satellite positions. The absolute antenna phase centers model was used at all stations, individual model was used on the stations when available.

The processing method was the double differenced observation with minimum baseline counts. Quasi-Iono Free (QIF) method was used for ambiguity strategy which also eliminate the ionospheric refraction error by the iono-free L3 linear combination of the L1 and L2 frequencies of observation. The tropospheric refraction was modelled in two steps. The dry part was determined by a priori Niell model, the wet part was computed by Niell model with estimated parameters – zenith troposphere delay one per hour and troposphere gradients one per day. Average repeatability of daily solutions was around 1.5 mm in horizontal coordinate components and up to 6 mm in vertical component.

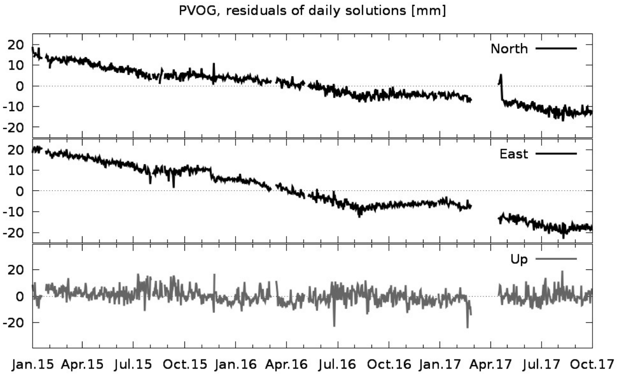

Figure 5: Example of coordinate time series for station PVOG. Residuals from average coordinates are displayed: Top panel, north component, middle panel east component, bottom panel up component. A slope and periodicities are clearly visible in north and east components.

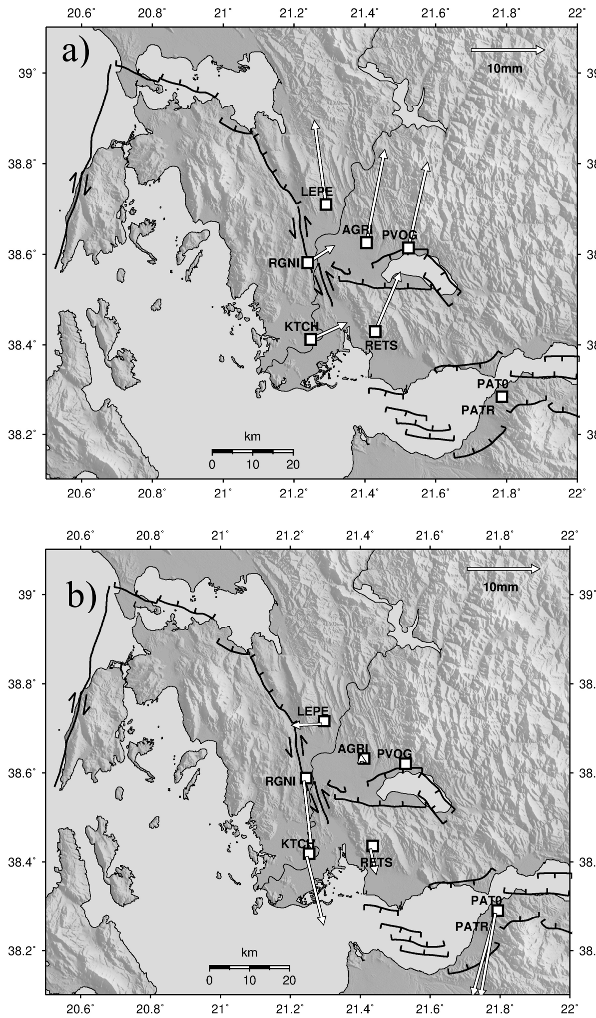

Figure 6: First results of the PPGNet, a) arrows denote relative movement of stations with respect to fixed PATR/PAT0 stations, b) relative movements with respect to fixed PVOG station, black lines indicate the main active faults in the area. The simplified fault traces have been taken from Pérouse et al., 2017.

Coordinate time series were checked for searching of jumps and yearly periodicities (Fig.5). The velocities (changes of coordinates in time) were fixed to Patras/Rio GNSS stations PATR/PAT0 (to the average of velocities of both stations) for first solution shown in Fig. 6a. For better description of fault movements in the area of KFZ fault zone, the second solution (Fig. 6b) of velocities was fixed to Paravola GNSS station PVOG.

Conclusions

The PPGNet scope is the study of the tectonic deformation in Aitolo-Akarnania Perfecture, in Western Greece, using GNSS data. It is believed that the data from PPGNet will provide valuable information on the Aitoloakarnania area internal deformation and eventually will help us to understand how this deformation is linked to the major active structures in the broader area. The first results are based on processing of coordinates of GNSS stations from years 2013 – 2017. Time series of coordinates were analyzed and the velocities (changes of coordinates in time) and periodicities were determined.

These first results (Fig. 6a, b) show a NNE movement of PVOG station at 12 mm/y and a similar movement of RETS station at about 9 mm/y (with respect to the PATR/PAT0 stations in Partas/Rio). This means that the Trichonis Lake normal fault system, that is located between these two stations, depicts a slip rate of 3mm/y.

The KTCH and RGNI stations move eastwards at a velocity of about 5 mm/y. Accuracy of determined velocities from time series longer than 2 years will be better than 1 mm/y. Keeping PVOG fixed (Fig.6b) stations RGNI and KTCH depict a SSE movement, while station RETS moves to the same direction but with significant smaller velocity. These motions are in accordance with the Katouna sinitral strike slip fault, while similar motion of RGNI and KTCH further supports the existence of a rigid block in the area.

It is believed that data from PPGNet will provide valuable information on the Aitolo-Akarnania area internal deformation and eventually will help us understand how this deformation is linked to the major active structures in the broader area.

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Appendix

Table of data with components in millimeters per year

Station	Location	Components in millimeters per year					
				Reduced to PATR/PAT0		Reduced to PVOG	
		North component	East component	North component	East component	North component	East component
AGRI	Agrinio	-7,86	-13,83	12,625	2,495	1	-0,12
KTCH	Katochi	-18,23	-11,39	2,255	4,935	-9,37	2,32
LEPE	Lepenou	-9,07	-17,91	11,415	-1,585	-0,21	-4,2
PAT0	Patras	-20,35	-16,87	0,135	-0,545	-11,49	-3,16
PATR	Patras	-20,62	-15,78	-0,135	0,545	-11,76	-2,07
PVOG	Paravola	-8,86	-13,71	11,625	2,615	0	0
RETS	Kato Retsina	-12,39	-12,9	8,095	3,425	-3,53	0,81
RGNI	Rigani	-18,18	-12,65	2,305	3,675	-9,32	1,06