СОФИЙСКИ УНИВЕРСИТЕТ ФИЗИЧЕСКИ ФАКУЛТЕТ
КАТЕДРА МЕТЕРИОЛОГИЯ И ГЕОФИЗИКА

ЧЕТВЪРТИ НАУЧЕН СЕМИНАР

Регистриране на хоризонтални и вертикални премествания настъпили вследствие на сеизмични събития по ГНСС данни на Балканите

доц. Мила Атанасова

Въведение

Косеизмични са онези премествания, които се получават по време на (силно) сеизмично събитие и имат проявления на повърхноста на земната кора в точки в близост до епицентъра на събитието.

Косеизмичните премествания се определят основно с методите на спътникови наблюдения.

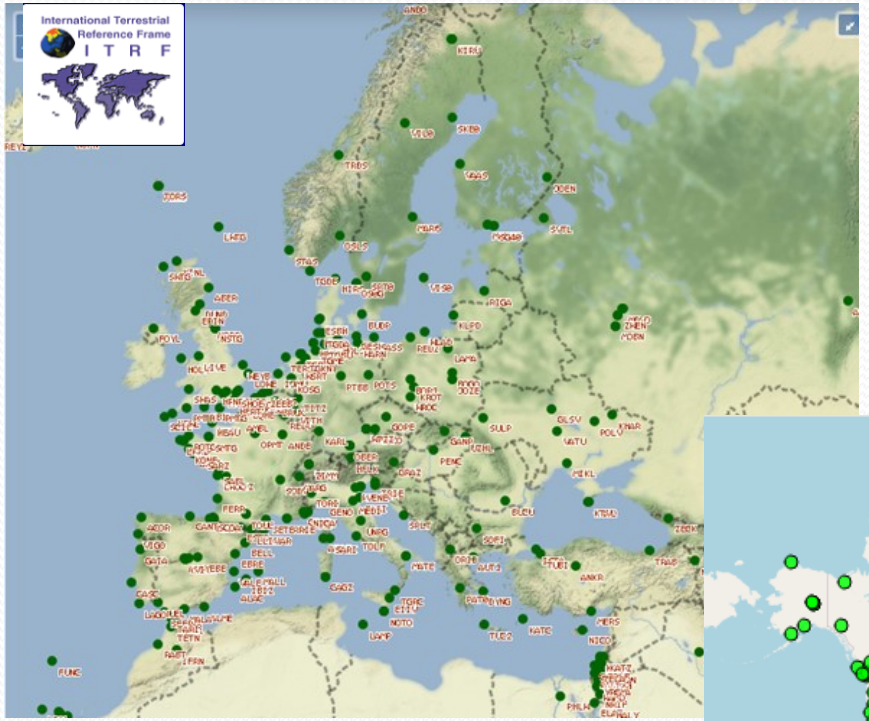
Най-разпространенО се използват данните от Глобалните навигационни системи GNSS (Global Navigation Satellite Systems) – GPS, Galileo и GLONASS. Прилага се много успешно през последните години и DinSAR технологията

Introduction

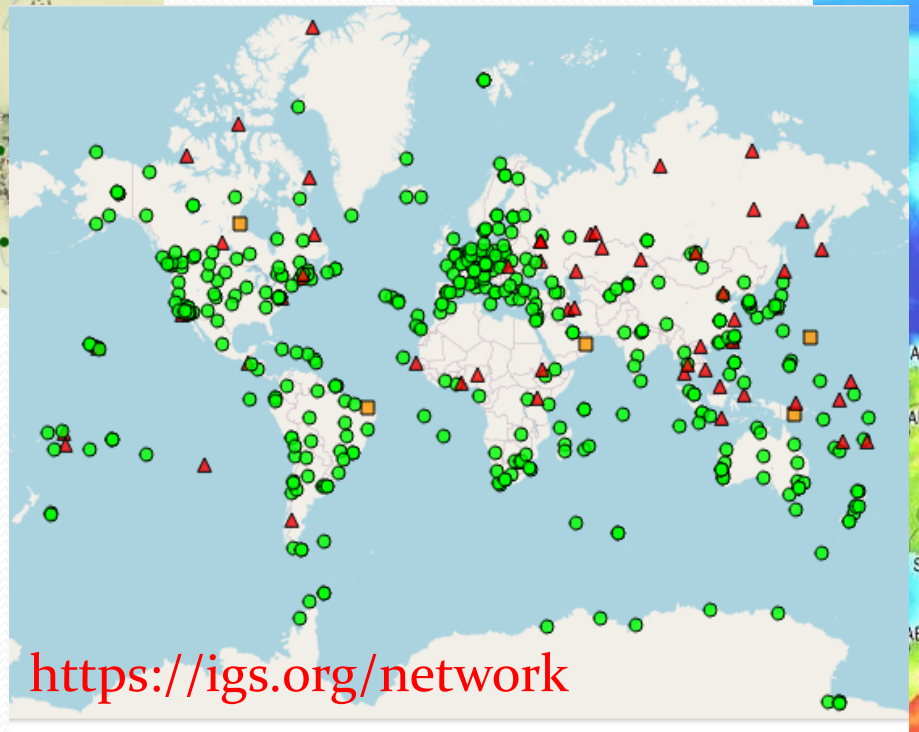
Coseismicl displacements are those, that occur during a (strong) seismic event and have manifestations on the surface of the earth's crust at points near the epicenter of the event. Coseismic displacements are mainly determined by satellite observation methods. The GNSS (Global Navigation Satellite Systems) data from GPS, Galileo and GLONASS - are most widely used.
DinSAR technology has also been applied very successfully in recent years

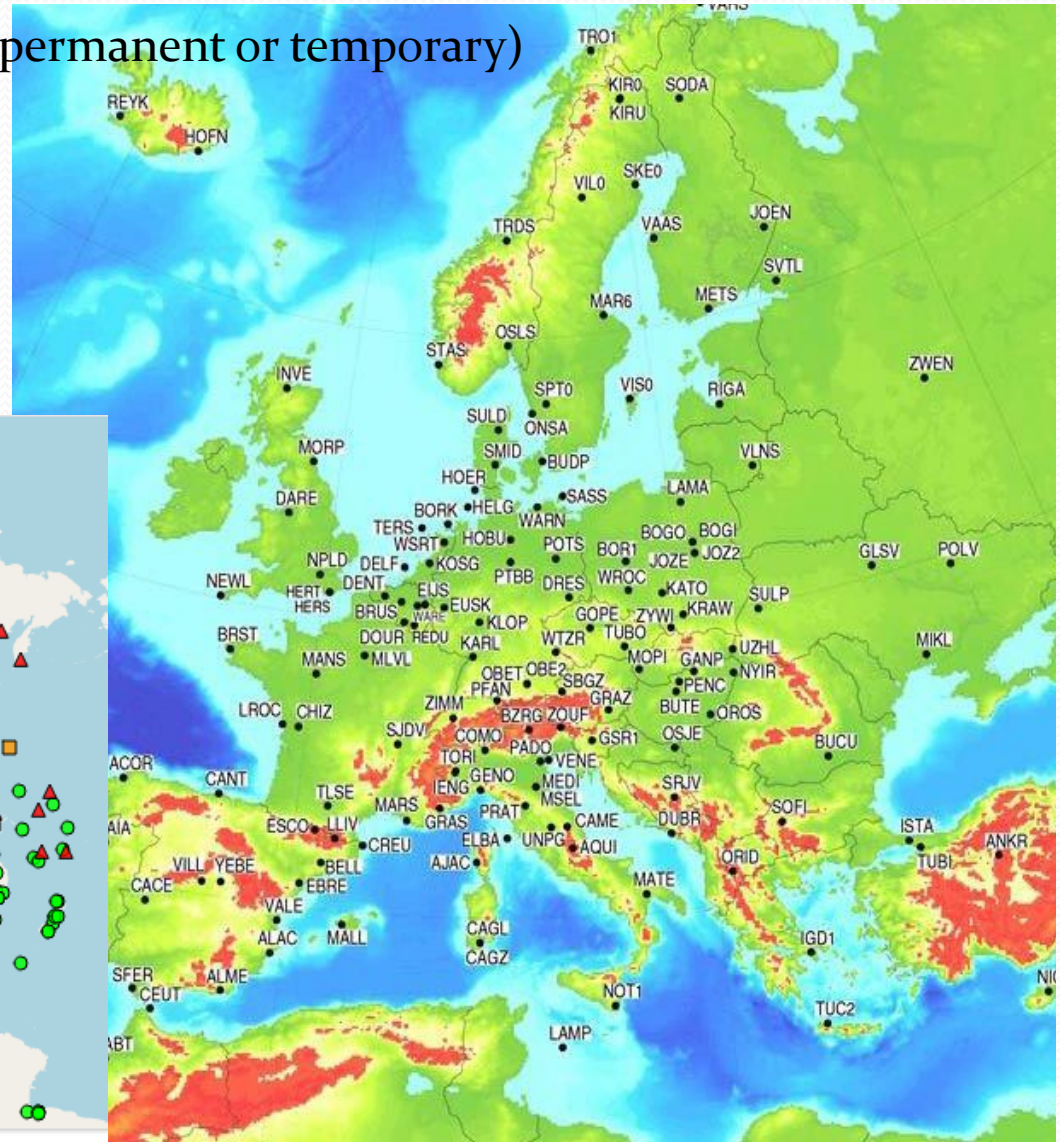
Геодезически референтни системи
Geodetic reference systems

EUREF Permanent GNSS Network



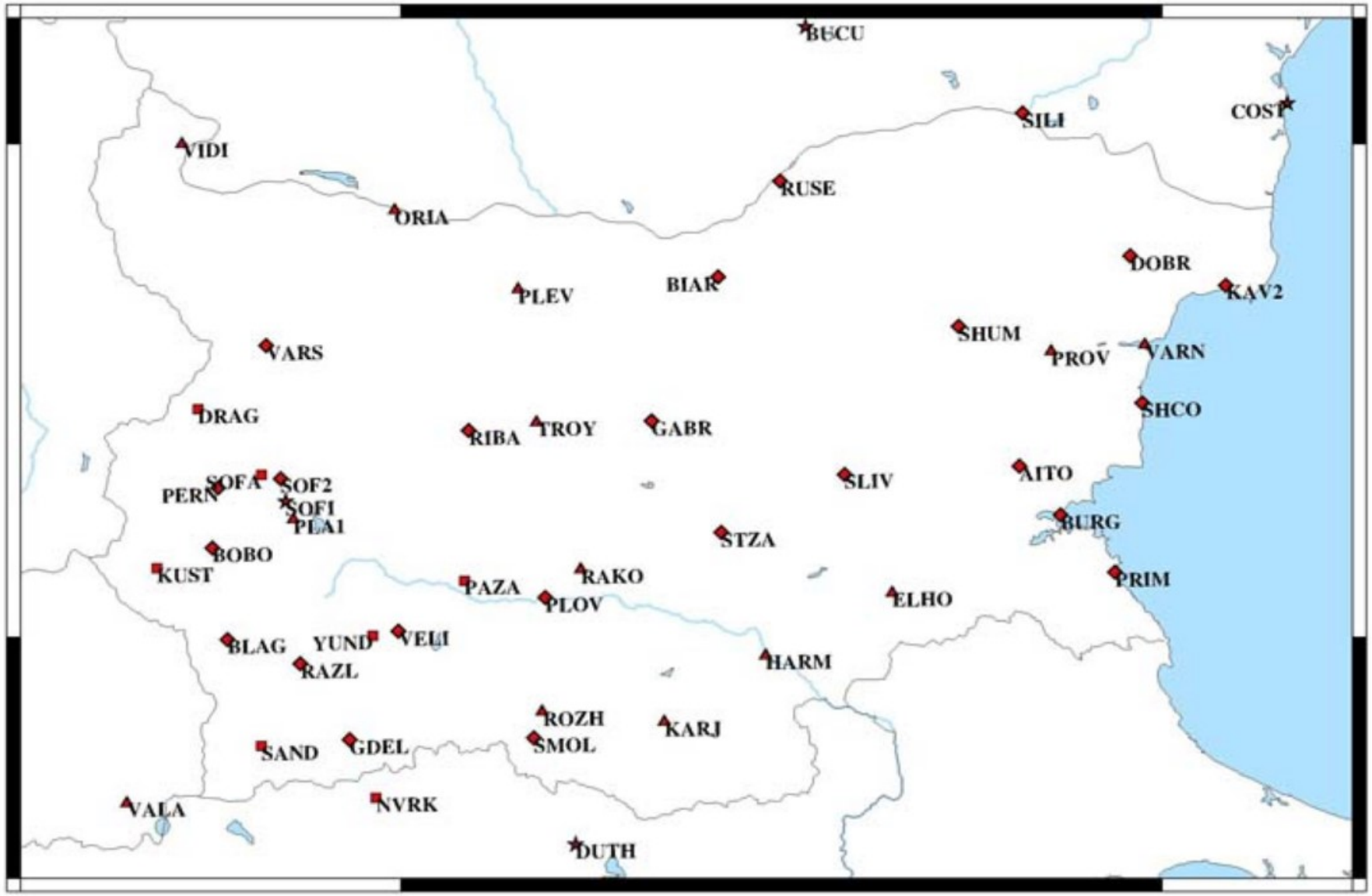
Geodetic reference systems(permanent or temporary)





- световна – ITRF, IGS
- регионални - EUREF
- национални

Национална парманентна ГНСС мрежа на НИГГГ- БАН
National permanent GNSS network of NIGGG-BAN

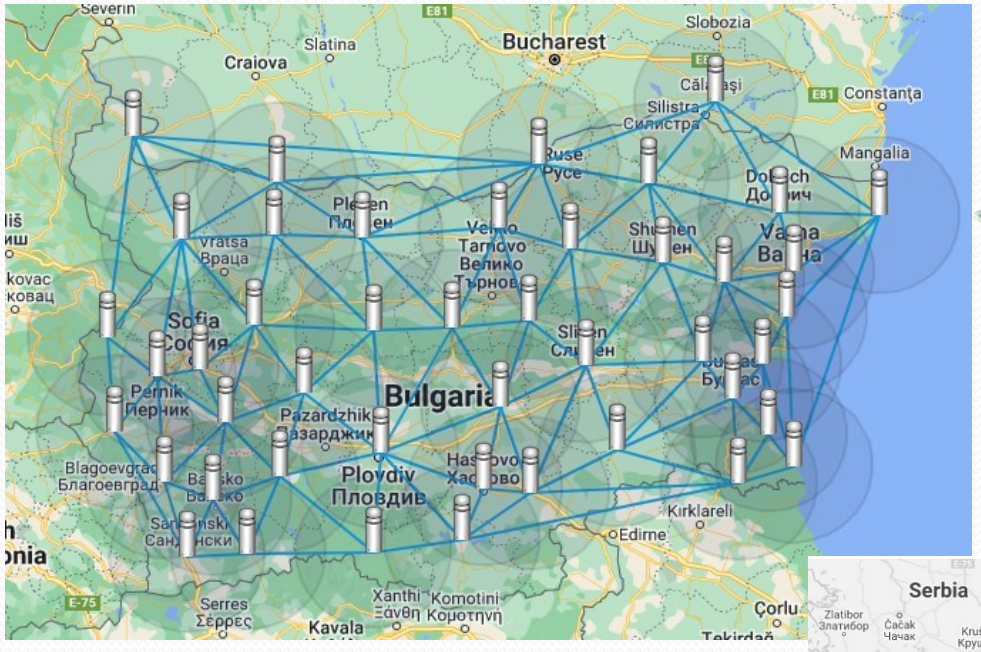


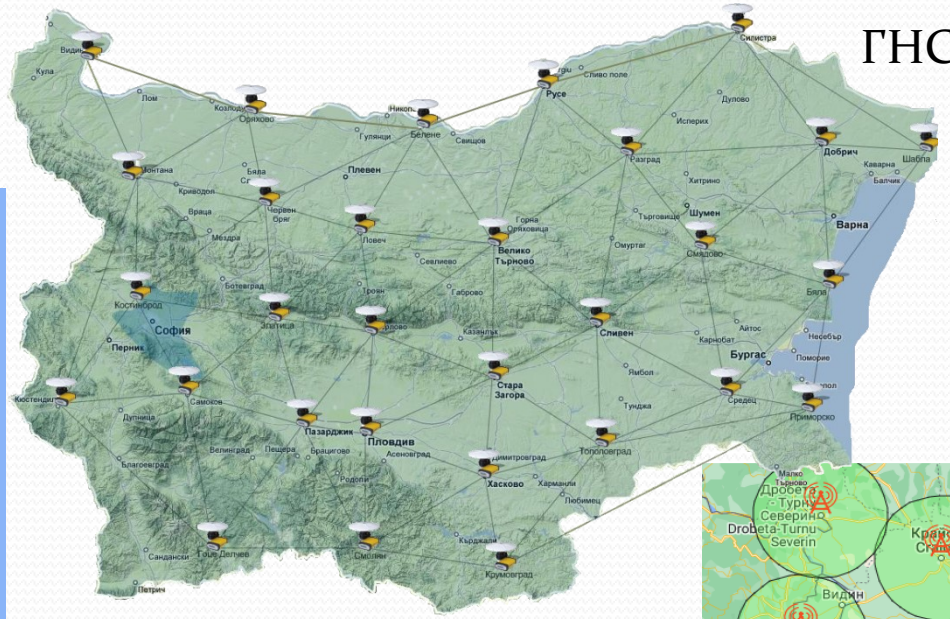
http://niggg.bas.bg/wp-content/uploads/2013/09/gnss.html

Частни перманентна ГНСС мрежа - 4бр.

Commercial GNSS network

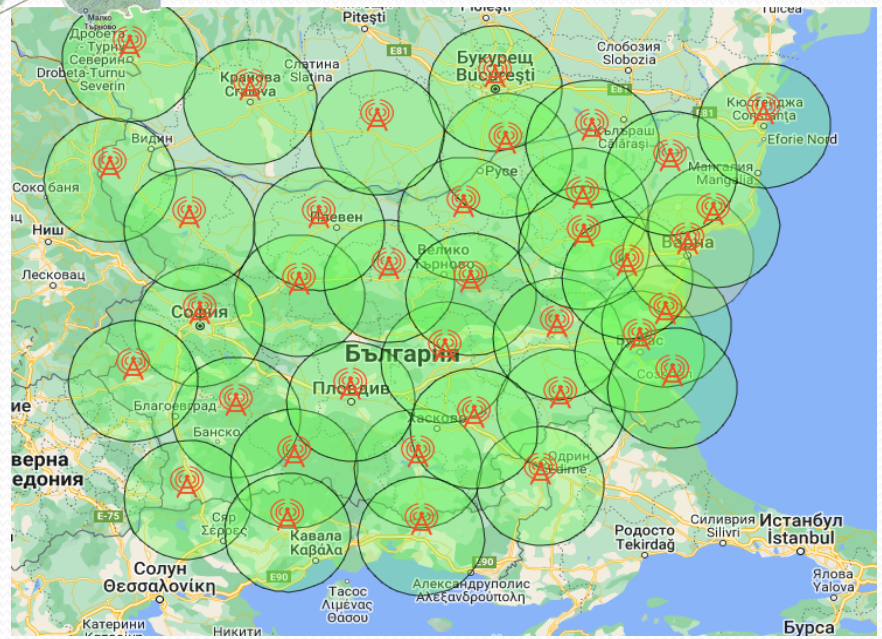
GNSS RTK мрежа – 1 Yocto

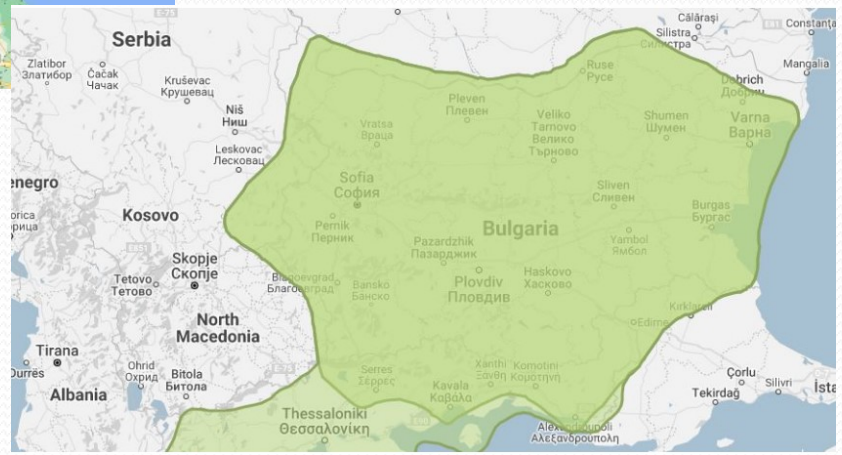




ГНСС мрежа ГеоНЕТ / GeoNET

ГЕОВАРА/ GeoVara





СмартБул.Нет/ SmartBul.Net

36 перманентни станции в BG
12 перманентни станции Сърбия и Гърция

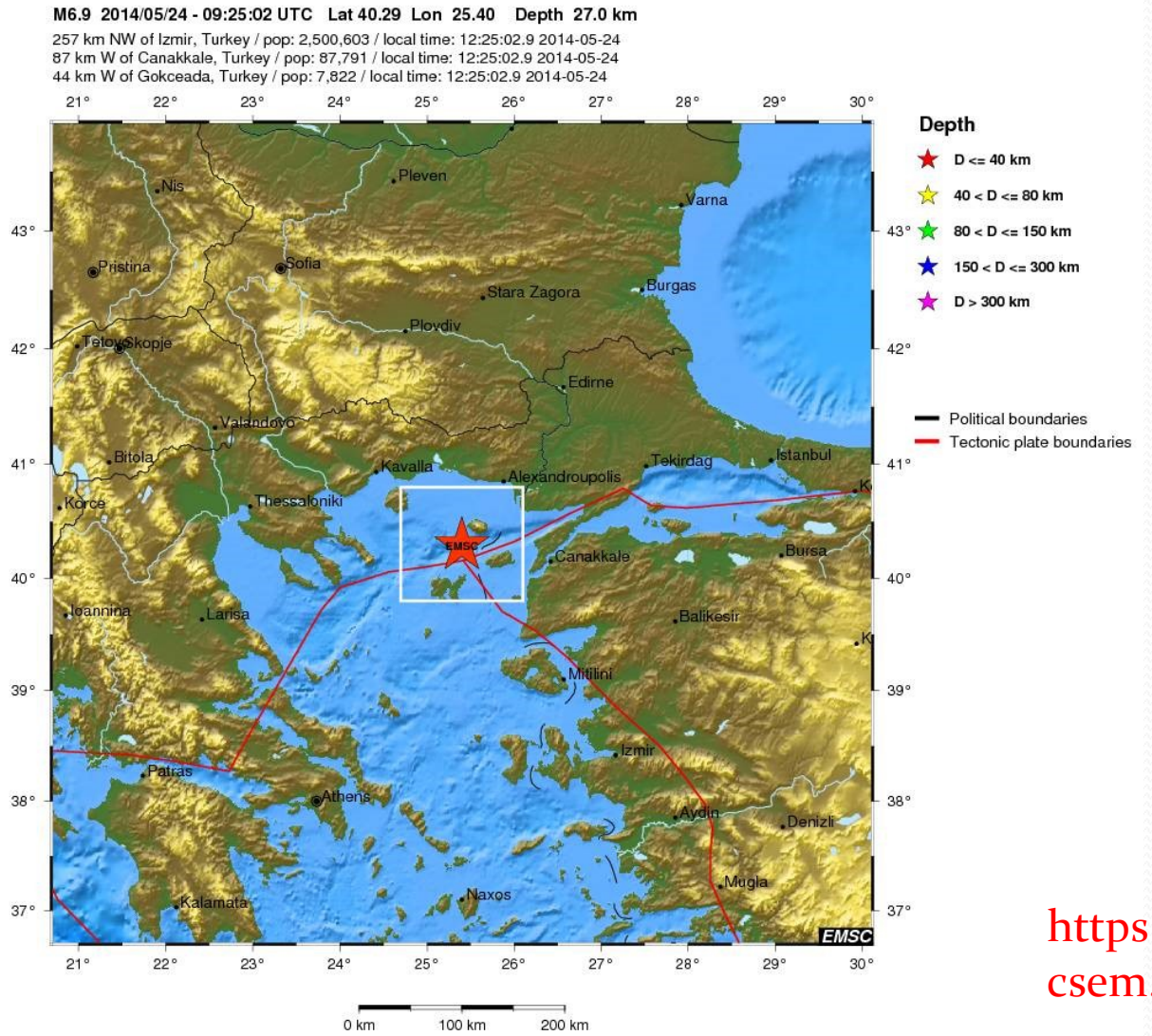
ОБЕКТИ НА ИЗСЛЕДВАНЕ

- земетресение с магнитуд Mw = 6.9 остров Лемнос / 24 май 2014 г.
- земетресение с магнитуд Mw = 5.8 гр. Перник / 22 май 2012 г.
- земетресение с магнитуд Mw = 6.0 в близост до гр. Лариса/ 03 март 2021г.
- земетресения с магнитуд Mw = 6.4 в близост до гр. Дуръс/ 21 септември 2019 г. и 26 ноември 2019 г
- земетресение с магнитуд Mw =6.9 на север от остров Самос (Егейско море)/30 октомври 2020 г.

STUDY AREAS

- earthquake with magnitude Mw = 6.9 Lemnos island / May 24, 2014
- earthquake with magnitude Mw = 5.8 g. Pernik / May 22, 2012
- earthquake with magnitude Mw = 6.0 near the city of Larisa/ March 3, 2021
- earthquakes with magnitude Mw = 6.0 near the city of Durast/ September 21, 2019 and November 26, 2019
- earthquake with magnitude Mw =6.9 north of the island of Samos (Aegean Sea)/October 30, 2020

Остров Лемнос /24 май 2014 г. Mw = 6.9
Lemnos Island / May 24, 2014 Mw = 6.9

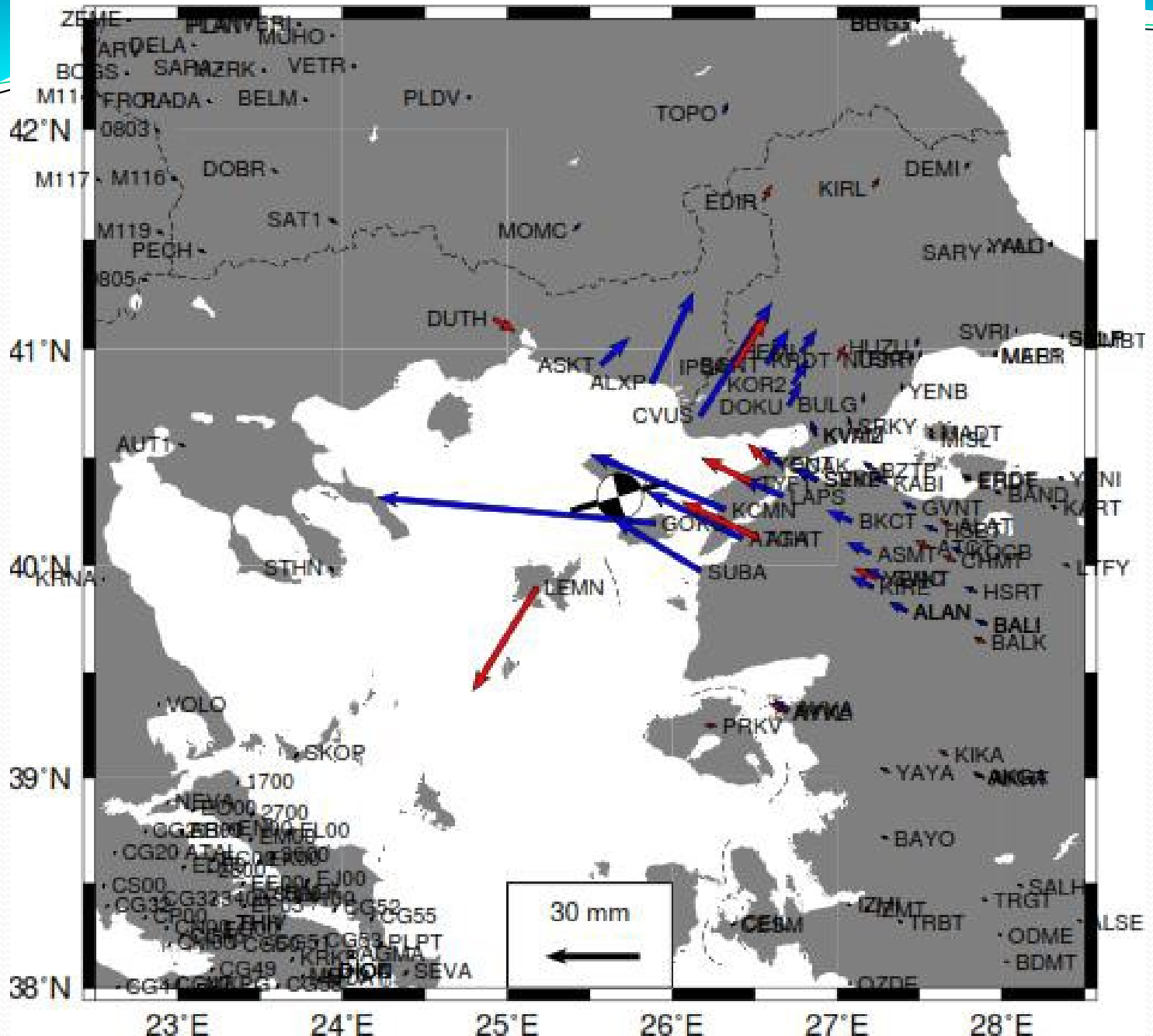


с координати 40.29 N; 25.40 E
дълбочина 27 километра

Перманентната GNSS станция на остров Лемнос е инсталирана в рамките на българо-гръцки проект финансиран по програмата на НАТО „Наука за мир“

The permanent GNSS station on the Lemnos island was installed within the framework of Bulgarian-Greek project financed by the NATO „Science for Peace“ program HemusNET (http://www.hemus-net.org/).

https://www.emsc-csem.org/Earthquake/earthquake.php?id=379935

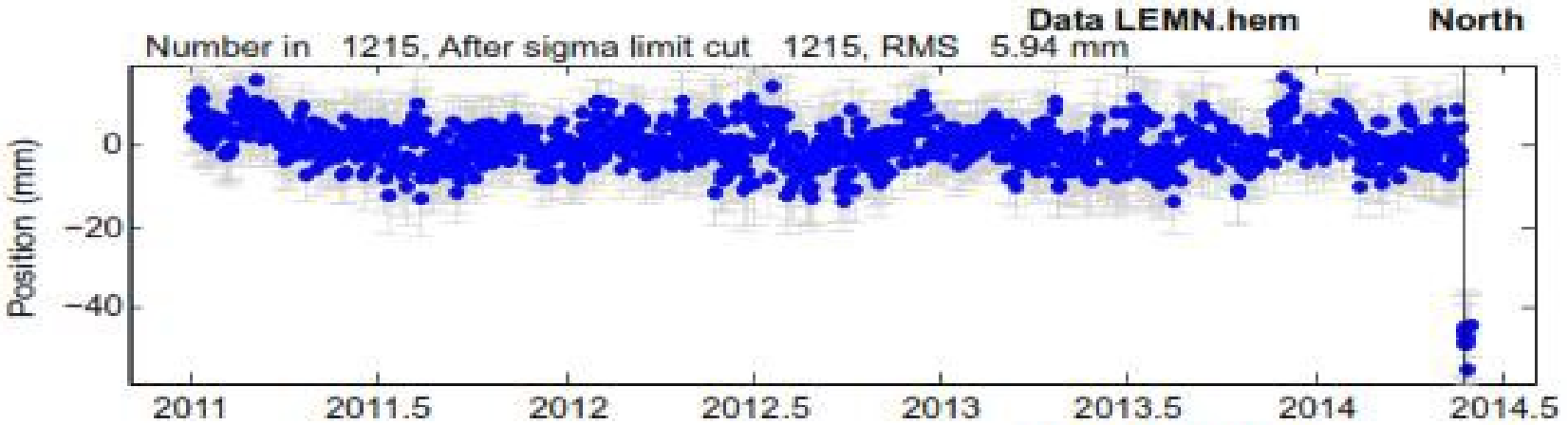


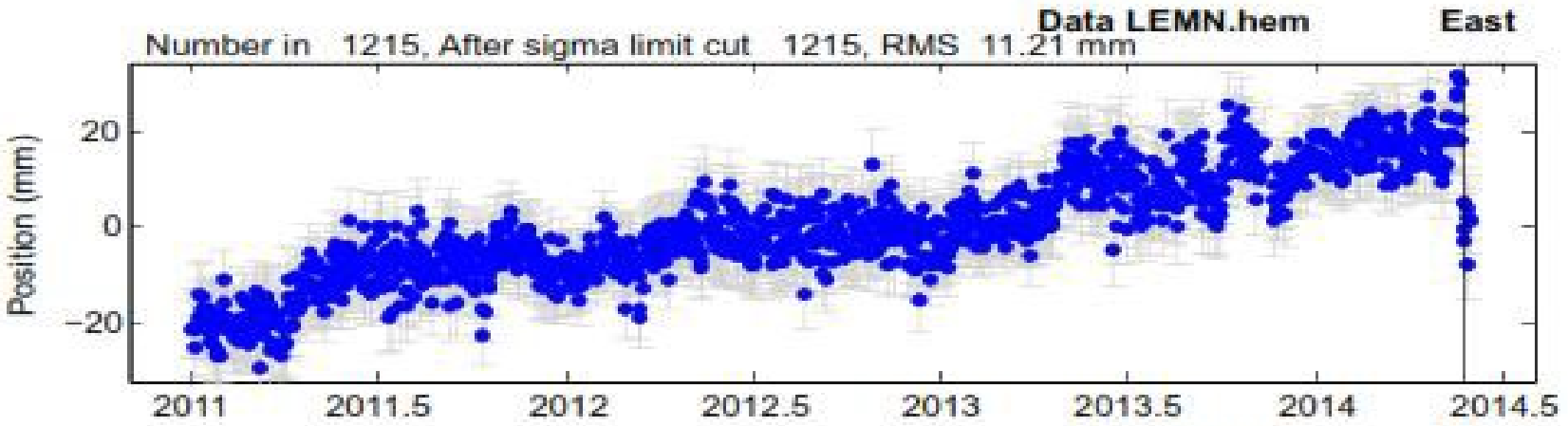
Резултатите от обработката и анализ на перманентните станции от Националната GNSS мрежа и станциите на Балканския полуостров позволяват получаването на временните редове с координати на GNSS станциите.

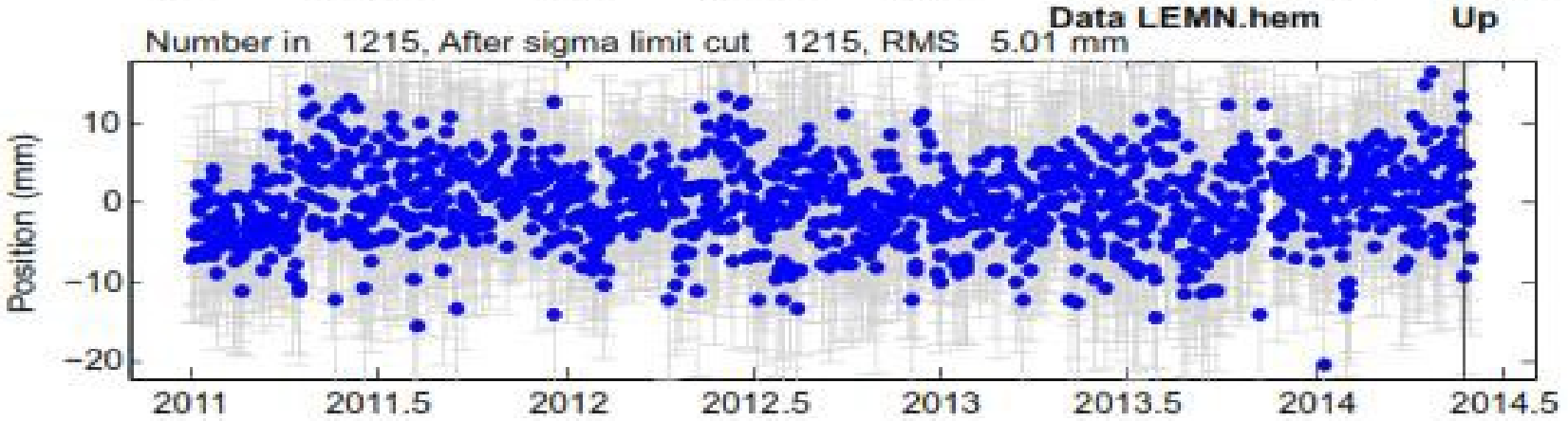
Червените вектори показват разположението на перманентни GNSS станции, а сините - GNSS точки, на които се извършват периодични измервания.

The results of the processing and analysis of the permanent stations from the National GNSS network and the stations of the Balkan Peninsula allow obtaining the time series with coordinates of the GNSS stations.

Red vectors show the location of permanent GNSS stations, and blue - GNSS points at which periodic measurements are made.



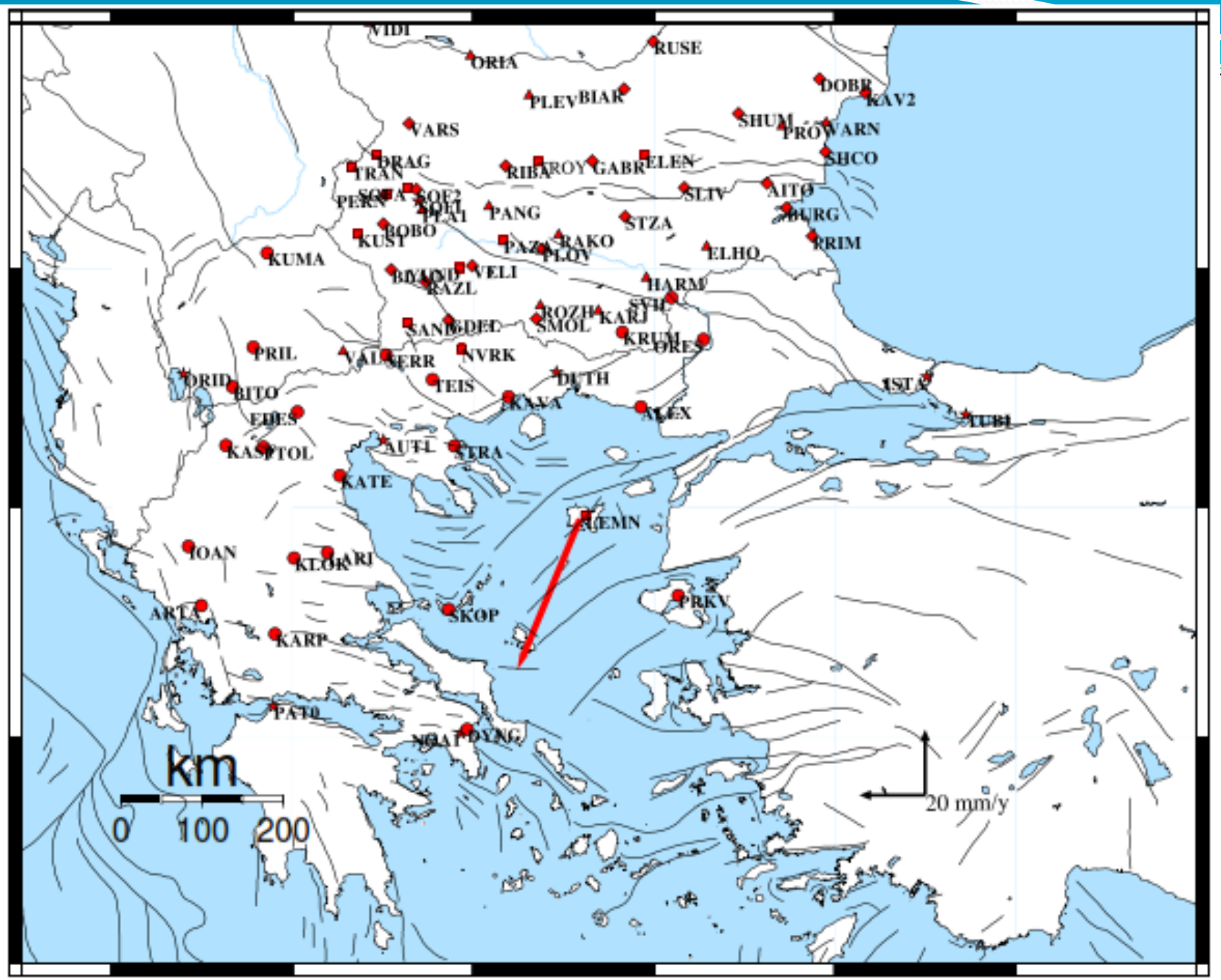




Detrend of LEMN.hem	North
Mean	0.11 +- 0.13 mm
Rate	-0.66 +- 0.13 mm/yr
Annual Cos	1.66 +- 0.19 mm
Annual Sin	0.91 +- 0.18 mm
EQBrk 2014 5 24 9 25	-45.81 +- 2.12 mm

Detrend of LEMN.hem	East
Mean	0.21 +- 0.14 mm
Rate	10.32 +- 0.14 mm/yr
Annual Cos	-2.23 +- 0.19 mm
Annual Sin	-0.39 +- 0.19 mm
EQBrk 2014 5 24 9 25	-18.95 +- 2.01 mm

Detrend of LEMN.hem	Up
Mean	0.10 +- 0.14 mm
Rate	0.26 +- 0.14 mm/yr
Annual Cos	-1.01 +- 0.20 mm
Annual Sin	0.05 +- 0.19 mm
EQBrk 2014 5 24 9 25	-2.15 +- 2.17 mm

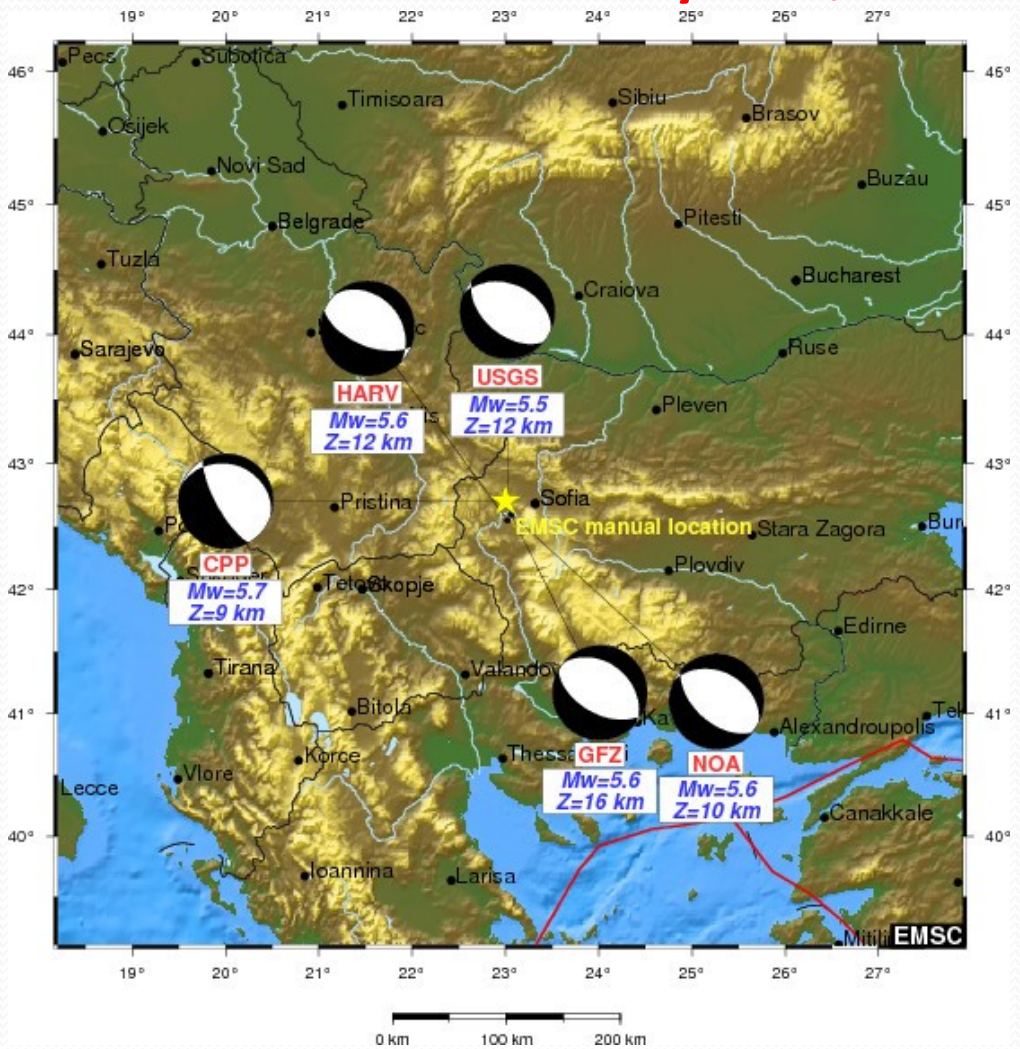


The values of the coseismic displacements of the LEMN station are respectively

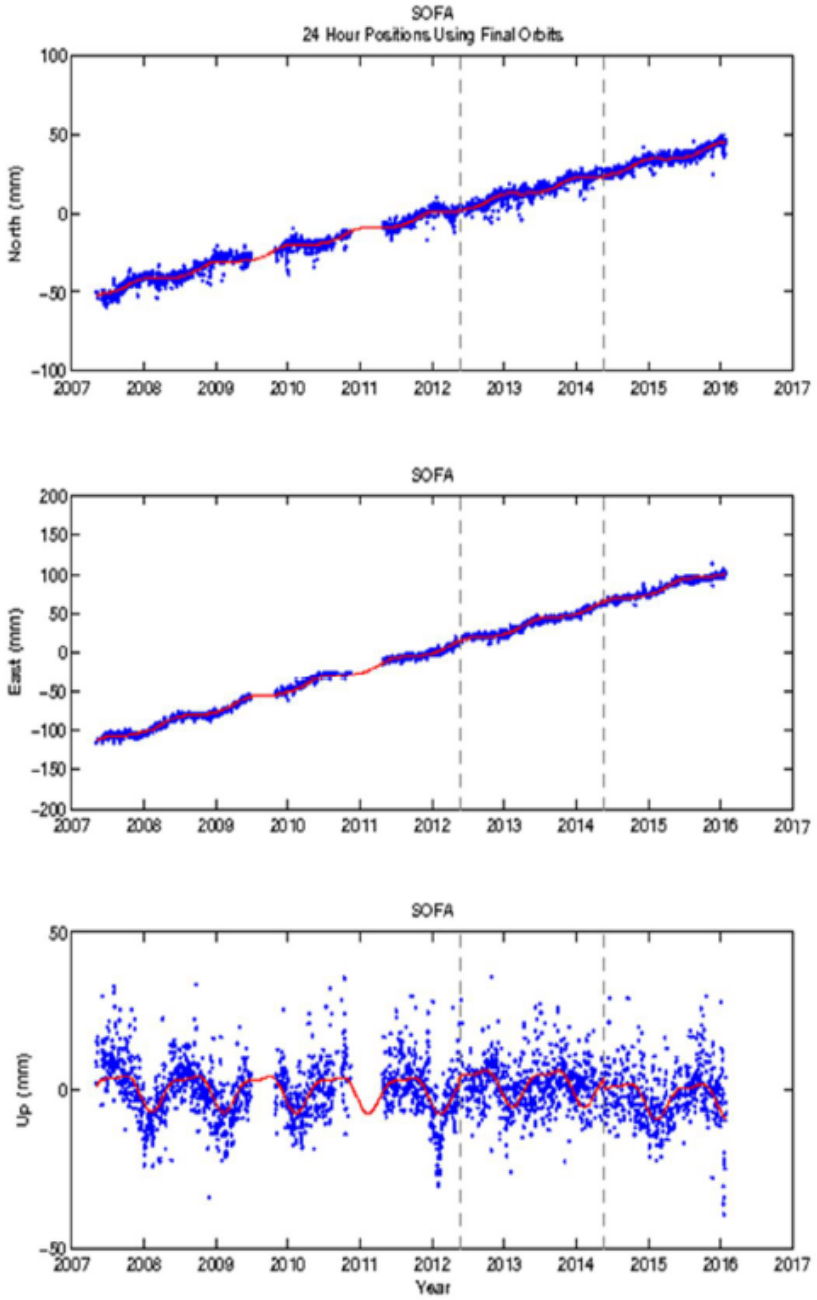
-45.8 +/- 2.1 mm in the northern and -18.9 +/- 2.0 mm in the eastern component.

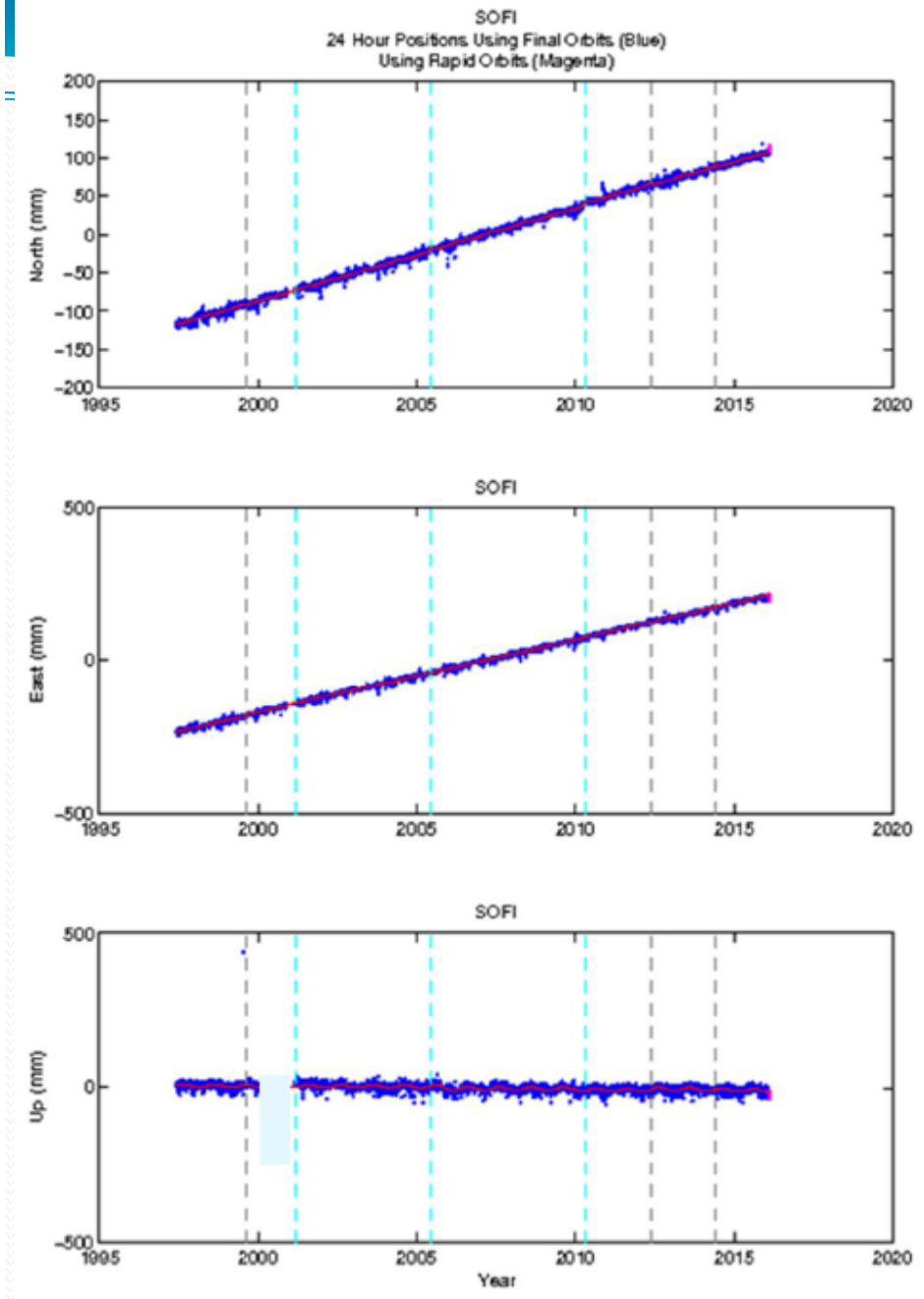
Coseismic movements at the height of the permanent station are not observed. The permanent GNSS stations north of the epicenter, including on the territory of Bulgaria, do not show significant coseismic displacements.

гр.Перник / 22 май 2012 г. Mw = 5.8
Pernik / May 22, 2012Mw = 5.8

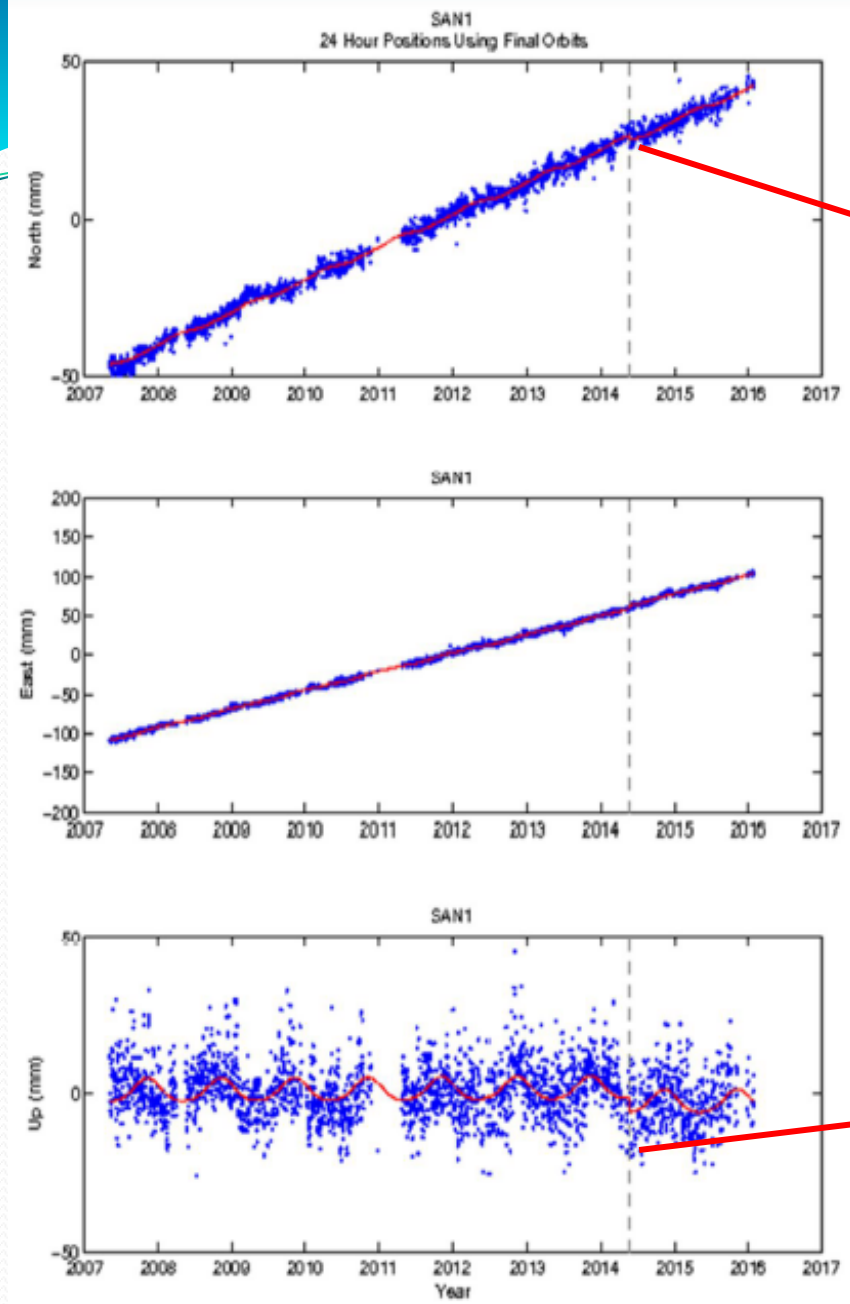


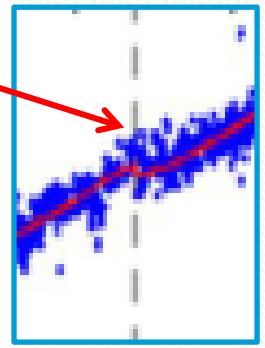
Една от трите охладителни кули на ТЕЦ „Република“ в Перник е разрушена наполовина при земетресението

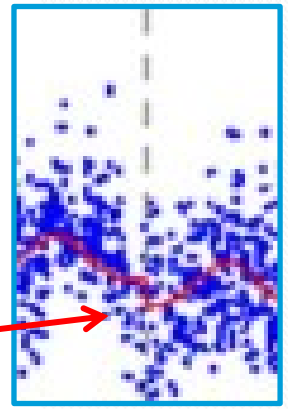


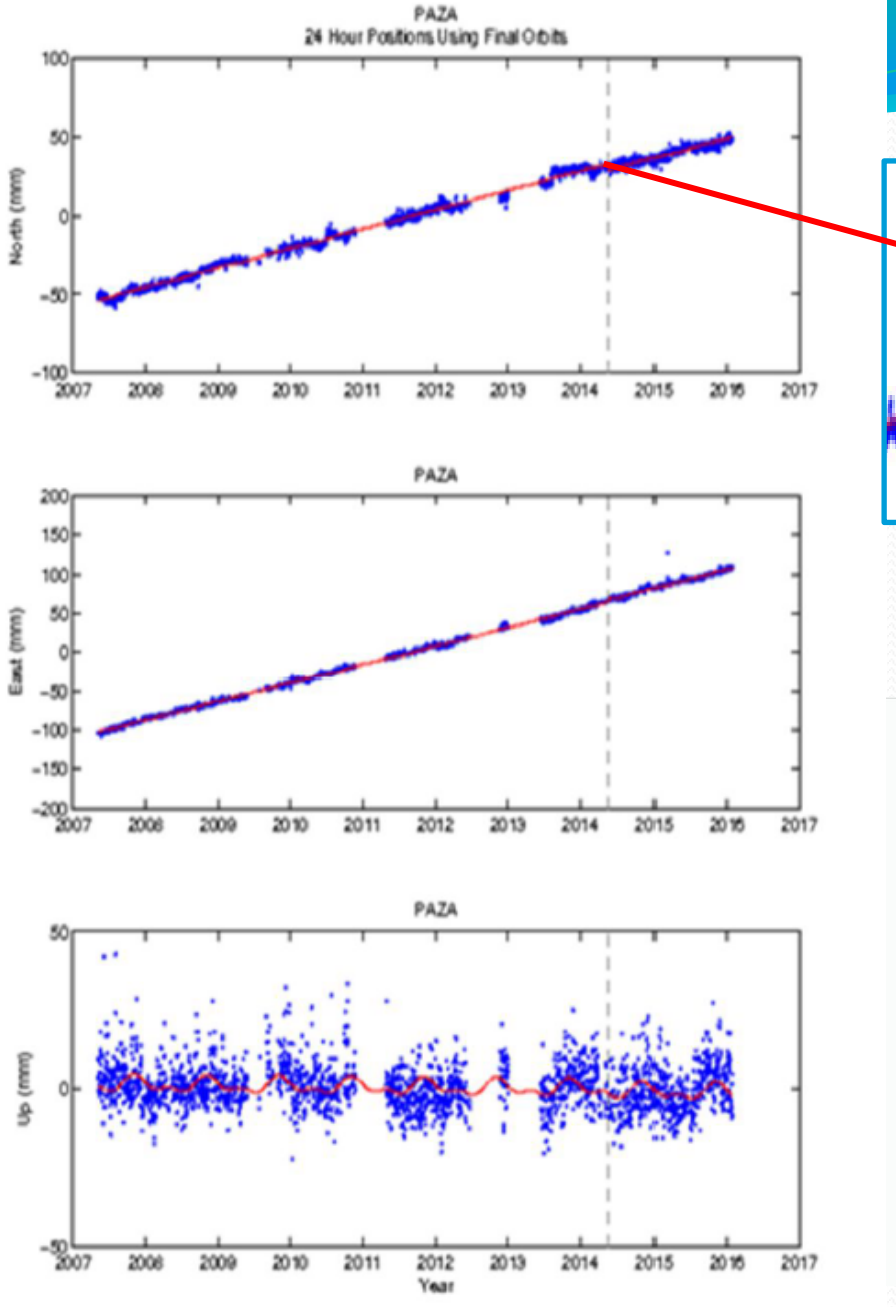


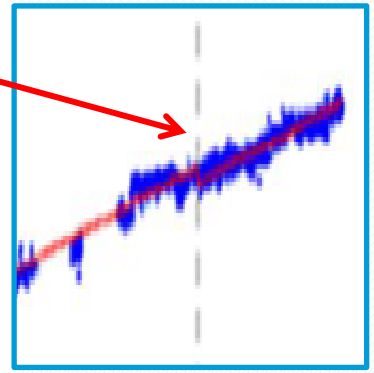
IGS станция SOFI (май 1997 г.)


SAN1
24 Hour Positions Using Final Orbits
North (mm)
East (mm)
Up (mm)
Year
gray dashed line = time of nearby earthquake
cyan dashed line = time of known equipment change
last data on 28-Jan-2016
Processed and Plotted by the Nevada Geodetic Laboratory on 17-Feb-2016






PAZA
24 Hour Positions Using Final Orbits
North (mm)
East (mm)
Up (mm)
Year
gray dashed line = time of nearby earthquake
cyan dashed line = time of known equipment change
last data on 28-Jan-2016
Processed and Plotted by the Nevada Geodetic Laboratory on 17-Feb-2016



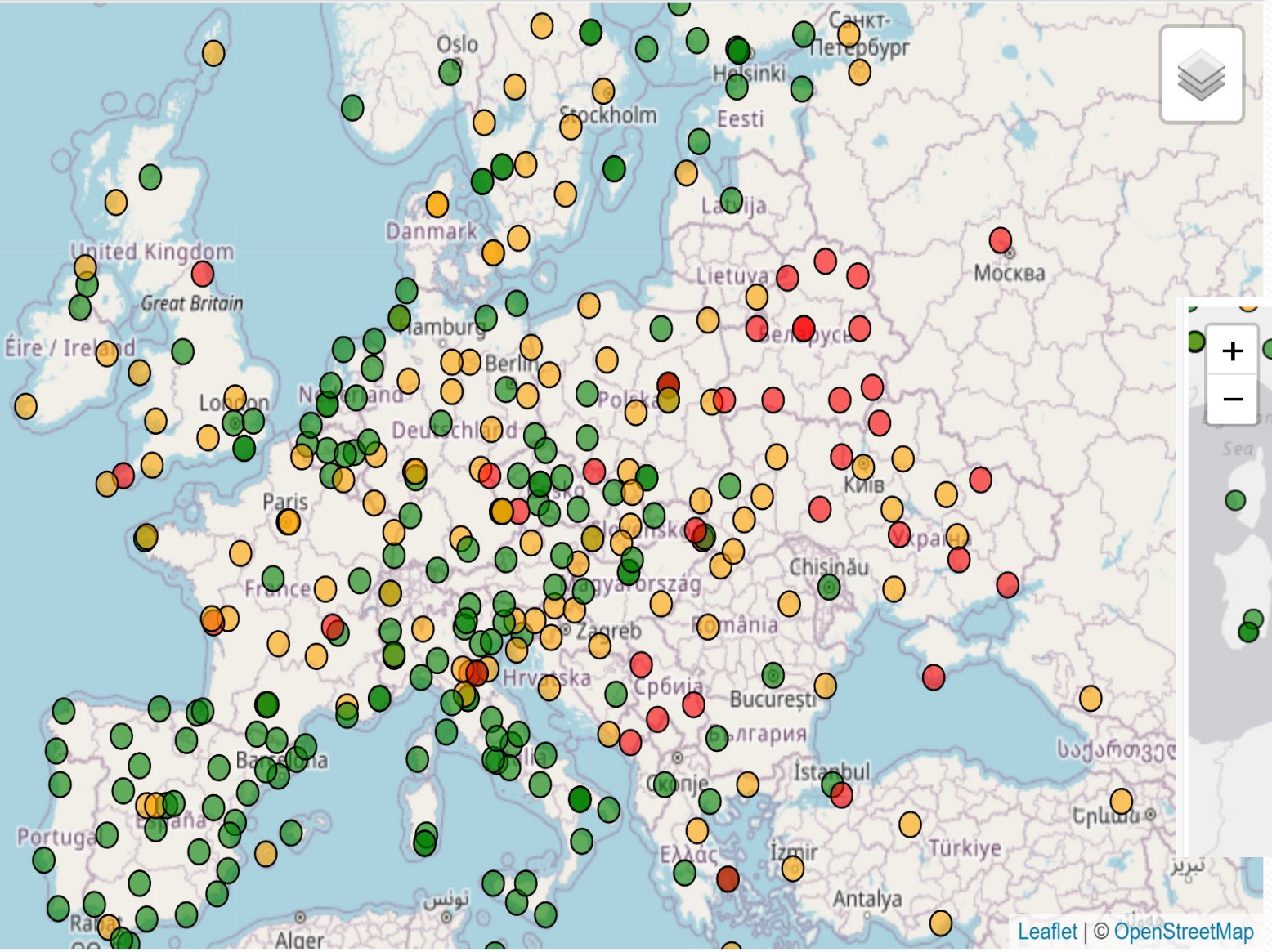
Земетресение близо до гр. Лариса 03.03.2021
earthquake near the city of Larisa/ March 3, 2021

Маг-нитуд	Дата и час	Географска дължина	Географска ширина
6.0	3. Март 2021 10:16	22.2102	39.7591
5.1	3. Март 2021 11:45	22.2478	39.6996
5.2	3. Март 2021 18:24	22.1013	39.7316
5.9	4. Март 2021 18:38	22.1260	39.7993
5.1	4. Март 2021 19:23	21.9424	39.8373
5.2	12. Март 2021 12:57	22.0134	39.8387

Поражения от основното събитие от 03.03.2021г.

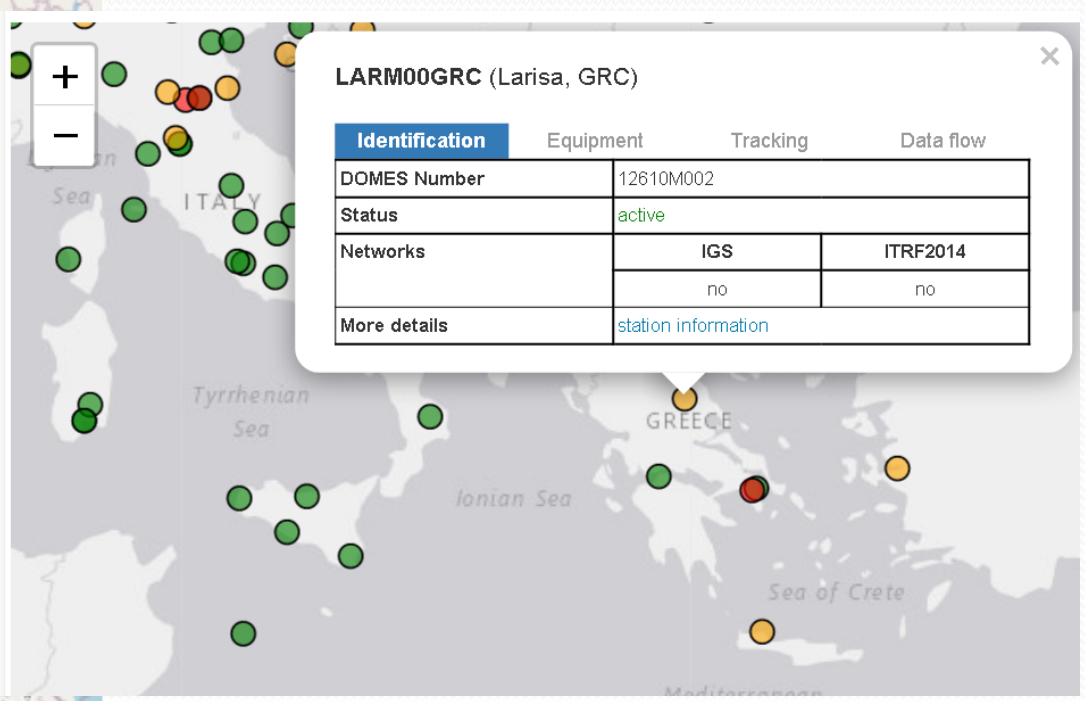
EUREF Permanent GNSS Network

http://epncb.eu/index.php



LEGEND:

- Providing daily, hourly & real-time data
- Providing only daily & hourly data
- Providing only daily data



LARM00GRC (Larisa, GRC)

Identification	Equipment	Tracking	Data flow

DOMES Number	12610M002	
Status	active	
Networks	IGS	ITRF2014
	no	no
More details	station information	

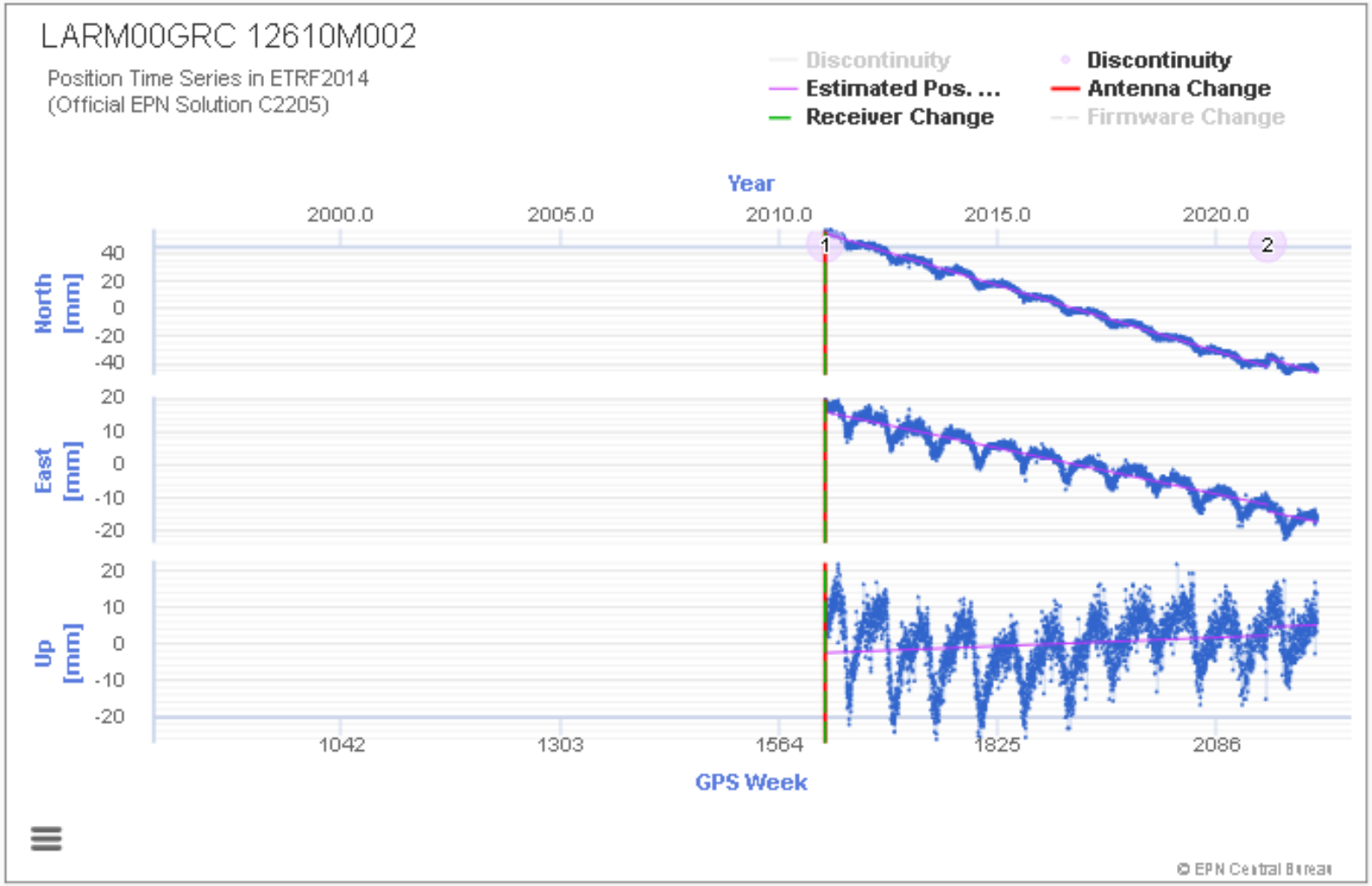
MULTI-YEAR EPN SOLUTION

EPN station position time series:

LARM00GRC (Larisa,Greece)

Other residual position time series: Nevada Geodetic Laboratory

OFFICIAL, SOLUTIONS INCLUDED UP TO 16-04-2022 (GPS WK 2205) (READ MORE)



Official Time Series up to week 2205

Extended Time Series up to week 2230/2

Residual Position Time Series

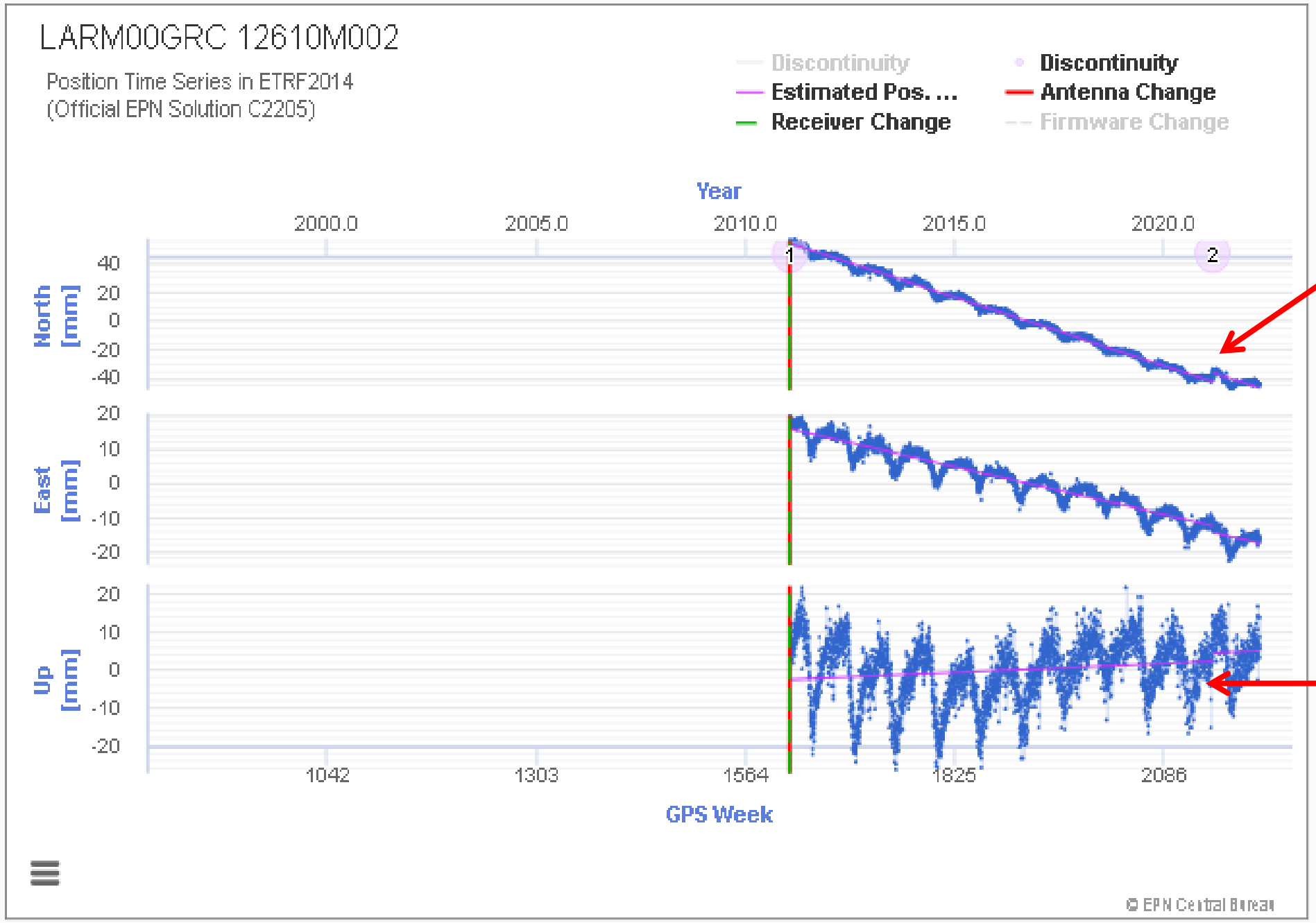
Position Time Series in ITRS (IGb14)

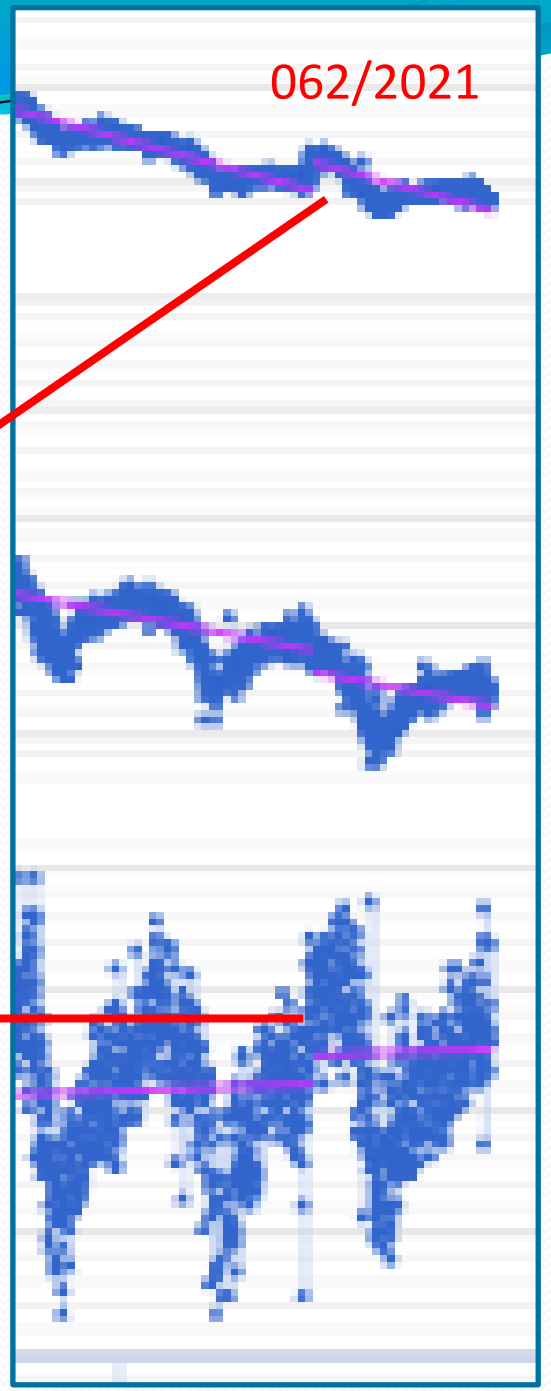
Position Time Series in ETRS89 (ETRF2014)

Official Station Velocities published by EUREF:

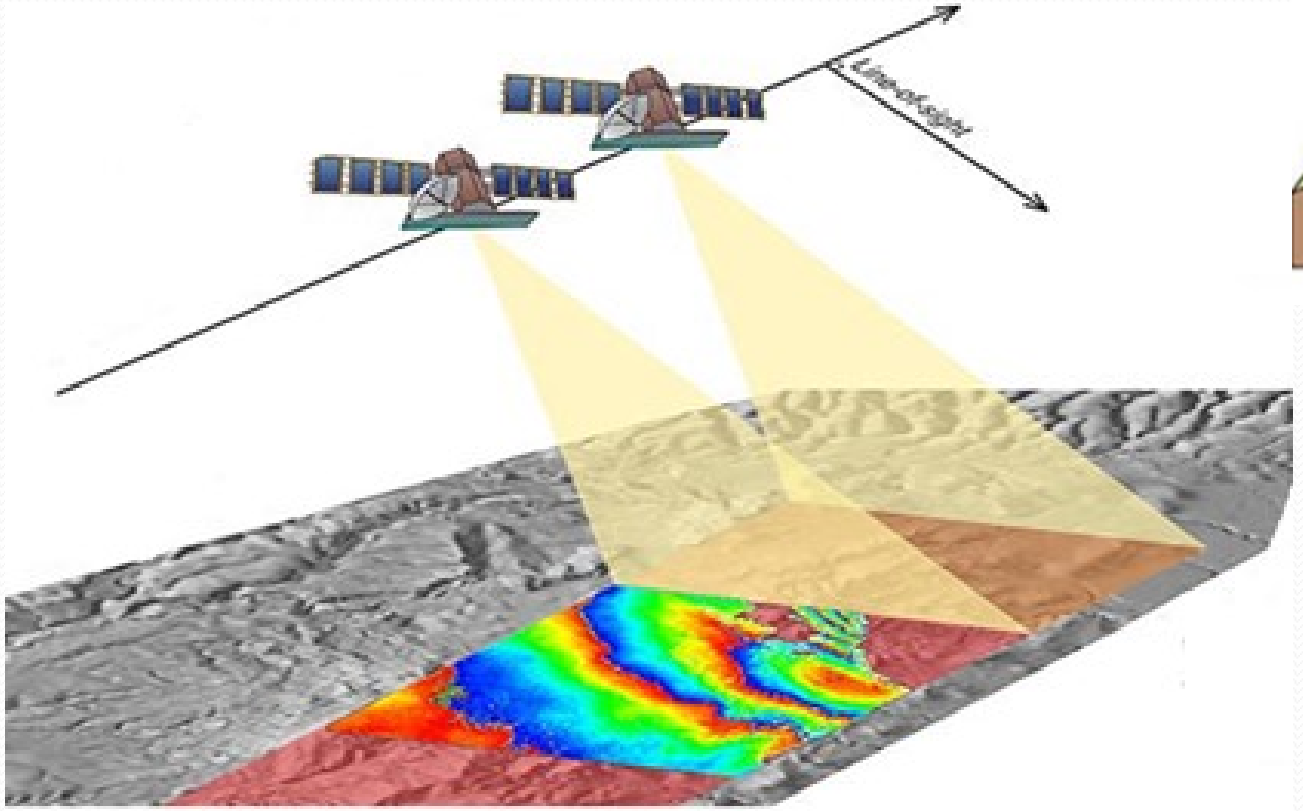
Frame	V_{North} [mm/yr]	V_{East} [mm/yr]	V_{Up} [mm/yr]
ETRF2014	-9.51	-2.80	0.47
	± 0.01	± 0.01	± 0.03

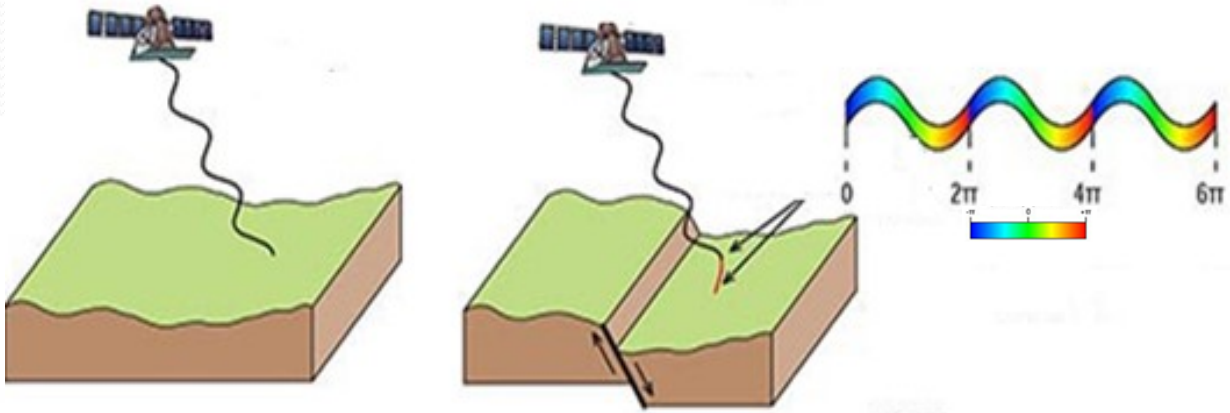
http://epncb.eu/_productsservices/timeseries/index.php?station=LARM00GRC&type=ITRS

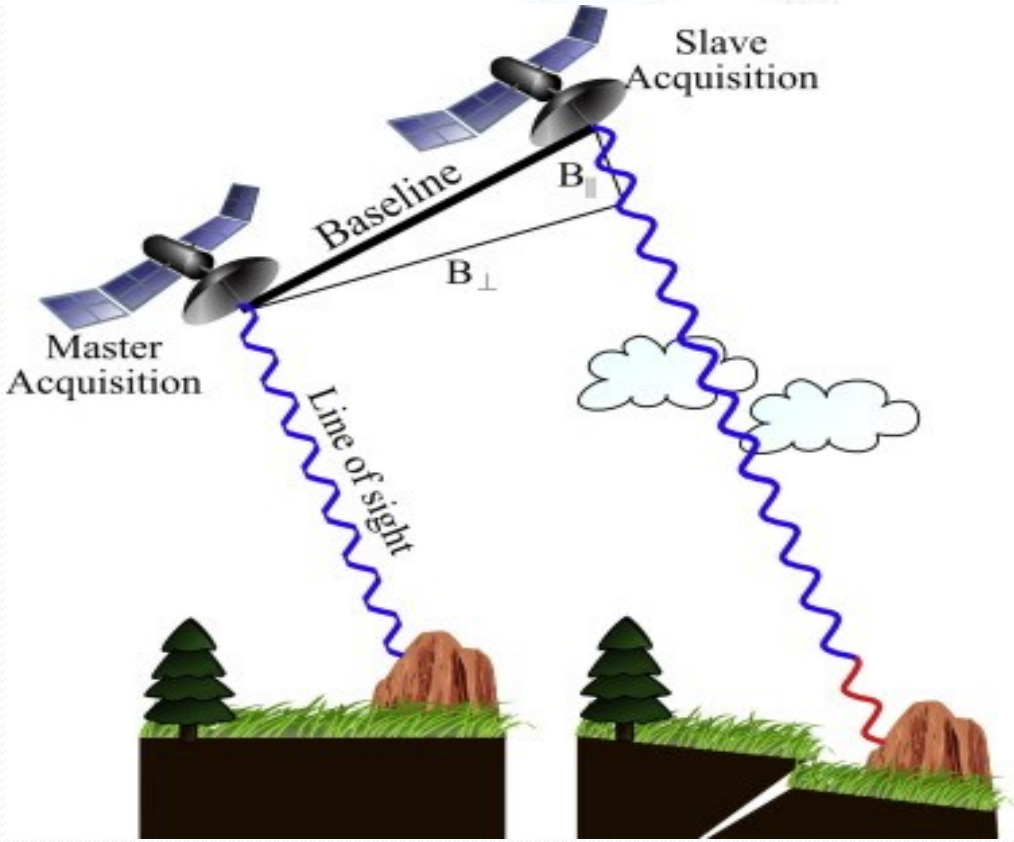

LARM00GRC 12610M002
Position Time Series in ETRF2014
(Official EPN Solution C2205)
Discontinuity
Estimated Pos. ...
Receiver Change
Discontinuity
Antenna Change
Firmware Change
Year
2000.0
2005.0
2010.0
2015.0
2020.0
North [mm]
East [mm]
Up [mm]
1
2
1042
1303
1564
1825
2086
GPS Week
© EPN Central Bureau


062/2021

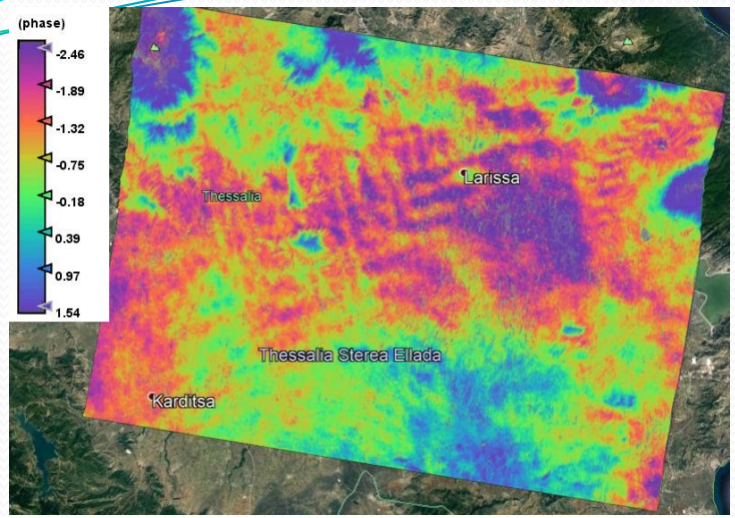
InSAR


Line-of-sight

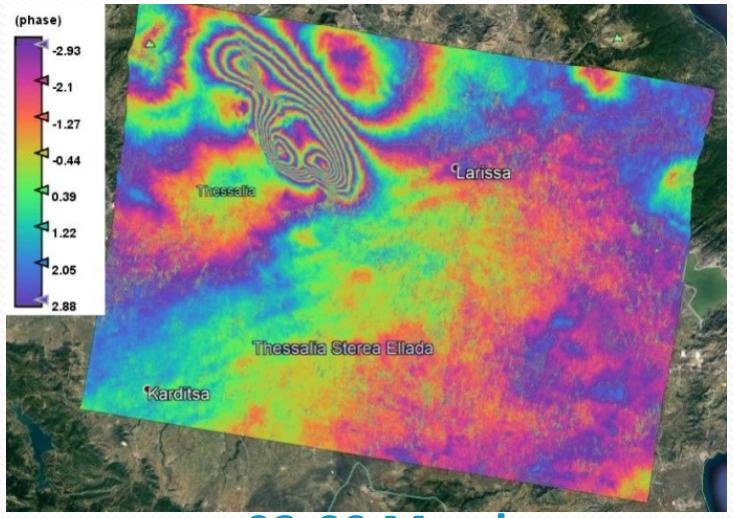

0
2π
4π
6π


Slave
Acquisition
Baseline
B∥
B⊥
Master
Acquisition
Line of sight

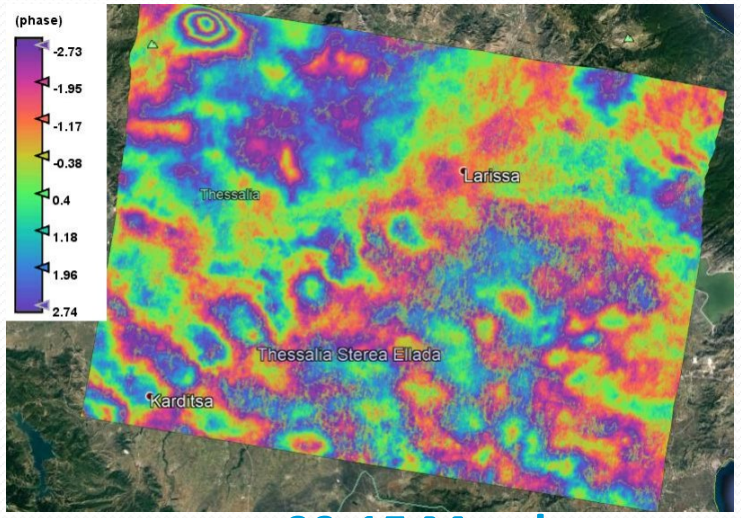
7 орбита



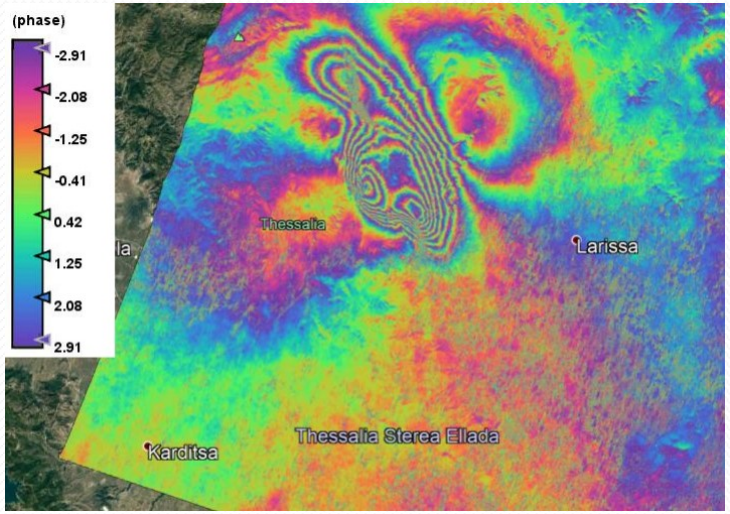
25 Feb -03 March



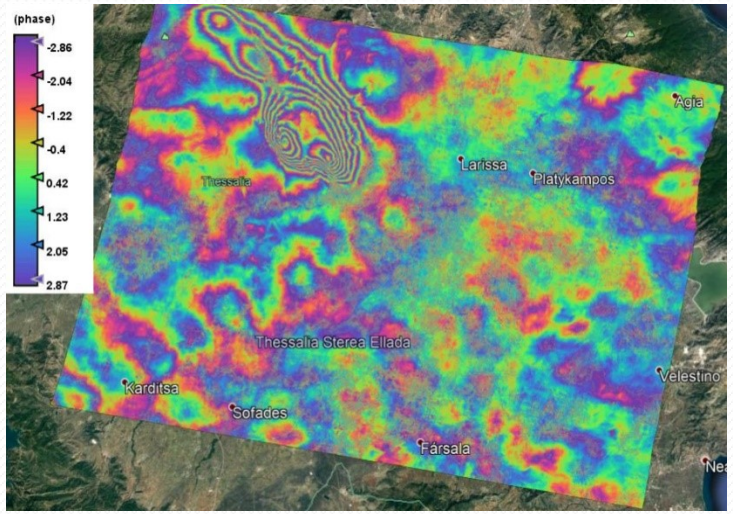
03-09 March



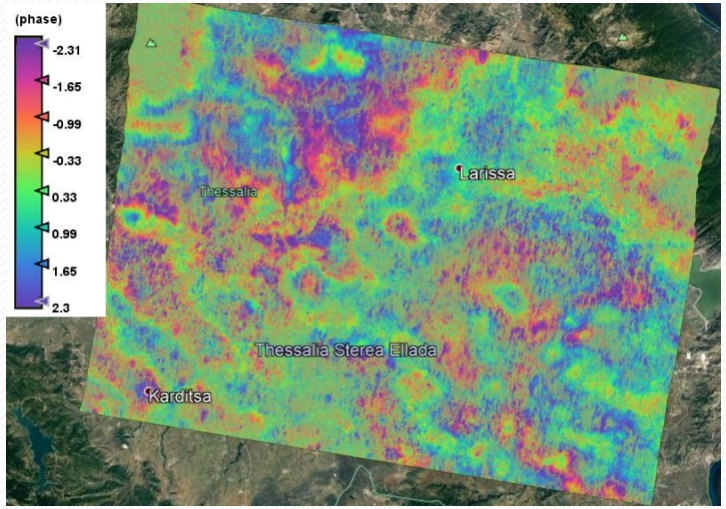
09-15 March



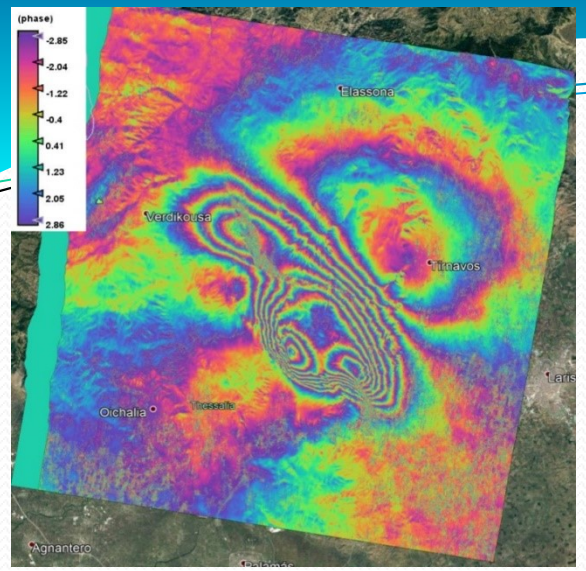
25Feb-09 March

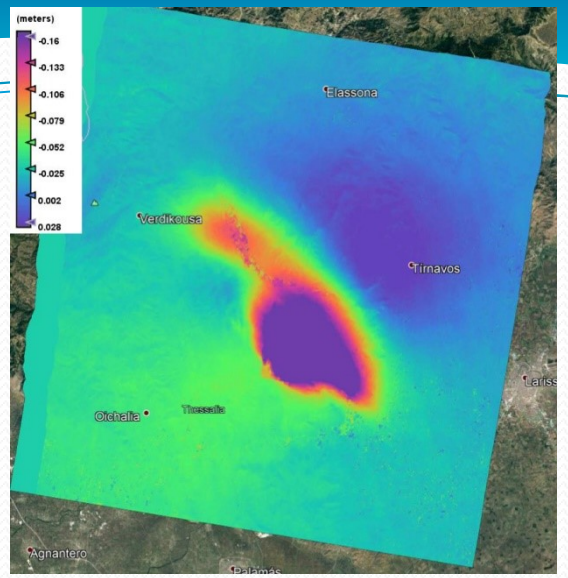


25Feb-21 March

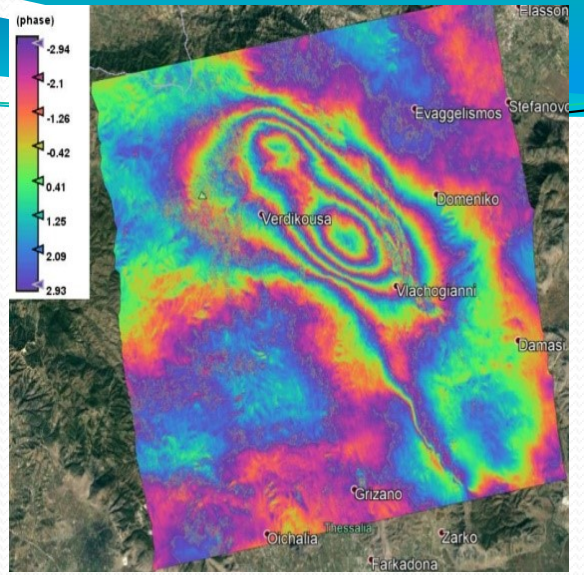


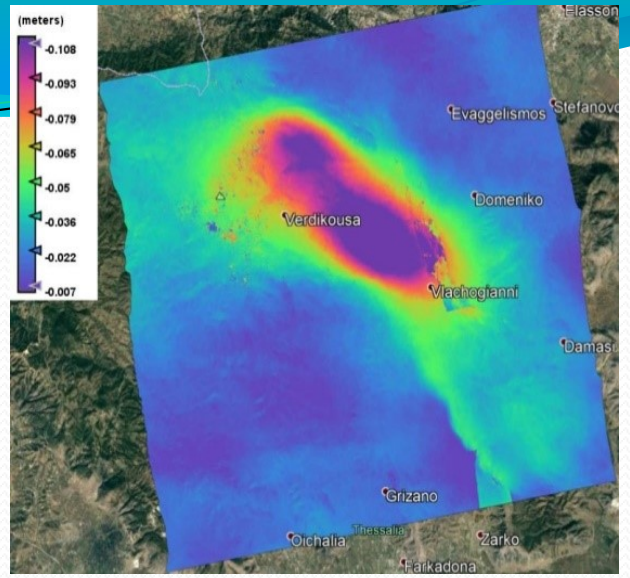
15-21 March



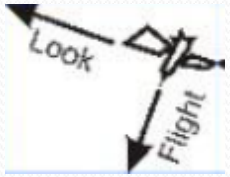


7 орбита 03-09 март

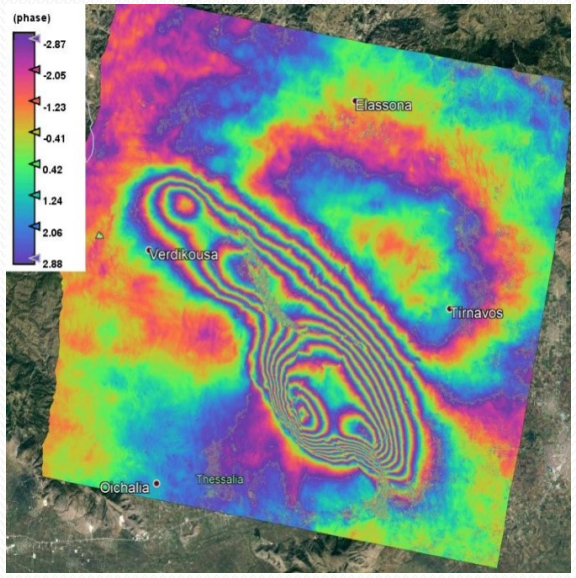


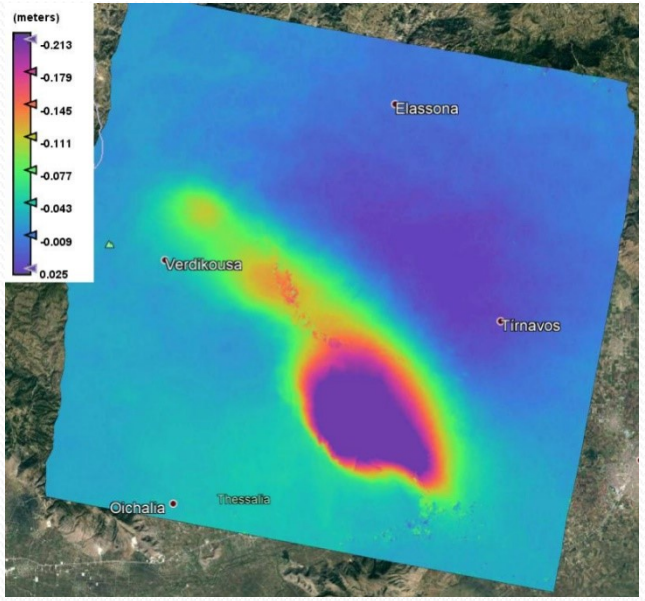


102орбита 03-09 Март

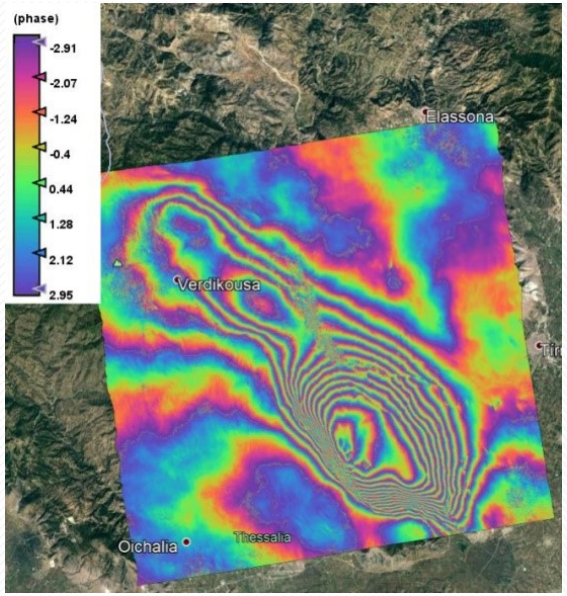


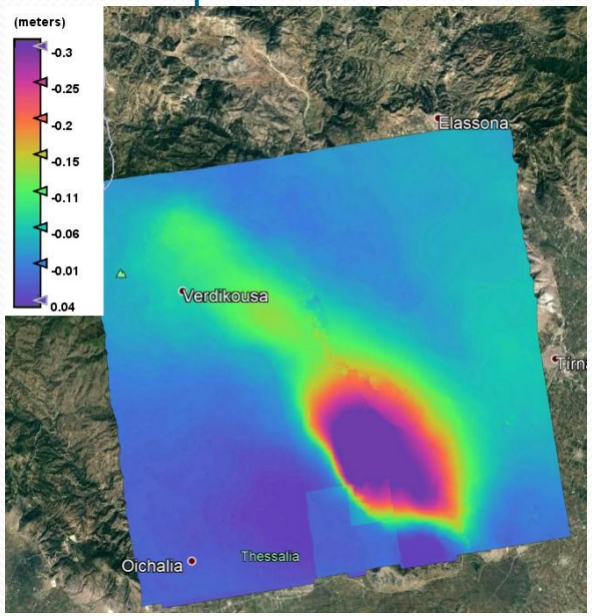
80 орбита 02-14 Март

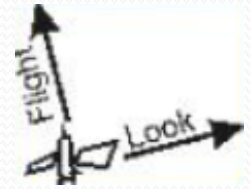




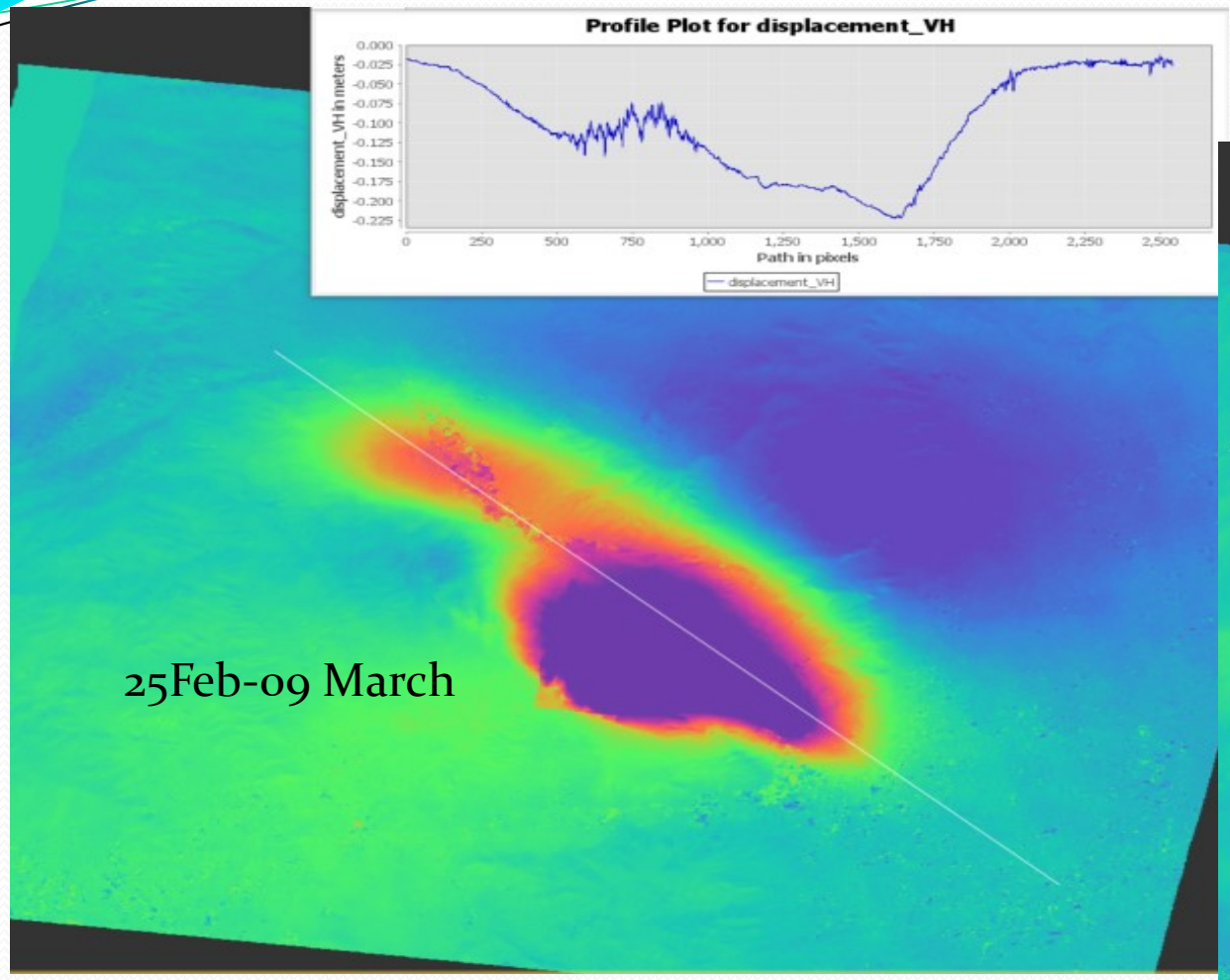
175 орбита 02-14 Март



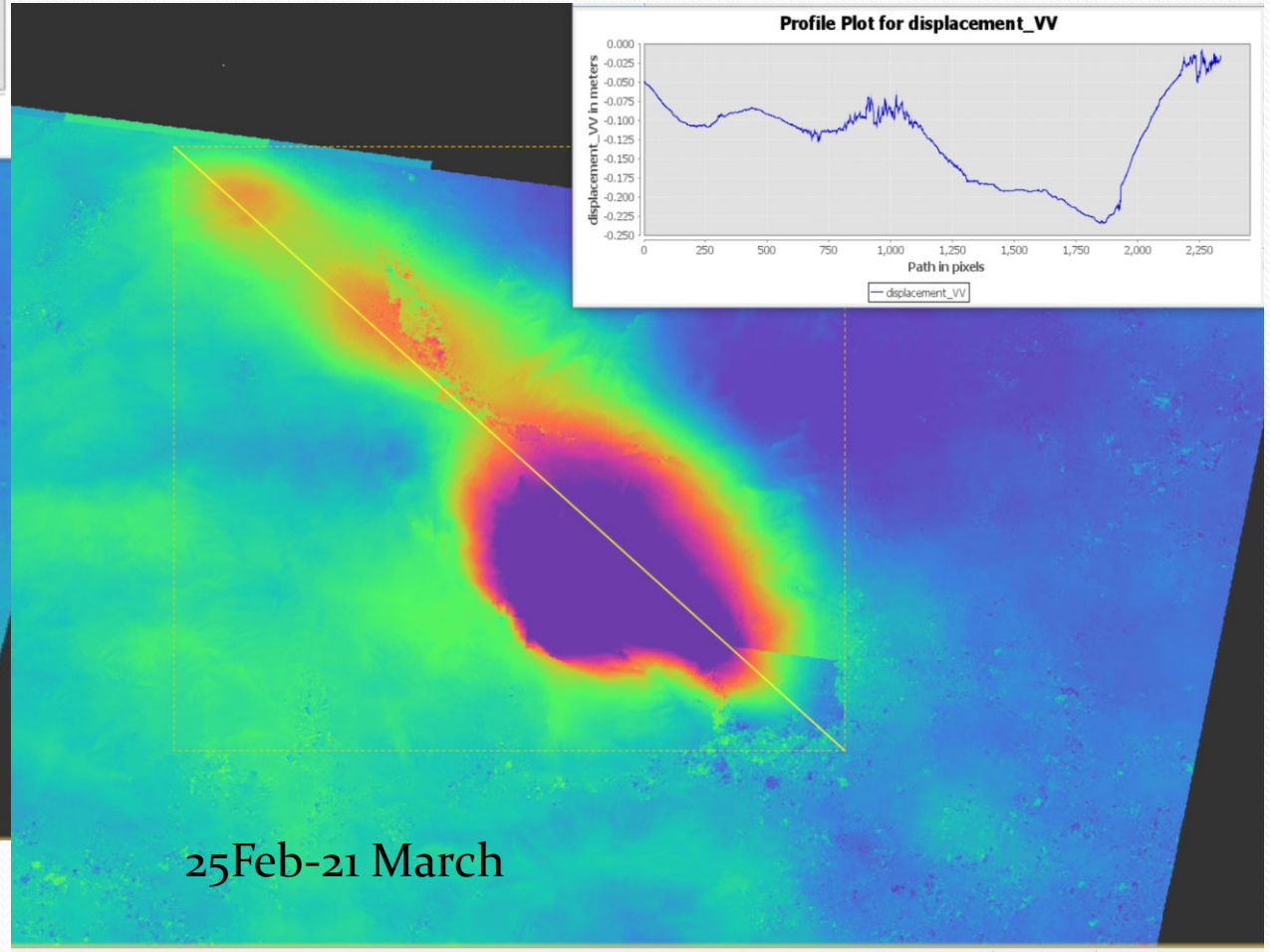




7 орбита



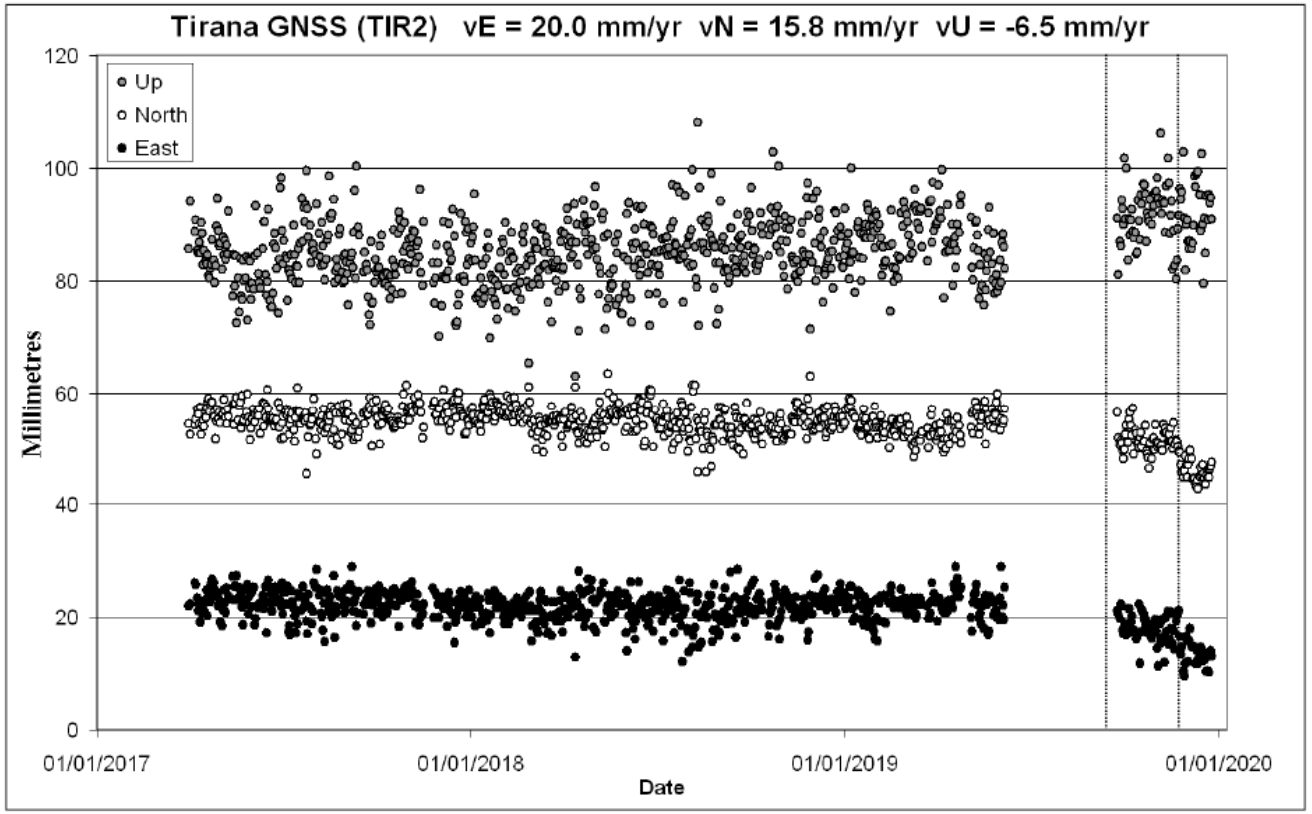
25Feb-09 March

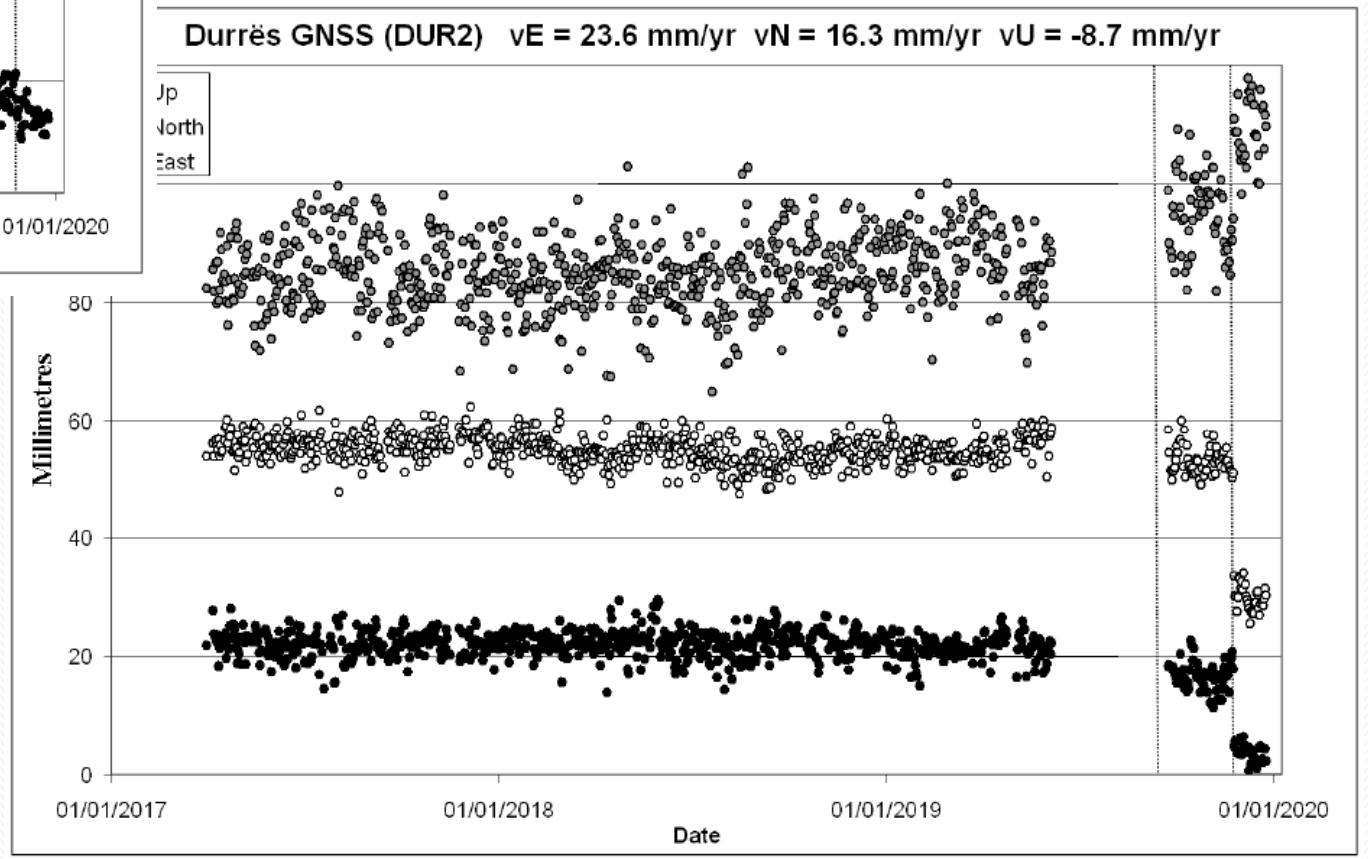


25Feb-21 March

гр. Дуръс/21 септември и 26 ноември 2019 Mw = 6.4
near the city of Durast/ Sept. 21 and Nov. 2019, Mw = 6.4

the time series of coordinates of two permanent GNSS stations (DUR2 and TIR2) http://www.geo/edu.al/gnss/albpos



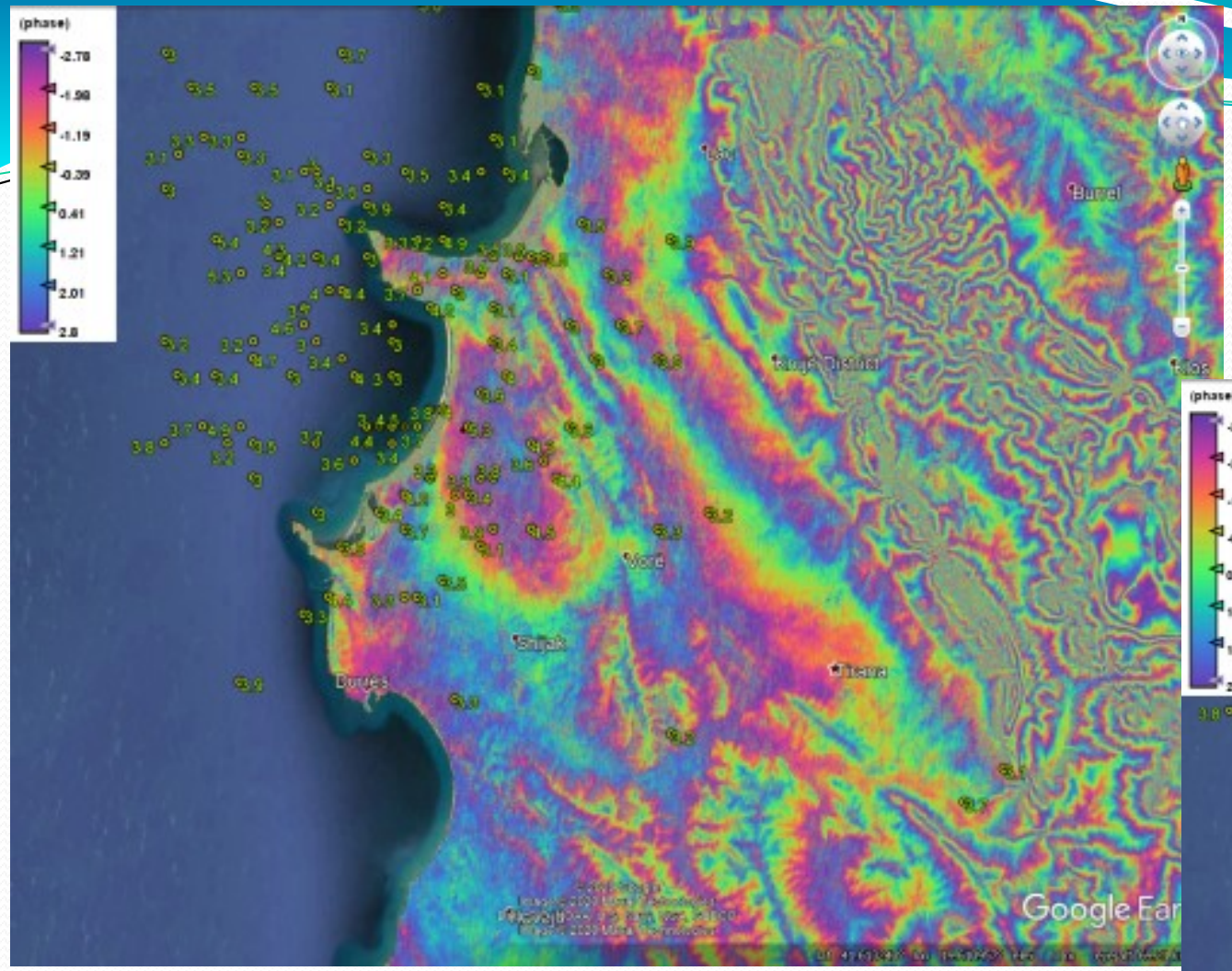


The long-term velocities, in the reference frame ITRF2014, are 23.6 mm /yr in east and 16.3 mm /yr in north at Durrës and 20.0 mm /yr and 15.8 mm/ yr at Tirana. Therefore, the net motion of DUR2, assuming TIR2 fix, is 3.6 mm/ yr of shortening in the azimuth N80. In addition, both GNSS stations exhibit long-term subsidence of -8.7 and -6.5 mm/ yr respectively presumably due mostly to anthropogenic reasons.

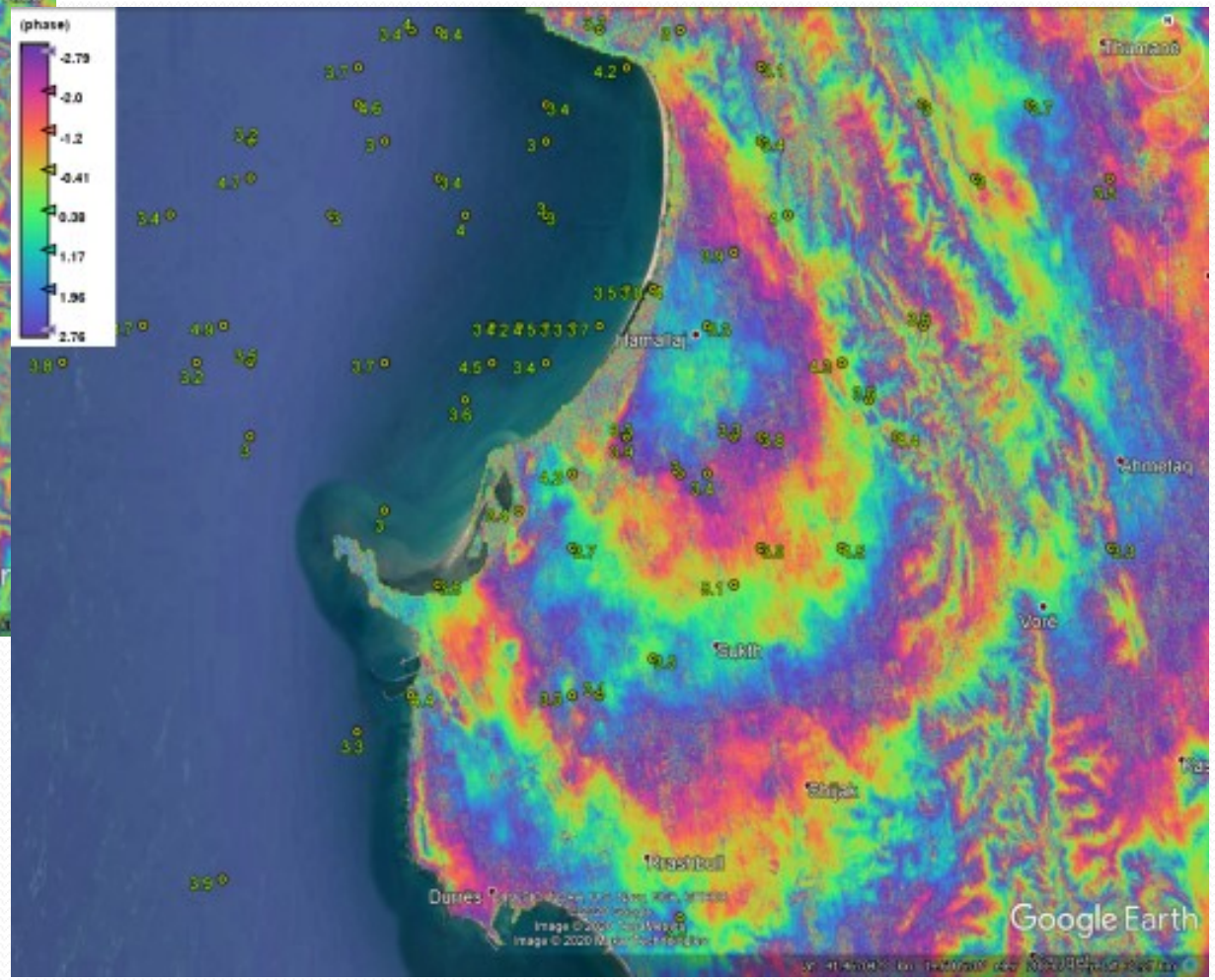
Table :Co-seismic displacements produced by the September 21, 2019 and November 26, 2019

Site	M_w = 5.7, September 21, 2019			M_w = 6.4, November 26, 2019		
	East (mm)	North (mm)	Up (mm)	East (mm)	North (mm)	Up (mm)
DUR2	−5 ± 4	−3 ± 4	10 ± 8	−13 ± 2	−23 ± 2	13 ± 4
TIR2	−4 ± 4	−4 ± 4	7 ± 8	−5 ± 2	−6 ± 2	0 ± 4

We used the GNSS data of the stations DUR2 (Durrës, 19.4510 E, 41.3156 N) and TIR2, (Tirana, 19.8095 E, 41.3357 N) both belonging to the Albanian Positioning Service (AlbPOS) geodetic network (http://www.geo/edu.al/gnss/albpos;
We calculated the static o sets for both September 21, 2019 and November 26, 2019 events.
The sets indicate mm/cm size motion towards west, south and upwards (i.e., uplift), for both events.
Regarding the large aftershock on Nov. 26, 2019 06:08:25 UTC (M = 5.4), we could not see any evidence of we could not see any evidence ofthis aftershock in the GNSS time series.

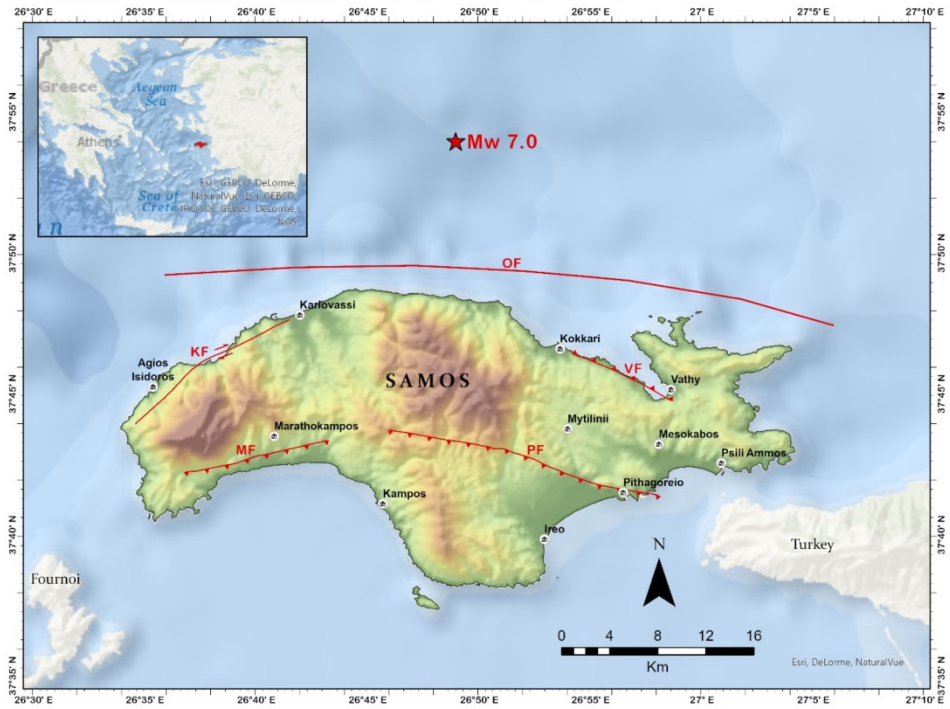


ИФД от дати 02.12 – 19.11.2020 възходяща орбита 175

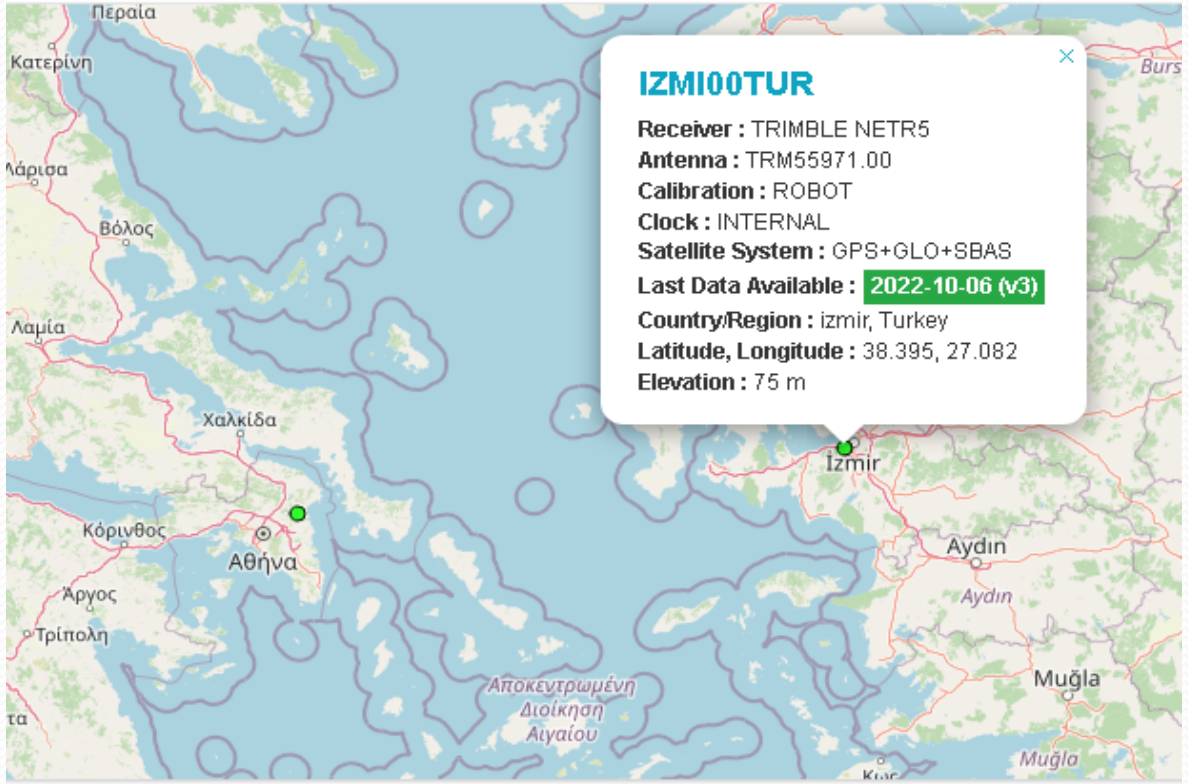


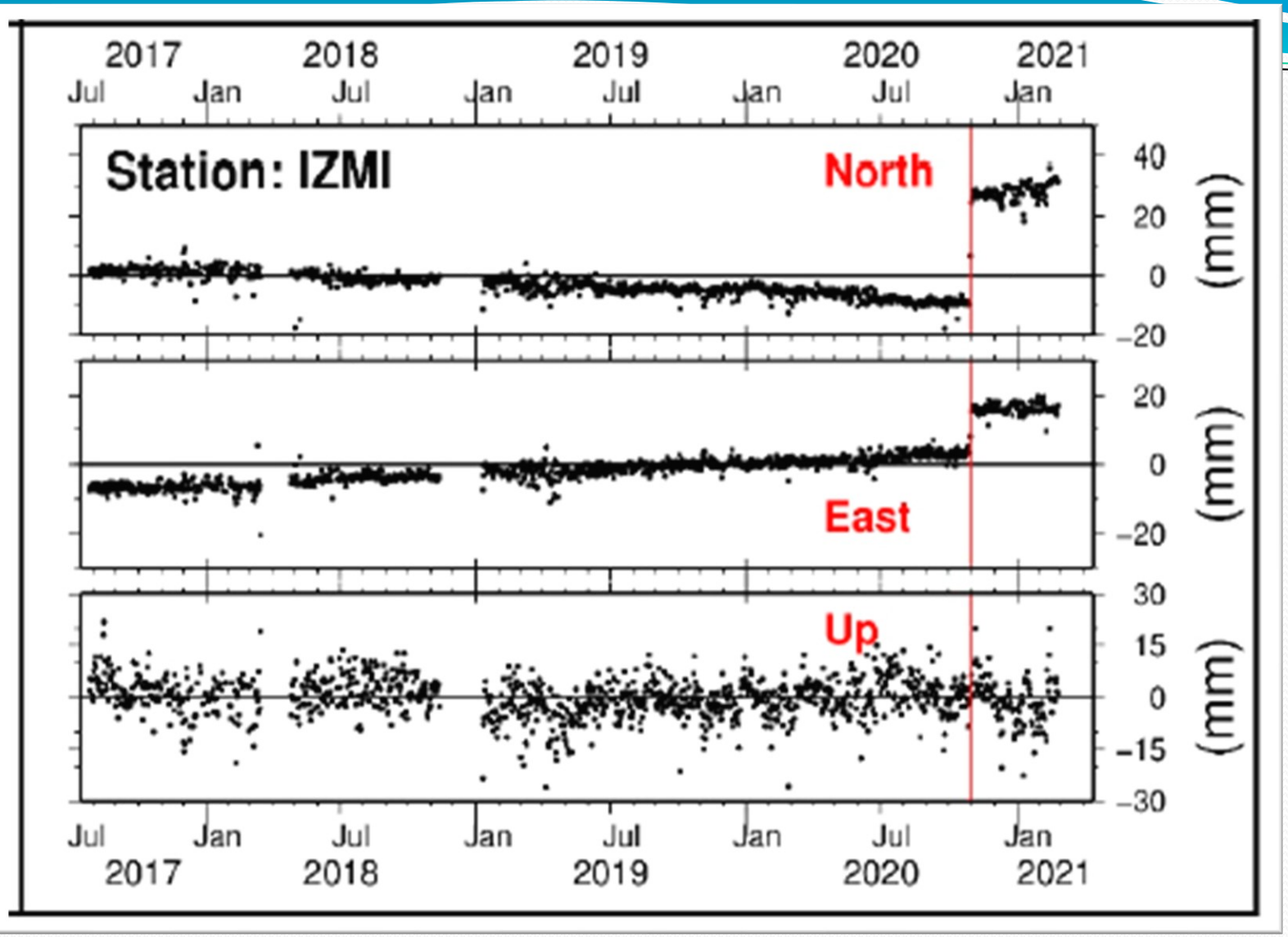
ИФД от дати 01.12. – 19.11.2020 низходяща орбита 153

Earthquake of the Mw=6.9 north of Samos Island (Aegean Sea) on 30 October 2020



(IGS) station https://www.igs.org





Co-Seismic displacements from the IZMI station

Time series of GNSS stations IZMI, which is an International GNSS Service The reference frame is ITRF2014.
Red line marks the day of the earthquake.

D-displacement;

STDV -standard deviation;

E- east–west;

N-north–south;

U- vertical/up.

Station	Longitude	Latitude	DE (mm)	DN (mm)	DU (mm)	STDVE (mm)	STDVN (mm)	STDVU (mm)
IZMI	27.0818	38.3948	12.21	35.20	5.03	2.20	6.05	4.71

Заключение

- През последните няколко десетилетия техниката на глобалната навигационна сателитна система (GNSS) е използвана за изследване на полето на скоростта на земната кора, както и на земните деформации, дължащи се на сеизмична, вулканична, геоложка или антропогенна дейност
- GNSS техниката може да определи абсолютен 3D вектор на преместване на земята (изчислени грешки 2–3 mm и 5–8 mm съответно за хоризонталния и вертикалния компонент), но е ограничена до точково покритие. InSAR осигурява пространствено покритие, но информацията е в посоката на пряката видимост (LOS) и е необходим допълнителен анализ, за да се получат истинските компоненти на земното движение.

Conclusion

- Over the past few decades, the Global Navigation Satellite System (GNSS) technique has been used to study the crustal velocity field, as well as ground deformations due to seismic, volcanic, geologic, or anthropogenic activity
- The GNSS technique can provide an absolute 3D vector of ground displacement (estimated errors ~2–3 mm and ~5–8 mm for the horizontal and vertical component, respectively), but it is limited to point-wise coverage. The InSAR provides spatial coverage, but the information is in the line-of-sight (LOS) direction, and further multi-geometrical analysis is required to obtain the true ground motion components.

Благодаря за вниманието !

mila_at_zl@abv.bg