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Crustal Deformation from GPS measurements at the Ionian Sea : Results from 3 years of observations

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The Ionian Sea region comprises a plate boundary between Africa and Eurasia plates where relative plate motion is mainly tangential. This area is the most seismic part of Greece. Deformation patterns are complex because the horizontal motion of blocks across the Kefallinia transform fault is accompanied by shortening (in the north) and extension (central and south Ionian Sea). Since 2006 NOA has established a network of permanent GPS stations in order to monitor rates of crustal deformation and evaluate the seismic hazard of the area. Station velocities using three years of observations were calculated and compared to previous studies. Preliminary results of the strain tensor in the north and central Ionian Sea are presented.

NTUA, Faculty of Rural and Surveying Engineering, Dionysos Satellite Observatory, Higher Geodesy Laboratory (1)
NOA, Institute of Geodynamics (2)

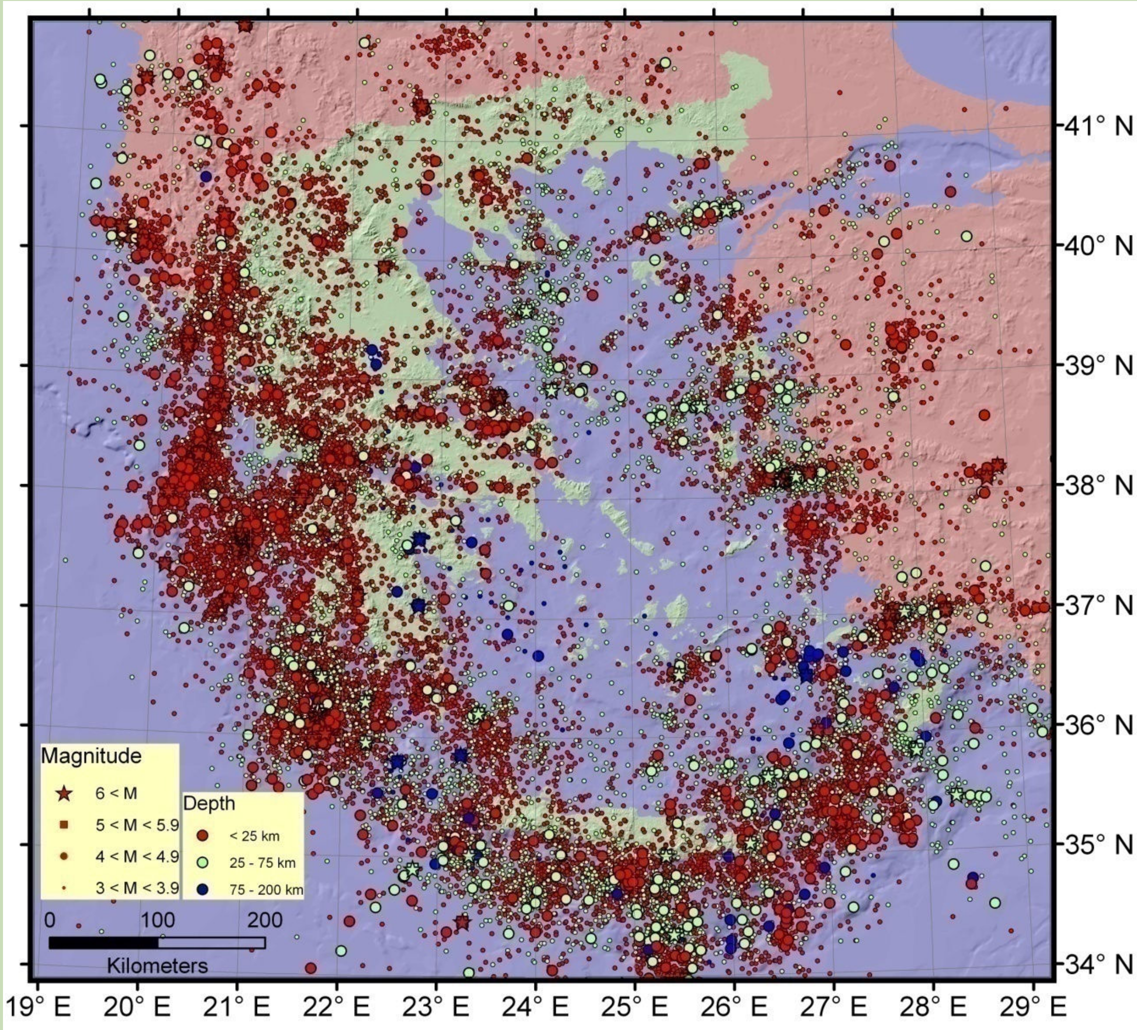
1. Tectonic Setting

Greece is located in the collision zone between the Nubian/Arabian and the Eurasian lithospheric plates .

<u>Main Tectonic features:</u>

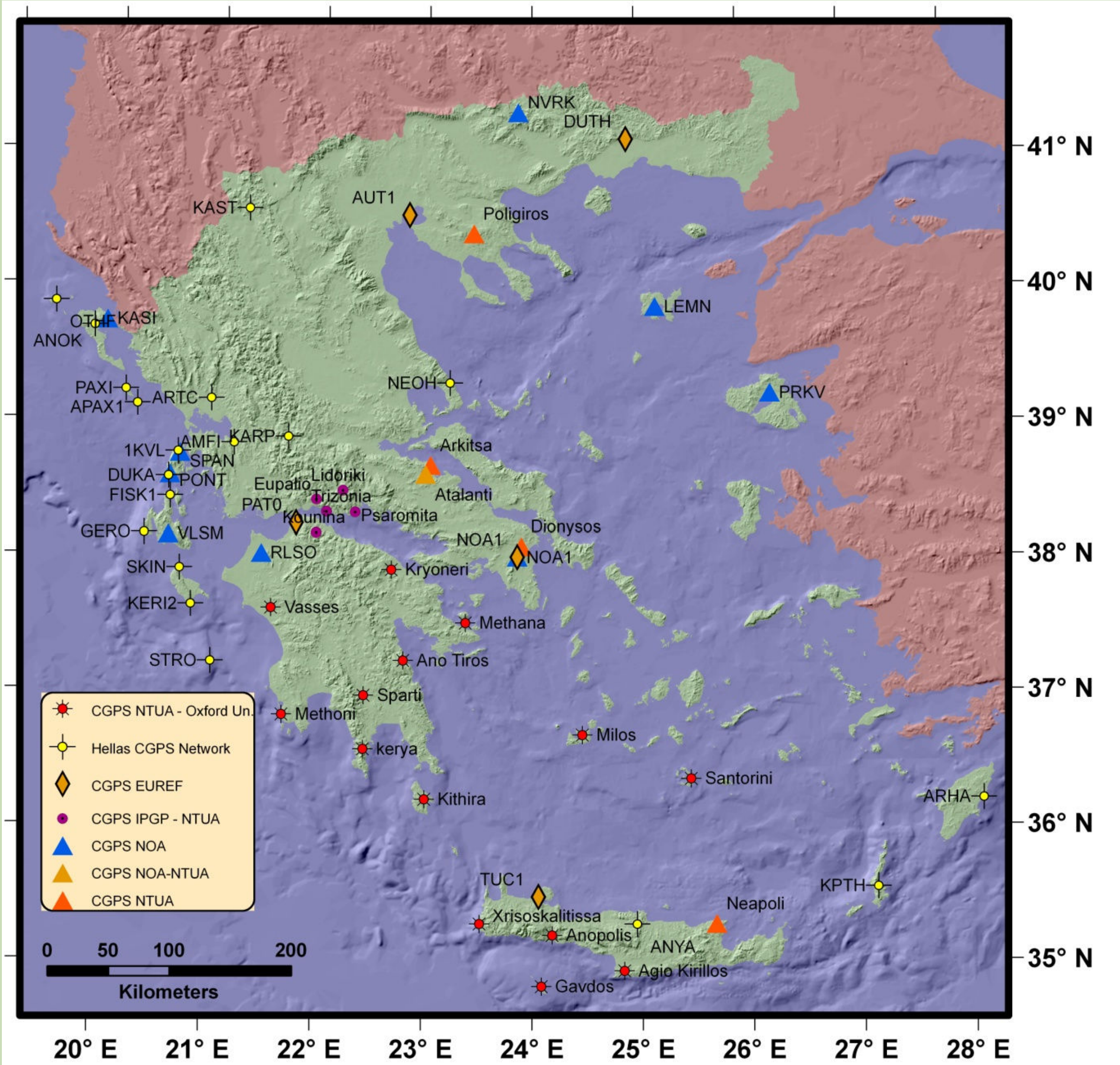
- Hellenic Trenches
- Hellenic Arc (Seismic and Volcanic)
- North Aegean Trough
- Kefallinia Transform Fault (KTF)

Currently. KTF is the most seismically active region in Greece.



2. Permanent GPS networks in Greece

- CGPS EUREF
- CGPS National Observatory of Athens
- CGPS NOA - NTUA
- CGPS NTUA
- CGPS Oxford University - NTUA
- Hellas CGPS Network (ETH – NTUA)
- CGPS IPGP France - NTUA



3. NOANET stations used in this study

Receivers Leica 1200 GRX Pro
Antennas Leica AX 1202
1-s observations

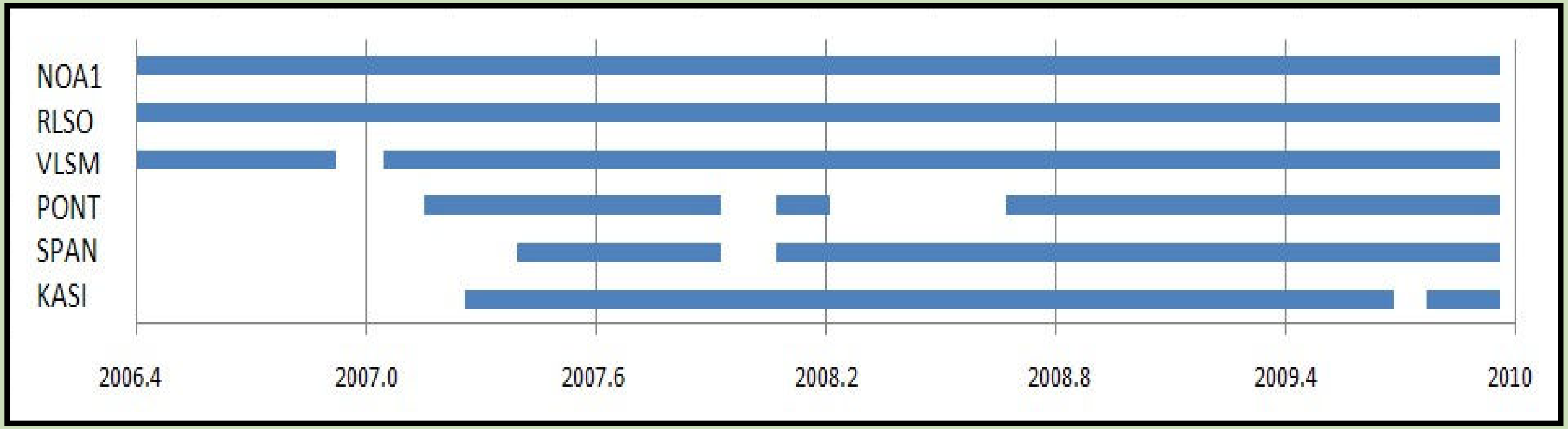
No	Code	Location	Start Date	No of days processed
1	KASI	Kassiopi – Kerkyra	30/3/2007	104
2	SPAN	Spanochori – Lefkada	21/5/2007	97
3	PONT	Ponti – Lefkada	14/2/2007	95
4	VLSM	Valsamata - Kefallinia	13/2/2006	141
5	RLSO	Riolos – Achaia	30/7/2006	145
6	NOA1	Pendeli- Attica	10/4/2006	120

Diagram of 30-s Data availability

Data available from the Internet:

http://194.177.194.200/services/GPS/GPS_DATA/

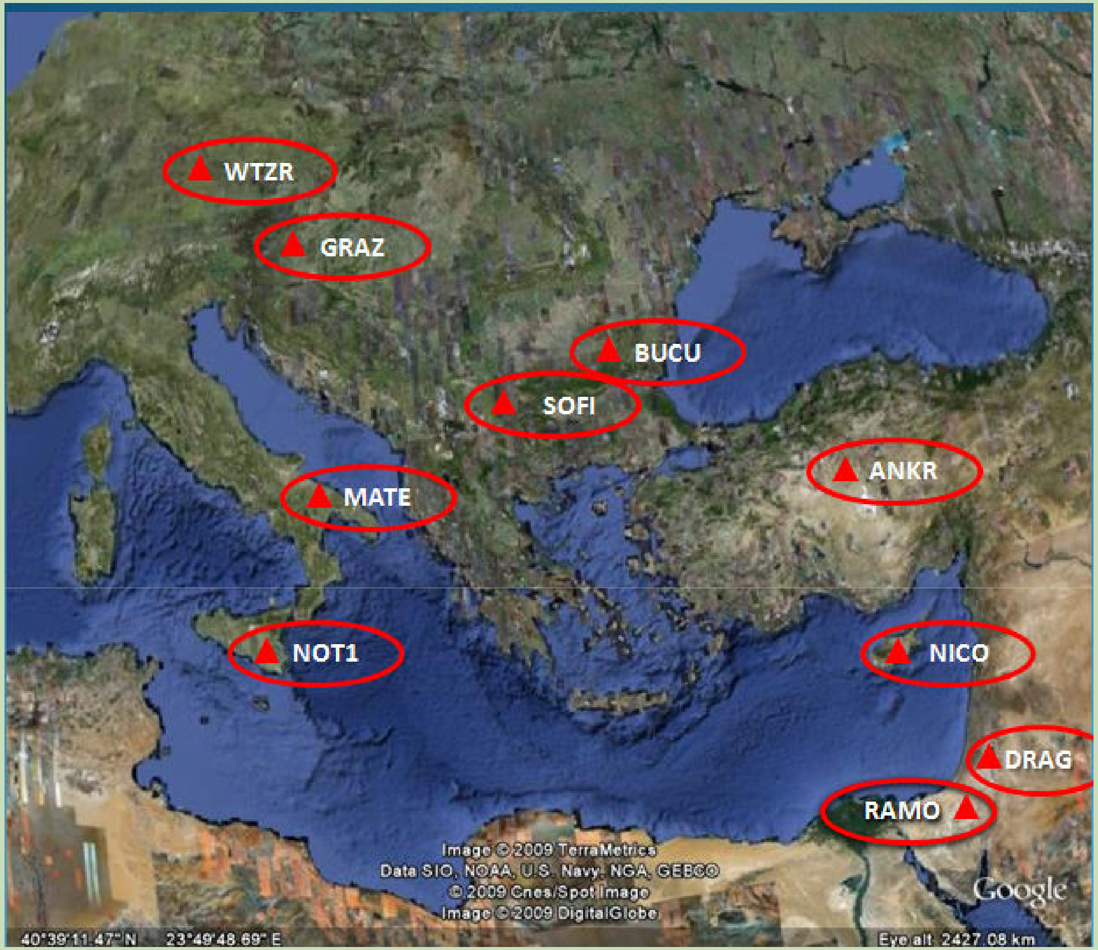
Data gaps due to Ethernet card damage



4. Data Processing

Bernese software V. 4.2 was used following the standards below :

- Precise IGS (International GNSS Service) orbits and corresponding pole
- IGS (International GNSS Service) phase eccentricity file
- Automatic phase check
- QIF(Quasi Ionosphere Free) ambiguity resolution strategy (accepted baselines with resolved ambiguities more than 70%)
- Ionosphere model used for baselines longer than 400km
- Normal equations for each day (loose constraints)
- Combined solution using each day’s normal equation file



- Realization of the Reference Frame ITRF 2005
- 10 IGS stations were used
- Main criterion for station selection was network geometry

Comparison to EUREF solution

• Calculation of 120 days.
4 days per month
total of 33 months

• EUREF solution includes 425 daily solutions

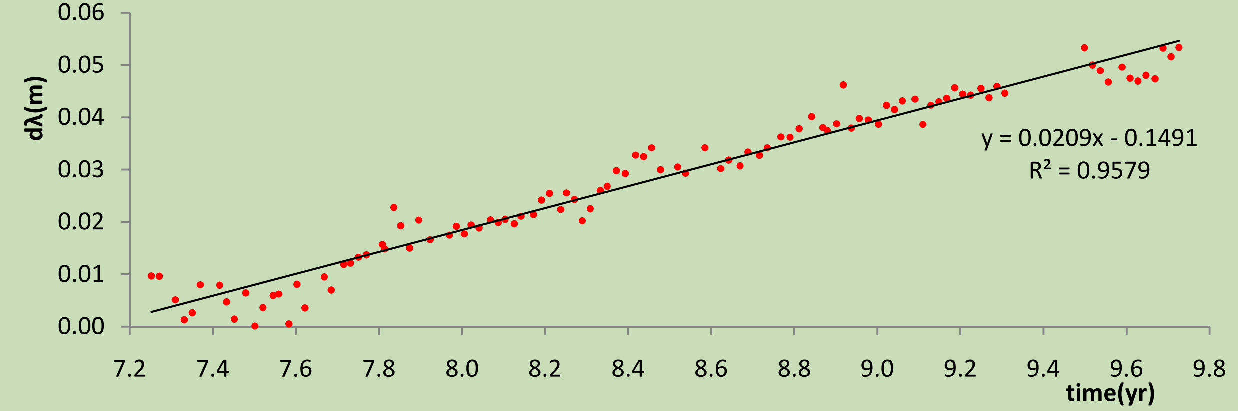
• For EUREF NOA station differences are:
Angular 5°
Linear 1 mm/yr

Velocities of NOA1 station with respect to a fixed Europe (mm/yr)		
	Vn	Ve
2006.5 - 2009.3	-25.6	-14.2
2006.5 – 2009.8	-25.5	-14.5

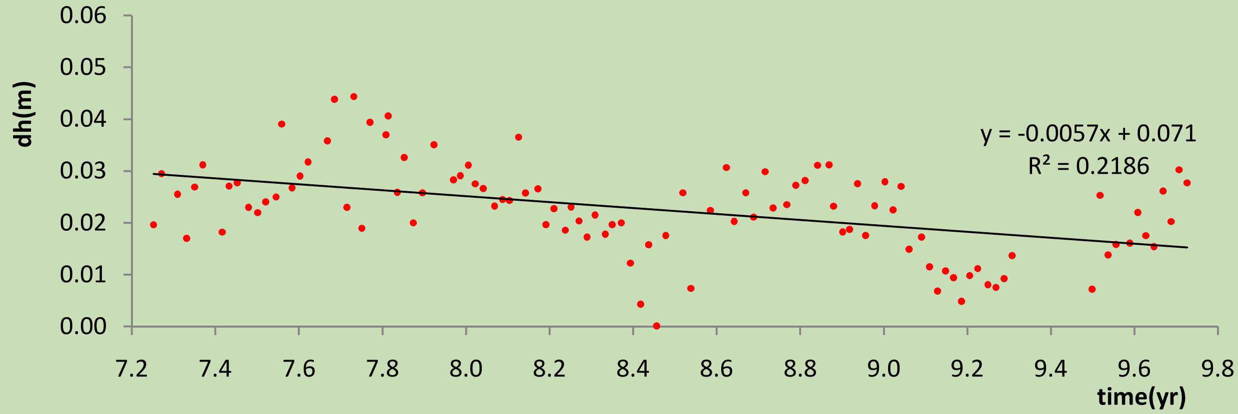
The differences from the comparison to the EUREF solution may be due to the realization of the reference frame.

Tectonic Motion of KASI in ITRF 2005

Vn (mm/yr)	12.4
σVn (mm/yr)	±0.4

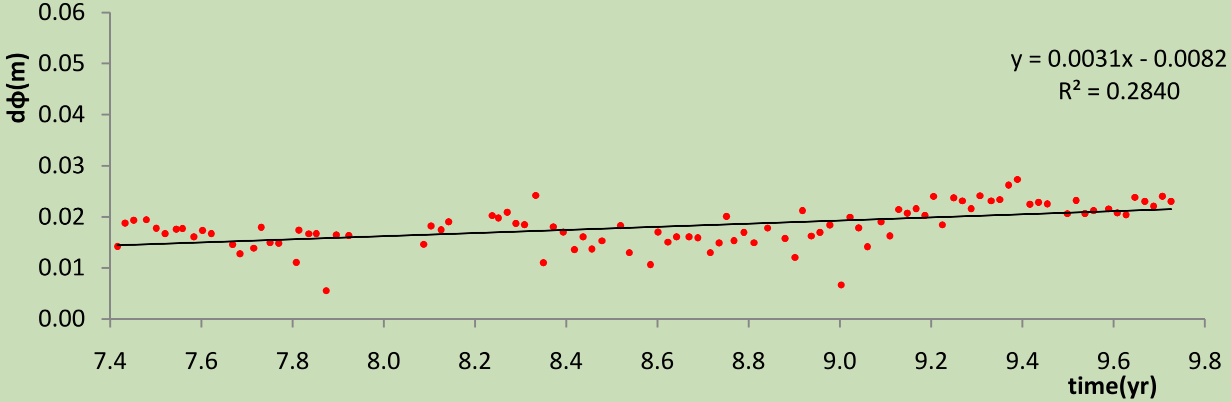


Ve (mm/yr)	20.9
σVe (mm/yr)	±0.4



Vu (mm/yr)	-5.7
σVu (mm/yr)	±1.1

Tectonic Motion of SPAN in ITRF 2005

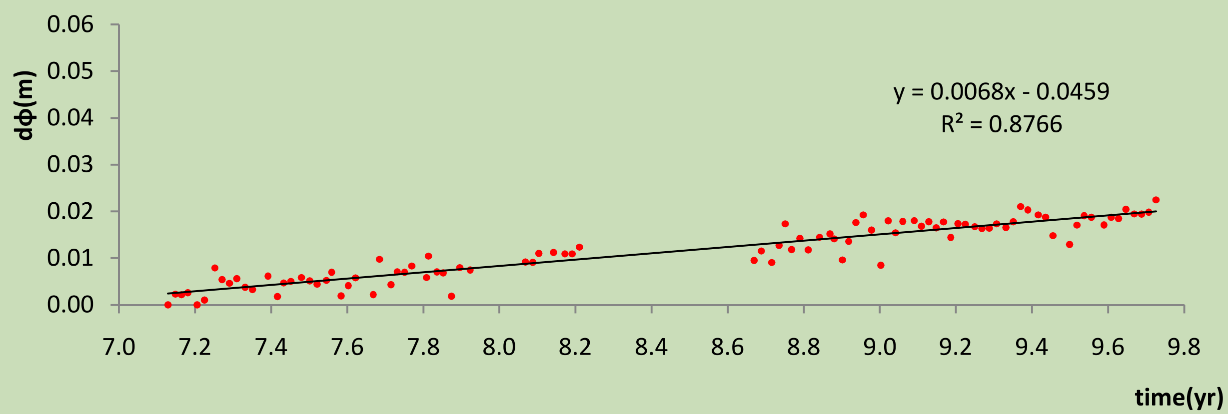


Vn (mm/yr)	3.1
σVn (mm/yr)	±0.5

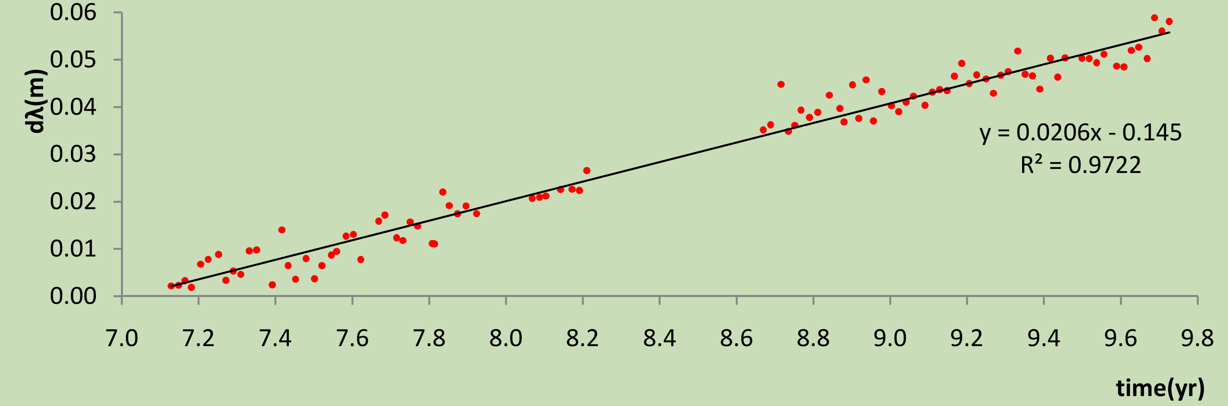
Ve (mm/yr)	22.5
σVe (mm/yr)	±0.5

Vu (mm/yr)	-5.5
σVu (mm/yr)	±1.1

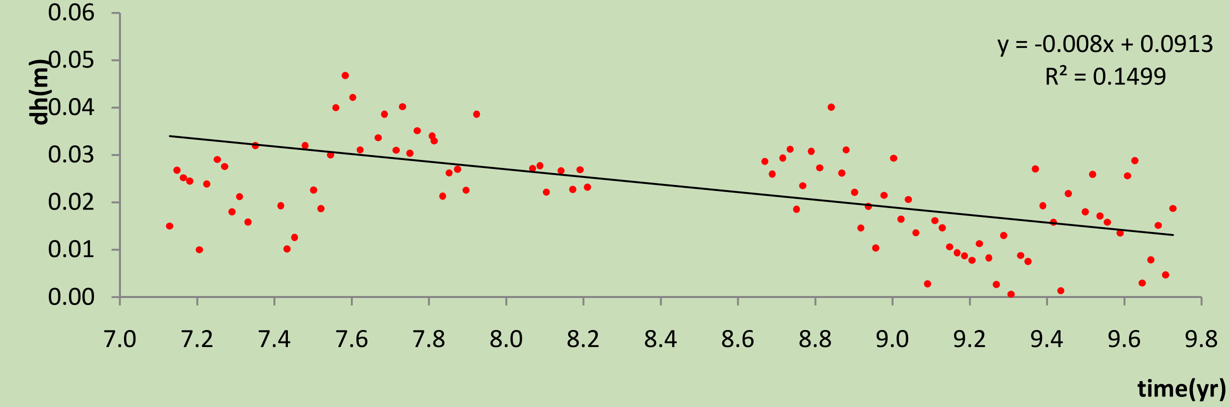
Tectonic Motion of PONT in ITRF 2005



Vn (mm/yr)	6.8
σVn (mm/yr)	±0.3

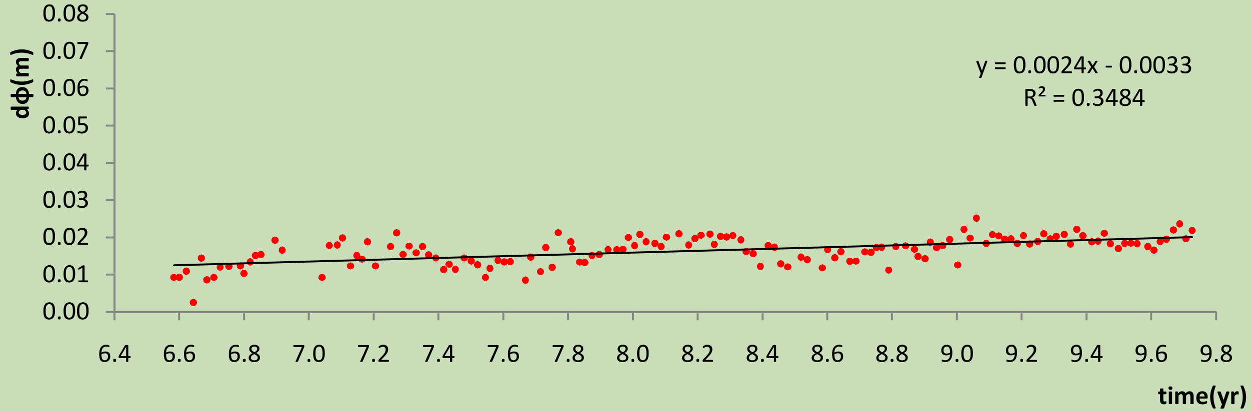


Ve (mm/yr)	20.6
σVe (mm/yr)	±0.4

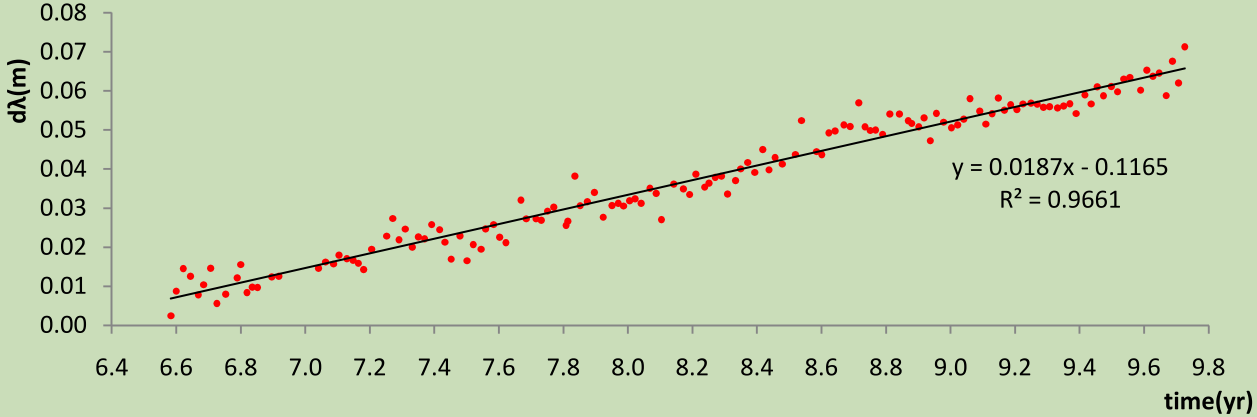


Vu (mm/yr)	-7.3
σVu (mm/yr)	±1.9

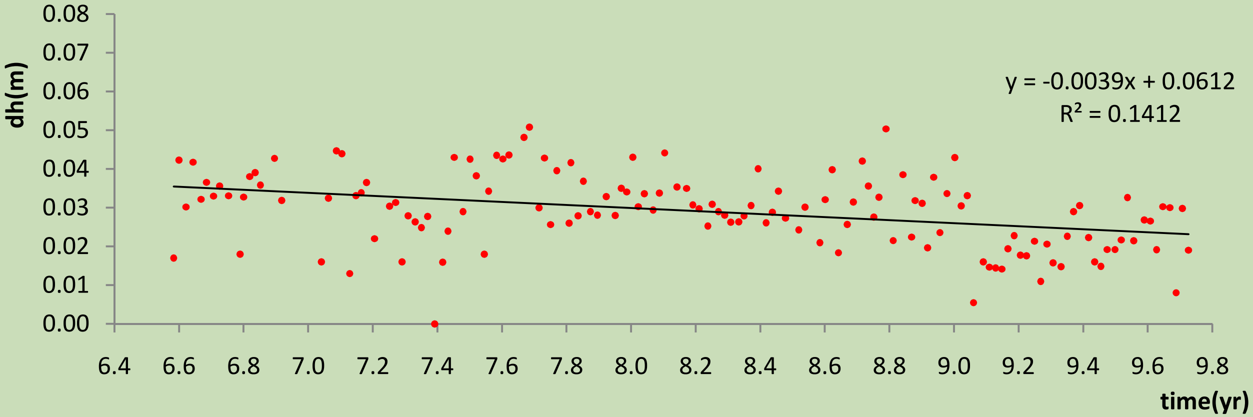
Tectonic Motion of VLSM in ITRF 2005



Vn (mm/yr)	2.4
σVn (mm/yr)	±0.3

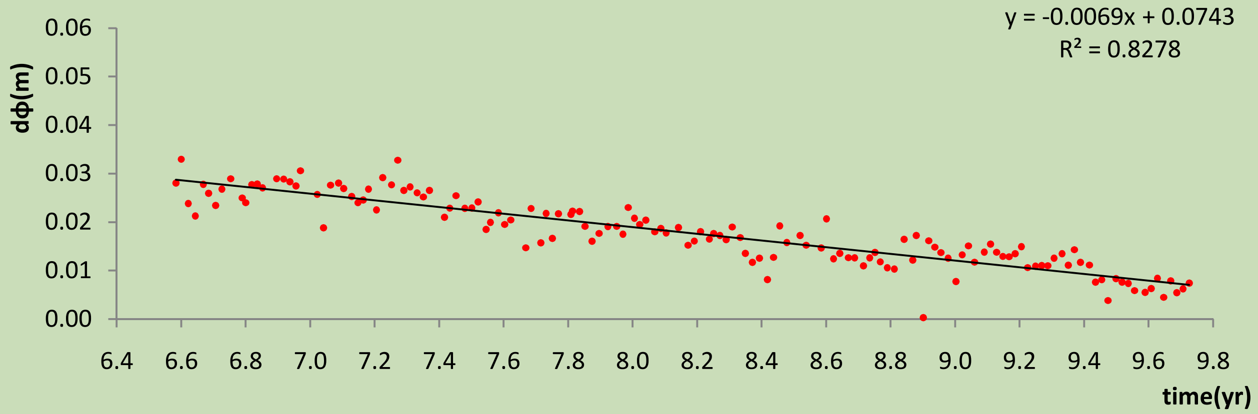


Ve (mm/yr)	18.7
σVe (mm/yr)	±0.3

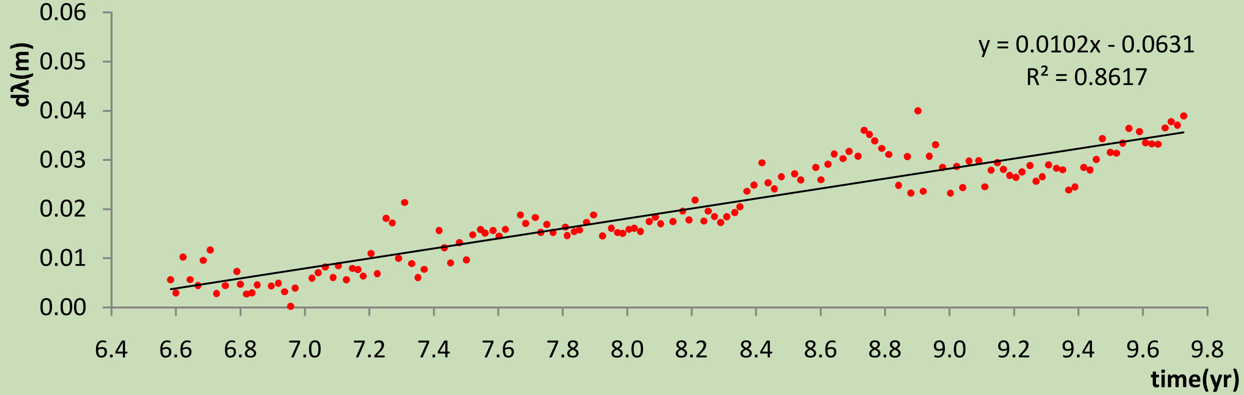


Vu (mm/yr)	-3.9
σVu (mm/yr)	±0.8

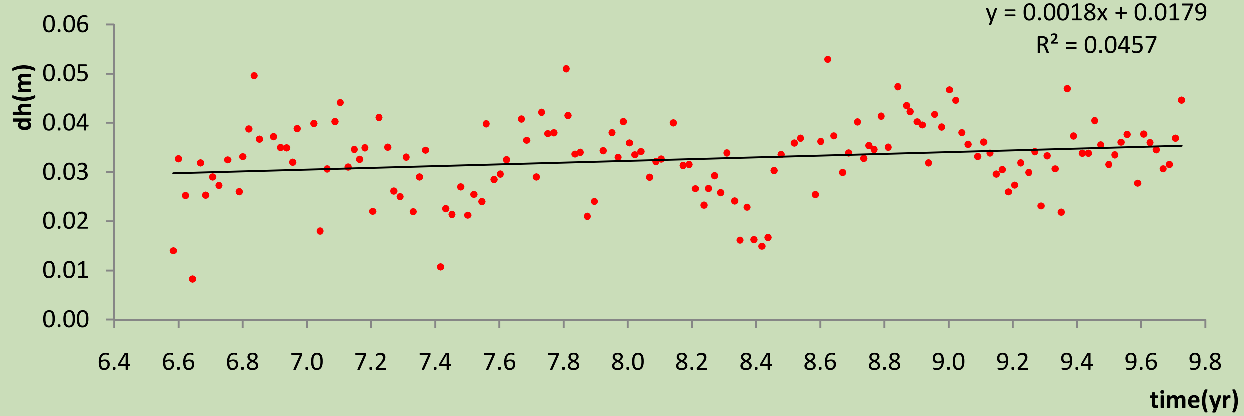
Tectonic Motion of RLSO in ITRF 2005



Vn (mm/yr)	-6.9
σVn (mm/yr)	±0.3



Ve (mm/yr)	10.2
σVe (mm/yr)	±0.3



Vu (mm/yr)	-1.8
σVu (mm/yr)	±0.7

Comparison of station velocities for different period analysis

Velocities for period 2006.5 – 2009.3 in ITRF2005 (mm/yr)						
CODE	Vn	σ	Ve	σ	Vu	σ
KASI	11.7	±1.0	23.1	±1.0	-8.4	±2.5
NOA1	-14.2	±0.5	9.3	±0.8	-1.5	±1.4
PONT	7.0	±0.4	21.5	±0.5	-7.4	±3.0
RLSO	-6.8	±0.4	11.0	±0.4	2.1	±0.9
SPAN	0.8	±0.7	23.0	±0.7	-6.6	±2.2
VLSM	2.4	±0.4	19.3	±0.4	-2.8	±1.1

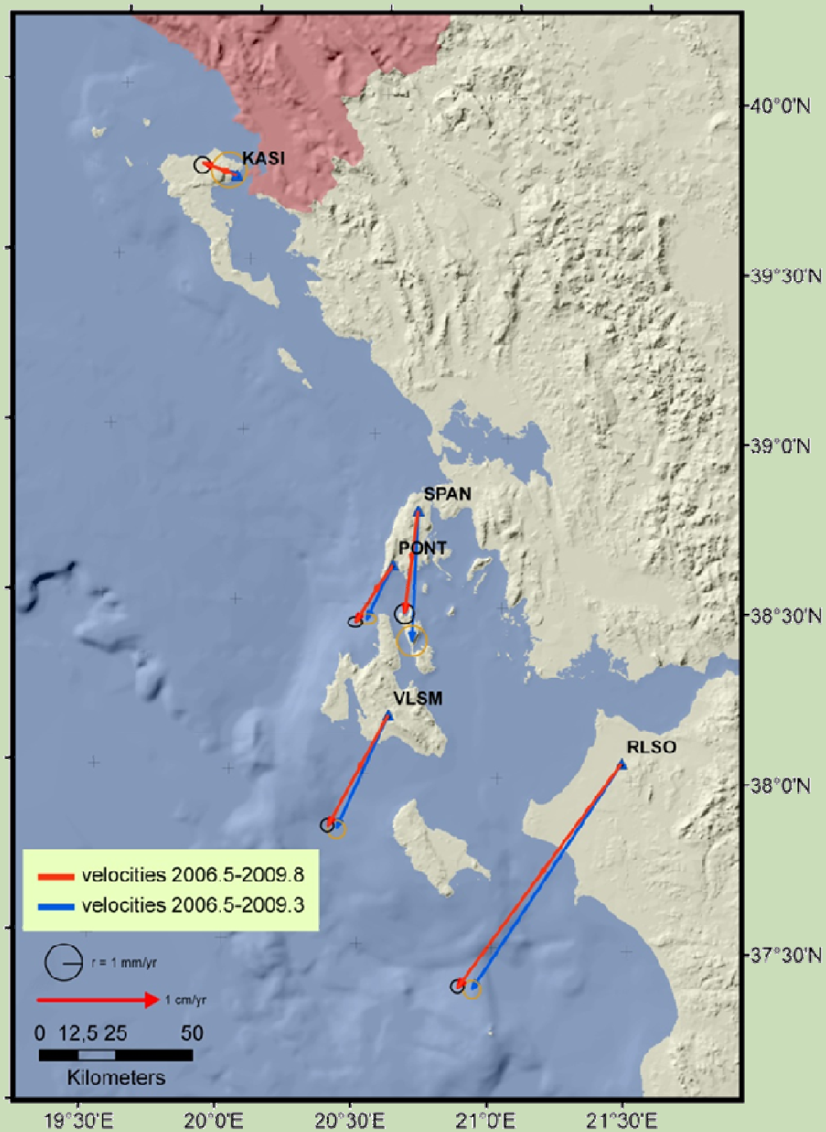
Velocities for period 2006.5 – 2009.8 in ITRF2005 (mm/yr)						
CODE	Vn	σ	Ve	σ	Vu	σ
KASI	12.4	±0.4	20.9	±0.4	-5.7	±1.1
NOA1	-14.1	±0.4	9.1	±0.6	-2.8	±0.0
PONT	6.8	±0.3	20.6	±0.4	-7.3	±1.9
RLSO	-6.9	±0.3	10.2	±0.3	1.8	±0.7
SPAN	3.1	±0.5	22.5	±0.5	-5.0	±1.1
VLSM	2.4	±0.3	18.7	±0.3	-3.9	±0.8

Comparison of two different period analysis (mm/yr)			
CODE	ΔVn	ΔVe	ΔVu
KASI	0.7	-2.2	2.7
NOA1	0.1	-0.2	-1.3
PONT	-0.2	-0.9	0.1
RLSO	-0.1	-0.8	-0.3
SPAN	2.3	-0.5	1.6
VLSM	0.0	-0.6	-1.1

Comparison of Station Velocities with respect to a fixed Europe

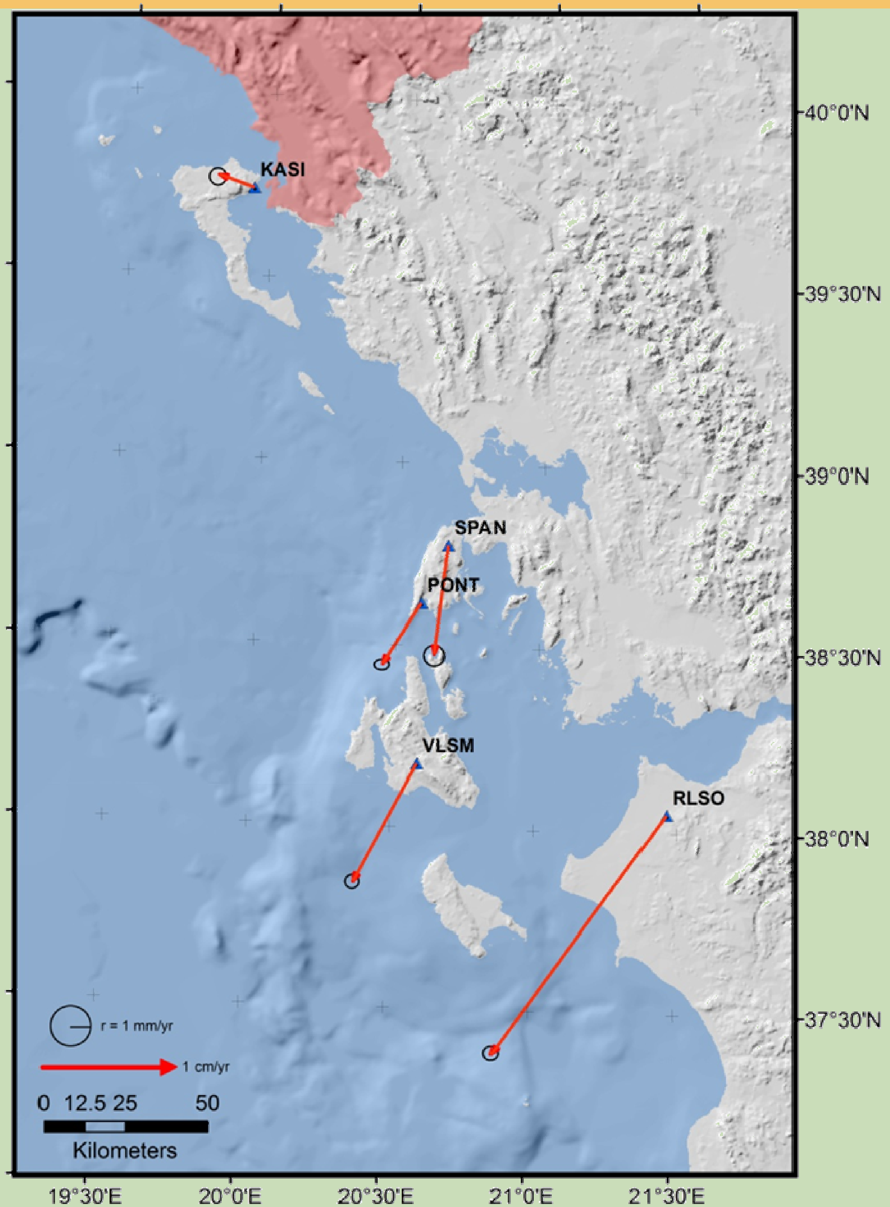
Velocities with respect to a fixed Europe for period 2006.5 – 2009.3 (mm/yr)				
CODE	Vn	σ	Ve	σ
KASI	0.3	±1.0	-0.5	±1.0
PONT	-4.4	±0.4	-2.1	±0.5
RLSO	-18.2	±0.4	-12.6	±0.4
SPAN	-10.6	±0.7	-0.6	±0.7
VLSM	-9.0	±0.4	-4.3	±0.4

Velocities with respect to a fixed Europe for period 2006.5 – 2009.8 (mm/yr)				
CODE	Vn	σ	Ve	σ
KASI	1.0	±0.4	-2.7	±0.4
PONT	-4.6	±0.3	-3.0	±0.4
RLSO	-18.3	±0.3	-13.4	±0.3
SPAN	-8.3	±0.5	-1.1	±0.5
VLSM	-9.0	±0.3	-4.9	±0.3

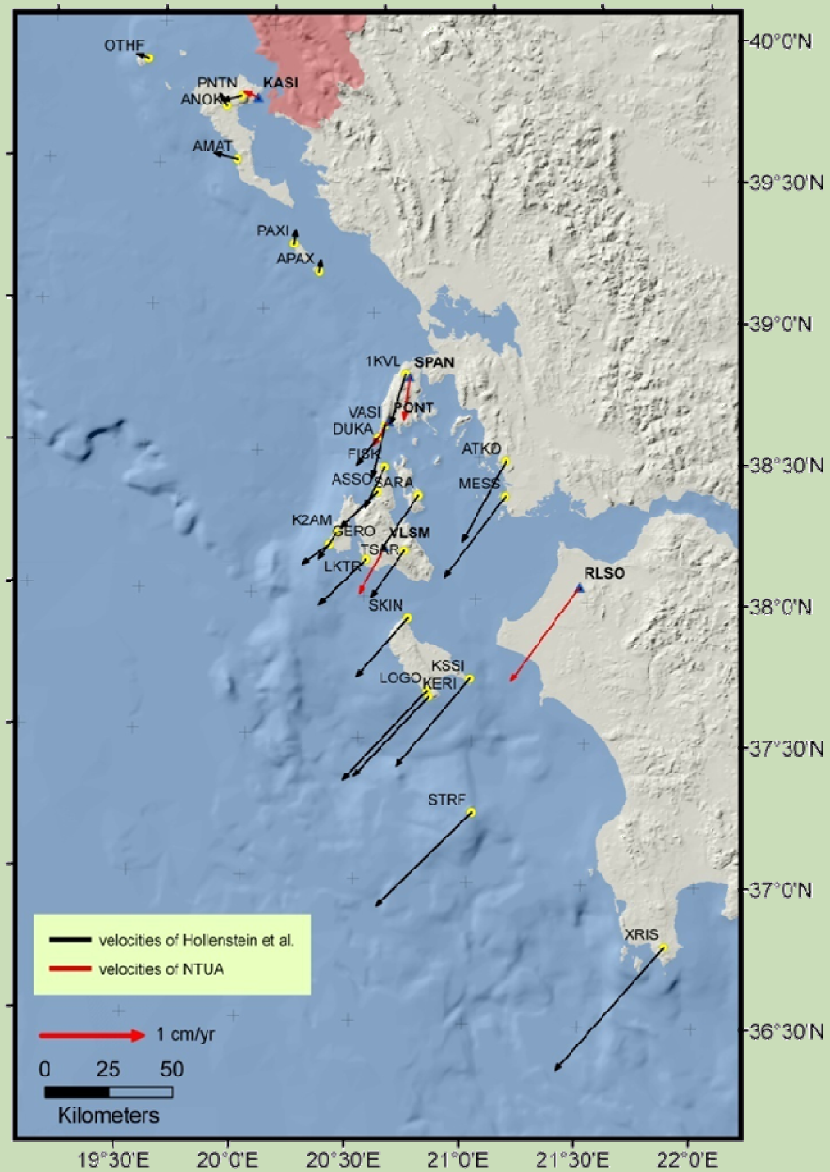


Station Velocities with respect to a fixed Europe

Velocities with respect to a fixed Europe for period 2006.5 – 2009.8 (mm/yr)				
CODE	Vn	σ	Ve	σ
KASI	1.0	±0.4	-2.7	±0.4
PONT	-4.6	±0.3	-3.0	±0.4
RLSO	-18.3	±0.3	-13.4	±0.3
SPAN	-8.3	±0.5	-1.1	±0.5
VLSM	-9.0	±0.3	-4.9	±0.3



Comparison with the research work of Hollenstein et al. (2008)



Hollenstein et al. data analysis

- 76 stations, 18 campaigns carried out between 1993 and 2003
- 22 stations, continuous data between 1995 and 2003
- 54 European IGS and EUREF sites
- Processed using the Bernese GPS Software version 4.2
- 15 European IGS stations used for the realization of ITRF2000
- Velocity of Eurasia calculated from 54 IGS and EUREF sites

We used for the comparison

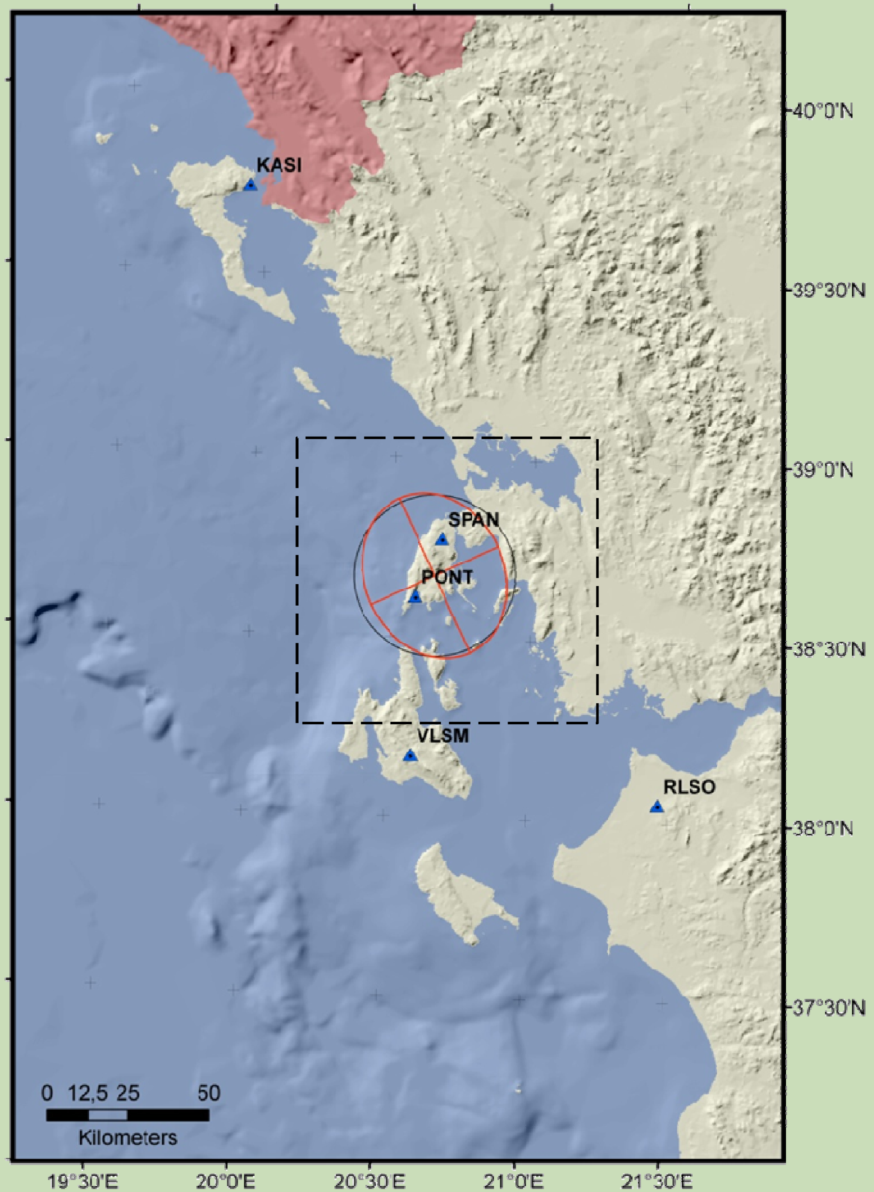
- 10 permanent stations
- 14 campaign sites

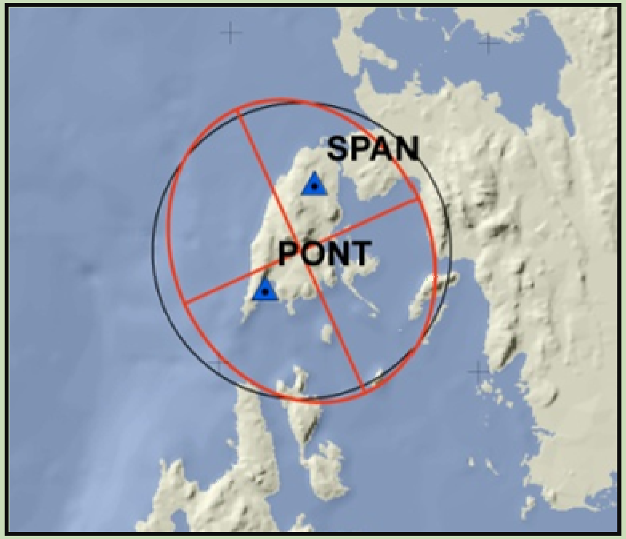
Calculation of Strain Tensor Parameters

Assumptions:

- 2-dimensional deformation of earth's crust in time
- Crust is considered a thin deformable shell on a spherical earth
- Mapping distortions are ignored for regions with radius of less than 5°
- Time (earthquakes) or space (faults) discontinuities are not included in the calculation

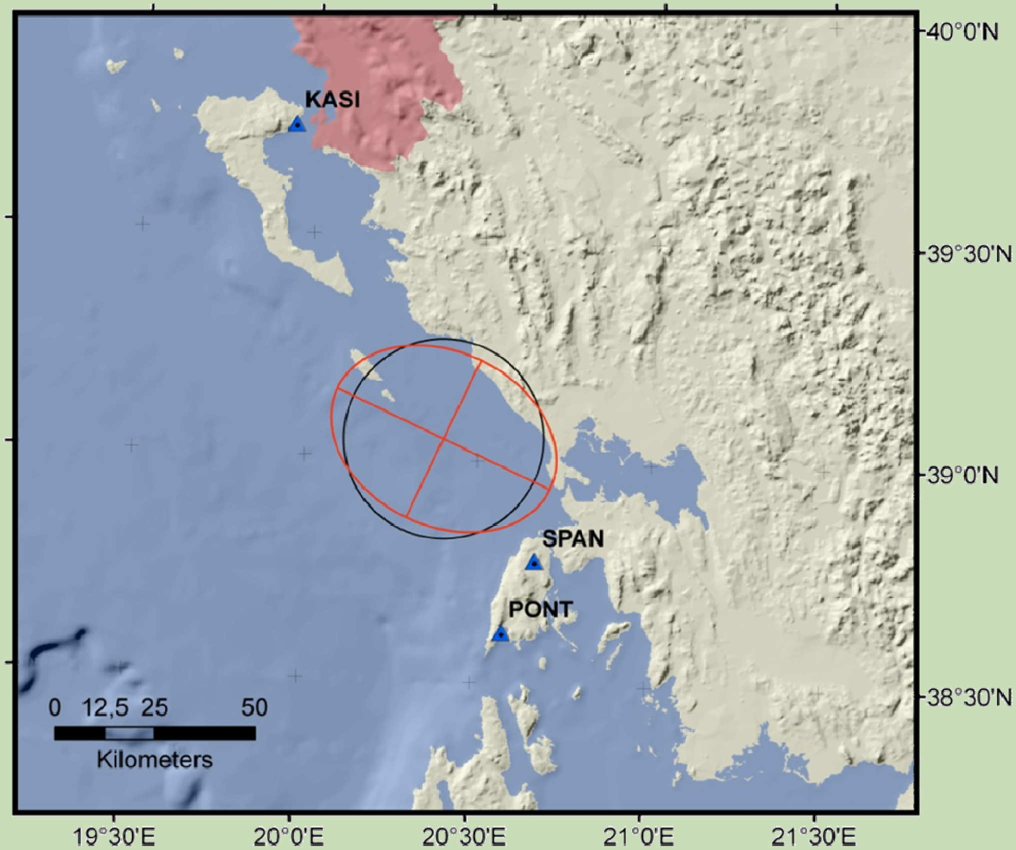
Strain tensor of the whole Ionian region
Period of Observations : 2006.5-2009.8





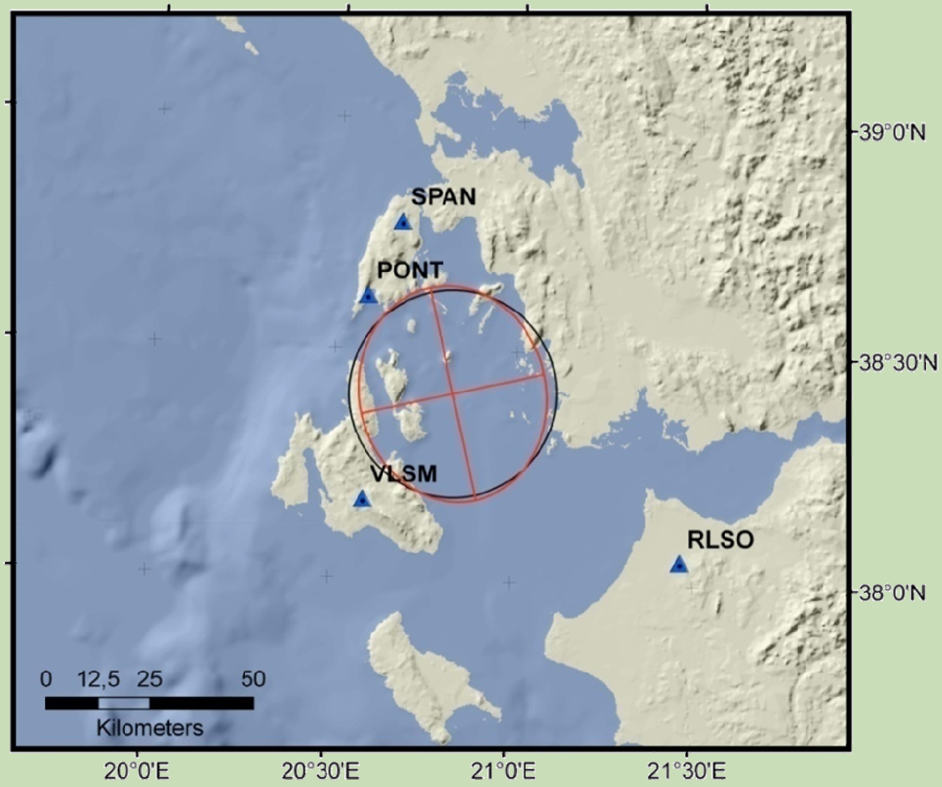
K_{max} (ppm)	K_{min} (ppm)	Az (deg)
0.050	-0.139	-24.388

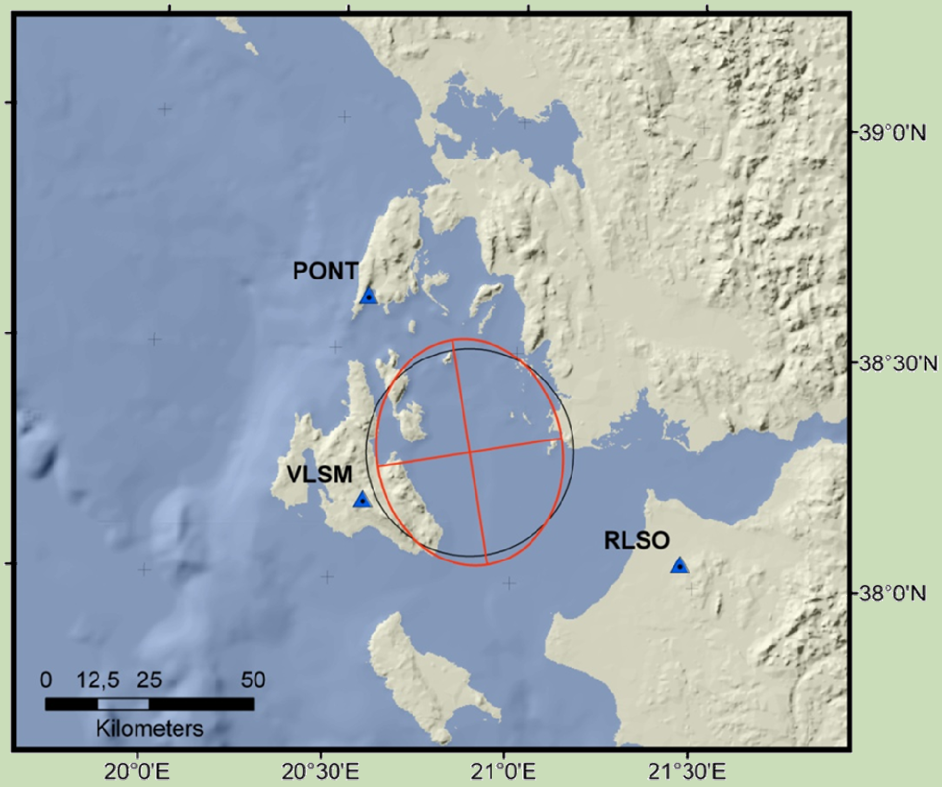
Strain tensor in the north Ionian Sea
Period of Observations : 2006.5-2009.8



K_{max} (ppm)	K_{min} (ppm)	Az (deg)
0.178	-0.129	115.622

Strain Tensors in the central Ionian Sea (Lefkada – Kefallinia islands and Peloponnese) Period of Observations : 2006.5-2009.8

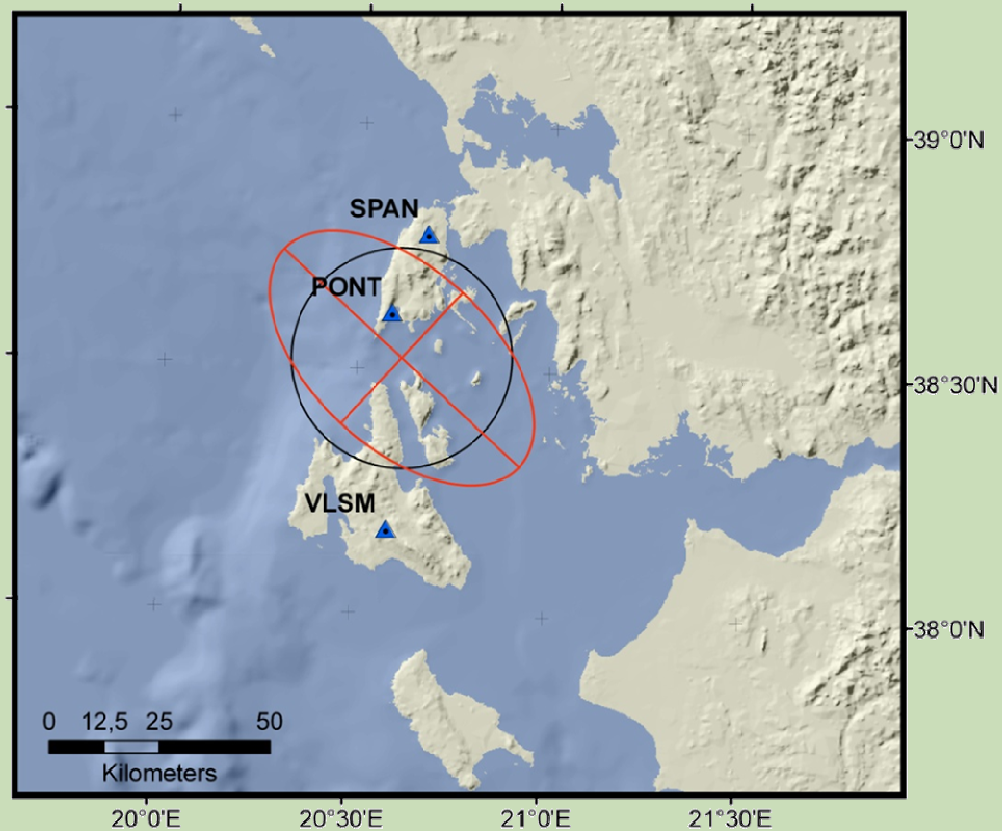




K_{max} (ppm)	K_{min} (ppm)	Az (deg)
0.046	-0.099	-11.978

K_{max} (ppm)	K_{min} (ppm)	Az (deg)
0.097	-0.107	-8.613

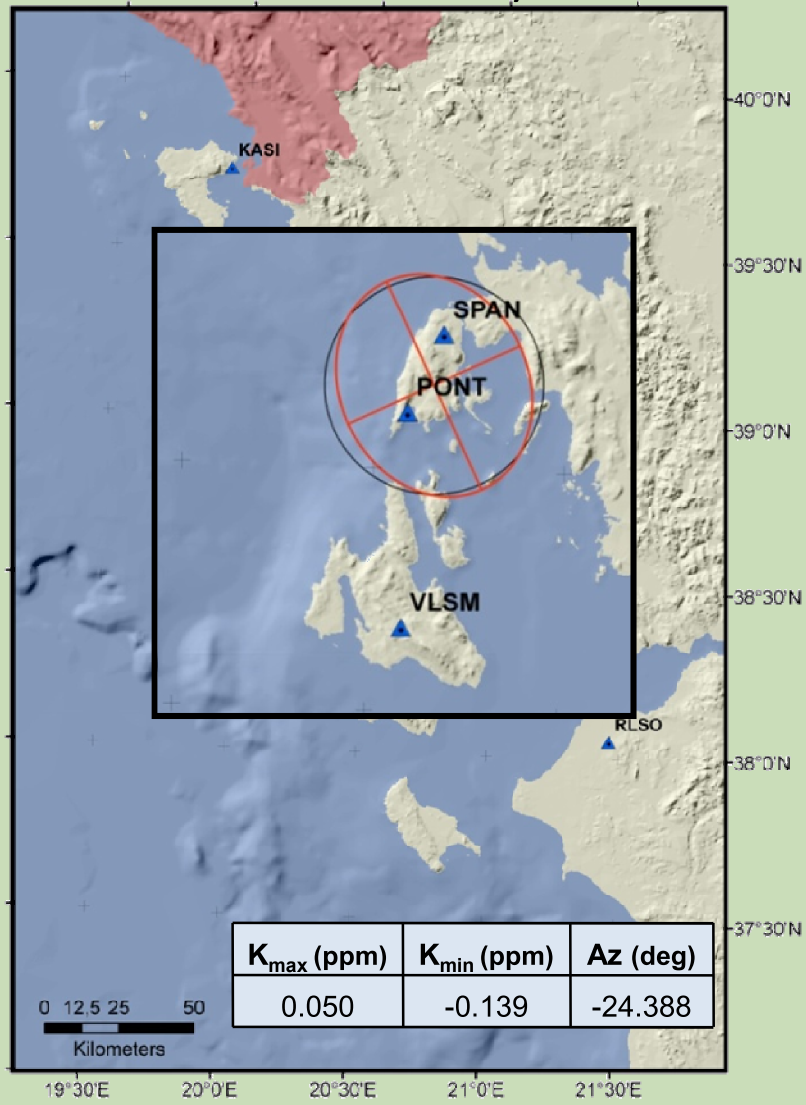
Strain Tensor in the central Ionian Sea (Lefkada – Kefallinia islands)
Period of Observations : 2006.5-2009.8



K_{max} (ppm)	K_{min} (ppm)	Az (deg)
0.455	-0.189	133.007

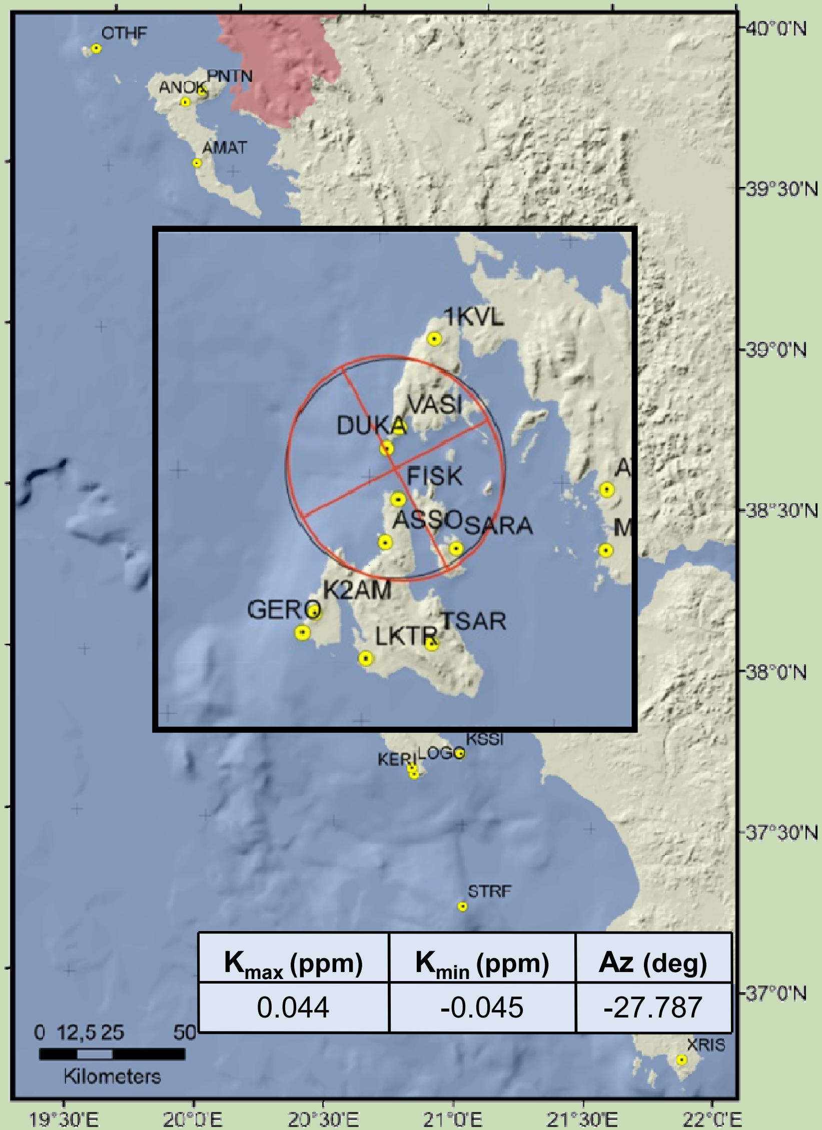
Comparison of Strain Tensors

From this study



K_{max} (ppm)	K_{min} (ppm)	Az (deg)
0.050	-0.139	-24.388

From the work of Hollenstein et al., 2008



K_{max} (ppm)	K_{min} (ppm)	Az (deg)
0.044	-0.045	-27.787

Conclusions

1. The reliability of velocity rates depends on observation duration. Standard deviations of the velocities calculated by linear regression are reduced as time of observations increases.

2. The station velocities in the central Ionian sea vary between 5-20 mm/yr with respect to a fixed Europe. Motion is to the SSW.

3. Station KASI in Kerkira Island has an almost zero velocity. The movement seems to be the same as the one of the Eurasian plate.

4. The differences in velocities compared with Hollenstein et al., 2008, may be due to the realization of the reference frame and the use of a different model for the velocity of Eurasia.

Conclusions

5. Strain tensor analysis shows that overall, the Ionian Sea region is extending in the NW-SE direction, as is also found by Hollenstein et al., 2008*.

6. However. different strain patterns are obtained for north and for central Ionian sea. The north Ionian is under NE-SW compression. The central Ionian is under NNW-SSE extension.

7. The north part of Lefkada seems to move faster than the south part.

*Hollenstein Ch., Muller M.D., Geiger A., Kahle H.-G., 2008. Crustal motion and deformation in Greece from decade of GPS measurements 1993-2003. *Tectonophysics 449. 17-40*.

Thank you

for your attention