Geodetic slip rate estimates for the Alhama de Murcia and Carboneras faults in the SE Betics, Spain

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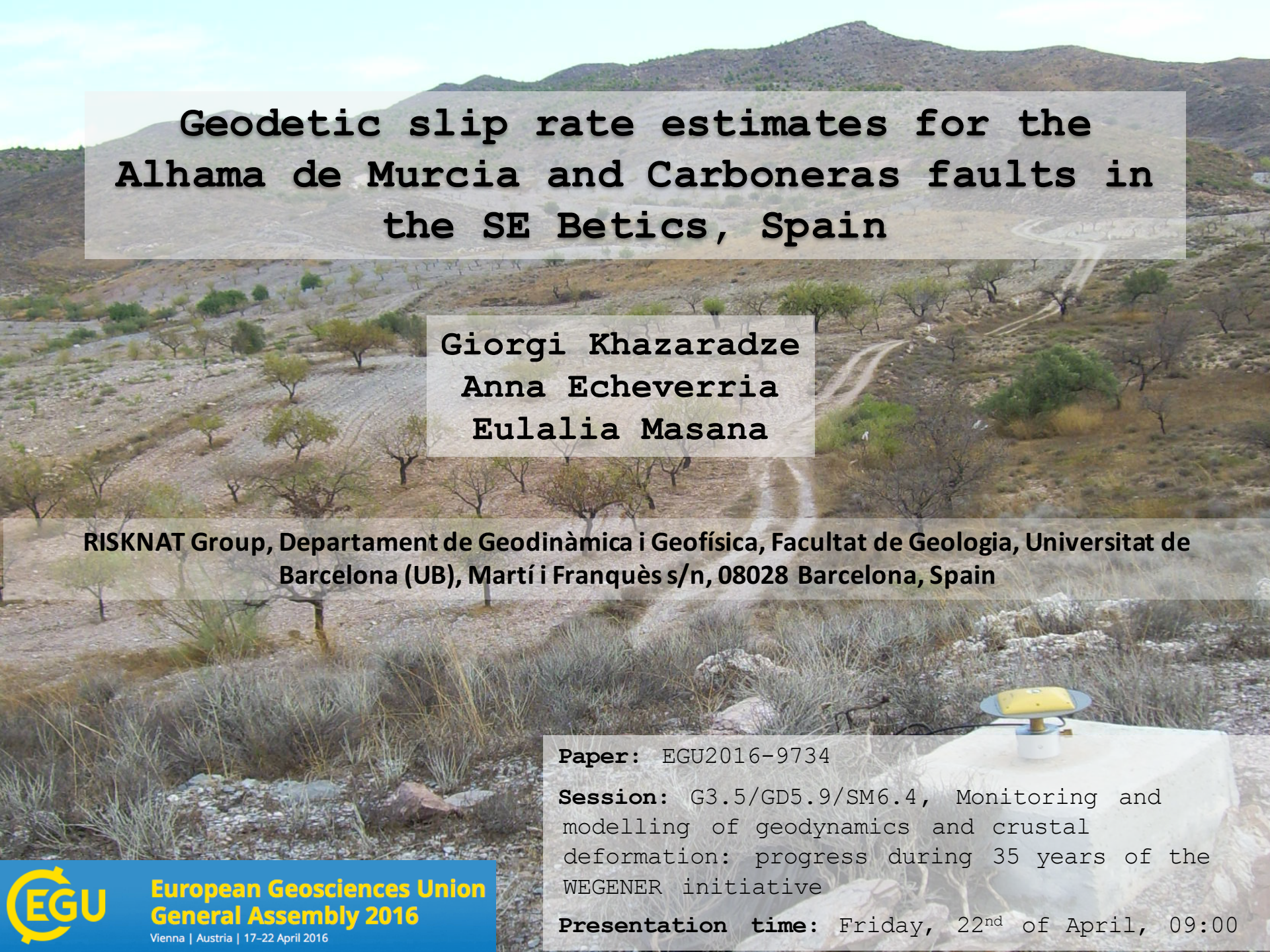

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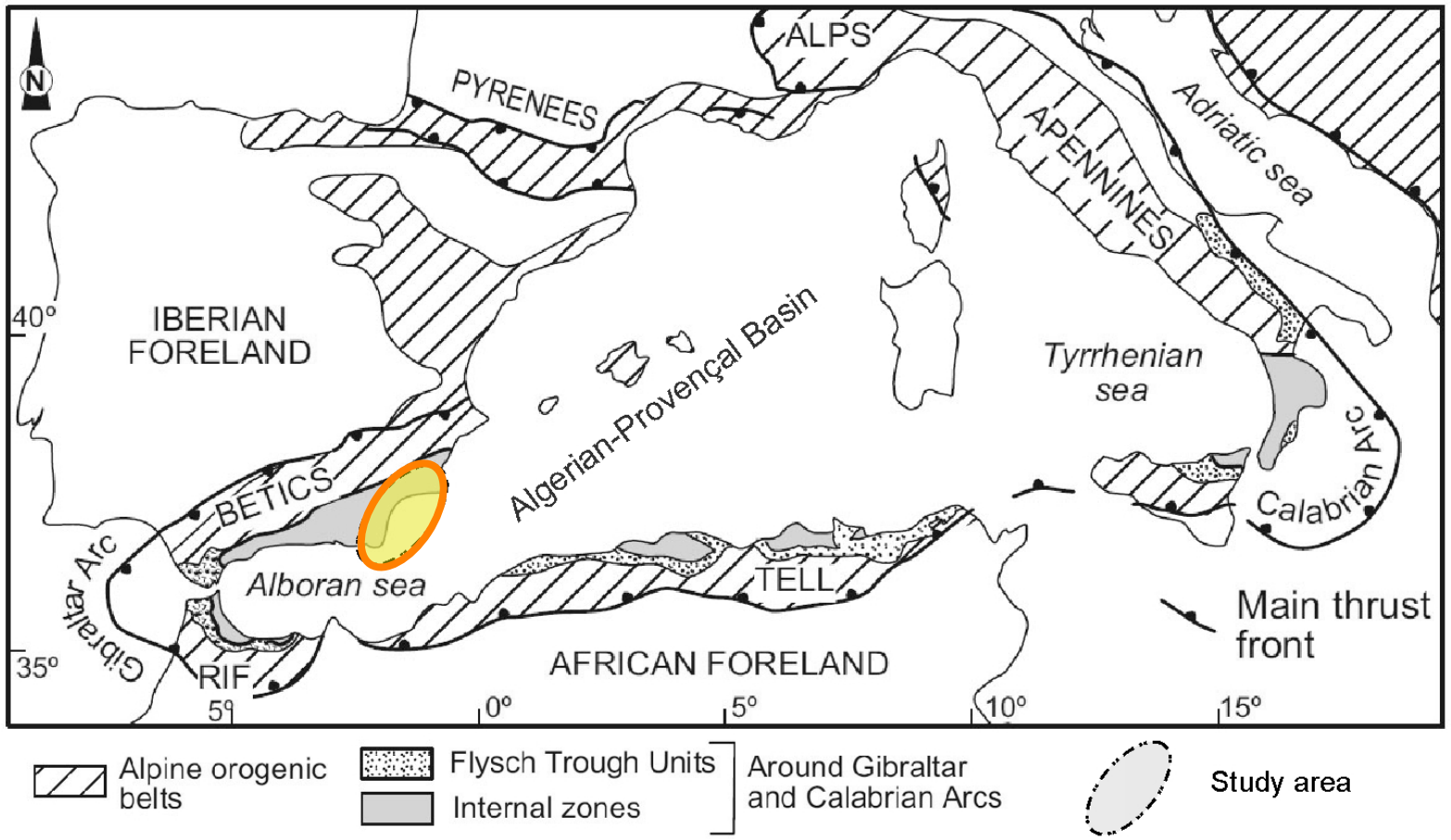
Alpine orogenic belts in the western Mediterranean



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Modified from Crespo-Blanc and Frizon de Lamotte (2006)

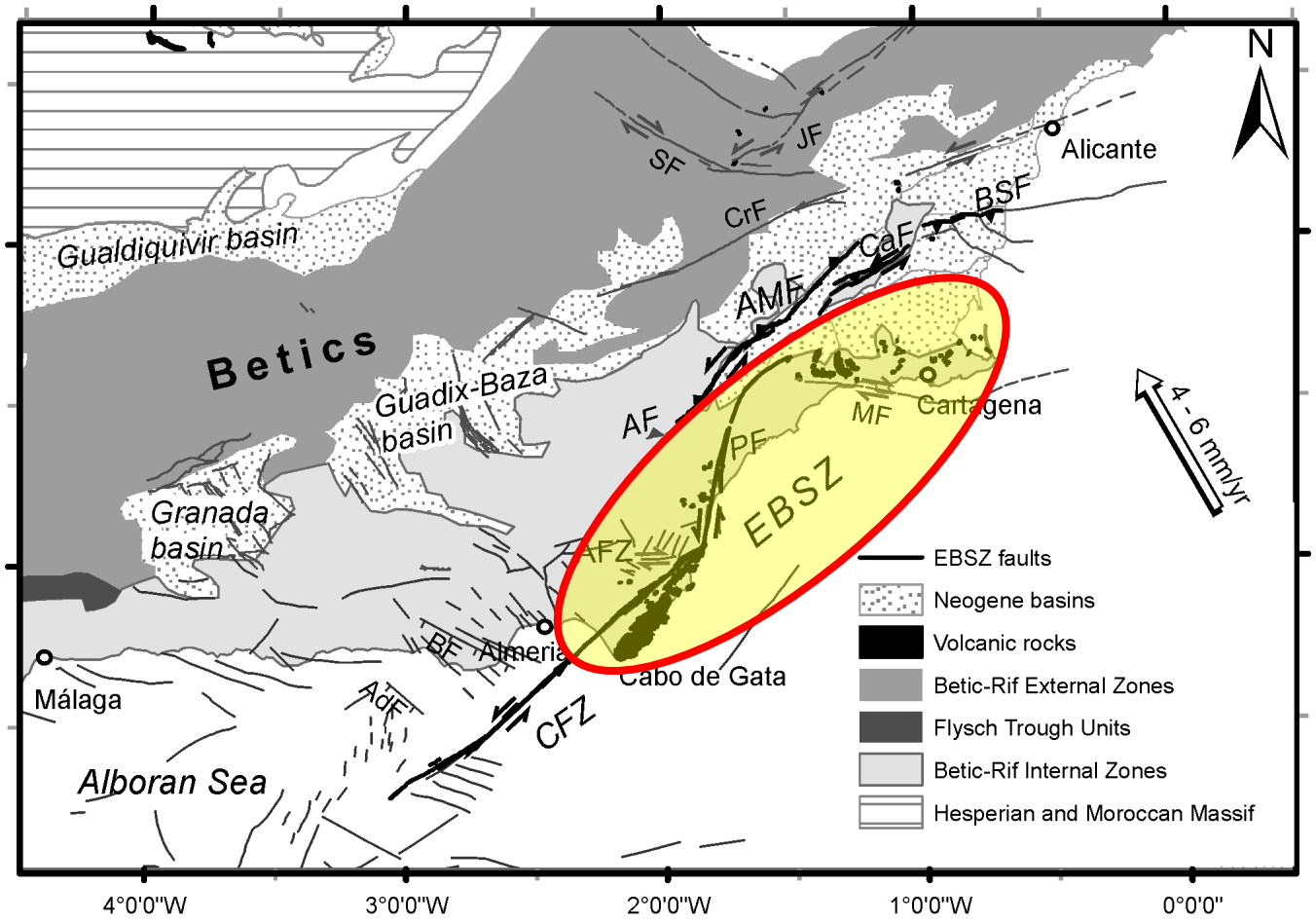
Eastern Betics

Africa-Eurasia convergence.

Slow deforming area

Two type of faults:
~NE-SW strike-slip
~NW-SE normal

EBSZ (Eastern Betic Shear Zone): left-lateral faults

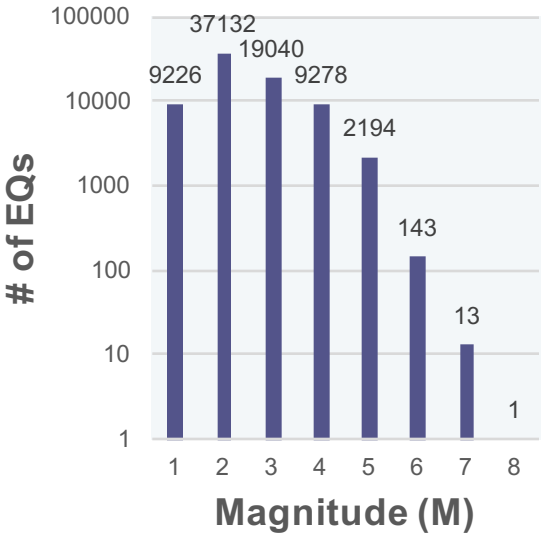


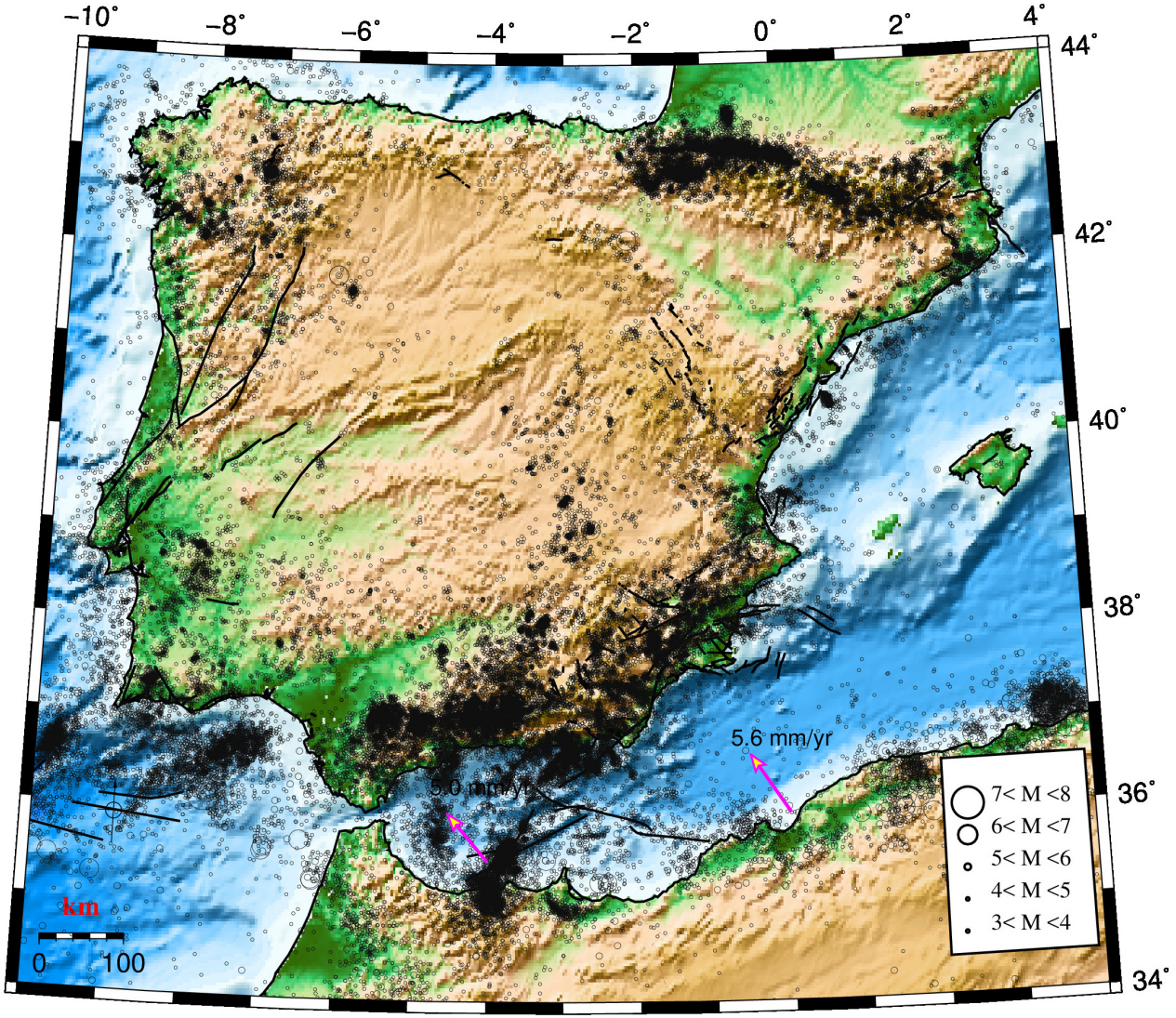
Active faults from QAFI database (García-Mayordomo et al., 2012) and Gràcia et al. (2012)

BSF: Bajo-Segura fault; CaF: Carrascoy fault; AMF: Alhama de Murcia fault; PF: Palomares fault; CFZ: Carboneras fault zone.

Instrumental Seismicity

Diffuse plate boundary





Instrumental seismicity from IGN catalog (1910-2016).

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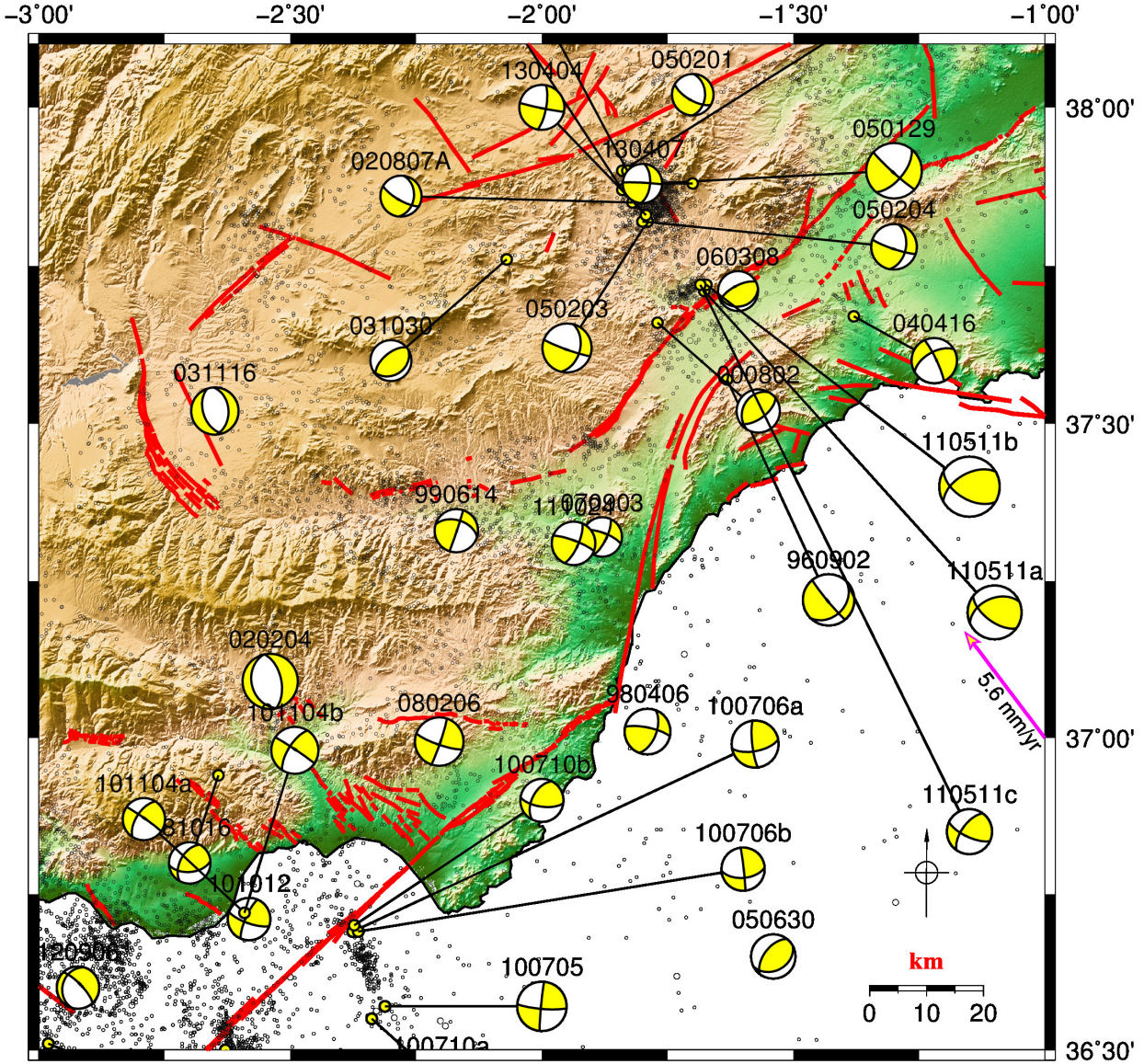
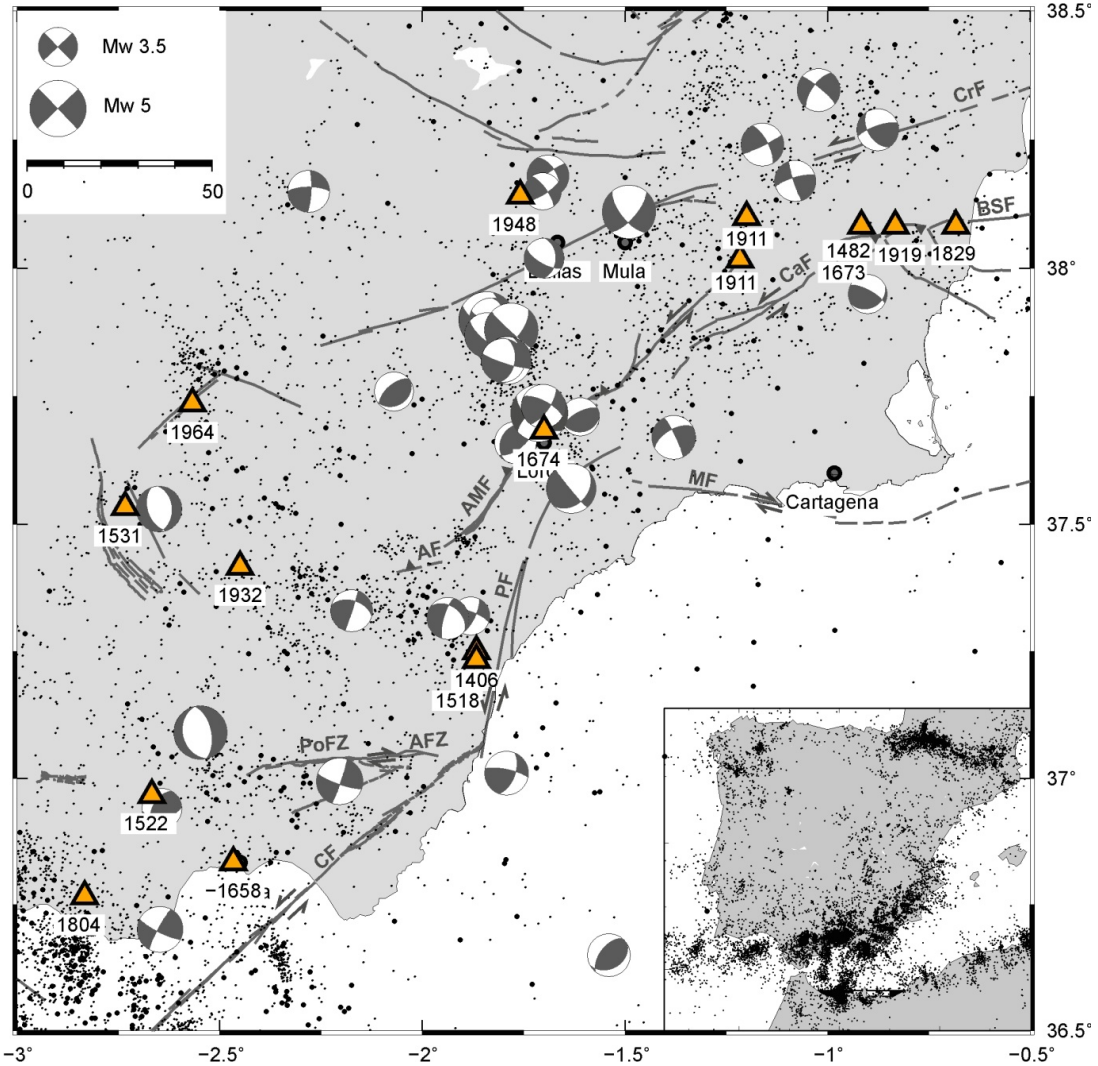
Focal Mechanisms

Mixed type faulting



Focal mechanisms from Stich et al. (2003; 2006; 2010): 1984-2008 and Martín et al (2015): 2009-2014.

Historical Seismicity



Historical seismicity from IGN (see Martínez Solares & Mezcua, 2002; Mezcua et al., 2013)

Historical Seismicity

Date	Long.	Latit.	Deaths	Intensity	est. M	Location
1048	0º 55' W	38º 5' N		VIII		Orihuela (Alicante)
1169	4º 0' W	38º 0' N		VIII-IX		Andujar (Jaén)
24-8-1356	10º 0' W	36º 30' N		VIII		SW. Cabo San Vicente
2-3-1373	0º 45' E	42º 30 'N		VIII-IX		CondadodeRibagorça (Huesca-Lleida)
18-12-1396	0º 13' W	39º 5' N		VIII-IX	6.5	Tavernes de la Valldigna (Valencia)
15-5-1427	2º 30' E	42º 12' N		VIII-IX		Olot (Girona)
2-2-1428	2º 10' E	42º 21' N	800	IX-X		Queralbs (Girona)
24-4-1431	3º 38' W	37º 8' N		VIII-IX	6.7	Sur de Granada
26-1-1494	4º 20' W	36º 35' N		VIII		Sur de Málaga
5-4-1504	5º 28' W	37º 23' N	32	VIII-IX	6.8	Carmona (Sevilla)
9-11-1518	**1º 52' W**	**37º 14' N**	**165**	**VIII-IX**		**Vera (Almeria)**
22-9-1522	**2º 40' W**	**36º 58' N**	**1000**	**VIII-IX**	**6.5**	**Mar de Alborán**
30-9-1531	2º 44' W	37º 32' N	400	VIII-IX		Baza (Granada)
19-6-1644	0º 25' W	38º 48' N	22	VIII		Muro de Alcoy (Alicante)
31-12-1658	**2º 28' W**	**36º 50' N**		**VIII-IX**		**Almería**
28-08-1674	**1°42' W**	**37°40' N**	**30**	**VIII**		**Lorca**
9-10-1680	4º 36' W	36º 48' N	70	VIII-IX	6.8	Alhaurín el Grande (Málaga)
23-3-1748	0º 38' W	39º 2' N	38	IX	6.2	Estubeny (Valencia)
1-11-1755	10º 0' W	36º 30' N	15000	X	8.5	SW. Cabo San Vicente
13-11804	3º 35' W	36º 5' N	2	VII-VIII	6.7	Mar de Alborán
25-8-1804	2º 50' W	36º 46' N	407	VIII-IX	6.4	Dalias (Almaria)
27-10-1806	3º 44' W	37º 14' N	13	VIII	5.3	Pinos Puente (Granada)
21-3-1829	0º 41' W	38º 5' N	389	IX-X	6.6	Torrevieja (Alicante)
25-12-1884	3º 59' W	37º 0' N	839	IX-X	6.5	Arenas del Rey (Granada)
29/03/54	3º 36' W	37º 0' N		V	7.0	Durcal (Granada)
19/04/56	3º 41' W	37º 11' N	11	VIII	4.7	Albolote (Granada)
28/02/69	10º 49' W	35º 59' N	19	VII	7.3	SW. Cabo San Vicente

Historical seismicity from IGN (see Martínez Solares & Mezcua, 2002; Mezcua et al., 2013)

Campaign and Continuous Observation

SGPS

Survey mode or campaign mode

16 stations; Duration: 15 yrs

CuaTeNeo Network (15)
ROA (1)

Campaigns:
1997, 2002, 2006, 2009 and 2011.

CGPS

Continuous mode

25 stations; Min Duration: 4.5 yrs

GNSS networks:

ERGNSS
RAP
Regam
Meristemum
ERVA
TopoIberia
Event

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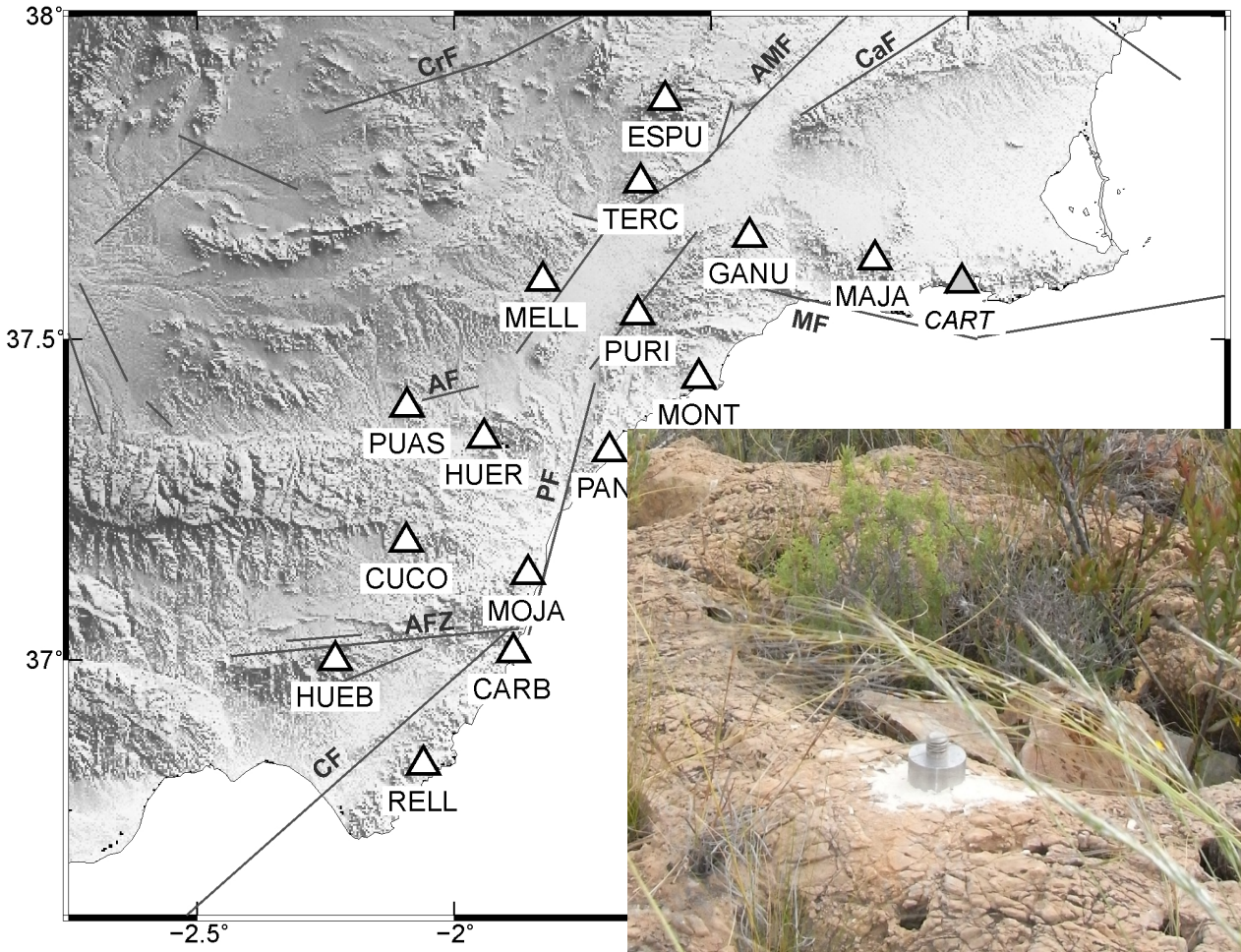
SGPS Observations: CuaTeNeo

Cuantificación de la Tectónica actual y Neotectónica

AMF, PF, CF

Monument types:
Concrete (11)
Nail type (4);
CART from ROA

Observed in 1997, 2002, 2006, 2009 and 2011*



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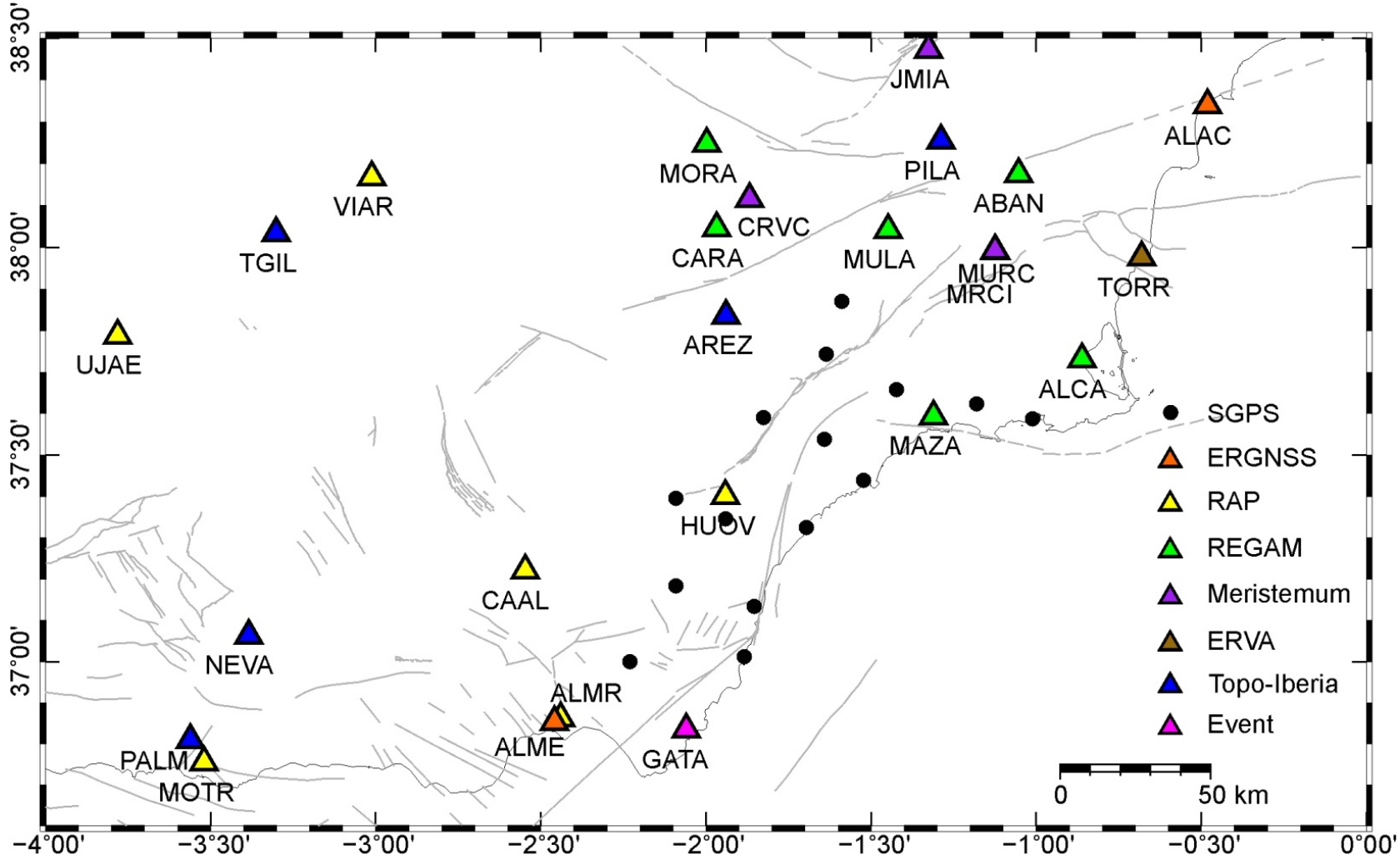
Continuous GPS Observation



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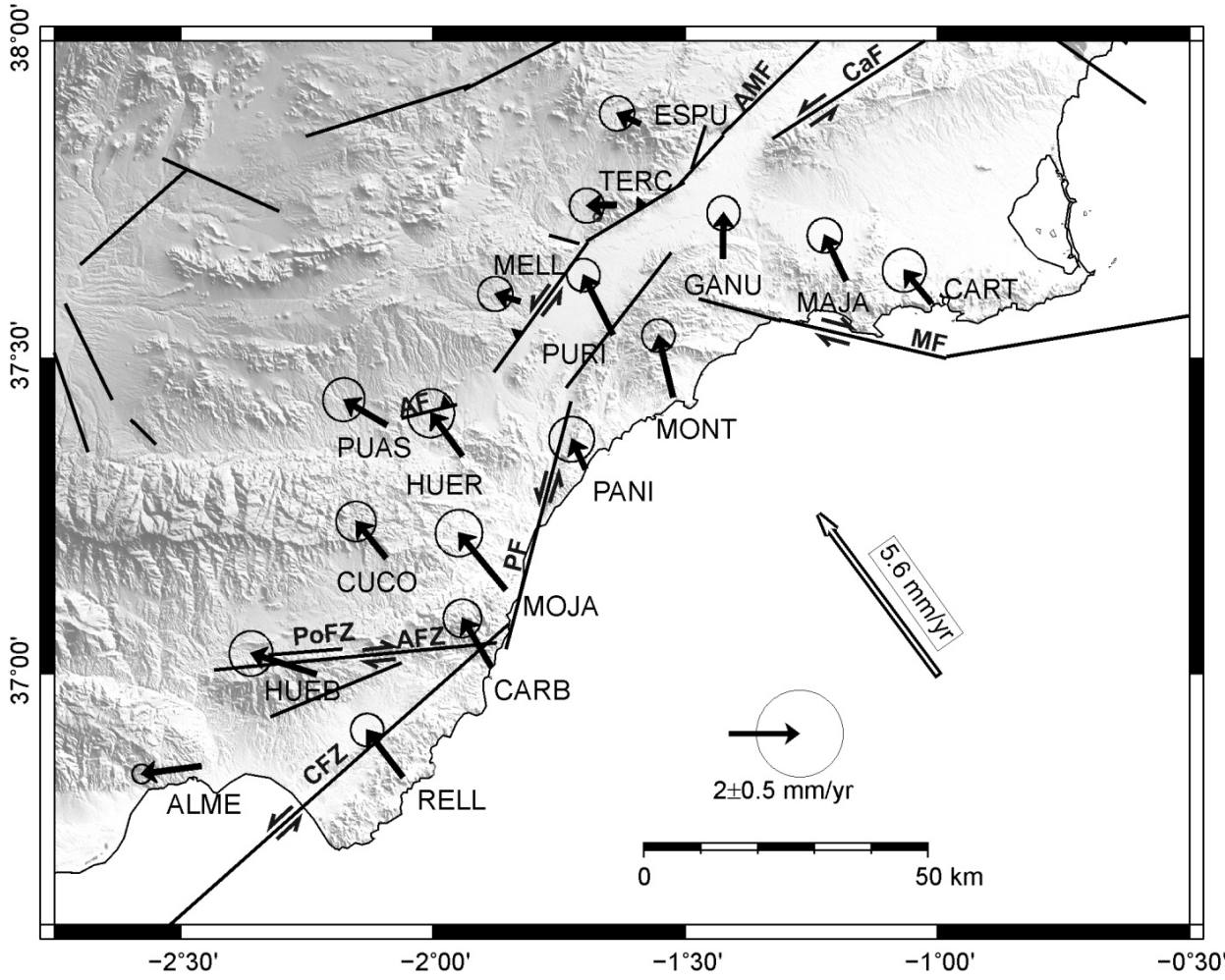
CuaTeNeo Velocity Field

~1-2 mm/yr to NW

Related to Africa/Eurasia convergence

Diminution of velocity (<1 mm/yr) west of AMF

Westerly component in HUEB-ALME



SGPS velocities in western Europe reference frame with 95% confidence error ellipses

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See: Echeverria et al., 2013, Tectonophysics

CuaTeNeo: Strain Rate Field

SSPX software (Cardozo et al., 2010)

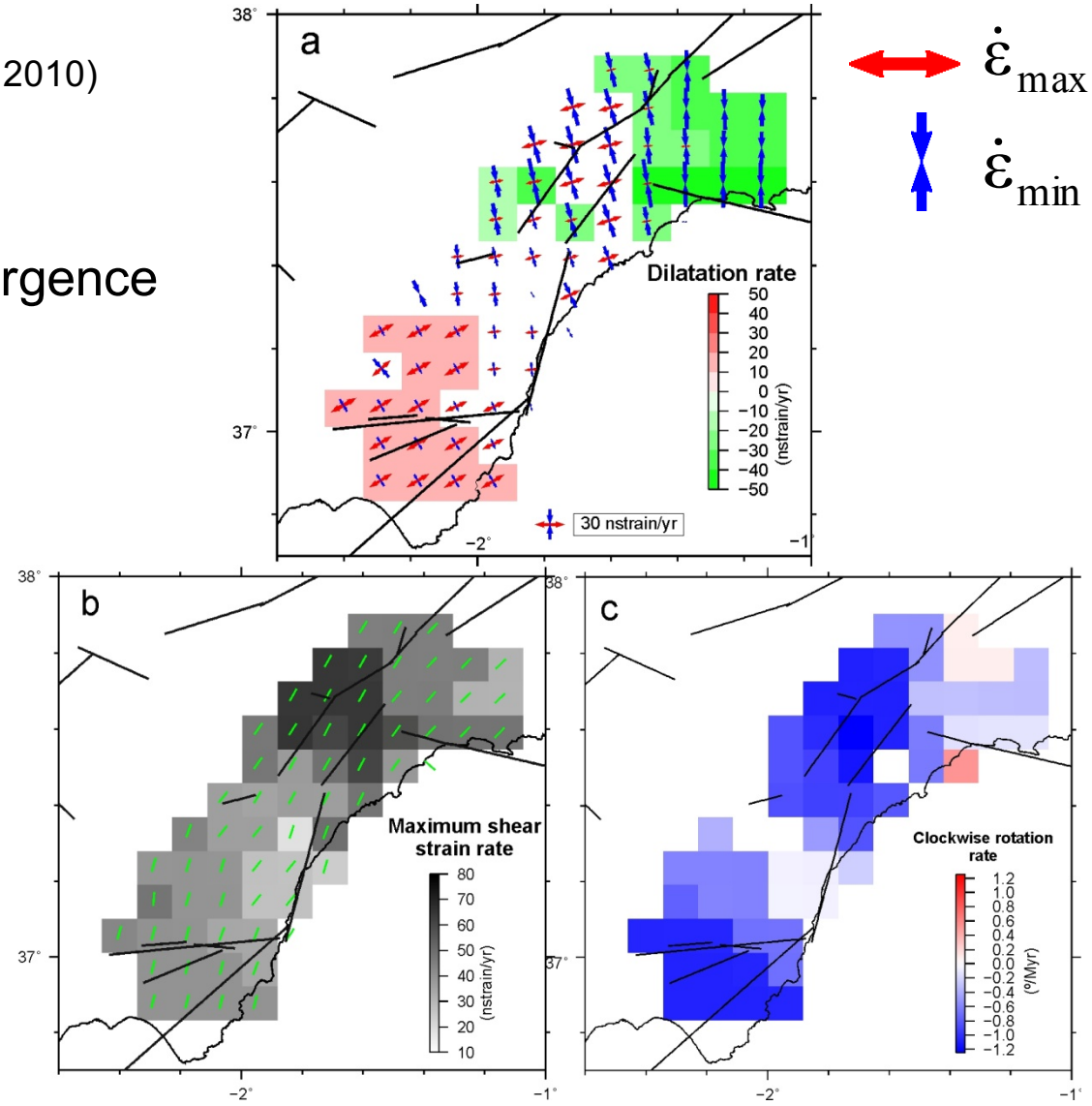
$|\dot{\varepsilon}_{min}| > |\dot{\varepsilon}_{max}|$

↳ parallel to plate convergence

Shortening in the NE part
Extension in the SW part

Maximum shear strain rates near AMF-PF

Counterclockwise rotation



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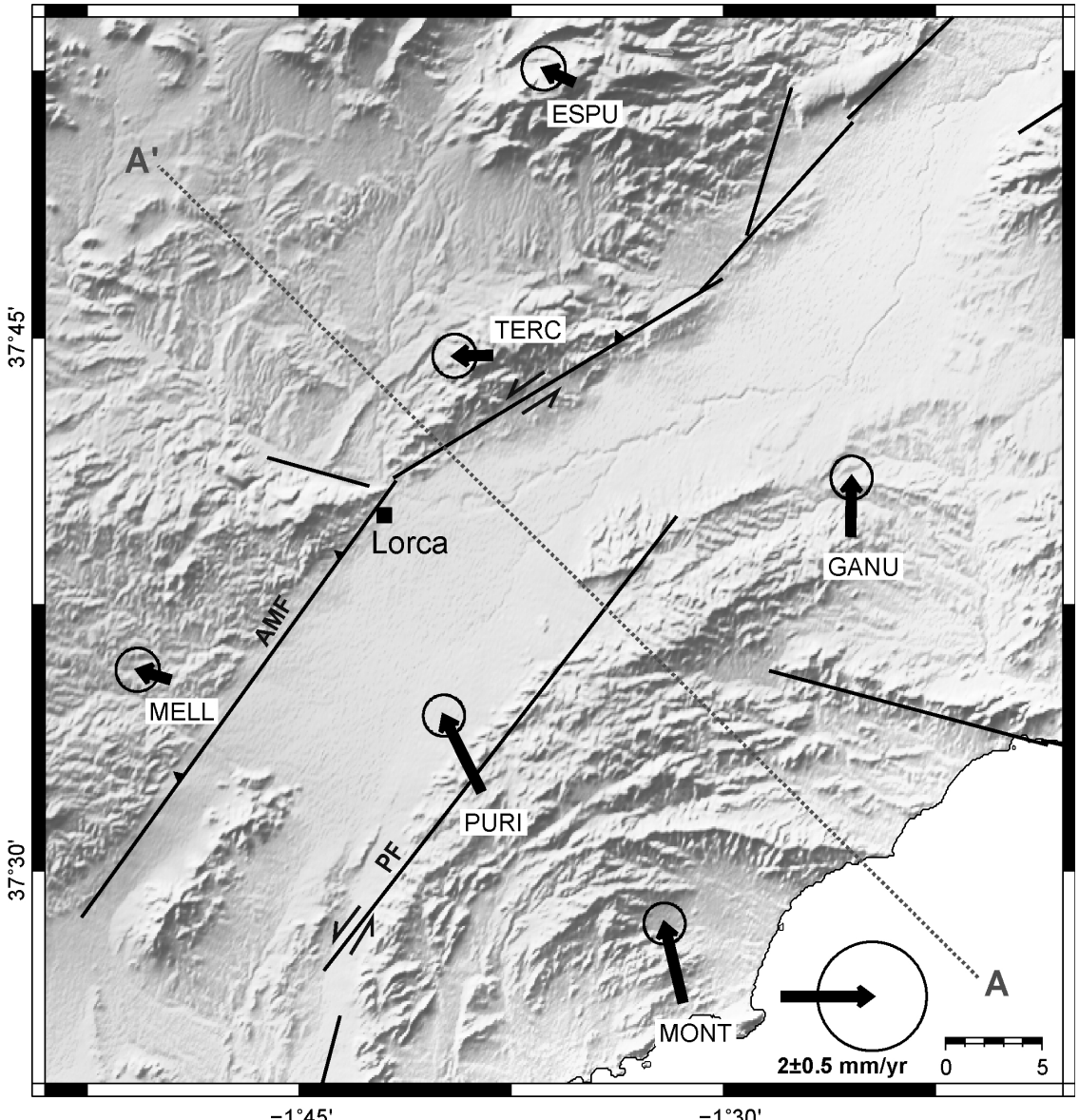
Alhama de Murcia fault: Lorca 2011 earthquake



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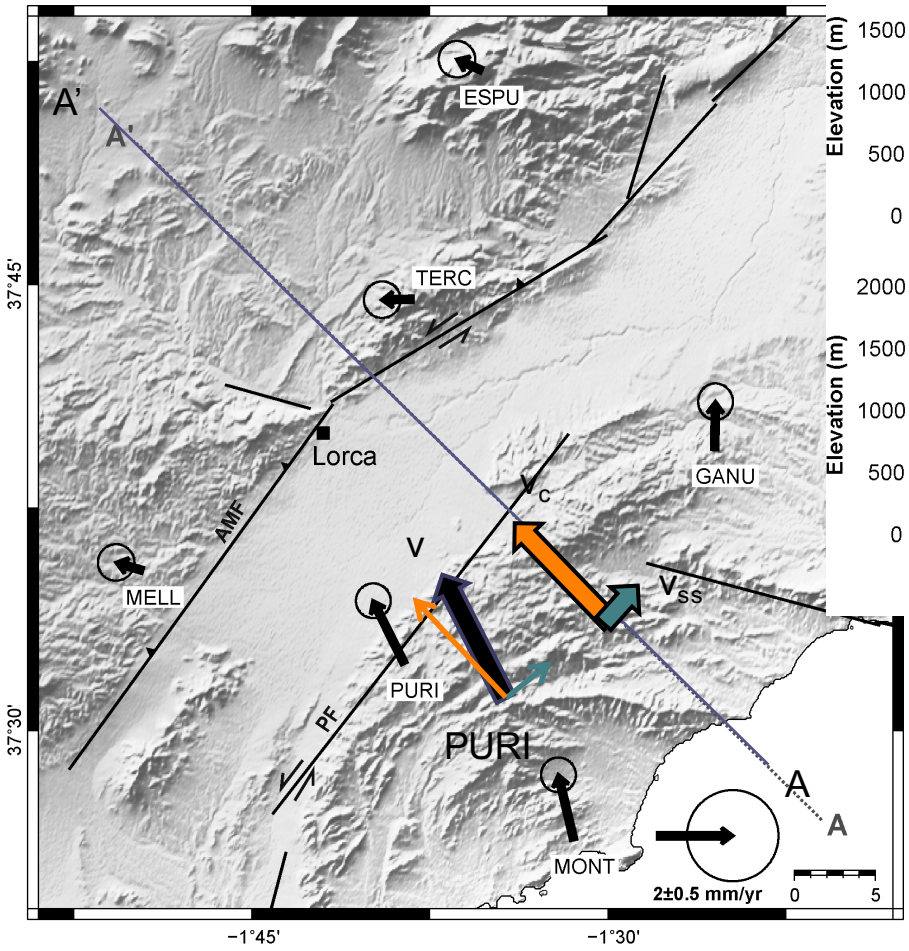
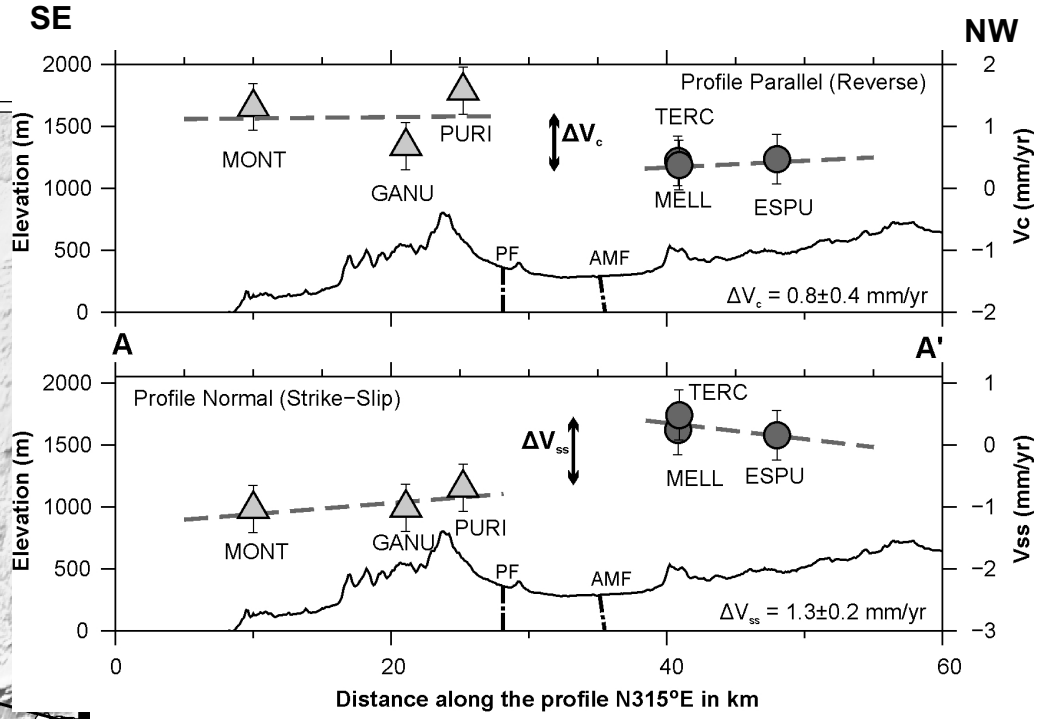
Alhama de Murcia fault: Lorca 2011 earthquake





Compression: 0.8±0.4 mm/yr

Left-lateral: 1.3±0.2 mm/yr

HORIZONTAL: 1.5±0.3 mm/yr

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AMF: Geodetic vs. Geologic Slip Rates

Paleoseismology

Horizontal slip rate of **0.06-0.53 mm/yr**

(Masana et al., 2004; Martínez-Díaz et al., 2012 ; Ortuño et al., 2012)

New 3D-trenches study: preliminary slip rate > **0.6 ± 0.1 mm/yr**

(Ferrater et al., 2015)

GPS

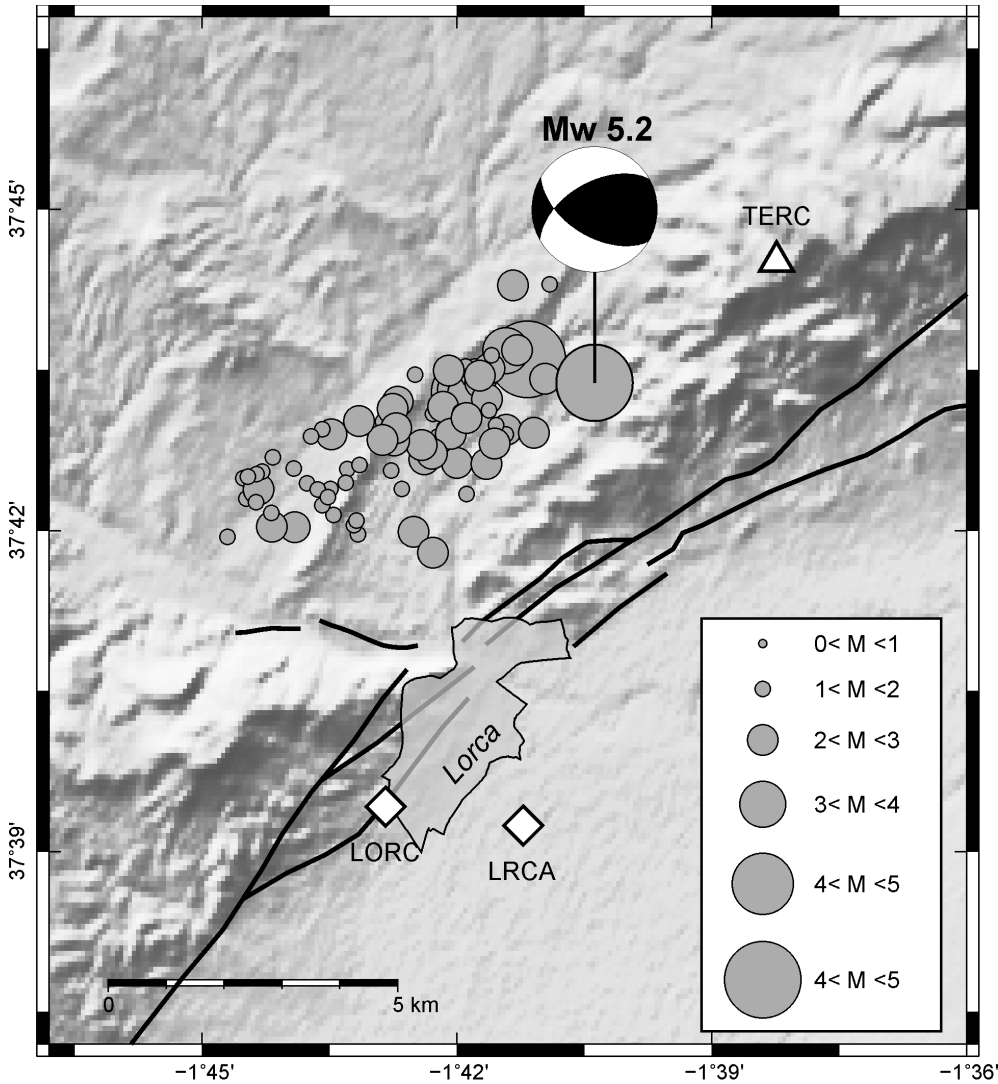
Horizontal slip rate of **1.5±0.3 mm/yr**

The involvement of the Palomares fault ?

GPS slip rate is an upper bound of the overall slip rate

Alhama de Murcia fault: Lorca 2011 earthquake

11/05/2011 Mw 5.2, Lorca
AMF related



Focal mechanism and seismic sequence from López-Comino et al. (2012)

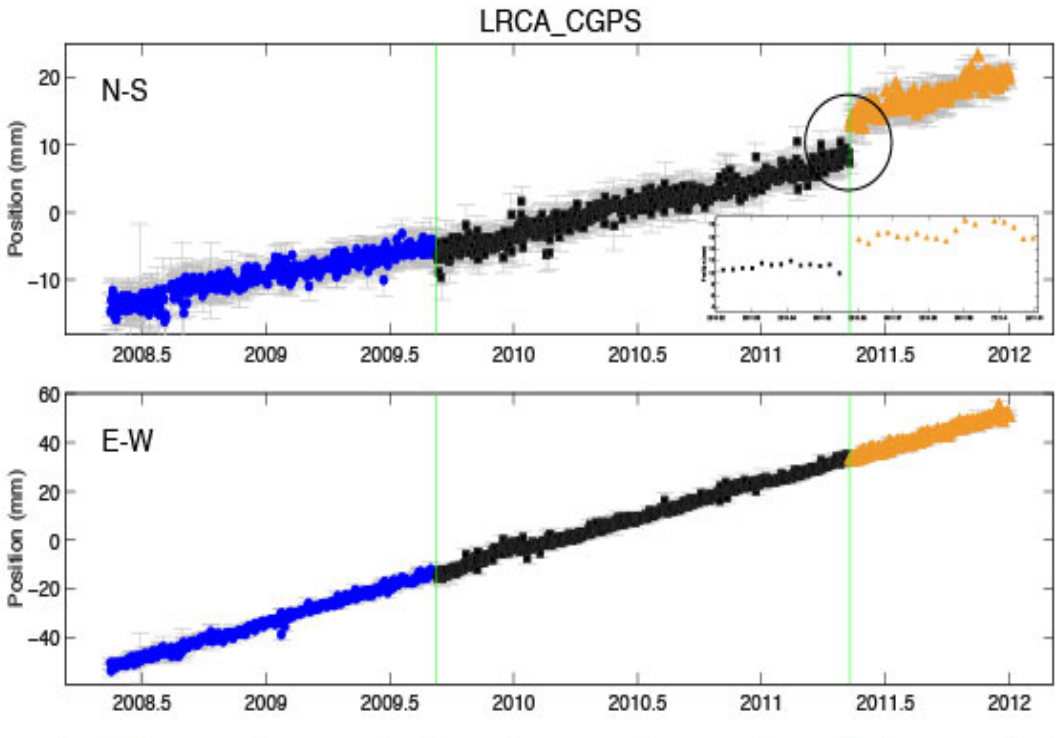
Alhama de Murcia fault: Lorca 2011 earthquake

GPS stations:

- TERC (CuaTeNeo)
- LRCA (Meristemum)
- *LORC (REGAM)*

Coseismic displacements:

- TERC: 0 mm
- LRCA: 6±0.6 mm to N
  0.7±0.5 mm to the W



Similar results were obtained by *González et al., 2012.*

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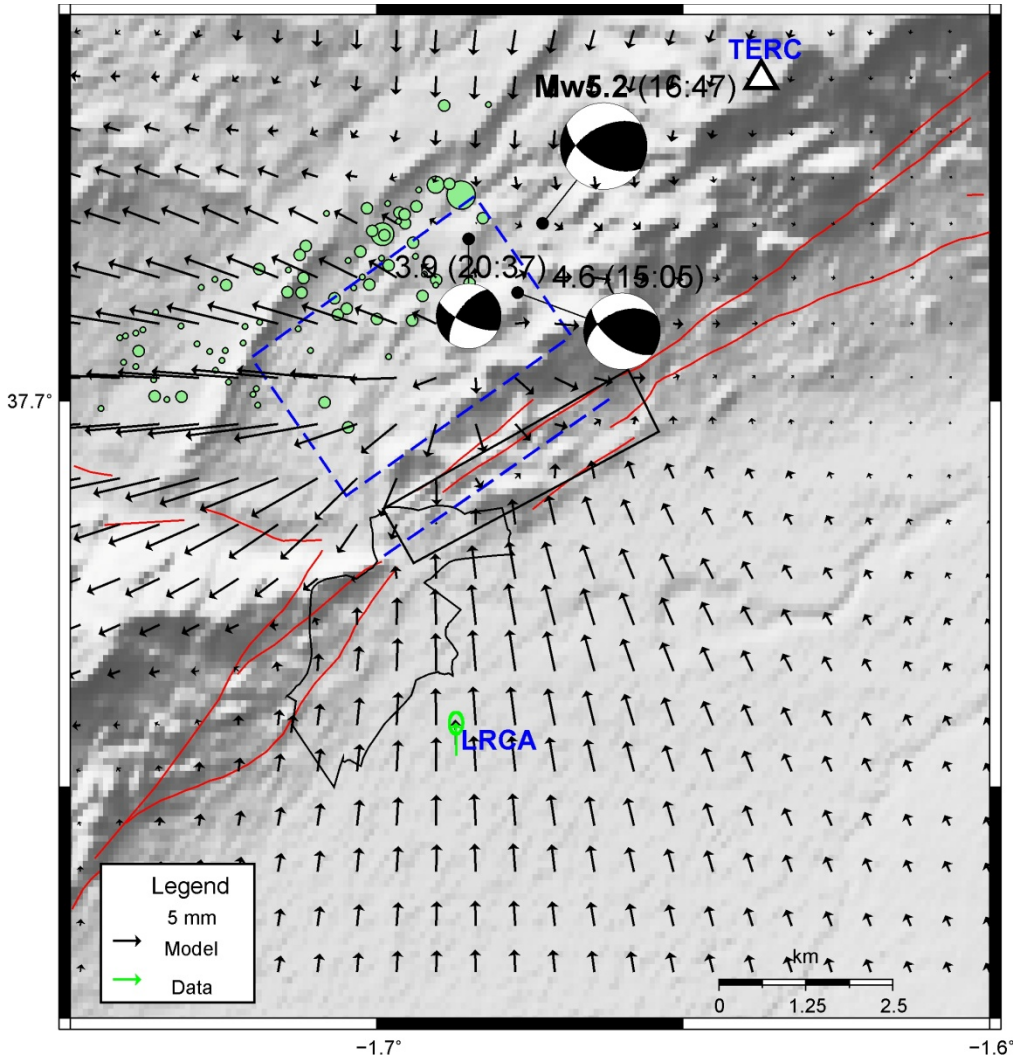
Lorca 2011 EQ: Dislocation Model

Elastic dislocation model (Okada 1985)

Co-seimic displacements:

LRCA	Observed	Modeled
S-N	6±0.6 mm	6.4 mm
W-E	-0.7±0.5 mm	-0.2 mm

No displacement from the model at TERC



Focal mechanism and seismic sequence from López-Comino et al. (2012). Model parameters from Martínez-Díaz et al. (2012); See Frontera et al (2012, *Solid Earth* for more details.

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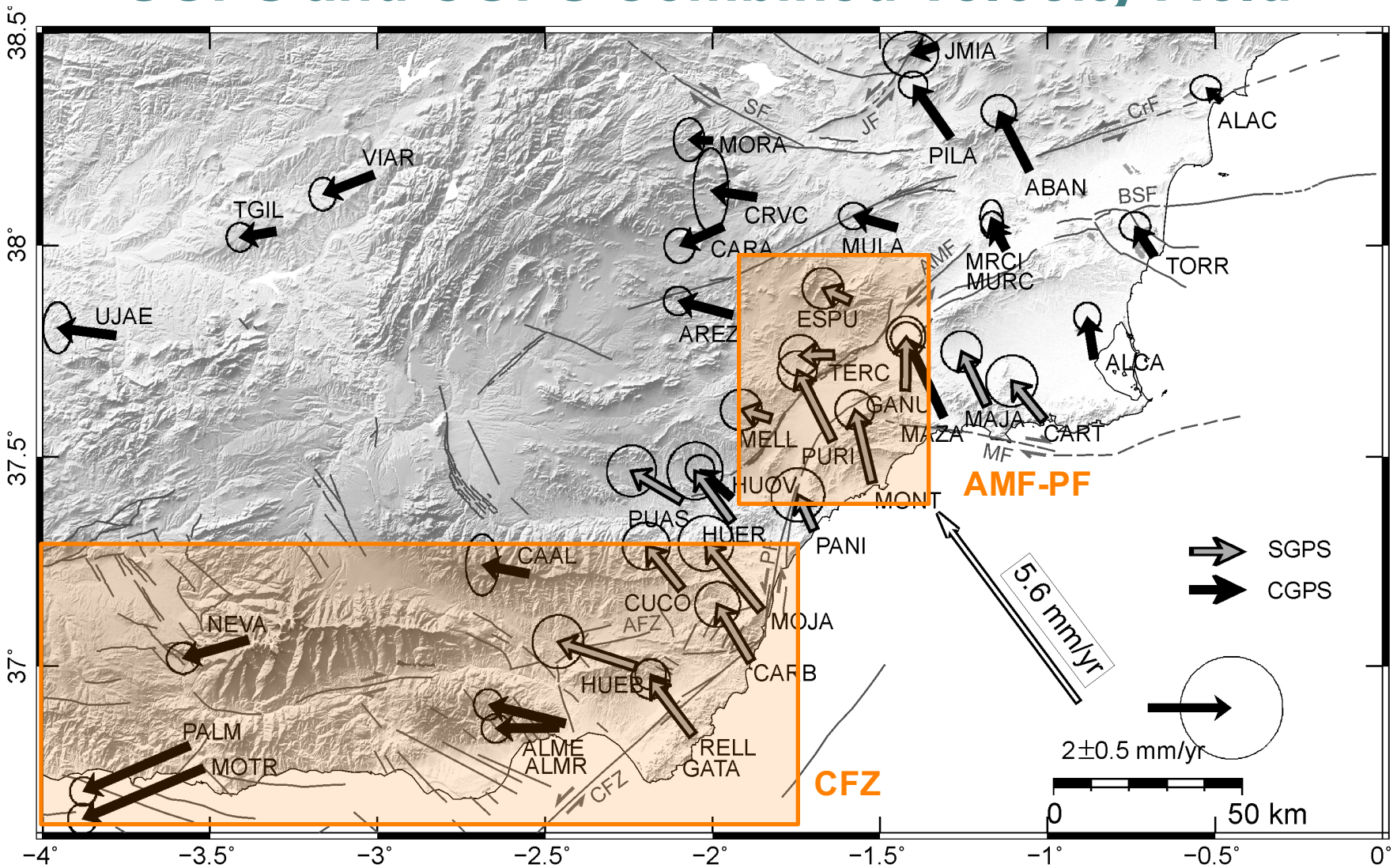
SGPS and CGPS Combined Velocity Field



Western Europe reference frame with 95% confidence error ellipses

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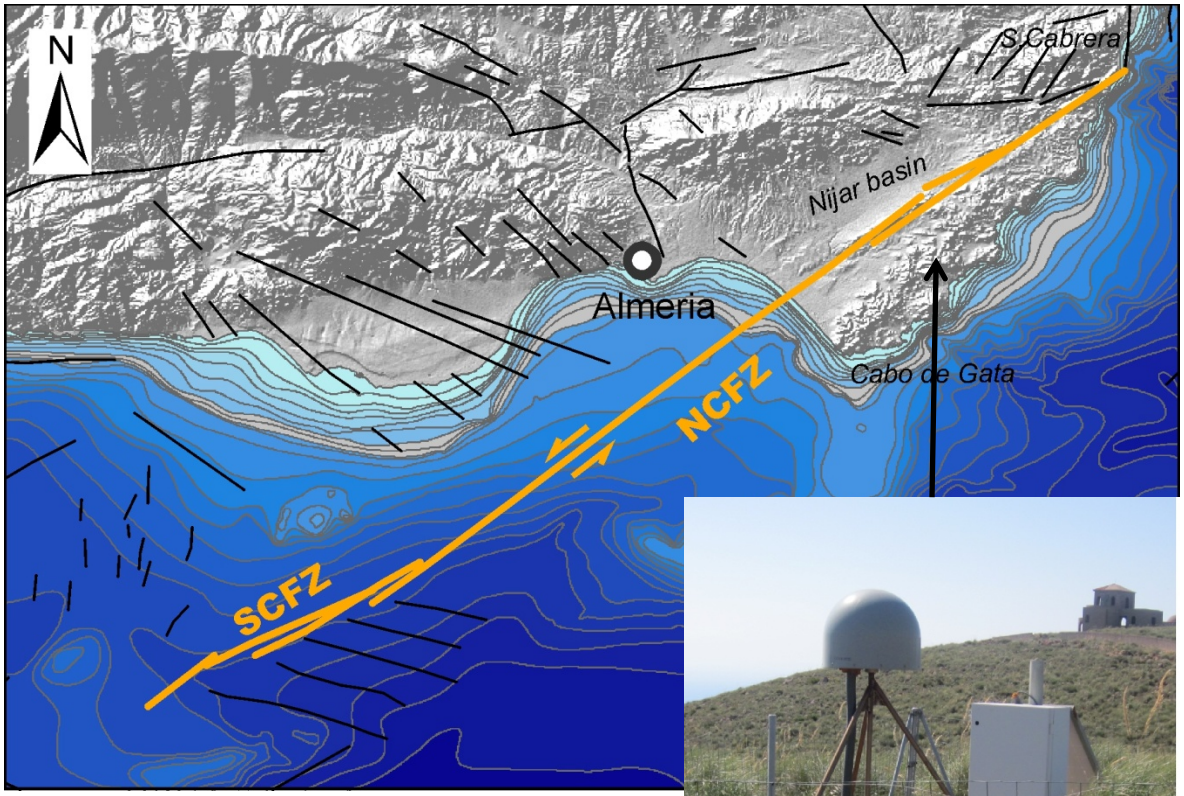
Carboneras Fault Zone (CFZ)



Left-lateral fault

NCFZ and SCFZ
(Moreno, 2011; Moreno et al., 2015)

GATA CGPS
Installed in 2008 (UB)
Short Drill Braced monument
0.2 km from RELL campaign station

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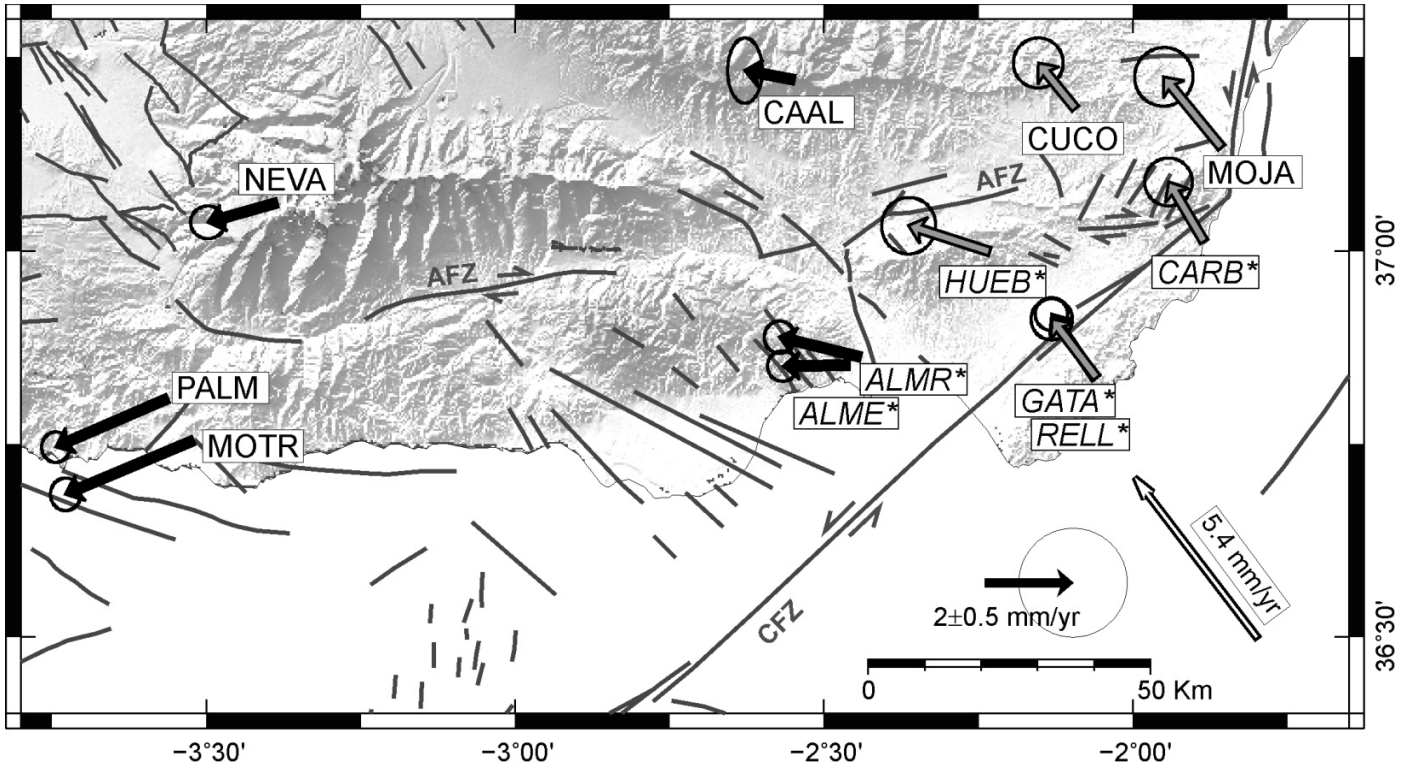
Europe Fixed reference frame



CFZ:
left-lateral

AFZ:
right-lateral

Carboneras Fault Zone (CFZ)
Alpujarras Fault Zone (AFZ)

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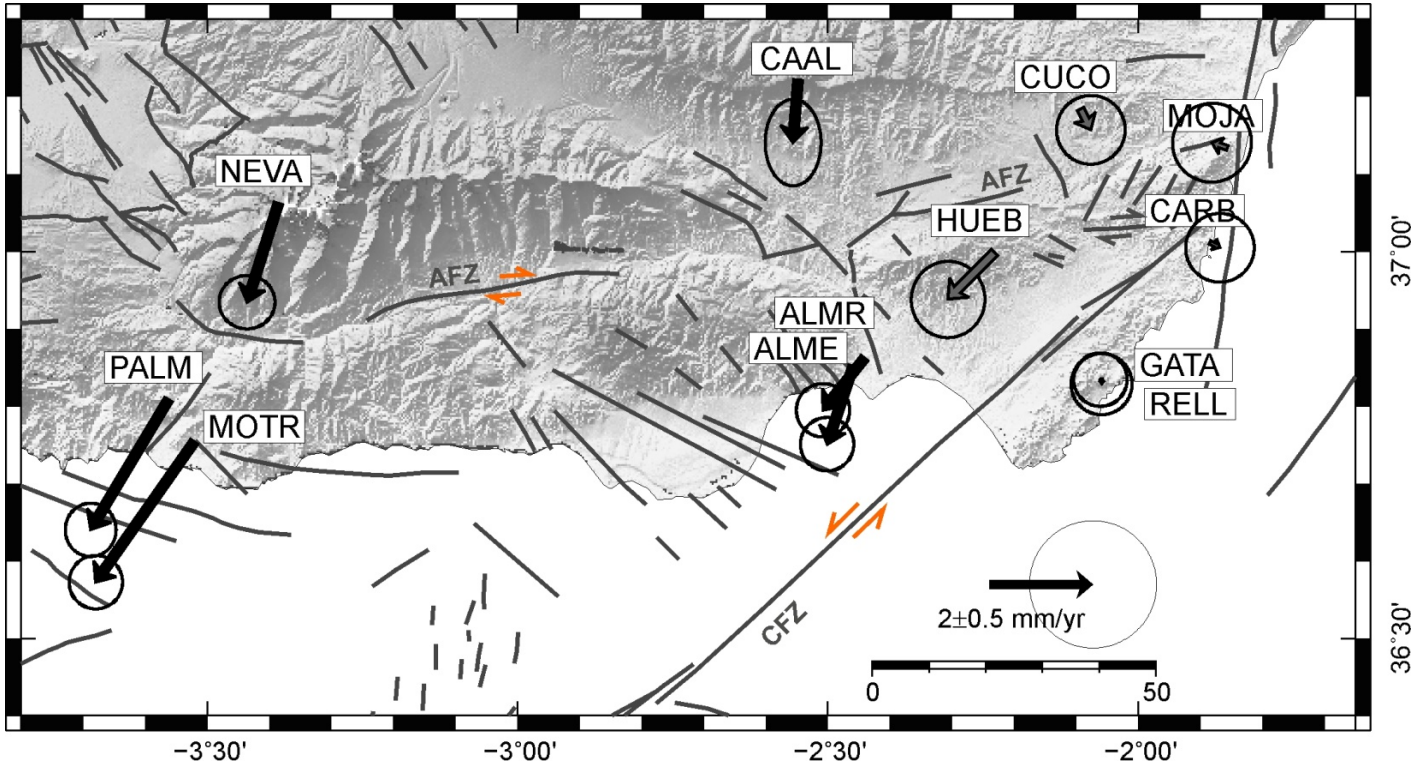
GATA Fixed reference frame



CFZ:
left-lateral

AFZ:
right-lateral

Carboneras Fault Zone (CFZ)
Alpujarras Fault Zone (AFZ)

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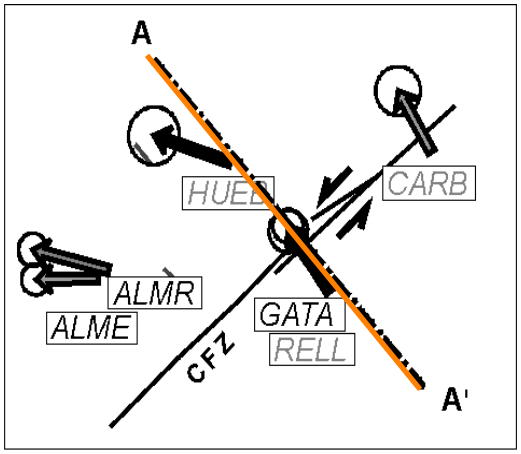
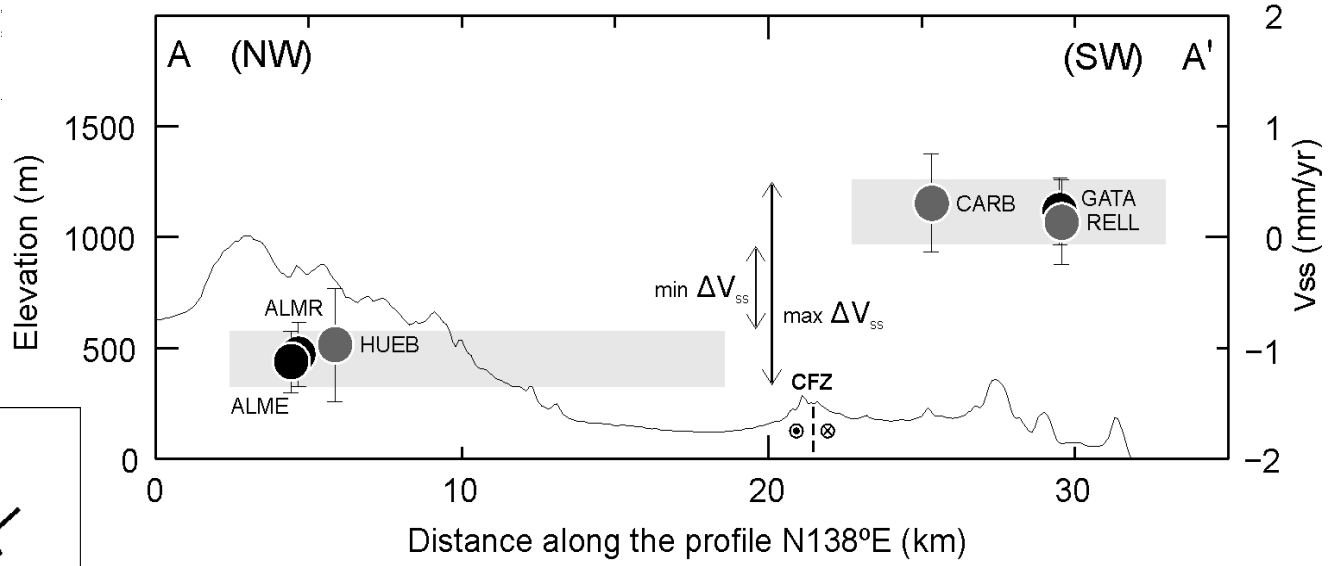
CFZ Perpendicular Profile





→ Max. slip rate for the CFZ:
1.3±0.2 mm/yr

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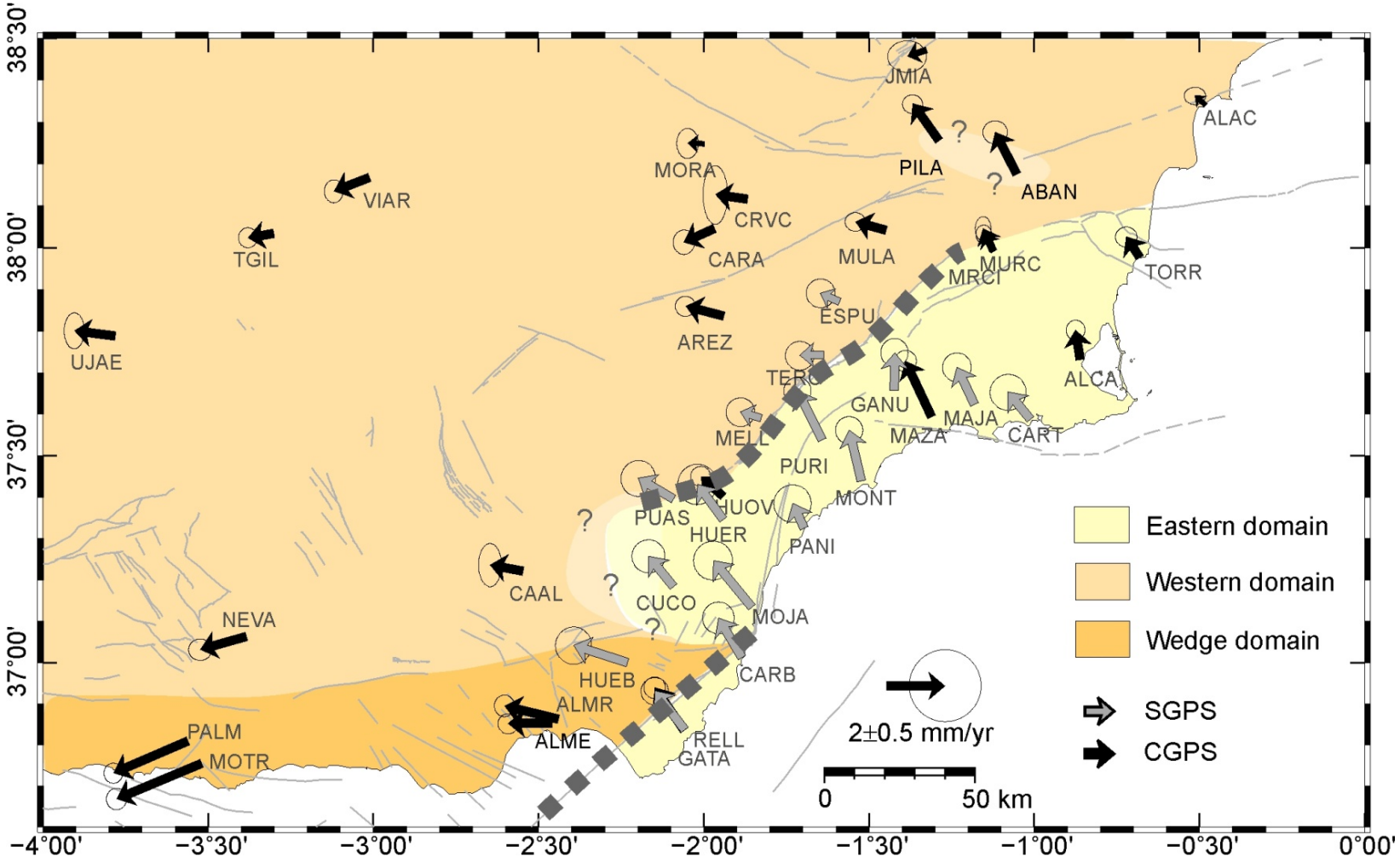
Rigid Block Model



The domain boundaries are the most active faults
Carboneras fault relays AMF (how and where?)

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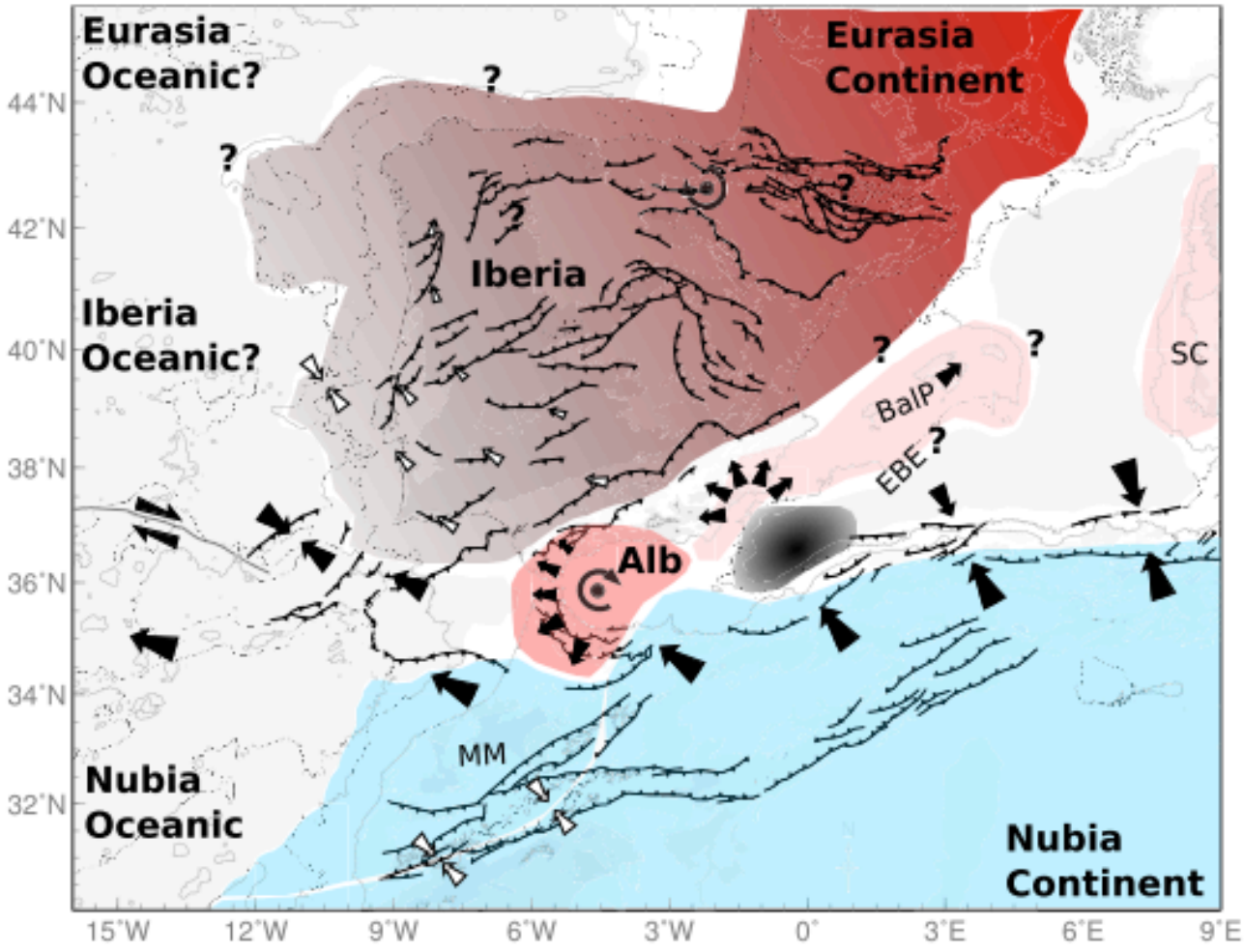
Alternative Model



From: Palano, M., P. J. González, and J. Fernández (2015), *Earth Planet. Sci. Lett.*

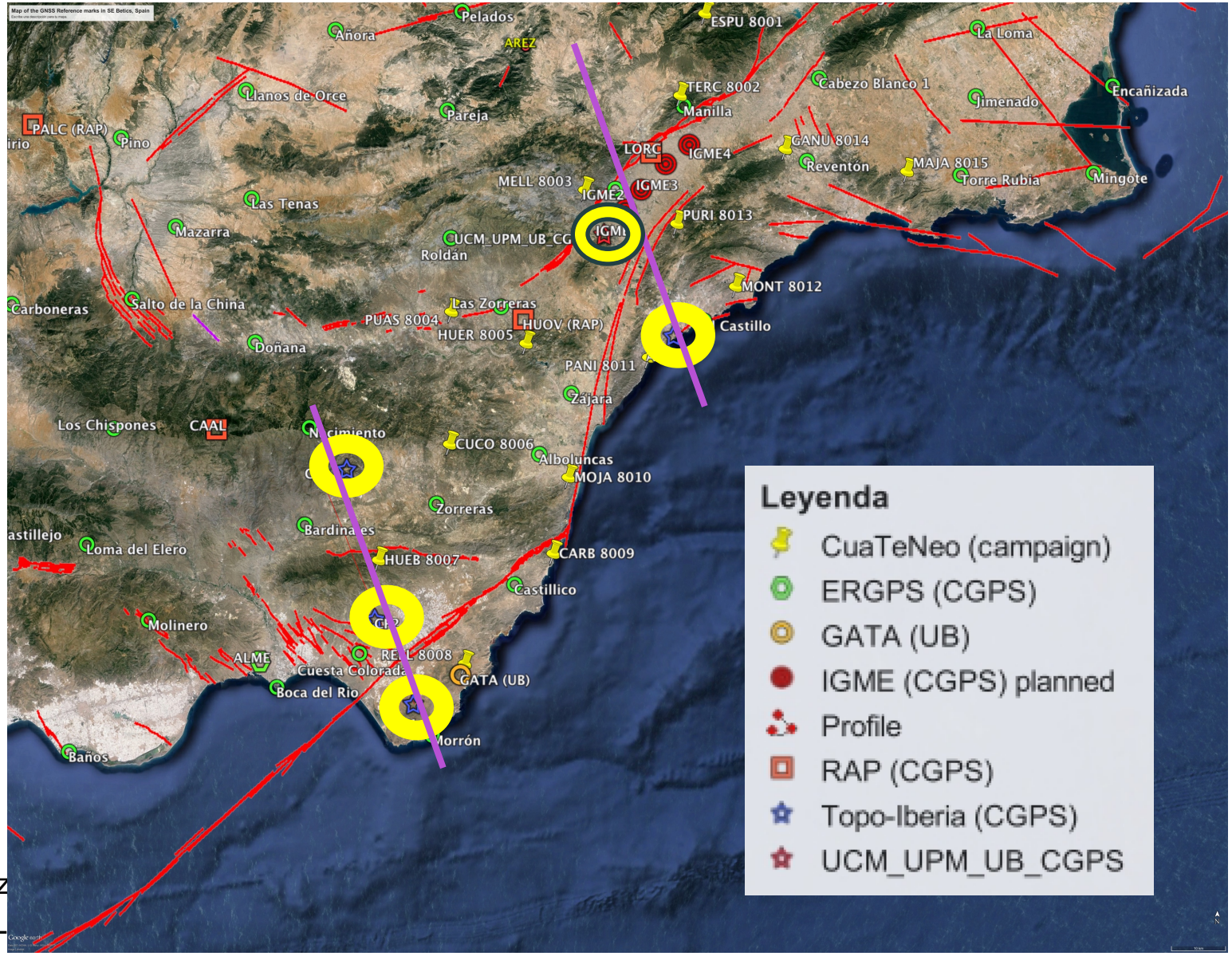
Conclusions

- GPS confirms ongoing tectonic activity in the SE Betics.
- NW oriented velocities ranging from 0.5 to 3 mm/yr

- The highest deformations are found in the region between AMF and PF
  - PF is slipping very slowly or is currently inactive
  - Geodetic slip rate for the AMF $< 1.5 \pm 0.3$ mm/yr

- Geodetic left-lateral strike-slip motion of 1.3 ± 0.2 mm/yr of CFZ.
- Geodetic strain rates higher than seismic strain rates for the southern area.
  - Aseismic processes in the area or underestimation of the seismic strain rates

Future Work



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¡MUCHAS GRACIAS!

Thanks!

Спасибо!

Teşekkür ederim!

მადლობთ!