Seismic sequence Capo di Giano 14/05/2023 - – now

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RISSC-Lab: Laboratorio di RIcerca in Sismologia Sperimentale e Computazionale

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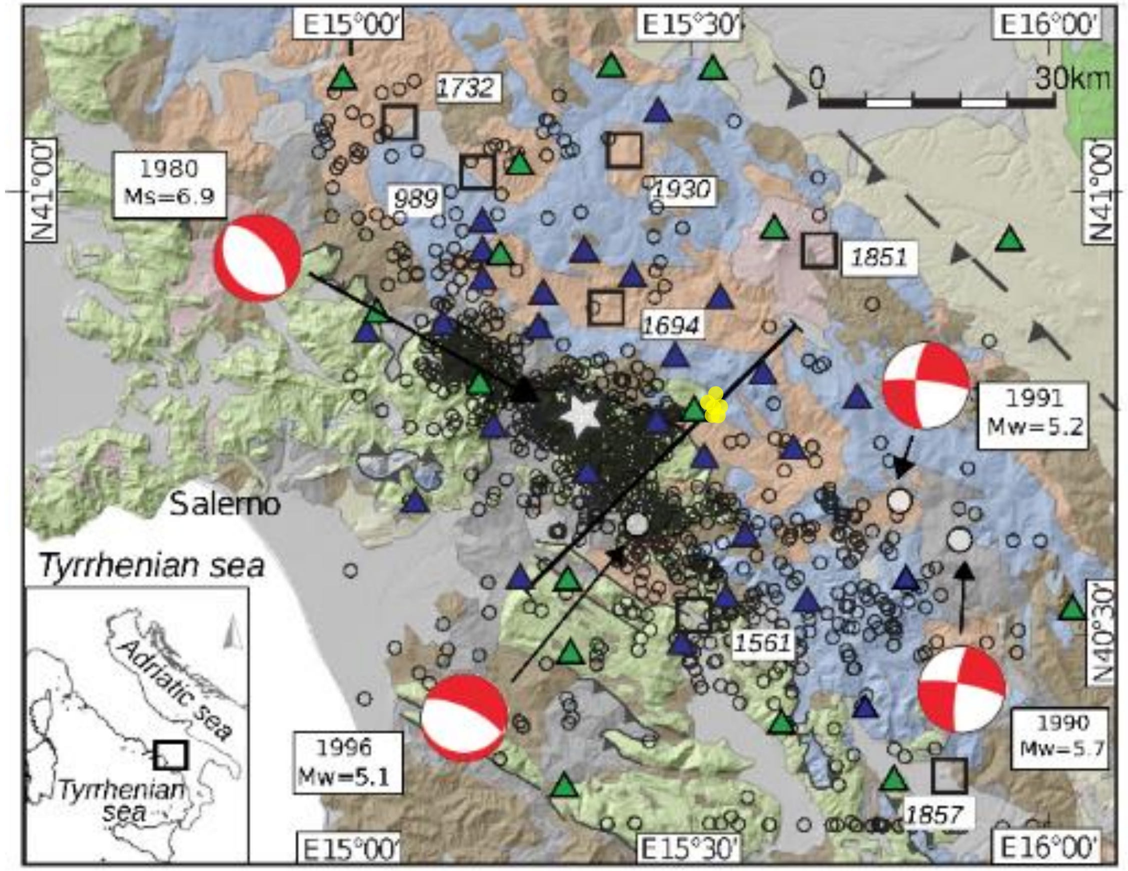
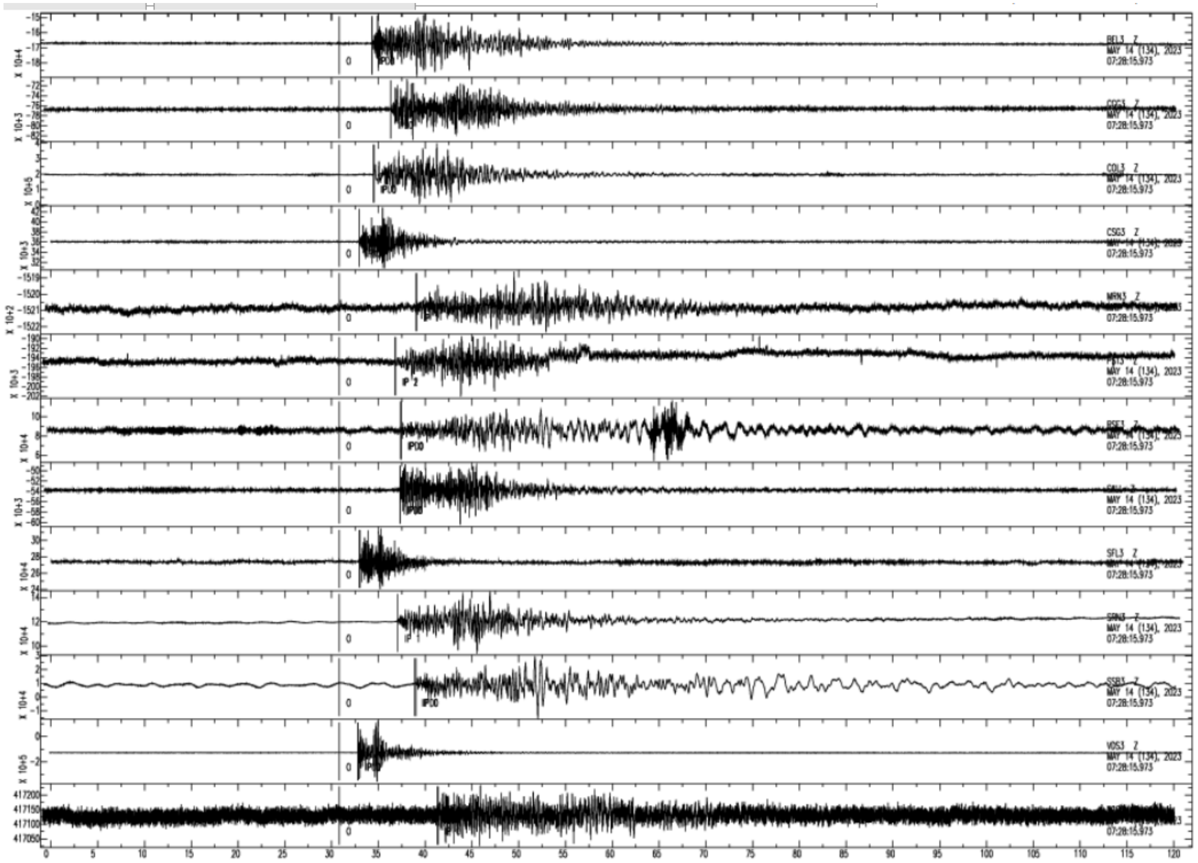
Summary





We are experiencing a seismic sequence (more than 240 events detected), occurring in the Muro Lucano – Capo di Giano area (PZ), at a depth between 7 and 9 km, at the Eastern boundary of the INFO, Irpinia Near Fault Observatory. The area was struck in the past by seismic events of magnitude > 6.0.

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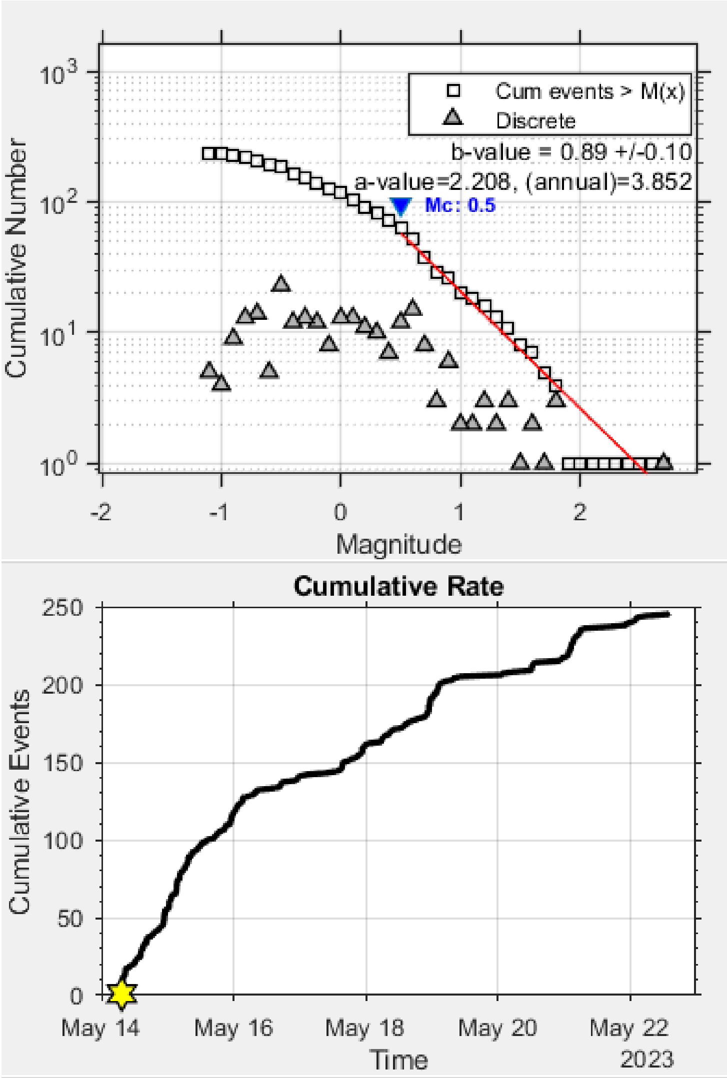
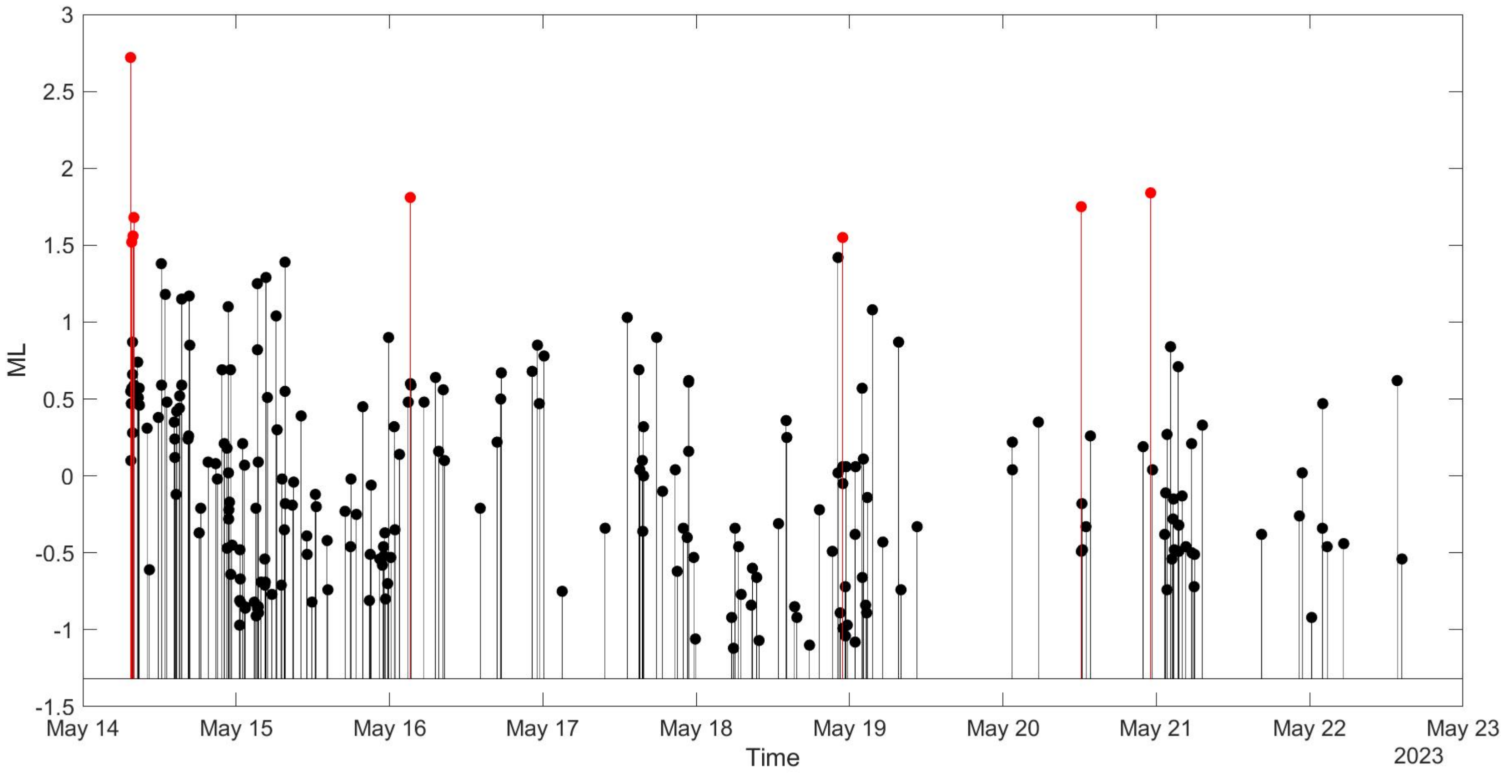
Catalog enhancement

We performed an advanced detection analysis based on Scotto di Uccio et al. (2023) integrating machine learning (**EQTransformer**, Mousavi et al. 2020) and template matching (**EQCorrscan**, Chamberlain et al. 2018) techniques. The resulting catalog (**14-23/05**) consists up to now of **246 earthquakes**, most of them only visible at VDS3 station.



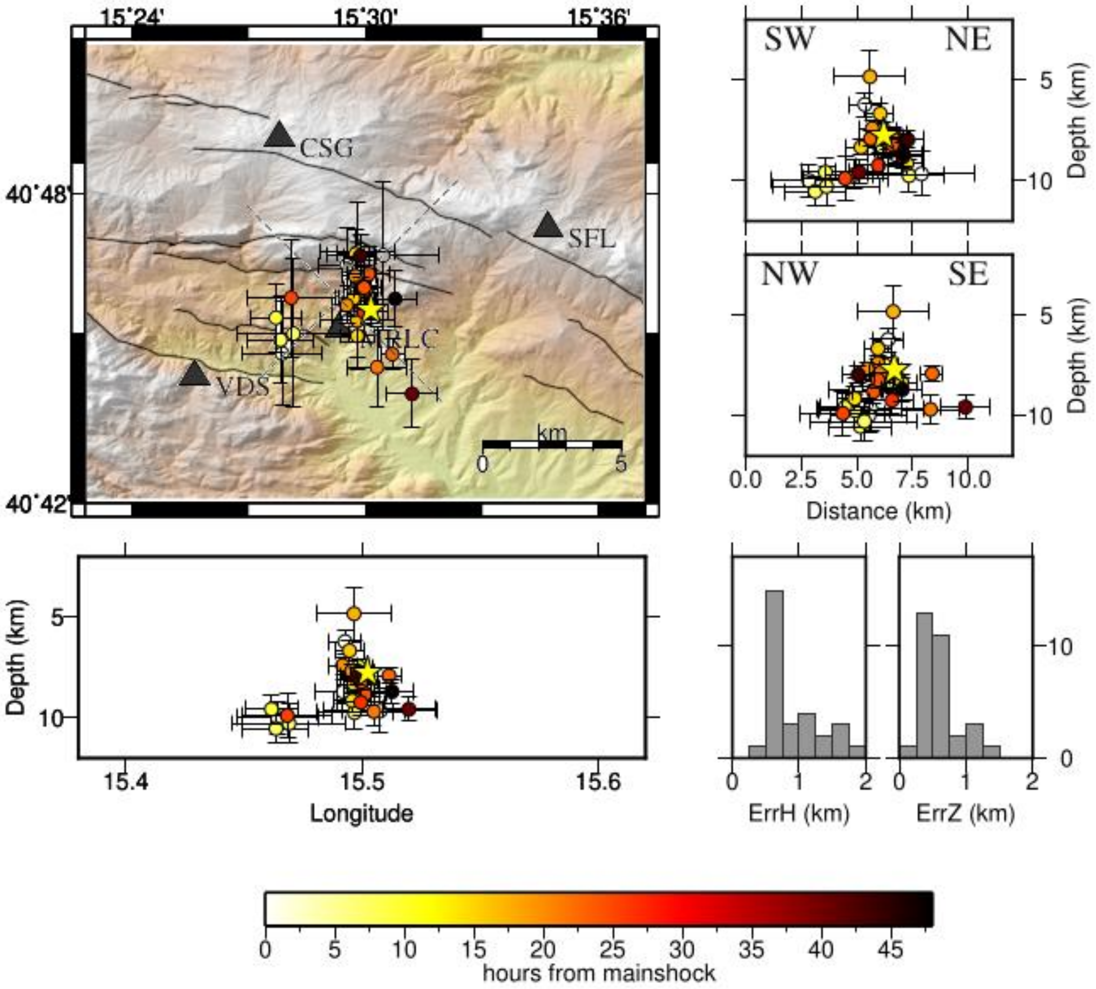
Z-map analysis for G-R computation



Time-magnitude distribution of the events. In red events featuring Ml > 1.5

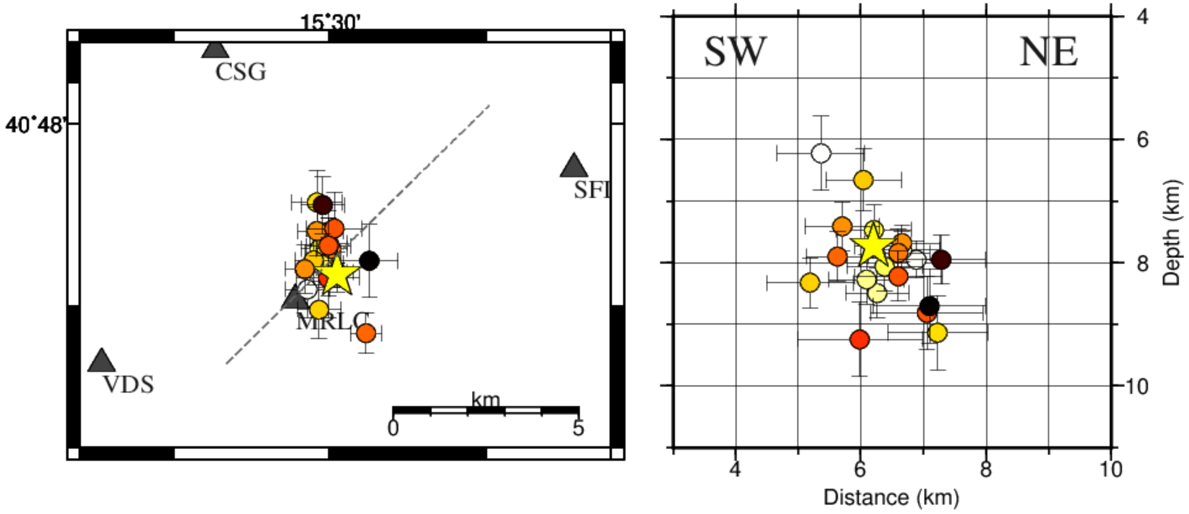
The G-R law feature **consistent b-value** (0.89±0.10) with the ones estimated for sequences in the area (Scotto di Uccio et al., 2023). Local magnitude have been estimated assuming colocation.

3D Absolute locations



We performed absolute locations of 33 events with NLLoc (Lomax, 2009) and the 3D P- and S-wave models optimized for the area (De Landro et al. 2022). The yellow star represents the mainshock. The colours correspond to the time occurrence of events after the mainshock. The gray dashed lines in plane view represent the projection of SW-NE and NW-SE sections. The black lines represent the fault traces as mapped by Bello et al. (2022).

The 20 best located events (errors < 1 km), in the figure below, show a clustered distribution within less than 2 km from the mainshock.



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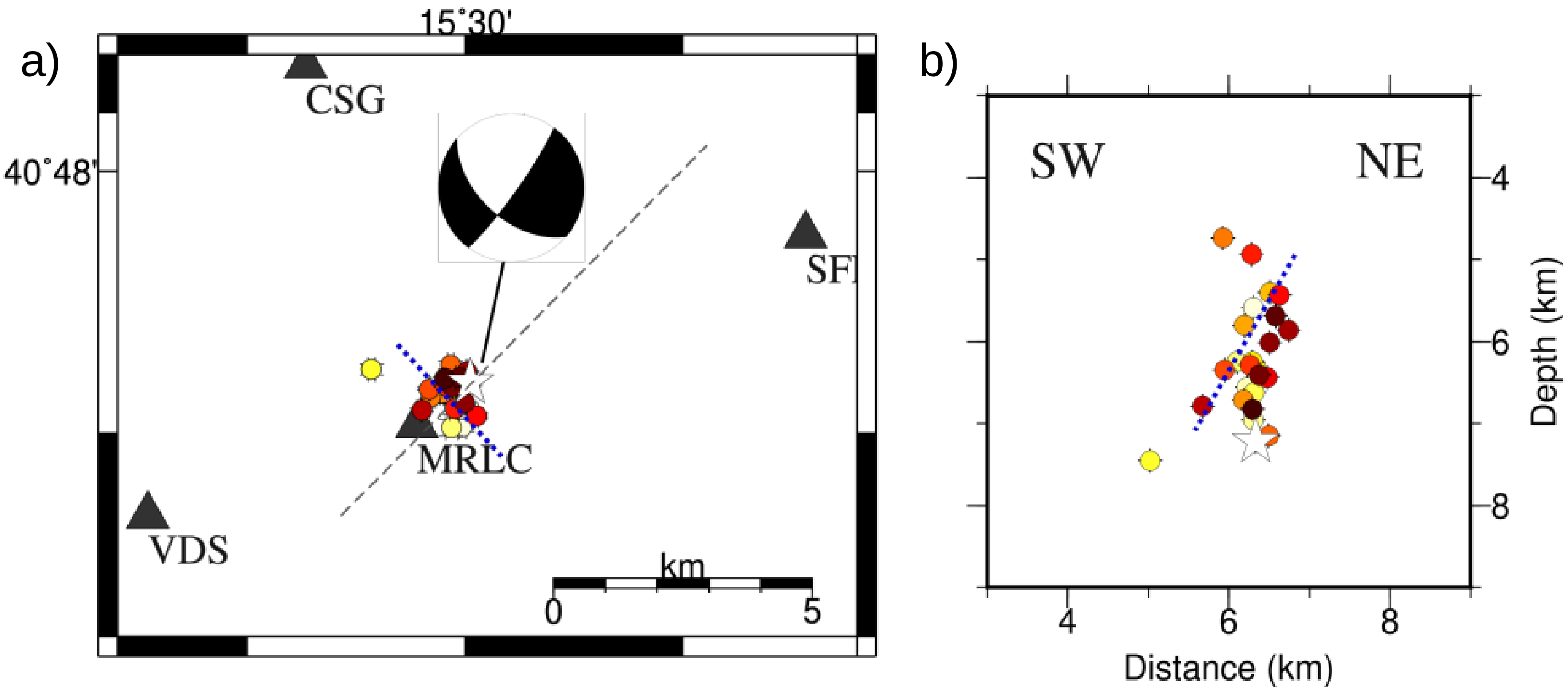
3D Double-Difference locations



We performed double difference locations of events of the sequence with HypoDD, using catalog and cross-correlation differential times. The gray dashed line in plane view (a) represent the projection of SW-NE section (b). The white star represents the mainshock location. The color is related to the occurrence time. The lcoation errors are whitin 100 meters and the average rms is 0.06 s. The sequence distribution in plane and section is coherent with the retrieved focal mechanism (see slide 11).

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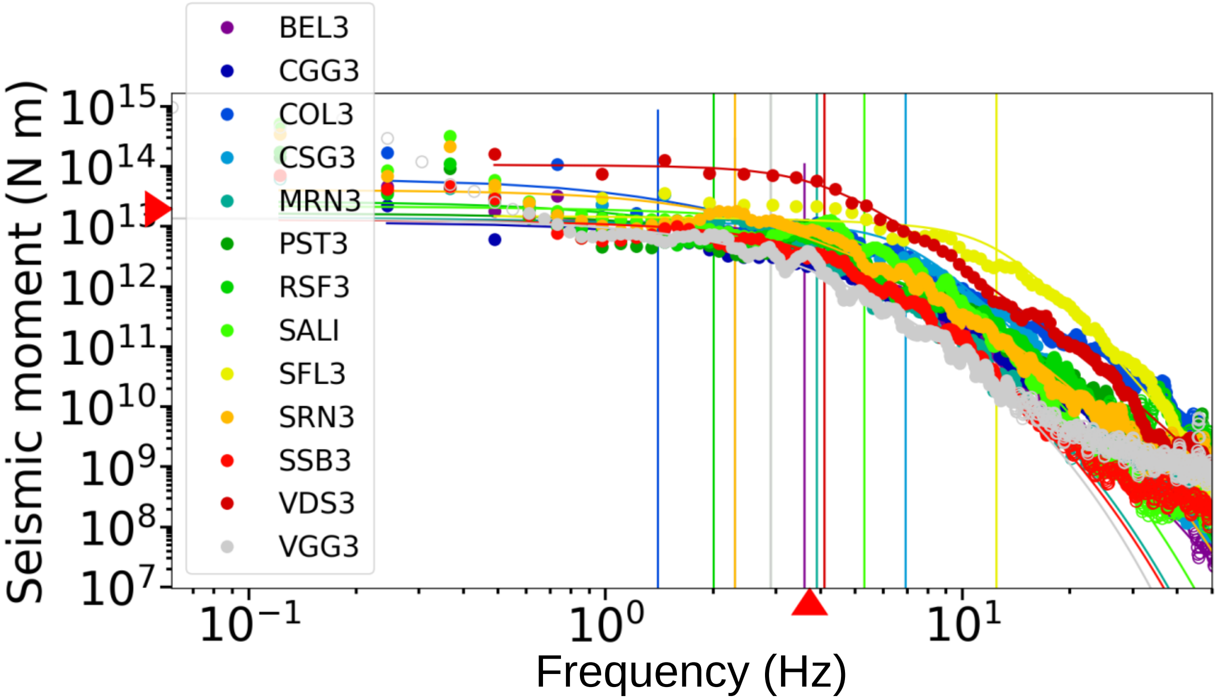
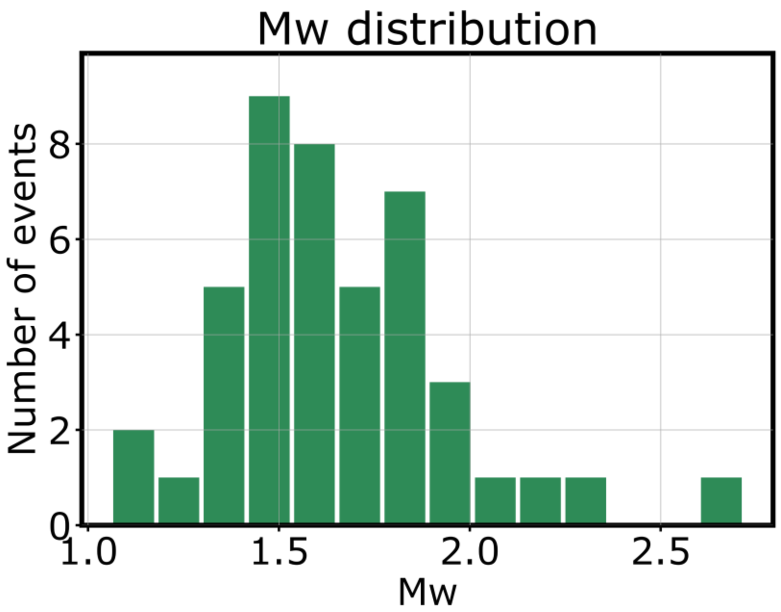
Source Parameters – SPAR





We inverted displacement amplitude spectra at stations of ISNet using a generalized Brune source model, through the software **SPAR** (Supino et al., 2019). For the main event we estimated an average moment magnitude of 2.78 ±0.02, a corner frequency of 3.8 ±0.2 Hz and a stress drop of 1.0 ±0.1 MPa (Left panel). For the inversion we set $v_s = 3030\ m/s$ and $Q_s = 230$. The histogram represents the distribution of the moment magnitude for 40 events in the sequence (Right panel).

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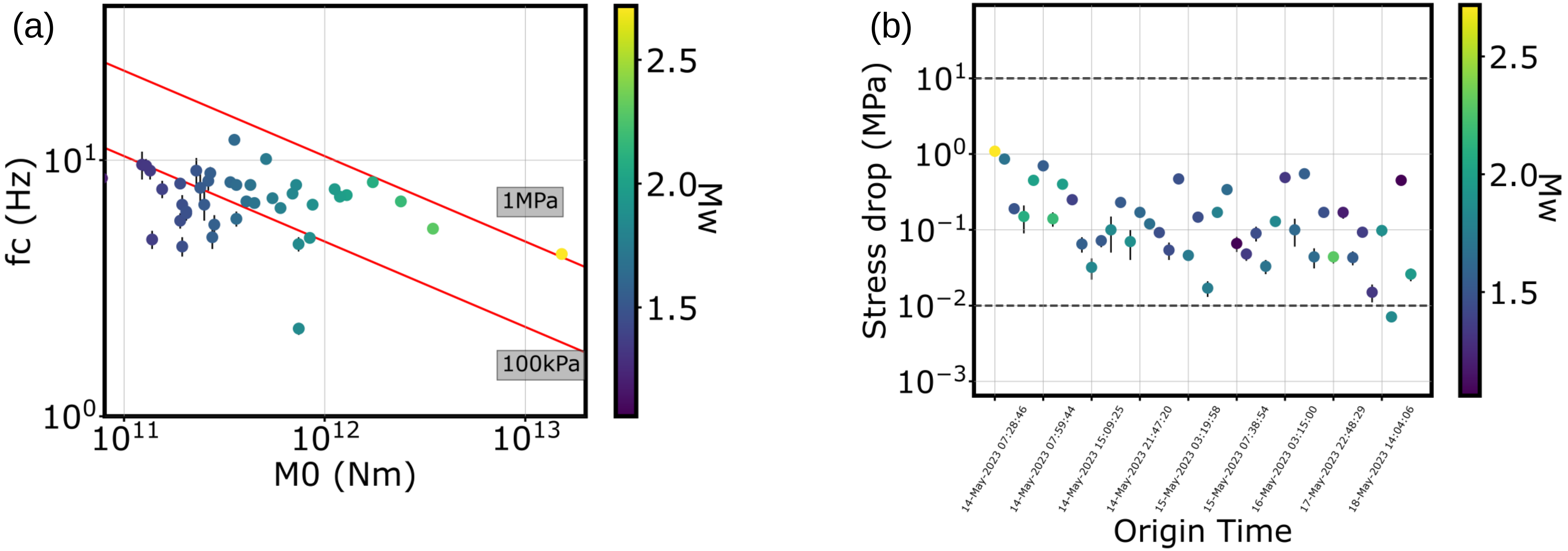
Source Parameters – SPAR



We found that corner frequencies show values ranging from 1Hz to 10 Hz and correspond to larger stress drops for larger magnitude. Saturation of corner frequency is observed for low moment magnitudes (moments < 5 10^{11} Nm). Stress drops (b) for the sequence have been found to vary between 10KPa and 1 Mpa, with few outliers.

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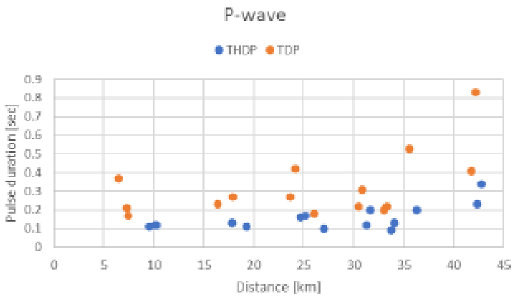
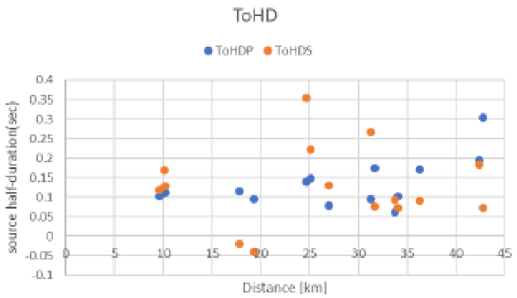
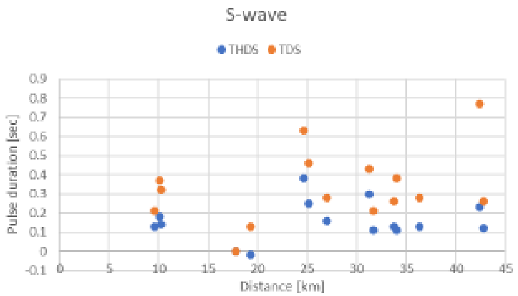
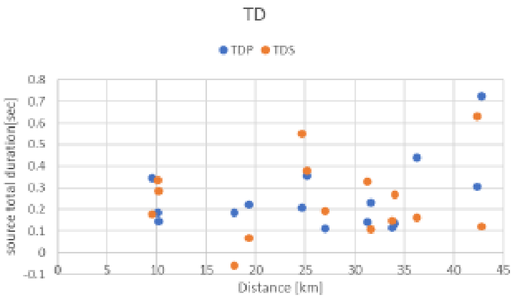
Time-domain, single-station estimates of source parameters for the mainshock









- (half)(total) Pulse widths are corrected for the attenuation (Qp=160; Qs=220) using the Kjartansson(1979) linear relation (k coefficients calibrated in J.Zheng et al, 2023 in preparation)
- Average source durations:
  - P-wave→ ToHD=0.13±0.06 sec; ToD=0.26±0.16 sec
  - S-wave→ ToHD=0.15±0.08 sec; ToD=0.27±0.17 sec

Source parameters – P wave

Parameter	Formula	Value
Seismic moment	$\langle M_0^c \rangle = \frac{2\pi\rho v_c^3}{F_S R_{\theta\varphi}^c} \langle Pd_c^0 \cdot R \rangle \langle ToDc \rangle$	$2.4 \times 10^{13} Nm$
Moment magnitude	$M_W = (\log\langle M_0^{P,S} \rangle - 9.1)/1.5$	2.8
Rupture radius	$\bar{a} = ToHD_c v_R (1 - \frac{2v_R}{\pi v_c})^{-1}$	440 m
Static Stress-Drop	$\Delta\sigma = \frac{7}{16} \frac{\langle M_o \rangle}{\bar{a}^3}$	0.1 MPa
Equivalent fc (S&Hmodel)	$f_c = 0.42 \frac{v_P}{a}$	4.3 Hz

Source parameters – S wave

Parameter	Formula	Value
Seismic moment	$\langle M_0^c \rangle = \frac{2\pi\rho v_c^3}{F_S R_{\theta\varphi}^c} \langle Pd_c^0 \cdot R \rangle \langle ToDc \rangle$	$3.1 \times 10^{12} Nm$
Moment magnitude	$M_W = (\log\langle M_0^{P,S} \rangle - 9.1)/1.5$	2.3
Rupture radius	$\bar{a} = ToHD_c v_R (1 - \frac{2v_R}{\pi v_c})^{-1}$	383 m
Static Stress-Drop	$\Delta\sigma = \frac{7}{16} \frac{\langle M_o \rangle}{\bar{a}^3}$	0.15 MPa*
Equivalent fc (S&Hmodel)	$f_c = 0.29 \frac{v_S}{a}$	1.9 Hz

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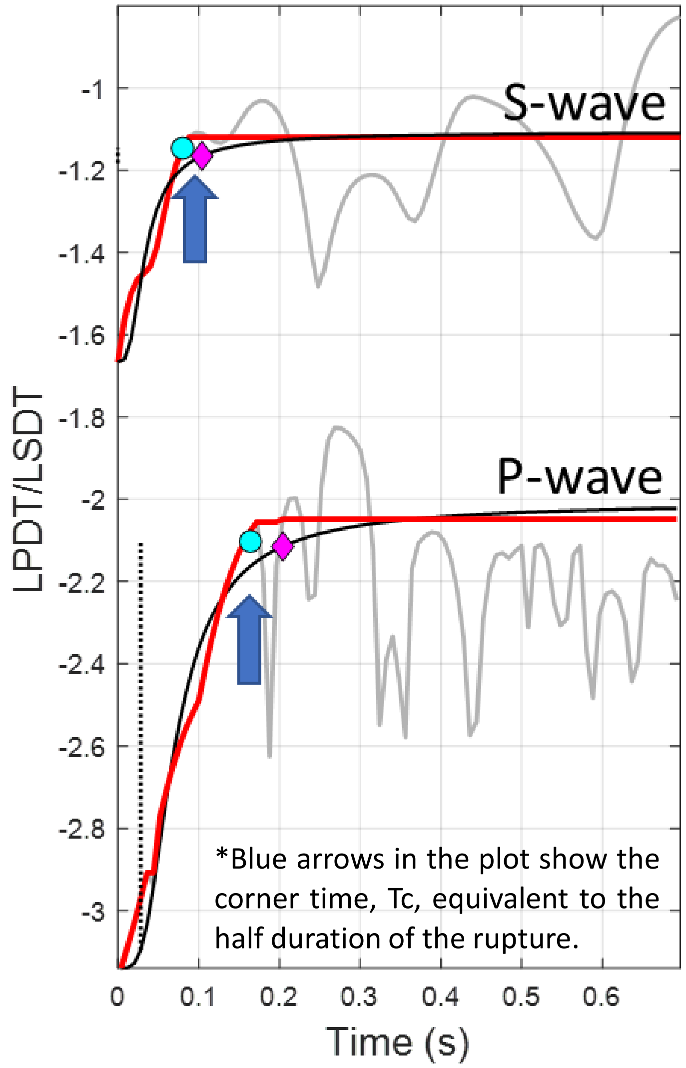
Time-domain, average-based estimate of source parameters of the mainshock, EASOt-AP



LPDT/LSDT: Logarithm of **P**- and **S**-wave **D**isplacement signal as a function of **T**ime

Input Parameters

Vp (km/s)	Vp/Vs	Qp/Qs
5.5	1.8	167/224

Table 1: Both P- and S-wave observations are used to estimate Vr, average a, and expected corner frequency.

Wave	Tc (s)	Vp (km/s)	Vs (km/s)	a (m)	Vr/Vs	Fc (Hz)
P	0.13	5.5	3.1	324.0	0.6	5.8
S	0.1					2.5

Table 2: Source Parameters estimation from Individual waves

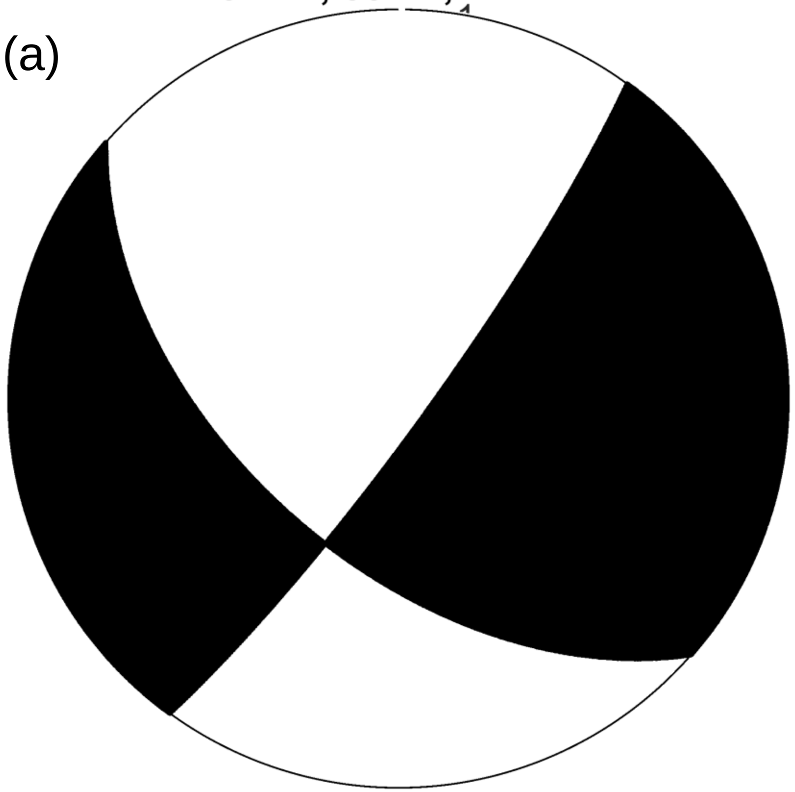
Wave	Vr/Vs	Vp (km/s)	M0 (Nm)	Mw	a (m)	Δσ (MPa)
P	0.6	5.5	8.7e12	2.6	302.5	0.1
S	0.6	5.5	7.3e12	2.5	296.6	0.1

Assuming a triangular moment-rate function, uniform speed, and circular rupture model, source parameters (rupture velocity, seismic moment, fault size and stress drop) are determined implementing a parametric approach based on the time evolution of the P-wave and S-wave amplitudes.
The proxy is a logarithm of the P- and S-wave displacement vs time curves (LPDT/LSDT). The constant-Q, anelastic attenuation effect is accounted for.

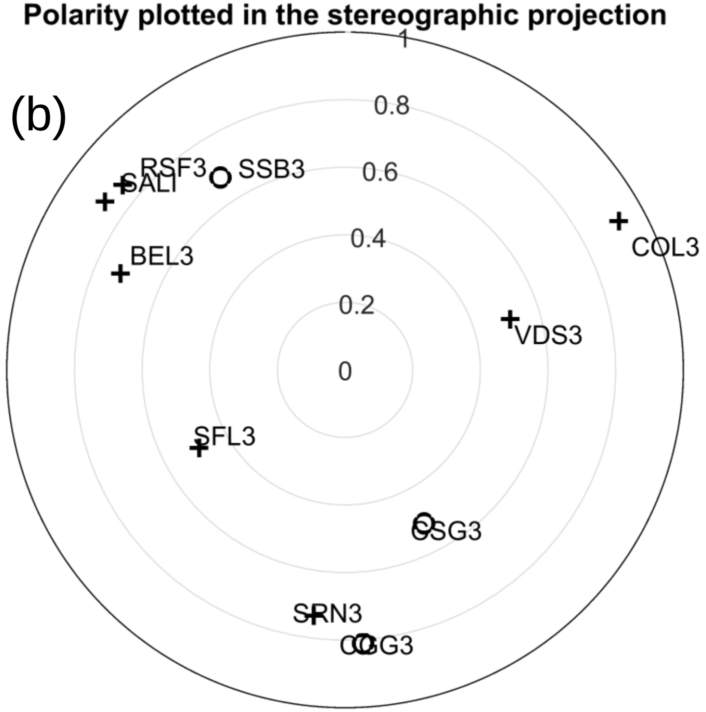
Focal Mechanism – Main event

MAP model
strike, dip, slip
36+-1, 83+-1, -37+-2;
131+-2, 53+-2, -171+-1

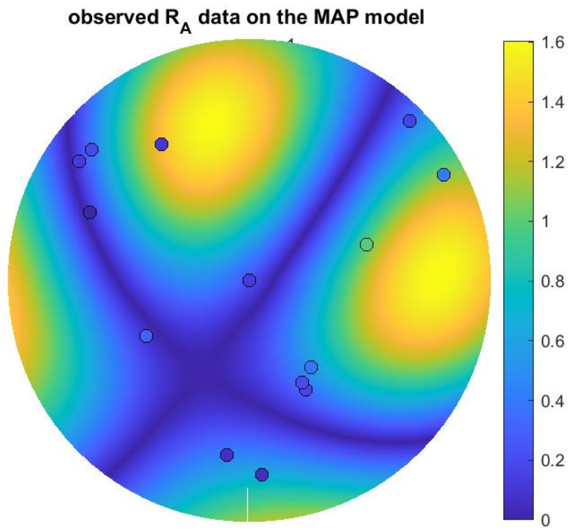
(a)



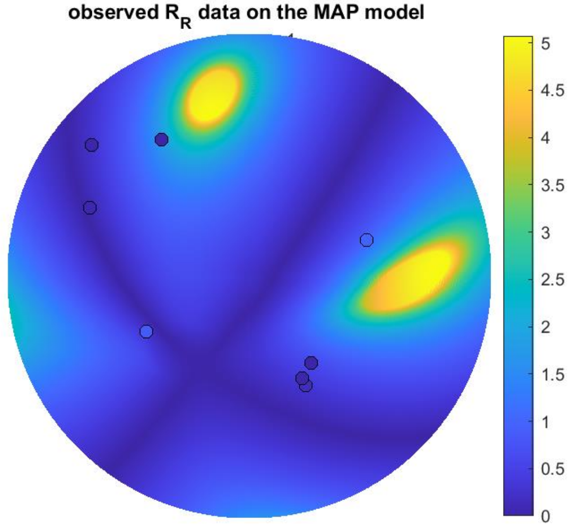
(b)



(c)



(d)



Inversion was performed for the main events by fitting the observed P (c) and S/P (d) amplitudes and the P polarities (b). The best solution shows a strike-slip source mechanism with a normal component.

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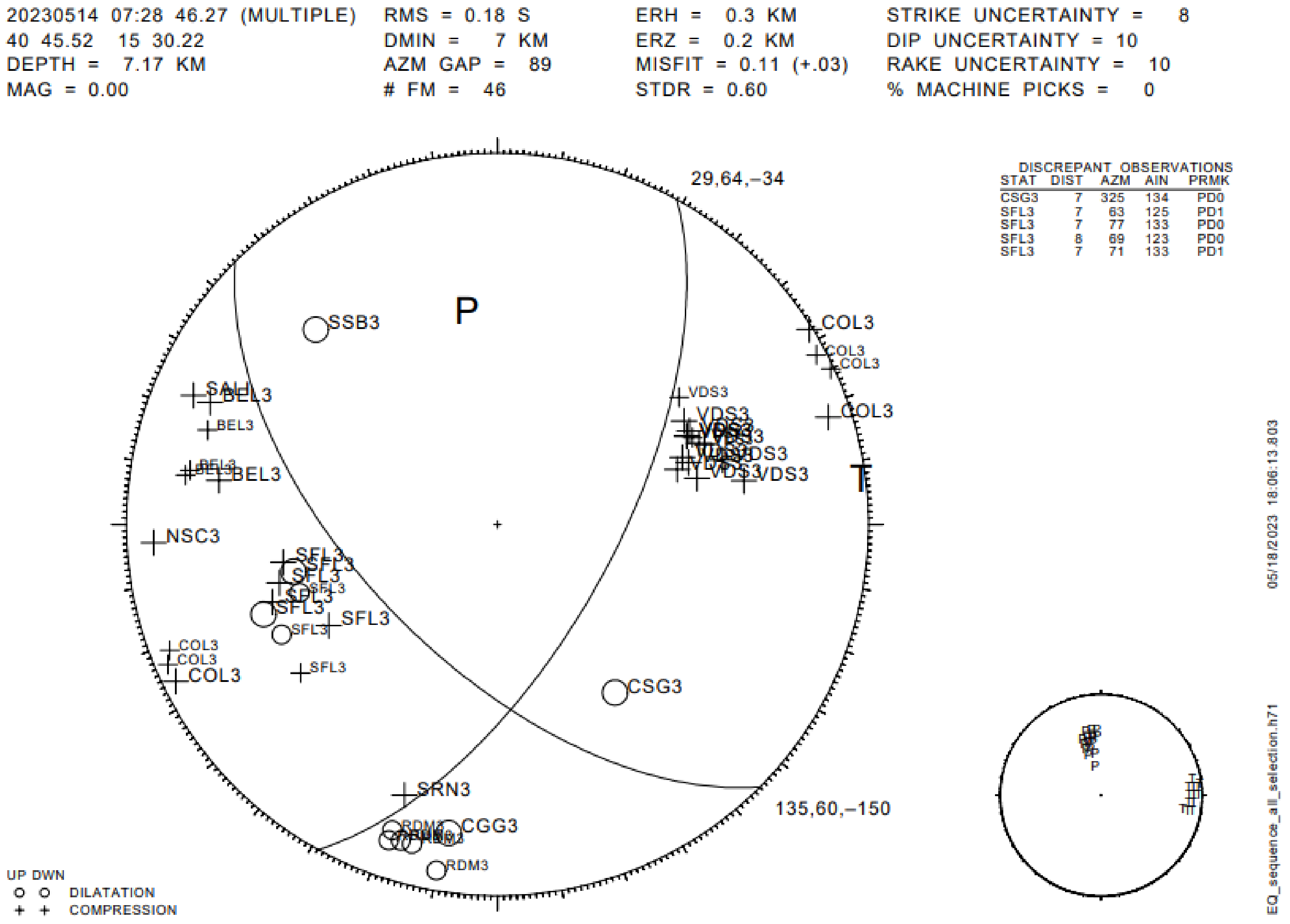
Composite Focal Mechanism

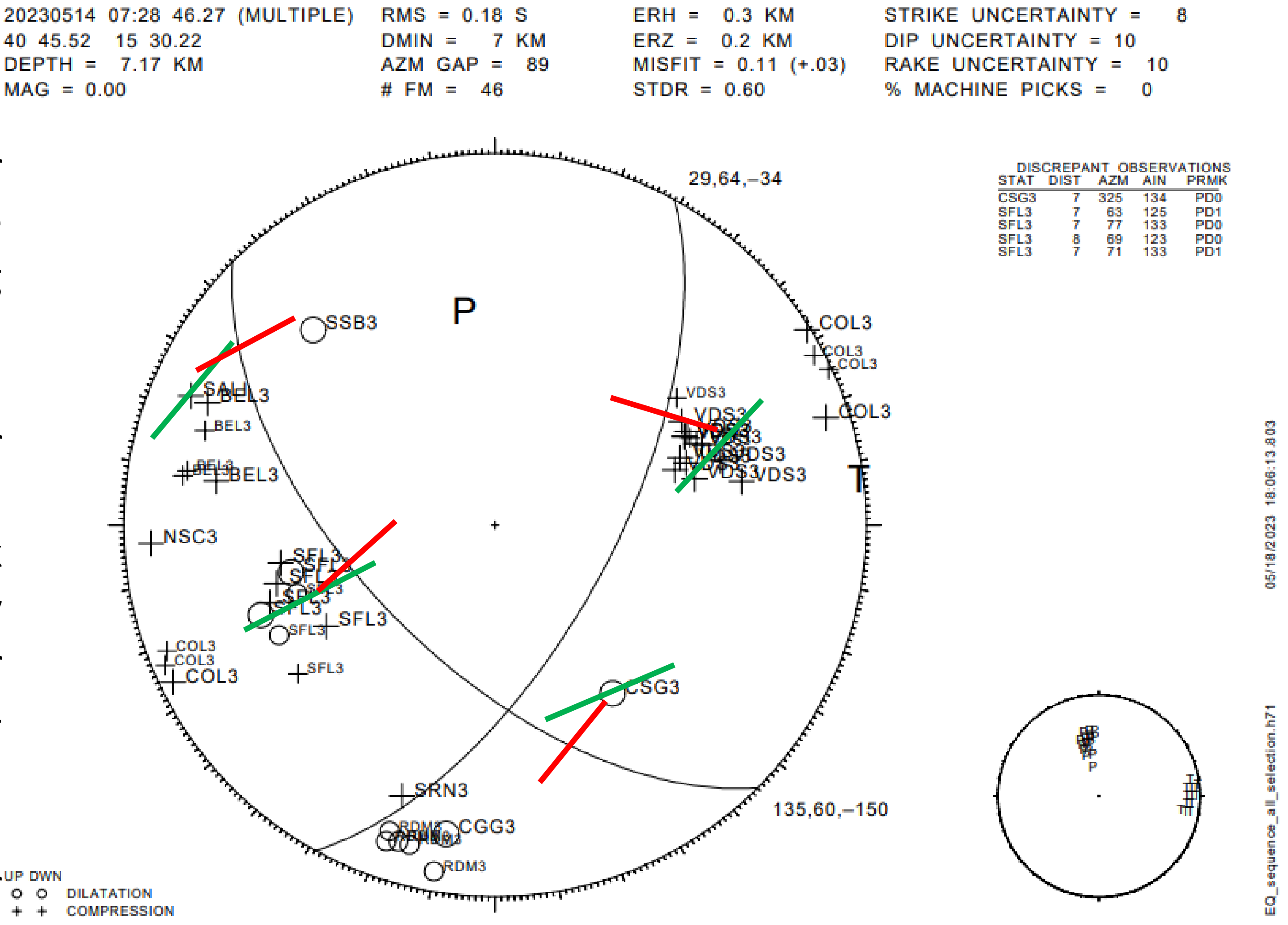
The focal mechanism has been computed for clustered events, as resulting from double difference location, takeoff angles from ray tracing in the 3D model (De Landro et al., 2022), and manually read polarities. We found a focal mechanism consistent with the results obtained for the main event.



Composite Focal Mechanism

The focal mechanism has been computed for clustered events, as resulting from double difference location, takeoff angles from ray tracing in the 3D model (De Landro et al., 2022), and manually read polarities. We found a focal mechanism consistent with the results obtained for the main event.

The measured S-polarization of the mainshock event (ML=2.7, Mw 2.8) are also generally consistent with theoretical horizontal S-vector direction in particular at stations close to the SW-dipping plane. A larger discrepancy between observed and theoretical S-polarization is instead observed at station VDS3 that needs further investigations.



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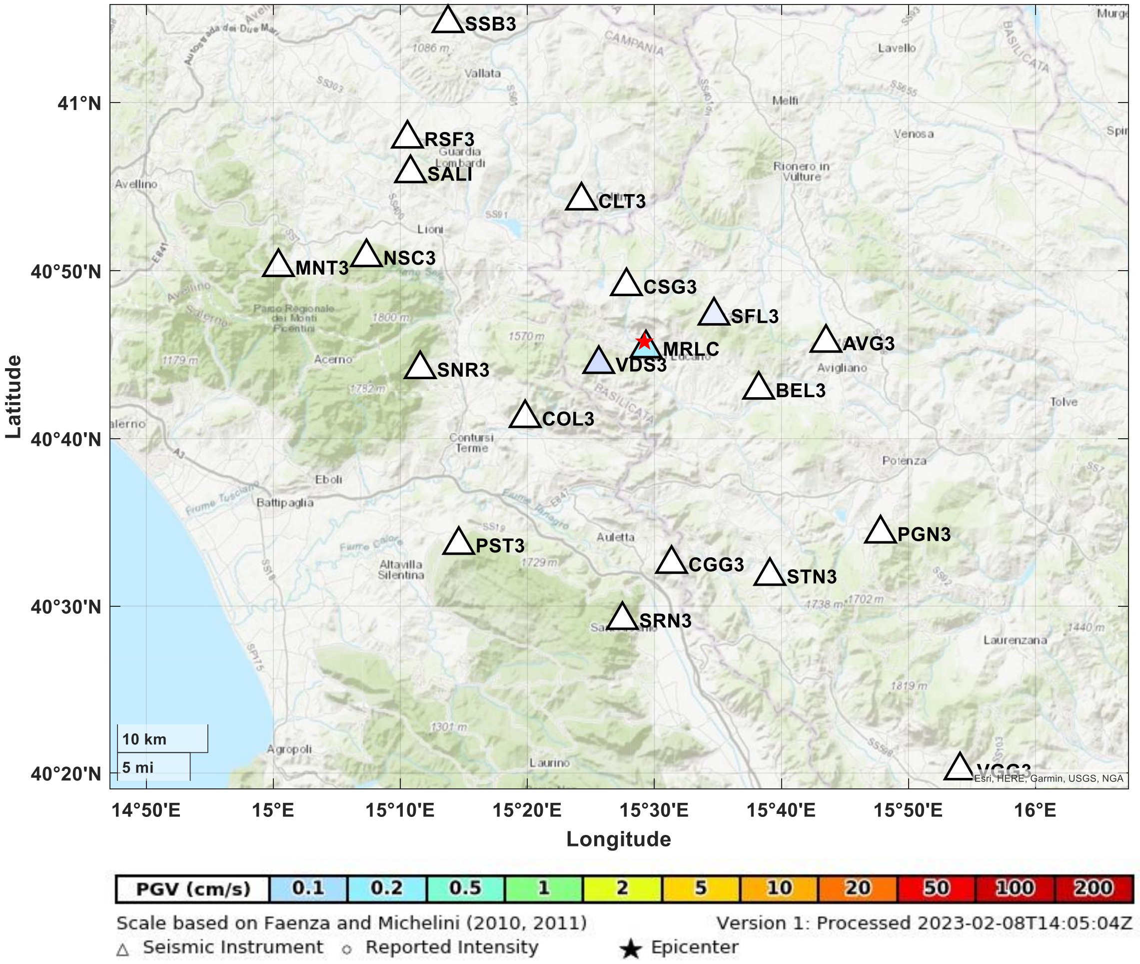
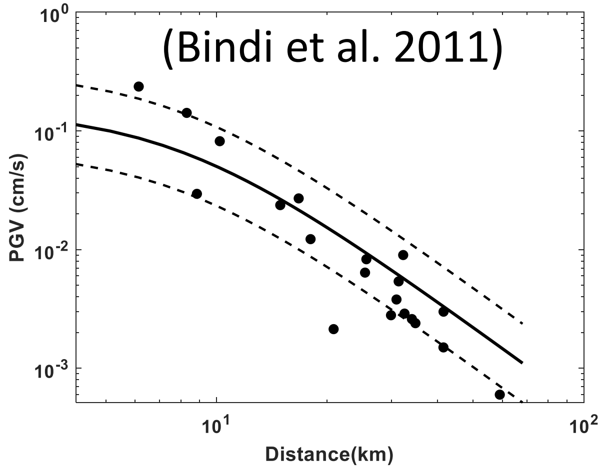
Ground motion (PGV)



- Average epicentral distance $\sim 26\ km$
  - ➢ Min distances IV.MRLC – $6.1\ km$ - IX.VDS3 – $8.3\ km$
  - ➢ Max distance IX.VGG3 – $59.1\ km$

- PGV observed on velocimeters (where available) and integrated from accelerometers

- PGV range
  - ➢ $PGV_{min} = 3 \cdot 10^{-5}\ cm/s$ (IX.NSC3)
  - ➢ $PGV_{max} = 0.24\ cm/s$ (IV.MRLC) - $0.14\ cm/s$ (IX.VDS3)



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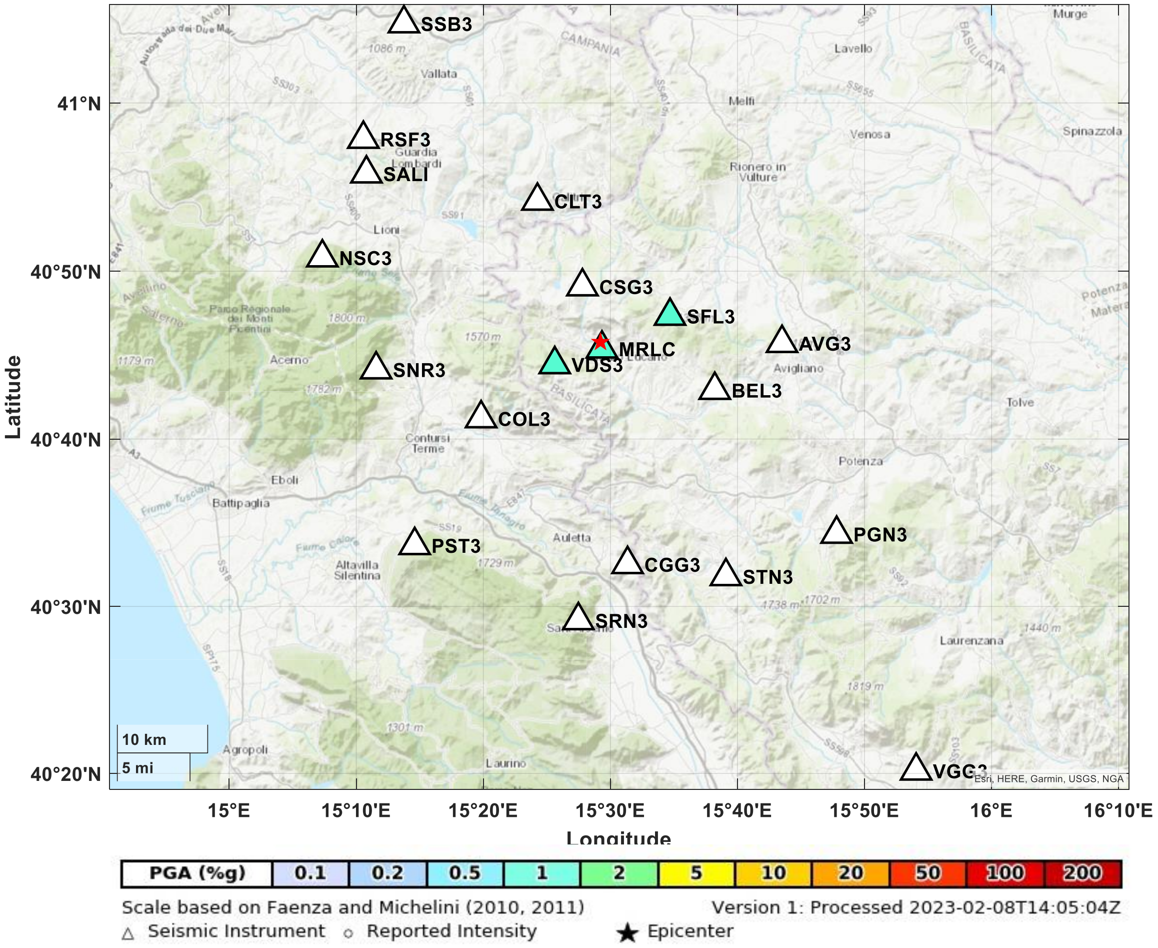
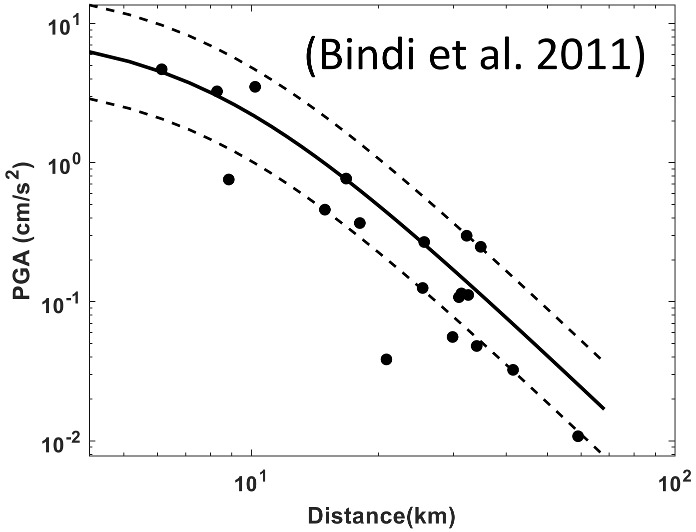
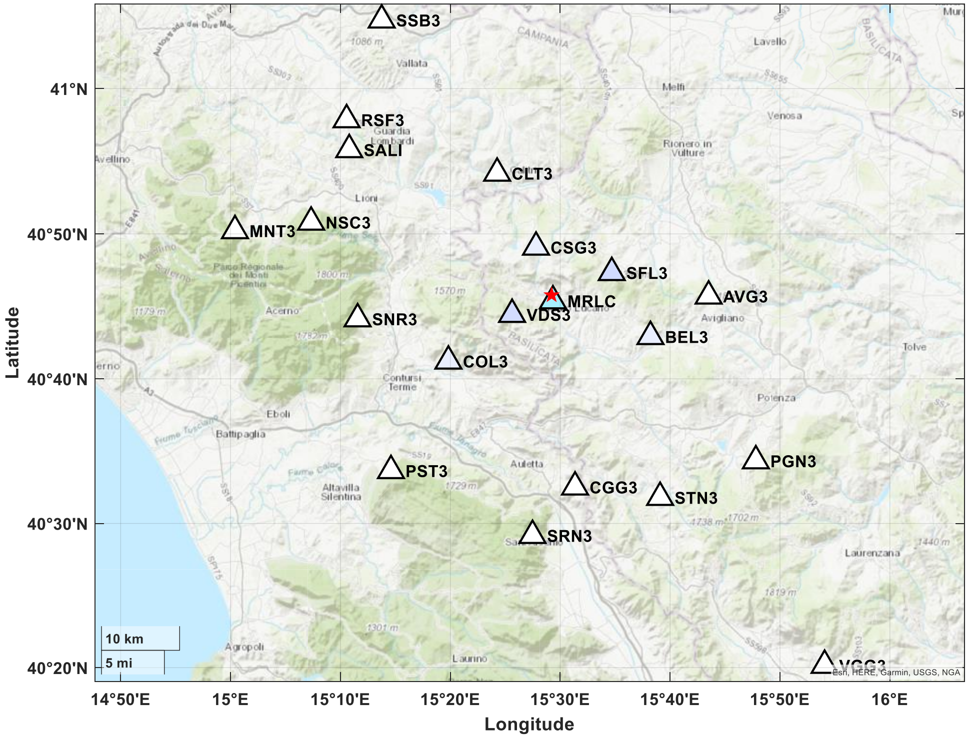
Ground motion (PGA)



- PGA range
  - $PGA_{min} = 1.0 \cdot 10^{-3}\%g$ (IX.VGG3)
  - $PGA_{max} = 0.48\%g$ (IV.MRLC) - $0.36\%g$ (IX.SFL3)



Ground motion (IMM)



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0556	0.212	0.808	1.97	4.82	11.8	28.7	70.1	>171
PGV(cm/s)	<0.0178	0.0775	0.337	0.898	2.39	6.37	17	45.2	>120
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Faenza and Michelini (2010, 2011) Version 1: Processed 2023-02-08T14:05:04Z

△ Seismic Instrument ○ Reported Intensity ★ Epicenter

- Average epicentral distance $\sim 26\ km$
  - ➢ Min distances IV.MRLC – $6.1\ km$; IX.VDS3 $- 8.3\ km$
  - ➢ Max distance VGG3 $-59.1\ km$

- IMM range
  - ➢ $IMM_{max} =\ \ IV$ (IV.MRLC)
    III (IX.VDS3 – IX.SFL3)

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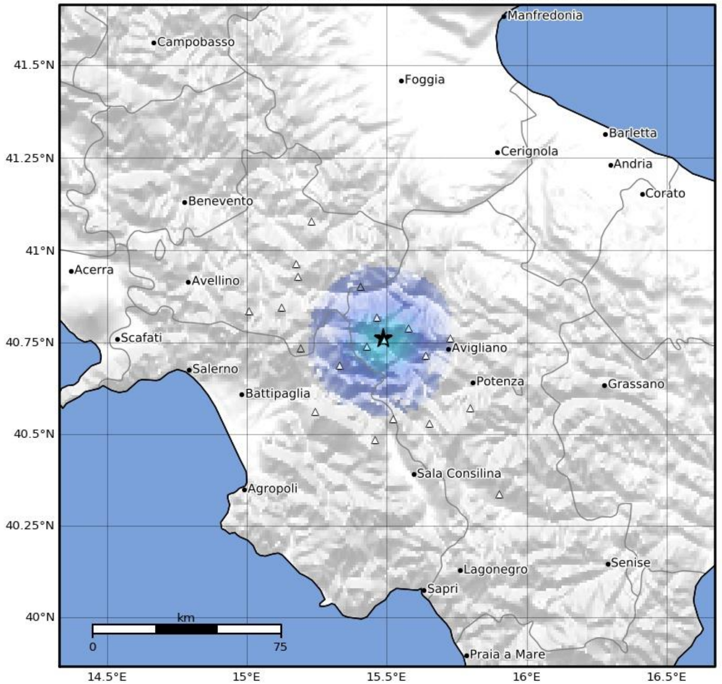
Ground motion (ShakeMaps)

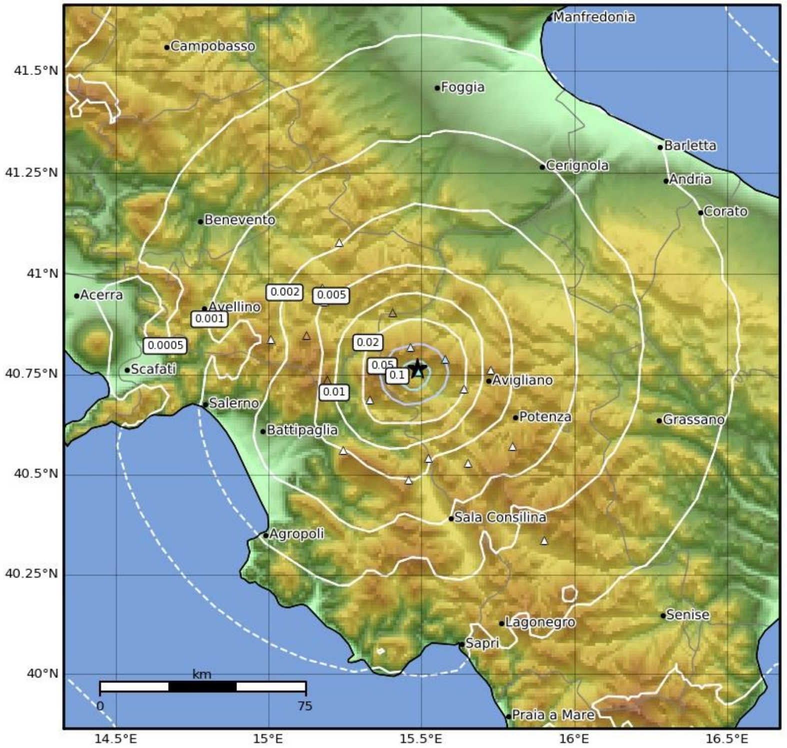
Macroseismic Intensity Map UNINA
ShakeMap: Capo di Giano (PZ)
May 14, 2023 07:28:46 UTC M2.7 N40.76 E15.49 Depth: 6.6km ID:17427r_vel



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0556	0.212	0.808	1.97	4.82	11.8	28.7	70.1	>171
PGV(cm/s)	<0.0178	0.0775	0.337	0.898	2.39	6.37	17	45.2	>120
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Faenza and Michelini (2010, 2011) Version 1: Processed 2023-05-19T13:57:59Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

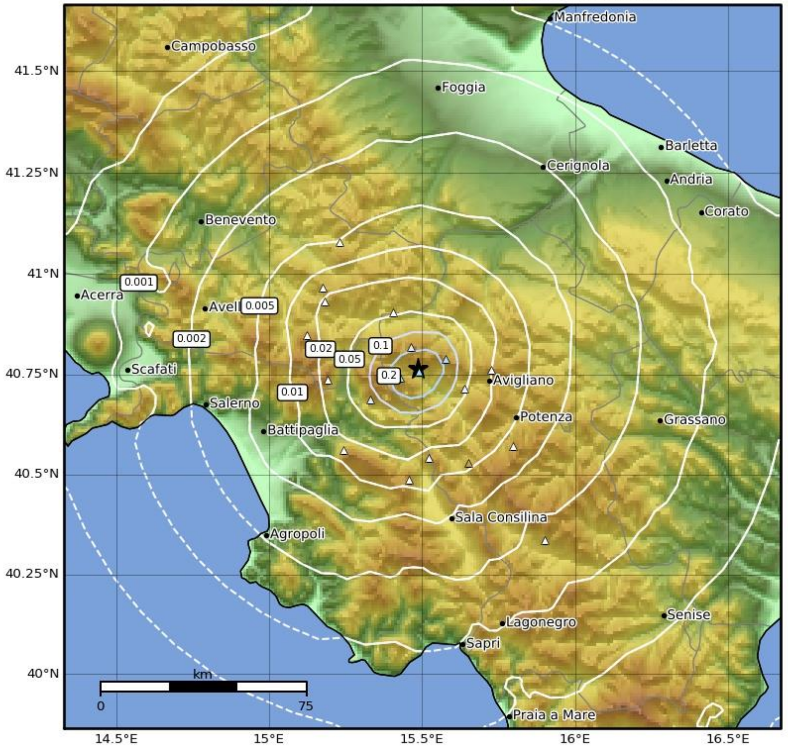
Peak Ground Velocity Map UNINA
ShakeMap: Capo di Giano (PZ)
May 14, 2023 07:28:46 UTC M2.7 N40.76 E15.49 Depth: 6.6km ID:17427r_vel



PGV (cm/s)	0.1	0.2	0.5	1	2	5	10	20	50	100	200

Scale based on Faenza and Michelini (2010, 2011) Version 1: Processed 2023-05-19T13:57:59Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

Peak Ground Acceleration Map UNINA
ShakeMap: Capo di Giano (PZ)
May 14, 2023 07:28:46 UTC M2.7 N40.76 E15.49 Depth: 6.6km ID:17427r_acc



PGA (%g)	0.1	0.2	0.5	1	2	5	10	20	50	100	200

Scale based on Faenza and Michelini (2010, 2011) Version 1: Processed 2023-05-19T13:45:00Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

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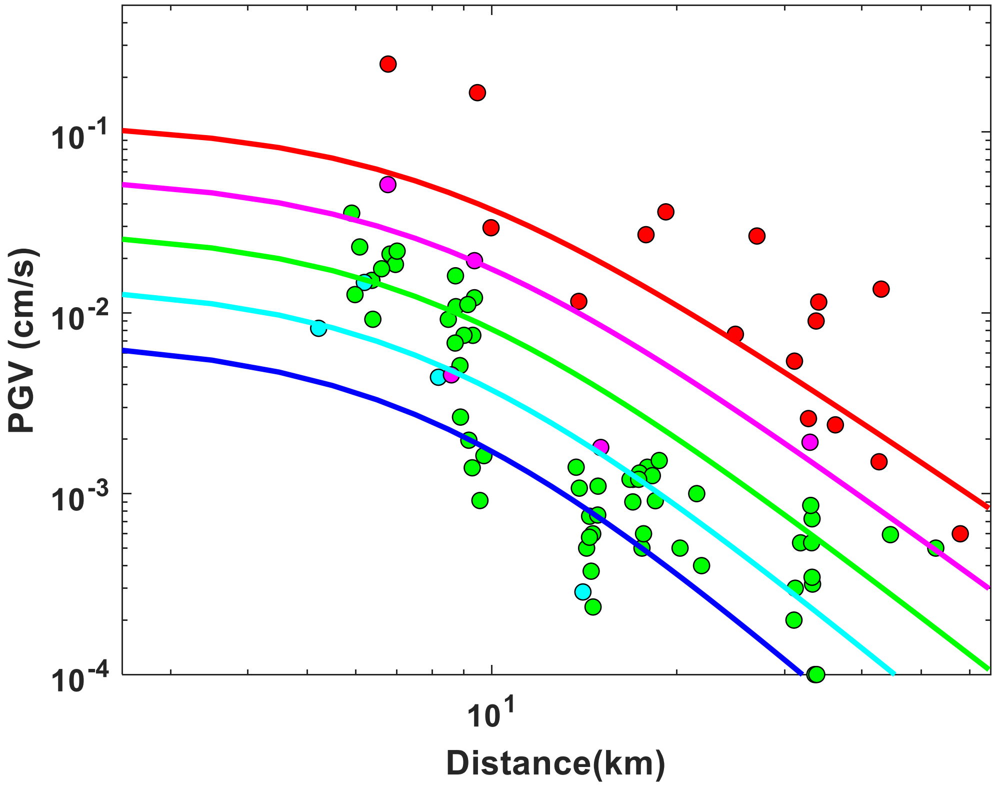
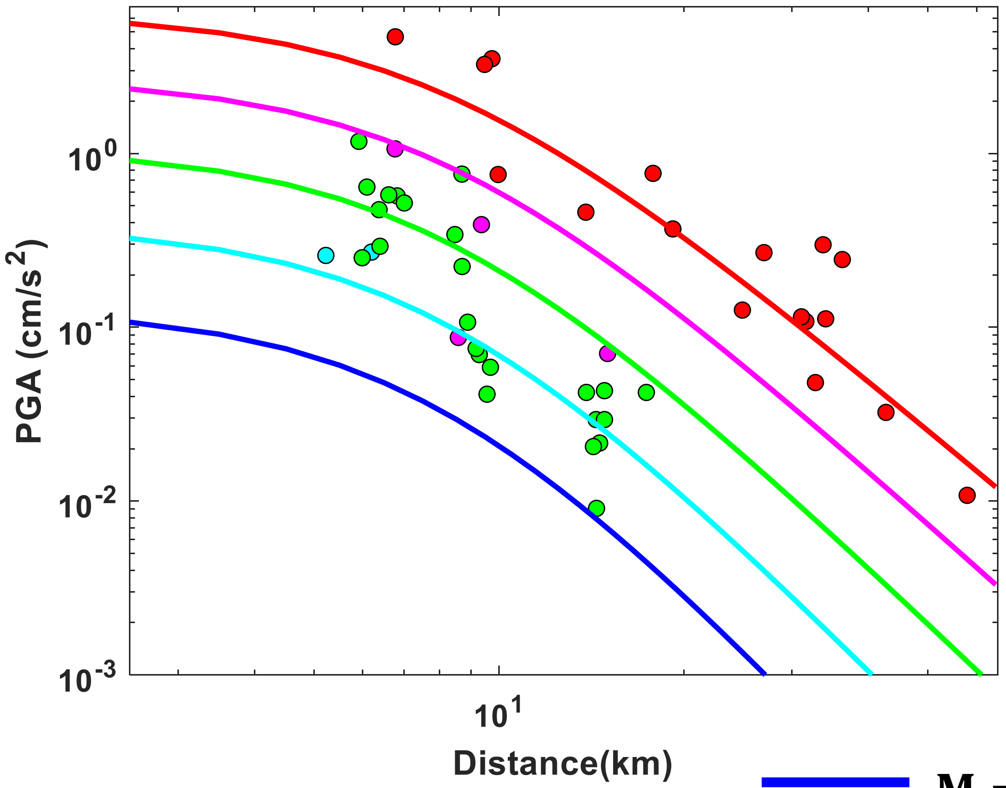
Ground motion (all events)





$0.75 < M < 1.25$

$1.25 < M < 1.75$

$1.75 < M < 2.25$

$2.25 < M < 2.75$

$M = 0.5$

$M = 1.0$

$M = 1.5$

$M = 2.0$

$M = 2.5$

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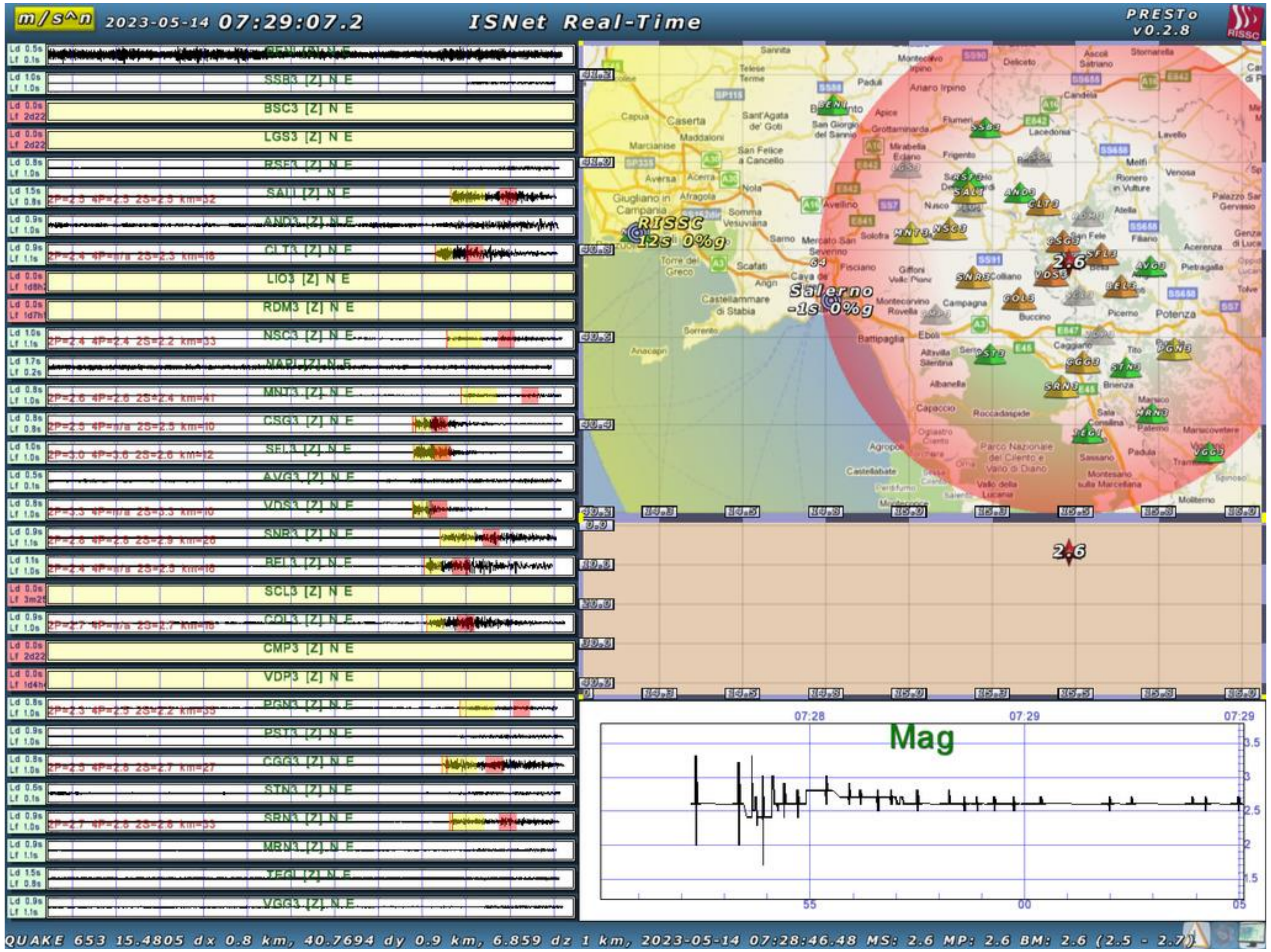
PRESTo



ML 2.7, Capo Di Giano (PZ)
40.763, 15.487, 6.6 km
2023-05-14 07:28:46 (UTC)

FIRST ALERT AFTER 6.2 sec from T0
(3.5 sec from 1st pick, 7 stations)
MAG error: -0.1
LOC_epi error : 3 km
LOC_dep_error: 6.8 km

LAST ALERT AFTER 11.1 sec from T0
(8.4 sec from 1st pick, 13 stations)
MAG error: -0.1
LOC_epi error : 1.5 km
LOC_dep_error: 0.3 km

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Final Message from PRESTo

Il sistema di Early Warning **PRESTo**, in fase di sperimentazione presso il RISSC-Lab,
ha rilevato automaticamente un evento:

ML: **2.6**
Data: **2023-05-14 07:28:46.48 (UTC)**
Località: **Muro Lucano (PZ)**
Google Map

utilizzando **13 stazioni** della rete **ISNet - Irpinia Seismic Network.**

La prima informazione su magnitudo e localizzazione dell’evento è stata disponibile al tempo:

2023-05-14 07:28:52.30 (UTC)

Cioè circa **3.5** secondi dopo il primo arrivo P rilevato alla stazione VDS3 al tempo:

2023-05-14 07:28:48.79 (UTC)

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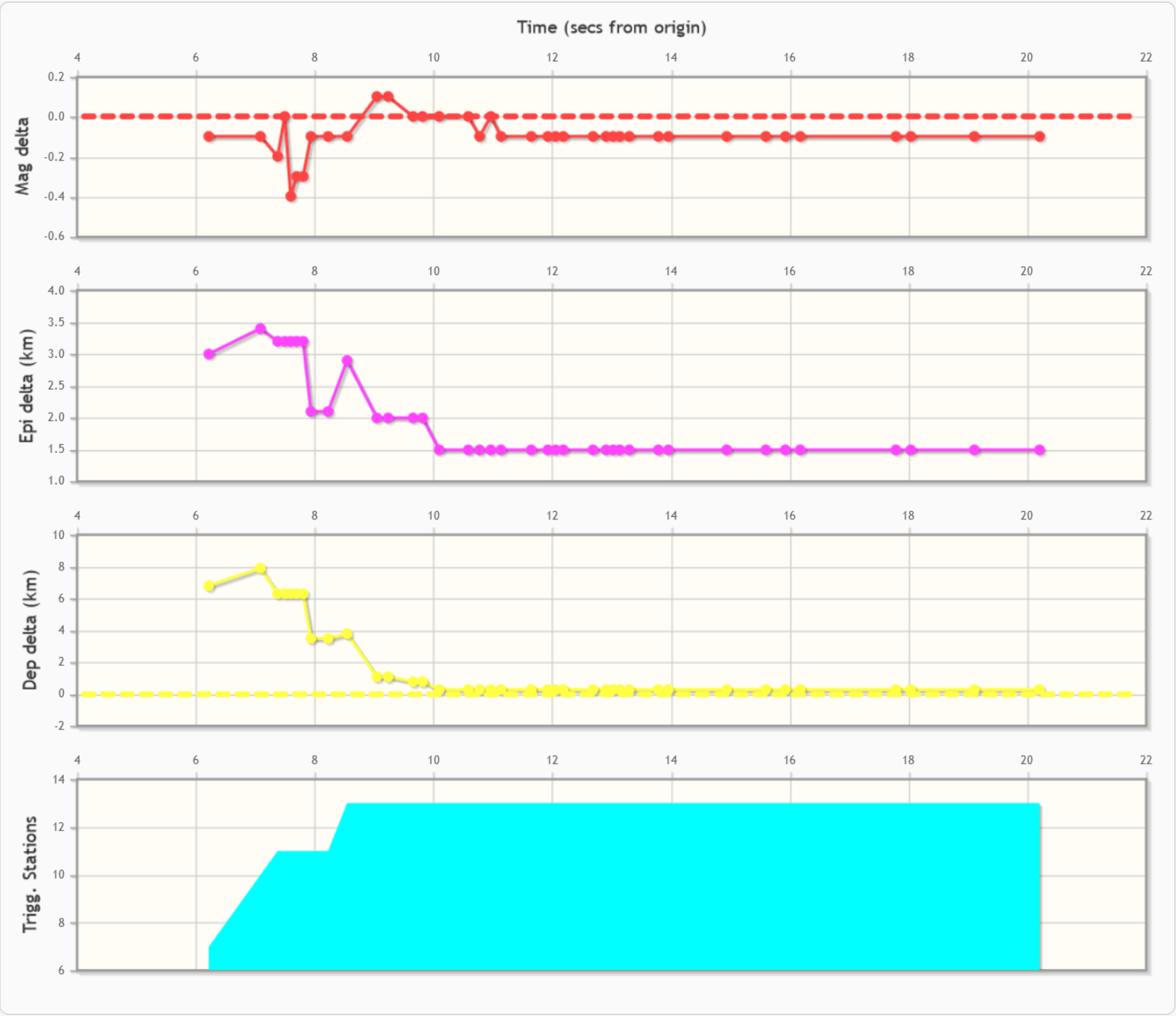
Real Time evolution PRESTO from CREW

Magnitude

Epicenter

Depth

Stations



Comparison of PRESTo estimates with ISNet bulletin values (dashed lines)

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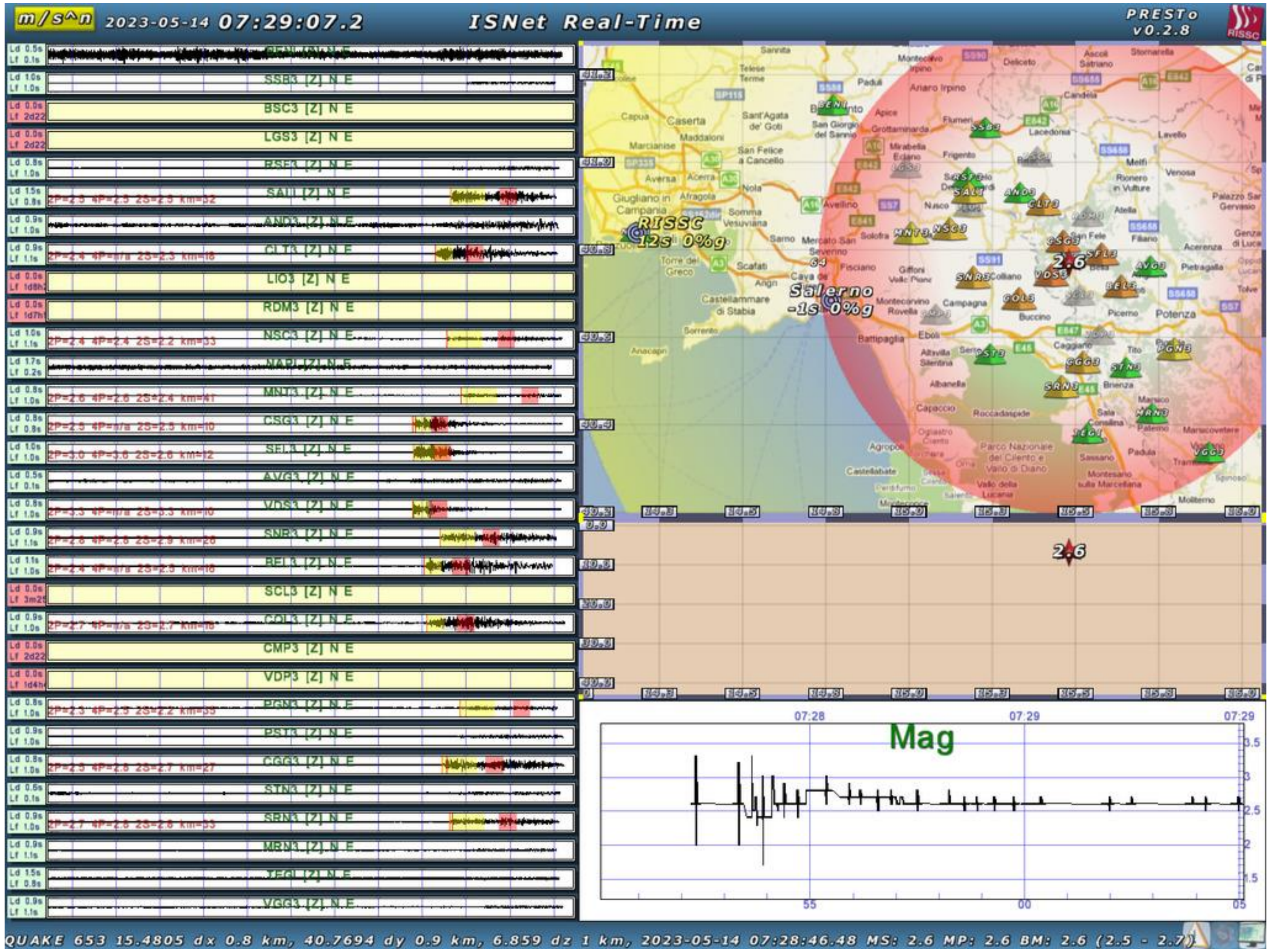
Data latency from PRESTo



Num.	Station	Latency (s)
1	AND3	0,67
2	AVG3	0,57
3	BEL3	1,16
4	BENI	0,68
5	BSC3	-
6	CGG3	0,60
7	CLT3	0,71
8	CMP3	-
9	COL3	0,57
10	CSG3	0,71
11	LGS3	-
12	LIO3	-
13	MNT3	0,70
14	MRN3	0,64
15	NAPI	1,70
16	NSC3	0,71
17	PGN3	0,63
18	PST3	0,68
19	RDM3	-
20	RSF3	0,69
21	SALI	1,73
22	SCL3	-
23	SFL3	0,71
24	SNR3	0,62
25	SRN3	0,63
26	SSB3	0,81
27	STN3	0,62
28	TEGI	1,59
29	VDP3	-
30	VDS3	0,71
31	VGG3	0,95

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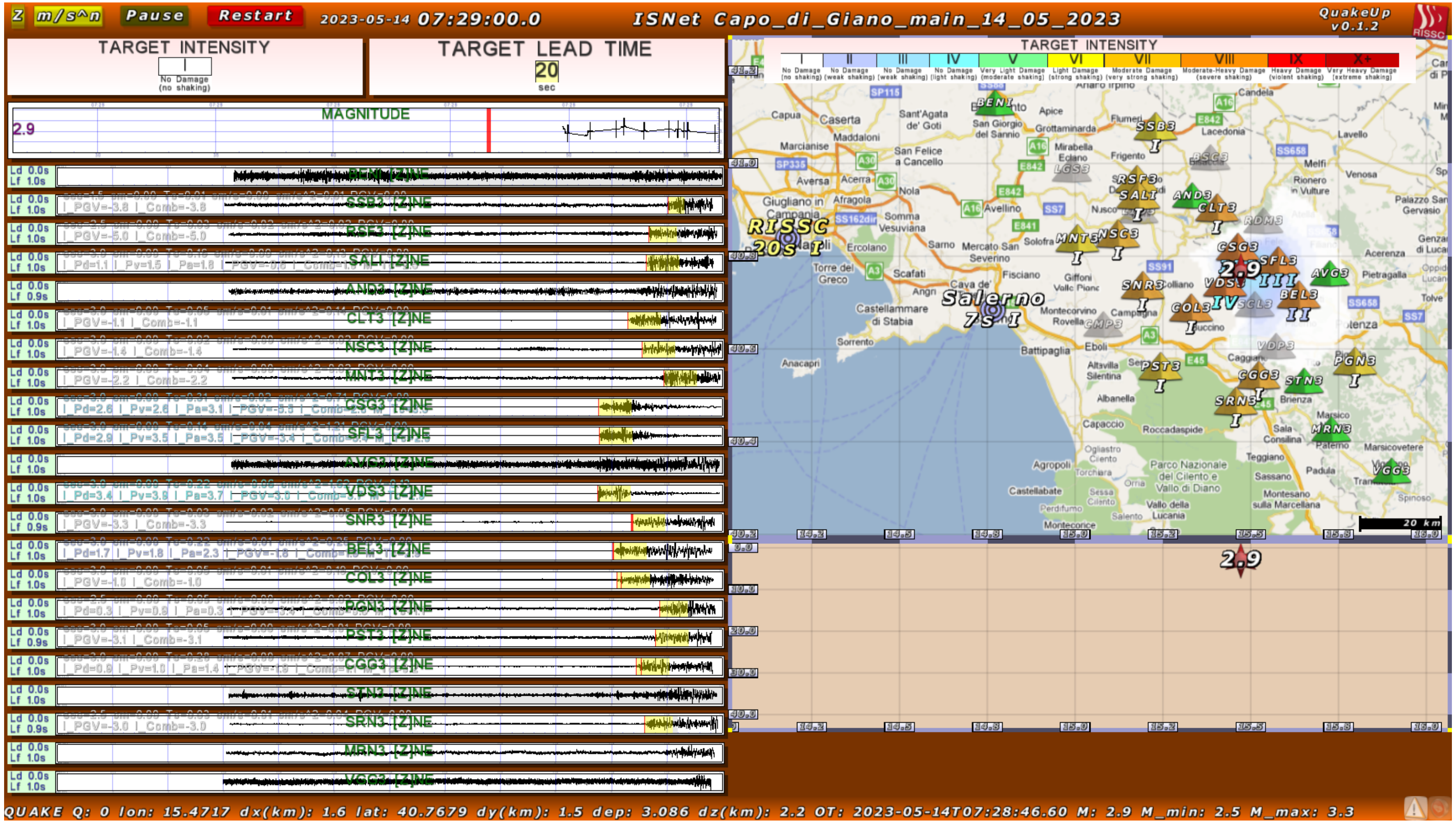
QUAKE-UP Performances



FIRST ALERT

AFTER 3 sec from T0

(2 sec from 1st pick, 3 stations)

MAG error: 0.4

LOC_epi error : 8.3 km

LOC_dep_error: 6.7 km

LAST ALERT AFTER 13 sec from T0

(12 sec from 1st pick, 3 stations)

MAG error: 0.4

LOC_epi error : 1.5 km

LOC_dep_error: 2.2 km

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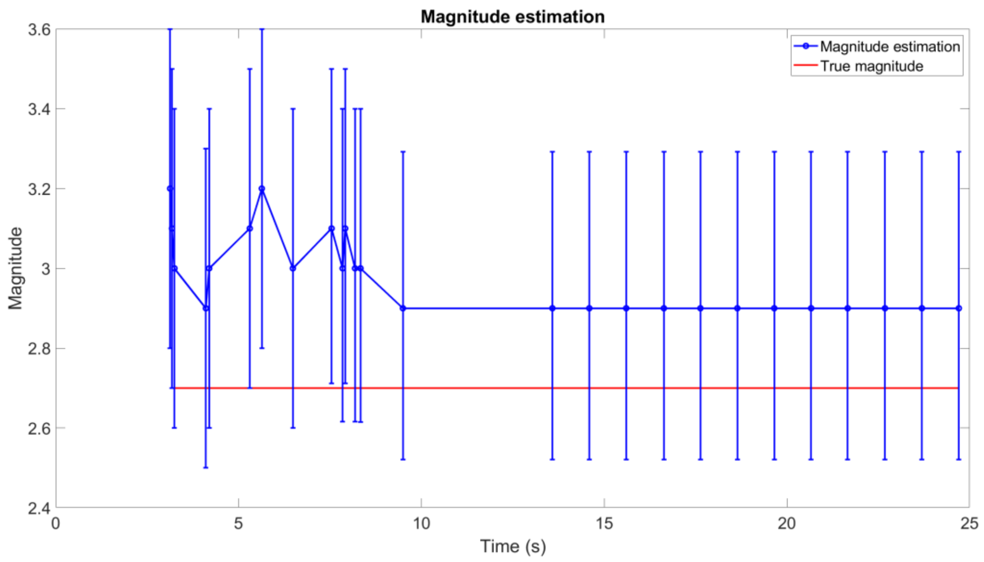
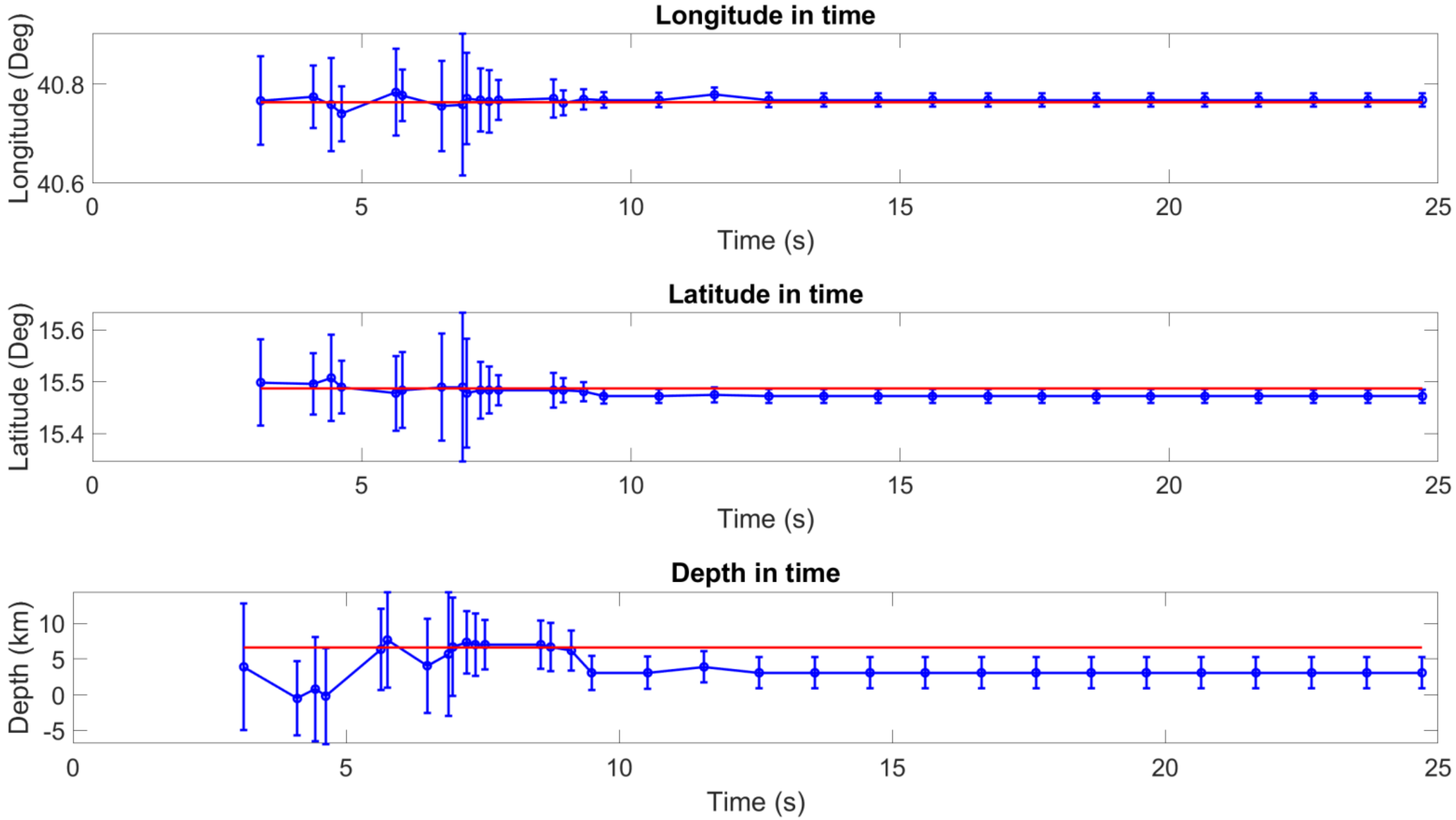
QUAKE-UP Performances

The first location and magnitude estimates are available 3 seconds after the O.T. Both epicentral location and magnitude are quite stable in time, while the epicenter depth reaches a stable value 9.5 seconds after the O.T.





Comparison of QuakeUp estimates (blue lines) with ISNet bulletin values (red lines)

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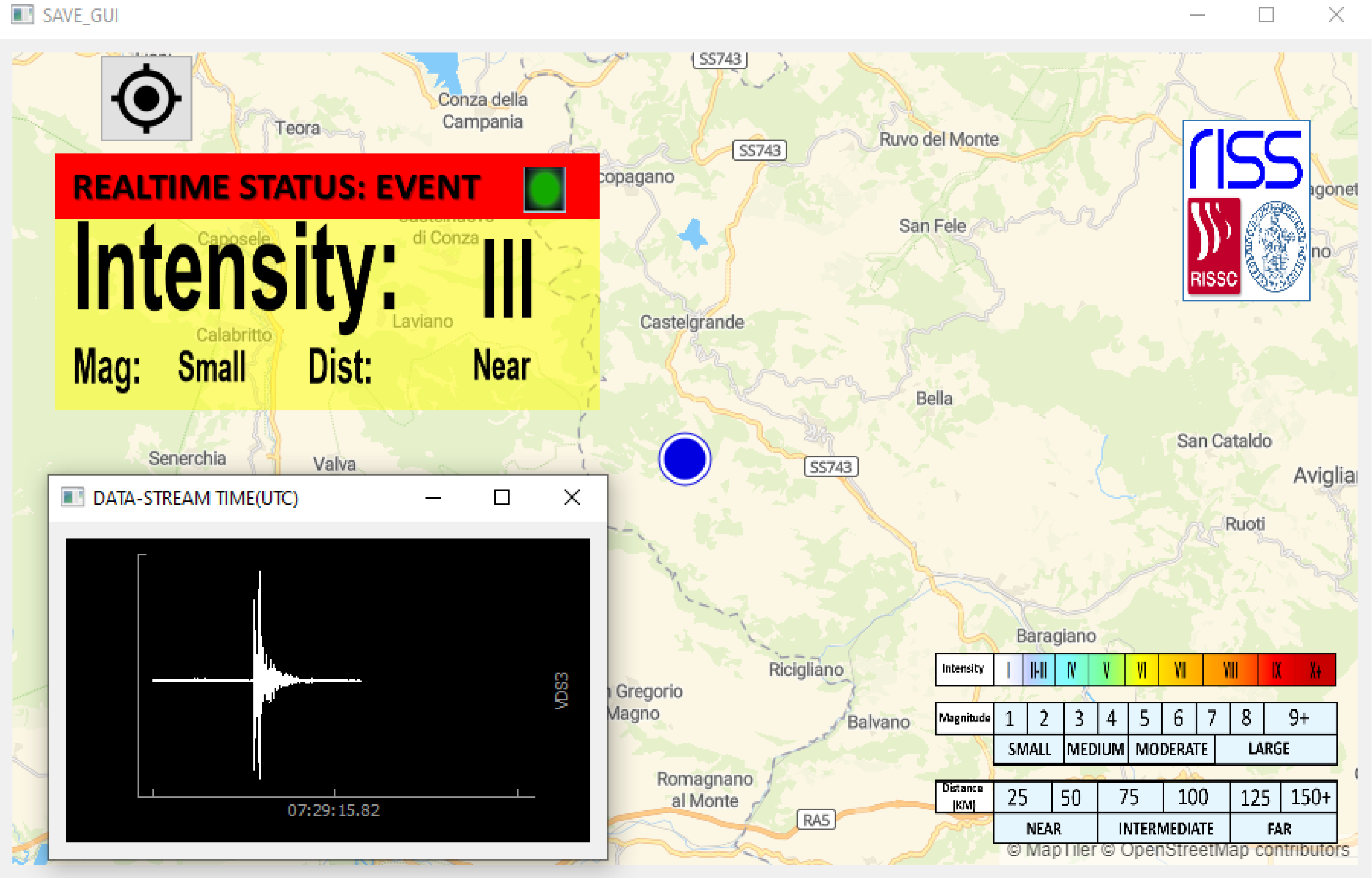
Offline Performances of SAVE@VDS

On-Site estimates of Intensity, Alert Level, Magnitude and Distance as provides by SAVE@VDS station (epicentral distance 8.3km), through the playback of recorded waveforms. All the estimates are obtained using the vertical component of acceleration waveforms and using the first 3 seconds of recorded P-wave signal.



The system was able to compute both the Pd amplitude and the Tauc parameter, and was able to provide estimates of magnitude, distance and intensity ranges.

The **estimated intensity (through the Pd) was III**, which is consistent with the observed value.

The event was correctly classified as a **small magnitude** event **nearby** the station.

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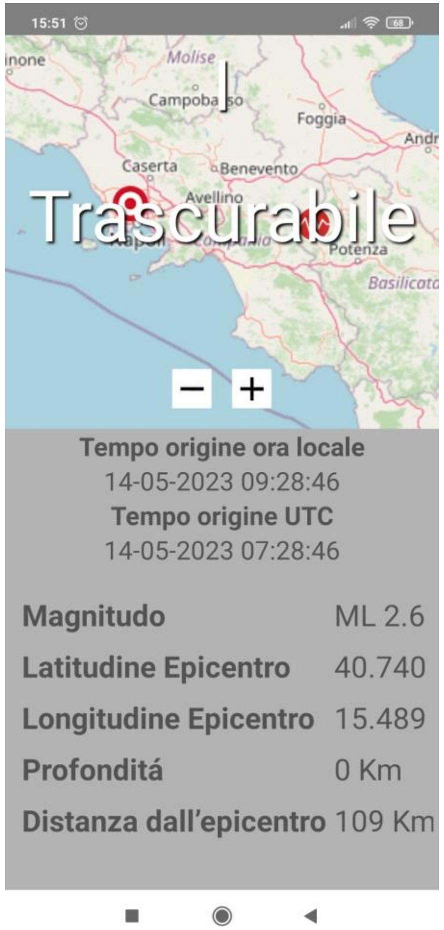
ISNet EW-APP

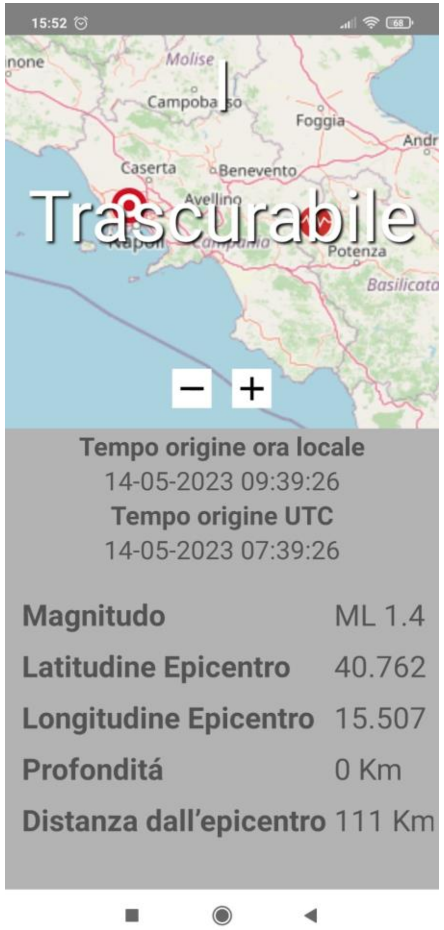
ISNET EWApp received the alerts from PRESTo for the following events during the sequence:

- Mag: 2.6, Time: 2023-05-14 07:28:46.48
- Mag: 1.4 (PRESTo Mag: 1.6), Time: 2023-05-14 07:39:26.63
- Mag: 1.5, Time: 2023-05-20 12:15:00.09
- Mag: 1.9, Time: 2023-05-20 23:06:18.87

The pictures show the screenshot of the app, on a smartphone located at Naples (epicentral distance of about 110 km), during the first two earthquakes.

5 smartphones received the alerts for the first two events and 6 smartphones received it for the latest two. The smartphones were located between Naples, Sorrento and Palomonte. The smartphones received the warning within an average time ranging between 0.8 and 1.7 s, for the different events.





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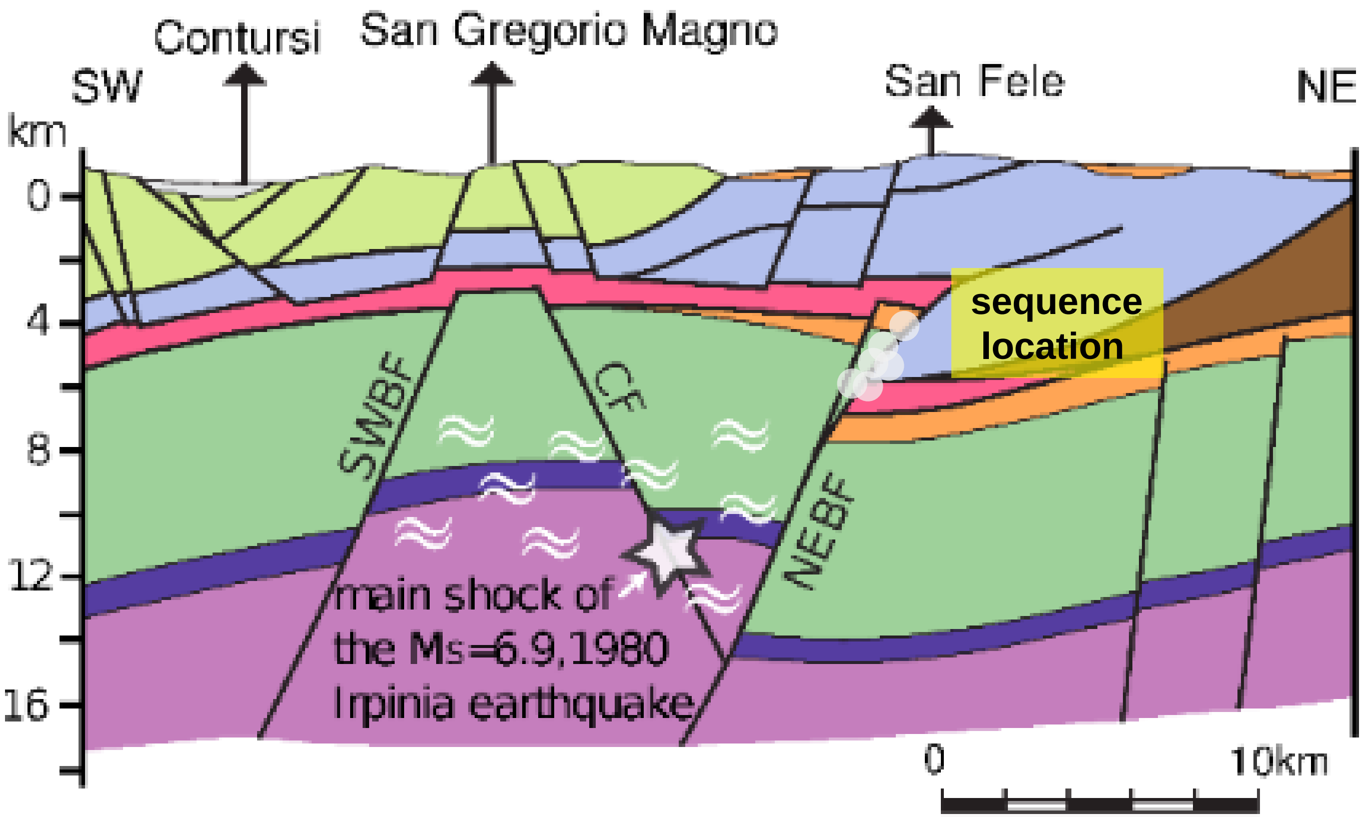
Seismic sequence and CROP model



From Amoroso et al. (2017)

The area of the sequence has been investigated in the past by the **CROP-04** exploration campaign. We found locations and focal mechanisms compatible with the NEBF of the Irpinia area, an antithetic structure which is believed to delimitate the fluid reservoir and the graben related to the 1980 Irpinia earthquake. The sequence extends for 2-3 km below the San Fele area.

RISSC-Lab: Laboratorio di RIcerca in Sismologia Sperimentale e Computazionale

Università degli studi di Napoli Federico II

Useful Links:

ISNet http://isnet.unina.it/

ISNet Bulletin http://isnet-bulletin.fisica.unina.it/cgi-bin/isnet-events/isnet.cgi

CREW: https://lccepos.fisica.unina.it/

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